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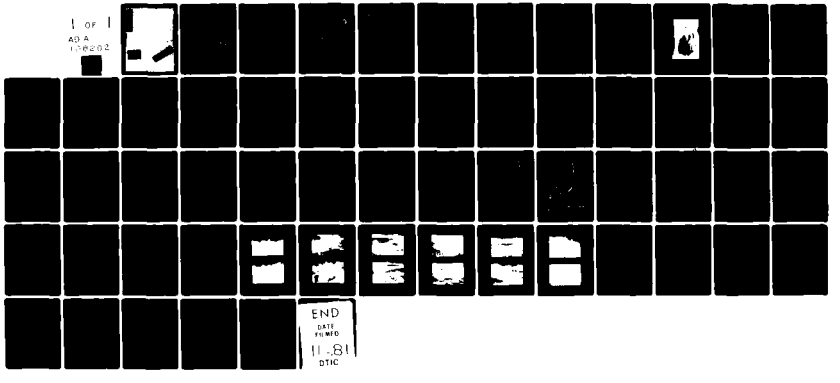

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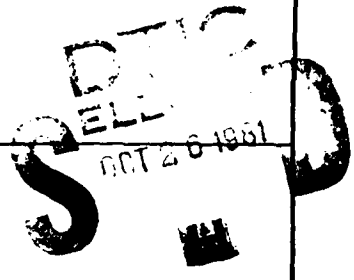

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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

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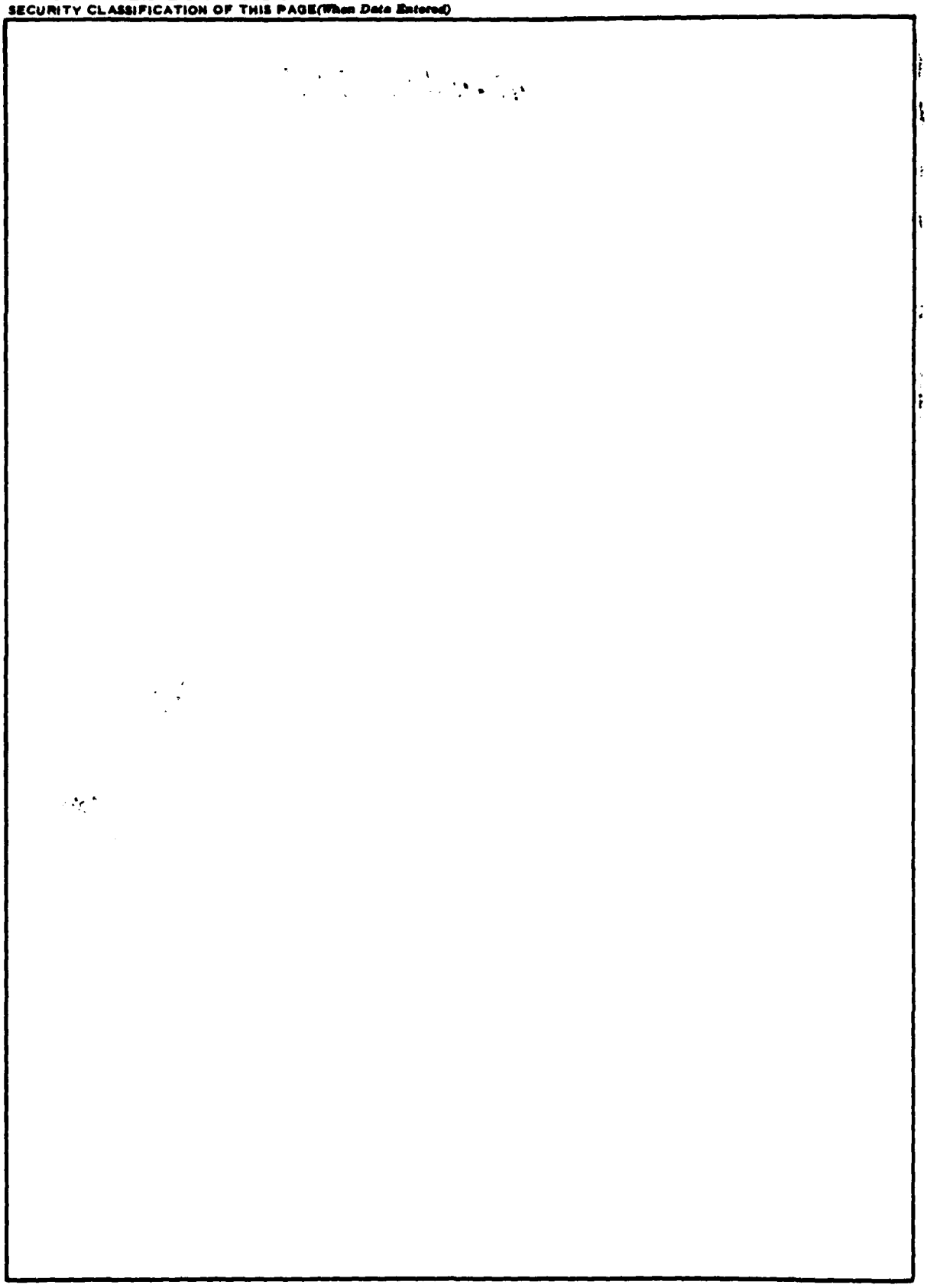

MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

MALLARD LAKE DAM
PERRY COUNTY, MISSOURI
MO 30807

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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

FEBRUARY 1980

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

IN REPLY REFER TO

SUBJECT: Mallard Lake Dam (Mo. 30807) Phase I Inspection Report

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

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St. Louis District as a result of the application of the following criteria:

1. Spillway will not pass 50 percent of the Probable Maximum Flood.

2. Overtopping of the dam could result in failure of the dam.

3. Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED
Chief, Engineering Division
1 APR 1980
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer
1 APR 1980
Date

MALLARD LAKE DAM - MISSOURI INVENTORY NO. 30807

PERRY COUNTY, MISSOURI

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.
5200 OAKLAND AVENUE
ST. LOUIS, MISSOURI 63110

FOR:

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS

FEBRUARY 1980

HS-7925

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Mallard Lake Dam
State Located:	Missouri
County Located:	Perry
Stream:	Tributary Whitewater River
Date of Inspection:	11 October 1979

The Mallard Lake Dam, was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety and, based upon this inspection and available data, determine if the dam poses a hazard to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team. Based on the visual inspection, the general condition of the dam was less than satisfactory. The following deficiencies were noticed during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam:

1. A majority of the upstream face of the dam is protected against erosion by by 4- to 6-inch gravel riprap. However, in some areas, notably at and near the left abutment, riprap is not provided, and only a grass cover serves to protect the upstream slope from erosion. Minor erosion of the upstream face of the dam at and above the normal waterline was noticed at several locations. A grass covered slope is not considered adequate to prevent erosion by wave action or by fluctuations of the lake water level.

2. A dense cover of vegetation (brush, trees and high grass) that may conceal animal burrows exists on the downstream face of the dam. A similar condition, although to a lesser extent, exists along the upstream face of the dam. An underwater animal trail and burrow was noted in the upstream face of the dam near the left abutment. Tree roots and animal burrows can provide passageways for seepage that could develop into a piping condition (progressive internal erosion) that can lead to failure of the dam.
3. Seepage, as evidenced by wet and soft ground, cattails and willows, was observed in the vicinity of the downstream toe of slope near the center of the dam. Uncontrolled seepage could develop into a piping condition that can lead to failure of the dam.
4. The subgrade at the downstream end of the concrete apron that lies adjacent to the spillway weir was eroded up to a depth of about 2 inches extending approximately 12 inches beneath the slab. Continued erosion of the apron subgrade may result in collapse of the projecting portion of the slab due to lack of support.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Mallard Lake Dam, which is classified as small in size and of high hazard potential, is specified to be a minimum of one-half the Probable Maximum Flood (PMF). Considering the fact that a church, a county highway, several dwellings and associated buildings, and a portion of the Town of Yount all lie within the possible flood damage zone, it is recommended that the spillway for this dam be designed for the PMF. The PMF is ordinarily accepted as the inflow design flood for dams where failure of the structure would increase the danger to human life. The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

Results of a hydrologic/hydraulic analysis indicated that the existing spillways are inadequate to pass lake outflow resulting from a storm of PMF magnitude or the lake outflow resulting from the 1 percent chance (100-year frequency) flood. However, they are adequate to pass lake outflow resulting from the 0.1 percent chance (10-year frequency) flood. The spillways, principal plus emergency, are capable of passing lake outflow corresponding to about 10 percent of the PMF lake inflow. According to the St. Louis District, Corps of Engineers, the length of the downstream damage zone, should failure of the dam occur, is estimated to be approximately three miles. Within the possible flood damage zone are a church, a county road and seven dwellings and associated buildings, including three in the Town of Yount.

A review of available data did not disclose that seepage or stability analyses of this dam were performed. This is considered a deficiency and should be rectified.

It is recommended that the Owner take the necessary action in the near future to correct or control the deficiencies and safety defects reported herein.

Harold B. Lockett
P.E. Missouri E-4189

Albert B. Becker, Jr.
P.E. Missouri E-9168

OVERVIEW MALLARD LAKE DAM

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

MALLARD LAKE DAM - ID. NO. 30807

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

MALLARD LAKE DAM - ID NO. 30807

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, directed that a safety inspection of the Mallard Lake Dam be made.

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

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams," Appendix D to "Report of the Chief of Engineers on the National Program of Inspection of Non-Federal Dams," dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Mallard Lake Dam is an earthfill type embankment rising approximately 24 feet above the original stream bed. The embankment has a variable upstream slope (above the waterline) of about 1v on 1h from the dam crest to a level just above the

normal waterline where the slope flattens to approximately 1v on 3h, a crest width of about 14 feet, and a downstream slope that varies from about 1v on 1.4h to about 1v on 1.9h. The length of the dam including the spillway sections is approximately 830 feet. An unsurfaced road traverses the dam crest crossing the emergency spillway. A plan and profile of the dam are shown on Plate 3 and a cross-section of the dam is shown on Plate 4. At normal pool elevation the reservoir impounded by the dam occupies approximately 15 acres. There are no drawdown facilities to lower the lake level.

The principal spillway, a concrete weir section 1-foot wide and 54 feet long with sloping earth sides adjacent to the weir is located at the right or east abutment. The spillway outlet channel just downstream of the weir consists of a trapezoidal section, cut into the abutment hillside, with a rock bottom, a near vertical rock wall on the right side, and a sloping earthen bank on the left side. The earthen bank on the left side of the channel is part of a berm approximately 5 feet high that serves to confine flow to the channel and protect the embankment.

