THE INFLUENCE OF DAM FAILURES ON DAM SAFETY LAWS IN PENNSYLVANIA

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Abstract

The origin and evolution of Pennsylvania's dam safety laws are intertwined with three historic dam failures. The 1911 failure of Austin Dam resulted in 78 deaths and lead to the passing of the nation's first dam safety law in 1913. In 1977, the failure of Laurel Run Dam near Johnstown resulting in the deaths of 40 residents, lead to the passing of Pennsylvania's Dam Safety and Encroachments Act in 1978. What is interesting is that these two dam failures are generally less well known than the 1889 failure of the earthen South Fork Dam near Johnstown, Pennsylvania which caused the infamous Johnstown flood, killing 2209. Although the magnitude of this earlier dam failure was clearly more significant, at the time it occurred in the 1880s the response calling for dam safety laws to protect the public was still in its infancy, and no laws were enacted. The development and evolution of Pennsylvania's dam safety laws is directly related to these three significant dam failures that resulted in substantial loss of life.

Introduction

Pennsylvania has an unfortunate history of dam failures resulting in significant loss of life and property. The 1889 failure of the earth embankment of the South Fork Dam near Johnstown resulted in 2209 deaths and is still the worst U.S. dam disaster in terms of loss of life. This tragedy, however, did not result in the establishment of any laws regarding dam safety in the Commonwealth. Twenty-two years later in 1911, the failure of Austin Dam in Potter County claimed 78 lives. As a result of this failure, in 1913 Pennsylvania became the first state to enact dam safety legislation. Pennsylvania's dam safety laws remained unchanged until 1978 when Pennsylvania's Dam Safety and Encroachments Act (Act 325 of 1978) was enacted. The legislative action of 1978 came soon after the 1977 Johnstown flood in which Laurel Run Dam failed claiming 40 lives. Why the 1889 South Fork Dam failure did not directly result in legislation but the 1911 Austin Dam failure and 1977 Laurel Run Dam failure did is of interest from an historical perspective. Figure 1 shows the locations of the three dam failures discussed in this paper.

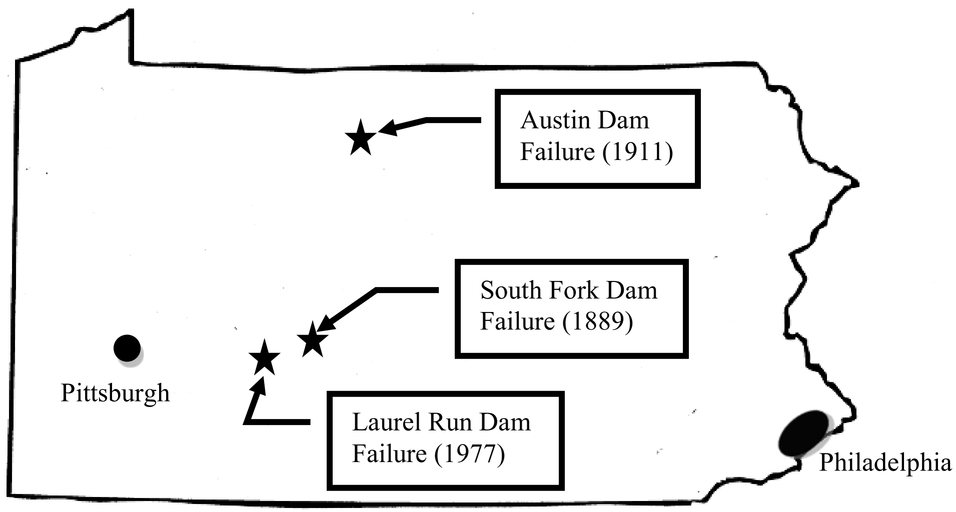

Figure 1. Location of dam failures discussed.

1889 Failure of South Fork Dam

The failure of the South Fork Dam and the resulting story of the Johnstown Flood have been documented in great detail by McCollough,[1] as well as on the Johnstown Area Heritage Association[2] (JAHA) website. Frank[3] also provides a description of the design and construction of the dam. Originally constructed in 1852, the South Fork Dam created a water supply for the western division of the Pennsylvania Canal. The canal ran from the western terminus of the Allegheny Portage Railroad at Johnstown to Pittsburgh. By the time of its completion, however, the state-owned canal and portage railroad system were essentially obsolete. The completion of the private Pennsylvania Railroad (PRR) in 1852 made travel faster and less expensive than the canal and portage railroad and by 1854, the portage railroad and canal were closed. Eventually the state sold the whole system to the PRR in 1857, including the South Fork Dam.[3]

According to Frank,[3] the original earth and rock fill dam was 72 ft high and 918 ft long with a width of 10 ft at the crest and 220 ft at the base. A stone lined culvert and control tower with 5 valves was included to release water to the canal, as needed. An 85 ft wide spillway was cut through rock on the eastern abutment. With little to no maintenance, in 1862, a portion of the culvert collapsed causing a portion of the dam to be washed out. The dam and surrounding land were purchased in 1879 by Benjamin Ruff. His plan was to repair the dam and create a mountain retreat for the wealthy. He convinced prominent Pittsburgh industrialists, such as Andrew Carnegie, Henry Clay Frick and Andrew Mellon to invest in the enterprise and chartered it as the South Fork Fishing and Hunting Club. After some difficulties, the dam was repaired, but not to a properly engineered state. Fill materials used in the washed out section were whatever was available. A subsequent washout occurred during construction and finally a man with railroad embankment construction experience was hired to complete the repairs. The collapsed outlet tunnel however, was not replaced so no outlet works were provided to drain the lake. The crest was widened to allow two carriages to pass by cutting down the height of the dam thereby reducing freeboard and spillway capacity. In addition, fill used to repair the collapsed culvert also settled creating a low point along the dam crest near the center. By the summer of 1881 the repairs were complete, the lake was stocked with fish and, the club opened. To access the club, a bridge with supports was built across the spillway and mesh screens were installed between the bridge supports to prevent loss of valuable game fish over the spillway.

