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NATIONAL DAM SAFETY PROGRAM. WELCH LAKE DAM (MO 10733), MISSOUR--ETC(U)

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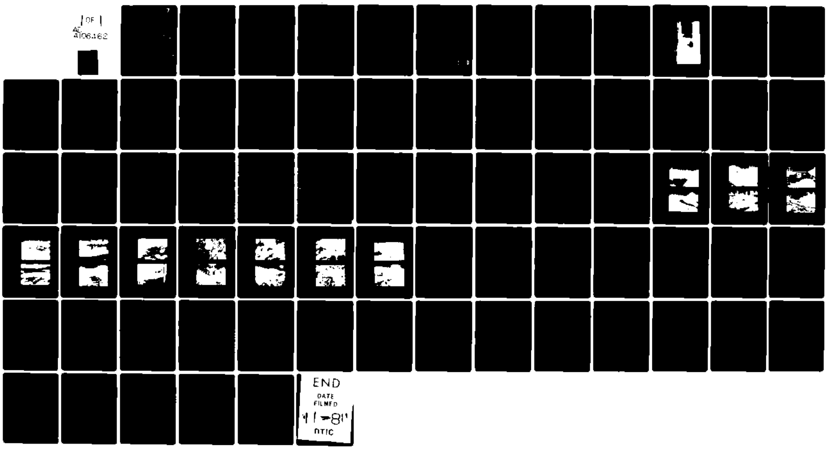

LEVEL II

MISSOURI-KANSAS CITY BASIN

AD A106462

WELCH LAKE DAM
BOONE COUNTY, MISSOURI
MO 10733

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

MARCH 1981

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

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National Dam Safety Program
Welch Lake Dam (MO 10733)
Boone County, Missouri

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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MISSOURI-KANSAS CITY BASIN

WELCH LAKE DAM
BOONE COUNTY, MISSOURI
MO 10733

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT. ST. LOUIS

FOR: STATE OF MISSOURI

MARCH 1981

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

LMSED-PD

SUBJECT: Welch Lake Dam, Mo. ID No. 10733
Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Welch Lake Dam.

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, emergency by the St. Louis District as a result of the application of the following criteria:

a. Spillway will not pass a 10-year frequency flood without overtopping of the dam. The spillway is, therefore, considered to be unusually small and seriously inadequate.

b. Overtopping could result in dam failure.

c. Dam failure significantly increases the hazard to life and property downstream.

Submitted By:	SIGNED Chief, Engineering Division	21 JUL 1981 Date
Approved By:	SIGNED Colonel, CE, Commanding	21 JUL 1981 Date

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WELCH LAKE DAM

BOONE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10733

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI

UNDER DIRECTION OF

ST. LOUIS DISTRICT CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

MARCH 1981

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Welch Lake Dam
State Located	Missouri
County Located	Boone County
Stream	Hominy Branch
Date of Inspection	10 March 1981

Welch Lake Dam was inspected by a team of engineers from Black & Veatch, Consulting Engineers for the St. Louis District, Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a small size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers, failure would threaten lives and property. The estimated damage zone extends approximately four miles downstream of the dam. Within the estimated damage zone are three dwellings, a building, two dams (Mo. ID. 11597 and a new dam), two highways, two light duty roads, and a sewage treatment plant. Contents of the estimated downstream damage zone were verified by the inspection team.

Our inspection and evaluation indicates that the spillways do not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillways will not pass the probable maximum flood without overtopping but will pass 4 percent of the probable maximum flood. The spillways will not pass the flood which has a ten percent chance of occurrence in any given year (10-year flood). The spillway design flood recommended by the guidelines is 50 to 100 percent of the probable maximum flood. Considering the damage zone and the reservoir storage volume, the spillway design flood should be 50 percent of the probable maximum flood. The probable maximum flood is defined as the flood discharge which may be expected from the most severe combination of critical meteorologic and hydrologic conditions which are reasonably possible in the region.

Based on visual observations, this dam appears to be in less than satisfactory condition. Deficiencies visually observed by the inspection team were severe erosion on the downstream face, erosion and sloughing on the upstream face, animal burrows in the embankment, a possible area of seepage below the dam, and trees growing on the embankment. Seepage and stability analyses required by the guidelines were not available.

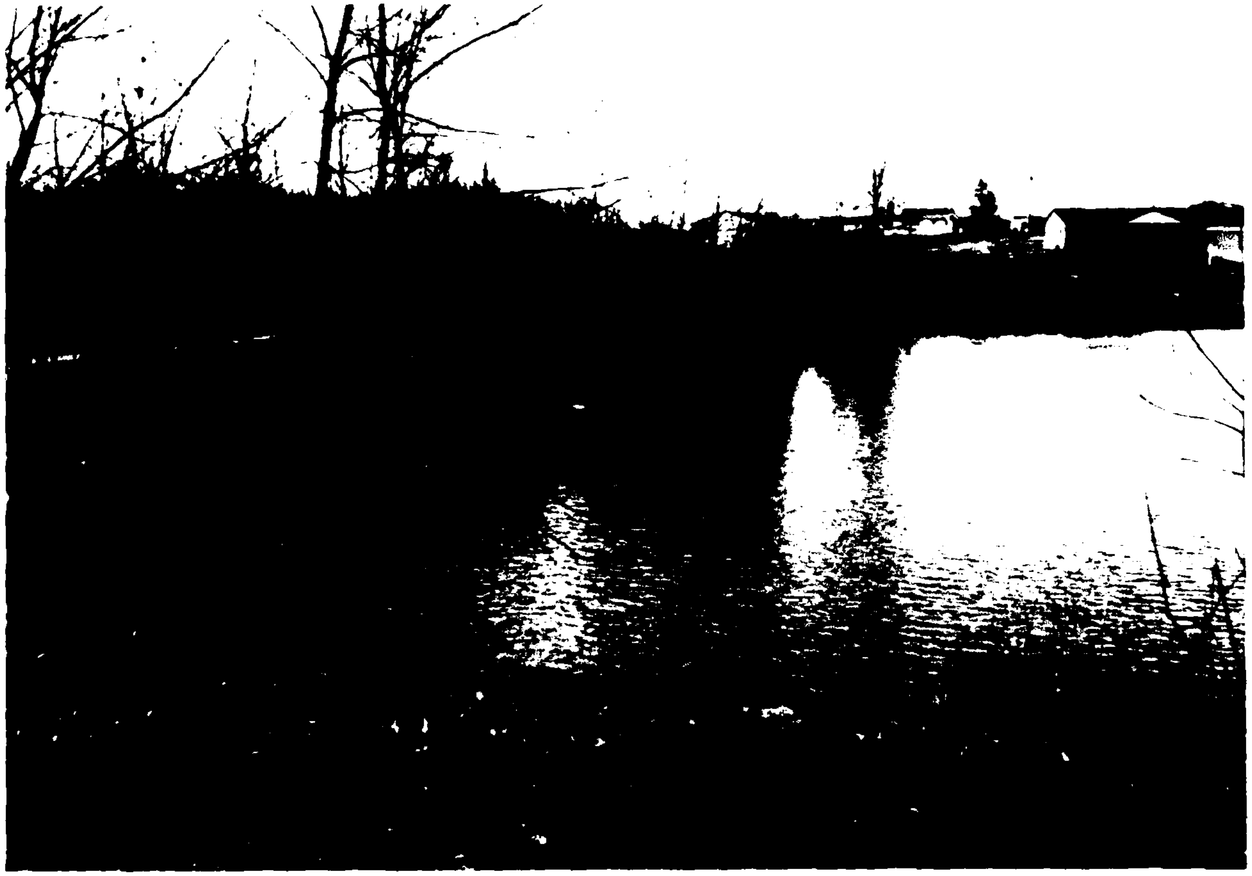
There were no observed deficiencies or conditions existing at the time of the inspection which indicated an immediate safety hazard; however, the erosion on the downstream face and the hydraulic inadequacy of the spillways constitute serious safety deficiencies that could lead to failure of the dam. They should be corrected without delay. Future corrective action and regular maintenance will be required to correct or control the other deficiencies described herein. In addition, detailed seepage and stability analyses of the existing dam, as required by the guidelines, should be performed. A detailed report discussing each of these deficiencies is attached.

Edwin R Burton

Edwin R. Burton, PE
Missouri E-10137

Harry L Callahan

Harry L. Callahan, Partner
Black & Veatch



OVERVIEW OF DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
WELCH LAKE DAM

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APPENDIX

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the District Engineer of the St. Louis District, Corps of Engineers, directed that a safety inspection of the Welch Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure located in the valley of Hominy Branch, a tributary to Hinkson Creek, (see Plate 1). The watershed is an area of low hills with gentle slopes consisting primarily of grassland with lesser areas of cropland and woodland. Part of the watershed is developed for residential use, particularly around the lake on the north side. The dam is approximately 570 feet long along its crest including the spillways. The dam crest is about 27 feet wide and supports a gravel road which provides access to the residents south of the lake. The dam embankment is about 22 feet high from its crest to the valley below. The embankment contains large flat limestone slabs, (Photo 16), in the upper part of the upstream fill. The downstream slope is irregular and also contains some large limestone slabs.

(2) The principal spillway is an uncontrolled 5.6 x 4.4-foot concrete box culvert, (Photo 4), through the abutment of the left (south) end of the dam. (Left and right as used herein gives directional reference while looking downstream). Flow through the culvert discharges with a free outfall to an excavated plunge pool then to an excavated open channel, (Photo 6), to the natural stream below the dam. A sanitary sewer line crosses the plunge pool to a manhole just downstream of the culvert outlet, (Photo 5). The sewer pipe is encased in concrete.

Three 12-inch vitrified clay pipes provide for drainage under the sewer line.

(3) The emergency spillway is an uncontrolled open channel excavated through the abutment at the right (north) end of the dam. The approach channel is nonuniform and poorly defined. It is covered by a heavy growth of grass and aquadic weeds, (Photo 7). Low-water crossing of the gravel road is provided by a double 2.3 x 4.5 concrete box culvert, (Photos 8 & 9). The channel downstream of the culvert is excavated through limestone and earth, and is about 51 feet wide, (Photo 10). An overfall in natural rock is located about 100 feet downstream from the culvert, (Photo 11). A natural rock control sill is located immediately below the outlet end of the culvert, (Photo 9). Erosion protection for the overflow section is provided by concrete grout on both sides of the gravel roadway.

(4) Pertinent physical data are given in paragraph 1.3.

b. Location. The dam is located in east central Boone County, Missouri, as indicated on Plate 1. The lake formed by the dam is shown on the United States Geological Survey 7.5 minute series quadrangle map for Millersburg, Missouri in Section 2 of T48N, R12W.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, the dam and impoundment are in the small size category. A small size dam is classified as having a height less than 40 feet, but greater than or equal to 25 feet and/or a storage capacity less than 1,000 acre-feet, but greater than or equal to 50 acre-feet. Welch Lake Dam is 22-feet high with a normal storage volume of 49 acre-feet.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers for this dam is as follows: The Welch Lake Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, and serious damage to homes, agricultural, industrial and commercial facilities, and to important public utilities, main highways, or railroads. For the Welch Lake Dam the estimated flood damage zone extends approximately four miles downstream of the dam. Within the estimated damage zone are three dwellings, a building, two dams (Mo. ID. 11597 and a new dam), two highways, two light duty roads, and a sewage treatment plant. Contents of the estimated downstream damage zone were verified by the inspection team.

e. Ownership. The dam is owned by EDW Inc., Route 1, Hartsburg, Mo. 65039, c/o Mr. E.D. Welch.

f. Purpose of Dam. The dam forms a 8-acre lake used for recreation.

g. Design and Construction History. Data relating to the design and construction were not available. According to the owner, the dam was constructed over ten years ago and was designed by his father, now deceased, who was the City Engineer for Columbia.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, evaporation, and overflow through the uncontrolled spillway all combine to maintain a relatively stable water surface elevation.

1.3 PERTINENT DATA

a. Drainage Area - 2,154 acres = 3.37 square miles

b. Discharge at Damsite.

(1) Normal discharge at the damsite is through a 5.6 x 4.4-foot concrete box culvert, principal spillway.

(2) Estimated experienced maximum flood at damsite - Unknown.

(3) Estimated ungated spillway capacity at maximum pool elevation 2,510 cfs (50% Probable Maximum Flood Pool El. 792.9).

c. Elevation (Feet above m.s.l. Approximate Tie to USGS Map).

(1) Top of dam - 790.4 (see Plate 3)

(2) Emergency spillway crest - 787.4

(3) Principal spillway outlet invert - 786.6

(4) Toe of dam - 767.6

(5) Maximum tailwater - Unknown.

d. Reservoir.

(1) Length of maximum pool - 4,000 feet ± (50% Probable maximum flood pool level)

(2) Length of normal pool - 1,600 feet ± (Principal spillway outlet invert)

e. <u>Storage (Acre-feet)</u>.

(1) Top of dam - 156

(2) Low-water crossing crest - 80

(3) Emergency spillway control sill - 56

(4) Principal spillway outlet invert - 49

(5) Emergency spillway inlet invert - 43

(6) Design surcharge - Not available.

f. <u>Reservoir Surface (Acres)</u>.

(1) Top of dam - 19.6

(2) Low-water crossing crest - 16.0

(3) Emergency spillway control sill - 10.2

(4) Principal spillway outlet invert - 7.7

(5) Emergency spillway inlet invert - 7.2

g. <u>Dam</u>.

(1) Type - Earth embankment

(2) Length - 570 feet

(3) Height - 22 feet ±

(4) Top width - 27 feet

(5) Side slopes - upstream face between 1.0 V on 1.6 H and 1.0 V on 2.1 H, downstream face between 1.0 V on 1.6 H and 1.0 V on 3.7 H (see Plate 4)

(6) Zoning - Unknown.

(7) Impervious core - Unknown.

(8) Cutoff - Unknown.

(9) Grout curtain - Unknown.

h. Diversion and Regulating Tunnel - None.

i. Principal Spillway.

(1) Type - 5.6 x 4.4 - foot concrete box culvert.

(2) Inlet invert elevation - 786.0 feet m.s.l.

(3) Outlet invert elevation - 786.6 feet m.s.l.

(4) Gates - None.

(5) Upstream channel - None.

(6) Downstream channel - Discharges to a plunge pool immediately downstream of culvert.

j. Emergency Spillway.

(1) Type - Grass and natural rock lined open channel with a 2.3 x 4.5-foot double box culvert low-water road crossing with concrete protected overflow section.

(2) Control Sill Crest Elevation - 787.4 feet m.s.l.

(3) Low-water crossing crest - 789.3

(4) Box culvert inlet invert - 785.4

(5) Gates - None.

(6) Upstream Channel - Grass-lined approach channel.

(7) Downstream Channel - partly grass-lined channel over limestone downstream of culvert to an overfall of exposed limestone to natural stream channel.

k. Regulating Outlets. Unknown - An abandoned withdrawal facility is located on downstream face of dam.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data were not available.

2.2 CONSTRUCTION

Construction records were unavailable.

