

MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

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BS

LEVEL II

CATES DAM

MONTGOMERY COUNTY, MISSOURI

MO. 10172

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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM.

Cates Dam (MO 10172),
Mississippi - Kaskaskia - St. Louis Basin,
Montgomery County, Missouri. Phase I
Inspection Report.

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9 Final rept.,

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

FOR: STATE OF MISSOURI

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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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CATES DAM
MONTGOMERY COUNTY, MISSOURI
MISSOURI INVENTORY NO. 10172

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY
HOSKINS-WESTERN-SONDEREGGER, INC.
CONSULTING ENGINEERS
LINCOLN, NEBRASKA

UNDER DIRECTION OF
ST. LOUIS DISTRICT, CORPS OF ENGINEERS

FOR
GOVERNOR OF MISSOURI

JUNE, 1979

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

IN REPLY REFER TO

SUBJECT: Cates Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Cates 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 10 DEC 1979
Chief, Engineering Division Date

APPROVED: SIGNED 10 DEC 1979
Colonel, CE, District Engineer Date

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
ASSESSMENT SUMMARY

Name of Dam	Cates Dam
State Located	Missouri
County Located	Montgomery County
Stream	Smith Branch Offstream
Date of Inspection	June 27, 1979

Cates Dam was inspected by an interdisciplinary team of engineers, from ~~Hoskins-Western-Sonderregger, Inc.~~ 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. Failure would threaten life and property. The estimated damage zone extends approximately three miles downstream of the dam. Within the damage zone are three residences, outbuildings, two county roads and State Highway 161.

Our inspection and evaluation indicates that the spillway does not meet the criteria set forth in the recommended guidelines for a small dam having a high hazard potential. Considering the small amount of water impounded and the large floodplain downstream one-half of the Probable Maximum Flood is the appropriate spillway design flood. The spillways will not pass the 100-year flood (flood having a one percent chance of being exceeded in any year) nor one-half of the Probable Maximum Flood without overtopping the dam. The spillways will pass 13% of the Probable Maximum Flood without overtopping the dam. The Probable Maximum Flood (PMF) is defined as the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Overtopping could result in failure of this dam and actions recommended in Section 7 of this report should be pursued on a high priority basis.

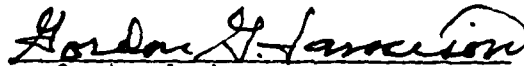
No design data were available for this dam. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These analyses should be obtained in the future and made a matter of record.

Other deficiencies observed during the inspection that should be corrected in the near future are: small trees growing along the water's edge and in the emergency spillway inlet and outlet sections and minor erosion on the upstream face of the dam.


Maintenance of this dam is good. Maintenance items detailed in the report are addressed to removal of trees and the future control of tree growth and embankment erosion.



Rey S. Decker
E-3703



Gordon Jamison



Michael McMeekin
E-4776



Harold P. Hoskins
Chairman of Board
Hoskins-Western-Sonderegger, Inc.
E-8696



PHOTO NO. 1 - OVERVIEW

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CATES DAM - MO 10172
MONTGOMERY COUNTY, MISSOURI

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 of Cates 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", Appendix D to "Report of the Chief of Engineers and the National Program of Inspection of Dams", dated May, 1975, and published by the Department of the Army, Office of the Chief of Engineers.

1.2 DESCRIPTION OF PROJECT

- a. Description of Dam and Appurtenances.
 - (1) The dam is a small earthfill located in the Central Clay Pan area of northeastern Missouri. Topography of the area is nearly flat to gently rolling.
 - (2) The uncontrolled principal spillway consists of a 10-inch diameter steel pipe with hooded inlet and antivortex flap on top.
 - (3) An uncontrolled vegetated earth spillway is cut through the right abutment of the dam.
 - (4) Pertinent physical data are given in paragraph 1.3 below.

- b. Location. The dam is located in the central portion of Montgomery County, Missouri, as shown on Plate A-2. The dam is shown on Plate A-1 in the NE $\frac{1}{4}$ of Section 16, T48N, R5W. The lake formed behind the dam is shown in the NE $\frac{1}{4}$ of Section 16, T48N, R5W.
- 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, this dam and impoundment is in the small size category.
- d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragraph 1.1c above. Based on referenced guidelines, this dam is in the High Hazard Classification. The estimated damage zone extends approximately three miles downstream of the dam. Within the damage zone are three residences, outbuildings, two county roads and State Highway 161.
- e. Ownership. The dam is owned by Mrs. Ardine Cates, 3102 Hillview Drive, Bridgeton, Mo. 63044.
- f. Purpose of Dam. The dam was evidently constructed as an erosion control structure.
- g. Design and Construction History. It was reported by Mrs. Cates that the dam was constructed in 1968 or 1969. No other information was available on the design or construction of this dam.
- h. Normal Operating Procedure. All spillways are uncontrolled, and there are no operating procedures for this dam.

1.3 PERTINENT DATA

- a. Drainage Area. 77 acres (0.12 square miles).
- b. Discharge at Damsite.
 - (1) All discharges at the damsite are through a principal spillway consisting of a 10-inch diameter steel pipe spillway with a hooded inlet and a grassed earth channel ungated emergency spillway.
 - (2) Estimated maximum flood at damsite -- unknown.
 - (3) The principal spillway capacity varies from 0 cfs at elevation 832.2 feet to 8 cfs at the crest of the

emergency spillway (elevation 833.6 feet) to 8 cfs at the minimum top of dam (elevation 834.2 feet).

- (4) The emergency spillway capacity varies from 0 cfs at its crest elevation 833.6 feet to 19 cfs at elevation 834.2 feet (minimum top of dam).
- (5) Total spillway capacity at the minimum top of dam is 27 cfs \pm .

c. Elevations (feet above M.S.L.).

- (1) Top of dam - varies irregularly from 834.4 (minimum) to 836.4 (maximum)
- (2) Principal spillway crest - 832.2 \pm
- (3) Emergency spillway crest - 833.6 \pm
- (4) Streambed at centerline - 814 \pm
- (5) Maximum tailwater - unknown

d. Reservoir. Length (feet) of maximum pool - 1200 \pm .

e. Storage (Acre-feet).

- (1) Top of dam - 80 \pm
- (2) Principal spillway crest - 58 \pm

f. Reservoir Surface (Acres).

- (1) Top of dam - 13 \pm
- (2) Principal spillway crest - 9 \pm

g. Dam.

- (1) Type - Earthfill
- (2) Length - 980 feet \pm (measured)
- (3) Height - 22 feet maximum (measured)
- (4) Top width - 8 feet (measured)
- (5) Side slopes
 - (a) Downstream - 3H on 1V (measured)
 - (b) Upstream - Exposed = 6.7 to 7.5H on 1V (measured)
- (6) Zoning - unknown
- (7) Impervious core - unknown
- (8) Cutoff - unknown
- (9) Grout curtain - unknown
- (10) Wave protection - vegetated berm

h. Diversion Channel and Regulating Tunnel. None.

i. Spillway.

(1) Principal

- (a) Type - uncontrolled, 10-inch steel pipe with hooded inlet.
- (b) Crest (invert) elevation = 832.2 feet \pm .
Outlet = 813.9 feet \pm .
- (c) Length = 92 feet \pm .

(2) Emergency

- (a) Type - uncontrolled vegetated earth channel cut through right abutment, "U" shaped section with 38 feet \pm width across the top.
- (b) Control section - weir crest
- (c) Crest elevation - 833.6 feet \pm
- (d) Upstream channel - well vegetated on slope of 3.8% \pm
- (e) Downstream channel - well vegetated on slope = 3% \pm

j. Regulating Outlets. None

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No design data were available.

2.2 CONSTRUCTION

No construction data were available. It was reported by Mrs. Cates that the dam was constructed in 1968 or 1969.

2.3 OPERATION

It was reported by Mrs. Cates that the emergency spillway operated twice about 3 or 4 years ago.

2.4 EVALUATION

- a. Availability. No data were available.
- b. Adequacy. The field surveys and visual observations presented herein are considered adequate to support the conclusion of this report. 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. Not applicable.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Cates Dam was made on June 27, 1979. Engineers from Hoskins-Western-Sonderegger, Inc., Lincoln, Nebraska, making the inspection were: R. S. Decker, Geotechnical; Gordon Jamison, Hydrology; and M. McMeekin, Civil Engineer. Mrs. Cates, the Owner, was not present during the inspection.

b. Dam.

(1) Geology and Soils. This site is located in the Central Claypan physiographic area. Soils in the area are classified in the Mexico-Putnam group which are developed in 8 to 10 feet of slowly permeable, plastic loess (CL). The loess overlies fine grained plastic glacial till (CL or CH) with a paleosol at the interface of the two deposits. Materials in the embankment and abutments are plastic clay (CL or CH). Foundation materials exposed in the pipe spillway outlet are plastic clays (CL or CH) derived from the upland loess and/or the till on the gentle valley slopes.

