Attachment 02.04.03-08H
TVA letter dated February 2, 2010
RAI Response

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8H: Dam Rating Curves, Douglas

(456 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 081223 001	Calculations (Nuclear)	L58 091230 020

Calc Title: Dam Rating Curves, Douglas

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080007	2	3	Entire calc ☒ Selected pages ☐
NEW								

ACTION										No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)
	NEW ☐ REVISION ☒		DELETE ☐ RENAME ☐		SUPERSEDE ☐ DUPLICATE ☐		CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)			

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
*See Below	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
wbbondurant	901.755.7166	CEB	See Page 6a	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Bryant Bondurant Bryant Bondurant	12/22/09	Janie Mauter Janie Mauter	12/22/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
L. Yu Lin L. Lin	12/22/09	K.R. Yates K.R. Yates	12/24/09

STATEMENT OF PROBLEM/ABSTRACT

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH (Simulated Open Channel Hydraulics) and TRBROUTE (Tributary Route) models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Douglas Dam.

*EDCN 22404A (SQN), EDCN 54018A (WBN), EDCN Later (BFN)

This calculation contains electronic attachments and must be stored in EDMS as an Adobe.pdf file to maintain the ability to retrieve the electronic attachments.

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: LP4D-C
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 081223 001	Calculations (Nuclear)	N/A

Calc Title: Dam Rating Curves, Douglas

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC						Entire calc ☐ Selected pages ☐
NEW	CN	NUC	GEN	CEB	CDQ000020080007	N/A	0	

ACTION									No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)
	NEW ☒ REVISION ☐	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)					

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
N/A	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
S. Martinez	632-6448, 220-4346	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Sara Martinez	12/02/2008	Chris Triplett	12/09/08
VERIFIER SIGNATURE	DATE	APPROVAL SIGNATURE	DATE
Dr. Lui Yu Lin / N. B. Hunt for R. G. Austin	12/09/08	K.R. Spater	12

STATEMENT OF PROBLEM/ABSTRACT

Headwater rating curves for 20 dams are required as inputs to TVA's SOCH (Simulated Open Channel Hydraulics) and TRBROUTE (Tributary Route) models, which perform flood-routing calculations for the Tennessee River and tributaries. The headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents headwater rating curves for Douglas Dam.

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NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 081223 001	Calculations (Nuclear)	L58 090210 003

Calc Title: Dam Rating Curves, Douglas

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080007	000	001	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION										No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)
	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)						

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
N/A	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
S. Martinez	632-6448, 220-4346	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Sara Martinez Sara Martinez	01/22/2009	Andrew Tinsley	1/22/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
J.V. Peyton J.V. Peyton	1/22/09	K.R. Yates K.R. Yates	2/10/09

STATEMENT OF PROBLEM/ABSTRACT

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH (Simulated Open Channel Hydraulics) and TRBROUTE (Tributary Route) models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Douglas Dam.

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NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 081223 001	Calculations (Nuclear)	L58 090406 002

Calc Title: Dam Rating Curves, Douglas

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080007	1	2	Entire calc ☒ Selected pages ☐
NEW								

ACTION										No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)
	NEW ☐ REVISION ☒		DELETE ☐ RENAME ☐		SUPERSEDE ☐ DUPLICATE ☐		CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)			

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
N/A	N/A	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
S. Martinez	(865) 220-4346	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE		DATE	CHECKER SIGNATURE		DATE
Sara Martinez	Sara Martinez	3-20-09	Andrew Tinsley	Andrew Tinsley	3/20/09
VERIFIER SIGNATURE		DATE	APPROVAL SIGNATURE		DATE
J.V. Peyton	J.V. Peyton	3-20-09	K.R. Yeates	K.R. Yeates	4/7/09

STATEMENT OF PROBLEM/ABSTRACT

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH (Simulated Open Channel Hydraulics) and TRBROUTE (Tributary Route) models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Douglas Dam.

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NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080007	3

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM BWSC	Print Report Yes ☐

CATEGORIES SR / LC

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	EN	WBN	CEB	54018	
A	P	EN	SQN	CEB	22404	
A	P	CN	GEN	CEB	CDQ000020080036	
A	P	CN	GEN	CEB	CDQ000020080053	
A	P	DW	GEN	CEB	407K905	
A	P	DW	GEN	CEB	407K906	
A	P	DW	GEN	CEB	407K907	
A	P	DW	GEN	CEB	407K908	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.	EDMS ACCESSION NO.

NPG CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER CDQ000020080007	
Title	Dam Rating Curves, Douglas
Revision No.	DESCRIPTION OF REVISION
0	Initial issue, 134 Total Pages Appendix A – 5 pages Appendix B – 21 pages Appendix C – 20 pages Appendix D – 3 pages
1	Revision to include turbine discharge for rising and falling headwater before inundation of the switchyard or powerhouse. This leads to three curves rather than two as well as four extra references. Change to terminology involving "dam rating curve". Now curves are referred to as "dam rating curves" throughout the document. NEDP forms have been updated to the latest version (10/2008). Revision 1, 145 Total Pages, including original Rev 0 cover sheet (page 1a) Appendix A – 5 pages Appendix B – 21 pages Appendix C – 20 pages Appendix D – 3 pages Changes have been made to pages 1-6, 8, 11-12, 17-23, 27-29 with the addition of Attachment 8A.
2	This revision is in response to PER 166623. Revision includes changes to the maximum elevation for turbine operation. Also, an error was found in the gated discharge coefficient. A value of $H_{L,min}$ = 36.86' was used rather than the actual value of $H_{L,min}$ = 37.26' to determine C_g. This error was corrected throughout. Revision 2, 149 Total Pages, including original Rev 1 cover sheet (page 1a) and Rev 0 cover sheet (page 1b). Appendix A – 5 pages Appendix B – 21 pages Appendix C – 20 pages Appendix D – 3 pages Changes have been made to pages 1, 2, 3, 4, 5, 6, 11, 12, 17, 19, 21, 23, 27, 28, A5, Att. 8A-1, Att. A13-1 and Att. A13-2 with the addition of pages Att. 8A-2, Att. 8A-3 and Att. 8A-4. In addition, page 18 and Attachment 7 have been changed to further refine the tailwater curve fits.
3	This calculation was revised to address the following: • PER 203951-The verification of the previous revision of this calculation was completed by personnel who had not completed the required NEDP-7 Job Performance Record (JPR). A verification JPR is now in place for all personnel engaged in verification tasks. Checking includes only changes made in this revision as the checking of the calculation was not impacted by PER 203851. The verification is inclusive of work completed prior to this revision. • PER 203872- replace NEDP-2 forms on Pages 2 through 5 and Page 7 with the forms from the NEDP-2 Revision in effect at the time of calculations issuance • Replaced Unverified Assumption 3.2.1 with Assumption 3.1.5 based on Ref. 36 • Replaced Unverified Assumption 3.2.2 with Assumption 3.1.6 based on Ref. 37 and Appendix E • Replaced Unverified Assumption 3.2.3 with Assumption 3.1.7 based on Technical Justification

NPG CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER CDQ000020080007	
Title	Dam Rating Curves, Douglas
Revision No.	DESCRIPTION OF REVISION
3	• Added References 36, 37 and 38 • Revised the turbine discharges based on updated turbine discharge curves (Refs. 29 – 32) • Added Appendix E to evaluate the margin of forces on tainter gates. Significant changes in Revision 3 are noted with a right margin revision bar. Administrative changes and typos are excluded. Pages Added: 1c, 3a, 6, E1, E2, E3 Pages Replaced: 1 - 6, 11 – 13, 17, 19, 21, 27, 28, Attachments 8A-5 through 8A-8 Total pages of calculation hard copy for Revision 3= 155

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080007 | Revision: 3

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	Revision 2 Coversheet	1c
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1	General plan, Douglas Dam (Ref. 1)	1 page
2	Pages from BLN FSAR (Ref. 2)	7 pages
3	Photograph of Douglas Dam (Ref. 17)	1 page
4	Hydraulic Design Chart 711 (Ref. 6)	1 page
5	Sluice Flow Parameters (Ref. 24)	3 pages
6	Tailwater Rating Curve	2 pages
7	Tailwater Calculation Formula Derived From Attachment 6	1 page
8	PMF Modification Documentation (Ref. 17)	6 pages
8-A	Turbine Discharge Determination (Refs. 13, 29, 30, 31, 32, 33, 34, 35, 35, 38)	8 pages
Appendix A	Spillway Discharge Coefficients for Douglas Dam from 1:35 Scale Model Data	5 pages
	Attachments Associated with Appendix A	
A1	Location and numbering of spillway and sluice gates (Ref. 3)	1 page
A2	Gate arrangements and gate openings (Ref. 3)	1 page
A3	Measured gate openings (spreadsheet calculation and data from Ref. 27)	12 pages
A4	Definition sketch for spillway discharge	1 page
A5	Excerpt from Reference 20	5 pages
A6	Excerpt from Reference 28	5 pages
A7	Pages 490 and 491 (Ref. 18) (model scale ratios)	1 page
A8	Geometry for flow over an open tainter gate	5 pages
A9	Gates, general arrangement, TVA drawing no: 54W200, R4 (Ref. 23)	1 page
A10	Spillway crest details, TVA drawing no: 51N207, R1 (Ref. 22)	1 page
A11	Determination of H_{Lmin} from V	1 page
A12	Free discharge coefficient (Ref. 20)	2 pages
A13	Orifice discharge coefficient calculations (Ref. 4)	3 pages

NPG CALCULATION TABLE OF CONTENTS (CONTINUED)

Calculation Identifier: CDQ000020080007 | Revision: 3

TABLE OF CONTENTS

SECTION	TITLE	PAGE
Attachments (continued)		
Appendix B	Overflow Parameters Before Failure	21 pages
Appendix C	Overflow Parameters After Seismic Failure	20 pages
Appendix D	Calculation of Spillway Gate Overflow Discharge Coefficient	3 pages
Appendix E	Hydrostatic Loads on the Spillway Tainter Gates	3 pages
	Electronic Attachments (For Reference Only)	
9	TVA drawing no. 10W200, R11 (Ref. 1)	1 page
10	TVA drawing no. 21E205-1, R3 (Ref. 8)	1 page
11	TVA drawing no. 21E205-2, R1 (Ref. 9)	1 page
12	TVA drawing no. 21E205-3, R3 (Ref. 10)	1 page
13	TVA drawing no. 10W201, R8 (Ref. 11)	1 page
14	TVA drawing no. 31N218, R1 (Ref. 12)	1 page
15	TVA drawing no. 46N200, R1 (Ref. 13)	1 page
16	TVA drawing no. 23W203, R8 (Ref. 14)	1 page
17	TVA drawing no. 23W200, R11 (Ref. 15)	1 page
18	TVA drawing no. 23W204, R7 (Ref. 16)	1 page
19	TVA drawing no. 51N207, R1 (Ref. 22)	1 page
20	TVA drawing no. 54W200, R4 (Ref. 23)	1 page
21	"Norris Dam Discharge Ratings for Assumed Dam Failures During and Earthquake" (Ref. 19)	32 pages
22	"Discharge Coefficients for Spillways at TVA Dams", Kirkpatrick (Ref. 20)	22 pages
23	"Rating Curves for Flow Over Drum Gates", Bradley (Ref. 7)	32 pages
24	"Douglas Dam Spillway and Sluice Discharge Tables" (Ref. 3)	51 pages
25	"TVA Douglas Dam Water Control Project", Blue Book (Ref.17)	54 pages
26	Spreadsheet, "Douglas Dam Rating Curves, Rev 3.xls"	15 pages
27	TVA calculation RIMS no. B25 '88 0520 308, (Ref. 21)	71 pages
28	TVA drawing no. 51N200, R5 (Ref. 25)	1 page
29	TVA drawing no. 21N201, R5 (Ref. 26)	1 page
30	"Tainter Gate Rating Data Determined from Eight TVA Model Studies" (Ref. 28)	44 pages
31	TVA drawing no. 47K905, R0 (Ref. 29, 38)	1 page
32	TVA drawing no. 47K906, R0 (Ref. 30, 38)	1 page
33	TVA drawing no. 47K907, R0 (Ref. 31, 38)	1 page
34	TVA drawing no. 47K908, R0 (Ref. 32, 38)	1 page
35	TVA drawing no. 10N204, R1 (Ref. 33, 38)	1 page
36	TVA drawing no. 31N211, R1 (Ref. 34)	1 page
37	TVA drawing no. 14N412, R4 (Ref. 35)	1 page

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080007 Revision 3

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Verifier L Yu Lin Date 12/22/09

L. Lin

Comments:

This calculation entitled, "Dam Rating Curve, Douglas," was verified by independent design review. The process involved a critical review of the calculation to ensure that it is correct and complete, uses appropriate methodologies, and achieves its intended purpose. The inputs were reviewed and determined to be appropriate inputs for this calculation. The results of the calculation were reviewed and were found to be reasonable and consistent with the inputs provided. Backup files and documents were consulted as necessary to verify data and analysis details found in the calculation.

Detailed comments and editorial suggestions for the changes made in this revision were transmitted to the author and reviewer by email along with a marked up copy of the calculation.

The methodology used to justify the operability of the gates is based solely on the conclusions of the "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates." Appendix E uses the same assumptions, methodology, and approach developed in the Watts Bar radial gate analysis to determine the forces on the radial gates in a closed position with the forces on the gates in the maximum open position. This appendix does not assert that a structural analysis has been performed beyond that found in the Watts Bar radial gate calculation.

(Note: The design verification of this calculation revision is for the total calculation, not just the changes made in the revision. This complete re-verification is performed to disposition PER 203951 as described in the Calculation Revision Log on Page 3).

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document CDQ000020080007	Rev. 3	Plant: GEN	

Subject:
Dam Rating Curves, Douglas

☐ Electronic storage of the input files for this calculation is not required. Comments:

There are no electronic input or output files associated with this calculation.

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

These files are electronically attached to the parent ADOBE.pdf calculation file. All files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation.

Attachment 9, TVA drawing no: 10W200, R11 (Ref. 1)
Attachment 10, TVA drawing no: 21E205-1,R3 (Ref. 8)
Attachment 11, TVA drawing no: 21E205-2, R1 (Ref. 9)
Attachment 12, TVA drawing no: 21E205-3, R3 (Ref. 10)
Attachment 13, TVA drawing no: 10W201, R8 (Ref. 11)
Attachment 14, TVA drawing no: 31N218, R1 (Ref. 12)
Attachment 15, TVA drawing no: 46N200, R1 (Ref. 13)
Attachment 16, TVA drawing no: 23W203, R8 (Ref. 14)
Attachment 17, TVA drawing no: 23W200, R11 (Ref. 15)
Attachment 18, TVA drawing no: 23W204, R7 (Ref. 16)
Attachment 19, TVA drawing no: 51N207, R1 (Ref. 22)
Attachment 20, TVA drawing no: 54W200, R4 (Ref. 23)
Attachment 21, "Norris Dam Discharge Ratings for Assumed Dam Failures During an Earthquake" (Ref. 19)
Attachment 22, "Discharge Coefficients for Spillways at TVA Dams", Kirkpatrick (Ref. 20)
Attachment 23, "Rating Curves for Flow Over Drum Gates", Bradley (Ref. 7)
Attachment 24, "Douglas Dam Spillway and Sluice Discharge Tables" (Ref. 3)
Attachment 25, "TVA Douglas Dam Water Control Project", (Blue Book), (Ref. 17)
Attachment 26, Spreadsheet, "Douglas Dam Rating Curves, Rev. 3.xls"
Attachment 27, TVA calculation RIMS no. B25 '88 0520 308, "Douglas Dam Stability Analysis for ½ SSE + ½ PMF", (Ref. 21)
Attachment 28, TVA drawing no: 51N200, R5 (Ref. 25)
Attachment 29, TVA drawing no: 21N201, R5 (Ref. 26)
Attachment 30, "Tainter Gate Rating Data Determined from Eight TVA Model Studies" (Ref. 28)
Attachment 31, TVA drawing no. 47K905, R0 (Ref. 29, 38)
Attachment 32, TVA drawing no. 47K906, R0 (Ref. 30, 38)
Attachment 33, TVA drawing no. 47K907, R0 (Ref. 31, 38)
Attachment 34, TVA drawing no. 47K908, R0 (Ref. 32, 38)
Attachment 35, TVA drawing no. 10N204, R1 (Ref. 33)
Attachment 36, TVA drawing no. 31N211, R1 (Ref. 34)
Attachment 37, TVA drawing no. 14N412, R4 (Ref. 35)

☐ Microfiche/eFiche

1. Purpose

Dam rating curves for twenty dams geographically located on the Tennessee River and its tributaries above the existing Bellefonte Nuclear facility are required as inputs to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations. The dam rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Douglas Dam.

TVA developed methods of analysis, procedures, and computer programs for determining design basis flood levels for nuclear plant sites in the 1970's. Determination of maximum flood levels included consideration of the most severe flood conditions that may be reasonably predicted to occur at a site as a result of both severe hydrometerological conditions and seismic activity. This process was followed to meet Nuclear Regulatory Guide 1.59. At that time, there were no computer programs available that would handle unsteady flow and dam failure analysis. As a result of this early work and method development, TVA developed a runoff and stream course modeling process for the TVA reservoir system. This process provided a basis for currently licensed plants (Sequoyah Nuclear Plant, Watts Bar Nuclear Plant, and Browns Ferry Nuclear Plant). The Bellefonte Nuclear Plant (BLN) Units 1 & 2 Final Safety Analysis Report (FSAR) was also based on this process.

BLN Unit 3 & 4 Combined Operating License Application (COLA) was submitted using data and analysis that was determined for the original BLN FSAR (Unit 1 and Unit 2) and was documented in a 1998 reassessment. In 1998, the analysis process and documentation was brought under the nuclear quality assurance process for the first time. A quality assurance audit conducted by NRC staff in early 2007 raised several questions related to the documentation of past work regarding design basis flood level determinations. This calculation supports a portion of the effort to improve this design basis documentation.

Preparation of all calculations supporting nuclear development and licensing are subject to TVA Standard Department Procedure NEDP-2. This standard dictates the process in which calculations are prepared, checked, verified, stored and cross referenced in a goal to provide the highest quality nuclear design input and output possible.

Figure 1 is a plan and elevation view of Douglas Dam (a portion of Reference 1). A site plan showing the dam and its saddle dams is shown in Figure 2. A photograph is included as Attachment 3 (Ref. 17). For headwaters in the normal operating range, discharge is passed through the turbines, the sluices, or the spillway. The spillway consists of eleven spillway bays, each with a radial, or tainter gate to control discharge. If, as during a probable maximum flood (PMF) event, headwater rises above the normal operating range, discharge may pass also over the portion of the nonoverflow section which has not been modified, the tops of the open spillway gates and the tops of the spillway piers. The previously mentioned modifications to the nonoverflow section include raising the elevations of Blocks 1a – 3 and 28 – 32 to the PMF elevation of 1022.5 ft. in order to divert overtopping flow to the spillway and powerhouse portions of the dam (PMF Modification: Ref. 17, Att. 8; Blocks as transverse sections of the dam: Ref. 11, Att. 13). Also included in the modifications was the raising of the top elevation of each of the ten saddle dams to above the PMF elevation. Consequently, the rating curves developed in this calculation do not include headwater elevations above the tops of the modified nonoverflow or saddle dams.

As required by NRC Regulatory Guide 1.59, the most severe seismically induced floods reasonably possible should be considered for each site in addition to the floods produced by the severe hydrometeorological conditions. Also, the consideration of seismically induced floods should include the same range of seismic events as is postulated for the design of the nuclear plant. The seismic design basis for the plant requires consideration of an Operating Basis Earthquake (OBE) or 0.5 Safe Shutdown Earthquake (SSE) and a full SSE.

To meet the requirement of Regulatory Guide 1.59, the Bellefonte flood design basis requires consideration of the following hydrological and seismic design conditions (see Attachment 2-5, 2-6 and 2-7):

1) Determination of the water level at the plant during a 0.5 Probable Maximum Flood (PMF) with full reservoirs combined with the postulated failure of upstream dams during an OBE.
2) Determination of the water level at the plant during a 25-year flood with full reservoirs combined with the postulated failure of upstream dams during a 1.0 SSE.

Three potentially critical seismic-flood combinations scenarios are evaluated for the plant design basis (see Attachment 2-5). Two of these critical events include Douglas dam in the seismic failure scenario: (1) concurrent OBE failures of the Cherokee and Douglas dams combined with a 0.5 PMF, (2) concurrent 1.0 SSE failures of the Norris, Cherokee and Douglas dams combined with a 25 year flood. Based on seismic attenuation studies, the 1.0 SSE produces the same postulated failure of Douglas dam as the 0.5 SSE. Therefore, only a post-OBE failure dam rating curve must be generated in addition to the non-seismic failure dam rating curve. The Douglas dam OBE (0.5 SSE) concrete stability analysis and the post-OBE failure configuration used to develop the seismic dam rating curve are provided in Reference 21 and are discussed in detail in Attachment C.

Rating curves are provided for three cases:

1. Pre-failure condition with turbine discharge: Spillway, nonoverflow dam, embankments and saddle dams intact. This rating curve is used for both rising and falling headwaters until the headwater rises far enough for water to enter the powerhouse (headwater elevation 1009 feet [4.14.4]), the tailwater rises far enough to wet the switchyard (tailwater elevation 927.5 feet [4.14.3]), or the headwater rises far enough above the crest of the saddle dams to cause their failure. If either of the first two conditions occurs, turbine operation is suspended and this rating curve is no longer valid. The dam rating shifts to the Case 1A rating curve.

1A. Pre-failure condition without turbine discharge: Spillway, nonoverflow dam, embankments and saddle dams intact. This rating curve is used for both rising and falling headwaters after turbine operation has been suspended and until the headwater rises far enough above the crest of the saddle dams to cause their failure. At that time, this rating curve is no longer valid.

2. Seismic failure condition: Spillway and nonoverflow dam failure; embankments, powerhouse and saddle dams intact. This rating curve is used for both rising and falling headwaters unless the headwater rises far enough above the crest of the saddle dams to cause their failure.

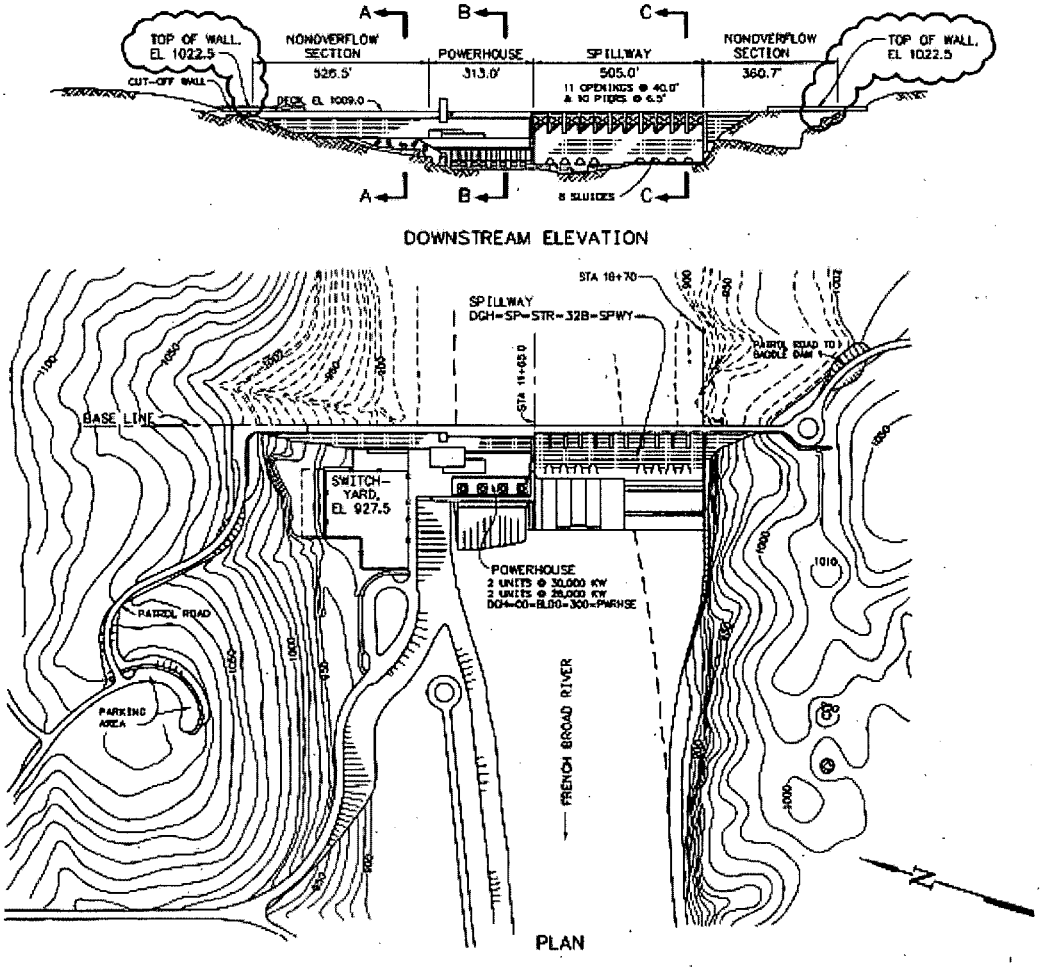
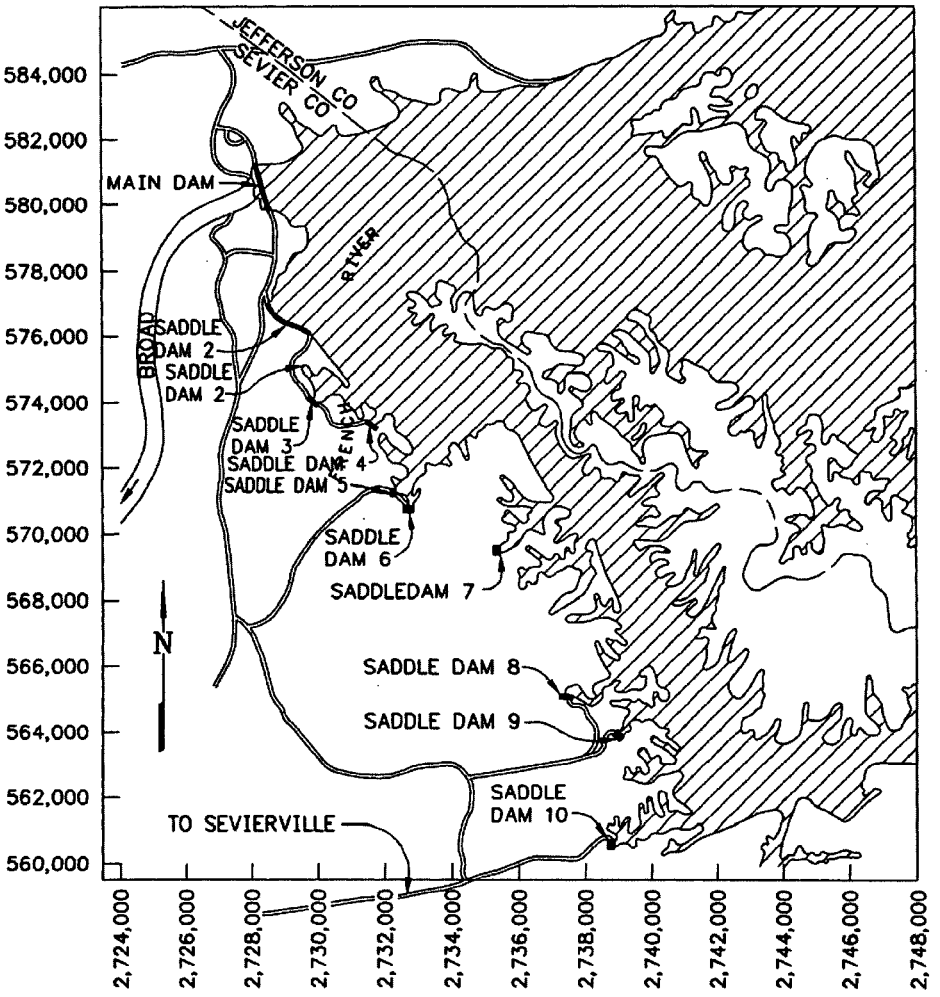


Figure 1 – Douglas Dam, General Plan and Elevation (Ref. 1).



SITE PLAN

Figure 2, Site Plan Including Saddle Dam Locations (Ref. 14)

2. References

1. TVA drawing no: 10W200, R11 (Attachments 1 and 9)
2. FSAR, Bellefonte Nuclear Plant, Units 1 and 2 (Attachment 2)
3. "Douglas Dam Spillway and Sluice Discharge Tables", River Operations, Tennessee Valley Authority, 2004, EDMS No. L58 081211 802 (Attachment 24).
4. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988.
5. Handbook of Hydraulics, E. F. Brater and H. W. King, Sixth Ed., McGraw Hill, 1976.
6. Hydraulic Design Chart 711 (HDC 711) from Reference 4 (Attachment 4).
7. "Rating Curves for Flow over Drum Gates," Joseph N. Bradley, Paper No. 2677, Transactions of the American Society of Civil Engineers, vol. 119, pp. 403-433, 1954 (Attachment 23).
8. TVA drawing no: 21E205-1, R3 (Attachment 10)
9. TVA drawing no: 21E205-2, R1 (Attachment 11)
10. TVA drawing no: 21E205-3, R3 (Attachment 12)
11. TVA drawing no: 10W201, R8 (Attachment 13)
12. TVA drawing no: 31N218, R1 (Attachment 14)
13. TVA drawing no: 46N200, R1 (Attachment 15)
14. TVA drawing no: 23W203, R8 (Attachment 16)
15. TVA drawing no: 23W200, R11 (Attachment 17)
16. TVA drawing no: 23W204, R7 (Attachment 18)
17. TVA Douglas Dam Water Control Project Manual (Blue Book), 1998 (Attachments 8 and 25)
18. Open Channel Flow, Sec. 2.7, F. M. Henderson, Macmillan, New York, 1966.
19. "Norris Dam Discharge Ratings for Assumed Dam Failures During an Earthquake, Advance Report No. 1", TVA Division of Water Control Planning Engineering Laboratory, January 1974. (Attachment 21)
20. "Discharge Coefficients for Spillways at TVA Dams," Kenneth W. Kirkpatrick, Paper No. 2855, Transactions of the American Society of Civil Engineers, vol. 22, pp. 190-210, 1957 (Attachment 22).
21. TVA calculation RIMS no. B25 '88 0520 308, "Douglas Dam Stability Analysis for ½ SSE + ½ PMF", (Att. 27 and Portion of Appendix C)
22. TVA drawing no: 51N207, R1 (Attachment 19 and A10)
23. TVA drawing no: 54W200, R4 (Attachment 20 and A9)
24. TVA files, binder "Douglas Sluice Rating Computations." (a portion is included in Att. 5)
25. TVA drawing no: 51N200, R5 (Attachment 28)
26. TVA drawing no: 21N201, R5 (Attachment 29)
27. TVA Files, binder "SPILLQ Vol. 3: Projects, Douglas through Hiwassee" (a portion is included in Att. A3)
28. "Tainter Gate Rating Data Determined from Eight TVA Model Studies," Tennessee Valley Authority, Division of Water Control Planning, Engineering Laboratory, Norris, TN, 1962, RIMS No. L58 080821 001 (Attachment 30)
29. TVA drawing no. 47K905, R0 (Attachment 31)
30. TVA drawing no. 47K906, R0 (Attachment 32)
31. TVA drawing no. 47K907, R0 (Attachment 33)
32. TVA drawing no. 47K908, R0 (Attachment 34)
33. TVA drawing no. 10N204, R1 (Attachment 35)
34. TVA drawing no. 31N211, R1 (Attachment 36)
35. TVA drawing no. 14N412, R4 (Attachment 37)
36. "SOCH Model Calibration, Ft. Loudoun - Tellico," CDQ000020080036 (EDMS L58 090814 003)
37. "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses," Tennessee Valley Authority, May 29, 2009 (EDMS No. L58 090529 800)
38. "Bellefonte Units 3 and 4 Hydrology Project Request for Information (RFI) Response Information Continuation Sheet," RFI Number: BWSC_75578_2009_056 (EDMS L58 091217 800)

3. Assumptions & Methodology

The dam rating curves developed in this calculation will be used to simulate probable maximum flood events. Consequently, the rating curves are calculated well above the normal operating range and several feet above the top of the dam.

3.1 Assumptions

3.1.1 Assumption: Power generation will be suspended at headwater elevations above the intake gate hoist opening on the upstream face of the dam. In addition, turbine discharge will be suspended when tailwater levels are high enough to flood electrical equipment.
Technical Justification: Drawing 10W200, R11 (Ref. 1, Att. 1) shows the elevation of the switchyard to be 927.5', directly below the portion of the nonoverflow dam which is expected to be overtopped during a PMF event. The photograph in Attachment 3 clearly shows the susceptibility of the switchyard to flooding from both high tailwater elevations and overtopping headwater elevations. Procedure dictates that generation be suspended should the switchyard be inundated. Attachment 8 provides supporting evidence of critical elevations.

3.1.2 Assumption: The ten saddle dams are assumed to be above the PMF level. In order to make this assumption, the reservoir water elevation at each of the saddle dams may be assumed to equal the PMF headwater elevation at Douglas Dam.
Technical Justification: The ten saddle dams stretch from around a quarter mile to two miles south of Douglas Dam at the end of a branch that connects to the main reservoir less than a mile upstream from the dam (see Figure 2). References 14, 15 and 16 show the elevations of the saddle dams to be greater than or equal to the PMF elevation.

3.1.3 Assumption: Steady-state tailwater rating is sufficient for computing submergence effects on the sluice discharge contribution to the dam rating curves.
Technical Justification: Use of a tailwater rating curve developed from steady-state flow analyses to compute submergence effects on a dam rating curve is an approximation. The unsteady-state tailwater elevation during a flood event would be lower than the steady state value while the tailwater is rising and higher than the steady state value while the tailwater is falling. Consequently, during times of rising tailwater the actual discharge would be somewhat larger than the rating value and during times of falling tailwater the discharge would be somewhat smaller than the rating value. However, the sluice discharge is a relatively small percent of the total discharge, except at the lowest headwater elevations, and any error associated with using a steady-state tailwater value to compute submergence effects would be only a small percent of the sluice discharge. For these reasons, the affect of this assumption on the total discharge values for the dam rating curve is expected to be negligible.

3.1.4 Assumption: Sluice discharge can be neglected during the seismic failure scenario.
Technical Justification: 1) The possibility exists that the debris from the failed spillway section could block the sluice tunnels. This can be seen in Appendix C which bases the discharge coefficient determination on Ref. 19. Case F1 (page C-11) clearly shows the failure debris in a position which would block the sluice tunnels, 2) The sluice discharge is such a small portion of the total discharge that it can be neglected for the purpose of seismic failure discharge determination, 3) The larger flow from the failed sections will lead to higher tailwater, and as tailwater rises, the sluice discharge decreases, therefore reinforcing justification (2).

3.1.5 Assumption: The tailwater rating curve provided in Attachment 6 is acceptable for use in development of the initial dam rating curve.
Technical Justification: The final tailwater curve is validated in the SOCH Model Calibration, Ft. Loudoun - Tellico (Reference 36) by ensuring consistency with the headwater-tailwater relationship across the modeled dam configuration.

3.1.6 Assumption: All spillway gates will remain operable and will be set to the maximum openings specified in the spillway discharge table. In addition, all sluice gates will be considered fully opened.
Technical Justification: For technical justification, see Reference 37, "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses", and Appendix E. The radial gates will remain operable in the maximum opened position based on the findings of the "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates" (Reference E1). Appendix E uses the same assumptions, methodology, and approach as the Watts Bar radial gate analysis to compare forces on the gates in a closed position with forces on the gates in the maximum open position to provide technical justification for the gates to remain operable in the maximum open position during a PMF.

3.1.7 Assumption: The modified wall over the nonoverflow dams and the saddle dams will not be overtopped during a PMF event.
Technical Justification: This PMF is sufficient for the resulting dam rating curve. If a SOCH/TRBROUTE analysis requires a PMF flood elevation higher than the maximum elevation considered, the change will be identified by the SOCH/TRBROUTE analyst and a revision to this dam rating curve calculation will be required.

3.2 Unverified Assumptions (UVA)

None.

3.3 Methodology -- Discharge Equations

Discharges past the dam are computed as either "free" discharge or "orifice" discharge. Free discharge refers to free surface overflow and is computed using a weir-type equation as follows (Reference 4 shows weir flow equations for overflow discharges and Reference 20 shows the discharge equation for both free and submerged flow over a spillway crest):

$$Q_f = C_f L H_c^{1.5} \quad (1)$$

in which Q_f = free discharge (cfs)
C_f = free discharge coefficient (may vary with HW)
L = length of overflowing section (ft)
H_c = head on crest (ft) = HW - Z_c
HW = headwater elevation (ft)
Z_c = top, or crest, elevation of overflowing section (ft)

This equation need not be modified to account for tailwater submergence, as no portion of the dam which has free surface overflow is expected to be submerged by tailwater.

Flow over the unmodified nonoverflow section, the tops of the open spillway gates and the tops of the spillway piers is treated as free discharge. Flow over the spillway crest is treated as free discharge for headwater elevations below $H_c = H_{Lmin}$, the head at which the overflowing nappe first touches the bottoms of the open gates (see Attachment A4). H_{Lmin} varies with gate opening, V, defined as the vertical distance between the bottom of the gate and the spillway crest.

For headwater elevations above $H_c = H_{Lmin}$ flow through the spillway gates is treated as orifice discharge. Orifice discharge refers to flow passing through a contracted opening and is computed as follows for a spillway gate (e.g., Reference 4, Hydraulic Design Chart 311-1):

$$Q_g = C_g G_n L\sqrt{2g(H_c - H_{mp})} \quad (2)$$

in which Q_g = orifice discharge (cfs)
C_g = orifice discharge coefficient (dimensionless--varies with gate opening and H_c)
G_n = effective gate opening = minimum distance between the gate lip and the crest (ft)
g = acceleration of gravity
H_{mp} = vertical distance between the mid-point of G_n and the crest

This equation need not be modified to account for tailwater submergence.

Sluice (spillway regulating conduit) discharge is also treated as orifice flow and computed using a simplified form of the orifice equation as follows (Att. 5):

$$Q_s = K\sqrt{HW - 878} \quad (3)$$

in which Q_s = sluice orifice discharge (cfs),
K = coefficient that varies with gate opening ($ft^{2.5}/s$),
HW = headwater elevation (ft), and 878 feet is the bottom elevation of the sluice tunnel at the gate location (Ref. 11, Att. 13)

The coefficient K lumps the constant quantities effecting orifice flow into one parameter. It may be thought of as equal to $CA(2g)^{0.5}$, where C = discharge coefficient and A = area under sluice gate. Because the discharge is through a closed conduit, both C and A, and consequently K, are constant for a given gate opening. In Equation 3, the head differential term is defined as $HW - Z_{bottom\ of\ sluice}$. The K - values for all sluice openings were determined from field measurements (Att. 5).

The above equation assumes no tailwater effects. Under the conditions for which this dam rating is developed, the tailwater may affect the sluice discharge. For the Douglas sluices set to their maximum openings of 10 feet ([3.2.2] and Reference 3), tailwater submergence effects will be computed for tailwater elevations, TW, at or above the conduit roof elevation at the gate location (888 feet) and the following equation will be used:

$$Q_{sl} = K\sqrt{HW - TW + 10} \quad (4)$$

where the Q_{sl} = discharge affected by submergence (cfs). By adding 10 feet (888 - 878) to the head difference term (HW-TW), the desirable result that $Q_{sl} = Q_s$ at TW = 888 feet, the elevation at which the tailwater is assumed to first affect the sluice discharge, is obtained. This formula has been developed to handle the specific conditions at Douglas Dam regarding tailwater affects on sluice discharge. Because the tailwater level varies with total dam discharge, an iterative process is used to determine submerged sluice discharge.

3.4 Methodology -- Spillway Discharge Calculations

The discharge coefficient, C_f, for free discharge over a spillway crest varies with head, H_c (References 4 and 5). For the Douglas spillway crest, the relationship $C_f(H_c)$ is available from Douglas model test data (Appendix A). The discharge coefficient, C_g, for orifice discharge varies with H_c and vertical gate opening, V. The relationships $H_{Lmin}(V)$ and $C_g(H_c,V)$ are available from Watts Bar model test data (Appendix A). Watts Bar data are applicable for these orifice flow parameters because the Douglas and Watts Bar spillway crests and gates are identical. The final paragraph on page 192 of Reference 20 states, "...the Douglas-Watts Bar set ... in Tennessee, have crest shapes that are identical..." The crest length, L, and crest elevation, Z_c, are shown on TVA drawings (e.g., Reference 1). The parameters G_n and H_{mp} are determined from geometry (Appendix A).

3.5 Methodology -- Discharge Coefficients for Overflow Sections

Values of the discharge coefficient for flows over the unmodified nonoverflow section, the powerhouse and the tops of the spillway piers are estimated using Hydraulic Design Chart 711 (Reference 6) which is included as Attachment 4. Length, L, and crest elevation, Z_c, in each case is determined from TVA drawings (all relevant drawings are defined as References). Appendix B contains calculations which determine the values of C_f before failure for each section which is expected to overflow. Appendix C contains calculations which determine the values of C_f after a probable seismic failure (Ref 21) for each section which is expected to overflow.

The upper plot of HDC 711 (Reference 6) shows that C_f is about 2.65 for very broad crests ($H_1/B < 0.4$ where $H_1 = H_c$ and B = streamwise length of the crest) and gradually increases to 3.1, the maximum value for a "broad-crested" weir, as H_1/B increases to about 1.2. As H_1/B increases above 1.2, C_f continues to increase as the weir transitions from broad-crested to sharp-crested at about $H_1/B = 2.0$. Since the estimation of discharge over the top of various sections of a dam and its embankments is an approximation, small variations in C_f with H_c are not modeled and the effects of end contractions are neglected. A single representative value for C_f within the range of its variation is used for all headwater elevations included in the rating. Neglecting minor variations in C_f values and end contractions has negligible impact on the dam rating curve.

Appendix D contains calculations which determine the discharge coefficient for flow over the tops of the open spillway gates using Reference 7 as a basis.

3.6 Methodology—Sluice Gates Discharge Coefficient

Douglas has eight 10 feet high by 5.667 feet wide sluice gates. Reference 11 (Att. 13) shows a cross-section through a sluice tunnel. All sluice gates will be considered fully open to 10 feet [3.2.2]. Attachments 5-1 and 5-2 contain two pages (4 & 5) from Reference 24 which documents field measurements and analyses used to establish discharge coefficients for the Douglas sluices. The first page shows that an average value of 344.1 was determined for a 10-foot sluice opening. The second page shows the final K-values that were determined for different sluice openings. The bases for these values were numerous field measurements collected between 1946 and 1960. This is the best information available and the K-values listed in Attachments 5-1 and 5-2 have been used by TVA since 1962 to compute and record discharges from the Douglas sluices. Attachment 5-3 contains a spot check on K-values used in the "Douglas Dam Spillway and Sluice Discharge Tables" (Ref. 3, Att. 24). It indicates values that differ slightly from those in Attachment 5-1 but this is because a polynomial curve fit for K vs. opening was derived from Att. 5-1 in order to produce Reference 3.

4. Design Input

Sect.	Input Parameter	Source	Symbol	Value
4.1	**Acceleration of gravity**	Common knowledge, Ref. 4, sheet. 000-1 for example	g	32.2 ft/sec^2
4.2	**Spillway crest parameters**			
4.2.1	Crest length	11 40-foot wide bays; Ref. 1 or Ref. 11	L	440 feet
4.2.2	Crest elevation	Ref. 1 or Ref. 11	Z_c	970 feet
4.2.3	Free discharge coefficient	Polynomial curve fit to points scaled from Figure 3 of Reference 20 (Att. A12-12). C_f is needed to an H_c of 36.86 feet (at the point where the nappe touches the bottom of the gate). The extrapolation is arbitrary but the extrapolated values of C_f are expected to be within plus or minus .05 or 1.5 percent of the true values.	$C_f(H_c)$	Equation A4
4.3	**Spillway gate parameters**			
4.3.1	Vertical opening	Field measurements given in Att. A3 and discussed in Appendix A	V	29.371 feet
4.3.2	Effective gate opening	Computed in Appendix A	G_n	29.783 feet
4.3.3	Mid-point elevation of opening relative to crest	Computed in Appendix A	H_{mp}	14.588 feet
4.3.4	Headwater elevation at which nappe touches gates	H_{Lmin} estimated in Appendix A	$H_{Lmin} + Z_c$	1007.26 feet
4.3.5	Orifice discharge coefficient	Extrapolated curve given in Att. A13 and Table A2 and discussed in Appendix A	$C_g(H_c)$	Interpolation between points in Table A2
4.4	**Spillway gate overflow**			
4.4.1	Overflow discharge coeff.	Justification in Appendix D	C_f	3.4
4.4.2	Overflow elevation	Computed in Appendix A	Z_f	1016.88 feet
4.4.3	Overflow length	Same as spillway crest, Ref. 1 or Ref. 11	L_f	440 feet
4.5	**Powerhouse Overflow Before Failure**	Does not consider the section of the powerhouse between the nonoverflow section and the tower		
4.5.1	Overflow discharge coeff.	Justification in Appendix B	C_f	2.7
4.5.2	Overflow elevation	Ref. 1 and 13	Z_c	1009 feet
4.5.3	Overflow length	Determined in Appendix B	L	269.3 feet
4.6	**Powerhouse Overflow After Failure**	Does not consider the section of the powerhouse between the nonoverflow section and the tower		
4.6.1	Overflow discharge coeff.	Justification in Appendix C	C_f	2.7
4.6.2	Overflow elevation	Ref. 1 and 13	Z_c	1009 feet
4.6.3	Overflow length	Determined in Appendix C	L	269.3 feet
4.7	**Nonoverflow overflow before failure**	Considers the portion of the powerhouse between the nonoverflow section and the tower		
4.7.1	Discharge coefficient	Justification in Appendix B	C_f	2.8
4.7.2	Overflow elevation	Ref. 1 and Ref. 11	Z_c	1009 feet
4.7.3	Overflow length	Determined in Appendix B	L	399.2 feet
4.8	**Nonoverflow overflow after failure (portion which does not fail)**	Considers the portion of the powerhouse between the nonoverflow section and the tower		
4.8.1	Discharge coefficient	Justification in Appendix C	C_f	2.8
4.8.2	Overflow elevation	Ref.1 and Ref. 11	Z_c	1009 feet
4.8.3	Overflow length	Determined in Appendix C	L	120.2 feet

4.9	**Nonoverflow overflow after failure (portion which fails)**			
4.9.1	Discharge coefficient	Justification in Appendix C	$C_f(H_c)$	Equation (5)
4.9.2	Overflow elevation	Ref. 21 (documented in Appendix C)	Z_c	927.5 feet
4.9.3	Overflow length	Ref. 21 (documented in Appendix C)	L	279 feet
4.10	**Spillway piers before failure**			
4.10.1	Discharge coefficient	Justification in Appendix B	C_f	2.7
4.10.2	Overflow elevation	Ref. 1 and Ref. 11	Z_c	1009 feet
4.10.3	Overflow length	Determined in Appendix B	L	65 feet
4.11	**Spillway after failure**			
4.11.1	Discharge coefficient	Justification in Appendix C	$C_f(H_c)$	Equation (5)
4.11.2	Overflow elevation	Ref. 21 (documented in Appendix C)	Z_c	937 feet
4.11.3	Overflow length	Ref. 21 (documented in Appendix C)	L	538 feet
4.12	**Sluice gates**			
4.12.1	Discharge coefficient with or without tailwater effects	Discussed in [3.3]	K	344.1
4.12.2	Elevation at which tailwater effects flow	Ref. 11, Att. 13		888 feet
4.12.4	Width of sluice gate	Ref. 11, Att. 13	W_s	5.667 feet
4.12.5	Height of sluice gate	Ref. 11, Att. 13	b_s	10 feet
4.12.5	Elevation of bottom of sluice gate	Ref. 11, Att. 13		878 feet
4.13	**Tailwater Curve**			
	TW v/s Total Discharge, Q	Paragraph 4.16	TW(Q)	Equation 6a or 6b
4.14	**Turbine Discharge**			
4.14.1	Discharge, Case 1	Section [4.18]		19,800 cfs
4.14.2	Discharge, Case 2	Section [4.18]		0
4.14.3	Maximum TW elev.	Section [4.18]		927.5 feet
4.14.4	Maximum HW elev.	Section [4.18]		1004.68 feet
4.14.5	Minimum gross head	Gross head = HW - TW, Section [4.18]		25 feet

4.15 Seismic Failure

Appendix C shows the postulated seismic failure section for Douglas Dam. The failure was considered in TVA calculation RIMS no. B25 '88 0520 308 (Ref. 21). The failure section extends from block 6 to block 11 of the nonoverflow dam, and block 18 to 28 which contains the entire spillway. The failure planes are considered roughly vertical and horizontal with the non-failed sections considered intact and structurally sound. Appendix C contains the details of failure with the overflow dimensions. The location and geometry of the resulting debris was considered. Case F1 from the Norris Dam Failure Study (Ref. 19. Att. 21) was used to model debris related to this failure scenario. From this case study information, a relationship between C_f and H_c was developed (App. C-3). The relationship is as follows:

$$C_f = 0.0103\ H_c + 2.53 \qquad (5)$$

For the purpose of the dam rating curve calculation the following parameter values are used for the failed portion of the nonoverflow dam: overflow elevation, $Z_c = 927.5$ feet; overflow length, L = 279 feet; and $C_f = 3.12$ (@ HW_{max}). The following parameter values are used for the failed spillway section: overflow elevation, $Z_c = 937$ feet; overflow length, L = 518 feet; and $C_f = 3.03$ (@ HW_{max}). It is not possible to accurately determine these values without conducting a physical model study. Given, that the dam failure scenario is an estimate and that the goal of this calculation is to analyze the effects of a sudden large discharge of uncertain magnitude into the Douglas tailwater, the indicated parameter values are adequate. The value for C_f is appropriate for a crest that is very broad compared to the depth of water flowing over it (Ref. 6, Att. 4).

4.16 Tailwater Rating Curve

Three models were used to develop tailwater rating curves for Douglas Dam (Att. 6). These models were used in the development of the curve used to calculate sluice flow in this calculation. Attachment 7 contains a polynomial fit to the model data. The resulting formula follows:

$$TW = 872 + 0.3015Q - 9.891\times10^{-4}Q^2 + 2.046\times10^{-6}Q^3 - 1.602\times10^{-9}Q^4 \quad \text{for } Q < 500{,}000 \text{ cfs} \qquad (6a)$$

$$TW = 896.0 + 8.543\times10^{-2}Q - 2.857\times10^{-5}Q^2 \quad \text{for } Q > 500{,}000 \text{ cfs} \qquad (6b)$$

in which Q = total discharge past the dam in cfs divided by 1000 ("1000 cfs").

It should be noted that the tailwater data which is used in the development of the above polynomial has been collected in the field by TVA over the course of many years. The values are currently in use at Douglas Dam.

4.17 Upper Limit on Headwater Elevation Included in Rating Curves

The dam rating curves need to include all headwater elevations that may occur during a PMF event. A PMF level of 1022.5 has been used to modify the nonoverflow dam and the ten saddle dams (Ref. 17, Att.8). This value will be used as the maximum headwater elevation. The saddle dams are not assumed to fail.

4.18 Turbine Discharge

Douglas Dam has four turbines (see Attachment 1). The turbines will be operated during a PMF until the tailwater or headwater reaches a level at which electrical components will get wet or excessive vibration occurs. The occurrence of excessive vibration is not predictable so turbine discharge is added to the total dam discharge until the limiting tailwater or headwater elevations are reached.

Electrical components may get wet if the tailwater rises above the level of the switchyard or if the tailwater or headwater rises to a level where water may enter the powerhouse. Once water enters the powerhouse, generation will be suspended and the units will not be restarted until a thorough inspection of the electrical equipment is done. Attachment 1 indicates that the switch yard would be under water for tailwater elevations above 927.5 feet, which is therefore the maximum tailwater elevation for turbine operation. Attachment 8A-1 verifies that water cannot enter the powerhouse for tailwater elevations below 928 feet. For headwater elevations above 1004.68 feet, water will flow through the gate hoist chamber into the elevator shaft, flooding the turbine room. Drawing detailing the location of overflow are included in Attachments 8A-2 through 8A-4. Therefore, the maximum headwater for turbine operation is 1004.68 feet.

Turbine discharge is included for case 1, but not for the case 2 rating curve. The case 2 rating curve is used only after the dam has failed in a seismic event. Power generation would necessarily be suspended if the dam were destroyed to the degree postulated in Appendix C.

Turbine discharge versus gross head, where gross head is the difference between the headwater elevation and the tailwater elevation, is estimated from the operating characteristics included as Attachments 8A-5 through 8A-8. The turbines are expected to be operated for maximum capacity, with the wicket gates open as far as possible (100% on Attachments 8A-5 through 8A-8). The lowest gross head included in the characteristics is 70 feet. Because the dam rating curves are used only when all spillway gates are fully open, resulting in much higher than normal tailwater elevations, turbine discharges for gross heads lower than 70 feet are needed for the rating curves. The turbine discharges for lower values of gross head are determined by linear extrapolation from the points given for maximum gate opening. As shown on Attachments 8A-5 through 8A-8, generator output would be less than zero for gross heads below an average of 25 feet. Therefore, the minimum gross head for turbine operation is 25 feet.

The results for case 1 show several headwaters at which gross head is greater than 25 feet but turbine discharge is zero. In those cases the gross head is greater than 29 feet with the turbines off but less than 25 feet with the turbines on. For the rating curves, turbine discharge is set to zero if the gross head with turbines operating is below 25 feet.

The case 1 rating curve was computed first without turbine discharge to determine the range of gross heads that occur during the PMF. Then, discharges for Units 1, 2, 3 and 4 at a nominal gross head within the range of variation above the lower limit of 25 feet were estimated from Attachments 8A-5 though 8A-8. The total discharge at this nominal head is used for all headwaters at which turbine discharge is expected. Table 1 summarizes the results. Use of a nominal gross head within the range of variation to estimate turbine discharge for all headwater elevations and rounding the turbine discharge does not significantly affect the results since the turbine discharge is a small percentage of the total dam discharge.

Table 1: Turbine Discharge for Case 1 Rating Curve

Case	Gross Head Range feet	Nominal Gross Head feet	Discharge at Nominal Gross Head, cfs				
			Unit 1	Unit 2	Unit 3	Unit 4	Total
1	25≥105	65	4,900	5,100	4,800	5,000	19,800

Because the turbines will not be restarted until a thorough inspection is made, two curves are included in Case 1. The first is for rising headwaters. This curve includes turbine discharge. The second is Case 1A. Turbine discharge is not included in this curve, as the turbines are not expected to be operated for some time following a flooding of the electrical equipment.

5. Special Requirements/Limiting Conditions

N/A

6. Calculations

The calculations consist of computing spillway, sluice and dam overflow discharges (from Equations 1 through 4) for a list of headwater elevations ranging from the minimum for which discharge exceeds zero up to 1022.5 feet [4.17], which is at the same elevation as the tops of the nonoverflow dam modifications and the lowest of the saddle dams. During a design seismic event, portions of the dam are expected to fail [4.15]. The ten saddle dams are not expected to fail. The dam rating curve for each case is a plot of headwater elevation versus total dam discharge.

6.1 Case 1, Pre-Failure Condition With Turbines Operating

For the pre-failure condition, discharges are computed for headwaters ranging from 960 feet, ten feet below the spillway crest elevation, to 1022.5 feet, the PMF elevation. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs through the sluice gates divided by 1000.

Figure 3 shows the spreadsheet calculations for the pre-failure dam rating curve (spreadsheet included as Attachment 26). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The third column (TW) gives the tailwater associated with the "Total Discharge" from the tailwater rating curve polynomial fit [4.16]. This is computed to check for tailwater submergence effects on the sluice discharge. Tailwater does not affect any other flow.

Spillway discharge in cfs is given in the sixth column (under the header "Spillway"). H_c and $C_f|C_g$ are the parameters used to determine the spillway discharge, $Q_f|Q_g$. Free discharge occurs for headwater elevations below 1007.26 feet [4.3.4] and orifice discharge occurs for headwaters above this elevation. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation (A4) and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation from Table A2. Column $Q_f|Q_g$ is the spillway discharge computed from Equation (1) for free discharge and from Equation (2) for orifice discharge.

Sluice discharge in cfs is given in the seventh column (under the header "Sluices"). Because there are eight sluices, the total discharge is computed by multiplying either Equation (3) or (4) by eight. Equation (3) is used before tailwater effects are considered. Equation (4) is used when the tailwater elevation affects the discharge (at elev. 888' [4.12.2]). A line is used to denote the transition point.

The column following the sluice discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next four columns are overflow discharges in cfs for the spillway gates, spillway piers, nonoverflow section and powerhouse. The overflow discharge coefficient C_f ([4.4.1], [4.5.1], [4.7.1], [4.10.1]), elevation Z_c ([4.4.2], [4.5.2], [4.7.2], [4.10.2]), and length L ([4.4.3], [4.5.3], [4.7.3], [4.10.3]) in each case is indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1.

The final two columns contain the gross head and turbine discharge. The gross head is the difference between the headwater and tailwater elevations. The turbine discharge was determined in section 4.18.

Pre-Failure Overflow Discharge Calculations: Spillway, Nonoverflow Dam and Saddle Dams Intact

g = 32.2 ft/s^2

Spillway Parameters
L_c = 440 feet
Z_c = 970 feet
G_n = 29.783 feet
H_{mp} = 14.588 feet

HW feet	Q Total Discharge 1000 cfs	TW feet	Spillway H_c feet	Spillway C_f / C_g	Spillway Q_f / Q_g cfs	Sluices 8 gates cfs	Overflow Discharge, Q_f in cfs: C_f = / Z_c = / L = Spill Gate Overflow	Spillway Pier Overflow	Non Overflow Dam	Power-House	Turbine Discharge: Gross Head ft	Turbine Discharge cfs
							3.4 / 1016.88 / 440	2.7 / 1009 / 65	2.8 / 1009 / 399.2	2.7 / 1009 / 269.33		
878	**0.00**	872.00	0.00	3.16	0	0	0	0	0	0	6.0	0
880	**3.89**	873.16	0.00	3.16	0	3893	0	0	0	0	6.8	0
890	**9.54**	874.79	0.00	3.16	0	9536	0	0	0	0	15.2	0
900	**12.91**	875.73	0.00	3.16	0	12912	0	0	0	0	24.3	0
910	**35.37**	881.52	0.00	3.16	0	15572	0	0	0	0	28.5	19800
920	**37.64**	882.05	0.00	3.16	0	17840	0	0	0	0	37.9	19800
930	**39.65**	882.52	0.00	3.16	0	19851	0	0	0	0	47.5	19800
940	**41.48**	882.94	0.00	3.16	0	21676	0	0	0	0	57.1	19800
950	**43.16**	883.33	0.00	3.16	0	23358	0	0	0	0	66.7	19800
960	**44.73**	883.68	0.00	3.16	0	24928	0	0	0	0	76.3	19800
970	**46.20**	884.01	0.00	3.16	0	26404	0	0	0	0	86.0	19800
972	**50.52**	884.96	2.00	3.24	4031	26689	0	0	0	0	87.0	19800
974	**58.42**	886.63	4.00	3.31	11647	26972	0	0	0	0	87.4	19800
976	**68.85**	888.70	6.00	3.37	21801	27251	0	0	0	0	87.3	19800
978	**81.45**	891.03	8.00	3.43	34123	27528	0	0	0	0	87.0	19800
980	**95.26**	893.38	10.00	3.48	48401	27058	0	0	0	0	86.6	19800
982	**111.28**	895.88	12.00	3.53	64493	26989	0	0	0	0	86.1	19800
984	**129.02**	898.38	14.00	3.57	82300	26918	0	0	0	0	85.6	19800
986	**148.41**	900.87	16.00	3.61	101756	26849	0	0	0	0	85.1	19800
988	**169.40**	903.32	18.00	3.65	122813	26786	0	0	0	0	84.7	19800
990	**191.97**	905.73	20.00	3.70	145440	26728	0	0	0	0	84.3	19800
992	**216.09**	908.12	22.00	3.74	169612	26673	0	0	0	0	83.9	19800
994	**241.73**	910.51	24.00	3.78	195311	26616	0	0	0	0	83.5	19800
996	**268.86**	912.96	26.00	3.81	222511	26553	0	0	0	0	83.0	19800
998	**297.46**	915.47	28.00	3.85	251176	26479	0	0	0	0	82.5	19800
1000	**327.45**	918.09	30.00	3.89	281254	26391	0	0	0	0	81.9	19800
1002	**358.76**	920.80	32.00	3.93	312667	26289	0	0	0	0	81.2	19800
1004	**391.28**	923.56	34.00	3.96	345302	26180	0	0	0	0	80.4	19800
1005	**388.39**	923.31	35.00	3.97	362032	26359	0	0	0	0	81.7	0
1006	**405.31**	924.71	36.00	3.99	379007	26302	0	0	0	0	81.3	0
1007	**422.45**	926.08	37.00	4.00	396198	26249	0	0	0	0	80.9	0
1007.26	**426.94**	926.43	37.26	4.00	400700	26236	0	0	0	0	80.8	0
1008	**425.18**	926.29	38.00	0.784	398818	26362	0	0	0	0	81.7	0
1009	**422.39**	926.07	39.00	0.762	395854	26536	0	0	0	0	82.9	0
1010	**420.97**	925.96	40.00	0.740	392257	26695	0	176	1118	727	84.0	0
1011	**420.61**	925.94	41.00	0.718	388051	26840	0	496	3161	2057	85.1	0
1012	**431.48**	926.78	42.00	0.716	394118	26863	0	912	5808	3779	85.2	0
1013	**443.05**	927.64	43.00	0.714	400009	26882	0	1404	8941	5818	85.4	0
1014	**455.22**	928.49	44.00	0.711	405733	26902	0	1962	12496	8130	85.5	0
1015	**467.92**	929.33	45.00	0.709	411297	26925	0	2579	16426	10687	85.7	0
1016	**481.08**	930.12	46.00	0.707	416707	26954	0	3250	20700	13468	85.9	0
1016.88	**494.18**	930.82	46.88	0.707	422504	26980	0	3882	24723	16086	86.1	0
1017	**496.05**	930.91	47.00	0.707	423288	26984	62	3971	25290	16454	86.1	0
1018	**513.02**	932.31	48.00	0.707	429769	26929	1773	4739	30177	19634	85.7	0
1019	**531.58**	933.34	49.00	0.707	436153	26924	4618	5550	35344	22996	85.7	0
1020	**551.31**	934.41	50.00	0.707	442444	26914	8244	6403	40776	26530	85.6	0
1021	**572.04**	935.52	51.00	0.707	448648	26899	12511	7295	46461	30229	85.5	0
1022	**593.68**	936.65	52.00	0.707	454767	26881	17332	8226	52388	34085	85.4	0
1022.5	**604.81**	937.22	52.50	0.707	457796	26871	19931	8705	55439	36070	85.3	0

Figure 3 – Calculations for Case 1, Pre-Failure Condition With Turbines Operating

6.2 Case 2, Pre-Failure Condition Without Turbines Operating

For the pre-failure condition, discharges are computed for headwaters ranging from 960 feet, ten feet below the spillway crest elevation, to 1022.5 feet, the PMF elevation. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs through the sluice gates divided by 1000.

Figure 4 shows the spreadsheet calculations for the pre-failure dam rating curve (spreadsheet included as Attachment 26). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The third column (TW) gives the tailwater associated with the "Total Discharge" from the tailwater rating curve polynomial fit [4.16]. This is computed to check for tailwater submergence effects on the sluice discharge. Tailwater does not affect any other flow.

Spillway discharge in cfs is given in the sixth column (under the header "Spillway"). H_c and $C_f|C_g$ are the parameters used to determine the spillway discharge, $Q_f|Q_g$. Free discharge occurs for headwater elevations below 1007.26 feet [4.3.4] and orifice discharge occurs for headwaters above this elevation. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation (A4) and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation from Table A2. Column $Q_f|Q_g$ is the spillway discharge computed from Equation (1) for free discharge and from Equation (2) for orifice discharge.

Sluice discharge in cfs is given in the seventh column (under the header "Sluices"). Because there are eight sluices, the total discharge is computed by multiplying either Equation (3) or (4) by eight. Equation (3) is used before tailwater effects are considered. Equation (4) is used when the tailwater elevation affects the discharge (at elev. 888' [4.12.2]). A line is used to denote the transition point.

The column following the sluice discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next four columns are overflow discharges in cfs for the spillway gates, spillway piers, nonoverflow section and powerhouse. The overflow discharge coefficient C_f ([4.4.1], [4.5.1], [4.7.1], [4.10.1]), elevation Z_c ([4.4.2], [4.5.2], [4.7.2], [4.10.2]), and length L ([4.4.3], [4.5.3], [4.7.3], [4.10.3]) in each case is indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1.

TVA

Calculation No. CDQ000020080007	Rev: 2	Plant: GEN	Page: 23
Subject: Dam Rating Curves, Douglas	Prepped	S.E.M.	
	Checked	J.C.T. (R0), A.T.T. (R1), A.T.T. (R2)	

Pre-Failure Overflow Discharge Calculations Without Turbine Operation: Spillway, Nonoverflow Dam and Saddle Dams Intact

g = 32.2 ft/s²

Spillway Parameters
L_c = 440 feet
Z_c = 970 feet
G_n = 29.783 feet
H_{mp} = 14.588 feet

			Spillway				Overflow Discharge, Q_f in cfs			
							Spill Gate Overflow	Spillway Pier Overflow	Non Overflow Dam	Power-House
	Q Total					Sluices	Cf = 3.4	2.7	2.8	2.7
HW	Discharge	TW	H_c	C_f / C_g	Q_f / Q_g	8 gates	Zc = 1016.88	1009	1009	1009
feet	1000 cfs	feet	feet		cfs	cfs	L = 440	65	399.2	269.33
878	0.00	872	0		0	0	0	0	0	0
880	3.89	873.159	0		0	3893	0	0	0	0
890	9.54	874.787	0		0	9536	0	0	0	0
900	12.91	875.732	0		0	12912	0	0	0	0
910	15.57	876.463	0		0	15572	0	0	0	0
920	17.84	877.075	0		0	17840	0	0	0	0
930	19.85	877.611	0		0	19851	0	0	0	0
940	21.68	878.091	0		0	21676	0	0	0	0
950	23.36	878.528	0		0	23358	0	0	0	0
960	24.93	878.9	0		0	24928	0	0	0	0
970	26.40	879.3	0	3.16	0	26404	0	0	0	0
972	30.72	880.4	2	3.24	4031	26689	0	0	0	0
974	38.62	882.3	4	3.31	11647	26972	0	0	0	0
976	49.05	884.6	6	3.37	21801	27251	0	0	0	0
978	61.65	887.3	8	3.43	34123	27528	0	0	0	0
980	75.92	890.0	10	3.48	48401	27524	0	0	0	0
982	91.91	892.8	12	3.53	64493	27414	0	0	0	0
984	109.60	895.6	14	3.57	82300	27303	0	0	0	0
986	128.95	898.4	16	3.61	101756	27199	0	0	0	0
988	149.92	901.1	18	3.65	122813	27104	0	0	0	0
990	172.46	903.7	20	3.70	145440	27020	0	0	0	0
992	196.56	906.2	22	3.74	169612	26945	0	0	0	0
994	222.18	908.7	24	3.78	195311	26874	0	0	0	0
996	249.31	911.2	26	3.81	222511	26802	0	0	0	0
998	277.90	913.8	28	3.85	251176	26724	0	0	0	0
1000	307.89	916.4	30	3.89	281254	26635	0	0	0	0
1002	339.20	919.1	32	3.93	312667	26532	0	0	0	0
1004	371.72	921.9	34	3.96	345302	26417	0	0	0	0
1005	388.39	923.3	35	3.97	362032	26359	0	0	0	0
1006	405.31	924.7	36	3.99	379007	26302	0	0	0	0
1007	422.45	926.1	37	4.00	396198	26249	0	0	0	0
1007.26	426.94	926.4	37.26	4.00	400700	26236	0	0	0	0
1008	425.18	926.3	38	0.784	398818	26362	0	0	0	0
1009	422.39	926.1	39	0.762	395854	26536	0	0	0	0
1010	420.97	926.0	40	0.740	392257	26695	0	176	1118	727
1011	420.61	925.9	41	0.718	388051	26840	0	496	3161	2057
1012	431.48	926.8	42	0.716	394118	26863	0	912	5808	3779
1013	443.05	927.6	43	0.714	400009	26882	0	1404	8941	5818
1014	455.22	928.5	44	0.711	405733	26902	0	1962	12496	8130
1015	467.92	929.3	45	0.709	411297	26925	0	2579	16426	10687
1016	481.08	930.1	46	0.707	416707	26954	0	3250	20700	13468
1016.88	494.18	930.8	46.88	0.707	422504	26980	0	3882	24723	16086
1017	496.05	930.9	47	0.707	423288	26984	62	3971	25290	16454
1018	513.02	932.3	48	0.707	429769	26929	1773	4739	30177	19634
1019	531.58	933.3	49	0.707	436153	26924	4618	5550	35344	22996
1020	551.31	934.4	50	0.707	442444	26914	8244	6403	40776	26530
1021	572.04	935.5	51	0.707	448648	26899	12511	7295	46461	30229
1022	593.68	936.6	52	0.707	454767	26881	17332	8226	52388	34085
1022.5	604.81	937.2	52.50	0.707	457796	26871	19931	8705	55439	36070

Figure 4 – Calculations for Case 1, Pre-Failure Condition Without Turbines Operating

6.3 Case 2, Seismic Failure of Spillway and Portion of Nonoverflow Dam

Figure 4 shows the spreadsheet calculations for the dam rating curve following seismic failure of the spillway and a portion of the nonoverflow dam [4.14]. For the pre-failure condition, discharges are computed for headwaters ranging from 927.5 feet [4.9.2] to 1022.5 feet [4.16]. The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge.

