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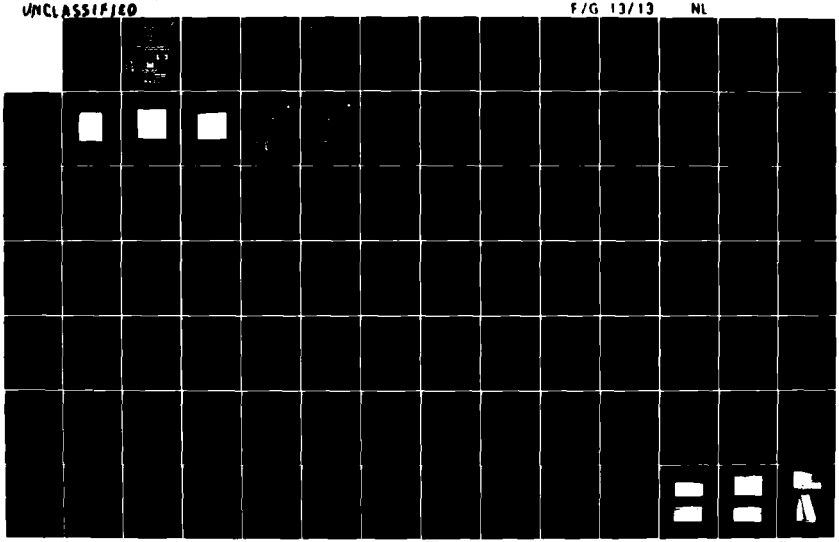

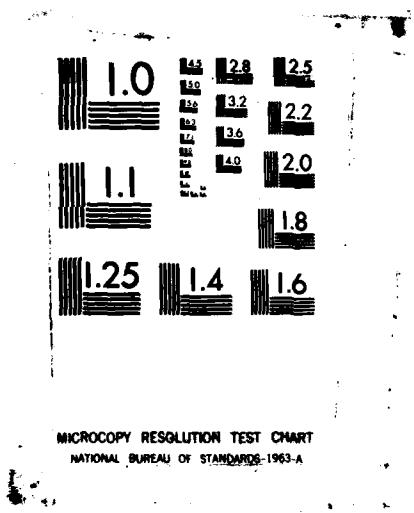
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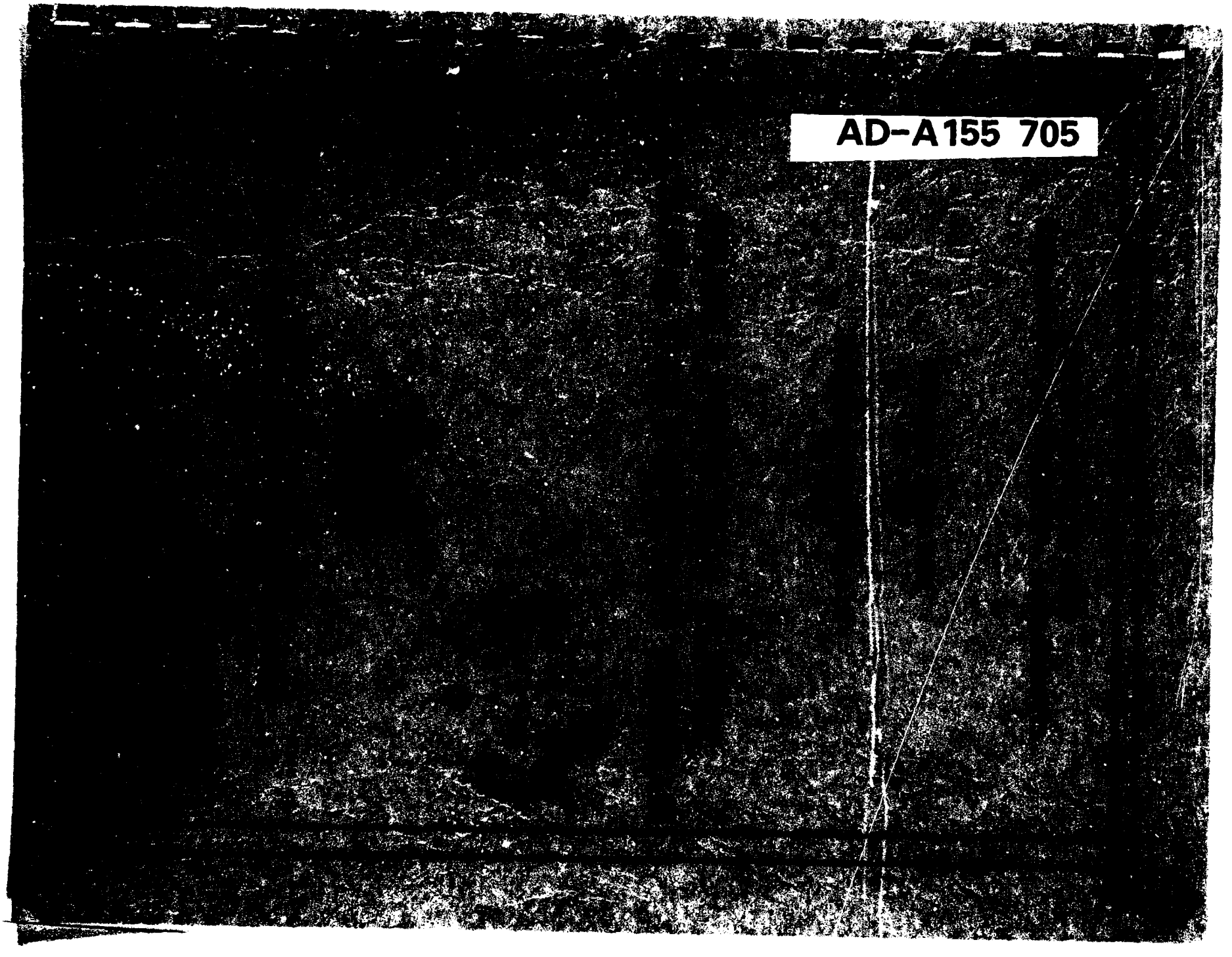
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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4. TITLE (and Subtitle) Bickford Pond Dam Bickford Reservoir Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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18. SUPPLEMENTARY NOTES

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,

Connecticut River Basin
Hubbardston and Princeton, Massachusetts
East Branch, Ware River, tributary of the Ware River

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

The dam has a maximum height of 51.2 ft. and includes a drop inlet spillway and box conduit outlet structure. There are deficiencies which must be corrected to assure the continued performance of the dams. Generally the dams are in good condition. The dams are classified as intermediate in size with a high hazard potential.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254

REPLY TO
ATTENTION OF:
NEDED

OCT 21 1980

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

Inclosed is a copy of the Bickford Pond & Reservoir 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 Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, city of Fitchburg, Mass..

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 Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely,

Max B. Schreider

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

MA 01021
MA 01022

CONNECTICUT RIVER BASIN
HUBBARDSTON & PRINCETON,
MASSACHUSETTS

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION
PROGRAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

BRIEF ASSESSMENT

Identification No. and name of Dam: MA01021 - Bickford Pond
MA01022 - Bickford Reservoir

Town: Hubbardston & Princeton

County and State: Worcester County, Massachusetts

Stream: East Branch, Ware River, tributary of the Ware River

Date of Inspection: May 13, 1980

Bickford Pond Dam which was built in 1970 is a 933-foot long earth dam with concrete core wall. The dam has a maximum height of 51.2 feet and includes a drop inlet spillway and box conduit outlet structure. The low point on the top of the dam is at Elevation (El) 1051.2. The spillway is a 20 foot by 30 foot drop inlet with a concrete wall dividing it into two separate chambers. The crest of the spillway is at El 1045.0. The outlet from the spillway is a 12 foot square concrete box conduit with the invert at El 1002.0. The low level outlet is controlled by a sluice gate with a floor stand located on the upstream end of the service bridge on the spillway.

Bickford Reservoir Dam, also known as the Bickford Dike, was built in 1970 and is a 507-foot long earth dam with a concrete core wall. The dam has a maximum height of 18.3 feet. The low point on the top of the dam is at elevation (El) 1051.3. There are no spillways or outlet structures at this dam. Pond levels are controlled at Bickford Pond Dam approximately 1,500 feet to the southeast of Bickford Reservoir Dam.

There are deficiencies which must be corrected to assure the continued performance of the dams. This conclusion is based on the visual inspection of the site and a review of the available data. Generally the dams are in good condition.

The following deficiencies were observed at Bickford Pond Dam: seepage through cracks and joints in the box conduit outlet structure; unmonitored seepage through core wall toe drains and

downstream slope toe drains; siltation and partial blockage of discharge ditches from toe drains; riprap dislodged from the upstream face of the dam; cracked, spalled and eroded concrete in the box conduit and spillway; growth of brush and saplings through riprap on upstream face of dam; and tire ruts along the top of the dam.

The following deficiencies were observed at the Bickford Reservoir Dam: unmonitored seepage through downstream slope toe drains; siltation and partial blockage of discharge ditches from toe drains; growth of brush and saplings through riprap on upstream face of dam; and growth of brush and saplings on downstream face of dam.

Based on Corps of Engineers' guidelines, the dams have been classified in the intermediate size and high hazard categories. A test flood equal to the full probable maximum flood (PMF) was used to evaluate the capacity of the spillway. The test flood outflow is 5,480 cfs, resulting in a pond level at El 1051.4. The test flood would overtop the Bickford Pond Dam by 0.2 foot and Bickford Reservoir Dam by 0.1 foot. Hydraulic analyses indicate that the spillway can discharge 5,100 cfs, or 93 percent of the test flood outflow before the dam is overtopped.

It is recommended that the Owner employ a qualified registered professional engineer to evaluate and monitor the quantity of flow discharging from the core wall toe drains and downstream slope toe drains for Bickford Pond Dam and the toe drains at Bickford Reservoir Dam and to evaluate the condition of the low level outlets, the condition of the spillway and box conduit outlet structure. In addition, the Owner should repair the deficiencies listed above, as described in Section 7. The Owner should also implement a program of biennial technical inspections, a plan for surveillance of the dams during and after periods of heavy rainfall, and a plan for notifying downstream residents in the event of an emergency at the dams.

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

The measures outlined above and in Section 7 should be implemented by the Owner within a period of 2 years after receipt of this Phase I Inspection Report.

Edward M. Greco, P.E.
Project Manager
Metcalf & Eddy, Inc.

Massachusetts Registration
No. 29800

Approved by:

Stephen L. Bishop, P.E.
Vice President
Metcalf & Eddy, Inc.

Massachusetts Registration
No. 19703

This Phase I Inspection Report on Bickford Reservoir & Pond 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.

RICHARD DIBUONO, MEMBER
Water Control Branch
Engineering Division

ARAMAST MAHTESIAN, MEMBER
Geotechnical Engineering Branch
Engineering Division

CARNEY M. TERZIAN, CHAIRMAN
Design Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. 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 investigations, 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 aud 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 will 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 th magnitude and rarity of such a storm event, a finding that a spi .way 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 aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general conditions and the downstream damage potential.

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

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 trespass 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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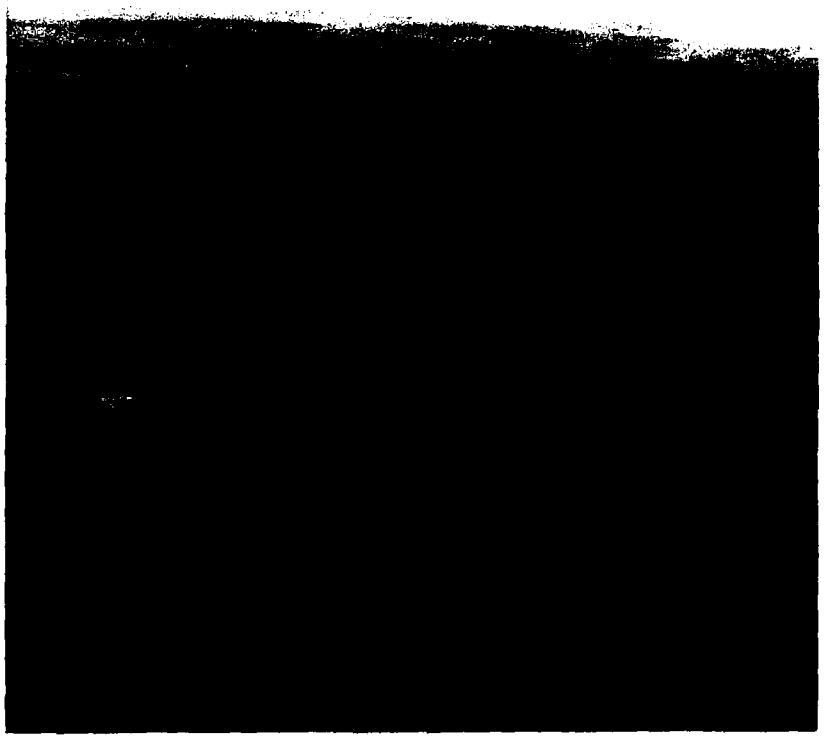
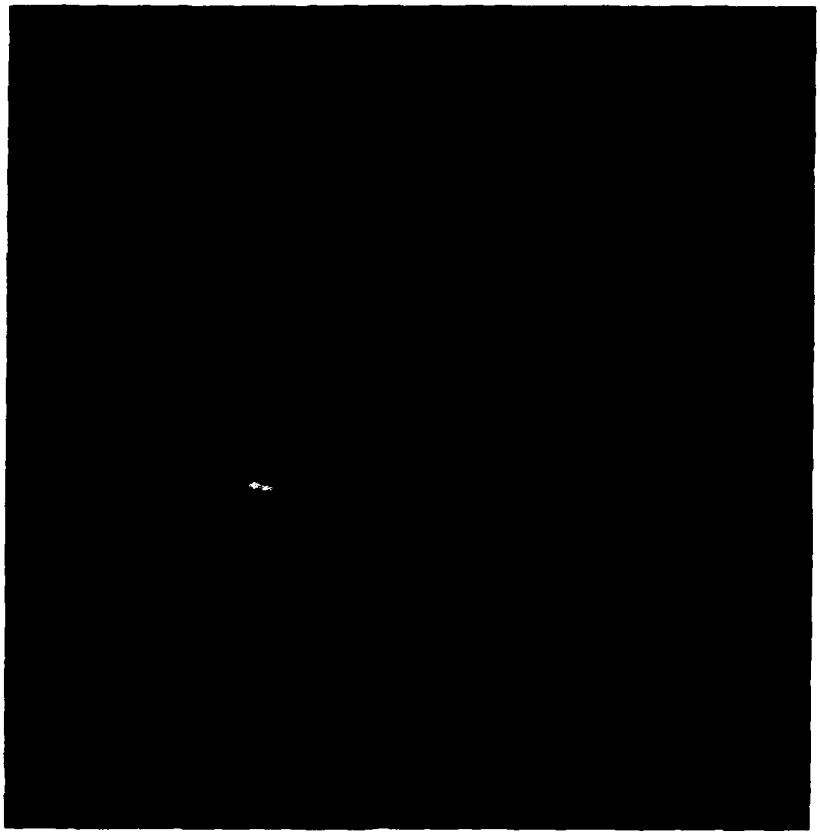


BICKFORD
RESERVOIR
DAM
MA 01022

OVERVIEW
BICKFORD POND DAM & BICKFORD RESERVOIR DAM
HUBBARDSTON & PRINCETON, MASSACHUSETTS

OVERVIEW
BICKFORD POND DAM
HUBBARDSTON & PRINCETON, MASSACHUSETTS



OVERVIEW
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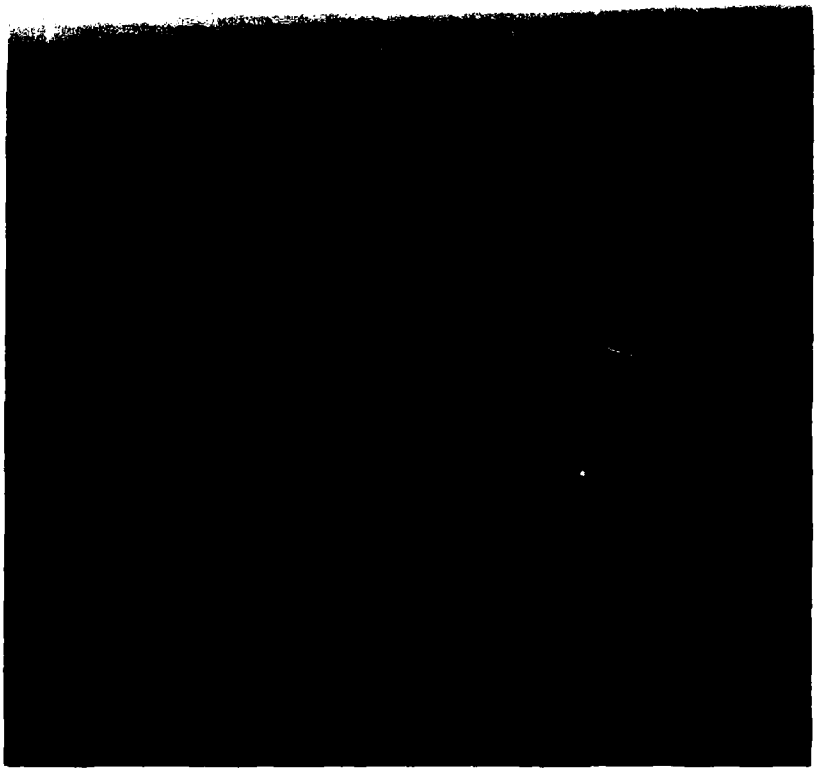
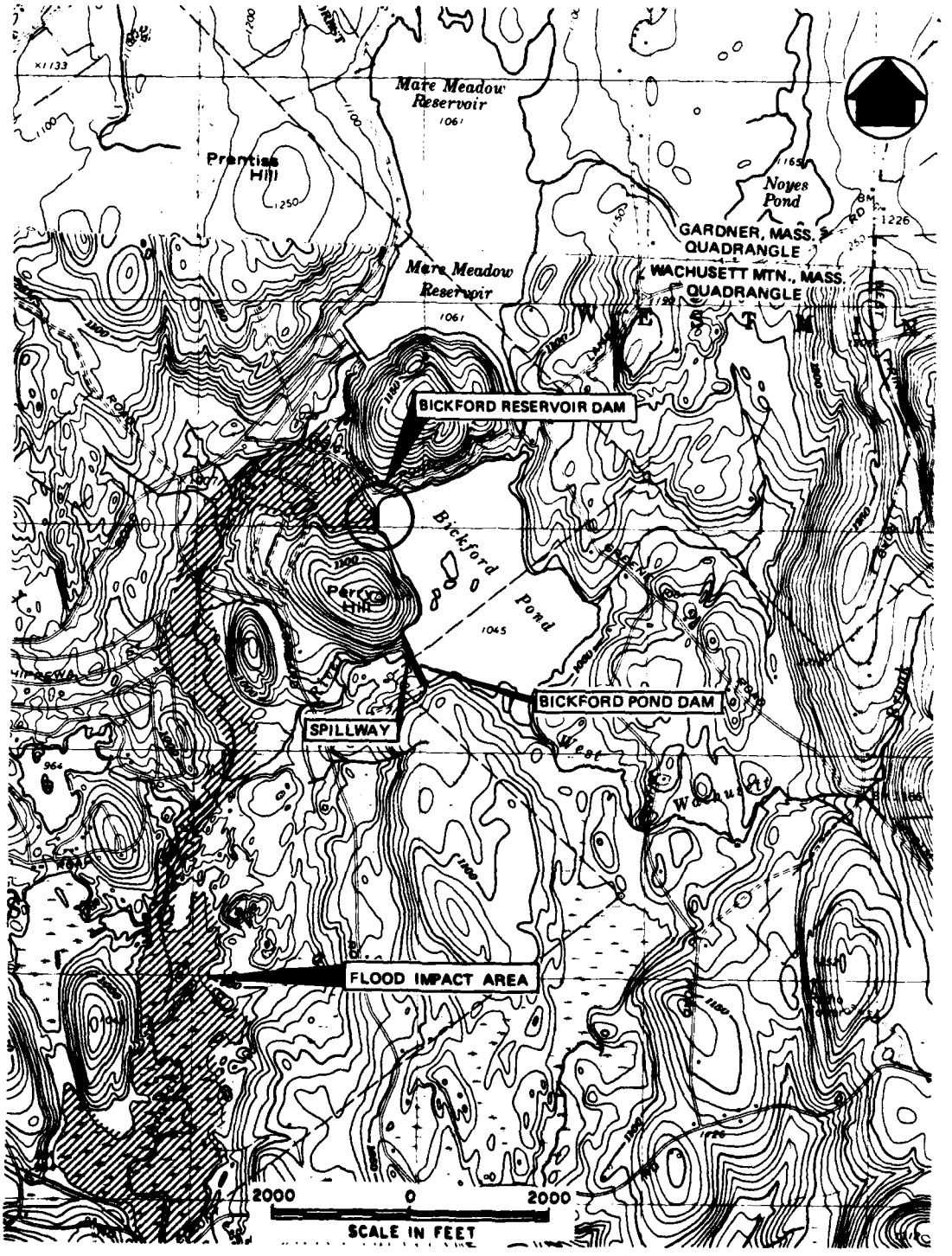
HUBBARDSTON, MASSACHUSETTS



LOCATION MAP – BICKFORD POND DAM



LOCATION MAP – BICKFORD RESERVOIR DAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

BICKFORD POND DAM
BICKFORD RESERVOIR 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. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Contract No. DACW 33-80-C-0054, dated April 18, 1980, has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) 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) Encourage and assist the States to quickly initiate effective dam safety programs for non-Federal dams.

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

1.2 Description of Project

a. Location. The dams are located on the East Branch of the Ware River in the Towns of Hubbardston and Princeton, Worcester County, Massachusetts and in the Connecticut River Basin (see Location Maps). The coordinates of Bickford Pond Dam are Latitude 42 deg. 29 min. north and Longitude 71 deg. 55.9 min. west.

The coordinates of Bickford Reservoir Dam are Latitude 42 deg. 29.4 min. north and Longitude 71 deg. 56.1 min. west.

b. Description of Dams and Appurtenances. Bickford Pond Dam is a 933-foot long, earth embankment dam with a 15-inch thick concrete core wall and a height of 51.2 feet (see Plan of Dam and Sections in Appendix B and photographs in Appendix C). The top of the dam is grass covered, 20 feet wide and varies from El 1051.2 to 1051.5. An earth roadway is located on the top of the dam. The upstream face is a 2:1 (horizontal:vertical) slope covered with riprap. Except for a 6-foot wide bench at El 1019.2 the downstream face is a 2:1 slope and is covered with grass. Available drawings indicate that the dam is an unzoned embankment with a concrete core wall (see Figure B-3). The drawings also show that the dam is founded on bedrock with a cutoff trench 15.5 feet below the base of the dam. The bottom of the core wall extends to a maximum depth of 63.2 feet below the top of the dam.

The spillway, located near the center of the Bickford Pond Dam, is a 20-foot long, by 30-foot wide rectangular drop inlet concrete structure.

The crest of the spillway is at El 1045.0, and the invert is at El 1002.0. The spillway outlet is a 12-foot square concrete box conduit extending through the dam.

The discharge channel below the spillway is 12-feet wide. The side slopes are 2:1 for a distance of 290 feet downstream. The floor of the channel is gravel covered and slopes at approximately 1 percent.

The low-level outlet for the dam is a 20-inch diameter ductile-iron pipe with invert at El 1003.0. that is controlled by a 30-inch sluice gate. Flow from the outlet is controlled by a floor stand with an 18-inch diameter hand wheel located at the end of the service bridge on the upstream side of the spillway.

There is also a 4-inch diameter ductile-iron pipe which parallels the 20-inch pipe. Flow from this outlet is controlled by a 4-inch butterfly valve. The butterfly valve is operated to maintain minimum water flows in the East Branch of the Ware River when the drop inlet spillway is not discharging. It is reported that this outlet has been operated once. The pipes are both

approximately 75 feet long and originate from a concrete headwall, located 20 feet from the upstream toe of the dam (see Figure B-4).

Two 6-inch diameter porous concrete core wall drain pipes discharge at the downstream end of both sides of the spillway box conduit. Also there are three 6-inch diameter porous concrete drains along the toe of the downstream slope. One is located to the left of the downstream end of the spillway box conduit; two drains discharge from a headwall located approximately 125 feet to the right of the spillway box conduit. The discharge from these pipes were clear at the time of the field inspection.

Bickford Reservoir Dam is a 507-foot long earth embankment dam with a 15-inch thick concrete core wall with a maximum height of 22.5 feet. (see Plan of Dam and Sections in Figure B-2). The top of the dam is 20-feet wide and varies from El 1051.3 to 1051.5. The upstream face is a 2:1 (horizontal:vertical) slope covered with riprap. The downstream face is a 2:1 slope covered with grass and brush. Available drawings indicate that the dam is an unzoned embankment with a concrete central core wall (see Figure B-2). The footings for the core wall are reportedly founded on bedrock with a cutoff trench 6.5 feet below the base of the dam. The core wall was apparently placed in two lifts with a construction joint at El 1034.0 with a steel water stop. A 6-inch diameter drain pipe was installed along the toe of the dam. An inspection of the two drains indicated that the outlet ends were 6-inch diameter vitrified clay pipe with a flow of approximately 3 gpm. The flow from the pipes was clear. Water from the toe drains discharge to a swamp located approximately 42 feet downstream of the toe of the dam.

