The Mud Pond / Lake Lee Dam Failures – A Story of Fatal Mistakes in Two Centuries

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Abstract-- The Berkshires of western Massachusetts have been a perilous setting to build dams on at least three occasions. The Williamsburg Reservoir Dam failure, which killed 139 people in 1874, was the deadliest of these events. We look at two other dam failures that occurred on one site in another Berkshire community - East Lee. At about 5 a.m. on April 20, 1886, the stone dam at Mud Pond failed and released flood waters that swept through East Lee, killing seven residents. In 1965, Mud Pond was enlarged with another dam, constructed over the same footprint as the previous dam, and renamed Lake Lee. Eighty-two years after the first dam failure, on March 25, 1968, Lake Lee Dam failed, killing two downstream residents. The failures had common contributing conditions in addition to their location - poor foundation conditions, steep and narrow floodways, deficient engineering and construction, and little regulatory oversight.

I. INTRODUCTION

A. Berkshire Setting

The Berkshires of western Massachusetts are well known for their rural bucolic scenery, cultural offerings (Tanglewood, Massachusetts Museum of Modern Art, Norman Rockwell's Stockbridge, Arlo Guthrie's Great Barrington), nearby educational institutions (University of Massachusetts, Smith, Amherst, Williams, Holyoke), and numerous old mill towns. We can thank the collision of Africa with North America about a half billion years ago for elevating this area between the Connecticut River and the New York border as part of the Appalachians. As Appalachians go, the Berkshires are the shorter members of the family due to that half billion years of erosion, resulting in elevations that range between 700 and 3,500 feet. Even as small mountains and hills, the Berkshires provide elevation gradients and distinct valleys that proved very useful to industrialists of the 1800s, who harnessed the hydraulic energy of mountain streams by building dams across the region. Unfortunately, in at least two locations – Williamsburg and East Lee (see Fig. 1), Berkshire dams proved deadly.

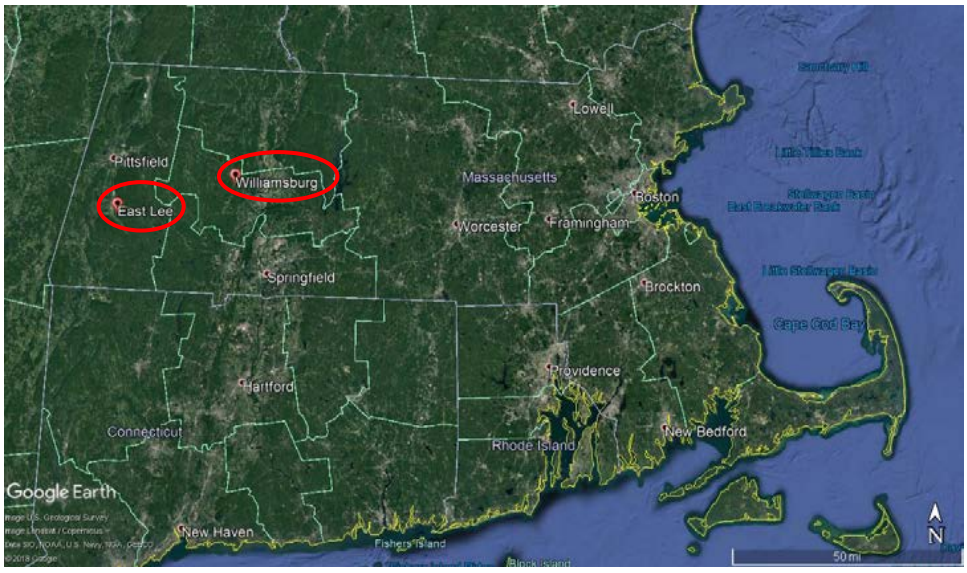


Figure 1. Map of Massachusetts – Locations for Williamsburg and East Lee (Google Earth [1]).

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B. Williamsburg Reservoir Dam Failure of 1874

The Mill River valley in 1874 reflected the pattern of development during the early industrial era in Massachusetts, with numerous factories powered by Mill River water as it dropped 1100 feet in elevation to the Connecticut River. The villages of Williamsburg, Skinnerville, Haydenville, Leeds, and Florence had grown around the sixty-four mill factories of the valley. Control of the water for consistent and predictable power gave rise to numerous dams along the valley, the most important being the upstream Williamsburg Reservoir Dam, which captured the spring runoff for power during the drier summer months.

On Saturday morning, May 16, 1874, the persistent seepage pressure through the Williamsburg Reservoir Dam and foundation caused the steep downstream slope to slide away, releasing the 2000 acre-feet of stored water down the narrow valley, wiping out the valley villages and factories and killing 139 people. It was the first major dam failure in the United States. Figures 2 and 3 are a stereograph photo of one area of the flood destruction and a sketch of the dam remnant. To briefly describe the underlying reasons for the failure, the dam was poorly designed, poorly built, and poorly regulated. The story of the Williamsburg Reservoir Dam failure has been well told in extensively-researched detail by Elizabeth Sharpe in her book *In the Shadow of the Dam, The Aftermath of the Mill River Flood of 1874* [2].



Figure 2. Stereograph of Williamsburg Reservoir Dam Failure Destruction - Hayden Brass Works (Knowlton Brothers, 1886 [3]).

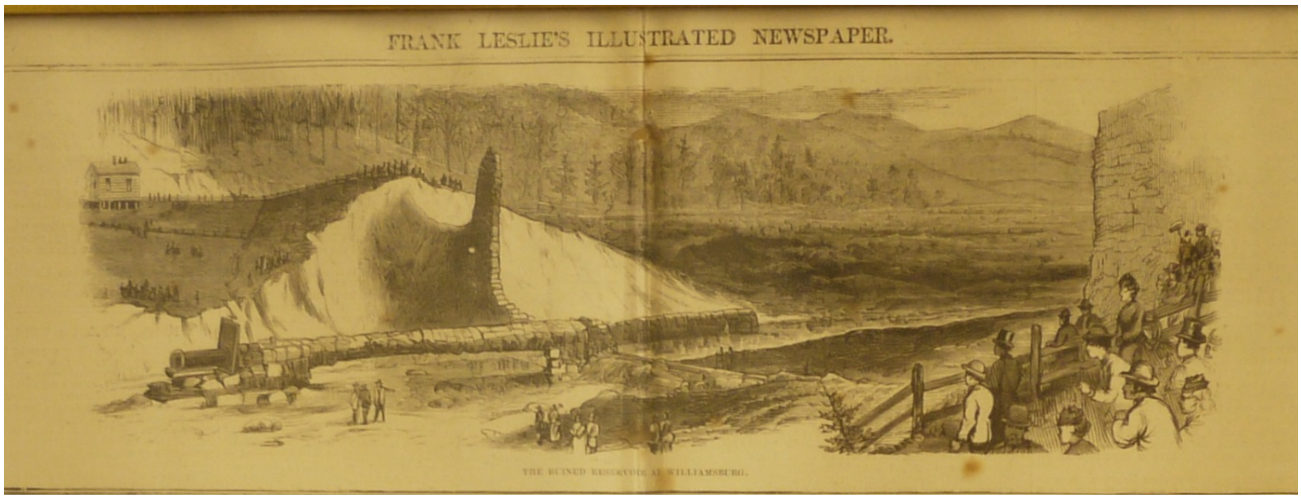


Figure 3. Sketch of Williamsburg Reservoir Dam Remnant (Taylor, 1874 [4]).

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C. East Lee Geographic Setting

Lee, Massachusetts, is located on the west side of the Berkshires about 12 miles east of the New York border, just at the location where the Berkshires drop to the valley floor of the Housatonic River. East Lee is a village within the town of Lee, located in the hillier east part of the town. The topography of East Lee is mountainous with steep slopes and narrow valleys. The site of the Mud Pond and Lake Lee dams is in one of these valleys where a small natural feature, currently named Basin Pond, exists as shown on Figure 4. Outflow from this site follows Basin Pond Brook (400 feet of elevation drop over 2.2 miles, 3.4% grade) to Greenwater Brook (270 feet of elevation drop over 1.5 miles, 3.4% grade) to Goosepond Brook, which flows to the Housatonic River (120 feet of elevation drop over 0.9 miles 2.5% grade). The drainage area for the pond is relatively small, about 0.78 square miles (500 acres). The Greenwater Brook valley provides the flattest and easiest east-west route through the hilly topography, and, consequently, has been the location for both major roadways and residential development.

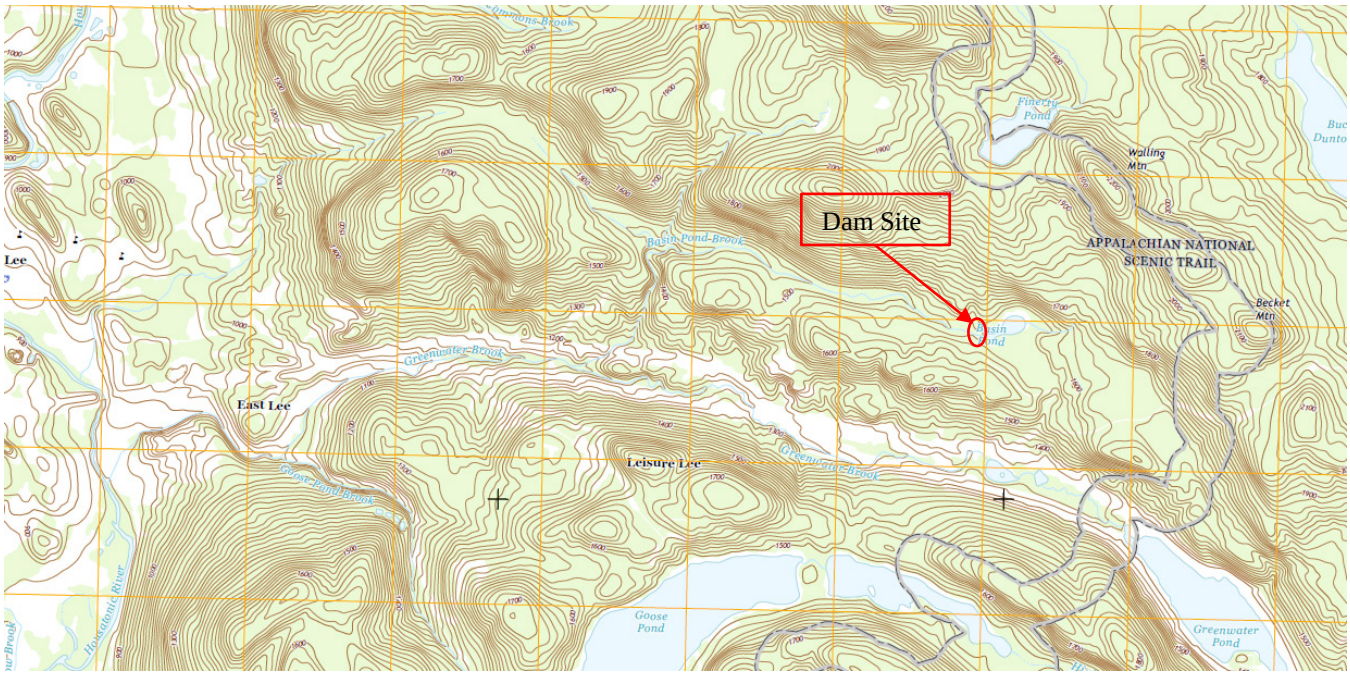


Figure 4. Topography – Mud Pond / Lake Lee / Basin Pond to East Lee (2015 USGS topographic mapping without roads and structures [5]).

II. MUD POND DAM BACKGROUND

A. East Lee – 1886

The village of Lee settled largely along the flood plain of the Housatonic River, at the juncture of the Greenwater Brook valley with the Housatonic River. The Greenwater Brook valley provided a favorable pass through the Berkshires for travel, specifically, the Otis Turnpike. Settlement on the east side of town, East Lee, was largely along Greenwater Brook and the Otis Turnpike. The Gonsett, Gardner, and Baker family homes were located in the upper part of the brook valley, near the Basin Pond Brook junction. Development continued down the Greenwater Brook with numerous homes and factories dependent on hydraulic power managed by dams on Greenwater Brook. The region had also developed a tourism industry with nearby "fashionable summer resorts of Stockbridge and Lenox" (Engineering News and American Contract Journal, 1886 [6]).

