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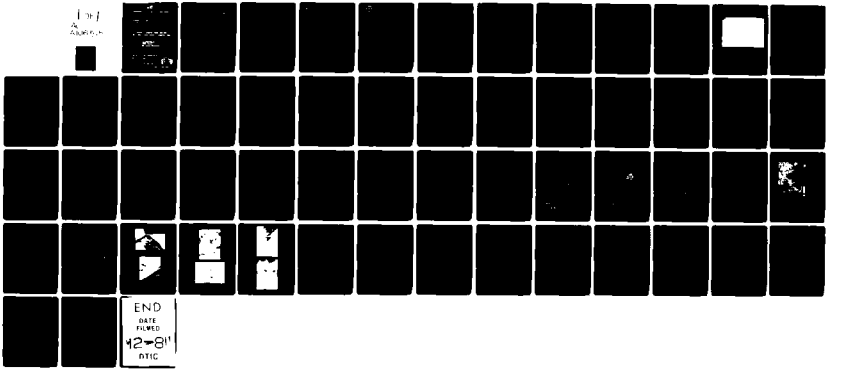

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REDWOODS POND DAM
WASHINGTON COUNTY, MISSOURI
MO 30727

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

St. Louis District

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

FOR STATE OF MISSOURI

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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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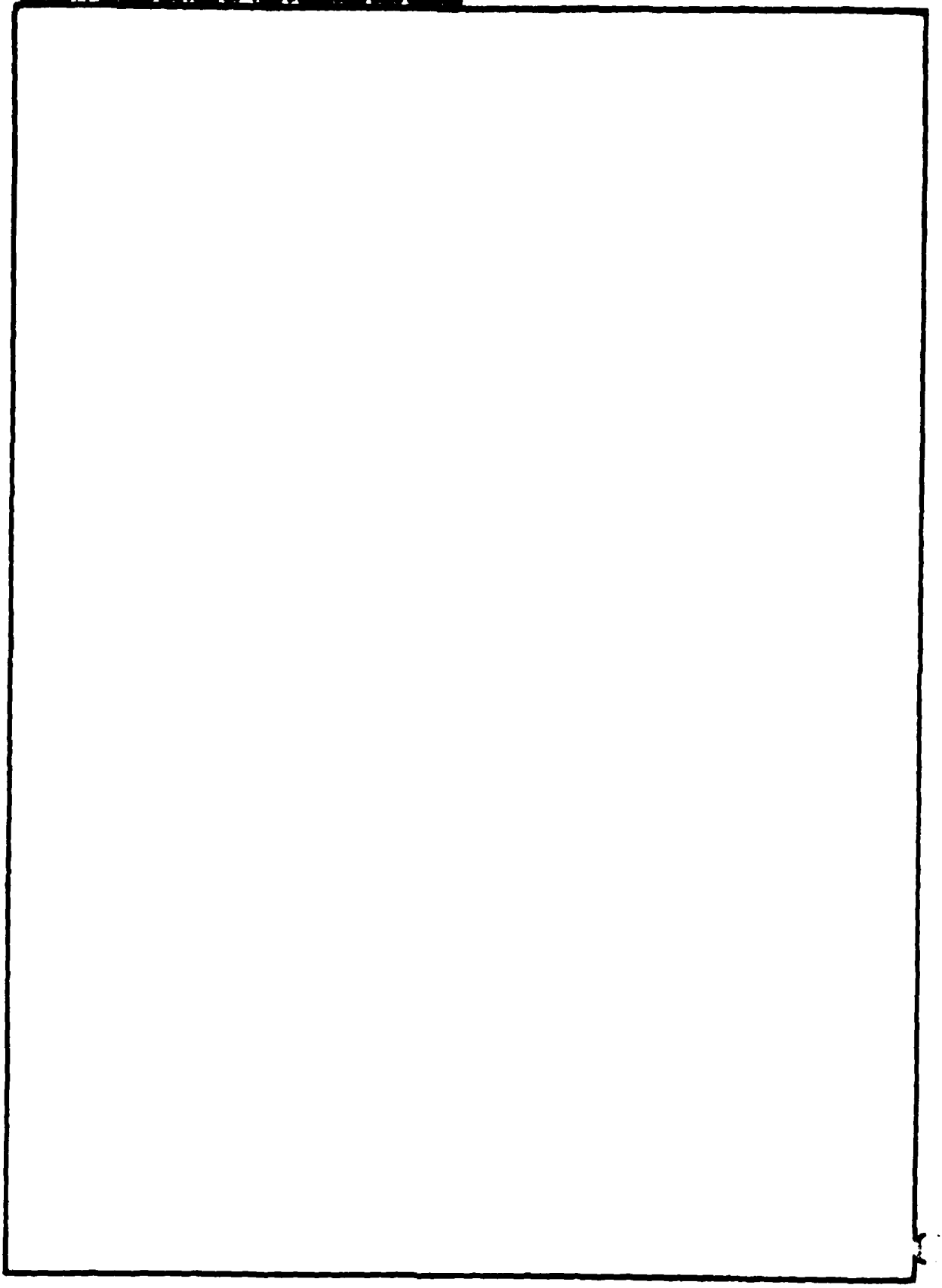

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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

SUBJECT: Richwoods Pond Dam (MO 30727)

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

The inspection results indicate problems with the toe of the dam. Previous mining activity at the toe of the dam is noteworthy in that it has produced an oversteepended face below the dam. Erosion has further steepended this cut face, (see photo 5 and 6).

SUBMITTED BY: SIGNED
Chief, Engineering Division
26 SEP 1980
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer
29 SEP 1980
Date

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RICHWOODS POND DAM

Washington County, Missouri

Missouri Inventory No. 30727

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

September 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	Richwoods Pond Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Ditch Creek
Date of Inspection	3 June 1980

The Richwoods Pond Dam, Missouri Inventory Number 30727, was inspected by Richard Berggreen (engineering geologist), David Hendron (geotechnical engineer), and Sean Tseng (hydrologist). The dam is an abandoned barite tailings dam.

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.

Based on the criteria in the guidelines, the dam is judged to be in the high hazard classification. The St Louis District, Corps of Engineers (SLD) has estimated the potential damage zone to extend approximately 20 mi downstream of the dam. Within the first four mi of the damage zone are three unimproved roads, two improved roads and one occupied structure. Within the next 16 mi are numerous occupied structures. The population within the 20 mi damage zone indicates that significant loss of property and life is possible in the event of overtopping and failure of the dam.

Richwoods Pond Dam is in the intermediate size classification based on its maximum height of 74 ft. The storage capacity of the reservoir is 350 ac-ft.

Our inspection and evaluation indicate the dam to be in generally fair to good condition. There is no formally designed spillway or other outlet facilities at this dam. However, two low areas to the north and west of the left dam abutment act as informal spillways with adequate capacities. The cohesionless nature of the coarse tailings comprising the embankment, indicates the dam could be significantly eroded if overtopped. The hydrologic analysis, however, shows the dam embankment will not be overtopped by a flood with 1 percent probability-of-occurrence (100-yr flood) or by 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 considerations that are reasonably possible in the region.

Mining activities at the south toe of the dam have left cut faces which have undermined portions of the toe of the dam and have reduced the apparent stability of the embankment. The downstream face of the dam appears steep, 33 to 35 degrees, and future stability of the slope is questionable if small changes occur to conditions observed during the inspection.

It is recommended that, as a minimum, the following studies be made and the following actions be taken under the guidance of an engineer experienced in design and construction of dams:

1. A study of the informal spillway and discharge channel areas. This study should consider potential improvements in these areas to direct and channel the flow, remove any obstructions and minimize potential for erosion. Also included, should be an evaluation of the minimum dam section allowable in the area where the chat is currently being excavated from the thickened section of the dam.

2. Assessment of the effects of mining at the toe of the dam by an appropriate slope stability analysis. Mining activities should not be reactivated at the toe of the dam until stability criteria for future mining can be established.

3. Analysis of the static and seismic stability of the dam and of the effects of seepage on the stability of the dam, in accordance with the requirements of the guidelines.

4. Initiation of a program of periodic inspection and monitoring for this facility. This program should include, but not be limited to, the following:

   a. Monitoring seepage at the toe of the dam to identify changes in the amount of flow or turbidity of the seepage water;

   b. Inspecting the embankment periodically to identify slumping or evidence of instability in the areas where cracks were observed and where mining activities have resulted in oversteeepened slopes; and

c. Performing maintenance work as needed on the basis of the recommended inspection program.

5. Assessment of the practicality of establishing a warning system for advising downstream residents and traffic should unsafe emergency conditions develop at the dam.

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

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

Stanley F. Gizienski, P.E.
Vice-President

OVERVIEW
RICHWOODS POND DAM

MISSOURI INVENTORY NUMBER MO 30727

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
RICHWOODS POND DAM, MISSOURI INVENTORY NO. 30727

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
RICHWOODS POND DAM, MISSOURI INVENTORY NO. 30727

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 the Richwoods Pond Dam, Missouri Inventory Number 30727.

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, "Engineering and Design, National Program for Inspection of Non-Federal Dams", 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.** Richwoods Pond Dam is an abandoned barite tailings dam. Its construction procedure and its usage are typical of other such dams in the area but it is not typical of other dams constructed for the impoundment of water. The unique nature of these tailings dams has a significant impact on their evaluation. A brief description of the general construction procedure and usage of Missouri barite tailings dams is necessary to understand the unique nature of these dams, and understand the differences between these dams and more conventional water-retaining dams.

At the start of a barite mining operation in this area, 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 then 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 construction 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 waste which is called "chat".

As the level of the fine tailings impounded in the reservoir increases, the dam is raised. The usual method is to dump chat on the dam crest. The chat is 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 or 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 embankment 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 barite processing, 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 is that formal spillways or regulating outlets are generally not constructed. In most cases a low point on or near the dam is provided for overflow, should the reservoir storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of 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 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 contents. 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. The consistency is very gradually modified by a slow process of consolidation.

