Hydrology

7

“The river hides itself in motion. It holds layers of meaning,
and so it adds mystery to the landscape, a sense of complexity and risk,
a sense that the important facts are hidden from view.”
— Kathleen Dean Moore

In the broadest sense, **hydrology** is the study of water—its properties, where it comes from, how it circulates, and how it is distributed. Hydrology is a broad field of study with several specialty areas. One specialty area studies water flowing in streams and rivers. How water carves channels and carries materials is the primary focus of this field of study.

Another field of hydrology looks at water in specific types of watersheds, such as forest hydrology, wetland hydrology, or range hydrology. Hydrologists in these fields study how vegetation and land management affect water quantity and quality, **erosion**, and **sedimentation**.

To make the connections between land and water, upstream and downstream, and precipitation, groundwater, and streamflow, one must understand the basic concepts and interactions of hydrology. These include gravity, friction, **velocity**, **scouring** and **deposition**.

An understanding of hydrology is also essential to manage natural resources in a watershed. It is hard to understand how to reduce erosion if the connections between plants, soils, and the way water moves across the landscape are unclear. How water moves to a stream and how it moves through a stream are necessary to understand seasonal flows and the frequency and size of floods. This link also determines how well a stream meets the needs of **salmonids** and other aquatic organisms.

Vocabulary

erosion
hydrology
salmonids
sedimentation
velocity
scouring
deposition

Water dynamics

7.1

"The larger streams run still and deep,
Noisy and swift the small brooks run,…"
— Edna St. Vincent Millay

Structures in streams, whether fallen logs, boulders, root wads, or artificial placements, provide habitat diversity and help meet the needs of fish. To understand how these structures function, you must understand the basics of stream hydraulics.

The principal forces acting on water in a stream channel are gravity and friction. Gravity propels water downstream, and friction between the water, streambed, and banks resists this flow.

Water velocity is influenced by:

- steepness of slope,
- size of substrate materials,
- type and amount of riparian area and stream vegetation,
- shape, depth and frequency of pools and riffles,
- meanders of the stream, and
- obstructions.

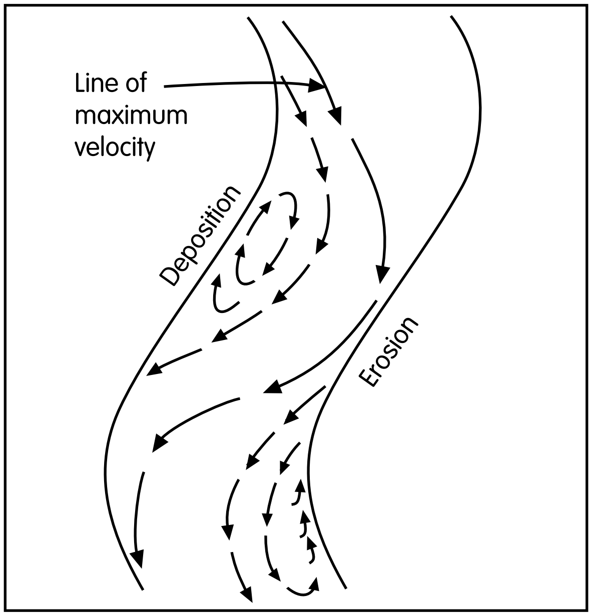
As velocity increases, these factors provide more resistance to flow. This causes eddies, chutes and waterfalls that can dislodge and move objects downstream.

There are three basic stream forms:

1. **straight**—relatively straight or nonmeandering channels,
2. **braided**—channels that meet and re-divide, and
3. **meandering**—single channels with "S"-shaped channel patterns.

A stream will naturally meander whenever possible. In larger streams, a line of maximum velocity, called the **thalweg**, wanders back and forth across a channel in response to streambed configuration. Thalwegs are generally found near the center of a water column because of friction with the streambed and surface tension.

Figure 7. Line of Maximum Velocity



Source: Adapted from Marie Morisawa, *Streams: Their Dynamics and Morphology*, 1968.

Water spiral

Friction between water and streambanks causes water to move in a corkscrew fashion down the channel. This

Vocabulary

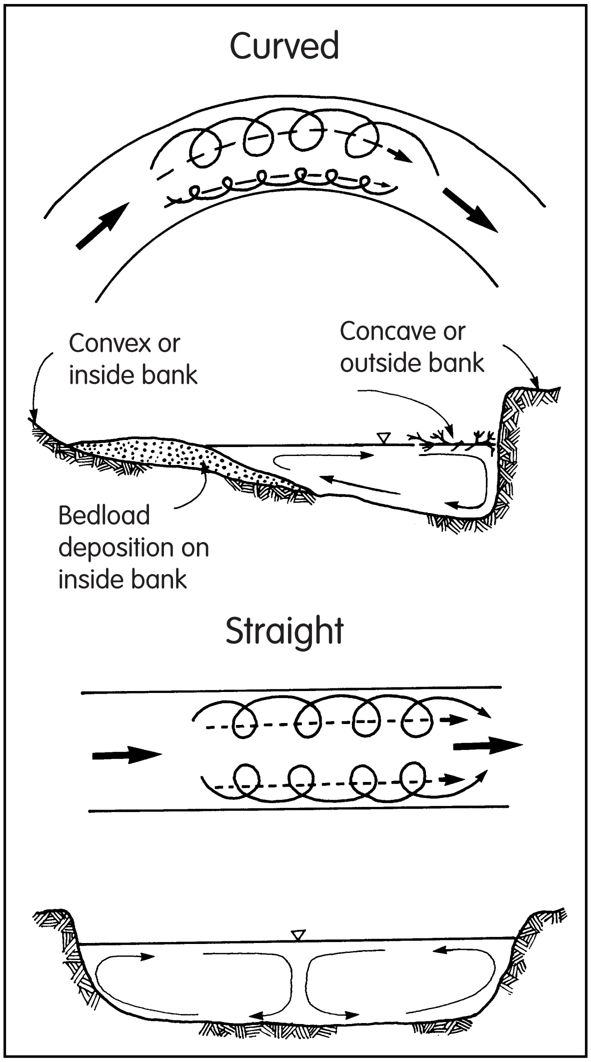
thalweg
water spiral
straight
braided
meandering

corkscrew, or helical flow, is called a **water spiral**. As changes occur in the stream channel (straight or curved, high or low gradient, or as a result of instream structures), the water spiral will change.

A water spiral slows and becomes smaller as it moves along the inside of a curve in a stream channel. As velocity decreases, suspended material carried by the current drops out of the flow and settles along the bend. This change in velocity forms gravel bars and deposits spawning gravel.

A water spiral enlarges and accelerates as it moves around the outside of a curve or an obstruction, such as a boulder. The force of the water is dispersed over a larger area. Thus, increased velocity scours or digs pools during high flows. These pools provide excellent feeding and rearing habitat for fish during low flow periods.

Figure 8. Water Spiral



Source: Adapted from John W. Anderson, “Nuts and Bolts of Stream Rehabilitation,” presentation, 1986; and Province of British Columbia, *Stream Enhancement Guide*, 1980.

Extensions

1. The helical flow of water is not constant. It is altered by changes in volume and speed of water. This can be shown with a squeeze bottle of colored water and a pane of glass. Tilt the glass and, using constant pressure on the bottle, squeeze a stream of water onto the raised end.

