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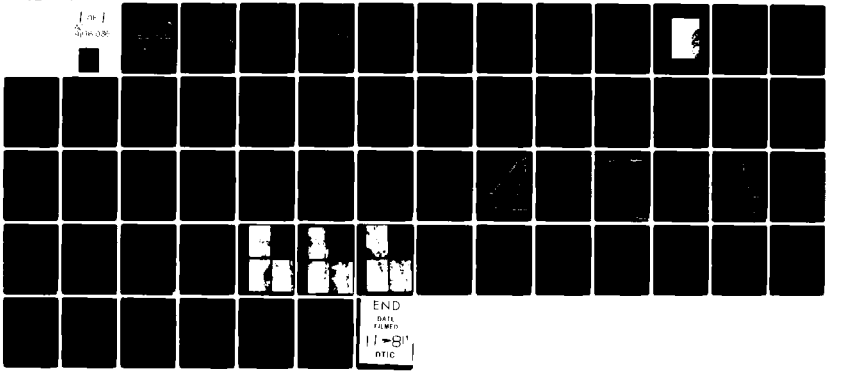

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UPPER MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

HIGHWAY 21 LAKE DAM

JEFFERSON COUNTY, MISSOURI

MO 31402

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
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St. Louis District

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

FOR: STATE OF MISSOURI

JANUARY 1981

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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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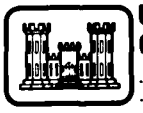
UPPER MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

HIGHWAY 21 LAKE DAM

JEFFERSON COUNTY, MISSOURI

MO 31402

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



United States Army
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St. Louis District

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

FOR: STATE OF MISSOURI

JANUARY 1981

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

REPLY TO ATTENTION OF

LMSED-P

SUBJECT: Highway 21 Lake Dam, MO 31402, Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Highway 21 Lake Dam (MO 31402):

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

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

1) Spillway will not pass 50 percent of the Probable Maximum Flood without overtopping the dam.

2) Overtopping of the dam could result in failure of the dam.

3) Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED
Chief, Engineering Division

28 JAN 1981
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

29 JAN 1981
Date

HIGHWAY 21 LAKE DAM

MISSOURI INVENTORY NO. 31402

JEFFERSON COUNTY, MISSOURI

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.
5200 OAKLAND AVENUE
ST. LOUIS, MISSOURI 63110

FOR:

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS

CORPS OF ENGINEERS

JANUARY 1981

HS-8011

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Highway 21 Lake Dam
State Located:	Missouri
County Located:	Jefferson
Stream:	Tributary of Heads Creek
Date of Inspection:	8 October 1980

The Highway 21 Lake Dam was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety, and, based upon this inspection and available data, determine if the dam poses an inordinate danger to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team. Based on the visual inspection and the results of these hydrologic/hydraulic investigations, the present general condition of the dam is considered to be less than satisfactory. Deficiencies observed during the visual inspection which are considered to have an adverse effect on the overall safety and future operation of the dam include such items as dense brush and trees on both the upstream and downstream faces of the dam, the lack of a suitable form of erosion protection on the upstream face of the dam, a spillway that is littered with rubbish and overgrown with brush and small trees, possible settlement of the dam crest at the location of the original stream crossing, and the possibility of geologic conditions that could impair the structural stability of the dam.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Highway 21 Lake Dam, which is classified as small in size and of high hazard potential, is specified to be a minimum of one-half the Probable Maximum Flood (PMF). Considering the fact that a relatively small volume of water is impounded by the dam, that the flood plain downstream of the dam is fairly broad, and that there are but

three dwellings within the estimated flood damage zone, it is recommended that the spillway for this dam be designed for one-half the Probable Maximum Flood. The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

According to the former owners, the reservoir has experienced excessive leakage for many years, as indicated by the inability of the lake to reach the level of the spillway or even, more recently, to come anywhere close to it. The former owners reported that during their period of ownership, approximately 36 years, the reservoir had never reached the level of the spillway and that about 20 years ago when flow from a nearby spring which fed the lake began to diminish and then stopped, the lake level soon receded until it reached a depth of only 3, or so, feet. At the time of the inspection, the lake level was about 18.6 feet below the spillway crest and the lake appeared to be only about 1 foot deep. Judging by a waterline mark across the upstream face of the dam, the lake had been, at some period of time, approximately 2 feet higher than the observed level. A hunter (name unknown) encountered during a recent reconnaissance of the site indicated that the deepest he had seen the lake during the time he was familiar with the area, a period of several years, was about waist (approximately 3.5 feet) high. For the purpose of the hydrologic/hydraulic investigations performed for this dam, the level of the lake just prior to the beginning of the assumed antecedent storms for the Probable Maximum Flood and the one percent chance (100-year frequency) flood, was assumed to be approximately one foot higher than the elevation of the observed waterline mark on the face of the dam, or about 16.0 feet below the spillway crest.

Results of a hydrologic/hydraulic analysis indicated that the spillway is inadequate to pass lake outflow resulting from a storm of one-half PMF magnitude without overtopping the dam. However, the spillway is capable of passing lake outflow resulting from the one percent chance (100-year frequency) flood and the lake outflow corresponding to about 10 percent of the PMF lake inflow, without overtopping the dam. According to the St. Louis District, Corps of Engineers, the length of the downstream damage zone, should failure of the dam occur, is estimated to be approximately two miles.

Accordingly, within the possible damage zone are three dwellings and several other kinds of buildings.

No indication was found that seepage or stability analyses of the dam were performed. This is considered a deficiency and should be rectified.

Since the dam is scheduled to be removed sometime in the foreseeable future when construction of new Highway 21 in this area is implemented, there appears to be no practical value to remedying the deficiencies and safety defects noted herein. Therefore, it is recommended that the Owner, without undue delay, eliminate this hazard by either removing or breaching the dam. However, if the Owner elects not to remove or breach the dam, it is recommended that the necessary action be taken sometime in the near future to correct or control the deficiencies and safety defects reported herein.

Harold B. Lockett
P. E. Missouri E-4189

Albert B. Becker, Jr.
P. E. Missouri E-9168

OVERVIEW HIGHWAY 21 LAKE DAM

PHASE 1 INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

HIGHWAY 21 LAKE DAM - MO 31402

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
HIGHWAY 21 LAKE DAM - NO 31402

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, 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 St. Louis District, Corps of Engineers, directed that a safety inspection of the Highway 21 Lake Dam be made.

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

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams", Appendix D to "Report to the Chief of Engineers on the National Program of Inspection of Non-Federal Dams", dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Highway 21 Lake Dam is an earthfill type embankment rising approximately 28 feet above the natural streambed at the downstream toe of the embankment. The embankment has a maximum upstream slope of approximately 1v on 2.6h, a crest width of about 13 feet, and a downstream slope on the order of 1v on 2.3h. The length of the dam is approximately 271 feet and an unsurfaced roadway that is partially overgrown with weeds, traverses the crest of the dam. A plan and profile of the dam is shown on Plate 4 and a cross-section of the dam at about the

location of the original stream channel is presented on Plate 5. At spillway crest level, the reservoir impounded by the dam would occupy approximately 5 acres. At the present level, which is nearly 18.6 feet below the spillway crest, the reservoir is only about 1 foot deep and occupies approximately 0.1 acre. The dam has no drawdown facility to drain the lake. An overview photo of the Highway 21 Lake Dam is shown following the preface at the beginning of the report.

The spillway for the dam, an excavated earth trapezoidal section, is located at the right, or north, abutment. An earthen bank on the left side of the outlet serves to confine flow to the spillway channel and to protect the dam. The spillway outlet channel appears to join the original stream on which the dam is constructed, at a point about 20 feet downstream of the toe of the dam. A profile and cross-section of the spillway channel are also shown on Plate 5.

b. Location. The dam is located on an unnamed tributary of Heads Creek, about one-half mile north of the intersection of Route MM and State Highway 21, and approximately 4 miles southeast of the Community of House Springs, Missouri, as shown on the Regional Vicinity Map, Plate 1. The dam is located within the northeast one-quarter of Section 18, Township 42 North, Range 5 East, in Jefferson County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as small (per Table 1, Recommended Guidelines for Safety Inspection of Dams).

d. Hazard Classification. The Highway 21 Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, or extensive damage to agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, as determined by the St. Louis District, extends approximately two miles downstream of the dam. Within the possible damage zone are three dwellings and several other kinds of buildings. Those features lying within the downstream damage zone as reported

by the St. Louis District, Corps of Engineers, were verified by the inspection team.

e. Ownership. The property on which the dam lies is owned by the Missouri State Highway Commission, having been acquired in 1978 by the State as right-of-way for the relocation of Highway 21. According to information shown on the construction plans prepared by the State Highway Department, the dam is to be removed when the new highway in this area is constructed. The Commission's address is: Highway Department Building, Jefferson City, Missouri 65101. Mr. Robert N. Hunter is Chief Engineer of the State Highway Commission of Missouri.

f. Purpose of Dam. The original purpose of the dam was to impound water for recreational benefit.

g. Design and Construction History. According to the former owners, Mr. and Mrs. George F. Langenback, Sr. of Crestwood, Missouri, the dam was constructed about 1940 by two engineers with the Missouri State Highway Department by the names of Steffens and Ferguson. The present status or whereabouts of Messrs. Steffens and Ferguson is unknown and no detail information relative to the design or construction of the dam is known to exist.

h. Normal Operational Procedure. The lake level is unregulated. Lake outflow is governed by the capacity of an excavated earth type spillway. However, according to the former owners, Mr. & Mrs. George Langenback, during 36 years of ownership, the level of the lake had never reached the spillway crest, and for the last 20 years, or so, the lake has held very little water.

1.3 PERTINENT DATA

a. Drainage Area. With the exception of some commerical and residential type development along the Highway 21 ridge line of the watershed, the area tributary to the lake is essentially in a native state covered with timber. The watershed above the dam amounts to approximately 150 acres. The watershed area is outlined on Plate 3.

b. Discharge at Damsite.

(1) Estimated known maximum flood at dam site ... None*
(2) Spillway capacity ... 50 cfs (W.S. Elev. 699.1)

c. Elevation (Ft. above MSL). Unless otherwise indicated, the following elevations were determined by survey and are based on the elevation of Bench Mark No. 69 (696.05) as shown on the plans for the relocation of Highway 21 as prepared by the Missouri State Highway Department and described on the plans as follows:

"80d Spike in Root of 24-inch Black Oak, 35 feet (±) West of North End of Dam of Lake, 10 feet (±) Right of Station 419+70(±) Baseline N.B.L."

(1) Observed pool ... 679.4
(2) Normal pool ... Unknown
(3) Mean annual high water ... 682.0 (based on depth reported by hunter)
(4) Spillway crest ... 698.0
(5) Maximum experienced pool ... 697.0 (per former owner)
(6) Top of dam ... 699.1 (Min.)
(7) Streambed at centerline of dam ... 674± (Est.)
(8) Maximum tailwater ... Unknown
(9) Observed tailwater ... None

d. Reservoir.

(1) Length at spillway crest (Elev. 698.0) ... 870 ft.
(2) Length at maximum pool (Elev. 699.1) ... 900 ft.

e. Storage.

(1) Spillway crest ... 47 ac. ft.
(2) Top of dam (incremental) ... 6 ac. ft.

*According to the former owners, the level of the lake has never reached the elevation of the spillway crest.

f. Reservoir Surface.

(1) Spillway crest ... 5.0 acres
(2) Top of dam (incremental) ... 0.3 acres

g. Dam. The height of the dam is defined to be the overall vertical distance from the lowest point of foundation surface at the downstream toe of the barrier, to the top of the dam.

(1) Type ... Earthfill
(2) Length ... 271 ft.
(3) Height ... 28 ft.
(4) Top width ... 13 ft.
(5) Side slopes
    a. Upstream ... 1v on 2.6h (max.)
    b. Downstream ... 1v on 2.3h
(6) Cutoff ... Unknown
(7) Slope protection
    a. Upstream ... Grass
    b. Downstream ... Grass

h. Principal Spillway.

(1) Type ... Uncontrolled, excavated earth, trapezoidal section
(2) Location ... Right abutment
(3) Crest elevation ... 698.0
(4) Width ... 10 ft. (min.)
(5) Side slopes ... Irregular
(6) Approach channel ... Lake
(7) Outlet channel ... Trapezoidal section through crest section, unconfined beyond crest section

i. Emergency Spillway. ... None

j. Lake Drawdown Facility. ... None

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No data relating to the design of the dam are known to exist.

2.2 CONSTRUCTION

As previously stated the dam was constructed about 1940 by Messrs. Steffens and Ferguson, two engineers with the Missouri State Highway Department. The present whereabouts and status of Mr. Steffens and Mr. Ferguson is unknown. According to Mrs. Langenback, one of the former owners, the dam was constructed with material obtained from the construction of Highway 21. No other information relative to the construction of the dam was available.

2.3 OPERATION

Under normal conditions, the level of the lake would be governed by the crest of the excavated earth spillway located at the right abutment. It was reported by the former owners, Mr. & Mrs. Langenback, that during their period of ownership, approximately 36 years, the lake level had never reached the elevation of the spillway, and that, about 20 years ago, when the spring which fed the lake began to diminish and then stopped flowing, the lake level receded until it reached a depth of only 3, or so, feet.

No indication was found during the inspection that the dam had been overtopped. According to Mr. and Mrs. Langenback, the highest lake level observed occurred during their earlier period of ownership when the lake surface was about 1 foot below the spillway crest.