Richwoods Pond Dam is approximately 1,880 ft long and borders the impounded area on the east and south. It is approximately 74 ft high at the maximum section. There is no formal spillway or discharge channel for this dam. Two low-lying areas north of the dam may act as natural spillways, but did not appear to have passed any overflow at the time of our visual inspection. The lowest point controlling flow out of the impoundment appears to be at elevation 837 ft (MSL). High water marks on trees in the impoundment area were measured at elevation 838.7 ft. Elevation of the dam crest ranges

from 841 ft at the south end to 850 ft at the north end. No low level outlet was located at this facility. No control structures exist in the natural spillway areas.

b. **Location.** The dam is located about 1.6 mi northeast of Richwoods, Washington County, Missouri on an unnamed tributary of Ditch Creek. The dam and impoundment are in the Richwoods Area of the Washington County Barite District Survey 2161, T40N, R2E; see Fig. 1.

c. **Size classification.** The dam is classified intermediate size due to its 74 ft height. The storage capacity of the reservoir is 350 ac-ft.

d. **Hazard classification.** The SLD has classified the dam as high hazard; we concur with this classification. The SLD has estimated the damage zone to extend approximately 20 mi downstream. Many occupied structures, unimproved and improved roads and a park are located within the potential damage zone.

e. **Ownership.** We understand the dam is owned by Desoto Mining Co. Box 35, Richwoods, Missouri 63071. Correspondence should be addressed to Mr Durward Spees.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings produced by the washing of barite ore mined in the vicinity. Water impounded by the dam was recycled from the reservoir and used in the barite processing operation. The dam is currently abandoned.

g. **Design and construction history.** The owner has no records of the design and construction of the dam. According to Wharton (1972), the dam was started in late 1944. Visual observations indicate that the coarse tailings range in size from sand to gravel. Following typical local practice, the coarse tailings are end-dumped to form the embankment. Compaction was probably limited to that provided by construction equipment. The fine tailings from the processing plant, consisting of clay with small amounts of sand, were sluiced into and sedimented in the impoundment area from the processing plant.

Since mining and processing operations were terminated in 1957 (Wharton, 1972) the dam has been abandoned and apparently not maintained. Some mining in the surrounding area has encroached upon the toe of the dam.

h. **Normal operating procedure.** The dam is abandoned and no operating procedures are in effect.

1.3 Pertinent Data

a. **Drainage area.** Approximately 0.29 mi^2 (not including influence of Ditch Creek Dam's drainage basin area of 0.20 mi^2)

b. **Discharge at dam site.**

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	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	3630 ft^3/sec at elevation 841 ft (MSL)
Total spillway capacity of maximum pool elevation	3630 ft^3/sec at elevation 841 ft (MSL)

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

Top of Dam	841 to 850
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	770

d. **Reservoir.**

Length of maximum pool	2600 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	350

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

Top of dam	68 at elevation 841 ft (MSL)
Maximum pool	68 at elevation 841 ft (MSL)
Flood control pool	N/A
Recreation pool	N/A
Spillway crest	55

g. **Dam.**

Type	Tailings
Length	1,880 ft
Height	74 ft
Top width	25 to 35 ft
Side slopes	U/S Unknown; D/S 1.5 to 2.0H; 1V
Zoning	Unknown (probably none)
Impervious core	Unknown (probably none)
Cutoff	Unknown (probably to shallow bedrock)
Grout curtain	Unknown (probably none)

h. **Diversion and regulating tunnel.**

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

i. **Spillway.**

Type	No formally constructed spillway. Low areas are in local residual soils with some chat lining at north portion of dam.
Length of weir	Spillway #1; 105 ft at elevation 841 ft (MSL) Spillway #2; 290 ft at elevation 841 ft (MSL)
Crest elevation	Spillway #1 & #2; 837 ft (MSL)
Gates	None
Downstream channel	Intermittent stream valley, residual soil lined with grass and brush vegetation and mature trees.

j. **Regulating outlets.** None.

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or other engineering data are known to exist.

2.2 Construction

Construction of the dam was started in 1944 (Wharton, 1972). No detailed information was found to be available.

2.3 Operation

No operating records were available. Wharton (1972) states that the pond was part of a barite mining operation until 1957. At that time operations were discontinued.

2.4 Evaluation

a. **Availability.** There are no engineering data available.

b. **Adequacy.** The available information is insufficient to evaluate the design of Richwoods Pond 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.** Not applicable.

2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped as Cambrian age Eminence and Potosi Dolomite Formations on the Geologic Map of Missouri (Fig. 4). The Potosi Formation typically contains an abundance of quartz druse characteristic of chert bearing formations. The Eminence Formation conformably overlies the Potosi Formation, and contains less quartz and chert.

The soil at the dam site is a dark red-brown, plastic residual clay (CH), characteristicly developed on the Potosi Formation. It is locally overlain by a 1 to 5 ft thick silty loess soil profile. The area is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Richwoods Fault zone lies approximately 2 mi south of the dam site and is mapped on the Structural Features Map of Missouri (1971) as discontinuous for approximately 19 mi, in a WNW-ESE direction. The Ditch Creek Fault System is located about 3 mi north of the site and is mapped on the Structural Features map as approximately 11 mi long, paralleling the Richwoods Fault zone. The Ditch Creek System is mapped as north side down; the Richwoods fault is mapped as north side up. The faults are Pre-Cambrian in age and are not in a seismically active area.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** Richwoods Pond Dam was inspected 3 June 1980. The owner's representative was not present. This inspection indicated the dam is in generally fair to good condition.

b. **Dam.** The embankment is comprised of coarse tailings, locally called "chat". This material (sandy gravel and sand, GW-SW) is cohesionless and permeable. and would likely be severely eroded if the dam were overtopped. No detrimental settlement, depressions, cracking, sinkholes, erosion or animal burrows were observed in or near the embankment.

Mining activities have taken place immediately below the toe of the embankment near the southern end of the dam. Seepage was noted in this area exiting the cut face at the base of the dam, at the loessial soil/residual soil contact, and at the residual soil/bedrock contact. Quantity of seepage was estimated at about 5 to 10 gal/min. The seepage water was clear but moving some sand away from the seepage area. An undetermined amount of the seepage is probably coming from the consolidation of the saturated tailings. However, the major portion of the seepage is from the runoff/infiltration water cycle.

Although no construction activity has occurred on the dam since about 1957, mining at the toe of the dam was done 5 to 6 years ago, according to a mine employee. The mining activity at the toe of the dam is noteworthy in that it has produced an oversteepened face below the dam. Erosion has further undercut this face. Should this oversteepened and undercut face fail, it would likely involve the portion of the dam immediately above this area. The effect of this cannot be fully evaluated without an analysis of the static stability of the dam, but a local failure would reduce the overall stability of the dam.

At the north end of the embankment, the dam cross section is 100 feet thick at the base. This area appears to be a stockpile of coarse tailings. This stockpile is currently being excavated. Although mining of this stockpile does not pose any immediate hazard to the dam's stability, care must be taken to limit excavations in the material comprising the face of the embankment to areas where the section is thick enough that such excavations do not reduce the stability to unacceptable levels. Determination of minimum dam thickness will require a stability analysis by an engineer experienced in the design and construction of dams.

c. **Appurtenant structures.**

1. Spillway. No formal spillway was constructed for this dam. Two low areas at the north end of the dam act as "informal" spillways. The informal spillways can be seen at the right of the overview photo and in Fig. 3a. The easternmost spillway, spillway #1, is partially lined with grass, brush and trees. The western spillway, spillway #2, is crossed by a road, and is gravel-lined. The informal spillway areas are located on the site residual soil, and are moderately to highly erodible. Where there is sparse or no vegetation covering the soil the potential for erosion is high. The gravel lining will be eroded if subjected to flow velocities of more than 5 ft/sec. Our analyses indicate that velocities above this order of will be experienced at 100% of the Probable Maximum Flood event.

Vertical and lateral erosion is likely to occur at the informal spillways during periods of high outflow. The erosion will occur near the left dam abutment. These outflows are not expected to significantly erode the chat portion of the dam due to the large chat pile that thickens the dam section at this point. This erosion, therefore, is not expected to cause a sudden failure of the dam. This stockpile of chat however, is currently being excavated. The risk of erosion at this point should be considered in a study which should be made to determine a minimum safe dam section.

d. **Reservoir area.** Approximately 75 percent of the impoundment surface area was above the water level at the time of inspection. This area is underlain by

tailings which consist primarily of a mixture of relatively impervious sand, silt and clay. Low brushy vegetation and trees are growing on the tailings.

Slopes surrounding the reservoir area are relatively flat and estimated to be flatter than 10(H): 1 (V). No indication of potential instability of these slopes was observed.

e. **Downstream channel.** The apparent downstream channel cuts through residual clay soil. The area is obstructed by gravel roads, trees and hummocky areas caused by mining.

Downstream of the dam site, outflow follows the intermittent stream valley through a wooded, rural area. The downstream channel confluences with the Big River approximately 5.7 mi downstream.

3.2 Evaluation

At present the dam is in generally fair to good condition. However, the eroded and oversteepened slopes at the toe of the dam and the mining of the material at the north end of the dam need to be analyzed to evaluate the static and seismic stability of the embankment. Lack of static and seismic stability analysis is a deficiency.

There is no formal spillway or other constructed overflow discharge structure. Evaluation of the potential erosion hazard in the spillway area should be made when the above-mentioned stability study is conducted to determine the minimum safe dam section. Excavation of chat should be controlled accordingly.

Seepage at the toe of dam did not appear to constitute a hazard due to its low volume and lack of soil in the flow. This seepage should be monitored to detect any significant changes in amount or turbidity of flow.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

No operating procedures currently exist at this facility as the dam has been abandoned.

4.2 Maintenance of Dam and Spillway

No maintenance is performed as the dam has been abandoned. There is no known planned maintenance in the future.

4.3 Maintenance of Operating Facilities

There are no facilities requiring mechanical operation at this dam.

4.4 Description of Any Warning System in Effect

Our visual inspection did not disclose any warning system in effect at this dam.

