Taking Engineering by Storm

The Great Easter Flood of 1913 turned the Midwest from Illinois to Pennsylvania into a veritable inland sea. Then America's worst weather disaster, the catastrophe revolutionized flood control methods, which later became a model for the Tennessee Valley Authority.

by Trudy E. Bell

Water in downtown Dayton, OH, from the Great Easter Flood of 1913 had receded by the time this photograph was taken, but the dark staining on the lower half of all the brick buildings shows it had crested at the second story. Snow on the roofs also indicates the freezing temperatures while people were waiting to be rescued.

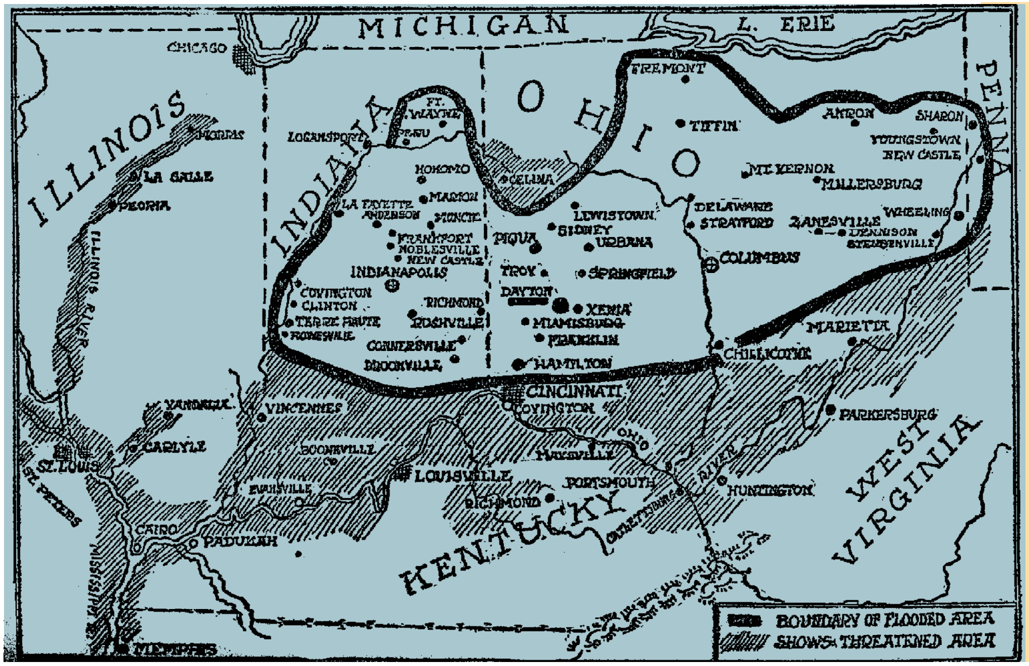
Source: Miami Conservancy District

ON EASTER WEEKEND IN LATE MARCH 1913, three enormous, powerful spring storms fatefully converged over the United States, lashing the nation with the most widespread natural disaster it had ever suffered.

The wreckage began on Good Friday, March 21, the first day of spring, with a freak windstorm. Between dawn Friday and dawn Saturday, the temperature plummeted from 60°F to 23°F as hurricane-force southwestern winds whipped across Ohio, Michigan, and Ontario, Canada, sustaining 70 to 80 miles an hour for several hours, in some places even gusting above 90. Telegraph poles splintered and fell, steeples toppled, trees were uprooted, and passenger wagons were tumbled off roads into farm fields.

Then on Easter morning, March 23, rain began falling over Illinois, Indiana, Iowa, and Wisconsin from an intense cyclonic system that had moved in from the southwest. On Sunday afternoon, tornadoes ripped through Michigan, Indiana, Illinois, Iowa and Nebraska, killing more than 150 people—94 in Omaha alone. By nightfall, rain was falling in sheets over the Great Lakes, West Virginia, Pennsylvania, and New York. Worse, an equally intense storm system formed in the Southwest on Monday and moved northeastward in the same track. Both storms stalled in a long trough across the Midwest between two stationary highs.[6, 8, 9, 15]

Through Thursday, March 27, the merged storms dumped more than six inches of rain over Tennessee, Kentucky, Pennsylvania, and New York. Worse, they hammered parts of Ohio with up to 11 inches—*three months worth* of rain in four days—still the all-time record. The soils across the Midwest and Mid-Atlantic, already saturated by an unusually warm and wet winter, could not absorb such a Noachian deluge. Water gushed off every hillside, turning creeks into full-fledged rivers, and major rivers into raging torrents that overflowed levees and banks and spread as wide



Map in one of the "instant books" published after the Great Easter Flood of 1913 shows the sweep of the disaster, with floodwaters covering virtually all of lowland Ohio and much of Indiana and even spreading into Illinois, Pennsylvania, and West Virginia.

