Winooski River Stream Table Unit

Companion Curriculum Guide

for the

Emriver Em2 Geomodel ("The Flume")

For Teachers and Students in Grades 4 to 8

This unit was developed for the Friends of the Winooski River (www.winooskiriver.org) by Jennifer Guarino of Ecotone Education and Verdana Ventures LLC with funding from the Lake Champlain Basin Program.

FRIENDS OF THE Winooski

Lake Champlain Basin Program

March 2017

Table of Contents

	Page Number
Introduction & Gratitudes	**4**
Unit Goal and Learning Objectives	**5**
Teaching With the *Winooski River Stream Table Unit*	**6**
Using the Stream Table	**12**
Streams & Watersheds Lesson (Before the Stream Table Arrives)	**13**
Lesson 1. Corridors & Channels	**17**
Overview	17
Lesson 1.1. Why Meanders Form	20
Lesson 1.2. The Changing Channel	20
Lesson 1.3. Stream Anatomy Parts	20
Lesson 1.3. Stream Anatomy Parts - Student Activity Sheet	23
Lesson 2. Water & Sediments	**24**
Overview	24
Lesson 2.1. Gravel Mining	26
Lesson 2.2. High Banks & Low Banks	26
Lesson 3. Streambanks	**27**
Overview	27
Lesson 3.1. Streambank Protection	27
Lesson 3.2. Streambanks & Habitat	28
Lesson 4. Stream Crossings	**30**
Overview	30
Lesson 4.1. Stream Crossing Experiments	32
Lesson 4.1 Stream Crossing Experiment - Student Activity Sheet, Grades 4 to 6	36
Lesson 4.1 Stream Crossing Experiment - Student Activity Sheet, Grades 6 to 8	38
Lesson 4.2. Community Crossings	40
Lesson 5. Upstream, Downstream	**42**
Overview	42
Option A. Farm to City	42
Option B. City to Farm	43
Lesson 5. Upstream, Downstream, Option A. Farm to City - Student Activity Sheet	45
Lesson 5. Upstream, Downstream, Option B. City to Farm - Student Activity Sheet	47
Lesson 6. Stream Erosion Prevention	**49**
Advanced Student Activity: Lane's Balance	**52**
Lane's Balance Scenarios – Student Activity Sheet	56
Glossary	**58**
Teaching Resources: An Annotated List	**60**
Teacher Evaluation Form – *Please Complete and Return!*	**62**

FIGURES

	Page Number
Figure 1. Sample 5-Day and 10-Day Units	7
Figure 2. Helpful NGSS Resources	8
Figure 3. NGSS Dimensions and Stream Table Education	8
Figure 4. NGSS Performance Expectations Addressed by Stream Table Education	10
Figure 5. The Water (Hydrologic) Cycle	13
Figure 6. Winooski Basin Map	14
Figure 7. Lake Champlain to Richlieu River	15
Figure 8. Helical Flow in a River	17
Figure 9. Comparing Inner Bend and Outer Bend	18
Figure 10. Channel, Meander Belt, and Buffer	19
Figure 11. Meanders & Corridors	22
Figure 12. Cross-section of a streambed before and after gravel mining	25
Figure 13. Streambank Materials and Habitat Benefits	29
Figure 14. A perched culvert	30
Figure 15. Recommended Width of a Stream Crossing	31
Figure 16. Improving the Rigor of the Stream Crossing Experiment	35
Figure 17. Types of Crossings, Pros and Cons	40
Figure 18. Diagram of Sawyer Brook and Surrounding Landscape	50
Figure 19. Stream Erosion Prevention Rubric	51
Figure 20. Lane's Balance	53

<u>INTRODUCTION & GRATITUDES</u>

In the summer of 2012, The Ottauquechee Natural Resources Conservation District (ONRCD, onrcd.org), based in White River Junction, Vermont, purchased a stream table to foster understanding of stream dynamics in Vermont communities. Called the Emriver Em2 Geomodel by its creator, Little River Research and Design (www.emriver.com), this tool is used for hydroscience research and education all over the world.

At that time, Vermont was recovering from Tropical Storm Irene, which hit the region in August 2011 with severe flooding that devastated numerous communities. ONRCD believed that allowing people to observe actual stream dynamics in a scaled-down model would help them understand how to work with streams to minimize future flood damage.

Jenny Hewitt, a teacher at the Pomfret School in Vermont, saw the stream table's potential for enhancing her watershed curriculum. She borrowed it from ONRCD in the fall of 2012 for her third/fourth grade class. Jenny's unit, developed in collaboration with Larry Kasden of ONRCD and Jennifer Guarino (jguarino556@gmail.com), Watershed Education Specialist with Ecotone Education, formed the basis of the *Vermont Stream Table Lesson Packet*.

Stream table fever hit New Hampshire in 2014, when the Maple Avenue School in Claremont, NH, borrowed it from ONRCD. The Sullivan County (NH) Conservation District purchased a stream table for New Hampshire schools in the fall of 2014. That year, Jennifer worked with Kevin Gianini, fifth grade teacher at Grantham Village School in Grantham, NH, to adapt the Vermont lesson packet for New Hampshire's schools and geographic setting to produce the *New Hampshire Stream Table Unit*.

Stream table education advanced another step in 2016 through the efforts of The Friends of the Winooski River, a non-profit organization in Vermont that is dedicated to the restoration and protection of the Winooski River and its tributaries. The Friends purchased a "flume", or stream table, and secured a grant from the Lake Champlain Basin Program to bring this dynamic teaching tool to its communities. The resulting ***Winooski River Stream Table Unit*** is another offspring of the original ONRCD publication, enhanced through experiences gained in multiple schools in two states and tailored for the communities in this particular watershed.

We are deeply grateful for ONRCD's permission to adapt their original work to support stream table education beyond their region. And we express our thanks to Mike Kline of the Vermont Rivers Program, who lent us his expertise on river dynamics. Through continuing collaboration among community organizations, schools, state agencies, and stream scientists, we can help people learn how to live in balance with the vital flowing waters in our communities.

As you use this unit with your own students, please consider ways you can foster its further development. A *Teacher Evaluation Form* is included on the last page to gather your feedback, or you can email us your comments directly.

<u>Contact</u>:
Larry Montague, Friends of the Winooski River
PO Box 777 Montpelier, VT 05601
802-882-8276 info@winooskiriver.org.

Unit Goal & Learning Objectives

Goal of the *Stream Table Unit*:

To educate school children and their communities about the ways streams behave and how people can live in harmony with streams.

Learning Objectives of the *Stream Table Unit*:

1. To understand how streams…
    - move over time within a predictable corridor
    - form meanders as they flow through valleys
    - create and follow a pattern
    - seek to balance energy by moving water and sediments
2. To demonstrate human impacts on a stream and the ways a stream responds. Human impacts include:
    - straightening, berming, and armoring
    - removing gravel
    - installing different sizes and types of stream crossings
    - opening and closing access to floodplains

TEACHING WITH THE *WINOOSKI RIVER STREAM TABLE UNIT*

The STREAM TABLE UNIT was created for use with the Emriver Em2 Geomodel (stream table or "flume"), which can be borrowed from the Friends of the Winooski River. Please see the FWR STREAM TABLE RENTAL PROGRAM MANUAL for more information, and to request the use of the stream table.

- These lessons are geared for students in **grades 4, 5, 6, 7 and 8**.
- **Each lesson** has the following parts:
  - An **Overview** section that provides context for the lesson. ***More Info*** boxes are included that direct you to resources that pertain to that lesson. Two such resources are used extensively in this lesson packet: Living in Harmony with Streams: A Citizen's Handbook to How Streams Work, prepared by the Friends of the Winooski River and partners; and *After the Flood: Vermont's Rivers,* a Youtube series of 4 videos made by River Bank Media.
  - A **Set-Up** box with information on how to prepare for the lesson.
  - A **Timeframe** box with a rough estimation of the time needed to teach the lesson.
  - A **Materials** box that lists items needed for each part of the lesson.
  - **Instructions** for teaching each part of the lesson.
- Some lessons have ***Student Activity Sheets,*** which can be copied for student work and used to assess student learning.
- An **Advanced Lesson on the Lane's Balance** is provided for students who need a challenge and/or for teachers interested in fostering engineering thinking and practices.
- A **Glossary** of terms used in this unit is included after the lessons.
- An annotated list of **Teaching Resources** is provided for more information.
- A **Teacher Evaluation Form** is included to gather feedback on the unit for future improvement. *Please complete this form and send it to* Larry Montague: info@winooskiriver.org, Friends of the Winooski River, PO Box 777 Montpelier, VT 05601, 802-882-8276.
- The Friends have developed the FWR STREAM TABLE RENTAL PROGRAM MANUAL to accompany this stream table unit, which includes set-up and maintenance guidance. Please contact The Friends.

Curriculum Planning

We recommend that teachers who are new to the stream table borrow it for 1 week. As teachers become familiar with it, many choose to extend their curriculum over two weeks. Please contact The Friends to discuss its lending program and your curriculum interests in using it.

Below are sample units based on the use of the table for 5 days and 10 days. We would love to hear from you as you adapt this unit to your own teaching goals, environment, and students. Please send us your ideas through the enclosed ***Evaluation Form*** or through email. We look forward to hearing from you!

We recommend that you hold a ***Parent-Community Night*** toward the end of your time with the stream table. During this event, students can teach what they've learned to adults and other children, extending the learning into the community and providing a powerful opportunity for student self-assessment.

Figure 1. Sample 5-Day and 10-Day Units

Most teachers borrow the stream table for 5 or 10 school days. Here are suggested unit formats for these two timeframes.

Before the stream table arrives:

- ❒ Determine how you will get the table to your school and then return it to The Friends.
- ❒ Consider your goals and student learning outcomes for the unit; decide which lessons to teach.
- ❒ Decide whether other classes will use the table and, if so, set up a schedule for their visits.
- ❒ Review the *FWR Stream Table Rental Program Manual* to become familiar with set-up, maintenance, and take-down procedures.
- ❒ Discuss guidelines and expectations with your students for using the stream table.
- ❒ Do the *Streams & Watersheds Lesson* in this unit with your students.

Once it's in your school:

- ❒ Teach students how to run it and maintain it properly and safely.
- ❒ Discuss a system for keeping all of the pieces organized.
- ❒ Decide how you will pack up the stream table, and whether you will involve students in this process.

A Sample 5-Day Unit

Lessons are in italics; those with student assessment sheets are <u>underlined</u>

Mon	Tues	Wed	Thurs	Fri
Lesson 1: Corridors and Channels	*Lesson 2: Water & Sediments*	*Lesson 3: Streambanks*	<u>*Lesson 4: Stream Crossings*</u> Parent / Community Night	<u>*Lesson 5: Upstream, Downstream*</u>

A Sample 10-Day Unit

Lessons are in italics; those with student assessment sheets are <u>underlined</u>

Mon	Tues	Wed	Thurs	Fri
Allow students to visit the stream table in pairs or small groups. Ask them to record Observations, Thoughts, and Questions as they explore in an unstructured way. This discuss their thoughts.	*Lesson 1: Corridors and Channels*	*Lesson 2: Water & Sediments*	Introduce students to the scientific method, and explain that each experiment begins with a question that can be tested using this method. Discuss the Questions generated on Monday during unstructured explorations. Choose one Class Question that is *testable* and ask pairs of students to design an experiment to test it.	*Lesson 3: Streambanks*
Allow each student pair to take turns implementing their experiment on the stream table and gathering data. Have each pair present its work to the class. Discuss their exper. design and results. As a class, formulate a set of conclusions that capture student learning.	*Lesson 4: <u>Stream Crossings</u>*	<u>*Lesson 5: Upstream, Downstream*</u>	<u>*Lesson 6: Stream Erosion Prevention*</u> Have students complete this lesson and present their work at a Parent / Community Night	<u>*Lesson 6: Stream Erosion Prevention*</u> Have students discuss their Parent / Community Night presentations. Topics could include: • Their experience presenting their work • Questions and feedback from their audience • How they could improve their work the next time.

THE NEXT GENERATION SCIENCE STANDARDS

In the spring of 2013, Vermont and 25 other states adopted the *Next Generation Science Standards* (NGSS), which are built on the *Framework for K-12 Science Education* developed by the National Research Academy in 2011.

NGSS introduced a new approach to teaching standards. Three dimensions – *Science and Engineering Practices*, *Disciplinary Core Ideas*, and *Cross-Cutting Concepts* – are intertwined to help students learn science content and gain important process skills. Starting in the fall of 2013, the Vermont Agency of Education launched a plan to implement NGSS in Vermont schools.

Figure 2. Helpful NGSS Resources

- Next Generation Science Standards http://www.nextgenscience.org/
- Vermont Education Exchange: A site for educators to share what works in classrooms; see NGSS page. http://ve2.vermont.gov/vt_science/n_g_s_s
- *Developing and Using Models for NGSS*, a video by Gail Hall, math and science coordinator, Vermont Agency of Education and Robin Bebo Long, science teacher, Cavendish Elementary https://www.youtube.com/watch?v=D1BU20gsc6Y&feature=youtu.be

THE WINOOSKI RIVER STREAM TABLE UNIT represents a powerful way to address many parts of NGSS. It emphasizes key components of the three NGSS dimensions and represents a powerful way to teach both *science* and *engineering*. Figure 3 below highlights practices, disciplinary core ideas, and cross-cutting concepts that align with this stream table unit. Please note that the unit can also address many other NGSS components, but we chose a subset of standards that we believe fits especially well.

