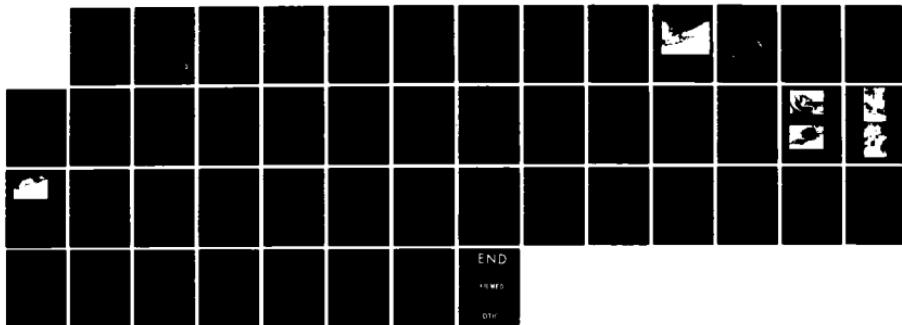


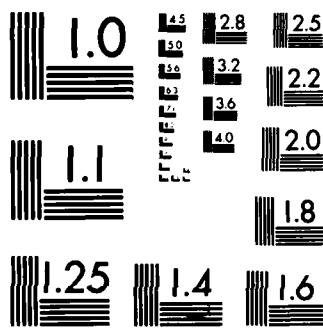
AD-A156 265 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS 1/1
GRAND LAKE DAM (ME 88) (U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV SEP 81

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GRAND LAKE DAM
ME 00180

PENOBSCOT RIVER BASIN
GRAND LAKE MATAGAMON

PHASE 1 INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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1. REPORT NUMBER ME 90180	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Grand Lake Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT
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
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254		12. REPORT DATE September 1981
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 25
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
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, Penobscot River Basin Grand Lake Maragamon		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This dam is a straight-axis, concrete gravity structure 218.5 ft. long and 35 ft. high. It serves as a water storage structure for the Bangor Hydroelectric Co. The spillway is 78 ft. long and contains 9 vertical lift gates 5' high x 7' wide. The dam has 4 10x10 sluice gates plus a 10' wide by 7' high log sluice gate. An unused boiler house in the center of the structure separates the sluice area from the spillway. The watershed classification is "flat and coastal". In event of failure of the dam no homes will be damaged.		

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MAIN

CHAS. T. MAIN, INC.

PRUDENTIAL CENTER, BOSTON, MASSACHUSETTS 02199 • TELEPHONE 617-262-3200

September 28, 1981

1345-72-20

SUBJECT: Grand Lake Dam

The Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Attention: E. P. Gould
Project Management Division

Gentlemen:

On November 15, 1979, Grand Lake Dam on the East Branch of the Penobscot River was inspected by Stanley S. Marshall, P.E. and Jan N. Jonas of this office.

Following inspection and subsequent investigation, we concluded that the dam should be reclassified as having a low hazard potential.

Enclosed is a letter report substantiating our finding.

Very truly yours,

CHAS. T. MAIN, INC.

J. E. Giles Jr.
J. E. Giles, Jr.



pel

Enclosure

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DESCRIPTION

Grand Lake Dam

The Grand Lake Dam built in 1890 is a straight-axis, concrete gravity structure 218.5' long and 35' high. It serves as a water storage structure for the Bangor Hydroelectric Co. The spillway is 78' long and contains 9 vertical lift gates 5' high x 7' wide. In addition, the dam has 4 10x10 sluice gates plus a 10' wide by 7' high log sluice gate. An unused boiler house in the center of the structure separates the sluice area from the spillway.

A 20' bay on the left abutment contains a fishway designed by the Maine Fish and Game Commission.

EVALUATION OF HYDROLOGIC AND HYDRAULIC FEATURES

5.1 General - The watershed is 485 square miles of undeveloped rolling terrain and it contains two large lakes, Allapash and Chamberlain. The dam is located on East Branch Penobscot River, on the outlet of Grand Lake Matagamon. The concrete gravity dam develops sufficient storage to reduce the Probable Maximum Flood (PMF) peak from 66370 cfs to 15000 cfs (about 77% reduction).

5.2 Design Data - The dam was designed by the East Branch Improvement Co., Bangor, Maine. The top of the dam elevation is at Elev. 665 with a maximum height of 25 feet (capacity 8200000 ac-ft). This dam is classified as intermediate size. The principal spillway consists of five roller gates. The emergency spillway is equipped with nine sliding gates with total width of 60.3 feet which has a crest elevation of 650 feet.

5.3 Experience Data - There are no records of past floods or any overtopping of the dam.

5.4 Test Flood Analysis - Based upon "Preliminary Guidance for Estimating Maximum Probable Discharge", dated March 1978, the watershed classification "flat & coastal" (although the terrain is rolling terrain, due to flood retarding effects of the big lakes in the drainage basin, it is assumed to be flat), and our hydraulic computations, the test flood for this low hazard, intermediate size dam is estimated to be equivalent to the PMF of 66370 cfs. The flood routing starting elevation was selected to be maximum normal pool elevation 655.

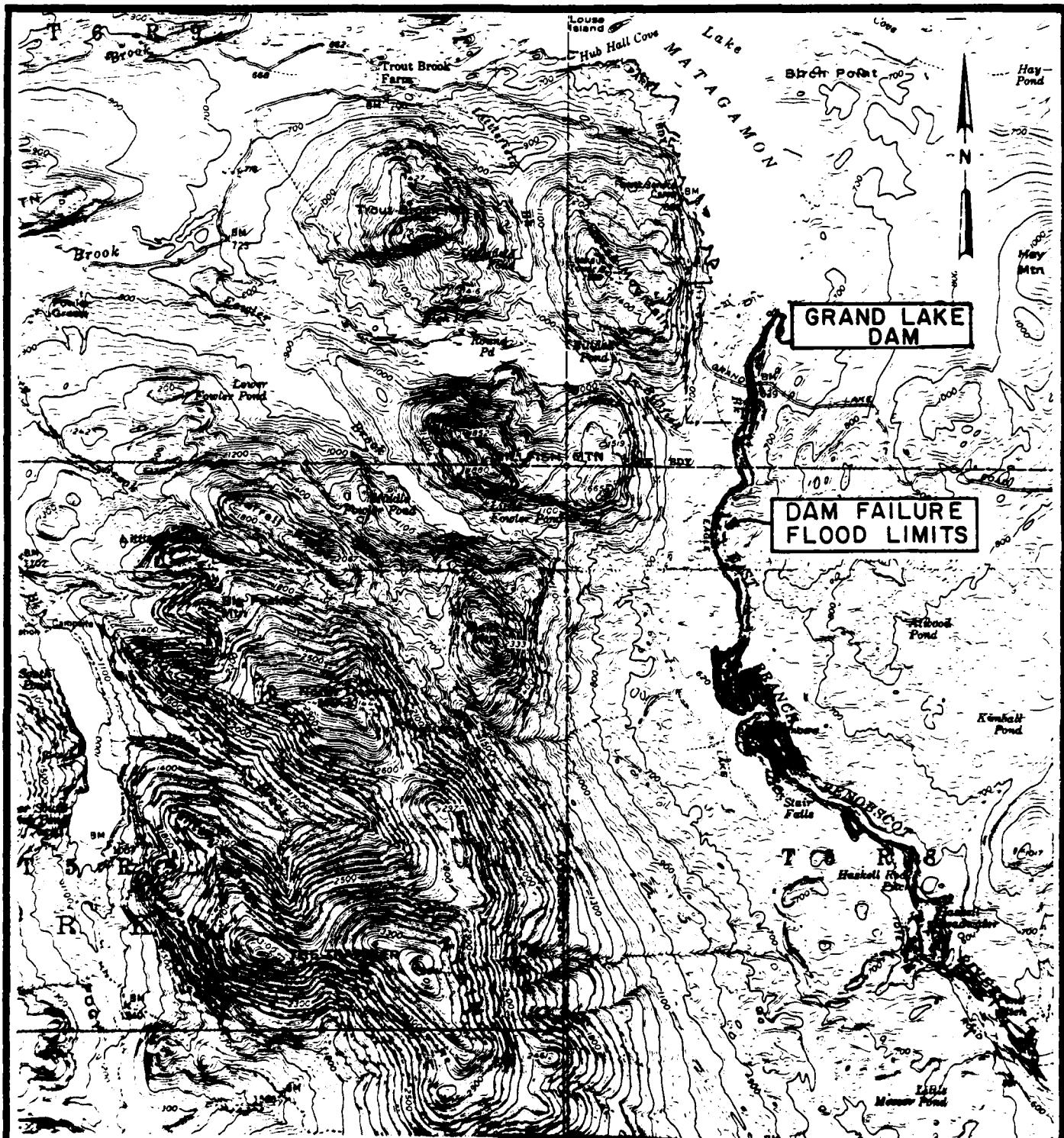
For this particular portion of Maine, the PMF runoff is assumed to be 13". The routed test flood outflow was determined in accordance with Corps of Engineers "Guidance for Estimating Effect of Surcharge Storage on Maximum Probable Discharges", and the hydraulic characteristics of the dam spillway discharge was computed as sharp crested weir. The routed test flood outflow was determined to be approximately 15000 cfs and corresponding water surface elevation 656.3 feet. The top of the dam elevation is 655 feet and thus the dam would not be overtopped.

