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NATIONAL DAM SAFETY PROGRAM. STAR MINE DAM (MO 31005), MISSISSI--ETC(U)
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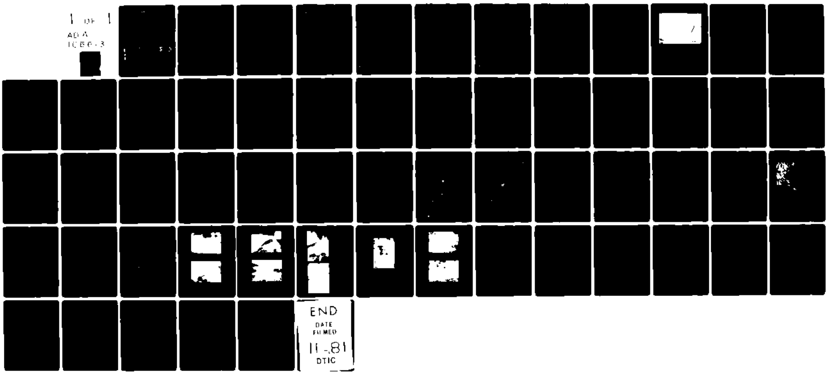

LEVEL II

MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A106613

STAR MINE DAM
WASHINGTON COUNTY, MISSOURI
MO 31005

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

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

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

FOR: STATE OF MISSOURI

DECEMBER 1980

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A [illegible]	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Star Mine Dam (MO 31005) Washington County, Missouri		5. TYPE OF REPORT & PERIOD COVERED 9 Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Woodward-Clyde Consultants		8. CONTRACT OR GRANT NUMBER(s) 15 DACW43-80-C-0066
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 58
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	11	12. REPORT DATE December 1980
		13. NUMBER OF PAGES Approximately 70
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (10) Richard G. /Berggreen Leonard M. /Krazynski		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

6 National Dam Safety Program. Star Mine Dam (MO 31005), Mississippi - Kaskaskia - St. Louis Basin, Washington County, Missouri. Phase I Inspection Report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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

REPLY TO
ATTENTION OF

Subject: Star Mine Dam (31005)

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

SUBMITTED BY: SIGNED — Chief, Engineering Division — Date: 8 JAN 1981

APPROVED BY: SIGNED — Colonel, CE, District Engineer — Date: 8 JAN 1981

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STAR MINE DAM

Washington County, Missouri

Missouri Inventory No. 31005

Phase I Inspection Report

National Dam Safety Program

Prepared by

Woodward-Clyde Consultants

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

for

Governor of Missouri

December 1980

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Star Mine Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Old Mines Creek
Date of Inspection	16 July 1980

The Star Mine Dam, Missouri Inventory Number 31005 was inspected by Richard Berggreen (engineering geologist), Leonard M. Krazynski (geotechnical engineer), John Seymour (geotechnical engineer), and Sean Tseng (hydrologist).

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. These guidelines are intended to provide for an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited nature of the study, no assurance can be given that all deficiencies have been identified.

Star Mine Dam, which is an abandoned barite tailings dam, is classified as intermediate size due to its 57 ft height. The dam has a storage capacity of 187 ac-ft. The intermediate size classification criteria are: height between 40 and 100 ft or storage between 1000 and 50,000 ac-ft.

The St Louis District, Corps of Engineers (SLD) has classified this dam as having a high hazard potential. This dam is in an inactive state and some degree of desiccation of the impounded tailings might have occurred, as indicated by the dense growth of trees in the impoundment. The true nature of the tailings cannot be determined without further investigations which are beyond the scope of the Phase I Study. However, based on the assumption that the impounded tailings are in a liquid state, the damage zone length estimated by the SLD extends approximately three miles downstream of the dam. Within this estimated damage zone are several dwellings, a school, a bridge and State Hwy. 21.

Hydrologic/hydraulic studies indicate the spillway will pass the one percent probability-of-occurrence flood (100 yr flood) without overtopping of the dam. These analyses also indicate that the dam will be overtopped for a hydrologic event which produces greater than 90 percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Our inspection and evaluation indicate the dam is in generally fair condition. Slope movements have taken place in the embankment but have apparently ceased within the past five to ten years. Depressions were noted in the dam crest above the slumped areas; settlement of the dam is a possible cause for the depressions. Some gully erosion is taking place but at present does not appear to affect the safety of the dam. The spillway and downstream channel are obstructed by rock pinnacles, some large trees, two access roads, a trash pile and a piece of mining equipment.

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.

To help improve safety of the dam, the following specific measures are recommended:

1. Prepare a hydrologic analysis to design a spillway capable of passing 100 percent of the PMF.

2. Improve flow through the spillway and downstream channel by removing major flow obstructions.

3. Prepare static and seismic stability analyses and a seepage analysis for the facility to meet the recommended guidelines.

4. Implement a periodic inspection program to identify any evidence of potential instability such as further slope movements, excessive settlement or appearance of significant seepage. Erosion of the embankment and condition of the spillway and discharge channel should also be checked under this program.

These recommendations should be performed under the guidance of an engineer experienced in the design, construction, and maintenance of tailings dams.

It is recommended that the owner take action on these recommendations without undue delay.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

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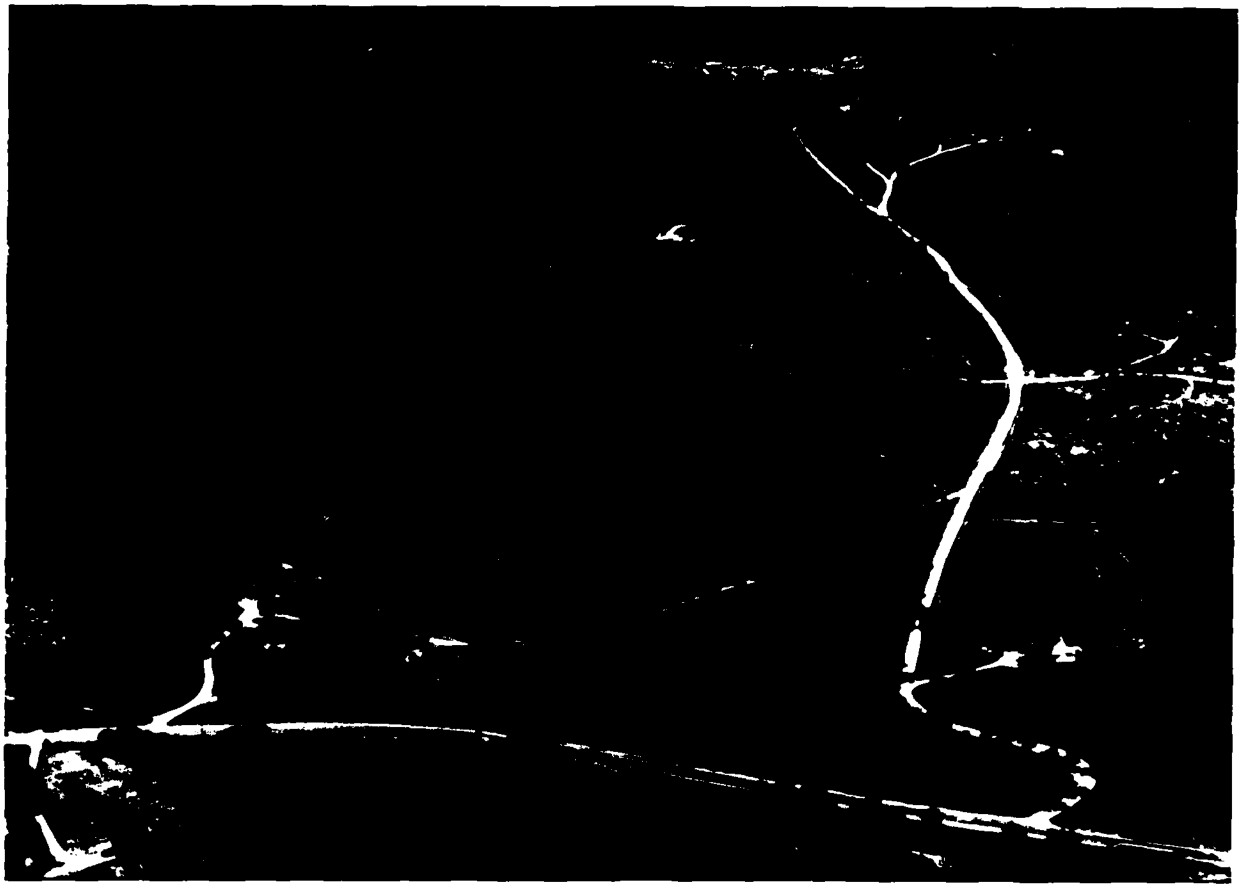

OVERVIEW

STAR MINE DAM

MISSOURI INVENTORY NO. 31005

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
STAR MINE DAM - MISSOURI INVENTORY NO. 31005
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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
STAR MINE DAM, MISSOURI INVENTORY NO. 31005

SECTION 1
PROJECT INFORMATION

1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of Star Mine Dam, Missouri Inventory Number 31005.

b. **Purpose of Inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted" (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams", Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "National Program for Inspection of Non-Federal Dams," prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers (SLD). 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.** Star Mine Dam is an abandoned barite tailings dam. Although its construction and usage is typical of other barite tailings dam in this area, it is not typical of dams constructed for impoundment of water. The unique nature of these tailings dams has a significant impact on their evaluation. A description of their construction and usage is presented to highlight the differences between this dam and a typical water-retaining dam.

At the start of a barite mining operation, a 10 to 20-ft high starter dam is typically first constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is generally limited to that provided by the equipment.

The barite ore is contained within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden wash water and water from other steps in the process is then discharged into the reservoir. There the soil is deposited by sedimentation and the water recycled. Another step in the process removes the broken gravel-sized portion which is called "chat".

As the level of the fine tailings increases, the dam is raised. The usual method is to place chat, by dumping, on the dam crest. The chat is then spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is also maintained. However, the crest centerline location will move upstream if there is insufficient chat available and downstream if an excessive quantity of chat is available. The latter is uncommon because it is indicative of a poor ore deposit.

This method of construction results in slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for a processing operation, on the order of 2000 to 5000 gal/min. Thus, it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation, the result being that spillways or regulating outlets are generally not constructed. In most cases a low point on or near the dam is provided should the storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the practice of operators maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest. The differential is usually greater further away from the tailings discharge point and also typically further away from the dam.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water content. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crust, the tailings retain their soft consistency for long periods of time. This consistency is gradually modified by a slow process of consolidation.

The Star Mine Dam is approximately 1550 ft long and is "horse-shoe" shaped in plan, with the impounded tailings to the west (see Fig 3-A). The southern portion and the eastern (central) portion of the dam are made of chat. The northern portion is constructed of gravelly residual clay (CL-CH). The dam crest varies in elevation from 704.5 to 711.1 ft (MSL). The spillway is at the far southwest corner of the dam. The discharge channel follows the toe of the dam along its southern perimeter in an easterly direction. No flow control structures exist at this facility.

b. <u>Location</u>. The dam is located on an unnamed tributary of Old Mines Creek, approximately 7.5 mi southeast of the town of Richwoods in Washington County, Missouri, in the northeast portion of Mineral Land Survey #3039, T39N, R03E. It is on the USGS Tiff and Richwoods SE 7.5 minute quadrangle maps.

c. **Size classification.** The dam is classified as intermediate size due to its approximately 57 ft height. The dam has a storage capacity of approximately 187 ac-ft. The intermediate size classification criteria are: height between 40 and 100 ft or storage volume between 1000 and 50,000 ac-ft.

d. **Hazard classification.** The St Louis District, Corps of Engineers (SLD) has classified this dam as having a high hazard potential. This dam is in an inactive state and some degree of desiccation of the impounded tailings might have occurred, as indicated by the dense growth of trees in the impoundment. The true nature of the tailings cannot be determined without further investigations which are beyond the scope of the Phase I Study. However, based on the assumption that the impounded tailings are in a liquid state, the damage zone length estimated by the SLD extends approximately three miles downstream of the dam. Within this estimated damage zone are several dwellings, a school, a bridge and State Highway 21.

e. **Ownership.** The dam is reportedly owned by Mr Tom Casey, E. High Street, Potosi, Missouri 63664.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings and is currently abandoned.

g. **Design and construction history.** The present owner has no records of the design or construction of the dam. A Mr Bob Johnson has lived at the base of the dam since he helped build the dam in 1944. According to Mr Johnson, the dam was built by first stripping the vegetation and topsoil from the land. The dam was then founded on the natural clay soil. The dam was not keyed to bedrock. The facility was in operation until 1957 when the mill burned down (Wharton, 1972).

h. **Normal operating procedures.** No operating records were found for this facility.

