# Reconnaissance Report on the Failure of Kelly Barnes Lake Dam, Toccoa Falls, Georgia (1978)

Pages
24

Size
8.5 x 11

ISBN
0309336341

Sowers, George F.; Committee on Natural Disasters; Commission on Sociotechnical Systems; National Research Council

# RECONNAISSANCE REPORT ON THE FAILURE

# OF

# KELLY BARNES LAKE DAM, TOCCOA FALLS, GEORGIA

by

George F. Sowers
Senior Geotechnical Consultant
Law Engineering Testing Company
Regents Professor of Civil Engineering
Georgia Institute of Technology

Committee on Natural Disasters
Commission on Sociotechnical Systems
NATIONAL RESEARCH COUNCIL

National Academy of Sciences
Washington, D.C.
1978

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

---

Financial support for publication of this report was provided by the National Science Foundation.

---

The National Research Council was established in 1916 by the National Academy of Sciences to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy by authority of its Congressional charter of 1863, which established the Academy as a private, non-profit, self-governing membership corporation. Administered jointly by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (all three of which operate under the charter of the National Academy of Sciences), the Council is their principal agency for the conduct of their services to the government, the public, and the scientific and engineering communities.

---

Copies of this report may be obtained from the office of the Committee on Natural Disasters, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

---

Printed in the United States of America

# RECONNAISSANCE REPORT ON THE FAILURE OF KELLY BARNES LAKE DAM, TOCCOA FALLS, GEORGIA

by

George F. Sowers
Senior Geotechnical Consultant
Law Engineering Testing Company
Regents Professor of Civil Engineering
Georgia Institute of Technology

## Introduction

At 1:20 a.m., Sunday, November 6, 1977, a small earth dam on Toccoa Creek failed suddenly during a period of very intense rainfall following several days of modest rain. The flood of water released produced a wave about 25 feet high. It traveled down the narrow stream gorge about 1/2 mile to where it dropped over the 160-foot-high Toccoa Falls. The impact of water created a second wave that spread over the creek valley below the falls, damaging buildings, collapsing house trailers, washing out several bridges, breaking a 16-inch water main that supplied the town of Toccoa, and killing 38 persons. The damage was confined to the flood-plain of Toccoa Creek below the falls, a path 200 to 500 feet wide and 1 1/2 miles long. Still farther downstream, there was flooding of farm-land, local erosion, and bridge damage, but apparently no major damage.

## Site Inspection

On November 9, 1977, I examined the site in the company of David Mitchell, Chief of Geotechnical Engineering for the Georgia Department of Transportation (DOT), and Lewis Canup, Chief Maintenance Engineer, Gainesville, Georgia, District, Georgia Department of Transportation. Mr. Mitchell had previously inspected the site on Sunday, November 6. Mr. Mitchell and I examined the dam site and the damaged area using a helicopter provided by the Georgia Department of Natural Resources. Later, on the ground, we examined the remains of the dam and made preliminary measurements using tape and Brunton compass. We also examined the flooded area briefly, particularly the reconstruction of Georgia Highway 17. Additional information on damage was provided by engineers working under Mr. Mitchell who were observing the cleanup and repair work of the DOT. Professor Jim Grant of the Toccoa Falls College provided some information on the dam in a brief interview. The remainder of the information in this report has been obtained from newspaper accounts and from miscellaneous, unverified sources.

At the present time, quantitative data on the dam are lacking; much of the information available is conflicting. The actual failure of the dam apparently was not observed by anyone, although the dam had been inspected less than 1 hour before it failed (those who inspected it were not specialists in dam behavior and the inspection was done shortly after midnight during heavy rain). Thus, the material in the report should be regarded as preliminary and the conclusions reached based on limited information. A somewhat more detailed report has been submitted by the U.S. Army Corps of Engineers to Governor George Busbee of the State of Georgia.

## Location

The dam is located on the headwaters of Toccoa Creek, 1.7 miles northwest of the center of Toccoa, Stephens County, Georgia. A portion of the USGS 1:24,000 Topographic Maps, Toccoa and Ayersville, Georgia, showing the area of interest, appears in Figure 1. The dam is located in the eastern edge of the Blue Ridge physiographic province. The area of damage is in the western edge of the Piedmont Plateau.