   Vary the volume of water and angle of the glass to show the effects of changing gradients and flows. Performing this demonstration over the stage of an overhead projector with a pan to collect runoff projects the process onto a screen.

   Note: Be aware of the danger from electrical shock when using water near electrical equipment.

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Go with the flow!

***Activity Education Standards:** Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will explain how water contributes to the process of erosion and demonstrate four ways that streams carry sediments.

Method

Students will build a model stream and observe four different ways streams move sediments:
- in solution (salt dissolved in the water)
- as a colloidal suspension (clay particles in suspension)
- by saltation (the bouncing motion of sand particles)
- by rolling and sliding (how large rocks move in real streams)

For younger students:

1. Perform the demonstration in the Extensions on page 202 to teach younger students about flows, speed of flow, and slope before attempting this activity.
2. Help younger students understand the vocabulary in this exercise before beginning the exercise. Modify as needed.
3. Do the activity as a demonstration.

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Materials

Each group will need:
- copies of student sheets pp. 209-212
- stream set-up
  - stream trough (24" length of plastic gutter)
  - collecting pan
  - 1 gallon jug
  - pencils
  - supports (set up as shown in illustration)
- sediments
  - sand
  - round pebbles (light weight, between ½" to 1" in size)
  - flat pebbles (light weight, between ½" to 1" in size)
  - powdered clay (china clay, kaolin, or pottery clay)
  - ion mixture (a saturated solution of table salt and water).
- eyedropper
- mixing jar (paper cup, baby food jar, or other container)
- stirring rod (pencil or a plastic straw)
- clean glass microscope slide
- magnifying glass
- ruler
- water source
- rags, paper towels, or sponges for cleaning up

Note: The teacher will provide a bucket to collect all wet sediments. Do not dump sediments in a sink–they will clog the drain.

Vocabulary

collodial suspension	sediments
saltation	suspended sediments

Notes to the teacher

Use a pencil or screwdriver to punch one hole near a corner of the gallon-size plastic milk jug. Locate the center of the hole about three-quarters of an inch above the jug's base. If want to use two holes to create greater flow, add a second hole about an inch away from the first at the same height.

The holes must be small enough so that a pencil stopper can make the jug water tight. Test the jug for leaks by placing a pencil in the hole and filling it with water. Remove the pencil to see if the holes are large enough to allow water to flow freely from the jug. Use sharp scissors to trim the flaps of plastic around the edges of the hole if necessary.

Ideally, the sand, round pebbles, and flat pebbles should all be quartz or materials of similar density. The point of this activity is to vary particle size, not composition.

Mix a saturated salt solution as follows: Add salt to one-half cup (Approximately 100 ml) of water and stir. Continue adding salt and stirring until no more salt dissolves. Allow the undissolved salt to settle on the bottom of the container. Pour off the clear salt solution above the salt granules without disturbing the undissolved salt.

If you do not have ready access to dry clay from which to make the colloidal suspension called for in Step 7, you can make an acceptable substitute as follows. Take a fist-sized clump of soil that contains some clay, break it up into small pieces, and place it in about two and one-half cups (500 ml) of water. Stir the soil and water vigorously. The smallest particles of the soil (the clay components) will become suspended in the water, making it appear cloudy. The particles in this type of mixture are less than 1/256 mm in diameter. They settle out of the water extremely slowly unless chemicals (such as alum) are added to clump them together.

Pour off the top layer of cloudy water from the container, and use it in Step 6. When decanting the cloudy water, avoid disturbing the larger particles of soil that sink to the bottom. Skim off any organic material that floats to the top.

You may want to discuss the definitions of clay, sand, and pebbles with students before performing this activity.

Background

Do you know . . .

… that streams move more than water from the mountains to the sea? In this activity, you will investigate how a stream carries **sediments**. All streams carry a load of sediments including sand, pebbles, dissolved minerals, and **organic materials**. Flowing water can quite literally move mountains—one small piece at a time—to a river delta or an ocean basin.

Sediments are the fragments of rocks, minerals, and organic material produced by weathering and erosion. Sediments can be as large as huge boulders moved by flooding streams, as small as atom-sized minerals dissolved as ions or salts in stream water, or anywhere in between.

Fast, rain-swollen streams carry heavy sediment loads; wherever they slow down, part of that load is deposited on the streambed. The largest particles fall to the bottom first. Smaller particles suspended in the water eventually settle to the bottoms of lakes or ocean basins. All streams carry sediments in an endless trip from dry land to the ocean basins, where the lower layers of sediments are slowly transformed back into rock by the pressure of overlying sediments.

Water is an important agent of erosion. Water running over the surface of the ground or in streams is constantly lowering and leveling the land above sea level. Waterborne sediments are the tools of the streams, carving out valleys and canyons as they move along. As anyone who has noticed the smooth, rounded rocks in a swift-running mountain stream may know, the tumbling and scraping tends to smooth and round the sediments as they move downstream.

Procedure

Now it's your turn . . .

Use the illustration to help you set up the stream. Set the stream trough with the upper end elevated about 2½ inches above the table surface. Place the collecting pan at the lower end. Adjust the level of the jug supports so that the base of the jug is about 4 inches above the table (1½ inches above the end of the trough). Place the pencils in the holes in the jug. Fill it with water and set it on the support.

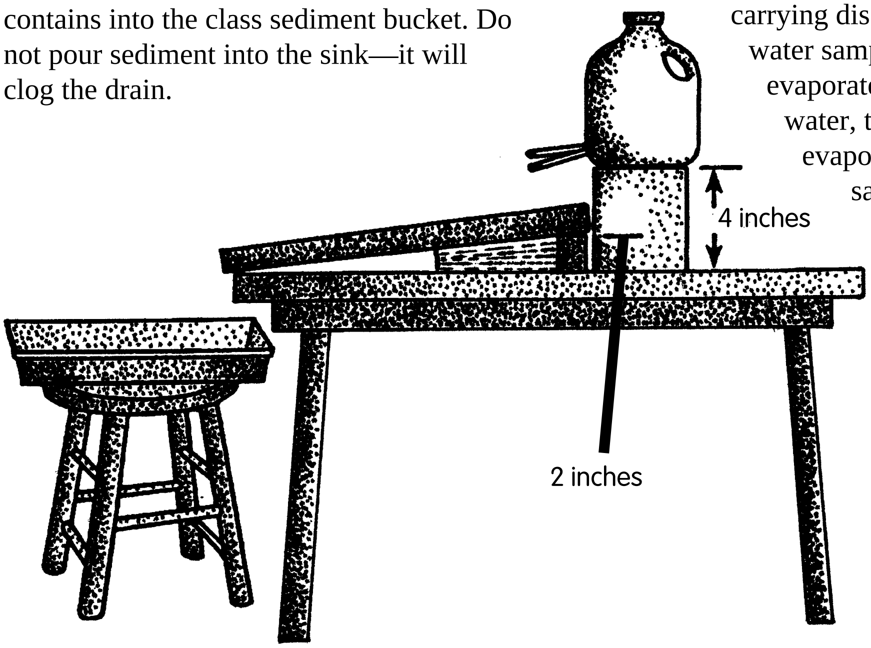
Sand

Allow water to flow from the hole in the jug. Drop a pinch of sand (no more than you can hold between two fingers) into the flowing water near the upper end of the trough and observe the movement of the sand particles.

