Stream Order

Adapted from: An original Creek Connections activity.
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Grade Level: Basic to Advanced

Duration: One class period

Setting: Classroom

Summary: Students learn how to determine stream order using topographic maps.

Objectives: Students will be able to define stream order and determine the stream order of waterways using topographic maps. They will also be able to distinguish among perennial, intermittent, and ephemeral streams.

Vocabulary:
Watershed, stream order, tributary, perennial, permanent stream, intermittent stream, and ephemeral stream

Related Module Resources:
- Activities: Stream Length, Stream Gradient, and Watershed Area

Materials (Included in Module):
- Topographic maps, overhead transparencies, wet-erase markers, removable tape
- Overhead: Stream Order Figures
- 6 Stream Order Worksheets and Answer Key transparencies
  -Wolf Run
  -Little Conneauttee Creek
  -Temple Run
  -Mackey Run
  -Tributary of East Branch of Leboeuf Creek
  -Elk Creek

Additional Materials (NOT Included in Module):
- Overhead projector

ACADEMIC STANDARDS: ECOLOGY & ENVIRONMENT

10th Grade
4.1.10.C. Describe the physical characteristics of a stream and determine the types of organisms found in aquatic environments.
- Categorize aquatic organisms found in a watershed continuum from headwater to mouth (e. g., shredder, predator, decomposer).

12th Grade
4.1.12.A. Categorize stream order in a watershed.
- Explain the concept of stream order.
- Identify the order of watercourses within a major river's watershed.
- Compare and contrast the physical differences found in the stream continuum from headwaters to mouth.

BACKGROUND:

A **watershed** is the total land area that drains into a particular waterway. Watersheds can consist of chains or networks of streams of different sizes. The waterway is the central feature of the watershed. Just as smaller watersheds combine to form larger watersheds, small streams combine to create larger streams. However, "smaller" and "larger" are relative, qualitative terms. What one person considers "large" might be described as "small" by another person. For this reason, Horton (1845) came up with the **stream order** system that was improved by Strahler (1952, 1964) to uniformly classify waterways by size. In general, the greater the stream order, the larger and longer the waterway.

Scientists and environmental government agencies can use stream order as one way to describe the size of a particular waterway being studied. Creek Connections schools could also do this. If your research was published in an ecology journal read around the world, and you described your waterways as a 2nd order stream, then anyone in the science community could understand the approximate size of your waterway because of the established stream order system.

In the stream order system, streams with no **tributaries** are referred to as first order streams (Figures 1and 2). Tributaries are small streams that flow into larger streams. (*See the note at the end of the background section for information on counting intermittent and/or perennial streams and these

designations as the US Geological Survey's best guesses.) First order streams have no tributaries but can themselves be tributaries of larger waterways. While higher order streams are fed by tributaries, first order streams are fed by springs, lakes, and/or surface runoff. First order streams combine with other first order streams to form second order streams. Second order streams have only first order streams as tributaries. Examples of first and second order streams include mountain cascades, small streams coming out of a hillside, and narrow, riffled, shallow forested brooks. Second order streams combine with other second order streams to form third order streams. Third order streams combine to form fourth order streams, and so on. The order of a stream can only increase by one unit when it joins a stream of equal order. That is, a fourth order stream with a third order tributary remains fourth order. It can only become a fifth order stream upon merging with another fourth order stream. Also, stream order never decreases. If a second order stream flows into a third order stream, the main branch of the stream remains third order.

Streams that are good fishing waters are generally third or fourth order streams. Seventh order streams are typically wide, deep, muddy and silty rivers. By the time streams reach seventh order or greater, they are nearing the end of their journey to the ocean. In fact, the only tenth order stream in North America is the mighty Mississippi!