2.4 EVALUATION

a. Availability. Engineering data for assessing the design of the dam and spillway were unavailable.

b. Adequacy. No data available. 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.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Highway 21 Lake Dam was made by Horner & Shifrin engineering personnel, R. E. Sauthoff, Civil Engineer, H. B. Lockett, Hydrologist, and A. B. Becker, Jr., Civil and Soils Engineer, on 8 October 1980. An examination of the dam area was also made by an engineering geologist, Jerry D. Higgins, Ph. D., a consultant retained by Horner & Shifrin for the purpose of assessing the site geology. Also examined at the time of the inspection were the areas and features below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on pages A-1 through A-3 of Appendix A. The locations of the photographs taken during the inspection are indicated on Plate 4.

b. Site Geology. The topography at the dam site is moderately rugged, and there is approximately 180 feet of relief between the reservoir and the surrounding drainage divide. The area is included within the northeastern part of the Ozark Plateaus Physiographic Province, and the regional dip of the bedrock is northeastward into the Illinois Basin. The site is located near the axis of the House Springs Anticline. Although the structure changes the regional dip of the strata in this area, the bedrock formations at the site still dip toward the northeast. Several faults are associated with the anticlinal structure; however, no faulting was observed at the site. The bedrock at the lake site consists of Ordovician- and Mississippian-age limestone and sandstone formations. Limestone of the Kimmswick formation outcrops at the dam site, overlain by Bushberg sandstone. The uplands surrounding the reservoir are underlain by limestone, principally of the Burlington formation.

The Kimmswick is a coarsely crystalline, light grey, massive- to medium-bedded limestone. It has a distinctive pitted weathering surface, and nodular chert is scattered in the upper portions of the formation. The Kimmswick is extremely permeable and will transmit water readily. The contact between the weathered bedrock surface and the overlying residuum is usually irregular. The residual soils, when not modified by colluvium, are quite thin

and typically a reddish-brown, well-structured, plastic clay, CH, as classified by the Unified Soil Classification System. The soils are generally rated as poor for water impoundments due to the thin cover over permeable bedrock.

Overlying the Kimmswick in this area is the Bushberg sandstone. This is a massive, cross-bedded, brown, fine- to coarse-grained, porous sandstone that transmits water readily. Soils derived from the Bushberg are sandy, but at the site include colluvial components from overlying formations. They generally may be differentiated as light grey, silty or sandy clays that are classified as ML-CL.

The principal bedrock formation underlying the drainage basin is the Burlington limestone. This formation is a light grey, massively- to medium-bedded limestone with considerable amounts of nodular and bedded chert. The residual soils are light red to reddish-brown clays mixed with chert, stoney CH. In general, the chert and clay residuum from the Burlington are the major components of the soils comprising the uplands surrounding the reservoir.

The Highway 21 Lake has not been a successful impoundment and is currently holding only a slight amount of water. Significant leakage apparently is flowing through the permeable Kimmswick limestone which underlies the reservoir. No seepage was noted in the immediate vicinity of the embankment and, since the channel downstream from the embankment is dry, it is most likely that the seepage is flowing through the permeable limestone into adjacent drainage basins.

It is apparent that at this site adverse geologic conditions are responsible for the lack of reservoir storage; however, these conditions do not appear at this time to affect the stability of the dam embankment. Since the Kimmswick formation has undergone extensive solution weathering, there is always a possibility that large voids may exist beneath the dam that could, at some future time, result in a sudden collapse of the structure.

c. Dam. The visible portions of the dam (see Photo 1) were examined and found to be in sound condition. However, both the upstream and downstream faces of the dam (see Photos 5, 6 and 7), and to some extent the dam crest (see Photo 2), were covered by dense brush and trees up to about 12 inches in diameter. No sliding or sloughing of the embankment slopes, cracking of the surface, misalignment of the structure, or excessive settlement of the dam, was noted; although, according to survey data obtained during the inspection, the dam crest was somewhat lower, approximately 0.8 foot, at the location of the original stream crossing than it was near the ends of the dam. There was no riprap slope protection across the upstream face of the dam. No seepage was observed at the junction of the dam and the abutments or within the original stream channel downstream of the dam within the area inspected, a distance of approximately 100 feet. No animal burrows were observed within the embankment; however due to the presence of dense brush over most of the structure, it can not be assumed that none exist. Examination of a soil sample obtained from the downstream face of the embankment indicated the surficial material to be a dark brown, silty lean clay (CL) of low-to-medium plasticity.

The excavated earth spillway (see photos 8 and 9) at the right, or north, abutment was also examined and found to be in sound but unkept condition, with the crest section overgrown with brush and small trees and littered with rubbish. Through the exit section, the channel was undefined but appeared to follow the natural hillside, joining the original stream channel at a point about 20 feet downstream of the dam.

d. Appurtenant Structures. No appurtenant structures were observed at this dam site.

e. Downstream Channel. Except at roadway crossings, the channel downstream of the dam within the estimated flood damage zone is unimproved. The section is irregular and for the most part lined with trees. The stream joins Heads Creek approximately one mile downstream of the dam.

f. Reservoir. At the time of the inspection the reservoir (see Photo 4) was nearly empty with only about 1 foot of water at the deepest point.

The elevation of the mud line, i.e. the level where vegetation began (see Photo 5), indicated the lake had been, for some period of time, approximately 1 foot higher than the observed level. Numerous trees up to about 6 inches in diameter and larger were observed within the reservoir area (see Photo 3) above this level. It was evident that there was some sediment within the reservoir area; however, the quantity did not appear to be an inordinate amount.

3.2 EVALUATION

Since the dam is scheduled to be removed during construction of new Highway 21, there seems to be no practical value in remedying the deficiencies noted herein; and, as indicated in Section 7, paragraph 7.2a, it is recommended that this dam be removed or breached without undue delay in order to eliminate the hazard. In any event, the deficiencies observed during the inspection and noted herein are not considered of significant importance to warrant immediate remedial action.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillway is uncontrolled. The lake surface level is governed by precipitation runoff, evaporation, seepage, and the capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM

Judging by the unkept condition of the dam as observed during the inspection, it is evident that the dam has received no meaningful maintenance for a good number of years. The former owners, Mr. and Mrs. Langenback, reported that at one time a caretaker resided on the property and it was the responsibility of the caretaker to maintain the dam.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

No outlet facilities requiring operation exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection did not reveal the existence of a dam failure warning system.

4.5 EVALUATION

Lack of maintenance is considered detrimental to the safety of the dam. Further, since acquisition of the dam property in 1978 by the Missouri State Highway Commission, the dam has been unattended and certain areas, such as the spillway, have been used as a dumping place for rubbish. Without proper maintenance on a regular basis and periodic inspection by a qualified engineer, the safety of the dam is jeopardized.

SECTION 5 - HYDRAULIC/HYDROLGOIC

5.1 EVAULATION OF FEATURES

a. Design Data. Design data were not available.

b. Experience Data.

(1) The drainage area and lake surface area were determined from the 1954 House Springs and Maxville, Missouri, Quadrangle Maps (photorevised 1968 and 1974). The proportions and dimensions of the spillway and dam were developed from surveys made during the inspection. Records of rainfall, streamflow, or flood data for the watershed were not available.

(2) The lake level prior to the beginning of all antecedent storms was assumed to be at elevation 682.0 with storage equivalent to 1.2 acre-feet. This elevation is based on an estimate of the lake depth as observed by a hunter (name unknown) encountered during a recent reconnaissance of the site. Observations of conditions at the site substantiated the selection of this elevation.

In accordance with criteria established by the St. Louis District, Corps of Engineers, for the one percent chance (100-year frequency) storm, the 24-hour runoff from the rainfall distribution for the 24 hours preceding the maximum 24 hours was evaluated and found to be about 0.40 inch, and the computed volume of runoff for the antecedent storm amounted to 5.3 acre-feet, resulting in accumulated storage equal to 6.5 acre-feet at elevation 686.5 at the beginning of the one percent chance (100-year frequency) storm.

In accordance with the hydrologic/hydraulic standards of the St. Louis District, Corps of Engineers, a storm of one-half the selected PMF ratio storm was assumed to precede the selected PMF ratio storm by four days. The appropriate antecedent storm was routed through the lake (starting lake level equal to elevation 682.0) and the starting elevation for each selected PMF ratio storm was thus determined. For the 10 percent PMF ratio storm, the initial level of the reservoir, i.e., the level of the lake at the end of the

5 percent PMF ratio storm, was determined to be elevation 692.0. For the 25 percent PMF storm, the assumed antecedent storm for the 50 percent PMF event, it was found that elevation 698.0, the spillway crest, was exceeded by about 1.1 feet, and that the lake level receded to the elevation of the spillway crest by the end of the second day. It is evident, therefore that a similar analysis for the 100 percent PMF storm, using an antecedent storm of 50 percent PMF magnitude, would also result in the level of the lake exceeding the crest of the spillway with the lake level receding to the elevation of the spillway crest within two days. The lake surface at the beginning of the 50 percent and 100 percent PMF storms was therefore taken as the level of the spillway crest, elevation 698.0. Failure of the dam due to overtopping by the 25 percent or 50 percent PMF antecedent storms was not assumed to occur in these investigations of overtopping by the 50 percent PMF and 100 percent PMF events.

(3) According to the St. Louis District, Corps of Engineers, the estimated flood damage zone, should failure of the dam occur, extends two miles downstream of the dam.

c. Visual Observations.

(1) The principal spillway, a broad-crested, trapezoidal excavated earth section, is located at the right abutment.

(2) There is no emergency spillway or lake drawdown facility.

(3) The observed level of the lake (elevation 679.4) at the time of the inspection was approximately 18.6 feet below the elevation of the spillway crest.

d. Overtopping Potential. The spillway is inadequate to pass the PMF or one-half the PMF, the recommended design flood, without overtopping the dam (lake surface at spillway crest elevation 698.0 at beginning of 0.50 and 1.00 PMF storms). Under the assumed antecedent conditions and with the level of the lake at elevation 686.5 at the beginning of the one percent chance storm, the spillway is adequate to pass the runoff from the one percent chance (100-year frequency) storm without overtopping the dam.

(Note: The data appearing in the following table were extracted from the computer output data appearing in Appendix B. Decimal values have been rounded to the nearest one-tenth in order to prevent assumption of unwarranted accuracy.)

Ratio of PMF	Q-Peak Outflow (cfs)	Max. Lake W.S. Elev.	Max. Depth (Ft.) of Flow over Dam (Elev. 699.1)	Duration of Overtopping of Dam (Hours)
0.50	1,462	700.9	1.8	10.7
1.00	3,071	701.9	2.8	14.1
1% chance flood	29	698.8	0.0	0.0

Elevation 699.1 was found to be the lowest point in the dam crest. The velocity of spillway discharge corresponding to elevation 699.1 was determined to be 4.6 feet per second, which is less than the assumed maximum permissible (non-erosive) velocity of 5.0 feet per second.

With the initial level of the lake at elevation 692.0, the flow safely passing the spillway just prior to overtopping was determined to be approximately 50 cfs, which is the routed outflow corresponding to about 10 percent of the probable maximum flood inflow. During peak flow of one-half the PMF, the recommended spillway design flood, the greatest depth of flow over the dam is projected to be 1.8 feet and overtopping will extend across almost the entire length of the dam.

e. Evaluation. Experience with embankments constructed of similar material (a silty lean clay of low-to-medium plasticity) to that used to construct this dam has shown evidence that under certain conditions, such as high velocity flow, the material can be very erodible. Such a condition exists during the PMF when large lake outflow, accompanied by high flow velocities, occurs. For the PMF condition where the depth of flow over the dam crest, a maximum of 2.8 feet, and the duration of flow over the dam, 14.1 hours are appreciable, damage by erosion to the crest and downstream face of the dam is expected. The extent of these damages is not predictable within the scope of this investigation; however, there is a possibility that they

could result in failure by erosion of the dam. A similar condition, but not as severe, also exists during occurrence of one-half the PMF.

f. Reference. Procedures and data for determining the probable maximum flood, the 100-year frequency flood, and the discharge rating curve for flow passing the spillway and dam crest are presented on pages B-1 and B-2 of the Appendix. Listings of the HEC-1 (Dam Safety Version) input data for both the PMF and the one percent chance (100-year frequency) flood are shown on pages B-3 through B-6. Computer output data, including unit hydrograph ordinates, tabulation of PMF rainfall, loss and inflow data are shown on pages B-7 through B-10; tabulation of lake surface area, elevation and storage volume and tabulation titled "Summary of Dam Safety Analysis" for the 0.10 PMF ratio event are shown on page B-11 and tabulations titled "Summary of Dam Safety Analysis" for the PMF and one percent chance (100-year frequency) flood are shown on page B-12 of the Appendix.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

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

b. Design and Construction Data. Design or construction data relating to the structural stability of the dam were not available. 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. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam.

d. Post Construction Changes. According to the former owners, Mr. and Mrs. Langenback, no post construction changes were made or have occurred that would adversely affect the structural stability of the dam. It is noted that the reservoir has been experiencing excessive leakage for a number of years, presumably due to an underlying permeable bedrock formation. The possibility exists that the underlying formation may also contain large voids, and that the dam could, at some future time, collapse from lack of foundation support.

e. Seismic Stability. The dam is located within a Zone II seismic probability area. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading for this zone be applied in any stability analyses performed for this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicated that the spillway is capable of passing lake outflow of about 50 cfs without the level of the lake exceeding the low area in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicated that for storm runoff of one-half the probable maximum flood magnitude, the lake outflow would be on the order of 1,462 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be approximately 29 cfs. Since the existing spillway is inadequate to pass lake outflow resulting from a storm of one-half probable maximum flood magnitude (the recommended spillway design flood for this dam) without overtopping the dam, the possibility exists that overtopping could result in failure by erosion of the dam. A description of the features within the potential flood damage zone should failure of the dam occur is presented in Section 1, paragraph 1.2d.

Seepage and stability analyses of the dam were not available for review and therefore no judgment could be made with respect to the structural stability of the dam.

