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BLACK AND VEATCH KANSAS CITY MO
NATIONAL DAM SAFETY PROGRAM. LAKE LUNA DAM (MO 20076), MISSOURI--ETC(U)
APR 79 P R ZAMAN, E R BURTON, H L CALLAHAN

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MISSOURI-KANSAS CITY BASIN

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LEVEL II

LAKE LUNA DAM

CASS COUNTY, MISSOURI

MO 20076

**PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION**

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St. Louis District

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FOR: STATE OF MISSOURI

APRIL 1979

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MISSOURI-KANSAS CITY BASIN

LAKE LUNA DAM

CASS COUNTY, MISSOURI

MO 20076

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PHASE 1 INSPECTION REPORT NATIONAL DAM SAFETY INSPECTION



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

APRIL 1979



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

IN REPLY REFER TO

SUBJECT: Lake Luna Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Lake Luna Dam:

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
- 2) Overtopping could result in dam failure.
- 3) Dam failure significantly increases the hazard to loss of life downstream

SUBMITTED BY:

SIGNED

Chief, Engineering Division

31 JUL 1979

Date

APPROVED BY:

SIGNED

Colonel, CE, District Engineer

31 JUL 1979

Date

LAKE LUNA DAM
CASS COUNTY, MISSOURI

MISSOURI INVENTORY NO. 20076

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

APRIL 1979

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Lake Luna Dam
State Located	Missouri
County Located	Cass County
Stream	Town Creek
Date of Inspection	12 April 1979

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

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a small size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers failure would threaten the life and property of approximately eight families, damage two buildings and would potentially cause appreciable damage to U.S. Highway 71 and the St. Louis/San Francisco and Missouri Pacific railroads within the estimated damage zone which extends approximately one mile downstream of the dam.

Our inspection and evaluation indicates the spillway does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will not pass the probable maximum flood without overtopping but will pass 10 percent of the probable maximum flood, which is smaller than the 100-year flood. The spillway design flood recommended by the guidelines is 50 to 100 percent of the probable maximum flood. Considering the fact that there are eight homes within one mile downstream of the dam, 100 percent of the probable maximum flood is the appropriate spillway design flood. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Deficiencies visually observed by the inspection team were erosion of the upstream slope due to lack of riprap bedding, presence of a manmade excavation near the downstream toe, erosion undercutting of the discharge channel, and the presence of brush and trees on the downstream

embankment slopes. 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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Harry L. Callahan, Partner
Black & Veatch



OVERVIEW OF LAKE AND DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE LUNA 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 Lake Luna Dam be made.

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

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

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure located in the Town Creek Valley in central Cass County, Missouri (Plate 1). The dam has a minimum height of 17 feet and an average crest width of 14 feet. It is approximately 700 feet long with a normal free board of 3 feet. Topography in the vicinity of the dam is shown on Plate 2.

(2) A concrete straight-drop or free overfall type spillway is located near the left abutment which empties into a trapezoidal concrete discharge channel. An emergency spillway does not exist, but high flows may exit from the left lake perimeter just above the dam and flow along the park road.

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

b. Location. The dam is located in central Cass 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 Harrisonville, Missouri in Section 34 of T45N, R31W. The dam is located in Section 4 of T44N, R31W.

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 Lake Luna Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, and serious damage to homes, agricultural, industrial and commercial facilities, and to important public utilities, main highways, or railroads. For the Lake Luna Dam the estimated flood damage zone extends downstream for approximately one mile. Within the damage zone are eight homes, two buildings, U.S. Highway 71, and the St. Louis/San Francisco and the Missouri Pacific railroads.

e. Ownership. The dam is owned by the City of Harrisonville, P.O. Box 367, Harrisonville, Missouri, 64701.

f. Purpose of Dam. The dam forms a 17-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 - 1,310 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 1,400 cfs (top of Dam El.904.7).

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

(1) Top of dam - 904.7_± (see Plate 4)

- (2) Spillway crest - 901.5
- (3) Streambed at toe of dam - 886.0 ±
- (4) Maximum tailwater - Unknown.

d. Reservoir.

- (1) Length of maximum pool - 2,200 feet ±
- (2) Length of normal pool - 1,900 feet ±

e. Storage (Acre-feet).

- (1) Top of dam - 190
- (2) Spillway crest - 120 (from 1975 inventory)
- (3) Design surcharge - Not available.

f. Reservoir Surface (Acres).

- (1) Top of dam - 26
- (2) Spillway crest - 17

g. Dam.

- (1) Type - Earth embankment
- (2) Length - 700 feet ±
- (3) Height - 17 feet ±
- (4) Top width - 14 feet
- (5) Side slopes - varies (see Plates 4 and 5)
- (6) Zoning - Unknown.
- (7) Impervious core - Unknown.
- (8) Cutoff - Unknown.
- (9) Grout curtain - Unknown.

h. Diversion and Regulating Tunnel - None.

i. Spillway.

(1) Type - Concrete free overfall.

(2) Crest length - 67.0 feet.

(3) Crest elevation - 901.5 feet m.s.l.

(4) Gates - None.

(5) Upstream channel - Not applicable.

(6) Downstream channel - 28 feet bottom width concrete trapezoidal.

j. Regulating Outlets - None operating. An intake structure is located in the lake. A concrete box structure is located at the downstream toe which houses a hand-operated valve and a pump. The two structures seem to be connected by an unknown size pipe, used in the past for water supply. The system is presently not in working condition and no plans are being made for its rehabilitation.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data were unavailable.

2.2 CONSTRUCTION

Construction records were unavailable, however, the owners estimated that the dam was built in about 1920.

2.3 OPERATION

The maximum recorded loading on the dam is unknown.

2.4 GEOLOGY

Bedrocks in the site area consist of limestones and shales of the Kansas City Group and shales and sandstones of the Pleasanton Group. The overburden soils generally consist of silt loam and silty clays of loessial and residual origin respectively. Soils in the watershed area consist of Grundy, Polo-Sogn, and Dennis-Roseland soils. Grundy soils were formed from loess and tend to lie on broad and gently sloping divides. The Polo-Sogn soil association lies downslope from Grundy soils and are over limestone. Polo soils have over five feet of loess over residual silty clay and shales or weathered limestone. Sogn soils have limestone at shallow depths and lie on steeper slopes than Polo. The lower part of the watershed area consists of residual soils of the Dennis-Roseland soil Association. Dennis soils lie on the more gently sloping areas whereas Roseland soils lie on short steep slopes where soft shales are at shallow depths. The above Soil Association information was obtained from "Regional Soil Guide", published by the Mid-America Regional Council in December of 1976. It is likely that along the Town Creek the surface deposits are of alluvial origin. No rock outcrops were observed in the site area of the dam.

2.5 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 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 Lake Luna Dam was made on 12 April 1979. The inspection team included professional engineers with experience in dam design and construction, hydrology - hydraulic engineering, and geotechnical 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. Portions of the downstream slope are unprotected from erosion. The upstream slope protection consists of large pieces of concrete and stone block rubble directly over the embankment material. The absence of a suitable bedding layer between the embankment and the riprap is causing erosion by loss of fines through the voids in the riprap. There were trees and brush present on the dam. A manmade excavation (approximately 3 feet by 3 feet in area and 2 feet deep) was observed on the downstream slope, possibly dug by children or vandals. There was observed some areas of water ponding below the downstream toe at the time of the initial inspection. It was difficult at that time to say if it was from seepage because it had rained heavily on the day and the night prior to the initial inspection. On a subsequent visit to the dam, the previously noted areas of ponding were not evident, and therefore it is believed to be a surface drainage problem. Several small rodent holes were noted in the downstream slope.

c. Appurtenant Structures. The inspection team observed the following items pertaining to appurtenant structures. A concrete face overfall type spillway which was constructed near the left abutment appears in fair condition. The spillway is acting as a broad-crested weir. The spillway discharges into a concrete trapezoidal channel. The embankment slopes on both sides of the spillway are protected with concrete. This concrete embankment protection and the right wing wall has cracked and moved in places, but no significant embankment erosion is evident. The concrete discharge channel is being eroded on the downstream end. The erosion is caused by loss of support due to undercutting and cracking of concrete. Several feet of the channel have been lost by erosion and the erosion will continue to progress upstream unless preventive measures are taken. However, the existing channel is several feet long and the erosion process is slow. Therefore, it should not be a cause for immediate concern.