The third column contains the overflow parameters for the failure sections. The elevation of the horizontal failure plane is denoted Z_c [4.9.2], [4.11.2]. The length of the failure section is denoted L [4.9.3], [4.11.3].

The fourth and seventh columns contain the calculation of H which is the difference between the headwater elevation and the failure plane elevation.

Failure section discharge, Q_f, in cfs is computed in the sixth and ninth columns (under the header "Failure Section"), H_c and C_f are the parameters used to determine the discharge, Q_f. Free discharge occurs for headwater elevations above 927.5 feet [4.9.2]. This encompasses all elevations with overflow.

The tenth column shows "C_f=", "Z_c=", and "L=" indicating parameters used to determine discharges in the "Non-Failed Section" columns. The discharge coefficients [4.6.1], [4.8.1] and section lengths [4.6.2], [4.8.2] were calculated in Appendix C. The final two columns contain the overflow discharge, Q_f, for the non-failed sections.

Rating for Assumed Seismic Failure Condition

			Failure Sections							Non-Failed Section	
										Nonoverflow Dam	Powerhouse
	Total	Zc =			927.5			937	Cf =	2.8	2.7
	Discharge	L =			279			538	Zc =	1009	1009
Headwater	1000 cfs		Hc	Cf	Qf, cfs	Hc	Cf	Qf, cfs	L =	120.17	269.33
927.5	0.00		0	2.53	0			0		0	0
930	2.79		2.5	2.53	2790			0		0	0
933	9.10		5.5	2.53	9105			0		0	0
937	20.67		9.5	2.53	20669	0	2.53	0		0	0
940	38.27		12.5	2.53	31195	3	2.53	7073		0	0
950	139.13		22.5	2.53	75335	13	2.53	63800		0	0
960	280.92		32.5	2.53	130783	23	2.53	150139		0	0
970	457.71		42.5	2.58	199673	33	2.53	258032		0	0
975	560.32		47.5	2.63	240630	38	2.54	319688		0	0
980	677.70		52.5	2.69	285073	43	2.59	392629		0	0
985	805.30		57.5	2.74	333018	48	2.64	472278		0	0
990	943.14		62.5	2.79	384485	53	2.69	558652		0	0
992	1001.16		64.5	2.81	406065	55	2.71	595091		0	0
994	1060.83		66.5	2.83	428214	57	2.73	632613		0	0
996	1122.16		68.5	2.85	450935	59	2.75	671221		0	0
998	1185.15		70.5	2.87	474229	61	2.77	710919		0	0
1000	1249.81		72.5	2.89	498100	63	2.79	751709		0	0
1009	1561.58		81.5	2.98	612700	72	2.89	948882		0	0
1015	1804.17		87.5	3.05	695703	78	2.95	1092834		4945	10687
1020	2028.30		92.5	3.10	768961	83	3.00	1220531		12276	26530
1022.5	2146.80		95	3.12	806997	86	3.03	1287041		16690	36070

Figure 5 – Calculations for Case 2, Seismic Failure

7. Results/Conclusions

For convenience, the dam rating results, separate from the calculation details provided above, are tabulated as total discharge in cfs vs. headwater elevation in feet in Figure 6. The Case 1 & 1A dam rating curves are plotted in Figure 7. The Case 2 dam rating curve is plotted in Figure 8.

Tailwater affects only sluice discharge. The tailwater elevations never reach within 35 feet of the spillway crest [Fig. 3].

The dam rating curves developed in this calculation provide Douglas total dam discharge vs. headwater elevation for use in TVA's SOCH and TRBROUTE models for simulation conditions satisfying the assumptions in [3.1] and [3.2]. In particular, the spillway gates must all be fully raised and the sluices must all be fully open. The Case 1 and 1A (pre-failure) curves are used for both rising and falling headwaters with the assumption that the saddle dams and the nonoverflow modification walls are not overtopped and remain structurally sound. Then the Case 2 (seismic event causing dam failure) curve is used for both rising and falling headwaters with no further failures or sluice flow.

Case 1 and Case 1A
Pre-Failure Condition

	With Turbines		Without Turbines	
HW (ft)	TW (ft)	Q (1000 cfs)	TW (ft)	Q (1000 cfs)
878	872.00	0.00	872.00	0.00
880	873.16	3.89	873.16	3.89
890	874.79	9.54	874.79	9.54
900	875.73	12.91	875.73	12.91
910	881.52	35.37	876.46	15.57
920	882.05	37.64	877.08	17.84
930	882.52	39.65	877.61	19.85
940	882.94	41.48	878.09	21.68
950	883.33	43.16	878.53	23.36
960	883.68	44.73	878.93	24.93
970	884.01	46.20	879.31	26.40
972	884.96	50.52	880.39	30.72
974	886.63	58.42	882.28	38.62
976	888.70	68.85	884.64	49.05
978	891.03	81.45	887.28	61.65
980	893.38	95.26	890.03	75.92
982	895.88	111.28	892.83	91.91
984	898.38	129.02	895.63	109.60
986	900.87	148.41	898.38	128.95
988	903.32	169.40	901.05	149.92
990	905.73	191.97	903.66	172.46
992	908.12	216.09	906.19	196.56
994	910.51	241.73	908.70	222.18
996	912.96	268.86	911.20	249.31
998	915.47	297.46	913.76	277.90
1000	918.09	327.45	916.39	307.89
1002	920.80	358.76	919.11	339.20
1004	923.56	391.28	921.91	371.72
1005	923.31	388.39	923.31	388.39
1006	924.71	405.31	924.71	405.31
1007	926.08	422.45	926.08	422.45
1007.26	926.43	426.94	926.43	426.94
1008	926.29	425.18	926.29	425.18
1009	926.07	422.39	926.07	422.39
1010	925.96	420.97	925.96	420.97
1011	925.94	420.61	925.94	420.61
1012	926.78	431.48	926.78	431.48
1013	927.64	443.05	927.64	443.05
1014	928.49	455.22	928.49	455.22
1015	929.33	467.92	929.33	467.92
1016	930.12	481.08	930.12	481.08
1017	930.82	494.18	930.82	494.18
1017	930.91	496.05	930.91	496.05
1018	932.31	513.02	932.31	513.02
1019	933.34	531.58	933.34	531.58
1020	934.41	551.31	934.41	551.31
1021	935.52	572.04	935.52	572.04
1022	936.65	593.68	936.65	593.68
1022.5	937.22	604.81	937.22	604.81

Case 2
Seismic Failure

HW (ft)	Q (1000 cfs)
927.5	0.00
930	2.79
933	9.10
937	20.67
940	38.27
950	139.13
960	280.92
970	457.71
975	560.32
980	677.70
985	805.30
990	943.14
992	1001.16
994	1060.83
996	1122.16
998	1185.15
1000	1249.81
1009	1561.58
1015	1804.17
1020	2028.30
1022.5	2146.80

Figure 6 – Dam Rating Results for Cases 1, 1A and 2

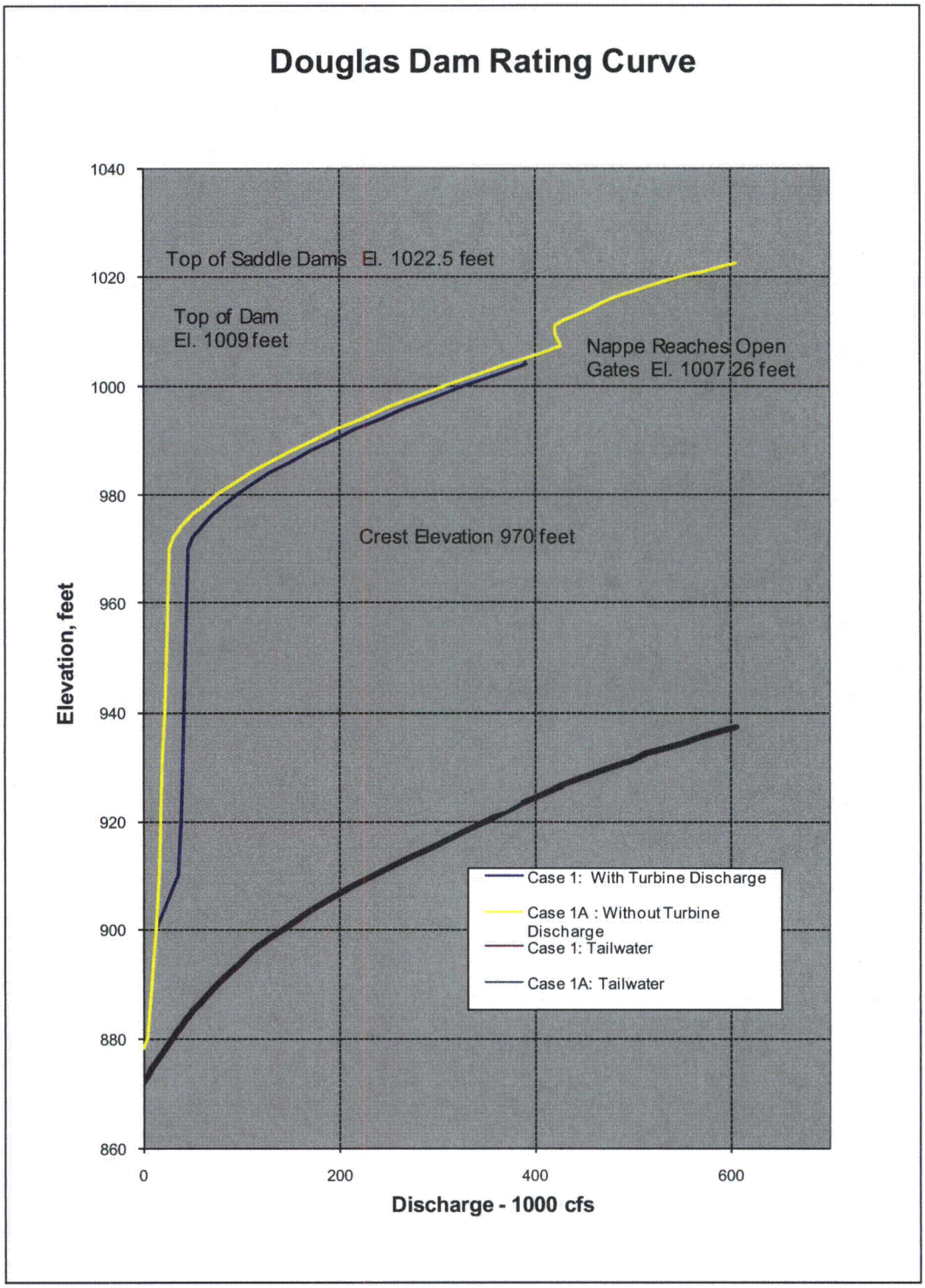


Figure 7 – Dam Rating Curves for Cases 1 and 1A

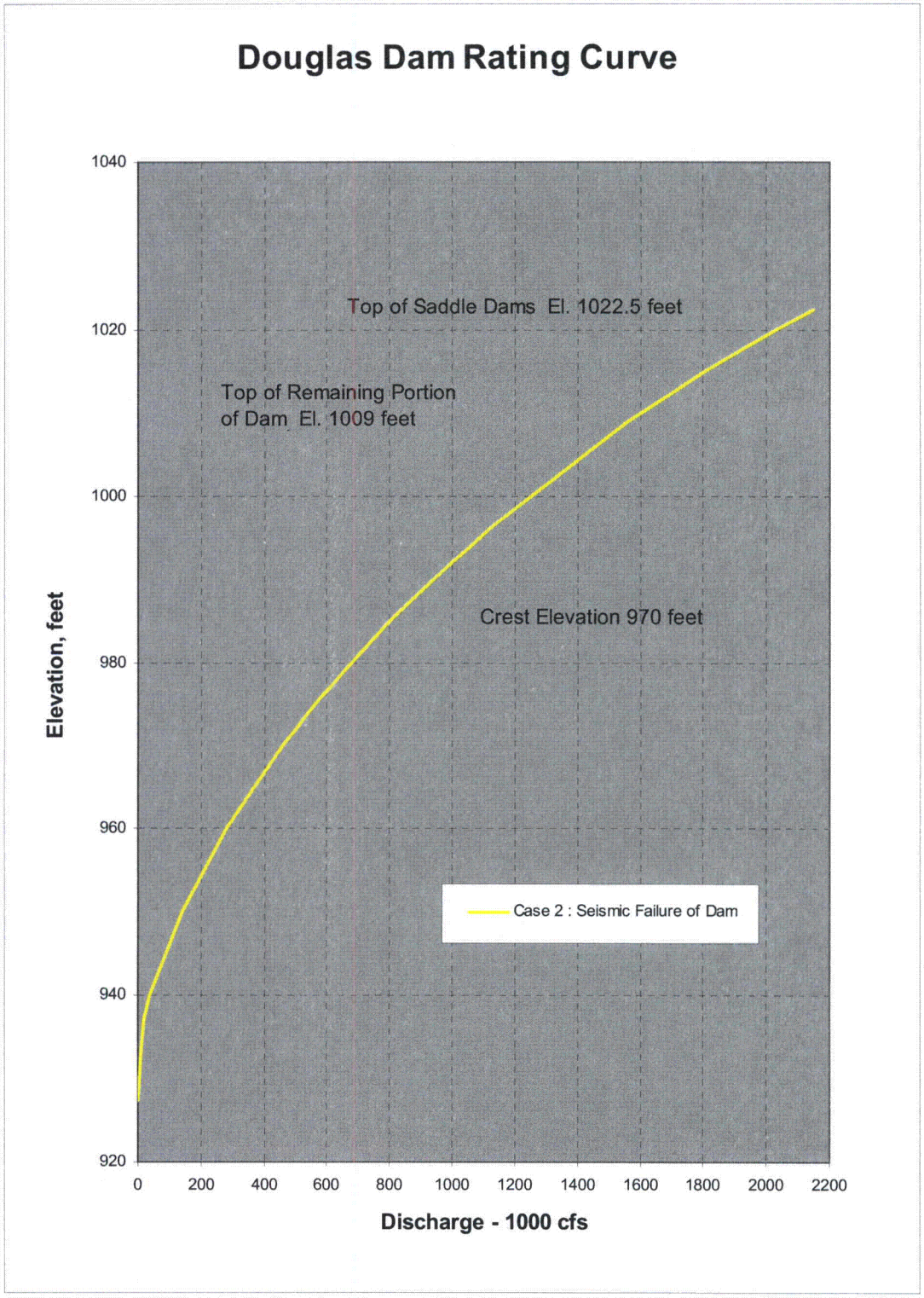
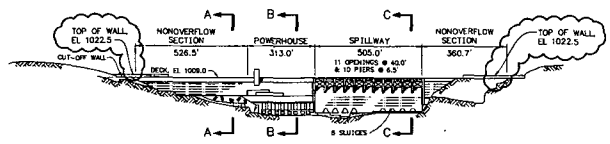


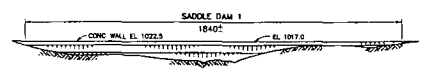
Figure 8 – Dam Rating Curve for Case 2

Attachment 1
Ref. 1
1 page

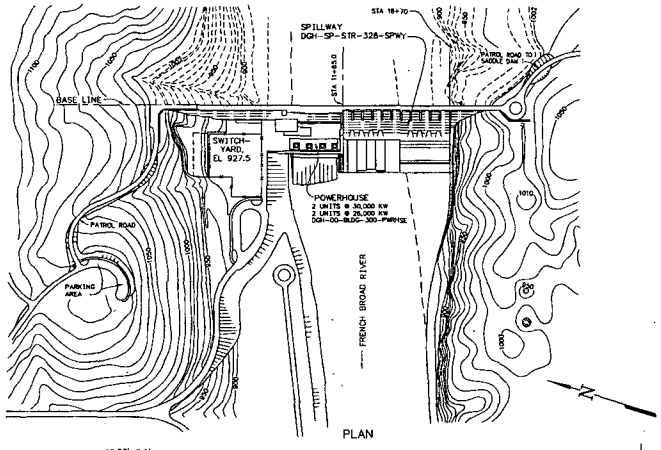
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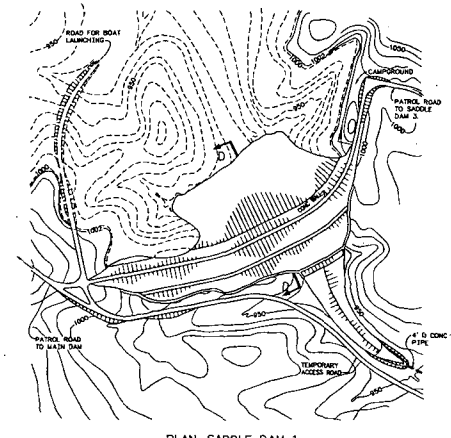
DOWNSTREAM ELEVATION



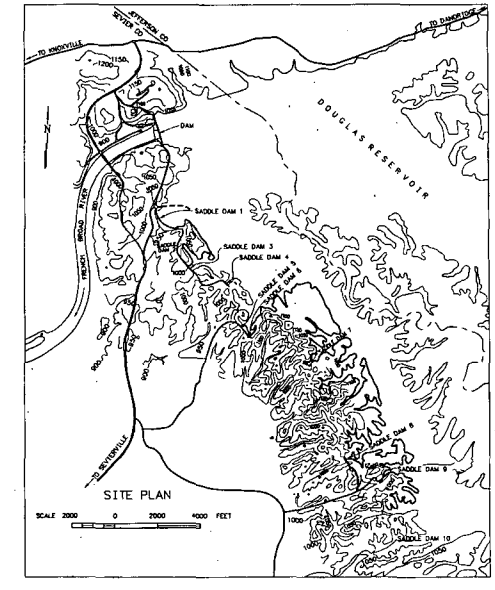
DOWNSTREAM ELEVATION



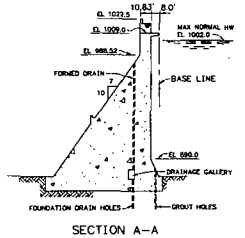
PLAN



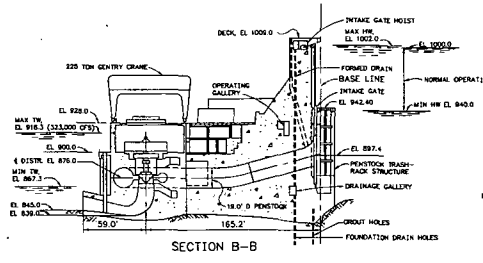
PLAN–SADDLE DAM 1
DGH-SP-SDAM-328-STRUCT-1



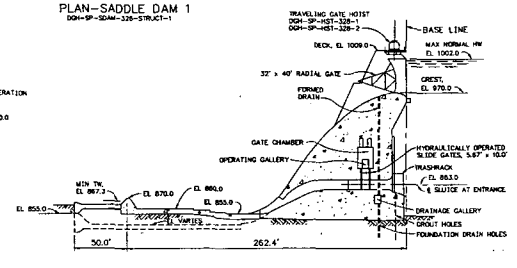
SITE PLAN



SECTION A–A

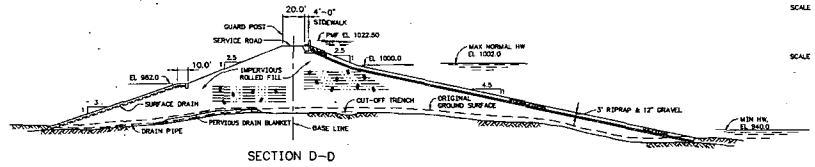


SECTION B–B



SECTION C–C

UNIDS TABULATION	
ASSET	UNIDS NUMBER
POWERHOUSE	DGH-SP-BLDG-300-PWRHSE
DAM STRUCTURE	DGH-SP-DAM-328-STRUCT
SADDLE DAM 1	DGH-SP-SDAM-328-STRUCT/1
SADDLE DAM 10	DGH-SP-DAM-328-STRUCT/10
SADDLE DAM 2	DGH-SP-DAM-328-STRUCT/2
SADDLE DAM 3	DGH-SP-DAM-328-STRUCT/3
SADDLE DAM 4	DGH-SP-DAM-328-STRUCT/4
SADDLE DAM 5	DGH-SP-DAM-328-STRUCT/5
SADDLE DAM 6	DGH-SP-DAM-328-STRUCT/6
SADDLE DAM 7	DGH-SP-DAM-328-STRUCT/7
SADDLE DAM 8	DGH-SP-DAM-328-STRUCT/8
SADDLE DAM 9	DGH-SP-DAM-328-STRUCT/9
SPILLWAY STRUCTURE	DGH-SP-STR-328-SPWY



SECTION D–D

SCALE 200 0 200 400 FEET
PLANS & ELEVATIONS

SCALE 40 0 40 80 FEET
SECTIONS

UNID NOTES:
1. COMPONENT UNID NUMBERING SCHEME:
PLANT DGH, UNIT SP, FUNCTION HST, SEQUENCE NO. 328 1
2. UNIDS ARE LISTED IN WHOLE ON THIS DRAWING. SEE UNIDS TABULATION FOR ASSETS SHOWN ON THIS DRAWING.
3. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS – SYSTEM NAME	FUNCTION CODES – FUNCTION CODE NAME
300 – FACILITIES AND GROUNDS	BLDG – BUILDING
328 – DAM	DAM – DAM STRUCTURE
325 – SPILLWAY	SDAM – SADDLE DAM
	HST – HOIST

4. FOR PROBABLE MAXIMUM FLOOD MODIFICATIONS, SEE DRAWINGS 31E305-SERIES ——— DAM SAFETY MODIFICATIONS

REV	DATE	DESCRIPTION	ORIG	TECH	CHK	SUPV	APPD
R10	JAN 05 2007	ADDED PWF INFORMATION TO DOWNSTREAM ELEVATION VIEW	JPD	JPD	JLW	TRM	RWT	MAC	DGH-05-18
R9		REVISED AS PART OF CRITICAL STRUCTURES, SYSTEMS, AND COMPONENTS VERIFICATION	JPD	JPD	JLW	TRM	RWT	MAC	DGH-05-18

SCALE: 1"=200'-0" EXCEPT AS NOTED

MAIN DAM WORKS

GENERAL PLAN,
ELEVATION & SECTIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
	E.W.S.	S.D.C.	M.R.S.			

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
GEOLOGIC AND HYDRO ENGINEERING

AUTOCAD R14 | DATE 1-31-42 | 20 | C | 10W200 | R 11

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(10W200 R9)

PLOT FACTOR:2400
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: REV MC

Bellefonte PSAR in that the 1973 flood was added for verification replacing the 1957 flood. The 1973 flood is the largest flood after closure of South Holston Dam in 1950 and the only large flood which has occurred since Nickajack Dam, TRM 424.7, replaced Hales Bar Dam, TRM 431.1, in 1967. The 1963 flood is the third largest flood since 1950. It was retained for verification in place of the 1957 flood, the second largest since 1950, because of its shorter duration, which is more typical of the PMF, and to save effort. Observed volumes of precipitation excess were input and reservoir operations were simulated by specifying observed headwater levels. Comparisons between observed and computed outflows from Hales Bar and Guntersville Dams for the 1963 flood are shown in Figure 2.4.3-9. The comparisons for the 1973 flood at Nickajack and Guntersville Dams are shown in Figure 2.4.3-10. | 27

Figures 2.4.3-9 and 2.4.3-10 show that the watershed model predicts flood peaks somewhat in excess of observed values in both floods. | 17

From a study of the basic units of the predicting system and the system's response to alterations in various basic elements, and the fact it somewhat overestimates the peak discharges of the 1963 and 1973 floods it is concluded that the runoff model serves adequately and conservatively to determine maximum flood levels. This conclusion is based in part upon studies by others, references [9], [10], and [11], and unpublished work of TVA which indicate the assumption of linearity in unit hydrographs, an important element of the system, is valid when they are developed from large, out-of-bank floods produced by major, basinwide storms or will duplicate such floods. | 17

Unsteady flow stream course models for the Holston River upstream to Watauga Dam and the French Broad River upstream to Douglas Dam used as adjuncts to the basic runoff stream course model just described to route flood waves from PMF failure of Watauga and Douglas Dams are described in the Watts Bar FSAR, reference [8].

Reservoir routings started at median observed elevations for the appropriate season, mid-March for the large area PMP storms and July for the potentially critical Watauga and Douglas PMP storms. Median levels were reevaluated using operating experience for:

1. The total project period, or

2. The 5-year period, 1972-1976, for those projects whose operating guides were changed in 1971.

Because of the wet years of 1972-1975 and the operating guide changes, median elevations were higher for 7 of the 13 tributary reservoirs where routing is involved. Normal reservoir operating procedures were used in the antecedent storm. These used turbine

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and sluice discharge in the tributary reservoirs. Turbine discharges are not used in the main river reservoirs after large flood flows develop because head differentials are too small. Normal operating procedures were used in the principal storm except that turbine discharge was not used in either the tributary or main river dams. The Bellefonte PSAR analysis did include turbine discharge in tributary reservoirs. All gates were determined to be operable without failures during the flood. Gate crews would be called to respective dams during or before the first hours of the main storm when access would not be a problem. Normal practice of having gate crews remain at the dams during major floods would be followed. Gates on main river dams would be fully raised, thus requiring no additional operations, by the last day of the storm which is before the structures and access roads would be inundated.

Median initial reservoir elevations were used at the start of the storm sequence used to define the PMF to be consistent with statistical experience and to avoid unreasonable combinations of extreme events. As a result 53 percent of the total reserved system flood detention capacity was occupied at the start of the main flood. This is considered to be amply conservative. Neither the initial reservoir levels nor the operating rules would have significant effect on maximum flood discharges and elevations at the plantsite because spillway capacities, and hence uncontrolled conditions, were reached early in the flood.

2.4.3.4 Probable Maximum Flood Flow

The PMF discharge at Bellefonte Nuclear Plant was determined to be 1,268,000 cfs. This flood would result from a storm producing PMP depths on the 21,400-square-mile watershed above Chattanooga with downstream orographically fixed storm pattern (Figure 2.4.3-1). | 17

Fort Loudoun-Tellico, Watts Bar, Chickamauga, and Nickajack Dams, upstream, and Guntersville Dam, downstream, would be overtopped and the earth embankments breached. These are the only dams that would fail. The upstream breaching adds to the Bellefonte PMF, and the Guntersville breach reduces the PMF elevation at the site. The PMF hydrograph is shown in Figure 2.4.3-11. | 17

The PMF discharge of 1,268,000 cfs is 108,000 cfs greater than the 1,160,000 cfs determination for the Bellefonte PSAR. | 17

The next most critical candidate storm is the 7,980-square-mile storm centered at Bulls Gap, Tennessee, 50 miles northeast of Knoxville, shown in Figure 2.4.3-2. The flood from this storm was postulated to overtop and breach the earth embankments at Fort Loudoun-Tellico, Watts Bar, Chickamauga, Nickajack, and Guntersville Dams. Melton Hill Dam would be overtopped and was postulated to fail. The flood from the 7,980-square-mile storm

would be 29,000 cfs less than from the total basin storm, resulting in a flood level 0.6 foot lower. 17

The effect on plantsite flood levels of failure of the Watauga and Douglas Dams under site PMF conditions was reexamined using recently developed unsteady flow stream course models. The reexamination confirmed that plantsite flood levels from these events would not be controlling.

The PMF at Douglas Dam would overtop the dam. The concrete portion of the dam was examined and would not fail. The earth saddle dams would be overtopped and breached. Fort Loudoun-Tellico, and Watts Bar Dams, downstream, would be overtopped with resulting embankment failures. This event was routed down to the Sequoyah Nuclear Plant site, 93 miles upstream of Bellefonte, as described in the Sequoyah FSAR, reference [13]. The resulting discharge at Sequoyah was 248,000 cfs less than the 21,400-square-mile total basin storm. Routing was carried no further as this situation is less critical than the total basin storms. 17

A fourth candidate situation is the PMF at Watauga Dam which would overtop the dam. The resulting flood wave at Holston River mile 122 is described in the Phipps Bend PSAR, reference [12]. This flood was routed through Cherokee Reservoir and the earth embankment would be overtopped and postulated to disappear at the maximum headwater level. The Cherokee Dam failure wave was routed down the Holston River and through Fort Loudoun-Tellico Dams as described in the Watts Bar FSAR, reference [8]. Headwaters would reach elevation 829.3, 0.7 foot below the embankment top. Routing was carried no further as this situation was less critical at Fort Loudoun than Douglas failure in its PMF. 17

Following is a more complete description of dam stability and earth embankment breaching analysis made to define PMF conditions.

Concrete Section Analysis

For concrete dam sections, comparisons were made between the original design headwater and tailwater levels and those that would prevail in the PMF. The concrete structures were investigated for sliding and overturning from the increased water loads. All upstream dams were judged to be safe against failure except Melton Hill. The nonoverflow portion of Melton Hill Dam, left of station 19+54 and above elevation 774.5, was judged to fail by overturning when headwaters reached elevation 804 (Figure 2.4.1-13).

DAM RATING CURVES - DOUGLAS

Calculation No: CDQ000020080007

Attachment 2-4
taken from Ref. 2
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Spillway Gate Failures

Consideration was given to the potential effect at Bellefonte of the failure of spillway gates at upstream dams resulting from any cause. The analysis for the Watts Bar FSAR, reference [8], showed that at Fort Loudoun and Watts Bar Dams the gates would remain intact except possibly when struck by water-borne objects. All mainstream dams are overtopped in the PMF. Gate failure would only make relatively small changes in the timing of such failure. Because of this it was concluded that gate failures are not important to this analysis and were dropped from further consideration. Gates were assumed operable and not to fail in all routings.

Lock Gates

The lock gates at all main river dams--Fort Loudoun, Watts Bar, Chickamauga, Nickajack, and Guntersville--were examined for possible failure with the conclusion that no potential for failure exists because the gates are designed for a differential hydrostatic head greater than that which exists during the PMF.

Embankment Breaching

Earth embankments at Fort Loudoun-Tellico, Watts Bar, Chickamauga, Nickajack, and Guntersville Dams would be overtopped and breached by the PMF. Breaching of upstream dams would add to PMF elevations at Bellefonte. The Guntersville breach would reduce flood levels at Bellefonte.

The adopted relationship to compute the rate of erosion in an earth dam failure is that developed and used by the Bureau of Reclamation in connection with its safety of dams program, reference [14]. The expression relates the volume of eroded fill material to the volume of water flowing through the breach. The equation is: $\frac{Q_{soil}}{Q_{water}} = Ke^{-X}$

where: Q_{soil} =Volume of soil eroded in each time period,

Q_{water} =Volume of water discharged each time period,

K=Constant of proportionality, 1 for the soil and discharge relationships in this study,

e=Base of natural longarithm system,

$X=\frac{b}{H}\tan\phi$

b=Base length of overflow channel at any given time,

DAM RATING CURVES - DOUGLAS

Calculation No: CDQ000020080007

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Attachment 2-5
taken from Ref. 2
7 total pages

2.4.4 Potential Dam Failures, Seismically Induced

The procedures described in Appendix A of Regulatory Guide 1.59 were followed when evaluating potential flood levels from seismically induced dam failures.

2.4.4.1 Dam Failure Permutations

There are 21 major dams above Bellefonte Nuclear Plant. These were examined individually and in groups to determine if failure might result from a seismic event and if so would failure concurrent with storm runoff create maximum flood levels at the plant. Dam locations with respect to the plant site are shown in Figure 2.1.1-1.

Two situations were examined for the seismic failure analysis:

1. Determination of the water level at the plant during one-half the PMF with full reservoirs if its crest were augmented by flood waves from the postulated failure of upstream dams during an Operating Basis Earthquake (OBE).

2. Determination of the water level at the plant during a 25-year flood with full reservoirs if its crest were augmented by flood waves from the postulated failure of upstream dams during a Safe Shutdown Earthquake (SSE).

The OBE and SSE are defined in Sections 2.5.2.7 and 2.5.2.6 as having maximum horizontal rock acceleration values of 0.09 g and 0.18 g respectively. The NRC guide requires use of a maximum earthquake based on historic seismicity for this situation. In Section 2.5.2.3, TVA has determined the maximum intensity felt at the site in the recorded history of the area to probably be a Modified Mercalli V (MM V) and certainly no more than MM VI. It is to be noted that the acceleration values associated with these intensities are for ground surface and are greater than the accompanying acceleration of the rock surface on which the dams are founded. This comparison simply reiterates the extreme conservatism contained in the analysis.

The FSAR for Sequoyah Nuclear Plant, reference [13], fully describes the investigation of potential single and multiple failures of all dams upstream of Chickamauga Dam during the two postulated seismic and flood conditions. All events referred to in that report were reexamined using Bellefonte flood conditions.

Three of these events having the potential to create maximum flood levels at Bellefonte--the three events which produced the maximum seismic-caused flood levels at the Sequoyah Nuclear Plant upstream which included the controlling Bellefonte PSAR event--were routed past the site. These were the: 17 17

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DAM RATING CURVES - DOUGLAS

Calculation No: CDQ000020080007

Attachment 2-6
taken from Ref. 2
7 total pages

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1. The simultaneous failure of Fontana, Hiwassee, Appalachia, and Blue Ridge Dams in the OBE during one-half the PMF,

2. The simultaneous failure of Norris, Cherokee, and Douglas Dams in the SSE during a 25-year flood, and

3. The simultaneous failure of Cherokee and Douglas Dams in the OBE during one-half the PMF, respectively.

The condition producing maximum flood levels at Bellefonte was the postulated simultaneous failure of Fontana, Hiwassee, Appalachia, and Blue Ridge Dams in the OBE coincident with 1/2 the PMF. This is a different controlling condition than that given in the Bellefonte PSAR and results from use of an unsteady flow model for the Little Tennessee River (described in Watts Bar FSAR, reference [8]) for the routing of the Fontana seismic dam failure wave which replaced approximate routing procedures used in the PSAR analysis. The flood wave from Fontana failure would overtop and fail Tellico Dam. Transfer of water into Fort Loudoun reservoir would occur but would not be sufficient to overtop Fort Loudoun Dam or to prevent failure of Tellico Dam. Tellico was postulated to completely fail. Watts Bar would be overtopped with resulting embankment failure. The flood wave from the failure of Hiwassee, Appalachia and Blue Ridge on the Hiwassee River would augment the Fontana failure surge. Maximum Chickamauga headwater would reach elevation 707.5, 1.5 feet of overflow. Overtopping would be for about 19 hours. Although breaching computations indicated that Chickamauga would not fail, the north embankment was assumed to fail at maximum headwater level because of the duration of overtopping. 17

Nickajack Dam would be overtopped with resulting embankment failure. Guntersville headwater, downstream of the plant, would reach elevation 606.6, 3.4 feet below top of dam. The resulting flood level at Bellefonte would be elevation 615.1.

The event producing the second highest elevation at Bellefonte was the simultaneous failure of Cherokee and Douglas in the OBE coincident with 1/2 the PMF, which produced elevation 614.2. This compared with elevation 615 quoted in the PSAR. The difference results from improvements in the hydraulic models in Fort Loudoun and Guntersville. The flood wave from failed Cherokee and Douglas would overtop and fail Fort Loudoun-Tellico Dams. Watts Bar would be overtopped with resulting embankment failure. Chickamauga headwater would reach elevation 707, 1 foot of overflow. Erosion computations indicated that Chickamauga would not fail. Nickajack Dam would be overtopped and the earth embankment breached. The maximum headwater reached in Guntersville would be elevation 605.3, 4.7 feet below dam top. 17

The event producing the third highest elevation at Bellefonte was the postulated simultaneous failure of Norris, Cherokee and 17

DAM RATING CURVES - DOUGLAS

Calculation No: CDQ000020080007

Attachment 2-7
taken from Ref. 2
7 total pages

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FSAR RLN 1.2

7 of 7

Douglas in the SSE coincident with the 25-year flood. Fort Loudoun gates were assumed inoperable in the closed position as a result of the postulated bridge failure falling on any open gates and on gate hoisting machinery as described in the Watts Bar FSAR, reference [8]. Fort Loudoun would be overtopped with resulting embankment breaching. Although transfer of water into Tellico would be sufficient to overtop the dam, the early failure of Fort Loudoun would provide enough relief to prevent Tellico failure. Tellico would be overtopped only one hour to a maximum depth of 0.8 foot before Fort Loudoun failure. After failure of Fort Loudoun, Tellico headwater would drop below dam top elevation 830 in less than an hour. TVA concludes that Tellico would not fail because of the short overtopping time and shallow overflow depth. Watts Bar would be overtopped with resulting embankment failure. Maximum Chickamauga headwater would reach elevation 706.9, 0.9 foot of overflow. Overtopping would be for about 15 hours of which only 9 hours would be at a depth over 0.5 foot. Breaching computations indicated that Chickamauga would not fail. Nickajack Dam would be overtopped with resulting embankment failure. Guntersville headwater, downstream of the plant, would reach elevation 603.3, 6.7 feet below top of dam. The resulting flood level at Bellefonte would be elevation 612.7. 17 18

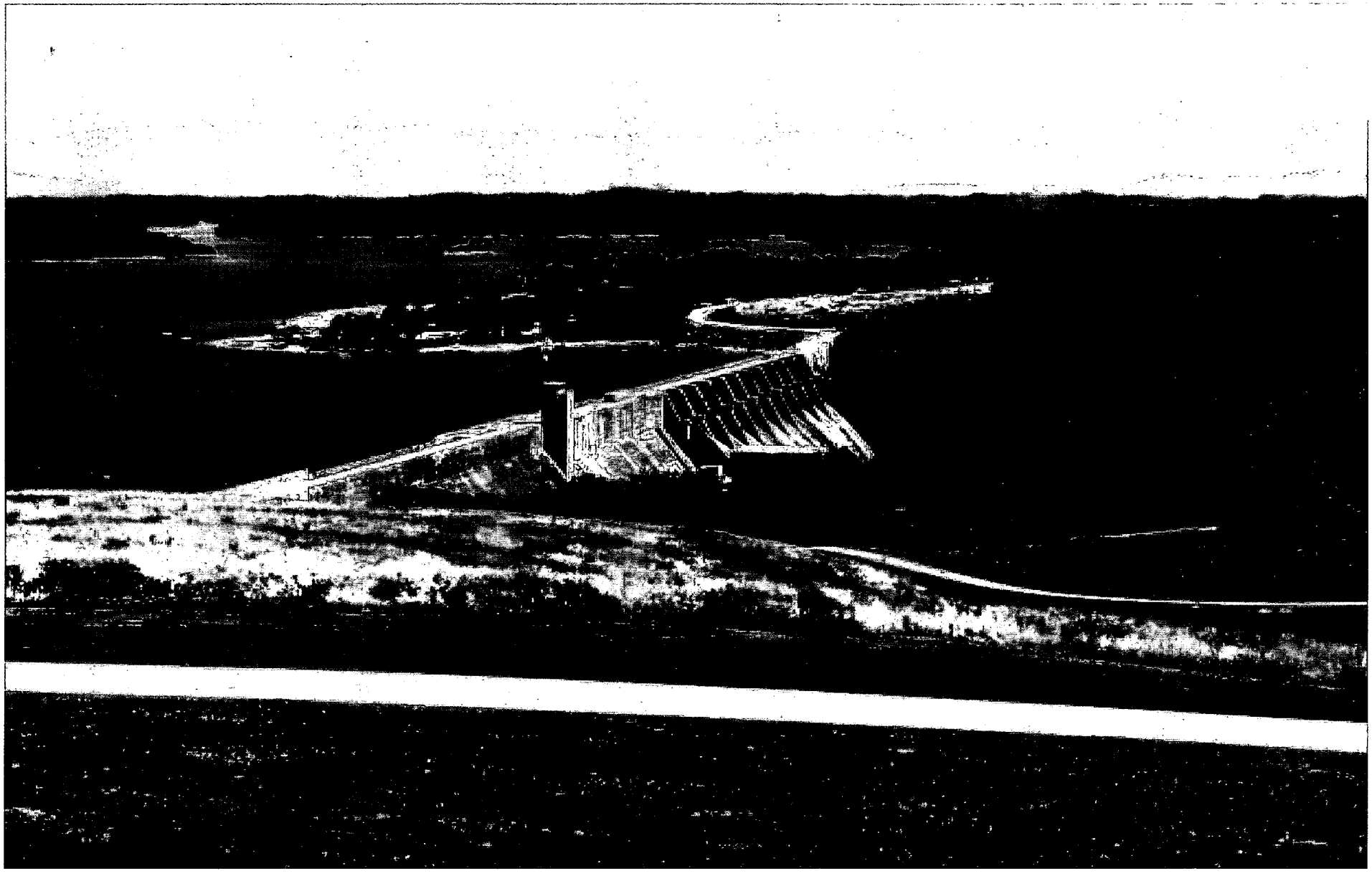
To complete the testing of seismic failure analysis the potential effects of failure of Chickamauga and Nickajack Dams on plant flood levels were investigated for the Bellefonte PSAR. The dams were not analyzed structurally. Instead Chickamauga and Nickajack Dams were considered to be removed instantly and completely both singly and simultaneously at the critical moment in the one-half Bellefonte PMF. A reevaluation of these conditions using the revised Guntersville unsteady flow model was not made, but flood levels would not be significantly different than that given in the Bellefonte PSAR, elevation 609 which resulted from the simultaneous failure of both dams.

Raccoon Mountain pumped storage dam was not analyzed specifically because of its small capacity, 37,800 acre-feet, and its considerable upstream distance, 53 miles. Its complete and coincidental failure would not add measurably to the flood level.

Attachment 3
from Ref. 17
1 page

DOUGLAS DAM

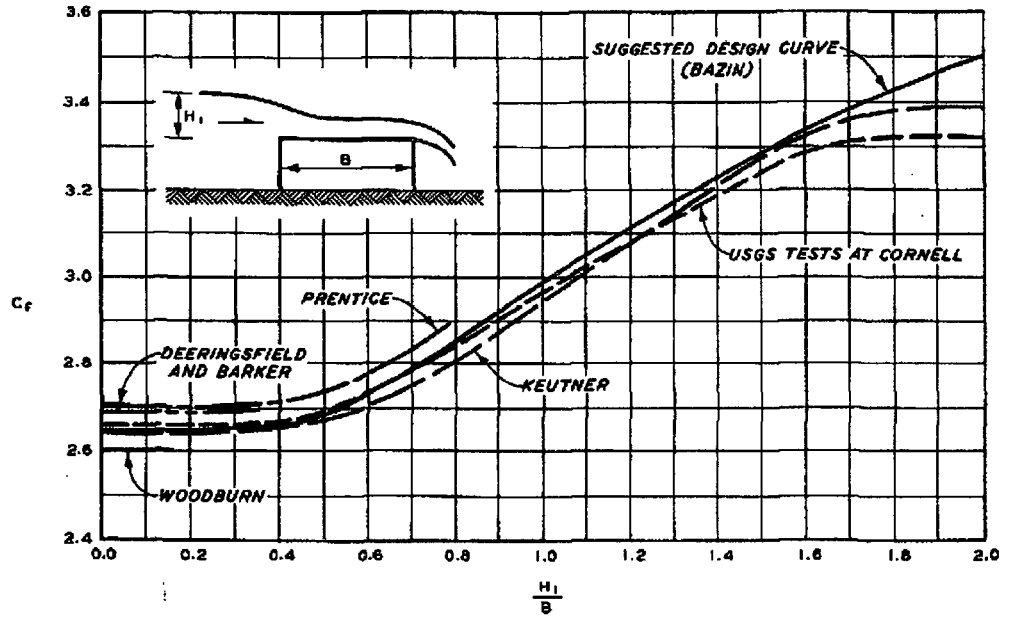
Calculation No: CDQ000020080007



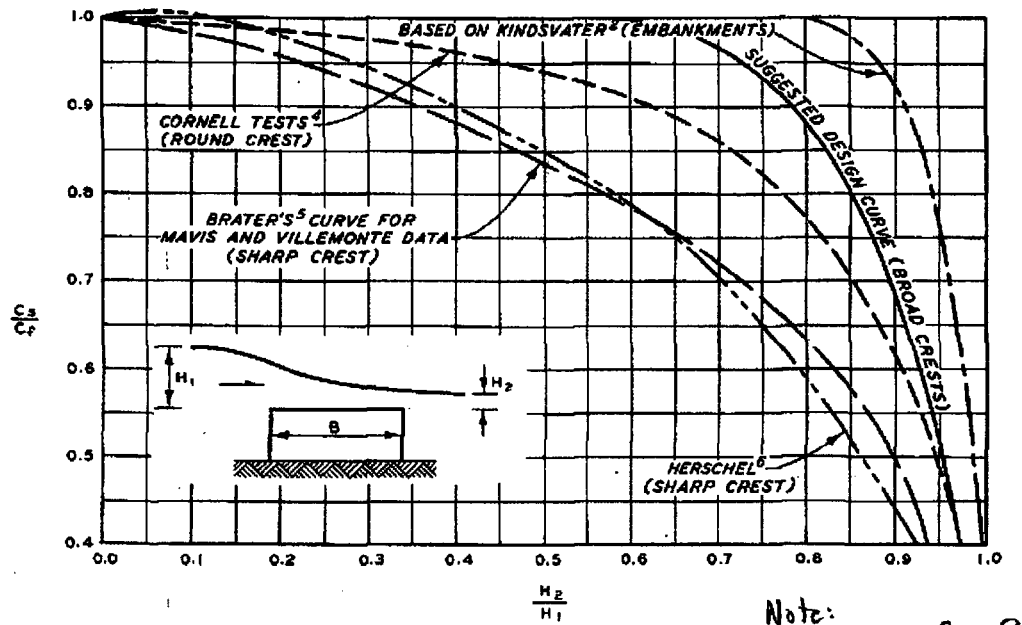
July 1998

Attachment 4
Ref. 6
1 page

Calculation No: CDQ000020080007



a. FREE FLOW



b. SUBMERGED FLOW

Note:
$\frac{H_1}{B} \equiv H_c$
$H_2 \equiv d$
$\frac{C_s}{C_f} \equiv S_f$

NOTE: C_f = FREE-FLOW COEFFICIENT
C_s = SUBMERGED-FLOW COEFFICIENT
NEGLIGIBLE VELOCITY OF APPROACH
RAISED NUMBERS ON SUBMERGED FLOW CHART ARE REFERENCE NUMBERS FROM TEXT.

LOW-MONOLITH DIVERSION
DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 711

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

WES 1-65

TAKEN FROM REF. 24

Calculation No: CDQ000020080007

Attachment 5-1
from Ref. 24
3 total pages

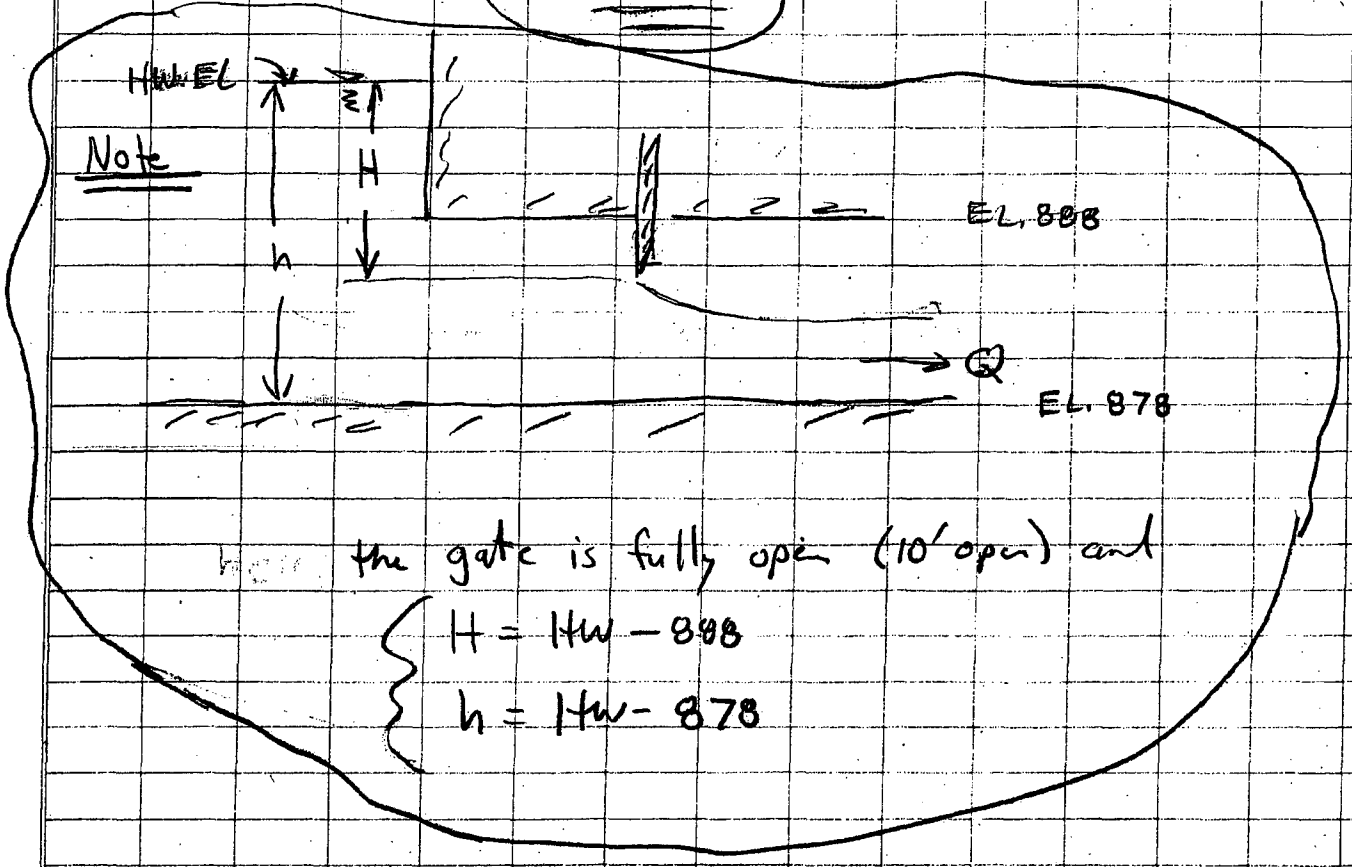
DISCHARGE FORMULA CORRESPONDING TO THE BELOW GIVEN K.

Douglas Sluice Rating

COMPUTED LWH DATE 9-4-62

CHECKED JWC DATE 9-13-62

Sluice Nos.	Head water Ele.	Sluice channel bottom	h	$\sqrt{h}$	Q	K = $Q/5\sqrt{h}$	Top of Gate open.	H	$\sqrt{H}$	Q	K' = $Q/5\sqrt{H}$
2,4,5,7,8	970	878.0	92'	9.592	16600	346.5	888.0	82	9.055	16620	367.1
	965	"	87'	9.327	16100	345.2		77	8.750	16100	368.0
	960	"	82'	9.055	15600	344.6		72	8.485	15600	367.7
	955	"	77'	8.750	15100	344.7		67	8.185	15100	369.
	950	"	72'	8.485	14570	343.4		62	7.874	14570	370.1
	945	"	67'	8.185	14000	342.1		57	7.549	14000	370.9
	940	"	62'	7.874	13450	341.6		52	7.211	13450	373.0
	~~935~~										
	~~930~~										
				Ave K = 344.1						Ave K'	369.4



Note: the gate is fully open (10' open) and

$H = HW - 888$

$h = HW - 878$

$K = Q/5\sqrt{h}$; 5 = number of sluices combined to get Q

h = HW - 878 (SEE ABOVE)

Q = discharge from gates 2, 4, 5, 7 & 8

TVA 485 (REV-9 47)

Attachment 5-2
from Ref. 24
3 total pages

Calculation No: CDQ000020080007

SHEET 20 OF EL-93-I

Douglas Sluice Rating

COMPUTED LWH DATE 9-6-62

CHECKED DATE

22-24

Head Water Ele.	G.O. Ft	h	$\sqrt{h}$	K $= \frac{Q}{\sqrt{h}}$	Total Q $= 8K\sqrt{h}$	Diff
	0.50					
1000	~~0.05~~	122	11.045	18.0	1590	
	1.00					1503
	~~0.10~~			35.0	3093	
	1.50					1369
	~~0.15~~			50.5	4462	
	2.00			65.8	5814	1352
	2.50			~~80.0~~	7069	1255
	3.00			95.5	8438	1365
	3.50			112.0	9896	1462
	4.00			128.0	11310	1414
	4.50			147.0	12989	1679
	5.00			165.0	14579	1590
	5.50			~~186.5~~ 186.3	16479	1500
	6.00			206.0	18202	1723
	6.50			227.6	20058	1856
	7.00			248.0	21930	1872
	7.50			267.0	23592	1662
	8.00			288.0	25448	1856
	8.50			305.0	26950	1502
	9.00			327.0	28364	1414
	9.50			339.0	29512	1148
	10.00			348.1	30405	893

Attachment 5-3 3 total pages	Calculation No: CDQ000020080007

Verification of Sluice Discharge Coefficient, K

Headwater Elevation	Discharge, Q No tailwater effects	K	
890	9520	343.5	
895	11330	343.5	
900	12890	343.5	
905	14280	343.5	
910	15540	343.4	
915	16710	343.4	
920	17800	343.3	
925	18830	343.3	
930	19810	343.4	
935	20740	343.4	
940	21630	343.4	
945	22490	343.4	
950	23310	343.4	
955	24110	343.4	
960	24880	343.4	
965	25620	343.3	
970	26350	343.4	
975	27060	343.4	
980	27750	343.5	
985	28480	344.2	
990	29070	343.4	
995	29720	343.5	
1000	30340	343.4	
1005	30960	343.4	
	Average K	343.4	
	K value to be used:	344.1	
	Percent Difference:	0.19 %	Acceptable

This data has been taken directly form Reference 3, "Douglas Dam Spillway and Sluice Discharge Tables"

Attachment 6-1
2 total pages

Calculation No: CDQ000020080007

Douglas Tailwater Rating
Riverware

Q (thousand cfs)	Q (cfs)	Elevation (ft)
0	0	870.9
3	3000	870.9
4	4000	871.4
8	8000	873
12	12000	874.2
16.4	16400	875.5
30	30000	880.5
40	40000	883
50	50000	885.5
60	60000	887.6
80	80000	891
100	100000	894.3
120	120000	896.6
140	140000	899.3
160	160000	901.9
180	180000	904.2
200	200000	906.4
220	220000	908.5
240	240000	910.5
260	260000	912.4
280	280000	914.2
300	300000	916
320	320000	917.6
340	340000	919.2
360	360000	921
380	380000	922.7
400	400000	924.1
420	420000	925.8
440	440000	927.2
460	460000	928.6
480	480000	930
500	500000	931.5

HEC-RAS Analysis

Discharge (cfs)	Elevation (ft)	Frequency (Years)
31000	880.07	10
46000	883.43	50
57000	885.59	100
114000	894.13	500
200000	903.1	
402900	921.2	MPF
652500	940.3	PMF

Flood Control Section 10/1948

Discharge (cfs)	Elevation (ft)
0	868
25000	878.4
50000	884.37
75000	889.2
100000	893.2
125000	896.8
150000	900
175000	903
200000	905.9
225000	908.5
250000	911.1
275000	913.6
300000	916

Actual Data

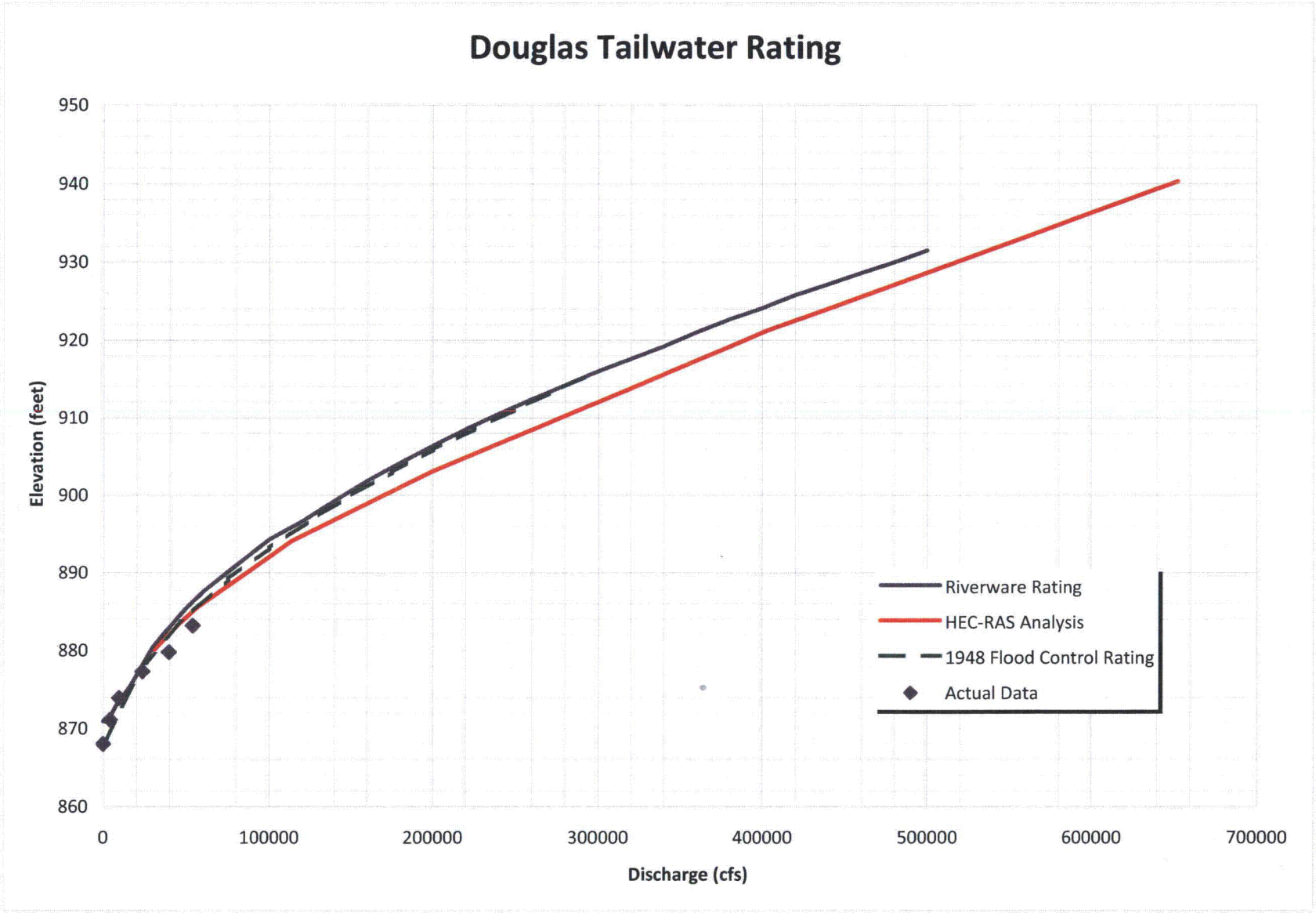
0	868	
4100	871.1	
9530	873.9	
23500	877.3	
39500	879.8	
53847	883.2	
402900	917.49	MPF*
652500	933.8	PMF*

* Estimated from Floodwave Model
MPF = Maximum Probable Flood
PMF = Probable Maximum Flood

These tailwater rating values come from years of model testing and field measurements. These values have been in use at Douglas Dam for many years. The values on this page are used to develop the polynomial fit tailwater rating curve in Attachment 7. The worst case was used to develop the fit.

Attachment 6-2
2 total pages

Calculation No: CDQ000020080007



Attachment 7
1 page

Calculation No: CDQ000020080007

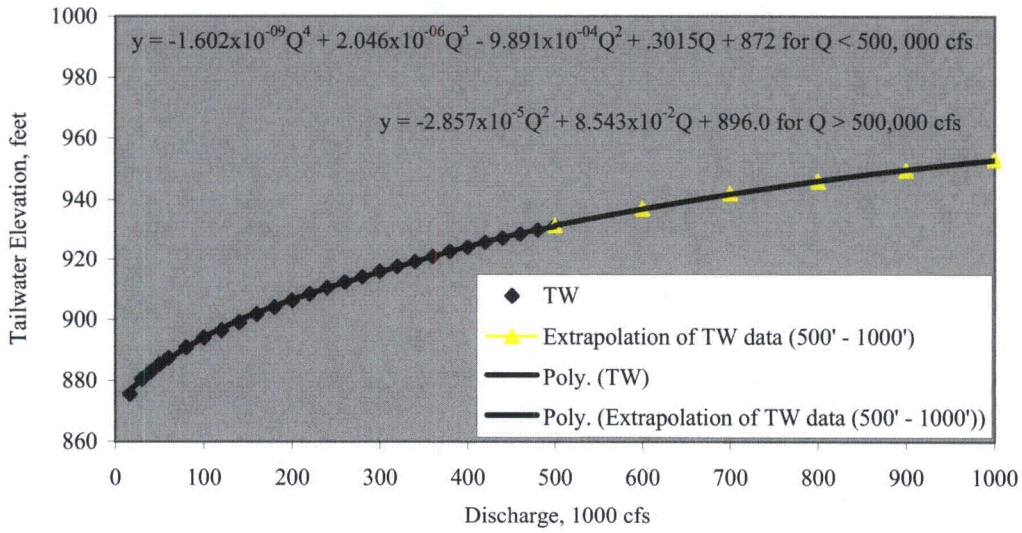
Douglas Dam Tailwater Polynomial Fit

Riverware TW Rating

1000 Q	TW EL	
16.4	875.5	
30	880.5	
40	883	
50	885.5	
60	887.6	
80	891	
100	894.3	
120	896.6	
140	899.3	
160	901.9	
180	904.2	
200	906.4	
220	908.5	
240	910.5	
260	912.4	
280	914.2	
300	916	
320	917.6	
340	919.2	
360	921	
380	922.7	
400	924.1	
420	925.8	
440	927.2	
460	928.6	
480	930	
500	931.5	
600	937	*
700	942	*
800	946	*
900	949.5	*
1000	953	*

This curve is being developed for use in the headwater rating curve to be used for PMF calculations at Douglas Dam. The worst case data from Attachment 6 has been fit to a polynomial in order to determine the interaction of the sluice flow and the tailwater. Segments beyond the extent of the tailwater data have been extrapolated using a polynomial fit.

* Extrapolated



SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD

Chronology

Safety analysis studies for Douglas Dam for the Probable Maximum Flood were started at the beginning of fiscal year 1985 and were completed with the submittal of *DOUGLAS PROJECT DAM SAFETY ANALYSIS REPORT HEP-C85-1 BY MEMORANDUM FROM R. G. DOMER TO R. W. CANTRELL ON JUNE 17, 1985 (B66 850617 0001)*. Final design started in October 1985. Onsite construction began in March 1986 and was completed in May 1987.

Cost of Modification

Design costs for the capital safety modifications to Douglas Dam were approximately $403,000. This did not include costs for dam safety evaluation studies which resulted in the modifications, construction costs were approximately $1.8 million. The total project cost was approximately $2.5 million.

Controlling Features

Modifications for the PMF consisted of increasing the height of the north and south concrete nonoverflow dams and their earth abutments by 13.5 feet, increasing the height of saddle dam one by 5 feet and the remaining existing seven saddle dams by 6.5 feet, and adding two new saddle dams. These modifications will prevent overtopping and erosion of the embankment and saddle dams but would permit overtopping of the concrete dam spillway area with possible major damage to the powerhouse and switchyard. The elevation of the headwater for a PMF resulting from combined storage and discharge through the spillway and over the top of the concrete structures is 1022.5.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Concrete Dam Modifications

Stability of a typical nonoverflow block was investigated for the increased water loads resulting from a PMF. Stresses resulting from these increased loads were judged to be acceptable for this extreme loading conditions. The original stability analysis for the concrete structure is shown in an Appendix to the report referenced under Chronology.

Nonoverflow blocks 1A through 3 and 28 through 32 were modified by placing concrete on top of the existing structures. This modification was primarily to enable vehicular access from the new top of embankment elevation 1018.5 to the spillway operating equipment at elevation 1009.0. Additionally, a 12-inch-think concrete wall with top elevation at 1022.5 was placed on the downstream side of blocks 1A through 3 and 28 through 32. Due to the increased hydrostatic loads on the additional concrete and wall, blocks 1 through 3 and 28 through 31 had to be strengthened by installing high strength dowels on the upstream side of the blocks. Details of the modification to the top of nonoverflow blocks 1A through 3 and 28 through 32 are shown on drawings 21E 205-1,2, and 3. Existing drain holes, wells, electrical manholes, equipment shaft, ladder, air vent, and access shaft were extended through the new concrete with new embedded frames where required. *FIGURES 12* and *13* at the end of this section are photos which show the key features of this modification.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)



FIGURE 12
Access Ramp and Wall Atop Nonoverflow Blocks 1A through 3, August 1998



FIGURE 13
Access Ramp and Wall Atop Nonoverflow Blocks 28 through 32
August 1998

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

North and South Earth Abutment Modifications

The north and south earth abutments were stripped of pavement, curbs, and stabilized roadway base, and increased in height to elevation 1018.5 using impervious rolled earthfill, filter blanket, and riprap. A 12-inch-think concrete wall with top elevation at 1022.5 was placed on the north abutment, joined to the wall on the downstream side of nonoverflow block 1A, and extended along the river side of the patrol road to the 1022.5 contour. These walls, along with the walls on nonoverflow blocks 1A through 3 and 28 through 32, are for the purpose of diverting overtopping flow to the spillway and powerhouse portions of the dam. Details of these walls are shown on drawing 23E210-1.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Saddle Dam 1 Modifications

A 12-inch-thick concrete wall with top elevation 1022.5 was placed 14 feet upstream of the centerline of saddle dam 1 roadway. The wall begins near the intersection of the boat launching road with saddle dam 1 and parallels the saddle dam roadway to the Sevier County campground on the south end of the dam. The wall then turns away from the roadway and is routed upstream of the campgound, approximately parallel to the roadway, until it intersects the 1022.5 contour. *FIGURE 14* at the end of this section is a photo which shows the location and configuration of saddle dam 1. Details of modified features for saddle dam 1 are shown on drawings 23E209-1, 2, and 3.

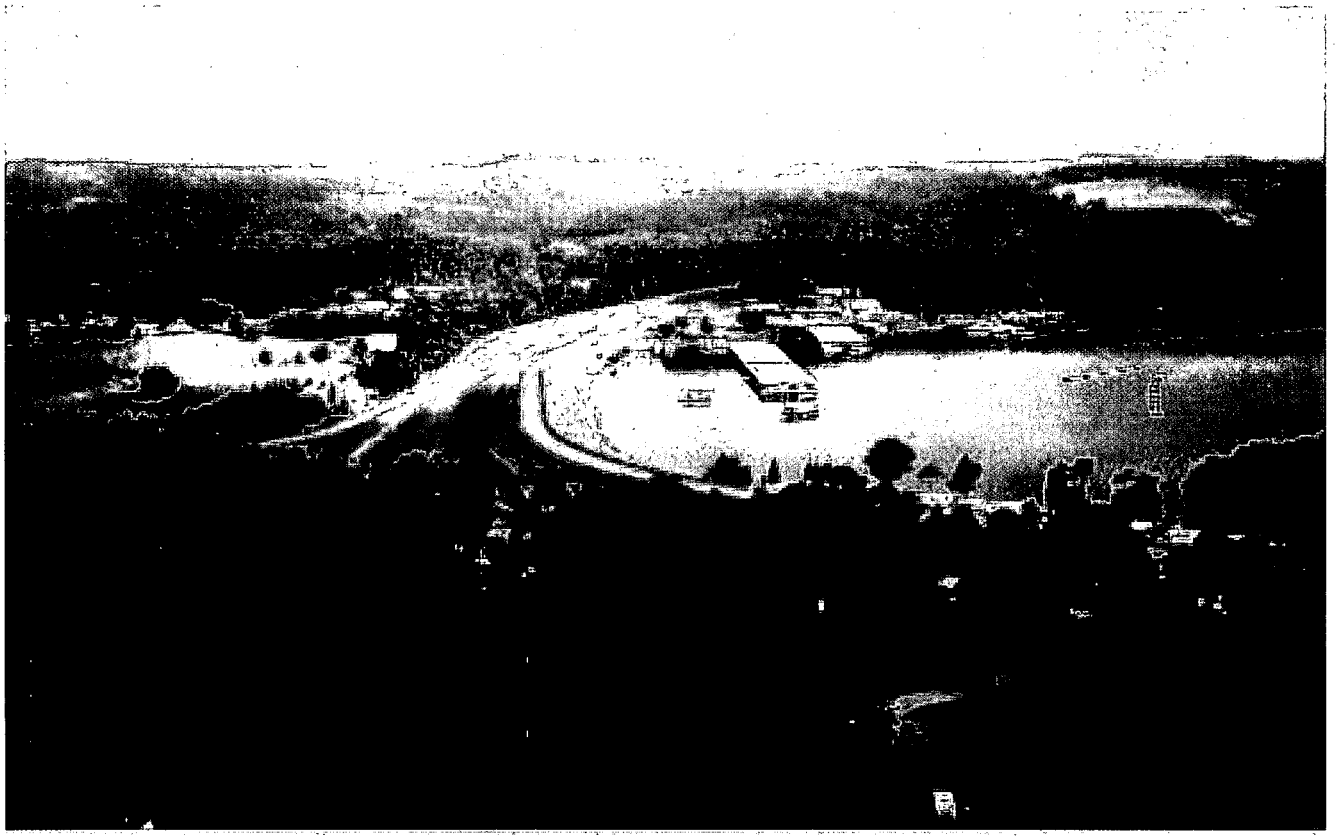


FIGURE 14

Saddle Dam 1, July 1998

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Saddle Dams 3, 4, 5, 6, 8, 9, and 10 Modifications

Saddle dams 3, 4, 5, 6, 8, 9, and 10 were stripped of topsoil on the downstream side, the crushed stone was excavated from the roadway, and the saddle dams were raised 6.5 feet to elevation 1023.5 by placing impervious rolled earthfill, filter blanket, and riprap. A crushed stone roadway was constructed on top of each dam, topsoil was placed on disturbed areas, and the dams were seeded and mulched. Details for raising saddle dams 3, 4, 5, 6, 8, 9, and 10 are shown on drawings 23N203 and 23N204. *FIGURE 4* shows the location of these saddle dams.