The emergency spillway, a shallow trapezoidal section founded in earth about 18 feet wide, is located at the left or west abutment. The outlet channel is unimproved; however, lake outflow is directed away from the dam. A small masonry structure that appeared to be a fruit cellar is partially buried in the downstream face of the embankment at the left side of the dam adjacent to the emergency spillway. A utility pole is also located in the bank adjacent to the spillway channel at a point about 60 feet downstream of the emergency spillway crest.

b. Location. The dam and lake are located on an unnamed tributary of the Whitewater River, approximately 3 miles northwest of the Town of Yount, as shown on the Regional Vicinity Map, Plate 1. The dam is located in Section 30, Township 34 North, Range 9 East, in Perry County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as small. (Per Table 1, Recommended Guidelines for Safety Inspection of Dams.)

d. Hazard Classification. The Mallard Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, extensive damages to agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, as determined by the St. Louis District, extends approximately three miles downstream of the dam. Within the possible damage zone are a church, a county highway and seven dwellings and buildings, including three in the Town of Yount.

e. Ownership. The lake and dam are owned by Mr. George A. Matkins. Mr. Matkins' address is: 737 Meriwether, Barnhart, Missouri 63012.

f. Purpose of Dam. The dam impounds water for recreational use.

g. Design and Construction History. According to the Owner, the dam was constructed in 1953 by his father-in-law, Mr. Truman Hicks, now deceased. It was reported that prior to construction of the embankment, a core trench was excavated across the valley to rock, and that the rock was sealed with concrete. The Owner also reported that the dam was raised approximately 3 feet in 1959 or 1960 by Mr. E. Paul Black, an excavating and grading contractor from Elvins, Missouri. Mr. Matkins reported that the dam was overtopped and washed out in 1961, and rebuilt in 1963, again by Mr. Black.

In 1976, the spillway was improved by the Owner. According to the Owner, these improvements included construction of a new concrete wall, founded on solid rock, 38 inches high by 12 inches wide and approximately 65 feet long with an 8-foot wide concrete apron immediately downstream of the wall.

According to Mr. Matkins, no formal engineering design or plans were prepared for the original dam construction, for the raising of the dam, for the reconstruction of the dam after being washed out, or for the concrete spillway improvement.

h. Normal Operational Procedure. The lake level is unregulated.

1.3 PERTINENT DATA

a. Drainage Area. The area tributary to the lake is essentially undeveloped and in a native state covered with timber. There are several dwellings and other buildings adjacent to the county road at the north side of the drainage area. The watershed above the dam amounts to approximately 1,314 acres. The watershed area is outlined on Plate 2.

b. Discharge at Damsite.

(1) Estimated known maximum flood at damsite ... 145 cfs*

(2) Spillway capacity (principal) ... 1,010 cfs (W.S. = Elev. 714.2)

(3) Spillway capacity (principal + emergency) ... 1,408 cfs (W.S. = Elev. 714.8)

c. Elevation (Ft. above MSL). The following elevations were determined by survey and are based on USGS Bench Mark 4T1957, described as follows:

> "Bench Mark - Elevation 695, T.34N., R.9E., near south line of Section 19, 125 feet east of end of asphalt pavement of County Highway BB, and 35 feet south of centerline of gravel surfaced county road, concrete monument with brass tablet in top, stamped 4T1957."

(1) Top of dam ... 714.8 (min.)

(2) Normal pool (spillway weir) ... 711.0

(3) Streambed at centerline of dam ... 692±

(4) Maximum tailwater ... Unknown

*Based on an estimate of depth of flow at improved spillway as observed by the Owner.

d. Reservoir.

(1) Length at normal pool (Elev. 711.0) ... 1,700 ft.

(2) Length at maximum pool (Elev. 714.8) ... 1,900 ft

e. Storage.

(1) Normal pool ... 134 ac. ft.

(2) Top of dam (incremental) ... 63 ac. ft.

f. Reservoir Surface.

(1) Normal Pool ... 15 acres

(2) Top of dam (incremental) ... 3 acres

g. Dam.

(1) Type ... Earthfill, homogeneous*

(2) Length ... 830 ft.

(3) Height ... 24 ft.

(4) Top width ... 14 ft.

(5) Side slopes

a. Upstream ... variable, 1v on 1h to 1v on 3h

b. Downstream ... variable, 1v on 1.4h to 1v on 1.9h

(6) Cutoff ... Clay core*

(7) Slope protection

a. Upstream ... Gravel riprap

b. Downstream ... Grass

h. Principal Spillway.

(1) Type ... Uncontrolled, 12-inch wide broad-crested concrete weir

(2) Length of weir ... 54 ft.

(3) Crest (top of weir) elevation ... 711.0

(3) Approach channel ... Lake

(4) Outlet channel ... Earth and rock cut trapezoidal section

*Per Owner

i. Emergency Spillway.

(1) Type ... Uncontrolled, dish-shaped, broad-crested weir, earth section

(2) Crest elevation ... 714.2

(3) Approach channel ... Lake

(4) Exit channel ... Earth, trapezoidal section

j. Lake Drawdown Facility. ... None

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

According to the Owner, engineering data relating to the design of the dam do not exist.

2.2 CONSTRUCTION

As previously stated, the dam was originally constructed in 1953 and was raised in 1959 or 1960. It was also reported that the dam was overtopped and washed out in 1961 and rebuilt in 1963. According to the Owner, the contractor who repaired the dam, E. Paul Black of Elvins, Missouri, used a sheepsfoot roller to compact the new fill material placed in the dam. The Owner also stated that the concrete weir type spillway was improved in 1976. No additional records of construction activities were available.

2.3 OPERATION

The lake level is uncontrolled and is governed by the crest elevation of the concrete weir (principal spillway) located at the right abutment. An emergency spillway, with a crest elevation approximately 3.2 feet higher than the crest elevation of the principal spillway and about 0.6 feet lower than the top of the dam at its lowest point, is located at the right abutment. The Owner reported that the dam was washed out in 1961 and that the highest lake level observed since reconstruction of the dam and improvement of the principal spillway produced a depth of flow at the principal spillway estimated to be about 12 inches.

2.4 EVALUATION

a. Availability. Engineering data for assessing the design of the dam and spillways were unavailable.

b. Adequacy. No data available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Mallard Lake Dam was made by Horner & Shifrin engineering personnel, T. K. Deddens, Geological Engineer, H.B. Lockett, Civil Engineer and Hydrologist and A.B. Becker, Jr., Civil and Soils Engineer, on 11 October 1979. An examination of the dam site was also made by an engineering geologist, Jerry D. Higgins, a consultant retained by Horner & Shifrin for the purpose of assessing the area geology. Also examined at the time of the inspection, was the area below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on Pages A-1 through A-6 of Appendix A. The locations of the photographs taken during the inspection are shown on Plate 3.

b. Area Geology. The dam site lies on the eastern flank of the Ozark Uplift on Ordovician-age sedimentary rock. The bedrock is composed primarily of dolomite, chert and sandstones dipping gently to the east.

The dam and reservoir are founded on the Gasconade formation and its residuum. The Gasconade is predominantly a light brownish-gray, crystalline and cherty dolomite with a few thin, irregular sandstone lenses. Cryptozoan, cellular and ropey cherts are common. Bedrock exposures are limited to the spillway and stream channel below the dam. The residuum is composed of a red, cherty clay, which tends to be relatively permeable and susceptible to erosion.

The abutments are gently sloping, composed of thin clay residuum overlying dolomite. The right abutment is cut by the spillway. The spillway channel floor is formed by nearly horizontal dolomite. Solution-weathered dolomite pinnacles are exposed along the sides of the

spillway channel. The abutments appear stable, and no severe erosion was noted. Only minor seepage was noted along bedding planes in the spillway channel.

No adverse geologic conditions were noted which would influence the performance of the dam or reservoir.

c. Dam. The visible portions of the upstream and downstream faces of the dam (see Photos 1 and 2) appeared to be in sound condition, although a dense cover of vegetation (brush, briars, weeds and grass up to 36 inches high) exists on the downstream face of the dam. A similar condition, although to a lesser extent, was observed at the upstream face. An underwater animal trail and burrow (see Photo 12) was also noticed at the upstream face of the dam near the left abutment. Three 6-inch diameter sycamore trees in the upstream face adjacent to the principal spillway, a 48-inch diameter hackberry tree (see Photo 3) at the downstream toe near the left abutment, and numerous small trees across the entire downstream face of the dam were noted. No apparent structural defects were noted nor was there any evidence of seepage at the junction of the dam and the left abutment although a small masonry structure that appeared to be a fruit cellar (see Photo 10) was partially buried in the downstream face of the embankment at this location.

A majority of the upstream face of the dam was protected against erosion by 4- to 6-inch gravel riprap; however, in some areas of the upstream face, mainly near the left abutment, riprap was not provided, and only a grass cover serves to protect the slope from erosion. Minor erosion of the upstream face of the dam was noted at several locations. No cracking or misalignment of the dam crest was evident.

Underseepage, as evidenced by wet, soft ground, cattails and willows (see Photo 11) was observed in the vicinity of the downstream toe of slope near the center of the dam. Since flow was indistinguishable, an estimate of the amount of seepage occurring at this location could not be made.

The 12-inch concrete wall (weir) (see Photos 4 and 5) at the principal spillway was found to be in good condition without evidence of cracking or spalling of the surface. The concrete slab adjacent to the wall was also in good condition however, the subgrade at the downstream end of the slab was eroded (see Photo 6) up to a depth of about 2 inches and extending approximately 12-inches under the slab.

No apparent deficiencies were noted in the improved section of outlet channel that lies just downstream of the principal spillway weir. However, except for a low, free-formed concrete wall constructed to direct flow away from the bank, there was no protection to prevent erosion of the earthen bank on the left side of the channel. At a location just downstream of the 16-foot high rock bluff that exists at the end of the improved channel section, erosion has created two rather large potholes in the channel floor. The pothole on the left (see Photo 7) appeared to be approximately 25 feet in diameter and about 5 feet deep, while the pothole on the right (see Photo 8) was approximately 20 feet in diameter and about 5 feet deep. The outlet channel downstream of the rock bluff is unimproved, and except for the area where the potholes were found, congested with brush and small trees.

The emergency spillway (see Photos 9 and 10) was found to be in good condition although it would appear to be of limited value since the spillway crest is only about 0.6 foot lower than the low point in the top of the dam.

d. Downstream Channel. The unimproved section of channel downstream of the dam extends for approximately 1,000 feet before joining the Whitewater River. County Road J crosses the Whitewater River at the Town of Yount which lies approximately 3 miles downstream of the dam.

e. Reservoir. The area adjacent to the lake is for the most part in a natural state and wooded, although there are several scattered dwellings and other buildings along the west side of the lake.

3.2 EVALUATION

The deficiencies observed during this inspection and noted herein, are not considered of significant importance to warrant immediate remedial action.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillways are uncontrolled. The lake water surface level is governed by precipitation runoff, evaporation, seepage, and the capacity of the uncontrolled principal and emergency spillways.

4.2 MAINTENANCE OF DAM

Based on the substantial cover of brush on the upstream and downstream slopes of the dam as well as the presence of numerous small-to-medium sized trees and one large tree on the dam proper, it is apparent that these areas could receive additional attention. The Owner did report that rock (large gravel) had been placed along the upstream face of the dam to prevent erosion.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

No outlet operating facilities exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

The inspection did not reveal the existence of a dam warning system.

4.5 EVALUATION

Insufficient maintenance is considered detrimental to the safety of the dam. It is recommended that maintenance of the dam be undertaken on a regular basis and that records be kept of all maintenance performed.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data were not available.

b. Experience Data. The drainage area and lake surface area were developed from the USGS Parker Lake, Missouri, and Patton, Missouri, Quadrangle Maps, 7.5 Minute Series. The proportions and dimensions of the spillways and dam were developed from surveys made during the inspection. Vertical control and elevations were referenced to USGS Bench Mark 4T1957.

c. Visual Observations.

