Watershed Area

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

Duration: One class period

Setting: Classroom

Summary: Students learn three methods to determine the area of a watershed on a topographic map.

Objectives: Students will be able to delineate a watershed and then use graph paper, mass, and/or a planimeter to determine the area of a watershed on a topographic map.

Vocabulary: watershed, stream order, planimeter

Related Module Resources:
- Activities: Watershed Delineation, Stream Order

Materials (Included in Module):
- Tracing paper, 1 planimeter, topographic maps, overhead transparencies, wet-erase markers, removable tape, calculators
- Handout: "Planimeter Parts, Set-up, and Reading"
- Handout: Watershed Area Calibration Sheet
- Overhead Transparency: "Planimeter Parts, Set-up, and Reading"
- Watershed Area Worksheets and Answer Keys for each of the three methods for the eight streams delineated in the Watershed Delineation activity
- Reproducible graph paper
- Topographic maps: laminated 11x17" Meadville, Conneaut Lake, & Cambridge Springs NE (20 each) and laminated full Townville quads (8)

Additional Materials (NOT Included in Module):
- Scissors, rulers, overhead projector, electronic balance(s) (that display results to the 0.00 or 0.000 gram)

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.
- Delineate the boundaries of a watershed.

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 headwater to mouth.

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. Watersheds can consist of chains or networks of streams of different sizes and lengths. Likewise, watersheds vary greatly in size. In this case, size refers to the area of the watershed. The size or area of a watershed is related to the size and length of the network of streams within it. **Stream order** is used to classify waterways by their length. Streams of order *n-1* drain 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 mi^2 (161 $kilometers^2$), whereas the area of a first order stream would be approximately 20 mi^2 (32.2 $kilometers^2$).

There are several methods to determine the area of a watershed. Some are complicated, involving computer programs and on-line maps. Some methods are simple using simple office supplies. All methods require that the watershed first be delineated using appropriately scaled topographic maps (See the Watershed Delineation activity).

The graph paper and mass methods both require tracing the delineated watershed onto graph paper. Using the graph paper method, the area of the watershed on the graph paper is then converted to the actual area of the watershed using the topographic map scale. The mass method is a rather indirect but accurate way of determining the area of a watershed. The delineated watershed that has been traced onto paper is cut out and its mass determined. The mass of one graph paper square is determined and a proportion is set up to determine the ratio of watershed "mass" to area.

A more technical and accurate tool for measuring the area of a watershed using only a map is a planimeter. A **planimeter** is an instrument with a wheeled arm used to determine the area of small irregular planes or shapes, such as watersheds. Details on the use of a planimeter are found under "Procedure: Student Activity—*Planimeter Method*."

Knowing the watershed area for a waterway has many useful implications. A city or municipality may want to know how large an area of land drains into a small creek before they install a culvert or bury the creek using a pipe. The U.S. Army Corp of Engineers would want to know watershed size prior to implementing a flood control project or deciding on where a flood control project is needed. A wildlife ecologist might categorize biodiversity based on watershed size. Scientists, especially stream ecologists and water quality specialists, would want to include watershed areas for waterways they are studying when they set up experimental designs, write scientific papers, or publish their work in journals. This helps give a better description to their waterway and makes it easier for other scientists to make comparisons to it. In addition, watershed size correlates with natural changes in certain water chemistry/physical parameters, such as total dissolved solids, turbidity, sediment load, temperature, and discharge.

OVERVIEW:
Students learn three methods to determine watershed area using graph paper, mass, or a planimeter and then determine the area of watersheds on worksheets or watersheds that they have delineated themselves.

PROCEDURE:
There are two options for this activity: using ready-made Watershed Area Worksheets in which the watersheds are already delineated or starting from scratch and working with topographic maps to delineate a watershed and then proceeding to determine its area. Procedures for both options are outlined below. Also note that, because planimeters are expensive, we have only included one planimeter in the module. We suggest dividing students into three groups and assigning each group to a method: graph paper, mass, and planimeter. Then students can rotate among the different methods and the limited number of planimeters (and potentially balances) won't create major problems.

Teacher Preparation:

Worksheets

1. Select one of the seven worksheets and make copies for your students.

2. Choose which method you want your students to use to determine the area of the watershed on the worksheet.

3. Locate the appropriate additional materials in the module or at your school:
   ~Graph paper method—no additional materials needed.
   ~Mass method—electronic balance (that displays results to the 0.00 or 0.000 gram) and scissors.
   ~Planimeter—planimeter, copies of Figures: Planimeter Parts, Set-up and Reading at the end of this activity, an overhead projector and the overhead transparency of Planimeter Parts, Set-up and Reading also located at the end of this activity.

