As Lake Berryessa Flows:
A Combination of Science, Engineering, and Natural Beauty

by Peter Kilkus

The Science and Engineering Elements of a Major Natural Resource

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Lake Berryessa is almost a living creature. It breathes in and out, grows and shrinks. But it breathes water not air. Actually it is always breathing out a bit through evaporation and outflows through Monticello Dam all year. All of these processes define its hydrological cycle.

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As Lake Berryessa Turns! Temperature and Fishing in a Warm, Monomictic Lake

The phenomenon called "turnover" is well-known to anglers, but not so much to other lake visitors. Some people think that Lake Berryessa turns in both spring and fall. But scientific data shows that the lake only turns once per year - in the fall.

The Ins and Outs & Ups and Downs of Lake Berryessa

Most of us have heard of the rule of thumb that Lake Berryessa rises 1foot for every 1 inch of rain. As with most rules of thumb, this is not accurate. Lake level rise depends on many variables like the actual lake level when it rains and how saturated is the ground.

Seeing Underwater at Lake Berryessa

In the Spring of 2007 the Solano County Water Agency (SCWA) performed a survey of the underwater landscape of Lake Berryessa. They wanted to accurately determine the capacity of the lake using the latest technology.

Could Monticello Dam Fail? (By Margaret Burns,Davis Enterprise, September 05, 2014)

This thought was probably running through the minds of everyone close to the dam following the 6.0-magnitude earthquake that devastated Napa on Aug. 24, 2014. The simple answer is yes, because anything is possible. But is it probable? Not very.

<u>As Lake Berryessa Flows:</u>
<u>A Combination of Science, Engineering, and Natural Beauty</u>

By Peter Kilkus (7/14/17)

Lake Berryessa is almost a living creature. It breathes in and out, grows and shrinks. But it breathes water not air. Actually it is always breathing out a bit through evaporation and outflows through Monticello Dam all year. All of these processes define its hydrological cycle.

Hydrology is the scientific study of the waters of the earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes, and on or below the land surface - the cycle from precipitation to re-evaporation or return to the water of the seas. But Lake Berryessa's hydrology is heavily modified by man from the time the water drops from the sky until its return to the ocean.

<u>California Droughts are Common</u>

Long-term weather patterns are cyclic in nature but unpredictable in practice. The master chart below shows the history of Lake Berryessa since Monticello Dam was built in 1957. The lake has had previous droughts, one in the late 1970's, a ten-year drought from 1986 to 1996, and the latest from 2006 to 2017.

California endured severe droughts in 1976 and 1977, which ended in 1978. The master chart below shows that Lake Berryessa levels did not even show the usual winter uptick during those years and had dropped to less than 50% of capacity by 1978.

The 1987-92 statewide drought was notable for its six-year duration and the statewide nature of its impacts. Statewide reservoir storage was about 40 percent of average by the third year of the drought, and did not return to average conditions until 1994. But Lake Berryessa had dramatically dropped to only 30% of capacity by then and did not fill up again until 1996. 1991 was the single driest year of the drought.

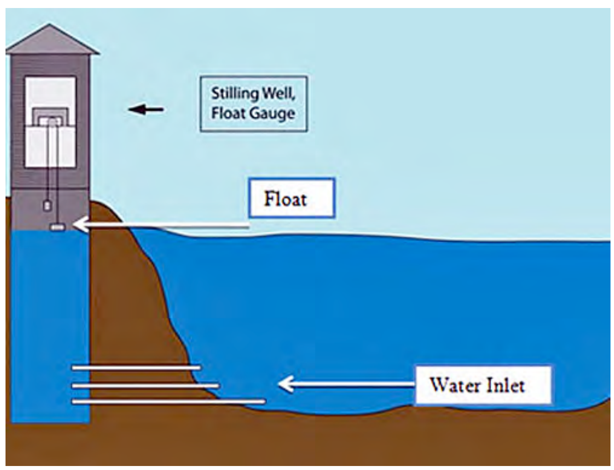
A 1994 study of relict tree stumps rooted in present day lakes, rivers, and marshes suggested that California sustained two epic drought periods, extending over more than three centuries. The first epic drought lasted more than two centuries before the year 1112; the second drought lasted more than 140 years before 1350. In this study, the researcher used drowned tree stumps rooted in Mono Lake, Tenaya Lake, West Walker River, and Osgood Swamp in the central Sierra. A conclusion that can be drawn from these investigations is that California is subject to droughts more severe and more prolonged than anything witnessed in the historical record.

Lake Berryessa, or Solano Water Project, is the main drinking water source for more than 400,000 people so a drought can have a serious impact. SCWA member agencies and their annual Lake Berryessa allocations in are-feet are: Solano Irigation District (SID) - 141,000 AF, Fairfield – 9,200 AF, Vacaville – 5,600 AF, Suisun City – 1,600 AF, Maine Prairie – 15,000 AF, and Vallejo – 14,750 AF for a total allocation of 187,150 acre-feet.

The Solano County Water Agency (SCWA) uses a wide variety of water management tools and options to maximize resource and minimize the need to import water. The SCWA and its member agencies have comprehensive urban and agricultural water conservation programs. They also have a Drought Contingency Plan which specifies that when storage in Lake Berryessa falls below 800,000 acre-feet as measured on December 1, they will implement reasonable water conservation measures, investigate potential emergency supplies and other reasonable measures which could reduce the depletion of storage in Lake Berryessa.

Measuring Levels and Rainfall

The Lake Berryessa water level is actually measured on the Monticello Dam in a “stilling well”. The simplest method of measuring lake water levels is 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. SCWA is considering changing this gauge location.

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 576–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.

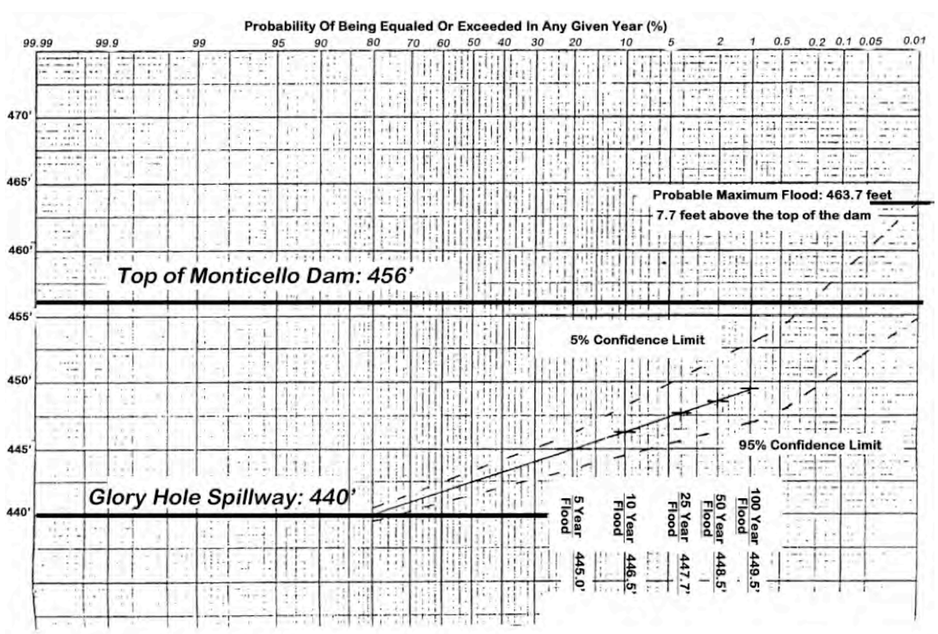
But Can Lake Berryessa Flood (Over the Dam)?

Not very likely. The lake level has never been higher than 446.7 feet (1983) since the dam was constructed. Since 1985 it has only reached 444 feet once in 1998. It is typically at or below 440 feet (Glory Hole). The master chart below shows that the lake has reached 440 feet twenty-five times in its 60-year existence. According to the Bureau of Reclamation, droughts are a significantly higher risk than floods since this is a reservoir which has some control over outflow rates but must provide water by law even if there is low rainfall.

There is only a 1 in 100 chance that there will be a flood level up to 450 feet. The top of the dam is at 455 feet. Highway 128 was designed to be the emergency spillway before the lake overtops the dam. Economic impacts due to potential floods are a very low probability and thus a low planning priority. The following table, based on an analysis completed in 1986, depicts the water elevation that, on the average, may be reached or exceeded for various time periods.

Frequency (Years)	Probability (%)	Elevation (Feet)
1.25	80	440
5	20	445
10	10	446.5
25	4	448
50	2	449
100	1	450

The Bureau of Reclamation did a Flood Elevation Probability Study in 1986. Although this is a bit of statistical game-playing, it is interesting to see the worst-case scenarios and the probability of their occurrence. Flood flows in this study were assumed to start at the initial elevation of 440 feet. All the frequency floods used in this study had a duration of 7 days. In other words, if the lake were already at 440 feet and then the various rainfall levels and flood flows (5-yr, 10-yr, 25-yr, 50-yr, 100-yr) began and lasted for 7 days, how bad could it get?



The impact of the 1984 Probable Maximum Flood flow produced a water surface elevation of 463.7 feet, or 7.7 feet ABOVE the dam for several days. This level was assumed to be the maximum reservoir elevation that could ever be reached during a flood. A related note in the study said, "Monticello Dam was assumed not to fail."

Not to worry too much since this worst case scenario had a VERY low probability – somewhere between 10,000 and 1,000,000 years. Even the probability of the lake reaching the top of the dam at 456 feet was very low with a

5% confidence limit of 417 years recurrence and 95% confidence limit of 16,667 years recurrence. As stated in the study, “computed probabilities beyond a 100-year recurrence are not considered to be reliable; therefore, only confidence limits are provided. There is a 90% probability of a specific event occurring somewhere in the interval between confidence limits.”

A 90% probability sounds high, but would you place a “sure bet” that the lake would hit 463.7 feet, 7.7 feet above the dam, if you had to wait somewhere between 400 and 16,000 years to collect?

Can Monticello Dam Break?

This is also highly unlikely. The Solano County Water Agency is under contract with the U.S. Bureau of Reclamation to operate, maintain, and administer all of the programs of the dam. Subsequently, it is SID who sub-contracts with the Solano County Water Agency to perform the day-to-day operations.

With the 2017 scare in Oroville, in which its dam’s primary and emergency spillways were substantially damaged, prompting nearly 200,000 evacuations of nearby residents, organizations like SID were put on alert with making sure the Monticello Dam doesn’t endure a similar scenario.

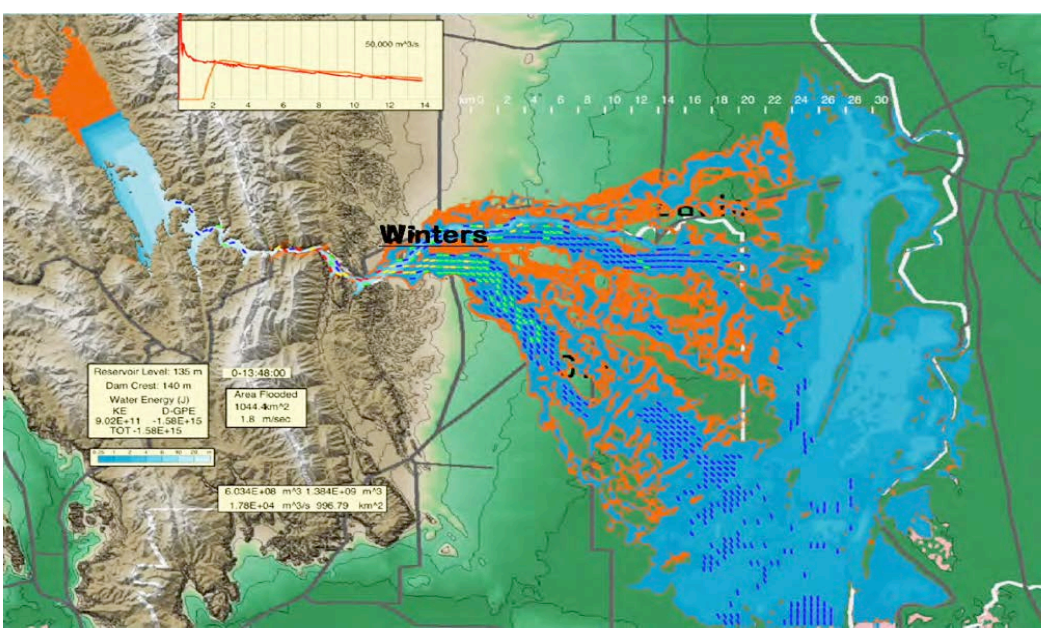
Reclamation has protocol and inspections, and with every inspection, everything has checked out so far, according to SID. The construction and structure of Monticello Dam are much different from Oroville. Monticello Dam is in very narrow canyon embedded in bedrock.

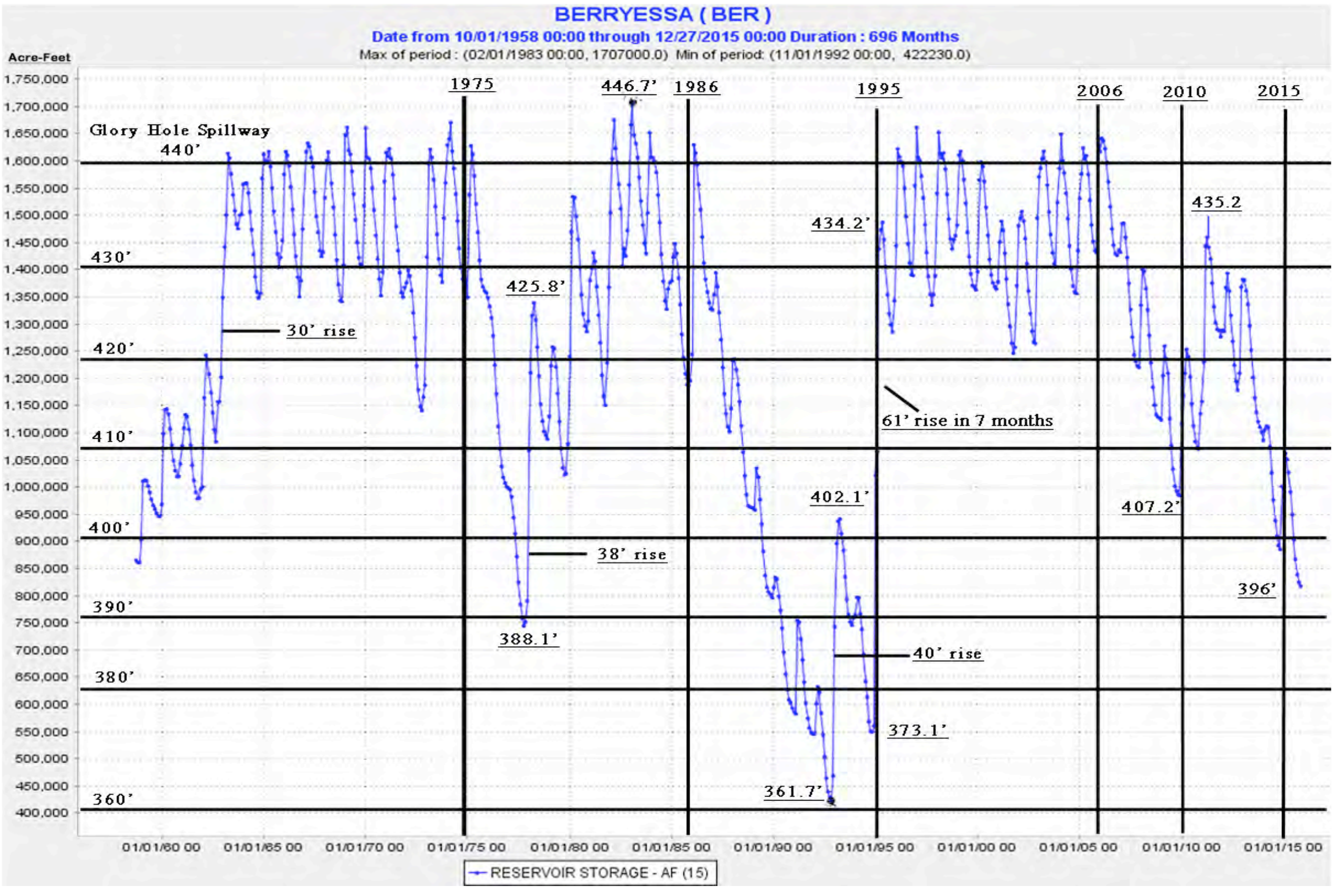
The traditional spillway construction wouldn’t have fit here. It would have been very costly to drill into the side of the mountains here. It’s very far-fetched and unlikely that something like that would happen at Lake Berryessa. The recent peak of 8,500 cubic feet per second the dam experienced was just a fifth of what the dam is able to handle. A SID spokesman boasted, “We’re not concerned. I can’t emphasize that enough.”

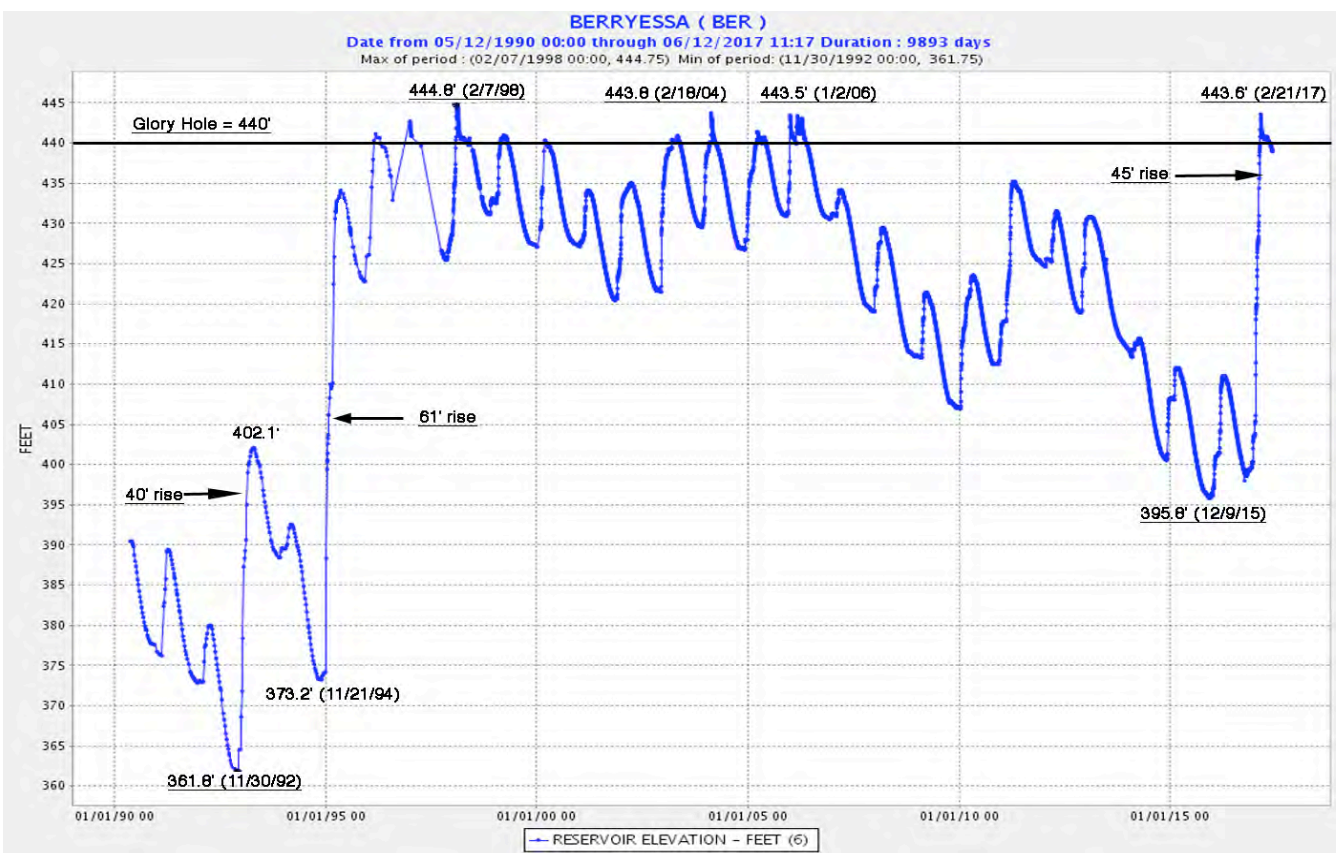
Monticello Dam Failure Simulation

Steven Ward, a research geophysicist at the Institute of Geophysics and Planetary Physics at UC Santa Cruz has created a computer simulation of the first 16 hours of flooding that might be expected from the failure of Monticello Dam from a possible earthquake. This worst-case scenario envisions a nearly instantaneous breakdown of the structure and a reservoir filled to capacity. This is unlikely but informative.