(1) The principal spillway crest section consists of a concrete weir, approximately 58 feet long and 12 inches wide, with sloping ends. A concrete apron about 8 feet wide has been constructed immediately adjacent to and downstream of the weir.

(2) The spillway is located adjacent to the embankment in a sidehill cut at the right (east) abutment of the dam.

(3) The spillway outlet channel directs flow away from the toe of the embankment. Spillway releases within the capacity of the spillway channel section will not endanger the integrity of the dam.

(4) An emergency spillway, a broad-crested, shallow, trapezoidal earth section about 18 feet wide, is located at the left (west) abutment. The outlet channel, of the same shape and material as the crest section, directs flow away from the dam.

(5) Lake level drawdown facilities are not provided.

d. Overtopping Potential. The spillways, principal and emergency, are inadequate to pass the probable maximum flood or 1/2 the probable maximum flood without overtopping the dam. The 1 percent chance (100-year frequency) flood overtops the low point in the dam crest by a depth of about 1.0 foot for a duration of 0.8 hour; as a result, the spillways are inadequate to pass lake outflow corresponding to the 100-year flood. However, they are adequate to pass the 0.1 percent chance (10-year frequency) flood without overtopping the dam. The results of a dam overtopping analysis are as follows:

Ratio of PMF	Q-Peak Outflow (cfs)	Max. Lake W.S. Elev.	Max. Depth of Flow over Dam (Elev. 714.8)	Duration of Overtopping of Dam (Hrs.)
0.10	1,408	714.8	0.0	0.0
0.50	8,659	717.1	2.3	5.4
1.00	17,371	718.4	3.6	6.6
100 Yr.-Flood	3,113	715.8	1.0	0.8
10 Yr.-Flood	1,257	714.6	0.0	0.0

Elevation 714.8 was found to be the lowest point in the dam crest. The flow safely passing the spillway just prior to overtopping was determined to be approximately 1,408 cfs, which amounts to about 10 percent of the probable maximum flood inflow. This flow is less than the outflow of the 1 percent chance (100-year frequency) flood, however, it is greater than the outflow from the 0.1 percent chance (10-year frequency) flood. During peak flow of the probable maximum flood, the greatest depth over the dam would be 3.6 feet and the overflow would extend across the entire length of the dam.

e. Evaluation. Experience with embankments constructed of similar material (gravelly, red clay) to that used to construct this dam have shown evidence that the material under certain conditions, such as high velocity flow, can be very erodible. Such a condition exists during the

PMF when large lake outflow, accompanied by high flow velocities occurs. For the PMF condition where the depth of flow over the dam crest, a maximum of 3.6 feet, and the duration of flow over the dam, 6.6 hours, are appreciable, damage by erosion to the crest and downstream face of the dam is expected. The extent of these damages is not predictable, however there is a possibility that they could result in failure of the dam.

f. References. Procedures and data for determining the probable maximum flood, the 100-year frequency flood, the 10-year frequency flood, and the discharge rating curve for flow over the spillways and the dam crest are presented on Pages B-1 and B-2 of the Appendix. A listing of the HEC-1 (Dam Safety Version) input data is shown on Pages B-3 thru B-5 of the Appendix. A copy of the computer output table entitled "Summary of Dam Safety Analysis" is presented on Pages B-6 and B-7. The inflow and outflow hydrographs for the probable maximum flood are shown on Page B-8 of the Appendix. Area-storage curves for the reservoir are shown on Plate 5 and the spillway discharge rating curves are shown on Plate 6 of the report.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations which adversely affect the structural stability of the dam are discussed in Section 3, paragraph 3.1c.

An additional item of interest is the two large potholes that exist within the spillway outlet channel just downstream of the rock bluff. Within the scope of these investigations, it is not possible to say if their presence has an adverse effect on the stability of the spillway or dam at this location. It would appear that these potholes have been eroded into the shallow alluvium of the Whitewater River floodplain that abuts the base of the bluffs at this location. Since the bluff rock is believed to be solid and competent having no large openings or underlying cavities, continued enlargement of the potholes should not affect the integrity of the spillway or dam.

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam are known to exist. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam. According to the Owner, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. According to information obtained from the Owner there have been several post construction changes that could have a bearing on the structural stability of the dam. These

changes include raising the dam approximately 3 feet in 1959 or 1960, rebuilding of the dam in 1963 after being overtopped and washed out in 1961, and improvements to the principal spillway in 1976 that included a new and slightly higher concrete weir wall.

e. Seismic Stability. The dam is located within a Zone II seismic probability area, and an earthquake of the magnitude predicted is not expected to produce a hazardous condition to the dam, provided that static stability conditions are satisfactory and conventional safety margins exist.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicated that the existing spillways (principal plus emergency) are capable of passing lake outflow of about 1,408 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicated that for storm runoff of probable maximum flood magnitude, the lake outflow would be on the order of 17,371 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be about 3,113 cfs. A similar analysis indicated that for the 10-year frequency flood, the lake outflow would be on the order of 1,257 cfs.

Several items were noticed during the inspection that could adversely affect the safety of the dam. These items include seepage, brush and trees on the upstream and downstream faces of the dam, and the lack of adequate riprap protection on the upstream face of the dam.

Seepage and stability analyses of the dam were not available for review and therefore no judgment could be made with respect to the structural stability of the dam.

b. Adequacy of Information. Due to lack of design and construction data, the assessment of the dam as reported herein was based on external conditions as determined during the visual inspection. The assessments of the hydrology of the watershed and capacity of the spillway were based on a hydrologic/hydraulic study as indicated in Section 5. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. The items concerning the safety of the dam noted in Paragraph 7.1a and the remedial measures recommended in paragraph 7.2 should be accomplished within a reasonable time. It is advised that

priority be given to increasing the spillway capacity which is considered to be seriously inadequate.

d. Necessity for Phase II. Based on the results of the Phase I Inspection, a Phase II investigation is not recommended.

e. Seismic Stability. The dam is located within a Zone II seismic probability area, and an earthquake of the magnitude predicted is not expected to produce a hazardous condition to the dam, provided that static stability conditions are satisfactory and conventional safety margins exist.

7.2 REMEDIAL MEASURES

a. Recommendations. The following actions are recommended:

(1) Based upon criteria set forth in the recommended guidelines, alterations to the design of the dam should be made in order to pass lake outflow resulting from a storm of probable maximum flood magnitude.

(2) Obtain the necessary soil data and perform dam seepage and stability analyses in order to determine the structural stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of dams. The existence of the masonry structure that is partially buried in the downstream face of the embankment at the left side of dam should be considered when seepage and stability analyses are performed.

b. Operations and Maintenance (O & M) Procedures. The following O & M Procedures are recommended:

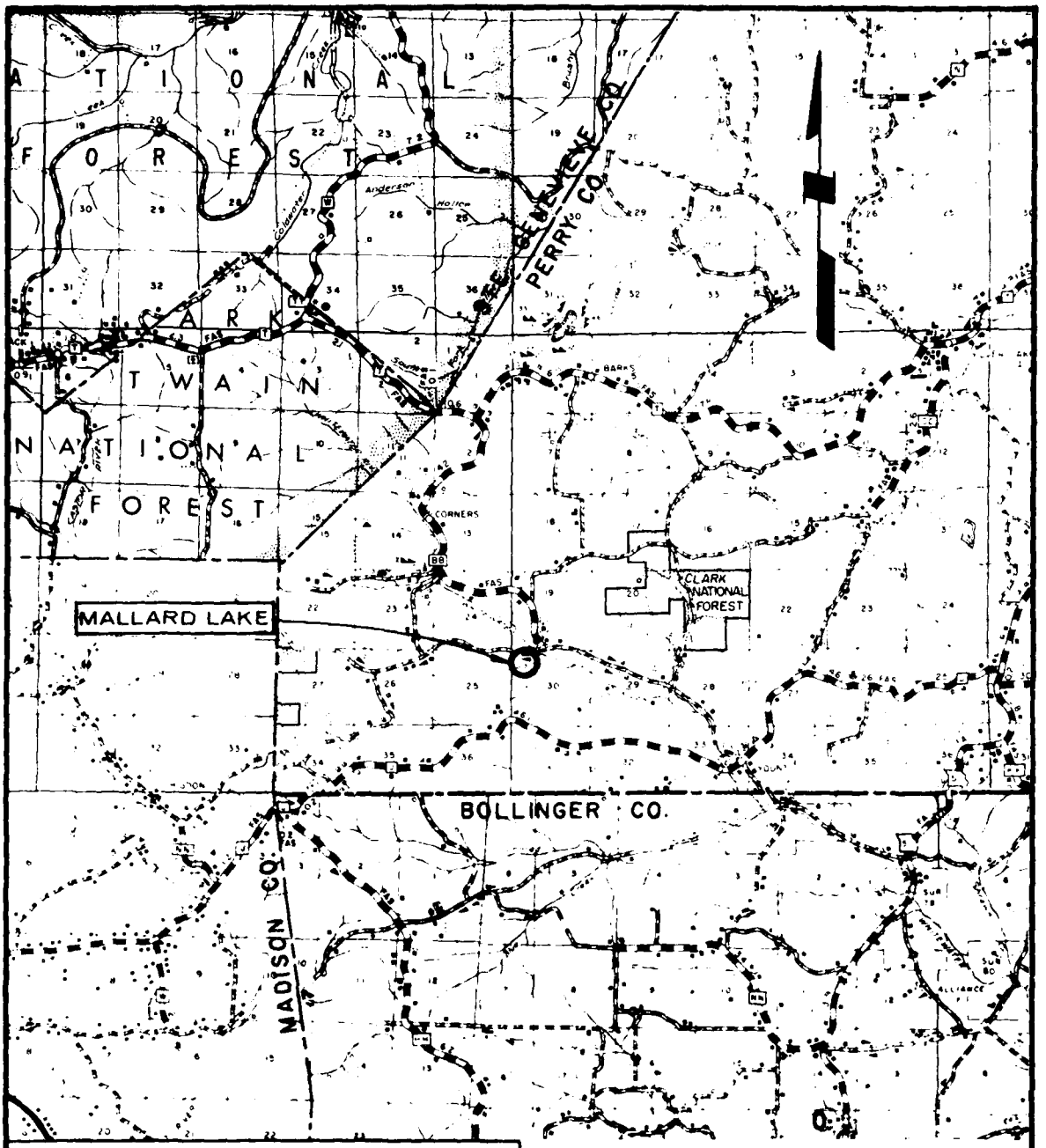
(1) Restore where required the minor erosion of the upstream face of the dam, and where not present, provide some form of protection (other than grass) for the dam face at and above the normal waterline in order to prevent erosion by wave action or by fluctuations in the lake level.

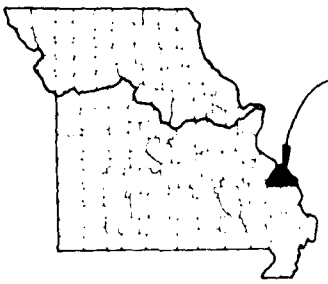
(2) Remove the trees and brush that may conceal animal burrows from the upstream (a hole believed to be an animal burrow exists in the upstream face of the dam near the left abutment) and downstream slopes of the dam. Tree roots and animal burrows provide a passageway for seepage than can lead to a piping condition (progressive internal erosion) and subsequent failure of the dam. The existing plant cover should be restored if destroyed or missing. Maintain the plant cover on the slopes at a height that will not hinder inspection of the slope or provide cover for burrowing animals. The removal of trees should be performed under the direction of an engineer experienced in the design and construction of earthen dams since indiscriminate clearing can jeopardize the safety of the dam.