You may see particles of sand bouncing along in the flowing water. This type of movement is called **saltation**. Both wind and water move sand in this way.

Answer the questions about the movement of sand.

After observing the motion of the sand, remove any sediment remaining in the trough. Empty the collecting pan and the sediments it contains into the class sediment bucket. Do not pour sediment into the sink—it will clog the drain.



Pebbles

Place four round and four flat pebbles in the upper end of the trough. Allow the water to begin flowing over them. Observe what happens and answer the questions about the movement of pebbles. After observing the movements of the pebbles, remove them from the trough. Empty the collecting pan into the class sediment bucket.

Clay

Put two pinches of powdered clay in a mixing cup of water and stir vigorously until the mixture appears cloudy. This clay-and-water mixture is called a **colloidal suspension**. Start the water flowing down the trough from one hole and pour the suspension of clay and water into the upper end of the stream. Observe what happens and answer the questions about the movement of clay. After observing the motion of the clay, remove any clay remaining in the trough. Empty the collecting pan into the class sediment bucket.

Salt solution

Use the eye dropper to add a small amount of salt solution to the upper end of the flowing stream of water. Observe what happens and answer the questions about the movement of solutions.

One way to tell whether or not a stream is carrying dissolved materials is to get a water sample and allow the water to evaporate. If salts are present in the water, they will **crystalize** as the water evaporates. Test for the presence of salt in the ion mixture as follows. Place two drops of the ion mixture on a clean microscope slide. Set the slide in a warm place and allow the water to evaporate. Use a hand magnifying lens (or microscope, if one is available) to observe what remains after the water evaporates. Sketch or describe your observations in the space provided for Question 7.

Questions

Sand

1. Imagine millions of grains of sand bouncing along in the water of a stream. How might the sand change the streambed?

   Millions of sand particles bouncing along a streambed act like a grinder, smoothing out the streambed and any large rocks lying in it.

2. Would the grains of sand be changed by bouncing along? In what way?

   Yes, the sand grains themselves become smoother and rounder from rubbing against the streambed and each other.

Pebbles

3. Describe how the pebbles move down the trough. Do round pebbles move in the same way as flat pebbles? How are their movements different? Which do you think would move down the stream the fastest? Why?

   Round pebbles roll down the trough. Flat pebbles slide along. The round pebbles move faster and are less likely to catch on other materials in the streambed.

4. How do you think the shape of the pebbles might change if they were moving down a stream over long distances?

   As rocks slide and tumble over one another and because of abrasive sediments like sand, they tend to develop smooth surfaces and rounded edges. The smooth, rounded gravel found in fast-moving mountain streams is produced in this manner.

Clay

5. How is the colloidal suspension transported by the stream? How fast do colloids move compared to sand or pebbles?

   Particles in colloidal suspensions are carried along suspended in the moving water of a stream. They move at the same speed as the water, faster than sand or pebbles.

Salt solution

6. Can you see the salt solution being carried by the stream? How fast do dissolved materials move compared to sand, pebbles, or colloids? Describe how solutions are carried by streams.

   You cannot directly observe solutions carried by streams. Like colloids, solutions move at the same speed as the water. The material is carried by the water in a form that is invisible to the naked eye, but can be detected by various tests, such as the one suggested.

7. If you tested for salt in the solution, describe or sketch the results of your test.

   The sodium chloride (NaCl, or table salt) used to prepare the ion solution will form cubic crystals.

8. List four ways streams move sediments.

   Sediments are transported:

   - ***in solution (like the salt dissolved in the water)***
   - ***as a colloidal suspension (such as clay particles that are too small to see individually, but give the water an overall milky appearance)***
   - ***by saltation (the bouncing motion of sand particles)***
   - ***by rolling and sliding (like rocks and boulders in a real streams)***

9. Is a faster-moving stream able to carry more, less, or the same amount of sediments as a slower-moving stream?

   A faster-moving stream can carry *more* ***sediments than a slower stream.***

10. Is a faster-moving stream able to carry larger, smaller, or the same size sediments as a slower-moving stream.

    A faster-moving stream can carry *larger* ***sediments than a slower stream.***

Going further

1. Use the following procedures to investigate how the speed of the stream affects the sediment it can transport.
   - Measure out two equal quantities of mixed sediments (consisting of sand, soil, and small pebbles).
   - Set the stream trough at a “low” setting (about an inch above the table) so that it will have a slow rate of flow.
   - Place one of the sediment samples at the upper end of the stream trough and time how long it takes the water coming from the one-hole jug to carry the sediments to the bottom of the trough.
   - Reset the stream trough at a “high” setting (4 inches above the table), increasing the speed of the water flowing though it.
   - Place the second sediment sample at the upper end of the stream trough and time how long it takes the water coming from the one-hole jug to carry the sediments to the bottom of the trough.
   - Compare the times required to move the sediments for the “slow” and the “fast” streams.
2. Design an experiment to determine the speeds needed to carry specific-size sediments or sediments of different densities.

Name

Go with the flow!

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Sediments are the fragments of rocks, minerals, and organic material produced by weathering and erosion. Sediments can be as large as huge boulders moved by flooding streams, as small as atom-sized minerals dissolved as ions or salts in stream water, or anywhere in between.

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Water is an important agent of erosion. Water running over the surface of the ground or in streams is constantly lowering and leveling the land above sea level. Waterborne sediments are the tools of the streams, carving out valleys and canyons as they move along. As anyone who has noticed the smooth, rounded rocks in a swift-running mountain stream may know, the tumbling and scraping tends to smooth and round the sediments as they move downstream.

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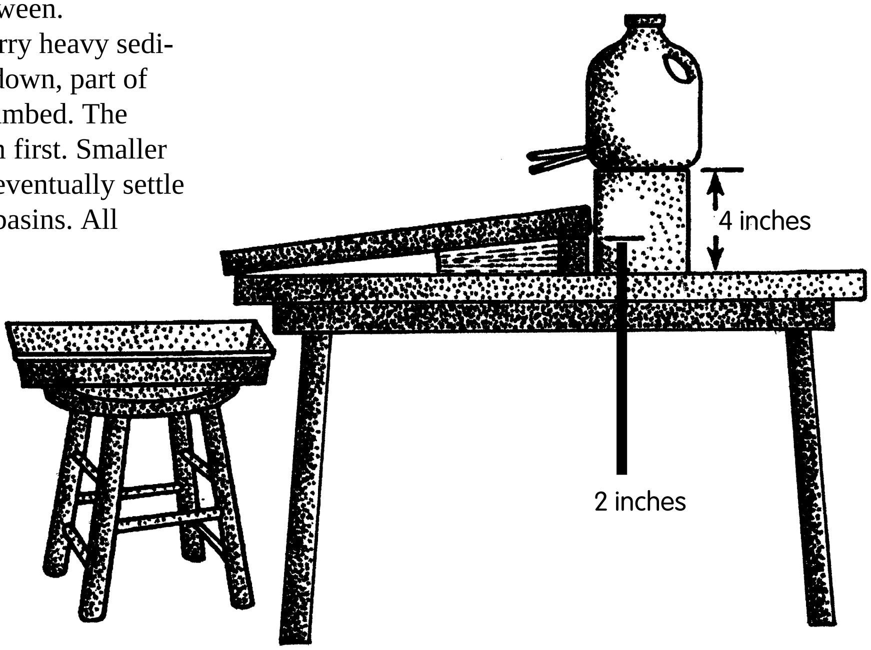

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Vocabulary

collodial suspension
saltation
sediments
suspended sediments

Student sheet

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Questions

Sand

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2. Would the grains of sand be changed by bouncing along? In what way?

