The Little Deer Creek Dam Failure

A Forensic Review of a Fatality

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Utah Dam Safety

As the dam breach flood waters crashed down on four year old Bradley Gale Brown early on Sunday morning June 16, 1963, he had no idea that there was a brand new, but defective dam only 5 miles upstream from his family. This dam had just failed catastrophically, on its first filling, sending 8 million gallons per minute downstream. While his father frantically moved the station wagon full of some of his sleeping family, he could not imagine the magnitude of the flood that was sweeping the adjacent tent full of young boys down the river. Bradley's older brother survived but had to go to the hospital after the incident. His two friends swallowed copious amounts of water and sand but were uninjured. Bradley (pictured here) was not so fortunate; he became the first dam failure casualty in Utah history. Bradley would be 45 today (2004), if he had survived.

Bradley Gale Brown

When the Browns selected the campground on the Duchesne River in the Uinta Mountains, 50 miles east of Salt Lake City (Figure 2), they had no concept that they were camping at the headwaters of a tributary to the mighty Colorado River. Years before the Depression, the Colorado River waters had been politically appropriated among the contiguous states. With the Colorado River Compact, the participating states were finally taking their designated share of the water. The young family was unaware of the plan, devised years before the Second World War, to divert some of Utah's share of the Colorado from the river's natural basin towards

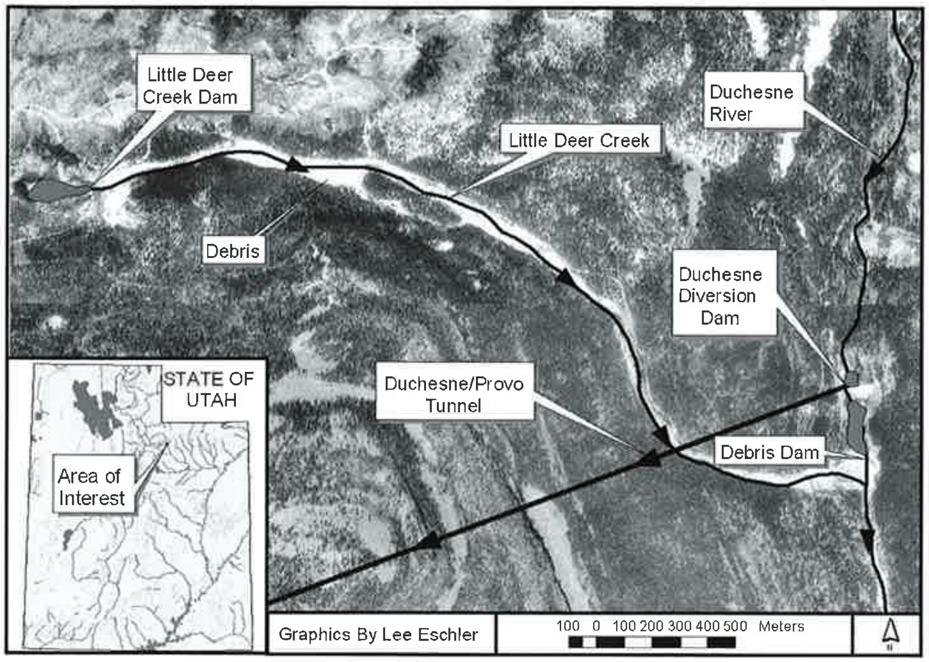

Figure 2: Aerial View of Little Deer Creek to Duchesne River

the Provo River and Salt Lake City. There was no Economic or Environmental Impact Assessment, no Hazard Assessment or Risk Analysis, and no Standard Operating Procedures or initial filling plan devised for the Little Deer Creek water project. There was no Emergency Action Plan, Inundation Study or Evacuation Plan prepared in case of an accident at the dam. It was the early 1960s, when John Kennedy was President and the country still enjoyed a post war confidence and prosperity. These were heady times when seemingly infallible scientists and engineers ruled the country, putting a TV in every home, a man in outer space, and a dam on every river.