There are no outlets or spillway in this dam. The reservoir level is controlled by the spillway/low level outlets at Bickford Pond Dam.

c. Size Classification. Bickford Pond Dam is classified in the "intermediate" category since it has a maximum height of 51.2 feet and a maximum storage capacity of 4021 acre-feet.

Bickford Reservoir Dam is also classified in the intermediate category since it has a maximum height of 18.3 feet and the Bickford Pond has a maximum storage capacity of 4021 acre-feet.

d. Hazard Classification. There are two residential structures located along the stream approximately 1,500 feet downstream of the Bickford Pond Dam (see Flood Impact Area shown on the Location Map). The foundations of these structures are approximately 15 feet above the floor of the stream. Due to the fact that a house was recently constructed adjacent to the stream downstream from the dam, it is assumed that there are no restrictions to additional residential construction within the flood impact area. An assumed failure of the dam would result in a flood wave 39 feet high 1,500 feet downstream of the dam. More than a few lives could possibly be lost and a significant amount of property damage could occur. Accordingly, the Bickford Pond dam has been placed in the "high" hazard category.

There are four residential structures located approximately 900 feet downstream of Bickford Reservoir Dam (see Flood Impact Area shown on the Location Map). The foundations of these structures are in a low lying area downstream of the dam. An assumed failure of the dam would result in a flood wave 9 feet high 900 feet downstream of the dam. More than a few lives could possibly be lost and a significant amount of damage could occur. Accordingly, the Bickford Reservoir dam has been placed in the "high" hazard category.

e. Ownership. The dams are owned by The City of Fitchburg, 718 Main Street, Fitchburg, Massachusetts 01420. Mr. Andre Provencial (617-342-5722) granted permission to enter the property and inspect the dam.

f. Operator. The dam is operated by personnel from Fitchburg Water Department.

g. Purpose of the Dam. The water in Bickford Pond is used for water supply by the City of Fitchburg. Water is pumped into Mare Meadow Reservoir through a 24 inch pipe line. A pump house is located along the northern shore of the pond adjacent to the Mare Meadow Reservoir Spillway.

h. Design and Construction. Bickford Pond Dam and Bickford Reservoir Dam were constructed by Welch & Corr Construction Corporation, West Springfield, Massachusetts and were completed in 1970. Drawings and specifications dated July, 1969 and prepared by Whitman & Howard, Engineers, Wellesley, Massachusetts are available. The drawings show that the dam was constructed essentially as it appears today.

Previous inspection reports indicate that since construction the dam has been in good condition. Repairs have been made such as replacing the 4-inch butterfly valve wheel damaged by vandals in 1971; patching leaks in spillway and tunnel (1971 and 1972) by Welch and Corr, the contractors who originally constructed the dam.

i. Normal Operating Procedures. Personnel from City of Fitchburg Water Department reportedly visit the dam once a week. At that time, they measure the depth of water either above or below the spillway crest. The 20-inch low-level outlet is reportedly opened at least once a year. The 4-inch butterfly valve was last opened in 1977.

1.3 Pertinent Data

a. Drainage Area. The drainage area is approximately 3,968-acre (6.2 square miles) and consists of gently rolling, land (see Figure D-1 in Appendix). Bickford Pond has a direct drainage area of 3.2 square miles. The additional 3 square miles of drainage area is contributory from Mare Meadow Reservoir. The spillway at Mare Meadow Reservoir discharges directly to Bickford Pond. About 18 percent of the drainage area is ponds and swamps. In general, the undeveloped portions of the drainage area are mostly woodland.

b. Discharge. Discharge from Bickford Pond Dam flows over the crest of the drop inlet spillway and into a 12-foot square concrete box conduit and then into a gravel-lined discharge channel. Water also discharges from the low level outlets into the box conduit.

(1) Outlet: 20-inch diameter pipe - 79 cfs - Invert-El. 1002.

(2) Maximum known flood at damsite: unknown.

(3) Ungated spillway capacity at top of dam 5100 cfs at El 1051.2.

(4) Ungated spillway capacity at test flood elevation: 5320 cfs at El 1051.4.

(5) Gated spillway capacity at normal pool elevation: N/A.

(6) Gated spillway capacity at test flood elevation: N/A.

(7) Total spillway capacity at test flood elevation: 5320 cfs at El 1051.4.

(8) Total project discharge at test flood elevation: 5480 cfs at El 1051.4.

c. Elevation (feet above National Geodetic Vertical Datum of 1929 (NGVD)). A benchmark was established at El. 1045.0 at the spillway crest. This elevation was obtained from as-built drawings by Whitman & Howard, Inc. and vertified from a United States Geological Survey (U.S.G.S.) topographic map.

Bickford Pond Dam

(1) Streambed at toe of dam: 1000.0

(2) Bottom of cutoff: 988.0

(3) Maximum tailwater: unknown

(4) Normal pool: 1045.0

(5) Full flood control pool: N/A

(6) Spillway crest: 1045.0

(7) Design surcharge (Original Design): 1049.0

(8) Top of dam: 1051.2

(9) Test flood surcharge: 1051.4

Bickford Reservoir Dam

(1) Streambed at toe of dam: N/A (toe of dam 1033.0)

(2) Bottom of cutoff: unknown

(3) Maximum tailwater: unknown

(4) Normal pool: 1045.0

(5) Full flood control pool: N/A

(6) Spillway crest: N/A (Bickford Pond Dam 1045.0.)

(7) Design surcharge (Original Design): 1049.0

(8) Top of dam: 1051.3.

(9) Test flood surcharge: 1051.4.

d. Reservoir (Length in feet)

(1) Normal pool: 3600.

(2) Flood control pool: N/A.

(3) Spillway crest pool: 3200.

(4) Top of dam: 3600.

(5) Test flood pool: 3600.

e. Storage (acre-feet)

(1) Normal pool: 3029

(2) Flood control pool: N/A.

(3) Spillway crest pool: 3029

(4) Top of dam: 4021

(5) Test flood pool: 4053

f. Reservoir Surface (acres)

*(1) Normal pool: 160.

*(2) Flood-control pool: N/A.

(3) Spillway crest: 160.

*(4) Test flood pool: 160.

*(5) Top of dam: 160.

*Based on the assumption that the surface area will not significantly increase with changes in pool elevation from 1051.2 to 1051.4.

g. Dam

Bickford Pond Dam

(1) Type: earthfill.

(2) Length: 930 feet.

(3) Height: 51.2 feet.

(4) Top width: 20 feet.

(5) Side slopes: 2H:1V.

(6) Zoning: none.

(7) Impervious core: 15-inch concrete core wall.

(8) Cutoff: concrete corewall extends to bedrock.

(9) Grout curtain: none.

(10) Other: on downstream slope 6-foot wide bench in embankment at El. 1019.2.

Bickford Reservoir Dam

(1) Type: earthfill.

(2) Length: 507 feet.

(3) Height: 18.3 feet.

(4) Top width: 20 feet.

(5) Side slopes: 2H:1V.

(6) Zoning: none.

(7) Impervious core: 15-inch concrete corewall.

(8) Cutoff: concrete corewall extends to bedrock.

(9) Grout curtain: none.

(10) Other: none.

h. Diversion and Regulating Tunnel. N/A.

i. Spillway

Bickford Pond Dam

(1) Type: Drop inlet discharging to 12 foot by 12 foot concrete conduit.

(2) Length of weir: 100* feet.

(3) Crest elevation: 1045.0.

(4) Gates: N/A.

(5) Upstream channel: N/A.

(6) Downstream channel: 12-foot wide channel with 2:1 side slopes 3 to 4 feet high.

(7) General: none.

Bickford Reservoir Dam. N/A.

j. Regulating Outlets

Bickford Pond Dam

(1) Invert El: 1003.0.

(2) Size: 20 inches.

(3) Description: Ductile-iron pipe.

(4) Control mechanism: 20-inch flat frame sluice gate, controlled by rising stem floor stand located on service bridge on the upstream end of spillway.

(5) Other: 4-inch diameter ductile-iron pipe with 4-inch butterfly valve - control wheel at the upstream face of spillway. Invert El.: 4-inch pipe 1003.7 feet.

Bickford Reservoir Dam: N/A.

*Total length.

SECTION 2

ENGINEERING DATA

2.1 General. The engineering data available for this Phase I inspection includes drawings and specifications dated July 1969 prepared by Whitman & Howard, Inc. (see Figures B-1 through B-13). Design calculations by Whitman & Howard were not available for review except for information relating to spillway capacity as shown on Figures B-14 and B-15. Shop drawings for the sluice gate and floor stand were available for review. The drawings/specifications were obtained from Whitman & Howard, Inc. There are no other drawings, specifications, or computations available from the Owner, State, or County agencies. Copies of previous inspection reports dated 1972 to 1975, prepared by Massachusetts Department of Public Works, District No. 3, Highway Department, Worcester and Massachusetts Department of Public Works, Division of Waterways are included in Appendix B.

We acknowledge the assistance and cooperation of personnel from the Massachusetts Department of Environmental Quality Engineering, Division of Waterways; the Massachusetts Department of Public Works; and the Worcester County Engineers Office. In addition, we acknowledge the assistance of Mr. Joseph A. Murphy of Whitman & Howard, Inc. and Mr. Norman Cormier of the City of Fitchburg, Water Department, who provided information on the history and operation of the dam.

2.2 Construction Records. Construction records were not available for review. As-built drawings were available for the dam and appurtenances and several of these drawings are included in Appendix B. (Bickford Pond Dam is referred to as Bickford Dam on the drawings while Bickford Reservoir Dam is referred to as Bickford Dike.) Daily field reports and correspondence by Whitman & Howard, Inc. provided some construction information concerning repairs and post-construction changes at the site.

2.3 Operating Records. No operating records are available, and there is no daily record kept of the elevation of the pool or rainfall at the dam site. The only records available are weekly readings of depth of water above or below spillway crest.

2.4 Evaluation

a. Availability. There is some engineering data available for this dam.

b. Adequacy. The lack of detailed hydraulic, structural and geotechnical design data did not allow for a definitive review. Therefore, the evaluation of the adequacy of this dam is based on the as-built drawings, construction data, visual inspection, past performance history, and engineering judgment.

c. Validity. Comparison of the available drawings with the field survey conducted during the Phase I inspection indicates that the available information is valid.

SECTION 3

VISUAL INSPECTION

3.1 Findings

a. General. The Phase I Inspections of the two dams at Bickford Pond were performed on May 13, 1980. A copy of the inspection checklist is included in Appendix A. Previous inspections were conducted by the Massachusetts Department of Public Works in 1972 and 1975. Copies of these reports are given in Appendix B. Selected photographs taken during our Visual Inspection are included in Appendix C.

b. Dam

(1) Bickford Pond Dam - The Bickford Pond dam is a 930-foot long earthfill structure with a drop inlet spillway, box conduit outlet.

Along the top of the dam there is evidence of tire ruts due to vehicular traffic (see Photo No. 1).

There is a 6-foot wide berm (see drawing B-4) in the embankment at El. 1019.2 which extends to the toe of the dam (see Photo No. 2).

Slight erosion was noted on the downstream slope of the dam. (see Photo No. 1.)

The upstream face of the embankment appears to be intact. There are several areas adjacent to the spillway where there has been minor movement of the riprap (see Photo No. 5).

Brush and small saplings are growing on the upstream face through the riprap (see Photo No. 4).

Two 6-inch porous concrete drains are located along the core wall as shown on Figure B-1 and then run adjacent to each side of the box conduit. Invert elevation of the core wall drains is [illegible]. 1003 (see Photos No. 7, 9 and 10). Flow from each of these drains was clear and estimated to be 10 to 15 gallons per minute. There are three 6-inch porous concrete toe drains, the locations of which are also shown on Figure B-1 (see Photos No. 8 and 10). The left toe drain outlet is located approximately

4 feet from the left core wall drain outlet. The flow from this drain was also clear and estimated to be 5 to 8 gpm. The remaining two toe drain outlets are approximately 125 feet to the right of the box conduit. These two toe drains pass through a field stone head wall into a small ditch which discharges into the overflow channel. (see Photo No. 3 and 8). Flow from these toe drains was clear and estimated to be approximately 1 to 3 gallons per minute. The area immediately around the toe drains is rusty colored while downstream of the toe drain outlets there is an occasional oily sheen at the water surface. The discharge from these toe drains are restricted due to an accumulation of silt in the ditch which leads to the discharge channel. The ditch is covered with marsh type vegetation and the bottom is soft and spongy.

(2) Bickford Reservoir Dam - The Bickford Reservoir Dam is a 507-foot long earthfill structure with a concrete core wall. The riprap on the upstream face of the embankment appears to be intact. Brush and saplings are growing through the riprap on the upstream face of the dam and also on the downstream face (see Photos No. 11 and 12). There are two 6-inch diameter toe drains along the centerline of the dam which discharges at the toe of the dam. The visible portions of the toe drains at the outlet ends are vitrified clay pipe (see Photo No. 14). The drains were flowing clear at approximately 3 gpm. There is a swamp immediately downstream of the dam. Flow from the toe drains discharges into a short channel approximately 42 feet long covered with marsh type vegetation (see Photo No. 13).

c. Appurtenant Structures. The Bickford Pond Dam spillway is a 20-foot by 30-foot rectangular drop inlet type divided into two chambers by a 1-foot thick concrete wall. The top of the wall is at El. 1040. The crest of the spillway is at El. 1045. At the time of the inspection, water was discharging over the spillway into the drop inlet, so that the low level outlets, the floor and walls of the drop inlet spillway and the floor of the box conduit could not be examined. The concrete on the crest of the spillway, visible from the service bridge appeared to be in good condition (see Photo No. 5 and 6).

The walkway over the spillway is a 3-1/2-foot wide 18-inch thick precast prestressed concrete channel section approximately 38-feet long. The beam rests on a concrete footing on the embankment side of the walkway and on a pier on the upstream face of the drop inlet spillway. The walkway is in good condition. A chain-link fence protects the entrance to the walkway. At the time of the inspection, the chain at the gate had to be cut by Fitchburg Water Department personnel to allow access to the spillway and gate operation for the low level outlet (see Photo No. 5). Since our inspection a lock has been added.

The 20-inch flat frame sluice gate located on the upstream side of the right chamber of the spillway is reportedly in good operating condition. A 4-inch butterfly valve adjacent to the sluice gate also is reportedly in good operating condition. The sluice gate is opened yearly while the butterfly valve was reported last to be opened three years ago. Due to the water discharging over the spillway no inspection of these outlets could be made. The rising stems and stem guides, viewed from the service bridge appear to be in good condition with no breaks visible (see Photo No. 6).

The 12-foot by 12-foot concrete box conduit outlet is in fair condition. An inspection of the interior of the conduit was made from the downstream opening to the vertical shaft of the spillway. The inspection revealed that the first two construction joints from the spillway looking downstream are stained on the roof and walls with orange-brown deposits of seepage. Approximately 9.5 feet from the spillway there are vertical cracks, in both the left and right walls of the culvert which also are stained orange-brown. There are numerous hairline cracks on the roof and walls of the conduit. Approximately 12 feet upstream of the angle point on the left wall there is also some seepage discharging approximately 2 feet above the invert where a small piece of concrete is missing. The discharge end of the outlet is clear of debris, and a moderate amount of water was discharging at the time of the inspection (see Photo No. 3 and 7).

Bickford Reservoir Dam has no structures or regulating outlets. All controls for Bickford Pond are located at the Bickford Pond Dam.

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

d. Reservoir Area. The reservoir area is not developed. Most of the land is wooded with gentle slopes. All of the surrounding land around the dam is owned by the City of Fitchburg and there is no potential that future development will occur in the reservoir area.

e. Downstream Channel. Both the spillway and outlet discharge into the downstream channel (see Photo No. 3). The earth slopes that form the sides of the channel are slightly eroded. The floor of the channel is covered with gravel (see Photo No. 7).

3.2 Evaluation. The visual inspection indicates that the dams are in good condition. The stated deficiencies which must be corrected to assure the continued performance of this dam and measures to improve this condition are stated in Section 7.

SECTION 4

OPERATING AND MAINTENANCE PROCEDURES

4.1 Operating Procedures

a. General. There are operating facilities, however, there are no regular operating procedures for this dam. Personnel from Fitchburg Water Department reportedly visit the dam once a week to check the embankment and read the lake level above or below the crest of the spillway. The flow from the toe drains is not noted or recorded during these visits.

b. Warning System. There is no warning system in effect at this dam.

4.2 Maintenance Procedures

a. General. The dam is generally adequately maintained. The City of Fitchburg Water Department is responsible for maintenance of the facility.

b. Operating Facilities. Maintenance of the operating facilities at the dam consists of opening the 20-inch sluice gate which controls the low level outlet at least once a year. The 4-inch low level outlet butterfly valve was last opened in 1977.

4.3 Evaluation. There are no regular programs of maintenance or technical inspections for the dams. There are also no plans for surveillance of the dam during periods of heavy rainfall, or for warning people in downstream areas in the event of an emergency at the dams. The lack of standard operating and maintenance procedures is undesirable, considering that the dams are in the "high" hazard category. These programs should be implemented as recommended in Section 7.3.

SECTION 5

EVALUATION OF HYDRAULIC/ HYDROLOGIC FEATURES

5.1 General. Bickford Pond Dam and Bickford Reservoir Dam have a 6.2-square mile drainage area, about 18 percent of which is ponds and swamps (see Figure D-1, Drainage Area Map). The land is gently rolling and generally undeveloped. Of the total drainage area, approximately 3.2 square miles flows directly into Bickford Pond. The remaining 3 square miles of drainage area flows into Mare Meadow Reservoir. The Mare Meadow Reservoir spillway discharges excess water directly into Bickford Pond.

Bickford Pond has a surface area of approximately 160 acres, and a maximum storage capacity of 4,021 acre-feet at El 1051.2.

The low-level outlet can discharge a flow of 79 cfs when the pond is at El 1045 which is the crest of the spillway. At this pond elevation and with no additional inflow, the outlet can lower the pond by 1 foot in about 24 hours.

5.2 Design Data. Hydraulic and hydrologic information is presented in Appendix B (pages B-14 and 15). The design high water level for the reservoir was El 1049. The spillway was designed to discharge a maximum 2,400 cfs.

5.3 Experience Data. The original dam located within the existing Bickford Pond was overtopped and washed out during heavy rains in 1936. There is no record of overtopping of the present dam, which was constructed in 1970. The highest recorded reservoir elevation occurred on May 2, 1977 with 1 foot of water flowing over the spillway (Pond El. 1046).

5.4 Test Flood Analysis. Bickford Pond Dam and Bickford Reservoir Dam have been classified in the "intermediate" size and "high" hazard categories. According to the Corps of Engineers guidelines, a test flood equal to full PMF (Probable Maximum Flood) should be used to evaluate the capacity of the spillway.

The PMF rate for the Mare Meadow Reservoir watershed which flows through a spillway directly into Bickford Pond was calculated to be 2,000 cfs per square mile of drainage area.

This calculation is based on the average slope of 5 percent in the drainage area, the general shape of the drainge area surrounding the reservoir, the pond-plus-swamp area to drainage area ratio of 5.4 percent, and the U.S. Army Corps of Engineers' guide curves for Maximum Probable Flood Peak Flow Rates (dated December 1977). For this analysis, the peak flow rate was determined to be at the guide curve for rolling topography.

The PMF rate for the Bickford Pond watershed was calculated to be 1,700 cfs per square mile of drainage area. This calculation is based on the average slope of 4 percent in the drainage area, the longer drawn out shape of the drainage area, the pond-plus-swamp area to drainage area ratio of 9.3 percent, and the U.S. Army Corps of Engineers guide curves for Maximum Probable Flood Peak Flow Rates (dated 1977). For this analysis, the peak flow rate was determined to be slightly below the guide curve for rolling topography.

Applying the full PMF rate to the direct 3.2 square mile drainage area of Bickford Pond results in a peak test flood inflow of 5,490 cfs. An additional inflow of 1,700 cfs of routed outflow from the Mare Meadow Reservoir drainage area (3 square miles) results in a peak test flood inflow of 7,190 cfs for the total 6.2 square mile drainage area (direct and indirect). By adjusting the test flood inflow for surcharge storage, the peak test flood outflow was calculated to be 5,480 cfs (884 cfs per square mile).

During the test flood (full PMF) the pond level would rise to El 1051.4.

Hydraulic analyses, utilizing the full length of the spillway crest, indicate that the Bickford Pond Dam spillway can discharge 5,100 cfs or 93 percent of the test flood outflow with the pond at El 1051.2, which is the low point on top of the dam. Water access to the spillway crest is partially limited by the closeness of the dam. However, the resulting discharge would be reduced by less than 5 percent of the outflow. This value is within the accuracy of the PMF storm and no modifications were made due to this restriction.

During the test flood, the low point on the dam would be overtopped by 0.2 feet. About 5,100 cfs would discharge over the spillway, and about 380 cfs would discharge over the dam.

Bickford Reservoir Dam has no spillway. The low point of the dam is at El. 1051.3 resulting in overtopping of the dam by 0.1 feet.

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

5.5 Dam Failure Analysis - Bickford Pond Dam. The peak discharge rate due to failure of the dam was calculated to be 147,700 cfs with the pond at El 1051.2. This calculation is based on a maximum head of 51.2 feet and an assumed 240-foot wide breach occurring in the center of the embankment. Failure of the dam would produce a flood wave 39 feet deep 1500 feet downstram as compared to channel flow 9 feet deep prior to failure. It would take about 1 hour to drain the pond.

There are two residential structures located along the stream/channel approximately 1,500 feet downstream of the dam. The foundations of these structures are approximately 15 feet above the floor of the stream. Discharge due to failure of the dam could result in overflowing of the channel farther downstream. Due to the configuration of the channel, little attenuation of the flood flow is expected. It is likely that failure of the dam would result in significant property damage and possible loss of more than a few lives in developed areas downstream of the dam. Accordingly, the dam has been placed in the "high" hazard category.

Bickford Reservoir Dam. The peak discharge rate due to failure of the dam was calculated to be 14,600 cfs with the pond at El 1051.2. This calculation is based on a maximum head of 18.2 feet and an assumed 112-foot wide breach occurring in the center of the embankment. Failure of the dam would produce a flood wave 8 feet deep approximately 900 feet downstream where there was no flow in the channel prior to failure. It would take about 5 hours to drain the pond to El. 1033.

There are four residential structures located approximately 900 feet downstream of the dam. Discharge due to failure of the dam could result in overflowing of the channel farther downstream. Due to the configuration of the channel, little attenuation of the flood flow is expected. It is likely that failure of the dam would result in significant property damage and possibel loss of more than a few lives in developed areas downstream of the dam. Accordingly, the dam has been placed in the "high" hazard category.

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

SECTION 6

STRUCTURAL STABILITY

6.1 Visual Observations. The evaluation of the structural stability of Bickford Pond Dam and Bickford Reservoir Dam is based on a review of previous inspection reports, a review of available drawings, and the visual inspection conducted on May 13, 1980.

As discussed in Section 3, Visual Inspection, the dams are in good condition. Seepage was not observed along the toe or slopes of either embankment indicating that core wall and toe drains were adequately drawing down the phreatic surface within the embankment. Areas of minor erosion were observed on the downstream slope of the dam. A growth of saplings and vegetation exists on the upstream face of both of the dams through the riprap and on Bickford Reservoir Dam on the downstream slope.

6.2 Design and Construction Data. Construction of Bickford Pond Dam and Bickford Reservoir Dam was completed in 1970. Computations for design of the dam, spillway and outlet are not available.

Drawings dated September 1972 prepared by Whitman & Howard, Inc. show the as-built construction of the dams (see Figures B-1 through B-4). The drawings show that the dam is a unzoned earthfill embankment founded on bedrock. An impervious reinforced concrete core wall with steel water stops installed (according to specifications) at all construction joints is located along the centerline of the embankment. The remaining earthfill is shown as compacted glacial till and pervious fill on the drawings. At Bickford Pond Dam the core wall extends 15.5 feet below the base of the dam at its deepest point (see Figure B-3). At Bickford Reservoir Dam the cutoff wall extends 6.5 feet below the base of the dam (see Figure B-2). The side slopes of embankments are 2H:1V upstream and 2H:1V downstream.

Specifications for construction of the dam are available. They include details on the types of earth materials, riprap, and concrete used in construction. Selected portions of the specifications are given in Appendix B.

There is no information on the shear strength or permeability of the soil and/or rock materials of the embankment. The specifications required compaction of the embankment to be achieved by running a heavy catepiller type tractor over the fill until compacted to 90 percent of the maximum density obtained at optimum moisture content. The dam core wall is reinforced concrete. The specifications required that the concrete be tested for compressive strength "core wall 3,000 psi spillway conduit 3,500 psi". Records of test results for soil compaction and concrete were not available for review.