(2) Upstream Slope. The upstream slope is well vegetated with adapted grasses and reeds. A few small willows are growing along the water line. There appears to be a berm at or near the principal spillway elevation. The water surface was just below the berm elevation when inspected. A few small (1/8" wide x 2' long) drying cracks were noted in the berm on both sides of the principal spillway inlet. No deformation was noted on the upstream slope. Some very minor erosion was noted toward the west (right) end of the dam at the junction of the berm and upstream slope.

(3) Crest. The crest is well vegetated with adapted grasses. A few small (1/8" wide x 2' long) cracks parallel with the axis of the dam were observed on both sides of the principal spillway. The cracks appear to be the result of desiccation. No rodent holes or deformations were noted on the crest. The crest and downstream slope had been recently mowed.

- (4) Downstream Slope. The downstream slope is very well vegetated with adapted grasses. No cracks, rodent holes or deformations were observed. There was no sign of seepage on the slope or along the toe of the dam.
- (5) Miscellaneous. The excellent vegetative cover and the apparent materials in the embankment indicate that this structure could withstand considerable overtopping without serious damage.

c. Appurtenant Structures.

- (1) The principal spillway consists of a 10-inch steel pipe with hooded inlet and antivortex device. No deterioration of the pipe was observed. The inlet was clear and open. The reservoir level was about 1 foot below the inlet of the spillway.
- (2) The emergency spillway is cut through CL-CH soils on the right abutment. It is very well vegetated and open. No erosion, slump, slides or deformations were observed in the spillway. The exit channel for the spillway parallels the downstream slope of the dam but discharges should not cause any serious damage to the dam.

A few small trees are growing in the inlet to the spillway.

- (3) Drawdown Facilities. The only operating facility for this dam consists of a 1-inch diameter iron pipe through the embankment to the right of the principal spillway. This line is connected to a hydrant on the downstream end. The hydrant is operable.

d. Reservoir Area. Some shoreline erosion was observed in the northeast corner and along the north shore of the reservoir. The erosion did not appear to be significant.

e. Downstream Channel. The outlet channel for the principal spillway is clogged with concrete rubble and trash. No slides or significant erosion was noted in the scour hole or outlet channel.

3.2 EVALUATION

This dam looks good and does not appear to have any serious potential of failure. The few small trees on the upstream slope, in the emergency spillway inlet and in the principal spillway outlet should be removed. Significant overtopping of the dam should not cause serious damage to the structure.

Minor erosion on the upstream slope toward the right end of the dam could ultimately impair the integrity of the structure and should be corrected.

Drying cracks observed on the upstream berm and crest of the dam should not affect the stability of the dam.

Obstructions in the outlet channel of the pipe spillway should not significantly affect the overall efficiency of spillway operation since pipe discharges are very small compared to total spillway discharges.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

There are no controlled outlet works for this dam. The pool level is controlled by rainfall, evaporation, and the capacity of the uncontrolled spillways.

4.2 MAINTENANCE OF DAM

The dam and emergency spillway had been recently mowed. Maintenance, in general, seems to be good. The few trees on the dam and in the spillway channels should be removed.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection team found no warning system in effect for this dam.

4.5 EVALUATION

There does not appear to be any serious potential of failure of this structure.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

- a. Design Data. No design data were found for this dam. All computations are based on field inspection and surveys by the consultant. The plan, profiles and cross sections from the survey are attached in Appendix C.
- b. Experience Data. The drainage area, reservoir surface area, and elevation-storage data were developed from the USGS New Florence, Missouri 7 1/2 minute topographic quadrangle map. The hydraulic computations for the spillway and dam overtopping discharge ratings were based on data collected in the field at the time of the field inspection.
- c. Visual Observations.
 - (1) The principal spillway pipe appeared to be in good condition.
 - (2) The emergency spillway is located in the right abutment of the dam. A few small trees are located at the entrance of the spillway. Spillway releases flow along the downstream toe of the dam and into the old stream channel.
 - (3) The outlet channel of the spillway pipe is clogged with concrete rubble and debris.
 - (4) No drawdown facilities are available to evacuate the pool with the possible exception of the 1-inch pipe described in paragraph 3.1.c(3).
- d. Overtopping Potential. The spillways are too small to pass 50% of the probable maximum flood and the 100-year flood without overtopping. The spillways will pass 13% of the probable maximum flood without overtopping. In addition, the spillway will pass the 10-year storm. Materials in this dam and the excellent vegetative cover indicate that the dam could withstand significant overtopping without potential of failure. The results of the routings through the dam are tabulated in regards to the following conditions:

<u>Frequency</u>	<u>Inflow Discharge c.f.s.</u>	<u>Outflow Discharge c.f.s.</u>	<u>Maximum Pool Elevation</u>	<u>Freeboard Top of Dam Min. Elev. 834.2</u>	<u>Time Dam Overtopping Hr.</u>
10 Yr.	300	12	833.8	+ 0.4	0
100 Yr.	400	35	834.4	- 0.2	3 ±
1/2 PMF	700	600	835.1	- 0.9	6 +
PMF	1400	1300	835.4	- 1.2	10 ±
0.13 PMF	180	27	834.2	0	0

According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, this dam is classified as having a high hazard rating and a small size. Therefore, the 1/2 PMF to the PMF is the test for the adequacy of the dam and its spillway.

The estimated damage zone is described in Paragraph 1.2d in this report.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

- a. Visual Observation. The dam appears to be structurally stable. The apparent materials in the embankment and the relatively flat side slopes should provide adequate safety against shear failures. No indications of seepage through the embankment or along the toe were observed.

Analyses presented in Section 5 indicate that the dam will be overtopped by about 0.9 feet for about 6 hours by one-half the Probable Maximum Flood. It would appear that such overtopping would not seriously affect the structural stability of the dam.

- b. Design and Construction Data. No design or construction data were available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.
- c. Operating Records. There are no controlled operating facilities for this dam.
- d. Post Construction Changes. The inspection team is not aware of any post construction changes for this dam.
- e. Seismic Stability. This dam is located in Seismic Zone 1. An earthquake of the magnitude predicted in this area is not expected to cause structural failure of this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

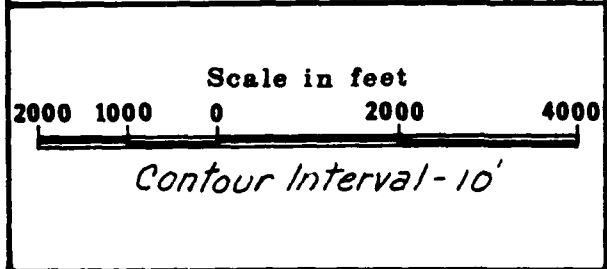
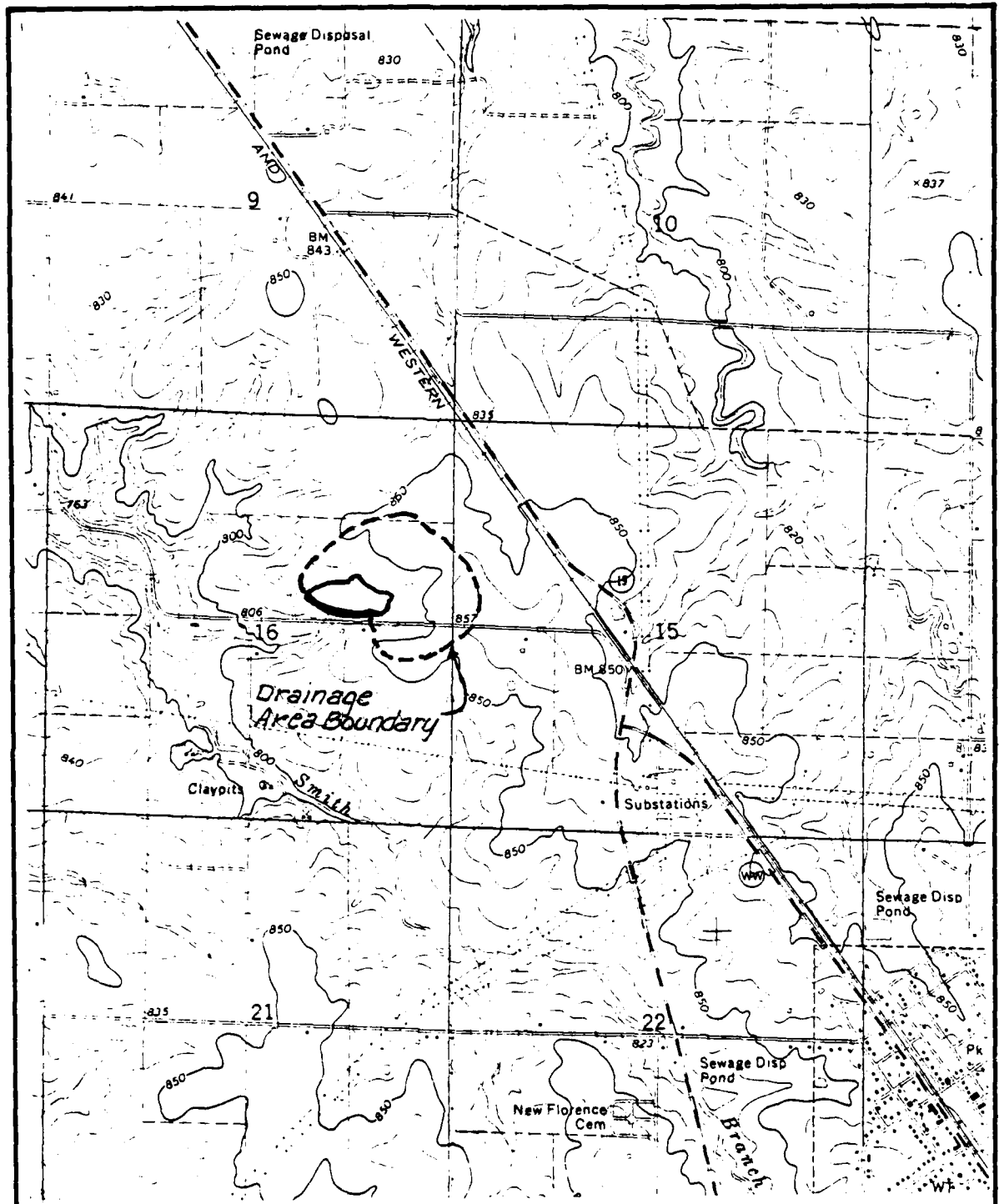
- a. Safety. This structure appears to be in good shape with no serious potential of failure. Additional studies would be required to assess the hazard classification; the potential for overtopping; and the affects of such overtopping on the erosional stability of the dam. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available which is considered a deficiency.
- b. Adequacy of Information. Due to the lack of engineering data, the conclusions in this report are based upon performance history and visual observations. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available which is considered a deficiency.
- c. Urgency. The item recommended in paragraph 7.2.a. should be pursued on a high priority basis.
- d. Necessity for Phase II. Phase II investigation is not considered necessary.
- e. Seismic Stability. This dam is located in Seismic Zone 1. An earthquake of this magnitude is not expected to be hazardous to this dam.

