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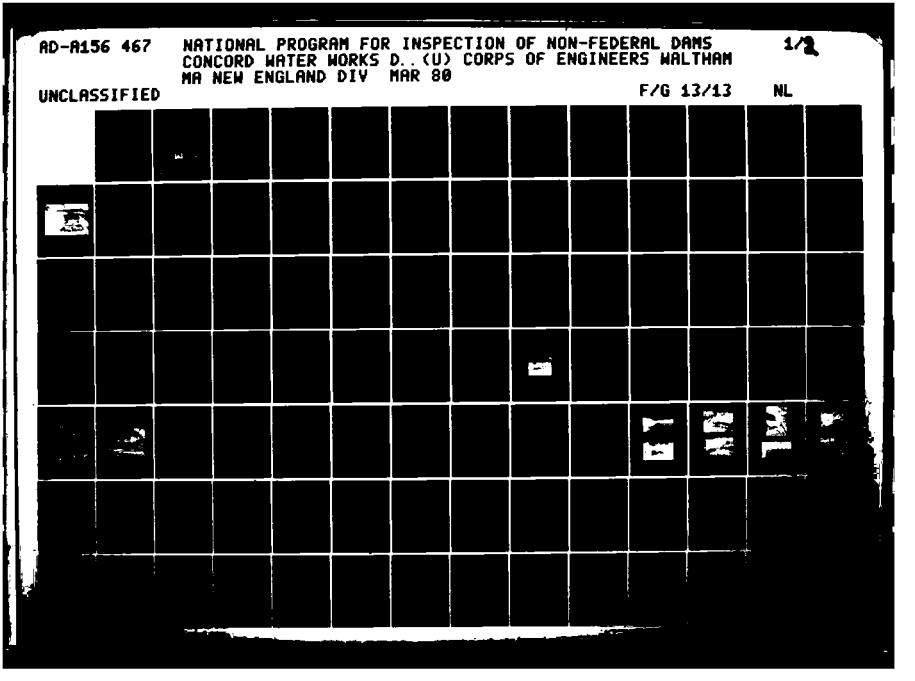

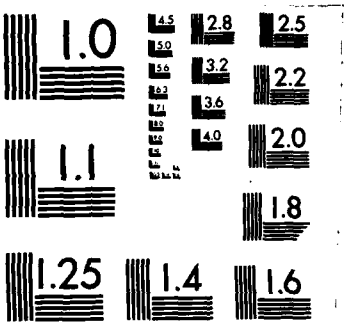

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MERRIMACK RIVER BASIN
CONCORD, NEW HAMPSHIRE

CONCORD WATER WORKS DAM

NH 00360

NHWRB NO. 51.13

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

MARCH 1980

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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

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

DAMS, INSPECTION, DAM SAFETY,

Merrimack River Basin
Concord, New Hampshire
Rattlesnake Brook.

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

The dam is an earthen embankment about 9 ft. high and 265 ft. long. There is no emergency spillway. The dam is in fair condition with a few major concerns which must be corrected. The dam is intermediate in size with a significant hazard potential. The test flood ranges from ½ the PMF to full PMF. There are various remedial measures which should be implemented by the owner.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO ATTENTION OF:
NEDED

MAY 01 1979

Honorable Hugh J. Gallen
Governor of the State of New Hampshire
State House
Concord, New Hampshire 03301

Dear Governor Gallen.

Inclosed is a copy of the Concord Water Works Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Water Resources Board, the cooperating agency for the State of New Hampshire. In addition, a copy of the report has also been furnished the owner, City of Concord Water Works, 16 Penacook Street, Concord, New Hampshire 03301.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Water Resources Board for your cooperation in carrying out this program.

Sincerely,

Max B. Scheider

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

CONCORD WATER WORKS DAM

NH 00360

NHWRB 51.13

MERRIMACK RIVER BASIN
CONCORD, NEW HAMPSHIRE

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
BRIEF ASSESSMENT

Identification No.: NH 00360

Name of Dam: Concord Water Works Dam

Town: Concord

County and State: Merrimack, New Hampshire

Stream: Rattlesnake Brook

Date of Inspection: December 4, 1979

Concord Water Works Dam is an earthen embankment approximately 9 feet high from crest of dam to toe of slope and 265 feet long. The upstream face of the embankment is protected by a 1.0 foot thick concrete wall, a concrete slab and granite block riprap which extends to the bottom of the reservoir. The crest width is approximately 21.5 feet and is asphalt paved. The Concord Water Treatment Plant is located on the left abutment (north end) of the dam. The principal spillway is located on the north side of the water treatment plant and consists of a granite block weir, 40 feet long, with flashboards and granite block training walls. There is no emergency spillway.

The dam impounds Penacook Lake and the discharge flows through Rattlesnake Brook in an easterly and southeasterly direction for approximately 1.0 mile to its confluence with the Merrimack River. The dam was originally constructed and is still used to provide a primary water supply for the city of Concord. The reservoir is 2.18 miles in length with a surface area of about 358 acres. The maximum storage capacity is about 2,210 acre-feet.

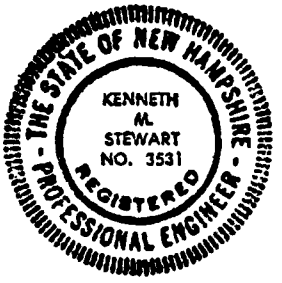
As a result of the visual inspection and the review of available data regarding this facility, the dam is considered to be in FAIR condition. Major concerns are: deterioration of the concrete wall forming the upper 2 feet of the upstream slope; displacement of the upstream slope protection; a wet area 90 feet downstream of the dam at the base of the hillside which forms the right abutment; and extensive cracking and settlement of the bottom of the concrete spillway discharge channel.

This dam is classified as INTERMEDIATE in size and a SIGNIFICANT hazard structure in accordance with the recommended guidelines established by the Corps of Engineers. The test flood for this dam, therefore, ranges from one-half the Probable Maximum Flood (1/2 PMF) to the Probable Maximum Flood (PMF). Since the dam falls on the lower end of the intermediate size range, the 1/2 PMF was utilized for this hydrologic analysis. The test flood inflow was estimated to be 4,460 cfs and resulted in an outflow discharge equal to 1,450 cfs which would overtop the dam crest by about 0.8 feet. The maximum spillway capacity (with flashboards in place) with the water level at the dam crest was estimated to be

290 cfs or about 20 percent of the test flood discharge. A major breach with the reservoir surface at the dam crest could cause damage to 6 to 8 houses, a community swimming pool, a factory, the pumping station at the water treatment plant, a town street and a highway. Water could be 1 to 2 feet above the sill of two or three houses, and only approach the sill elevation in the remainder of the houses. The pumping station would be inundated, with water 6 to 8 feet above the sill. The failure discharge would enter the swimming pool (around 1 foot above the deck), and be 2 to 3 feet above the lower foundation of the factory. Water would flow about 2 to 3 feet deep over the town street and highway. The potential for loss of life exists, but it appears that this would not be a likely occurrence.

It is recommended that the owner engage a qualified registered professional engineer to investigate a means of stabilizing the upstream slope protection including the vertical wall, to investigate the possibility that the springs downstream of the dam on the right abutment may be influenced by the reservoir, to do a detailed hydrologic-hydraulic investigation to assess further the potential of overtopping the dam, the adequacy of the spillway to pass the test flood, and the need for and means to increase project discharge capacity, and to assess the need for and means to provide a low level regulating outlet that would allow drawdown of the reservoir in an emergency. It is also recommended that the owner repair the cracking and settlement of the bottom of the concrete spillway discharge channel.

The recommendations and remedial measures are described in Section 7 and should be addressed by the owner within one year after receipt of this Phase I Inspection Report.



Kenneth M. Stewart
Project Manager
N.H.P.E. 3531

S E A Consultants Inc.
Rochester, New Hampshire

This Phase I Inspection Report on Concord Water Works Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Richard J. DiBuono

RICHARD DIBUONO, MEMBER
Water Control Branch
Engineering Division

ARAMAST MAHTESIAN, CHAIRMAN
Geotechnical Engineering Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

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. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through 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. Because of the magnitude and

rarity of such a storm event, finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. 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.

The Phase I investigation does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespassing and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

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OVERVIEW PHOTO - CONCORD WATER WORKS DAM

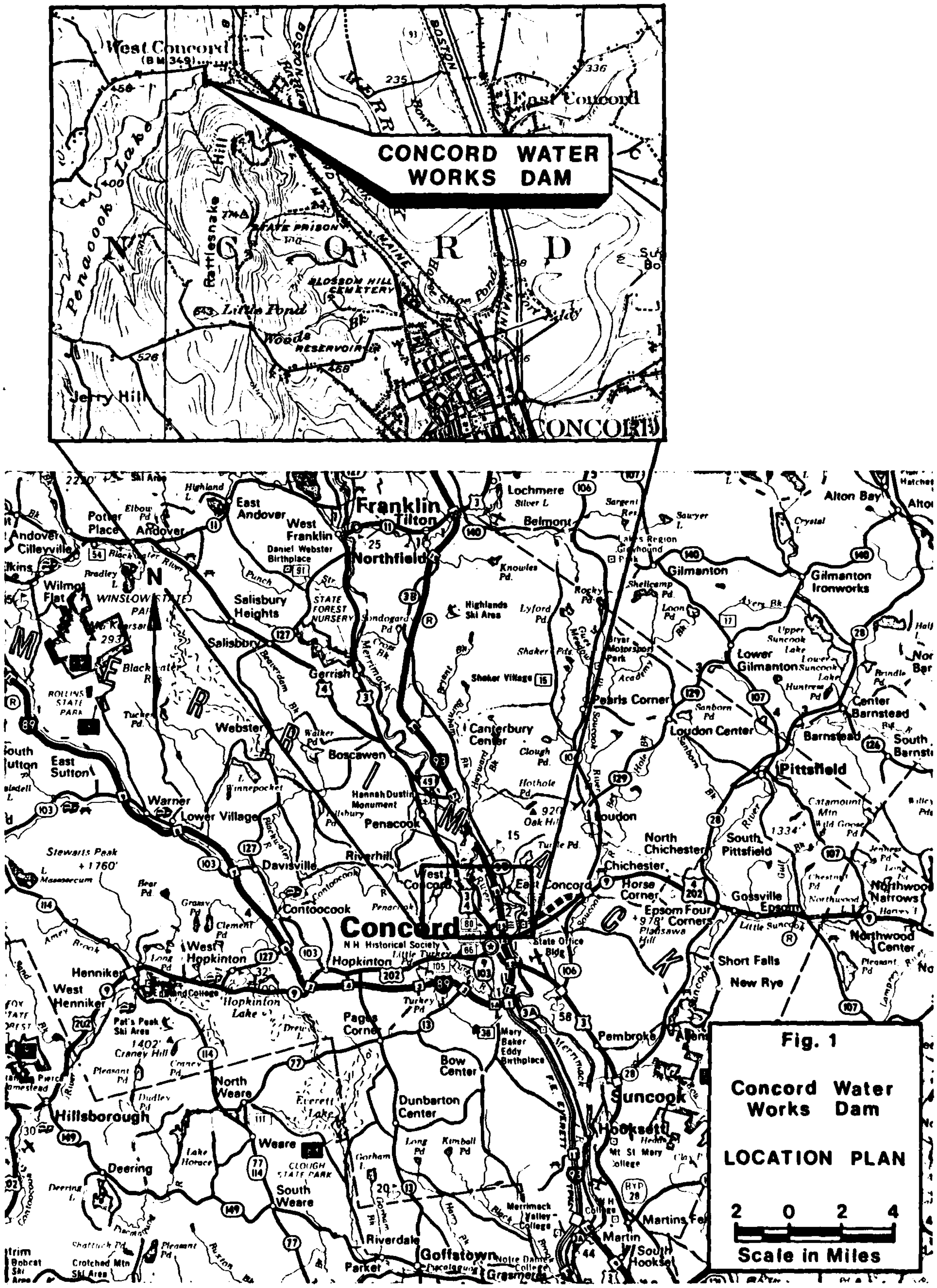


Fig. 1

Concord Water Works Dam

LOCATION PLAN

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
CONCORD WATER WORKS DAM

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. S E A Consultants Inc. has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to S E A Consultants Inc. under a letter of November 5, 1979 from William Hodgson, Jr., Colonel, Corps of Engineers. Contract No. DACW33-80-C0008 has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) To perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-federal interests.

(2) To encourage and prepare the states to initiate quickly effective dam safety programs for non-federal dams.

(3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. The Concord Water Works Dam is located in the City of Concord, New Hampshire, at the Concord Water Treatment Plant off Hutchins Street. The dam impounds water for Penacook Lake, which after passing over the spillway, flows through Rattlesnake Brook in an easterly and southeasterly direction for approximately 1.0 miles to its confluence with the Merrimack River in Concord, New Hampshire. The dam is shown on U.S.G.S. Quadrangle, Concord, New Hampshire, with coordinates approximately at N43°14'33", W71°34'40", Merrimack County, New Hampshire, (See Location Plan.)

b. Description of Dam and Appurtenances. Concord Water Works Dam is an earthen embankment approximately 9 feet high from crest of dam to toe of slope and 265 feet long. The reservoir face consists of a 1.0 foot thick concrete wall which extends from the crest of the dam down 2 feet to the top of a concrete slab which slopes 1 foot vertical to 4 feet horizontal (1:4) down to the top of a

granite block riprap slope of approximately 1 foot vertical to 2 feet horizontal (1:2) which terminates at the bottom of the reservoir. The downstream slope of the embankment is approximately 1 foot vertical to 2.5 feet horizontal (1:2.5) to toe of slope. The crest width is approximately 21.5 feet and is asphalt paved.

Beginning at the left end of the dam and running in a westerly and then northerly direction approximately 480 feet until its termination at the spillway is a granite block riprap which protects the earth fill that the water treatment plant is constructed upon. This riprap begins approximately 2.0 feet down from the top of the fill, slopes 1 foot vertical to 2.5 feet horizontal (1:2.5) and terminates at the bottom of the reservoir.

Located at the north end of the site, at the termination of the stone block riprap, is the principal spillway which consists of granite block training walls and a granite block weir with flashboards that discharges into a 12 foot wide concrete spillway channel that begins Rattlesnake Brook. A 3.5 foot high earth berm extends from the left training wall north to Hutchins Street where it terminates at a stone wall.

c. Size Classification. Intermediate (height - 9 feet, storage - 2,210 acre-feet at the crest of the dam) based on storage (greater than or equal to 1,000 acre-feet and less than 50,000 acre-feet) as given in the Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. Significant hazard. A major breach in the Concord Water Works Dam could cause damage to 6 to 8 houses, a community swimming pool, a factory, the pumping station at the water treatment plant, a town street, and a highway. Water could be 1 to 2 feet above the sill of two or three houses, and only approach the sill elevation in the remainder of the houses. The pumping station would be inundated, with water 6 to 8 feet above the sill. The failure discharge would enter the swimming pool (around 1 foot above the deck), and would be 2 to 3 feet above the lower foundation of the factory. Water would flow about 2 to 3 feet deep over the town street and highway (U.S. Routes 3 and 4). The potential for loss of life exists, but it does not appear that this would be a likely occurrence.

e. Ownership. The early structures of the dam are believed to have been constructed in 1873 as part of the City of Concord Water Collection and Distribution System, and is owned by the City of Concord Water Works, 16 Penacook Street, Concord, New Hampshire 03301. Phone: (603) 225-5575.

f. Operator. The dam is maintained and operated by Robert N. Gillis, Director of Water Works, City of Concord, New Hampshire 03301. Phone: (603) 225-5575.

g. Purpose of Dam. The dam was constructed to provide a water supply for the City of Concord.

h. Design and Construction History. The early structures of the dam are believed to have been constructed in 1873 when the initial intake structure for the Concord Water Works was built. A plan of this dam indicates the earth fill structure has a stone block core. It is not known when the concrete and granite block riprap on the upstream face of the dam, the concrete face walls and railings on the upstream and downstream face of the dam, or the asphalt pavement on the dam crest were added. Photographs on file at the New Hampshire Water Resources Board indicate these changes were made before 1934.

It is not known when the granite block spillway and concrete spillway channel were built. The earliest records of the spillway are dated 1934.

Prior to construction of the new water treatment facility, an earth berm dike and stone wall bridged the gap between the dam and spillway. The design of the Concord Water Treatment Plant was completed in 1968 by Camp, Dresser & McKee, Consulting Engineers, Boston, Massachusetts. During construction of the plant in 1974 by Pizzagalli Construction Company, Wolfeboro, New Hampshire, the earth dike and stone wall were replaced by an earth fill which is protected on the upstream side by granite block riprap.

The plan of the dam, showing profile and cross-section was obtained from the Concord Water Works Department, Concord, New Hampshire. The plans of the Concord Water Treatment Plant showing grading and cross-sections of riprap were obtained from Camp, Dresser & McKee, Consulting Engineers, Boston, Massachusetts. No in-depth design calculations or as-built drawings were disclosed for this dam.

i. Normal Operating Procedures. The Concord Water Works Dam is used primarily to impound the water of Penacook Lake which provides a water supply for the City of Concord, New Hampshire. There is no normal operating procedure for this dam.

1.3 Pertinent Data

a. Drainage Area. The drainage area above the Concord Water Works Dam covers nearly 3.88 square miles (approximately 2,480 acres), consisting of steeply sloped terrain surrounding Penacook Lake. The topography in the drainage basin ranges from 793 feet NGVD on top of Pine Hill to less than 390 feet NGVD near the base of the dam. The majority of the basin is heavily wooded and generally undeveloped. The development which does exist consists of widely scattered houses, which are not located close to the lake.

b. Discharge at Dam Site

(1) Discharge over the spillway occurs only during the wetter periods of the year. Discharge at the dam site normally occurs through the intake structure at the new water treatment facility. This intake structure is 10 feet wide by 14 feet high, with a bar rack. Discharge through the structure is controlled by two

2 feet by 2 feet sluice gates which are operated from inside the treatment facility. Water passing through these gates enters one of two channels which convey the water to two wet wells so that it may be pumped up to the settling basins. The intake structure cannot be used to drain the pond by by-passing the water treatment process.