6.3 Post-Construction Changes. Since the original construction of the dam, several changes/repairs have been made. 1971 - Repairs made to riprap. 1971 and 1972 - Repairs made to box culvert and spillway to prevent leakage. 1972 - New butterfly valve handwheel installed.

6.4 Seismic Stability. The dam is located in Seismic Zone No. 2, and in accordance with Corps of Engineers' guidelines does not warrant further seismic analysis at this time.

SECTION 7

ASSESSMENT, RECOMMENDATIONS,
AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. As a result of the visual inspection, the review of available data, and limited information on operation and maintenance, the dam is considered to be in good condition.

The following deficiencies observed at Bickford Pond Dam must be corrected to assure the continued performance of the dam: seepage through cracks and joints in the box conduit outlet structure; unmonitored seepage through core wall toe drains and downstream slope toe drains; siltation and partial blockage of discharge ditches from toe drains; riprap dislodged from the upstream face of the dam; cracked, spalled and eroded concrete in the box conduit and spillway; growth of brush and saplings through riprap on upstream face of dam; and tire ruts along the top of the dam.

The following deficiencies observed at the Bickford Reservoir Dam must be corrected to assure the continued performance of the dam: unmonitored seepage through downstream slope toe drains; siltation and partial blockage of discharge ditches from toe drains; growth of brush and saplings through riprap on upstream face of dam; and growth of brush and saplings on downstream face of dam.

The peak test flood (full PMF) outflow is estimated to be 5,480 cfs with the pond at El 1051.4. The test flood would overtop the low point on the Bickford Pond Dam by 0.2 feet and Bickford Reservoir Dam by 0.1 feet. Hydraulic analyses indicate that the spillway can discharge 5,100 cfs or 93 percent of the test flood outflow before the dam is overtopped.

b. Adequacy. The lack of detailed design data did not allow for a definitive review. Therefore, the evaluation of this dam is based on a review of the as-built drawings, construction information, the visual inspection, past performance and engineering judgment.

c. Urgency. The recommendations and remedial measures outlined below should be implemented by the Owner within two years after receipt of this Phase I Inspection Report.

7.2 Recommendations. It is recommended that the Owner employ a qualified registered engineer to:

a. Evaluate the condition of the spillway and box conduit outlet at Bickford Pond Dam. This should include an inspection of the spillway under a no flow condition to assess the condition of the low level outlets, the drop inlet spillway floor and walls and the box conduit floor and an investigation of the seepage noted along the first two construction joints of the box culvert and vertical cracks on both walls 9.5 feet from the spillway.

b. Monitor and evaluate the flow through the core wall drains and drains at the downstream toe for Bickford Pond Dam and the drains at the downstream toe for Bickford Reservoir Dam. Recommend measures for monitoring the volume of flow out of the toe drains and core wall drains in relation to reservoir level and rainfall. A substantial increase or decrease in flow in a short period of time, unrelated to reservoir level could indicate a potential problem. Monitoring should be done at least monthly for a period of two years and then the monitoring program should be adjusted based on the results of observations made.

c. Develop recommendations for clearing saplings, brush and roots from the upstream face of the embankment, particularly in the areas of riprap slope protection, and recommendations for backfilling with select material.

The Owner should implement the recommendations of the Engineer.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. It is recommended that the Owner accomplish the following:

Bickford Pond Dam

(1) Mow grass on downstream slopes at least once a year to control growth of brush and trees on embankment.

(2) To prevent continued erosion, the minor eroded areas on the downstream face of the earth embankment should be filled in and repair ruts caused by vehicular traffic on top of the dam.

(3) Replace dislodged riprap on the upstream face of the embankment.

(4) Clean area around discharge end of toe drains located 125 feet to the right of the box conduit. Regrade drainage ditch to allow for free flow of water from the toe drains to the discharge channel.

(5) Repair all spalled and deteriorated concrete on the spillway and box conduit outlet structure in accordance with recommendations of the Engineer.

(6) Repair concrete at first two construction joints and crack 9.5 feet from spillway where seepage occurs. Repair all other areas where seepage is entering through the walls of the box conduit.

(7) Monitor the volume of flow out of the core wall and toe drains in accordance with the program established under Section 7.2.

(8) Inspect outlet works monthly to ensure it is free of debris.

Bickford Reservoir Dam

(1) Remove brush on downstream face of the embankment. Mow grass on downstream slope at least once a year to control growth of brush and trees and the embankment.

(2) Clean area around discharge end of toe drains to allow free flow of water from the toe drains to the swamp downstream of the dam.

(3) An area at least 25 feet from the downstream toe and along the dam should be cleared and maintained free of trees, brush. Also, the grass should be cut.

(4) Monitor volume of flow out of toe drains in accordance with the program established under Section 7.2.

Bickford Pond Dam and Bickford Reservoir Dam

(1) Institute a definite plan for surveillance of the dams and spillway during and after periods of heavy rainfall and a plan to warn people in downstream areas in the event of an emergency at the dams.

(2) Implement a systematic program of maintenance inspections. As a minimum, the inspection program should consist of a monthly inspection of the dams and appurtenances and be supplemented by additional inspections during and after severe storms. All repairs and maintenance should be undertaken in compliance with all applicable State regulations.

(3) Institute a program of technical inspections on an biennial basis.

7.4 Alternatives. There are no recommended alternatives.

APPENDIX A

PERIODIC INSPECTION CHECKLIST

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

PERIODIC INSPECTION

PARTY ORGANIZATION

PROJECT BICKFORD POND DAM
BICKFORD RESERVOIR DAM

DATE May 13, 1980

TIME 8 A.M.-4 P.M.

WEATHER Cloudy-Rain

W.S. ELEV. 1045.0 U.S. 1003.0 DN.S.

PARTY:

1. N. D'Agostino (Metcalf & Eddy - Geotechnical)
2. S. Nagel (Metcalf & Eddy - Geotechnical)
3. W. Checchi (Metcalf & Eddy - Geotechnical)
4. W. Diesl (Metcalf & Eddy - Geotechnical)
5. L. Branagan (Metcalf & Eddy - Hydraulics)
6. Norman Cormier (City of Fitchburg - Water Dept.)

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Dam Embankment-Bickford Pond	N. D'Agostino/S. Nagel	
2.	Dam Embankment-Bickford Reservoir	N. D'Agostino/S. Nagel	
3.	Outlet Works - Spillway	N. D'Agostino	
4.	Outlet Works - Box Culvert	N. D'Agostino	
5.	Outlet Works - Service Bridge	N. D'Agostino/S. Nagel	
6.	Outlet Works - Low Level Outlets	N. D'Agostino	
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD POND DAM DATE May 13, 1980

PROJECT FEATURE Dam NAME N. D'Agostino

DISCIPLINE Geotechnical NAME S. Nagel

d/s = downstream u/s = upstream

AREA EVALUATED	CONDITIONS
DAM EMBANKMENT	
Crest Elevation	1051.5
Current Pool Elevation	1045.3
Maximum Impoundment to Date	1046.0
Surface Cracks	None visible
Pavement Condition	Crest of dam is unpaved-dirt road some rutting on left side
Movement or Settlement of Crest	None visible
Lateral Movement	None visible
Vertical Alignment	Level
Horizontal Alignment	Straight
Condition at Abutment and at Concrete Structures	Ties into natural ground-low spot at right abutment with some rutting from tires
Indications of Movement of Structural Items on Slopes	None
Trespassing on Slopes	Some minor rutting & erosion
Sloughing or Erosion of Slopes or Abutments	None visible
Rock Slope Protection - Riprap Failures	One localized riprap failure right side of spillway - water line-brush & sapplings growing in riprap - d/s clear
Unusual Movement or Cracking at or near Toes	None visible
Unusual Embankment or Downstream Seepage	None visible
Piping or Boils	None
Foundation Drainage Features	Two porous concrete 6" core wall drains exit @ d/s outlet of culvert-flow is approx.10-15 gpm for each.
Toe Drains	Three toe drains-to right of outlet two 6" porous concrete drains are seeping approx. 3-5gpm. One toe drain to left of outlet flow approx. 5-8 gpm.
Instrumentation System	None

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD RESERVOIR DAM DATE May 13, 1980

PROJECT FEATURE Dam NAME N. D'Agostino

DISCIPLINE Geotechnical NAME S. Nagel

AREA EVALUATED	CONDITIONS
DAM EMBANKMENT	
Crest Elevation	1051.5
Current Pool Elevation	1045.3
Maximum Impoundment to Date	Unknown
Surface Cracks	None visible
Pavement Condition	None-crest is grass covered
Movement or Settlement of Crest	None visible
Lateral Movement	None visible
Vertical Alignment	Level
Horizontal Alignment	Straight
Condition at Abutment and at Concrete Structures	Good-embankment ties into natural ground
Indications of Movement of Structural Items on Slopes	None
Trespassing on Slopes	None //Brush & sapplings on d/s slope
Sloughing or Erosion of Slopes or Abutments	None visible
Rock Slope Protection - Riprap Failures	u/s - brush & sapplings growing through riprap
Unusual Movement or Cracking at or near Toes	None visible
Unusual Embankment or Downstream Seepage	None visible// Swamp vegetation 10' rt. of toe drain @ d/s toe
Piping or Boils	None visible-Swamp 42' d/s of dam toe
Foundation Drainage Features	None
Toe Drains	Two vitrified clay 6"diameter pipes flowing approx. 2 to 3 gpm. Located @ approx. ℄ of dam @ toe - orange stain
Instrumentation System	None

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD POND DAM DATE May 13, 1980

PROJECT FEATURE Spillway NAME N. D'Agostino

DISCIPLINE Geotechnical NAME S. Nagel

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	Drop inlet - Morning Glory
General Condition	Good
Loose Rock Overhanging Channel	N/A
Trees Overhanging Channel	N/A
Floor of Approach Channel	N/A
b. Weir and Training Walls	Partly obscured by flow into inlet
General Condition of Concrete	Good
Rust or Staining	None visible
Spalling	None visible
Any Visible Reinforcing	None visible
Any Seepage or Efflorescence	None visible
Drain Holes	None visible
c. Discharge Channel	Stream channel
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	None within 200' of d/s toe of dam
Floor of Channel	Stream bed-gravel
Other Obstructions	None

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD POND DAM DATE May 13, 1980

PROJECT FEATURE Box Culvert NAME N. D'Agostino

DISCIPLINE Geotechnical NAME W. Checchi

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	
General Condition of Concrete	Fair
Rust or Staining on Concrete**	Some orange-brown seepage at first 2 construction joints from vertical shaft.
Spalling	Minor spalling near drop inlet 2' diam. 6"deep dished out void @ left transition wall ceiling.
Erosion or Cavitation	Approx. 12' u/s of angle point-orange brown seepage 2' above invert-chunk of concrete missing.
Cracking*	Hairline cracking-walls & ceiling near drop inlet & at d/s end of culvert.
Alignment of Monoliths	Straight
Alignment of Joints	Tight-some evidence of seepage @ first 3 construction joints.
Numbering of Monoliths	9

*Vertical cracks on left and right walls approximately 9.5' from drop inlet spillway.
Vertical crack to roof approximately 45' from spillway - left wall

**1st construction joint heavy leak all across joint (walls, floor & roof) 21' from spillway.
2nd construction joint heavy leak at base left wall (spurting) seepage ob erved walls, ceiling.
Left wall approximately 56' from spillway heavy efflorescence & leaking along base of wall approximately 1.5' long.
Left wall some seepage @ construction joint 60' from spillway.
Left wall some seepage along lower portion of wall @ construction joint 90' from spillway.

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD POND DAM DATE May 13, 1980

PROJECT FEATURE Service Bridge NAME N. D'Agostino

DISCIPLINE Geotechnical NAME S. Nagel

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	
a. Super Structure	Precast concrete beam
Bearings	None visible
Anchor Bolts	None visible
Bridge Seat	Bears on footing pier on dam slope and on drop inlet on other end
Longitudinal Members	Precast concrete deck
Under Side of Deck	Good
Secondary Bracing	None
Deck	Concrete - good condition
Drainage System	None
Railings	Painted 2" wrought iron pipe-good condition-some rust stains on concrete where railing meets it.
Expansion Joints	None
Paint	Railing is painted-good condition
b. Abutment and Piers	
General Condition of Concrete	Good
Alignment of Abutment	Straight
Approach to Bridge	From dam-protected by chain link fence - no erosion visible
Condition of Seat and Backwall	Good

PERIODIC INSPECTION CHECK LIST

PROJECT BICKFORD POND DAM DATE May 13, 1980

PROJECT FEATURE Low Level Outlets NAME N. D'Agostino

DISCIPLINE Geotechnical NAME W. Checchi

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	
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	

There are two low level outlets-one according to as-built drawings, a 20" diameter ductile iron pipe with a flat frame sluice gate with a rising stem. Control is by means of floorstand located on u/s end of service bridge. Hand wheel for floorstand is stored at pump station near Mare Meadow Spillway at east end of Reservoir.

-The other outlet is a 4" ductile iron pipe controlled by a 4" butterfly valve also located on the u/s face of the drop inlet. Both outlets are located in the right chamber of the spillway. Due to the water flowing into the drop inlet spillway, neither of these outlets were inspected or opened.

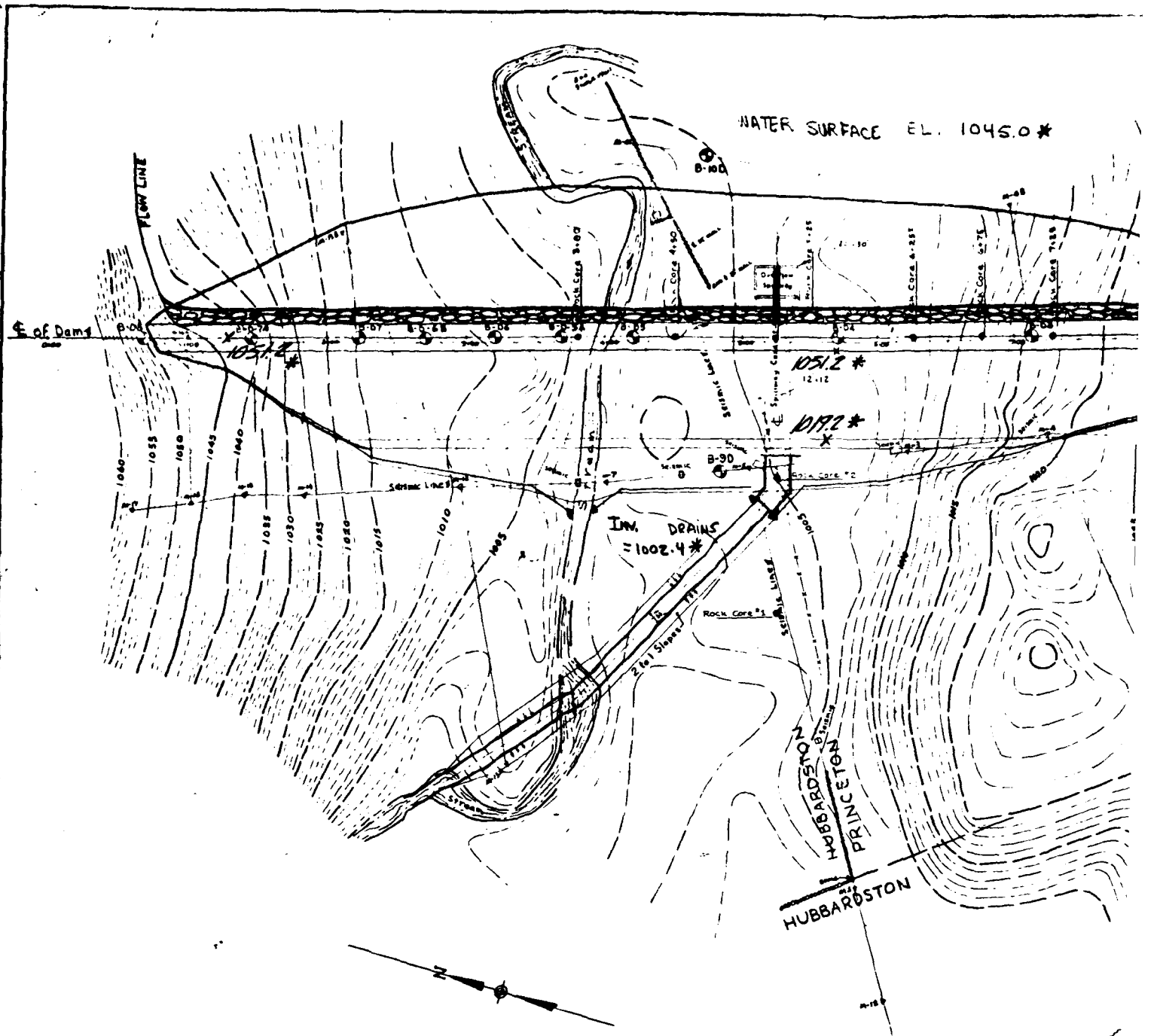
It is reported that the sluice gate is opened at least once a year. The butterfly valve has been opened only once since installed. There is no maintenance performed on either of these outlets.

There is some rusting/corrosion of floorstand where hand wheel control for sluice gate is inserted.

Rising stem from sluice gate to floorstand is straight with no apparent breaks. Stem guides on u/s face of drop inlet appear to be in good condition. (Viewed from service bridge looking down drop inlet spillway.)

APPENDIX B

PLANS OF DAM AND PREVIOUS
INSPECTION REPORTS

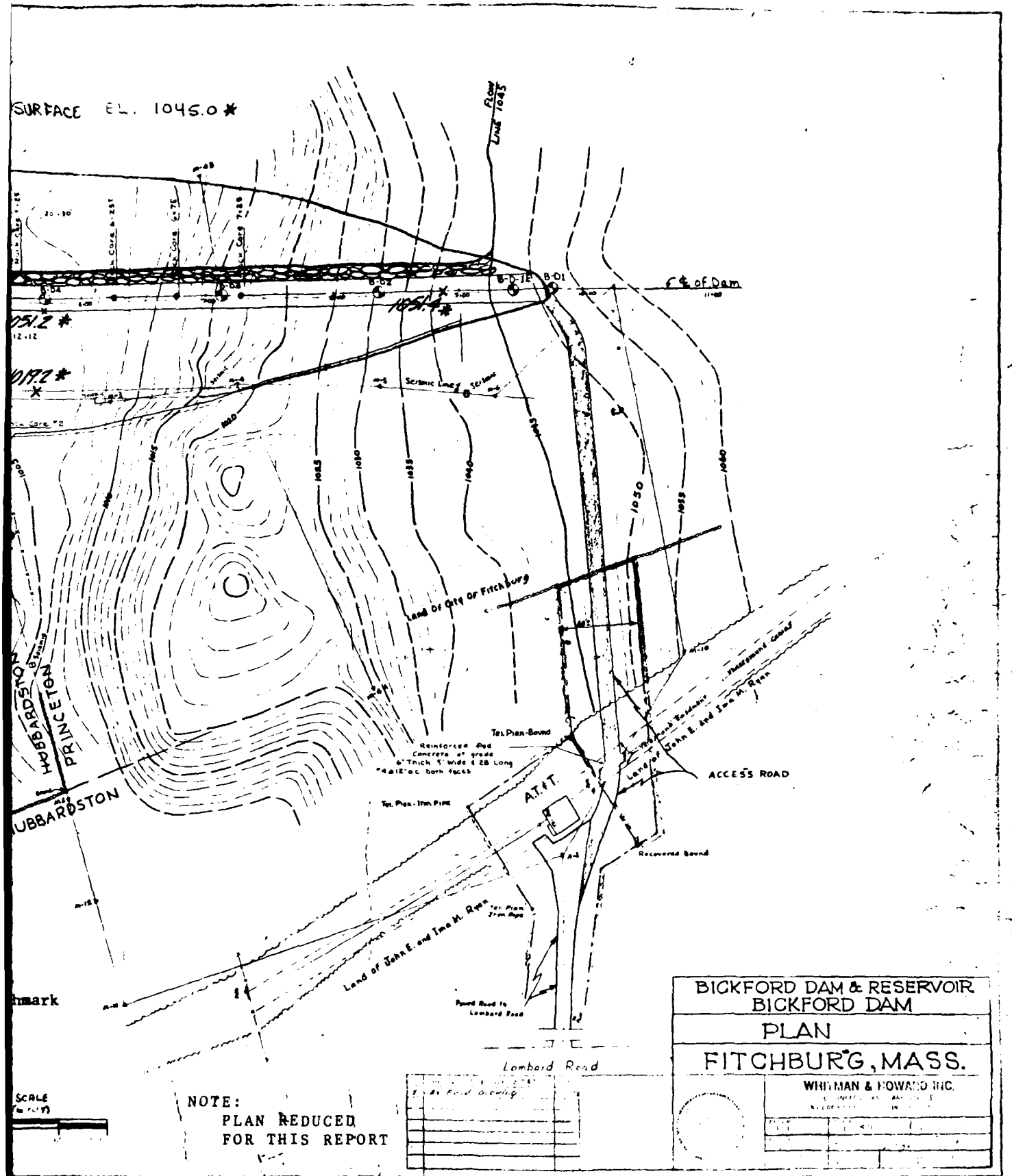


NOTE:

*Elevations verified in field on 13 May 1980, and based on an assumed benchmark elevation 1045.0 (NGVD) at spillway crest.

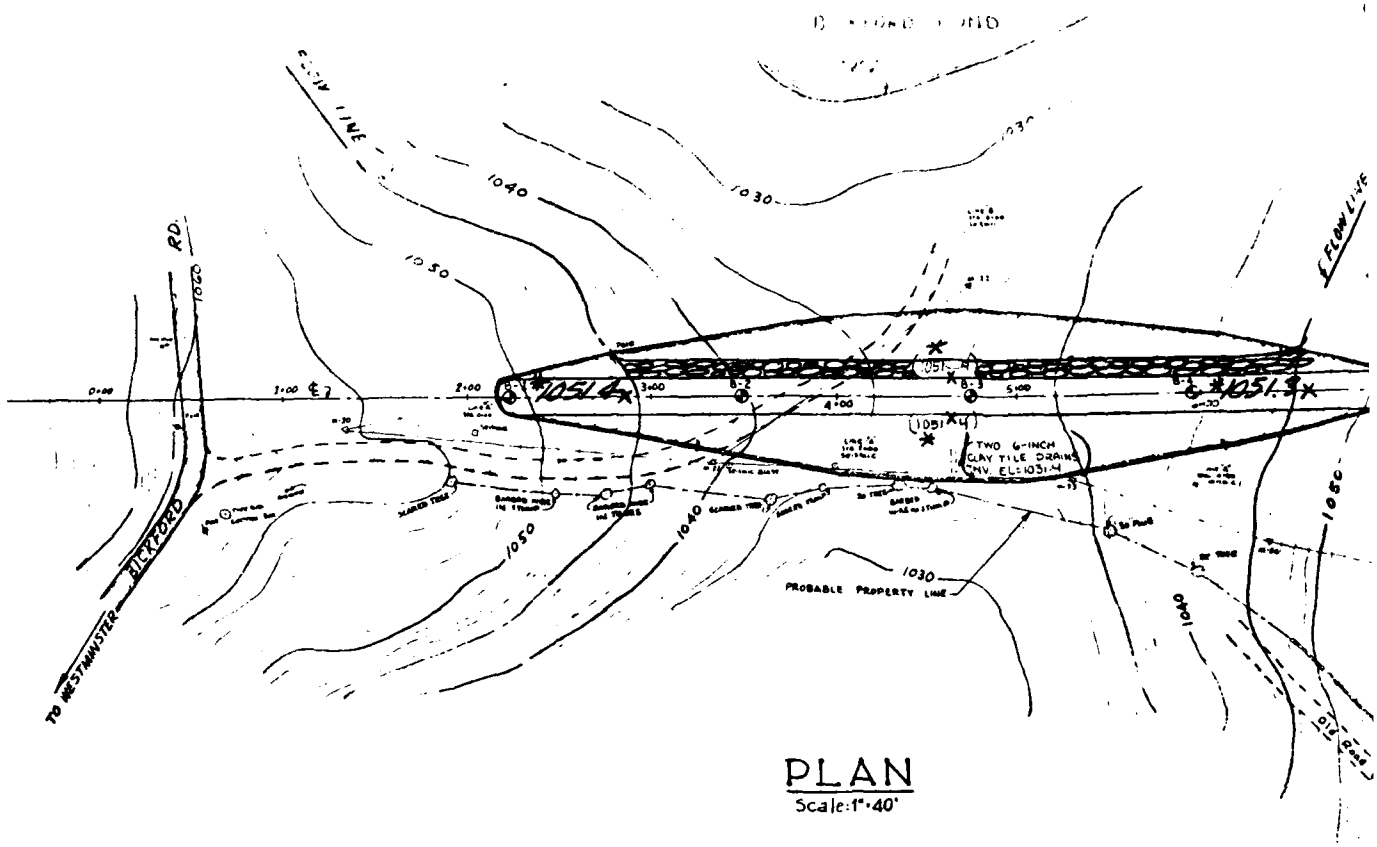
NOTE:
PLAN RED
FOR THIS

BICKFORD



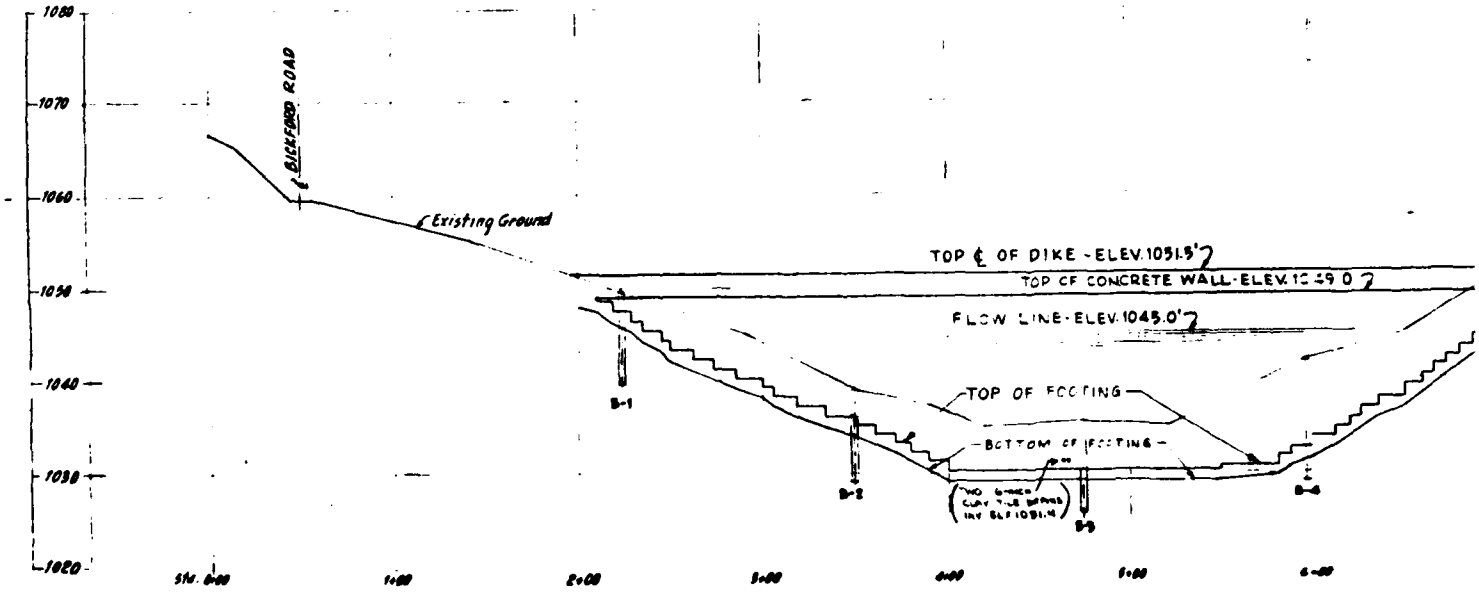
BICKFORD POND DAM

FIGURE B-1



PLAN

Scale: 1"=40'