(3) Provide some means of controlling seepage at the downstream toe near the center of the dam. Uncontrolled seepage can result in a piping condition.

(4) Provide maintenance of all areas of the dam and spillways on a regularly scheduled basis in order to insure features of the dam being in satisfactory operational condition.

(5) A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.





LOCATION MAP

MALLARD LAKE

1 0 1 2 3 4

SCALE (MILES)

REGIONAL VICINITY MAP

PLATE 1

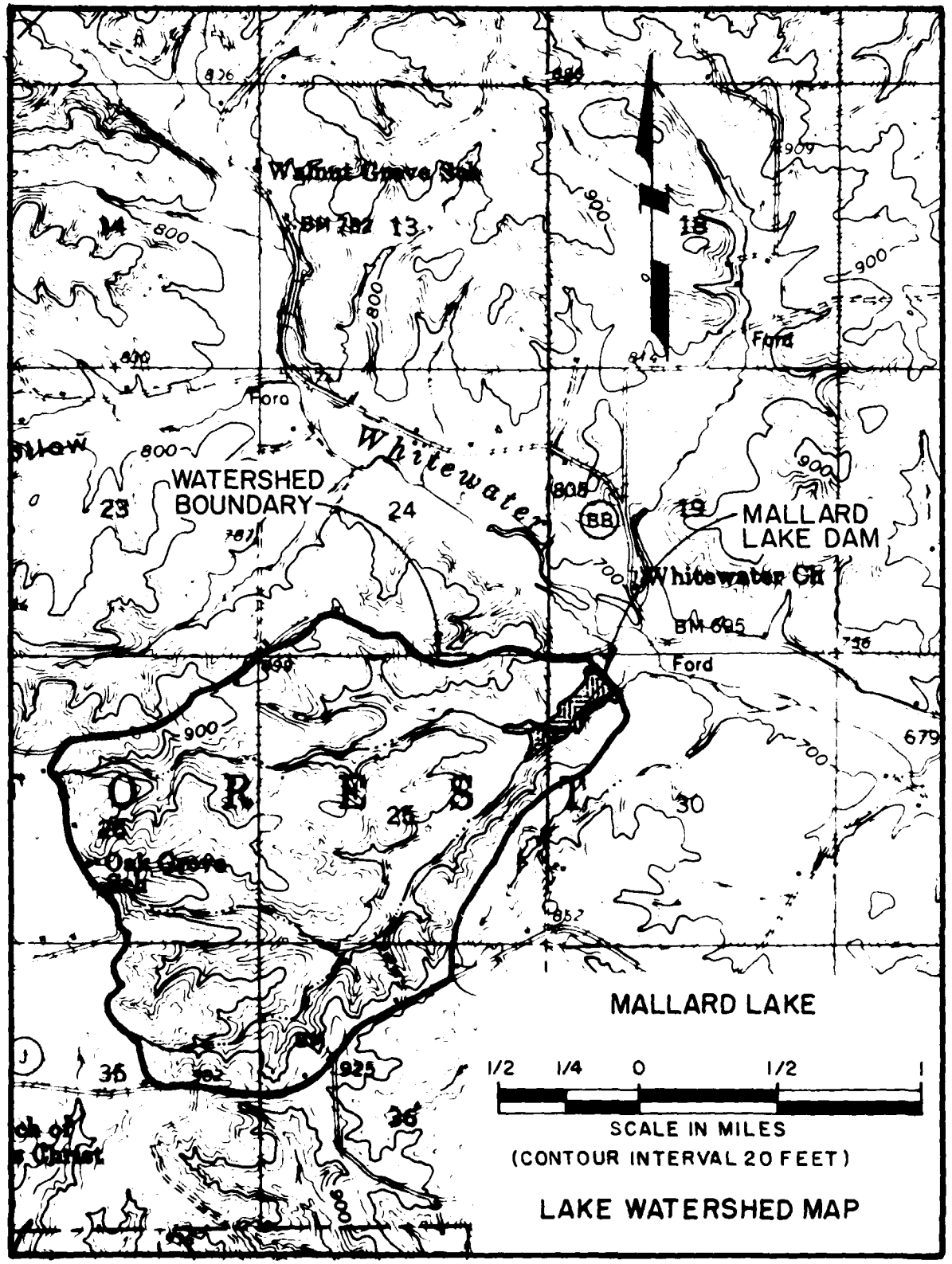
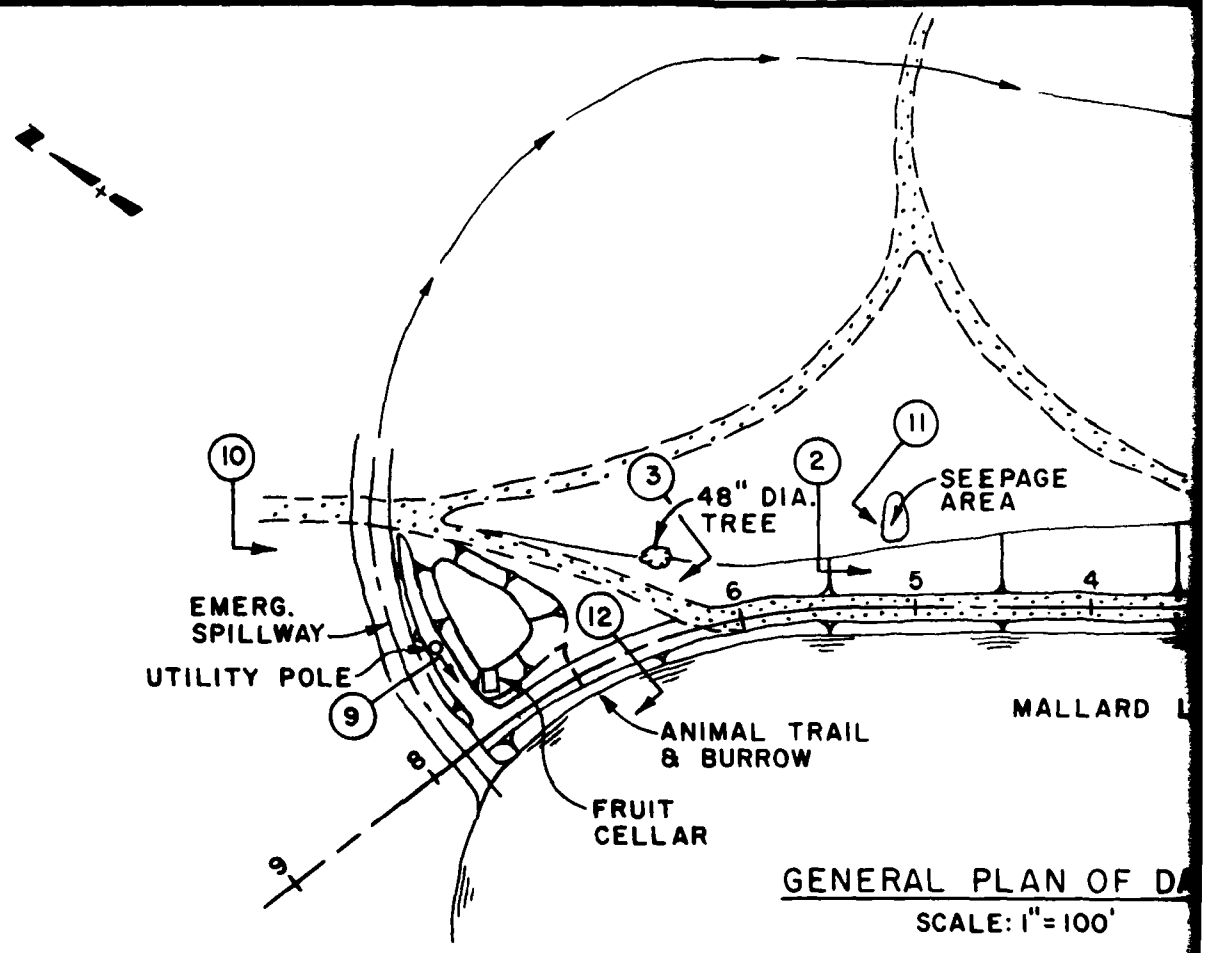
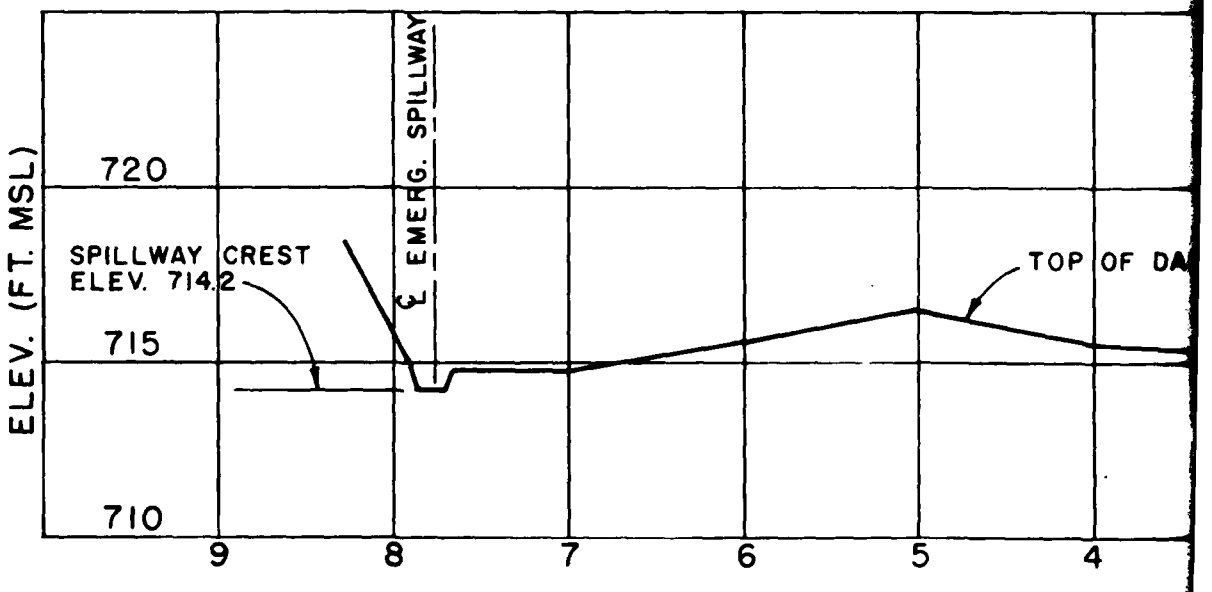

WATERSHED BOUNDARY
MALLARD LAKE DAM
MALLARD LAKE
1/2 1/4 0 1/2 1
SCALE IN MILES
(CONTOUR INTERVAL 20 FEET)
LAKE WATERSHED MAP

