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Determining Volume in a Small Pond with a Staff Gauge and Depth-Capacity Curve

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INTRODUCTION AND BACKGROUND

Determining stored water volume in ponds and reservoirs is required for many landowners throughout California. Pursuant to SB88, the California State Water Resources Control Board (SWRCB) now requires monitoring of surface water being diverted and put to beneficial use. Stock water ponds are also included in this regulation.

Exceptions to these reporting requirements include individuals who receive all of their water through a municipal water system, public water agency, or private water agency. In these cases, the city, agency, or entity that delivers water is responsible for SWRCB reporting. Any questions related to specific water measurement requirements can be submitted to:

Division of Water Rights
 Phone: (916) 341-5300
 Reporting: ewrims@waterboards.ca.gov
 Measurement: dwr-measurement@waterboards.ca.gov

Depending on the size of your pond, the frequency of reporting pond volume will vary. As of 2019, the reporting requirements listed by the water board are shown in table 1.

A depth-capacity curve (sometimes called a pond curve) demonstrates the relationship between pond depth (as read on a staff gauge) and water volume at that depth. This publication provides a method to develop a depth-capacity curve for individual ponds. Ponds with a capacity of 10 acre-feet or less typically fall into a “stock pond” category under which owners are allowed to estimate the monthly change in storage volume (typically increasing during the rainy season and decreasing during dry season). Under SB88, smaller ponds under 100 acre-feet will require an individual with experience in measurement and monitoring to design and install measurement equipment. For ponds over 100 acre-feet, land managers have the option to complete the UC water measurement course so they can select and install their own measurement devices (pond owners with under 100 acre-feet of storage may also want to take this course to become more familiar with water measurement terms and techniques). The SWRCB notes that for purposes of this SB88 regulation, “diverter” means an individual authorized to divert water under a valid water right, a lessee of a property that is subject to a water right who is acting as a representative of the water right holder, or a bona fide employee of the water right holder or lessee. For land managers who are not inclined to “do it yourself,” they have the option to hire a professional contractor or engineer to do to do this for them.

Table 1. SWRCB reporting requirements

| Pond size (acre-feet) | Required monitoring frequency |
|-----------------------|---------------------------------|
| <10 | monthly (estimation is allowed) |
| 10–49 | monthly |
| 50–99 | weekly |
| 200–999 | daily |
| >1,000 | hourly |

Source: SWRCB website, https://www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/water_use.html.



Figure 1. Staff gauge.



Figure 2. GPS unit noting area.

1. Stock ponds (<10 acre-feet): While depth-capacity curves are less essential for <10 acre-feet ponds, the calculator is still useful in determining and documenting the overall capacity of the ponds, but is optional and not required by the state.
2. Ponds (between 10 and 49 acre-feet): A depth-capacity curve is a practical method for determining pond volume. Monitoring and recording monthly changes in volume can likely be done visually.
3. Ponds (with a volume greater than 50 acre-feet): For larger ponds, the development of a depth-capacity curve using this method is still valid; however, the reporting requirement (weekly, daily, or hourly) will likely require the use of an automated device (i.e., pressure transducer) to collect depth data practically.

Since stock ponds are not flat bottomed, the simplest way to monitor water volume is with a depth-capacity curve showing the total volume stored at various water levels throughout the season. While depth-capacity curves are available for some ponds in California, it is not uncommon for ponds constructed decades ago to have never had a staff gauge installed or a depth-capacity curve developed. If your pond is registered with the Bureau of Dam Safety, was designed by the USDA Natural Resources Conservation Service (NRCS) or local Resource Conservation District (RCD), or was surveyed during an inspection by the SWRCB, a depth-capacity curve may be available. Check with those agencies first.

Licensees of ponds (Water Right IDs begin with “A”) can send an email request to the SWRCB at dwr-measurement@waterboards.ca.gov with the Water Right IDs of interest, to see if the Division has an existing depth-capacity curve or survey information that the diverters can use to construct their own curve. The SWRCB does not maintain survey information for Domestic, Permits, Irrigation, or Livestock Registrations (Water Right IDs beginning with “D,” “H,” or “L,” respectively); Stock Pond Certificates (Water Right IDs beginning with “CC”); or Riparian and Pre-1914 claims of right (Water Right IDs beginning with “S”).