B. Mud Pond Dam

Much like the mills on the other side of the Berkshires in Williamsburg, industry in East Lee depended upon upstream water to power their machinery. Nathan Gibbs, Harrison Garfield, John Dowd, and other mill owners in Lee consolidated their funds and constructed a 10- to 15-foot-high dam in East Lee at Mud Pond (Basin Pond) in about 1883.

The Massachusetts Public Statues of 1881, Chapter 190, placed the burden for dam safety regulation on the county commissioners. Under those laws, the Berkshire County Commissioners would have approved the plans and specifications for Mud Pond Dam and would have inspected the dam construction. The commissioners could have also inspected the dam

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"with the assistance of a competent engineer" if they or a downstream petitioner requested such an inspection (Commonwealth of Massachusetts, 1881 [7]).

The dam and impoundment were so small and out of the way that no map of the period bothered to show them, and many downstream residents did not even know of the dam's existence. Engineering News and American Contract Journal (Watson, 1886 [8]) published sketches of post-failure dam features (Figure 5) and described the following features of the dam:

- An embankment constructed with a downstream "dry wall of rough boulders laid together without much care about 6 feet thick at the bottom, and 3 feet at the top" and an upstream zone of earthfill ranging in width from 3 feet at the top to 13 feet at the base, which was on natural ground. Reports on the height of the embankment ranged from 10 feet to 15 feet and the length of the dam was reported as 365 feet.
- An outlet "ditch about 7 feet wide and 3 feet deep … scraped in the soil of the hillside near the northerly end of the dam."
- A low-level "iron cylinder" outlet pipe with an upstream "fitted gate."
- Foundation soils described as "a layer of swamp soil a foot or more thick underlayed by a blue clay with a slight admixture of sand (which would have made a good puddle if so used) and this latter underlaid by hard pan with a few boulders."[5]

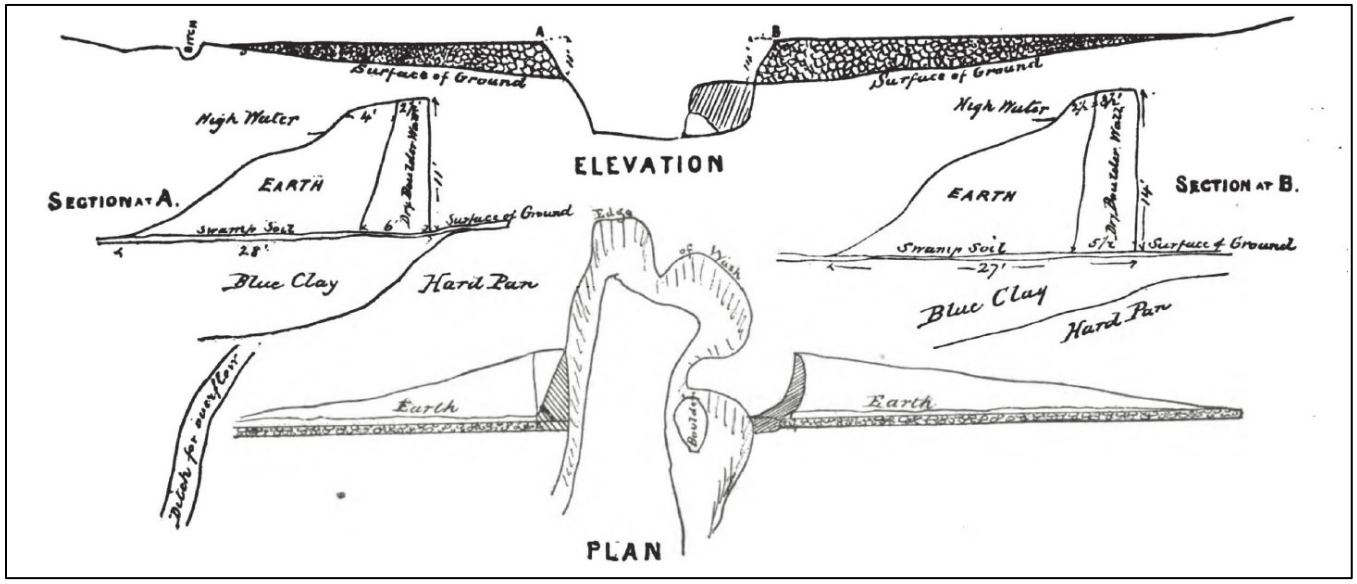


Figure 5. Mud Pond dam post-failure renderings from Engineering News and American Contract Journal (Watson,1886 [8]).

Dams in the region had gained a reputation as described in the following quote from the Engineering News and American Contract Journal following the events of April 20, 1886:

> *THROUGHOUT the New England states, the waters of every brook and stream that can be utilized for manufacturing purposes by the thrifty property owners, are held back by dams, many of which are so cheaply and insecurely built that they are a perpetual menace to the dwellers in the low lands adjacent to them. The fact that most of them survive from year to year, the pressure of the spring freshets or of heavy rainfalls during the seasons, begets a feeling of forgetfulness and a habit of neglect until a day arrives when the little leak through the bottom of the small dam up on the hill-side has weakened the structure by undermining, and the whole reservoir full of water, carrying the debris of the broken dam is first let loose upon the adjoining valley.* (Engineering News and American Contract Journal, 1886 [6]).

[5] The description of blue clay, a term usually applied to the marine clay of the Boston Basin, is curious but may be explained by the tendency of organic silts and clays to take on a grey or bluish color. In light of later investigations, this foundation description was either incorrect or explained by upstream parts of the dam footprint that may have extended over finer deposits of the natural basin.

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III. 1886 Failure and Consequences

A. 1886 Dam Failure Sequence

At 5:30 a.m. on Monday, April 20, 1886, Mr. Gonsett, a resident along the upstream part of Greenwater Brook in East Lee, heard and saw an approaching flood, described as a 10-foot-high wall of water, which seemed to gain velocity with its progress, carrying logs, trees, stones, and debris. He quickly warned his neighbors, the Bakers, who escaped and in turn warned other downstream residents ("Swept Away by a Flood," 1886 [9]).

The flood progressively displaced or severely damaged the marble shop of Edwin Sturges, the grinding shop of John Dowd, the Fletcher and Gardner houses, the paper machinery factory of John Dowd, the A.N. White carriage shop, Simeon Dowd's house, Mrs. James White's house, the P. Morin store, which served as the local post office, the Couch and Oakley millwright buildings, Freeland Oakley's barn, the Strickland Hotel, Theron Foote's grist mill and dam, four tenement houses belonging to the E.& S. May paper mill including the King family residence, the saw-mill and machine shop of John McLauglin, the Harrison Garfield Forrest Mill machine shop and dam, a store, a barn, the Veran fine paper mill, the Decker and Sabin mill and dam, Bottomley's mill, and E.P. Turner's machine shop before reaching the Housatonic flood plain where the flood energy dissipated and the severity of damage was less ("Swept Away by a Flood," 1886 [9]).

The New York Times reported the following causation hypothesis:

> *The theory of the disaster is that the ground was so thoroughly soaked with water that probably a small stream found its way through the bottom, and, no one visiting the place, this was unnoticed until Gonsett was alarmed by the roar of the water.* ("Swept Away by a Flood," 1886 [9]).

This theory of a seepage induced failure would have relevance again in the 20th century. Figure 6 shows a photograph of the dam breach.



Figure 6. Photograph of Mud Dam breach (Digital Commonwealth Photo Archives, Lee Library Historical Photograph Collection, 1886 [10]).

B. Consequences

The flood killed seven East Lee residents. The A.N. White carriage shop, which also served as the White family home, was destroyed, killing the White parents and their daughters Alice Irene and Ida May, ages 9 and 11. Their son, a 15-year old, was swept into a tree and recounted that the family had just arisen when they saw the flood approach, having the appearance of an advancing flock of sheep. The family huddled together in their third-floor residence but were carried away when the house pulled apart. Simeon Dowd, their neighbor, died when he left his house to let loose his hens. Mr. and Mrs.

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Theodore King, their son and daughter-in-law, Mr. and Mrs. Charles King, and their two-year old child tried to escape their tenement house only to be caught in the flood waters. Both women perished after they were separated from other family members. Charles, his son Theodore, and the two-year old survived ("Swept Away by a Flood," 1886 [9]). Figure 7 show photographs of damage along the flood path.



Figure 7. Various photographs of the 1886 post-flood damage (Digital Commonwealth Photo Archives, Lee Library Historical Photograph Collection, 1886 [10]).

Property damage included the homes, mills, dams, shops, and other structures mentioned previously and totaled in value $100,000 to $300,000. Liability for the damage became a moot point because the mill owners responsible for the dam were

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ruined by the flood (Engineering News and American Contract Journal, 1886 [6]). The New York Times described the aftermath scene thusly:

> *In the track of this devastating flood from where it began in Cape-street, through East Lee proper, then to Water-street, where Goose Pond brook intersects, there is hardly a house but is injured more or less, and in the upper part of Cape-street the destruction is more severe. Houses everywhere have from one to six feet of mud on the floors; fences are gone, lawns spoiled, furniture wrecked. and everywhere the work is shown of this unexpected destructive force. On the streams six bridges are carried away, the highways are gullied and in some places are washed away to the depth or several feet.* ("Swept Away by a Flood," 1886 [9]).

The Times also noted that over 5,000 people visited the scene on the following afternoon, "driving in from miles around. All the trains were packed" ("Swept Away by a Flood," 1886 [9]).

IV. LAKE LEE DAM BACKGROUND

A. East Lee – 1965-1968 community setting

In the mid-1960s, the Town of Lee had a population of about 6,000, and the village of East Lee was reasonably prosperous. The community was well served by road transportation, having two east-west highways: Route 20, which is the longest numbered highway in the country, and the I-90 Massachusetts Turnpike ("Mass Pike"), which parallels Route 20 to afford interstate highway travel. Figure 8 is an aerial photo taken during the construction of the Massachusetts Turnpike in about 1958-1959, showing, from left to right, Mud Pond with the remnants of Mud Pond Dam still visible at the west end of the pond, the ridge separating the Goose Pond Brook valley from the Mud Pond/Basin Pond valley, Route 20 (old Otis Turnpike), Greenwater Pond, and the Turnpike. Clark-Aiken Co., a machinery producer for the paper mill and defense industries, had been in town for about 50 years and provided employment to about 250 people. The company had a recent contract for construction of military airplane parts. Tourism was also a source of income for the region.

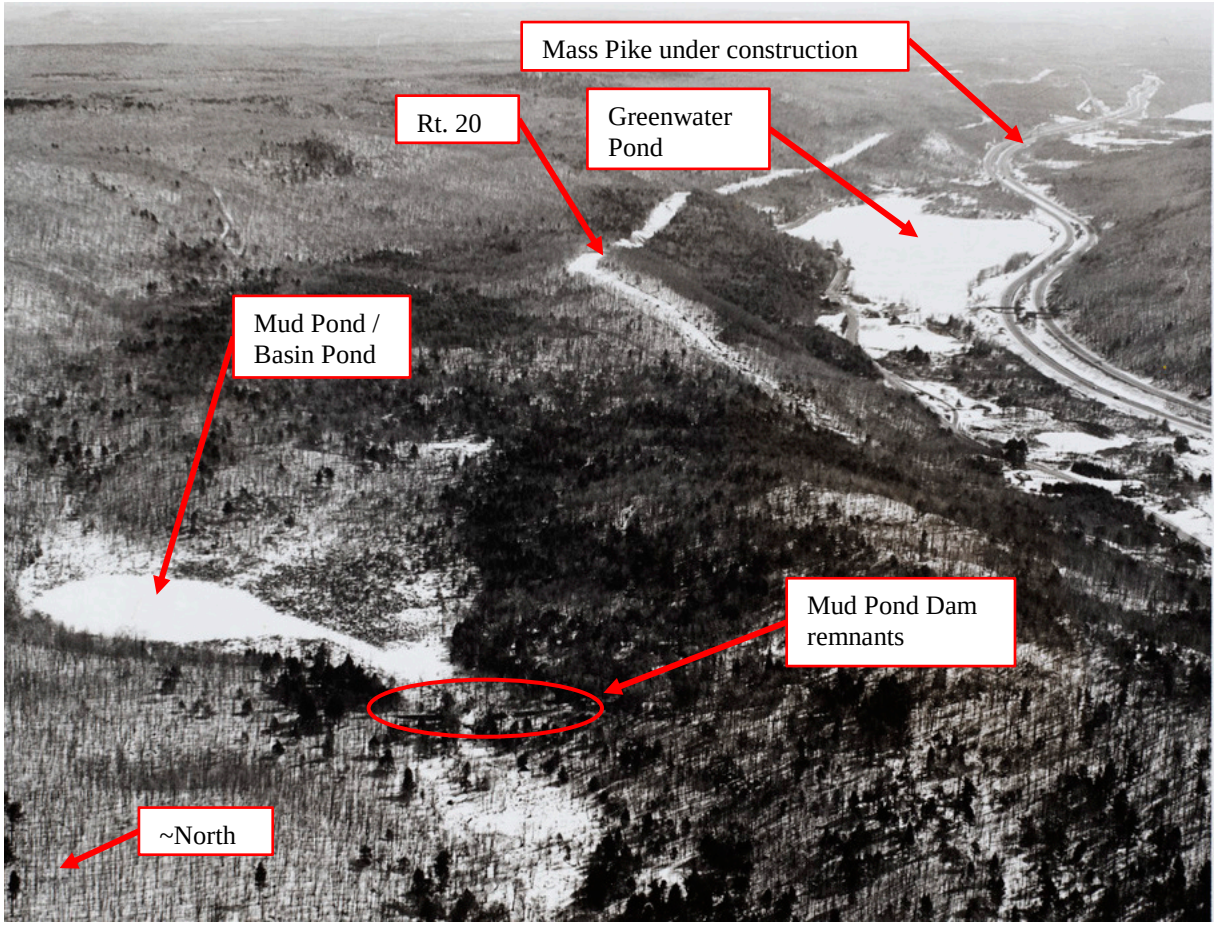


Figure 8. Aerial oblique photo circa 1958-1959 (pre-Lake Lee Dam construction) (Librizzi [11]).