(2) Maximum known flood at dam site was estimated at 45 cfs (based on water surface elevation of 402.88 recorded for the period April 25, 1955 to May 2, 1955).

(3) Spillway capacity with the water surface elevation at the top of the dam (elevation 404.04 feet) was estimated to be:

(a) with flashboards in place - 290 cfs
(b) with flashboards removed - 511 cfs

(4) Spillway capacity with the water surface at the test flood elevation (elevation - 404.8 feet) was estimated to be:

(a) with flashboards in place - 515 cfs
(b) with flashboards removed - 725 cfs

(5) The gated spillway capacity at normal pool elevation - not applicable since the reservoir surface is below the spillway crest for much of the year.

(6) The gated spillway capacity (flashboards in place) at test flood elevation was estimated to be 515 cfs at 404.8 elevation.

(7) The total spillway capacity (all flashboards removed) at test flood elevation was estimated to be 725 cfs at 404.8 elevation.

(8) Total project discharge at top of dam was estimated to be 571 cfs at 404.04 elevation with all flashboards removed and 350 cfs at 404.04 elevation with flashboards in place.

(9) Total project discharge at test flood elevation was estimated to be 1,450 cfs at 404.8 elevation.

c. Elevation (ft, NGVD). Based on USGS datum from plans of water treatment plant construction by Camp, Dresser & McKee, Consulting Engineers.

(1) Toe of dam - 395.0

(2) Bottom of cutoff - unknown

(3) Maximum tailwater - unknown

(4) Normal pool - 402.0 (elevation shown on U.S.G.S. quadrangle sheet; the actual water surface elevation varies considerably with water usage)

(5) Full flood control pool - N/A

(6) Spillway crest:

(a) permanent crest - 401.15
(b) top of flashboards - 402.48

(7) Design surcharge (Original Design) - Unknown

(8) Top of dam - 404.04

(9) Test flood design surcharge - 404.8

d. Reservoir (Length in feet)

(1) Normal pool - 11,500 (corresponds to pool shown on U.S.G.S. sheet)

(2) Flood control pool - N/A

(3) Permanent spillway crest pool - 11,400

(4) Top of dam - 11,600

(5) Test flood pool - 11,650

e. Storage (acre-feet)

(1) Normal pool - 1,515 (corresponds to pool shown on U.S.G.S. sheet)

(2) Flood control pool - N/A

(3) Permanent spillway crest pool - 1,160

(4) Top of dam - 2,210

(5) Test flood pool - 2,420

f. Reservoir Surface (acres)

(1) Normal pool - 358 (corresponds to pool shown on U.S.G.S. sheet)

(2) Flood-control pool - N/A

(3) Permanent spillway crest - 347

(4) Test flood pool - 387

(5) Top of dam - 379

g. Dam

(1) Type - earth fill with stone block core, granite block and concrete riprap on upstream face

(2) Length - 265 feet

(3) Height - 9 feet

(4) Top Width - 21.5 feet

(5) Side slopes - upstream face 1V to 4H (concrete) 1V to 2H (riprap). Downstream face 1V to 2.5H

(6) Zoning - unknown

(7) Impervious core - stone block

(8) Cutoff - unknown

(9) Grout curtain - none

(10) Other - none

h. Diversion and Regulating tunnel. Not applicable (see Section j).

i. Spillway

(1) Type - granite block, with straight drop

(2) Length of weir - 40.0 feet

(3) Crest elevation - 402.48 (with flashboards)
401.15 (permanent crest)

(4) Gates - none

(5) U/S Channel - Penacook Lake. The slopes of the lake appear stable. No evidence of significant sedimentation was observed.

(6) D/S Channel - The dam's spillway discharges into a concrete spillway channel about 12 feet wide and with an average depth of 1.0 foot. The channel runs in an easterly direction for about 190 feet where it terminates at an 8 foot wide by 6 foot high structural pipe plate arch culvert passing underneath the access road to the treatment plant. From this point, the discharge from the concrete channel runs into Rattlesnake Brook which travels in an easterly direction, passing under U.S. Routes 3 and 4 until it discharges into the Merrimack River, approximately 1.0 miles east from the dam site.

j. Regulating Outlets

(1) Invert - Water treatment facility intake structure - 390.7

(2) Size - Total opening 10 feet wide by 14 feet wide

(3) Description - 10 feet wide by 14 feet high cast in place concrete structure with bar screen

(4) Control mechanism - Two 2 feet by 2 feet sluice gates

(5) Other - Old intake structure has been abandoned and filled with concrete

SECTION 2
ENGINEERING DATA

2.1 Design

A plan, circa 1873, showing elevation and section for construction of the dam, intake house, and gate and screen house was obtained from the Concord Water Works, Concord, New Hampshire 03301. A set of plans dated 1968 showing plan, grading, and section of the earth fill and riprap around the Concord Water Treatment Plant were obtained from Camp, Dresser & McKee, Consulting Engineers, Boston, Massachusetts 02108. No in-depth engineering calculations, as-built drawings, or specifications were found.

2.2 Construction

No construction records are available for use in evaluating the dam. The Concord Water Treatment Plant and surrounding site work (including the earth fill and riprap) were built by Pizzagalli Construction Company, Wolfboro, New Hampshire, and completed in 1974.

2.3 Operation

No engineering operational data were found.

2.4 Evaluation

a. Availability. The earth fill and riprap around the Concord Water Treatment Plant was designed by Camp, Dresser & McKee, Consulting Engineers, Boston, Massachusetts. Other than the plans described above, no additional engineering data was found.

b. Adequacy. Available engineering data and drawings are considered adequate for a Phase I investigation.

c. Validity. The field investigation indicated that the external features of the Concord Water Works Dam have changed substantially from the detail shown on the original construction plan, circa 1872. The earth fill and riprap around the Concord Water Treatment Plant substantially agree with those shown on the furnished plans dated 1968.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. Concord Water Works Dam impounds a lake of intermediate size. The watershed above the dam consists of steeply sloped terrain surrounding Penacook Lake. The majority of the drainage basin is heavily wooded and generally undeveloped. The downstream area is heavily developed until it passes underneath U.S. Routes 3 and 4.

The field inspection of the Concord Water Works Dam was made on December 4, 1979. The inspection team consisted of personnel from S E A Consultants Inc. and Geotechnical Engineers Inc. Inspection checklists, completed during the visual inspection, are included in Appendix A. At the time of the inspection, no water was flowing over the spillway. The pool elevation was at approximately 397.6 NGVD. The upstream face of the dam could only be inspected above this water level.

b. Dam. Concord Water Works Dam is an earthen embankment about 9 feet high, 265 feet long, and 21.5 feet wide at the crest (See Photo No. 2).

The upstream face of the dam consists of a 12" thick vertical concrete wall which forms the upper 2 feet of the upstream slope (See Photo No. 3). Immediately below the base of this concrete wall, the embankment slope is covered with a concrete slab on a slope of 1V:4H for a distance of about 4 feet. Below the concrete slab, the slope is protected by flat slabs of cut granite with a slope of 1V:2H which terminates at the bottom of the reservoir (See Photo No. 3). There are several locations where the granite block slope protection has experienced 6 to 8 inches of vertical displacement. An asphalt paved roadway passes over the crest of the dam. The paving has longitudinal cracks approximately on the centerline and running the full length of the embankment section. The location of these cracks coincides approximately with the location of a 2 foot wide stone block wall forming the core of the dam (See Plans and Details in Appendix B).

The vertical concrete wall forming the upper 2 feet of the upstream slope has tilted upstream approximately 1 inch at the walkway leading to the abandoned intake structure. The horizontal restraint provided by this walkway slab has prevented movement of the section of the wall immediately adjacent to the abutment. This restraint has led to the crack which is a few feet left of the walkway abutment (See Plans and Details in Appendix B and Photo No. 4).

The downstream slope of the dam is inclined at 1V:2.5H and is covered with a well-maintained grass cover (See Photo No. 5). Approximately 90 feet downstream of the axis of the dam and along the hillside forming the right abutment, the ground surface is soft and there is standing water (See Photo No. 6). The wetness in this area is attributed to springs which exit from the hillside, including springs on the hillside above the reservoir level. An employee of the Water Department stated that this area is always wet regardless of the reservoir level.

c. Appurtenant Structures. The spillway is located on the left abutment at the termination of the stone block riprap around the water treatment plant (See Overview Photo). The spillway intake area which is several hundred feet wide is located well upstream from the embankment. The floor of the spillway channel is strewn with boulders and covered with a dense grass mat (See Photo No. 8).

The spillway structure has granite block training walls approximately 3 feet high and in good condition (See Photo Nos. 9 and 12). A chain link fence has been installed across the crest of the spillway, to which flashboards have been attached (See Photo Nos. 9 and 12). About 20 feet downstream of the spillway crest, the right side of the spillway is protected by a concrete wall which is about 3 feet high and is in good condition (See Photo Nos. 13 and 14). The left side of the spillway is protected by a 9 inch high granite block wall and is also in good condition.

The floor of the spillway channel has a concrete paving in very poor condition (see Section e.) which extends about 190 feet below the spillway crest to an 8 foot wide and 6 foot high structural plate pipe arch metal culvert (See Photo Nos. 14 and 15).

An abandoned intake structure is located near the center of the dam just upstream from the dam face (See Plans and Details in Appendix B and Photo No. 2). According to existing drawings, a total of three cast iron pipes exit from this intake structure. However, the intake structure's wet wells have been filled with concrete thereby plugging the three pipes. The condition of the outlets could not be verified since they were buried. No evidence of leakage was observed.

d. Reservoir Area. The slopes of the reservoir in the vicinity of the dam appear stable. No evidence of significant sedimentation was observed.

e. Downstream Channel. There is extensive cracking and settlement of the concrete bottom of the spillway channel (See Photo No. 15). There is considerable seepage between these cracks and underneath the concrete slabs.

3.2 Evaluation. On the basis of the visual examination, the dam is considered to be in fair condition.

Deterioration and displacement of the concrete facewall of the upstream slope of the dam indicate the presence of unknown conditions in the interior of the embankment. Further deterioration and collapse of the wall could lead to overtopping of the dam.

The vertical displacement of the granite block slope protection on the upstream face of the dam is further evidence of unknown conditions in the interior of the embankment described above.

The presence of a wet area 90 feet downstream of the dam, along the base of the hillside forming the right abutment, is thought to be due to natural springs on the hillside which are believed not to be influenced by the reservoir. These springs should be observed regularly when the reservoir is at its maximum normal operating level to verify this observation.

Cracking and settlement of the concrete bottom of the spillway channel with visible seepage indicates undermining of the concrete slabs which could lead to extensive erosion when water is passing over the spillway.

SECTION 4
OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 Operational Procedures

a. General. The Concord Water Works Dam is used primarily for the retention of Penacook Lake which acts as a water supply for the City of Concord. The normal operating procedure for this dam is to monitor the water level of the reservoir approximately once a week.

b. Description of Any Warning System in Effect

No written warning system exists for the dam.

4.2 Maintenance Procedures

a. General. The owner, Concord Water Department, is responsible for the maintenance of the dam. No formal plan for maintenance was discussed.

b. Operating Facilities

No formal plan for maintenance of operating facilities was disclosed.

4.3 Evaluation

The current operation and maintenance procedures for Concord Water Works Dam are inadequate to ensure that all problems encountered can be remedied within a reasonable period of time. The owner should establish a written operation and maintenance procedure as well as establishing a warning system to follow in event of flood flow conditions or imminent dam failure.

SECTION 5
EVALUATION OF HYDROLOGIC/HYDRAULIC FEATURES

5.1 General. The Concord Water Works Dam is an earthen embankment approximately 9 feet high from crest of dam to toe of slope and 265 feet long. The spillway structure is located to the north of the dam on the opposite side of the water treatment facility. The spillway is 40 feet long with a permanent concrete block weir, with flashboards installed on the weir crest. Th flashboards are 1.33 feet high, with a 7.5 feet long by 0.33 foot high removable section. Flow over the spillway discharges into a channel which narrows to a width of 12 feet, with a depth of 1 foot. Approximately 190 feet downstream from the spillway weir, the channel discharges into an 8.0 feet wide by 6.0 feet high corrugated metal pipe arch which passes beneath the entrance road to the water treatment facility. The dam impounds Penacook Lake which serves as a water source for the City of Concord. The water surface fluctuates in response to water usage and runoff into the lake. Consequently, during periods of high water usage and low natural runoff to the lake, the impoundment offers a control for stormwater runoff since the reservoir is likely to be lower than the spillway crest.

5.2 Design Data. No hydrological or hydraulic design data were disclosed.

5.3 Experience Data. Records of water surface elevations dating back to the 1880's were examined. The maximum water surface recorded (elevation 402.88 feet NGVD), occurred during the period from April 25, 1955 to May 2, 1955. It was estimated that this water surface elevation would have resulted in a discharge of 45 cfs through the spillway (flashboards in place with 7.5 feet by 0.33 feet removable section removed).

5.4 Test Flood Analysis. Due to the absence of detailed design and operational information, the hydrologic evaluation was performed utilizing data gathered during field inspection, watershed size and an estimated test flood equal to one-half the Probable Maximum Flood (1/2 PMF). The 1/2 PMF test flood was selected over the full PMF, because the dam falls on the lower end of the intermediate size range. The drainage basin is essentially mountainous, however, the "rolling" curve from the Corps of Engineers set of guide curves was used to account for the large reservoir surface area as compared to the size of the drainage area.

Based on an estimated maximum probable flood peak flow rate of 2,300 cfs per square mile and on a drainage area of 3.88 square miles, the test flood inflow was estimated to be 4,460 cfs. The test flood was routed through the dam in accordance with the Corps of Engineers procedure for Estimating Effect of Surcharge Storage on Maximum Probable Discharge. The reservoir water surface was assumed to be at elevation 402.0 prior to the flood routing. The project discharge was estimated to be 1,450 cfs. This analysis indicated that the dam crest would be overtopped by approximately 0.8 feet. The maximum spillway capacity (with flashboards in place) with the water level at the dam crest was estimated to be 290 cfs, which is only about 20 percent of the test flood discharge.

Both the 12 feet wide by 1 foot deep spillway channel and the 8.0 feet wide by 6.0 feet high corrugated metal pipe arch at the end of the spillway channel do not have adequate capacity to handle the test flood discharge. The capacity of the spillway channel was estimated to be approximately 130 cfs while the culvert capacity was estimated to be approximately 400 cfs.

5.5 Dam Failure Analysis. The impact of dam failure with the reservoir surface at the dam crest was assessed utilizing the "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs published by the Corps of Engineers. The analysis covered a reach extending approximately 0.4 mile downstream to a point where the stream channel begins to drop rapidly to the Merrimack River flood plain. Based on this analysis, the Concord Water Works Dam was classified as a significant hazard.

A major breach in the Concord Water Works Dam would increase the stage along the immediate downstream channel by approximately 10 feet, and the stage would be reduced to less than 6 feet after crossing the highway (U.S. Routes 3 and 4), approximately 1,750 feet downstream. Such a breach could damage six to eight houses along the stream reach. In two or three of these houses, water could rise to 1 to 2 feet above the sill, while for the remainder the water would approach the elevation of the sill. The pumping station located near the base of the dam would be inundated with water 6 to 8 feet above the sill of the building. Water would probably be high enough to enter the community swimming pool located about 500 feet below the dam. The failure discharge would rise to about 2 to 3 feet above the lower foundation of the factory which has been constructed adjacent to the stream channel. It appears that the capacity of the culverts beneath a town street and the state highway would not be adequate to handle the failure discharge. Consequently, these roads would be overtopped by water which would be about 2 to 3 feet deep. The potential for loss of life does exist, but it appears that this would not be a likely occurrence.

SECTION 6
EVALUATION OF STRUCTURAL STABILITY

6.1 Visual Observations

The visual inspection indicates the following potential structural problems:

(1) The concrete wall forming the upper 2 feet of the upstream slope has deteriorated and the wall has tilted about its base in some areas as much as 2 inches. Further deterioration and collapse of the wall could lead to overtopping of the dam.

(2) The upstream slope protection has been displaced vertically and horizontally in several areas. Continued movement of the slope protection could lead to further movement of the concrete wall described above.

(3) A wet area 90 feet downstream of the embankment was thought to be due to springs on the abutment hillside which were not influenced by the reservoir. However, if further inspection indicates that the springs are influenced by the reservoir, this seepage, if left uncontrolled, could lead to failure of the dam.

(4) Cracking and settlement of the concrete spillway channel which could lead to extensive erosion when water is passing over the spillway.

6.2 Design and Construction Data

A plan, circa 1873, showing elevation and section for construction of the dam, intake house, and gate and screen house was obtained from the Concord Water Department. A set of plans dated 1968 showing plan, grading and section of the earth fill and riprap around the Concord Water Treatment Plant were obtained from Camp, Dresser & McKee, Consulting Engineers. No design data were found for the spillway structure, and the date of its construction is unknown.

6.3 Post-Construction Changes

Considerable changes have been made to the dam in comparison to the design detail shown on the 1873 plan. Concrete face walls on the upstream and downstream face of the dam have been constructed. Concrete and stone riprap on the upstream slope, asphalt pavement on the crest of the dam and concrete rail posts have also been added. Photographs on file at the New Hampshire Water Resources Board indicate these changes were made before 1934.

During the construction of the Concord Water Treatment Plant in 1974, some changes were made to the spillway structure. The right wall of the spillway channel which was constructed with granite block was replaced with a 3 foot high concrete wall, and an existing granite block culvert underneath the road at the end of the spillway was replaced with a pipe arch culvert.

Once the water treatment plant was finished and in operation, the existing works at the dam were abandoned. The valves to the pipes were closed and the inlets at the intake house and gate and screen house were plugged with concrete.