PLATE 2



GENERAL PLAN OF DA

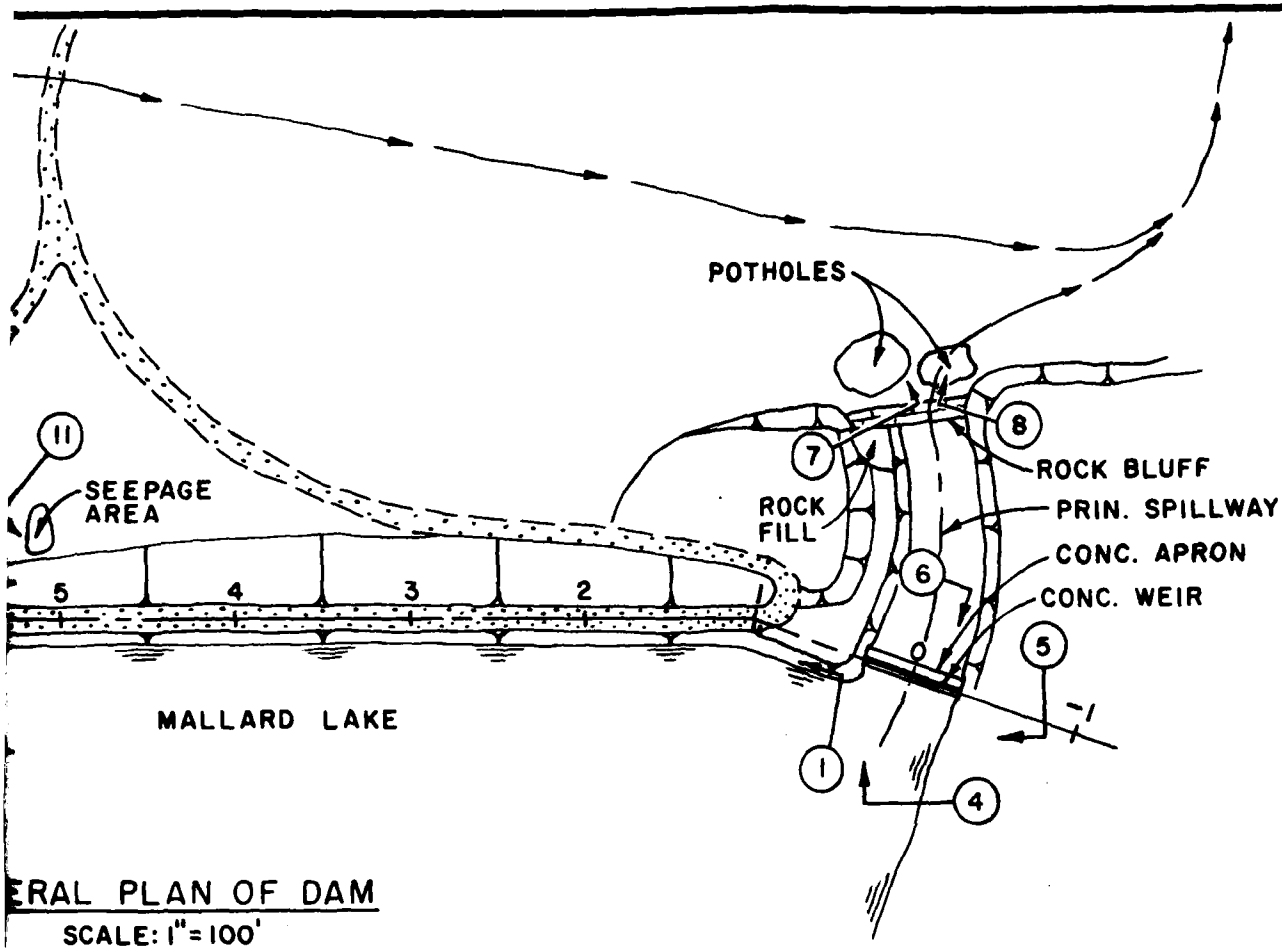
SCALE: 1" = 100'



PROFILE DAM CRES

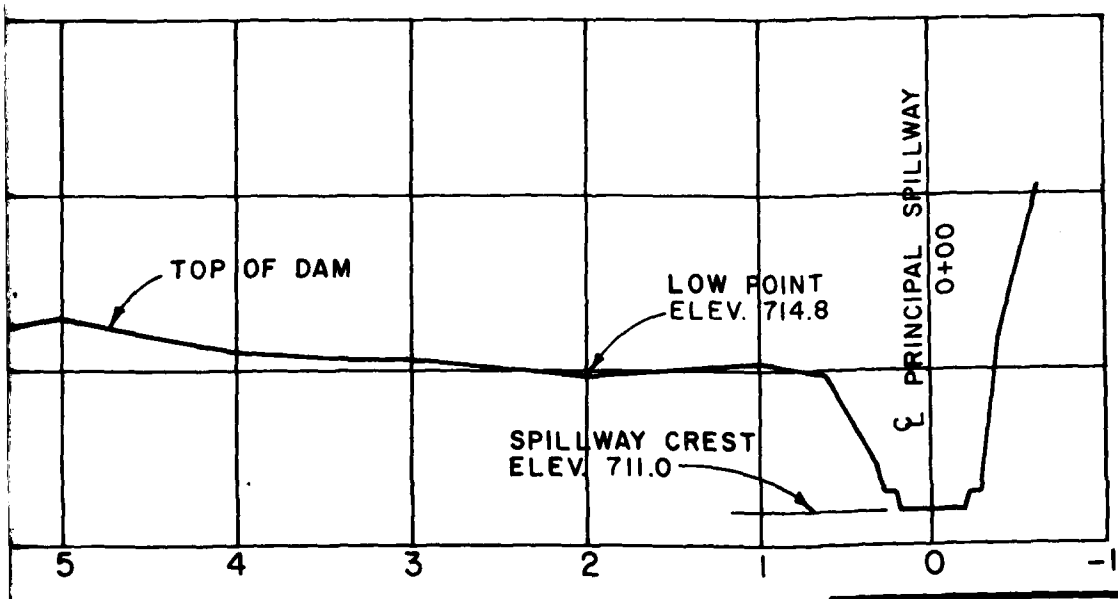
SCALES: 1" = 5' V., 1" = 100' H

(6) PHOTO LOCATION & KEY (SEE APPENDIX A)



ERAL PLAN OF DAM

SCALE: 1"=100'



OFILE DAM CREST

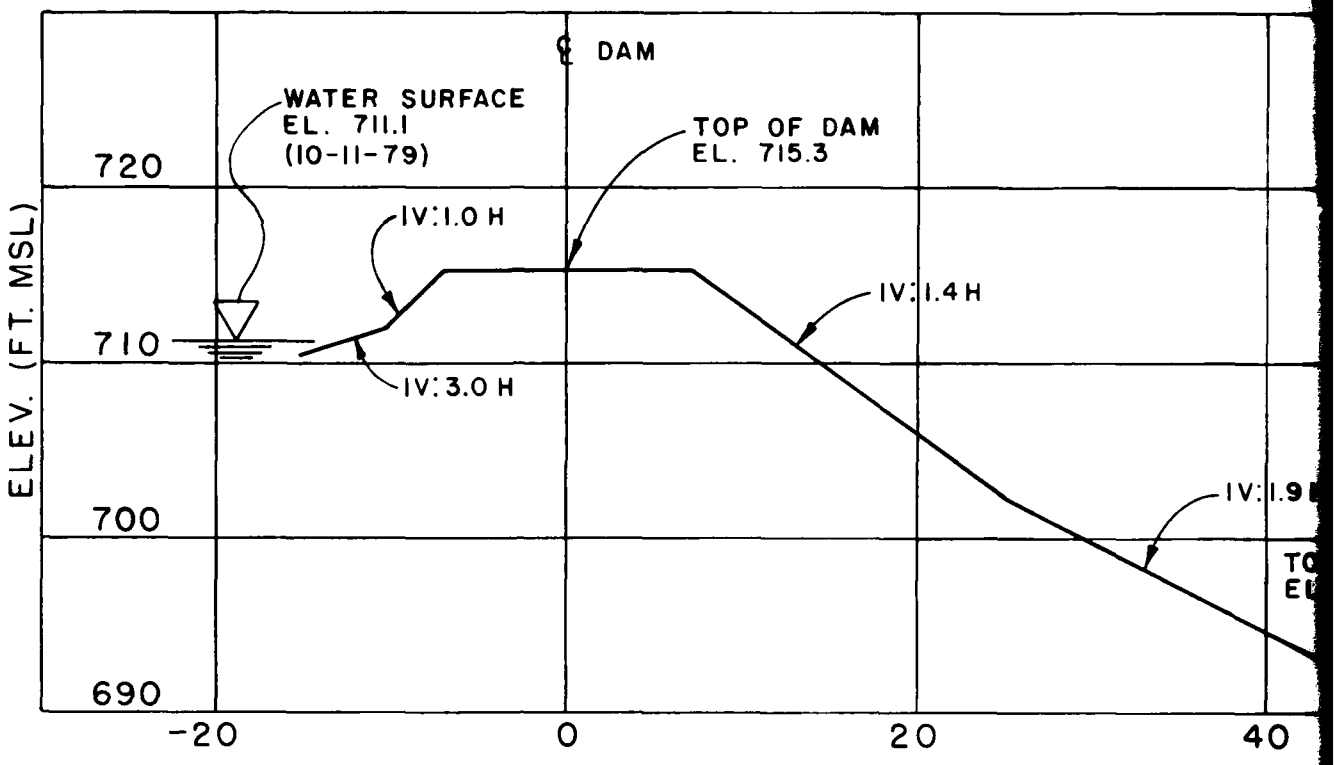
CALES: 1"=5'V., 1"=100'H.