1.3 Pertinent Data

a. **Drainage area.** 0.16 mi^2.

b. **Discharge at damsite.**

Maximum known flood at damsite	Not known
Warm water outlet at pool elevation	Not applicable (N/A)
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	900 ft^3/sec
Total spillway capacity at maximum pool elevation	900 ft^3/sec

c. **Elevation (ft above MSL).**

Top of dam	704.5 to 711.1
Maximum pool-design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	648.4

d. **Reservoir.**

Length of maximum pool (estimated)	1000 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. **Storage (acre-feet).**

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A
Top of dam	187

f. **Reservoir surface (acres).**

Top of dam	13.0
Maximum pool	13.0
Flood-control pool	N/A
Recreation pool	N/A
Spillway crest	9.4

g. **Dam.**

Type	Barite tailings
Length	1550 ft
Height	57 ft
Top width	15 to 26 ft
Side slopes	Downstream, 1.5(H) to 1(V); Upstream, unknown
Zoning	Unknown (probably none)
Impervious core	Unknown (probably none)
Cutoff	None
Grout curtain	None

h. **Diversion and regulating tunnel.**

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating Facilities	N/A

i. **Spillway.**

Type	Grass-lined, uncontrolled earth and chat
Length of weir	37 ft (at el 704.5)
Crest elevation	698.2 ft
Gates	None
Upstream channel	None
Downstream channel	Unlined earth

j. **Regulating outlets.** None

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or other engineering data were found for this dam.

2.2 Construction

No construction records are known to exist. All information has been obtained from Mr Bob Johnson (a local resident), Mr Tom Casey (the dam owner), and a published Missouri Geological Survey Report (Wharton, 1972).

2.3 Operation

No operation records are known to exist.

2.4 Evaluation

a. **Availability.** No engineering data were available for review.

b. **Adequacy.** The available information is insufficient to evaluate the design of the Star Mine Dam. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by an engineer experienced in the design and construction of dams.

c. **Validity.** Mr Johnson's information and information from published sources correlated well, and conditions observed in the field were not in conflict with this information.

2.5 Project Geology

The dam is located on the northern flank of the Ozark structural dome. The regional dip of the bedrock is to the north. The bedrock in the vicinity of the dam is mapped on the Geologic Map of Missouri (1979) as Cambrian age Potosi and Eminence Formations (Fig 4). The dam site is near the upper part of this mapped unit, suggesting the bedrock is Eminence Formation. Wharton (1972) indicates the dam is approximately on the contact between the two formations.

The Eminence Formation is principally medium- to massively-bedded, medium- to coarse-grained, light gray dolomite. The formation also contains small amounts of quartz druse and chert. Numerous large springs and some major caves have been reported in the Eminence Formation in other parts of Missouri. The pinnacled bedrock surface exposed in the drainage channel below the spillway showed some evidence of small scale solutioning. However, no evidence of sinkholes or karst topography was noted at the dam site during the visual inspection.

The soil at the dam site consists of a red-brown, gravelly, plastic, residual clay, (CL-CH). This soil apparently developed as a residual insoluble residue on the weathered carbonate bedrock in the area. The soil is mapped on the Missouri General Soils Map (1979) as Union-Goss-Gasconade-Peridge Association.

The Cruise Mill-Fertile Fault Zone is mapped approximately 1.5 mi northeast of the site. The zone is mapped as short, curving fault trending northwest-southeast for approximately 6 miles. Displacement on the fault is north side up.

The Valle Mines - Vineland Fault Zone is mapped approximately 6 miles northeast of the site and trends parallel to the Cruise Mill-Fertile Fault Zone. It has a mapped length of approximately 22 miles and displacement on the fault is south side up.

These faults, like others in the Ozark area, appear confined to the Paleozoic bedrock. No evidence of recent faulting was noted. The faults are likely Paleozoic in age. The area is not considered seismically active and the faults do not appear to pose an unusual hazard to the dam.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** The dam was inspected on 16 July 1980 without the owner's representative present. The inspection indicated that the dam is in generally fair condition.

b. **Dam.** The embankment is comprised of coarse tailings referred to locally as "chat". This material is a light tan sandy gravel with about 80 percent hard angular particles and has less than 5 percent fines (GW). The chat has a moderate to high potential for erosion by flowing water.

The downstream and upstream slopes of the dam are approximately 1.5(H) to 1(V) and are sparsely vegetated by weeds and small bushes (Photo 3). They are composed of chat from Sta 0+00 to approximately Sta 13+00 as recorded in Fig 3-A. From this point to the end of the dam at Sta 15+48 the dam is constructed from clayey soil. The soil portion consists of residual gravelly clay soil (CL-CH) and is vegetated by grasses, small trees and bushes. The soil portions of the dam slopes are relatively low and are flatter than the chat slopes. These slopes appear to be stable with no slumping noticed.

The chat portion of the dam has a number of erosion gullies approximately 24 inches wide and 12 inches deep (Photo 4). No effort to control this gullying is apparent.

The crest of the dam had depressions or broad swales that would indicate that the embankment had settled (Photos 3 and 5). Without prior monitoring of the dam, however, this cannot be confirmed. One small possible slump scarp was noted on the downstream side of the dam crest. It is only a few inches deep and may possibly be a rut from vehicular traffic rather than a slump scarp (Photo 6).

An area just above the toe of the slope from Sta 7+75 to 8+75 has apparently undergone some type of slope movement. A distinctive bulge is present with variable slopes as indicated in a sketch enclosed as Figure 5. The older trees growing on the bulge are curved outward or leaning outward (Photo 7). Trees growing farther up the slope and located approximately at Sta 9+75 are also curved. Younger trees on the slope (apparently less than 10 years old) have grown vertically without any noticeable curvature. Both younger and older trees located further downslope at the toe are also not affected (see Fig 5). Possible reasons for the curved trunks of the older trees are as follows:

1. The uppermost surface of chat (probably limited to 1 or 2 feet) is slowly moving down slope in a form of mass wasting, similar to talus creep. The process gradually pushes the tree trunks downhill. Because the process is slow, the tree tops continue to reach for the best sunshine and the tree tops grow vertically. The bulge at the bottom of the slope is from accumulated chat where the downhill migration has been partially arrested by the maturing trees. As the chat settles into a more dense arrangement and more stable slope configuration after a number of years, the younger trees grow straight, not affected by prior slope creep.

2. The surface of the embankment may have been affected by chat added to the dam crest. Excess chat would roll down the embankment, creating the bulges and curved tree trunks. When no new chat was added, the embankment would stabilize and the younger trees would consequently not be affected.

3. A combination of causes 1 and 2 above would also yield the observed results. The depressions and a small scarp which were noted at this dam could have also arisen from a limited slope failure, which has now stabilized itself by assuming the present slope configuration.

No visible seepage or swamp-like vegetation was found on the embankment, but mossy rocks and tree trunks were noted at the toe near the maximum dam section. This indicates moist or humid conditions, probably from a very slow rate of seepage.

There were no animal burrows or sinkholes observed in the dam embankment.

c. **Appurtenant structures.** The only identifiable appurtenant structure is a "V"-shaped spillway that was constructed at the southwest end of the dam. It is approximately 37 ft wide and 7 ft deep and is composed primarily of natural gravelly clay (CL-CH) residual soil. Where the spillway abuts the dam it is formed from chat. The spillway floor has bedrock pinnacle obstructions and is heavily vegetated by weeds and bushes with some 15 to 20 year old trees (Photos 8 and 9). The exposed native soil is judged to be moderately susceptible to erosion while the chat is judged to be highly erodible, due to its lack of cohesion.

d. **Reservoir area.** The tailings within the impoundment consist of clay, silt, and fine sand-sized particles. The surface has partially desiccated and supports trees of up to 12 inches in diameter. There is also an abundance of bushes and weeds growing in the reservoir, probably due to the amount of moisture retained by the tailings (Photos 2 and 5).

No standing water was seen in the reservoir, but small depressions that have held seasonal runoff were noted.

The slopes surrounding the reservoir are generally quite flat, but are irregular and locally steeper in mined-out areas. The soils making up the slopes are gravelly residual clays. No evidence of slope instability was identified. The erosion potential of the vegetated slopes is low. The erosion potential for the nonvegetated slopes is moderate.

e. **Downstream channel.** The discharge channel from the spillway runs parallel to the southern perimeter of the dam near the toe of the embankment. Significant erosion of the embankment toe was not noticed at the time of our inspection.

At approximately Sta 1+50, a trash pile has been placed on the slopes of the channel and it appears not to have been recently disturbed. Mr Bob Johnson lives about 200 ft from the channel and stated the channel carries water only after periods of intense rain. The age and undisturbed condition of the trash pile indicates this statement to be reasonably accurate.

A gravel access road crosses the channel at the southeast corner of the dam, rising about 2 to 3 ft above the bottom of the channel. A piece of abandoned mining equipment is located just upstream of the road and would obstruct flood flow. Photo 9 is taken from this road, looking downstream.

The discharge channel continues in an easterly direction near the dam and intersects another access road approximately 800 ft from the dam's south-eastern corner. The channel then joins Old Mines Creek approximately 200 ft east of this access road.

The entire discharge channel is heavily vegetated with mature trees, bushes and weeds. The channel has been excavated into gravelly residual clay soil. The vegetated soil has a low erosion potential, but there exists substantial opportunity for obstruction to flow in the discharge channel.

3.2 Evaluation

The inspection indicates the dam is in generally fair condition. The embankment has apparently undergone some forms of slope adjustment. Erosion is taking place in the form of minor gullying and sheet wash. The gullying would have to become much more severe to pose a safety hazard. Monitoring of the erosion is advisable, however, as the process is likely to become worse with time and may require future remedial action.

Local settling of the dam crest seems to have occurred but does not appear to pose a safety hazard at this time.

Near-surface slope movement of the chat embankment has occurred in the past but appears to be inactive at present. The angular chat may have attained a stable particle orientation, or the causes of the slumping may have ceased. Reactivation of the slope movements is possible and may pose a future hazard to safety.

The spillway was found to be vegetated with weeds, bushes and small trees. The spillway has bedrock pinnacles in its narrowest section. The trees and the pinnacles can obstruct high flood flows and reduce the capacity of both the spillway and the discharge channel. The latter has the additional obstructions of trash, abandoned equipment and two gravel roads.

The inspection did not identify animal burrows, sinkholes or seepage on the dam.

Overtopping of this dam could result in serious erosion and subsequent failure of the chat embankment and pose a threat to the safety of downstream residents and structures.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

As far as could be determined there are no operational procedures for this dam. The water level is controlled by the crest of the spillway.

4.2 Maintenance of Dam

There appears to be little to no maintenance on the dam or appurtenant structures.

4.3 Maintenance of Operating Facilities

There are no operating facilities at this dam.

4.4 Description of Any Warning System in Effect

The visual inspection did not identify any warning system in effect at this facility.

4.5 Evaluation

There is no plan for periodic inspections and performance of maintenance. In view of the abandoned nature of the dam, the obstructed downstream channel and spillway, and the potential erodibility of the embankment, the dam could erode and deteriorate without being noticed. The lack of a warning system is also considered a deficiency for the conditions observed.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic design data were available for evaluation of this dam or reservoir. However, pertinent dimensions of the dam were field surveyed, measured during the field inspection, or estimated from topographic mapping. The map used in the analysis was the USGS advance print Tiff, Missouri 7.5 minute quadrangle sheet.

b. **Experience data.** No recorded history of rainfall, runoff, discharge or pool stage data were found for this reservoir. No evidence of overtopping was observed.

c. **Visual observations.**

1. Watershed. The watershed is natural woods, forested with mixed hardwoods and softwoods. The area of the reservoir is approximately 13 percent of the total drainage area of approximately 0.16 mi^2.