Pebbles

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Clay

5. How is the colloidal suspension transported by the stream? How fast do colloids move compared to sand or pebbles?

Salt solution

6. Can you see the salt solution being carried by the stream? How fast do dissolved materials move compared to sand, pebbles, or colloids? Describe how solutions are carried by streams.

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9. Is a faster-moving stream able to carry more, less, or the same amount of sediments as a slower-moving stream?

10. Is a faster-moving stream able to carry larger, smaller, or the same size sediments as a slower-moving stream.

Student sheet

7.2 Water quantity

"Don't pray for the rain to stop. Pray for good luck fishing when the rivers flood."
— Wendell Berry

The quantity of water directly affects plants and animals that live in a stream and humans that use it. *Volume and velocity are key dimensions of water quantity.* These change with the season and are influenced by human actions, soil movement from erosion and landslides, and vegetation changes from fire, logging, grazing, disease and windstorms.

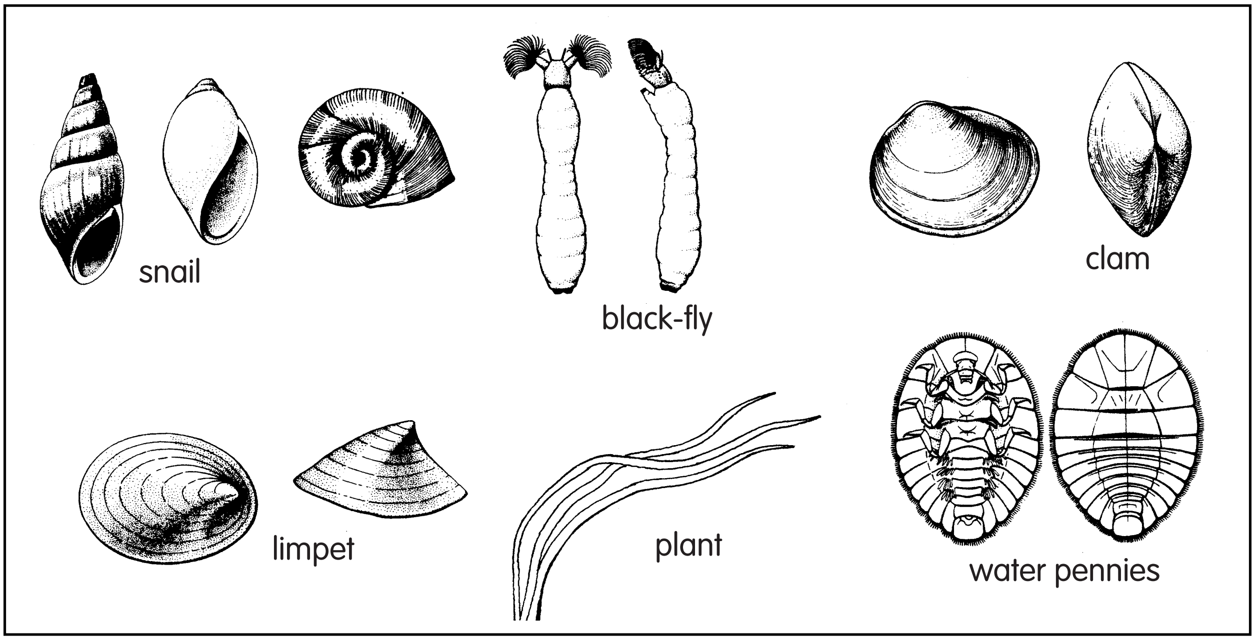
The volume of water affects composition of the streambed by moving and depositing sediments and debris. Fast-moving water carries more and larger material. The channel of a rapidly moving stream will have larger material, but a slowly moving stream will have a bed covered with mud and silt.

Velocity

Flow velocity is one of the main factors that determines the character of a stream. Velocity directly influences:

- dissolved oxygen (DO) concentration through aeration at the surface,
- water temperature through evaporation,
- composition of the streambed, and

Figure 9. Plant and Animal Adaptations to Water Velocity



Source: Kenneth W. Cummins and Margaret A. Wilzbach, *Field Procedures for Analysis of Functional Feeding Groups of Stream Macroinvertebrates,* 1985.

- amount of nutrients available to organisms.

Velocity is a measure of how fast water moves. Velocity is calculated in feet per second (velocity = ft/sec). The substrate also influences streamflow. A factor of 0.9 is used for smooth mud, silt or bedrock streambeds, and 0.8 for rubble, gravel or plant-covered streambeds. Streamflow (or discharge) is calculated in cubic feet per second (cfs). (Average width × average depth × velocity × bottom factor = streamflow in cfs.)

Volume and velocity are key dimensions of water quantity.

Adaptations to velocity

The rate at which a stream flows determines which plants and animals can live there. Plants adapted to fast water have strong, spreading roots for secure attachment. Their thin flexible stems offer little resistance to the current and have less chance of breaking. Algae adapted to fast flowing water have filaments that "stream" in the direction of the current.

Animals have a variety of adaptations. Clams and mussels burrow into the bottom avoiding the current. Blackfly larvae and limpets attach to rocks with sucker-like structures and use streamlined shapes to avoid being swept away. Water pennies have a streamlined, flattened shape. Snails adhere to the bottom with a broad foot. Fish and other organisms move to pockets of slower water.

Extensions

1. "We'll Form a Bucket Brigade," *Earth: The Water Planet*, pp. 85-89. Grades 4-8.
2. "Building A Model of A Stream," *Earth: The Water Planet*, pp. 35-38. Grades 4-8.
3. "What Factors Affect the Speed of A Stream?" *Earth: The Water Planet*, pp. 43-46. Grades 4-8.
4. "Calculating the Rate of Flow of A Stream," *Earth: The Water Planet*, pp. 39-42. Grades 4-8.

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A study in streamflows

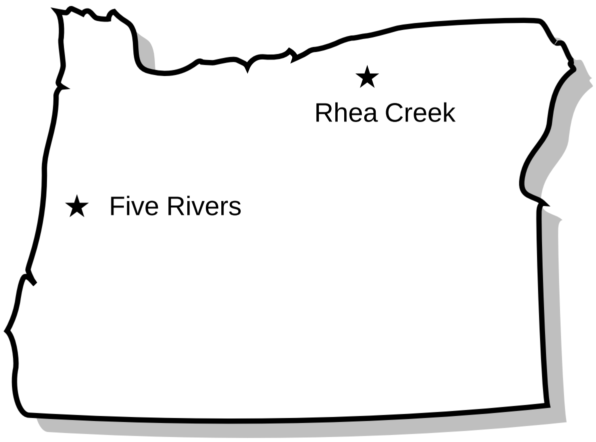
Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

Students will (1) examine annual streamflow rates for two Oregon streams; (2) compare streamflows in an eastern Oregon stream and a western Oregon stream in terms of peak flows, critical periods, and related water quality aspects; (3) calculate the number of people who could be supported by average and minimum streamflows in these streams; and (4) predict how streamflow patterns can affect fish, wildlife, and human populations.

