AD-A106 296 BLACK AND VEATCH KANSAS CITY MO F/G 13/13
NATIONAL DAM SAFETY PROGRAM. WOOD LAKE DAM (MO 20135), MISSOURI--ETC(U)
AUG 78 D P GUPTA, B A AINSWORTH, H L CALLAHAN DACW43-78-C-0148
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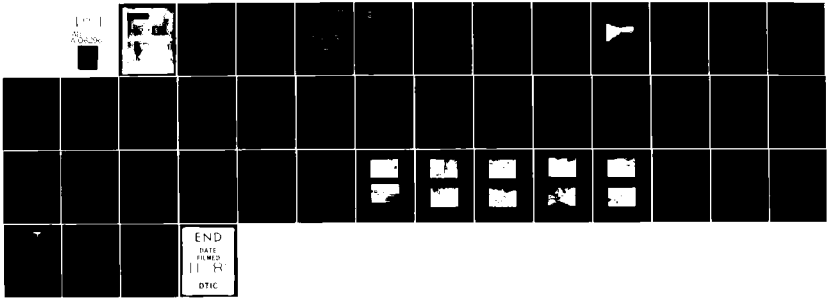

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National Dam Safety Program. Wood Lake Dam (MO 20135), Missouri - Kansas City Basin, Jackson County, Missouri. Phase I Inspection Report.

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

WOOD LAKE DAM
JACKSON COUNTY, MISSOURI
MO 20135

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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

FOR: STATE OF MISSOURI

AUGUST 1978

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 NORTH 12TH STREET
ST. LOUIS, MISSOURI 63101

REPLY REFER TO

SUBJECT: Wood Lake Dam (Mo. 20135), Phase I Inspection Report

This report presents the results of field inspection and evaluation of Wood Lake Dam (Mo. 20135).

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

The St. Louis District has classified this dam as unsafe because of steep embankment slopes, severe erosion on downstream face, sloughing on upstream and downstream side of embankment, seepage near left abutment and from under spillway, undercutting of the downstream end of the spillway, and heavy tree growth on the downstream slope of the embankment.

SUBMITTED BY: SIGNED
Chief, Engineering Division

28 DEC 1978
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

28 DEC 1978
Date

NO NAME 82 DAM
(WOOD LAKE DAM)

JACKSON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 20135

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

AUGUST 1978

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	No Name 82 Dam (Wood Lake Dam)
State Located	Missouri
County Located	Jackson County
Stream	Tributary to West Fork
Date of Inspection	3 August 1978

No Name 82 (Wood 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 significant downstream hazard potential. Failure of No Name 82 Dam (Wood Lake Dam) would cause damage to the agricultural land downstream for 1.5 miles and to a light-duty road which crosses the valley below the dam.

Our inspection and evaluation indicates the spillway does meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will not pass either the probable maximum flood or 50 percent of the probable maximum flood without overtopping but will pass 20 percent of the probable maximum flood, which is greater than the estimated 100-year flood. Due to the lack of downstream structures, the absence of industry, minimal agriculture development, and small amount of water impounded by the dam, the 100-year flood is the appropriate spillway design flood.

Deficiencies visually observed by the inspection team were erosion, seepage, sloughing of the riprap, sloughing of the embankment, on both upstream and downstream faces, erosion of the discharge channel, undercutting of the concrete exit apron, and the presence of excessive brush and trees on the downstream embankment slope. 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. Future corrective action and regular maintenance will be required to correct or control the described deficiencies. 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.

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Overview of Lake and Dam

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
NO NAME 82 (WOOD LAKE) DAM

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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 No Name 82 (Wood Lake) Dam be made. Throughout the remainder of this report No Name 82 Dam will be referred to by its common name of Wood Lake Dam.

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 a tributary to the West Fork in east central Jackson County, Missouri (Plate 1). A dirt roadway has been constructed across the top of the dam. Topography of the contributing watershed is characterized by rolling hills. The watershed is primarily comprised of residential areas and farmland. Topography in the vicinity of the dam is shown on Plate 2.

(2) A spillway is located at the right abutment. This spillway is comprised of a concrete-lined rectangular open channel over which the road was constructed. An approach channel with a concrete floor directs flow to the spillway which discharges to a concrete exit apron. The existing discharge channel which is approximately 20 feet downstream from the centerline of the dam has an earth bottom with no side slope protection.

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

b. Location. The dam is located in east central Jackson 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 Tarsney Lakes, Missouri in Section 23 of T48N, R30W.

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.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers for this dam is as follows: The Wood Lake Dam has a significant hazard potential, meaning that the dam is located where failure may damage isolated homes, secondary highways or minor railroads or cause interruption of use or service of relatively important public utilities. For the Wood Lake Dam the flood damage zone extends downstream for 1.5 miles through agricultural land. One road crosses the valley approximately 1.3 miles below the dam.

e. Ownership. The dam is owned by the City of Tarsney Lakes, P.O. Box 1528, Oak Grove, Missouri 64075.

f. Purpose of Dam. The dam forms a 6-acre recreational lake.

g. Design and Construction History. Data relating to the design and construction were not available.

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

1.3 PERTINENT DATA

a. Drainage Area - 140 acres

b. Discharge at Damsite.

(1) Normal discharge at the damsite is through an uncontrolled spillway

(2) Estimated experienced maximum flood at damsite - unknown

(3) Estimated ungated spillway capacity at maximum pool elevation 230 cfs (top of Dam El.847.5).

c. Elevation (Feet Above M.S.L.).

