

---

## CHAPTER 9

# CALIBRATION – APPLYING THE RIGHT AMOUNT OF HERBICIDE

### Introduction

Aquatic pesticide application boats should be operated by an application team of at least two persons. The two-person team can safely share responsibilities for monitoring application rates. One person may drive the boat, monitor and set boat speed, and monitor the dispersement or application rate of the given pesticide. The other person is usually responsible for filling the spray tank or granular pesticide spreader hopper, directing the spray wand or handgun, and ensuring that the spray or spreading equipment is operating properly. The spray equipment or spreaders used to apply aquatic pesticides should be calibrated so they deliver the proper amount of pesticide to a specific area over a given amount of time. A fairly complete calibration method for aquatic herbicides is included below, although many of the principles and safety precautions are also appropriate for other types of pesticide applications, such as when applying piscicides.

Aquatic pesticides are applied by broadcasting pellets or granules over the water surface, spraying a solution over the water surface with a handgun, and injecting solutions below the water surface with submerged hoses. The applicator must know how much pesticide needs to be applied to a specific area to achieve control of a particular pest or group of pests such as weeds.

Numerous factors must be considered to apply aquatic pesticides accurately. These include boat speed; the total area to be treated; the width of the area to which the pesticide can be applied with a handgun, spreader or trailing hoses as the boat moves forward; pump speed; and the rate at which water is drawn from the lake or pond to dilute and propel the pesticide application.

Many variables complicate the matter. First, it is extremely difficult for the aquatic pesticide applicator to achieve a constant boat speed because of winds, vegetation density and water flows. Pump pressure can also vary during the application if

vegetation is sucked into the water supply lines. For this reason, it is necessary for the spray team to work together closely to adjust boat and pump speed to ensure even application rates. A translucent pesticide tank and a detailed area grid map are essential to permit rapid visual confirmation that a specified amount of pesticide is being placed in an area of known dimensions. Hand signals help to facilitate good communication between team members. The application team is the most important component of proper aquatic pesticide application.

As Paracelsus stated in the 16th century, “Only the dose makes the poison.” This is particularly true when you’re applying aquatic herbicides. All pesticides must be applied at a rate that does not exceed the recommendations that appear on the federal label. Inaccurate application rates may result in sublethal doses — when too little herbicide is applied to a target plant pest. Or “burn off” can occur — when an excessive dose of systemic herbicide is applied and the plant parts contacted by the herbicide die before the herbicide is translocated to the roots of the plant.

Proper selection of application rates is required to:

- 1) Achieve adequate control of the target weed or pest.
- 2) Avoid damage to nontarget plants and animals.
- 3) Avoid waste of pesticides.
- 4) Satisfy regulatory requirements.

Aquatic herbicide application rates can be figured three ways. The most common method is based on pounds or gallons of herbicide required per acre, usually expressed as surface acre, for control of a given target species. Secondly, aquatic herbicide labels may base application rates on a desired concentration of active ingredient, usually expressed as parts per million (ppm). Some herbicides used for emergent plant control are to be

applied as a percent active ingredient in a solution applied to the target pest.

No matter which rate the label requires, knowing the amount of product needed for a particular water body requires knowing the size of the treatment area. Always determine the treatment area size before purchasing pesticides. Knowing the treatment area size will help you avoid buying too much or too little pesticide product.

### Applications Based on Area

When determining the amount of herbicide to be applied for a given surface area or for a specific concentration in the water, the first thing you need to do is measure the area to be treated. Small ponds can be measured with a tape measure, by stepping off, if you know your step length, or with a rangefinder. When using a rangefinder, check frequently to make sure it is accurate within the distances being measured. On water, distances can be measured by dragging a floating rope of known length behind a boat and dropping buoys every time the end of the rope passes a buoy (so that the distance equivalent to the length of the rope can be measured again), by using a rangefinder, or by using a map and some type of planimeter, if a map with an adequate legend is available. Once accurate distances have been measured and marked, boat speed (in feet per second or other convenient measure) at a specific rpm can be determined by timing the boat through any marked distance. Distances can then be estimated by operating the boat for the length of time equivalent to a desired distance. Boat speed should be measured in two directions and averaged to allow for differences caused by wind or current.

The acreage of small rectangular ponds and lakes is easily calculated by multiplying their length times their width, measured in feet, and dividing by the number of square feet in 1 acre, which is 43,560, as follows (Example 1):

$$\text{SURFACE ACRES} = \frac{\text{length (ft)} \times \text{width (ft)}}{43,560 \text{ (sq ft per acre)}}$$

**Example 1.** What is the acreage of a rectangular pond that measures 800 ft by 440 ft?

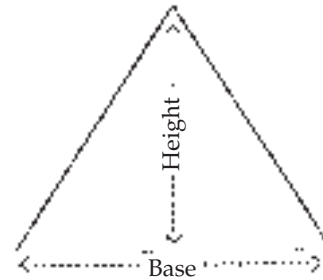
$$\text{SURFACE ACRES} = \frac{\text{length (ft)} \times \text{width (ft)}}{43,560 \text{ (sq ft per acre)}}$$

$$\begin{aligned} \text{SURFACE ACRES} &= \frac{800 \text{ ft} \times 440 \text{ ft}}{43,560 \text{ sq ft}} \\ &= \frac{352,000 \text{ sq. ft.}}{43,560 \text{ sq. ft.}} \end{aligned}$$

$$\text{SURFACE ACRES} = 8.1$$

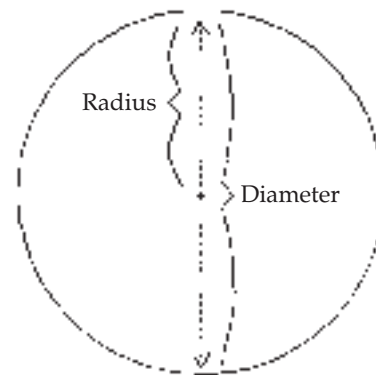
Many lakes and small coves are not rectangular but may be more or less triangular or circular. The equations for determining the area of a triangle or circle are as follows (Example 2).