2. Reservoir. The reservoir and dam is best described by the figures and photographs enclosed herewith.

3. Spillway. The spillway is located at the southwest end of the dam abutting the natural hillside. It is approximately triangular in shape and is partially obstructed by bedrock pinnacles. The 4 to 5^o slope of the discharge channel below the spillway indicates that the spillway serves as the control section for flow.

4. Seepage. The magnitude of seepage through this dam is not hydrologically significant to the overtopping potential.

d. **Overtopping potential.** One of the primary considerations in the evaluation of Star Mine is the assessment of the potential for overtopping and consequent failure by erosion of the embankment. Since the spillway of this dam is rather rocky and well covered by plants, significant erosion of the spillway due to high velocity discharge is not expected. The lowest portion of the dam is approximately 300 ft from the spillway at the point marked as "depression" in the attached Figure 3-A. Our analyses indicate that spillway discharge of greater than 900 cubic feet per second would result in overtopping of this embankment. This flow corresponds to approximately 90 percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

The following analyses for the PMF were computed for this dam:

Percent PMF	Maximum Water Surface Elevation, ft (MSL)	Maximum Depth Over Dam, ft	Maximum Outflow, ft^3/sec	Duration of Overtopping, hrs
50	703.0	0	435	0
90	704.5	0	901	0.17
100	704.8	0.30	1023	0.50

It should be noted that more than 90 percent of the PMF is required for the dam to be overtopped. However, the potential for erosion of a chat embankment is considered high. Overtopping could result in sufficient erosion to jeopardize the safety of the dam. Clearing and modest widening of the spillway should be undertaken. This will likely preclude the short time period of overtopping and reduce the likelihood of erosion. Some erosion of the toe of the dam along the uppermost part of the downstream channel is expected during high outflows. This erosion could lead to slope failure and possibly dam failure if it occurred in a hazardous section, for instance near the maximum section. The southwest corner of the dam is the highest dam section subject to potential erosion by spillway outflows. This corner has been protected by increasing the width of the total section with chat.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** The inspection identified several adverse conditions present at the site which are recorded in Section 3. The most serious conditions on the dam are the apparent slumping and the gully erosion of the chat portion of the dam. The most serious conditions existing in the spillway and downstream channel are the obstructions that can inhibit flood flows or divert them toward the toe of the dam. These diverted flood flows could erode the toe and jeopardize the safety of the dam.

b. **Design and construction data.** No design or construction data relating to the stability of the dam were available. Stability and seepage analysis comparable to the requirements in the "Recommended Guidelines for Safety Inspections of Dams" are not on record, which is considered a deficiency.

c. **Operating records.** No operating records were available.

d. **Post construction changes.** The lack of drawings or construction reports precludes identification of post construction changes. However, no obvious changes were observed.

e. **Seismic stability.** The dam is Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are fine-grained saturated materials and the embankment consists of loose, granular material, it is expected that substantial deformation or failure of the embankment could occur in the event of a severe seismic event.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. Safety. Based on the visual inspection and hydrologic analysis the dam appears to be in fair condition. The dam will pass 90 percent of the PMF without overtopping. Obstructions in the spillway and downstream channel could inhibit the dam's capability to pass flood flows or could divert the flow toward the chat embankment causing possible erosion. Stability and seepage analyses comparable to the requirements in the "Recommended Guidelines for Safety Inspections of Dams" are not on record, which is considered a deficiency.

As a consequence of the widely-used construction procedure, the downstream slopes of tailings dams are placed at the angle of natural repose for the "chat" material at any given operation. This results in slopes that are very steep and exist in a state close to incipient failure with safety factors close to one. This situation is subject to some gradual improvement with time as consolidation and/or desiccation of the fine-grained tailings results in an increase in strength and a resultant decrease in lateral pressures on the dam. Such increase in strength, however, will be very slow.

The slopes which are placed at the angle of natural repose will only remain stable, if they are protected against potential harmful changes, among which are:

1. Overtopping by water
2. Higher pore pressures (or seepage forces)
3. Undercutting of the toe of the slope by erosion or mining activity
4. Increase in the height of the dam
5. Harmful effects of vegetation (particularly tree roots)
6. Liquefaction (such as may result from a seismic event).

The first five changes are subject to control by owners and operators and must receive careful attention in order to maintain stable and safe dam embankments. The sixth influence represents a risk the magnitude of which is not well understood without further study.

b. **Adequacy of information.** The lack of design documents such as static and seismic stability analyses and seepage analysis are deficiencies according to the guidelines. These analyses should be conducted by an engineer experienced in the design and construction of dams.

c. **Urgency.** The deficiencies described in this report could affect the long term stability of this dam. Corrective action should be implemented without undue delay.

d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspections of Dams", the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed without undue delay are described in Section 7.2b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

7.2 Remedial Measures

a. **Alternatives.** There are several general options which may be considered to reduce the possibility (or limit the effects) of dam failure. Some of these options are:

1. Remove the dam or breach it to prevent storage of water.

2. Increase the height of dam and/or spillway size to pass the probable maximum flood without overtopping the dam.

3. Purchase downstream land that would be adversely impacted by dam failure, and restrict human occupancy.

4. Provide a highly reliable flood warning system (generally does not prevent damage but diminishes chances for loss of life).

b. **Recommendations.** Based on our inspection of Star Mine Dam, we recommend that as a minimum the following action be undertaken:

1. A hydraulic/hydrologic analysis should be performed to determine spillway size requirements to pass the PMF;

2. Improve flow characteristics in the spillway and the downstream discharge channel by removing major obstructions, and protect the toe of the dam against severe erosion during high outflows;

3. Perform static and seismic stability analyses, and a seepage analysis in accordance with the guidelines.

These actions should be performed by or under the guidance of an engineer experienced in the design and construction of dams.

c. **O & M procedures.** It is recommended that a maintenance program and a program of periodic inspections be developed to identify changes in the facility that may lead to a decrease in the safety of the dam. Some items that should be periodically checked are the following:

1. Increase in size or number of depressions on the crest;

2. Increase in size or number of erosion gullies;

3. Reactivation of slope movement indicated by larger scarps or more deformation in the trees on the slope;

4. Appearance of significant seepage through the dam;

5. Inspection of the spillway and downstream discharge channel for erosion and obstructions.

Records of all inspections and resultant maintenance should be kept. All maintenance and inspections should be performed under the guidance of an engineer experienced in the design and construction of dams.

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Missouri Geological Survey, 1979, Geologic Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

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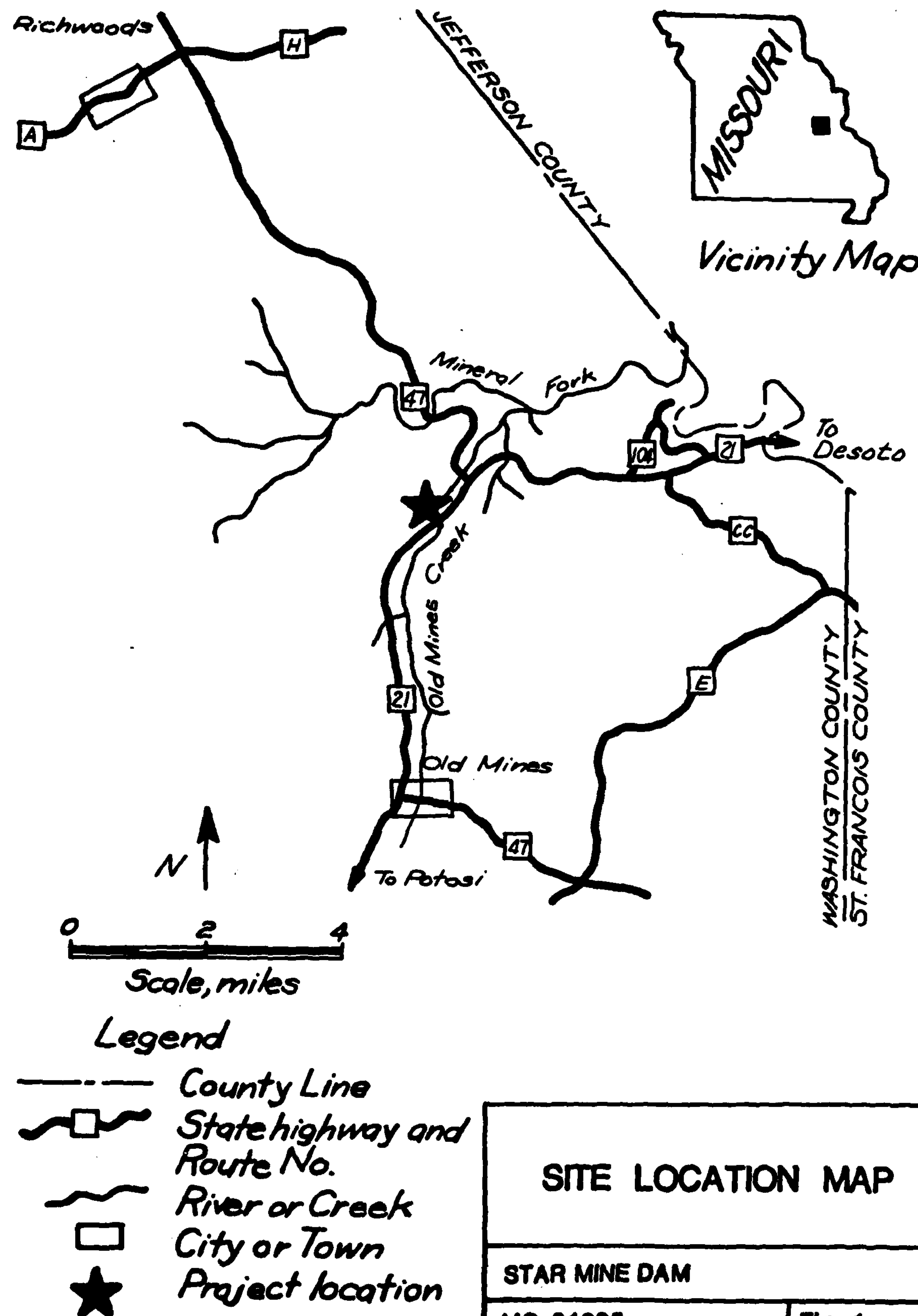
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.

