01 Jan 1980

Phase 1 Inspection Report: National Dam Safety Program. Mississippi - Kaskaskia - St. Louis Basin. Carden Lake Dam, Crawford County, Missouri

Anderson Engineering, Inc., Springfield, Missouri

Hanson Engineers, Inc., Springfield, Illinois

MISSISSIPPI-KASKASKIA-ST. LOUIS RIVER BASIN

CARDEN LAKE DAM

CRAWFORD COUNTY, MISSOURI

MO 30987

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
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St. Louis District

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

FOR: STATE OF MISSOURI

NOVEMBER, 1980

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

REPLY TO
ATTENTION OF

SUBJECT: Carden Lake Dam, MO I.D. No. 30987

This report presents the results of field inspection and evaluation of the Carden Lake Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED
Chief, Engineering Division

4 MAR 1981
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

5 MAR 1981
Date

MISSISSIPPI-KASKASKIA-ST. LOUIS RIVER BASIN

CARDEN LAKE DAM

CRAWFORD COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30987

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared By

Anderson Engineering, Inc., Springfield, Missouri
Hanson Engineers, Inc., Springfield, Illinois

Under Direction Of

St. Louis District, Corps of Engineers

For

Governor of Missouri

DECEMBER 1980

PHASE 1 REPORT
NATIONAL DAM SAFETY PROGRAM
SUMMARY

Name of Dam:	Carden Lake Dam
State Located:	Missouri
County Located:	Crawford
Stream:	Tributary of Cherry Valley Creek
Date of Inspection:	6 October 1980

Carden Lake Dam was inspected by an interdisciplinary team of engineers from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. 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 they have been developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, the St. Louis District, Corps of Engineers has determined that this dam is in the high hazard potential classification, which means that loss of life and appreciable property loss could occur if the dam fails. The estimated damage zone extends approximately 2 miles downstream of the dam. Located within this zone are one trailer, three dwellings, and a building. The existence of these downstream features was verified during the field inspection and at the time the aerial photographs were taken. The dam is in the small size classification, since it is greater than 25 ft high but less than 40 ft high, and the maximum storage capacity is greater than 50 acre-ft but less than 1,000 acre-ft.

Our inspection and evaluation indicates that the spillway does meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will pass 50 percent of the Probable Maximum Flood without overtopping. 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 guidelines require that a dam of small size with a high downstream hazard potential pass 50 to 100 percent of the PMF. Considering the small height of the dam and the low reservoir storage capacity, 50 percent of the PMF has been determined to be the appropriate spillway design flood. The 1 percent probability flood will not overtop the dam. The 1 percent probability flood is one that has a 1 percent chance of being exceeded in any given year.

Deficiencies visually observed by the inspection team were: (1) tree and brush growth on both the upstream and downstream

face; (2) lack of wave protection for the upstream embankment face; (3) lack of a non-erodible spillway conrol section; (4) an apparent seepage area near the left downstream abutment-dam contact; and (5) lack of access to the buried drawdown pipe valve. Another deficiency was the lack of seepage and stability analysis records.

It is recommended that the owners take the necessary action promptly to correct the deficiencies reported herein. A detailed discussion of these deficiencies is included in the following report.

Steve Brady, P.E. (AEI)

Tom Beckley, P.E. (AEI)

Gene Wertepny, P.E. (HEI)

Dan Kerns, P.E. (HEI)

AERIAL VIEW OF LAKE AND DAM

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APPENDICES

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 St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection be made of Carden Lake Dam in Crawford County, Missouri.

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 a 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, "Recommended Guidelines for Safety Inspection of Dams, Appendix D." 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:

Carden Lake Dam is an earth fill structure approximately 35 ft high and 550 ft long at the crest. In this report, right and left orientation is based on looking in the downstream direction. The appurtenant works consist of an earth cut swale in the left abutment and an 8 in. drawdown pipe under the center of the dam with a valve on the downstream end. The outlet of the drawdown pipe could not be found during the inspection visit. The owner indicated that the outlet has been buried with soil for years (slopewash from the dam). Sheet 3 of Appendix A shows a plan, profile, and typical section of the embankment. Sheet 4 of Appendix A shows a section and profile of the spillway.

B. Location:

The dam is located in the west-central part of Crawford County, Missouri on a tributary of Cherry Valley Creek. The dam and lake are within the Steelville, Missouri 7.5 minute quadrangle sheet (Section 8, T37N, R3W-latitude 37 deg. 56.7 min. , longitude 91 deg. 17.1 min.). Sheet 2 of Appendix A shows the general vicinity.

C. Size Classification:

With an embankment height of 35 ft and a maximum storage capacity of approximately 118 acre-ft, the dam is in the small size category.

D. Hazard Classification:

The St. Louis District, Corps of Engineers has determined that this dam is in the high hazard potential classification. The estimated damage zone extends approximately 2 miles downstream of the dam. Located within this zone are one trailer, three dwellings, and a building. The existence of these downstream features was verified during the field inspection and at the time the aerial photographs were taken.

E. Ownership:

The dam is owned by Oliver Carden. The owner's address is 975 W. Highway 66, Sullivan, Missouri 63080 (telephone:314-468-4194).

F. Purpose of Dam:

The dam was constructed primarily for recreation.

G. Design and Construction History:

The dam was constructed in 1968 by Elmer Bailey, then of St. Clair, Missouri. Mr. Bailey could not be located. The owner indicated that the dam consisted of a mixture of soil and rock taken mainly from the lake area. He said that a 5 ft to 6 ft compacted clay key was constructed beneath the base of the dam. He was not sure whether a clay core was incorporated from the base to the top of the dam. He indicated that an 8 in. diameter steel drawdown pipe with a perforated riser on the intake end and a valve on the outlet end was incorporated in the center of the dam. He said that the pipe has not been used for many years and that the valve is buried with slopewash. The owner indicated that no modifications have been made except for a slight widening of the spillway some years ago.

H. Normal Operating Procedures:

Normal flows are discharged over an uncontrolled earth swale spillway. The drawdown pipe has not been used for many years. The owner reported that the dam has never been overtopped, and that the highest water level was approximately 8 in. above the crest of the spillway.

1.3 PERTINENT DATA:

Pertinent data about the dam, appurtenant works, and reservoir are presented in the following paragraphs. Sheet 3 of Appendix A presents a plan, profile, and typical section of the embankment.

A. Drainage Area:

The drainage area for this dam, as obtained from the USGS quad sheet, is approximately 79 acres.

B. Discharge at Dam Site:

(1) All discharge at the dam site is through an uncontrolled spillway.

(2) Estimated Total Spillway Capacity at Maximum Pool (Top of Dam - El. 928.2): 530 cfs

(3) Estimated Capacity of Primary Spillway: 530 cfs

(4) Estimated Experienced Maximum Flood at Dam site: Unknown

(5) Diversion Tunnel Low Pool Outlet at Pool Elevation: Not Applicable

(6) Diversion Tunnel Outlet at Pool Elevation: Not Applicable

(7) Gated Spillway Capacity at Pool Elevation: Not Applicable

(8) Gated Spillway Capacity at Maximum Pool Elevation: Not Applicable

C. Elevations:

All elevations are consistent with an assumed mean sea level elevation of 926 for the crest of the spillway (estimated from quadrangle map).

(1) Top of Dam: 928.2

(2) Principal Spillway Crest: 926

(3) Emergency Spillway Crest: None

(4) Principal Outlet Pipe Invert: Not Applicable

(5) Streambed at Centerline of Dam: 894.0

(6) Pool on Date of Inspection: 922.5

(7) Apparent High Water Mark: Not Evident

(8) Maximum Tailwater: Unknown

(9) Upstream Portal Invert Diversion Tunnel: Not Applicable

(10) Downstream Portal Invert Diversion Tunnel: Not Applicable

D. Reservoir Lengths:

(1) At Top of Dam: 1,070 ft

(2) At Principal Spillway Crest: 1,000 ft

(3) At Emergency Spillway Crest: Not Applicable

E. Storage Capacities:

(1) At Principal Spillway Crest: 100 acre-ft

(2) At Top of Dam: 118 acre-ft

(3) At Emergency Spillway Crest: Not Applicable

F. Reservoir Surface Areas:

(1) At Principal Spillway Crest: 7.4 acres

(2) At Top of Dam: 8.7 acres

(3) At Emergency Spillway Crest: Not Applicable

G. Dam:

(1) Type: Earth

(2) Length at Crest: 550 ft

(3) Height: 35 ft

(4) Top Width: 10 ft

(5) Side Slopes: Upstream 2.4:1 (Top), 3.0:1 (Bottom), Downstream 2.0:1 (Top), 2.6:1 (Bottom)

(6) Zoning: None

(7) Impervious Core: Unknown

(8) Cutoff: 6 ft Below Base

(9) Grout Curtain: None

H. Diversion and Regulating Tunnel:

(1) Type: Not Applicable

(2) Length: Not Applicable

(3) Closure: Not Applicable

(4) Access: Not Applicable

(5) Regulating Facilities: Not Applicable

I. Spillway:

I.1 Principal Spillway:

(1) Location: Left Abutment

(2) Type: Trapezoidal Earth Cut Swale With 43 ft Bottom Width and Variable Side Slopes

I.2 Emergency Spillway:

(1) Location: Not Applicable

(2) Type: Not Applicable

J. Regulating Outlets:

The only regulating outlet is an 8 in. diameter steel drawdown pipe located in the center of the dam. The outlet valve of the pipe is covered with soil, and the pipe has not been used for many years.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN:

No engineering data exist for this dam. No documentations of construction inspection records were available. There are no documented maintenance data.

A. Surveys:

No information regarding pre-construction surveys was obtained. Sheet 3 of Appendix A presents a plan, profile, and cross section of the dam from survey data obtained during the site inspection. The crest of the spillway (reservoir normal pool) was used as a reference point to determine all other elevations. It is estimated that this site datum approximately corresponds to mean sea level (MSL) elevation 926.0 (estimated from quad sheet).