2.3 OPERATION

Operational records and documentation of past floods were unavailable.

2.4 GEOLOGY

The site of the dam and reservoir is located across a broad, moderately steep sided valley. The dam impounds Hominy Branch, an intermittant tributary to Hinkson Creek.

The soil in the dam and reservoir area consist of Lindley loam and clay loam and Mexico silt loam. The Lindley series consists of deep, well and moderately well drained, moderately slowly permeable soils formed in Kansan and Nebraskan age glacial till on valley side slopes and narrowly dissected ridges between stream courses. For engineering purposes these soils are classified as silty clay (CL). The Mexico series consists of deep, somewhat poorly drained soils formed in loess on uplands. The upper 9 inches of this series is classified for engineering purposes as silty clay to clayey silt (CL to CL-ML). The remaining part of the soil profile is classified as silty clay to clay (CL to CH). Bedrock of the area consists of the Pennsylvanian age Marmaton Group, cyclic deposits with prominant limestone units and several coal beds. Depth to bedrock could not be determined but is assumed to be generally greater than 5 feet based on Soil Conservation Service information.

2.5 EVALUATION

a. Availability. No engineering data were available.

b. Adequacy. No engineering data were available. Thus, an assessment of the design, construction, and operation could not be made. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity. The validity of the design, construction, and operation could not be determined due to the lack of engineering data.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Welch Lake Dam was made on 10 March 1981. The inspection team consisted of Edwin Burton, team leader; Shannon Casey, geologist; Gary Van Riessen, geotechnical engineer; and John Ruhl, hydraulic/hydrologic engineer. The dam is in less than satisfactory condition. Specific observations are discussed below. No observations were made of the condition of the upstream face of the dam below the pool elevation at the time of the inspection.

b. Dam. The inspection team observed the following conditions at the dam. An area of severe erosion was observed on the downstream face of the dam near the left end. The erosion area was approximately 100 feet wide and extended from the crest to the toe. It is the opinion of the inspection team that this erosion was due to the dam having been overtopped. Tree and brush cuttings and rubble had been dumped into the eroded area which made it difficult to evaluate the extent of the damage, (Photos 13 & 14). Erosion is forming a gulley at the interface between the right abutment and the downstream face of the embankment. Minor sloughing due to wave action erosion along the upstream face of the dam was observed. Erosion and animals are undermining the large limestone slabs on the upstream face and causing them to slide down the slope, (Photos 15 & 16). One large hollow area was found in the upstream face that is believed to be a beaver lodge. An underwater opening to this hollow area and a hole in the upstream face exposing the hollow area are shown in Photos 17 and 18. Standing water and a heavy growth of aquadic weed was observed downstream of the dam. It was not determined if the water was from seepage or due to poor drainage of local runoff. There appeared to have been a small pond downstream of the dam at one time. Its dam had been breached. There was also a pool of standing water downstream of the right abutment. This pool was in what appeared to be an excavation off of an old road along the abutment.

Both the upstream and downstream faces contained a heavy growth of grass, weeds, brush, and trees. The trees ranged in size from 1-inch to 6-inch trunk. The gravel surfaced road along the crest of the dam was in good condition. The crest had a thin cover of grass on either side of the road. The appearance of the crest indicated that the road and grass cover were being maintained. No other maintenance of the dam was noticeable.

No cracking or sinkholes were observed nor were there any toe drain system or instrumentation on the dam.

c. Appurtenant Structures. The principal spillway is a concrete box culvert at the left end of the dam. It appeared to be in serviceable condition; however, there has been considerable erosic around the box at both upstream and downstream ends, (Photos 4 & 5). Some repair efforts have been made by pouring concrete grout in the eroded areas. The foundation of the box at the outlet end has been undermined by erosion. The box appeared to have been displaced from its original alignment and grade. The plunge pool and downstream channel were badly eroded and cluttered with fallen trees and rubble, (Photo 6).

The emergency spillway appeared to be in serviceable condition. However, the capacity of the emergency spillway is probably reduced considerably by the accumulation of silt and heavy growth of weeds, grass, and aquadic plants in the approach channel, (Photo 7). The inlet end of the double box culvert under the road was about 50 percent filled with silt, (Photo 8). Some repairs to erosion have been made by pouring concrete grout along the roadway overflow section. The downstream channel contained exposed rock and had a fairly good grass cover, (Photo 10). Minor erosion of the channel was observed. There was no development in the spillway area which would suffer damage due to flow through the spillway except for an exposed pipeline crossing the channel downstream of the overfall, (Photo 11).

An abandoned rectangular concrete tank was observed on the downstream face of the dam, (Photo 12). There is a pipe through the upstream wall and another one through the downstream wall. A valve box is located just upstream of the tank. It is suspected that the tank once served as a wet well and pump house foundation for drawing water from Welch Lake. No inlet pipe was observed in the lake.

There is a sanitary sewer manhole located near the upstream edge of the road at the right end of the dam and another manhole located downstream of the principal spillway box outlet, (Photo 5). It is unknown if these manholes are connected. If they are connected, the sewer pipe would have to pass through the dam embankment.

d. Geology. The soils surrounding the dam and reservoir consist of silty clays developed in glacial till. These clays are classified as having low plasticity and a Unified Classification of CL.

The foundation of the dam is silty clay over limestone bedrock. The left abutment is limestone, the right abutment is silty clay developed in glacial till. The emergency spillway is cut through limestone that outcrops around the lake shore and is exposed in the valley downstream of the right abutment. Where exposed, this limestone shows open vertical jointing with spacing of approximately 5 feet and bedding of 1 to greater than 12 inches.

Based on visual examination of auger samples taken near the crest of the dam, the embankment material consists of silty clay with a Unified Soils Classification of CL.

e. Reservoir Area. No slumping or slides of the reservoir banks were observed. The upstream channel to the lake contains some minor debris and a few trees. The lake level was very low at the time of inspection. The lake contained a noticeable amount of silt.

f. Downstream Channel. The spillways discharge to a small lake bed downstream of Welch Lake Dam. The dam that formed the small pond has been breached.

3.2 EVALUATION

The various deficiencies observed at the time of the inspection are not believed to represent an immediate safety hazard. However, the erosion on the downstream face of the dam and the hydraulic inadequacy of the spillways constitute serious safety deficiencies that could lead to failure of the dam and should be corrected without delay. The other observed deficiencies warrant monitoring and control.

The potential for sloughing or sliding of embankment material is enhanced by the presence of the relatively steep slope of the upstream face and the lack of erosion protection.

The growth of trees and brush and the uncut grass, if allowed to go unchecked, could cause deterioration of the embankment. The roots of trees can loosen the embankment material and also can leave voids through which water can pass. Brush on the dam prevents inspection of the embankment and kills the smaller grasses whose roots are more effective in protecting the surface soil of the slope from erosion. The brush and tall uncut grass provides habitat for burrowing animals which can damage the embankment.

The standing water downstream of the dam and below the right abutment could be the result of seepage through or under the dam. It could also be due to poor drainage of local runoff. Regular periodic observations should be made to accertain if the standing water is dam related.

The presence of beaver and other burrowing animals has caused considerable damage to the embankment along the upstream face. If allowed to continue unchecked, this animal activity can greatly increase the potential of failure of the dam. Animal burrowing can provide channels for piping water through the dam, it aggravates erosion and promotes instability.

The silt and heavy growth of grass and weeds reduce capacity of the emergency spillway.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The pool is primarily controlled by rainfall, runoff, evaporation, transpiration, and capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM

There was no evidence that a maintenance program was in effect at the time of inspection. Vegetal growth was uncontrolled and large animal burrows were observed on the embankment. The area of erosion on the downstream face due to overtopping has gone unrepaired; although, cut brush and rubble has been placed over this area in an effort to prevent further erosion.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities exist.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no existing warning system or preplanned scheme for alerting downstream residents for this dam.

4.5 EVALUATION

The lack of maintenance is evident and has led to deterioration of the dam. The brush and rubble placed on the downstream face is not likely to be effective in preventing further erosion, particularly if the dam is overtopped again.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. No design data were available.

b. Experience Data. The drainage area and lake surface area are developed from USGS Millersburg (1969) and Hallsville (1969), Mo. Quadrangle Maps. The dam layout is from a survey made during the inspection.

c. Visual Observations.

(1) The principal spillway appears to be in less than satisfactory condition. The lake level at the time of the inspection (El. 783.4) was below the principal spillway invert elevation. The existence of the concrete encased sewer pipe below the spillway outlet has no appreciable effect on discharge capacity of the principal spillway.

(2) The emergency spillway is an excavated open channel with a double concrete box culvert low-water road crossing. Low flow is through the culvert and controlled by a natural rock sill downstream of the box culvert. High flow is controlled by the low-water crossing overflow section.

(3) Spillway discharges do not endanger the integrity of the dam.

d. Overtopping Potential. The spillways will not pass the probable maximum flood without overtopping the dam. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The spillways will pass 4 percent of the probable maximum flood without overtopping the dam. The spillways will not pass the ten percent chance flood estimated to have a peak outflow of 1,570 cfs developed from a 48-hour, ten percent chance rainfall. According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, a high hazard dam of small size should pass 50 to 100 percent of the probable maximum flood. Considering the downstream damage zone and the reservoir storage volume, the appropriate spillway design flood should be 50 percent of the probable maximum flood. The portion of the estimated peak discharge of 50 percent of the probable maximum flood overtopping the dam would be 3,470 cfs of the total discharge from the reservoir of 5,980 cfs. The estimated duration of overtopping is 15.0 hours with a maximum height of 2.5 feet. The portion of the estimated peak discharge of the probable maximum flood overtopping the dam would be 7,950 cfs of the total discharge from the reservoir of 11,950 cfs. The estimated duration of overtopping is 19.0 hours with a maximum height of 3.8 feet. The embankment would be jeopardized should overtopping occur for these periods of time.

As stated in Section 3.1.b, it was the opinion of the inspection team that the dam has been overtopped in the past. The results of past overtopping are seen in Photos 13 and 14.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately four miles downstream of the dam. Three dwellings, a building, two dams (Mo. ID. 11597 and a new dam), two highways, two light duty roads, and a sewage treatment plant are located within the estimated damage zone. Lives could be lost should failure of the dam occur. Contents of the estimated downstream damage zone were verified by the inspection team. A part of the damage zone is within the corporate limits of the City of Columbia and is subject to regulation under the Flood Insurance Program.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which affect the structural stability of this dam are discussed in Section 3, paragraph 3.1b.

b. Design and Construction Data. No design data relating to the structural stability of the dam were found. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Operating Records. No operational records exist.

d. Postconstruction Changes. It is not known whether or not any changes have been made to the dam subsequent to its construction.

e. Seismic Stability. The dam is located in Seismic Zone 1 which is a zone of minor seismic risk. A properly designed and constructed earth dam using sound engineering principles and conservatism should pose no serious stability problems during earthquakes in this zone. The seismic stability of an earth dam is dependent upon a number of factors: embankment and foundation material classifications and shear strengths; abutment materials, conditions, and strengths; embankment zoning; and embankment geometry. Adequate descriptions of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the stability analysis required by the guidelines.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several conditions observed during the visual inspection by the inspection team should be corrected, monitored and/or controlled. These are erosion, on the downstream face, erosion and sloughing on the upstream face, animal burrows on the embankment, a possible seepage area below the dam, and trees growing on the embankment. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

b. Adequacy of Information. Due to the absence of engineering design data, the conclusions in this report were based only on performance history and visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. It is the opinion of the inspection team that a program should be developed as soon as possible to implement remedial measures recommended in paragraph 7.2b. If the safety deficiencies listed in paragraph 7.1a are not corrected, they will continue to deteriorate and lead to a serious potential of failure. The item recommended in paragraph 7.2a should be pursued on a high priority basis.

d. Necessity for Phase II. Based on the Phase I investigation, no Phase II investigation is required. However, the additional analyses noted in paragraph 2.5b are necessary for compliance with the guidelines.

e. Seismic Stability. This dam is located in Seismic Zone 1. Adequate description of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the recommended stability analysis.

7.2 REMEDIAL MEASURES

a. Alternatives. Spillway capacity and/or storage volume would need to be increased or the lake level would need to be permanently lowered to increase available flood storage in order to effectively pass the spillway design flood. Spillway capacity could be increased by modifying the existing emergency spillway. The area of erosion at the left end of the downstream face should be repaired with suitable compacted material, the slope redressed, and slope protection provided to prevent erosion of the repaired area. Another viable alternative would be the removal of the dam.

b. Operation and Maintenance Procedures. The following operation and maintenance procedures are recommended and should be carried out under the direction of a professional engineer experienced in the design, construction, and maintenance of earth dams.

(1) The erosion and sloughing on the upstream face should be repaired and the slope redressed. Riprap should be placed on the upstream face to an elevation above normal lake level to prevent erosion of the embankment material.

(2) The standing water areas noted during the visual inspection should be closely monitored to determine if these areas are due to seepage from the reservoir. Any significant changes should be evaluated.

(3) The areas of erosion noted in sections 3.1.b and 3.1.c should be repaired.

(4) A maintenance program should be formulated and implemented to remove and control the growth of trees and brush on the embankment. Grass/weed cover on the embankments should be cut periodically. Frequent observation of the upstream slope should be made to note any evidence of erosion, sloughing, or sliding of embankment material.

(5) The animal burrows in the embankment should be repaired since they can contribute to the occurrence of piping. Control measures should be implemented to discourage animal activity in the area. The embankment slope should be monitored by a qualified engineer during repair of the embankment.

(6) Seepage and stability analyses should be performed.

(7) A detailed inspection of the dam should be made periodically. Findings of the inspection should be documented and made a matter of record. More frequent inspections may be required if additional deficiencies are observed or the severity of the reported deficiencies increase.

