Watershed Delineation

Adapted from: An original Creek Connections activity.
Creek Connections, Box E, Allegheny College, Meadville, Pennsylvania, 16335

Grade Level: Intermediate to Advanced

Duration: One class period

Setting: Classroom

Summary: Students use prominent topographic map features to delineate the boundaries of a watershed.

Objectives: Students will be able to identify hills, valleys, tributaries, and ridges and use contour lines to delineate a watershed.

Vocabulary: watershed, watershed delineation, stream order, tributaries

Related Module Resources:
- Activity: Watershed Area

Materials (Included in Module):
- White plastic 3-D contour model #1
- Worksheet, Answer Key, & Overhead Transparency: Watershed Delineation—Contour Model Work
- Tracing paper, blank overhead transparencies, wet-erase markers, removable tape
- 4 Overhead Transparencies: Watershed Delineation
- 8 Watershed Delineation Keys and associated topographic maps:
  Meadville Quadrangle
  Laminated 11x17" sections (20)
  -French Creek Tributary downstream of McGuffintown Bridge
  -French Creek Tributary south-east of Blacks Corner
  -Bennyhoof Creek
  Townville Quadrangle
  Laminated full quads (8)
  -Muddy Creek Tributary
  -Temple Run Tributary
  Cambridge Springs NE Quad
  Laminated 11x17" sections (20)
  -Small Elk Creek Tributary
  -large Elk Creek Tributary
  Conneaut Lake Quadrangle
  Laminated 11x17" sections (20)
  -McDowell Run
- Topographic map transparencies for all sections of the laminated quads above

Additional Materials (NOT Included in Module):
- None

ACADEMIC STANDARDS:

ECOLOGY & ENVIRONMENT

7th Grade
4.1.7.B. Understand the role of the watershed.
- Identify and explain what determines the boundaries of a watershed.

10th Grade
4.1.10.A. Describe changes that occur from a stream's origin to its final outflow.
- Describe changes by tracing a specific river's origin back to its headwaters including its major tributaries.

4.1.10.B. Explain the relationship among landforms, vegetation and the amount and speed of water.
- Describe how topography influences streams.
- Delineate the boundaries of a watershed.

GEOGRAPHY

6th Grade
7.1.6.A. Describe geographic tools and their uses.
- Geographical representations to display spatial information: topography
- Basic spatial elements for depicting the patterns of physical and human features: point, line, area, location, distance, scale

7.2.6.A. Describe the physical characteristics of places and regions.
- Components of Earth's physical systems (e.g., relief and elevation (topography))
- Comparisons of the physical characteristics of different places and regions (e.g., topography)

12th Grade
7.2.12.A. Analyze the physical characteristics of places and regions including the interrelationships among the components of Earth's physical systems.
- Watersheds and river basins

BACKGROUND:

A **watershed** is the total land area that drains into a particular waterway. Land areas drain into chains or networks of streams of different sizes and lengths. Every waterway has its own watershed, or land area whose runoff drains into that waterway. Small streams each have their own, generally small watersheds. Small streams combine with other small streams to form larger stream networks. Their watersheds also combine to form larger watersheds. The land area around all streams in complex stream networks becomes part of an even larger watershed, and so forth, as more streams converge. That is, large waterways generally drain larger land areas and thus have larger watersheds. More specifically, the size of a watershed is related to the **stream order,** or size classification, of the waterways within it. (See the Stream Order Activity for more details on the concept of stream order.) The watershed of a high order stream consists of the land area that drains into that waterway and the land area that drains into all of its **tributaries,** or small streams that flow into the larger stream. Thus, higher order streams generally have larger watersheds than lower order streams. Simply put, larger waterways generally drain larger areas and thus have larger watersheds. This is because the watershed of a large waterway includes all the watersheds of the smaller streams that drain into it (tributaries).