Addition of Saddle Dams 2 and 7

In addition to the saddle dams previously described, two new saddle dams, numbers 2 and 7, were required at low areas which would be overtopped by a PMF. Since these areas were small, the saddle dams were constructed by stripping the topsoil, adding impervious rolled earthfill to elevation 1023.5, and seeding and mulching. Riprap was not required. Saddle dam 2 is located near the Sevier County campground just off the roadway between saddle dams 1 and 3. Borrow for saddle dam 2 was obtained from the adjacent borrow area previously described for saddle dam 3. Saddle dam 7 is located approximately halfway between saddle dams 6 and 8 on TVA property. Borrow for saddle dam 7 was obtained adjacent to the saddle dam. Details for saddle dam 2 and 7 are shown on drawings 23N203 and 23N204. *FIGURE 4* shows the location of these saddle dams.

Other Modifications

Other modifications that were made included: reinstalling handrail on the nonoverflow blocks of the dam retaining walls to retain embankment slopes; relocating parking areas and turnarounds, security fencing, and campground area modifications; and resurfacing the saddle dam roadway.

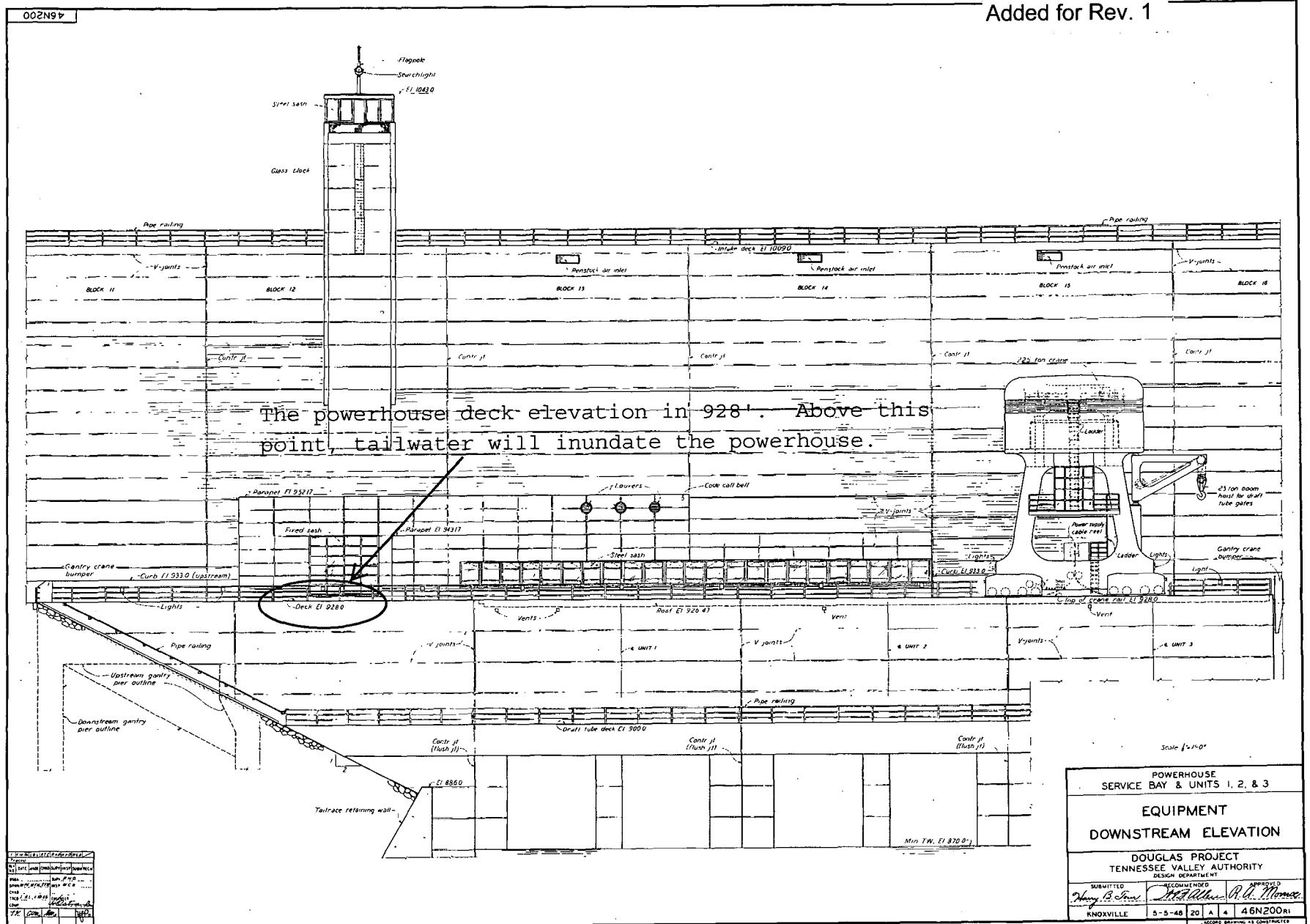
HOUSING FACILITIES

(Original Project)

Permanent houses built ..... None
Tents (40 total capacity) 4
Dormitories built:
    Men (528 total capacity) 6
    Women (26 rooms plus kitchen and dining room) 1
Family housing ..... 92-trailer village
Other camp buildings included a cafeteria 178 seats), community building, and hospital.

Prepared by: S.E.M.
Checked by: A.T.T.

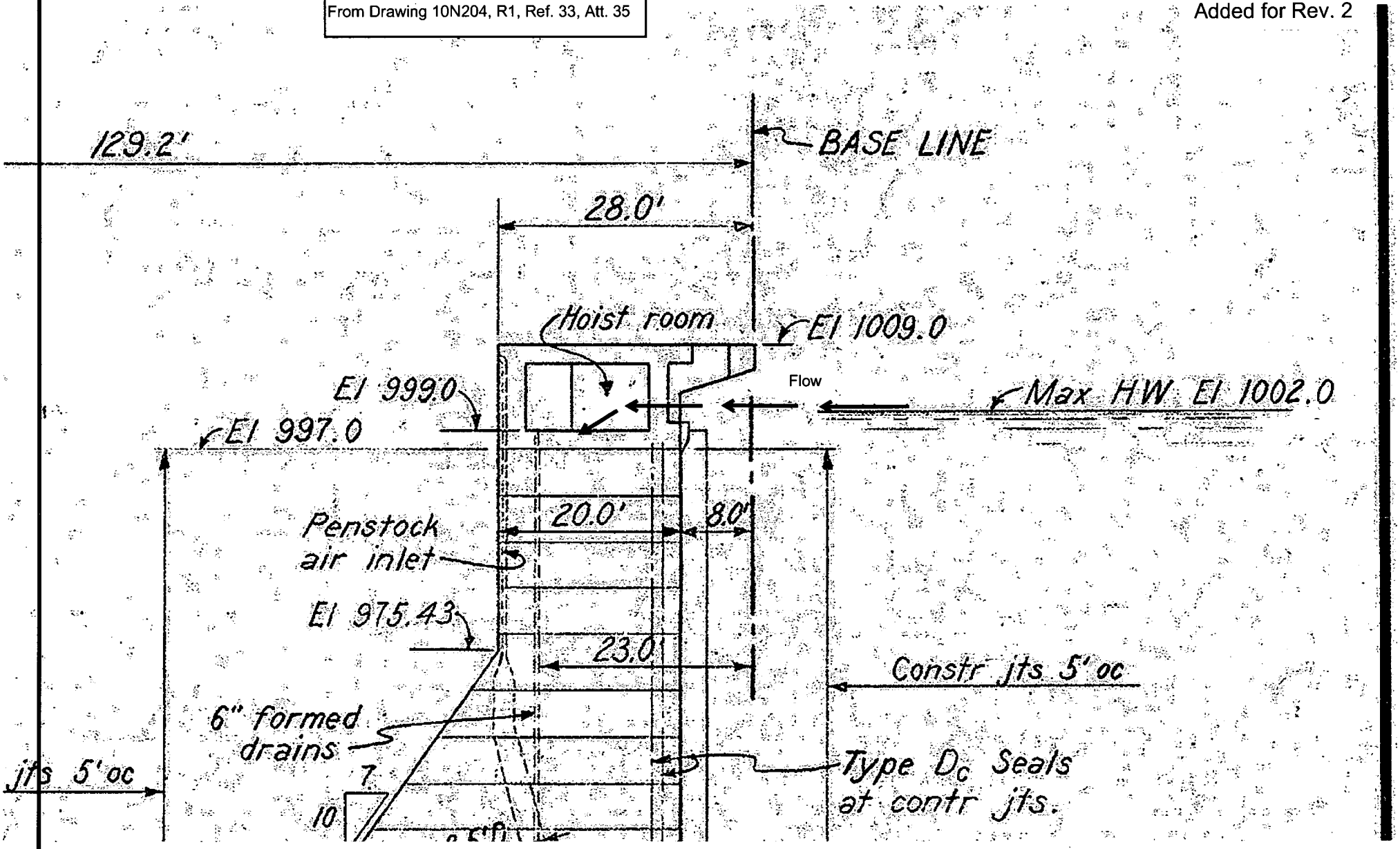
Attachment 8A-1
Reference 13
8 total pages
Added for Rev. 1



Prepared by: S.E.M.
Checked by: A.T.T.

Attachment 8A-2
Reference 33
8 total pages
Added for Rev. 2

From Drawing 10N204, R1, Ref. 33, Att. 35

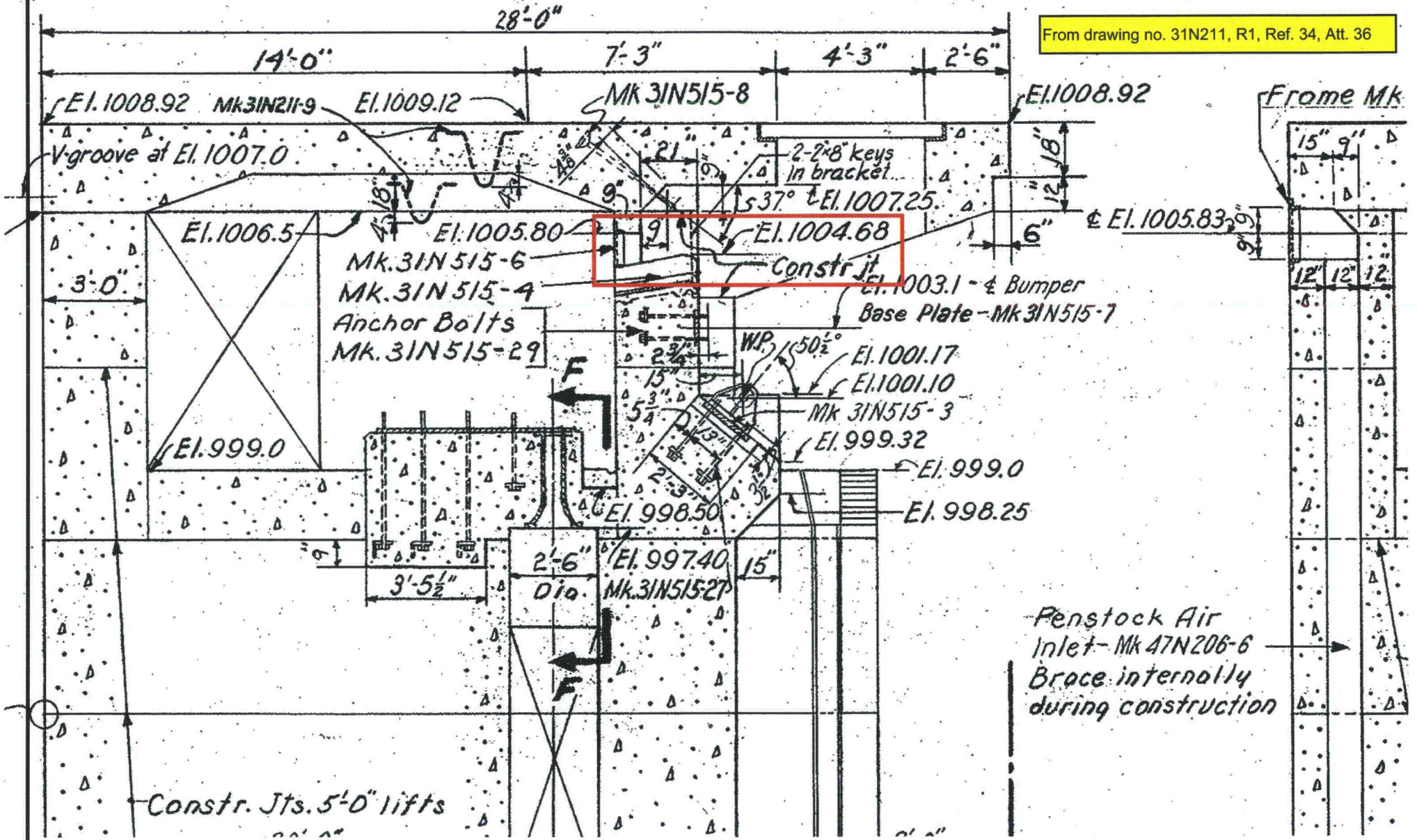


Prepared by: S.E.M.
Checked by: A.T.T.

Attachment 8A-3
Reference 34
8 total pages
Added for Rev. 2

PLAN CHAMBER EL. 999.0

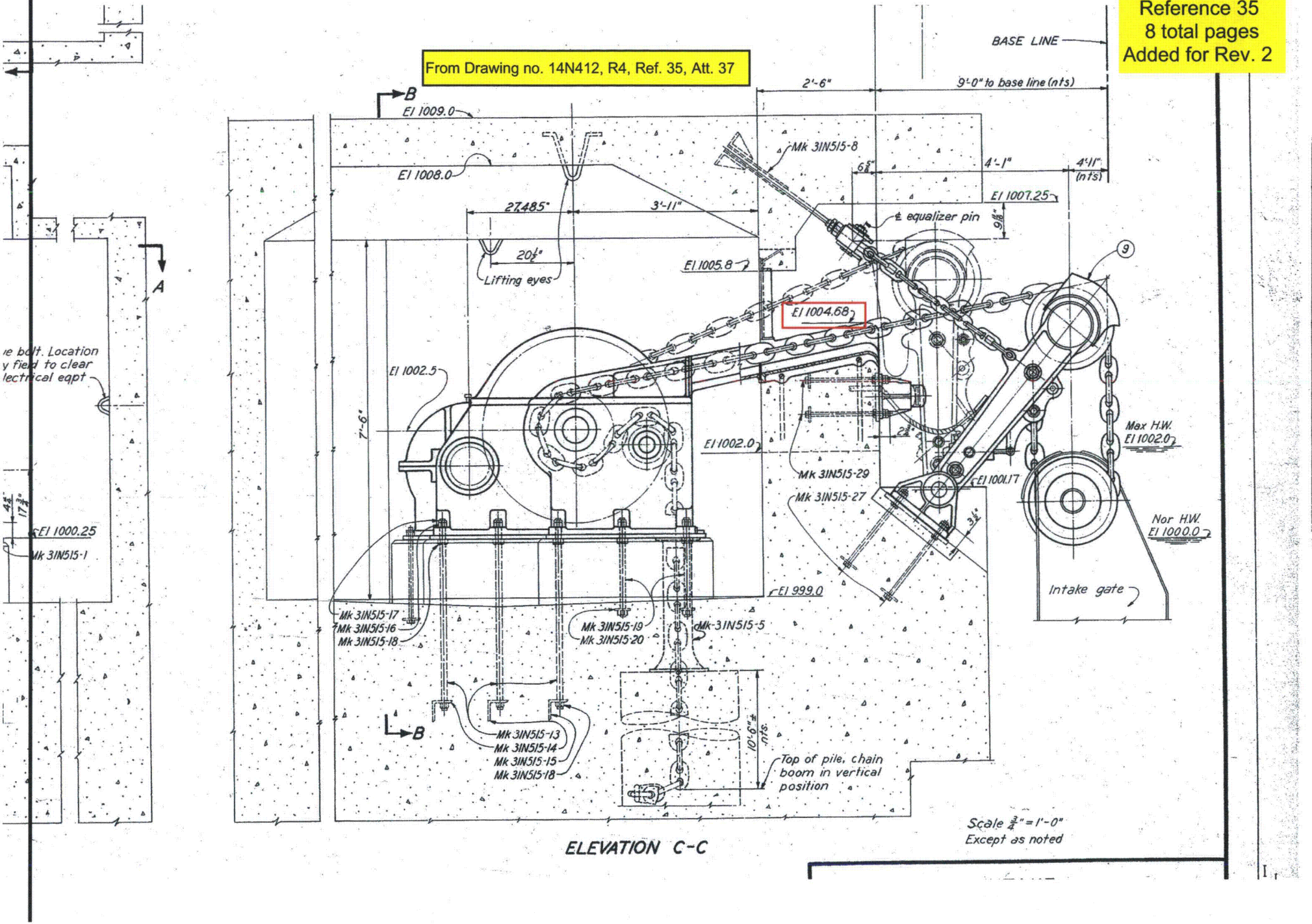
From drawing no. 31N211, R1, Ref. 34, Att. 36



Prepared by: S.E.M.
Checked by: A.T.T.

Attachment 8A-4
Reference 35
8 total pages
Added for Rev. 2

From Drawing no. 14N412, R4, Ref. 35, Att. 37

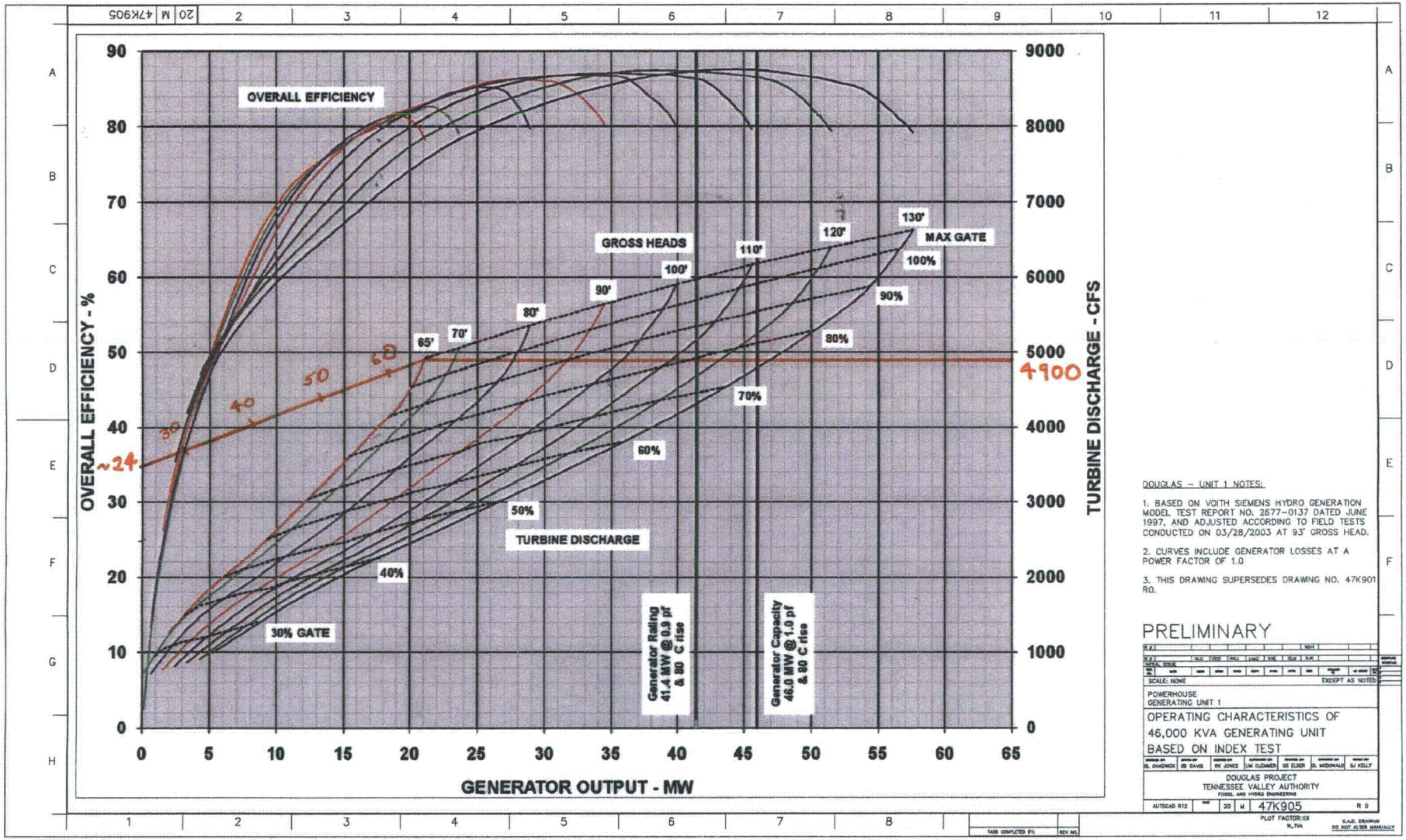


ELEVATION C-C

Scale ¾" = 1'-0"
Except as noted

Attachment 8A-5
Reference 29, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 1 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0137 DATED JUNE 1997, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 03/28/2003 AT 93' GROSS HEAD.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K901 R0.

PRELIMINARY

SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 1

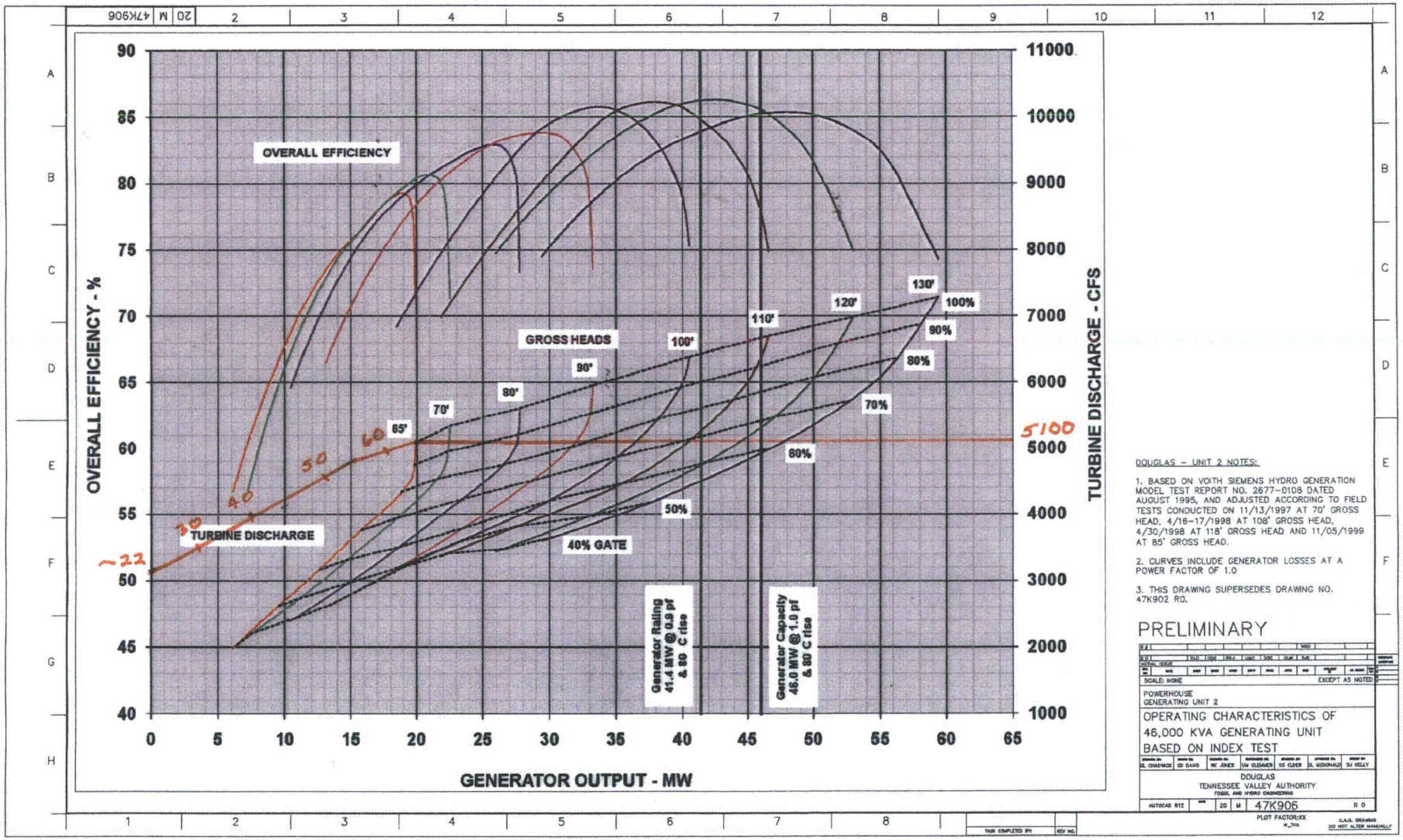
OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | 20 | M | 47K905 | R 0

Attachment 8A-6
Reference 30, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 2 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0108 DATED AUGUST 1995, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 11/13/1997 AT 70' GROSS HEAD, 4/16-17/1998 AT 108' GROSS HEAD, 4/30/1998 AT 118' GROSS HEAD AND 11/05/1999 AT 85' GROSS HEAD.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K902 R0.

PRELIMINARY

SCALE: NONE — EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 2

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DRAWN BY: SL CHADWICK | DESIGN BY: DD DAVIS | DESIGNED BY: RK JONES | CHECKED BY: LM CLEMMER | APPROVED BY: SS CLIDER | APPROVED BY: DL MCDONALD | ISSUED BY: SJ KELLY

DOUGLAS
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | DATE | 20 | M | 47K906 | R 0

PLOT FACTOR:XX
W_TVA

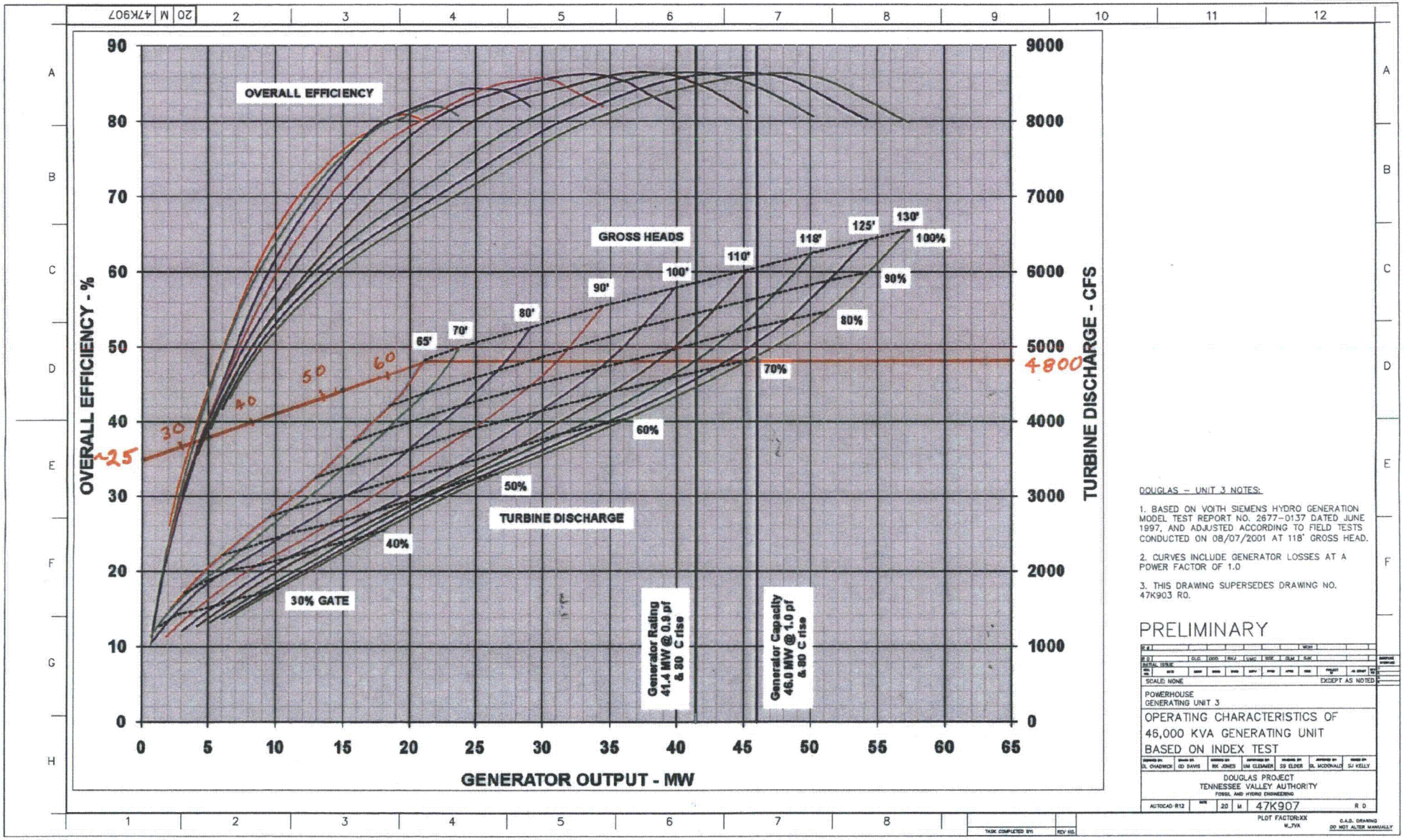
C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.

20 M 47K906

Attachment 8A-7
Reference 31, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 3 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0137 DATED JUNE 1997, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 08/07/2001 AT 118' GROSS HEAD.
2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0
3. THIS DRAWING SUPERSEDES DRAWING NO. 47K903 R0.

PRELIMINARY

SCALE: NONE — EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 3

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DRAWN BY GL CHADWICK | TRACED BY GD DAVIS | DESIGNED BY RK JONES | SUPERVISED BY LM CLEAVER | REVIEWED BY SG ELDER | APPROVED BY GL MCDONALD | ISSUED BY SJ KELLY

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | DATE | 20 M 47K907 | R 0

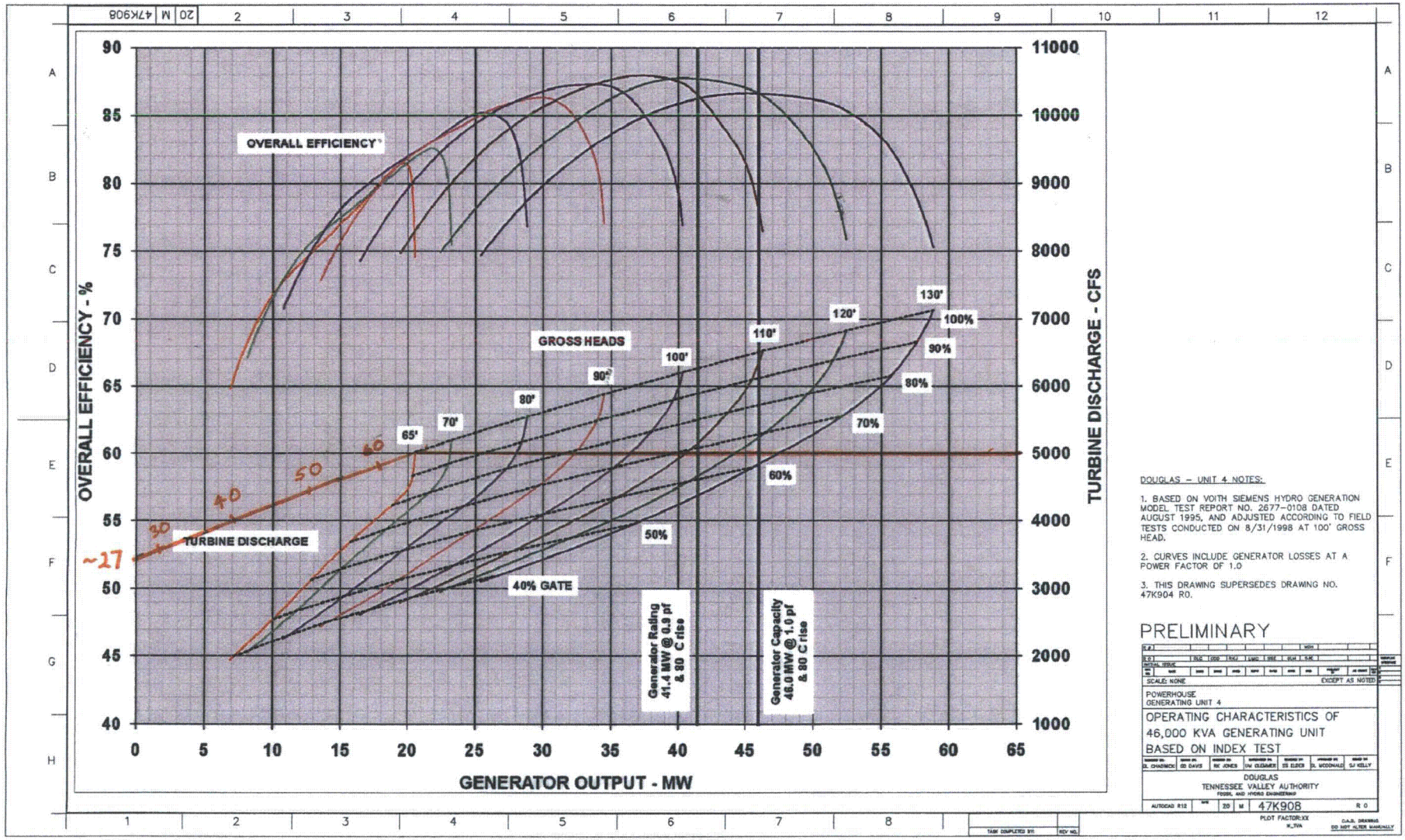
PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.

Attachment 8A-8
Reference 32, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 4 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0108 DATED AUGUST 1995, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 8/31/1998 AT 100' GROSS HEAD.
2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0
3. THIS DRAWING SUPERSEDES DRAWING NO. 47K904 R0.

PRELIMINARY

SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 4

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DOUGLAS
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

47K908 R 0

Appendix A: Spillway Discharge Coefficients for Douglas Dam from 1:35 Scale Model Test Data

A.1 Background

TVA has model test data describing the relationships between discharge, headwater, tailwater, and gate opening for most of its spillways. These data, which are the basis for the spillway discharge tables developed for each dam, are used in the dam rating curve calculations. Use of reference book discharge coefficients for standard crests would result in inferior results because TVA's spillway crests are not standard.

The spillway gates and crests at Douglas Dam are identical to the spillway gates and crests at Watts Bar Dam, Fort Loudoun Dam, and Cherokee Dam. Consequently, the orifice flow discharge characteristics for these four dams are identical and the orifice relationships provided below apply to all four dams (for the same vertical openings, V, of the gates). The free discharge characteristics vary somewhat with upstream reservoir depth (approach depth). The free discharge relationships provided below apply to both Douglas and Cherokee Dams because they have similar upstream depths, but not to Watts Bar and Fort Loudoun Dams, which have lower upstream reservoir depths.

Douglas Dam has eleven spillway bays, each controlled by a radial (tainter) gate as illustrated in Attachment A1. For dam rating curve calculations the gates are assumed to be open to their maximum opening position as specified in the Spillway Gate Arrangements table in Reference 3 and included as Attachment A2. As shown in this table, the maximum opening corresponds to reading "X" on the gate position indicators for the spillway. Field measurements of V, the vertical distance between the bottom lip of a raised spillway gate and the spillway crest, are summarized in Attachment A3 (from Reference 27). For gate position indicator reading "X" the average value of V for the eleven gates is 29.371 feet.

Test data from a 1:35 scale model (circa 1950) are available for free discharge conditions (Reference 20) and for orifice discharge conditions for nine different gate openings varying from V = 1.82 feet to V = 23.83 feet (Reference 28, data tabulated for Watts Bar dam). Orifice discharge data were not collected for gate openings as large as V = 29.371 feet, however, because under normal operating conditions the overflowing nappe will never touch the bottom of a gate open this far. But under the PMF conditions considered for the dam rating curves the nappe will touch the gate in this position. Consequently, the data for gate openings V = 23.83, 19.84, 15.86, 11.83, and 7.80 feet are used here to estimate orifice flow discharge characteristics for V = 29.371 feet.

A.2 Discharge Equations

Attachment A4 is a definition sketch for flow over the Douglas Dam spillway. Free discharge occurs for headwater elevations below the elevation at which the overflowing nappe first touches the bottom lip of the gate, or $H_c <= H_{Lmin}$, and is computed using a weir equation (e.g., Reference 4):

$$Q_f = C_f L H_c^{1.5} \qquad \text{(A1)}$$

in which
- Q_f = free discharge (cfs)
- C_f = free discharge coefficient ($ft^{0.5}/s$ -- varies with H_c)
- L = length of overflowing section (ft)
- H_c = head on crest (ft) = HW - Z_c
- HW = headwater elevation (ft)
- Z_c = top, or crest, elevation of overflowing section (ft)

This equation is not modified to account for tailwater submergence because the tailwater will not rise to a level which will influence spillway discharge.

For headwater elevations above the elevation at which the nappe touches the gate lip, or $H_c > H_{Lmin}$, orifice flow occurs and is computed from (e.g., Reference 4):

$$Q_g = C_g G_n L\sqrt{2g(H_c - H_{mp})} \qquad \text{(A2)}$$

in which Q_g = orifice discharge (cfs)
C_g = orifice discharge coefficient (dimensionless -- varies with gate opening and H_c)
G_n = effective gate opening = minimum distance between the gate lip and the crest (ft)
g = acceleration of gravity (32.2 ft/s^2 -- common knowledge, Reference 4, sheet. 000-1 for example)
H_{mp} = vertical distance between the mid-point of G_n and the crest

Again, no modification to account for tailwater submergence is necessary.

A.3 Model Test Data

The 1:35 scale Douglas and Watts Bar model test data (References 20 and 28) are used to determine

- $C_f(H_c)$
- H_{Lmin} and $C_g(H_c)$ for V = 29.371 ft.

The Douglas model test results for $C_f(H_c)$ were published in graphical form in Reference 20. Figure 3 (Att. A12-2) of this reference shows model data based $C_f(H_c)$ values. Reference 20 includes Watts Bar results for orifice discharge but in terms of a different discharge coefficient than the coefficient C_g used in Equation (A2), and Reference 20 includes no information on the relationship between H_{Lmin} and gate opening. However, Watts Bar model test data for orifice discharge are tabulated in Reference 28 and these data are used below to estimate H_{Lmin} and $C_g(H_c)$ for V = 29.371 feet.

Attachment A5 provides the relevant pages from Reference 20. Attachment A6 provides the relevant pages from Reference 28. Reference 28 includes a few pages (Attachment A6-4, for example) with penciled corrections by the original author.

Model data are scaled to prototype values using the following scale ratios from Attachment A7 (Reference 18):

- V_p/V_m and $H_p/H_m = 35$
- $Q_p/Q_m = (35)^{2.5} = 7247.2$

in which H is "head" in feet and represents any water level difference (d or H_c, for example), the p-subscript denotes prototype, and the m-subscript denotes model.

A.4 Geometry

Parameters G_n, H_{mp}, Z_o (gate overflow elevation), and β (angle plotted against discharge coefficient in Reference 4) are computed from crest and gate geometry as described in Attachment A8. Table A1 gives the values of these parameters for V = 7.80, 11.83, 15.86, 19.84, 23.83, and 29.371 feet.

Table A1: Geometrical Parameters for Relevant Gate Openings

V, feet	G_n, feet	H_{mp}, feet	Z_o, feet	β, deg.
7.80	7.865	3.881	1008.27	78.4
11.83	11.868	5.906	1010.76	86.4
15.86	15.904	7.921	1012.86	93.1
19.84	19.919	9.906	1014.56	98.9
23.83	23.994	11.892	1015.85	104.0
29.371	29.783	14.588	1016.88	112.8

As an example, the procedure for computing the geometrical parameters for V = 29.371 feet is given here. From Attachment A9 (Reference 23),

- R = 35 feet
- Z_c = 970 feet
- Z_{tr} = 982 feet
- z_1 = 982 – 969.636 = 12.364 feet
- z_2 =1002 - 982 = 20.0 feet

where the parameters are defined in Attachment A8-2. Referring to Attachment A8:

Angle θ: $$\theta = \sin^{-1}\left(\frac{12.364}{35}\right) + \sin^{-1}\left(\frac{20.0}{35}\right) = 55.537°$$

Angle α: $$\alpha = \tan^{-1}\left(\frac{982 - 970 - 29.371}{\sqrt{35^2 - (982 - 970 - 29.371)^2}}\right) = -29.756°$$

Overflow elevation Z_o: $$Z_o = 982 + 35\sin[55.537 - (-29.756)] = 1016.88 \ \textit{feet}$$

Gate lip y-coordinate: $$y_\ell = 982 - 970 - 29.371 = -17.371 \ \textit{feet}$$

Gate lip x-coordinate: $$x_\ell = \sqrt{35^2 - (-17.371)^2} = 30.385 \ \textit{feet}$$

From Attachment A10 (Reference 22), the equation for the spillway crest is:

$$y_s^* = f(x_s^*) = 0.045 + \frac{x_s^* - 8.38}{10} + \frac{(x_s^* - 8.38)^2}{127} \quad \text{for } x_s^* \geq 0$$

in which $y_s^* = y_s - 12$ *and* $x_s^* = 43.708 - x_s$. In terms of y_s and x_s:

$$y_s = f(x_s) = 25.4051 - 83.356\left(\frac{x_s}{127}\right) + 127\left(\frac{x_s}{127}\right)^2 \quad \text{for} \quad x_s \leq 35.328 \text{ feet}$$

and

$$\frac{dy_s}{dx_s} = -0.65635 + \frac{x_s}{63.5}$$

To get effective gate opening, G_n, solve the following equation for x_{sn}:

$$x_{sn} - 30.385 + \left[25.4051 - 83.356\left(\frac{x_{sn}}{127}\right) + 127\left(\frac{x_{sn}}{127}\right)^2 - (-17.371)\right]\left[-0.65635 + \frac{x_{sn}}{63.5}\right] = 0$$

Solution:

- $x_{sn} = 33.973$ feet (by iteration)
- $y_{sn} = 25.4051 - 83.356(33.973/127) + 127(33.973/127)^2 = 12.195$
- $G_n = \sqrt{(33.973 - 30.385)^2 + (12.195 - (-17.371))^2} = 29.783$ *feet*

and

- $H_{mp} = 29.371 - [12.195 - (-17.371)]/2 = 14.588$ feet
- $\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{-17.371}{30.385}\right) - \tan^{-1}\left(\frac{33.973 - 30.385}{12.195 - (-17.371)}\right) = 90 - (-29.76) - 6.92 = 112.8°$

A.5 Determination of $H_{Lmin}(V)$

Attachment A11 shows the Watts Bar model test data (Attachments A6-4 and A6-5) for H_{Lmin} and a polynomial curve fit to the data (spreadsheet included as Attachment 26). A value of H_{Lmin} for V = 29.371 feet is established by using the polynomial to extrapolate the data. The following formula is used to calculate H_{Lmin} for varying values of V:

$$H_{Lmin} = 0.00516V^2 + 1.06709V + 1.46248 \qquad \text{(A3)}$$

From this formula, the following value is used for the Douglas dam rating curve calculations: $H_{Lmin} = 37.26$ feet for V = 29.371 feet. Therefore, the elevation at which the headwater nappe touches the gate is 970 feet + 37.26 feet = 1007.26 feet.

A.6 Determination of $C_f(H_c)$

Figure 3 in Reference 20 (Attachment A12-2) provides a curve of C_f vs. H_c for Douglas Dam determined from model test data. Attachment A12-1 shows a polynomial curve fit to points scaled from Figure 3 in Reference 20. The polynomial indicated in Attachment A12-1 is used for the dam rating curve calculations:

$$C_f = 3.159 + 0.04253H_c - 0.0014216H_c^2 + 4.107\text{x}10^{-5}H_c^3 - 4.62\text{x}10^{-7}H_c^4 \qquad \text{(A4)}$$

No adjustment factor for submergence is necessary.

A.7 Determination of $C_g(H_c)$ for V = 29.371 feet

Attachment A13-1 shows the calculations and results for extrapolating $C_g(H_c)$ for V = 29.371 feet from the model data for various gate openings at Watts Bar. The first column in Attachment A13-1 indicates the data for which $H_c = H_{Lmin}$, at which H_c is just high enough to touch the bottom of the gate. The discharge indicated for V = 29.371 feet at $H_c = H_{Lmin}$ is the free discharge computed using $C_f(H_c)$ from Equation (A4). In order to have a smooth transition from free discharge conditions to orifice flow conditions as the nappe just touches the gate, free discharge is considered equal to orifice discharge at $H_c = H_{Lmin}$ feet in order to extrapolate C_g values from model data. The first three numerical columns list the model data (scaled to prototype dimensions) for V = 7.8, 11.83, 15.86, 19.84, and 23.83 feet as listed in Attachment A6 and the measured and calculated values for the maximum gate opening of 29.371 feet. The rows that do not include values of discharge, Q, were added to extrapolate the data. The next two columns after the model data list prototype geometrical parameters. The last numerical column lists the C_g values computed from the data. Values that were "estimated" for extrapolation purposes are labeled as such to the right of the C_g column.

Attachment A13-2 shows C_g plotted against H_c for all gate openings from both Watts Bar model tests and Douglas reference values. The model data points are shown along with lines drawn through the data and extended to H_c = 60 feet. The estimated curve for V = 29.371 feet starts with the value for $H_c = H_{Lmin}$ and runs approximately parallel to the curve for V = 23.83 feet. Given the absence of data, this extrapolated line segment fit for $C_g(H_c)$ at V = 29.371 feet for varying headwater elevations given in Attachment A13 is used for the dam rating calculations. Table A2 lists the points describing the extrapolated relationship.

Table A2: Points Defining Extrapolated Douglas Curve for $C_g(H_c)$ at V = 29.371 feet.

H_c, feet	C_g
37.26	.800
41.00	.718
46.00	.707
60.00	.707

As further justification for the extrapolation, Attachment A13-3 shows the Douglas C_g values at H_c = 60 feet plotted against angle β on Hydraulic Design Chart 311-1 from Reference 4 showing U.S. Army Corps of Engineers data for tainter gates on standard crests. The value of X/H_d for Douglas is 0.15 (X = 3.43 feet, Attachment A9, and H_d = 23.5, Attachment A6-1). Presumably because TVA's spillway crests are not standard, TVA data always lie to the left of the suggested design curves on this chart. Note that C_g = 0.707 at H_c = 60 feet and V = 29.371 feet (β = 112.8 degrees) is a very reasonable extrapolation of the Douglas data curve and appears reasonable compared with the suggested design curves on the chart.

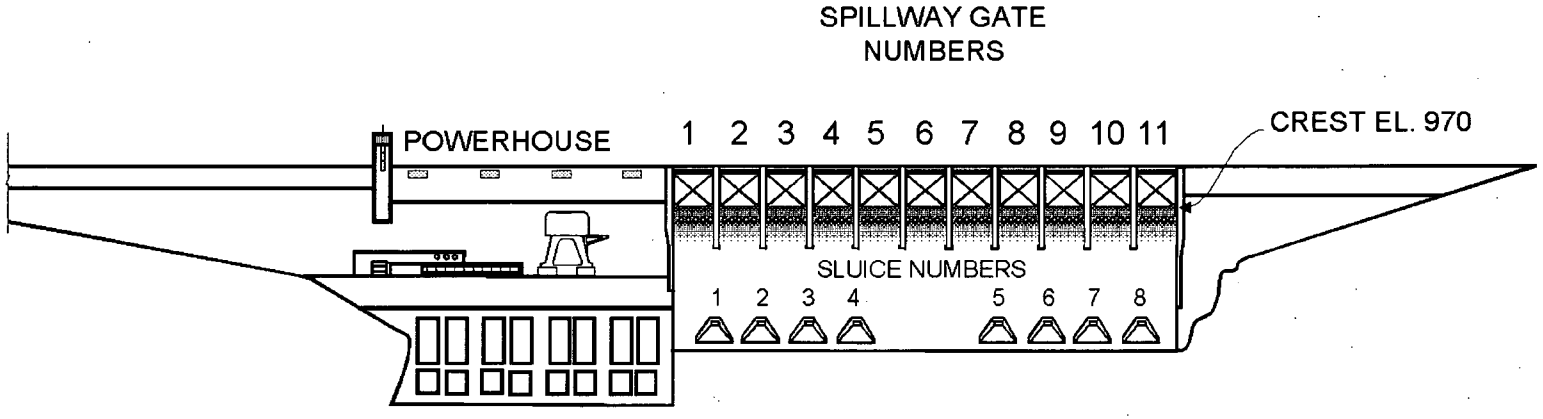
4

Attachment A1
from Ref. 3
1 page

Calculation No: CDQ000020080007

DOUGLAS DAM

LOCATION OF SPILLWAY AND SLUICE GATES



DOWNSTREAM ELEVATION

Attachment A2
from Ref. 3
1 page

Calculation No: CDQ000020080007

DOUGLAS DAM

SPILLWAY GATE ARRANGEMENTS

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0	0	0	0	0	2	0	0
2	0	0	2	0	0	0	0	0	2	0	0
3	0	0	2	0	2	0	0	0	2	0	0
4	0	0	2	0	2	0	2	0	2	0	0
5	0	0	2	0	2	0	2	0	2	0	2
6	2	0	2	0	2	0	2	0	2	0	2
7	2	0	2	0	2	0	2	0	2	2	2
8	2	2	2	0	2	0	2	0	2	2	2
9	2	2	2	0	2	0	2	2	2	2	2
10	2	2	2	2	2	0	2	2	2	2	2
11	2	2	2	2	2	2	2	2	2	2	2
12	2	2	2	2	2	2	2	2	4	2	2
13	2	2	4	2	2	2	2	2	4	2	2
14	2	2	4	2	4	2	2	2	4	2	2
15	2	2	4	2	4	2	4	2	4	2	2
16	2	2	4	2	4	2	4	2	4	2	4
17	4	2	4	2	4	2	4	2	4	2	4
18	4	2	4	2	4	2	4	2	4	4	4
19	4	4	4	2	4	2	4	2	4	4	4
20	4	4	4	2	4	2	4	4	4	4	4
21	4	4	4	4	4	2	4	4	4	4	4
22	4	4	4	4	4	4	4	4	4	4	4
23	4	4	4	4	4	4	4	4	6	4	4
24	4	4	6	4	4	4	4	4	6	4	4
25	4	4	6	4	6	4	4	4	6	4	4
26	4	4	6	4	6	4	6	4	6	4	4
27	4	4	6	4	6	4	6	4	6	4	6
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29	6	4	6	4	6	4	6	4	6	6	6
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34	6	6	6	6	6	6	6	6	10	6	6
35	6	6	10	6	6	6	6	6	10	6	6
36	6	6	10	6	10	6	6	6	10	6	6
37	6	6	10	6	10	6	10	6	10	6	6
38	6	6	10	6	10	6	10	6	10	6	10
39	10	6	10	6	10	6	10	6	10	6	10
40	10	6	10	6	10	6	10	6	10	10	10

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
41	10	10	10	6	10	6	10	6	10	10	10
42	10	10	10	6	10	6	10	10	10	10	10
43	10	10	10	10	10	6	10	10	10	10	10
44	10	10	10	10	10	10	10	10	10	10	10
45	10	10	10	10	10	10	10	10	14	10	10
46	10	10	14	10	10	10	10	10	14	10	10
47	10	10	14	10	14	10	10	10	14	10	10
48	10	10	14	10	14	10	14	10	14	10	10
49	10	10	14	10	14	10	14	10	14	10	14
50	14	10	14	10	14	10	14	10	14	10	14
51	14	10	14	10	14	10	14	10	14	14	14
52	14	14	14	10	14	10	14	10	14	14	14
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72	22	18	22	18	22	18	22	18	22	18	22
73	22	18	22	18	22	18	22	18	22	22	22
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76	22	22	22	22	22	18	22	22	22	22	22
77	22	22	22	22	22	22	22	22	22	22	22
78	22	22	22	22	22	22	22	22	26	22	22
79	22	22	26	22	22	22	22	22	26	22	22
80	22	22	26	22	26	22	22	22	26	22	22

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
81	22	22	26	22	26	22	26	22	26	22	22
82	22	22	26	22	26	22	26	22	26	22	26
83	26	22	26	22	26	22	26	22	26	22	26
84	26	22	26	22	26	22	26	22	26	26	26
85	26	26	26	22	26	22	26	22	26	26	26
86	26	26	26	22	26	22	26	26	26	26	26
87	26	26	26	26	26	22	26	26	26	26	26
88	26	26	26	26	26	26	26	26	26	26	26
89	26	26	26	26	26	26	26	26	UP	26	26
90	26	26	UP	26	26	26	26	26	UP	26	26
91	26	26	UP	26	UP	26	26	26	UP	26	26
92	26	26	UP	26	UP	26	UP	26	UP	26	26
93	26	26	UP	26	UP	26	UP	26	UP	26	UP
94	UP	26	UP	26	UP	26	UP	26	UP	26	UP
95	UP	26	UP	26	UP	26	UP	26	UP	UP	UP
96	UP	UP	UP	26	UP	26	UP	26	UP	UP	UP
97	UP	UP	UP	26	UP	26	UP	UP	UP	UP	UP
98	UP	UP	UP	UP	UP	26	UP	UP	UP	UP	UP
99	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
100	UP	UP	UP	UP	UP	UP	UP	UP	X	UP	UP
101	UP	UP	X	UP	UP	UP	UP	UP	X	UP	UP
102	UP	UP	X	UP	X	UP	UP	UP	X	UP	UP
103	UP	UP	X	UP	X	UP	X	UP	X	UP	UP
104	UP	UP	X	UP	X	UP	X	UP	X	UP	X
105	X	UP	X	UP	X	UP	X	UP	X	UP	X
106	X	UP	X	UP	X	UP	X	UP	X	X	X
107	X	X	X	UP	X	UP	X	UP	X	X	X
108	X	X	X	UP	X	UP	X	X	X	X	X
109	X	X	X	X	X	UP	X	X	X	X	X
110	X	X	X	X	X	X	X	X	X	X	X

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator readings.

Attachment A3-1
12 total pages

Calculation No: CDQ000020080007

Field Measurements Of Maximum Tainter Gate Opening, V, For Douglas Dam

Preparer: S.E.M.
Checker: J.C.T.

Gate	Average Measured Maximum Opening By Gate	Overall Average Maximum Opening
1	29.557	
2	29.523	
3	29.609	
4	29.598	
5	29.545	
6	27.522	
7	29.494	
8	29.296	
9	29.767	
10	29.573	
11	29.592	
Average		29.371

TVA 469 (EN DES-11-78)

SHEET ____ OF ____

Attachment A3-2
from Ref. 27
12 total pages

Douglas Dam

Calculation No: CDQ000020080007

Meas. above Crest

Gate No 1

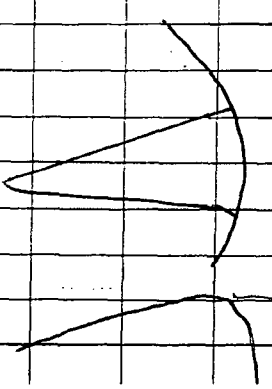
COMPUTED GAS DATE 10/21/96

Dan McBee

Jon Cliff CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reel	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg.
2	6	1.884		0.904	1.880		0.900	.902
4	10	3.502		2.522	3.492		2.512	2.517
6	14	5.160	-.980	4.180	5.150	-.980	4.170	4.175
10	18	6.825		5.845	6.825		5.845	5.845
14	24	9.342		8.362	9.350		8.370	8.366
18	32	12.698		11.718	12.710		11.730	11.724
22	42	16.895		15.915	16.892		15.912	15.914
26	52	21.040		20.060	21.030		20.050	20.055
UP	62	25.132		24.152	25.135		24.155	24.154
mid	74	30.532		29.552	30.542		29.562	29.557

Zero corr = -1.1 feet (for tape attached to gate) + 0.12 (height of level channel)
= -.98 feet



TVA 489 (EN DES-11-76)

Attachment A3-3
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Gate [illegible] ue Crest

Calculation No: CDQ0000020080007

Gate No 2

COMPUTED GAS DATE 10/21/96

Dan Joe CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reel	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg. ft
2	6	1.885		.905	1.875		.895	.900
4	10	3.484		2.504	3.477		2.497	2.501
6	14	5.123	-.98	4.143	5.113	-.98	4.133	4.138
10	18	6.771		5.791	6.760		5.780	5.786
14	24	9.269		8.289	9.253		8.273	8.281
18	32	12.612		11.632	12.607		11.627	11.630
22	42	16.831		15.851	16.810		15.830	15.841
26	52	20.992		20.012	20.972		19.992	20.002
UP	62	25.095		24.115	25.070		24.090	24.103
rod	74	30.521		29.541	30.485		29.505	29.523

TVA 489 (EN DES-11-76)

Attachment A3-4
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate opening vs. Crest

Gate No 3

COMPUTED GAS DATE 10/21/96

CHECKED ____ DATE ____

Dam Tie

Gate IND Reel	Link No	Left Side Tape Read ft	Left Side Zero Corr ft	Left Side Beam Corr ft	Right Side Tape Read ft	Right Side Zero Corr ft	Right Side Beam Corr ft	Avg ft
2	6	1.930		0.950	1.993		1.013	.982
4	10	3.541		2.561	3.600		2.620	2.591
6	14	5.200	-.98	4.220	5.257	-.98	4.277	4.249
10	18	6.853		5.873	6.908		5.928	5.901
14	24	9.358		8.378	9.410		8.430	8.404
18	32	12.717		11.737	12.762		11.782	11.760
22	42	16.891		15.911	16.945		15.965	15.938
26	52	21.030		20.050	21.075		20.095	20.073
UP	62	25.100		24.120	25.155		24.175	24.148
mid	74	30.572		29.592	30.606		29.626	29.609

TVA 489 (EN DES-11-76)

Attachment A3-5
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate, Above Crest

Gate No 4

COMPUTED GAS DATE 10/21/96

CHECKED ____ DATE ____

			Left Side			Right Side			
Gate IND Rad	Link No		Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	
2	6		1.961		.981	1.998		1.018	1.060
4	10		3.570		2.590	3.592		2.612	2.601
6	14		5.235	-.98	4.255	5.238	-.98	4.258	4.257
10	18		6.879		5.899	6.885		5.905	5.902
14	24		9.380		8.400	9.375		8.395	8.398
18	32		12.741		11.761	12.748		11.768	11.765
22	42		16.915		15.935	16.910		15.930	15.933
26	52		21.030		20.050	21.040		20.060	20.055
UP	62		25.105		24.125	25.140		24.160	24.143
mid	74		30.340		29.560	30.615		29.635	29.598

South side pointer is broken

TVA 489 (EN DES-11-76)

Attachment A3-6
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate opening above Crest

Gate No 5

COMPUTED GHS DATE 10/21/96

Dan Joe CHECKED ____ DATE ____

Gate IND Read	Link No	Left Side Tape Read ft	Left Side Zero Corr ft	Left Side Beam Corr ft	Right Side Tape Read ft	Right Side Zero Corr ft	Right Side Beam Corr ft	Avg ft
2	6	1.890		.910	1.918		.938	.924
4	10	3.495		2.515	3.535		2.555	2.535
6	14	5.152	-.98	4.172	5.188	-.98	4.208	4.190
10	18	6.810		5.830	~~6.842~~ 6.842		5.862	5.846
14	24	9.315		8.335	9.340		8.360	8.348
18	32	12.672		11.692	12.693		11.713	11.703
22	42	16.855		15.875	16.878		15.898	15.887
26	52	20.991		20.011	21.025		20.045	20.028
UP	62	25.076		24.096	25.110		24.130	24.113
mid	74	30.506		29.526	30.543		29.563	29.545

TVA 489 (EN DES-11-76)

Attachment A3-7
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate ____ e Crest

Gate No 6

COMPUTED GAS DATE 10/21/96

Dan Joe CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reel	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg. ft
2	6	1.996		1.016	1.982		1.002	1.009
4	10	3.592		2.612	3.585		2.605	2.609
6	14	5.240	-.98	4.260	5.235	-.98	4.255	4.258
10	18	6.888		5.908	6.880		5.900	5.904
14	24	9.365		8.385	9.368		8.388	8.387
18	32	12.710		11.730	12.712		11.732	11.731
22	42	16.881		15.901	16.910		15.930	15.916
26	52	21.017		20.037	21.000		20.020	20.029
UP	62	25.096		24.116	25.082		24.102	24.109
rod	70	28.511		27.531	28.492		27.512	27.522

Too much friction above 70 links

Attachment A3-8
from Ref. 27
12 total pages

SHEET _____ OF _____

Douglas Dam

Calculation No: CDQ0000020080007

Gate [illegible] Crest

Gate No 7

COMPUTED GAS DATE 10/21/96

CHECKED _____ DATE _____

Gate IND Rad	Link No	Left Side Tape Read ft	Left Side Zero Corr ft	Left Side Beam Corr ft	Right Side Tape Read ft	Right Side Zero Corr ft	Right Side Beam Corr ft	Avg. ft
2	6	1.930		.950	1.990		1.010	.980
4	10	3.537		2.557	3.590		2.610	2.584
6	14	5.183	-.98	4.203	5.237	-.98	4.257	4.230
10	18	6.830		5.850	6.880		5.900	5.875
14	24	9.321		8.341	9.378		8.398	8.370
18	32	12.663		11.683	12.722		11.742	11.713
22	42	16.850		15.870	16.915		15.935	15.903
IC	52	20.984		20.004	21.055		20.075	20.040
UP	62	25.063		24.083	25.128		24.140	24.116
mx	74	30.455		29.475	30.492		29.512	29.494

TVA 489 (EN DES-11-76)

Attachment A3-9
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate opening [illegible] above Crest

Gate No 8

COMPUTED GAS DATE 10/21/96

CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reel	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg ft
2	6	1.956		.976	2.000		1.020	.998
4	10	3.560		2.580	3.600		2.620	2.600
6	14	5.211	-.98	4.231	5.258	-.98	4.278	4.255
10	18	6.859		5.879	6.905		5.925	5.902
14	24	9.360		8.380	9.410		8.430	8.405
18	32	12.707		11.727	12.749		11.769	11.748
22	42	16.881		15.901	16.935		15.955	15.928
26	52	21.028		20.048	21.060		20.080	20.064
UP	62	25.094		24.114	25.125		24.145	24.130
max	74	30.452		29.472	30.500		29.520	29.496

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Attachment A3-10
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Gate [illegible] ve Crest

Calculation No: CDQ000020080007

Gate No 9

COMPUTED GHS DATE 10/21/96

CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reel	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg. ft.
2	6	1.975		.995	2.005		1.025	1.010
4	10	3.600		2.620	3.630		2.650	2.635
6	14	5.295	-.98	4.315	5.318	-.98	4.338	4.327
10	18	6.945		5.965	6.988		6.008	5.987
14	24	9.448		8.468	9.495		8.515	8.492
18	32	12.811		11.831	12.863		11.883	11.857
22	42	17.010		16.030	17.078		16.098	16.064
26	52	21.150		20.170	21.210		20.230	20.200
UP	62	25.255		24.275	25.300		24.320	24.298
rod	74	30.740		29.760	30.753		29.773	29.767

Chains different on each side - link near shackle longer on left side than on right. Uneven dogging. ~~Set~~ One chain slack for setting 22

Attachment A3-11
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ0000020080007

Gate ~~Opening~~ Crest

Gate No 10

COMPUTED GAS DATE 10/21/96

CHECKED ____ DATE ____

		Left Side			Right Side			
Gate IND Reading	Link No	Tape Read ft	Zero Corr ft	Beam Corr ft	Tape Read ft	Zero Corr ft	Beam Corr ft	Avg. ft
2	6	1.961		.981	1.775		.795	.888
4	10	3.570		2.590	3.402		2.422	2.506
6	14	5.237	-.98	4.257	5.070	-.98	4.090	4.174
10	18	6.890		5.910	6.730		5.750	5.830
14	24	9.395		8.415	9.232		8.252	8.334
18	32	12.759		11.779	12.600		11.620	11.700
22	42	16.965		15.985	16.802		15.822	15.904
26	52	21.118		20.138	20.953		19.973	20.056
UP	62	25.200		24.220	25.055		24.075	24.148
max	74	30.615		29.635	30.490		29.510	29.573

TVA 489 (EN DES-11-76)

Attachment A3-12
from Ref. 27
12 total pages

SHEET ____ OF ____

Douglas Dam

Calculation No: CDQ000020080007

Gate ... Crest

Gate No 11

COMPUTED GAS DATE 10/21/96

CHECKED ____ DATE ____

Gate IND Read	Link No	Left Side Tape Read ft	Left Side Zero Corr ft	Left Side Beam Corr ft	Right Side Tape Read ft	Right Side Zero Corr ft	Right Side Beam Corr ft	Avg. ft
2	6	2.027		1.047	2.018		1.038	1.043
4	10	3.511		2.531	3.630		2.650	2.591
6	14	5.180	-.98	4.200	5.282	-.98	4.302	4.251
10	18	6.821		5.841	6.935		5.955	5.898
14	24	9.324		8.344	9.435		8.455	8.400
18	32	12.684		11.704	12.790		11.810	11.757
22	42	16.879		15.899	16.980		16.000	15.950
26	52	21.015		20.035	21.110		20.130	20.083
~~UP~~	~~62~~							
max	60	24.290		23.310	24.350		23.410	~~23.360~~
								UP 24.169
								MAX 29.592

~~State~~

~~Gate~~

~~Gate~~

Metal to metal on south side, seal rolls up at contact area (at top of wall)

Afraid to take it above link 60

Rubbing noises

11/10/98 Set "Max" and "Up" indicators to correct positions.
Link 74 Link 62

Didn't measure openings but by considering average changes in opening for link no" changes from 24 to up to Max for gate 9 & 7, concluded that

TVA 489 (EN DES-11-76)

Attachment A-4
1 page

SHEET ____ OF ____

Calculation No: CDQ000020080007

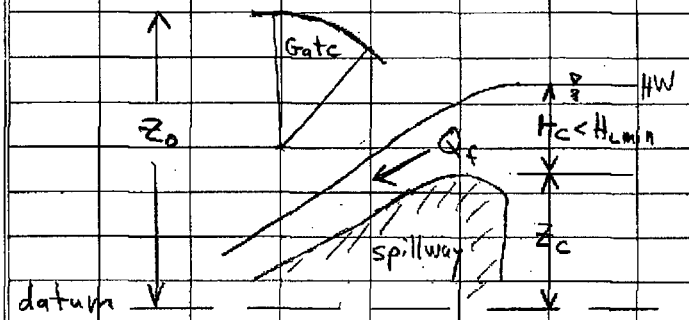
Attachment A4

Definition Sketch for Spillway Discharge

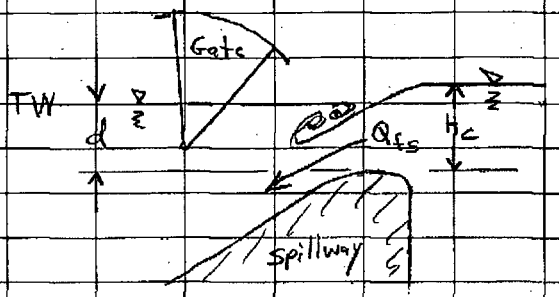
COMPUTED GAS DATE 8/12/2008

CHECKED J.C.T DATE

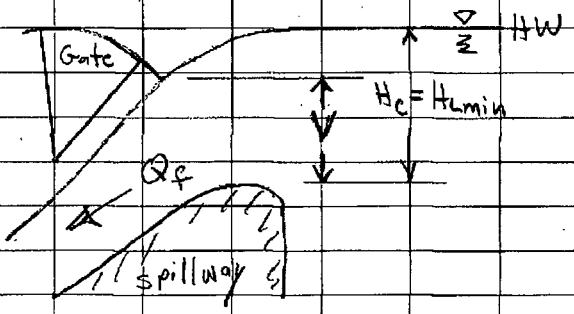
Free Discharge - No Tailwater effect



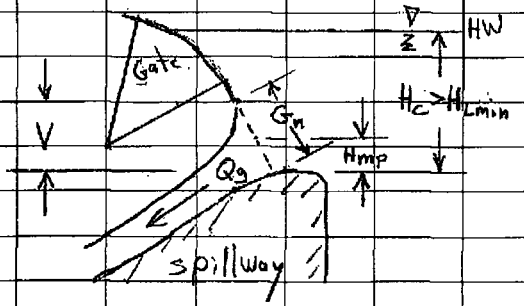
Free Discharge affected by Tailwater



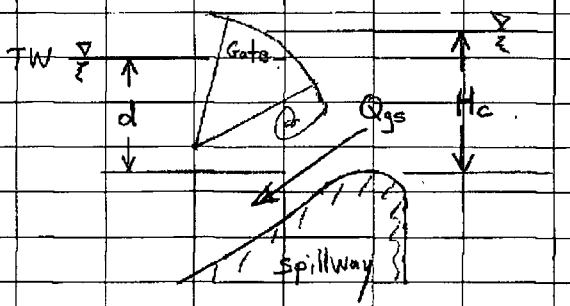
Nappe Touches Gate



Orifice Discharge - No Tailwater Effect



Orifice Discharge affected by Tailwater



Trans. ASCE, Vol. 22, pp. 190-210, 1957

Attachment A5-1
from Ref. 20
5 total pages

Calculation No: CDQ000020080007

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

TRANSACTIONS

Paper No. 2855

DISCHARGE COEFFICIENTS FOR SPILLWAYS AT TVA DAMS

By Kenneth W. Kirkpatrick,[1] A. M. ASCE

Synopsis

Spillway ratings derived from model studies have been used in the preparation of spillway rating tables for the Tennessee Valley Authority dams. As a result of these studies, discharge coefficients for eleven of the Tennessee Valley Authority dams are given in this paper. Coefficients for both submerged and free discharge conditions are presented for discharges over standard spillway crests, irregular spillway crests, and a vertical-lift spillway gate. Discharge coefficients for Tainter gates placed on curved spillway crests are also given for various gate openings under free discharge conditions. In addition, data on the effect of model scale on the discharge coefficient and the effect of closing adjacent spillway bays and gates are presented. The coefficient relationships are shown in a form that may be used by designers as a guide in making determinations of the discharges for future spillways.

