AD-A065 834 TIPPETTS-ABBETT-MCCARTHY-STRATTON NEW YORK F/G 13/2
NATIONAL DAM SAFETY PROGRAM. TITICUS DAM, CROTON RIVER BASIN, W--ETC(U)
JUN 78 E O'BRIEN DACW51-78-C-0024
UNCLASSIFIED NL

1 OF 1
AD A065834

END
DATE FILMED
5-79
DDC

LEVEL

CROTON RIVER BASIN

TITICUS DAM

WESTCHESTER COUNTY, NEW YORK

INVENTORY NO. [illegible]

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

CONTRACT NO. DACW-51-78-C-0024

NEW YORK DISTRICT CORPS OF ENGINEERS

[illegible] 24, 1978

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Inspection Report Titicus Dam Croton River Basin, Westchester County, N.Y. Inventory No. N.Y. 50	5. TYPE OF REPORT & PERIOD COVERED Phase I Inspection Report National Dam Safety Program 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Eugene O'Brien P.E. (15)	8. CONTRACT OR GRANT NUMBER(s) DACW-51-78-C-0024
9. PERFORMING ORGANIZATION NAME AND ADDRESS Tippetts-Abbett-McCarthy-Stratton 345 Park Avenue New York, New York 10021	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army 26 Federal Plaza / New York District, CofE New York, New York 10007	12. REPORT DATE 30 June 1978 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) (12) 63p.	15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(6)

18. SUPPLEMENTARY NOTES

National Dam Safety Program.
Titicus Dam, Croton River Basin,
Westchester County, New York,
(Inventory Number 50) . Phase I
Inspection Report.

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

Dam Safety
National Dam Safety Program
Visual Inspection
Hydrology, Structural Stability
Westchester County
Titicus River
Titicus Dam

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

This report provides information and analysis on the physical condition of the dam as of the report date. Information and analysis are based on visual inspection of the dam by the performing organization.

Titicus Dam was judged to be safe, although minor maintenance and monitoring procedures were recommended.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

411046

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Dat

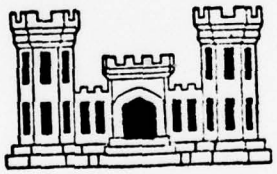
LEVEL II (1)

CROTON RIVER BASIN

TITICUS DAM

WESTCHESTER COUNTY, NEW YORK
INVENTORY NO. 50

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



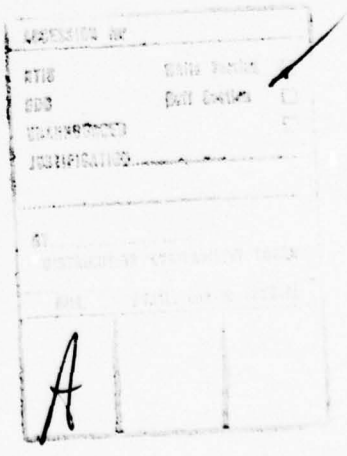
Prepared by: TIPPETTS-ABBETT-McCARTHY-STRATTON

NEW YORK DISTRICT CORPS OF ENGINEERS

MAY 24, 1978

CROTON RIVER BASIN
TITICUS DAM
INVENTORY NO. 50
PHASE I INSPECTION REPORT

TABLE OF CONTENTS



PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	TITICUS DAM (I.D. No. 50)
State Located:	NEW YORK STATE
County Located:	WESTCHESTER COUNTY
Stream:	TITICUS RIVER
Date of Inspection:	24 APRIL 1978

ASSESSMENT

Examination of available documents and visual inspection of the Titicus Dam and appurtenant structures did not reveal conditions which are considered to be unsafe. Some existing inadequacies regarding maintenance and operation of the project features were observed.

The total discharge capacity of the spillway and regulating gates without overtopping of the dam is approximately 19,200 cfs. This is less than the estimated probable maximum flood (PMF) of 40,000 cfs but greater than the standard project flood of 14,800 cfs, both as determined using the Corps of Engineer's screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the Standard Project Flood.

No remedial measures are required at the present time. Certain measures, however, are recommended regarding:

- Monitoring movement of riprap
- Maintenance of the earth embankment
- Improvement of seepage condition at the toe of the south embankment
- Repair of a regulating gate valve
- Programs for operation, maintenance and inspection
- Monitoring piezometers already installed

Eugene O'Brien

Eugene O'Brien, P.E.
New York No. 29823

Clark H. Benn

Approved By: Col. Clark H. Benn
New York District Engineer

Date: 30 June 78

OVERVIEW OF MASONRY DAM AND SPILLWAY

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
TITICUS DAM, INVENTORY NO. 50
CROTON RIVER BASIN
WESTCHESTER, NEW YORK

SECTION I PROJECT INFORMATION

1.1 GENERAL

a. Authority

The Phase I Inspection reported herein was authorized by the DEPARTMENT OF THE ARMY, NEW YORK DISTRICT, CORPS OF ENGINEERS by letter dated 31 March 1978, in fulfillment of the requirements of the National Dam Inspection Act, Public Law 92-367, 8 August 1972.

b. Purpose of Inspection

The purpose of this inspection and report is to investigate and evaluate the existing conditions of subject dam in order to: identify deficiencies and hazardous conditions; determine if they constitute hazards to human life or property; and notify the State of New York of these results along with recommendations for remedial measures where necessary.

1.2 DESCRIPTION OF THE PROJECT

a. Description of the Dam

The Titicus Dam consists of a central cyclopean masonry gravity section extended on each side by earth embankments. The central masonry structure, which includes a 200-ft long ungated stepped (or ladder) spillway, is 534 ft long. The lengths of the north and south embankment sections are 732 ft and 253 ft respectively. The masonry section is reportedly (1) founded entirely on rock and was constructed of rubble, faced upstream and downstream with cut stone lain in regular courses. The principal dimensions of the masonry dam are:

Width under coping	20.7 ft
Width about 109 feet under coping	75.2 ft
Maximum height above foundation	135.0 ft
Maximum height above surface	109.0 ft

---

(1) Wegmann, The Design and Construction of Dams, pubs. John Wiley and Sons, 1918.

The embankment section constructed on both sides of the masonry structure has a crest width of 30 feet and upstream and downstream slopes of 1 (V):2.5 (H). The upstream face below El 330 is covered with paving stones (18 inches deep placed on 12 inches of broken stone). The rubble masonry core wall is 5 feet wide at the top (El 330) and 17 feet wide at a depth of 98 feet, both faces being evenly battered. The core wall has a maximum height of 124 feet above the foundation.

Flow from the reservoir is regulated by multilevel gates at a gate house on the upstream face of the masonry dam. A central wall (perpendicular to the dam) divides the gate house; each division has an inlet and outlet chamber. Each inlet chamber has three openings to the reservoir (6 ft wide x 8 to 9.5 ft high); one at high level (sill El 319), one at mid-depth (sill El 285) and one near the bottom (sill El 250).

According to the documents reviewed (See Section 2), the walls separating the inlet and outlet chambers each have two openings, one at mid-depth (sill El 285) and one at the bottom (sill El 250), which are controlled by 2 x 5 ft sluice gates operated from the gate house floor. The top of the separating wall (El 319) can be used as an overflow weir which can be raised by the use of stop-planks set in grooves. In actuality, there are three gate operating stands and stems for each division of the gate house, rather than the two indicated by the documents. The extra gate operating stands and stems are located upstream of the two which are indicated on the documents. There is no record of the modification and no indication to the purpose of the two additional gate stands and stems.

Two 48-inch outlet pipes (one for each division of the gate house) convey water from the outlet chamber to the old channel of the Titicus River, which was excavated to rock for a short distance. Each of the outlet pipes is controlled by a 48-inch gate valve located in an underground vault approximately 80 feet downstream of the masonry dam.

It is reported that in addition to these pipes, a 24-inch diameter drainage pipe that was used during construction of the reservoir, passes through the dam. The upstream end of the pipe is reported to be closed by a flap valve.

b. Location

The dam is located on the Titicus River, a tributary of the Croton River, and is approximately one half mile upstream of the Croton Reservoir. The nearest downstream community, Purdy's Station, is less one half mile downstream of the dam.

c. Size Classification

The dam is more than 100 feet high and is therefore considered to be a "large" dam.

d. Hazard Classification

The dam is in the "high" hazard potential category.

e. Ownership

Titicus Dam is owned and operated by the New York City Bureau of Water Supply (BOWS); day-to-day operation and maintenance is managed from the Katonah Section of the East-of-Hudson Division of the BOWS.

f. Use of Dam

The impoundment provided by the dam is a water storage reservoir for the City of New York.

g. Design and Construction History

The dam and appurtenances were designed by the Aqueduct Commission of New York. The contract for the Titicus Reservoir was let on February 18, 1890 to Washburn, Shaler and Washburn; construction was completed by January 1, 1895.

h. Normal Operating Procedures

Water releases from the Titicus Reservoir, either from the regulating gates or over the service spillway, flow into the Titicus River and down to the Croton Reservoir. BOWS personnel report that water is normally removed from the middle level of the reservoir using the sluice gates at the gate house; two 48-inch regulating gates are cracked open to permit a constant flow of approximately 5 mgd into the Titicus River.

1.3 PERTINENT DATA

a. Drainage Area, sq. miles	23.35
b. Discharge at Dam Site, cfs	
Maximum known flood at site (Oct. 16, 1955)	6,240
Maximum regulating gate outlet, (Estimated)	1,200
Ungated spillway at pool elevation, El 330	6,240
Ungated spillway at maximum pool, El 334	18,000
Total discharge capacity at maximum pool	19,200
c. Elevation (feet above M.S.L., Croton Datum)	
Top of dam	334.0
Maximum design pool (Top of riprap and core)	330.0
Spillway crest	325.0
Stream bed at centerline of dam	225.0
d. Reservoir	
Length of Max. design pool, miles	2.6
Length of shoreline at El 325, miles	8.1
Surface area at El 325, acres	669.4
e. Storage, acre-feet	
Top of spillway crest (El 325)	22,000
Maximum design pool (El 330)	25,500
Top of dam (El 334)	30,100

f. Dam

Masonry Section

Type:	Cyclopean masonry with cut stone facing
Length:	534 ft including spillway
Height:	135 ft above foundation
Top width:	20.7 ft

Embankment Section

Type:	Earth Embankment with rubble masonry central core
Length:	732 ft, north embankment 253 ft, south embankment
Crest Width:	30 ft
Side Slopes:	2.5 (H) on 1.0 (V) upstream and downstream
Impervious core:	Rubble masonry 5 ft wide at top and 18 ft wide at base
Grout Curtain:	None

g. Spillway

Type:	Stepped (or ladder)
Length:	200 ft
Crest Elevation:	325 ft above MSL - Croton Datum 324.5 ft above MSL - Sandy Hook
Gates:	Ungated
Upstream Channel:	None
Downstream Channel:	200 ft long channel excavated in rock, joins Titicus River bed

h. Regulating Outlets

The weirs and multilevel sluice gates in the inlet tower control the water level sources to the two 48-inch discharge lines. Flow is regulated by the two gate valves in these lines. Each channel in the intake tower has a weir at invert El 319.0 and, according to available drawings, a 2-ft x 5-ft sluice gate at invert El 285.0 and El 250.0.

SECTION 2: ENGINEERING DATA

2.1 DESIGN

The design of the dam was made by the Aqueduct Commission of New York prior to 1890. There are no design data or specific design memoranda available for the project features.

The available information on the dam consists of:

a. Contract Drawings, Dam and Appurtenances for "Reservoir M" on Titicus River near Purdy's Station, prepared by the Aqueduct Commission, dated September 11, 1889.

b. The Aqueduct Commission's Reports on the New Croton Aqueduct Dams and Reservoirs,

1887-1895
1895-1907

c. Edward Wegmann, The Design and Construction of Dams, Sixth Edition, 1918 (John Wiley & Sons, Inc.)

Drawings found in (b) and (c) are the same and reflect changes made to the drawings contained in (a). There is no information on subsurface conditions contained in the above documents.

2.2 CONSTRUCTION RECORDS

No detailed construction records are available; however, there are brief narratives pertaining to the construction of the dam in Wegmann's text and also in the Aqueduct Commission's Reports.

2.3 OPERATION RECORDS

There exists a written record of operation of the gates at the dam, and also records of maintenance and repair work orders. There does not exist a formal operation and maintenance manual for the project.

There is a record of pool elevation and rainfall on a daily basis.

2.4 EVALUATION OF DATA

Existing information was made readily available either at the BOWS' New York City Offices as at the Katonah Section Office.

The available data reviewed is considered adequate for this Phase I inspection and evaluation of safety.

SECTION 3: VISUAL INSPECTION

3.1 FINDINGS

a. General

A visual inspection of Titicus Dam was made on Monday, April 24, 1978. At the time of the inspection the reservoir level was at El 525.16.

b. Embankment Dam

There were no visible signs of sloughing, erosion, cracking or other distress on the crest and downstream slopes of the embankments except for some ruts and other depressions caused by traffic.