Figure 1 below illustrates this concept well. The watershed indicated with the arrow is the Pennsylvania portion of the French Creek watershed. Included within the boundary of the French Creek watershed are all the small streams (tributaries) that flow into French Creek, as well as all the land area that they drain. Although some runoff within these boundaries drains directly into French Creek, most of the runoff in this drainage area drains first into one of the tributaries of French Creek, and then travels downstream, eventually draining into French Creek. Although French Creek is a relatively large waterway, it is part of an even larger watershed. French Creek, along with all of the other watersheds in dark gray below, empties eventually into the Ohio River. The Ohio River is significantly larger than French Creek; therefore, its watershed is also much larger than that of French Creek. (Figure 1.)

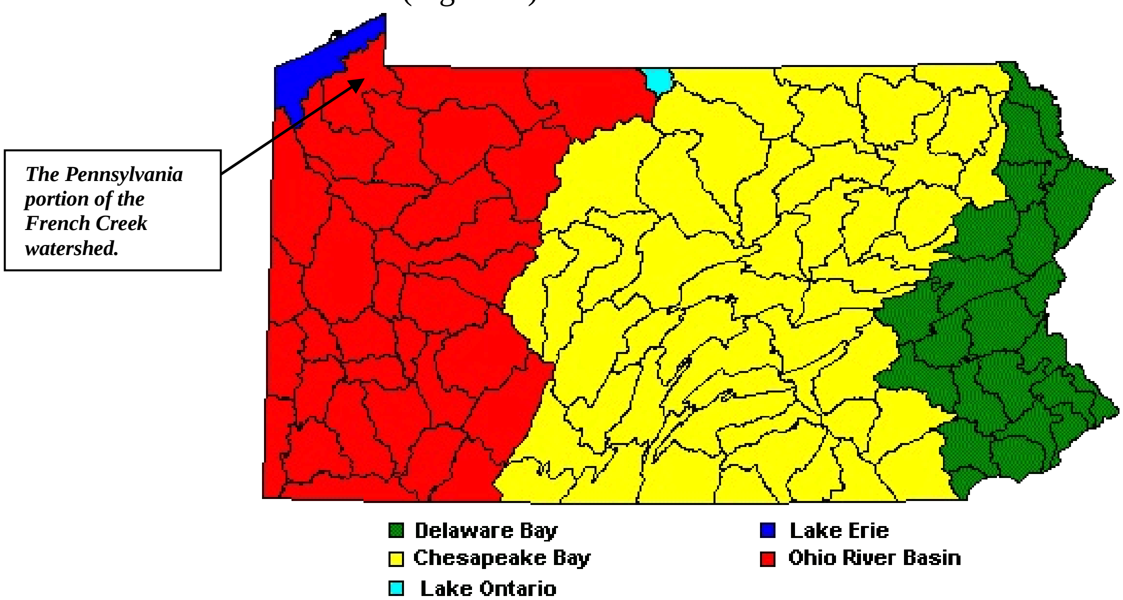


Figure 1. The large Ohio River Basin watershed in Pennsylvania includes the drainage from all of the smaller watersheds within it, including the French Creek watershed.
Source: *http://www.dep.state.pa.us/river/images/PAdrainage.gif*
Note: This version of the Watersheds of Pennsylvania map combines the Potomac River Watershed and Susquehanna River Watershed into the larger Chesapeake Bay Watershed.

The watershed concept is best illustrated on topographic maps. By looking at the prominent physical features of the land around a waterway, one can determine if runoff or a raindrop at any given point on the map will eventually drain into that waterway or not. After determining the destination of runoff at many such points, one starts to get a sense of where the boundaries of the watershed are. The process of locating and drawing the boundaries of a watershed is called **watershed delineation**. If one has correctly delineated a watershed, all water that falls within the watershed boundaries should flow into the waterway that is the focal point of that watershed. Conversely, all water that falls outside the watershed boundaries should flow into another waterway that is in another watershed.

Topographic map features are helpful for watershed delineation. First and foremost, contour lines allow us to imagine the direction of the flow of runoff over the land and also the groundwater flow, since groundwater flow usually mimics the flow that would occur on the land surface. Both surface runoff and groundwater flow downhill and we can determine elevations using contour lines on a topographic map. Flow will also be affected by the topography (hills, valleys, flatland). These features are also revealed by the contour lines.