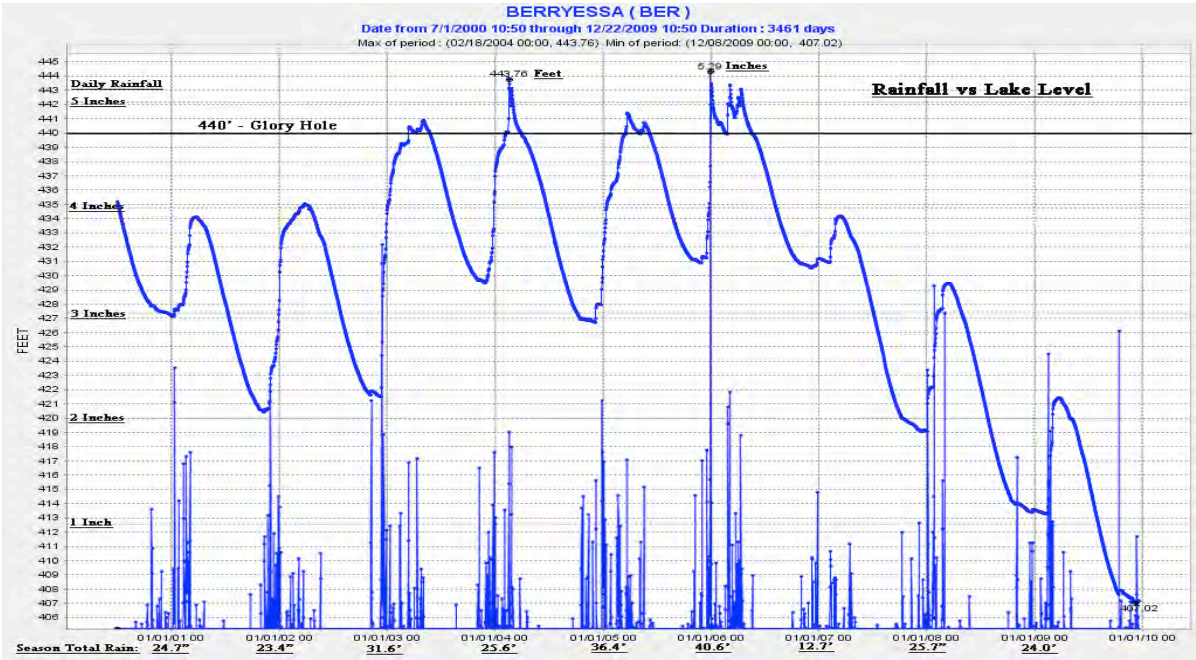
The simulation can be downloaded at: http://es.ucsc.edu/~ward/berryessa-dam.mov or on YouTube at: www.youtube.com/watch?v=HEJEHnKrueo

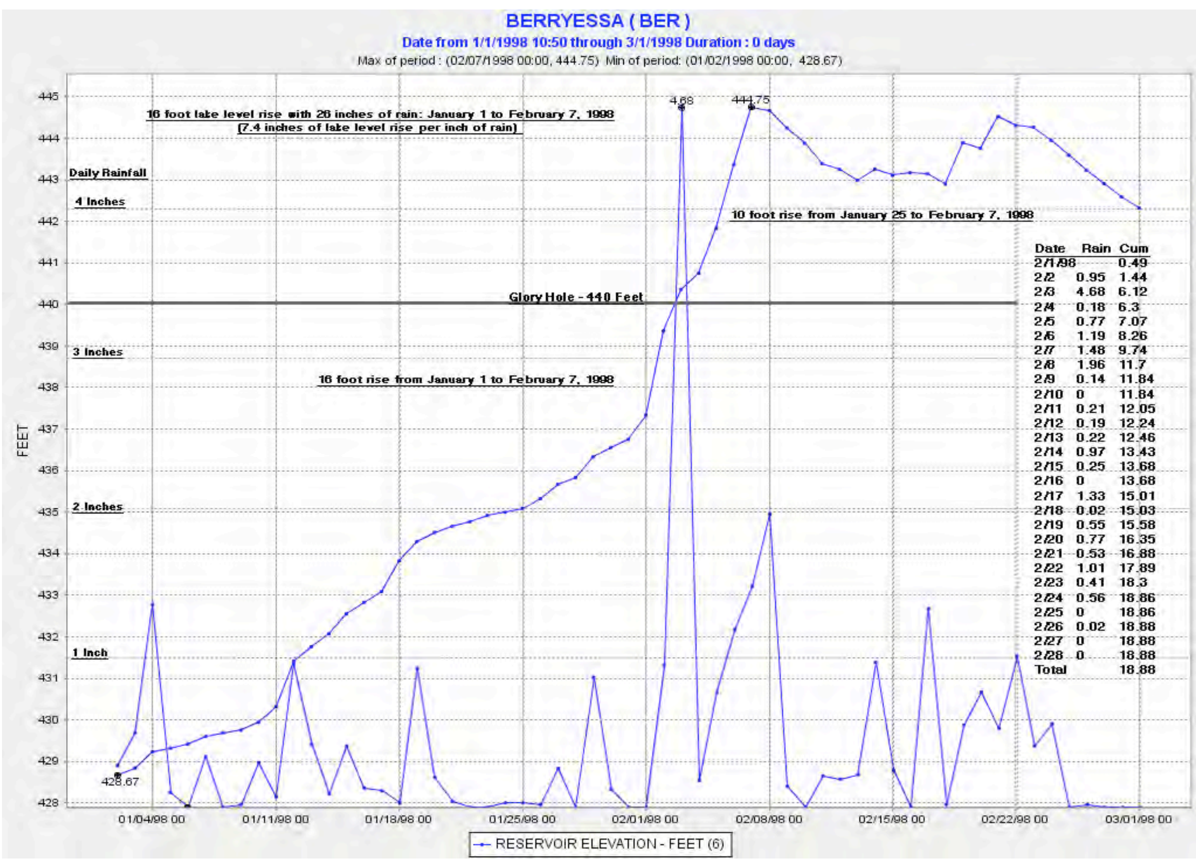



BERRYESSA (BER)
Date from 10/01/1958 00:00 through 12/27/2015 00:00 Duration : 696 Months
Max of period : (02/01/1983 00:00, 1707000.0) Min of period: (11/01/1992 00:00, 422230.0)
Acre-Feet
Glory Hole Spillway
440'
430'
420'
410'
400'
390'
380'
360'
1975
446.7'
1986
1995
2006
2010
2015
30' rise
425.8'
38' rise
388.1'
434.2'
61' rise in 7 months
402.1'
40' rise
373.1'
361.7'
435.2
407.2'
396'
RESERVOIR STORAGE - AF (15)


BERRYESSA (BER)
Date from 05/12/1990 00:00 through 06/12/2017 11:17 Duration : 9893 days
Max of period : (02/07/1998 00:00, 444.75) Min of period: (11/30/1992 00:00, 361.75)
FEET
Glory Hole = 440'
444.8' (2/7/98)
443.8 (2/18/04)
443.5' (1/2/06)
443.6' (2/21/17)
45' rise
61' rise
402.1'
40' rise
373.2' (11/21/94)
361.8' (11/30/92)
395.8' (12/9/15)
RESERVOIR ELEVATION - FEET (6)

The early 1980s were mostly above average in precipitation in northern California and throughout the West, with the wettest year of the decade occurring in 1983 – also the highest level the lake ever reached, 446.7 feet, almost 7 feet above Glory Hole! The rainfall versus lake level chart below gives daily and annual rainfall totals versus lake levels for the 2000 to 2008 seasons.



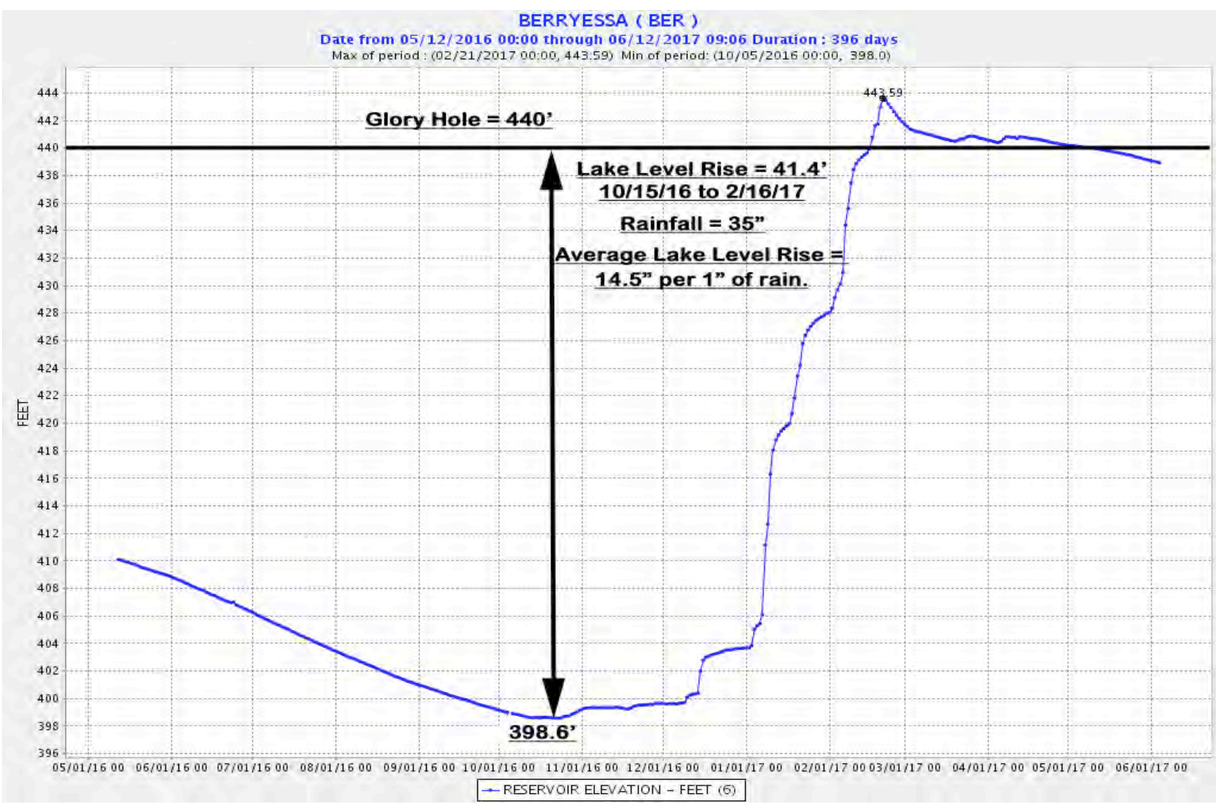


Lake Level vs Acre-Feet of Storage

Local residents use a rule of thumb that the lake increases a foot in level for every inch of rainfall after the ground has been saturated by several initial inches of rain. This is not completely accurate since the relationship between the lake level and its storage capacity is not linear. The lake is shaped roughly like a bowl (with peaks and valleys and inlets and large flat areas), which means that the higher the water level gets the more rain is needed to raise it further. From the data below we can see that it takes about 25% more rain to go from 430' to 440' than it does to go from 390' to 400'. The chart below showing rainfall versus level for the first three months of 1998 shows that the lake rose 16 feet with 26 inches of rain – or 7.4 inches of level per inch of rain.

Lake Level	Acre-Feet of Storage per Foot of Level Increase
350' – 380'	11,500
380' – 390'	13,270
390' – 400'	14,820
400' – 430'	17,050
430' – 440'	18,500
440' – 445'	19,500

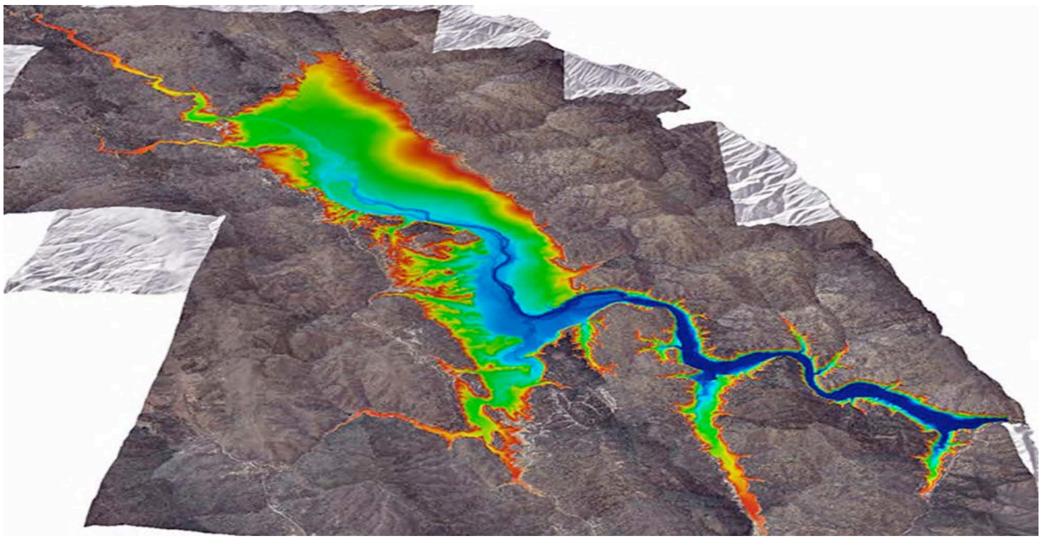
However, the unexpectedly rapid rise of the lake in 2017 provided data that showed the rise was twice as great as the normal average.



The number of acre-feet rise with a 1-foot level rise implies the lake surface area is approximately 18,500 acres when full. The surface area when full at 440' is 25% greater than the surface area at 400' and 60% greater than at its low water mark of 362' during the drought of 1986 to 1996.

The water at the dam is 275’ deep. The lowest level during the drought of 86-96 of 362’ (78 feet down) meant that the lake had dropped in level by 30%. But the capacity had dropped from 1,600,000 acre-feet to 400,000 acre-feet – a decrease of 75%.

A few years ago, SCWA hired a consultant to survey the bathymetry (bottom surface) of Lake Berryessa and determine if the lake had experienced significant sedimentation as well as create new capacity curves based upon the new survey data. In general, the sedimentation was found to be fairly minimal, but the new capacity curves did show a reduction in Lake Berryessa capacity due to more precise measurements.



Lake Berryessa Hits Full Capacity, But 51,708 Acre-Feet Are Missing!

The world-wide attention focused on Lake Berryessa”s Glory Hole Spillway overflowing for the first time in a decade raised some questions from some sharp-eyed observers. Using the published standard capacity of 1,602,000 acre-feet (AF), they noticed that as the level approached the 440 foot mark (100%), the capacity was less than that figure. In fact, at 440 feet (100%) the official storage value was only 96.2% of capacity - a 3.7% discrepancy.

The 1,602,000 AF is a number that was derived from the original Area-Capacity curve developed from surveys of the empty lake bed when the project was being built. In 2007 the Solano County Water Agency (SCWA) performed a comprehensive bathymetric survey of Lake Berryessa to look at sediment accumulation over the last 50 years of the project. Another goal was to verify the accuracy of the Area-Capacity curve. The sedimentation in the lake was determined to be less than expected - minimal considering the 50 year life of the project. A new dataset was developed that can be compared to any future bathymetric study to accurately determine the actual sedimentation rate. The scuba divers who went down to the old Putah Creek Stone Bridge found only a few inches of fine silt on the bridge surface.

During this study a new Area-Capacity curve was developed that was slightly lower than the previous curve. This new lake level versus capacity was officially adopted by the Reclamation and SCWA in 2009. The new curve has a lake capacity of 1,551,292 AF at a level of 440 feet - 50,708 AF less than previously calculated. The difference between the present and former AC curves is a combination of some sedimentation and the difference in technology used to derive the new curve. Obviously another traditional survey of the dry lake bed will not be possible. The bathymetric survey was the only option that could be used to provide a dataset that could be compared in future studies.

The new AC curve has been officially accepted by Reclamation, but the old 1,602,000 AF is still used by most agencies. That figure remains in public descriptions of lake capacity and is proving to be very hard to change since it’s been used for so long.

Monticello Dam: Tear it down and build it bigger?

The rumor of raising Monticello Dam has been around for decades. Where did this rumor start and why does it pop up every now and again? According to David Okita, general manager of the Solano County Water Agency, CalFed, a collaboration among 25 state and federal agencies, did a "brainstorming" survey many years go of every potential future water project in northern California.

Although raising Monticello Dam made the original list of possible projects, after practical criteria such as cost, safety, flooding adjacent property, were applied to screen the list down to real opportunities, raising the dam was dropped from the list. It has never been discussed seriously since then. It is NOT in any plan and never will be.

But there is another potential source to this rumor, and it was a much more ambitious project than just raising the dam.

According to "The Solano Water Story" published by the Solano Irrigation District, banner headlines in California's newspapers in September, 1963 announced Governor Edmund G. Brown's startling new state water plan in which Berryessa would have a major role.

The $3.7 billion plan included 35 dams, 70 miles of tunnels, 10 pumping plants, and 15 powerplants. The time-table called for start-up in 1976 and completion about 2020.

According to the plan, the still-young, 304-foot high Monticello Dam would he removed, rather than letting it remain as an underwater barrier. It would he replaced with a 650-foot high earth and rockfill dam a mile downstream from the concrete arch dam. The new reservoir would be three times larger than Lake Berryessa, with 10 times its capacity or 16 million acre-feet (compared with Shasta's 4.5 million acre-feet).

The enlarged lake would extend into Pope Valley almost as far as Aetna Springs in Napa County and into Capell Valley, taking nearly 18,000 acres of agricultural and grazing land out of production.

Estimated cost of the Greater Berryessa Project, as it was called, was put at $360 million by the State Department of Water Resources (DWR). The timetable for this part of the project indicated a start-up in about 1990.

In essence, the idea was to integrate the Greater Berryessa Project with the $280 million Clear Lake Diversion Project. The latter included three dams on the Middle Fork of the Eel River, with tunnels to the Main Eel River, Russian River, and Clear Lake to Putah Creek, then through two more dams and Lake Berryessa to the Sacramento River.

From Clear Lake, the water would be diverted by a two-mile tunnel to Soda Creek in the Upper Putah Creek basin, developing 400 feet of powerhead that would he harnessed with the construction of two dams on Soda Creek.