Source: Marshall Everett, Tragic Story of America's Greatest Disaster: Tornado, Flood, and Fire in Ohio, Indiana, Nebraska, and Mississippi Valley *(J. S. Ziegler Co., Chicago, IL, 1913), p. 40.*

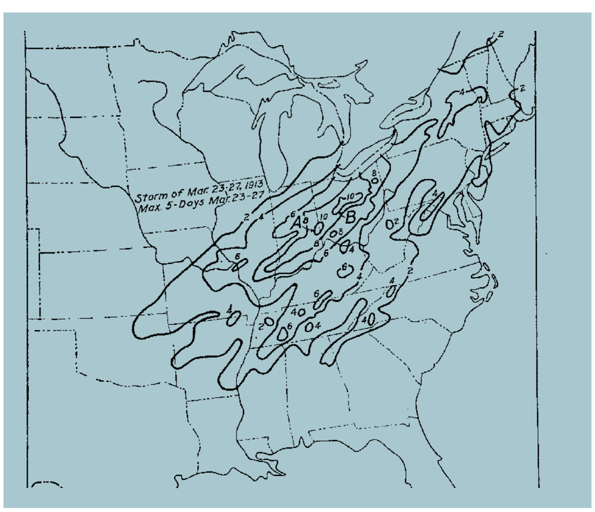
as *four miles*, converting parts of six states into a frigid, turbid inland sea.

For nearly 1,000 miles from Pittsburgh, PA, to Cairo, IL, the Ohio River and every tributary blasted through record high-water marks by up to 15 feet, submerging as much as *three-quarters* of the property of riverside cities. By the time the Ohio crested in Cairo in early April, it was so swollen with runoff that it remained above flood stage for *more than three weeks*, and caused subsequent major flooding down the Mississippi River. Meanwhile, Buffalo, Syracuse, Rochester, and other major cities were flooded in New York, and the Hudson River reached record highs from Hadley to Troy.

Within that one week, the death toll topped 700 (467 in Ohio), more than perished in the Great Chicago Fire of 1871. At least 140,000 people were left homeless and instantly destitute, as 1913 was before widespread use of home insurance. More than 500 highway and railway bridges were washed away, severing all through-train service between New York City and Chicago and interrupting the mail for up to two weeks. So many telephone, telegraph, and powerline poles were downed that much of the Midwest was plunged into a communications blackout. *[Page 20: "Advent of Emergency Wireless"]* The newly restored Ohio and Erie Canal was destroyed, ending Ohio's canal era. Thousands of carcasses of farm animals and wildlife lay rotting in roads and streets, posing grave risk to public health. Farm fields were stripped of topsoil and strewn with river rocks. Streets and buildings still standing were coated with up to a foot and a half of viscous yellow mud, which was permeated by human waste from flooded privies. Estimated property damage in 1913 dollars topped $300 million—equivalent to several billion dollars today. President Woodrow Wilson declared a national emergency, sending the National Guard into Dayton and placing the Secretary of War in charge of sanitation and medical relief.

To this day, the Great Easter Flood of 1913 still ranks as Ohio's worst weather disaster, and the Omaha tornadoes still rank as the deadliest on record in the U.S. The widespread catastrophes made the front page of newspapers across the nation and were also the subject of a number of what today would be called instant books—compilations of sensational newspaper articles and photographs collated and published within months.

But timing is everything. The flood also struck right in the midst of long-raging heated debates about the proper role of the federal government in flood control and the most effective engineering solutions. It inspired the creation of novel methods of flood control and engineering design in Ohio's Miami Valley—methods that carried one unusual hydraulic engineer to national prominence and into the leadership of the Tennessee Valley Authority.



Rainfall map shows the wide extent of record rainfall that fell between March 23 and March 27, 1913. Over parts of Ohio, rainfall exceeded 10 inches—about three months worth of rain in four days.
Source: A.E. Morgan, The Miami Conservancy District *(McGraw-Hill, 1951),* p. 12.

CONTENTIOUS HISTORY OF FLOOD CONTROL

The Midwest is no stranger to floods. Every year between 1873 and 1913, the Ohio River had overflowed its banks at least once somewhere, most frequently between January and April. Other major Midwestern rivers as well as the mighty Mississippi itself flooded with similar frequency. So the two operative questions were: How bad were future floods likely to be? And what protective measures should be taken against them?