There was no sign of sloughing, erosion, cracking or other distress on the upstream slope and visible portion of the riprap of the north embankment. There are indications of minor downslope movement of the riprap, below the top course of stone, on the south embankment near the spillway approach wall. The affected area is limited to a section from the wall to a distance 25 ft south of the wall, with the maximum downslope movement of 1.0 to 1.5 ft occuring at a location approximately 15 ft south of the wall. There appears to be a 4 to 9 inch separation between the north edge of the riprap paving stones and the south face of the south spillway approach wall.

The crest and downstream slope of the north embankment are grass covered and free of bushes or shrubs. There are some brush and shrubs at the level of the top riprap paving stones in the upstream slope.

There are some shrubs and small saplings on the grass covered crest of the south embankment. The downstream slope of the south embankment is covered with heavy brush, shrubs and saplings. There are brush and shrubs at the top paving stones on the upstream slope of the south embankment also.

There is no visible evidence of seepage emerging from the slopes or toe of the north embankment.

A zone of seepage exists at the toe of the south embankment. The affected area, which extends for a distance of 8 to 10 ft (measured along the slope from the toe) up the slope, was soft and muddy; however, there were no signs of sloughing or other distress. Seepage was noted emerging from the contact between the toe and the abutment for a distance of approximately 42 ft (measured along the toe, from the intersection of the downstream wingwall and the toe). The quantity of seepage was extremely small

(not measurable). The ground surface below the toe in this area was wet within a radius of 20 to 30 ft downstream of the intersection of the wingwall and the toe of the south embankment. This wet area corresponds to an old stream channel which is indicated on the Contract Drawings (circa 1889). The drawings in Wegmann's text show a toe drain at this location.

The top portions of piezometer standpipes were observed protruding from both embankment sections of the dam (numbering at least 9 at the north embankment and 3 at the south embankment). Most of the standpipes were capped and the caps "frozen" to the pipes by rust; some of the pipes were bent just below the embankment surface. These piezometers have been installed circa 1910-1920; no records were found of any of the readings.

c. Masonry Dam

The downstream surfaces of the masonry dam were wet in several areas as a result of slight seepage through the joints. There were no visible signs of distress or movement.

d. Spillway

At the time of the inspection water was spilling over the spillway section of the masonry dam. Except for some downstream movement of the top row of stones which forms the sill of the spillway, there was no evidence of distress or movement. Inspection of the base of the downstream toe of spillway indicated no signs of scour or other erosion of the rock. There was no evidence of erosion or other sign of distress along the spillway tailrace channel.

e. Appurtenant Structures

There was evidence of cracking at two locations on the face of the retaining wall between the north embankment and the masonry dam. One diagonally trending crack, which traces its way along the joints in the dimension stone facing, is near the low end of the northern leg; the other crack is located near the high end of this north leg. The latter crack is nearly vertical, has a maximum opening of 1/8 inch and traces its way along vertical cracks in the stone blocks as well as along vertical joints; some seepage emerges from the wall at and near the crack.

Some minor seepage was observed in the form of moss covered wet areas below the joints of the lowest courses of stone in the downstream retaining wall for a distance of approximately 25 ft north of the low end of the wall.

There was no evidence of distress or movement of the headwall for the 48 inch outlet pipes below the toe of the dam. In addition to the 48-inch outlets, the headwall contains outlets for a 6-inch pipe which drains

the gate valve vault and also a fourth pipe (approximately 24-inch diameter). The fourth pipe may be that which was reportedly used during construction; it is reported to be closed now by a flap valve.

f. Regulating Gates

As described under SECTION 1, there were two additional gate operating stands, one for each channel, which were not shown on available drawings and that could not be explained by the BOWS Staff. Further, the sluice gate operating stands were labeled contrary to the drawings, with the downstream units marked "bottom", and those immediately upstream pencil marked "top", the reverse order of what was shown on drawings. Again, this contradiction could not be explained by the BOWS staff. Regarding stem positions of the six operating stands, the stem at the middle stand at the left channel was raised (open) 32 inches; the stem at the right upstream stand was raised 5 inches; the stem at the right middle stand was raised 9 inches, and the stems at all other stands were at or near closure.

In the regulating valve vault, the left hand gate valve was in a "cracked" open position, and was inoperable. One connecting post was disengaged from the operating gear cap and the stem packing was leaking appreciably. The right valve was opened enough to discharge minimum flow and was said to be operable. The stem packing was not leaking and no evidence of malfunction was visible.

g. Abutments

There were no signs of seepage or other unusual conditions on the north abutment downstream of the dam. Seepage (5 gpm±) was observed emerging from the ground above the spillway south training wall at a location 40 ft downstream of the spillway and 10 ft south of the wall. This seepage is at the same location as the old stream bed which passes near the toe of the south embankment.

h. Downstream Channel

The channel downstream of the spillway tailrace is the Titicus River. Although the river channel contained trees and heavy bushes, its present condition would not impede discharges from the dam.

i. Reservoir Area

In the vicinity of the dams, there was no evidence of sloughing, potentially unstable slopes or other unusual conditions which would adversely affect the dam.

3.2 EVALUATION OF OBSERVATIONS

Visual observations made during the course of the inspection did not indicate any serious problems which would adversely affect the safety

of the dam and require either immediate investigation or immediate remedial action.

a. The downslope movement of the riprap on the south embankment appears to have resulted from either wave or ice action which may be amplified at that corner location. The riprap should be monitored on a regular basis, after heavy storms and at the end of each winter season.

b. The growth of heavy unmanaged vegetation, especially trees, on the crest and slopes of the embankment should be discouraged.

c. The seepage emerging from the toe of the south embankment is considered to be partly caused by the high ground water level at the old stream bed which passes immediately adjacent to the toe. The toe drain, if one were installed in the original construction, would have lowered the ground water level and the phreatic level in the embankment toe. Clogging of the drain by fine material carried by the stream would cause the phreatic surface to become elevated until it emerged on the toe of the dam. Although this condition is not considered to represent a danger to the dam, measures to improve the wet condition of the toe and to manage the flow of water should be undertaken, as recommended in Section 7.

d. Cracking of the unreinforced masonry retaining walls are not considered to represent a danger to the safety of the dam. The cracks should be monitored on regular basis to determine whether they open further.

e. The inoperable 48-inch gate valve does not, for all practical purposes, reduce the maximum discharge capacity of the facility during high floods. The valve is considered not serviceable and could not be relied on if the reservoir had to be lowered.

SECTION 4: OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 PROCEDURES

The minimum water release at Titicus Dam to satisfy downstream environmental conditions in the river in the short reach between the dam and the Croton Reservoir is 5 mgd. This release is made using the multi-level sluice gates to control which level of the pond the water comes from, and the 48-inch gate valves to control the quantity. It was reported that usually water is taken from mid-level of the reservoir and that the 48-inch gates are always "cracked open" to provide 5 mgd.

4.2 MAINTENANCE OF THE DAM

There is no operation and maintenance manual for the project. The reservoir is visited daily by the watershed inspector who does not necessarily examine the dam or other project features. There is no formally established program of inspection visits by other BOWS personnel.

The embankment dam is maintained only by periodic (yearly, more or less) mowing of the grass slope protection. Maintenance of the north earth embankment appears to be adequate except for the growth of brush at the top of the riprap. Maintenance of the south embankment, which is not as easily accessible, is less than adequate.

No regular maintenance procedures are established for the masonry structure and spillway. The loose top row of stones forming the sill of the spillway should be reset and fixed into position.

4.3 MAINTENANCE OF OPERATING FACILITIES

With the exception of the left regulating valve, the sluice gates and right gate valve appeared operable insofar as equipment was visible. There was confusion, however, regarding which sluice gates would be operated by the various stands in the gate house. All sluice gates, and all gate valves are manually operated.

It was reported that the gates and valves were periodically exercised at approximately yearly intervals until March 1976 when the gate valve was reported broken. The 1973 Annual Report disclosed that "the blow-off gates were closed in January" after the reservoir was drawn down 17 feet to expose aquatic weeds.

4.4 WARNING SYSTEMS IN EFFECT

There is no warning system in effect or in preparation.

4.5 EVALUATION

The maintenance of the Titicus River Dam is considered less than adequate in the following areas:

a. Control of heavy brush and saplings on the surface of the dam.

b. Disrepair of a 48-inch regulating gate.

c. Disrepair of the spillway sill.

In order to clarify the service gate operating procedures, the nature and purpose of all six sluice gate operating stands should be determined by a detailed inspection.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 DRAINAGE AREA CHARACTERISTICS

The drainage areas contributing to the Titicus Reservoir totals 23.35 square miles and is undeveloped except for scattered vacation-type or suburban developments. The physical features, consisting of steep hills and ridges, interspersed with swamps and natural lakes, are typical of a glaciated region. The lakes and swamps are believed to provide substantial natural storage, which in turn would modify peak flood runoff. The elongated shape of the basin, with a length to width ratio of about 2.7 can be expected to cause elongated flood hydrographs with relatively small flood peaks.

5.2 SPILLWAY CAPACITY

The spillway is uncontrolled and 200 feet in length. In shape it consists of a flat crest about 5 feet in width followed by a stepped downstream face. No head-discharge relation was available, so it was necessary to estimate the discharge characteristics. It was assumed that the spillway would act as a broad-crested weir with coefficient increasing from 2.34 to 3.01 between heads of 1 and 8 feet and above 8 feet it would act as a sharp-crested weir with a coefficient of 3.33. The computed spillway rating curve is shown on Figure 1. The computed spillway capacity at a head of 9.0 feet, corresponding to the top of the dam, is 18,000 cfs (789 cfs/sq. mi.).

5.3 RESERVOIR CAPACITY

The total reservoir capacity at the spillway crest is 7,167 million gals (22,000 acre-feet). The storage capacity curve, based on a table furnished by the Department of Water Supply, is shown in the Appendix on Figure 2. The capacity curve has been extrapolated to an elevation corresponding to the top of the dam and indicates a surcharge storage above the spillway crest of 7,160 acre-feet which is equivalent to a runoff depth of 5.89 inches over the drainage area. This is an important factor in considering the adequacy of the spillway capacity to pass design floods.

5.4 FLOODS OF RECORD

Historic data in the Croton River Basin indicate that the greatest floods since the completion of the New Croton Dam in 1905, and probably since completion of the Titicus Dam in 1893 were in August and October 1955. Daily readings of the head on the spillway crest gave the following data on these floods:

Date	Elev. (feet)	Head (feet)	Discharge (cfs)	(cfs/sq. mi.)
Aug. 19, 1955	328.23	3.23	3,100	136
Oct. 16, 1955	330.00	5.00	6,240	274

The flood in August was caused by 7.85 inches of precipitation on August 11-13, inclusive, followed four days later by 5.84 inches on August 17 and 18. The eight day total was 13.73 inches. The October storm was much more concentrated, with 10.20 inches in three days, of which 9.70 inches fell in two days. The discharges per square mile resulting from these extraordinary storms appear to be relatively low and may reflect the retarding effect of the natural and artificial storage.

5.5 OVERTOPPING POTENTIAL

The estimated maximum spillway discharge capacity of 18,000 cfs has been compared with generalized design flood criteria as explained below. The Probable Maximum Flood for the 23.35 mile drainage area has been extrapolated from maps of Probable Maximum Flood potential for selected sizes of drainage area.[2] The smallest drainage area for which floods have been computed was 100 sq. mi. The extrapolation to 23.35 mi. must be considered approximate but indicates a Probable Maximum Flood peak inflow of about 40,000 cfs. or about 2.2 times the spillway discharge capacity.

A second criteria for evaluating a design flood is the Standard Project Flood which is usually about one half of the Probable Maximum Flood. Deviations of Standard Project Floods in the Lower Hudson River Basin are available in a report made for the Corps of Engineers.[3] Data in this report permitted interpolation of the Standard Project Flood for an area of 23.35 square miles and indicated a flood potential of 650 cfs per sq. mi. or a total discharge of 14,800 cfs, or 82 percent of the spillway capacity.

5.6 EVALUATION

The estimated Probable Maximum Flood inflow of 40,000 cfs and the Standard Project Flood inflow of 14,800 cfs must be considered as representing potential inflow to a reservoir from a drainage area that has little natural or

---

(2) Design Basis Floods for Nuclear Power Plants, Regulatory Guide 1.59, U.S. Nuclear Regulatory Commission, Revision 2, August 1977

(3) Lower Hudson River Basin Hydrologic Flood Routing Model, Water Resources Engineer, Inc., January 1977.

artificial storage. To properly evaluate the relation between the Titicus Dam spillway capacity and the probable outflow from these design floods it would be necessary to develop a complete hydrograph and route them through the substantial surcharge storage. A greater refinement would require development of sub-area hydrographs which would be routed through the natural storage in each sub-area. Without these detailed analyses it is not possible to say whether or not the spillway capacity is inadequate relative to the runoff from Probable Maximum Precipitation, but the capacity is obviously adequate to pass the Standard Project Flood.