7.2 REMEDIAL MEASURES

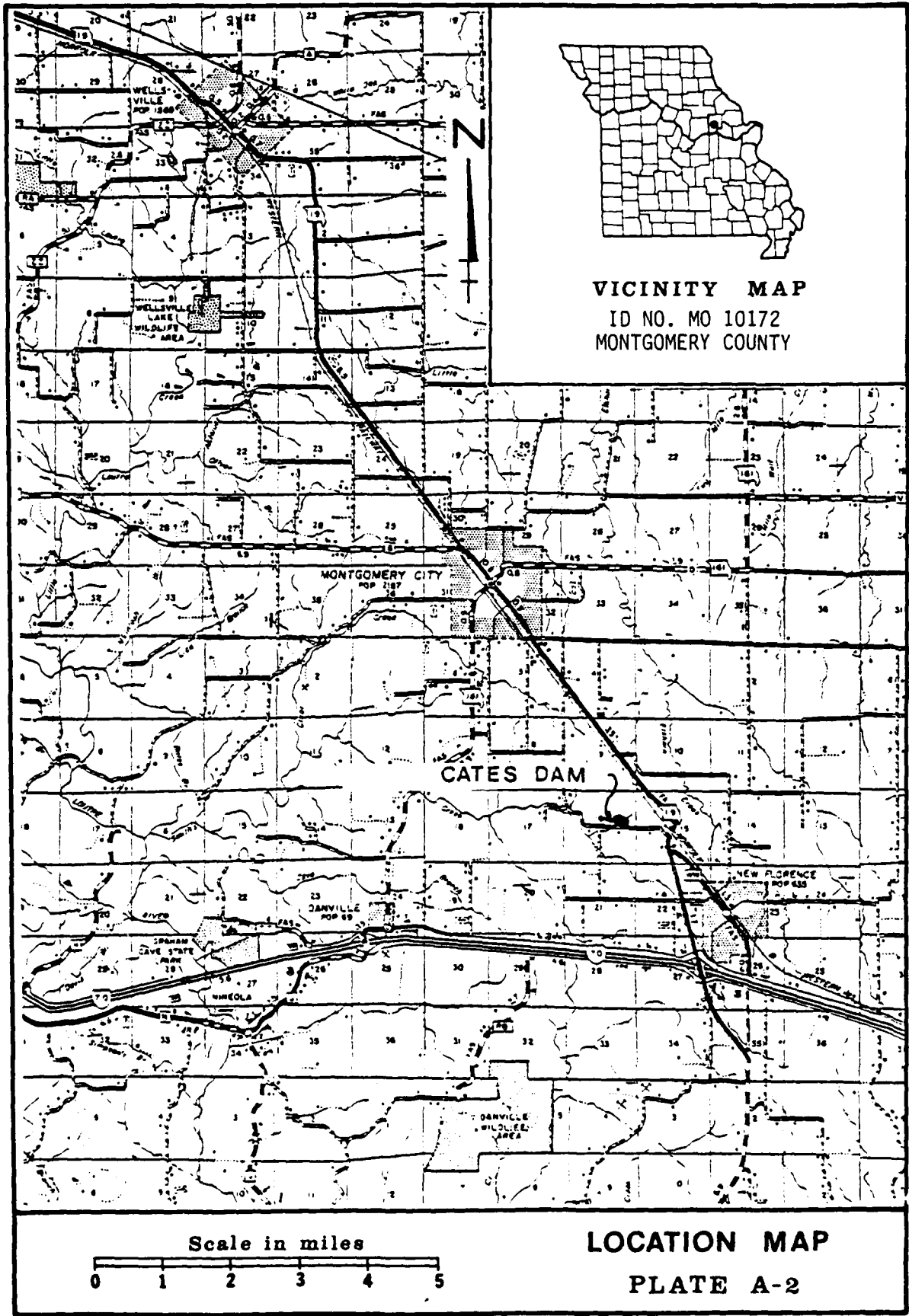
- a. Alternatives. Additional information should be obtained on the potential hazards of failure, and on the topographic characteristics of the reservoir area to determine the increase in the height of dam or the size of the spillway that is necessary to pass one-half the Probable Maximum Flood without overtopping the dam. The services of an engineer experienced in the design and construction of dams should be obtained to evaluate the present reservoir storage capacity, to provide seepage and stability analyses of the present dam, and to design protective measures, if required.
- b. O & M Procedures.
 - (1) Trees should be removed from the upstream face of the dam and from the emergency spillway inlet and outlet channel.

- (2) Minor erosion on the upstream slope should be corrected.
- (3) A program of periodic inspection and maintenance should be initiated to control tree growth and erosion on the embankment and appurtenant channels.

APPENDIX A
MAPS



VICINITY TOPOGRAPHY
 CATES DAM
 MONTGOMERY COUNTY, MO.
 MO. 10172
PLATE A-1



APPENDIX B
PHOTOGRAPHS

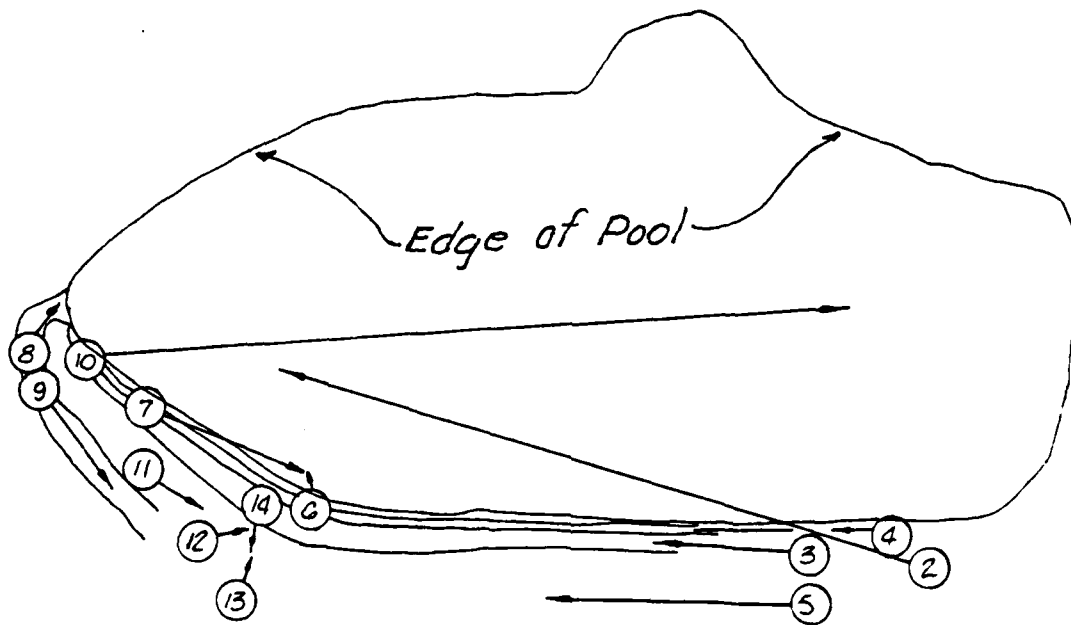


PHOTO INDEX
CATES DAM
MONTGOMERY COUNTY, MISSOURI
MO. 10172
PLATE B-1



PHOTO NO. 2 - OVERVIEW FROM LEFT END



PHOTO NO. 3 - CREST FROM LEFT END



PHOTO NO. 4 - UPSTREAM SLOPE FROM LEFT END



PHOTO NO. 5 - DOWNSTREAM SLOPE FROM LEFT END



PHOTO NO. 6 - PRINCIPAL SPILLWAY INLET. HOODED INLET WITH ANTI-VORTEX FLAP.