PROFILE

Scale: Horiz 1"=40'
Vert. 1"=8'

INCHES

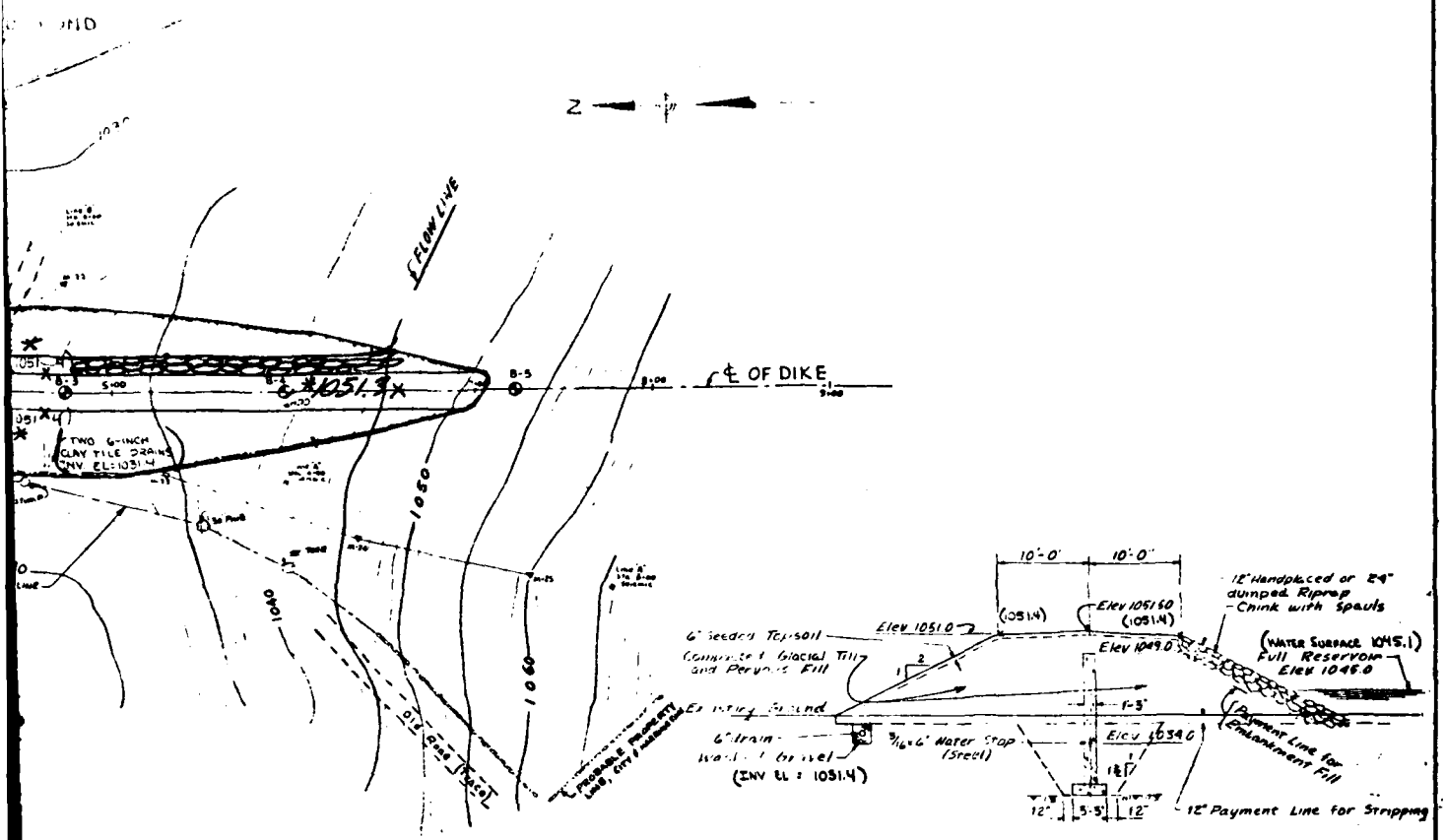
0' 40' 80' 120' 160' 200'

NOTE:

*Elevations verified in field on 13 May 1980, and based on an assumed benchmark elevation 1045.0 (NGVD) at spillway crest.

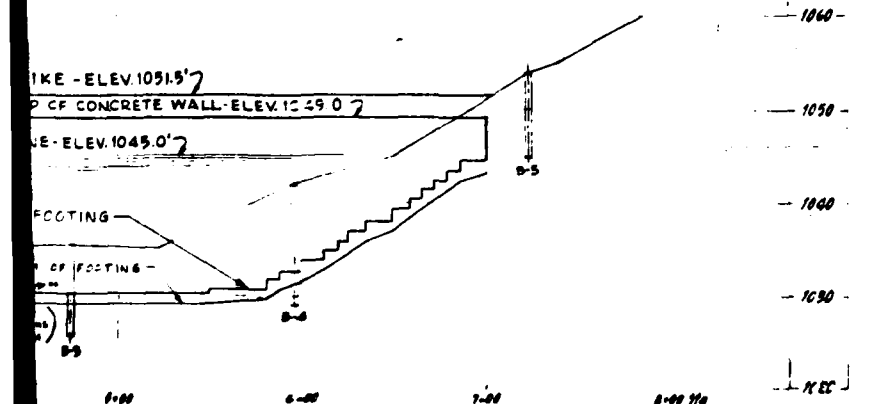
NOTE:
PLAN REDU
FOR THIS

BICKFORD RI



TYP. SECTION OF DIKE.

Scale: 1/8" = 1'-0"



NOTE:
PLAN REDUCED
FOR THIS REPORT

1	As Built Drawing	
NO	REVISIONS	DATE

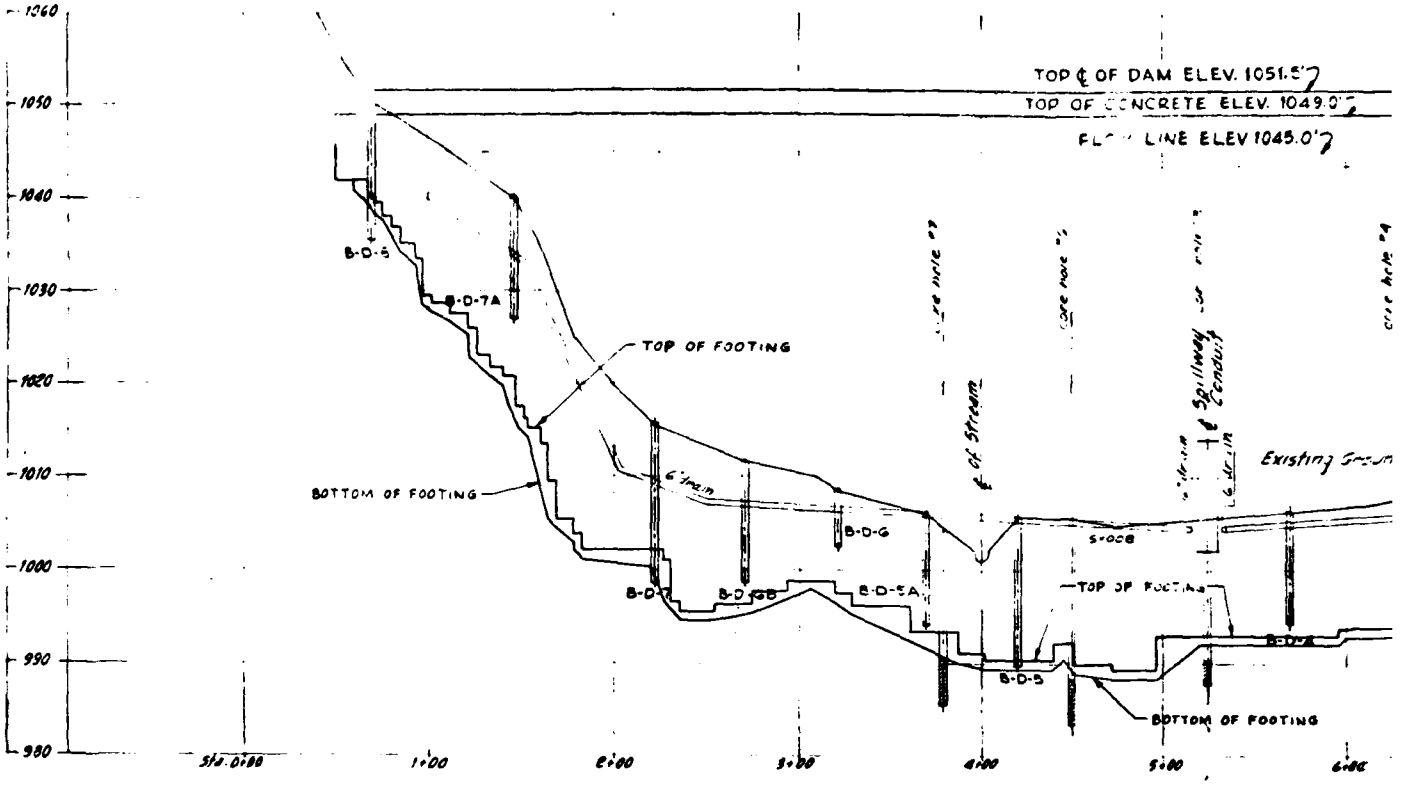
BICKFORD DAM & RESERVOIR
BICKFORD DIKE
PLAN AND PROFILE
FITCHBURG, MASS.

WHITMAN & HOWARD INC.
ENGINEERS AND ARCHITECTS
89 BROAD ST BOSTON MASS

DESIGNED BY R D	SCALE AS SHOWN	DATE AUG. 1969
DRAWN BY R.C.S.C.N	APPROVED	
TRACED BY H.D.	JOB NO. 8-149	SHEET 3 OF 7

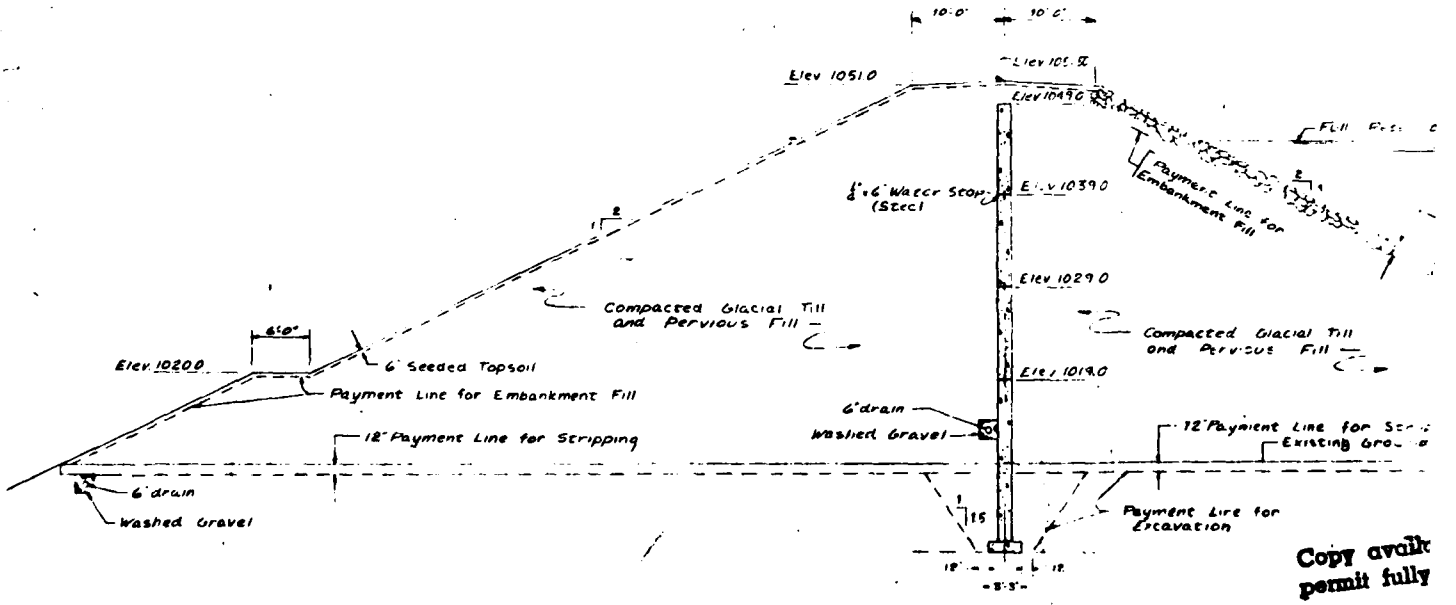
BICKFORD RESERVOIR DAM

FIGURE B-2

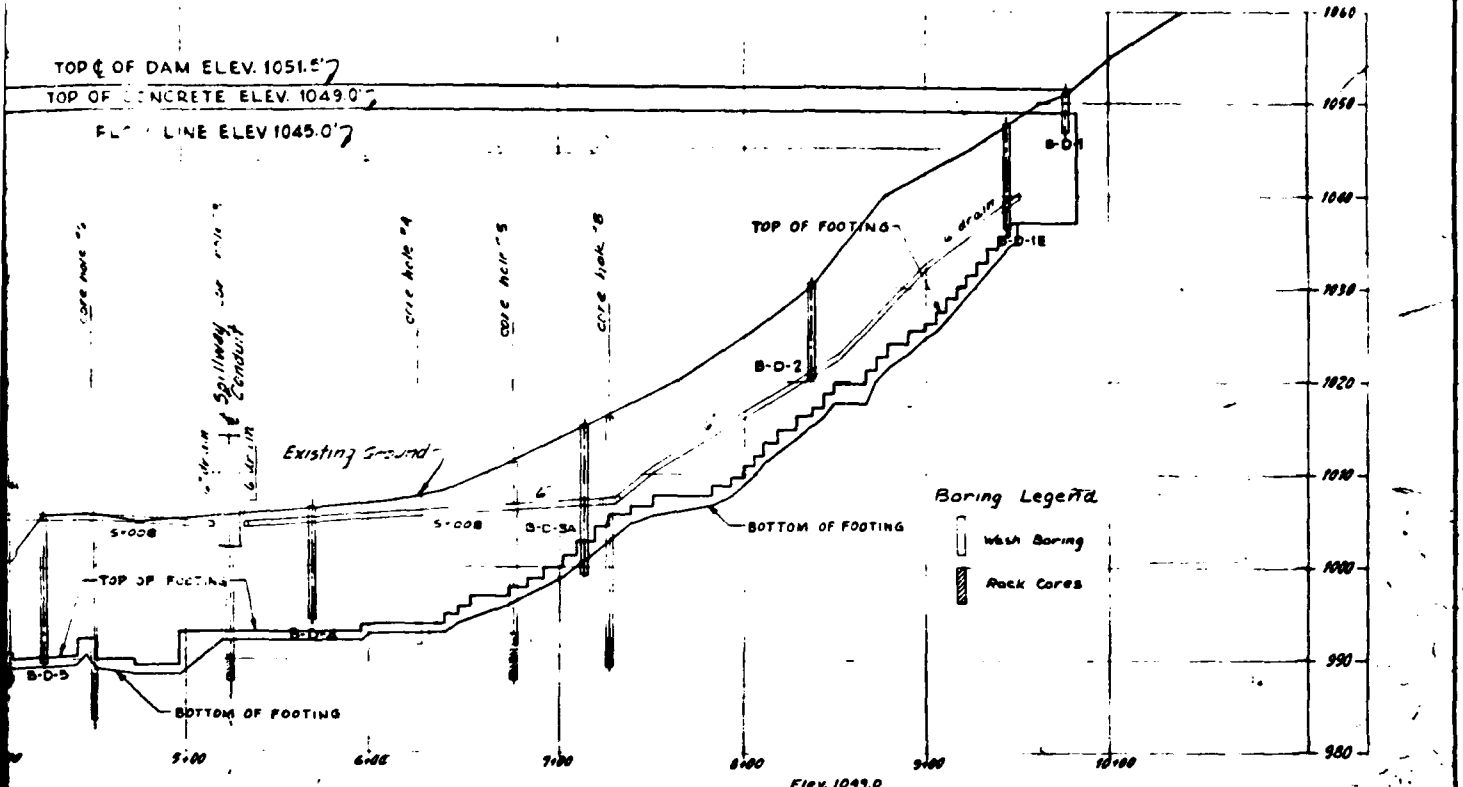


PROFILE OF DAM

Scale: Horizontal 1" = 40'
Vertical 1" = 8'

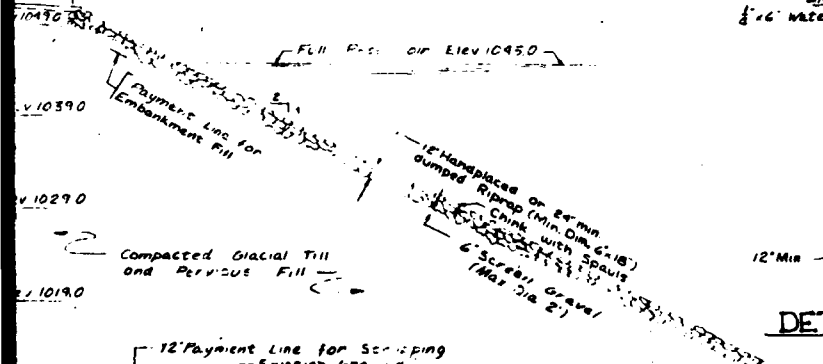


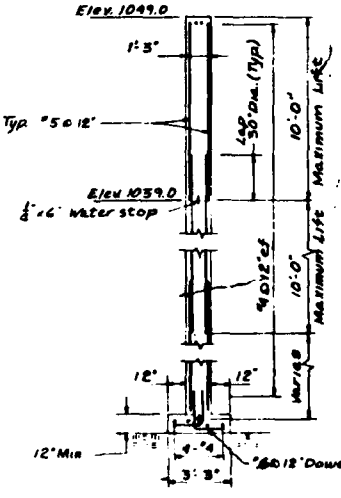
TYP. SECTION THROUGH DAM AT STA. 3+00



PROFILE OF DAM

Scale: Horizontal 1" = 40'
Vertical 1" = 8'





DETAIL OF CORE WALL

Scale: ¼" = 1'-0"

GENERAL NOTES

1. Foundations may be altered if necessary to suit conditions encountered during construction with the approval of the Engineers.
2. These notes shall apply to all concrete structures throughout the dam project.
3. Use of construction joints other than those shown will require approval of the Engineers.
4. All reinforcing steel shall be intermediate grade deformed bars. Reinforcement splices shall be a minimum of 30 bar diameters except where noted, and shall conform to the provisions of A.C.I. 318. Reinforcement cover shall comply with the specifications unless otherwise noted.
5. Water stops are not necessary, only where shown, it is intended that they shall be continuous throughout that particular structure.
6. Final locations and elevations of Core Wall Base to be set in the field by the engineers as determined by soil conditions.

NOTE:
PLAN REDUCED FOR THIS REPORT

BICKFORD DAM & RESERVOIR
BICKFORD DAM
PROFILE & DETAILS
FITCHBURG, MASS.