There was no quantitative method for estimating the worst possible future flood. The customary rule-of-thumb was to take measures to prevent devastation equal to that from the most recent worst flood. But that rule of thumb often failed because of an all-too-human underestimation: the implicit assumption that no future flood could be worse than any recent worst flood. Yet, the Miami Valley flood of 1884 was far worse than the previous record-setter of 1866, and the Great Easter Flood of 1913 dwarfed them both. So after March 1913, flood-control engineers began questioning how to get a grip on quantifying actual risk.

Moreover, until 1913, the principal flood-control technique was to build levees, earthen dikes along a river's banks as high and as strong as deemed adequate to hold back waters as high as that of the most recent worst flood. But levees posed major problems. First, their massive structures gave people a sense of false confidence, to the point where cities would allow the building of homes and businesses on known flood plains—one major reason the 1913 flood's devastation of Dayton was so great. Second, floodwaters overflowing a levee 20 feet high could erode and weaken it so quickly that it would give way all at once, like a breaking dam. Again in Dayton, collapsing levees released several 10-foot walls of water that roared down the city's main streets like veritable juggernauts, their tons of force wrecking the city's structures far worse than quietly rising waters ever could. After 1913, it was widely acknowledged that levees alone were not only inadequate, but also capable of exacerbating flood damage.

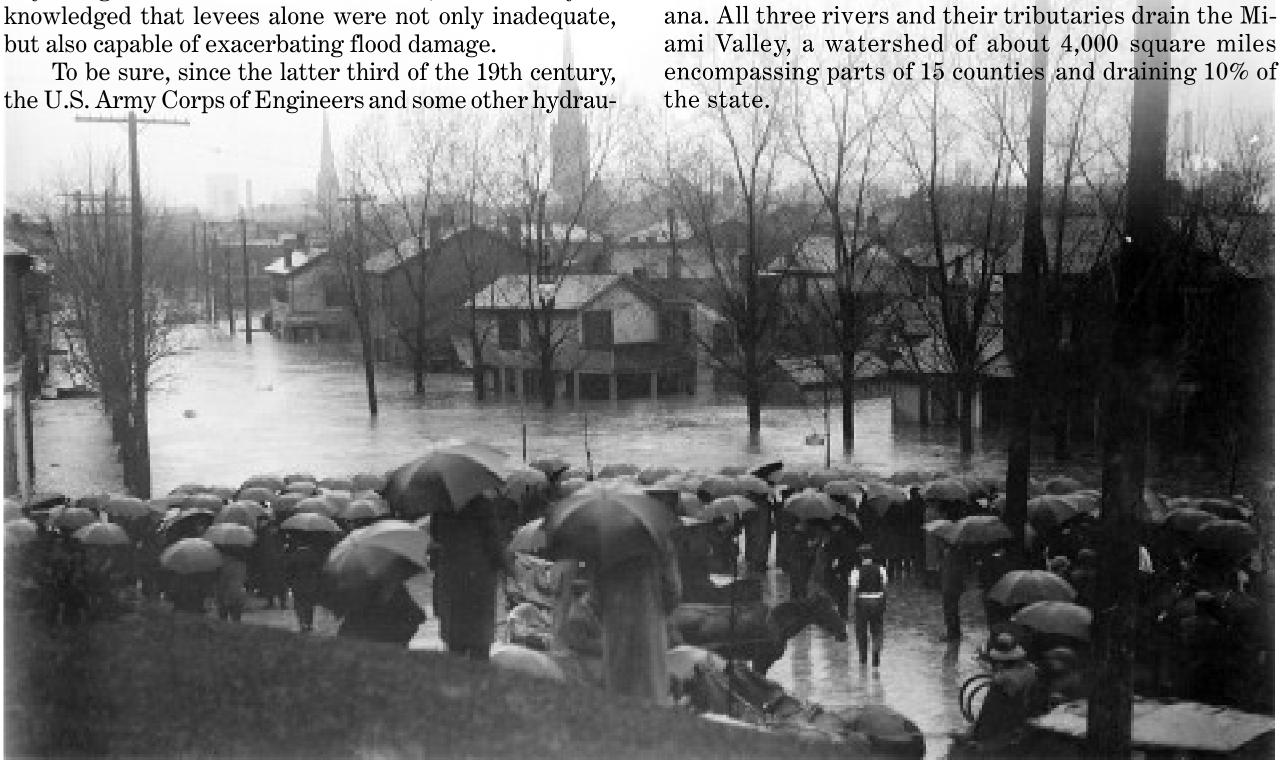
To be sure, since the latter third of the 19th century, the U.S. Army Corps of Engineers and some other hydraulic engineers had advocated upstream dams and reservoirs for flood control as supplements or alternatives to levees around the immediate areas to be protected. In theory, such upstream structures would trap runoff closer to its source, preventing rivers downstream from reaching flood stage, meantime offering a source of drinking water and hydroelectric power.