Notation

The letter symbols adopted for use in this paper are defined where they first appear, in the illustrations or in the text, and are arranged alphabetically, for convenience of reference, in the Appendix.

Introduction

The Tennessee Valley Authority (TVA) operates a system of nine dams on the Tennessee River and twenty-three on the tributary rivers. The successful operation of such a system requires accurate discharge ratings for each structure. Although enough water is seldom available to make complete ratings for most spillways from measurements conducted on the prototype structure, ratings can be determined from scale model tests. Therefore, the necessary ratings for the TVA spillways have been determined by this means. Model studies have been made at the TVA Hydraulic Laboratory at Norris, Tenn.,

Note.—Published, essentially as printed here, in February, 1955, as *Proceedings-Separate No. 626*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.

[1] Hydr. Engr., Hydr. Lab., Tennessee Valley Authority, Norris, Tenn.

on nine different spillway crest shapes equipped with three types of control gates.

Seven of the nine crests were curved sections which approximated the shape of the lower nappe of a sharp-crested weir. The other two crests were flat. The two flat-crested weirs and one of the curved crests were equipped with double-leaf vertical lift gates. Five of the curved crests were equipped with Tainter gates and the other with vertical lift gates.

Data Presented.—Data are presented for the following conditions: (1) Free, ungated flow through a series of spillway bays; (2) submerged, ungated flow through a series of spillway bays; (3) free, ungated flow through a series of spillway bays, with adjacent bays fully open or closed; (4) free flow over a vertical lift gate; (5) submerged flow over a vertical lift gate; (6) flow under a series of Tainter gates set with equal openings; and (7) flow under a series of Tainter gates with adjacent gates closed.

Data are also presented to show the effect of model scale for the condition of free, ungated flow through a series of spillway bays.

General Model Arrangement.—The models were tested in flumes either 3.5 ft wide or 8 ft wide. Models installed in the smaller flume usually consisted of a reproduction of three of the prototype spillway bays. In the larger flume five or six spillway bays were reproduced. Each of these flumes was provided with glass panels for observation purposes. The models placed in the larger flume were constructed at scale ratios of from 1:28.72 to 1:50 with a ratio of approximately 1:35 generally used. Those tested in the smaller flume were built at scale ratios of 1:50, 1:100, and 1:200.

The models were usually provided with concrete crests and concrete piers to insure dimensional stability. Half piers were constructed on the ends of each model. If the model did not completely fill the flume one side was placed against the glass side of the flume and the other against a false wall. The river bed upstream and downstream from the model was reproduced at the elevation of the prototype river bed. Suitable baffling was provided to obtain a uniform distribution of flow in the spillway approach channel. The tailwater level was controlled at the end of the flumes by means of slat gates. Model discharges were determined from readings of a carefully calibrated diaphragm orifice located in the water supply line.

Headwater heights were measured at two piezometers at distances equal to approximately 5 and 8 times the design head upstream from the spillway crest. Tailwater heights were obtained at 2 piezometers at distances equal to approximately 9 and 12 times the design head downstream from the spillway crest—in all cases, sufficiently far enough downstream to eliminate the effect of the spillway apron.

In most studies the headwater and tailwater levels were determined by means of hook gages reading to 0.001 ft. For the 1/200-scale model the heads were measured with a micrometer point gage reading to 0.0001 ft.

Discharge Equations.—The model data have been reduced by the use of two commonly accepted discharge equations. For both free and submerged flow over a spillway crest the equation,

$$Q = C\,L\,H^{3/2} \qquad (1)$$

Attachment A5-2
from Ref. 20
5 total pages

Calculation No: CDQ000020080007

was used, in which Q is the discharge in cubic feet per second, C is the coefficient of discharge determined from the model tests, L is the length of the crest, and H is the total head as shown in Fig. 1(*a*). Use was made of the same equation in the reduction of the data for free and submerged flows over a vertical gate with D, H, d, and P (Fig. 1(*a*)) being measured from the top of the gate.

For flow under a gate the equation for a rectangular orifice under low head,

$$Q = C\,L\,[H^{3/2} - (D_1 + h)^{3/2}] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

was used, in which D_1 is the depth of water to the bottom of the gate as defined in Fig. 1(*b*) and h is the approach velocity head.

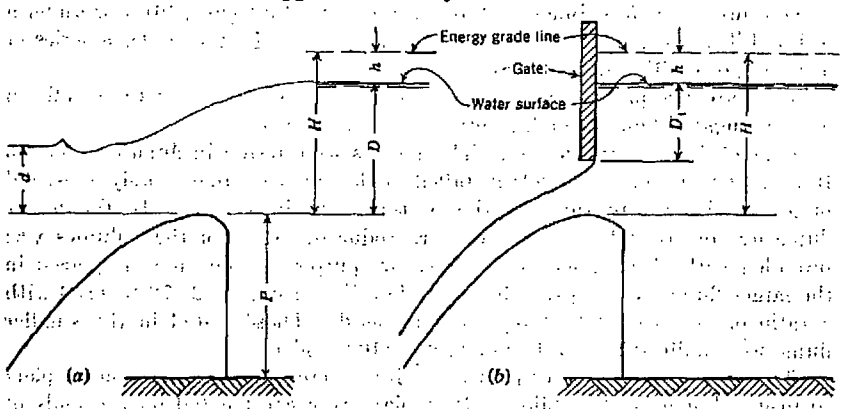


FIG. 1.—SPILLWAY-CREST DIAGRAM

FREE-DISCHARGE COEFFICIENTS, FLOW OVER SPILLWAY CRESTS

It is common practice for engineers to design spillway crests to approximate closely the shape of the lower portion of a jet issuing from a sharp-crested weir, and this type of crest is designated a standard crest.[2] Because the shape of the jet changes with the head on the weir, some particular head must be used for each design. This head for which a particular crest is designed is termed the design head. At this head, pressures approximating atmospheric pressure are developed at the spillway surface. At smaller heads, pressures are greater than atmospheric. Seven of the nine TVA crests for which data are available approximate standard crests in shape whereas the other two crests, which are flat, do not. Fig. 2 shows the basic details and dimensions of each of these crests. Fig. 3 presents the coefficient data obtained on the crests of Fig. 2. Pertinent design data concerning each crest, together with the scale to which each was modeled, appear in Table 1. Eleven spillways are also listed in Table 1. Two pairs of these, the Ocoee No. 3-Apalachia set, and the Douglas-Watts Bar set, both in Tennessee, have crest shapes that are identical within the pair but which were tested for different values of the approach depth, P.

[2] "Hydroelectric Handbook," by W. P. Creager and J. D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950.

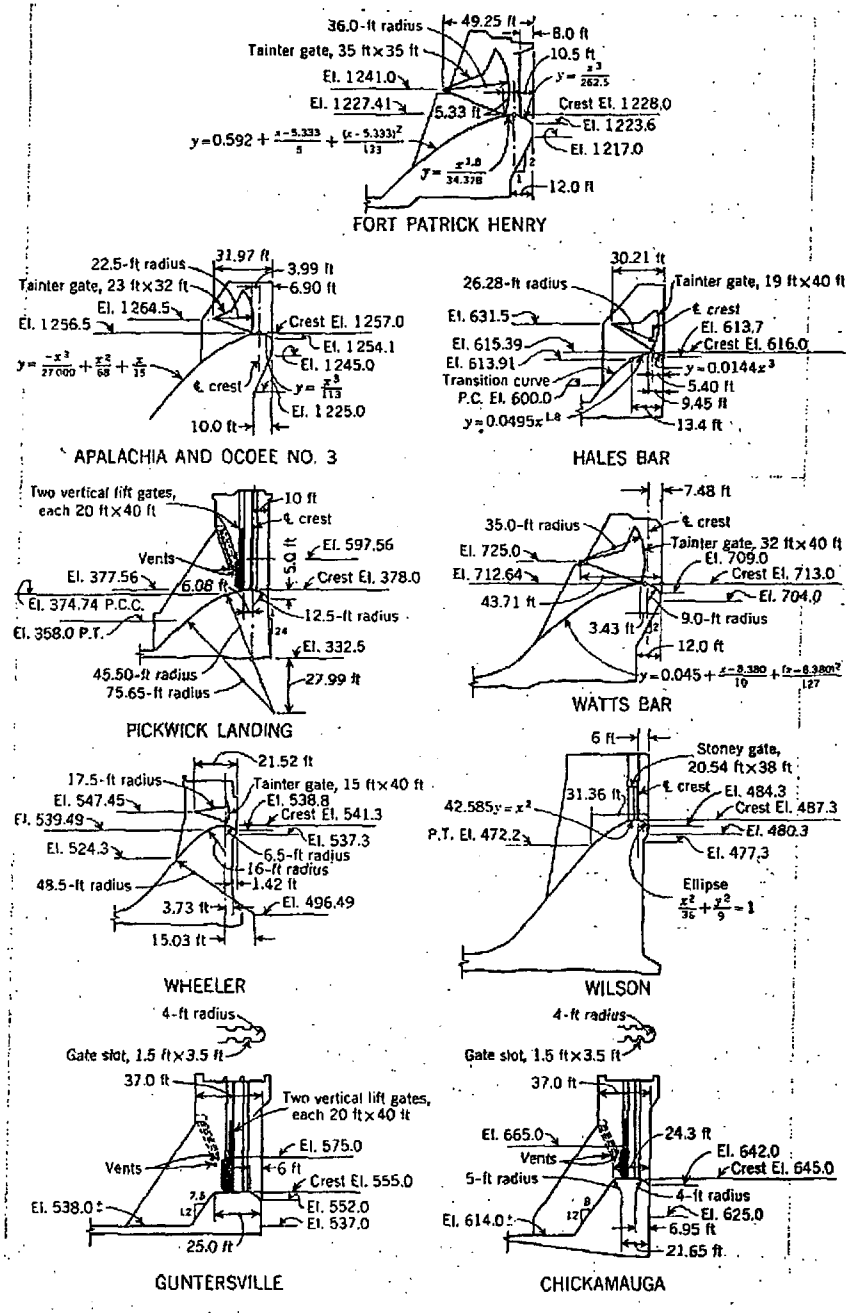


FIG. 2.—TVA SPILLWAY CRESTS (DATA IN FIG. 3)

Attachment A5-3
from Ref. 20
5 total pages

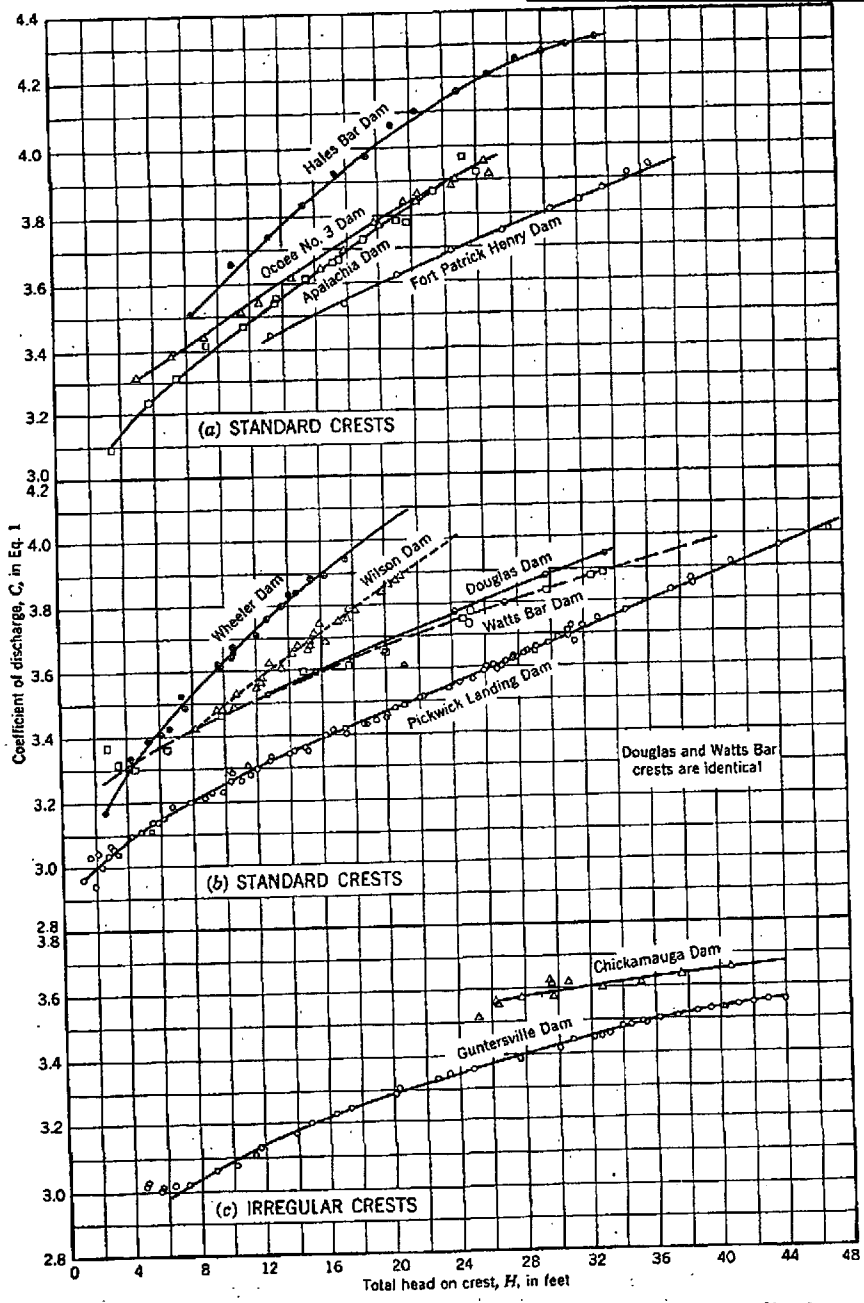


FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

Calculation No: CDQ000020080007

The accuracy of the data is evidenced by the plotting of the data points in Fig. 3. Except in some cases at low heads, the deviation of any plotted point from the coefficient curve does not exceed 0.5%.

Standard Crests.—It has been shown by various authors that the discharge coefficients for all standard crests can be related to each other and that, conversely, the coefficients to be used for a new design can be taken from previous test data.[2,3,4,5] Unfortunately, in most crest designs, due to other design considerations, it is necessary that the shape be varied from the standard form. Nevertheless, satisfactory coefficients can be obtained as sufficient data are now available on a range of crest shapes. By comparison of crest shapes designers may select a coefficient for any particular crest.

Dimensionless plotting provides a means for comparison of crest shapes. This method is used in Fig. 4 on which seven TVA crests which closely approximate standard crests are shown by the solid lines, with the dashed line representing a standard crest shape.[2] The horizontal coordinate, x, and the vertical coordinate, y, of the crest curve have been divided by the design head, H_o.

TABLE 1.—DESIGN DATA FOR ELEVEN MODELS OF TVA SPILLWAYS

Project	Model scale	Design head, H_o, in feet	Upstream depth, P, in feet	$\frac{H_o}{P}$	Pier nose radius, in feet
Hales Bar	1:34.76	18	32	0.56	3.00
Ocoee No. 3	1:28.72	23	67	0.35	3.00
Apalachia	1:28.72	23	97	0.24	3.00
Fort Patrick Henry	1:50	35	43	0.81	3.25
Wheeler	1:34.35	16.5	43	0.38	2.50
Wilson	1:39.4	19	75	0.25	4.00
Douglas	1:35	23.5	133	0.18	3.25
Watts Bar	1:35	23.5	52	0.45	3.25
Pickwick Landing	1:50	31.5	32	0.98	3.75
Chickamauga	1:50		20		4.00
Guntersville	1:50		18		4.00

The design head was determined by fitting the real and standard curves at the crest point ($x = 0$) and at the intersection of the curve with the upstream vertical face. These design-head values are presented in Table 1. The design-head discharge coefficients (C_o) determined from Fig. 3 are shown in Fig. 4.

The TVA crests all fairly closely approximate the standard curve from the upstream spillway face to a point somewhere downstream from the crest which was determined by the position of the gate seal. Below this latter point, the crest shape was modified to fit the trajectory of a jet issuing from under the gate when set at a small opening. The upstream face for a standard crest is vertical. The upstream face of the TVA crests, as shown in Fig. 4, deviates from the vertical. Other experimenters have established the fact that the shape of the upstream face generally has little influence on the discharge coefficient.[3]

[3] "Final Reports of Boulder Canyon Project," *Bulletin No. 3*, Part VI, Hydraulic Investigations, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1947.

[4] "Engineering Hydraulics," edited by Hunter Rouse, John Wiley & Sons, Inc., New York, N. Y., 1950.

[5] "Discharge Coefficients for Irregular Overfall Spillways," by J. N. Bradley, *Engineering Monograph No. 9*, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1952.

Attachment A5-4
from Ref. 20
5 total pages

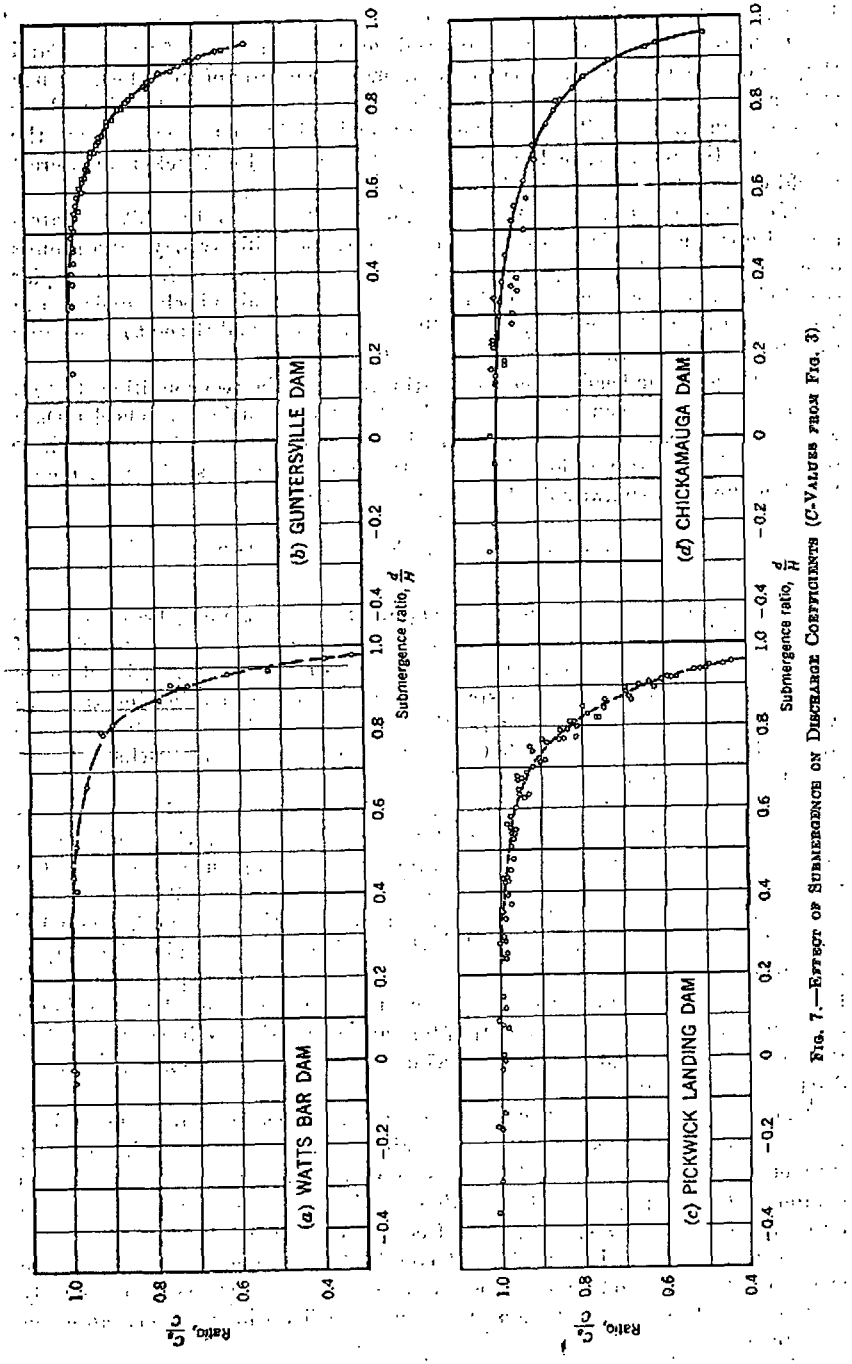


FIG. 7.—EFFECT OF SUBMERGENCE ON DISCHARGE COEFFICIENTS (C-VALUES FROM FIG. 3).

Calculation No: CDQ000020080007

In Fig. 8 the four curves of Fig. 7 are shown on a single plot. Although the maximum spread between curves is about 10%, this is to be expected considering the wide range of crest shapes used in the tests.

FREE-DISCHARGE COEFFICIENTS FOR FLOW OVER VERTICAL LIFT GATES

The Pickwick Landing vertical lift gates are representative of this type of gate, which has been used on several TVA projects. In Fig. 9(*a*) are shown details of the lower spillway gate leaf. For heads greater than 2 ft, this gate is essentially a sharp-crested weir 40 ft long and 20 ft high with piers 7.5 ft thick at each end of the gate. Air intakes were installed in the sides of the piers just below the top of the gate to ventilate the underside of the nappe.[6] Model tests were conducted with the 1/50-scale, 3-bay spillway model.

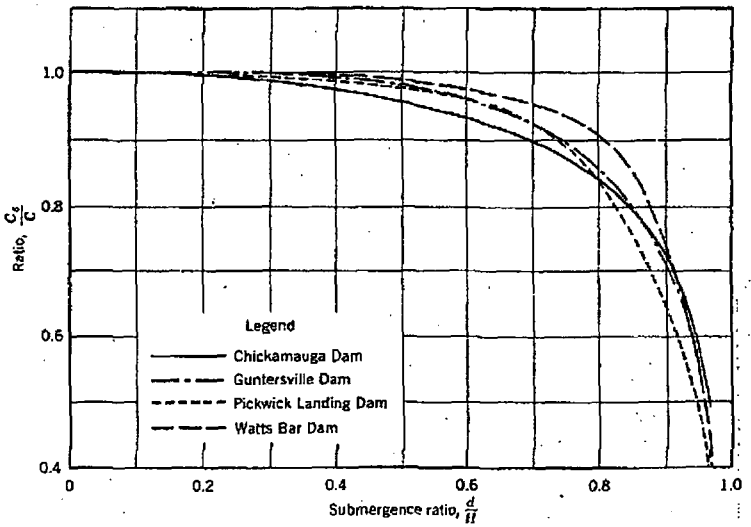


FIG. 8.—COMPARISON OF SUBMERGENCE EFFECTS FOR VARIOUS SPILLWAY CREST SHAPES

In Fig. 9(*b*) is shown the head-coefficient relationship for flow over the crest of the spillway gate. The coefficient, C, was computed from Eq. 1 using the top of the gate as crest elevation. The points define the head-coefficient relationship for heads between 3 ft and 28 ft. Each point was determined from the average of from 3 to 5 separate tests. A constant value of C equal to 3.428 is shown for heads in excess of 12 ft. For heads of from 12 ft to about 4 ft the model test curve shows a gradual rise in the coefficient, with an abrupt drop-off when the heads are approximately 4 ft and less. This curve takes the characteristic form for the coefficients of a sharp-crested weir, the rise and fall in the coefficient curve being due to the nappe clinging to the surface of the weir. This phenomenon is a function of the absolute head. Therefore, similarity between the model and prototype did not exist for prototype heads

[6] "Aeration of Spillways," by G. H. Hickox, *Transactions*, ASCE, Vol. 109, p. 537.

Attachment A5-5
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Calculation No: CDQ000020080007

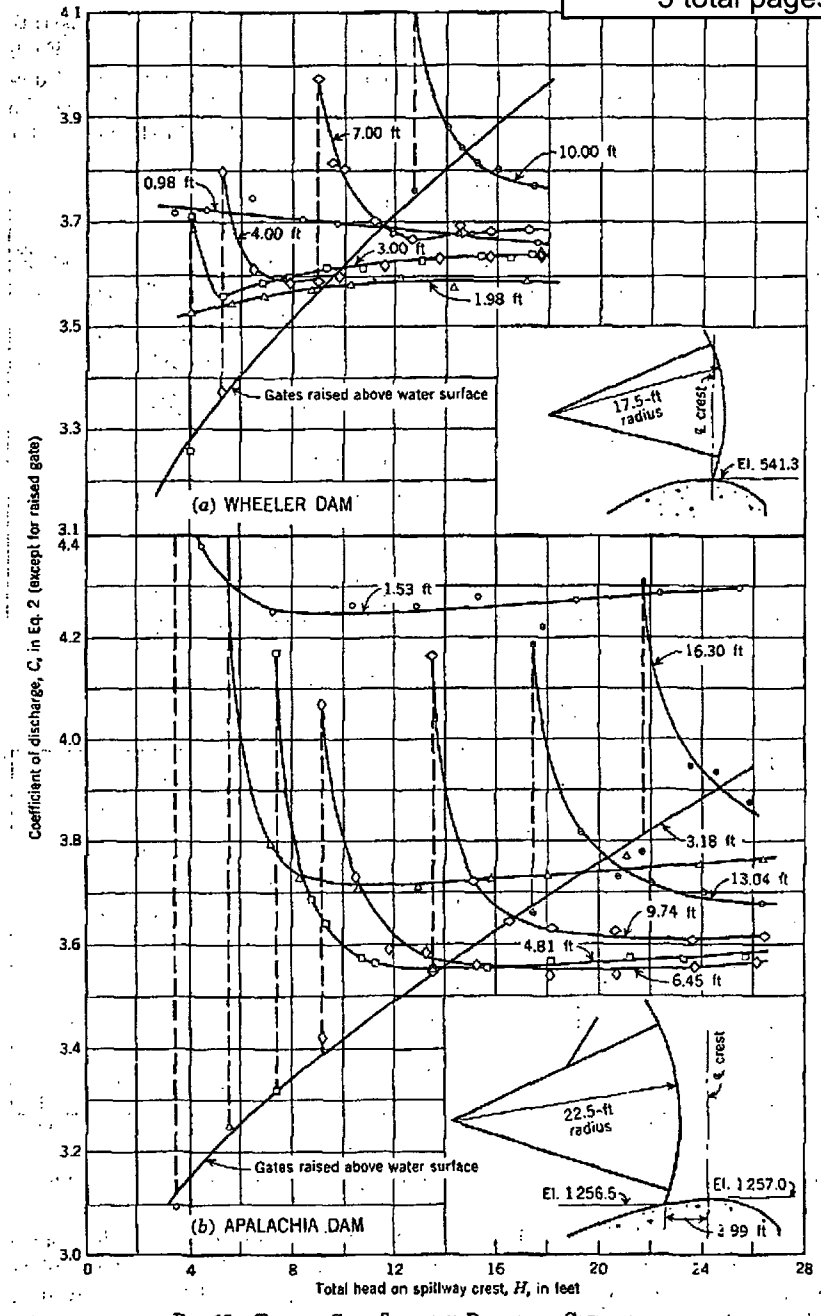


FIG. 12.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

discharge over the gate was thus increased with a consequent lowering of the headwater level.

The flow conditions of plunging nappe and flowing nappe, previously described, also occurred in this type of flow. In this case the change from one to the other is apparent in the data. The dashed line in Fig. 10 indicates the approximate location of the change. At these points the curves show a definite discontinuity in shape. The data of Fig. 10 can be reduced in coefficient form to the single-curve representation shown in Fig. 11. In this illustration, a constant value of C, equal to 3.428, was used in computing the ratio of C_s/C.

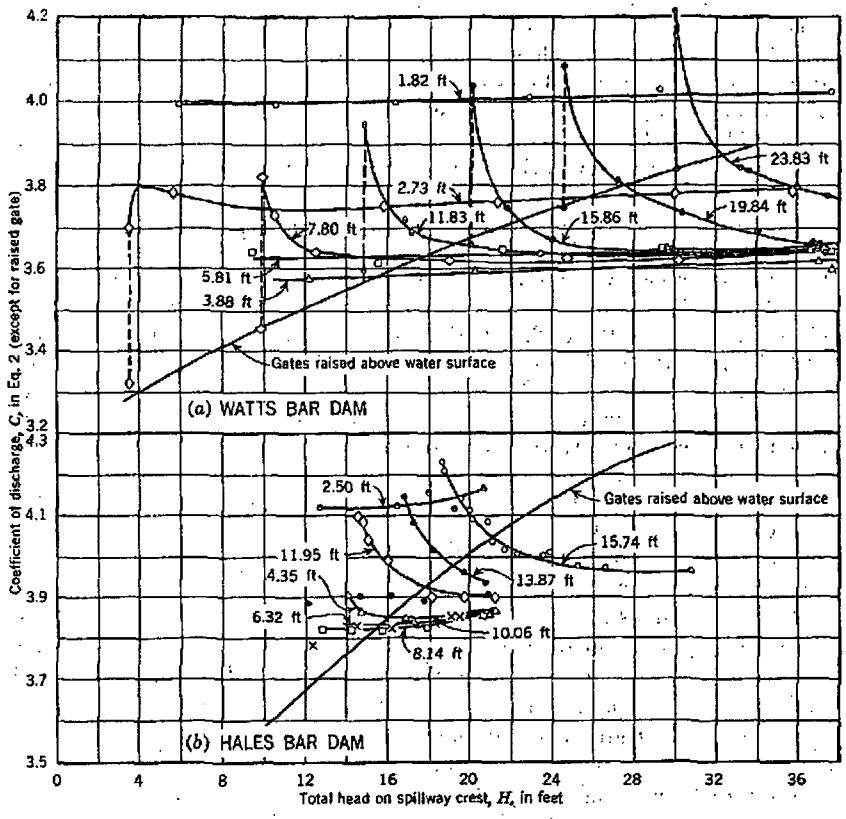


FIG. 13.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

DISCHARGE COEFFICIENTS FOR FLOW UNDER TAINTER GATES

The flow under Tainter gates mounted on curved crests is controlled by the geometry of three interrelated variables—the crest shape, the gate, and the gate setting. The major factors which influence the discharge relation-

Tennessee Valley Authority

Tainter Gate Ratings
Basic Model and Prototype Data

	MODEL					PROTOTYPE		
Project	Model Scale	No. of Spill-way Bays	Crest Length L	Approach Width W	Up-stream Depth P	Crest Elev.	Design Head H_o	Pier Nose Radius R
Apalachia	1:28.72	6	6.684	8.00	3.38	1257.0	23.0	3.00
Boone	1:50	5	3.480	(1)	(1)	1350.0	35.0	12.75(2) 11.25(3) 3.50(4)
Ft. Patrick Henry	1:15	1	2.333(5)	2.77(5)	2.29	1228.0	35.0	3.25
Hales Bar	1:34.76	6	6.908(6) 6.905(7)	7.94	0.921	616.0	18.0	3.00
Hiwassee	1:55	7	4.050	8.00	6.35	1503.5		3.00
Watts Bar	1:35	6	6.866	8.00	1.5	713.0	23.5	3.25
Wheeler	1:34.35	6	6.984	7.97	1.253	541.3	16.5	2.50

(1) Variable because approach was reproduced in model.

(2) Right end pier.

(3) Left end pier.

(4) Intermediate piers.

(5) Except as noted on data tabulations.

(6) Gates partially opened.

(7) Gates raised above water surface.

Definition of Symbols

- Q = Total discharge in cubic feet per second.
- D = Depth of flow above crest in feet.+
- D_1 = Depth, bottom of gate to water surface.*
- H = Total head above crest, including velocity head of approach in feet.*
- H_o = Design head for standard crest, including velocity head of approach, in feet.
- h = Velocity head of approach in feet.*
- C = Coefficient of discharge for any head.
- G.O. = Gate opening - vertical distance above spillway crest in feet.
- b = Shortest distance between spillway surface and gate lip in feet.*
- L = Length of spillway crest in feet.
- P = Depth of model approach channel, crest to river bed, in feet.+
- W = Width of model approach in feet.
- x = Horizontal distance from upstream face of dam in feet.*
- y = Vertical distance above spillway crest in feet.*

Discharge Equations

For flow under a gate:

$$Q = CL\ [H^{3/2} - (D_1 + h)^{3/2}] \qquad (A)$$

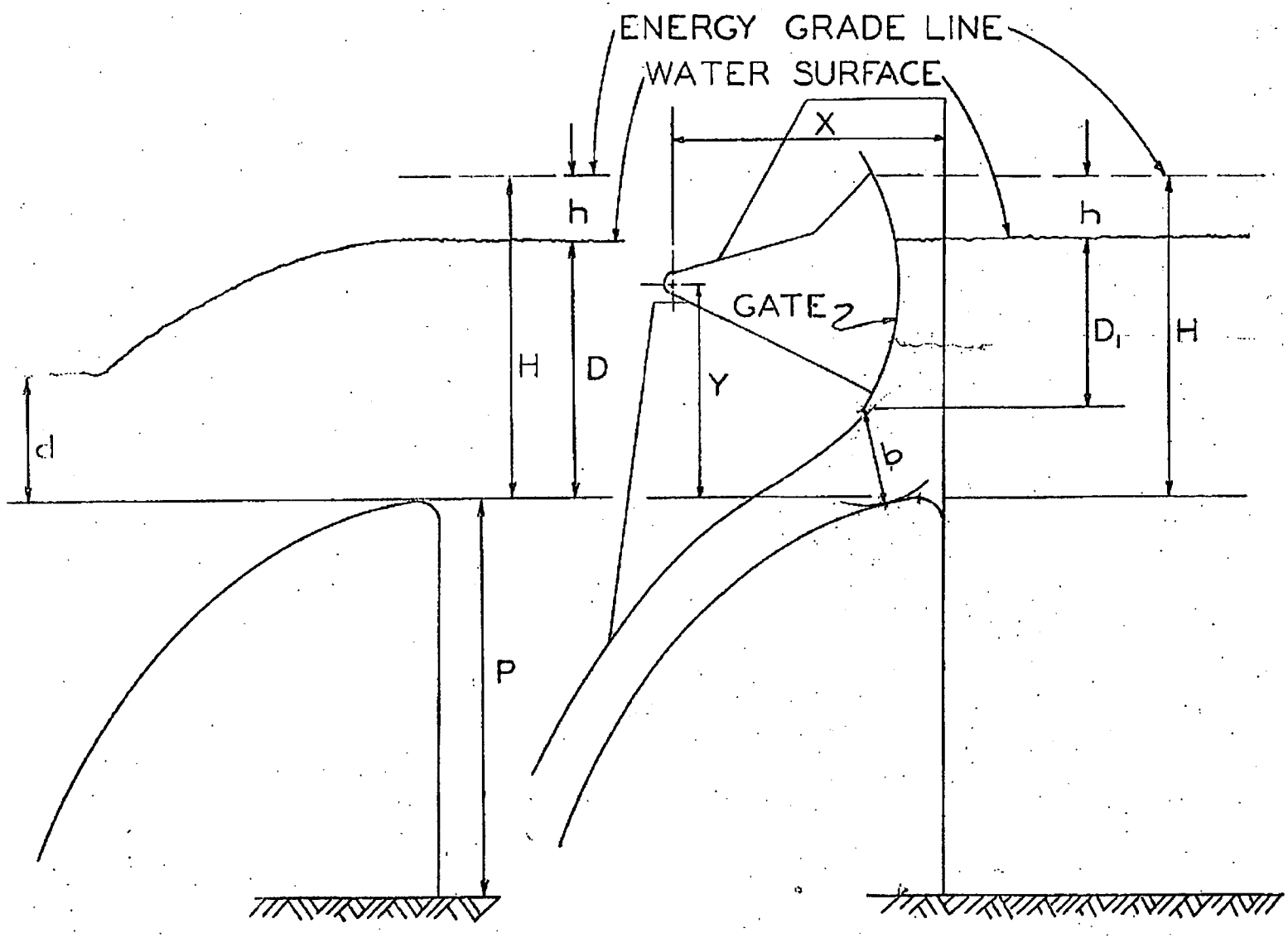
For flow over a spillway crest with the spillway gate raised above the water surface:

$$Q = CLH^{3/2} \qquad (B)$$

+See Figure 1(a) on page 4.
*See Figure 1(b) on page 4.

Attachment A6-3
from Ref. 28
5 total pages

Calculation No: CDQ000020080007



[a] FIGURE 1 [b]

Attachment A6-4
from Ref. 28
5 total pages

Calculation No: CDQ000020080007 26

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.052	0.168	0.803	0.000	1.82	5.88	5,819	3.99
	0.301	1.119	0.000		10.54	8,110	3.99
	0.463	1.411	0.000		16.20	10,230	3.99
	0.650	1.695	0.000		22.75	12,280	4.01
	0.831	1.932	0.000		29.08	14,000	4.03
	1.068	2,198	0.000		37.38	15,930	4.02
~~0.078~~	0.100	0.719	0.000	~~2.73~~	3.50	5,211	3.31+ ~~3.70~~ 4.96*
0.078	1.023	3.024	0.000	2.73	35.80	21,920	3.79
	0.608	2.278	0.000		21.28	16,510	3.76
	0.856	2.746	0.000		29.96	19,900	3.78
	0.451	1.932	0.000		15.78	14,000	3.75
	0.165	1.072	0.000		5.78	7,769	3.78
	0.299 0.127	1.523 1.025	0.000 0.000		10.46 4.44	11,040 7,428	3.72 3.30+ 4.34*
0.111	0.346	2.196	0.000	3.88	12.11	15,910	3.57
	0.576	2.962	0.000		20.16	21,470	3.59
	0.842	3.703	0.001		29.50	26,840	3.65
	1.074	4.161	0.001		37.62	30,160	3.61
	1.056	4.140	0.001		37.00	30,000	3.62
	~~0.183~~ 1.044	~~1.803~~ 4.149	0.001		~~36.48~~	~~13,070~~ 30,070	~~3.35+~~ 3.65
~~0.166~~	~~1.044~~	~~4.149~~	~~0.001~~	~~5.81~~	~~36.58~~	~~30,070~~	~~3.65~~
0.166	0.271	2.679	0.001	5.81	9.52	19,420	3.63
	1.068	6.182	0.001		37.42	44,800	3.64
	0.837	5.417	0.001		29.33	39,260	3.65
	0.616	4.552	0.001		21.60	32,990	3.65
	0.441	3.688	0.001		15.47	26,730	3.61
0.223	0.280	3.538	0.001	7.80	9.84	25,640	3.46+ 3.82*
	0.356	4.102	0.001		12.50	29,730	3.64
	0.540	5.436	0.002		18.97	39,400	3.62
	0.702	6.396	0.002		24.64	46,350	3.62
	0.858	7.189	0.002		30.10	52,100	3.62
	1.064	8.186	0.002		37.31	59,330	3.65

+Gate lip touching nappe C from Equation B.
*Gate lip touching nappe C from Equation A.

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.338	1.061	11.98	0.005	11.83	37.28	86,820	3.64
	0.854	10.49	0.005		30.06	76,020	3.64
	0.663	8.894	0.004		23.34	64,460	3.64
	0.484	7.141	0.003		17.04	51,750	3.68
	0.420	6.781	0.003		14.80	49,140	3.59+ 3.95*
	0.476	7.102	0.003		16.76	51,470	3.70
	1.050	11.94	0.005		36.92	86,530	3.65
0.453	0.616	10.82	0.006	15.86	21.77	78,410	3.74
	0.565	10.85	0.007		20.02	78,630	3.65+ 4.04*
	0.679	11.48	0.007		24.01	83,200	3.67
	0.840	13.33	0.008		29.68	96,600	3.65
	1.047	15.50	0.009		36.96	112,300	3.66
0.567	0.688	15.07	0.012	19.84	24.50	109,200	3.75+ 4.09*
	0.765	15.39	0.011		27.16	111,500	3.81
	0.854	16.46	0.012		30.31	119,300	3.73
	0.957	17.72	0.013		33.95	128,400	3.69
	1.035	18.60	0.013		36.68	134,800	3.67
0.681	0.833	20.71	0.019	23.83	29.82	150,100	3.84+ 4.21*
	0.937	20.81	0.018		33.42	150,800	3.84
	1.007	21.82	0.018		35.88	158,100	3.80
	1.048	22.36	0.019		37.34	162,000	3.78
	0.928	20.69	0.018		33.11	149,900	3.85

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Attachment A7
from Ref. 18
1 page

Calculation No: CDQ000020080007

The state of kinematic similarity can be maintained if, and only if, the corresponding force ratios remain constant. That is, if F_a and F_b are the net forces exerted on the fluid elements at A and B,

$$\frac{(F_a)_p}{(F_a)_m} = \frac{(F_b)_p}{(F_b)_m} \tag{11–3}$$

Each of these net forces may be thought of as an inertia force, mass × acceleration. It is made up of a number of different forces (those due to gravity,

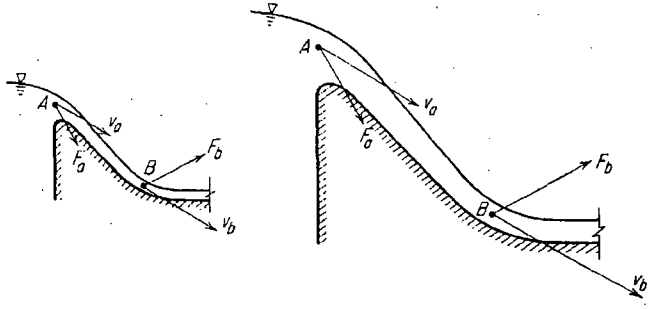


Figure 11-1. *Basic Model-Prototype Relationships*

viscosity, etc.), all of which vary in different ways with v, L, ρ, etc. If each of the ratios in Eq. (11–3) is to be kept constant at all points in the field of flow, then the various components of force must bear a constant ratio to one another. Now it can be shown (Prob. 11.1) that the Froude number is the ratio of inertia force to gravitational force, expressed in general dimensional form; similarly that the Reynolds, Weber, and Cauchy numbers are the ratios of the inertia force to viscous, capillary, and compression forces respectively. The final conclusion is the same as that already drawn from Eq. (11–1): that if a certain type of force is effective in a certain flow situation, the appropriate dimensionless number must be given the same value in the model as in the prototype.

Secondary Scale Ratios

The detailed interpretation of model measurements requires that scale ratios be available for translating model values of various quantities, e.g., velocity, discharge, etc., into the corresponding prototype values. Scales can be deduced for all physical quantities if scales are known for mass, length, time, and the physical properties of prototype and model fluids. It is convenient to introduce here the subscript r to indicate the ratio of prototype : model quantity, e.g., if model lengths are one-tenth those of the protoype, then $L_p/L_m = L_r = 10$, the subscripts p and m indicating prototype and model as before. Now it is always true that the mass ratio $M_r = \rho_r L_r^3$, so we have

scale ratios for mass and length. The time scale T_r is deduced indirectly from the relationship between velocity scale and length scale dictated by the fact that the appropriate dimensionless number, e.g., the Froude number, must be kept constant.

In open channel flow the presence of a free surface means that the Froude number Fr is always significant, indeed dominant. The secondary scale ratios based on the constancy of Fr and its corollary

$$v_r = L_r^{1/2} \tag{11–4}$$

will therefore be applicable, although they may be modified in some case by the action of influences other than gravity. A complete list of scale ratios is therefore as follows

$\frac{V_p}{V_m}$ & $\frac{H_p}{H_m}$ →

Mass	M_r	$= \rho_r L_r^3$
Length	L_r	$= L_r$
Velocity	v_r	$= L_r^{1/2}$
Time	$T_r = L_r v_r^{-1}$	$= L_r^{1/2}$

$\frac{Q_p}{Q_m}$ →

Discharge	$Q_r = v_r L_r^2$	$= L_r^{2\frac{1}{2}}$
Force	$F_r = M_r L_r T_r^{-2}$	$= \rho_r L_r^3$
Pressure	$p_r = F_r L_r^{-2}$	$= \rho_r L_r$

(11–5)

as the reader can verify (Prob. 11.2).

The Influence of Forces Other Than Gravity

Compressibility effects are never significant in open channel flow models. Surface tension effects are appreciable only when radii of curvature of the liquid surface, and the distances from solid boundaries, are very small. They will therefore be negligible in all real prototype situations, and care must be taken to keep them negligible in model situations. This is accomplished by keeping model water depths no less than an inch or two, and similarly for channel widths. Beyond the taking of this precaution, capillary effects do not warrant any further attention.

Viscosity is much more important, and exerts its influence in many different situations. The term *scale effect* can be introduced here; it is the name given to the slight distortions introduced by forces—for example, viscosity—other than the dominant one, such as gravity. Such effects are often slight without being altogether negligible. For example, the flow over a spillway will encounter some slight viscous resistance down the face of the spillway, although resistance will be negligible at the crest itself, where the discharge-head relation is determined.

The only perfect way of dealing with the effect of viscosity is to keep both

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Attachment A8-1
5 total pages

SHEET 1 OF 5

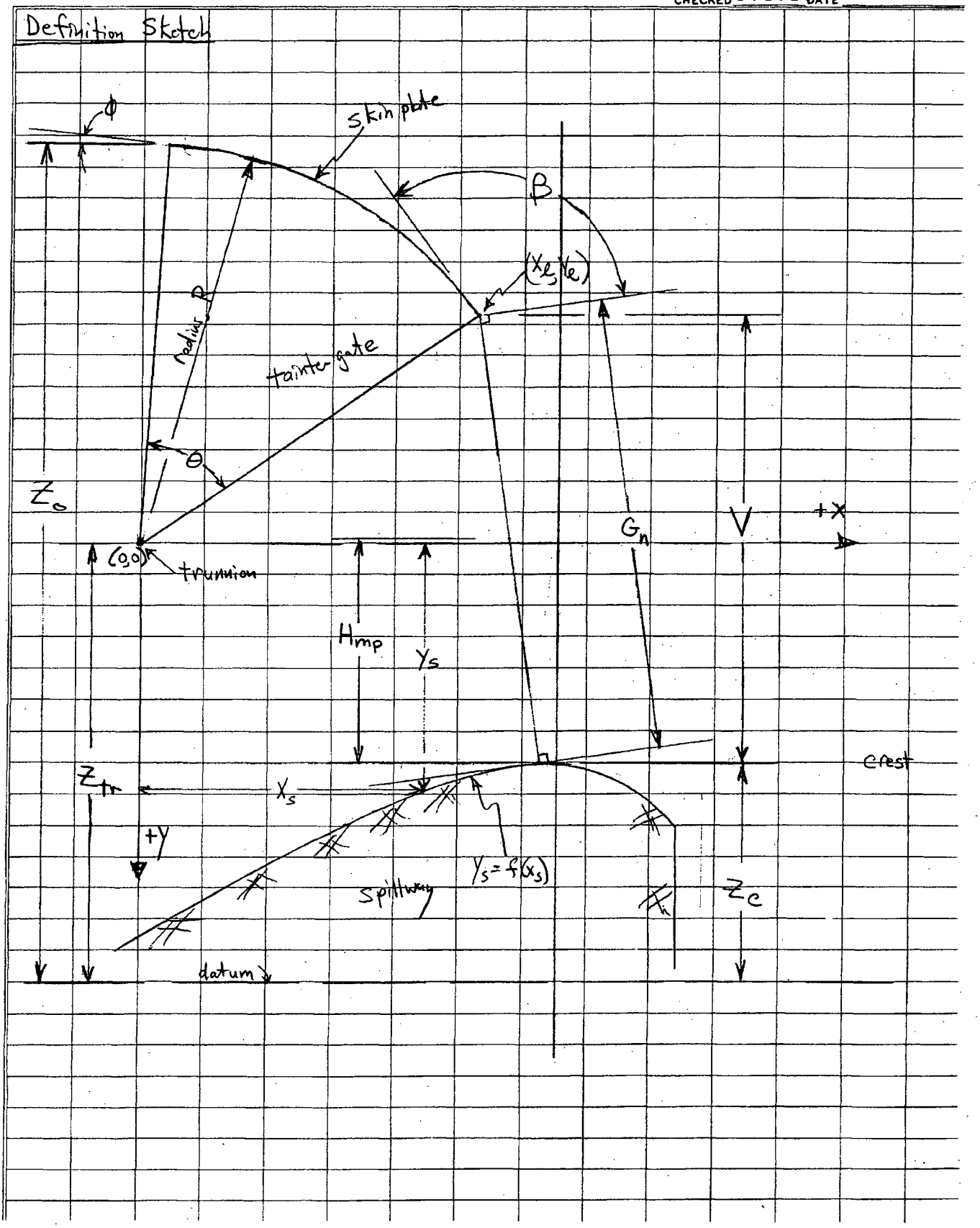
Spillway Discharge Calculations Geometry for Flow Under an Open Tainter Gate

Calculation No: CDQ000020080007

COMPUTED GAS DATE 8/11/2008

CHECKED J.C.T DATE

Definition Sketch



Calculation No: CDQ000020080007

Spillway Gate Geometry

COMPUTED GAS DATE 8/11/2008

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Variables

V = Vertical distance between the bottom of the open gate and the crest

Z_c = crest elevation

Z_{tr} = trunnion elevation

Z_o = overflow elevation

R = radius of the tainter gate

G_n = minimum distance between the gate lip and the crest

H_{mp} = vertical distance between the mid-point of G_n and the crest

β = angle formed by the tangent to the gate lip and the tangent to the crest curve at the nearest point of the crest curve

θ = angle of the sector of a circle formed by two lines connecting the trunnion axis to the bottom and top of the radial gate.

X, Y = Coordinates relative to trunnion axis (Y positive downward)

X_s, Y_s = Coordinates of spillway surface defined by $Y_s = f(X_s)$

X_l, Y_l = Coordinates of the gate lip relative to trunnion axis

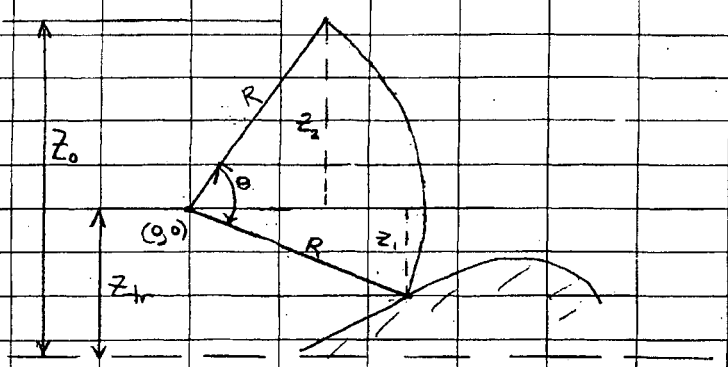
notes: Y positive downward for all coordinates
all coordinates relative to trunnion axis

ϕ = angle formed by the tangent to the gate top and horizontal

Angle, θ

$$\theta = \sin^{-1}\left(\frac{Z_2}{R}\right) + \sin^{-1}\left(\frac{Z_1}{R}\right)$$

Z_1 & Z_2 are determined from drawings



Closed Gate

Calculation No: CDQ000020080007

Spillway Gate Geometry

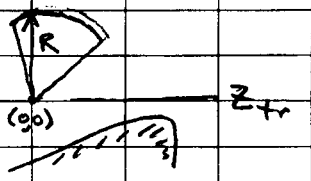
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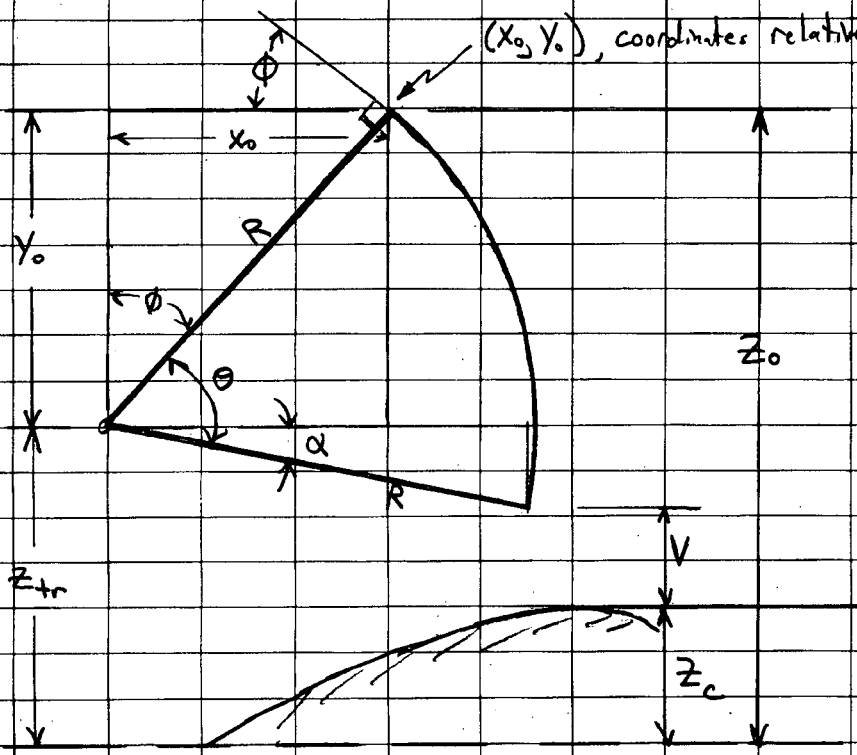
Overflow Elevation, Z_o and Angle, Φ

For a gate opened so far that its upper edge is downstream of the trunnion:

$$Z_o = Z_{tr} + R$$



For a gate opened less:



$$\alpha = \tan^{-1}\left(\frac{Z_{tr} - (Z_{cr} + V)}{\sqrt{R^2 - (Z_{tr} - Z_{cr} - V)^2}}\right)$$

V given

$$\boxed{Z_o = Z_{tr} + R\sin(\theta - \alpha)}$$

and $$\boxed{\Phi = \tan^{-1}\left(\frac{X_o}{Y_o}\right)}$$ with $$\begin{cases} Y_o = Z_o - Z_{tr} \\ X_o = R\cos(\theta - \alpha) \end{cases}$$

Calculation No: CDQ000020080007

Spillway Gate Geometry

COMPUTED GAS DATE 8/11/2008

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Gate Opening, G_n

Gate lip coordinates: $\begin{cases} Y_\ell = Z_{tr} - Z_c - V \\ X_\ell = \sqrt{R^2 - Y_\ell^2} \end{cases}$

Distance between gate lip and any point on spillway surface is

$$\ell = \sqrt{(X_s - X_\ell)^2 + (Y_s - Y_\ell)^2} \equiv \sqrt{(X_s - X_\ell)^2 + [f(X_s) - Y_\ell]^2}$$

G_n is the minimum distance. ℓ is minimum when $\frac{d\ell}{dX_s} = 0$

$$\frac{d\ell}{dX_s} = \frac{1}{2}\left\{(X_{s_n} - X_\ell)^2 + [f(X_{s_n}) - Y_\ell]^2\right\}^{-1/2} \cdot \left\{2(X_{s_n} - X_\ell) + 2[f(X_{s_n}) - Y_\ell]\frac{df(X_{s_n})}{dX_s}\right\} = 0$$

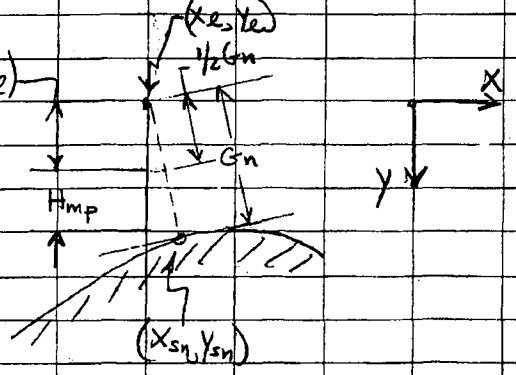
$$\Rightarrow 0 = \frac{(X_{s_n} - X_\ell) + [f(X_{s_n}) - Y_\ell]\frac{df(X_{s_n})}{dX_s}}{\ell_{minimum}}$$

where $X_{s_n} = X_s$ for minimum ℓ, $\ell_{minimum} \equiv G_n$.

Solve: $X_{s_n} - X_\ell + [f(X_{s_n}) - Y_\ell]\frac{df(X_{s_n})}{dX_s} = 0$ for X_{s_n}

Then: $Y_{s_n} = f(X_{s_n})$ and $\boxed{G_n = \sqrt{(X_{s_n} - X_\ell)^2 + (Y_{s_n} - Y_\ell)^2}}$

Mid-Point Head, H_{mp}



$H_{mp} = Z_{tr} - Z_c - Y_\ell - \frac{1}{2}(Y_{s_n} - Y_\ell)$

$\Rightarrow \boxed{H_{mp} = V - \frac{1}{2}(Y_{s_n} - Y_\ell)}$

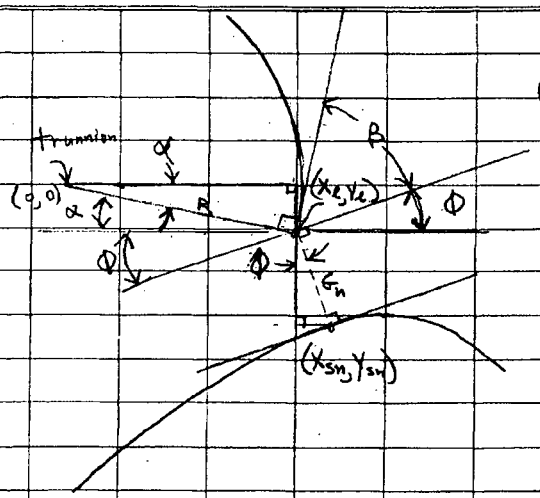
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Spillway Gate Geometry

COMPUTED GAS DATE

CHECKED J.C.T DATE

Angle, β



$$\beta + \frac{\pi}{2} + \alpha + \Phi = \pi$$

$$\beta + \Phi = \frac{\pi}{2} - \alpha$$

$$\beta = \frac{\pi}{2} - \alpha - \Phi$$

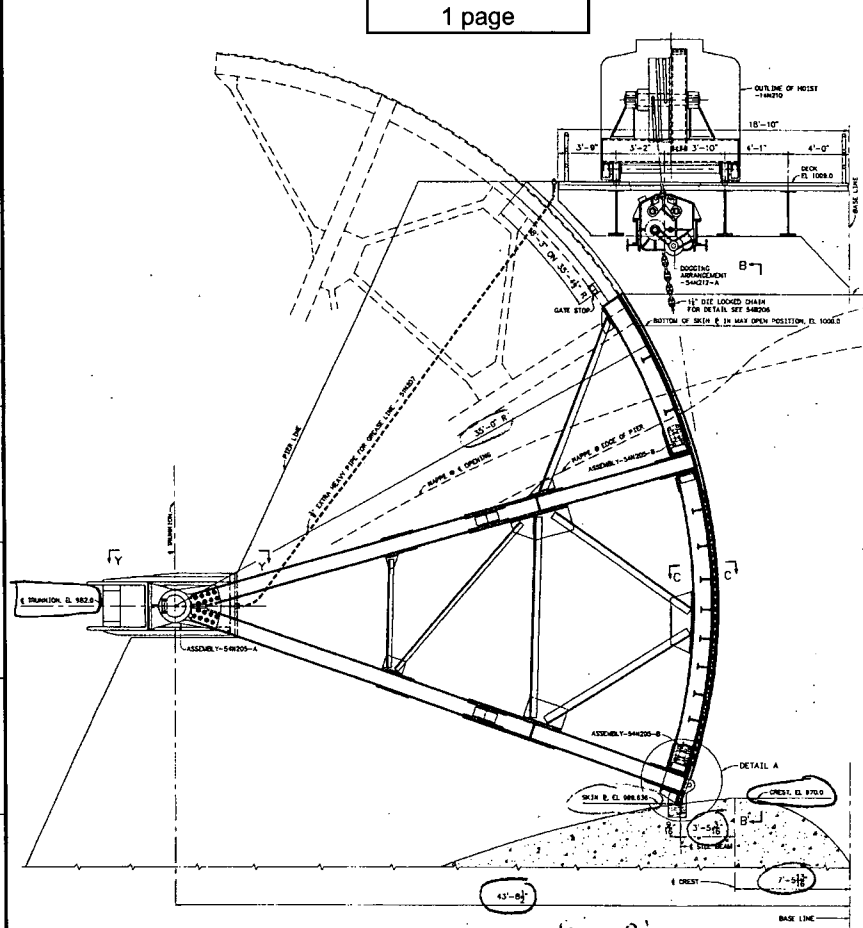
$$\alpha = \tan^{-1}\left(\frac{Y_e}{X_e}\right)$$

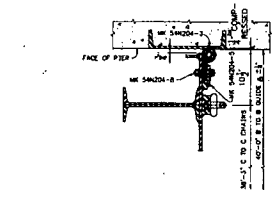
$$\Phi = \tan^{-1}\left(\frac{X_{sn} - X_e}{Y_{sn} - Y_e}\right)$$

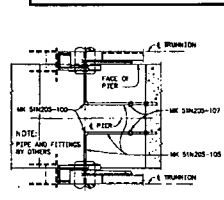
$$\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{Y_e}{X_e}\right) - \tan^{-1}\left(\frac{X_{sn} - X_e}{Y_{sn} - Y_e}\right)$$

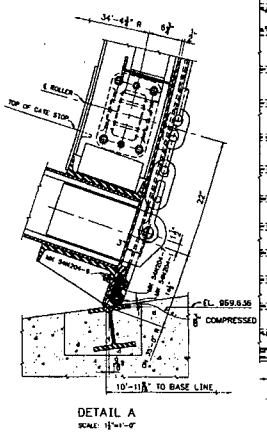
Attachment A9
Ref. 23
1 page

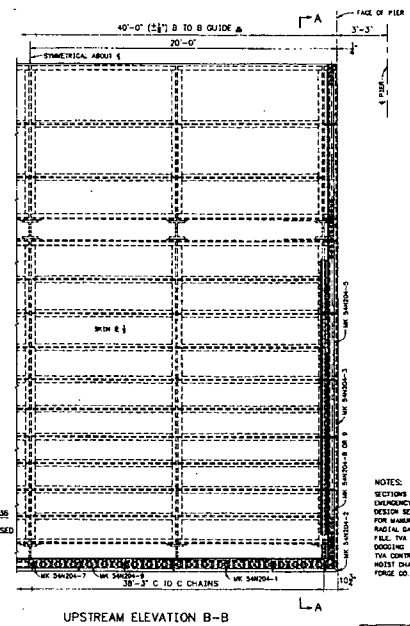
Calculation No: CDQ000020080007











NOTES:
SECTIONS USED ARE THOSE AVAILABLE UNDER NATIONAL EMERGENCY ACT OF FEB 1, 1942. FOR ORIGINAL DESIGN SECTIONS, SEE CHEROKEE PROJECT.
FOR MANUFACTURER'S DETAILS OF:
RADIAL GATES, REFER TO LAKESIDE BRIDGE & STEEL CO. FILE, TVA CONTRACT NO. TV-88717.
DOGGING UNITS, REFER TO PHILLIPS & DAVIES, INC. FILE, TVA CONTRACT NO. TV-88784.
HOIST CHAINS, REFER TO BALDT ANCHOR CHAIN & FORGE CO. FILE, TVA CONTRACT NO. K-42-42038.

$\Delta ELEV$ TRUNION TO CREST = 982' - 970' = 12'

3'- 5 3/16" + 7'- 5 3/16" = 10' 11" = 10.917'

ELECTRONICALLY RESTORED

SCALE: 1/8"=1'-0" EXCEPT AS NOTED

SPILLWAY

GATES
GENERAL ARRANGEMENT

DESIGNED BY C.D.W. DRAWN BY H.J.C. CHECKED BY W.L.M. SUBMITTED BY APPROVED BY TRACED BY

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | DATE 2-27-42 | 20 | M | 54W200 | R 4

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES: (54N200 R3)

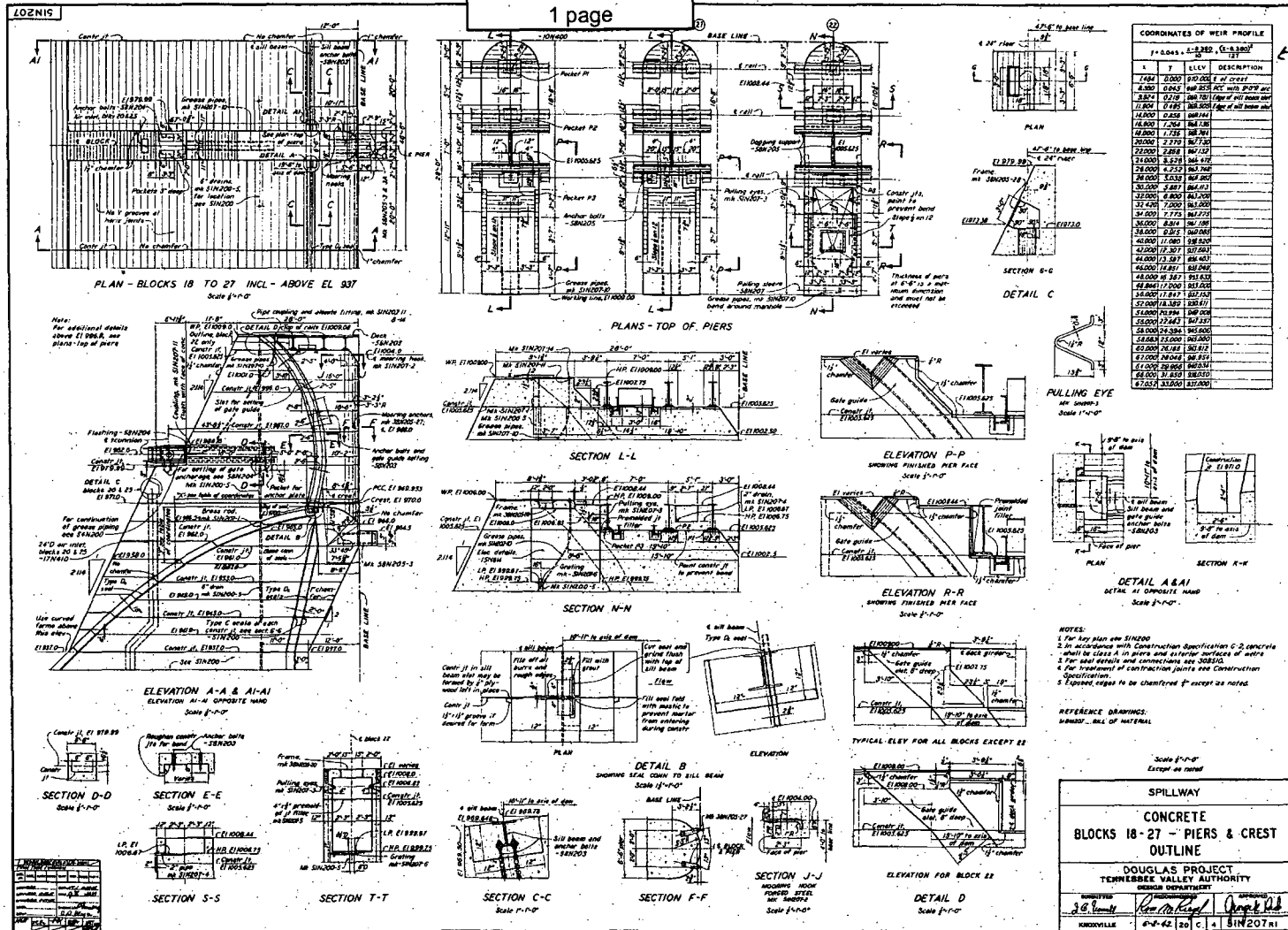
TASK COMPLETED BY | REV NO

PLOT FACTOR: 32
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment A10
Ref. 22
1 page

Calculation No: CDQ000020080007



COORDINATES OF WEIR PROFILE			
$y = 0.045 + \frac{x-9.380}{3} + \frac{(x-9.380)^2}{27}$			
x	y	ELEV	DESCRIPTION
7.484	0.000	910.000	℄ of crest
8.380	0.045	910.045	PC with 9'0"R arc
9.874	0.218	910.218	Edge of sill beam slot
11.804	0.485	910.500	Edge of sill beam slot
14.000	0.858	910.841	
16.000	1.264	911.185	
18.000	1.735	911.591	
20.000	2.270	912.126	
22.000	2.868	912.722	
24.000	3.528	913.382	
26.000	4.253	914.107	
28.000	5.038	914.892	
30.000	5.881	915.735	
32.000	6.800	916.654	
34.000	7.800	917.654	
36.000	8.814	918.668	
38.000	9.845	919.699	
40.000	11.080	920.934	
42.000	12.307	922.161	
44.000	13.527	923.381	
46.000	14.861	924.715	
48.000	16.387	926.241	
48.846	17.000	926.854	
50.000	17.847	927.701	
52.000	18.389	928.243	
54.000	20.394	929.248	
56.000	22.643	931.497	
58.000	24.384	933.238	
58.663	25.000	933.854	
60.000	26.188	935.042	
62.000	28.046	936.900	
64.000	29.966	938.820	
66.000	31.858	940.712	
67.052	33.000	941.854	

Attachment A11
1 page

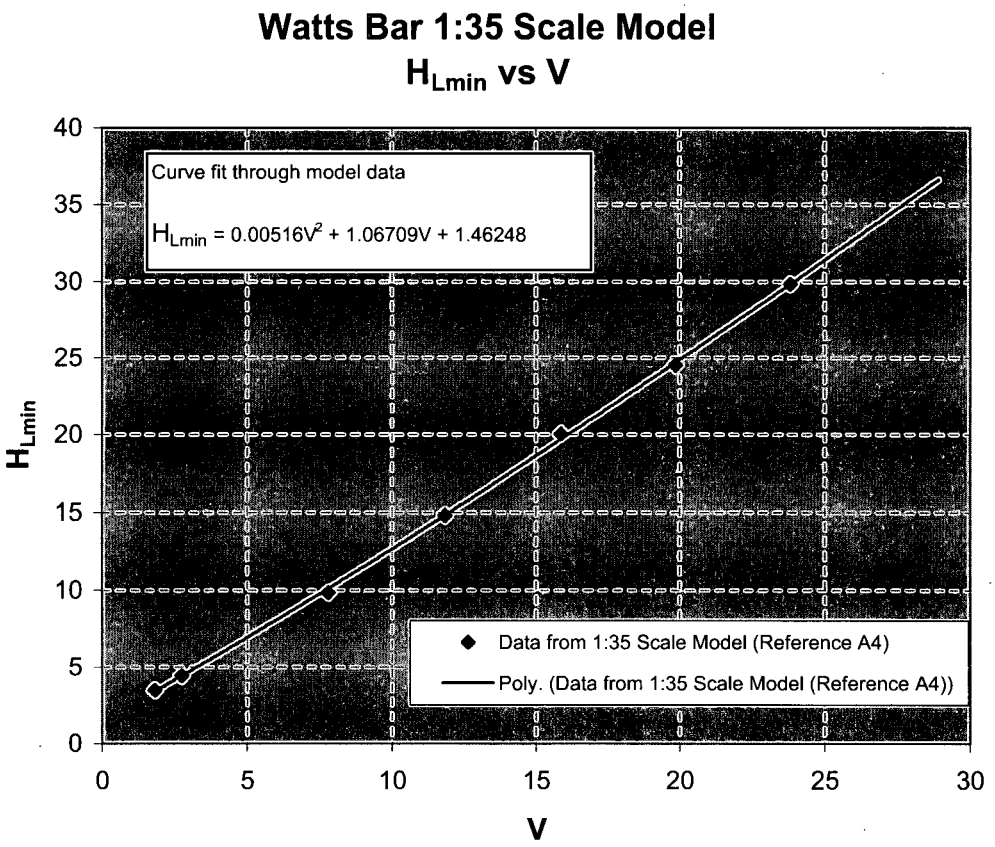
Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker: J.C.T.

