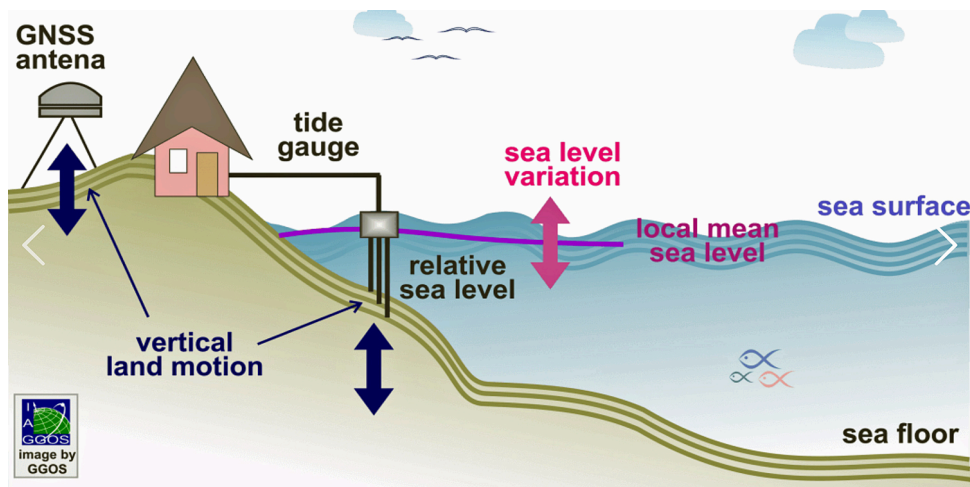


## Mean Sea Level: Is There Such A Thing As Accurate Height?

Mean Sea Level (msl) is an average level of the surface of one of Earth's oceans from which heights such as lake and mountain elevations may be measured. Height above mean sea level (msl) is the elevation (on the ground) or altitude (in the air) of an object, relative to the average sea level datum. For at least the last 100 years, sea level has been rising at an average rate of about 1.8 mm (0.07 in) per year - 4.2 inches since Monticello Dam was completed. At present, the maximum cumulative uncertainty for operational Vertical Datum regions in San Francisco Bay Area, which includes Lake Berryessa, is 4 inches. So, what does a measurement of 439.96 feet mean in that context? We can precisely measure the lake level to 439.96 feet within a tenth of an inch, BUT we only know the accuracy of that measurement to plus or minus 2 inches!



The National Geodetic Vertical Datum of 1929 (NGVD29) (previously titled the Mean Sea Level Datum) was derived using 26 long-term tidal gauge stations and 1st order leveling stations constrained at mean sea level. These 26 tide gauges were set up in harbors along the east and west coast of the United States (and along the Gulf of Mexico). Twenty-one stations were in the United States and five in Canada. During a twenty-year period beginning in 1877, a “level line” was surveyed across the entire United States. As the network of level lines across the country expanded, this became the basis for the vertical datum.

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There are several methods of measuring the height of a point above msl. The choice depends on the accuracy required and the equipment available. Satellite altimeters have been making precise measurements of sea level since the launch of the TOPEX/Poseidon satellite in 1992. But there were no satellites in 1955 when the dam was being built. Surveyors used precise optical instruments to do the job.

A surveying instrument known as an optical level is used to project a horizontal line in two directions (forwards and backwards) so that differences in height can be measured. At each end of the line being measured the value is noted where this horizontal line intersects a vertical staff (basically just a big ruler). This is the

equipment you see when you drive by surveyors planning a new road. The difference between the values at each end of the line gives the difference in height.

