

Monticello Dam - Could It Fail?

The simple answer is yes, because anything is possible. But is it probable? Not very. The dam is 100 feet thick at the base and tapers to 12 feet at the crest.

Dams fail due to several distinct causes. The most common is overtopping of the dam, 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.

In years past, the Solano Irrigation District's dam manager said that the only way Monticello Dam could fail and put Winters underwater would be a complete immediate failure along the lines of the entire structure crumbling at once. If such an event should ever occur, it was estimated that Winters would be under 40 feet of water in about 15 minutes, with floodwaters reaching all the way to Davis. However, it is unlikely that the level would ever go over the top of the Monticello Dam because the dam was designed to let water flow around it and out onto the Highway 128 rather than go over the top. The lake level would have to rise to 455 feet, which would be 15 feet over the Glory Hole rim.

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. BOR headquarters in Denver and the local area office take turns overseeing these inspections, which are exhaustive. It is visual, looking for anomalies like seepage in the internal galleries that house some of the sensing equipment relied on for data. But they also evaluate how much loading the horizontal joints are bearing, review other structural parameters, and evaluate seismic data.

If anything is out of specification, they will do more studies to analyze those potential weaknesses. If unwanted changes are found, they make plans for corrective actions and do it then. BOR routinely take cores of concrete from various points in their dams and test them for compressibility — how much load can they stand before giving way. In their experience, overloading of dams from seismic events is less frequent than static loads from the water being held in check. BOR engineers say that Monticello is one of the better dams they've ever built.

Locally, daily visual inspections of the entire dam site take place looking for any potential signs of change that could have consequences. Once every few years, the Bureau of Reclamation has people crawling all over the dam, checking every aspect of its stability. After any event in an area that could affect a dam, the dam is immediately inspected. Nothing unusual was seen at Monticello Dam after the Napa 6.0 earthquake in 2016.

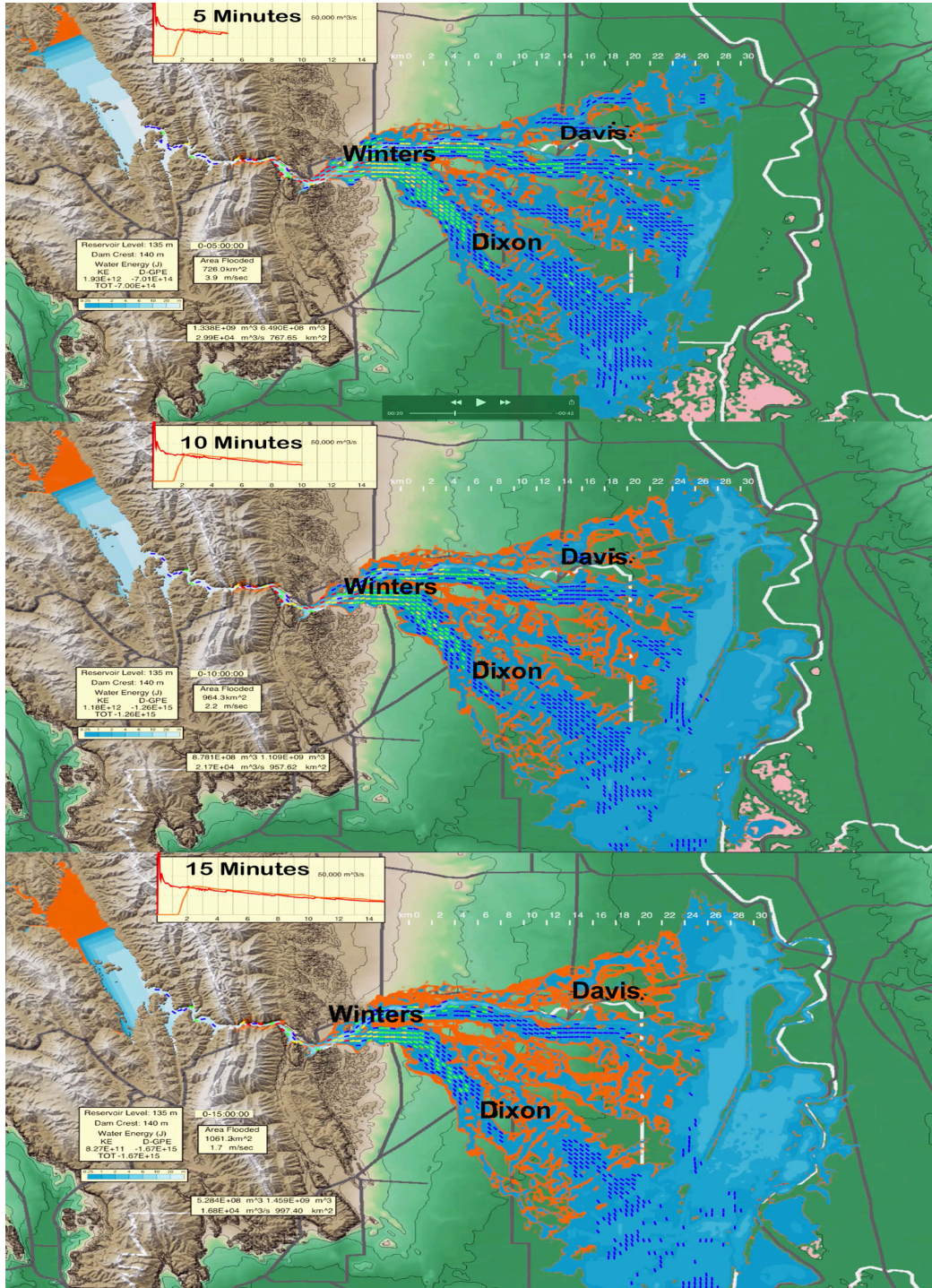
What is the probability of an earthquake at Monticello Dam? There is historic evidence that a serious earthquake can occur in this area, as it did in 1892 with a magnitude 6.4 quake that leveled downtown Winters. What would happen if the Great Valley fault, which basically runs under the dam, were to 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 no one can say that it absolutely won't happen.