4.5 Evaluation

There is no known plan for periodic inspections nor performance of maintenance on this dam. In view of the abandoned nature of the dam and the erodibility of the embankment, this is considered a deficiency, as potentially dangerous changes in the condition of the dam may develop (see Section 7.1 of this report) and may escape detection.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic design information was available for evaluation of the dam or the reservoir. Contour maps prepared in February, 1980 were supplied by Desoto Mining Company for evaluation of the dam. Other dimensions of the dam and reservoir were measured and/or surveyed on the date of inspection or estimated from USGS topographic mapping. The map used in the analysis was the advanced print of the USGS 7.5 minute Richwoods NE quadrangle map.

b. **Experience data.** No recorded history of rainfall, runoff, discharge, or pool stage data were available for this reservoir or dam.

c. **Visual observations.**

1. Watershed. The watershed is rural, forested with a mixture of hardwoods and softwoods predominantly of oak, hickory, pine and cedar varieties. Much of the area has been subjected to barite strip mining in the past, and has now been reclaimed by nature in varying degrees.

2. Reservoir. The reservoir consists of mostly exposed fine-grained tailings that are saturated or desiccated at the surface. The above-water area covers about 75 percent of the total reservoir area and is heavily vegetated by bushes, cattails, saplings and a mature poplar forest. The reservoir surface area is approximately 30 percent of the total drainage basin area of 0.29 square miles.

3. Spillway. There is no formally designed or constructed spillway for this facility. The term "informal spillways" have been assigned to the low areas at the north end of the dam (left abutment). The residual clayey soil containing varying amounts of chat that line the informal spillways have a moderate to

high erosion potential. The erodibility is dependent upon the amount and type of vegetation covering the soil lining the spillways (see Section 3.1.c.1).

4. Downstream channel. Flow in the downstream channel is not significantly restricted laterally by side slopes. Erosion of the sides of the ill-defined channel, therefore, is not expected to be significant. The bottom of the channel is susceptible to deepening by erosion where the bottom gradient is increased.

d. **Overtopping potential.** The Richwoods Pond Dam has no formal spillway or discharge channel. However, the low areas at the north end of the dam are able to pass the PMF without overtopping the dam embankment.

Hydrologic analysis at this dam takes into consideration the proximity and influence of Ditch Creek Dam, Missouri Inventory Number 30726. For the PMF analysis of the Ditch Creek Dam, the outflow is assumed to pass from the informal spillway of Ditch Creek Dam over a low area on State Highway H, and into the Richwoods Pond impoundment (see Fig. A-1). The outflow from the 0.20 mi^2 drainage area of Ditch Creek Dam therefore, directly contributes to the storage and outflow of Richwoods Pond.

Hydrologic and hydraulic analyses indicate that a flow with a one percent probability of occurrence will not cause overtopping of the dam embankment. The dam will also be able to pass 100 percent of the PMF without overtopping the embankment. The PMF is defined as the flood event that may be expected to occur from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Although overtopping of the dam embankment will not happen, there will be substantial flow in the informal spillways. The depth, velocity and duration of the flow indicate that the spillway areas way be eroded vertically and laterally. Such erosion will take place at the end of the dam however, far away from the maximum dam section. Therefore, sudden failure or breach of the main dam embankment is not expected. A study of the erosion potential in this area is recommended. This study should include an evaluation of the minimum dam section in the area where chat is currently being excavated from the thickened dam section. Also considered should be potential improvements in the spillway and dis-

charge channel areas in order to direct and channel the flow, remove obstructions and minimize potential for erosion.

The following overtopping data for selected PMF events were computed for the dam, assuming no erosion of the spillway or dam embankment:

Precipitation Event	Maximum Reservoir W.S. Elev. ft	Maximum Inflow ft^3/sec	Maximum Outflow ft^3/sec	Depth Over Dam ft	Duration of Overtopping hrs
50% PMF	839.5	1700	1200	0	0
100% PMF	840.5	3400	2500	0	0

Details of the hydraulic and hydrologic analyses are given in Appendix B.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** Features identified during the visual inspection which adversely affect the structural stability of this dam are reported in Section 3. See also Section 6.1.d, Post construction changes.

b. **Design and construction data.** No design or construction data relating to the structural stability of the dam were found. Seepage and stability analyses comparable to the guidelines are not on record. This is a deficiency which should be rectified. These analyses should be conducted under the guidance of an engineer experienced in the design and construction of dams.

c. **Operating records.** No appurtenant structures requiring operation exist at this facility. No operating records on reservoir level regulation of any kind were found.

d. **Post construction changes.** Mining activities and dam construction were terminated in this area in approximately 1957 (Wharton, 1972). However, mining was reactivated near the toe of the dam in 1974 or 1975 (B. Davidson, mine employee). This mining undercut the toe of the dam. Erosion has further steepened this cut face.

e. **Seismic stability.** The dam is in 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 dam is of loose, granular material, substantial damage or failure 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, the Richwoods Pond Dam appears to be in generally fair to good condition. This is based primarily on the lack of a designed spillway, and recent mining and erosion at the downstream toe of the dam which has oversteepened the dam face.

As a consequence of the widely-used construction procedure, the downstream slopes of the tailings dams are placed at or near the angle of natural repose for the "chat" material. This results in slopes that are very steep and exist in a state close to incipient failure with safety factors close to one. The slopes placed at 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 slope
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 visual inspection provided a reasonable base of information for the recommendations and conclusions presented in this Phase I report. The lack of stability and seepage analyses for the dam as recommended by the guidelines preclude an evaluation of the structural and seismic stability of the dam. This is a deficiency which should be rectified.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated without undue delay.

d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspection 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 available which may be considered to avoid the serious consequences of dam failure resulting from overtopping. These alternatives include:

1. Remove or breach the dam;

2. Increase the height of the 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. Enhance the stability of the dam to permit overtopping without failure.

5. Provide a highly reliable flood warning system. This generally does not prevent property damage but decreases the chance of loss of life.

b. **Recommendations.** Based on our inspection of the Richwoods Pond Dam, it is recommended that, as a minimum, the following studies be made and the following actions be taken under the guidance of an engineer experienced in the design and construction of dams:

1. A study of the informal spillway and discharge channel areas. This study should consider potential improvements in these areas in order to direct and channel the flow, remove obstructions and minimize potential for erosion. Also included, should be an evaluation of the minimum dam section allowable in the area where chat is currently being excavated from the thickened section of the dam.

2. Assessment of the effects of mining at the toe of the dam by an appropriate slope stability analysis. Mining activities should not be re-activated at the toe of the dam until stability criteria for future mining can be established.

3. Analysis of the static and seismic stability of the dam and of the effects of seepage on the stability of the dam, in accordance with the requirements of the guidelines.

4. Implementation of a program of periodic inspection and monitoring for this facility. This program should include, but not necessarily be limited to , the following:

a) Monitoring seepage at the toe of the dam to identify changes in the amount of flow or turbidity of the seepage water;

b) Inspecting the embankment periodically to identify slumping or evidence of instability in the areas where mining activities have resulted in oversteepened slopes; and

c) Recommendations for maintenance work, as determined on the basis of the inspection program.

5. Assessment of the practically of establishing a warning system for advising downstream residents and traffic should unsafe emergency conditions develop at the dam.

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

c. **O & M procedures.** Periodic inspections should be made, as recommended in Section 7.2b by an engineer experienced in the construction and maintenance of dams. Records should be kept of these inspections and of any recommended maintenance activity.

REFERENCES

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Department of the Army, Corps of the Chief of Engineers, 1977, EC 1110-2-188, "National Program of Inspection of Non-Federal Dams".

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McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1 inch equals approximately 8 miles (1:500,000).

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St Louis District, US Army Corps of Engineers, 1979, "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams".

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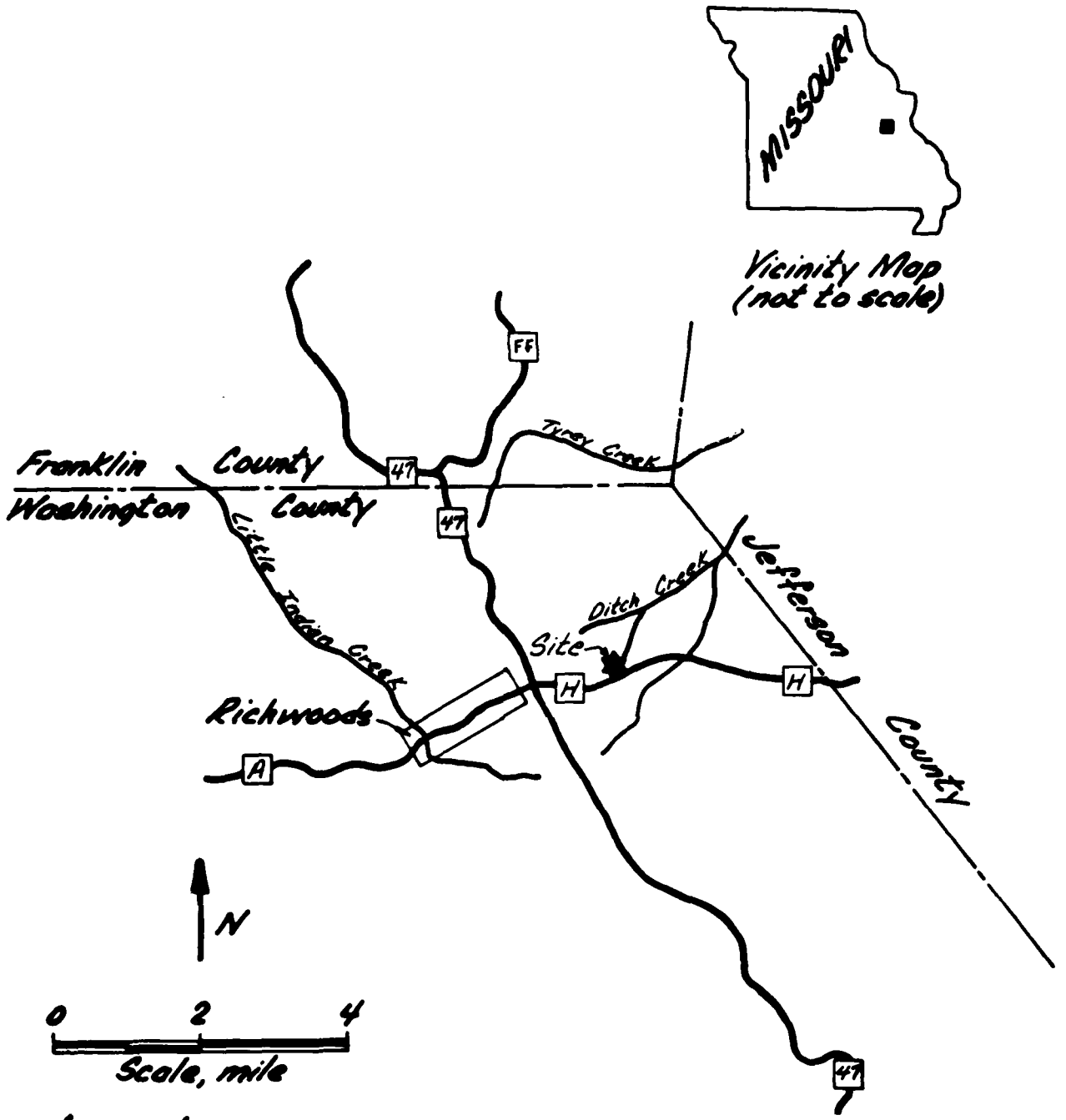
US Soil Conservation Service, 1971, "National Engineering Handbook", Section 4, Hydrology.