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B. Lake Lee Dam

The Berkshires have long been a major vacation attraction and, for many, a vacation home location. In 1965, two Connecticut developers, Hamilton Wright and Walter Cromwell, owners of the Cromwell-Wright Corp., hoped to entice vacation home buyers to East Lee by enlarging Mud Pond with a dam to create Lake Lee with a normal pool volume of about 405 acre-feet (based on the HEC-RAS 5.0.3 E-V Table derived from LIDAR Terrain). The dam would be at the same location as the previous Mud Pond Dam (see Figures 9, 10, and 11).

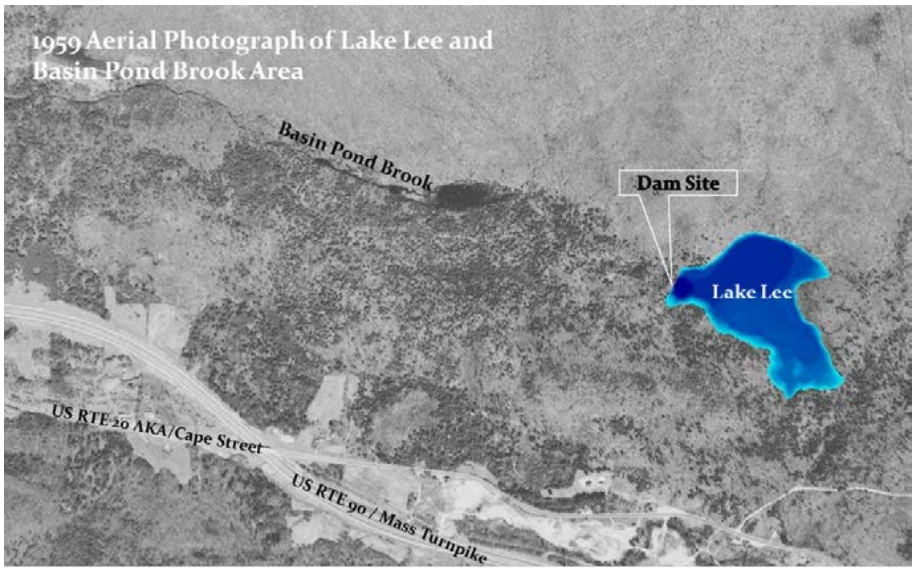


Figure 9. 1959 Aerial photograph with Lake Lee superimposed and Basin Pond Brook valley highlighted (Google Earth, 1959 [1]).

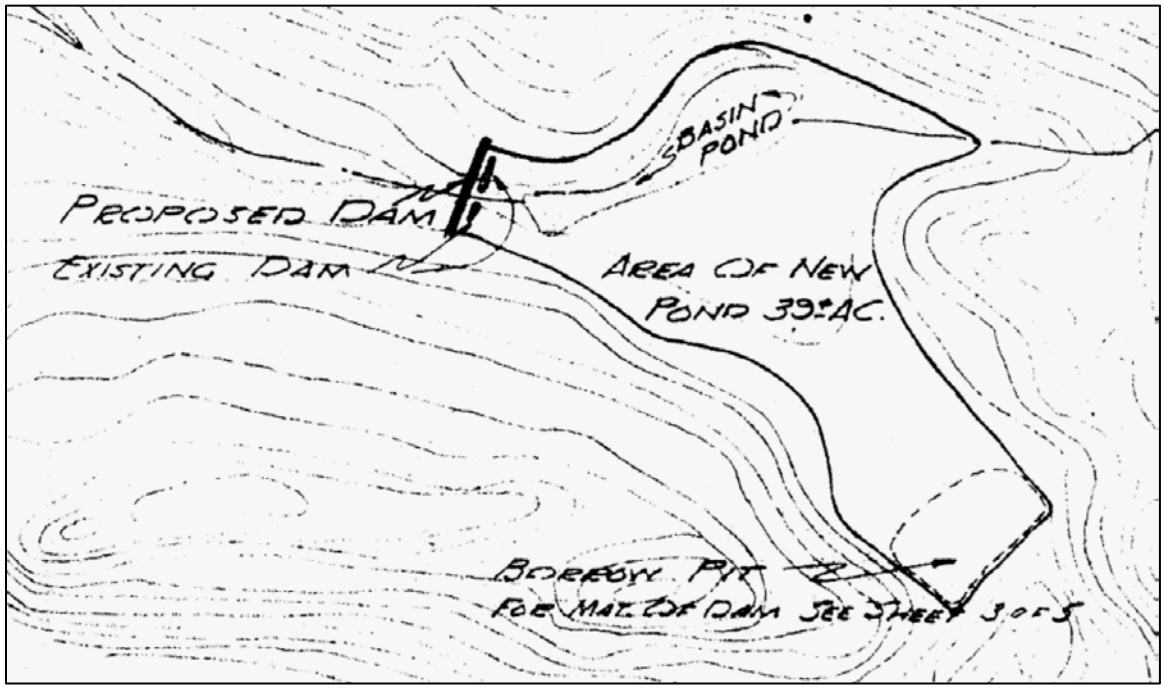


Figure 10. From Lake Lee Dam design drawing Sheet 1, showing the new dam relative to the remnants of Mud Pond Dam (Tighe & Bond, 1968 [12]).

Wright and Cromwell engaged a Connecticut-based engineer, Clarence Welti, to design their dam on the site of the previous Mud Pond dam. Figures 11, 12, and 13 show the plan, central cross section, and an off-set cross section from the design plans.

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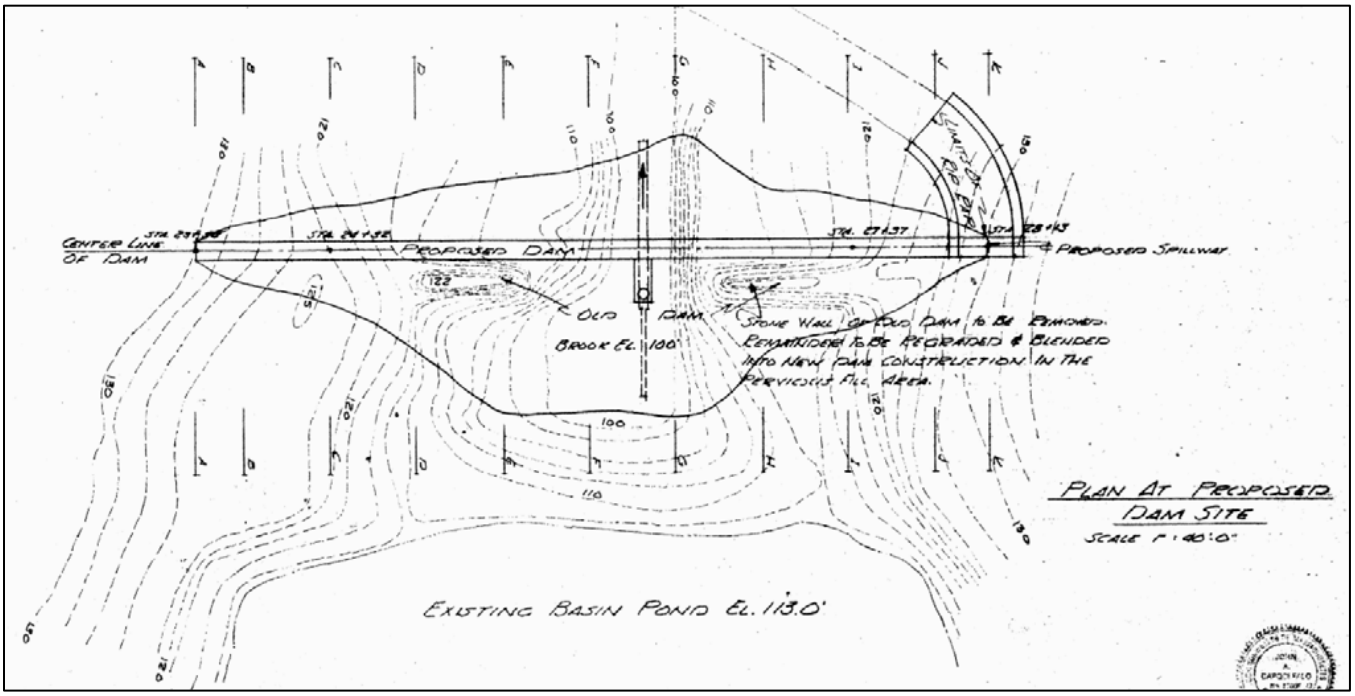


Figure 11. From Lake Lee Dam design drawing Sheet 2, showing the dam plan and the existing site topography, including the remnants of Mud Pond Dam. Note that the plans called for "Stone wall of old dam to be removed. Remainder to be regraded & blended into new dam construction in pervious fill area." (Tighe & Bond, 1968 [12]).

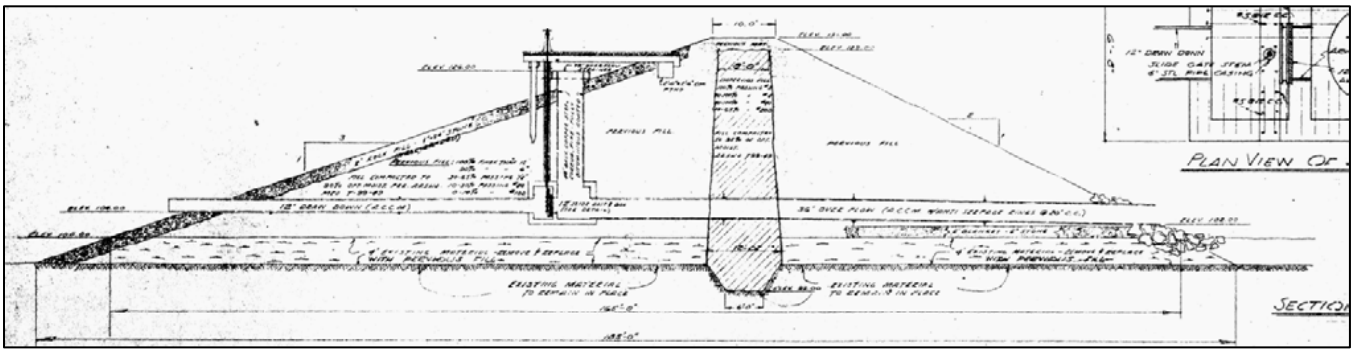


Figure 12. From Lake Lee Dam design drawing Sheet 2, showing the dam cross section at the outlet works (Tighe & Bond, 1968 [12]).