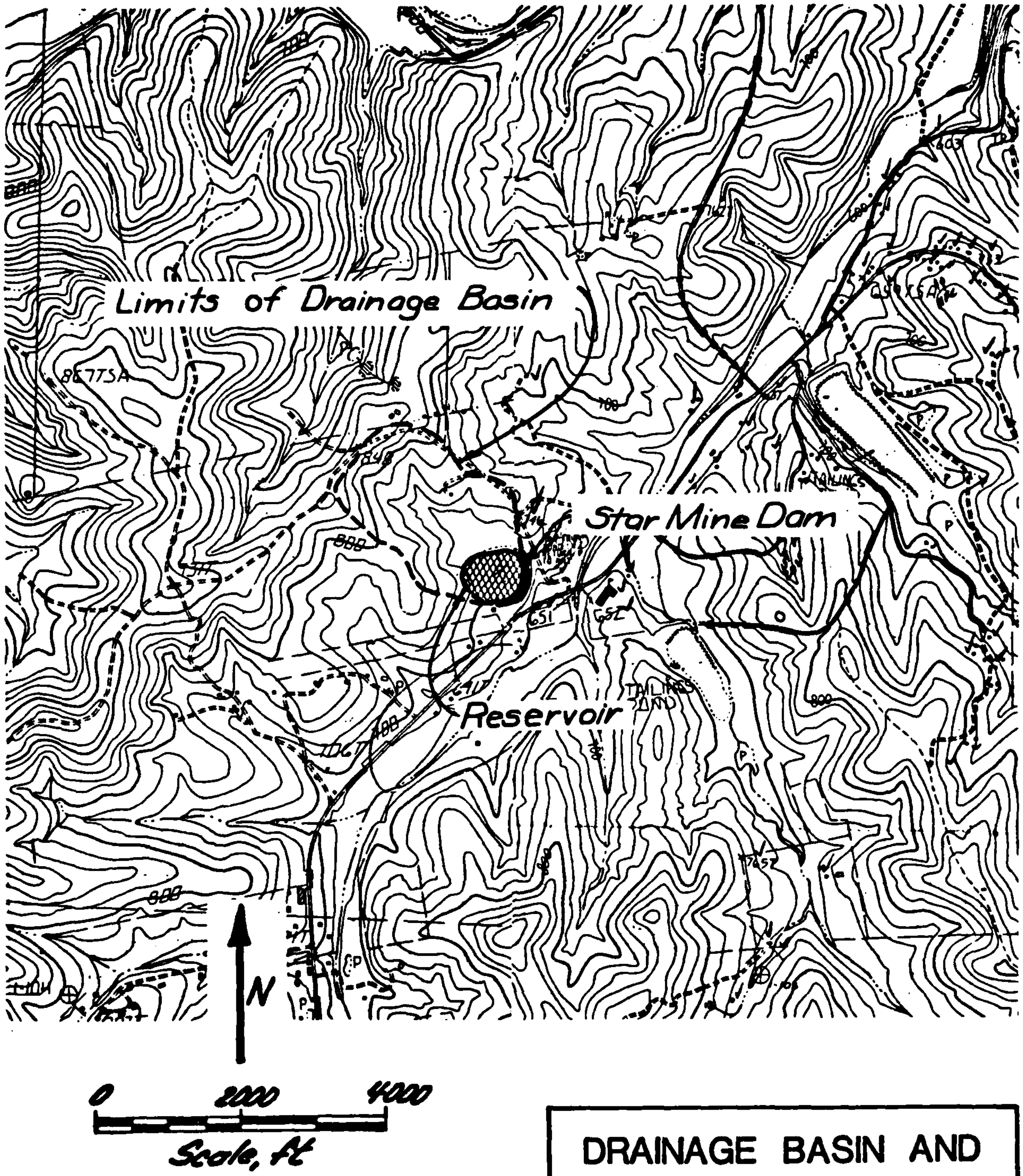
Wharton, Heyward M., 1972, "Barite Ore Potential of Four Tailings Ponds, Washington County Barite District Missouri," Missouri Geological Survey & Water Resources, Report of Investigations No. 53.



SITE LOCATION MAP

STAR MINE DAM

MO 31005 | Fig. 1



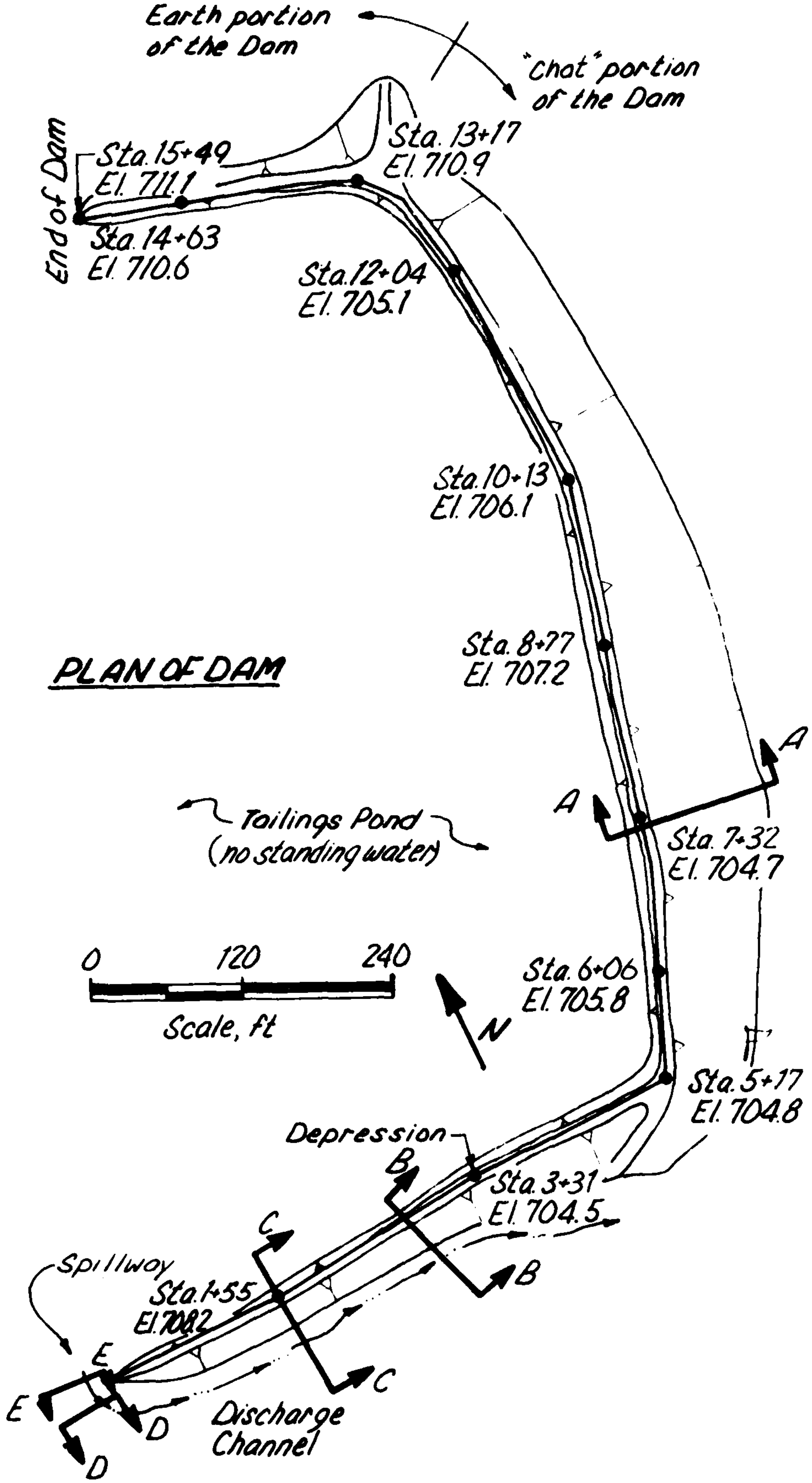
DRAINAGE BASIN AND SITE TOPOGRAPHY

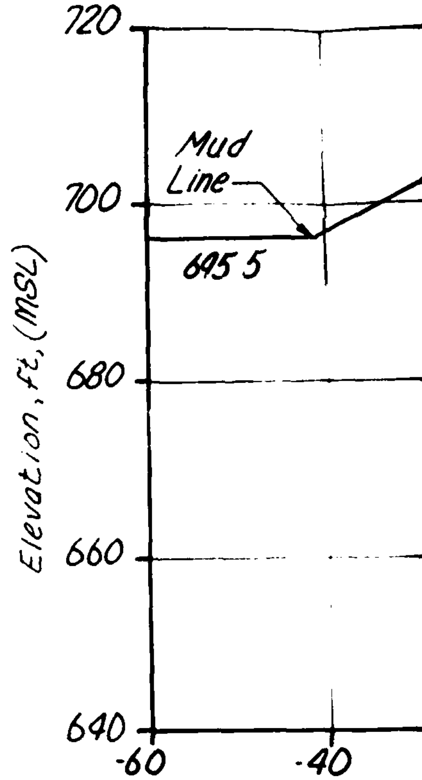
STAR MINE DAM

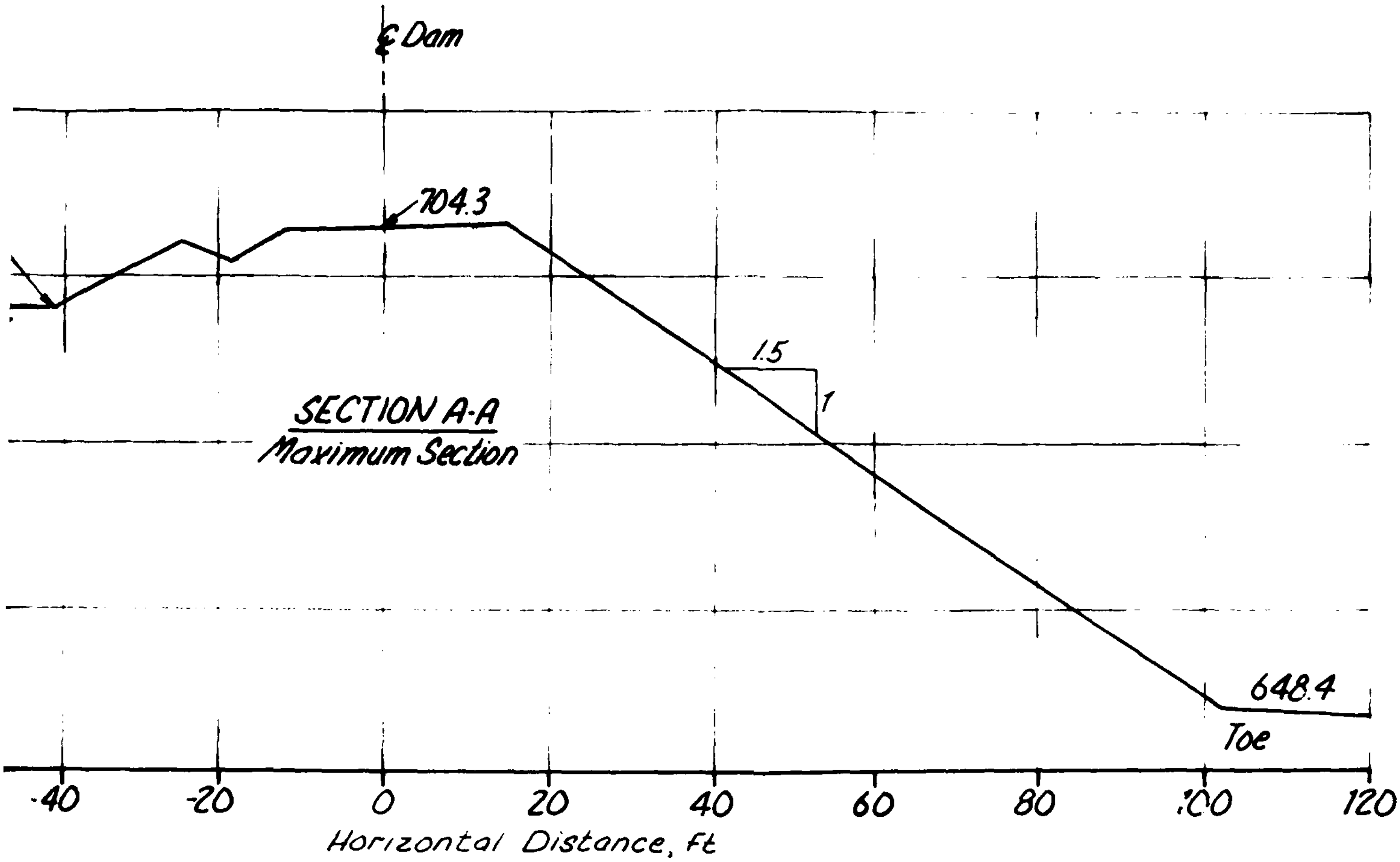
MO 31005	Fig. 2

Note:

1. Topography from U.S.G.S. Tiff and Richwoods SE 7½ minute quadrangle maps.


Earth portion of the Dam
"Chat" portion of the Dam
End of Dam
Sta. 15+49
El. 711.1
Sta. 13+17
El. 710.9
Sta. 14+63
El. 710.6
Sta. 12+04
El. 705.1
Sta. 10+13
El. 706.1
Sta. 8+77
El. 707.2
PLAN OF DAM
A
A
Tailings Pond
(no standing water)
Sta. 7+32
El. 704.7
0
120
240
Scale, ft
N
Sta. 6+06
El. 705.8
Sta. 5+17
El. 704.8
Depression
B
Sta. 3+31
El. 704.5
C
B
Spillway
Sta. 1+55
El. 708.2
E
C
E
D
Discharge
Channel
D