The stream table is an effective *scientific model*. In the video, Developing and Using Models for NGSS, Gail Hall of the Vermont Agency of Education explains that a scientific model is useful for helping to predict or explain a system. Please see Figure 2 for the Youtube website where you can find this video.

Figure 3. NGSS Dimensions & Stream Table Education

Science and Engineering Practices	Disciplinary Core Ideas (DCI)	Cross-Cutting Concepts
• Asking questions and defining problems • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations and designing solutions • Engaging in Argument from Evidence	• ESS2.A. Earth Materials and Systems • ESS2.C. The Roles of Water in Earth's Surface Processes • ESS3.B. Natural Hazards • ESS3.C. Human Impacts on Earth Systems • EST1.A. Defining and Delimiting Engineering Problems • ETS1.B. Developing Possible Solutions • ETS1.C. Optimizing the Design Solution	• Patterns • Cause and Effect • Stability and Change • Systems and System Models • Influence of Engineering, Technology, and Science on Society and the Natural World

Figure 4 below includes four Disciplinary Core Ideas (ESS2.A, ESS3.C, ETS1.B and ETS1.C), examples of Performance Expectations for grades 4, 5, and 6-8 (middle school) connected to each of these DCIs, and lessons in this unit that can be used to assess student learning of the standards. STUDENT ACTIVITY SHEETS contained in this unit can be used to assess student learning and gauge achievement of the NGSS standards identified here.

For more information about the *Next Generation Science Standards*, the *Framework for K-12 Science Education*, and the work of the Vermont Agency of Education, please contact:

Kathy Renfrew
Grade K-5 science and math assessment coordinator
Vermont Agency of Education
kathy.renfrew@vermont.gov; (802) 479-1448

Figure 4. NGSS Performance Expectations Addressed by Stream Table Education (Some Examples) (http://www.nextgenscience.org/)				
Grade-Level Performance Expectations (examples)	Disciplinary Core Ideas			
	ESS2.A Earth Materials and Systems	ESS3.C Human Impacts on Earth Systems	ETS1.B Developing Possible Solutions	ETS1.C Optimizing the Design Solution
4th Grade	4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [*Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]	4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]	3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
5th Grade	5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]	5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.		

Middle School (6^{th} – 8^{th} Grades)	MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]	MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]	MS-ETS-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	MS-ETS1.3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
Unit Lessons for Performance Expectations	Lesson 1: Corridors & Channels Lesson 2: Water & Sediments	Lesson 4: Stream Crossings Lesson 5: Upstream, Downstream	Lesson 3: Streambanks Lesson 5: Upstream, Downstream	Lesson 6: Stream Erosion Prevention

USING THE STREAM TABLE

The WINOOSKI RIVER STREAM TABLE UNIT was designed to accompany the Emriver Em2 geomodel (often called the stream table or "flume"), an educational tool that models stream dynamics and human impacts on streams through demonstrations and hands-on activities. The Friends of the Winooski River has purchased a stream table for education and outreach activities and is lending it to communities within the Winooski River watershed.

Little River Research and Design is the maker of the Emriver Em2 geomodel. This company provides services in river science and conservation, including applied river geomorphology, biotechnical engineering, urban stream management, river ecosystem restoration and science education. Their website, http://www.emriver.com, offers rich and varied resources for stream table education.

Stream Table Location, Set-Up, and Management

The stream table's dimensions are roughly 3 feet by 6 feet and its footprint is about 8 feet by 10 feet (this allows students to surround the table comfortably). It comes with all needed equipment for operation as well as a floor tarp that is laid down before the table is set up.

Experienced stream table assemblers can set it up in about 45 minutes (including time to bring all equipment into the building). A person new to its set-up should allow up to 2 hours. For more information, please view the following manuals:

- ***Use and Care of the Emriver Em2 Geomodel*** by Little River Research and Design: http://www.emriver.com/wp-content/uploads/2011/09/Emriver_Em2x_manual_2012_05-02_AQ.pdf
- ***FWR Stream Table Rental Program Manual*** by The Friends of the Winooski River.

Recommendations for choosing a location and managing the stream table:

- Many schools put the stream table in a classroom, but some put it in a common space in the school, like an extra classroom or a lobby. *Please note: If the stream table is in a common space, student access to it should be controlled. See below.*
- The stream table combines "sediments" (small plastic particles), running water, electrical equipment, and an electrical cord. Students should always be supervised around the stream table.
- The stream table requires 25 gallons of water. You need easy access to a sink to fill up its reservoir.
- Because it contains sediments and water, the stream table tends to be messy. Please consider this when deciding on its location.
- Please consult the **Emriver Em2 Specifications** webpage for a full list of equipment in photos and words: http://www.emriver.com/?page_id=382.
- When the stream table is not being used, please cover it with a tarp or tablecloth. Some teachers also place a sign on it that reads "Stream Table Closed". This prevents students from playing with it when they are not supervised.

To reserve the stream table in the Winooski River watershed, please contact:

Larry Montague, The Friends of the Winooski River, PO Box 777, Montpelier, VT 05601
info@winooskiriver.org or 802-882-8276

STREAMS & WATERSHEDS LESSON

*(Complete with students **before** the stream table arrives)*

SET-UP none **TIMEFRAME** 30 to 45 minutes	**MATERIALS** • Winooski River Basin Map (Figure 3 or TEACHING RESOURCES), or an appropriate map of your river's watershed • Richlieu River Basin Map (Figure 4) • An atlas or road map that includes the students' town and school • Water Cycle illustration (Figure 2)

OVERVIEW

Every stream is the result of gravity pulling water downhill over a particular landscape. Raindrops that fall on high points of land course down the slope and join other drops of water, forming a small brook that continues to flow downward. A brook eventually joins other brooks, creating a stream. Streams join other streams to form a river, and so on down the slope until the gathering waters collect in the lowest valley. Eventually, this collected water flows out its "mouth" into another water body: a larger river, a pond, a lake, a wetland, or the ocean. At every step in this process, water evaporates back into rain clouds, powering a continuous water cycle.

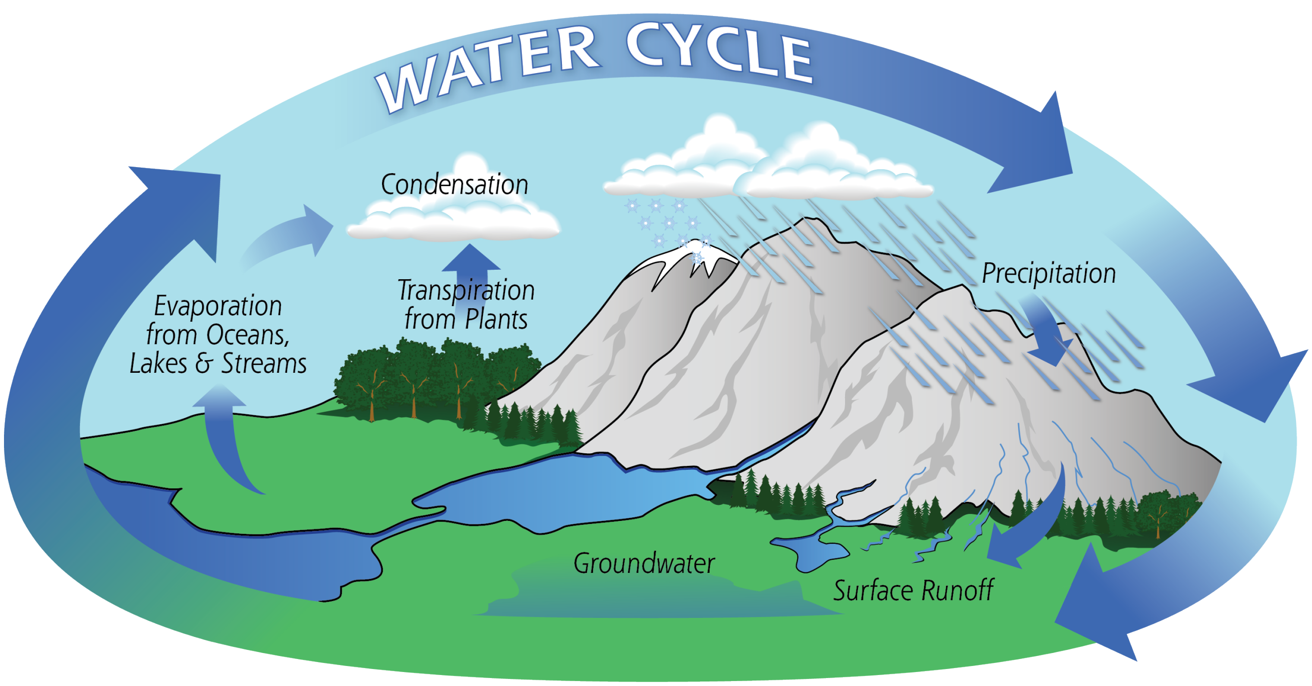


Figure 5. The Water (Hydrologic) Cycle

(From the National Aeronautics and Space Administration's (NOAA) Precipitation Education Program: http://pmm.nasa.gov/education/water-cycle)

All connected flowing waters create a *river system*, which occupies a basin of land called a *watershed* (see GLOSSARY). The brooks and streams that form at high elevations comprise the *headwaters* of the watershed. They come together to create *tributaries*, which flow into the *mainstem* (the largest river at the lowest elevation in the watershed).

Please note: The stream table represents one slice of a watershed and one section of a mainstem; it does not include the whole imaginary basin in which this model stream flows, or any tributaries flowing into the mainstem on the table.

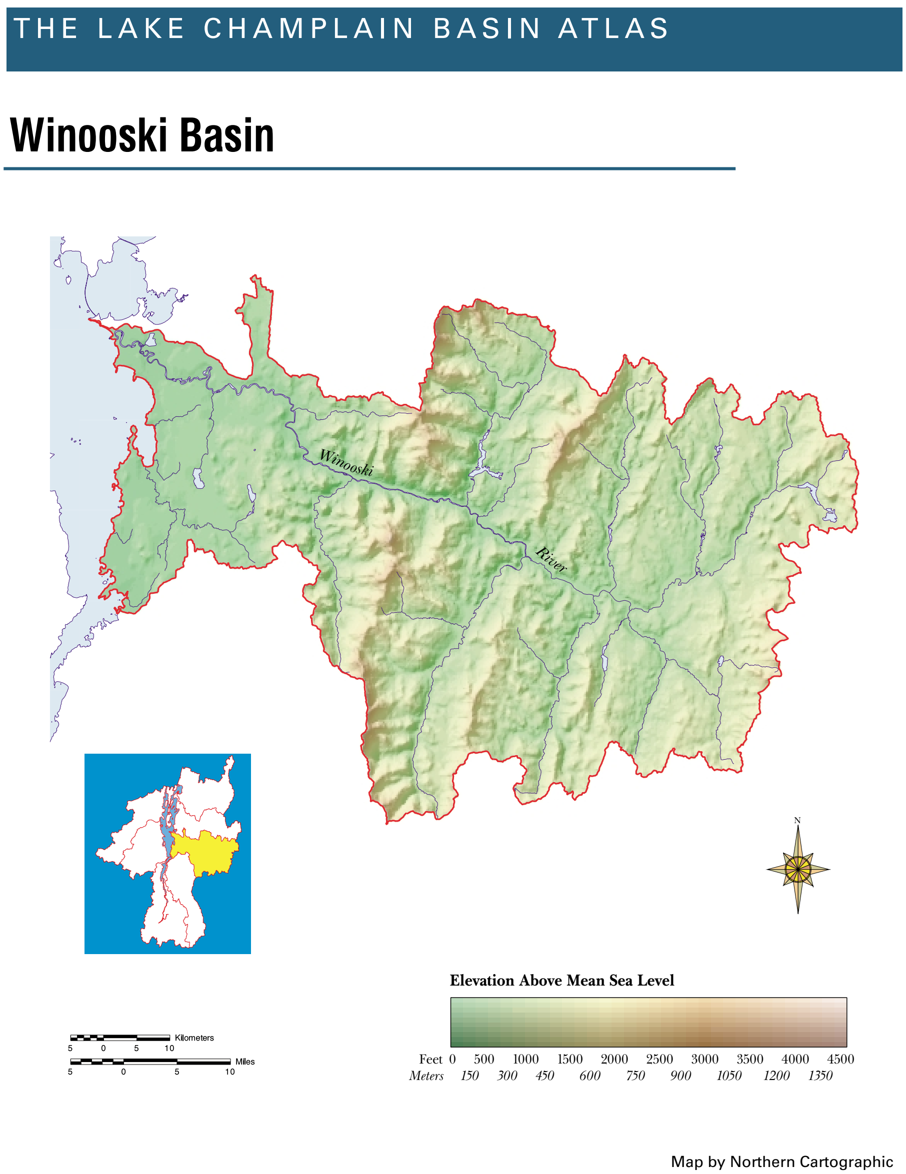


Figure 6. Winooski River basin (watershed) boundary, topography, and river system. The small map shows the Winooski basin within the larger Lake Champlain basin.