But opposition had proven stiff. For one thing, the bare concept of dams had scared many since 1889, when a privately built dam above Johnstown, PA, collapsed after heavy rains had overfilled its reservoir and the wall of water claimed more than 2,200 lives in the valley below. How could engineers guarantee that no such tragedy would ever recur? For another, flood control by an arm of the federal government raised the hackles of many states-rights activists. In their eyes, floods were local phenomena, and thus the responsibility for controlling them properly rested only with local, county, and state governments. Indeed, many felt that federal intervention in flood control was positively unconstitutional, as it would use tax money collected from all the states on works that would benefit only a few.

Although the 1913 flood did not single-handedly change people's minds, its interstate devastation starkly revealed that a major regional flood could disrupt the entire nation. Dayton's decision-makers vowed "never again," and determined to seek a permanent solution.

DAYTON'S WHITE KNIGHT

As a result of meteorological and geographical peculiarities, the brunt of the 1913 flood hit Dayton, then a bustling industrial metropolis of about 115,000 souls in southwestern Ohio. Dayton lay—as it still lies today—at the confluence of three major rivers (the Mad, the Miami, and the Stillwater), whose waters join within the city limits and then flow southward as the Miami into the Ohio River at the border between Ohio and Indiana. All three rivers and their tributaries drain the Miami Valley, a watershed of about 4,000 square miles encompassing parts of 15 counties and draining 10% of the state.



In 1913, the converging storm systems stalled almost directly over Dayton. Worse, the runoff—a total of some four trillion gallons, equivalent to about a month's discharge of water over Niagara Falls—was funneled down the three river channels at rates up to *a quarter of a million cubic feet per second,* directly into downtown Dayton, a good part of which was built on flood plain. (Thus, in provincial disregard for the breathtaking national sweep of the disaster, in Ohio the event is better known as the Great Dayton Flood.)

Source: Miami Conservancy District

Because of its new universally acknowledged vulnerability, Dayton became the focus of the country's first comprehensive program for flood control. The floodwaters had not yet receded in the city when on March 27, Ohio Governor James M. Cox appointed the Dayton Citizens' Relief Committee—composed of the mayor and several leading industrialists—to oversee immediate relief and rehabilitation. Three weeks later, after the legislature passed an emergency act authorizing the mayor of any city to appoint an emergency commission to expedite long-term repair and reconstruction, Dayton officially incorporated its relief committee into a not-for-profit citizens' relief commission.

By May 2, the city commission had become convinced that the federal government would not act to prevent a recurrence of a future disastrous flood in the Miami Valley. So, it was up to the citizens themselves to raise funds and begin work. The commission established a flood-prevention fund as seed money to begin financing engineering surveys, plans, and construction contracts for a fix-it-forever, flood-control program. After a monumental campaign of only 10 days, the fund had received pledges for more than $2 million (in 1913 dollars) from 23,000 subscribers.

Equally important, the commission also had retained exactly the man it wanted to head the flood-control program: **Arthur E. Morgan,** *Tennessee Alpha 1934*, president of Morgan Engineering Company in Memphis, TN.

Morgan was a man fired by uncompromising idealism and missionary zeal to improve the world both physically and socially. Born in Ohio in 1878 but growing up north of Minneapolis in St. Cloud, MN, by age 15 he was deeply influenced by both scientific philosophers and utopian writers. After completing high school he walked west, ending up in Colorado in 1897. Earning money by day as a logger, evenings he immersed himself in the works of authors ranging from Charles Darwin and Herbert Spencer to Edward Bellamy. He also swore a youthful vow never to accept any job that did not contribute to the general good, embracing what his biographer calls "a moral reformism, a kind of perfectionism buttressed by the scientific method, Christian Socialism for a technological society."[16]

At age 22, Morgan returned to Minnesota and joined his father's small hydraulic engineering firm, which drained wetlands for industrial and residential development, a booming business in the era of Theodore Roosevelt's conservation movement and progressive emphasis on land reclamation. Conservation of a century ago was not the same as environmentalism today. Indeed, neither elder nor younger Morgan seemed to give thought to the ecosystems