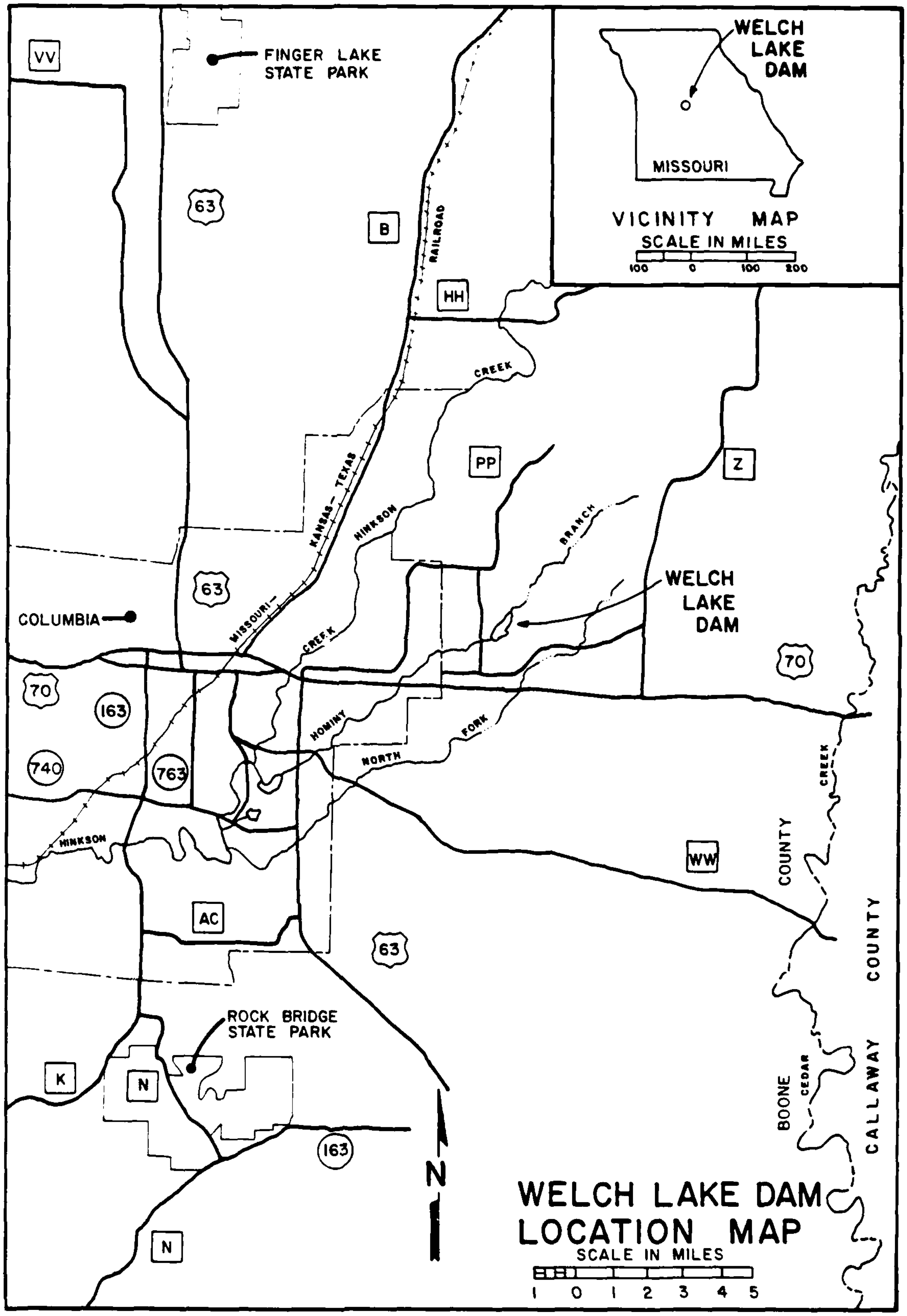
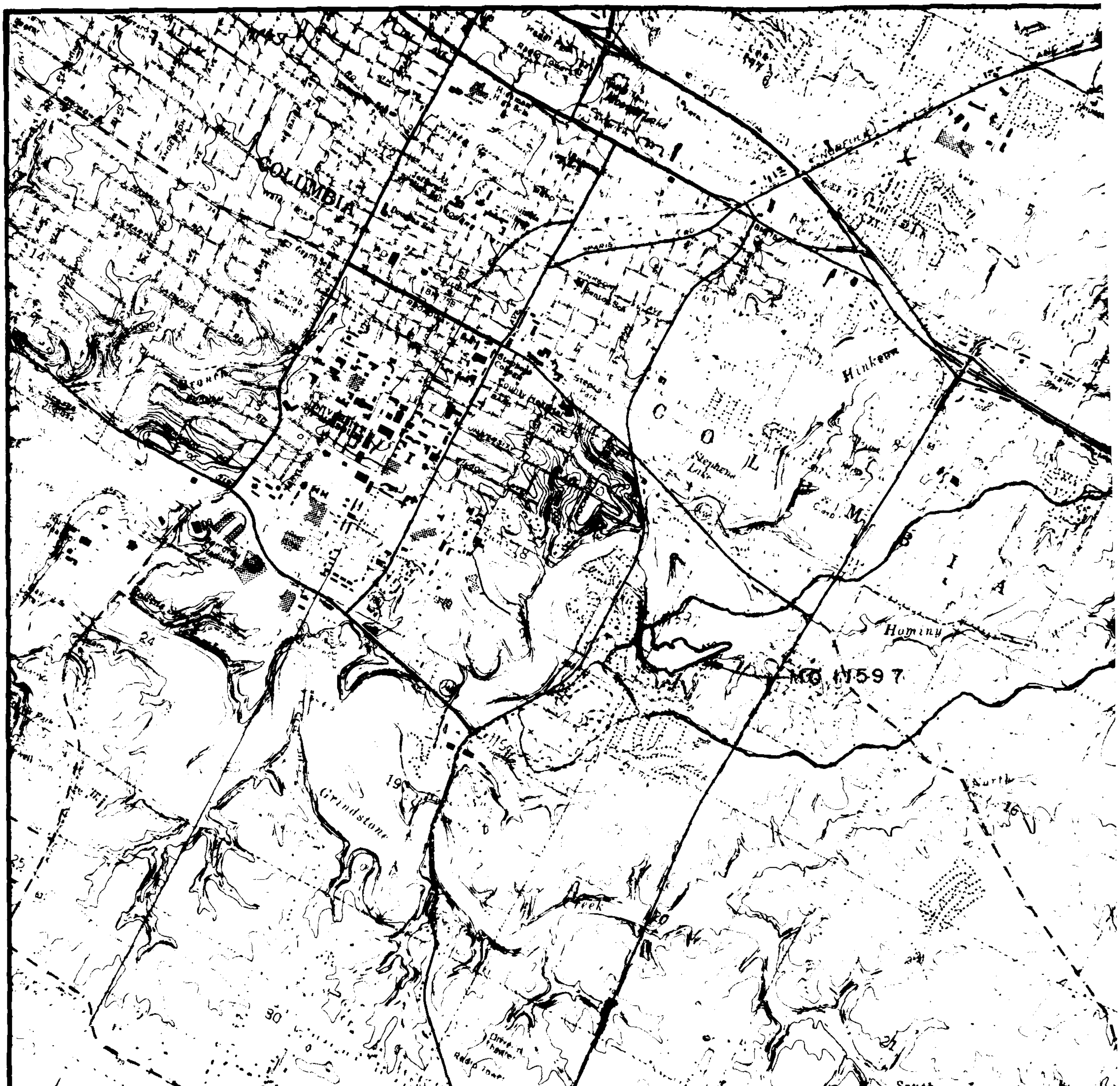
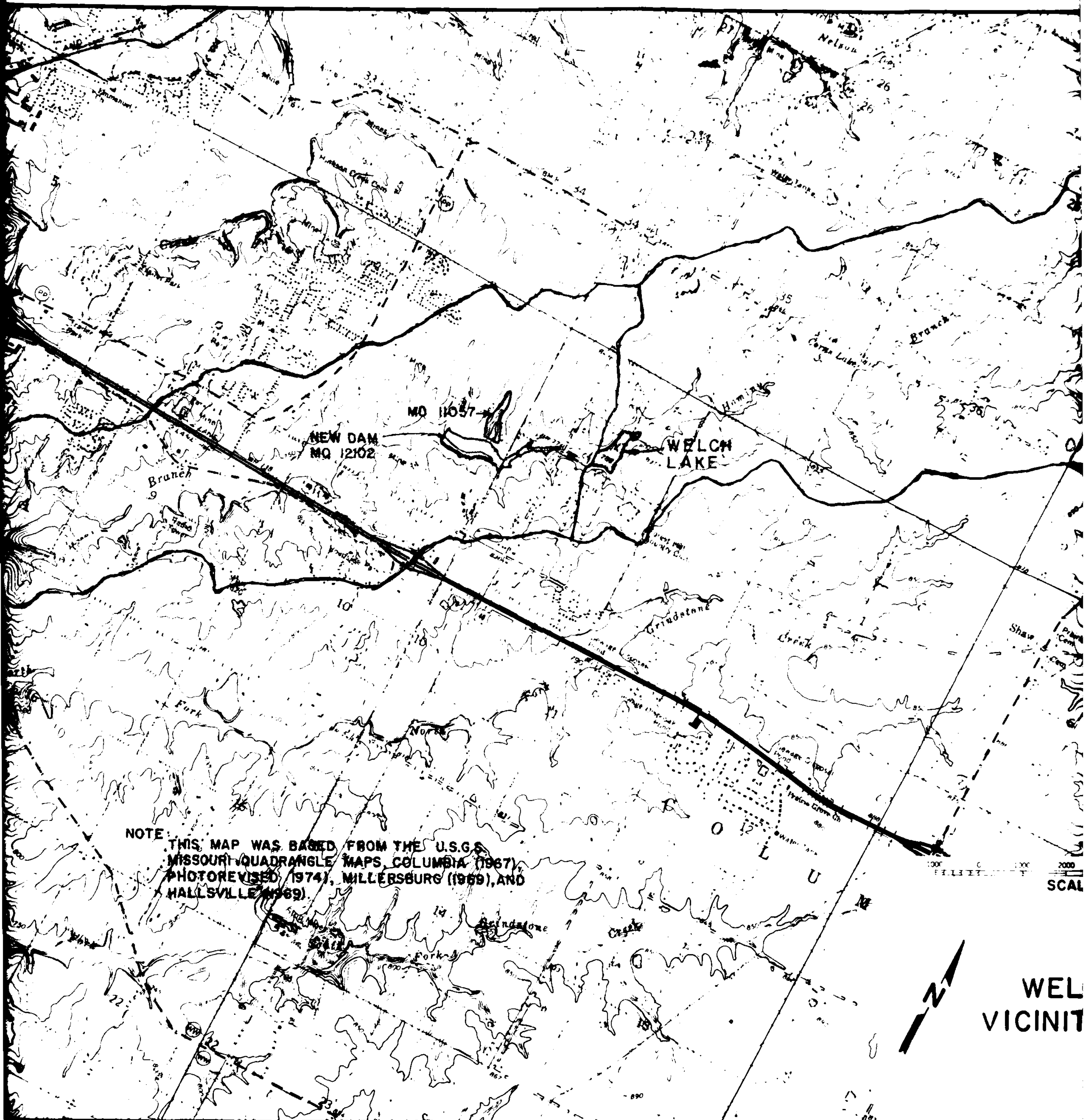
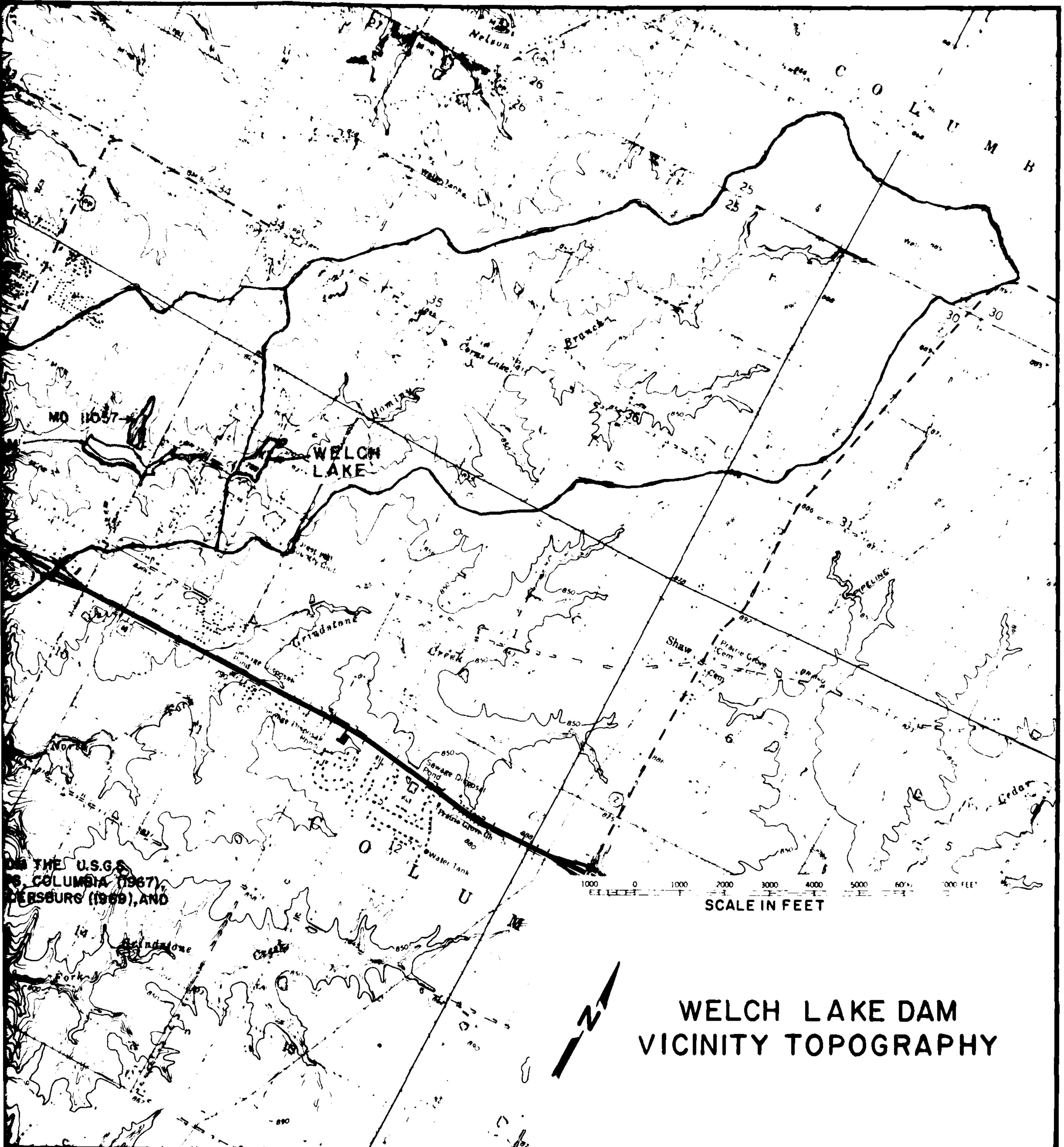

FINGER LAKE
STATE PARK
VV
63
B
RAILROAD
HH
WELCH
LAKE
DAM
MISSOURI
VICINITY MAP
SCALE IN MILES
100 0 100 200
CREEK
PP
Z
KANSAS-TEXAS
HINKSON
BRANCH
WELCH
LAKE
DAM
63
COLUMBIA
MISSOURI-
CREEK
70
70
163
740
763
HOMINY
NORTH
FORK
HINKSON
CREEK
COUNTY
WW
AC
63
COUNTY
ROCK BRIDGE
STATE PARK
K
N
163
N
BOONE
CEDAR
CALLAWAY
WELCH LAKE DAM
LOCATION MAP
SCALE IN MILES
1 0 1 2 3 4 5
N