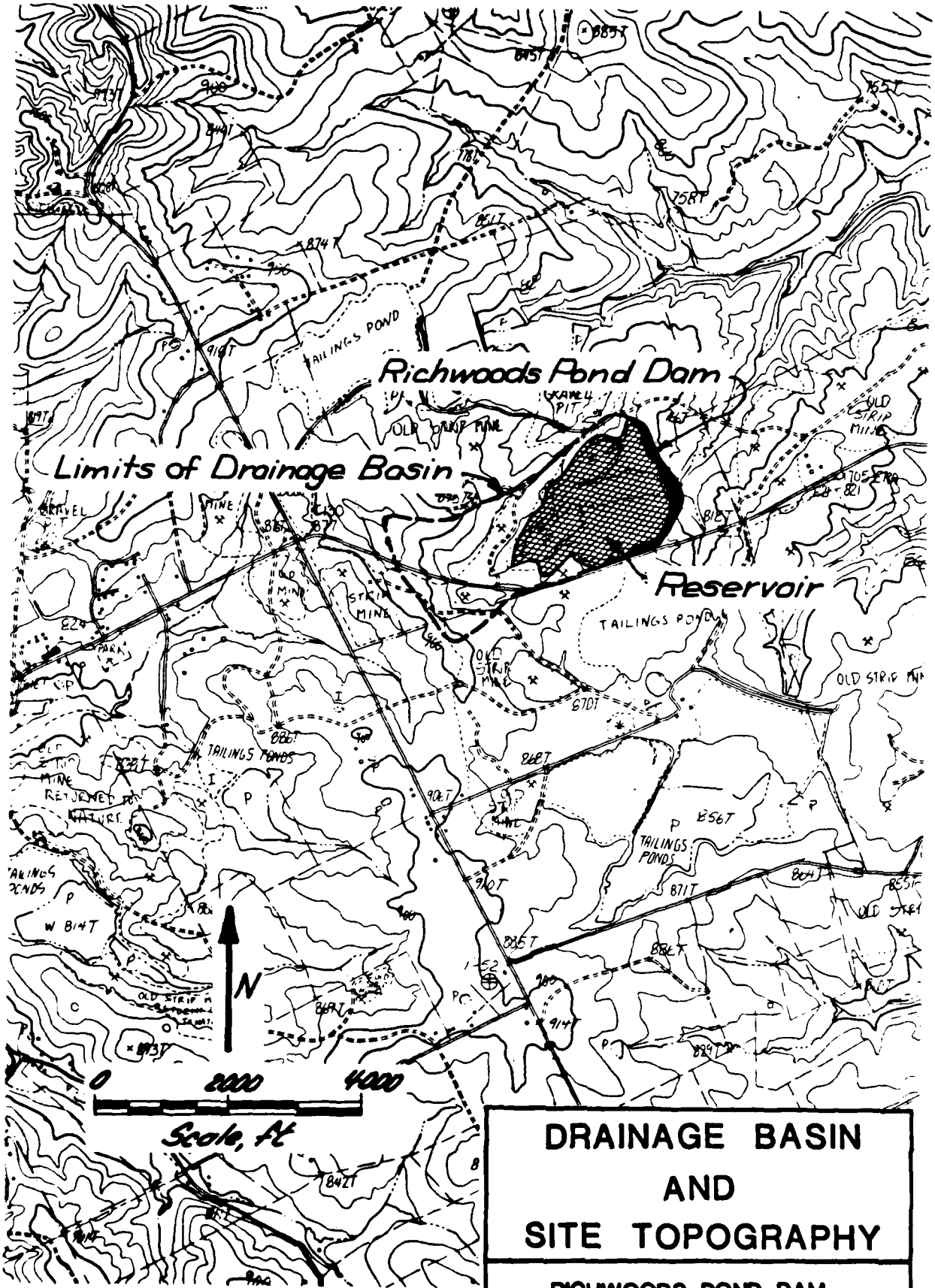
Wharton, Heyward, M., 1972, Barite Ore Potential of Four Tailings Ponds in the Washington County Barite District, Missouri: Missouri Geological Survey Report of Investigations No. 53.