(1) Top of dam - 847.5 ± (see Plate 3)

(2) Spillway crest - 845.0

(3) Streambed at centerline of dam - 819.0 ±

(4) Maximum tailwater - unknown.

d. Reservoir

(1) Length of maximum pool - 1,000 feet +

(2) Length of normal pool - 730 feet +

e. Storage (Acre-feet)

(1) Top of dam - 58

(2) Spillway crest - 38 from 1975 inventory

(3) Design surcharge - not available

f. Reservoir Surface (Acres)

(1) Top of dam - 10

(2) Spillway crest - 6

g. Dam

(1) Type - earth embankment

(2) Length - 550 feet

(3) Height - 28 feet +

(4) Top width - 8 feet

(5) Side slopes - upstream face approximately 3 to 1, downstream face approximately 2.5 H to 1.0 V, (see Plate 4)

(6) Zoning - unknown

(7) Impervious core - unknown

(8) Cutoff - unknown

(9) Grout curtain - unknown

h. Diversion and Regulating Tunnel - none

i. Spillway

(1) Type - Chute

(2) Width of channel - 11.5 feet

(3) Crest elevation - 845.0 feet m s l

(4) Gates - none

(5) Upstream channel - Rectangular channel with a concrete base and walls. Beyond the rectangular channel is a grass channel that slopes to the edge of the lake.

(6) Downstream channel - Rectangular channel with a concrete base and stone retaining walls. Beyond the rectangular channel is a steep earth incline with no side slope protection that is heavily eroded. The left wing wall has failed and fallen into the channel. Part of the discharge channel is filled with debris and heavy vegetation.

d. Regulating Outlets - none

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data were unavailable.

2.2 CONSTRUCTION

Construction records were unavailable, however the dam was reportedly built circa 1949

2.3 OPERATION

The maximum recorded loading on the dam is unknown.

2.4 EVALUATION

a Availability. No engineering data could be obtained.

b Adequacy. No engineering data were available upon which to make a detailed assessment of the design, construction, and operation. 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 Wood Lake Dam was made on 3 August 1978. The inspection team included professional engineers with experience in dam design and construction, hydrology - hydraulic engineering, and structural engineering. 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 items at the dam. The upstream slope of the embankment above the water level is very steep. The riprap has slid beneath the water level. The lake is silted close to the dam, and sediments are within 4-1/2 feet of the top of the dam. An apparently recent sloughing of a 20 foot length occurred about 200 feet from the left abutment. On the downstream face, two areas of major erosion exist approximately 50 feet from the left abutment. The two eroded areas are approximately 4 feet wide, 2 feet deep, have a 1 to 1 slope, and extend from the top of the dam to the toe of the dam. At the toe of the dam in the eroded area the ground is extremely soft with clear seepage. This seepage is estimated to be approximately 5 gallons per minute. The downstream face is covered with heavy tree and bush growth. Some of the trees were observed as being dead.

c. Appurtenant Structures. The bridge at the right abutment acts as the spillway which consists of a rectangular channel with a concrete base and stone retaining walls. The spillway is acting as a broad-crested weir. The roadway deck across the spillway is constructed of wood. The base of the channel is non-reinforced concrete (grouted riprap) and is severely cracked. Undermining has occurred for approximately 3 feet under the spillway. Seepage of approximately 1 gallon per minute seems to be coming from under the spillway and is clear. It was impossible to determine whether a vertical cutoff exists at the upstream edge of the spillway. The downstream channel is heavily eroded and the base of the channel is cluttered with debris.

d. Reservoir Area. No slides or excessive erosion due to wave action were observed along the shore of the reservoir.

e. Downstream Channel. Heavy vegetation comprised of trees and brush at the lower end of the discharge channel were observed. At the upper end of the channel, near the spillway, the slopes are steep to vertical with heavy erosion. The left wing wall has failed and fallen into the channel. The bottom of the channel is filled with debris that obstructs flow.

3.2 EVALUATION

Remedial action should be taken on the following reservoir conditions, or a serious potential for failure will develop.

(1) Undercutting of the downstream end of the spillway.

(2) Severe erosion of the downstream channel just beyond the spillway.

(3) Sloughing on the upstream side of the embankment.

(4) Sloughing and erosion on the downstream side of the embankment.

(5) Heavy tree growth on the downstream slope of the embankment.

(6) Seepage near the left abutment and from under the spillway.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

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

4.2 MAINTENANCE OF DAM

Maintenance performed was unknown.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities are known to exist.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection team is not aware of any existing warning system for this dam.

4.5 EVALUATION

Existing seepage, erosion, and sloughing observed on the upstream and downstream side of the dam, a heavy growth of trees and vegetation on the downstream side of the dam, seepage under the spillway, undercutting of the downstream end of the spillway, and excessive erosion of the channel immediately downstream of the spillway increase the potential for failure and warrant repair and regular monitoring.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data pertaining to hydrology and hydraulics were unavailable.

b. Experience Data. The drainage area and lake surface area are developed from USGS Tarsney Lakes Quadrangle Map. The spillway and dam layouts are from surveys made during the inspection.

c. Visual Observations.

(1) The bridge of the spillway is in good condition. The discharge channel and exit apron of the spillway are badly deteriorated.

(2) No facilities are available that could serve to draw down the pool.

(3) A spillway and exit channel are located at the right abutment. Spillway discharges may endanger the integrity of the dam due to the fact that the left wing wall has failed and erosion of the embankment material has occurred.

d. Overtopping Potential. The spillway will not pass 50 to 100 percent of the probable maximum flood without overtopping the dam. The probable maximum flood (PMF) 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 spillway will pass 20 percent of the PMF without overtopping. This flood is greater than the 100-year estimated according to the methodology outlined by the USGS in "Technique for Estimating the Magnitude and Frequency of Missouri Floods". According to the Recommended Guidelines for Safety Inspection of Dams a significant hazard dam of small size should pass a 100-year to 50 percent of the PMF. Due to the lack of downstream structures, the absence of industry, minimal agricultural development, and small amount of water impounded by the Wood Lake Dam, the spillway should be capable of passing a 100-year flood without overtopping the dam. The portion of the estimated peak discharge of the PMF overtopping the dam would be 2,600 cfs of the total discharge from the reservoir of 2,900 cfs. The estimated duration of overtopping is 5.3 hours. The portion of the estimated peak discharge of 50 percent of the PMF overtopping the dam would be 1,000 cfs of the total discharge of the reservoir of 1,300 cfs. The estimated duration of overtopping is 2.6 hours. Failure of upstream water impoundments shown on the 1975 revised USGS map would not have a significant impact on the hydrologic or hydraulic analysis.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately 1.5 miles downstream of the dam through agricultural land. One road crosses the valley within the damage zone.