PLATE 1

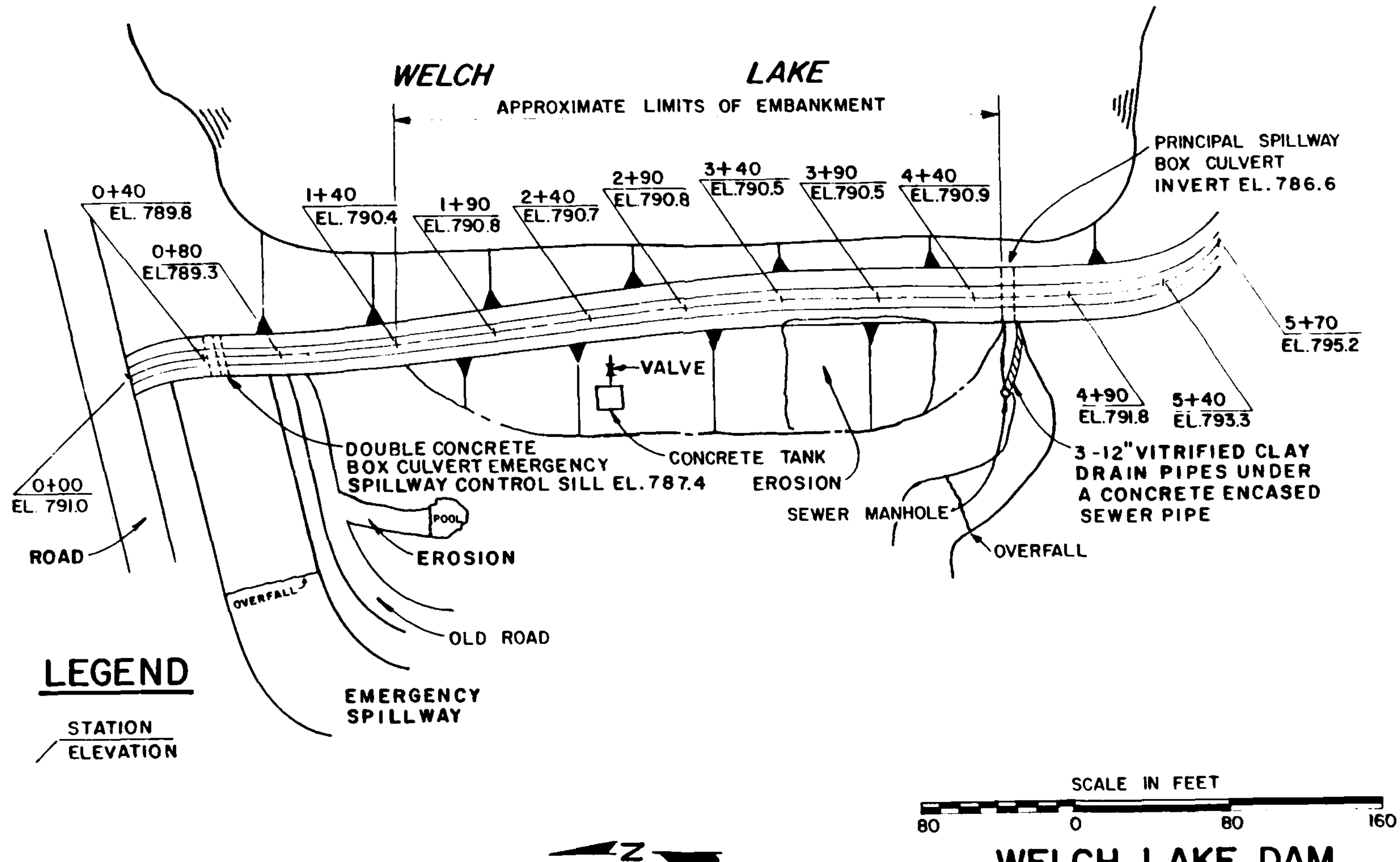

COLUMBIA
MO 11597
Hominy
Grindstone
Creek
North
South
Creek


MO 11057
NEW DAM
MO 12102
WELCH
LAKE
NOTE: THIS MAP WAS BASED FROM THE U.S.G.S. MISSOURI QUADRANGLE MAPS, COLUMBIA (1967), PHOTOREVISED 1974), MILLERSBURG (1969), AND HALLSVILLE (1969).
Hominy
Branch
Grindstone
Creek
North
Fork
COLUM
SCAL
WEL
VICINIT



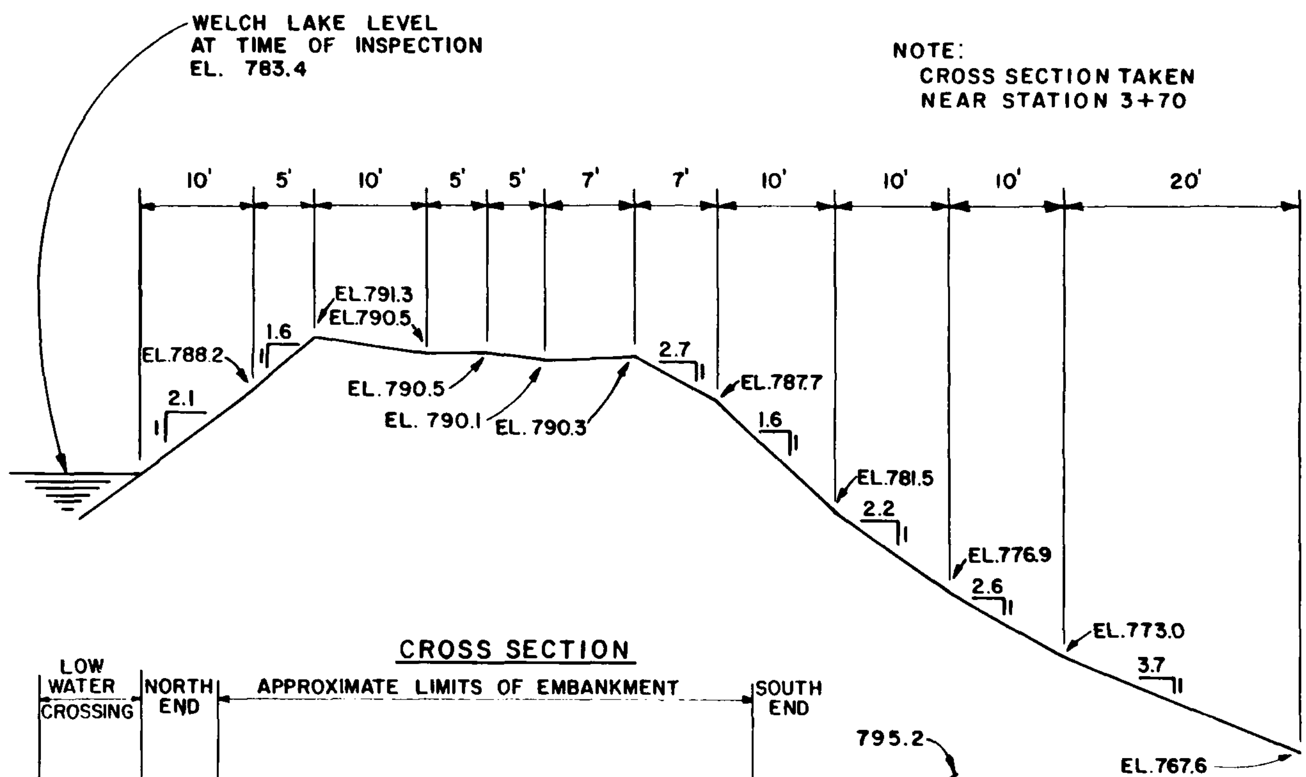
WELCH LAKE DAM
VICINITY TOPOGRAPHY

PLATE 2

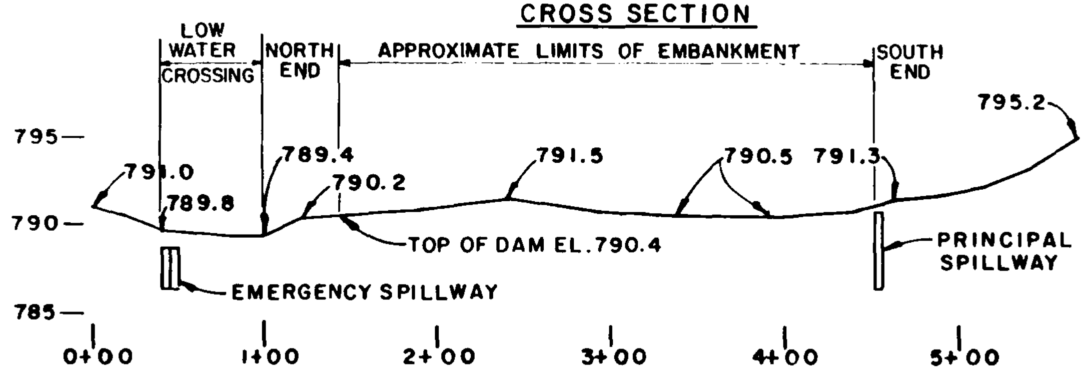


WELCH LAKE DAM
DAM PLAN

PLATE 3



CROSS SECTION

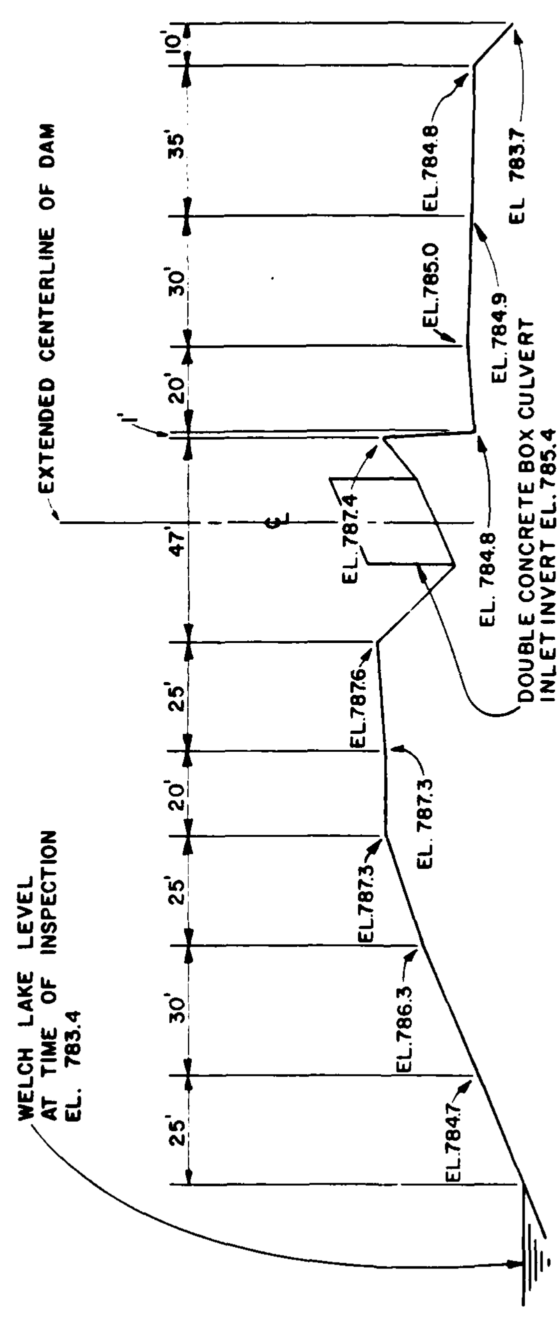


PROFILE

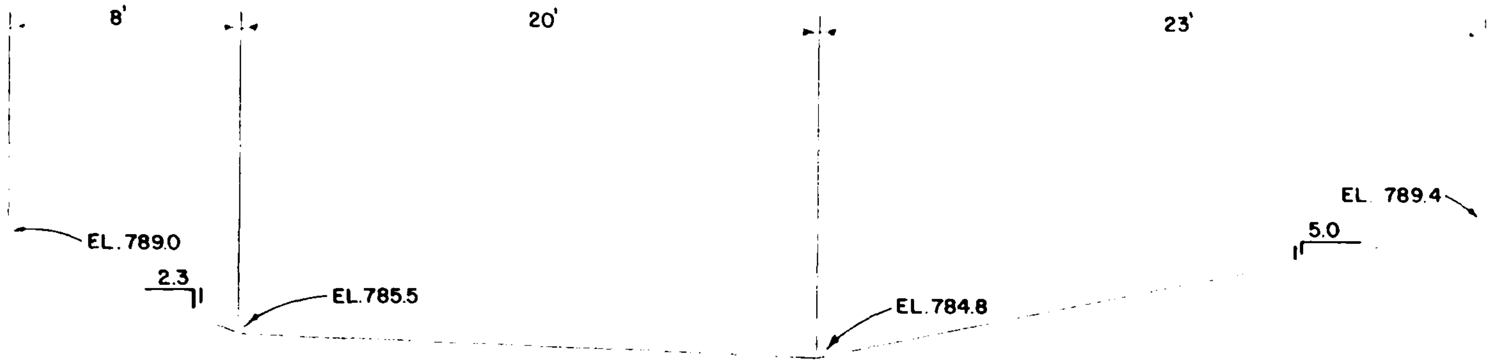
WELCH LAKE DAM
DAM CROSS SECTION
DAM CREST PROFILE