Stilling pool at the base of the spillway *(left)* is viewed from the top of the Lockington Dam, the northernmost dam of the Miami Conservancy District near Piqua, OH, looking downstream (water would flow toward the upper right). Stair-step structures on the spillway's floor, as well as the wall at the end, are part of the hydraulic jump used to dissipate high-velocity water's kinetic energy under flood conditions. In the photograph taken June 11, 1919, construction equipment is being removed just before water was allowed to enter. The finished permanently open outlet conduit at Englewood Dam is shown on June 28, 1919 *(right)*, just before water was allowed to enter. View is looking upstream from the end wall at the base of the spillway toward the dam, showing the stair-step structures on the spillway's floor (water would flow toward the viewer and off to the lower right).

Source of both photographs: Miami Conservancy District being destroyed by such wholesale drainage. On the contrary, they—like other members of the conservation movement—viewed themselves as rectifying nature's "flaws" by converting apparent wastelands to efficient use. Between 1900 and 1904, seven million acres of wetlands nationwide were "reclaimed," and by 1908 another 18 million—and the Morgan business was buoyed by that dramatic growth.

Strong young Arthur started by digging drainage ditches and building levees. He rapidly worked his way up to being a field engineer, slogging through swamps with a surveyor's transit to map drainage basins and to prepare engineering plans for draining peat marshes. When his father retired, the 27-year-old took over the family business, and within a year he was lobbying the legislature on behalf of the Minnesota Engineers and Surveyors Society to change antiquated statutes and conflicts in drainage laws. Morgan had become convinced that each river and drainage system had to be treated as a unit, irrespective of any arbitrary human-drawn town or county boundaries it crossed; thus, the political process for approvals had to be made to conform with nature's reality. He pushed his bill through the legislature and won, and soon afterward was elected secretary-treasurer of the Engineers Society and editor of its annual publication.

In 1907, Morgan was recruited as a field engineer by the U.S. Department of Agriculture to join its office of drainage investigations, where he was to provide technical advice on large drainage programs managed by various state governments. In 1908, he directed the design of a large project to drain the St. Francis River basin in Missouri and Arkansas. In 1910, armed with both know-how and know-who, he left governmental service and moved to Memphis to open his own firm, Morgan Engineering Company. His business grew as he built dams, bridges, drainage canals, and flood-control levees along the Mississippi River. In 1912, he also made national headlines by testifying before the U.S. Congress, exposing a widely-publicized conspiracy between dishonest governmental engineers and real-estate speculators who were trying to dupe the public into buying land in the Florida Everglades on the basis of a false report that declared the wetlands suitable for drainage.

So in early May 1913, six weeks after the Great Easter Flood, it was a no-brainer for the Dayton Citizens' Relief Commission to turn to brilliant, 35-year-old Arthur E. Morgan for expertise and deliverance.

'FIND A WAY OUT'

The brief given Morgan was *carte blanche:* "The valley has suffered a calamity that must not be allowed to occur again. Find a way out."[4]

The commission wanted to see dirt flying by fall in building the last word in local protections. Morgan countered that any local solutions were likely to be as ineffectual in the future as they had been in the past. In fact, he asserted, no plan should be adopted before calculating the actual volume of water of the 1913 flood, estimating the likely magnitude of the largest possible future flood, and conducting what he called a "conclusive engineering analysis" of the merits of all possible engineering solutions—tasks requiring six to 12 months.

Within days of being hired, Morgan opened a branch office in Dayton and fielded more than 50 engineers around the Miami Valley watershed to determine the flood's volume of runoff as well as the flood-crest's rate of travel. As remarkable as this might sound to engineers today, gathering such fundamental data was pioneering work in 1913. Only parts of the valley had been covered by topographic maps published by the U.S. Geological Survey, so Morgan's men had to survey the land themselves to obtain measurements of the desired accuracy. Before 1913, the U.S. Weather Bureau had established only eight river-gaging stations within the entire valley; only three routinely measured daily river stages. Thus, Morgan armed his men with buckets of paint and sent them from house to house throughout the valley's 120-mile length, carefully marking high-water lines and recording information about the time and height of various flood stages.