SITE LOCATION MAP

RICHWOODS POND DAM

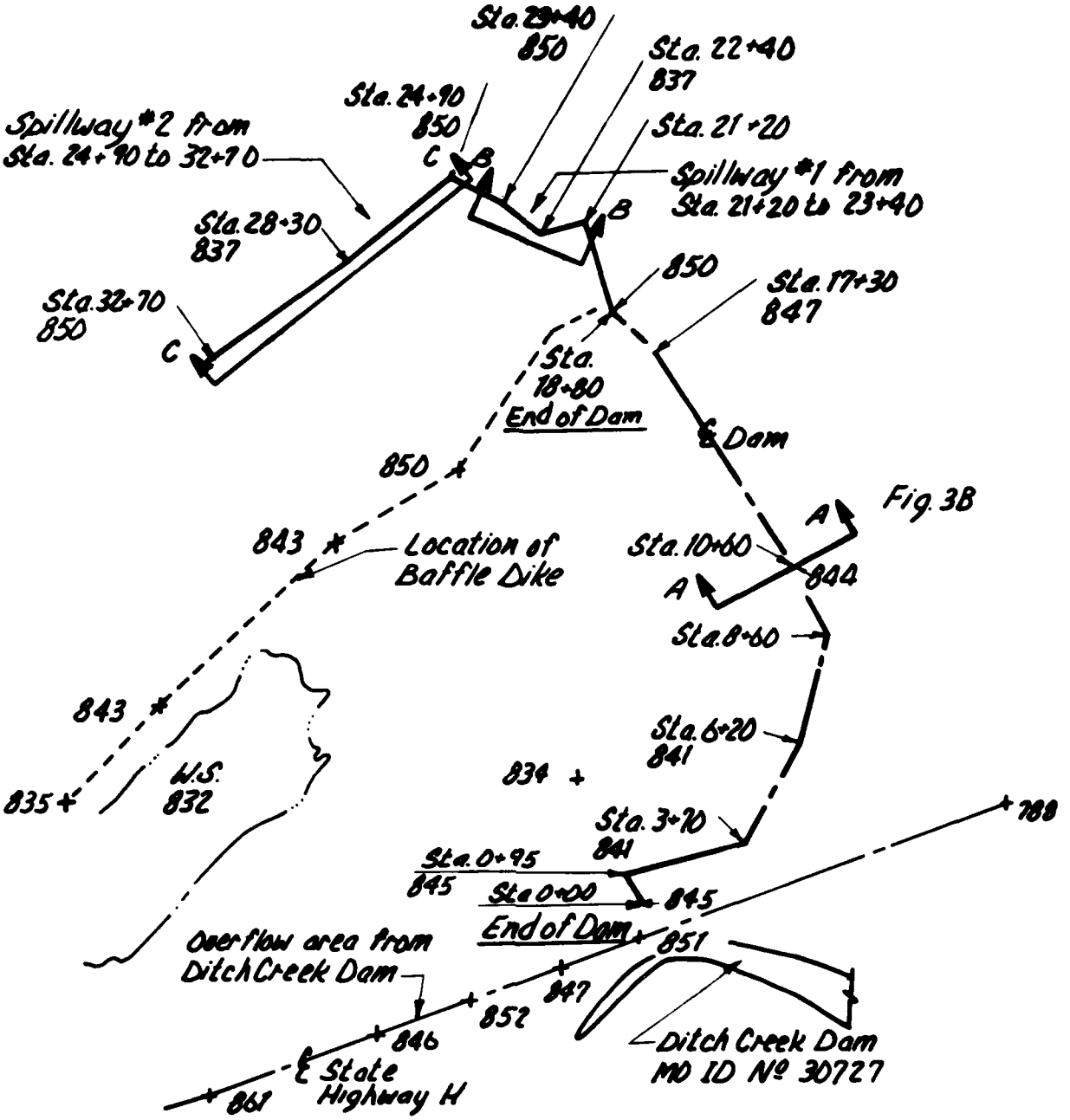
MO. 30727 | Fig. 1



DRAINAGE BASIN AND SITE TOPOGRAPHY

RICHWOODS POND DAM	
MO. 30727	Fig. 2

1. Topography from U.S.G.S. Richwoods N.E. 7½ minute quadrangle map.

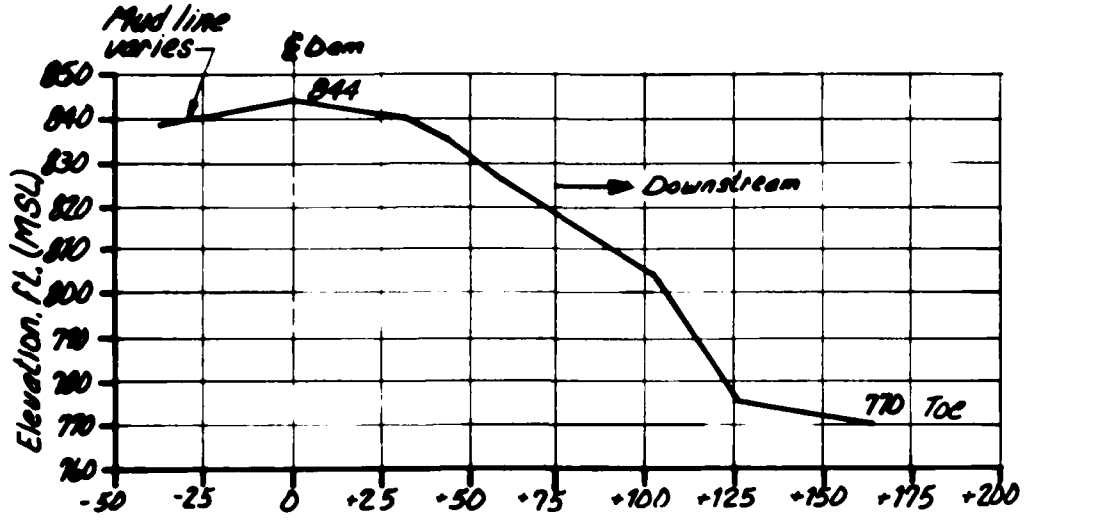


Note:
Data supplied by the Desoto Mining Co. Topographic Maps, Feb. 1980 and Field Survey.

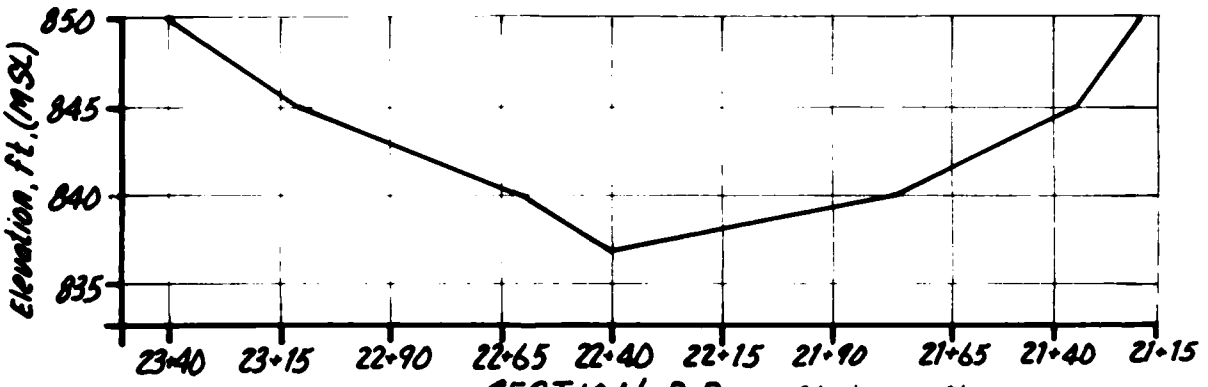
PLAN OF DAM CREST

RICHWOODS POND DAM

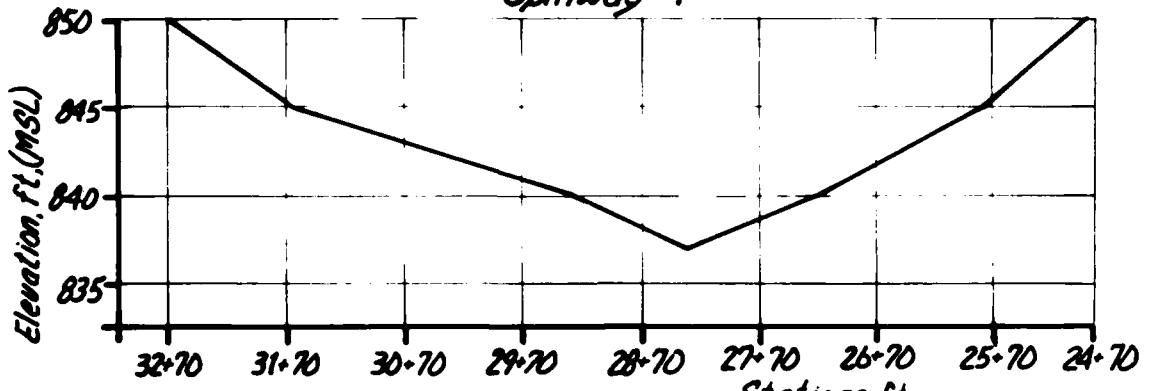
MO 30727 | Fig. 3.A



SECTION A-A
Maximum Dam Section

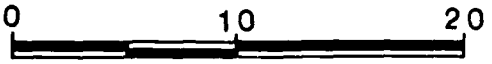


SECTION B-B
Spillway #1



SECTION C-C
Spillway #2

CROSS-SECTIONS OF DAM & SPILLWAY	
RICHWOODS POND DAM	
MO 30727	Fig. 3B



Scale, mile

Legend

- Or — Roubidoux Formation
- Gasconade Dolomite
  - Gunter Sandstone Member
- Cep — Eminence Dolomite
- Potosi Dolomite
- Derby-Doerun Dolomite
- Ceb — Davis Formation
- Bonneterre Formation
  - Whetstone Creek Member
  - Sullivan Siltstone Member
- Reagan Sandstone (subsurface, western Missouri)
- Lamotte Sandstone
- Diabase (dikes and sills)
- St. Francois Mountains Intrusive Suite
- St. Francois Mountains Volcanic Supergroup

REGIONAL GEOLOGIC MAP

RICHWOODS POND DAM

MO 30727 | Fig. 4

APPENDIX A

Photographs

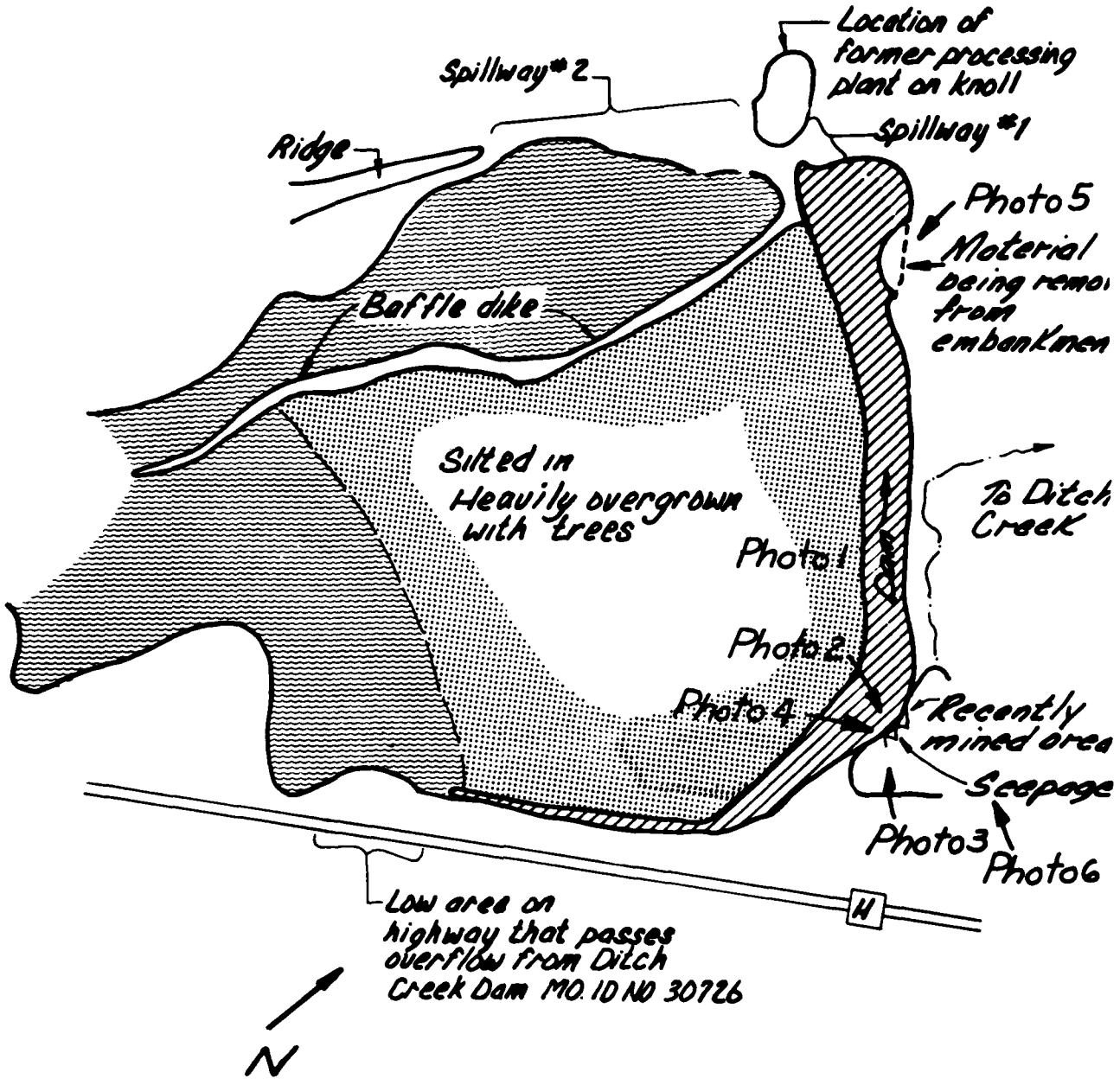


PHOTO LOCATION SKETCH

RICHWOODS POND DAM	
MO 30727	Fig. A-1

1. Roadway or crest of dam, looking northwest.

2. Mined area at toe of dam. Looking southwest from crest of dam.

3. Undercut and eroded slope with minor seepage. Looking west at toe of dam.

4. Seepage from bedrock contact at toe of dam. Looking east from face of dam.

5. Mining cut at toe of dam near north end of embankment. Looking southwest.

6. Erosion of mining cut face at toe of dam. Looking west.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B

Hydraulic/Hydrologic Analyses

B.1 Procedures

a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. Inflow hydrographs were developed by applying various precipitation events to a synthetic unit hydrographs. The inflow hydrographs, thus obtained, were then routed through the reservoir and appurtenant structures by the modified Puls reservoir routing method used in the HEC-I program to determine overtopping potential.

b. **Precipitation events.** Various percentages including 100 percent of the Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The PMP was determined from regional charts prepared by the US Weather Bureau (1956). The 1 and 10 percent probability-of-occurrence events were provided by SLD.

c. **Unit hydrograph.** The Soil Conservation Service (SCS) unit hydrograph (SCS, 1971) for a storm duration of 24 hrs was used to develop the inflow hydrograph. The unit hydrograph was divided into 5 min increments.

d. **Infiltration losses.** The SCS curve number (CN) loss function was used to compute infiltration losses. Curve numbers were selected on the basis of antecedent moisture conditions in accordance with the guidelines, present land usage and hydrologic soil group of the soils in the drainage basin. Where more than one soil group was present, the group giving the highest CN was used for the entire basin.

e. **Lag time.** Lag time was computed by the SCS method (National Engineering Handbook 4, Equation 15-4).

