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NATIONAL DAM SAFETY PROGRAM. CRYSTAL SPRING LAKE (NJ 00231), PA--ETC(U)
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LEVEL

PASSAIC RIVER BASIN
RAMSEY BROOK
BERGEN COUNTY
NEW JERSEY

AD A069594

# CRYSTAL SPRING LAKE
# NJ 00231

DDC
JUN 8 1979

## PHASE 1 INSPECTION REPORT
## NATIONAL DAM SAFETY PROGRAM

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DEPARTMENT OF THE ARMY

Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania

May, 1979

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- National Dam Inspection Act Report
- Crystal Spring Dam, N.J.

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

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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DEPARTMENT OF THE ARMY
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PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, NJ 08621

18 MAY 1979

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Crystal Spring Lake Dam in Bergen County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Crystal Spring Lake Dam, a high hazard potential structure, is judged to be in fair to poor overall condition. The dam's spillway is considered inadequate since 11 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be initiated to determine the dam's embankment condition and structural stability. This should include test borings to determine material properties relative to stability and seepage. Any remedial measures found necessary should be initiated within calendar year 1980.

c. The source of seepage near the left side of the embankment should

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NAPEN-D
Honorable Brendan T. Byrne

be determined within three months from the date of approval of this report. If the seepage is determined to be from the reservoir, the seriousness of it should be evaluated and remedial measures implemented.

d. Within six months from the date of approval of this report, the following remedial actions should be completed:

(1) Riprap should be placed on the upstream slope and rock facing on the downstream slope of the embankments to provide at least minimal protection in times of overtopping.

(2) Remove all trees and brush from the embankment.

(3) Repair any excessively steep slopes of the embankment to a stable slope.

(4) Repair and clean out the outlet area of the emergency drain and regularly operate the valves to verify that they are in working order.

e. Inspect the dam yearly, and immediately after any overtopping. Make timely repairs as necessary and keep records of all maintenance work.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman Andrew Maguire of the Seventh District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

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Honorable Brendan T. Byrne

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Copies furnished:
Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N. J. Dept. of Environmental Protection
P. O. Box CN029
Trenton, NJ 08625

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## CRYSTAL SPRING LAKE DAM (NJ00231)

## CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 30 November 1978 and 4 January 1979 by Jenny-Leedshill Engineers under contract to the State of New Jersey. The State, under agreement with the U. S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Crystal Spring Lake Dam, a high hazard potential structure, is judged to be in fair to poor overall condition. The dam's spillway is considered inadequate since 11 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be initiated to determine the dam's embankment condition and structural stability. This should include test borings to determine material properties relative to stability and seepage. Any remedial measures found necessary should be initiated within calendar year 1980.

c. The source of seepage near the left side of the embankment should be determined within three months from the date of approval of this report. If the seepage is determined to be from the reservoir, the seriousness of it should be evaluated and remedial measures implemented.

d. Within six months from the date of approval of this report, the following remedial actions should be completed:

(1) Riprap should be placed on the upstream slope and rock facing on the downstream slope of the embankments to provide at least minimal protection in times of overtopping.

(2) Remove all trees and brush from the embankment.

(3) Repair any excessively steep slopes of the embankment to a stable slope.

(4) Repair and clean out the outlet area of the emergency drain and regularly operate the valves to verify that they are in working order.

e. Inspect the dam yearly, and immediately after any overtopping. Make timely repairs as necessary and keep records of all maintenance work.

APPROVED: James G. Ton
JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE: 18 May 79

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

| | |
|---|---|
| Name of Dam: | Crystal Spring Lake<br>I. D. No. NJ00231 |
| State Located: | New Jersey |
| County Located: | Bergen |
| Stream: | Ramsey Brook |
| Dates of Inspection: | November 30, 1978 and January 4, 1979 |

Brief Assessment of General Condition of dam

The dam is generally in fair to poor overall condition. The spillway can pass 10 percent of the Probable Maximum Flood and is classified as inadequate. The spillway was recently repaired and appears to be in good condition.

Seepage of undetermined origin was observed near the toe of the embankment. The downstream embankment is very uneven, and both slopes are covered with a heavy growth of vegetation.

It is recommended that the source of seepage in the embankment be determined very soon and remedial measures implemented if it appears to endanger the dam. Seepage and stability analyses are recommended in the near future. More detailed and sophisticated hydraulic and hydrologic studies are recommended to more accurately determine the spillway capacity prior to any remedial action. Riprap and rock facing should be placed on the embankment slopes.

Recommendations for operation and maintenance that should be implemented in the near future include: (1) removal of vegetation from the embankments, (2) repair of locally steep slopes, (3) repair of the outlet drain and regular operation of the drain, (4) annual and post-flood inspection of the dam, (5) recording of all maintenance work, and (6) implementation of a warning system with specific notice to houses downstream of the dam as to flood potential and danger to life and property.

Frank L. Panuzio

Frank L. Panuzio, P.E.
Project Manager

Robert J. Jenny, P.E.
Project Director
New Jersey License No. 9878

CRYSTAL SPRING DAM

Upstream view looking east. Spillway in center of photograph. (Nov. 30, 1978)

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## PLATES



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## 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 Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

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 data available to the inspection team. 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 continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

CRYSTAL SPRING LAKE DAM

Federal I.D. No. NJ 00231
New Jersey I.D. No. 23-77

## SECTION 1: PROJECT INFORMATION

### 1.1 General

a. Authority

The National Dam Inspection Act, Public Law 92-367, 1972, provides for the National Inventory and Inspection Program by the U. S. Army Corps of Engineers. This report has been prepared in accordance with this authority, through contract between the State of New Jersey and Jenny-Leedshill Engineers. The State of New Jersey has also entered into an agreement with the U.S. Army Engineer District, Philadelphia, to have this work performed.

b. Purpose of Inspection

The purpose of this inspection was to evaluate the general structural integrity and hydraulic adequacy of the dam, and to determine if the dam constitutes a hazard to human life or property.

### 1.2 Description of Project

a. Description of Dam and Appurtenances

Crystal Spring Lake Dam is an earthfill dam with a concrete core. The dam impounds a reservoir of 130 acre feet maximum storage capacity. The dam is approximately 550 feet long, 12 feet high, and has a crest width of 25 to 30 feet. A paved roadway traverses the entire length of the crest. Embankment slopes are highly variable on both the upstream and downstream sides, averaging about 2.5H:1V on the upstream side and 2H:1V on the downstream side. Locally, the downstream embankment is as steep as about 1.5H:1V. The spillway is a rubble masonry weir located near the right abutment. The 30-foot long weir is divided into 2 bays separated by a pier. The end walls and center pier support a bridge over the spillway. Downstream of the spillway a lined channel and masonry training walls direct flow through a 90 degree angle over a toe wall to the stream channel. The emergency outlet consists of 2 parallel 10-inch diameter pipes near the center of the dam, with controls located in a manhole in the crest of the dam.

b. Location

The dam is located across Ramsey Brook in northeastern New Jersey in the Borough of Ramsey, Bergen County, about 10 miles north of Paterson. The location of the dam is shown on Plate 1.

c. Size Classification

The size classification of the dam based on the 12-foot height of the dam and the maximum storage capacity of 130 acre feet is small. The criteria for size classification are set forth in the Corps' Guidelines. A small size dam is one in which the storage capacity is equal to or greater than 50 acre feet and less than 1000 acre feet, and/or the height of the dam is equal to or greater than 25 feet and less than 40 feet.

d. Hazard Classification

Crystal Spring Lake Dam is classified as a high hazard dam because of the potential damage and loss of more than a few lives that could occur in the event of dam failure at two residences immediately downstream and perhaps about 20 houses in community of Allendale (pop. 6,200) further downstream.

e. Ownership

The dam is owned by the Ramsey Golf and Country Club, Inc., 105 Lakeside Drive, Ramsey, New Jersey, 07446.

f. Purpose of Dam

The primary purpose of the dam and reservoir is for recreation and scenic value. A small amount of water is pumped from the reservoir for irrigation of the nearby golf course.

g. Design and Construction History

Crystal Spring Lake Dam, variously called Crystal Springs Dam, Crystal Lake Dam and Wyckoff Lake Dam, was built sometime prior to 1913. Correspondence in the owner's files indicates that the dam may have been built about the turn of the century. Wooden flashboards were added to the spillway in about 1966 but were removed shortly thereafter. In December, 1975 the State ordered the reservoir dewatered because the spillway could not pass the 100-year flood and because of deterioration of the existing spillway and possible underflow beneath it. The action was witheld in February, 1976 pending engineering studies. Repairs of the spillway were made in 1977 to the satisfaction of the State.

h. Normal Operational Procedures

The reservoir is unregulated, with flood flows passing over the ungated spillway weir. The emergency outlet is only occasionally operated for maintenance work on the dam or to clean the reservoir.

## 1.3 Pertinent Data

a. Drainage Area - 1.77 square miles

b. Discharge at Damsite

- Ungated spillway capacity at maximum pool elevation - 450 cfs.

c. Elevation (ft. above MSL)

| | | |
|---|---|---|
| . Top Dam | 352.9 | |
| . Spillway crest | 349.3 | |
| . Streambed at centerline of dam | 341 | (Approx.) |

d. Reservoir Length (ft.)

| | |
|---|---|
| . Top of dam | 2800 |
| . Spillway Crest (recreation pool) | 2100 |

e. Storage (acre-feet)

| | |
|---|---|
| . Spillway crest | 65 |
| . Top of dam | 130 |

f. Reservoir Surface (acres)

| | |
|---|---|
| . Top dam | 20 |
| . Spillway crest | 14 |

g. Dam

| | | |
|---|---|---|
| . Type | Earthfill with concrete core wall | |
| . Length | 550 ft. (approx.) | |
| . Height | 12 ft. | |
| . Top Width | 25 - 30 ft. (Paved road) | |
| . Side Slopes - upstream | 2.5H:1V | (Estimated) |
| - downstream | 2H:1V | (highly variable) |

- Zoning — Not known
- Impervious Core — Concrete core wall

h. Spillway

- Type — Two-bay rubble masonry, free overfall
- Length of weir — 30 ft.
- Width — 2.5 ft.
- Crest elevation — 349.3 ft.
- U/S Channel — Reservoir
- D/S Channel — Lined channel with masonry training walls

i. Regulating Outlets

- 2 parallel 10-in. diameter C.I. pipes and gate valves (emergency outlet)

## SECTION 2: ENGINEERING DATA

### 2.1 Design

a. Geological Conditions

Crystal Spring Lake and Dam are situated in the northern New Jersey Piedmont Lowlands. The regional geology at this area is presented in Appendix C to this report.

Geologically, the dam is located in the broad, rolling ground moraine (till) plain deposited by the most recent continental glaciation. The ground moraine is characterized as a non-residual, unsorted and heterogeneous mixture of unstratified soil. The size of the materials range from clay through boulders with silt and sand sizes predominating. Permeability through this material is typically low to medium, depending on the amount of fines.

Within stream valleys, recent alluvium, typically derived from local materials, occupies the flood plains. Swampy ground with a high water table is usually found on either side of the immediate stream where it has not been altered by urbanization.

Bedrock was not observed at or near the dam and is probably located at depths greater than 20 feet below the present ground surface. At depth, the underlying formation is the Brunswick formation, a soft red shale with interbedded sandstone layers.

The dam is located in a Seismic Zone 1 and no active faults are known to exist in the immediate vicinity of the dam. However, seismic shaking due to distant earthquakes should be expected.

2.1 b. Design Data

No data are available pertaining to the original design of the dam. Based on field measurements at the time of inspection, the dam is believed to be substantially as shown in plan on Plate 2. The spillway and a downstream channel are shown in plan and elevation on Plate 3.

2.2 <u>Construction</u>

Nothing is known of the original construction methods nor of as-built embankment materials. It was reported that the concrete core wall was constructed 18 inches thick and about 14 feet deep. In 1977 the spillway weir and downstream apron were repaired as shown on Plate 3.

2.3 <u>Operation</u>

No records of reservoir levels are maintained by the owner. Records of recent repairs are available. There are no monitoring devices or survey markers on the dam.

2.4 <u>Evaluation</u>

a. Availability

Data are not available on the original design or construction of the dam or on as-built material properties. Data are available on recent repairs of the spillway. All available data are listed in Appendix A.

b. Adequacy

Available data are insufficient to adequately evaluate the design. Calculations relating to the structural design of the dam or the stability of the as-built structure are not available. Nothing is known of construction methods, testing methods, or as-built material properties. Foundation conditions are unknown.

c. Validity

Because no recent surveys of the dam have been made other than at the spillway, the crest elevation of the dam is not known with precision. Plans of the spillway (Plate 3) appear to adequately represent the present configuration. The information on the core wall was reported in the owner's correspondence and by a local caretaker, and there is no assurance of its validity.

## SECTION 3: VISUAL INSPECTION

### 3.1 Findings

a. General

The visual inspection of Crystal Spring Lake Dam was made on November 30, 1978 and a subsequent inspection made on January 4, 1979. The water surface elevation at the time of the first inspection was 349.5 feet or just above the top of the spillway crest.

The visual inspection did not reveal any critical signs of distress in the dam; however, generally the dam has not been well maintained.

Although certain remedial work has been done at the spillway in recent years, it was apparent from the visual inspection that there has been little or no maintenance work on the embankment in many years.

Detailed inspection was made of the dam, appurtenant structures, reservoir area, and the downstream channel. Descriptions of the findings of these inspections are summarized in the paragraphs which follow. The checklist of visual inspection items is included in Appendix A. Geologic and foundation conditions observed at the time of inspection are noted in greater detail in Section 2.1-a.

b. Dam

The dam was inspected for signs of settlement, seepage, erosion, cracking and any other evidence of undesirable behavior which might affect the stability of the structure.

An asphalt paved roadway transverses the entire length of the top of the dam, including a bridge deck over the spillway. There is no evidence of settlement or horizontal misalignment of the crest. Both the upstream and downstream slopes of the embankment are very uneven. The unevenness of the downstream slope is probably attributable to a number of factors, including erosion from overtopping and rainfall runoff, the action of large tree roots, and the buildup of debris over the years. There is a heavy growth of trees, up to 2 feet in diameter, on the downstream slope (Photo 1). Scattered large boulders on this slope may be remnants of a rock facing. The junctions of the embankment with its abutment and with the spillway appear to be tight, with no evidence of separation or movement.

About 2 to 5 gpm seepage was noted flowing from a 15-foot wide area at the toe of the embankment, approximately 100 feet from the left (east) abutment. (Photo 2). The discharge was clear but there was some indication of possible quick conditions. The source of the seepage could be from the reservoir, from recent precipitation runoff, or it could be related to a sewer line which is reported to have pierced the embankment and concrete core in this vicinity. The area below the toe is marshy.

Little of the upstream embankment was exposed above the waterline. There is no evidence that the embankment has a riprap facing. The embankment is covered with a heavy growth of vegetation (Photo 3).

c. Appurtenant Structures

### Spillway

The spillway is a 2-bay overflow weir separated by a bridge deck support pier (Photo 4). Because of its rock masonry construction, discharge over the weir was rather uneven, but the crest and downstream face appeared to be in good condition, with no evidence of erosion or plucking of the masonry (Photo 5). The center bridge pier and masonry training walls have been repaired recently and are in good condition. A new toe wall has been installed at the base of the spillway apron (Photo 4), and the underside of the bridge was recently covered with wire mesh and gunite.

### Outlet Works

Little of the emergency drain could be observed. It is reported to consist of 2 10-inch pipes controlled by valves in a manhole on the crest of the dam. The manhole was observed to be filled with water to the level of the reservoir and the valves were submerged in 9 feet of water. The downstream outlet was obscured by debris. There was about 1/2 gpm seepage from the outlet area (Photo 6).

d. Reservoir Area

Water in the reservoir was clear and without any evidence of sediment. It was reported, however, that there is a sedimentation problem requiring dredging of the lake bottom.

Slopes around the reservoir are gentle and wooded (Photo 7). Numerous houses face the reservoir on the surrounding roadways.

e. Downstream Channel

A concrete lined channel with vertical block and masonry training walls extends about 70 feet downstream from the toe of the spillway apron, terminating at a low weir (Photo 8). A house is located on the right bank of the lined channel (Photo 9) and there is another house in the flood plain downstream. Below the lined channel, the natural stream meanders considerably and the flow channel is not well defined in places. The overbank flood channel has moderate slopes and is heavily wooded.

## SECTION 4: OPERATIONAL PROCEDURES

### 4.1 Procedures

The reservoir is operated to maintain maximum water levels for recreational and aesthetic purposes. A minor amount of water is pumped from the reservoir to irrigate an adjacent golf course. There is no regulation of reservoir levels other than for occasional inspections and maintenance work. Sediment has been dredged from the reservoir on at least one occasion.

### 4.2 Maintenance of Dam

There has apparently been little or no maintenance work done on the embankment in many years.

The spillway weir and downstream apron were repaired in 1977. This work included patching of concrete in the masonry walls, removal of concrete stop blocks (for flashboards) on the upstream side of the spillway, repairs of the apron, construction of a new toe wall at the end of the apron, and installation of wire mesh and gunite on the bottom surface of the bridge over the spillway.

There are no instrumentation or monitoring systems on the dam or reservoir.

### 4.3 Maintenance of Operating Facilities

The emergency outlet is apparently operated only occasionally. The manhole housing the valve controls is flooded, but the valves reportedly can be operated without draining the manhole. It is not known what maintenance work has been done on the outlet.

### 4.4 Description of Warning System

There is no warning system or emergency contingency plan in event of possible dam failure or overtopping.

### 4.5 Evaluation of Operational Adequacy

In general, maintenance of the dam has been deficient. Recent work to repair the spillway and appurtenances was of good quality. Other than this recent work, there are no records of operations or maintenance.

## SECTION 5: HYDRAULIC/HYDROLOGIC

### 5.1 Evaluation of Features

a. Design Data

As already stated, Crystal Spring Lake Dam is classified as high hazard and small in size. In accordance with the Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams", the Spillway Design Flood (SDF) should be 50 to 100 percent of the Probable Maximum Flood (PMF). The 100 percent PMF was selected as the SDF because of the high hazard to loss of life immediately downstream of the dam.

Data obtained from State files indicate the drainage basin area of the dam is 1.77 square miles. Elevations range from a maximum of about 640 feet above mean sea level along the perimeter of the drainage basin to a minimum of about 350 feet in the valley floor. Land use patterns within the watershed consist mostly of forests and cultivated land. Only a minor portion of the basin is residential developments. About 1 percent of the watershed area is the reservoir of the dam. The drainage basin is delineated on a U.S.G.S. topographic map and is presented on Plate D-1, Appendix D.

The hydraulic and hydrologic features of the dam were evaluated using criteria set forth in the Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams", and additional guidance and criteria provided by the Philadelphia District, Corps of Engineers. The Probable Maximum Precipitation (PMP) was calculated using Hydrometeorological Report No. 33 and the standard Hops Brook reduction factor of 0.80 for misalignment of the storm.

The Probable Maximum Flood (PMF) was calculated using the Corps' computer program HEC-1, Dam Break Version. In computing the PMF the Corps requested that the SCS triangular unit hydrograph with curvilinear transformation be used. The computer program was used to calculate this unit hydrograph from the basin lag. A lag time of 1.1 hours was calculated for the basin and used in the program.

An initial infiltration loss of 1.5 inches and a final infiltration loss rate of 0.15 inches per hour were used in the HEC-1 program to give the rainfall excess. Using the excess rainfall and the unit hydrograph, the program computed the peak inflow of the 10 percent, 15 percent, 50 percent and 100 percent PMF. These discharges are approximately 610 cfs, 920 cfs, 3070 cfs, and 6140 cfs, respectively.

The various percentages of the PMF inflow hydrograph were routed through the reservoir using the Modified Puls Method by the HEC-1 program. The peak outflow discharges of the 10 percent, 15 percent, 50 percent, and 100 percent PMF were calculated to be approximately 420 cfs, 840 cfs, 3060 cfs and 6130 cfs, respectively. The flood routings indicate that all floods greater than about 10 percent of the PMF will overtop the dam. A plot of percent PMF versus peak outflow is presented as Plate D-2 in Appendix D.

The spillway and overtop stage-discharge rating curve used in the flood routing was calculated using the weir equation and the orifice equation. For all flows up to the bottom elevation of the bridge over the spillway the weir equation was used assuming free overflow. The spillway is a broad-crested weir with a discharge coefficient of 2.9. For flows above the bottom elevation of the bridge, the orifice equation was used to calculate flows through the spillway, and a discharge coefficient of 0.61 was assumed. To calculate flows over the dam crest, the weir equation was used and free overflow as assumed. The dam crest is a round-crested weir with trees and other vegetation. A discharge coefficient of 2.6 was assumed. The reservoir stage-storage curve was determined from U.S.G.S. 7.5-minute topographic maps and data obtained from State files. This stage-storage curve was extended above the dam crest to include surcharge storage during peak flood discharges. In the reservoir routing computations possible discharges through the outlet works were excluded because their capacity is small compared to the PMF and because of the possibility that the outlet valves may be closed. The stage-storage and the spillway and overtop stage-discharge curves are presented in Appendix D as Plates D-3 and D-4, respectively.

Because the spillway cannot pass one-half the PMF, the various percentages of the PMF, assuming the dam would not breach and assuming the dam would breach, were routed 1.2 miles downstream through three successive reaches to the community of Allendale. For the routing calculations, estimates of channel shapes, slopes and roughnesses were made based on conditions observed in the field and U.S.G.S. topographic maps. The locations of the cross-sections used in these routings are shown on page D-9, Appendix D.

The breach parameters used in the HEC-1 analysis are: the breach is rectangular in shape, 270 feet long, will extend to the approximate original reservoir floor elevation (340'), will begin breaching when the dam is first overtopped, and will develop to its maximum size in 4.0 hours. The peak outflow for the 10 percent, 15 percent, 50 percent and 100 percent PMF were calculated to be approximately 420 cfs, 1480 cfs, 3560 cfs, and 6410 cfs, respectively.

Three floods were compared in assessing the downstream hazard: (1) the PMF assuming the dam is breached: (2) the PMF assuming the dam is not breached; and (3) the flood that is approximately equal to the existing capacity of the spillway (10% PMF). The flood depth, width and mean flow velocity of these three floods at the community of Allendale are summarized in the following tabulation.

Flooding Characteristics
at Allendale

| | 10% PMF Without Breaching | PMF Without Breaching | PMF With Breaching |
|---|---|---|---|
| Peak Discharge, cfs | 420 | 5900 | 6260 |
| Peak Flood Depth, ft. | 1.8 | 4.6 | 4.7 |
| Peak Flood Top Width, ft. | 50 | 700 | 710 |
| Peak Flow Velocity, fps | 4.7 | 4.9 | 4.9 |

There are two parallel drain pipes for the reservoir. A representative of the dam owner indicated that one drain pipe is 8 inches in diameter and the other is 12 inches in diameter. Drawings obtained from the owner's engineer indicate the drain pipes are both 10 inches in diameter. The two 10-inch diameter pipes have less capacity and were assumed in this analysis. Using the orifice flow equation, and assuming no inflow into the reservoir or outlet tailwater, the time required to drain the reservoir from a spillway crest elevation was calculated to be a little over 4 days.

b. Experience Data

Records of lake levels are not maintained for this site. The reservoir is operated to maintain maximum water levels for aesthetic and recreational purposes. It is reported that the dam was overtopped as recently as July, 1977, but the flooding characteristics of this flood are not known.

c. Visual Observations

Just downstream of the spillway there is a masonry training wall and spillway channel that turns flow through a 90-degree angle and directs it along the downstream toe of the dam towards the main channel. This wall and channel diverts most flows away from the two homes located just downstream of the spillway. A resident of one of the downstream homes reported that during the flood of July, 1977 her house was almost inundated and her neighbor's house was inundated. Thus, the training wall and spillway channel are not adequate to divert all of the larger floods that overtop the dam away from the hazard area.