Several items were noticed during the visual inspection that could adversely affect the safety of the dam. These items include dense brush and trees on the dam, the lack of a suitable form of protection to prevent erosion of the embankment by wave action or by fluctuations of the lake level, a spillway that is littered with rubbish and overgrown with weeds and small trees, and possible settlement of the dam.

b. Adequacy of Information. Due to lack of design and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. The assessment of the hydrology of the watershed and capacity of the spillway were based on a hydrologic/hydraulic study as indicated in Section 5. 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. Unless measures are taken to remove or breach the dam without undue delay, the remedial measures recommended in paragraph 7.2 for the items concerning the safety of the dam noted in paragraph 7.1a should be accomplished sometime in the near future. Provision of additional spillway capacity should be given a high priority.

d. Necessity for Phase II. Based on the results of the Phase I inspection, a Phase II investigation is not recommended.

e. Seismic Stability. The dam is located within a Zone II seismic probability area. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading for this zone be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES

a. Recommendations. Present planning by the Owner (the Missouri State Highway Commission) calls for removal of the dam sometime in the foreseeable future, when construction of new Highway 21 through this area is undertaken. However, in accordance with the criteria set forth in the guidelines, the dam (in its present condition) was determined to pose a hazard to human life and property, and unless certain improvements to the dam and spillway are made, a potentially dangerous and unsafe situation exists. It is recommended that the Owner either remove or breach the dam in order to eliminate the unsafe conditions described herein, and that this action be accomplished without undue delay. However, if the Owner elects not to remove or breach the dam as indicated, the following actions are recommended:

(1) Based upon criteria set forth in the recommended guidelines, spillway size and/or height of dam should be increased in order to pass lake outflow resulting from a storm of one-half probable maximum flood magnitude (the recommended spillway design flood for this dam); in any event the spillway should be protected to prevent erosion.

(2) Obtain the necessary soil data and perform dam seepage and stability analyses in order to determine the structure stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of dams.

(3) Restore the dam crest to a uniform elevation and monitor the top of the dam through the area of suspected settlement in order to determine the extent of possible future settlement and the remedial work required to compensate for such settlement. In any event the crest of the dam should be uniform throughout without low areas that penalize spillway capacity.

(4) Investigations should be performed to determine the cause of excessive loss of water from the lake and if a condition related to the loss of water exists that could jeopardize the safety of the dam, such as cavernous bedrock underlying the dam that could collapse, resulting in failure of the dam. Recommendations concerning methods by which such loss of water could be prevented or controlled if considered critical to the safety of the dam should be a part of the investigating procedures.

b. Operations and Maintenance (O & M) Procedures. As previously stated, should the Owner elect not to remove or breach the dam, then the following O & M procedures are recommended:

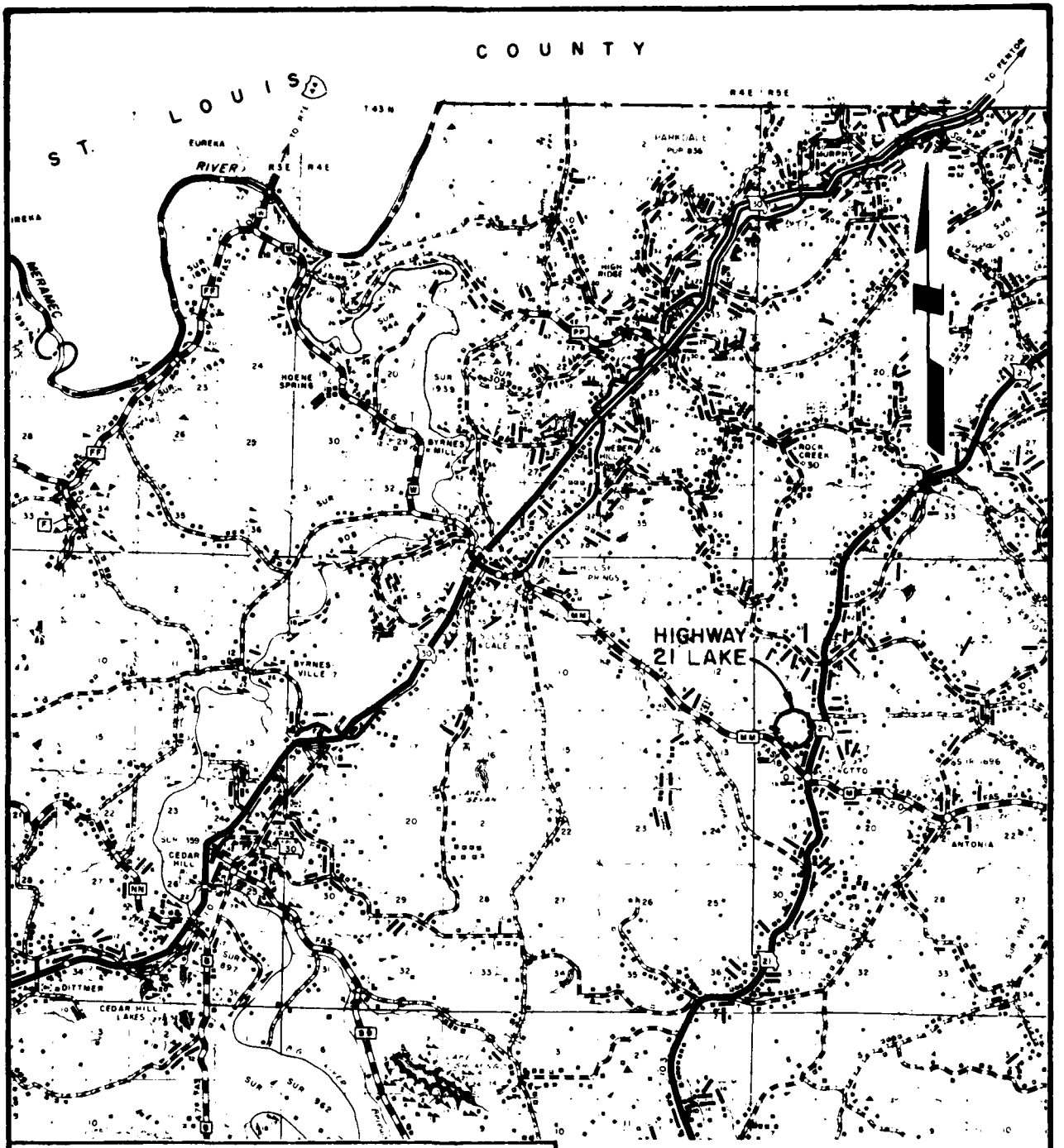
(1) Remove the trees and brush that may conceal animal burrows from the dam. Larger trees should be removed under the guidance of an engineer experienced in the design and construction of earthen dams, since indiscriminate clearing could jeopardize the safety of the dam. All holes should be filled with compacted impervious material (clay) and the existing turf cover should be restored if destroyed or missing. Maintain the turf cover at a height that will not hinder inspection of the embankment or provide cover for burrowing animals. Holes from tree roots and voids created by burrowing animals can provide pathways for lake seepage that could lead to a piping condition (progressive internal erosion) and potential failure of the dam.

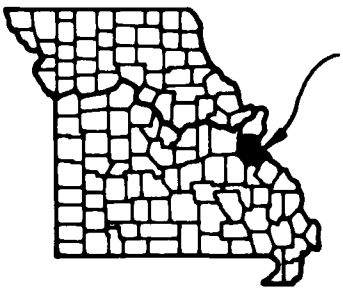
(2) Provide some durable form of protection for the upstream face of the dam in order to prevent erosion of the embankment by wave action or by fluctuations of the lake level. Loss of embankment material due to erosion can impair the structural stability of the dam.

(3) Remove the trees, brush and litter from the spillway channel in order to allow flow to reach the downstream channel unimpeded. Obstructions within the spillway will restrict flow and reduce the discharge capacity of the section that could result in flooding of the area adjacent to the spillway with flow impinging upon the dam.

(4) Provide maintenance of all areas of the dam and spillway on a regularly scheduled basis in order to insure features of being in satisfactory operational condition.

(5) A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.





LOCATION MAP

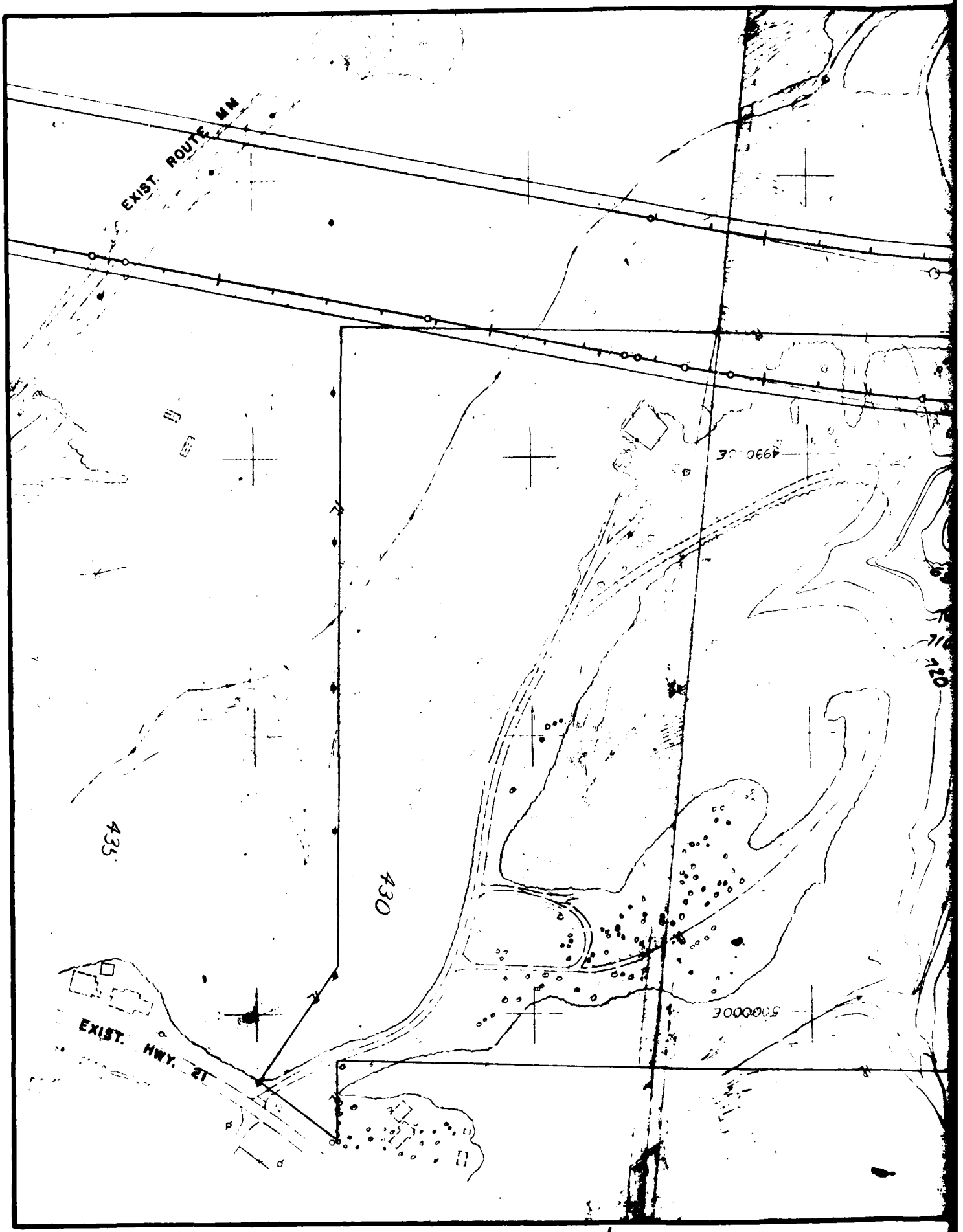
HIGHWAY 21 LAKE

1 0 1 2 3 4

SCALE (MILES)