The Blue Ridge is underlain by gneiss bedrock with local lenses of quartzite, which probably produced the ditches and ledges responsible for the rapids immediately below the dam and Toccoa Falls. The watershed is entirely within the Blue Ridge range. In the area, the watershed divides are approximately 1,500 feet above sea level, with local peaks approaching 2,000 feet above sea level. The relief, hilltop to valley floor, is from 300 to 500 feet. Generally, headwaters of the creeks are steep, with average slopes exceeding 10 percent. To the north and west, the Blue Ridge rises to elevations greater than 3,000 feet above see level. To the south and east, typical Piedmont elevations are about 1,000 feet above sea level, with relief of 100 to 200 feet between hilltops and stream valleys.

## Dam Site

The dam was built in a narrow gorge between two low ridges, possibly defined by quartzite-rich formations. The creek bottom at the site was at approximately 1,110 feet elevation. The dam was built at the point where the creek steepens into rapids, dropping 70 feet in 2,500 feet to the top of Toccoa Falls.

The channel at the site was probably 20 feet wide when the dam was built, with valley walls rising at an angle of about 20 degrees for 15 or 20 feet immediately adjacent to the creek. Beyond, the slopes are somewhat flatter.

## Dam Construction

Information on the dam construction is sketchy and conflicting. A log crib dam, possibly 10 to 15 feet high, was constructed at the site

nearly 80 years ago. A nameplate in an abandoned powerhouse has the date 1899. A 30-inch riveted steel penstock extended from the dam to a small powerhouse below the waterfall to utilize the 280-foot head difference for power generation. The remains of the dam indicated that the steel pipe was supported on flat boulders, probably as a rubble wall, or filling within the timber crib.

The project was developed by a local businessman to supply electric power to the town of Toccoa. In 1927 he went bankrupt, although the plant continued to generate power. The ownership is uncertain until the 1930s, when Georgia Power Co. purchased the local power distribution system and title to the dam, lake, and power station passed to the Toccoa Falls Institute. The dam height was increased by earth filling, probably in 1937. Mr. R. G. LeTourneau, inventor of the articulated self-powered scraper, had become interested in the Institute and had built a new factory nearby. He lent heavy construction equipment to the school to be operated by students in a work-training program supervised by Mr. Kelly Barnes of the Institute staff. Whether this was the first augmentation of the 1899 timber crib and what the final dimensions were after the fill was added are not known. The 1937 date of construction appears in the National Inventory of Dams (U.S. Army Corps of Engineers).

Other additions were made, including a stone masonry intake for the 30-inch penstock to the powerhouse and a second 30-inch intake with a vertical riser to act as an operating spillway. The date of these additions are not known. Possibly they were included in the 1937 construction. There is some recollection of pipe additions in 1949. These could coincide with reported modernization of the old powerhouse by the Institute in the late 1940s. No evidence is available of engineering design for the original dam or the additions.

More than one occurrence of earth-fill dam placement is suggested by (1) an abrupt change in downstream slope 20 to 25 feet above the stream bottom and (2) a 4-foot layer of different-colored soil in the upper 4 feet of dam fill. Therefore it is concluded that the earth-fill dam was superimposed on the old stone-filled timber crib in 2 or more stages, producing an eventual height of 40 feet.

## Dam Before Failure

No plans or cross sections of the dam have been discovered so far. Figures 2 and 3 show a plan and cross section based on field observations which include estimated dimensions. More accurate plans and cross sections must await ground surveys. Because the maximum section of the dam was completly obliterated by the failure, it can only be presumed that the cross section of the dam seen on the abutments continued across the creek. If anything, the maximum cross section of the dam might have been steeper, as suggested by the scour and rock staining. The dam was generally crescent-shaped in plan, concave upstream, following a low ridge. The dam height above the present eroded stream

channel was approximately 40 feet. The upstream slope is relatively flat, approximately 25 degrees with respect to the horizontal. The downstream slope is very steep, averaging 40 degrees for the upper 15 feet and 35 degrees below. Crude leveling with the Brunton compass indicates that the south end of the failure area is 1 to 2 feet higher than the northwest.