There are a number of things to keep in mind when determining the direction of flow. Since water flows downhill, you might first want to find the higher land around your waterway (hilltops, mountains). Contour lines and index contour lines are used to determine the high points, or points of highest elevation, in the area around a waterway. This higher land might create the boundary for your watershed. Rain or runoff falling on one side of a hill or high point will flow in one direction, while water on another side might flow in a different direction toward a different waterway. Connecting points between hilltops and following the ridges can form the <u>general</u> (not necessarily the specific) outline of a watershed. Hilltops on topographic maps are represented by concentric (having the same center) contour lines (Figure 2).

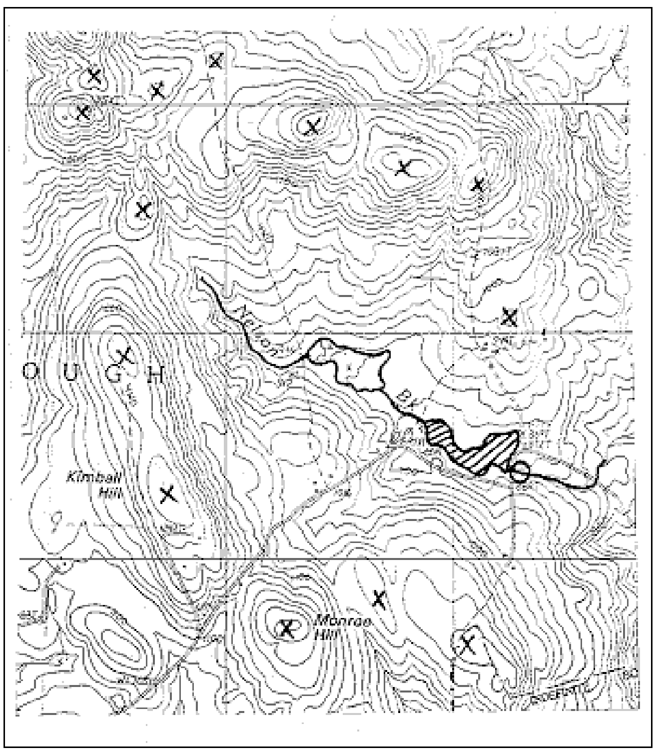


Figure 2. Concentric contour lines represent hilltops (Xs).
High points of land around a waterway help form the watershed boundary.
Source: http://www.nh.nrcs.usda.gov/other/ws_delineation.htm

To determine which direction water will flow off of a hillside, there is a very important rule to keep in mind. Surface runoff and groundwater always flows perpendicular to the contour lines. To understand why, imagine you are standing on the side of a hill (shown in Figure 3 with a cross hair indicating the hilltop). If you were to dump a bucket of water, the water would flow downgrade, along the plane of the hillside (indicated by the ⟶ arrow). Your dumped water would not flow sideways or diagonally across the hillside (indicated by the - - - - → arrow).

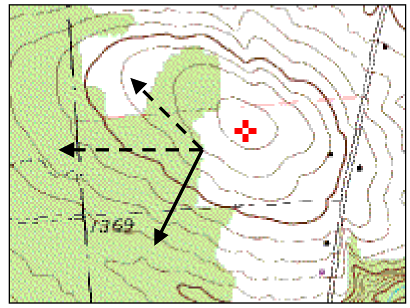


Figure 3. Surface/groundwater flow is always perpendicular to contour lines (⟶ arrow).

Water also flows in valleys, ravines, or gullies, represented by V-shaped contour line patterns. As small streams cut into hillsides to form valleys, ravines, or gullies, they erode away V-shaped sections of hillsides, resulting in these V-shaped patterns on topographic maps. You can determine the direction of flow through these valleys. During and after heavy rains, tiny streams or runoff may flow through these V-shaped valleys, and the V-shaped contour lines always point in the opposite direction of the direction of stream/runoff flow (Figures 4 and 5 and 6).