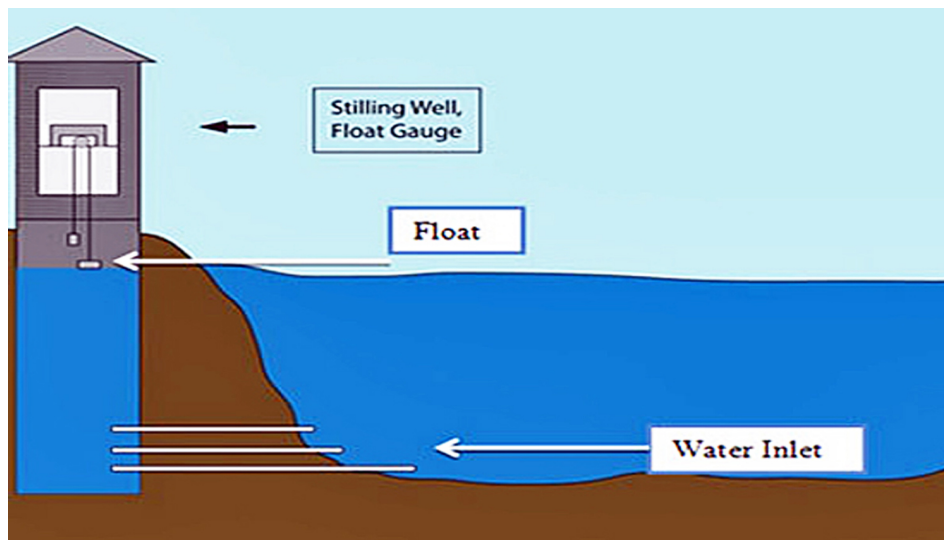
Provided the line of sight is kept relatively short (usually less than 150 feet) the measurements are quite accurate. By repeating this process in a leap-frog manner and adding up all the differences in height, the total difference in height between two very distant points can be calculated.

Over long distances this is a tedious technique, but it produces accurate results. It depends on the instrument used and the care taken, but for the typical standard of optical leveling the accuracy is about 1 inch over 6 miles, or 3 inches over 62 miles.

Because Lake Berryessa is approximately 15.5 miles long and 3 miles wide with approximately 165 miles of shoreline, surveying the whole area was a major design task. But who cares how high above mean sea level the lake actually is? Basically no one. Lake Berryessa is a reservoir providing agricultural irrigation water and drinking water to Solano County (recreation was not a goal). So, the important measurement is the volume of the lake at any given time - not its absolute height above sea level.

And the volume of a lake is measured by knowing the relative heights of the valley in which it sits. Lake Berryessa could be a hundred feet higher than it is and it would not matter - because the important measurement is its volume. The surface area of the lake is about 20,700 acres (plus or minus what?). If the height of the lake level is off by 2 inches that's an uncertainty of about plus or minus 3.5 acre-feet - or about .02% - a very small number. On the other hand, an average California household uses between one-half and one acre-foot of water per year for indoor and outdoor use. From that perspective it may seem like a lot to some folks.

The Lake Berryessa water level is actually measured on the Monticello Dam in a "stilling well" equipped with a float tape attached to a digital rotary encoder that measures accurately to 0.01 ft. Rainfall is measured using a tipping bucket rain gauge. However, the rain gauge on the top of Monticello Dam has never been very representative of precipitation in the overall Lake Berryessa area. The gauge is working well but the location, surrounded by mountains on two sides with a strong up-draft coming up the canyon and over the dam, prevents getting reliable data.



Rainfall measurements at the dam may not be representative of the area, but they are also not the best indicator of how fast the lake may rise. The Lake Berryessa watershed encompasses the 568 square mile area primarily fed by Putah Creek which originates from springs on the eastside of Cobb Mountain in Lake County. Putah Creek enters Napa County about 11 miles east of Middletown. It merges with Butts Creek just before it empties

into Lake Berryessa. Therefore, rainfall over the Cobb Mountain and Middletown areas provides the bulk of water entering Lake Berryessa. One reason that Lake Berryessa rose so quickly in 2017 was the very heavy rainfall that occurred on Cobb Mountain and the Middletown area.