An old 30-inch conduit or penstock leading to the abandoned power plant is exposed in the southeast face of the breach (Figure 6). The steel appears to be in good condition. Further down the stream near the toe of the dam the pipe had been cut. It appears to be in good condition considering its age.

According to Professor Grant, the conduit was controlled by a gate valve at the upstream toe of the dam. A valve has been retrieved from the creek below the waterfall and was found to be closed. He recollected that the conduit used to drain the lake was kept slightly open. If so, the valve recovered was possibly the upstream control for the power penstock and there were, in fact, two 30-inch conduits through the dam.

There was a side channel spillway on the northwest abutment. The channel was approximately 5 to 6 feet deep and 6 feet wide at the base, with approximately 1.5 (H) to 1 (V) side slopes. Swish marks and leaves accumulated in the side of this channel indicate that the water was 3.8 feet deep before the dam failed.

The spillway channel above a depth of 2 feet was partially obstructed by brush and small trees of the type that can grow in and adjacent to running water. There was no evidence of large debris jamming the spillway channel. The size of the brush and trees in the channel indicates that it might have been cleaned out 4 or 5 years ago. They also indicate that the continuous overflow was about 2 feet deep.

The downstream face of the intact portions of the dam are covered with brush and trees up to 8 inches in diameter (Figure 8). The size and species of the largest trees suggest that they are 20 to 25 years old. The upstream face of the dam was covered by small trees and brush. The absence of stumps and large trees suggests that the dam face had been well maintained until about 20 years ago. This coincides with the abandonment of power generation in 1955 or 1957.

There is an earth trail on the top of the dam accessible to off-the-road vehicles. There is an earth parapet 2 to 2.5 feet high on the upstream side of the 15-foot-wide crest road on the south end of the dam but not on the north end. There is a small erosion gully on the upstream face of the northwest end of the dam, south of the spillway.

There is a sharp irregularity on the downstream face of the southeast end of the dam near the creek. The topography and the attitude of the trees suggest that this irregularity was caused by a small slump or landslide in the steep downstream face of the dam. If so, the vegetation surrounding it suggests that it is several years to tens of years old.

## 1976 Flooding

In May, 1976, Toccoa Creek flooded below the falls. Many other small rivers in the region also flooded, doing considerable damage to roads, bridges, and farmlands. The area was declared eligible for federal disaster relief.

The U.S. Army Corps of Engineers examined the area and authorized $30,000 for repairs to roads of Toccoa Falls College. No inspection of the dam was made at that time, despite accounts in the Atlanta newspapers following the dam failure that "the dam had been inspected and found safe." It is likely that the flooding was from local inflow of tributaries below Toccoa Falls as well as from Toccoa Creek above the dam.

## Conditions Leading to Failure

The 5 days immediately preceding failure was a period of continuous moderate rain. The total rain for this period measured at Toccoa was 5.6 inches. This amount of rainfall in 5 days is not unusual for the area. It is likely that rainfall over the Toccoa Creek watershed in the Blue Ridge was considerably greater because of the orographic effect of the hills. On the Saturday night preceding failure, intense rainfall was reported in the vicinity of the college.

A small tornado was reported 5 miles southeast of the lake on Saturday evening, verifying meteorologic conditions for localized intense rainfall.

The local residents were concerned for the safety of the dam apparently because of the age of the structure and the rainfall intensity. Moreover, there was local flooding of the trailer court area, about 3/4 mile below the falls where a tributary joins the creek. Two volunteer firemen, associated with the college. were sufficiently concerned to examine the dam near midnight. They could see nothing. However, continued rain caused them to become alarmed. They were warning the residents in the floodplain below the dam of the potential for trouble when the dam broke.

## Failure

At the time of failure, the lake was apparently not full. Swish and debris marks on the upstream face of the dam indicate that there was 1.5 to 2 feet of freeboard below the earth road at the dam crest. The water depth in the spillway was 3.8 feet, with more than 1 foot of freeboard. (Of course, the amount of freeboard in the failure area cannot be determined because that portion of the dam was washed away.)