DEVELOPING A POND CURVE

If a depth-capacity curve cannot be found, one will need to be developed. This can be accomplished by measuring the water depth and corresponding surface area of the pond for at least three different levels between full and empty. An installed staff gauge (fig. 1) is crucial to monitoring the fill level of the pond. Because of the irregularity of many reservoir bottoms, the staff gauge needs to be installed in a location that represents the average ground level of the bottom of the pond. A handheld GPS unit (or smart phone with GPS capability) can then be used to determine surface area (fig. 2). Using these tools and the online calculator, you can develop your own depth-capacity curve.

PROCEDURE

Collecting the Data

Begin this project in late summer/early fall when the pond is at its lowest elevation. Doing so allows you to develop the most accurate measurement of the pond storage size by increasing the number of measurement opportunities throughout the year.

1. Install the staff gauge in a location that represents the average ground level of the pond bottom. It must be plumb (straight up and down) to get an accurate reading. If you have an existing staff gauge that is installed at an angle, a relationship must be made between the demarcations on the angled staff gauge and actual pond depth to collect accurate readings.
2. Using a GPS unit or smartphone app, set to “determine area” and walk around the water line (at water’s edge) of the pond to determine the surface area. Record the surface area in square feet and corresponding depth in feet. Table 2 shows potential sources and cost for example types of equipment.

Table 2. Selected GPS equipment costs

| Equipment name | Cost | Platform |
|-------------------------|-------|--------------------------------|
| Garmin Etrex 10 | \$110 | Standalone GPS Unit |
| GPS Fields Area Measure | free | IOS smartphone application |
| Fields Area Measure | free | Android smartphone application |
| Field Navigator | free | Android smartphone application |

Table 3. Example measurements across 4 days as the pond fill

| Date | Depth (ft) | Surface area (square ft) | Surface area (ac) |
|------------|------------|--------------------------|-------------------|
| N/A | 0.0 | 0 | 0 |
| 8/31/2018 | 1.0 | 27,940 | 0.64 |
| 11/15/2020 | 3.5 | 230,860 | 5.30 |
| 1/31/2019 | 5.5 | 426,888 | 9.80 |
| 2/28/19* | 6.0 | 495,713 | 11.38 |

*Pond is at capacity-overflowing.

3. As the pond fills, repeat this process at least three times to establish a robust relationship between depth of the pond and corresponding surface area of the water. Table 3 is an example of measurements taken across four different days throughout the season.

Developing the Curve with an App

To generate a personalized depth-capacity curve, use this online calculator: <https://ucanr-igis.shinyapps.io/PondCalc/> (fig. 3). This tool is built on Appendix A of the USDA NRCS Agriculture Handbook 590, Ponds-Planning, Design and Construction, and it can be found at the NRCS website, <https://nrcspad.sc.egov.usda.gov/Distribution-Center/pdf.aspx?productID=115>. For the best experience, view this website using a Chrome or Firefox browser.

Step 1: Upload Pond Measurements

If you have a spreadsheet with your pond measurements, you may upload it here. If you don't have a spreadsheet, you can enter your pond measurements one-by-one in Step 2 or download a [blank template](#) and fill it in. You can also load some [sample data](#).

Browse... No file selected

Step 2: Edit / Add Measurements

If needed, you can edit or add your pond measurements here.

Depth (ft) Surface Area
 Acres
 Square feet

Add Row

Step 3: Estimate Volume from Depth

Enter current pond depth (feet)

Calculate

Figure 3. Screenshot of the stock pond volume calculator.

Pond Measurements **Pond Curve** Volume Table A

The table below is automatically generated using your data. If there are incorrect data, remove the row by (1) clicking once on each row containing incorrect values, (2) then clicking on the 'Remove Selected Rows' button below. To add rows, use the 'Add Row' button in the sidebar.