REGIONAL VICINITY MAP

PLATE 1


EXIST. ROUTE MM
435
430
EXIST. HWY. 21

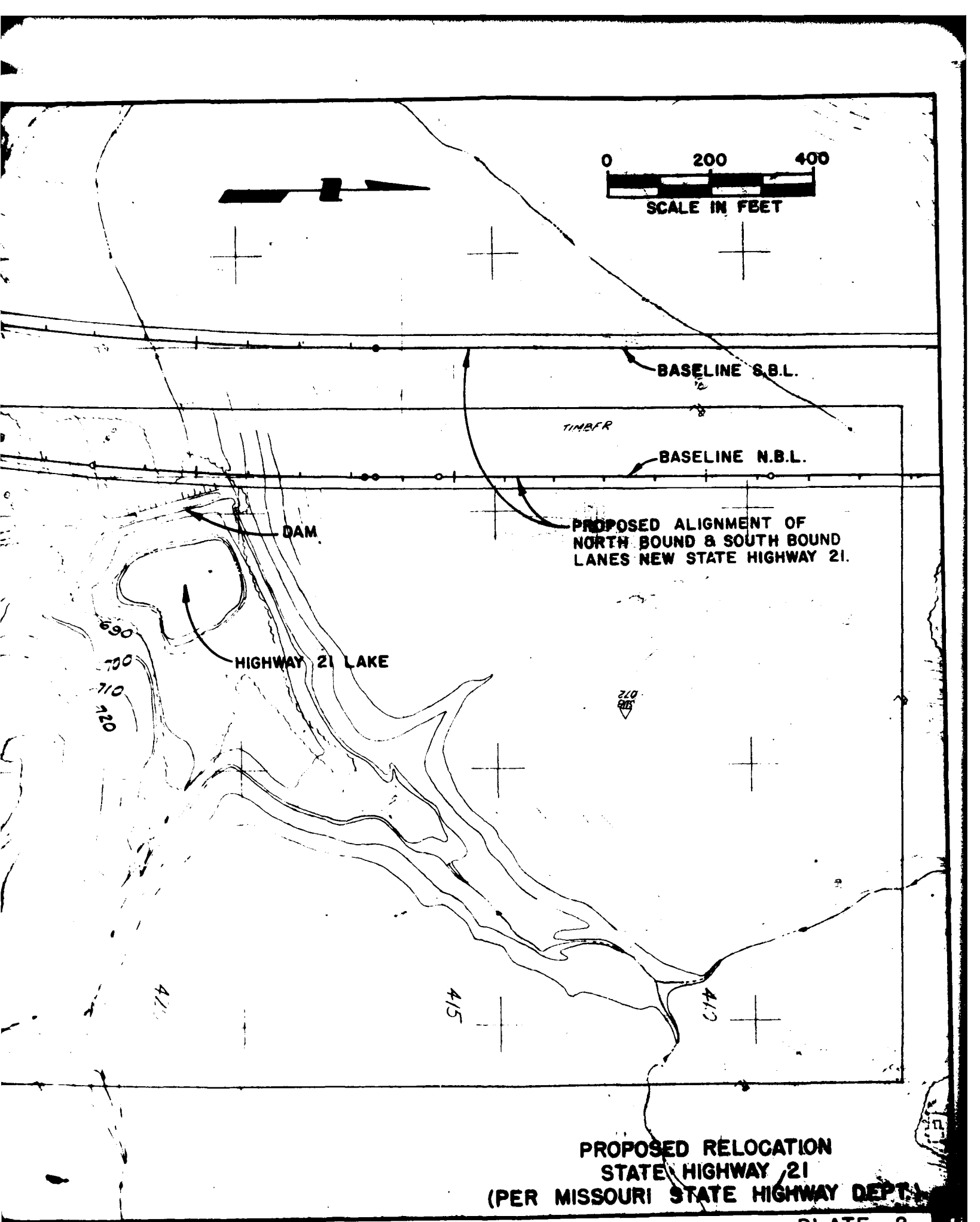
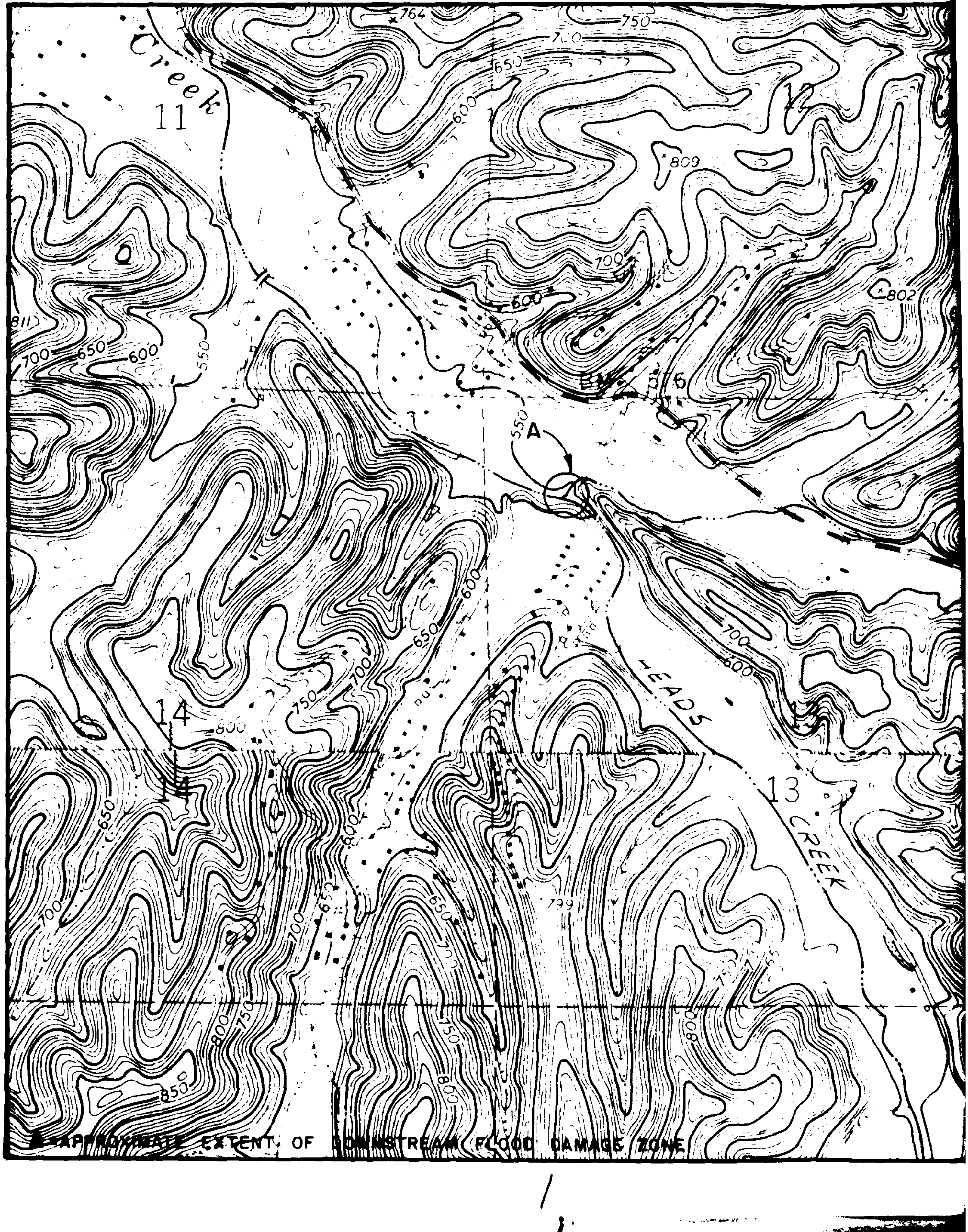

0
200
400
SCALE IN FEET
BASELINE S.B.L.
TIMBER
BASELINE N.B.L.
DAM
PROPOSED ALIGNMENT OF
NORTH BOUND & SOUTH BOUND
LANES NEW STATE HIGHWAY 21.
HIGHWAY 21 LAKE
690
700
710
720
715
PROPOSED RELOCATION
STATE HIGHWAY 21
(PER MISSOURI STATE HIGHWAY DEPT.)

PLATE 2


Creek
11
764
750
700
650
600
809
802
811
550
A
HEADS
CREEK
13
14
800
850
799
APPROXIMATE EXTENT OF DOWNSTREAM FLOOD DAMAGE ZONE

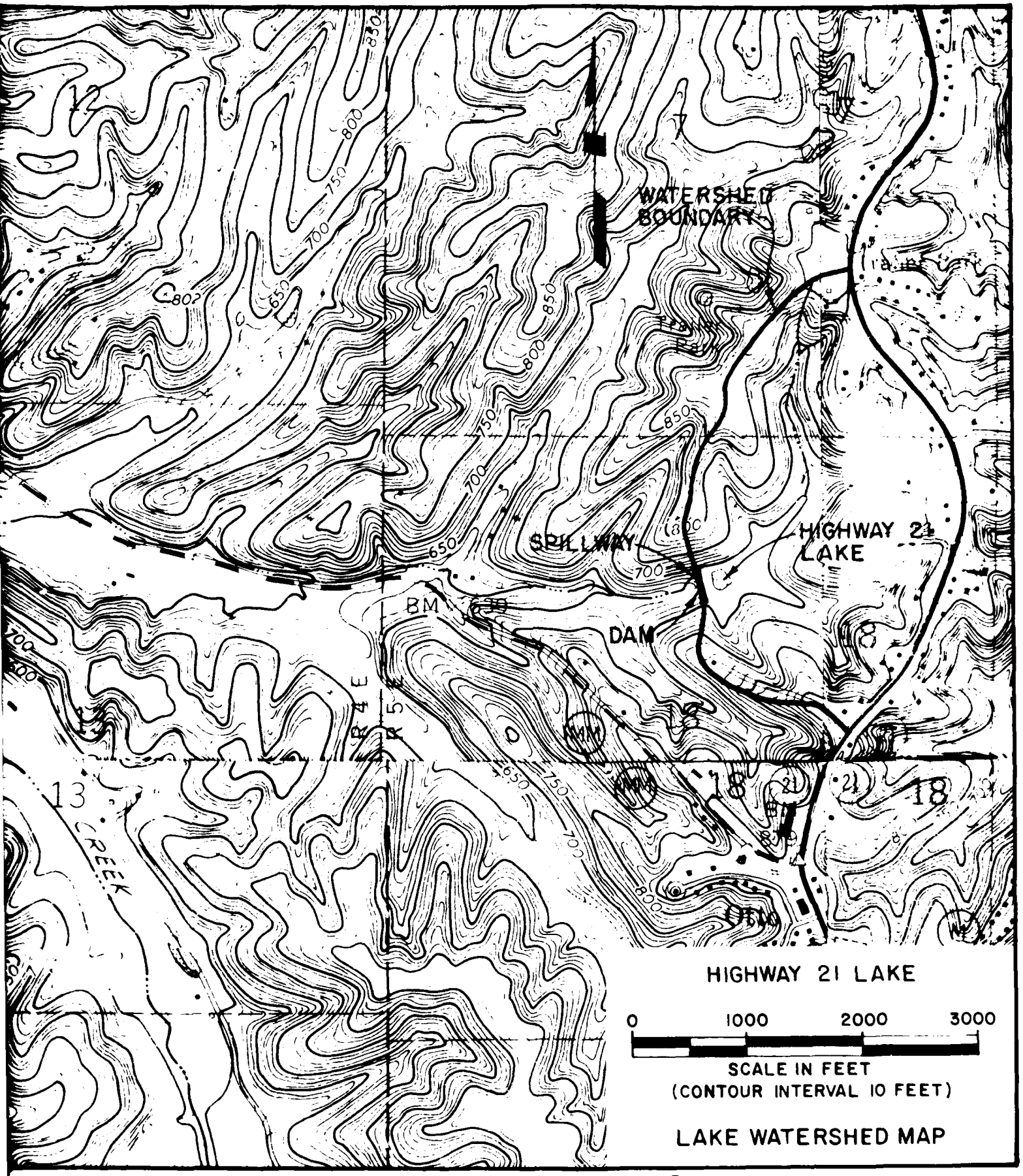
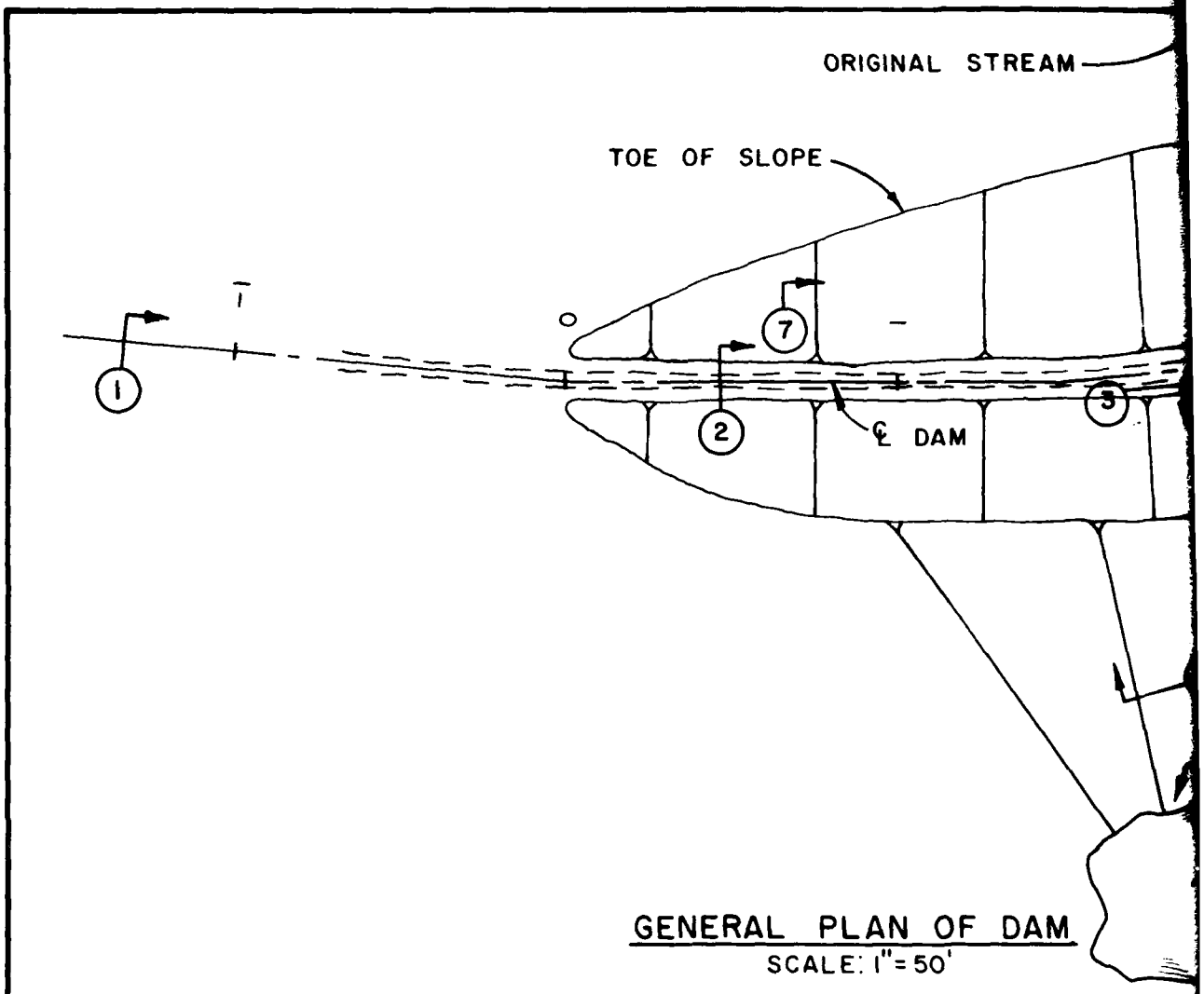
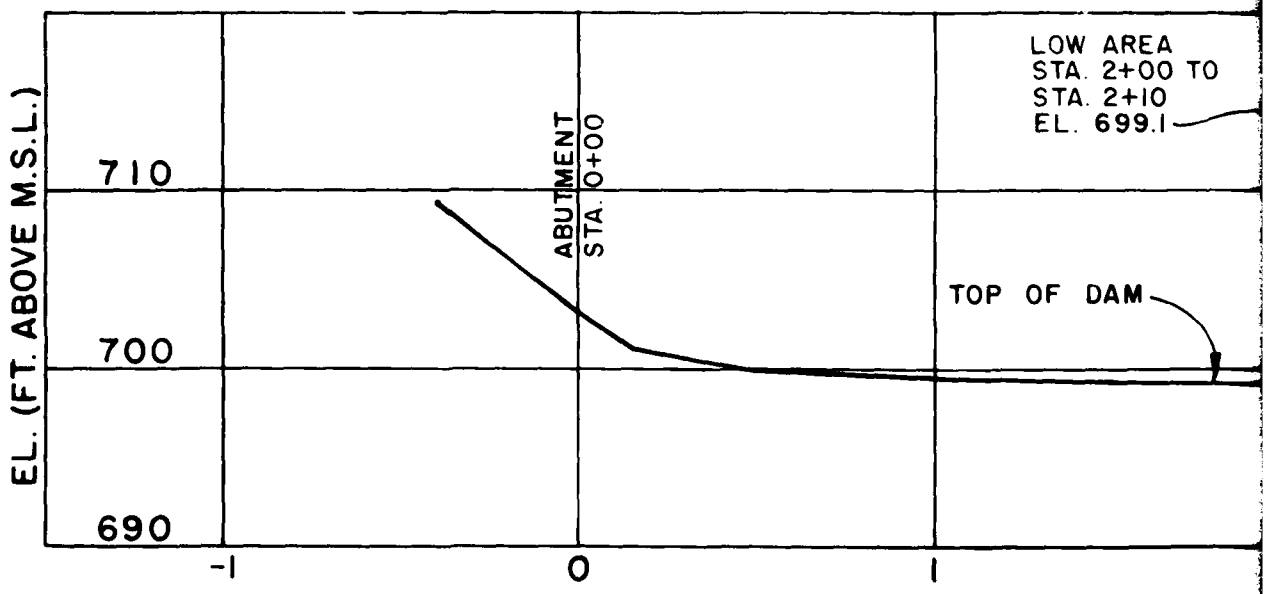