(From Nature of the Basin: Lake Champlain Basin Atlas: http://atlas.lcbp.org/HTML/nat_winooski.htm)

Figure 7. Lake Champlain Basin drains into Richlieu River, which then flows into the St. Lawrence River. From there, it flows northeast to join the Atlantic Ocean.

(From Wikimedia Commons: https://commons.wikimedia.org/wiki/File:Champlainmap.png)

MORE INFO:
Living in Harmony With Streams booklet, page 8:
http://www.winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf

STREAMS & WATERSHEDS LESSON INSTRUCTIONS

Introduce students to the definition of *watershed* (see GLOSSARY). Show them the Winooski River Basin Map (Figure 3 above) or a watershed map of their area.

Explain that every *river system* drains a basin (watershed) of land, from the highest elevations (the "rim" of the basin) to the lowest valley. A river system flows out its "mouth" into another river, a pond, a lake, a wetland, or the ocean.

Have students find the location of their town on the watershed map, their school, and their homes (if, in fact, their homes are within this watershed). When water leaves their river system, where does it go? (into Lake Champlain). Where does the water go after that? (into the Richlieu River, then to the St. Lawrence River, then into the Atlantic Ocean. See Figure 4 above).

Explain that water in any watershed is part of the hydrologic (water) cycle, which continuously circulates water through our atmosphere and our earth's crust. Show students the NASA water cycle diagram above (or another one) and have them trace the flow of water through this cycle.

LESSON 1. CORRIDORS & CHANNELS

SET-UP	TIMEFRAME FOR LESSON 1 (1.1, 1.2, AND 1.3)
• Make Stream Anatomy Part signs (Student Activity Sheet) • Get the stream table ready to run.	60 minutes

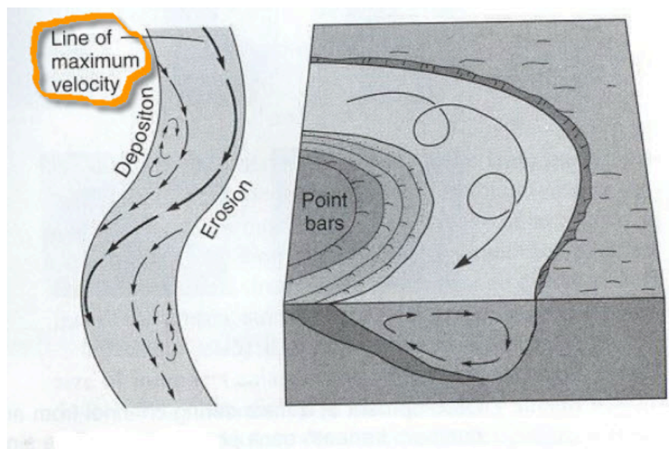
OVERVIEW

Flowing water carries energy as it courses across a landscape. This energy, and the water's natural "corkscrew" motion, erode a *channel* through the landscape and often create bends called *meanders*. (You can see the same meandering motion as you watch a water drop move down your car's windshield while the car is still: the drop twists from side to side rather than running straight down.) The friction of water molecules hitting each other and other obstacles in their path initiates the twist.

The corkscrew motion of flowing water is called "helical flow" by fluvial geomorphologists (scientists who study the physical processes that shape rivers). As meanders form, the fastest part of the flow is carried into an outer bend, where it piles up along the bank. As the current pushes this water along, it drops down the bank, eroding the bank and losing velocity. The water along the inner bend continues to corkscrew but its slower flow carries less energy. Here, the current rises up to the surface, dropping its load of sediment. Because of helical flow, a river carves its outer banks and deposits sediment at its inner banks. (Figure 9) For more information about helical flow in rivers, please see the MORE INFO box below.

Figure 8. Helical Flow in a River

(http://thebritishgeographer.weebly.com/river-landforms.html)

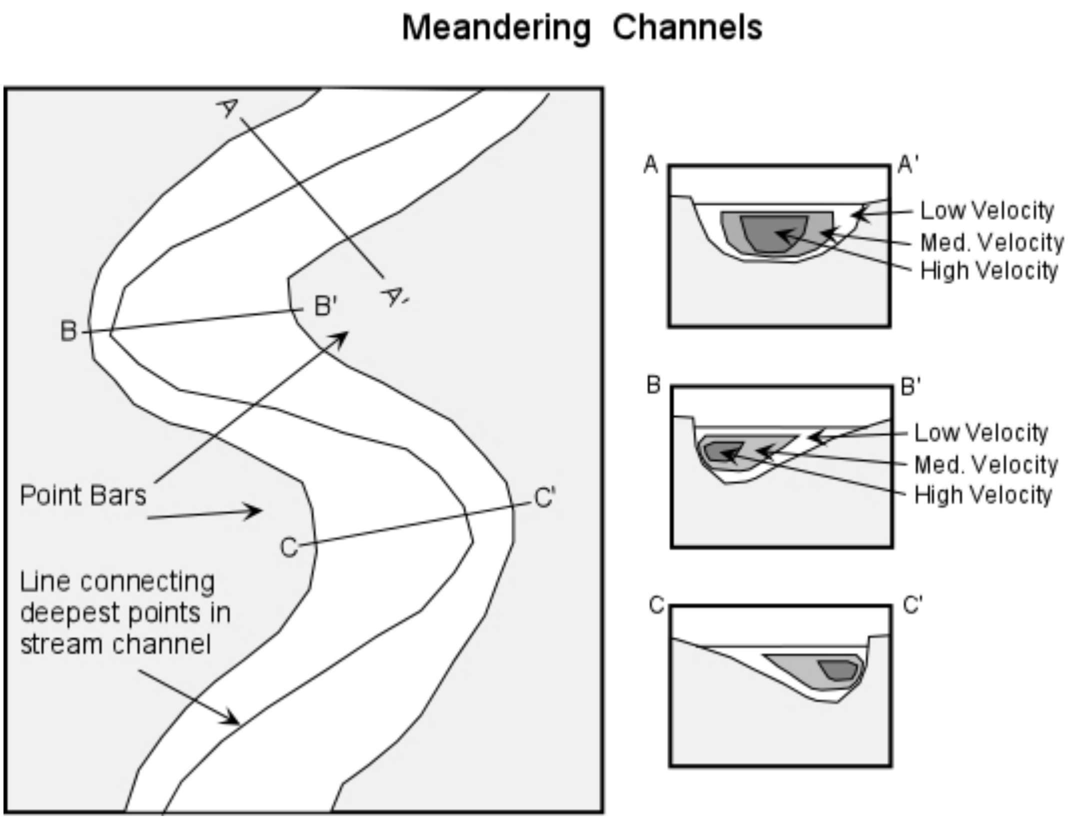


Helical flow in a meander.

On the landscape, a stream continually carves into its bends, eroding the soil and making the bends more pronounced over time. This process lengthens the stream and makes the stream's slope more gradual, which slows down the water. As flowing water hits the bends, it loses some of its energy and is further slowed. In this way, meanders help to absorb the force of the stream moving through the landscape.

A skier making turns down a snowy slope models a stream's meander pattern. As the skier turns to the left, her outer (right) ski travels a bit further and moves faster, pushing forcefully against the snow and carving into the outside of the curve. The inner (left) ski moves slower and carries less force. In between turns, her skis move at equal speeds, producing less overall pressure on the snow. As she turns from side to side, she slows down, transfers some of her energy into the slope, and lengthens her route down the mountain. Both the skier's turns and the stream's carving action create a *meander belt,* the side-to-side (lateral) extent of a series of meanders (see GLOSSARY). A stream's meanders can change over time, depending on many factors. A big storm can cause significant movement, as seen in the aftermath of recent large flooding events.

Figure 9. Comparing Inner Bend and Outer Bend (in vertical cross-section)
(https://www.geocaching.com/geocache/GC36NKM_meander-on-over?guid=94355dce-ffc7-49c4-9a83-d90e74f09ce0)



Inner Bend (depositing)
- slow velocity – drops sediments from upstream; often forms a *point bar*
- gradual slope
- shallow water
- smaller particles of sediment on bottom

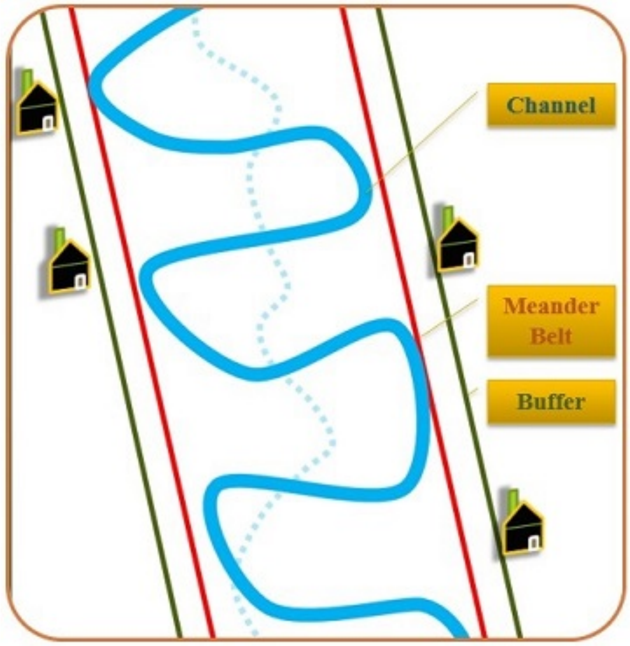
Outer Bend (eroding/scouring)
- fast velocity – carries sediments from upstream and erodes more sediments from the bend
- steep, sometimes concave (undercut) slope
- deep water
- coarser particles of sediment on bottom

Each meander in a stream has a similar profile in a vertical cross-section. The inner bend has slower water and a gradual slope, while the outer bend has faster water and a steeper slope. Sometimes a *point bar* of deposits forms within the inner bend. The erosive force of the water gouging the outer bend often forms a steep or concave *cut bank.* The table in Figure 9 summarizes the physical conditions found in each location.

A stream channel meanders within a broader *corridor*, which is defined as the land that includes the active channel of a stream, its meander belt, the *riparian buffer* along the stream, and the stream's *floodplain* (see GLOSSARY and Figure 10 below).

Figure 10. Channel, Meander Belt, and Buffer within a river corridor

(From Vermont Department of Environmental Conservation, River Corridor and Floodplain Maps: http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/river-corridor-and-floodplain-maps)



The stream table models an *alluvial* stream, which erodes and deposits sediments, forming meanders in the process. Please note that not all streams form meanders. For example, mountain (non-alluvial) streams tend to drop straight down steep gradients. They dissipate their energy as they flow across rough, rocky beds and over cascades and falls. There is little soil to erode along the banks and streambed, and therefore little sediment to move downstream.

MORE INFO:

Living in Harmony with Streams booklet, page 10 – 11

Aquatic Hydraulics: Helical Flow, Oxbow River and Stream Restoration: http://www.oxbowriver.com/Web_Pages/Stream_Ecology_Pages/Ecology_Aquatic/Ecology_Helical.html

Introduction to River Processes, The British Geographer: http://thebritishgeographer.weebly.com/river-processes.html

River Processes and Landforms (Youtube video of helical flow and meander development): https://www.youtube.com/watch?v=m7xwWGXUCXA&list=PLD6F7281C06931F4C&index=14

Little River Research and Design Educational Videos: http://www.emriver.com/?page_id=1521

- Emriver straight channel simulation
- Grand River remeandering, 1939-1996
- Grand River remeandering comparison

After the Flood videos: http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: Staci Pomeroy using stream table; starting at 4:08 minutes
- Video 1: straightening a stream; starting at 8:13 minutes
- Video 2: river corridor; starting at 5:50 minutes
- Video 2: urban areas, mitigating flood damage, and berms; starting at 9:09 minutes
- Video 3: straightening a river; starting at 6:38 minutes

LESSON 1 INSTRUCTIONS

Lesson 1.1. Why Meanders Form

> **MATERIALS**
> - stream table
> - student science notebooks, or sheets of paper on clipboards
> - pencils

Give each student a science notebook, or a sheet of paper on a clipboard, and a pencil. On the stream table, use your hand to create a straight channel from top to bottom. Ask students to observe what happens as you turn on the water and let it flow for a few minutes. Then ask them to write down 3 of their observations. (Another option is to have students draw a before and an after picture of the channel.)

They will see bends (meanders) form along the channel. Why does this happen?

(Flowing water moves in a corkscrew pattern, which eats into the channel and begins to form bends. As the flowing water scours the outer bend, it further erodes it, causing the bend to become more pronounced and deeper.)

Discuss student observations and explain that most (but not all) streams and rivers naturally form meanders as they flow over the landscape. Introduce the term *meander belt* (see GLOSSARY) and ask them to observe any changes to the shape and size of the meander belt as the water continues to flow.

Lesson 1.2. The Changing Channel

> **MATERIALS**
> - small sticks or popsickle sticks
> - toy houses or wooden blocks
> - camera
> - clock

Turn off the water on the stream table. Using your hand, create a straight channel down the stream table, and have students place sticks along the channel on both sides to define the width and path of the channel. Have a student stand at the "mouth" end of the table and take a photo of the channel. Ask them to predict where it is safe to build houses along the stream, and have them place some toy houses (or blocks to represent houses) on those spots.

Run the water and have a student take a photo from the same spot every 5 minutes for about 30 minutes (see Figure 7 below). Occasionally, turn up the volume of water to model a heavy rainstorm. (For younger students or a large class, use a shorter period of time.)