The outlet works for the Lake Luna consist of a concrete inlet structure in the lake and an outlet structure located near the downstream toe which houses the hand-operated valve and a pump. The size

and type of the water pipe connecting the two structures are unknown. It appears that the valve and the pump are not operable and have been abandoned. At the time of the inspection there was 2 to 3 feet of water in the structure submerging both the pump and the valve. The cover on the structure remains unlocked and poses a potential hazard to children.

d. Reservoir Area. Topography of the contributing watershed is characterized by gently rolling hills of low relief. The watershed is primarily comprised of grassland and woods. No slides or excessive erosion due to wave action were observed along the shore of the reservoir. An old railroad trestle which crossed the upper reaches of the lake at one time has been removed. A small pond exists directly upstream of Lake Luna and below the City Lake dam, which may have been formed by borrowing operations for construction of the City Lake dam. The water in the pond was a few inches above water level in Lake Luna at the time of inspection.

e. Downstream Channel. The channel below the spillway was full of water at the time of inspection and was overflowing an existing bituminous paved road because of an apparent partial blockage of the culvert below the road.

3.2 EVALUATION

The various deficiencies observed at the time of the inspection are not believed to represent any immediate safety hazard. They do, however, warrant repair and future monitoring and control.

(1) Undercutting and eroding of the downstream end of the spillway discharge channel should be repaired so that further deterioration of the channel is prevented.

(2) Erosion on the upstream side of the embankment is due to loss of fines in the large riprap. If this condition is not corrected, the erosion will only promote additional damages.

(3) Tree and brush growth on the embankment slopes should be controlled and consideration should be made for the removal of large trees and their root systems. If large water seeking roots should someday rot and decay, these roots could be channels for piping. Large brush growth on the embankments prevents inspection and kills the smaller grasses whose roots are more effective in protecting the surface soil of the slope. Brush growth could also hide the existence of animal burrowings.

(4) Presence of man- or animal-made excavation on the downstream slope will endanger the integrity of the dam.

(5) The cover to the outlet structure should be locked at all times. When left open it presents a potential safety hazard.

(6) The ponding water at the toe of the dam was believed to be caused from surface runoff. Proper drainage should be made so that this water will no longer collect at the toe.

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. According to the City of Harrisonville the dam is inspected periodically by City Personnel.

4.3 MAINTENANCE OF OPERATING FACILITIES

The operating facilities appear to be abandoned.

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

The erosion on the upstream side of the dam, excavation on the downstream slope, a growth of trees and vegetation on the dam, and undercutting and erosion of the downstream end of the spillway discharge channel 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 Harrisonville Quadrangle Map. The spillway and dam layouts are from surveys made during the inspection.

c. Visual Observations.

(1) The spillway is in fair condition. The discharge channel is being undermined by erosion on the downstream end. Measures to prevent further undermining and erosion are needed.

(2) No facilities are available which could serve to draw down the pool. It is unknown if the abandoned water supply facilities can be made operable for drawdown purposes.

d. Overtopping Potential. The spillway will not pass the probable maximum flood without overtopping the dam. The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The spillway will pass 10 percent of the probable maximum flood without overtopping the dam. This flood is smaller than the 100-year flood estimated to be 3,400 cfs developed by a 24 hour, 100-year rainfall but is greater than the 10-year flood estimated to be 1,760 cfs developed by a 24 hour, 10-year rainfall. According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, a high hazard dam of small size should pass 50 to 100 percent of the probable maximum flood. Considering the fact that there are eight homes within one mile downstream of the dam, 100 percent of the probable maximum flood is the appropriate spillway design flood. The portion of the estimated peak discharge of the probable maximum flood overtopping the dam would be 13,900 cfs of the total discharge from the reservoir of 15,300 cfs. The estimated duration of overtopping is 6.4 hours with a maximum height of 3.2 feet. The portion of the estimated peak discharge of 50 percent of the probable maximum flood overtopping the dam would be 6,050 cfs of the total discharge of the reservoir of 7,450 cfs. The estimated duration of overtopping is 5.1 hours with a maximum height of 1.9 feet. The portion of the estimated peak discharge of the 100-year flood overtopping the dam would be 1,440 cfs of the total discharge from the reservoir at 2,840 cfs. The estimated duration of overtopping is 1.1 hours with a maximum height of 0.8 feet. Failure of upstream water impoundments shown on the 1954 revised USGS map would have a significant

impact on the hydrologic or hydraulic analysis. Due to the erodability of the embankment material and the lack of erosion protection, overtopping could result in failure of the embankment.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately one mile downstream of the dam. There are eight homes, two buildings, U.S. Highway 71, and the St. Louis/San Francisco and the Missouri Pacific railroads crossing downstream of the dam which could be severely damaged and lives could be lost should failure of the dam occur.

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. Detailed seepage and stability analysis should be performed as required by the guidelines.
- 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. An assessment of the seismic stability should be included as part of the stability analysis required by the guidelines.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items noted during the visual inspection by the inspection team which should be monitored or controlled are erosion of the upstream embankment slope, undercutting and erosion of the concrete discharge channel and an uncontrolled stand of brush and trees on the embankment slopes. The existing manmade excavation on the downstream slope should be backfilled and such excavations should be prevented in future.

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. However, seepage and stability analyses are needed to satisfy the requirements of the guidelines.

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. The Phase I investigation does not raise any serious questions relating to the safety of the dam or identify any serious dangers that would require a Phase II investigation.

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

7.2 REMEDIAL MEASURES

a. Alternatives. The present spillway has the capacity to pass 10 percent of the probable maximum flood without overtopping the dam. In order to pass 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 or additional spillway capacity provided by constructing an emergency spillway.

b. O&M Maintenance and Procedures. The following O&M maintenance and procedures should be implemented to correct the deficiencies observed at the time of inspection. If left unattended or unrepaired each could ultimately become a potential source of failure.

(1) The upstream slope should be inspected periodically for loss of fines and erosion through the riprap. If erosion continues, properly designed bedding layers should be provided below the riprap.

(2) The manmade excavation on the back slope of the embankment should be repaired by filling and compacting to original specifications. The grass cover should be reestablished.

(3) 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 spillway discharge channel should be protected from erosion and undermining.

(5) The control and prevention of rodent activity should be considered. Animal burrows could lead to a piping failure. The holes should be filled and compacted to the original specification.

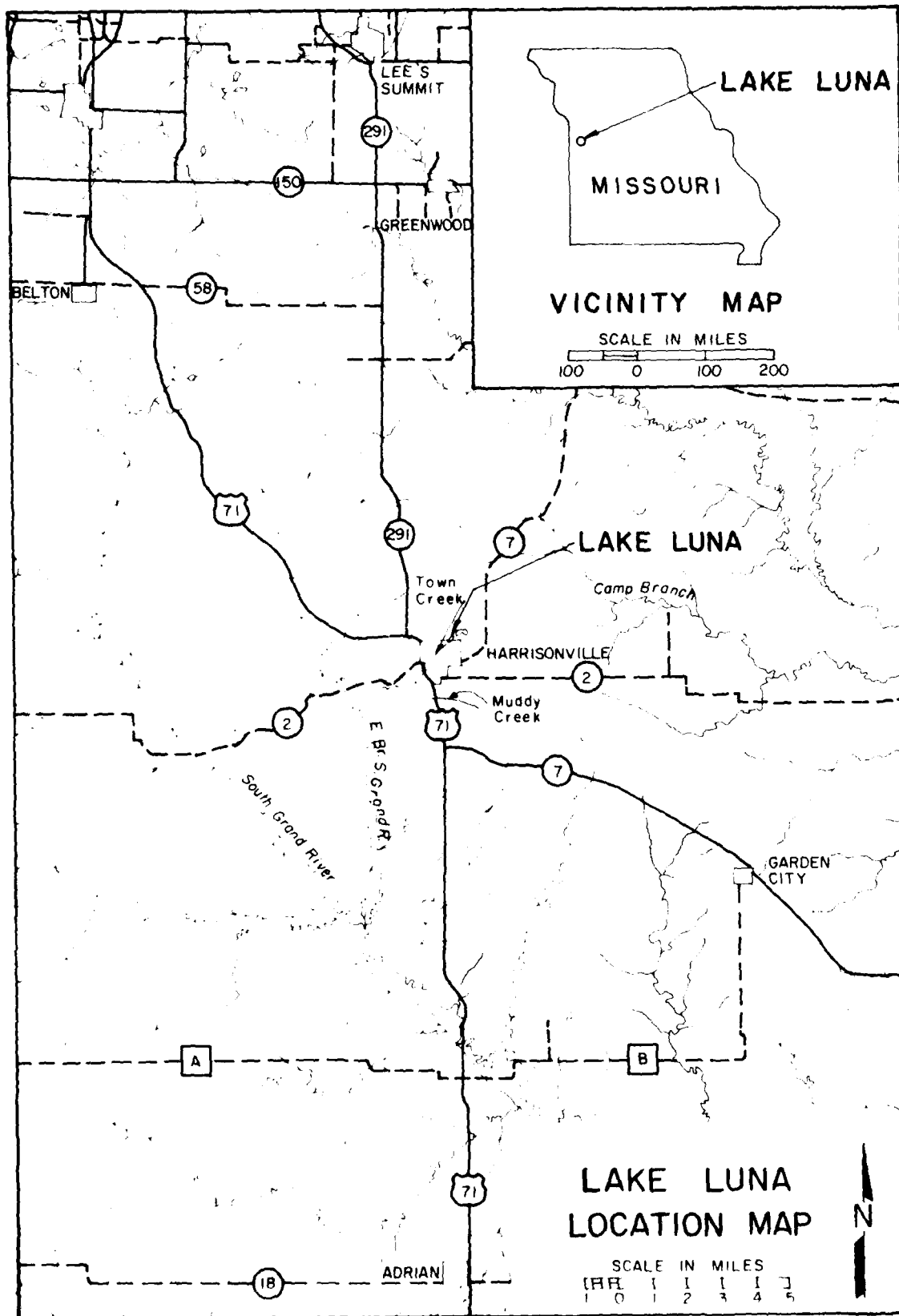
(6) Check the downstream face of the dam periodically for seepage and stability problems. If seepage flows are observed or sloughing on the downstream embankment slope is noted, the dam should immediately be inspected, and the condition evaluated, by an engineer experienced in design and construction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