5.5 Dam Failure Analyses - The volume in the reservoir corresponding to the water surface elevation 656.3 (maximum test flood elevation) is 5,265,650 acre-feet which is considered at the time of dam failure. The impact of failure was assessed using the "Rule of Thumb, Guidance for Estimating Downstream Dam Failure Hydrographs" prepared by the Corps of Engineers. The breach discharge was estimated with the maximum water surface elevation during PMF event. The breach width was selected to be 35 per-cent of the length of the dam at mid-height. The downstream discharge from the principal and emergency spillways. The total peak discharge was estimated to be 23240 cfs. The result of the calculations included in Appendix D.

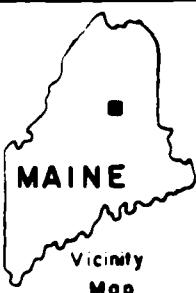
In view of these results, it can be concluded that during prefailure and postfailure conditions no homes will be damaged; on the downstream channel no development exists. Thus this dam represents a low hazard structure.



GRAND LAKE DAM



FROM U.S.G.S. TRAVELER
MOUNTAIN, ME. 15 MIN.
QUADRANGLE MAP.



0 1
SCALE: 1" = 1 MILE

GRAND LAKE DAM LOCATION MAP

U.S. ARMY CORPS OF ENGINEERS
PHASE I INSPECTION PROGRAM

MAIN

DATE SEPT. 1981

CLIENT 100 PLATE
1345 72

APPENDIX A
CHECKLIST

INSPECTION CHECK LIST

PARTY ORGANIZATION

PROJECT Grand Lake DamDATE Nov 15, 1979TIME 10:00 - 11:30WEATHER part. cloudy, windy, 29°FW.S. ELEV. 655 U.S. 641 DN.S.PARTY:

1. Stanley S. Marshall Civil Eng 6.
2. John N. Jones Civil Eng 7.
3. _____ 8.
4. _____ 9.
5. _____ 10.

PROJECT FEATURE	INSPECTED BY	REMARKS
1. <u>Concrete gravity dam with gated spillway and sluice gates.</u>		
2. _____		
3. _____		
4. _____		
5. _____		
6. _____		
7. _____		
8. _____		
9. _____		
10. _____		

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 15, 1979PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Jean N. Jonas

AREA EVALUATED	CONDITIONS
<u>DAM EMBANKMENT</u>	
Crest Elevation	665
Current Pool Elevation	655
Maximum Impoundment to Date	not known
Surface Cracks	
Pavement Condition	not applicable
Movement or Settlement of Crest	none visible
Lateral Movement	" "
Vertical Alignment	good
Horizontal Alignment	"
Condition at Abutment and at Concrete Structures	"
Indications of Movement of Structural Items on Slopes	not applicable
Trespassing on Slopes	" "
Vegitation on Slopes	" "
Sloughing or Erosion of Slopes or Abutments	" "
Rock Slope Protection - Riprap Failures	right abutment - good condition
Unusual Movement or Cracking at or near Toes	none
Unusual Embankment or Downstream Seepage	none
Piping or Boils	not applicable
Foundation Drainage Features	none visible
Toe Drains	none
Instrumentation System	none

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 16, 1979PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Tom N. Jonas

AREA EVALUATED	CONDITION
<u>CUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE</u> a. Approach Channel Slope Conditions Bottom Conditions Rock Slides or Falls Log Boom Debris Condition of Concrete Lining Drains or Weep Holes b. Intake Structure Condition of Concrete Stop Logs and Slots	Not applicable

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 16, 1979PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Jan N. Jonas

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - CONTROL TOWER</u>	
a. Concrete and Structural	
General Condition	good
Condition of Joints	visible
Spalling	minor at edges and stairs
Visible Reinforcing	at stairs and deck slab
Rusting or Staining of Concrete	limited areas
Any Seepage or Efflorescence	minor efflorescence at sluice gate
Joint Alignment	good
Unusual Seepage or Leaks in Gate Chamber	not applicable
Cracks	minor
Rusting or Corrosion of Steel	to a small extent
b. Mechanical and Electrical	
Air Vents	not applicable
Float Wells	not applicable
Crane Hoist	working condition
Elevator	not applicable
Hydraulic System	" "
Service Gates	wood slide gates in working cond.
Emergency Gates	" " "
Lightning Protection System	diesel aggregate in adjoining wood house is used for regular operation
Emergency Power System	not applicable
Wiring and Lighting System in Gate Chamber	

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 16, 1979PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Jan N. Jonas

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - TRANSITION AND CONDUIT</u> General Condition of Concrete Rust or Staining on Concrete Spalling Erosion or Cavitation Cracking Alignment of Monoliths Alignment of Joints Numbering of Monoliths	<i>not applicable</i>

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 16, 1979PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Jan N. Jonas

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL</u>	
General Condition of Concrete	satisfactory, showing minor damage due to frost
Rust or Staining	none
Spalling	minor, limited
Erosion or Cavitation	none
Visible Reinforcing	none
Any Seepage or Efflorescence	none
Condition at Joints	good
Drain holes	none visible
Channel	natural river channel with rocky bottom
Loose Rock or Trees Overhanging Channel	none
Condition of Discharge Channel	satisfactory