PHOTO NO. 7 - UPSTREAM SLOPE FROM RIGHT ABUTMENT.



PHOTO NO. 8 - LOOKING UPSTREAM IN EMERGENCY SPILLWAY ON RIGHT
END



PHOTO NO. 9 - LOOKING DOWNSTREAM IN EMERGENCY SPILLWAY



PHOTO NO. 10 - UPSTREAM ACROSS LAKE FROM RIGHT END



PHOTO NO. 11 - DOWNSTREAM SLOPE FROM RIGHT END

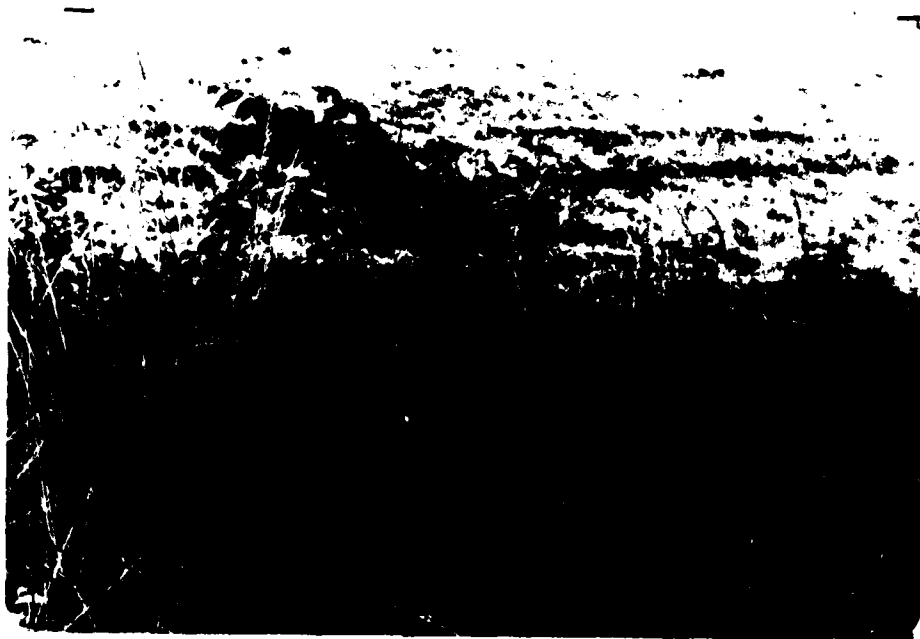


PHOTO NO. 12 - HYDRANT NEAR PRINCIPAL SPILLWAY OUTLET



PHOTO NO. 13 - OUTLET
END OF PRINCIPAL SPILLWAY.
ROD DIRECTLY IN FRONT OF
PIPE.

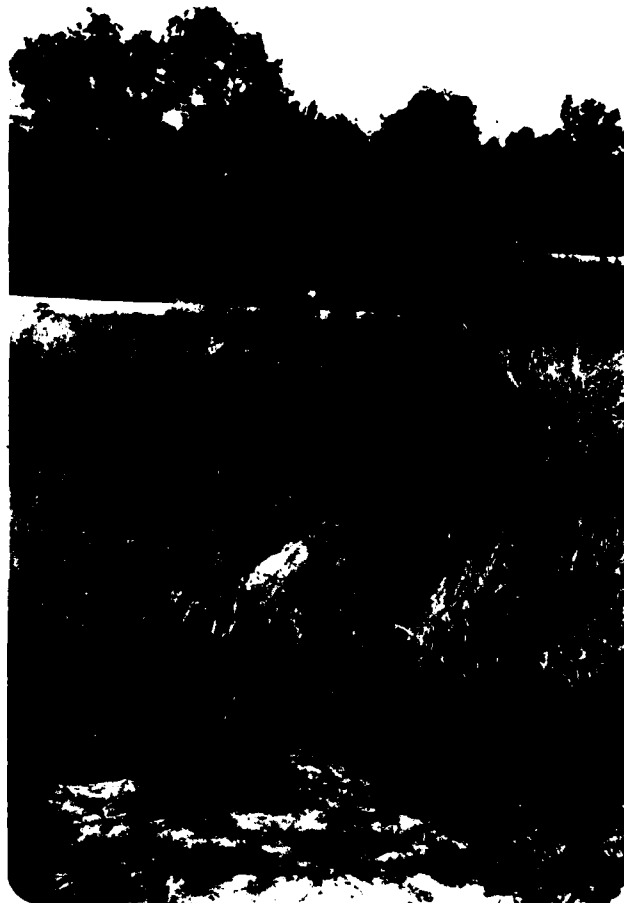
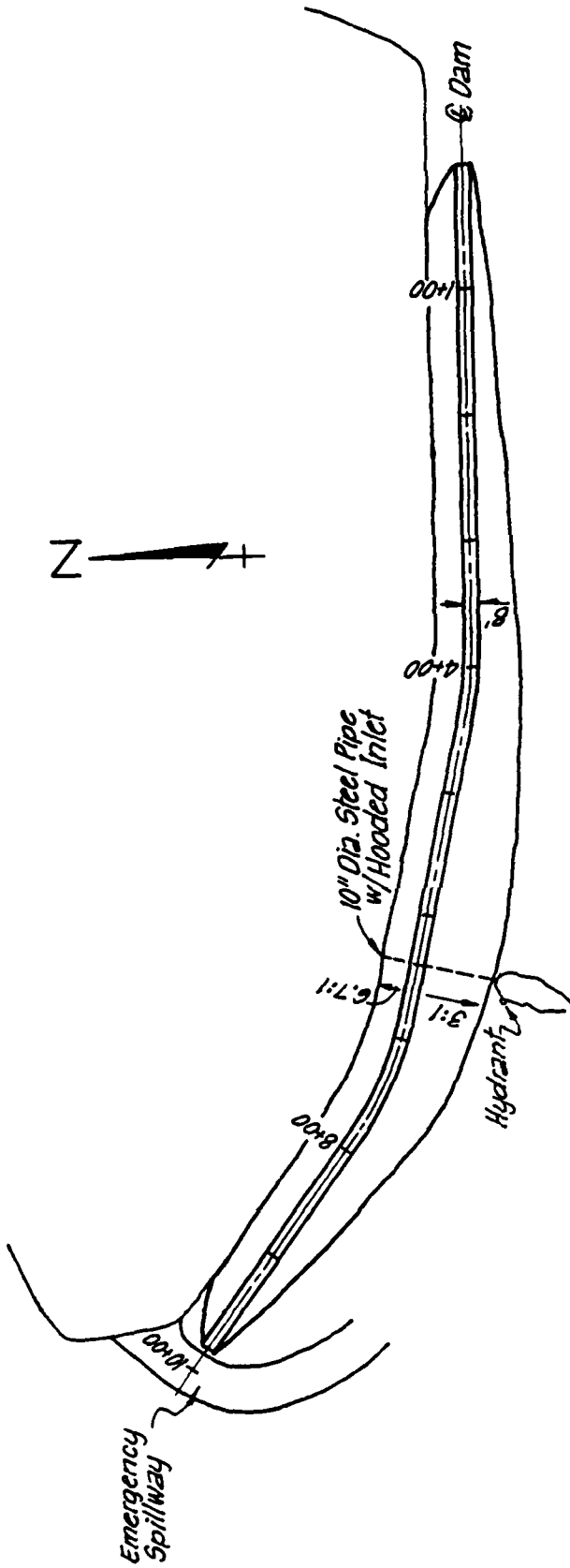
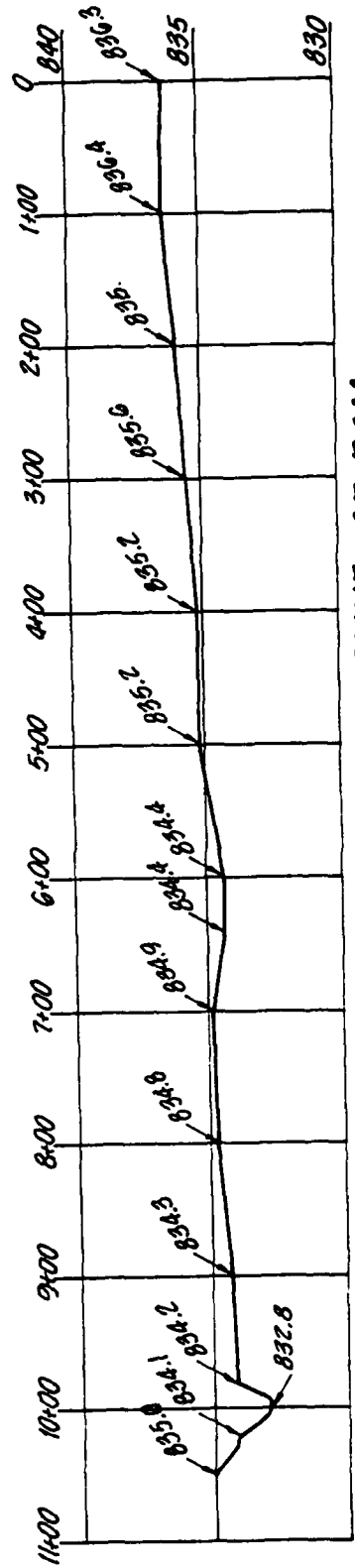