The Little Deer Creek dam was part of the Kamas Water Project, conceived in 1944 and eventually approved by the Utah State Water and Power Board in 1958. The dam was planned in conjunction with the Duchesne Tunnel project that piped Colorado River water to the Provo River. Little Deer Creek was a small tributary to the upper Duchesne River. These tributary waters could be collected, stored and diverted to flow through the tunnel after spring runoff, with the construction of a 1,500 acre-feet in stream reservoir behind a 75-foot high dam perched at elevation 9,000 feet. The Duchesne Tunnel was already functioning at its design capacity in 1958, diverting as much of the peak snowmelt runoff as it could handle. The Provo River was showing the effects of this additional water and energy on the natural peak spring runoff flows which caused the adjacent landowners to justifiably fear flooding, bank erosion and destabilization of the river. Flows from the adjacent Weber River were also added to the Provo and a protective dike system was consequently constructed to contain the additional flows, which further exacerbated the destabilization of the river. Upstream storage on the Duchesne would allow diversion of snowmelt water during the summer months when flows in both rivers declined substantially and additional waters could help the wildlife and the riparian environment.

The three pages of the dam's design drawings, prepared in 1961, were based on only three test pits and three drill holes. The simple homogeneous design included a 3-foot deep cutoff, an 18-inch reinforced concrete culvert in a concrete cradle, and a spillway over the left abutment. Elvon Bay was the site engineer for the State Water and Power Board and recorded the construction log. The Weyher Construction Company won the bid and began work late, in August of 1961, after finally receiving design approval from the State Engineer. Wayne Criddle. Les Staples was the job superintendent for the Weyher

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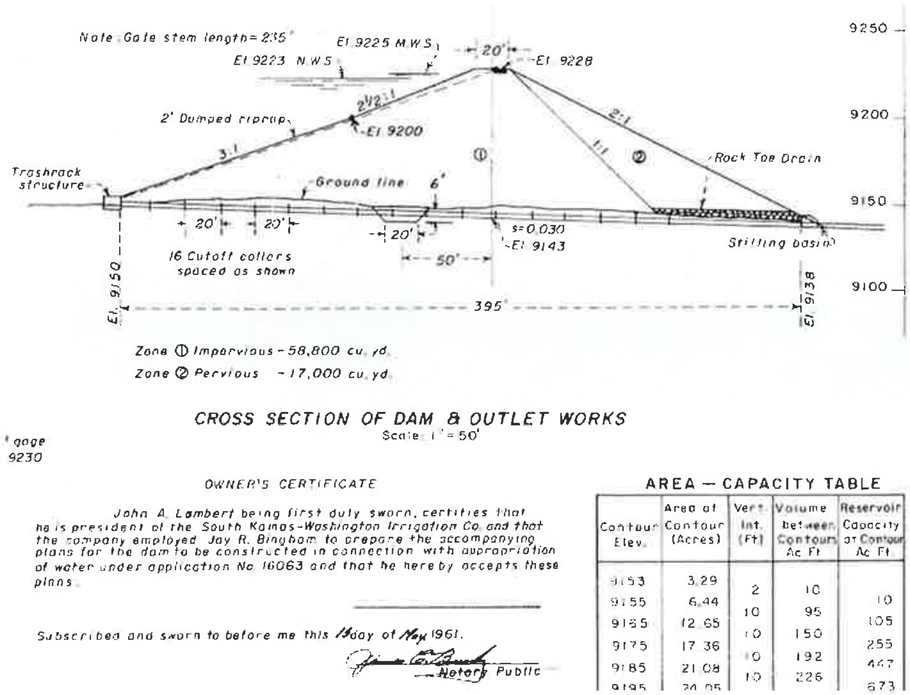

Figure 3: Profile of Maximum Section of Dam by Utah Water and Power Board Design Drawing (1961). Note: Actual Section Built was a Homogeneous Section

Company. The earthwork subcontractor was the Berquist Construction Company, represented by John Mills.

The autumn of that year was especially inclement and the contractors worked in difficult, wet and cold, early winter conditions. The construction log made many references to the freezing weather, the wet fill, the jointed and fractured condition of the rock on the right abutment, the probability that it could seep and pipe, the inadequate cutoff (bedrock was 17 feet deep) and the lack of structural integrity of the outlet pipe. The US Soil Conservation Service, in their review of the dam, made several comments about the design and recommended a drainage system on the seep area on the right abutment (Figure 3). During the first construction season, water was noted flowing from the right abutment downstream of the dam but it was determined that it was "not to be coming from the dam." This water, however, was noted to be flowing with a muddy color, the color of the fill material of the dam. Instances were noted of the placement of wet, sloppy fill during rain and snow events with moisture as high as 16.8 percent.

Instructions were given to leave rocks in the wet fill, not to over compact, to place fill in 1-foot layers and compact to 95 percent density. This was later reduced to 92 percent density and 9 percent moisture, not the design tested optimum of 6 percent. Work was stopped on October 26, 1961 because of bad weather and wet fill conditions. The outlet gate was not installed and the reservoir did not fill that first year. Heavy snows closed all the roads a few days later; and some of the work crews barely got off the site before winter set in.

