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The 1983 Flood at Glen Canyon

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Powell reservoir first filled in June 1980, seventeen years after the diversion tunnels around the new dam near the lower end of Glen Canyon were closed. Brim full, the reservoir holds almost exactly two average annual flows of the Colorado River: twenty-seven million acre feet (An acre foot will cover one acre with one foot of water. A football field, minus the end zones, is about an acre). During the fill period most of the water had to be bypassed to meet downstream users needs, human as well as wildlife.

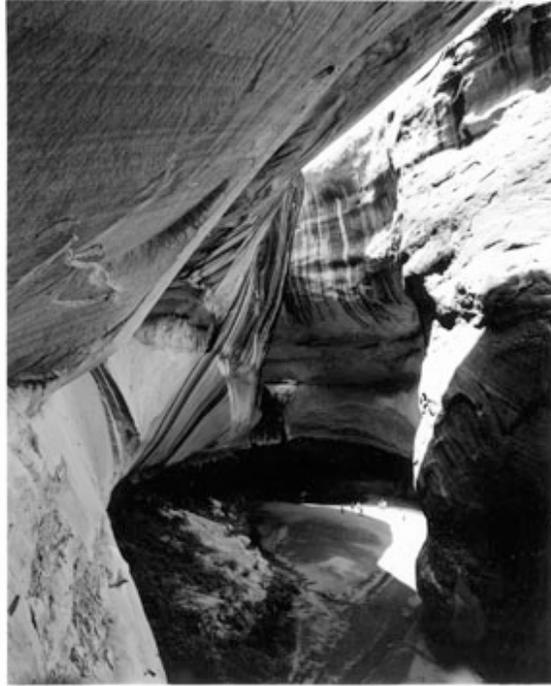
Glen Canyon Dam and its reservoir are managed to maximize electrical power production—a “cash register” that was intended not only to pay its own construction cost but also the costs of other Bureau of Reclamation structures in the Colorado River Basin. Accordingly, once the reservoir topped off, the Bureau has consistently interpreted the Congressional authorization for the “Glen Canyon Unit” as requiring Powell to be kept as full as Nature will permit. Under the government’s ideal scenario, in a non-drought situation, every year the spring runoff will just, exactly, fill the tank again. The snowpack in the mountains ringing the Colorado River Upper Basin is monitored and educated guesses are made about late spring precipitation events.

In early May 1983 the Bureau found itself with too much water in Powell Reservoir. Winter had lingered unusually long and cold in much of the high country, and the government’s runoff modeling was, to be kind, inaccurate. Then it suddenly turned warm and rain began to fall over much of the 108,000 square mile basin above the reservoir. For the first time other than for brief tests, the dam’s spillways had to be placed in service.

Many dams have simple over-the-crest spillways, but large dams, particularly ones with their powerplants located at the toe of the dam, must route overflows around the structures. The Bureau’s first big dam, Hoover, built in the 1930s, uses tunnels. Glen Canyon Dam was designed in much the same way, incorporating portions of the river diversion tunnels that had to be constructed around the dam site to manage the river during construction. It was an efficient arrangement, therefore appealing to the engineers, because the diversion tunnels could be partially utilized for the lower ends of the spillways. The downside, however, is that tunnels have a finite capacity. Boring two or three thousand feet of tunnel through rock is time consuming and expensive, so the tunnels were sized in a tradeoff between anticipated flood flows and cost.

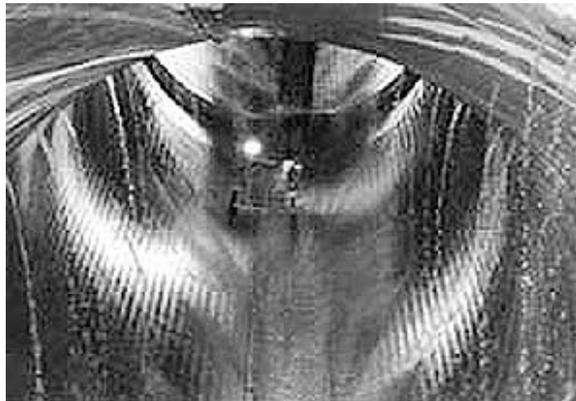
The tunnel spillways at both Hoover and Glen Canyon are not designed to run full, for then they would be under pressure, like water pipes. In fact, the tunnels are intended to operate like covered flumes, with a minimum 30% air gap, at atmospheric pressure, throughout their lengths. The design capacity of the combined spillways at Glen Canyon is 276,000 cubic feet per second when the reservoir is full. Historic flows in the Colorado at Lees Ferry (fifteen miles downstream from the dam) have often exceeded 200,000 cfs, and there is strong evidence, from debris found at the time Hoover was surveyed, that flows through the Grand Canyon have exceeded 400,000 cfs.