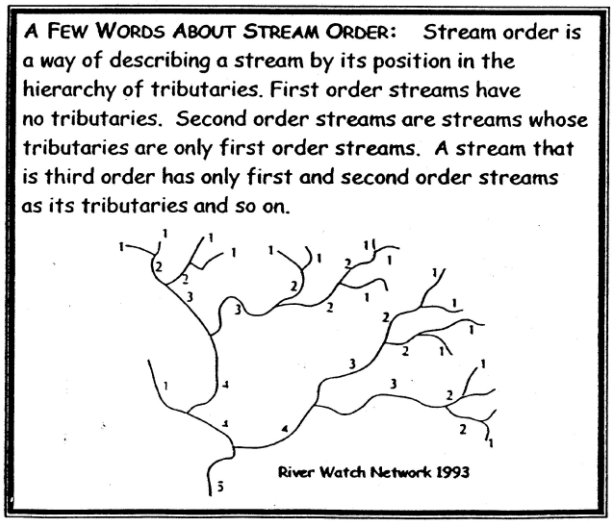

Figure 1. A few words about stream order.
Source: River Watch Network, 1993.

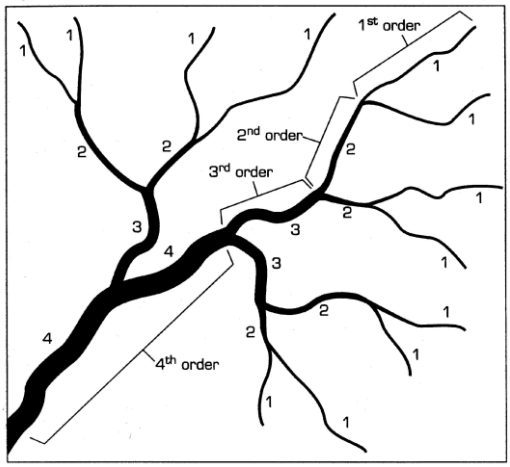

Figure 2. Stream Order
Source: Fink Martin, Patricia A. Rivers and Streams. Danbury, Connecticut: Franklin Watts, 1999.

In addition to being a useful system of classifying waterways by size, stream order is also related to other watershed characteristics: stream length and the number of streams of a given order in a watershed. Stream order is positively correlated with stream length, meaning that as stream order increases, so does stream length (Figure 3, left graph). In other words, longer streams are generally of higher order. Furthermore, because there are more smaller, lower order streams than larger, higher order streams, stream order is negatively correlated with the number of streams of a given stream order. That is, there are hundreds of thousands of small, first order streams, only several thousand fourth order streams, and mere hundreds of sixth and seventh order streams. According to Allan

(1996), "There are usually some three to four times as many stream of order *n-1* as of order *n*, each of which is roughly less than half as long" (18) (Figure 3, right graph). For example, if there are approximately 10 second order streams, Allan suggests that there are 30-40 first order streams. And, if the second order streams average 10 miles in length, the first order streams are approximately 5 miles long.

Stream order is also useful because it is related to the area of its watershed and stream gradient. A stream of order *n-1* drains about one fifth of the area drained by a stream of order *n*. For example, a second order stream might have a watershed area of 100 mile^2 whereas the area of a first order stream would be approximately 20 mi^2. Furthermore, low (first and second) order streams generally have steeper stream gradients than higher (fourth and fifth) order streams. Another important use of stream order is the river continuum concept. As stream order increases, the relative abundance of different types of feeders (i.e., shredders, grazers, predators, and collectors) changes (Figure 4). For example, first and second order streams contain more shredders than do fifth order streams. Grazers are more prominent in fifth and sixth order streams than in first and second order streams.