The main stream channel downstream of the dam has a very irregular cross section, low channel banks and many meanders. The immediate flood plain slopes gently into the main stream, is thickly wooded and has considerable undergrowth.

d. Overtopping Potential

As indicated in Section 5.1-a, all floods greater than about 10 percent of the PMF, when routed through the reservoir, will overtop Crystal Spring Lake Dam. The PMF will overtop the dam by 2.4 feet for 7.3 hours. One-half the PMF will overtop the dam 1.4 feet for 5.8 hours. These overtopping heights assume the dam remains in its current condition. Thus, a dam breach analysis, described in Section 5.1-a, was made because the spillway may be Seriously Inadequate. One of the Corps' criteria for classifying a spillway as Seriously Inadequate is, "Dam failure resulting from overtopping would significantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure."

The data tabulated in Section 5.1-a were used to assess the degree of significance that overtopping failure would increase the downstream hazard. Assuming the dam does not breach, the discharge at Allendale would be about 5900 cfs as compared to a breach peak discharge of about 6260 cfs. The flow depth, top width and velocity would be only slightly greater during the breach peak discharge and not result in a significantly higher downstream hazard. Thus, the spillway is classified as Inadequate.

## SECTION 6: STRUCTURAL STABILITY

### 6.1 Evaluation of Structural Stability

a. Visual Observations

The embankment slopes, particularly those downstream, are very uneven. There is a heavy growth of vegetation on the slopes, including numerous large trees. Seepage at the rate of 2 to 5 gpm was observed from one area of the embankment on the left side of the dam. The source of the seepage could not be determined. The crest of the embankment has no visually obvious vertical or horizontal misalignments.

The spillway appears to be structurally sound, as is the lined channel downstream. The condition of the reservoir drain could not be determined.

b. Design and Construction Data

Almost nothing is known of the design or construction of the dam. Nothing is known of as-built embankment materials, and no original hydrologic or hydraulic computations are known to exist. Engineering drawings prepared for rehabilitation of the spillway are adequate and represent as-built conditions.

c. Operating Records

No records of reservoir levels are maintained by the owner, nor is there any systemitized recording of maintenance events. There have been no recent surveys of the embankments of the dam. There is no instrumentation of the dam.

d. Post-Construction Changes

The only known post-construction change is the rehabilitation of the spillway and appurtenant structures. It appears that this work was well engineered and well constructed. Because of the age of this dam, it is likely that there have been other post-construction changes, about which nothing is known.

e. Seismic Stability

The dam is located in Seismic Zone 1, in which it may generally be assumed that there is no hazard from earthquake, provided static stability conditions are satisfactory and conventional safety margins exist. Although the dam appears to have satisfactory static stability, a stability analysis would be required to verify this.

## SECTION 7: ASSESSMENT, RECOMMENDATIONS AND PROPOSED REMEDIAL MEASURES

### 7.1 Dam Assessment

a. Safety

The spillway can pass only 10 percent of the Probable Maximum Flood. The dam has been overtopped a number of times, most recently in 1977. At least one house is known to have been inundated in the most recent flood. There are a few residences immediately downstream which are endangered by overtopping and the community of Allendale is further downstream.

The embankment is very uneven, shows signs of erosion, and is heavily overgrown by vegetation. Seepage of undeterminable origin was observed near the toe of the dam.

The spillway appears to be in good structural condition. The outlet works are seldom operated and their condition is unknown.

b. Adequacy of Information

There are insufficient data to evaluate the stability of the dam, since nothing is known of the design, construction methods, or as-built properties of the dam. Recent data indicate the presence of a concrete core wall, and although there is no reason to doubt this information, its presence was not verified by the visual inspection. There have been no recent surveys of the embankment, and there are conflicting data regarding the size of the two outlet drains.

c. Urgency

The source of apparent embankment seepage should be determined very soon. Consideration should be given in the future to construction of a supplemental spillway. Other recommendations should be implemented in the near future.

d. Necessity for Additional Data/Evaluation

Corps of Engineers Guidelines require that, in general, seepage and stability analysis should be on record for all high hazard dams. In view of the hazard potential of this dam and the possible seepage problem, it is recommended that such analyses be performed by the owner, including soil borings and laboratory tests of embankment and foundation materials.

## 7.2 Remedial Measures

a. Corrective Procedures

The following corrective procedures are recommended:

(1) The source of seepage near the left side of the embankment should be determined very soon. If the seepage is determined to be from the reservoir, the seriousness of it should be evaluated and immediate remedial measures implemented.

(2) The owner should undertake more detailed and sophisticated hydraulic and hydrologic studies to more accurately determine the spillway capacity. Depending on the results of these studies, remedial action should be taken as required.

(3) In the near future riprap should be placed on the upstream slope and rock facing on the downstream slope of the embankments to provide at least minimal protection in times of overtopping.

b. Operation and Maintenance Procedures

The following operation and maintenance procedures are recommended to be implemented in the near future:

(1) Remove all trees and brush from the embankment, since the roots endanger the core wall and could lead to piping problems.

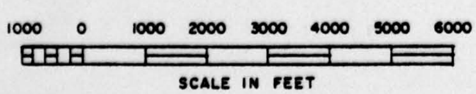
(2) Repair any excessively steep slopes of the embankment to a stable slope.

(3) Repair and clean out the outlet area of the emergency drain and regularly operate the valves to verify that they are in working order.

(4) Inspect the dam yearly, and immediately after any overtopping, and make timely repairs as necessary.

(5) Keep records of all maintenance work.

(6) Implement a warning system in cooperation with local authorities and devise a contingency plan in event of flooding conditions or possible failure of the dam. Post warning signs or give specific notice to houses downstream of the dam as to flood potential and danger to life and property.

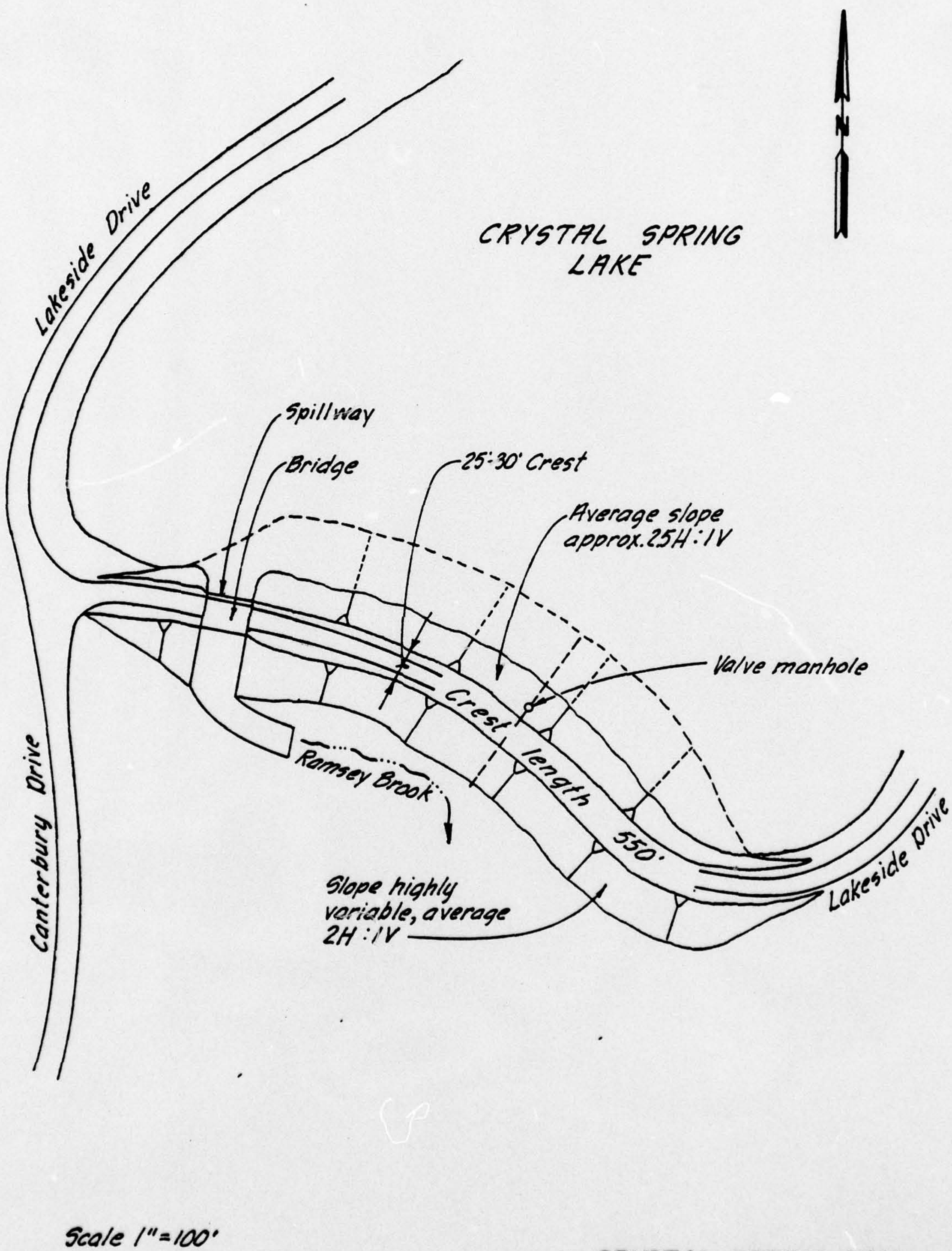


AREA LOCATION

# VICINITY MAP

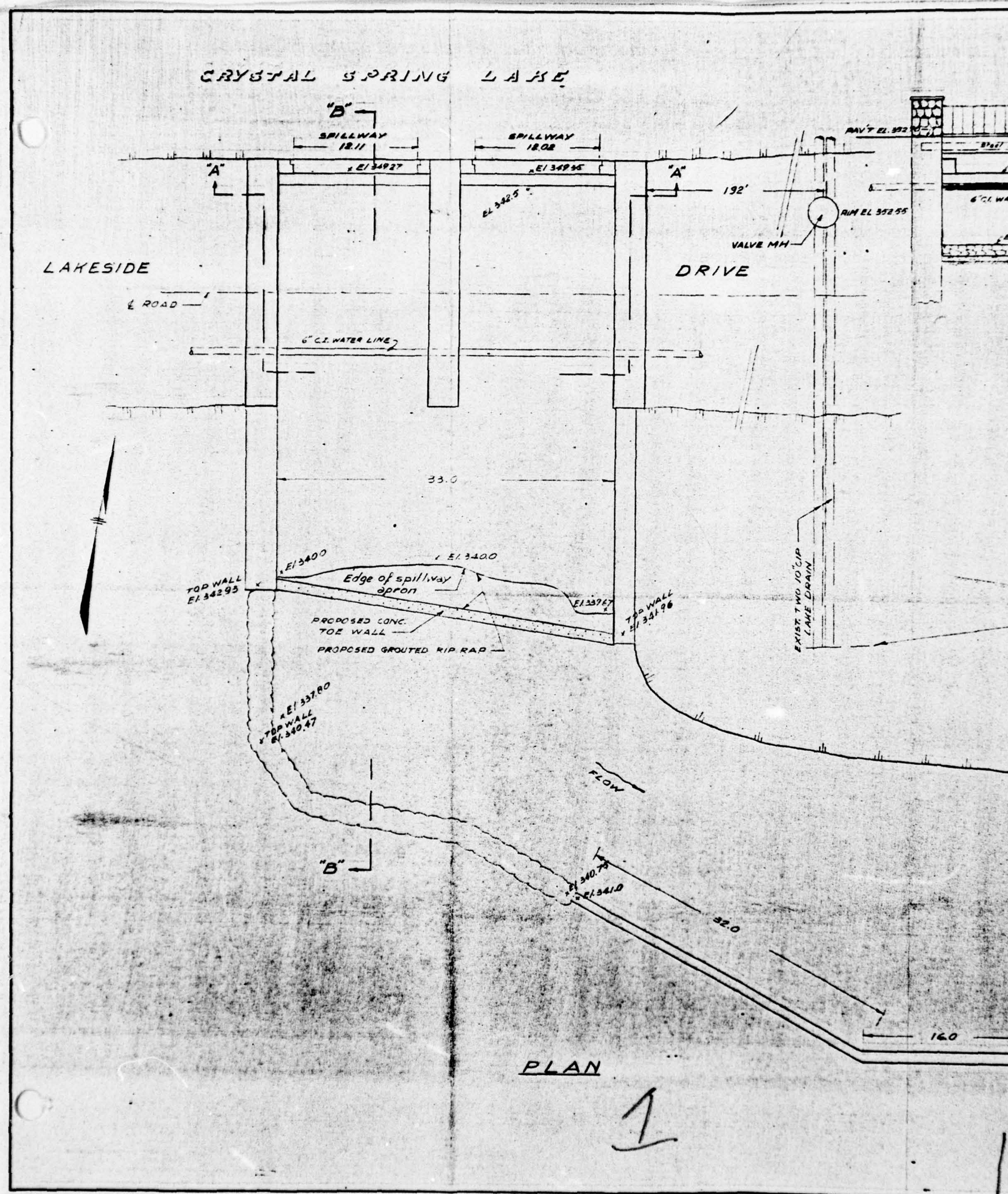
JENNY - LEEDSHILL JANUARY 1979

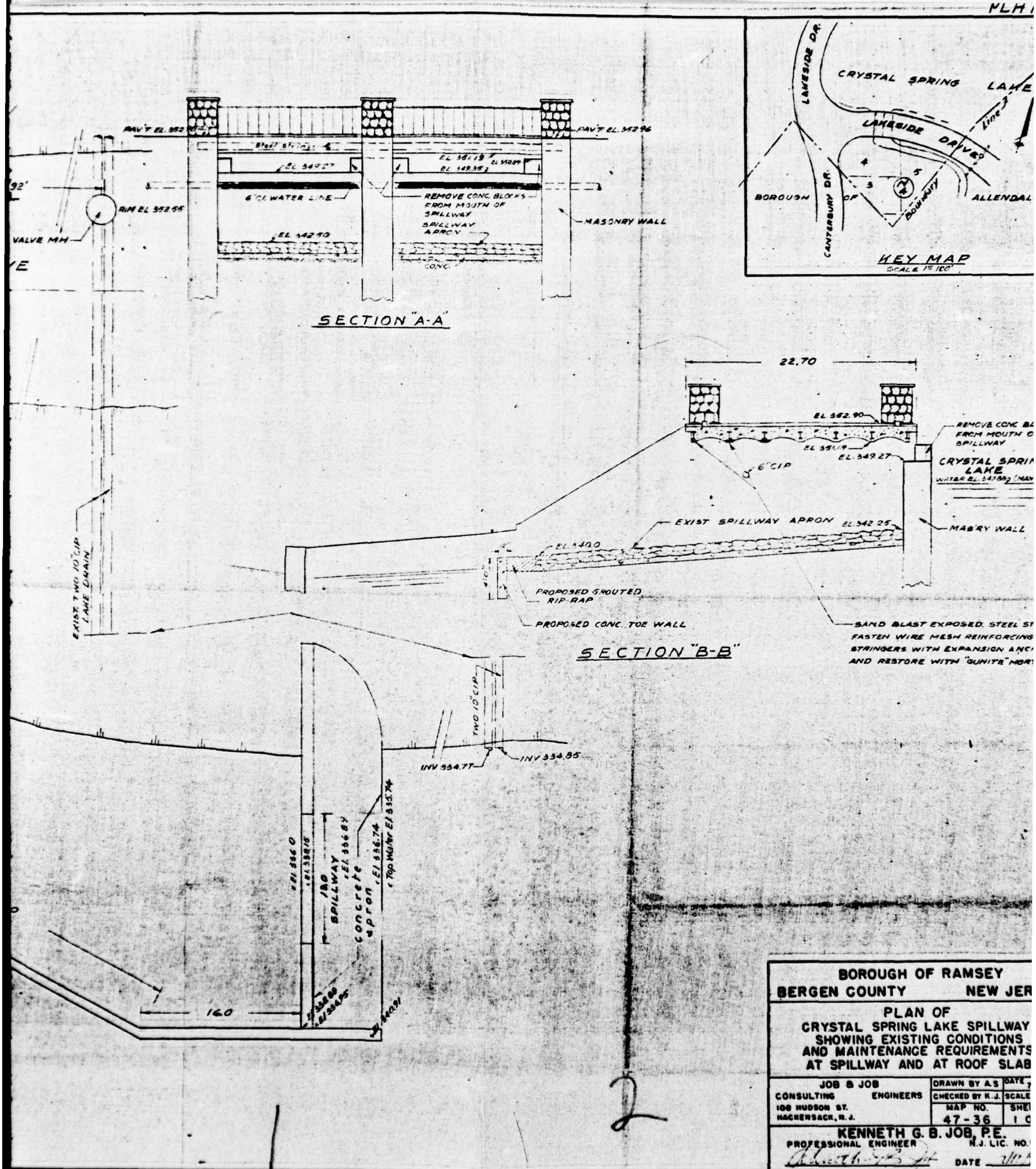
PLATE 2




CRYSTAL SPRING DAM
GENERAL VIEW

JENNY-LEEDSHILL JANUARY 1979


CRYSTAL SPRING LAKE
"B"
SPILLWAY 12.11
SPILLWAY 12.02
x El 349.27
x El 349.55
"A"
"A"
El 342.5
192'
RIM EL 352.55
VALVE MH
PAV'T EL 352
6" C.I. WAT
LAKESIDE
DRIVE
℄ ROAD
6" C.I. WATER LINE
33.0
EXIST. TWO 10" CIP LAKE DRAIN
x El 340.0
x El 340.0
Edge of spillway apron
TOP WALL El 342.93
El 337.67
TOP WALL El 341.96
PROPOSED CONC. TOE WALL
PROPOSED GROUTED RIP RAP
x El 337.80
x TOP WALL El 340.47
FLOW
"B"
El 340.75
El 341.0
32.0
16.0
PLAN
1



PAV'T EL. 352.96
6" C.I. WATER LINE
REMOVE CONC. BLOCKS FROM MOUTH OF SPILLWAY
SPILLWAY APRON
MASONRY WALL
RIM EL. 352.55
VALVE MH
SECTION "A-A"
CRYSTAL SPRING
LAKE
LAKESIDE DR.
LAKESIDE DRIVE
BOROUGH OF
ALLENDAL
CANTERBURY DR.
Boundary
KEY MAP
22.70
EL. 352.90
EL. 349.27
6" CIP
CRYSTAL SPRIN
LAKE
EXIST. SPILLWAY APRON
EL. 342.25
MAS'RY WALL
PROPOSED GROUTED RIP-RAP
PROPOSED CONC. TOE WALL
SAND BLAST EXPOSED STEEL ST
FASTEN WIRE MESH REINFORCING
STRINGERS WITH EXPANSION ANCH
AND RESTORE WITH "GUNITE" MORT
EXIST. TWO 10" CIP LAKE DRAIN
SECTION "B-B"
TWO 10" CIP
INV 334.77
INV 334.85
18.0
SPILLWAY
concrete apron
16.0
BOROUGH OF RAMSEY
BERGEN COUNTY
NEW JER
PLAN OF
CRYSTAL SPRING LAKE SPILLWAY
SHOWING EXISTING CONDITIONS
AND MAINTENANCE REQUIREMENTS
AT SPILLWAY AND AT ROOF SLAB
JOB & JOB
CONSULTING ENGINEERS
100 HUDSON ST.
HACKENSACK, N. J.
DRAWN BY A.S.
CHECKED BY K.J.
MAP NO.
47-36
1 C
KENNETH G. B. JOB, P.E.
PROFESSIONAL ENGINEER
N.J. LIC. NO.
DATE

# APPENDIX A

CHECK LIST - VISUAL OBSERVATIONS

CHECK LIST - ENGINEERING, CONSTRUCTION

MAINTENANCE DATA

**Check List**
**Visual Inspection**
**Phase 1**

**Name Dam** Crystal Spring Lake **County** Bergen **State** New Jersey Coordinators NJDEP

Coordinates: Lat. 41° 02' 50" N
Long. 79° 08' 06" W

**Date(s) Inspection** Nov. 30, 1978 & Jan 4, 1979 **Weather** Partly Cloudy **Temperature** 42° F

**Pool Elevation at Time of Inspection** 349.5' M.S.L. **Tailwater at Time of Inspection** 342.5' M.S.L.

Inspection Personnel:
(November 30, 1978)

| | | |
|---|---|---|
| | | (January 4, 1979) |
| J. A. Bischoff | T. C. MacDonald | R. J. Jenny |
| R. C. Gaffin | F. L. Panuzio | A. L. Slaughter |
| D. J. Lachel | A. R. Slaughter<br>P. L. Wagner | |

P.L. Wagner **Recorder**

Owner Representative:
(November 30, 1978)

Otto M. Cavallo

## CONCRETE/MASONRY DAMS

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| SEEPAGE OR LEAKAGE | Not Applicable | |
| STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS | Not Applicable | |
| DRAINS | Not Applicable | |
| WATER PASSAGES | Not Applicable | |
| FOUNDATION | Not Applicable | |

CONCRETE/MASONRY DAMS

| VISUAL EXAMINATION OF | OBERSVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| SURFACE CRACKS<br>CONCRETE SURFACES | Not Applicable | |
| STRUCTURAL CRACKING | Not Applicable | |
| VERTICAL AND HORIZONTAL<br>ALIGNMENT | Not Applicable | |
| MONOLITH JOINTS | Not Applicable | |
| CONSTRUCTION JOINTS | Not Applicable | |

EMBANKMENT

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| SURFACE CRACKS | Asphalt roadway along crest of embankment. No surface cracks were observed on crest or face. | |
| UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE | No movement or cracking could be detected. The toe at the downstream side of the dam was extremely uneven due to the unevenness of the face. Marshy area downstream of left side of dam. | |
| SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES | Very uneven downstream slope with numerous large (3'-6') glacial boulders on surface. Some unevenness undoubtedly due to erosion, including overtopping. Also probably due to tree roots and trash building with time. Upstream slope also uneven, but less so. | Certain areas of downstream embankment are very steep (1:1) and should be graded. |
| VERTICAL AND HORIZONTAL ALINEMENT OF THE CREST | Asphalt roadway on crest appears relatively new. No settlement or horizontal misalignment of the crest could be detected. | |
| RIPRAP FAILURES | No riprap observed on upstream face. There may have been some dumped rock facing on downstream face at one time, but is now very sporadic. | Riprap should be placed on upstream slope. |

EMBANKMENT

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| VEGETATION | Numerous large trees and heavy undergrowth cover both upstream and downstream slopes. | Tree roots could endanger core wall and should be removed. |
| JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM | Abutments are earth, at about same elevation as dam. Junction of the embankment and its abutments and the embankment and the spillway appear to be tight, with no evidence of separation or movement. | Concrete core wall reportedly pierced when utilities were brought to developments on left side of lake. |
| ANY NOTICEABLE SEEPAGE | Seepage at toe of embankment about 100 ft. from left abutment. Flow 2 to 5 gpm. over a 15-foot length. Water is clear but there is some indication of possible quick conditions. Other seepage ($\pm$ 1/2 gpm) at outlet discharge. | Source of seepage should be determined by owner. |
| STAFF GAGE AND RECORDER | None | |
| DRAINS | None observed | |

## OUTLET WORKS

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT | Not Applicable | |
| INTAKE STRUCTURE | Intake structure was submerged and could not be observed. | |
| OUTLET STRUCTURE | 2 parellel 10-inch outlet pipes, with valves located in a manhole on north side of road 200 feet east of spillway. Manhole filled with water. Outlet pipes on downstream side were hidden by a large stone & debris and could not be observed. | |
| OUTLET CHANNEL | Outlet empties into shallow, poorly defined ravine tributary to main stream. About 1/2 gpm seepage or leakage at outlet. | |
| EMERGENCY GATE | The outlet works described above is the emergency gate. | |