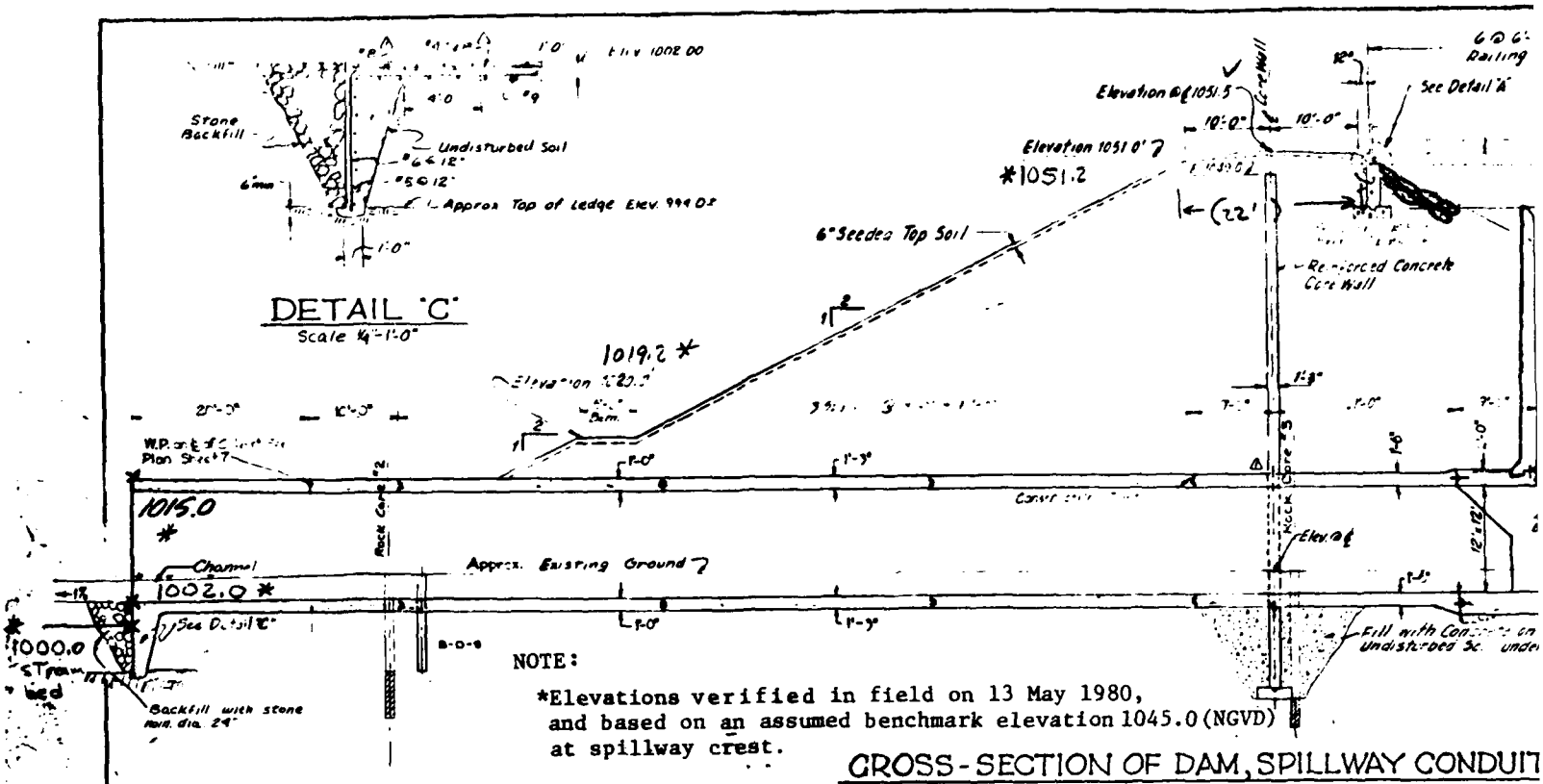
WHITMAN & HOWARD INC.
ENGINEERS AND ARCHITECTS
89 BROAD ST BOSTON

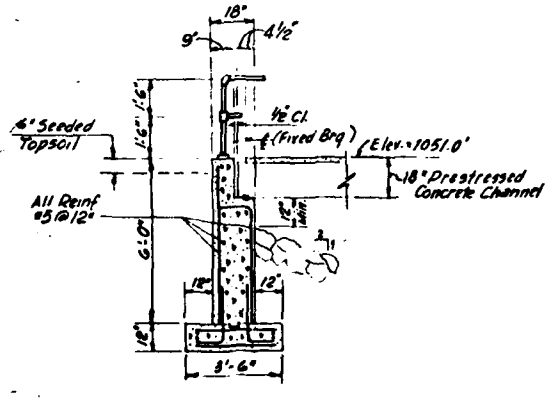
AS SHOWN

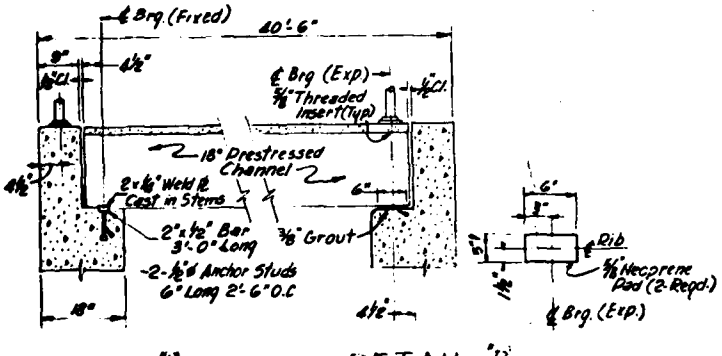
DAM AT STA. 3+00)

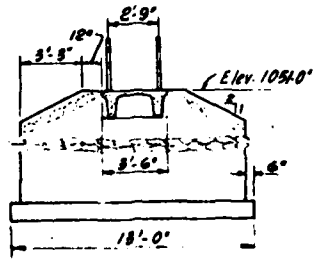
BICKFORD POND DAM

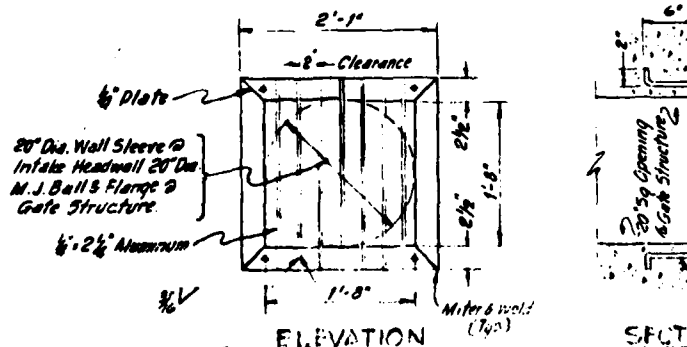
FIGURE B-3



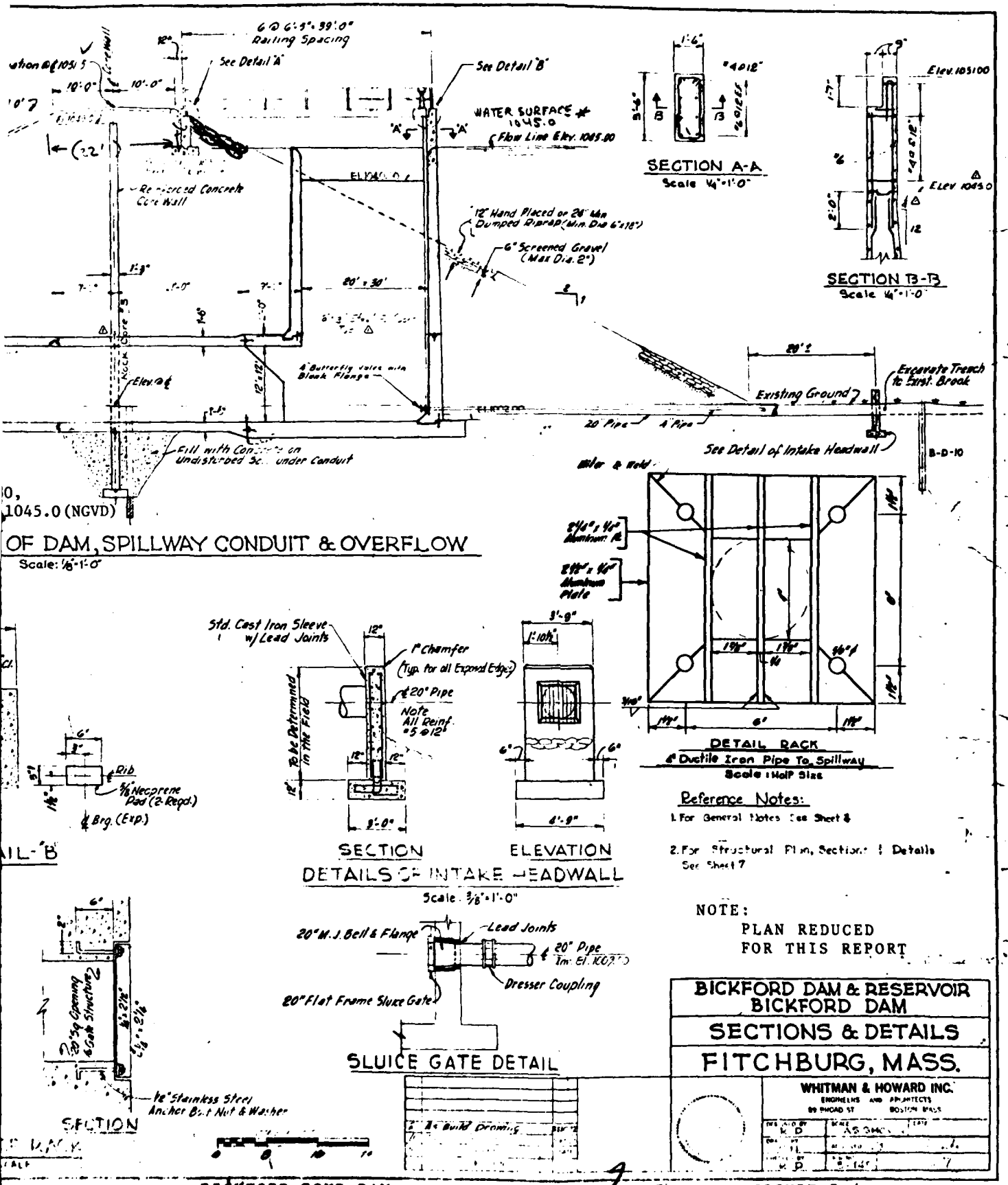








BICKFORD



Reference Notes:

1. For General Notes See Sheet 8
2. For Structural Plan, Sections & Details See Sheet 7

NOTE:
PLAN REDUCED
FOR THIS REPORT

BICKFORD DAM & RESERVOIR
BICKFORD DAM
SECTIONS & DETAILS
FITCHBURG, MASS.

WHITMAN & HOWARD INC.
ENGINEERS AND ARCHITECTS
89 BROAD ST BOSTON MASS

BICKFORD POND DAM

FIGURE B-4

Section 15. EXCAVATION

(a) Scope of Work

The work covered by this section of the specifications includes performing all operations in excavating for the concrete core walls and spillway conduit.

(b) Earth Excavation at Dam Site and Dike Site

Earth excavation at the dam and dike sites shall be unclassified excavation and shall include all material below a depth of 12" including boulders, regardless of whether the depth removed under stripping is more than or less than 12-inches.

All earth excavation shall be sufficient to allow room for forms and sub-drains.

Excavation for any section of the core wall that will rest on ledge shall consist of removing all earth and loose ledge that can be removed with bars or picks. Before commencing form work, the ledge shall be thoroughly cleaned by means of compressed air and water.

All earth excavation that is suitable for earth fill, as specified under Section 16, shall be incorporated in the earth embankment of the dam. In general, all core wall excavation shall be backfilled in the same area backfilling shall be done in the manner prescribed in Section 16, Embankment.

Excavated material that the Engineers shall decide is unsuitable for use in the dam embankment shall be disposed of in a manner satisfactory to the Engineers.

(c) Method of Measurement

The total yardage of earth excavation to be paid for shall be the net number of cubic yards excavated, as determined by the depth of the excavation and the payment lines of the excavation as shown on the drawings, regardless of whether or not the contractor considers it necessary to excavate less than or more than is indicated by such payment lines and computed by the average and area method.

Section 16. EMBANKMENTS

(a) Scope of Work

The work covered by this section of the specifications includes performing all operations in connection with the furnishing and placing of pervious earth fill in the dam and dike.

(b) Earth Fill in Dam & Dike

The material used in constructing the earth fill shall be glacial till or a sand and gravel mixture free of all organic matter, brush, roots, and other debris and shall not contain any clay. The maximum dimension of any stone shall be 8-inches.

The fill shall be placed in layers not exceeding one foot in depth and shall be well consolidated by successive passes with a heavey caterpillar type tractor or by other methods approved by the Engineers until compacted to 90% of the maximum density obtained at optimum moisture content.

Special care shall be taken to consolidate fills made with the material excavated for the core wall which is constructed on glacial till. This material shall be re-deposited next to the core wall base and core wall in the same general area in 4-inch layers, as specified above.

All fill shall be deposited so that at all times the difference in the level of the fill on either side of the core wall shall not exceed one foot.

No fill will be placed next to the concrete core wall without approval of the Engineers.

No fill will be deposited when any ground within the reservoir area is frozen or when freezing temperatures have occurred within 24 hours or shall be expected within 24 hours.

(c) Borrow Area

Embankment fill shall be furnished by the Contractor and the source of the embankment fill shall be the sole responsibility of the Contractor. If suitable fill is available in the reservoir site the borrow area must be below elevation 1045.0. Borrow pits or excavations shall be left in such conditions that they will be self-draining. No area located within 200 feet of the toe of the dam will be excavated below the natural ground level of the general area.

Section 17. SUB-DRAINAGE

(a) Scope of Work

The work covered by this section of the specifications includes furnishing and installing sub-drainage pipe and drainage stone.

(b) Sub-Drainage Pipe

Sub-drainage pipe shall be placed in the down-stream section of the dam as shown on the drawings or as directed by the Engineers.

The sub-drainage pipe shall be extra strength porous concrete pipe.

The minimum wall thickness shall be as follows:

6-inch diameter pipe	1.25 inches
8-inch diameter pipe	1.50 inches
10-inch diameter pipe	1.625 inches

The drainage stone shall be screened uniformly graded 1/4-inch-3/4-inch wash gravel. This stone to be carefully placed around the drainage pipe as shown on the drawings.

(c) Method of Measurement

The unit of measurement for drainage pipe shall be the linear foot and shall be based on the linear footage of pipe installed in place and shall include all excavation and backfill.

The unit of measurement for drainage stone shall be the cubic yard. The cubic yardage shall be determined by the product of the gross area, as shown on the drawings without any deduction for the drainage pipe, and the total linear footage as measured in the preceding paragraph.

(d) Payment

Payment for 8-inch porous concrete pipe, including all fittings, excavation and backfill shall be at the unit price per linear foot of pipe.

Payment for 6-inch porous concrete pipe, including all fittings, excavation and backfill shall be at the unit price per linear foot of pipe.

Payment for drainage stone shall be at the unit price per cubic yard.

Section 19. RIP-RAP

(a) Scope

The work under this section shall consist of placing rip-rap on the upstream face of the dam, the end of the spillway and such other locations as the Engineers may direct. Rip-rap shall be placed on a 6-inch layer of gravel. Rip-rap may be either hand placed in a 12-inch thickness or dumped rip-rap in a 24-inch thickness as the Contractor may elect, in either case conforming to the following:

(b) Hand Placed Rip-rap

Hand placed rip-rap shall be built of sound, durable stone and laid to the thickness and extent shown on the drawings or otherwise required. The Contractor will be allowed to use for this purpose stone walls within the reservoir site below elevation 40.00 and the boulders from the excavation, providing such stone is of satisfactory size and quality.

(c) Dumped Rip-rap

Dumped rip-rap shall consist of stone 50 per cent of which shall be over 12 inches in diameter and not less than 18 inches in diameter. Up to 50 per cent may be 4 to 12 inches in diameter. The maximum diameter shall be 18 inches.

(d) Gravel

Gravel shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings, and deleterious materials. Gradation requirements shall be as follows:

Sieve	Per Cent Passing
1/2-inch	50 - 85
# 4	40 - 75
# 40	10 - 35
# 200	0 - 10

Maximum stone size shall be 2 inches. Gravel shall be rolled and compacted such that it will not be displaced by the rip-rap.

(b) have an Average Weighted Loss of not more than 12% when subjected to five alternations of the sodium sulfate soundness test A.S.T.M. C88.

(c) Concrete

1. Quality and Working Stresses. Concrete shall have the following minimum compressive strengths at 28 days,

Spillway Conduit	3500 pounds per sq. inch
Core Wall	3000 pounds per sq. inch

2. Proportions of concrete ingredients shall

(a) be such as to produce a concrete fulfilling every requirement of this specification,

(b) be submitted for approval as proposed by the Contractor at least thirty (30) days before commencing any concreting operations, unless otherwise permitted by the Engineer.

3. Consistency of concrete shall be such that it can be worked readily into the corners and angles of the forms and around the reinforcement without segregation of materials or the accumulation of laitance, sand, streaks, air pockets, bridging of material or honeycomb,

(d) Mixing Concrete

1. Mixing and conveying equipment shall be thoroughly clean and free from hardened concrete and foreign materials before commencing concreting operations.

2. Each batch of concrete shall

(a) be thoroughly mixed, so that there is a uniform distribution of materials.

(b) be entirely discharged from the mixer before recharging.

3. Stationary Plant Mixing shall

(a) be in a drum rotating with a peripheral speed of about 200 feet per minute.

(b) be continued after all materials (including water) are in the drum for at least

1-1/2 minutes for a mixer of capacity of 1 yard.

4. Transportation to the site from central mixing plant of concrete already mixed shall

(a) be in a vehicle which will provide proper and continuous agitation of the concrete until discharged.

(b) consume not more than one hour from charging to discharging of the vehicle.

Mixing Concrete

5. Truck Mixing shall be

(a) in an approved revolving drum mixer.

(b) continued for not less than five minutes after all materials (including water) are in the drum, at a rate of 10-20 revolutions per minute. All the materials, including water, shall be entirely charged into the truck at the batching plant.

(c) continued until the concrete is discharged, but no batch mixed longer than one hour shall be used,

(e) Testing Concrete

1. General. The Contractor shall furnish the concrete for test samples. Not more than six (6) cylinders will generally be made for each class of concrete used in any one day's operation, unless in the judgment of the Engineer additional samples are needed. The specimen containers will be furnished by the Contractor.

2. Testing for compressive strength will be made in accordance with A.S.T.M. standard method C39.

3. Results of Twenty-eight day test.

(a) If the average strength of any set of twenty-eight day test specimens is less than the requirements of (c) 1, the Town may take core samples from the portion of the structure determined by the Engineer as represented by the deficient twenty-eight day test specimens.

(b) If the average strength of such core samples is less than the requirements of (c) 1, the Town;

Section 21. WATER PIPE

(a) Scope of Work

The work covered by this section of the specifications includes furnishing and installing cast iron water pipe, fittings, concrete cylinder pipe and appurtenances and flexible couplings as required.

(b) Cast Iron Water Pipe

The water pipe to be installed within the dam shall be 20-inch diamter ductile iron, cement lined with asphaltic seal coat, tar coated, mechanical joint pipe and shall have an average metal thickness of 0.72" and shall comply in every respect to the latest ASA Specifications.

The tee head bolts and nuts shall be conrten T-head bolts and hexnuts, having a minimum tensile strength of 50,000 psi.

The following glands shall be ductile iron.

No blocking shall be used under pipe in the dam and the final 6-inches of the trench shall be excavated by hand to the same shape as the pipe.

All water pipe shall be tested by the Contractor in the presence of the Engineers to a water pressure of at least 125 pounds per square inch for two continuous periods of at least 15 minutes. Between each 15 minute period, the water pressure to drop to about 0 to 30 pounds. The Contractor will furnish all material, labor, pumps, water, etc., for the test

Cast iron water pipe special fittings shall be tar coated. These fittings shall comply in every respect with the latest standard A.S.A. Specifications for such fittings.

(c) Flexible Couplings

The flexible couplings shall be Dresser, or equal, and shall be coated with asphalt after installation.

(d) Embankment

Material used for embankment at all pipe locations, shall be as specified for the dam.

The Contractor shall fill around, under and twelve inches above the pipe and compact this by means of hand tamping. The next twelve inches above the pipe shall be filled by hand and thoroughly compacted by means of mechanical tamps. Extreme care shall be taken with the remainder of the fill over the pipe so that excessive stresses are not set up in the pipe.

Section 22. MISCELLANEOUS METALS

(a) Scope

This section of the Specifications shall cover the furnishing of all labor, tools, equipment and materials necessary to fabricate and install and/or erect when applicable all the ferrous and non-ferrous metal items specified herein and/or shown on the plans.

(b) Materials

1. Structural Steel shall conform to ASTM Designation A36-67 for structural grade.

2. Cast Iron shall conform to ASTM Designation A48-64.

3. Aluminum Items shall be fabricated from bars, plates, pipes, rolled and extruded shapes conforming to the following alloy designations unless otherwise indicated or specified:

4. a. Standard Structural Shapes - rolled or extruded 6061-T6 conforming to ASTM Designation B308-67.

b. Rolled Rod and Bar - 6061-T6 conforming to ASTM Designation B211-67.

c. Sheets, Plates, Checkered Plates - 6061-T6 conforming to ASTM Designation B209-67.

d. Bolts shall be 2024-T4;

Nuts 6061-T6; and

Washers Alclad 2024-T4.

4. Bolts, Nuts and Washers for structural steel connections shall be high strength conforming to the requirements of ASTM Designation A325-666, Quenched and Tempered Steel Bolts and Studs with suitable nuts and plain washers.

5. Red Lead shall conform to the provisions of ASTM B209-67

6. Welding shall be in accordance with the Standard Code for Arc and Gas Welding Building Construction of the American Welding Society.

7. Galvanizing shall conform to ASTM Designation A123-66.

(c) Sluice Gates

Sluice gate shall be cast iron, bronze mounted and shall be equal to Rodney Hunt Model 180 H.

Wall thimbles for the 20-inch diameter pipe shall be cast iron bell and flange wall thimbles, 20-inch diamter and 28 inch deep with attaching studs for sluice gates and bell to take 0.72 inch thick, 20-inch ductile iron pipe. Thimbles shall be as manufactured by Rodney Hunt Machine Co. or approved equal.

Operating floor stand shall be for use with rising stems with two sets of tapered Timken bearings and 18-inch cast iron hand-wheel, and shall be Rodney Hunt S-2600, or equal.

The operating stem shall be cold rooled steel with the exception of the threaded section which shall be bronze. Adjustable stem guides shall be provided according to the requirements of the gate manufacturer.

The floor stand shall be painted with one coat of first quality red lead paint and two finish coats of dark green lead paint.

(d) Fence Railing

The pipe rail fence shall be 2-inch standard pipe, genuine wr wrought iron, with anchors, pipe supports, etc. all as shown on the drawings.

The pipe fence shall be painted two coats of first quality heavy read lead paint and one finish coat of dark green lead pa paint.

(e) Racks

Intake racks shall be of aluminum and frames shall be fabricated as shown on the drawings.

(f) Channel Runners and Screen Well Frame and Cover

The channel ru-ners, frame and cover shall be of aluminum and fabricated as shown on the plans.

(g) Payment

Payment for all work done under this section shall be enclosed in the applicable lump sum bid.

July 30, 1969

Mr. John C. O'Toole
County Engineer
Worcester County Engineering Dept.
Room 101 Court House
Worcester, Massachusetts 01608

Dear Mr. O'Toole:

The following data may be of assistance in evaluating the Spillway Capacity of the proposed Bickford Dam in Hubbardston for the City of Fitchburg,

1. The U.S.C.S. Rare flood formula was used to compute the design flood flow of 2400 C.F.S. We understand this formula results in somewhat high flows.

   The Mare Meadow Reservoir has a capacity of 11,700,000 Cu. ft. per foot at Spillway grade.

   Bickford Pond Reservoir will have a capacity of 6,400,000 cu. ft. per ft. or at total capacity of 25,600,000 cu. ft. for the design Spillway depth of 4 feet.

   Flood routing would permit a lower design flow.

2. The required wier length for a flow of 2400 c.f.s. is 91 ft. The design wier length is 100 feet.

July 30, 1969

3. At the design flow there will be no pressure on the outlet end of the conduit (i.e. the hdg. will be at the roof = 1014.0).

   The depth of water over the top of the conduit at the entrance will be 8.7 feet. This will result in a water depth of 20.7 at the upper end of the conduit. or a h.g. of 1022.7. The Spillway grade will be 1045.0 so there will be additional head available of 22 feet for a factor of safety.

4. The Valley is 200 feet wide at the 1005 contour at the conduit outlet and 300 feet wide 200 feet below the outlet widening to over 1000 feet wide at Lombard Road so it is evident the stream depth will be insignificant below the Dam.

5. We realize that the Spillway and conduit are over-designed and that probably a 10' x 10' conduit would be ample but we believe the additional cost of a 12' x 12' conduit is worth while.

6. Rock Cores have been taken at the conduit outlet and 100 feet below the outlet. There is 11 feet of Overburden at this Point. A thick cut off wall will extend to ledge. This cut off wall will only be about 6 feet in depth.

The writer will be on vacation starting August 11, 1969. Mr. Joseph Murphy of this office is familiar with the design flows.

Very truly yours,

WHITMAN & HOWARD, INC.

Roger Disken

Roger P. Disken

RPD/nph

GEORGE J. LANIDES
COMMISSIONER AND CITY ENGINEER

CITY OF FITCHBURG
DEPARTMENT of PUBLIC WORKS

City Hall, 718 Main Street
FITCHBURG, MASSACHUSETTS 01420

ENGINEERING
HIGHWAYS
SEWERS
SEWAGE DISPOSAL
STREET LIGHTING
WATER SUPPLY
REFUSE COLLECTION

May 14, 1971

Inspection of Bickford Reservoir:
Joe Murphy and E. A. Cooney (Whitman and Howard Eng.), George Lanides and Andy Provencial

Following items to be corrected, partly by previous contracts and others by new contracts:

1. Grade area rear Mare Meadow Pumping Station, used as borrow pit. (Welch and Corr) Last Sat 6/5/71
2. Grading and widening road leading to Bickford Reservoir and paving same. (New contract)
3. Grading various fill areas. (C and M)
4. Cutting of trees along steep slopes on road leading to Bickford Reservoir for widening purposes and to prevent power outages. (New contract)
5. Estimate of removal of floating stumps and debris. (New contract)
6. Grade and riprap slopes rear and sides of Bickford Pumping Station. (New contract)
7. Repair roof and flashing of Bickford Pumping Station and check for leaks. (Greenview)
8. Clean Mare Meadow and Bickford stations. (Greenview)
9. Grade rear Prouty property and provide outlet for trapped water. (C and M)
10. Repair leaks at dam and tunnel. (Welch and Corr)
11. Grade slopes westerly side of Bickford dam. (C and M)
12. Backblade perimeter of reservoir beyond high water mark.(C and M)
13. Seeding of all waste (fill) areas. (New contract)
14. Remove [illegible] but not used (Mare Meadow Spillway). (C and M)

BICKFORD POND AND
RESERVOIR DAMS

CITY OF FITCHBURG
DEPARTMENT of PUBLIC WORKS
City Hall, 718 Main Street
FITCHBURG, MASSACHUSETTS 01420

GEORGE J. LANIDES
COMMISSIONER AND CITY ENGINEER

ENGINEERING
HIGHWAYS
SEWERS
SEWAGE DISPOSAL
STREET LIGHTING
WATER SUPPLY
REFUSE COLLECTION

Inspection of Bickford Reservoir

15. Level riprap at dam and clean area in immediate vicinity. (Welch and Corr)

16. Replace 4" butterfly wheel at spillway. (Welch and Corr)

17. Repair and substantiate amount of leakage of drains at ends of tunnel; also reasons for rusty water at these locations. (Welch and Corr) Water Heat Tech.