There is an unverified report that the firemen who inspected the dam shortly before it failed found no water in the spillway and the lake level falling. If so, the dam was failing at that time after cresting

as shown by the high water marks in the spillway. Alternatively, a sudden inflow from local runoff filled the lake very rapidly after their inspection.

Apparently failure was sudden. According to the residents below the dam, a roar was heard accompanied by popping sounds, probably from breaking of trees and the impact of the old crib logs on the walls of the gorge. Some of the persons living in the floodplain heard the sound and were able to scramble for higher ground before the flood reached them. Others were not so fortunate.

Below the falls the creek floodplain is 100 feet wide for a distance of 1,200 feet, with a drop of 30 feet. The floodplain widens to between 300 and 500 feet and drops 50 feet in the next 6,000 feet. The structure nearest the falls is an old stone building on the bank of the creek channel. Water rose to the center of the main floor windows, 20 to 25 feet above the creek bottom. The building appears reasonably intact despite damage to the interior.

A few hundred feet further downstream is a college dormitory building, partially in the floodplain. The flood wave reached a height of about 8 feet in the ground floor. Three of the students occupying this floor were drowned; others were able to swim or scramble to safety. The upper floors were not damaged.

About 3/4 mile downstream from the falls, the floodplain width increases somewhat and the slope becomes flatter where a tributary joins the creek. In this area a wood-frame garage and maintenance building was partially demolished by water impact. A trailer park on the right floodplain near the garage was demolished. Debris marks in this area indicate that the water depth was about 10 feet. Some of the trailers floated away, others were smashed. Most of the fatalities were to the occupants of this trailer village: married students, children, faculty, and some employees of the college. The flood velocity at this point was great enough to carry a large intercity bus nearly 1/2 mile downstream.

One-half mile downstream the creek passes under Georgia Highway 17. The concrete bridge, supported by spread footings on weathered rock, remained intact. The debris lodging against it produced a crude dam. The water rose, flowed across the approach fills, and washed out the highway on both sides of the abutments. The bridge partially dampened the flood wave. The velocities downstream were somewhat lower and the flood heights above the floodplain appeared to be 5 to 7 feet. Although there was some bridge damage downstream from Highway 17, most of the damage was between Highway 17 and the falls.

## The Cause of Failure

The exact mechanism of failure may never be known because the maximum section of the dam was entirely obliterated, including foundation for the crib dam and the earth embankment. However, the short period of time for the flood wave to rise and the loud noises suggest a sudden failure.

In my opinion there are four reasonable explanations for the failure:

1. Overtopping followed by rapid erosion of the embankment,

2. Local gullying followed by overtopping and rapid erosion,

3. Local sliding of the saturated steep downstream face of the dam, causing either piping or overtopping and rapid erosion, or

4. Piping around the old penstock, followed by collapse.

Of these four hypotheses, the fourth appears least likely. The water level in the lake was not higher than it had been previously, based on wave erosion marks on the upstream face of the dam. There would be no reason for piping failure to coincide with a period of intense rainfall. Such a piping failure would have been just as likely at any other time, considering the relatively constant lake level. However, this hypothesis is consistent with the unverified report that the lake level was falling just before failure.

Overtopping of the dam would not have occurred if the dam crest were level between the remaining flanks of the dam. The debris lines indicate at least 1.5 feet of freeboard at maximum lake level. However, if the dam crest had a pronounced sag or if erosion gullys had cut across the dam crest, simple overtopping would explain the failure. The erosion during the intense rainfall would have provided the trigger. Aerial photographs made in 1955 and 1973 do not indicate a sag, within the accuracy of photogrammetry (possibly 1 to 2 feet).

The steep slope of the dam and the suggestion of an earlier slide on the southeast downstream face support the concept of a slide in the downstream face initiating failure. The micaceous soils of which the dam is built are susceptible to weakening upon saturation from rain. The 5 days of continuous rain would have saturated the somewhat porous micaceous soils, and the final intense rain the night of failure would have provided a trigger. Saturation could have been aggravated by leakage of the old penstock or by piping along it.

The Chief Maintenance Engineer, Gainesville District, Georgia DOT, was called to the disaster area Sunday morning and reached there about 3:00 a.m. By daylight he had mobilized equipment from the Georgia Highway Department to repair Highway 17 and to help with the rescue operations.