General view of the partially completed Englewood Dam, March 25, 1921, looks east along the dam's centerline from near the spillway. The largest of the five dams, it stretches 6,400 feet across the Stillwater River. *Source: Miami Conservancy District*

Aerial photograph taken in 1993 shows Englewood Dam as it appears today under U.S. Route 40. *Source: Miami Conservancy District*

Meanwhile, Morgan sent other researchers to libraries to comb through old newspapers for information about river crests at various towns along smaller tributaries, to estimate flows through the Miami Valley in previous floods. To quantify risk—that is, to determine *how big* was big enough to protect against the maximum possible future flood—Morgan also deployed experts to Europe to examine stream-flow records going back centuries and even millennia for the Seine at Paris, the Danube at Vienna, and the Tiber at Rome.

On October 3, 1913, Morgan presented a preliminary report to the relief commission, outlining eight possible plans for flood protection; remedies ranged from diverting rivers around cities to enlarging or straightening river channels to building a system of reservoirs. Initially, Morgan had almost dismissed the concept of reservoirs; but the detailed surveys of the rolling Miami watershed with its alternately widening and narrowing principal river valleys led him to reverse his opinion. Better yet, he pointed out, "To protect the entire valley by means of reservoirs would require about half as much time as to protect Dayton alone by local works."[11] He estimated the construction of storage reservoirs would take only two or three years (after completing legal proceedings to obtain the land).

The proposed reservoirs were not the ones familiar today for drinking water, irrigation, or recreation. Nor were they traditional dams used to generate hydroelectric power. Morgan meant *dry* dams or what he named "detention basins" or "retarding basins." He was dead set against allowing such basins to be filled with water for any purpose other than temporary flood control. Why? All his data-gathering had revealed something remarkable about the Miami River: its variation from greatest flood to least flow is so extreme that it's matched by few rivers outside of semi-desert areas prone to flash flooding. And given construction technology in 1913, dry detention basins would be most effective for controlling short flash floods.

Morgan's basic vision was elegantly simple, offering complete control with no moving parts. Five heavy earthen dams would be built at strategic narrow locations across the valleys of the Miami River and four major tributaries (the Mad and Stillwater rivers and the Twin and Loramie Creeks). At the base of each dam would be outlets that would be left *permanently open*, through which each river would ordinarily flow unimpeded, even during normal spring freshets. The conduits would be proportioned so that they would pass no flow greater than that which could be safely handled by the river channels below. During large floods, each earthen dam would temporarily restrain excess floodwater in the dry basins above the dams. Had such a system of detention basins been in place before March 1913, the excess runoff would have been distributed over more than two weeks rather than all descending on Dayton in four days. Supplementing the system of detention basins would be local works in each Miami Valley city and town, to widen and deepen channels, straighten sharp bends in rivers, and raise and lengthen bridges.

Moreover, Morgan had also quantified risk and thus determined the height and thickness for each earthen dam. Studies of all known past floods in the Miami Valley and elsewhere in the Midwest indicated that the storms producing the 1913 flood were of unusual duration, intensity of rainfall, and extent of territory covered, and likely would not be greatly exceeded. That finding was corroborated by the studies of centuries-long flood records in Europe, which showed that the maximum flood in one or two millennia is likely to be not much more than 20 or 25 percent greater than the maximum flood of a century or two. And a flood of 40 percent greater appeared beyond all possibility.

Thus, the cautious Morgan recommended planning the flood-control works large enough to control runoff 40 percent greater than that of March 1913. The citizens' relief commission, in approving his final plan in 1914, agreed, noting: "The works being planned are not to endure fifty or a hundred years, but must stand for all time as the security of this valley. . . ."[4]

ADVENT OF EMERGENCY WIRELESS

The windstorm and Great Easter Flood of 1913 also ushered in what became another major engineering revolution: emergency radio service.

With so many telegraph and telephone poles and wires downed throughout the Midwest, Chicago was unreachable to the East Coast for at least part of one day. Western Union had not one working wire inside the area bounded by Indianapolis on the west, Pittsburgh on the east, Cleveland on the north, and the Ohio River on the south.

Now, by 1913, so many amateur radio operators had become fascinated by the brand new technology of "wireless telegraphy" that between March 24 and 31, amateur radio stations at the Ohio State University and the University of Michigan, as well as numerous hams, handled widespread communications in and around the stricken area—the first use of radio technology for emergency communications.[5] The stranding of so many people also created public furor in favor of establishing a nationwide system of wireless emergency communications.

MORGAN'S GREAT PYRAMIDS

In 1914, Morgan's plans mapped the single largest-scale engineering project ever undertaken in the United States until then. As such, it blazed a trail both legislatively and technically.

