Stream Velocity And Discharge

Equipment:
- 2 meter tapes at least 10 m long
- 2-3 meter sticks
- 2-3 oranges or other citrus fruit
- 1 stopwatch
- Calculators
- Waders for students if stream is deep or cold
- Pencils

Objectives: After this lesson, students should be able to:
- Describe a watershed
- Determine the velocity of a stream
- Determine how much water is flowing past a given point in a stream
- Understand the importance of abundant clean water to fish, humans, and economic vitality

Words in *italics* are vocabulary words that can be found at the end of the lesson.

Estimating Stream Velocity and Discharge

Hydrologists are interested in how much water flows in streams and how these levels fluctuate over time. We will collect data to estimate the *velocity* and *discharge*, of the stream. To find the discharge, we need 3 things: the velocity of the stream, the width of the stream, and the average depth of the stream.

1) Measure a 10 meter length along the bank of the stream. You want to find a section of the stream that has a steady flow, avoiding sections with deep pools or rapids.
2) Assign the following tasks:
   a. 1 student to drop the orange just upstream of the10 meter section marked off earlier
   b. 1 student to call out "Start" when the orange crosses the beginning of the 10 m section
   c. 1 student to call out "Stop" when the orange crosses the end of the 10 m section
   d. 1 student to operate the stop watch
   e. 1 student to collect the data that others will then copy on their own data sheets
   f. 2-3 students to act as the orange "catchers" to keep the oranges from floating downstream
3) Have the student drop the orange in the stream and time it to see how long it takes to travel 10 m. Do this 5 times, dropping it in different sections in the stream (i.e., near the sides, in the middle, etc.) to try and get an "average" *velocity*. Place these times in the boxes below:

Trial 1 ______ sec.

Trial 2 ______ sec.

Trail 3 ______ sec.

Trail 4 ______ sec.

Trial 5 ______ sec.

4) Add the 5 trials together and divide by 5 to find the average number of seconds it takes the orange to travel 10 meters:

______ Average seconds

5) Now that we have the average number of seconds, we can find the *velocity*. *Velocity* is determined by dividing the distance the orange travelled by the average number of seconds it took the orange to travel the 10 m. The equation is V = d/t, where V = velocity, d = distance, and t = time. We will need to keep our units of measurement all the same to find the discharge of the stream, so we will go ahead and convert meters (m) to centimeters (cm). Since 1 m = 100 cm, then 10 m = 1000 cm. Fill in the rest of the equation to find the *velocity*:

1000 cm ÷ ______ average seconds = ______ cm/sec downstream

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6) Now that we have determined the *velocity*, it is time to find the width of the stream at the end of the 10 m section that the orange travelled. Stretch a meter tape across the stream and measure the width in cm:

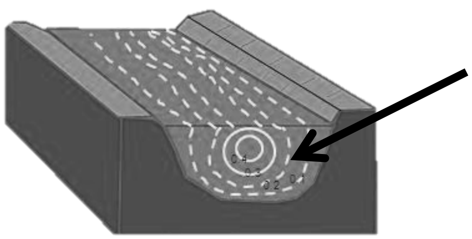
_______ = width of stream in cm

7) Now we need to find the average depth of the stream. Using the meter sticks, take a depth measurement every meter (or every half meter if the stream is <10 m wide) along the same meter tape that you used to record the width. Record the depths (cm) in the boxes below:

8) Now we need to find the average depth. Add all the depths and divide by the total number of depth measurements taken to find the average:

_______ = average depth in cm

9) Now it is time to estimate the area (width × depth). In the stream cross-section diagram below, the arrow is pointing to the portion of the stream where we are estimating area:



Find the area of the stream cross-section using the data from our width (#6) and depth (#8) measurements:

_______ cm × _______ cm = _______ cm^2

Width Depth Area

Stream Velocity and Discharge

10) Now it is time to find the discharge. Multiply the area of the stream cross-section (#9) by the velocity (#5) to estimate discharge or the volume of water moving past per second:

[ ] cm^2 × [ ] cm/sec = [ ] cm^3/sec

Area — Velocity — Discharge

11) Finally, let's convert this measurement into cubic meters per second (m^3/sec) by dividing cubic centimeters/sec (cm^3/sec) by 1,000,000. Why do we divide it by 1,000,000? Well, there are 100 cm in 1 m, but we are dealing with a cube, so we need to divide by: 100 cm × 100 cm × 100 cm = 1,000,000 cm^3 to convert to 1m^3.