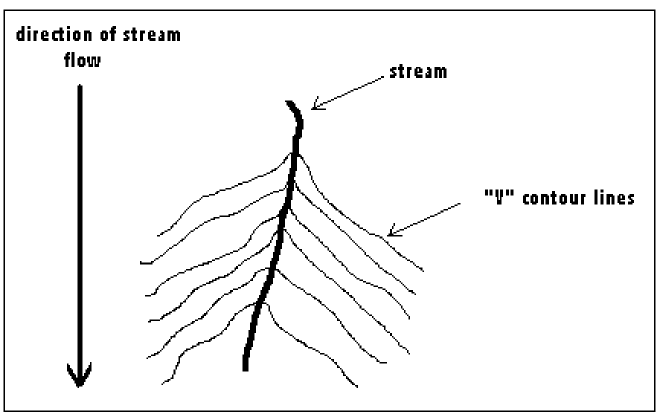
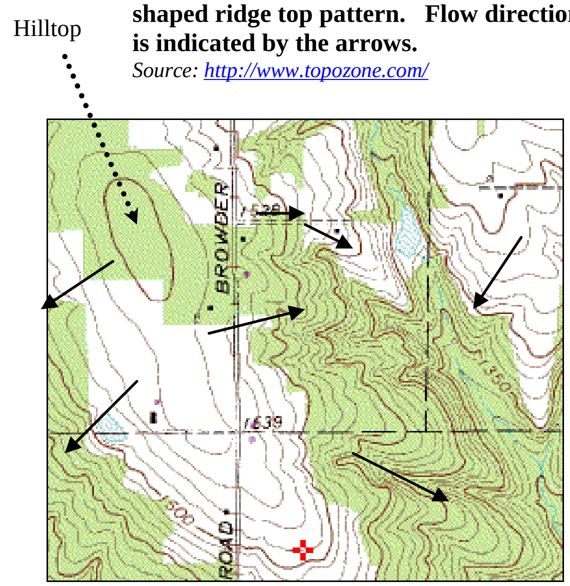


Figure 4. V-shaped contour lines point in the opposite direction of stream flow.

Figure 5. **You will notice that there are small ravines (V-shaped) being cut back up into the hillside. This illustration also shows the U-shaped ridge top pattern. Flow direction is indicated by the arrows.**
Source: *http://www.topozone.com/*



The rules of water flow also pertain to flow over U-shaped contour lines. U-shaped contour lines represent ridges or crests of hills. As always, runoff flows perpendicular to contour lines. Thus, runoff on one side of a ridge might flow towards the waterway whose watershed is being delineated, while runoff at another point on a hillcrest might flow towards a completely different waterway (Figure 5 and 6).