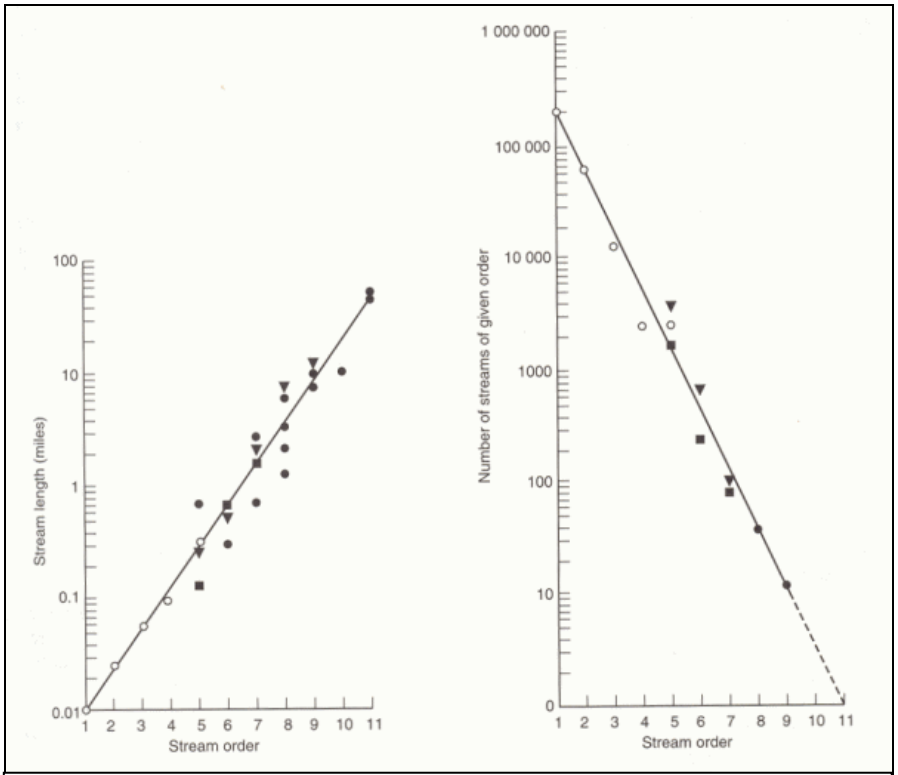

Figure 3. The relationship of stream order to stream length and to number of streams of a given order, from a network of arroyos near Santa Fe, New Mexico. Open circles= Average values, Arroyo Caliente, squares=Arroya de los Frijoles, triangles=Arroya de las Trampas to Rio Santa Fe, black circles=Rio Santa Fe, Rio Galisteo and Cañada Ancha (del oriente). (Redrawn from Leopold, Wolman and Miller, 1964.)

Source: Allan, J. David. Stream Ecology. New York: Chapman & Hall, 1995.

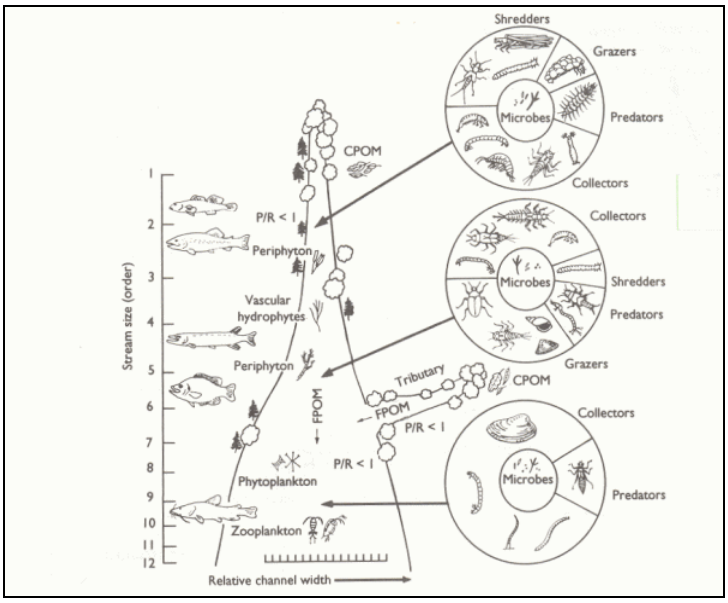

Figure 4. Generalized depiction of the relationship between stream size (order), Energy inputs and ecosystem function expected under the river continuum concept. (From Vannote et al., 1980).