The dam failed on May 31, 1889 after a period of heavy spring rain. With no outlet or means to lower the lake level, a spillway partially blocked by fish screens, a lower spillway capacity due to the cutting down of the dam crest and the low point of the crest near the center of the dam due to settlement, the conditions were perfect for disaster.[3] The sustained heavy rains had saturated the ground and the runoff from adjacent hillsides filled the lake beyond its capacity so that eventually the dam was overtopped and washed away releasing 20 million tons of water from Lake Conemaugh into the Little Conemaugh River to descend on and destroy Johnstown. Figure 2 shows a contemporary map of the the Conemaugh valley and nearby Johnstown published after the flood.[2] Figure 3 shows a photograph of the dam area after the failure with the location of the failed dam indicated.[2]

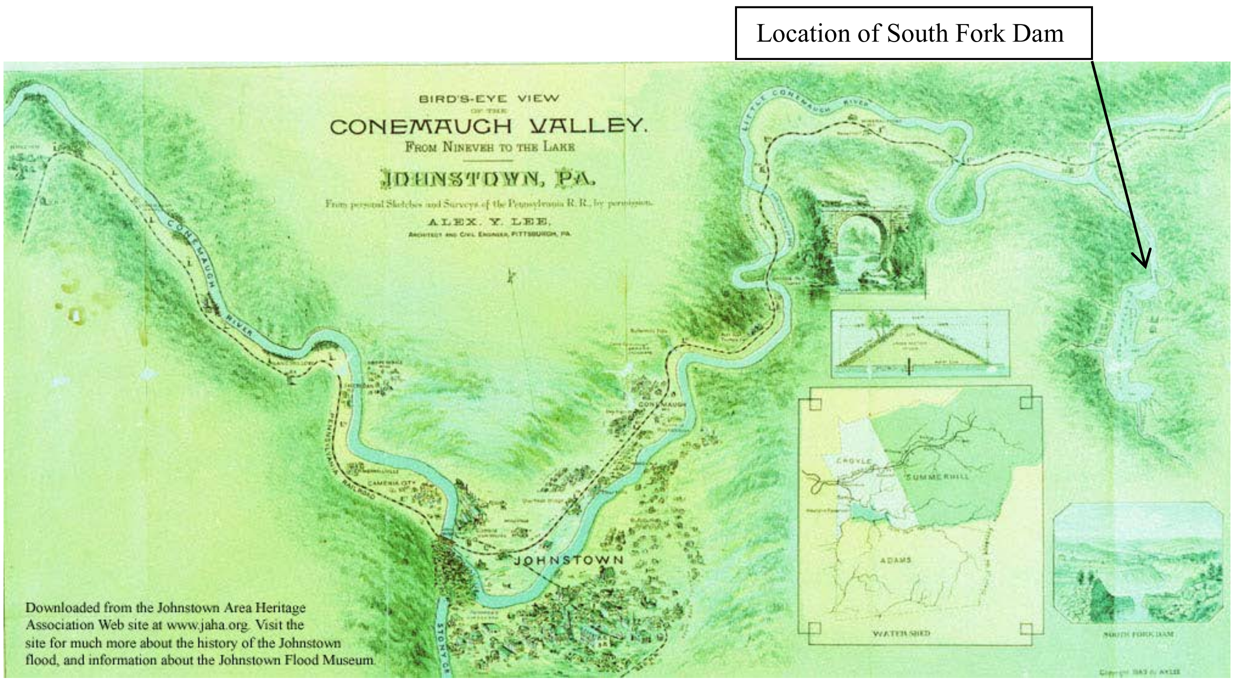

Figure 2. Contemporary map of Conemaugh Valley and Johnstown (Courtesy of the Johnstown Area Heritage Association).[2]

The flooding of Johnstown as a result of the South Fork Dam failure claimed 2209 lives. The nation took a compassionate interest in the Johnstown disaster. National newspapers sent reporters to cover the tragedy and the relief effort. Clara Barton who led battlefield relief efforts during the Civil War, brought in American Red Cross workers to provide their first major peacetime relief effort.[2] Some newspaper reporters covering the disaster exaggerated details of the disaster, while others repeated unfounded myths, generally to draw in readers and sell newspapers.[2,4]

The local *Johnstown Tribune* newspaper, however tended to be more balanced in its reporting and did not sensationalize the event, as other newspapers did.[4] Its reporting has been identified as providing needed information to the survivors and helping the community unite in the face of tragedy.[4]

Contemporary magazines, such as Harpers Weekly, included sketches and stories on the Johnstown disaster, as shown in Figure 4.[2] And a satirical magazine of the times, *Puck*, published a cartoon, shown in Figure 5, indicating the opinion of many regarding the South Fork Fishing and Hunting Club and the Johnstown flood.[2]

Figure 3. Remains of failed dam with original dam profile shown (Courtesy of the Johnstown Area Heritage Association).[2]

Figure 4. Contemporary illustration from Harpers Weekly showing the failed dam (Courtesy of the Johnstown Area Heritage Association).[2]

The cartoon in Figure 5 depicts a group of wealthy club members, considered “robber barons” by many for their wealth gained through various exploitations of the common people, enjoying themselves on the lake retained by the “high tariff dam” that is leaking and about to burst onto the industrial town below.[2]

According to JAHA,[2] The overriding sentiment was that the South Fork Fishing and Hunting Club was responsible for the devastation in Johnstown. As interest in the relief effort and stories of survivors subsided, new interest developed in investigating the cause of the disaster. Over time Johnstown residents and many Americans began expressing wrath toward the South Fork Fishing and Hunting Club and its members. National newspapers continued to hold the club responsible, but few ventured to mention club members by name. Some club members contributed to the relief effort at various levels, but no club member ever indicated they felt any personal sense of responsibility for the dam failure. Although lawsuits against the club were filed, the power and influence of club members is felt to have played a role in none of the lawsuits being successful.