PHOTO NO. 14 - DOWNSTREAM
OUTLET CHANNEL PLUGGED
WITH CONCRETE RUBBLE AND
BRUSH

APPENDIX C
PROJECT PLATES

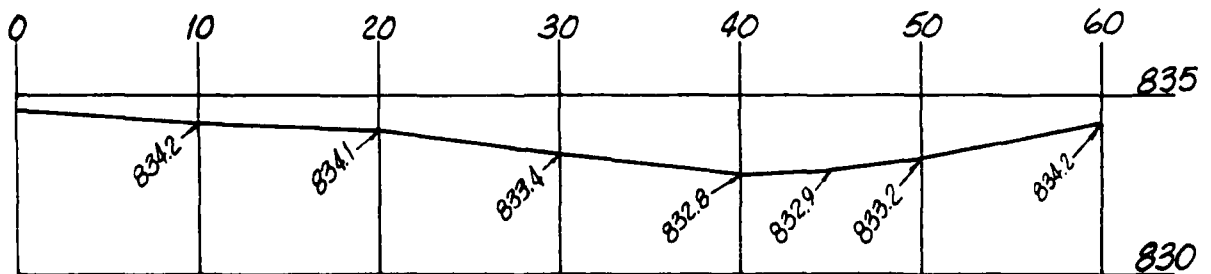
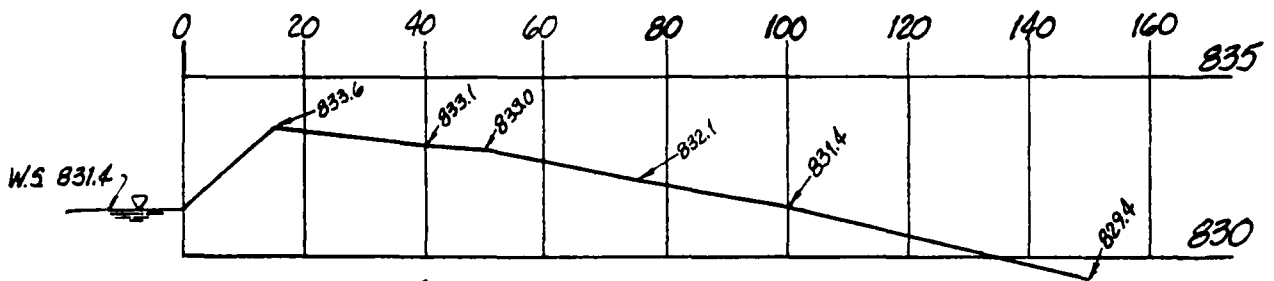
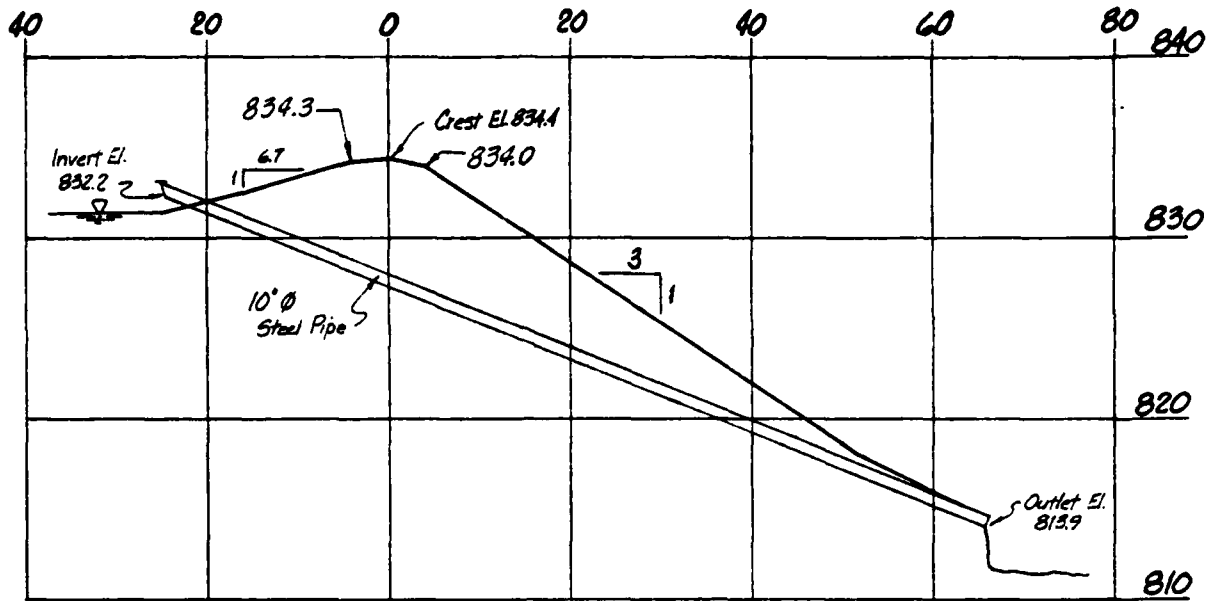


PLAN OF DAM



PROFILE ALONG CENTERLINE OF DAM

PLATE C-1



APPENDIX D
HYDRAULIC AND HYDROLOGIC DATA

HYDROLOGIC COMPUTATIONS

1. The SCS dimensionless unit hydrograph and the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U.S. Corps of Engineers, Davis, California, were used to develop the inflow hydrographs (see Appendix D).
 - a. Twenty-four hour, 100-year and 10-year rainfall for the dam location were taken from the data for the rainfall station at Sullivan, MO. as supplied by the St. Louis District, Corps of Engineers per their letter dated 6 March 1979. The twenty-four hour probable maximum precipitation was taken from the curves of the Hydrometeorological Report No. 33 and current Corps of Engineers and St. Louis policy and guidance for hydraulics and hydrology.
 - b. Drainage area = 0.12 square miles (77 acres).
 - c. Time of concentration of runoff = 14 minutes (computed from Kirpich formula).
 - d. The antecedent storm conditions for the probable maximum precipitation were heavy rainfall and low temperatures which occurred on the previous 5 days (SCS AMC III). The antecedent storm conditions for the 100-year and 10-year precipitation were an average of the conditions which have preceded the occurrence of the maximum annual flood on numerous watersheds (SCS AMC II). The initial pool elevation was assumed at the invert of the principal spillway.
 - e. The total twenty-four hour storm duration losses for the 100-year storm were 1.53 inches. The total losses for the PMF storm were 0.62 inches. These data are based on SCS runoff curve No. 95 and No. 87 for antecedent moisture conditions SCS AMC III and AMC II respectively. The watershed is composed of soils primarily from the SCS soil group D (Mexico Silt Loam and Mexico Silt Clay Loam). The entire watershed is cropland.
 - f. Average soil loss rates = 0.03 inch per hour approximately. (for PMF storm, AMC III)
2. The combined discharge rating consisted of three components: the flow through the principal spillway, the flow through the emergency spillway and the flow going over the top of the dam.

- a. The principal spillway rating was developed by using the full conduit flow equation:

$$Q = a \sqrt{\frac{2gH}{1 + K_e + K_b + K_p L}}$$

where a = cross-sectional area of pipe, ft² = 0.545

H = total head, ft.