Watts Bar Project
Tainter Gates Partially Opened
Data from 1:35 scale model (Reference A4)
EQUIVALENT PROTOTYPE

V	H_{Lmin} (data)	H_{Lmin} (fit)
feet	feet	feet
1.82	3.5	3.42
2.73	4.44	4.41
7.80	9.84	10.10
11.83	14.8	14.81
15.86	20.02	19.68
19.84	24.5	24.66
23.83	29.82	29.82
29.371		**37.26** extrapolated using polynomial shown on plot

Note: These data are also applicable to Douglas Dam



Attachment A12-1
2 total pages

Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker: J.C.T.

Douglas Dam
Tainter Gates Raised Above the Water Surface

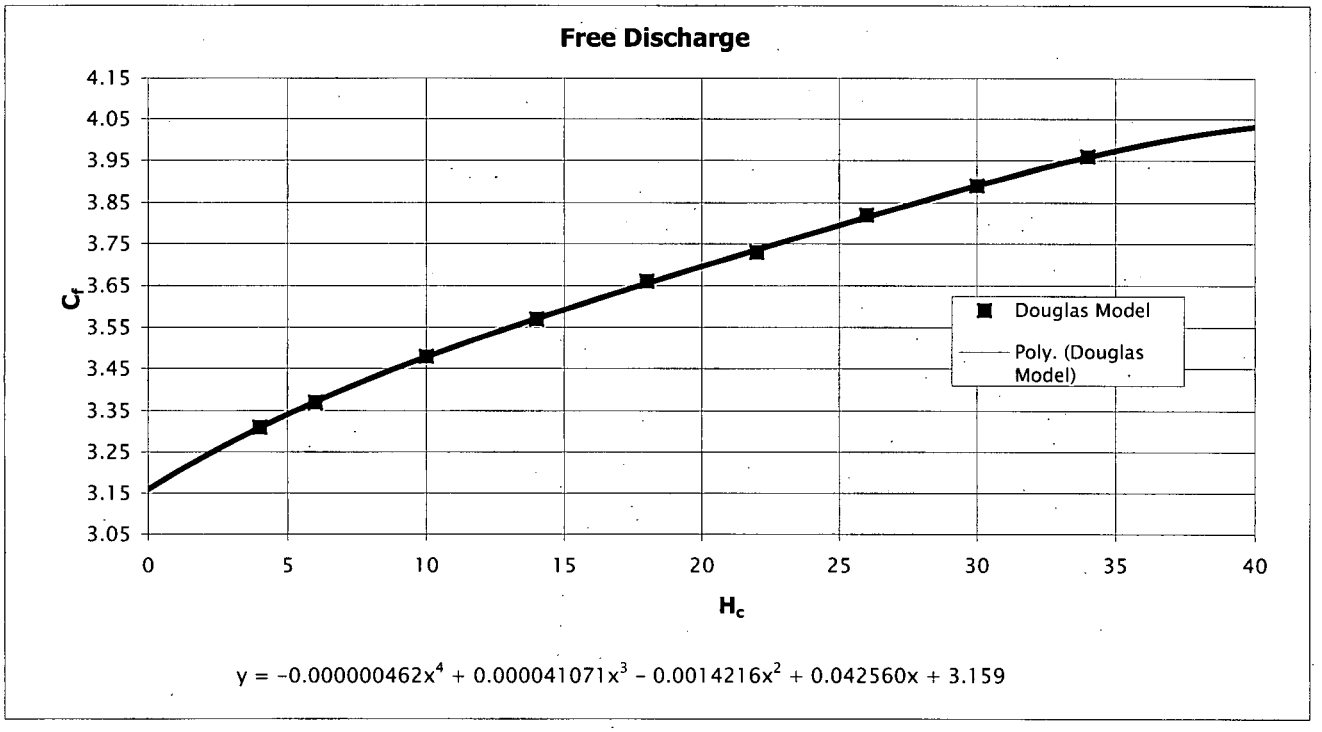
See Reference A3, Attachment A5-3

Scaled data from Fig. 3 from above reference (plotted points on this figure are on the following page)

H_c, ft	C_f
4.00	3.31
6.00	3.37
10.00	3.48
14.00	3.57
18.00	3.66
22.00	3.73
26.00	3.82
30.00	3.89
34.00	3.96

Curve fit using 4th-order polynomial (see plot)

H_c, ft	C_f from polynomial
0.00	3.16
0.25	3.17
0.50	3.18
0.75	3.19
1.00	3.20
2.00	3.24
3.00	3.27
4.00	3.31
6.00	3.37
8.00	3.43
10.00	3.48
12.63	3.54
15.50	3.60
20.96	3.71
24.50	3.79
29.53	3.88
33.23	3.95
37.00	4.00
39.00	4.02
40.00	4.03



Attachment A12-2
from Ref. 20
2 total pages

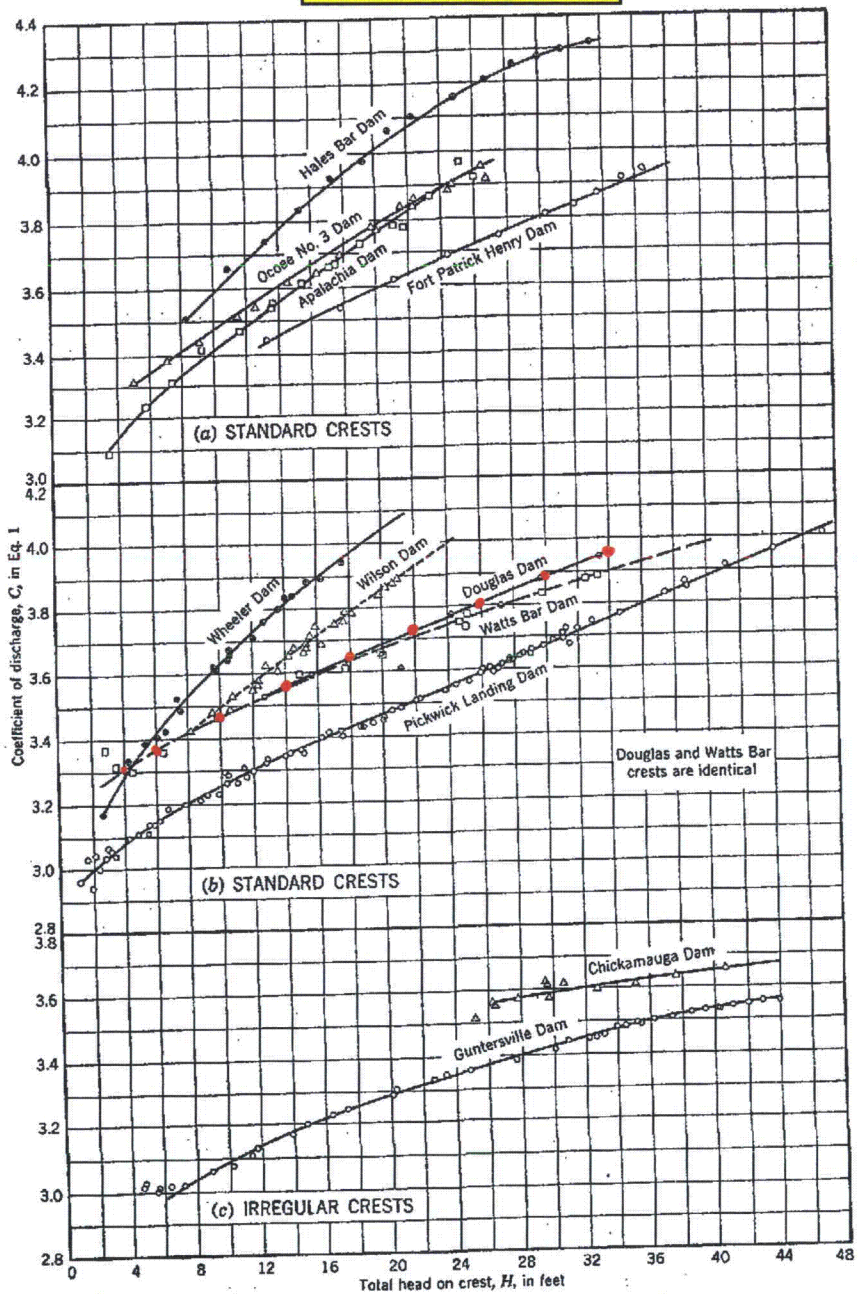


FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

Calculation No: CDQ000020080007

The accuracy of the data is evidenced by the plotting of the data points in Fig. 3. Except in some cases at low heads, the deviation of any plotted point from the coefficient curve does not exceed 0.5%.

Standard Crests.—It has been shown by various authors that the discharge coefficients for all standard crests can be related to each other and that, conversely, the coefficients to be used for a new design can be taken from previous test data.[2,3,4,5] Unfortunately, in most crest designs, due to other design considerations, it is necessary that the shape be varied from the standard form. Nevertheless, satisfactory coefficients can be obtained as sufficient data are now available on a range of crest shapes. By comparison of crest shapes designers may select a coefficient for any particular crest.

Dimensionless plotting provides a means for comparison of crest shapes. This method is used in Fig. 4 on which seven TVA crests which closely approximate standard crests are shown by the solid lines, with the dashed line representing a standard crest shape.[2] The horizontal coordinate, x, and the vertical coordinate, y, of the crest curve have been divided by the design head, H_o.

TABLE 1.—DESIGN DATA FOR ELEVEN MODELS OF TVA SPILLWAYS

Project	Model scale	Design head, H_o, in feet	Upstream depth, P, in feet	$\frac{H_o}{P}$	Pier nose radius, in feet
Hales Bar	1:34.76	18	32	0.56	3.00
Ocoee No. 3	1:28.72	23	67	0.35	3.00
Apalachia	1:28.72	23	97	0.24	3.00
Fort Patrick Henry	1:50	35	43	0.81	3.25
Wheeler	1:34.35	16.5	43	0.38	2.50
Wilson	1:39.4	19	75	0.25	4.00
Douglas	1:35	23.5	133	0.18	3.25
Watts Bar	1:35	23.5	52	0.45	3.25
Pickwick Landing	1:50	31.5	32	0.98	3.75
Chickamauga	1:50		20		4.00
Guntersville	1:50		18		4.00

The design head was determined by fitting the real and standard curves at the crest point ($x = 0$) and at the intersection of the curve with the upstream vertical face. These design-head values are presented in Table 1. The design-head discharge coefficients (C_o) determined from Fig. 3 are shown in Fig. 4.

The TVA crests all fairly closely approximate the standard curve from the upstream spillway face to a point somewhere downstream from the crest which was determined by the position of the gate seal. Below this latter point, the crest shape was modified to fit the trajectory of a jet issuing from under the gate when set at a small opening. The upstream face for a standard crest is vertical. The upstream face of the TVA crests, as shown in Fig. 4, deviates from the vertical. Other experimenters have established the fact that the shape of the upstream face generally has little influence on the discharge coefficient.[3]

[2] "Final Reports of Boulder Canyon Project," *Bulletin No. 3*, Part VI, Hydraulic Investigations, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1947.

[4] "Engineering Hydraulics," edited by Hunter Rouse, John Wiley & Sons, Inc., New York, N. Y., 1950.

[5] "Discharge Coefficients for Irregular Overfall Spillways," by J. N. Bradley, *Engineering Monograph No. 9*, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1952.

Attachment A13-1

Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker:

Determination of C_g From Model Data

Watts Bar Project, Tainter Gates Partially Opened
Data from 1:35 scale model as published in Reference A4
"Tainter Gate Rating Data Determined from Eight TVA Model Studies," Norris, Tennessee, March 1962

Model Scale = 35 g = 32.2 ft/s2

L_{model} = 6.866 ft Attachment A7-1

$L_{prototype}$ = 240.31 ft $35*L_{model}$

Definition: $C_q = Q / \{G_n*L*sqrt[2*g*(H_c-H_{mp})]\}$

	Model Test Data In Prototype Dimensions			Geometry			
	V	H_c	Q	G_n	H_{mp}	C_q	C_q Line
	ft	ft	cfs	ft	ft		
$H_c=H_{Lmin}$	7.80	9.84	25640	7.865	3.881	0.692	0.692
	7.80	12.50	29730	7.865	3.881	0.668	0.668
	7.80	18.97	39400	7.865	3.881	0.669	0.669
	7.80	24.64	46350	7.865	3.881	0.671	0.671
	7.80	30.10	52100	7.865	3.881	0.671	0.671
	7.80	37.31	59330	7.865	3.881	0.677	0.671
	7.80	60.00					0.671 (1)
$H_c=H_{Lmin}$	11.83	14.81	49140	11.868	5.906	0.720	0.720
	11.83	16.76	51470	11.868	5.906	0.683	0.683
	11.83	17.04	51750	11.868	5.906	0.678	0.678
	11.83	23.34	64460	11.868	5.906	0.675	0.675
	11.83	30.06	76020	11.868	5.906	0.676	0.676
	11.83	36.92	86530	11.868	5.906	0.679	0.678
	11.83	37.28	86820	11.868	5.906	0.677	0.678
	11.83	60.00					0.678 (1)
$H_c=H_{Lmin}$	15.86	20.02	78630	15.904	7.921	0.737	0.737
	15.86	21.77	78410	15.904	7.921	0.687	0.687
	15.86	24.01	83200	15.904	7.921	0.676	0.676
	15.86	29.68	96600	15.904	7.921	0.675	0.675
	15.86	36.96	112300	15.904	7.921	0.679	0.680
	15.86	60					0.680 (1)
$H_c=H_{Lmin}$	19.84	24.50	109200	19.919	9.906	0.744	0.744
	19.84	27.16	111500	19.919	9.906	0.699	0.699
	19.84	30.31	119300	19.919	9.906	0.688	0.688
	19.84	33.95	128400	19.919	9.906	0.682	0.682
	19.84	36.68	134800	19.919	9.906	0.678	0.678
	19.84	60					0.678 (1)
$H_c=H_{Lmin}$	23.83	29.82	150100	23.994	11.892	0.766	0.766
	23.83	33.11	149900	23.994	11.892	0.703	0.703
	23.83	33.42	150800	23.994	11.892	0.702	0.702
	23.83	35.88	158100	23.994	11.892	0.698	0.698
	23.83	37.34	162000	23.994	11.892	0.694	0.694
	23.83	40					0.690 (1)
	23.83	60					0.690 (1)
$H_c=H_{Lmin}$	29.37	37.26	218910	29.783	14.588	0.800	0.800
	29.37	41					0.718 (1)
	29.37	46					0.707 (1)
	29.37	60					0.707 (1)

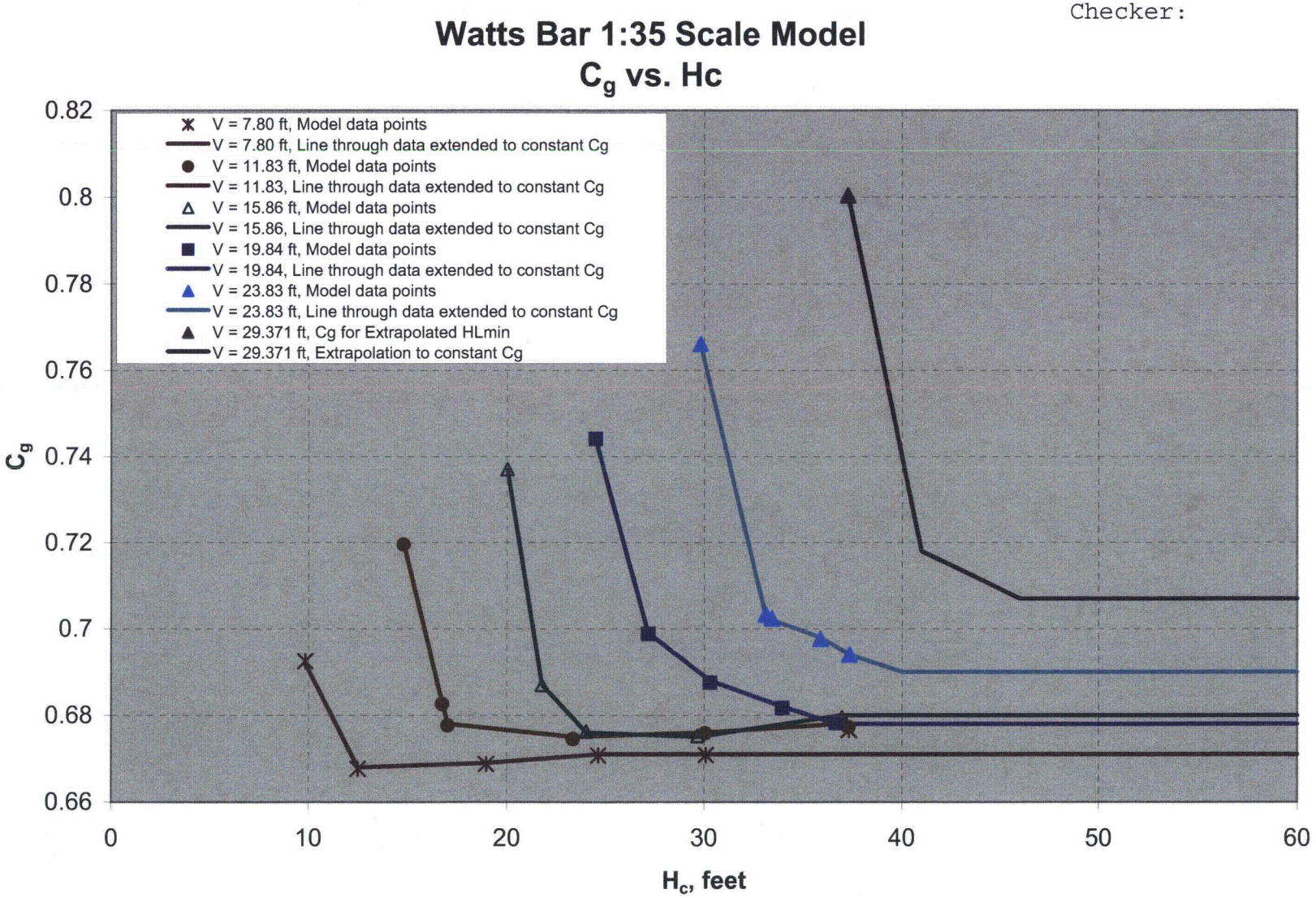
These values have been extrapolated in order to develop a curve which correlates to the model test data. The curve and its correspondence to model data curves can be seen on the following page.

(1) Value of Cg is estimated; no model data, so no value for Q; geometrical parameters not needed

Attachment A13-2

Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker:

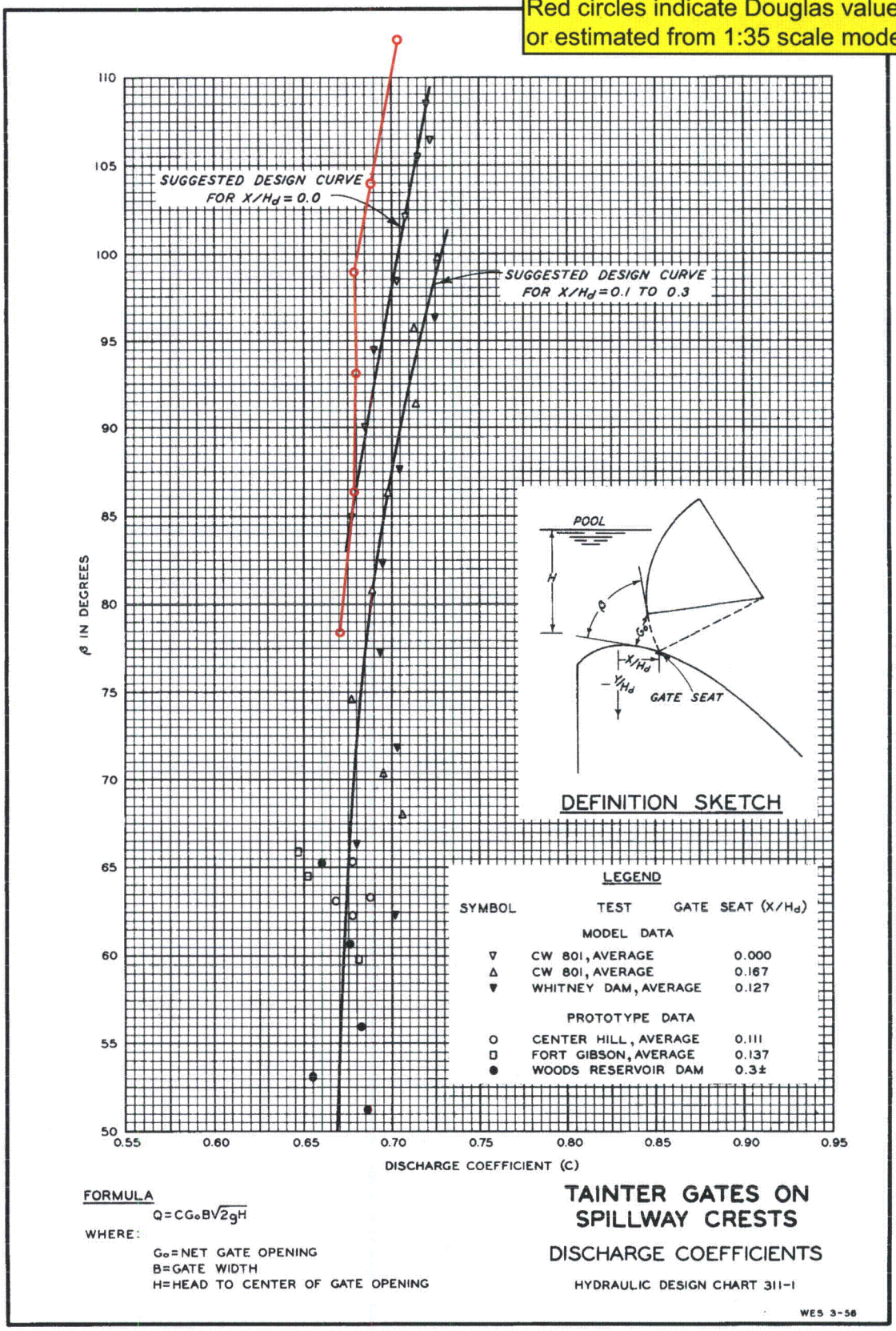


Preparer: S.E.M.
Checker: J.C.T.

Calculation No: CDQ000020080007

Attachment A13-3
Reference 4

Red circles indicate Douglas values determined or estimated from 1:35 scale model data



FORMULA

$Q = CG_oB\sqrt{2gH}$

WHERE:

G_o = NET GATE OPENING
B = GATE WIDTH
H = HEAD TO CENTER OF GATE OPENING

TAINTER GATES ON SPILLWAY CRESTS

DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 311-1

WES 3-56

DAM RATING CURVES - DOUGLAS

SUBJECT OVERFLOW PARAMETERS - BEFORE FAILURE PI

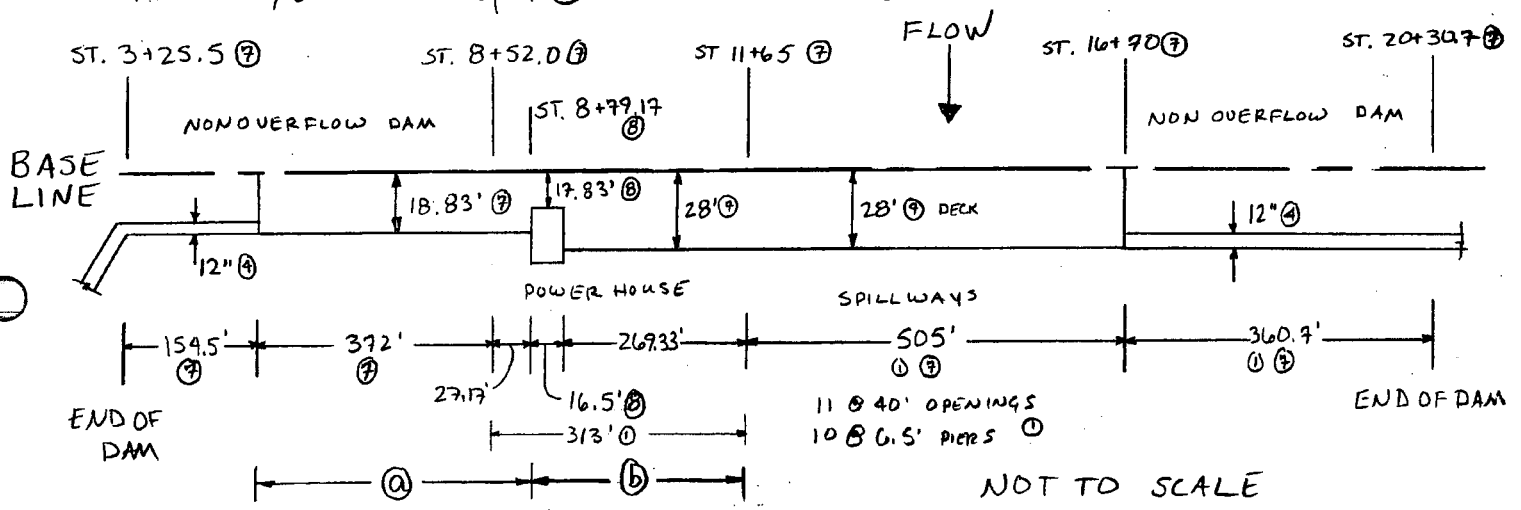
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SEM 10-21-08 J.C.T.

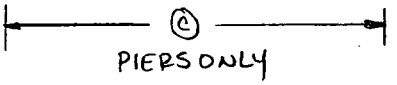
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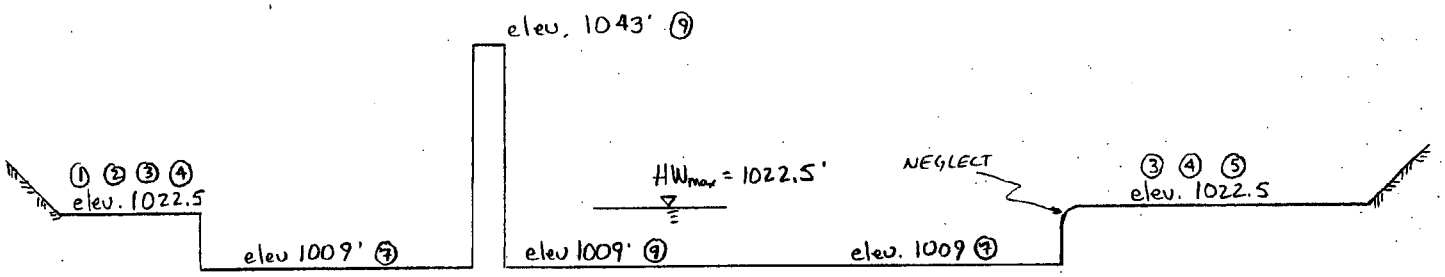
Appendix B-1

- THE FOLLOWING CALCULATION DEVELOPS THE OVERFLOW PARAMETER FOR DOUGLAS DAM BEFORE FAILURE WITH A MAXIMUM FLOOD LEVEL OF 1022.5'. THERE ARE TEN SADDLE DAMS ASSOCIATED WITH DOUGLAS DAM. DRAWINGS (10a) THROUGH (10i) SHOW THAT THE MAXIMUM ELEVATIONS OF EACH DAM ARE GREATER THAN OR EQUAL TO THE MAXIMUM FLOOD LEVEL. FOR THIS REASON, NO OVERFLOW PARAMETERS ARE NECESSARY FOR THE SADDLE DAMS.
- MODIFICATIONS WERE MADE TO THE DAM DURING THE 1980's. DRAWINGS (2) THROUGH (6) PROVIDE DETAILS OF THE MODIFICATIONS.



PLAN VIEW





ELEVATION VIEW

NOT TO SCALE

DAM RATING CURVES - DOUGLAS

SUBJECT OVERFLOW PARAMETERS - BEFORE FAILURE

Calculation No: CDQ000020080007

SEM 10-21-08 J.C.T.

COMPUTED BY DATE CHECKED BY

Appendix B-2

DRAWINGS

① 10W200, R11 (Ref. 1, Att. 1)
② 21E205-1, R3 (Ref. 8, Att. 10)
③ 21E205-2, R1 (Ref. 9, Att. 11)
④ 21E205-3, R3 (Ref. 10, Att. 12)
⑤ DOUGLAS DAM BLUE BOOK, p.47 (Ref. 17)
⑥ DOUGLAS DAM BLUE BOOK, p.45; 48 (Ref 17)
⑦ 10W201, R8 (Ref. 11, Att. 13)
⑧ 31N218, R1 (Ref. 12, Att. 14)
⑨ 46N200, R1 (Ref. 13, Att. 15)
⑩a, ⑩c to ⑩g 23W203, R8 (Ref. 14, Att. 16)
⑩b 23W200, R11 (Ref. 15, Att. 17)
⑩h ⑩i 23W204, R7 (Ref. 16, Att. 18)

OVERFLOW PARAMETERS

ⓐ $Z_c = 1009'$, $B = 18.83'$, $L = 399.17'$
ⓑ $Z_c = 1009'$, $B = 28'$, $L = 269.33'$ ⓒ $Z_c = 1009'$, $B = 28'$, $L = 65'$

$0 \leq H_c \leq (1022.5' - Z_c)$

(FROM REF 6, ATT. 4)

ⓐ $0 \leq H_c/B \leq (1022.5' - 1009')/18.83' = .717$; $2.65 \leq C_f \leq 2.8$
ⓑ ⓒ $0 \leq H_c/B \leq (1022.5' - 1009')/28' = .482$; $2.65 \leq C_f \leq 2.7$

SUMMARY OF OVERFLOW PARAMETERS BEFORE FAILURE

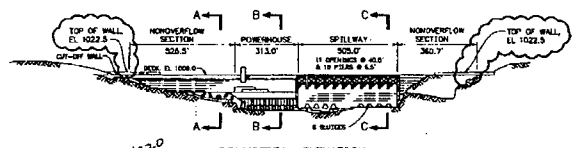
Z_c (ft)	L (ft)	C_f	
1009'	399.17'	2.8	(NON OVERFLOW FROM WALL TO TOWER)
1009'	269.33'	2.7	(POWERHOUSE FROM TOWER TO SPILLWAY)
1009'	65'	2.7	(PIERS ONLY)

Appendix B-3
Ref. 1

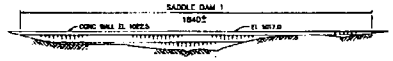
Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker: J.C.T.

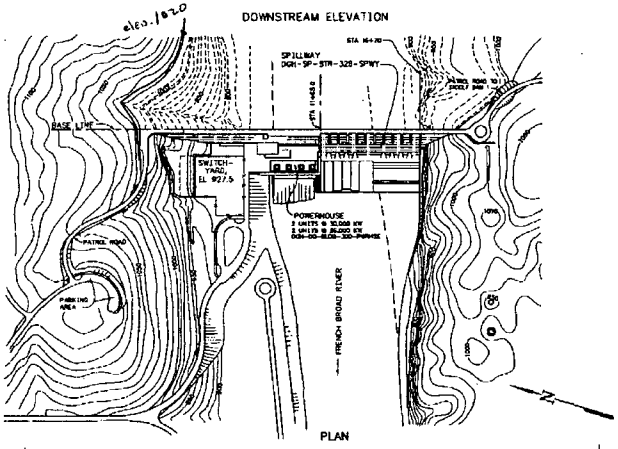
DAM RATING CURVE - DOUGLAS / DOWNSTREAM PARAMETERS
CDQ 000020080007
SECTION 1 PAGE 1



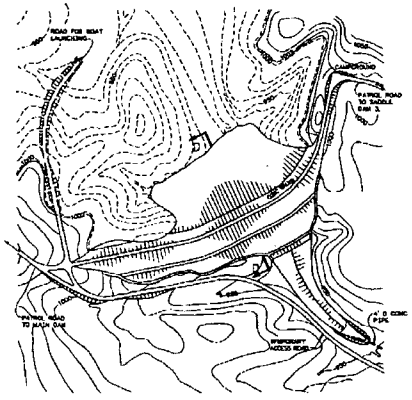
DOWNSTREAM ELEVATION



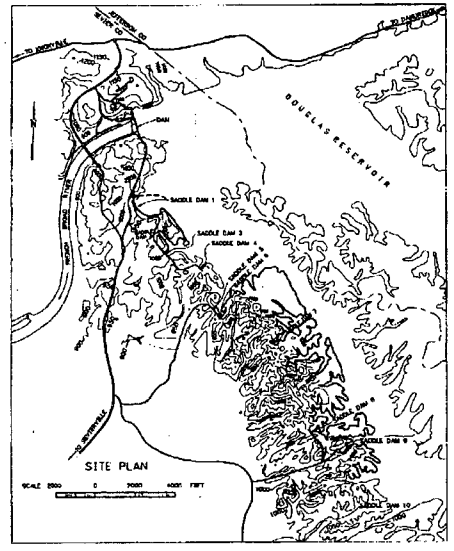
DOWNSTREAM ELEVATION



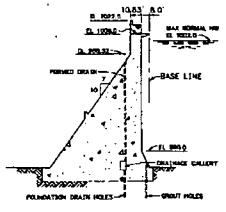
PLAN



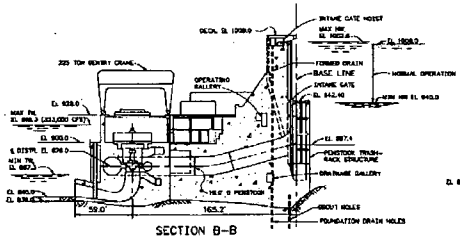
PLAN—SADDLE DAM 1



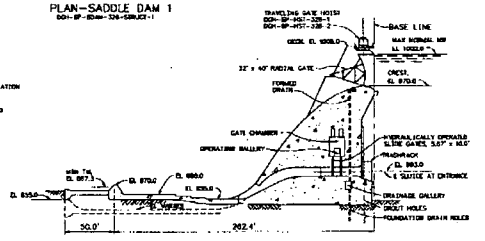
SITE PLAN



SECTION A–A

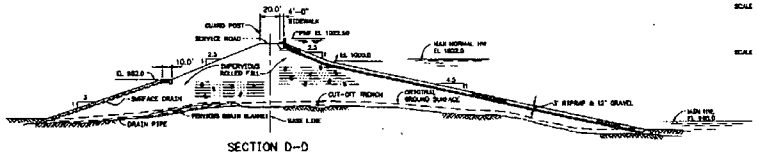


SECTION B–B



SECTION C–C

UNOS TABULATION	
ASSET	UNOS NUMBER
DAM TAILWORK	
GATES 1	
GATES 2	
GATES 3	
GATES 4	
GATES 5	
GATES 6	
GATES 7	
GATES 8	
GATES 9	
GATES 10	
GATES 11	
SPILLWAY	



SECTION D–D



NOTES:
1. COMPONENT AND NUMBERING SCHEME:
2. UNOS ARE LISTED IN WHOLE ON THIS DRAWING SEE UNOS TABULATION FOR ASSETS SHOWN ON THIS DRAWING.
3. COMPONENT NMB NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS – SYSTEM NAME	FUNCTION CODES – FUNCTION CODE NAME
300 – FACILITIES AND GROUNDS	BLDG – BUILDING
326 – DAM	DAM – DAM STRUCTURE
328 – SPILLWAY	SDDM – SADDLE DAM
	MISC – MISCELLANEOUS

4. FOR PROBABLE MAXIMUM FLOOD MODIFICATIONS, SEE DRAWINGS 216300-SERIES ——— DAM SAFETY MODIFICATIONS

NO.	DATE	BY	CHK	APP
1	01 2007			

ADDED PMF INFORMATION TO HORSESHOE ELEVATION VIEW

REVISED AS PART OF CRITICAL STRUCTURAL SYSTEMS AND COMPONENTS VERIFICATION									

SCALE: 1"=200'-0" EXCEPT AS NOTED

MAIN DAM WORKS

GENERAL PLAN, ELEVATION & SECTIONS

DESIGNED BY	DRAWN BY	QUANTITIES BY	CHECKED BY	SUBMITTED BY	RECOMMENDED BY	APPROVED BY	DATE
	E.M.S.	S.G.C.	W.R.B.				

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
POWER, AND WATERS ENGINEERING

AUTOCAD R14 | 20 | C | 10W200 | R 11

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES 119200 dgn

TASK COMPLETED BY: | REV NO:

PLOT FACTOR: 2400 W_TVA

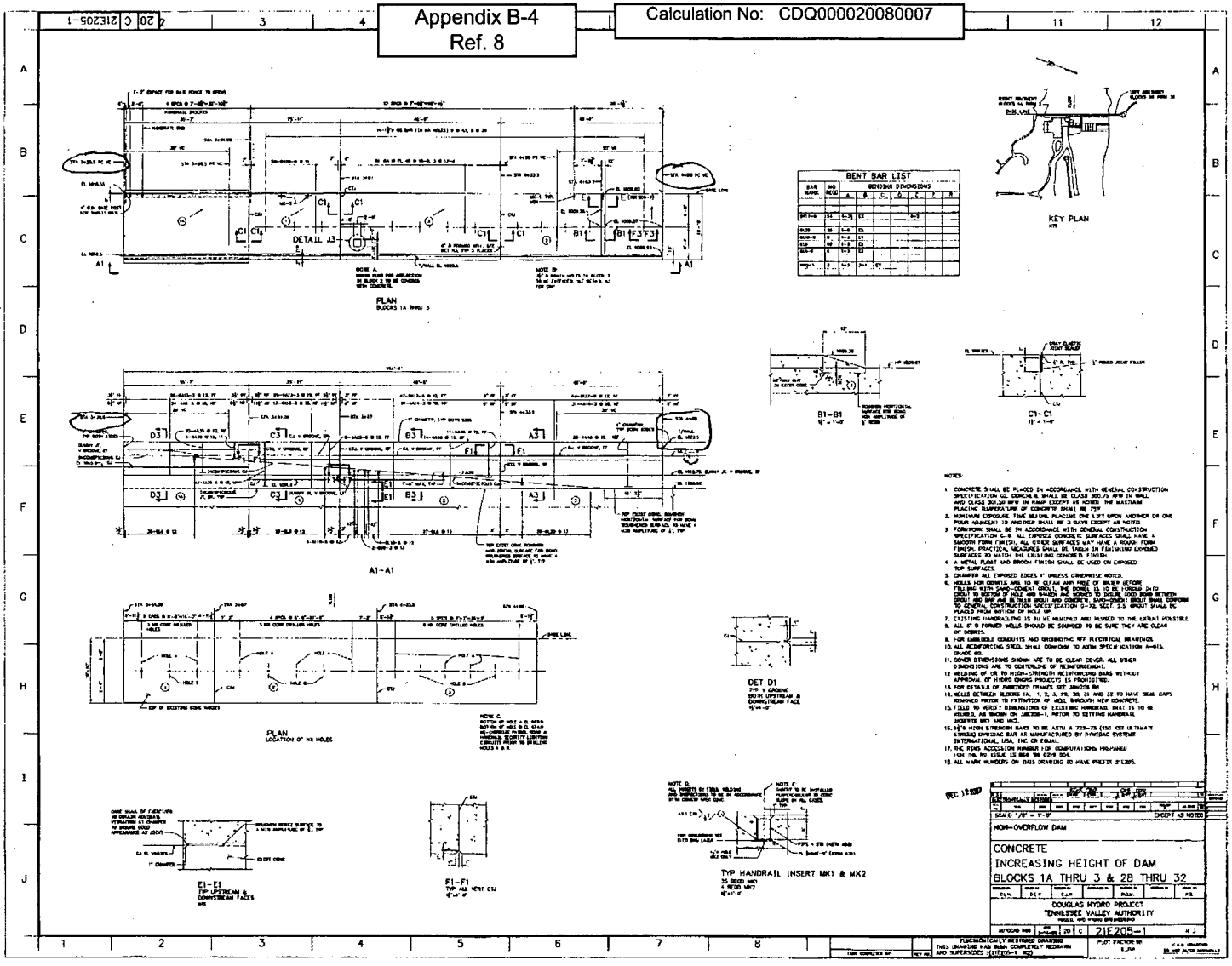
C.A.D. DRAWING DO NOT REVISE MANUALLY

3 of 19

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-4
Ref. 8

Calculation No: CDQ000020080007



DAM RATING CURVE - DOUGLAS (DO 000020080007
OVERFLOW RAPA METERS ISSUED FAILURE

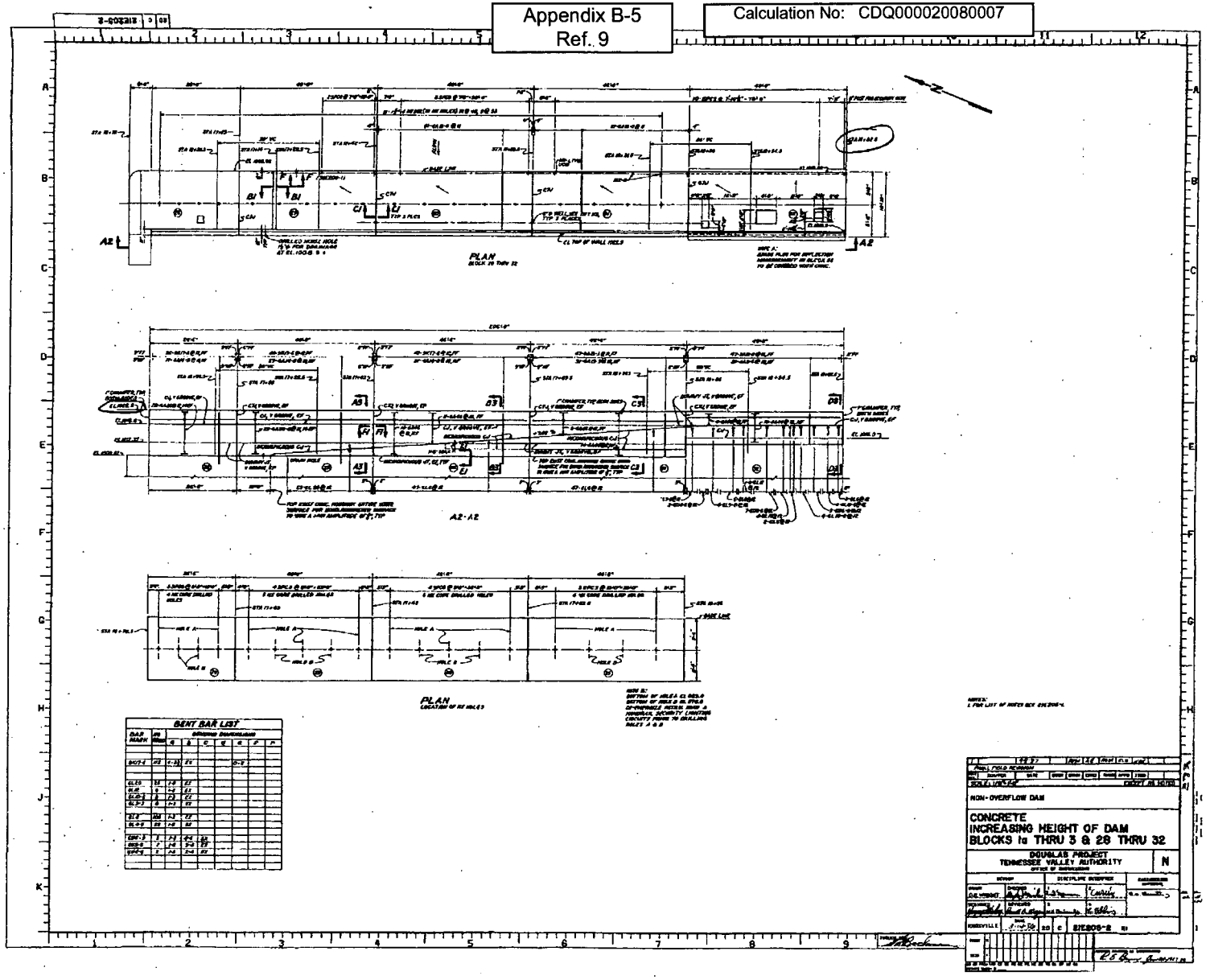
(2)

4 of 19

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-5
Ref. 9

Calculation No: CDQ000020080007



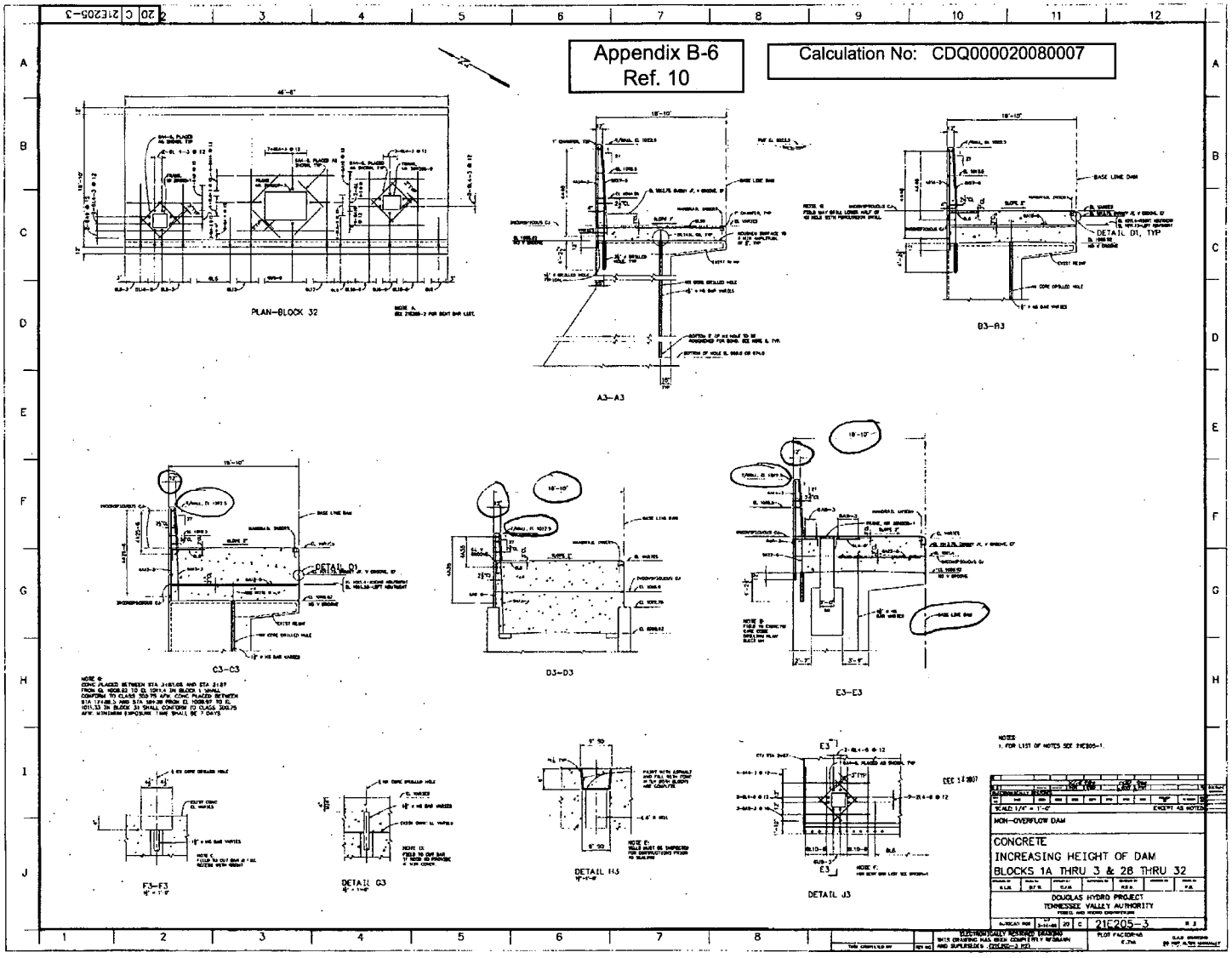
DAM RATING CURVES - OVERFLOW PARAMETERS BEFORE FAILURE

CDQ0000200800007

5 of 19

(3)

Preparer: S.E.M.
Checker: J.C.T.



DAM RATING CHANGE - DOUGLAS (CDQ0000020080007)
OVERFLOW GATED SPILLWAY EARTHQUAKE FAILURE

4

6 of 19

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

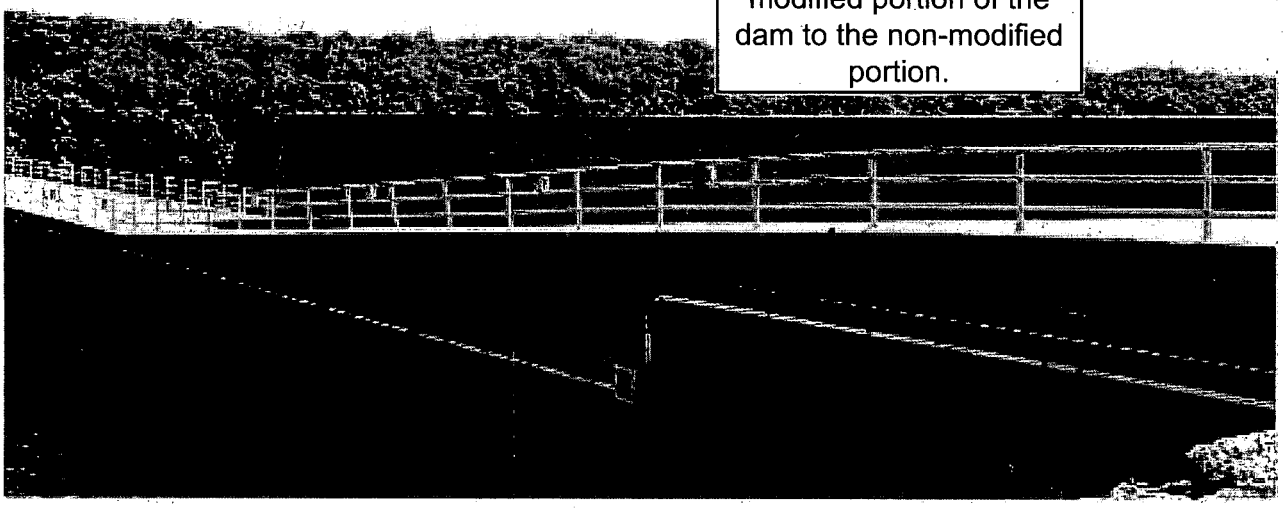


FIGURE 12
Access Ramp and Wall Atop Nonoverflow Blocks 1A through 3, August 1998

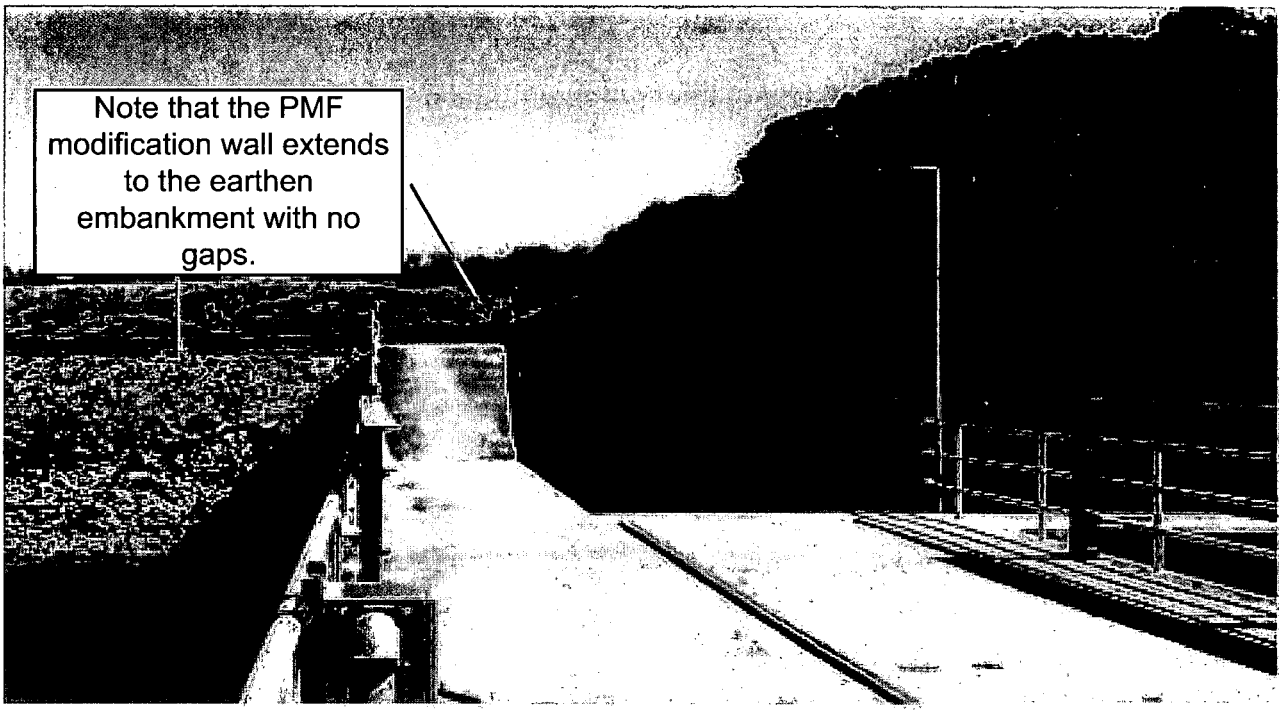


FIGURE 13
Access Ramp and Wall Atop Nonoverflow Blocks 28 through 32
August 1998

DAM RATING CURVE - DOUGLAS CDQ000020080007

OVERFLOW PARAMETERS BEFORE FAILURE 8 of 19

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-8
from Ref. 17

Calculation No: CDQ000020080007

September 1998 Douglas 45

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD

Chronology

Safety analysis studies for Douglas Dam for the Probable Maximum Flood were started at the beginning of fiscal year 1985 and were completed with the submittal of *DOUGLAS PROJECT DAM SAFETY ANALYSIS REPORT HEP-C85-1 BY MEMORANDUM FROM R. G. DOMER TO R. W. CANTRELL ON JUNE 17, 1985 (B66 850617 0001)*. Final design started in October 1985. Onsite construction began in March 1986 and was completed in May 1987.

Cost of Modification

Design costs for the capital safety modifications to Douglas Dam were approximately $403,000. This did not include costs for dam safety evaluation studies which resulted in the modifications, construction costs were approximately $1.8 million. The total project cost was approximately $2.5 million.

Controlling Features

Modifications for the PMF consisted of increasing the height of the north and south concrete nonoverflow dams and their earth abutments by 13.5 feet, increasing the height of saddle dam one by 5 feet and the remaining existing seven saddle dams by 6.5 feet, and adding two new saddle dams. These modifications will prevent overtopping and erosion of the embankment and saddle dams but would permit overtopping of the concrete dam spillway area with possible major damage to the powerhouse and switchyard. The elevation of the headwater for a PMF resulting from combined storage and discharge through the spillway and over the top of the concrete structures is 1022.5.

6.a

DAM RATING CURVE - DOUGLAS CDQ 000020080002

OVERFLOW PARAMETERS BEFORE FAILURE 9 of 19

Appendix B-9 from Ref. 17

Preparer: S.E.M.
Checker: J.C.T.

Calculation No: CDQ000020080007

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

North and South Earth Abutment Modifications

The north and south earth abutments were stripped of pavement, curbs, and stabilized roadway base, and increased in height to elevation 1018.5 using impervious rolled earthfill, filter blanket, and riprap. A 12-inch-think concrete wall with top elevation at 1022.5 was placed on the north abutment, joined to the wall on the downstream side of nonoverflow block 1A, and extended along the river side of the patrol road to the 1022.5 contour. These walls, along with the walls on nonoverflow blocks 1A through 3 and 28 through 32, are for the purpose of diverting overtopping flow to the spillway and powerhouse portions of the dam. Details of these walls are shown on drawing 23E210-1.

This drawing is not available. It will be assumed that the length of the non-overflow dam extends between the elev. 1022.5 contours on each end. This will lead to "no flow" over the wall.

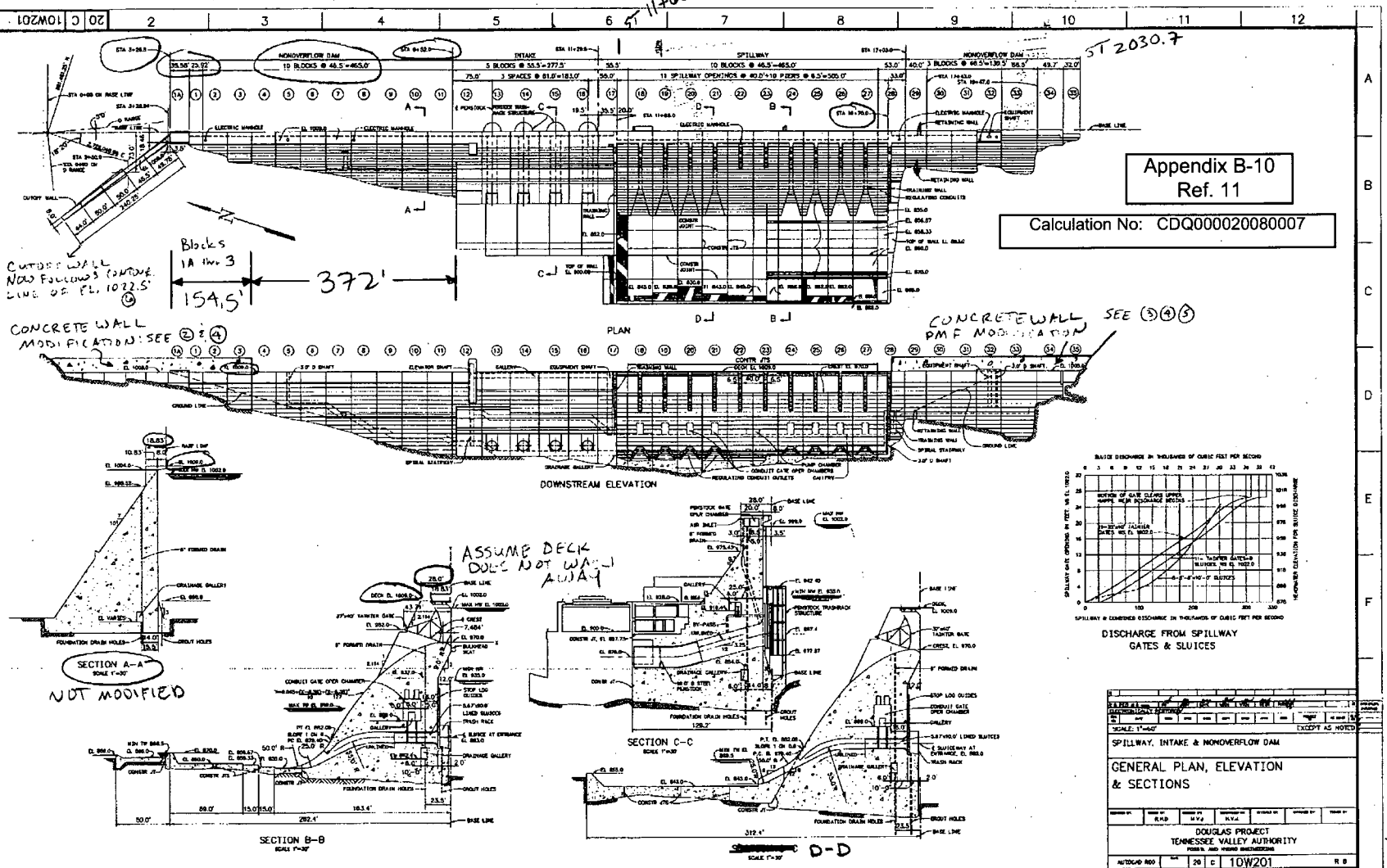
6b

Preparer: S.E.M.
Checker: J.C.T.

DAM RATING CURVE - DOUGLAS CDQ 2000320007

Appendix B-10
Ref. 11

Calculation No: CDQ000020080007



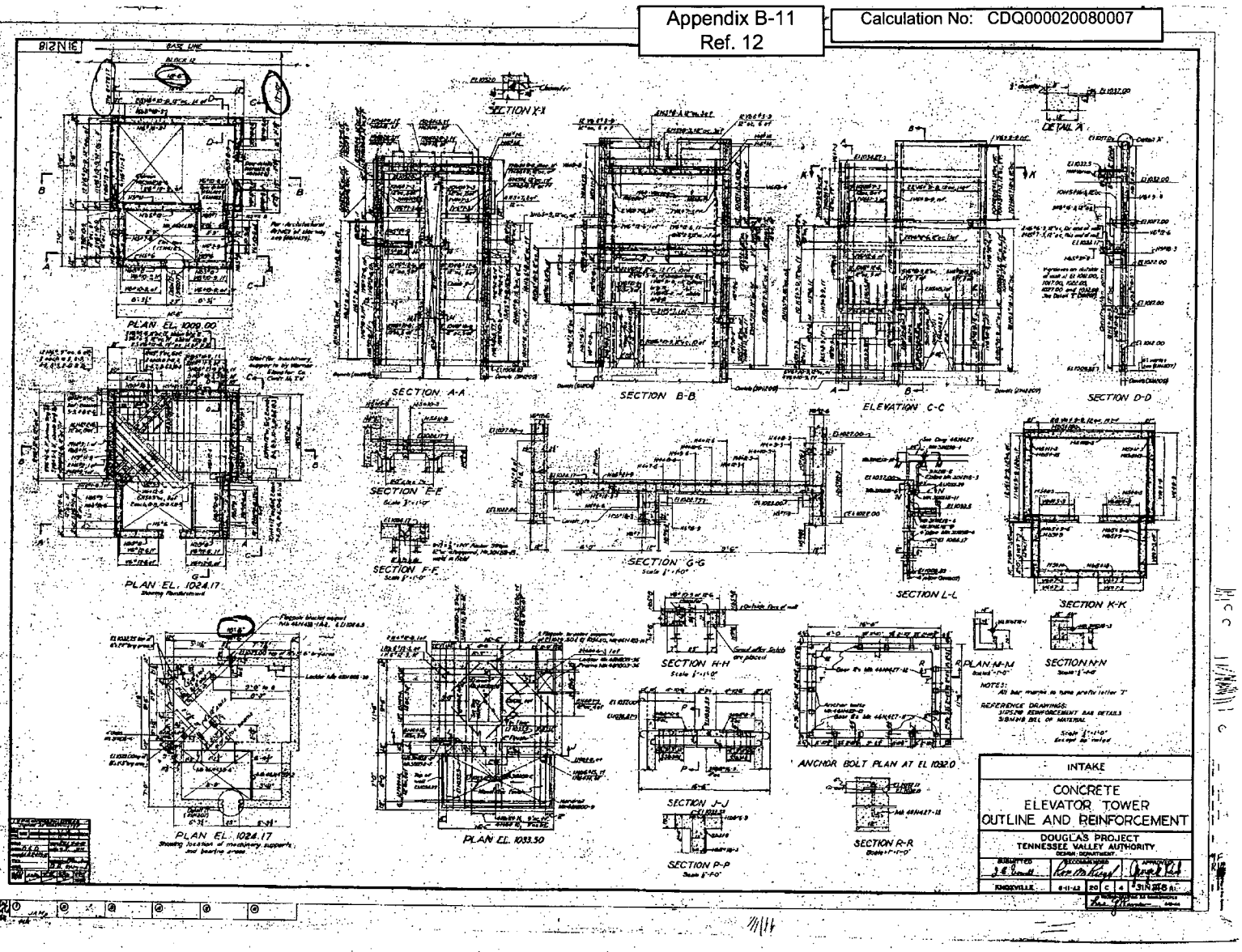
10 of 19

(7)

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-11
Ref. 12

Calculation No: CDQ000020080007

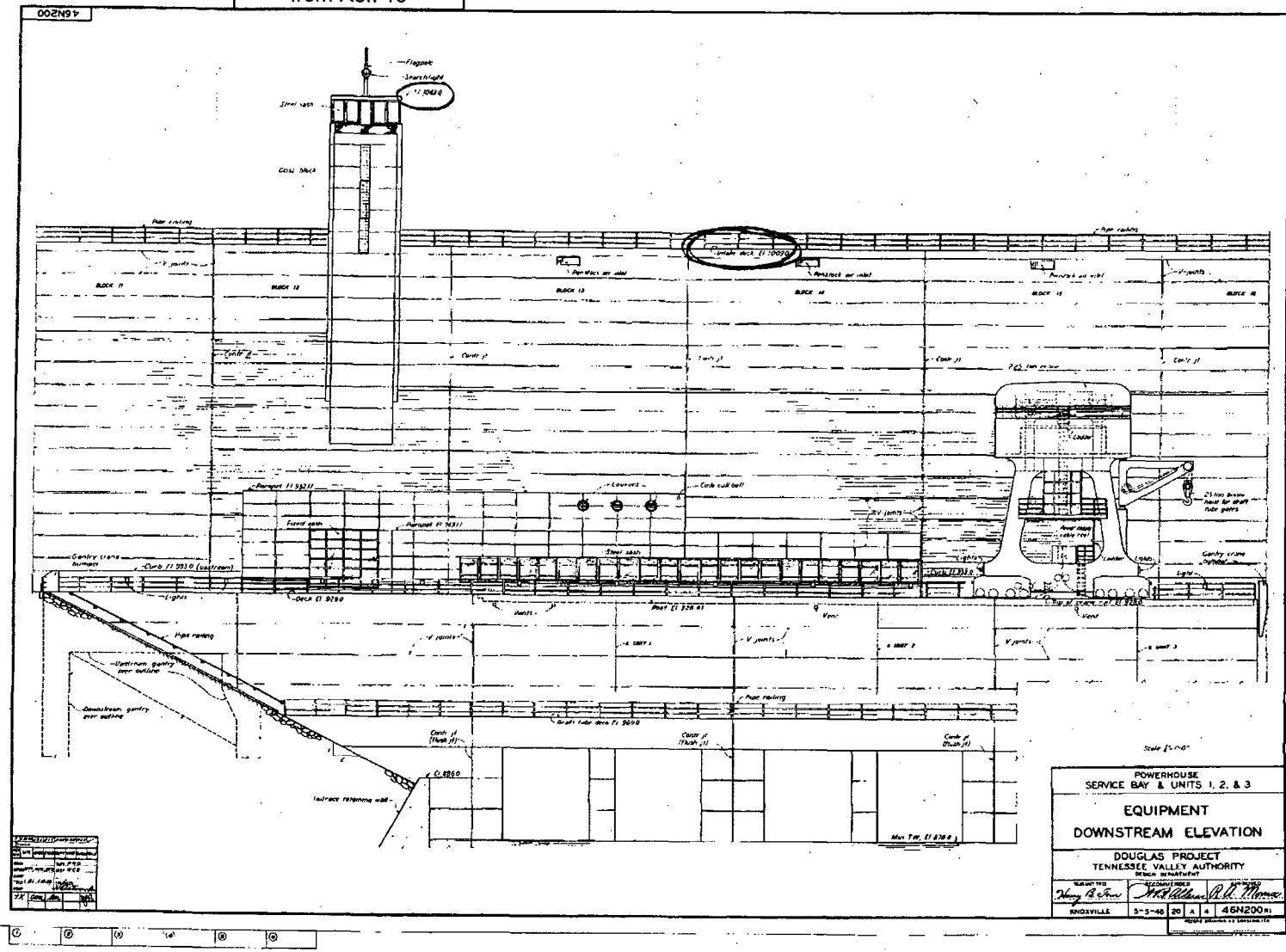


DAM RATING CURVE - DOUGLAS CDQ 000020080007
OVERFLOW PARAMETERS REVISE FAILURE
11 of 19
(8)

Appendix B-12
from Ref. 13

Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker: J.C.T.