Figure 5. Satirical Cartoon from *Puck* magazine (Courtesy of the Johnstown Area Heritage Association).[2]

At issue in the lawsuits was whether the South Fork Fishing and Hunting Club was legally responsible for damages and destruction caused in Johnstown due to the failure of its dam. In Pennsylvania's courts at the time of the dam failure, it would have to be shown that the Club was at *fault or negligent* in some way, leading to the failure of the dam. While today it would appear that their poor reconstruction of the dam and improper maintenance would indicate negligence, at that time it was not interpreted that way in Pennsylvania's courts.[5] The courts saw the failure of the dam as an act of God, with no fault being placed on the club or its members.[2] What had not been established yet in Pennsylvania's courts was the principle of *strict liability.* In England, however, in the 1860's, a dam used to supply water to a textile mill burst causing flooding in a neighbor's underground mine workings. In *Rylands vs. Fletcher*, the English courts found that the dam owner was liable for the damages to the neighbor's property even though no negligence was indicated.[5,6] Some U.S. courts adopted the notion of strict liability as a result of *Rylands vs. Fletcher*, but Pennsylvania did not. However, the Johnstown flood did influence the adoption of strict liability in other states and eventually in Pennsylvania in the 1890's.[5]

JAHA[2] notes that the Johnstown flood of 1889 resulted in the first widespread feelings of outrage toward industrial companies and powerful trusts that were gaining control of the US economy in the period following the Civil War. As the nation transitioned from an agricultural society to a more industrialized economy, the livelihood of the people was gradually being taken over by industrialists and their associated ventures. While the Johnstown flood brought on a feeling of outrage, it did not reach the breaking point that would follow in later years.

1911 Failure of Austin Dam

The town of Austin in Potter County Pennsylvania was the site of a catastrophic dam failure on September 30, 1911 when a concrete gravity dam constructed across Freeman Run slid on its foundation and broke apart.[7] The flood waters destroyed the towns of Austin (pop. 3,200) and Costello (pop. approx. 400-500) and claimed 78 lives.[8] Figure 6 shows the strikingly visual reminder of the 1911 Austin dam failure.

Located near the headwaters of the Allegheny, Genesee, and Susquehanna Rivers, Freeman Run flows from the north through Austin and then south and east reaching the west branch of the Susquehanna via the Sinnamahoning River.[9] The early industries of Austin focused on lumbering in the nearby hills. As the hardwood resources were depleted, new industries were able to use the waste materials and new growth for pulp and paper making.[8] Located on Freeman Run, the town was home to the Bayless Paper Mill. Established in 1900 by George C. Bayless of Binghamton, NY, the company had constructed a small dam further upstream on Freeman Run. By 1909, the existing reservoir was deemed inadequate and the company decided to construct a new concrete gravity dam. Bayless hired engineer T. Chalkley Hatton of Wilmington, Delaware in early 1909 to design a new dam across Freeman Run. Dam construction began in May 1909 and was completed about December 1, 1909. The contractor was C.J. Britnall & Co. of Binghamton, NY. The construction involved 7,925 cu. yds. of foundation excavation, 6,360 cu. yds. of embankment, and 15,780 cu. yds. of concrete. The total cost was $71,821.48, not including engineering.[10] Figure 7 shows the dam under construction. The 540 ft long, 45 ft high concrete dam was completed in December 1909.

Figure 6. The remnants of Austin Dam as of 2007. (Andrew T. Rose).

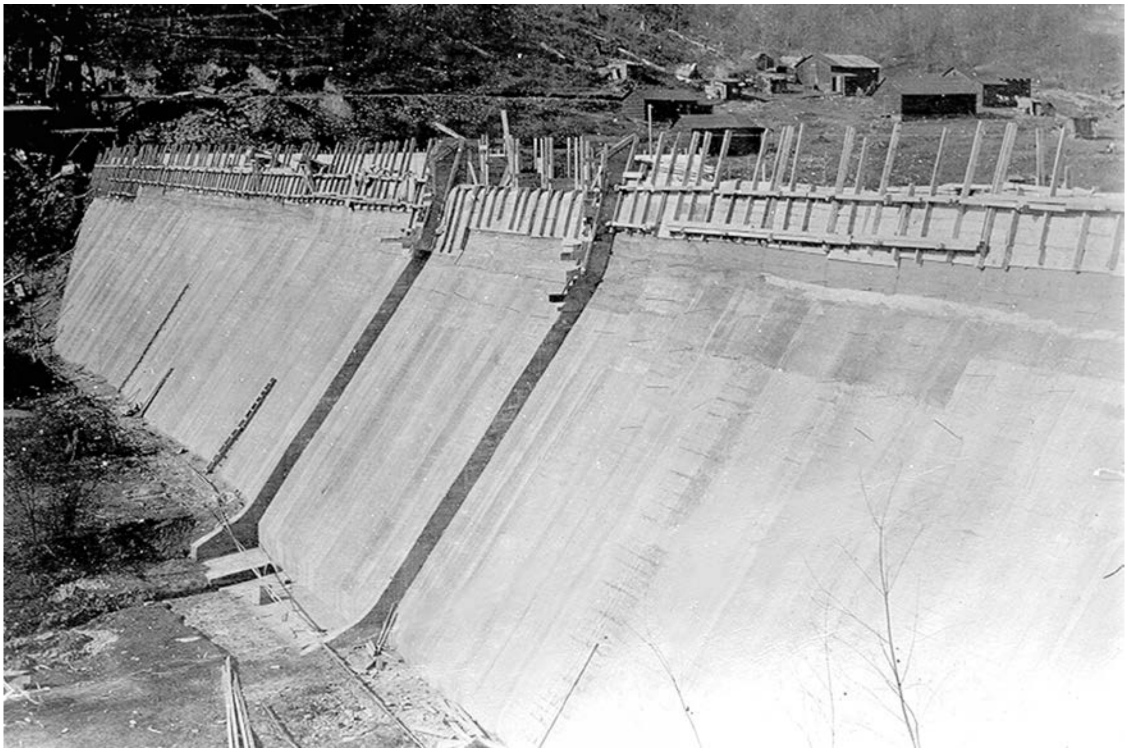

Figure 7. Austin Dam during construction (Courtesy of the Potter County Historical Society)