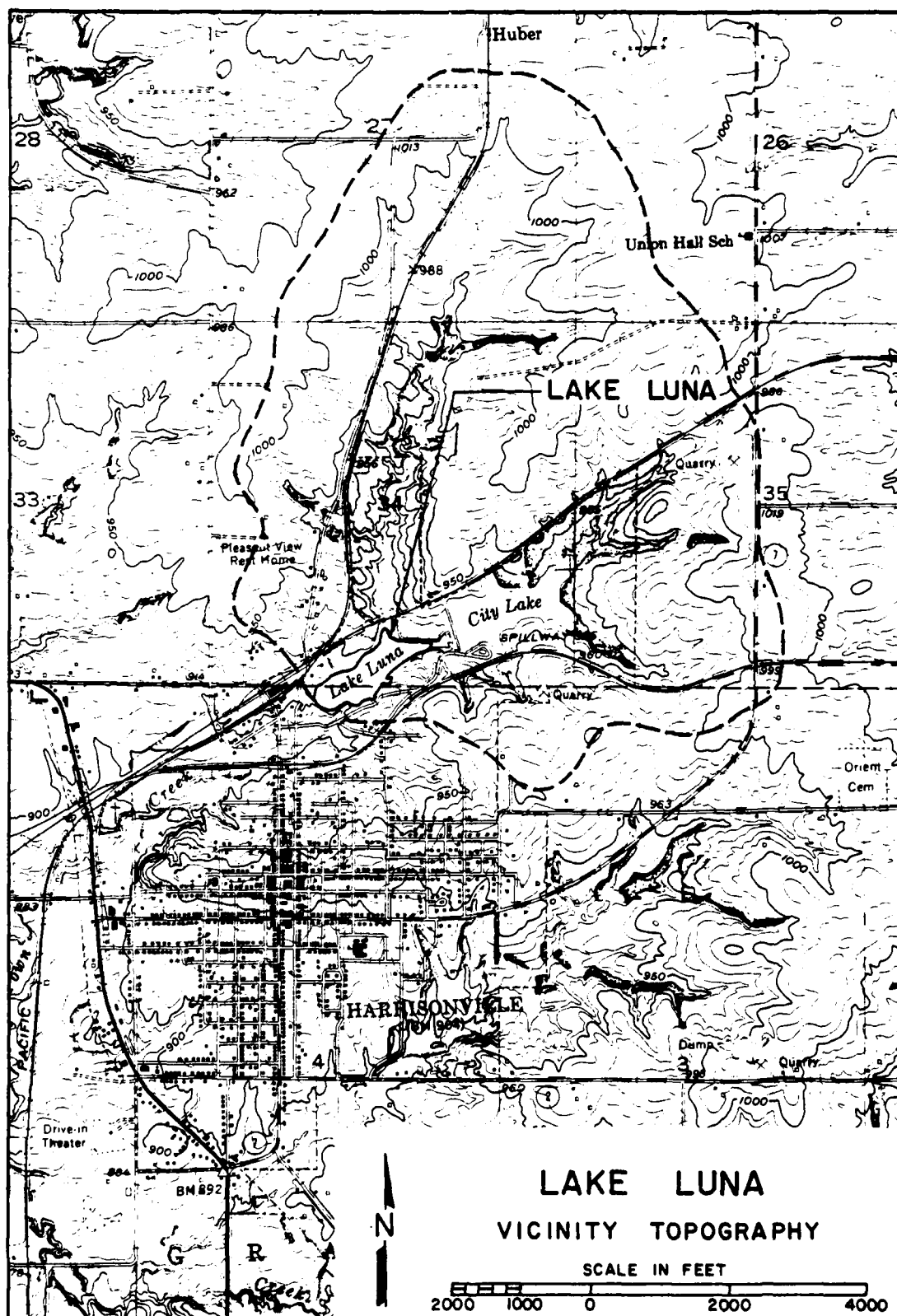
(7) The outlet structure located near the downstream toe is an extreme safety hazard as long as it remains unlocked. The cover should be secured and locked to prevent unauthorized entry into the pump pit.

(8) An investigation of the water supply intake and outlet structures should be performed by a engineer experienced in the design and construction of such structures. This would be to further identify the present operating condition of this system and its useage as an emergency lake drawdown facility.

(9) Seepage and stability analysis should be performed by a professional engineer experienced in the design and construction of dams.

(10) A detailed inspection of the dam should be made periodically 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.