After 30 minutes, discuss what happened. Did the stream behave as they predicted it would? Did any houses get dangerously close to the stream, or even fall into the stream? Ask them to explain what happened and why.

(Since water corkscrews through the landscape, flowing water carves meanders, which tend to get wider over time until a stable meander belt is formed.)

Lesson 1.3. Stream Anatomy

> **MATERIALS**
> - STREAM ANATOMY PARTS - STUDENT ACTIVITY SHEET (below)
> - Science notebooks or sheets of paper on clipboards

After the stream table has run for a little while and nice meanders have formed, tell students that they will learn about the "anatomy" of a stream. Hand out a STREAM ANATOMY PART sign (see below) to each student. Taking turns, have each student read his/her sign and place the sign in an appropriate spot on the stream table. Clarify any confusion over terms and definitions.

Ask students to write some new observations in their science notebooks using the vocabulary they just learned. This gives them a chance to practice the new vocabulary and sharpens their observation skills.

Meanders & Corridors

Figure 11.

Patti Collins' 5th graders at Reading School in Vermont took 21 photos at regular intervals to record changes in their flowing stream. The photos above are a subset.

Directions: Laminate this sheet (so it can get wet on the stream table). Cut out the cards and tape each one to a stick. Discuss each term with the students and have them post each "sign" in an appropriate place in the stream table.

Bank The land along a stream, between the water and the landscape.	**Point Bar** A low, curved bank of sediment along the *inner bend* of a meander. (It points to the *outer bend*.)
Cut bank An eroded bank carved by the flow of water around a bend.	**Riparian Area** The area along the banks with growing plants.
Stream Channel The area that contains flowing water, and the area that used to contain flowing water.	**Streambed** The bottom of a stream channel that is covered by water.
Headwaters Areas at high elevation where a stream starts.	**Mouth** The place where a stream empties into another body of water.
Groundwater Water that collects underground and sometimes flows beneath the surface.	**Surface Water** Water that is visible on the Earth's surface (lakes, streams, oceans, etc.)
Meander A winding curve or bend of a stream.	**Flood Plain** An area of flat land along a stream that is flooded when a stream flows over its banks.

LESSON 2. WATER & SEDIMENTS

SET-UP	TIMEFRAME FOR LESSON 2 (2.1 AND 2.2)
• View this video: *Inchannel gravel mining and bar pit capture* (http://www.emriver.com/?page_id=1521, bottom of page); shows *headcut* and other erosion conditions. • Practice using your hand as a backhoe and scoop out some sediment in the stream table's channel, watching the result. Look for a *headcut* to form. This is the effect that you want for this activity	60 minutes

OVERVIEW

People have been removing *sediments* from streams for a long time. This is done to straighten a channel, to collect gravel for construction, or to deepen a channel to "make room" for floodwaters. Ironically, removing sediments from a stream can create unstable conditions and increase flood damage, which can lead to further change in the stream channel as the stream seeks to reestablish balance. Here are two hypothetical examples of gravel removal (cause) and the stream's response (effect):

Example 1: Deepening the Channel to Make More Room

1. A community dredges a stream channel, lowering the streambed, so it can hold more water during a flood.
2. A huge rainstorm occurs, during which a slug of water enters the channel.
3. The water in the stream rises rapidly, but is contained within the banks because the streambed is now lower. The stream cannot overflow its banks and spill out over its floodplain, which would have absorbed both the larger volume of water and the increased energy created by rapidly moving water.
4. The energy of the high, fast water eats away at the banks, making them unstable and susceptible to collapse.
5. The swollen stream (which includes both water and eroded soil particles) barrels downstream at high velocity, hits a bend in the stream, bites into the bank, and takes out the road at that bend.

Example 2: Mining Gravel for Construction Material *(numbered steps below correspond to numbered steps in Figure 8 below)*

1. A landowner removes gravel from the streambed and sells it to a construction company. This creates a "hole" (depression) in the streambed. The slopes around the hole are steeper than the slope of the original streambed.
2. When flowing water tips into the hole at the upstream end, it falls down the steep slope, picks up speed (becoming "hungry" for sediment), and erodes the streambed along that steep slope.
3. Sediments continue to erode off the upstream slope, causing a *headcut* to work its way upstream (see MORE INFO: Little River video on in-channel gravel mining). This causes high, steep, unstable banks to form downstream of the headcut.
4. The sediments that are scoured off the upstream slope of the hole flow over the hole, where the water slows down and drops its load. (Eventually, these sediments fill the hole.)

5. The flowing water is then forced up the slope at the downstream end of the hole, where it picks up speed again (becoming "hungry") and erodes the sediment on that downstream slope.
6. Once beyond the hole, the water tends to slow down again and drop its load of sediments, causing deposition downstream of the hole.
7. Another flood occurs, which bites into the unstable banks, causing them to collapse.

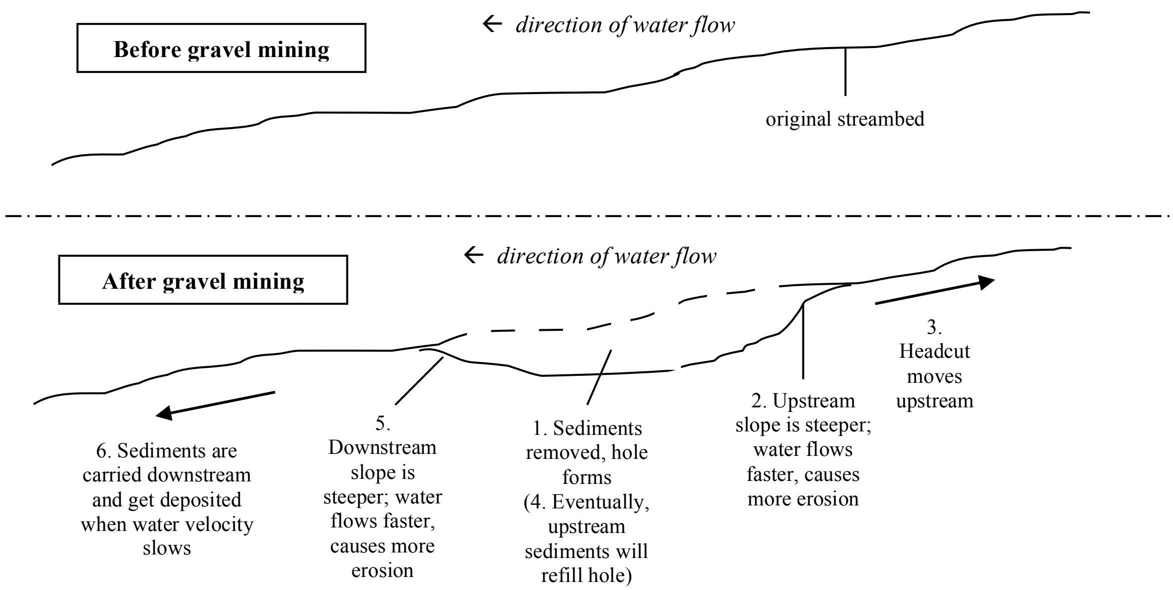


Figure 12. Cross-section of a streambed before and after gravel mining.

(Note: Numbers in the "After gravel mining" section refer to the steps in Example 2 above.)

MORE INFO:
Living in Harmony with Streams booklet, page 14 and page 19
After the Flood videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: floodplain, headcut; starting at 5:53
- Video 1: high banks; starting at 8:53
- Video 3: recovering from flood damage; starting at 6:38
- Video 3: traditional river management and dredging; starting at 10:15

Little River Research and Design, Educational Videos, In-channel gravel mining
http://www.emriver.com/?page_id=1521

Lesson 2 Instructions

Lesson 2.1. Gravel Mining

Run the water in the stream table and allow meanders to form. Discuss gravel mining with students and ask them to imagine that your hand is a backhoe. When you scoop out (dredge) some sediment, what will happen to:

Materials
- Science notebooks or sheets of paper on clipboards
- pencils

- the water velocity?
- the streambed?
- the banks of the stream?
- the area downstream of the dredged area?

Ask them to write their predictions in their science notebooks.

- Now use your "backhoe" (hand) to scoop out sediments and have students observe the effects. Discuss the reasons why the stream adjusts as it does. (see OVERVIEW and MORE INFO above).

Lesson 2.2. High Banks & Low Banks

On the stream table, build a channel section with very high vertical banks and another channel section with low banks. Place a house (or block) on each, the same distance from the channel. Run a "storm event" (high water volume) and see what happens to each bank, and the house on each bank.

Materials
- Science notebooks or sheets of paper on clipboards
- Pencils
- Toy houses or wooden blocks

Here are some probable scenarios:

- The steep bank erodes and becomes unstable. It eventually collapses, taking the house with it.
- Water along the low bank surges up the bank and spreads out over the floodplain around the house, where it loses its velocity and force.
- The low house floods, but the land around it doesn't erode as much as the land under the high bank house. And the house remains intact (if wet).

LESSON 3. STREAMBANKS

SET-UP	TIMEFRAME FOR LESSON 3 (3.1 AND 2) 45 minutes
• Get the stream table ready to run. Allow water to flow and meanders to form.	

Overview

Vegetation growing along streams – the *riparian buffer* – protects water quality and improves flood resilience. Riparian plants hold streambanks and prevent erosion, filter pollutants from water that runs off the land, and absorb the energy of floodwaters. In addition, these plants directly benefit the stream ecosystem in several ways. They shade the water, keeping it cool and providing cover for aquatic organisms. Leaves, branches, and logs that fall into the water contribute resources to the stream's food web. On land, the riparian buffer provides cover for terrestrial animals that come to the stream for water and food, and offers them a safe travel corridor. In general, riparian trees are more ecologically valuable than riparian herbs and grasses; their bigger roots systems hold the banks more securely, and they often harbor a diverse plant community beneath their canopies that supports a diverse wildlife community.

Humans often remove riparian vegetation to establish buildings, roads, industrial developments, and agricultural areas along streams. In doing so, we tend to destabilize stream banks and increase the risk of erosion. To protect the banks, we often implement streambank stabilization programs that call for building various structures along streams, including "riprap" (rocks that line the bank) and cement walls. While these artificial materials armor the banks and prevent erosion at that site, they can transfer the force of flowing water downstream, where it can cause significant erosion.

MORE INFO:
Living in Harmony with Streams booklet, page 11
After the Flood videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 3: armoring banks; starting at 7:54 minutes
- Video 4: VT's fisheries; starting at 4:24 minutes
- Video 4: aquatic habitat; starting at 10:04 minutes

LESSON 3 INSTRUCTIONS

Lesson 3.1. Streambank Protection.

MATERIALS
- Rocks
- Washcloths
- Cheesecloth, cut into long strips
- scissors

Define the term *riparian buffer* (see OVERVIEW and GLOSSARY). Explain that people often remove the plants along a streambank and then armor it with artificial materials. Ask students to think about the kinds of artificial materials they see along streams. (The list should include rocks and cement walls).

Allow the water to run and meanders to form on the stream table. Give students various materials – rocks, solid surfaces that model cement walls, and washcloths and cheesecloth strips to represent vegetation. Have students use each material in turn to line the streambanks and make observations to answer the following questions:

1. Which materials hold the bank?
2. Which material holds the bank the longest and the most effectively?
3. Which material absorbs more water? (Talk about the holding capacity of roots, which can absorb and hold large amounts of water during flooding. *Please note: washcloths and cheesecloth are used here to model vegetation, but they lack the root structure that serves to hold stream banks so effectively in nature. Discuss this limitation as you model riparian vegetation with these materials.)*
4. Does erosion occur upstream and/or downstream with each kind of material?

Lesson 3.2. Streambanks & Habitat

Explain that streams and their riparian vegetation provide resources for wildlife and fish. Have students brainstorm some important habitat benefits provided by vegetation, riprap, and cement walls.

MATERIALS

- Flipchart paper, easel, and markers or white board and dry-erase markers

A table with possible answers is provided below. Older students can conduct research to complete such a table. A couple of resources to get them started:

- *Values of Riparian Buffers*, by Vermont Department of Environmental Conservation: http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_riparianvalues.pdf.
- *Riparian Areas Environmental Uniqueness, Functions, and Values*, by the USDA Natural Resouces Conservation Service: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014199.

Figure 13. Streambank Materials and Habitat Benefits

Streambank Materials	Habitat Benefits	
	For terrestrial organisms on land	**For aquatic organisms in the water**
riparian vegetation	• plant foods (seeds, berries, leaves, etc.) for terrestrial animals • cover from predators • easy access to water • aquatic prey species (e.g., crayfish) for terrestrial predators (e.g., raccoon) • homes like holes in trees and nests that are close to food and water resources • enriched soil from nutrient cycling of plants and animals, and from periodic flooding (which deposits nutrient-rich stream sediments on the land)	• plant parts drop into the water to provide food and habitat structures for aquatic animals • shade cools the water (which increases dissolved oxygen in water), which benefits fish and other aquatic animals • shade and overhanging vegetation provides cover for fish and other aquatic animals • plant roots hold soil along the banks, preventing excess erosion of soil into the stream.
riprap (rocks that line the bank)	• cover for small animals (if they can hide among or under the rocks) • others?	• rocks hold soil along the banks, preventing excess erosion of soil into the stream (but may divert the water's force downstream and lead to erosion there) • others?
cement walls	• attachment location for some plants, which may serve as food and shelter for small animals	• any plants that attach and grow drop plant parts into the water, which provides some food. • any plants that attach and grow provide some shade (see above) • walls hold soil along the banks, preventing excess erosion of soil into the stream (but divert the water's force downstream and can lead to flooding and erosion there)

LESSON 4. STREAM CROSSINGS

SET-UP	TIMEFRAME FOR LESSON 4 (4.1 AND 4.2)
• Get the stream table running • Prepare a chart on the board or large sheet of paper for the class brainstorm in Lesson 4.2.	60 minutes or more; ideally carried out over 2 such time periods

OVERVIEW

Since many of our human activities occur in stream valleys, we often need to cross various flowing waters. *Stream crossings* are **culverts (pipes), open-bottom arches**, and **bridges** that are installed to convey water under a "travelway" such as a road, railroad, or a path. The size, shape, material, and placement of the stream crossing should be carefully considered to accommodate high flows and to allow for the migration of aquatic organisms such as fish and salamanders.