6.4 Seismic Stability

This dam is located in Seismic Zone 2 and, in accordance with the Phase I guidelines, does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATION, AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual examination indicates that the dam is in fair condition. The major concerns with respect to the integrity of the dam are:

(1) Deterioration of the concrete wall forming the upper 2 feet of the upstream slope.

(2) Displacement of the upstream slope protection.

(3) A wet area 90 feet downstream of the dam at the base of the hillside which forms the right abutment.

(4) Cracking and settlement of the concrete spillway bottom.

(5) Inadequacy of the spillway to pass the test flood.

(6) Apparent lack of a low level regulating outlet that would allow drawdown of the reservoir in an emergency.

b. Adequacy of Information. The information available from the visual inspection and hydraulic computations is adequate to identify the problems listed in 7.2. These problems will require the attention of a qualified registered professional engineer who will have to make additional engineering studies to design or specify remedial measures. No additional information is needed for the purposes of this Phase I investigation.

c. Urgency. The owner should implement the recommendations in 7.2 and 7.3 within one year after receipt of this Phase I report.

7.2 Recommendations

The owner should retain a registered professional engineer qualified in the design and construction of dams to:

(1) Investigate a means of stabilizing the upstream slope protection, including the vertical wall.

(2) Investigate the possibility that the springs downstream of the dam on the right abutment hillside may be influenced by the reservoir.

(3) Do a detailed hydrologic-hydraulic investigation to assess further the potential of overtopping the dam, the adequacy of the spillway to pass the test flood, and the need for and means to increase project discharge capacity.

(4) Assess the need for and means to provide a low level regulating outlet that would allow drawdown of the reservoir in an emergency.

The owner should carry out the recommendations made by the engineer.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The owner should:

(1) Monitor the displacement of the concrete wall on the upstream slope of the dam until the recommendation made in 7.2(1) has been carried out.

(2) Monitor the wet area 90 feet downstream of the dam periodically until the recommendation made in 7.2(2) has been carried out.

(3) Repair the cracking and settlement of the concrete spillway bottom.

(4) Remove the chain link fence from the spillway.

(5) Engage a registered professional engineer qualified in the design and construction of dams to make a comprehensive technical inspection of the dam once every year.

(6) Establish a surveillance program for use during and immediately after heavy rainfall and also a warning program to follow in case of emergency conditions.

7.4 Alternatives

There are no practical alternatives to the recommendations of Section 7.2 and 7.3 except that on an interim basis, the owner may consider operating the reservoir at its present lower level throughout the year so as to provide more storage for extreme flood events.

APPENDIX A

INSPECTION CHECK LIST

INSPECTION CHECK LIST
PARTY ORGANIZATION

PROJECT: Concord Water Works Dam, N.H.

DATE: December 4, 1979

TIME: 9:00 A.M.

WEATHER: Cloudy and cold

W.S. ELEV. 397.6 U.S. N/A DN.S.
(U.S.G.S. Datum)

PARTY:

1. Kenneth Stewart, S E A
2. Robert Durfee, S E A
3. Bruce Pierstorff, S E A
4. Philip Ricardi, S E A
5. Dan LaGatta, GEI
6. Kenneth Stern, N.H.W.R.B.
7.
8.
9.
10.

	PROJECT FEATURE	*INSPECTED BY*	*REMARKS*
1.	Structural stability	K.Stewart/R.Durfee	
2.	Hydrology/hydraulics	B. Pierstorff/P. Ricardi	
3.	Soils and geology	D. LaGatta	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, NH DATE: December 4, 1979

PROJECT FEATURE: Dam Embankment NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
DAM EMBANKMENT	
Crest Elevation	404.04
Current Pool Elevation	397.6
Maximum Impoundment to Date	402.88 from 9/25/55 to 5/2/55
Surface Cracks	Asphalt cracked longitudinally along core wall
Pavement Condition	Asphalt pavement in good condition
Movement or Settlement of Crest	Slight differential settlement transverse sections
Lateral Movement	None observed
Vertical Alignment	Concrete wall on upstream face has moved upstream and rotated outward about its base
Horizontal Alignment	Concrete wall on upstream face has moved upstream and rotated outward about its base
Condition At Abutment and at Concrete Structures	Condition at abutments is good
Indications of Movement of Structural Items on Slopes	Concrete wall on upstream slope & concrete decking on upper slope have experienced small movements
Trespassing on Slopes	No evidence observed
Vegetation on Slopes	Well maintained
Sloughing or Erosion of Slopes or Abutments	None observed
Rock Slope Protection - Riprap Failures	Slope protection is cut granite and there has been minor displacements
Unusual Movement or Cracking at or near Toe	None observed
Unusual Embankment or Downstream Seepage	Ponded water @ 90 ft downstream on rt. abutment. This water attributed to springs in hillside above dam.
Piping or Boils	None observed
Foundation Drainage Features	None observed
Toe Drains	None observed
Instrumentation System	None observed

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Dike Embankment NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
DIKE EMBANKMENT	No dike
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Vegetation on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	
Unusual Movement or Cracking at or near Toes	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Intake Channel NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	Original outlet works which consisted of an intake below reservoir level has been plugged with concrete. New intake through riprap at water treatment plant.
a. Approach Channel	
Slope Conditions	Good
Bottom Conditions	Not visible beneath reservoir surface
Rock Slides or Falls	None
Log Boom	None
Debris	None
Condition of Concrete Lining	Not applicable
Drains or Weep Holes	None
b. Intake Structure	
Condition of Concrete	Good
Stop Logs and Slots	Moderate rust on 1" x 3/8" bar stock screen

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Control Tower NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	Original control tower no longer in use
a. Concrete and Structural	
General Condition	
Condition of Joints	
Spalling	
Visible Reinforcing	
Rusting or Staining of Concrete	
Any Seepage or Efflorescence	
Joint Alignment	
Unusual Seepage or Leaks in Gate Chamber	
Cracks	
Rusting or Corrosion of Steel	
b. Mechanical and Electrical	
Air Vents	
Float Wells	
Crane Hoist	
Elevator	
Hydraulic System	
Service Gates	
Emergency Gates	
Lightning Protection System	
Emergency Power System	
Wiring and Lighting System in Gate Chamber	

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Transition and Conduit NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	Not visible
General Condition of Concrete	
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Outlet Structure NAME:

DISCIPLINE: NAME:

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	Outlet is through water treatment plant to municipal water supply system
General Condition of Concrete	
Rust or Staining	
Spalling	
Erosion or Cavitation	
Visible Reinforcing	
Any Seepage or Efflorescence	
Condition at Joints	
Drain Holes	
Channel	
Loose Rock or Trees Overhanging Channel	
Condition of Discharge Channel	

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Spillway Weir NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	Very wide approach channel around left abutment of dam. Usually water in channel.
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	None
Floor of Approach Channel	Good condition. Glacial till with small swampy areas.
b. Weir and Training Walls	
General Condition of Concrete	Training walls upstream are granite cut blocks; downstream the granite cut block stops and the right training wall continues as a concrete wall.
Rust or Staining	None
Spalling	None
Any Visible Reinforcing	None
Any Seepage or Efflorescence	None
Drain Holes	None
c. Discharge Channel	
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	None
Floor of Channel	At base of weir the channel is lined with flat cut granite blocks and is in good condition; downstream, the channel floor is concrete and is in poor condition with numerous cracks and evidence of extensive undermining.
Other Obstructions	There is a culvert beneath access road to the site approximately 200 feet downstream of spillway weir

INSPECTION CHECK LIST

PROJECT: Concord Water Works Dam, N.H. DATE: December 4, 1979

PROJECT FEATURE: Service Bridge NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	No service bridge
a. Super Structure	
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Under Side of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

APPENDIX B

ENGINEERING DATA

AVAILABLE ENGINEERING DATA

A plan, circa 1873, showing elevation and section for construction of the dam, intake house, and gate and screen house was obtained from the Concord Water Department, 16 Penacook Street, Concord, New Hampshire 03301. A set of plans dated 1968 showing plan, grading, and section of the earth fill and riprap around the Concord Water Treatment Plant were obtained from Camp, Dresser, and McKee, Consulting Engineers, One Center Plaza, Boston, Massachusetts 02108. No in-depth engineering calculations, as-built drawings, or specifications were found.

PAST INSPECTION REPORTS

M E M O

Date: December 5, 1979

To: Vernon A. Knowlton,
Chief Engineer

From: Ken Stern,
Water Resources Engineer

Subject: Corps Inspection of Concord Water Works Dam No. 51.13, Concord

On December 4, 1979 I accompanied the inspection team from SEA Consultants. At the time of inspection the lake was down several feet.

The items in need of attention are as follows:

1- The upstream concrete retaining wall is in fair to poor condition. It is cracked in several locations, badly spalled in several locations and leaning. The wall is only 2 ft. high.

2- The upstream concrete apron is badly spalled just left of the service bridge to the old intake structure.

3- The upstream split stone slope paving has settled in areas. This should be monitored.

4- The concrete channel downstream of the spillway is undermined in areas. The water flows on the surface then underneath and then on the surface again.

There is water coming out of the right downstream hillside. This is apparently from springs.

The dam should be reinspected during the spring for seepage at the toe when the pond is full.

I believe any action on this dam can wait until receipt of the Corps' report.

KS:paf

NEW HAMPSHIRE WATER RESOURCES BOARD

INSPECTION REPORT

Town: CONCORD WATER WORKS Dam Number: 51.13

Name of Dam, Stream and/or Water Body: PENACOOK LAKE

ATT: ~~Owner~~: ROBERT GILLIS, DIRECTOR Telephone Number: 225-5575

Mailing Address: 16 PENACOOK ST

Max. Height of Dam: _____ Pond Area: _____ Length of Dam: _____

FOUNDATION: _____

OUTLET WORKS:

- 35' SPILLWAY 1' FREEBOARD OVER 16" BOARDS

80" x 58" ELLIPTICAL PIPE UNDER DRIVE

ABUTMENTS: 300' LONG GRANITE BLOCK DAM

EMBANKMENT: _____

Note: Give Sizing, Condition and detailed description for each item, if applicable.

Dam No._____

SPILLWAY: Length:_____ Freeboard:_____

SEEPAGE: Location, estimated quantity, etc.

_____

_____

_____

_____

_____

Changes Since Construction or Last Inspection:

_____

_____

_____

Tail Water Conditions:

_____

_____

Overall Condition of Dam: _____

Contact With Owner: _____

Date of Inspection:_____ Suggested Reinspection Date SPRING 79

Class of Dam:_____

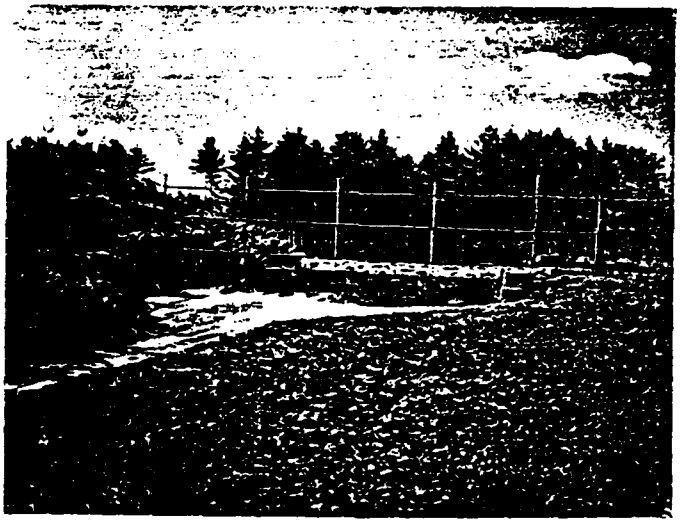
Signature Ken Stern

Date _____

Note: Give Sizing, Condition and detailed description for each item,if applicable.

Dam No._____

COMMENTS:



NEW HAMPSHIRE WATER RESOURCES BOARD

INSPECTION REPORT

Town: Concord Dam Number: 51.13

Name of Dam, Stream and/or Water Body:

Owner: Concord Water Works Telephone Number:

Mailing Address:

Max. Height of Dam: 9' ± Pond Area: Length of Dam:

FOUNDATION: Earth

OUTLET WORKS:

ABUTMENTS:

EMBANKMENT: Seemed well maintained however should return in spring to see if there are any signs of seepage - at time of inspection H2O level was very low.

Dam No. _____

SPILLWAY: Length: _____ Freeboard: _____

SEEPAGE: Location, estimated quantity, etc.

To be determined in Spring

Changes Since Construction or Last Inspection:

Tail Water Conditions:

Overall Condition of Dam: Seemed well maintained however should retrace in sp

Contact With Owner: _____

Date of Inspection: 12-5-77 Suggested Reinspection Date Spring 78

Class of Dam: _____

Signature James J. Dunn

Date 12-5-77

FORM 82 8252

NEW HAMPSHIRE
WATER RESOURCES
BOARD
CONCORD, N. H.

PROJECT

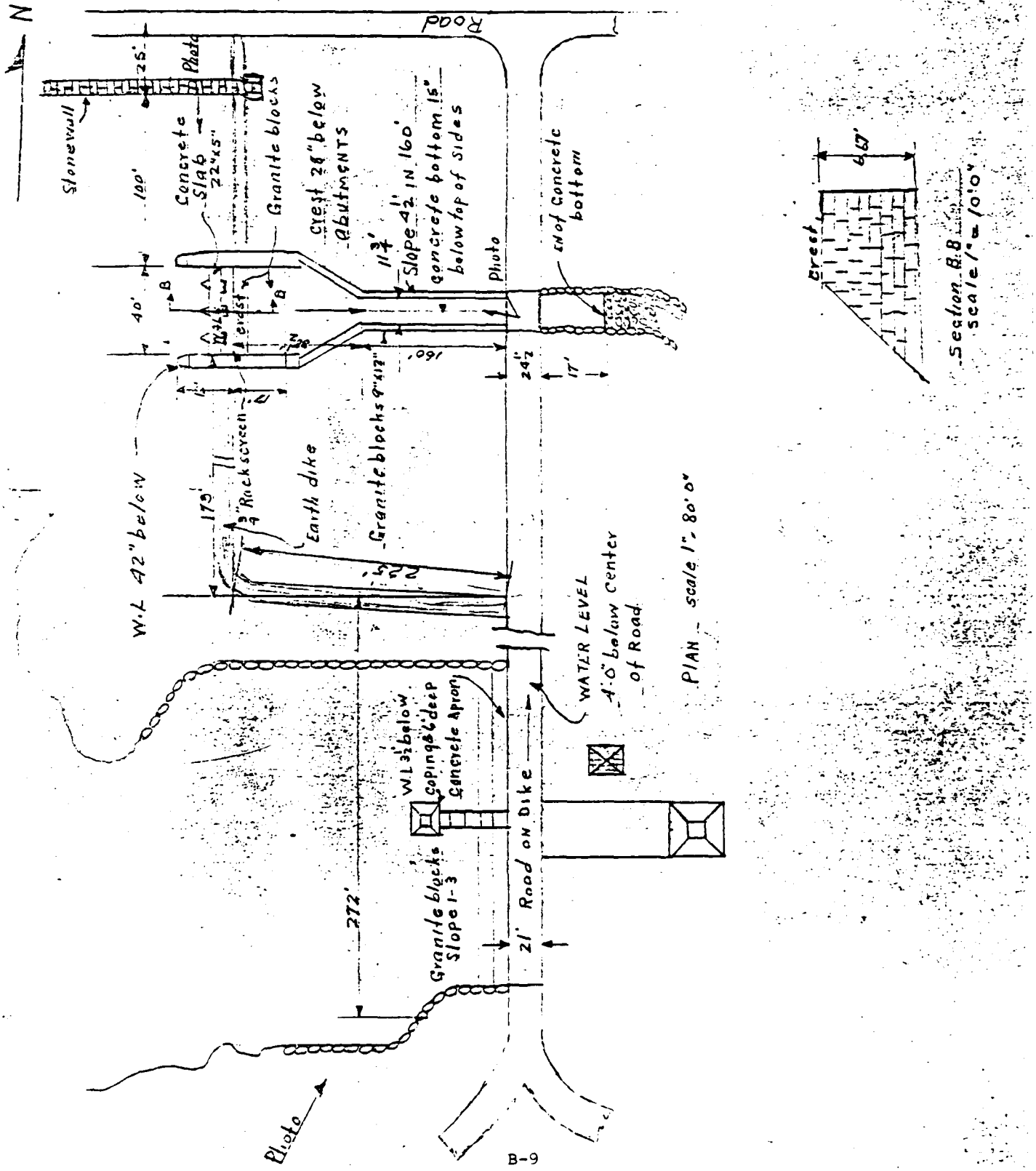
FILE 51.13

SUBJECT PENACOOK LAKE CONCORD ACC

MERRIMACK. CONCORD WATER WORKS

COMPUTER G. S. N. CHECKER R.L.T. CONT. FROM ACC. CONT. ON ACC. SUMMARY ON ACC. DATE 8/16/39

PENACOOK LAKE



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I-5

NEW HAMPSHIRE WATER CONTROL COMMISSION
DATA ON DAMS IN NEW HAMPSHIRE

LOCATION STATE NO. 51.13

Town Concord ✓ : County Merrimack

Stream Penacook Lake ✓

Basin-Primary Merrimack R ✓ : Secondary Rattlesnake Brs.

Local Name

Coordinates—Lat. 43° 15' - 2,500 FT. Long. 71° 35' - 1400 Ft. ✓

GENERAL DATA

Drainage area: Controlled ~~X.X~~ Sq. Mi.: Uncontrolled Sq. Mi.: Total 3.89 ✓ ~~X4~~ Sq. Mi.

Overall length of dam 810 ✓ ft.: Date of Construction

Height: Stream bed to highest elev. 9 ✓ ft.: Max. Structure 6.67 ✓ ft.

Cost—Dam : Reservoir

DESCRIPTION Earth Embankment- Earth Granite Concrete on Earth ✓

Waste Gates

Type

Number : Size ft. high x ft. wide

Elevation Invert : Total Area sq. ft.