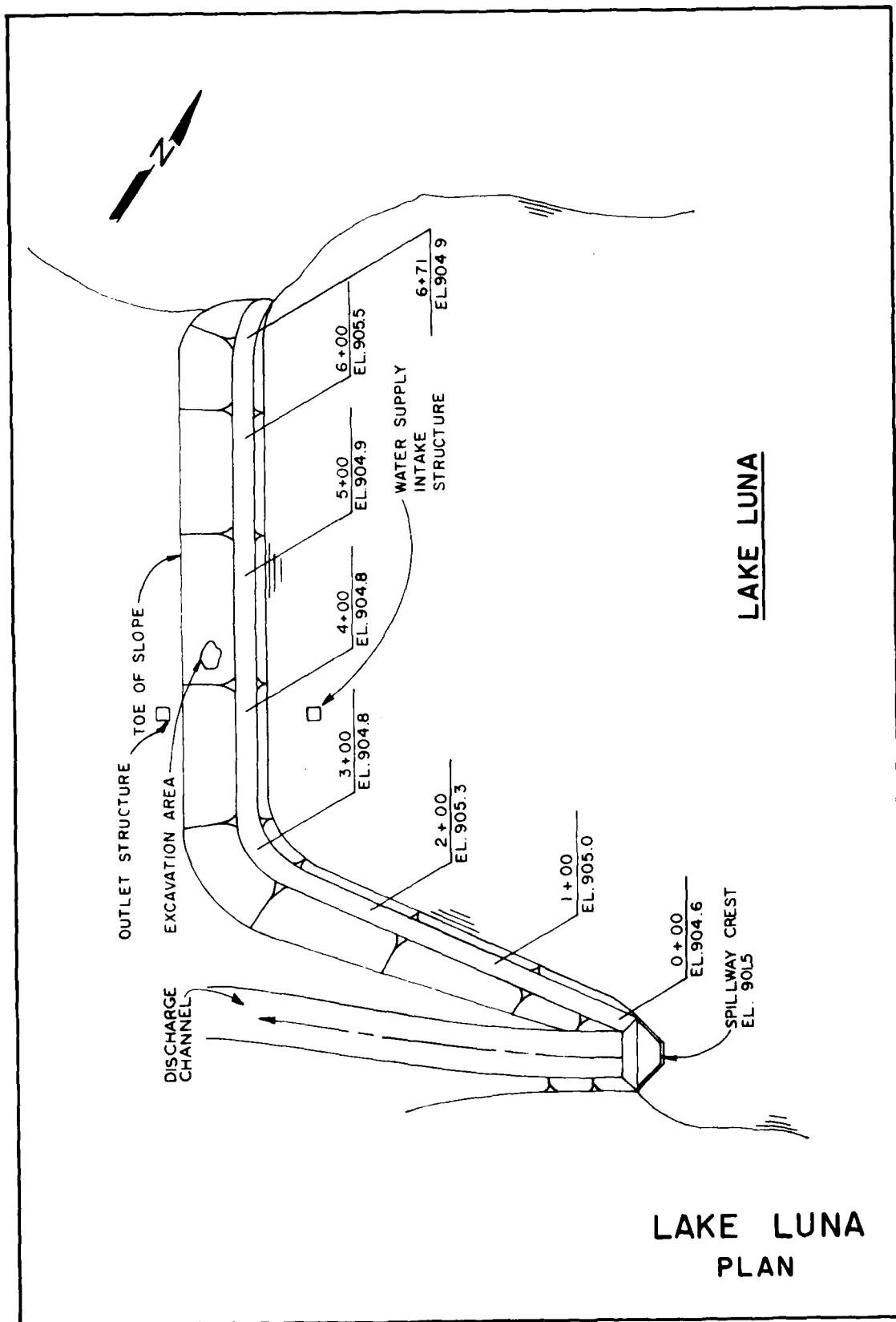
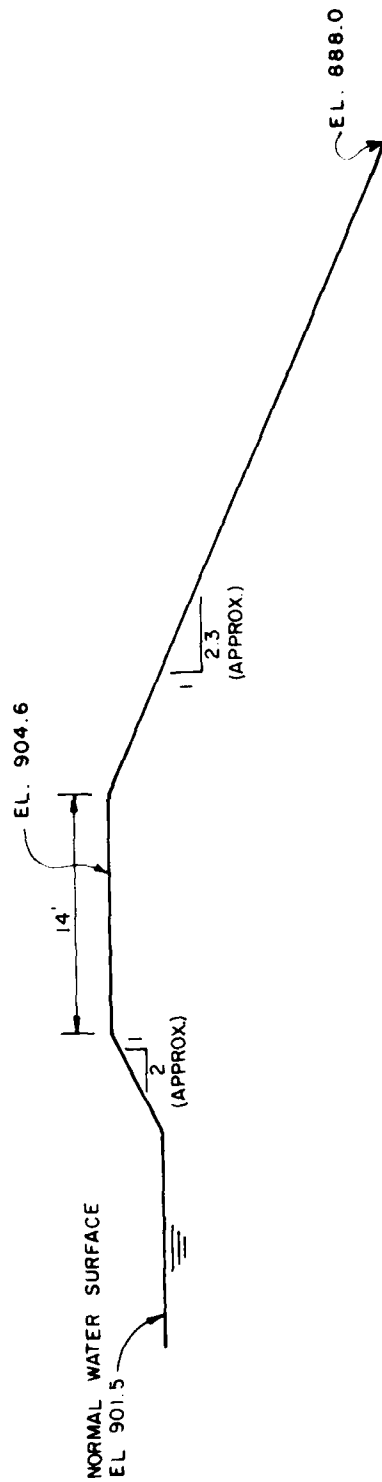
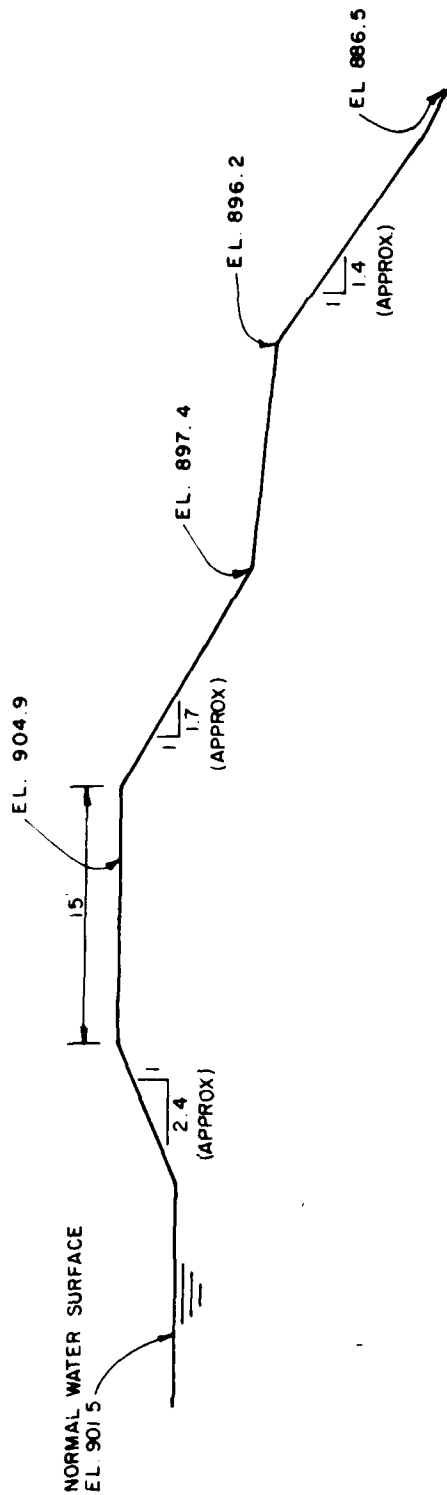


PLATE 3



SECTION TAKEN NEAR STATION 4+00
(TYPICAL BETWEEN STATIONS 3+50 to 6+50)

LAKE LUNA
TYPICAL SECTION



SECTION TAKEN NEAR STATION 1+50
(TYPICAL BETWEEN STATIONS 0+50 to 2+50)