## UNGATED SPILLWAY

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| **CONCRETE WEIR** | Spillway is 2-bay overflow masonry weir separated by bridge deck support pier. Weir appears in generally good condition, with no appreciable erosion of crest or downstream face. | |
| **APPROACH CHANNEL** | None | |
| **DISCHARGE CHANNEL** | Discharge from masonry spillway apron flows over toe wall into a concrete lined curved channel bordered by vertical masonry and block walls. Both walls and channel appear structurally sound. No erosion or plucking of slab was evident. | |
| **BRIDGE AND PIERS** | Bridge over spillway has composite steel and concrete deck with the underside recently gunited. Appears to be in good condition. Masonry block center pier and 2 spillway training walls have been repaired with mortar patching and appear in good condition. | |
| | | |

## GATED SPILLWAY

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| CONCRETE SILL | Not Applicable | |
| APPROACH CHANNEL | Not Applicable | |
| DISCHARGE CHANNEL | Not Applicable | |
| BRIDGE AND PIERS | Not Applicable | |
| GATES AND OPERATION EQUIPMENT | Not Applicable | |

# INSTRUMENTATION

| VISUAL EXAMINATION | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| MONUMENTATION/SURVEYS | None | |
| OBSERVATION WELLS | None | |
| WEIRS | None | |
| PIEZOMETERS | None | |
| OTHER | None | |

RESERVOIR

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| **SLOPES** | Urban area of large residences on lots of about 1/2 acre with numerous trees on eastern side of reservoir. Golf course on western side. Gentle slopes. Little freeboard between reservoir and top of roadway. | |
| **SEDIMENTATION** | Water was clear with no evidence of sedimentation, however, it was reported that it has been necessary to dredge the reservoir. | |
| DEBRIS | Minor debris at spillway. | |
| | | |
| | | |

DOWNSTREAM CHANNEL

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|---|
| CONDITION (OBSTRUCTIONS, DEBRIS, ETC.) | Lined channel about 100' downstream of spillway. Stream meanders considerably thereafter, area is heavily wooded. Right bank flood plain is residential development. | |
| SLOPES | Moderate slopes | |
| APPROXIMATE NO. OF HOMES AND POPULATION | 2 houses immediately downstream of spillway and several on right bank further downstream | High hazard conditions, especially for houses immediately downstream. |
| | | |
| | | |

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

| ITEM | REMARKS |
|---|---|
| PLAN OF DAM | Plan prepared from field measurements made during inspection (See Plate 2) |
| REGIONAL VICINITY MAP | U.S. Geological Survey map (See Plate 1) |
| CONSTRUCTION HISTORY | Limited information from owner's files |
| TYPICAL SECTIONS OF DAM | Not available |
| HYDROLOGIC/HYDRAULIC DATA | Computations of spillway capacity available in State files. |
| OUTLETS - PLAN | Not Available |
| - DETAILS | Not Available |
| -CONSTRAINTS -DISCHARGE RATINGS | Not Available |
| RAINFALL/RESERVOIR RECORDS | Not Available |

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

| ITEM | REMARKS |
|---|---|
| DESIGN REPORTS | Not Available |
| GEOLOGY REPORTS | Not Available. Reconnaissance made during inspection. |
| DESIGN COMPUTATIONS<br>HYDROLOGY & HYDRAULICS<br>DAM STABILITY<br>SEEPAGE STUDIES | Not Available |
| MATERIALS INVESTIGATIONS<br>BORING RECORDS<br>LABORATORY<br>FIELD | Not Available |
| POST-CONSTRUCTION SURVEYS OF DAM | Have survey of spillway area only (See spillway). |
| BORROW SOURCES | Not Known |

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

| ITEM | REMARKS |
|---|---|
| SPILLWAY-PLAN<br>-SECTIONS<br>-DETAILS | "Plan of Crystal Spring Lake Spillway, showing existing Conditions and Maintenance Requirements at Spillway and at Roof Slab", July 12, 1976, Scale 1" = 5', by Job and Job, Consulting Engineers (See Plate 3). |
| OPERATING EQUIPMENT PLANS & DETAILS | Not Available |
| MONITORING SYSTEMS | None |
| MODIFICATIONS | Spillway repairs as above. |
| HIGH POOL RECORDS | Not Available. |
| POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS | Not Available |
| PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS | None Reported. Dam has been overtopped. |

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

| ITEM | REMARKS |
| --- | --- |
| MAINTENANCE OPERATION RECORDS | Not Available. |

# APPENDIX B

Photographs

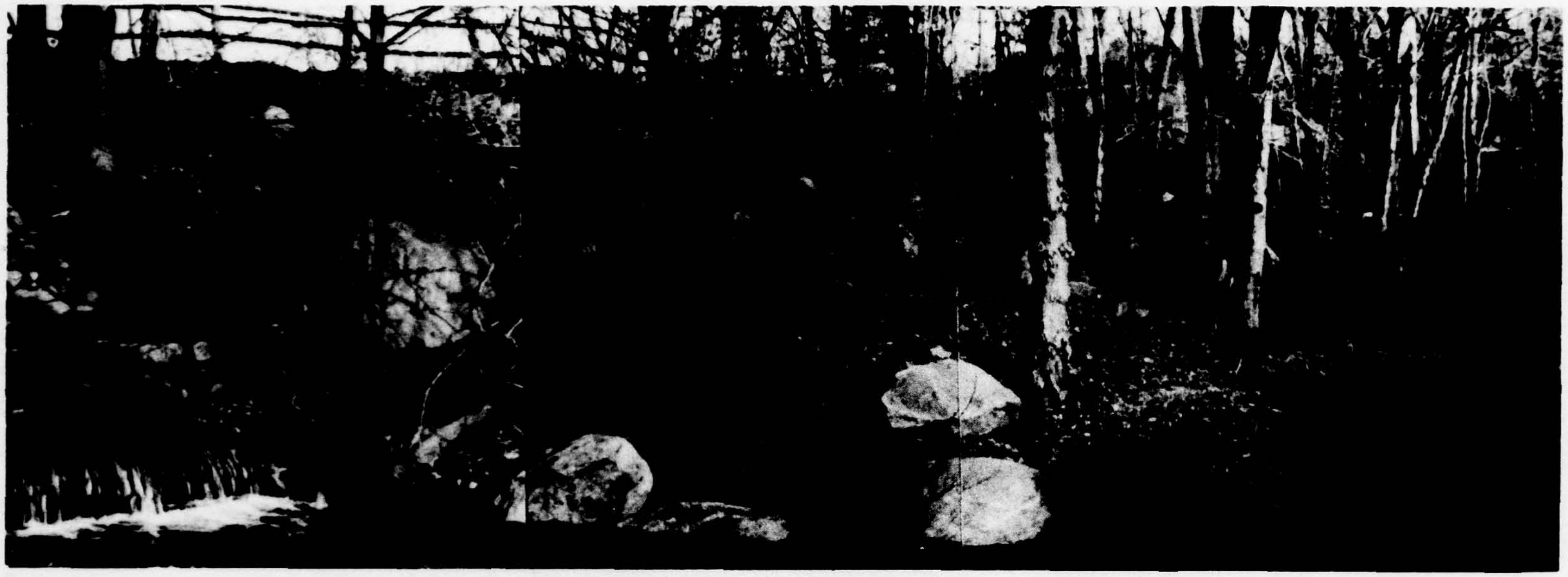


Photo 1 - Downstream embankment looking east from spillway area. (November 30, 1978)

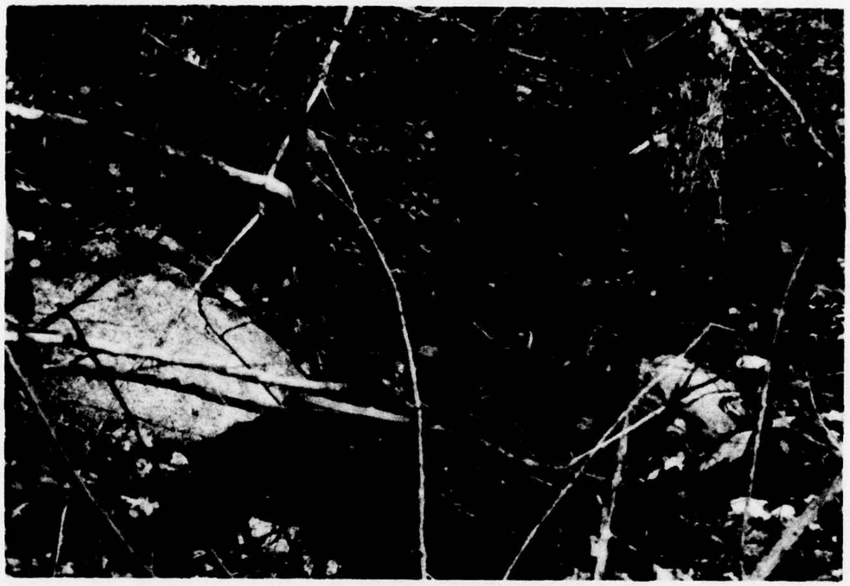


Photo 2 - Seepage (arrow) at downstream toe of embankment near left abutment. (November 30, 1978)

Photo 3 - Crest of dam and upstream embankment, showing heavy growth of trees. (November 30, 1978)

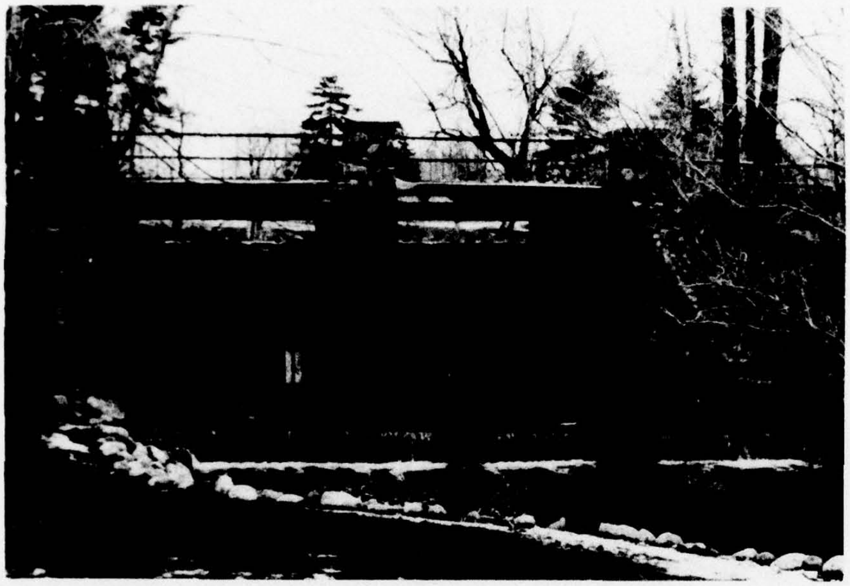


Photo 4 - Downstream View of Spillway.
(November 30, 1978)

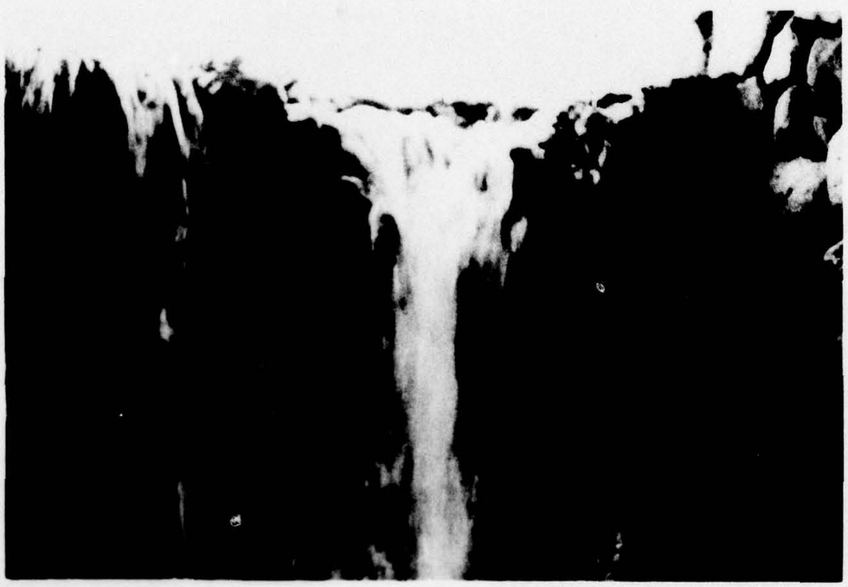


Photo 5 - Flow over portion of rock masonry spillway weir. (November 30, 1978)

Photo 6 - Reservoir drain outlet obstructed by debris. (November 30, 1978)

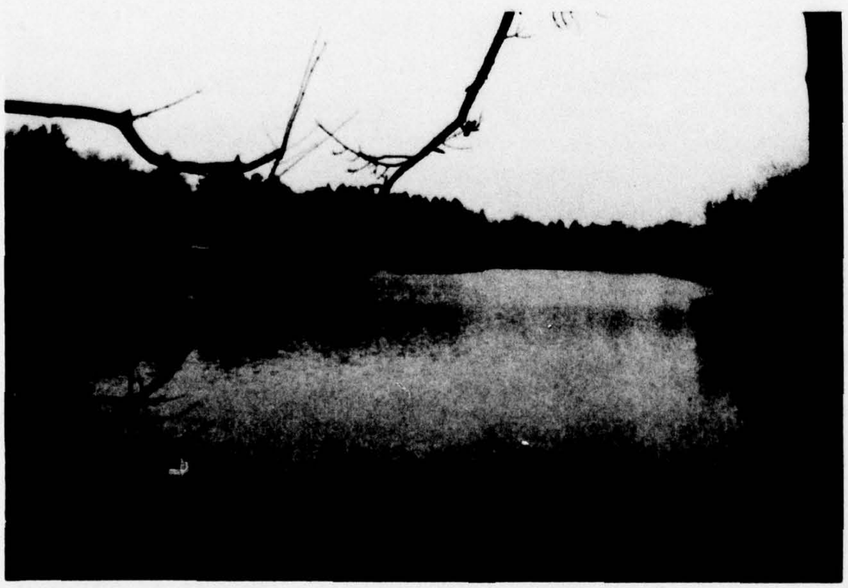


Photo 7 - Reservoir area, looking north. (November 30, 1978)

Photo 8 - Concrete weir at end of lined channel downstream of the spillway. (November 30, 1978)

Photo 9 - House on right side of lined channel downstream of spillway. (November 30, 1978)

# APPENDIX C

## REGIONAL GEOLOGY - PIEDMONT LOWLANDS

## REGIONAL GEOLOGY - PIEDMONT LOWLANDS

### Physiography

The Piedmont Lowlands Province of New Jersey lies northwest of a line approximately between Trenton and Perth Amboy and southeast of an approximate line between Milford on the Delaware River and Mahwah near the New York State border. Physiographically, the province is situated between the predominantly Precambrian age New Jersey Highlands Province to the northwest and the typically unconsolidated Createaceous age and younger sediments of the Coastal Plain Province to the southeast. (See Figure C-1).

### Bedrock

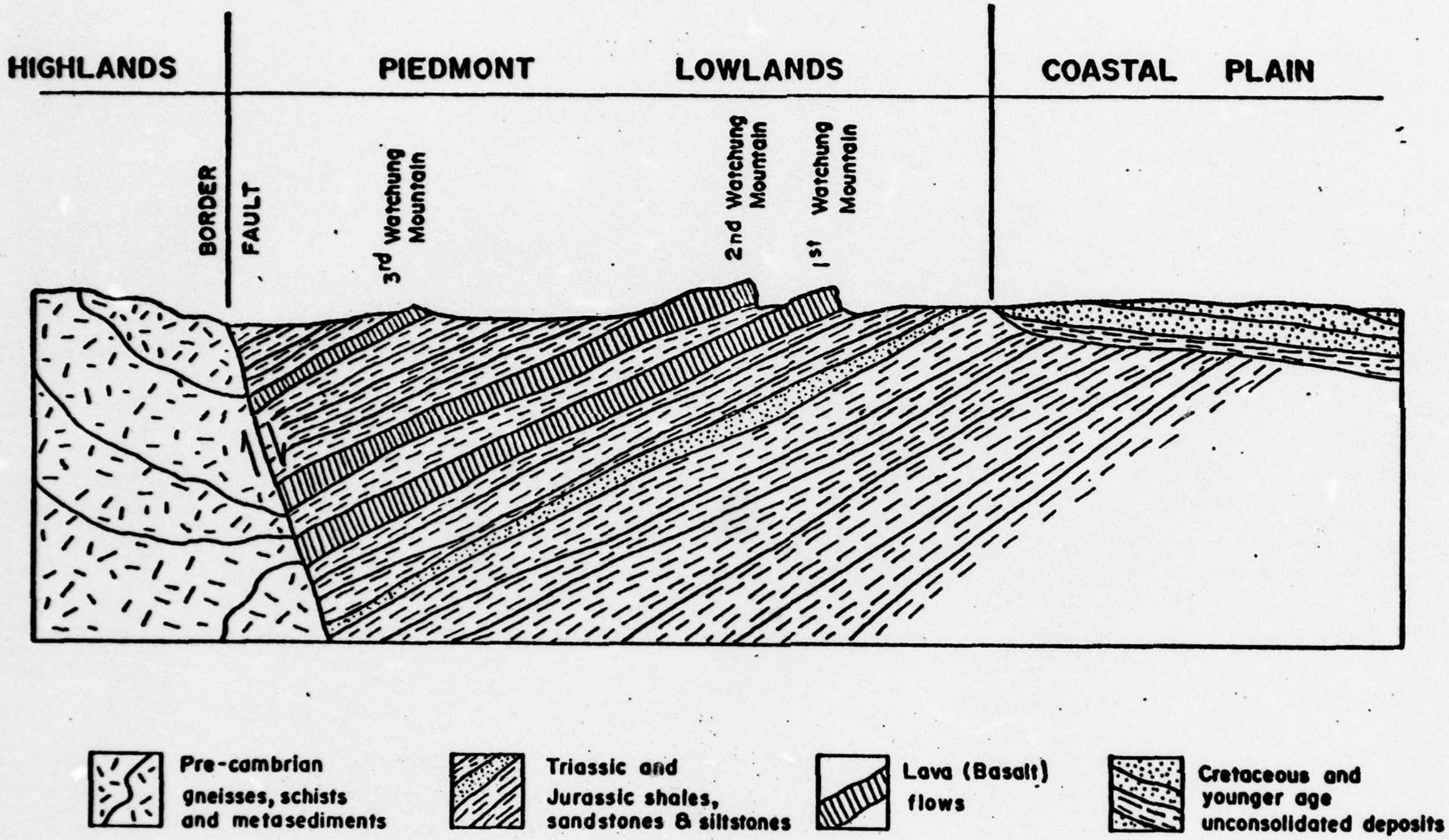
The Piedmont Lowlands, encompassing about one-fifth of the state, is characterized by northwestward dipping bedrock composed of interbedded red shales, siltstones and sandstones of Triassic and Jurassic age and igneous basalt extrusions (lava flows) and diabase intrusions of Jurassic age. The sedimentary rocks have been eroded to a broad southeastward sloping piedmont plain. The northwest border of the province is a northeast-southwest trending fault zone (Ramapo Fault) which truncates the sedimentary beds. Total vertical displacement on the fault may reach 10,000 feet.

The gently rolling lowland topography of the piedmont lowlands is pierced by long asymetric ridges of hard and resistant igneous rocks which were intruded into or on top of the sedimentary sequences. With the subsequent erosion of the softer sedimentary rocks, these igneous formations have been left standing, often in bold relief, up to 400 ft. above the surrounding plains. The igneous bodies composed of diabase and basalt form the Palisades along the Hudson River and the three Watchung Mountain ridges of the central Piedmont. The ridges are all steeper on the southeast with gentle dip slopes to the northwest.

Overburden

The Pleistocene Age Wisconsin continental glacier has smoothed and filled approximately the northern half of the province. The terminal moraine of the glacier extends from Perth Amboy to Summit then northwestward to Morris Plains. North of the morainal line the soils characteristically consist of glacial tills overlying the bedrock with scattered overlying stratified outwash deposits. At least three large glacial lakes occupied portions of the area north of the moraine at different periods, resulting in a relatively flat topography composed predominantly of silts and clays.

South of the terminal moraine, most of the overburden consists of alluvial deposits overlying a more highly developed weathered transition zone on top of the bedrock. Some highly weathered tills of pre-Wisconsin glaciation can be found on the top of intervalley ridges. Much of the alluvium is glacial outwash.