B. Geology and Subsurface Materials:

The site is located in the north-central portion of the Ozarks geologic region of Missouri. The Ozarks are characterized topographically by hills, plateaus, and deep valleys. The most common bedrock types are dolomite, sandstone, and chert. The "Geologic Map of Missouri" indicates that the bedrock in the site area consists primarily of the Gasconade formation of the Canadian Series in the Ordovician System. The Gasconade formation is predominantly a light brownish-gray, cherty dolomite. In this area, the average thickness of the Gasconade is 200 ft. Caves and springs are common in this formation. The publication "Caves of Missouri" lists a total of seven caves known to exist in Crawford County. Most of these caves are clustered in a 3 sq mile area about 6 miles northeast of the site. The rest are farther northeast.

The "Geologic Map of Missouri" indicates a normal fault passing about 8 miles west of the site in a northwest-southwest direction. The Missouri Geological Survey has indicated that the faults in this area are generally considered to be inactive and have been for several hundred million years (rock associated with the Ordovician Period - 500 million years old).

Soils in the area of the dam site appear to be primarily thin deposits of residual silts and clays with rock fragments. The soils are of the Clarksville-Fullerton-Talbott Soil Association and have developed from thin loessial soils deposited over weathered material from cherty dolomites. The loessial thickness map indicates that upland areas may have between 2.5 and 5.0 ft of loess cover.

Soils in the embankment and in abutment areas near the dam are described as sandy silts with a trace of clay and rock fragments (ML). These soils are somewhat erodible as indicated by the erosional area in the right abutment near the dam (see Sheet 5 of Appendix A).

C. Foundation and Embankment Design:

No foundation and embankment design information was available. Seepage and stability analyses apparently were not performed as required in the guidelines. The owner indicated that the dam consisted of a mixture of soil and rock taken mainly from the lake area. He said that a 5 ft to 6 ft compacted clay key was constructed beneath the base of the dam. He was not sure whether a clay core was incorporated from the base to the top of the dam.

D. Hydrology and Hydraulics:

No hydrologic or hydraulic design computations for this dam were available. Based on a field check of spillway dimensions and embankment elevation, and a check of the drainage area on USGS quad sheets, hydrologic analyses using U.S. Army Corps of Engineers guidelines were performed and appear in Appendix C.

E. Structure:

There are no appurtenant structures associated with this dam.

2.2 CONSTRUCTION:

No construction inspection data were available.

2.3 OPERATION:

Normal flows are passed by an uncontrolled earth cut spillway located in the left abutment. The only operating facility is an 8 in. diameter steel drawdown pipe under the center of the dam which has not been operated for many years. The outlet of the pipe could not be found during the inspection. The owner indicated that it has been buried by slopewash soils.

2.4 EVALUATION:

A. Availability:

No engineering data, seepage or stability analyses, or construction test data were available.

B. Adequacy:

The engineering data available were inadequate to make a detailed assessment of the design, construction, and operation of this structure. 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:

To our knowledge, no valid engineering data on the design or construction of the embankment are available.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS:

A. General:

The field inspection was made on 6 October 1980. The inspection team consisted of personnel from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. The team members were:

Steve Brady - Anderson Engineering, Inc. (Civil Engineer)
Tom Beckley - Anderson Engineering, Inc. (Civil Engineer)
Gene Wertepny - Hanson Engineers, Inc. (Hydraulic Engineer)
Dan Kerns - Hanson Engineers, Inc. (Geotechnical Engineer)

The owner was not present during the field inspection. Photographs of the dam, appurtenant structures, reservoir, and downstream features are presented in Appendix D.

B. Dam:

The dam appears to be in good condition. The upstream face is heavily overgrown with brush and small trees. There is no riprap, but there is a mixture of rocks left by moderate wave erosion. No significant sloughing was observed (see Photos 3 and 4).

The crest of the dam is fairly clear with some weed growth. The horizontal and vertical alignment appeared good, and no surface cracking or unusual movement was obvious (see Photo No. 5).

The downstream face was heavily overgrown with briars, brush, small trees, and high weeds making it difficult to inspect. No sloughing, animal holes, or significant erosion was noted (see Photos 6 and 7). The abutment-dam contacts were not significantly eroded.

An apparent seepage area was noted at the left abutment-dam downstream contact (see Photo No. 8). This area was soft and wet with marsh vegetation. No measurable flows were seen.

Auger probes in the crest of the dam indicated a light brown sandy silt with a trace of clay and rock fragments (ML).

A large erosion area was noted in the right abutment (see Sheet 5 of Appendix A). This area is somewhat apart from the dam and would not appear to affect the embankment stability.

C. Appurtenant Structures:

C.1 Principal Spillway:

The spillway is a trapezoidal earth cut in the left abutment (43 ft bottom width, variable side slopes) with no permanent control section. The approach area is clear, and the outlet area is well separated from the dam (see Photos 9 and 10). The outlet channel has experienced some erosion (see Photo 11), but the embankment is not affected.

The owner reported the existence of an 8 in. diameter drawdown pipe with a valve on the outlet end. He indicated that the outlet is buried with soil, and the pipe has not been used for many years. The inspection team could not locate the pipe during the site visit.

C.2 Emergency Spillway:

There is no emergency spillway.

D. Reservoir:

The watershed is generally heavily wooded with some cleared areas on both sides of the lake (see Photos 1 and 2). The slopes adjacent to the lake are moderate, and no sloughing or serious erosion was noted. No significant sedimentation was observed.

E. Downstream Channel:

Spillway flows pass into a wooded area, then cascade down a wooded valley slope and into the original stream channel.

3.2 EVALUATION:

Trees and brush on the dam constitute a potential seepage hazard and encourage animal burrowing. There is no wave protection provided for the upstream face of the embankment. A non-erodible control section is not provided for the spillway; therefore, progressive erosion could lower the elevation of the spillway, and thus lower the normal pool elevation of the reservoir.

Because the 8 in. diameter pipe valve is located on the downstream side of the dam, the full head of water impounded by the dam is acting entirely through the dam. The valve and outlet should be located, and the area around the drain outlet should be periodially inspected for seepage which might indicate a leak or rupture of the pipe and could eventually initiate a piping failure through the embankment.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES:

The only operating facility is the valve for the 8 in. diameter drawdown pipe, which has not been operated for years. The pool is normally controlled by rainfall, runoff, evaporation, and the capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM:

The presence of tree and brush growth on the embankment indicates that little maintenance is done.

4.3 MAINTENANCE OF OPERATING FACILITIES:

There is no regular maintenance of operation facilities.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT:

The inspection team is unaware of any existing warning system for this dam.

4.5 EVALUATION:

The vegetation on the dam, and lack of riprap and a non-erodible spillway control section are deficiencies which could become serious if not corrected. A program of regular operation and maintenance of the drawdown pipe valve should be established.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES:

A. Design Data:

No hydrologic or hydraulic design computations for this dam were available.

B. Experience Data:

No recorded rainfall, runoff, discharge, or reservoir stage data were available for this lake and watershed. The owner indicated that the maximum depth of water over the spillway was 8 in.

C. Visual Observations:

The approach area to the spillway is clear. Spillway flows pass into a wooded area and then cascade down a woded valley slope. There is no non-erodible spillway control section. The spillway outlet channel is well separated from the embankment, and spillway releases would not be expected to endanger the dam.

D. Overtopping Potential:

The hydraulic and hydrologic analyses (using the U.S. Army Corps of Engineers guidelines and the HEC-1 computer program) were based on: (1) a field survey of spillway dimensions and embankment elevation, and (2) an estimate of the reservoir storage and the pool and drainage areas from the Steelville, Missouri, 7.5 minute USGS quad sheet.

Based on the hydrologic and hydraulic analysis presented in Appendix C, the spillway will pass 50 percent of the Probable Maximum Flood. The Probable Maximum Flood is defined as the flood dischage that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The recommended guidelines from the Department of the Army, Office of the Chief of Engineers, require that this structure (small size with high downstream hazard potential) pass 50 percent to 100 percent of the PMF, without overtopping. Considering the small height of the dam and the low reservoir capacity, 50 percent of the PMF has been determined to be the appropriate spillway design flood. The spillway will pass the 1 percent probability flood without overtopping the dam.

Application of the probable maximum precipitation (PMP), minus losses, resulted in a flood hydrograph peak inflow of 1,964 cfs. For 50 percent of the PMP, the peak inflow was 982 cfs.

The routing of the PMF through the spillway and dam indicates that the dam will be overtopped by 0.9 ft at elevation 929.1. The duration of the overtopping will be 0.6 hours, and the maximum outflow will be 1,716 cfs. The maximum discharge capacity of the spillways is 530 cfs. The routing of 50 percent of the PMF indicates that the dam will not be overtopped. The maximum outflow will be 564 cfs. Overtopping of an earthen embankment could cause serious erosion and could possibly lead to failure of the structure.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY:

A. Visual Observations:

Observed features which could adversely affect the structural stability of this dam are discussed in Sections 3.1.B and 3.2.

B. Design and Construction Data:

No design and construction data for the foundation and embankment were available. Seepage and stability analyses comparable to the requirements of the guidelines were not available, which constitutes a deficiency which should be rectified.

C. Operating Records:

No operating records have been obtained.

D. Post-Construction Changes:

There have been no post-construction changes except for some widening of the spillway a few years ago.

E. Seismic Stability:

The structure is located in seismic zone 1. An earthquake of this magnitude would not generally be expected to cause severe structural damage to a well constructed earth dam of this size. However, it is recommended that the prescribed seismic loading for this zone be applied in stability analyses performed for this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT:

This Phase I inspection and evaluation should not be considered as being comprehensive since the scope of work contracted for is far less detailed than would be required for an in-depth evaluation of dams. Latent deficiencies, which might be detected by a totally comprehensive investigation, could exist.