An undersized crossing, such as a pipe culvert that cannot pass large volumes of water, can create lots of problems. During a big storm, streams collect more water than usual and can rise dramatically. A small culvert pinches the flow, causing a backup of water upstream of the culvert, where its swirl can erode the banks and streambed. When a large volume of water is squeezed through the small pipe, the water speeds up and carries more force, creating a "fire hose" effect, often causing severe erosion downstream. If the culvert becomes clogged with debris, it passes even less water or completely dams the stream. In this situation, water flows around and/or over the culvert, often gouging the land and destroying roads. Eventually, the culvert can get washed out, causing the backed up water to surge downstream where it can do significant damage. Because of this, large crossings (pipes, arches, and bridges) that can accommodate increased water volumes are more effective at managing floodwaters than small crossings. Even small streams can flood enormously.

Small pipe culverts can also become "perched" when the outflow from the culvert erodes the streambed downward. (This is often the result of the fire-hose effect described above.) If a culvert becomes perched, the downstream end of the culvert is higher than the streambed. A small waterfall forms, causing additional erosion and creating a barrier to fish movements. This can interfere with spawning and prevent fish from escaping predators, moving away from pollution events, and/or finding food.

Figure 14. A perched culvert

(From Wildfishasaurus: https://wildfishasaurus.wordpress.com/category/restoration/)

The New Hampshire Crossing Guidelines, developed by the University of New Hampshire in 2009 (see TEACHING RESOURCES) recommends that a stream crossing structure (culvert, arch, or bridge) should be designed to:

- be wide enough to allow for high flows without constriction
- contain natural streambed sediments
- maintain water depths within or under the structure that are similar to the water depths of the stream itself
- have a slope that is similar to the slope of the streambed

These measures generally prevent severe flooding and erosion. They also allow aquatic organisms to migrate upstream and downstream to access critical parts of their habitats and mix up breeding populations, which increases their genetic diversity and contributes to stable populations.

To design a stream crossing that achieves these objectives, we must consider bankfull width. *Bankfull width* is the typical high water mark that is reached about every other year and can generally be seen as a line along the bank where vegetation changes. It is the area where rising water tips onto its floodplain.

The New Hampshire Crossing Guidelines recognize that every stream is unique, so its authors say that it is unrealistic to follow one standard approach for designing crossings. The general recommendation given by the NH Guidelines is that a stream crossing should be 1.2 times bankfull width plus 2 feet. (See Figure 10 on the right.)

Figure 15. Recommended Width of a Stream Crossing:

1.2 x bankfull width + 2 feet

Example 1:

A stream is 3 feet wide at bankfull width.
Therefore, its crossing should be

(3 feet x 1.2) + 2 feet
= 6 feet wide at the streambed

Example 2:

A stream is 12 feet wide at bankfull width.
Therefore, its crossing should be

(12 feet x 1.2) + 2 feet
= 16.4 feet wide at the streambed

(New Hampshire Stream Crossing Guidelines, University of New Hampshire, 2009: https://streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf)

MORE INFO:

Living in Harmony with Streams booklet, page 2

New Hampshire Stream Crossing Guidelines, University of New Hampshire:
http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

Vermont Stream Crossing Handbook:
http://www.vtfishandwildlife.com/library/Reports_and_Documents/Aquatic%20Organism%20Passage%20at%20Stream%20Crossings/__AOP_%20Handbook.pdf

After the Flood videos

- Video 2: culverts; starting at 11:36 minutes
- Video 3: culverts; starting at 00:00 minute (beginning)

LESSON 4 INSTRUCTIONS

Lesson 4.1. Stream Crossing Experiments

(See appropriate section below -– Grades 4 to 6 or Grades 6 to 8 -- for your students' grade or ability level)

MATERIALS

- small culvert (small metal can, like a tomato paste can)
- large culvert (large metal can, like a large soup can)
- bottomless arch (half a wide PVC pipe)
- bridge (a long, straight piece of wood with supports)
- STREAM CROSSING EXPERIMENT - STUDENT ACTIVITY SHEET (either Grades 4 to 6 or Grades 6 to 8; see below)
- Clipboards, one per student
- pencils

Grades 4 to 6

Show students two sizes of stream crossings: the small pipe and the large pipe. Give each student the Grades 3 to 5 STREAM CROSSING EXPERIMENT STUDENT ACTIVITY SHEET. Read the *Question* to students, clarifying as needed. Ask them to *hypothesize* which crossing size will minimize erosion by checking one of the boxes next to their crossing of choice, then have them explain their reasoning on the line below (their "because" statement). (**Step 1** and **Step 2** on the sheet.)

Step 3 asks students to run an *Experiment* that compares the two stream crossing structures to test students' hypotheses. Follow the procedure below to set up a comparable scenario with each type of crossing: *Small Pipe Culvert* and *Large Pipe Culvert*.

Small Pipe Culvert

1. Create a straight channel in the stream table that is the same width as your small pipe.
2. Install the small pipe in the flowing water on the stream table. Pack sediment against it on either side. (If you have a "road" that you can put across it and some toy cars to drive the road, all the better.)
3. Run the water at low volume and watch it flow through the culvert for a few minutes. Have students write an observation in the first box of the **Observation** table on the STUDENT ACTIVITY SHEET. (You may choose to have students draw their observation instead of writing it.) Encourage students to observe water movements, sediment movements, and the changing stream channel.
4. Now turn the volume up a bit (heavy rain) and have students write (or draw) their second **Observation**.
5. Finally, turn the volume up high to simulate a storm surge and have students write (or draw) their third **Observation**.

Large Pipe Culvert

1. Turn off the water flow and rebuild the channel to its original, small-pipe width.
2. Install the large pipe. Note: *The large pipe will be wider than the channel of flowing water. Pack sediment on either side of it.*

Repeat numbers 3, 4, and 5 as above (low flow and Observation, medium flow and Observation, high flow and Observation).

Grades 6 to 8

Show students three stream crossings: the small pipe, the bottomless arch, and the bridge. Give each student the Grades 6 to 8 STREAM CROSSING EXPERIMENT - STUDENT ACTIVITY SHEET. Read the *Question* to students, clarifying as needed. Ask them to *hypothesize* which crossing structure will minimize erosion by checking one of the boxes next to their crossing of choice, then have them explain their reasoning on the line below (their "because" statement). (**Step 1** and **Step 2** on the sheet.)

Step 3 asks students to run an *Experiment* that compares the 3 stream crossing structures to test students' hypotheses. Follow the procedure below to set up a comparable scenario with each type of crossing: *Small Pipe Culvert, Large Bottomless Arch,* and *Bridge*.

A Note to teachers of older and/or more accomplished students: See the box below entitled "Designing a More Rigorous Experiment"

Small Pipe Culvert

1. Create a straight channel in the stream table that is the same width as your small pipe.
2. Install the pipe in flowing water on the stream table. Pack sediment against it on either side. (If you have a "road" that you can put across it and some toy cars to drive the road, all the better.)
3. Run the water at low volume and watch it flow through the culvert for a few minutes. Have students write an observation in the first box of the **Observation** table on the student activity sheet. Encourage students to observe water movements, sediment movements, and the changing stream channel.
4. Now turn the volume up a bit (heavy rain) and have students write their second **Observation**.
5. Finally, turn the volume up high to simulate a storm surge and have students write their third **Observation**.

Bottomless Arch

1. Turn off the water flow and rebuild the channel to its original, small-pipe width.
2. Install the bottomless arch. Note: *The arch will be wider than the channel of flowing water. Pack sediment on either side of it.*

Repeat numbers 3, 4, and 5 as above (low flow and Observation, medium flow and Observation, high flow and Observation).

Bridge

1. Turn off the water flow and rebuild the channel to its original, small-pipe width.
2. Install the bridge (long span with bridge supports). *Note: The bridge span will be wider than the channel of flowing water. Pack sediment around the supports.*

Repeat numbers 3, 4, and 5 as above (low flow and Observation, medium flow and Observation, high flow and Observation).

Discussion – Gear it for your students' grade and ability level

1. Ask for volunteers to read their Observations to the class – what happened with each of the stream crossing structures? At each flow level (low, medium, high)?
2. Ask students if they see any patterns and/or relationships in their Observations. For instance, did the water behave in a particular way with any of the crossings? Did the water's flow change in a predictable way from one flow level to the next?
3. Have students review the *Question* that started this experiment, then their *Hypothesis* and their "because" statement. Remind them that a scientist's hypothesis is often proven wrong because the world is a complex place and sometimes things happen that you can't predict. But even disproving a hypothesis leads to tremendous learning, and scientific knowledge is often advanced when we get unexpected results.
4. Have students record their *Results* by checking the box next to the structure that they believe created minimal erosion. *Please note that a viable choice is "Not enough data*" (see below).
5. Ask students for a show of hands as follows:
   a. Grades 4 to 6: Who chose the small pipe? Large pipe? Not enough data? Record the number of votes that each choice received on a flipchart sheet. Have them explain their choices and encourage student discussion.
   b. Grades 6 to 8: Who chose the small pipe? Bottomless arch? Bridge? Not enough data? Record the number of votes that each choice received on a flipchart sheet. Have them explain their choices and encourage student discussion.

   Explain that professional scientists often work with lots of colleagues, some of whom may disagree about experimental results. By discussing their observations, questions, and understandings, they help to inform each other and produce more accurate, useful results overall.
6. Now that students have reviewed and discussed their *Observations* and *Results*, they are ready to draw *Conclusions*. What do they know now, after doing their experiment, that they didn't know beforehand? As students provide ideas, list them on flipchart paper. As a class, summarize students' ideas into 3 concluding statements. Or have each student summarize his/her own conclusions as an independent exercise. Then have them write their Conclusions on their STUDENT ACTIVITY SHEET.

7. Explain that, in the event that a scientist determines he/she doesn't have enough data for analysis, he/she should review the experiment's design, improve it if needed, and run the experiment again.

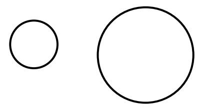
   If students chose "Not enough data," ask them to follow this process (above) and describe how they might work to produce more clear-cut data. Older students may want to review Figure 11 for some suggestions of ways to improve the rigor of this experiment.

Figure 16. Improving the Rigor of the Stream Crossing Experiment

- For each crossing structure, dig the exact same channel (location and width) before installing the structure.
- Mark the flow dial to standardize your flow settings: low, medium, and high. (Please do note leave permanent marks on the stream table.)
- For each Observation, run the water for the same amount of time.
- Measure the amount of sediment that flows out of the mouth each time you run the water for each Observation. Record the volume for each Observation, then compare volumes.

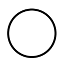
Thanks to Kevin Gianini, teacher at Grantham Village School, Grantham, NH, for contributing ideas.

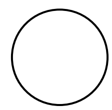
Name: ____Date: ______________

Look at 2 sizes of pipe culverts: 

1. **Question**: *Which size will cause the least erosion?*

2. **Hypothesis**: Check one box below:

small culvert ☐ 

large culvert ☐ 

I chose this size culvert because

____

3. **Experiment**.

A. Install the small culvert. Watch the stream flow through it. Write or draw 3 observations, one for low flow, one for medium flow, and one for high flow.

Small Culvert Observations
1. low flow
2. medium flow
3. high flow

B. Install the large culvert. Watch the stream flow through it. Write or draw 3 observations, one for low flow, one for medium flow, and one for high flow.

Large Culvert Observations
1. low flow
2. medium flow
3. high flow

4. **Results**: Which size culvert caused the least erosion? Check one.

small culvert	large culvert	Not enough data
❒	❒	❒

5. **Conclusions**: Review your *Observations* and *Results*. What do you know now that you didn't know before the experiment? Write 3 conclusions.

____

____

____

LESSON 4.1. STREAM CROSSING EXPERIMENT

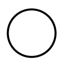
Student Activity Sheet
(Grades 6 to 8)

Name: _______________________________________ Date: ____________

Look at 3 kinds of stream crossing structures: small pipe culvert, bottomless arch, and bridge.

1. **Question**: *Which crossing structure will minimize erosion along the stream?*

2. **Hypothesis**: Check one box below

Small culvert	Bottomless arch	Bridge
❒ 	❒ 	❒ 

I chose this crossing structure because:

____

____

3. **Experiment**. Install each crossing structure, one at a time, and run the stream table. Write 3 observations for each structure below, one observation for each flow level.