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. 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 accessed at <http://es.ucsc.edu/~ward/berryessa-dam.mov>.



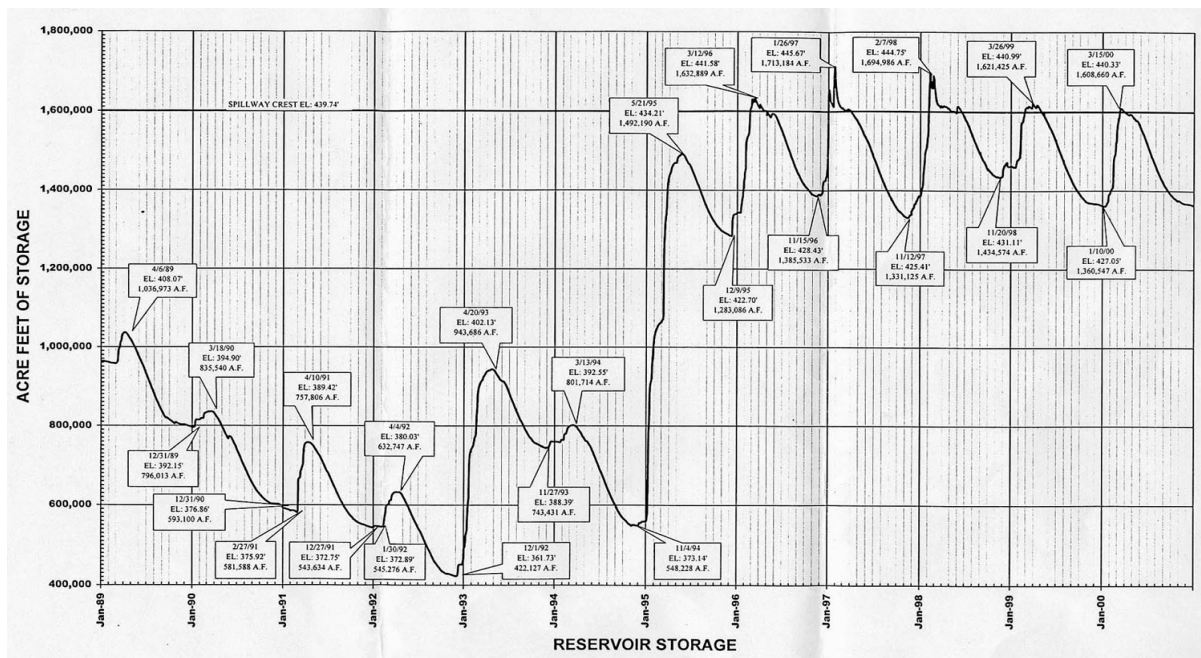
Ward writes, “Rather than flush-and-gone, a dam break here is akin to opening a valve to a hose that will spray at a nearly constant rate for hours and hours. Second, just downstream is California’s Central Valley,

a very flat and nearly unchanneled 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."