18. Inspection and approval of dam by proper state agency; also approval of dam leakage.

19. Table of water content at contour intervals.

20. Effect of leakage on concrete at form ties during freezing season.

21. Fill in large voids on riprap with small stones. (Welch and Corr)

22. Cut and remove dead trees in vicinity of dam and dike. (Welch and Corr)

23. Widening area at toe of slope (Dike).

24. Cut and clean area adjacent to pond between pumping station and dike. (New contract)

25. Re-seed area (Allard's) stripped by Welch and Corr. (Welch and Corr)

The Commonwealth of Massachusetts

Department of Public Works

Division of Waterways

100 Nashua Street, Boston 02114

November 3, 1971

Nov 5 8 53 AM '71
PUBL. WORKS DEPT.
FITCHBURG, MASS.

Mr. George J. Lanides
Commissioner of Public Works
City Hall
718 Main Street
Fitchburg, Massachusetts 01420

RE: Inspection - Bickford Reservoir Dam
Hubbardston and Princeton

Dear Commissioner Lanides:

Your letter dated October 21, 1971, requesting inspection of the completed Bickford Reservoir dam and dike in Hubbardston and Princeton has been received.

It is suggested that you contact Mr. George E. Lybrand, District #3 Highway Engineer, Worcester Office, telephone 754-7204, to arrange a meeting to discuss the matter. At the present time District Highway Engineering personnel have been given the responsibility to make inspections of dams and reservoirs. The availability of construction plans and specifications would be very helpful.

Enclosed please find an "Application for Authorization to Construct or Alter a Reservoir, Reservoir Dam or Mill Dam". For our records, please complete the application and attach a copy of the Worcester County Commissioners approval.

If this office can be of further assistance to you, please do not hesitate to contact us.

Very truly yours,

Fred C. Schweim

FRED. C. SCHWEIM, P.E.
Deputy Chief Engineer

LRA:hlb
cc:G.E.Lybrand
Enclosure

THE COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATERWAYS
100 Nashua St., Boston, Mass. 02114

APPLICATION FOR AUTHORIZATION TO CONSTRUCT OR ALTER A RESERVOIR, RESERVOIR DAM OR MILL DAM

JURISDICTION - Chapter 253 of the General Laws as amended by Chapter 595 of the Acts of 1970.

CONDITIONS OF D.P.W. JURISDICTION

Shall not apply to small dams, constructed for irrigation or for other purposes, the breaking of which would involve no risk to life or property, nor to standpipes or tanks, nor to a dam where the area draining into the pond formed thereby does not exceed one square mile; unless the dam is more than ten feet in height above the natural bed of the stream at any point, or unless the quantity of water which the dam impounds exceeds one million gallons.

IF DAM IN QUESTION LIES WITHIN THE JURISDICTION OF THE COMMISSIONER OF THE DEPARTMENT OF PUBLIC WORKS THEN THE FOLLOWING INFORMATION IS REQUESTED:

(N.A. - Indicates Not Applicable)

1. Location of Dam (City or Town) Princeton & Hubbardston

2. U. S. Geological Survey Topographic Map Quadrangle Wachusett Mtn.

3. Name of Waterway East Branch Ware River

4. Navigable: Yes ( ) No (x)

5. Detailed Description of Dam Location

   Dam - 42° 29' - 71° 56'

   Dike - 42° 29' 20" - 71° 56'

6. Present or Prospective Owner(s) of Dam City of Fitchburg

7. Nature of Work: Proposed Dam (x) Alteration ( ) (Complete)

8. Purpose of Dam Water Storage

9. Specific Legislative Authority to Construct Dam: Yes ( ) No (x)
   Identify

BICKFORD POND AND RESERVOIR DAMS

* 10. Contributory Drainage Area 6.3 Sq.Mi. 4030 Acres

11. Height of Dam 49.5 (a) Top Elevation of Dam 1051.5
(b) Top Elevation of Spillway 1045.0

12. Volume of Water Impounded 2460 Acre-Ft. = 800 Million Gallons

13. Datum Used (Preferably Mean Sea Level of 1929) Mean Sea Level of 1929

14. Previous Known Flood of Record (Month) March (Year) 1936

15. Present River Bed or Channel Grade at Dam 1002

16. Normal Pond Area 55 Acres

17. Normal Water Level: Elevation 1045.0

18. Maximum Flood Level: Elevation 1049.0

19. Type (Earthen, Concrete, etc.) Earth With Concrete Core

20. Length of Principal Spillway 100 Feet

21. Description of Principal Spillway Morning Glory 20' x 30'

22. Emergency Spillway: Yes ( ) No (X)
If Yes, Describe

23. Gated: Yes ( ) No (X)

24. No. of Gates

25. Size of Gates

26. Nature of Slope Protection
(Rip-rap, Sodding, etc.) Rip-Rap Upstream, loam-seed downstream

27. Stop Log Structure(s): Yes ( ) No (x)
Describe

28. Control for Removal of Stop Logs: Mechanical ( ) Manual ( )

29. Freeboard 4.0 Feet

30. Peak Discharge (Outflow) (Kinnison-Colby) 2420 c.f.s.

31. Design Storm Duration _____ Hours

32. Design Storm Runoff _____ Inches

33. Degree of hazard to life and property downstream.

(Field Investigation)

(A) The estimated number of people affected by possible overtopping or failure of the structure, and to what degree they would be affected. One family could be severly affected by severe failure of the structure. Wet basements could occur in a few other locations.

(B) The estimated number of properties (homes, buildings etc.) and extent of possible damage by overtopping or failure Failure could cause wet basements and land erosion to approximately 6 properties.

(C) Roads (type) or other structures possibly affected by overtopping or failure Lombard Road could be flooded and damaged. Major failure could damage Westminster Road, Bemis Road, and Thompson Road.

Applicant: Name:_____

Address:_____

_____

_____

Signature:_____ Date:_____

Date:_____

**Consultant Engineering Firm:

Whitman & Howard, Inc.

89 Broad St., Boston

Mass. 02110

By: Joseph A. Murphy Date: 7/10/72

* Submit outline on topographic map.

** Final Construction Drawings and Specifications must be submitted with this application. Approval will not be considered unless all submissions bear the stamp and signature of a Registered Professional (Civil) Engineer.

Additional Notes:

Dam may be in Princeton

Ⓠ W.S.

INSPECTION REPORT & DATA FOR DAMS

Dam No. 140-32
Town: Hubbardston
Stream: West Branch Ware
Pond: Bickford Res.
Date: 4-4-72
By: EJ Ton & Cong

Owner: City of Fitchburg
His Address: Water Dept. Fitchburg, Mass.
Function of Dam: Water Supply

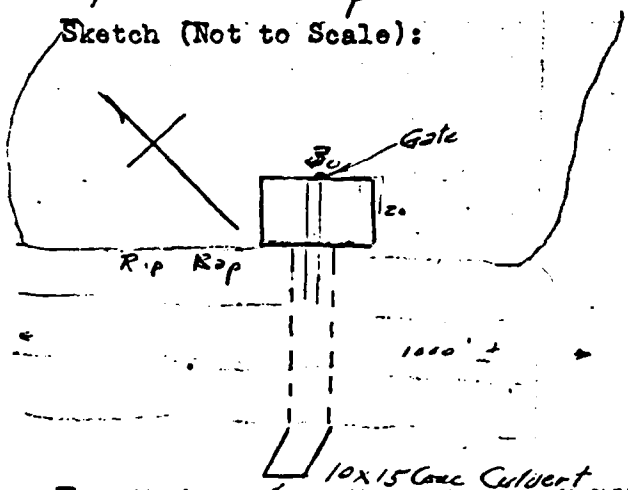
Location & Access: Access Road from Leonard Road
USGS Quad. Lat. Long.
Drain.Ar.: Sq.Mi.; Ponds: ac.; Res.@dam:
Character of D.A.:

CONDITION RATING
Structural: Exc.
Hydraulic: 10x15
General: Exc.
PRIORITY:

Estimated Discharge Capacity:

General Description of Dam and Discharge Control:
Earth dam with rip rap on upper side. A 20' x 30' morning glory 40' deep handles the overflow. There is also a screw gate to drain pond

Sketch (Not to Scale):



Remarks and Recommendations: This Dam is New - Facility expande. 1970 ~ 1971

Date 4-4-72 By EJ Tong & Cong Comment

Dam No. 314-140-32
BICKFORD POND AND RESERVOIR DAMS

WHITMAN & HOWARD, INC.
Engineers and Architects
89 BROAD STREET, BOSTON, MASS. 02110 • TEL. (617) 426-6400

January 29, 1973

Mr. George J. Lanides
Commissioner of Public Works
City Hall
718 Main Street
Fitchburg, MA 01420

Dear Mr. Lanides:

In response to your questions on the seepage at the Bickford Dam we have the following comments.

The toe drains downstream of the concrete core wall are designed to relieve water pressure an the downstream side of the dam. The amount of water flowing out of these drains is a normal amount for this size dam. There is no indication of any movement of fines through these drains. The dam is structurally stable and the drains are working as designed.

Very truly yours,

WHITMAN & HOWARD, INC.

Joseph A. Murphy

JAM/djm

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: ~~City~~/Town Hubbardston Dam No. 3-14-140-32

Name of Dam Bickford Pond / MAIN (East) DIKE Inspected by W. REGAN, R. RIZKALLA

Date of Inspection 5/9/75

2. Owner/s: per: Assessors _____ Prev. Inspection _____

Reg. of Deeds _____ Pers. Contact ✓

1. The Hon. Hedley Bray, MAYOR, City Hall, 718 MAIN St., Fitchburg, MASS.
Name Copy To St. & No. City/Town State Tel. No.

2. George LAWIDES, Comm. of Public Works & City Engineer - City Hall
Name St. & No. City/Town State Tel, No.

3. _____
Name St. & No. City/Town State Tel. No.

3. Caretaker (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name: St. & No.:

City/Town: State: Tel.No.:

4. No. of Pictures taken _____

5. Degree of Hazard: (if dam should fail completely)*

1. Minor ✓ 2. Moderate _____

3. Severe _____ 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual ✓

Operative ✓ yes; _____ No.

Comments: Cated MAINS & 1 drawdown gate See Sketch

7. Upstream Face of Dam: Condition:

1. Good ✓ 2. Minor Repairs _____

3. Major Repairs ___ 4. Urgent Repairs _____

onComments:

8. Downstream Face of Dam:

Condition: 1. Good _____ 2. Minor Repairs ✓

3. Major Repairs ___ 4. Urgent Repairs _____

Comments: One 10'± x 2'± Eroded Patch Noted 150'± East of The Western Extremity of The d.s. Face

9. Emergency Spillway:

Condition: 1. Good ✓ 2. Minor Repairs _____

3. Major Repairs ___ 4. Urgent Repairs _____

Comments:

10. Water Level at time of inspection: 7½'± ft. above ___ below ✓

top of dam Emb principal spillway _____

other @ drop Spillway Lip

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment —

Animal Burrows and Washouts —

Damage to slopes or top of dam Minor Erosion on d.s. Face

Cracked or Damaged Masonry —

Evidence of Seepage —

Evidence of Piping —

Erosion Minor Erosion Near Toe of d.s. Face 150'± From W. End of Emb

Leaks ✓ See (12)

Trash and/or debis impeding flow —

Clogged or blocked spillway —

Other _____

12. Remarks & Recommendations: (Fully Explain)

This dam appears To be in good Condition (Constructe 68:69-70. With only 2 minor deficiencies in Evidence:

(1) MINOR Erosion Note in The foregoing.

(2) Minor leakage IN The Roof of The discharge Tunnel Through The FIRST 3 Overhead Construction Joints (Nearest The Vertical drop Spillway Shaft) This leakage is minor and These 3 Joints are Probably ON The upstream Side of The Core WALL

13. Overall Condition:

1. Safe ✓
2. Very Minor repairs needed ✓
3. Conditionally safe - major repairs needed
4. Unsafe
5. Reservoir impoundment no longer exists (explain)

Recommend removal from inspection list

DESCRIPTION OF DAM

DISTRICT 3

Submitted by W. Regan Dam No. 3-14-140-32

Date 5/30/75 ~~City~~/Town Hubbardston

Name of Dam Bickford Pond
MAIN (EAST DIKE)

1. Location: Topo Sheet No. 20A

Provide 8½" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: 1968 To 1970 Year/s of subsequent repairs N/A

3. Purpose of Dam: Water Supply ✓ Recreational _____

Irrigation _____ Other _____

4. Drainage Area: 6.3± sq. mi. _____ acres

5. Normal Ponding Area: 150± acres; Ave. depth _____

Impoundment: 800 million gals.; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir

None i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 900'± Max. Height 45'±

Slopes: Upstream Face 2:1

Downstream Face 2:1

Width across top 20'±

8. Classification of Dam by Material:

Earth ✓ Conc. Masonry ✓ { Drop Spillway, Discharge Tunnel, & Core Wall } Stone Masonry _____

Timber _____ Rockfill _____ Other Rip Rap U.S. FACE

9. A. Description of present land usage downstream of dam:

100 % rural; _____ % urban.

B. Is there a storage area or flood plain downstream of dam which could accomodate the impoundment in the event of a complete dam failure? yes _____ no ✓.

The failure discharge would reach Storage After (Probably) washing out Lombard Rd.

DAM NO. 3-14-140-32

10. Risk to life and property in event of complete failure.

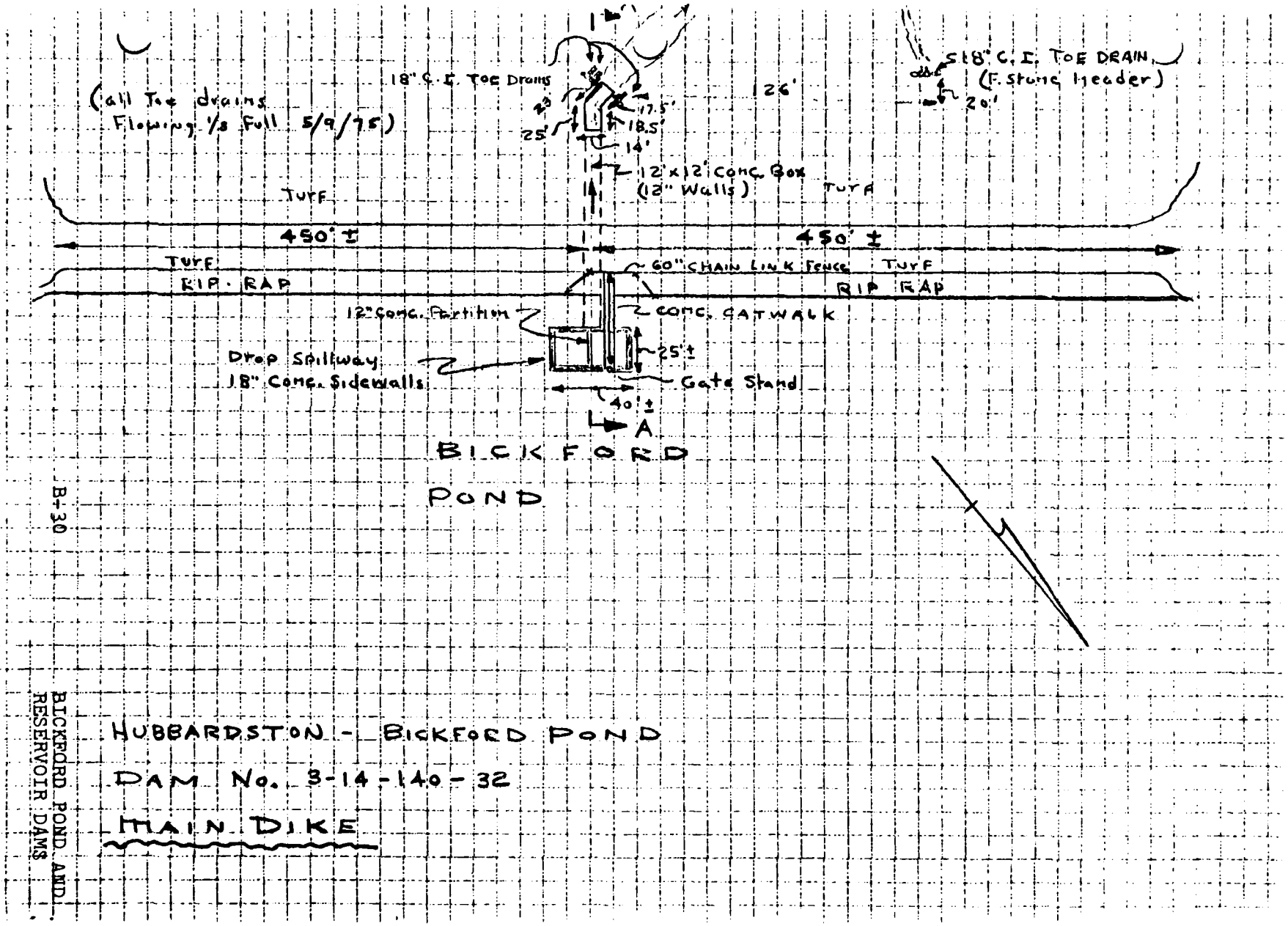
See Note Below

No. of people _____.
No. of homes _____.
No. of Businesses _____.
No. of industries _____. Type _____
No. of utilities _____. Type _____
Railroads _____.
Other dams _____.
Other _____.

11. Attach Sketch of dam to this form showing section and plan on 8½" x 11" sheet.

12. How to Locate:
Access To This dam is Controlled by The Fitchburg Water Dept. Contact Andy Provencial. Fitch Water Dept Supt. @ KIMBALL Place (off Rte 31) and he will have a man Take you To The dam.

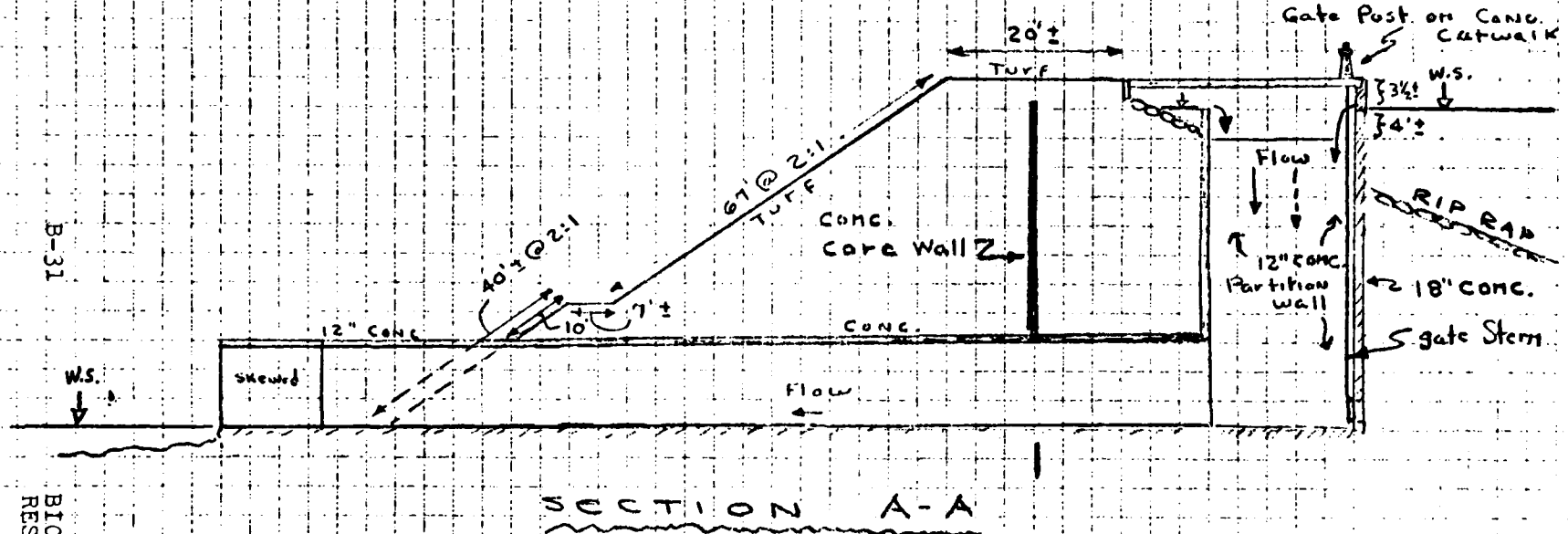
Note (10)
Failure discharge would Wash out Lombard Rd ~~&~~ & is a Threat To 1 d.s. Residence, large Sawmill & 1 capped & occupied Conc Foundation + 2 Trailers (as of MAY 75) These are located IN The Vicinity of Clark Rd Near The Hubbards Tow - Princeton Town line


18" C. I. Toe Drains
(all Toe drains Flowing 1/8 Full 5/9/75)
18" C. I. TOE DRAIN (F. Stone Header)
126'
20'
25'
17.5'
18.5'
14'
12'x12' Conc. Box (12" Walls)
TURF
TURF
450' ±
450' ±
TURF
RIP-RAP
60" CHAIN LINK FENCE
TURF
RIP RAP
12" Conc. Partition
CONC. CATWALK
Drop Spillway
18" Conc. Sidewalls
25' ±
Gate Stand
40' ±
A
BICKFORD
POND
B+30
BICKFORD POND AND RESERVOIR DAMS
HUBBARDSTON - BICKFORD POND
DAM No. 3-14-140-32
MAIN DIKE

HUBBARDSTON - Bickford POND

DAM No. 3-14-140-32

Main DIKE X-SECTION



SECTION A-A

B-31

BICKFORD POND AND RESERVOIR DAMS

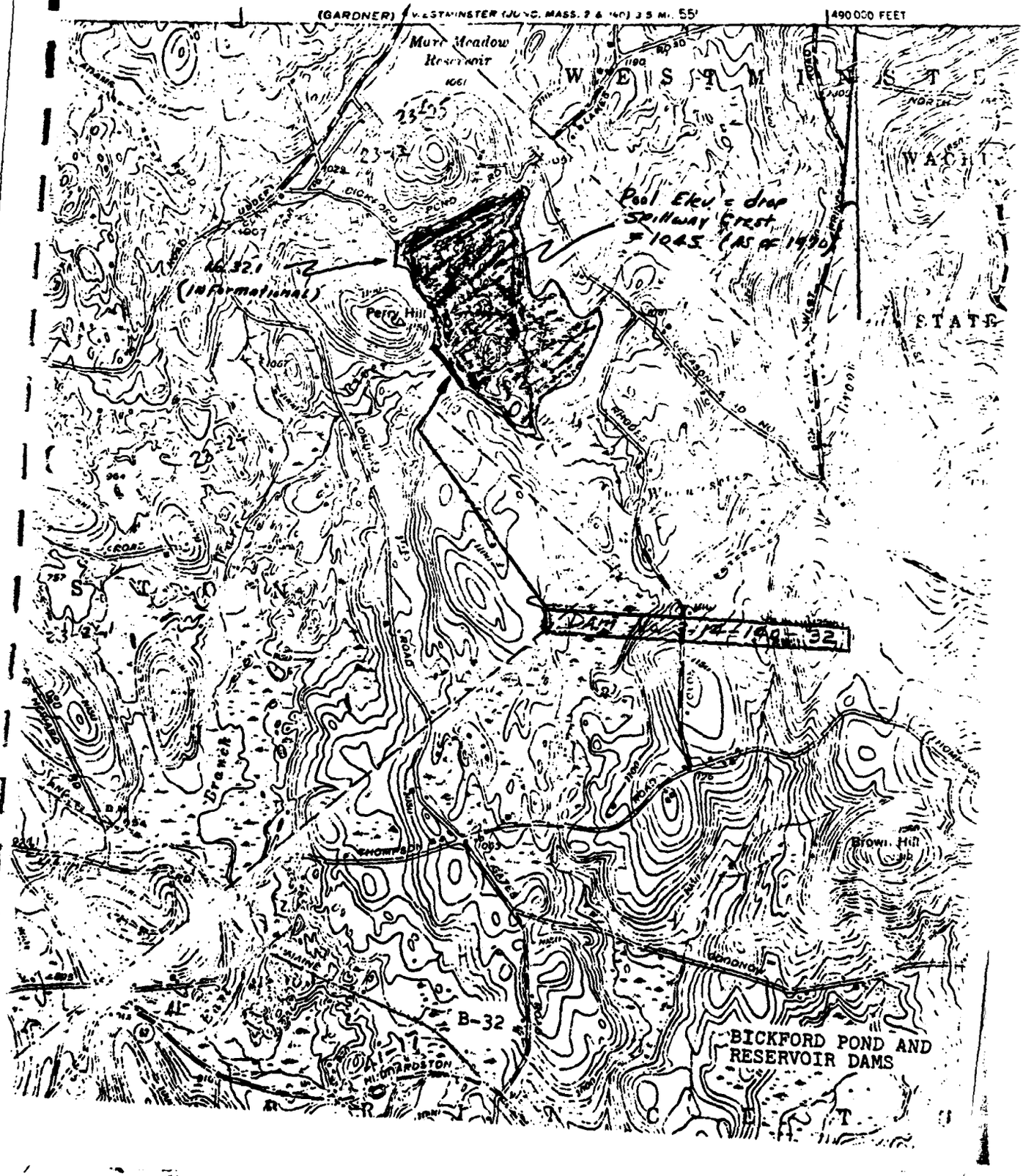
LOCUS PLAN

HUBBARDSTON

Sheet 20A

STATE OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS

196



1. Seepage deltas, saturated toe areas and rivulets, indicate the possibility of a major problem at this dam. An immediate investigation followed by prompt action is necessary.