INSPECTION CHECK LIST

PROJECT Grand Lake Dam
 PROJECT FEATURE Concrete gravity, dam
 DISCIPLINE Hydro

DATE Nov 16, 1979
 NAME Stanley S. Marshall
 NAME Jon N. Jonas

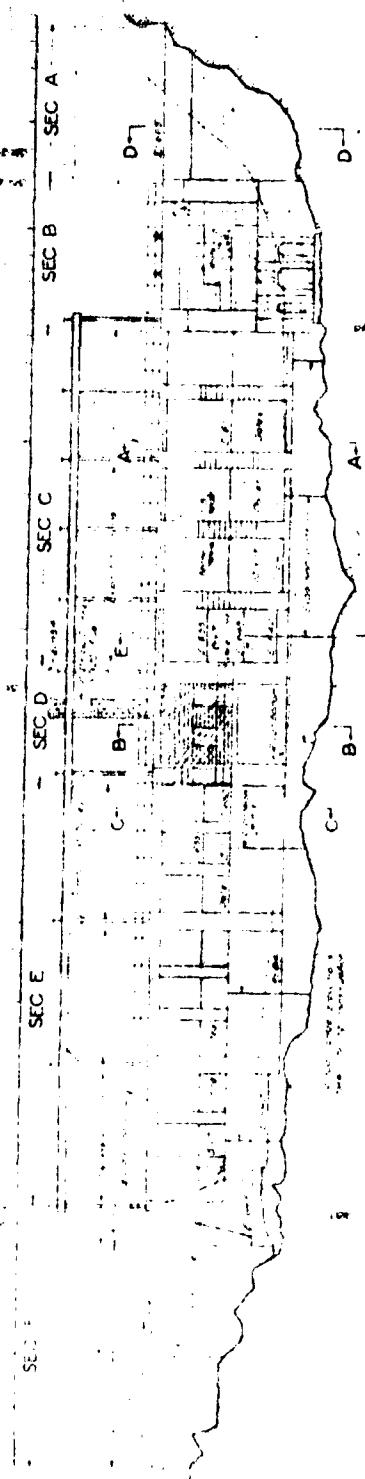
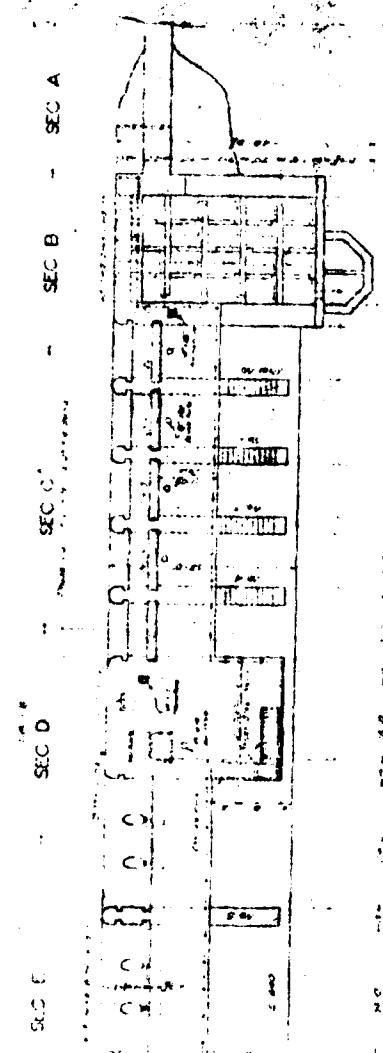
AREA EVALUATED	CONDITION
<u>CUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS</u>	
a. Approach Channel	Not applicable
General Condition	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Approach Channel	
b. Weir and Training Walls	
General Condition of Concrete	satisfactory
Rust or Staining	minor rusting
Spalling	minor spalling at edges
Any Visible Reinforcing	none
Any Seepage or Efflorescence	negligible
Drain Holes	none visible
c. Discharge Channel	natural river bed
General Condition	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Channel	
Other Obstructions	

INSPECTION CHECK LIST

PROJECT Grand Lake DamDATE Nov 16, 1977PROJECT FEATURE Concrete gravity damNAME Stanley S. MarshallDISCIPLINE HydroNAME Jan N. Jonas

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SERVICE BRIDGE</u>	<u>Not applicable</u>
a. Super Structure	
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Under Side of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

APPENDIX B
ENGINEERING DATA



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NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE

ONE SIDE SHEET

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3

4

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8

EAST BRANCH MINE PLATEAU

2

3

4

5

6

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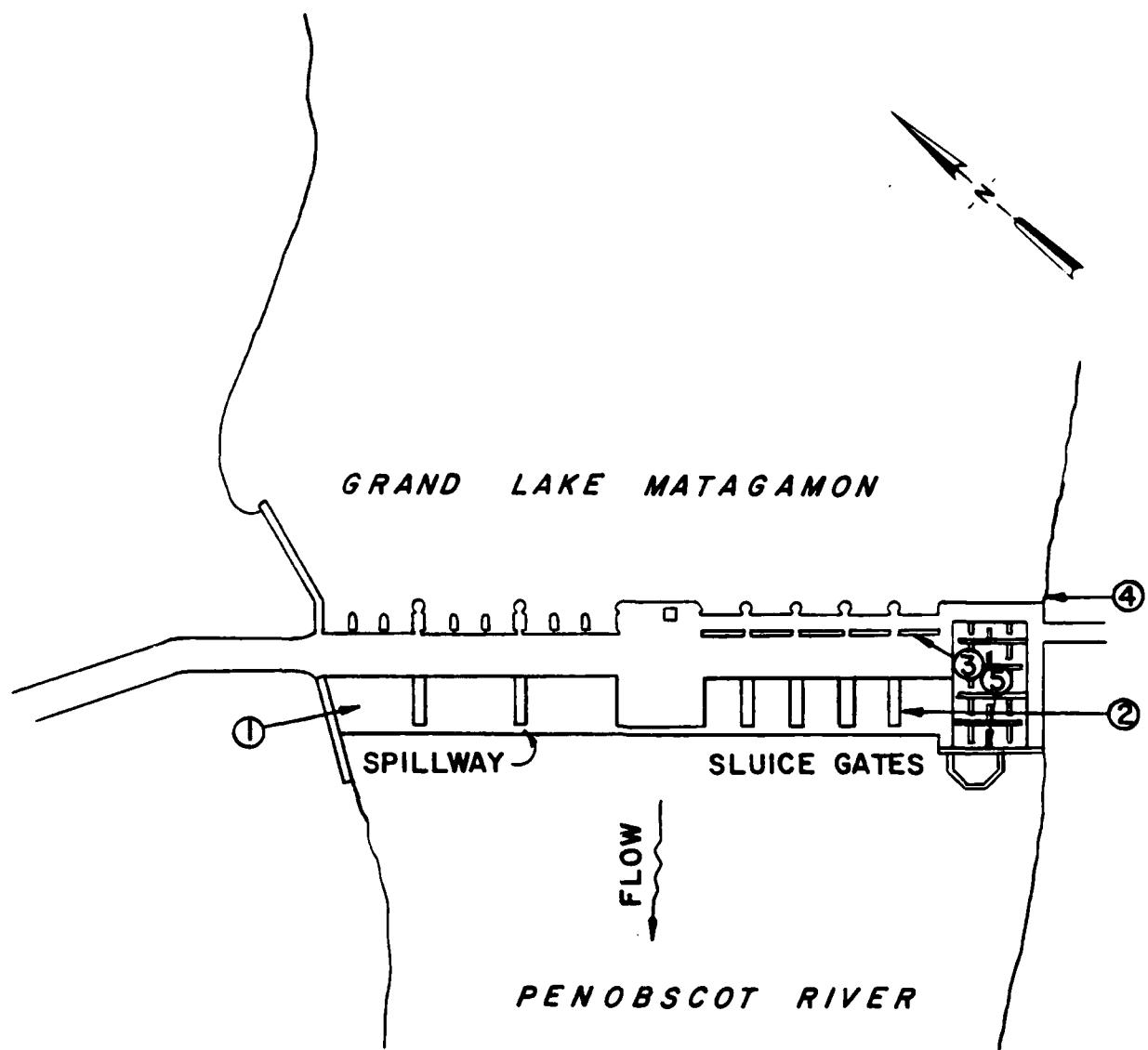
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GENERAL PLAN