B.2 Pertinent Data

a. **Drainage area:**

0.29 mi^2 for Richwoods Pond Dam (MO 30727); 0.20 mi^2 for Ditch Creek Dam (MO 30726)

b. **Lag time:**

0.58 hrs for Richwoods Pond; 0.45 hrs for Ditch Creek

c. **Hydrologic soil group:** C, for Richwoods Pond and Ditch Creek

d. **SCS curve numbers.**

1. For PMF:

   Richwoods Pond, 89 (AMC III); Ditch Creek, 91 (AMC III)

2. For 1 and 10 percent probability-of-occurrence events:

   Richwoods Pond, 77 (AMC II); Ditch Creek, 80 (AMC II)

e. **Storage.** Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Richwoods NE 7.5-minute quadrangle map. The data were entered on the $A and $E cards so that the HEC-I program could compute storage volumes.

f. **Outflow capacity.** The elevation - discharge relationship was developed from rating curves developed from cross sections of the informal spillways and input into the HEC-2 step backwater program. The data was entered on the Y4 and Y5 cards.

g. **Outflow over crest.** As the profile of the dam crest is irregular, flow over the crest cannot be determined by conventional weir formulas. Flow over the dam crest was computed according to the "Flow over Non-level Dam Crest" supplement to the HEC-1 user's manual. Crest length-elevation data and hydraulic constants for the crest were entered on $D, $L and $V cards.

h. **Reservoir elevations.** For all fractions of the PMF and the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was taken as the elevation at the informal spillway crest, elevation 837 ft.

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 and HEC-2 output are available in the Chicago office of Woodward-Clyde Consultants.

```
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
**********
    1                 A1       PENGNAME 960 - DAM NO. 30727, WASHINGTON COUNTY, MISSOURI
    2                 A2       MCDONALD-CLYDE CONSULTANTS, MISSION JOB NO. 79CM009
    3                 A3       PROBABLE MAXIMUM FLOOD (PMF) ANALYSIS
    4                 B     299        0        5       -0       -0       -0       -0       -0       -0       -0
    5                 B1      5
    6                 J       1        2        1
    7                 J1    .50      1.0
    8                 K       0     LAKE                                        5        1
    9                 K1       DAM NO. 30726 FLOOD HYDROGRAPH COMPUTATIONS
   10                 M       1        2     0.20                          1.0
   11                 P       0      26.      102      120      130
   12                 T                                                                -1      -91                0.60
   13                 M2            0.55
   14                 K      -1     -.05        5
   15                 K       1      DAM                                        5        1
   16                 K1       DAM NO. 30726 FLOOD ROUTING AND OVERTOPPING ANALYSIS
   17                 V                                        1        1
   18                 V1      1                                                -852.
   19                 SA      0.       21.      62.      82.      91.
   20                 SE    850.     853.     855.     860.     865.
   21                 SS  852.0
   22                 SD    852.      2.6      1.5
   23                 SL      0.     400.     645.     890.     935.     985.
   24                 SV    852.     854.     894.     855.     856.     857.
   25                 K       0     LAKE                                       1
   26                 K1       COMPUTE FLOOD HYDROGRAPH
   27                 M       1        2     0.29                          1.0
   28                 P       0      26.      102      120      130
   29                 T                                                                -1      -89                .3
   30                 M2            .45
   31                 K      -1     -.05        5
   32                 K       2     LAKE                                               1
   33                 K1   COMBINE FLOOD HYDROGRAPH WITH OUTFLOW FROM DAM NO. 30726
   34                 K       1      DAM                                               1
   35                 K1       FLOOD ROUTING AND OVERTOPPING ANALYSIS
   36                 V                                        1        1
   37                 V1      1                                                -837.      -1
   38                 V4  837.0    838.0    838.5    839.0    839.5    840.0    840.5    841.0    841.4
   39                 V5      0.     100.     200.     640.    1220.    1760.    2540.    3630.    4600.
   40                 SA    48.7     55.0     64.3     68.0     82.6    104.
   41                 SE  835.0    837.0    840.0    841.0    845.0    850.0
   42                 SS  837.0
   43                 SD  841.0      2.8      1.5
   44                 SL  300.0    800.0
   45                 SV  841.0    844.0
   46                 K      99
```