Source: Allan, J. David. Stream Ecology. New York: Chapman & Hall, 1995.

Another way to classify streams is by the frequency at which water flows through them. Streams that flow all year round are referred to as **perennial** or **permanent** streams. They are depicted as dark solid blue lines on topographic maps. Streams that flow only during the wet season or after heavy rains are called **intermittent** streams (Figure 5). During the dry season, they are nothing but parched streambeds. Intermittent streams are represented by dashed light blue lines on topographic maps. Although not depicted on topographic maps, the third and most short-lived type of stream is **ephemeral**. These streams most commonly form in V-shaped valleys, ravines, or gullies during and immediately after heavy rains. However, the ephemeral streams dry up shortly after those rains have ended. The depiction of waterways on topographic maps as perennial or intermittent is simply the US Geological Survey's best guess. (See note at the end of this background section.) It is possible that streams represented as perennial dry up at certain points during the year or that waterways denoted as intermittent flow year round. It is important to keep these possibilities in mind when using topographic maps.

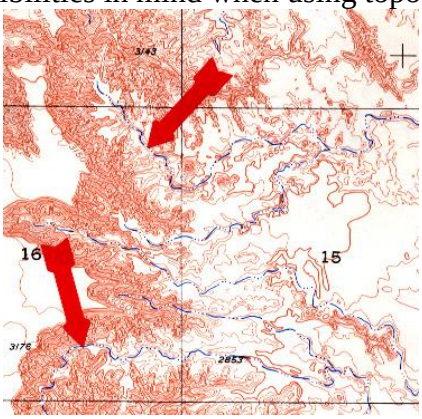

Figure 5. Intermittent streams on a topographic map.

Source: http://www.csus.edu/indiv/s/slaymaker/Geol10L/interstream1.jpg

*NOTE: Some schools of thought on the stream order system hold that only perennial streams should be considered when determining stream order. Others consider both perennial and intermittent streams when determining stream order. Ultimately, it is up to you, the teacher, to determine which method you would like your students to use. Counting intermittent as well as perennial streams usually increases the stream order by one or two but also makes the stream order determination slightly more complex and challenging. Furthermore, the representation of streams as perennial or intermittent on topographic maps is merely USGS's best guess. They have not visited each and every waterway on all map quads. Thus, it is possible that streams indicated as intermittent on topographic maps flow year round while other streams depicted as perennial run dry from time to time. For most Creek Connections activities, both perennial and intermittent streams and tributaries are considered when determining stream order.

References:

Allan, J. David. Stream Ecology. New York: Chapman & Hall, 1995.

Fink Martin, Patricia A. Rivers and Streams. Danbury, Connecticut: Franklin Watts, 1999.

OVERVIEW:

Students are introduced to the concept of stream order and then use their new skill to determine the stream order of numerous waterways on worksheets and topographic maps.

PROCEDURE:

There are two options for this activity, both with instructions below:

Option A: Using pre-made Stream Order Worksheets

Option B: Selecting a waterway of your choice on a topographic map and determining its stream order.

For Option B, you will generally be limited to smaller order streams for this exercise unless you plan to lay out many different topographic maps. (For instance, determining the stream order of French Creek at its mouth in Franklin, PA would require you to view topographic map quadrangles of the entire watershed). Though less accurate, you could use County Topographic Maps (1:50,000 scale) to determine the stream order of larger creeks, however these maps sometimes don't show very small, first order streams, so your exact stream order for a larger creek may be off by 1 or 2 orders.

Teacher Preparation:

Option A—Worksheets

1. Procure and set up an overhead projector.

2. Make copies of the "Stream Order Worksheet(s)" for your students. Worksheets and Answer keys for Wolf Run, Little Conneauttee Creek, Temple Run, Mackey Run, and a tributary of East Branch of Leboeuf Creek are included at the end of this activity. Overhead transparencies of the Answer Keys are also included at the end of this activity.

3. Locate the "Overhead: Stream Order" overhead transparency, which you can use to illustrate key points as you introduce the concept of stream order. This overhead may also be photocopied and distributed to students.