The local fire department and civil defense from Toccoa were summoned immediately and began rescue operations before the flood had subsided. Fortunately, the County Hospital is on Highway 17, 1/4 mile north of the creek. Rescue access was hampered by the washout of Highway 17 leading to Toccoa. Later on Sunday, the State Civil Defense Mobile Command Post was established on the hospital grounds to coordinate rescue and cleanup activities. National Guard units including helicopters were available Sunday to look for the injured and bodies.

By late Sunday, traffic had been restored to Highway 17. By November 9, the highway repairs were nearly complete. The Highway Department maintenance crews rebuilt the 16-inch water main and had it in operation by Thursday, November 10. Meanwhile, some water service was reestablished using an abandoned 10-inch water main that had not been destroyed.

Cleanup operations and the search for bodies were conducted by maintenance forces of the Highway Department, the Civil Defense workers, and the National Guard. The construction activities were coordinated by the DOT Regional Maintenance Engineer. By Wednesday, November 9, most of the damaged buildings had been cleaned out and the unsafe structures demolished. All but one of the missing bodies had been recovered. The DOT forces withdrew from cleanup to concentrate on highway repair, and local contractors were retained by the DOT and Civil Defense to continue cleanup and reconstruction.

WATERSHED AND CREEK DATA
TOCCOA CREEK, GEORGIA

(Preliminary from USGS Topographic Maps, 1:24,000, 20-ft contours, Ayerville and Toccoa quadrangles)

| | | | |
|---|---|---|---|
| Area of watershed above dam | 4.5 sq mi = 2,900 acres | = | 11.7 $km^2$ |
| Area of Lake Barnes | 40 acres | = | 161,900 $m^2$ |
| Length of main stream, from divide to head of lake | 3 mi | = | 5 km |
| Elevation of highest divides | 1,500 ft | = | 457 m |
| Elevation difference, divide to lake | 350 ft | = | 107 m |
| Elevation of lake | 1,148 ft | = | 350 m |
| Length, head of lake to dam | 4,000 ft | = | 1,220 m |
| Elevation, creek below dam | 1,110 ft | = | 338 m |
| Length of creek, dam to falls | 2,500 ft | = | 762 m |
| Elevation, top of Toccoa Falls | 1,040 ft | = | 317 m |
| Height, Toccoa Falls | 160 ft | = | 49 m |
| Elevation, base of Toccoa Falls | 880 ft | = | 268 m |
| Length of creek, falls to Dead Man Branch | 1,200 ft | = | 366 m |
| Elevation of creek, junction with Dead Man Branch | 850 ft | = | 259 m |
| Length of creek, Dead Man Branch to old school | 2,500 ft | = | 762 m |
| Elevation of creek at old school | 820 ft | = | 250 m |
| Length of creek, old school to Highway 17 | 3,500 ft | = | 1,067 m |
| Elevation of creek at Highway 17 bridge | 800 ft | = | 244 m |
| Length, base of falls to Highway 17 bridge | 7,200 ft | = | 2,200 m |
| Change in elevation, base of falls to Highway 17 | 80 ft | = | 24 m |

Geographic coordinates of dam N 34° 35.6', W 83° 21.5'

NOTE: Height of dam, date of construction, and stream in National Inventory of Dams are not correct.