A. Safety:

The embankment is generally in good condition. Several items were noted during the visual inspection which should be investigated further, corrected, or controlled. These items are: (1) tree and brush growth on both the upstream and downstream face; (2) lack of wave protection for the upstream embankment face; (3) lack of a non-erodible spillway control section; (4) apparent seepage at the left abutment-dam downstream contact; and (5) lack of access to the buried drawdown pipe valve.

Another deficiency was the lack of seepage and stability analyses records.

The dam will be overtopped by flows in excess of 50 percent of the Probable Maximum Flood. Overtopping of an earthen embankment could cause serious erosion and could possibly lead to failure of the structure.

B. Adequacy of Information:

The conclusions in this report were based on the performance history as related by others, and visual observation of external conditions. The inspection team considers that these data are sufficient to support the conclusions herein. Seepage and stability analyses comparable to the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

C. Urgency:

The remedial measures recommended in paragraph 7.2 should be accomplished in the near future. If the deficiencies listed in paragraph 7.1.A are not corrected, and if good maintenance is not provided, the embankment condition will continue to deteriorate and possibly could become serious in the future. The items recommended in paragraph 7.2.A should be pursued promptly.

D. Necessity for Additional Inspection:

Based on the result of the Phase I inspection, no Phase II inspection is recommended.

E. Seismic Stability:

The structure is located in seismic zone 1. An earthquake of this magnitude would not generally be expected to cause severe structural damage to a well constructed earth dam of this size. 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:

The following remedial measures and maintenance procedures are recommended. All remedial measures should be performed under the guidance of a professional engineer experienced in the design and construction of dams.

A. Alternatives:

(1) Our analysis indicate that the spillway size and height of dam are adequate to pass 50 percent of the PMF, which meets the requirements of the guidelines for this size dam.

B. O and M Procedures:

(1) Seepage and stability analyses comparable to the requirements of the recommended guidelines should be performed by an engineer experienced in the construction of dams.

(2) A non-erodible spillway control section should be provided so that progressive erosion of the spillway will not lower the normal pool of the reservoir.

(3) Wave protection should be provided for the upstream face of the dam.

(4) The tree and brush growth on the dam should be cut annually.

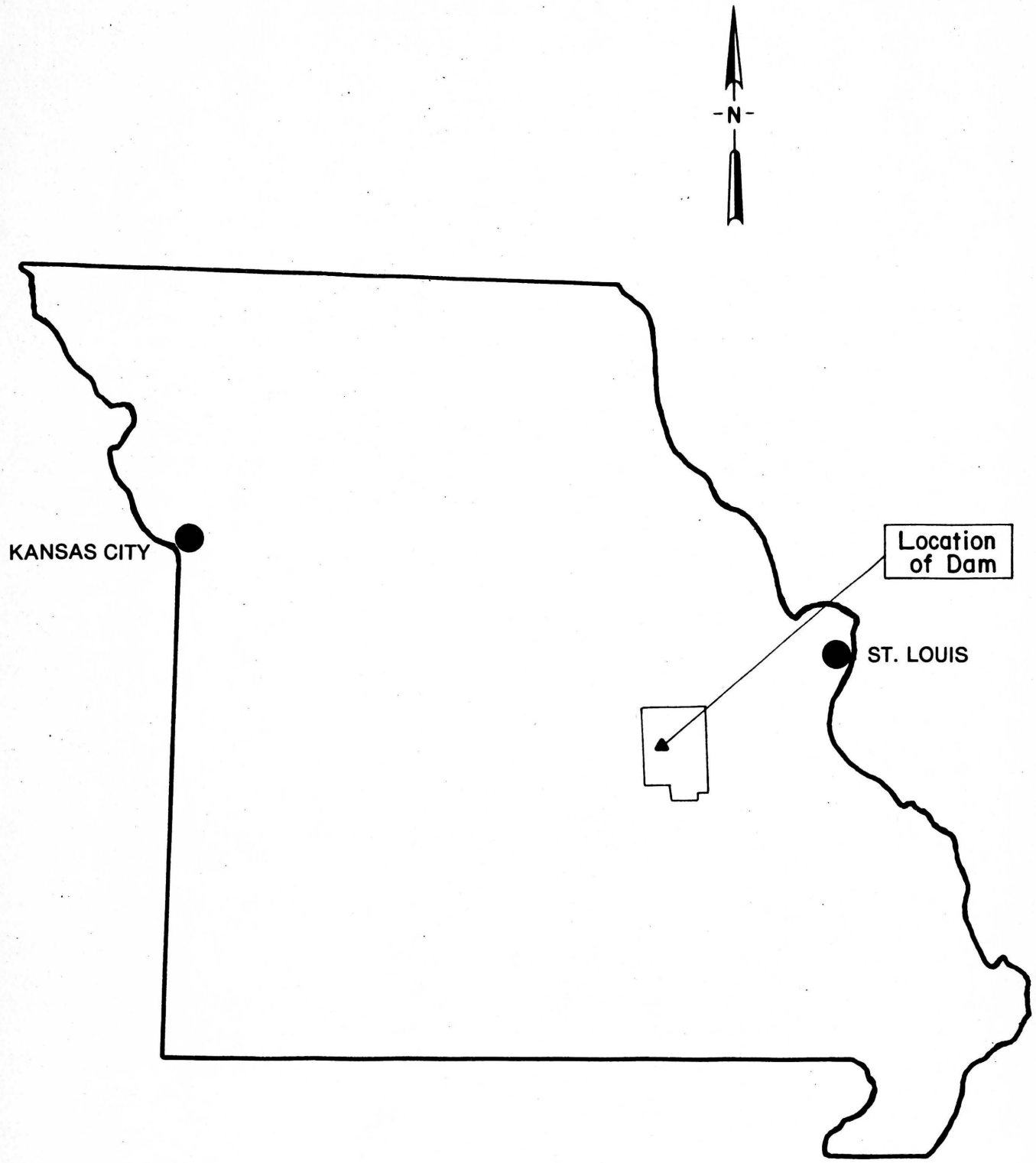
(5) The apparent seepage area previously described should be investigated by an engineer experienced in the design and construction of dams. Remedial measures may be required. As a minimum, this area should be monitored to determine if there is any increase in flow quantities and whether soil particles are being carried with the seepage water.

(6) The drawdown pipe valve should be located, operated periodically, and maintained.

(7) A detailed inspection of the dam should be made periodically by an engineer experienced in the design and construction of dams.