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.

c. Operating Records. No operational records exist.

d. Post Construction Changes. No known post construction changes.

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: The important factors being embankment and foundation material classification and shear strengths; abutment materials, conditions, and strength; 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.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items noted during the visual inspection by the inspection team which should be monitored or controlled are seepage through the embankment, movement of upstream riprap, sloughing of the upstream and downstream embankment slope, erosion of the discharge channels and undercutting of the concrete exit apron, and an uncontrolled stand of brush and trees on the downstream embankment slope.

b. Adequacy of Information. Due to the lack 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. Due to the lack of data, detailed analyses of the dam comparable in scope to the requirements of the Recommended Guidelines should be performed.

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.

d. Necessity for Phase II. As a result of this Phase I inspection the St. Louis District of the Corps of Engineers has classified the Wood Lake Dam as unsafe. A Phase II inspection is not required.

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

7.2 REMEDIAL MEASURES

a. Alternatives. The present spillway has the capacity to pass 20 percent of the probable maximum flood without overtopping the dam. In order to pass 50 to 100 percent of the probable maximum flood as required by the Recommended Guidelines, the spillway size and/or height of dam would need to be increased. It is the opinion of the inspection team that the freeboard above the spillway crest is inadequate when compared to current design practices.

b. O&M Maintenance and Procedures. The following O&M maintenance and procedures are recommended:

(1) Check the downstream face of the dam periodically for seepage and stability problems. If increased seepage flows are observed or additional sloughing on the downstream embankment slope is noted, the dam should immediately be inspected and the condition evaluated by an engineer experienced in design and construction of earthen dams.

(2) Measures to curtail seepage should be undertaken to prevent the development of a piping condition.

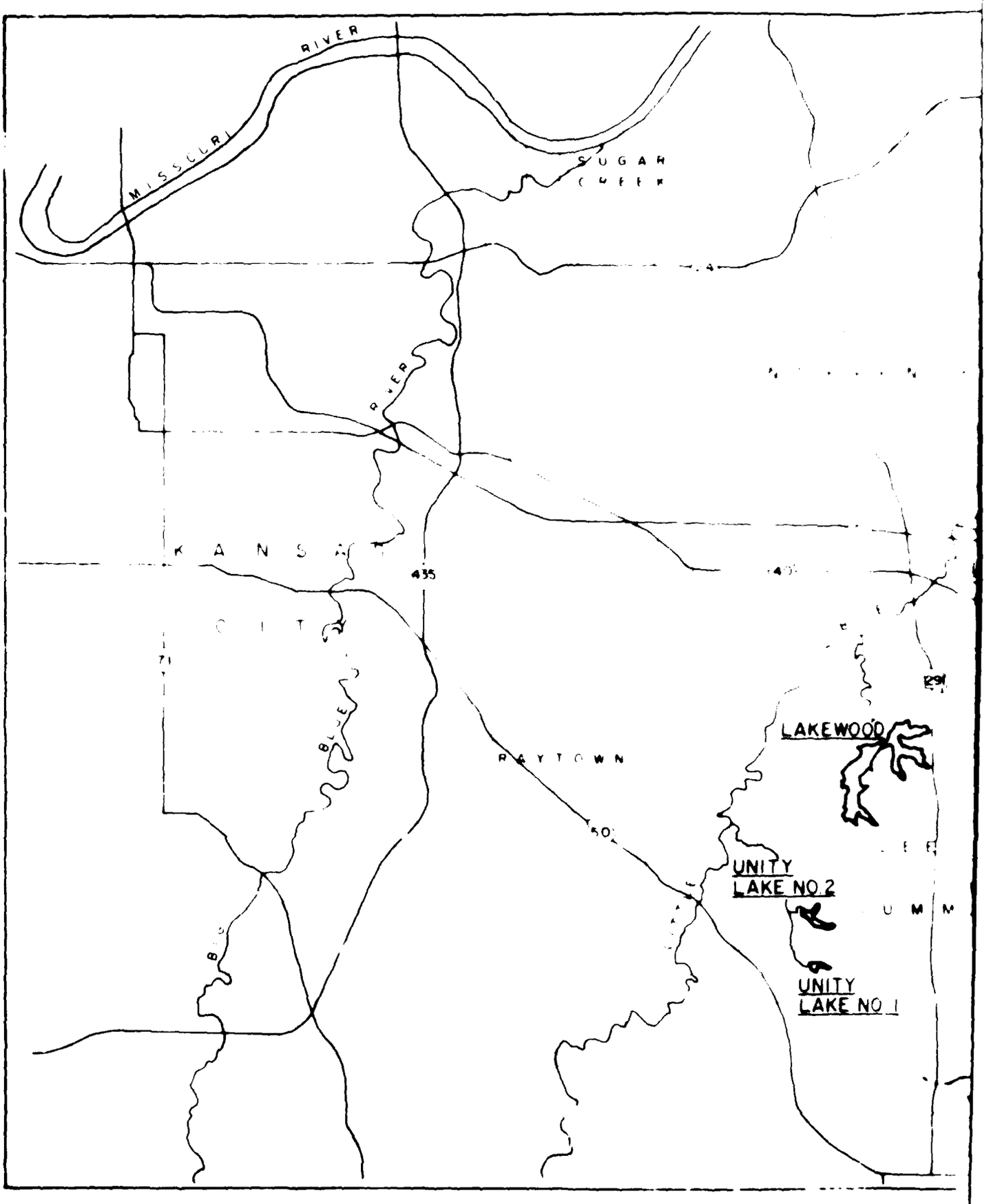
(3) Due to the density and large size of the trees on the downstream slope of the dam, an engineer experienced in the maintenance and design of earthen dams should be retained to recommend procedures to control the growth of the trees and establish proper slope protection.