Hoist

Waste Gates Conduit

Number : Materials

Size ft.: Length ft.: Area sq. ft.

Embankment

Type

Height—Max. ft.: Min. ft.

Top—Width : Elev. ft.

Slopes—Upstream on : Downstream on

Length—Right of Spillway : Left of Spillway

Spillway

Materials of Construction

Length—Total 40 ✓ ft.: Net ft.

Height of permanent section—max. 6.67 ✓ ft.: Min. ft.

Flashboards—Type None : Height ft.

Elevation—Permanent Crest : Top of Flashboard

Flood Capacity 400 cfs.: 102.8 cfs/sq. mi.

Abutments

Materials:

Freeboard: Max. 2.33 ✓ ft.: Min. ft.

Headworks to Power Devel.—(See "Data on Power Development")

OWNER Concord Water Works

Condition Good

REMARKS Water Supply Domestic

Tabulation By A.A.M. & R.L.T. Date November 14, 1938.

NEW HAMPSHIRE WATER RESOURCES BOARD

INVENTORY OF DAMS AND WATER POWER DEVELOPMENTS

DAM

BASIN Merrimack NO. 13 — 304 — I-3847
RIVER Penacook Lake MILES FROM MOUTH ____ D.A.SQ.MI. 2.4
TOWN Concord OWNER Concord Water Board
LOCAL NAME OF DAM
BUILT ____ DESCRIPTION Earth Embankment — Earth Granite, Concrete on Earth

POND AREA-ACRES 35&165 DRAWDOWN FT. ____ POND CAPACITY-ACRE FT. ____
HEIGHT-TOP TO BED OF STREAM-FT. 9± MAX. ____ MIN. ____
OVERALL LENGTH OF DAM-FT. 810 MAX.FLOOD HEIGHT ABOVE CREST-FT. ____
PERMANENT CREST ELEV.U.S.G.S. ____ LOCAL GAGE ____
TAILWATER ELEV.U.S.G.S. ____ LOCAL GAGE ____
SPILLWAY LENGTHS-FT. 40 FREEBOARD-FT. 2.33
FLASHBOARDS-TYPE, HEIGHT ABOVE CREST None

WASTE GATES-NO.	WIDTH	MAX. OPENING	DEPTH SILL BELOW CREST
—	—	—	43° 15'-2700'
—	—	—	71° 35'-14400'

REMARKS Condition Good

-5 1- Rattlesnake Bk into Merrimack

POWER DEVELOPMENT

UNITS	NO.	RATED HP	HEAD FEET	C.F.S. FULL GATE	KW	MAKE

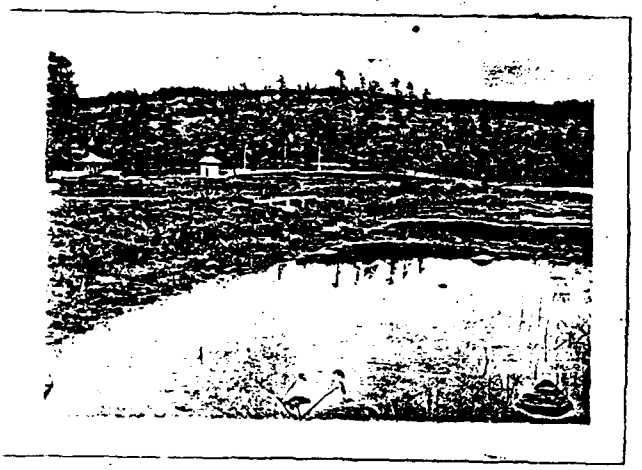
USE Conservation. Public Utility

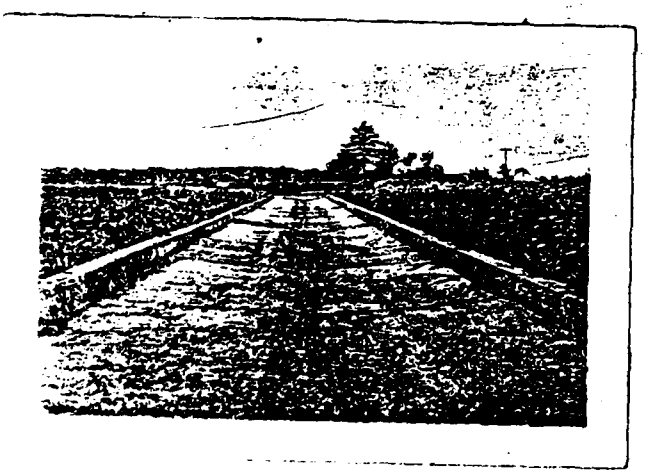
REMARKS Water Supply

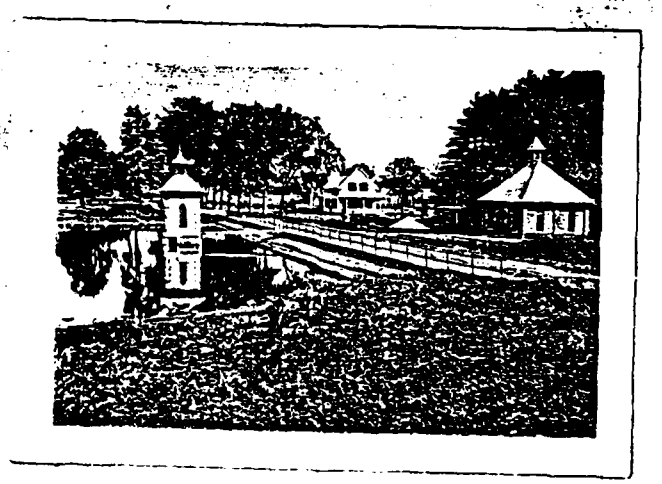
DATE 8/15/34

No. 51.13

PENACOOK LAKE IN CONCORD
Concord Water Works
August 15, 1934

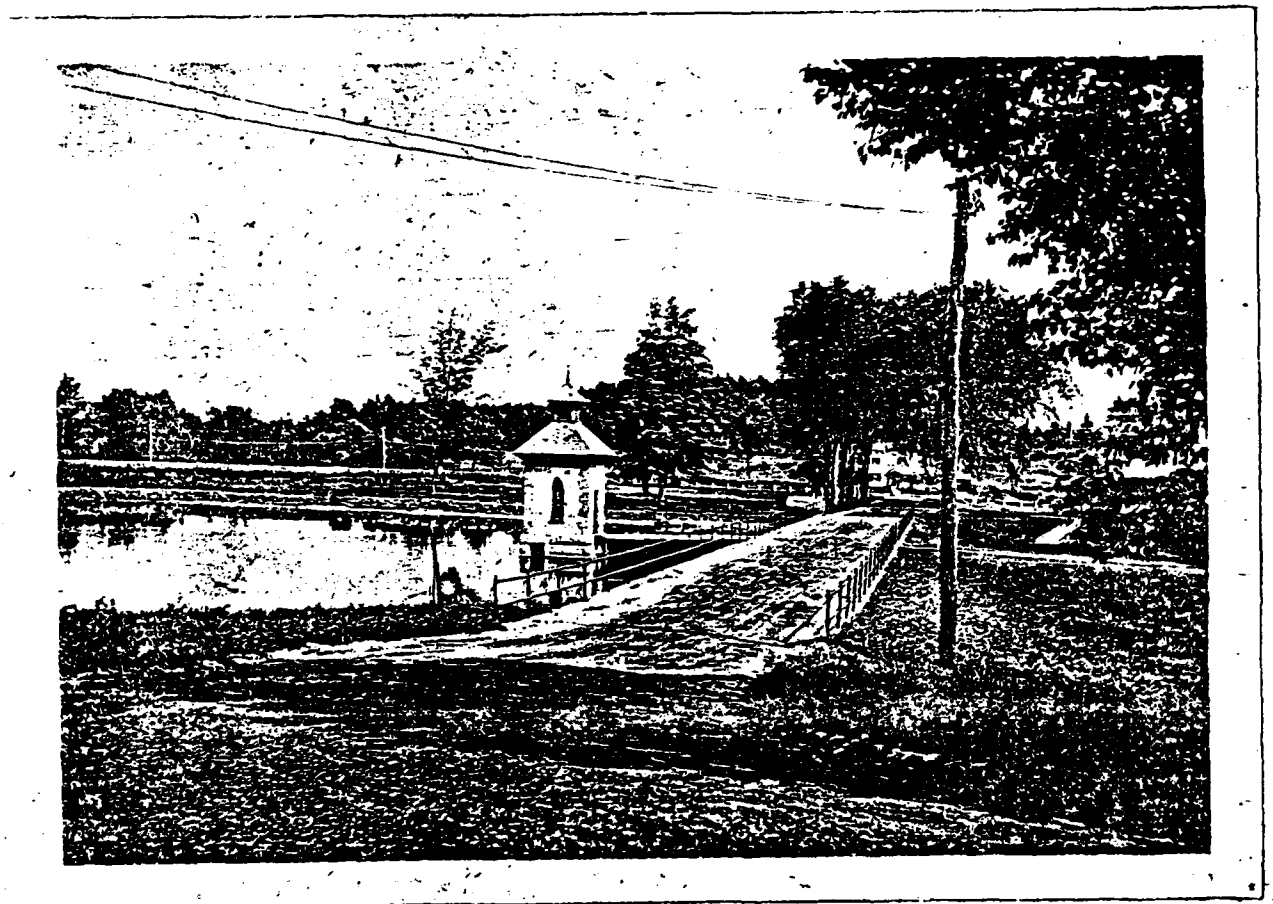




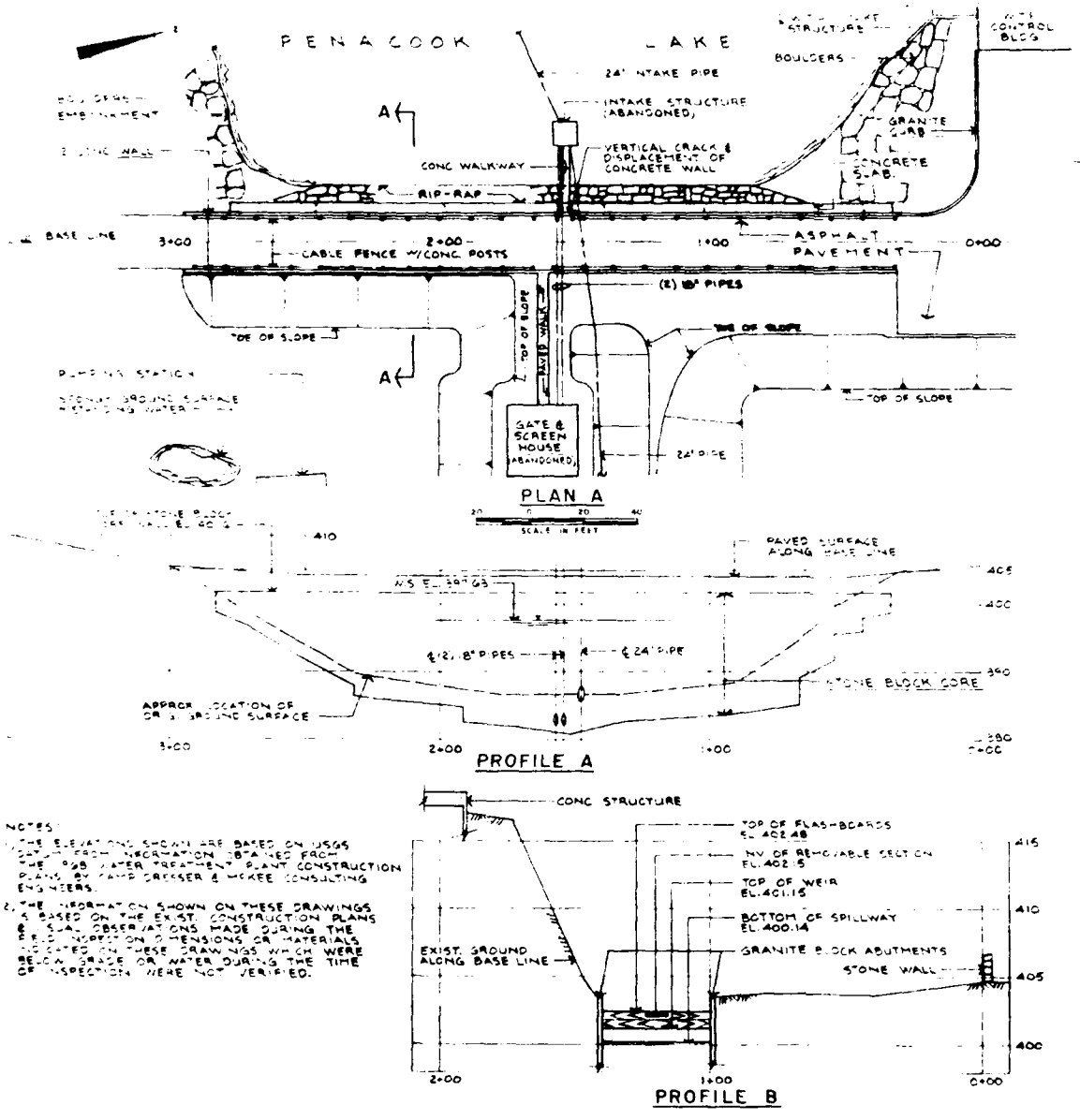


No. 51.13

PENACOOK LAKE IN CONCORD
Concord Water Works
August 15, 1934

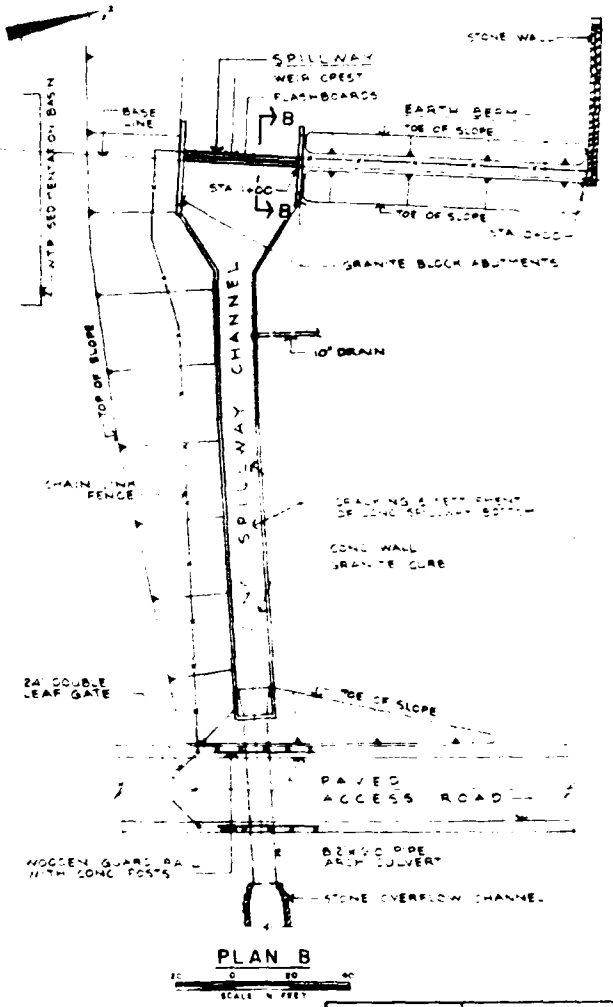


PLANS AND DETAILS



NOTES:

1. THE ELEVATIONS SHOWN ARE BASED ON USGS DATA FROM RECREATION OBTAINED FROM THE PSNH WATER TREATMENT PLANT CONSTRUCTION PLANS BY CAMP DRESSER & MCKEE CONSULTING ENGINEERS.
2. THE INFORMATION SHOWN ON THESE DRAWINGS IS BASED ON THE EXIST. CONSTRUCTION PLANS & VISUAL OBSERVATIONS MADE DURING THE FIELD INSPECTION. DIMENSIONS OR MATERIALS INDICATED ON THESE DRAWINGS WHICH WERE BELOW GRADE OR WATER DURING THE TIME OF INSPECTION WERE NOT VERIFIED.