APPENDIX A

Dam Location and Plans



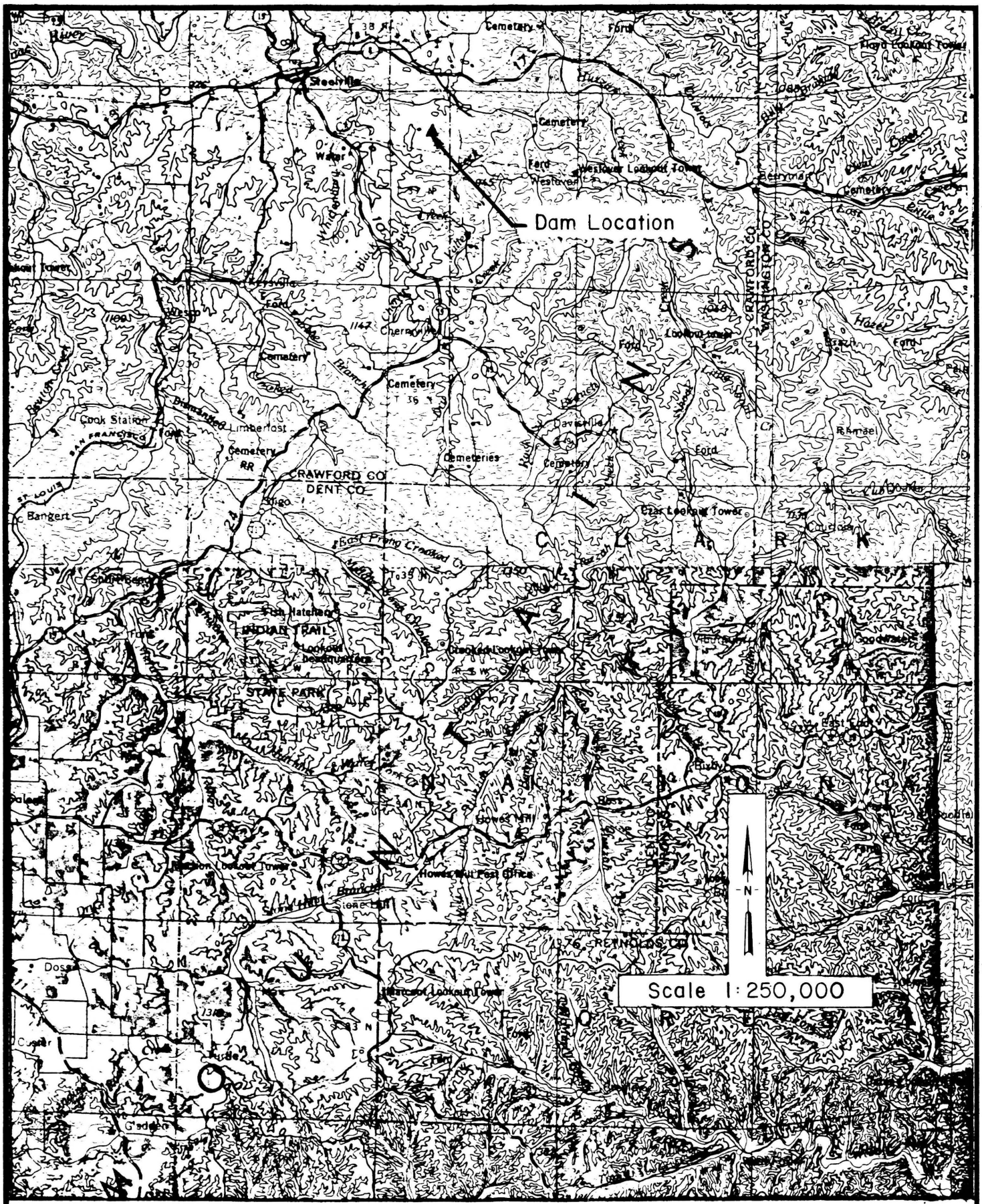
LOCATION MAP

HANSON ENGINEERS INCORPORATED

SPRINGFIELD, IL • PEORIA, IL • ROCKFORD, IL

Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

SHEET 1, APPENDIX A



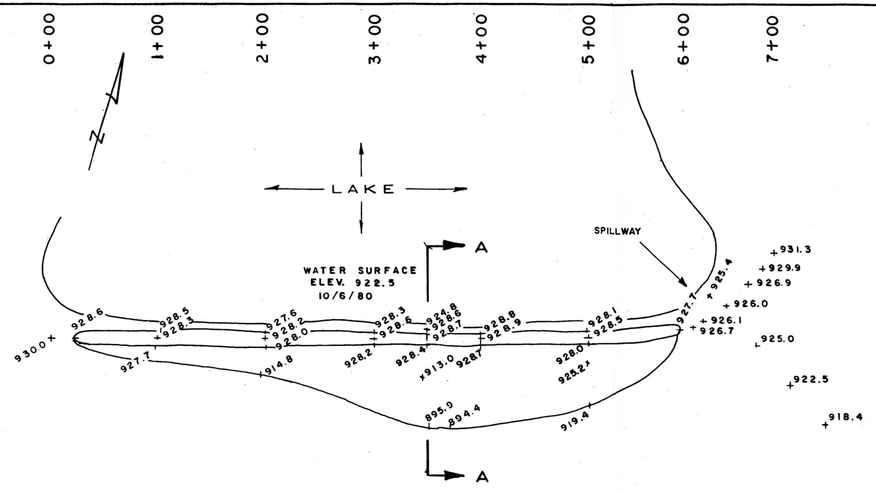
VICINITY MAP

HANSON ENGINEERS INCORPORATED

SPRINGFIELD, IL • PEORIA, IL • ROCKFORD, IL

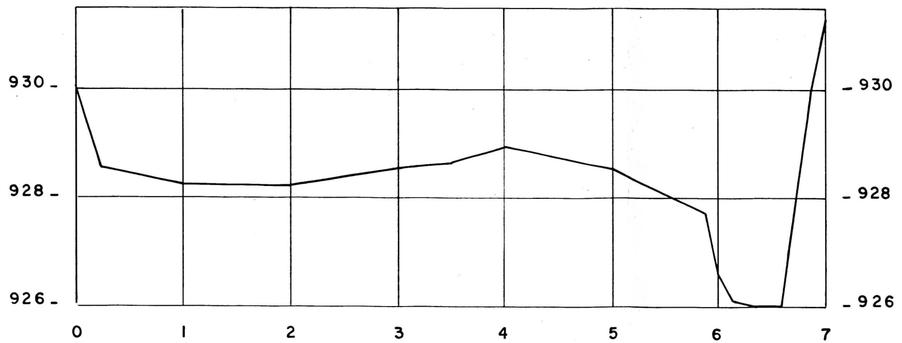
Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

Sheet 2, Appendix A

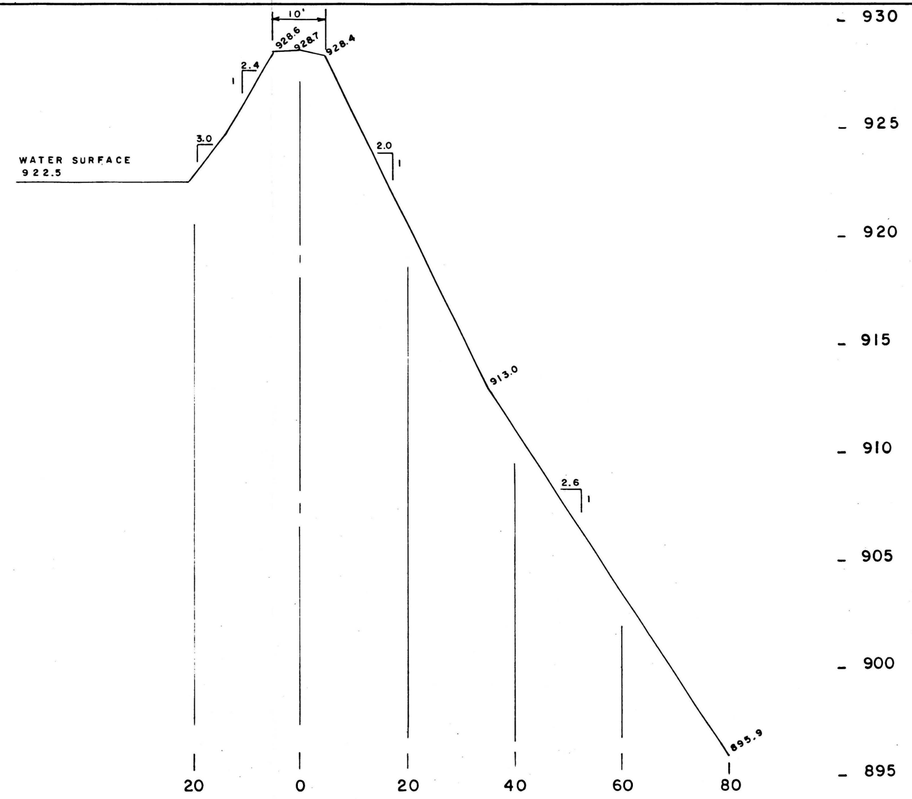


PLAN VIEW

SCALE: 1" = 100'



PROFILE



SECTION A-A STA 3+50

ANDERSON ENGINEERING, INC.

730 N. BENTON AVE. • SPRINGFIELD, MO. 65802

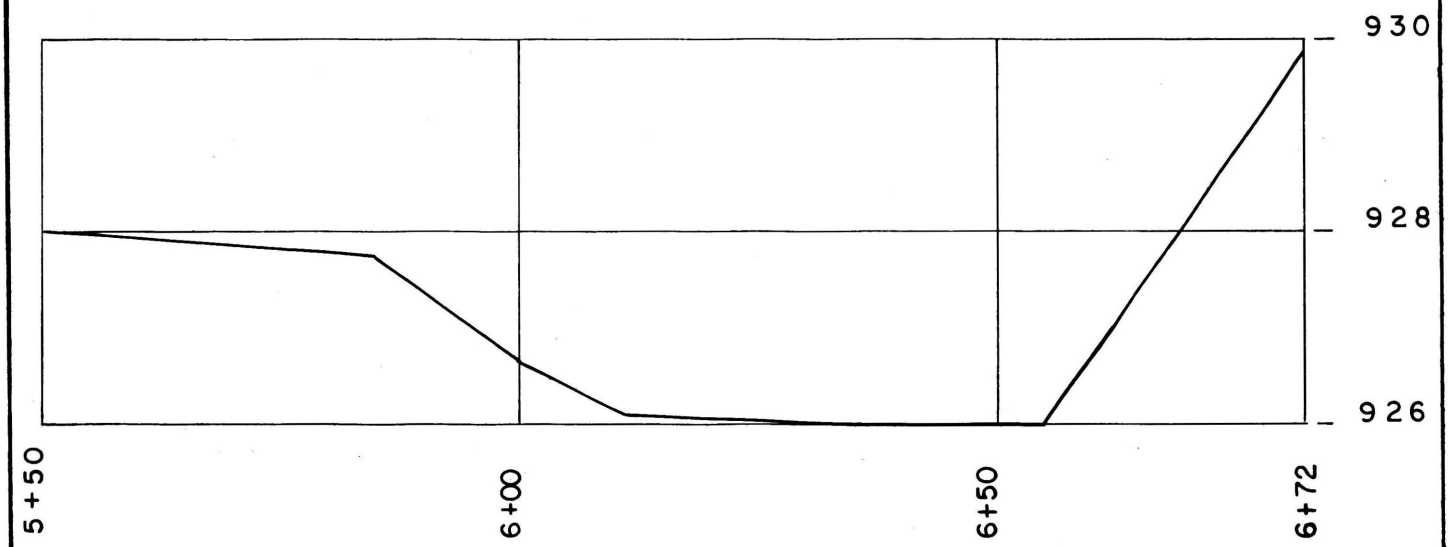
CARDEN LAKE DAM

MO. No. 30987

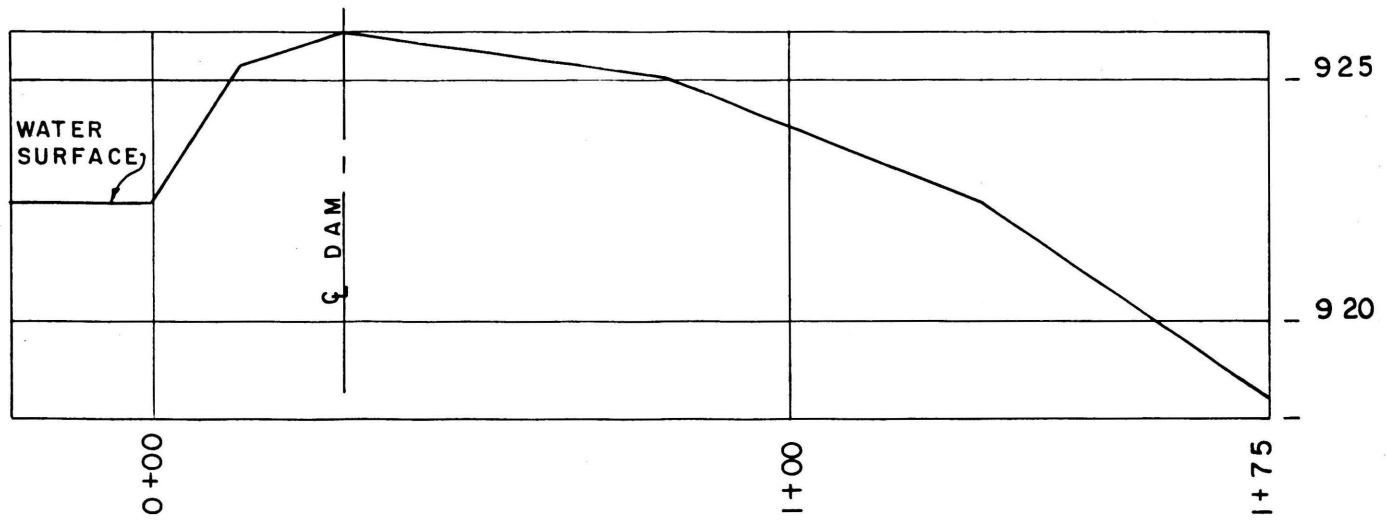
PLAN & PROFILE

CRAWFORD COUNTY, MO.

