Dam Failure Study
At Glen Canyon Dam

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Note: This document is abridged

Purpose of Study

The purpose of this study is to estimate the magnitude of flooding that would result along the Colorado River from Lake Powell to Hoover Dam due to the failure of Glen Canyon Dam. This study was requested, pursuant to policy, by the Bureau of Reclamation. This information can be used in Reclamation's emergency action plan for Glen Canyon Dam, and as a reference in preparing inundation maps for areas downstream of the dam. It can also be used to help local authorities develop warning and evacuation plans.

Flood Scenarios Evaluated

The following two scenarios were considered to cover the range of events that could cause failure of Glen Canyon dam. Both scenarios represent worst-case scenarios that result in the largest uncontrolled releases of the reservoir. Various assumptions were made to help test the sensitivity of results to these assumptions.

1) Dam failure caused by foundation failure or other defect (Sunny-Day Failure). This scenario includes a 100-year base snowmelt inflow to Lake Powell.

2) Dam failure caused by overtopping brought about by the overtopping failure of Flaming Gorge Dam. This scenario involves an extremely large flood inflow to Lake Powell 580 miles upstream.

For this study, it was assumed that Flaming Gorge Dam would fail during overtopping. Should this overtopping failure occur with the starting reservoir water surface at normal capacity, a combined outflow of 5,320,300 acre-feet would result. With Lake Powell at its normal capacity (elevation 3700 feet), this combined outflow would exceed the available surcharge storage capacity at Glen Canyon by 2,498,560 acre-feet.

The flood forecasting computer program, BOSS DAMBRK (DAMBRK), was used to help prepare this study.

For the Sunny-Day Failure, the initial water surface for the computer model was assumed to be elevation 3711, which is the design maximum water surface at Lake Powell.

For the Overtopping Failure, the initial reservoir water surface for the computer model was assumed to be elevation 3700, or the top of active conservation pool. To determine the duration and magnitude of overtopping potential, a flood inflow hydrograph (due to the Flaming Gorge failure) was first estimated. The Dam Failure Inundation Study for Flaming Gorge Dam of January 1990, was used as a reference to help develop this hydrograph. Since that study ended at Green River, Utah (about 130 miles from the upper reaches of Lake Powell), peak discharges were extrapolated downstream to Lake Powell, and an estimated inflow hydrograph was generated using the Flaming Gorge failure volume (5,320,300 acre-feet). It would take roughly 34 hours for the maximum stage of the flood wave to arrive at the upper reaches of Lake Powell. Routing the estimated flood inflow hydrograph indicated that Glen Canyon Dam would be overtopped for a duration of about 40 hours, with a peak depth of 2.9 feet over the parapet wall. While it is unlikely this overtopping flow would cause the dam to fail, for the purposes of evaluating this scenario, failure was assumed.

Outflow assumptions prior to the Overtopping Failure were as follows. Measures would likely have been taken at Glen Canyon Dam to lower Lake Powell, probably by opening the spillways 2 to 3 hours after notification of the Flaming Gorge Dam failure. Upon arrival of the flood wave at Lake Powell, it was assumed that the spillway gates would be opened uniformly to the normal maximum discharge of 238,000 cfs.

Study Results

Evaluation indicates that the leading edge of the flood wave from Glen Canyon Dam failure would likely reach Diamond Creek (Mile 225) in 10 hours to 12 hours for either failure scenario. This converts to a flood wave travel rate of 20 miles per hour (mph). Arrival of maximum flood stage would occur about 20 hours to 22 hours after dam failure.

The leading, edge of the Overtopping Failure flood wave would likely reach South American Point (Mile 296) in 13 hours to 15 hours after dam failure. This equates to a flood rate in the upper reaches of Lake Mead of 17 mph to I8 mph. Arrival of maximum flood stage would occur about 19 hours to 20 hours after dam failure

The reason for the maximum flood stage times at South American Point being less than at Diamond Creek is likely due to a combination of at least two things: 1) a much shallower channel slope at the upper reaches of Lake Mead, and (2) the fact that the canyon cross section at South American Point is suddenly very narrow and creates a constriction producing some backwater.

The Overtopping Failure of Glen Canyon was routed through Lake Mead and Hoover Dam. The results were practically identical for the water surface elevations assumed for Lake Mead. Assuming Hoover Dam does not fail, overtopping would begin about 23 to 24 hours after the failure of Glen Canyon Dam, continue for about 258 hours (10.75 days), and reach a peak depth of about 68 feet over the parapet wall on the dam crest at hour 74. The depth corresponds to a maximum water surface elevation in Lake Mead of 1304 feet. Maximum discharges would be about 485,600 cfs through the river outlet works, powerplant, and spillways, and 2.02 million cfs over the dam crest. This makes a total discharge immediately downstream from Hoover Dam of over 2.5 million cfs.

Obviously any type of structure less than 400 feet to 500 feet above the Colorado River between Glen Canyon Dam and Lake Mead as shown on USGS topographic maps would be completely inundated and destroyed by the flood from either type of failure. Even Navajo Bridge, which is about 400 feet above the Colorado River, could be damaged or destroyed. Results indicate depths of around 500 feet at this location. Flooding of this altitude here in the

canyon would be very severe and lethal. Anyone still on the river at the time, would have to climb the equivalent of a 40-story building, at a minimum, to have any hope of surviving.