720
700
680
660
640
-60
-40
Mud
Line
695.5
Elevation, ft, (MSL)



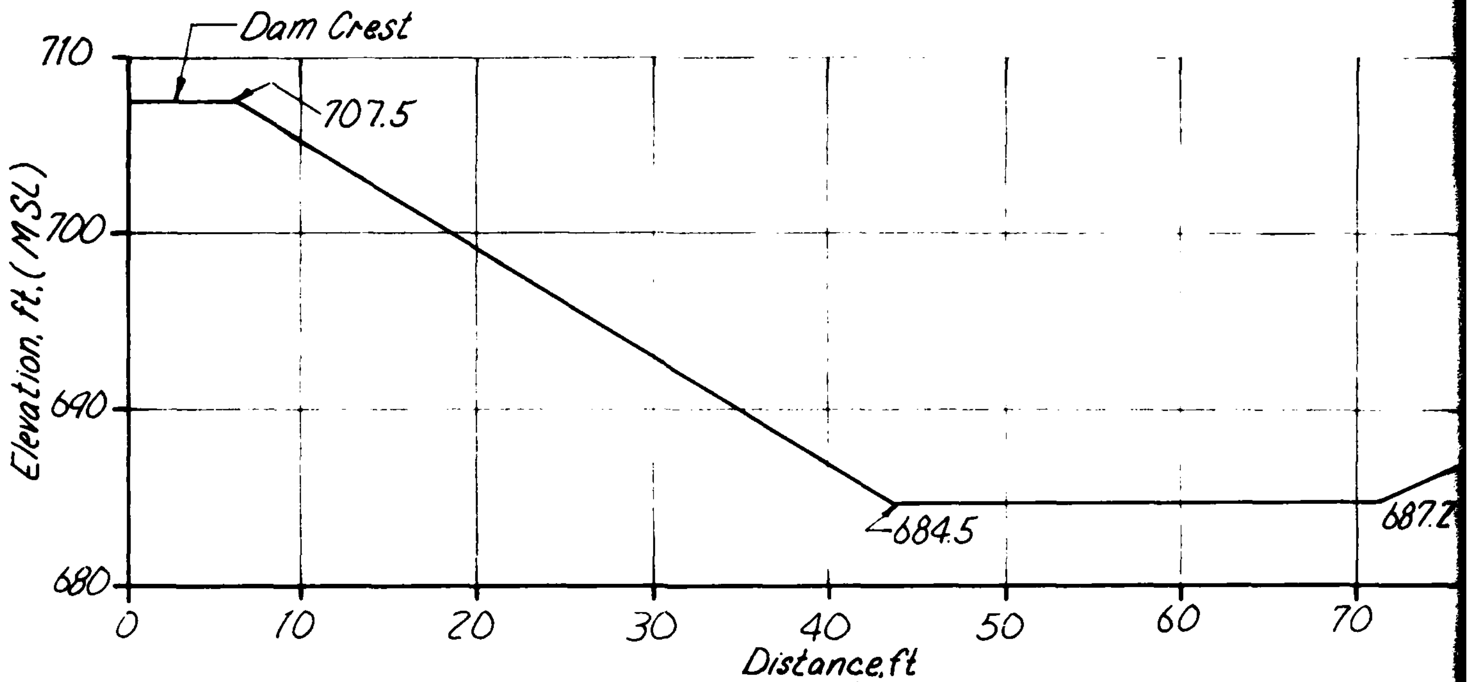
PLAN AND MAXIMUM SECTION OF DAM

STAR MINE DAM

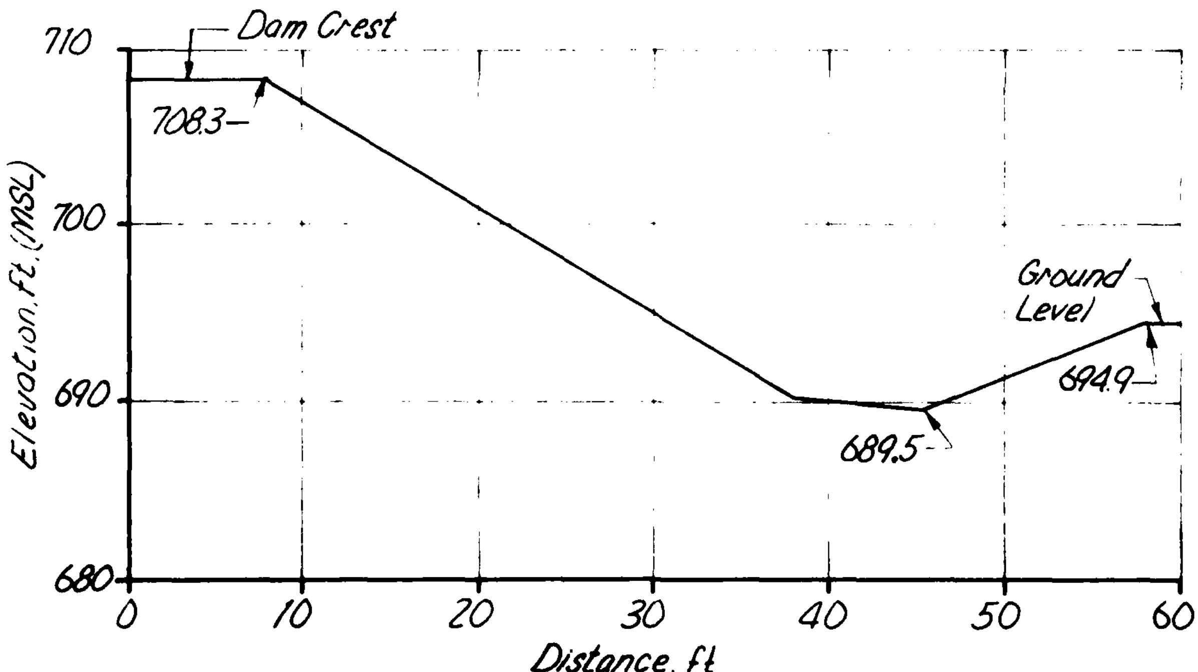
MO 31005

Fig. 3-A

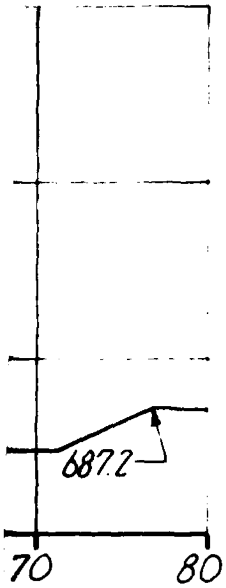
12

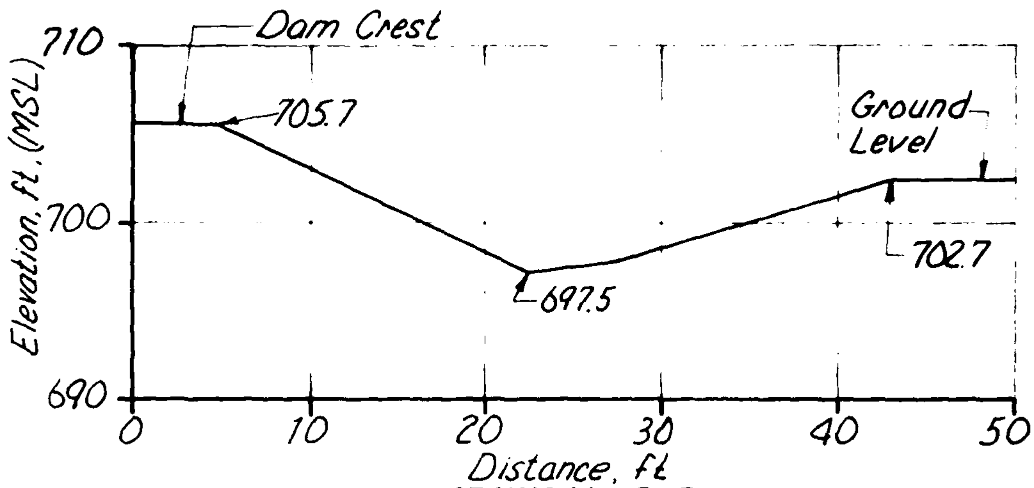


SECTION B-B
Discharge Channel

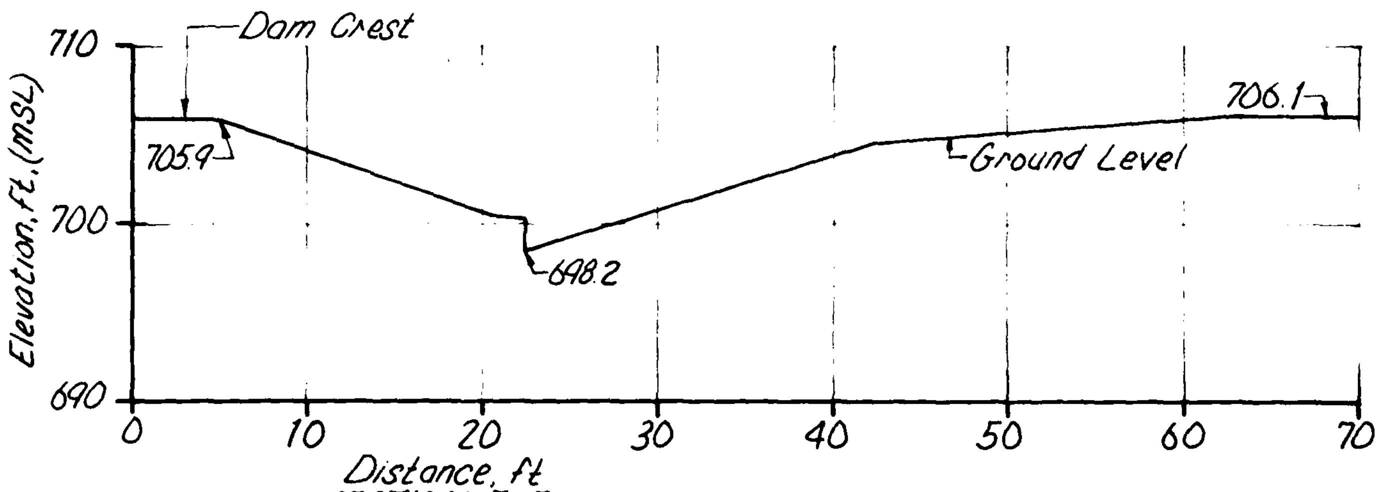


SECTION C-C
Discharge Channel





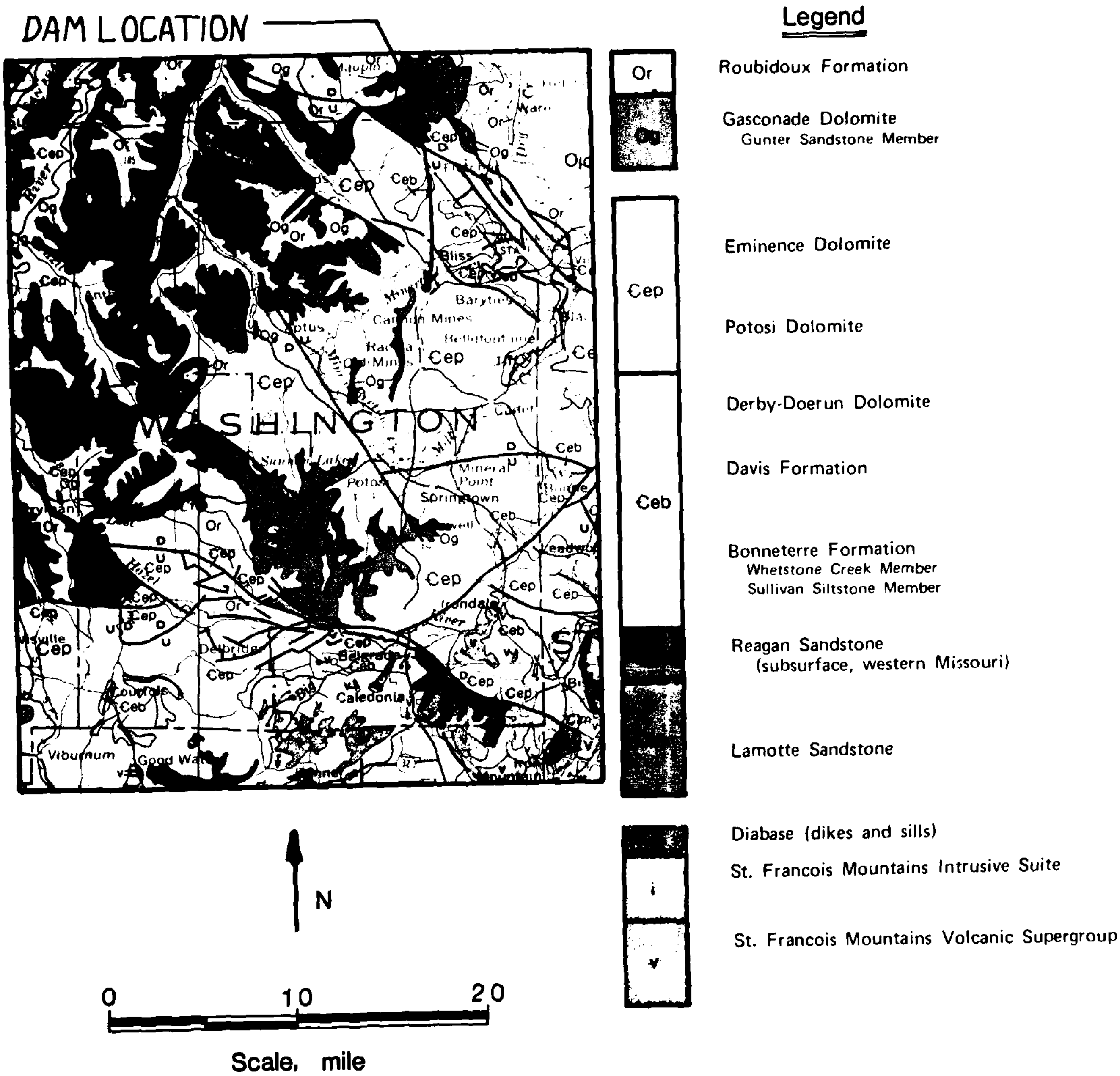
SECTION D-D
Spillway



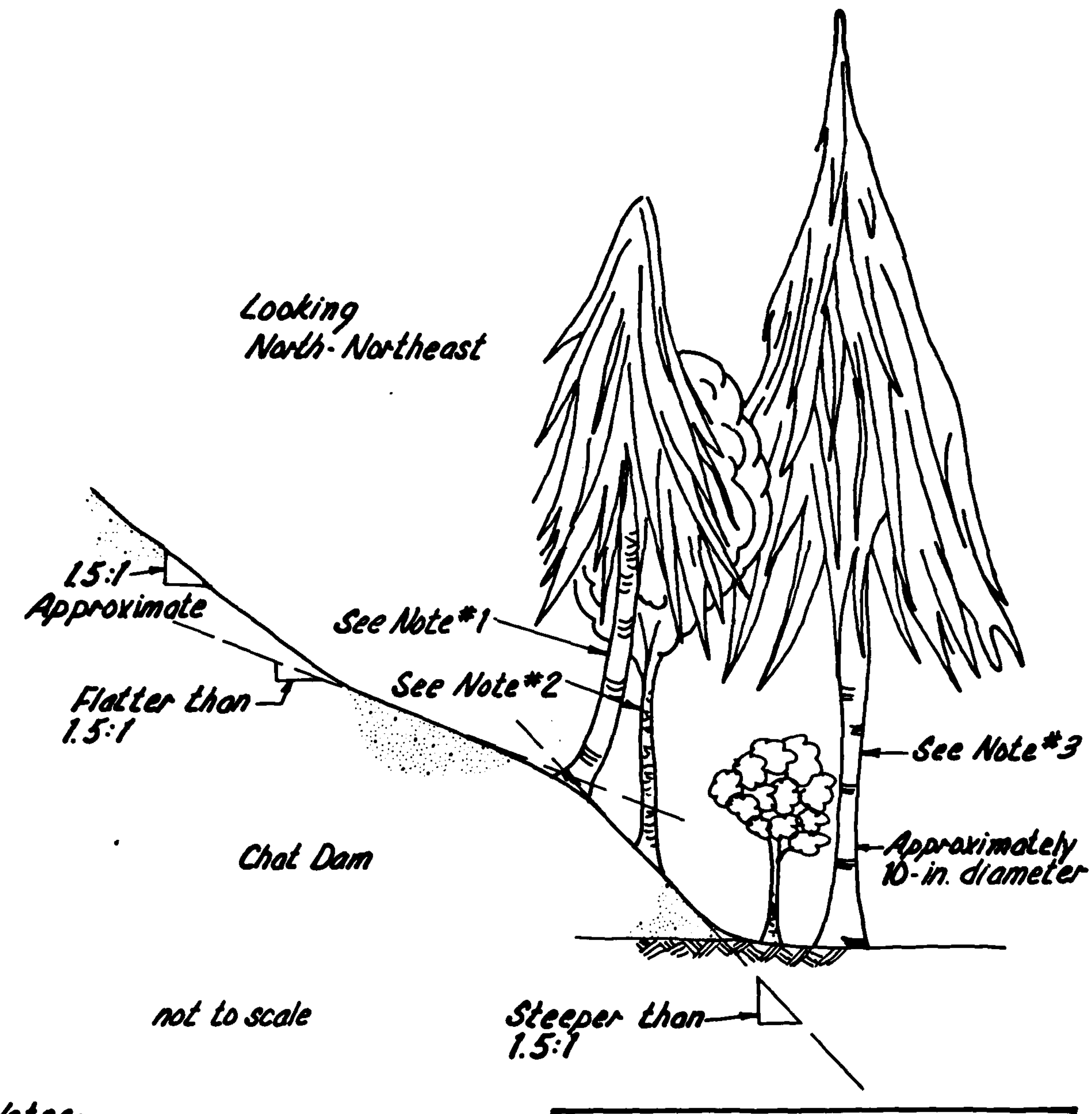
SECTION E-E
Spillway

SECTIONS OF SPILLWAY AND DISCHARGE CHANNEL	
STAR MINE DAM	
MO 31005	Fig. 3-B

2



REGIONAL GEOLOGIC MAP	
STAR MINE DAM	
MO 31005	Fig. 4



Notes:

1. Older trees on bulge are curved.
2. Younger trees on bulge are unaffected.
3. Both older and younger trees are unaffected at toe of Dam.

TOE OF SLOPE

INDICATING MOVEMENT

STAR MINE DAM

MO 31005 | Fig. 5

APPENDIX A

Photographs

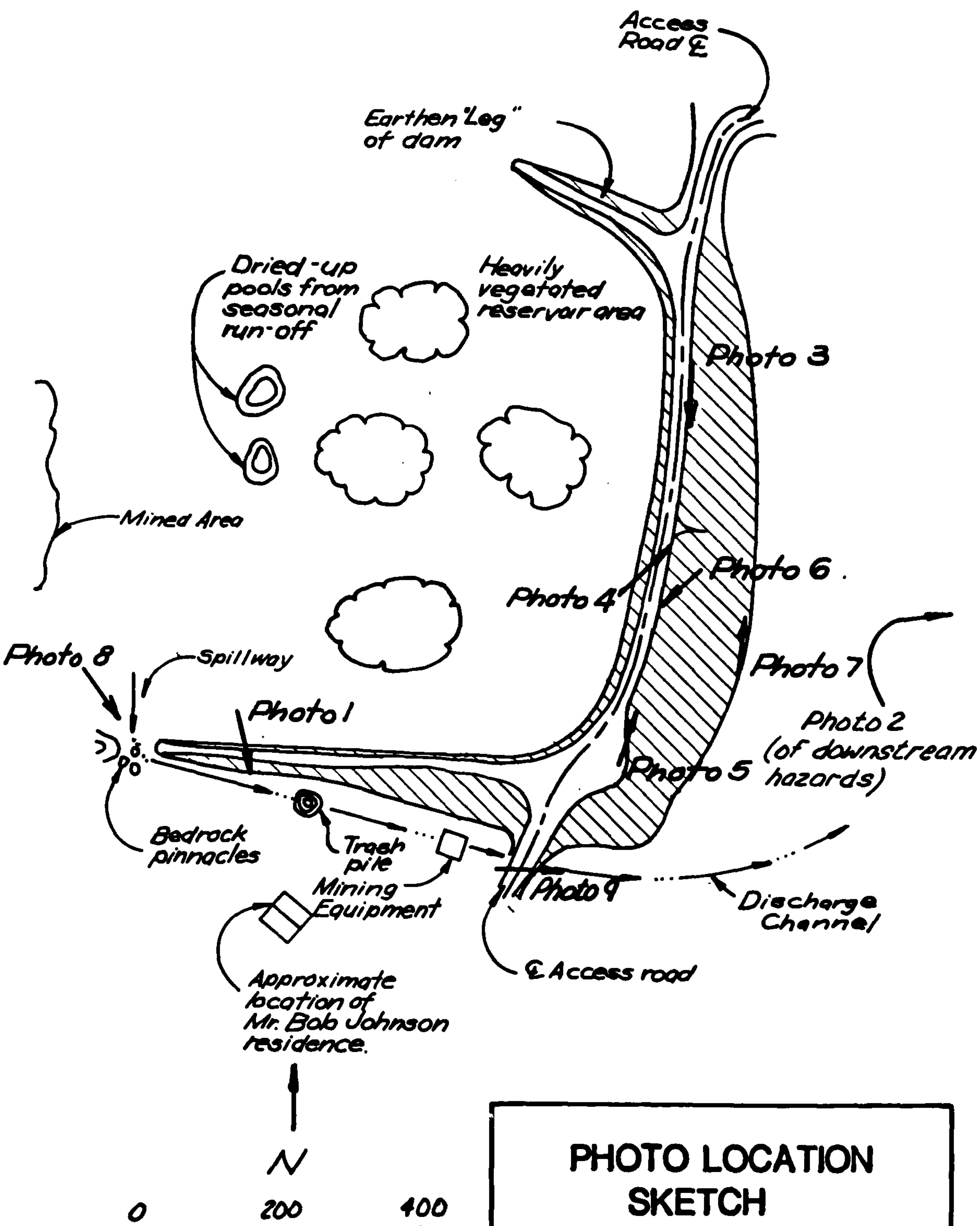


PHOTO LOCATION SKETCH

STAR MINE DAM

MO 31005	Fig. A-1

1. Downstream hazard - view from crest of Star Mine Dam; looking south.

2. Downstream hazard - school; looking west.

3. Crest alignment, slope irregularities and vegetation of Star Mine Dam.

4. Erosional gully formed in dam crest.

5. Dam crest depressions and irregularities.

6. Depression at dam crest.

7. Rotation and deformation of trees above the toe of the Star Mine Dam; looking north-northeast with the embankment to the left.

8. Spillway of Star Mine Dam and vegetation of channel; looking southeast.

9. Downstream channel of spillway; looking northwest.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B
Hydraulic/Hydrologic Data and Analyses

B.1 Procedures

a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.

b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956).

c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi^2, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8}(s+1)^{0.7}}{1900\ Y^{0.5}} \qquad \text{(Equation 15-4)}$$

where: L = lag in hours
ℓ = hydraulic length of the watershed in feet
s = $\frac{1000}{CN} - 10$ where CN = hydrologic soil curve number
Y = average watershed land slope in percent

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \qquad \text{(Equation 15-3)}$$

where: T_c = time of concentration in hours

L = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_c \qquad \text{(Equation 16-12)}$$

where: ΔD = duration of unit excess rainfall
T_c = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 5 minutes was used.

d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

(1) 1 and 10 percent probability events - average between the spillway crest and mud line elevation;

(2) Probable Maximum Storm - spillway crest elevation.

f. Spillway Rating Curve. The spillway rating curve was calculated using spillway cross sections and conveyance characteristics and entered to the HEC-1 program on the Y-4 and Y-5 cards.