MALLARD LAKE
DAM PLAN & PROFILE

Horner & Shifrin, Inc. Nov. 1979

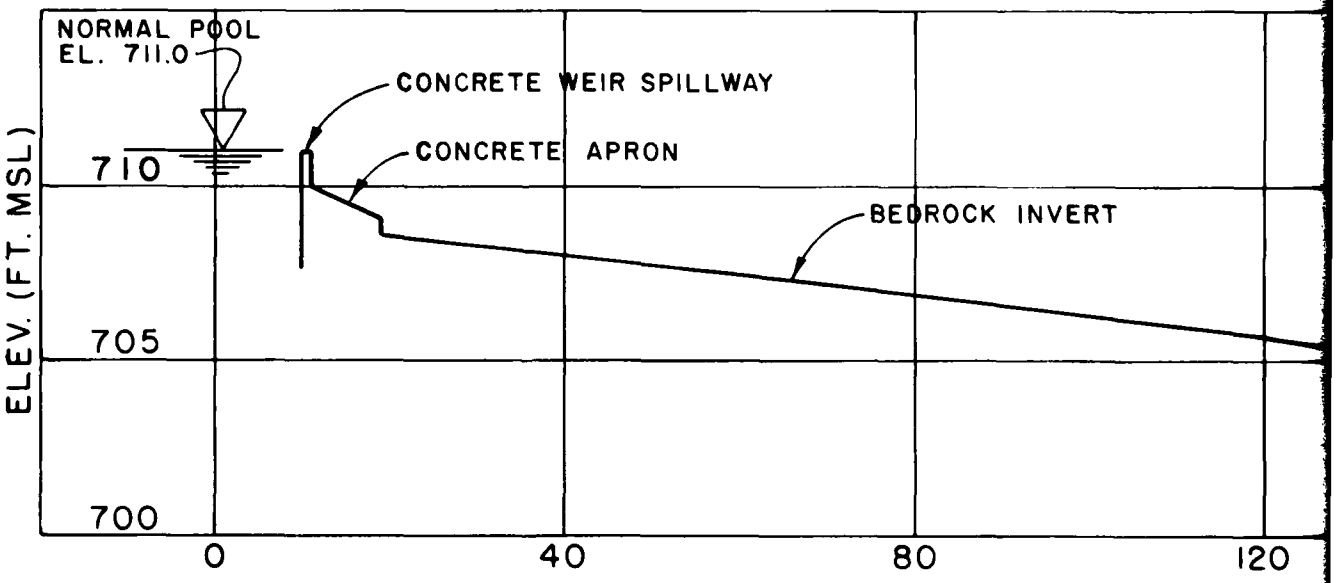
1 2

PLATE 3



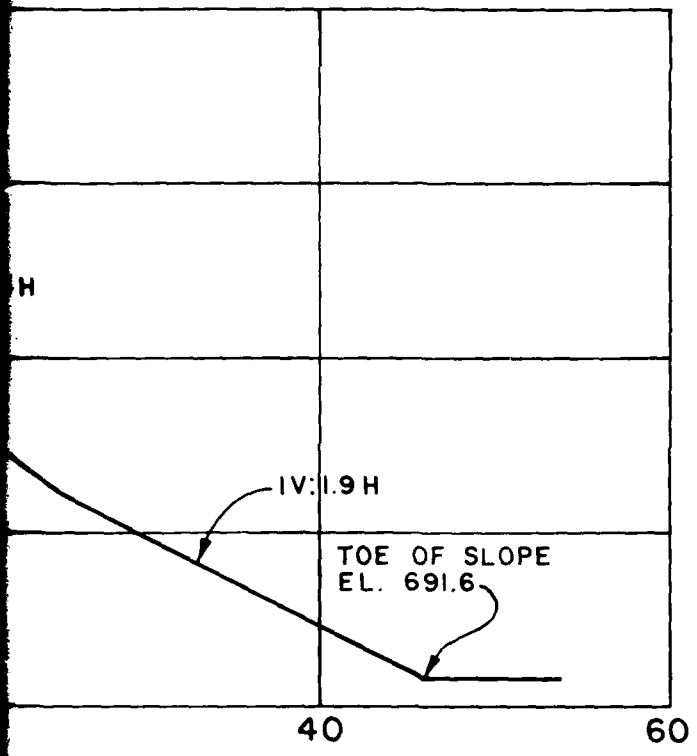
DAM CROSS SECTION STA. 3+35

SCALES: 1"=10' V., 1"=10' H.

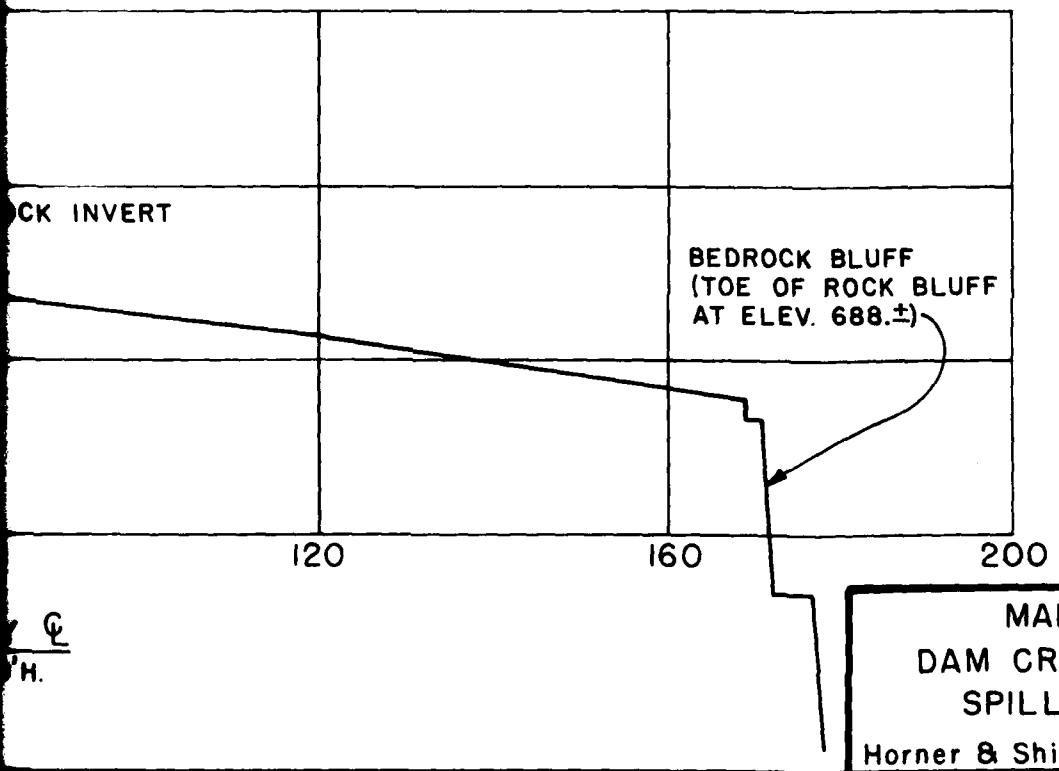


PROFILE SPILLWAY ℄

SCALES: 1"=10' V., 1"=20' H.



STA. 3+35
D'H.



℄
'H.

MALLARD LAKE
DAM CROSS-SECTION &
SPILLWAY PROFILE
Horner & Shifrin, Inc. Nov. 1979

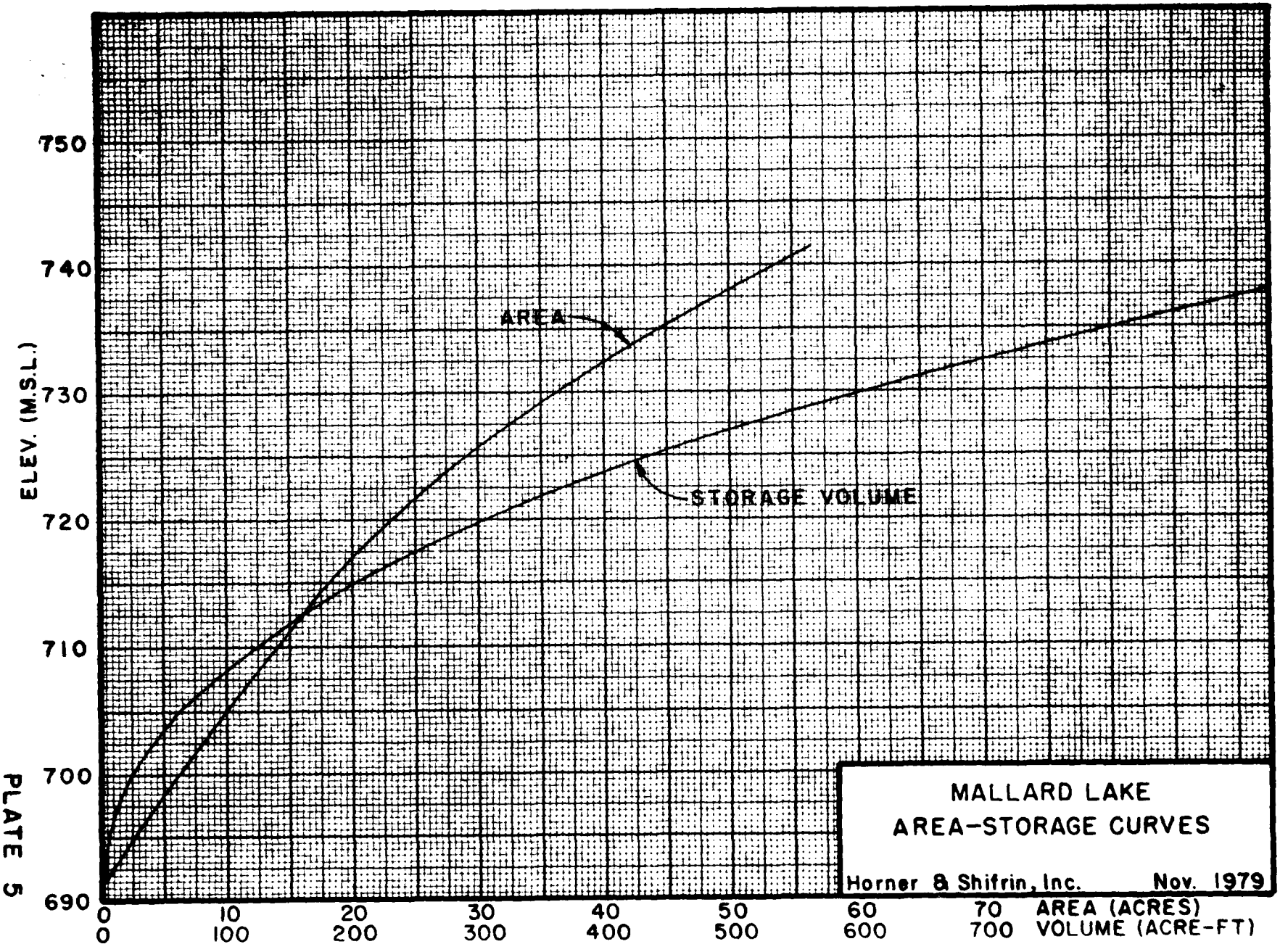
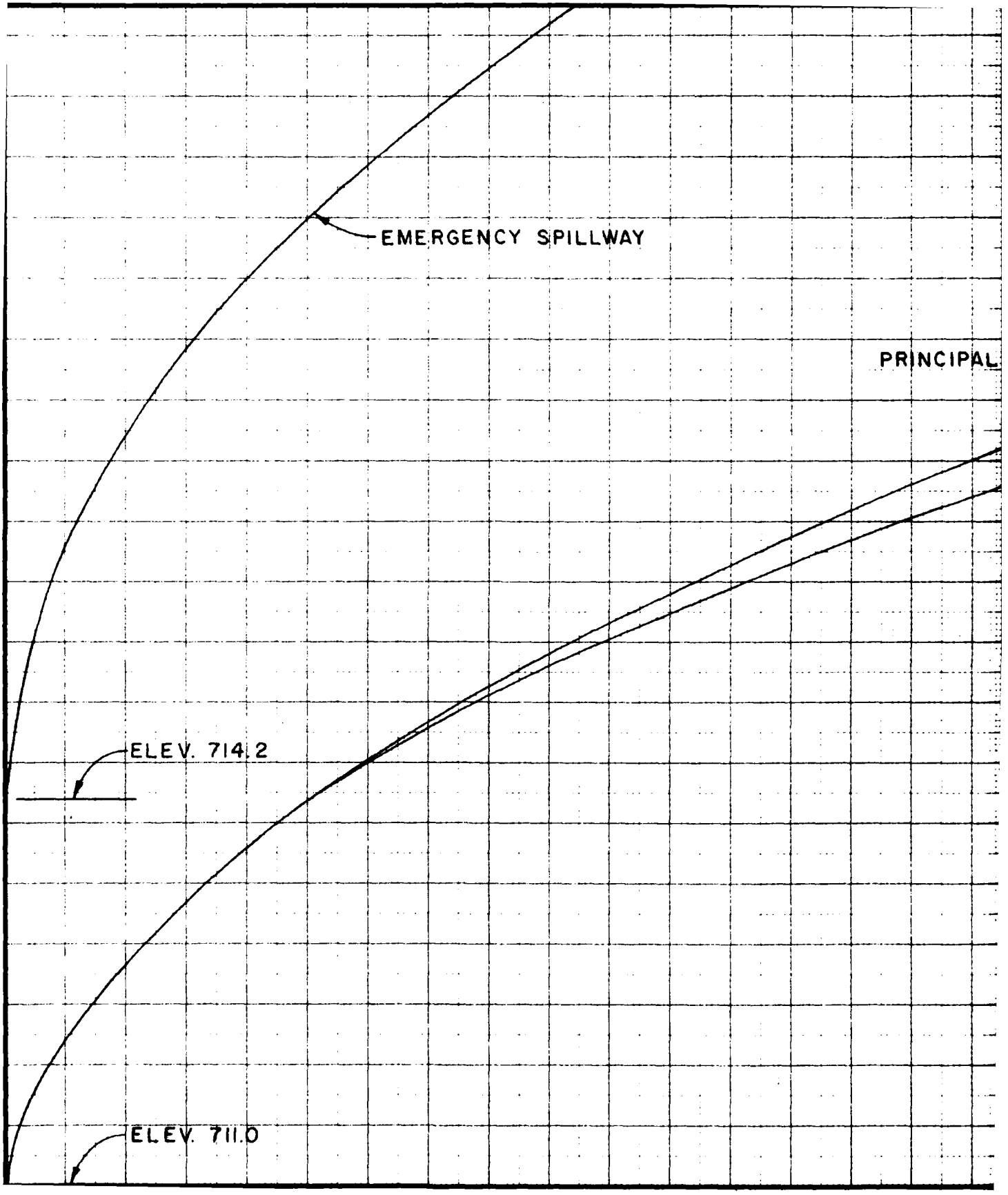
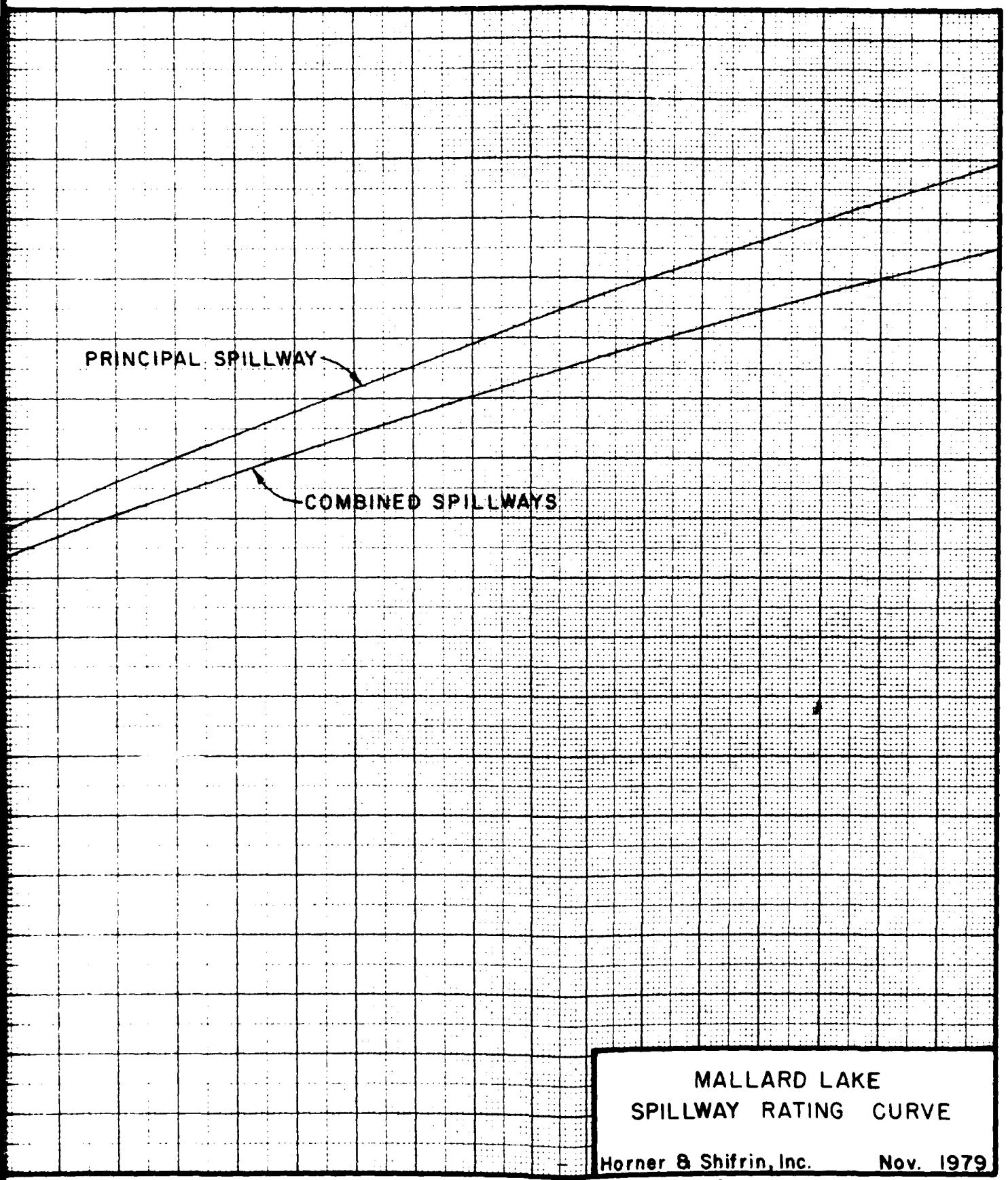