(4) The side slopes of the spillway discharge channel should be protected from erosion especially near the dam embankment to prevent additional erosion and undermining of the dam embankment.

(5) An engineer experienced in the design and construction of earth dams should be retained to develop procedures to prevent further undermining of the spillway exit apron.

(6) Erosion protection should be added on the upstream slope to take the place of the riprap that slid into the lake. This protection is needed to prevent erosion of the embankment material due to wave action.

(7) A detailed inspection of the dam should be made at least every year by an engineer experienced in design and construction of dams. More frequent inspections may be required if additional deficiencies are observed or the severity of the reported deficiencies increases.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RIVER
KANSAS
CITY
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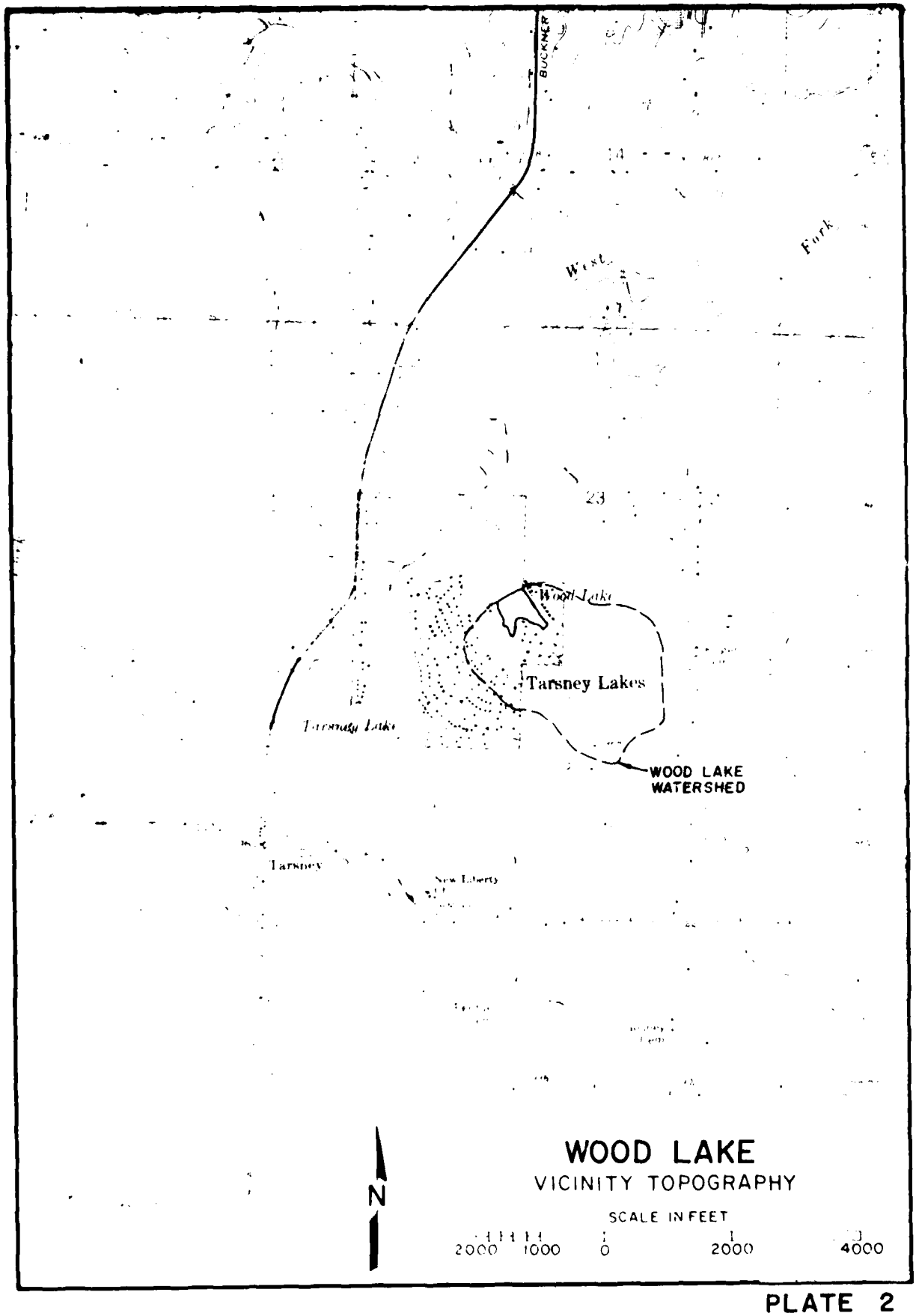
BLUE
RAYTOWN
50
LAKEWOOD
UNITY LAKE NO. 2
UNITY LAKE NO. 1

WOOD LAKE
MISSOURI
VICINITY MAP
LAKE TAPAWINGO
LAKE JACOMO
PRAIRIE LEE LAKE
WOOD LAKE
LAKE LOTAWANA
N
WOOD LAKE LOCATION MAP
SCALE IN MILES