In July 1962 work began anew after melt-off and the downstream dam face, or "backside," was described as "spongy" with a small slump formed in wet material, emanating either from a seep or a snowdrift. A serious shear zone was defined, removed and recompacted. Although the dam appeared in "rough" condition, the dam builders confidently said they could repair the slump, re-compact, and make the dam structurally safe. A spillway was dug from the natural ground on the left abutment and coated with rough concrete on the right (dam) side of the channel to a point where it passed the downstream toe of the dam and dropped steeply down the slope to the main channel. A large section of the reservoir basin and right abutment were cleared of trees. There was a small stream/spring noted entering the reservoir just upstream of the dam. A diversion was made from lower Little Deer Creek to the entrance of the Duchesne tunnel. The outlet gate was installed and closed. The dam was completed that autumn (1962) at a cost of approximately $100,000.

The dam failed during its first filling in the Spring of 1963 with the water at elevation 9,215 feet, or 62 feet on the concrete stage gage, with 1,200 acre-feet in the reservoir, inundating over 29 acres of surface area. The spillway elevation was 9,223 feet, with the top of the dam at 9,228 feet. Breach times were recently estimated at between 1.0 - 1.5 hours, with maximum flows estimated at between

14,000 and 17,000 c.f.s. The final breach was 80 feet deep and 75 feet wide and extended below the dam to bedrock 17 feet below (Figure 4). Downstream damage was extensive and is still visible today. There was a scouring of the immediate downstream toe area, followed by several acres of deposition above a grade control rock out-crop where pieces of the outlet remain. Downstream of this grade break, is another steep, scoured channel that dumps into the much flatter Duchesne River, downstream of the diversion dam for the Duchesne Tunnel. There is a huge debris deposit at the confluence that backs up a small lake/wetland area to the base of the diversion dam. After the dam failed the flood waters took 5 hours to reach the towns of Hanna and Tabiona, 15 miles away, and roughly 12 hours to reach the town of Duchesne, 45 miles away. It was reported that 10 out of 11 bridge crossings on the Duchesne River were washed away with the flood and there was also minor damage to farms next to the river. It also inundated the small Ashley National Forest campground on the Duchesne River. The bridge repairs were estimated at $190,000, the Browns filed a claim for $31,000; additional claims totaled $96,000. No civil suits or criminal charges were ever filed and no licenses were reviewed or revoked on account of this failure. There have been several other catastrophic dam failures in the state of Utah, with two other related

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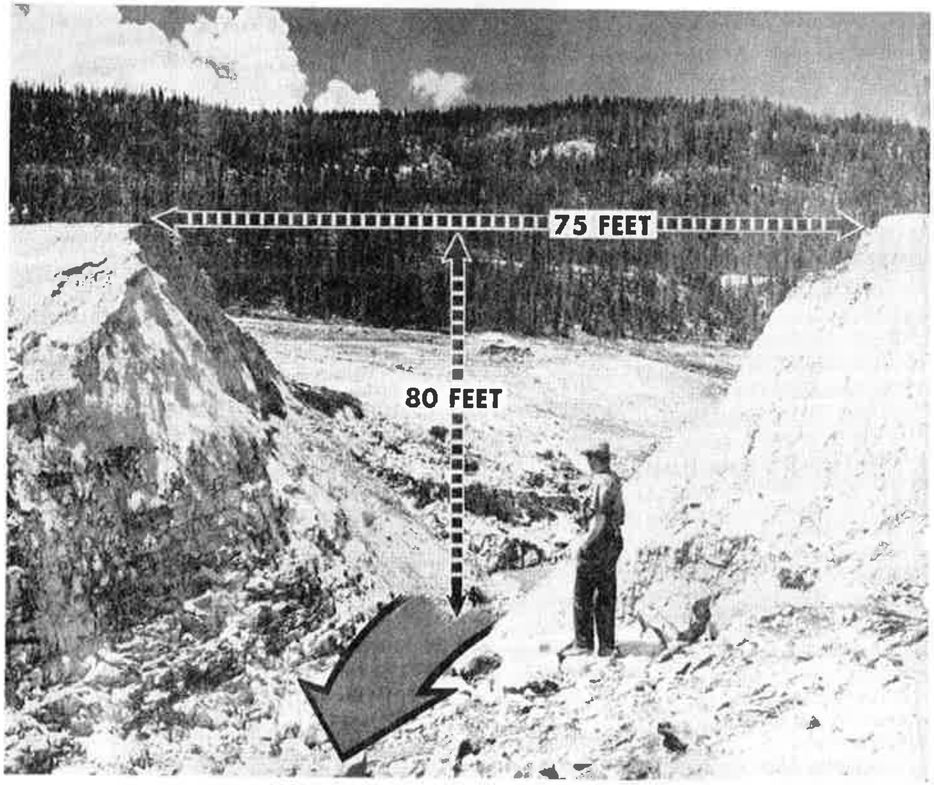