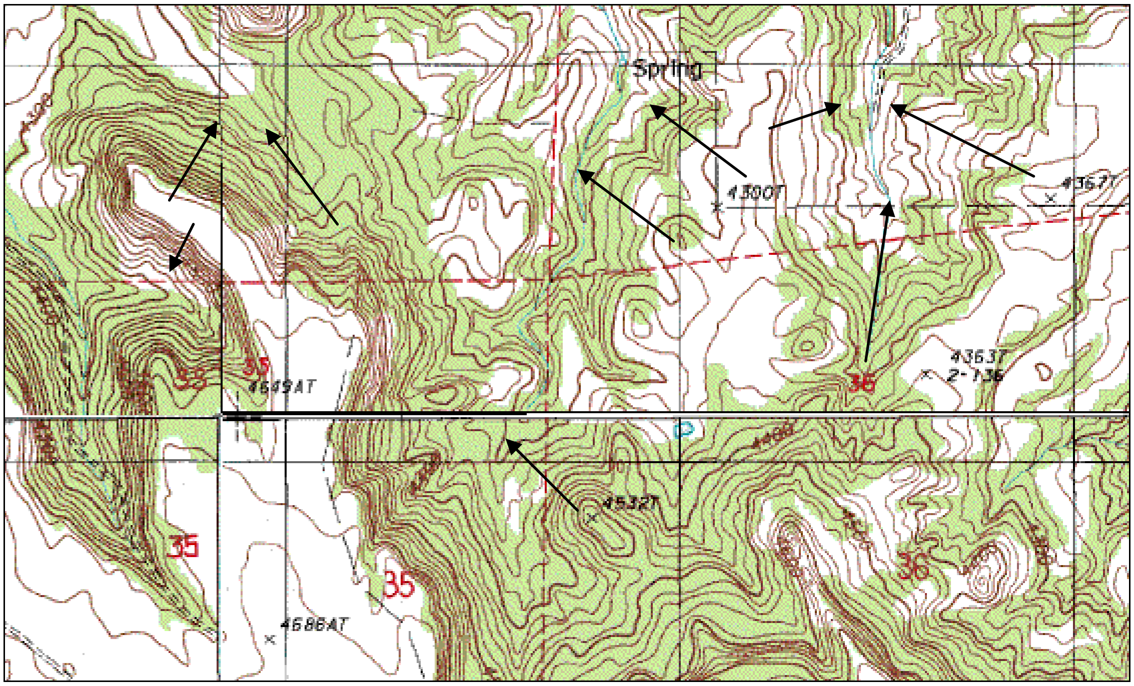


Figure 6. Runoff and groundwater flows perpendicular to contour lines, whether flowing down a hill or through a ravine. Arrows show the direction of flow.
Source: http://www.topozone.com/

The aforementioned physical features are used to draw arrows representing the direction of flow of runoff or groundwater flow at various points on the land. These arrows as well as hilltops and high points are used to determine the watershed boundary (Figure 7). Because a watershed boundary divides the runoff and groundwater flow between two different waterways, the flow arrows (perpendicular to contour lines) would help you figure out if a hill or ridge is the divide, if the hill is in a sense splitting the flow arrows. Also, it is worth noting that technically the watershed delineation line is also a flow line, but it is the precise spot/line where the water does not really have an inclination to flow toward either waterway. A raindrop there could flow either way toward one stream or another, one watershed or another. The delineation line/boundary is the perfect dividing spot.

When drawing in the watershed boundary delineation line, there are a few additional things to keep in mind. Most importantly, the delineation line is also to be drawn perpendicular to the contour lines (it just works out this way). So the delineation line should not trace a contour line at any point; it always crosses contour lines at 90^{o} angles. The delineation line often follows the ridges of a hill to the top of a hill. A delineation line does not cut sideways across a stream or even a "streamless" ravine (V shaped valley). Watershed boundaries never cut across Vs. Be sure to follow the Vs up into hillsides as much as possible and include them in your watershed area delineations.

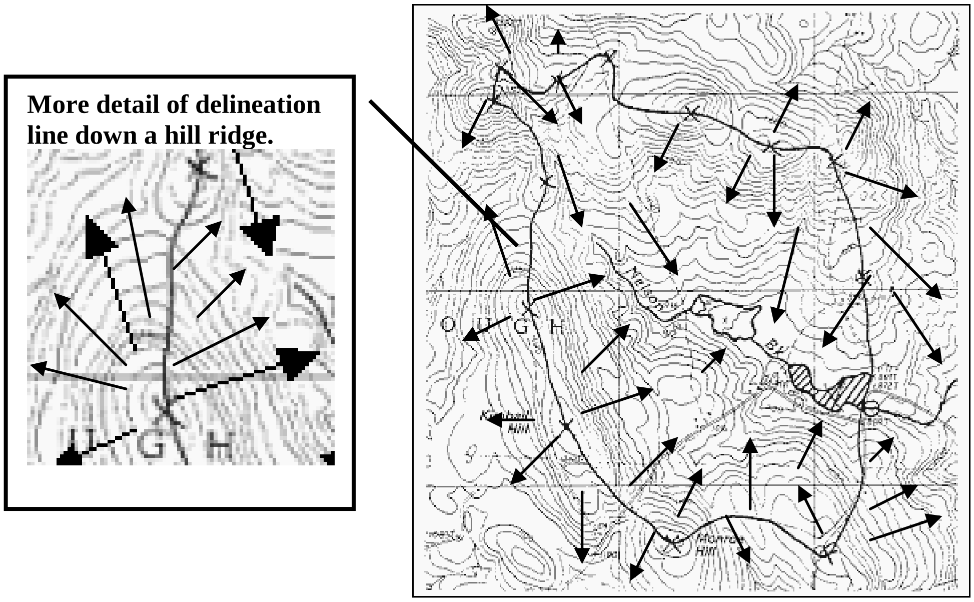


Figure 7. Delineated watershed with arrows pointing in the direction of runoff flow and X'ed hilltops and high points.
Adapted from: http://www.nh.nrcs.usda.gov/other/ws_delineation.htm