LAKE LUNA
TYPICAL SECTION

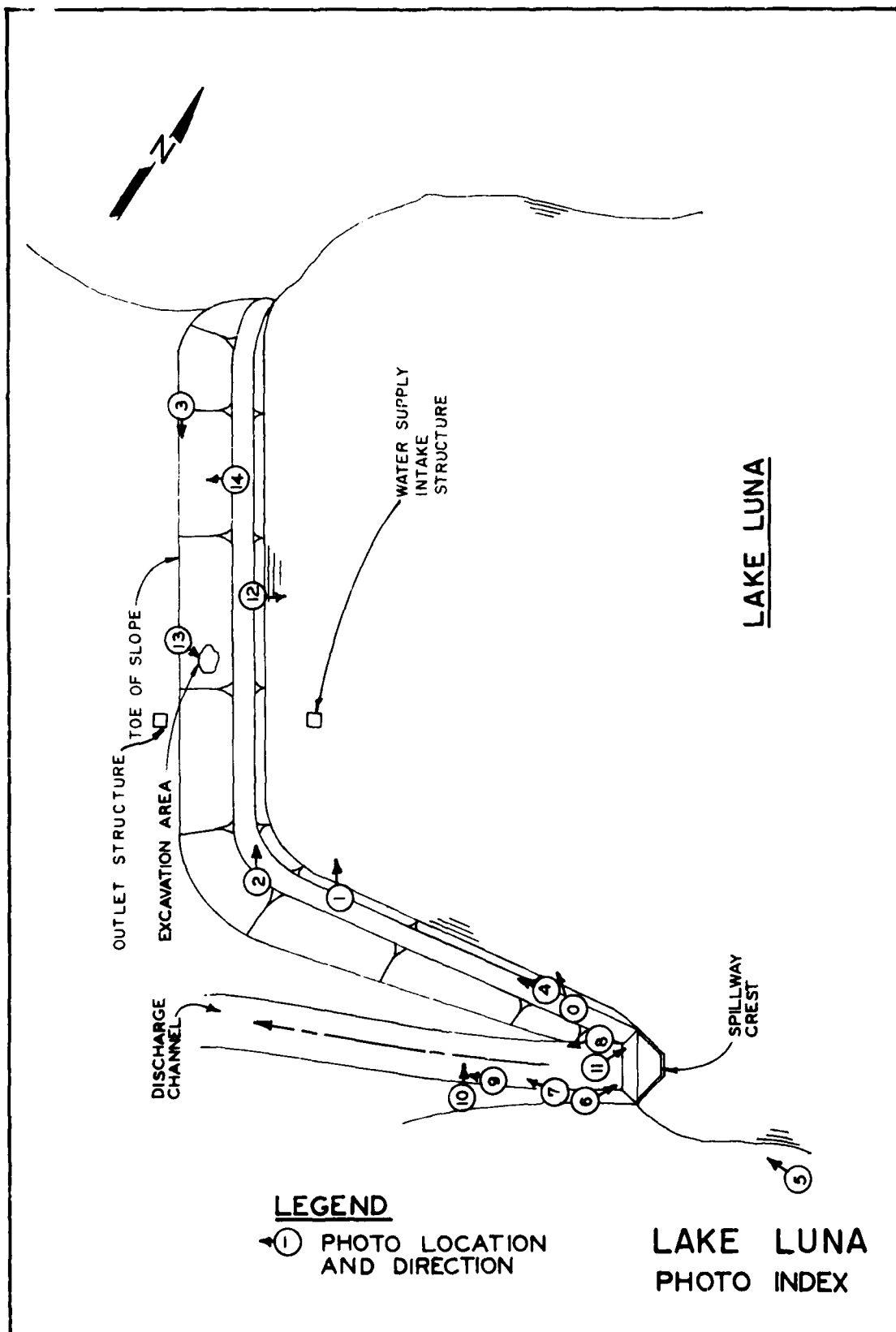




PHOTO 1: UPSTREAM FACE OF DAM



PHOTO 2: CREST OF DAM



PHOTO 3: DOWNSTREAM SLOPE OF DAM



PHOTO 4: RIPRAP ON UPSTREAM FACE



PHOTO 5: SPILLWAY APPROACH

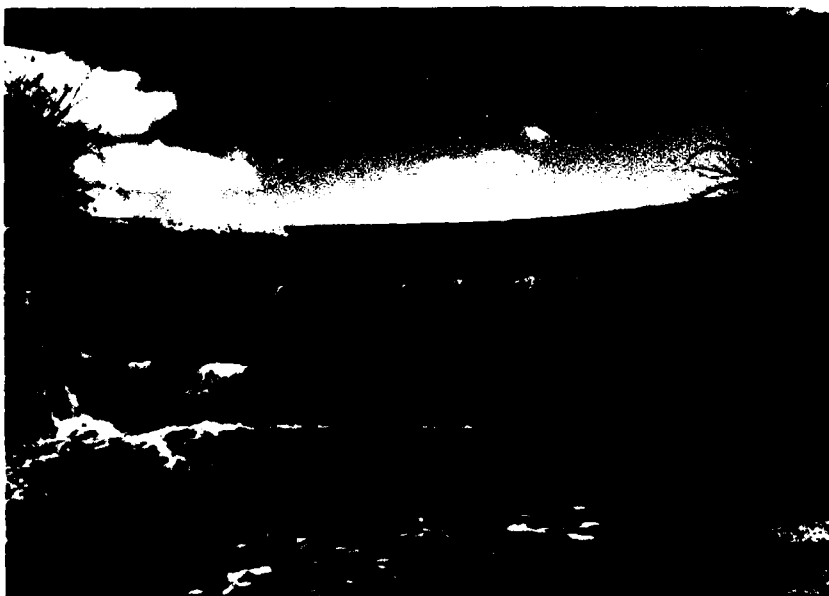


PHOTO 6: SPILLWAY LOOKING UPSTREAM



PHOTO 7: SPILLWAY EXIT CHANNEL

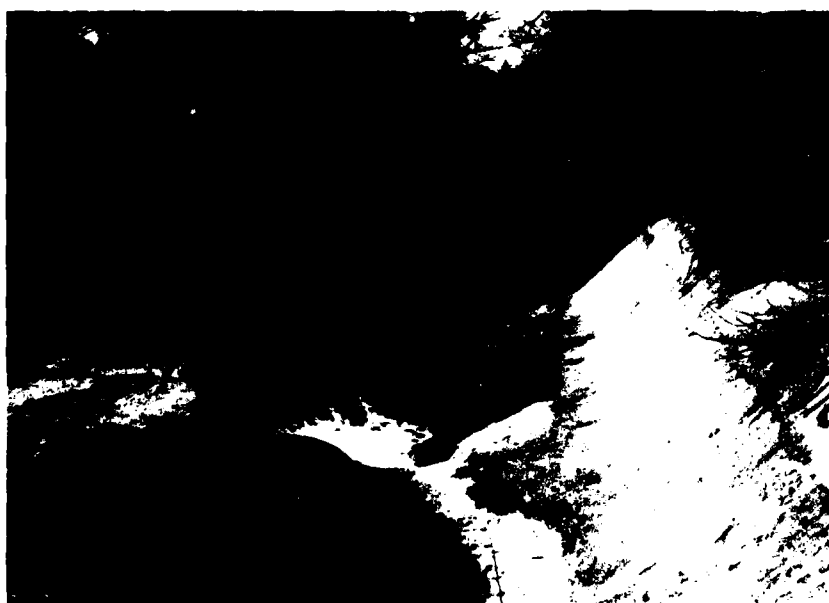


PHOTO 8: CHANNEL BELOW SPILLWAY LOOKING DOWNSTREAM



PHOTO 9: CHANNEL DOWNSTREAM FROM SPILLWAY



PHOTO 10: DOWNSTREAM END OF SPILLWAY EXIT CHANNEL



PHOTO 11: RIGHT WING WALL BELOW SPILLWAY



PHOTO 12: WATER SUPPLY INTAKE STRUCTURE



PHOTO 13: MANMADE EXCAVATION ON EMBANKMENT SLOPE



PHOTO 14: DRAINAGE PROBLEM AT RIGHT TOE OF DAM

C

APPENDIX A
HYDROLOGIC COMPUTATIONS

C

HYDROLOGIC COMPUTATIONS

1. The Soil Conservation Service (SCS) dimensionless unit hydrograph (1) and HEC-1 (2) were used to develop the inflow hydrographs (see Plates A-1, A-2, A-3 and A-4), 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 - 25.0

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 = 1,310 acres.

c. Time of concentration: $T_c = (11.9 \times L^3/H)^{0.385} = 0.82$ hours = 49 minutes ($L = 1.82$ miles = length of longest watercourse in miles, $H = 120$ feet = elevation difference in feet) (3)

d. The Soil Associations in this watershed are mainly Grundy, Polo-Sogn, and Dennis-Roseland (4).

e. Losses were determined in accordance with SCS methods for determining runoff using a curve number of 89 and antecedent moisture condition III. The hydrologic soil groups in the basin were B, C, and D (1).

f. The 100-year frequency inflow hydrograph was developed using a curve number of 76 and antecedent moisture condition II. The 100-year, 24 hour rainfall totaled 7.7 inches was provided by the Corps of Engineers, St. Louis District.

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

Broad-crested weir equation:

$$Q = CLH^{1.5} \quad (C = 3.0, L = 67.0 \text{ feet, } H \text{ is the head on weir}) \quad (3).$$