SECTION 6: STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations

Visual observation did not indicate either existing or potential problems with the masonry dam and spillway section. The observed cracks in the retaining walls are not considered to represent a dangerous condition to either the walls or the embankment dam. The small amount of seepage from the masonry dam are not detrimental to its safety.

The small quantity of seepage emerging from the toe of the south embankment is not detrimental to the stability of the embankment; however, remedial measures to improve the condition should be taken, as recommended in Section 7.

b. Design and Construction Data

There exist no design computations or other data regarding the structural stability of the dam.

On the basis of the performance experience of the embankment dam, as well as engineering judgment, the embankment section of the dam is considered to be stable.

Although there are no design computations available, it is likely that the masonry gravity sections were designed in accordance with the appropriate sections of E. Wegmann's text, DESIGN AND CONSTRUCTION OF DAMS, 6th Edition dated 1918, in which illustrations of Titicus Dam appear. If the gravity sections were designed accordingly, the stability of the gravity section would be considered to be adequate. Performance experience with the maximum water level 5 feet above the spillway crest level is good.

c. Operating Records

Records of gate operation and repairs are available at the Katonah Section Office of the BOWS. No major operational problems which would affect the stability of the dam were reported.

d. Post Construction Changes

There are no recorded post construction changes. However, there is no record of the two additional gate operating stands and stems at the gate house.

e. Seismic Stability

The dam is located in Seismic Zone No. 1, therefore no seismic analyses are warranted.

SECTION 7: ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety

Examination of the available documents and visual inspection of the Titicus Dam and appurtenant structures did not reveal any conditions which are unsafe.

The total discharge capacity of the spillway and regulating gates without overtopping of the dam is approximately 19,200 cfs. This is less than the estimated probable maximum flood (PMF) of 40,000 cfs but greater than the standard project flood of 14,800 cfs, both as determined using the Corps of Engineer's screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the Standard Project Flood.

b. Adequacy of Information

The information and data available were adequate for performance of this investigation. However, there are some inadequacies in information with regard to operation and maintenance of the project, as follows:

1. Record drawings of the project
2. Records of modifications and/or additions of gates at the gate house
3. Operation and maintenace manuals
4. Records of inspections

c. Additional Investigations

Additional investigations to assess the safety of the dam and appurtenant structures do not appear necessary.

7.2 REMEDIAL MEASURES

No remedial measures are required at the present time.

Certain measures, however, are recommended as follows:

a. Monitoring of riprap and cracking of the masonry retaining walls, as called for in Section 3.2, should be initiated and continued on a periodic basis.

b. Heavy brush, shrubs and saplings should be removed from all locations on the embankment dams.

c. Appropriate action should be taken to improve the wet condition of the toe of the south embankment and control the seepage effluent. Such action might include, but not necessarily be limited to, the following items:

1. Determine whether or not the toe drain shown on the available drawings actually exists and is clogged with fines.

2. If the toe drain exists, clean or reconstruct it so that it will perform the intended function.

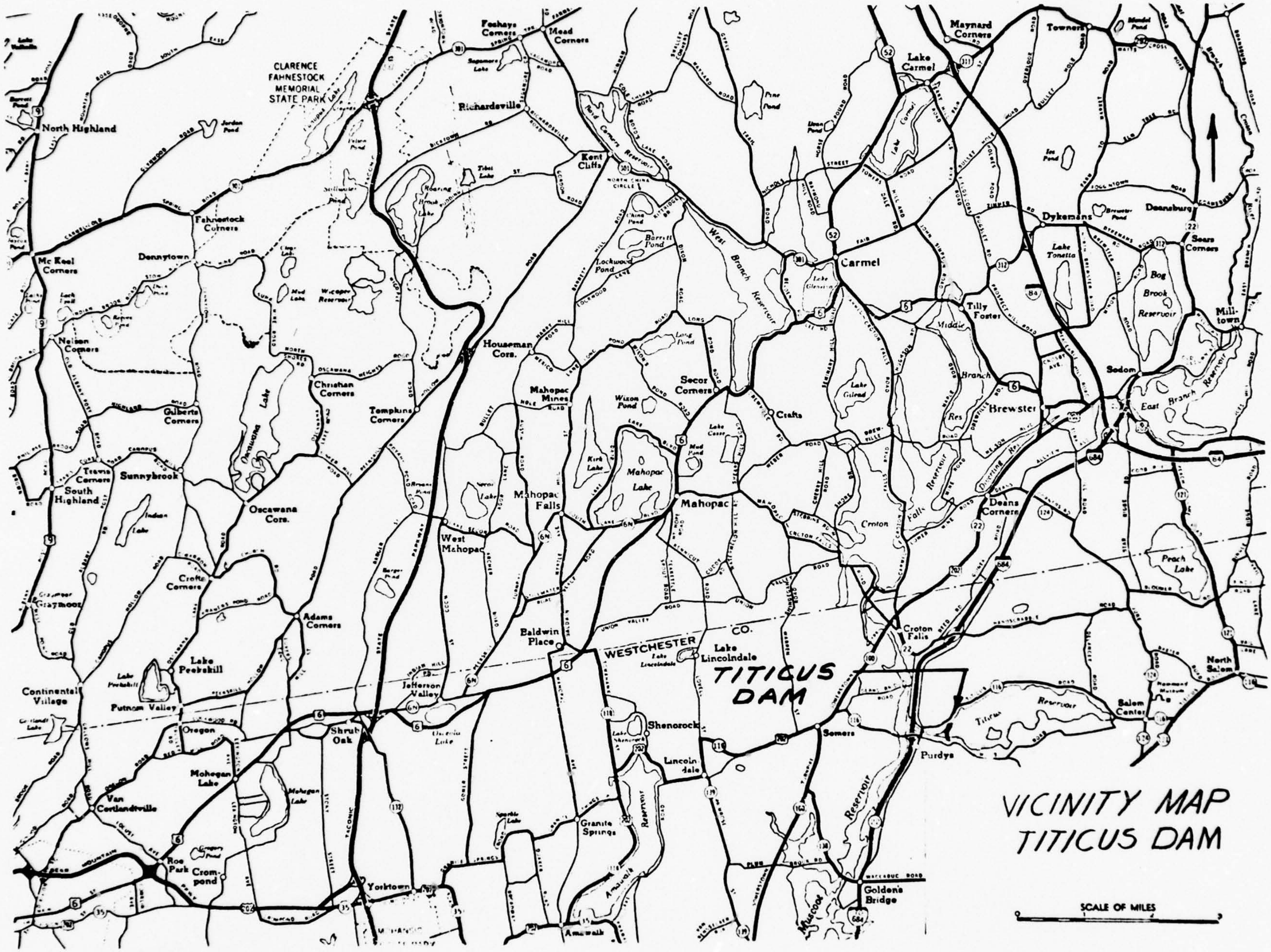
3. Place a filter blanket on the wet portion of the downstream toe.

d. Repair the inoperable 48-inch gate valve.

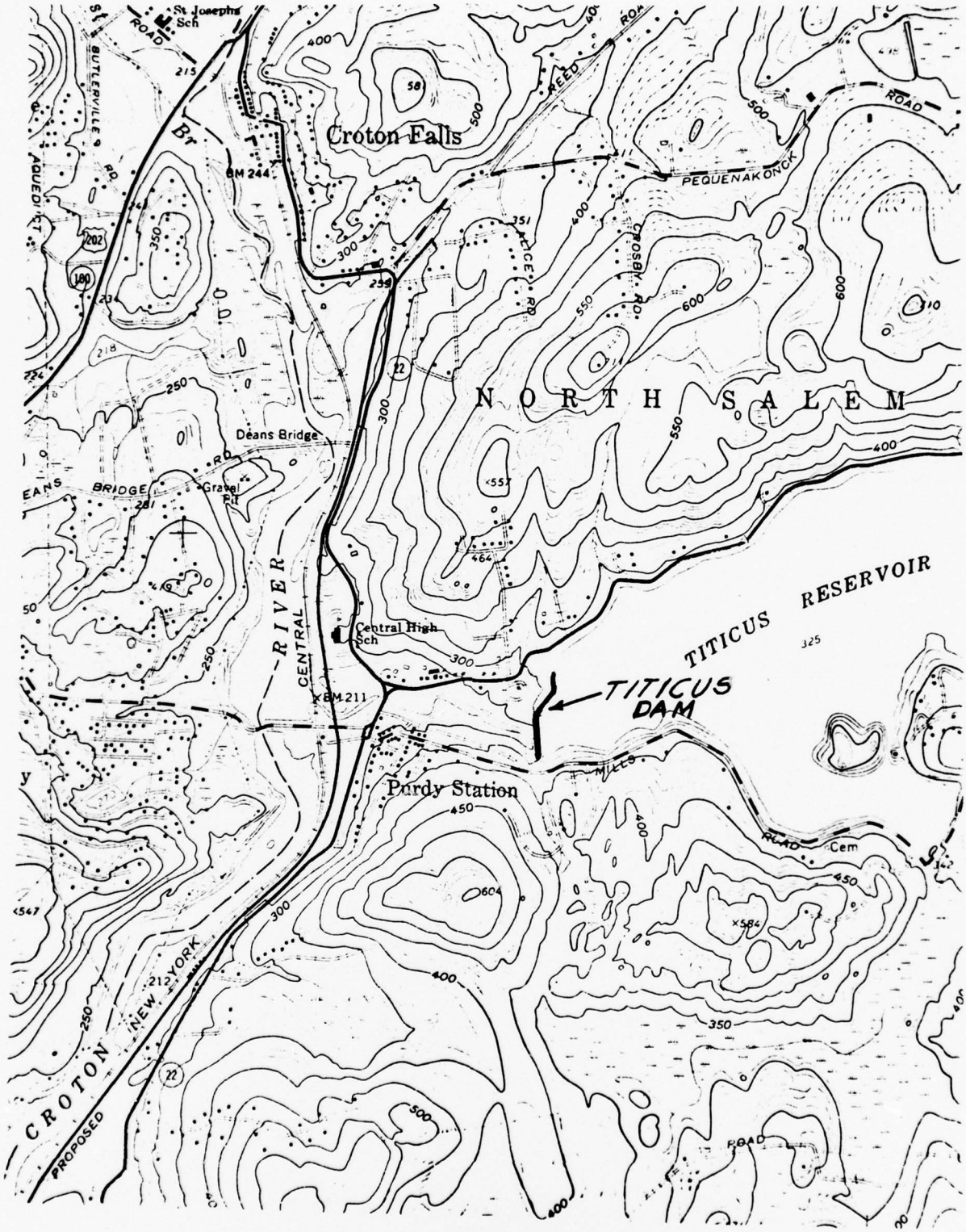
e. Prepare an operation and maintenance manual for the project.

f. Establish a program of periodic inspections of the project features.

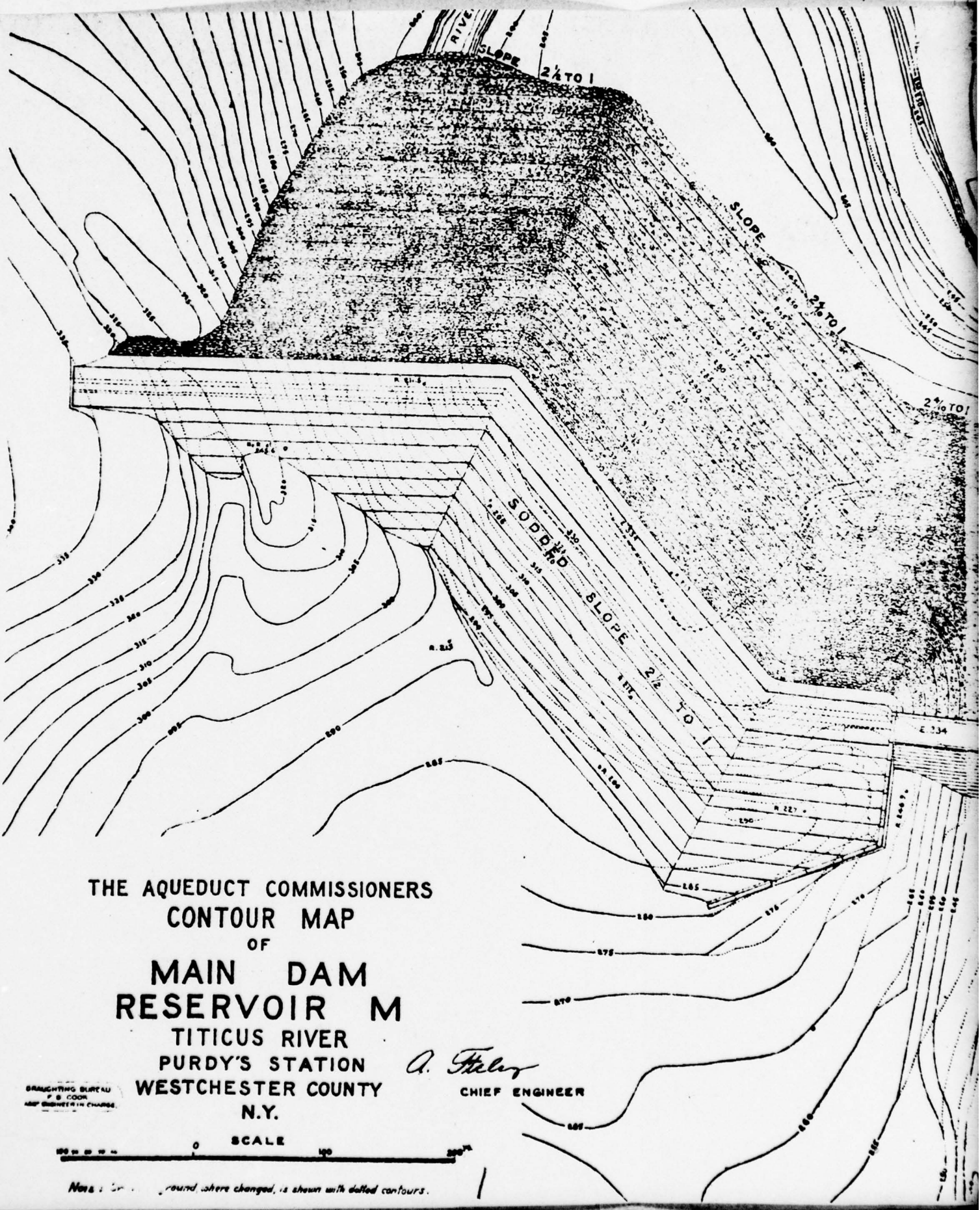
g. Reestablish the piezometric system by opening the "frozen" caps, straightening the bent standpipes, and make periodic piezometric measurements on a regular basis thereafter as part of standard maintenance and operation procedures. Piezometric measurements should be evaluated as part of the periodic inspection program.