PROGRESS REPORT
GENERAL PLAN
OF PROJECT

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APPENDIX C
PHOTOGRAPHS



**GRAND LAKE DAM
PHOTO LOCATION MAP**

**U.S. ARMY CORPS OF ENGINEERS
PHASE I INSPECTION PROGRAM**

MAIN

DATE SEPT. 1981

**CLIENT 100 PLATE
1345 72**

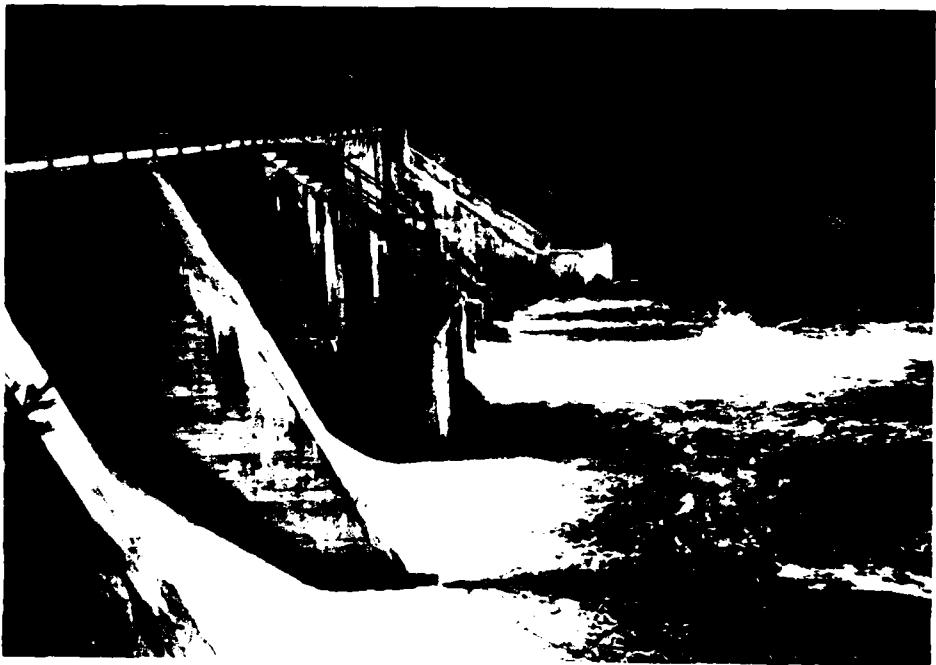


Fig. 1 Downstream view of dam from right bank. Note fish ladder at left embankment



Fig. 2 Downstream view of dam from left bank. Stairs in center of picture lead to abandoned boiler house.



Fig. 3 Chain supporting spillway slide gate. Note dogging device.



Fig. 4 Upstream view of dam from left abutment. Wheel operated gates in foreground are for fishway.



Fig. 5 Downstream entrance to fish-way.

APPENDIX D
HYDROLOGIC AND HYDRAULIC COMPUTATIONS

MAIN

Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-072 Sheet 1 of 18
By J. OTTO JR. Date 03-IX-1981
Ckd. _____ Rev. _____

Although Grand Lake Bosim is located inland, because it contains two large lakes (Allagash Lake, Chamberlain Lake), excluding Grand Lake Madepanom), the curve for Flat & Coastal terrain of the PMF Curves (Corps of Engineers Guidelines, March 1978) was used in estimating peak discharge. For drainage area of 485 square miles this curve shows 200 cfs /sq.mi of unit peak discharge.

The total peak discharge = $485 \times 200 = 97000 \text{ cfs}$.
The Guideline Curves are derived for 19" runoff. In this part of New England, Maine, Depth-Area-Duration curves show a 13" of runoff and this is confirmed by the Corps of Engineers.

Then, test flood is assumed to be equal to PMF which its peak is,

$$Q_{test} = 97000 \times \frac{13}{19} = 66368 \text{ cfs.}$$

MAIN

Client CORPS OF ENGINEERS Job No. 1345-072-4 Sheet 2 of 18
Subject GRAND LAKE DAM By T. TOVARA Date 24-IX-1981
HYDROLOGY - HYDRAULICS Ckd. _____ Rev. _____

There are two kind of spillways in the Grand Lake Dam:

- 1.- Roller Gates (5 number),
- 2.- Sliding Gate (9 number).

Their rating curves are presented in pages 4 and 5, respectively.

The rating curve of total discharges, and for the discharges occurring only above elevation 655 are also shown in page 8.

The Area - capacity curves are estimated from 1:62,500 scale topographic maps and by using logarithmic curve fitting procedure (pages 9, 10 and 11).

The effects of surcharge storage on maximum probable discharges are estimated according to Corps of Engineers' procedure presented in the previous pages. Calculations are shown in page 12.

RESULTS: Due to very large size of the Grand Lake, the reservoir level will rise 1.3 ft. during a test flood event.

MAIN

Client CORPS OF ENGINEERS Job No. 1345-072 Sheet 3 of 18
Subject GRAND LAKE DAM By T. OTAVIA⁴ Date 03-IX-1981
HYDROLOGY - HYDRAULICS Ckd. _____ Rev. _____

FIVE ROLLER GATESRATING CURVE

$$Q = C \times L \times H^{3/2}$$

Q is discharge cfs

C is discharge coefficient = 3.9

L is total length in ft.

H is surcharge ft.

$$L = 10 \times 5 = 50 \text{ ft.}$$

$$Q = 3.9 \times 50 \times H^{3/2} = 195 H^{3/2}$$

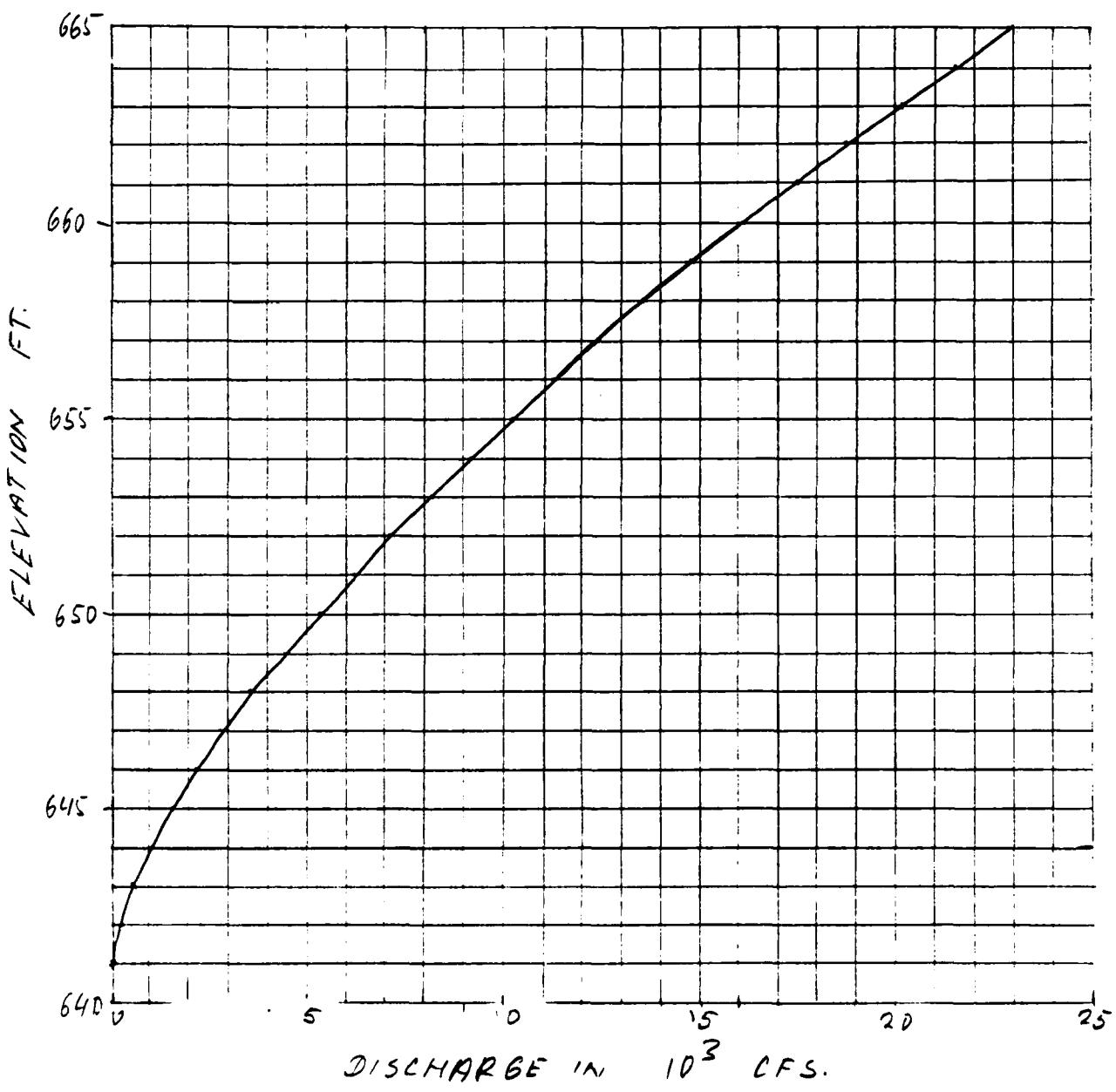
The rating curve is presented in the next page.