SCHEMATIC CROSS-SECTION OF
NEW JERSEY PIEDMONT LOWLANDS
PHYSIOGRAPHIC PROVINCE

JENNY / LEEDSHILL
JANUARY 1979

FIGURE C-1

# APPENDIX D

## HYDROLOGIC AND HYDRAULIC COMPUTATIONS

CRYSTAL SPRING LAKE

**CHECK LIST**
**HYDROLOGIC AND HYDRAULIC DATA**
**ENGINEERING DATA**

DRAINAGE AREA CHARACTERISTICS: 1.77 SQ. MI

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 349.3 (65 AF)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): 352.9 (130 AF)

ELEVATION MAXIMUM DESIGN POOL: 355.3

ELEVATION TOP DAM: 352.9

CREST: SPILLWAY

a. Elevation 349.3
b. Type CONCRETE WALL
c. Width 4I
d. Length 30'
e. Location Spillover —
f. Number and Type of Gates NONE

OUTLET WORKS:

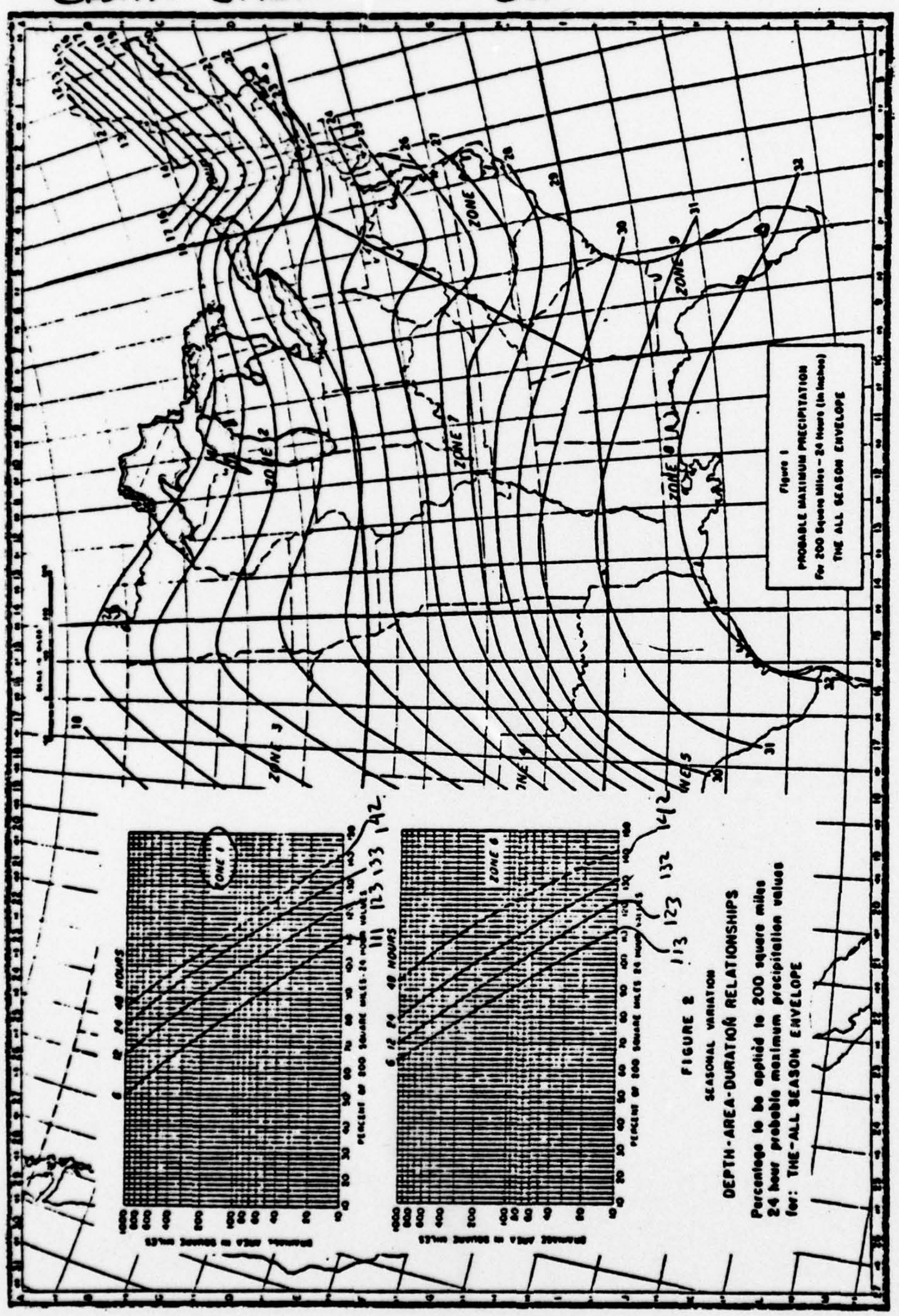
a. Type 2-10" PIPE
b. Location —
c. Entrance inverts 340 MSL
d. Exit inverts —
e. Emergency draindown facilities —

HYDROMETEOROLOGICAL GAGES: NONE

a. Type
b. Location
c. Records

MAXIMUM NON-DAMAGING DISCHARGE: 450 CFS

# Crstal Spring Lake Dam



CRYSTAL SPRING LAKE



DATA

L = STREAM LENGTH FROM WATERSHED OUTLET TO THE MOST DISTANT RIDGE = 4.55 MI

$L_{CA}$ = STREAM LENGTH FROM BASIN CENTROID = 1.89 MI

H = DIFF BETWEEN ELEV AT OUTLET AND ELEV AT MOST DISTANT POINT = 540-340 = 200 FT

$T_C$ = TIME OF CONCENTRATION OR TIME FOR WATER TO FLOW FROM THE MOST DISTANT POINT IN THE WATERSHED TO THE WATERSHED OUTLET

$T_L$ = LAG TIME FROM CENTER OF EXCESS RAINFALL TO TIME OF PEAK. = $0.6 T_C$

METHOD 1

$$T_C = \frac{L^{1.15}}{7700\, H^{0.38}}$$

L IN FT
H IN FT

$$T_L = \frac{0.6\, L^{1.15}}{7700\, H^{0.38}}$$

METHOD 2

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

L IN MILES
H IN FT.

$$T_L = 0.6\left(\frac{11.9\, L^3}{H}\right)^{0.385}$$

METHOD 3

$$T_L = C_T\left(\frac{L L_C}{S^{1/2}}\right)^{0.38}$$

S IN FT/MI   S = H/L = 0.83%

$$T_L = C_T\left(\frac{L L_C}{(H/L)^{1/2}}\right)^{0.38}$$

$C_T$ = 1.2 MOUNTAIN
= (0.72) FOOTHILL
= 0.35 VALLEY DRAINAGE AREA

METHOD 4

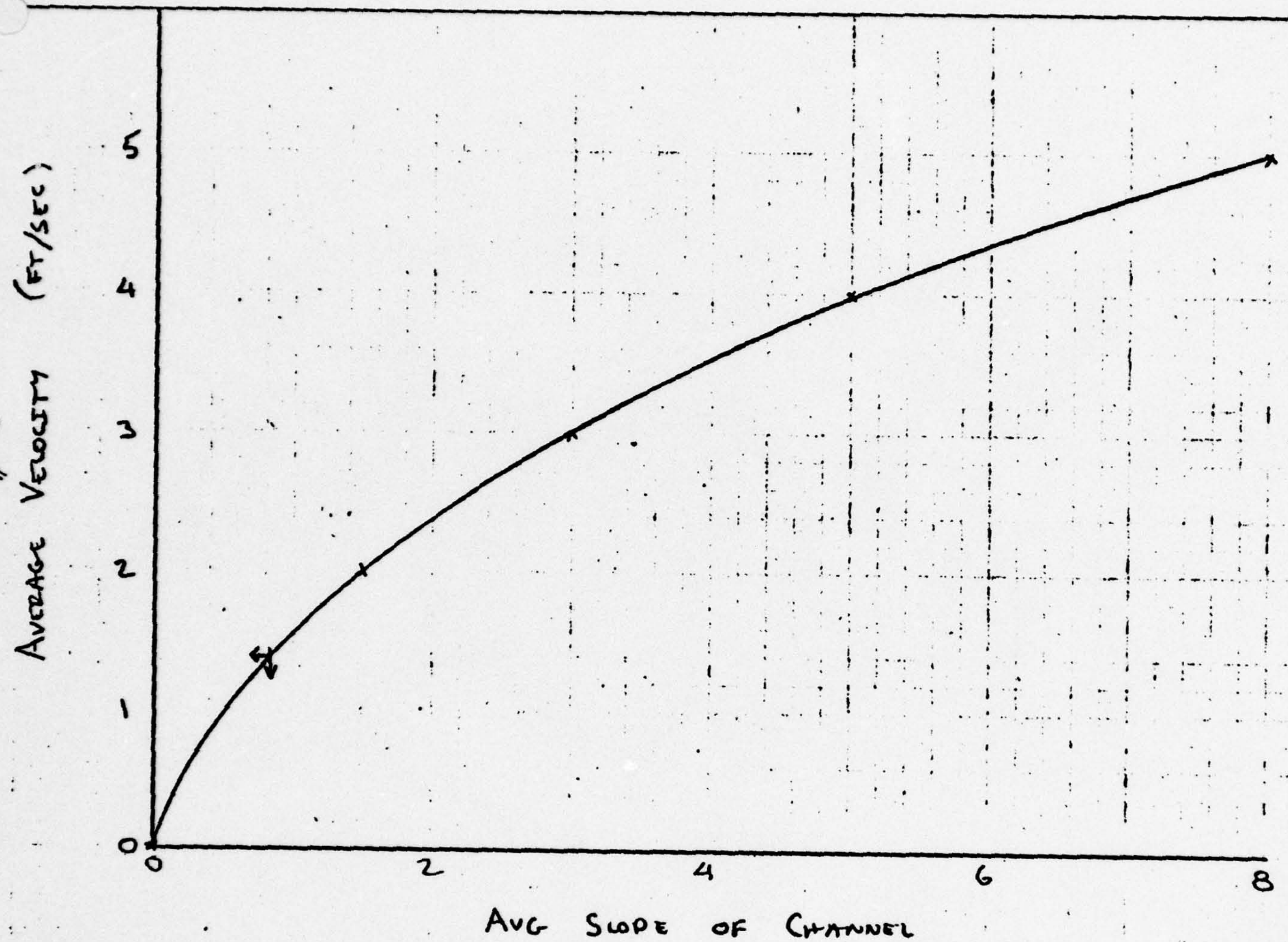
$T_C = L/V$

$T_L = 0.6\, L/V$

V = AVG VELOCITY FROM CURVE OF V VS. AVG SLOPE
V = 1.4 fps

LAG IN HOURS

| | METHODS 1 | 2 | 3 | 4 | USE |
|---|---|---|---|---|---|
| CRYSTAL SPRING | 1.1 | 1.2 | 0.8 | 2.9 | 1.1 |




KBE 781220 302 2/2

LEEDS, HILL AND JEWETT, INC.

BY RBE DATE ______ CLIENT N.J. DAM SAFETY SHEET NO. ______ OF ______

CHKD ______ DATE ______ JOB ______ JOB NO. 302-03

REFERENCES

METHOD 1 - FROM "HANDBOOK OF APPLIED HYDROLOGY"
BY CHOW
McGRAW HILL PP 21-10, 11

METHOD 2 - FROM CALIFORNIA CULVERTS PRACTICE, CALIF HIGHWAYS AND PUBLIC WORKS, SEPT 1942
SEE USBR DESIGN OF SMALL DAMS
PG. 71

METHOD 3 - FROM HYDROLOGY FOR ENGINEERS
LINSLEY / KOHLER / PAULHUS 1975
PP. 247-248

METHOD 4 - FROM U.S. NAVY - TECHNICAL PUBLICATION
NAVDOCKS TP-PW-5 TABLE 8B, MARCH 1953
SEE USBR DESIGN OF SMALL DAMS PG. 70

OVER SPILLWAY $C = 2.9$ FROM DATA (SEE LAST SHEET)

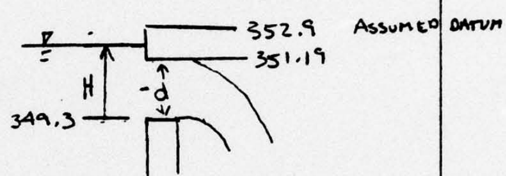
OVER BRIDGE $C = 2.6$ BROADCRESTED WEIR

ORIFICE FLOW $C_c = 0.61$ COMPARISON OF CASE WITH MODEL (MODEL A) IN KINGS HANDBOOK TABLE 4-8, AVG VALUE OVER RANGE CONSIDERED

$$Q = CLH^{1.5}$$

$$Q = C_c d \sqrt{2g(H - d/2)}\, L$$

$L = 30'$




| H (FT) | C | Q (CFS) |
|---|---|---|
| 0 | | 0 |
| 0.5 | | 31 |
| 1.0 | 2.9 | 87 |
| 1.5 | | 160 |
| 1.89 | | 226 |
| 1.89 | | 270 |
| 2.0 | | 285 |
| 2.2 | | 311 |
| 2.5 | 0.61 | 346 |
| 3.0 | | 398 |
| 3.6 | | 453 |
| 3.6 | | 453 |
| 4.0 | | 505 |
| 4.5 | 0.61 | 590 |
| 5.0 | + | 688 |
| 6.0 | 2.6 | 914 |
| 8.0 | | 1457 |

$d = 1.89$

SAMPLE $H = 4.0$

$$Q = (0.61)\sqrt{(4 - 1.89/2)\,2g}\,(30)(1.89) + (4 - 3.6)^{1.5}\,30\,(2.6)$$

$Q = 505$ CFS

Channel Cross-Sections L1

| Station | Distance Downstream of Dam (FT) | Mannings "n" L2 Left Over-Bank | Mannings "n" Main Channel | Mannings "n" Right Over-Bank | Channel Invert (FT) | Max Elev. (FT) | Reach Length (FT) | Energy Grade Line Slope | X or Y | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 - Below Dam | 0 | | | | 340 | | | | | | | | | | | | |
| 3 4 | 4000 | 0.10 L4 | 0.045 L3 | 0.10 L4 | 310 | 320 | 3950 | 0.0078 | X | 0 | 400 | 550 | 550 | 600 | 600 | 825 | 1025 |
| | | | | | | | | | Y | 330 | 320 | 312 | 310 | 310 | 312 | 320 | 325 |
| A5 | 6400 | 0.05 L5 | 0.045 | 0.05 L5 | 286 | 300 | 2400 | .016 | X | 0 | 250 | 375 | 375 | 485 | 425 | 900 | 1450 |
| | | | | | | | | | Y | 300 | 290 | 288 | 286 | 286 | 288 | 290 | 300 |
| 3 | 50 | 0.10 | 0.045 | 0.10 | 338 | 360 | 50 | 0.01 | X | 0 | 280 | 540 | 540 | 560 | 560 | 1000 | 1050 |
| | | | | | | | | | Y | 360 | 350 | 340 | 338 | 338 | 340 | 350 | 360 |

L1 Looking Upstream
L2 Vents Chow Open Channel Flow Table 5-6
L3 Minor Stream (<100') clean winding with some stones and weeds
L4 Heavy Timber, little undergrowth
L5 Urban Area

**Table 5-6. Values of the Roughness Coefficient n (continued)**

| Type of channel and description | Minimum | Normal | Maximum |
|---|---|---|---|
| C. Excavated or Dredged | | | |
| a. Earth, straight and uniform | | | |
| 1. Clean, recently completed | 0.016 | 0.018 | 0.020 |
| 2. Clean, after weathering | 0.018 | 0.022 | 0.025 |
| 3. Gravel, uniform section, clean | 0.022 | 0.025 | 0.030 |
| 4. With short grass, few weeds | 0.022 | 0.027 | 0.033 |
| b. Earth, winding and sluggish | | | |
| 1. No vegetation | 0.023 | 0.025 | 0.030 |
| 2. Grass, some weeds | 0.025 | 0.030 | 0.033 |
| 3. Dense weeds or aquatic plants in deep channels | 0.030 | 0.035 | 0.040 |
| 4. Earth bottom and rubble sides | 0.028 | 0.030 | 0.035 |
| 5. Stony bottom and weedy banks | 0.025 | 0.035 | 0.040 |
| 6. Cobble bottom and clean sides | 0.030 | 0.040 | 0.050 |
| c. Dragline-excavated or dredged | | | |
| 1. No vegetation | 0.025 | 0.028 | 0.033 |
| 2. Light brush on banks | 0.035 | 0.050 | 0.060 |
| d. Rock cuts | | | |
| 1. Smooth and uniform | 0.025 | 0.035 | 0.040 |
| 2. Jagged and irregular | 0.035 | 0.040 | 0.050 |
| e. Channels not maintained, weeds and brush uncut | | | |
| 1. Dense weeds, high as flow depth | 0.050 | 0.080 | 0.120 |
| 2. Clean bottom, brush on sides | 0.040 | 0.050 | 0.080 |
| 3. Same, highest stage of flow | 0.045 | 0.070 | 0.110 |
| 4. Dense brush, high stage | 0.080 | 0.100 | 0.140 |
| D. Natural Streams | | | |
| D-1. Minor streams (top width at flood stage <100 ft) | | | |
| a. Streams on plain | | | |
| 1. Clean, straight, full stage, no rifts or deep pools | 0.025 | 0.030 | 0.033 |
| 2. Same as above, but more stones and weeds | 0.030 | 0.035 | 0.040 |
| 3. Clean, winding, some pools and shoals | 0.033 | 0.040 | 0.045 |
| 4. Same as above, but some weeds and stones | 0.035 | 0.045 | 0.050 |
| 5. Same as above, lower stages, more ineffective slopes and sections | 0.040 | 0.048 | 0.055 |
| 6. Same as 4, but more stones | 0.045 | 0.050 | 0.060 |
| 7. Sluggish reaches, weedy, deep pools | 0.050 | 0.070 | 0.080 |
| 8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.075 | 0.100 | 0.150 |

STATION 3, 4, & 5

**Table 5-6. Values of the Roughness Coefficient n (continued)**

| Type of channel and description | Minimum | Normal | Maximum |
|---|---|---|---|
| b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages | | | |
| 1. Bottom: gravels, cobbles, and few boulders | 0.030 | 0.040 | 0.050 |
| 2. Bottom: cobbles with large boulders | 0.040 | 0.050 | 0.070 |
| D-2. Flood plains | | | |
| a. Pasture, no brush | | | |
| 1. Short grass | 0.025 | 0.030 | 0.035 |
| 2. High grass | 0.030 | 0.035 | 0.050 |
| b. Cultivated areas | | | |
| 1. No crop | 0.020 | 0.030 | 0.040 |
| 2. Mature row crops | 0.025 | 0.035 | 0.045 |
| 3. Mature field crops | 0.030 | 0.040 | 0.050 |
| c. Brush | | | |
| 1. Scattered brush, heavy weeds | 0.035 | 0.050 | 0.070 |
| 2. Light brush and trees, in winter | 0.035 | 0.050 | 0.060 |
| 3. Light brush and trees, in summer | 0.040 | 0.060 | 0.080 |
| 4. Medium to dense brush, in winter | 0.045 | 0.070 | 0.110 |
| 5. Medium to dense brush, in summer | 0.070 | 0.100 | 0.160 |
| d. Trees | | | |
| 1. Dense willows, summer, straight | 0.110 | 0.150 | 0.200 |
| 2. Cleared land with tree stumps, no sprouts | 0.030 | 0.040 | 0.050 |
| 3. Same as above, but with heavy growth of sprouts | 0.050 | 0.060 | 0.080 |
| 4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches | 0.080 | 0.100 | 0.120 |
| 5. Same as above, but with flood stage reaching branches | 0.100 | 0.120 | 0.160 |
| D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance. | | | |
| a. Regular section with no boulders or brush | 0.025 | ..... | 0.060 |
| b. Irregular and rough section | 0.035 | ..... | 0.100 |

# OPEN-CHANNEL HYDRAULICS

STATION 3 & 4

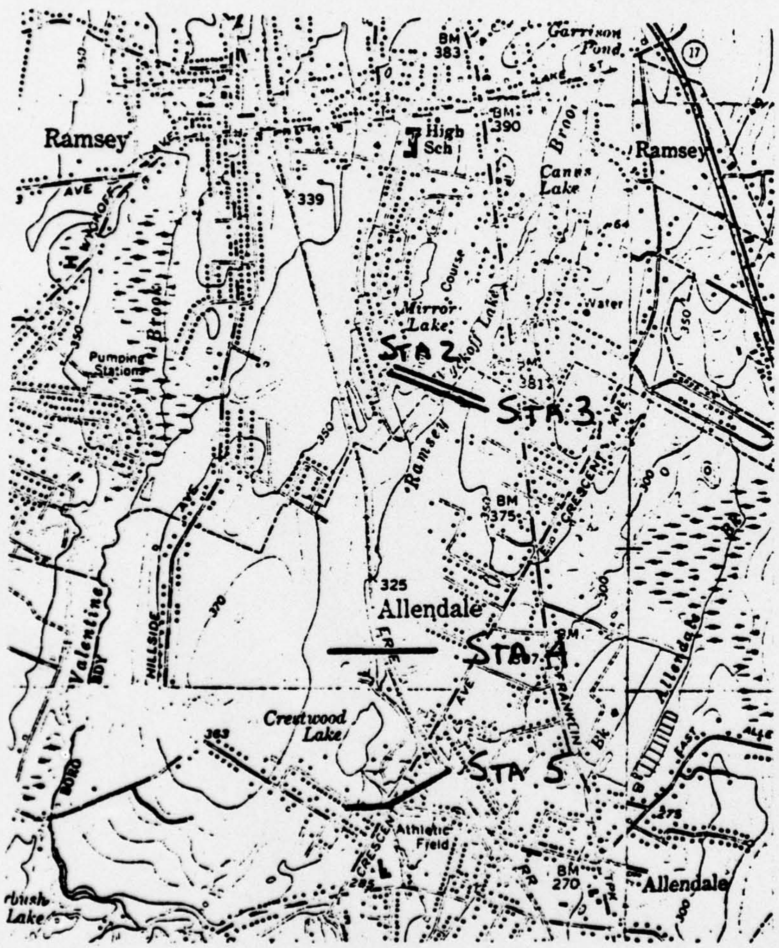
**VEN TE CHOW, Ph.D.**

*Professor of Hydraulic Engineering*
*University of Illinois*

D.8

CRYSTAL SPRINGS

LOCATION MAP OF CROSS-SECTIONS
USED IN ROUTING



# ASSUMED BREACH PARAMETERS

WIDTH OF BREACH BOTTOM: 270

SIDE SLOPES: VERTICAL

BREACH BOTTOM ELEV.: 340

TIME TO FAIL: 4.0 hrs

ELEV. @ WHICH FAILURE OCCURS: 352.9 FT

INITIAL WATER SURFACE ELEV.: 349.3 FT

(1) BASED ON PREVIOUS STUDIES OF ACTUAL DAM FAILURES.

# Reservoir Drawdown Time

ASSUME ORIFICE EQUATION WITH NO TAILWATER, AND NO INFLOWS INTO THE RESERVOIR.

$$Q = CA\sqrt{2gh}$$

For 1-8" & 1-12", $A = 1.13\ ft^2$

For 2-10" $A = 1.09\ ft^2$ ← USE

Assume $C = 0.6$

$$Q = 0.6 \times 1.09 \times \sqrt{2g} \times H^{1/2}$$

$$Q = 5.25\ H^{1/2}$$

| Elev, ft | Sto | ΔSto | Avg h | Avg Q cfs | Drain Hours | ΣDrain Hours |
|---|---|---|---|---|---|---|
| 340 | 0 | | | | | |
| | | 20 AF | 6.8 | 13.69 | 17.7 | 17.7 |
| 345 | 20 | | | | | |
| | | 15 AF | 3.3 | 9.54 | 19.0 | 36.7 |
| 347 | 35 | | | | | |
| | | 30 AF | 1.15 | 5.63 | 64.5 | 101.2 |
| → 349.3 | 65 | | | | | |