WATERSHED BOUNDARY
HIGHWAY 21 LAKE
SPILLWAY
DAM
BM
CREEK
HIGHWAY 21 LAKE
0 1000 2000 3000
SCALE IN FEET
(CONTOUR INTERVAL 10 FEET)
LAKE WATERSHED MAP

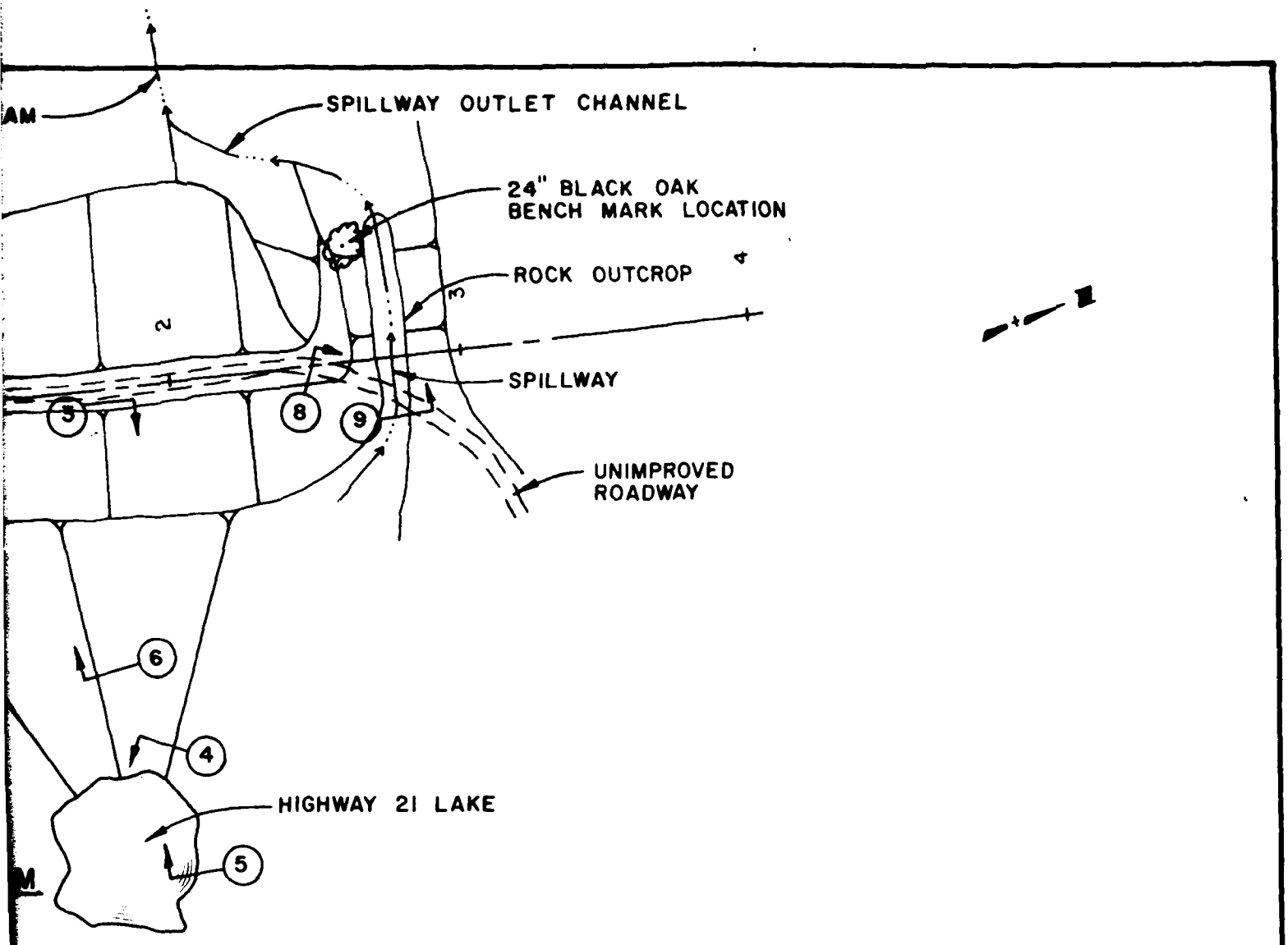
PLATE 3

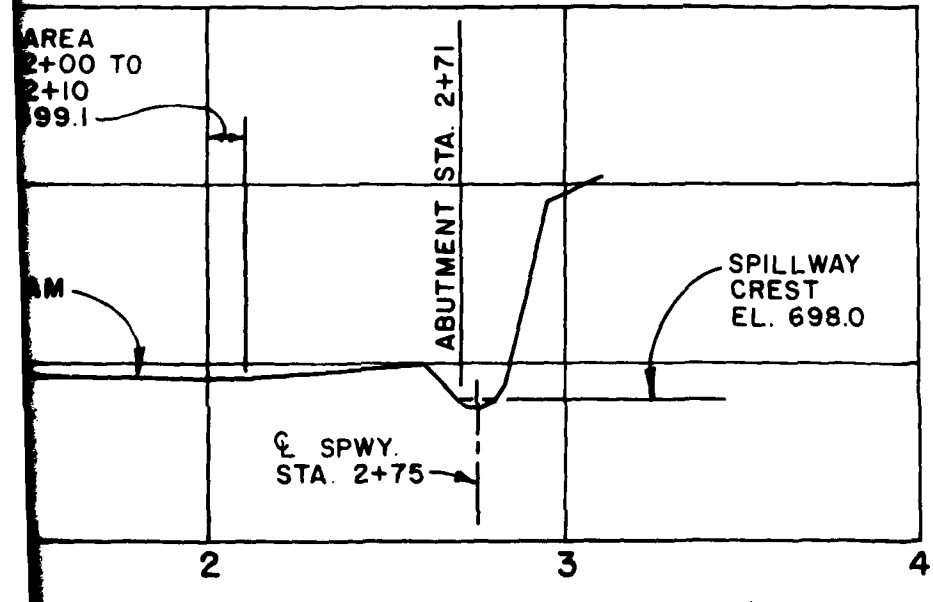


GENERAL PLAN OF DAM
SCALE: 1"=50'



PROFILE DAM CR
SCALES: 1"=10'V., 1"=50'





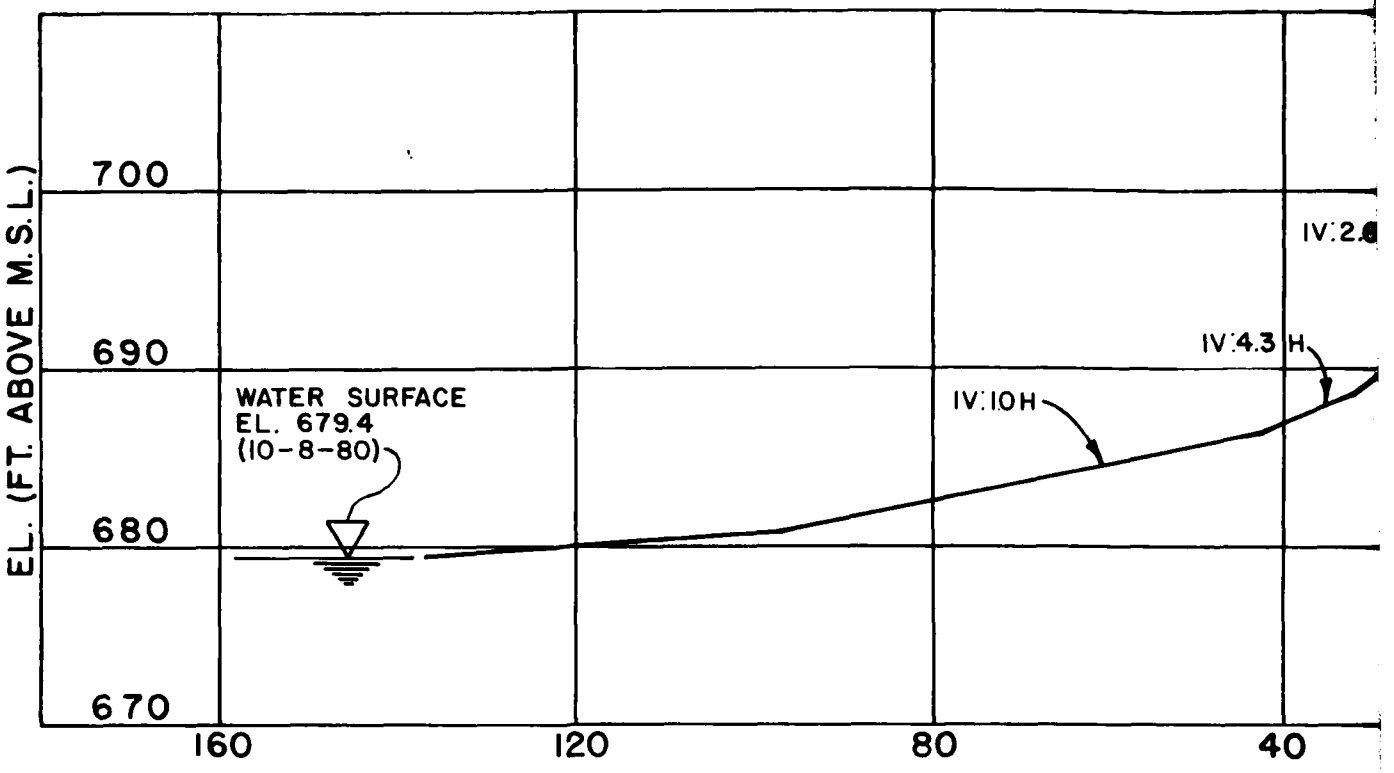
AM CREST
V., 1"=50' H.