$$\text{AREA OF A TRIANGLE (ACRES)} = \frac{1/2 \text{ base (ft)} \times \text{height (ft)}}{43,560 \text{ sq ft per acre}}$$



$$\text{AREA OF A CIRCLE (ACRES)} = \frac{3.14 \times \text{radius}^2 \text{ (ft)}}{43,560 \text{ sq ft per acre}}$$

$$\text{Radius} = 1/2 \text{ diameter}$$



**Example 2.** Estimate the area, in acres, of the following cove.

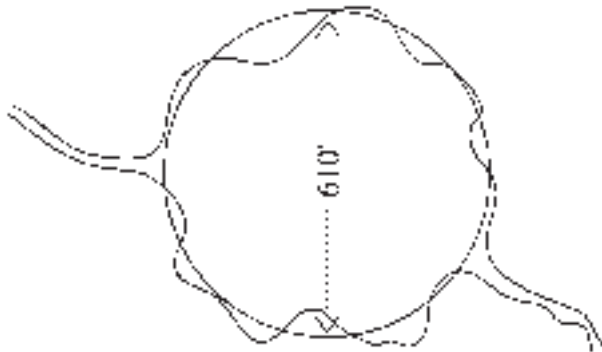


$$\text{AREA OF TRIANGLE (ACRES)} = \frac{1/2 \text{ base (ft)} \times \text{height (ft)}}{43,560}$$

$$\text{AREA OF TRIANGLE (ACRES)} = \frac{1/2(1000) \times 970}{43,560}$$

$$\text{AREA OF TRIANGLE (ACRES)} = 11.1$$

**Example 3.** Estimate surface area, in acres, of the following water body.



$$\text{DIAMETER} = 610 \text{ ft}$$

$$\text{RADIUS} = 1/2 \times \text{diameter}$$

$$\text{RADIUS} = 1/2 \times (610)$$

$$\text{RADIUS} = 305 \text{ ft}$$

$$\text{AREA OF CIRCLE (ACRES)} = \frac{3.14 \times \text{radius}^2}{43,560}$$

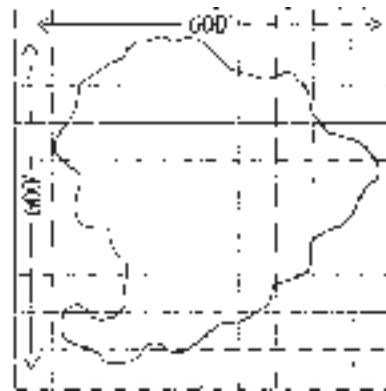
$$\begin{aligned} \text{AREA OF CIRCLE (ACRES)} &= \frac{3.14 \times (305)^2}{43,560 \text{ sq. ft.}} \\ &= \frac{292,098.5 \text{ sq. ft.}}{43,560 \text{ sq. ft.}} \end{aligned}$$

$$\text{AREA OF CIRCLE (ACRES)} = 6.7$$

The shapes of many lakes and coves are very irregular and do not conform to any geometric figure. In this case, the area can be estimated as follows:

- 1) Inscribe a sketch of the lake inside a rectangle.
- 2) Measure the area of the rectangle.
- 3) Estimate the proportion of the rectangle that is occupied by the lake (this step can be facilitated by using graph paper and dividing the number of blocks occupied by the lake by the total number of blocks in the rectangle).
- 4) Multiply the fraction of the rectangle occupied by the lake times the area of the rectangle for the lake's acreage (Example 4).

**Example 4.** Estimate the surface area, in acres, of the following irregularly shaped lake.



Step 1

$$\text{AREA OF RECTANGLE (ACRES)} = \frac{\text{Length (ft)} \times \text{Width (ft)}}{43,560}$$

$$\begin{aligned} \text{AREA OF RECTANGLE (ACRES)} &= \frac{600 \text{ ft.} \times 600 \text{ ft}}{43,560 \text{ sq. ft.}} \\ &= \frac{360,000 \text{ sq. ft.}}{43,560 \text{ sq. ft.}} \end{aligned}$$

$$\text{AREA OF RECTANGLE (ACRES)} = 8.26$$

Step 2

The number of squares in the rectangle is 100 and the number of squares in the lake is 51. Therefore the fraction of the rectangle occupied by the lake is 51/100.

Step 3

$$\text{AREA OF LAKE} = \frac{\text{area of rectangle} \times \text{number of squares in lake}}{\text{number of squares in rectangle}}$$

$$\text{AREA OF LAKE} = \frac{8.26 \text{ acres} \times 51}{100}$$

$$\text{AREA OF LAKE} = 4.2 \text{ acres}$$

Measurement of areas for large herbicide applications is best done in rectangular shapes, and plots should be marked as subplots of smaller areas. For example, a 200-acre area should be marked in subplots of 25 acres or smaller so that the application rate can be continually checked (Example 5).

It may be helpful to lay plots out to conform to swath width so that a certain number of swaths

will be equivalent to an acre (43,560 square feet)(Example 6). Dividing swath width into 43,560 tells how long a one-acre swath would be. Using this as one dimension of the plot, you can calculate the other dimension by dividing the length of a one-acre swath into the area of the entire plot. In this way, you can keep very close track of your application because you know that, with every swath, you should apply the rate prescribed per acre.

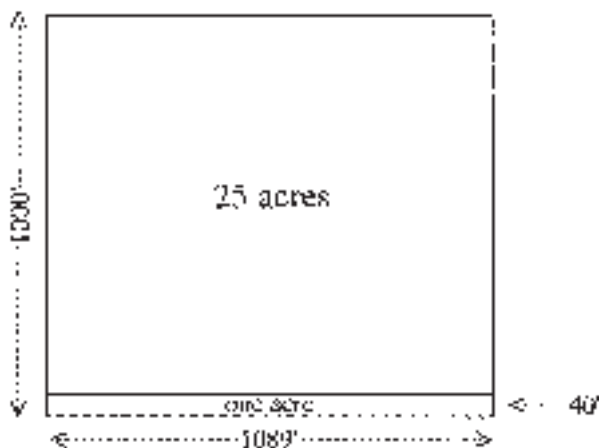
Depending on the size of the plot, you can make a dimension a half swath, two swaths, etc. Also, you can assume that the herbicide diffuses between swaths and define the "effective swath" as the distance between the centers of two adjacent treated swaths (Example 6).