Method

Students will graph annual streamflow patterns for two Oregon streams—one representative of eastern Oregon and one representative of western Oregon—then compare and contrast the two. In addition, students will calculate and compare how many people could be supported by the discharge (streamflow) in these streams.



Activity adapted from *Investigating Your Environment—Water*, Pacific Northwest Region, 1993 and earlier versions.

For younger students

1. Read activity background information aloud to younger students or modify for your students' reading level.
2. Enlarge the graph on a copy machine or use a large piece of graph or chart paper. Modify questions to fit student vocabulary levels.
3. Part 2: Calculate streamflow usage and use as an example with students. Questions for Part 2 may require significant modification.

Materials

- copies of student sheets (pp. 223-230)

Background

Do you know . . .

The amount of water in a stream varies throughout a year. We can predict some of this variation because it is related to the **climate** (long-term weather patterns) of a region. Other variations are harder to predict, because they are caused by removal of watershed vegetation, associated with urban development, agricultural practices, and logging and grazing practices.

When the vegetation is removed, the soil cannot store and hold as much water. This means more water will run off the watershed, creating

Vocabulary

climate	erosion
cubic feet per second	sediment

higher peak flows. Higher flows carry more **sediment** and **erosion** of stream channels is greater. Less water storage in the watershed also means lower minimum flows during dry periods, leading to higher water temperatures and reduced oxygen.

People manage watersheds so the water in the watershed can be used to the best advantage for the resource and all other concerns. It is easy to imagine how many uses there are for a stream's water—human drinking water, irrigation for crops, hydroelectric power, water transportation, and the needs of aquatic and terrestrial life, to name a few. When decisions must be made about what uses will have priority over a year's time, it is necessary to predict peak and minimum flows.

Obviously, it is beneficial to all uses to store water in a healthy watershed. Disturbed watersheds cannot store as much water and much of the water goes to waste. Water management is tricky business!

In the Pacific Northwest, precipitation comes primarily in the form of rain or snow, and lowest streamflows generally occur in late summer. Also, rainfall tends to affect streamflow more quickly than snowfall. Streams with snow as a water source tend to experience peak flows later in the spring when the snow is melting.

Procedure

Now it's your turn . . .

Are streamflows west of the Cascade mountain range different from those east of the Cascades? How many people can be supported by water in our streams? In this exercise, you will look at streamflow data from Rhea Creek, in northeastern Oregon, and compare it with Five Rivers, a stream in the western Oregon Coast Range. Then, you will learn how to estimate the number of people who could potentially rely on those streams for their water.

Part 1

Five Rivers is a tributary of the Alsea River in the Coast Range west of the Cascades. Rhea Creek is a tributary of Willow Creek in the Blue Mountains east of the Cascades.

Streamflow (discharge) rates combine the two key dimensions of water quantity (volume and rate of flow) into one figure—cubic feet per

Streamflow Data

Rhea Creek, near Heppner, Oregon

Drainage area: 120 mi^2
Altitude: 2,320 feet at measuring station
Many irrigation diversions above measuring station.

Average discharge: 18.9 cfs
Highest recorded maximum discharge: 1,280 cfs, June 10, l969
Lowest recorded minimum discharge: no flow at times

Mean discharge (streamflow) in cubic feet per second (cfs)

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5	10	21	37	48	63	35	18	19	6	2	2

Five Rivers, near Fisher, Oregon

Drainage area: 114 mi^2
Altitude: 130 feet at measuring station
No regulation or diversion above measuring station

Average discharge = 551 cfs
Highest recorded maximum discharge: 17,200 cfs, Jan. 21, l972
Lowest recorded minimum discharge: 16 cfs, Oct. 1, l967

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Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
223	552	1146	1423	703	721	613	186	111	60	34	30

Stream Discharge Comparison

second (cfs). **One cubic foot per second is a block of water one foot high, one foot across, and one foot deep, passing by a given point every second.**

Streamflows (discharge rates in cubic feet per second) vary throughout the year and may influence activities and aquatic life associated with streams. Plot monthly streamflow on the graph provided, using two colored lines. Create a legend that shows the appropriate color for each stream. After the graph has been completed, answer the questions that follow.

Note: This information includes only one year of streamflow data for these two streams. Varying seasonal conditions may change streamflow patterns over a number of years.

Questions

1. What could explain the peak flow of Rhea Creek occurring two months later than the peak flow of Five Rivers?

   Rhea Creek's source is melting snow rather than seasonal rainfall.

2. During which month would the most gravel and sediment be carried downstream in Five Rivers?

   January

   In Rhea Creek?

   March

3. Could streamflow influence or modify the temperature of a stream? What other factors could modify stream temperature?

   Yes. Shading, stream depth and the temperature of water coming into the stream.

4. Could streamflow affect the amount of dissolved oxygen in the water? How?

   Yes. Low flows mean less turbulence to mix air and water.

5. In which month(s) would you predict Five Rivers would have the lowest dissolved oxygen level?

   July through September.

   In Rhea Creek?

   June through October.

   Why?

   High temperatures reduce the ability of the water to hold oxygen.

6. What would be the two most critical periods for fish survival in Five Rivers or Rhea Creek? Why would these time periods be so critical to survival of fish?

   Lowest streamflow and highest streamflow. Low streamflows mean higher temperatures and less DO. High streamflows mean high velocity water and more suspended sediments.

7. What could fish or other wildlife do to survive these periods?

   During low flows, they could congregate where there are pools or migrate to other sources of water. During high flows, fish could find cover along edges or behind boulders to avoid being swept downstream. Wildlife must have water to drink. During drier periods, when streamflows are lowest, they must congregate near a water source.

8. What is the fate of fish or other wildlife in an area if streamflows are too low during critical periods?

   If streamflows are too low, fish and wildlife are in greater competition for the water, and they might die if the water source will not support the population.

9. How would irrigation diversions on a stream affect the fish in that stream? What information would a biologist need to know in order to manage the stream?
It would lower the amount of water in the stream and affect the ability of the fish population to survive. A biologist would have to know how much water is being withdrawn and when it is being withdrawn. Unfortunately, the critical period for fish is also the period when irrigation is needed most.

Part 2

Streamflow information is needed to estimate the amount of water available for use in a watershed. Generally, one needs to consider the period of time when flows are the lowest, in order to make decisions based on the amount of water available. In the following activity you will calculate the amount of water available for human use based on average streamflows and compare it with the number of people that could be supported by the minimum streamflows. **Average streamflow** refers to the average discharge over the entire 12-month period shown in the data and is listed in the Streamflow Data table on page 216 describing each stream system. **Minimum average streamflow** refers to the lowest mean discharge for any one month during the 12-month period covered by the data.

10. Predict the number of people that could be supported by the average streamflow for Rhea Creek.
Answers will vary.

Minimum average streamflow for Rhea Creek.
Answers will vary.

Minimum average streamflow for Five Rivers.
Answers will vary.