Crossing Structure	Observations
small pipe culvert	1. low flow
	2. medium flow
	3. high flow

bottomless arch	1. low flow
	2. medium flow
	3. high flow
bridge	1. low flow
	2. medium flow
	3. high flow

4. **Results**: Which structure minimized erosion? Check one. *Please check "Not enough data" if your results are not clear.*

Small culvert	Bottomless arch	Bridge	Not enough data
☐	☐	☐	☐

5. **Conclusions**: Review your original *Question,* your *Hypothesis,* your *Observations,* and your *Results*. What do you know now (after your experiment) that you didn't know before? That is, what can you conclude? What new questions do you have about crossing structures?

Conclusions: ____________________

____

New questions: ____________________

____

LESSON 4.2. COMMUNITY CROSSINGS

> **MATERIALS**
> - Flipchart paper, easel, and markers or white board and dry-erase markers

Different members of a community have different perspectives on installing stream crossings. Things to consider include:

- cost
- life-span (how long it will last, which affects the replacement cost)
- affects on fish and wildlife habitats
- affects on water quality
- affects on local roads, landowners, settlements, farms, etc.
- local, state, and federal requirements that need to be met to receive a permit for the culvert (see *Vermont Stream Crossing Handbook* in TEACHING RESOURCES).

Imagine that a town has to replace a culvert or bridge on Trout Brook, a popular fishing location. Have students brainstorm the pros and cons of each type of crossing using a table format such as the one below. (Possible answers are provided for the teacher.)

Figure 17. Types of Crossings, Pros and Cons

Types of Crossings	Pros (+)	Cons (-)
small culvert	• minimal cost • adequate for moving typical water volumes • minimal movement of earth required to install it • takes up a small "footprint"	• may not be able to handle storm waters, causing them to flood the land around it • may get blocked with debris or "blown out" during a storms, causing flooding around it • often becomes "perched," interfering with fish passage • water often speeds up as it enters culvert, causing "firehose" effect downstream
large culvert	• relatively inexpensive • adequate for moving typical and greater water volumes	• higher cost than small culvert • requires more movement of earth to install than small culvert • larger "footprint" than small culvert • often becomes "perched," interfering with fish passage and causing more erosion.
bridge	• lasts longer than culverts • much less likely to wash out than culverts. • does not change the velocity of water • has natural streambed, which provides aquatic habitat • does not become "perched" • provides benthic habitat for fish, waterbugs, and other aquatic organisms.	• higher cost than either small or large culvert • longer construction process

Ask students to play the roles of the following individuals. Which type(s) of crossing would they choose and why?

- town manager, who’s in charge of balancing the town’s budget and dealing with flooding
- owner of Joe’s Fishing Store
- owner of the Riverview Motel, which is on the floodplain next to the stream
- school principal, whose athletic fields are on the floodplain next to the stream

LESSON 5. UPSTREAM, DOWNSTREAM

SET-UP	TIMEFRAME FOR LESSON 5 (OPTION A OR OPTION B)
• Get the stream table running	60 minutes or more

OVERVIEW

Watershed neighbors are the people, settlements, and businesses that share the land and water resources within the landscape drained by a particular river system. Human activities in and along our streams often lead to changing sediment and water flow conditions as the stream responds. Most changes occur downstream, but some human activities can create changes that occur upstream as well. Some activities are felt broadly throughout the watershed. Therefore, our activities can affect our watershed neighbors.

Often, a stream's response to human activities presents problems for watershed residents. For example, a straightened stream may develop meanders that cut into a farmfield, or an eroding channel may deliver its load of sediments onto a road during a flood. By responding in these ways, the stream is trying to stabilize its forces and adopt a pattern that it can generally maintain over time.

Dynamic equilibrium describes the process by which streams constantly change to re-establish balance after a disturbance and maintain balance over time. Living in Harmony with Streams (see TEACHING RESOURCES) explains it this way:

> Dynamic equilibrium means that the stream moves and adjusts toward the most efficient distribution of the energy of the system. Change is what makes the equilibrium dynamic.

INSTRUCTIONS

Please note:

Two options (Option A – Farm to City, and Option B – City to Farm) are provided for this activity. Both options teach the same basic concepts. Please choose the one that better represents your students' experiences. Or do both to encourage your students to adopt different perspectives on watershed resource use and cause and effect.

MATERIALS
- small culvert (small metal can, like a tomato paste can)
- large culvert (large metal can, like a large soup can)
- bottomless arch (half a wide PVC pipe)
- bridge (a long, straight piece of wood with supports)
- toy houses, barns, livestock, roads, vehicles
- LESSON 5, OPTION A OR OPTION B - STUDENT ACTIVITY SHEET
- Clipboards, one per student
- pencils

Option A. Farm to City

On the stream table, have students create a farm along the stream and build a city *downstream* of the farm along the stream. The farm and/or city can be built on both sides of the stream with a bridge connecting the two halves.

Hand out the FARM TO CITY - STUDENT ACTIVITY SHEET. Ask students to set up one or more of the scenarios on the sheet, each of which reflects some ways in which the farm might change the flow of surface and/or groundwater and affect the city downstream.

As students run these scenarios, have them complete the activity sheet.

Class Discussion Ideas

After the scenario(s) is/are run, ask students to discuss the following questions:

- Do activities that occur upstream affect downstream people and activities? Explain.
- Do activities that occur downstream affect upstream people and activities? Explain.
- We share our watershed with many people, human settlements, and businesses. What kinds of responsibilities do we have to each other when it comes to land and water resources within our shared watershed?
- If our farming activities change the stream, how can we minimize negative impacts downstream? Discuss student recommendations from their activity sheets. Here are some possible options:
    - The farmer can establish a forested buffer between his/her farmland and the stream. This will (1) absorb the volume and force of floodwaters, (2) reduce the erosion of the farmfields, which can cause sedimentation downstream, and (3) filter pollutants out of runoff, improving water quality downstream.
    - The farmer can allow the stream to meander, which flattens the streambed's slope and slows down floodwaters. This will decrease erosion and protect water quality downstream.

Option B. City to Farm

On the stream table, have students build a city along the stream and create a farm *downstream* of the city along the stream. The city and/or farm can be built on both sides of the stream with a bridge connecting the two halves.

Hand out the CITY TO FARM - STUDENT ACTIVITY SHEET. Ask students to set up one or more of the scenarios on the sheet, each of which reflects some ways in which the city might change the flow of surface and/or groundwater and affect the farm downstream.

As students run these scenarios, have them complete the activity sheet.

Class Discussion Ideas

After the scenario(s) is/are run, ask students to discuss the following questions:

- Do activities that occur upstream affect downstream people and activities? Explain.
- Do activities that occur downstream affect upstream people and activities? Explain.
- We share our watershed with many people, human settlements, and businesses. What kinds of responsibilities do we have to each other when it comes to land and

water resources within our shared watershed?

- If our city's activities change the stream, how can we minimize negative impacts downstream? Discuss student recommendations from their activity sheets. Here are some possible options:
    - The city can establish parks and other green spaces along the stream between the city and the farm. This will (1) absorb the volume and force of floodwaters, and (2) filter pollutants out of runoff from the city, improving water quality downstream.
    - The city can install "green infrastructure"[*] such as rain barrels, bioswales, and green roofs to catch rainfall and process it within the city. This prevents excess runoff into nearby streams and filters out urban pollutants.
    - The city can reimburse the farmer for lost crops whenever the land floods.

[*] What is Green Infrastructure?, American Rivers: https://www.americanrivers.org/threats-solutions/clean-water/green-infrastructure/what-is-green-infrastructure/

LESSON 5. UPSTREAM, DOWNSTREAM **OPTION A. FARM TO CITY**	**Student Activity Sheet**

Name: ____ Date: _____________

Choose one or more of the following actions to take on your farm. Check each action that you take:

- ❒ farm ripraps the streambanks
- ❒ farm builds a berm along the stream to prevent flooding onto its fields
- ❒ farm straightens the channel to deliver high water downstream, past the farm
- ❒ your own Scenario – describe: ____

Predictions: During a flood, what do you think will happen:
to surface water at the farm?
to groundwater at the farm?
to surface water at the city?
to groundwater at the city?
Experiment: Run the stream table at low and high flows, and write or sketch your observations.

Analysis: Summarize the important findings of your experiment.
Conclusions: Review your Predictions. What do you know now that you didn't know before this experiment?
Recommendations for improvement (designing possible solutions): Make 3 recommendations of actions that the farm can take to protect its land and water resources *and* minimize impacts on the city.
1. 2. 3.

If there is time, try one of your recommendations on the stream table and observe the results. Did it accomplish your goals?

LESSON 5, UPSTREAM, DOWNSTREAM **OPTION B - CITY TO FARM**	**Student Activity Sheet**

Name: ____ Date: _____________

Choose one or more of the following actions to take in your city. Check each action that you take:

❒ city ripraps the streambanks with rocks

❒ city builds concrete walls along both sides of the stream.

❒ city straightens the channel, from just upstream to just downstream of the city

❒ your own Scenario – describe: ____

Predictions: During a flood, what do you think will happen:
to surface water at the farm?
to groundwater at the farm?
to surface water at the city?
to groundwater at the city?
Experiment: Run the stream table at low and high flows, and write or sketch your observations.

Analysis: Summarize the important findings of your experiment.
Conclusions: Review your Predictions. What do you know now that you didn't know before this experiment?
Recommendations for improvement (designing possible solutions): Make 3 recommendations of actions that the city can take to protect its land and water resources *and* minimize impacts on the farm.
1.   2.   3.

If there is time, try one of your recommendations on the stream table and observe the results. Did it accomplish your goals?

LESSON 6. STREAM EROSION PREVENTION

This lesson was originally developed by Jenny Hewitt, 4th grade teacher at Pomfret School in Pomfret, VT. It was adapted by Kevin Gianini, 5th grade teacher at Grantham Village School in Grantham, NH, to culminate his stream table unit.

MATERIALS	SET-UP
• sketch paper • pencils, colored pencils, crayons • Diagram of Sawyer Brook and Surrounding Landscape (below) • Stream Erosion Prevention Rubric (below) • Poster paper for final illustration of plan	none **TIMEFRAME FOR LESSON 6** 60 minutes; students will need followup time as well

Present this scenario to students:

You are a river scientist. You have been asked by the town of Smithville to create a plan to do erosion control work along Sawyer Brook, which runs through the center of town. The Smithville select-board is counting on your expertise to help prevent damage to existing roads, houses, and to the brook. It was discovered that there is significant runoff from the pastures of a family farm located along the banks of the brook. This causes pollutants to enter the brook during heavy rains. The select-board also wants your recommendations as to areas best suited for future development.

The select-board will choose **the plan that provides the clearest explanations as to how each method you choose will best prevent erosion and decrease runoff.** As the select-board members are not experts on stream dynamics or erosion control, they will be looking for the **most complete diagrams, explanations, and recommendations.**

Your plan must include:

❒ 1. Road access to Smithville School from Route 10

❒ 2. Ways to keep Sawyer Brook from damaging Route 10

❒ 3. Ways to reduce runoff at the family farm

❒ 4. Areas that can be sold as building sites for new river view houses

❒ 5. A way to fix the crumbling supports of the foot bridge that leads to Smithville School

See the map below for a view of the landscape under consideration.