According to the DWR, discharges from the power facilities would be released into an enlarged Lake Berryessa capable of meeting the export demands of the Sacramento-San Joaquin Delta and those of the Solano Project.

Even the Bureau of Reclamation, which had never been accused of thinking small, was impressed by the scope of Governor Brown's plan, describing the overall project as "staggering but physically possible and since the Greater Berryessa Project would not be built for at least another 30 years, the present Monticello Dam by that time will have served its useful life."

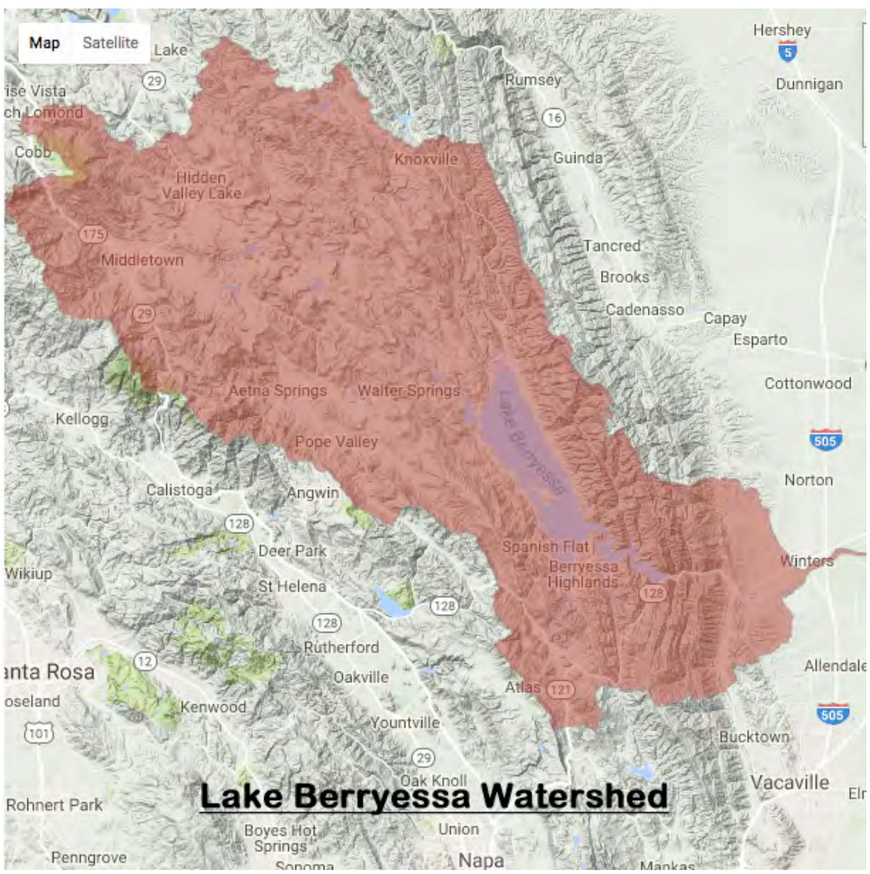
Brown's master plan for the state's water problems never caught on with the public or the legislature. His grand plans are collecting dust at the DWR.

The number one project on the list continues to be Sites, east of Maxwell. Those of you who are ATV/dirt bike/jet ski enthusiasts have probably gone to Stonyford or East Park Reservoir to ride. You've driven through Sites and seen the narrow canyon at the brown rock quarry where a dam similar to Monticello Dam could be built.

A simpler approach to storing more water in Lake Berryessa would be to raise Glory Hole itself by installing movable gates that could be raised and lowered as necessary to impound more water during the rainy season. Raising Glory Hole by 5 feet to 445' would increase Lake Berryesssa storage by approximately 100,000 acre-feet without significantly affecting facilities along the shoreline. Although the highest the lake level has ever reached was 446.7 feet in 1983, and it has often exceeded 440 feet, according to David Okita of SCWA, a review of the historical data shows that the level does not exceed 440 feet often enough to justify the expense of installing this type of control device on Glory Hole, much less justifying raising the dam itself. The lake level has reached or exceeded Glory Hole only 25 times in 60 years.

<u>Rainfall Impacts</u>

The water supply for Lake Berryessa is derived from the 568 square mile drainage basin above the dam. The elevation of the basin ranges from 182 feet at the dam to 4,722 feet at the upper end of Putah Creek with most of the basin lying below 1,500 feet. There are four principal creeks that flow into Lake Berryessa: Capell Creek, Pope Creek, Eticuera Creek, and Putah Creek, the main drainage of the basin.



How fast the lake rises is dependent on rainfall over the whole watershed. The lake is 23 miles long, 3 miles wide, with 165 miles of shoreline and is fed by the headwaters to the 576 square mile Putah Creek watershed. Rainfall levels vary significantly by location. Moskowite Corners is usually about 10% - 20% higher in rain totals than the nearby (7 miles) Berryessa Highlands. Below are some average rainfall totals for the region.

Calistoga, Angwin, and Napa provide an interesting precipitation comparison, but they are not within the Putah Creek Watershed. Middletown rainfall is a better comparison since it is really the headwaters to Putah Creek and flows directly into the lake.

Average annual rainfalls:

Monticello Dam (97-08): 28”
Markley Cove: 25.7”
Middletown (1938-1995): 48.6”
Angwin (1939-1995): 41”
Napa: 24”
St. Helena: 34.4”
Calistoga: 37.4”
Winters: 22.8”

Putah Creek Flows: Water In, Water Out, But From Where?

The rain causing the rapid increase in 2017 lake levels raised questions for some about where all the water comes from and where it goes. The lake was rising and lower Putah Creek was flowing fast, but not much water was being released from the dam. And some people questioned why any water was being released from Lake Berryessa when it was not yet full.

Many people don’t understand that Lake Berryessa was created for: 1. Irrigation in Solano County, 2. Drinking water (now for 500,000 people). Recreational use was not considered a priority because of the large swings in water level expected. Many also don’t realize that Napa County gets little of Lake Berryessa water except for the small villages scattered around the lake like the Berryessa Highlands, Spanish Flat, Berryessa Pines, and Berryessa Estates. But that’s a political history story for another day.

The watershed for Lake Berryessa is derived from the 568 square mile drainage basin above the dam. There are four principal creeks that flow into Lake Berryessa: Capell Creek, Pope Creek, Eticuera Creek, and Putah Creek - the main drainage of the basin.

Although there’s a lot of water flowing in Lower Putah Creek, people need to remember that nearly 90% of the Putah Creek watershed is above Lake Berryessa. Nearly all of the rain that we have received is flowing into Lake Berryessa NOT OUT OF IT. Nearly all of the flow in Putah Creek near Winters today is from the main creeks below Lake Berryessa.

For example, the total flow out of Lake Berryessa was 1,625 acre-feet (AF) for January, 2017. During that same period, the lake’s capacity rose by 399,970 AF. The output was only 0.4% of the input. (1 CFS = 1.98 acre-feet per day; 1 AF = 325,851 US gallons per day)

The Solano Irrigation District monitors this and actually reduces flows from the bottom of Lake Berryessa during rain events to conserve as much water as possible in the lake. But the flow needs to be at least 45 CFS in order to properly operate the power house - this has been the average outflow every day for the full month of January, 2017.

There are four main creeks below Berryessa. They are Wildhorse Creek (Cold Creek) right next to the Monticello Dam, Pleasant's Creek which empties into Lake Solano, and McCune Creek and Dry Creek below the Diversion Dam just upstream of the railroad bridge at Winters.

These creeks can contribute significant inflow to the system before entering Winters. It is estimated that during the 1/8/2017 storm the flow through Winters was between 2,500 and 3,000 CFS.

Combined, there is normally 2100 CFS of water flowing underneath the bridge at Winters during the winter rains, which is much higher than the normal flow 25 CFS in the same spot seen during summer. All of this water entered the system from tributaries below the Monticello Dam, not from Lake Berryessa.

Since there is no need for irrigation flows during rain events, and to keep the diversion canal free of silt and mud, nearly all the water from Pleasants Creek and Wildhorse Creek flows over the Diversion Dam at Lake Solano and continues downstream towards Winters.

Power Generation at Monticello Dam

The Power House at the base of Monticello Dam is owned and operated by the Solano Irrigation District. The only water released from the dam or through the power house is being used for agriculture and maintaining minimum flows in Putah Creek. The only other time water is released is when the lake is above 438 feet to generate power instead of letting it flow through the Glory Hole.

When the power house is operating all of the flow is diverted through the turbines and is output below the concrete pad which is below the water surface. There is no indication it is running unless you look very closely and notice the turbulence from under the pad. Normally the only time the bypass valves are operating is when they are doing maintenance on the power house and need it shut down but still need to deliver the water required for the Putah South Canal and Putah Creek downstream of the Diversion Dam. The smaller of the two visible jet valves is used when the required flow is at the lower levels which is between 45-90 cubic feet peer second (cfs). When the required flow is above this they will switch to the big jet valve. When the powerhouse is running at full capacity it is only using around 900 cfs. The reason for this is that the maximum summer flows required by the PSC and Putah Creek is around 900 cfs.

Water is never released above what is being used downstream so there is no reason to have the ability to go above this value. During heavy rain conditions like 2017 they run everything wide open to assist the Glory Hole in controlling the lake level. If the Glory Hole releases so much water that the jet valves become submerged they need to be shut down, and at those flows they aren't really doing much compared to the Glory Hole anyway.

The Monticello Dam, which began construction in 1953 and commenced operations in 1957, also is a backbone for local energy. Due to a 50-year contract that started in the 1980s, SID sells wholesale power to Pacific Gas and Electric, which they then place into their grid. Primarily, the power is transferred to PG&E's Santa Rosa substation, but the power is capable of being sent elsewhere. During the recent heavy rain conditions and rapid lake level rise, SID was producing 11.5 megawatts, which is peak production. Along with its contract with PG&E, SID also works with several other organizations on the dam, one of which is the Bureau of Reclamation.

Predicting the Future

Several climate prediction centers are forecasting El Niño conditions for the later part of 2009 and the early part of 2010. California does not always see an increase in precipitation during El Niño years. With the majority of the last ten years showing below normal precipitation in much of the state, researchers are hoping for a potential abundance of rainfall without flooding or coast-damaging storms.

The National Weather Service issues 30 and 90-day forecasts. Academic institutions, such as the Scripps Institution of Oceanography in San Diego, have attempted experimental seasonal forecasts. The accuracy and level of detail of these efforts remains insufficient for water project operations. It is only recently, for example, that researchers have had sufficient understanding of global weather patterns and atmospheric/oceanic interactions to be able to identify conditions associated with the El Niño Southern Oscillation (ENSO) in the Pacific Ocean. That understanding has yet to be translated to forecasts of runoff, partly because ENSO events affect different parts of California differently.

Lake Berryessa had normal fluctuations in water levels from 1995 to 2006. A middling El Niño brought steady rains that filled Lake Berryessa to the brim in January, 2006 – the last year the lake spilled over Glory Hole. A previous El Niño brought seemingly nonstop rains in the winter of 1997-1998. See February, 1998 chart above – 18.9 inches in that one month – more than the total of 12.7 inches of rainfall in 2006-2007! I witnessed Lake Berryessa go up 9 feet in 12 days in 1998 from my deck at Steele Park Resort.

Glory Hole did spill in January, 2006; however, the lake did not exceed 440 feet again until February, 2017 - the first time in 11 years.

2017 Breaks An 11-Year Drought: Lake Berryessa Fills, Glory Hole Spills (Drone Videos)

This amazing series of Lake Berryessa News Drone videos by Evan Kilkus documents the 45 foot rise of Lake Berryessa in 2017. It was the second largest annual increase in the history of the lake. It was also the second highest level the lake has reached in its 58 year history. The lake has only spilled into Glory Hole 26 times in those 58 years. Also the rainfall total (46.4 inches as of 4/12/17) is the highest in 20 years.

The first video shows how low the lake was 2 years ago. You should watch it before the others to get some perspective on the amazing rise of the lake in 2017.

December 2014: The lake is LOW: https://youtu.be/5d-WIJcmu60

January 10, 2017: The Action Begins: https://youtu.be/bGJvofIyTwQ

February 10, 2017: Only 2 Feet To Go!: https://youtu.be/PRWAfVw9DBU

February 12, 2017 - First Time Lake Berryessa Water Splashes Into Glory Hole!: https://youtu.be/8pIPsgLFggk

February 13, 2017: Lake Berryessa Is Full!: https://youtu.be/EH0LQW7iduY

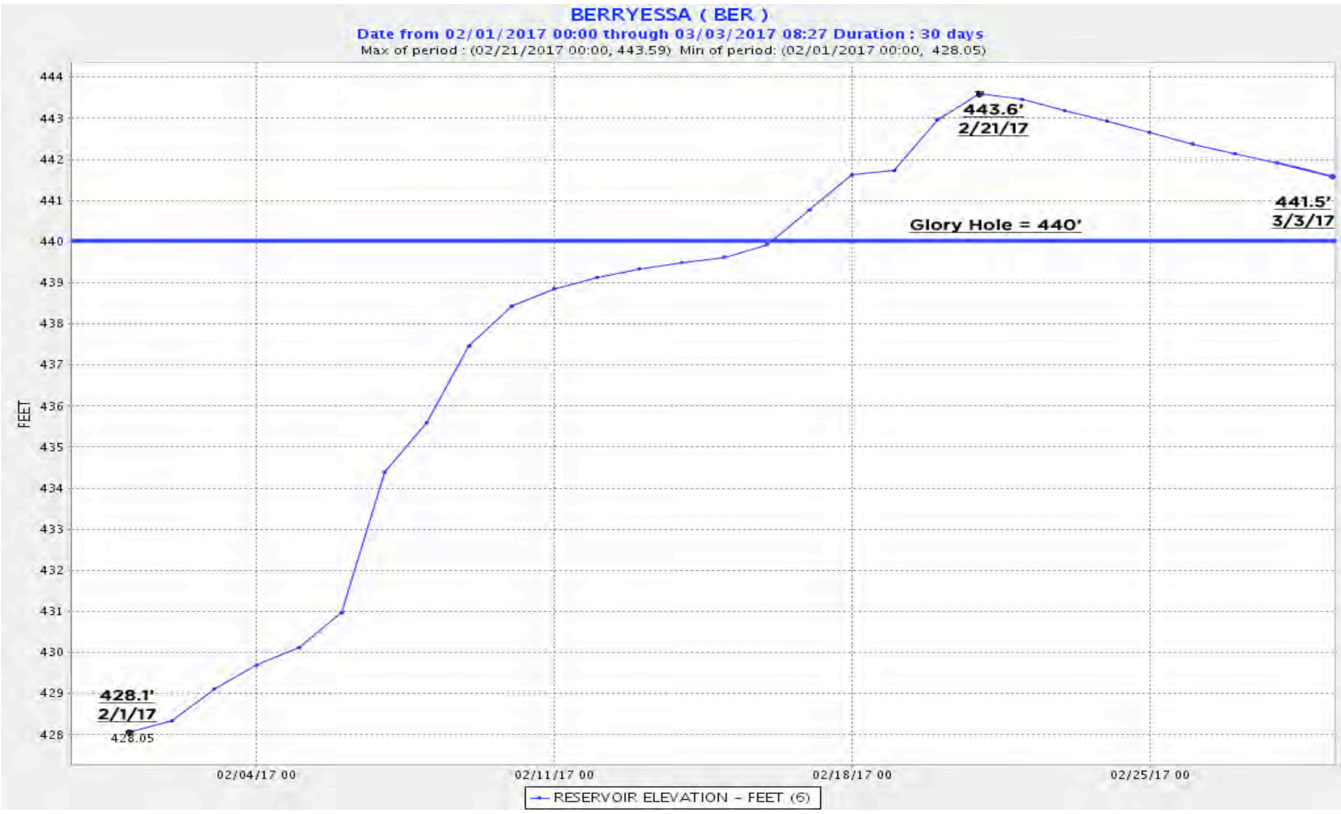
February 16, 2017: Lake Berryessa Officially Spills Into Glory Hole: https://youtu.be/cB0BKIm1EzM

February 18, 2017: Overflowing Glory Hole: https://youtu.be/NxOOnKL265I

February 21, 2017: Lake Berryessa Hits Second Highest Water Level In History!: https://youtu.be/-iHAjOrrU4k

February 21, 2017: A Full Lake Just Feels Good: https://youtu.be/qhPzR2Gqzs0

April 14, 2017: Spring Comes to a Full Lake Berryessa: https://youtu.be/1TVX9Euix3E


BERRYESSA (BER)
Date from 02/01/2017 00:00 through 03/03/2017 08:27 Duration : 30 days
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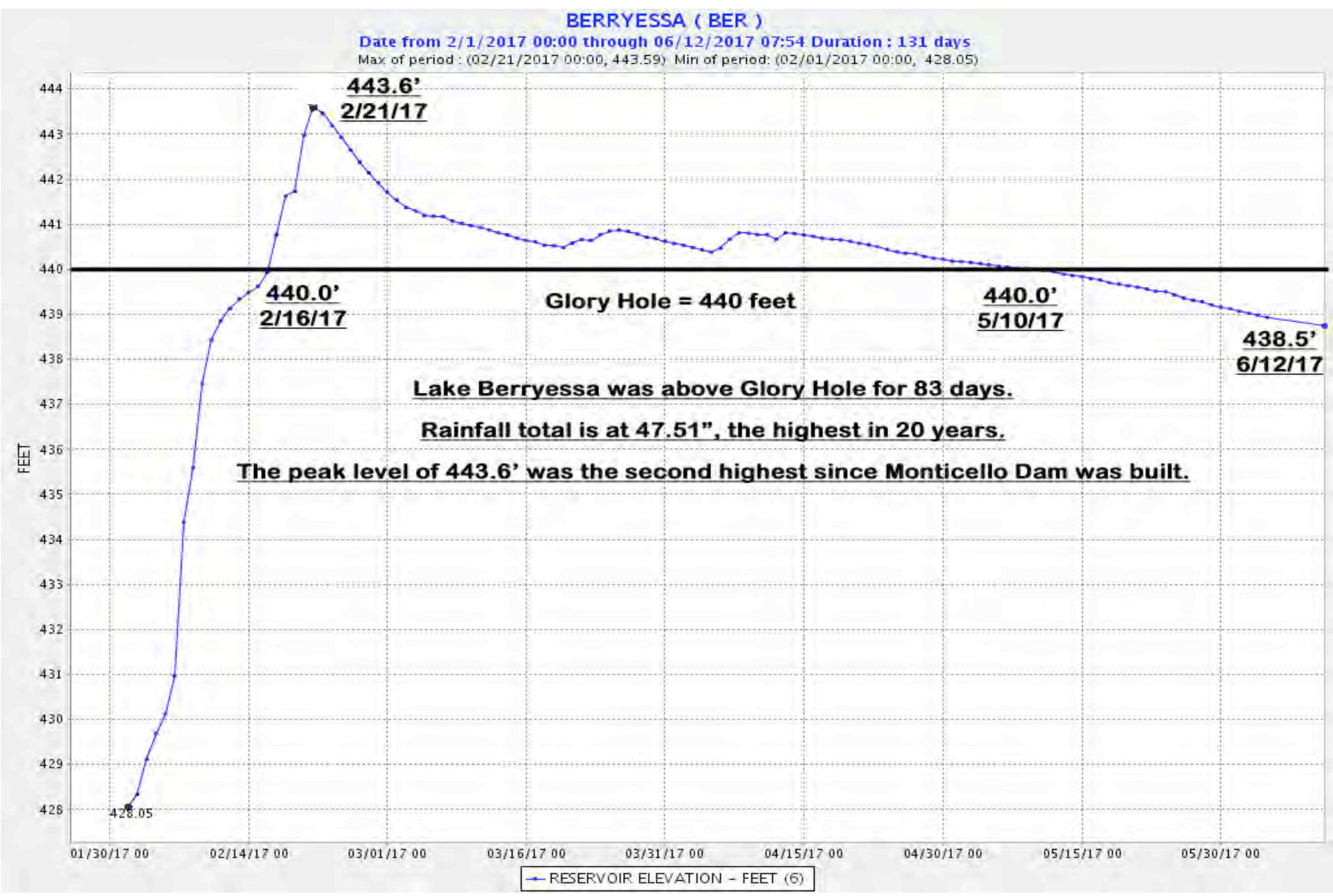
FEET
443.6'
2/21/17
441.5'
3/3/17
Glory Hole = 440'
428.1'
2/1/17
428.05
02/04/17 00
02/11/17 00
02/18/17 00
02/25/17 00
RESERVOIR ELEVATION - FEET (6)


BERRYESSA (BER)
Date from 2/1/2017 00:00 through 06/12/2017 07:54 Duration : 131 days
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FEET
443.6'
2/21/17
440.0'
2/16/17
Glory Hole = 440 feet
440.0'
5/10/17
438.5'
6/12/17
Lake Berryessa was above Glory Hole for 83 days.
Rainfall total is at 47.51", the highest in 20 years.
The peak level of 443.6' was the second highest since Monticello Dam was built.
428.05
01/30/17 00
02/14/17 00
03/01/17 00
03/16/17 00
03/31/17 00
04/15/17 00
04/30/17 00
05/15/17 00
05/30/17 00
RESERVOIR ELEVATION - FEET (6)

As Lake Berryessa Turns!