SHEET 3 , APPENDIX A



CROSS SECTION AT ℄ OF DAM



PROFILE OF SPILLWAY AT STA. 6 + 30

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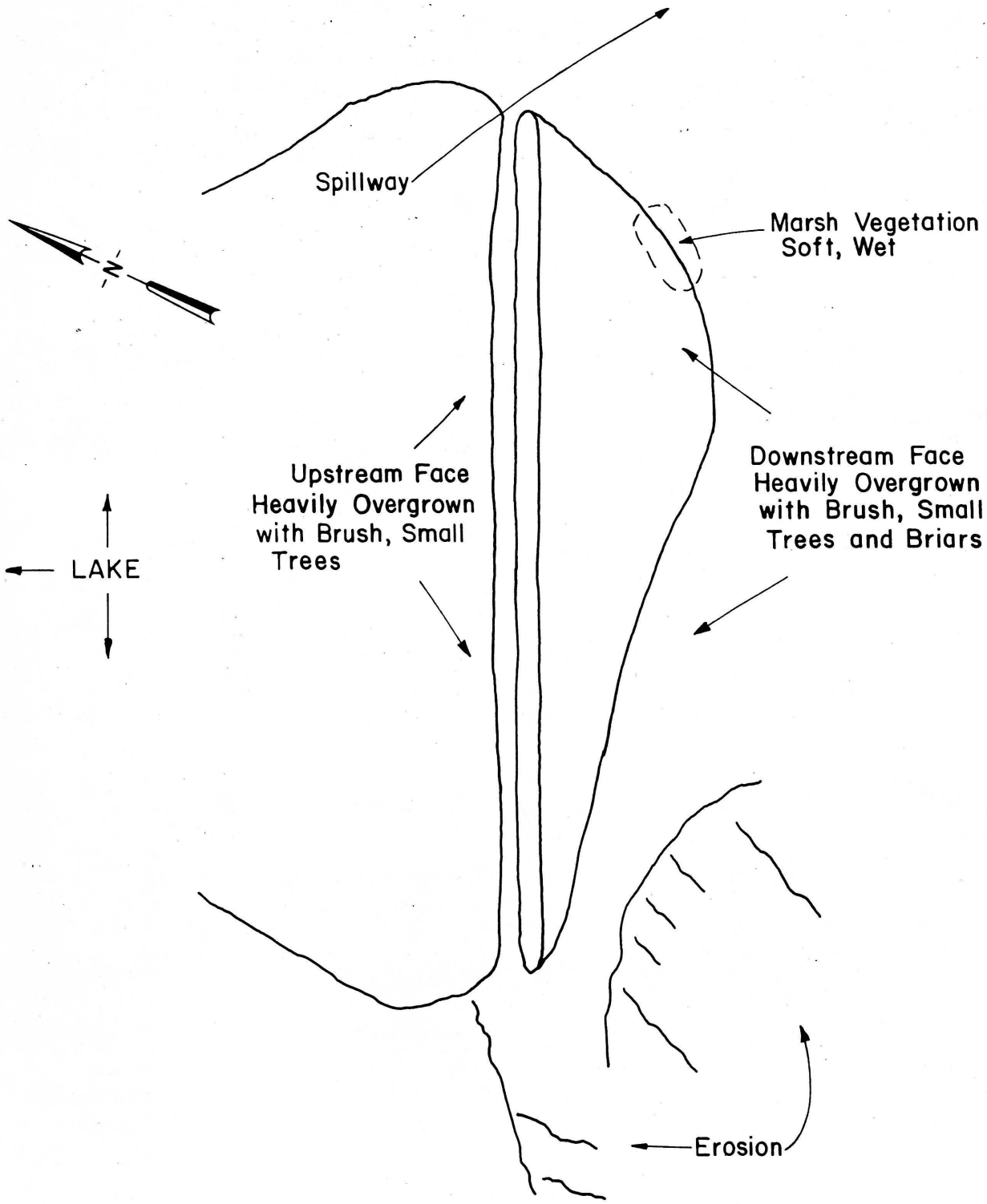
CARDEN LAKE DAM
CRAWFORD COUNTY, MISSOURI
MO. I. D. No. 30987

SPILLWAY SECTION & PROFILE



PLAN SKETCH OF FEATURES

HANSON ENGINEERS INCORPORATED

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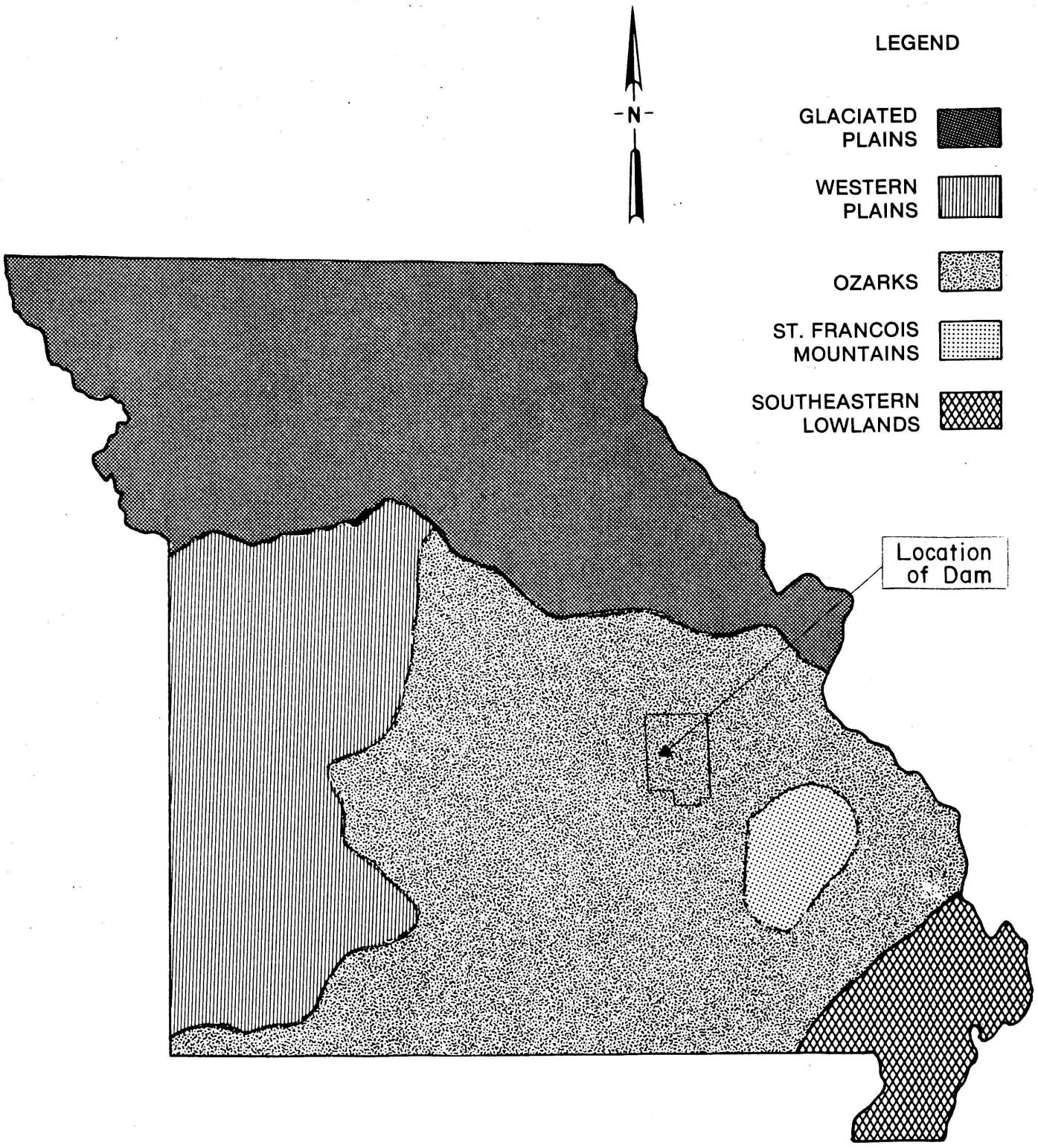
Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