Copy CSV Excel Print

| Measured Depth (feet) | Measured Surface Area (feet ²) |
|-----------------------|--|
| 0.0 | 0.0 |
| 1.0 | 27940.0 |
| 3.5 | 230860.0 |
| 5.5 | 42688.0 |
| 6.0 | 495713.0 |

Showing 1 to 5 of 5 entries

Remove selected rows

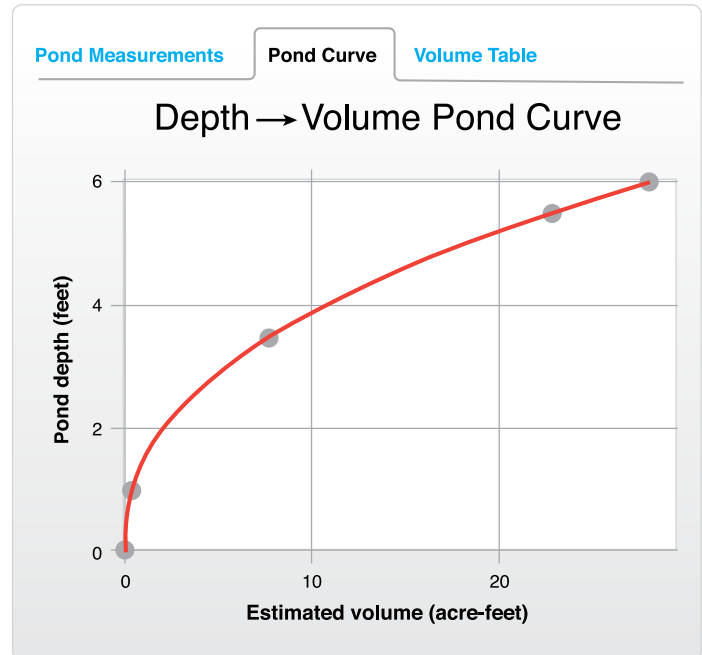


Figure 4. (A) Pond measurement table showing submitted depth and surface area. (B) Calculated depth-capacity curve showing relationship between pond depth and water volume (acre-feet).

- (Optional) Step 1: Upload pond measurements. This optional step allows a user to load a prefilled spreadsheet of pond depth and surface area measurements into the tool. No information is stored by this tool between uses. Landowners with multiple ponds may use this function to quickly generate depth-capacity curves for individual ponds in lieu of manually entering recorded measurements.
- Step 2: Edit/add measurement. Enter the depth and corresponding surface area for each measurement here. It is important that after entering each depth and surface area, you confirm your entry with the “Add Row” button. A first-time user may want to input the data from table 3 to become familiar with how the app works.
- As you enter collected data (depth and corresponding surface area), a pond measurement table (fig. 4A) and pond curve (fig. 4B) will be automatically generated.
 - Please note: The depth-capacity curve will only populate once sufficient measurements have been submitted to produce a curve with relative confidence.
 - Use the table to review the data modeling your curve. If an incorrect

measurement is present, click on the incorrect row to select the value, and click “Remove selected rows.” The depth-capacity curve should adjust automatically.

- The calculator will also provide volume for the pond at ½-foot-depth intervals. To see and print the volume table, select the third tab.
- The equation used to develop the pond curve is noted below the output on the Pond Curve tab. If an automated device (i.e., pressure transducer) is used to monitor changes in pond depth, the pond curve equation can be used with the depth data to determine associated changes in pond volume.

DETERMINING CHANGE IN POND VOLUME

A pond curve demonstrates the relationship between pond depth (as read on a staff gauge) and water volume at that depth. The online calculator derives the depth-capacity curve with a three-factor polynomial equation that is suitable for most ponds. To improve the accuracy of the curve, increase the number of data

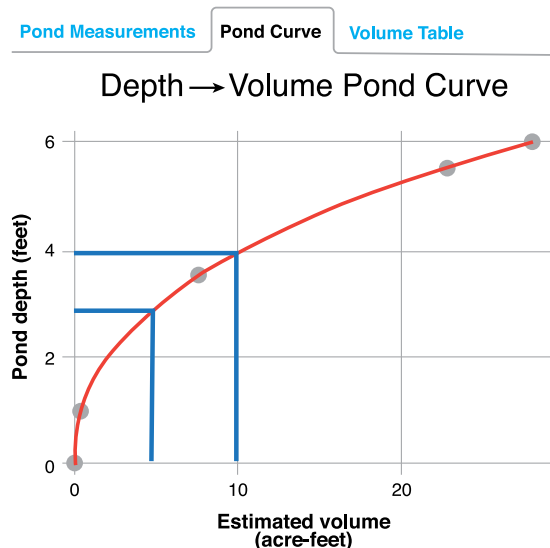
Table 4. Volume-change data based on pond curve