**Example 5.** A pellet herbicide formulation is to be applied to a 25 acre plot in a large lake with a spreader that has a swath width of 40 feet. Show the rectangular plot layout that could be used so that each pass would treat one acre.

$$\text{LENGTH OF ACRE SWATH} = \frac{\text{sq ft per acre}}{\text{swath (ft)}}$$

$$\text{LENGTH OF ACRE SWATH} = \frac{43,560 \text{ sq ft}}{40 \text{ ft}}$$

$$\text{LENGTH OF ACRE SWATH} = 1,089 \text{ ft}$$



Therefore, the length of one side of the plot can be 1089 feet. Now determine the length of the other side of the plot as follows:

$$\text{AREA OF PLOT (SQ FT)} = \text{area of plot (acres)} \times \text{sq ft per acre}$$

$$\text{AREA OF PLOT (SQ FT)} = 25 \times 43,560$$

$$\text{AREA OF PLOT (SQ FT)} = 1,089,000$$

$$\text{WIDTH (FT)} = \frac{\text{area of plot (sq ft)}}{\text{length (ft)}}$$

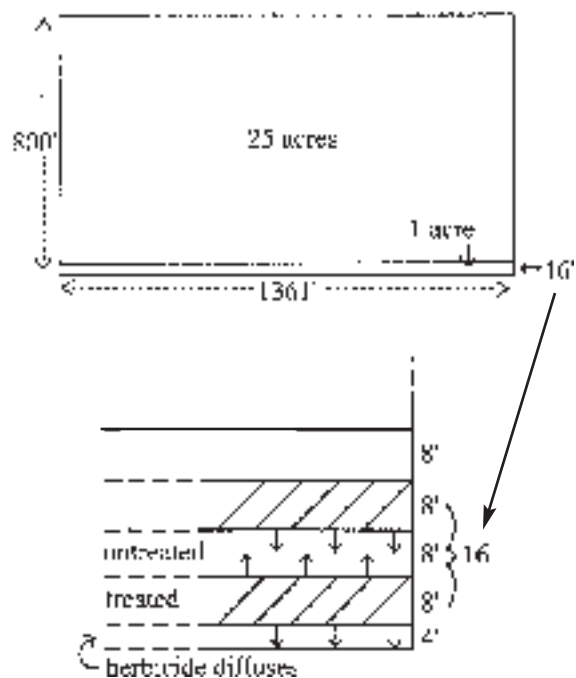
$$\text{WIDTH (FT)} = \frac{1,089,000}{1089}$$

$$\text{WIDTH (FT)} = 1,000$$

Note that the number of 1-acre swaths (25) could have been multiplied times the swath width of 40 ft to arrive at the 1000-ft width. This can also be used to check your calculations.

**Example 6.** Swath width for boom applications to submersed aquatic weeds can be considered the boom length or an approximation. Often only alternate swaths are actually treated, so the effective swath width becomes twice the boom length. It is assumed that the herbicide, with the help of turbulence caused by the spray boat and environmental factors, will mix throughout the water column.

Show the rectangular plot layout that could be used if 25 acres are to be treated with a liquid herbicide, using an 8-foot boom treating alternate swaths, so that each pass would treat one-half acre.



If every other 8 feet is actually covered, then the effective swath width is 16 ft.

$$\text{LENGTH OF ACRE SWATH (FT)} = \frac{\text{sq ft per acre}}{\text{length of effective swath (ft)}}$$

$$\text{LENGTH OF 1/2 ACRE SWATH (FT)} = \frac{1/2 (\text{sq ft per acre})}{\text{length of effective swath (ft)}}$$

$$\text{LENGTH OF 1/2 ACRE SWATH (FT)} = \frac{1/2 (43,560)}{16}$$

LENGTH OF 1/2 ACRE SWATH (FT) = 1,361

The length of the plot can be 1,361 feet. Now determine the width of the plot as follows:

AREA OF PLOT (SQ FT) = area of plot (acres)  
x sq ft per acre

AREA OF PLOT (SQ FT) = 25 x 43,560

AREA OF PLOT (SQ FT) = 1,089,000

WIDTH OF PLOT (FT) =  $\frac{\text{area of plot (sq ft)}}{\text{length of plot (ft)}}$

WIDTH OF PLOT (FT) =  $\frac{1,089,000}{1,361}$

WIDTH OF PLOT (FT) = 800

To determine the amount of herbicide needed for an application, multiply the recommended rate per acre times the surface area.

**Example 7.** How much herbicide is needed to treat an 8.1-acre lake at the rate of 120 pounds of granular herbicide per acre?

HERBICIDE NEEDED = pounds per acre x acres

HERBICIDE NEEDED = 120 pounds per acre  
x 8.1 acres

HERBICIDE NEEDED = 972 pounds

## Applications Based on Herbicide Concentrations

Herbicide labels usually have tables from which the applicator can determine the appropriate amount of herbicide formulation for a desired concentration and given water depth. If a table is not provided, or if you need to calculate the (potential) concentration of herbicide in water for a given depth when the recommendation is given only as a surface acre application, you will need to calculate the amount of herbicide to use (Example 9).