Watershed boundary delineations are useful. Knowing watershed boundaries would allow you to determine what land uses, human activities, and/or possible sources of water pollution are contained within your watershed or are outside of your watershed, thus not affecting your stream. It is also sometimes useful to classify the land use types within your watershed (ie. 50% forest, 35% agriculture, 10% suburban, 5% amusement park). If delineate a watershed, you can determine its size using a few different methods (covered in the Watershed Area activity). Also, scientists might want to show a watershed delineated on a map for a scientific article, environmental report, or research display.

Because watershed delineation involves reading topographic maps and identifying prominent features of the land area around a waterway, watershed delineation is a great review and test of topographic map skills. Although it is somewhat challenging at first, watershed delineation gets easier as one becomes more familiar and comfortable with topographic maps.

OVERVIEW:

Students use topographic maps to delineate watersheds by interpreting contour lines and identifying prominent features around a waterway such as hilltops, high points, valleys, rifts and hillcrests.

PROCEDURE: *Part A—Contour Model Work*

Teacher Preparation:

1. Locate white 3-dimensional contour model #1 and a wet erase marker in the module.

2. Trace the "contour lines" on the 3D contour model in wet-erase marker to help students see the lines more clearly. There are even brown wet-erase markers to use for this purpose.

3. Make copies of the Watershed Delineation—Contour Model Work Worksheet and locate the corresponding Answer Key and/or transparency at the end of this activity.

Student Activity: ***Part A—Contour Model Work***

1. Lead a lecture and stimulate a discussion about watershed delineation and review the prominent features that will help your students accurately delineate a watershed. See background section to do this.

2. To review and illustrate how and why the flow arrows are always perpendicular to contour lines and how and why these flow arrows will help figure out watershed boundary delineations, present the white contour model #1 to the class and select a student volunteer.

3. Ask this student to point to the hilltop and the streambed. Have him/her use a wet erase marker to draw three arrows representing the flow of runoff in different directions from that hilltop. Which arrows are pointing toward the streambed? Which arrows are pointing away?

4. Then invite several more students (one at a time) to come to the front of the class and draw arrows on the model with a wet erase marker to illustrate the flow of runoff down the hillside and over other areas of the model. Again, ask them if the arrows are pointing toward or away from the streambed.

5. Once the model is full of arrows, ask students to imagine the boundary between arrows that are pointing toward the streambed and those that are pointing away from it. Invite two or three students (one at a time) to come up front and trace the boundary with their finger.

6. Finally, use a different color wet erase marker to draw in the watershed boundary of this small stream, that splits the flow arrows between ones going toward the creek and ones going away from the creek.

7. Now distribute the Watershed Delineation—Contour Model Work Worksheet. Explain that the enlarged image is the topographic map of the 3-D model. In the same way they just drew arrows on the 3-D model, have them draw arrows perpendicular to the contour lines on their worksheets and then use those arrows to draw the watershed boundary. Compare students' delineations to the Watershed Delineation—Contour Model Work Answer Key transparency at the end of this activity.

<u>PROCEDURE</u>: ***Part B—Delineating Watersheds on Topographic Maps***

Teacher Preparation

1. Select the stream(s) whose watershed(s) your students will determine. Watershed Delineation Keys are included at the end of this activity for the streams listed below. Note that they are listed by level of difficulty. We suggest you introduce watershed delineation using the "Beginner" level examples, and then proceed to the "Intermediate." The two "Expert" level examples are quite challenging and might be used as bonuses.