Input Data
Various PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B3

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

RUN  DATE: 12 SEP 80
     TIME: 09.58.29
```

PERCHASE 560 - DAM NO. 30727, WASHINGTON COUNTY, MISSOURI
MCDONALD-CLYDE CONSULTANTS, HELSTEN JOB NO. 79CH009
PACKAGE PANIMUM FLOOD (PMF) ANALYSIS

JOB SPECIFICATION

NO	NMIN	MPIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
299	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= 2 LRTIO= 1

RTIOS= .50 1.00

SURFACE AREA=	0.	21.	62.	82.	91.
CAPACITY=	0.	21.	100.	459.	852.
ELEVATION=	850.	853.	855.	860.	865.

CREL	SPWID	COOW	EXPW	ELEVL	COOL	CAREA	EXPL
852.0	-0.	-0.	-0.	-0.	-0.	-0.	-0.

DAM DATA

TOPEL	COOD	EXPD	DAMWID
852.0	2.6	1.5	-0.

PEAK OUTFLOW IS 636. AT TIME 16.33 HOURS

PEAK OUTFLOW IS 1300. AT TIME 16.33 HOURS

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

SUB-AREA RUNOFF COMPUTATION

COMPLETE FLOOD HYDROGRAPH

ISTAO	ICOPP	ICON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
LAKE	0	-0	-0	-0	1	-0	-0	-0

Input Data (Continued)
Various PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B4

SUB-AREA RUNOFF COMPUTATION

COMPLETE FLOOD HYDROGRAPH

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

HYDROGRAPH DATA

IHYDG	IUNG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.29	-0.	.29	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

LKOPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOR	STRTL	CNSTL	ALSMX	RTIMP
-0	-0.	-0.	1.00	-0.	-0.	1.00	-1.00	-89.00	-0.	.30

CURVE NO = -89.00 HETNESS = -1.00 EFFECT CN = 89.00

UNIT HYDROGRAPH DATA

TC= -0. LAG= .45

RECESSION DATA

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

UNIT HYDROGRAPH 29 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .45 VOL= 1.00

27.	68.	139.	224.	273.	285.	267.	232.	189.	133.
100.	76.	56.	44.	34.	26.	19.	15.	11.	9.
6.	5.	4.	3.	2.	2.	1.	1.	0.	

END-OF-PERIOD FLOW

0												
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	12.30	150	.22	.22	.00	263.
1.01	.10	2	.01	.00	.01	1.	1.01	12.35	151	.22	.22	.00	339.
1.01	.15	3	.01	.00	.01	1.	1.01	12.40	152	.22	.22	.00	334.
1.01	.20	4	.01	.00	.01	2.	1.01	12.45	153	.22	.22	.00	402.
1.01	.25	5	.01	.00	.01	3.	1.01	12.50	154	.22	.22	.00	423.
1.01	.30	6	.01	.00	.01	4.	1.01	12.55	155	.22	.22	.00	434.
1.01	.35	7	.01	.00	.01	6.	1.01	13.00	156	.22	.22	.00	441.
1.01	.40	8	.01	.00	.01	7.	1.01	13.05	157	.27	.26	.00	461.
1.01	.45	9	.01	.00	.01	7.	1.01	13.10	158	.27	.26	.00	481.
1.01	.50	10	.01	.00	.01	8.	1.01	13.15	159	.27	.26	.00	483.
1.01	.55	11	.01	.00	.01	8.	1.01	13.20	160	.27	.26	.00	483.
1.01	1.00	12	.01	.00	.01	9.	1.01	13.25	161	.27	.26	.00	512.
1.01	1.05	13	.01	.00	.01	9.	1.01	13.30	162	.27	.26	.00	533.
1.01	1.10	14	.01	.00	.01	9.	1.01	13.35	163	.27	.26	.00	541.
1.01	1.15	15	.01	.00	.01	9.	1.01	13.40	164	.27	.26	.00	543.
1.01	1.20	16	.01	.00	.01	9.	1.01	13.45	165	.27	.26	.00	542.
1.01	1.25	17	.01	.00	.01	9.	1.01	13.50	166	.27	.26	.00	544.
1.01	1.30	18	.01	.00	.01	10.	1.01	13.55	167	.27	.26	.00	534.
1.01	1.35	19	.01	.00	.01	10.	1.01	14.00	168	.27	.26	.00	538.
1.01	1.40	20	.01	.00	.01	10.	1.01	14.05	169	.33	.33	.00	603.
1.01	1.45	21	.01	.01	.01	10.	1.01	14.10	170	.33	.33	.00	646.
1.01	1.50	22	.01	.01	.01	10.	1.01	14.15	171	.33	.33	.00	661.
1.01	1.55	23	.01	.01	.01	10.	1.01	14.20	172	.33	.33	.00	670.
1.01	2.00	24	.01	.01	.01	10.	1.01	14.25	173	.33	.33	.00	630.
1.01	2.05	25	.01	.01	.01	11.	1.01	14.30	174	.33	.33	.00	698.
1.01	2.10	26	.01	.01	.01	11.	1.01	14.35	175	.33	.33	.00	634.

Input Data
Various PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B5

1.01	2.15	27	.01	.01	.01	11.	1.01	14.35	175	.33	.33	.00	[illegible]
1.01	2.15	27	.01	.01	.01	11.	1.01	14.40	176	.33	.33	.00	[illegible]
1.01	2.20	28	.01	.01	.01	12.	1.01	14.45	177	.33	.33	.00	[illegible]
1.01	2.25	29	.01	.01	.01	12.	1.01	14.50	178	.33	.33	.00	[illegible]
1.01	2.30	30	.01	.01	.01	13.	1.01	14.55	179	.33	.33	.00	[illegible]
1.01	2.35	31	.01	.01	.01	13.	1.01	15.00	180	.33	.33	.00	[illegible]
1.01	2.40	32	.01	.01	.01	13.	1.01	15.05	181	.20	.20	.00	[illegible]
1.01	2.45	33	.01	.01	.01	14.	1.01	15.10	182	.40	.40	.00	[illegible]
1.01	2.50	34	.01	.01	.01	14.	1.01	15.15	183	.40	.40	.00	[illegible]
1.01	2.55	35	.01	.01	.01	14.	1.01	15.20	184	.60	.60	.00	[illegible]
1.01	3.00	36	.01	.01	.01	15.	1.01	15.25	185	.70	.70	.00	[illegible]
1.01	3.05	37	.01	.01	.01	15.	1.01	15.30	186	1.71	1.71	.00	[illegible]
1.01	3.10	38	.01	.01	.01	16.	1.01	15.35	187	2.82	2.82	.01	[illegible]
1.01	3.15	39	.01	.01	.01	16.	1.01	15.40	188	1.11	1.11	.00	[illegible]
1.01	3.20	40	.01	.01	.01	16.	1.01	15.45	189	.71	.70	.00	[illegible]
1.01	3.25	41	.01	.01	.01	16.	1.01	15.50	190	.60	.60	.00	[illegible]
1.01	3.30	42	.01	.01	.01	17.	1.01	15.55	191	.40	.40	.00	[illegible]
1.01	3.35	43	.01	.01	.01	17.	1.01	16.00	192	.40	.40	.00	[illegible]
1.01	3.40	44	.01	.01	.01	17.	1.01	16.05	193	.31	.31	.00	[illegible]
1.01	3.45	45	.01	.01	.01	18.	1.01	16.10	194	.31	.31	.00	[illegible]
1.01	3.50	46	.01	.01	.01	18.	1.01	16.15	195	.31	.31	.00	[illegible]
1.01	3.55	47	.01	.01	.01	18.	1.01	16.20	196	.31	.31	.00	[illegible]
1.01	4.00	48	.01	.01	.01	18.	1.01	16.25	197	.31	.31	.00	[illegible]
1.01	4.05	49	.01	.01	.01	19.	1.01	16.30	198	.31	.31	.00	[illegible]
1.01	4.10	50	.01	.01	.01	19.	1.01	16.35	199	.31	.31	.00	[illegible]
1.01	4.15	51	.01	.01	.01	19.	1.01	16.40	200	.31	.31	.00	[illegible]
1.01	4.20	52	.01	.01	.01	19.	1.01	16.45	201	.31	.31	.00	[illegible]
1.01	4.25	53	.01	.01	.01	20.	1.01	16.50	202	.31	.31	.00	[illegible]
1.01	4.30	54	.01	.01	.00	20.	1.01	16.55	203	.31	.31	.00	[illegible]
1.01	4.35	55	.01	.01	.00	20.	1.01	17.00	204	.31	.31	.00	[illegible]
1.01	4.40	56	.01	.01	.00	20.	1.01	17.05	205	.24	.24	.00	[illegible]
1.01	4.45	57	.01	.01	.00	21.	1.01	17.10	206	.24	.24	.00	[illegible]
1.01	4.50	58	.01	.01	.00	21.	1.01	17.15	207	.24	.24	.00	[illegible]
1.01	4.55	59	.01	.01	.00	21.	1.01	17.20	208	.24	.24	.00	[illegible]
1.01	5.00	60	.01	.01	.00	21.	1.01	17.25	209	.24	.24	.00	[illegible]
1.01	5.05	61	.01	.01	.00	21.	1.01	17.30	210	.24	.24	.00	[illegible]
1.01	5.10	62	.01	.01	.00	21.	1.01	17.35	211	.24	.24	.00	[illegible]
1.01	5.15	63	.01	.01	.00	22.	1.01	17.40	212	.24	.24	.00	[illegible]
1.01	5.20	64	.01	.01	.00	22.	1.01	17.45	213	.24	.24	.00	[illegible]
1.01	5.25	65	.01	.01	.00	22.	1.01	17.50	214	.24	.24	.00	[illegible]
1.01	5.30	66	.01	.01	.00	22.	1.01	17.55	215	.24	.24	.00	[illegible]
1.01	5.35	67	.01	.01	.00	22.	1.01	18.00	216	.24	.24	.00	[illegible]
1.01	5.40	68	.01	.01	.00	22.	1.01	18.05	217	.02	.02	.00	[illegible]
1.01	5.45	69	.01	.01	.00	23.	1.01	18.10	218	.02	.02	.00	[illegible]
1.01	5.50	70	.01	.01	.00	23.	1.01	18.15	219	.02	.02	.00	[illegible]
1.01	5.55	71	.01	.01	.00	23.	1.01	18.20	220	.02	.02	.00	[illegible]
1.01	6.00	72	.01	.01	.00	23.	1.01	18.25	221	.02	.02	.00	[illegible]
1.01	6.05	73	.07	.05	.02	24.	1.01	18.30	222	.02	.02	.00	[illegible]
1.01	6.10	74	.07	.05	.02	27.	1.01	18.35	223	.02	.02	.00	[illegible]
1.01	6.15	75	.07	.05	.01	32.	1.01	18.40	224	.02	.02	.00	[illegible]
1.01	6.20	76	.07	.05	.01	41.	1.01	18.45	225	.02	.02	.00	[illegible]
1.01	6.25	77	.07	.05	.01	52.	1.01	18.50	226	.02	.02	.00	[illegible]
1.01	6.30	78	.07	.05	.01	63.	1.01	18.55	227	.02	.02	.00	[illegible]