The study indicated that the travel rate for the leading edge of the flood wave was estimated to be 20 mph to 25 mph. Although there have been no dam failures of this magnitude observed, historically, these travel rates may be reasonable for this huge a failure outflow. Some flood wave travel times from other dam failures with similar downstream reaches include:

(1) St. Francis Dam, California, failed on March 12, 1928. Flows traveled 18 mph in the first 1.5 miles downstream from the dam. Peak discharge unknown.

(2) Hell Hole Dam, California, failed on December 23, 1964. Flows traveled 14 mph through the narrow and uninhabited rock canyon 56 miles to Folsom Reservoir. Peak discharge was estimated to be 260,000 cfs. Volume released was 24,800 acre-feet.

(3) Teton Dam, Idaho, failed on June 5, 1976. Flows traveled 19 mph in the narrow canyon for 2.5 miles and averaged 16 mph for the first 8.8 miles downstream from the dam. Peak discharge was estimated to be 2,300,000 cfs. Volume released was 251,700 acre-feet.

(4). Little Deer Creek Dam, Utah, failed on June 16, 1963. Flows traveled 18.9 mph for the first 2.2 miles downstream from the dam, Peak discharge was estimated to be 47,000 cfs. Volume released was 1000 acre-feet.

The study indicated that flood depths in the upper reaches of Lake Mead would progress 507 feet at river mile 238, to 246 feet at river mile 281.5 (approximate end of Pearce Basin).

More populated areas around Lake Mead that would be inundated include marinas, campgrounds, and other concentrations of population and activity. Water depths would be around 94 feet above the July target elevation of 1219.61 feet for Lake Mead.

Glen Canyon Dam Specifications

Structural height of dam: 710 feet
Hydraulic height of dam: 583 feet
Crest length of dam: 1560 feet
Crest elevation of dam: 3715 feet
Top of parapet wall: 3719 feet
Each spillway crest elevation: 3648.0 feet
Elevation top of gates: 3700
Combined spillway capacity at 3711 feet: 276,000 cfs
River outlet works: 15,000 cfs
Powerplant: 28,640 cfs
3711 feet (maximum water surface): 28,230,000 acre-feet
3700 feet (active conservation pool): 26,210,000 acre-feet
3490 feet (top of inactive storage): 5,905,000 acre-feet
(minimum depth for power generation)
3370 feet (top of dead pool) 1,906,000 acre-feet
(level below river outlets)
3132 feet (streambed at dam axis) 0 acre-feet

Table 1

Location (River Miles from Lees Ferry)	Summary of Data Ranges [A]				
	Water surface elev. [B]	Max. depth above water surface [B]	Arrival time of leading edge [C]	Arrival time of peak stage	Maximum discharge
-15.5 Glen Canyon Dam	3700 ft	11.0 - 21.9 ft [D]	0 hr	0 hr	18.0 - 19.2 (million cfs)
0.0 Lees Ferry	3115.5 ft	480 - 520 ft	0.6 - 0.7 hr	5.5 - 6.5 hr	10.0 - 14.7 (million cfs)
4.7 Navajo Bridge	3094.7 ft	470 - 530 ft	0.7 - 0.8 hr	5.6 - 6.7 hr	7.8 - 12.2 (million cfs)
87.0 Phantom Ranch	2428.5 ft	400 - 480 ft	4.0 - 5.5 hr	10 - 14 hr	7.0 - 11.4 (million cfs)
135.3 Granite Narrows	1947.5 ft	440 - 480 ft	6.5 - 8.5 hr	13 - 19 hr	6.9 - 11.2 (million cfs)
178.0 Lava Pinnacle	1680 ft	360 - 430 ft	8.0 - 11.5 hr	15 - 23 hr	6.7 - 11.0 (million cfs)
225.0 Diamond Creek	1327 ft	470 - 540 ft	10.5 - 15.0 hr	18 - 27 hr	6.5 - 10.7 (million cfs)
281.5 [E] End of Pearce Basin	1181 ft [F]	246 ft [G]	14.5 hr	20 hr	8.7 (million cfs)

Footnotes:
[A] Ranges cover extremes for both Sunny-Day Failure and Overtopping Failure plus extremes for Manning's n roughness assumptions.
[B] Water surfaces as shown on USGS 7.5 minute quadrangle maps.
[C] It should be noted that for the Overtopping Failure, major flooding will already be occurring prior to the arrival of the leading edge of the flood wave caused by dam failure.
[D] Depths at this section (the upstream face of the dam) are referenced above Lake Powell normal capacity water surface elevation, 3700 feet.
[E] Values for this location are only for flood from an Overtopping Failure.
[F] "Ballpark" estimate of channel invert for this study (due to accumulated sediments since 1964).
[G] Depth above estimated channel invert.

References

Stephen Latham, 303 445-2519

Peer reviewed by: Wayne Graham, 303-445-2553

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