B.2 Pertinent Data

a. Drainage area. 0.16 mi^2

b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 24 hours duration was divided into 5 minute intervals in order to develop the inflow hydrograph.

c. Lag time. 0.26 hrs

d. Hydrologic soil group. D

e. SCS curve numbers.

1. For PMF- AMC III - Curve Number 91
2. For 1 and 10 percent probability-of-occurrence events AMC II - Curve Number 79

f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Tiff and Richwoods SE 7.5 minute quadrangle maps. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the $D, $L, and $V cards.

h. Outflow capacity. The spillway rating curve was developed from the cross-section data of the spillway. The results of the above were entered on the Y-4 and Y-5 cards of the HEC-1 program.

i. Reservoir elevations. For the 50 and 100 percent of the PMF events, the starting reservoir elevation was 698.2 ft, the spillway crest elevation. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 696.9 ft, the average between the spillway crest and mud line elevations (high water mark not distinguishable).

B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
 LAST MODIFICATION   01 APR 80
**********************************
    1        A1     DAM NO. 31005 - ( Star Mine  TAILINGS DAM, WASHINGTON COUNTY, MISSOURI.
    2        A2     WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
    3        A3     PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.
    4        B    288      0       5      -0      -0      -0      -0      -0      -0      -0
    5        B1     5
    6        J      1      4       1
    7        J1   .25    .50     .75    1.00
    8        K      0   0-IN                                    1
    9        K1  CASEY LAKE INFLOW COMPUTATION, PMF RATIO FLOODS.
   10        M      1      2    0.16                    1.0
   11        P      0    26.    102.    120.    130.
   12        T                                                 -1     -.91            .13
   13        W2          0.26
   14        X     -1   -.05       5
   15        K      1    DAM                                    1
   16        K1  CASEY LAKE PMF FLOOD ROUTINGS.
   17        Y                             1       1
   18        Y1     1                                     -698.2    -1
   19        Y4 698.2  699.4   700.1   701.1   702.5   703.3   704.8
   20        Y5    0.    10.     30.    100.    300.    500.   1000.
   21        $A    0.    5.7     9.4     10.     13.     17.     25.
   22        $E  660.   690.   698.2    700.   704.5    710.    720.
   23        $$ 698.2
   24        $D 704.5    2.6     1.5
   25        $L    0.   215.    455.    750.    920.
   26        $V 704.5   705.   705.5    706.   706.5
   27        K     99
```

Note: Star Mine Dam was incorrectly entered as "Casey Lake" on computer input.

Input Data
Various PMF Events
Star Mine Dam
MO 31005

B4

36

Output Summary
Various PMF Events
Star Mine Dam
MO 31005

B5

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
 LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 04 SEP 80
     TIME: 08.07.56

              DAM NO. 31005 -   Star Mine TAILINGS DAM. WASHINGTON COUNTY. MISSOURI.
              WOODWARD-CLYDE CONSULTANTS. HOUSTON JOB 79CH009.
              PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.

                                      JOB SPECIFICATION
          NQ      NHR     NMIN    IDAY     IHR    IMIN    METRC    IPLT    IPRT   NSTAN
         288        0        5      -0      -0      -0       -0      -0      -0      -0
                                 JOPER     NWT   LROPT    TRACE
                                     5      -0      -0       -0

                              MULTI-PLAN ANALYSES TO BE PERFORMED
                                NPLAN= 1 NRTIO= 4 LRTIO= 1
            RTIOS=     .25     .50     .75    1.00

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

                               SUB-AREA RUNOFF COMPUTATION

          CASEY LAKE INFLOW COMPUTATION. PMF RATIO FLOODS.

                    ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                     Q-IN       0      -0      -0      -0      -0       1      -0      -0

                                        HYDROGRAPH DATA
          IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1       2     .16     -0.     .16    1.00    -0.       -0      -0      -0

                                         PRECIP DATA
                  SPFE     PMS      R6     R12     R24     R48     R72     R96
                    0.   26.00  102.00  120.00  130.00     -0.     -0.     -0.

                                          LOSS DATA
        LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
           -0     -0.     -0.    1.00     -0.     -0.    1.00   -1.00  -91.00     -0.     .13

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

                                      UNIT HYDROGRAPH DATA
                                  TC=   -0.      LAG=    .26

                                        RECESSION DATA
                           STRTQ=   -1.00   QRCSN=    -.05   RTIOR= 5.00

          UNIT HYDROGRAPH 18 END OF PERIOD ORDINATES. TC=   -0.   HOURS. LAG=    .26  VOL= 1.00
```

RECESSION DATA

STRTQ= -1.00 QRCSN= -.05 RTIOR= 5.00

UNIT HYDROGRAPH 18 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .26 VOL= 1.00

43.	146.	242.	253.	203.	129.	80.	52.	33.	21.
13.	9.	5.	3.	2.	2.	1.	0.		

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	.00	.01	0.	1.01	12.05	145	.22	.22	.00	[illegible]
1.01	.10	2	.01	.00	.01	0.	1.01	12.10	146	.22	.22	.00	[illegible]
1.01	.15	3	.01	.00	.01	1.	1.01	12.15	147	.22	.22	.00	[illegible]
1.01	.20	4	.01	.00	.01	1.	1.01	12.20	148	.22	.22	.00	[illegible]
1.01	.25	5	.01	.00	.01	2.	1.01	12.25	149	.22	.22	.00	[illegible]
1.01	.30	6	.01	.00	.01	2.	1.01	12.30	150	.22	.22	.00	[illegible]
1.01	.35	7	.01	.00	.01	2.	1.01	12.35	151	.22	.22	.00	[illegible]
1.01	.40	8	.01	.00	.01	2.	1.01	12.40	152	.22	.22	.00	[illegible]
1.01	.45	9	.01	.00	.01	2.	1.01	12.45	153	.22	.22	.00	[illegible]
1.01	.50	10	.01	.00	.01	2.	1.01	12.50	154	.22	.22	.00	[illegible]
1.01	.55	11	.01	.00	.01	2.	1.01	12.55	155	.22	.22	.00	[illegible]
1.01	1.00	12	.01	.00	.01	2.	1.01	13.00	156	.22	.22	.00	[illegible]
1.01	1.05	13	.01	.00	.01	2.	1.01	13.05	157	.27	.26	.00	[illegible]
1.01	1.10	14	.01	.00	.01	2.	1.01	13.10	158	.27	.26	.00	[illegible]
1.01	1.15	15	.01	.00	.01	2.	1.01	13.15	159	.27	.26	.00	[illegible]
1.01	1.20	16	.01	.00	.01	2.	1.01	13.20	160	.27	.26	.00	[illegible]
1.01	1.25	17	.01	.00	.01	3.	1.01	13.25	161	.27	.26	.00	310.
1.01	1.30	18	.01	.00	.01	3.	1.01	13.30	162	.27	.26	.00	[illegible]
1.01	1.35	19	.01	.00	.01	3.	1.01	13.35	163	.27	.26	.00	[illegible]
1.01	1.40	20	.01	.00	.01	3.	1.01	13.40	164	.27	.26	.00	322.
1.01	1.45	21	.01	.00	.01	4.	1.01	13.45	165	.27	.26	.00	323.
1.01	1.50	22	.01	.00	.01	4.	1.01	13.50	166	.27	.26	.00	[illegible]
1.01	1.55	23	.01	.00	.01	4.	1.01	13.55	167	.27	.26	.00	[illegible]
1.01	2.00	24	.01	.00	.01	5.	1.01	14.00	168	.27	.26	.00	[illegible]
1.01	2.05	25	.01	.01	.01	5.	1.01	14.05	169	.33	.33	.00	[illegible]
1.01	2.10	26	.01	.01	.01	5.	1.01	14.10	170	.33	.33	.00	[illegible]
1.01	2.15	27	.01	.01	.01	6.	1.01	14.15	171	.33	.33	.00	[illegible]
1.01	2.20	28	.01	.01	.01	6.	1.01	14.20	172	.33	.33	.00	[illegible]
1.01	2.25	29	.01	.01	.01	6.	1.01	14.25	173	.33	.33	.00	[illegible]
1.01	2.30	30	.01	.01	.01	7.	1.01	14.30	174	.33	.33	.00	[illegible]
1.01	2.35	31	.01	.01	.01	7.	1.01	14.35	175	.33	.33	.00	[illegible]
1.01	2.40	32	.01	.01	.01	7.	1.01	14.40	176	.33	.33	.00	403.
1.01	2.45	33	.01	.01	.01	7.	1.01	14.45	177	.33	.33	.00	[illegible]
1.01	2.50	34	.01	.01	.01	8.	1.01	14.50	178	.33	.33	.00	[illegible]
1.01	2.55	35	.01	.01	.01	8.	1.01	14.55	179	.33	.33	.00	407.
1.01	3.00	36	.01	.01	.01	8.	1.01	15.00	180	.33	.33	.00	[illegible]
1.01	3.05	37	.01	.01	.01	8.	1.01	15.05	181	.20	.20	.00	[illegible]
1.01	3.10	38	.01	.01	.01	9.	1.01	15.10	182	.40	.40	.00	[illegible]
1.01	3.15	39	.01	.01	.01	9.	1.01	15.15	183	.40	.40	.00	[illegible]
1.01	3.20	40	.01	.01	.01	9.	1.01	15.20	184	.60	.60	.00	[illegible]
1.01	3.25	41	.01	.01	.01	9.	1.01	15.25	185	.71	.70	.00	474.
1.01	3.30	42	.01	.01	.01	9.	1.01	15.30	186	1.71	1.71	.00	[illegible]
1.01	3.35	43	.01	.01	.01	10.	1.01	15.35	187	2.82	2.82	.01	[illegible]
1.01	3.40	44	.01	.01	.01	10.	1.01	15.40	188	1.11	1.11	.00	1297.
1.01	3.45	45	.01	.01	.01	10.	1.01	15.45	189	.71	.70	.00	[illegible]
1.01	3.50	46	.01	.01	.01	10.	1.01	15.50	190	.60	.60	.00	[illegible]
1.01	3.55	47	.01	.01	.01	10.	1.01	15.55	191	.40	.40	.00	1448.
1.01	4.00	48	.01	.01	.01	10.	1.01	16.00	192	.40	.40	.00	1202.
1.01	4.05	49	.01	.01	.01	11.	1.01	16.05	193	.31	.31	.00	[illegible]
1.01	4.10	50	.01	.01	.01	11.	1.01	16.10	194	.31	.31	.00	[illegible]
1.01	4.15	51	.01	.01	.01	11.	1.01	16.15	195	.31	.31	.00	[illegible]
1.01	4.20	52	.01	.01	.01	11.	1.01	16.20	196	.31	.31	.00	[illegible]
1.01	4.25	53	.01	.01	.01	11.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Output Summary
Various PMF Events
Star Mine Dam
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Output Summary
Various PMF Events
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[illegible]	[illegible]	[illegible]	.01	.01	.01	11.	1.01	16.05	193	.31	.31	.00	512.
1.01	4.10	50	.01	.01	.01	11.	1.01	16.10	194	.31	.31	.00	[illegible]
1.01	4.15	51	.01	.01	.01	11.	1.01	16.15	195	.31	.31	.00	[illegible]
1.01	4.20	52	.01	.01	.01	11.	1.01	16.20	196	.31	.31	.00	[illegible]
1.01	4.25	53	.01	.01	.01	11.	1.01	16.25	197	.31	.31	.00	497.
1.01	4.30	54	.01	.01	.01	11.	1.01	16.30	198	.31	.31	.00	459.
1.01	4.35	55	.01	.01	.00	11.	1.01	16.35	199	.31	.31	.00	[illegible]
1.01	4.40	56	.01	.01	.00	11.	1.01	16.40	200	.31	.31	.00	412.
1.01	4.45	57	.01	.01	.00	12.	1.01	16.45	201	.31	.31	.00	402.
1.01	4.50	58	.01	.01	.00	12.	1.01	16.50	202	.31	.31	.00	[illegible]
1.01	4.55	59	.01	.01	.00	12.	1.01	16.55	203	.31	.31	.00	389.
1.01	5.00	60	.01	.01	.00	12.	1.01	17.00	204	.31	.31	.00	388.
1.01	5.05	61	.01	.01	.00	12.	1.01	17.05	205	.24	.24	.00	[illegible]
1.01	5.10	62	.01	.01	.00	12.	1.01	17.10	206	.24	.24	.00	371.
1.01	5.15	63	.01	.01	.00	12.	1.01	17.15	207	.24	.24	.00	354.
1.01	5.20	64	.01	.01	.00	12.	1.01	17.20	208	.24	.24	.00	338.
1.01	5.25	65	.01	.01	.00	12.	1.01	17.25	209	.24	.24	.00	324.
1.01	5.30	66	.01	.01	.00	13.	1.01	17.30	210	.24	.24	.00	318.
1.01	5.35	67	.01	.01	.00	13.	1.01	17.35	211	.24	.24	.00	310.
1.01	5.40	68	.01	.01	.00	13.	1.01	17.40	212	.24	.24	.00	307.
1.01	5.45	69	.01	.01	.00	13.	1.01	17.45	213	.24	.24	.00	309.
1.01	5.50	70	.01	.01	.00	13.	1.01	17.50	214	.24	.24	.00	[illegible]
1.01	5.55	71	.01	.01	.00	13.	1.01	17.55	215	.24	.24	.00	302.
1.01	6.00	72	.01	.01	.00	13.	1.01	18.00	216	.24	.24	.00	302.
1.01	6.05	73	.07	.05	.02	[illegible]	1.01	18.05	217	.02	.02	.00	[illegible]
1.01	6.10	74	.07	.05	.01	20.	1.01	18.10	218	.02	.02	.00	259.
1.01	6.15	75	.07	.05	.01	30.	1.01	18.15	219	.02	.02	.00	206.
1.01	6.20	76	.07	.05	.01	40.	1.01	18.20	220	.02	.02	.00	[illegible]
1.01	6.25	77	.07	.05	.01	49.	1.01	18.25	221	.02	.02	.00	104.
1.01	6.30	78	.07	.05	.01	54.	1.01	18.30	222	.02	.02	.00	80.
1.01	6.35	79	.07	.05	.01	58.	1.01	18.35	223	.02	.02	.00	[illegible]
1.01	6.40	80	.07	.05	.02	61.	1.01	18.40	224	.02	.02	.00	58.
1.01	6.45	81	.07	.06	.01	63.	1.01	18.45	225	.02	.02	.00	45.
1.01	6.50	82	.07	.06	.01	65.	1.01	18.50	226	.02	.02	.00	42.
1.01	6.55	83	.07	.06	.01	66.	1.01	18.55	227	.02	.02	.00	38.
1.01	7.00	84	.07	.06	.01	67.	1.01	19.00	228	.02	.02	.00	30.
1.01	7.05	85	.07	.06	.01	[illegible]	1.01	19.05	229	.02	.02	.00	29.
1.01	7.10	86	.07	.06	.01	69.	1.01	19.10	230	.02	.02	.00	28.
1.01	7.15	87	.07	.06	.01	70.	1.01	19.15	231	.02	.02	.00	27.
1.01	7.20	88	.07	.06	.01	70.	1.01	19.20	232	.02	.02	.00	27.
1.01	7.25	89	.07	.06	.01	71.	1.01	19.25	233	.02	.02	.00	27.
1.01	7.30	90	.07	.06	.01	71.	1.01	19.30	234	.02	.02	.00	27.
1.01	7.35	91	.07	.06	.01	72.	1.01	19.35	235	.02	.02	.00	27.
1.01	7.40	92	.07	.06	.01	72.	1.01	19.40	236	.02	.02	.00	27.
1.01	7.45	93	.07	.06	.01	72.	1.01	19.45	237	.02	.02	.00	27.
1.01	7.50	94	.07	.06	.01	73.	1.01	19.50	238	.02	.02	.00	27.
1.01	7.55	95	.07	.06	.01	73.	1.01	19.55	239	.02	.02	.00	27.
1.01	8.00	96	.07	.06	.00	73.	1.01	20.00	240	.02	.02	.00	27.
1.01	8.05	97	.07	.06	.00	74.	1.01	20.05	241	.02	.02	.00	27.
1.01	8.10	98	.07	.06	.00	74.	1.01	20.10	242	.02	.02	.00	27.
1.01	8.15	99	.07	.06	.00	74.	1.01	20.15	243	.02	.02	.00	27.
1.01	8.20	100	.07	.06	.00	74.	1.01	20.20	244	.02	.02	.00	27.
1.01	8.25	101	.07	.06	.00	75.	1.01	20.25	245	.02	.02	.00	27.
1.01	8.30	102	.07	.06	.00	75.	1.01	20.30	246	.02	.02	.00	27.
1.01	8.35	103	.07	.06	.00	75.	1.01	20.35	247	.02	.02	.00	27.
1.01	8.40	104	.07	.06	.00	75.	1.01	20.40	248	.02	.02	.00	27.
1.01	8.45	105	.07	.06	.00	75.	1.01	20.45	249	.02	.02	.00	27.
1.01	8.50	106	.07	.06	.00	76.	1.01	20.50	250	.02	.02	.00	27.
1.01	8.55	107	.07	.06	.00	76.	1.01	20.55	251	.02	.02	.00	27.
1.01	9.00	108	.07	.06	.00	76.	1.01	21.00	252	.02	.02	.00	27.
1.01	9.05	109	.07	.06	.00	76.	1.01	21.05	253	.02	.02	.00	27.
1.01	9.10	110	.07	.06	.00	76.	1.01	21.10	254	.02	.02	.00	27.
1.01	9.15	111	.07	.06	.00	76.	1.01	21.15	255	.02	.02	.00	27.
1.01	9.20	112	.07	.06	.00	77.	1.01	21.20	256	.02	.02	.00	27.