VICINITY MAP
TITICUS DAM



TOPOGRAPHIC MAP
TITICUS DAM AND RESERVOIR



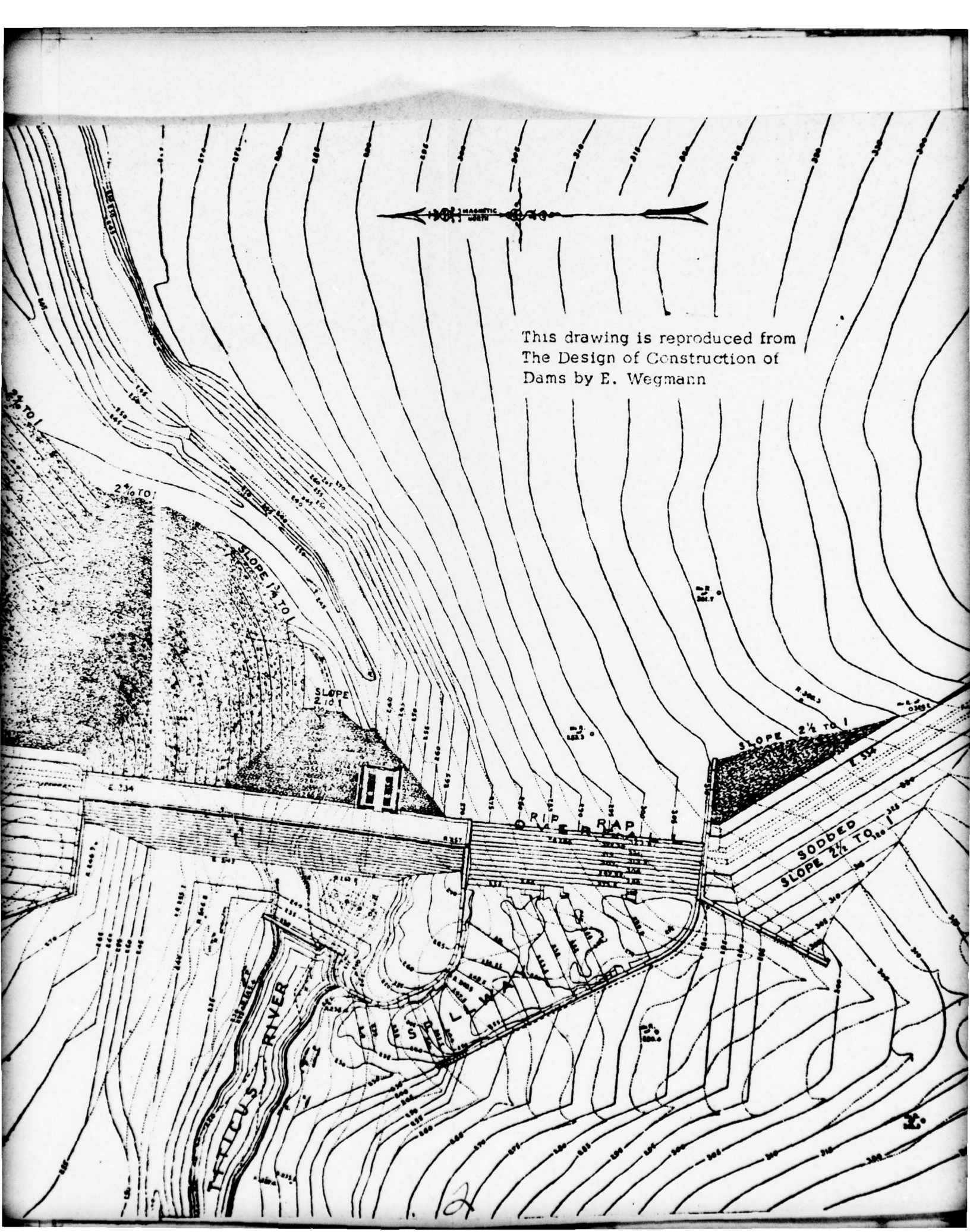
THE AQUEDUCT COMMISSIONERS
CONTOUR MAP
OF
MAIN DAM
RESERVOIR M
TITICUS RIVER
PURDY'S STATION
WESTCHESTER COUNTY
N.Y.

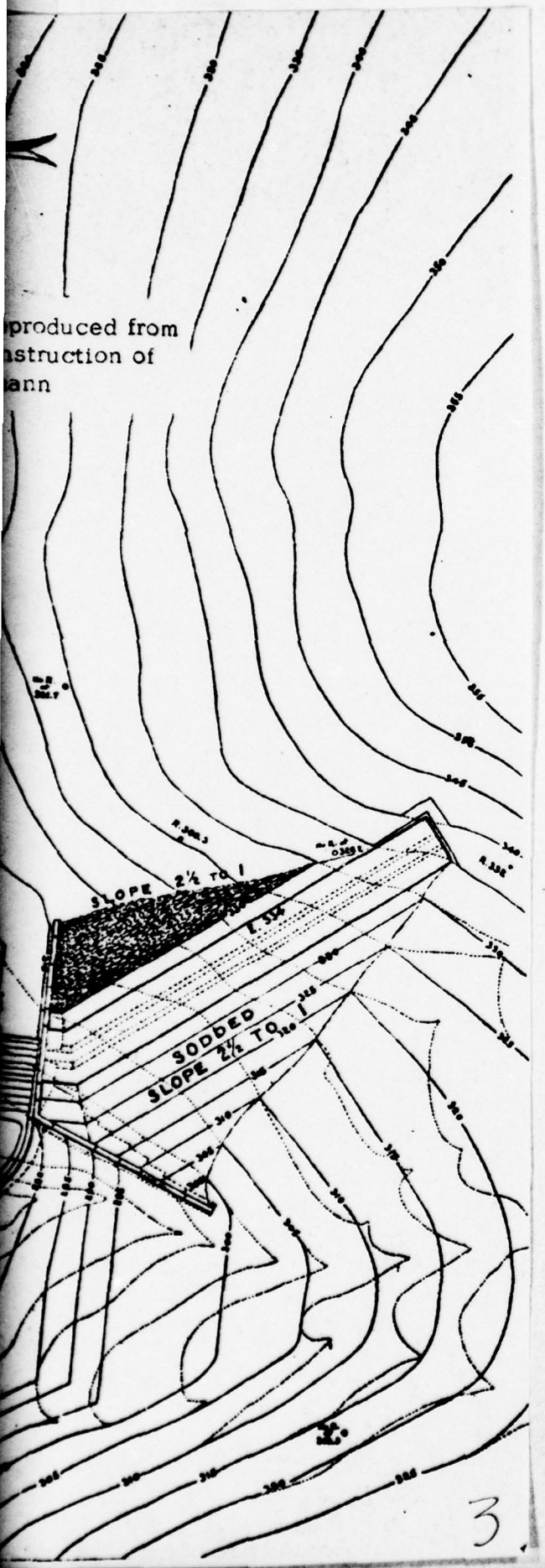
DRAUGHTING BUREAU
F. S. COOK
ASST. ENGINEER IN CHARGE

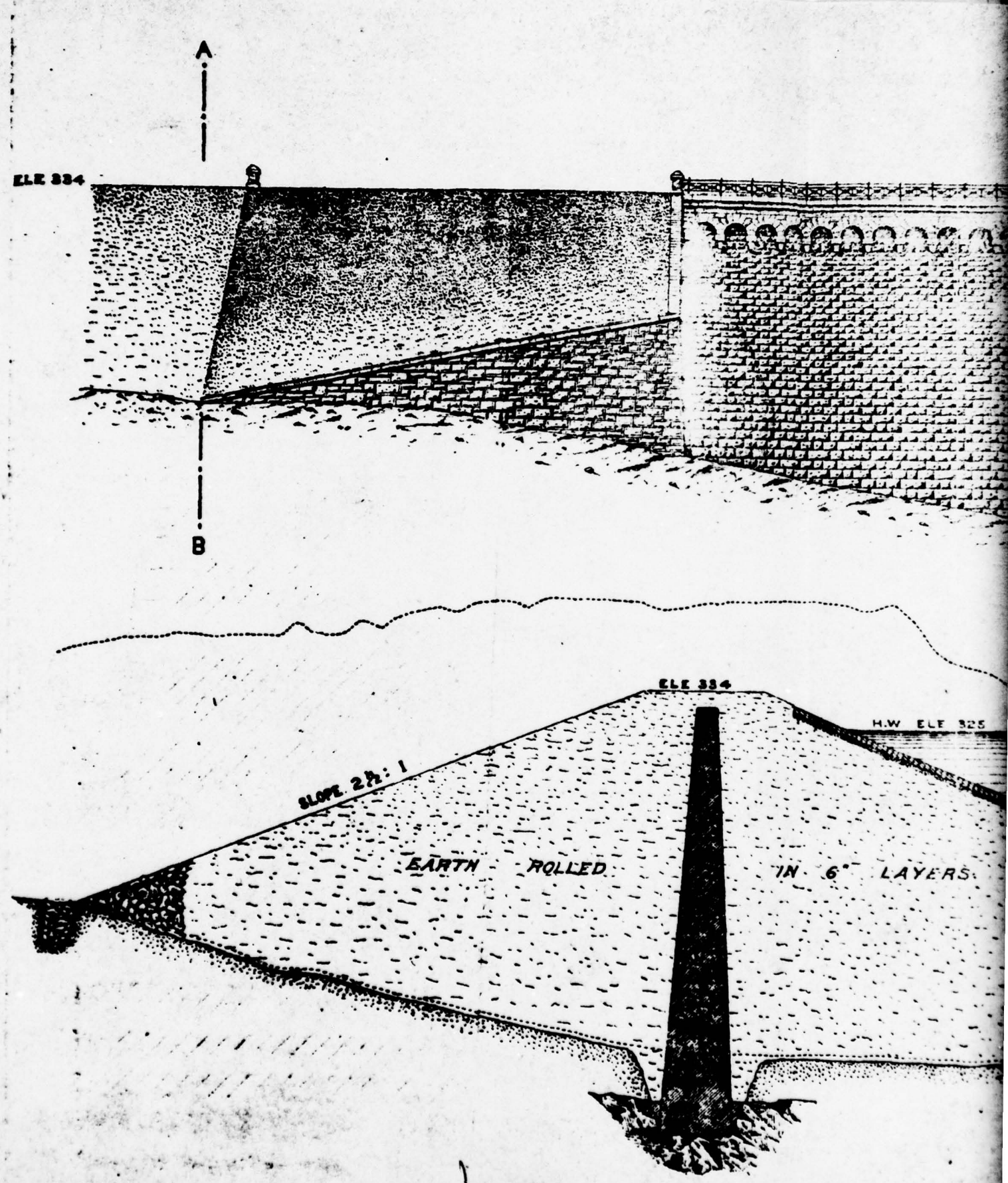
A. Fteley
CHIEF ENGINEER

SCALE
0 100 200 Ft.