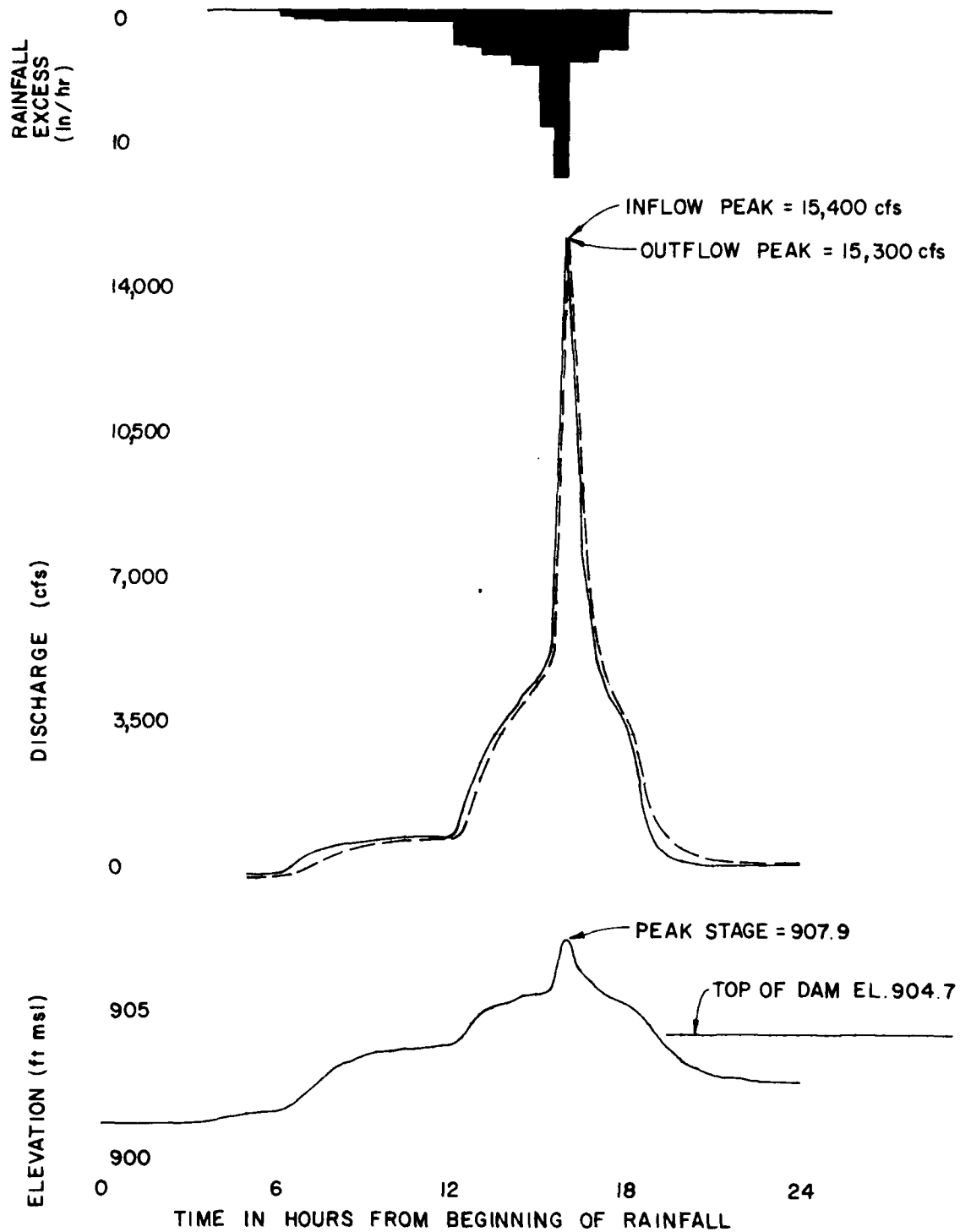
Discharge rates over the top of the dam are also based on the broad-crested weir equation:

$$Q = CLH^{1.5} \quad (C = 2.7, L = 50 \text{ to } 880 \text{ feet}).$$

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.

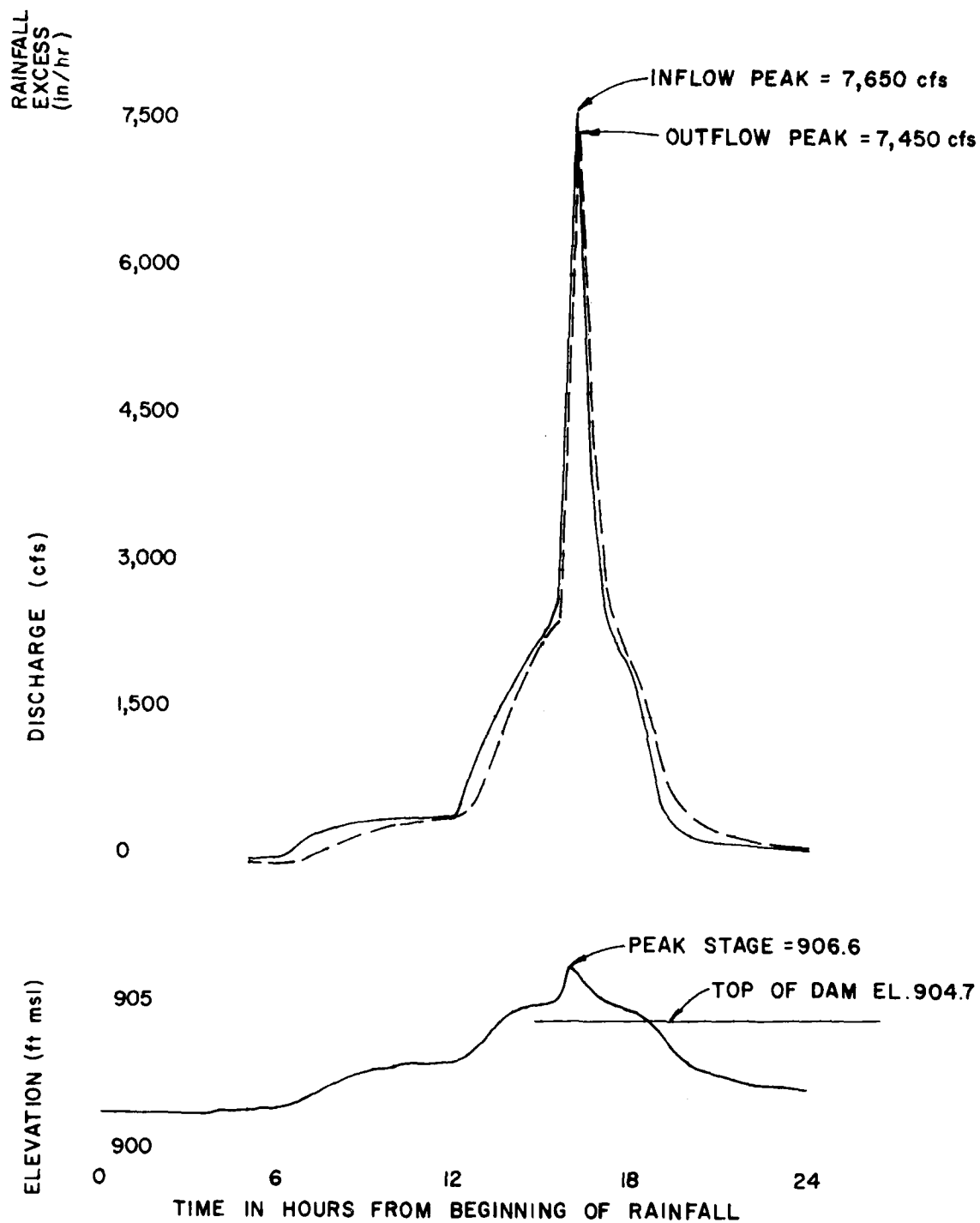
4. Floods are routed through the spillway using HEC-1, modified Puls to determine the capability of the spillway. Inflow and outflow hydrographs are shown on Plates A-1, A-2, A-3 and A-4.

- (1) U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.
- (2) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version, July 1978, Davis, California.
- (3) U.S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, 1974, Washington, D.C.
- (4) Mid-America Regional Council, Regional Soil Guide, Kansas City, Missouri, March 1976.