750
740
730
720
710
700
690
ELEV. (M.S.L.)
AREA
STORAGE VOLUME
0
10
20
30
40
50
60
70
AREA (ACRES)
0
100
200
300
400
500
600
700
VOLUME (ACRE-FT)
MALLARD LAKE
AREA-STORAGE CURVES
Horner & Shifrin, Inc.
Nov. 1979

PLATE 5


EMERGENCY SPILLWAY
PRINCIPAL
ELEV. 714.2
ELEV. 711.0



MALLARD LAKE
SPILLWAY RATING CURVE

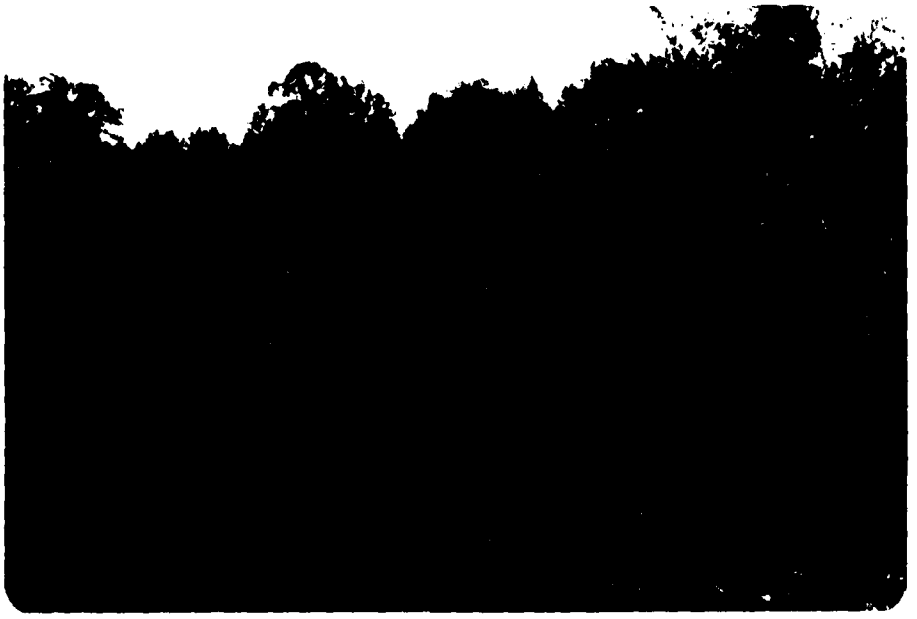
Horner & Shifrin, Inc. Nov. 1979

PLATE 6

APPENDIX A

INSPECTION PHOTOGRAPHS

NO. 1: UPSTREAM FACE OF DAM



NO. 2: DOWNSTREAM FACE OF DAM

NO. 3: LARGE TREE IN DOWNSTREAM FACE OF DAM

NO. 4: LAKE APPROACH TO SPILLWAY WEIR

NO. 5: SPILLWAY WEIR AND UPSTREAM FACE OF DAM

NO. 6: ERODED AREA UNDER CONCRETE SPILLWAY APRON

NO. 7: POTHOLE AT LEFT SIDE OF SPILLWAY CHANNEL BELOW ROCK LEDGE

NO. 8: POTHOLE AT RIGHT SIDE OF SPILLWAY CHANNEL BELOW ROCK LEDGE

NO. 9: EMERGENCY SPILLWAY (LOOKING UPSTREAM)

NO. 10: EMERGENCY SPILLWAY AND LEFT SIDE OF DAM

NO. 11: SEEPAGE AREA BELOW LEFT SIDE OF DAM

NO. 12: TRAIL TO ANIMAL BURROW NEAR LEFT ABUTMENT

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 26.5 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent (100-year frequency) flood and the 0.1 percent (10-year frequency) flood was provided by the St. Louis District, Corps of Engineers.

b. Drainage area = 2.05 square miles = 1,314 acres.

c. SCS parameters:

*Soil type CN = 84 (Soil type B, AMC III, PMF condition)
= 68 (Soil type B, AMC II, 100-Year and 10-Year Flood Condition)

Lag Time = 0.60 Tc (SCS Method) = 0.40 hours

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

Where; T_c = Travel time of water from hydraulically most distant point to point of interest, hours
L = Length of longest watercourse, miles
H = Elevation difference, feet.

2. The spillways (principal and emergency) consist of broad-crested, trapezoidal sections for which conventional weir formulas do not apply. Spillway release rates for these sections were determined as follows:

a. Spillway crest section properties (area, "a" and top width, "t") were computed for various depths, "d."

b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth (Qc) was computed as $Qc = (\frac{a^3 g}{t})^{0.5}$ for the various depths, "d." Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.

c. Static lake levels corresponding to various values passing the spillways were computed as critical depths plus critical velocity heads ($d_c + H_{vc}$) for each spillway and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

d. Flows over the principal and emergency spillways for equal elevations were summated and entered into the HEC-1 Program on the Y4 and Y5 cards.