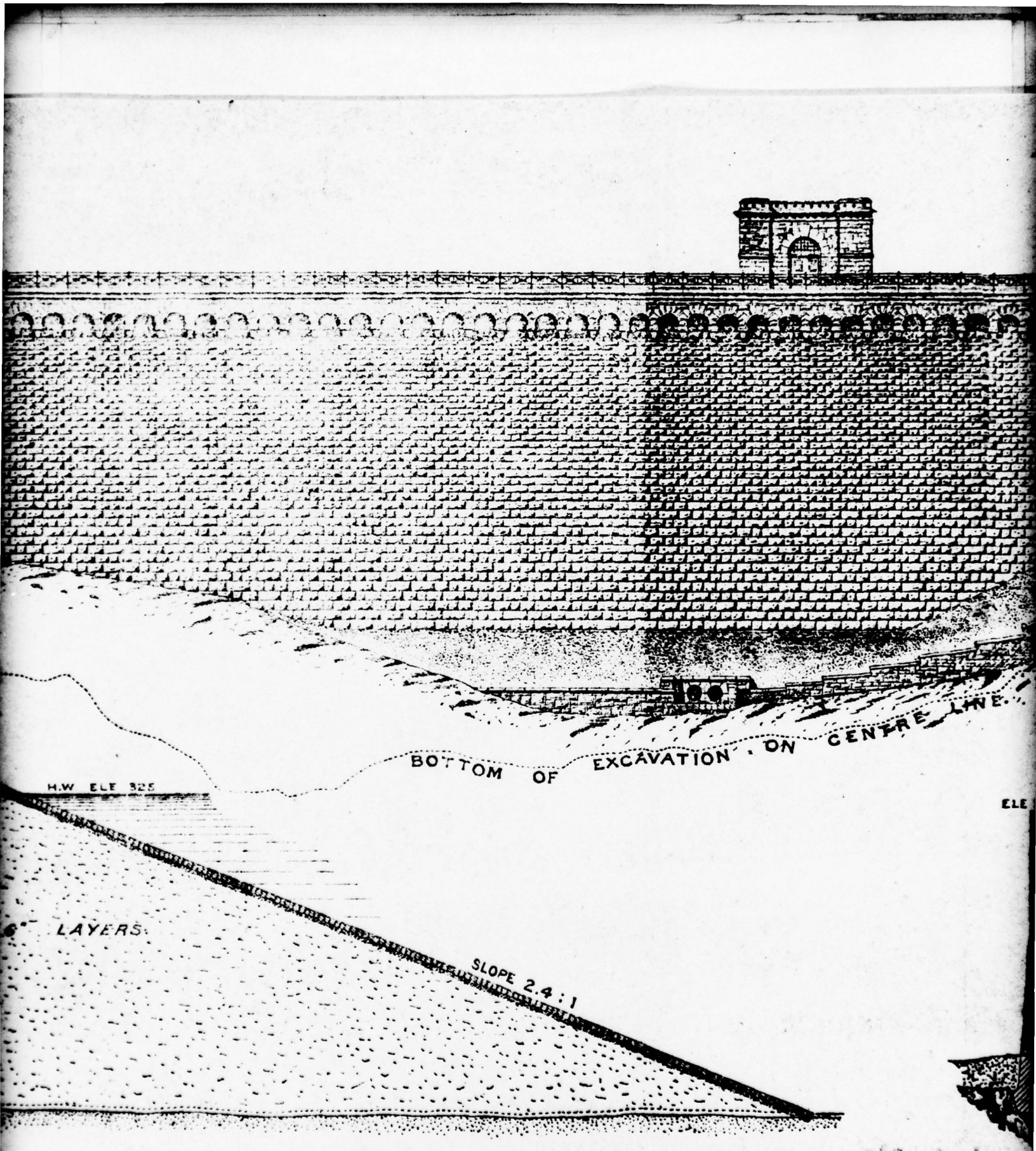
Note: [illegible] ground where changed, is shown with dotted contours.

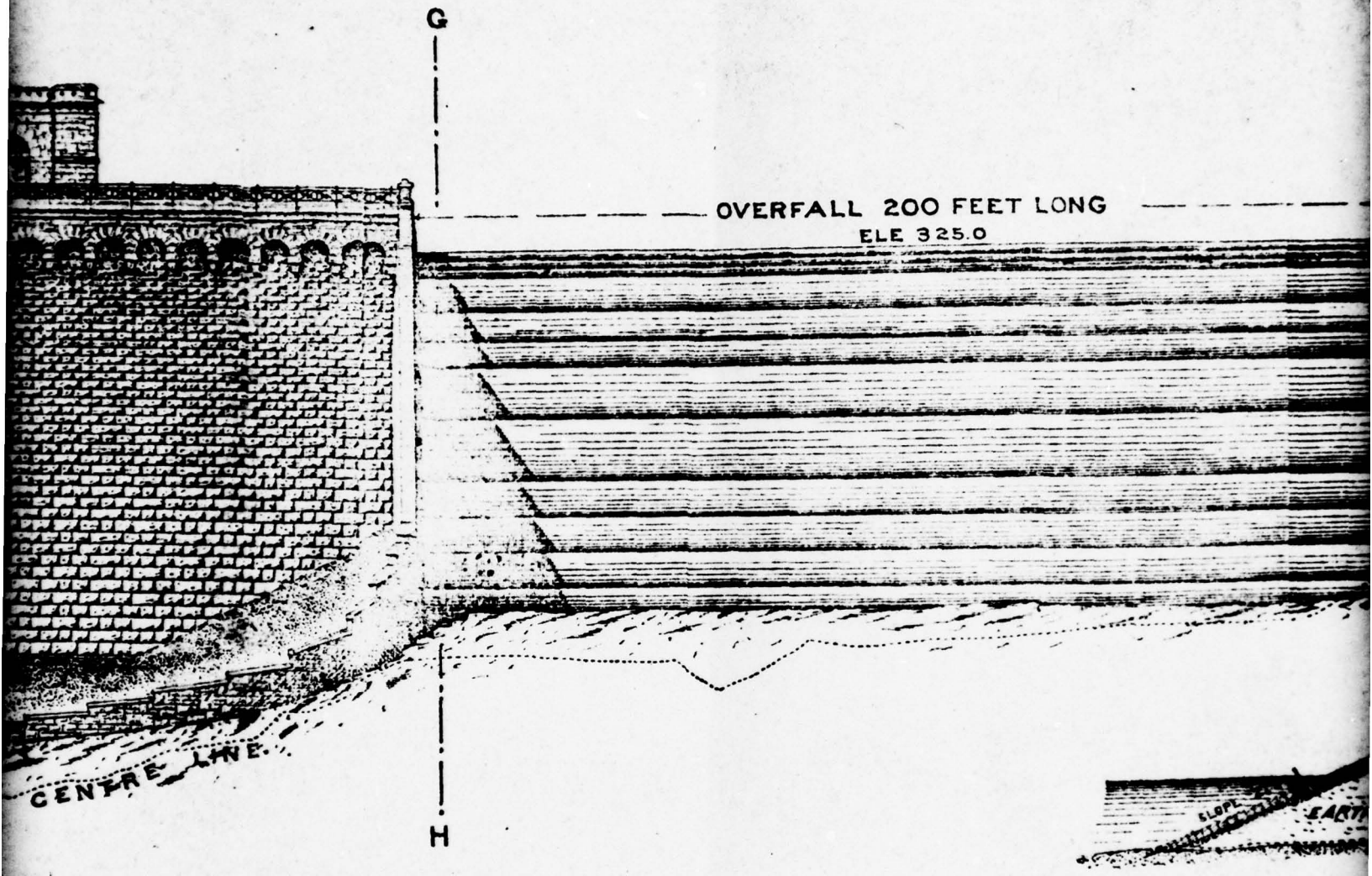

This drawing is reproduced from
The Design of Construction of
Dams by E. Wegmann
MAGNETIC NORTH
2¼ TO 1
SLOPE 2 TO 1
SLOPE 1¾ TO 1
SLOPE 2 TO 1
SLOPE 2½ TO 1
RIP RAP
RIP RAP
SODDED
SLOPE 2½ TO 1
TTICUS RIVER
12

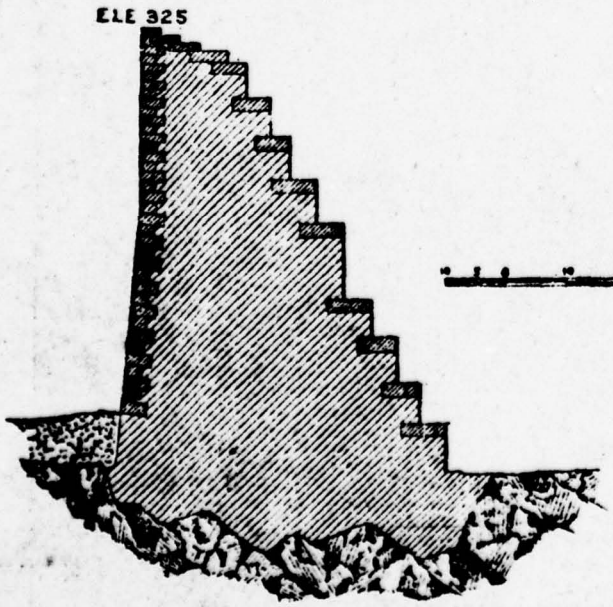

produced from
nstruction of
lann
SLOPE 2½ TO 1
SODDED
SLOPE 2½ TO 1


A
ELE 334
B
ELE 334
H.W ELE 325
SLOPE 2½ : 1
EARTH ROLLED IN 6" LAYERS.

SECTION A B


BOTTOM OF EXCAVATION ON CENTRE LINE.
H.W ELE 325
LAYERS.
SLOPE 2.4 : 1



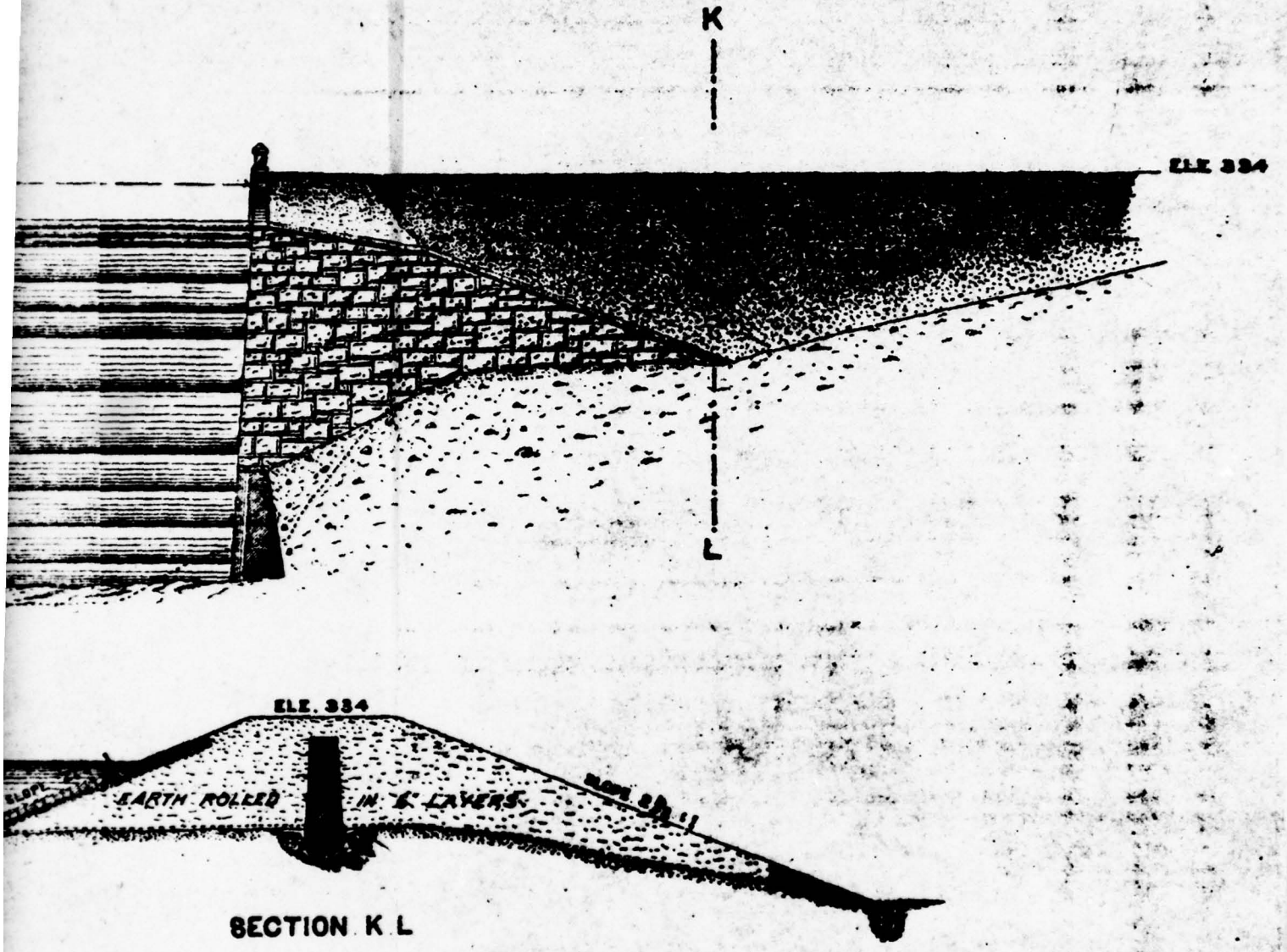


SCALE.