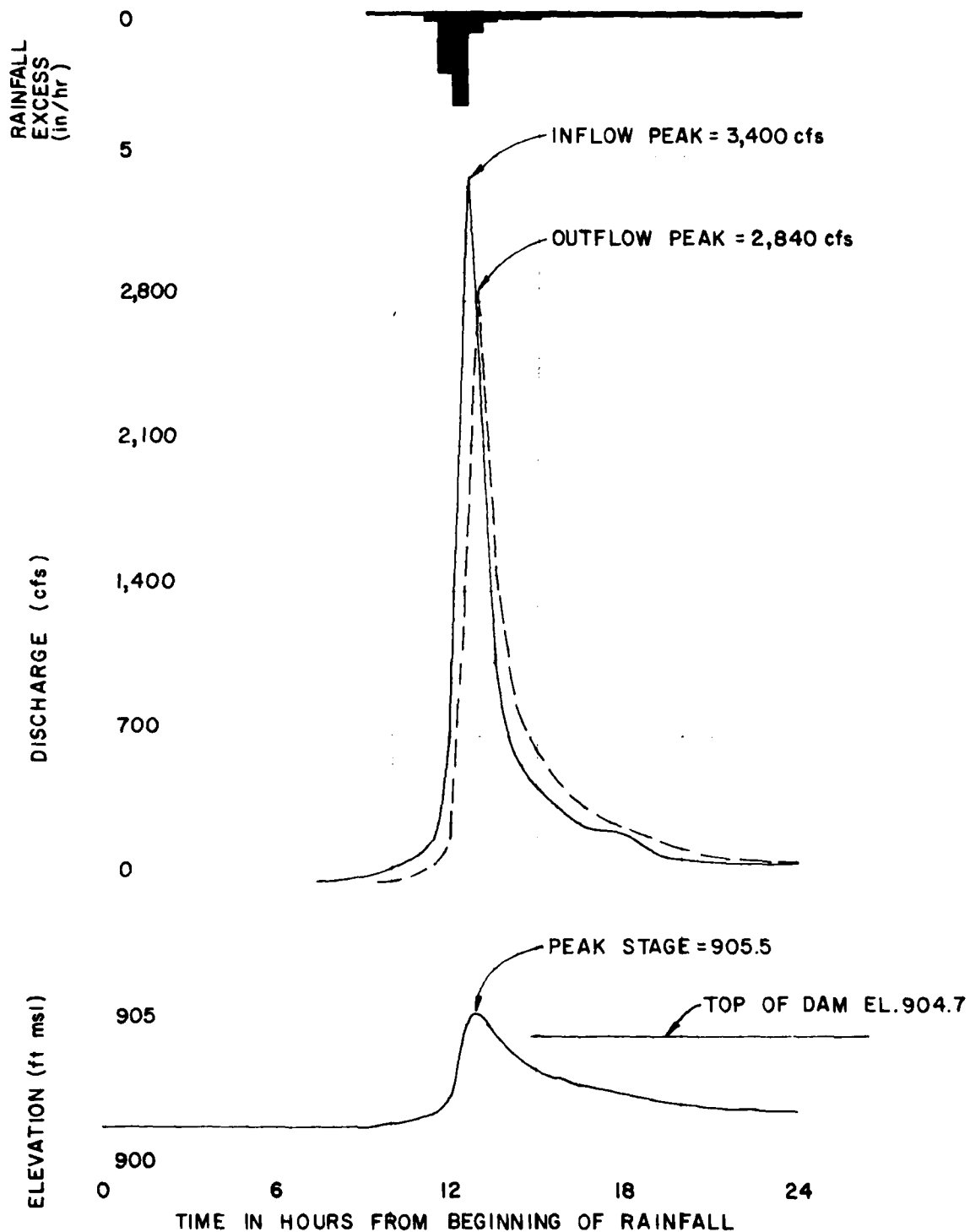


LAKE LUNA
PROBABLE MAXIMUM FLOOD
HYETOGRAPH, HYDROGRAPHS
AND STAGE - TIME CURVE

PLATE A-1

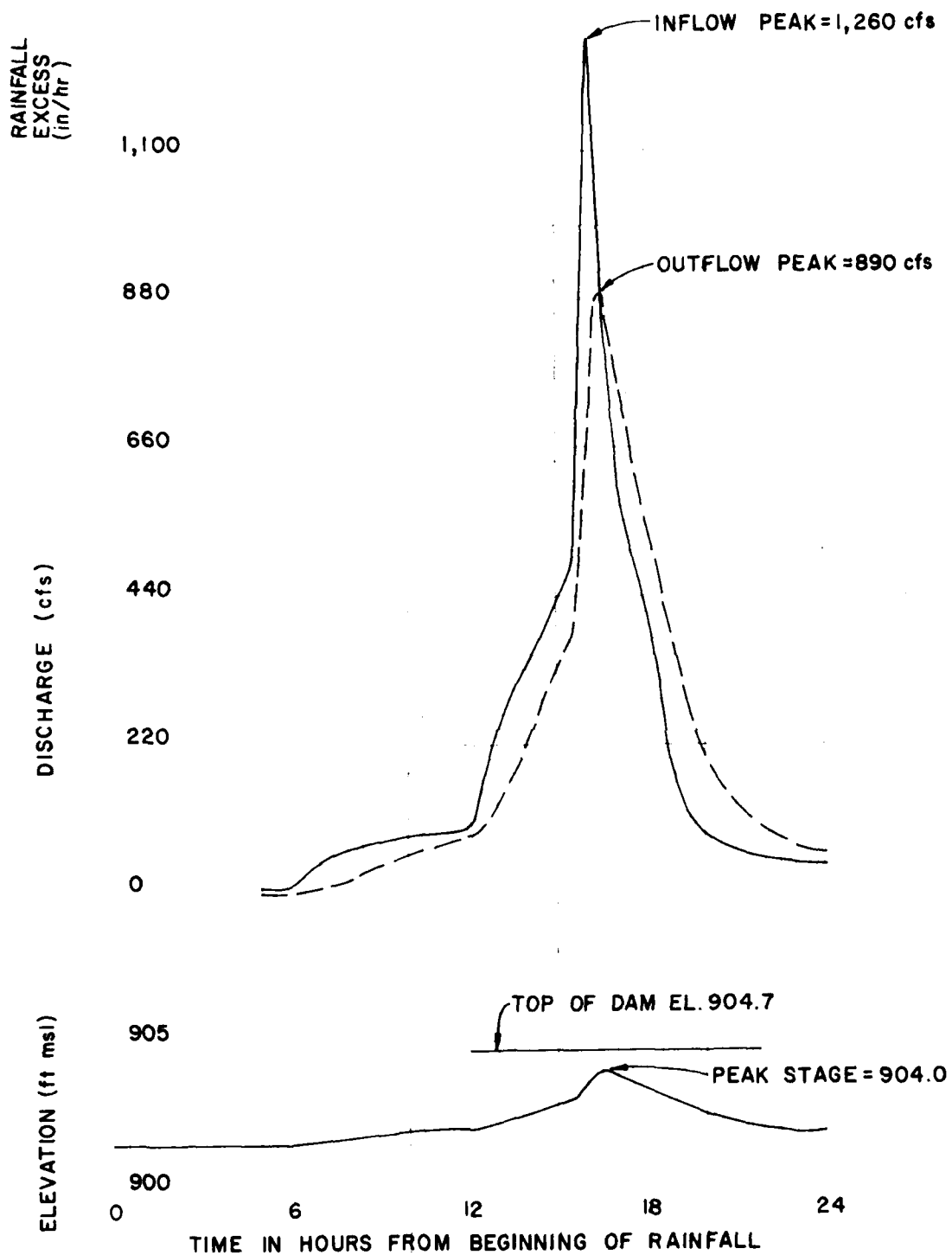


LAKE LUNA
50% PROBABLE MAXIMUM FLOOD
HYETOGRAPH, HYDROGRAPHS
AND STAGE - TIME CURVE



LAKE LUNA
100 YEAR FREQUENCY FLOOD
HYETOGRAPH, HYDROGRAPHS
AND STAGE - TIME CURVE

PLATE A-3



LAKE LUNA
10% PROBABLE MAXIMUM FLOOD
HYETOGRAPH, HYDROGRAPHS
AND STAGE - TIME CURVE

PLATE A-4

.....
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78
.....

A1 MISSOURI DAM INSPECTION PROGRAM
A2 ST LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
A3 CITY LAKE I.D.#20314 & LAKE LUNA I.D.#20076

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K1 CITY LAKE (24HR. PROBABLE MAXIMUM RUNOFF)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1970	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1971	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1972	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1973	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1974	1	2	3	4</																																																																																																

P	25.9	101	130	-1	-39
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ROUTING THROUGH CITY LAKE RESERVOIR

[illegible]

928.6	928.0	927.5	927.0	926.5	926.4	926.3	926.2	926.1	926.0	926.1
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Year	1950	1951	1952	1953	1954	1955
Population	1,000,000	1,050,000	1,100,000	1,150,000	1,200,000	1,250,000
Area (sq. miles)	100	100	100	100	100	100
Population density	10,000	10,500	11,000	11,500	12,000	12,500

12010	21	12	459	918	172	622
12011	21	12	459	918	172	622
12012	21	12	459	918	172	622
12013	21	12	459	918	172	622
12014	21	12	459	918	172	622
12015	21	12	459	918	172	622
12016	21	12	459	918	172	622
12017	21	12	459	918	172	622
12018	21	12	459	918	172	622
12019	21	12	459	918	172	622
12020	21	12	459	918	172	622
12021	21	12	459	918	172	622
12022	21	12	459	918	172	622
12023	21	12	459	918	172	622
12024	21	12	459	918	172	622
12025	21	12	459	918	172	622
12026	21	12	459	918	172	622
12027	21	12	459	918	172	622
12028	21	12	459	918	172	622
12029	21	12	459	918	172	622
12030	21	12	459	918	172	622
12031	21	12	459	918	172	622
12032	21	12	459	918	172	622
12033	21	12	459	918	172	622
12034	21	12	459	918	172	622
12035	21	12	459	918	172	622
12036	21	12	459	918	172	622
12037	21	12	459	918	172	622
12038	21	12	459	918	172	622
12039	21	12	459	918	172	622
12040	21	12	459	918	172	622
12041	21	12	459	918	172	622
12042	21	12	459	918	172	622
12043	21	12	459	918	172	622
12044	21	12	459	918	172	622
12045	21	12	459	918	172	622
12046	21	12	459	918	172	622
12047	21	12	459	918	172	622
12048	21	12	459	918	172	622
12049	21	12	459	918	172	622
12050	21	12	459	918	172	622
12051	21	12	459	918	172	622
12052	21	12	459	918	172	622
12053	21	12	459	918	172	622
12054	21	12	459	918	172	622
12055	21	12	459	918	172	622
12056	21	12	459	918	172	622
12057	21	12	459	918	172	622
12058	21	12	459	918	172	622
12059	21	12	459	918	172	622
12060	21	12	459	918	172	622
12061	21	12	459	918	172	622
12062	21	12	459	918	172	622
12063	21	12	459	918	172	622
12064	21	12	459	918	172	622
12065	21	12	459	918	172	622
12066	21	12	459	918	172	622
12067	21	12	459	918	172	622
12068	21	12				

550. 109. 607.