Sheet 5, Appendix A

APPENDIX B

Geology and Soils



MAJOR GEOLOGIC REGIONS OF MISSOURI

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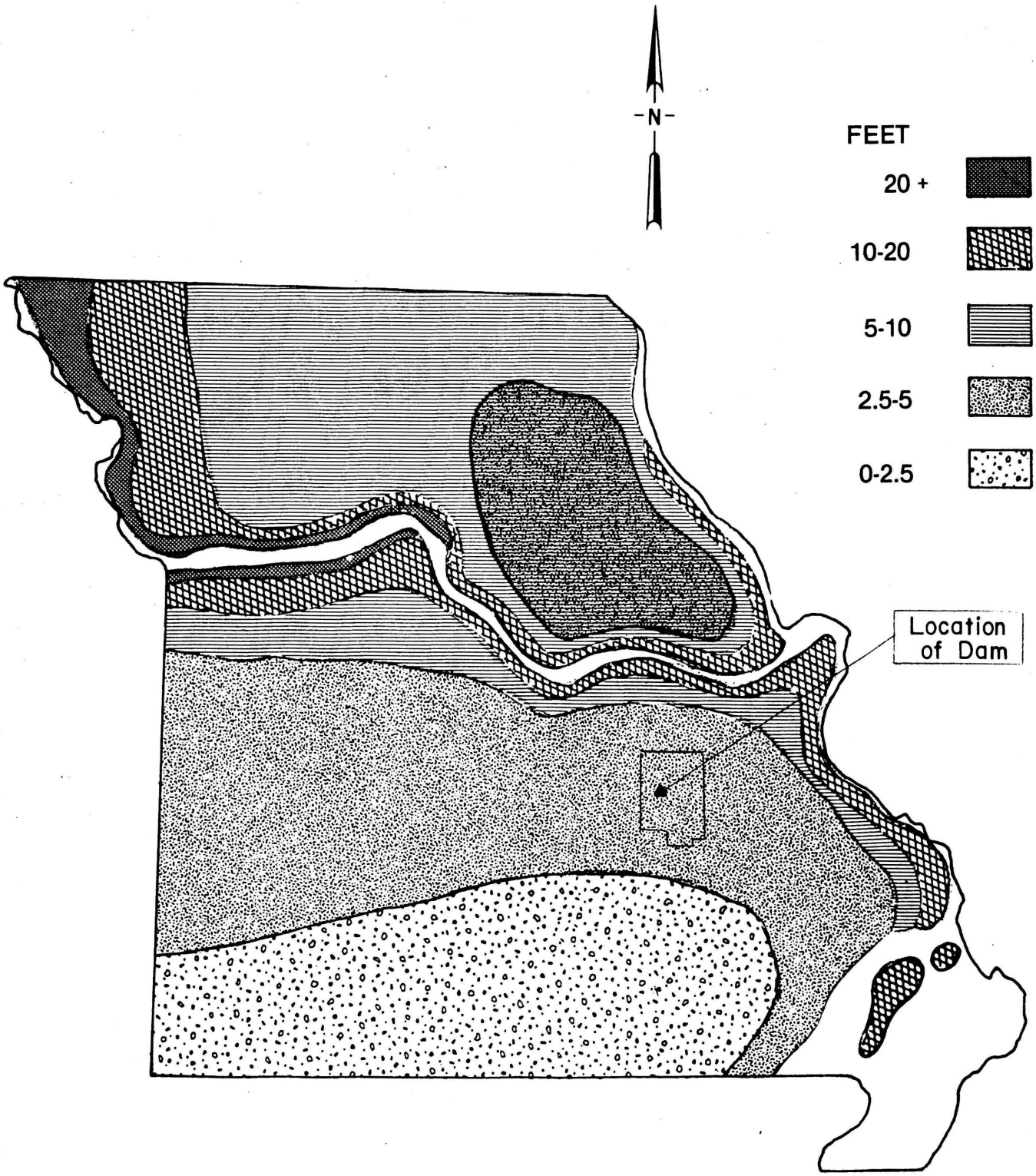
Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

SHEET 1, APPENDIX B



THICKNESS OF LOESSIAL DEPOSITS

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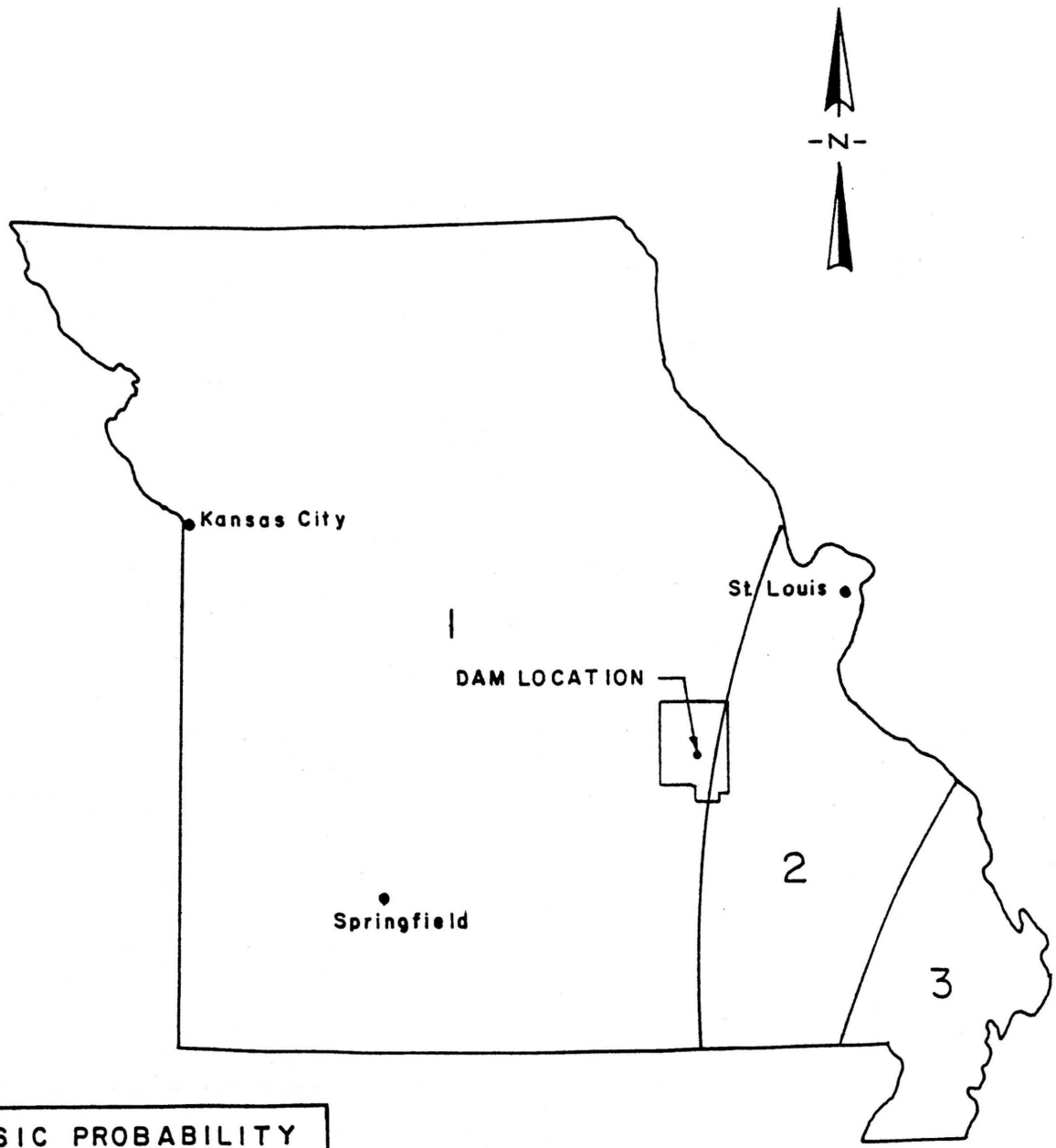
Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