PLATE 1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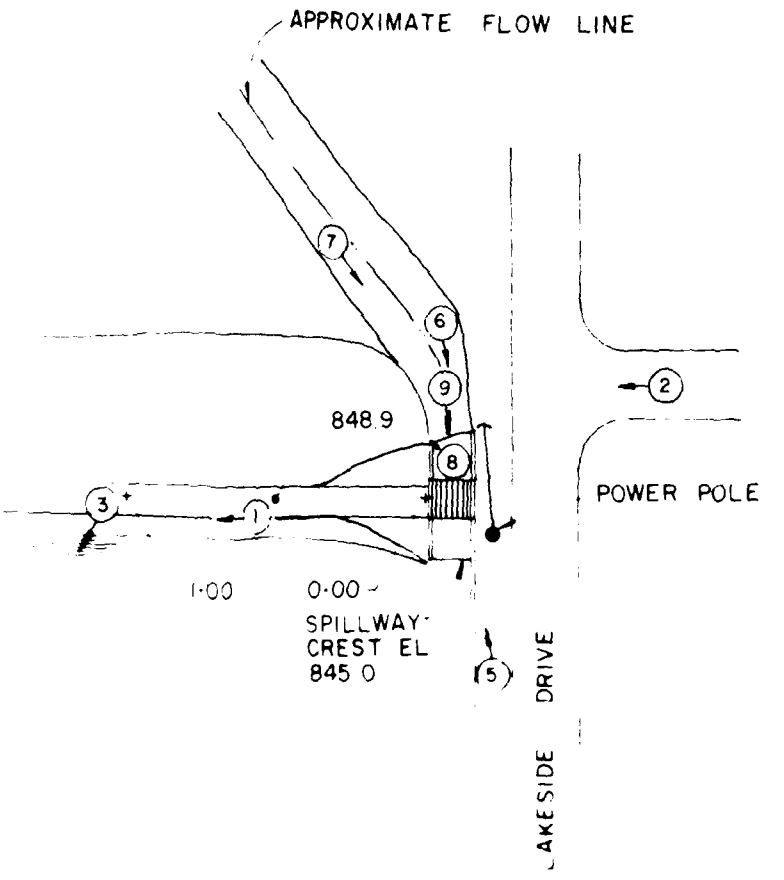
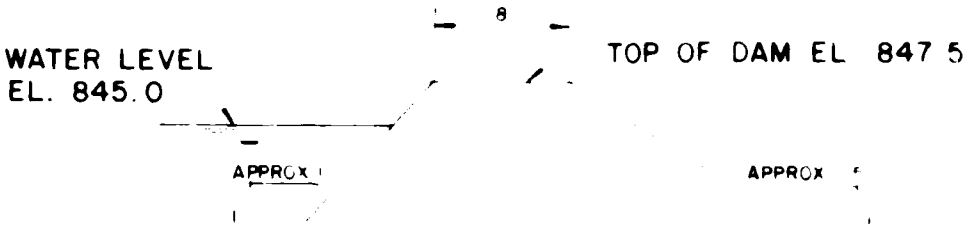
2000 1000 0 2000 4000