Option B—Working with Topographic Maps

1. Procure and set up an overhead projector.

2. Go through the topographic map quads and/or laminated quads or 11x17 sections. Select a stream location or various stream locations on different maps whose order your students will determine. Make sure all of the tributaries that will be necessary to determine stream order are shown on the map(s).

3. Lay out the maps on flat surfaces around the classroom. Distribute wet-erase markers at the map stations. If using unlaminated maps, distribute blank overhead transparencies or tracing paper and have students secure them to the map with the special, removable tape (not regular scotch tape – it will rip the map) over the section of the topographic map you are studying.

4. Trace the waterway(s) of interest onto an overhead transparency and use this to go over the answer with the entire class at the end of the activity.

5. Locate the "Overhead: Stream Order" overhead transparency, which you can use to illustrate key points as you introduce the concept of stream order. This overhead may be photocopied and distributed to students.

Student Activity: *Options A & B*

1. Stimulate a discussion about stream order and how it relates to stream length and gradient, the area of a watershed, the river continuum, and the number of streams of a given order. Use the "Overhead: Stream Order" overhead transparency to illustrate key points.

2. If a worksheet is being used, skip to step 3. If a topographic map is being used, select a stream whose stream order you will determine.

3. Use tracing paper or an overhead transparency and wet-erase marker to trace the entire length of the stream of interest and all of its tributaries.

4. Locate all perennial first order streams (streams with no tributaries) and mark them as "1" to indicate first order stream. *Teachers: Some Stream Order Worksheets require that students consider both perennial and intermittent tributaries when determining stream order. If this is the case, it is noted on the worksheet. When using streams of your choice on topographic maps, be sure to indicate whether you want students to consider intermittent and perennial tributaries, or just perennial tributaries.*

5. Locate all points where first order streams meet and mark them as "2" to indicate second order stream.

6. Locate all points where second order streams meet and mark them as "3" to indicate third order stream.

7. Continue this process, keeping in mind that stream order only increases by one unit where two streams of the same order *n* combine, forming a stream of order *n+1*. Stream order does not change at points where streams of different order meet, such as a first order stream flowing into a third order stream. The third order stream remains third order. Fourth order streams only arise where two third order streams meet. Also, keep in mind that stream order can never decrease.

8. Check students' work with the corresponding "Stream Order Answer Key" or use the overhead transparency onto which you traced the stream of interest.

DISCUSSION:

What is stream order? *See background.*

What is a tributary? *See background.*

Why is stream order an important piece of information to know about a waterway? *Because a) it allows us to classify the waterway based on its size, b) stream order tells us about the relative length and gradient of the waterway, the area of its watershed and the types of feeders (macroinvertebrates) we might expect to find in the waterway.*

What are the sources of water in first order streams? *See background.*

What are the sources of water in higher order ($\geq$ second order) streams? *See background.*

How is stream order related to…

a.) stream length?
b.) stream gradient?
c.) the area of a watershed?
d.) the river continuum?
e.) the number of streams of that order?

See background for all.

What are perennial/permanent, intermittent, and ephemeral streams? *See background and Figure 4.*

EXTENSIONS AND MODIFICATIONS:

- Discussion questions above.
- Students correctly complete stream order worksheets and correctly determine the stream order of waterways on topographic maps.
- Have students draw pictures of second and third order streams.
- Give students a topographic map and a copy of the river continuum and ask them to determine the stream order of two waterways of their choice on the topographic map. Then, have them use what they know about the relationship between stream order and stream length, stream gradient, the area of a watershed, and the river continuum to

determine the relative stream length, stream gradient, watershed area, and types of feeders they'd expect to find in the two streams.

- Investigate the different types of macroinvertebrate feeders (shredders, collectors, predators, etc.) in streams of different order and compare your results to the river continuum concept (Figure 4).

NOTES (PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS USING THIS ACTIVITY IN THE FUTURE):