2. There is differential seettlement of the cobble floor of the principal spillway. Seepage and tree and brush growth should be corrected or removed as necessary.

3. Slope protection (riprap) is recommended on the upstream embankment at the westerly end of the dam.

4. Remove the heavy growth of brush and trees from the downstream embankment.

Marshall Reservoir - Dam #3-14-97-42

The results of the inspection indicate that this dam appears safe; however, the following conditions were noted that require attention:

1. There are animal burrows, one at the top of the dam and another on the downstream embankment which should be filled.

2. Remove the growth of brush from the embankment of the dam.

3. There is some surface erosion on the downstream, easterly embankment which should be corrected.

For Dams Located in Hubbardston

Marc Meadow - Dam #3-14-140-25

The results of the inspection indicate that the seepage and underdrain system should be investigated and corrected as necessary.

Bickford Pond Main (East) Dike - Dam #3-14-140-32

The results of the inspection indicate that this dam is safe; however, the following conditions were noted that require attention:

1. There is some erosion about 150 ft. easterly of the west end of the downstream embankment which should be filled with suitable material, properly compacted and graded.

2. There is some leakage through the roof of the first 3 construction joints near the drop spillway which should be sealed.

Bickford Reservoir Secondary Dike - Dam #3-14-140-32.1
(Northwest of Main Dike)

The results of the inspection indicate that a seepage investigation is recommended followed by the necessary corrective action. Aside from the seepage condition, the light growth of brush on the embankment of the dam should be removed.

For Dams Located in Westminster

Wyman Pond - Dam #3-14-332-17

The results of the inspection indicate that this dam is safe; however, the following conditions were noted that require attention:

1. Remove the growth of brush from the embankment of the dam and in the spillway floor.

2. There is erosion behind the easterly spillway sidewall on the upstream side which should be filled with suitable material, properly compacted and graded.

3. Repair the sections where the masonry is missing from the upstream sidewall of the principal spillway.

Smith Pond - Dam #3-14-332-18

The results of the inspection indicate that minor repairs are needed. The following conditions were noted that require attention:

1. Remove the growth of brush and trees from the embankment of the dam and in the emergency spillway.

2. There is some minor seepage which should be investigated and corrected as needed.

3. Fill the animal burrow on the downstream embankment.

4. The emergency spillway floor should be rebuilt and the sidewall joints repointed.

Meetinghouse Pond - Dam #3-14-332-19

The results of the inspection indicate that a seepage investigation should be conducted followed by the necessary corrective action. The following conditions were also noted that require attention:

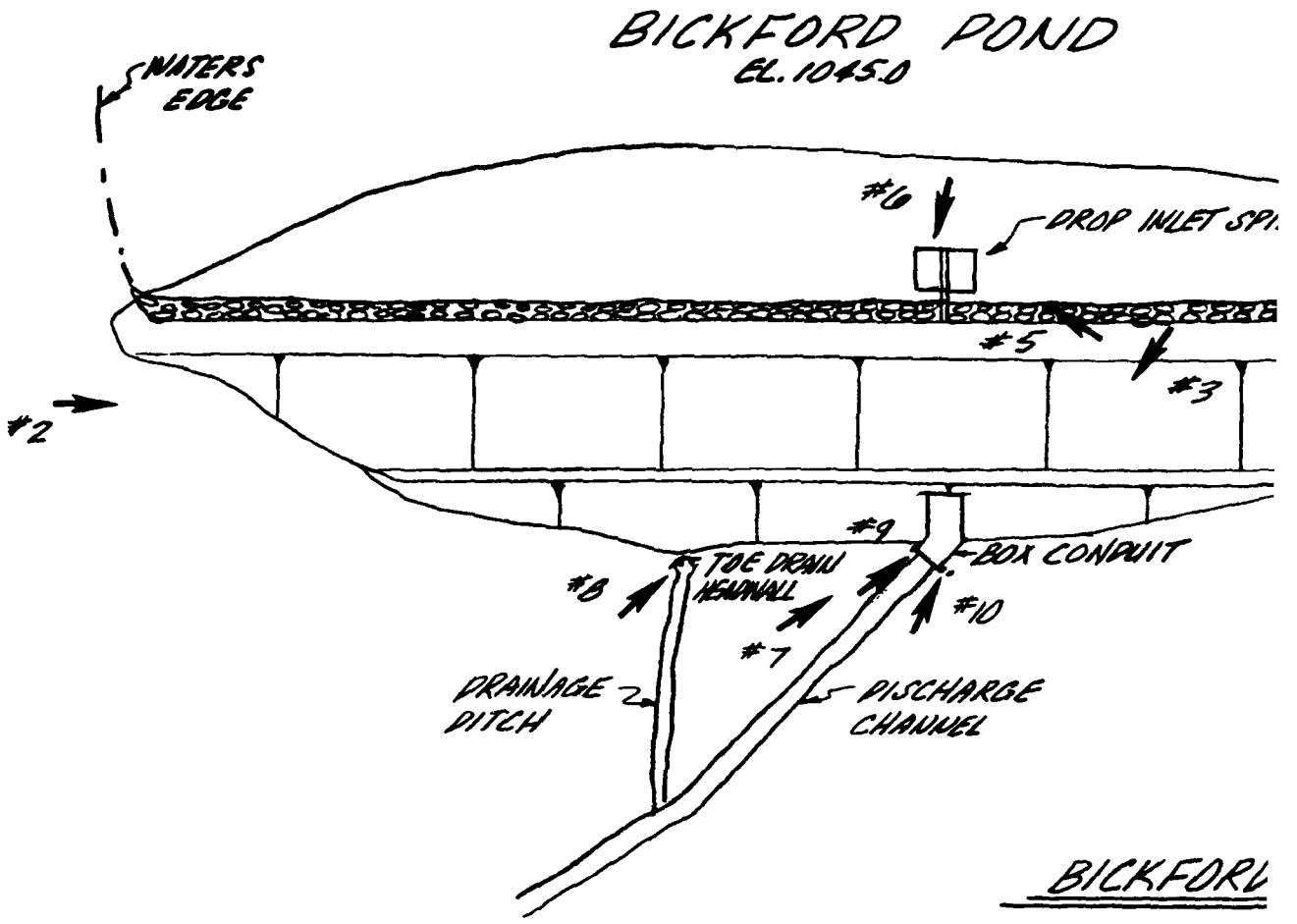
1. Remove the growth of brush and trees from the embankment of the dam.

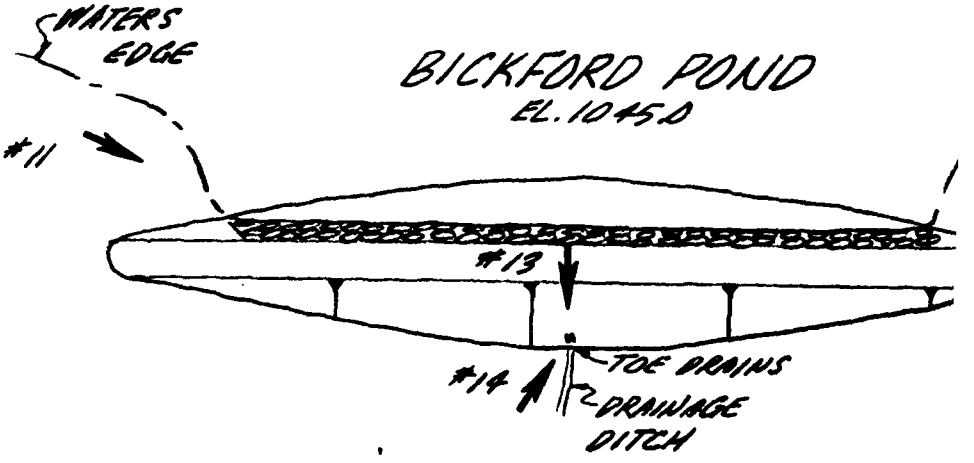
2. The gunite repairs are failing as evidenced by deterioration and seepage most noticeable from beneath the spillway floor. The seepage investigation would probably indicate the best method to correct this condition.

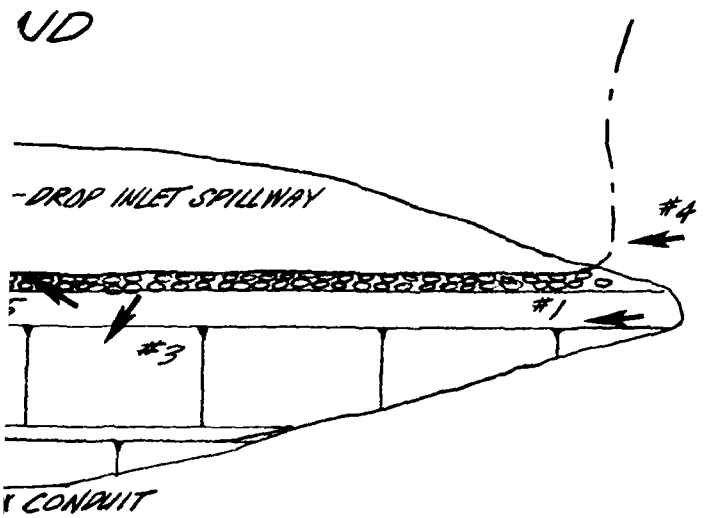
APPENDIX C

PHOTOGRAPHS

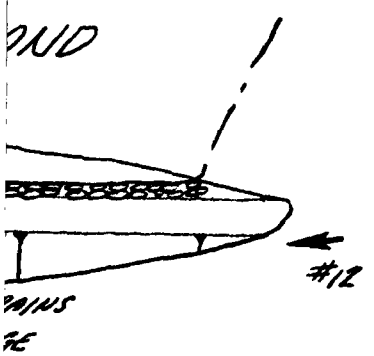
Note: Location and direction of photographs shown on Figure C-1.


BICKFORD POND
EL. 1045.0
WATERS EDGE
#16
DROP INLET SPI
#5
#3
#2
#9
BOX CONDUIT
TOE DRAIN
#8
#10
#7
DRAINAGE DITCH
DISCHARGE CHANNEL
BICKFORD


WATERS EDGE
BICKFORD POND
EL. 1045.0
#11
#13
#14
TOE DRAINS
DRAINAGE DITCH
BICKFOR



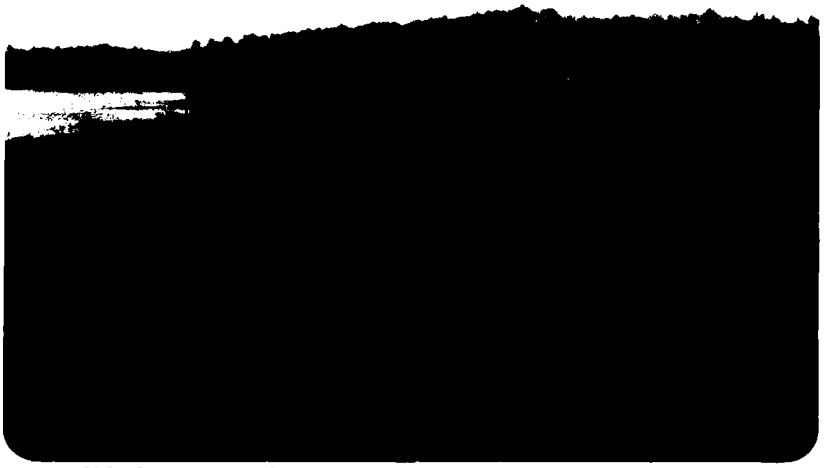
BICKFORD POND DAM



BICKFORD RESERVOIR DAM

	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MA.
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	
BICKFORD POND AND RESERVOIR DAMS	
FIGURE C-1 PHOTO LOCATION PLAN	
TRIBUTARY EAST BRANCH WARE RIVER	MASSACHUSETTS
SCALE: NONE	DATE: MAY, 1980

NO. 1 DOWNSTREAM SLOPE LOOKING FROM LEFT ABUTMENT



NO. 2 DOWNSTREAM SLOPE LOOKING FROM RIGHT ABUTMENT

NO. 3 BOX CONDUIT OUTLET AND DISCHARGE CHANNEL

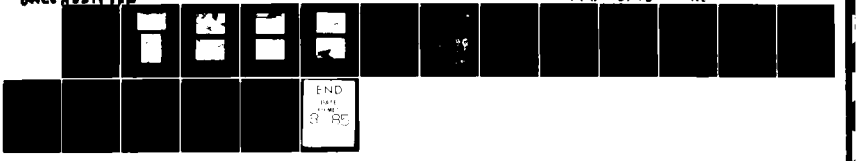
NO. 4 UPSTREAM FACE LOOKING FROM LEFT ABUTMENT

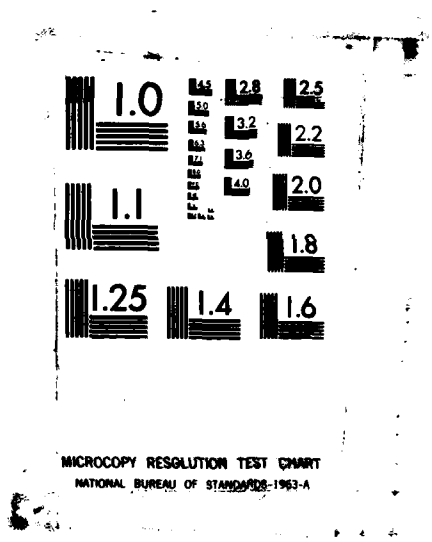
NO. 5 DROP INLET SPILLWAY (20' X 30')

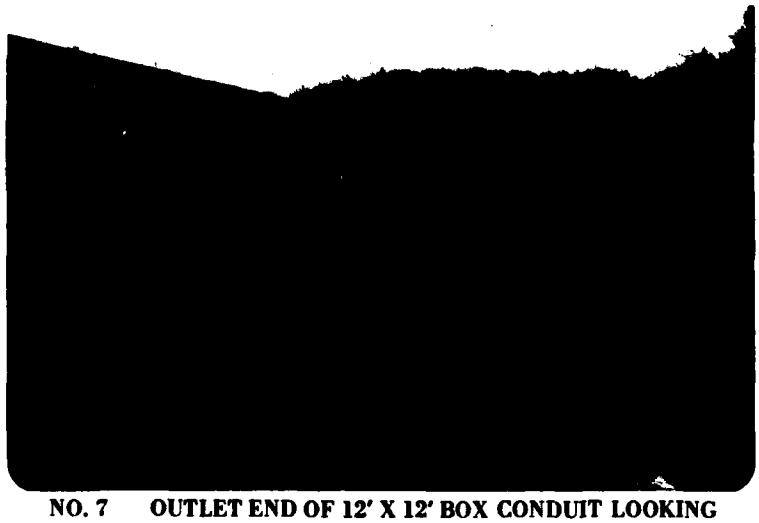
NO. 6 RISING STEMS FROM SLUICE GATE TO FLOORSTAND.

AD-A155 705 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS 3/2
BICKFORD POND DAM (MA.. (U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV JUN 80

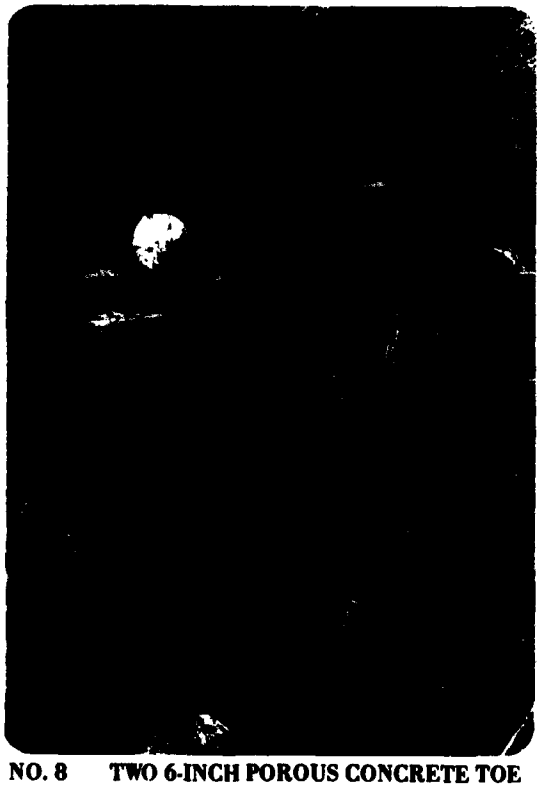
UNCLASSIFIED F/G 13/13 NL



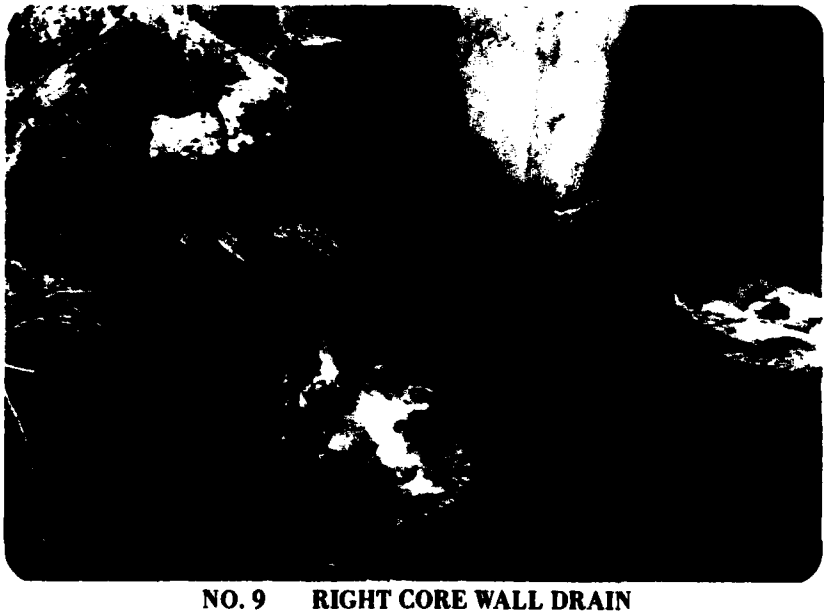

1.0
1.1
1.25
1.4
1.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.8
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



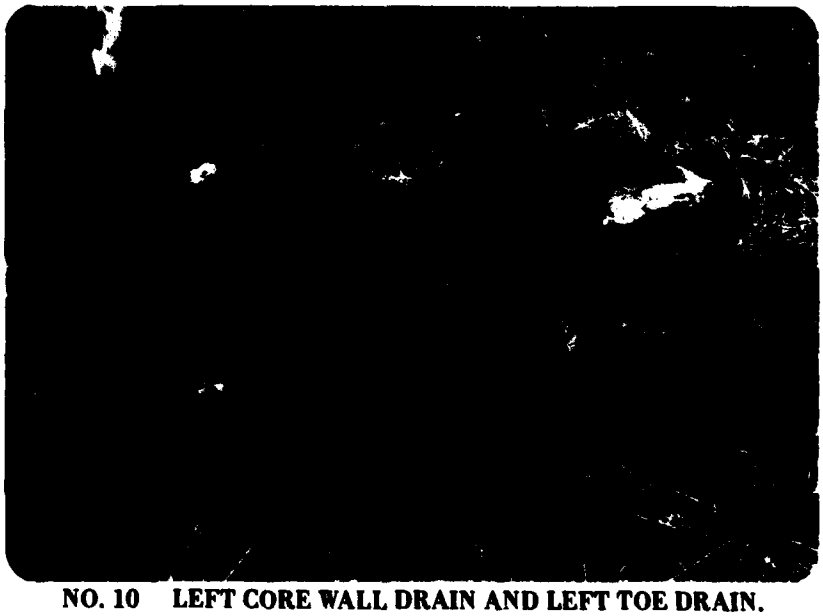
NO. 7 OUTLET END OF 12' X 12' BOX CONDUIT LOOKING UPSTREAM



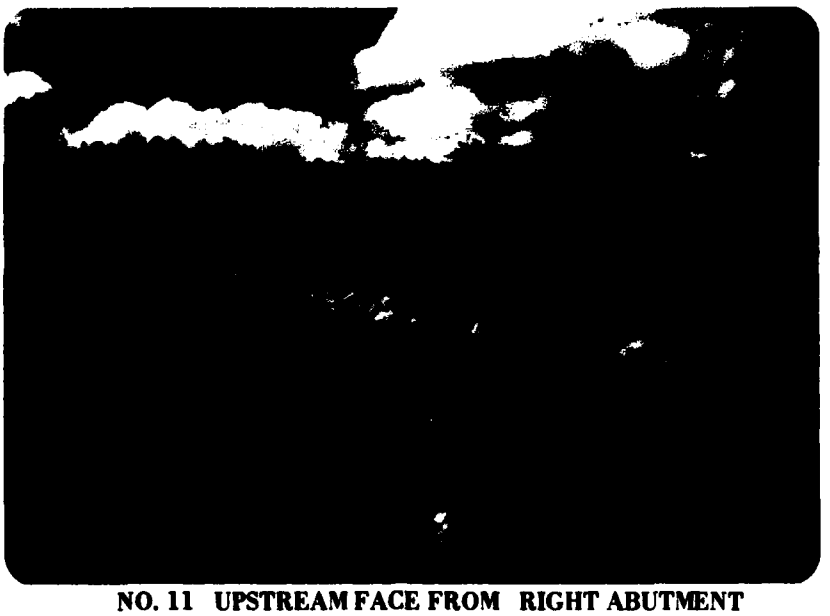
NO. 8 TWO 6-INCH POROUS CONCRETE TOE DRAINS LOCATED APPROXIMATELY 125 FT RIGHT OF BOX CONDUIT.



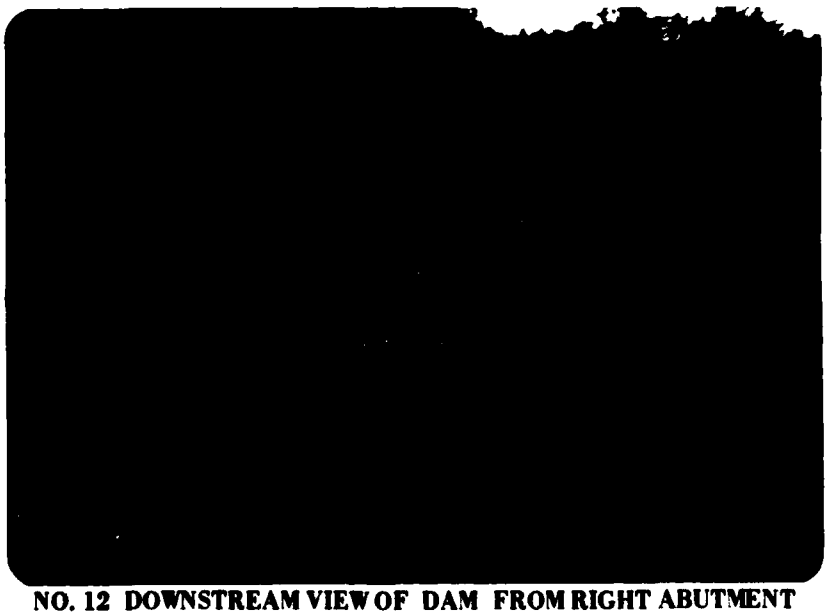
NO. 9 RIGHT CORE WALL DRAIN



NO. 10 LEFT CORE WALL DRAIN AND LEFT TOE DRAIN.