A few legal highlights deserve note. As the proposed system of detention basins would involve land in nine counties, Morgan drafted a flood-control bill for the legislature. The final version, quickly passed and signed into law by Governor Cox, was named the Ohio Conservancy Act, introducing the word "conservancy" into American English. Like Morgan's Minnesota bill a decade earlier, this act allowed watersheds to be treated as holistic entities. It was broadly worded to allow conservancy districts for flood control to be created anywhere in Ohio, granting them essential powers to acquire land and raise money through bonds or assessments. And it harmonized conflicts among local ordinances governing activities such as building levees, dredging channels, and laying sewers.

The day after the act became law, Dayton, other Miami Valley cities and counties, and 1,500 individuals filed petitions to establish a conservancy district. Fifteen months later (after prolonged political opposition questioning of the act's constitutionality that went to the state supreme court), the Miami Conservancy District became a reality in June 1915.

One of the district's first acts was to hire Morgan Engineering Company to turn its engineering plans into reality, with Morgan himself named as chief engineer. The district immediately set about buying more than 30,000 acres for the five detention basins, its biggest single expense; preparations included rerouting bridges and 25 miles of railroad lines and moving an entire town (Osborn, population 200) to a site two miles away. Because the normally dry basins would encompass prime agricultural real estate, much of the land was gradually sold back to farmers. In fact, the episodic flooding was advertised as an agricultural benefit, as topsoil washed off the hills into the detention basins was expected to settle quietly behind the dams instead of being stripped away by strong currents. Other land was earmarked for recreation or for gravel mining. In all cases, however, the district retained legal rights to restrict use, as well as to allow the territory to be under water.

During construction, Morgan foresaw that hundreds of thousands of dollars of excavation equipment would be at the mercy of the five waterways' seasonal freshets as well as of floods. A few hours' warning of a river's sudden rise of even several feet would allow the equipment to be hauled up to dry land. So even before the district was established, he launched a program to measure precipitation, surface runoff, and soil moisture at isolated plats of land to document the conditions under which water stops percolating into the soil and begins running off. In 1916, based on this data, the district inaugurated a system for forecasting rising water on those five waterways even if the rise remained *below* flood stage—essential, as then the U.S. Weather Service predicted only if rivers would exceed flood stage.

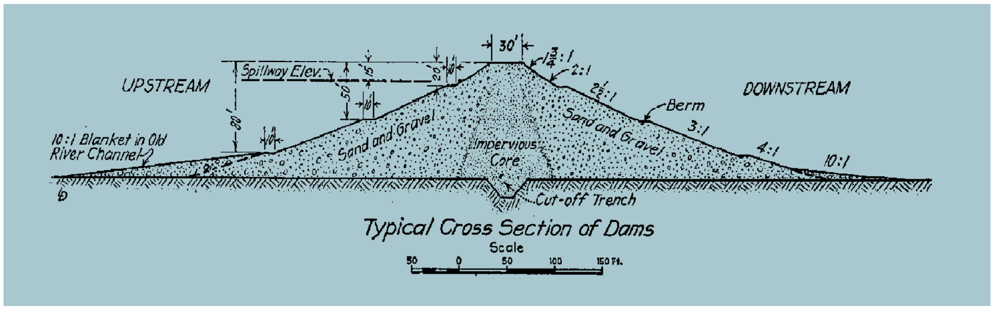


Diagram of the flood-control dams of the Miami Conservancy District shows their squat, triangular cross section. Each of the five dams, made of compacted earth, was topped by a roadway. Berms (shoulders or ledges) were provided at each change in slope to break the flow of rainwater down the faces of the dams as well as to function as roadways for inspection or maintenance.
Source: Arthur E. Morgan, The Miami Conservancy District *(McGraw-Hill, 1951), p. 249.*

Arthur E. Morgan
Tennesee Alpha 1934
Source: Courtesy of the Tennessee Valley Authority.

In 1918 (after delays for World War I), the Miami Conservancy District sold two issues of 30-year bonds totaling $34 million—then the largest special-assessment bond issue for flood control in U.S. history—and began moving earth.

The earthen dams were mammoth. Building all five required excavating more than 18 million cubic yards of dirt and stone plus pouring more than 250,000 cubic yards of concrete for the outlets, spillways, and roads across their crests. The dams ranged in height from 65 to 110 feet, and their crests from 1,200 to 6,400 feet long; their bases were all hundreds of feet thick. Their squat, triangular cross sections were far more massive than traditional dams to, in Morgan's words, "relieve the public mind of any apprehension as to their possible failure."[11] Indeed, Morgan compared the intention of their architecture to that of the Pharaoh "who built his pyramids on so broad a base that no matter what mistakes of judgment might be made, or how faulty the work might be done in the building, they would yet stand through the thousands of years."[2]