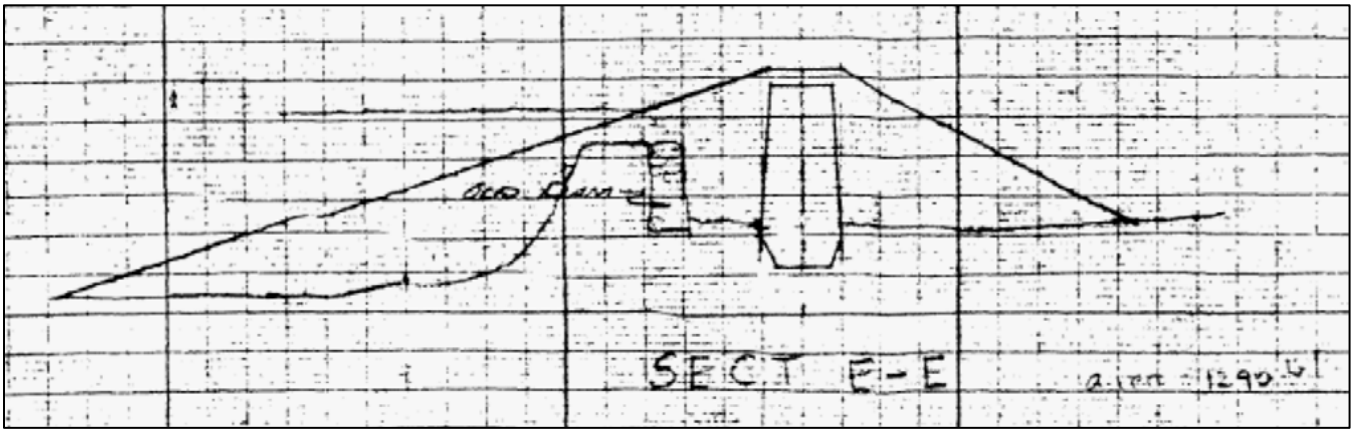


Figure 13. From Lake Lee Dam design drawing Sheet 5, showing an off-set cross section (Tighe & Bond, 1968 [11]).

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That design called for an earth embankment dam, about 475 feet long, with the features described below. Our descriptions of the dam and the dam construction relied almost entirely on the 1968 investigation report and attachments prepared by Tighe & Bond, (Tighe & Bond, 1968 [12]), which we cite here to avoid multiple citations throughout the descriptions.

- An embankment with a 10-foot-wide crest at El. 131. El. 100 was the site datum, which roughly corresponded with the natural ground level at the base of the dam. The design called for the following embankment material zones:
    - A central core, keyed about 8 feet below the existing ground surface, to El. 92. The central core design called for "Impervious Fill" with 40% to 65% fines (passing the #200 sieve). The core design varied in width from 8 feet at the top to 12 feet at a depth of 4 feet to a base width of 6 feet at a depth of 8 feet. Beyond requiring a depth of 8 feet, the design did not call for the core to extend to any specific formation for seepage cutoff. The top of the core extended up to El. 129, 3 feet below the dam crest. The upstream edge of the core would be located about 10 feet downstream of the previous Mud Pond Dam (see Figure 13).
    - Pervious fill upstream and downstream shells with slopes of 3H:1V and 2H:1V respectively. The pervious fill specs call for gravelly sand to sandy gravel. The top 4 feet of existing soil were to be removed under the pervious shell footprints.
    - A 2-foot-thick drainage blanket set within the downstream pervious fill at El. 100. The drainage blanket material is described as 2-inch stone. The blanket extended from the downstream toe to about 10 feet from the core, but the lateral extent of the blanket was not well defined in the drawings, which only showed the blanket at the center outlet section. The center section also showed the downstream end of the blanket exiting through a zone that was graphically shown as riprap.
    - A 2-foot-thick upstream slope protection blanket of 1-inch to 24-inch stone.
- An outlet consisting of (1) an overflow drop intake at El. 126 at the top of (2) a vertical 48-inch-diameter steel pipe that connected to (3) a concrete gate/junction structure with a base at about El. 102 connected to both (4) a 12-inch diameter, low-level / draw-down intake pipe, which extended to the upstream toe of the embankment, with a gate at the junction structure, and (5) a 36-inch-diameter outlet pipe that extended to the downstream toe of the embankment with three anti-seep collars at 20-foot intervals. All pipes are labelled "A.C.C.M.P.," which we believe to be asphalt-coated corrugated-metal pipe.
- A riprap-lined overflow spillway at the right end of the dam with a crest at El. 127.

Three preconstruction boring logs are shown on the plans with locations along the dam centerline. Boring 1, at the middle of the dam by the brook, encountered 4 feet of "soft wet peaty silt and gravel" over sand of variable descriptions ranging from medium to coarse sand and gravel to fine sand. Boring 1 stopped at "refusal rock or boulder" at a depth of 7.5 feet. Borings 2 and 3 were performed on the sides of the valley and encountered sands with little or no surface organic soils (1 foot of "loamy sand" at Boring 2) and stopped at depths of 4 and 5 feet respectively with no note of refusal.

Dam construction in the mid-1960's was regulated under Massachusetts General Law Chapter 253 (MGL 253), which, like the precursor 1881 law, empowered and tasked the county commissioners with regulation of dam safety. MGL 253 required prospective dam owners to obtain county commissioner approval of dam plans and specifications and called for the commissioners to inspect dam construction, which could be performed by an appointed inspector "engaged at the expense of the owners" (Commonwealth of Massachusetts, 1932 [13]). The Berkshire County Commissioners approved the dam plans on January 26, 1965, and Clarence Welti described a proposed inspection program to the County Engineer consisting of one inspection for core excavation, one inspection for the outlet junction / gate structure placement and weekly inspections for material and compaction.

Whipple Brothers Inc. of Norwalk, Connecticut, constructed the dam starting in the spring of 1965, and inspections were reported on seven dates up to a final inspection on September 9, 1965. The March 25th inspection report called for continued excavation in the streambed area to look for pervious layers. The April 2nd inspection report indicated problems with the core placement such that Welti called for placement of the core in the dry, requiring diking streamflow and pumping. The reports also indicate that Welti followed up the inspection with two phone calls, which were documented in memos, to require pumping and additional excavation when gravel was encountered to determine actual depth to rock or hardpan, which, in this area should have been a dense till. Welti also raised the possibility of constructing the lower portions of the core with concrete in his April 6th report of one telephone discussion. The July 8th inspection report documented that the core excavation was "[s]atisfactory to place core up to 4 feet height using 6 bags of cement in each layer (1' layers)." That report also directed "[e]xcavate gravel layer on east section of core prior to placing core." Subsequent documentation from Welti provided no confirmation of either gravel layer excavation or concrete placement.

Welti's letter report to the County Engineer concluded with "On September 9, 1965 I made my final inspection of the dam and the dike, and have included any changes from the plans on file." Welti's as-built drawings indicated one major difference from the design drawings, that the base of the core at El. 96 was widened to 60 feet (see Fig. 14). We presume that Lake Lee filled soon thereafter.

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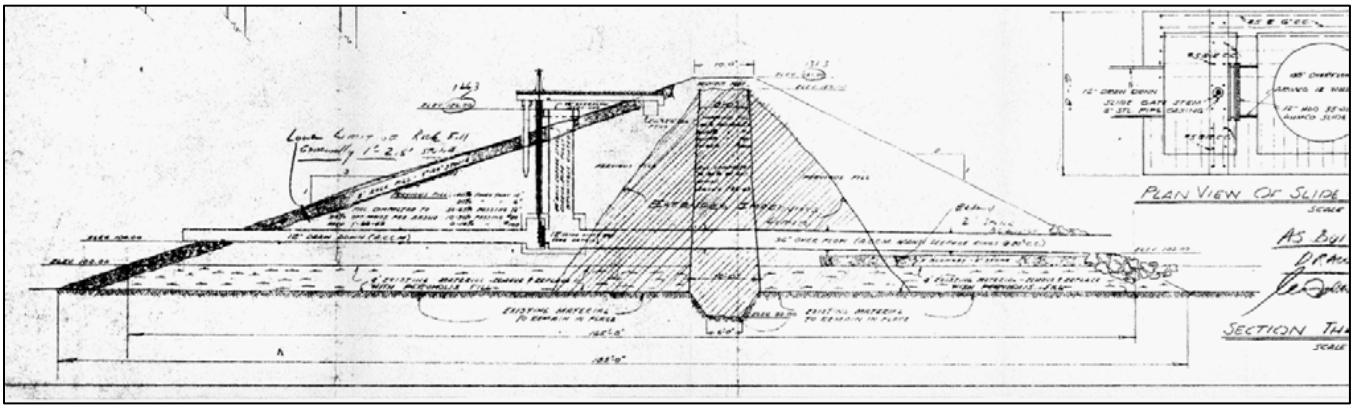


Figure 14. As-built drawing cross-section with wider core (Tighe & Bond, 1968 [12]).

The Berkshire County Commissioners continued to perform their dam safety obligations and had the dam inspected on April 26, 1967, an inspection that gave the dam a passing grade (Associated Press, March 26, 1968 [14]).

V. 1968 FAILURE

A. 1968 Flood and Consequences

In the early afternoon of March 24, 1968, the residents of East Lee were engaged in normal activities for a Sunday – finishing dinner, washing up, tending chores, or pursuing hobbies or games. They had experienced freezing weather over the previous week, which was common for March in the Berkshires, and Friday had brought over one inch of rain to the area.

At about 1:26 p.m., Emily Welch, after getting out of the bath, heard the sound of rushing water, which she initially attributed to a running bath faucet. She soon learned otherwise when she "saw a great black mass of water rushing down the street." She quickly dressed and, after realizing that she was trapped by flood waters, called the police, who were able to rescue her. Her house, which had survived three previous floods[6], was washed away (Corea, 1968 [15]).

Tom Garrity, a neighbor across the street, saw the flood waters carry a flipped car about 15 feet above a nearby bridge. He told the Berkshire Eagle that the car "was flipping like a peanut." That car came to rest 300 feet below the bridge. Many of the local residents were alerted to the flood by their children, who were probably paying attention to anything other than the Sunday dinner conversations. The flood waters trapped Mr. and Mrs. Julius Naventi in their house, which, luckily, withstand the flood forces. Their cars and garage, however, were swept away. George Allen heard the flood and jumped into his truck to warn the residents of his trailer court, which was east on Route 20. The flood caught George's truck before he could get to the trailer court and carried it across the highway. George survived, as did the trailer court, which was above the flood level. Many of the residents along the flood path had some slight warning and the good sense to flee up the hills behind their houses (Corea, 1968 [15]). Shirley Gage was driving home, east on Route 20, when the flood picked up her car and pushed it back down the highway to the west. She survived without injury (Hulick, 1968 [16]).

Not everyone was lucky enough to have suffered only property damage. The flood swept the house of Shirley's father, Edward Gage, completely off its foundation, carrying the intact second floor and attic into the Route 20 bridge (Figure 15). Stephen Gage, Shirley's twin brother, was awakened by his father as the house started to move. Stephen jumped from the first-floor porch into the flood, was carried downstream, and survived. Edward also attempted to swim from the house, but with fatal consequences. His body was deposited downstream, near the upper part of his house (Marchaud and McLean, 1968 [17]). The flood also sliced off one side of the house of Olive Cordonier[7] (Figure 16). Unfortunately, Olive, who had attended church earlier that day, was in the wrong part of the house. Her body was found about 200 yards downstream of the house foundation (Hulick, 1968 [16]).

[6] Based on photo archives (Digital Commonwealth, Lee Library Historical Photograph Collection), in addition to the 1886 and 1968 floods, the East Lee area experienced floods in 1914, 1927, and 1938. As part of a story on the 1968 flood, the Boston Herald-Traveler reported that the 1938 flood involved a failure of the rebuilt Mud Pond Dam (Marchaud and McLean 1968 [17]), which would have raised the total number of dam failures at the site to three. We were unable to find corroborating information about a 1938-era rebuilt dam.

[7] It is likely that 60-year-old Olive Cordonier experienced previous flooding. The Digital Commonwealth, Lee Library Historical Photograph Collection includes a photo from showing how the 1927 flood demolished the Cordonier barn.