PLATE 4

WELCH LAKE DAM
EMERGENCY SPILLWAY PROFILE



NOTE:
PROFILE TAKEN NEAR
STATION 0+46



NOTE:
CROSS SECTION TAKEN NEAR STATION 2+23 OF EMERGENCY SPILLWAY PROFILE

WELCH LAKE DAM
EMERGENCY SPILLWAY CROSS SECTION

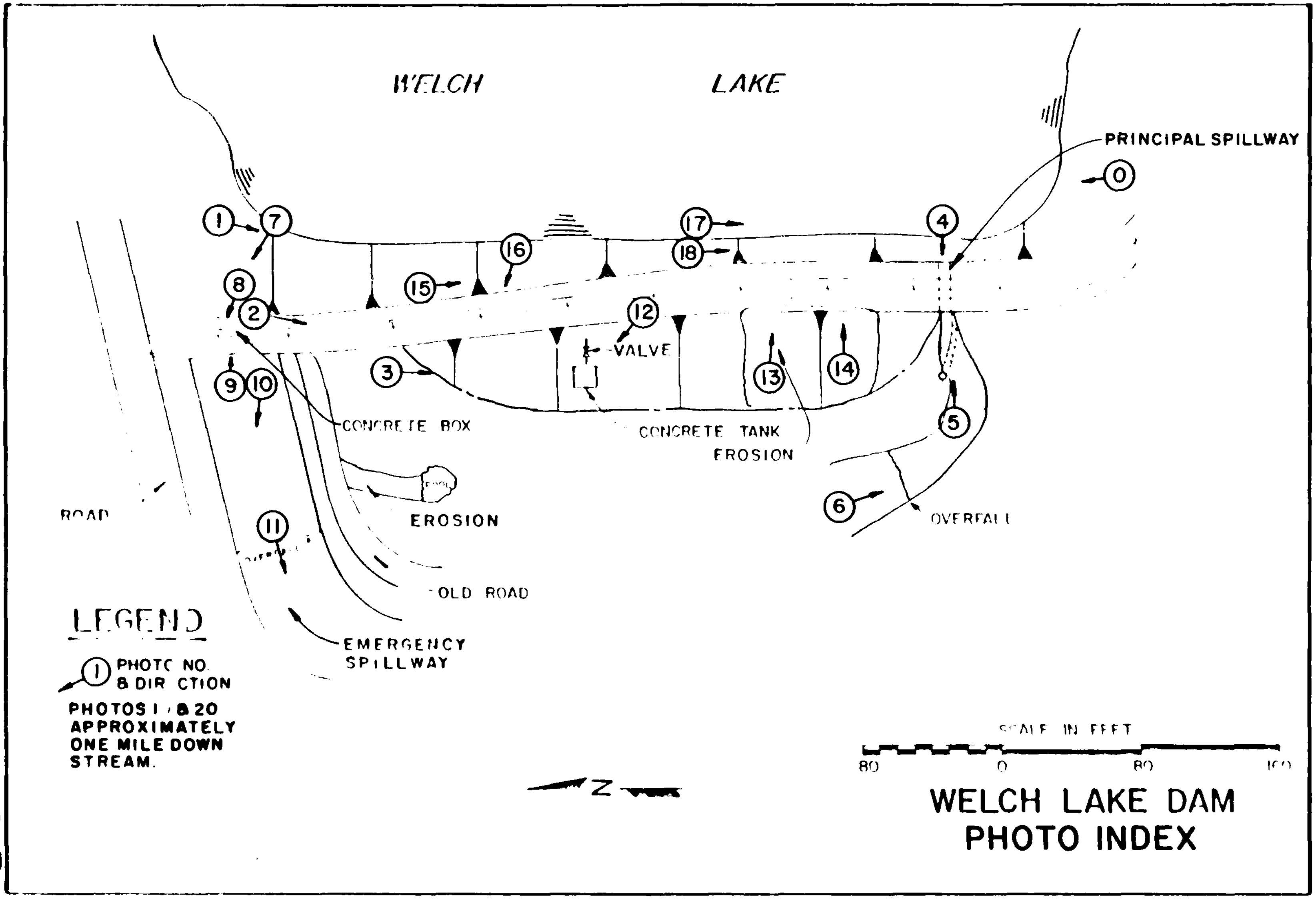

WELCH
LAKE
PRINCIPAL SPILLWAY
VALVE
CONCRETE BOX
CONCRETE TANK
EROSION
EROSION
OVERFALL
ROAD
OLD ROAD
EMERGENCY SPILLWAY
LEGEND
PHOTO NO. & DIRECTION
PHOTOS 1, & 20 APPROXIMATELY ONE MILE DOWN STREAM.
N
SCALE IN FEET
80 0 80 160
WELCH LAKE DAM
PHOTO INDEX

PLATE 7

PHOTO 1. UPSTREAM FACE OF DAM

PHOTO 2: CREST OF DAM

PHOTO 3: DOWNSTREAM FACE OF DAM

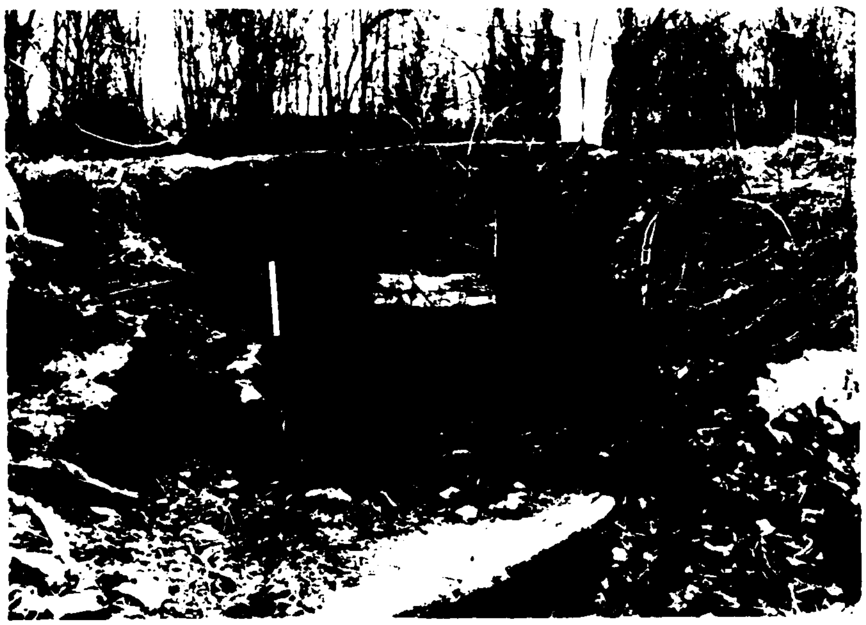


PHOTO 4: UPSTREAM END OF PRINCIPAL SPILLWAY CULVERT

PHOTO 5: DOWNSTREAM END OF PRINCIPAL SPILLWAY CULVERT

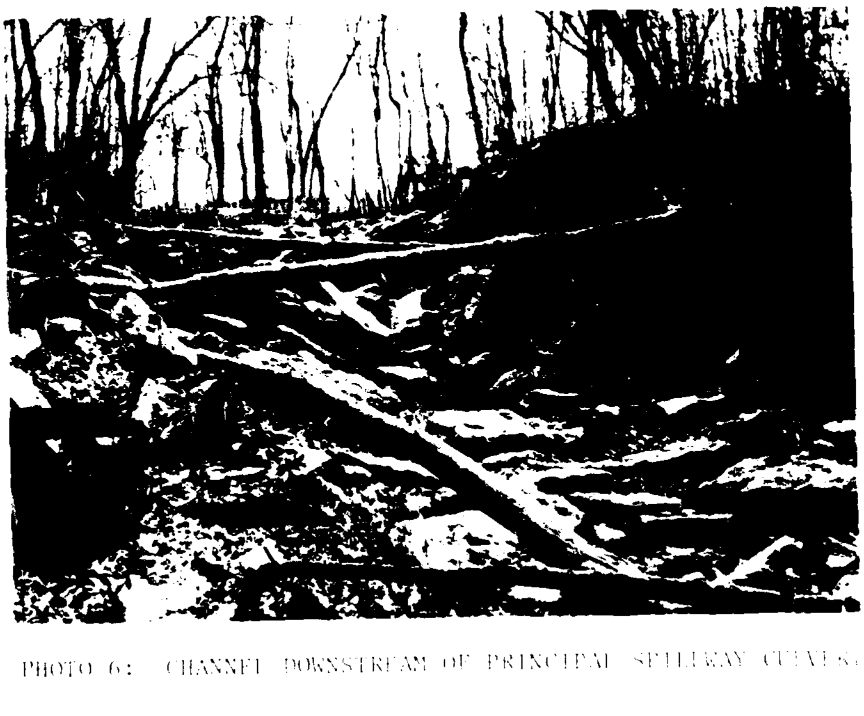


PHOTO 6: CHANNEL DOWNSTREAM OF PRINCIPAL SPILLWAY CULVERT

PHOTO 7: EMERGENCY SPILLWAY APPROACH CHANNEL

PHOTO 8: INLET TO LOW WATER CULVERT AT EMERGENCY SPILLWAY [illegible]

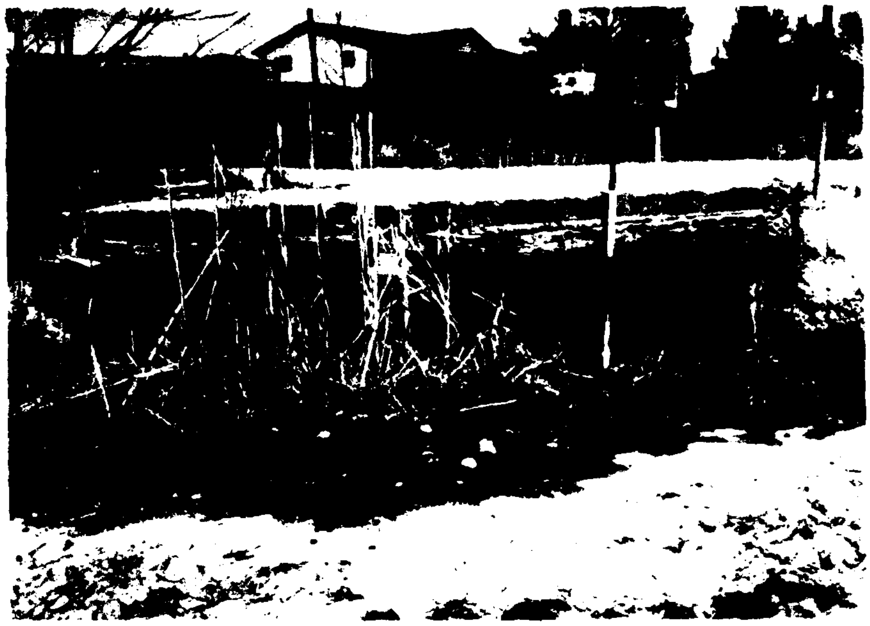


PHOTO 9: OUTLET OF LOW WATER CULVERT AT EMERGENCY SPILLWAY [illegible]

PHOTO 10: CHANNEL DOWNSTREAM OF EMERGENCY SPILLWAY CREST

PHOTO 11: OVERFALL DOWNSTREAM OF EMERGENCY SPILLWAY CHANNEL

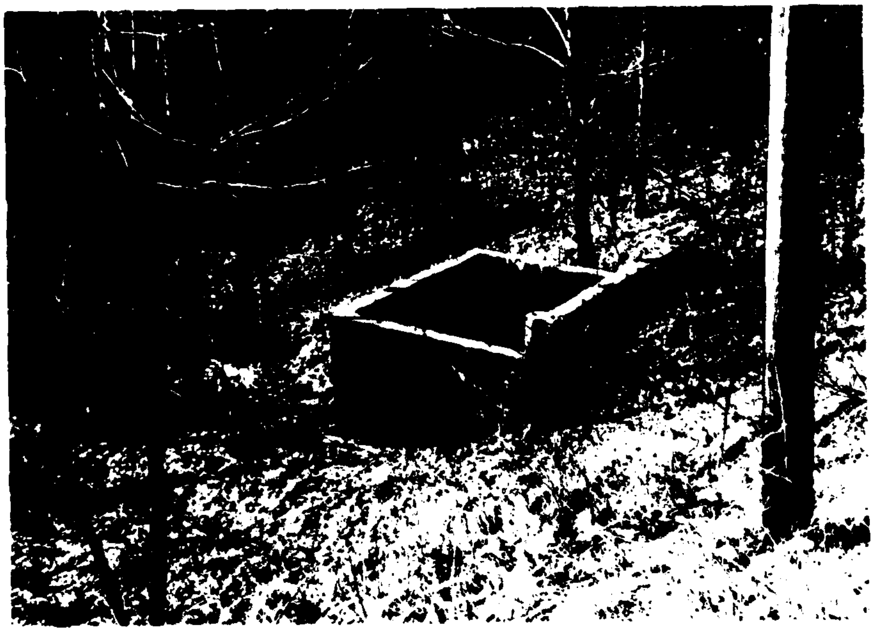


PHOTO 12: CONCRETE TANK ON DOWNSTREAM FACE OF DAM

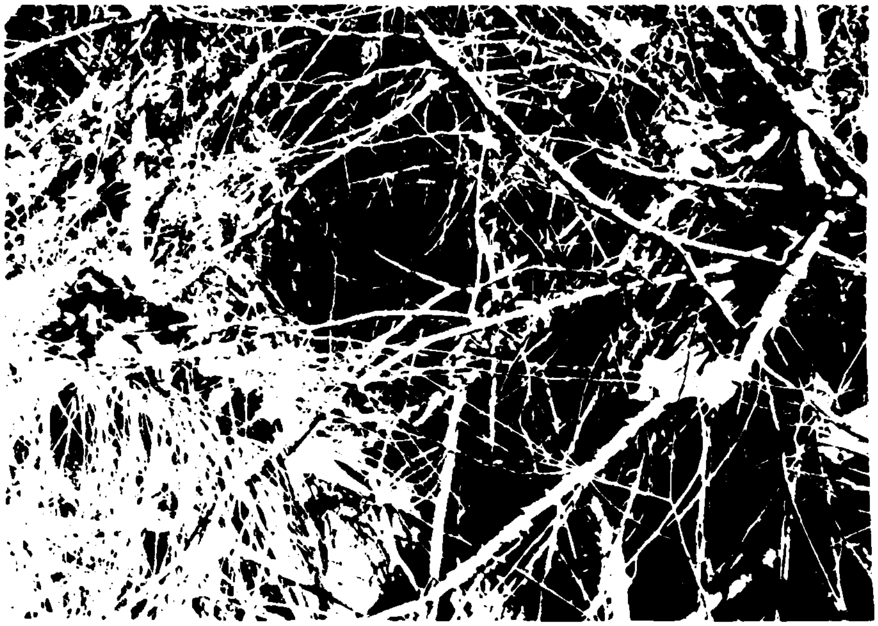


PHOTO 13: EROSION OF DOWNSTREAM FACE NEAR MID SLOPE

PHOTO 14: EROSION OF DOWNSTREAM FACE NEAR CREST

PHOTO 15: EROSION OF UPSTREAM FACE

PHOTO 16: UNDER CUTTING AND ANIMAL BURROWS ON UPSTREAM FACE

PHOTO 17: POSSIBLE BEAVER LODGE ENTRANCE ON UPSTREAM FACE

PHOTO 18: POSSIBLE BEAVER LODGE OPENING ON UPSTREAM FACE

PHOTO 19: NEW DAM ACROSS HOMINY CREEK DOWNSTREAM OF [illegible]

PHOTO 20: WASTE WATER TREATMENT FACILITY ON DOWNSTREAM SIDE OF NEW DAM

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC ANALYSES

To determine the overtopping potential, flood routings were performed by applying the Probable Maximum Precipitation (PMP) to a synthetic unit hydrograph to develop the inflow hydrograph. The inflow hydrograph was then routed through the reservoir and spillways. The overtopping analysis was determined using the computer program HEC-1 (Dam Safety Version) (1).

The PMP was determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33" (HMR-33) (2). Reduction factors were not applied. The rainfall distribution for the 48-hour PMP storm was determined according to the procedures outlined in HMR-33 and EM 1110-2-1411 (3). The Jefferson City, Missouri rainfall distribution (15 min. interval - 48 hours duration), as provided by the St. Louis District, Corps of Engineers, was used when the ten percent chance probability flood was routed through the reservoir and spillways.

The synthetic unit hydrograph for the watershed was developed by the computer program using the Soil Conservation Service (SCS) method (1,4). The parameters for the unit hydrograph are shown in Table 1. The formula from which the lag time was derived is noted in Table 1 (5). The lag time was verified by the SCS curve number method (4).

The SCS curve number (CN) method was used in computing the infiltration losses for the rainfall-runoff relationship. The CN values used, and the result from the computer output, are shown in Table 2.

The reservoir routing was performed using the modified Puls Method. The initial reservoir pool elevation for the routing of each storm was determined to be equivalent to the outlet invert elevation of the principal spillway at elevation 786.6 feet m.s.l. This is in accordance with antecedent storm conditions AMC II and AMC III preceding the one percent and ten percent probability and probable maximum storms outlined by the U.S. Army Corps of Engineers, St. Louis District (6). The hydraulic capacity of the spillway and the storage capacity of the reservoir were defined by the elevation, surface area, storage, and discharge relationships shown in Table 3.