\$926.09

33928:0
30929:7

1	1	3	3
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OTHER AREA ABOVE LAKE LUNA (24HR. PROBABLE MAXIMUM RUNOFF)

1.327	120	130
25.0	101	130

1-69

2. 69.

1 7 2 1

K1 COMBINE HYDROGRAPHS - TOTAL INFLOW HYDROGRAPH TO LAKE LUNA (24HR. PMF)

15 1 1

ROUTING THROUGH LAKE LUNA RESERVOIR

$\frac{1}{\sqrt{2}}$

Year	1990	1991	1992	1993	1994	1995	1996
Value	901.5	901.7	902.0	902.5	903.2	903.9	904.5
Value	905.5	905.0	905.0	905.5	906.0		

44906.5	907.3	907.5	905.0	910.0	
45	0.018	71	201	446	803
					1310
					1713
					3926
					4807

15	0.0010	171	450	303	1173	2720	4801
16	0.0010	171	450	303	1173	2720	4801
17	0.0010	171	450	303	1173	2720	4801
18	0.0010	171	450	303	1173	2720	4801
19	0.0010	171	450	303	1173	2720	4801
20	0.0010	171	450	303	1173	2720	4801
21	0.0010	171	450	303	1173	2720	4801
22	0.0010	171	450	303	1173	2720	4801
23	0.0010	171	450	303	1173	2720	4801
24	0.0010	171	450	303	1173	2720	4801
25	0.0010	171	450	303	1173	2720	4801
26	0.0010	171	450	303	1173	2720	4801
27	0.0010	171	450	303	1173	2720	4801
28	0.0010	171	450	303	1173	2720	4801
29	0.0010	171	450	303	1173	2720	4801
30	0.0010	171	450	303	1173	2720	4801
31	0.0010	171	450	303	1173	2720	4801
32	0.0010	171	450	303	1173	2720	4801
33	0.0010	171	450	303	1173	2720	4801
34	0.0010	171	450	303	1173	2720	4801
35	0.0010	171	450	303	1173	2720	4801
36	0.0010	171	450	303	1173	2720	4801
37	0.0010	171	450	303	1173	2720	4801
38	0.0010	171	450	303	1173	2720	4801
39	0.0010	171	450	303	1173	2720	4801
40	0.0010	171	450	303	1173	2720	4801
41	0.0010	171	450	303	1173	2720	4801
42	0.0010	171	450	303	1173	2720	4801
43	0.0010	171	450	303	1173	2720	4801
44	0.0010	171	450	303	1173	2720	4801
45	0.0010	171	450	303	1173	2720	4801
46	0.0010	171	450	303	1173	2720	4801
47	0.0010	171	450	303	1173	2720	4801
48	0.0010	171	450	303	1173	2720	4801
49	0.0010	171	450	303	1173	2720	4801
50	0.0010	171	450	303	1173	2720	4801
51	0.0010	171	450	303	1173	2720	4801
52	0.0010	171	450	303	1173	2720	4801
53	0.0010	171	450	303	1173	2720	4801
54	0.0010	171	450	303	1173	2720	4801
55	0.0010	171	450	303	1173	2720	4801
56	0.0010	171	450	303	1173	2720	4801
57	0.0010	171	450	303	1173	2720	4801
58	0.0010	171	450	303	1173	2720	4801
59	0.0010	171	450	303	1173	2720	4801
60	0.0010	171	450	303	1173	2720	4801
61	0.0010	171	450	303	1173	2720	4801
62	0.0010	171	450	303	1173	2720	4801
63	0.0010	171	450	303	1173		

150.0 247.

3E901.5 910.

23901:3
23906:5
23904:7

κ 99

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

OPERATION	STATION	AREA	PLAN	RATIO	RATIOS APPLIED TO FLOWS								
					1	2	3	4	5	6	7	8	9
					.10	.15	.20	.25	.30	.40	.45	.50	1.00
HYDROGRAPH AT	1	.72	1	763.	1144.	1525.	1906.	2268.	3050.	3431.	3813.	7625.	
	(	1.86)	(	21.59)	(43.18)	(53.48)	(64.78)	(86.37)	(97.16)	(107.96)	(118.75)	(237.50)	
ROUTED TO	2	.72	1	311.	531.	787.	1121.	1514.	2325.	2732.	3102.	6436.	
	(	1.86)	(	8.82)	(15.05)	(22.28)	(31.73)	(42.88)	(65.63)	(77.36)	(87.84)	(182.26)	
HYDROGRAPH AT	3	1.33	1	954.	1431.	1908.	2395.	2861.	3815.	4292.	4769.	9538.	
	(	3.44)	(	27.01)	(40.51)	(54.02)	(67.52)	(81.03)	(108.04)	(121.54)	(135.04)	(270.09)	
2 COMBINED	4	2.05	1	1264.	1962.	2696.	3505.	4376.	6034.	6852.	7650.	15446.	
	(	5.30)	(	35.79)	(55.56)	(76.29)	(99.25)	(123.91)	(170.87)	(196.03)	(216.61)	(433.22)	
ROUTED TO	5	2.05	1	887.	1521.	2418.	3308.	4150.	5861.	6559.	7452.	15307.	
	(	5.30)	(	25.12)	(43.06)	(68.48)	(93.69)	(117.53)	(165.96)	(188.56)	(211.05)	(433.45)	

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1

ELEVATION STORAGE OUTFLOW	INITIAL VALUE 901.50 0. 0.	SPILLWAY CREST 901.50 0. 0.	TOP OF DAM 904.70 93. 1411.

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	FAILURE HOURS
.10	904.02	0.00	73.	827.	0.00	16.50	0.00
.15	904.51	.11	96.	1521.	.42	16.42	0.00
.20	905.29	.59	110.	2419.	1.17	16.25	0.00
.25	905.60	.90	119.	3308.	1.75	16.17	0.00
.30	905.83	1.13	126.	4150.	2.33	16.08	0.00
.40	906.23	1.53	137.	5861.	4.08	16.03	0.00
.45	906.40	1.70	142.	6659.	4.67	16.08	0.00
.50	906.56	1.86	147.	7453.	5.08	16.08	0.00
1.00	907.86	3.16	185.	15307.	6.42	16.00	0.00

A1 MISSOURI DAM INSPECTION PROGRAM
A2 ST LOUIS DISTRICT US ARMY CORPS OF ENGINEERS
A3 CITY LAKE I.D.#20314 L LAKE LUNA I.D.#20076

[illegible]

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102
103
104

SE901.5 910.
SE901.5
SE904.7
K 99

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

HYDROGRAPH AT		1	PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
			1989.	315.	94.	94.	.72
		(	56.32)(	8.91)(	2.66)(	2.66)(	1.86)
ROUTED TO		2	891.	297.	89.	89.	.72
		(	25.22)(	8.41)(	2.53)(	2.53)(	1.86)
HYDROGRAPH AT		3	2523.	579.	172.	172.	1.33
		(	71.44)(	16.40)(	4.87)(	4.87)(	3.44)
2-COMBINED		4	3398.	873.	261.	261.	2.05
		(	96.21)(	24.71)(	7.40)(	7.40)(	5.30)
ROUTED TO		5	2863.	843.	253.	253.	2.05
		(	80.50)(	23.87)(	7.16)(	7.16)(	5.30)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1

ELEVATION	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
STORAGE	901.50	901.50	904.70
OUTFLOW	0.	0.	93.
	0.	0.	1411.

RATIO OF PRF	MAXIMUM RESERVOIR U.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
0.00	905.47	.77	115.	2843.	1.08	12.83	0.00

END

DATE
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