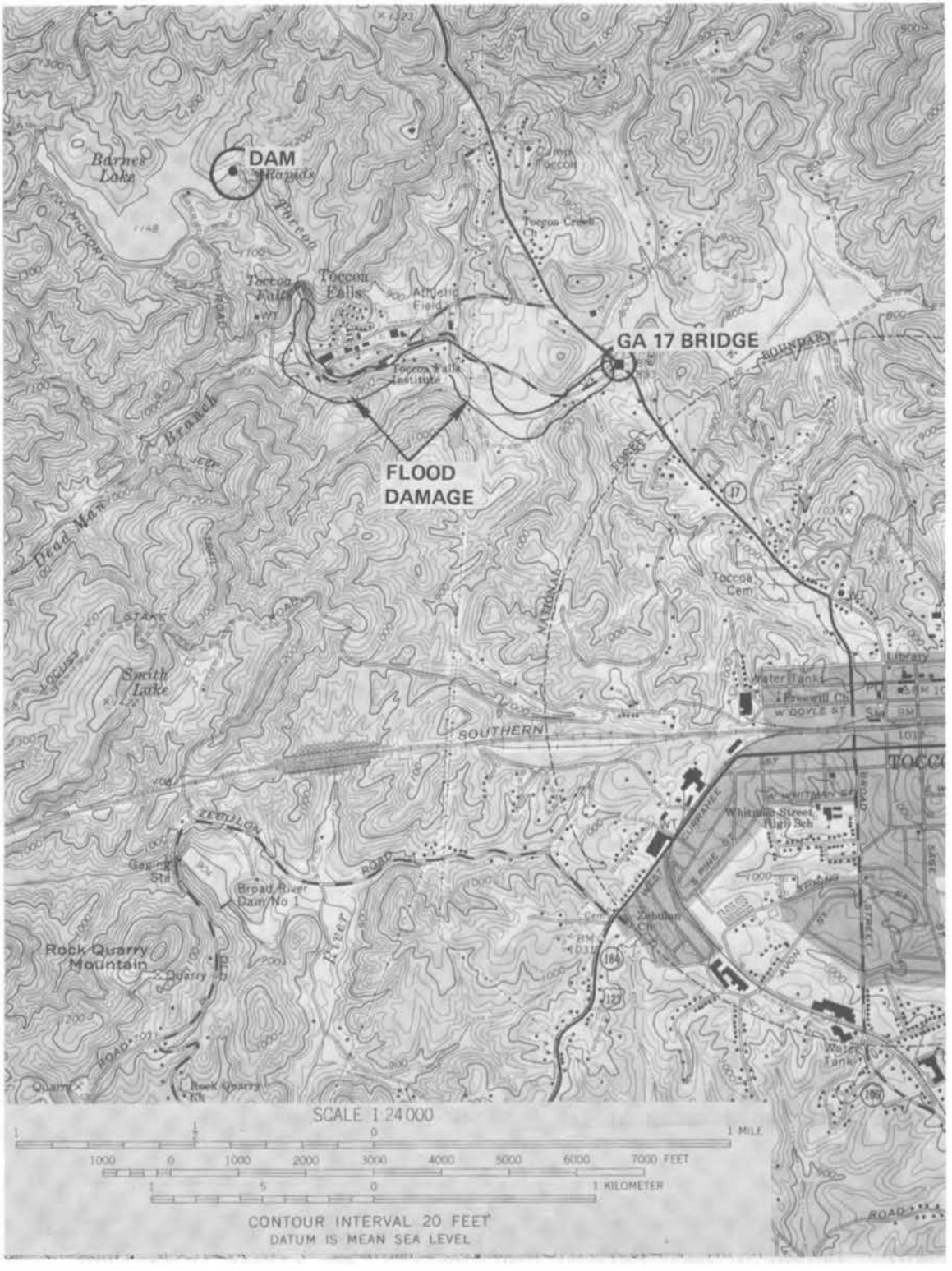


FIGURE 1 Location of Kelly Barnes Lake and Toccoa Falls Institute

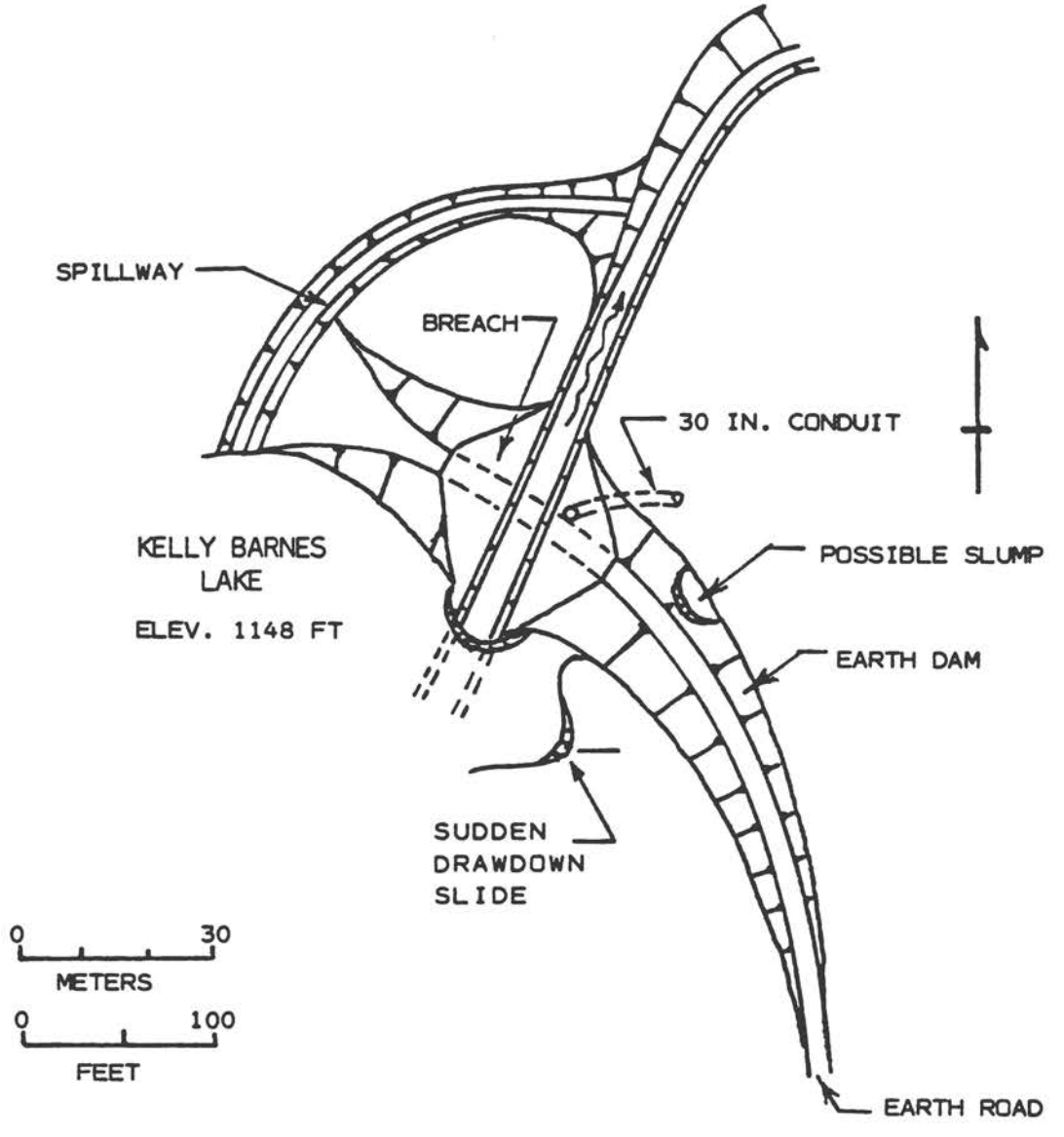


FIGURE 2 Kelly Barnes Lake Dam, Toccoa Falls, Georgia. Estimated plan of dam before failure (Field Notes, George F. Sowers, 9 November 1977)

