Virtual River

This activity can be found online at: http://www.sciencecourseware.org/VirtualRiver/

Click on the link for “River Discharge.”

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The goal of this exercise is to introduce you to some basic concepts about how rivers work.

The term river describes water moving through a well-defined channel.

This is a picture of Herd Creek in eastern Idaho with water flowing through its well-defined channel. The channel here is about 7 meters wide.

Where do rivers get their water?

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Streams can gain much of their flow from groundwater springs. Here is a picture of a spring in Idaho which produces a moderate size creek – Tom’s Creek -- that flows off to the right.

Rivers also get their water during storms. This is especially true when the underlying soil is saturated and the rain can no longer seep into the ground. This picture of a hillside in California shows that the soil has become saturated with water ponding at the surface. Notice that some channels are starting to form and the standing water is beginning to move downhill.

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**Discharge**

The amount of water flowing in a stream is called its **DISCHARGE**, which is the volume of water moving in a stream during a given time interval. Time is usually expressed as seconds, but volume can be in cubic feet (ft³) or cubic meters (m³). So, discharge can be either cubic feet per second (ft³/s, also termed cfs) or cubic meters per second (m³/s). We'll be using the metric system for our determinations, but at the end of this activity you have the opportunity to convert from m³/s to cfs.

Click "Start" to observe the block of water move downstream at a rate of 1.0 meters per second. (It takes 10 seconds for the cubic meter block to move 10 meters.) The example
stream above is confined to a 1 meter square channel. Discharge here then, is 1.0 cubic meters/s. Later in this exercise you will determine the cross-sectional area of a stream and the stream's velocity through that area. By multiplying the area times the stream's velocity, you will be able to estimate the stream discharge.

Answer these questions:

1. Discharge is an important concept. What statement best describes stream discharge?
   a. It’s a measure of stream volume per distance traveled.
   b. It’s a measure of stream velocity.
   c. It’s a measure of how much water is moving past a certain location along the stream each second.

2. If the stream above were moving twice as fast, what would the discharge be?
   a. cubic meters/s
   b. 0.5 cubic meters/s
   c. 1.5 cubic meters/s

Stream Terminology
But, natural stream channels don't have a square meter cross-section shape and their velocity values vary a lot from spot to spot. As we shall see over the next few pages, a stream's cross-section can be complicated such that carrying out velocity measurements can be challenging. Before we consider how velocity values and channel shape are determined, let’s examine a few terms used to describe streams.

Notice that there is a right and left bank of the stream. The sides of a stream are named (right or left) relative to a view downstream. The arrow shows the direction of flow, which in the diagram on the right is away from us.

Answer these questions:

3. In this diagram, which side of the river is the left side? (A or B)

In order to measure discharge, we need to measure both the area of the cross section and the velocity of the water. (We’ll measure the area later.) Remember that velocity has the units of speed which can be expressed as either feet per second, or meters per second.

In a stream, velocity is measured by using a velocity sensor attached to a wading rod. Below (left) is a picture of a wading rod with the velocity sensor attached. The sensor has a
set of cups (or a propeller device) that spins in moving water. The faster the cups spin, the greater the stream's velocity.

(The following relates to photos embedded in the website) Above John Stamm, a hydrologist, is holding a wading rod with a velocity sensor attached to the lower part of the rod. The sensor is connected by a wire to a digital display meter held by Professor Stamm.

Above is a close-up of the velocity sensor (top) and its digital display meter (bottom).

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Below, two students are measuring velocity near the right bank of a muddy stream. They mark their "position" in the stream by using a tape measure. Their position is the point where the wading rod touches the tape. The rotating cups are down in the water spinning like crazy.

You might ask "At what depth should they place the spinning cups to measure the velocity?" At the surface of the water? At the bottom of the stream? Where? Let's find out.

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The animation on the left is a look inside a flowing stream. Notice the particles flowing past your view.

4. Which part of the stream is flowing fastest?
   a. Near the top
   b. In the middle
   c. At the bottom of the stream

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That's right!

The water in a stream moves fastest near the surface and slowest near the bottom where the flow is slowed by friction from the roughness of the bed material.