   <u>Beginner</u>

   Townville Quadrangle [use laminated full quads included in module]
   - small, unnamed intermittent tributary of Muddy Creek that empties into Muddy Creek near Hamilton Road
   - small, unnamed intermittent tributary of Temple Run just north of the word "Temple" on the map and whose headwaters are a pear-shaped lake/pond

   Meadville Quadrangle [use laminated 11x17" quad sections included in module]
   - small, unnamed intermittent tributary of French Creek just downstream of McGuffintown Bridge

   <u>Intermediate</u>

   Meadville Quadrangle [use laminated 11x17" quad sections included in module]
   - small, unnamed intermittent tributary of French Creek southeast of Blacks Corner

   Cambridge Springs NE Quadrangle [use laminated 11x17" sections included in module]
   - small, unnamed intermittent tributary of Elk Creek that enters Elk Creek between the words "Elk" and "Creek" on the map
   - large, unnamed intermittent/perennial tributary of Elk Creek that drains into Elk Creek near Rt. 86

   <u>Expert</u>

   Meadville Quadrangle [use laminated 11x17" quad sections included in module]
   - Bennyhoof Creek

   Conneaut Lake Quadrangle [use laminated 11x17" quad sections included in module]
   - McDowell Run

2. Locate the appropriate topographic maps or laminated topographic map sections (as indicated above) in the module and lay them out around the classroom on flat surfaces. You may want to secure the maps to the flat surfaces using <u>removable</u> tape (or permanent tape if maps are laminated and tending to curl up). Also locate the corresponding Watershed Delineation Key transparencies and topographic map transparencies in the module.

3. Locate blank overhead transparencies (not necessary if using laminated map sections) and <u>wet-erase</u> markers in the module and distribute around the classroom at the map stations.

4. If you are having your students delineate a watershed not listed in Step 1 above, delineate the watershed yourself in advance on an overhead transparency so that you can check your students' answers.

Student Activity
Part B—Delineating Watersheds on Topographic Maps

1. Locate the waterway whose watershed you will be delineating as well as all of its tributaries.

2. Use removable tape to tape down a blank overhead transparency over the waterway and all of its tributaries – *this way you do not write directly onto the map!* (This step is not necessary if using laminated map sections.)

3. On the laminated map or on the overhead transparency, use a blue (or other color) wet erase marker to trace the waterway of interest and all of its tributaries.

4. Now imagine that there are additional tributaries to your waterway of interest that are not shown in blue on your map. These would be very small streams that would be formed after a huge rainfall, and these streams would form in the V-shaped patterned contour lines (representing ravines and valleys). Find these ravines near your waterway and draw in streams flowing down them toward the creek. The flow direction will be opposite of the way the V's are pointing, so draw arrows in the correct direction to represent the flow of water in the V-shaped valleys (Fig 4.). Keep in mind if these streams flowed into your creek, then they must be part of the watershed.

5. Obtain a different color marker. Now find hilltops and high points (Fig. 2) around the waterway and mark these points with X's.

6. Now draw numerous short arrows (⟶) to represent the direction of the flow of runoff and groundwater at that point. These arrows will be perpendicular to the contour lines. Draw the arrows for other areas around the waterway of interest and its tributaries, perhaps down the hillsides or other high points or through other ravines and valleys. Start near the waterway and progress away from it. It is okay to have arrows pointing away from your waterway of interest; these are helpful to have. Stay in land areas around your waterway. The more arrows you draw, the more easily and accurately you will be able to delineate the watershed.

7. At this point, the area around the waterway should be filled with arrows and X's. The next step is to attempt to delineate the watershed and draw in the watershed boundary line. To do so, use a different color marker to draw a line on the land around the waterway and its tributaries that *includes* all arrows that point *toward* the waterway and *excludes* all arrows that point *away* from the waterway. So in other words, you are drawing a line that will "split" or "divide" the arrows. Use the hilltops and high points as a general outline of the watershed – these hilltops and ridges might be part of the watershed if they "divide arrows". It does not suffice to simply connect the

X'ed hill tops and high points—you must pay attention to the direction of flow of runoff down the hillcrests and ridges as well as the direction of flow of runoff elsewhere in between the high points. When drawing in the watershed boundary delineation line, there are a few additional things to keep in mind. Most importantly, the delineation line is also to be drawn <u>perpendicular</u> to the contour lines (it just works out this way). So the delineation line should not trace a contour line at any point; it always crosses contour lines at 90^{o} angles. The delineation line often follows the ridges of a hill to the top of a hill. A delineation line does not cut sideways across a stream or even a "streamless" ravine (V shaped valley). Watershed boundaries never cut across Vs. Be sure to follow the Vs up into hillsides as much as possible and include them in your watershed area delineations.