Figure 18. Diagram of Sawyer Brook & Surrounding Landscape

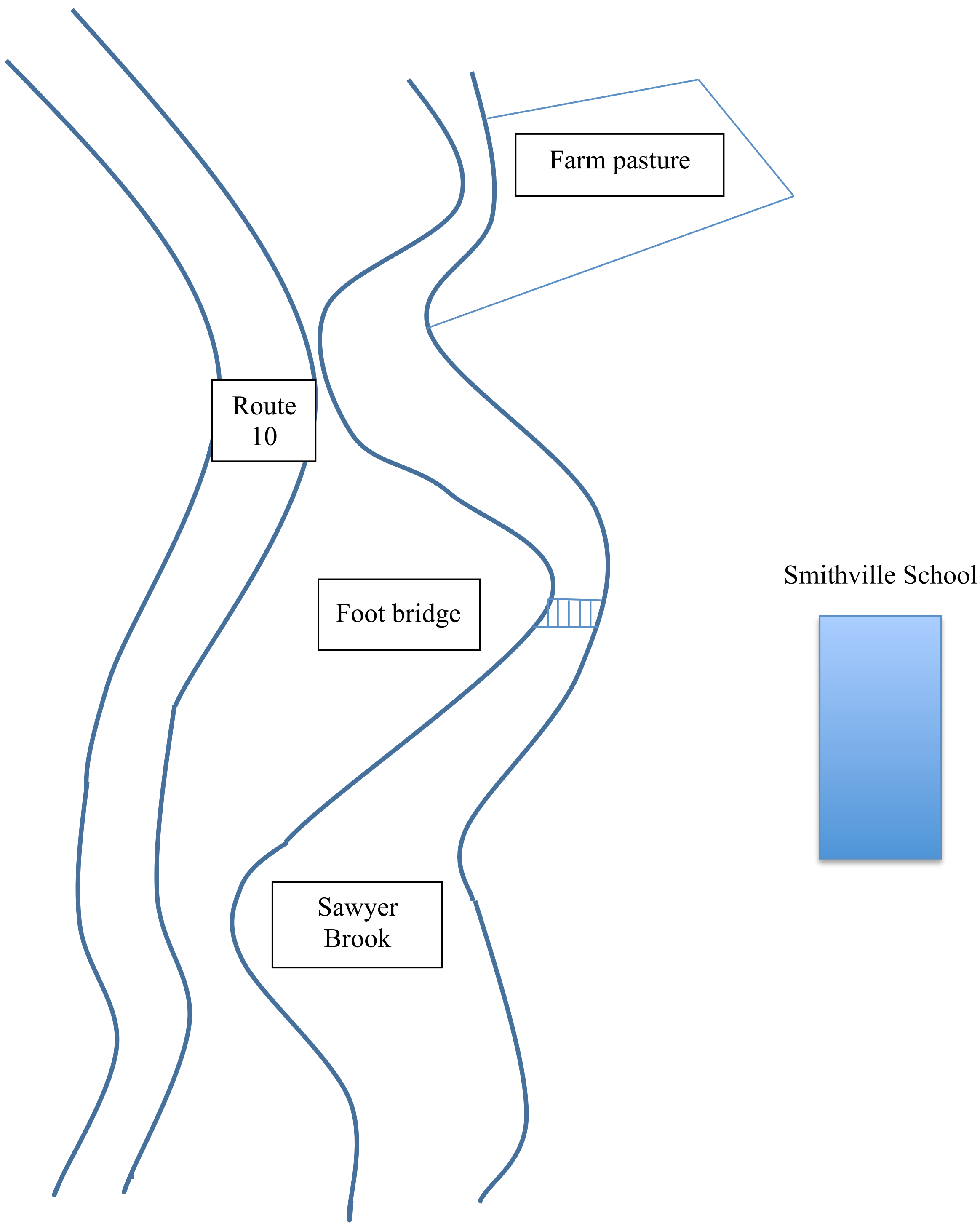


Figure 19. Stream Erosion Prevention Rubric

Name______________________________ Date _____________

Category	**3**	**2**	**1**	**Comments**
Erosion Control Methods	The plan addresses all 5 areas indicated by the Select-board as needing attention.	The plan addresses 3-4 areas indicated by the Select-board as needing attention.	The plan addresses 0-2 areas indicated by the Select-board as needing attention.	
Diagrams	Accurate, easy to follow diagrams with labels.	Some parts of the diagram were easy to follow and contained labels.	The diagrams were incomplete, hard to follow, and missing labels.	
Vocabulary	6 or more vocabulary words relating to streams and erosion are used accurately and appropriately.	3-5 vocabulary words relating to streams and erosion are used accurately and appropriately.	0-2 vocabulary words relating to streams and erosion are used accurately and appropriately.	
Elaboration	It is clear what methods of erosion control are being recommended and why they are suited to each area.	Some parts of the explanation of erosion control methods are clear.	Erosion control methods are not recommended, or are not at all clear.	
Points Earned				

Adapted by K. Gianini from J. Hewitt

ADVANCED STUDENT ACTIVITY: LANE'S BALANCE

(Most appropriate for older students and students who need a challenge!)

MATERIALS	SET-UP
• Lane's Balance Student Activity Sheet	• Watch this video of Steve Nelle explaining Lane's Balance: (http://www.youtube.com/watch?v=Js7wDZE4I7o) • Refer to Figure 16 below for an illustration of a simple Lane's Balance
	TIMEFRAME 60 minutes

OVERVIEW

A stream is a very dynamic system. Water flows change for many reasons, including:

- more water enters the stream with precipitation
- less water enters the stream in dry conditions
- people change the stream channel by straightening it
- people change the stream channel and/or stream corridor by building structures within and along the stream
- people change the riparian buffer zone by cutting down vegetation or building within it.

These adjustments cause the erosion of soil particles in some places and the deposition of soil particles in other places. In between, the soil particles become suspended and carried in the water. Therefore, streams move both water and sediments.

Lane's Balance is a model that shows how a stream balances the relationship between water flow and sediment transport to maintain or regain *dynamic equilibrium* (see GLOSSARY). It can help us to understand cause and effect in a stream. This model incorporates 4 variables in a typical old-fashioned balance-beam scale:

- amount of moving water
- slope (gradient) of the streambed
- amount of sediment
- size of sediment particles

If one of these variables changes, one or more of the other variables must change to regain balance in the river system.

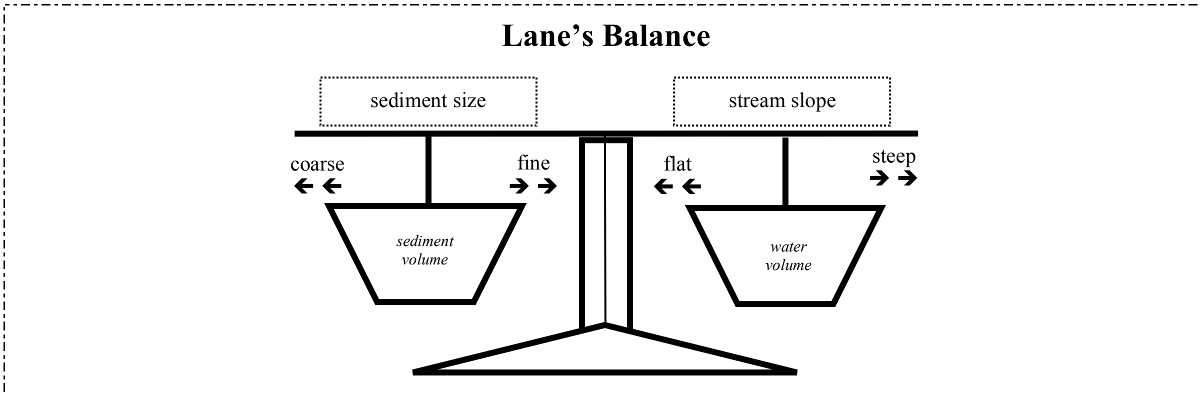


Figure 20. Lane's Balance (a simplified version); adapted from the American Society of Civil Engineers.

MORE INFO:
Living in Harmony with Streams booklet

- Pages 12 – 14
- Pages 29 - 36

After the Flood videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: river stability; starting at 2:14 minutes
- Video 2: water flows and floodplain functions; starting at 0:00 minute (beginning)
- Video 2: the need for river corridor maps; starting at 4:55 minutes
- Video 3: berms; starting at 8:50 minutes
- Video 4: equipment in streams, re-engineering channels; starting at 0:53 minute

Youtube video: *Steve Nelle explaining Lane's Balance* (http://www.youtube.com/watch?v=Js7wDZE4I7o

LANE'S BALANCE INSTRUCTIONS

Introduce students to Lane's Balance (see Figure 12 above), which is a model that shows the relationships between water, slope, and sediments in a stream.

Hand out the LANE'S BALANCE SCENARIOS - STUDENT ACTIVITY SHEET and discuss each scenario with the class, using the questions and answers below. Once students understand how the stream "rebalances" itself in each scenario, ask them to describe it in writing on the activity sheet. Then ask for volunteers to read their answers to the class, and clarify any confusing concepts.

Questions to accompany the Lane's Balance Scenarios activity

1. What happens if *__more water__* enters the stream channel? (for instance, during a storm)

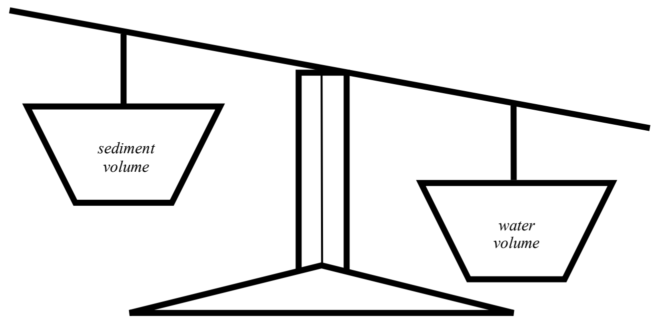
The *water bucket* becomes heavier, which tilts the water bucket arm down and raises the sediment arm.

How do you re-balance the scale?

Add more sediment. More water causes water velocity to increase, which makes the water "hungry" for more sediment; it eats into the streambed and/or banks, causing more sediment to enter the stream through erosion.

More water

- How do you regain balance?
- Add more sediment ("hungry" water erodes sediment from the banks and/or streambed)



2. What happens if *__more sediment__* enters the stream channel? (for instance, if upstream erosion causes downstream deposition)

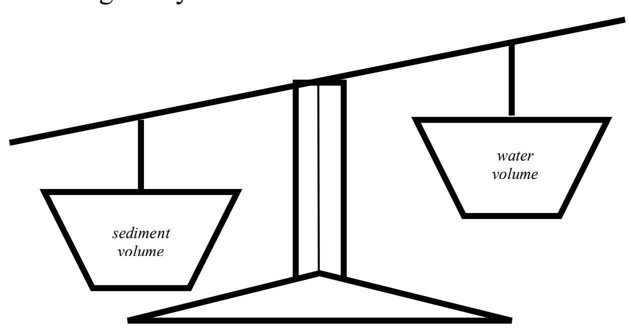
The *sediment bucket* becomes heavier, which tilts the sediment arm down and causes the water arm to rise.

How do you re-balance the scale?

Add more water. During the next flood, the increased volume of water will increase velocity, which scours out sediments, rebalancing the system.

More sediment

- How do you regain balance?
- Add more water to carry the sediment away



3. What happens if *__stream slope__* becomes *__flatter__* (for instance, through greater meandering)

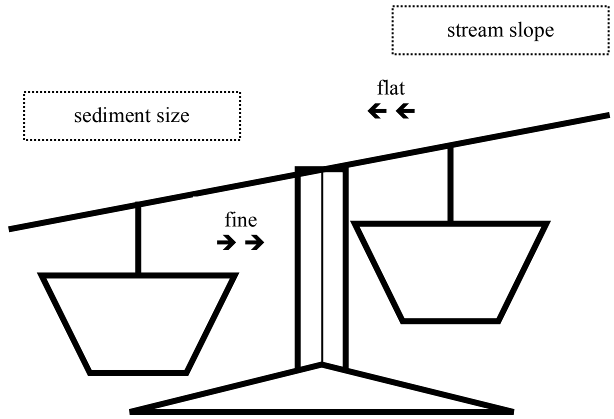
The *water bucket* moves to the left on its arm (toward "flat") and the *sediment size arm* tilts down.

How do you re-balance the scale?

Move the sediment bucket to the right toward the center post (toward "fine"). When a stream's slope becomes more gradual, the water slows down and drops the fine sediments that it has been carrying in suspension. The streambed under a flat slope with slow water is covered with fine sediment.

Flatter slope

- How do you regain balance?
- Water drops its load of ***fine sediment*** (bucket moves right to rebalance)



4. What happens if the ***stream slope*** becomes ***steeper***? (for instance, when we cut through meanders and straighten a channel)

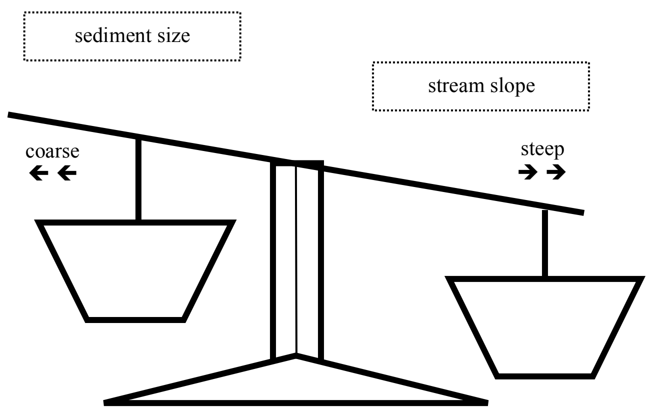
The *water bucket* moves to the right (toward "steep") and the *sediment size arm* tilts up.

How do you re-balance the scale?

Move the sediment bucket to the left (toward "coarse"). When a streambed becomes steeper, the water picks up velocity and becomes "hungrier", which means that it eats into the streambed and banks and can move coarser, larger particles.

