Appendix A

Measuring Lake Surface Area

Lake surface area can be measured with a bathymetric map using any of the following techniques:

1. One of the most accurate methods is to use a planimeter to trace the shoreline contour of a lake. This hand-held instrument is designed for measuring the area of a shape as drawn on a two-dimensional plane.

   Using the tracer point of a planimeter, you can carefully follow the outermost contour of a bathymetric map. The planimeter calculates the area of the shape in planimeter units (PU) while tracing its outline. Once you have the area in planimeter units you can compare it with the scale of the map to convert the PU to the lake’s actual surface area.

   Note: For detailed information about how to do this, refer to a limnology methods manual.

2. Digital tablets or computer scanners can also be used to trace or scan a bathymetric map image. Once the image is digitally memorized (i.e., traced or scanned), computer mapping software can be used to calculate surface area.

3. Another method involves placing a grid pattern over a lake map and counting the squares (of a known dimension) from the grid, to determine lake surface area.

   **Step 1:** Trace the lake map on a piece of graph paper or draw a square grid on top of a copy of the map, as illustrated in Figure A-1 on page 30.

   **Step 2:** Count all the squares that fall within the shoreline of the lake. At the shoreline, count only those squares that are more than half inside the lake shoreline area. Do not count squares that are more than one-half outside the lake boundary.
Step 3: Using the map scale, determine the area represented by one square. For example, suppose the map scale shows that 1 inch represents 1000 feet and the squares of the grid are one-half inch on a side. Using this information, we can see that each square represents a measurement of 500 feet per side \[ 0.5 \times 1000 = 500 \text{ ft}. \] Therefore, the area of one square would equal 250,000 square feet \[ 500 \times 500 = 250,000 \text{ sq ft}. \]

Step 4: The area of the lake, in square feet, would be equal to the number of squares counted from the grid \[ (N) \times 250,000. \] To convert the area from square feet to acres, divide by 43,560.\(^6\)

\[
\frac{N \times 250,000}{43,560} = \text{lake surface area in acres}
\]

\(43,560\) is the conversion factor for converting square feet to acres.

There is another way to calculate surface area that is relatively simple, but it does require a weight scale that is sensitive enough to weigh a piece of paper.

Step 1: Lightly trace an outline of the lake (from a bathymetric map or satellite map, for instance) onto a heavy grade of paper such as construction paper. Cut out your newly drawn lake shape and weigh it.

Note: The lake shape example shown here is much smaller than you should use. Your cutout should be closer in size to the lake map in Figure A-1 (or larger) for obtaining a weight on most laboratory scales.

Find the AREA of the square paper cutout (to scale).

For instance, if the map’s scale equates 1 inch with 1000 feet, then one side of the 3-inch cutout square represents 3000 feet. Consequently, that 3-inch square piece of paper represents 9,000,000 sq ft of surface area. (See below.)

\[ 3,000 \text{ ft} \times 3,000 \text{ ft} = 9,000,000 \text{ sq ft} \]

Multiply by the WEIGHT of the lake shape paper cutout.

If the lake shape cutout weighs 0.35 oz, then you would multiply 0.35 with the number from the bottommost portion of the equation at left:

\[ 0.35 \text{ oz} \times 36,000,000 \text{ sq ft/oz} = 12,600,000 \text{ square feet} \]

Step 2: Using the same piece of paper that you cut the lake shape from, but from an area outside of the lake shape cutout, measure and cut out a square of known dimensions and weigh that too.

Note: The square cutout should be similar in size to the lake shape cutout. For this example, we’ll use a 3-inch square cutout.

Step 3: Once weights are obtained for the lake shape and the square cutout, use the equation below to find the area of the lake in square feet.

Note: To convert the area from square feet to acres, divide by 43,560.\(^6\)
Appendix B

Measuring Lake Volume

There are several ways to calculate and/or estimate the volume of a lake:

1. The simplest way involves using basic algebraic equations for determining volume. To do this, one has to have the approximate dimensions of the waterbody such as average depth, length and width. Note: This method is used as a quick way to determine volume for ponds or smaller lakes and is generally less accurate than the following methods.

   See A Quick Way of Estimating the Volume of a Lake in Acre-Feet on page 32.

2. For lake basins that are almost conical in shape and structure (i.e., some solution lakes), a rough estimate can be made using the same equation used for determining the volume of a cone:

   \[ V = 1.047 r^2 h \]

   - \( r \) is the radius of the top (surface) of the cone (lake)
   - \( h \) is the height (maximum depth) of the cone (lake)

3. Hypsographic curves can also be used. As you can see in Figure B-1, volume is proportional to the area between the x-axis, the y-axis and the curve itself. Based on this knowledge, we can determine the lake’s volume using the following method:

   **Step 1:** First, draw the hypsographic curve onto lined graph paper, as shown in Figure B-1. Then count the number of squares found between the x-axis, the y-axis and the curve itself. Note: squares that are more than half-way inside this area are to be counted and squares that are more than half outside the area should not be counted.

4. Bathymetric maps can be used to determine lake volume and it’s done like this:

   **Step 1:** Using the same technique of counting squares described in Appendix A Part 3 (see Figure A-1), place a grid of small squares on a bathymetric map of your lake and calculate the area found within the various individual contour lines. Note: Using Figure A-1, you should have three separate area measurements: one for the surface area of the entire lake, one for the area within the 1.5 contour line, one for the 3.0 contour line and one for the 4.5 line.)

   **Step 2:** The next step is to calculate the volume of water layer by layer, starting with the top layer. (See Figure B-1.) You can do this by finding the area at
the top of the first layer ($A_{\text{top}}$) and the area at the bottom of the first layer ($A_{\text{bottom}}$). Plug both numbers into the equation provided in Figure B-2. Note: See Appendix A Part 3 for more on calculating a lake’s surface area using a bathymetric map.

**Step 3:** After finding the volume of the top layer, calculate the volume of the second deepest layer, using the same technique, and continue on down for each layer of the lake. (See Figure B-1.)

**Step 4:** Add the volumes of the respective layers to find the total volume for the lake.

**Step 5:** If the areas are in units of square feet and the depth interval is in feet also, the volume would be in cubic feet. If the areas are in acres and the depth interval in feet, then the area would be in units of acre-feet.

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**A quick way of estimating the volume of a small lake in acre-feet**

**Step 1:** First determine the average depth of the lake. This is also referred to as its mean depth. You can find this number by collecting a series of water depth measurements at various locations in the waterbody, and then averaging them. An electronic fathometer, or something as simple as a weighted line, marked in increments of feet or meters, can be used to collect water depth measurements. Collect these measurements every 10 to 20 feet for both the long and short axis of the waterbody. Add all of these numbers together and then divide by the total number of readings that were taken to obtain the average depth.

**Step 2:** Once you’ve determined the average depth of the lake, you can use this number, along with the waterbody’s length and width to solve the following equations. Notice that the equations are different, depending on the general shape of the waterbody:

**If your lake or pond is rectangular in shape** — multiply the lake’s length, width, and average depth and divide by 43,560 to find its volume in acre-feet.

\[
\text{length} \times \text{width} \times \text{average depth} = \frac{\text{____ acre-feet}}{43,560}
\]

*43,560 is the conversion factor used to convert cubic feet into acre-feet.*

**If your lake is circular in shape** — use its radius, pi ($\pi$ or 3.14), and average depth in the following equation:

\[
3.14 \times r^2 \times \text{average depth} = \frac{\text{____ acre-feet}}{43,560}
\]

*43,560 is the conversion factor used to convert cubic feet into acre-feet.*
As always, we welcome your questions or comments.