Herbicide concentration in water is usually referred to in **parts per million (ppm)** on a weight:weight basis. Before determining concentration or amount of herbicide to use for a given concentration, you must first measure the surface area, as described earlier, and water depth so that you can calculate water volume. If water depth is not uniform, it is important to determine average depth. In small ponds, depth should be measured across the pond in at least two directions, taking sufficient measurements to describe the pond's depth adequately. The number of directions needed will depend on the shape and the bottom unifor-

mity of the pond and will have to be determined on site. Average depth is calculated as follows:

AVERAGE DEPTH =  $\frac{\text{sum of all measurements}}{\text{number of measurements}}$

A convenient unit for measuring water volume for determining herbicide concentration is the acre-foot, which is determined by multiplying the average depth times the surface area in acres as follows:

ACRE-FEET = average depth (feet) x surface area (acres)

The amount of herbicide needed for a desired concentration can now be calculated by using the following equation:

HERBICIDE NEEDED (POUNDS A.I.) = ppm x acre-feet x 2.7

**The number 2.7 is a constant because 1 acre-foot of water weighs 2,700,000 pounds. In other words, every 2.7 pounds of a substance in 1 acre-foot of water is equivalent to 1 ppm.**

The concentration of a pesticide in water can be calculated for a given application rate by rearranging the last equation so that:

PPM =  $\frac{\text{pesticide (pounds a.i.)}}{\text{acre-feet x 2.7}}$

One more calculation must be made. Because the amount of pesticide needed has been calculated for the active ingredient, the amount of formulation needed must be determined. For dry formulations (wettable powders, dry flowables, pellets and granules), the amount of active ingredient is divided by the percent active ingredient expressed as a decimal; i.e., if the formulation is an 80 WP, divide by 0.80. For liquid formulations, divide by the amount of herbicide per gallon to determine gallons of formulation to apply (e.g., for a 4-pound-per-gallon EC, divide by 4).

**Example 8.** A farm pond is found to be 1.6 acres in surface area, and the following depths are measured: direction one — 2, 3, 4, 4, 4, 6, 6, 4, 2 feet; direction two — 2, 4, 6, 6, 6, 6, 6, 4, 2 feet. How much copper sulfate is needed for a copper (as elemental) concentration of 0.5 ppm for algae control? (Hint: copper sulfate is sold as cupric sulfate pentahydrate, which is 25% elemental copper.)

AVERAGE DEPTH =  $\frac{\text{sum of measurements (ft)}}{\text{number of measurements}}$

AVERAGE DEPTH =  $\frac{(2+3+4+4+4+6+6+4+2) + (2+4+6+6+6+6+6+4+2) \text{ (ft)}}{18}$

AVERAGE DEPTH = 4.3 ft

ACRE-FEET = average depth x surface area (acres)

ACRE-FEET = 4.3 feet x 1.6 acres

ACRE-FEET = 6.88

HERBICIDE A.I. = ppm x acre-feet x 2.7

HERBICIDE A.I. = 0.50 x 6.88 x 2.7

HERBICIDE A.I. = 9.29 pounds elemental copper

Copper sulfate is 25% elemental copper.

Therefore:

$$\text{Pounds copper sulfate} = \frac{9.29}{.25} = 37.15, \text{ or roughly } 37 \text{ pounds of copper sulfate.}$$

**Example 9.** (optional). A granular herbicide (20% active ingredient) is applied at a rate of 150 pounds per acre to 5 acres of water 6 feet deep in a large lake to control spatterdock. A homeowner asks if this herbicide application will be toxic to fish. Although you are confident that there is no potential problem—there was caution on the label and you have experience with such applicatins—you can give the homeowner concrete facts to support your answer.

A call to the county MSU Extension office reveals that the experimental toxic concentration of this herbicide formulation is about 3.3 ppm to fathead minnows (a sensitive test organism).

The maximum potential concentration of herbicide in the water must be calculated so that it can be compared with the toxic level. First, calculate the amount of herbicide active ingredient applied by multiplying 150 pounds, the amount of formulation applied per acre, by 0.20, the percent active ingredient expressed as a decimal. Therefore, 30 pounds (150 pounds x 0.20 = 30 pounds) of herbicide active ingredient were applied per acre.

Before calculating the concentration of herbicide, calculate acre-feet as follows:

ACRE-FEET = average depth x surface area (acres)

ACRE-FEET = 6 x 5

ACRE-FEET = 30

The concentration of herbicide can now be calculated as follows:

$$\text{PPM} = \frac{\text{herbicide (pounds a.i.)}}{\text{acre-feet} \times 2.7}$$

$$\text{PPM} = \frac{30}{30 \times 2.7}$$

$$\text{PPM} = 0.37$$

After comparing the toxic concentration of 3.3 ppm to the maximum potential concentration of 0.37 ppm, you can tell the homeowner that even if the maximum concentration did occur, there would be almost a tenfold safety factor. You could further explain to the homeowner that this concentration would probably not occur because the herbicide is quickly taken up by aquatic plants, diluted in the surrounding water and adsorbed to bottom sediments, where it degrades over time.

## Applications by Parts or Percent of Herbicide in Spray Solution

Some herbicide labels recommend a proportion of herbicide to final spray tank mix. For example, a label may recommend using 1 gallon of herbicide formulation to 20 gallons of spray mix. Calculate the amount of herbicide to use for spray tank volumes other than that given on the label as follows:

$$\text{HERBICIDE PER TANK} = \frac{\text{volume of spray tank} \times \text{herbicide amount given}}{\text{spray mix amount given}}$$

This equation can be used for any unit as long as the same units are used on both sides of the equation.

**Example 10.** A herbicide label recommends mixing 1 gallon of herbicide formulation to 20 gallons final spray mix and spraying vegetation to wet. How much herbicide would be used with 500 gallons of spray mix?

$$\text{HERBICIDE PER TANK} = \frac{\text{volume of spray tank} \times \text{herbicide amount given}}{\text{spray mix amount given}}$$

$$\text{HERBICIDE PER TANK} = \frac{500 \times 1}{20}$$

$$\text{HERBICIDE PER TANK} = 25 \text{ gallons (since all units used are in gallons)}$$

Spray tank concentrations are often recommended as a specified percent solution (volume:volume). Percent actually means parts per 100. Therefore, for each 100 parts (volume) of spray tank mix, one part (volume) of herbicide would be added for each 1 percent recommended. The amount of herbicide to be added to a spray tank for a recommended percent (volume:volume) solution is calculated as follows:

$$\text{HERBICIDE PER TANK} = \frac{\text{spray tank volume} \times \% \text{ solution required}}{100}$$

The solution to this equation will be in whatever units the spray tank volume is in. Note: The concentration of herbicide active ingredient in the tank will depend on the amount of active ingredient per gallon of formulation. Therefore, percent solutions of different formulations of the same herbicide may not be the same.