0 5 10 20 30 40 50 60 70 80 90 100 FEET.

SECTION G H.

This drawing is reproduced from The Design of Construction of Dams by E. Wegmann

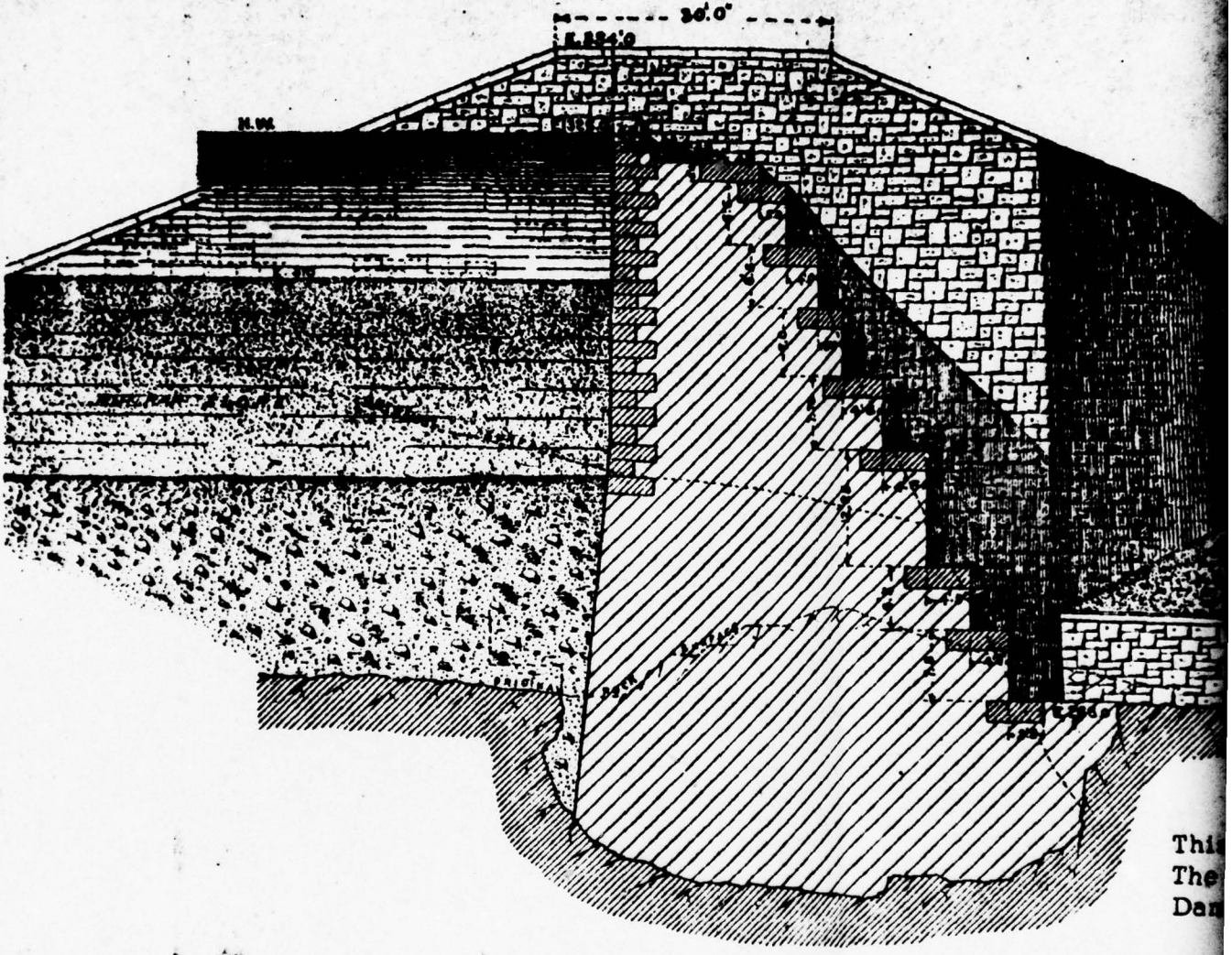


SECTION K L

THE AQUEDUCT COMMISSIONERS
ELEVATION AND SECTIONS
OF
MASONRY DAM
RESERVOIR "M"
TITICUS RIVER
PURDYS STATION
WESTCHESTER COUNTY N.Y.

A. Fteley
CHIEF ENGINEER.

4



SECTION AT CENTER OF OVERFALL

SCALE

0 1 2 3 4 5 6 7 8 9 10 20 30 40

This
The
Dam

THE AQUEDUCT COMMISSIONERS

RESERVOIR M

ON

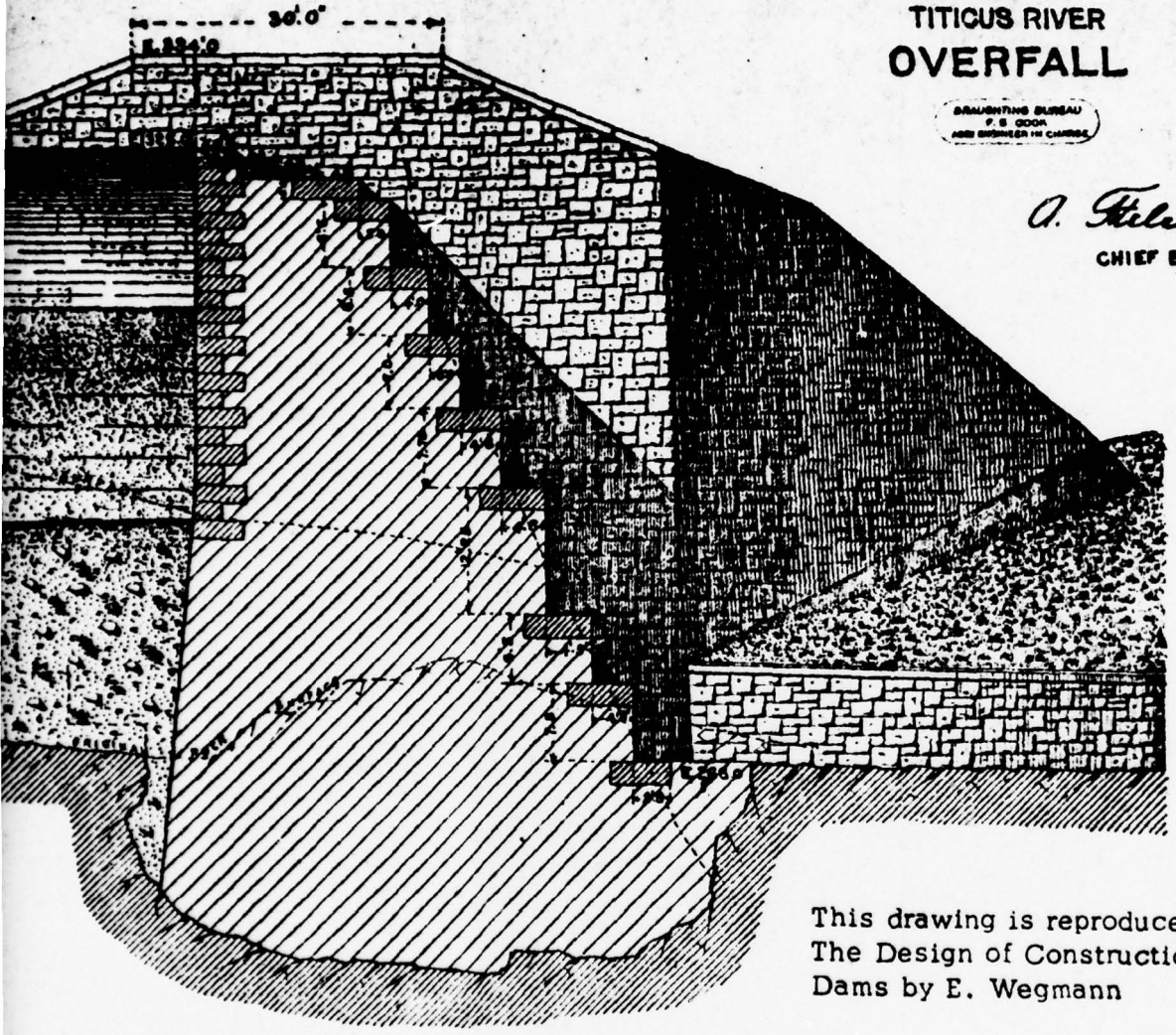
TITICUS RIVER

OVERFALL

DRAUGHTING BUREAU
F. S. ODOR
ASST. ENGINEER IN CHARGE

A. Fteley

CHIEF ENGINEER.



This drawing is reproduced from The Design of Construction of Dams by E. Wegmann

SECTION AT CENTER OF OVERFALL

SCALE

0 10 20 30 40

2

This drawing is reproduced from The Design of Construction of Dams by E. Wegmann

THE AQUEDUCT COMMISSIONERS

RESERVOIR M

ON

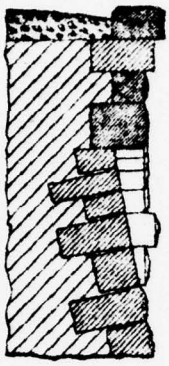
TITICUS RIVER

MASONRY DAM

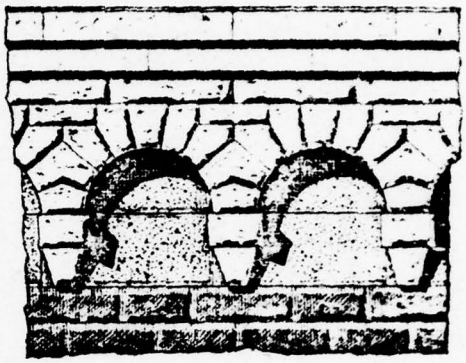
PRINCIPAL SECTION

DRAUGHTING BUREAU
F.S. COOP
ASST. ENGINEER IN CHARGE.