—Tribune Photo by Don Brooks

A raging torrent of water which took the life of a young boy and did extensive damage in Duchesne County poured through this gap in the Little Deer Creek Dam which is checked by District Forest Ranger Larry Colton. The earth-filled dam was completed during the past year.

Figure 4: Breach Opening. Salt Lake tribune, June 18, 1963.

fatalities, but this failure was perhaps the most costly.

Today, the remnant of the Little Deer Creek Lake has a small, natural grade control at the outlet and supports a healthy lake, wetland and littoral area (Figure 5). Moose were feeding in the lake as I performed the forensic reconnaissance in August 2002. The clearing originally done for the lake was evidenced only by the age of the younger trees growing below the old high water line. The stream flowing from the right abutment near the outlet intake was flowing 1 c.f.s. and an adjacent spring was flowing 5 - 10 g.p.m. during the latest visit. A complete section of the dam embankment, with a vertical face, remains on the right abutment but the left side of the dam has been completely removed. The most striking features of the small piece of the old embankment are the sandy gravel matrix with very little minus No. 200 sieve, excessive amounts of 3 - 6 inch cobbles and boulders as big as 3 - 10 feet in diameter. There is a slump on the right side of the remaining crest over the right abutment. The maroon quartzite, visible on the right abutment, is highly fractured and jointed with intermediate green siltstone layers every 8 - 12 inches. The main open joint patterns trend steeply downstream at approximately the slope

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Figure 5: Remnants of Dam in 2002 Looking Upstream
Note: Left Abutment Spillway Channel at Top Right in Photo

of the stream and appear to be at a favorable piping orientation. A piece of the old spillway structure remains high and dry on the left abutment, with a "Utah State Engineer" survey monument embedded in the concrete. A 72-foot section of the storage gage remains on the upstream left abutment; the borrow pit of the right abutment still contains an old culvert and plow blades.

The Fuhriman and Rollins Engineering Company prepared a report on the failure in November of 1963. This report cited seepage, through the unsealed and unfiltered right abutment, as the probable cause of failure. Attorney's briefs concerning the case also noted the wet weather, wet fill, insufficient cutoff, large boulders in the fill, insufficient bedrock preparation and a change in the specification from a zoned embankment to a homogeneous embankment. Optimum densities of the embankment soils tested after the failure were 137.8 lbs./cu. ft. and 6 percent moisture; more dense, dry and closer to optimum than those tested during construction. From the lateness of the dam design submittal and approval that delayed construction until August, to the bad weather encountered during construction, a series of mistakes, oversights and natural conditions contributed to the failure. The design and exploratory testing were marginal, the site preparation was minimal, the construction quality was questionable and the condition of the bedrock was underestimated. The dam was built 17 feet above bedrock with only a 3-foot cutoff and the right abutment was not blanketed, drained or filtered. Large boulders and wet soil further compounded the probability that something catastrophic could happen. Seeps and slumps after the first winter gave clues that something was not right, yet only Band-Aid solutions to these problems were implemented.

One mistake is usually not enough to cause a catastrophic failure of a modern earthen dam, given the redundancies of the design as well as the large factor of safety attributed to the materials and dam geometry. Earthen dams are usually very flexible and forgiving, provided that they are built properly out of the correct material and that seepage is properly collected, controlled, filtered and conveyed away from the dam. Most likely, it was a combination of several small deficiencies that caused the ultimate failure of Little Deer Creek Dam. Perhaps it was overzealous water resource development, bureaucratic delay, unfortunate weather, inexperienced personnel, budget constraints, unfavorable site conditions, ego, arrogance or our consistent underestimation of the patience and power of water.

The problem with dam breach forensics is that most of the evidence is flushed downstream. Hindsight is 20-20 but sometimes we don't know what we don't know. The remains of Little Deer Creek Dam still stand as a monument to the delicate humanity of Bradley Gale Brown, to the humility of the men who built it, and as a warning to future generations to respect the strength and complexity of nature. Hopefully we learn from our mistakes, ideally before we repeat them.