11. Use the following formulas to compute how many people could live from the water in these streams.

Rhea Creek

18.9	×	7.48	=	**141.4**				
Average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
141.4	×	60	=	**8,484**				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
8,484	×	1440	=	**12,216,960**	/	200*	=	**61,084.8**
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Rhea Creek

2	×	7.48	=	15
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second

15	×	60	=	900
Gallons of water/second		Seconds in minute		Gallons of water/minute

900	×	1440	=	1,296,000	/	200*	=	6,480
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Five Rivers

30	×	7.48	=	224.4
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second

224.4	×	60	=	13,464
Gallons of water/second		Seconds in minute		Gallons of water/minute

13,464	×	1440	=	19,388,160	/	200*	=	96,940.8
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

* The average person uses about 200 gallons of water a day for home use. This does not reflect each person's share of water used for industrial, public services, and commercial uses. (U.S. Office of Education figures.)

12. How did your predictions compare with the actual calculations for each of the situations above?
    Answers will vary.
13. In this activity, minimum average streamflows have only been considered with respect to the number of people that could be supported by these flows. If the minimum average streamflow required to support resident and anadromous (migratory) fish populations in the Five Rivers example was 20 cubic feet per second, then how many people would that exclude?

    20 × 7.48 = 149.6 gallons of water per second

    149.6 × 60 = 8,976 gallons of water per minute

    8,976 × 1,440 = 12,925,440 gallons of water per day

    12,925,440 ÷ 200 = 64,627.2 people.

14. If Five Rivers' flows were maintained for fish first and people second, how many people could be supported by the 30 cubic feet per second flow if 20 cubic feet per second of that amount were reserved for maintenance of the fish population? What does this example suggest about the conflicts for water usage?

    32,313.6 people. There are many demands on the available water supply and all must be carefully considered in management decisions affecting that water use.

15. Which of the following, average streamflow, maximum streamflow, or minimum streamflow, can be depended upon year-round?

    Minimum streamflow is the only amount that can be depended on year-round.

16. How can society change or affect the water quantity situation in a particular area?

    a. ***Human actions can destroy the natural functions of the watershed with poor management involving the practices of logging, agriculture, mining, road building, building construction, or livestock grazing.***

    b. ***Human actions can restore the natural functions of the watershed through better management decisions affecting practices which have in the past harmed the watershed's ability to provide plentiful, pure water.***

    c. ***Impoundments can be constructed to catch and store water during periods of high flows to be released during periods of low flow.***

Note: The pros and cons of these and other answers should be discussed to provide students with a fair treatment of the issues involved.

Going further

1. Design an experiment to measure the oxygen content of water at different temperatures and levels of agitation (or turbulence).
2. Make monthly streamflow measurements of a stream near your school (see Chapter 12 for the Streamflow Data Sheet). Compare your streamflow figures to those of Rhea Creek and Five Rivers.
3. Analyze historical streamflows for a river in your area and compare with present streamflows. Hypothesize reasons for differences, if any. Prepare a display to share the results of your research.

Name

A study in streamflows

Do you know . . .

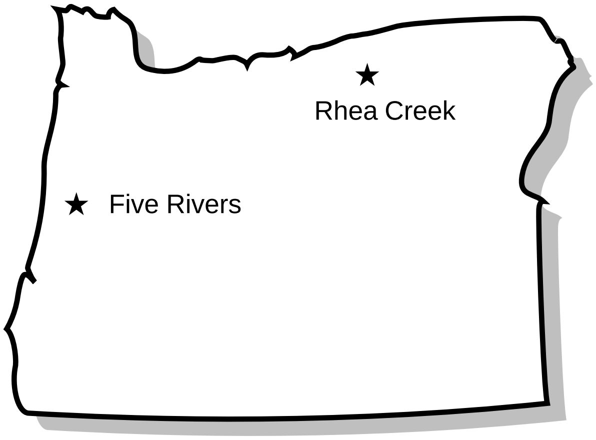
... that the amount of water in a stream varies throughout a year. We can predict some of this variation because it is related to the **climate** (long-term weather patterns) of a region. Other variations are harder to predict, because they are caused by removal of watershed vegetation, associated with urban development, agricultural practices, and logging and grazing practices.

When the vegetation is removed, the soil cannot store and hold as much water. This means more water will run off the watershed, creating higher peak flows. Higher flows carry more **sediment** and **erosion** of stream channels is greater. Less water storage in the watershed also means lower minimum flows during dry periods, leading to higher water temperatures and reduced oxygen.

People manage watersheds so the water in the watershed can be used to the best advantage for the resource and all other concerns. It is easy to imagine how many uses there are for a stream's water—human drinking water, irrigation for crops, hydroelectric power, water transportation, and the needs of aquatic and terrestrial life, to name a few. When decisions must be made about what uses will have priority over a year's time, it is necessary to predict peak and minimum flows.

Obviously, it is beneficial to all uses to store water in a healthy watershed. Disturbed watersheds cannot store as much water and much of the water goes to waste. Water management is tricky business!

In the Pacific Northwest, precipitation comes primarily in the form of rain or snow, and lowest streamflows generally occur in late summer. Also, rainfall tends to affect streamflow more quickly than snowfall. Streams with snow as a water source tend to experience peak flows later in the spring when the snow is melting.



Activity adapted from *Investigating Your Environment—Water,* Pacific Northwest Region, 1993 and earlier versions.

Vocabulary

climate
cubic feet per second
erosion
sediment

Student sheet

Now it's your turn . . .

Are streamflows west of the Cascade mountain range different from those east of the Cascades? How many people can be supported by water in our streams? In this exercise, you will look at streamflow data from Rhea Creek, in northeastern Oregon, and compare it with Five Rivers, a stream in the western Oregon Coast Range. Then, you will learn how to estimate the number of people who could potentially rely on those streams for their water.

Part 1

Five Rivers is a tributary of the Alsea River in the Coast Range west of the Cascades. Rhea Creek is a tributary of Willow Creek in the Blue Mountains east of the Cascades.

Streamflow (discharge) rates combine the two key dimensions of water quantity (volume and rate of flow) into one figure—cubic feet per second (cfs). **One cubic foot per second is a block of water one foot high, one foot across, and one foot deep, passing by a given point every second.**