3. The profile of the dam crest is irregular and flow over the dam crest cannot be determined by conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and the $V cards. The program computes internally the flow over the dam crest and adds this flow to the flow over the spillways as entered on the Y4 and Y5 cards.

```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF MALLARD LAKE DAM
A3       RATIOS OF PMF ROUTED THROUGH RESERVOIR
B     288          0         5                                                    0
B1      5
J       1          6         1
J1    .10        .11       .12       .13       .50       1.0
K       C  INFLOW                                                  1
K1       INFLOW HYDROGRAPH
M       1          2      2.05                                   1.0                1
P       0       26.5       102       120       130
T                                                                 -1       -84
T2                0.40
X    -1.0       -.10       2.0
K       1        DAM                                              1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                      1         1
Y1      1                                                       134        -1
Y4  711.0      711.5     712.0     712.5     713.0     713.6     714.2     714.8     715.0     715.5
Y4  716.0      716.5     717.0     717.5     718.0     719.0     720.0     721.0
Y5      0         50       145       285       460       705      1010      1265      1550      1945
Y5   2435       2955      3540      4180      4870      6400      8145     10100
$A      0       14.7      33.0      53.3
$E683.65        711       720       740
$$    711
$O  714.8
$L     66        133       337       404       495       517       707
$V  714.8      714.8     715.2     715.3     715.5     715.6     716.5
K       99
```

```
A1       ANALYSIS OF DAM OVERTOPPING USING 100YR FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF MALLARD LAKE DAM
A3       100YR FLOOD ROUTED THROUGH RESERVOIR
B     288          0         5                                                  0
B1      5
J       1          1         1
J1    1.0        .10       .15       .20       .25       .30       .35       .40       .50       1.0
K       0   INFLOW                                                  1
K1       INFLOW HYDROGRAPH
M       0          2      2.05                             1.0                  1
C0    288
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .013      .013      .013
C1   .013      .013      .013      .013      .013      .013      .013      .013      .013      .013
C1   .013      .013      .013      .013      .013      .013      .013      .013      .013      .013
C1   .013      .013      .013      .013      .013      .013      .013      .013      .013      .013
C1   .013      .013      .013      .013      .013      .013      .013      .013      .013      .013
C1   .013      .013      .013      .013      .013      .013      .013      .013      .013      .013
C1   .013      .013      .013      .013      .024      .024      .024      .024      .024      .024
C1   .024      .024      .024      .024      .024      .024      .024      .024      .024      .024
C1   .024      .024      .031      .031      .031      .031      .031      .049      .049      .049
C1   .049      .049      .049      .049      .138      .138      .138      .262      .262      .544
C1   .813      .378      .262      .138      .138      .138      .049      .049      .049      .049
C1   .049      .049      .031      .031      .031      .031      .031      .024      .024      .024
C1   .024      .024      .024      .024      .024      .024      .024      .024      .024      .024
C1   .024      .024      .024      .024      .024      .024      .024      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007      .007      .007
C1   .007      .007      .007      .007      .007      .007      .007      .007
T                                                                  -1        -1
W2              0.40
X    -1.0       -.10       2.0
K       1   DAM                                                     1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                          1         1
Y1      1                                                    134        -1
Y4  711.0     711.5     712.0     712.5     713.0     713.6     714.2     714.6     715.0     715.5
Y4  716.0     716.5     717.0     717.5     718.0     719.0     720.0     721.0
Y5      0        50       145       295       460       705      1010      1265      1550      1965
Y5   2435      2955      3540      4190      4870      6400      8140     10100
SA      0      14.7      23.0      33.1
SE583.65       711       720       740
SS    711
SD  714.8
SL     66       123       337       404       485       517       707
SV  714.8     714.9     715.2     715.3     715.5     715.6     716.5
K      99
```

```
A1       ANALYSIS OF DAM OVERTOPPING USING 10YR  FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF MALLARD LAKE DAM
A3       10YR FLOOD ROUTED THROUGH RESERVOIR
B      288       0       5                                                  0
B1       5
J        1       1       1
J1     1.0     .10     .15     .20     .25     .30     .35     .40     .50     1.0
K        0   INFLOW                                      1
K1       INFLOW HYDROGRAPH
M        0       2    2.05                     1.0                      1
O      288
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .010    .010    .010    .010    .010    .010
O1    .010    .010    .010    .010    .015    .015    .015    .015    .015    .015
O1    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
O1    .015    .015    .027    .027    .027    .027    .027    .027    .040    .040
O1    .040    .040    .040    .040    .091    .091    .091    .172    .172    .377
O1    .580    .262    .172    .091    .091    .091    .040    .040    .040    .040
O1    .040    .040    .027    .027    .027    .027    .027    .027    .015    .015
O1    .015    .015    .015    .015    .015    .015    .015    .015    .015    .015
O1    .015    .015    .015    .015    .015    .015    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005    .005    .005
O1    .005    .005    .005    .005    .005    .005    .005    .005
T                                                       -1     -68
W2            0.40
X     -1.0    -.10     2.0
K        1     DAM                                       1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                1       1
Y1       1                                             134      -1
Y4   711.0   711.5   712.0   712.5   713.0   713.6   714.2   714.6   715.0   715.5
Y4   716.0   716.5   717.0   717.5   718.0   719.0   720.0   721.0
Y5       0      50     145     285     460     705    1010    1265    1550    1955
Y5    2435    2955    3540    4180    4970    6400    8145   10100
$A       0    14.7    23.0    53.3
$E  683.65     711     720     740
$S     711
$D   714.8
$L      66     123     337     404     495     517     707
$V   714.8   714.9   715.2   715.3   715.5   715.6   716.5
K       99
```

SUMMARY OF DAM SAFETY ANALYSIS
RATIOS OF PMF

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	711.00	711.00	714.80
STORAGE	134.	134.	196.
OUTFLOW	C.	0.	1408.

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
.10	714.68	0.00	194.	1325.	0.00	16.17	0.00
.11	714.90	.10	198.	1490.	.33	16.17	0.00
.12	715.09	.29	201.	1692.	.50	16.17	0.00
.13	715.24	.44	204.	1903.	.58	16.17	0.00
.50	717.07	2.27	239.	8659.	5.42	16.00	0.00
1.00	718.43	3.63	267.	17371.	6.58	16.00	0.00

SUMMARY OF DAM SAFETY ANALYSIS

100 YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	711.00	711.00	714.80
STORAGE	134.	134.	196.
OUTFLOW	0.	0.	1408.

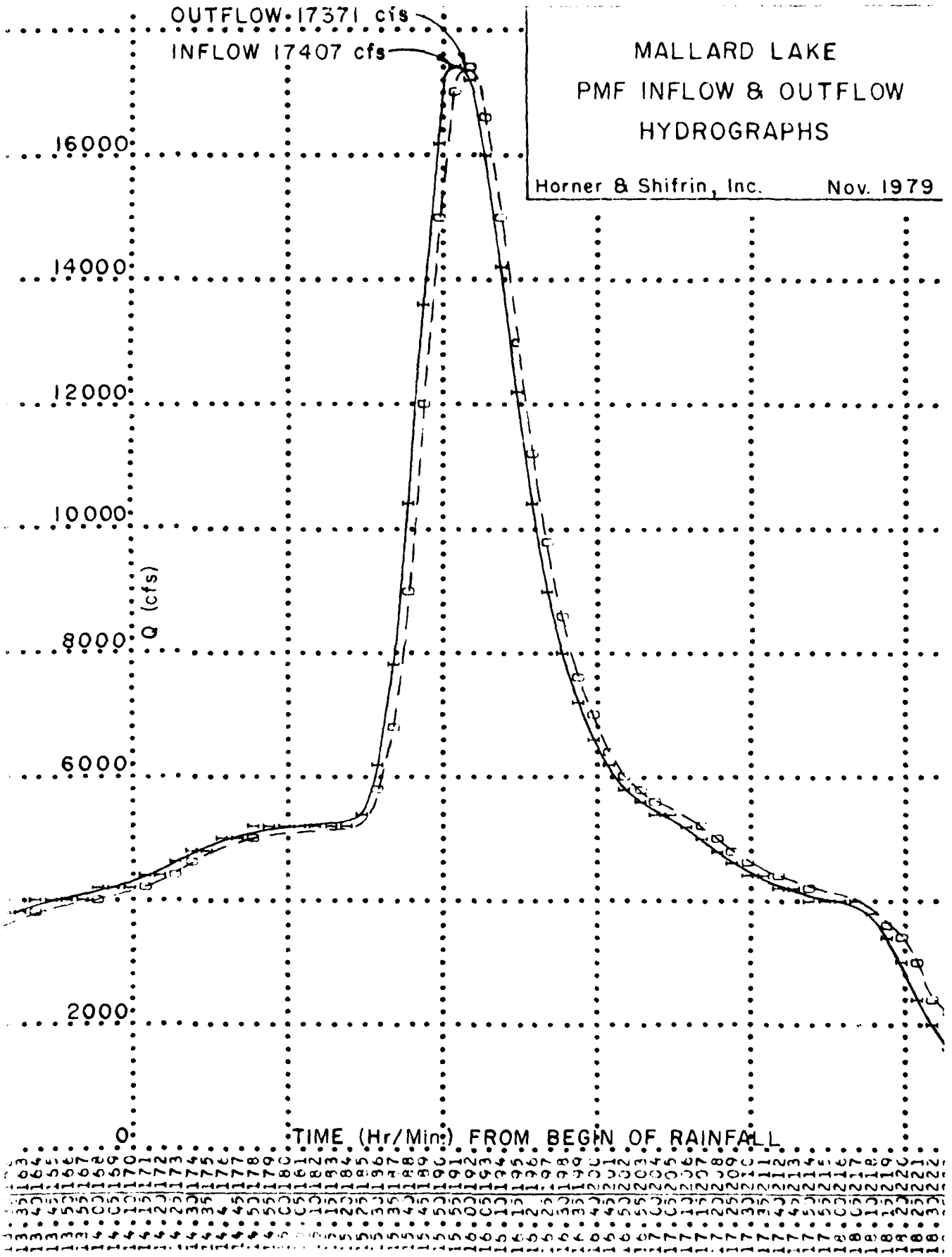
RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	715.77	.97	214.	3113.	.83	15.58	0.00

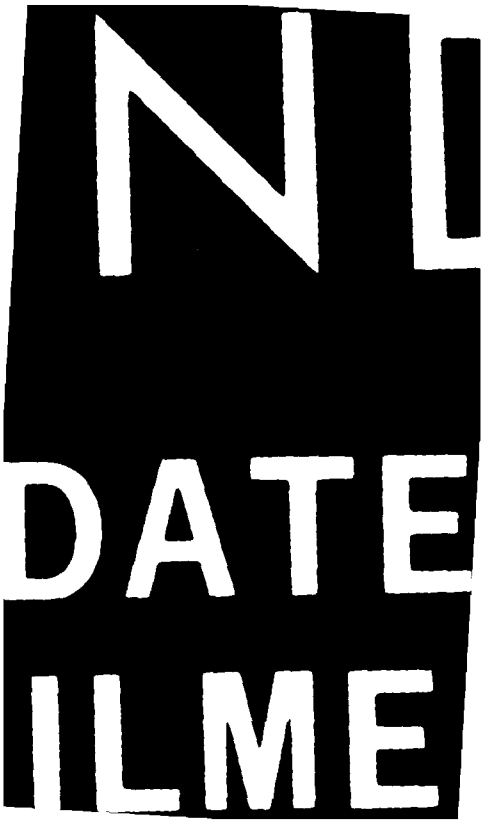
SUMMARY OF DAM SAFETY ANALYSIS

10 YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	711.00	711.00	714.80
STORAGE	134.	134.	196.
OUTFLOW	0.	0.	1408.

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
1.00	714.59	0.00	192.	1257.	0.00	15.83	0.00


OUTFLOW 17371 cfs
INFLOW 17407 cfs
MALLARD LAKE
PMF INFLOW & OUTFLOW
HYDROGRAPHS
Horner & Shifrin, Inc. Nov. 1979
16000
14000
12000
10000
8000
6000
2000
0
Q (cfs)
TIME (Hr/Min) FROM BEGIN OF RAINFALL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