8. The delineated watershed boundary should encompass the waterway and all of its tributaries. Check your delineation by randomly picking points within and outside of the watershed boundary and tracing the flow of runoff from that point.

9. *Teachers:* Check students' answers by using the corresponding overhead transparency Watershed Delineation Key or delineated watershed boundary you have drawn on a transparency, as well as the topographic map transparencies that correspond to the topo map section in which your students delineated a watershed. Simply line up the stream on the overhead transparency with the stream on the topographic map and compare the key boundaries to those the students have drawn.

SPECIAL NOTE: Do not erase the watershed boundaries students have drawn on the transparencies or laminated map sections if you plan to use the same examples for other activities in the module, namely Watershed Area and Land Use in Watersheds.

<u>**DISCUSSION**</u>:

What does it mean to delineate a watershed? *The process of locating and drawing the boundaries of a watershed is called* ***watershed delineation****. If one has correctly delineated a watershed, all water that falls within the watershed boundaries should flow into the waterway that is the focal point of that watershed. Conversely, all water that falls outside the watershed boundaries should flow into another waterway that is in another watershed.*

In general, what physical features on topographic maps are used to delineate watersheds? *Contour lines, valleys, hilltops, streams, tributaries, hillcrests, and ridges.*

What features were particularly useful when delineating the watershed you worked on? *Answers will vary.*

Why did you draw arrows during the watershed delineation? What do the arrows represent? *Students draw arrows to help them visualize the direction of surface runoff flow and groundwater flow at numerous points near the waterway. In general, groundwater flow mimics the surface flow direction.*

Why does surface runoff and groundwater flow perpendicular to contour lines? *To understand why, imagine you are standing on the side of a hill (shown in Figure 3 with a cross hair indicating the hilltop). If you were to dump a bucket of water, the water would flow downgrade, along the plane of the hillside. Your dumped water would not flow sideways or diagonally across the hillside.*

What direction do streams flow in V-shaped valleys? *Opposite of the V's (Figure 3).*

How does one recognize hilltops and high points on topographic maps? *Concentric contour lines (circle or oval patterns) represent hilltops and contour line elevations are used to identify high points.*

What parts of the watershed were the most challenging to delineate? *Answers will vary.*

Generate a list of why delineating a watershed would be a useful tool.
-- *To determine the land uses/ human activity/possible sources of water pollution that may be contained within your watershed.*
-- *To determine land uses/ human activities / possible sources of water pollution that are not affecting your waterway because they are outside the watershed boundary.*
-- *To classify land use types within your watershed boundary (ie. 50% forest, 35% agriculture, 10% suburban, 5% amusement park).*
-- *You can determine the size of your watershed after you figure out the delineation boundary lines. (This is a separate activity).*
-- *Scientists might want to show a watershed delineated on a map for a scientific article, environmental report, or research display.*
-- *It is a great way to practice your topographic map reading/interpretation skills.*

EVALUATION:

- Accuracy of boundaries of the watershed delineated by the class.
- Discussion questions above.
- Have students delineate a "mystery" watershed.
- Have students write the procedure for watershed delineation.
- Give students delineated watershed examples and have them determine if the boundaries are correct. If not, have them "fix" the delineation.

EXTENSIONS AND MODIFICATIONS:

- Delineate your watershed or additional watersheds on other maps.
- Have students compare the overall sizes of watersheds for streams of different orders and determine if lower order waterways generally have smaller watersheds than higher order streams.
- Research the actual boundaries of watersheds and compare these boundaries to those that students delineate themselves.
- Contact local conservation or environmental agents and research how they use watershed delineation in their work.

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