6
PHOTO LOCATION & KEY
(SEE APPENDIX A)

HIGHWAY 21 LAKE
DAM PLAN & PROFILE

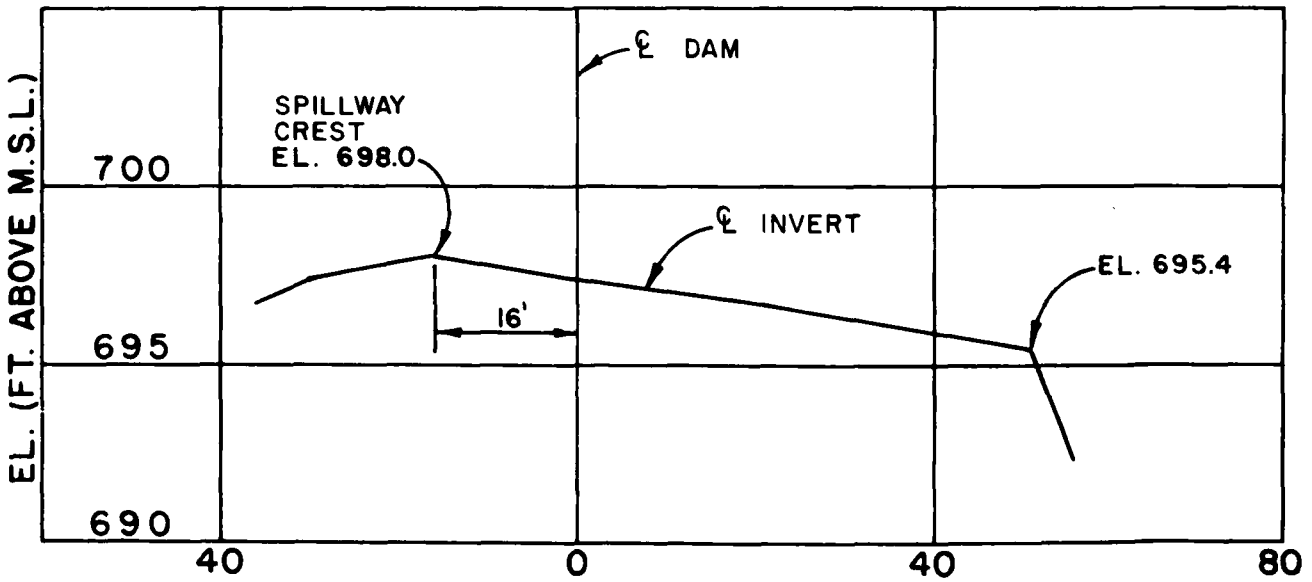
Horner & Shifrin, Inc. Oct. 1980

PLATE 4



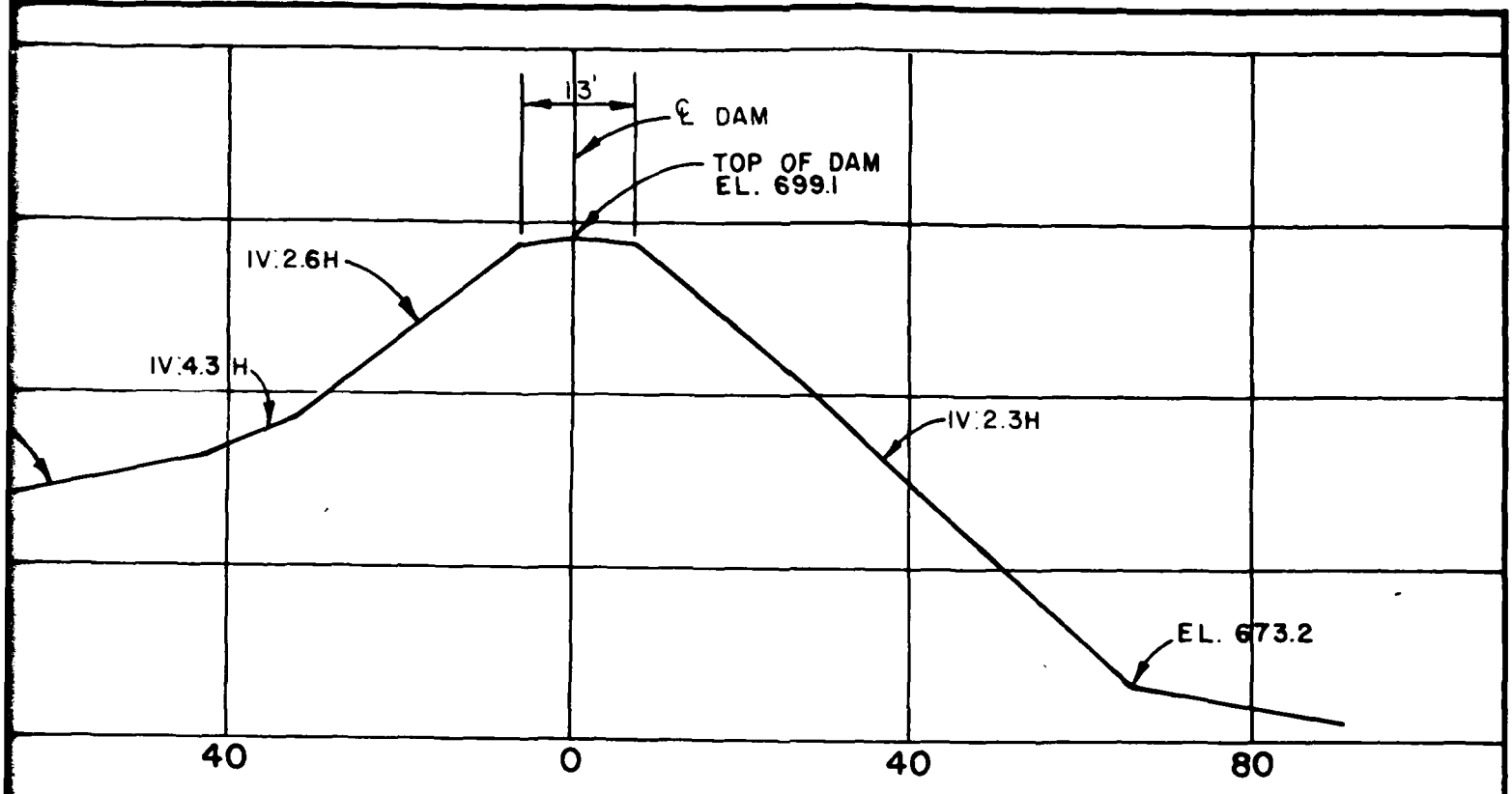
DAM CROSS

SCALES



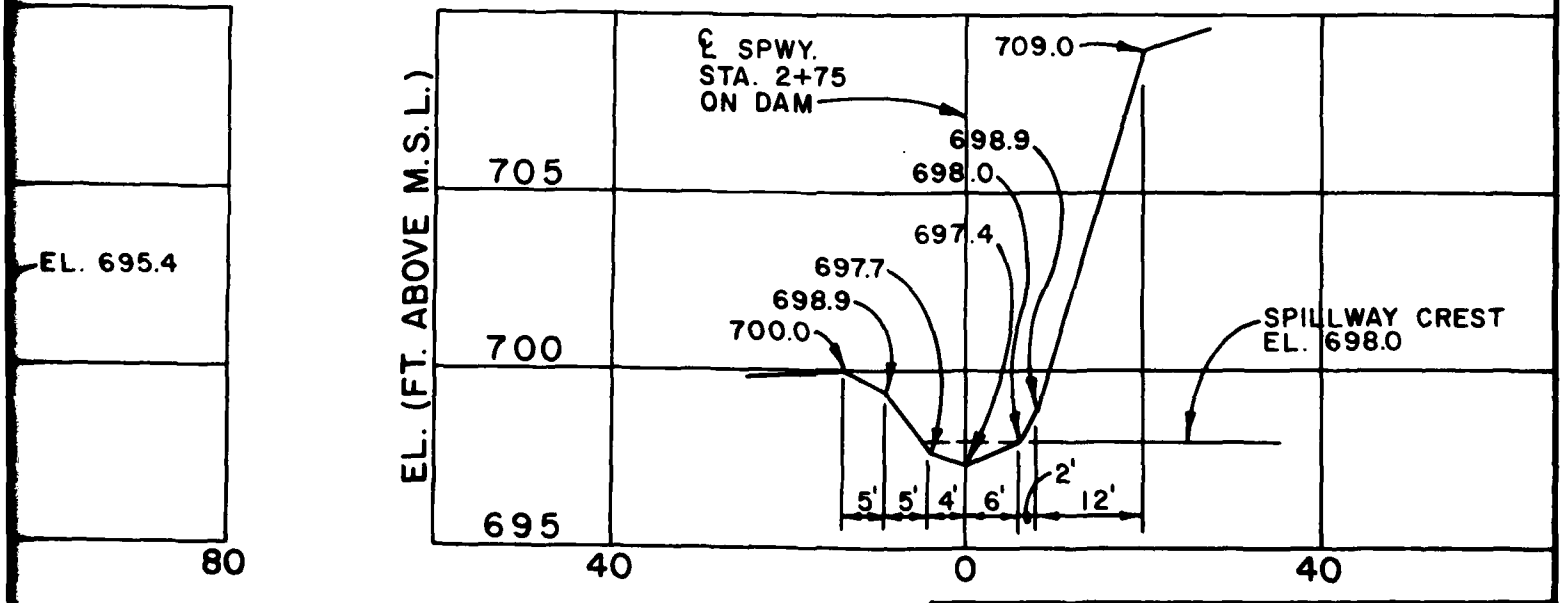
SPILLWAY PROFILE

SCALES: 1"=5' V., 1"=20' H.



DAM CROSS-SECTION STA. 2+10

SCALES: 1"=10'V., 1"=20'H.



SPILLWAY

CROSS-SECTION - ℄ DAM

SCALES: 1"=5'V., 1"=20'H.

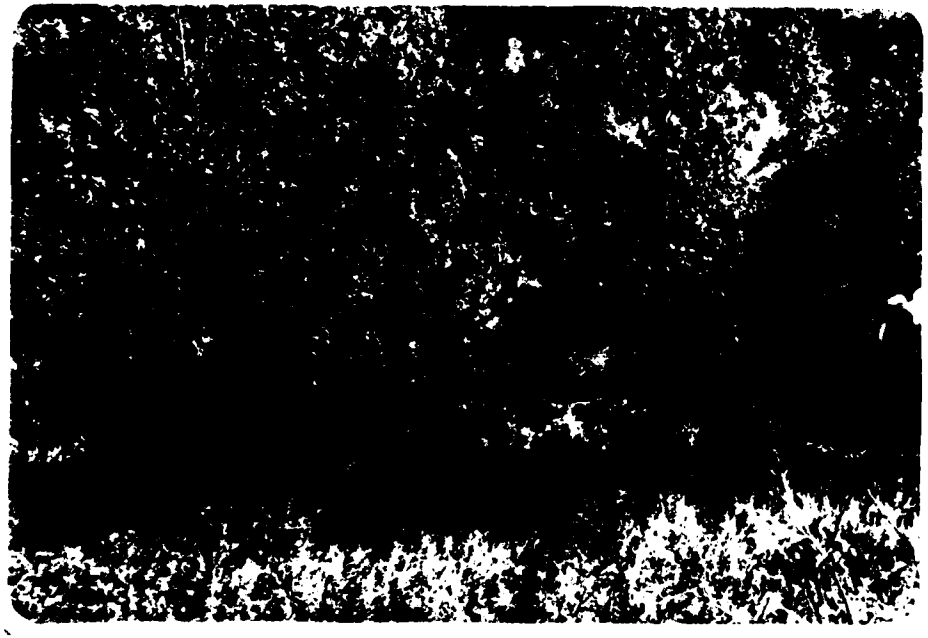
HIGHWAY 21 LAKE
DAM CROSS-SECTION
SPILLWAY PROFILE & SECTION

Horner & Shifrin, Inc. Oct. 1980

PLATE 5

APPENDIX A

INSPECTION PHOTOGRAPHS



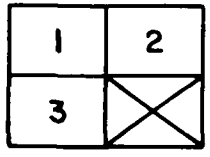


PHOTO KEY

NO.	DESCRIPTION
1	DAM OVERVIEW
2	DAM CREST
3	RESERVOIR FROM TOP OF DAM

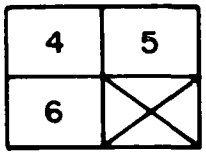
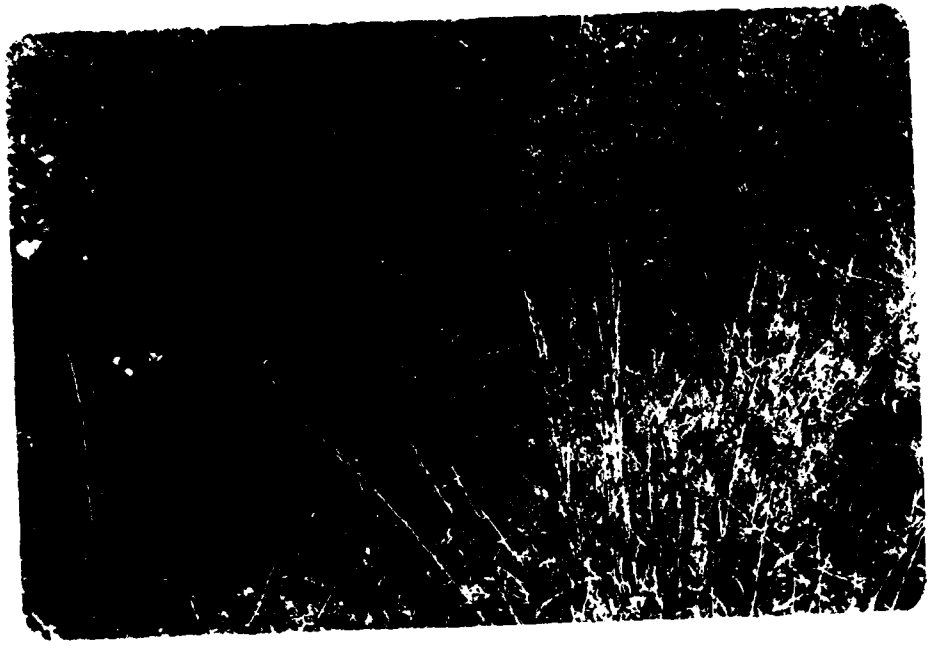


PHOTO KEY

NO.	DESCRIPTION
4	RESERVOIR
5	UPSTREAM FACE FROM WATER'S EDGE
6	UPSTREAM FACE FROM TOE OF DAM



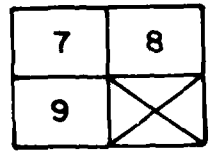


PHOTO KEY

NO.	DESCRIPTION
7	DOWNSTREAM FACE OF DAM
8	SPILLWAY CREST AREA
9	SPILLWAY OUTLET CHANNEL - LOOKING DOWNSTREAM FROM CREST

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 25.5 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent (100-year frequency) flood was provided by the St. Louis District, Corps of Engineers.

b. Drainage area = 0.234 square miles = 150 acres.

c. SCS parameters:
Time of Concentration (T_c) = $(\frac{11.9L^3}{H})^{0.385}$ = 0.184 hours

Where: T_c = Travel time of water from hydraulically most distant point to point of interest, hours.
L = Length of longest watercourse = 0.568 miles.
H = Elevation difference = 178 feet.

The time of concentration (T_c) was obtained using Method C as described in Figure 30, "Design of Small Dams", by the United States Department of the Interior, Bureau of Reclamation, and was verified using average channel velocity estimates and watercourse lengths.

Lag time = 0.110 hours (0.60 T_c)
Hydrologic soil group = 100% D (92% Gasconade Series with steep wooded hillsides and 8% commercial/residential, per SCS Missouri General Soil Map and field inspection)
Soil type CN = 79 (AMC II, 100-yr flood condition)
= 91 (AMC III, PMF condition)

d. In accordance with the St. Louis District Hydrologic/Hydraulic Standards, the minimum time interval available in the HEC-1 program for a 24-hour storm duration is 5 minutes. For the lag time, (0.11

hour) developed from the tributary area (0.234 square miles), one discharge before the peak of the unit hydrograph results.