Temperature and Fishing in a Warm, Monomictic Lake

By Peter Kilkus

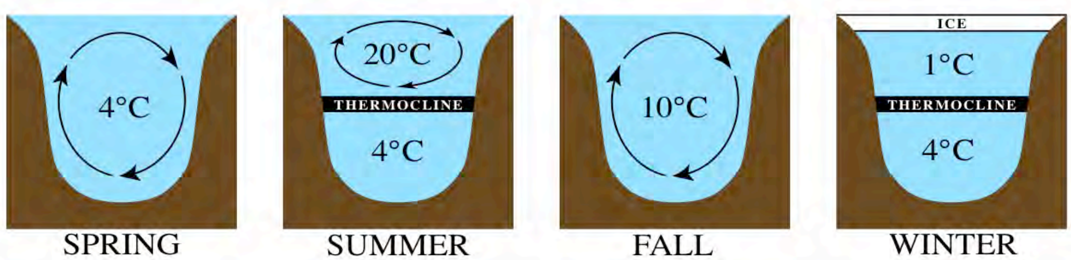
The phenomenon called "turnover" is well-known to anglers, but not so much to other lake visitors. Some people think that Lake Berryessa turns in both spring and fall. But scientific data shows that the lake only turns once per year - in the fall.

Turnover is essentially what it sounds like. The water on the bottom of the lake goes to the top, and the water on the top of the lake goes to the bottom. Although the turning of a lake is partly due to temperature and density differences in the layers, the major cause for the turnover (or mixing) is the wind. The wind causes full mixing of the lake when the temperature of the water is the same at all depths and there are no layers.

Thermal stratification of lakes is the separation of lakes into three layers caused by temperature differences among the layers:

1. Epilimnion - top of the lake.
2. Metalimnion (or Thermocline) - middle layer that may change depth throughout the day.
3. Hypolimnion - the bottom layer.

For ease of understanding, I'll call these the top layer, middle layer, and bottom layer. When layers mix and change places, a lake is said to turn over. Lakes that turn over once a year are said to be monomictic. Lakes that turn over twice a year, once in spring and once in fall, are called dimictic. Dimictic lakes usually freeze over during the winter. The reasons for both the spring and fall turnover in lakes that freeze are easy to understand so, with the help of the diagram below, I'll discuss them first.



In late summer lake surface waters of both monomictic and dimictic lakes have reached their annual maximum temperatures. At this time in a sufficiently deep lake, you will find a definite layering of water temperatures. Warmest, and therefore least dense, waters lie on top, and the water temperature decreases with depth, reaching its minimum temperature at the greatest lake depths. How cold the lake bottom water becomes depends on the lake depth and other characteristics, but it will never fall below 4 deg C (39 deg F) unless the lake freezes solid.

Summer breezes blowing over the lake generally keep the top layer stirred by pushing a quantity of surface water downwind. This draws a flow of deeper water upward (upwelling) along the lee shore to replace the pushed waters. But this upwelling is not coming from the deepest layer, only from the lower part of the top layer. As a result, top layer waters mix, producing generally warm temperatures and high oxygen content (important to fish and other creatures) throughout the top layer. The middle thermocline layer has minimal mixing, and what does occur is slow, thus isolating the bottom waters below it from the surface zone.

In fall, the surface water cools. Its drop in temperature eventually matches the temperature of the middle layer. When these top layer waters reach about 10 deg C (50 deg F), they sink into the middle layer waters below, erasing the temperature stratification between the top and middle layers that had built during summer. As fall air temperatures continue to drop, this new upper layer cools to the temperature of the bottom layer. The full water mass of the lake has now reached a uniform temperature, and the surface winds mix the full water body in the "fall turnover". The water temperatures then continue to decrease into the winter months.

For lakes that fall below 39 degrees and finally freeze, the surface becomes colder than the bottom, but this cold water now "floats" on top of the "warmer" water. (See above diagram) The colder surface water is now actually lighter than the warmer water and floats on it until it actually turns to floating ice. The key to this unusual process is how water density varies with water temperature.

Water is most dense (heaviest) at 39º F (4º C) and as temperature increases or decreases from 39º F, it becomes increasingly less dense (lighter). Thus, at 39 degrees and below, less dense but colder water is now at the surface and more dense but warmer water is now near the bottom.

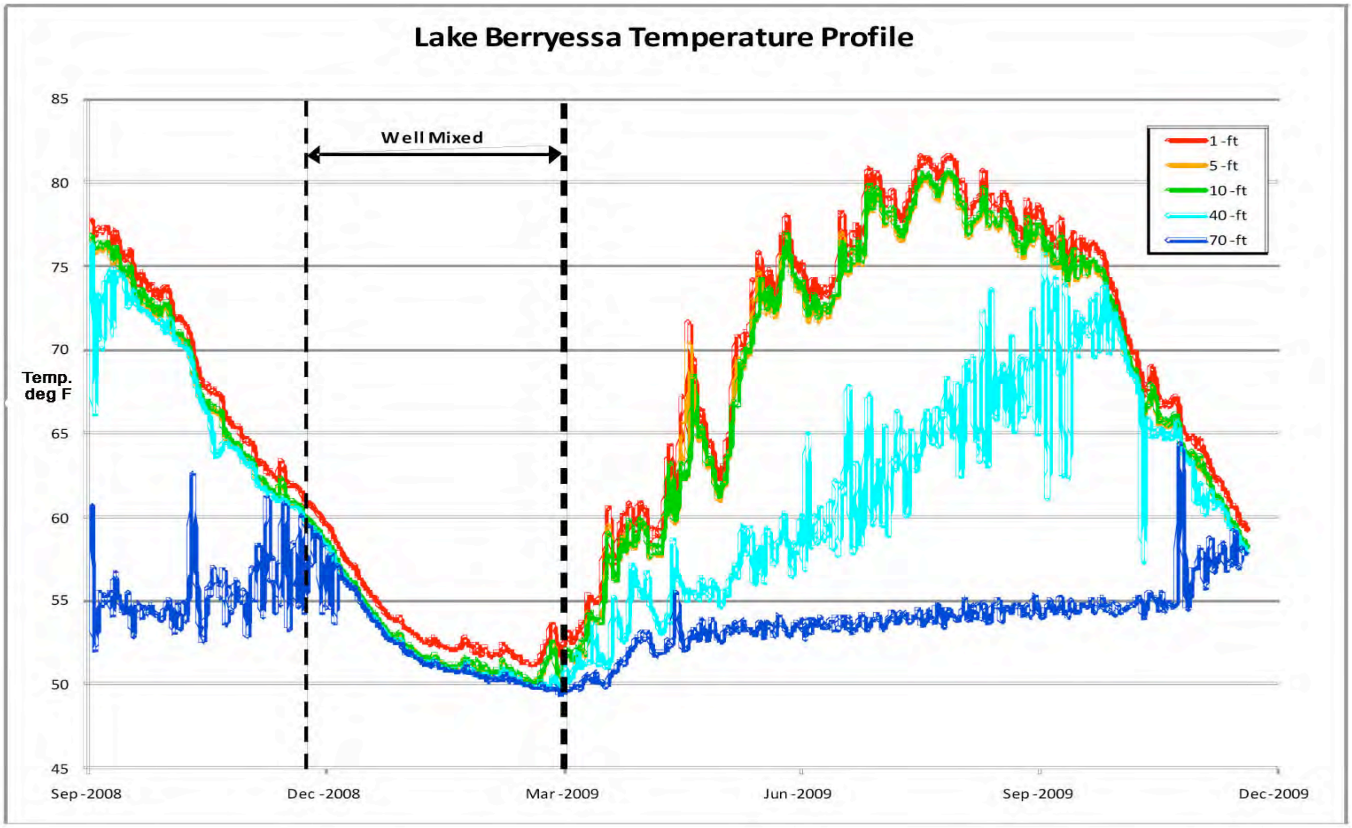
During spring, the process reverses itself. The ice melts and surface waters warm and sink until the water temperature at all depths reaches approximately 39º F. When this occurs, winds blowing over the lake again set up a full circulation system, this mixing known as "spring turnover". As the warming continues into the summer, the top water layer becomes much warmer and less dense. The warm surface layer now "floats" on the cooler lower layers. Over time into the summer the three water layers again become established, and our cycle has been completed.

Since Lake Berryessa water temperatures never get below 39 degrees, it is classified as a warm, monomictic lake. During winter, the surface waters cool to a temperature equal to the bottom waters. But lacking significant thermal stratification, since the water never gets below 39 degrees, much less freeze, these lakes mix thoroughly each winter from top to bottom and continue to mix until spring.

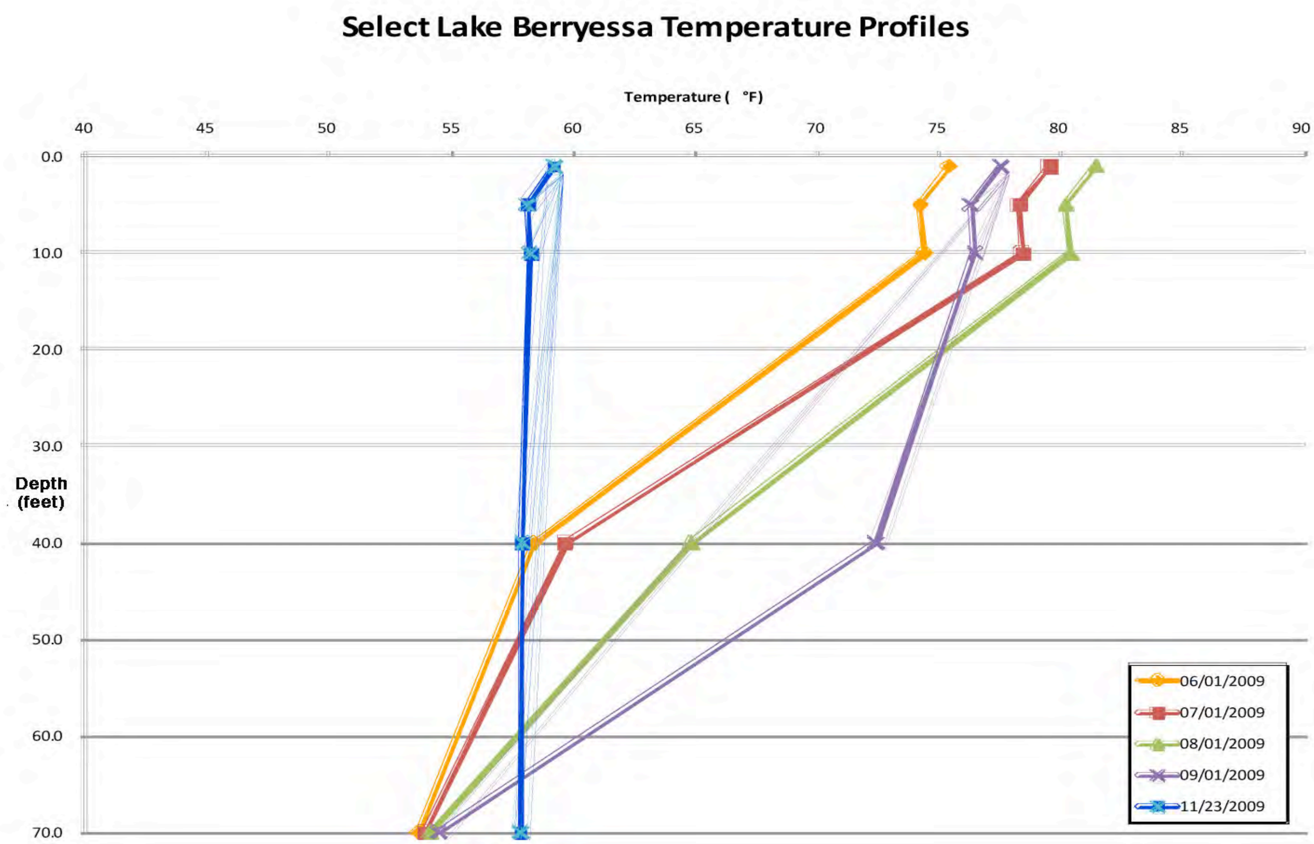
This situation is graphically illustrated by the following 2008-2009 charts from the Solano County Water Agency. SCWA maintains a thermistor chain of sensors to a depth of 70-ft near Monticello Dam. The charts below show 1-year's worth of data indicating that Lake Berryessa experiences one mix per year.

In 2008 mixing occurred in November followed by several months where the lake was well mixed. The stratification began again in March, 2009. For Water Year 2010, there was a similar pattern where Lake Berryessa became well mixed in mid November.

The thermocline is usually around 40 feet deep, but there are not enough temperature sensors to say with absolute certainty without finer resolution. Anglers with good depth finders can usually find the thermocline quite easily because algae and protoplankton will form a layer there, and the deeper, colder water is much more dense.



Lake Berryessa Temperature Profile
Well Mixed
Temp. deg F
85
80
75
70
65
60
55
50
45
Sep-2008
Dec-2008
Mar-2009
Jun-2009
Sep-2009
Dec-2009
1-ft
5-ft
10-ft
40-ft
70-ft



Select Lake Berryessa Temperature Profiles
Temperature (°F)
40
45
50
55
60
65
70
75
80
85
90
Depth (feet)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
06/01/2009
07/01/2009
08/01/2009
09/01/2009
11/23/2009

The classic description of lake turnover is describing “dimictic” lakes or those having two mixes per year. Many larger lakes and reservoirs are “monomictic” - having only one mix per year. Without ice formation and the colder, less dense water rising to the top, reservoirs such as Lake Berryessa will not experience a spring turnover.

Winds in the Lake Berryessa region also play a large role in keeping the lake well mixed or de-stratified until summer when surface water temperatures are significantly different, allowing the stratification into the epilimnion, metalimnion and hypolimnion.

The fishermen at Lake Berryessa probably have the best data regarding the lake turnovers and where the metalimnion demarcation typically is located because that is where the fish feed on the zooplankton accumulating at the density gradient. Different arms of the lake may behave differently due to the wind fetch, sun exposure and interflows from streams.

Remember also that the total depth in the vicinity of the dam is almost 250 feet. The lower depths are pretty consistent, VERY COLD. Another interesting fact is that the Monticello Dam is what is called a “hypolimnetic discharge”, meaning that water discharged downstream is drawn off the lower portion of the water volume so it is very cold and very nutrient rich. These nutrients support the large biomass of aquatic plants (and algae) in Lake Solano which is predominately Myriophyllum sp., also known as Eurasian Milfoil.

The Bureau of Reclamation rangers monitor some of the biological impacts of lake turnover. They have a thermometer down at their boat dock in about 1.5 feet in the water. On November 20, 2009, for example, it read 60 degrees, roughly the same temperature since the beginning of the month. Typically, the lake turns in the fall sometime in November, but they've never noticed too dramatic a drop on any given day, or week for that matter. Usually by January it's around 50 degrees. The lowest they've seen it is 48 degrees.

The big, noticeable change in the spring relates more to direct sunlight on the lake surface, warming water temperatures, and the biological processes that "kick into gear." During this time phytoplankton/algae become more numerous, changing the water from clear to cloudy green - "The Spring Bloom". In response to the algae growth, small invertebrates (i.e. copepods, tiny shrimp-like critters, and insect larva) become abundant followed by increased feeding and reproductive activity by larger aquatic animals like fish and frogs. The fishermen respond to all this new fish activity and spawning in the early spring - which may be the source of the “spring turnover” concept among anglers at Lake Berryessa.

By late spring, nutrients typically become depleted from the lake and planktonic populations crash, causing the lake to clear a bit and fishing activity to taper-off. The summer is a period of "lake exhaustion", when food becomes scarce and only the hardiest aquatic creatures survive. All the dead organisms sink to the bottom of the lake becoming food for decomposers like bacteria. The biological processes of bacteria can deplete deep water O_2 supplies which make the fall turnover especially important, not only for recycling nutrients through the water column but also in restoring deep water O_2 levels.

Upwelling in the fall can cause planktonic blooms, but they are usually short-lived because water temperatures are too low and the days lengths too short to sustain much photosynthetic activity. Sometimes when deepwater decomposition is anaerobic, toxic byproducts are produced (for example, hydrogen sulfide) that are brought to the lake surface. If undiluted, these byproducts along with O_2-starved water from the deeper parts of the lake can become a lethal combination for fish, but this typically does not happen at Lake Berryessa.

Fishing and Turnover

Fish have a metabolic rate dependent on water temperature. This dependence on water temperature also affects their immune system, wound healing, and digestion. Each fish has a different range of water temperature in which it can survive. Although fish cannot always find the exact temperature they prefer, they are usually found in water close to that temperature.

Trout, for example, will actively seek 64-degrees or the closest temperature to it. Sixty-four degrees is the optimal temperature for a trout body to function at its peak. Below 50-degrees the trout will start to shut down. Above 70-degrees the trout will also start to shut down. So, you can safely guess that trout actively feeding and swimming will be found where water temperatures are in the 55-65 degree range.

Species and their preferred temperatures:

Brown Trout	60-65 F
Lake Trout	48-52 F
Rainbow Trout	55-60 F
Chinook Salmon	48-55 F
Coho Salmon	48-55 F
Largemouth Bass	68-78 F
Smallmouth Bass	67-71 F
Striped Bass	60-70 F
Bluegill	75-80 F
Crappie	70-75 F

The angler should know how to locate fish by temperature. Probe a lake's depth with a thermistor on a calibrated cord. The thermistor registers instant temperatures and the cord marks the depth. There are newer models out which also register oxygen content, pH, and water clarity. Simply find the depth corresponding to the preferred temperature range of the fish species you are seeking. Then identify the ideal temperature-depth which coincides with the lake's bottom structures that produce both food and cover. This is a likely spot to find actively foraging fish. Other factors such as light intensity, water clarity, pH, and oxygen content influence the fish by forcing them to migrate where these factors are favorable.