(349.3 = Spillway)

$$\frac{101.2}{24} = 4.2 \text{ days}$$

No Breach

```
*************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  29 SEP 79
*************************************
      A1        NEW JERSEY DAM SAFETY - CRYSTAL SPRING LAKE DAM  I.D. NO. 00231
      A2        HYDRAULIC-HYDROLOGIC ANALYSIS   302-03
      A3        PROBABLE MAXIMUM FLOOD                                     -RBE-
      B       96       0      15       0       0       0       0       0       0       0
      B1       5
      J        1       4       1
      J1     0.1    0.15    0.50     1.0
      K        0       1                                       1
      K1                        INFLOW HYDROGRAPH TO RESERVOIR
      M        1       2    1.77            1.77                                1
      P             22.0     111     123     133
      T                                                      1.5    0.15
      W2             1.1
      X       -1    -.05     2.0
      K        1       2                                       1
      K1                        ROUTED FLOWS THROUGH RESERVOIR
      Y                                 1       1
      Y1       1                                              65      -1
      Y4   349.3   350.3   353.0  351.19  351.20   351.3   352.3   352.9   353.3   354.3
      Y4   355.3   357.3
      Y5       0      85     160     225     270     285     400     450     505     690
      Y5     915    1455
      $S       0      20      35      65     110     170     300
      $E     340     345     347   349.3     352     355     360
      $$   349.3
      $D   352.9     2.6     1.5     525
      K        1       3                                       1
      K1        CHANNEL ROUTING -MODIFIED PULS- STATION 2 TO 3
      Y                                 1       1
      Y1       1
      Y6    0.10   0.045    0.10     339     360      50    0.01
      Y7       0     366     150     350     540     340     540     338     560     338
      Y7     560     340    1000     350    1150     360
      K        1       4                                       1
      K1        CHANNEL ROUTING -MODIFIED PULS- STATION 3 TO 4
      Y                                 1       1
      Y1       1
      Y6    0.10   0.045    0.10     310     330    3950  0.0071
      Y7       0     330     400     320     550     312     550     310     600     310
      Y7     600     332     925     320    1025     325
      K        1       5                                       1
      K1        CHANNEL ROUTING -MODIFIED PULS- STATION 4 TO 5
      Y                                 1       1
      Y1       1
      Y6    0.05   0.045    0.05     286     300    2400    0.01
      Y7       0     300     250     290     375     288     375     286     425     286
      Y7     425     288     900     290    1450     360
      K       99


            PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

                  RUNOFF HYDROGRAPH AT          1
                  ROUTE HYDROGRAPH TO           2
                  ROUTE HYDROGRAPH TO           3
                  ROUTE HYDROGRAPH TO           4
                  ROUTE HYDROGRAPH TO           5
                  END OF NETWORK
```

```
NEW JERSEY DAM SAFETY - CRYSTAL SPRING LAKE DAM  I.D. NO. 00231
HYDRAULIC-HYDROLOGIC ANALYSIS   382-03
PROBABLE MAXIMUM FLOOD                                    -RBE-

                      JOB SPECIFICATION
   NQ    NHR   NMIN   IDAY    IHR   IMIN  METRC   IPLT   IPRT  NSTAN
   96      0     15      0      0      0      0      0      0      0
                      JOPER    NWT  LROPT  TRACE
                          5      0      0      0

              MULTI-PLAN ANALYSES TO BE PERFORMED
                 NPLAN= 1 NRTIO= 4 LRTIO= 1
   RTIOS=   .10    .15    .50  1.00

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

                   SUB-AREA RUNOFF COMPUTATION

                  INFLOW HYDROGRAPH TO RESERVOIR

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

                         HYDROGRAPH DATA
   IHYDG   IUHG  TAREA   SNAP  TRSDA  TRSPC  RATIO  ISNOW  ISAME  LOCAL
       1      2   1.77   0.00   1.77   0.00  0.000      0      1      0

                           PRECIP DATA
           SPFE    PMS     R6    R12    R24    R48    R72    R96
           0.00  22.00 111.00 123.00 133.00   0.00   0.00   0.00
TRSPC COMPUTED BY THE PROGRAM IS  .000

                            LOSS DATA
   LROPT  STRKR  DLTKR  RTIOL  ERAIN  STRKS  RTIOK  STRTL  CNSTL  ALSMX  RTIMP
       0   0.00   0.00   1.00   0.00   0.00   1.00   1.50    .15   0.00   0.00

                       UNIT HYDROGRAPH DATA
                      TC=  0.00   LAG=  1.10

                          RECESSION DATA
            STRTQ=   -1.00   QRCSN=   -.05   RTIOR= 2.00

   UNIT HYDROGRAPH 24 END OF PERIOD ORDINATES, TC=   0.00 HOURS, LAG=   1.10  VOL= 1.00
     72.     226.     474.     656.     697.     637.     525.     368.     257.     185.
    135.      96.      69.      49.      35.      25.      18.      13.       9.       7.
      5.       4.       2.       1.
```

| 0<br>NO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | END-OF-PERIOD FLOW<br>COMP Q | NO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | .15 | 1 | .03 | 0.00 | .03 | 2. | 1.01 | 12.15 | 49 | .49 | .45 | .04 | 257. |
| 1.01 | .30 | 2 | .03 | 0.00 | .03 | 2. | 1.01 | 12.30 | 50 | .49 | .45 | .04 | 348. |
| 1.01 | .45 | 3 | .03 | 0.00 | .03 | 1. | 1.01 | 12.45 | 51 | .49 | .45 | .04 | 538. |
| 1.01 | 1.00 | 4 | .03 | 0.00 | .03 | 1. | 1.01 | 13.00 | 52 | .49 | .45 | .04 | 802. |
| 1.01 | 1.15 | 5 | .03 | 0.00 | .03 | 1. | 1.01 | 13.15 | 53 | .59 | .55 | .04 | 1088. |
| 1.01 | 1.30 | 6 | .03 | 0.00 | .03 | 1. | 1.01 | 13.30 | 54 | .59 | .55 | .04 | 1365. |
| 1.01 | 1.45 | 7 | .03 | 0.00 | .03 | 1. | 1.01 | 13.45 | 55 | .59 | .55 | .04 | 1622. |
| 1.01 | 2.00 | 8 | .03 | 0.00 | .03 | 1. | 1.01 | 14.00 | 56 | .59 | .55 | .04 | 1834. |
| 1.01 | 2.15 | 9 | .03 | 0.00 | .03 | 1. | 1.01 | 14.15 | 57 | .73 | .70 | .04 | 2015. |
| 1.01 | 2.30 | 10 | .03 | 0.00 | .03 | 1. | 1.01 | 14.30 | 58 | .73 | .70 | .04 | 2185. |
| 1.01 | 2.45 | 11 | .03 | 0.00 | .03 | 1. | 1.01 | 14.45 | 59 | .73 | .70 | .04 | 2359. |
| 1.01 | 3.00 | 12 | .03 | 0.00 | .03 | 1. | 1.01 | 15.00 | 60 | .73 | .70 | .04 | 2533. |
| 1.01 | 3.15 | 13 | .03 | 0.00 | .03 | 1. | 1.01 | 15.15 | 61 | .74 | .70 | .04 | 2695. |
| 1.01 | 3.30 | 14 | .03 | 0.00 | .03 | 1. | 1.01 | 15.30 | 62 | 1.48 | 1.45 | .04 | 2873. |
| 1.01 | 3.45 | 15 | .03 | 0.00 | .03 | 1. | 1.01 | 15.45 | 63 | 4.16 | 4.12 | .04 | 3342. |
| 1.01 | 4.00 | 16 | .03 | 0.00 | .03 | 1. | 1.01 | 16.00 | 64 | 1.04 | 1.00 | .04 | 4151. |
| 1.01 | 4.15 | 17 | .03 | 0.00 | .03 | 1. | 1.01 | 16.15 | 65 | .69 | .65 | .04 | 5236. |
| 1.01 | 4.30 | 18 | .03 | 0.00 | .03 | 1. | 1.01 | 16.30 | 66 | .68 | .65 | .04 | 5931. |
| 1.01 | 4.45 | 19 | .03 | 0.00 | .03 | 0. | 1.01 | 16.45 | 67 | .68 | .65 | .04 | 6143. |
| 1.01 | 5.00 | 20 | .03 | 0.00 | .03 | 0. | 1.01 | 17.00 | 68 | .68 | .65 | .04 | 5853. |
| 1.01 | 5.15 | 21 | .03 | 0.00 | .03 | 0. | 1.01 | 17.15 | 69 | .54 | .50 | .04 | 5303. |
| 1.01 | 5.30 | 22 | .03 | 0.00 | .03 | 0. | 1.01 | 17.30 | 70 | .54 | .50 | .04 | 4591. |
| 1.01 | 5.45 | 23 | .03 | 0.00 | .03 | 0. | 1.01 | 17.45 | 71 | .54 | .50 | .04 | 4019. |
| 1.01 | 6.00 | 24 | .03 | 0.00 | .03 | 0. | 1.01 | 18.00 | 72 | .54 | .50 | .04 | 3592. |
| 1.01 | 6.15 | 25 | .09 | 0.00 | .09 | 0. | 1.01 | 18.15 | 73 | .04 | .01 | .04 | 3222. |
| 1.01 | 6.30 | 26 | .09 | 0.00 | .09 | 0. | 1.01 | 18.30 | 74 | .04 | .01 | .04 | 2940. |
| 1.01 | 6.45 | 27 | .09 | 0.00 | .09 | 0. | 1.01 | 18.45 | 75 | .04 | .01 | .04 | 2436. |
| 1.01 | 7.00 | 28 | .09 | 0.00 | .09 | 0. | 1.01 | 19.00 | 76 | .04 | .01 | .04 | 1938. |
| 1.01 | 7.15 | 29 | .09 | 0.00 | .09 | 0. | 1.01 | 19.15 | 77 | .04 | .01 | .04 | 1492. |
| 1.01 | 7.30 | 30 | .09 | 0.00 | .09 | 0. | 1.01 | 19.30 | 78 | .04 | .01 | .04 | 1106. |
| 1.01 | 7.45 | 31 | .09 | 0.00 | .09 | 0. | 1.01 | 19.45 | 79 | .04 | .01 | .04 | 794. |
| 1.01 | 8.00 | 32 | .09 | 0.00 | .09 | 0. | 1.01 | 20.00 | 80 | .04 | .01 | .04 | 575. |
| 1.01 | 8.15 | 33 | .09 | 0.00 | .09 | 0. | 1.01 | 20.15 | 81 | .04 | .01 | .04 | 421. |
| 1.01 | 8.30 | 34 | .09 | .05 | .04 | 4. | 1.01 | 20.30 | 82 | .04 | .01 | .04 | 311. |
| 1.01 | 8.45 | 35 | .09 | .05 | .04 | 15. | 1.01 | 20.45 | 83 | .04 | .01 | .04 | 280. |
| 1.01 | 9.00 | 36 | .09 | .05 | .04 | 30. | 1.01 | 21.00 | 84 | .04 | .01 | .04 | 260. |
| 1.01 | 9.15 | 37 | .09 | .05 | .04 | 71. | 1.01 | 21.15 | 85 | .04 | .01 | .04 | 250. |
| 1.01 | 9.30 | 38 | .09 | .05 | .04 | 106. | 1.01 | 21.30 | 86 | .04 | .01 | .04 | 234. |
| 1.01 | 9.45 | 39 | .09 | .05 | .04 | 138. | 1.01 | 21.45 | 87 | .04 | .01 | .04 | 218. |
| 1.01 | 10.00 | 40 | .09 | .05 | .04 | 165. | 1.01 | 22.00 | 88 | .04 | .01 | .04 | 203. |
| 1.01 | 10.15 | 41 | .09 | .05 | .04 | 184. | 1.01 | 22.15 | 89 | .04 | .01 | .04 | 190. |
| 1.01 | 10.30 | 42 | .09 | .05 | .04 | 197. | 1.01 | 22.30 | 90 | .04 | .01 | .04 | 177. |
| 1.01 | 10.45 | 43 | .09 | .05 | .04 | 207. | 1.01 | 22.45 | 91 | .04 | .01 | .04 | 165. |
| 1.01 | 11.00 | 44 | .09 | .05 | .04 | 213. | 1.01 | 23.00 | 92 | .04 | .01 | .04 | 154. |
| 1.01 | 11.15 | 45 | .09 | .05 | .04 | 218. | 1.01 | 23.15 | 93 | .04 | .01 | .04 | 144. |
| 1.01 | 11.30 | 46 | .09 | .05 | .04 | 222. | 1.01 | 23.30 | 94 | .04 | .01 | .04 | 134. |
| 1.01 | 11.45 | 47 | .09 | .05 | .04 | 225. | 1.01 | 23.45 | 95 | .04 | .01 | .04 | 125. |
| 1.01 | 12.00 | 48 | .09 | .05 | .04 | 226. | 1.02 | 0.00 | 96 | .04 | .01 | .04 | 117. |
| | | | | | | | | | SUM | 23.41 | 19.55 | 3.86 | 98740. |
| | | | | | | | | | | ( 595.)( | 496.)( | 98.)( | 2569.47) |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6143. | 3311. | 945. | 945. | 90682. |
| CMS | 174. | 94. | 27. | 27. | 2568. |
| INCHES | | 17.48 | 19.86 | 19.86 | 19.86 |
| MM | | 441.94 | 504.39 | 504.39 | 504.39 |
| AC-FT | | 1642. | 1874. | 1874. | 1874. |
| THOUS CU M | | 2025. | 2311. | 2311. | 2311. |

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 4

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2. | 2. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 0. | 0. |
| 0. | 0. | 0. | 4. | 15. | 38. | 0. | 0. | 0. | 0. |
| 104. | 197. | 207. | 213. | 218. | 222. | 71. | 106. | 138. | 165. |
| 530. | 802. | 1088. | 1365. | 1622. | 1834. | 225. | 226. | 257. | 340. |
| 2605. | 2873. | 3342. | 4151. | 5236. | 5991. | 2015. | 2185. | 2359. | 2530. |
| 4019. | 3592. | 3222. | 2840. | 2406. | 1938. | 6143. | 5853. | 5300. | 4591. |
| 421. | 311. | 288. | 260. | 258. | 234. | 1492. | 1106. | 794. | 575. |
| 165. | 154. | 144. | 134. | 125. | 117. | 210. | 203. | 198. | 177. |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6143. | 3311. | 945. | 945. | 90602. |
| CMS | 174. | 94. | 27. | 27. | 2568. |
| INCHES | | 17.40 | 19.86 | 19.86 | 19.86 |
| MM | | 441.94 | 504.39 | 504.39 | 504.39 |
| AC-FT | | 1642. | 1874. | 1874. | 1874. |
| THOUS CU M | | 2025. | 2311. | 2311. | 2311. |

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

HYDROGRAPH ROUTING

ROUTED FLOWS THROUGH RESERVOIR

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | LSTR |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 65. | -1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STAGE | 349.30 | 350.30 | 350.80 | 351.19 | 351.20 | 351.30 | 352.30 | 352.90 | 353.30 | 354.30 |
| | 355.30 | 357.30 | | | | | | | | |
| FLOW | 0.00 | 85.00 | 160.00 | 225.00 | 270.00 | 285.00 | 400.00 | 450.00 | 505.00 | 690.00 |
| | 915.00 | 1455.00 | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CAPACITY= | 0. | 20. | 35. | 65. | 110. | 170. | 300. |
| ELEVATION= | 340. | 345. | 347. | 349. | 352. | 355. | 360. |

| CREL | SPWID | COQW | EXPW | ELEVL | COQL | CAREA | EXPL |
|---|---|---|---|---|---|---|---|
| 349.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

DAM DATA

| TOPEL | COQD | EXPD | DAMWID |
|---|---|---|---|
| 352.9 | 2.6 | 1.5 | 525. |

STATION 2, PLAN 1, RATIO 4

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 1. | 1. | 4. | 9. | 17. | 27. | 40. |
| 53. | 67. | 80. | 99. | 119. | 136. | 151. | 164. | 179. | 202. |
| 245. | 336. | 487. | 619. | 1397. | 1735. | 1935. | 2112. | 2247. | 2402. |
| 2625. | 2799. | 3155. | 3856. | 4480. | 5720. | 6131. | 5965. | 5522. | 4859. |
| 4179. | 3729. | 3347. | 2978. | 2574. | 2130. | 1689. | 1295. | 969. | 726. |
| 559. | 454. | 439. | 425. | 412. | 397. | 378. | 358. | 336. | 316. |
| 297. | 276. | 214. | 200. | 187. | 174. | | | | |

STORAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 66. | 67. | 68. | 70. | 73. |
| 75. | 78. | 81. | 83. | 85. | 87. | 89. | 90. | 92. | 94. |
| 98. | 106. | 118. | 132. | 142. | 146. | 148. | 149. | 151. | 152. |
| 153. | 155. | 158. | 163. | 169. | 176. | 179. | 178. | 174. | 169. |
| 165. | 162. | 159. | 156. | 153. | 149. | 145. | 141. | 139. | 134. |
| 131. | 120. | 125. | 122. | 119. | 115. | 112. | 109. | 106. | 103. |
| 130. | 97. | 95. | 94. | 93. | 91. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.4 | 349.5 | 349.6 | 349.8 |
| 349.9 | 350.1 | 350.2 | 350.4 | 350.5 | 350.6 | 350.7 | 350.8 | 350.9 | 351.1 |
| 351.3 | 351.7 | 352.4 | 353.1 | 353.6 | 353.8 | 353.9 | 354.0 | 354.0 | 354.1 |
| 354.2 | 354.2 | 354.4 | 354.6 | 355.0 | 355.2 | 355.3 | 355.3 | 355.2 | 355.0 |
| 354.7 | 354.6 | 354.4 | 354.3 | 354.2 | 354.8 | 353.8 | 353.6 | 353.4 | 353.2 |
| 353.1 | 352.9 | 352.8 | 352.6 | 352.4 | 352.3 | 352.1 | 351.9 | 351.7 | 351.6 |
| 351.4 | 351.2 | 351.1 | 351.6 | 351.0 | 350.9 | | | | |

PEAK OUTFLOW IS 6131. AT TIME 16.75 HOURS

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6131. | 3295. | 931. | 931. | 89403. |
| CMS | 174. | 93. | 26. | 26. | 2532. |
| INCHES | | 17.33 | 19.58 | 19.58 | 19.58 |
| MM | | 440.21 | 497.27 | 497.27 | 497.27 |
| AC-FT | | 1635. | 1847. | 1847. | 1847. |
| THOUS CU M | | 2017. | 2278. | 2278. | 2278. |

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 2 TO 3

| | ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 1 | 0 | 0 | C | 0 | 1 | C | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.C0 | 1 | 1 | ( | 0 | | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.G00 | C.00G | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
----------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .1CG0 | .1450 | .1009 | 338.0 | 360.0 | 90. | .01000 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC
0.00 363.00 150.00 350.C0 540.00 340.00 540.00 338.00 560.00 338.C0
56C.0G 343.00 1009.00 350.00 1150.00 360.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.00 | .03 | .06 | .18 | .44 | .92 | 1.33 | 1.96 | 2.73 | 3.62 |
| | 4.64 | 5.77 | 6.95 | 8.18 | 9.45 | 10.77 | 12.14 | 13.55 | 15.01 | 16.52 |
| OUTFLOW | 0.00 | 79.60 | 239.51 | 576.77 | 1268.77 | 2454.04 | 4251.13 | 6767.17 | 10101.42 | 14347.29 |
| | 19593.33 | 26473.66 | 34720.18 | 43991.97 | 54282.76 | 65591.57 | 77921.24 | 91277.38 | 105667.72 | 121101.62 |
| STAGE | 338.00 | 339.16 | 340.32 | 341.47 | 342.63 | 343.79 | 344.95 | 346.11 | 347.26 | 348.42 |
| | 349.58 | 350.74 | 351.89 | 353.05 | 354.21 | 355.37 | 356.53 | 357.68 | 358.84 | 360.00 |
| FLOW | 0.00 | 79.60 | 239.51 | 576.77 | 1268.77 | 2454.04 | 4251.13 | 6767.17 | 10101.42 | 14347.29 |
| | 19593.33 | 26473.66 | 34720.18 | 43991.97 | 54282.76 | 65591.57 | 77921.24 | 91277.38 | 105667.72 | 121101.62 |

STATION 3, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 1. | 0. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 1. | 4. | 9. | 17. | 27. | 40. |
| 53. | 67. | 86. | 99. | 119. | 136. | 151. | 164. | 178. | 202. |
| 283. | 346. | 404. | 613. | 1376. | 1745. | 1919. | 2122. | 2273. | 2469. |
| 2613. | 2806. | 3139. | 3052. | 4856. | 5720. | 6120. | 5979. | 5519. | 4877. |
| 4178. | 3742. | 3344. | 2990. | 2574. | 2143. | 1690. | 1366. | 973. | 734. |
| 957. | 459. | 434. | 430. | 408. | 401. | 375. | 361. | 334. | 319. |
| 294. | 279. | 213. | 201. | 186. | 175. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 2. | 2. | 2. | 2. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 |
| 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 |
| 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.0 |
| 338.0 | 338.0 | 338.0 | 338.0 | 338.0 | 338.1 | 338.1 | 338.2 | 338.4 | 338.6 |
| 338.8 | 339.0 | 339.2 | 339.3 | 339.4 | 339.6 | 339.7 | 339.8 | 339.9 | 340.0 |
| 340.5 | 340.6 | 340.9 | 341.5 | 342.7 | 343.1 | 343.3 | 343.5 | 343.6 | 343.8 |
| 343.9 | 344.0 | 344.2 | 344.7 | 345.2 | 345.6 | 345.8 | 345.7 | 345.5 | 345.2 |
| 344.9 | 344.6 | 344.4 | 344.1 | 343.9 | 343.5 | 343.0 | 342.7 | 342.1 | 341.7 |
| 341.4 | 341.1 | 341.0 | 341.0 | 340.9 | 340.9 | 340.8 | 340.7 | 340.6 | 340.6 |
| 340.5 | 340.5 | 340.1 | 340.0 | 339.9 | 339.9 | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6120. | 3298. | 931. | 931. | 89401. |
| CMS | 173. | 93. | 26. | 26. | 2532. |
| INCHES | | 17.33 | 19.58 | 19.58 | 19.58 |
| MM | | 440.25 | 497.26 | 497.26 | 497.26 |
| AC-FT | | 1635. | 1847. | 1847. | 1847. |
| THOUS CU M | | 2017. | 2278. | 2278. | 2278. |

MAXIMUM STORAGE = 2.

MAXIMUM STAGE IS 345.8

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 3 TO 4

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.600 | 0.00 | 1 | 1 | 0 | 0 | | 0 |

| NSTPS | NSTOL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
------------------------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .1000 | .0450 | .1000 | 310.0 | 330.0 | 3950. | .00710 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC

0.00 330.00 400.00 320.00 550.00 312.00 550.00 310.00 600.00 310.00

600.00 312.00 825.00 320.00 1025.00 325.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.00 | 4.77 | 9.57 | 17.17 | 29.48 | 46.49 | 68.22 | 94.86 | 125.81 | 161.66 |
| | 262.65 | 291.25 | 307.90 | 372.58 | 445.30 | 524.92 | 608.70 | 696.49 | 788.30 | 884.13 |
| OUTFLOW | 0.00 | 147.93 | 458.33 | 928.17 | 1608.57 | 2544.39 | 3774.47 | 5334.46 | 7257.86 | 9576.52 |
| | 12109.13 | 15214.90 | 18853.93 | 23153.10 | 28161.55 | 34436.81 | 41646.16 | 49624.50 | 58381.28 | 67927.20 |
| STAGE | 310.00 | 311.05 | 312.11 | 313.16 | 314.21 | 315.26 | 316.32 | 317.37 | 318.42 | 319.47 |
| | 320.53 | 321.58 | 322.63 | 323.68 | 324.74 | 325.79 | 326.84 | 327.89 | 328.95 | 330.60 |
| FLOW | 0.00 | 147.03 | 458.33 | 928.17 | 1608.57 | 2544.39 | 3774.47 | 5334.46 | 7257.86 | 9576.52 |
| | 12109.13 | 15214.90 | 18853.93 | 23153.10 | 28161.55 | 34436.81 | 41646.10 | 49624.50 | 58381.28 | 67927.20 |

STATION 4, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. |
| 0. | 0. | 0. | 0. | 1. | 2. | 4. | 8. | 15. | 24. |
| 35. | 47. | 60. | 74. | 91. | 109. | 126. | 141. | 161. | 184. |
| 231. | 294. | 355. | 478. | 880. | 1370. | 1700. | 1934. | 2125. | 2303. |
| 2476. | 2647. | 2887. | 3336. | 4096. | 5600. | 5707. | 5974. | 5799. | 5331. |
| 4722. | 4145. | 3691. | 3304. | 2919. | 2506. | 2079. | 1658. | 1283. | 969. |
| 720. | 555. | 471. | 440. | 423. | 408. | 392. | 373. | 352. | 331. |
| 312. | 297. | 255. | 217. | 198. | 184. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. |
| 1. | 2. | 2. | 2. | 3. | 4. | 4. | 5. | 5. | 5. |
| 6. | 7. | 8. | 10. | 16. | 25. | 31. | 35. | 39. | 42. |
| 45. | 48. | 53. | 66. | 74. | 89. | 101. | 105. | 102. | 95. |
| 84. | 74. | 67. | 60. | 53. | 46. | 38. | 30. | 24. | 18. |
| 14. | 11. | 10. | 9. | 9. | 9. | 9. | 8. | 8. | 8. |
| 7. | 7. | 6. | 6. | 6. | 5. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.1 | 310.1 | 310.2 |
| 310.2 | 310.3 | 310.4 | 310.5 | 310.6 | 310.8 | 310.9 | 311.0 | 311.1 | 311.2 |
| 311.3 | 311.5 | 311.8 | 312.1 | 313.1 | 313.9 | 314.3 | 314.6 | 314.8 | 315.0 |
| 315.2 | 315.4 | 315.6 | 315.9 | 316.5 | 317.1 | 317.6 | 317.7 | 317.6 | 317.4 |
| 317.0 | 316.6 | 316.2 | 315.9 | 315.6 | 315.2 | 314.7 | 314.3 | 313.7 | 313.2 |
| 312.7 | 312.3 | 312.1 | 312.0 | 312.0 | 311.9 | 311.9 | 311.8 | 311.7 | 311.7 |
| 311.6 | 311.5 | 311.4 | 311.3 | 311.2 | 311.2 | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 5974. | 3284. | 929. | 929. | 89143. |
| CMS | 169. | 93. | 26. | 26. | 2524. |
| INCHES | | 17.26 | 19.52 | 19.52 | 19.52 |
| MM | | 438.33 | 495.82 | 495.82 | 495.82 |
| AC-FT | | 1628. | 1842. | 1842. | 1842. |
| THOUS CU M | | 2008. | 2272. | 2272. | 2272. |

MAXIMUM STORAGE = 105.