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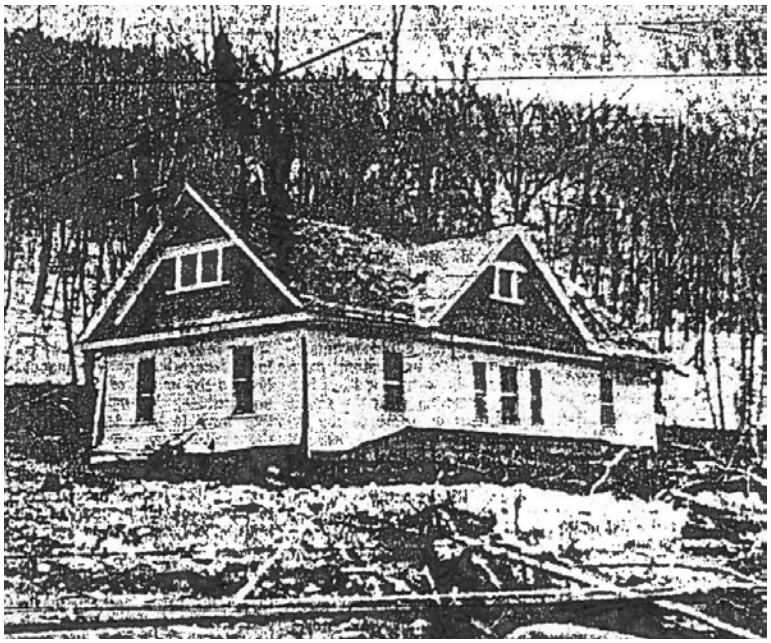



Figure 15. Second floor and attic, detached from first floor, from home of Edward Gage, one of the flood victims (McCarthy, 1968 [18]) and wrecked car near Gage house (in background) (*Berkshire Eagle* [19]).

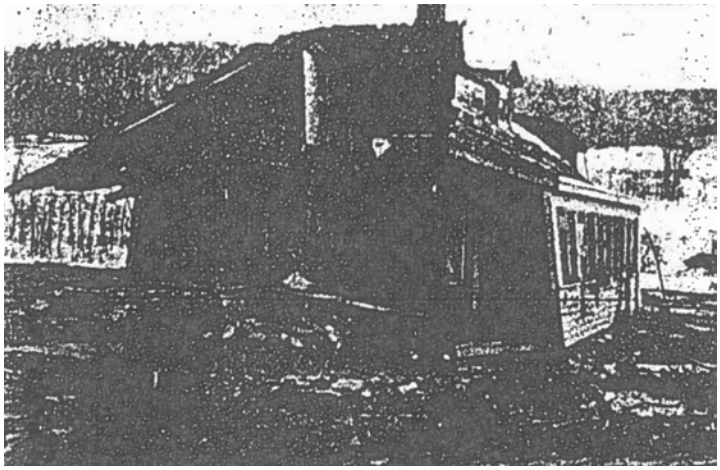
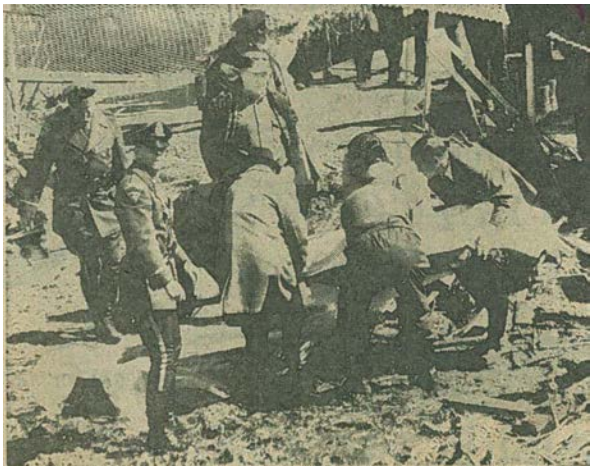



Figure 16. The remains of the Olive Cordonier house ((McCarthy, 1968 [18]) and the retrieval of her body one day after the flood (Bielinski, 1968 [20]).

The flood progressed downstream and inundated the Clark-Aiken industrial plant, causing several millions of dollars in damages. The only occupants in the plant, Donald Holcomb and his two sons, ran up to the second floor and survived. The flood forced their car and other debris, including a 16-ton dump truck through the walls of the plant (Figure 17). Residents speculated that the flood would likely have killed many of the 250-person plant workforce if it had occurred on a weekday (*Berkshire Eagle*, 1968 [21]).

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Figure 17. Post-flood photos of the Clark-Aiken plant (Digital Commonwealth Photo Archives, Lee Library Historical Collection, 1968 [22]).

The immediate reconnaissance of the flood led to its obvious source. A breach in the center of the Lake Lee Dam (Figures 18 and 19) had released the lake impoundment on the downstream community. The narrow, steep-sided valleys had conveyed the flood progressively down Basin Brook, under the Mass Turnpike, into Greenwater Brook, under Route 20, under the Tyringham Road bridge, and eventually into the Housatonic River. The major areas of damage were along the Greenwater Pond Brook valley, with much of the damage from the Mass Turnpike bridge to and along Goose Pond Brook (see Figure 20) (Tighe & Bond, 1968 [12]). The fatalities occurred in the neighborhood just upstream of the Route 20 bridge over Greenwater Brook (see Figure 21). The flood also damaged the Town of Lee's new sewage treatment plant on the east shore of the Housatonic River (Hulick, 1968 [16]).

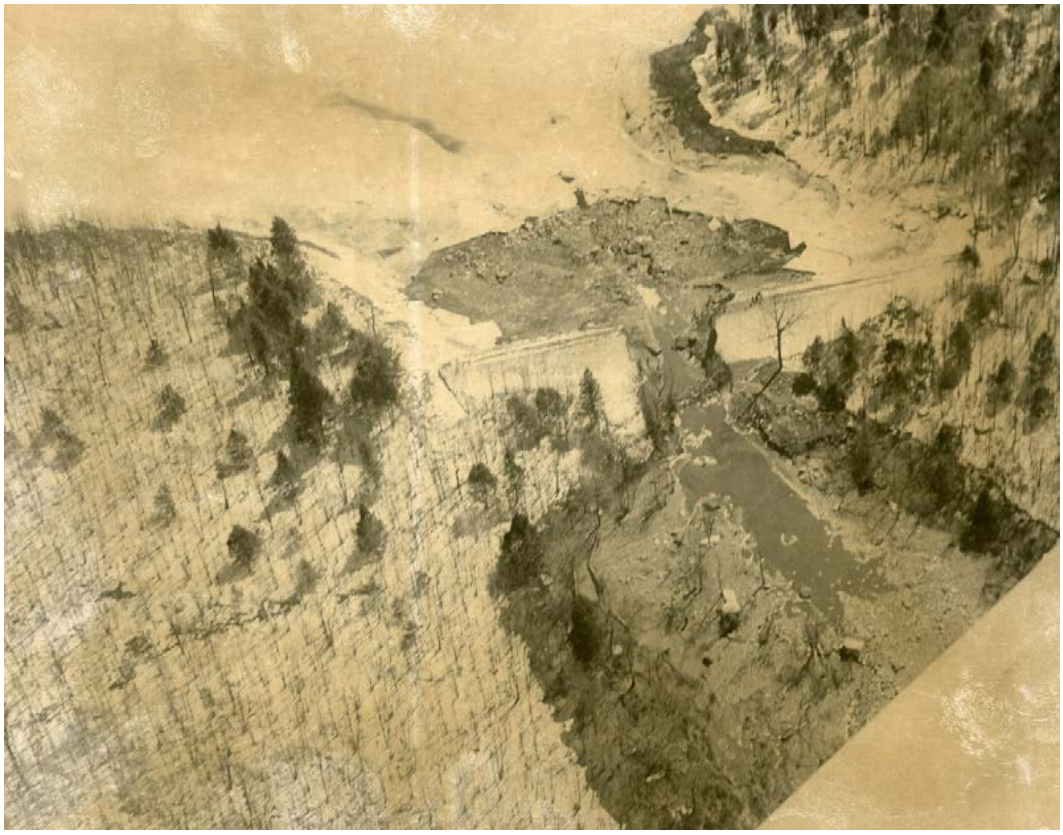


Figure 18. Aerial photograph of Lake Lee Dam after failure. Upstream is to the top of the photo. Note lake ice remnants. (Berkshire Eagle [19]).

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Figure 19. Photograph of dam during post-failure investigation, May 13, 1968 (Tighe & Bond, 1968 [12]).

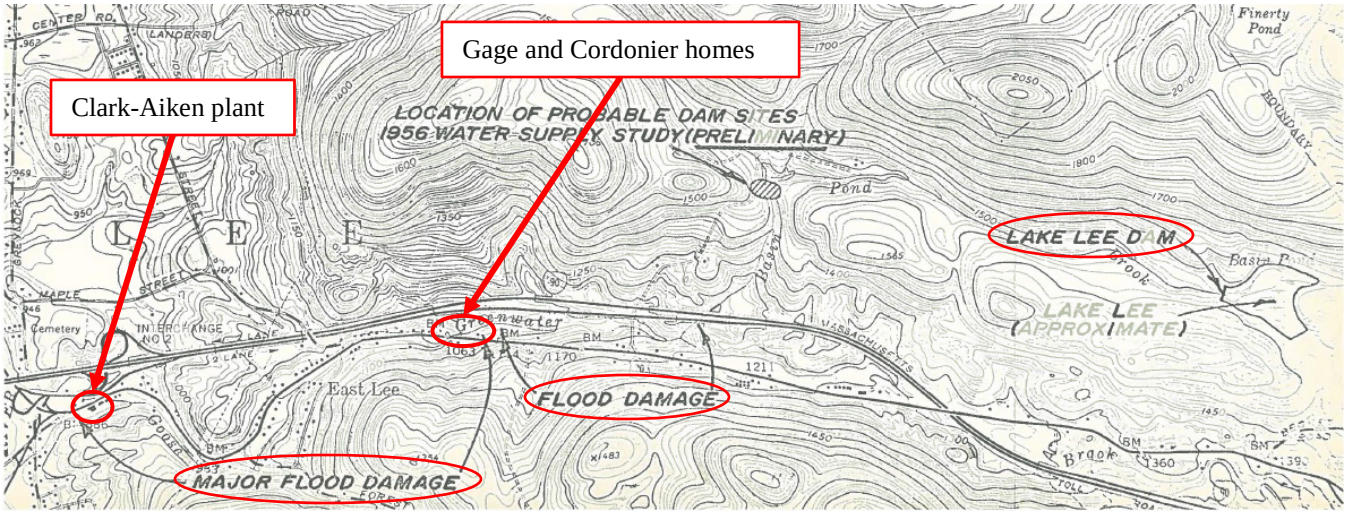


Figure 20. Location map from 1968 Tighe & Bond study showing location of damage (Tighe & Bond, 1968 [12]).

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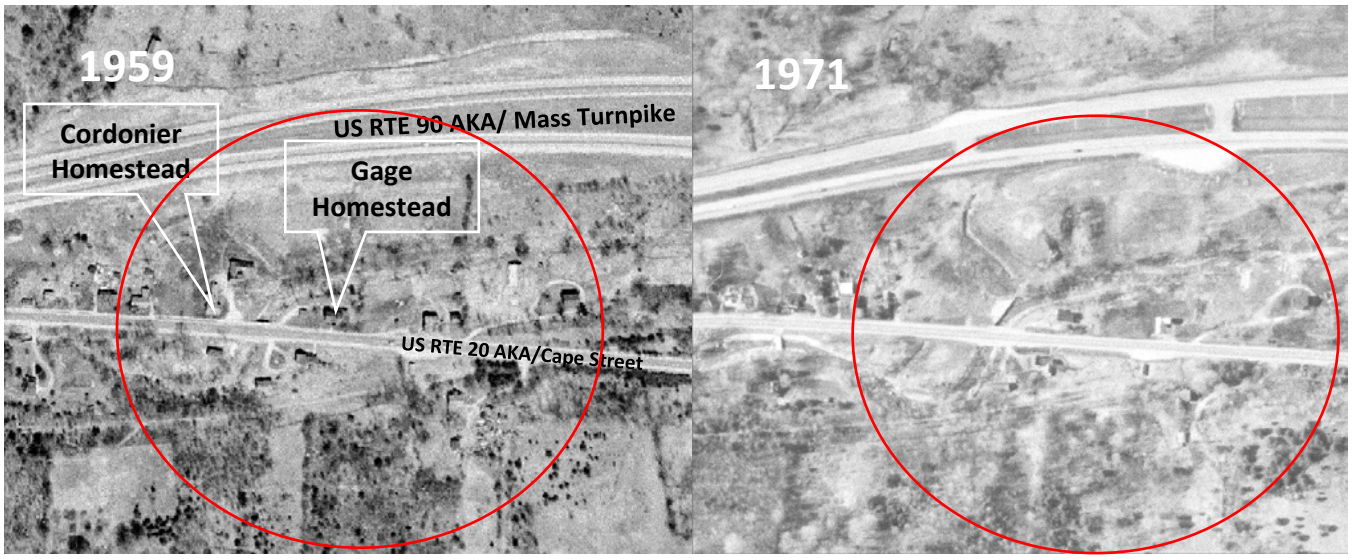


Figure 21. Pre- (1959) and post-flood (1971) aerial photographs of Lake Lee failure flood fatality area showing absence of several 1959 buildings and changes in landscape (Google Earth, 1959 and 1971 [1]).