During summer, the surface of a lake the water will be very warm and stays warm down to a certain level. As the Lake Berryessa chart above shows, the surface might be at its maximum of 82 degrees in August, while 40 feet deep it is 70 degrees. At 70 feet the water is about 55 degrees and it will stay that cool all summer. Lake Berryessa bottom water temperatures never go below about 50 degrees.

After turnover the whole lake has good oxygen content and fish can move anywhere. They are hard to pattern because they roam a lot for a few weeks before setting up on deeper winter structure.

Some professional anglers are unsure what happens to bass during the turnover, but they agree that the fish are affected, almost like a cold front situation. It disorients them a little bit and they can get somewhat "goofy" about that time. Before the turnover, fishing tends to improve with the cooling water conditions. During and after the turnover, however, fishing tapers off.

The Ins and Outs & Ups and Downs of Lake Berryessa

By Peter Kilkus

In & Up

Most of us have heard of the rule of thumb that Lake Berryessa rises 1foot for every 1 inch of rain. As with most rules of thumb, this is not accurate. Lake level rise depends on many variables like the actual lake level when it rains and how saturated is the ground.

It usually takes about 3 inches of rain on dry hills before there is any appreciable runoff into the lake. That's why the 3-week dry period in January slowed this year's rise and it took an inch or more to start the runoff again.

Also the lake is roughly like a V-shaped bowl, so the higher the level to start, the more rain it takes to make the lake rise even further.

A look at the actual data during the last few years shows that the average increase in 2009 was 3.4" rise per inch of rain. In 2010 the number was 7.5" rise per inch of rain. In 2011, that figure (seven day average) went from 3 inches rise per inch of rainfall in early February to 11 inches per inch in early March to a peak of 13 - 16 inches per inch during the wettest part of late March.

Date	Level (Feet msl)	Rain (Inches)	Cum Rain (Inches)	Daily Level Rise (Inches)	Level Rise (14 day ave) (Inches per inch of rain)	Level Rise (7 day ave) (Inches per inch of rain)
2/14/11	417.85	0.08	13.66	0.00	3.0	3.0
2/15/11	418.08	0.46	14.12	2.76	5.6	5.3
2/16/11	419.07	1.63	15.75	11.88	6.9	6.8
2/17/11	419.93	0.6	16.35	10.32	9.1	9.1
2/18/11	420.45	1.35	17.70	6.24	7.6	7.6
2/19/11	420.84	0.83	18.53	4.68	7.3	7.3
2/20/11	421.05	0.02	18.55	2.52	7.8	7.7
2/21/11	421.21	0	18.55	1.92	8.2	8.2
2/22/11	421.32	0	18.55	1.32	8.4	8.8
2/23/11	421.43	0	18.55	1.32	8.7	10.1
2/24/11	421.53	0	18.55	1.20	8.9	8.7
2/25/11	421.86	1.55	20.10	3.96	7.4	7.1
2/26/11	422.04	0.02	20.12	2.16	7.7	9.1
2/27/11	422.15	0	20.12	1.32	7.9	8.4
2/28/11	422.24	0	20.12	1.08	8.2	7.9
3/1/11	422.24	0	20.12	0.00	8.3	7.0
3/2/11	422.55	0.48	20.60	3.72	8.6	6.6
3/3/11	422.73	0.23	20.83	2.16	7.5	6.3
3/4/11	422.84	0	20.83	1.32	9.2	16.1
3/5/11	422.93	0	20.83	1.08	10.9	15.0
3/6/11	423.15	0.52	21.35	2.64	9.0	9.8
3/7/11	423.3	0.8	22.15	1.80	7.0	6.3
3/8/11	423.4	0	22.15	1.20	6.9	6.9
3/9/11	423.46	0	22.15	0.72	6.8	7.0
3/10/11	423.57	0	22.15	1.32	6.8	7.6
3/11/11	423.64	0	22.15	0.84	10.4	7.3
3/12/11	423.68	0	22.15	0.48	9.7	6.8
3/13/11	423.72	0	22.15	0.48	9.3	8.6

3/14/11	423.96	0.91	23.06	2.88	7.0	8.7
3/15/11	424.24	0	23.06	3.36	8.2	11.1
3/16/11	424.63	0.54	23.60	4.68	8.3	9.7
3/17/11	424.82	0	23.60	2.28	9.1	10.3
3/18/11	425.33	0.17	23.77	6.12	10.2	12.5
3/19/11	426.22	1.22	24.99	10.68	9.5	10.7
3/20/11	428.06	2.89	27.88	22.08	9.0	9.1
3/21/11	428.57	0.14	28.02	6.12	10.8	11.2
3/22/11	428.9	0	28.02	3.96	11.2	11.3
3/23/11	429.52	1.07	29.09	7.44	10.5	10.7
3/24/11	431.03	0.34	29.43	18.12	12.3	12.8
3/25/11	431.83	2.01	31.44	9.60	10.6	10.2
3/26/11	432.67	1	32.44	10.08	10.5	10.4
3/27/11	433.2	0.05	32.49	6.36	11.0	13.4
3/28/11	433.54	0.03	32.52	4.08	12.2	13.3
3/29/11	433.82	0	32.52	3.36	12.2	13.1
3/30/11	434.05	0	32.52	2.76	12.7	15.8
3/31/11	434.19	0	32.52	1.68	12.6	12.3
4/1/11	434.31	0	32.52	1.44		

The lake did go up 61 feet in one year in 94-95 but that was due to an unusually wet season with two significant storms - a January flood event and a March flood event. A state report said heavy rains began during the second week of January, 1995 with the Coast Range north of San Francisco and the upper Sacramento Valley hardest hit. The Russian River jumped from low flow levels to near record levels (set in February 1986) in just three days. Levels on the Napa and Eel rivers, although not as high as in 1986, were well above flood stage.

A series of early March storms dropped significant precipitation. The March storms produced a new record stage on the Salinas River near Spreckles and exceeded the 1986 peak on the Napa River by 0.3 feet.

This Old House was doing a Napa restoration and described the weather on their web site: The Napa Valley House - The renovation of Dennis Duffy's 1906 Victorian farmhouse in the vineyards of northern California.

“The stunning vistas and rich agricultural and cultural history of Napa Valley proved irresistible to us back in the winter of 1994-95. If only we'd known about the rain. And then the skies opened. The rain came down 22 days in a row that February; 52 inches fell in one month; the nearby Napa River leapt its banks. Contractor Nolan and crew persevered, however, working in the mud to pour new foundation walls, frame up the new kitchen and make the structure weather tight. Scene after scene was shot with cast and crew increasingly sodden. And then, a week before our wrap, the skies turned blue, the sun reappeared and the mustard bloomed in all its glory.”

*****

From the Napa Valley Vintners Harvest updates for 1995:

“A year of weather extremes marked the 1995 vintage, which saw winter floods, spring rains and a June hailstorm. The dramatic weather events got the growing season off to a late start, and although summer heat pushed grapes to maturity, harvest was late and yields were down. Moderate Indian Summer temperatures permitted extended hang time for red varieties, important to the development of rich flavors and deep color. Overall, vintners characterized the year as late, light and luscious.”

*****

Out & Down

During an unusually wet 2011 season, conspiracy theory rumors still circulated. One was that the lake would have risen faster if the Solano Irrigation District (SID) and the Solano County Water Agency (SCWA) were not letting out water so fast. Several years ago some people claimed that the dam managers were letting out water faster than necessary because electricity prices were so high that they were trying to make a profit from the power generated by Lake Berryessa.

The actual Lake Berryessa output is controlled by the water allocations established when the dam was built, as well as certain Bureau of Reclamation flow specifications. SID cannot exceed specific annual allocations and water is not simply flushed for power generation exclusively. Power is an added bonus as water is sent to consumers.

During February and March of 2011, the power plant was shut down completely for it's annual maintenance. There was zero power generation for that period. What can be a little misleading is that if someone looks over the edge of the dam they will typically see the very visible release spouting out through the outlet pipe as it was originally designed.

This is not water passing through the powerhouse. The total power generated also remains relatively constant from year to year...peaking during the summer months when agriculture demands also peak.

Winter (Oct 15 through mid March...depending on temperatures) is the time for filling Lake Berryessa - except for a base amount of release required to maintain stream flows and dam safety. The Bureau of Reclamation requires a minimum of 45 cubic feet per second (CFS) to be released through Monticello at all times. This supports the Lower Putah Creek fishery and keeps Lake Solano "charged".

There are many variables when it comes to stream flows and runoff from the watershed. Soil saturation, ground water levels, sun exposure, air temps, wind speed and direction plus the downstream demands and how soon those deliveries begin in the season. So how do we measure input and output and how does it affect lake levels.

Let's start with some simple arithmetic.

- 1 Cubic Foot per Second equals 1.98 Acre-Foot per day
- 1 AF of water equals 1 foot of water on 1 acre
- The required minimum output of 45 CFS equates to 89.1 AF per day.
- Lake Berryessa has a surface level of about 19,500 acres when full but decreases as it empties.
- At the minimum output it would take 219 days for the lake to drop 1 foot when full.

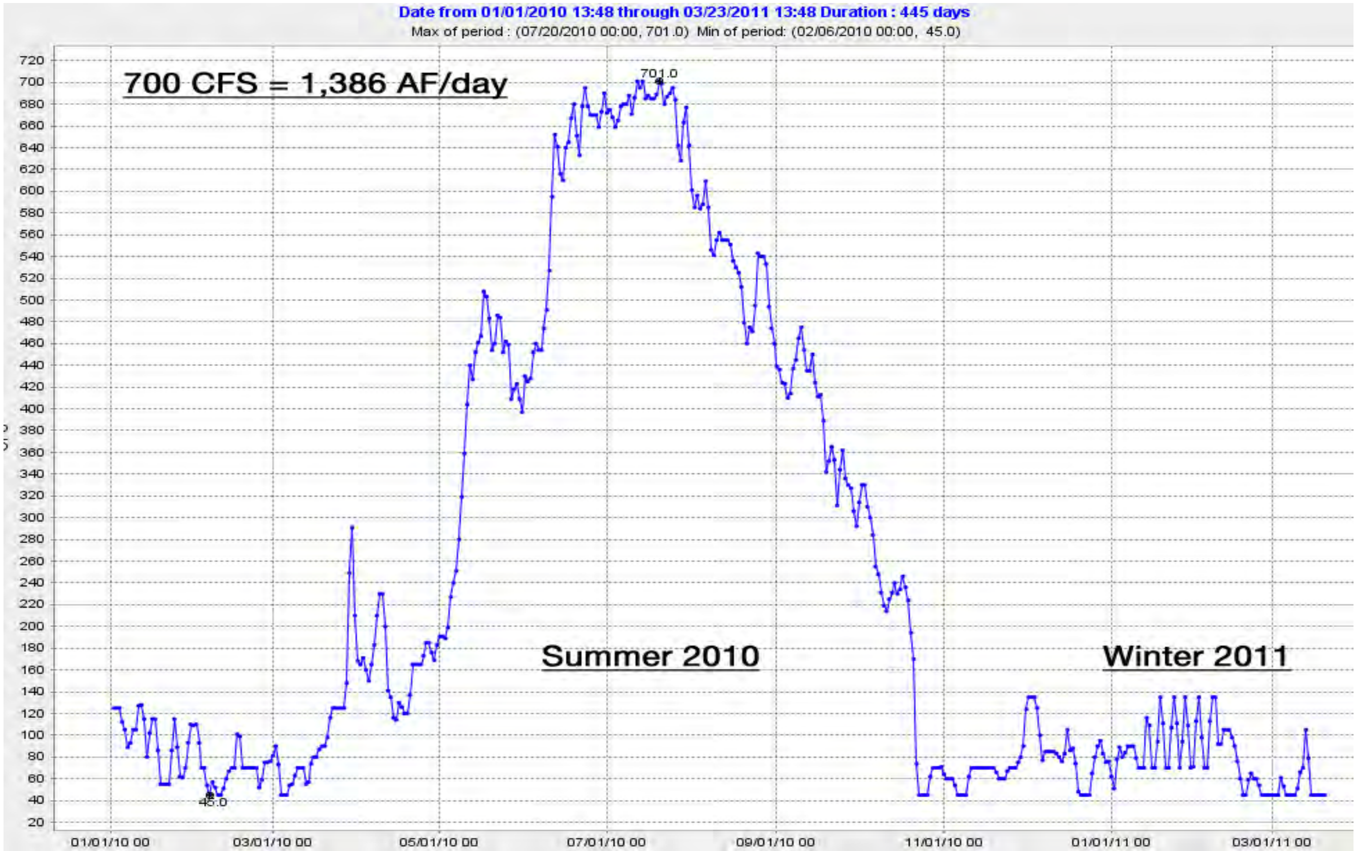
Lake Level: Acre-Feet of Storage per Foot of Level Increase

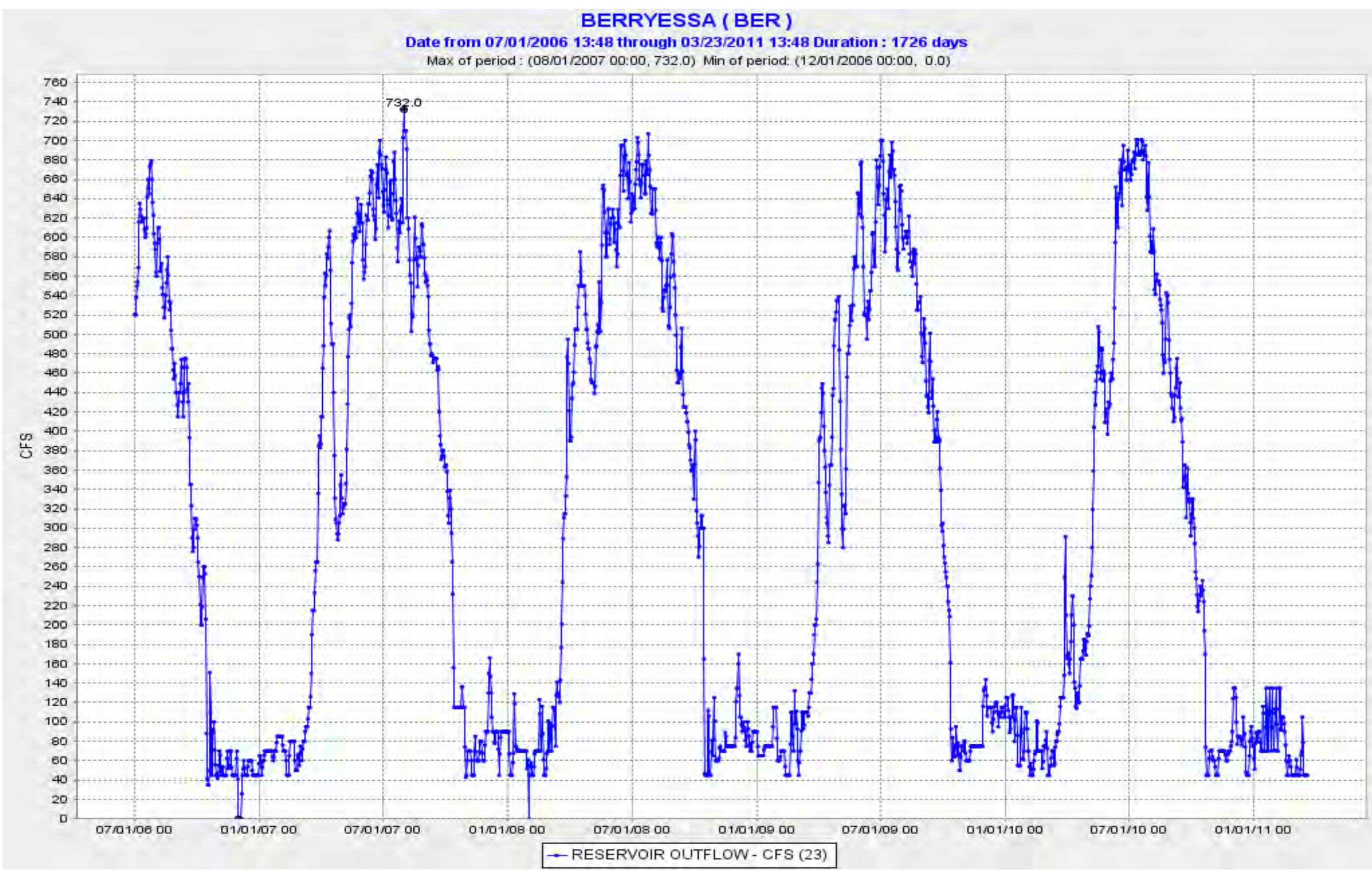
440' – 445': 19,500
430' – 440': 18,500
400' – 430': 17,050
390' – 400': 14,820
380' – 390': 13,270
350' – 380': 11,500

From December 31, 2005 until January 31, 2006 the lake remained above 440 feet. It hit 443.5 feet maximum level on Jan 2 and didn't get back down to 440 feet until May 19. Its maximum outflow was 5,363 cfs (10,600 AF/day) on April 14. The average outflow for April, 2005 was 2,000 cfs or 3,960 AF/day. This would equate to about a foot drop every 5 days. It rained 6.7 inches during that same April time frame.

The maximum outflow obviously occurs during the summer. The dam was originally built to supply irrigation water to Solano County. That is still its main purpose, although it also provides drinking water to about 500,000 people in Solano County. The Budweiser brewery in Fairfield has a contract that requires the use of Lake Berryessa water only. Thus the old joke we've heard so many times… No Lake Berryessa water is used in the Napa Valley, but some does go to the residential communities around the lake.

The majority of Lake Berryessa water is released during May-September – the growing season. Peak outflow is about 700 cfs or 1,400 AF/day.

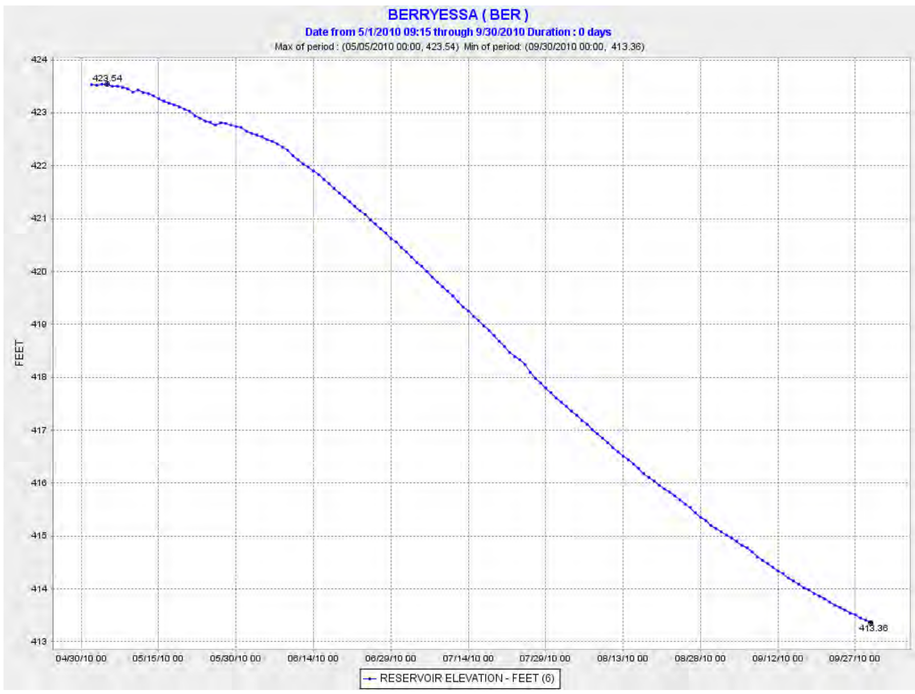

Date from 01/01/2010 13:48 through 03/23/2011 13:48 Duration : 445 days
Max of period : (07/20/2010 00:00, 701.0) Min of period: (02/06/2010 00:00, 45.0)
700 CFS = 1,386 AF/day
701.0
45.0
Summer 2010
Winter 2011
01/01/10 00
03/01/10 00
05/01/10 00
07/01/10 00
09/01/10 00
11/01/10 00
01/01/11 00
03/01/11 00


BERRYESSA (BER)
Date from 07/01/2006 13:48 through 03/23/2011 13:48 Duration : 1726 days
Max of period : (08/01/2007 00:00, 732.0) Min of period: (12/01/2006 00:00, 0.0)
732.0
CFS
07/01/06 00
01/01/07 00
07/01/07 00
01/01/08 00
07/01/08 00
01/01/09 00
07/01/09 00
01/01/10 00
07/01/10 00
01/01/11 00
RESERVOIR OUTFLOW - CFS (23)

Total outflow in 2010 was 202,825 AF. Total outflow from May 1 – Sept. 30 was 156,588 AF. Only about 46,000 AF were released during the winter. To put that in perspective, evaporation in 2010 total was 4.7 feet. From May to September it was 3.06 feet.