Rich[8] identified several flaws in the dam's design and construction, largely by researching the correspondence between the owner, George C. Bayless, and T. Chalkley Hatton, the engineer. In reviewing the correspondence, Rich[8] saw repeated instances of the owner trying to cut costs to such an extent that the failure of the dam was inevitable. While Hatton stressed in his correspondence with Bayless his desire to design a dam that was safe, he also gave in to Bayless on several requests to reduce costs. These compromises combined with poor construction and bad foundation conditions ultimately resulted in the failure. In his design Hatton called for a cut-off wall approximately 11 feet deep into the underlying rock. Bayless pushed Hatton to reduce the depth of the cut-off wall such that the final depth was only 4 ft into the underlying rock. Another design aspect called for a gatehouse with appropriate valves for cleaning the filter screens and for providing the water supply to the mill. To reduce costs further, Bayless asked for the gatehouse and valves to be eliminated and instead a single pipe through the dam serve both purposes. With some hesitation, Hatton apparently relented and agreed to the change but requested a Y at the lower end splitting the pipe and providing two valves, one to serve the mill and the other to drain the reservoir, if needed. Bayless responded that he did not see the need for the valve on the outlet pipe and instead indicated it would just be capped for the present time and that would be sufficient.

Further along in the construction, Rich[8] documents another series of correspondence where Hatton discovers that Bayless has directed the construction crew to raise the height of the dam and spillway by 2 ft, without consulting Hatton. Hatton protests and provided a sketch indicating that the stability of the structure will be affected and that changes such as this cannot be made without consulting him. Bayless countered that Hatton's assistant onsite was made aware of the changes.

According to Delatte[11] the dam was constructed of cyclopean concrete, with large rock inclusions in the matrix. In addition, some of the work was performed under cold weather conditions with concrete being placed under freezing conditions. Horizontal and vertical construction joints were present in the structure and it is not certain of the efforts taken to keep these joints from forming planes of weakness and seepage paths within the structure. Although a minimal amount of twisted iron rods were used to anchor the dam to rock and in the thinner upper portion of the dam near the crest, no record exists of rods being used across cold joints in the concrete structure. Figure 8 shows the cyclopean nature of the concrete in a remnant of the dam. Figure 9 shows a portion of the dam after years of weathering with vertical and horizontal joints apparent. Figure 10 shows one of the rods used to anchor the dam to the underlying rock.

Figure 8. Dam remains in 2007 showing cyclopean concrete. (Andrew T. Rose)

Figure 9. Spillway section of dam in 2007 showing vertical and horizontal joints after years of weathering. (Andrew T. Rose)

Figure 10. Rod used in construction of dam. (Andrew T. Rose)

After the dam was completed and put into service in December 1909, a problem occurred which should have foretold of eventual failure. After snowmelt and heavy rains in January 1910, the dam was subject to a full reservoir and a portion of the dam east of the spillway slid downstream about 31 inches at the crest,[12] as shown in Figure 11. The movement was accompanied by the observation of vertical cracks and seepage on the downstream face and seepage in the channel 10 to 12 ft below the toe.[10] The photograph shown in Figure 12 indicates that with water going over the spillway, the newly completed dam had seepage at several locations on the downstream face, possibly originating from construction joints in the concrete structure.

Figure 11. Bulging of dam crest east of spillway observed in January 1910 (Courtesy of the Potter County Historical Society).

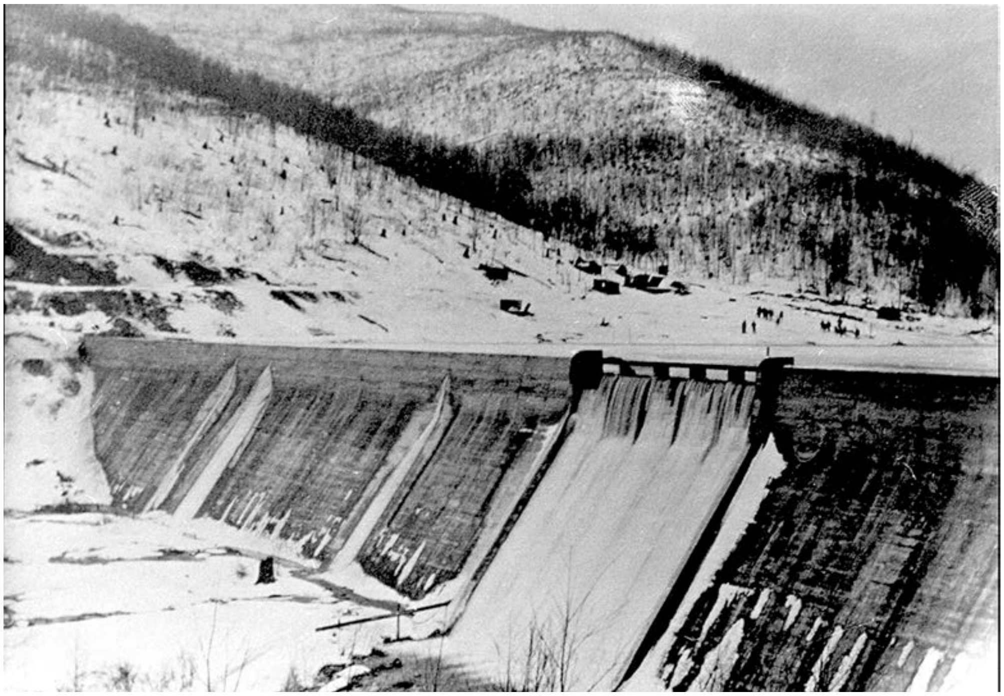

Figure 12. Seepage on downstream face of dam in January 1910 (Courtesy of the Potter County Historical Society).