| Date staff gauge read | Staff gauge reading | Volume estimate from depth-capacity curve | Calculated volume from online calculator |
|-----------------------|---------------------|---|--|
| November 1 | 3.0' | ~5 acre-feet | 5.37 acre-feet |
| November 30 | 4.0' | ~10 acre-feet | 10.66 acre-feet |
| Change | — | 5 acre-feet | 5.29 acre-feet |

points (pond depth and corresponding surface area). This app will not be accurate if islands or channels are cut into the pond.

Once a pond curve is developed (see fig. 4B), it can be used to track changes in total volume using staff gauge readings. For example:

- If you want to know the change in volume during the month of November, you would note the staff gauge reading on November 1 and November 30.
- In this example, the staff gauge reads 3.0' on November 1 and 4.0' on November 30.
 - Reading the completed pond curve can identify the corresponding volume estimate at these depths (fig. 5).

**Figure 5.** Pond curve with hand-drawn lines at various depths.

- By estimating the pond volumes at 5 acre-feet and 10 acre-feet during the two periods, the increase in volume can be estimated to be 5 acre-feet (table 4).

- For more precise measurements, enter the depth into this step to derive the exact estimated pond volume (fig. 6).
 - Enter the current depth and select “Calculate” to display the precise volume measurement.
- Once complete, you can save your inputs so that you do not have to manually enter all the individual values. To do this, select one of the export options (CSV, Excel) using the buttons above the table. This generated file can be modified and uploaded to the app as more information is collected (fig. 7).

Step 3: Estimate Volume from Depth

Enter current pond depth (feet)

3.0

Calculate

Your pond has an estimated volume of 5.37 acre-feet

Step 3: Estimate Volume from Depth

Enter current pond depth (feet)

4.0

Calculate

Your pond has an estimated volume of 10.66 acre-feet

Figure 6. Calculated pond volume estimates for depths on November 1 and November 30.

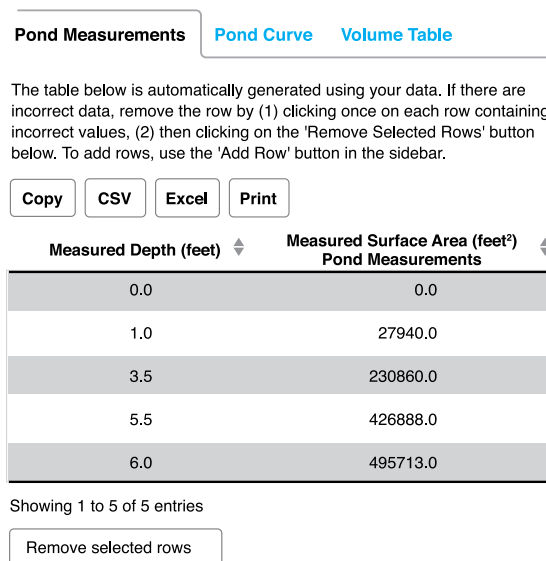


Figure 7. Example of completed depth and area table.

REPORTING DIVERSION VOLUME TO THE SWRCB

The need for data collection and development of a pond curve is to meet SWRCB reporting requirements for established stored water. Diversion volume must be reported online using the SWRCB online portal.

Access to the online reporting process portal is only available to landowners with recorded ponds. If no record exists for the pond, the owner will need to file an Initial Statement of Diversion at the State Water Resources Control Board website, https://www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/docs/intl_stmnt_form.pdf, or register a stock pond (<10 acre-feet storage). For more information, go to the SWRCB website, https://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/#stockpond.

If the SWRCB has your water right on record (i.e., has issued a stock pond certificate or reservoir permit or license), the agency will acknowledge this by issuing the owner a username and password. Without a username and password, the online reporting process cannot be initiated.