K_e = coefficient for entrance loss = 1.08

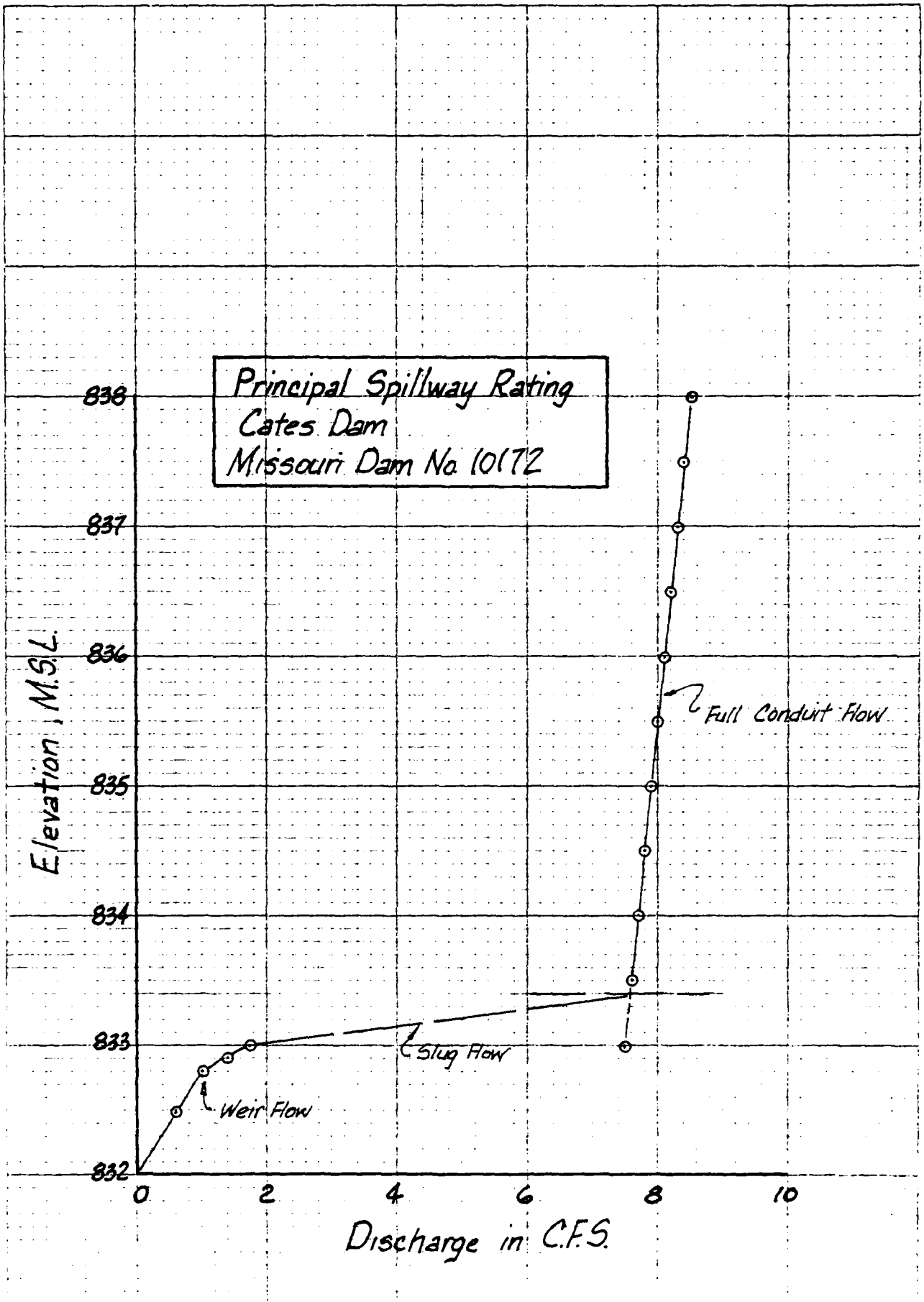
K_b = coefficient for bend loss = 0

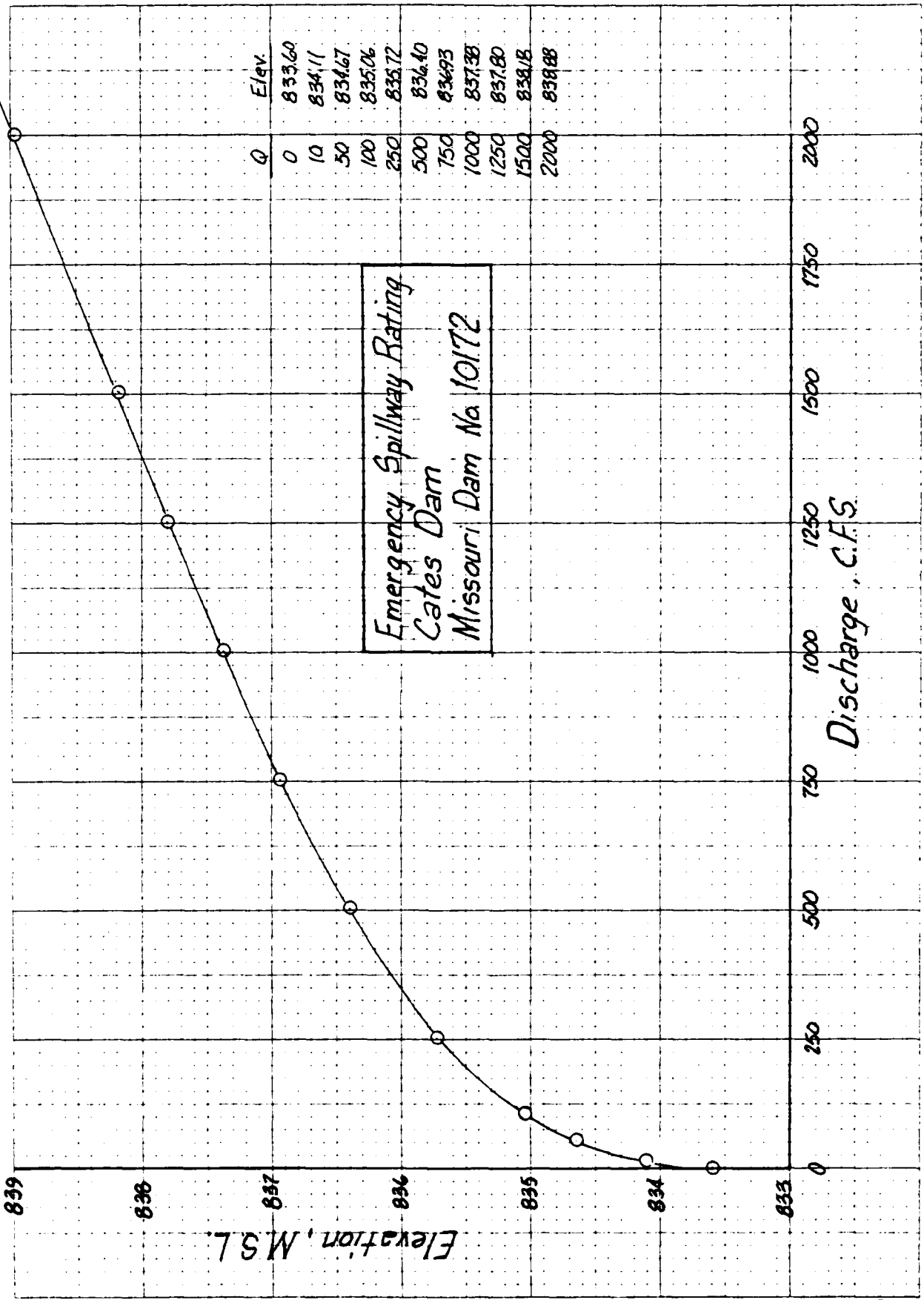
K_p = coefficient for pipe friction loss = 0.0464 (n=0.014)