This initial movement of the dam by sliding caused concern and the effort to relieve pressure behind the dam was hampered by the lack of a relief valve, which had been eliminated from the design by Hatton, at the owner's request, to save money. In addition, the cap on the outlet pipe was inaccessible due to the heavy flow, thus removing the cap was not possible.[10] Instead the Bayless company undertook a somewhat foolish measure and using dynamite, blasted out a small section of the crest about 6 to 8 ft wide and 4 ft below the crest. This lowered the head of water behind the dam to about 37 ft, as shown in Figure 13. Even with the lowering of the water level, concern remained, so a second charge was used to blow off the cap on the outlet pipe and the reservoir was drained.[10] At that time it was observed that part of the embankment on the upstream face had eroded away through the outlet pipe and possibly under the dam. It was further observed that a section of the dam had moved downstream relative to the inlet chamber wall through which the outlet pipe passed.[10]

Comparing Figures 11, 12, and 13, the hole blasted in the crest was located near the point where the sliding of the dam appeared greatest. No indication is provided as to whether the opening of the hole in the dam crest followed by water pouring through the new opening lead to erosion at the toe in this region where the stability of the dam appears to be worst.

After the movement of the dam in January 1910, dam engineer Hatton was contacted and reviewed the situation. Hatton felt the need to call on E. Wegmann, a consulting engineer based in New York City to assess the situation. Wegmann proposed adding a rockfill buttress on the downstream face to increase the stability of the structure, as shown in Figure 14. Hatton passed Wegmann's recommendations on to Bayless, but the recommendations were not adopted. The hole blasted in the dam crest was patched and within a month of the partial failure, Bayless had the reservoir filled to within 2 ft of the spillway. Even with a loss of about 600 gallons per minute of seepage visual at the toe of the dam, there seemed to be no further concern.[10]

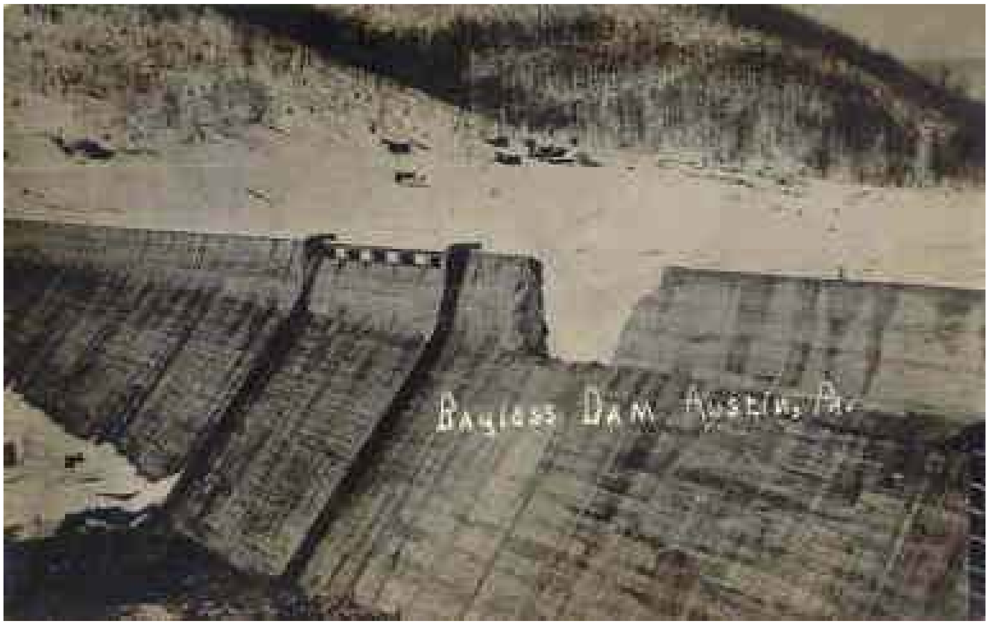

Figure 13. Concrete removed by dynamite to relieve pressure behind dam, January 1910 (Courtesy of the Austin Dam Memorial Association, URL http://austindam.net/).

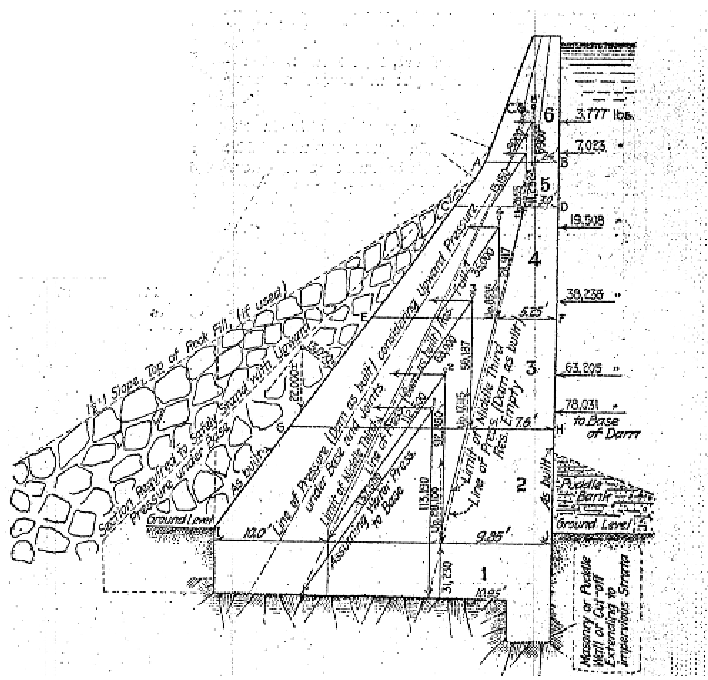

Figure 14. E. Wegmann's Feb. 14, 1910 proposal for strengthening Dam[10]

The dam appears to have functioned adequately until the final and complete failure on September 30, 1911. The dam essentially broke into pieces as the water pressure from the reservoir behind the dam pushed the massive concrete blocks downstream. Figure 15 shows a view of the dam blocks strewn across the valley. An observer living near the dam saw the impending dam failure and telephoned downstream to the town of Austin, giving warning of the inevitable flood. Records indicate at least 78 people died as a result of the flood, but more would have likely perished if the warning had not been provided. Most of the casualties were in Austin which was about 1½ miles below the dam, but there were also casualties further downstream in the smaller community of Costello. Figure 16 shows some of the destruction caused by the flood.