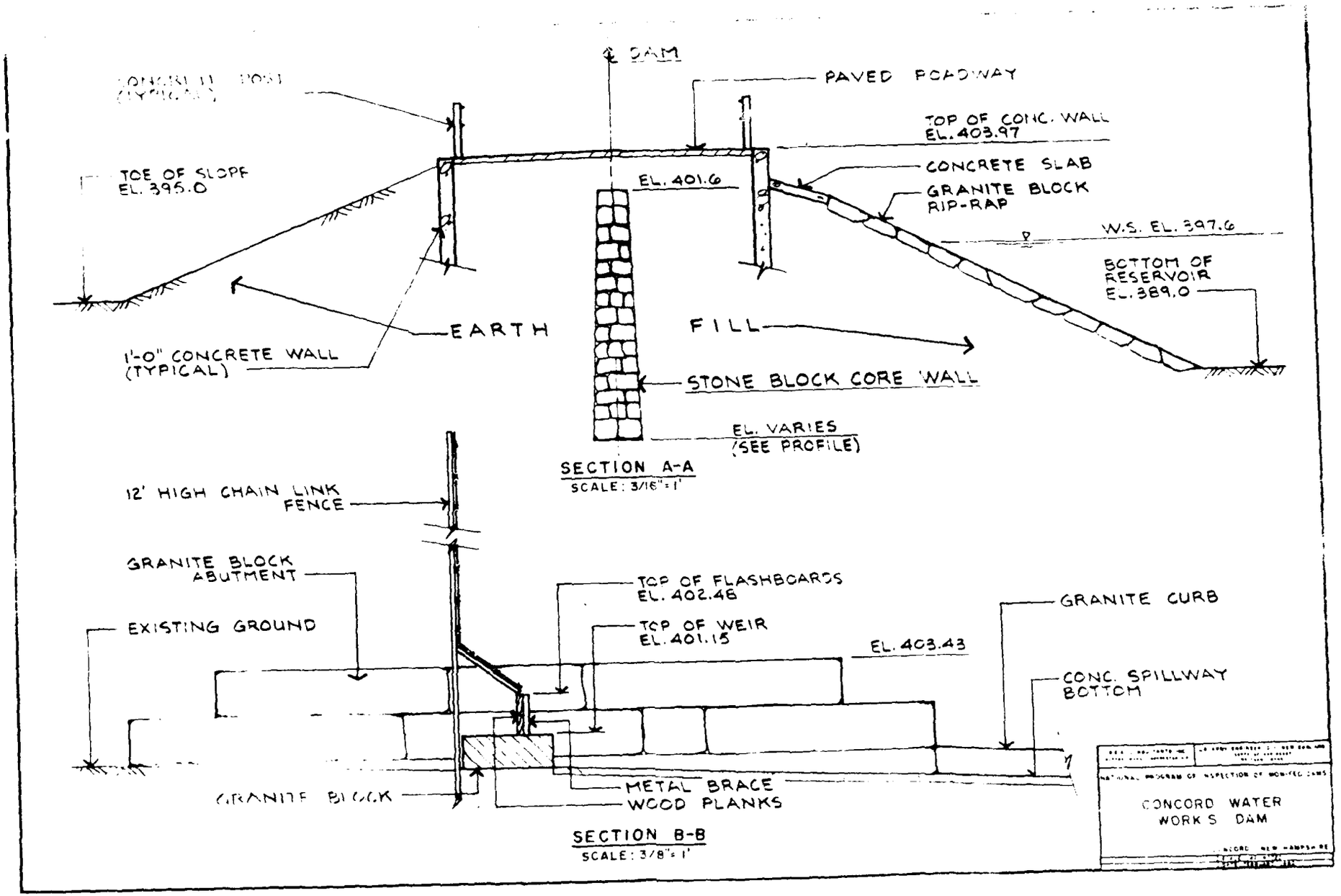


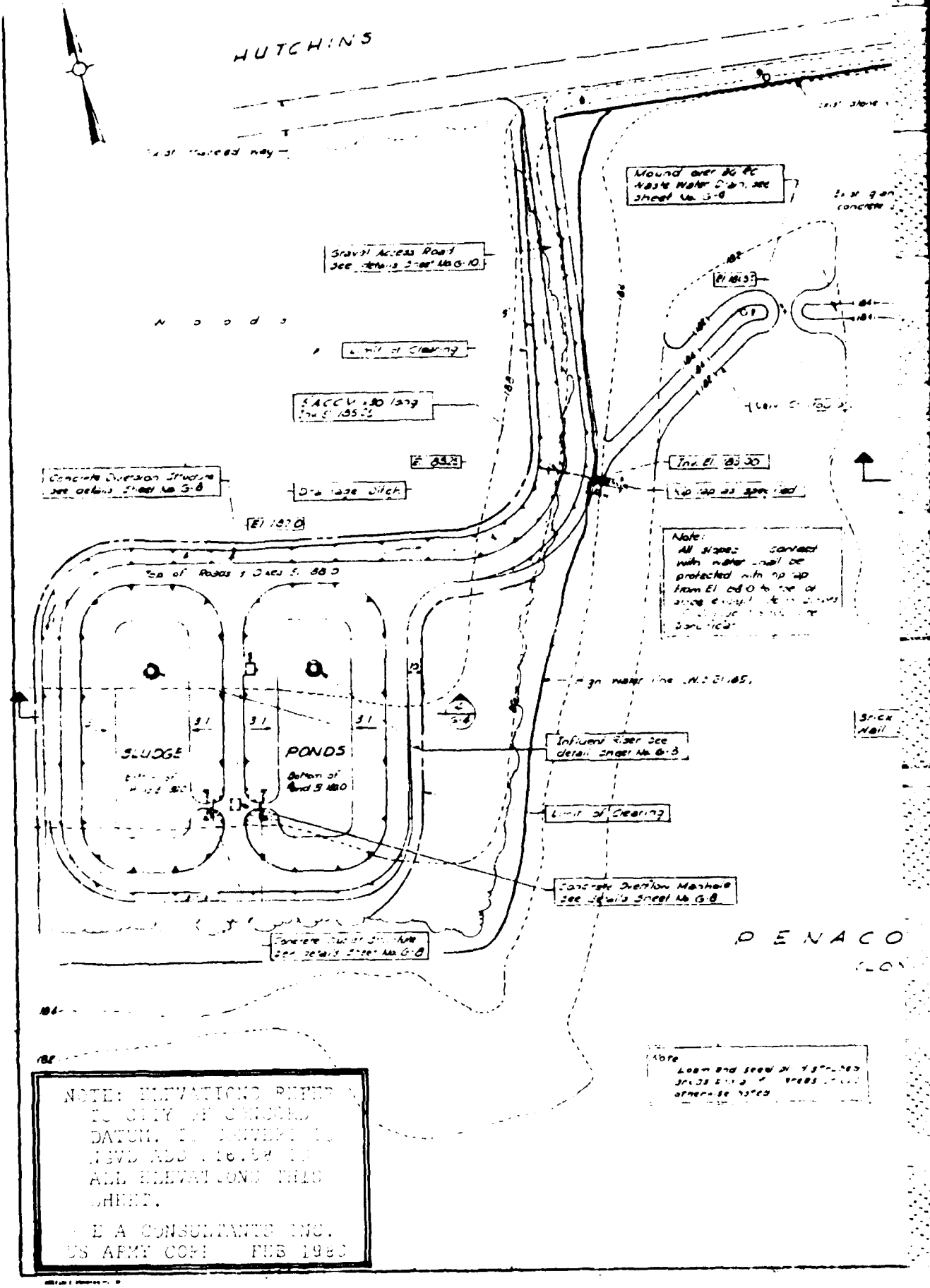
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

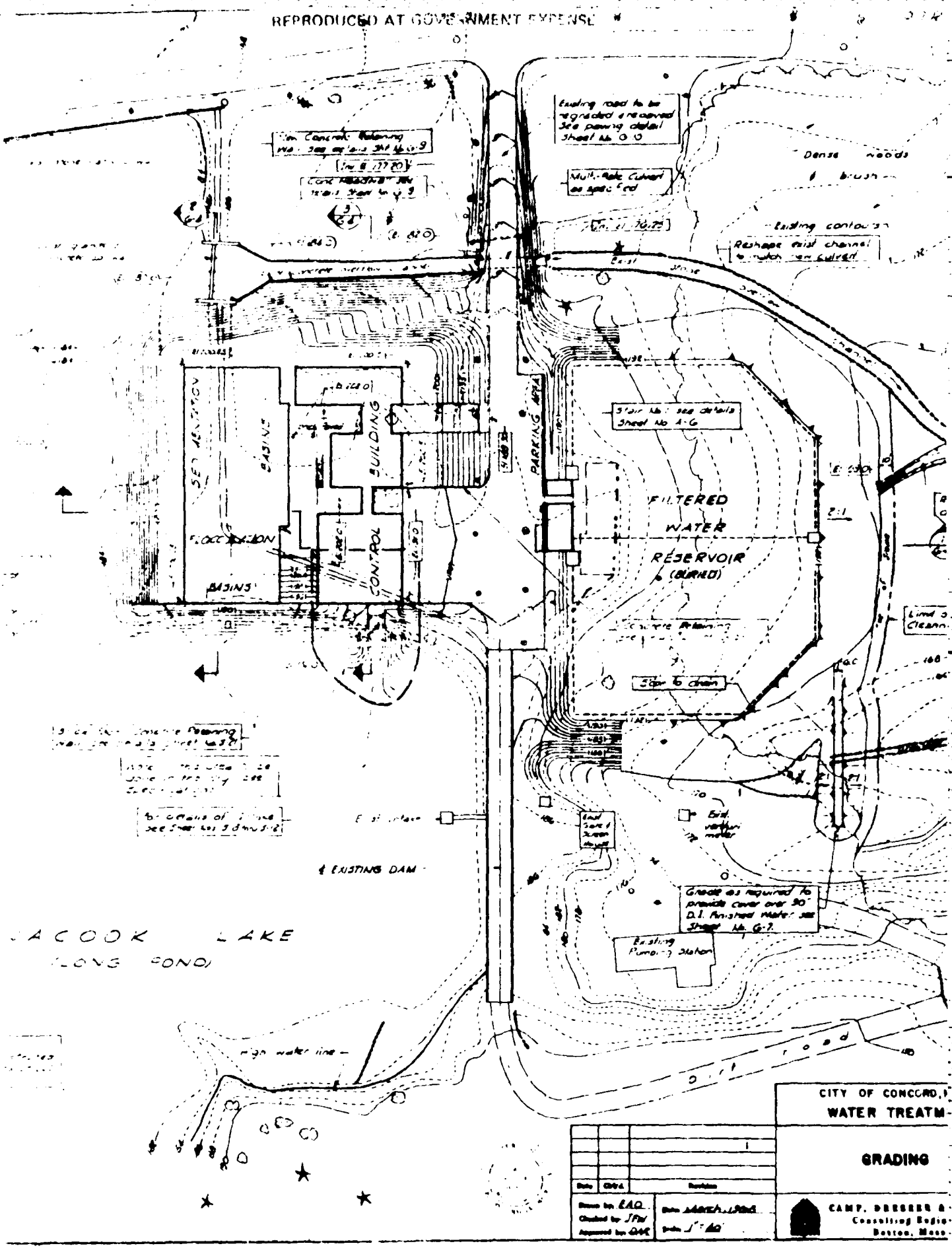
CONCORD WATER WORKS DAM

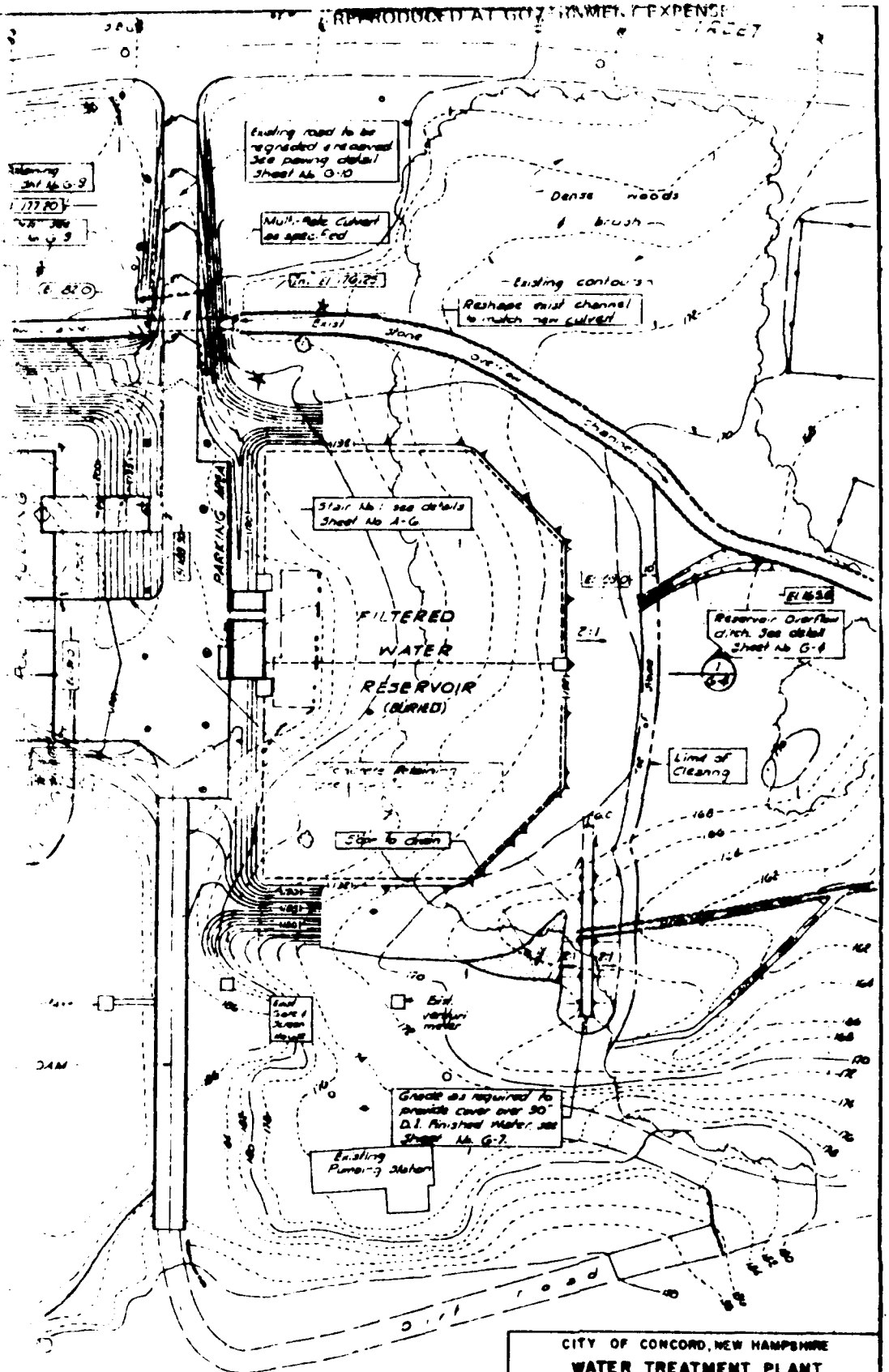
CONCORD, NEW HAMPSHIRE

APPROVED AT GOVERNMENT EXPENSE


℄ DAM
CONCRETE POST (TYPICAL)
PAVED ROADWAY
TOP OF CONC. WALL EL. 403.97
CONCRETE SLAB
GRANITE BLOCK RIP-RAP
TOE OF SLOPE EL. 395.0
EL. 401.6
W.S. EL. 397.6
BOTTOM OF RESERVOIR EL. 389.0
EARTH
FILL
1'-0" CONCRETE WALL (TYPICAL)
STONE BLOCK CORE WALL
EL. VARIES (SEE PROFILE)
SECTION A-A
SCALE: 3/16" = 1'
12' HIGH CHAIN LINK FENCE
GRANITE BLOCK ABUTMENT
TOP OF FLASHBOARDS EL. 402.48
TOP OF WEIR EL. 401.15
EL. 403.43
GRANITE CURB
EXISTING GROUND
CONC. SPILLWAY BOTTOM
GRANITE BLOCK
METAL BRACE
WOOD PLANKS
SECTION B-B
SCALE: 3/8" = 1'
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS
CONCORD WATER WORKS DAM







CITY OF CONCORD, NEW HAMPSHIRE

WATER TREATMENT PLANT

GRADING PLAN

Date	Chkd.	Revision

Drawn by EAO
Checked by JFM
Approved by CHF
Date March, 1968
Scale 1" = 40'

CAMP, DRESSER & McKEE
Consulting Engineers
Boston, Mass.

SHEET NO. G-3

189-0987

APPENDIX C

SELECTED PHOTOGRAPHS

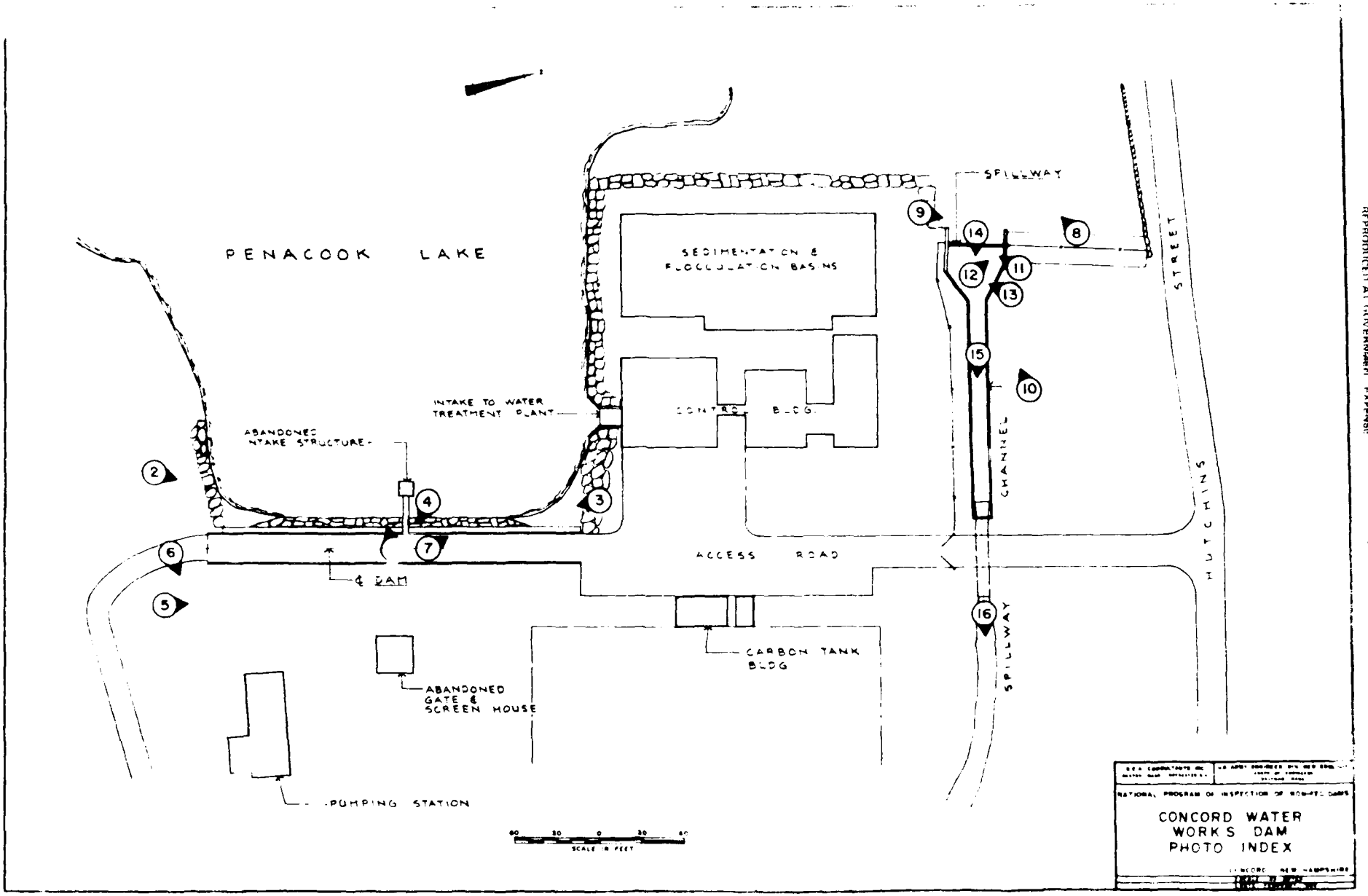

PENACOOK LAKE
SEDIMENTATION & FLOCCULATION BASINS
CONTROL BLDG.
SPILLWAY
STREET
HUTCHINS
CHANNEL
INTAKE TO WATER TREATMENT PLANT
ABANDONED INTAKE STRUCTURE
ACCESS ROAD
℄ DAM
CARBON TANK BLDG
SPILLWAY
ABANDONED GATE & SCREEN HOUSE
PUMPING STATION
SCALE IN FEET
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS
CONCORD WATER WORKS DAM
PHOTO INDEX

Photo No. 1 - General view of reservoir from dam.