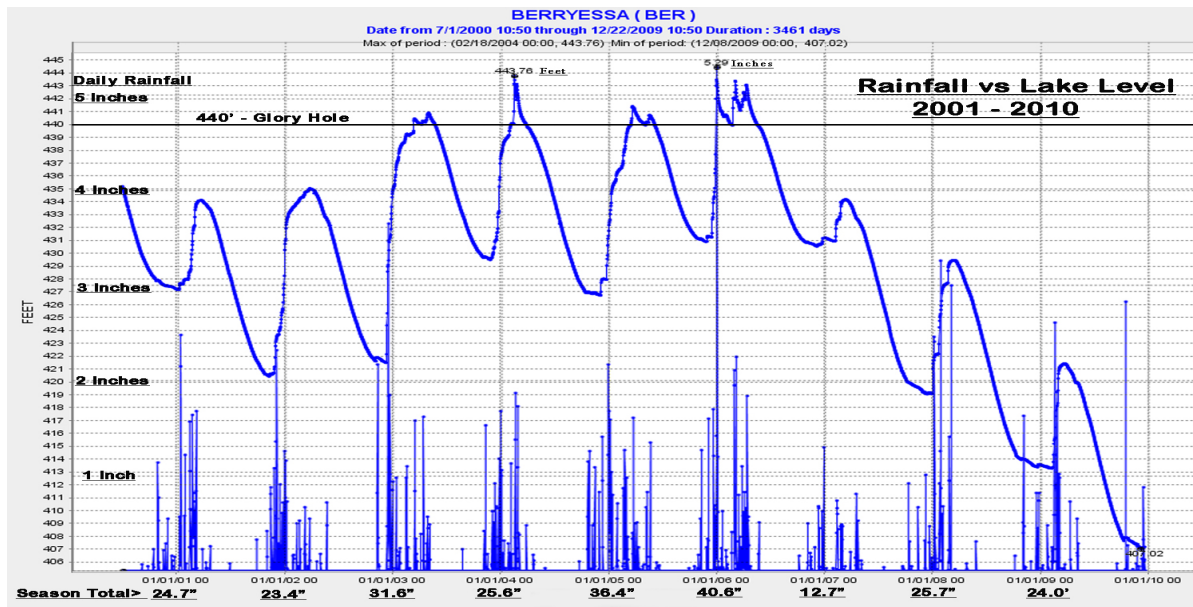
But Can Lake Berryessa Flood Over the Dam?

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 lake has reached 440 feet only 25 times in its 65-year existence. Although consistently accurate rainfall data at Monticello Dam is not available before 1998 and the lake level measured in feet above mean sea level (MSL) only exists after 1998, the Bureau of Reclamation has been keeping detailed data on lake capacity measured in acre-feet since the dam was constructed.

Although the Solano County Water Agency charts below are in acre-feet (AF), each of the peaks and valleys has a text box with the date, level in feet above MSL, and capacity in acre-feet. This allowed a correlation between acre-feet and lake elevation and is how the elevation levels were derived for the latest master charts. The chart below shows the levels and capacity during the drought of the early 1990s.



The early 1980s had mostly above average precipitation in northern California and throughout the West, with the wettest year of the decade occurring in 1983. The highest level the lake ever reached, 446.7 feet, is 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 2010 seasons.



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. Glory Hole overflows at 440 feet. 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. During the construction phase, Lake Berryessa did rise high enough in 1955 to spill over the top of the dam when it was at about half its finished height, causing damage and delays.

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."