PLATE 2



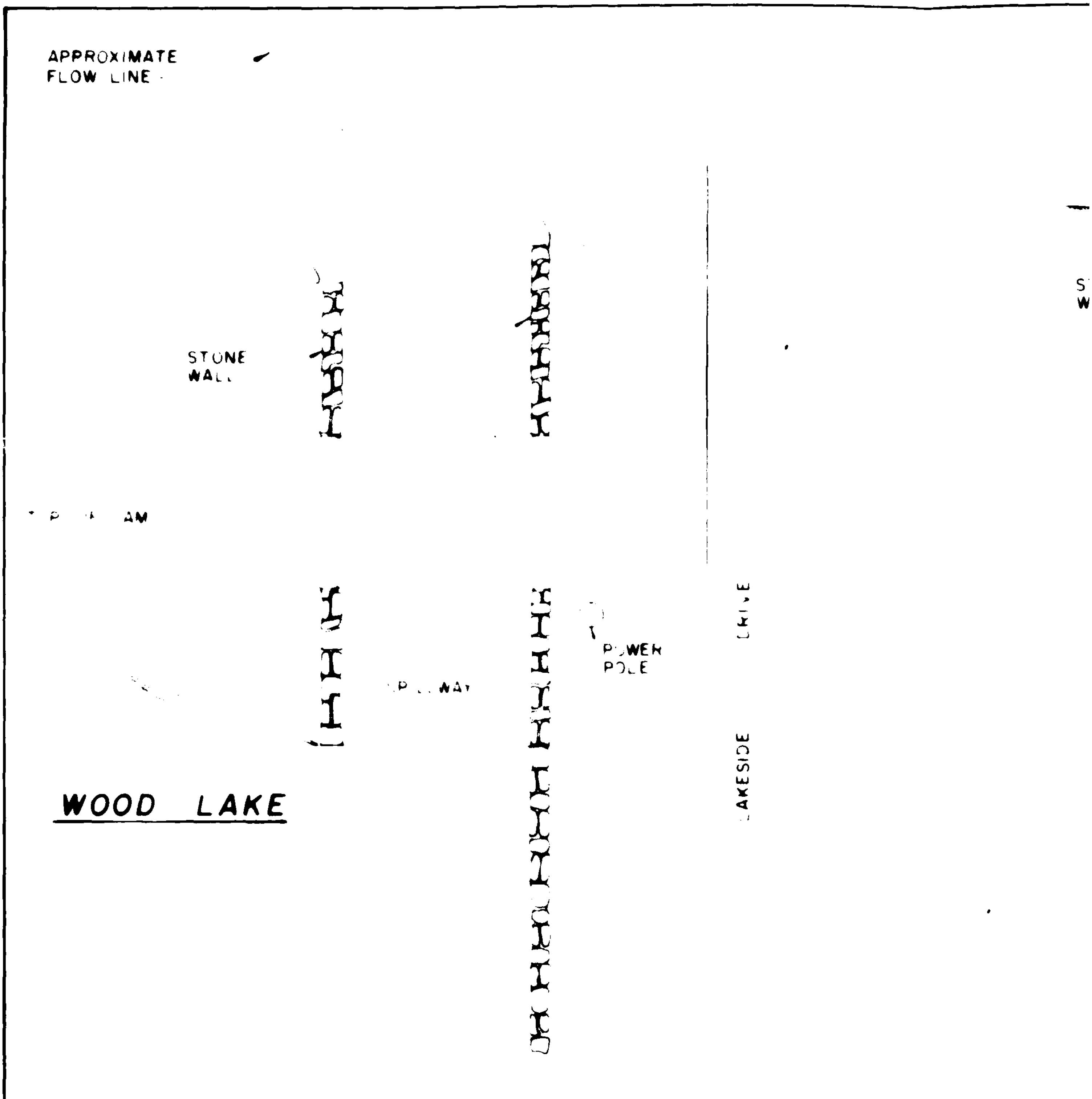
WOOD LAKE
PLAN

PLATE

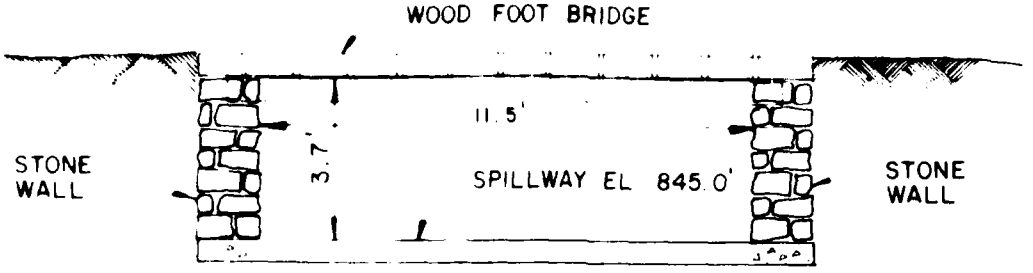

WATER LEVEL
EL. 845.0
TOP OF DAM EL 847.5
APPROX
APPROX

WOOD LAKE
TYPICAL SECTION

PLATE 4



PLAN



SECTION LOOKING DOWNSTREAM

N

WOOD LAKE SPILLWAY DETAILS

PLATE 5

Photo 1: Upstream Face of Dam (Looking East)

Photo 2: Downstream Face of Dam (Looking East)

Photo 3: Sloughing of Upstream Embankment

Photo 4: Typical Vegetation on Downstream Embankment

Photo 5: Spillway Approach Channel (Looking Downstream)

Photo 6: Spillway Discharge Channel (Looking Upstream)

Photo 7: Spillway Discharge Channel Near Toe of Dam (Looking Upstream)

Photo 8: Erosion on Left Side of Spillway Discharge Channel

Photo 9: Undercutting and Seepage at Downstream Edge Spillway Slab (Looking Upstream)

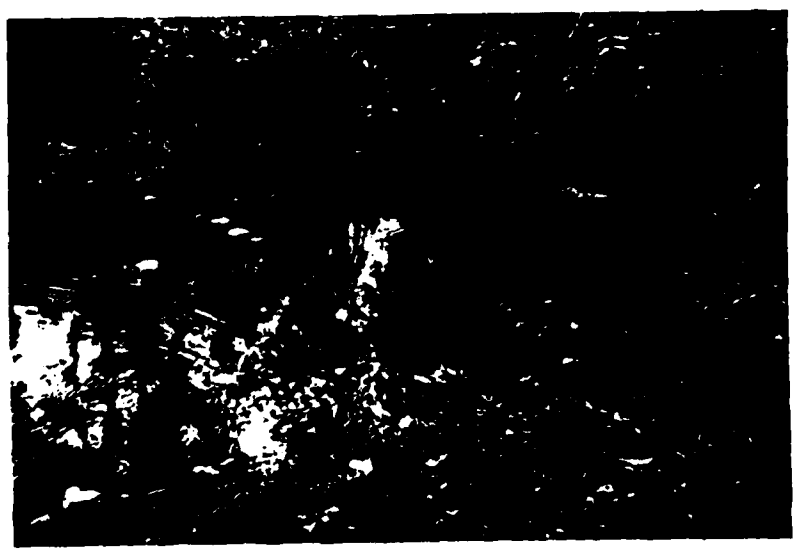


Photo 10: Seepage Pool at Toe of Dam Near Left Abutment

APPENDIX A

HYDROLOGIC COMPUTATIONS

HYDROLOGIC COMPUTATIONS

1. The Soil Conservation Service (SCS) dimensionless unit hydrograph and HEC-1 (1) were used to develop the inflow hydrographs (see Plates A-1, A-2, and A-3), and hydrologic inputs are as follows:

a. Twenty-four hour, probable maximum precipitation determined from U.S. Weather Bureau Hydrometeorological Report No. 33.

200 square mile, 24 hour rainfall inches	- 24.8
10 square mile, 6 hour percent of 24 hour 200 square mile rainfall	- 101%
10 square mile, 12 hour percent of 24 hour 200 square mile rainfall	- 120%
10 square mile, 24 hour percent of 24 hour 200 square mile, rainfall	- 130%

b. Drainage area = 140 acres.

c. Time of concentration: $Tc = (11.9 \times L^3/H)^{0.385} = 0.16$ hours = 10 minutes (L = length of longest watercourse in miles, H = elevation difference in feet) (2)

d. Losses were determined in accordance with SCS methods for determining runoff using a curve number of 85 and antecedent moisture condition III.

2. Spillway release rates are based on broad-crested weir equation and the orifice equation.

Broad-crested weir equation:

$Q = CLH^{1.5}$ (C = 2.5, L = 11.5 feet, H is the head on weir).

Orifice equation:

$Q = C_dA(2gh)^{0.5}$ (C_d = 0.7, A = 42.6 square feet, h is head on the orifice).

Discharge rates over the top of the dam are based on the broad-crested weir equation:

