Reservoir Diversions to Storage

Any water body constructed by a dam or earthen berm across a stream is considered a reservoir under the definition of a water right. There are two ways to measure reservoir diversions (by "diversion" we mean how much water is captured in the reservoir from stream inflows). (1) Measure the rates of incoming stream-flows, (2) Measure the change in reservoir water levels over time. The first method requires instream flow measurement and typically involves some sort of stream alteration which can be challenging than using the depth-capacity curve method. This document will focus on measuring changes in reservoir water levels over time and converting to volume using a depth-capacity curve.

The quantity diverted into a reservoir is defined as the change in reservoir storage over a specific period of time, otherwise referred to as the volume change (ΔV). Change in volume is calculated by measuring different reservoir levels over time and converting water elevation changes into volume using a depth-capacity curve (i.e. conversion factor) derived by surveying the reservoir. The Division of Water Rights has created depth-capacity curves for *licensed* reservoirs throughout the state. If you own a water right license, you may contact the Division of Water Rights to obtain a copy of your depth-capacity data. The Division does not have depth-capacity curves for permits or pre-1914 reservoirs. Note: Permitted and pre-1914 reservoir owners are required to develop their own depth-capacity curve.

Water Balance Calculations

To measure the volume of water diverted into a reservoir, a "water balance" needs to be performed to find the net change in reservoir volume (over a specific period of time). Depending on the reservoir category either weekly, daily or hourly stage measurements are needed to account for the net quantity of water stored during the diversion season. The volume of water captured (i.e. diverted) into a reservoir is governed by the following water balance equations:

Under normal conditions of stream inflows and outflows, one need only measure the change in reservoir water levels over time to obtain the volume diverted.

Under conditions of no imported water and no withdrawals:
Diversion to Storage = change in volume = [sum of all stream inflows] – [stream bypasses through reservoir]

If there is imported water and withdrawals in addition to stream inflows and bypasses, then you must also measure the imported water deliveries and withdrawals from the reservoir.

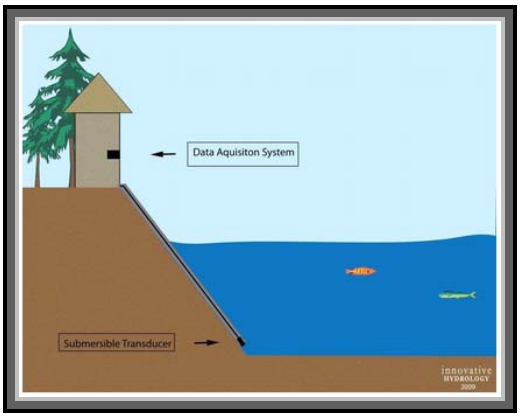
Under conditions when imported water is delivered and/or withdrawals are taken from reservoir:
Diversion to Storage = [change in volume] – [sum of all imported and non-jurisdictional water] + [withdrawals]

Definitions:
Change in volume (ΔV): Is calculated by recording water levels over time and using the depth-capacity curve to make volume conversions.
Stream inflows: Natural flow from rivers, creeks and springs diverted or collected into the reservoir.
Stream bypasses: Bypassed water released through the reservoir to meet down-stream flow requirements.
Imports and transfers: Includes foreign sources such as purchased water, groundwater and other water transfers.
Withdrawals: Consumptive use of appropriated water. Includes withdrawals of imported/transferred water and groundwater.
Note: Only water collected from rivers, creeks and springs is reported as a diversion.

Measuring Reservoir Storage

A simple method of measuring water level changes is by reading a staff gage installed in the reservoir. Monthly water levels can be recorded by taking a staff gage reading and recording the data in a log book. A more practical method for measuring reservoir levels is to record water levels using a data-logger whenever weekly, daily or hourly measurements are required. How does a data-logger measure water level? Water level data-loggers consist of a device that measures water pressure at various depths (hydrostatic pressure) below the surface. The data-logger automatically converts pressure into standing water depths or reservoir levels[1]. Water levels are recorded at pre-determined intervals of time and data is collected at scheduled intervals and can be downloaded manually to a mobile device such as a laptop during visits to the site. They are often referred to as remote data-loggers because they are suitable for use in back-country areas and other remote areas with limited site access.