The rating curve for the spillway is shown in Table 4. The flows over the emergency spillway crest and over the crest of the dam were determined using the non-level dam crest option ($L and $V cards) of the HEC-1 program. The program assumes critical flow over a broad-crested weir.

The result of the routing analysis indicates that a flood equivalent to a maximum of 4 percent of the PMF will not overtop the dam.

A summary of the routing analysis for different ratios of the PMF is shown in Table 5.

The computer input data and a summary of the output data are presented at the back of this appendix.

TABLE 1

SYNTHETIC UNIT HYDROGRAPH

Parameters:

Drainage Area (A)	3.37 square miles
Length of Watercourse (L)	3.90 miles
Length of Watercourse to Centroid of Drainage Area (L_c)	1.70 miles
Slope (s)	0.0056

C_t = coefficient for basin characteristics = 0.35 for valleys

Time of concentration (T_c)	3.20 hours
Lag Time (t_p)	1.92 hours
Duration (D)	25 min. (use 15 min.)

Time (Min.) *	Discharge (cfs) *
0	0
15	36
30	111
45	215
60	360
75	540
90	682
105	767
120	794
135	788
150	728
165	656
180	567
195	456
210	360
225	294
240	240
255	200
270	165
285	135
300	110

* From HEC-1 computer output

TABLE 1

SYNTHETIC UNIT HYDROGRAPH

(Continued)

FORMULAS USED:

$t_p = C_t \ (LL_c/S^{0.5})^{0.38}$ (5)

$t_p = 0.6 \ T_c$

$D = 0.133 \ T_c$

TABLE 2

RAINFALL-RUNOFF VALUES

Selected Storm Event	Storm Duration (Hours)	Rainfall (Inches)	Runoff (Inches)	Loss (Inches)
PMF	48	34.72	33.14	1.58
50% PMF	48	18.11	16.57	1.54
10% Probability	48	5.89	3.09	2.80

Additional Data:

1) The soil associations in this watershed are Gara, Hatton, Lindley, Mexico, and Westerville (7).
   70 percent of drainage area is hydrologic soil Group C
   30 percent of drainage area is hydrologic soil Group D
   75 percent of the land use was grassland
   20 percent of the land use was woodland
   5 percent of the land use was residential
2) SCS Runoff Curve CN = 88 (AMC III) for the PMF.
3) SCS Runoff Curve CN = 74 (AMC II) for the ten percent probability flood (4).

TABLE 3

ELEVATION, SURFACE AREA, STORAGE, AND DISCHARGE RELATIONSHIPS

Elevation (feet-MSL)	Lake Surface Area (acres)	Lake Storage (acre-ft)	Spillway Discharge (cfs)
*786.6	7.7	49	0
**787.4	10.2	56	11
788.4	13.3	67	69
***789.3	16.0	80	132
****790.4	19.6	99	452

*Principal Spillway Outlet Invert Elevation
**Emergency Spillway Control Sill Elevation
***Low-Water Crossing Crest Elevation
****Top of Dam Elevation

The relationships in Table 3 were developed from the Millersburg and Hallsville, Missouri 7.5 minute quadrangle maps and the field measurements.

TABLE 4

SPILLWAY RATING CURVE

Reservoir Elevation (ft)	Principal Spillway Discharge (cfs)	Emergency Spillway Discharge (cfs)	Total Spillway Discharge (cfs)
*786.6	0	-	0
**787.4	11	0	11
788.5	24	51	75
***789.3	37	95	132
****790.4	76	376	452

*Principal Spillway Outlet Invert Elevation
**Emergency Spillway Control Sill Elevation
***Low-Water Crossing Crest Elevation
****Top of Dam Elevation

METHOD USED:

The principal spillway release rates and the emergency spillway release rates through the culvert are based on nomographs for a box culvert with inlet and outlet control (8).

Additional emergency spillway release rates above elevation 789.3 were based on flow over the crest determined using the non-level dam crest option ($L and $V cards) of the HEC-1 program. The equations for flow over non-level crests:

$$d_c = 2/3\ (H_m + 1/4 \Delta Y)$$

$$A = 1/2\ T\ (2d_c - \Delta Y)$$

$$Q = (A^3\ g/T)^{0.5}$$

where:

d_c = critical depth (feet)
H_m = available specific energy which is taken to be the height of the water surface in the reservoir above the bottom of the section (feet)
ΔY = change in elevation across the section (feet)
A = flow area (sq. ft.)
T = top width (feet)
Q = flow (cfs)
g = 32.2 ft/sec^2 = acceleration due to gravity.

TABLE 5

RESULTS OF FLOOD ROUTINGS

Ratio of PMF	Peak Inflow (cfs)	Peak Lake Elevation (ft.-msl)	Total Storage (ac.-ft.)	Peak Outflow (cfs)	Depth (ft.) Over Top of Dam	Duration of Over-topping (hrs)
-	0	*786.6	49	0	-	-
0.04	479	790.4	99	456	0	-
0.50	5,990	792.9	155	598	2.5	15.0
1.00	11,980	794.2	193	11,950	3.8	19.0

* Principal spillway outlet invert elevation

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(1) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version, July 1978, Modification April 1980, Davis, California.

(2) HMR 33, Seasonal Variations of Probable Maximum Precipitation, East of the 105th Meridian for Areas 10 to 1000 Square Miles and Durations from 6 to 48 Hours, U.S. Department of Commerce, NOAA, National Weather Service, 1956.

(3) EM-1110-2-1411, Standard Project Flood Determinations, U.S. Army Corps of Engineers, 26 March 1952.

(4) U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.

(5) Linsley, Ray K., Kohler, Max A., and Paulhus, Joseph L.H., Hydrology for Engineers, New York: McGraw-Hill, 1975.

(6) U.S. Army Corps of Engineers, St. Louis District, Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams, 22 August 1980.

(7) U.S. Department of Agriculture, Soil Conservation Service, Soil Survey of Boone County, Missouri, 1962.

(8) U.S. Department of Commerce, Bureau of Public Roads, Hydraulic Charts For The Selection Of Highway Culverts, December 1965.

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FLOOD HYDROGRAPH PACKAGE - HEC-1                                                  PROGRAM H21/02-1V  TIME  19:57:21    CASE PMF

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
*********************************
                    A1MISSOURI DAM INSPECTION PROGRAM   H219457*MDI.WELCH
                    A2ST. LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
                    A3WELCH LAKE DAM AND MOON VALLEY DAM
                    B     192       0      15       0       0       0       0       0       0       0
                    B1      5
                    J       1       9       1
                    J1    .01     .02     .03     .04     .05     .06     .07     .50     1.0
                    K       0       1                               3       1
                    K1    WELCH LAKE DAM (48 HR. PROBABLE MAXIMUM RUNOFF)
                    M       1       2 3.37                  1.0
                    P           24.80     101     120     130     140
                    T                                                      -1     -88
                    W2           1.92
                    X                       1
                    K       1       2                                       1
                    K1    ROUTING THROUGH WELCH LAKE DAM
                    Y                               1       1
                    Y1      1                                          -786.6      -1
                    Y4  786.6   787.0   787.4   787.5   788.0   788.5   789.0   789.5   790.0   790.5
                    Y4  791.0   792.0   793.0   794.0   795.0   796.0
                    Y5     0.      6.     11.     16.     45.     75.    110.    147.    194.    244.
                    Y5   279.    371.    464.    538.    581.    627.
                    $A     0.     7.7    18.2    52.5
                    $E  767.6   786.6    790.    800.
                    $$  786.6
                    $D  790.4
                    $L     0.     30.     45.     71.    141.    320.    372.    494.    549.    632.
                    $V  789.3   789.4   789.6   789.8   790.5   790.8   791.0   791.5   792.3   795.2
                    K      99
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FLOOD HYDROGRAPH PACK    - HEC-1                                              PROGRAM H21/02-1V  TIME  19:5.      CASE PMF

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  01 APR 80
********************************
                        MISSOURI DAM INSPECTION PROGRAM   H219457*PDI.WELCH
                        ST. LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
                        WELCH LAKE DAM AND MOON VALLEY DAM

                                           JOB SPECIFICATION
              NQ      NHR     NMIN     IDAY      IHP     IMIN    METRC     IPLT     IPRT    NSTAN
             192        0       15        0        0        0        0        0        0        0
                                       JOPER      NWT    LROPT    TRACE
                                           5        0        0        0

                                     MULTI-PLAN ANALYSES TO BE PERFORMED
                                         NPLAN= 1 NRTIO= 9 LRTIO= 1
              RTIOS=    .01     .02     .03     .04     .05     .06     .07     .50    1.00


      **********         **********         **********         **********         **********

                                         SUB-AREA RUNOFF COMPUTATION

          WELCH LAKE DAM (48 HR. PROBABLE MAXIMUM RUNOFF)

                        ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                            1       0       0       0       0       3       1       0       0

                                              HYDROGRAPH DATA
             IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                 1       2    3.37     .00    3.37    1.00    .000       0       0       0

                                                PRECIP DATA
                       SPFE     PMS      R6     R12     R24     R48     R72     R96
                        .00   24.80  101.00  120.00  130.00  140.00     .00     .00

                                                 LOSS DATA
         LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
             0     .00     .00    1.00     .00     .00    1.00   -1.00  -88.00     .00     .00