Steeper slope

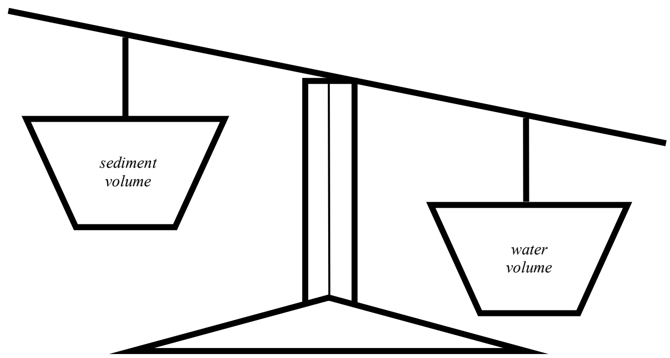
- How do you regain balance?
- Water picks up speed and gets "hungrier", eating ***coarse sediments*** from banks and streambed



LANE'S BALANCE SCENARIOS — Student Activity Sheet

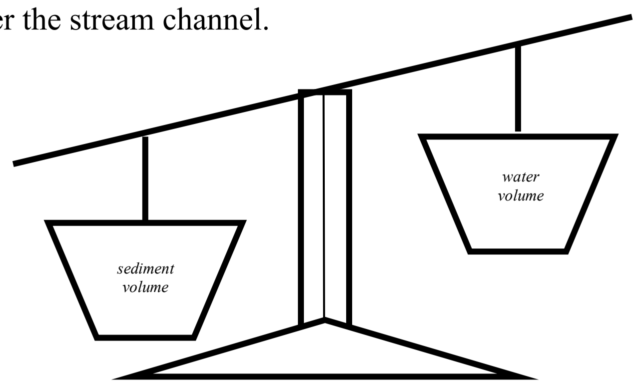
Name ____ **Date** ____________

1. It rains heavily all day and *more water* enters the stream channel.



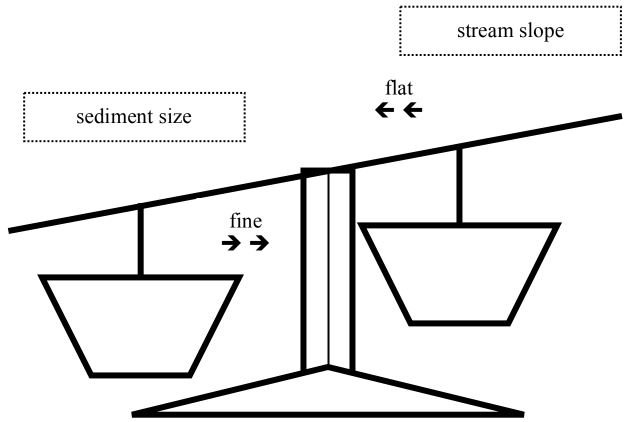
How does the stream regain balance?

2. A person upstream drives his car across the stream, creating erosion that causes *more sediment* to enter the stream channel.



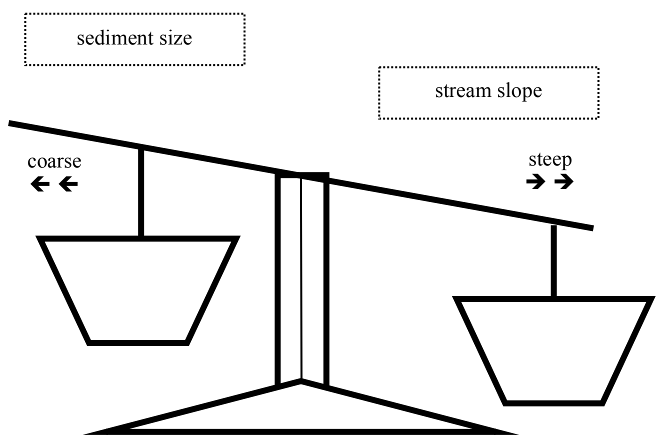
How does the stream regain balance?

3. A stream slows down and carves wider meanders, making the stream slope *flatter*.



How does the stream regain balance?

4. A town cuts through a series of meanders to straighten the stream, making the stream slope steeper.



How does the stream regain balance?

GLOSSARY

Definitions adapted from Living in Harmony with Streams; the Vermont Stream Geomorphic Assessment, Appendix Q; the dictionary tool in Microsoft Word; and other sources of definitions.

aggradation – a progressive buildup, or raising, of the channel bed and floodplain due to sediment deposition; opposite of degradation.

alluvial – refers to a stream or river that flows through sedimentary deposits, which it sorts, carries downstream, and deposits.

bankfull channel depth -- the maximum depth of a channel within a riffle segment when flowing at a bank-full discharge.

bankfull channel width – the typical high water mark along a stream that is reached about every other year and can generally be seen along the bank where vegetation changes.

bankfull discharge -- the stream discharge corresponding to the water stage that first overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years.

benthic – refers to the streambed and other underwater surfaces in a stream, such as a submerged log, and the bottom-dwelling organisms that live there.

berm – a mound of soil or other materials, constructed along a stream, a road, or other area, to protect against flooding and/or erosion.

channel -- an area confined by the banks and streambed that contains continuously or periodically flowing water.

channelization -- the process of changing (usually straightening) the natural path of a waterway.

culvert -- a buried pipe that allows flowing water to pass under a road.

degradation (of a streambed) -- a progressive lowering of the stream's channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation.

dredging -- removing material (usually sediments) from wetlands or waterways to make them deeper or wider.

dynamic equilibrium – describes a stream system that has achieved a balance in transporting its water and sediments over time without building up sediments, cutting into its streambed, or migrating laterally (eroding its banks and changing course). A stream in dynamic equilibrium resists flood damage, resists erosion, and provides good aquatic habitat.

floodplain -- land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

groundwater -- subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.

head cut – a marked change in the slope of a streambed that creates a small waterfall with increased water velocity, which causes erosion of the streambed that eats its way upstream.

headwaters – small, flowing waters that form in the upper elevations of a watershed.

Lane's Balance – a model with balance beam arms that demonstrates some of the interactions in a stream between water, slope (gradient), and sediments.

mainstem – the largest river in a watershed; it collects all flowing water within the watershed and occupies the lowest valley in that watershed.

meander – *noun:* a bend in a stream; *verb:* to wind back and forth through the landscape. A meandering stream generally exhibits a characteristic pattern of bank erosion (outer bend) and point bar deposition (inner bend).

meander belt – the side to side (lateral) extent of stable meanders in a stream.

point bar – a gradual shelf extending out from the inner bend of a stream that forms when slow water drops its load of sediments.

pool -- a reach of stream that is characterized by deep, low-velocity water and a smooth surface.

riffle – a stream feature in which water flow is shallow, rapid, and turbulent compared to adjacent areas. Riffles typically alternate with pools along the length of the stream.

riparian – the strip of land along a streambank in which vegetation directly influences stream processes.

riparian buffer – a vegetated zone along a streambank that helps to stabilize the bank and fosters a healthy terrestrial habitat on one side and a healthy aquatic habitat on the other side.

riprap -- rock or other material used to stabilize streambanks or riverbanks from erosion or to create habitat features in a stream.

river system – the mainstem of a river and all of the waters that flow into it. It forms a branching pattern that resembles a tree, with the trunk being the mainstem, the major tributaries being the large branches, and the high-elevation streams being the twigs.

run (in stream or river) -- a reach of stream characterized by fast-flowing, low-turbulence water.

sediments – materials eroded from soil or rocks that are carried by water, wind, or ice and deposited somewhere else.

slope (gradient) – the amount of change in elevation as a stream flows across the landscape.

stream corridor – the land that includes the active channel of a stream, its meander belt, the riparian buffer along the stream, and the stream's floodplain. The corridor is the area within which the channel can meander to distribute sediments and the energy of flowing water, which leads to a balanced condition called dynamic equilibrium.

thalweg – a line connecting the deepest areas of a stream channel or valley.

tributary – a stream that flows into another stream or river; it is usually smaller than the mainstem.

watershed – a basin of land in which all water flows to a common water body, such as a river, lake, pond, wetland, or the ocean.

TEACHING RESOURCES

AN ANNOTATED LIST

Vermont Organizations

Friends of the Winooski River is a nonprofit organization dedicated to the protection and restoration of the Winooski River, its tributaries and watershed. http://www.winooskiriver.org.

Lake Champlain Basin Program (LCBP) works in partnership with government agencies from New York, Vermont, and Québec, private organizations, local communities, and individuals to coordinate and fund efforts that benefit the Lake Champlain Basin's water quality, fisheries, wetlands, wildlife, recreation, and cultural resources. http://www.lcbp.org/about-us/mission/.

Vermont Department of Environmental Conservation (DEC), a department of the Agency of Natural Resources, preserves, enhances, restores, and conserves Vermont's natural resources, and protects human health for the benefit of this and future generations.

Watersheds United Vermont (WUV) is a state-wide network of local groups dedicated to the health of their home watersheds. Our mission is to empower community-based watershed groups in all parts of the state to protect and restore Vermont's waters. http://www.watershedsunitedvt.org.

Internet Publications

Living in Harmony with Streams: A Citizen's Handbook to How Streams Work, Friends of the Winooski River, White River Natural Resources Conservation District, Winooski Natural Resources Conservation District, 2012. http://www.winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf.

Very concise and informative handbook for laypersons. Lots of useful photos and illustrations.

New Hampshire Stream Crossing Guidelines, University of New Hampshire, May 2009. http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

An extensive, somewhat technical document written to assist in the design, construction, and permitting of stream crossings (culverts, arches, and bridges) in New Hampshire.

Vermont Stream Crossing Handbook, Vermont Fish and Wildlife Department. http://www.vtfishandwildlife.com/common/pages/DisplayFile.aspx?itemId=111508.

A concise citizens' handbook that is full of color photographs and illustrations. Includes a list of State and Federal Regulations and Additional Resources.

Use and Care of the Emriver Em2 River Process Geomodel: http://www.emriver.com/wp-content/uploads/2011/09/Emriver_Em2x_manual_2012_05-02_AQ.pdf

A step-by-step guide for setting up and maintaining the stream table.

Internet Videos

River Geomorphology Videos: http://serc.carleton.edu/NAGTWorkshops/geomoph/emriver/index.html

Created by Little River Research and Design to help students better understand geomorphic processes in rivers with special attention to the effects of channelization and gravel mining. The clips are intended for use by an instructor.

After the Flood: Vermont's Rivers and the Legacy of Irene, Riverbank Media, June 2013. http://www.youtube.com/playlist?list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

A series of 4 videos that explore the condition of rivers in the Green Mountain State following the devastating flooding from Tropical Storm Irene. Topics include: river dynamics, floodplains and flood resiliency, impact of improperly sized culverts and the benefits of upgrading, consequences of river modification, and the current state of Vermont's fisheries.

Vermont Rivers Program Videos, Vermont Agency of Natural Resources, May 2012.

A somewhat technical series of videos made by the Vermont Rivers Program that shows how to minimize flood damage by better understanding river dynamics.

Segment One: Vermont Rivers Program. http://www.youtube.com/watch?v=w8BWjRM-ptI

Segment Two: River Dynamics. http://www.youtube.com/watch?v=0Va7E7KOz94

Segment Three: Meanders and Floodplains. http://www.youtube.com/watch?v=RQ6oyf9C8Lc

Segment Six: River Restoration. http://www.youtube.com/watch?v=E_a-nYl9Ak4

Books

Stream Ecology: Structure and Function of Running Waters, by J. David Allen, School of Natural Resources and Environment, University of Michigan. 2006. ISBN: 0-412-35530-2.

A textbook that covers the stream's chemical, physical, and biological factors, and how they interact to create the unique conditions of a particular stream. Includes a chapter on modification of running waters by humankind.

Pond and Brook: A Guide to Nature in Freshwater Environments, by Michael J. Caduto, University Press of New England, 1990.

A conversational yet thorough overview of freshwater ecology.

Streams: Their Ecology and Life, by Colbert E. Cushing and J. David Allen, Academic Press, 2001

A textbook that covers river ecology; types of rivers; biota of rivers; and management, conservation, and restoration of rivers.

Riparia: Ecology, Conservation, and Management of Streamside Communities, by Robert J. Naiman, Henri Decamps, and Michael E. CmClain. Elseveir Academic Press, 2005.

A technical textbook that covers catchments and the physical template; riparian typology; structural patterns; biotic functions of riparia; biophysical connectivity and riparian functions; disturbance and agents of change; management; conservation; and restoration. Beautiful color illustrations and photos.

The River Book, by James Grant MacBroom, Natural Resources Center, Connecticut Department of Environmental Protection. 1998. ISBN: 0-942085-06-X.

A book written for a variety of audiences that covers hydrologic, biologic, water quality, hydraulic, and geologic disciplines of stream study. Includes information on ways in which human activities affect natural stream processes.

WINOOSKI RIVER STREAM TABLE UNIT

TEACHER EVALUATION FORM

Grade of students: ________ Number of Students ________ Number of days that you used the stream table: ____________

Subject(s) taught with stream table: ____

Stream Table Unit lessons that you taught to your students (please check):			
1. Corridors & Channels	❒ 1.1. Why Meanders Form	❒ 1.2. Changing Channel	❒ 1.3. Stream Anatomy
2. Sediments & Erosion	❒ 2.1. Gravel Mining	❒ 2.2. High Banks, Low Banks	❒ 2.3. Understanding Lane's Balance
3. Streambanks	❒ 3.1 Bank Protection	❒ 3.2 Streambanks & Habitat	
4. Stream Crossings	❒ 4.1 Stream Crossing Experiments	❒ 4.2. Community Crossings	
5. Upstream, Downstream	❒ Option A: Farm to City	❒ Option B: City to Farm	
Which lessons (above) were particularly effective? Explain.			
Which lessons (above) did not work well? Explain.			

Please rank the following items.	1 (not useful)	2	3 (somewhat useful)	4	5 (very useful)
Usefulness of stream table as a teaching tool					
Usefulness of Winooski River Stream Table Unit					
Suggestions for improvement:					

Please check all that apply:

❒ I received training to teach with the stream table. *Please tell us about your experience:*

❒ I received a visit from a stream table educator (planning and/or teaching). *Please tell us about your experience:*

❒ I would like to receive training to teach with the stream table and Stream Table Unit.

❒ I would like to receive a visit from a stream table educator to help me teach with the stream table.

Please send form to Larry Montague, Friends of the Winooski River, PO Box 777, Montpelier, VT 05602. 802-882-8276. info@winooskiriver.org.