To compute the discharge of a stream, we need to compute velocity, which, as you now know, changes with depth. To make the best estimate of a stream's velocity hydrologists use the average velocity of a stream.

The question is "where is the average velocity measured?" Is it near the middle, or nearer the top, or nearer the bottom?

Click the "Next" button to find out.
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**Determining the Average Velocity of a Stream**
For each of the four layers use the stop watch to time the movement of particles from one post to the other. The wooden posts are 5.0 meters apart. (Some of the values have been measured and recorded for you.)

Make each measurement twice to the nearest 0.2 seconds. Record your data in the table below. Then record the average of the two times.

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Students calculate stream velocity

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**Making a Depth verses Velocity Graph**
To visualize the relationship between the depth of water in the stream and its velocity let's plot up the velocity and depth data that you collected.

Use your mouse cursor to drag the symbols representing each of the four points from the table on the right to the graph on the left. When the depth and velocity coordinates on the graph match those from the table release the mouse button. You may not be able to plot each point perfectly. Point # 1 has already been plotted for you.

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**The Velocity verses Depth curve for streamflow.**
The blue line connects the points you just plotted. The blue line curve tells us that there is a definite and measurable relationship between the velocity of a stream's flow and the depth at which the measurement is taken.

Rather than measuring velocity at many depths to determine the average velocity, let's use the curve to determine the velocity at many different depths and then calculate the average of those numbers.

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The interactive graph to the left shows that streams flow fastest near the water surface and slowest near the bottom of the stream. Use your mouse to move the "crosshairs" and read the velocity at different depths. Record your results. The velocity data from your prior measurements is already displayed.
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**The 6-tenths rule.**
That’s right. The average velocity for this hypothetical stream is 0.29 m/sec. (Your value may have been slightly different.) This value is for a very rapidly flowing stream.

Rather than make a number of measurements at various depths to estimate the average velocity, let’s use the graph to figure out approximately what depth in a stream would have the "average" velocity.

**This is a very important concept.** The graph can tell us that there is a certain depth at which we could make just one measurement to estimate a stream’s average velocity.

Move the cross hairs to the depth where the velocity in the stream is closest to the average velocity. What is that relative depth value?

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**The SIX-TENTHS Rule**
That’s right! The average velocity at any location in a stream can be estimated by measuring the velocity at six-tenths of the depth of the stream at that location. This is called the **six-tenths rule.**

If the stream is 3.2 meters deep, the average velocity at that spot can be estimated by measuring the velocity at 3.2 m times 0.6, which equals 1.92 m

Answer these questions.
5. At what depth should a velocity sensor be placed to estimate a stream’s average velocity if it’s 12.5 meters deep?
6. Same questions as above, but for a stream that’s 2.0 meters deep.

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**Working with a very simple stream**
Next we will estimate the discharge of a simple stream where the velocity changes with depth, but stays constant from side to side. Below is a **cross section** of such a stream. There is a "wading rod" tool, which you can move back and forth. Attached to the rod is a velocity sensor (a propeller device), which you can move up and down. The velocity and depth sensor readings can be seen below to the left.

**Questions:**
7. What is the velocity value at a sensor depth of 0.30 m at 6.2 m on the tape measure?
8. How does the velocity at 9.1 m on the tape (also at a sensor depth of 0.3) compare with that at 6.2 m and 0.30 sensor depth?
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**Determining a stream's depth, width, velocity and discharge:** For this stream, the average velocity is the same (provided the depth is the same) no matter what position on the tape it is measured. Answer the questions below.