4. Determine the area of the watershed of interest using the directions below so that you have an answer against which to check your students' work.

Working with Topographic Maps

<u>All methods</u>

1. Select the watershed whose area your students will determine and the method(s) they will use to determine it.

2. Locate the appropriate topographic maps 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 permanent tape if the map is laminated or <u>removable</u> tape if the map is unlaminated.

3. Make copies of the reproducible graph paper for your students.

3. Distribute blank overhead transparencies, wet erase markers, graph paper, rulers, and tracing paper and/or the planimeter at the map stations around the classroom.

<u>Planimeter Method Only</u>

1. Make copies of the "Planimeter Parts, Set-up, and Reading" and Watershed Area Calibration Sheet handouts at the end of this activity write-up and distribute these sheets at the map stations.

2. Procure and set up an overhead projector to project the "Overhead: Planimeter Parts, Set-up and Reading" overhead transparency.

Student Activity:
Graph Paper Method

1. Discuss watershed area, particularly as it relates to stream size/order.

2. Delineate the selected watershed on an overhead transparency. OR Distribute Watershed Area worksheets to students and skip to Step 4.

3. Use tracing paper to transfer the watershed boundary to graph paper or transfer the watershed directly from the overhead to the graph paper if you can see through the graph paper well enough.

4. Use a ruler and the topographic map scale to determine the length in inches of one mile on the map. (For 1:24,000 maps, 1 mile = 2.64 inches or 1inch = 0.3788 mile).

   1 mile = ________ map inches

5. Now measure the same distance (1 mile or X map inches) on your graph paper, starting in the corner of one square. Draw a line equivalent to one mile long on your graph paper or worksheet. Count the number of squares long one mile is on your graph paper.

   1 mile = ________map inches = _______squares long

6. Determine the number of graph paper squares equivalent to one square mile. Area is measured in square miles so the area of one square mile is equal to the number of squares long from step 3 squared, i.e.

   1 mile^2 = (_____squares long) X (_____squares long) = _______ graph paper squares

7. Count the number of squares within the traced watershed drawn in step 3. Some of the squares will be cut in half. When that occurs, count two halves as one square. Other squares will only have a corner within the watershed area. Count one of these squares and another square that has everything but a corner within the watershed area as one complete square. Any squares that don't match up with others can be counted as parts of squares (fractions).

8. Mark off or color in squares you've counted to help you keep track.

9. Next add up the squares and partial squares and divide this number by the number of graph paper squares per square mile to determine the area (in square miles) of the watershed. (Refer to step 6).

10. Teachers—check your students' answers by referring to the corresponding Watershed Area Answer Key or the answer you determined beforehand.

Mass Method

1. Discuss watershed area, particularly as it relates to stream size/order.

2. Delineate the selected watershed on an overhead transparency. OR Distribute Watershed Area Worksheets to students and skip to Step 4.

3. Use tracing paper to transfer the watershed boundary to graph paper or transfer the watershed directly from the overhead to the graph paper if you can see through the graph paper well enough.

4. Use a ruler and the topographic map scale to determine the length in inches of one mile on the map. (For 1:24,000 maps, 1 mile = 2.64 inches or 1inch = 0.3788 mile).

   1 mile = ________ map inches

5. Use graph paper and a ruler to draw a square that is equal to one square mile according to your measurement from Step 4.

6. Now carefully cut out this 1 mile^2 square.

7. Use an electronic balance to find the mass of the square and use the mass to complete the following ratio:

$$\frac{1 \text{ mile}^2}{\text{mass of square mile}}$$

8. Now carefully cut out your delineated watershed and find its mass.

9. Use this mass and the ratio from step 7 to set up the following proportion:

$$\frac{1 \text{ mile}^2}{\text{mass of square mile}} = \frac{\text{area of watershed}}{\text{mass of watershed}}$$

10. Next, solve for "area of watershed":

$$\text{Area of watershed (mile}^2\text{)} = \frac{\text{(mass of watershed) x (1 mile}^2\text{)}}{\text{(mass of square mile)}}$$

11. Teachers—check your students' answers by referring to the corresponding Watershed Area Answer Key or the answer you determined beforehand.

Planimeter Method

1. Discuss watershed area, particularly as it relates to stream size/order. Briefly go over the parts of the planimeter (Figure 1) and how to use it to determine watershed area.

2. Delineate the selected watershed on an overhead transparency. OR Distribute Watershed Area worksheets to students and skip to Step 4.

3. Use tracing paper to transfer the watershed boundary to graph paper or transfer the watershed directly from the overhead to the graph paper if you can see through the graph paper well enough.