            CURVE NO =  -88.00  WETNESS =   -1.00  EFFECT CN =   88.00

                                           UNIT HYDROGRAPH DATA
                                        TC=    .00    LAG=  1.92

                                              RECESSION DATA
                              STRTQ=      .00    GRCSN=     .00     RTIOR= 1.00

           UNIT HYDROGRAPH 40 END OF PERIOD ORDINATES, TC=      .00 HOURS, LAG=   1.92  VOL= 1.00
            36.      111.      215.      360.      540.      682.      767.      794.      788.      728.
           656.      567.      456.      360.      294.      240.      200.      165.      135.      110.
            90.       74.       60.       50.       40.       33.       27.       22.       18.       15.
            12.       10.        8.        7.        6.        5.        4.        3.        2.        1.
```

0 END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.15	1	.00	.00	.00	0.	1.02	.15	97	.04	.04	.01	46.
1.01	.30	2	.00	.00	.00	0.	1.02	.30	98	.04	.04	.01	48.
1.01	.45	3	.00	.00	.00	0.	1.02	.45	99	.04	.04	.01	53.
1.01	1.00	4	.00	.00	.00	0.	1.02	1.00	100	.04	.04	.01	63.
1.01	1.15	5	.00	.00	.00	0.	1.02	1.15	101	.04	.04	.01	79.
1.01	1.30	6	.00	.00	.00	0.	1.02	1.30	102	.04	.04	.01	99.
1.01	1.45	7	.00	.00	.00	0.	1.02	1.45	103	.04	.04	.01	123.
1.01	2.00	8	.00	.00	.00	0.	1.02	2.00	104	.04	.04	.01	148.
1.01	2.15	9	.00	.00	.00	0.	1.02	2.15	105	.04	.04	.00	172.
1.01	2.30	10	.00	.00	.00	0.	1.02	2.30	106	.04	.04	.00	195.
1.01	2.45	11	.00	.00	.00	0.	1.02	2.45	107	.04	.04	.00	216.
1.01	3.00	12	.00	.00	.00	0.	1.02	3.00	108	.04	.04	.00	234.
1.01	3.15	13	.00	.00	.00	0.	1.02	3.15	109	.04	.04	.00	249.
1.01	3.30	14	.00	.00	.00	0.	1.02	3.30	110	.04	.04	.00	261.
1.01	3.45	15	.00	.00	.00	0.	1.02	3.45	111	.04	.04	.00	271.
1.01	4.00	16	.00	.00	.00	0.	1.02	4.00	112	.04	.04	.00	279.
1.01	4.15	17	.00	.00	.00	0.	1.02	4.15	113	.04	.04	.00	287.
1.01	4.30	18	.00	.00	.00	0.	1.02	4.30	114	.04	.04	.00	293.
1.01	4.45	19	.00	.00	.00	0.	1.02	4.45	115	.04	.04	.00	298.
1.01	5.00	20	.00	.00	.00	0.	1.02	5.00	116	.04	.04	.00	302.
1.01	5.15	21	.00	.00	.00	0.	1.02	5.15	117	.04	.04	.00	305.
1.01	5.30	22	.00	.00	.00	0.	1.02	5.30	118	.04	.04	.00	309.
1.01	5.45	23	.00	.00	.00	0.	1.02	5.45	119	.04	.04	.00	311.
1.01	6.00	24	.00	.00	.00	0.	1.02	6.00	120	.04	.04	.00	314.
1.01	6.15	25	.02	.00	.02	0.	1.02	6.15	121	.20	.18	.02	321.
1.01	6.30	26	.02	.00	.02	0.	1.02	6.30	122	.20	.18	.02	338.
1.01	6.45	27	.02	.00	.02	0.	1.02	6.45	123	.20	.18	.01	371.
1.01	7.00	28	.02	.00	.02	0.	1.02	7.00	124	.20	.18	.01	423.
1.01	7.15	29	.02	.00	.02	0.	1.02	7.15	125	.20	.18	.01	502.
1.01	7.30	30	.02	.00	.02	0.	1.02	7.30	126	.20	.18	.01	601.
1.01	7.45	31	.02	.00	.02	0.	1.02	7.45	127	.20	.19	.01	713.
1.01	8.00	32	.02	.00	.02	0.	1.02	8.00	128	.20	.19	.01	830.
1.01	8.15	33	.02	.00	.02	0.	1.02	8.15	129	.20	.19	.01	946.
1.01	8.30	34	.02	.00	.02	0.	1.02	8.30	130	.20	.19	.01	1054.
1.01	8.45	35	.02	.00	.02	0.	1.02	8.45	131	.20	.19	.01	1153.
1.01	9.00	36	.02	.00	.02	0.	1.02	9.00	132	.20	.19	.01	1239.
1.01	9.15	37	.02	.00	.02	0.	1.02	9.15	133	.20	.19	.01	1309.
1.01	9.30	38	.02	.00	.01	0.	1.02	9.30	134	.20	.19	.01	1366.
1.01	9.45	39	.02	.00	.01	0.	1.02	9.45	135	.20	.19	.01	1413.
1.01	10.00	40	.02	.00	.01	0.	1.02	10.00	136	.20	.19	.01	1453.
1.01	10.15	41	.02	.00	.01	0.	1.02	10.15	137	.20	.19	.01	1486.
1.01	10.30	42	.02	.00	.01	1.	1.02	10.30	138	.20	.19	.01	1515.
1.01	10.45	43	.02	.00	.01	1.	1.02	10.45	139	.20	.19	.01	1539.
1.01	11.00	44	.02	.00	.01	2.	1.02	11.00	140	.20	.19	.01	1559.
1.01	11.15	45	.02	.00	.01	3.	1.02	11.15	141	.20	.19	.00	1576.
1.01	11.30	46	.02	.00	.01	4.	1.02	11.30	142	.20	.19	.00	1590.
1.01	11.45	47	.02	.00	.01	5.	1.02	11.45	143	.20	.19	.00	1602.
1.01	12.00	48	.02	.00	.01	7.	1.02	12.00	144	.20	.19	.00	1613.
1.01	12.15	49	.05	.01	.04	9.	1.02	12.15	145	.63	.61	.01	1637.
1.01	12.30	50	.05	.01	.03	12.	1.02	12.30	146	.63	.62	.01	1692.
1.01	12.45	51	.05	.02	.03	16.	1.02	12.45	147	.63	.62	.01	1789.
1.01	13.00	52	.05	.02	.03	21.	1.02	13.00	148	.63	.62	.01	1947.

1.01	13.15	53	.06	.02	.04	29.	1.02	13.15	149	.75	.74	.01	2155.
1.01	13.30	54	.06	.02	.03	39.	1.02	13.30	150	.75	.74	.01	2492.
1.01	13.45	55	.06	.03	.03	51.	1.02	13.45	151	.75	.74	.01	2848.
1.01	14.00	56	.06	.03	.03	66.	1.02	14.00	152	.75	.74	.01	3233.
1.01	14.15	57	.07	.04	.03	83.	1.02	14.15	153	.94	.93	.01	3646.
1.01	14.30	58	.07	.04	.03	101.	1.02	14.30	154	.94	.93	.01	4064.
1.01	14.45	59	.07	.04	.03	122.	1.02	14.45	155	.94	.93	.01	4483.
1.01	15.00	60	.07	.04	.03	144.	1.02	15.00	156	.94	.93	.01	4895.
1.01	15.15	61	.07	.05	.03	168.	1.02	15.15	157	.95	.95	.00	5273.
1.01	15.30	62	.15	.10	.05	195.	1.02	15.30	158	1.90	1.90	.01	5704.
1.01	15.45	63	.41	.30	.11	233.	1.02	15.45	159	5.33	5.31	.02	6292.
1.01	16.00	64	.10	.08	.02	283.	1.02	16.00	160	1.33	1.33	.00	7062.
1.01	16.15	65	.07	.05	.01	343.	1.02	16.15	161	.88	.87	.00	7978.
1.01	16.30	66	.07	.05	.01	416.	1.02	16.30	162	.88	.87	.00	9077.
1.01	16.45	67	.07	.05	.01	495.	1.02	16.45	163	.88	.87	.00	10266.
1.01	17.00	68	.07	.06	.01	562.	1.02	17.00	164	.88	.87	.00	11207.
1.01	17.15	69	.05	.04	.01	608.	1.02	17.15	165	.69	.69	.00	11773.
1.01	17.30	70	.05	.04	.01	633.	1.02	17.30	166	.69	.69	.00	11980.
1.01	17.45	71	.05	.04	.01	643.	1.02	17.45	167	.69	.69	.00	11918.
1.01	18.00	72	.05	.04	.01	635.	1.02	18.00	168	.69	.69	.00	11549.
1.01	18.15	73	.00	.00	.00	616.	1.02	18.15	169	.06	.06	.00	11022.
1.01	18.30	74	.00	.00	.00	585.	1.02	18.30	170	.06	.06	.00	10312.
1.01	18.45	75	.00	.00	.00	542.	1.02	18.45	171	.06	.06	.00	9424.
1.01	19.00	76	.00	.00	.00	496.	1.02	19.00	172	.06	.06	.00	8524.
1.01	19.15	77	.00	.00	.00	450.	1.02	19.15	173	.06	.06	.00	7665.
1.01	19.30	78	.00	.00	.00	402.	1.02	19.30	174	.06	.06	.00	6895.
1.01	19.45	79	.00	.00	.00	355.	1.02	19.45	175	.06	.06	.00	5973.
1.01	20.00	80	.00	.00	.00	309.	1.02	20.00	176	.06	.06	.00	5173.
1.01	20.15	81	.00	.00	.00	266.	1.02	20.15	177	.06	.06	.00	4429.
1.01	20.30	82	.00	.00	.00	227.	1.02	20.30	178	.06	.06	.00	3766.
1.01	20.45	83	.00	.00	.00	193.	1.02	20.45	179	.06	.06	.00	3191.
1.01	21.00	84	.00	.00	.00	163.	1.02	21.00	180	.06	.06	.00	2701.
1.01	21.15	85	.00	.00	.00	140.	1.02	21.15	181	.06	.06	.00	2300.
1.01	21.30	86	.00	.00	.00	121.	1.02	21.30	182	.06	.06	.00	1983.
1.01	21.45	87	.00	.00	.00	105.	1.02	21.45	183	.06	.06	.00	1723.
1.01	22.00	88	.00	.00	.00	93.	1.02	22.00	184	.06	.06	.00	1511.
1.01	22.15	89	.00	.00	.00	83.	1.02	22.15	185	.06	.06	.00	1335.
1.01	22.30	90	.00	.00	.00	74.	1.02	22.30	186	.06	.06	.00	1190.
1.01	22.45	91	.00	.00	.00	67.	1.02	22.45	187	.06	.06	.00	1071.
1.01	23.00	92	.00	.00	.00	61.	1.02	23.00	188	.06	.06	.00	974.
1.01	23.15	93	.00	.00	.00	56.	1.02	23.15	189	.06	.06	.00	893.
1.01	23.30	94	.00	.00	.00	53.	1.02	23.30	190	.06	.06	.00	829.
1.01	23.45	95	.00	.00	.00	50.	1.02	23.45	191	.06	.06	.00	776.
1.02	.00	96	.00	.00	.00	47.	1.03	.00	192	.06	.06	.00	733.

SUM 34.72 33.14 1.58 282264.
(882.)(842.)(40.)(7992.83)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11980.	8030.	2817.	1468.	281896.
CMS	339.	227.	80.	42.	7982.
INCHES		22.17	31.10	32.42	32.42
MM		563.00	790.04	823.52	823.52
AC-FT		3982.	5568.	5824.	5824.
THOUS CU M		4911.	6892.	7184.	7184.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	120.	80.	26.	15.	2819.
CMS	3.	2.	1.	0.	80.
INCHES		.22	.31	.32	.32
MM		5.63	7.90	8.24	8.24
AC-FT		40.	56.	58.	58.
THOUS CU M		49.	69.	72.	72.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 2

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	240.	161.	56.	29.	5638.
CMS	7.	5.	2.	1.	160.
INCHES		.44	.62	.65	.65
MM		11.26	15.80	16.47	16.47
AC-FT		80.	112.	116.	116.
THOUS CU M		98.	138.	144.	144.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 3

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	359.	241.	85.	44.	8457.
CMS	10.	7.	2.	1.	239.
INCHES		.66	.93	.97	.97
MM		16.89	23.70	24.71	24.71
AC-FT		119.	168.	175.	175.
THOUS CU M		147.	207.	216.	216.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 4

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	479.	321.	113.	59.	11276.
CMS	14.	9.	3.	2.	319.
INCHES		.89	1.24	1.30	1.30
MM		22.52	31.60	32.94	32.94
AC-FT		159.	224.	233.	233.
THOUS CU M		196.	276.	287.	287.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 5

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	599.	401.	141.	73.	14095.
CMS	17.	11.	4.	2.	399.
INCHES		1.11	1.56	1.62	1.62

MM		28.15	39.50	41.18	41.18
AC-FT		199.	279.	291.	291.
THOUS CU M		246.	345.	359.	359.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 6

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	719.	482.	169.	88.	16914.
CMS	20.	14.	5.	2.	479.
INCHES		1.33	1.87	1.95	1.95
MM		33.78	47.40	49.41	49.41
AC-FT		239.	335.	349.	349.
THOUS CU M		295.	414.	431.	431.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 7

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	839.	562.	197.	103.	19733.
CMS	24.	16.	6.	3.	559.
INCHES		1.55	2.18	2.27	2.27
MM		39.41	55.30	57.65	57.65
AC-FT		279.	391.	408.	408.
THOUS CU M		344.	482.	503.	503.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 8

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	5990.	4015.	1409.	734.	140948.
CMS	170.	114.	40.	21.	3991.
INCHES		11.08	15.55	16.21	16.21
MM		281.50	395.02	411.76	411.76
AC-FT		1991.	2794.	2912.	2912.
THOUS CU M		2456.	3446.	3592.	3592.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 9

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11980.	8030.	2817.	1468.	281896.
CMS	339.	227.	80.	42.	7982.
INCHES		22.17	31.10	32.42	32.42
MM		563.00	790.04	823.52	823.52
AC-FT		3982.	5588.	5824.	5824.
THOUS CU M		4911.	6892.	7184.	7184.

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HYDROGRAPH ROUTING

ROUTING THROUGH WELCH LAKE DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
.0	.000	.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	.000	.000	.000	-787.	-1

STAGE	786.60	787.00	787.40	787.50	788.00	788.50	789.00	789.50	790.00	790.50
	791.00	792.00	793.00	794.00	795.00	796.00				
FLOW	.00	6.00	11.00	18.00	45.00	75.00	110.00	147.00	194.00	244.00
	279.00	371.00	464.00	538.00	581.00	627.00				

SURFACE AREA=	0.	8.	18.	52.
CAPACITY=	0.	49.	92.	430.
ELEVATION=	768.	787.	790.	800.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
786.6	.0	.0	.0	.0	.0	.0	.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
790.4	.0	.0	0.

CREST LENGTH	0.	30.	45.	71.	141.	320.	372.	494.	549.	632.
AT OR BELOW ELEVATION	789.3	789.4	789.6	789.8	790.5	790.8	791.0	791.5	792.3	795.2

STATION 2, PLAN 1, RATIO 1

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	3.	3.	3.	3.

INCHES	.60	.85	.87	.87
MM	15.13	21.59	22.15	22.15
AC-FT	107.	153.	157.	157.
THOUS CU M	132.	188.	193.	193.

STATION 2, PLAN 1, RATIO 4

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.	1.	1.
1.	1.	2.	2.	2.	3.	3.	4.	5.	5.
6.	7.	7.	8.	8.	8.	9.	9.	9.	9.
9.	9.	9.	9.	9.	9.	9.	9.	9.	8.
8.	8.	8.	8.	8.	8.	7.	7.	7.	7.
7.	7.	7.	7.	7.	7.	7.	7.	7.	7.
7.	7.	7.	7.	7.	8.	8.	8.	8.	8.
8.	8.	8.	9.	9.	9.	10.	10.	11.	15.
19.	22.	25.	28.	30.	33.	35.	38.	40.	42.
44.	46.	48.	49.	51.	52.	54.	56.	59.	62.
66.	71.	78.	86.	94.	103.	113.	123.	134.	151.
180.	220.	270.	326.	378.	419.	445.	456.	454.	442.
421.	395.	366.	336.	306.	277.	250.	225.	202.	182.
165.	150.	140.	132.	125.	118.	111.	104.	98.	92.
86.	80.								

STORAGE

49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	50.	50.	50.	50.	51.	51.	51.	52.
52.	52.	53.	53.	54.	54.	54.	54.	54.	54.
54.	54.	54.	54.	54.	54.	54.	54.	54.	54.
54.	54.	53.	53.	53.	53.	53.	53.	53.	53.
53.	53.	53.	53.	53.	53.	53.	53.	53.	53.
53.	53.	53.	53.	53.	53.	53.	53.	53.	54.
54.	54.	54.	54.	54.	54.	55.	55.	56.	56.
57.	57.	58.	59.	59.	60.	60.	61.	61.	61.
62.	62.	63.	63.	63.	64.	64.	64.	65.	66.
66.	67.	69.	70.	72.	74.	76.	78.	80.	83.
85.	88.	91.	94.	96.	98.	99.	99.	99.	99.
98.	97.	96.	94.	93.	92.	90.	89.	87.	86.
84.	83.	81.	80.	78.	77.	75.	74.	73.	71.
70.	69.								

786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.7
786.7	786.7	786.7	786.7	786.8	786.6	786.8	786.9	786.9	787.0
787.0	787.1	787.1	787.1	787.2	787.2	787.2	787.2	787.2	787.3
787.3	787.3	787.3	787.3	787.2	787.2	787.2	787.2	787.2	787.2
787.2	787.2	787.2	787.1	787.1	787.1	787.1	787.1	787.1	787.1
787.1	787.1	787.1	787.1	787.1	787.1	787.1	787.1	787.1	787.1
787.1	787.1	787.1	787.1	787.1	787.1	787.1	787.1	787.2	787.2
787.2	787.2	787.2	787.2	787.2	787.3	787.3	787.3	787.4	787.5
787.5	787.6	787.6	787.7	787.7	787.8	787.8	787.9	787.9	787.9
788.0	788.0	788.0	788.1	788.1	788.1	788.2	788.2	788.2	788.3
788.4	788.4	788.5	788.7	788.8	788.9	789.0	789.2	789.3	789.5
789.7	789.8	790.0	790.1	790.3	790.3	790.4	790.4	790.4	790.4
790.3	790.3	790.2	790.2	790.1	790.0	789.9	789.8	789.8	789.7
789.6	789.5	789.4	789.3	789.2	789.1	789.0	788.9	788.8	788.7
788.7	788.6								

PEAK OUTFLOW IS 456. AT TIME 42.00 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	456.	298.	105.	54.	10281.
CMS	13.	8.	3.	2.	291.
INCHES		.82	1.15	1.18	1.18
MM		20.90	29.32	30.03	30.03
AC-FT		148.	207.	212.	212.
THOUS CU M		182.	256.	262.	262.

STATION 2, PLAN 1, RATIO 5

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	1.	1.	1.	1.
1.	2.	2.	2.	3.	3.	4.	5.	6.	7.
7.	8.	9.	9.	10.	10.	10.	11.	11.	12.
12.	12.	12.	11.	11.	11.	11.	11.	10.	10.
10.	10.	10.	10.	9.	9.	9.	9.	9.	8.
8.	8.	8.	8.	8.	8.	8.	8.	8.	9.
9.	9.	9.	9.	9.	9.	10.	10.	10.	10.
10.	10.	10.	11.	11.	14.	16.	19.	22.	24.
28.	31.	34.	37.	40.	43.	46.	49.	52.	54.
57.	59.	61.	63.	64.	66.	68.	71.	74.	78.
84.	90.	99.	108.	118.	129.	142.	164.	193.	230.
275.	329.	390.	454.	510.	550.	574.	581.	572.	552.

STATION 2, PLAN 1, RATIO 8

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
1.	1.	2.	2.	3.	4.	5.	6.	8.	9.
12.	22.	30.	40.	51.	65.	80.	99.	118.	136.
163.	197.	228.	249.	259.	259.	252.	240.	226.	210.
193.	177.	162.	149.	139.	132.	125.	118.	110.	104.
97.	91.	84.	79.	73.	69.	65.	61.	57.	54.
53.	52.	52.	54.	56.	60.	64.	68.	73.	79.
84.	90.	95.	100.	104.	109.	113.	117.	120.	124.
127.	131.	135.	142.	156.	180.	216.	266.	329.	397.
465.	527.	582.	630.	669.	699.	722.	741.	756.	768.
779.	788.	795.	801.	809.	826.	859.	916.	1009.	1143.
1312.	1504.	1711.	1926.	2142.	2354.	2559.	2764.	3021.	3374.
3810.	4332.	4921.	5450.	5801.	5965.	5976.	5845.	5603.	5282.
4871.	4422.	3989.	3566.	3150.	2751.	2375.	2035.	1738.	1484.
1270.	1097.	957.	843.	749.	673.	609.	557.	513.	474.
441.	413.								

STORAGE

49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	50.	50.	50.	51.	52.	52.	53.	55.
56.	57.	59.	61.	63.	66.	69.	73.	77.	80.
84.	87.	89.	90.	91.	91.	90.	90.	89.	88.
87.	85.	84.	83.	81.	80.	78.	77.	75.	74.
72.	71.	70.	69.	68.	67.	66.	65.	65.	64.
64.	63.	64.	64.	64.	65.	66.	67.	68.	69.
70.	71.	72.	73.	74.	75.	76.	76.	77.	78.
79.	79.	80.	81.	83.	85.	88.	91.	94.	97.
99.	102.	103.	105.	105.	106.	107.	107.	107.	108.
108.	108.	108.	108.	108.	109.	109.	110.	112.	114.
116.	118.	120.	123.	125.	127.	129.	130.	133.	136.
139.	143.	147.	151.	154.	155.	155.	154.	152.	150.
147.	144.	140.	137.	134.	130.	127.	124.	121.	118.
115.	113.	111.	109.	107.	106.	104.	103.	101.	100.
99.	98.								

STAGE

786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6

786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.7	786.7	786.7	786.7	786.8	786.9	786.9	787.0	787.1	787.3
787.4	787.6	787.7	787.9	788.1	788.3	788.6	788.8	789.1	789.3
789.6	789.7	789.9	789.9	790.0	790.0	789.9	789.9	789.8	789.8
789.7	789.6	789.6	789.5	789.4	789.3	789.2	789.1	789.0	788.9
788.8	788.7	788.6	788.6	788.5	788.4	788.3	788.3	788.2	788.2
788.1	788.1	788.1	788.1	788.2	788.2	788.3	788.4	788.5	788.6
788.6	788.7	788.8	788.9	728.9	789.0	789.0	789.1	789.1	789.2
789.2	789.3	789.3	789.4	789.5	789.7	789.8	790.0	790.1	790.3
790.4	790.5	790.6	790.7	790.7	790.8	790.8	790.8	790.8	790.8
790.8	790.9	790.9	790.9	790.9	790.9	790.9	791.0	791.0	791.1
791.2	791.3	791.4	791.5	791.6	791.7	791.8	791.9	792.0	792.1
792.2	792.4	792.6	792.7	792.8	792.9	792.9	792.8	792.8	792.7
792.6	792.4	792.3	792.2	792.0	791.9	791.7	791.6	791.5	791.3
791.2	791.1	791.0	790.9	790.8	790.7	790.7	790.6	790.5	790.4
790.4	790.3								

PEAK OUTFLOW IS 5976. AT TIME 41.75 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	5976.	4013.	1393.	722.	138575.
CMS	169.	114.	39.	20.	3924.
INCHES		11.08	15.38	15.94	15.94
MM		281.34	390.66	404.83	404.83
AC-FT		1990.	2763.	2863.	2863.
THOUS CU M		2454.	3408.	3532.	3532.

STATION 2, PLAN 1, RATIO 9

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.	1.	1.
2.	2.	3.	4.	6.	7.	9.	13.	24.	35.
47.	60.	74.	93.	114.	140.	201.	300.	412.	507.
571.	608.	618.	608.	584.	550.	513.	477.	430.	388.
348.	309.	275.	244.	217.	195.	176.	161.	148.	139.
132.	126.	115.	113.	107.	101.	96.	91.	87.	84.
83.	83.	86.	91.	98.	106.	116.	126.	137.	154.
176.	198.	220.	240.	257.	270.	281.	290.	297.	302.
308.	316.	330.	354.	400.	467.	557.	678.	820.	957.
1077.	1178.	1262.	1330.	1384.	1427.	1466.	1498.	1525.	1547.
1566.	1582.	1596.	1607.	1624.	1661.	1739.	1867.	2069.	2350.
2692.	3073.	3482.	3905.	4329.	4749.	5155.	5563.	6083.	6800.
7677.	8723.	9900.	10945.	11628.	11940.	11951.	11678.	11185.	10536.
9702.	8799.	7932.	7081.	6244.	5440.	4685.	4004.	3407.	2896.
2468.	2125.	1848.	1621.	1434.	1278.	1149.	1042.	954.	882.
822.	774.								

STORAGE

49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
49.	49.	49.	49.	49.	49.	49.	49.	49.	49.
50.	50.	50.	51.	52.	53.	54.	56.	58.	60.
62.	65.	68.	72.	76.	81.	87.	93.	98.	101.
103.	104.	104.	104.	103.	102.	101.	100.	98.	97.
95.	93.	92.	90.	88.	87.	85.	84.	82.	81.
80.	78.	77.	76.	75.	73.	72.	71.	71.	70.
70.	70.	70.	71.	73.	74.	76.	78.	81.	83.
85.	87.	88.	90.	91.	91.	92.	92.	93.	93.
93.	94.	94.	95.	97.	100.	103.	106.	109.	111.
113.	114.	115.	116.	117.	117.	118.	118.	118.	119.
119.	119.	119.	119.	119.	120.	121.	122.	124.	127.
130.	133.	136.	140.	143.	146.	149.	152.	156.	160.
166.	173.	180.	187.	191.	193.	193.	191.	188.	184.
179.	173.	168.	162.	157.	151.	146.	141.	136.	132.
128.	125.	122.	119.	117.	115.	114.	112.	111.	110.
109.	108.								

STAGE

786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6
786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.6	786.7	786.7
786.7	786.8	786.9	786.9	787.0	787.1	787.3	787.4	787.6	787.8
788.0	788.3	788.5	788.8	789.1	789.4	789.8	790.1	790.3	790.5
790.6	790.7	790.7	790.7	790.6	790.6	790.5	790.4	790.4	790.3
790.2	790.1	790.0	789.9	789.8	789.7	789.6	789.6	789.5	789.4
789.3	789.2	789.1	789.0	789.0	788.9	788.8	788.7	788.7	788.6
788.6	788.6	788.7	788.7	788.8	788.9	789.1	789.2	789.4	789.5
789.6	789.7	789.8	789.9	789.9	790.0	790.0	790.0	790.1	790.1
790.1	790.1	790.1	790.2	790.3	790.4	790.6	790.7	790.9	791.0
791.1	791.1	791.2	791.2	791.3	791.3	791.3	791.3	791.3	791.4
791.4	791.4	791.4	791.4	791.4	791.4	791.5	791.5	791.6	791.7
791.9	792.0	792.1	792.3	792.4	792.5	792.6	792.8	792.9	793.1
793.3	793.5	793.8	794.0	794.2	794.2	794.2	794.2	794.1	793.9
793.7	793.6	793.4	793.1	792.9	792.7	792.5	792.3	792.1	791.9
791.8	791.6	791.5	791.4	791.3	791.2	791.1	791.1	791.0	790.9
790.9	790.8								

PEAK OUTFLOW IS 11951. AT TIME 41.75 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11951.	8028.	2800.	1453.	279029.
CMS	338.	227.	79.	41.	7901.
INCHES		22.16	30.91	32.09	32.09
MM		562.88	785.16	815.14	815.14
AC-FT		3981.	5553.	5765.	5765.
THOUS CU M		4910.	6850.	7111.	7111.

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PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1 .01	RATIO 2 .02	RATIO 3 .03	RATIO 4 .04	RATIO 5 .05	RATIO 6 .06	RATIO 7 .07	RATIO 8 .50	RATIO 9 1.00
				RATIOS APPLIED TO FLOWS								
HYDROGRAPH AT	1	3.37	1	120.	240.	359.	479.	599.	719.	839.	5990.	11980.
	(	8.73)	(	3.39)(	6.78)(	10.18)(	13.57)(	16.96)(	20.35)(	23.75)(	169.62)(	339.24)
ROUTED TO	2	3.37	1	84.	185.	326.	456.	581.	704.	830.	5976.	11951.
	(	8.73)	(	2.37)(	5.24)(	9.22)(	12.91)(	16.44)(	19.94)(	23.49)(	169.22)(	338.42)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	786.60	786.60	790.40
STORAGE	49.	49.	99.
OUTFLOW	0.	0.	452.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.01	788.63	.00	70.	84.	.00	43.00	.00
.02	789.68	.00	86.	185.	.00	42.75	.00
.03	790.13	.00	94.	326.	.00	42.25	.00
.04	790.41	.01	99.	456.	.50	42.00	.00
.05	790.61	.21	103.	581.	2.25	42.00	.00
.06	790.77	.37	106.	704.	3.00	41.75	.00
.07	790.89	.49	109.	830.	3.75	41.75	.00
.50	792.87	2.47	155.	5976.	15.00	41.75	.00
1.00	794.22	3.82	193.	11951.	19.00	41.75	.00

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=============================================================================================================================
FLOOD HYDROGRAPH PACKAGE - HEC-1                                                PROGRAM H21/02-1V  TIME  19:57:21   CASE 10

********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
********************************
       1              A1MISSOURI DAM INSPECTION PROGRAM    H219457*MDI.WELCH
       2              A2ST. LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
       3              A3WELCH LAKE DAM AND MOON VALLEY DAM
       4              B     192       0      15       0       0       0       0       0       0       0
       5              B1      3
       6              K       0       1                               3       1
       7              K1   WELCH LAKE DAM (48 HP. 10-YEAR RUNOFF)
       8              M       0       2    3.37                     1.0
       9              O     192   5.889
      10              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      11              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      12              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      13              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      14              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      15              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      16              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      17              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      18              O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
      19              O1   .007    .007    .007    .007    .007    .007    .014    .014    .014    .014
      20              O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
      21              O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
      22              O1   .032    .032    .032    .032    .032    .032    .032    .032    .032    .032
      23              O1   .032    .032    .032    .032    .032    .032    .032    .032    .032    .032
      24              O1   .032    .032    .032    .032    .046    .046    .046    .046    .046    .046
      25              O1   .088    .088    .179    .160    .242    .435   1.178    .245    .161    .160
      26              O1   .088    .088    .046    .046    .046    .046    .046    .046    .014    .014
      27              O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
      28              O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
      29              O1   .014    .014
      30              T                                                -1     -74
      31              W2           1.92
      32              X                       1
      33              K       1       2                                       1
      34              K1   ROUTING THROUGH WELCH LAKE DAM
      35              Y                               1
      36              Y1      1                                          -786.6      -1
      37              Y4  786.6   787.0   787.4   787.5   788.0   788.5   789.0   789.5   790.0   790.5
      38              Y4  791.0   792.0   793.0   794.0   795.0   796.0
      39              Y5     0.      6.     11.     18.     45.     75.    110.    147.    194.    244.
      40              Y5   279.    371.    464.    538.    581.    627.
      41              $A     0.     7.7    18.2    52.5
      42              $E  767.6   786.6    790.    800.
      43              $$  786.6
      44              $D  790.4
      45              $L     0.     30.     45.     71.    141.    320.    372.    494.    549.    632.
      46              $V  789.3   789.4   789.6   789.8   790.5   790.8   791.0   791.5   792.3   795.2
      47              K      99
```