When the Upper Basin decided to relieve itself purposefully in late May 1983, the Bureau began to bypass a few thousand cfs. To do so, the spillways’ radial gates were raised, permitting the water to flow under their lower edges and down the tunnels. Each tunnel carried the water down at a 55 degree slope through a smooth curve into a horizontal section that was part of the original river diversion tunnel in both abutments. Each diversion tunnel was plugged at the point where the descending spillway curves into the horizontal section. (Behind each plug is the water pressure at the bottom of the reservoir: 250 pounds per square inch with a full reservoir.) At the end of each tunnel, the 120-mph jet of water was directed away from the canyon wall and deflected upward by a 40 degree ramp to dissipate much of the water’s energy before it hit the river.



June 10, 1965. Bureau of Reclamation visits Cathedral in the Desert just as reservoir begins to enter. Photograph by Mel Davis, courtesy US Department of Interior, Bureau of Reclamation.

The spillways had only operated for a few days when a slight rumbling and vibration began to be felt in the abutments and the dam itself. Close inspection of the jets emerging from the tunnel portals revealed some debris being ejected in the flow: chunks of concrete, sections of rebar, and, most disturbingly, what looked like pieces of sandstone, arced high above the river. The tunnels had run only briefly at 20,000 cfs and had been throttled back to 10,000 before they were shut down. Since the reservoir was still below the tops of the radial gates, the gates were shut and inspection teams descended into the tunnels in a little cart eased down the 55 degree slopes by a cable. The cart was named the "I Challenge U2."



"I Challenge U2", descending left spillway. Air slot is just above cart. Photograph courtesy US Department of Interior, Bureau of Reclamation.

Right at the curves in both tunnels the three-foot reinforced concrete lining had been eroded away, in a stair-step fashion, and the much softer and porous (20-25% void) Navajo sandstone was exposed. Meanwhile, the reservoir was beginning to rise more quickly as the steady rains and melting snows obeyed the law of gravity. The Bureau had no choice but to reopen the spillways—and increase the flows. The engineers decided to hold the right tunnel somewhat in reserve and pass most of the swelling reservoir down the left tunnel. They were already running as much water as they could through the power turbines and the river outlet works, the former about maxed out at 28,000 cfs and the latter limited to 15,000 due to a design deficiency in its expansion joints. Still the reservoir surface climbed as the rains

continued and the snow fields melted. The vibration in the dam and abutments had now become a steady shaking, accompanied by sharp jolts and rumbling sounds. Four-foot-high wooden flashboards were then installed on the tops of the spillway gates—to permit the reservoir to rise higher without having to open the gates further.

By the time the left tunnel was up to 12,000 and the right at 4,000, another “event” occurred. The smooth sweep of water at the left tunnel outlet was replaced by a surging, boiling flow that filled the portal. Obviously, the engineers concluded, the damage had gotten so bad that a “hydraulic jump” had been created. The tunnel was being converted into a pressure conduit. This was bad. Very bad. The sweep had to be restored and the only way to do it was to increase the flow. But the increased flow would intensify the rate of damage. Soon the flow at the right portal lost its sweep, so its flow also had to be raised. In the meanwhile the fronts kept coming. The National Weather Service predicted increasing rain storms in the Upper Basin.

Shortly, the water level was so high that the gates could no longer be shut. The flimsy flashboards would be overtopped and quickly carried away, sending a massive, uncontrolled, and prolonged surge from 190 miles of reservoir down each tunnel.

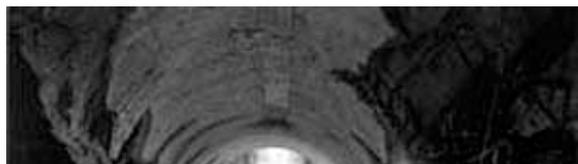
In a demonstration of astonishing bureaucratic efficiency, the Bureau designed, built, and attached eight-foot steel flashboards to the tops of the gates in just a few days. Still the reservoir crept toward the crests of the new boards as the rains continued without relief and the snows disappeared with the rain. By the time the left tunnel was running at 32,000 its discharge was turning the whole river below the dam a distinct amber color. Navajo sandstone was being excavated from within the dam abutment like soil before a placer miner’s hydraulic nozzle. Down in the employee dining room, located at the base of the dam adjacent to the left abutment, a worker later said that it sounded like the artillery barrages he had experienced in Viet Nam. Everyone was “pretty nervous and on edge” he said.