Figure 15. Austin Dam after the failure of September 30, 1911 (Courtesy of the Potter County Historical Society).

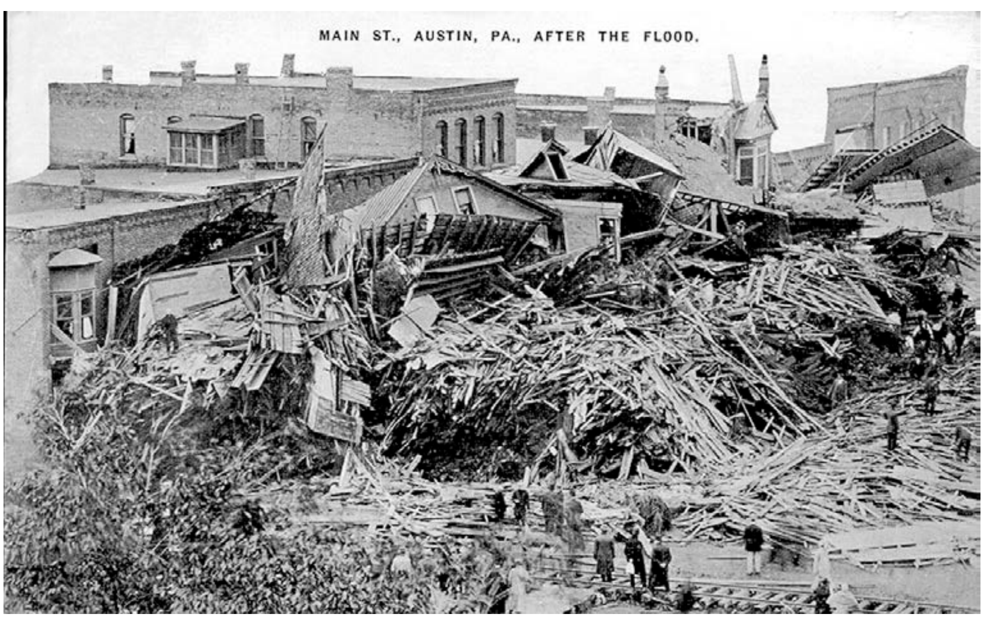

Figure 16. Main St., Austin, PA, after the flood (Courtesy of the Potter County Historical Society).

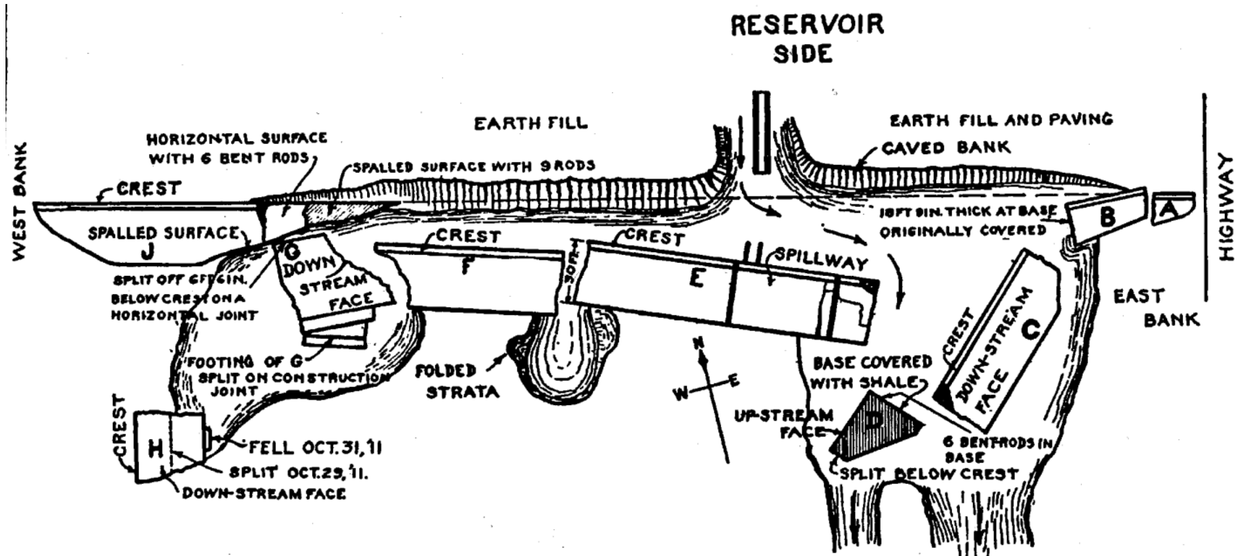

Figure 17. Plan of Austin Dam after failure.[13]

As the dam failed, it essentially broke apart into massive pieces that slid downstream. Figure 17 shows a plan view of the dam after the failure. As can be seen, the portion of the dam east of the spillway where the initial movement in January 1910 occurred, appears to have been where the dam broke apart and the force of the escaping water moved the dam sections greatest.[13]

The failure of the dam has been discussed and analyzed to a great extent. At the time of the failure, articles in Engineering News,[10] the local and national newspapers, and professional society publications[13,16] analyzed and discussed the failure of Austin dam. The overwhelming consensus was that the dam slid on its foundation. In some discussions the concept that water seeping beneath the dam had softened the rock strata, leading to sliding. Others proposed the effect of uplift water pressure on the base of the dam was the real contributor to the failure. The analyses and discussion was a useful attempt to clarify the cause of the failure and learn from this incident. Even Hatton[14] provided his opinion and essentially blamed himself for not considering how the proposed reservoir full of water would affect the rock strata below the dam he was designing. He states that his big mistake was assuming the rock foundation would be impervious.