Below the permanently open outlets of each dam was an expanding channel that led the issuing water into a stilling pool. The stilling pool embodied several novel engineering features, the most innovative being a "hydraulic jump"—the project's most fundamental contribution to hydraulic engineering. Although a river at normal levels would meander through the permanently open outlets, under flood conditions the outlets' restricting size would cause high-velocity water to gush out as a powerful jet, with the risk of undermining the earthen dam's foundations. To eliminate that threat, three of Morgan's engineers (Sherman M. Woodward, *Iowa Beta 1895*, Ross M. Riegel, *Tennessee Alpha 1904*, and John Beebe) designed a spillway that used the water's force against itself. It had long been known that a diving jet of high-velocity water can spontaneously jump up to a higher level when it encounters tailwater washing back from an elevation (a radial hydraulic jump is readily visible when tapwater is run forcefully onto the bottom of an empty kitchen sink). That elevated water washes backwards, literally flowing on top of the water beneath, dissipating kinetic energy. The engineers designed a spillway that directs water down a series of concrete steps, where standing waves further dissipate energy. Their pioneering design has since become a standard for dam spillways.

The physical scale of the project also required pioneering techniques in engineering management. One of the most remarkable techniques for the era was what Morgan called the principle of "dynamic design"—of keeping the design fluid throughout construction, giving field engineers the flexibility to exercise judgment and make modifications depending on actual field conditions. Another was his principle of "conclusive engineering analysis"—of exploring every possibility for a solution, whether it initially seemed promising or not, in effort to become aware of unrealized or unexpected approaches[11, 12] (an approach similar to that taken by NASA in engineering the Apollo lunar hardware).

Construction lasted five years and was completed without fanfare in 1923. Morgan's analogy of the project to Pharaoh's pyramids was apt. Whereas the Great Pyramid of Cheops stands 40 stories tall and has a volume of 3.5 million cubic yards, the men building these dams had rearranged a volume of earth almost equal to *five* Great Pyramids.[15]

In 1922, *Engineering Record* awarded the district's flood protection system its distinguished project of the year award, placing it in the company of such other international engineering design feats as the Brooklyn Bridge (1883), Eiffel Tower (1889), Golden Gate Bridge (1937), Gateway Arch (1965), and the Channel Tunnel (1994). In 1972, the five earthen dams were designated a National Historic Civil Engineering Landmark.

Most importantly, the dams have held back floodwaters more than 1,500 times. In 1937 and 1982 (when rain and flood stages approached the magnitude of 1913) and in 1959 (year of highest watershed runoff in the valley since 1913), the areas protected—including downtown Dayton—never flooded.

ENGINEERING UTOPIA

True to his utopian values and his youthful vow never to take on a job unless it benefited the social good, Morgan also saw the Miami Conservancy District project as a social enterprise. His temporary communities for the construction workers included schools for children as well as night classes to teach the immigrant laborers English, technical skills, and values. He provided accident insurance, encouraged community self-government through town meetings, and provided recreational programs.

A vision of a self-supporting community traveled with him elsewhere as well. In 1921, before the project was completed, Morgan took over the presidency of the then-failing Antioch College in Yellow Springs, OH. Fired by his vision, he extended the idea of students working part-time with industry from engineering programs to the liberal arts, making such a cooperative or "co-op" program a core part of the curriculum. By the late 1920s, Antioch was back on its feet financially and on its way to pioneering cultural changes in American higher education.

In April 1933, five weeks after taking office, President Franklin D. Roosevelt asked Congress to create the Tennessee Valley Authority, a centerpiece of his New Deal for pulling the nation out of the Great Depression. On May 18, he signed the measure into law and appointed Arthur E. Morgan as the project's chairman and chief engineer. The TVA was a multipurpose project dedicated not only to flood control on a scale even more monumental than the Miami Conservancy District, but also to electric power generation, locks for river navigation, soil erosion control, reforestation, land management, and (in the words of Morgan's biographer) "something vaguely wonderful called social and economic development."[16]

At the TVA's helm for five years (although besieged and ultimately sabotaged by his idealistic blindness to internal politics), Morgan hired many of the same engineers who had pioneered the design of the Miami Conservancy District's detention basins and the hydraulic jump. He ran the project much the same way he had in Ohio two decades earlier and supervised the building of all eight dams on the Tennessee River below Knoxville.

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Her previous articles for THE BENT were "The Victorian Global Positioning System" (Spring 2002) and "The Victorian Space Program" (Spring 2003). She may be reached at *t.e.bell@ieee.org*.

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