Water level/Data-logger

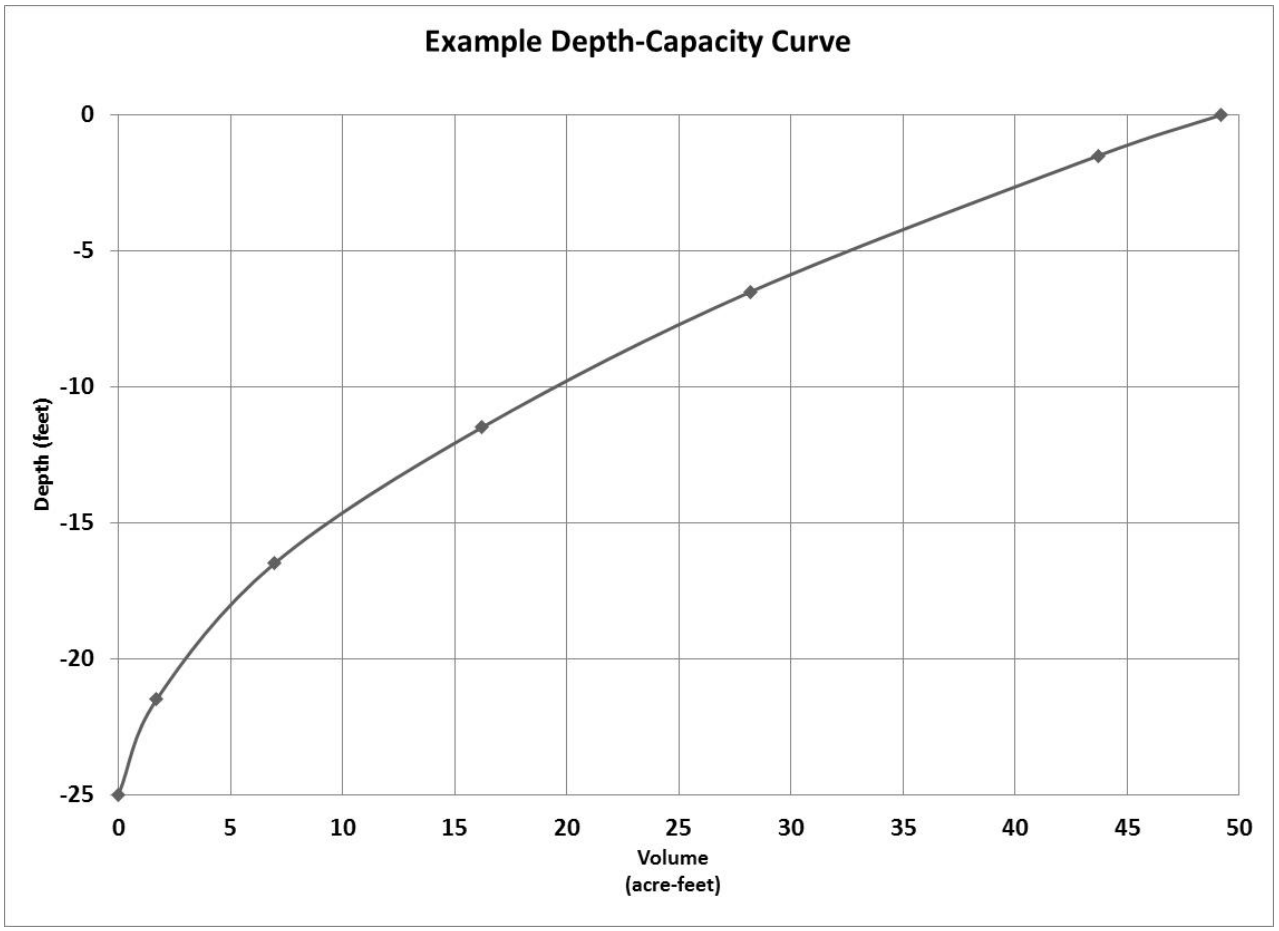


Telemetric Data-logger

[1] In some cases, water pressure readings have to be converted manually to depth using conversion factors.