A 3.06 foot decrease when the lake is nearly full equates to about 56,600 AF. **As incredible as it may seem, more Lake Berryessa water is lost to evaporation during the summer than is actually released from the lake during the winter.** Evaporation is measured in inches using actual evaporation measurements. An evaporation pan, 48" in diameter 10" deep, is located at Markley Cove.

Actual 2010 figures show the lake dropped from 423.55’ on 5/1 to 413.38’ on 9/30 - a 10.17’ decrease



At the 423 foot level the lake has a surface area of about 17,050 AF so the loss in AF was 173,399 AF (10.17’ x 17,050 AF/foot). And evaporation accounted for an actual loss of approximately 52,173 AF (3.06’ x 17,050).

At 700 cfs (1,400 AF/day) summer outflow with a surface area of 17,050 AF at the 430 foot level the lake experiences a one-foot drop every 12 days – which matches observation.

Once again the conclusions are that rumors are only rumors and all conspiracy theories about Lake Berryessa water are false. Numbers don’t lie, but do take some thought to unravel.

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Some fun facts about water use from the Montana Department of Natural Resources:

- 1 human family (up to 5 people) uses 1 AF/Yr
- 1 dairy cow or horse uses .038 AF/Yr
- Therefore 1 human family = 26 cows or 26 horses
- 300 chickens or 3 pigs use .017 AF/yr
- 1 human family = 17,648 chickens or 176 pigs
- 100 turkeys or rabbits or 125 prairie dogs use .017 AF/yr
- 1 human family = 5,882 turkeys or rabbits or 7,353 prairie dogs!

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- 1 CFS equals 1.98 AF per day
- 1 family (up to 5 people) uses 1 AF/YR
- 1 Cubic foot of water equals 7.48 Gallons
- 1 AF of water equals 1 foot of water on 1 acre
- 1 AF of water equals 325,851 Gallons
- 1 AF of water equals 43,560 Cubic feet
- 1 CFS equals 448.8 GPM
- 1 GPM equals 1,440 Gallons per 24 hour day
- 1 GPM equals 1.61 AF per year

Seeing Underwater at Lake Berryessa

By Peter Kilkus

In the Spring of 2007 the Solano County Water Agency (SCWA) performed a survey of the underwater landscape of Lake Berryessa. They wanted to accurately determine the capacity of the lake using the latest technology. Siltation from a lake's shoreline is often a factor in lowering the total water-carrying capacity of reservoirs. SCWA wanted to investigate the sedimentation rate and establish a baseline as well as create accurate bathymetric maps.

The data used to make bathymetric maps today typically comes from an echosounder (sonar) mounted beneath or over the side of a boat, "pinging" a beam of sound downward at the lake bottom. The amount of time it takes for the sound or light to travel through the water, bounce off the lake bottom, and return to the sounder tells the equipment the depth at that location.

Of course, doing this from a moving boat requires a lot of calibration and measurement. The SCWA system used a motion reference unit, a gyrocompass, and attitude sensor for dynamic corrections for vessel movement. Deep water surveys can produce a large variation of sound velocity values due to thermal changes. Sound velocity casts were performed hourly to account for sound velocity changes through thermoclines. A "cast" is the process of slowly lowering a sensor through the water until it reaches the bottom. Then it is hoisted back to the surface. As the instrument runs through the water column, the sensor obtains conductivity, temperature, and pressure data.

For you techies out there the list of survey equipment is fascinating:

26 ft. Research Vessel Sounder with Multibeam Sonar (300 kHz Dual-Head, Vertical Accuracy 1cm)
17 ft. Survey Skiff with Singlebeam Sonar (200 kHz Single Head, Vertical Accuracy 1cm)
Real-Time Kinematic (RTK) Global Positioning System
DMS Motion Reference Unit and SG Gyrocompass
Odom Sound Velocimeter

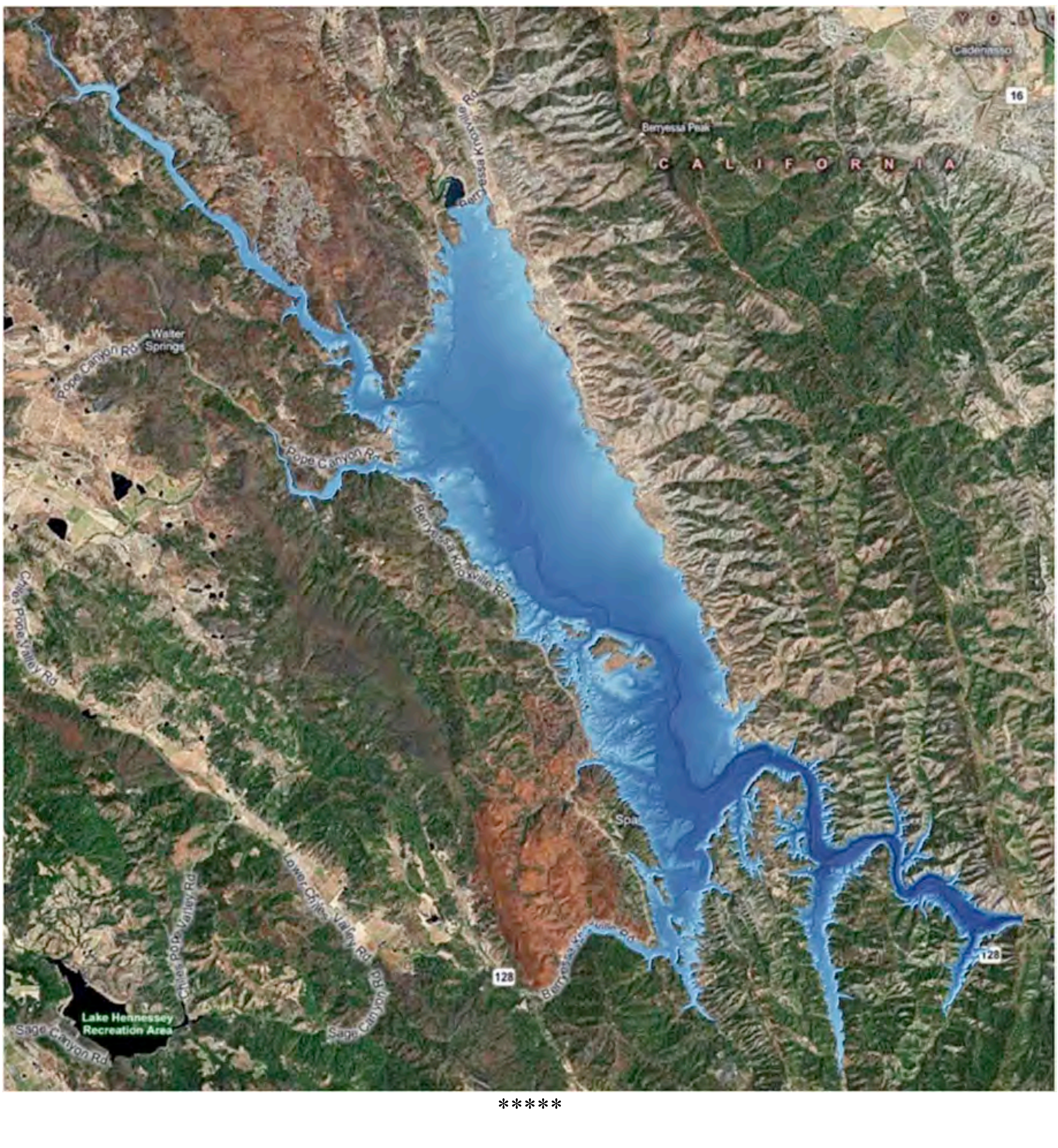
The Dual Head System has 125 beams per head with an across-track beam width of 1.5 deg. The system provides an approximately 200 degree swath coverage, or ten times depth. Maximum survey speed is 5 knots with sonar pings rate of 15 pings/sec.

The MultiBeam system was used for measurements in areas with depths greater than 10 ft. The SingleBeam system was used in shallow areas from 3 to 15 ft depths. MultiBeam and SingleBeam depth resolution was an amazing 1cm (0.4 in.) Each dual beam (set at 40 degrees) has 125 transducers and in ideal conditions provide a swath width that is 10 times the depth.

The Real-Time Kinematic (RTK) Global Positioning System survey data was used to merge the bathymetric data with the existing Napa County Digital Terrain Model (DTM) resulting in some astonishing visuals. Depth data is shown as color variations rather than contour lines.

A SCWA engineer said that you can see the old roads if you look closely at some of the images. I had hoped that the old Town of Monticello streets might stand out, or the Putah Creek Stone Bridge. Although there is a lot of detail visible, the images don't seem to show the old town. You can download the high resolution images I've posted on the Lake Berryessa News web site and look for yourselves. The old Town of Monticello was just northeast of the Big Island on the east side of Putah Creek. A map of Monticello is included below so you can make your own comparisons.

The survey results confirmed that Lake Berryessa retains its full capacity – which is now more accurately known. Siltation has not been a factor in reducing the total volume of water behind Monticello Dam.


Cadenasso
16
Berryessa Peak
CALIFORNIA
Berryessa Knoxville Rd
Walter Springs
Pope Canyon Rd
Pope Canyon Rd
Chiles Pope Valley Rd
Lower Chiles Valley Rd
128
128
Sage Canyon Rd
Sage Canyon Rd
Lake Hennessey Recreation Area

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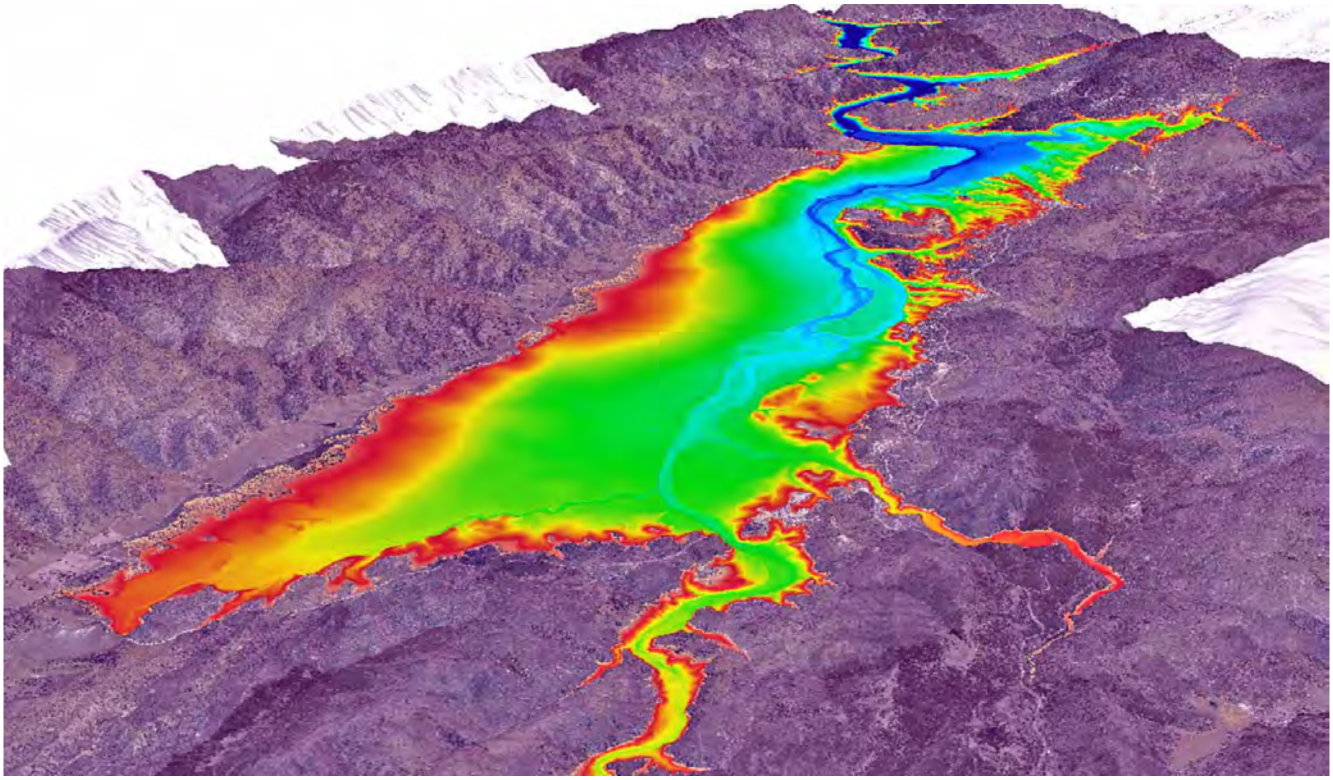

Lake from the North
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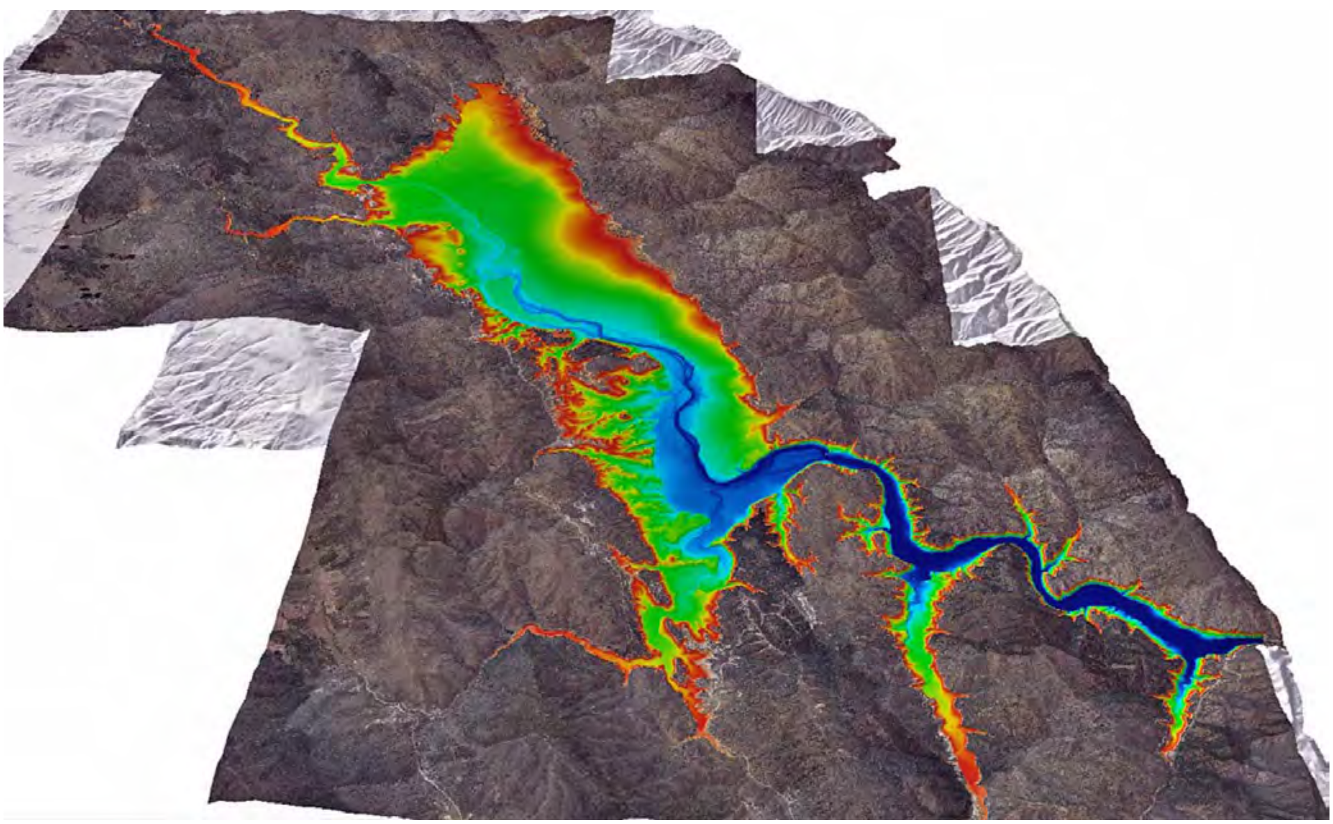

Lake from the South
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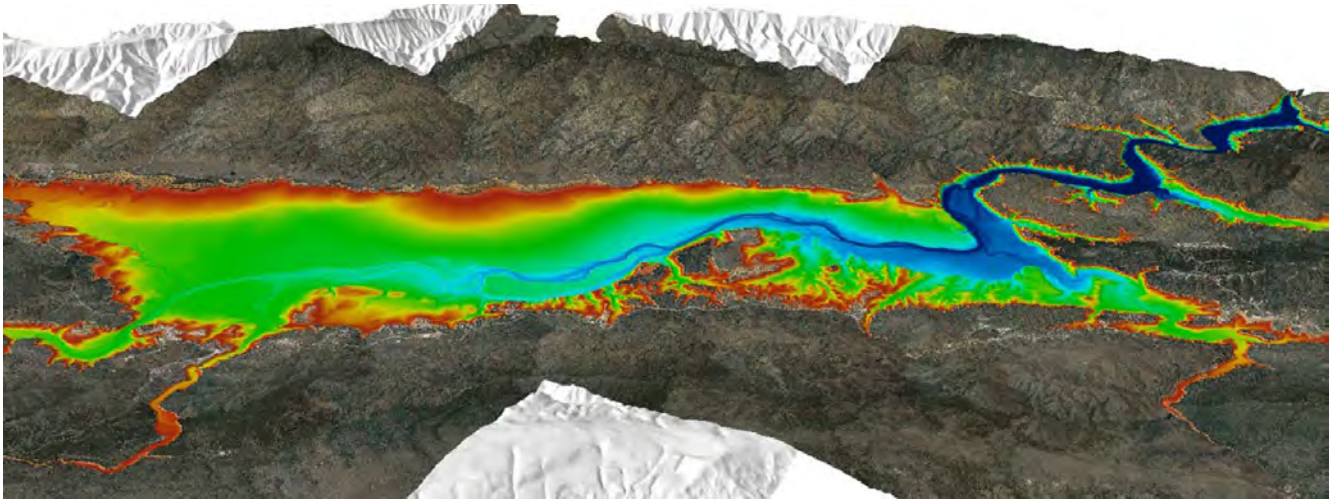