1. The SWRCB online reporting system is called eWRIMS (Electronic Water Rights Information Management) and can be accessed at the SWRCB website, https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/. The software will ask the user for username and password information. Once these credentials are established, the user will be prompted through a series of questions associated with the user's diversion.
2. Eventually the user will reach a screen asking for diversion information by month. The volume of water reported here should be in acre-feet regardless of the required measuring interval. For situations where the measuring requirement is more frequent than monthly, the interval measurement data must be distilled to reflect the total monthly water diverted. The data used to calculate monthly volume diverted will need to be uploaded to the eWRIMS system. Figure 8 is an example of the form where volume of water diverted to storage by month is completed. Using the example from table 3, note that 5.29 acre-feet were added to storage in the month of November. That number is entered on the report form.
3. Note that no water was "beneficially used." *If water from this pond were used for irrigation or stock watering during the summer months, the amount of water put to a beneficial use would be recorded.*

| 6. Amount of Water Diverted and Used | | | |
|--------------------------------------|--------------------------------------|---|--------------------------------------|
| Month | Amount directly diverted (acre-feet) | Amount diverted or collected to storage (acre-feet) | Amount beneficially used (acre-feet) |
| January | 0 | 0 | 0 |
| February | 0 | 0 | 0 |
| March | 0 | 0 | 0 |
| April | 0 | 0 | 0 |
| May | 0 | 0 | 0 |
| June | 0 | 0 | 0 |
| July | 0 | 0 | 0 |
| August | 0 | 0 | 0 |
| September | 0 | 0 | 0 |
| October | 0 | 0 | 0 |
| November | 5.29 | 5.29 | 0 |

Figure 8. Example of SWRCB monthly reporting form.

GLOSSARY

acre-foot: A volume of water that can be most easily visualized as 1 acre in area (approximately the size of a football field) and that is 1 foot deep. However, the surface area and depth dimensions may vary. An acre-foot of water equals 43,560 cubic feet of water or 325,851 gallons.

Android smartphone application: Cellular devices offered by Samsung and other competing manufacturers.

beneficially used: California water law defines many beneficial uses, including domestic, agricultural, and environmental uses. For purposes of SB88 reporting, irrigation is a primary beneficial use.

California State Water Resources Control Board (SWRCB, the State Water Resources Control Board): The regulating agency in California responsible for enforcement of SB88 water measurement and reporting of California surface water diversions.

depth-capacity curve (pond curve): A graphical representation of the volume of water in a pond when filled or emptied to different levels. Because ponds have irregular shapes and depths, there is not a linear relationship between depth and surface area.

diversion volume: The volume of water diverted between two measurement dates, possibly monthly or weekly. This can be water that is either diverted into the pond or removed from storage.

engineer's scale: Measurement instrument with gradation in feet and tenth of feet (rather than feet and inches).

GPS unit: An electronic device capable of connecting to satellites and used to accurately track one's position on earth. Useful for measuring distances and land areas or changes in distances and land areas over time. Smartphones typically have GPS capabilities.

groundwater: Water that is extracted from the ground. Typically, a well and pump arrangement. Where wells are located near surface water sources and there is connectivity to the surface water, the extraction through a well might be considered surface water.

IOS smartphone application: Cellular devices offered by Apple, Inc.

plumb: Exactly straight, vertically.

pond capacity: The stored volume of water just prior to reaching the spillway. This includes

the volume up to the top of the spillway and volume retained by any freeboard above that.

pond volume: The amount of space occupied by water in a pond. A three-dimensional measurement of length times width times depth. Usually expressed in cubic feet or acre-feet.

pressure transducer: Electronic device that measures and records the elevation of water above it at programmed intervals (i.e., hourly).

staff gauge: A stationary measurement rod or post properly located in the pond that is clearly marked in feet and tenths of feet to conveniently measure change in water elevation of pond.

surface area: The uppermost or outer part of a layer. A two-dimensional expression of length multiplied by width that is usually expressed as square feet or acres.

surface water: Water that flows on top of the ground.

United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS): A federal agency under the Department of the Interior responsible for oversight and management of land resources in the United States. A USDA NRCS office is located in each county of California.

water right: Legal authority to divert and/or store water.

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