MAXIMUM STAGE IS 317.7

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 4 TO 5

| | ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
----------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .0500 | .0450 | .0500 | 286.0 | 300.0 | 2400. | .01000 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC

0.00 303.00 250.00 290.00 375.00 288.00 375.00 286.00 425.00 286.00
425.00 288.00 900.00 290.00 1450.00 300.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.00 | 2.03 | 4.06 | 6.46 | 15.54 | 33.59 | 59.55 | 88.50 | 119.84 | 153.58 |
| | 189.71 | 228.24 | 269.16 | 312.47 | 358.17 | 406.27 | 456.76 | 509.64 | 564.92 | 622.59 |
| OUTFLOW | 0.00 | 97.61 | 304.11 | 594.37 | 1196.69 | 2512.86 | 5012.90 | 8687.91 | 13357.83 | 19016.67 |
| | 25674.83 | 33351.33 | 42070.11 | 51858.13 | 62744.18 | 74758.24 | 87930.98 | 102293.51 | 117877.14 | 134713.29 |
| STAGE | 286.00 | 286.74 | 287.47 | 288.21 | 288.95 | 289.68 | 290.42 | 291.16 | 291.89 | 292.63 |
| | 293.37 | 294.11 | 294.84 | 295.58 | 296.32 | 297.05 | 297.79 | 298.53 | 299.26 | 300.00 |
| FLOW | 0.00 | 97.61 | 304.11 | 594.37 | 1196.69 | 2512.86 | 5012.90 | 8687.91 | 13357.83 | 19016.67 |
| | 25674.83 | 33351.33 | 42070.11 | 51858.13 | 62744.18 | 74758.24 | 87930.98 | 102293.51 | 117877.14 | 134713.29 |

STATION 9, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 2. | 2. | 2. | 2. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. |
| 0. | 0. | 0. | 0. | 1. | 1. | 2. | 5. | 9. | 16. |
| 25. | 35. | 47. | 60. | 75. | 92. | 119. | 134. | 151. | 173. |
| 208. | 264. | 328. | 426. | 677. | 1045. | 1464. | 1771. | 1993. | 2103. |
| 2360. | 2536. | 2767. | 3111. | 3715. | 4546. | 5390. | 5900. | 5804. | 5522. |
| 4966. | 4435. | 3919. | 3499. | 3113. | 2713. | 2324. | 1933. | 1534. | 1183. |
| 908. | 688. | 527. | 447. | 430. | 414. | 398. | 380. | 360. | 340. |
| 319. | 300. | 273. | 235. | 207. | 191. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1. | 1. | 1. | 1. | 2. | 2. | 2. | 2. | 3. | 3. |
| 3. | 4. | 4. | 5. | 8. | 13. | 19. | 23. | 25. | 29. |
| 32. | 34. | 36. | 40. | 46. | 55. | 63. | 67. | 66. | 64. |
| 59. | 54. | 48. | 44. | 40. | 36. | 31. | 26. | 20. | 15. |
| 11. | 8. | 6. | 5. | 5. | 5. | 5. | 5. | 5. | 4. |
| 4. | 4. | 4. | 3. | 3. | 3. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.1 | 286.1 |
| 286.2 | 286.3 | 286.4 | 286.5 | 286.6 | 286.7 | 286.8 | 286.9 | 286.9 | 287.0 |
| 287.1 | 287.3 | 287.5 | 287.8 | 288.3 | 288.8 | 289.1 | 289.3 | 289.4 | 289.5 |
| 289.6 | 289.7 | 289.8 | 289.9 | 290.0 | 290.3 | 290.5 | 290.6 | 290.6 | 290.5 |
| 290.4 | 290.3 | 290.1 | 290.0 | 289.9 | 289.7 | 289.6 | 289.4 | 289.1 | 288.9 |
| 288.6 | 288.3 | 288.0 | 287.8 | 287.8 | 287.8 | 287.7 | 287.7 | 287.6 | 287.6 |
| 287.5 | 287.5 | 287.4 | 287.2 | 287.1 | 287.1 | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 5930. | 3279. | 927. | 927. | 89000. |
| CMS | 167. | 93. | 26. | 26. | 2520. |
| INCHES | | 17.23 | 19.49 | 19.49 | 19.49 |
| MM | | 437.74 | 495.03 | 495.03 | 495.03 |
| AC-FT | | 1626. | 1839. | 1839. | 1839. |
| THOUS CU M | | 2006. | 2268. | 2268. | 2268. |

MAXIMUM STORAGE = 67.

MAXIMUM STAGE IS 290.6

No Breach

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| OPERATION | STATION | AREA | PLAN | RATIO 1 .10 | RATIO 2 .15 | RATIO 3 .50 | RATIO 4 1.00 |
|---|---|---|---|---|---|---|---|
| | | | | RATIOS APPLIED TO FLOWS | | | |
| HYDROGRAPH AT | 1 | 1.77 | 1 | 614. | 922. | 3072. | 6143. |
| | ( | 4.58) | ( | 17.40)( | 26.09)( | 86.98)( | 173.96)( |
| ROUTED TO | 2 | 1.77 | 1 | 419. | 842. | 3060. | 6131. |
| | ( | 4.58) | ( | 11.87)( | 23.84)( | 86.65)( | 173.61)( |
| ROUTED TO | 3 | 1.77 | 1 | 420. | 840. | 3063. | 6120. |
| | ( | 4.58) | ( | 11.90)( | 23.78)( | 86.74)( | 173.31)( |
| ROUTED TO | 4 | 1.77 | 1 | 418. | 804. | 2972. | 5974. |
| | ( | 4.58) | ( | 11.83)( | 22.77)( | 84.17)( | 169.16)( |
| ROUTED TO | 5 | 1.77 | 1 | 418. | 786. | 2937. | 5900. |
| | ( | 4.58) | ( | 11.83)( | 22.25)( | 83.16)( | 167.08)( |

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ..............

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 349.30 | 349.30 | 352.90 |
| STORAGE | 65. | 65. | 128. |
| OUTFLOW | 0. | 0. | 450. |

No BREACH

| 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 | 352.53 | 0.00 | 121. | 419. | 0.00 | 17.75 | 0.00 |
| .15 | 353.29 | .39 | 136. | 842. | 2.00 | 17.00 | 0.00 |
| .50 | 354.34 | 1.44 | 157. | 3060. | 5.75 | 16.75 | 0.00 |
| 1.00 | 355.33 | 2.43 | 179. | 6131. | 7.25 | 16.75 | 0.00 |

PLAN 1 STATION 3

| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 420. | 340.9 | 17.75 |
| .15 | 840. | 341.9 | 17.25 |
| .50 | 3063. | 344.2 | 16.75 |
| 1.00 | 6120. | 345.8 | 16.75 |

PLAN 1 STATION 4

| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 418. | 312.0 | 18.00 |
| .15 | 804. | 312.9 | 17.25 |
| .50 | 2972. | 315.6 | 17.00 |
| 1.00 | 5974. | 317.7 | 17.00 |

PLAN 1 STATION 5

| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 418. | 287.8 | 18.00 |
| .15 | 786. | 288.4 | 17.50 |
| .50 | 2937. | 289.8 | 17.25 |
| 1.00 | 5900. | 290.6 | 17.00 |

```
  FLOOD HYDROGRAPH PACKAGE (HEC-1)
  DAM SAFETY VERSION        JULY 1978
    LAST MODIFICATION  25 SEP 78
  ********************************
A1        NEW JERSEY DAM SAFETY - CRYSTAL SPRING LAKE DAM  I.D. NO. 00231
A2        HYDRAULIC-HYDROLOGIC ANALYSIS   302-03
A3        PROBABLE MAXIMUM FLOOD                                     -RBE-
B      96       0      15       0       0       0       0       0       0       0
B1      5
J       1       4       1
J1    0.1    0.15    0.50     1.0
K       0       1                                       1
K1                      INFLOW HYDROGRAPH TO RESERVOIR
M       1       2    1.77            1.77                               1
P            22.0     111     123     133
T                                                     1.5    0.15
W2            1.1
X      -1    -.05     2.0
K       1       2                                       1
K1                      ROUTED FLOWS THROUGH RESERVOIR
Y                               1       1
Y1      1                                              65      -1
Y4  349.3   350.3   350.8  351.19  351.20   351.3   352.3   352.9   353.3   354.3
Y4  355.3   357.3
Y5      0      65     160     225     270     285     400     450     505     690
Y5    915    1455
$S      0      20      35      65     110     170     300
$E    340     345     347   349.3     352     355     360
$$  349.3
$D  352.9     2.6     1.5     525
$9    270       0     140       4   349.3   352.9
K       1       3                                       1
K1        CHANNEL ROUTING -MODIFIED PULS- STATION 2 TO 3
Y                               1       1
Y1      1
Y6   0.10   0.045    0.10     330     360      50    0.01
Y7      0     360     150     350     540     340     540     330     560     330
Y7    560     340    1000     350    1150     360
K       1       4                                       1
K1        CHANNEL ROUTING -MODIFIEG PULS- STATION 3 TO 4
Y                               1       1
Y1      1
Y6   0.10   0.045    0.10     310     330    2950  0.0071
Y7      0     330     400     320     550     312     550     310     600     310
Y7    600     312     825     320    1025     325
K       1       5                                       1
K1        CHANNEL ROUTING -MODIFIED PULS- STATION 4 TO 5
Y                               1       1
Y1      1
Y6   0.05   0.045    0.05     286     300    2400    0.01
Y7      0     300     250     290     375     280     375     286     425     286
Y7    425     280     900     290    1450     300
K      99
```

BREACH CALC

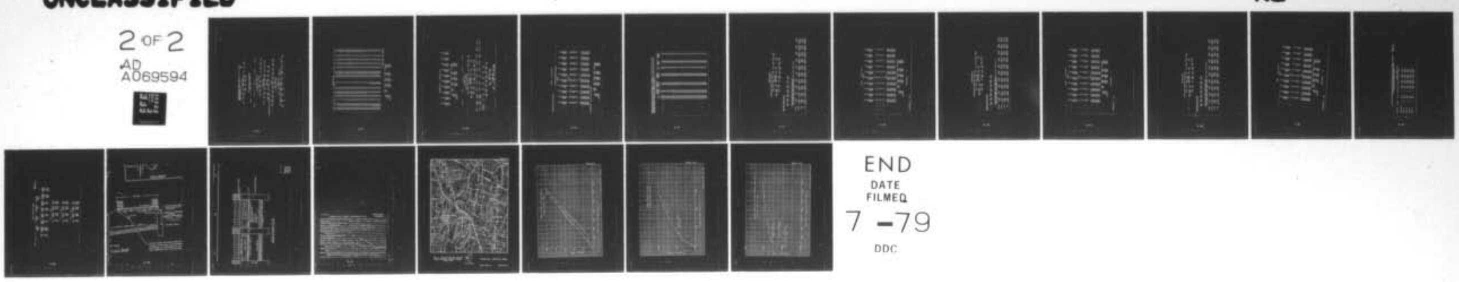
PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

| | |
|---|---|
| RUNOFF HYDROGRAPH AT | 1 |
| ROUTE HYDROGRAPH TO | 2 |
| ROUTE HYDROGRAPH TO | 3 |
| ROUTE HYDROGRAPH TO | 4 |
| ROUTE HYDROGRAPH TO | 5 |
| END OF NETWORK | |

AD-A069 594 NEW JERSEY STATE DEPT OF ENVIRONMENTAL PROTECTION TRENTON F/G 13/2
NATIONAL DAM SAFETY PROGRAM. CRYSTAL SPRING LAKE (NJ 00231), PA--ETC(U)
MAY 79 R J JENNY DACW61-78-C-0124

UNCLASSIFIED NL

2 OF 2
AD
A069594



END
DATE
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```
                    NEW JERSEY DAM SAFETY - CRYSTAL SPRING LAKE DAM  I.D. NO. 00231
                    HYDRAULIC-HYDROLOGIC ANALYSIS   302-03
                    PROBABLE MAXIMUM FLOOD                                      -RBE-

                                        JOB SPECIFICATION
            NQ      NHR     NMIN    IDAY     IHR     IMIN   METRC    IPLT    IPRT   NSTAN
            96        0      15        0       0        0       0       0       0       0
                                   JOPER     NWT    LROPT   TRACE
                                       5       0        0       0

                                   MULTI-PLAN ANALYSES TO BE PERFORMED
                                       NPLAN= 1 NRTIO= 4 LRTIO= 1
            RTIOS=    .10     .15    .53    1.03

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

                                    SUB-AREA RUNOFF COMPUTATION

                                  INFLOW HYDROGRAPH TO RESERVOIR

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

                                          HYDROGRAPH DATA
            IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                1       2    1.77    0.00    1.77    0.00   0.000       0       1       0

                                            PRECIP DATA
                       SPFE     PMS      R6     R12     R24     R48     R72     R96
                       0.00   22.00  111.00  123.00  133.00    0.00    0.00    0.00
TRSPC COMPUTED BY THE PROGRAM IS  .000

                                             LOSS DATA
          LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
              0    0.00    0.00    1.00    0.00    0.00    1.00    1.50     .15    0.00    0.00