Photo No. 2 - General view of dam from right abutment.

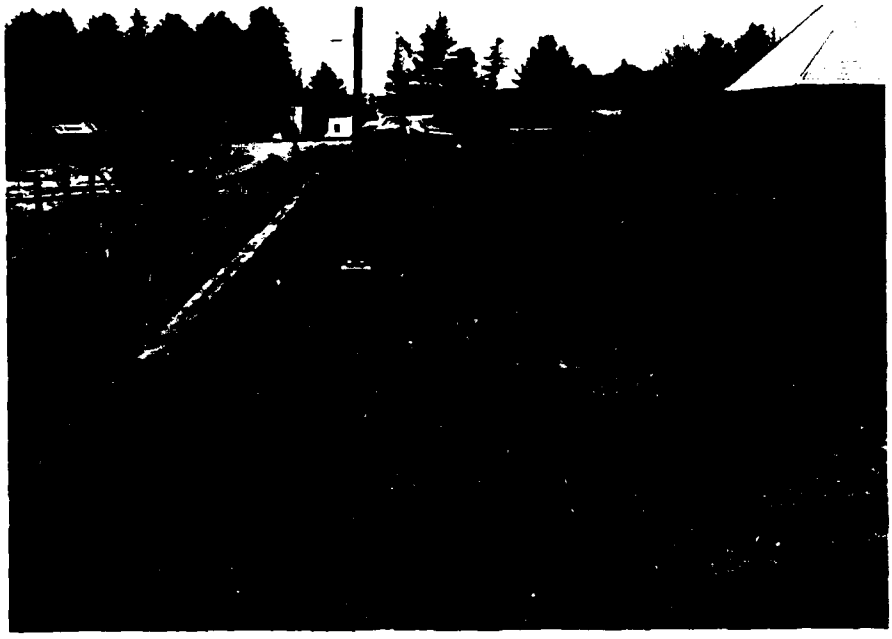


Photo No. 5 - Downstream slope of dam from right abutment.

Photo No. 6 - Wet area at toe of downstream slope of dam at right abutment.

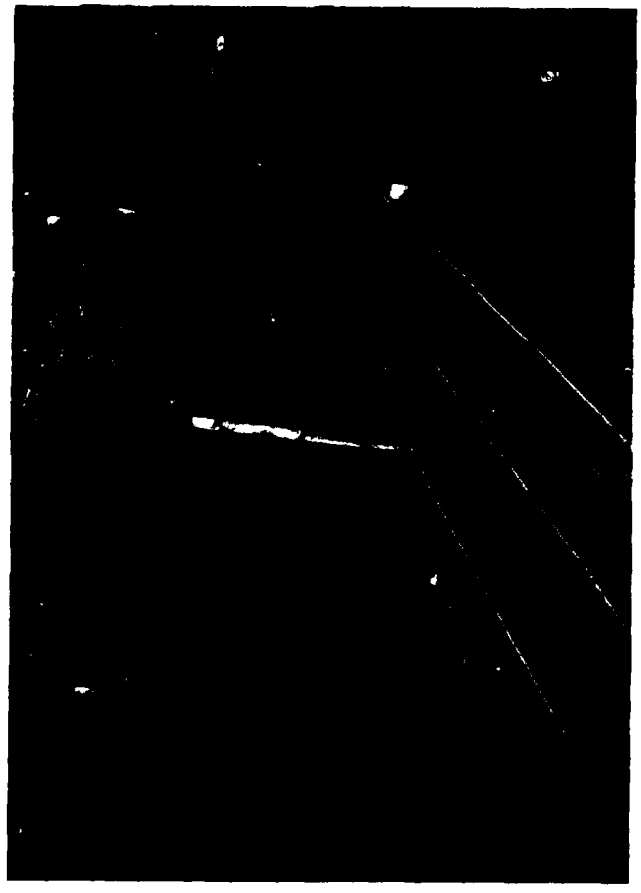


Photo No. 9 - Upstream face of dike from slope at right abutment looking toward left abutment.

Photo No. 10 - Downstream face of spillway stoplog section.

Photo No. 13 - Right training wall of spillway discharge channel.

Photo No. 14 - View of spillway discharge channel from spillway stoplog section.

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

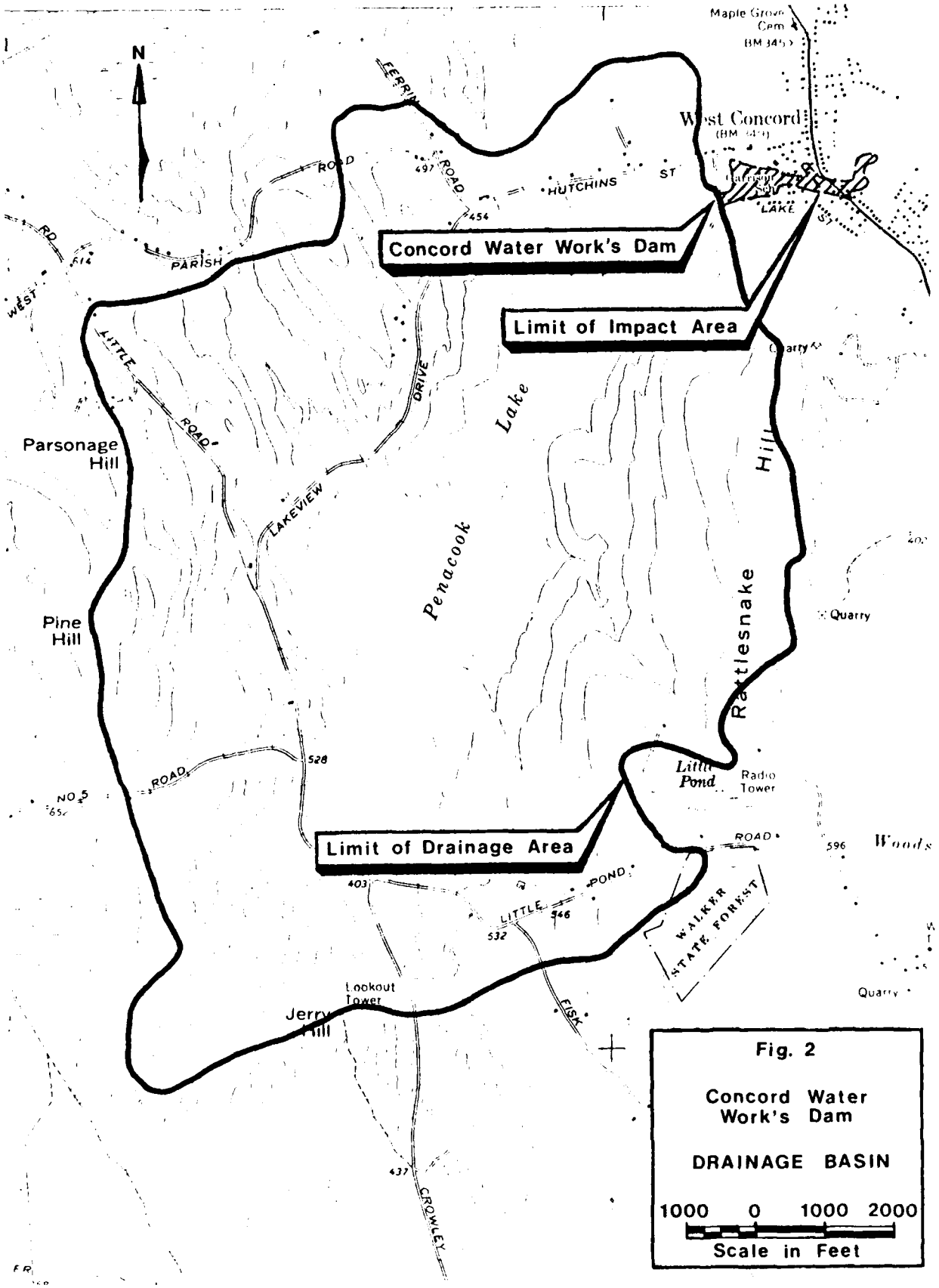


Fig. 2

Concord Water Work's Dam

DRAINAGE BASIN

1000 0 1000 2000

Scale in Feet

I. Basic Data

A. Drainage Area

1. 3.89 sq. mi. – as defined on U.S.G.S sheets and then planimetered

2. drainage area would classify as mountainous, but since reservoir large compared to drainage area use rolling curve for estimating MPF

B. Dam and Storage Information

1 Size Classification: INTERMEDIATE based on storage (≥ 1000 and < 50,000 acre-ft)

is intended below Storage at crest of dam estimated to be 2210 acre-ft

2 Hazard Potential: SIGNIFICANT

May impact 6-8 houses, a community swimming pool, a storage bldg at WTP, a factory, a town street and a state road. Also loss of a few lives.

3. Storage Information

Descriptive Information	Elevation * (ft)	Reservoir * Area (acres)	Storage * (acre-ft)
410' contour	410.0	447	4675
Crest of dam	404.04	379	2210
Crest of berm	403.43	374	2035
Top of flood control pool	401.43	363	1870

Descriptive Information	Elevation * (ft.)	Surface * Area (acres)	Storage * (acre-ft.)
Top of flash-boards with 7.5' long X 0.33' wide section removed	402.15	358	1515
Top of permanent weir crest	401.15	347	1160

* Notes: (1) elevations: USGS datum
(2) normal pool taken to correspond with pool shown on USGS sheet, elevation of pool assumed to correspond with elevation of flashboards with 4" removable section removed
(3) surface area at crest of dam determined by interpolating between the surface areas defined by the pool shown on the USGS sheet and the 410 foot contour shown on the sheet
(4) Storage at Top of flashboards estimated by dividing reservoir into pyramidal frustrum sections and determining the volume of each section with the appropriate formula

C Spillway Information

1. The [illegible] spillway (located on the north of the water treatment facility adjacent to the earth berm) consists of [illegible] with granite abutments and a granite ogee weir. Flashboards have been installed on the weir crest and are attached to an aluminum frame which has been installed across the crest of the spillway and dike; the 7.5' long by 0.33' wide section is removable [illegible] the normal pool [illegible]

This section removed

a. for the subsequent calculations of spillway capacity it was assumed that the flashboards have been washed away and the fence destroyed so that it creates no flow restriction

2 Discharge over the spillway given by broad-crested weir formula

$$Q = C L H^{3/2}$$ (Standard Handbook for CE's, Merritt)

where: Q = discharge cfs
C = discharge coefficient
use 2.6
L = weir length, feet
H = head over weir feet

II Estimate Effect of Surcharge Storage on Maximum Probable Discharge

A Develop stage-discharge curve for ... dam-berm complex

1. define sources of outflow

a flow over permanent spillway - flashboards washed away

b discharge over earth berm adjacent to spillway - above elev. 403.3
(1) use broad-crested weir equation with C = 2.6

c. discharge over dam - above elevation 404.04
(1) use broad-crested weir equation with C = 2.6

d discharge over and around west end of Stone wall which is ≈ perpendicular to north end of earth berm and parallel to roadway - above elevation 406.5
(1) use broad-crested weir equation with C = 2.6

2. Discharge Through Spillway

Elevation (feet)	C	L (feet)	H feet)	Q (cfs)
401.15	—	—	—	0
402.0	2.6	40	0.85	92
403.0			1.85	262
404.0			2.85	500
405.0			3.85	786
406.0			4.85	1110
407.0			5.85	1470
408.0			6.85	1860
409.0			7.85	2290
410.0			8.85	2740

3. Discharge over berm (including flow by passing south spillway abutment)

Elevation (feet)	C	L (feet)	H (feet)	Q (cfs)
403.43	—	—	—	0
404.0	2.6	29	avg ≈ 0.4	32
405.0		107	1.4	401
406.0		110	2.4	1060
407.0		112	3.4	1930
408.0		114	4.4	2740
409.0		116.5	5.4	3510
410.0		119	6.4	5010

4 Discharge over dam

Elevation (feet)	C	L (feet)	H (feet)	Q (cfs)
404.04	—	—	—	0
405.0	2.6	257	avg ≈ 0.9	571
406.0		302	1.9	2060
407.0		320	2.9	4010
408.0		334	3.9	6690
409.0		347	4.9	9790
410.0		361	5.9	13,500

5. Discharge over masonry stone wall

Elevation (feet)	C	L (feet)	H (feet)	Q cfs
406.5	—	—	—	0
407.0	2.6	330	0.5	303
408.0			1.5	590
409.0			2.5	3390
410.0			3.5	5620

6 Discharge around west end of stone wall

Elevation (feet)	C	L (feet)	H (avg) (feet)	Q (cfs)
406.5	—	—	—	0
407.0	2.6	40	0.25	[illegible]
408.0		125	0.75	211
409.0		210	1.25	763
410.0		300	1.75	[illegible]

7 Total discharge from Project site

Elev. (feet)	Q Spillway	Q berm	Q dam	Q [illegible]	Q [illegible]	Q TOTAL
401.15	0	0	0	0	0	0
402.0	82	0	0	0	0	82
403.0	262	0	0	0	0	262
404.0	500	52	0	0	0	552
405.0	786	461	571	0	0	≈1910
406.0	1110	1060	2060	0	0	4230
407.0	1470	1830	4110	303	13	≈7730
408.0	1860	2740	6690	1580	211	≈13,090
409.0	2290	3900	9790	3690	763	≈ 20,330
410.0	2740	5010	13,500	5620	1910	≈ 28,780

Discharge vs Elevations shown graphically in Figure 1

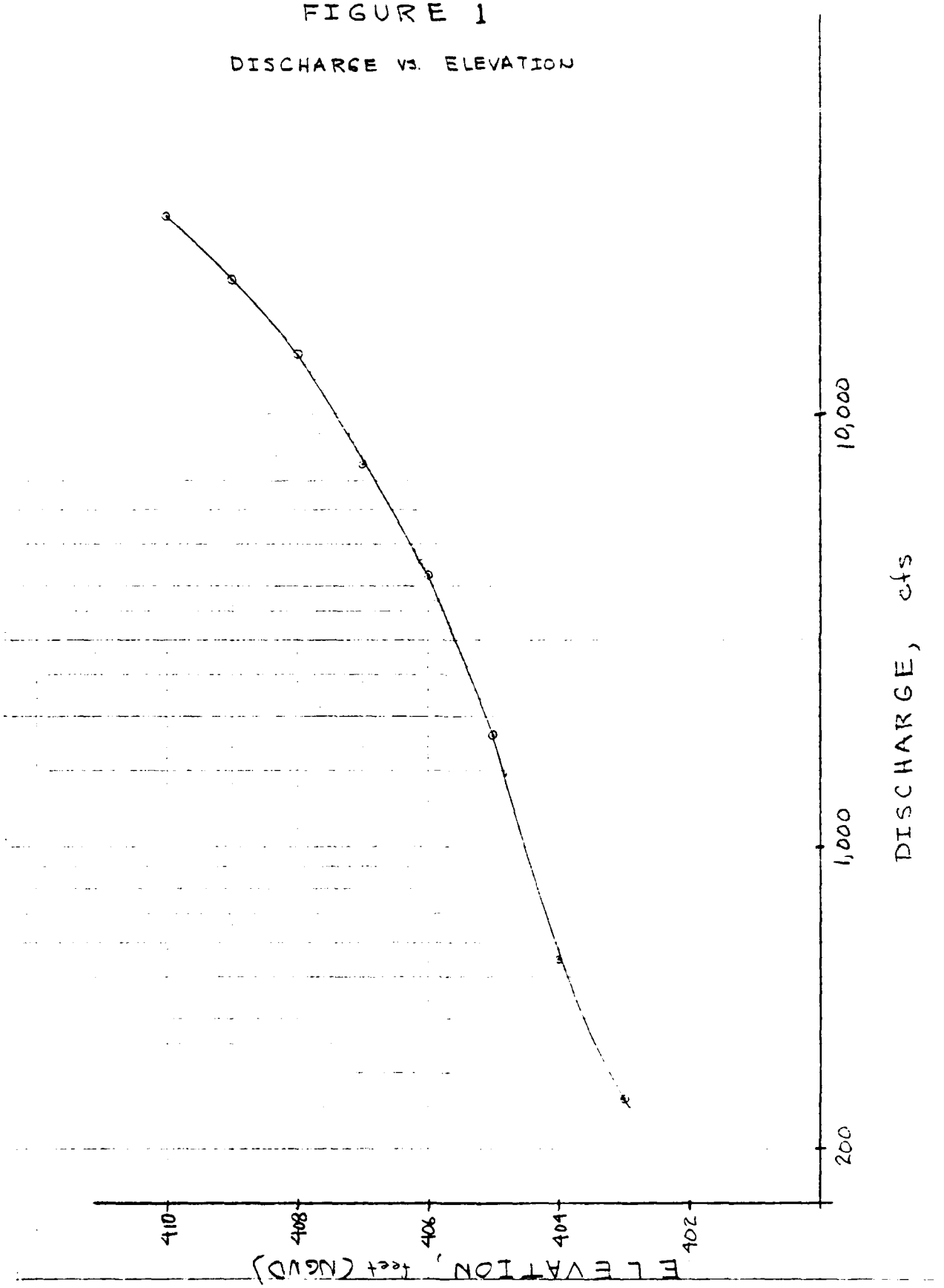
Concord N.N Dam

Jso # 274-7901

-2:: 7 of 27
1/18/95

FIGURE 1

DISCHARGE vs. ELEVATION



B. Effect of surcharge storage on max. prob. discharge

1. Pertinent Data

a. Drainage area = 3.83 square miles
b. Characteristics of basin - mountainous basin, however, use rolling curve since reservoir large compared to drainage basin
c. Test flood = ½PMF (Intermediate size and significant hazard)
d. Follow Army Corps' procedure

2. STEP 1: Determine Peak Inflow Q_{P1} from Guide Curve

a. the maximum probable discharge was estimated to be 2300 cfs/sq.mi

$\therefore$ PMF = (2300 cfs/sq.mi) (3.83 sq.mi.)