2. The trapezoidal spillway section consists of a broad-crested section for which conventional weir formulas do not apply.

Spillway release rates were determined as follows:

a. Spillway crest section properties (areas, "a", and top width, "t") were computed for various depths, "d".

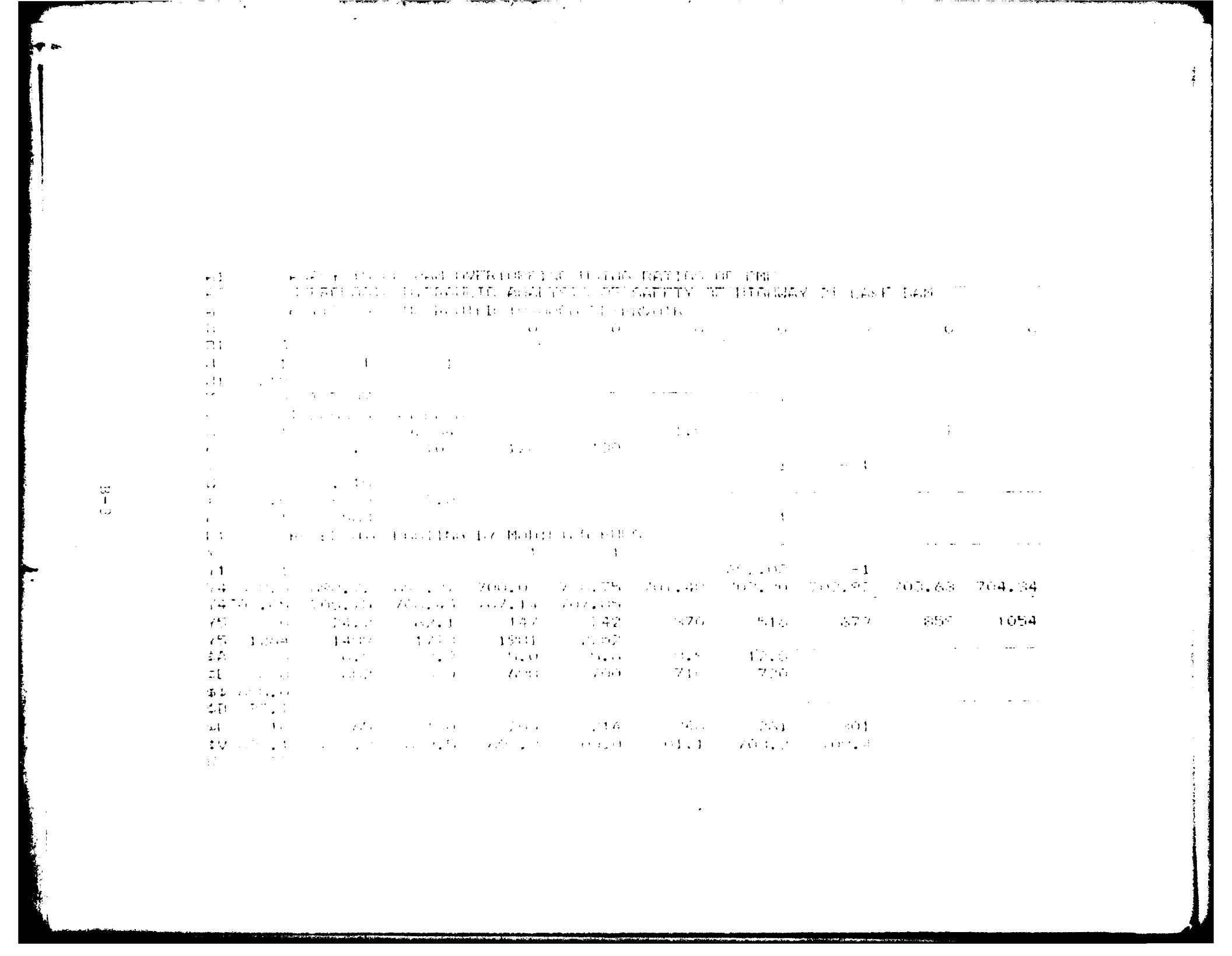
b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth was computed as $Q_c = (\frac{a^3 g}{t})^{0.5}$ for the various depths, "d". Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.* Reference, "Handbook of Hydraulics", Fifth Edition, by King & Brater, page 8-7.

c. Static lake levels corresponding to the various flow values passing the spillway were computed as critical depths plus critical velocity heads ($d_c + H_{vc}$), and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

d. The spillway discharges and corresponding elevations were entered on the Y4 and Y5 cards.

3. The profile of the dam crest is irregular and flow over the dam cannot be determined by application of conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and $V cards. The program assumes that flow over the dam crest section occurs at critical depth and computes internally the flow over the dam crest and adds this flow to the flow over the spillway as entered on the Y4 and Y5 cards.

* $v_c = \frac{Qc}{a}$; $Hvc = \frac{v_c^2}{2g}$



```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF HIGHWAY 21 LAKE DAM
A3       RATIOS OF PMF ROUTED THROUGH RESERVOIR
B     288        0        5                                                         0
B1      5
J       1        2        1
J1   0.50     1.00
K       0   INFLOW
K1       INFLOW HYDROGRAPH
M       1        2    0.234                         1.0                             1
P       0     25.5      107      120      130
T                                                           1       [illegible]
W2            0.110
X    -1.0      .10      1.0
K       1      DAM                                          1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                  1        1
Y1      1                                              [illegible]  [illegible]
Y4 [illegible] [illegible] [illegible] [illegible] [illegible] 701.48 [illegible] [illegible] [illegible] [illegible]
Y4705.05  705.75   706.45   707.14   707.85
Y5      0     24.2     62.1      147 [illegible] [illegible] [illegible] [illegible]   [illegible]  [illegible]
Y5   1264     1407     1726     1981 [illegible]
$A      0      0.9      2.9      5.0 [illegible] [illegible] 17.3
$E    678      682 [illegible] [illegible] 700   710 [illegible]
$$ 698.0
$D 699.1
$L     10 [illegible]   130 [illegible] [illegible] 248   261 [illegible]
$V 699.1    699.2 [illegible] [illegible] [illegible] 701.1 [illegible] [illegible]
K      99
```

```
1A1       ANALYSIS OF DAM OVERTOPPING USING 1 PERCENT PROBABILITY FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF HIGHWAY 21 LAKE DAM
A3       1 PERCENT PROBABILITY FLOOD ROUTED THROUGH RESERVOIR
B     288        0        5                                                4
B1      5
J       1        1        1
J1   1.00
K       0   INFLOW                                          1
K1        INFLOW HYDROGRAPH
M       0        2    0.234                        1.0                    1
O     288    6.974
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1   .007     .007     .012     .012     .012     .012     .012     .012     .012     .012
O1   .012     .012     .012     .012     .012     .012     .012     .012     .012     .012
O1   .012     .012     .012     .012     .012     .012     .012     .012     .012     .012
O1   .012     .012     .012     .012     .012     .012     .012     .012     .023     .023
O1   .023     .023     .023     .023     .023     .023     .023     .023     .023     .023
O1   .023     .023     .023     .023     .023     .023     .030     .030     .030     .030
O1   .030     .030     .048     .048     .048     .049     .049     .049     .134     .134
O1   .134     .255     .255     .546     .817     .380     .255     .134     .134     .134
O1   .049     .049     .049     .048     .048     .048     .030     .030     .030     .030
O1   .030     .030     .023     .023     .023     .023     .023     .023     .023     .023
O1   .023     .023     .023     .023     .023     .023     .023     .023     .023     .023
```

1 PERCENT PROBABILITY FLOOD (Cont'd)

```
O1  .012     .012     .012     .012     .012     .012     .012     .012     .012     .012
O1  .012     .012     .012     .012     .012     .012     .012     .012     .012     .012
O1  .012     .012     .012     .012     .012     .012     .012     .012     .012     .012
O1  .012     .012     .012     .012     .012     .012     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007     .007     .007
O1  .007     .007     .007     .007     .007     .007     .007     .007
T                                                     -1      -79
W2           0.110
X   -1.0     -.10      2.0
K      1      DAM                                      1
K1      RESERVOIR ROUTING BY MODIFIED PULS
Y                                1        1
Y1     1                                            -686.5      -1
Y4 698.0   698.72   699.27   700.09   700.75   701.48   702.20   702.92   703.63   704.34
Y4705.05   705.75   706.45   707.14   707.85
Y5     0     24.2     62.1      147      242      370      516      679      859     1054
Y5  1264     1489     1728     1981     2250
$A     0      0.7      2.9      5.0      5.6      8.9     12.8
$E   678      682      690      698      700      710      720
$$ 698.0
$D 699.1
$L    10       45      130      200      214      246      261      301
$V 699.1    699.2    699.5    699.9    700.0    701.1    703.2    709.4
K     99
```

ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF HIGHWAY 21 LAKE DAM
RATIOS OF PMF ROUTED THROUGH RESERVOIR

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
288	0	5	0	0	0	0	0	0	0

JOPER	NWT	LROPT	TRACE
5	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 4 LRTIO= 1

RTIOS= .04 .05 .50 1.00

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

SUB-AREA RUNOFF COMPUTATION

INFLOW HYDROGRAPH

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

HYDROGRAPH DATA

IHYDG	IUNG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.23	0.00	.23	1.00	0.000	0	1	0

PRECIP DATA

SPFE	PMS	R5	R12	R24	R48	R72	R96
0.00	25.50	102.00	120.00	120.00	0.00	0.00	0.00

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	-1.00	-91.00	0.00	0.00

CURVE NO = -91.00 WETNESS = -1.00 EFFECT CN = 91.00

UNIT HYDROGRAPH DATA
TC= 0.00 LAG= .11

RECESSION DATA
STRTQ= -1.00 QRCSN= -.10 RTIOR= 2.00

TIME INCREMENT TOO LARGE--(TIMQ IS GT LAG/2)

UNIT HYDROGRAPH 9 END OF PERIOD ORDINATES, TC= 0.00 HOURS, LAG= .11 VOL= 1.00

423.	743.	384.	150.	64.	28.	11.	5.	0.

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	.05	1	.01	0.00	.01	0.	1.01	12.05	145	.22	.21	.01	176.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.10	146	.22	.21	.00	287.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.15	147	.22	.21	.00	345.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.20	148	.22	.21	.00	369.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.25	149	.22	.21	.00	379.
1.01	.30	6	.01	0.00	.01	0.	1.01	12.30	150	.22	.21	.00	383.
1.01	.35	7	.01	0.00	.01	0.	1.01	12.35	151	.22	.21	.00	385.
1.01	.40	8	.01	0.00	.01	0.	1.01	12.40	152	.22	.21	.00	3[illegible].
1.01	.45	9	.01	0.00	.01	0.	1.01	12.45	153	.22	.21	.00	386.
1.01	.50	10	.01	0.00	.01	0.	1.01	12.50	154	.22	.21	.00	387.
1.01	.55	11	.01	0.00	.01	0.	1.01	12.55	155	.22	.21	.00	387.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.00	156	.22	.21	.00	387.
1.01	1.05	13	.01	0.00	.01	0.	1.01	13.05	157	.26	.26	.00	406.
1.01	1.10	14	.01	.00	.01	0.	1.01	13.10	158	.26	.26	.00	438.
1.01	1.15	15	.01	.00	.01	0.	1.01	13.15	159	.26	.26	.00	455.
1.01	1.20	16	.01	.00	.01	0.	1.01	13.20	160	.26	.26	.00	462.
1.01	1.25	17	.01	.00	.01	1.	1.01	13.25	161	.26	.26	.00	465.
1.01	1.30	18	.01	.00	.01	2.	1.01	13.30	162	.26	.26	.00	466.
1.01	1.35	19	.01	.00	.01	2.	1.01	13.35	163	.26	.26	.00	467.
1.01	1.40	20	.01	.00	.01	3.	1.01	13.40	164	.26	.26	.00	467.
1.01	1.45	21	.01	.00	.01	3.	1.01	13.45	165	.26	.26	.00	467.
1.01	1.50	22	.01	.00	.01	4.	1.01	13.50	166	.26	.26	.00	467.
1.01	1.55	23	.01	.00	.01	5.	1.01	13.55	167	.26	.26	.00	468.
1.01	2.00	24	.01	.00	.01	5.	1.01	14.00	168	.26	.26	.00	468.
1.01	2.05	25	.01	.00	.01	6.	1.01	14.05	169	.33	.32	.00	495.
1.01	2.10	26	.01	.00	.01	6.	1.01	14.10	170	.33	.32	.00	543.
1.01	2.15	27	.01	.00	.01	7.	1.01	14.15	171	.33	.32	.00	568.
1.01	2.20	28	.01	.00	.01	7.	1.01	14.20	172	.33	.32	.00	579.
1.01	2.25	29	.01	.00	.01	8.	1.01	14.25	173	.33	.32	.00	583.
1.01	2.30	30	.01	.00	.01	8.	1.01	14.30	174	.33	.32	.00	585.
1.01	2.35	31	.01	.00	.01	8.	1.01	14.35	175	.33	.32	.00	585.
1.01	2.40	32	.01	.01	.01	9.	1.01	14.40	176	.33	.32	.00	586.
1.01	2.45	33	.01	.01	.01	9.	1.01	14.45	177	.33	.32	.00	586.
1.01	2.50	34	.01	.01	.01	10.	1.01	14.50	178	.33	.32	.00	586.
1.01	2.55	35	.01	.01	.01	10.	1.01	14.55	179	.33	.32	.00	586.
1.01	3.00	36	.01	.01	.01	10.	1.01	15.00	180	.33	.32	.00	586.
1.01	3.05	37	.01	.01	.01	11.	1.01	15.05	181	.20	.20	.00	533.
1.01	3.10	38	.01	.01	.01	11.	1.01	15.10	182	.40	.39	.00	522.
1.01	3.15	39	.01	.01	.01	11.	1.01	15.15	183	.40	.39	.00	620.
1.01	3.20	40	.01	.01	.01	12.	1.01	15.20	184	.59	.59	.00	759.
1.01	3.25	41	.01	.01	.01	12.	1.01	15.25	185	.69	.69	.00	970.
1.01	3.30	42	.01	.01	.01	12.	1.01	15.30	186	1.68	1.68	.00	1545.
1.01	3.35	43	.01	.01	.01	12.	1.01	15.35	187	2.77	2.76	.01	2[illegible].
1.01	3.40	44	.01	.01	.01	13.	1.01	15.40	188	1.09	1.09	.00	3[illegible].
1.01	3.45	45	.01	.01	.01	13.	1.01	15.45	189	.69	.69	.00	2[illegible].
1.01	3.50	46	.01	.01	.01	13.	1.01	15.50	190	.59	.59	.00	1744.
1.01	3.55	47	.01	.01	.01	13.	1.01	15.55	191	.40	.39	.00	1271.
1.01	4.00	48	.01	.01	.01	14.	1.01	16.00	192	.40	.39	.00	957.
1.01	4.05	49	.01	.01	.01	14.	1.01	16.05	193	.30	.30	.00	775.
1.01	4.10	50	.01	.01	.01	14.	1.01	16.10	194	.30	.30	.00	647.
1.01	4.15	51	.01	.01	.01	14.	1.01	16.15	195	.30	.30	.00	555.