The integrity of the dam itself was never really an issue, even for the most timid hand-wringer in the Bureau’s engineering staff in Denver. But what was of growing concern, and not even hinted at in public statements both during and after the flood, was the possibility that the plunging water, now working on the abutment at 1,000 tons per second, would erode enough sandstone from around the diversion tunnel plug in the left spillway that there would be a connection to the bottom of the reservoir. There would be no way to stop the high pressure leak that would uncontrollably grow in volume as it cut like a liquid laser through the aeolian rock. The whole reservoir would drain. No more water skiing. Besides the rain and snowmelt, over the course of a month or two the entire 27 million acre feet behind the dam would be sent on its way to the Gulf of California, in the process taking out much of the riverside municipal development, from Laughlin to Yuma, and all the rest of the dams down the river—except Hoover. Wedged into Black Canyon’s concrete-like andesite breccia, Hoover is so over-designed that it could withstand a prolonged and extreme overtopping.

All the early flood flow in 1983 was contained behind Hoover because, unlike Powell, Mead Reservoir is required to maintain at least five million acre feet of flood storage space. But as the flood persisted, the Lower Basin bosses at Boulder, Nevada, were obliged to open the spillways on their old art deco dam. Lowland flooding occurred from below Bullhead City to beyond the Parker Strip as the discharges from Hoover rose to over 40,000 cfs.

The total discharge from Glen Canyon peaked at 92,000 cfs and the reservoir topped out on July 15, lapping less than a foot below the tops of the steel flashboards and only six feet below the crest of the dam. Inspection of the left tunnel revealed a hole carved into the sandstone at the tunnel plug nearly 50 feet deep and 135 feet long. A ten by fifteen foot boulder was found halfway down the tunnel beyond the hole. The right tunnel had similar but less severe damage. One-inch rebar had been pulled out of the concrete like bones from a cooked fish.

Once the sweat dried out of the Bureau engineers’ suit jackets, they confidently announced that there really never had been any problem. But later rumors and leaks were to the effect that had the series of storms continued into the peak of the snowmelt hydrograph, given the rate of excavation of sandstone near the plug in the left tunnel, there was a “significant” chance that a leak from the bottom of the reservoir would have occurred. The recognized existence of a number of joints and seams in the left abutment, possibly opened up by the weeks of shaking, could have helped create the leak.





July 7, 1983. Flashboards, Right Spillway; original 4 feet on right, 8 feet on left. Photograph by Tom Fridmann, courtesy US Department of Interior, Bureau of Reclamation.



September 21, 1983. Left spillway; view upstream across "Big Hole". Photograph by Tom Fridmann, courtesy US Department of Interior, Bureau of Reclamation.

A year after the flood, the Bureau firmly declared that the "cavitation" that had started the damage, that soon turned into rapidly increasing mechanical erosion, had been dealt with. After the damage was repaired (2,300 cubic yards of concrete), the fix consisted of cutting an annular slot, four feet by four feet, around three-quarters of the bore in each tunnel, located halfway down the inclined section. The cavitation had started because there was no air in the water. Minute vacuum bubbles downstream of bumps and ridges in the tunnel linings had imploded, starting the cavitation that, in turn, led to cratering. Air will now be entrained in the flow as it goes over the slot and this will provide a "cushion" to prevent cavitation from starting. Okay, but what if the tunnels have to run so full that much of the air will be cut off? That cannot happen, say the keepers of the dam.

Meanwhile, the Bureau is maintaining the reservoir as full as it can each year, keeping the cash register running with as much back-up hydraulic head as possible. And as time goes on, we're learning more about how the canyon country formed: steady erosion—"uniformitarianism"—to be sure, but an increasing number of knowledgeable folks are saying that thousands of severe floods—"catastrophism"—really sped up the process.

So, the Bureau of Reclamation got away with one in 1983. No one can know, but perhaps in near-term, non-geologic time Nature will decide to take another crack at the plug in Her river canyon.

Steven Hannon is the author of [Glen Canyon](#), a novel inspired by the 1983 flood. The book contains expanded documentation, including numerous photographs, of what happened sixteen years ago at Glen Canyon Dam, and is available through Glen Canyon Institute.