B. The 1968 Investigation

The Berkshire County Commissioners immediately directed the County Engineer to conduct an investigation of the failure and eventually engaged Tighe & Bond of Holyoke, Massachusetts to perform that investigation in May of 1968. The Commonwealth of Massachusetts provided funding for the study. George McDonnell, P.E., the Chief Engineer of Tighe & Bond submitted their investigation report to the County Commissioners on September 5, 1968. The investigation findings reported by Tighe and Bond were as follows:

- The dam was not overtopped. Ice level remnants around the lake provided evidence that the Lake Lee level at the time of the breach was below the level of the outlet works intake (El. 126), at least 5 feet below the top of the dam.
- Seepage through the foundation sand and gravel was not cut off by the core construction. This seepage through the foundation soils and from the left abutment was the likely force that triggered the breach.
- The dam construction was "not in keeping with the highest degree of workmanship expected in constructing an earth embankment dam having a vertical shaft and conduit tube-type spillway" (Tighe & Bond, 1968 [12]). Tighe and Bond found the following construction deficiencies:
  - The core "did not extend to bed rock or to a basic impervious material" even in the central section of the dam where an existing pervious sand layer was found in test pit investigations. Figures 22 and 23 show the location of test pit T-1 and the cross-section log prepared by Tighe and Bond. The test pit cross-section shows that the core was placed on relatively pervious material at this location. The test pit itself did not reach bedrock or a relatively impervious zone but rather stopped on "big cobbles and boulders," probably because of the "heavy groundwater inflow." The T-1 cross-section also shows a zone of "gravel and cobbles" immediately adjacent to the upstream side of the core.

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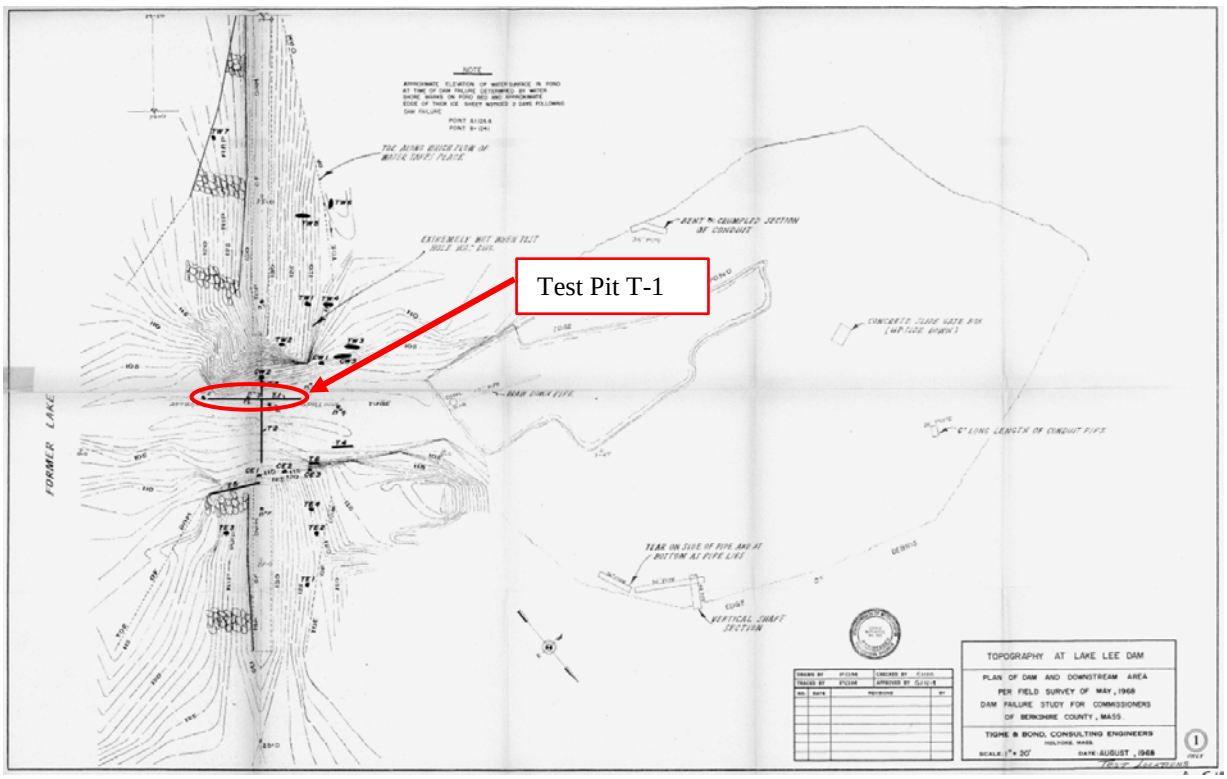


Figure 22. Post-failure investigation survey and investigation plan (Tighe & Bond, 1968 [12]).

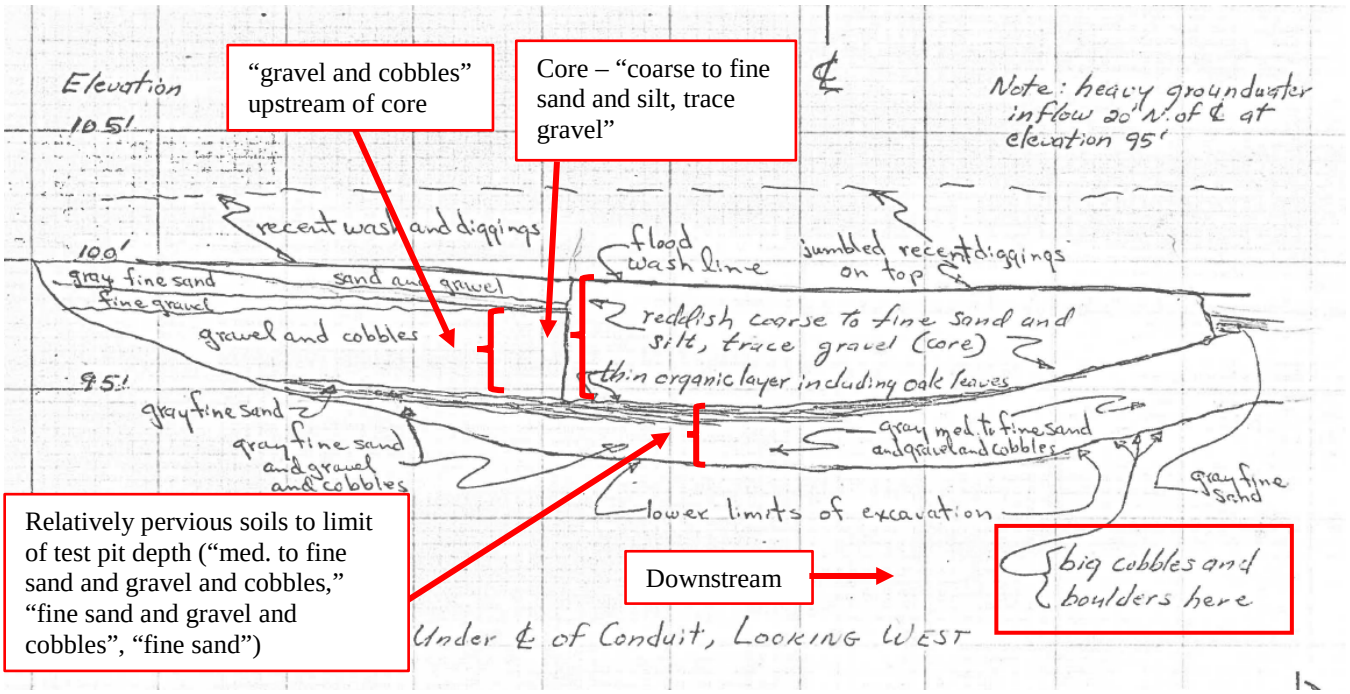


Figure 23. Cross section from test pit T-1 under centerline of conduit and breach (Tighe & Bond, 1968 [12]).

- The core was not keyed into existing ground as required by the design drawings except in the central section of the embankment with the outlet structure that was washed out. Investigation test pits revealed an organic layer at the base of the embankment, including the core, on both sides of the central section of the dam. Figure 24 shows Tighe and Bonds comparison of the pre-construction ground surface, the observed as-built bottom of the

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core from the test pits, and the design bottom of core level. Figure 25 shows a photograph of the side of the embankment at the breach in which the organic layer is visible at the embankment base.

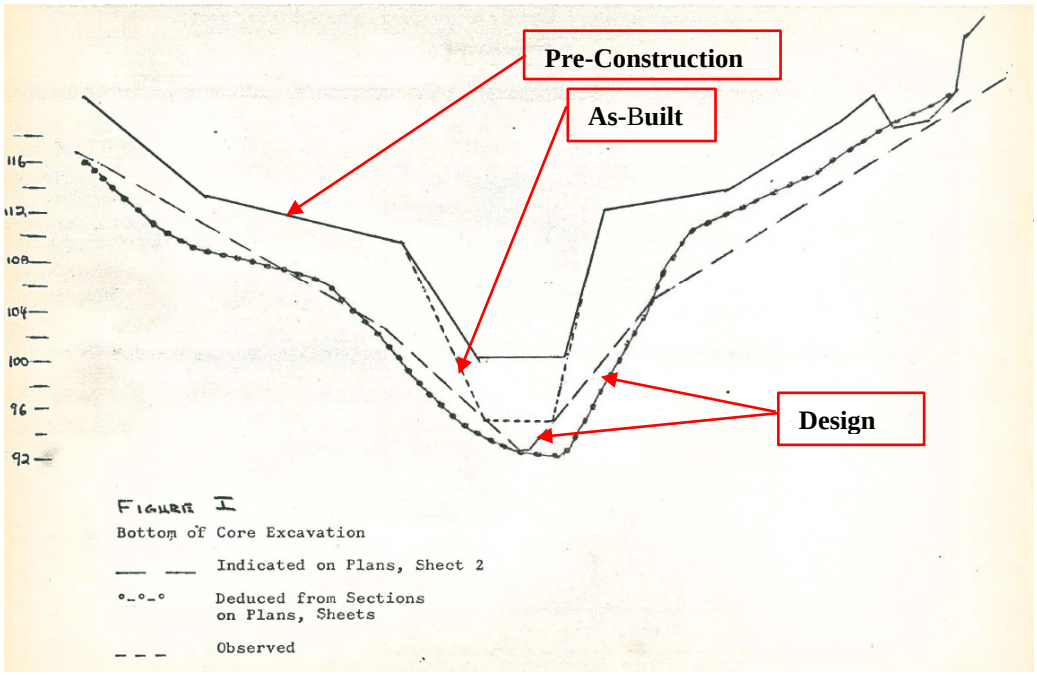


Figure 24. Bottom of core elevation from 1968 investigation (Tighe & Bond, 1968 [12]).