Questions:
9. What is the maximum depth of water in this hypothetical stream?
10. At what actual depth should the velocity sensor be set to record the average velocity? (Remember that the average velocity is best measured at 6/10ths of the total depth.)
11. What is the average velocity of this stream, as measured by the virtual stadia rod and velocity sensor?
12. What is the distance on the tape of the left edge of stream? (Note that the edge of the stream is NOT at "0.0" on the tape.)
13. What is the distance on the tape of the right edge of the stream?
14. Compute the width of the stream. (This is the difference between the right and left sides.)
15. Discharge is computed as the volume of water in the stream passing by in one second. 
   \[
   \text{DISCHARGE} = \text{DEPTH} \times \text{WIDTH} \times \text{AVERAGE VELOCITY}.
   \]
   (Keep in mind that for this very simplistic stream the velocity at a fixed depth is constant from side to side. Water velocity in a real stream varies not only with depth, but from side to side.)
   What is the discharge of this stream? (Calculate to TWO decimal places in cubic meters per second)

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**Sure!** The discharge determined for the hypothetical stream on the prior page is a little less than 0.9 cubic meters per second. This calculation was pretty easy: it's just the product of the rectangular cross sectional area and the average velocity from bank to bank which is a constant value.

Real streams are not as simple. Cross sections are irregular because the water depth varies from side to side. Also a stream's velocity varies from spot to spot because of the frictional effects of the sides and bottom of the channel.

Furthermore, a complex stream commonly flows in sinuous paths called **meanders**.

Meanders are a product of the stability of stream banks, which are controlled by the bank's vegetation, the size of the sediment within the banks, and the power of the water in the stream (which increases as discharge increases).
More about real streams
Meandering is produced by both erosion and deposition of sediment.

Riffles (straight sections between bends) and point bars (on the inside of a meander bend) are places where sediment is deposited and temporarily stored. Pools and cutbanks (on the outside of a bend) are places where sediment is eroded or removed. Stream erosion and deposition generally occur during periods of flooding. An imaginary line connecting the deepest parts of a stream channel is called a thalweg.

Move your mouse cursor over the points marked "X" on the left diagram to find descriptions of some of the features of a meandering stream. Then respond to the questions below by matching the red letter in the image on the right with its corresponding term.

Stream Channel cross sections
The previous page shows us that streams have complicated channels with deep pools and shallow riffles. In a real stream the channel’s cross section can be quite complicated.

How do we measure discharge where the channel geometry is complicated? We divide the stream into several smaller sections called verticals. Each vertical has its own depth, width, and velocity.

Below is a diagram showing verticals for a stream and students measuring water velocity in the middle of a vertical.

Above we see two students measuring water velocity in the middle of a vertical. The measuring tape is used to determine the location of the middle of each vertical.

A reasonable question to now ask is "How many verticals should be used to accurately determine a stream's discharge?"

If we use only a few verticals, we could miss the high-velocity band of water, and our discharge measurement will be too low. Using at least 20 verticals gives us a good chance of getting a measurement in the high velocity area and therefore having a more accurate measurement of discharge.

Less than 20 verticals can be used, but at the expense of accuracy.
If a stream is 30 meters wide, and we want to compute discharge in a stream using 20 verticals, how many meters wide would each vertical be?

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Instructions: Hang in there! You’re almost finished. Measure the width of this stream by using the mouse to drag across the stream. Set the number of verticals to 10 or more. (If you use less, the discharge you calculate will be too inaccurate.) You will only have to measure the area of 5 of these, as the program will measure the rest. Click the Read To Measure button to advance to the next page.

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**Converting Cubic Meters per Second to Cubic Feet per Second (cfs)**
The total discharge you determined for this stream is 4.012 cubic meters per second. Recall that discharge often is reported in units of cubic feet per second (cfs). It’s important to be able to convert from one set of units to the other.

The conversion from feet to meters is 0.3048. In other words, one foot equals 0.3048 meters.

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Congratulations! You have successfully completed this activity about river discharge.

Determining discharge is just the first step in understanding rivers. You can learn more about other important river processes, such as floods and erosion, by completing the other lessons in this virtual lab. (You’ll find a link on the next page.)

**Enter information below to get a certificate of completion**

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VERY NICE WORK!

**Summary of Discharge Data for this Hypothetical River**

<table>
<thead>
<tr>
<th>Vertical Number</th>
<th>Width (meters)</th>
<th>Depth (meters)</th>
<th>Average Velocity (m/sec)</th>
<th>Area of Vertical (sq m)</th>
<th>Discharge of Vertical (cubic m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Value here) cu m/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Value here) cu ft/sec</td>
</tr>
</tbody>
</table>