Jackson[15] considered the state of dam design at the time of the Austin disaster. He notes that there had been prior recognition of the role of uplift pressures on dam stability. By the 1890's European engineers were beginning to consider uplift pressures in their designs in both England and France, while in the United States, uplift was still not being considered. The sliding failure of Austin Dam in 1911 and California's St. Francis dam in 1928 brought the uplift discussion to the forefront in US dam design.[15,16] This example of how new knowledge related to design concepts may be slowly adopted and influenced by engineering failures is a good example of the importance of continual professional development for practicing engineers. Hatton[14] adds that he should have consulted an engineer more experienced in dam design, especially as they relate to dam foundations for this project.

More recent papers have revisited the failure.[9,12,17,18] USBR[17] performed an analysis of the dam cross-section for both sliding and overturning stability, indicating safety factors of 0.32 and 1.03, respectively.

Martt et al.[9] performed a more detailed analysis of the failure. Their research included describing the regional geology of the site, performing test pits adjacent to some of the dam remnants and performing laboratory classification and strength tests for the various rock strata present at the site. They looked at shear strength and sliding between various interfaces in the geologic strata. From the analysis of their dam cross-section, they determined that the sliding failure of the dam occurred at the interface between the sandstone layer immediately below the dam and the underlying shale layer.

Delatte[11] discusses some other aspects that likely contributed to the failure. Addressing the issues of materials and construction, he cites the use of cyclopean concrete in the dam, the construction of the concrete during freezing temperatures leading to contraction in the dam, and the presence of cold joints in the dam as helping contribute to the dam's overall weakness.

The relief efforts and stories of the suffering and triumph of the human spirit resulting from the Austin Dam failure have also been documented. Nuschke,[19] Largey[20,21] and Dixon[22] present overviews of how the community, region, state and nation responded to the tragedy. A contemporary article published in *The Survey* questioned the cause of the failure and related it to the greed of the owners, the townspeople who were dependent on the Bayless Paper Mill, and the conflict of interest between those representing the interests of the town and those representing the interests of the mill, in light of the social charity movement of the early 20th century.[23] Rich[8] has revisited the social responsibility aspects of the failure. He considered the responsibility of a number of various parties including the owner, the engineer, the townspeople, the Commonwealth of Pennsylvania, and professional societies of the time. It is noted too that the town of Austin provided an attractive incentive package to Bayless to build his mill in Austin. The people of Austin and their leaders were quite dependent on the Bayless mill for their livelihood and were reluctant to show any concern for the dam that would hinder the economic life of the town.

Shortly after the failure, calls for state regulation of dams were made.[13,16,24] While some states had already enacted some regulations for waterways, mainly for navigation purposes, many were not necessarily strict and often were applicable only to publicly owned dams and not those built and operated by industry. Within Pennsylvania, legislation was enacted by 1913 to provide state oversight for dams.[8,25]

Jackson,[15] Rich,[8] and Vesilind[26] discuss the ethical issues of the failure. While there is no record of Hatton ever being reprimanded or found legally responsible for the failure, Vesilind[26] notes Hatton would have been reprimanded by today's professional societies for ethics violations. He adds that Hatton's career continued and prospered after the Austin Dam failure. He was active in professional environmental societies and served as chief engineer for the Milwaukee, WI sanitary authority.

1977 Failure of Laurel Run Dam

The history of Laurel Run Dam, its catastrophic failure, and aftermath have been documented by Long and Moffitt.[27] Laurel Run dam was an earthen embankment dam constructed between 1915 and 1918 to replace a smaller dam on Laurel Run near Johnstown.[27] Constructed to meet growing drinking and industrial water needs, the new dam was 42 ft high and held 101 million gallons of water. At the time of its failure, the dam was owned by the Greater Johnstown Water Authority. The overtopping failure of the dam occurred in the early morning hours of July 20, 1977 following torrential storms which dropped up to 11.8 inches of rain in 24 hours on the area.[27] Described as a 500-year storm,[28] the dam's spillway, which had been identified as inadequate in studies dating back to 1943, was greatly undersized leading to the overtopping failure. In addition, the embankment dam was constructed using hydraulic fill and had low resistance to erosion due to overtopping.[29] Figure 18 shows the remains of Laurel Run Dam following the failure.

Figure 18. View of Laurel Run Dam looking upstream after overtopping failure of July 20, 1977.[30]

The final dam failure occurred at about 2:15 am, engulfing the narrow 2 mile long valley, destroying homes in Tanneryville, and claiming 40 lives, almost half of the lives lost in the 1977 Johnstown flood. The failure during the night greatly increased the number of casualties.

Criticism after the dam failure focused on the prior engineering reports claiming the spillway was inadequate and the dam had other problems related to its stability.[27] The owner, however, did not address the engineering concerns and ignored the recommendations presented by various consultants. In addition, as the rain began falling and the reservoir was observed to be rising at a rate of about 1.4 ft per hour, no warning or call to evacuate the village below the dam was considered.[27]

Long and Moffitt[27] discuss a letter written shortly after the failure to the secretary of the state Department of Environmental Resources stressing the need for state dam safety reform. Elio D'Appolonia, a prominent Pittsburgh geotechnical engineer had studied Laurel Run Dam and recommended it be rebuilt. In 1977 he wrote, "Laurel Run is well known to me. We investigated this dam in the '60s. Its deficiencies were recognized and reports prepared for modification, but for various reasons, over a period of one-and-a-half decades, remedial steps or new construction was not taken. If the dam had been upgraded in accordance with today's prudent engineering practice, the dam would have been able to store and/or pass the storm."