Depth-Capacity Curve

In order to calculate reservoir diversions to storage a depth-capacity curve is normally used to convert water level changes into volume. The change in reservoir volume (either storage or depletion) is calculated using measured water levels (stages) over time and using a chart like the one below to derive "diverted" volume. The Division of Water Rights has records of depth-capacity curves for *licensed* reservoirs throughout the state.



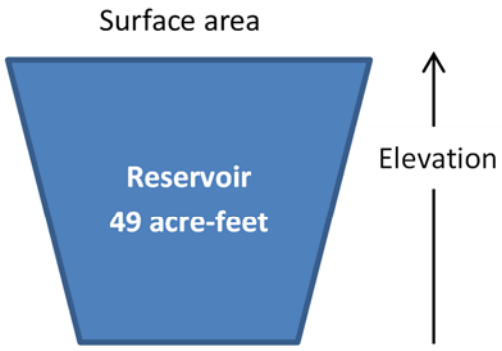
Small Reservoirs on Ephemeral Streams

Reservoirs in this category typically have no releases during the collection season. Many stock-ponds fall into this category. The applicable water balance equation:

During the Collection Season: Diversion to Storage = change in volume

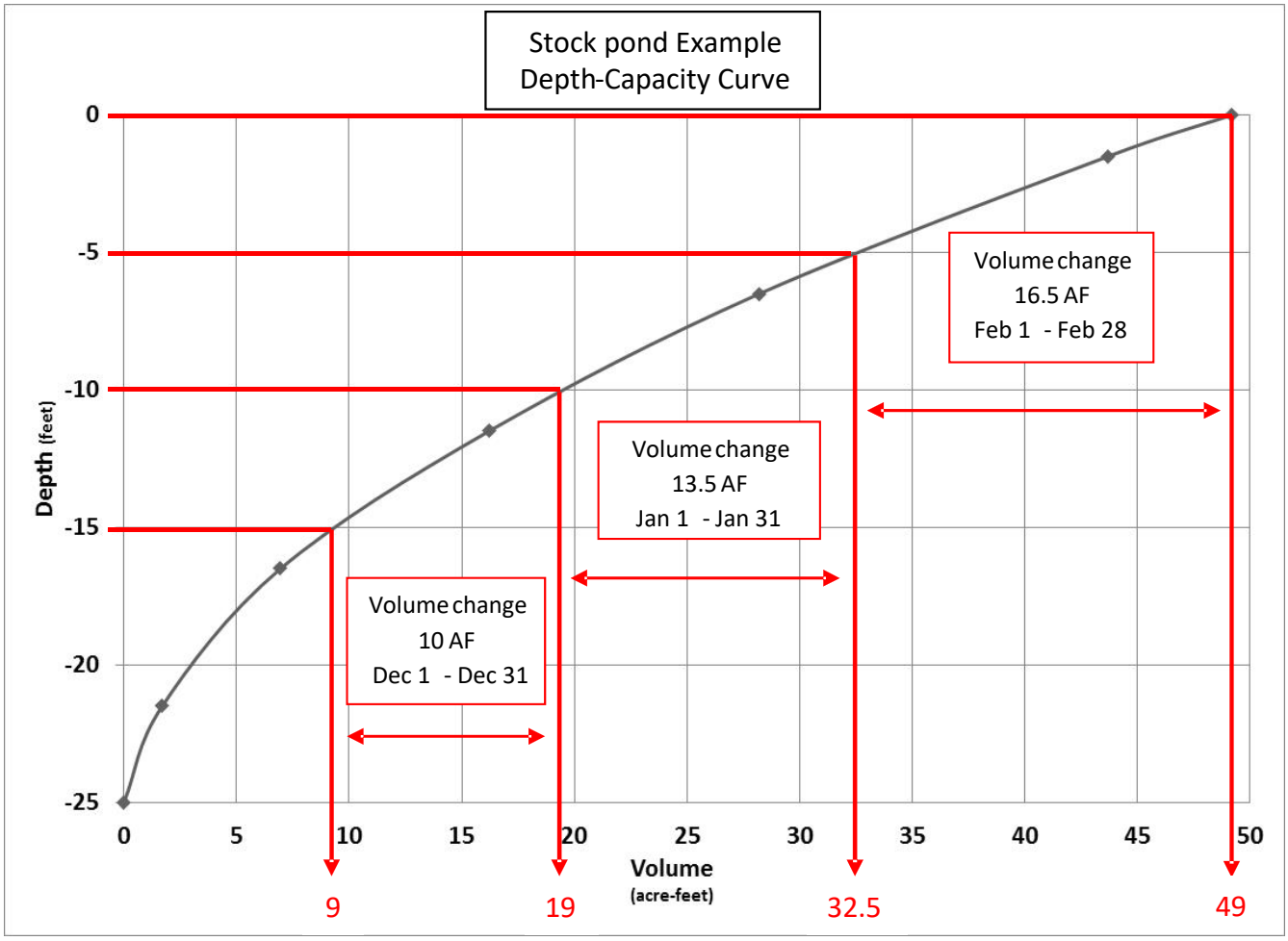
Outside of Collection Season: Consumptive Use = change in volume