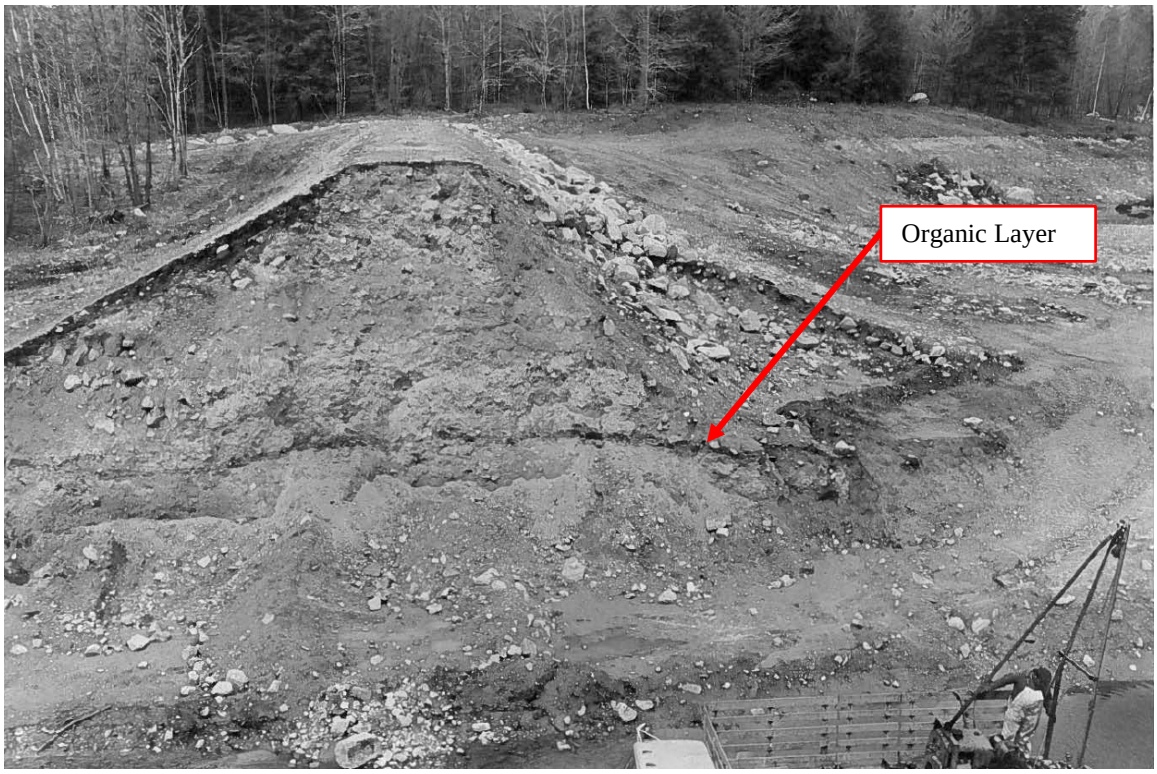


Figure 25. Photograph of right side of embankment breach, May 13, 1968. Note organic layer at embankment base. (Tighe & Bond, 1968 [12]).

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- The embankment fill included sticks and logs and clusters of boulders.
- The concrete walls of the slide gate / junction structure were poorly consolidated below both the intake and outlet pipes, with "voids and rat holes," which would have allowed seepage from within the structure into the embankment below the outlet pipe. Figure 26 shows the poorly consolidated concrete below the outlet pipe.



Figure 26. Poorly consolidated concrete below outlet pipe at slide gate/junction box downstream wall (Tighe & Bond, 1968 [12]).

- "Boulders" (possibly large gravel or cobbles) were observed in the bottom concrete slab of the slide gate / junction structure.

- A tear was observed in the washed out downstream corrugated metal outlet pipe but was discounted as likely occurring due to the dam failure wash out. Figure 27 shows the disposition of the outlet pipe and riser after the flood.



Figure 27. Outlet riser (bottom 48-inch-diameter pipe) and outlet pipe (upper 36-inch-diameter pipe) after breach (Tighe & Bond, 1968 [12]).

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- Even at the time of the investigation, with no upstream impoundment, the toe along the left side of the embankment was very wet from abutment seepage around and over a huge buried boulder.
- The most likely failure mechanism "was the seepage thru and under the dam embankment, coupled with the wet conditions that existed and still exist at the downstream toe of the dam on the west (left) side." The seepage caused the "wet soils at the toe" to be "washed away." Tighe & Bond also expected that the stone blanket drainage layer facilitated the seepage flow.
- Frozen ground in the toe area may have also confined and concentrated the seepage.
(Tighe & Bond, 1968 [12]).

VI. SUBSEQUENT EVENTS

A. Litigation and Ultimate Disposition of Basin Pond

Damages from the failure resulted in lawsuits against Cromwell-Wright by the families of the deceased, the Town of Lee, Clark-Aiken, the Massachusetts Turnpike Authority, Western Mass. Electric Co., and Lee Auto Sales seeking more than $5 million. The initial court ruled that the plaintiffs could not assign liability simply due to the fact of ownership or construction. The Massachusetts Supreme Court overturned this ruling and found that those who impound a substance of "an abnormally dangerous nature" are strictly liable for damages caused by that substance. The high court based their ruling on a 19th century English case. The strict liability ruling meant that the plaintiffs did not have to prove negligence by the owner to establish liability. The Berkshire Eagle reported this ruling exactly seven years after the failure, on March 24, 1975 (Sanders, 1975 [23]).

We understand that the case was settled after this ruling. Among the settlements, the estate of Olive Cordonier received $25,000, and Clark-Aiken, with the largest claims, was given title to the Lake Lee lands. Clark-Aiken later sold the property to conservationist N. Robert Thieriot, who, at his death, passed the property to the Berkshire Natural Resources Council. The Basin Pond / Mud Pond / Lake Lee property is now conservation land with recreational hiking trails open to the public (see Figure 28) (Berkshire Natural Resources Council (circa 2006) [24]).

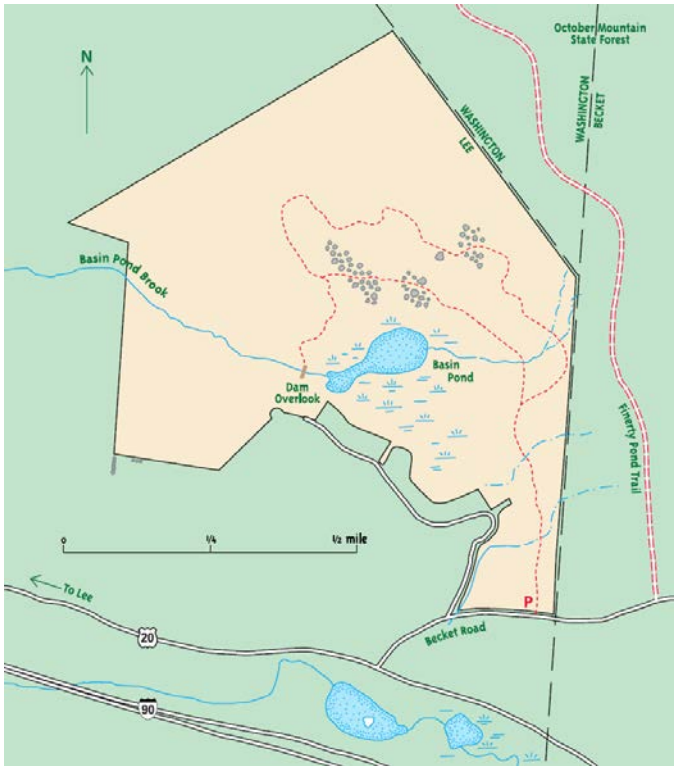


Figure 28. Map for the Berkshire Natural Resources Council Basin Pond Reserve (Berkshire Natural Resources Council (circa 2006) [24]).

The pond itself has been enlarged slightly beyond its post-failure dimensions by a group of builders acting without a Chapter 253 permit, the local beaver population (see Figure 29).

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Figure 29. Current Basin Pond impoundment and dam from upstream side, June 1, 2018 (Wooten photo, 2018).

B. Regulatory Evolution

In retrospect, shifting interests and catastrophic events shaped the progression of laws pertaining to dams in Massachusetts. These laws transitioned from being protective of fish in the colonial days, to dam owner rights as mills and industry proliferated across the Commonwealth, to inclusion of rights for land owner who were flooded out by impoundments or deprived of river flow downstream, to the addition of downstream residents protection in the 1854 Act that initiated dam safety laws (Commonwealth of Massachusetts, 1854 [25]). The 139 deaths and associated destruction from the Williamsburg Reservoir Dam failure spurred major changes to the dam safety law in 1875, giving County Commissioners more oversight authority and responsibility for dam design, construction, and inspection (Commonwealth of Massachusetts, 1875 [26]). Similarly, the Lake Lee Dam failure tragedy prompted significant and meaningful dam safety regulatory changes.

Within 10 days of the Lake Lee Dam failure, the Massachusetts governor, John Volpe, called for the legislature to create a 14-member commission to study and recommend law revisions on the supervision and maintenance of private dams (Berkshire Eagle, April 3, 1968 [27]). In 1970, the Massachusetts legislature transferred the regulation and inspection of dams from the County Commissioners to the Commissioner of Public Works and the associated Department of Public Works-Division of Waterways, establishing Massachusetts's first dam safety officials within state government (Commonwealth of Massachusetts, 1970 [28]). Subsequent legislation resulted in several transfers of the Division of Waterways and the dam safety officials, eventually to the Department of Conservation and Recreation, the present home of the Office of Dam Safety.

VII. LESSONS LEARNED

The failures of the Lake Lee / Mud Pond Dams offer a smorgasbord of possible contributing factors and lessons. The most obvious and important of the lessons were that:

- Poor design and poor construction of dams should never be allowed. The Massachusetts dam safety regulations prior to 1970 placed the responsibility for dam safety regulation on the County Commissioners, a group poorly equipped to understand dam engineering. The County Commissioners, in turn, relied on their County Engineer, again, an individual who typically lacked specialized dam safety engineering training, and on the owner's engineer.
- Engineers charged with designing and monitoring dam construction must address all site difficulties and insist on construction that follows those designs using frequent and, when appropriate, continuous monitoring. The Lee Dam construction did not adhere to the design requirements despite periodic site visits by the owner's engineer.
- Control of seepage is critical. The post-failure investigation revealed highly pervious layers in the soils under Lake Lee Dam. These features allowed seepage conditions that appear to be the cause of the 1968 failure and, most likely, the 1886 failure. We don't know if the seepage conditions induced internal erosion / piping loss of foundation or embankment soils or if seepage pressures destabilized the downstream embankment slope, two likely failure modes. Several elements of the design and construction of the Lake Lee dam failed to adequately address seepage:
    - The design investigation failed to extend to bedrock and to identify all pervious layers, especially the gravel and cobbles layer that was immediately upstream of the core. The investigation also lacked sufficient coverage of the dam footprint to suitable characterize the foundation.
    - The dam core design did not extend deep enough and was not compatible with the abutting gravel and cobbles foundation layer.

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- Although, the engineer eventually accepted the excavation for the mid-valley section of the core, based on the limited inspection reports and the test pit difficulties described by Tighe & Bond, we expect that construction of the core was performed without suitable dewatering, and consequently failed to extend sufficiently below the level of water in the excavation to remove seepage layers.
- The embankment cross-sections exposed by the breach show that the contractor failed to perform both the 8-foot design excavation required for the core wings and the 4-foot-deep design excavation required for the pervious shells.
- The open matrix of the concrete in the junction / gate structure would have contributed to seepage issues.
- The design of the intake and outlet pipes with seepage collars and without a concrete cradle increased the likelihood that soils under pipes and around the collars would be poorly compacted and susceptible to internal erosion.

- The slightly steep (2H:1V) downstream slope would have been susceptible to failure in the event of either loss of support of eroded foundation soils or increased seepage pore pressures.

One lesson from the failures falls into the less obvious category. Distance from even a modest sized dam and reservoir will not provide significant mitigation of a flood wave if valleys are steep and constrained. For the Lake Lee Dam failure, the distance between the dam and first fatalities was about 2.8 miles, and the distance to the major damage at the Clark-Aiken plant was about 4.3 miles. The Mud Pond and Lake Lee flood waves may have spread out slightly over those distances but also gained energy and debris with the steep elevation drops.

VIII. 2018 DAM BREAK SIMULATION ANALYSIS

Because we are engineers with a numerical tool at our disposal, we (Edward Connor) developed a dam breach model to replicate and simulate flood flows of the Lake Lee Dam Failure of 1968 based on post breach evaluations, newspapers articles, and anecdotal information. If you are primarily interested in the historical details of the event, feel free to skip our technical text. However, you may find that the figures developed from our research and analysis are of interest.

Our simplified Dam Break model was developed using the USACE Hydraulic Engineering Center River Analysis System (HEC RAS 5.03) two-dimensional unsteady flow simulation. The 2D program solves the depth-averaged dynamic wave equation with an implicit finite volume numerical method to provide a two-dimensional representation of the breach flood wave in the downstream area.

The computational mesh for the evaluation was based on LiDAR terrain data available from MassGIS or the MassGIS statewide digital elevation model (base terrain). Manning's N values selected for the model were based on MassGIS Land-use maps and our judgment. We also used composite N values to simplify the analysis. The computational mesh cell size typically varied between 5-feet to 20-feet, and two-dimensional break lines were incorporated along the river channel and typically at embankments (barriers to flow). Pertinent dam data was developed from the historical 1965 construction plan for Lake Lee Dam and the 1968 Tighe & Bond report.