Lake from the West

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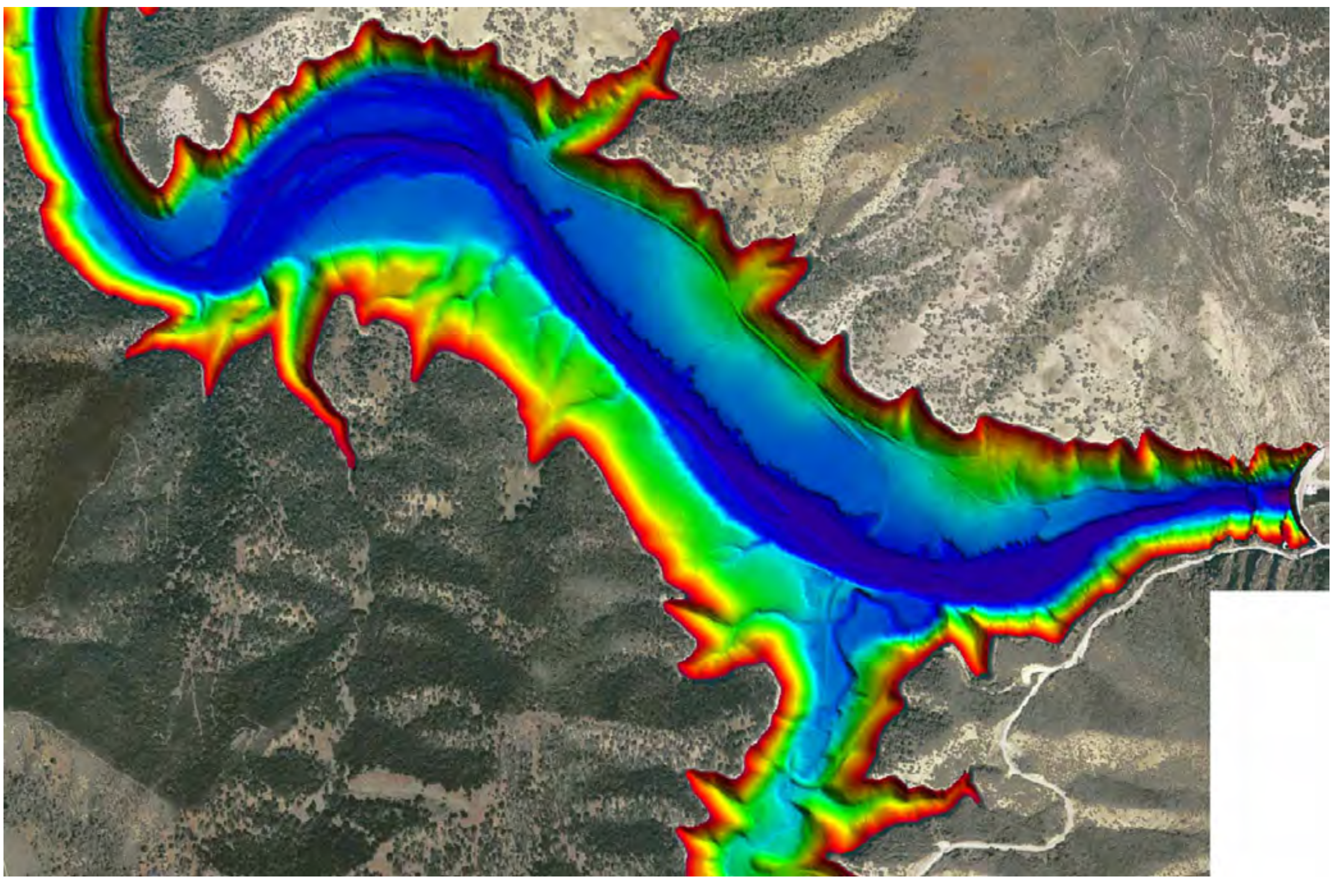

Monticello Dam on the right with Markley Cove at the lower center

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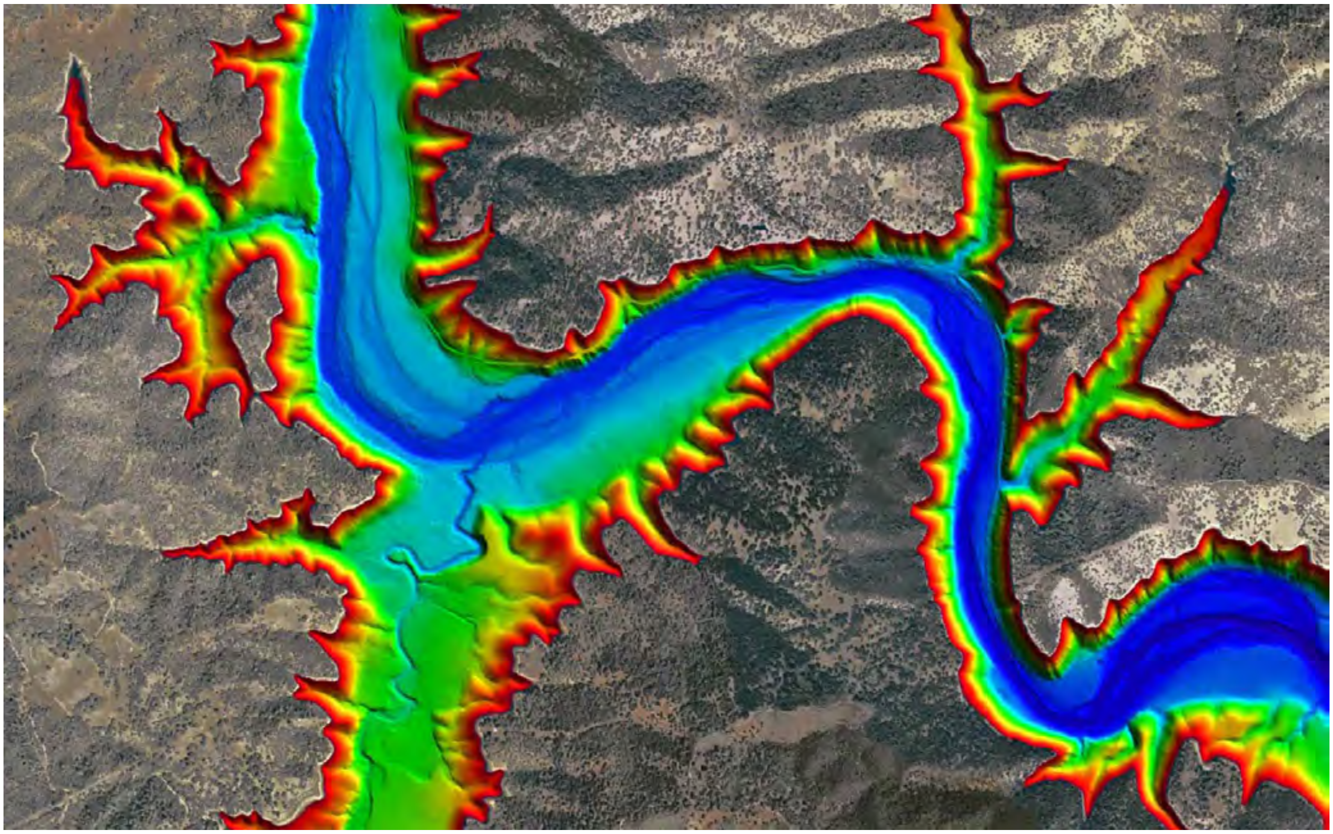

The Narrows with Wragg Canyon on the lower left
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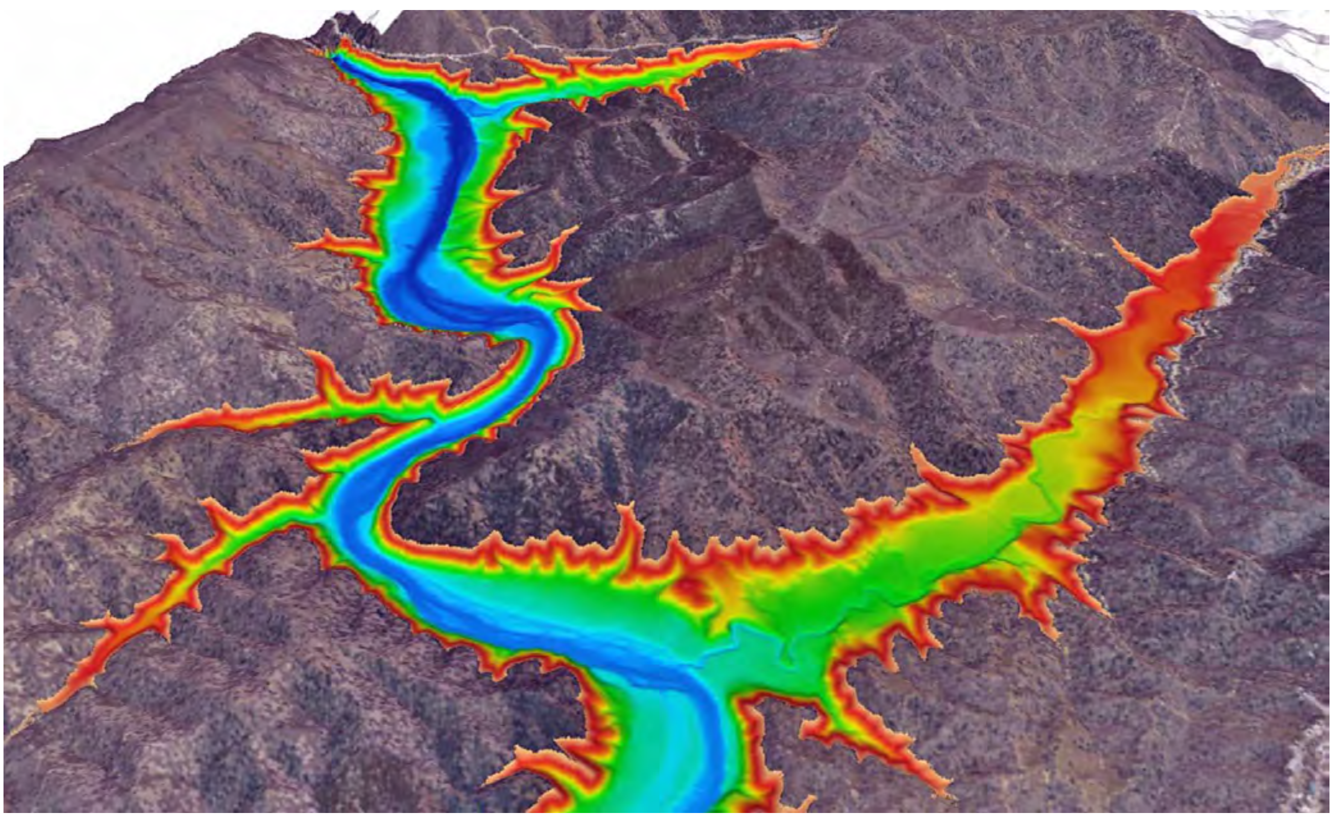

The Narrows from the North with Monticello Dam at the upper left
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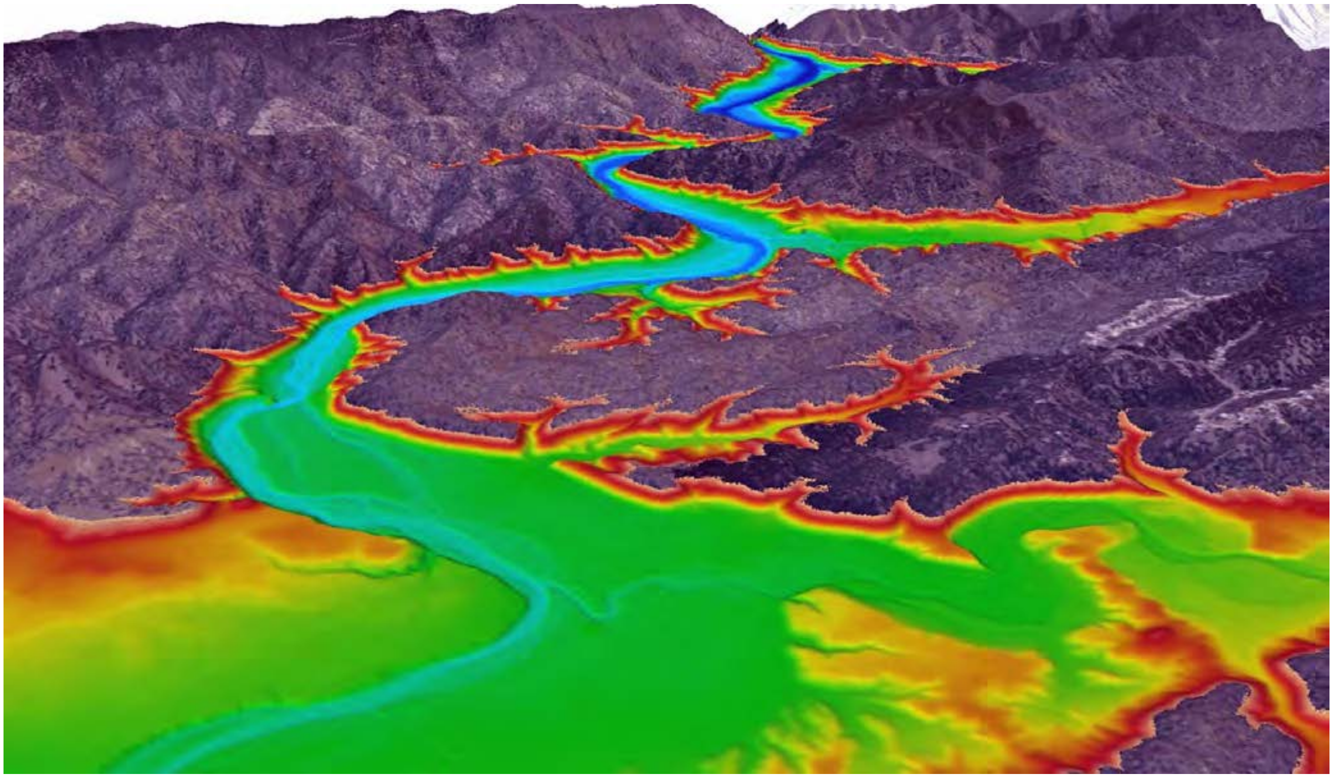

The Narrows and South Lake with Monticello Dam at the top center

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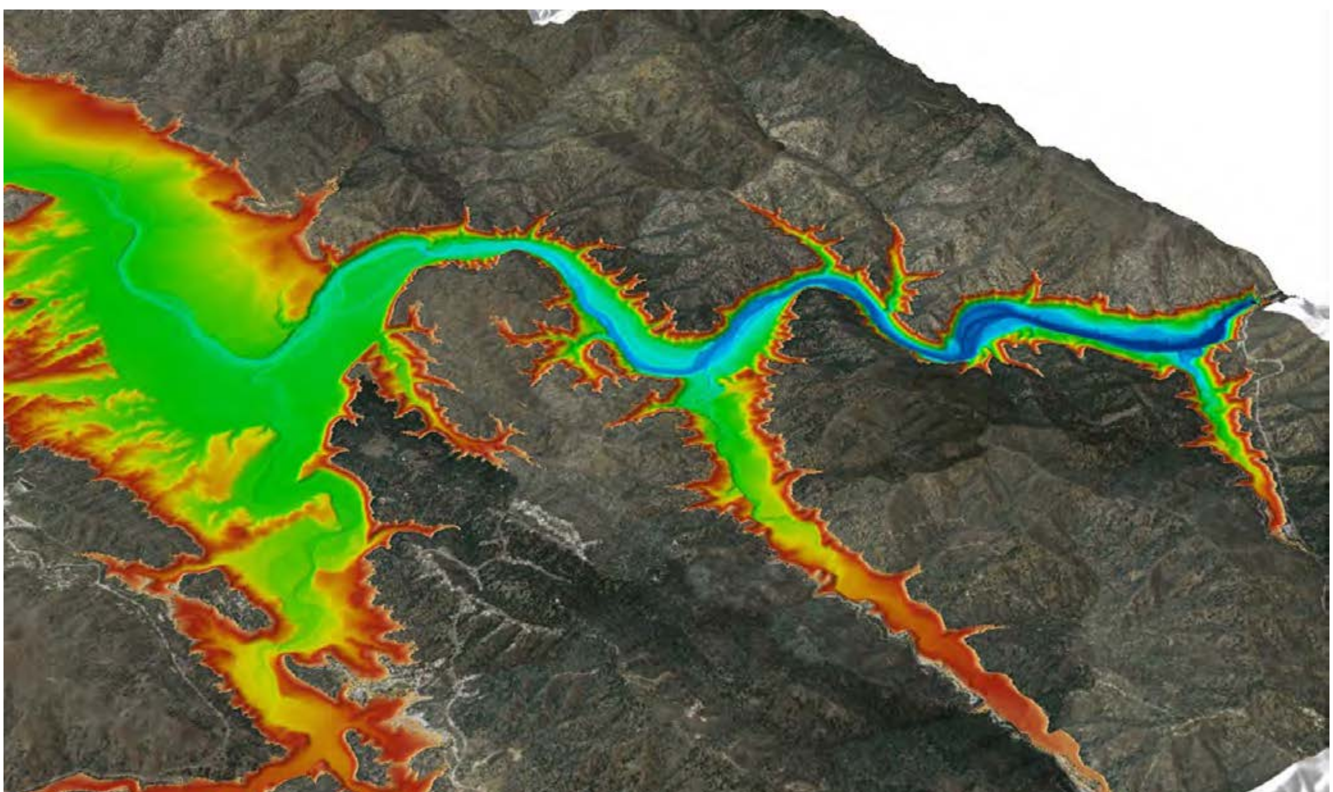

South Lake and the Narrows with Monticello Dam at the right

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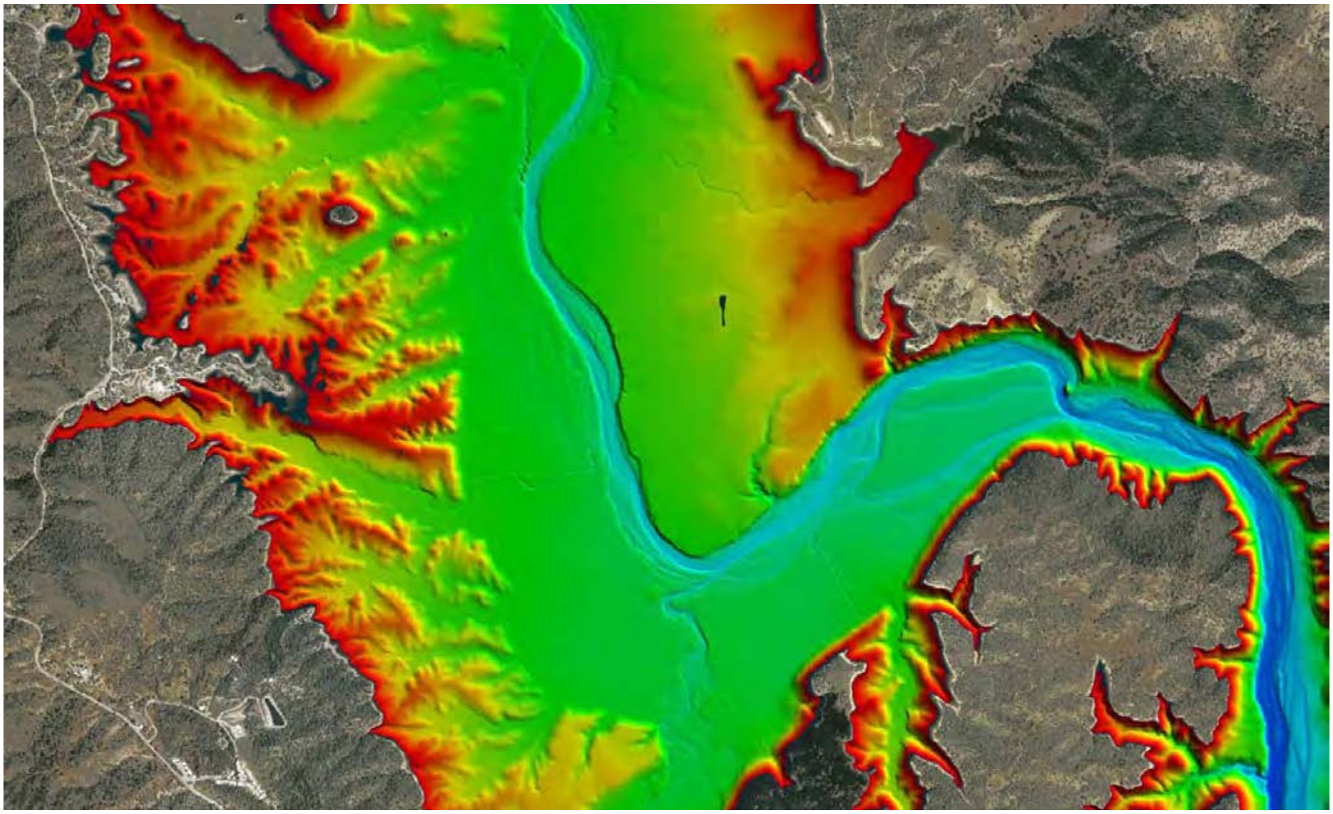