                                       UNIT HYDROGRAPH DATA
                                     TC=  0.00    LAG=  1.10

                                          RECESSION DATA
                          STRTQ=   -1.00    QRCSN=    -.05    RTIOR= 2.00

            UNIT HYDROGRAPH 24 END OF PERIOD ORDINATES, TC=    0.00 HOURS, LAG=   1.10  VOL= 1.00
          72.      226.      474.      656.      697.      637.      525.      360.      257.      185.
         135.       96.       69.       49.       35.       25.       18.       13.        9.        7.
           5.        4.        2.        1.
```

| MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | END-OF-PERIOD FLOW COMP Q | MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.01 | .15 | 1 | .03 | 0.00 | .03 | 2. | 1.01 | 12.15 | 49 | .49 | .45 | .04 | 257. |
| 1.01 | .30 | 2 | .03 | 0.00 | .03 | 2. | 1.01 | 12.30 | 50 | .49 | .45 | .04 | 346. |
| 1.01 | .45 | 3 | .03 | 0.00 | .03 | 1. | 1.01 | 12.45 | 51 | .49 | .45 | .04 | 536. |
| 1.01 | 1.00 | 4 | .03 | 0.00 | .03 | 1. | 1.01 | 13.00 | 52 | .49 | .45 | .04 | 702. |
| 1.01 | 1.15 | 5 | .03 | 0.00 | .03 | 1. | 1.01 | 13.15 | 53 | .59 | .55 | .04 | 1040. |
| 1.01 | 1.30 | 6 | .03 | 0.00 | .03 | 1. | 1.01 | 13.30 | 54 | .59 | .55 | .04 | 1365. |
| 1.01 | 1.45 | 7 | .03 | 0.00 | .03 | 1. | 1.01 | 13.45 | 55 | .59 | .55 | .04 | 1622. |
| 1.01 | 2.00 | 8 | .03 | 0.00 | .03 | 1. | 1.01 | 14.00 | 56 | .59 | .55 | .04 | 1834. |
| 1.01 | 2.15 | 9 | .03 | 0.00 | .03 | 1. | 1.01 | 14.15 | 57 | .73 | .70 | .04 | 2315. |
| 1.01 | 2.30 | 10 | .03 | 0.00 | .03 | 1. | 1.01 | 14.30 | 58 | .73 | .70 | .04 | 2105. |
| 1.01 | 2.45 | 11 | .03 | 0.00 | .03 | 1. | 1.01 | 14.45 | 59 | .73 | .70 | .04 | 2354. |
| 1.01 | 3.00 | 12 | .03 | 0.00 | .03 | 1. | 1.01 | 15.00 | 60 | .73 | .70 | .04 | 2536. |
| 1.01 | 3.15 | 13 | .03 | 0.00 | .03 | 1. | 1.01 | 15.15 | 61 | .74 | .70 | .04 | 2605. |
| 1.01 | 3.30 | 14 | .03 | 0.00 | .03 | 1. | 1.01 | 15.30 | 62 | 1.48 | 1.45 | .04 | 2873. |
| 1.01 | 3.45 | 15 | .03 | 0.00 | .03 | 1. | 1.01 | 15.45 | 63 | 4.16 | 4.12 | .04 | 3342. |
| 1.01 | 4.00 | 16 | .03 | 0.00 | .03 | 1. | 1.01 | 16.00 | 64 | 1.08 | 1.04 | .04 | 4151. |
| 1.01 | 4.15 | 17 | .03 | 0.00 | .03 | 1. | 1.01 | 16.15 | 65 | .68 | .65 | .04 | 5236. |
| 1.01 | 4.30 | 18 | .03 | 0.00 | .03 | 1. | 1.01 | 16.30 | 66 | .68 | .65 | .04 | 5741. |
| 1.01 | 4.45 | 19 | .03 | 0.00 | .03 | 0. | 1.01 | 16.45 | 67 | .68 | .65 | .04 | 6143. |
| 1.01 | 5.00 | 20 | .03 | 0.00 | .03 | 0. | 1.01 | 17.00 | 68 | .68 | .65 | .04 | 5853. |
| 1.01 | 5.15 | 21 | .03 | 0.00 | .03 | 0. | 1.01 | 17.15 | 69 | .54 | .50 | .04 | 5360. |
| 1.01 | 5.30 | 22 | .03 | 0.00 | .03 | 0. | 1.01 | 17.30 | 70 | .54 | .50 | .04 | 4591. |
| 1.01 | 5.45 | 23 | .03 | 0.00 | .03 | 0. | 1.01 | 17.45 | 71 | .54 | .50 | .04 | 4619. |
| 1.01 | 6.00 | 24 | .03 | 0.00 | .03 | 0. | 1.01 | 18.00 | 72 | .54 | .50 | .04 | 3992. |
| 1.01 | 6.15 | 25 | .09 | 0.00 | .09 | 0. | 1.01 | 18.15 | 73 | .04 | .01 | .04 | 3222. |
| 1.01 | 6.30 | 26 | .09 | 0.00 | .09 | 0. | 1.01 | 18.30 | 74 | .04 | .01 | .04 | 2846. |
| 1.01 | 6.45 | 27 | .09 | 0.00 | .09 | 0. | 1.01 | 18.45 | 75 | .04 | .01 | .04 | 2456. |
| 1.01 | 7.00 | 28 | .09 | 0.00 | .09 | 0. | 1.01 | 19.00 | 76 | .04 | .01 | .04 | 1932. |
| 1.01 | 7.15 | 29 | .09 | 0.00 | .09 | 0. | 1.01 | 19.15 | 77 | .04 | .01 | .04 | 1492. |
| 1.01 | 7.30 | 30 | .09 | 0.00 | .09 | 0. | 1.01 | 19.30 | 78 | .04 | .01 | .04 | 1106. |
| 1.01 | 7.45 | 31 | .09 | 0.00 | .09 | 0. | 1.01 | 19.45 | 79 | .04 | .01 | .04 | 794. |
| 1.01 | 8.00 | 32 | .09 | 0.00 | .09 | 0. | 1.01 | 20.00 | 80 | .04 | .01 | .04 | 575. |
| 1.01 | 8.15 | 33 | .09 | 0.00 | .09 | 0. | 1.01 | 20.15 | 81 | .04 | .01 | .04 | 421. |
| 1.01 | 8.30 | 34 | .09 | .05 | .04 | 4. | 1.01 | 20.30 | 82 | .04 | .01 | .04 | 311. |
| 1.01 | 8.45 | 35 | .09 | .05 | .04 | 15. | 1.01 | 20.45 | 83 | .04 | .01 | .04 | 246. |
| 1.01 | 9.00 | 36 | .09 | .05 | .04 | 38. | 1.01 | 21.00 | 84 | .04 | .01 | .04 | 266. |
| 1.01 | 9.15 | 37 | .09 | .05 | .04 | 71. | 1.01 | 21.15 | 85 | .04 | .01 | .04 | 256. |
| 1.01 | 9.30 | 38 | .09 | .05 | .04 | 106. | 1.01 | 21.30 | 86 | .04 | .01 | .04 | 234. |
| 1.01 | 9.45 | 39 | .09 | .05 | .04 | 136. | 1.01 | 21.45 | 87 | .04 | .01 | .04 | 210. |
| 1.01 | 10.00 | 40 | .09 | .05 | .04 | 165. | 1.01 | 22.00 | 88 | .04 | .01 | .04 | 203. |
| 1.01 | 10.15 | 41 | .09 | .05 | .04 | 194. | 1.01 | 22.15 | 89 | .04 | .01 | .04 | 193. |
| 1.01 | 10.30 | 42 | .09 | .05 | .04 | 197. | 1.01 | 22.30 | 90 | .04 | .01 | .04 | 177. |
| 1.01 | 10.45 | 43 | .09 | .05 | .04 | 207. | 1.01 | 22.45 | 91 | .04 | .01 | .04 | 165. |
| 1.01 | 11.00 | 44 | .09 | .05 | .04 | 213. | 1.01 | 23.00 | 92 | .04 | .01 | .04 | 154. |
| 1.01 | 11.15 | 45 | .09 | .05 | .04 | 218. | 1.01 | 23.15 | 93 | .04 | .01 | .04 | 144. |
| 1.01 | 11.30 | 46 | .09 | .05 | .04 | 222. | 1.01 | 23.30 | 94 | .04 | .01 | .04 | 134. |
| 1.01 | 11.45 | 47 | .09 | .05 | .04 | 225. | 1.01 | 23.45 | 95 | .04 | .01 | .04 | 125. |
| 1.01 | 12.00 | 48 | .09 | .05 | .04 | 226. | 1.02 | 0.00 | 96 | .04 | .01 | .04 | 117. |
| | | | | | | | | | SUM | 23.41 | 19.95 | 3.46 | 90743. |
| | | | | | | | | | | ( 595.) | ( 490.) | ( 90.) | ( 2569.47) |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6143. | 3311. | 945. | 945. | 90682. |
| CMS | 174. | 94. | 27. | 27. | 2568. |
| INCHES | | 17.40 | 19.66 | 19.66 | 19.66 |
| MM | | 441.94 | 984.39 | 984.39 | 984.39 |
| AC-FT | | 1642. | 1874. | 1874. | 1874. |
| THOUS CU M | | 2025. | 2311. | 2311. | 2311. |

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 4

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2. | 2. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 3. | 3. | 0. | 0. | 0. |
| 0. | 0. | 0. | 4. | 15. | 38. | 71. | 100. | 130. | 165. |
| 184. | 197. | 207. | 213. | 218. | 222. | 225. | 226. | 227. | 228. |
| 538. | 802. | 1088. | 1365. | 1622. | 1834. | 2015. | 2165. | 2259. | 2333. |
| 2685. | 2873. | 3342. | 4151. | 5236. | 5991. | 6143. | 5853. | 5338. | 4591. |
| 4819. | 3592. | 3222. | 2848. | 2486. | 1938. | 1492. | 1166. | 794. | 575. |
| 421. | 311. | 288. | 268. | 250. | 234. | 218. | 203. | 190. | 177. |
| 165. | 154. | 144. | 134. | 125. | 117. | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6143. | 3311. | 945. | 945. | 96662. |
| CMS | 174. | 94. | 27. | 27. | 2564. |
| INCHES | | 17.40 | 19.86 | 19.86 | 19.86 |
| MM | | 441.94 | 504.39 | 504.39 | 504.39 |
| AC-FT | | 1642. | 1874. | 1874. | 1874. |
| THOUS CU M | | 2025. | 2311. | 2311. | 2311. |

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

HYDROGRAPH ROUTING

ROUTED FLOWS THROUGH RESERVOIR

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | LSTR |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 65. | -1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STAGE | 349.30 | 350.30 | 350.80 | 351.19 | 351.20 | 351.30 | 352.30 | 352.90 | 353.30 | 354.30 |
| | 355.30 | 357.30 | | | | | | | | |
| FLOW | 0.00 | 85.00 | 160.00 | 225.00 | 270.00 | 285.00 | 400.00 | 450.00 | 505.00 | 690.00 |
| | 915.00 | 1455.00 | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CAPACITY= | 0. | 20. | 35. | 65. | 110. | 170. | 300. |
| ELEVATION= | 340. | 345. | 347. | 349. | 352. | 355. | 360. |

| CREL | SPWID | COQW | EXPW | ELEVL | COQL | CAREA | EXPL |
|---|---|---|---|---|---|---|---|
| 349.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

DAM DATA

| TOPEL | COQD | EXPD | DAMWID |
|---|---|---|---|
| 352.9 | 2.6 | 1.5 | 525. |

DAM BREACH DATA

| BRWID | Z | ELBM | TFAIL | WSEL | FAILEL |
|---|---|---|---|---|---|
| 270. | 0.00 | 340.00 | 4.00 | 349.30 | 352.90 |

STATION 2, PLAN 1, RATIO 4

BEGIN DAM FAILURE AT 13.50 HOURS

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 1. | 1. | 4. | 9. | 17. | 27. | 46. |
| 93. | 67. | 80. | 99. | 119. | 136. | 151. | 164. | 179. | 202. |
| 205. | 336. | 407. | 664. | 1017. | 2227. | 2619. | 2762. | 2863. | 3062. |
| 3244. | 3350. | 3700. | 4424. | 5440. | 6382. | 6414. | 6189. | 5500. | 4009. |
| 4066. | 3626. | 3250. | 2880. | 2456. | 1992. | 1546. | 1155. | 830. | 607. |
| 447. | 331. | 207. | 275. | 255. | 230. | 222. | 200. | 194. | 181. |
| 169. | 150. | 147. | 137. | 120. | 120. | | | | |

STORAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. | 65. |
| 65. | 65. | 65. | 65. | 65. | 66. | 67. | 68. | 70. | 73. |
| 79. | 70. | 81. | 83. | 85. | 87. | 89. | 90. | 92. | 94. |
| 99. | 106. | 118. | 132. | 135. | 129. | 118. | 105. | 94. | 83. |
| 72. | 61. | 53. | 47. | 42. | 36. | 30. | 23. | 17. | 13. |
| 12. | 11. | 10. | 9. | 8. | 7. | 6. | 5. | 4. | 3. |
| 3. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 |
| 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.3 | 349.4 | 349.5 | 349.6 | 349.8 |
| 349.9 | 350.1 | 350.2 | 350.4 | 350.5 | 350.6 | 350.7 | 350.8 | 350.9 | 351.1 |
| 351.3 | 351.7 | 352.4 | 353.1 | 353.3 | 352.9 | 352.4 | 351.7 | 351.0 | 350.4 |
| 349.7 | 349.0 | 348.4 | 347.9 | 347.5 | 347.1 | 346.3 | 345.4 | 344.3 | 343.2 |
| 342.9 | 342.7 | 342.5 | 342.3 | 342.1 | 341.8 | 341.5 | 341.2 | 341.0 | 340.8 |
| 340.7 | 340.5 | 340.5 | 340.5 | 340.5 | 340.4 | 340.4 | 340.4 | 340.4 | 340.4 |
| 340.3 | 340.3 | 340.3 | 340.3 | 340.3 | 340.3 | | | | |

PEAK OUTFLOW IS 6414. AT TIME 16.75 HOURS

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6414. | 3561. | 976. | 976. | 93659. |
| CMS | 182. | 101. | 28. | 28. | 2652. |
| INCHES | | 18.72 | 20.51 | 20.51 | 20.51 |
| MM | | 475.40 | 520.94 | 520.94 | 520.94 |
| AC-FT | | 1766. | 1935. | 1935. | 1935. |
| THOUS CU M | | 2178. | 2387. | 2387. | 2387. |

THE DAM BREACH HYDROGRAPH WAS DEVELOPED USING A TIME INTERVAL OF .083 HOURS DURING BREACH FORMATION.
DOWNSTREAM CALCULATIONS WILL USE A TIME INTERVAL OF .250 HOURS.
THIS TABLE COMPARES THE HYDROGRAPH FOR DOWNSTREAM CALCULATIONS WITH THE COMPUTED BREACH HYDROGRAPH.
INTERMEDIATE FLOWS ARE INTERPOLATED FROM END-OF-PERIOD VALUES.

| TIME (HOURS) | TIME FROM BEGINNING OF BREACH (HOURS) | INTERPOLATED BREACH HYDROGRAPH (CFS) | - | COMPUTED BREACH HYDROGRAPH (CFS) | = | ERROR (CFS) | ACCUMULATED ERROR (CFS) | ACCUMULATED ERROR (AC-FT) |
|---|---|---|---|---|---|---|---|---|
| 13.500 | 0.000 | 664. | | 664. | | 0. | 0. | 0. |
| 13.583 | .083 | 1048. | | 1202. | | -154. | -154. | -1. |
| 13.667 | .167 | 1432. | | 1583. | | -151. | -305. | -2. |
| 13.750 | .250 | 1817. | | 1817. | | -0. | -305. | -2. |
| 13.833 | .333 | 1953. | | 1973. | | -20. | -325. | -2. |
| 13.917 | .417 | 2090. | | 2100. | | -10. | -334. | -2. |
| 14.000 | .500 | 2227. | | 2227. | | 0. | -334. | -2. |
| 14.083 | .583 | 2357. | | 2391. | | -33. | -368. | -3. |
| 14.167 | .667 | 2488. | | 2520. | | -32. | -399. | -3. |
| 14.250 | .750 | 2619. | | 2619. | | 0. | -399. | -3. |
| 14.333 | .833 | 2666. | | 2697. | | -31. | -430. | -3. |
| 14.417 | .917 | 2714. | | 2756. | | -41. | -471. | -3. |
| 14.500 | 1.000 | 2762. | | 2762. | | 0. | -471. | -3. |
| 14.583 | 1.083 | 2796. | | 2798. | | -2. | -473. | -3. |
| 14.667 | 1.167 | 2829. | | 2845. | | -16. | -489. | -3. |
| 14.750 | 1.250 | 2863. | | 2863. | | 0. | -489. | -3. |
| 14.833 | 1.333 | 2929. | | 2934. | | -5. | -494. | -3. |
| 14.917 | 1.417 | 2996. | | 3000. | | -5. | -499. | -3. |
| 15.000 | 1.500 | 3062. | | 3062. | | 0. | -499. | -3. |
| 15.083 | 1.583 | 3123. | | 3126. | | -3. | -502. | -3. |
| 15.167 | 1.667 | 3183. | | 3187. | | -4. | -507. | -3. |
| 15.250 | 1.750 | 3244. | | 3244. | | 0. | -507. | -3. |
| 15.333 | 1.833 | 3279. | | 3301. | | -22. | -528. | -4. |
| 15.417 | 1.917 | 3315. | | 3349. | | -34. | -563. | -4. |
| 15.500 | 2.000 | 3350. | | 3350. | | 0. | -563. | -4. |
| 15.583 | 2.083 | 3469. | | 3426. | | 44. | -519. | -4. |
| 15.667 | 2.167 | 3589. | | 3558. | | 31. | -488. | -3. |
| 15.750 | 2.250 | 3708. | | 3708. | | 0. | -488. | -3. |
| 15.833 | 2.333 | 3947. | | 3905. | | 42. | -446. | -3. |
| 15.917 | 2.417 | 4186. | | 4156. | | 29. | -416. | -3. |
| 16.000 | 2.500 | 4424. | | 4424. | | 0. | -416. | -3. |
| 16.083 | 2.583 | 4765. | | 4731. | | 34. | -382. | -3. |
| 16.167 | 2.667 | 5107. | | 5083. | | 23. | -359. | -2. |
| 16.250 | 2.750 | 5448. | | 5448. | | 0. | -359. | -2. |
| 16.333 | 2.833 | 5732. | | 5772. | | -40. | -399. | -3. |
| 16.417 | 2.917 | 6017. | | 6044. | | -27. | -425. | -3. |
| 16.500 | 3.000 | 6302. | | 6302. | | 0. | -425. | -3. |
| 16.583 | 3.083 | 6339. | | 6380. | | -41. | -466. | -3. |
| 16.667 | 3.167 | 6377. | | 6358. | | 18. | -448. | -3. |
| 16.750 | 3.250 | 6414. | | 6414. | | 0. | -448. | -3. |
| 16.833 | 3.333 | 6339. | | 6386. | | -47. | -495. | -3. |
| 16.917 | 3.417 | 6264. | | 6285. | | -21. | -516. | -4. |
| 17.000 | 3.500 | 6189. | | 6189. | | 0. | -516. | -4. |
| 17.083 | 3.583 | 5959. | | 6046. | | -87. | -603. | -4. |
| 17.167 | 3.667 | 5730. | | 5690. | | 39. | -564. | -4. |
| 17.250 | 3.750 | 5500. | | 5500. | | 0. | -564. | -4. |
| 17.333 | 3.833 | 5269. | | 5284. | | -14. | -578. | -4. |
| 17.417 | 3.917 | 5039. | | 5042. | | -3. | -581. | -4. |
| 17.500 | 4.000 | 4809. | | 4809. | | 0. | -581. | -4. |

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 2 TO 3

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
----------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .1000 | .0450 | .1000 | 338.0 | 360.0 | 50. | .01000 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC
0.00 340.00 150.00 350.00 540.00 340.00 540.00 330.00 560.00 330.00
560.00 340.00 1000.00 350.00 1150.00 360.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.00 | .03 | .06 | .18 | .44 | .82 | 1.33 | 1.96 | 2.73 | 3.62 |
| | 4.64 | 5.77 | 6.95 | 8.18 | 9.45 | 10.77 | 12.14 | 13.56 | 15.01 | 16.52 |
| OUTFLOW | 0.00 | 78.60 | 239.51 | 576.77 | 1260.77 | 2454.34 | 4251.13 | 6767.17 | 10101.42 | 14347.25 |