Example Stock-pond diversion calculation:



Storage-Elevation Table	
Surface Elevation (feet)	Volume (acre-feet)
-25	0
-20	3
-15	9
-10	19
-5	32.5
0	49

For example, a 49 acre-foot stock-pond has a depth-capacity curve illustrated in the figure below. The licensed collection season is from Nov. 1 through March 31. The depth-capacity curve shows that a 15-foot increase in water level elevation equates to a 40 acre-foot change in volume. The difference in volume from an elevation stage of – 15 feet on November 1 to a stage of 0 feet (full) on March 31, equates to 40 acre-feet of water collected during the season based on the depth-capacity curve below. The monthly record-keeping log for diversion reporting is shown below.



Diversion Record for period Nov. 1 – Mar. 31

	Surface Elevation (feet)	Res. Volume (AF)	Amount Collected to Storage (AF)
Jan. 31	- 5.0	32.5	13.5
Feb. 28	0.0	49	16.5
Mar. 31	0.0	49	0
Apr. 30			
May 31			
Jun. 30			
Jul. 31			
Aug. 31			
Sep. 30			
Oct. 31			
Nov. 30	-15.0	9	0
Dec. 31	-10.0	9	10.0

Monthly or manual water level measurement

There are many ways to measure reservoir water levels manually. One method is to install a vertical or inclined staff gage. A staff gage is a device used to measure water surface levels in a reservoir. It is pipe or rod ("staff') with a ruler ("gage") marked on or attached to it. The difference in water levels taken at two different times or dates will show the change in reservoir storage using a depth-capacity curve. The information can be used to determine the amount of water collected in the reservoir. The staff gage should be permanently anchored vertically or at in incline in a location that is easy and convenient to read from the dam or shoreline. It should also be protected from vandalism and located where it is not a boating or swimming hazard (If manual water level measurements with a staff gage are inconvenient, consider using a battery powered data-logger).

At a minimum, the staff gage should have permanent markings at 0.1-foot intervals with high-visibility numerals. The staff gage should be capable of determining water surface levels from the high water-level to the low water level in the reservoir. A reference point should be established and permanently marked for the high water-level. Ideally, the reference point will normally read "zero" at the water level so that the staff gage reads the vertical drawdown in feet. The high water-level is usually the level where the reservoir is full. The maximum high water occurs when the reservoir is spilling at the spillway crest.

Staff gage material

The staff gage should be made of a durable material that resist rust and discoloration, and sturdy enough to minimize movement due to wind; wave action, and ice. Recommended materials include porcelain-enameled iron, steel pipe, fiberglass, redwood, etc.

Remote data-loggers

Use of a battery powered data-logger is one option for recording water level measurements in reservoirs over time when manual water level measurements are not possible. Water levels are recorded at pre-set time intervals with a pressure transducer or other device that measures change in water levels. The device can be mounted on a permanent structure in the reservoir. Data is collected at pre-scheduled intervals and can be downloaded manually to a mobile device such as a laptop during visits to the site. Data loggers are well suited in back-country or other remote areas with limited site access. Even if you use a data-logger, you may still want to utilize staff gages to confirm the data-logger is working properly.