The crest elevation = 641.

MAIN

Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-077 Sheet 4 of 18
By T. OTOUKA Date 03-17-1981
Ckd. _____ Rev. _____

FIVE ROLLER GATES**RATING CURVE:**

MAIN

Client CORPS OF ENGINEERS Job No. 1345-072 Sheet 5 of 18
Subject GRAND LAKE DAM By T. DTOV Date 03-IX-1981
HYDROLOGY - HYDRAULICS Ckd. _____ Rev. _____

NINE SLIDING GATES

RATING CURVE

$$Q = C \times L \times H^{3/2}$$

$$L = 9 \times 6.7 = 60.3 \text{ FT.}$$

$$Q = 3.9 \times 60.3 \times H^{3/2} = 235.2 H^{3/2}$$

The crest elevation is 650 FT.

The rating curve is presented in the next page.

MAIN

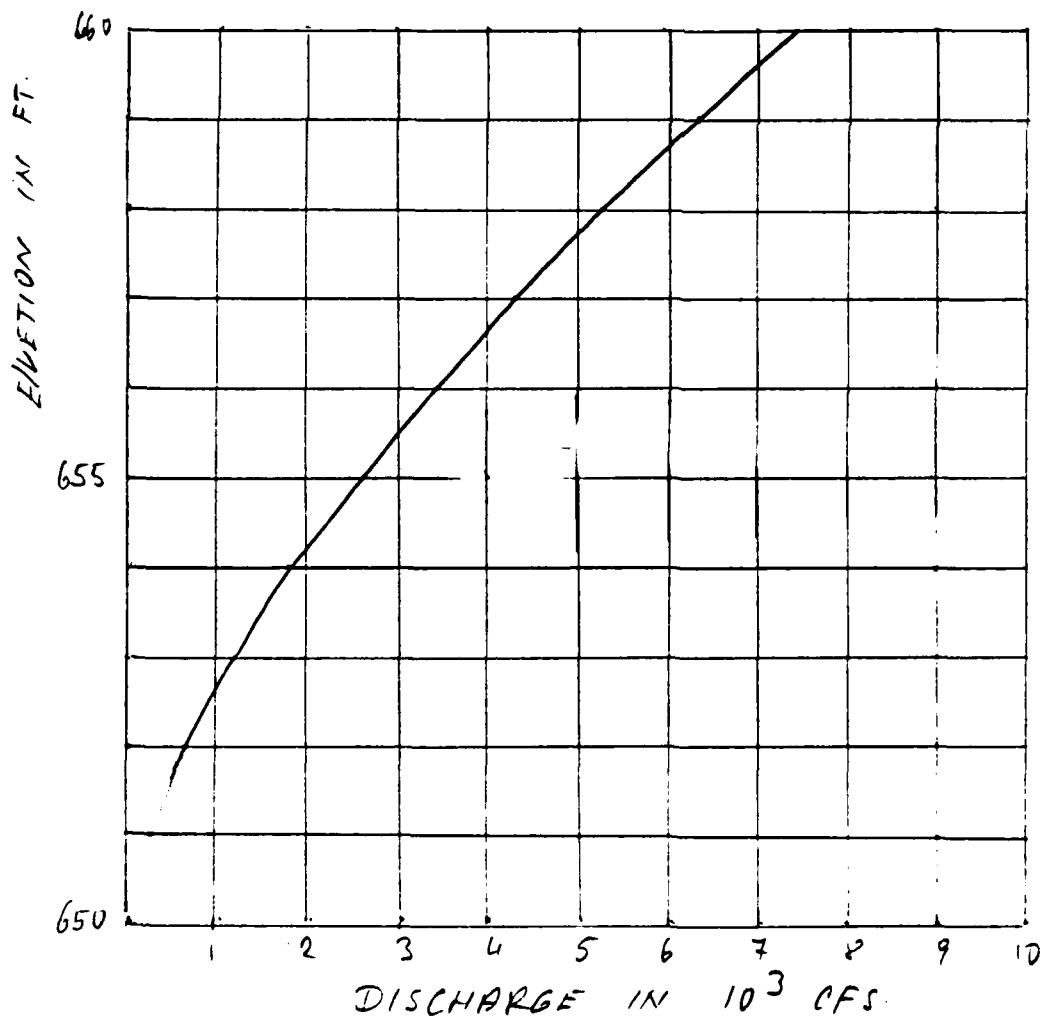
Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-072 Sheet 6 of 18
By T. OTOKA Date 03-IX-1981

Ckd. _____ Rev. _____

NINE SLIDING GATES

RATING CURVE:



MAIN

Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-072 Sheet 7 of 18
By T. OTOUA Date 03-1x-1981
Ckd. Rev.

TOTAL RATING CURVE

FOR ROUTING STARTING ELEVATION 655 (Maximum Normal Pool Elevation).

Total Discharge at Elv. 655:

- From 5 roller gates: 10220 CFS
- From 9 sliding gates: 2630 CFS

Total 12850 CFS.

Discharge Formula:

$$Q = C \cdot L \cdot H^{3/2}$$

$$Q = 3.9 \times (235.2 + 195.0) \times H^{3/2}$$

$$Q = 1677.8 H^{3/2} + 12850$$
$$H = (0.0005960186 \cdot Q - 7.658838956)^{2/3}$$

Routing Starting Elev. 655

The rating curve is presented in the next page.