[ ] cm^3/sec ÷ 1,000,000 = [ ] m^3/sec

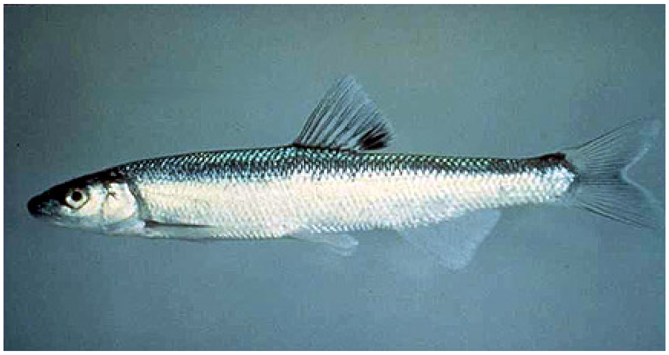
How many gallons does this represent? (*Hint – There are 264.2 gallons in 1cubic meter*).

Take a look at the table below. How does this stream compare with other rivers in the world? How many streams would it take to match the volume of water discharged from the Amazon River? The Mississippi?

Name of River	Discharge
Amazon River, Brazil	212,400 m^3/sec
Congo River, Zaire	39,650 m^3/sec
Yangtze River, China	21,800 m^3/sec
Mississippi River, USA	17,300 m^3/sec

Stream Velocity and Discharge

Spotfin Chub (Erimonax monachus) Status Report



The Spotfin Chub is a type of minnow *endemic* to the Tennessee River system. It was listed as a Federally Threatened Species in 1977. Populations of this species declined because of the building of dams, *sedimentation* of streams, and pollution. Today, this rare fish is found in four *watersheds* of the Tennessee River, including the section of the Little Tennessee River between Franklin and Lake Fontana.

Adult fish are only 9 cm long, which is about the length of your index finger. They are thought to live about 4 years in the wild. They are insectivores, feeding on stream insects such as caddisflies and mayflies. They are distinguished from other minnow species by the black area on the rear of their *dorsal* fin.

Spotfin Chub require cool, clean water. They are found in streams that have a lot of boulders and *cobble* and are not found in areas that have sandy or muddy bottoms. They are found in larger creeks and mountain rivers in waters that are 9 to 85 cm deep. A study of Spotfin Chub living in the Emory River in Tennessee found that the early summer velocity of these waters range from 0-0.88 m/sec (meters per sec).

The US Fish and Wildlife Service and North Carolina Wildlife Resources Division are responsible for managing this species and are interested in looking for large streams that might provide suitable habitat for this species. Part of the objective of this field trip is for you to help out with this important work to see if this particular stream might be suitable habitat for this fish.

Both federal and state biologists need you to assess the stream and answer the following questions:

1) What is the average depth of the stream? Is the depth of the portion of the stream that you measured suitable for Spotfin Chub?

2) What is the mean velocity of the stream? Is the velocity of the stream suitable for Spotfin Chub?

3) Does the stream *substrate* (bottom of the stream) contain habitat suitable for Spotfin Chub?

4) Is the stream suitable for the reintroduction of the Spotfin Chub?

Stream Velocity and Discharge

Smoky Madtom (Notorus baileyi) Status Report

The Smoky Madtom *(Noturus baileyi)* is a Federally *Endangered* fish *endemic* to the southern Appalachian Mountains. The Smoky Madtom is in the catfish family, but grows to only about 7.3 cm. Today the fish is found only in a 6.5 mile section of Citico Creek in Cherokee National Forest, TN, and in the lower sections of Abrams Creek in the western side of Great Smoky Mountains National Park.

The Smoky Madtom was *extirpated* from Abrams Creek in the 1957. In perhaps one of the most foolish management decisions in the park's history, it was decided that Abrams Creek should be poisoned to remove native "trash" fish to make it more suitable for *exotic* Rainbow Trout, a popular game fish. During the poisoning of the stream, scientists gathered the dead fish to put in jars for museums. One fish stood out as a new species – the Smoky Madtom. It almost became one of the first species to simultaneously be discovered as a new species and made extinct all within the same day. Fortunately, it was later found in Citico Creek in the 1980s. It was probably found in other tributaries of the Little Tennessee River, including the main channel of the Little Tennessee River; however, dams, sedimentation, and other human activities probably extirpated these populations. At existing locations of the Smoky Madtom, small dams built by children and adults threaten Smoky Madtom populations by slowing down the velocity of stream flow in shallow riffles, the primary habitat of the small fish.