NO. 11 UPSTREAM FACE FROM RIGHT ABUTMENT



NO. 12 DOWNSTREAM VIEW OF DAM FROM RIGHT ABUTMENT

NO. 13 DOWNSTREAM VIEW FROM CENTER OF DAM

NO. 14 TOE DRAINS

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

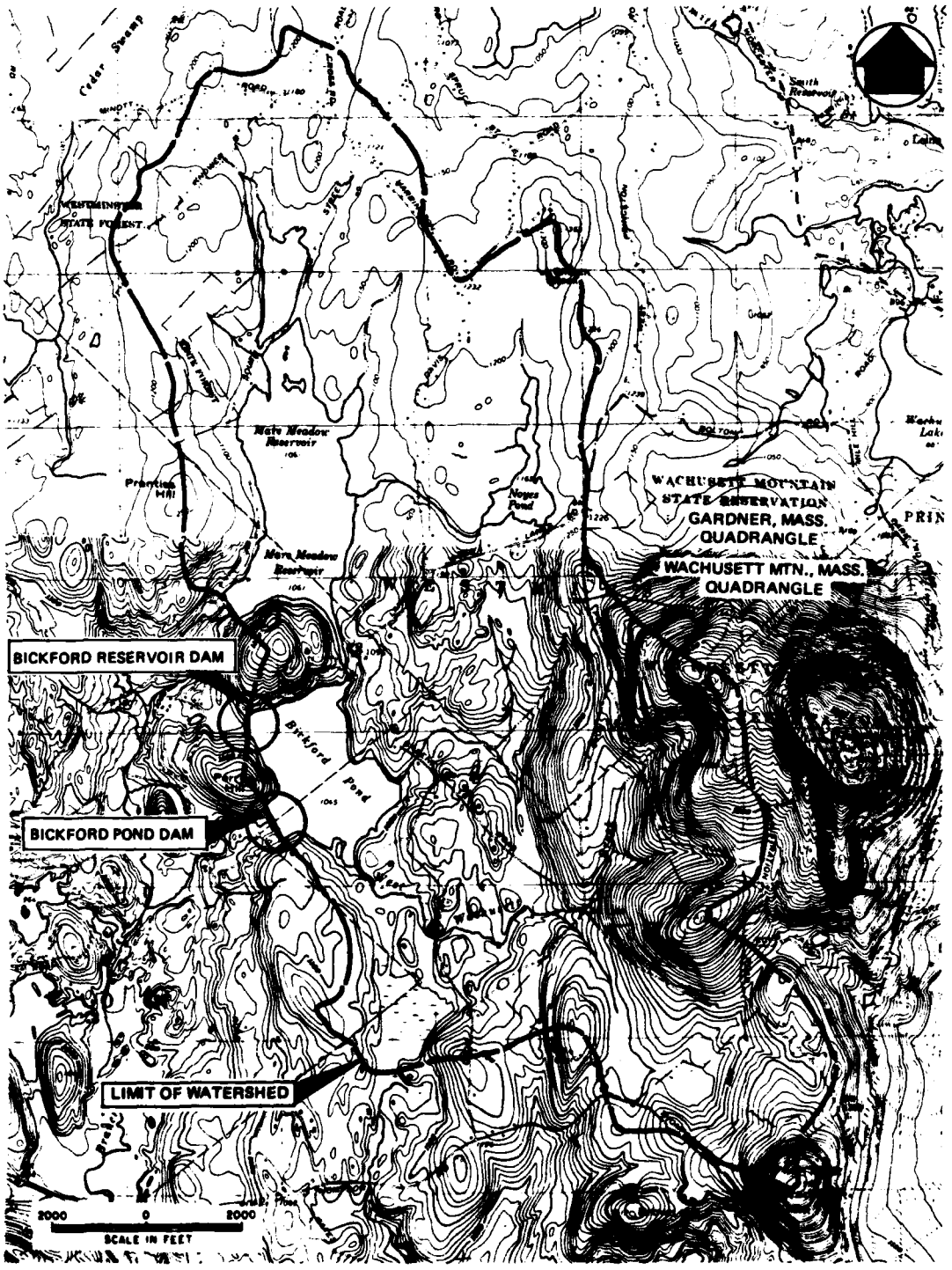


FIG. D-1 DRAINAGE AREA MAP

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

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Subject Worcester County, Mass. Compld. By LEB Date 4/22/80
Detail Bickford Pond Ck'd. By RNH Date 6/13/80

(I) Test Flood, Storage & Storage Function - Mare Meadow Res.

1- Total Drainage Area - 2.97 mi²

2- Pond(s) Area: .0625 = 0.06 mi²
Swamp(s) Area: .02 + .02 + .05 + .01 = 0.10 "
Total Area Pond(s) & Swamp(s): 0.16 "

% Ponds & Swamps: $\frac{0.16}{2.97} = 5.4\%$

3- $\frac{1215-1061}{2300} = .0669$; $\frac{1363-1061}{10100} = .0299$ } Say Ave Slope = 5.0%

4- Using C. of E Curves for Peak Flow Rate & above guide values the Peak Flow Rate was estimated to be about at
" Rolling " and taken at 2000 c.f.s./mi.
Size Class: — ; Hazard Pot.: — ; Spill. Des. Flood: —
Use: Test Flood = Full PMF (Based on Bickford Pd. dam criteria)

5- Test Flood Inflow = (2000) 2.97 = 5940 c.f.s.

6- Pond Storage
The pond area is 0.422 sq. mi. at elev.
Based on a const. area, storage increases at 270 ac. feet per foot of depth increase.

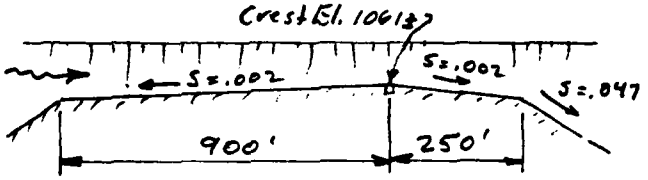
7- Spillway crest elev. is 1061 ±

8- Storage Functions are based on $Q_{out} = Q_{in}\left[1 - \frac{S_{out}}{R}\right]$
S_{out} = Storage Vol. in Reservoir related to final Q_{out} in terms of inches of rain over the drainage area
S(in Inches) = $12\,D\left(\frac{.422}{2.97}\right) = 1.705\,D$; R = 6hr rain of storm
D = Storage depth in feet above spillway crest in reservoir

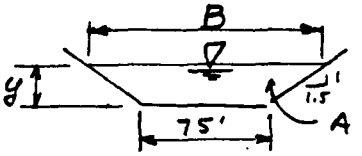
9- Storage Functions: (Test Flood & ½ PMF - if needed)

$F_{TF} = 5940 - 312.6\,S = 5940 - 533\,D$	
$F_{½PMF} = 2970 - 312.6\,S = 2970 - 533\,D$	

(II) Mare Meadow Res. Spillway (to Bickford)



Spillway Profile



Typ. X-Section

1- Critical Flow @ Crest

$$Q^2 = \frac{A^3}{B}(g) \quad ; \quad A = \tfrac{1}{2}(75+B)y \; ; \; B = 75+3y$$

y	1	2	3	4	5	6
B	78	81	84	87	90	93
A	76.5	156	238.5	324	412.5	504
Q	430	1130	2280	3550	5010	6660
V	5.62	7.24	9.56	10.95	12.15	13.21
h_v	0.5	1.0	1.4	1.9	2.3	2.7
Res. El.	1062.5	1064.0	1065.4	1066.9	1068.3	1069.7

2- Friction Loss in Spillway approach

$$S = \left[\frac{V\,n}{1.49\,R^{1/3}}\right]^2 \quad ; n = .03 \; ; \text{ Const. cross section w/ } y' = y + h_v \text{ from above}$$

$A = 37.5(1+3y')y'$

$P = 75 + 3.6y'$

y'	1.5	3.0	4.4	5.9	7.3	8.7
Q	430	1130	2280	3550	5010	6660
A	309.4	1125	2343	4187	6269	
P	80.4	85.8	90.8			
V	1.39	1.00	0.973	0.858	0.799	
S	.00013	.000013	.000005			
h_f in 900':	0.1	0.012	0.0045			

Approach channel losses too small to include ∴ omit

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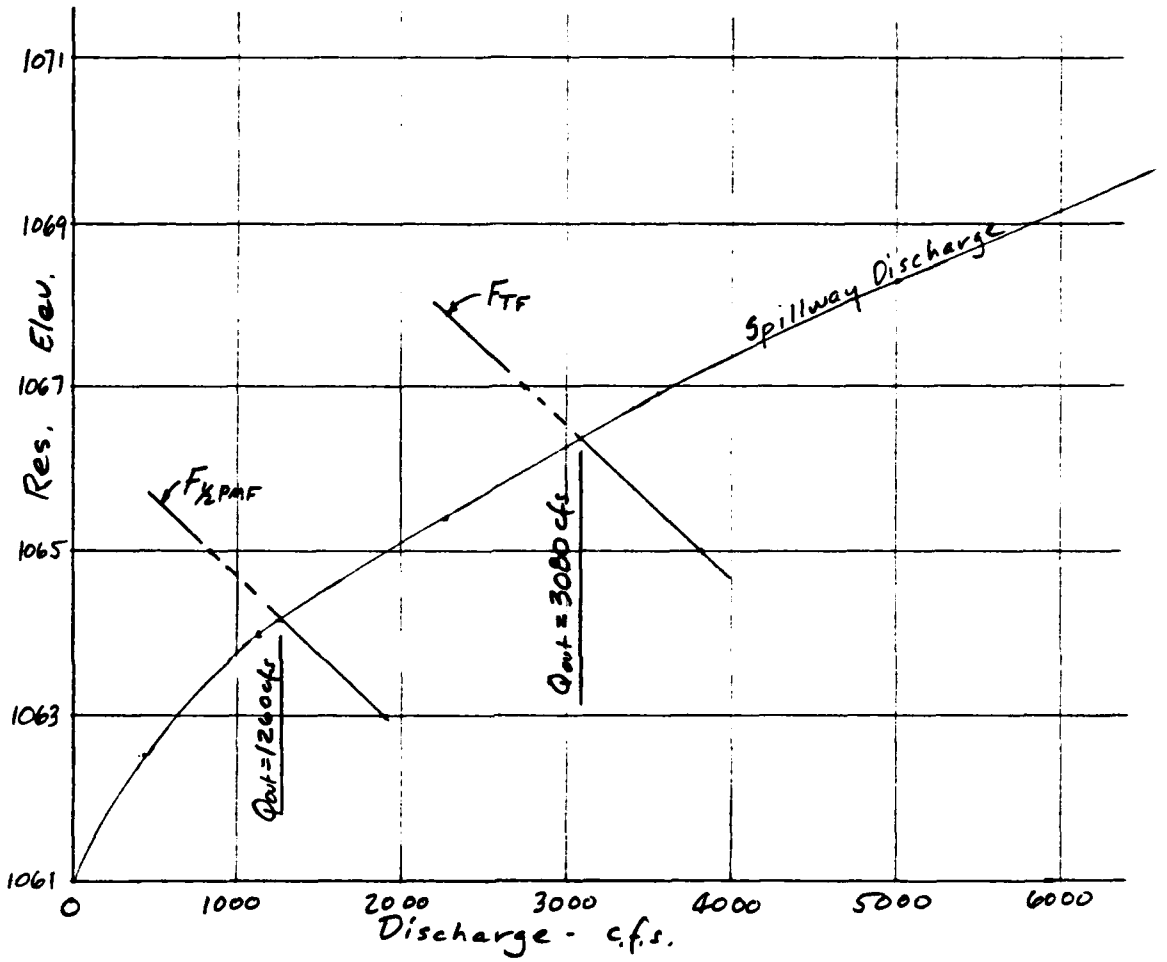
(III) Discharge & Storage Function vs Res. Elev. - Mare Meadow Res



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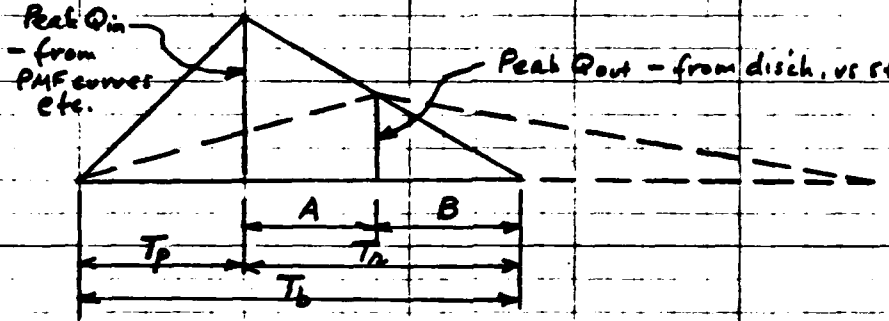
Subject Worcester County, Mass. Compld. By LEB Date 6/4/80
Detail BICKFORD POND Ck'd. By RNH Date 6/13/80

(IV) **Storage Lag** - Mare Meadow Res. disch. to Bickford Pond

Est. time lag between time of peak inflow rate and time of peak out flow rate due to reservoir/pond storage. Assume triangular inflow/outflow hydrographs.



$(\frac{1}{2}$ Peak $Q_{in})(T_b)$ = Volume Rain = (Depth rain)(Drainage Area)

$$T_b = 1291\left[\frac{R'(DA)}{Q_{in}}\right]$$

R' = inches of rainfall excess
DA = drainage area in sq. miles.
Q_{in} = peak Q_{in} in cfs.
Q_{out} = " Q_{out} " "

$$T_p = \frac{T_b}{2.67} \; ; \; T_r = 1.67(T_p) = 0.6255\, T_b$$

$$B = T_r\left(\frac{Q_{out}}{Q_{in}}\right) \; ; \; A = T_r - B = T_r\left(1 - \frac{Q_{out}}{Q_{in}}\right)$$

$$\therefore \boxed{A = 807.3\,(R')(D.A.)\left[\frac{Q_{in} - Q_{out}}{Q_{in}^2}\right] \text{ — in hours}}$$

$$A = 807.3\,(19)(2.97)\left[\frac{5940 - 3080}{(5940)^2}\right] = 3.7 \text{ hours}^*$$

$$T_p = 483.5\left[\frac{19(2.97)}{5940}\right] = 4.6 \text{ hours} \; ; \; T_p + A = 8.3 \text{ hours}$$

$$Q_{Add} = \frac{4.6}{8.3}(3080) = \underline{1700}\ \text{cfs}$$ - flow to be added to peak rate of runoff from Bickford Pond's direct drainage area.

* Value of R' is high - but is elim. in ratio to find Q_{add}

For ½ PMF: $Q_{Add} = \underline{640}$ cfs - by similar method

(V) Test Flood, Storage & Storage Function

1 – Total Drainage Area – 3.23 mi² (Mare Meadow Res. excluded)

2 – Pond(s) Area: –
Swamp(s) Area: .02+.05+.01+.04+.02+.09+.02+.05 = 0.30 mi²
Total Area Pond(s) & Swamp(s): 0.30 "

$\%$ Ponds & Swamps $= \frac{0.30}{3.23} = 9.3\%$

3 – $\frac{1559-1045}{16100} = .0319$; $\frac{1722-1045}{14200} = .0477$ } Say Ave Slope = 4%

4 – Using C. of E Curves for Peak Flow Rate & above guide values the Peak Flow Rate was estimated to be somewhat below "Rolling" and taken at 1700 c.f.s./mi
Size Class: Interm ; Hazard Pot.: High ; Spill. Des. Flood: Full PMF
Use: Test Flood = Full PMF

5 – Test Flood Inflow = (1700) 3.23 = *5490 c.f.s.
* Add 1700 cfs from Mare Meadow Res – add 640 cfs for ½ PMF

6 – Pond Storage
The pond area is 0.25 sq. mi. at elev. 1045
Based on a const. area, storage increases at 160 ac. feet per foot of depth increase.

7 – Spillway crest elev. is 1045.0

8 – Storage Functions are based on $Q_{out} = Q_{in}\left[1 - \frac{S_{out}}{R}\right]$
S_{out} = Storage Vol. in Reservoir related to final Q_{out} in terms of inches of rain over the drainage area

S(in Inches) $= 12\,D\left(\frac{0.25}{3.23}\right) = .929\,D$; R = 6hr rain of storm
D = Storage depth in feet above spillway crest in reservoir

9 – Storage Functions: (Test Flood & ½ PMF – if needed)

F_{TF} = 7190 – 289	S = 7190 – 268 D
$F_{½\,PMF}$ = 3385 – 289	S = 3385 – 268 D

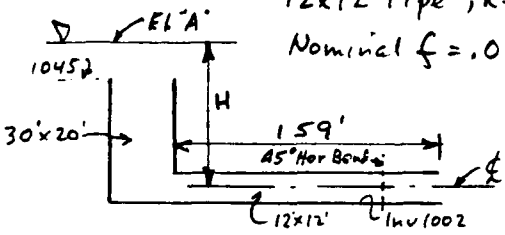
(VI) Discharge Relations

1- Spillway - Entrance Weir Control

Crest length: $2(31.5+21.5) - 3.5 = 102.5'$ - say $100'$ (loss @ corners)
Crest elev. 1045.0, use Williams & Hazen "Hydr. Tables"

Res. El.	1046	1047	1048	1049	1050	1050.5	1051	1051.5
h	1	2	3	4	5	5.5	6	6.5
Q_1	330	930	1710	2640	3690	4260	4870	5470

2- Spillway - Pipe Control



12'x12' Pipe, $R = \frac{144}{48} = 3$, Equiv. $D = 4R = 12'$; $\frac{e}{D} = \frac{.0045}{12} = .000375$
Nominal $f = .0155$ (fully turb. flow)

$$H = \frac{V^2}{2g}\left[.0155\frac{159}{12} + 1.0 + 0.5 + 0.3\right]$$ (Exit, Ent, Bend)

$$H \simeq 2.0\frac{V^2}{2g}; \quad V = 5.67\sqrt{H}$$

Elev. "A"	1040	1045	1047	1049	1050	1051	1052
H	32	37	39	41	42	43	44
V	32.1	34.5	35.4	36.3	36.8	37.2	37.6
Q_2	4620	4970	5100	5230	5300	5360	5420

← $Q_2 > Q_1$ ∴ Q_1 controls

3- Spillway - Entrance Orifice Control.

$Q_3 = CA\sqrt{2gH} = 0.6(20\times30)\sqrt{64.4H} = 2889\sqrt{H}$

Res. El. 1051.5; $H = 6.5$; $Q_3 = 7365$; Since $Q_3 > Q_1$, weir still controls

4. Crest Flow

$q = 2.55\,h^{1.5}$; Dam 900': 300'@1051.2, 300'@1051.4, 300'@1051.5
Dike 490': 200'@1051.3, 290'@1051.4

Pond El.	1051.3	1051.5	1051.7	1051.4
Q_A	20	130	270	70
Q_B	—	50	130	20
Q_C	—	50	250	—
Q_D	—	—	70	—
ΣQ_4	20	230	720	90

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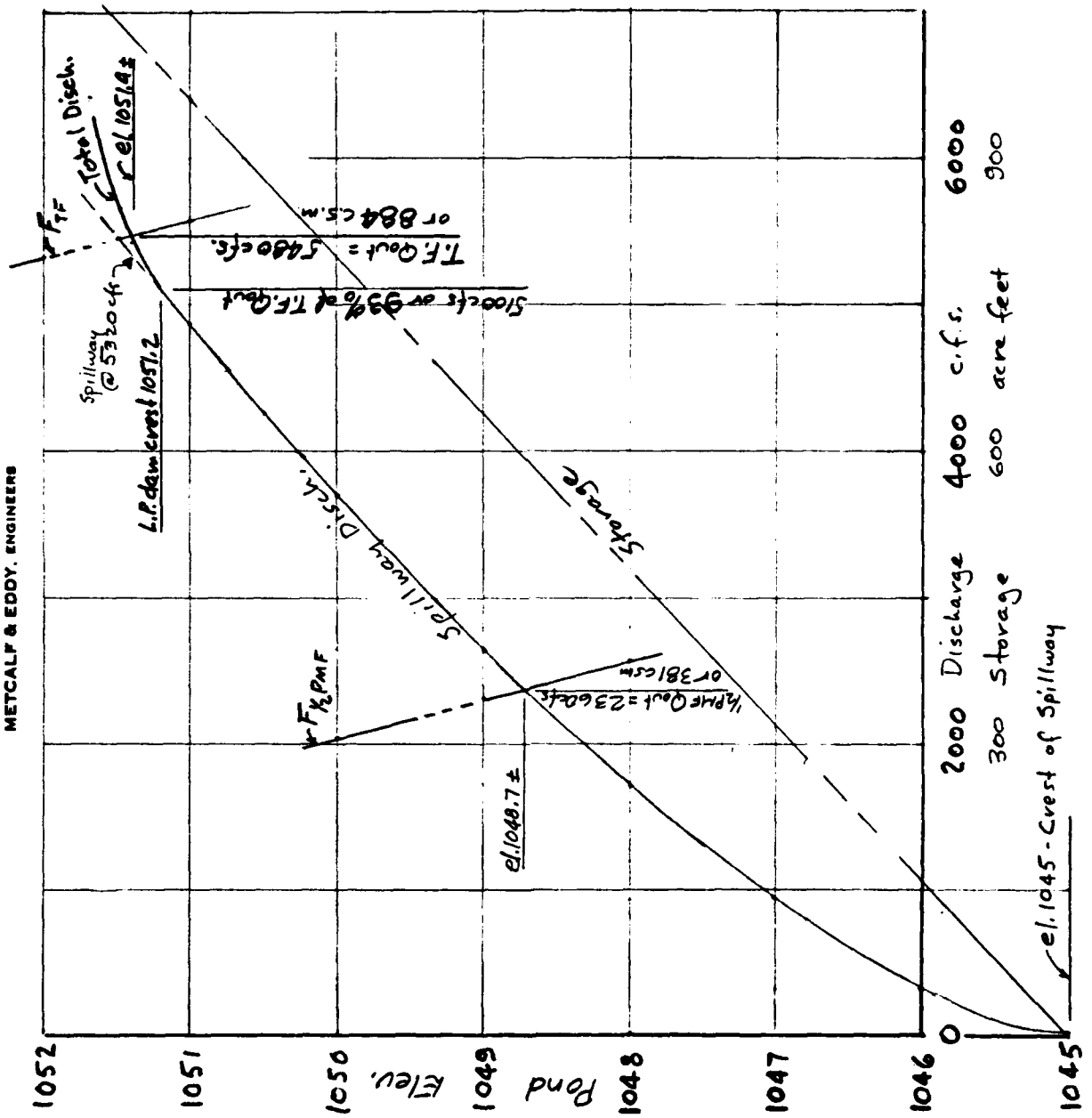
(VII) Discharge, Storage & Storage Funct. vs Pond Elev. – BICKFORD POND



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(VIII) Test Flood Crest Flow

Max. hd on crest : 1051.4 - 1051.2 = 0.2 ft.

Flow/ft of crest = $q = 2.55(0.2)^{1.5} = 0.23$ cfs/ft

Where flow is "critical": $y_c = 0.12'$, $V_c = 1.9$ fps

(IX) Low Level Outlet

±73' straight 20"ϕ pipe, exit & cut loss = $1.5 h_v$, fric. loss = $\frac{73}{1.67}(.013)\ h_v$

Head = $2.07 \frac{V^2}{2g}$; $V = 5.59\sqrt{H}$; $Q = 12.2\sqrt{H}$; ϕ Pipe @ 1003

Water El.	1045	1044
H	42	41
Q	79	78

← Ave Q = 78.5 cfs for 1' drop

Time to lower res. 12" = $\frac{160(43560)}{78.5(3600)} = 24.7$ hrs or 1480 minutes

(X) Failure of Dam - Main Dam

Peak Failure Flow:

Pond Elevation - 1051.2
Toe Elevation — 1000.0
Y_o = 51.2'

Dam Length Subject to Breaching = 600
$W_o = 40\%(600) = 240'$

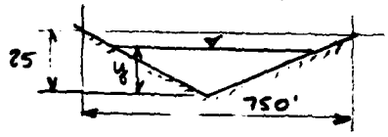
$$Q_{P_1} = 1.68\, W_o\, (Y_o)^{1.5} = 1.68(240)(51.2)^{1.5} = 147{,}700 \text{ cfs}$$

Ongoing disch. = 5100 cfs ; Not coincident with peak failure flow since spillway would loose head before full 240' failed.

Storage Volume Released:

Storage Above Spillway 160 × 6.2 = 992 ac. ft.
Storage Below Spillway From Capacity Table = 3029 " "
S = Total Storage = 4021 " "

Channel Hydraulics:



$S = \frac{10}{600}$; $n = 0.125$; $R \simeq \frac{1}{2}y$, $V = 0.97\, y^{2/3}$
$A = 15y^2$.

y	A	V	Q
5	375	2.83	1060
10	1500	4.50	6750
15	3375	5.90	19900
20	6000	7.15	42900
25	9375	8.29	77800
30	13500	9.36	126400
35	18375	10.38	190700
32	15360	9.78	150200
8	960	3.90	3720

Water level rises from ±9 feet deep to ±32 feet deep. (38' depth occurs ±1500 downstream from dam - no effective backwater assumed at toe of failure)

Time to Drain:

$$\frac{43560\,(4021)}{3600\,(\frac{1}{2})\,(147{,}700)} = 0.66 \text{ Hours.} = 39 \text{ Minutes.}$$

(XI) Failure of Dam - Dike

Peak Failure Flow:

Pond Elevation - 1051.2
Toe Elevation — 1033 ±
Y_o = 18.2

Dam Length Subject to Breaching = 280 ft.
$W_o = 40\%(280) = 112$ ft.

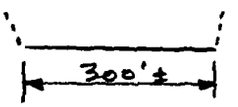
$$Q_{P_1} = 1.68\, W_o\, (Y_o)^{1.5} = 1.68\,(112)(18.2)^{1.5} = 14{,}600$$

Storage Volume Released:

Storage Above Spillway	992	ac. feet
Storage Below Spillway	1762	" " (from capacity table El. 1045 to 1033)
S = Total Storage =	2754	" "

Channel Hydraulics:

$S = \frac{20}{1900}$; $n = 0.10$; $R \simeq y$, $V = 1.53\, y^{2/3}$



y	A	V	Q
5	1500	4.47	6,700
10	3000	7.10	21,300
8	2400	6.11	14,700

Failure causes a ± 8 ft depth of flow, where none occurred previously.

Time to Drain:

$$\frac{43560\,(2754)}{3600\,(\frac{1}{2})\,(14600)} = 4.6 \text{ Hours, or } 274 \text{ minutes}$$

APPENDIX E

INFORMATION CONTAINED IN THE NATIONAL INVENTORY OF DAMS

BICKFORD POND DAM
BICKFORD RESERVOIR DAM

END

DATE
FILMED

8-85