The dam breach hydrographs (flow v. time), routed through downstream reaches, were computed within the dam breach model based on hydraulic parameters assumed in the model. In general, the top of dam elevation provided in the 1965 construction plan was tied into the observed top of dam in the terrain model while maintaining relative elevation differences and storage volumes. The following table summarizes parameters used in our model.

Dam Break Parameters	
Breach Parameters	
Failure Mode	Piping
Breach Bottom Width (feet)	24
Breach Right Side Slopes (H:V)	0.9:1
Breach Left Side Slopes (H:V)	1.5:1
Breach Formation (hours)	0.37
Other Parameters	
Water El. at Failure (feet, NAVD88)	1545.5*
Storage at Failure (acre-feet)	367

* 0.5 foot below normal pool elevation, 5.5' below the crest (Tighe & Bond, 1968 [12]).

As noted above, we assumed a piping failure mode and a pond elevation slightly lower than normal pool consistent with the Tighe & Bond observations. Roadway structures within the inundation area where the terrain formed a barrier to flow were modeled as culverts with dimensions approximated from areal/bird's-eye, street-level imagery, and our judgment, with

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reductions to account for partial clogging of openings. Our model did not consider sequential failure of downstream bridges, culverts, dams or embankments.

The inundation map (Figure 29) generated by the HEC-RAS 2D had a path and flooding expanse similar to that shown in the photographic and newspaper reporting articles of the incident in 1968. The simulation results show that the breach flow velocity increased very quickly as the flow travelled into the steep gradient and narrow streambed of the Basin Pond Brook Reach just downstream of the dam. Spot elevations extracted from the terrain model used in the model showed that first 2 miles of stream reach for Basin Pond Brook had a vertical drop in excess of 400 feet and a channel width no greater than 50 feet. At 45 minutes into the failure, the lead wave of the breach flow was already 3 miles downstream and nearing 6 feet in height. This 6-foot-high wall of water had velocities averaging 14 feet/second and an inundation zone that engulfed Edward Gage's homestead. This same wave had less than 350 feet to travel from the Gage Homestead before it reached Olive Cordonier's residence. As it continued downstream of Olive Cordonier's home for approximately1.3 miles, the lead wave lost very little energy in the steep and narrow channel of Greenwater Brook towards the Clark Aikens Plant. At minute 52 of the simulation the force of the wave reached the Clark Aikens Plant with a wave height of 5 feet and velocities 12-14 feet/sec.

Figures 29, 30, and 31 show the inundation map generated by the dam break model, an enhanced 1959 aerial of the fatality area, and a focus of the inundation zone in that area, showing the engulfment of the Gage and Cordonier homes.

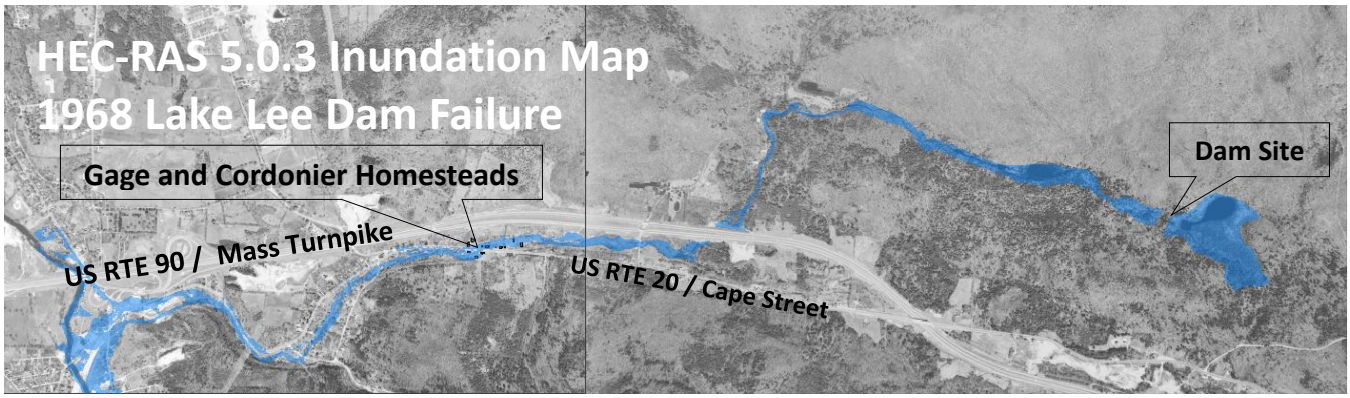


Figure 29. Inundation map of 1968 Lake Lee Dam failure estimated by dam break analysis (Google Earth, 1959 [1]).

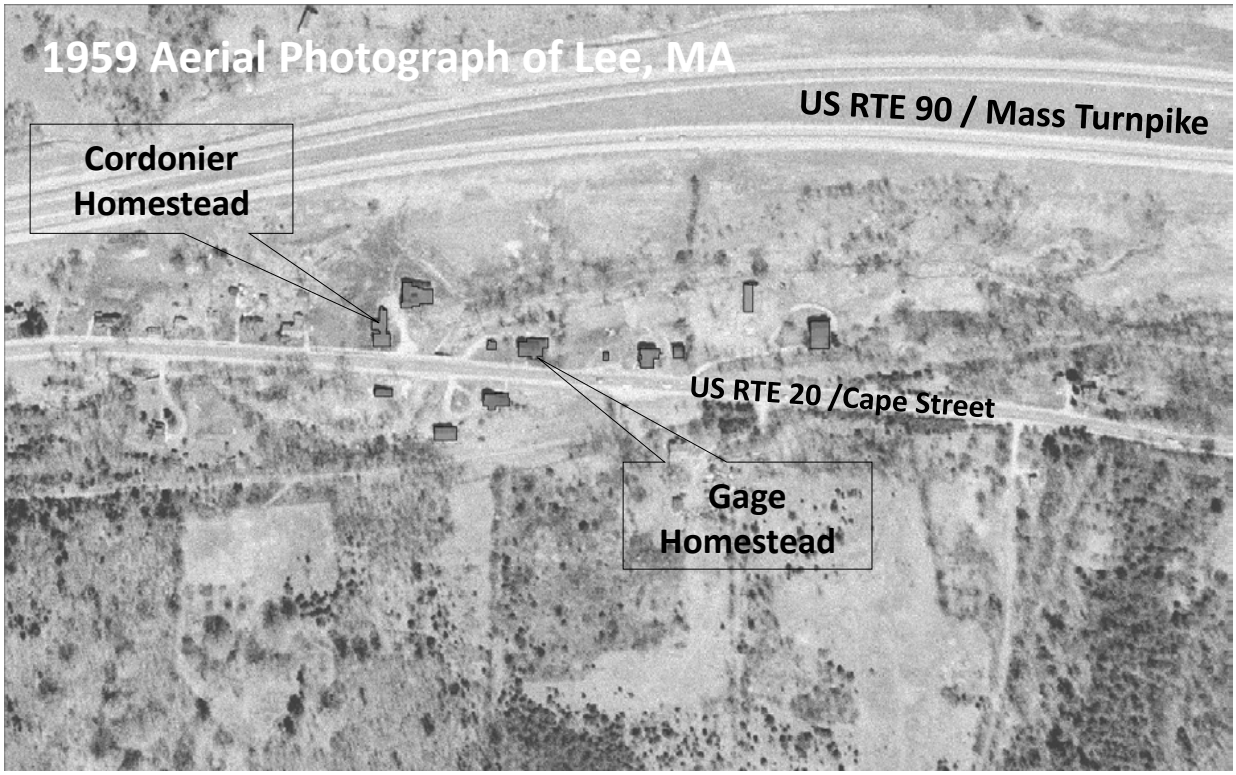


Figure 30. 1959 aerial photograph enhanced to show structures in the Lake Lee failure flood fatality area (Google Earth, 1959 [1]).

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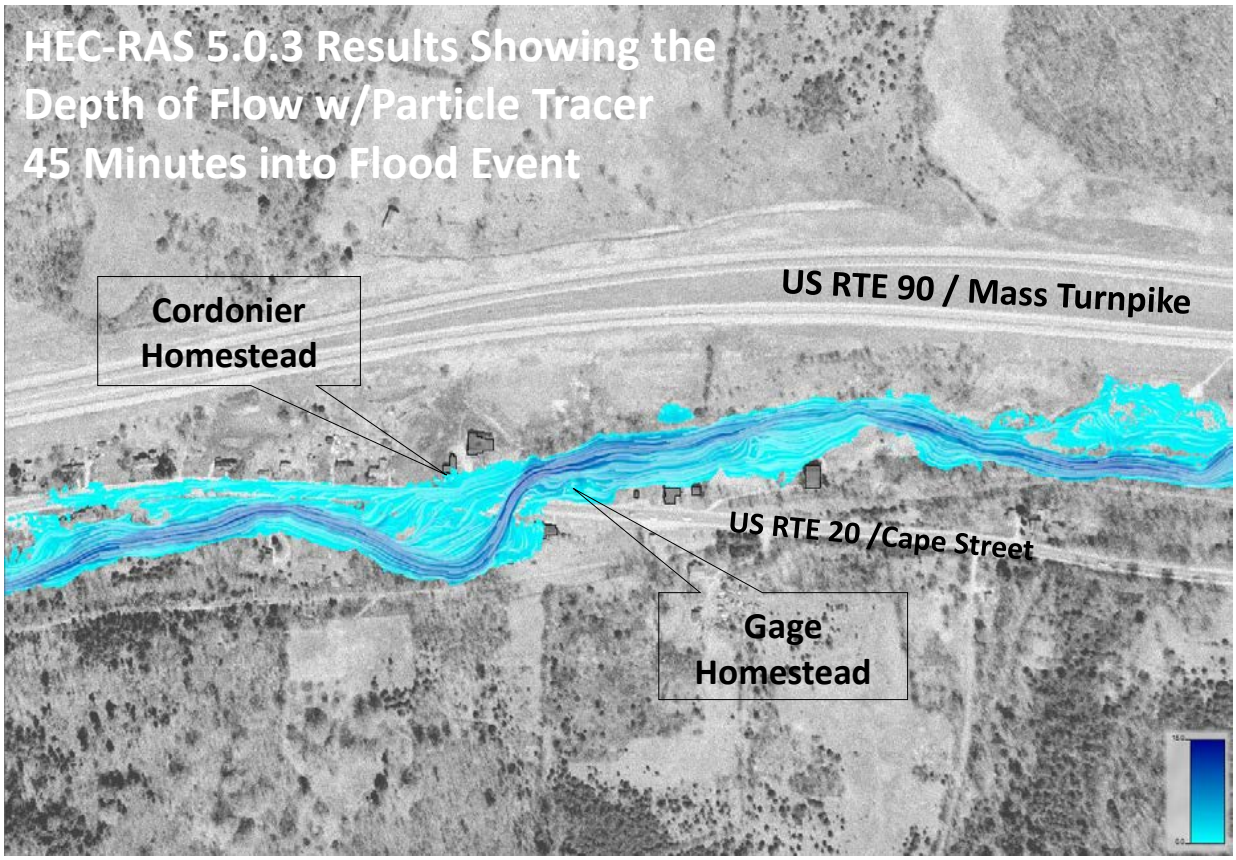


Figure 31. 1959 aerial photograph with the dam break model inundation zone in the Lake Lee failure flood fatality area (Google Earth, 1959 [1]).

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Lee Wooten is civil engineer specializing in soil mechanics, dam engineering, foundation engineering, underground engineering, and geohydrology. He received his BSE from Duke University in 1974 and, after four years of driving ships for the Navy, studied for (and received) his MS at MIT. He joined GEI in 1980 and has served as a geotechnical engineer, director of the laboratory, project manager, division manager, and principal. His experience includes a practice focused on inspection, analyses, and remedial designs for dams as well as geotechnical support for infrastructure projects. ASDSO has twice presented awards for remedial projects designed by GEI teams on which Lee was the lead designer or project manager - in 1992 for remedial designs of the Blue Ridge Parkway Dams and in 2009 for the City of Norfolk's Lake Burnt Mills Dam project. He served on the ASCE Geo-Institute Levee Assessment Team sent to New Orleans in 2005 following the hurricane Katrina, and he led recon teams for the Geotechnical Extreme Events Reconnaissance (GEER) Association following hurricanes Gustav and Ike (New Orleans) in 2008 and Harvey (Houston) in September 2017. He also assisted the GEER team recon of hurricane Sandy (New Jersey) in 2012.

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