**Example 11.** Four gallons of 1.5 percent spray mix are to be prepared for application to emergent vegetation on a pond bank using a backpack sprayer. How much herbicide should be mixed in the spray tank before bringing up to the final volume?

$$\text{HERBICIDE PER TANK} = \frac{\text{spray tank volume} \times \% \text{ solution required}}{100}$$

$$\text{HERBICIDE PER TANK} = \frac{4 \text{ gal} \times 1.5\%}{100}$$

$$\text{HERBICIDE PER TANK} = .06 \text{ gal}$$

Because containers graduated in hundredths of a gallon are rare, to say the least, the answer can be converted to fluid ounces by multiplying by 128 (the number of fluid ounces in 1 gallon) as follows:

$$\text{FLUID OUNCES} = \text{gal} \times 128 \text{ (fluid ounces per gal)}$$

$$\text{FLUID OUNCES} = .06 \times 128$$

$$\text{FLUID OUNCES} = 7.68$$

Alternatively, liquid ounces could have been used initially in the equation to obtain the same answer as follows:

$$\text{HERBICIDE PER TANK} = \frac{\text{spray tank volume} \times \% \text{ solution desired}}{100}$$

$$\text{HERBICIDE PER TANK} = \frac{(4 \text{ gal} \times 128 \text{ fluid ounces per gal}) \times 1.5\%}{100}$$

$$\text{HERBICIDE PER TANK} = 7.68 \text{ fluid ounces}$$

## Equipment Calibration

Once you have determined the size of the area to be treated and the desired concentration of pesticide, you must adjust your equipment's output to ensure that the label rate of pesticide is being applied. The process of equipment adjustment to obtain a desired application rate is known as **calibration**.

Maintaining an accurate application rate is difficult when applying aquatic herbicides because the equipment is mounted in a boat. Environmental factors such as wind velocity and speed, water flow and vegetation density make it difficult to maintain a constant speed and perfect course. Although the initial calibration of equipment for application of aquatic herbicides should be precise, the applicator's constant attention is necessary to make the application rate as constant as possible. When applying herbicides to water, the herbicides will mix within the treatment area so that precision becomes a little less important. Still, without any question, proper calibration and constant attention by the applicator are the most important components of any application.

The following materials will be needed to calibrate aquatic herbicide application equipment:

- (1) Watch (a stopwatch that is marked in tenths of a minute is useful).
- (2) Calculator (unless you are good at doing math in your head).
- (3) Tape measure – or known length of your steps.
- (4) 100-ft floating rope with a float tied to the end.
- (5) Buoys or poles.
- (6) Scale that will weigh up to 20 pounds.
- (7) Blank herbicide granules. Enough 5-gallon buckets to measure water from each nozzle of your spray boom; one of these should be marked or graduated in pints or quarts.
- (9) Quart container calibrated in ounces (only if calibrating suction/induction system).

You can calibrate equipment in various ways. Any is acceptable as long as the correct end is achieved. In any of the methods, you must determine the gallons per acre (**GPA**) of spray solution for tank-mix equipment, the actual **GPA** of herbicide for suction systems, or pounds per acre (**PPA**) of granular or pellet herbicide formulations.

The equations for determining **GPA** and **PPA** are:

$$\text{GPA} = \frac{\text{gallons per minute (GPM) from spray system}}{\text{acres per minute}}$$

and

$$\text{PPA} = \frac{\text{pounds per minute from spreader}}{\text{acres per minute}}$$

**GPM** or **POUNDS PER MINUTE** are measured directly from the equipment.

There are several ways to determine GPM for boom-applied tank mix equipment:

- (1) Run the pump until all air is out of the lines. Place a bucket under each nozzle of the boom. Run the pump for one minute while catching the discharge. Measure the water in each bucket and add these quantities together, or pour them into one bucket and measure this quantity to get the **GPM**.

If you measure the amount from each nozzle, you can determine nozzle uniformity as follows: add the quantities from each nozzle together and divide by the number of nozzles to determine the average nozzle output. Then determine the percent deviation of each nozzle by dividing the actual nozzle output into the difference between the average and actual output and multiplying by 100. If a nozzle deviates by 10 to 15 percent (an acceptable range of deviation depends on the accuracy needed for particular type of application), check it for clogging or size (wrong size or wear). (Alternatively, a quick check for nozzle uniformity can be made visually.) The equation for nozzle uniformity is:

$$\% \text{ DEVIATION} = \frac{\text{average nozzle output} - \text{individual nozzle output}}{\text{average nozzle output}} \times 100$$

- (2) If nozzle uniformity is not a concern, and hoses are long enough, all hoses can be placed into one bucket and the output measured and the pump run for 1 minute. Using this method, if the pump output is greater than 5 GPM, it will be necessary to run the test for less time. For example, run the pump for 30 seconds and multiply the output by 2 for the GPM.
- (3) If nozzle uniformity is not a concern, the tank refill method can be used as an alternative. Put some water in the tank and run it until all air is out of the lines. Fill the tank completely and run the pump for 1 minute. Measure the amount of water that is necessary to refill the tank to determine **GPM**. For greater accuracy, the pump can be run for a longer period of time and the amount required to fill the tank divided by the number of minutes that the pump was run to obtain **GPM**.

**GPM** for handgun applications can be determined either by using the tank refill method or by catching the output from the handgun in a bucket for 1 minute (or some other known period of time).

**GPM** for direct metering equipment is determined by measuring the amount of liquid that is drawn out of a container graduated in ounces in a minute or greater period of time. Ounces are converted to gallons by dividing by 128 (because there are 128 ounces in a gallon).

Pounds per minute can be measured by two methods:

- (1) Fill the hopper on the spreader with blank herbicide and catch the output with a box or bag that is constructed to fit underneath. When calibrating for rates exceeding 100 PPA, 1 minute is sufficient. For lower rates, 2 or 3 minutes will be necessary for accurate weighing.
- (2) If a container is not available to catch the output (be careful with plastic bags because they tend to get caught and tangle in the spreader's paddle), weigh a known quantity — 10 pounds is good — of blank herbicide and measure the time in seconds that it takes for all of the material to go out. To obtain pounds per minute, divide the pounds that were put in the hopper by the seconds that it took to run out and multiply by 60 (number of seconds in a minute).