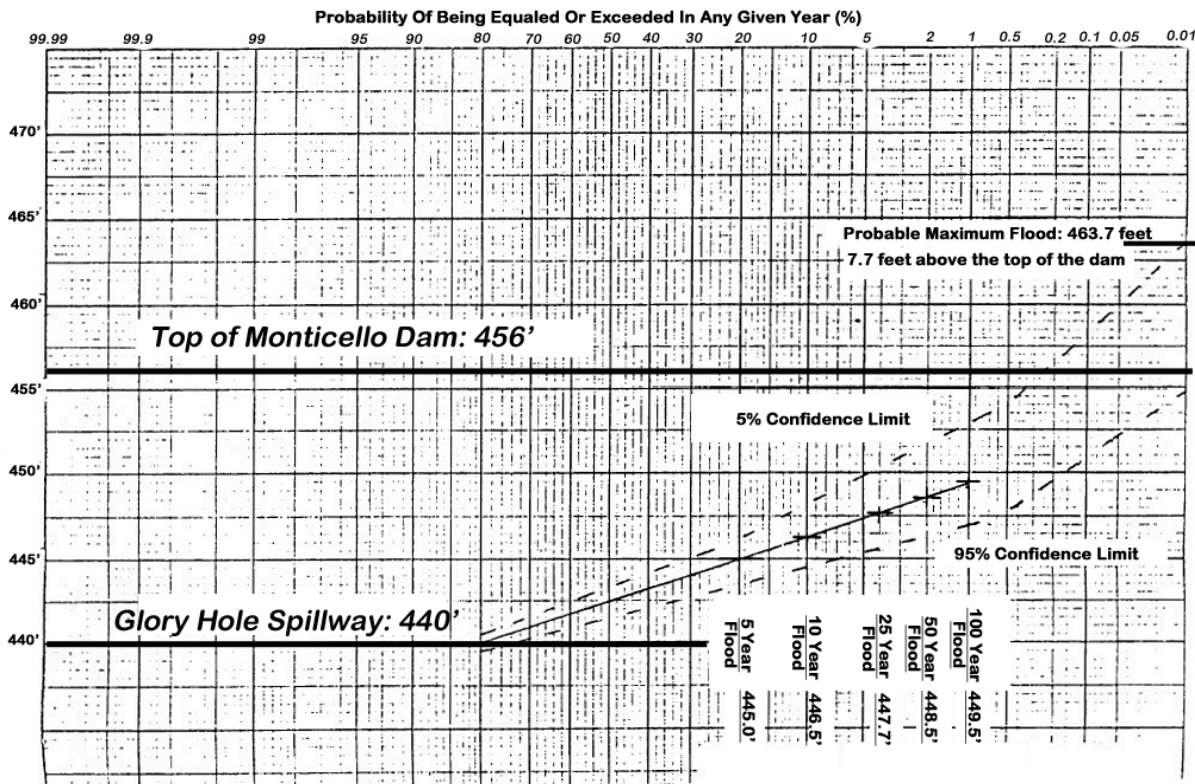
Not to worry too much since this worst-case scenario had a VERY low probability – somewhere between 10,000 and 1,000,000 years. Even the probability of the lake reaching the top of the dam at 456 feet was very low with a 5% confidence limit of 417 years recurrence and 95% confidence limit of 16,667 years 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." According to the US Federal Energy Regulatory Commission, the Probable Maximum Flood (PMF) is the theoretically largest flood resulting from a combination of the most severe meteorological and hydrologic conditions that could conceivably occur in a given area. PMF is mainly used as a security assessment for existing dams and other impounding structures, and as a design criterion for proposed similar hydraulic structures, in order to avoid dam failures and catastrophic floods.

Probable maximum precipitation (PMP) is the key parameter used to estimate the probable maximum flood (PMF), both of which are important for dam safety. PMP is commonly used for estimating the probable

maximum flood (PMF). Based on hydrologic and meteorological knowledge, extremes are the results of many components interacting in a complex way. Typically, PMP is computed as a combination of the maximum of component values, where the rationale is that this combination is unlikely to be exceeded. The following table, based on an older 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)	Confidence Range
1.25	80	440	+ or - .05
5	20	445	+ or - 1.5
10	10	446.5	+ or - 2.0
25	4	447.5	+ or - 2.5
50	2	448.5	+ or - 2.75
100	1	449.5	+ or - 3.0

Flood routing studies indicate the Probable Maximum Flood (PMF) would overtop the dam parapet walls by 7.7 feet (elevation 463.7') for 51 hours. Floods equal to or larger than 80 percent of the PMF will overtop the dam. Such overtopping is not expected to affect the safety of the dam. The Reservoir Floodplain, behind the dam from elevation 440 feet to 455 feet, can be encroached at various times. 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?



The frequency floods derived for Lake Berryessa were developed using USGS stream gage records at Putah Creek near Winters for water years 1931 through 1956, and Bureau of Reclamation computed inflows to Lake Berryessa for water years 1957 through 1986. The Putah Creek flows near Winters were assumed to be representative of the flows at Monticello dam site for water years 1931 through 1956.