4. Use the distance legend at the bottom of the map or on the worksheet to determine the length (in map inches) of one mile. Use this measurement to draw one square mile (1 $mile^2$) on your graph paper or use the supplied 1 $mile^2$ on the "Watershed Area Calibration Sheet."

5. Next, position the planimeter such that the adjustable tracer arm has enough room to trace this one square mile drawing **as well as** the watershed boundary of the watershed whose area you are trying to determine. (See Figure 1 for planimeter parts and set-up).

6. Set the planimeter's numbered wheels to zero using the zero setting wheel.

7. Now position the tracer point of the tracer lens in the upper right corner of the one square mile drawing. Carefully trace the square in a clockwise direction, keeping the tracer point on the line drawing as closely as possible, until you arrive back at the starting point. Do not lift up the tracer point at any point.

8. Read and record the counting dial to the first whole number to the left of the screw. Next, using the measuring wheel vernier as the pointer, read and record the major division of the measuring wheel, which is the whole number below the measuring wheel vernier zero on the measuring wheel itself. Then, read and record the minor division of the measuring wheel, which is the lowest whole number in the tenths place from the major division reading, using the vernier zero as the pointer. Finally, read and record the vernier by finding its line that best lines up with one of the measuring wheel's lines. As a result of these measurements, you should end up with a four-digit value. The first digit may be 0. This value has no units; it will simply be used to set up a ratio later.

9. **Without changing the length of the tracer arm**, repeat steps 7 through 9 to trace the boundary of your watershed instead of the one square mile drawing to obtain a four-digit value for the watershed. Make sure you keep the tracer point on your watershed boundary line as closely as possible. Do not lift up the tracer point at any point.

10. Use the values from the one square mile and watershed boundary drawings to set up the following ratio:

$$\frac{1\ \text{mile}^2}{\text{(planimeter value for square)}} = \frac{\text{area of watershed (mile}^2\text{)}}{\text{(planimeter value for watershed)}}$$

11. Solve for area of watershed (mile^2):

$$\text{area of watershed (mile}^2\text{)} = \frac{\text{(planimeter value for watershed) x (1 mile}^2\text{)}}{\text{(planimeter value for square)}}$$

12. Check your answer by completing the process again using the counterclockwise direction. The readings on the wheels will be different but the final answer (watershed area) should be the same. Take three readings in each direction and average them to get an accurate estimate of the land area of the watershed.

13. Teachers—check your students' answers by referring to the corresponding Watershed Area Answer Key or the answer you determined beforehand. Note that the planimeter reading will vary depending on the length of the tracer arm. However, the ratio of the planimeter value for the watershed to the planimeter value for the square mile remains constant as long as the same tracer arm position is used for both the calibration and the actual watershed boundary measurement.

DISCUSSION:

What is a watershed? *See background.*

How is the size of a watershed determined? *See background and procedures.*

If more than one method was used, were the answers comparable? If not, why? *If answers vary, discrepancies may be due to human error, map error, and/or device error*

Of the three methods presented in this activity, which is the most accurate method of determining the area of a watershed? Why? *The mass and planimeter methods are both significantly more accurate than the graph paper method. The graph paper method involves a lot of estimation, whereas the other two methods do not. As long as the watershed boundaries are cut out or traced accurately, the mass and planimeter methods should both be fairly accurate.*

Why might someone (a scientist, geographer, geologist, etc.) want to determine the area of a watershed? *See background section.*

What is the stream order of the major waterway in this watershed? *Answers will vary*.

How is the size of a watershed related to stream order? *In general, a stream of order* n-1 *drains an area equal to approximately one-fifth the area drained by a stream of order* n.

How might the size of a watershed be related to the amount of sediment that accumulates in its waterways? *Typically, the greater the land area drained by a stream, the greater the sediment load of that waterway. This will depend on the land uses that are occurring in the watershed though.*

Trace the stream from mouth to headwaters and describe changes (topographic/physical/land use) that occur along the way. *Answers will vary.*

EVALUATION:

- Discussion questions above.
- Accurate determination of watershed area.
- Have students write the procedure for one or more of the watershed area determination methods.
- Have students determine the area of a "mystery watershed" using one or more methods.

EXTENSIONS AND MODIFICATIONS:

- Use topographic maps to determine the area of your watershed or watersheds in other parts of the country.
- Divide your students into three groups and have each group determine the area of the watershed of interest using one method. Compare the results to the actual area of the watershed and discuss the shortcomings and advantages of the various methods.
- Determine the area of several watersheds with streams of different order and test the hypothesis: streams of order *n-1* drain areas approximately equal to 1/5 the area of streams of order *n*.
- Contact local conservation or environmental agents and research how they use watershed area measurements in their work.

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