Now **ACRES PER MINUTE** must be determined. The following equation can be used to determine **ACRES PER MINUTE**:

$$\text{ACRES PER MINUTE} = \frac{\text{swath width (ft)} \times \text{speed (mph)} \times 88}{43,560 \text{ (sq.ft/acre)}}$$

For ease of calculation, this equation can be simplified by dividing both the top and the bottom of the equation by 88 (the number of feet traveled per minute at 1 mph; this converts mph to miles per minute). The new equation is:

$$\text{ACRES PER MINUTE} = \frac{\text{swath width (ft)} \times \text{speed (mph)}}{495}$$

{43,560 ÷ 88 = 495}

Because it is easy to multiply by 2 and divide by 1,000 (simply move the decimal point three places to the left), this equation can be simplified further by multiplying both the top and the bottom of the equation by 2 and rounding 990 in the bottom to 1,000, with the introduction of only 1 percent error, to:

$$\text{ACRES PER MINUTE} = \frac{2 \times \text{swath width (ft)} \times \text{speed (mph)}}{1000}$$

Swath width is measured directly from the equipment to be used. For agricultural boom applications, swath width is defined as nozzle spacing times the number of nozzles. Swath width for boom applications to submersed aquatic weeds can be considered the boom length or an approximation. Often, only every other strip is treated in the treatment area and the swath width becomes twice the boom length. It is assumed that the herbicide, with the help of turbulence caused by the spray boat and environmental factors, will mix throughout the water column. Swath width for a handgun is measured by actually spraying water as the boat comes in toward shore and having someone on shore mark the distance covered. Swath width of a granular spreader is measured in a similar fashion.

Another measurement must be made: **SPEED**.

To determine boat speed, measure a distance at least 100 feet long in the lake, using the 100-foot floating rope, and mark the distance with the buoys or poles. Operate the boat, with the spray tank half full and the number of persons and other gear that the boat will carry at a comfortable speed (usually a fast idle or equivalent to a fast walking pace), and approach the front marker. As you pass the first marker start timing. As you pass the end marker, note the time in seconds that it required to cover the distance. Do this in the opposite direction and average the two numbers to compensate for going with and against the wind. Determine MPH by the following equation:

$$\text{MPH} = \frac{\text{distance traveled (ft)} \times 3600 \text{ (sec)}}{5,280 \times \text{time to cover distance (sec)}}$$

This equation can be simplified to:

$$\text{MPH} = \frac{\text{distance traveled (ft)}}{\text{time to cover distance (sec)} \times 1.47}$$

If you have a stopwatch that reads in tenths of a minute, you can measure your time in minutes and use the equation:

$$\text{MPH} = \frac{\text{distance traveled (ft)}}{\text{time to cover distance (min)} \times 88}$$

The drawback of using the previous equations for determining **ACRES PER MINUTE** is that speed must be calculated in mph. An alternative "one-shot" equation is:

$$\text{ACRES PER MINUTE} = \frac{\text{swath width (ft)} \times \text{distance traveled (ft)} \times 60}{43,560 \times \text{time to cover distance (sec)}}$$

If a stopwatch that measures in tenths of a minute is used, 60 in the top part of the equation (numerator) can be eliminated if the time to cover the distance is expressed in minutes, rather than seconds.

## Varying Rate of Application

Rate of application can be regulated by varying equipment output, **GPM** or **POUNDS PER MINUTE**, or by changing the rate at which the equipment covers area, **ACRES PER MINUTE**.

**GPM** can be varied by changing pressure or changing the size or number of nozzles. Changing the size or number of nozzles is used for large changes and changing the pressure regulator for small changes (output will double only when pressure is increased four times).

Herbicide withdrawn by direct metering systems can be varied only by changing the metering orifice in the suction line. There is a small difference in the output of consecutive sizes, so accurate calibration is possible. Changes in output of centrifugal granular spreaders are made by changing settings on the spreader.

Swath width and speed determine the rate of coverage. Changes in swath width or speed will inversely change the rate of coverage. For example, if swath width or speed is doubled, the rate of coverage or **ACRES PER MINUTE** will be cut in half. When spraying with a handgun, the swath can be varied considerably. Although actual boom length is fixed, the effective swath width of a boom for submersed weed control applications can be changed by applying in bands. Forward speed can be varied within a relatively narrow range. Normally the speed is 3 to 4 mph when treating by boat at idle speed. Greater or lesser boat speeds can be used under certain circumstances.

All of the equations, along with some alternatives, that are needed to calibrate equipment have now been explained. The following examples should help further clarify the process of equipment calibration.

**Example 12.** Assume that a 100-gallon tank mix sprayer mounted in a johnboat is being calibrated. The sprayer has an 8-foot boom with four drop hoses. A herbicide is to be applied at the rate of 2 gallons per acre for weed control.

A 200-foot distance is marked off. It is found that the boat travelled the 200 feet in one direction

in 54 seconds and the opposite direction in 56 seconds. The numbers are averaged:

$$\frac{54 + 56}{2} = 55$$

MPH is calculated as follows:

$$\text{MPH} = \frac{\text{distance traveled (ft)}}{5,280} \times \frac{3600}{\text{time to cover distance (sec)}}$$

$$\text{MPH} = \frac{200}{5,280} \times \frac{3600}{54}$$

$$\text{MPH} = 2.5$$

Calculate acres per minute as follows:

$$\text{Acres per minute} = \frac{\text{swath width (ft)} \times \text{speed (mph)}}{495}$$

$$\text{Acres per minute} = \frac{8 \times 2.5}{495}$$

$$\text{Acres per minute} = 0.04$$

Output was measured from each drop hose for 1 minute to determine **GPM**, and the following values were obtained:

- hose 1 – 60 fluid ounces
- hose 2 – 100 fluid ounces
- hose 3 – 110 fluid ounces
- hose 4 – 105 fluid ounces