END-OF-PERIOD FLOW (Cont'd)

1.01	4.20	52	.01	.01	.01	15.	1.01	16.20	196	.30	.30	.00	562.
1.01	4.25	53	.01	.01	.01	15.	1.01	16.25	197	.30	.30	.00	554.
1.01	4.30	54	.01	.01	.01	15.	1.01	16.30	198	.30	.30	.00	550.
1.01	4.35	55	.01	.01	.01	15.	1.01	16.35	199	.30	.30	.00	549.
1.01	4.40	56	.01	.01	.01	15.	1.01	16.40	200	.30	.30	.00	549.
1.01	4.45	57	.01	.01	.01	16.	1.01	16.45	201	.30	.30	.00	549.
1.01	4.50	58	.01	.01	.01	16.	1.01	16.50	202	.30	.30	.00	549.
1.01	4.55	59	.01	.01	.01	16.	1.01	16.55	203	.30	.30	.00	549.
1.01	5.00	60	.01	.01	.01	16.	1.01	17.00	204	.30	.30	.00	549.
1.01	5.05	61	.01	.01	.01	16.	1.01	17.05	205	.24	.24	.00	521.
1.01	5.10	62	.01	.01	.01	16.	1.01	17.10	206	.24	.24	.00	475.
1.01	5.15	63	.01	.01	.00	17.	1.01	17.15	207	.24	.24	.00	448.
1.01	5.20	64	.01	.01	.00	17.	1.01	17.20	208	.24	.24	.00	438.
1.01	5.25	65	.01	.01	.00	17.	1.01	17.25	209	.24	.24	.00	434.
1.01	5.30	66	.01	.01	.00	17.	1.01	17.30	210	.24	.24	.00	432.
1.01	5.35	67	.01	.01	.00	17.	1.01	17.35	211	.24	.24	.00	432.
1.01	5.40	68	.01	.01	.00	17.	1.01	17.40	212	.24	.24	.00	431.
1.01	5.45	69	.01	.01	.00	17.	1.01	17.45	213	.24	.24	.00	431.
1.01	5.50	70	.01	.01	.00	18.	1.01	17.50	214	.24	.24	.00	431.
1.01	5.55	71	.01	.01	.00	18.	1.01	17.55	215	.24	.24	.00	431.
1.01	6.00	72	.01	.01	.00	18.	1.01	18.00	216	.24	.24	.00	431.
1.01	6.05	73	.06	.05	.02	33.	1.01	18.05	217	.02	.02	.00	340.
1.01	6.10	74	.06	.05	.02	60.	1.01	18.10	218	.02	.02	.00	310.
1.01	6.15	75	.06	.05	.02	75.	1.01	18.15	219	.02	.02	.00	290.
1.01	6.20	76	.06	.05	.02	82.	1.01	18.20	220	.02	.02	.00	270.
1.01	6.25	77	.06	.05	.01	85.	1.01	18.25	221	.02	.02	.00	252.
1.01	6.30	78	.06	.05	.01	89.	1.01	18.30	222	.02	.02	.00	235.
1.01	6.35	79	.06	.05	.01	90.	1.01	18.35	223	.02	.02	.00	219.
1.01	6.40	80	.06	.05	.01	92.	1.01	18.40	224	.02	.02	.00	205.
1.01	6.45	81	.06	.05	.01	93.	1.01	18.45	225	.02	.02	.00	191.
1.01	6.50	82	.06	.05	.01	95.	1.01	18.50	226	.02	.02	.00	178.
1.01	6.55	83	.06	.05	.01	96.	1.01	18.55	227	.02	.02	.00	166.
1.01	7.00	84	.06	.05	.01	97.	1.01	19.00	228	.02	.02	.00	155.
1.01	7.05	85	.06	.05	.01	98.	1.01	19.05	229	.02	.02	.00	145.
1.01	7.10	86	.06	.05	.01	99.	1.01	19.10	230	.02	.02	.00	135.
1.01	7.15	87	.06	.06	.01	99.	1.01	19.15	231	.02	.02	.00	126.
1.01	7.20	88	.06	.06	.01	100.	1.01	19.20	232	.02	.02	.00	118.
1.01	7.25	89	.06	.06	.01	101.	1.01	19.25	233	.02	.02	.00	110.
1.01	7.30	90	.06	.06	.01	101.	1.01	19.30	234	.02	.02	.00	102.
1.01	7.35	91	.06	.06	.01	102.	1.01	19.35	235	.02	.02	.00	96.
1.01	7.40	92	.06	.06	.01	103.	1.01	19.40	236	.02	.02	.00	89.
1.01	7.45	93	.06	.06	.01	103.	1.01	19.45	237	.02	.02	.00	83.
1.01	7.50	94	.06	.06	.01	104.	1.01	19.50	238	.02	.02	.00	78.
1.01	7.55	95	.06	.06	.01	104.	1.01	19.55	239	.02	.02	.00	72.
1.01	8.00	96	.06	.06	.01	105.	1.01	20.00	240	.02	.02	.00	68.
1.01	8.05	97	.06	.06	.01	105.	1.01	20.05	241	.02	.02	.00	63.
1.01	8.10	98	.06	.06	.01	105.	1.01	20.10	242	.02	.02	.00	59.
1.01	8.15	99	.06	.06	.01	106.	1.01	20.15	243	.02	.02	.00	55.
1.01	8.20	100	.06	.06	.00	106.	1.01	20.20	244	.02	.02	.00	51.
1.01	8.25	101	.06	.06	.00	106.	1.01	20.25	245	.02	.02	.00	48.
1.01	8.30	102	.06	.06	.00	107.	1.01	20.30	246	.02	.02	.00	45.
1.01	8.35	103	.06	.06	.00	107.	1.01	20.35	247	.02	.02	.00	42.

END-OF-PERIOD FLOW (Cont'd)

1.01	8.40	104	.06	.06	.00	107.	1.01	20.40	248	.02	.02	.00	39.
1.01	8.45	105	.06	.06	.00	108.	1.01	20.45	249	.02	.02	.00	38.
1.01	8.50	106	.06	.06	.00	108.	1.01	20.50	250	.02	.02	.00	38.
1.01	8.55	107	.06	.06	.00	108.	1.01	20.55	251	.02	.02	.00	38.
1.01	9.00	108	.06	.06	.00	108.	1.01	21.00	252	.02	.02	.00	38.
1.01	9.05	109	.06	.06	.00	109.	1.01	21.05	253	.02	.02	.00	38.
1.01	9.10	110	.06	.06	.00	109.	1.01	21.10	254	.02	.02	.00	38.
1.01	9.15	111	.06	.06	.00	109.	1.01	21.15	255	.02	.02	.00	38.
1.01	9.20	112	.06	.06	.00	109.	1.01	21.20	256	.02	.02	.00	38.
1.01	9.25	113	.06	.06	.00	109.	1.01	21.25	257	.02	.02	.00	38.
1.01	9.30	114	.06	.06	.00	110.	1.01	21.30	258	.02	.02	.00	38.
1.01	9.35	115	.06	.06	.00	110.	1.01	21.35	259	.02	.02	.00	38.
1.01	9.40	116	.06	.06	.00	110.	1.01	21.40	260	.02	.02	.00	38.
1.01	9.45	117	.06	.06	.00	110.	1.01	21.45	261	.02	.02	.00	38.
1.01	9.50	118	.06	.06	.00	110.	1.01	21.50	262	.02	.02	.00	38.
1.01	9.55	119	.06	.06	.00	110.	1.01	21.55	263	.02	.02	.00	38.
1.01	10.00	120	.06	.06	.00	110.	1.01	22.00	264	.02	.02	.00	38.
1.01	10.05	121	.06	.06	.00	111.	1.01	22.05	265	.02	.02	.00	38.
1.01	10.10	122	.06	.06	.00	111.	1.01	22.10	266	.02	.02	.00	38.
1.01	10.15	123	.06	.06	.00	111.	1.01	22.15	267	.02	.02	.00	38.
1.01	10.20	124	.06	.06	.00	111.	1.01	22.20	268	.02	.02	.00	38.
1.01	10.25	125	.06	.06	.00	111.	1.01	22.25	269	.02	.02	.00	38.
1.01	10.30	126	.06	.06	.00	111.	1.01	22.30	270	.02	.02	.00	38.
1.01	10.35	127	.06	.06	.00	111.	1.01	22.35	271	.02	.02	.00	38.
1.01	10.40	128	.06	.06	.00	111.	1.01	22.40	272	.02	.02	.00	38.
1.01	10.45	129	.06	.06	.00	111.	1.01	22.45	273	.02	.02	.00	38.
1.01	10.50	130	.06	.06	.00	112.	1.01	22.50	274	.02	.02	.00	38.
1.01	10.55	131	.06	.06	.00	112.	1.01	22.55	275	.02	.02	.00	38.
1.01	11.00	132	.06	.06	.00	112.	1.01	23.00	276	.02	.02	.00	38.
1.01	11.05	133	.06	.06	.00	112.	1.01	23.05	277	.02	.02	.00	38.
1.01	11.10	134	.06	.06	.00	112.	1.01	23.10	278	.02	.02	.00	38.
1.01	11.15	135	.06	.06	.00	112.	1.01	23.15	279	.02	.02	.00	38.
1.01	11.20	136	.06	.06	.00	112.	1.01	23.20	280	.02	.02	.00	38.
1.01	11.25	137	.06	.06	.00	112.	1.01	23.25	281	.02	.02	.00	38.
1.01	11.30	138	.06	.06	.00	112.	1.01	23.30	282	.02	.02	.00	38.
1.01	11.35	139	.06	.06	.00	112.	1.01	23.35	283	.02	.02	.00	38.
1.01	11.40	140	.06	.06	.00	112.	1.01	23.40	284	.02	.02	.00	38.
1.01	11.45	141	.06	.06	.00	112.	1.01	23.45	285	.02	.02	.00	38.
1.01	11.50	142	.06	.06	.00	112.	1.01	23.50	286	.02	.02	.00	38.
1.01	11.55	143	.06	.06	.00	113.	1.01	23.55	287	.02	.02	.00	38.
1.01	12.00	144	.06	.06	.00	113.	1.02	0.00	288	.02	.02	.00	38.
									SUM	33.15	31.99	1.16	60546.
										(842.)	(813.)	(29.)	(1714.)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3315.	648.	210.	210.	60543.
CMS	94.	18.	6.	6.	1714.
INCHES		25.74	33.43	33.43	33.43
MM		653.92	849.07	849.07	849.07
AC-FT		321.	417.	417.	417.
THOUS CU M		396.	514.	514.	514.

SURFACE AREA=	0.	1.	3.	5.	6.	9.	13.
CAPACITY=	0.	1.	16.	47.	57.	129.	237.
ELEVATION=	678.	682.	690.	698.	700.	710.	720.

SUMMARY OF DAM SAFETY ANALYSIS

PMF

.....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	692.03	698.00	699.10
	STORAGE	22.	47.	53.
	OUTFLOW	0.	0.	50.

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	697.05	0.00	52.	47.	0.00	17.17	0.00

SUMMARY OF DAM SAFETY ANALYSIS

PMF

.....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	698.00	698.00	699.10
	STORAGE	47.	47.	53.
	OUTFLOW	0.	0.	50.

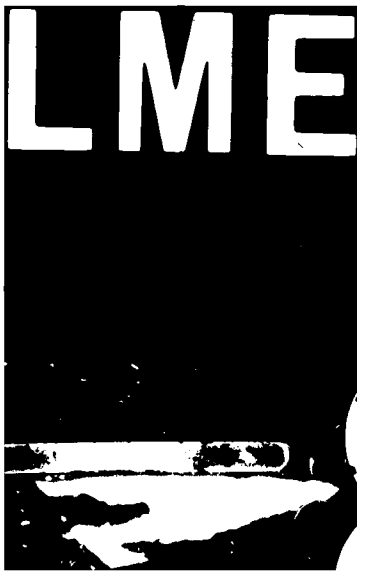
RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	700.89	1.79	53.	1462.	10.67	15.67	0.00
1.00	701.65	2.75	55.	3071.	14.08	15.67	0.00

SUMMARY OF DAM SAFETY ANALYSIS

1 PERCENT PROBABILITY FLOOD

.....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	686.50	698.00	699.10
	STORAGE	7.	47.	53.
	OUTFLOW	0.	0.	50.

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
1.00	698.79	0.00	51.	29.	0.00	15.33	0.00


LME