L = length of pipe, ft. = 92

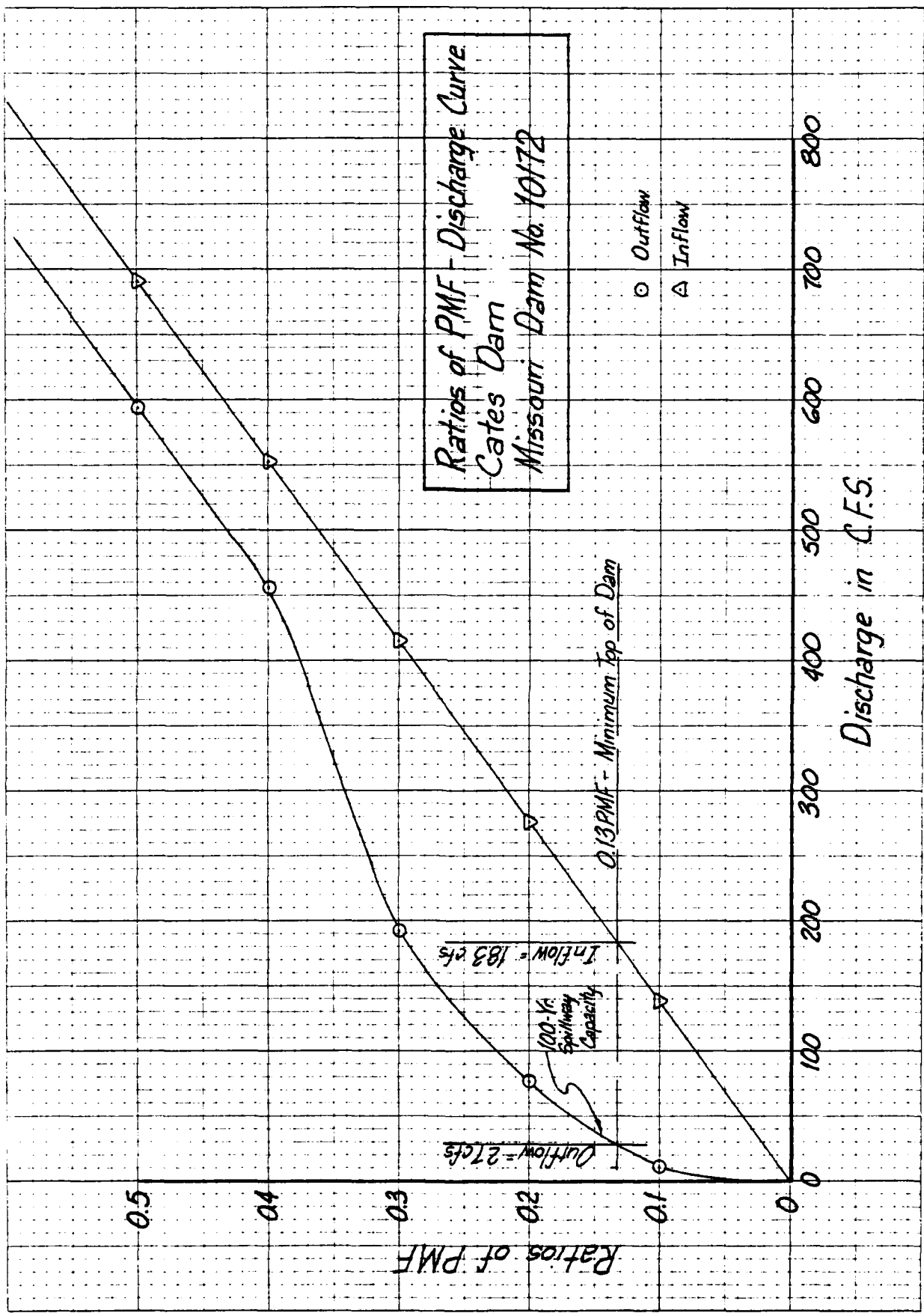
Weir flow for low heads was determined from Table 21.37 "Upstream Head and Discharge Ratios For Pipes Flowing Partly Full" in Handbook of Applied Hydrology, Ven TeChow.

- b. The emergency spillway rating was developed using the Corps of Engineers Surface Water Profile HEC-2 computer program.
- c. The flows over the dam were developed using the dam overtopping analysis (irregular top of dam) within the HEC-1 (Dam Safety Version) program.
3. Floods were routed through the reservoir using the HEC-1 (Dam Safety Version) program to determine the capabilities of the spillway and dam embankment crest. The output and plotted hydrographs are attached.





Emergency Spillway Rating
 Cates Dam
 Missouri Dam No 10172



Discharge in C.F.S.

Ratios of PMF

 FLUID HYDROGRAPH PACKAGE (HEC-11)
 DAM SAFETY VERSION: JULY 1978
 LAST MODIFICATION: 26 FEB 79

RUN DATE= 79/JB/22
 TIME= 11.12.57.

ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
 HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF ~~NO NAME~~ 13-10172 CATES DAM
 RATIOS OF PMF ROUTED THRU THE RESERVOIR

NO	NHR	NMIN	IDAY	JOB SPECIFICATION						
				JOPER	NMT	LROPT	TRACE	IPLT	IPRT	NSTAN
288	0	5	0	5	0	0	0	0	3	0

MULTI-PLAN ANALYSES TO BE PERFORMED
 NPLAN= 1 NRTIO= 8 LRTIO= 1

RTIOS= .10 .20 .30 .40 .50 .65 .80 1.00

SUB-AREA RUNOFF COMPUTATION

CALCULATION OF INFLOW HYDROGRAPH TO 10172 RESERVOIR

ISTAQ	ICOMP	TECON	ITIAE	JPLT	JPR1	INAME	ISTAGE	TAUTO
000001	0	0	0	2	0	1	0	0

HYDRO	TUNG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.12	0.00	.12	1.00	0.000	0	1	3

PRECIP DATA
 SPFE PMS R6 R72 R96
 0.00 24.87 102.50 121.00 130.00 0.00 0.00 0.00

LOSS DATA
 LPOPT STRKR DLIKR MTIUL ERAIN STRKS RTIOK STRTL CNSTL ALSMX RTIMP
 0 0.00 0.00 1.00 0.00 0.00 1.00 -1.00 -95.00 0.00 0.00

CURVE NO = -95.00 METHRES = -1.00 EFFECT CN = 95.00

UNIT HYDROGRAPH DATA
 TC= 0.00 LAG= .17

RECESSION DATA
 STRIC= 0.00 GRUSN= -.01 RTIUR= 1.00

UNIT HYDROGRAPH 12 END OF PERIOD ORDINATES, TC= 0.00 WUMS, LAG= .17 VOL= 1.00
 81. 252. 257. 162. 81. 44. 23. 12. 6. 3.
 2. 1.

END-OF-PERIOD FLOW

HYDROGRAPH AT STAG0001 FOR PLAN 1, RTIO 6

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	497.	210.	66.	66.	19056.
INCHES	25.	6.	2.	2.	540.
AC-FT	16.27	20.52	20.52	20.52	521.14
THOUS CU M	413.24	521.14	521.14	521.14	131.
	104.	131.	131.	131.	162.
	128.	162.	162.	162.	

HYDROGRAPH AT STAG0001 FOR PLAN 1, RTIO 7

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1104.	250.	81.	81.	23454.
INCHES	31.	7.	2.	2.	664.
AC-FT	20.02	25.25	25.25	25.25	641.40
THOUS CU M	508.60	641.40	641.40	641.40	162.
	128.	162.	162.	162.	199.
	150.	199.	199.	199.	

HYDROGRAPH AT STAG0001 FOR PLAN 1, RTIO 8

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1380.	323.	102.	102.	29310.
INCHES	39.	9.	3.	3.	830.
AC-FT	25.03	31.56	31.56	31.56	801.75
THOUS CU M	635.73	801.75	801.75	801.75	202.
	160.	202.	202.	202.	249.
	197.	249.	249.	249.	

HYDROGRAPH ROUTING

ROUTED FLOWS THRU 10172 RESERVOIR

	ESTAG	ICOMP	RECON	ITAPE	JPLT	JPR1	ENAME	ISTAGE	IAUTO
	000002	1	0	0	2	0	1	0	0
	QLDSS	CLOSS	AVG	IPRES	ISAME	IUPI	IPMP	LSTR	
	0.0	0.000	0.00	1	1	0	0	0	
	NSIPS	INSTDL	LAG	AMSCK	X	TSK	STORA	ISPRAT	
	1	0	0	0.000	0.000	0.000	-832.	-1	
STAGE	837.20	832.80	833.00	833.50	834.00	834.50	835.00	835.50	836.00
	836.50	837.50	838.00						
FLOW	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	519.00	774.00	1069.00	1329.00	1600.00	1930.00	2280.00	2630.00	2980.00
SURFACE AREA	0.	9.	19.	38.	57.	76.	95.	114.	133.
CAPACITY	0.	50.	160.	310.	460.	610.	760.	910.	1060.