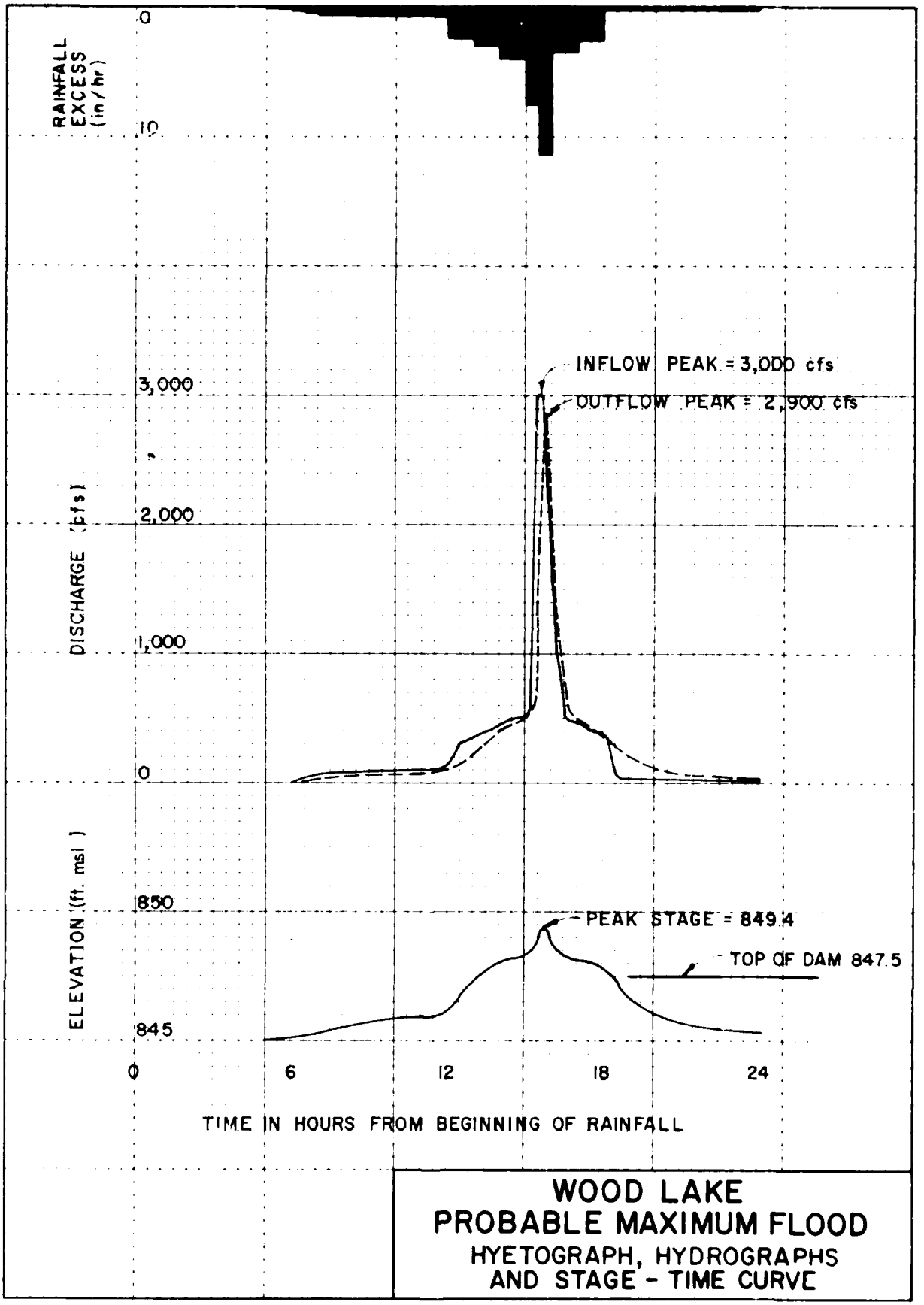
$Q = CLH^{1.5}$ (C = 2.6, L = 50 to 550 feet).

3. The elevation-storage relationship above normal pool elevation was constructed by planimetering the area enclosed within each contour above normal pool. The storage between two elevations was computed by multiplying the average of the areas at the two elevations by the elevation difference. The summation of these increments below a given elevation is the storage below that level.

4. Floods are routed through the spillway using HEC-1, modified Puls to determine the capability of the spillway. Inflow and outflow hydrographs are shown on Plates A-1, A-2, and A-3.

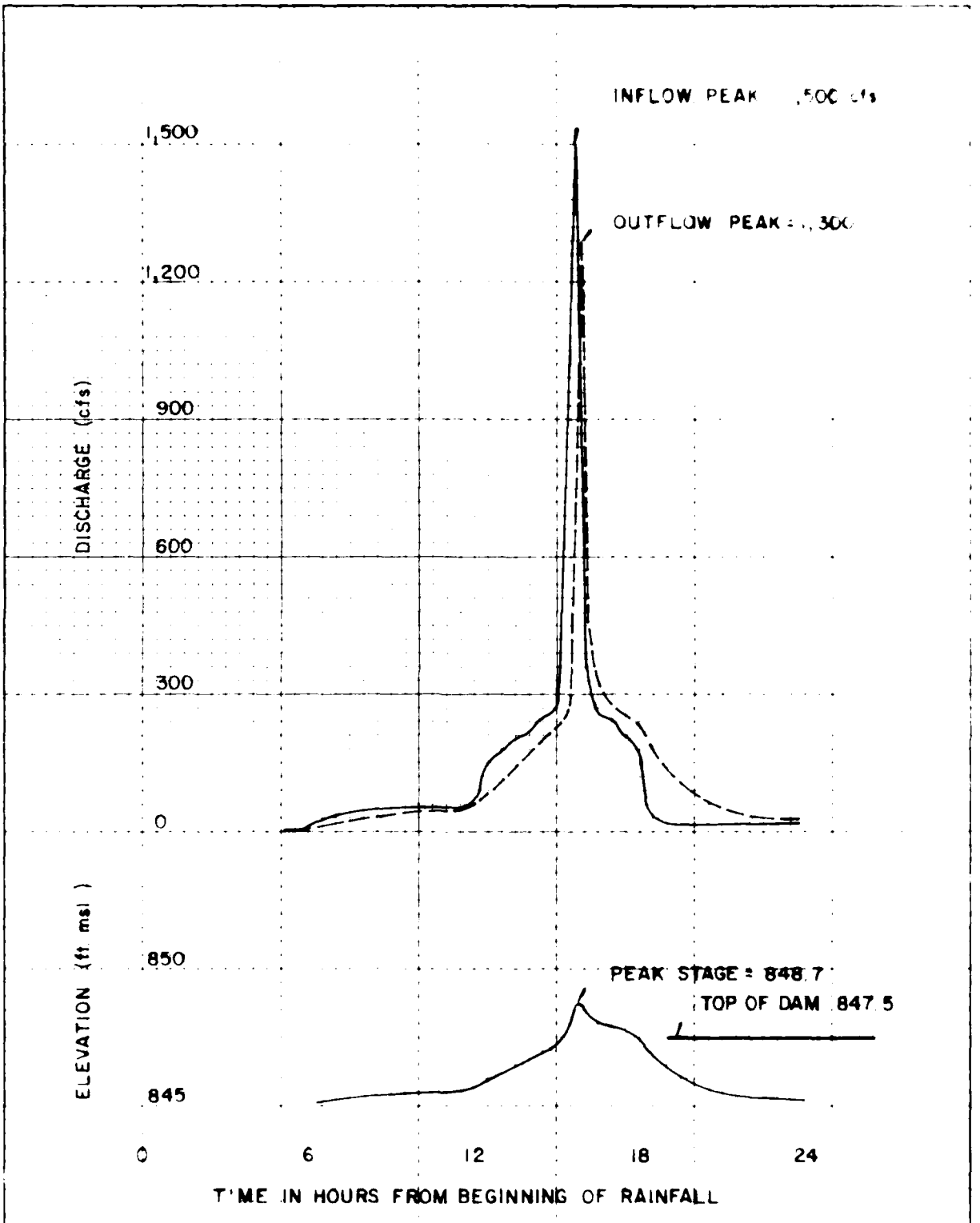
(1) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version, July 1978, Davis, California.