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Streamflow Data

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Drainage area: 120 mi^2
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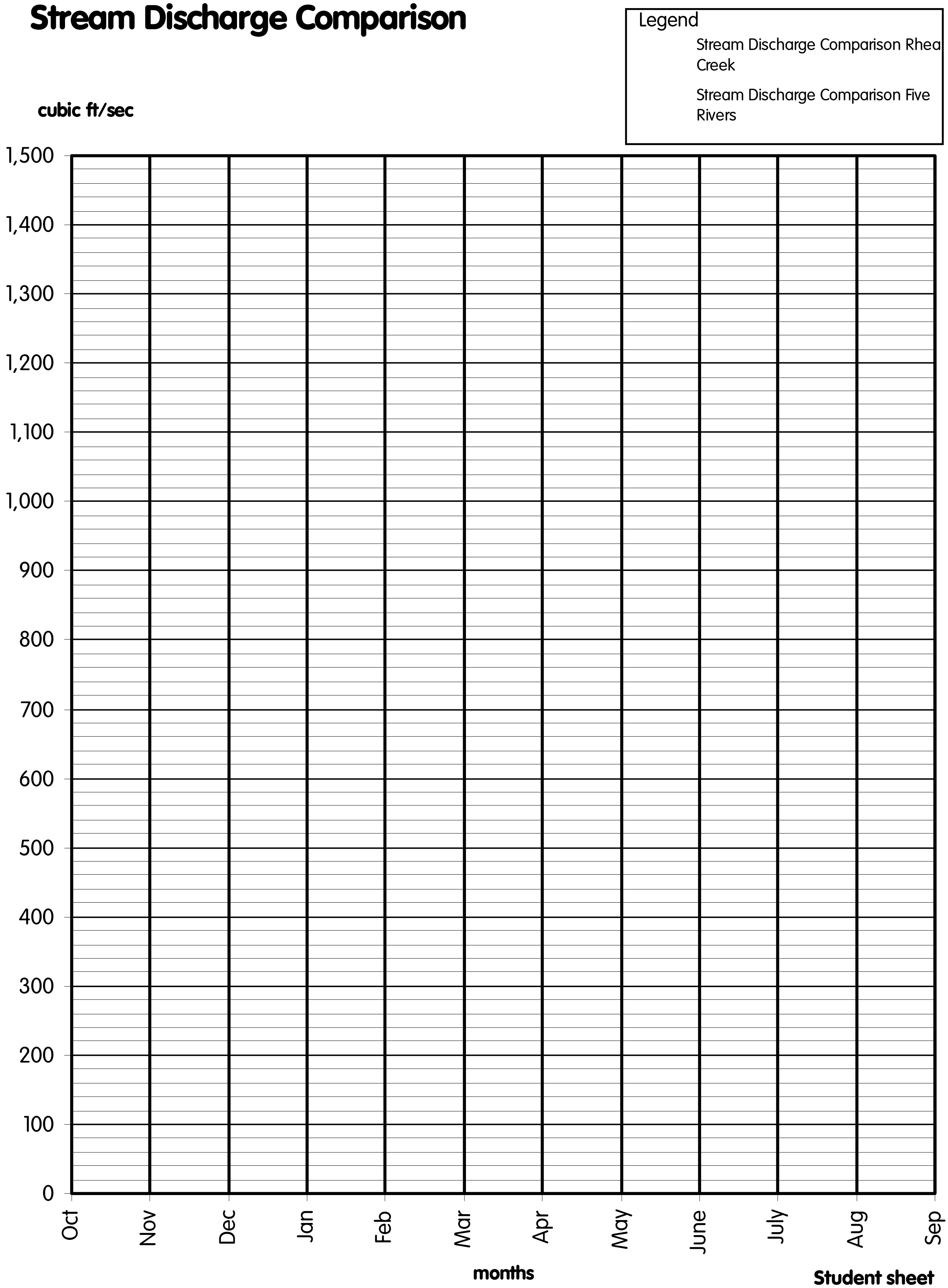
Student sheet

Stream Discharge Comparison



Questions

1. What could explain the peak flow of Rhea Creek occurring two months later than the peak flow of Five Rivers?

2. During which month would the most gravel and sediment be carried downstream in Five Rivers?

   In Rhea Creek?

3. Could streamflow influence or modify the temperature of a stream? What other factors could modify stream temperature?

4. Could streamflow affect the amount of dissolved oxygen in the water? How?

5. In which month(s) would you predict Five Rivers would have the lowest dissolved oxygen level?

   In Rhea Creek?

   Why?

6. What would be the two most critical periods for fish survival in Five Rivers or Rhea Creek? Why would these time periods be so critical to survival of fish?

7. What could fish or other wildlife do to survive these periods?

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Student sheet

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Streamflow information is needed to estimate the amount of water available for use in a watershed. Generally, one needs to consider the period of time when flows are the lowest, in order to make decisions based on the amount of water available. In the following activity you will calculate the amount of water available for human use based on average streamflows and compare it with the number of people that could be supported by the minimum streamflows. **Average streamflow** refers to the average discharge over the entire 12-month period shown in the data and is listed in the Streamflow Data table on page 224 describing each stream system. **Minimum average streamflow** refers to the lowest mean discharge for any one month during the 12-month period covered by the data.

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Minimum average streamflow for Rhea Creek.

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Rhea Creek

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____________________	×	_____60_____	=	__________________				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
____________________	×	__1440__	=	___________	/	____200*__	=	________
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Rhea Creek

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Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second

____________________	×	_____60_____	=	___________________
Gallons of water/second		Seconds in minute		Gallons of water/minute

____________________	×	_1440_	=	____________	/	____200*___	=	________
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Five Rivers

____________________	×	______7.48______	=	__________________
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second

____________________	×	_____60_____	=	___________________
Gallons of water/second		Seconds in minute		Gallons of water/minute

____________________	×	__1440__	=	____________	/	____200*___	=	________
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Student sheet

Streambed

7.3

"Regard now the sloping, mountainous rocks.
And the river that batters its way over stones…"
— Wallace Stevens

The bottom composition of a streambed determines the types of habitats and aquatic life found in a stream. Generally, the steeper the gradient and harder the rock layers, the faster and more narrow the stream will be. Gently sloping gradients and "S"-shaped curves characterize a slow moving stream. Different types of streams will have specific substrates, habitat types and aquatic organisms.

The **streambed** is the part of a stream over which water moves. **Substrate** is the mineral or inorganic material that forms a streambed.

Vocabulary

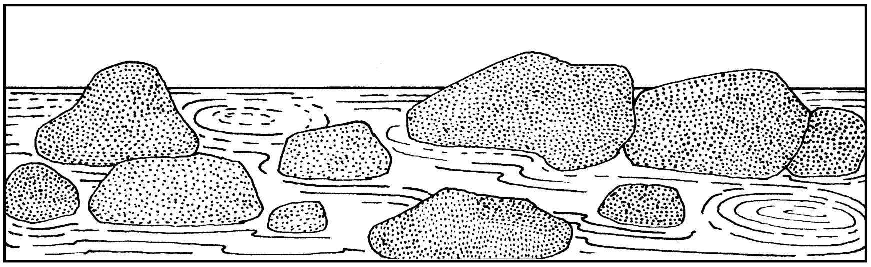
- body
- boulders
- cobble
- fine sediments
- gravel
- head
- lateral habitats
- pools
- riffles
- rubble
- streambed
- substrate
- tailout

Substrate types

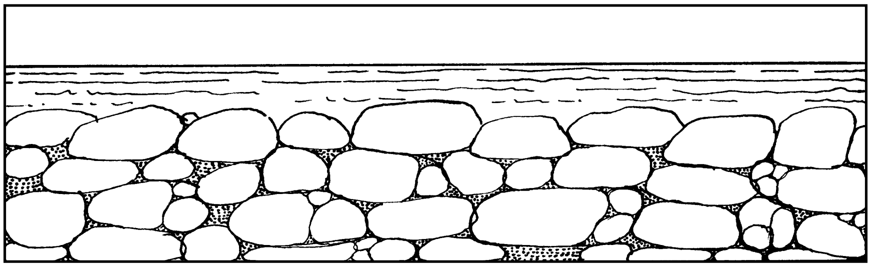
Boulders are 12 inches or more in size and are the largest substrate materials. Movement of water around boulders scours small pools in which fish rear and rest.

Rubble or **cobble** stabilizes the bottom of streams and provides habitat for fish rearing.