Obviously there was a problem with hose #1 because its output was substantially lower than the others. Deviations from the average output are calculated as follows:

$$\text{AVERAGE OUTPUT} = \frac{60+100+110+105}{4} = 93.75$$

(93.75 can be rounded off to 94 for ease of calculation)

$$\% \text{ DEVIATION} = \frac{\text{average nozzle output} - \text{individual nozzle output}}{\text{average nozzle output}} \times 100$$

$$\% \text{ DEVIATION (hose \#1)} = \frac{60-94}{94} \times 100 = -36\%$$

$$\% \text{ DEVIATION (hose \#2)} = \frac{100-94}{94} \times 100 = 6\%$$

$$\% \text{ DEVIATION (hose \#3)} = \frac{110-94}{94} \times 100 = 17\%$$

$$\% \text{ DEVIATION (hose \#4)} = \frac{105-94}{94} \times 100 = 12\%$$

Because one nozzle in this example was very low, it made the average very low and several deviations are high. Hoses 2, 3 and 4 are consistent with each other, however, so they are probably ok. Removal of the nozzle from hose #1 reveals that it is clogged with pieces of a disk that was replaced in the pressure regulator last week. Because foreign matter has been found in the system, all nozzles are removed and the system is flushed to avoid another problem. Remeasuring output for one minute yielded the following values:

- hose #1 – 115 fluid ounces
- hose #2 – 120 fluid ounces
- hose #3 – 110 fluid ounces
- hose #4 – 118 fluid ounces

Check these to see if they fall within 15 percent of the average output.

**GPM** can now be calculated by adding up the output from all four nozzles as follows:

$$\text{GPM} = 115+120+110+118$$

$$\text{GPM} = 463 \text{ fluid ounces}$$

Convert fluid ounces to gallons by dividing by 128, the number of fluid ounces per gallon, as follows:

$$\frac{463 \text{ fluid ounces per min}}{128 \text{ fluid ounces per gal}} = 3.6 \text{ GPM}$$

Now calculate **GPA** as follows:

$$\text{GPA} = \frac{\text{GPM}}{\text{Acres per minute}}$$

$$\text{GPA} = \frac{3.6}{0.04}$$

$$\text{GPA} = 90$$

Two gallons of herbicide are to be applied per acre, and the spray volume is 90 **GPA**, so 2 gallons of herbicide plus adjuvants will be mixed with enough water to make a final volume of 90 gallons, and this will treat 1 acre. But **REMEMBER** that this is an approximation because environmental conditions can change while applying and the applicator must pay constant attention to his output and the area being treated (i.e., when 1/4 acre has been treated 1/4 of the 90 gallon tank should have been applied; if not, the boat must be slowed or speeded up accordingly).

Remember that the herbicide you apply can be in strips and assume diffusion between the strips. In this example, every other 8 feet (swath width) could be treated to give an effective swath width of 16 feet. This will be advantageous because it

will cut both spray time and spray volume in half and save additional time in tank mixing. It might be obvious that this change will double **ACRES PER MINUTE** and cut **GPM** in half, but the calculations go as follows:

$$\text{ACRES PER MINUTE} = \frac{\text{swath (ft)} \times \text{speed (mph)}}{495}$$

$$\text{ACRES PER MINUTE} = \frac{16 \times 2.5}{495}$$

$$\text{ACRES PER MINUTE} = 0.08$$

$$\text{GPA} = \frac{\text{GPM}}{\text{ACRES PER MINUTE}}$$

$$\text{GPA} = \frac{3.60}{0.08}$$

$$\text{GPA} = 45$$

Therefore, four gallons of herbicide and sufficient water are placed in the tank for a total volume of 90 gallons that will treat 2 acres.

**Example 13.** A direct metering system is to be calibrated to apply herbicide by handgun to control an emergent weed. The herbicide label requires an application rate of 2 to 4 quarts of herbicide per acre in a spray volume of 100 to 200 gallons of water. Because the label requires a specified spray volume, two measurements must be made — output from the handgun and rate of herbicide metered into the system.

Because this is a foliar application to the weed, it is desirable to go as slowly as possible to ensure good coverage. With the boat idled down as low as possible, it takes an average of 114 seconds to cover the distance of 200 feet (**MPH** will not be used in this solution, but the student should use the equation previously given to calculate **MPH** for practice — it should work out to 1.2 **MPH**). Swath width is measured to be 15 feet and output from the handgun is measured to be 6 **GPM**.

Calculate **ACRES PER MINUTE** as follows (using the “one-shot” equation):

$$\text{ACRES PER MINUTE} = \frac{\text{swath (ft)} \times \text{distance traveled (ft)} \times 60}{43,560 \times \text{time to cover distance (seconds)}}$$

$$\text{ACRES PER MINUTE} = \frac{15 \times 200 \times 60}{43,560 \times 114}$$

$$\text{ACRES PER MINUTE} = .036$$

Now calculate **GPA** as follows:

$$\text{GPA} = \frac{\text{GPM}}{\text{Acres per minute}}$$

$$\text{GPA} = \frac{6}{.036}$$

$$\text{GPA} = 167$$

The equipment is delivering the desired spray volume of 100 to 200 gallons per acre.

Now measure **GPM** of herbicide being metered so that this can be used to calculate **GPA** of herbicide being applied. Because the rate of herbicide withdrawal is low, the pump is run for 5 minutes while herbicide withdrawal is measured, and it is found that 17 fluid ounces are withdrawn in the 5 minutes. Therefore, 3.4 fluid ounces (17 divided by 5) are withdrawn per minute. This is converted to **GPM** by dividing by 128, the number of fluid ounces in a gallon. Therefore, **GPM** is 0.027. Now calculate **GPA** as follows:

$$\text{GPA} = \frac{\text{GPM}}{\text{Acres per minute}}$$

$$\text{GPA} = \frac{0.027}{0.036}$$

$$\text{GPA} = 0.75$$

Because there are 4 quarts in a gallon, 0.75 gallons is 3 quarts. Three quarts per 167 gallons will be perfect to allow for small amounts of under-spray and overspray and still be within the label requirement of 2 to 4 quarts in 100 to 200 gallons of spray mix per acre.