DAM RATING CURVE
DOUGLAS DAM TAILWATER ELEVATION

CDQ 000020080007

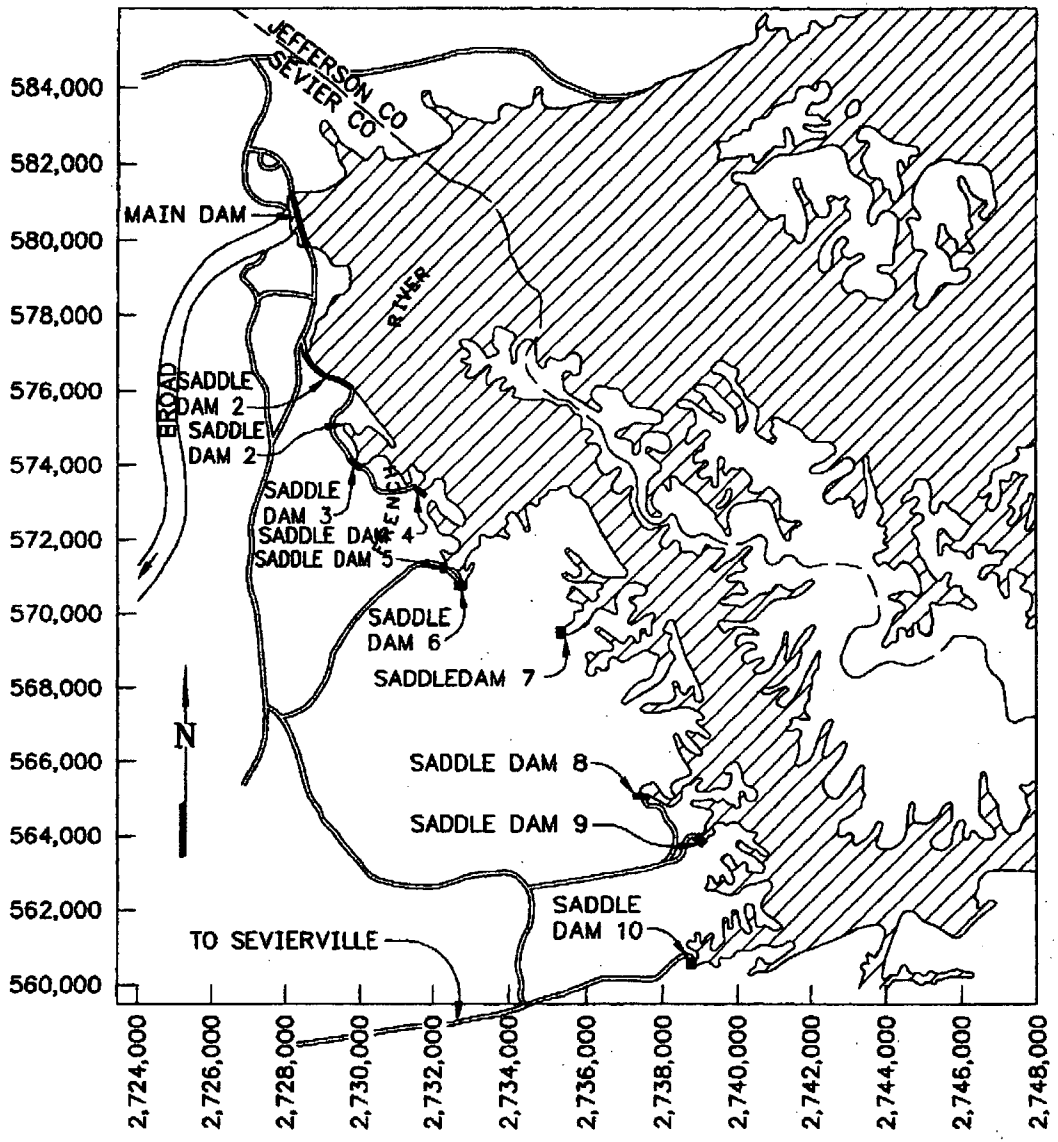
2 of 19

(9)

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-13
from Ref. 14

Calculation No: CDQ000020080007



SITE PLAN
SCALE 1"=4000'

SADDLE DAM LOCATIONS
DWG 23W203, R8

DAM RATING CURVE - DOUGLAS / SADDLE DAMS CDQ000020080007
OVERFLOW PARAMETERS FOR SPF FAILURE
A B C 13 of 19

10a

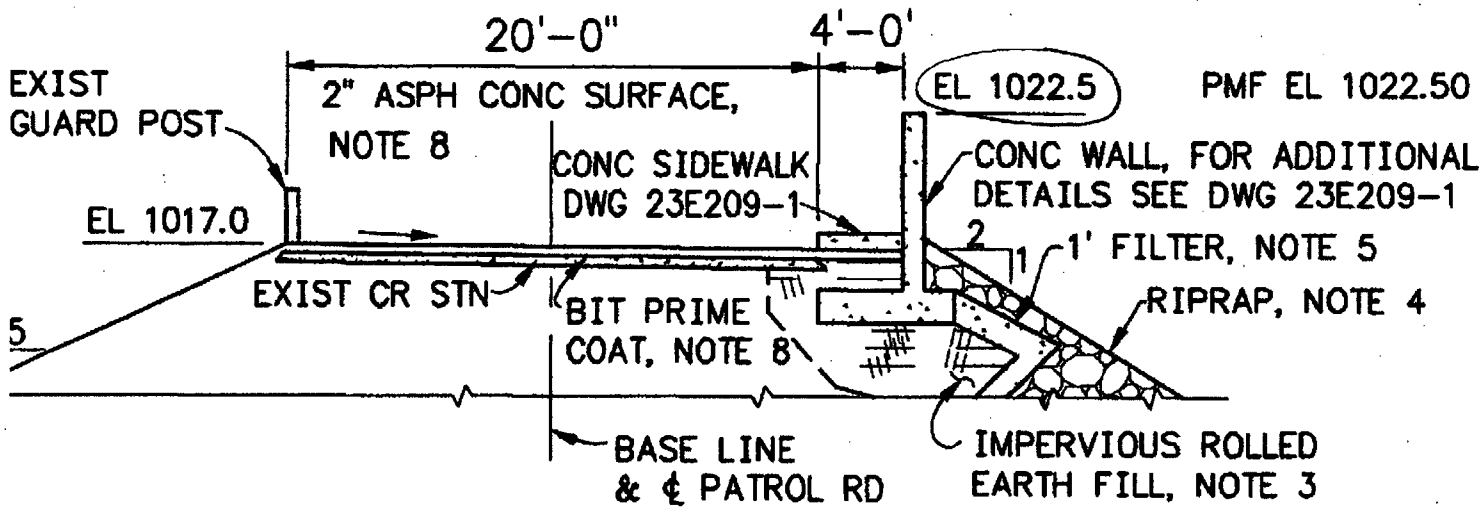
Preparer: S.E.M.
Checker: J.C.T.

Appendix B-14
from Ref. 13

Calculation No: CDQ000020080007



ECTION C–C

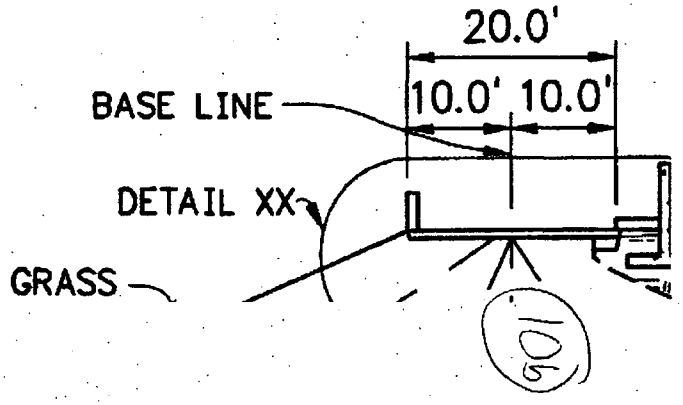


DETAIL XX

TYPICAL CREST DETAIL

SCALE $\frac{1}{8}$"=1'–0"

SADDLE DAM 1 DWG 23W200, R11

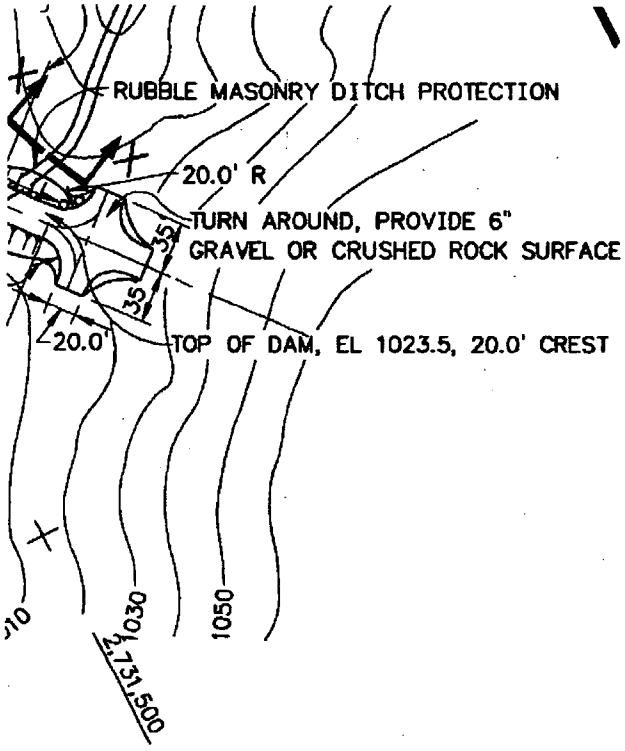


DAM RATING CURVE - DOUGLAS / SADDLE DAMS
CDQ 00020080007
OVERFLOW PARAMETERS
14 of 19

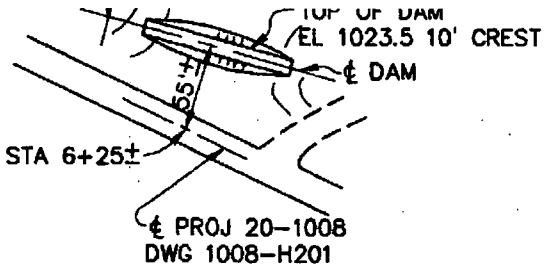
Preparer: S.E.M.
Checker: J.C.T.

Appendix B-15
from Ref. 14

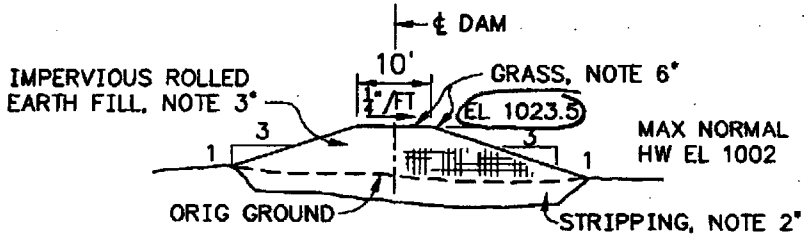
Calculation No: CDQ000020080007



.E DAM 4

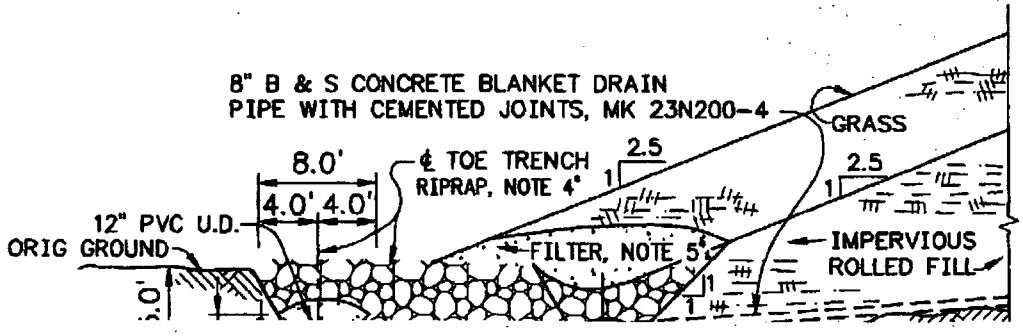


PLAN-SADDLE DAM 2



TYP SEC-SADDLE DAM 2
SCALE 1"=20'

DWG 23W203, R8



DAM RATING CURVE - DOUGLAS / SADDLE DAMS
CDQ00020080007
10c
15 of 19

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-16
from Ref. 14

Calculation No: CDQ000020080007

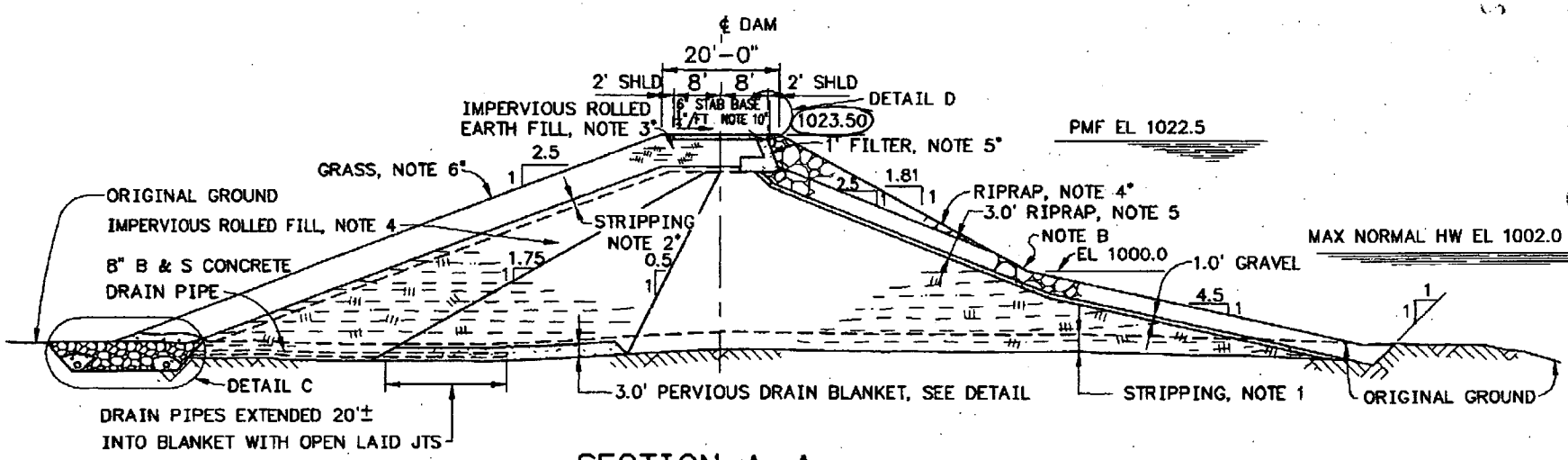
OVERFLOW PARAMETERS
BEFORE FAILURE

CRUSHE
GRAVEL
5.0' MA

DAM RATING CURVES - DOUGLAS
SADDLE DAMS
CDQ0000200800S2

132.000 571.0 101 103 132.500

PLAN–SADDLE DAM 5



SECTION A–A
SADDLE DAM 3 ONLY
SCALE 1"=20'

1 2 3 4 5

DWG 23W203, R8

10d

16 of 19

DAM RATING CURVES - DOUGLAS

SADDLE DAMS - OVERFLOW PARAMETERS

Appendix B-17
from Ref. 14

Calculation No: CDQ000020080007

DRAIN PIPE LAID
JTS, MK 23N200-3

Preparer: S.E.M.

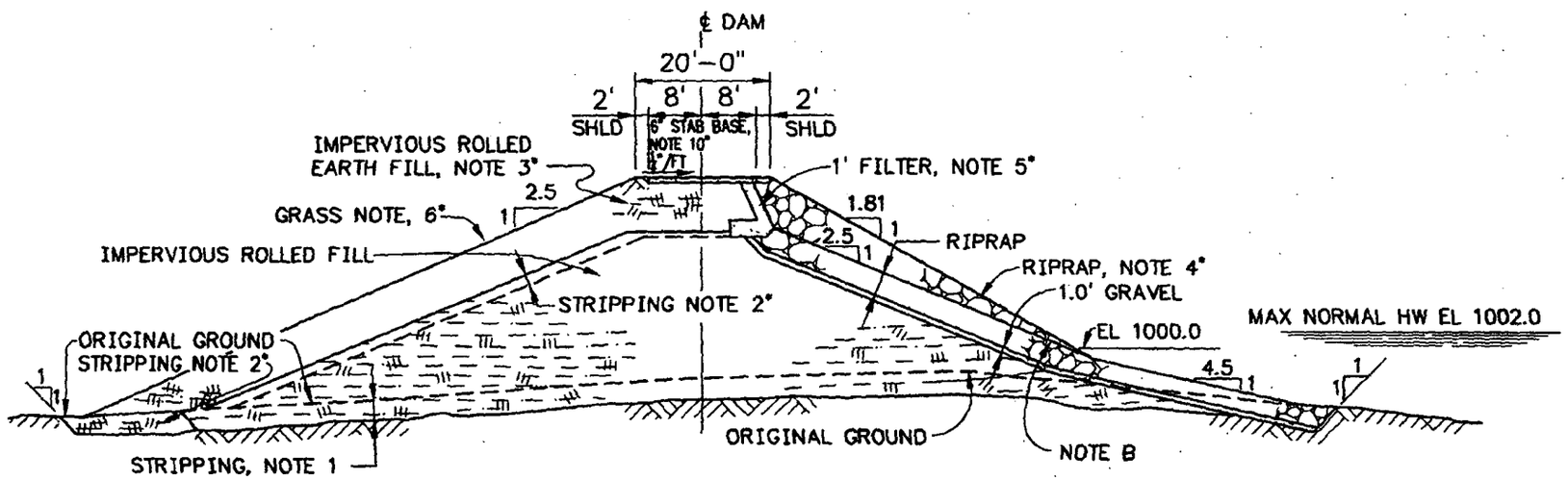
Checker: J.C.T.

DETAIL-DRAIN BLANKET

SCALE 1"= 5'

CDQ000020080007

10e



FROM

DWG 23W203, R8

SECTION B-B

TYPICAL-SADDLE DAMS 4 & 5

SCALE 1"=20'

ELEVATIONS FOR SADDLE DAMS ARE LOCATED ON THE FOLLOWING TWO PAGES.

7	8				
			TASK COMPLETED BY:	REV NO.	TH AN

DAM RATING CURVES - DOUGLAS

SADDLE DAM ELEVATIONS

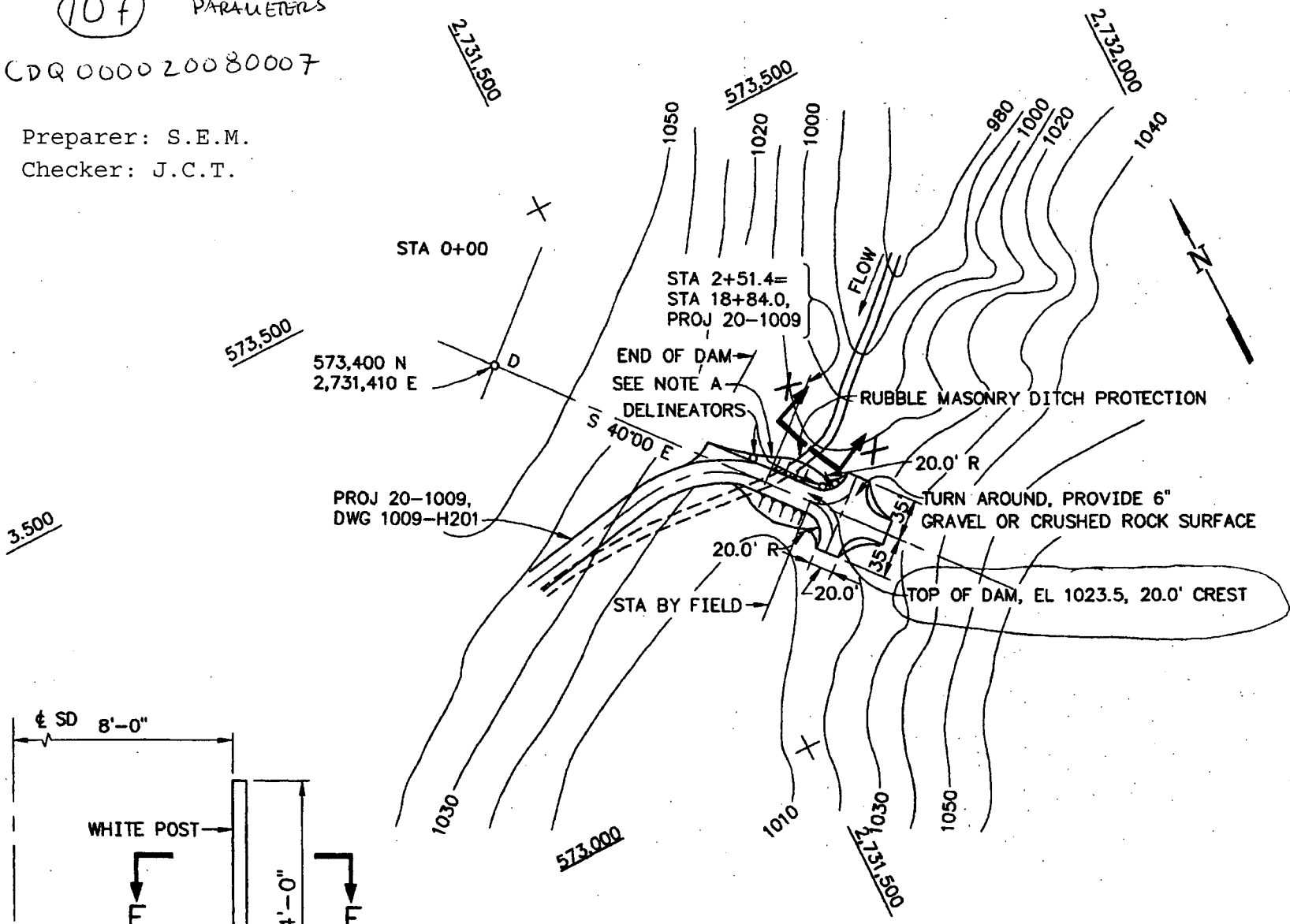
(10f) OVERFLOW PARAMETERS

CDQ00002008000 7

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-18
from Ref. 14

Calculation No: CDQ000020080007



PLAN-SADDLE DAM 4

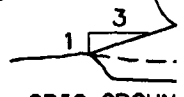
FROM DWG 23W203, R8



STA 6+25

PLAN-

IMPERVIOUS ROLLED
EARTH FILL, NOTE 3°



ORIG GROUN

TYP

DAM RATING CURVES - DOUGLAS

SADDLE DAM ELEVATIONS

10g

OVERFLOW PARAMETERS

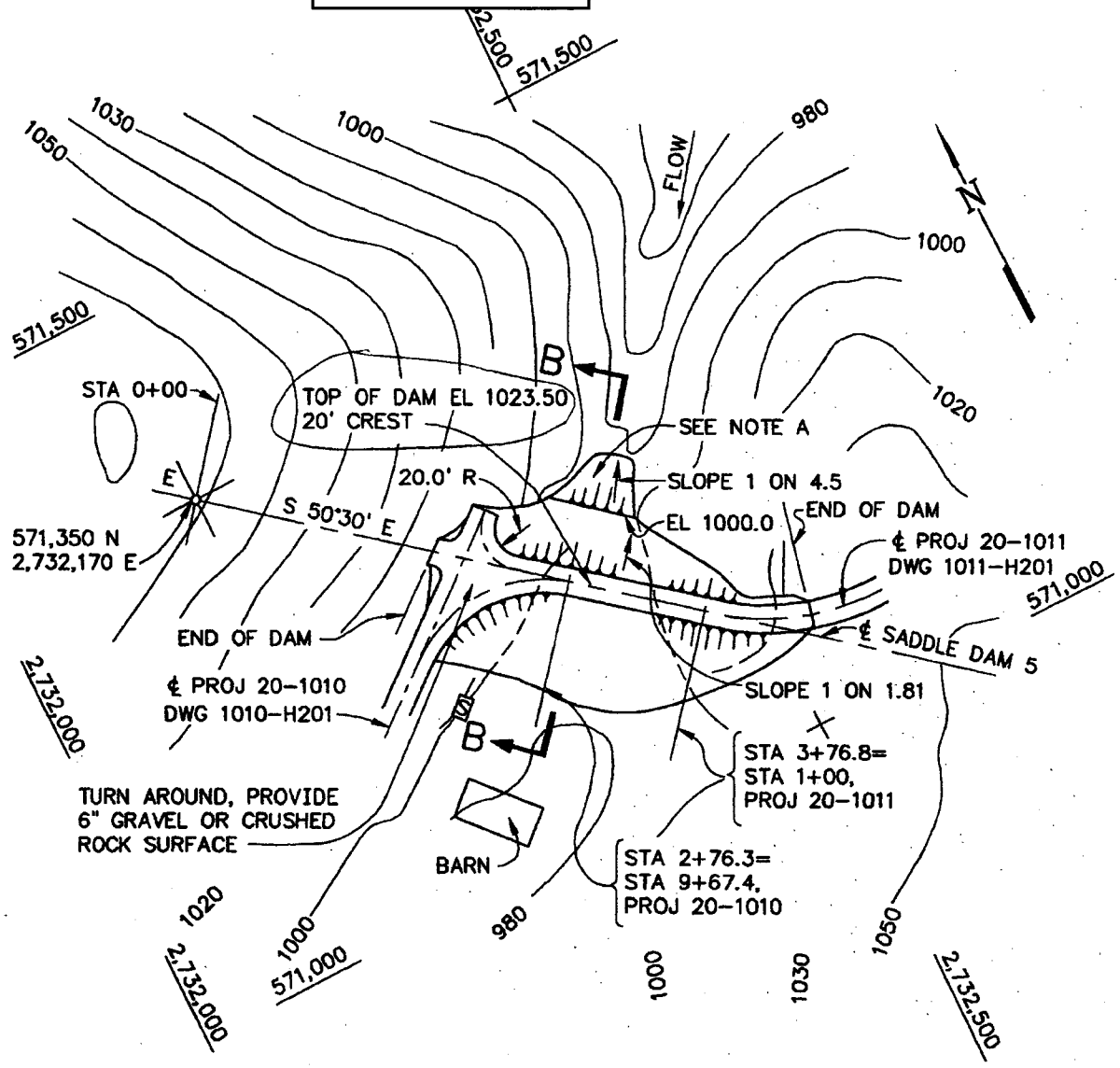
CDQ000020080007

Preparer: S.E.M.

Checker: J.C.T.

Appendix B-19 from Ref. 14

Calculation No: CDQ000020080007



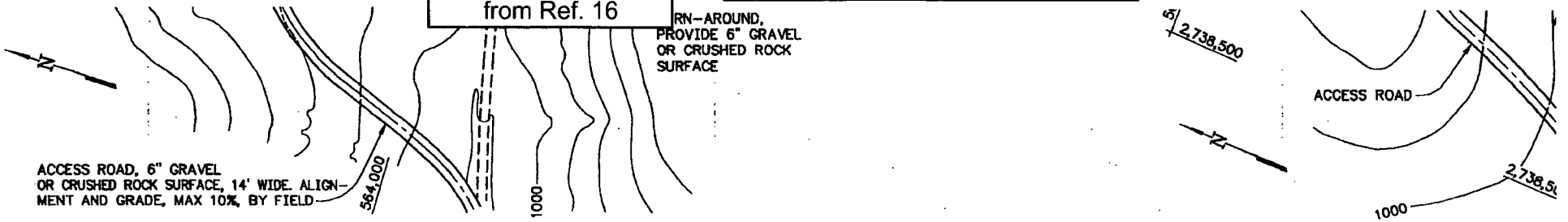
PLAN-SADDLE DAM 5

FROM DWG 23W203, R8

Preparer: S.E.M.
Checker: J.C.T.

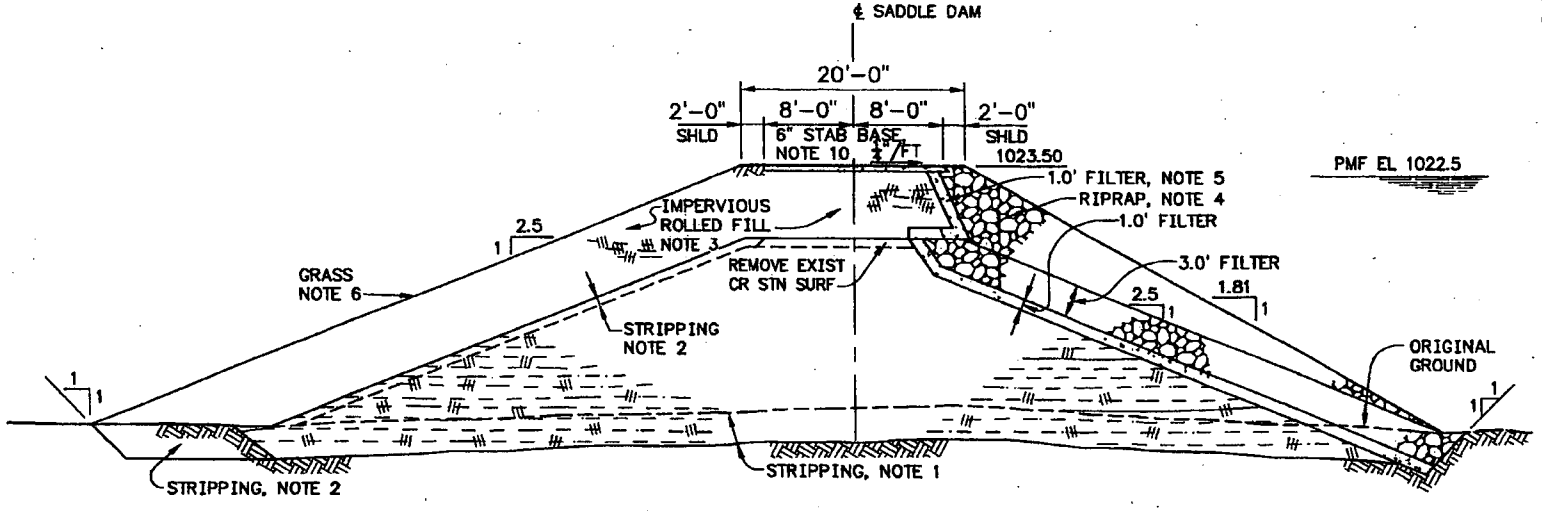
Appendix B-20
from Ref. 16

Calculation No: CDQ000020080007



PLAN–SADDLE DAM 9

PLAN–



SECTION A–A
TYPICAL–SADDLE DAMS 6, 8, 9 & 10
SCALE 1"=10'

DWG 23W204, R7

DAM RATING CURVES - DOUGLAS
CDQ 00002008000?
SADDLE DAMS

DOUBLE FLOW PARAMETERS
BEFORE FAILURE

18 of 19

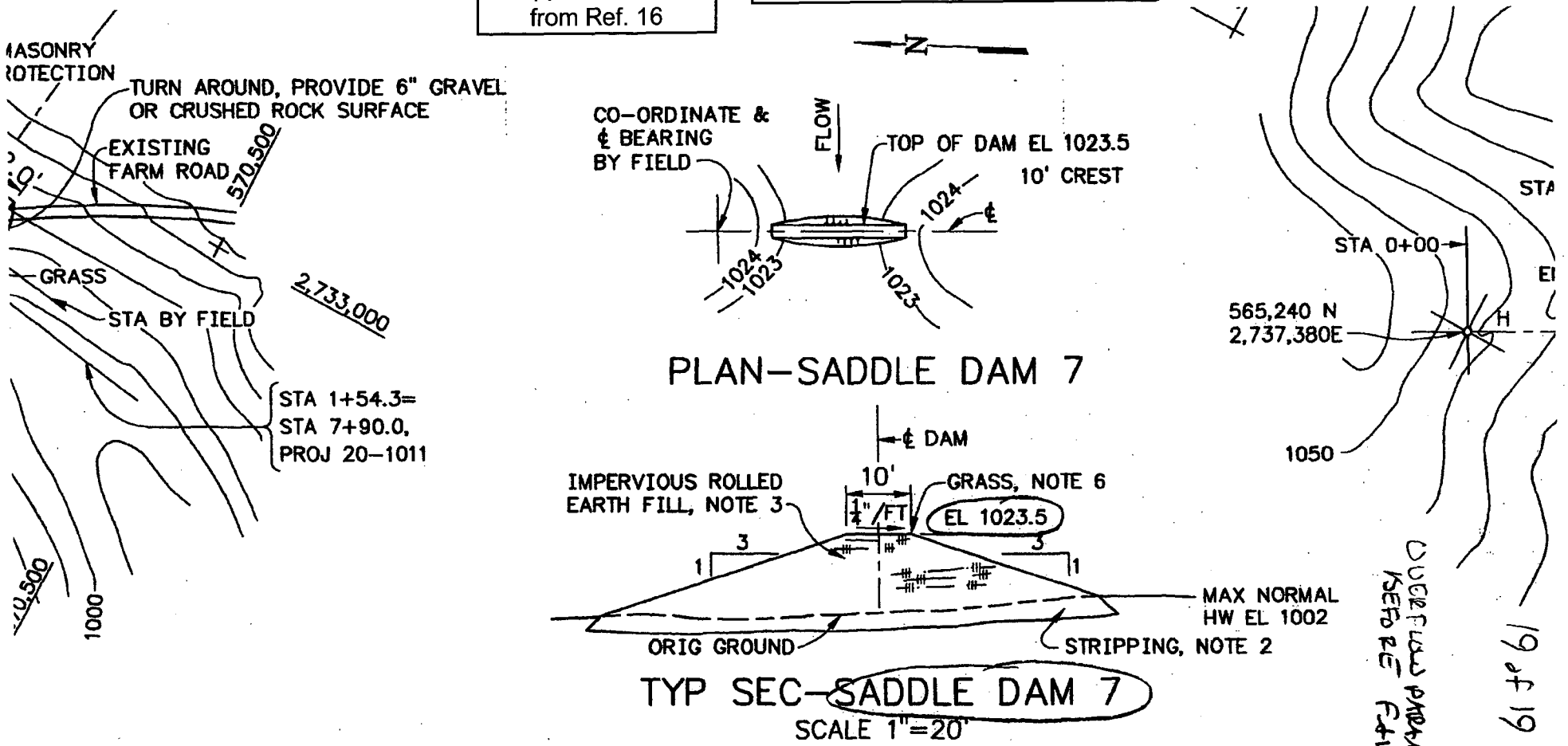
10h

2 | 3 | 4 | 5 | 6

Preparer: S.E.M.
Checker: J.C.T.

Appendix B-21
from Ref. 16

Calculation No: CDQ000020080007



DWG 23W204, R7

NOTE:
COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES. TOPOGRAPHY OF SIGHTS WERE TAKEN FROM THE FOLLOWING DRAWINGS: 461K504-F8, G9, G11, H11, H12 AND H13. COORDINATES OF POINTS F TO K AND BEARINGS OF CENTER LINES OF SADDLE DAMS HAVE BEEN OBTAINED BY SCALING.

DAM RATING CURVE
DOUGLAS
SADDLE DAMS
CDQ 0000 20080007
000 //

DOUGLAS PARAMETERS USED RE FAILURE

19 of 19 PLA

10

DAM RATING CURVE - DOUGLAS

SUBJECT OVERFLOW PARAMETERS - AFTER FAILURE PR

Calculation No: CDQ000020080007

SEM 10-21-08 J.C.T.

COMPUTED BY DATE CHECKED BY

Appendix C-1

- FAILURE SCENARIOS FOR DOUGLAS DAM ARE CONTAINED IN A TVA CALCULATION, "DOUGLAS DAM STABILITY ANALYSIS FOR ½ SSE + ½ PMF" (Ref. 21). THIS CALCULATION (REF. 21 - SEE P. (1c)) INDICATES THAT BLOCKS 12 - 17 (POWERHOUSE) AND BLOCKS 1a - 5 & 29 - 35 (NON OVERFLOW DAM) REMAIN INTACT. THE NON-OVERFLOW DAM IS PROJECTED TO FAIL ABOVE ELEVATION 927.5' WITH A FLOW WIDTH OF ≈53' (9). SPILLWAYS ARE PROJECTED TO FAIL ABOVE ELEVATION 937' WITH A WIDTH OF ≈60' (8). THESE VALUES ARE SPECIFIC TO DOUGLAS DAM AND ARE INCLUDED AS (1a) thru (1c) OF THIS CALCULATION.
- IN ORDER TO DETERMINE THE DISCHARGE COEFFICIENT FOR A FLOW OVER THE FAILED SECTION WITH DEBRIS AT A LOWER ELEVATION, A MODEL OF FLOW FROM THE NORRIS DAM FAILURE STUDY WAS USED TO APPROXIMATE "C". THIS STUDY (REF. 19) IS THE ONLY KNOWN STUDY REGARDING DISCHARGE COEFFICIENTS AND SEISMIC FAILURE DEBRIS. IT IS ALSO BASED ON MODEL TESTIN SEE (2).

REFERENCES AND DRAWINGS:

(1) TVACALC, "DOUGLAS DAM STABILITY STUDY FOR ½ SSE + ½ PMF," RMS # B25 880520 308
(2) NORRIS DAM FAILURE STUDY, NORRIS DAM PROJECT (Ref. 19) (REF. 21, ATT. 27)
(3) 10W200, R11 (Ref. 1, Att. 1)
(4) 10W201, R8 (Ref. 11, Att. 13)
(5) 21E205-2, R1 (Ref. 9, Att. 11)
(6) 21E205-1, R3 (Ref. 8, Att. 10)
(7) 31N218, R1 (Ref. 12, Att. 14)
(8) 51N200, R5 (Ref. 25, Att. 28)
(9) 21N201, R5 (Ref. 26, Att. 29)

- SADDLE DAMS ARE ASSUMED TO REMAIN STRUCTURALLY SOUND FOLLOWING A SEISMIC EVENT OF THE MAGNITUDE CAUSING DAM FAILURE. (REF 21, (1c))

- THE REFERENCE CALCULATION (REF. 21) ASSUMES ½ PMF AND ½ SSE OCCUR CONCURRENTLY. VERIFICATION OF THIS IS BEYOND THE SCOPE OF THIS WORK AND, THEREFORE WILL BE CONSIDERED VALID.

DAM RATING CURVE - DOUGLAS

SUBJECT OVERFLOW PARAMETERS AFTER FAILURE

Calculation No: CDQ000020080007

Appendix C-2

SEM 10-22-08 COMPUTED BY DATE J.C.T. CHECKED BY DATE

- DETERMINING THE DISCHARGE COEFFICIENT FOR A FAILURE OF DOUGLAS DAM AS POSTULATED IN ① SHOULD BE DETERMINED EXPERIMENTALLY. SUCH AN EXPERIMENT EXISTS FOR NORRIS DAM. IT WILL BE ASSUMED THAT FLOW OVER THE SUBMERGED, FAILED SECTIONS OF DOUGLAS DAM CAN BE APPROXIMATED BY USING COLLECTED DATA CORRELATING HEADWATER ELEVATION AND DISCHARGE IN THE NORRIS DAM FAILURE STUDY "F1" ⑳.

FROM THE USACE HYDRAULIC DESIGN CRITERIA (Ref 4.) :

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

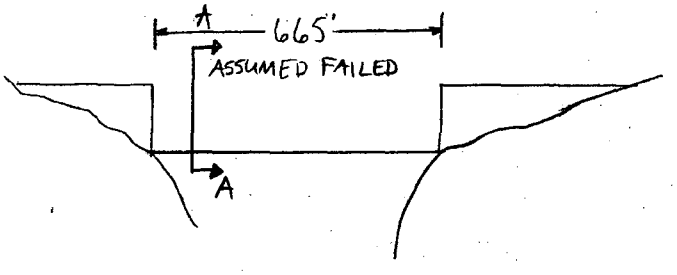
$H = HW - Z_c$ where HW = HEADWATER ELEVATION (PMF)
Z_c = ELEVATION OF SUBMERGED OBSTRUCTION

ENTERING THE NORRIS DATA ⑳ INTO EXCEL, THE SPREADSHEET ON Sh. 3 WAS DEVELOPED. FITTING THE DATA TO A LINEAR EXPRESSION SHOWS THAT:

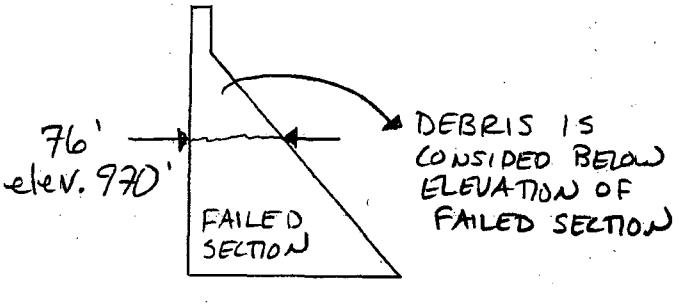
FOR $H > 37.35' \Rightarrow C_f = 2.53 + (.0103)(H - 37.35)$

FOR $H < 37.35' \Rightarrow C_f = 2.53$ (ASSUMED, SEE FOLLOWING PAGE)

NORRIS DAM FAILURE MODEL (CASE F1) ⑳ :



PLAN VIEW



SECTION A-A

NOT TO SCALE

Appendix C-3

Calculation No: CDQ000020080007

Preparer: S.E.M.

Checker: J.C.T.

Determination of C_f For Failure Sections

In order to detremine a value of C_f which is applicable to the seismic failure section of Douglas Dam, a relationship between the data for failure Case F1 from the Norris Dam model study must be developed. In order to do this, the relationship $Q = C_f * L * H_c^{3/2}$ will be used to back out a free discharge coefficient. It is known that H_c, or the head on crest, is equal to the headwater elevation minus the crest elevation, Z_c. Because the minimum collected model data was at H_c = 37.35, no coefficient values below this point were developed.

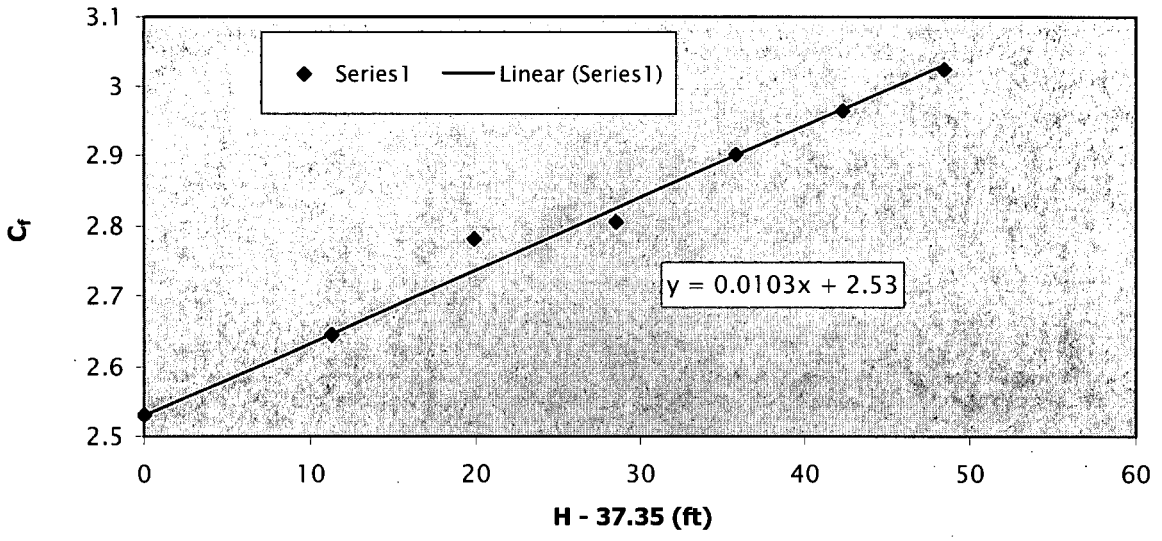
In addition, tabular values for free discharge over a broad crested weir do not range less than the 2.53. This value will be held constant for all head on crest values below 37.35 feet. The value of 2.53 is slightly lower than the value of 2.65 which has been used as a minimum throughout this calculation. It will be considered appropriate to use the value of 2.53 as a minimum because model test data is much more reliable than generic. The normalized value of "H - 37.35" has been used to develop the curve below, in order to force Excel to start the curve at 2.53. This is the only application of this fourth column. The head values used in the calculation of Cf are the H values in the third column.

Norris Dam Failure Study, Case F1

Headwater (ft)	Q 1000 cfs	H (ft)	[H - 37.35] (ft)	C_f
1007.35	384.1	37.35	0.00	2.53
1018.63	596.6	48.63	11.28	2.65
1027.25	801.3	57.25	19.90	2.78
1035.85	997.0	65.85	28.50	2.81
1043.15	1207.1	73.15	35.80	2.90
1049.65	1401.7	79.65	42.30	2.97
1055.80	1598.7	85.80	48.45	3.02

Z_c = 970 ft

L = 665 ft



TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET 4 OF

DAM RATING CURVE – DOUGLAS

SUBJECT OVERFLOW PARAMETERS AFTER FAILURE

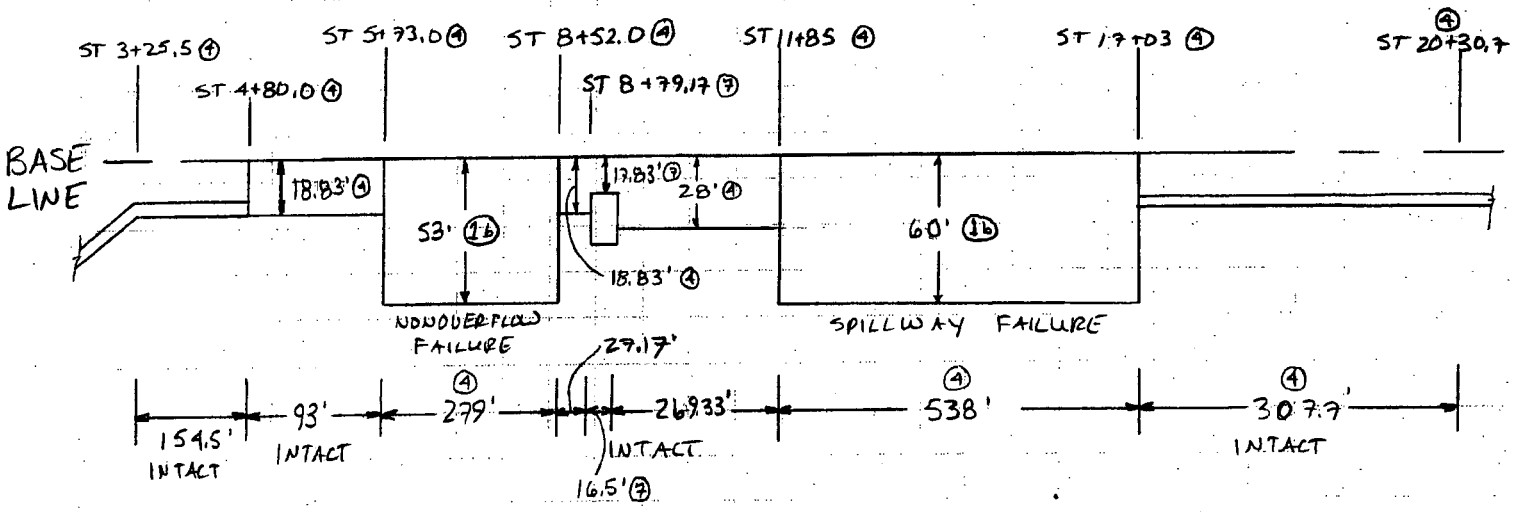
Calculation No: CDQ000020080007

SEM 10-22-08 J.C.T.

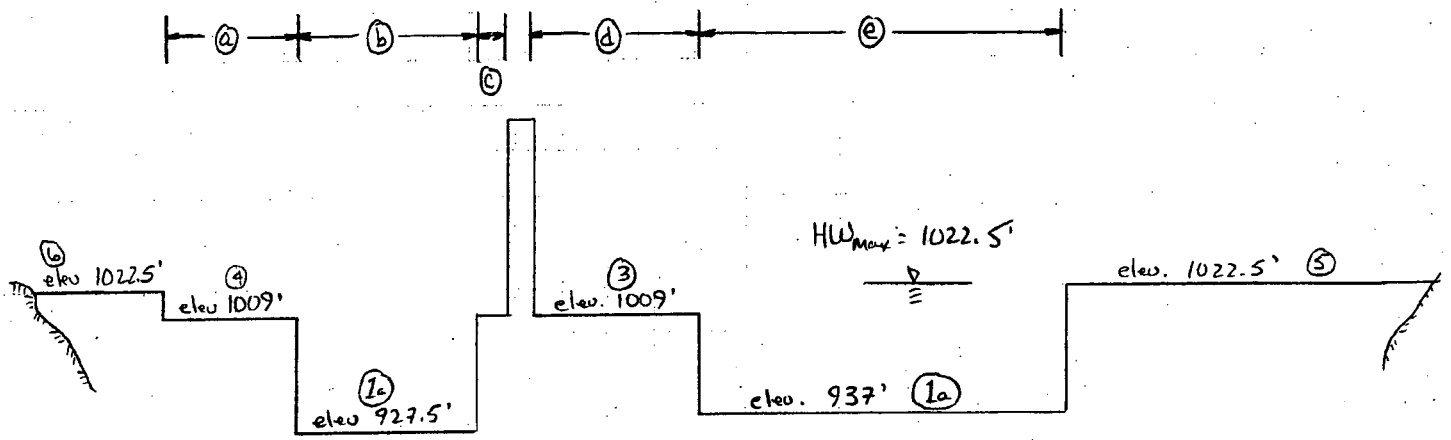
COMPUTED BY DATE CHECKED BY

Appendix C-4

DOUGLAS DAM AFTER SEISMIC FAILURE SIMULTANEOUS W/PMF



PLAN VIEW NOT TO SCALE



ELEVATION VIEW NOT TO SCALE

- SADDLE DAMS REMAIN STABLE FOLLOWING SSE (REF 21, 1a)

DAM RATING CURVE - DOUGLAS

SUBJECT OVERFLOW PARAMETERS AFTER FAILURE

Calculation No: CDQ000020080007

SEM COMPUTED BY 10-22-08 DATE J.C.T. CHECKED BY

Appendix C-5

OVERFLOW PARAMETERS

OVERFLOW ELEVATIONS, Z_c, VARY WITH LOCATION. BECAUSE THE PMF WALLS AT EACH SIDE ARE NOT OVERTOPPED, THEY WILL BE NEGLECTED. THE REMAINDER WILL BE DIVIDED AS SUCH:

ⓐ $B = 18.83'$, $Z_c = 1009'$, $L = 93'$
ⓑ $B = 53'$, $Z_c = 927.5'$, $L = 279'$
ⓒ $B = 18.83'$, $Z_c = 1009'$, $L = 27.17'$
ⓓ $B = 28'$, $Z_c = 1009'$, $L = 269.33'$
ⓔ $B = 60'$, $Z_c = 937'$, $L = 538'$

SECTIONS ⓐ, ⓒ AND ⓓ WILL BE ANALYZED USING THE USACE HYDRAULIC DESIGN CRITERIA (REF 4). SPECIFICALLY, DESIGN CHART 711 (REF 6, ATT. 4) WILL DETERMINE "C_f".

$$0 \le H_c \le (HW_{max} - Z_c)$$

ⓐ & ⓒ $0 \le H_c/B \le (1022.5' - 1009')/18.83' = .717$; $2.65 \le C_f \le 2.8$

ⓓ $0 \le H_c/B \le (1022.5' - 1009')/28' = .482$; $2.65 \le C_f \le 2.7$

BECAUSE EXPERIMENTAL DATA EXISTS, THE FIT CURVE FROM Sh. 3 WILL BE USED TO DETERMINE C_f FOR ⓑ & ⓔ.

$$0 \le H_c \le (HW_{max} - Z_c)$$

ⓑ $H_c = 1022.5' - 927.5' = 95' > 37.35'$

$C_f = 2.53 + (.0103)(95' - 37.35') = 3.12$

ⓔ $H_c = 1022.5' - 937' = 85.5' > 37.35'$

$C_f = 2.53 + (.0103)(85.5' - 37.35') = 3.03$

} @ HW_{max}

DAM RATING CURVE - DOUGLAS

SUBJECT OVERFLOW PARAMETERS AFTER FAILURE

Calculation No: CDQ000020080007

SEM 10-22-08 J.C.T.

COMPUTED BY DATE CHECKED BY

Appendix C-6

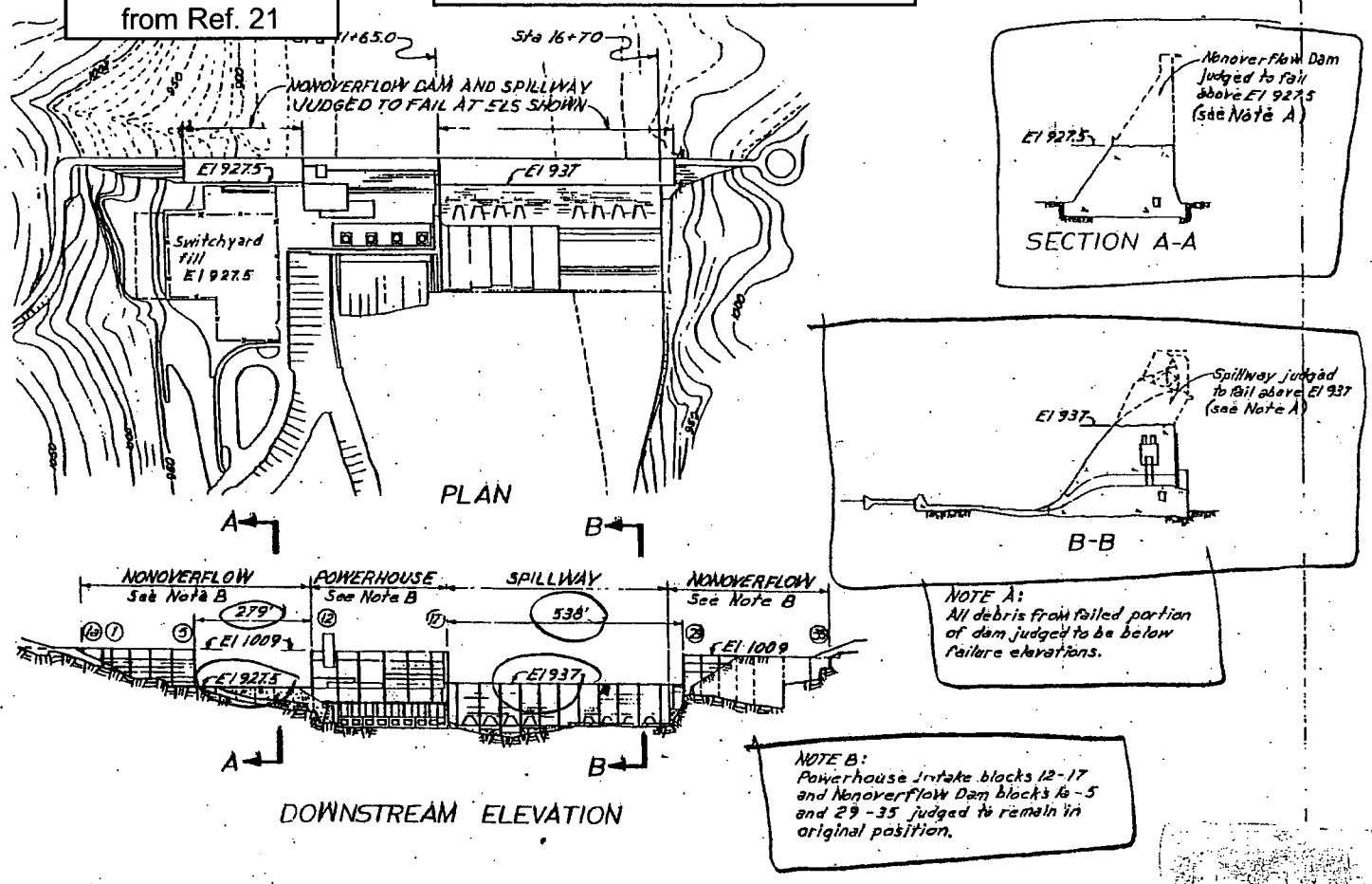
SUMMARY OF OVERFLOW PARAMETERS AFTER SEISMIC FAILURE

Z_c (ft)	L (ft)	C_f	
1009'	120.17'	2.8	
1009'	269.33'	2.7	
927.5'	279'	3.12	VALUE AT HW_{max}
937'	538'	3.03	

Appendix C-7
from Ref. 21

Calculation No: CDQ000020080007

Preparer: S.E.M.
Checker: J.C.T.



FROM TVA CALC:

"DOUGLAS DAM STABILITY ANALYSIS FOR 1/2 SSE + 1/2 PMF"

RIMS

B25 '88 0520 308

pages 68, 69 and 70 of 72

DAM RATING CURVE - DOUGLAS / OUTFLOW PARAMETERS AFTER FAILURE
CDQ 0000200800007

(1a)

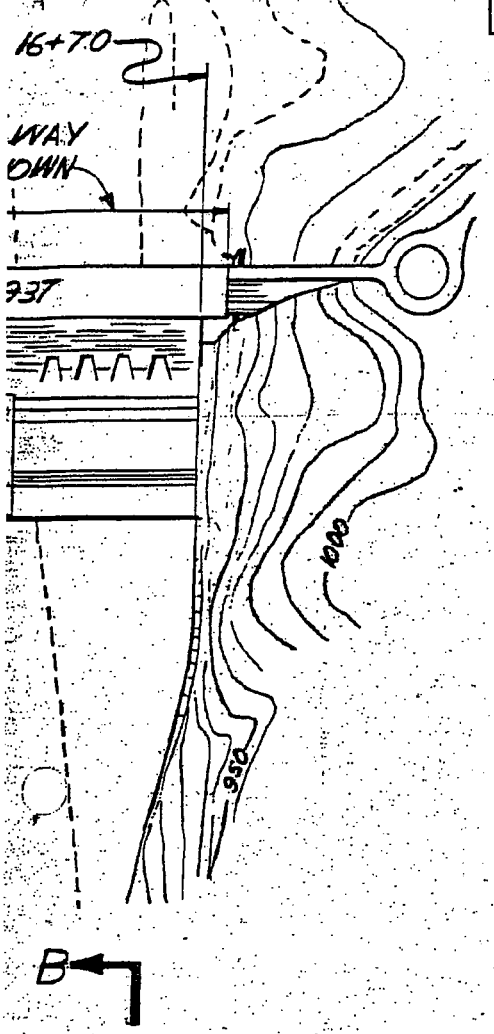
DAM RATING CURVE - DOUGLAS / OVERFLOW PARAMETERS AFTER FAILURE

Preparer: S.E.M.

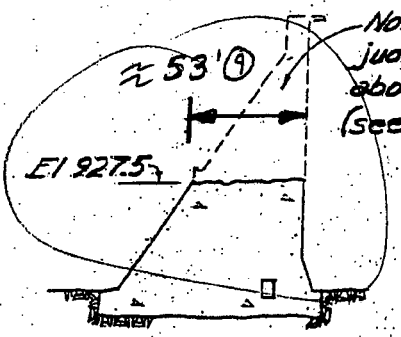
Checker: J.C.T.

Appendix C-8
from Ref. 21

Calculation No: CDQ000020080007

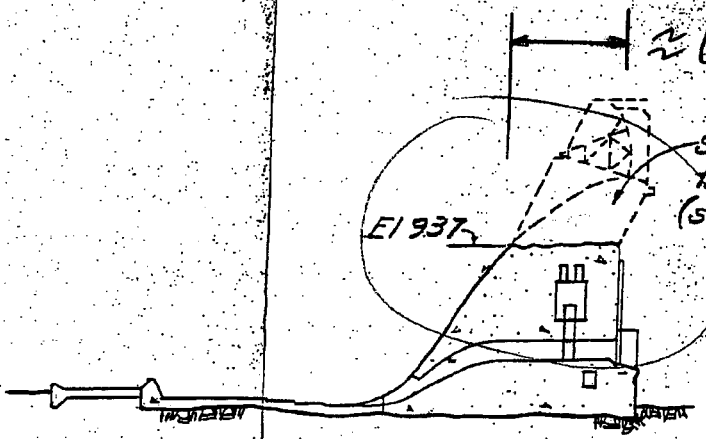


B



SECTION A-A

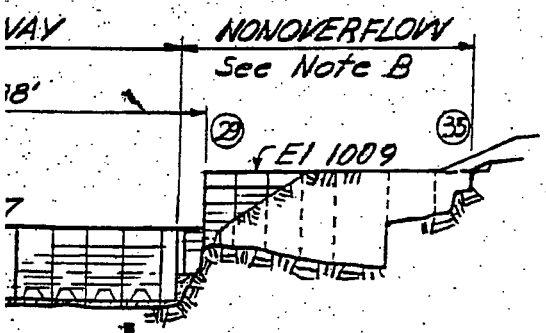
1b



B-B

Norris crest section
=76'

NOTE A:
All debris from failed portion of dam judged to be below failure elevations.



B

TION

NOTE B:
Powerhouse intake blocks 12-17 and Nonoverflow Dam blocks 1a-5 and 29-35 judged to remain in original position.

Ref. 21
page 70 of 72

Douglas Dam, Assumed Condition of Dam After Failure, 1/2 SSE and 1/2 Maximum Possible Flood Figure

DAM RATING CURVE - DOUGLAS
CDQ00002008 0007
OVERFLOW PARAMETERS
AFTER SEISMIC FAILURE
Preparer: S.E.M.
Checker: J.C.T.

(k)

Page 7 of 72
TVA Calc. no. B25 '88 0520 80?
RIMS #

Appendix C-9
from Ref. 21

Calculation No: CDQ000020080007

Douglas - Summary of Mode of failure

HEPESDGHSQN-WBNBLNBFN

Recommended by: LFS 3-7-87
CDW 3-9-87

Saddle Dam: The Saddle dam has factor of safety of 1 and was judged not to fail since more thorough analysis including soil test to determine the soil constants more accurately would improve the F.S.

Nonoverflow:
The nonoverflow section at Douglas (above el 890) is identical to Cherokee and is assumed to fail at a point corresponding to failure at Cherokee (ie Switchyard Elevation 927.5). This is a judgment on the conservative side since Douglas is not as high as Cherokee and amplification of ground acceleration is slightly less.

Douglas is also similar to Tellico. Analysis of 110' high section (rock foundation) at Tellico showed that it could resist the OBE + ½ Max probable flood. Analysis 110' high section at Douglas showed that it was borderline failure (77 psi tension resultant 1' outside base), the main difference being the difference in tailwater between the two projects. From this it was judged that an 80' high section at Douglas would resist the OBE + ½ Max probable flood without failure.

Spillway:
The spillway at Douglas is identical to the Spillway at Cherokee above the break point where failure occurs at Cherokee. Douglas is 5' higher than Cherokee but the amplification of ground acceleration is almost identical. Therefore it was judged that Douglas would fail at an elevation corresponding to failure at Cherokee (ie. Douglas Spillway judged to fail at el 937).

Intake:
The intake at Douglas is more massive than the nonoverflow section and is backed up by the powerhouse. The increased rigidity was judged to reduce amplification. Therefore the Intake was judged Not to fail

Remark: All debris is assumed to be below el 937 & 927.5

DAM RATING CURVES - DOUGLAS
OVERFLOW PARAMETERS AFTER FAILURE
CDQ 0000200800007 Preparer: S.E.M.
Checker: J.C.T.

Appendix C-10
from Ref. 21

Calculation No: CDQ000020080007

COVER SHEET FROM CALC IN REF. 21

1d

TVA 10697 (DNE 6-86) DNE CALCULATIONS

TITLE Douglas Dam - Concrete Stability Analysis For ½ SSE + ½ PMF	PLANT/UNIT SQN, WBN, BLN, BFN
PREPARING ORGANIZATION DNE&C	KEY NOUNS (Consult RIMS DESCRIPTORS LIST) Sequoyah NP, Douglas Dam, Concrete Stability Analysis, ½ SSE + ½ PMF
BRANCH/PROJECT IDENTIFIERS HEPES DGH SQN WBN BLN BFN ESSENT. CALCS A 5	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.
	Rev (for RIMS' use) — RIMS accession number
	R0 8704150029 (65) B66 870316 002
APPLICABLE DESIGN DOCUMENT(S)	R1 8806060001 (71) B25 880520 308
	R —
SAR SECTION(S) / UNID SYSTEM(S)	R —

Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable)	N/A		
Prepared L. F. Schlomer	C.D. Wagner		
Checked C. D. Wagner	L.F. Schlomer		
Reviewed Archie T. Dean	Archie T. Dean		
Approved W. C. Buttrey	C.M. Johnson		
Date 3/23/87	5/20/88		
List all pages added by this revision.	ii, 52		
List all pages deleted by this revision.	—		
List all pages changed by this revision.	2-11, 14, 17, 24-35, 41, 44, 50, 51		

Safety-related? Yes ☒ No ☐

Statement of Problem:

Determine effect of seismic event concurrent with major flood on typical nonoverflow and spillway blocks. Analyze for ½ SSE + ½ PMF.

VERIFICATION OF CONCURRENT SSE & PMF

Abstract

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒

Concrete stability analysis on typical nonoverflow and spillway blocks for ½ SSE + ½ PMF

Note:

These calculations were accomplished over a period from 1972 through 1977 in support of the Sequoyah Nuclear Plant FSAR. At the request of DNE in March of 1987, they have been reviewed, verified, and put into RIMS to satisfy the nuclear calculation verification program.

☐ Microfilm and store calculations in RIMS Service Center. Microfilm and destroy. ☐

☒ Microfilm and return calculations to L. F. Schlomer Address: W3 C173 C-K

cc: RIMS, SL 26 C-K

0 0 0 1

Preparer: S.E.M.
Checker: J.C.T.

Appendix C-11
from Ref. 19

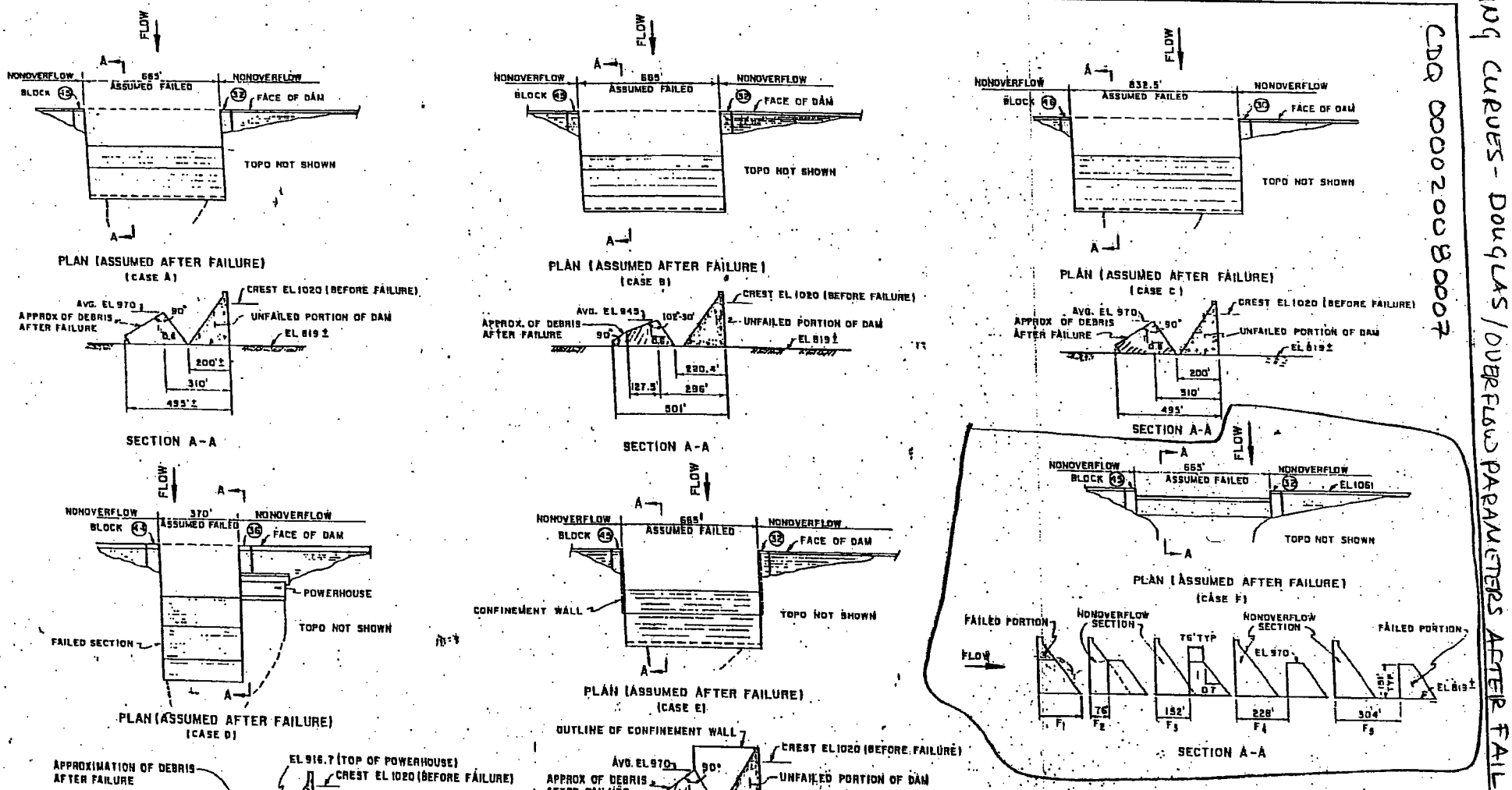
Calculation No: CDQ000020080007

2a

DAM RATING CURVES - DOUGLAS / OVERFLOW PARAMETERS AFTER FAILURE

CDQ 000020080007

PLATE



NORRIS DAM FAILURE STUDY

DETAILS OF

CASES A, B, C, D, E, & F 1 TO 5

NORRIS DAM PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY, NORRIS

DAM RATING CURVES - DOUGLAS / OVERFLOW PARAMETERS AFTER FAILURE

Calculation No: CDQ000020080007

Preparer: S.E.M.