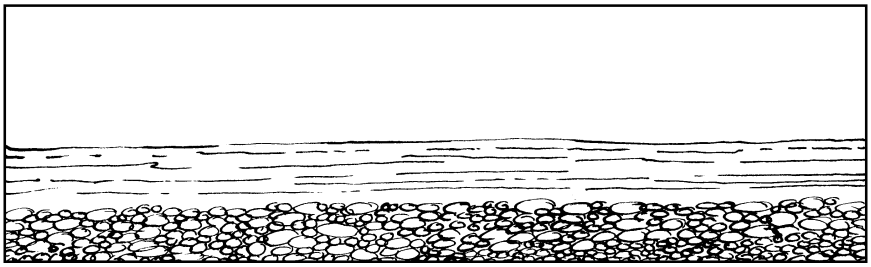
Boulders



Rubble or cobble



Gravel



Most fish food is produced in cobbled areas. Cobble ranges from 3 to 12 inches.

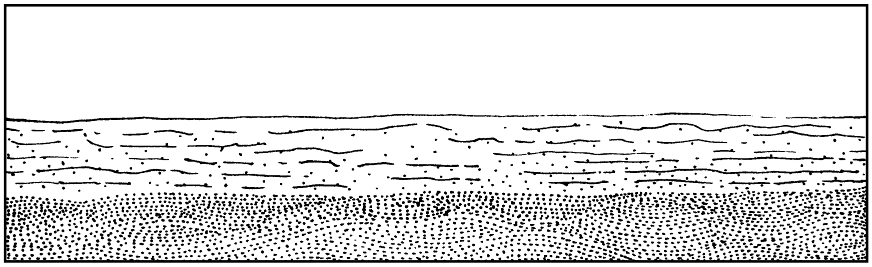
Gravel is 0.2 to 3 inches in size, (somewhere between peas and oranges in size). It provides habitat for spawning, egg incubation, and homes for aquatic invertebrates. Gravel must remain clean and porous so circulating water can bring enough oxygen to embryonic fish. Different species of fish require different size, depth and volume of gravel for spawning. Bigger fish need a larger area.

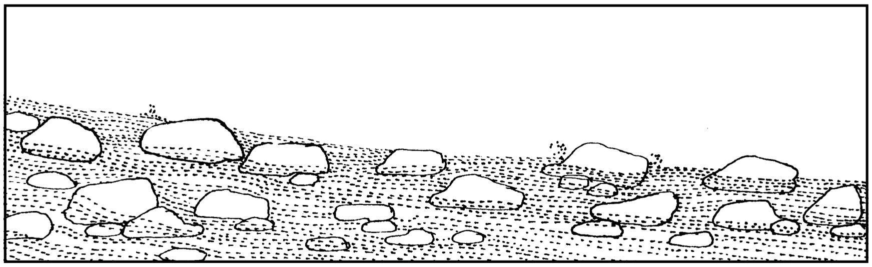
Fine sediments are less than 0.2 inch. “Large” fine particles can trap newly hatched fish in the redds and “small” fine particles decrease water percolation through spawning gravels. High sediment loads slow plant growth and reduce available food, oxygen and light.

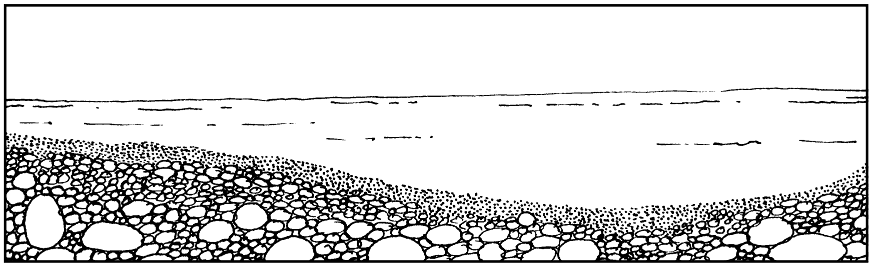
The substrate types described above create certain configurations in a streambed. These configurations form specific habitat types. Stream width, depth, velocity, and flow also contribute to habitat diversity within a stream.

> *Fish wait in pools for drifting insects.*

This diversity provides for specific needs of aquatic organisms, especially fish.


Fine sediments


Riffles


Pool

Stream habitats

Riffles are portions of a stream that are relatively shallow, fast and steep. They often have bedrock, cobbles, and sometimes boulders. In mountain streams, boulders and cobbles create rapids and cascades. As water rushes over these areas, the choppiness of the surface reflects the roughness of the bottom. Fish expend large amounts of energy to stay in riffle areas.

The sun shines through shallow riffle water and encourages algae to grow on the tops of rocks. The gravel and cobble bottom of a riffle provides nooks and crannies for insect larvae to live and feed. A rough cobble bottom slows water just above it, providing breaks, holding places and shelter for fish. Some organic material is scoured from the rocks and sent downstream to be used as food by aquatic organisms.

Pools are areas of deeper and slower waters often above and below riffles. Pools are important feeding and resting areas for fish. They are generally formed around stream bends or obstructions such as logs, root wads or boulders.

Pools contain three distinct areas: **head**, **body**, and **tailout**. Each part of a pool meets different fish needs. Turbulent water at the head collects food carried from upstream and provides cover and an area with a higher dissolved oxygen concentration.

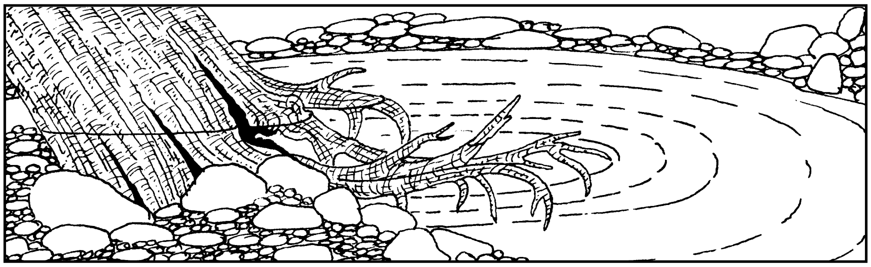
Slow water in the body of a pool indicates a reduced gradient. Organic material washes downstream, settles in pools, decomposes, and produces carbon dioxide and nutrients needed by plants in riffles. Drifting fine organic particles provide food for invertebrates. Fish wait in pools for drifting insects.

Gravel collects in pool tailouts. Fish use little energy to stay in this area and many wait here for food to pass by. Fish often use pool tailout areas with adequate flow as spawning beds.

The ratio of pools to riffles determines a stream's ability to provide suitable fish habitat. In general, a 1-to-1, pool-to-riffle ratio is optimum fish habitat.

Lateral habitats along the edges of streams are areas of quieter, shallow water. Boulders, root wads or logs can form small pools (pocket water or eddies). Fine sediments and gravels are found here. Accumulations of organic materials provide rich food sources for invertebrates. These areas provide important rearing habitat for young fish. Sculpins and crayfish wait for prey in pools near boulders or rootwads.

Lateral habitat



Illustrations in Chapter 7.3 adapted from original artwork by J. Nielsen, *Aquatic Habitat Inventory Glossary and Standard Methods,* American Fisheries Society, 1985.

Extensions

1. Create a model stream in an area of the schoolyard or use a stream table. Run water through the model stream. Observe the patterns of deposition and scour.

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