Additional Discharges above Elv. 655 can be presented as $Q = 1677.8 H^{3/2}$

and surcharge formula becomes

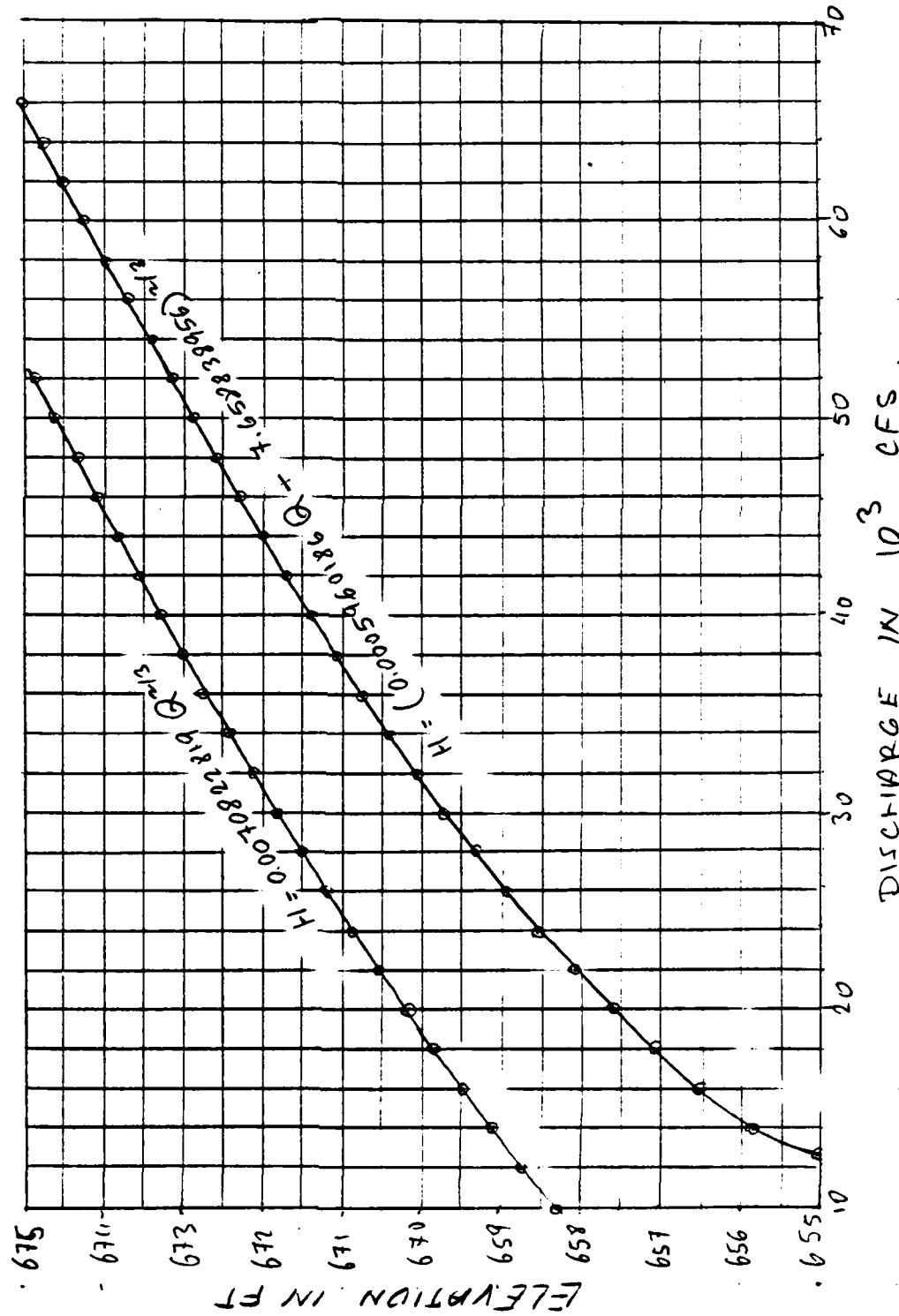
$$H = 0.0070822819 Q^{2/3}$$

MAIN

Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-072 Sheet 8 of 18
By T. OTOUR Date 03-IX-1981

Ckd. Rev.



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Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 1345-072 Sheet 9 of 19
By T. OTOUKA Date 12-IX-1981

Ckd. _____ Rev. _____

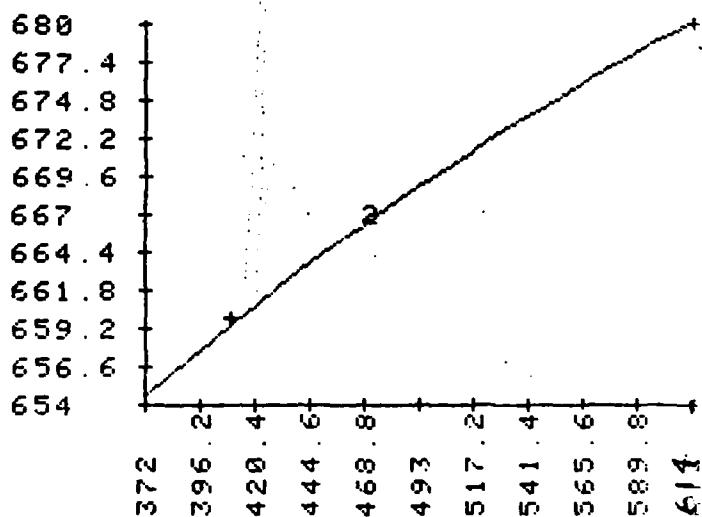
CORPS OF ENGINEERS

GRAND LAKE DAM AREA CURVE

I	X(I)	Y(I)
1	372.0000	654.0000
2	409.0000	660.0000
3	614.0000	680.0000

ADV: LOG REG: CODE 2
SOURCE/DF SS MS F
TOTAL 2 370.7
REG 1 370.0 370.0 536.9
RESID 1 0.7 0.7
R SQUARE = 0.998

$$YHAT = 352.094 + 51.094 \log X$$



MAIN

Client CORPS OF ENGINEERS Job No. 1345-072 Sheet 10 of 18
Subject GRAND LAKE DAM By T. OTTOVA Date 02-IX-1981
HYDROLOGY - HYDRAULICS Ckd. _____ Rev. _____