The Smoky Madtom was re-introduced to Abrams Creek in the late 1990s. The fish needs clean, cold water, but is only found in streams with abundant shallow riffles. Because the fish is currently found in only two streams, the U.S. Fish and Wildlife Service is attempting to find new sites for the Smoky Madtom to be re-introduced. As part of this field trip, the U.S. Fish and Wildlife Service needs your *velocity* and *discharge* data and to assess whether or not it the stream is suitable for the Smoky Madtom. The most recent research suggests that the Smoky Madtom requires streams with a minimum flow, or *discharge*, of 1.9 m^3/sec. This fish also needs shallow *riffles* with a *velocity* of 0.5-0.7 m/sec for breeding. Determine whether or not this stream would be a suitable site for re-introduction of the federally endangered Smoky Madtom.

1) What is the mean velocity of the stream? Is the velocity of the stream suitable for Smoky Madtom?

2) What is the discharge of the stream? Is the discharge high enough for Smoky Madtom?

3) Is the stream suitable for the reintroduction of the Smoky Madtom?

Stream Velocity and Discharge

How Many People Is This Stream Able to Support?

To live in the fashion to which we are accustomed, it has been estimated that each person needs 120 gallons of water each day. The following section will allow you to calculate how many people this stream will support.

1) Using your final answer from question #11 on p. 4 (gallons per second), multiply gallons per second by 60 to determine gallons per minute:

[ ] gal/sec × 60 sec/min = [ ] gal/min

2) Multiply gallons per minute by 60 to determine gallons per hour:

[ ] gal/min × 60 min/hour = [ ] gal/hour

3) Multiply gallons per hour by 24 to determine gallons per day.

[ ] gal/hour × 24 hrs/day = [ ] gal/day

4) Divide the gallons per day by 120 (the number of gallons each person needs per day). This will answer the question "How many people is this stream able to support?"

[ ] gal/day ÷ 120 = [ ] people

COOL FACTS: Did you know that toilet flushing makes up the largest percent of water use in our homes! An average of 27% of the water used in our homes is used to flush our toilets.

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The Economics of Clean Water

Compared to the rest of the country, western North Carolina has a lot of high quality water. Western North Carolina has ample rainfall and many of our streams originate on mountaintops that are forested and under public ownership, such as Nantahala National Forest and Great Smoky Mountains National Park. As a result, the streams flowing from these areas are clear, cool, and clean. This clean water has recently attracted large beverage producers, as well as industries that need abundant clean water, such as the computer industry, to western North Carolina.

A single micro-chip requires 10 gallons of ultra-pure water. This ultra-pure water requires 12 filtration steps beyond *reverse-osmosis*, a common process used to create safe drinking water. In fact the water used to clean semi-conductors in computer chips is so pure it is classified as a *solvent* and can harm you if you drink it, because it can leach vital vitamins and minerals from your body!

Intel, one of the largest makers of computer chips in the world, is interested in building a plant in this county, using water from the creek you have been researching today. Intel would like to make computer chips for the newest video game consoles. This new plant will bring many jobs to the area, but will also require a lot of water. The new plant is expected to produce 2 million integrated circuits per month, or roughly 67,000 circuits per day. Each circuit requires 10 gallons of ultra-pure water to rinse any impurities from the microscopic circuits.

Intel needs the following information from you before it can move ahead with its plans in building a new plant:

1) How many gallons of water will need to be pulled from this creek each day for 67,000 circuits to be produced?

2) Based on your earlier calculations of discharge, how long would the river have to "run" each day to meet Intel's water demands? Use your answer from question #11 on p.3 to help answer this question.

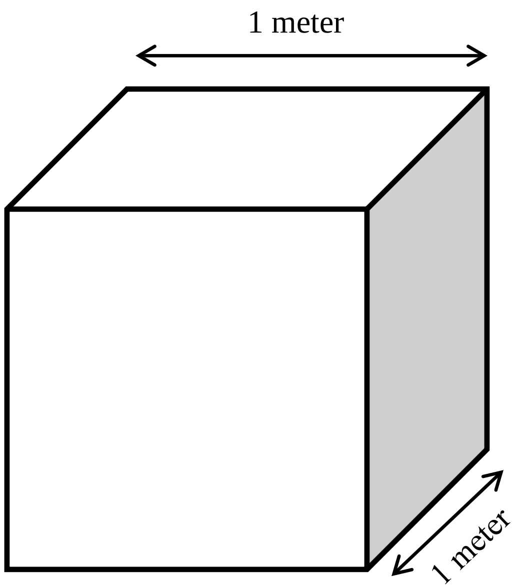
3) If the lowest discharge recorded for this creek was 81 cubic feet per second (606 gallons/sec), what percent of today's stream discharge does this represent? How long would the creek have to "run" to clean 67,000 circuits each day?

4) The average American uses about 120 gallons per day. Based on your answer for question #4 on the previous page, how many fewer people would this stream be able to support if Intel used the stream water to wash 67,000 circuits each day?