1.02	17.00	164	41.00	1570.	1528.	118.	791.3
1.02	17.15	165	41.25	1574.	1569.	119.	791.4
1.02	17.30	166	41.50	1510.	1544.	119.	791.4
1.02	17.45	167	41.75	1411.	1466.	118.	791.3
1.02	18.00	168	42.00	1282.	1356.	116.	791.3
1.02	18.15	169	42.25	1128.	1221.	115.	791.2
1.02	18.30	170	42.50	985.	1080.	113.	791.1
1.02	18.45	171	42.75	865.	954.	111.	791.0
1.02	19.00	172	43.00	758.	845.	109.	790.9
1.02	19.15	173	43.25	665.	750.	107.	790.8
1.02	19.30	174	43.50	581.	668.	105.	790.7
1.02	19.45	175	43.75	506.	596.	104.	790.6
1.02	20.00	176	44.00	441.	533.	102.	790.5
1.02	20.15	177	44.25	384.	476.	100.	790.4
1.02	20.30	178	44.50	335.	424.	98.	790.3
1.02	20.45	179	44.75	292.	377.	96.	790.3
1.02	21.00	180	45.00	257.	337.	94.	790.2
1.02	21.15	181	45.25	229.	302.	93.	790.1
1.02	21.30	182	45.50	206.	273.	91.	790.0
1.02	21.45	183	45.75	187.	249.	90.	789.9
1.02	22.00	184	46.00	172.	228.	89.	789.9
1.02	22.15	185	46.25	159.	211.	88.	789.8
1.02	22.30	186	46.50	149.	197.	87.	789.7
1.02	22.45	187	46.75	141.	185.	86.	789.7
1.02	23.00	188	47.00	134.	174.	85.	789.6
1.02	23.15	189	47.25	128.	165.	84.	789.6
1.02	23.30	190	47.50	124.	158.	83.	789.5
1.02	23.45	191	47.75	120.	152.	83.	789.5
1.03	.00	192	48.00	117.	147.	82.	789.5

PEAK OUTFLOW IS 1569. AT TIME 41.25 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1569.	855.	252.	126.	24180.
CMS	44.	24.	7.	4.	685.
INCHES		2.36	2.78	2.78	2.78
MM		59.95	70.64	70.64	70.64
AC-FT		424.	500.	500.	500.
THOUS CU M		523.	616.	616.	616.

********** ********** ********** ********** **********

RUNOFF SUMMARY, AVERAGE FLOW IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES(SQUARE KILOMETERS)

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	1	1574.	876.	269.	134.	3.37
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

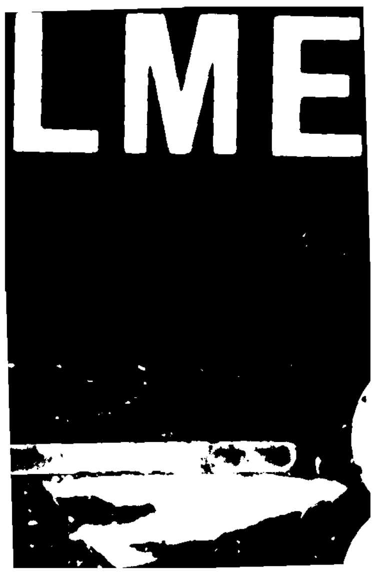
ROUTED TO	2	1569.	855.	252.	126.	3.37
	(	44.43)(	24.21)(	7.13)(	3.57)(	8.73)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	786.60	786.60	790.40
STORAGE	49.	49.	99.
OUTFLOW	0.	0.	452.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
10-YEAR ~~1.00~~	791.37	.97	119.	1569.	4.50	41.25	.00


LME