$\approx$ 8920 cfs

½PMF = 4,460 cfs

3. STEP 2: Determine surcharge height to pass Q_{P1}, $STOR_1$, and Q_{P2}

a. from Figure 1 determine surcharge height to pass Q_{P1} = 4,460 cfs

surcharge elevation = 406.1
elev. permanent weir crest = 401.15
surcharge height = 4.95

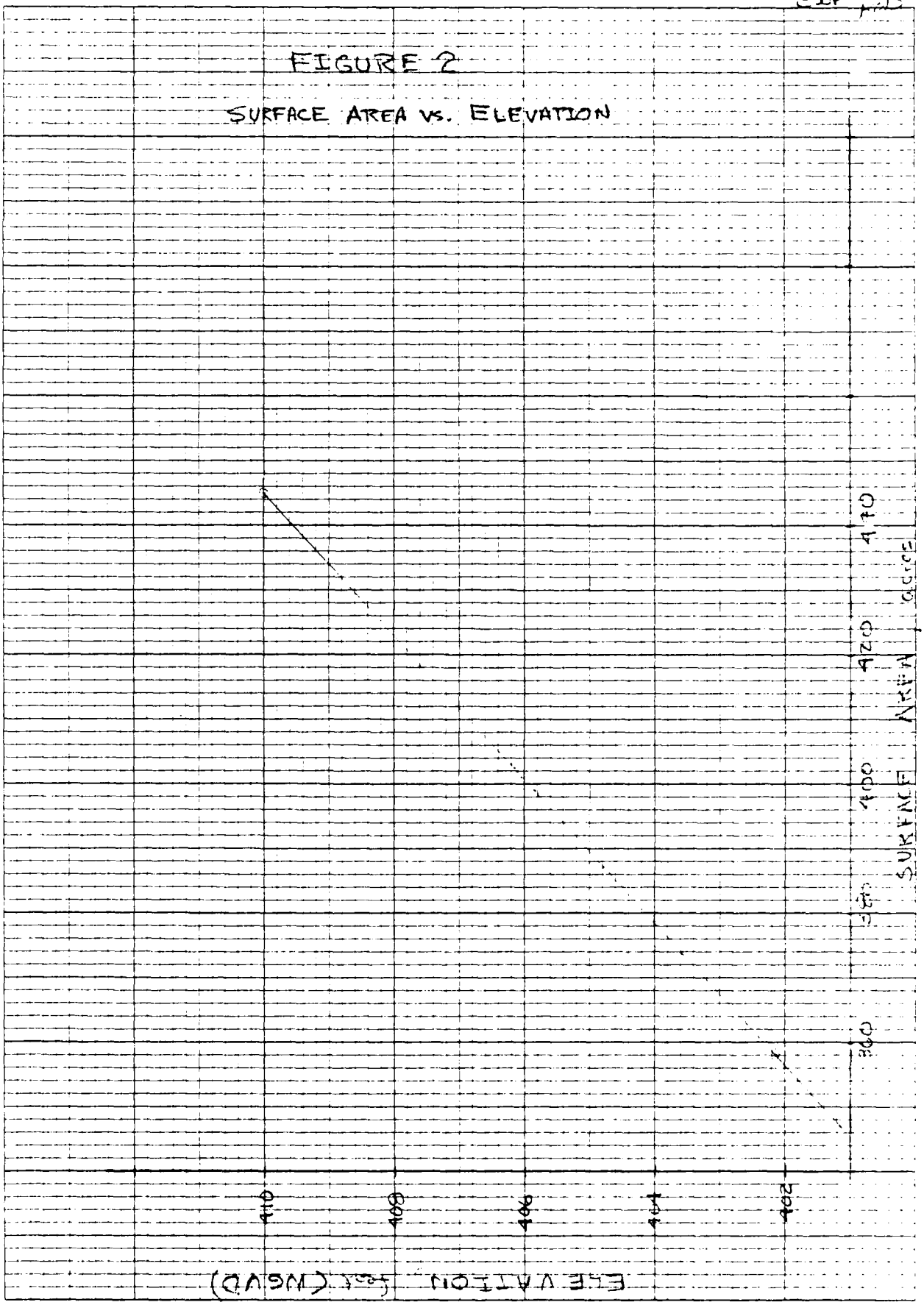
b. determine volume of surcharge $STOR_1$ in inches of runoff

determine volume of storage in acre-ft in following manner
(1) determine surface area of pond [illegible] to surcharge elevation from Figure 2

Enid W.W. Dam Job # 274-720 7 of 27 11/18/85 2nd proof

FIGURE 2

SURFACE AREA vs. ELEVATION



(2) average surface area for increment above the permanent crest pool (elev 401.15')

(3) multiply surcharge depth (depth above elev. 401.15') times average surface area to determine volume of storage

$$STOR_1 = \frac{\text{Volume of storage (as acre-inches)}}{\text{drainage area}}$$

$$STOR_1 = \frac{\left[\left(\frac{397\text{ac} + 401\text{ac}}{2}\right)(4.95')\,(12''/\text{ft})\right]}{2483 \text{ acres}}$$

$$STOR_1 = 8.95 \text{ inches}$$

c. determine Q_{P2}

$$Q_{P2} = Q_{P1}\left(1 - \frac{STOR_1}{9.5}\right)$$

$$Q_{P2} = (4{,}460 \text{ cfs})\left(1 - \frac{8.95}{9.5}\right)$$

$$Q_{P2} = 258 \text{ cfs}$$

4. STEP 3: Determine surcharge height and $STOR_2$ to pass Q_{P2} and then Q_{P3}

a. From Figure 1 determine surcharge height to pass $Q_{P2} = 258$ cfs

surcharge elevation = 403.0'
permanent weir crest = 401.15'
surcharge height = 1.85'

Surface area at 403.0 = 367 ac.

b. determine $STOR_2$

$$STOR_2 = \frac{\left(\frac{367ac + 347ac}{2}\right)(1.85')(12''/ft)}{2493 \text{ acres}}$$

$$= 3.19 \text{ inches}$$

c. Average $STOR_1$ and $STOR_2$

$$STOR_{AVG} = \frac{STOR_1 + STOR_2}{2}$$

$$STOR_{AVG} = \frac{8.95'' + 3.19''}{2}$$

$$STOR_{AVG} = 6.07 \text{ inches}$$

d. determine Q_{P3}

$$Q_{P3} = (4{,}460 cfs)\left(1 - \frac{6.07''}{9.5''}\right)$$

$$Q_{P3} = 1{,}610 \text{ cfs}$$

5. STEP 4: Determine surcharge height for Q_{P3} and $STOR_3$

a. from Figure 1 surcharge height for Q_{P3} = 1,610 cfs

surcharge elev. = 404.9'
weir crest = 401.15'
surcharge height = 3.75 feet

Surface area at 404.9 = 389 acres

b. determine $STOR_3$

$$STOR_3 = \frac{\left(\frac{389 ac + 347ac}{2}\right)(3.75')(12''/ft)}{2493 \text{ ac}}$$

$STOR_3$ = 6.67 inches

c. determine $STOR_{AVG}$

$$STOR_{AVG} = \frac{6.07" + 6.67"}{2}$$

$STOR_{AVG}$ = 6.37 inches

d. determine Q_{P4}

$$Q_{P4} = (4{,}460 \text{ cfs})\left(1 - \frac{6.37"}{9.5"}\right)$$

Q_{P4} = 1,470 cfs

6. STEP 5: Determine surcharge height for Q_{P4} and $STOR_4$

a. From Figure 1 surcharge height for Q_{P4} = 1,470 cfs

surcharge elev = 404.8'
[illegible] = 401.15'
surcharge height = 3.65 ft

Surface area at 404.8 = 387 [illegible]

b. determine $STOR_4$

$$STOR_4 = \frac{\left(\frac{387ac + 347a.}{2}\right)(3.65ft)(12"/ft)}{2483 \text{ acres}}$$

$STOR_4$ = 6.47 inches

c. determine $STOR_{AVG}$

$$STOR_{AVG} = \frac{6.37" + 6.47"}{2}$$

= 6.42 inches

d. determine Q_{PS}

$$Q_{PS} = (4{,}460 \text{ cfs})\left(1 - \frac{6.42''}{9.5''}\right)$$

$$Q_{PS} = 1{,}450 \text{ cfs}$$

7. STAGE 6: Determine surcharge height for Q_{PS} and $STOR_5$

a. From Figure 1 surcharge height for $Q_{PE} = 1{,}450$

surcharge elev = 404.8
weir crest = 401.15
surcharge height = 3.65'

Surface area at 404.8 = 397 acres

b. determine $STOR_4$

$$STOR_5 = \frac{\left(\frac{387\text{ac} + 347\text{ac}}{2}\right)(3.65')(12''/1')}{2483 \text{ acres}}$$

$$STOR_5 = 6.47 \text{ inches}$$

c. determine $STOR_{AVG}$

$$STOR_{AVG} = \frac{6.42'' + 6.47''}{2}$$

$$STOR_{AVG} = 6.45 \text{ inches}$$

$STOR_5$ and $STOR_{AVG}$ are less than 10% accept maximum proposed discharge = 1,450 cfs @ surcharge elevation = 404.8 feet (NGVD)

3. In Conclusion

a. Test flood discharge = 1450 cfs and will over top dam crest by approximately 0.3 feet and the berm crest by approximately 1.4 feet

(1) discharge will not by pass stone masonry wall

b. Spillway capacity

(1) water level at elevation 403.43' (top of spillway abutment - lowest point on berm)

(a.) flashboards removed

$Q = (2.6)(40ft)(2.28ft)^{3/2}$ = [illegible] cfs

(b.) flashboards in place (7.5'x4" section removed)

$Q = (3.5)(7.5)(1.28)^{3/2} + (3.5)(32.5)(0.95)^{3/2}$ = 143[illegible] cfs

(2) water level at elevation 404.04' (top of dam)

(a.) flash boards removed

$Q = (2.6)(40ft)(2.89ft)^{3/2}$ = 511 cfs

(b.) flashboards in place (7.5' x 4" section removed)

$Q = (3.5)(7.5')(1.89')^{3/2} + (3.5)(32.5')(1.56')^{3/2}$ = 290 cfs

(3) water level at test flood elevation - 404.8

(a.) flash boards removed

$Q = (2.6)(40')(3.65)^{3/2}$ = 725 cfs

(b.) flashboards in place (7.5' x 4" section removed)

$Q = (3.5)(7.5')(2.65')^{3/2} + (3.5)(32.5')(2.32')^{3/2}$ = 515 cfs

III. Using "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs examine impact of dam failure

1. Pertinent Data

a. Failure occurs when reservoir level at crest of dam - elevation = 404.04 feet

b. Storage at crest elevation estimated to be approximately 2210 acre-ft

A. Reach 1

1. STEP 1: Determine reservoir storage at time of failure

from previous calcs. storage = 2210 acre-ft

2. STEP 2: Determine Peak Failure Outflow Q_{Pl}

$$Q_{Pl} = (8/27)\, W_b \sqrt{g}\, Y_o^{3/2}$$

where: W_b = Breach width (use 40% of total length.
= (0.40) (265 feet)
≈ 106 feet

Y_o = Total height from channel bed to pool level at failure
≈ 15 feet

$$Q_{Pl} = (8/27)(106\text{ ft})(32.2)^{1/2}(15\text{ ft})^{3/2}$$

$$Q_{Pl} = 10{,}400 \text{ cfs}$$

3. STEP 3: Prepare stage-discharge curve for Reach 1

a. Pertinent Data

(1) Reach length = 725 feet
(2) Channel slope = 0.041
(3) Manning n = 0.08
(4) Channel shape - trapezoida (Side slope not constant compute X area accordingly)
(5) Base width ≈ 20 feet

b. See Figure 3 for stage-discharge curve

4. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{P1} = 10,400 cfs from Figure 3 and find volume in reach

(1) Stage (depth of flow) = 10.2 feet

(2) Volume in reach = (reach length) (cross-sectional area of channel)

$$\text{X-area} = (\tfrac{1}{2})(10')(20' + 150') + (\tfrac{1}{2})(0.2')(150' - 160')$$
$$= 881 \text{ ft}^2$$

$$\text{Volume} = V_1 = \frac{(881 \text{ ft}^2)(725 \text{ ft})}{43{,}560 \text{ ft}^2/\text{acre}}$$

$$= 14.7 \text{ acre-ft}$$

$V_1 < \frac{S}{2}$ ∴ reach length OK

b. Determine $Q_{P2(TRIAL)}$

$$Q_{P2(TRIAL)} = Q_{P1}\left(1 - \frac{V_1}{S}\right)$$

$$Q_{P2(TRIAL)} = (10{,}400 \text{ cfs})\left(\frac{14.7 \text{ acre-ft}}{2210 \text{ acre-ft}}\right)$$

$Q_{P2(TRIAL)}$ = 10,300 cfs

c. Compute V_2 using $Q_{P2(TRIAL)}$

From Figure 3 determine stage for $Q_{P2(TRIAL)}$

Stage = 10.2 feet

X-area = $(1/2)(10')(20' + 150') + (1/2)(0.2')(150' + 160')$

= $881\ ft^2$

$$V_2 = \frac{(881\ ft^2)(725\ ft)}{43{,}560\ ft^3/acre}$$

V_2 = 14.7 acre-ft

d. Average V_1 and V_2 and compute

(1) $$V_{avg} = \frac{V_1 + V_2}{2}$$

$$V_{avg} = \frac{14.7\ ac\text{-}ft + 14.7\ ac\text{-}ft}{2}$$

V_{avg} = 14.7 acre-ft

(2) $$Q_{P2} = Q_{P2}\left(1 - \frac{V_{avg}}{S}\right)$$

$$Q_{P2} = (10{,}400\ cfs)\left(1 - \frac{14.7}{720}\right)$$

Q_{P2} = 10,300 cfs

B. Reach 2

1. STEP 3: Prepare stage-discharge curve for Reach

a. Pertinent Data

(1) Reach length = 425 feet
(2) Channel slope = 0.046
(3) Manning n = 0.05
(4) Channel shape - trapezoidal
(5) Base width ≈ 20 feet

b. See Figure 3 for stage-discharge curve

2. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{P2} = 10,300 cfs from Figure 3 and find volume in reach

(1) Stage (depth of flow) = 8.6 feet

(2) Volume in reach = (reach length) (cross-sectional area of channel)

$$\text{X-area} = (0.5)(8.6\text{ ft})(20\text{ ft} + 115\text{ ft})$$
$$= 581\text{ ft}^2$$

$$\text{Volume} = V_1 = \frac{(581\text{ ft}^2)(425\text{ ft})}{43{,}560\text{ ft}^2/\text{acre}}$$

$$= 5.7\text{ acre-ft}$$

$V_1 < \frac{S}{2}$ ∴ reach length OK

b. Determine $Q_{P3(TRIAL)}$

$$Q_{P3(TRIAL)} = Q_{P2}\left(1 - \frac{V_1}{S}\right)$$

$$Q_{P3(TRIAL)} = (10{,}300\text{ cfs})\left(1 - \frac{5.7}{\quad}\right)$$

$Q_{P3(TRIAL)}$ = 10,250 cfs

c. Compute V_2 using $Q_{P2(TRIAL)}$

From Figure 3 determine stage for $Q_{P2(TRIAL)}$

Stage = 8.6 feet

X-area = (0.5)(8.6 ft)(20ft + 115 ft)

= 591 ft²

$$V_2 = \frac{(591\ ft^2)(425\ ft)}{43{,}560\ ft^2/acre}$$

V_2 = 5.7 acre-ft

d. Average V_1 and V_2 and compute Q_{P3}

(1) $Vavg = \frac{V_1 + V_2}{2}$

$$V_{avg} = \frac{5.7\ ac\text{-}ft + 5.7\ ac\text{-}ft}{2}$$

Vavg = 5.7 ac-ft

(2) $Q_{P3} = Q_{P2}\left(1 - \frac{Vavg}{S}\right)$

$$Q_{P3} = (10{,}300\ cfs)\left(1 - \frac{5.7}{22.0}\right)$$

Q_{P3} = 10,250 cfs

C. Reach 3

1. STEP 3: Prepare stage-discharge curve for Reach 3

   a. Pertinent Data

      (1) Reach length = 225 feet
      (2) Channel slope = 0.046
      (3) Manning n = 0.05
      (4) Channel shape - trapezoidal (side slope ... compute x-area accordingly)
      (5) Base width ≈ 20 feet

   b. See Figure 3 for stage-discharge curve

2. STEP 4: Estimate Reach Outflow

   a. Determine stage for Q_{P3} = 10,250 cfs from Figure 3 and find volume in reach