1.	8.45	105	.07	.06	.00	75.	1.01	20.40	248	.02	.02	.00	27.
1.01	8.50	106	.07	.06	.00	76.	1.01	20.45	249	.02	.02	.00	27.
1.01	8.55	107	.07	.06	.00	76.	1.01	20.50	250	.02	.02	.00	27.
1.01	9.00	108	.07	.06	.00	76.	1.01	20.55	251	.02	.02	.00	27.
1.01	9.05	109	.07	.06	.00	76.	1.01	21.00	252	.02	.02	.00	27.
1.01	9.10	110	.07	.06	.00	76.	1.01	21.05	253	.02	.02	.00	27.
1.01	9.15	111	.07	.06	.00	76.	1.01	21.10	254	.02	.02	.00	27.
1.01	9.20	112	.07	.06	.00	77.	1.01	21.15	255	.02	.02	.00	27.
1.01	9.25	113	.07	.06	.00	77.	1.01	21.20	256	.02	.02	.00	27.
1.01	9.30	114	.07	.06	.00	77.	1.01	21.25	257	.02	.02	.00	27.
1.01	9.35	115	.07	.06	.00	77.	1.01	21.30	258	.02	.02	.00	27.
1.01	9.40	116	.07	.06	.00	77.	1.01	21.35	259	.02	.02	.00	27.
1.01	9.45	117	.07	.06	.00	77.	1.01	21.40	260	.02	.02	.00	27.
1.01	9.50	118	.07	.06	.00	77.	1.01	21.45	261	.02	.02	.00	27.
1.01	9.55	119	.07	.06	.00	77.	1.01	21.50	262	.02	.02	.00	27.
1.01	10.00	120	.07	.06	.00	77.	1.01	21.55	263	.02	.02	.00	27.
1.01	10.05	121	.07	.06	.00	77.	1.01	22.00	264	.02	.02	.00	27.
1.01	10.10	122	.07	.06	.00	78.	1.01	22.05	265	.02	.02	.00	27.
1.01	10.15	123	.07	.06	.00	78.	1.01	22.10	266	.02	.02	.00	27.
1.01	10.20	124	.07	.06	.00	78.	1.01	22.15	267	.02	.02	.00	27.
1.01	10.25	125	.07	.06	.00	78.	1.01	22.20	268	.02	.02	.00	27.
1.01	10.30	126	.07	.06	.00	78.	1.01	22.25	269	.02	.02	.00	27.
1.01	10.35	127	.07	.06	.00	78.	1.01	22.30	270	.02	.02	.00	27.
1.01	10.40	128	.07	.06	.00	78.	1.01	22.35	271	.02	.02	.00	27.
1.01	10.45	129	.07	.06	.00	78.	1.01	22.40	272	.02	.02	.00	27.
1.01	10.50	130	.07	.06	.00	78.	1.01	22.45	273	.02	.02	.00	27.
1.01	10.55	131	.07	.06	.00	78.	1.01	22.50	274	.02	.02	.00	27.
1.01	11.00	132	.07	.06	.00	78.	1.01	22.55	275	.02	.02	.00	27.
1.01	11.05	133	.07	.06	.00	78.	1.01	23.00	276	.02	.02	.00	27.
1.01	11.10	134	.07	.06	.00	78.	1.01	23.05	277	.02	.02	.00	27.
1.01	11.15	135	.07	.06	.00	78.	1.01	23.10	278	.02	.02	.00	27.
1.01	11.20	136	.07	.06	.00	78.	1.01	23.15	279	.02	.02	.00	27.
1.01	11.25	137	.07	.06	.00	78.	1.01	23.20	280	.02	.02	.00	27.
1.01	11.30	138	.07	.06	.00	78.	1.01	23.25	281	.02	.02	.00	27.
1.01	11.35	139	.07	.06	.00	79.	1.01	23.30	282	.02	.02	.00	27.
1.01	11.40	140	.07	.06	.00	79.	1.01	23.35	283	.02	.02	.00	27.
1.01	11.45	141	.07	.06	.00	79.	1.01	23.40	284	.02	.02	.00	27.
1.01	11.50	142	.07	.06	.00	79.	1.01	23.45	285	.02	.02	.00	27.
1.01	11.55	143	.07	.06	.00	79.	1.01	23.50	286	.02	.02	.00	27.
1.01	12.00	144	.07	.06	.00	79.	1.01	23.55	287	.02	.02	.00	27.
							1.02	0.	288	.02	.02	.00	27.
									SUM	33.80	32.79	1.01	40588.
										(859.)(	833.)(	26.)(	1148.76)

Output Summary
Various PMF Events
Star Mine Dam
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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 1	RATIO 2	RATIO 3	RATIO 4
				RATIOS APPLIED TO FLOWS			
				.25	.50	.75	1.00
HYDROGRAPH AT	Q-IN	.16	1	411.	823.	1234.	1646.
	(	.41)	(	11.65)(	23.30)(	34.95)(	46.60)(
ROUTED TO	DAM	.16	1	188.	440.	755.	1069.
	(	.41)	(	4.76)(	12.45)(	21.38)(	30.28)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	698.20	698.20	704.50
STORAGE	118.	118.	187.
OUTFLOW	0.	0.	900.

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
.25	701.98	0.	152.	188.	0.	16.29	0.
.50	703.06	0.	169.	440.	0.	16.17	0.
.75	704.06	0.	182.	755.	0.	16.08	0.
1.00	704.88	.38	192.	1069.	.42	16.08	0.

Output Summary
Various PMF Events
Star Mine Dam
MO 31005

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 1 .85	RATIO 2 .86	RATIO 3 .87	RATIO 4 .88
				RATIOS APPLIED TO FLOWS			
HYDROGRAPH AT	O-IN	.16	1	1399.	1415.	1432.	1448.
		(.41)	(	39.61)(	40.07)(	40.54)(	41.00)(
ROUTED TO	DAM	.16	1	873.	884.	895.	906.
		(.41)	(	24.71)(	25.03)(	25.35)(	25.66)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	698.20	698.20	704.50
STORAGE	118.	118.	187.
OUTFLOW	0.	0.	900.

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
.85	704.42	0.	186.	873.	0.	16.08	0.
.86	704.45	0.	187.	884.	0.	16.08	0.
.87	704.49	0.	187.	895.	0.	16.08	0.
.88	704.52	.02	188.	906.	.08	16.08	0.

Output Summary
Various PMF Events
Star Mine Dam
MO 31005

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