South Lake with Goat Island and Big Island at upper left

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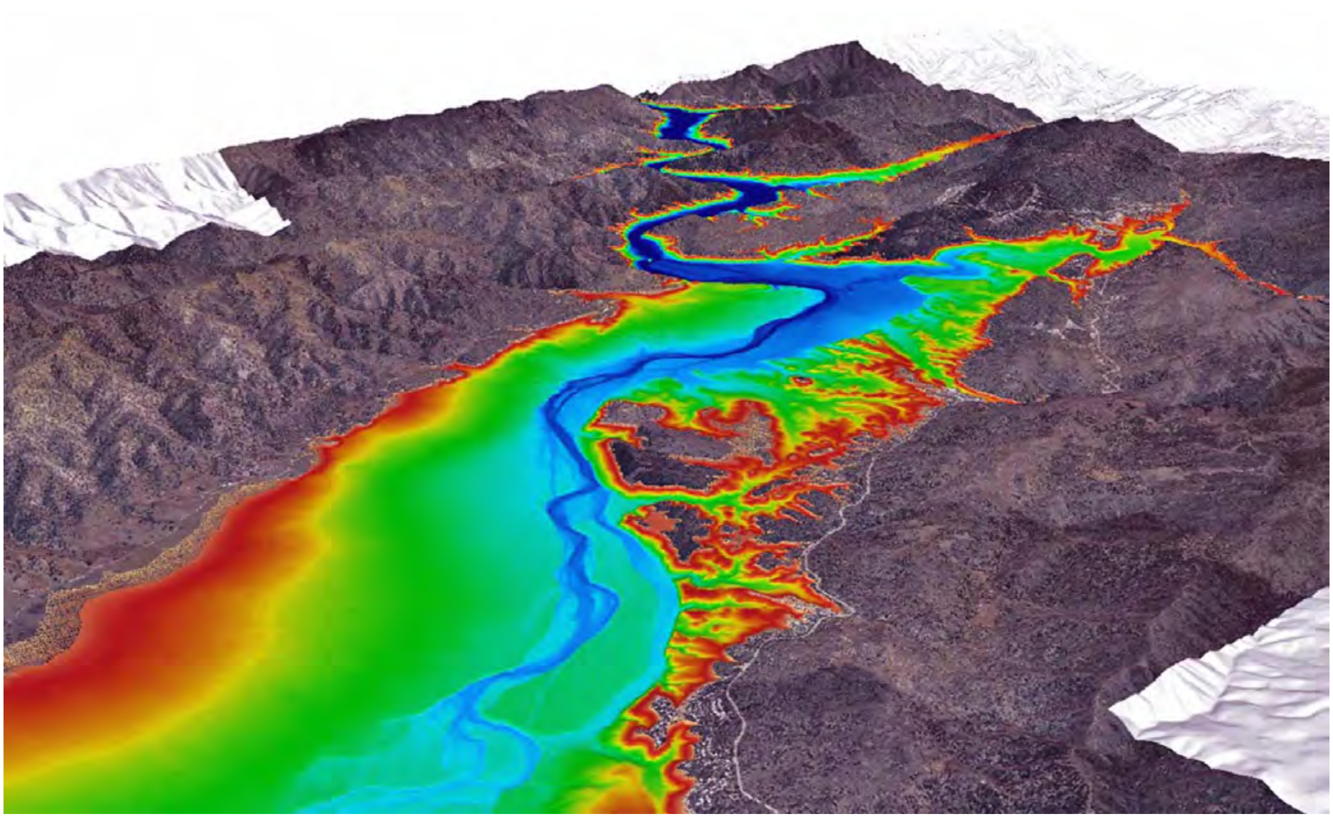

South Lake from the North with Big Island in the center

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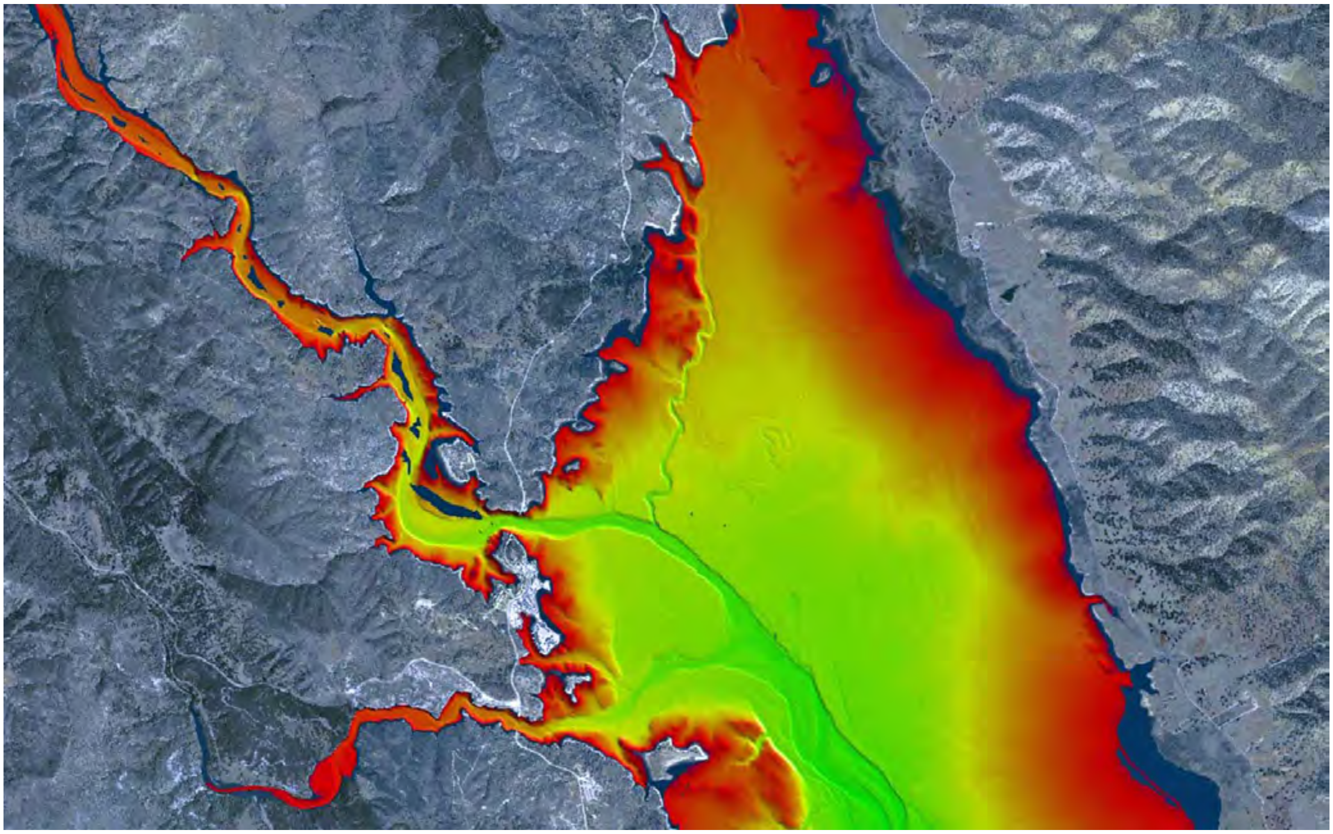

North Lake with Pope Creek and Putah Creek on the left

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The Town of Monticello

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Berryessa Valley Map at the Monticello History Exhibit in the Spanish Flat Village Center

Could Monticello Dam fail?

By Margaret Burns
Davis Enterprise, September 05, 2014

This thought probably is running through the heads of everyone living in Yolo County, following the 6.0-magnitude earthquake that devastated Napa on Aug. 24, 2014.

The simple answer is yes, because anything is possible. But is it probable? Not very.

Monticello Dam is a high concrete arch dam, completed in 1957 and filled to capacity in 1963, and owned by the federal Bureau of Reclamation. Daily operation of the dam is done by the Solano County Water Agency, contracted by the Solano Irrigation District.

The dam is 100 feet thick at the base and tapers to 12 feet at the crest, which has an elevation of 449 feet above sea level. It is filled by runoff from a 566-square-mile watershed, which amounts, in average years, to about 400,000 acre-feet of water. An acre-foot is enough water to flood one acre one foot in depth. Maximum capacity of the dam is 1.6 million acre-feet.

Dams fail due to several distinct causes. The most common is overtopping of the dam capacity, usually due to unexpectedly heavy rainfall in the watershed. This may be exacerbated by accidental blockage of the spillway or inadequate spillway design.

The second most common cause is defects in the foundation of the dam. These may be due to substandard construction methods or poor maintenance. The third most common cause is failure due to piping and seepage from internal erosion and cracks in the dam structure.

Problems with conduits and valves caused by the entry of embankment material into conduits are another source of dam failure. All of these reasons combined constitute an explanation for 94 percent of all dam failures, according to the 2011 Roseville Multi-Hazard Mitigation Plan.
That leaves approximately 6 percent for other causes of dam failure, of which earthquakes could be one.

Dam failure has the potential to cause more death and destruction than the failure of other man-made structures because of the force of rapid release of water. For this reason, there has been increasing regulatory oversight by federal and state governments to ensure the safety of dams.

Using the destructive force of dam failure as a deliberate offensive tactic, the Allies bombed the Eder and Möhne dams in Germany's Ruhr Valley in 1943. A listing of major dam failures and their causes can be found on the "Dam Failure" site of Wikipedia. Not one dam failure due to earthquakes is cited in that listing.

Most often used as an example of an earthquake-induced dam failure is the near-failure of the Lower Van Norman Dam in the 6.7-magnitude San Fernando earthquake in 1971. Severe damage to the dam lowered the crest about 30 feet. Residents in a 6-mile-long area down the valley were evacuated. The retained water was not at its maximum height, so the water did not overtop the dam, which had been constructed between 1912 and 1915.

The water behind the dam was further lowered over three days to protect the population, according to John Rundle, director of the UC Davis Computational Science and Engineering Center, and the U.S. Geological Service website on earthquake hazards.

The older dam was an earthen dam, known to be much less able to withstand shaking than Monticello Dam, a concrete arch dam. The more modern replacement dam built in San Fernando in 1975-76 withstood the Northridge earthquake (magnitude 6.7) in 1994 with little damage.

Dam monitoring

The Bureau of Reclamation has a systematic four-step program that continuously monitors the status of its dams. There is a review and inspection every four years, which involves looking at seismic, hydrologic and static parameters, says Drew Lessard, area manager of the Central California Area of the Bureau of Reclamation.

"Our headquarters in Denver and our area office take turns being in charge of these inspections, which are exhaustive," Lessard said. "It is visual, looking for anomalies like seepage in the internal galleries that house some of the sensing equipment we rely on for data. But we also evaluate how much loading the horizontal joints are bearing and other structural parameters, evaluate seismic data.

"If anything is out of kilter, we will do more studies to analyze those potential weaknesses. If unwanted changes are found, we make plans for corrective actions and do it then. "We routinely take cores of concrete from various points in our dams and test them for compressibility — how much load can they stand before giving way. In our experience, overloading of dams from seismic events is less frequent than static loads from the water being held in check."

Thomas Pate, principal water sources engineer of the Solano Water District, relates an experience he had while at the Denver headquarters of the Bureau of Reclamation some years ago. "There was a two-story-tall machine designed to test the compressibility of the concrete cylinders that are removed to evaluate the structural integrity of a dam," Pate said. "I looked at one pile of boxes and it was labeled Monticello Dam. 'That's my dam on the floor,' I thought. The engineer in charge told me that 'Monticello is one of the better dams we've built.' I found that reassuring.

"Locally, we have daily visual inspections of the entire dam site, looking for any potential signs of change that could have consequences. Once every few years, the Bureau of Reclamation comes and they have people crawling all over the dam, checking every aspect of its stability."
According to Lessard, after any event in an area that could affect a dam, the dam is immediately inspected. He said that nothing unusual was seen at Monticello Dam after the Napa quake last month.

Earthquake probability

What is the probability of an earthquake at Monticello Dam? There is historic evidence that a serious earthquake can occur in this area, as it did in 1892 with a magnitude-6.4 quake that leveled downtown Winters. However, it took 100 years for J.R. Unruh and Eldridge Moores, geologists at UC Davis, to establish the reason for the quake.

"It was difficult to establish until we had appropriate instrumentation because this is a concealed fault, a blind thrust as the Coast Ranges move up and into the Central Valley," Moores said. That specific fault line extends north of Winters along the eastern edge of the Coast Range. Fault maps also show a fault line running more or less linearly adjacent to the western edge of Lake Berryessa — the Hunting Creek-Berryessa Fault Line. The Great Valley fault line running north of Vacaville is close to the site of the Monticello Dam.

"The direct effect of the Napa earthquake on the Monticello Dam would have been very small," Rundle said, "therefore not a concern. However, there are several faults in the area of the dam.
"Earthquakes on a fault are known to affect other faults," Rundle added. "This is called 'fault interaction.' It is due to the transfer of stresses or forces on one fault to another close by. A concern might be that these nearby faults in Northern California might together start to be active.

"What would happen if the Great Valley fault, which basically runs under the dam, were to fail in an event such as the magnitude-6.4 Vacaville-Winters earthquake, which was located somewhere in that area? Very probably, this will not happen. But I can't and won't say that it absolutely won't happen."

Quake forecasts

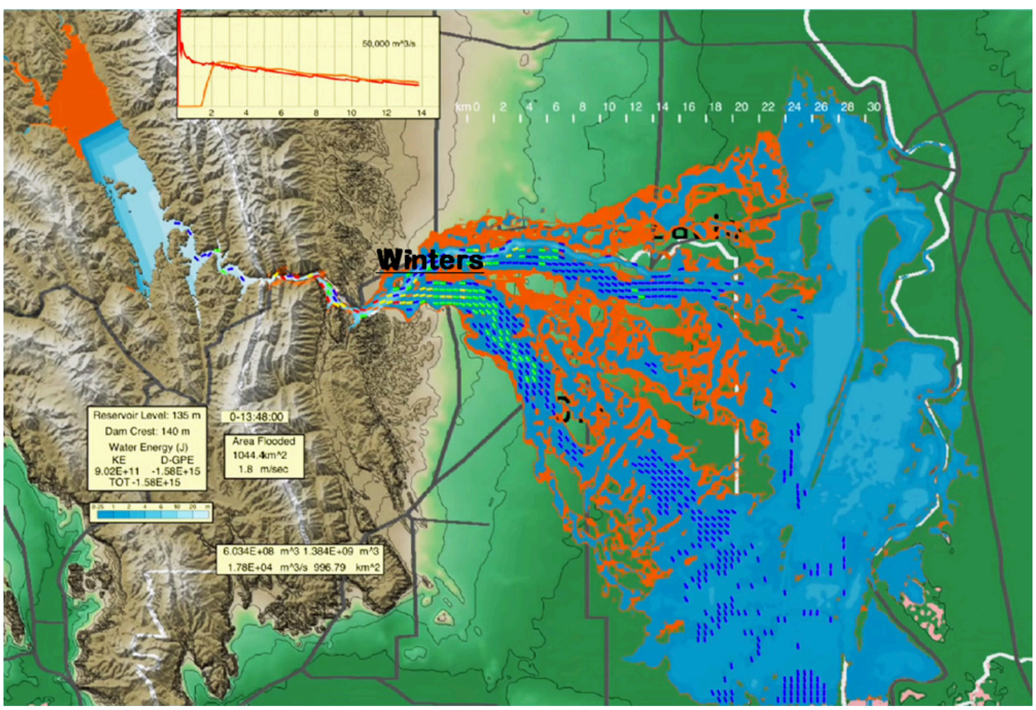
The Open Hazards website (www.openhazards.com), on which Rundle blogs, offers an earthquake forecast within a 50-mile radius. The probability of a greater than 7 magnitude earthquake within 50 miles of Winters is 5.27 percent in the next three years.

However, that 50-mile radius includes portions of the Bay Area with the active Hayward-Rodgers fault line, so it is not known exactly what the probability for Winters is specifically, because it is located in a less active area of the 100-mile-diameter circle.

Another blogger for the OpenHazards site is Steven Ward, a research geophysicist at the Institute of Geophysics and Planetary Physics at UC Santa Cruz. He has created a "computer simulation of the first 16 hours of flooding that might be expected from the failure of Monticello Dam. This worst-case scenario envisions a nearly instantaneous breakdown of the structure and a reservoir filled to capacity.

Steven Ward, a research geophysicist at the Institute of Geophysics and Planetary Physics at UC Santa Cruz has created a computer simulation of the first 16 hours of flooding that might be expected from the failure of Monticello Dam from a possible earthquake. This worst-case scenario envisions a nearly instantaneous breakdown of the structure and a reservoir filled to capacity. This is unlikely but informative. There are approximately 800,00 acre-feet of water in Lake Berryessa as of December, 2015, which has a normal capacity of about 1.6 million acre-feet.

The simulation can be accessed at http://es.ucsc.edu/~ward/berryessa-dam.mov. It shows water reaching Winters in roughly 30 to 40 minutes after a dam break.



However, the simulation is the worst-case scenario. Ward writes, "Rather than flush-and-gone, a dam break here is akin to opening a valve to a hose that will spray at a nearly constant rate for hours and hours. Second, just downstream is California's Central Valley, a very flat and nearly unchannelled place. Don't expect the flood to follow a well-defined river track as you might elsewhere. "The simulation suggests that about 1,000 square kilometers will be affected. Most areas would see water less than one or two meters deep, but the outburst would last a day or more."

The Glory Hole spillway is at 440 feet above mean sea level (msl). The height of the dam is 450 feet msl. Highway 128 is designed to be the initial spillway if water rises that high - watch out Winters. The water level has never been above 446.7 feet msl and has only been at or above Glory Hole (440' msl) 24 times in its 57 year history.

https://www.davisenterprise.com/local-news/could-monticello-dam-fail/