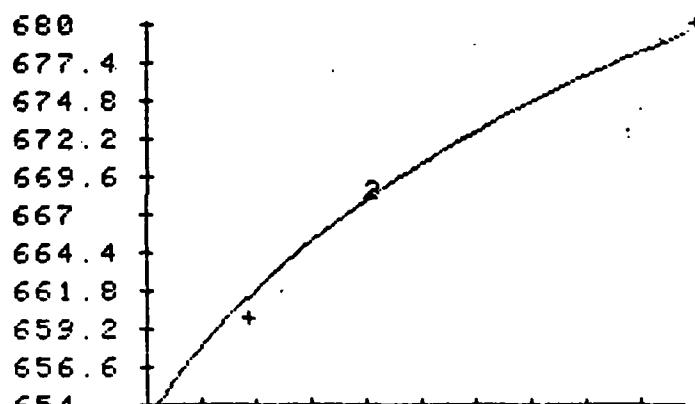
CORPS OF ENGINEERS

GRAND LAKE DAM CAPACITY CURVE

I	X(I)	Y(I)
1	4466760.0000	654.0000
2	6811152.0000	660.0000
3		668.0000

AOV: LOG REG:CODE 2
SOURCE/DF SS MS F
TOTAL 2 370.7
REG 1 367.6 367.6 120.2
RESID 1 3.1 3.1
R SQUARE = 0.992

YHAT= 349.892+ 19.798LOG X



XMIN=4466760 : TIC9=1258099.2

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Client CORPS OF ENGINEERS

Job No. 1345-072 Sheet 11 of 18

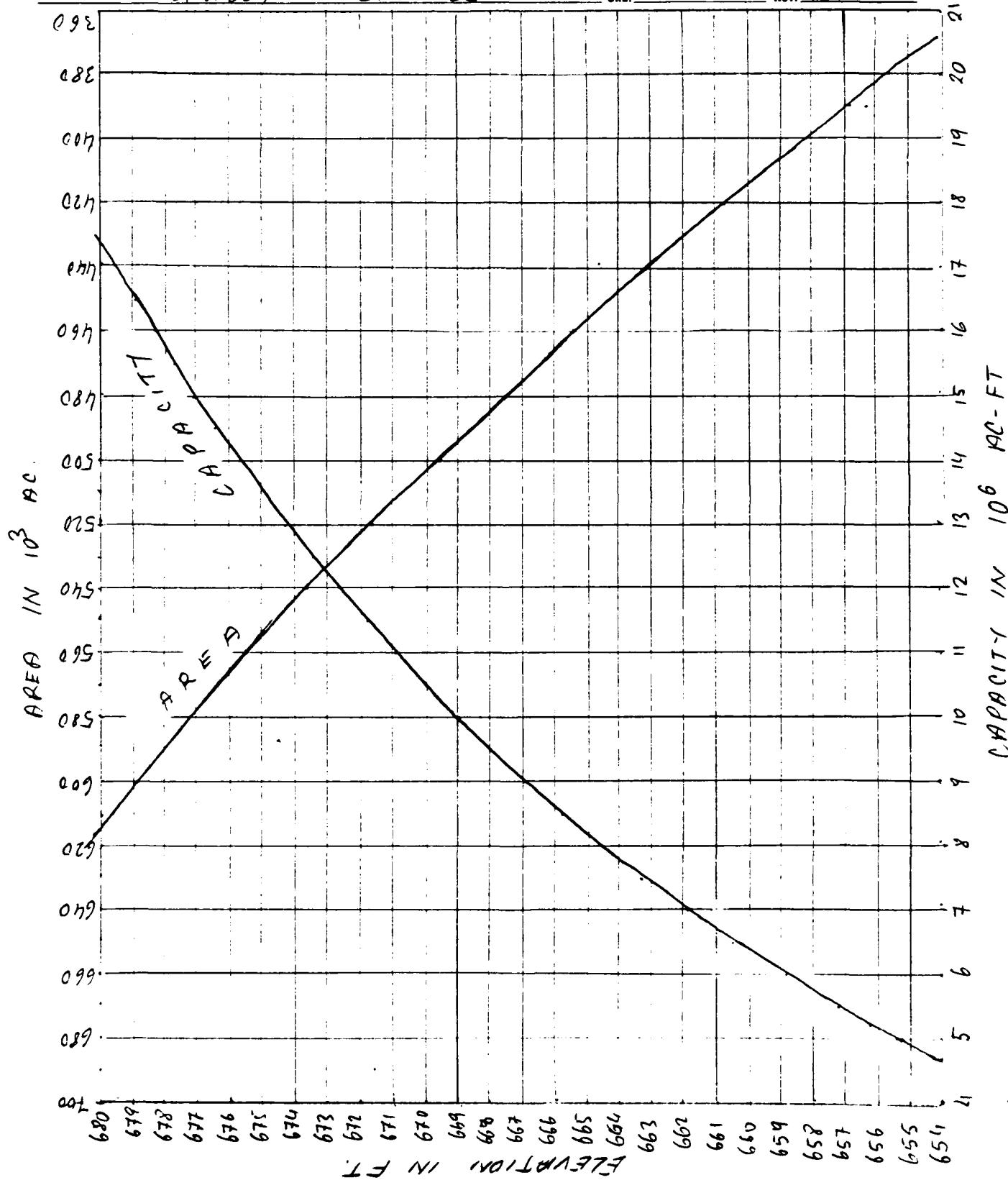
Subject GRAND LAKE DAM

By J. OTOVIA Date 02-FX-81

HYDROLOGY - HYDRAULICS

Ckd.

Rev.



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Client CORPS OF ENGINEERS
Subject GRAND LAKE DAM
HYDROLOGY - HYDRAULICS

Job No. 13115-072 Sheet 12 of 18
By T. DROUIN Date 02-IX-1981

Ckd. _____ Rev. _____

ESTIMATING**EFFECT OF SURCHARGE STORAGE
ON MAXIMUM PROBABLE DISCHARGES**

These calculations are performed according to the Corps of Engineers Guidelines

GRAND LAKE DAM**D A T A :**

DRAINAGE AREA,
 $A = 485$ (sq.mi.)

PEAK INFLOW,
 $Q_{P1} = 66368$ (cfs)

PRINCIPAL SPILLWAY CREST ELEV.,
 $ELV1 = 655$ (ft.)

EMERGENCY SPILLWAY CREST ELEV.,
 $ELV2 = 656.3$ (ft.)

Emergency Spillway Rating Curve is defined as ,

$$H = a * Q^b$$

$$a = .0070822819$$
$$b = .66666666667$$

The Capacity - Elv. curve is defined as,

$$Elv = m + n * \log(Volume)$$

$$m = 349.892$$
$$n = 19.798$$

TOTAL PMF RUNOFF,
 $R = 13$ (in.)

CALCULATIONS:**S T E P 1**

Reduction of the Q_{P1} due to starting elevation at Principal Spillway crest elev.

Volume at 655 (ft.)

$$Volume1 = EXP((ELV1-m)/n)$$
$$Volume1 = 4930996.332 \text{ (ac-ft)}$$

Volume at 656.3 (ft.)

$$Volume2 = EXP((ELV2-m)/n)$$
$$Volume2 = 5265648.246 \text{ (ac-ft)}$$

Diff. of Volumes,

$$\text{Diff. Volume} = 334651.914 \text{ (ac-ft)}$$

or,

$$\text{Diff. Volume, } D = 12.93 \text{ (in.)}$$

MAIN

Client CWPS OF ENGINEERS Job No. 1345-072 Sheet 13 of 18
Subject GRAND LAKE DAM By T. OTAVIO - 4 Date 04-TX-1981
HYDROLOGY - HYDRAULICS Ckd. _____ Rev. _____

DAM FAILURE ANALYSES:

The reservoir water elevation is assumed to be at the top of the sliding gates (Elv. 656.3) prior the failure of the dam. The five roller gates are assumed to be open and their total discharge of 10000 cfs is assumed as the test flood discharge during pre failure conditions.

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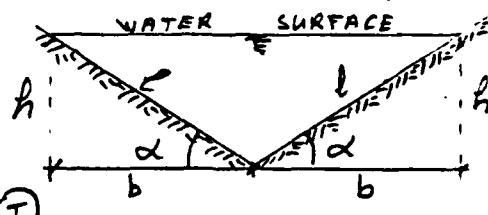
DERIVATION OF STAGE - DISCHARGE RELATIONSHIP

The flood plain is assumed to have a triangular shape, for simplification reason.

$$\text{Area, } A = \frac{h+b}{2} \times l \quad A = h + b$$

$$\frac{h}{b} = \tan \alpha \quad b = \frac{h}{\tan \alpha}$$

$$A = \frac{h^2}{\tan \alpha} \quad \boxed{\text{I}}$$



Wetted Parameter, W ,

$$W = 2l \quad \frac{b}{l} = \cos \alpha \quad l = \frac{b}{\cos \alpha}$$

$$W = \frac{2b}{\cos \alpha} \quad \boxed{\text{II}}$$

Hydraulic Radius, R ,

$$R = \frac{A}{W} = \frac{bh}{2b/\cos \alpha} = \frac{h}{2} \cdot \cos \alpha$$

$$R = \frac{h \cos \alpha}{2} \quad \boxed{\text{III}}$$

Manning's Formula,

$$Q = \frac{1.49 \times A \times R^{2/3} \times S^{1/2}}{m}$$

S is the channel slope

m is the roughness coefficient

By substituting in the formula A, R by the formulas I and II,

$$Q = \frac{1.49}{m} \times \frac{h^2}{\tan \alpha} \times \left(\frac{h + b \cos \alpha}{2} \right)^{2/3} \times S^{1/2} = \frac{1.49}{m} \times \frac{h^2}{\tan \alpha} \times \left(\frac{(h + b \cos \alpha)^2}{4} \right)^{1/3} \times h^{8/3}$$

then,

$$h = \left[\frac{m \cdot \tan \alpha \cdot 2^{2/3}}{1.49 \cdot (b \cos \alpha)^{1/3} \cdot S^{1/2}} \cdot Q \right]^{3/8}$$

or,

$$h = \frac{1.066 \cdot m \cdot \tan \alpha}{(b \cos \alpha)^{1/3} \cdot S^{1/2}} \cdot Q \quad \boxed{\text{IV}}$$