The above records were analyzed to determine the relative frequency of the highest mean daily flows greater than 2,660 cubic feet per second (CFS) for the following number of consecutive days, 1, 2, 3, ... , 20 or more. The flow of 2,660 CFS is the discharge capacity of Monticello Dam at elevation 440 feet. It was assumed that mean daily inflows less than this could be released without increasing the water surface elevation of Berryessa Reservoir. This analysis determined that 90 percent of all consecutive mean daily inflows greater than 2,660 CFS for water years 1931 through 1986 were of 7 days duration or less. An annual frequency analysis was performed on the highest consecutive 1-day, 3-day, 5-day, and 7-day flows for the period of record.

All frequency floods routed in this study were started at lake elevation 440 feet which is the top of active conservation pool and the recommended elevation to begin routing all floods. The initial elevation of 440 feet, which is a conservative estimate of the reservoir water surface elevation at the start of a flood, is also the crest elevation of the uncontrolled Glory Hole spillway. The probability curve developed in this study and shown on the graph can be used to assess the risk of development within Lake Berryessa's surcharge zone (elevation 440 feet to 455 feet).

The probable maximum flood (PMF) for Monticello Dam was last updated in 1996. The standard arrangement for the general storm Probable Maximum Flood (PMF) with an antecedent 100-year rain, centered on the west subbasin, was determined to be the critical flood, with a peak inflow of 524,700 CFS and a 10.3-day volume of 1,302,000 A-F. A flood routing of the 1996 PMF produced a larger estimate of dam overtopping for 66 hours with a maximum depth of 13.9 feet. The reservoir was assumed to be initially full to elevation 440 at the beginning of the flood routing, and the dam was assumed not to fail. Operation of the outlet works has a negligible effect on the flood routing results. Dam overtopping occurs for floods greater than about 51.5 percent of the PMF.

The largest one-season increases in lake level were 38 feet (1977), 40 feet (1993), 61 feet (1995) and 45 feet in 2017. Fortunately, all of these rainfall totals were coincident with very low lake levels. If these rainfall totals were to occur when the lake is already full, problems would arise. Both the Solano Irrigation District and the Solano County Water Agency have contingency plans for these unlikely events. These include increasing the dam outflows early if the predicted rainfall events appear to be very heavy. Glory Hole itself is a major factor in preventing dam overflows since it is capable of releasing huge amounts of water as the lake rises around it. Statistically the combination of a high lake level combined with excessive rainfall is highly unlikely, but not impossible.

Table 2.—PMF (1996) Study Results for Associated Floods

Monticello Dam PMF Hydrograph Summary						
Flood Description	Peak (ft³/s)	Volume (acre-feet)	Duration (hours)	Max WSE (feet)	Overtop Depth (feet)	Overtop Duration (hours)
Gen Storm PMF w/ 100-Year Rain – Reservoir Centered, Standard Arrangement	501,900	1,281,000	248	473.1	13.1	49.75
Gen Storm PMF w/ 100-Year Rain – Reservoir Centered, Front Loaded Arrangement	419,200	1,281,000	248	468.7	8.7	73
Gen Storm PMF w/ 100-Year Rain – West Subbasin Centered, Standard Arrangement	524,700	1,302,000	248	473.6	13.6	50.25
Gen Storm PMF w/ 100-Year Rain – West Subbasin Centered, Front Loaded Arrangement	434,800	1,302,000	248	469.0	9.0	73.75
Local Storm PMF – Reservoir Centered, Standard Arrangement	168,000	67,600	24	443.2	16.8*	0
Gen Storm PMF – Reservoir Centered, Front Loaded Arrangement	136,200	67,600	24	443.1	16.9*	0

* Denotes amount of freeboard left, no overtopping occurred.

Table 5.—Summary of Flood Routing Results from Reclamation (2005a)

AEP	Max RWSE (ft)	Peak Inflow (cfs)	Max Discharge (cfs)
1/100	447.1	60,981	14,361
1/200	447.8	73,887	16,728
1/5,000	453.3	155,173	38,987
1/50,000	459.1	240,133	47,106
1/10,000,000	473.9	524,700	50,486

1984 - 1986: Flood routing studies indicate the Probable Maximum Flood (PMF) would overtop the dam parapet walls by 7.7 feet (elevation 463.7') for 51 hours. Floods equal to or larger than 80 percent of the PMF will overtop the dam.

1996 - 2005: A flood routing of the 1996 PMF produced a larger estimate of dam overtopping for 66 hours with a maximum depth of 13.9 feet. Dam overtopping occurs for floods greater than about 51.5 percent of the PMF.