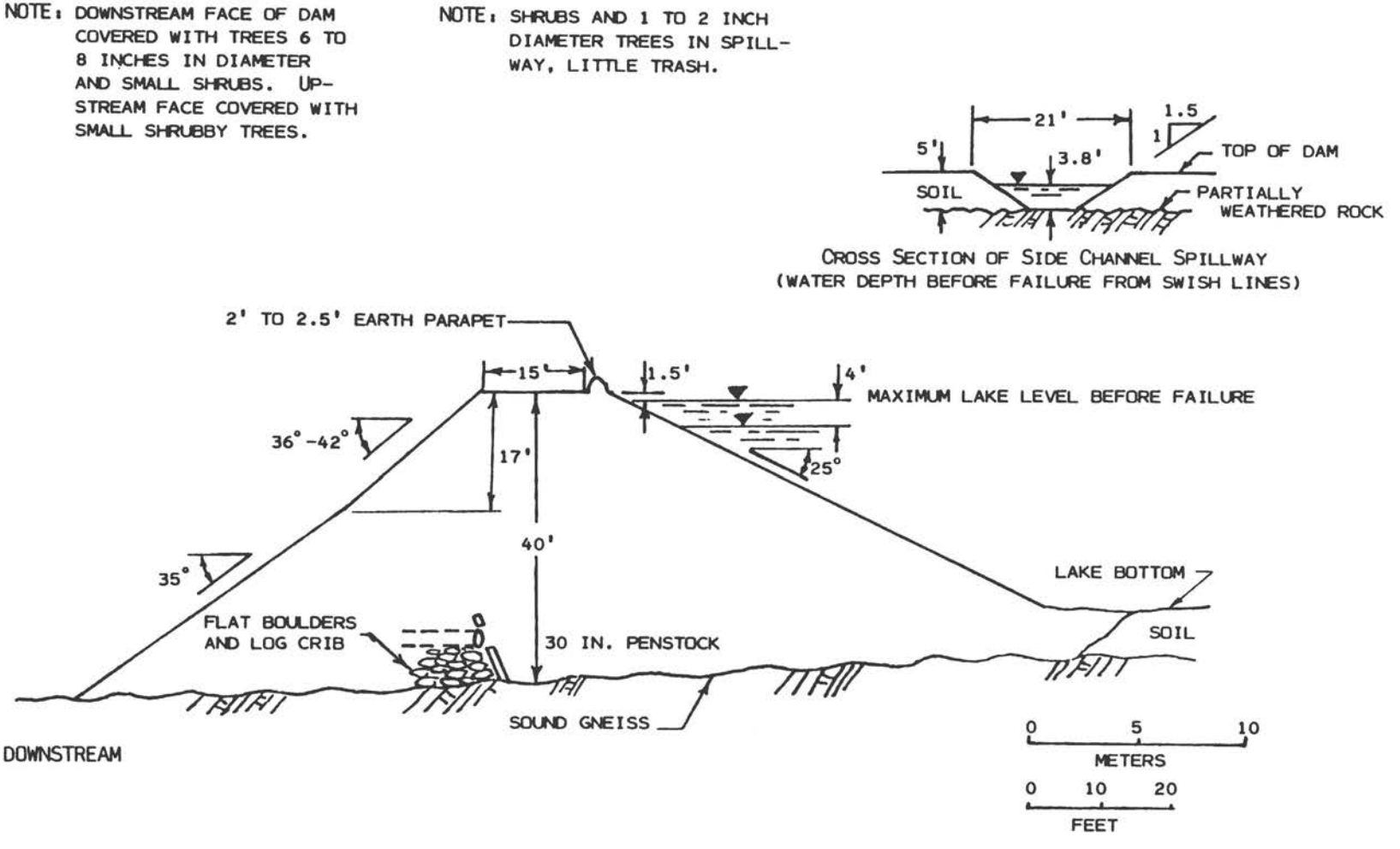


FIGURE 3 Kelly Barnes Lake Dam, Toccoa Falls, Georgia. Maximum cross section, center of Toccoa Creek, looking east-southeast, based on adjacent intact remains of dam (Field Notes, George F. Sowers, 9 November 1977)

FIGURE 4a Dam looking downstream through breach

FIGURE 4b Scoured creek immediately downstream from dam looking downstream

FIGURE 5 Face of breach on right abutment looking downstream

FIGURE 6 Face of breach on right side looking southwest, showing old penstock and remains of 1899 crib dam at downstream toe on left

FIGURE 7 Face of breach on left side, looking north, upstream to left

FIGURE 8 Right downstream face, 10-in. tulip poplar, 6 to 8-in. pines, old slide scar

FIGURE 9a Dormitory on left bank of flood plan; high water line in parking lot behind dormitory, creek in right corner

FIGURE 9b Dormitory looking at riverside face. High water line about top of windows, debris and mud shoveled from rooms looking for bodies

FIGURE 10a Maintenance garage and shop 1/2 mile downstream from dormitory looking downstream; creek to left

FIGURE 10b Aerial view of trailer court area on right with maintenance garage near center. Tributary enters valley on right

FIGURE 11 Damaged faculty home on right bank across from dormitory

FIGURE 12 Damaged cottage downstream from dormitory

FIGURE 13 Highway 17 with new asphalt paving on new approach fills