STATION000002

DATE

INFLW(1), 200.	300.	400.	500.	600.	700.	800.	900.	0.
05	11	17	23	29	35	41	47	53
10	21	31	41	51	61	71	81	91
15	31	46	61	76	91	106	121	136
20	47	72	97	122	147	172	197	222
25	63	98	133	168	203	238	273	308
30	79	134	199	264	329	394	459	524
35	95	175	250	325	400	475	550	625
40	111	216	311	406	501	596	691	786
45	127	257	372	487	602	717	832	947
50	143	298	433	568	703	838	973	1108
55	159	339	514	674	839	994	1149	1304
60	175	380	600	785	970	1145	1320	1495
65	191	421	691	906	1131	1326	1521	1716
70	207	462	787	1057	1292	1502	1702	1902
75	223	503	888	1233	1453	1683	1883	2083
80	239	544	994	1414	1614	1864	2064	2284
85	255	585	1105	1615	1795	2045	2265	2485
90	271	626	1221	1836	2006	2296	2526	2756
95	287	667	1342	2077	2227	2547	2797	3027
100	303	708	1468	2338	2468	2808	3058	3288
105	319	749	1600	2619	2719	3079	3339	3579
110	335	790	1737	2920	3000	3400	3630	3870
115	351	831	1880	3241	3301	3751	3981	4171
120	367	872	2029	3582	3622	4122	4342	4472
125	383	913	2183	3943	3963	4513	4723	4873
130	399	954	2344	4324	4324	4924	5134	5284
135	415	995	2511	4725	4705	5355	5565	5695
140	431	1036	2684	5146	5116	5806	6026	6156
145	447	1077	2863	5587	5547	6277	6477	6607
150	463	1118	3048	6048	6008	6768	6948	7078
155	479	1159	3239	6529	6469	7279	7429	7559
160	495	1200	3436	7030	6950	7810	7960	8090
165	511	1241	3639	7551	7451	8361	8491	8621
170	527	1282	3848	8092	7972	8922	9032	9162
175	543	1323	4063	8653	8513	9493	9583	9713
180	559	1364	4284	9234	9074	10074	10144	10274
185	575	1405	4511	9835	9655	10675	10725	10855
190	591	1446	4744	10456	10256	11296	11326	11456
195	607	1487	4983	11097	10877	11937	11947	12077
200	623	1528	5228	11758	11518	12598	12588	12718
205	639	1569	5479	12439	12179	13279	13249	13379
210	655	1610	5736	13140	12860	13980	13930	14060
215	671	1651	6000	13861	13561	14691	14621	14751
220	687	1692	6271	14602	14282	15412	15332	15442
225	703	1733	6548	15363	15023	16153	16053	16163
230	719	1774	6831	16144	15784	16914	16784	16884
235	735	1815	7120	16945	16565	17695	17545	17695
240	751	1856	7415	17766	17376	18506	18326	18476
245	767	1897	7716	18607	18207	19337	19127	19287
250	783	1938	8023	19468	19058	20188	19938	20068
255	799	1979	8336	20349	19929	21059	20789	20919
260	815	2020	8655	21250	20830	21950	21660	21780
265	831	2061	8980	22171	21751	22861	22541	22661
270	847	2102	9311	23112	22692	23792	23432	23572
275	863	2143	9648	24073	23653	24743	24333	24483
280	879	2184	10000	25054	24634	25714	25254	25404
285	895	2225	10367	26055	25535	26705	26185	26325
290	911	2266	10740	27076	26456	27716	27126	27246
295	927	2307	11119	28117	27397	28747	28077	28167
300	943	2348	11504	29178	28358	29798	29038	29088
305	959	2389	11895	30259	29339	30869	29919	29999
310	975	2430	12292	31360	30340	31960	30810	30910
315	991	2471	12695	32481	31361	33071	31711	31811
320	1007	2512	13104	33622	32402	34192	32622	32712
325	1023	2553	13519	34783	33463	35333	33543	33613
330	1039	2594	13940	35964	34544	36494	34484	34524
335	1055	2635	14367	37165	35645	37675	35445	35445
340	1071	2676	14800	38386	36766	38876	36426	36366
345	1087	2717	15239	39627	37907	40097	37427	37287
350	1103	2758	15684	40888	39068	41338	38448	38208
355	1119	2799	16135	42169	40249	42599	39489	39129
360	1135	2840	16592	43470	41450	43880	40550	40050
365	1151	2881	17055	44791	42671	45181	41631	40971
370	1167	2922	17524	46132	43912	46502	42732	41892
375	1183	2963	17999	47493	45173	47843	43853	42813
380	1199	3004	18480	48874	46454	49204	44994	43734
385	1215	3045	18967	50275	47755	50585	46155	44655
390	1231	3086	19460	51696	49076	52006	47336	45576
395	1247	3127	19959	53137	50417	53447	48537	46507
400	1263	3168	20464	54598	51778	54908	49758	47448
405	1279	3209	20975	56079	53159	56389	50999	48389
410	1295	3250	21492	57580	54560	57890	52360	49340
415	1311	3291	22015	59101	55981	59411	53741	50291
420	1327	3332	22544	60642	57422	60952	55142	51252
425	1343	3373	23079	62203	58883	62513	56563	52213
430	1359	3414	23620	63784	60364	64094	58004	53174
435	1375	3455	24167	65385	61865	65695	59465	54145
440	1391	3496	24720	66996	63386	67316	60946	55126
445	1407	3537	25279	68627	64927	68957	62447	56117
450	1423	3578	25844	70278	66488	70618	63968	57118
455	1439	3619	26415	71949	68069	72299	65509	58129
460	1455	3660	26992	73640	69670	74000	67070	59150
465	1471	3701	27575	75351	71291	75721	68651	60181
470	1487	3742	28164	77082	72932	77462	70252	61222
475	1503	3783	28759	78833	74593	79223	71863	62273
480	1519	3824	29360	80604	76274	80994	73494	63334
485	1535	3865	29967	82395	77975	82785	75145	64405
490	1551	3906	30580	84206	79696	84596	76816	65486
495	1567	3947	31199	86037	81437	86427	78507	66577
500	1583	3988	31824	87888	83198	88278	80218	67678
505	1599	4029	32455	89759	84979	90149	81949	68789
510	1615	4070	33092	91650	86780	92040	83700	69910
515	1631	4111	33735	93561	88601	93951	85471	71041
520	1647	4152	34384	95492	90442	95882	87262	72182
525	1663	4193	35039	97443	92303	97833	89073	73333
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535	1695	4275	36347	101405	96085	101795	92755	75665
540	1711	4316	37010	103416	98006	103806	94626	76846
545	1727	4357	37679	105447	99947	105837	96517	78037
550	1743	4398	38354	107498	101908	107888	98428	79238
555	1759	4439	39035	109569	103889	109959	100359	80449
560	1775	4480	39722	111660	105890	112050	102310	81670
565	1791	4521	40415	113771	107911	114161	104281	82901
570	1807	4562	41114	115902	109952	116292	106272	84142
575	1823	4603	41819	118053	112013	118443	108283	85393
580	1839	4644	42530	120224	114094	120614	110314	86654
585	1855	4685	43247	122415	116195	122805	112365	87925
590	1871	4726	43970	124626	118316	125016	114436	89206
595	1887	4767	44700	126857	120457	127247	116527	90507
600	1903	4808	45436	129108	122618	129498	118638	91818
605	1919	4849	46178	131379	124799	131769	120769	93139
610	1935	4890	46926	133670	126990	134060	122920	94470
615	1951	4931	47680	135981	129191	136371	125091	95811
620	1967	4972	48440	138312	131412	138702	127282	97162
625	1983	5013	49206	140663	133653	141053	129493	98523
630	1999	5054	49978	143034	135914	143424	131724	99894
635	2015	5095	50756	145425	138195	145815	133975	101275
640	2031	5136	51540	147836	140496	148226	136246	102676
645	2047	5177	52330	150267	142817	150657	138537	104087
650	2063	5218	53126	152718	145158	153108	140848	105508
655	2079	5259	53928	155189	147519	155579	143179	106949
660	2095	5300	54736	157680	149890	158070	145530	108400
665	2111	5341	55550	160191	152281	160581	147901	109861
670	2127	5382	56370	162722	154692	163112	150292	111332
675	2143	5423	57196	165273	157123	165663	152703	112813
680	2159	5464	58028	167844	159574	168234	155134	114304
685	2175	5505	58866	170435	162045	170825	157585	115805
690								

4.45 571
 4.50 581
 4.55 591
 4.60 601
 4.65 611
 4.70 621
 4.75 631
 4.80 641
 4.85 651
 4.90 661
 4.95 671
 5.00 681
 5.05 691
 5.10 701
 5.15 711
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 5.30 7401
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 5.55 7901
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 5.75 8301
 5.80 8401
 5.85 8501
 5.90 8601
 5.95 8701
 6.00 8801
 6.05 8901
 6.10 9001
 6.15 9101
 6.20 9201
 6.25 9301
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 6.55 9901
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 6.85 10501
 6.90 10601
 6.95 10701
 7.00 10801
 7.05 10901
 7.10 11001
 7.15 11101
 7.20 11201
 7.25 11301
 7.30 11401
 7.35 11501
 7.40 11601
 7.45 11701
 7.50 11801

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21.40288.10

PLAK 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	RATIOS APPLIED TO FLOWS							
				RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8
				.10	.20	.30	.40	.50	.65	.80	1.00
HYDROGRAPH AT	003001	.12	1	130.	276.	414.	552.	690.	827.	1104.	1380.
	(	.311	(	3.9111	7.8231	11.7351	15.6471	19.5591	23.4711	31.2831	39.0851
ROUTED TO	003002	.12	1	11.	76.	291.	456.	593.	794.	992.	1272.
	(	.311	(	.3211	2.1511	8.2411	12.9011	16.7911	22.4711	28.0911	36.0211

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1

INITIAL VALUE SPILLWAY CREST TOP OF DAM
 832.20 832.20 834.20
 58. 58. 80.
 0. 0. 27.

ELEVATION
 STORAGE
 OUTFLOW

RATIO OF PNF	MAXIMUM RESERVOIR M.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	833.72	0.00	74.	11.	0.00	18.25	0.00
.20	834.48	.28	83.	76.	3.33	16.17	0.00
.30	834.81	.61	87.	291.	4.42	15.92	0.00
.40	834.96	.76	89.	456.	5.50	15.83	0.00
.50	835.05	.85	90.	593.	6.42	15.83	0.00
.65	835.17	.97	92.	794.	7.25	15.83	0.00
.80	835.27	1.07	93.	992.	7.92	15.83	0.00
1.00	835.40	1.20	95.	1272.	9.58	15.75	0.00