(2) U.S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, 1974, Washington, D.C.



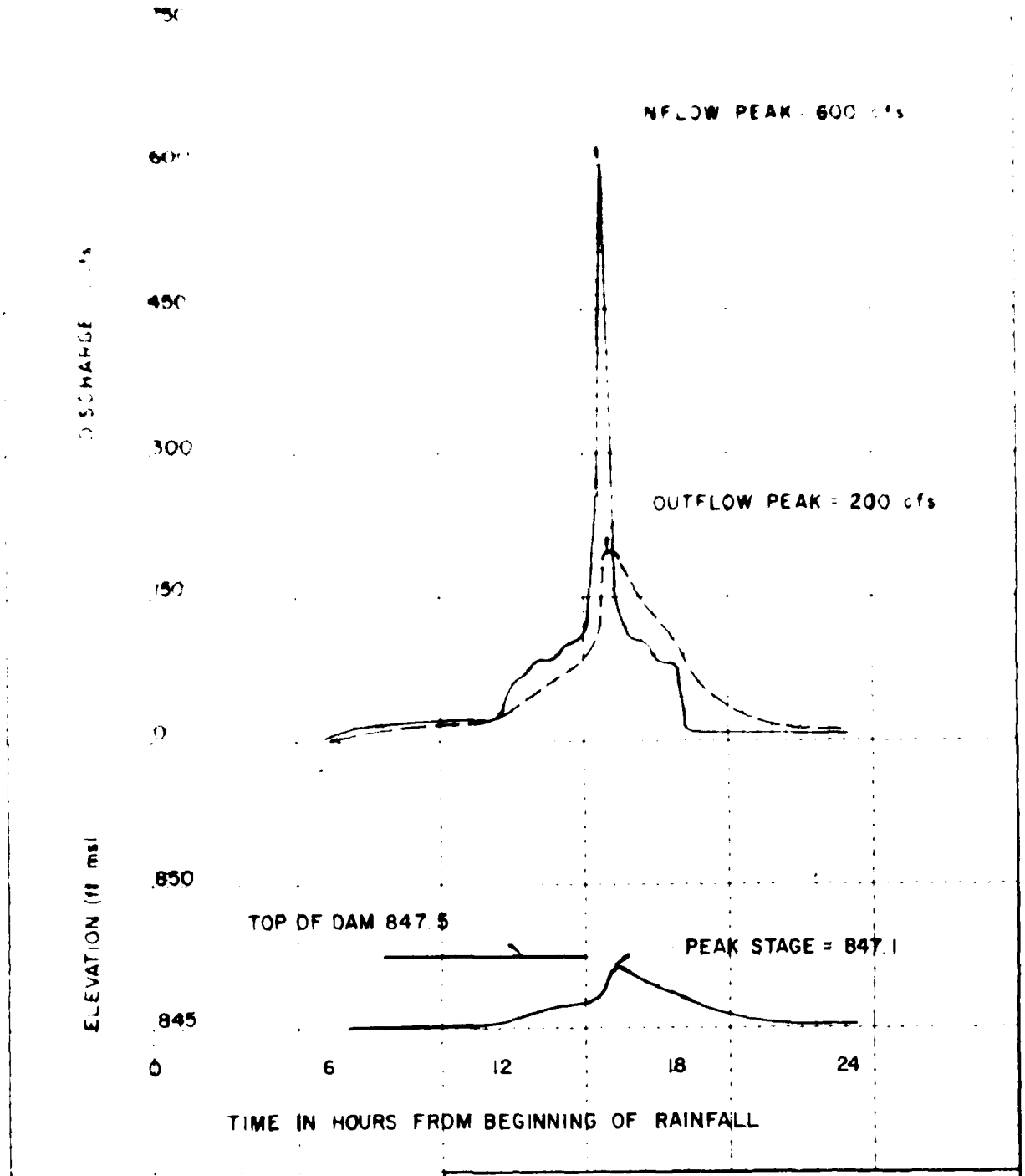
WOOD LAKE
PROBABLE MAXIMUM FLOOD
HYETOGRAPH, HYDROGRAPHS AND STAGE - TIME CURVE

PLATE A-1



WOOD LAKE
50% PROBABLE MAXIMUM FLOOD
HYDROGRAPHS AND STAGE - TIME CURVE

PLATE A-2



WOOD LAKE
20% PROBABLE MAXIMUM FLOOD
HYDROGRAPHS AND STAGE-TIME CURVE

PLATE A-3

END

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11-81

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