Checker: J.C.T.

Appendix C-12
from Ref. 19

(2b)

TABLE 6

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE F_1

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
81	1007.35	384,100	885.0
82	1018.63	596,600	900.5
83	1027.25	801,300	912.7
84	1035.85	997,000	923.4
85	1043.15	1,207,100	933.5
86	1049.65	1,401,700	943.0
87	1055.80	1,598,700	951.0
88[1]	983.80	96,800	851.5
89[1]	992.88	198,700	865.0
90[1]	1000.00	296,700	875.5

[1]Model flow was unstable because of the small head on the crest. Test classified as unreliable.

DAM RATING CURVES - DOUGLAS

Calculation No: CDQ000020080007

Appendix C-13
from Ref. 19

2c

FROM NORRIS DAM FAILURE STUDY

Preparer: S.E.M.
Checker: J.C.T.

TEST PROCEDURE

During each discharge rating test a constant discharge was set up using the appropriate tailwater level shown on Plate 5. Recordings were then made of the headwater elevation, tailwater elevation and the discharge. The test procedure was repeated at other constant flows so that sufficient information was obtained to establish a discharge rating curve of headwater elevation vs. discharge for each case tested.

TEST CASES

Six failure schemes designated as cases A, B, C, D, E and F_{1-5} were rated. Details of the schemes are shown on Plate 1. The existing topography both upstream and downstream from the dam was duplicated in the model from contours given on Plate 4. The debris configuration was assumed to be as shown on Plate 1 for each case.

Case E was identical to case A except that the sideflow to the left and right of the debris was prevented by constructing sheet metal walls as shown on Plate 1. The difference between the discharge of case A and E at any headwater elevation will give the discharge not going over the top of the debris.

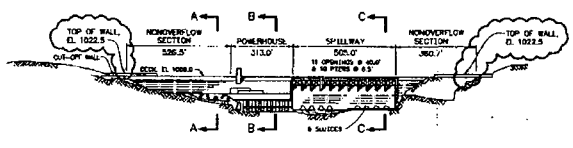
Four tests labeled No TW Effect on Plate 2 were conducted with the tailwater level lowered so that it would have no influence on the headwater level. At near maximum test Q the headwater level was reduced 5.4, 5.3 and 7.6 feet for cases A, B and D, respectively, by eliminating the tailwater effect.

For case F_{1-5} the remains of the dam, assumed broken off at elevation 970, was moved to five different positions as shown on Plate 1. A discharge rating was obtained for each location so that data would be available to estimate discharge coefficients which might be applicable to failures at other dams.

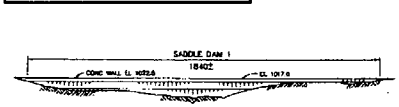
Appendix C-14
Ref. 1

Calculation No: CDQ000020080007

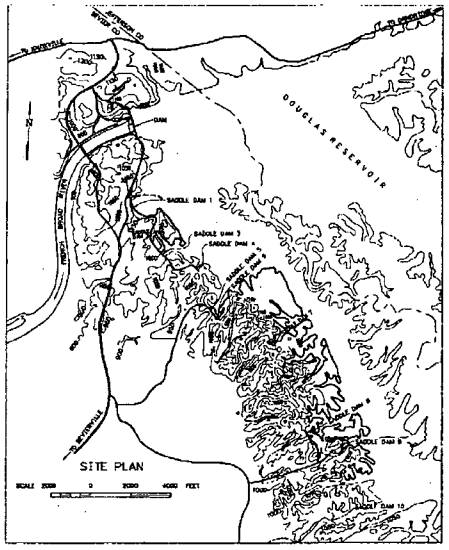
Preparer: S.A.E.M.
Checker: J.C.T.



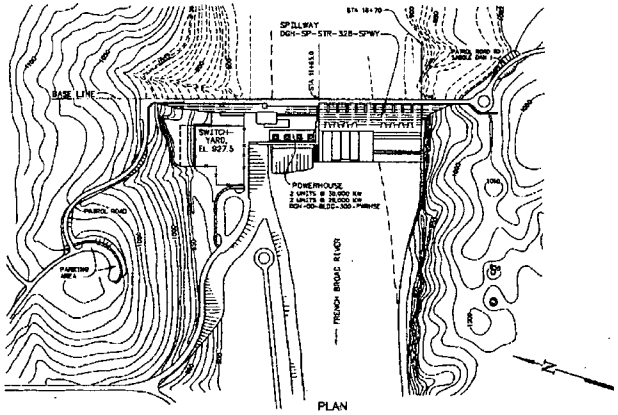
DOWNSTREAM ELEVATION



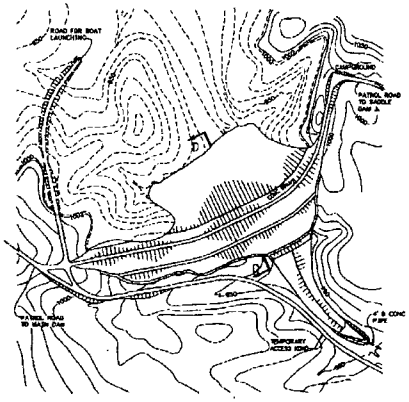
DOWNSTREAM ELEVATION



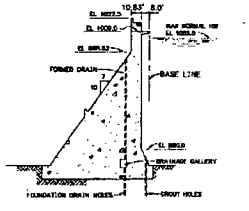
SITE PLAN



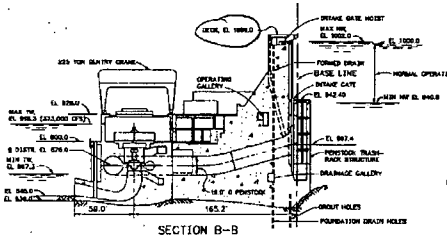
PLAN



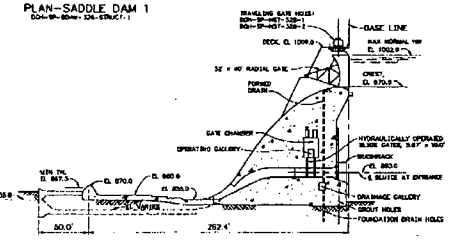
PLAN-SADDLE DAM 1



SECTION A-A

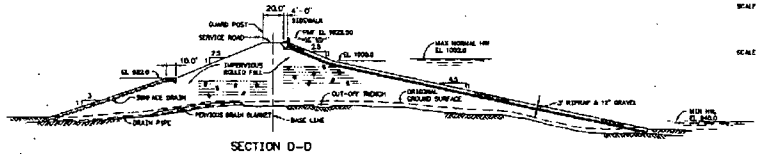


SECTION B-B



SECTION C-C

UNITS TABULATION	
ASSET	UNITS NUMBER
POWERHOUSE	DGH-SP-STR-328-PWRHSE
MAIN DAM WORKS	DGH-SP-STR-328-SPWY
SADDLE DAM 1	DGH-SP-EMBK-329-STRUCT-1
SADDLE DAM 1A	DGH-SP-EMBK-329-STRUCT-2
SADDLE DAM 2	DGH-SP-EMBK-329-STRUCT-3
SADDLE DAM 3	DGH-SP-EMBK-329-STRUCT-4
SADDLE DAM 4	DGH-SP-EMBK-329-STRUCT-5
SADDLE DAM 5	DGH-SP-EMBK-329-STRUCT-6
SADDLE DAM 6	DGH-SP-EMBK-329-STRUCT-7
SADDLE DAM 7	DGH-SP-EMBK-329-STRUCT-8
SADDLE DAM 8	DGH-SP-EMBK-329-STRUCT-9
SADDLE DAM 9	DGH-SP-EMBK-329-STRUCT-10
SADDLE DAM 10	DGH-SP-EMBK-329-STRUCT-11



SECTION D-D

PLANS & ELEVATIONS
SECTIONS

GENERAL NOTES:
1. COMPONENT LOAD NUMBERING SCHEME:
PLANT — UNIT — FUNCTION — SYSTEM — SEQUENCE NO.
DGH — SP — STR — 328 — 1
2. UNITS ARE LISTED IN WHOLE IN THIS DRAWING. SEE TABLE BELOW FOR ASSETS SHOWN ON THIS DRAWING.
3. COMPONENT LOAD NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:
SYSTEM NUMBERS — SYSTEM NAME — FUNCTION CODES — FUNCTION CODES NAME
300 — FACILITIES AND GROUNDS — BLDG — BUILDING
328 — SPILLWAY — DAM — DAM STRUCTURE
329 — DAM — EMBK — SADDLE DAM
HOIST — HOIST
4. FOR PROBABLE MAXIMUM FLOOD MODIFICATIONS, SEE DRAWINGS 312035-SERIES — DAM SAFETY MODIFICATIONS

NO.	DATE	BY	DESCRIPTION
1	1-31-47	EWS	ADDED PMF INFORMATION TO SUPERSEDES BLOCK

SCALE: 1"=200'-0" EXCEPT AS NOTED

MAIN DAM WORKS

GENERAL PLAN,
ELEVATION & SECTIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	APPROVED BY	ADDED BY
	EWS	B.D.C.	W.R.B.		

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
PLANS AND WORKS UNDERGROUND

AUTOCAD R14 | DATE 1-31-97 | 20 | C | 10W200 | R 11

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES: 10W200 R9

PLOT FACTOR: 2400

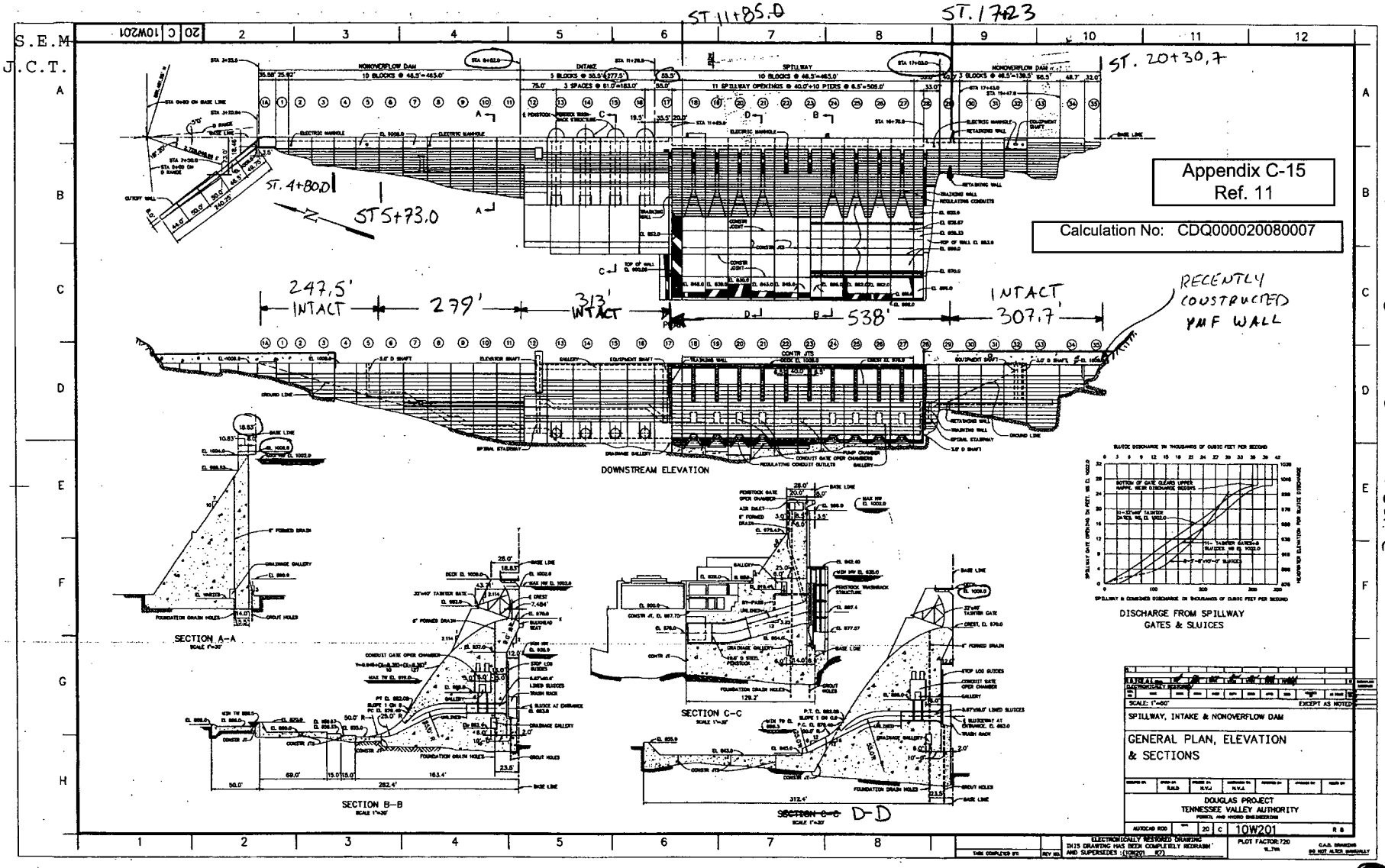
C.A.D. DRAWING DO NOT ALTER MANUALLY

DAM RATING CUPUT - DOUGLAS
DOUBLE FLOOD PARAMETERS AFTER PMF
CDQ 0000200800007
11 of 15
(3)

Preparer: S.E.M
Checker: J.C.T.

DAM RATING CURVE - DOUGLAS
OVERFLOW PARAMETERS AFTER FAILURE

CDQ 00020080007

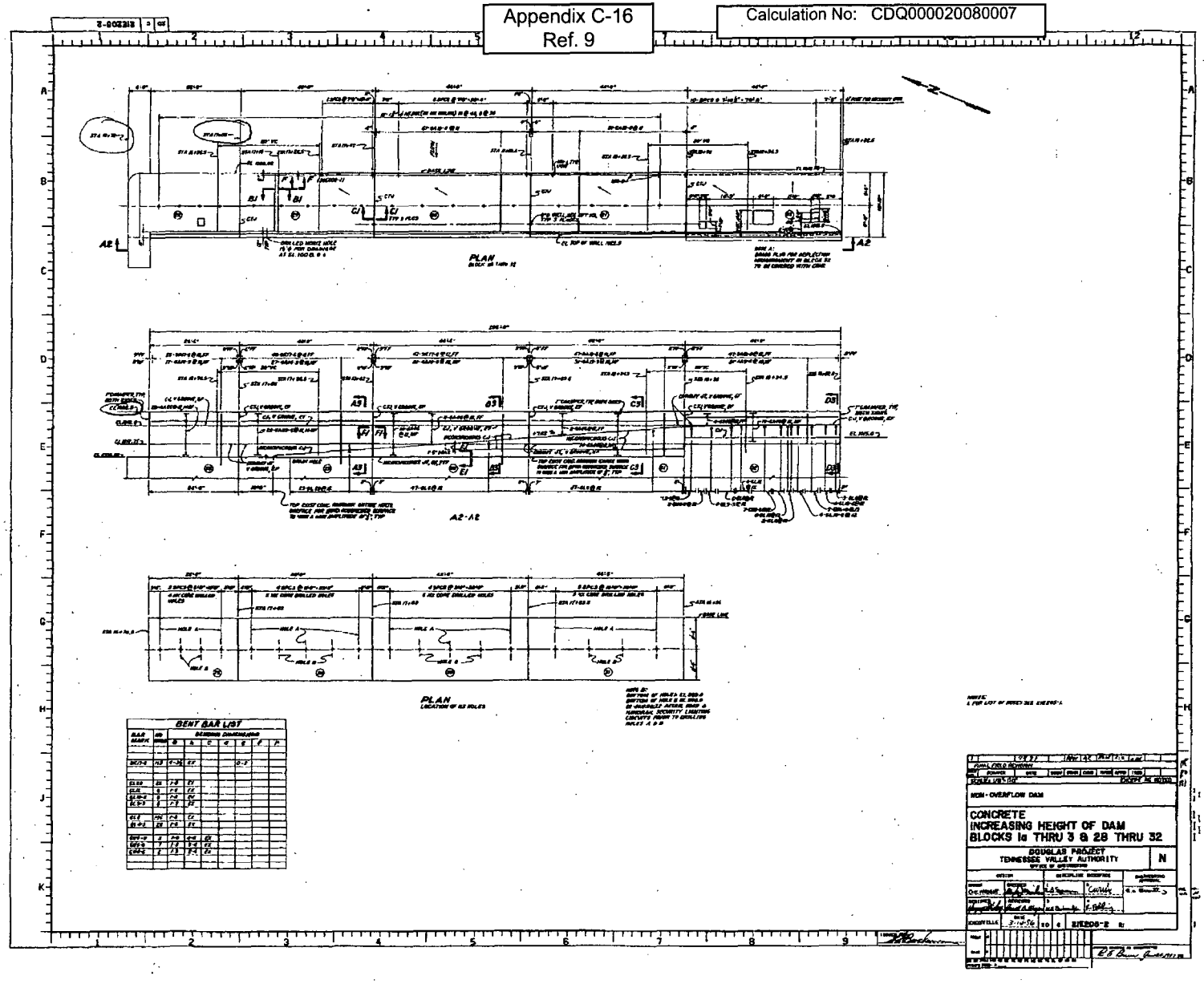


(4)

Preparer: S.E.M.
Checker: J.C.T.

Appendix C-16
Ref. 9

Calculation No: CDQ000020080007



DAM RATING CURVE - DOUGLAS
OVERFLOW DAM AFTER FAILURE

CDQ 000020080007

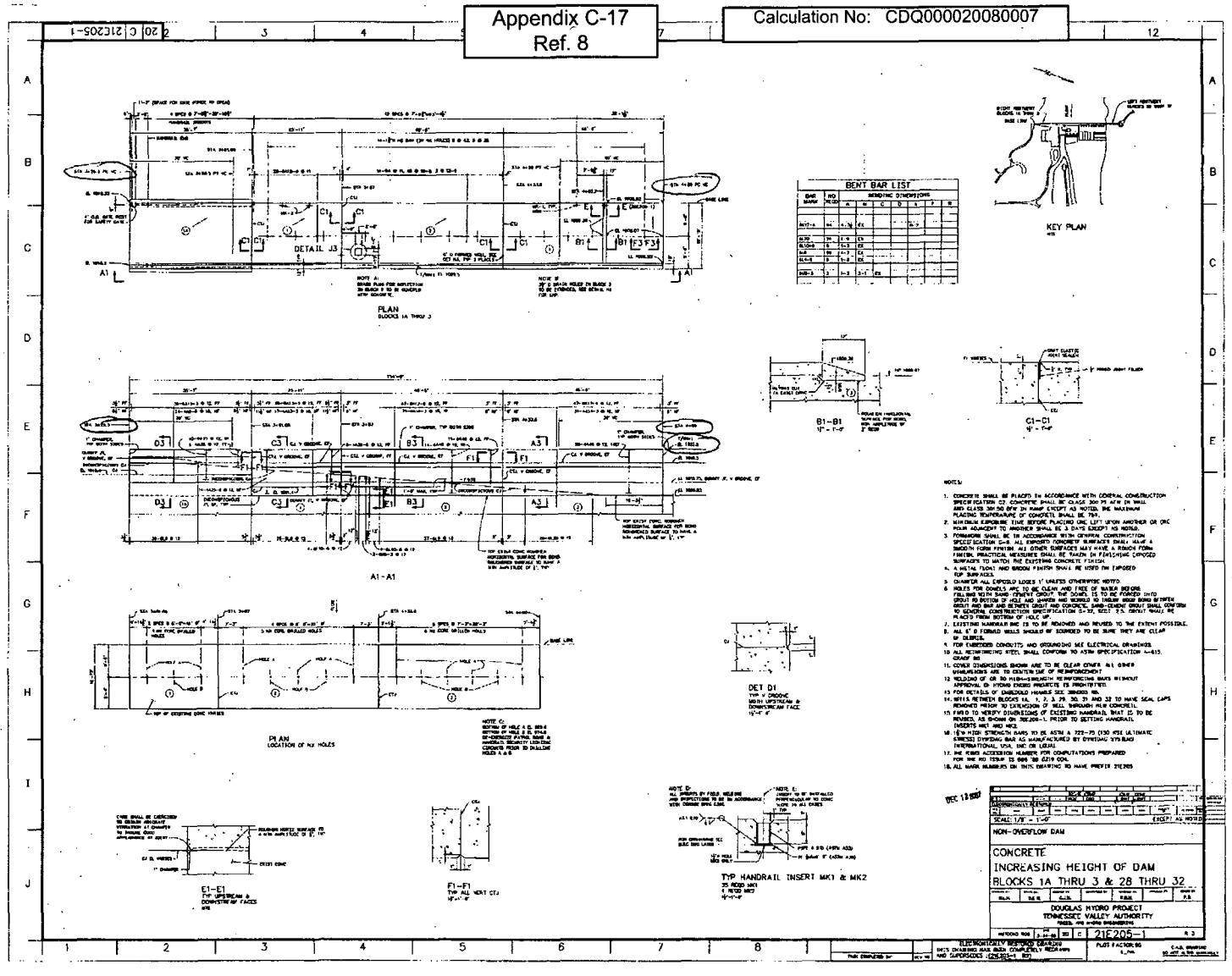
13 of 15

(5)

Preparer: S.E.M.
Checker: J.C.T.

Appendix C-17
Ref. 8

Calculation No: CDQ000020080007



DAM RATING & CURVE - DOUGLAS
OVERFLOW PARAMETERS AFTER FAILURE

CDQ 0000200 80007

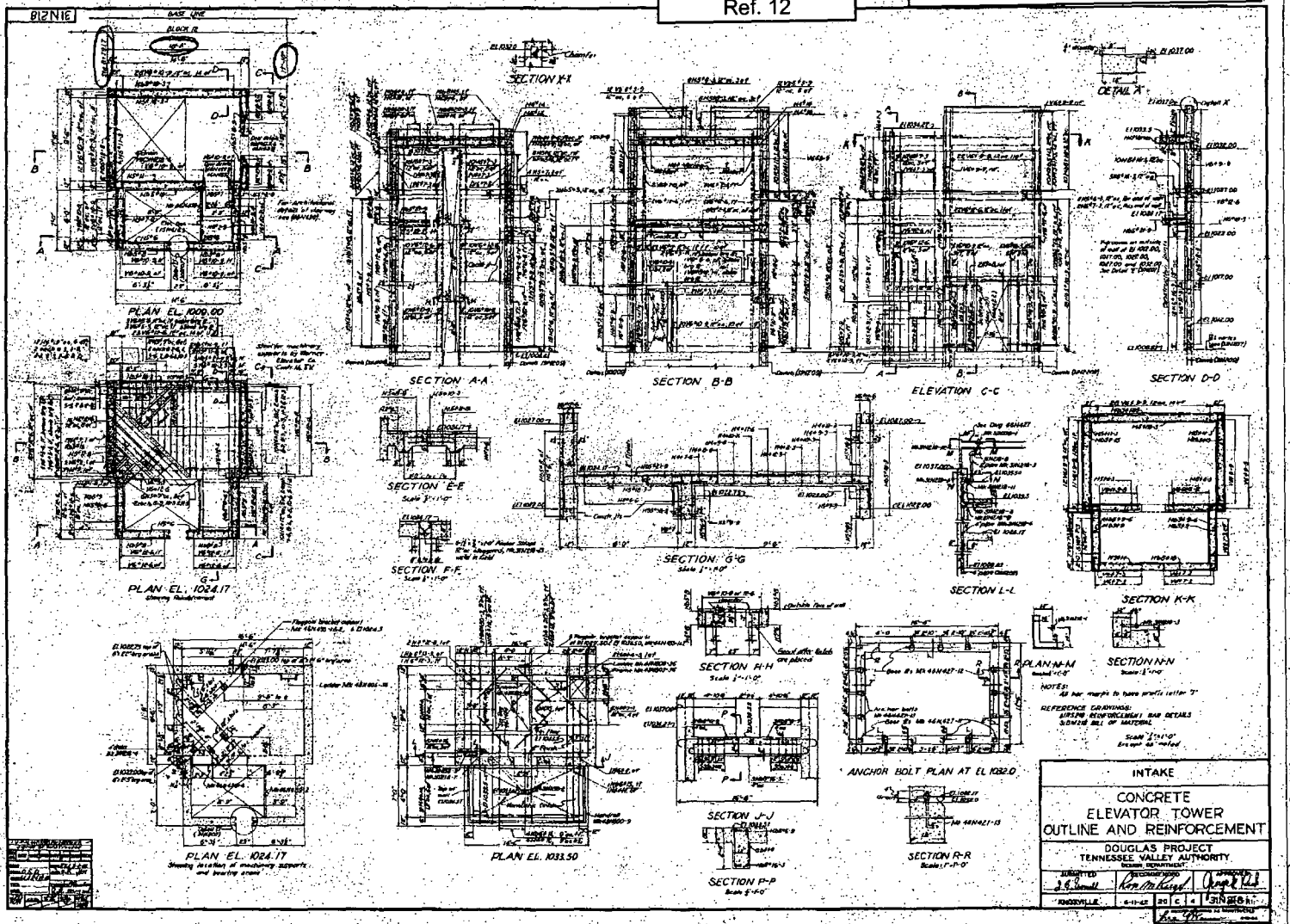
14 of 15

(6)

Preparer: S.E.M.
Checker: J.C.T.

Appendix C-18
Ref. 12

Calculation No: CDQ000020080007



DAM RATING CURVES - DOUGLAS
OVERFLOW DAM GATES AFTER FAILURE
CDQ 0000200800007

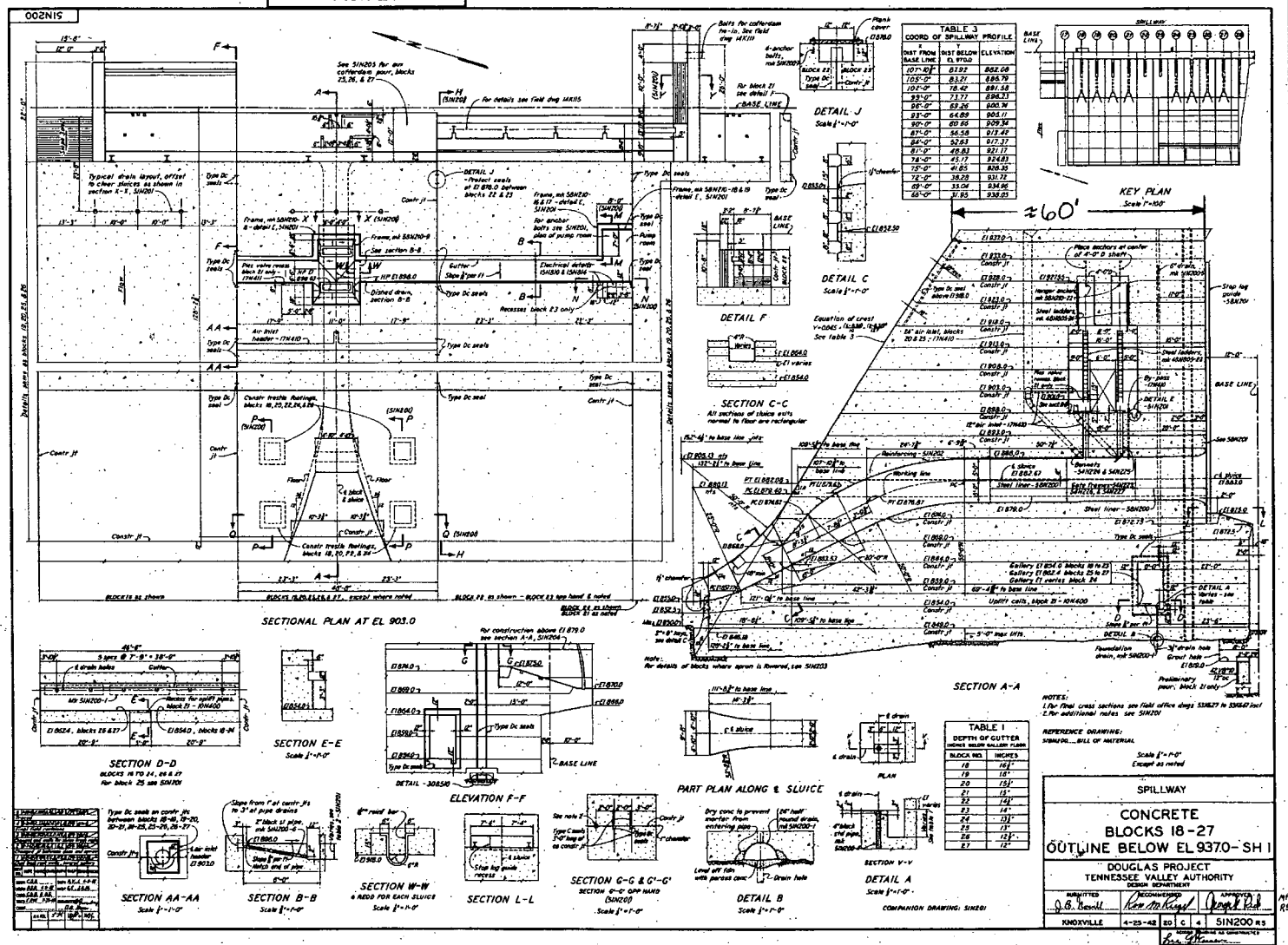
15 of 15

(7)

Preparer: S.E.M.
Checker: J.C.T.

Appendix C-19
Ref. 25

Calculation No: CDQ000020080007



SCALED SPILLWAY WIDTH @ ELEV. 937' SEISMIC FAILURE SECTION

DAM RATING CURVES - DOUGLAS OVERFLOW PARAMETERS AFTER FAILURE
CDQ000020080007

8

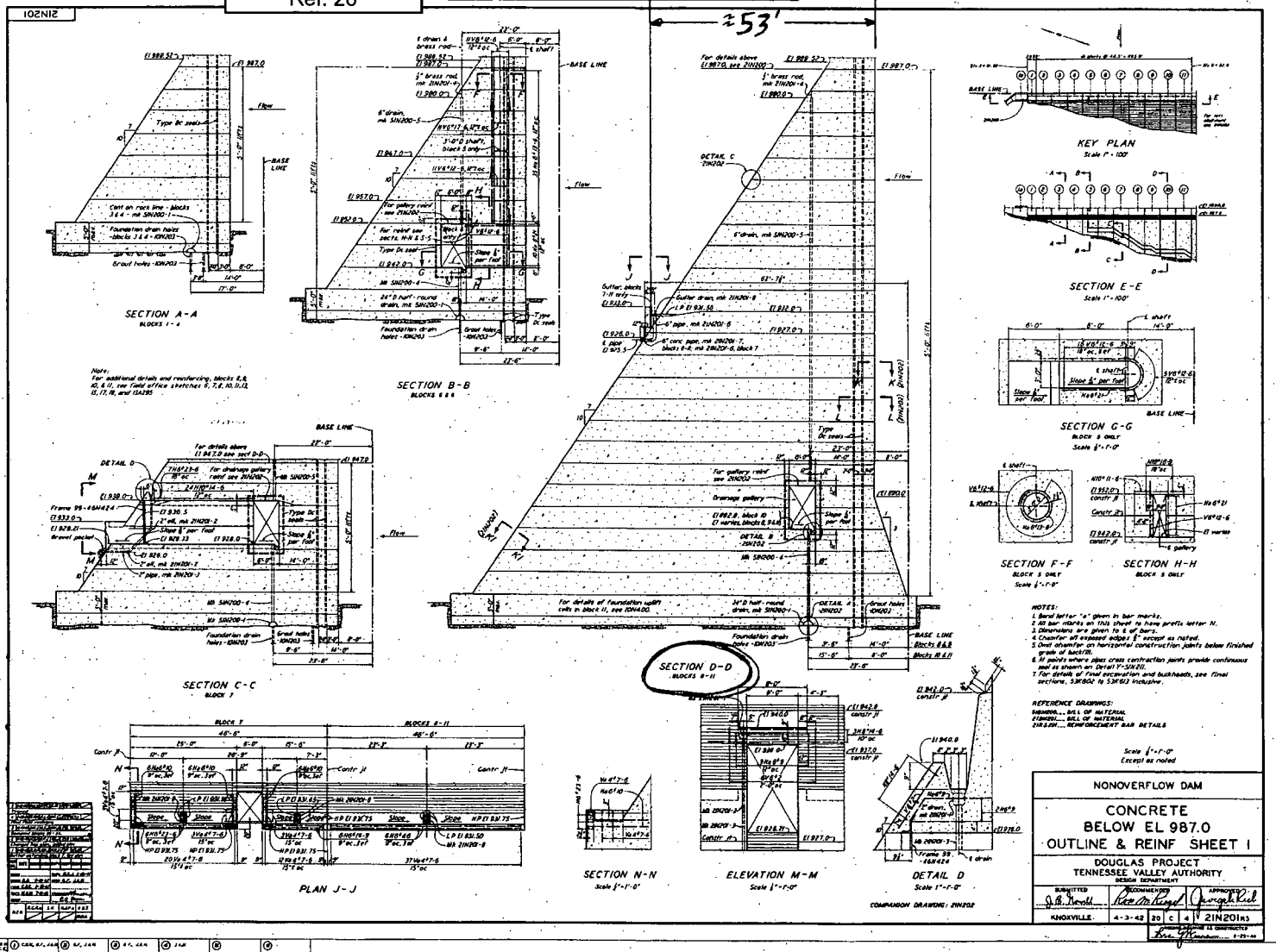
Preparer: S.E.M.
Checker: J.C.T.

Appendix C-20
Ref. 26

Calculation No: CDQ000020080007

SCALED NONOVERFLOW WIDTH @ ELEV. 929.5' SEISMIC FAILURE SECTION

DAM RADIAL CURVES - DOUGLAS
DWG 21N201 NONOVERFLOW CONCRETE BELOW EL 987.0 OUTLINE & REINF SHEET 1
CDQ000020080007



9

DAM RATING CURVES - DOUGLAS

SUBJECT FLOW OVER TOPS OF WIDE-OPEN TAINTER GATES

Calculation No: CDQ000020080007

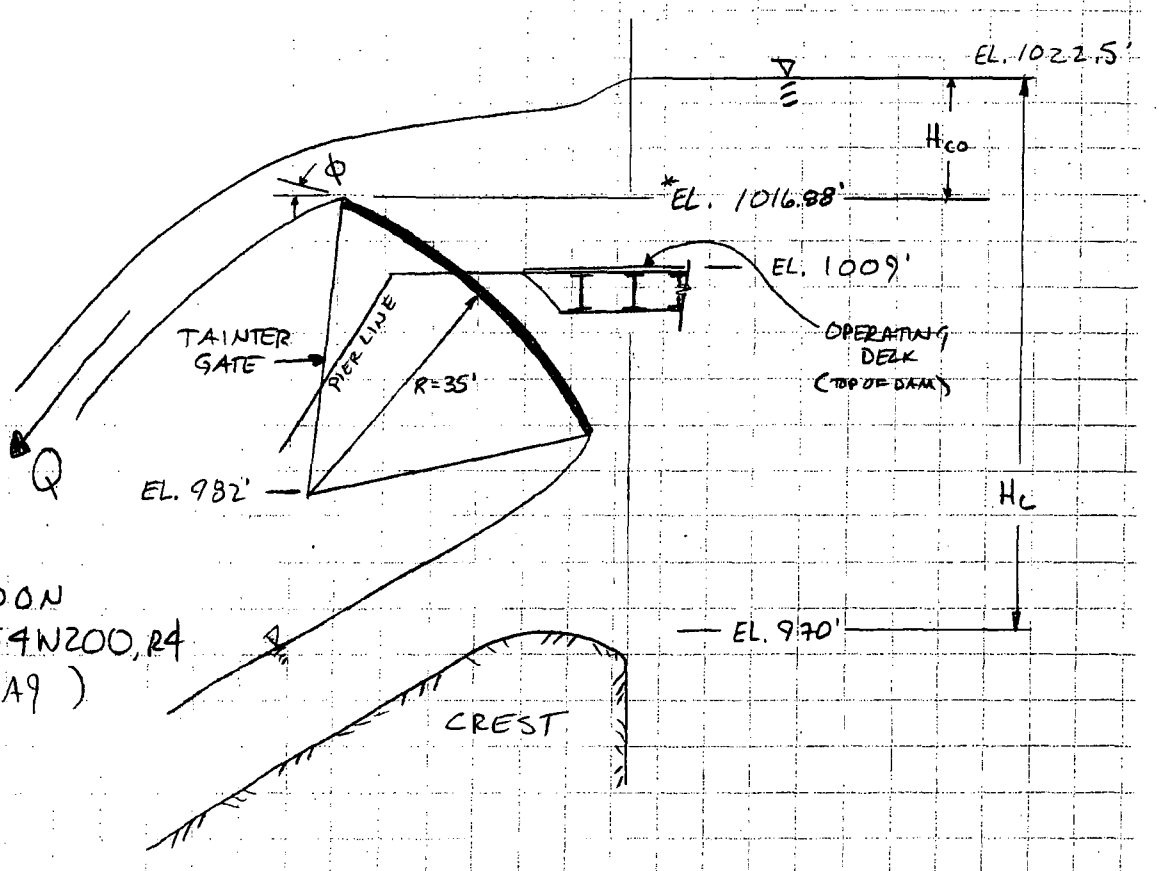
SEM	10-30-08	J.C.T.
COMPUTED BY	DATE	CHECKED BY

Appendix D-1

WITH REFERENCE TO THE SKETCH BELOW, DISCHARGE OVER THE TOPS OF THE OPEN TAINTER GATES IS COMPUTED AS

$$Q_o = C_o L_o H_{co}^{3/2}$$

WHERE L_o = TOTAL LENGTH OF OVERFLOWING GATES = TOTAL LENGTH OF SPILLWAY



* Z_o FROM APP. A

SKETCH BASED ON DRAWING NO. 54N200, R4 (Ref 23, ATTA 9)

A RESONABLE APPROACH TO SPECIFYING C_o IS TO USE DISCHARGE COEFFICIENTS FOR DRUM GATES WHICH PRESENT THE SAME CIRCULAR SURFACE TO OVERFLOW. DISCHARGE COEFFICIENTS FOR DRUM GATES ARE AVAILABLE IN REF. 7, FIG. 6 (ATTACHED AS PAGE 3 TO THIS CALC)

$$C_g = C_g(\theta, H/r)$$

where:

- C_g = SAME AS C_o ABOVE
- θ = SAME AS ϕ ABOVE
- H = SAME AS H_{co} ABOVE
- r = GATE RADIUS = 35' (R ABOVE)

DAM RATING CURVES - DOUGLAS

SUBJECT FLOW OVER TOPS OF WIDE OPEN TAINTER GATES

SEM | 10-30-08 | J.C.T. | Appendix D-2

COMPUTED BY | DATE | CHECKED BY

ANGLE Φ IS COMPUTED AS DESCRIBED IN ATT 8-3:

$$\Phi = \tan^{-1}\left(\frac{X_o}{Y_o}\right) \text{ WITH } \quad X_o = R\cos(\theta - \alpha)$$

$$Y_o = Z_o - Z_{trr} = 1016.88' - 982' = 34.8'$$

FROM APPENDIX A:

$R = 35'$, $\theta = 55.537°$, $\alpha = -29.756°$

$$\Rightarrow X_o = 35\cos\left(55.537° - (-29.756°)\right) = 2.872'$$

$$\Rightarrow \Phi = \tan^{-1}\left(\frac{2.872'}{34.8'}\right) = 4.72°$$

HEADWATER RATING CURVE COMPUTED TO HW ELEV. 1022.5'

$$\Rightarrow 0 \le H_{co} \le 1022.5' - 1016.88' = 5.62'$$

AND $0 \le H/r \le 5.62'/35' = .161$

FROM REF. 7 ("RATING CURVES FOR FLOW OVER DRUM GATES", BRADLEY)

FIGURE 6 $\Rightarrow$ $3.34 \le C_o \le 3.54$ $\boxed{C_o = 3.4}$

FOR HEADWATER RATINGS, IT IS BEST TO USE VALUES NEAR THE LOW END FOR ALL HEADS THIS IS BECAUSE UNCERTAINTIES AND THE MAGNITUDE OF THE OVERFLOW DISCHARGE DO NOT JUSTIFY FURTHER REFINEMENT. THE LOW END IS USED BECAUSE THE OVERFLOW "Q" IS PROBABLY LESS THAN DRUM GATE "Q". THE REASONING IS:

- TOTAL OVERFLOW DISCHARGE < 4 % OF TOTAL DAM DISCHARGE (SEE RESULTS), SO SMALL VARIATIONS IN C_o HAVE NEGLIGIBLE EFFECTS ON TOTAL DAM DISCHARGE. (.1 CHANGE IN $C_o \Rightarrow \frac{1}{3.4}(4\%) = .1\%$)
- FLOW UNDER GATE CAUSES SIGNIFICANT DRAWDOWN IN WATER LEVEL UPSTREAM FROM GATE WHICH SHOULD RESULT IN LESS OVERFLOW THAN PREDICTED FOR AN EQUIVALENT DRUM GATE.
- OPERATING DECK MAY IMPEDE FLOW AND REDUCE DISCHARGE.

Preparer: S.E.M.
Checker: J.C.T.

Appendix D-3
from Ref. 7

Calculation No: CDQ000020080007

been able to check the discharge measurements of Bazin. However, the actual values are not so important for the case at hand as is the significance of the trend.

Method of Combining Test Results

The method for combining results from the eleven drum gates tested (Table 2) consisted of first plotting the coefficient of discharge data separately

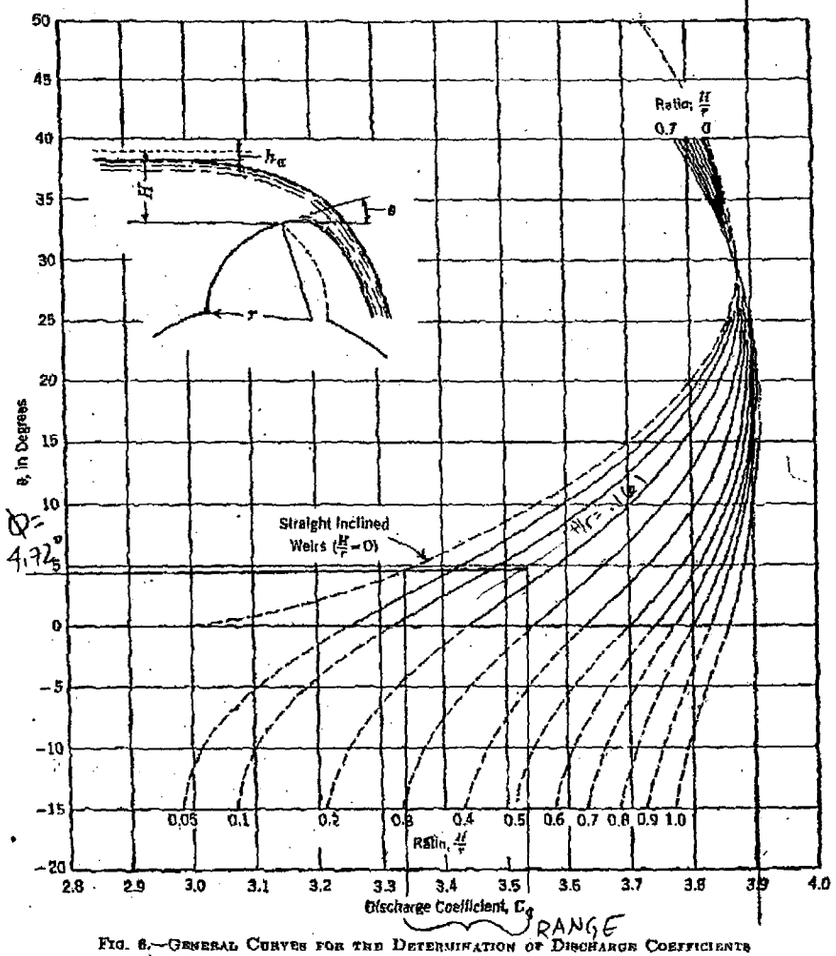


Fig. 6.—General Curves for the Determination of Discharge Coefficients

for each gate as illustrated by the sheet for the Shasta Dam gate (Fig. 5). With the coefficient of discharge as the abscissa and H/r as the ordinate, each curve in Fig. 5 represents a different gate angle θ, which the tangent to the downstream lip of the gate makes with the horizontal. In all cases, H is the

total head, including the velocity head of approach, measured above the high point of the gate, and r is the radius of the gate. In Fig. 5, C_s is based on the relationship, $Q = C_s L H^{\frac{3}{2}}$. For positive values of θ, the head was measured above the lip of the gate, whereas for negative angles it was observed above the high point, or crest, of the gate proper. The method of measuring the head is illustrated in Fig. 2.

Upon completion of a similar set of curves for each gate tested, the eleven sets of curves were replotted and combined into the chart exhibited as Fig. 6. The results from the various gates showed good general agreement; and the curves in Fig. 6 constitute the general experimental information needed for determining the discharge coefficients for gates in raised or partly raised positions. The supporting points are not shown in Fig. 6, but the individual information for each gate is listed in Table 2.

Analysis of Test Results

The curves in Fig. 6 show a tendency toward reversal, similar to that exhibited by the Bazin curve in Fig. 4, but the points of inflection vary from $\theta = 20°$ to $\theta = 30°$, depending on the value of H/r. Fig. 4 showed the coefficients to vary only slightly with the head, but in this case the coefficients definitely vary with the head.

A matter of significance is the reversal of the (H/r)-order which occurs at 29° (Fig. 6). The coefficient of discharge has but one value, 3.88, when θ approximates 29°; thus, it is insensitive to both the radius and the head on the gate for this angle. The curve for $H/r = 0$ approximates a drum gate of infinite radius and was obtained from the data of Bazin (Fig. 4) by applying a uniform adjustment.

As stated previously, similitude is valid for small negative angles of θ, as well as for positive angles up to 90°; thus, the curves in Fig. 6 are shown and recommended for use down to $\theta = -15°$. As the gate is lowered beyond this angle, the curves double back and converge, finally terminating in the free flow coefficient.

The discharge coefficients in the region between $\theta = -15°$ and the gate completely down are determined by graphical interpolation. Interpolation is accomplished by plotting head-discharge curves for several gate angles between −15° and the maximum positive angle. Also the head-discharge curve is plotted for the free crest. This information is then cross-plotted to obtain values in the transition zone. The method will be explained in the example that follows. It will be discovered that negative angles greater than −15° (with the exception of the free crest) are not particularly important from an operator's standpoint, as a change in gate position has little effect on the discharge in this range.

It must be assumed that the coefficient of discharge is known for at least one value of the head on the free crest (gate completely down) for the particular spillway under consideration. With the coefficient known for one or more heads, the complete coefficient curve for the free crest can be plotted by consulting Fig. 7, in which H_e and C_e are the designed head and the coefficient

DAM RATING CURVE - DOUGLAS
FLOW OVER TOPS OF WIDE OPEN TAINTER GATES
CDQ0000200800007
3 of 3

Appendix E: Hydrostatic Loads on the Spillway Tainter Gates

The Hydrostatic loads on the spillway tainter gates for Douglas Dam can be found in the following calculations.

E1 References

E1. "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates, pages 76-100" Tennessee Valley Authority, HEPE3WBHSQN-WBNBLNBFN.

E2 Calculations

Reference E1 evaluates the structural capacity of the radial spillway gates at Watts Bar Dam. This reference was used as a basis for evaluating the margin between the forces on the closed gates (FR_{closed}) when the headwater elevation is at the top of the gate (1002.00 feet) and when the gates are completely open (FR_{open}) and the headwater elevation is at 1022.50 feet. The margin is defined at the ratio of FR_{open} to FR_{closed}. The calculation of these forces and the results of this comparison are shown in Figure E1.

Douglas Hydrostatic Forces on Gates

Comparison of forces when gates are closed and HW is at 1002.00 feet (top of gate) vs. when gates are fully open and HW at an elevation of 1022.50 feet.

Attribute	Symbol	Value	Unit
top elev	Zo	1002.00	ft
trun elev	Ztr	982.00	ft
sill elev	Zsill	969.64	ft
radius	R	35	ft
length	L	40	ft
angle up	α2	34.85	deg
angle lwr	α	20.68	deg
angle tot	θ	55.53	deg
area of lower slice	Aslice1	593.62	ft^2
proj area	AProjected	1294.40	ft^2
Desgn LdH	FRx	1306867.66	lbs
Result elv	Z1	980.43	ft
Result ang deg		2.58	deg
Result ang rad		0.04	rad
Result Dsgn	Horiz	1305546.59	lbs
Area slice upper	Aslice2	372.55	ft^2
Area triangle	Atriangle	287.23	ft^2
project vert	x1	6.28	ft
vert weight water	FRy	100392.74	lbs
Resultant load - Gates Closed	FR_{closed}	**1310718.04**	lbs
vert open fm calc	calc App A	29.37	ft
max hw	calc	1022.50	ft
lwr lip elev	Z2	999.01	ft
bot angle	α3	29.08	deg
top elev	Zo	1016.85	ft
project area for h	AProjected	713.40	ft^2
Flood LdH	FRx	648713.21	lbs
Height over gate	y1	5.65	ft
Height ratio to orig		1.63	(ratio)
project vert	x2	27.30	ft
Flood LdV1		385320.34	lbs
Flood lLdV2		386333.18	lbs
Total Flood LdV	FRy	771653.53	lbs
Resultant load - Gates Fully Open	FR_{open}	**1008106.14**	lbs
Margin	FR_{open}/FR_{closed}	**0.77**	(ratio)

Figure E1: Douglas Spillway Gate Margin Evaluation

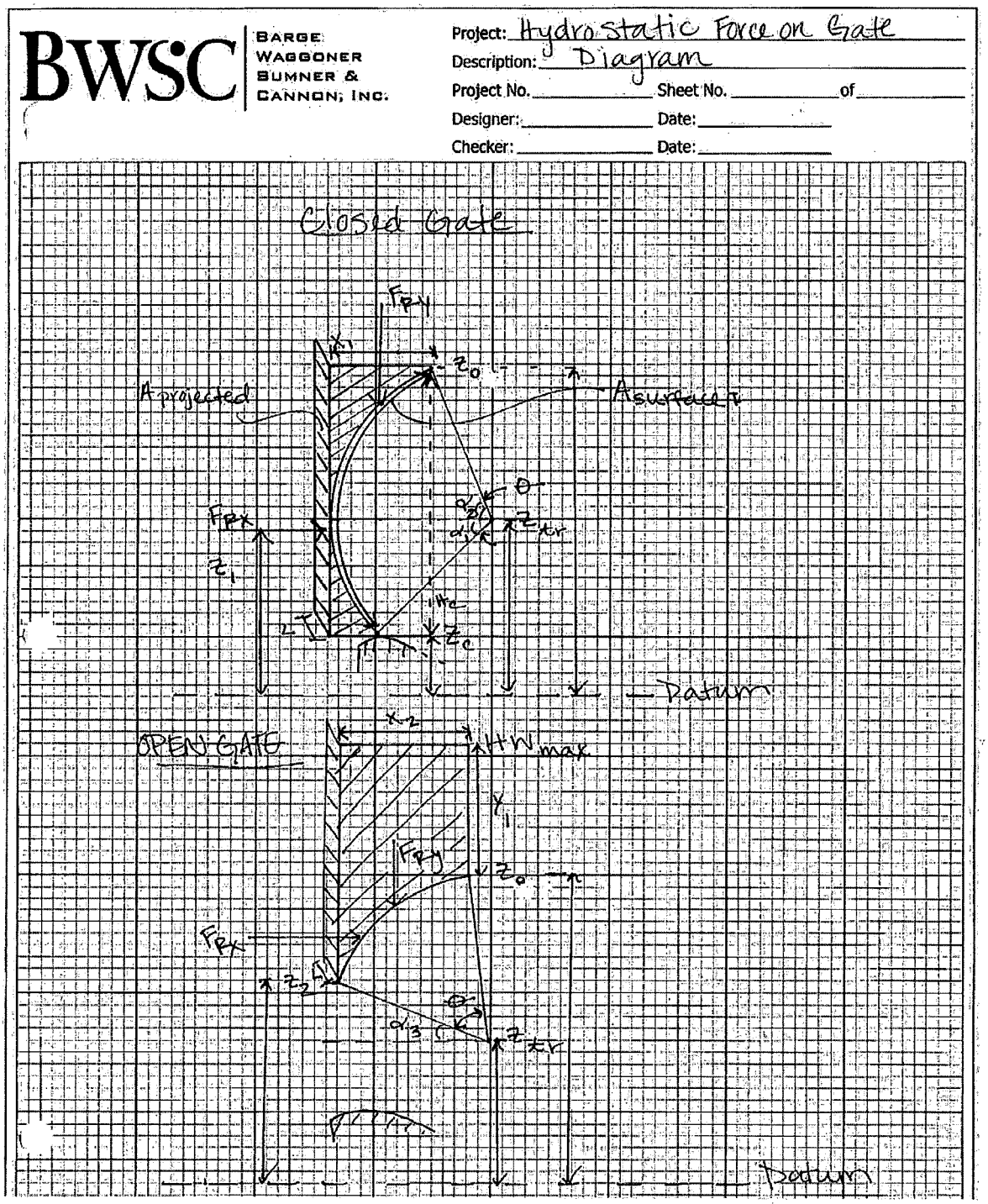
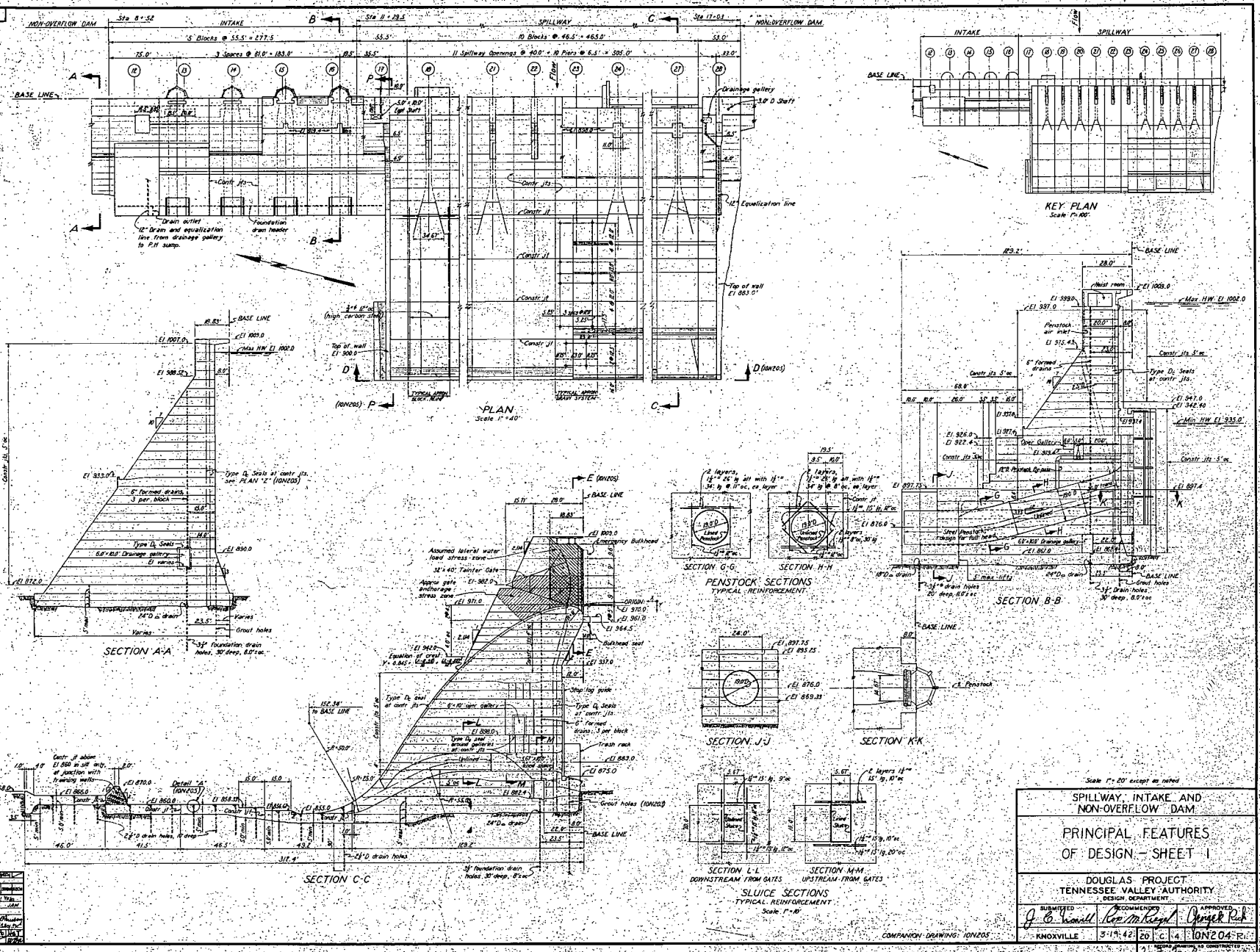
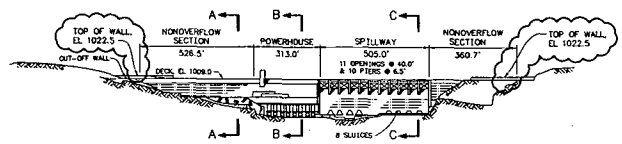


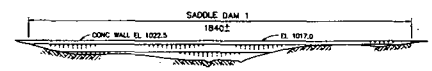
Figure E2: Diagram of Hydrostatic Forces

10N204

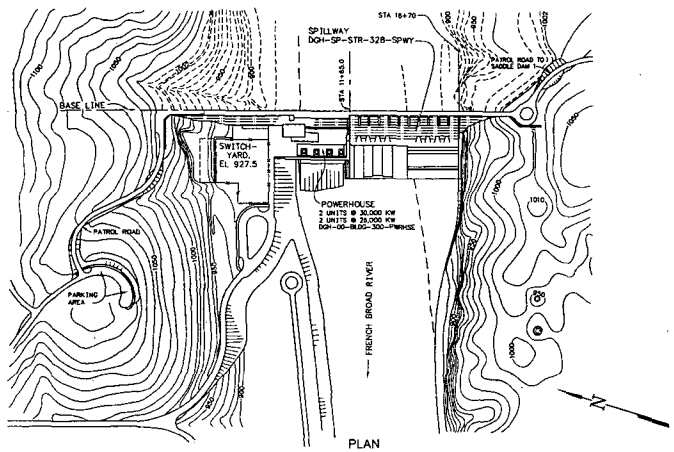

NON-OVERFLOW DAM
INTAKE
SPILLWAY
NON-OVERFLOW DAM
5 Blocks @ 55.5' = 277.5
3 Spaces @ 61.0' = 183.0'
11 Spillway Openings @ 40.0' = 10 Piers @ 6.5' = 505.0'
BASE LINE
Drain outlet
12" Drain and equalization line from drainage gallery to P.H. sump.
Foundation drain header
Drainage gallery
3.0' D Shaft
12" Equalization line
Top of wall El 883.0'
Constr jts
Flow
PLAN
Scale 1" = 40'
KEY PLAN
Scale 1" = 100'
SECTION A-A
SECTION C-C
SECTION B-B
SECTION G-G
SECTION H-H
PENSTOCK SECTIONS
TYPICAL REINFORCEMENT
SECTION J-J
SECTION K-K
SECTION L-L
DOWNSTREAM FROM GATES
SECTION M-M
UPSTREAM FROM GATES
SLUICE SECTIONS
TYPICAL REINFORCEMENT
Scale 1" = 10'
Scale 1" = 20' except as noted
COMPANION DRAWING: 10N205
SPILLWAY, INTAKE AND NON-OVERFLOW DAM
PRINCIPAL FEATURES OF DESIGN - SHEET 1
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
3-19-42
20
C
4
10N204 R1
RECORD DRAWING AS CONSTRUCTED



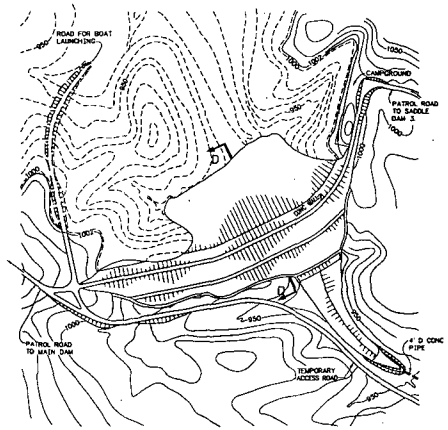
DOWNSTREAM ELEVATION



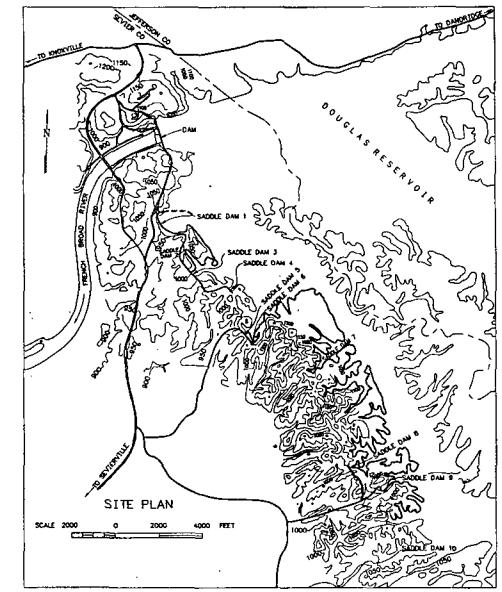
DOWNSTREAM ELEVATION



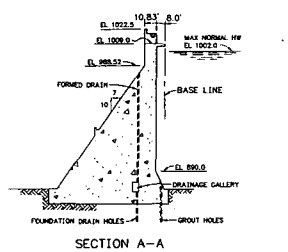
PLAN



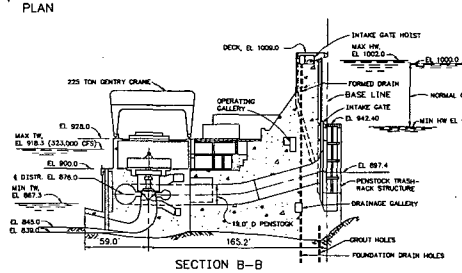
PLAN–SADDLE DAM 1
DGH-SP-SDAM-328-STRUCT-1



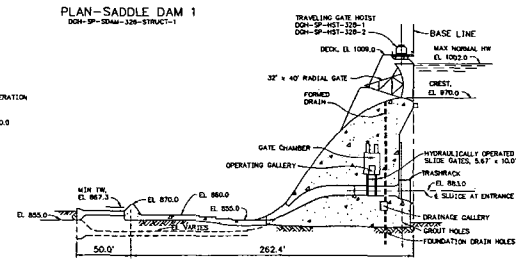
SITE PLAN



SECTION A–A

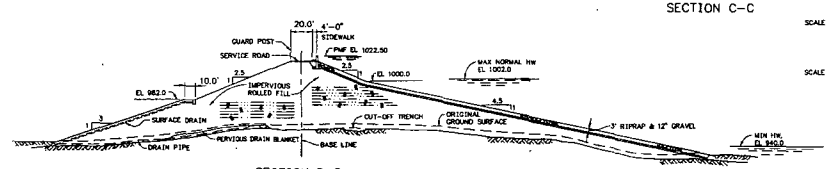


SECTION B–B



SECTION C–C

UNIDS TABULATION	
ASSET	UNIDS NUMBER
POWERHOUSE	DGH-00-BLDG-300-PWRHSE
DAM STRUCTURE	DGH-SP-DAM-328-STRUC
SADDLE DAM 1	DGH-SP-SDAM-328-STRUCT/1
SADDLE DAM 10	DGH-SP-DAM-328-STRUCT/10
SADDLE DAM 2	DGH-SP-DAM-328-STRUCT/2
SADDLE DAM 3	DGH-SP-DAM-328-STRUCT/3
SADDLE DAM 4	DGH-SP-DAM-328-STRUCT/4
SADDLE DAM 5	DGH-SP-DAM-328-STRUCT/5
SADDLE DAM 6	DGH-SP-DAM-328-STRUCT/6
SADDLE DAM 7	DGH-SP-DAM-328-STRUCT/7
SADDLE DAM 8	DGH-SP-DAM-328-STRUCT/8
SADDLE DAM 9	DGH-SP-DAM-328-STRUCT/9
SPILLWAY STRUCTURE	DGH-SP-STR-328-SPWY



SECTION D–D

SCALE 200 0 200 400 FEET
PLANS & ELEVATIONS

SCALE 40 0 40 80 FEET
SECTIONS

UNID NOTES:
1. COMPONENT UNID NUMBERING SCHEME:
PLANT UNIT FUNCTION SYSTEM SEQUENCE NO.
DGH SP HST 328 1
2. UNIDS ARE LISTED IN WHOLE ON THIS DRAWING. SEE UNIDS TABULATION FOR ASSETS SHOWN ON THIS DRAWING.
3. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS – SYSTEM NAME	FUNCTION CODES – FUNCTION CODE NAME
300 – FACILITIES AND GROUNDS	BLDG – BUILDING
328 – DAM	DAM – DAM STRUCTURE
328 – SPILLWAY	SDAM – SADDLE DAM
	HST – HOIST

4. FOR PROBABLE MAXIMUM FLOOD MODIFICATIONS, SEE DRAWINGS: 21E305-SERIES – – – – – DAM SAFETY MODIFICATIONS

R.11	JAN 08 2007	KGK	LJNC	CBD		AWT	MAC		B
ADDED PMF INFORMATION TO DOWNSTREAM ELEVATION VIEW.									
R10		JPD	JWE	A.S	JEW	TMW	MAC	DGH-00-18	E
REVISED AS PART OF CRITICAL STRUCTURES, SYSTEMS, AND COMPONENTS VERIFICATION									
NO.	DATE	DRAWN	DESIGNED	CHECKED	SUPV.	TRACED	APPROVED	DESIGN SUPV.	SYSTEM APPROVAL

SCALE: 1"=200'-0" EXCEPT AS NOTED

MAIN DAM WORKS

GENERAL PLAN, ELEVATION & SECTIONS

DRAWING BY:	DRAWN BY: E.W.S.	DESIGNED BY: S.G.C.	SUPERVISED BY: W.R.B.	IN CHARGE BY:	APPROVED BY:	DESIGN SUPV.