SHEET 2, APPENDIX B



SEISIC PROBABILITY	
ZONE	DAMAGE
1	MINOR
2	MODERATE
3	MAJOR

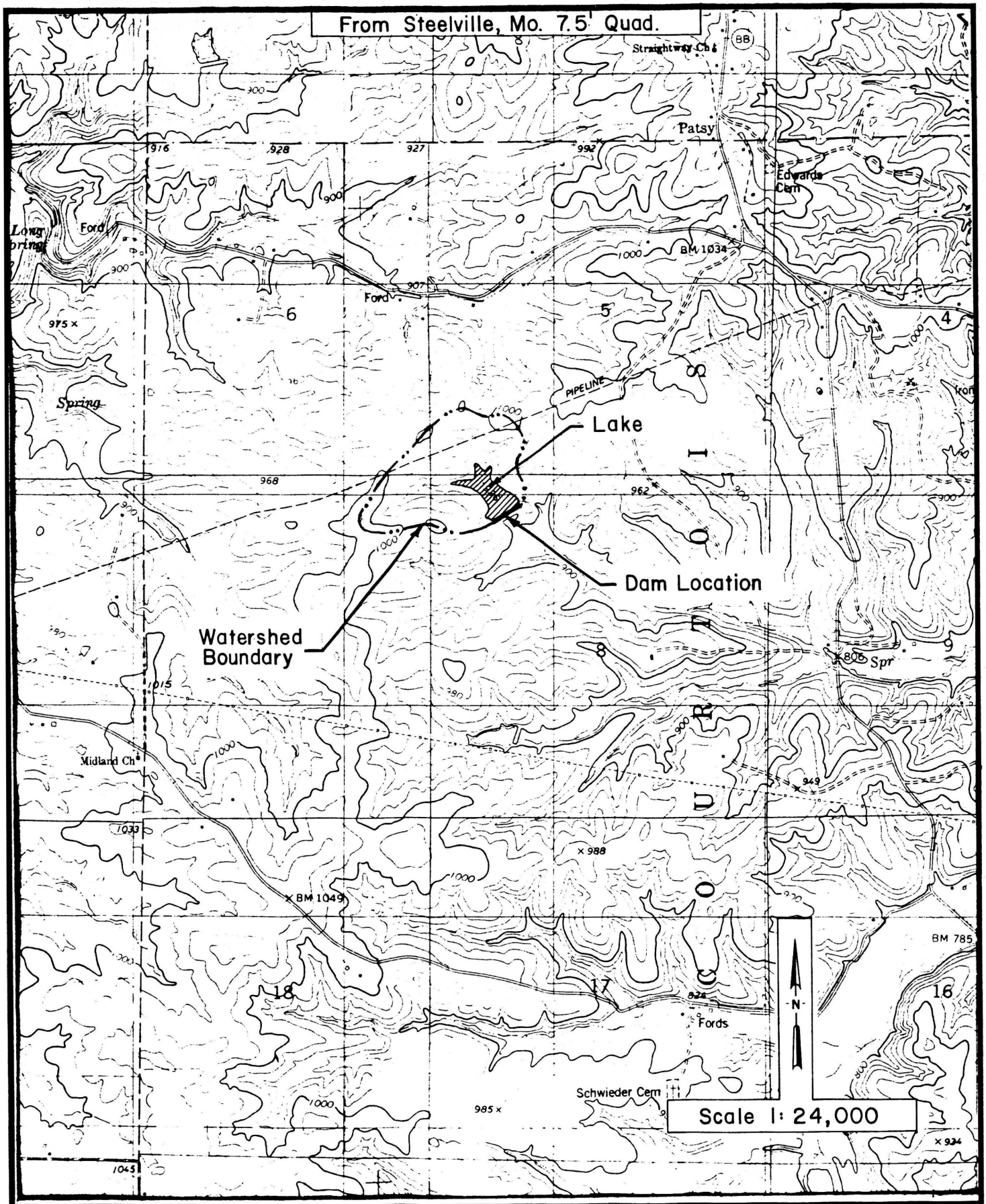
A/E ANDERSON ENGINEERING, INC.
730 N. BENTON AVE. • SPRINGFIELD, MO. 65802

SEISMIC ZONE MAP

CARDEN LAKE DAM
CRAWFORD COUNTY, MISSOURI
MO. I. D. No. 30987-

APPENDIX C

Overtopping Analysis



LAKE AND WATERSHED MAP

HANSON ENGINEERS INCORPORATED

SPRINGFIELD, IL • PEORIA, IL • ROCKFORD, IL

Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

Sheet 1, Appendix C

APPENDIX C

HYDROLOGIC AND HYDRAULIC ANALYSIS

To determine the overtopping potential, flood routings were performed by applying the Probable Maximum Precipitation (PMP) to a synthetic unit hydrograph to develop the inflow hydrograph. The inflow hydrograph was then routed through the reservoir and spillway. The overtopping analysis was accomplished using the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California.

The PMP was determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33." Reduction factors were not applied. The rainfall distribution for the 24-hour PMP storm duration was assumed according to the procedures outlined in EM 1110-2-1411 (SPD Determination). Also, the 1 percent chance probability flood was routed through the reservoir and spillway. Sullivan, Missouri rainfall distribution (5 min. interval - 24 hours duration), as provided by the St. Louis District, Corps of Engineers, was used in this case.

The synthetic unit hydrograph for the watershed was developed by the computer program using the SCS method. The time of concentration was estimated using the Kirpich formula. This formula and the parameters for the unit hydrograph are shown in Table 1 (Sheet 4, Appendix C). The time of concentration was also verified from velocity estimates for the average slopes of the watershed and the main channel (Design of Small Dams, page 70, 1974 Edition).

The SCS curve number (CN) method was used in computing the infiltration losses for rainfall-runoff relationship. The CN values used, and the result from the computer output, are shown in Table 2 (Sheet 5, Appendix C).

The reservoir routing was accomplished by using the Modified Puls Method assuming the starting lake elevation at normal pool. No antecedent storm was considered in this case. The hydraulic capacity of the spillway was used as an outlet control in the routing. The hydraulic capacity of the spillway and the storage capacity of the reservoir were defined by the elevation-surface area--storage-discharge relationships shown in Table 3 (Sheet 5, Appendix C).

The rating curve for the spillway (see Table 4 Sheet 6, Appendix C) was determined assuming critical flow condition at the control section.

The flow over the crest of the dam during overtopping was determined using the non-level dam option ($L and $V cards) of the HEC-1 program. The program assumes critical flow over a broad-crested weir. The lowest elevation of the crest of the dam, obtained from survey measurements, was assumed as top of dam elevation.

A summary of the routing analysis for different ratios of the PMF is shown in Table 5 (Sheet 7, Appendix C). The result of the routings indicates that the spillway will pass the 1 percent probability flood without overtopping the dam.

The computer input data, a summary of the output data, and a plot of the inflow-outflow hydrograph for the PMF are presented on Sheets 8, 9, and 10 of Appendix C.

TABLE 1

SYNTHETIC UNIT HYDROGRAPH

Parameters:

Drainage Area (A)	0.123	sq miles
Length of Watercourse (L)	0.30	miles
Difference in elevation (H)	94	ft
Time of concentration (Tc)	0.12	hrs
Lag Time (Lg)	0.07	hrs
Time to peak (Tp)	0.11	hrs
Peak Discharge (Qp)	540	cfs
Duration (D)	5	min.

Time (Min.)(*)	Discharge (cfs)(*)
0	0
5	452
10	357
15	101
20	29
25	9
30	3

(*) From the computer output

FORMULA USED:

$$Tc = \left(\frac{11.9\ L^3}{H}\right)^{0.385}$$

Kirpich Formula.
From California Culverts Practice, California Highways and Public Works, September, 1942.

$$Lg = 0.6\ Tc$$

$$Tp = \frac{D}{2} + Lg$$

$$Qp = \frac{484\ A.Q}{Tp}$$

Q = Excess Runoff = 1 inch

TABLE 2

RAINFALL-RUNOFF VALUES

Selected Storm Event	Storm Duration (Hours)	Rainfall (Inches)	Runoff (Inches)	Loss (Inches)
PMP	24	33.8	31.55	2.25
1% Prob. Flood	24	7.23	3.68	3.55

Additional Data:

1) Soil Conservation Service Soil Group B
2) Soil Conservation Service Runoff Curve CN = 82 (AMC III) for the PMF
3) Soil Conservation Service Runoff Curve CN = 65 (AMC II) for the 1 percent probability flood
4) Percentage of Drainage Basin Impervious 10 percent

TABLE 3

ELEVATION, SURFACE AREA, STORAGE AND DISCHARGE RELATIONSHIPS

Elevation (feet-MSL)	Lake Surface Area (acres)	Lake Storage (acre-ft)	Spillway Discharge (cfs)
894.0	0	0	-
*926.0	7.4	100	0
**928.2	8.7	118	530
930.0	9.7	135	1,560
940.0	15.6	260	-

*Principal spillway crest elevation
**Top of dam elevation

The above relationships were developed using data from the USGS Steelville, Missouri 7.5 minute quadrangle map and the field measurements.

TABLE 4

SPILLWAY RATING CURVE

Reservoir Elevation (MSL)	Principal Spillway Discharge (cfs)
926.0	0
926.5	35
927.0	130
927.5	270
*928.2	530
928.5	665
929.0	915
930.0	1,560
930.4	1,900

*Top of dam elevation

Method Used:

Assuming:

a) Critical flow condition at the control section.

b) Approach channel losses equal to 30 percent of the velocity head at the control section.

FORMULA:

$\frac{Q^2}{g} = \frac{A^3}{T}$ Design of Small Dams, 1974 Edition, Page 553, Water and Power Resources Service (Former USBR).

Q = Discharge in cubic feet per second
A = Cross sectional area in square feet
T = Water surface width in feet
g = Acceleration of gravity in ft/sec

TABLE 5

RESULTS OF FLOOD ROUTINGS

Ratio of PMF	Peak Inflow (cfs)	Peak Lake Elevation (ft, MSL)	Total Storage (acre-ft)	Peak Outflow (cfs)	Depth (ft) Over Top of Dam
-	0	*926.0	100	0	-
0.10	196	926.7	106	76	-
0.20	393	927.2	110	186	-
0.25	491	927.4	111	243	-
0.30	589	927.6	113	307	-
0.40	786	928.0	116	438	-
0.45	884	928.1	117	500	-
0.50	982	**928.2	118	564	0
0.75	1,473	928.7	123	1,030	0.5
1.00	1,964	929.1	126	1,716	0.9

The percentage of the PMF that will reach the top of the dam is 50 percent.

*Principal spillway crest elevation
**Top of dam elevation

```
A       OVERTOPPING ANALYSIS FOR CARDIN LAKE DAM ( # 26 )
A       STATE ID NO. 30987  COUNTY NAME : CRAWFORD
A       HANSON ENGINEERS INC. DAM SAFETY INSPECTION JOB # 80S3001
B    300                5
B1     5
J      1        9        1
J1   .10      .20      .25      .30      .40      .45      .50      .75      1.0
K      0        1                                  3        1
K1      INFLOW HYDROGRAPH COMPUTATION **
M      1        2    0.123             0.123        1                          1
P      0     26.0      102      120      130
T                                                                -1      -82             0.10
W2  0.12     0.07
X      0     -.1        2
K      1        2                             0        4        1
K1      RESERVOIR ROUTING BY MODIFIED PULS AT DAM SITE **
Y                                      1        1
Y1     1                                                        100       -1
Y4 926.0    926.5    927.0    927.5    928.2    928.5    929.0    929.5    930.0    930.4
Y5     0       35      130      270      530      665      915     1380     1560     1900
$S     0      100      118      135      260
$E 894.0    926.0    928.2    930.0    940.0
$$ 926.0
$D 928.2
$L     0      150      275      375      450      575      580      585
$V 928.2    928.3    928.5    928.6    928.7    928.9    929.5    930.0
K     99
```

PMF RATIOS
INPUT DATA

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

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)