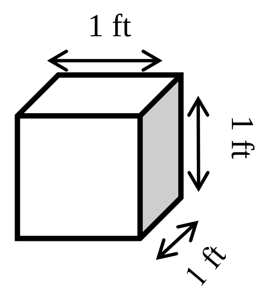
Water Volume and Mass Conversions

COOL FACTS: Did you know that water is the base standard used to calculate mass in the metric system? One kilogram is equal to $1m^3$ of water at 4°C and one gram is equal to $1cm^3$ (or 1 mL) of water at 4°C!

$1\ m^3 = 1m \times 1m \times 1m$



$1\ ft^3 = 1ft \times 1ft \times 1ft$



1 cubic meter of water =

- 264.2 gallons
- 1000 liters
- 35.3 cubic feet
- 1,000 kg
- 1 metric ton
- 2,204.6 pounds

1 cubic foot of water =

- 7.5 gallons
- 28 liters
- 28 kg
- 62 pounds

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Vocabulary

cobble – n. medium-sized rocks found in streams, usually smooth and round from erosion. *In the southern Appalachian Mountains, streams with a lot of **cobble** provides excellent habitat for caddisflies, mayflies, stoneflies, and other aquatic macroinvertebrates that trout and other fish feed upon.*

discharge – n. a term that hydrologists use to describe the volume and rate of water moving in a river or stream. *Today our class discovered that the stream **discharge** is 2.3* m^3*/sec.*

dorsal – adj. relating to or situated near the back, especially of an animal. *Everyone at the beach panicked when the **dorsal** fin of a shark appeared near the surf; however, because of my training as a marine biologist, I could plainly see it was simply the **dorsal** fin of a harmless dolphin playing in the waves.*

endemic – adj. native or restricted to a certain area or part of the country. *The Spotfin Chub is **endemic** to the southern Appalachian Mountains and Cumberland Plateau region of the southeastern United States.*

endangered – adj. at risk of becoming extinct. *The Smoky Madtom is a Federally **Endangered** fish and today can only be found in two small watersheds in the Southern Appalachian Mountains.*

exotic – adj. originating from a foreign area; not native. *In the eastern U.S., Rainbow Trout are considered an **exotic** species as they are only native to rivers and streams west of the Rocky Mountains.*

extinct – adj. a species that no longer exists. *The Passenger Pigeon was once the most numerous bird in North America, and perhaps the world, but became **extinct** due to habitat loss and over-hunting. It was the first time the exact time and location of an **extinction** took place, when Martha, the last Passenger Pigeon on Earth, died of old age in the Cincinnati Zoo on September 1st, 1914 at 1pm.*

extirpate – v. term used to describe a species that is locally extinct, but still occurs in other areas. *The Mountain Lion has been **extirpated** from the southern Appalachian Mountains, but populations of Mountain Lions can still be found in Florida and in the western U.S.*

hydrologist – n. a person who studies the movement and properties of water. *The **hydrologist** used their specialized equipment to measure stream velocity and discharge for the medium-sized stream that will be the new water source for the town of Franklin.*

reverse-osmosis – n. a water purification process that uses a semipermeable membrane and osmotic pressure to remove impurities from the water. *At Coweeta Hydrologic Laboratory, we use deionized water that is derived from **reverse-osmosis** to clean our glass and labware.*

riffle – n. a short, shallow length of stream where the water flows over a bed of cobble and smaller stones at a relatively high velocity. *Visitors who build small rock dams in Abrams Creek are raising the water height and slowing the flow of the water, thus altering the **riffle** habitat that the Smoky Madtom needs to breed and lay its eggs.*

Stream Velocity and Discharge

sedimentation – n. the natural process in which material, such as stones and sand, is carried to the bottom of a body of water and forms a solid layer. *Excess **sedimentation** is considered a type of pollution, resulting in poor water quality and causing rocks and pebbles on the bottom of the stream to be covered with mud.*

solvent – n. a substance that dissolves a solute. *Water is a common **solvent** and stream water carries many dissolved solutes such as nitrates and phosphates.*

substrate – n. the base on which an organism lives. *Hellbenders, the largest salamanders in North America, require clean, cold streams with a **substrate** full of large rocks and cobble in which the large salamanders can shelter and feed on crayfish, their primary prey.*

velocity – n. speed in a given direction. *The orange travelled downstream at a **velocity** of 1.5 meters per second.*

watershed – n. an area of land that is defined by having all the streams, rivers, or lakes draining into the same common point. *The Blue Ridge Divide runs along the spine of the mountains in western North Carolina; **watersheds** to the west of the divide ultimately drain into the Mississippi River and Gulf of Mexico, while **watersheds** to the east of the divide drain into the Atlantic Ocean.*