Lawsuits against the dam owner, the Greater Johnstown Water Authority, the Authority's engineer, the Authority's management company, Bethlehem Steel Corp., and the Pennsylvania Department of Environmental Resources, were filed by the families of the victims. The suits revealed that the owners, their engineers and state officials could have done something to prevent the disaster. The defendants denied responsibility, but resolved the suits out of court after about 12 years of legal haggling.[27] The out of court settlements were considered paltry leaving the victims' families feeling slighted by the sluggish and unsympathetic legal system.[27]

Legislation as a Result of Dam Failures

Pennsylvania's history of fatal dam failures had direct influence on the implementation of dam safety laws in the state. After the 1889 failure of the South Fork Dam, engineering publications called for the need for governmental oversight of dams. However, JAHA,[2] notes that even with the tragedy of Johnstown, laws protecting the public were not enacted, largely due to the influence of powerful business trusts and industrialists. The legislators were torn between the promise of industrial development and economic growth vs. the need for laws and regulations that protect the public. At the time, laws that would cause hardship on industrial enterprises and would hinder industrial growth were difficult to accept. Individuals made wealthy by America's new industrialization after the Civil War had strong influence in the political arena and were able to prevent the passage of laws regulating industry.[31] This was partly due to ownership interests and control of newspapers that portrayed industrial growth in a positive light while some of it was due to corruption in local government and politicians who governed while working for the very industries needing regulation.[31] This conflict of interest made it difficult for those elected to protect the interests of the people, to place restrictions on the industries that gave their communities economic life.[31] As the turn of the century approached, the interest in the needs of the people and how the wealthy industrialists were achieving their wealth at the expense of the public and exploited workers began to be exposed more openly in magazines and newspapers.[31] As the cost of the publications, especially *McClure's* magazine, became increasingly affordable, the public became more aware of the exploits of industry and the plight of common people leading to progressive movements in various cities against industrial trusts.[31]

In the period between 1901 until about World War I (~1914), journalists known as *muckrakers* published numerous articles, many inside accounts of the exploits of business and industry affecting the US.[31] Their articles fueled a new consciousness and concern for the influences of uncontrolled economic growth and wealth on American society. The plight of the less fortunate became more significant to the public and their calls for reform and improvements in social conditions were forced on those governing the people. Their expose' writing brought about reforms through governmental involvement and regulation of a number of industries.[31]

During the 22 years between the 1889 South Fork Dam failure and the 1911 Austin Dam failure, popular literature began to expose the exploits of big business resulting in less tolerance by the public for poor working conditions, corporate economic dominance, and negligence. *The Octopus*, published in 1901, by Frank Norris, exposed the control of farmland by railroad interests and its effect on California wheat farmers and their economic survival. In 1904, Ida Tarbell's *The History of the Standard Oil Company* exposed unfair business practices of John D. Rockefeller and the company, resulting in establishment of anti-trust laws. In 1906, Upton Sinclair published *The Jungle*, in which the conditions prevalent in America's meat-packing industry were exposed, resulting in government regulation of the food industry and social reform for factory workers. These literary works and other events in the United States and around the world in the 22 years between the two dam failures influenced the public and governments to respond to the Austin Dam failure differently than they did for the South Fork Dam failure.

After the 1911 failure of Austin Dam, a number of professional publications promoted the need for state oversight of dams.[10,13,16,23,24] Pennsylvania's first dam safety law, the *Water Obstructions Act*, was enacted in 1913, largely due to the failures of both the South Fork Dam and the Austin Dam.

Rich[8] notes that even today at the Pennsylvania Department of Environmental Protection, Division of Dam Safety, a commonly expressed rumor regarding the passage of the 1913 *Water Obstractions Act* persists. The first dam safety legislation was introduced in the Pennsylvania Legislature shortly after the Austin Dam failure calling for state oversight of dams. The legislation stalled in the legislature as lawmakers were reluctant to force regulations on businesses and members of industry who helped them get elected. The rumor is that the 1912 sinking of the Titanic renewed public outrage toward the exploits of big business and the *Water Obstructions Act* was finally signed into law on June 25, 1913.[8]

McConnell[32] discusses the history of the *Water Obstractions Act* of June 25, 1913 (P.L. 555) and its role in state oversight of dams up until 1973. In describing successes and limitations of Pennsylvania's dam safety program, McConnell notes one of the most pressing items was the lack of adequate funding to sufficiently staff the dam safety program and carry out the inspection program of dams in the state.[32]

This lack of adequate funding to effectively carry out the dam inspection program and enforcement of proper dam design, construction and maintenance became apparent only 4 years after McConnell's 1973 paper. The failure of Laurel Run Dam following the extreme rainfall event of July 19-20, 1977, brought to the forefront the need of proper inspection and enforcement of dam safety laws. As a result of this 1977 dam failure, the Pennsylvania Legislature repealed the earlier *Water Obstructions Act* and enacted the Dam Safety and Encroachments Act (Act No. 325, P.L. 1375) in 1978. The law was amended by Act No. 70 in 1979. In September, 1980, the Environmental Quality Board adopted Chapter 105, Rules and Regulations, Dam Safety and Waterway Management.[33]

Conclusions

The development and evolution of Pennsylvania's dam safety laws is directly related to three significant dam failures that resulted in substantial loss of life. The historical context of when each of these failures occurred influenced the reaction of the public and legislature. While each of the dam failures could have likely been prevented if the dams in question had been properly designed, constructed and maintained, the lack of regulations or the shortcomings of state oversight resulted in dams that were destined for failure. Each failure provides technical lessons for the dam engineering profession, as well as renewed appreciation of why dam safety laws are needed and must be properly enforced.

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