1.01	6.35	79	.07	.05	.01	75.	1.01	19.00	228	.02	.02	.00	[illegible]
1.01	6.40	80	.07	.05	.01	84.	1.01	19.05	229	.02	.02	.00	[illegible]
1.01	6.45	81	.07	.05	.01	93.	1.01	19.10	230	.02	.02	.00	[illegible]
1.01	6.50	82	.07	.06	.01	99.	1.01	19.15	231	.02	.02	.00	[illegible]
1.01	6.55	83	.07	.06	.01	104.	1.01	19.20	232	.02	.02	.00	[illegible]
1.01	7.00	84	.07	.06	.01	108.	1.01	19.25	233	.02	.02	.00	[illegible]
1.01	7.05	85	.07	.06	.01	112.	1.01	19.30	234	.02	.02	.00	[illegible]
1.01	7.10	86	.07	.06	.01	115.	1.01	19.35	235	.02	.02	.00	[illegible]
1.01	7.15	87	.07	.06	.01	117.	1.01	19.40	236	.02	.02	.00	[illegible]
1.01	7.20	88	.07	.06	.01	120.	1.01	19.45	237	.02	.02	.00	[illegible]

Input Data
PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B6

1.01	9.15	87	.07	.06	.01	117.	1.01	19.40	236	.02	.02	.00	44.
1.01	9.20	88	.07	.06	.01	120.	1.01	19.45	237	.02	.02	.00	44.
1.01	9.25	89	.07	.06	.01	121.	1.01	19.50	238	.02	.02	.00	44.
1.01	9.30	90	.07	.06	.01	123.	1.01	19.55	239	.02	.02	.00	44.
1.01	9.35	91	.07	.06	.01	124.	1.01	20.00	240	.02	.02	.00	44.
1.01	9.40	92	.07	.06	.01	126.	1.01	20.05	241	.02	.02	.00	44.
1.01	9.45	93	.07	.06	.01	127.	1.01	20.10	242	.02	.02	.00	44.
1.01	9.50	94	.07	.06	.01	128.	1.01	20.15	243	.02	.02	.00	44.
1.01	9.55	95	.07	.06	.01	128.	1.01	20.20	244	.02	.02	.00	44.
1.01	9.00	96	.07	.05	.01	129.	1.01	20.25	245	.02	.02	.00	44.
1.01	9.05	97	.07	.05	.01	130.	1.01	20.30	246	.02	.02	.00	44.
1.01	9.10	98	.07	.06	.01	131.	1.01	20.35	247	.02	.02	.00	44.
1.01	9.15	99	.07	.06	.00	131.	1.01	20.40	248	.02	.02	.00	44.
1.01	9.20	100	.07	.06	.00	132.	1.01	20.45	249	.02	.02	.00	44.
1.01	9.25	101	.07	.06	.00	133.	1.01	20.50	250	.02	.02	.00	44.
1.01	9.30	102	.07	.06	.00	133.	1.01	20.55	251	.02	.02	.00	44.
1.01	9.35	103	.07	.06	.00	134.	1.01	21.00	252	.02	.02	.00	44.
1.01	9.40	104	.07	.06	.00	134.	1.01	21.05	253	.02	.02	.00	44.
1.01	9.45	105	.07	.06	.00	134.	1.01	21.10	254	.02	.02	.00	44.
1.01	9.50	106	.07	.06	.00	135.	1.01	21.15	255	.02	.02	.00	44.
1.01	9.55	107	.07	.06	.00	135.	1.01	21.20	256	.02	.02	.00	44.
1.01	9.00	108	.07	.06	.00	136.	1.01	21.25	257	.02	.02	.00	44.
1.01	9.05	109	.07	.06	.00	136.	1.01	21.30	258	.02	.02	.00	44.
1.01	9.10	110	.07	.06	.00	136.	1.01	21.35	259	.02	.02	.00	44.
1.01	9.15	111	.07	.06	.00	136.	1.01	21.40	260	.02	.02	.00	44.
1.01	9.20	112	.07	.06	.00	137.	1.01	21.45	261	.02	.02	.00	44.
1.01	9.25	113	.07	.06	.00	137.	1.01	21.50	262	.02	.02	.00	44.
1.01	9.30	114	.07	.06	.00	137.	1.01	21.55	263	.02	.02	.00	44.
1.01	9.35	115	.07	.06	.00	138.	1.01	22.00	264	.02	.02	.00	44.
1.01	9.40	116	.07	.06	.00	138.	1.01	22.05	265	.02	.02	.00	44.
1.01	9.45	117	.07	.06	.00	138.	1.01	22.10	266	.02	.02	.00	44.
1.01	9.50	118	.07	.06	.00	138.	1.01	22.15	267	.02	.02	.00	44.
1.01	9.55	119	.07	.06	.00	139.	1.01	22.20	268	.02	.02	.00	44.
1.01	10.00	120	.07	.06	.00	139.	1.01	22.25	269	.02	.02	.00	44.
1.01	10.05	121	.07	.06	.00	139.	1.01	22.30	270	.02	.02	.00	44.
1.01	10.10	122	.07	.06	.00	139.	1.01	22.35	271	.02	.02	.00	44.
1.01	10.15	123	.07	.06	.00	139.	1.01	22.40	272	.02	.02	.00	44.
1.01	10.20	124	.07	.06	.00	139.	1.01	22.45	273	.02	.02	.00	44.
1.01	10.25	125	.07	.06	.00	140.	1.01	22.50	274	.02	.02	.00	44.
1.01	10.30	126	.07	.06	.00	140.	1.01	22.55	275	.02	.02	.00	44.
1.01	10.35	127	.07	.06	.00	140.	1.01	23.00	276	.02	.02	.00	44.
1.01	10.40	128	.07	.06	.00	140.	1.01	23.05	277	.02	.02	.00	44.
1.01	10.45	129	.07	.06	.00	140.	1.01	23.10	278	.02	.02	.00	44.
1.01	10.50	130	.07	.06	.00	140.	1.01	23.15	279	.02	.02	.00	44.
1.01	10.55	131	.07	.06	.00	141.	1.01	23.20	280	.02	.02	.00	44.
1.01	11.00	132	.07	.06	.00	141.	1.01	23.25	281	.02	.02	.00	44.
1.01	11.05	133	.07	.06	.00	141.	1.01	23.30	282	.02	.02	.00	44.
1.01	11.10	134	.07	.06	.00	141.	1.01	23.35	283	.02	.02	.00	44.
1.01	11.15	135	.07	.06	.00	141.	1.01	23.40	284	.02	.02	.00	44.
1.01	11.20	136	.07	.06	.00	141.	1.01	23.45	285	.02	.02	.00	44.
1.01	11.25	137	.07	.06	.00	141.	1.01	23.50	286	.02	.02	.00	44.
1.01	11.30	138	.07	.06	.00	141.	1.01	23.55	287	.02	.02	.00	44.
1.01	11.35	139	.07	.06	.00	141.	1.02	0.	288	.02	.02	.00	44.
1.01	11.40	140	.07	.06	.00	142.	1.02	.05	289	0.	0.	0.	44.
1.01	11.45	141	.07	.06	.00	142.	1.02	.10	290	0.	0.	0.	44.
1.01	11.50	142	.07	.06	.00	142.	1.02	.15	291	0.	0.	0.	44.
1.01	11.55	143	.07	.06	.00	142.	1.02	.20	292	0.	0.	0.	44.
1.01	12.00	144	.07	.05	.00	142.	1.02	.25	293	0.	0.	0.	44.
1.01	12.05	145	.22	.22	.01	145.	1.02	.30	294	0.	0.	0.	44.
1.01	12.10	146	.22	.22	.00	156.	1.02	.35	295	0.	0.	0.	44.
1.01	12.15	147	.22	.22	.00	177.	1.02	.40	296	0.	0.	0.	44.
1.01	12.20	148	.22	.22	.00	211.	1.02	.45	297	0.	0.	0.	44.

Input Data
PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B7

1.01	11.20	136	.07	.06	.00	141.	1.01	23.40	284	.02	.02	.01	45.
1.01	11.25	137	.07	.06	.00	141.	1.01	23.45	285	.02	.02	.00	44.
1.01	11.30	138	.07	.06	.00	141.	1.01	23.50	286	.02	.02	.00	44.
1.01	11.35	139	.07	.06	.00	141.	1.01	23.55	287	.02	.02	.00	45.
1.01	11.40	140	.07	.06	.00	142.	1.02	0.	288	.02	.02	.01	45.
1.01	11.45	141	.07	.06	.00	142.	1.02	.05	289	0.	0.	0.	48.
1.01	11.50	142	.07	.06	.00	142.	1.02	.10	290	0.	0.	0.	47.
1.01	11.55	143	.07	.06	.00	142.	1.02	.15	291	0.	0.	0.	44.
1.01	12.00	144	.07	.06	.00	142.	1.02	.20	292	0.	0.	0.	39.
1.01	12.05	145	.22	.22	.01	145.	1.02	.25	293	0.	0.	0.	33.
1.01	12.10	146	.22	.22	.00	156.	1.02	.30	294	0.	0.	0.	28.
1.01	12.15	147	.22	.22	.00	177.	1.02	.35	295	0.	0.	0.	24.
1.01	12.20	148	.22	.22	.00	211.	1.02	.40	296	0.	0.	0.	20.
1.01	12.25	149	.22	.22	.00	259.	1.02	.45	297	0.	0.	0.	17.
							1.02	.50	298	0.	0.	0.	15.
							1.02	.55	299	0.	0.	0.	13.
									SUM	33.80	32.79	1.01	73638.
										(859.1(	833.1(	26.1(	2085.2(

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2301.	806.	255.	246.	73607.
CMS	65.	23.	7.	7.	2084.
INCHES		25.85	32.77	32.79	32.79
MM		656.57	832.44	832.94	832.94
AC-FT		400.	507.	507.	507.
THOUS CU M		493.	625.	625.	625.

Input Data
PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B8

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	RATIOS APPLIED TO FLOWS RATIO 1 .50	RATIO 2 1.00
HYDROGRAPH AT	LAKE	.20	1	696.	1392.
		(.52)		(19.70)(	39.41)(
ROUTED TO	DAM	.20	1	636.	1300.
		(.52)		(18.02)(	36.81)(
HYDROGRAPH AT	LAKE	.29	1	1150.	2301.
		(.75)		(32.58)(	65.15)(
2 COMBINED	LAKE	.49	1	1666.	3397.
		(1.27)		(47.19)(	96.18)(
ROUTED TO	DAM	.49	1	1191.	2533.
		(1.27)		(33.43)(	71.73)(

Output Data
Various PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B9

SUMMARY OF DAM SAFETY ANALYSIS Ditch Creek

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	852.00	852.00	852.00
STORAGE	6.	6.	6.
OUTFLOW	0.	0.	0.

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
.50	853.14	1.14	24.	636.	24.92	16.33	0.
1.00	853.51	1.51	34.	1300.	24.92	16.33	0.

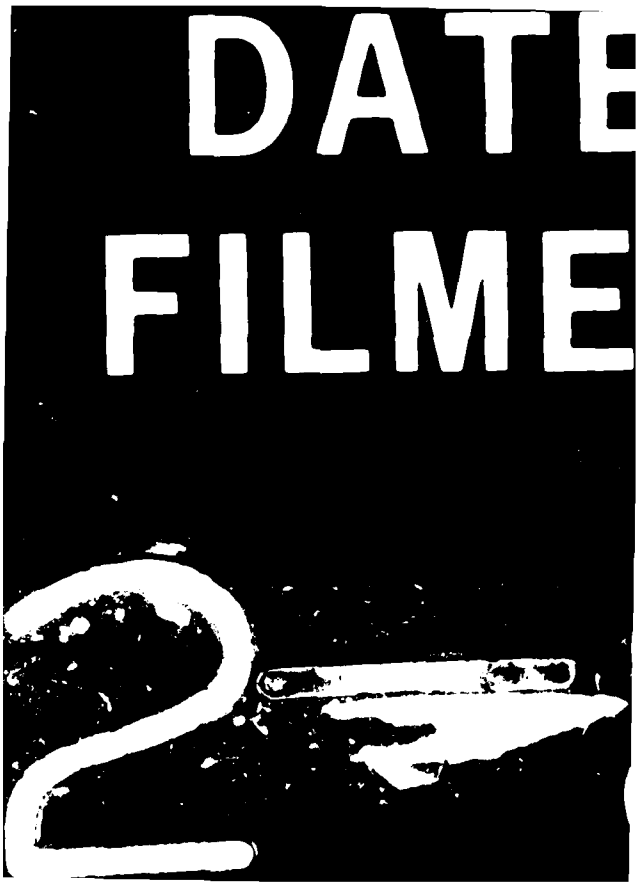
SUMMARY OF DAM SAFETY ANALYSIS Richwoods Pond

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	837.00	837.00	841.00
STORAGE	104.	104.	349.
OUTFLOW	0.	0.	3630.

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
.50	839.47	0.	246.	1181.	0.	16.50	0.
1.00	840.50	0.	315.	2533.	0.	16.50	0.

Output Data (Continued)
Various PMF Events
Richwoods Pond Dam
MO. ID. NO. 30727
B 10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