Note: If herbicide withdrawal had been too low, a larger orifice would have to be used. Conversely, if it had been too high, a smaller orifice would have to be installed.

**Example 14.** In Example 13 herbicide withdrawal was measured and it turned out to be the desired amount. It would be better to calculate beforehand the desired **GPM** (in fluid ounces) that are required for a given boat speed, swath width and application rate. Using the information from Example 13 the fluid ounces that should be withdrawn can be calculated as follows:

Rearrange the equation

$$\text{GPA} = \frac{\text{GPM}}{\text{Acres per minute}}$$

to

$$\text{GPM} = \text{Acres per minute} \times \text{GPA.}$$

Then

$$\text{GPM} = 0.036 \times 0.75$$

$$\text{GPM} = 0.027$$

or

$$0.027 \text{ GPM} \times 128 \text{ fluid ounces per gallon} = 3.5 \text{ fluid ounces per minute.}$$

If small (young) weeds were being treated and we wanted to use the low end of the label rate, or 2 quarts (0.50 gallon), it would be calculated as follows:

$$\text{GPM} = \text{Acres per minute} \times \text{GPA}$$

$$\text{GPM} = 0.036 \times 0.50$$

$$\text{GPM} = 0.018$$

or

$$0.018 \text{ GPM} \times 128 \text{ fluid ounces per gallon} = 2.3 \text{ fluid ounces per minute.}$$

**Example 15.** A centrifugal spreader must be calibrated to apply 40 pounds of herbicide formulation per acre. Swath width was measured to be 40 feet and speed was calculated to be 2.5 mph as in Example 11 (It may be helpful for you to go back and recalculate this now for practice in working a problem completely through.)

Calculate **ACRES PER MINUTE** using the simplified equation as follows:

$$\text{ACRES PER MINUTE} = \frac{2 \times \text{swath (ft)} \times \text{speed (mph)}}{1000}$$

$$\text{ACRES PER MINUTE} = \frac{2 \times 40 \times 2.5}{1000}$$

$$\text{ACRES PER MINUTE} = 0.2$$

Calculate how many **POUNDS PER MINUTE** are required for the necessary 40 **PPA** at the given 40-foot swath and 2.5 **MPH** (similar to the method that was used in Example 13 for calculating ounces to be withdrawn) as follows:

Rearrange the equation

$$\text{PPA} = \frac{\text{Pounds per minute}}{\text{Acres per minute}}$$

to

$$\text{POUNDS PER MINUTE} = \text{Acres per minute} \times \text{PPA}$$

then

$$\text{POUNDS PER MINUTE} = 0.20 \times 40$$

$$\text{POUNDS PER MINUTE} = 8$$

To calibrate the spreader you must find a setting that will deliver 8 **POUNDS PER MINUTE**. However, you find that the lowest setting on this spreader where clogging does not occur delivers pellets at a rate higher than 8 **POUNDS PER MINUTE**. To use a higher rate, you must increase boat speed and **ACRES PER MINUTE**. So, you operate the boat through the 200-foot course at increased engine RPM, timing it at an average of 34 seconds (down and back).

Calculate **ACRES PER MINUTE** using the one-shot equation (also calculate mph and use alternative equations for practice and to gain confidence) as follows:

$$\text{ACRES PER MINUTE} = \frac{\text{swath (ft)} \times \text{distance (ft)} \times 60}{43,560 \times \text{time to cover distance (sec)}}$$

$$\text{ACRES PER MINUTE} = \frac{40 \times 200 \times 60}{43,560 \times 34}$$

$$\text{ACRES PER MINUTE} = 0.32$$

Calculate the **POUNDS PER MINUTE** that will result in an application rate of 40 pounds per acre in a 40-foot swath at the new speed as follows:

$$\text{POUNDS PER MINUTE} = \text{Acres per minute} \times \text{PPA}$$

$$\text{POUNDS PER MINUTE} = 0.32 \times 40$$

$$\text{POUNDS PER MINUTE} = 12.8$$

To calibrate the spreader at the new speed, you need to find a spreader setting that will deliver 12 **POUNDS PER MINUTE**. It is helpful to determine spreader output (in **POUNDS PER MINUTE**) through a range of settings on the spreader to refer to for future applications at various rates and speeds. The following outputs are determined for the spreader in this example:

Spreader setting	Pounds per minute
1	clogs
2	clogs
3	10
4	15
5	20

It is not necessary to move the spreader setting small increments because variables such as boat speed, which will vary during the application, will have a greater effect on **PPA** than small changes that can be effected with the spreader setting. In this example, a spreader setting between 3 and 4 will give the desired 12 **POUNDS PER MINUTE**, which will in turn result in the required application rate of 40 **PPA** at the measured speed.

**REMEMBER** that calibration is the first approximation of what it will take to deliver the correct application rate. The applicator must pay constant attention to maintaining a constant speed and continually be aware of the area covered and the amount of herbicide applied.

Note: Spreader output will differ at given settings for different-sized particles. Separate calibration tables must be made for pellets and granules of various sizes.

## Other Useful Equations

$$\text{ACRES PER TANK} = \frac{\text{tank volume (gal)}}{\text{GPA}}$$

**HERBICIDE FORMULATION PER TANK** = acres per tank x recommended rate per acre

$$\text{ACRE-FEET} = \frac{\text{length (ft)} \times \text{width (ft)} \times \text{average depth (ft)}}{43,560 \text{ ft}^2/\text{acre}}$$

**VOLUME OF RECTANGULAR TANK (ft<sup>3</sup>)** = length (ft) x width (ft) x depth (ft)

**VOLUME OF RECTANGULAR TANK (gal)** = length (ft) x width (ft) x depth (ft) x 7.48 (gal/ft<sup>3</sup>)

**VOLUME OF CYLINDRICAL TANK (gal)** = area of the circular end x length x 7.48 (gal/ft<sup>3</sup>)

$$\text{SPEED (mph)} = \frac{\text{feet per minute}}{88}$$