| | 19593.33 | 26473.66 | 34720.10 | 43991.97 | 54282.76 | 65591.57 | 77921.24 | 91277.30 | 105667.72 | 121131.62 |
| STAGE | 338.00 | 339.16 | 340.32 | 341.47 | 342.63 | 343.79 | 344.95 | 346.11 | 347.26 | 348.42 |
| | 349.58 | 350.74 | 351.89 | 353.05 | 354.21 | 355.37 | 356.53 | 357.68 | 358.84 | 360.00 |
| FLOW | 0.00 | 78.60 | 239.51 | 576.77 | 1260.77 | 2454.34 | 4251.13 | 6767.17 | 10101.42 | 14347.25 |
| | 19593.33 | 26473.66 | 34720.10 | 43991.97 | 54282.76 | 65591.57 | 77921.24 | 91277.30 | 105667.72 | 121131.62 |

STATION 3, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 1. | 0. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 1. | 4. | 9. | 17. | 27. | 40. |
| 53. | 67. | 80. | 99. | 119. | 136. | 151. | 164. | 178. | 202. |
| 283. | 336. | 404. | 657. | 1705. | 2244. | 2591. | 2784. | 2839. | 3079. |
| 3223. | 3367. | 3603. | 4430. | 5410. | 6310. | 6404. | 6204. | 5502. | 4023. |
| 4071. | 3634. | 3261. | 2807. | 2460. | 2002. | 1550. | 1164. | 841. | 612. |
| 440. | 335. | 285. | 277. | 254. | 240. | 221. | 209. | 193. | 182. |
| 160. | 159. | 146. | 139. | 128. | 121. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 2. | 2. | 2. | 2. | 2. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 |
| 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 |
| 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.0 |
| 330.0 | 330.0 | 330.0 | 330.0 | 330.0 | 330.1 | 330.1 | 330.2 | 330.4 | 332.6 |
| 338.4 | 339.0 | 339.2 | 339.3 | 339.4 | 339.6 | 339.7 | 339.8 | 339.9 | 340.0 |
| 340.5 | 340.6 | 340.9 | 341.6 | 343.1 | 343.6 | 343.9 | 344.0 | 344.0 | 344.2 |
| 344.3 | 344.6 | 344.6 | 345.0 | 345.5 | 345.9 | 345.9 | 345.8 | 345.5 | 345.2 |
| 344.8 | 344.5 | 344.3 | 344.1 | 343.8 | 343.3 | 342.9 | 342.5 | 341.9 | 341.5 |
| 341.0 | 340.6 | 340.5 | 340.4 | 340.4 | 340.3 | 340.2 | 340.1 | 340.0 | 339.9 |
| 339.8 | 339.7 | 339.6 | 339.6 | 339.5 | 339.5 | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6404. | 3561. | 976. | 976. | 93657. |
| CMS | 181. | 101. | 28. | 28. | 2652. |
| INCHES | | 18.71 | 20.51 | 20.51 | 20.51 |
| MM | | 475.35 | 520.93 | 520.93 | 520.93 |
| AC-FT | | 1766. | 1935. | 1935. | 1935. |
| THOUS CU M | | 2178. | 2387. | 2387. | 2387. |

MAXIMUM STORAGE = 2.

MAXIMUM STAGE IS 345.9

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 3 TO 4

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
----------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .1000 | .0450 | .1000 | 310.0 | 330.0 | 3950. | .00710 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC

0.00 320.00 400.00 320.00 550.00 312.00 580.00 310.00 600.00 310.00

600.00 312.00 625.00 320.00 1025.00 325.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.00 | 4.77 | 9.57 | 17.17 | 29.40 | 46.49 | 68.22 | 94.66 | 125.81 | 161.66 |
| | 202.65 | 251.25 | 307.90 | 372.56 | 445.30 | 524.92 | 608.70 | 696.49 | 788.30 | 884.13 |
| OUTFLOW | 0.00 | 147.03 | 454.33 | 926.17 | 1600.57 | 2544.39 | 3774.47 | 5334.46 | 7257.86 | 9576.52 |
| | 12109.13 | 15214.90 | 18853.93 | 23153.18 | 28161.55 | 34436.01 | 41646.10 | 49624.50 | 58381.20 | 67927.20 |
| STAGE | 310.00 | 311.05 | 312.11 | 313.16 | 314.21 | 315.26 | 316.32 | 317.37 | 318.42 | 319.47 |
| | 320.53 | 321.58 | 322.63 | 323.68 | 324.74 | 325.79 | 326.84 | 327.89 | 328.95 | 330.00 |
| FLOW | 0.00 | 147.03 | 454.33 | 926.17 | 1600.57 | 2544.39 | 3774.47 | 5334.46 | 7257.86 | 9576.52 |
| | 12109.13 | 15214.90 | 18853.93 | 23153.18 | 28161.55 | 34436.01 | 41646.10 | 49624.50 | 58381.20 | 67927.20 |

STATION 4, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. | 0. |
| 0. | 0. | 0. | 0. | 1. | 2. | 4. | 8. | 15. | 24. |
| 35. | 47. | 60. | 74. | 91. | 109. | 126. | 141. | 161. | 184. |
| 231. | 294. | 355. | 495. | 1052. | 1751. | 2234. | 2563. | 2747. | 2903. |
| 3086. | 3240. | 3459. | 3581. | 4676. | 5583. | 6106. | 6278. | 5947. | 5336. |
| 4663. | 4049. | 3594. | 3211. | 2814. | 2387. | 1944. | 1518. | 1143. | 834. |
| 597. | 436. | 335. | 292. | 271. | 251. | 235. | 219. | 204. | 191. |
| 178. | 166. | 155. | 146. | 140. | 132. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. |
| 1. | 2. | 2. | 2. | 3. | 4. | 4. | 5. | 5. | 5. |
| 6. | 7. | 8. | 10. | 19. | 32. | 41. | 47. | 50. | 53. |
| 56. | 59. | 62. | 70. | 83. | 99. | 108. | 110. | 105. | 95. |
| 83. | 73. | 65. | 50. | 51. | 44. | 36. | 28. | 21. | 16. |
| 12. | 9. | 8. | 7. | 7. | 6. | 6. | 6. | 6. | 5. |
| 5. | 5. | 5. | 5. | 5. | 4. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 |
| 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.0 | 310.1 | 310.1 | 310.2 |
| 310.2 | 310.3 | 310.4 | 310.5 | 310.6 | 310.8 | 310.9 | 311.0 | 311.1 | 311.2 |
| 311.3 | 311.5 | 311.8 | 312.2 | 313.3 | 314.4 | 314.9 | 315.3 | 315.4 | 315.6 |
| 315.7 | 315.9 | 316.0 | 316.4 | 316.9 | 317.5 | 317.8 | 317.9 | 317.7 | 317.4 |
| 316.9 | 316.5 | 316.2 | 315.8 | 315.5 | 315.1 | 314.6 | 314.1 | 313.5 | 312.9 |
| 312.4 | 312.0 | 311.7 | 311.5 | 311.5 | 311.4 | 311.3 | 311.3 | 311.2 | 311.2 |
| 311.2 | 311.1 | 311.1 | 311.0 | 311.0 | 310.9 | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6278. | 3540. | 973. | 973. | 93451. |
| CMS | 178. | 100. | 28. | 28. | 2646. |
| INCHES | | 18.65 | 20.46 | 20.46 | 20.46 |
| MM | | 473.60 | 519.70 | 519.70 | 519.70 |
| AC-FT | | 1760. | 1931. | 1931. | 1931. |
| THOUS CU M | | 2170. | 2382. | 2382. | 2382. |

MAXIMUM STORAGE = 110.

MAXIMUM STAGE IS 317.9

HYDROGRAPH ROUTING

CHANNEL ROUTING -MODIFIED PULS- STATION 4 TO 5

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

ROUTING DATA

| QLOSS | CLOSS | AVG | IRES | ISAME | IOPT | IPMP | | LSTR |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.000 | 0.00 | 1 | 1 | 0 | 0 | | 0 |

| NSTPS | NSTDL | LAG | AMSKK | X | TSK | STORA | ISPRAT |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0. | 0 |

NORMAL DEPTH CHANNEL ROUTING
----------------------------

| QN(1) | QN(2) | QN(3) | ELNVT | ELMAX | RLNTH | SEL |
|---|---|---|---|---|---|---|
| .0500 | .0450 | .0500 | 286.0 | 300.0 | 2400. | .01000 |

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC
0.00 300.00 250.00 290.00 375.00 288.00 375.00 286.00 425.00 286.00
425.00 288.00 900.00 290.00 1450.00 300.00

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 0.90 | 2.03 | 4.06 | 6.46 | 15.94 | 33.59 | 59.55 | 88.50 | 119.64 | 153.58 |
| | 189.71 | 228.24 | 269.16 | 312.47 | 358.17 | 406.27 | 456.76 | 509.64 | 564.52 | 622.59 |
| OUTFLOW | 0.00 | 97.61 | 304.11 | 594.37 | 1196.69 | 2512.06 | 5012.98 | 8607.91 | 13357.03 | 19016.67 |
| | 25674.03 | 33351.33 | 42078.11 | 51050.13 | 62744.18 | 74750.24 | 87930.90 | 102293.51 | 117877.14 | 134713.29 |
| STAGE | 286.00 | 286.74 | 287.47 | 288.21 | 288.95 | 289.68 | 290.42 | 291.16 | 291.89 | 292.63 |
| | 293.37 | 294.11 | 294.84 | 295.58 | 296.32 | 297.05 | 297.79 | 298.53 | 299.26 | 300.00 |
| FLOW | 0.00 | 97.61 | 304.11 | 594.37 | 1196.69 | 2512.06 | 5012.98 | 8607.91 | 13357.03 | 19016.67 |
| | 25674.03 | 33351.33 | 42078.11 | 51050.13 | 62744.18 | 74750.24 | 87930.90 | 102293.51 | 117877.14 | 134713.29 |

STATION 5, PLAN 1, RTIO 4

OUTFLOW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 0. |
| 9. | 0. | 0. | 0. | 1. | 1. | 1. | 5. | 9. | 16. |
| 25. | 35. | 47. | 60. | 1. | 1. | 2. | 134. | 151. | 173. |
| 210. | 264. | 329. | 436. | 75. | 92. | 115. | 2327. | 2624. | 2824. |
| 2994. | 3163. | 3345. | 3675. | 753. | 1205. | 1093. | 6265. | 6892. | 5501. |
| 4932. | 4357. | 3025. | 1466. | 4207. | 5143. | 5904. | 1799. | 1397. | 1054. |
| 778. | 555. | 366. | 307. | 3814. | 3602. | 2215. | 226. | 211. | 197. |
| 104. | 172. | 161. | 150. | 200. | 261. | 243. | | | |
| | | | | 143. | 136. | | | | |

STOR

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1. | 1. | 1. | 1. | 2. | 2. | 2. | 2. | 3. | 3. |
| 3. | 4. | 4. | 5. | 9. | 17. | 25. | 31. | 35. | 37. |
| 39. | 40. | 42. | 46. | 52. | 61. | 67. | 69. | 68. | 64. |
| 59. | 53. | 47. | 43. | 39. | 35. | 38. | 24. | 18. | 13. |
| 9. | 6. | 5. | 4. | 4. | 4. | 3. | 3. | 3. | 3. |
| 3. | 3. | 3. | 3. | 2. | 2. | | | | |

STAGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 |
| 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.0 | 286.1 | 286.1 |
| 286.2 | 286.3 | 286.4 | 286.5 | 286.0 | 286.7 | 286.8 | 286.9 | 286.9 | 287.0 |
| 287.1 | 287.3 | 287.5 | 287.8 | 286.6 | 289.0 | 289.3 | 289.6 | 289.7 | 285.0 |
| 289.8 | 289.9 | 289.9 | 290.0 | 288.4 | 290.4 | 290.6 | 290.7 | 290.6 | 290.5 |
| 290.4 | 290.2 | 290.1 | 289.9 | 290.2 | 289.7 | 289.5 | 289.3 | 289.1 | 288.0 |
| 288.4 | 288.1 | 287.6 | 287.5 | 289.8 | 287.3 | 287.3 | 287.2 | 287.1 | 287.1 |
| 287.0 | 287.0 | 287.0 | 286.9 | 287.4 | 286.9 | | | | |
| | | | | 286.9 | | | | | |

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|---|---|---|---|---|---|
| CFS | 6265. | 3538. | 972. | 972. | 93334. |
| CMS | 177. | 100. | 28. | 28. | 2643. |
| INCHES | | 18.59 | 20.44 | 20.44 | 20.44 |
| MM | | 472.29 | 519.14 | 519.14 | 519.14 |
| AC-FT | | 1754. | 1928. | 1928. | 1928. |
| THOUS CU M | | 2164. | 2379. | 2379. | 2379. |

MAXIMUM STORAGE = 69.

MAXIMUM STAGE IS 290.7

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)

BREACH

| | | | | RATIOS APPLIED TO FLOWS | | | |
|---|---|---|---|---|---|---|---|
| OPERATION | STATION | AREA | PLAN | RATIO 1 .10 | RATIO 2 .15 | RATIO 3 .50 | RATIO 4 1.00 |
| HYDROGRAPH AT | 1 | 1.77 | 1 | 614. | 922. | 3072. | 6143. |
| | ( | 4.58) | ( | 17.40)( | 26.09)( | 86.98)( | 173.96)( |
| ROUTED TO | 2 | 1.77 | 1 | 419. | 1465. | 3554. | 6414. |
| | ( | 4.58) | ( | 11.07)( | 41.50)( | 100.64)( | 181.62)( |
| ROUTED TO | 3 | 1.77 | 1 | 420. | 1469. | 3567. | 6404. |
| | ( | 4.58) | ( | 11.89)( | 41.60)( | 100.99)( | 181.33)( |
| ROUTED TO | 4 | 1.77 | 1 | 418. | 1369. | 3392. | 6278. |
| | ( | 4.58) | ( | 11.83)( | 38.77)( | 96.05)( | 177.77)( |
| ROUTED TO | 5 | 1.77 | 1 | 418. | 1331. | 3369. | 6265. |
| | ( | 4.58) | ( | 11.83)( | 37.70)( | 95.40)( | 177.41)( |

BREACH

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ..............

| | INITIAL VALUE | SPILLWAY CREST | TOP OF DAM |
|---|---|---|---|
| ELEVATION | 349.30 | 349.30 | 352.90 |
| STORAGE | 65. | 65. | 120. |
| OUTFLOW | 0. | 0. | 450. |

| 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 | 352.53 | 0.00 | 121. | 419. | 0.00 | 17.75 | 0.00 |
| .15 | 353.13 | .23 | 133. | 1402. | .50 | 17.33 | 16.75 |
| .50 | 353.12 | .22 | 132. | 3556. | .50 | 16.03 | 14.25 |
| 1.00 | 353.29 | .39 | 136. | 6414. | .75 | 16.75 | 13.50 |

PLAN 1 STATION 3

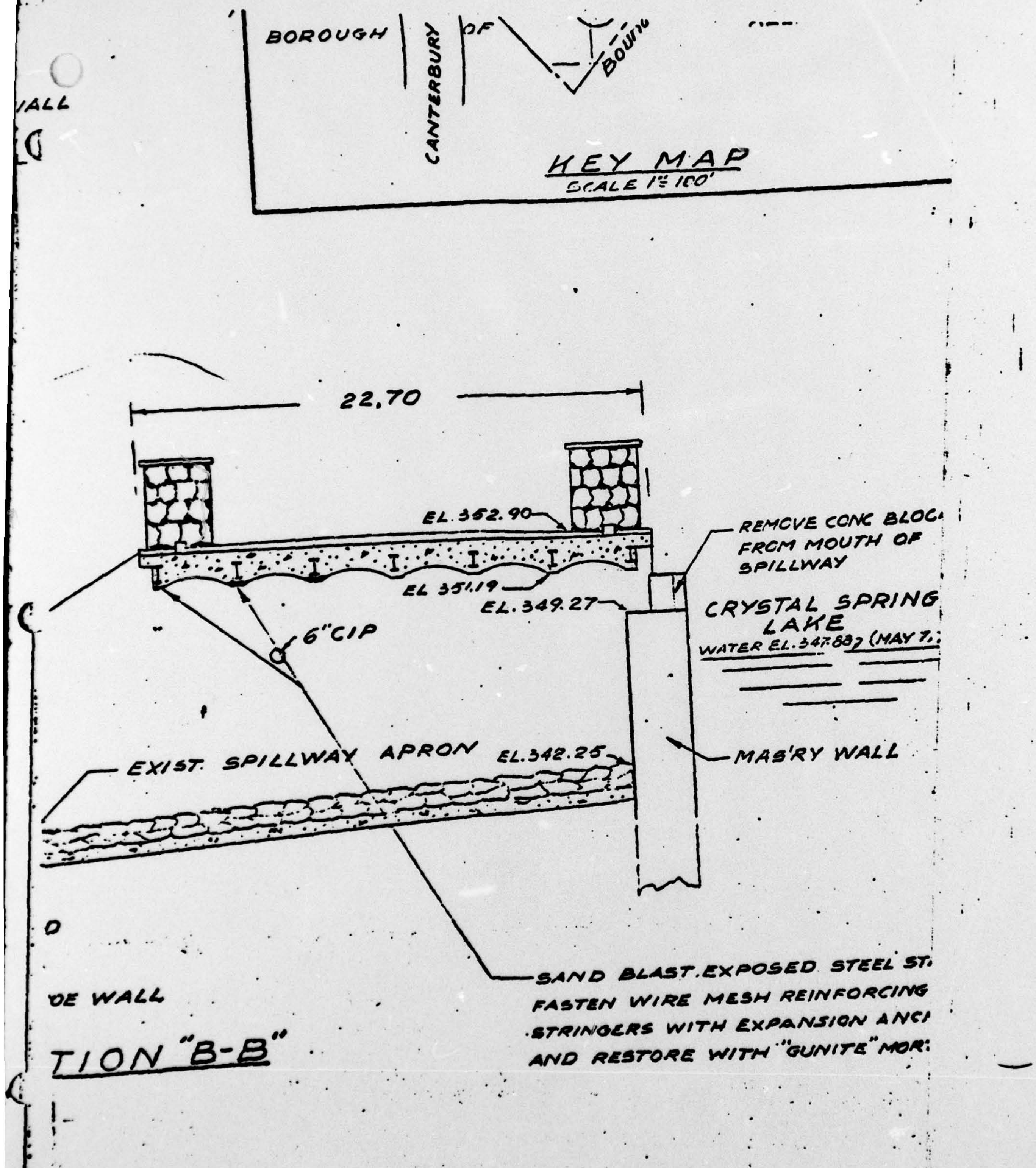
| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 420. | 340.9 | 17.75 |
| .15 | 1469. | 342.0 | 17.25 |
| .50 | 3567. | 344.5 | 16.75 |
| 1.00 | 6404. | 345.9 | 16.75 |

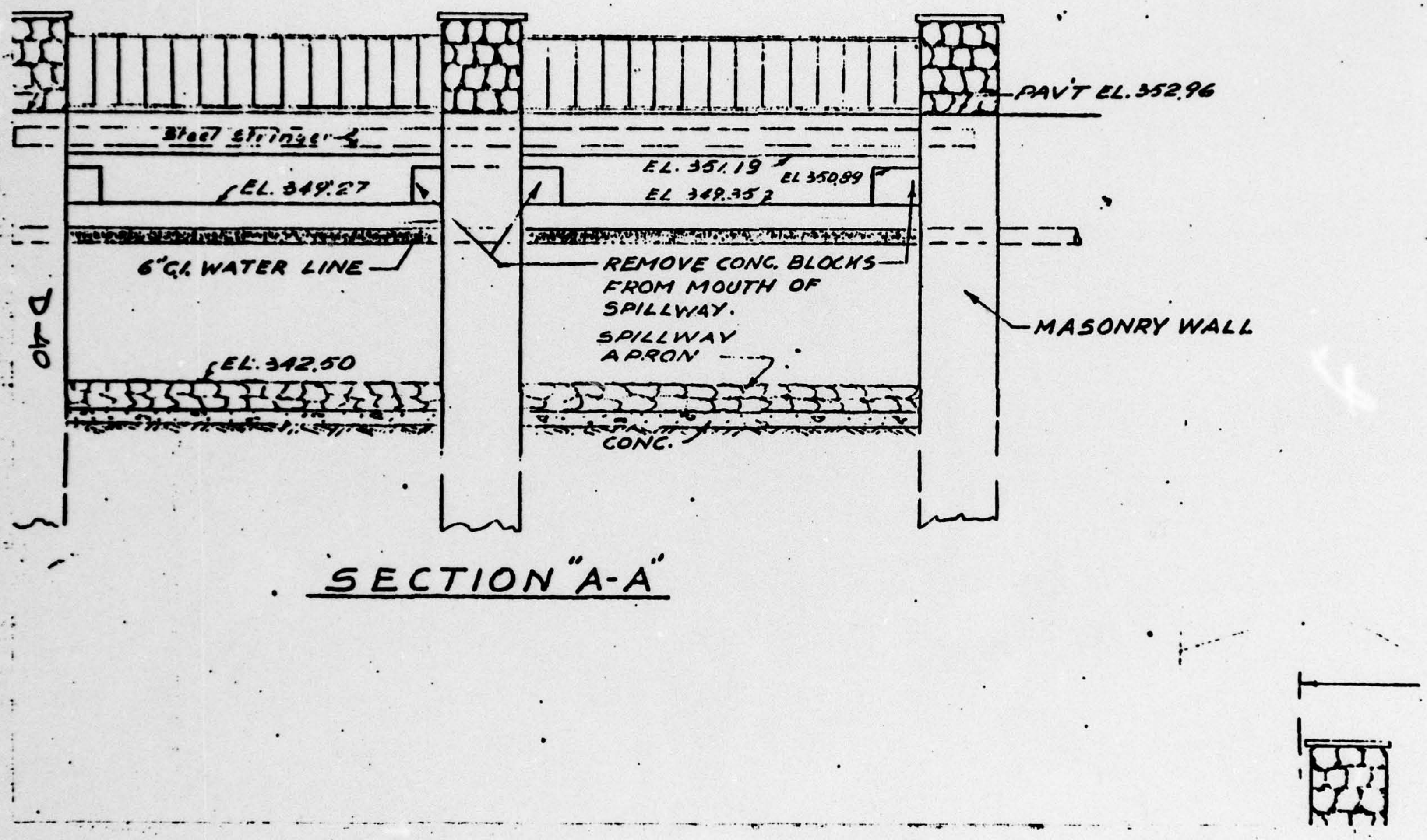
PLAN 1 STATION 4

| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 410. | 312.0 | 18.00 |
| .15 | 1369. | 313.8 | 17.50 |
| .50 | 3392. | 316.0 | 17.00 |
| 1.00 | 6278. | 317.9 | 17.00 |

PLAN 1 STATION 5

| RATIO | MAXIMUM FLOW,CFS | MAXIMUM STAGE,FT | TIME HOURS |
|---|---|---|---|
| .10 | 410. | 287.0 | 18.00 |
| .15 | 1331. | 289.0 | 17.75 |
| .50 | 3369. | 289.9 | 17.00 |
| 1.00 | 6265. | 290.7 | 17.00 |


BOROUGH
CANTERBURY
OF
BOUL
KEY MAP
SCALE 1"= 100'
22.70
EL. 352.90
REMOVE CONC BLOC
FROM MOUTH OF
SPILLWAY
EL 351.19
EL. 349.27
CRYSTAL SPRING
LAKE
WATER EL. 347.88 (MAY 7.
6"CIP
EXIST. SPILLWAY APRON
EL. 342.25
MAS'RY WALL
SAND BLAST EXPOSED STEEL ST.
FASTEN WIRE MESH REINFORCING
STRINGERS WITH EXPANSION ANC
AND RESTORE WITH "GUNITE" MOR
OE WALL
TION "B-B"


PAV'T EL. 352.96
Steel Stringer
EL. 351.19
EL 350.89
EL 349.35
EL. 349.27
6" C.I. WATER LINE
REMOVE CONC. BLOCKS FROM MOUTH OF SPILLWAY.
MASONRY WALL
SPILLWAY APRON
EL. 342.50
CONC.
D-40

SECTION "A-A"

Form 11-SC-10-12

HOHOKUS CREEK

# DAMS IN NEW JERSEY—REFERENCE DATA

No. 23-77

Name of Owner Ramsey Country Club Estates Address Ramsey, N. J.

Name of Dam County Bergen Location 23.32.6.6.9 [·]

CONSTRUCTION: Date Before 1923 By whom

Stream Ramsey Brook Tributary to Hohokus Creek

DRAINAGE BASIN: Area 1.77 sq. mi. Description Hilly, undeveloped

Description of valley below dam Boro of Allendale 1 mi. downstream

DAMAGE FROM FAILURE: Probable Heavy

Previous (date)

Purpose Real Estate Development Type

Foundation Unknown

Length 525 ft. Max. height 12 ft. Min. width of top 24 ft.

Upstream slope Unknown Downstream slope 1½:1 Volume Cu. yds.

SPILLWAY: Type 2.25' wide concrete wall (C=3.42) Length 30 ft.

Depth below top of dam 3.33 ft. Capacity 161 at 2.2' hd. c. f. s. per sq. mi. 100: South Jersey

RESERVOIR: Capacity mill. gals. Area 30 acres. Length ft.

Outlets

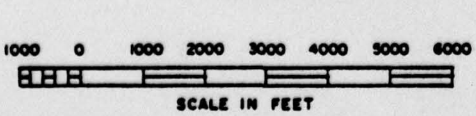
Remarks Flat slab concrete bridge over spillway, 2.2' high clear opening, crest to bridge underclearance. 12' wide bituminous road along top of dam.

Sources of data Inspection - N.C.W. Date 7/10/46

291

D-41

PLATE D-1



CRYSTAL SPRING DAM

JENNY - LEEDSHILL JANUARY 1979

Plate D-2

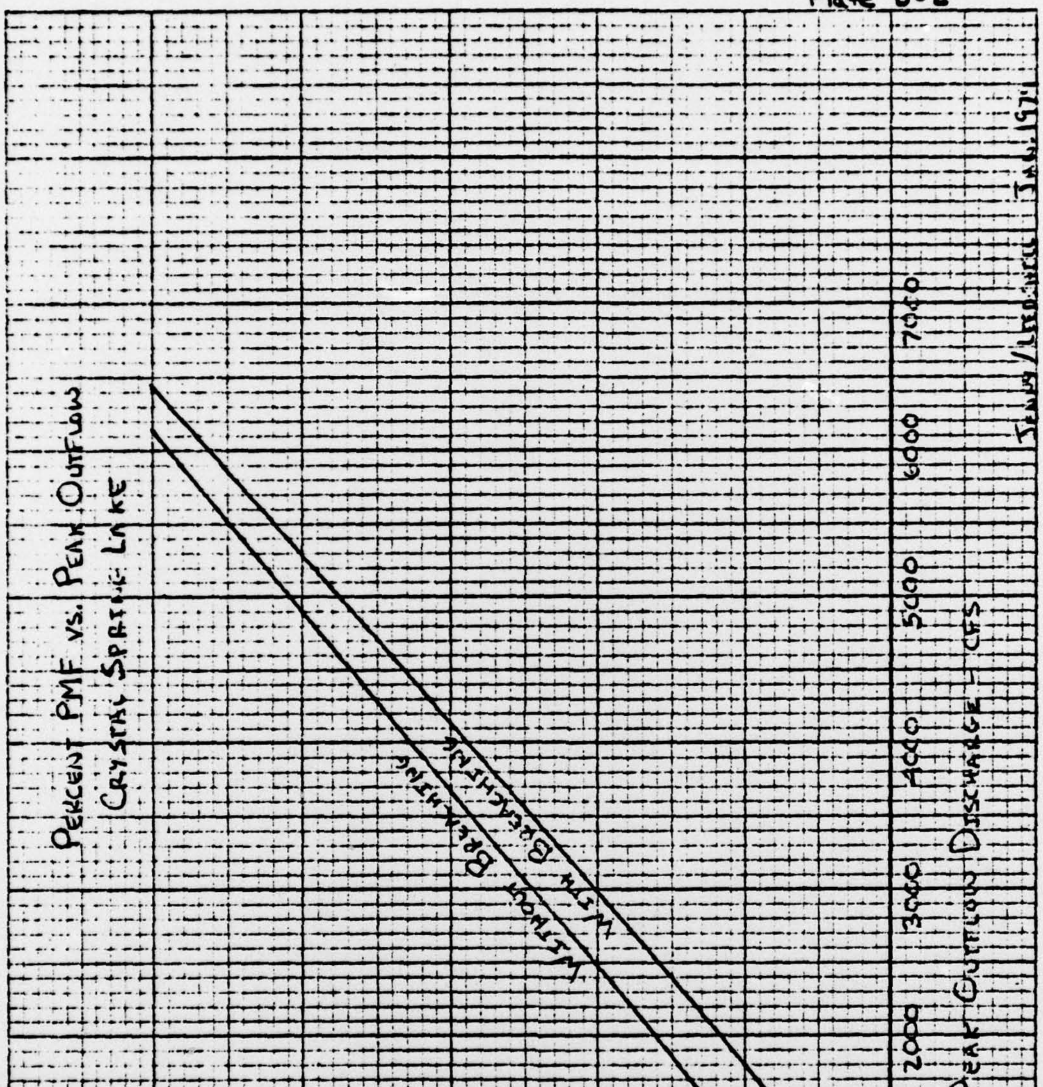

PERCENT PMF VS. PEAK OUTFLOW
CRYSTAL SPRING LAKE
WITHOUT BREACHING
WITH BREACHING
PEAK OUTFLOW DISCHARGE - CFS
0
1000
2000
3000
4000
5000
6000
7000
PERCENT PMF
0
20
40
60
80
100

Plate D-3

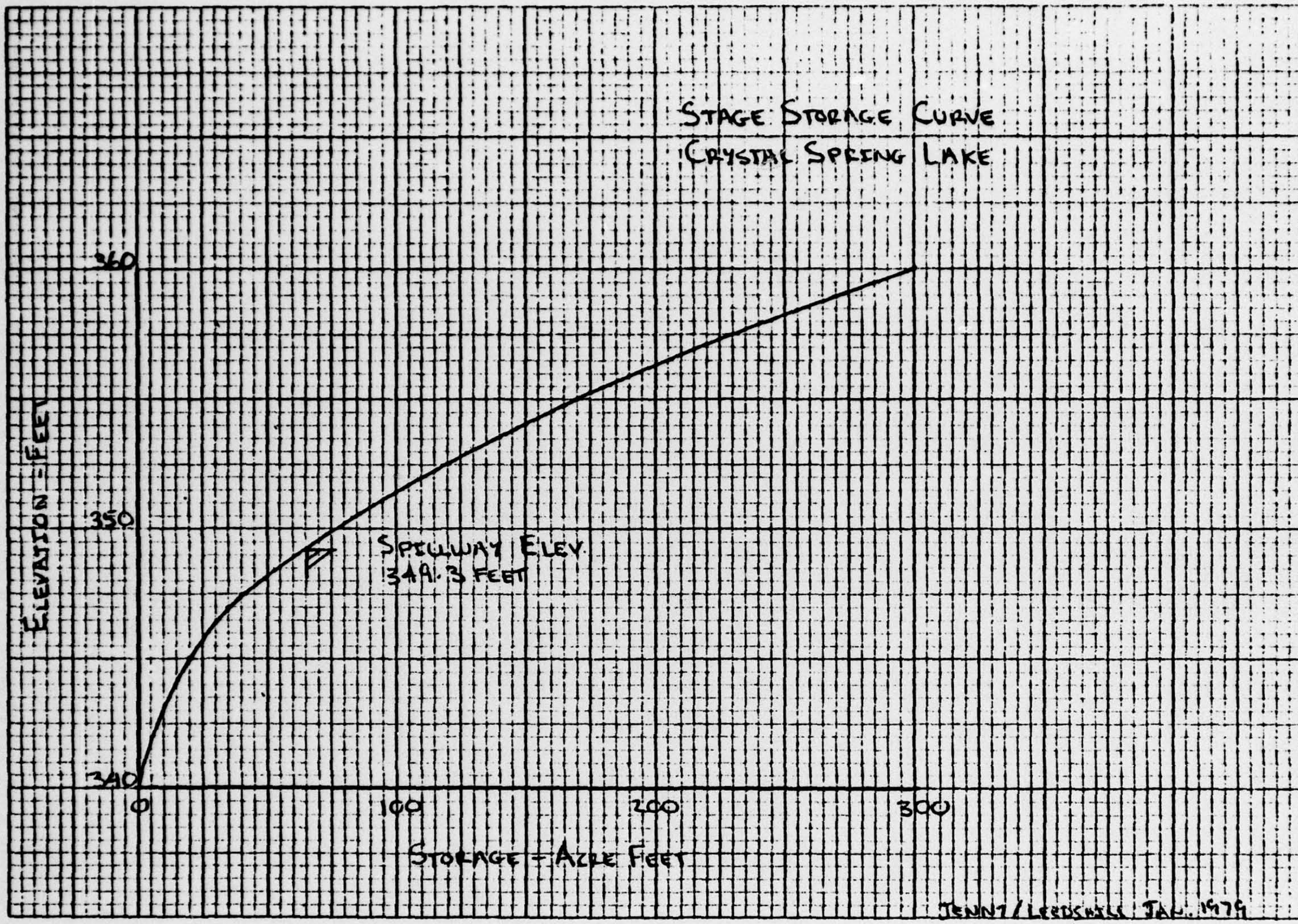
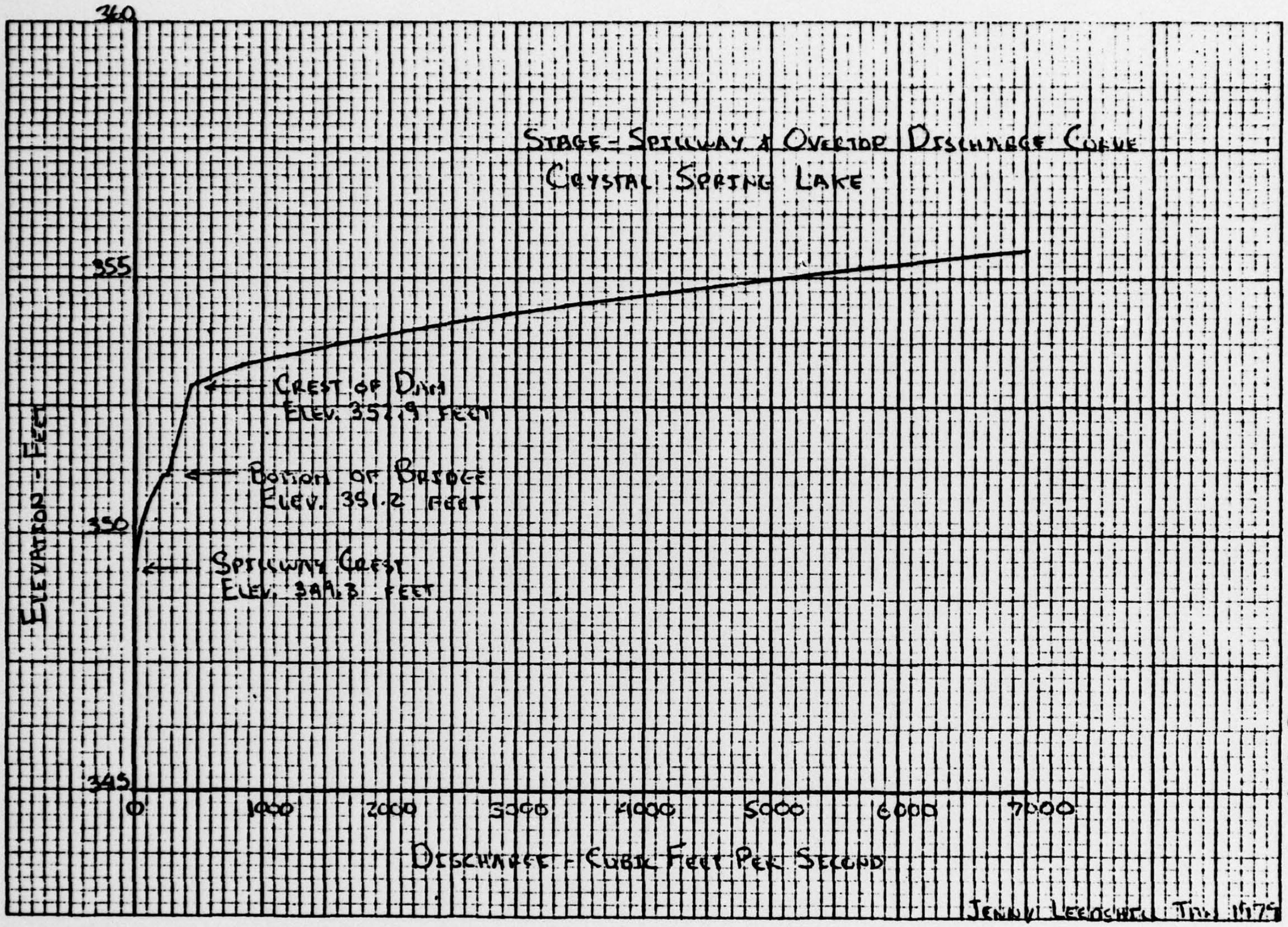

STAGE STORAGE CURVE
CRYSTAL SPRING LAKE
360
350
340
SPILLWAY ELEV
349.3 FEET
0
100
200
300
ELEVATION - FEET
STORAGE - ACRE FEET
JENNY/LEEDSHILL JAN. 1979

Plate D-4



Stage - Spillway & Overtop Discharge Curve
Crystal Spring Lake
Crest of Dam
Elev. 352.9 Feet
Bottom of Bridge
Elev. 351.2 Feet
Spillway Crest
Elev. 349.3 Feet
360
355
350
345
Elevation - Feet
0
1000
2000
3000
4000
5000
6000
7000
Discharge - Cubic Feet Per Second