PMF RATIOS
OUTPUT DATA

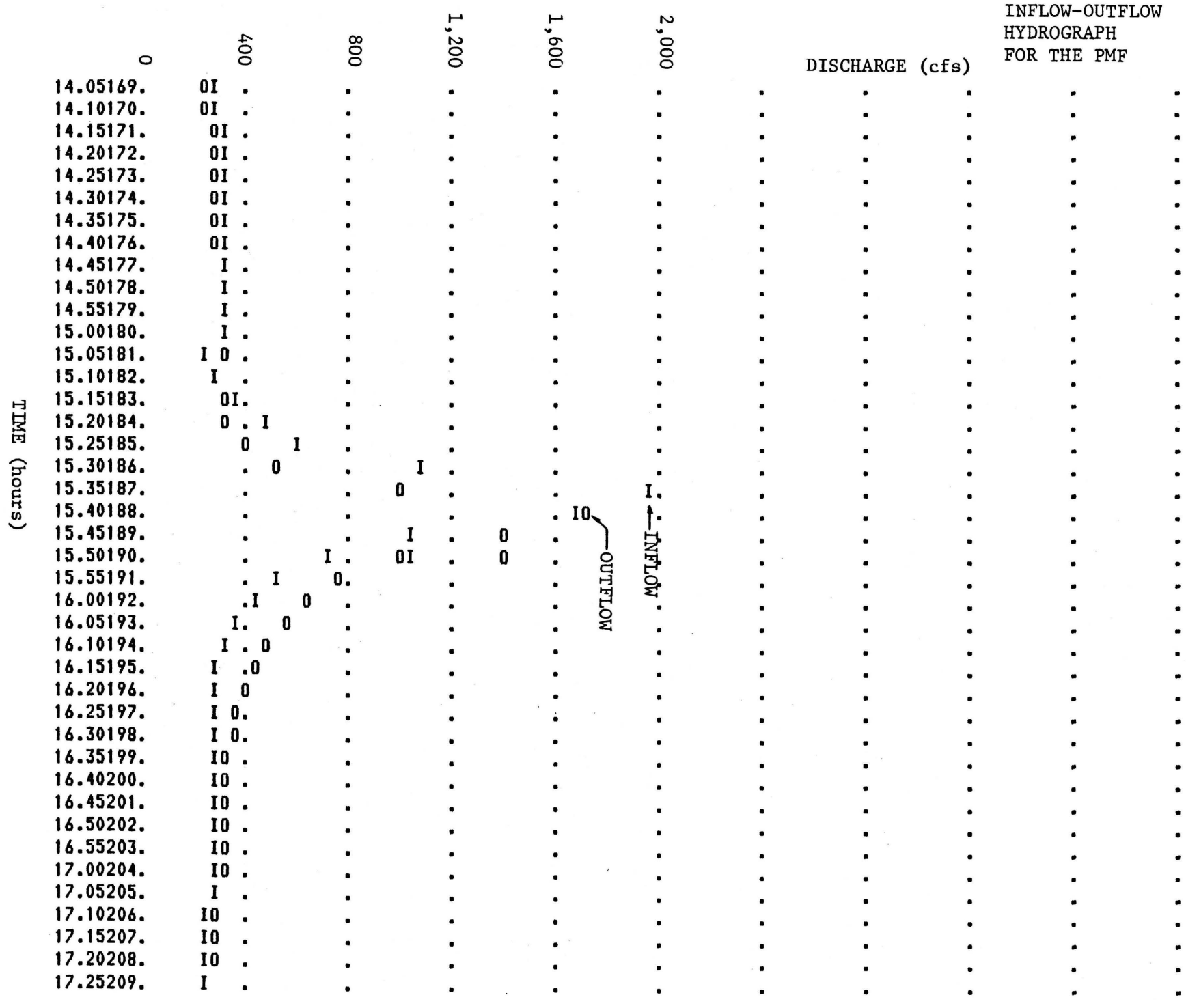
				RATIOS APPLIED TO FLOWS								
OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8	RATIO 9
				0.10	0.20	0.25	0.30	0.40	0.45	0.50	0.75	1.00
HYDROGRAPH AT	1	0.12	1	196.	393.	491.	589.	786.	884.	982.	1473.	1964.
	(	0.32)	(	5.56)(	11.12)(	13.90)(	16.69)(	22.25)(	25.03)(	27.81)(	41.71)(	55.62)
ROUTED TO	2	0.12	1	76.	186.	243.	307.	438.	500.	564.	1030.	1716.
	(	0.32)	(	2.16)(	5.27)(	6.88)(	8.68)(	12.41)(	14.17)(	15.97)(	29.16)(	48.60)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	926.00	926.00	928.20
STORAGE	100.	100.	118.
OUTFLOW	0.	0.	530.

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
0.10	926.72	0.00	106.	76.	0.00	15.83	0.00
0.20	927.20	0.00	110.	186.	0.00	15.75	0.00
0.25	927.40	0.00	111.	243.	0.00	15.75	0.00
0.30	927.60	0.00	113.	307.	0.00	15.75	0.00
0.40	927.95	0.00	116.	438.	0.00	15.75	0.00
0.45	928.12	0.00	117.	500.	0.00	15.75	0.00
0.50	928.27	0.07	119.	564.	0.08	15.75	0.00
0.75	928.73	0.53	123.	1030.	0.50	15.75	0.00
1.00	929.05	0.85	126.	1716.	0.58	15.67	0.00



Sheet 10, Appendix C

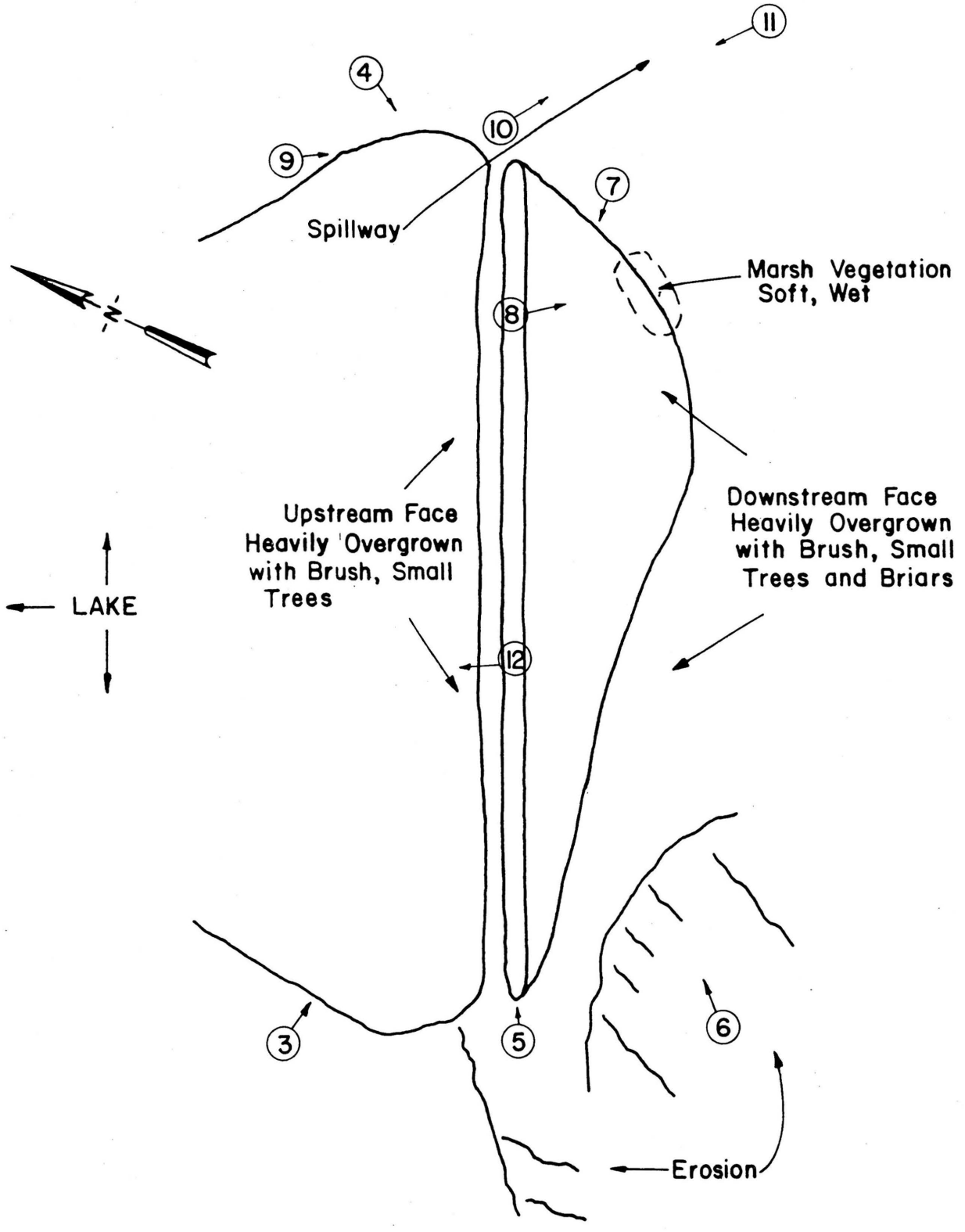
Max. Inflow = 1,964 cfs
Max. Outflow = 1,716 cfs

APPENDIX D

Photographs

LIST OF PHOTOGRAPHS

Photo No.	
1.	Aerial views of lake and dam, looking northwest.
2.	Aerial view of lake and dam, looking north.
3.	Upstream face of dam, looking east from right abutment, note heavy growth of brush and small trees.
4.	Upstream face of dam, looking west from left abutment.
5.	Crest of dam, looking east from right abutment.
6.	Downstream face of dam, looking northeast from left abutment area.
7.	Downstream face of dam, looking west from right abutment area, note heavy brush and small trees.
8.	Wet, marshy area at left abutment-downstream contact, looking south from crest of dam.
9.	Spillway approach area looking south.
10.	Spillway, looking downstream from crest.
11.	Spillway, looking upstream.
12.	Lake area looking north from crest of dam.



PHOTOGRAPH LOCATIONS

HANSON ENGINEERS INCORPORATED

SPRINGFIELD, IL • PEORIA, IL • ROCKFORD, IL

Carden Lake Dam
Crawford County, Missouri
Mo. I.D. No. 30987

Sheet 2, Appendix D


1


2


3


4


5


6


7


8


9


10


11


12