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By T. OTUVIT Date 04-IX-1981
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**GRAND LAKE
DAM FAILURE ANALYSES**

These calculations are performed according to the RULE OF THUMB procedures of the Corps of Engineers

The breach discharge:
 $Q_{p1} = 8/27 * W_b * g^{0.5} * Y_o^{3/2}$

Where,

Y_o is the height of the breach (from river bed to the max. pool level)

W_b is 35% of the length of the dam, or $W_b = .35 * W_d$

g is the acceleration of the gravity (32.2 ft/sec²)

$$Y_o = 16.3 \text{ (ft)}$$

$$W_d = 213 \text{ (ft)}$$

$$W_b = 74 \text{ (ft)}$$

From above equation,
 $Q_{p1} = 8248 \text{ (cfs)}$

The natural channel cross sections are simplified as triangular cross sections

The stage-discharge relationship becomes as,

$$h = [1.068 * n * \tan(a) * Q / C \cos(a)^{2/3} / S^{.5}]^{3/8} \dots \text{(I)}$$

Where,

Q = Discharge (cfs)

a = Side slope angle (deg)

S = Channel slope

The cross section Area:

$$A = h^2 / \tan(a) \dots \text{(II)}$$

The Volume of the Reservoir,
 $V = 5265648 \text{ (ac-ft)}$

or,

$$V = 229371626880 \text{ (cub-ft)}$$

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REACH (1) CALCULATIONS

$$h = 15 \text{ (ft)}$$

From Formula (II),

$$A = 6360 \text{ (ft)}$$

Residual Area,

$$A2 = A - A1$$

$$A2 = 1781 \text{ (ft)}$$

$$V2 = A2 * L$$

$$V2 = 7126096 \text{ (cub-ft)}$$

From Formula (I),

$$V_{ave} = (V1 + V2) / 2$$

Prefailure height,

$$V_{ave} = 7126201 \text{ (cub-ft)}$$

$$h1 = 13.1 \text{ (ft)}$$

$$Q_{P2} = Q_{P1} * (1 - V_{ave} / V)$$

From Formula (II),

$$Q_{P2} = 8248 \text{ (cfs)}$$

$$A1 = 4578 \text{ (sq-ft.)}$$

From Formula (I),

Total Height,

$$Q = Q_{P2} + Q_t$$

$$h = 15.5 \text{ (ft)}$$

$$h2 = 15.5 \text{ (ft)}$$

From Formula (II),

RESULTS :

Total Area,

$$A = 6360 \text{ (sq-ft.)}$$

Residual Area,

$$A2 = A - A1$$

$$A2 = 1781 \text{ (sq-ft.)}$$

$$1.) \text{ Prefailure Height} = 13.1 \text{ (ft)}$$

Residual Volume,

$$2.) \text{ Postfailure Height} = 15.5 \text{ (ft)}$$

$$V1 = L * A2$$

$$3.) \text{ Breach Discharge} = 8248 \text{ (cfs)}$$

$$V1 = 7126306 \text{ (cub-ft.)}$$

$$4.) \text{ Reach Length} = 4000 \text{ (ft.)}$$

$$Q_{P2} = Q_{P1} * (1 - V1 / V)$$

$$Q_{P2} = 8248 \text{ (cfs)}$$

From Formula (I),

$$Q = Q_{P2} + Q_t$$

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REACH (2) CALCULATIONS

Test flood discharge:
 $Q_t = 15000 \text{ (cfs)}$

$a = 1.35 \text{ (deg.)}$
 $S = .00193$
 $n = .07$
 $L = 15700 \text{ (ft)}$

From Formula (I),

Prefailure height,

$$h_1 = 11 \text{ (ft)}$$

From Formula (II),

$$A_1 = 5154 \text{ (sq.ft.)}$$

$$Q = Q_{P1} + Q_t$$

From Formula (I),
Total Height,
 $h = 12.9 \text{ (ft)}$

From Formula (II),
Total Area,
 $A = 7160 \text{ (sq-ft)}$

Residual Area,

$$A_2 = A - A_1$$

$$A_2 = 2005 \text{ (sq-ft)}$$

Residual Volume,

$$V_1 = L * A_2$$

$$V_1 = 31489022 \text{ (cub-ft)}$$

$$Q_{P2} = Q_{P1} * (1 - V_1 / V)$$

$$Q_{P2} = 8247 \text{ (cfs)}$$

From Formula (I),

$$Q = Q_{P2} + Q_t$$

$$Q = 23247 \text{ (cfs)}$$

$$h = 12 \text{ (ft)}$$

From Formula (II),

$$A = 7160 \text{ (ft)}$$

Residual Area,

$$A_2 = A - A_1$$

$$A_2 = 2005 \text{ (ft)}$$

$$V_2 = A_2 * L$$

$$V_2 = 31484915 \text{ (cub-ft)}$$

$$V_{ave} = (V_1 + V_2) / 2$$

$$V_{ave} = 31486968 \text{ (cub-ft)}$$

$$Q_{P2} = Q_{P1} * (1 - V_{ave} / V)$$

$$Q_{P2} = 8247 \text{ (cfs)}$$

From Formula (I),

$$Q = Q_{P2} + Q_t$$

$$h_2 = 12.9 \text{ (ft)}$$

RESULTS :

1.) Prefailure Height = 11 (ft)

2.) Postfailure Height = 12.9 (ft)

3.) Breach Discharge = 8247 (cfs)

4.) Reach Length = 15700 (ft)

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REACH (3) CALCULATIONS

Test flood discharge:
 $Q_t = 15000 \text{ (cfs)}$

$a = 1.76 \text{ (deg.)}$
 $S = .0033$
 $n = .07$
 $L = 12000 \text{ (ft)}$

From Formula (I),

Prefailure height,

$$h_1 = 11 \text{ (ft)}$$

From Formula (II),

$$A_1 = 3945 \text{ (sq.ft.)}$$

$$Q = Q_{P1} + Q_t$$

From Formula (I),

Total Height,
 $h = 12.9 \text{ (ft)}$

From Formula (II),
Total Area,
 $A = 5480 \text{ (sq-ft)}$

Residual Area.

$$A_2 = A - A_1$$
$$A_2 = 1534 \text{ (sq-ft)}$$

Residual Volume,

$$V_1 = L * A_2$$

$$V_1 = 18418692 \text{ (cub-ft)}$$

$$Q_{P2} = Q_{P1} * (1 - V_1 / V)$$

$$Q_{P2} = 8246 \text{ (cfs)}$$

From Formula (I),

$$Q = Q_{P2} + Q_t$$

$$Q = 23246 \text{ (cfs)}$$

$$h = 12 \text{ (ft)}$$

From Formula (II),

$$A = 5480 \text{ (ft)}$$

Residual Area,

$$A_2 = A - A_1$$

$$A_2 = 1534 \text{ (ft)}$$

$$V_2 = A_2 * L$$

$$V_2 = 18417286 \text{ (cub-ft)}$$

$$V_{ave} = (V_1 + V_2) / 2$$

$$V_{ave} = 18417989 \text{ (cub-ft)}$$

$$Q_{P2} = Q_{P1} * (1 - V_{ave} / V)$$

$$Q_{P2} = 8246 \text{ (cfs)}$$

From Formula (I),

$$Q = Q_{P2} + Q_t$$

$$h_2 = 12.9 \text{ (ft)}$$

RESULTS :

1.) Prefailure Height = 11 (ft)

2.) Postfailure Height = 12.9 (ft)

3.) Breach Discharge = 8246 (cfs)

4.) Reach Length = 12000 (ft)

APPENDIX E
INVENTORY FORMS

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