      (1) Stage (depth of flow) = 5.7 feet

      (2) Volume in reach = (reach length) (cross-sectional area of channel)

$$\text{X-area} = (0.5)(3.0')(20' + 135') + (0.5)(2.7')(135' + 350')$$
$$= 928 \text{ ft}^2$$

$$\text{Volume} = V_1 = \frac{(928 \text{ ft}^2)(225 \text{ ft})}{43,560 \text{ ft}^2/\text{ac}}$$

$$= 4.8 \text{ acre-ft}$$

$V_1 < \frac{S}{2}$ ∴ reach length OK

   b. Determine $Q_{P4(TRIAL)}$

$$Q_{P4(TRIAL)} = Q_{P3}\left(1 - \frac{V_1}{S}\right)$$

$$Q_{P4(TRIAL)} = (10,250 \text{ cfs})\left(1 - \frac{4.8}{220}\right)$$

$$Q_{P4(TRIAL)} = 10,200 \text{ cfs}$$

c. Compute V_2 using $Q_{P4(TRIAL)}$

From Figure 3 determine stage for $Q_{P4(TRIAL)}$

Stage = 5.7 feet

X-area = 929 ft² (per above)

$$V_2 = \frac{(929\ ft^2)(5.2\ ft)}{43{,}560\ ft^2/acre}$$

V_2 = 4.8 acre-ft

d. Average V_1 and V_2 and compute Q_{P4}

(1) $V_{avg} = \frac{V_1 + V_2}{2}$

$$V_{avg} = \frac{4.8\ ac\text{-}ft + 4.8\ ac\text{-}ft}{2}$$

Vavg = 4.8 acre-ft

(2) $Q_{P4} = Q_{P3}\left(1 - \frac{V_{avg}}{S}\right)$

$$Q_{P4} = (10{,}250\ cfs)\left(1 - \frac{4.8}{22.5}\right)$$

Q_{P4} = 10,200 cfs

D. Reach 4

1. STEP 3: Prepare stage-discharge curve for Reach 4

a. Pertinent Data

(1) Reach length = 375 feet
(2) Channel slope = 0.026
(3) Manning n = 0.05
(4) Channel shape - trapezoidal (compound, main + overbank)
(5) Base width ≈ 20 feet

b. See Figure 3 for stage-discharge curve

2. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{p4} = 10,200 cfs from Figure 3 and find volume in reach

(1) Stage (depth of flow) = 7.1 feet

(2) Volume in reach = (reach length) (cross-sectional area of channel)

$$\text{X-area} = (0.5)(5.0')(20' + 170') + (0.5)(2.1')(170' + 240')$$
$$= 958 \text{ ft}^2$$

$$\text{Volume} = V_1 = \frac{(958 \text{ ft}^2)(375 \text{ ft})}{43,560 \text{ ft}^2/\text{acre}}$$

$$= 8.2 \text{ acre ft}$$

$V_1 < \frac{S}{2}$ ... [illegible] length 4

b. Determine $Q_{P4(TRIAL)}$

$$Q_{P4(TRIAL)} = Q_{P4}\left(1 - \frac{\quad}{\quad}\right)$$

$$Q_{P4(TRIAL)} = (10,200 \text{ cfs})\left(1 - \frac{\quad}{\quad}\right)$$

$Q_{P4(TRIAL)}$ = 10,150 cfs

c. Compute V_2 using $Q_{P5(TRIAL)}$

From Figure 3 determine stage for $Q_{P5(TRIAL)}$

Stage = 7.1 feet

X-area = 958 ft^2 (per acre)

$$V_2 = \frac{(958\ ft^2)(375\ ft)}{43{,}560\ ft^2/acre}$$

V_2 = 8.2 acre-ft

d. Average V_1 and V_2 and compute Q_{P5}

(1) $Vavg = \frac{V_1 + V_2}{2}$

$$Vavg = \frac{8.2\ acre\text{-}ft + 8.2\ ac\text{-}ft}{2}$$

Vavg = 8.2 acre-ft

(2) $Q_{P5} = Q_{P4}\left(1 - \frac{Vavg}{S}\right)$

$$Q_{P5} = (10{,}200\ cfs)\left(1 - \frac{8.2}{\text{[illegible]}}\right)$$

Q_{P5} = 10,150 cfs

E. Reach 5

3. STEP 3: Prepare stage-discharge curve for Reach 5

a. Pertinent Data

(1) Reach length = 400 feet
(2) Channel slope = 0.15
(3) Manning n = 0.05
(4) Channel shape - trapezoidal
(5) Base width ≈ 20 feet

b. See Figure 3 for stage-discharge curve

4. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{p5} = 10,150 cfs from Figure 3 and find volume in reach

(1) Stage (depth of flow) = 5.5 feet

(2) Volume in reach = (reach length) (cross-sectional area of channel)

X-area = (0.5)(5.5 ft)(20 ft + 130 ft)
= 413 ft²

Volume = V_1 = (413 ft²)(400 ft) / 43,560 ft²/acre

= 3.8 acre-ft

$V_1 < \frac{S}{2}$ x reach length

b. Determine Q_{p5} (routed)

Q_{p5} (routed) = Q_{p5} (1 - [illegible])

Q_{p5} (routed) = (10,150 cfs) (1 - [illegible])

Q_{p5} = 10,100 cfs

c. Compute V_2 using $Q_{P6(TRIAL)}$

From Figure 3 determine stage for $Q_{P6(TRIAL)}$

Stage = 5.5 feet

X-area = (0.5)(5.5 ft)(204 + 130 ft)

= 413 ft²

$$V_2 = \frac{(413\ ft^2)(400\ ft)}{43{,}560\ ft^2/ac}$$

V_2 = 3.8 ac-ft

d. Average V_1 and V_2 and compute Q_{P6}

(1) $$Vavg = \frac{V_1 + V_2}{2}$$

$$V_{avg} = \frac{3.8\ ac\text{-}ft + 3.8\ ac\text{-}ft}{2}$$

Vavg = 3.8 acre-ft

(2) $$Q_{P6} = Q_{P5}\left(1 - \frac{Vavg}{S}\right)$$

$$Q_{P6} = (10{,}150\ cfs)\left(1 - \frac{3.8}{22.0}\right)$$

Q_{P6} = 10,100 cfs

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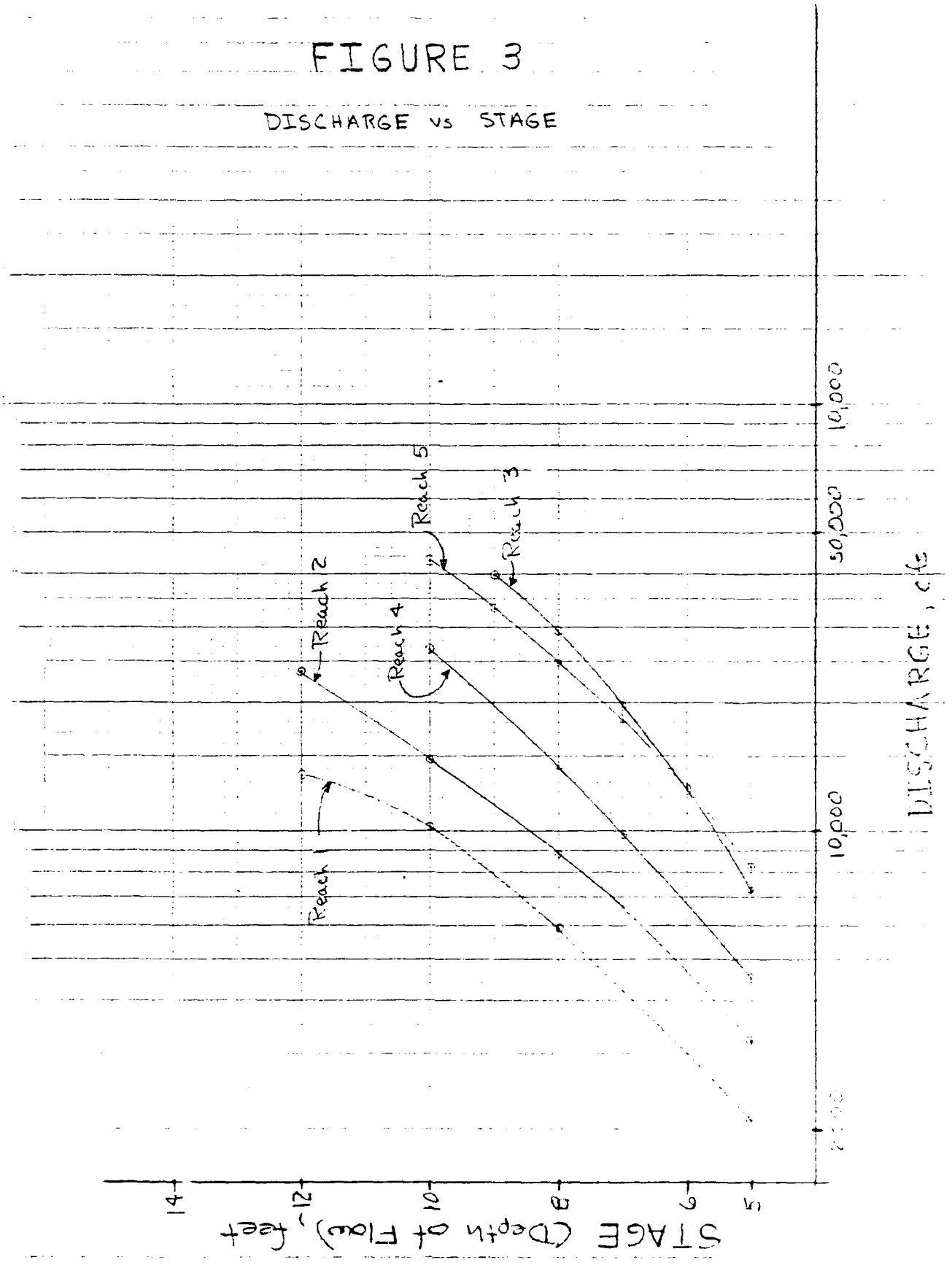
FIGURE 3

DISCHARGE vs STAGE



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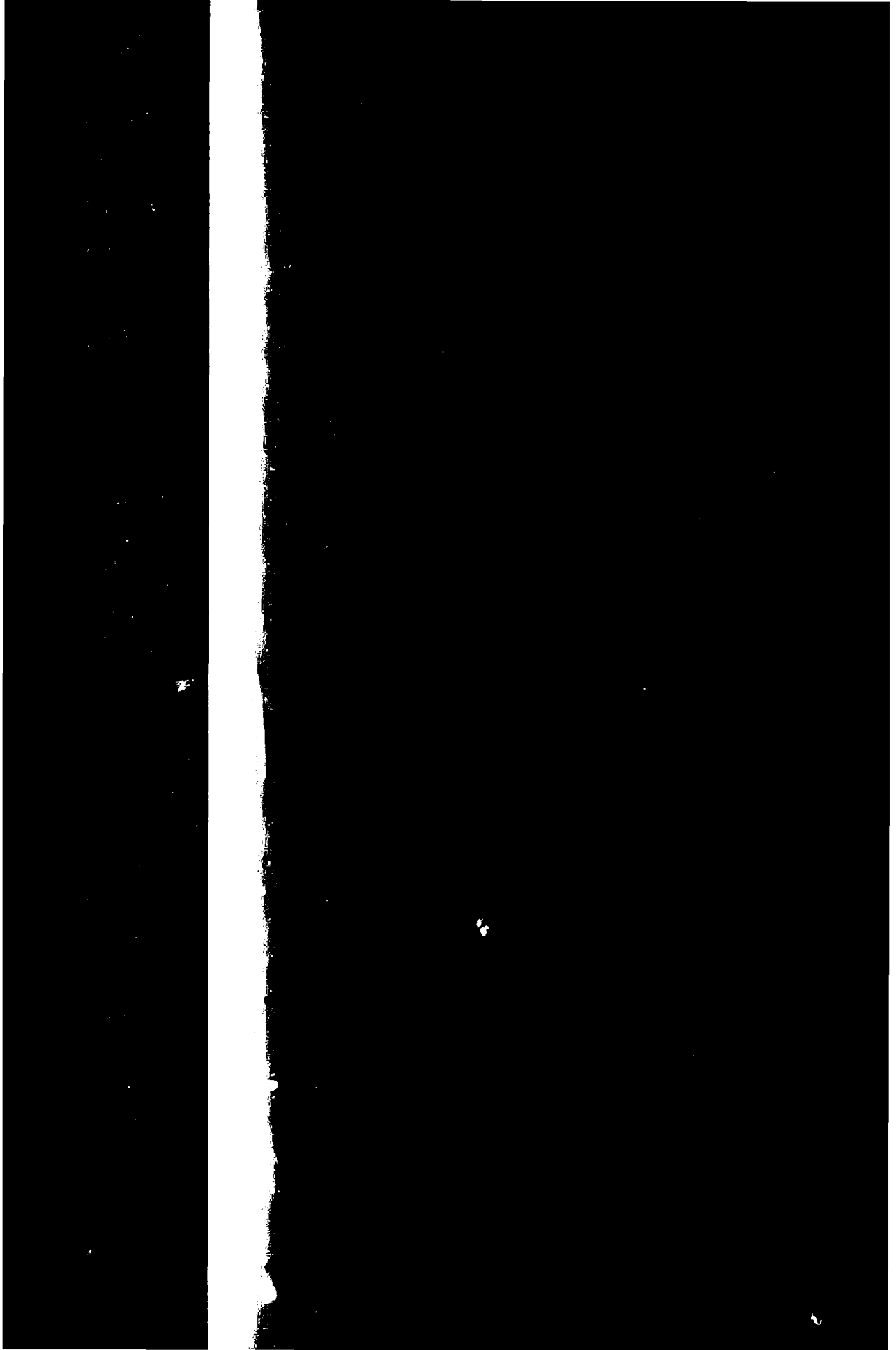

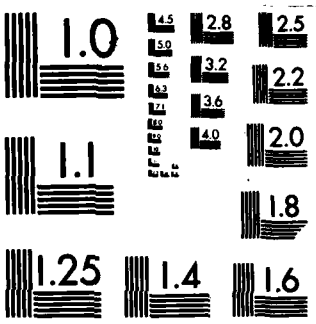

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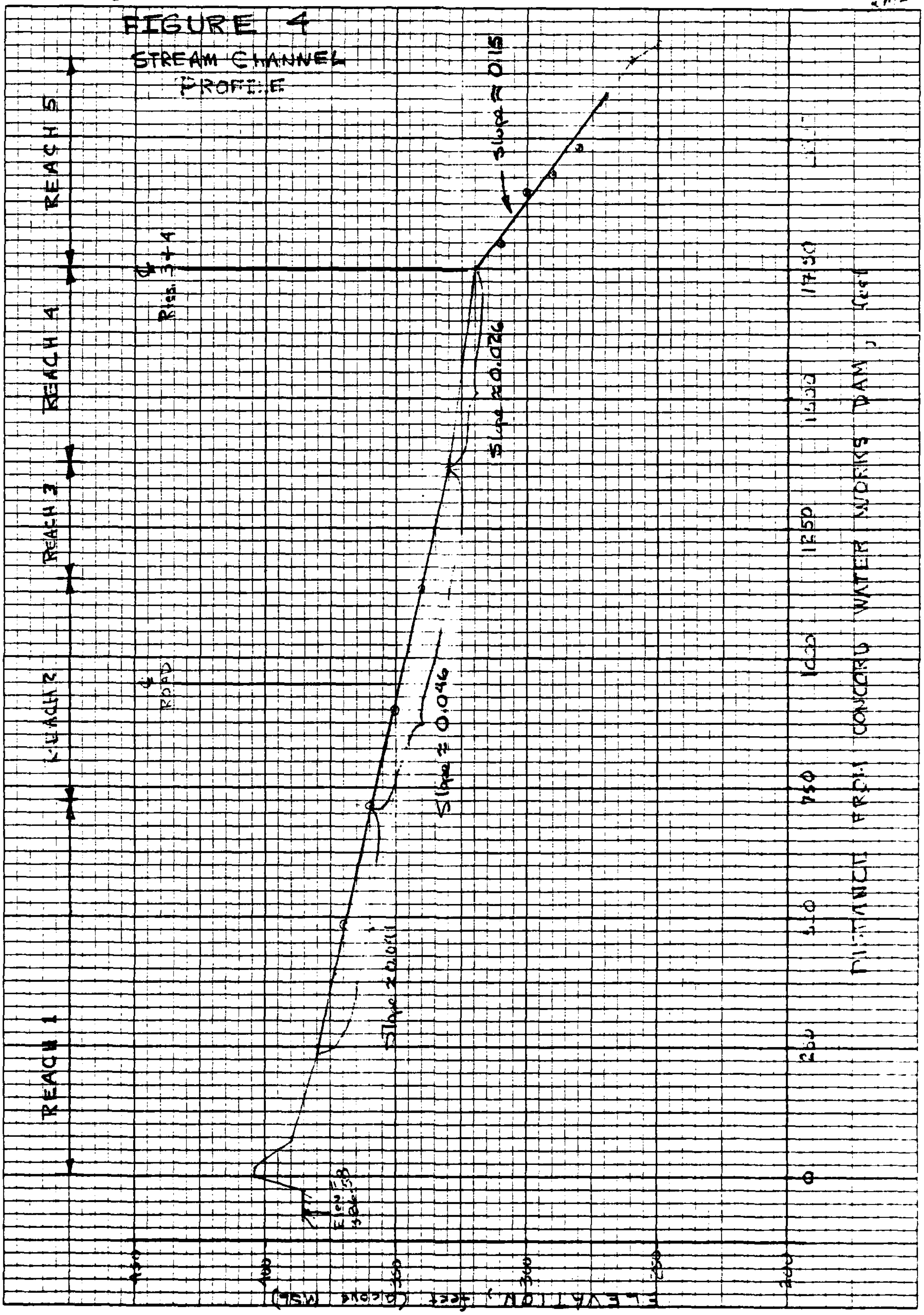

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