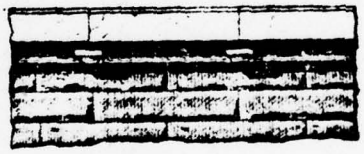
A. Fteley
CHIEF ENGINEER



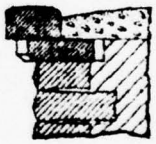
SECTION



FRONT ELEVATION



REAR ELEVATION



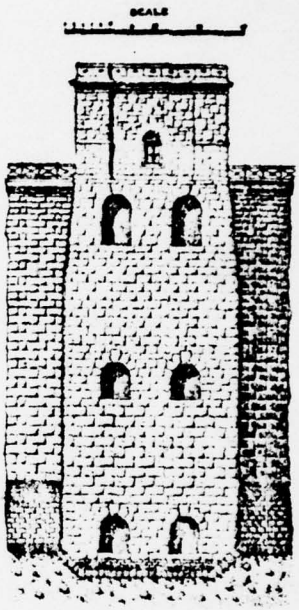
SECTION

SCALE FOR DETAILS

SECTION OF MASONRY DAM

THE AQUEDU
RE
TI
MA
GAT

This drawing is reproduced from
The Design of Construction of
Dams by E. Wegmann



ELEVATION OF GATE HOUSE

SECTION OF GATE HOUSE DAM & VAUL

THE AQUEDUCT COMMISSIONERS

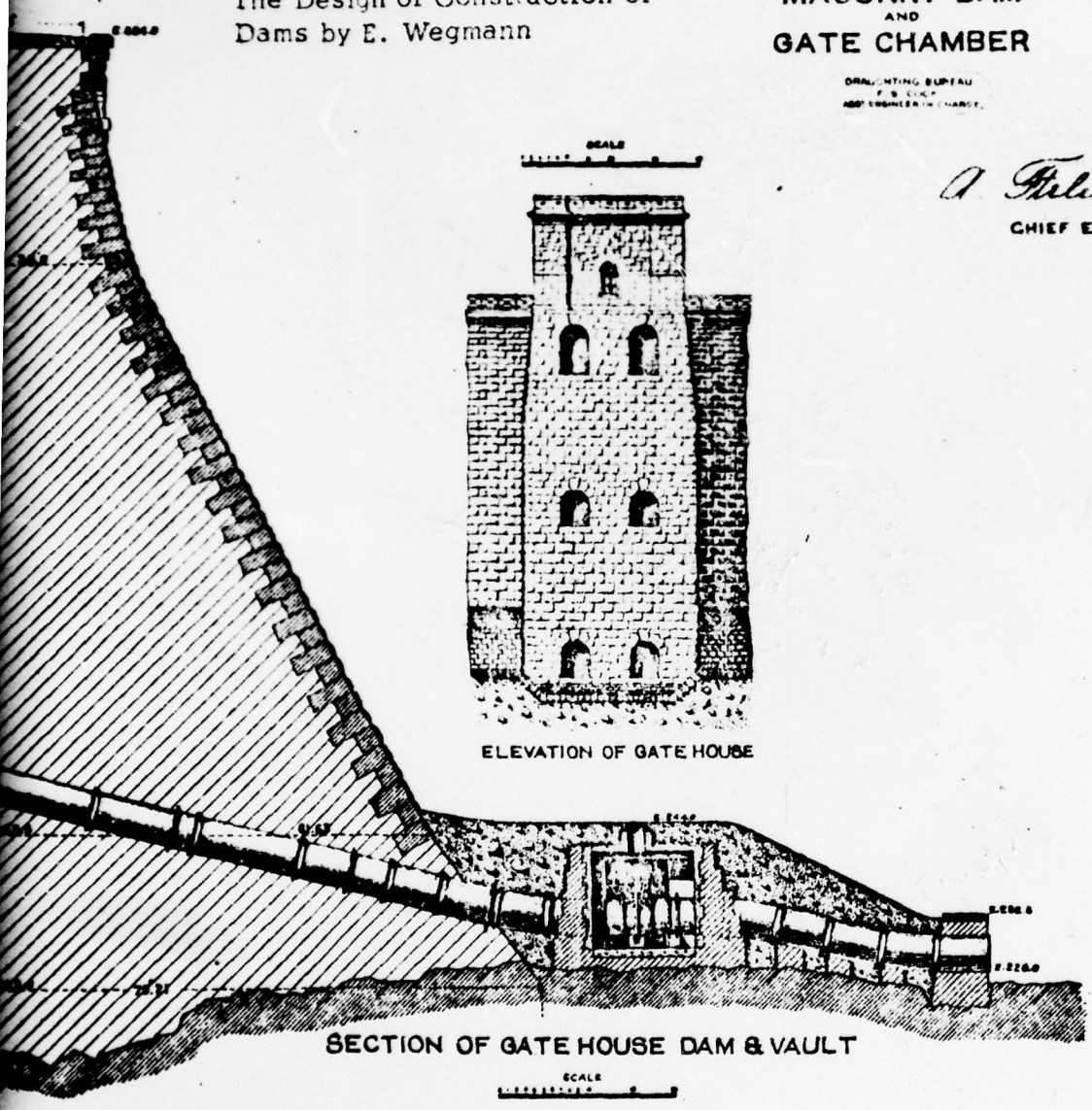
RESERVOIR M
ON
TITICUS RIVER

MASONRY DAM
AND
GATE CHAMBER

This drawing is reproduced from
The Design of Construction of
Dams by E. Wegmann

DRAUGHTING BUREAU
F. S. CHIEF
ASST. ENGINEER IN CHARGE.

A. Fteley
CHIEF ENGINEER



ELEVATION OF GATE HOUSE

SECTION OF GATE HOUSE DAM & VAULT

SCALE

2

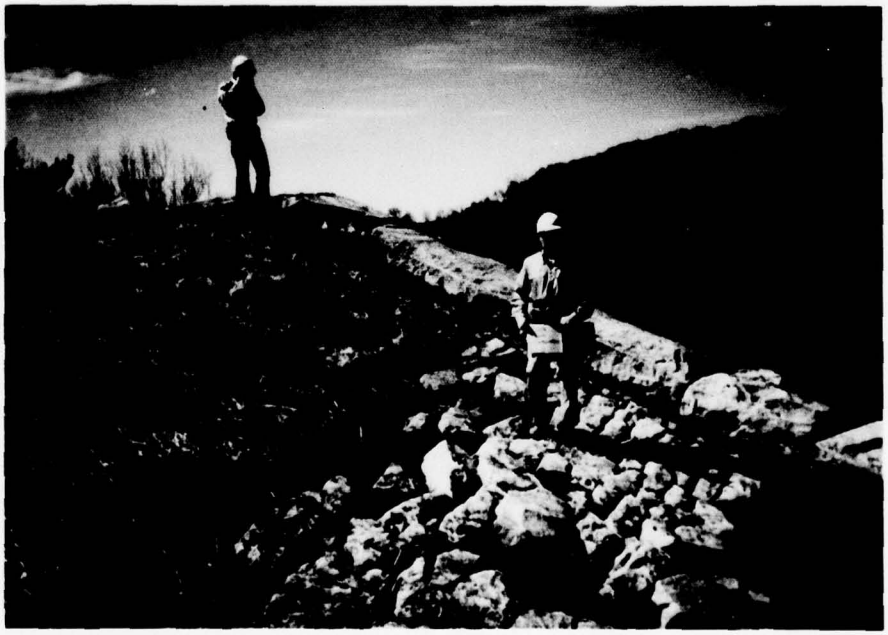
PHOTOGRAPHS

APPENDIX A

GATE OPERATING STANDS, SOUTH DIVISION OF GATEHOUSE

GATE OPERATING STANDS, NORTH DIVISION OF GATEHOUSE

SEPARATION OF RIPRAP FROM S. SPILLWAY APPROACH WALL, SOUTH EMBANKMENT



DOWNSLOPE MOVEMENT OF RIPRAP, SOUTH EMBANKMENT

UPSTREAM SLOPE OF NORTH EMBANKMENT

DOWNSTREAM SLOPE OF SOUTH EMBANKMENT

BROKEN 48-INCH GATE VALVE, SIDE VIEW

BROKEN 48-INCH GATE VALVE, FROM ABOVE

SEEPAGE AREA AT TOE OF SOUTH EMBANKMENT

ENGINEERING DATA CHECKLIST

APPENDIX B

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM TITICUS

ID # 50

ITEM	REMARKS
AS-BUILT DRAWINGS	None available. Drawings available include "Contract Drawings" dated Sept 11, 1889 which were modified. Most accurate drawings are found in Wegmann "Design and Const. of Dams", 1918
REGIONAL VICINITY MAP	USGS
CONSTRUCTION HISTORY	Described in Wegmann, "Design and Const of Dams", 1918
TYPICAL SECTIONS OF DAM	As above, Typical Section's
OUTLETS-PLAN	Schematics and sketches in Wegmann's book.
-DETAILS	Some details of gate valves in contract drawings on file with BOWS
-CONSTRAINTS	None available
-DISCHARGE RATINGS	None available.
RAINFALL/RESERVOIR RECORDS	Available from Katonah office, BOWS Max flood Oct 16, 1955

ITEM	REMARKS
DESIGN REPORTS	None available
GEOLOGY REPORTS	None available
DESIGN COMPUTATIONS	None available
HYDROLOGY & HYDRAULICS	None available
DAM STABILITY	None available
SEEPAGE STUDIES	None available from BOWS
MATERIALS INVESTIGATIONS	None available
BORING RECORDS	None available
LABORATORY	None available
FIELD	None available
POST-CONSTRUCTION SURVEYS OF DAM	Not available
BORROW SOURCES	No data available

ITEM	REMARKS
MONITORING SYSTEMS	None in use. Some piezometers were installed in early 1900's (1910±) but have not been read recently
MODIFICATIONS	Some modifications to Gatehouse valving. All drawings show 4 gates. Gatehouse contains 6 gate stands (hoists) and stems. No record of modification or location of all gates.
HIGH POOL RECORDS	Available at BOWS Katonah Section Office
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	None None available
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None reported
MAINTENANCE	No formal program or schedule
OPERATION	Little operation
RECORDS	Record kept of opening and closing of gates

Note: No O&M Manual

ITEM	REMARKS
SPILLWAY PLAN	Part of Drawings found in Wegmann's book
SECTIONS	As above
DETAILS	
OPERATING EQUIPMENT	Schematics in Wegmann's book
PLANS & DETAILS	Details are in "Contract Dwgs" dated, 1899

VISUAL INSPECTION CHECKLIST

APPENDIX C

VISUAL INSPECTION CHECKLIST

1. Basic Data

a. General

Name of Dam TITICUS Hazard Category HIGH

County WESTCHESTER ID# 50

Stream Name TITICUS RIVER Tributary of CROTON

Location WESTCHESTER County Nearest Town (P.O.) PURDYS STA

Longitude 73° 38' 45" ± Latitude 41° 19' 30" ± Other Directions

Located in Town of North Salem

Date of Insp 24 Apr 1978 Weather Partly Sunny Temperature 65° F

b. Inspection Personnel John Burdick, Mech. Eng; Glen Gaydar, Mech Eng.; Anatol Lange, Structural Eng; Harvey Feldman, Geotechnical Eng; Anthony Dolcimascolo, Geotech. Eng. - All with TAMS

c. Persons Contacted Mr. Carl Picha, District Eng, East of Hudson District, NYC-BOWS
Mr. John Byrnes, Section Engineer, Katonah Section

d. History: Date Constructed Feb 18, 1890 - Jan 1, 1895

Present Owner Bureau of Water Supply N.Y.C

Designed by Aqueduct Comm. N.Y.C.

Constructed by Washburn, Shaler & Washburn

Recent History —

2. Technical Data Masonry & Earth Embank

Type of Dam Earth Embank Drainage Area 23.35 sq. mi. ~~Acres~~

Height 135' above Found. Length 1519 ft

Upstream Slope 1(V):2.5(H) Downstream Slope 1(V):2.5(H) Earth Embank

Crest Width 30 ft-Earth Freeboard at Spillway Crest 9 ft
20.7ft-Masonry

Low Level Control: (Type and Size) Multi level Sluice gates & overflow weir, with inlet & outlet chambers of gate house: Two 48 inch gate valves in vault Sluice gate Number & Condition ?

Valve Condition One gate valve inoperable

~~Emergency~~ Spillway Type (Material) Masonry Width 200 ft

Only one service spillway, no emergency spillway

Side Slopes Vertical U/S ; Stepped D/S

Height (Crest to Top) 9 ft

Exit Slope 0.2± from base of masonry to river

Exit Length 200ft ±

Ponded Surface Area 669.4 Acres

Capacity (Normal Level) 22,000 Acre Feet

Capacity Emergency Spillway Level ___ Acre Feet

3. Embankment

North portion 732 ft ; South portion 253 fl long

a. Crest 30 ft wide (El 334 Croton Datum)

(1) Vertical Alignment Uniform, with crest El 334 some minor depressions and rutting, apparently not result of settlements

(2) Horizontal Alignment Inverted "S" dogleg in north embankment, Straight south portion

(3) Longitudinal Surface Cracks None visible

(4) Transverse Surface Cracks None visible

(5) General Condition of Surface Grassed surface, generally in good condition with occasional shrubs on south portion of embankment crest

(6) Miscellaneous

b. Upstream Slope 1(V) : 2.5(H) uniform
covered with riprap paving below El 330

(1) Undesirable Growth or Debris Some small shrubs just above top layer of riprap

(2) Sloughing, Subsidence, or Depressions Apparent u/s (downslope) movement of riprap paving stones for approx 25 ft south of spillway approach wall

(3) Slope Protection Hand placed riprap stone below El 330 ±, stones avg 1.5'x1.0'x1'

(a) Condition of Riprap Generally good, except for 25ft section on south embank. abuting spillway approach wall, 9 inch u/s movement

(b) Durability of Individual Stones Good

(c) Adequacy of Slope Protection Against Waves and Runoff
Apparently good – little or no damage

(d) Gradation of Slope Protection - Localized Areas of Fine Material
Uniform size stone; generally 1.5 ft x1.0 ft x0.5 to 1.0 ft. Riprap paving 18 inches thick.

(4) Surface Cracks None visible

c. Downstream Slope 1(V) : 2.5(H), grassed

(1) Undesirable Growth or Debris Small saplings, shrubs & heavy brush on south embank. D/S slope; north embankment well maintained

(2) Sloughing, Subsidence, or Depressions; Abnormal Bulges or Non-Uniformity

None visible

(3) Surface Cracks on Face of Slope None visible

(4) Surface Cracks or Evidence of Heaving at Embankment Toe

None visible

(5) Wet of Saturated Areas or Other Evidence of Seepage on Face of Slope; Evidence of "Piping" or "Boils" None on north embankment; seepage from south embank. toe at intersection of toe and retaining wall saturated embank area 6' x 40' (120 sq ft ±)

(6) Fill Contact with Outlet Structure Contacts with all structures generally good

(7) Condition of Grass Slope Protection generally good on north embankment; overgrown on south embankment

d. Abutments

(1) Erosion of Contact of Embankment with Abutment from Surface Water Runoff, Upstream or Downstream

None

(2) Springs or Indications of Seepage Along Contact of Embankment with the Abutments Seepage emerging from contact at south embankment for distance of 40 ± ft south of end of retaining wall. Seepage also from lower 3 ft ± of masonry retaining wall for 25 ±

(3) Springs or Indications of Seepage in Areas a Short Distance Downstream of Embankment - Abutment Tie-in Seepage of 5± gpm emerging from ground above spillway south training wall approx 40 ft D/S of spillway and 10' south of wall. Old stream?

e. Area Downstream of Embankment, Including Tailrace Channel

This area includes Titicus River valley.

(1) Localized Subsidence, Depressions, Sinkholes, Etc. None visible except for depression made by caving of top of 2'x2' masonry line vault north of gate vault below masonry dam

(2) Evidence of "Piping" or "Boils" None

(3) Unusual Presence of Lush Growth, such as Swamp Grass, etc.

None

(4) Unusual Muddy Water in Downstream Channel NO

(5) Sloughing or Erosion None; except for some minor erosion near toe of southembank, Could be stream!?

(6) Surface Cracks or Evidence of Heaving Beyond Embankment, Toe

None

(7) Stability of Tailrace Channel Sideslopes Low masonry walls line channel and serve as training walls. generally in good condition.

(8) Condition of Tailrace Channel Riprap No riprap; floor of channel is sound rock

(9) Adequacy of Slope Protection Against Waves, Currents and Surface Runoff

(10) Miscellaneous

f. Drainage System No drains for dam; 6" diameter drain for gate valve vault operating

(1) Condition of Relief Wells, Drains and Appurtenances No relief wells or drains

(2) Unusual Increase or Decrease in Discharge from Relief Wells Not applicable

4. Instrumentation

(1) Monumentation/Surveys None

(2) Observation Wells NONE

(3) Weirs NONE

(4) Piezometers Old piezometers found in earth dam, some have been bent; most are capped with caps frozen in place by corrosion. None in north embank.; three in south embankment. One was sounded to water (depth of 23'-3" at piezometer ~~(Other)~~ located 55' north measured along wall from dogleg in north D/S retaining wall and 13.5 east of wall ⊥.)

5. Reservoir

Inspected from dam and USGS topo.

a. Slopes Visible slopes in vicinity of dam are gentle

b. Sedimentation

6. Spillways

Only one spillway which is service spillway

a. Principal Spillway: Inlet Condition —

Pipe Condition —

General Remarks (include information such as recently repaired, potential for debris accumulation, special items of note, etc.)

Service Spillway is masonry and ungated stepped (or ladder) downstream face Top row of stone (sill) loose and slightly shifted as a result of ice pressure

b. Emergency Spillway: General Condition

Tree Growth

Erosion

Other Observations

7. Structural (if required) See Attached Appendix

See attached Appendix for structural comments

8. Downstream Channel

D/S Channel is Titicus River Valley

a. Condition (obstructions, debris, etc.)

No major debris which would be considered unusual

b. Slopes

c. Approximate No. Homes and Population limited number of structures in flood plain at Purdys station include ambulance corps garage, Boxtree restaraunt and one or two adjacent small buildings

d. General

A. Dolamascolo
TEAM CAPTAIN

STRUCTURAL INSPECTION CHECKLIST

PHASE I DAM INSPECTION

1. Concrete Surfaces Masonry surfaces of dam are generally good; some leaching in many areas. Leaching has sealed joints in other areas
2. Structural Cracking Retaining wall between north embank and masonry dam on D/S leg of wall. Minor cracking at stone joints in gate house
3. Movement - Horizontal and Vertical Alignment None visible
4. Junctions with Abutments or Embankments Generally good except at spillway left approach wall, where there is 3-9" gap between riprap and wall
5. Drains - Foundation, Joint, Face None under Masonry dam, Some seepage from D/S retaining walls; from cracks & weep holes on north side, from joints on south side
6. Water Passages, Conduits, Sluices Water passages could not be inspected.
7. Seepage or Leakage D/S face of retaining walls as per 5. above. Also on D/S face of masonry wall at toe of south embankment for 20 ft.
8. Monolith Joints - Construction Joints —
9. Foundation Not visible, Masonry dam founded on rock

10. Abutments

11. Control Gates Visible portion of gate stems, stands, hoists etc in generally good condition

12. Approach and Outlet Channels Not applicable

13. Stilling Basin Not applicable

14. Intake Structure

15. Settlement No differential settlement visible at structures

16. Stability
    a. Overturning Calculations not required for phase I
    b. Sliding " " " " "
    c. Seismic Zone I - No analysis required

17. Instrumentation No instrumentation
    a. Alignment
    b. Uplift
    c. Seismic

18. Miscellaneous

HYDROLOGIC DATA AND COMPUTATIONS

APPENDIX D

TIPPETTS-ABBETT-McCARTHY-STRATTON
ENGINEERS AND ARCHITECTS NEW YORK

Job No. 1477 Sheet ___ of ___
Project Tillery Dam Date 5/21/76
Subject Spillway Rating Curve By GRW
Ch'k. by ___

Spillway Rating Curve ; Length = 200'
Top width = 5'±

Head	C	Q	
1	2.34	468	
2	2.65	1499	
3	2.66	2764	
4	2.70	4320	
5	2.79	6239	
6	2.88	8465	
8	3.01	13620	
9.0	3.33	17980	Top of dam

Floods of Record

Date	Elev. (Croton)	Head	Q
Aug. 19, 1955	328.23	3.23	3100
Oct. 16, 1955	330.00	5.00	6240

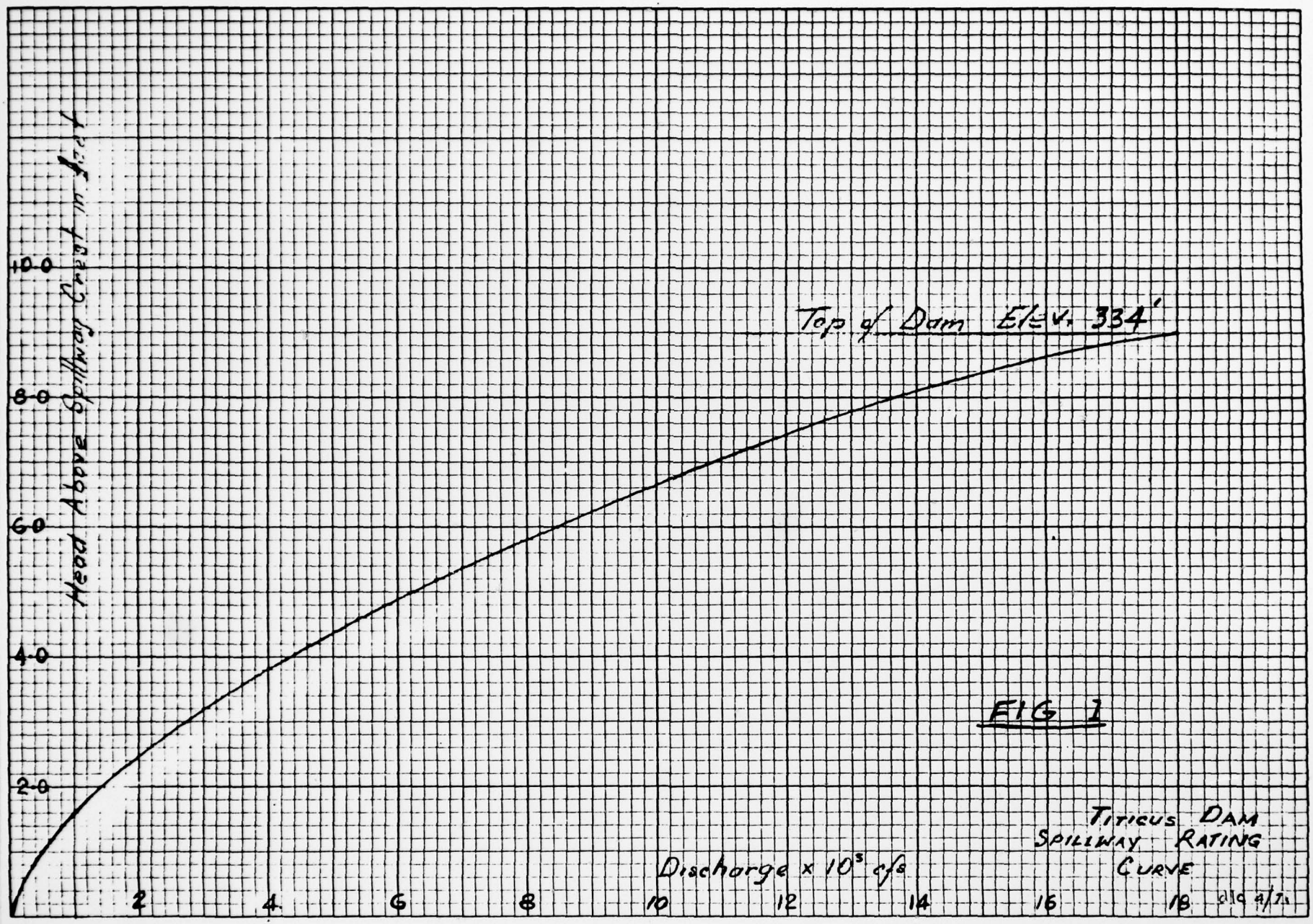
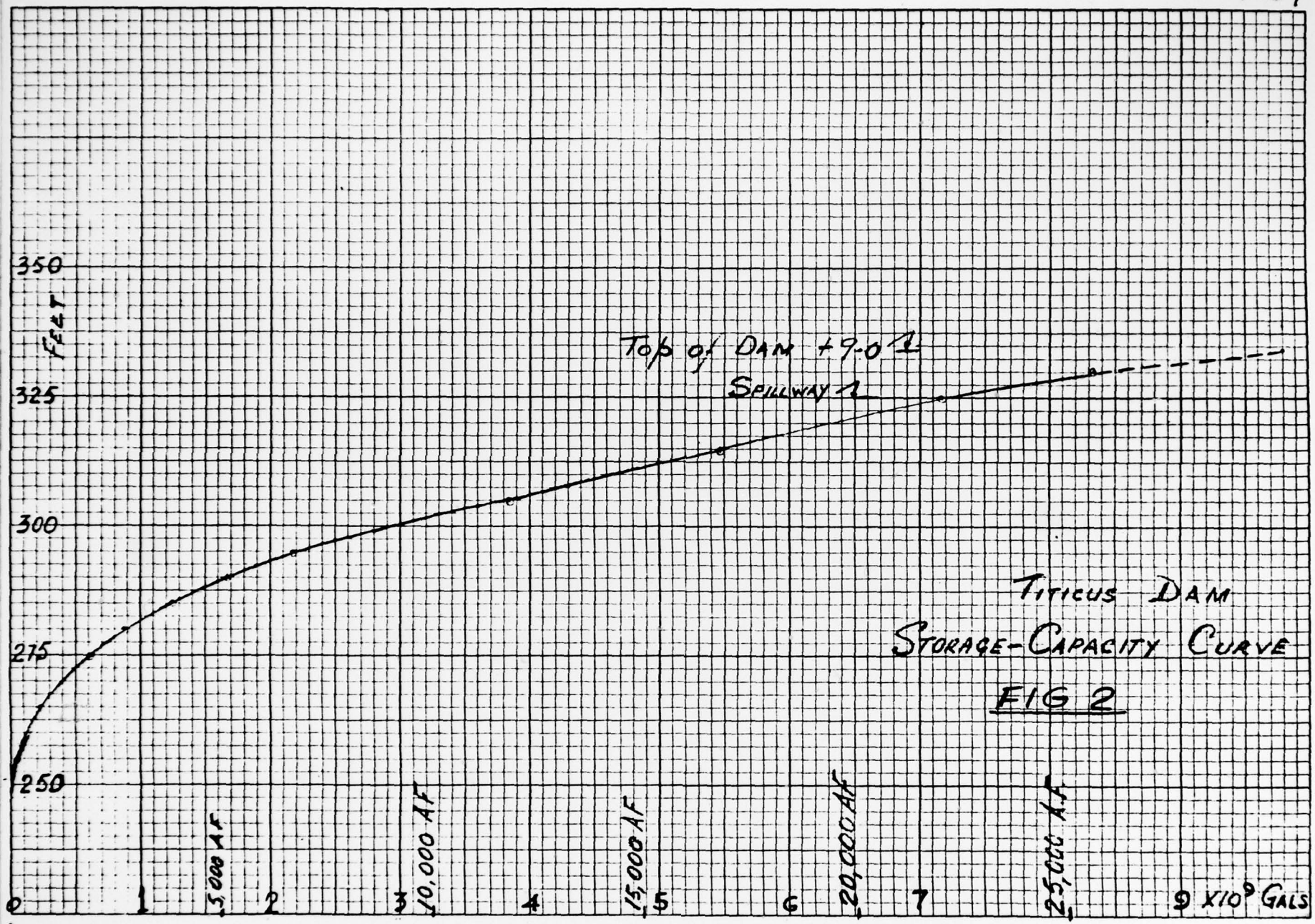


FIG 1

TITICUS DAM
SPILLWAY RATING
CURVE



TITICUS DAM

STORAGE-CAPACITY CURVE

FIG 2