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14	DATE 1-31-43	20	C	10W200	R 11

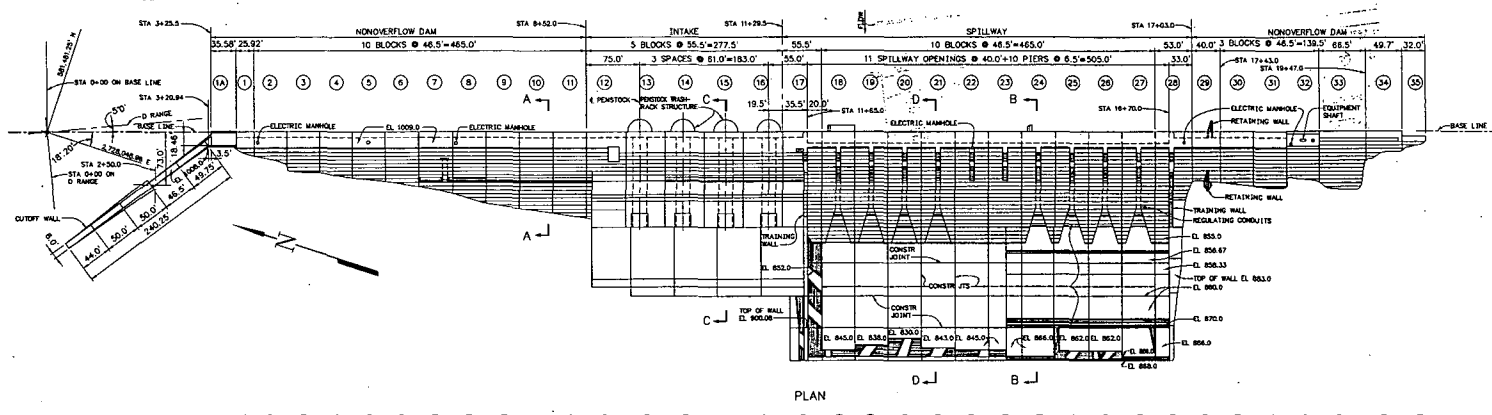
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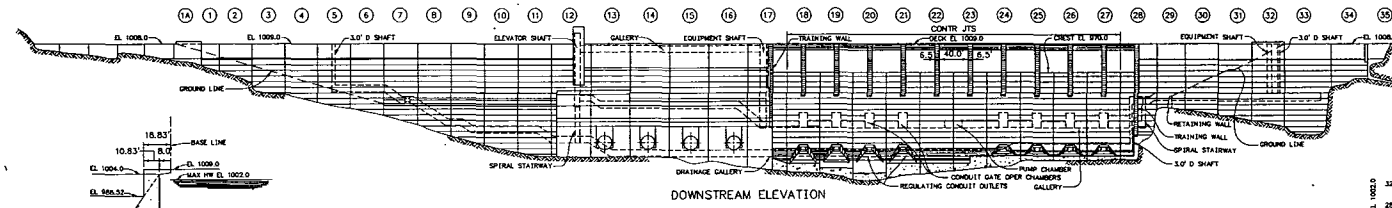
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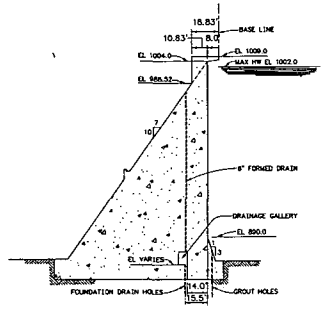
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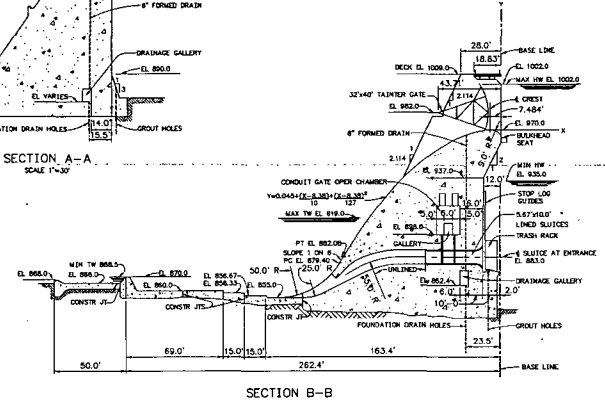
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DO NOT ALTER MANUALLY

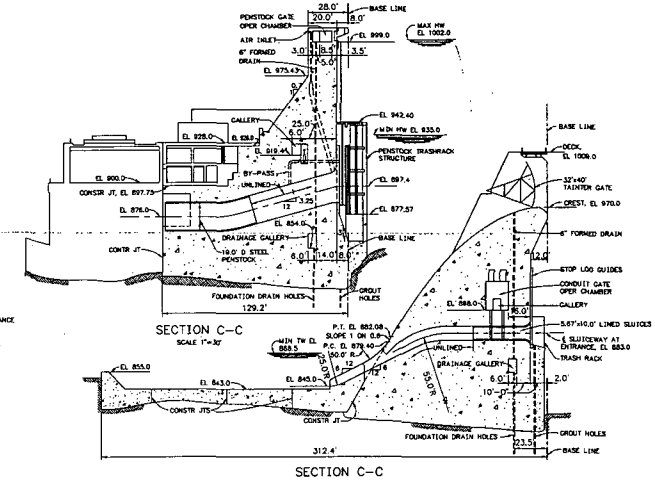
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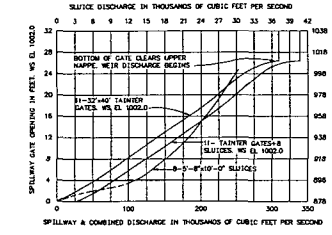












DISCHARGE FROM SPILLWAY GATES & SLUICES

ELECTRONICALLY RESTORED

SCALE: 1"=80' EXCEPT AS NOTED

SPILLWAY, INTAKE & NONOVERFLOW DAM

GENERAL PLAN, ELEVATION & SECTIONS

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
	R.M.D	M.V.J	M.V.J			

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R00 | 20 | C | 10W201 | R 8

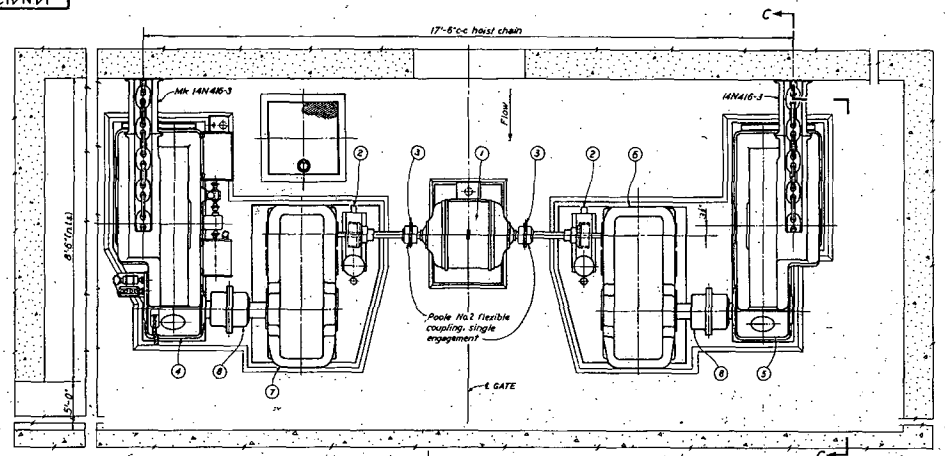
TASK COMPLETED BY: | REV NO:

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THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES :(10W201 R7)

PLOT FACTOR:720
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

14N412

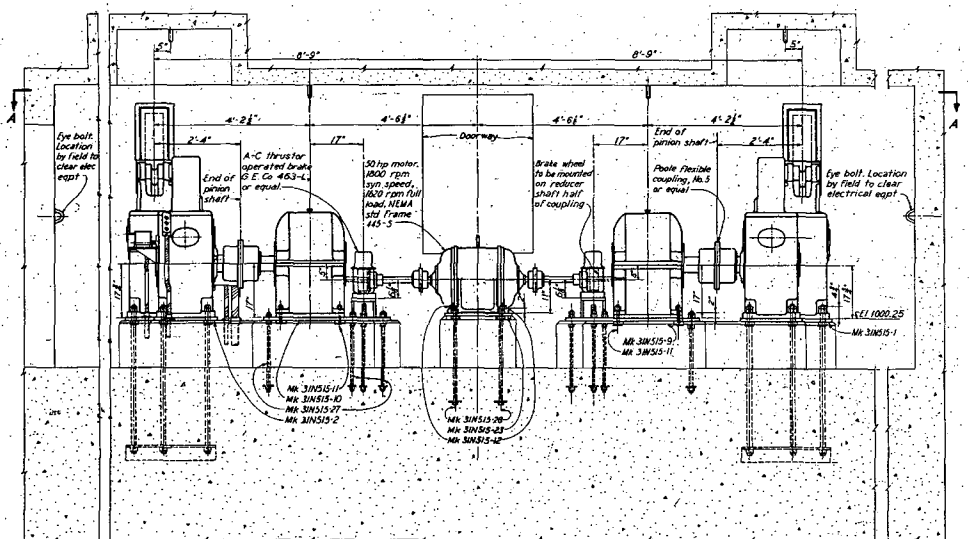


PLAN A-A

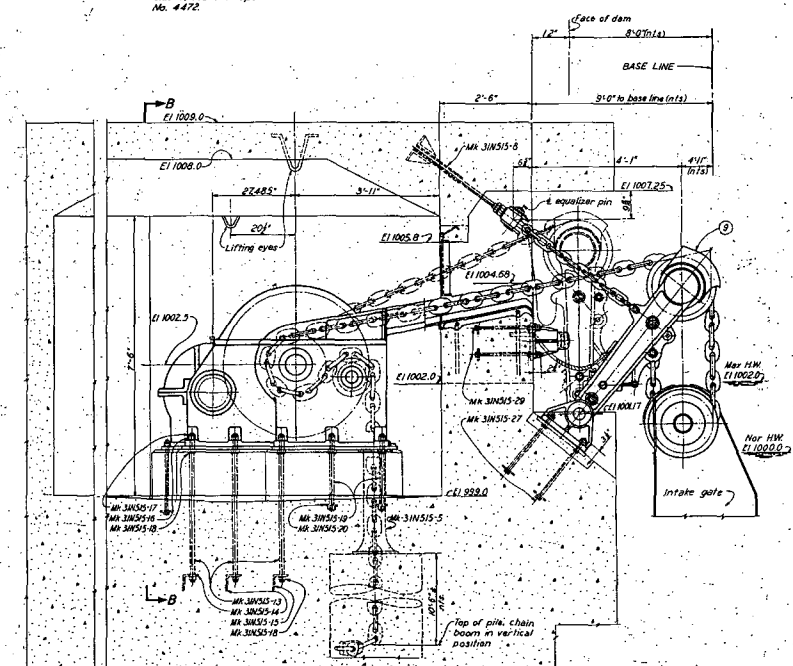
LIST OF MATERIAL FOR ONE GATE INSTALLATION			
ITEM NO.	DESCRIPTION	NO. REQD	REMARKS
1	Motor	1	
2	Brake	2	Torque - 125 ft-lb.
3	Flexible couplings	2	With shaft & brake wheel
4	Chain hoist	1	14N413 - assembly A
5	Chain hoist	1	14N413 - assembly B
6	Rh herringbone reducer	1	Triple reduction-ratio 103:1
7	Lh herringbone reducer	1	Triple reduction-ratio 103:1
8	Flexible coupling-half	2	
9	Chain boom	2	14N414 - assembly

MATERIAL SPECIFICATIONS**							
NO.	MATERIAL	ULTIMATE TEASION	YIELD PT TENSION	% EL 2"	% RED AREA	SPECIFICATIONS	REMARKS
1	Structural steel	60/72000	0.5 ts	22		ASTM A-7-39	33,000 min YP
2	Carbon steel casting	70,000	38,000	24	36	" A-27-39	Grade B
3	High tensile steel casting	90,000	60,000	22	45	" A-148-36	Class B, grade 2
4	Carbon steel forging	75,000	0.5 ts	20	33	" A-18-30	Class E
5	Nickel steel forging	90,000	60,000	20	41	" A-18-30	Class T
6	Hot rolled steel					" A-107-36	Grade 7
7	Bolt & nut steel					" A-107-36	Grade 21 or 22
8	Cold finished steel					" A-108-36	Grade 5
9	Spring steel					" A-58-27	Grade B
10	Steel					#	
11	Cast iron	35,000				ASTM A-48-36	Class 35
12	Welding electrodes					" A-206-37T	Grade 10
13	Die casting					#	
14							
15	Cast phosphor bronze	25,000	12,000	6		ASTM B-74-32T	
16	Cast manganese bronze	65,000		25		" B-54-27	
17	Brass rod	44,000	18,000	25		" B-16-29	Free-cutting
18	Rolled naval brass	60,000	30,000	30		" B-21-29	
19	Rolled high tensile bronze	93,000	50,000	16	15		Brinell 170 to 200
20	Cast high tensile bronze	90,000	45,000	20	20		Brinell 170 to 200
21	Bronze					#	
22	Bronze & graphite					#	
23	Brass & composition					#	
24	Brass					#	

Material identified by ASTM designation shall conform to the latest revision. (See specifications.)
* Manufacturer's standard.
** Materials shown hereon were used for Units 1, 2 and 3. For materials in Unit 4, see TVA Spec No. 4472.



ELEVATION B-B



ELEVATION C-C

Scale ½" = 1'-0" Except as noted

NOTES:
All steel castings and forgings shall be annealed in accordance with their material specs.
See specifications for workmanship, definition of finish marks, tolerances and allowances, protection of finished surfaces and cleaning.
All threads for bolts and screws shall be ASA coarse thread series, class 2 fit, unless otherwise noted.
For welding instructions see specifications.
For welding symbols see American Welding Society Symbols issued June 1937.
For paint see specifications.
For embedded steel details see 3IN515.

NOTES (Continued):
for manufacturer's details of intake gate hoist for Units 1, 2 and 3, refer to Lakeside Bridge & Steel Co file, TVA Contract No. TV-6971B.

COMPANION DRAWINGS: 14N413 TO 14N421 INCLUSIVE.

Schedule of Revisions for Unit 4							
1	7-24-42	MCC	Units 1 and 2				
2							
3							
4							

Traced
Signed as constructed
Checked

Approved							
Date							
Blue Print							

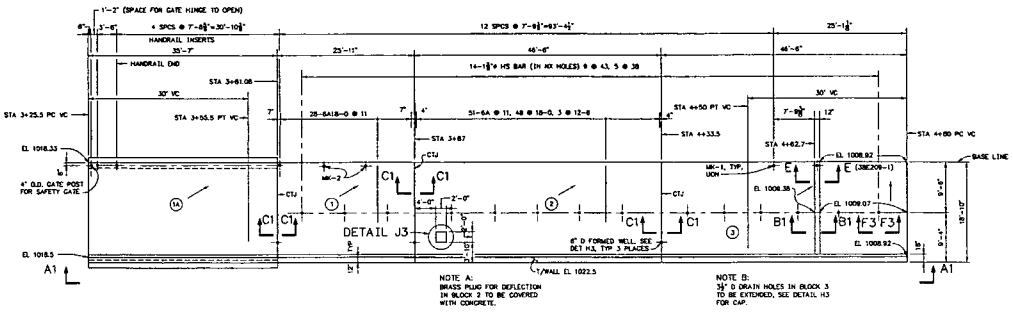
USER: A.E.C. R.D.D.M. — DESIGN: A.E.C. 7-24-42 — CHKD: H.C.E. 7-24-42 — TRCD: H.C.E. 7-24-42 — COMP: A.E.C. 7-24-42 — W. S. Hyatt

R.E.A.	A.A.M.	C.K.	M.E.D.
E.M.E.			W.B.A.

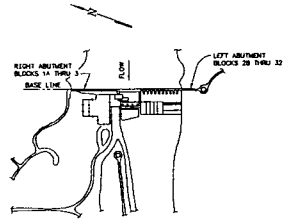
INTAKE				
GATE HOIST ARRANGEMENT				
DOUGLAS PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT				
SUBMITTED	RECOMMENDED	APPROVED		
J.G. Powell	R.E. Blaisdell	Joseph Ridsdale		
KNOXVILLE	2-26-42	20	M	4	14N412 R4
RECORD DRAWING AS CONSTRUCTED 12-16-43				

MF RA

449 H19-284-30 .18(1)

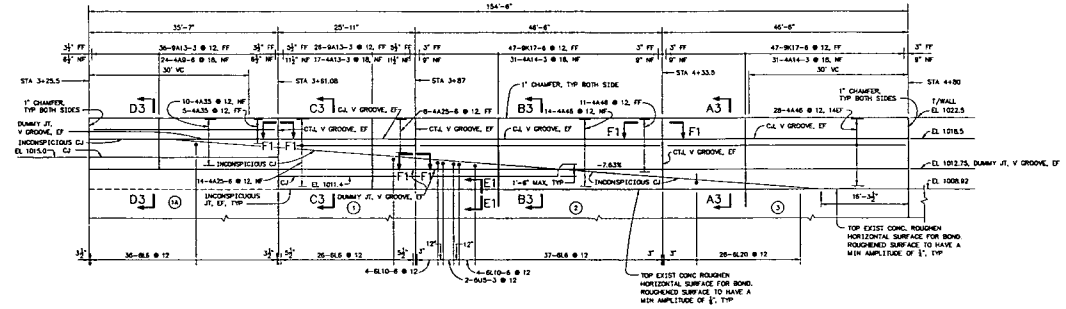


PLAN
BLOCKS 1A THRU 3

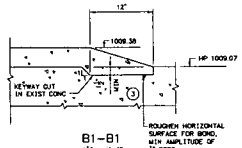


KEY PLAN
NTS

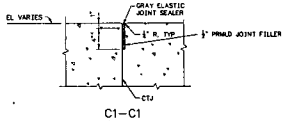
BENT BAR LIST									
BAR MARK	NO REQD	BENDING DIMENSIONS							
		A	B	C	D	E	F	R	
9K17-6	94	4-3½	EX			0-2			
6L20	28	1-9	EX						
6L10-6	8	1-3	EX						
9L6	99	1-3	EX						
6L4-6	6	1-3	EX						
6U5-3	2	1-3	3-1	EX					



A1–A1



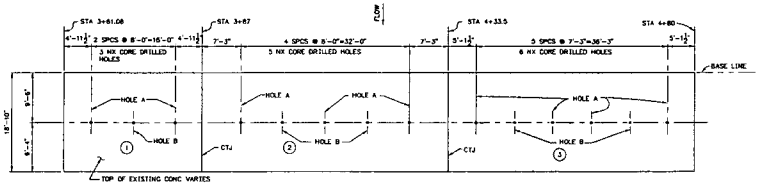
B1–B1
½" = 1'-0"



C1–C1
½" = 1'-0"

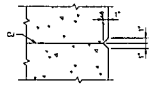
NOTES:

1. CONCRETE SHALL BE PLACED IN ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G2. CONCRETE SHALL BE CLASS 300.75 AFW IN WALL AND CLASS 301.50 BFW IN RAMP EXCEPT AS NOTED. THE MAXIMUM PLACING TEMPERATURE OF CONCRETE SHALL BE 75°F.
2. MINIMUM EXPOSURE TIME BEFORE PLACING ONE LIFT UPON ANOTHER OR ONE POUR ADJACENT TO ANOTHER SHALL BE 3 DAYS EXCEPT AS NOTED.
3. FORMWORK SHALL BE IN ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G-8. ALL EXPOSED CONCRETE SURFACES SHALL HAVE A SMOOTH FORM FINISH. ALL OTHER SURFACES MAY HAVE A ROUGH FORM FINISH. PRACTICAL MEASURES SHALL BE TAKEN IN FINISHING EXPOSED SURFACES TO MATCH THE EXISTING CONCRETE FINISH.
4. A METAL FLOAT AND BROOM FINISH SHALL BE USED ON EXPOSED TOP SURFACES.
5. CHAMFER ALL EXPOSED EDGES 1" UNLESS OTHERWISE NOTED.
6. HOLES FOR DOWELS ARE TO BE CLEAN AND FREE OF WATER BEFORE FILLING WITH SAND-CEMENT GROUT. THE DOWEL IS TO BE FORCED INTO GROUT TO BOTTOM OF HOLE AND SHAKEN AND WORKED TO INSURE GOOD BOND BETWEEN GROUT AND BAR AND BETWEEN GROUT AND CONCRETE. SAND-CEMENT GROUT SHALL CONFORM TO GENERAL CONSTRUCTION SPECIFICATION G-32, SECT. 2.5. GROUT SHALL BE PLACED FROM BOTTOM OF HOLE UP.
7. EXISTING HANDRAILING IS TO BE REMOVED AND REUSED TO THE EXTENT POSSIBLE.
8. ALL 6" D FORMED WELLS SHOULD BE SOUNDED TO BE SURE THEY ARE CLEAR OF DEBRIS.
9. FOR EMBEDDED CONDUITS AND GROUNDING SEE ELECTRICAL DRAWINGS.
10. ALL REINFORCING STEEL SHALL CONFORM TO ASTM SPECIFICATION A-615, GRADE 60.
11. COVER DIMENSIONS SHOWN ARE TO BE CLEAR COVER. ALL OTHER DIMENSIONS ARE TO CENTERLINE OF REINFORCEMENT.
12. WELDING OF OR TO HIGH-STRENGTH REINFORCING BARS WITHOUT APPROVAL OF HYDRO ENGRG PROJECTS IS PROHIBITED.
13. FOR DETAILS OF EMBEDDED FRAMES SEE 38N205 R6.
14. WELLS BETWEEN BLOCKS 1A, 1, 2, 3, 29, 30, 31 AND 32 TO HAVE SEAL CAPS REMOVED PRIOR TO EXTENSION OF WELL THROUGH NEW CONCRETE.
15. FIELD TO VERIFY DIMENSIONS OF EXISTING HANDRAIL THAT IS TO BE REUSED, AS SHOWN ON 38E209-1, PRIOR TO SETTING HANDRAIL INSERTS MK1 AND MK2.
16. 1¼"ø HIGH STRENGTH BARS TO BE ASTM A 722-75 (150 KSI ULTIMATE STRESS) DYWIDAG BAR AS MANUFACTURED BY DYWIDAG SYSTEMS INTERNATIONAL, USA, INC OR EQUAL.
17. THE RIMS ACCESSION NUMBER FOR COMPUTATIONS PREPARED FOR THE RD ISSUE IS 866 '86 0219 004.
18. ALL MARK NUMBERS ON THIS DRAWING TO HAVE PREFIX 21E205.

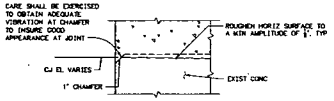


PLAN
LOCATION OF NX HOLES

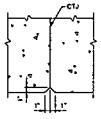
NOTE C:
BOTTOM OF HOLE A EL 969.0
BOTTOM OF HOLE B EL 974.0
DE-ENERGIZE PATROL ROAD & HANDRAIL SECURITY LIGHTING CIRCUITS PRIOR TO DRILLING HOLES A & B.



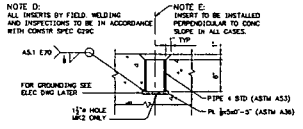
DET D1
TYP V GROOVE BOTH UPSTREAM & DOWNSTREAM FACE
1½"=1'-0"



E1–E1
TYP UPSTREAM & DOWNSTREAM FACES
NTS



F1–F1
TYP ALL VERT CTJ
1½"=1'-0"



TYP HANDRAIL INSERT MK1 & MK2
35 REQD MK1
4 REQD MK2
1½"=1'-0"

DEC 12 2007

R						
R 3		KGK CRD	CRD CTV2			
		HDR CRD	R WT R WT			

ELECTRONICALLY RESTORED

SCALE: 1/8" = 1'-0" EXCEPT AS NOTED

NON-OVERFLOW DAM

CONCRETE
INCREASING HEIGHT OF DAM
BLOCKS 1A THRU 3 & 28 THRU 32

DESIGNED BY	DRAWN BY	CHECKED BY	SUBMITTED BY	APPROVED BY	APPROVED BY	TRACED BY
G.L.H.	D.E.W.	C.J.M.		R.D.M.		P.B.

DOUGLAS HYDRO PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

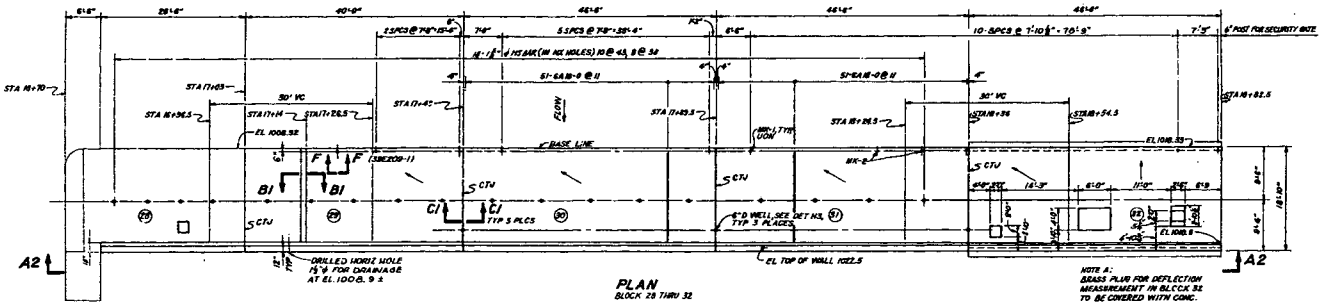
AUTOCAD RDB | DATE 3-14-88 | 20 | C | 21E205-1 | R 3

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(21E205-1 R2)

TASK COMPLETED BY. | REV NO.

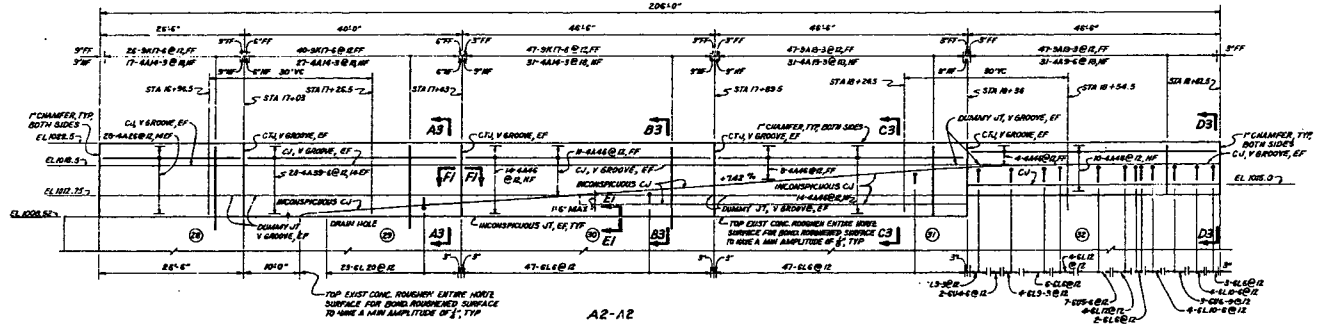
PLOT FACTOR:98
E_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

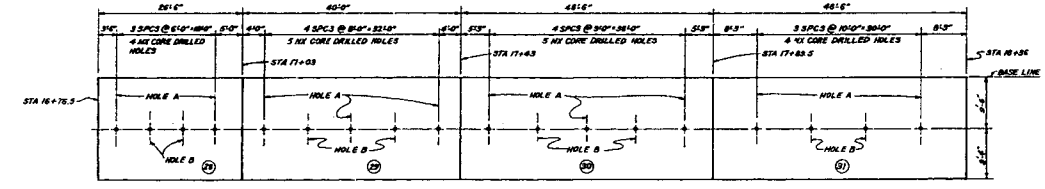


PLAN
BLOCK 28 THRU 32

NOTE A:
BRASS PLUG FOR DEFLECTION MEASUREMENT IN BLOCK 32 TO BE COVERED WITH CONC.



A2-A2



PLAN
LOCATION OF MX HOLES

NOTE B:
BOTTOM OF HOLE A EL 965.0
BOTTOM OF HOLE B EL 974.0
DE-ENERGIZE PATWIN ROAD & HANDRAIL SECURITY LIGHTING CIRCUITS PRIOR TO DRILLING HOLES A & B

NOTES:
1. FOR LIST OF NOTES SEE 21E205-1.

BENT BAR LIST

BAR MARK	NO BARS	BENDING DIMENSIONS a	b	c	d	e	f	ℓ
SK17-6	113	4-3½	EX			0-2		
EL20	25	1-9	EX					
EL12	8	1-9	EX					
ELD-6	8	1-9	EX					
EL9-9	8	1-9	EX					
EL6	105	1-9	EX					
EL4-9	28	1-9	EX					
EU6-9	9	1-9	4-8	EX				
EU5-6	7	1-9	3-4	EX				
EU4-6	2	1-9	2-4	EX				

1	7-8-77	RPW	AE	RDM	41.2
FINAL FIELD REVISION					
REV NO.	ECN/PCR	DATE	DSGN	DRWN	CHKD	PWNG	APPD	ISSD

SCALE: 1/8"=1'-0" EXCEPT AS NOTED

NON-OVERFLOW DAM

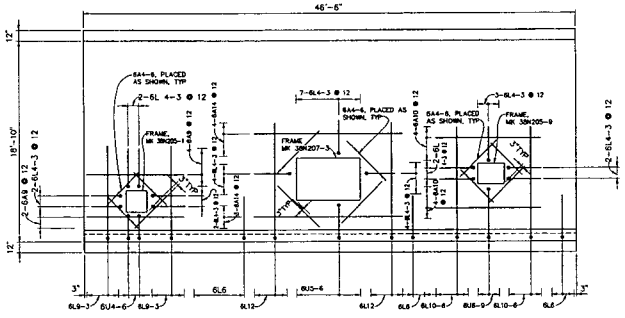
CONCRETE
INCREASING HEIGHT OF DAM
BLOCKS 1a THRU 3 & 28 THRU 32

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
OFFICE OF ENGINEERING

N

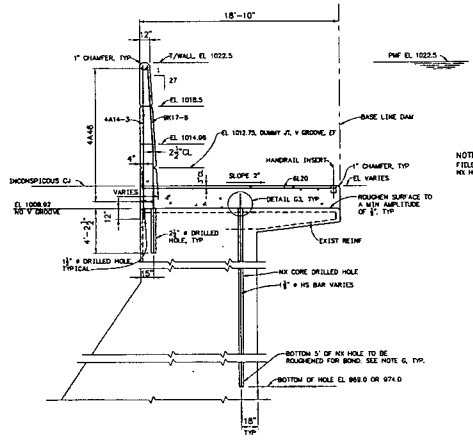
DESIGN		DISCIPLINE INTERFACE		ENGINEERING APPROVAL
DRAWN R.E. WRIGHT	CHECKED	1	2 Currie	G. A. Gamble
DESIGNED	REVIEWED	3	4	
KNOXVILLE	DATE 3-14-78	20	C	21E205-2 R1

RECORD DRAWING AS CONSTRUCTED R.E. Bruce June 26, 1987 PD

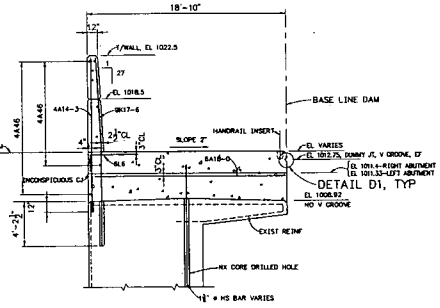


PLAN–BLOCK 32

NOTE A:
SEE 21E205-2 FOR BENT BAR LIST.

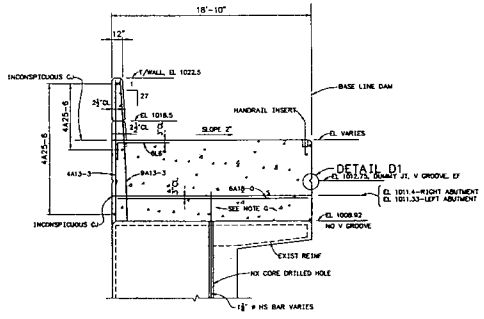


A3–A3



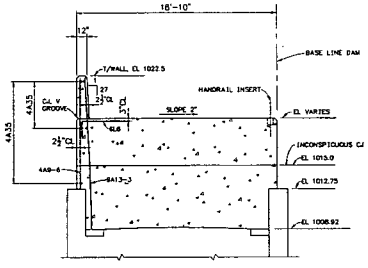
NOTE G:
INCONSPICUOUS CJ FIELD MAY DRILL LOWER HALF OF NX HOLE WITH PERCUSSION DRILL.

B3–B3

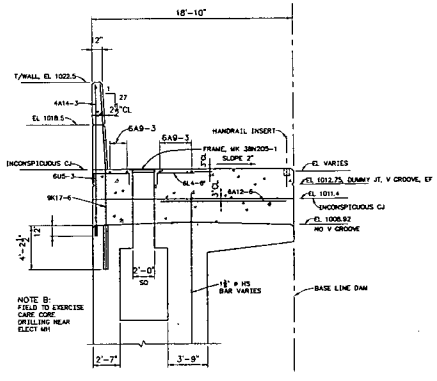


C3–C3

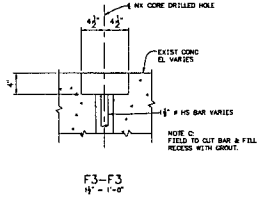
NOTE G:
CONC PLACED BETWEEN STA 3+61.08 AND STA 3+87 FROM EL 1008.92 TO EL 1011.4 IN BLOCK 1 SHALL CONFORM TO CLASS 300.75 AFW. CONC PLACED BETWEEN STA 17+89.5 AND STA 18+36 FROM EL 1008.92 TO EL 1011.33 IN BLOCK 31 SHALL CONFORM TO CLASS 300.75 AFW. MINIMUM EXPOSURE TIME SHALL BE 7 DAYS.



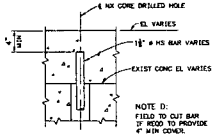
D3–D3



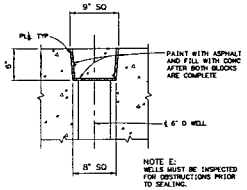
E3–E3



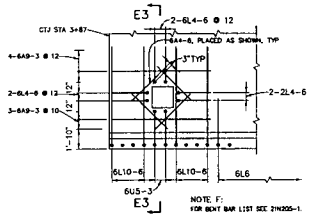
F3–F3
1½" = 1'-0"



DETAIL G3
1½" = 1'-0"



DETAIL H3
1½"=1'-0"



DETAIL J3

NOTES:
1. FOR LIST OF NOTES SEE 21E205-1.

DEC 12 2007

R			KJK	CRD			
R 3	ELECTRONICALLY RESTORED		KJK	CRD	NEED	CREW	
R 2					R.W.T.	R.W.T.	
R 1							

SCALE: 1/4" = 1'-0" EXCEPT AS NOTED

NON–OVERFLOW DAM

CONCRETE
INCREASING HEIGHT OF DAM
BLOCKS 1A THRU 3 & 28 THRU 32

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	RELEASED BY	APPROVED BY	ISSUED BY
G.L.H.	D.E.W.	C.J.M.		R.O.M.		P.D.

DOUGLAS HYDRO PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

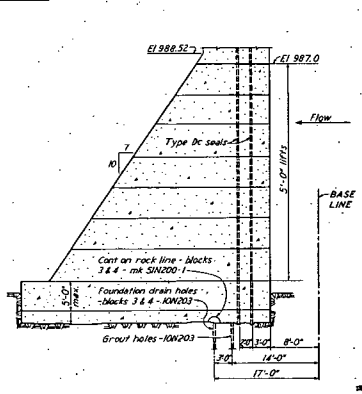
AUTOCAD R08	DATE 3-14-08	20	C	21E205-3	R 3

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(21E205-3 R2)

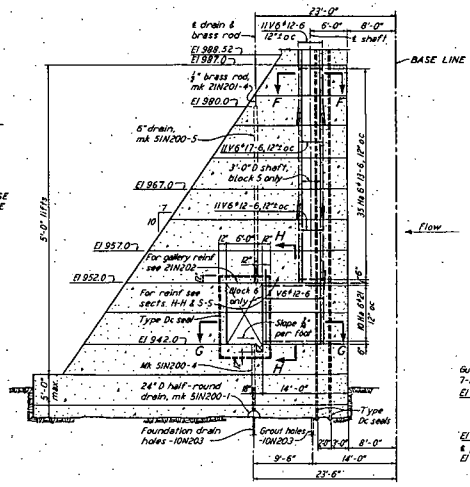
TASK COMPLETED BY: REV NO.

PLOT FACTOR:48
E..TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

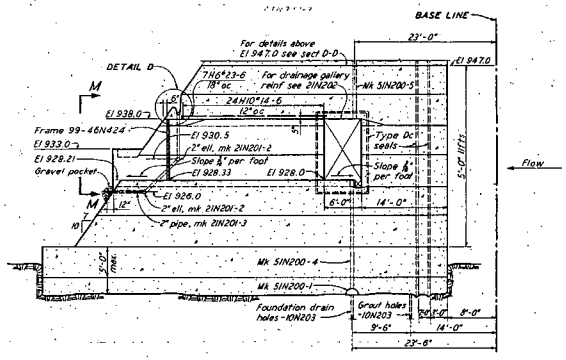


SECTION A-A
BLOCKS 1 - 4



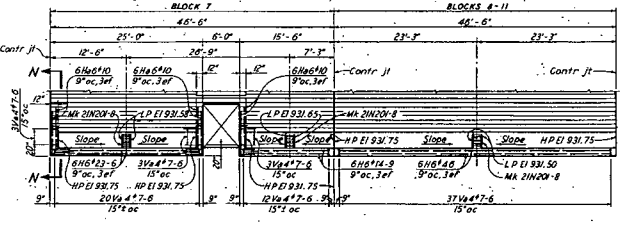
SECTION B-B
BLOCKS 5 & 6

Note:
For additional details and reinforcing, blocks 8, 9, 10, & 11, see field office sketches 6, 7, 8, 10, 11, 13, 15, 17, 18, and 17A295.

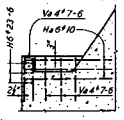


SECTION C-C
BLOCK 7

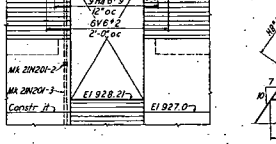
SECTION D-D
BLOCKS 8-11



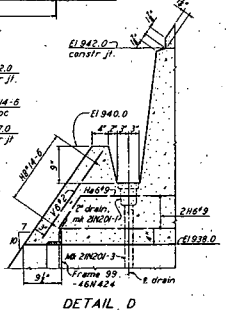
PLAN J-J



SECTION N-N
Scale ½"=1'-0"

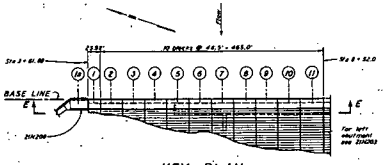


ELEVATION M-M
Scale ½"=1'-0"

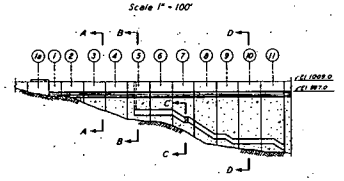


DETAIL D
Scale 1"=1'-0"

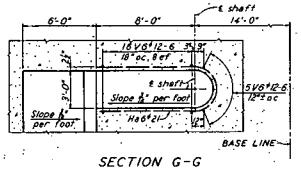
COMPANION DRAWING: 21N202



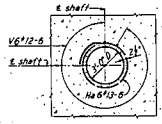
KEY PLAN
Scale 1" = 100'



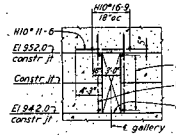
SECTION E-E
Scale 1"=100'



SECTION G-G
BLOCK 5 ONLY
Scale ½"=1'-0"



SECTION F-F
BLOCK 5 ONLY
Scale ½"=1'-0"



SECTION H-H
BLOCK 5 ONLY

NOTES:
1. Bend letter "a" given in bar marks.
2. All bar marks on this sheet to have prefix letter N.
3. Dimensions are given to ℄ of bars.
4. Chamfer all exposed edges ¾" except as noted.
5. Omit chamfer on horizontal construction joints below finished grade of backfill.
6. At points where pipes cross contraction joints provide continuous seal as shown on Detail 1-5IN211.
7. For details of final excavation and bulkheads, see final sections, 53K602 to 53K613 inclusive.

REFERENCE DRAWINGS:
5IN200.... BILL OF MATERIAL
21IN201.... BILL OF MATERIAL
21IN 5201.... REINFORCEMENT BAR DETAILS

Scale ½"=1'-0"
Except as noted

NONOVERFLOW DAM.

CONCRETE BELOW EL 987.0 OUTLINE & REINF SHEET 1

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

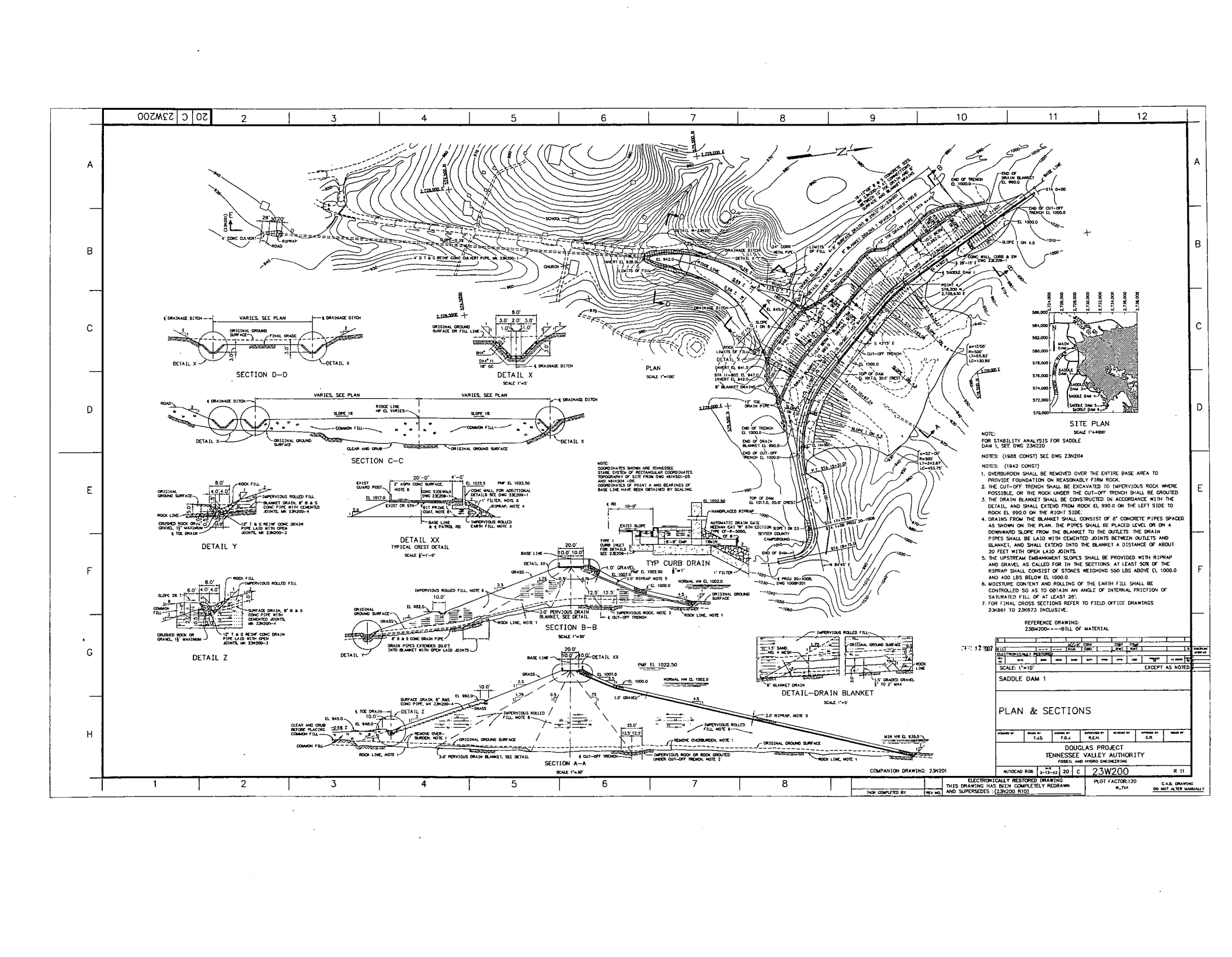
SUBMITTED	RECOMMENDED	APPROVED
O.B. Merrell	Ken McKay	Joseph Riel
KNOXVILLE	4-3-42	20 C 4 21N201RS

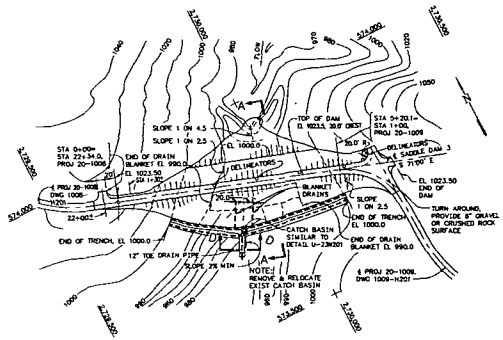
RECORD DRAWING AS CONSTRUCTED
K.C.R. 2-23-44

MF RS

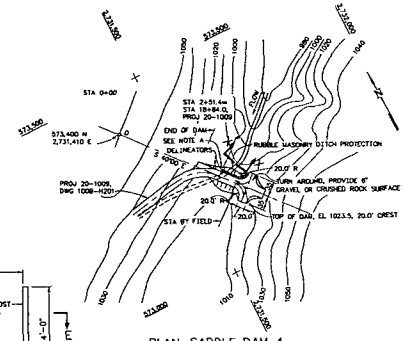
C&E, RES, W.E.M., R.E. C&E, RES, E.S.C., C.C. W.E.M., R.E.S., T.J.W.

① C.E.M., R.F., J.A.M.	② R.F., J.A.M.	③ R.F., J.A.M.	④ J.A.M.	⑤	⑥

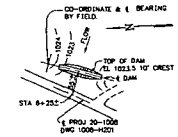

PLAN
SCALE 1"=100'
SITE PLAN
SCALE 1"=4000'
SECTION D–D
DETAIL X
SECTION C–C
SECTION B–B
SECTION A–A
DETAIL Y
DETAIL XX
TYPICAL CREST DETAIL
DETAIL Z
TYP CURB DRAIN
DETAIL–DRAIN BLANKET
NOTES:
1. OVERBURDEN SHALL BE REMOVED OVER THE ENTIRE BASE AREA TO PROVIDE FOUNDATION ON REASONABLY FIRM ROCK.
2. THE CUT–OFF TRENCH SHALL BE EXCAVATED TO IMPERVIOUS ROCK WHERE POSSIBLE, OR THE ROCK UNDER THE CUT–OFF TRENCH SHALL BE GROUTED.
3. THE DRAIN BLANKET SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE DETAIL AND SHALL EXTEND FROM ROCK EL 990.0 ON THE LEFT SIDE TO ROCK EL 990.0 ON THE RIGHT SIDE.
4. DRAINS FROM THE BLANKET SHALL CONSIST OF 8" CONCRETE PIPES SPACED AS SHOWN ON THE PLAN. THE PIPES SHALL BE PLACED LEVEL OR ON A DOWNWARD SLOPE FROM THE BLANKET TO THE OUTLETS. THE DRAIN PIPES SHALL BE LAID WITH CEMENTED JOINTS BETWEEN OUTLETS AND BLANKET, AND SHALL EXTEND INTO THE BLANKET A DISTANCE OF ABOUT 20 FEET WITH OPEN LAID JOINTS.
5. THE UPSTREAM EMBANKMENT SLOPES SHALL BE PROVIDED WITH RIPRAP AND GRAVEL AS CALLED FOR IN THE SECTIONS. AT LEAST 50% OF THE RIPRAP SHALL CONSIST OF STONES WEIGHING 550 LBS ABOVE EL 1000.0 AND 400 LBS BELOW EL 1000.0.
6. MOISTURE CONTENT AND ROLLING OF THE EARTH FILL SHALL BE CONTROLLED SO AS TO OBTAIN AN ANGLE OF INTERNAL FRICTION OF SATURATED FILL OF AT LEAST 26°.
7. FOR FINAL CROSS SECTIONS REFER TO FIELD OFFICE DRAWINGS 23K661 TO 23K673 INCLUSIVE.
NOTE:
FOR STABILITY ANALYSIS FOR SADDLE DAM 1, SEE DWG 23N220
NOTES: (1986 CONST) SEE DWG 23N204
NOTES: (1942 CONST)
NOTE:
COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES. TOPOGRAPHY OF SITE FROM DWG 46IK301-05 AND 46IK304 -06. COORDINATES OF POINT A AND BEARINGS OF BASE LINE HAVE BEEN OBTAINED BY SCALING.
REFERENCE DRAWING:
23BM200----BILL OF MATERIAL
COMPANION DRAWING: 23N201
SCALE: 1"=10'
EXCEPT AS NOTED
SADDLE DAM 1
PLAN & SECTIONS
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING
AUTOCAD R06
23W200
R 11
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23N200 R10)
PLOT FACTOR:120
W_TVA
C.A.D. DRAWING
DO NOT ALTER MANUALLY



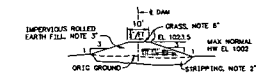
PLAN–SADDLE DAM 3



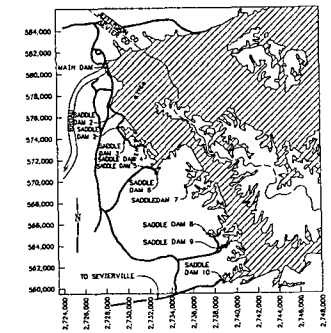
PLAN–SADDLE DAM 4



PLAN–SADDLE DAM 2

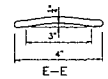


TYP SEC–SADDLE DAM 2
SCALE 1"=20'

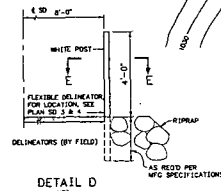


SITE PLAN
SCALE 1"=4000'

NOTE A:
BASE AND DRAINS OF EXISTING ROADS AND HIGHWAYS AND FOUNDATIONS OF EXISTING BUILDINGS SHALL BE COMPLETELY REMOVED UNDER THE EMBANKMENTS.

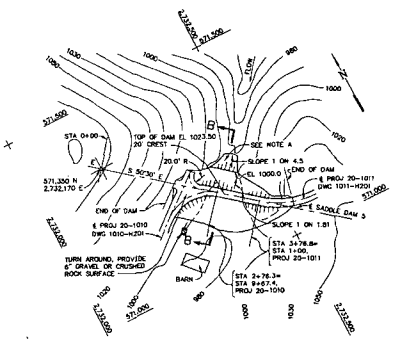


E–E

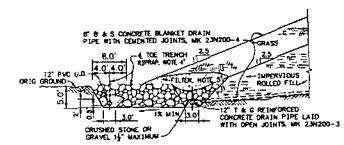


DETAIL D
NTS

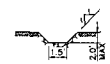
NOTE:
COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES. TOPOGRAPHY OF SIGHTS WERE TAKEN FROM THE FOLLOWING DWGS: 461K504–D6, D7, E7, E8 & F8. COORDINATES OF POINTS B TO E AND BEARINGS OF CENTER LINE OF SADDLE DAMS HAVE BEEN OBTAINED BY SCALING.



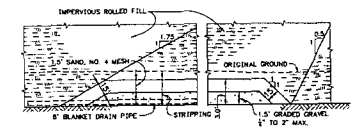
PLAN–SADDLE DAM 5



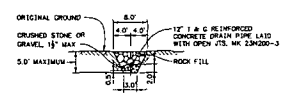
DETAIL C
SCALE 1"=10'



SECTION X–X
NOT TO SCALE

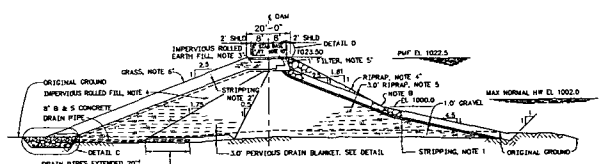


DETAIL–DRAIN BLANKET
SCALE 1"= 5'

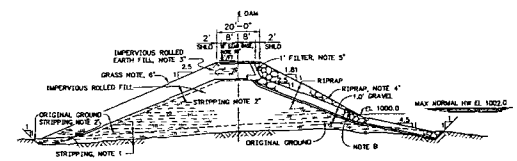


SECTION D–D
SCALE 1"=10'

NOTE B:
REARRANGE EXIST RIPRAP TO FORM A BERM TO PROVIDE TOE SUPPORT FOR ADDITIONAL RIPRAP, USE CARE TO AVOID DAMAGING EXIST RIPRAP.



SECTION A–A
SADDLE DAM 3 ONLY
SCALE 1"=20'



SECTION B–B
TYPICAL–SADDLE DAMS 4 & 5
SCALE 1"=20'

- NOTES: (1988 CONST) SEE DWG 23N204

NOTES: (1942 CONST)

1. ALL ORGANIC OR OTHERWISE OBJECTIONABLE MATERIAL SHALL BE REMOVED FROM THE NATURAL GROUND SURFACE AND THE SURFACE HARROWED BEFORE STARTING TO PLACE IMPERVIOUS ROLLED FILL.
2. THE DRAIN BLANKET SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE DETAIL AND SHALL EXTEND FROM STRIPPED EL 990.0 ON THE LEFT SIDE TO STRIPPED EL 980.0 ON THE RIGHT SIDE.
3. DRAINS FROM THE BLANKET SHALL CONSIST OF 8" CONCRETE PIPES SPACED AS SHOWN ON THE PLAN. THE PIPES SHALL BE PLACED LEVEL OR ON A DOWNWARD SLOPE FROM THE BLANKET TO THE OUTLETS. THE DRAIN PIPES SHALL BE LAID WITH CEMENTED JOINTS BETWEEN OUTLETS AND BLANKET, AND SHALL EXTEND INTO THE BLANKET A DISTANCE OF ABOUT 20' WITH OPEN LAID JOINTS.
4. MOISTURE CONTENT AND ROLLING OF THE EARTH FILL SHALL BE CONTROLLED SO AS TO OBTAIN AN ANGLE OF INTERNAL FRICTION OF SATURATED FILL OF AT LEAST 26°
5. THE UPSTREAM EMBANKMENT SLOPES SHALL PROVIDED WITH RIPRAP AND GRAVEL AS CALLED FOR IN THE SECTIONS. AT LEAST 50% OF THE RIPRAP SHALL CONSIST OF STONES WEIGHING 350 LBS OR MORE.
6. FOR FINAL CROSS SECTIONS SEE FIELD OFFICE DWGS 23K674 TO 23K677 INCLUSIVE.

REFERENCE DRAWING:
23BM200--- BILL OF MATERIAL

DEC 12 2007

ELECTRONICALLY RESTORED
SCALE: 1"=100' EXCEPT AS NOTED

SOUTH EMBANKMENT
SADDLE DAMS 2, 3, 4 & 5

PLANS & SECTIONS

DESIGNED BY: | DRAWN BY: TJS | CHECKED BY: FDJ | SUBMITTED BY: RRL | REVIEWED BY: | APPROVED BY: GR | ISSUED BY:

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

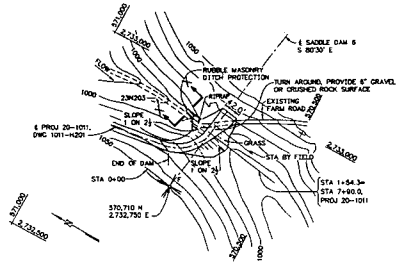
AUTOCAD R06 | DATE 4-29-42 | 20 | C | 23W203 | R 8

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES (23W203 R7)

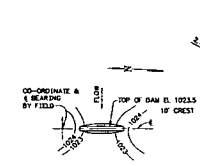
TASK COMPLETED BY: | REV NO.

PLOT FACTOR:1200

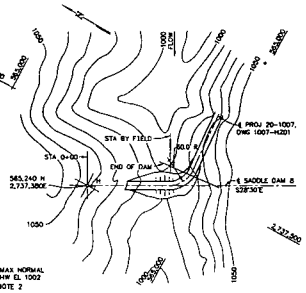
C.A.D. DRAWING
DO NOT ALTER MANUALLY



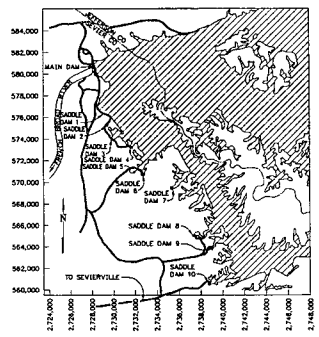
PLAN–SADDLE DAM 6



TYP SEC–SADDLE DAM 7
SCALE 1"=20'

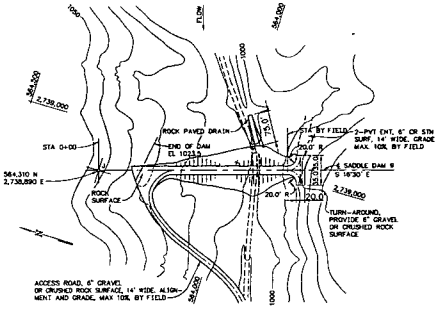


PLAN–SADDLE DAM 8

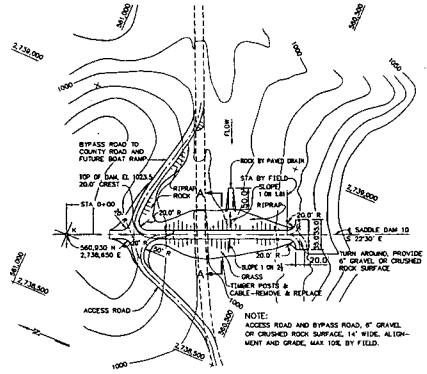


SITE PLAN
SCALE 1"=4000'

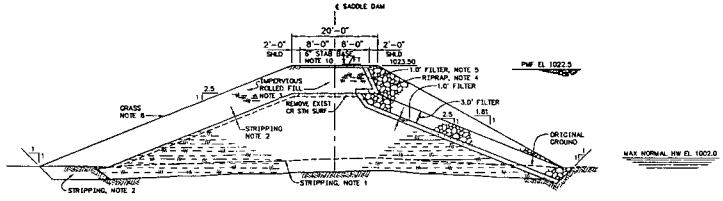
NOTE:
COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES. TOPOGRAPHY OF SIGHTS WERE TAKEN FROM THE FOLLOWING DRAWINGS: 46IK504-FB, GS, G11, H11, H12 AND H13. COORDINATES OF POINTS F TO K AND BEARINGS OF CENTER LINES OF SADDLE DAMS HAVE BEEN OBTAINED BY SCALING.



PLAN–SADDLE DAM 9



PLAN–SADDLE DAM 10



SECTION A–A
TYPICAL–SADDLE DAMS 6, 8, 9 & 10
SCALE 1"=10'

NOTES: (1986 CONST)

1. ALL EARTHWORK CONSTRUCTION SHALL BE IN ACCORDANCE WITH TVA CONSTRUCTION SPEC G-9.
2. ALL ORGANIC OR OTHERWISE OBJECTIONABLE MATERIAL SHALL BE REMOVED FROM THE NATURAL GROUND SURFACE AND THE SURFACE HARROWED BEFORE STARTING TO PLACE ROLLED FILL TOPSOIL TO BE STOCKPILED & REUSED.
3. IMPERVIOUS ROLLED FILL SHALL BE APPROVED MATERIAL UNIFORMLY COMPACTED TO AT LEAST 95% OF MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D-698 PROCEDURES (STANDARD PROCTOR). DETERMINED BY TVA SOILS LABORATORY, WITH MOISTURE CONTENT OF ±2% OF OPTIMUM. ROUTINE SAMPLING AND LABORATORY TESTING OF PLACED FILL SHALL BE REQUIRED.
4. RIPRAP SHALL CONFORM TO HIGHWAY SPECIFICATION T-1 SECTION 575 AND SHALL BE WELL GRADED WITH 50% OF THE RIPRAP BY WEIGHT 250 LB OR LARGER. MAX STONE SIZE SHALL BE 750 LB AND NOT MORE THAN 5% BY WEIGHT SHALL PASS THE 1" SIEVE. THE COLOR OF THE NEW RIPRAP SHALL MATCH THE COLOR OF THE EXISTING RIPRAP.
5. FILTER MATERIAL AND ROADWAY STABILIZED BASE CRUSHED STONE SHALL CONFORM TO HIGHWAY SPECIFICATION T-1, SECTION 1032, EXCEPT THE GRADATION SHALL BE WELL GRADED FROM 1-½ INCHES DOWN WITH NOT MORE THAN 5% BY WEIGHT PASSING THE NO. 200 SIEVE.
6. GRASSING–SEE DWG 16W210.
7. EXCAVATION AND RESTORATION OF ALL BORROW AREAS SHALL BE ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G-9 AND T-1.
8. RESURFACING OF SADDLE DAM NO. 1 PATROL ROAD IS TO CONSIST OF BITUMINOUS PRIME COAT AND 2" ASPHALTIC CONCRETE SURFACE IN ACCORDANCE WITH SECTIONS 320 & 346 OF THE T-1 HIGHWAY SPECIFICATION.
9. SURFACING OF THE SOUTH ABUTMENT TURNAROUND AND THE NORTH ABUTMENT PARKING AREA IS TO CONSIST OF A 6" STABILIZED BASE, BITUMINOUS PRIME COAT AND 2" ASPHALTIC CONCRETE SURFACE IN ACCORDANCE WITH SECTIONS 225, 320 AND 346 OF THE T-1 HIGHWAY SPECIFICATION.
10. SURFACING OF SADDLE DAM NUMBERS 3, 4, 5, 6, 8, 9 & 10 WILL BE 6" STABILIZED BASE IN ACCORDANCE WITH SECTION 225 OF THE T-1 HIGHWAY SPECIFICATION.

NOTES: (1942 CONST)

1. ALL ORGANIC OR OTHERWISE OBJECTIONABLE MATERIAL SHALL BE REMOVED FROM THE NATURAL GROUND SURFACE AND THE SURFACE HARROWED BEFORE STARTING TO PLACE IMPERVIOUS ROLLED FILL.
2. BASE AND DRAINS OF EXISTING ROADS AND FOUNDATIONS OF EXISTING BUILDINGS SHALL BE COMPLETELY REMOVED FROM THE AREA COVERED BY THE EMBANKMENTS.
3. MOISTURE CONTENT AND ROLLING OF THE EARTH FILL SHALL BE CONTROLLED SO AS TO OBTAIN AN ANGLE OF INTERNAL FRICTION OF SATURATED FILL OF AT LEAST 26°.
4. THE UPSTREAM EMBANKMENT SLOPES SHALL BE PROVIDED WITH RIPRAP AND GRAVEL AS CALLED FOR IN THE SECTION. AT LEAST 50% OF THE RIPRAP SHALL CONSIST OF STONES WEIGHING 350 LBS OR MORE.
5. FOR FINAL CROSS SECTIONS SEE FIELD OFFICE DWGS 23K678 TO 23K681 INCLUSIVE.

DEC 12 2007

R														
R 7						KLK	CSD		CSD	CSD				
	ELECTRONICALLY RESTORED					P.SD	CSD		L.SHT	J.WT				
R	DATE	BY	CHKD	CHKD	SUPV	PROJ	APPD	ITEM	REVISED	AS CONST	DESCRIPTION	SYSTEM NO.
7	12-7-07	KLK	CSD									

SCALE: 1"=100' EXCEPT AS NOTED

SOUTH EMBANKMENT
SADDLE DAMS 6, 7, 8, 9 & 10

PLANS & SECTIONS

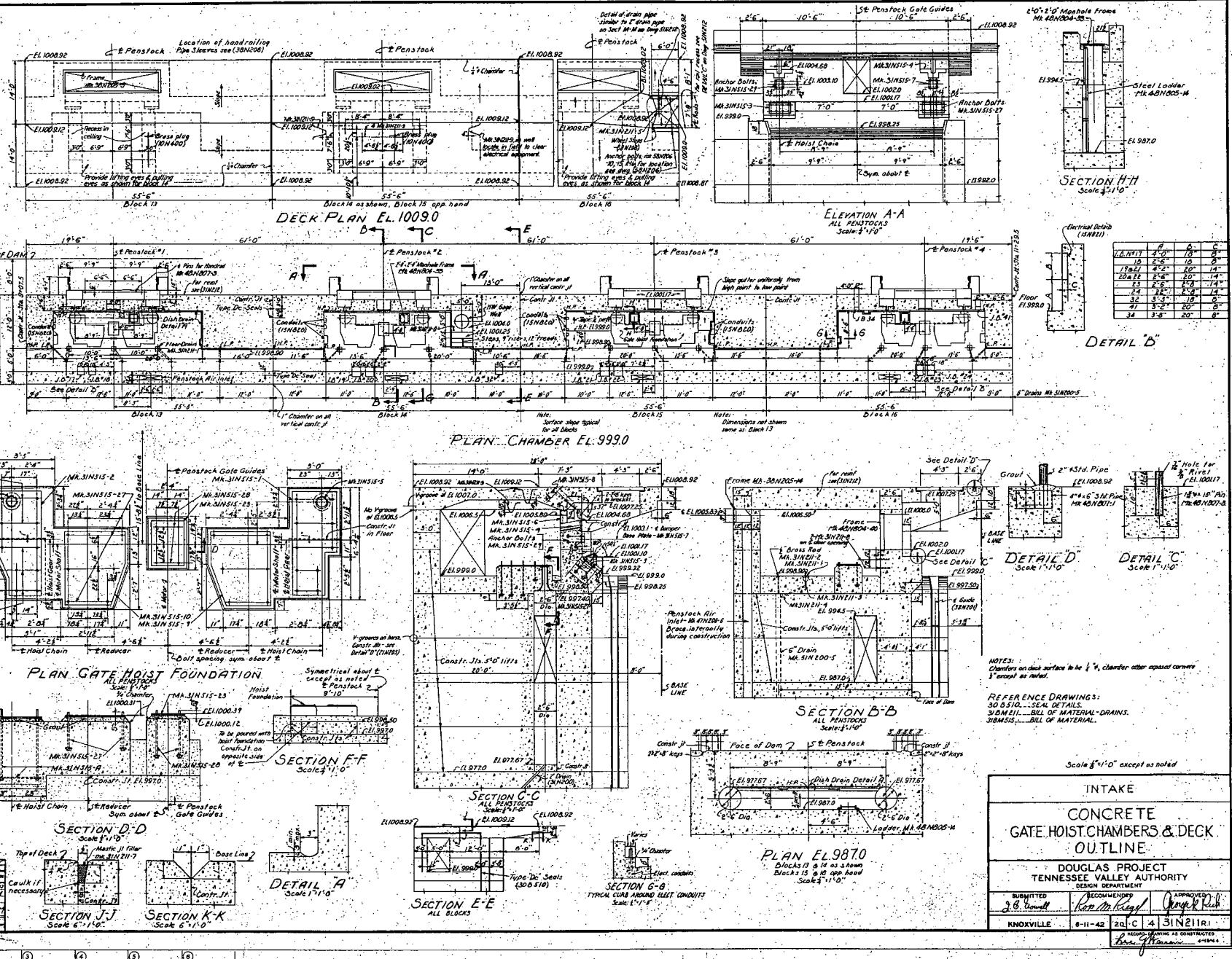
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	G.A.	FDJ	RRL		GR	

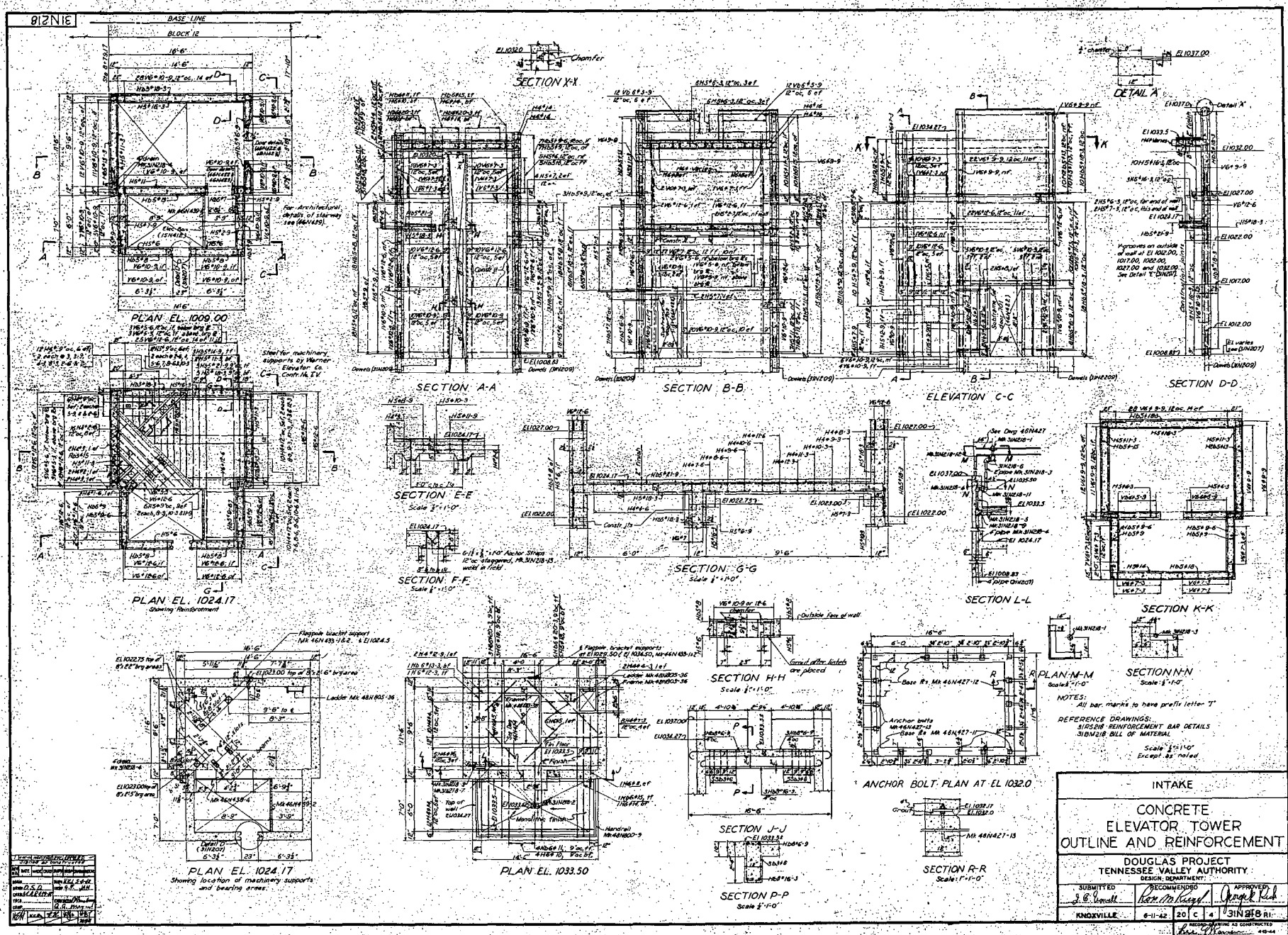
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R08	MM-DD-YY 4-29-43	20	C	23W204	R 7

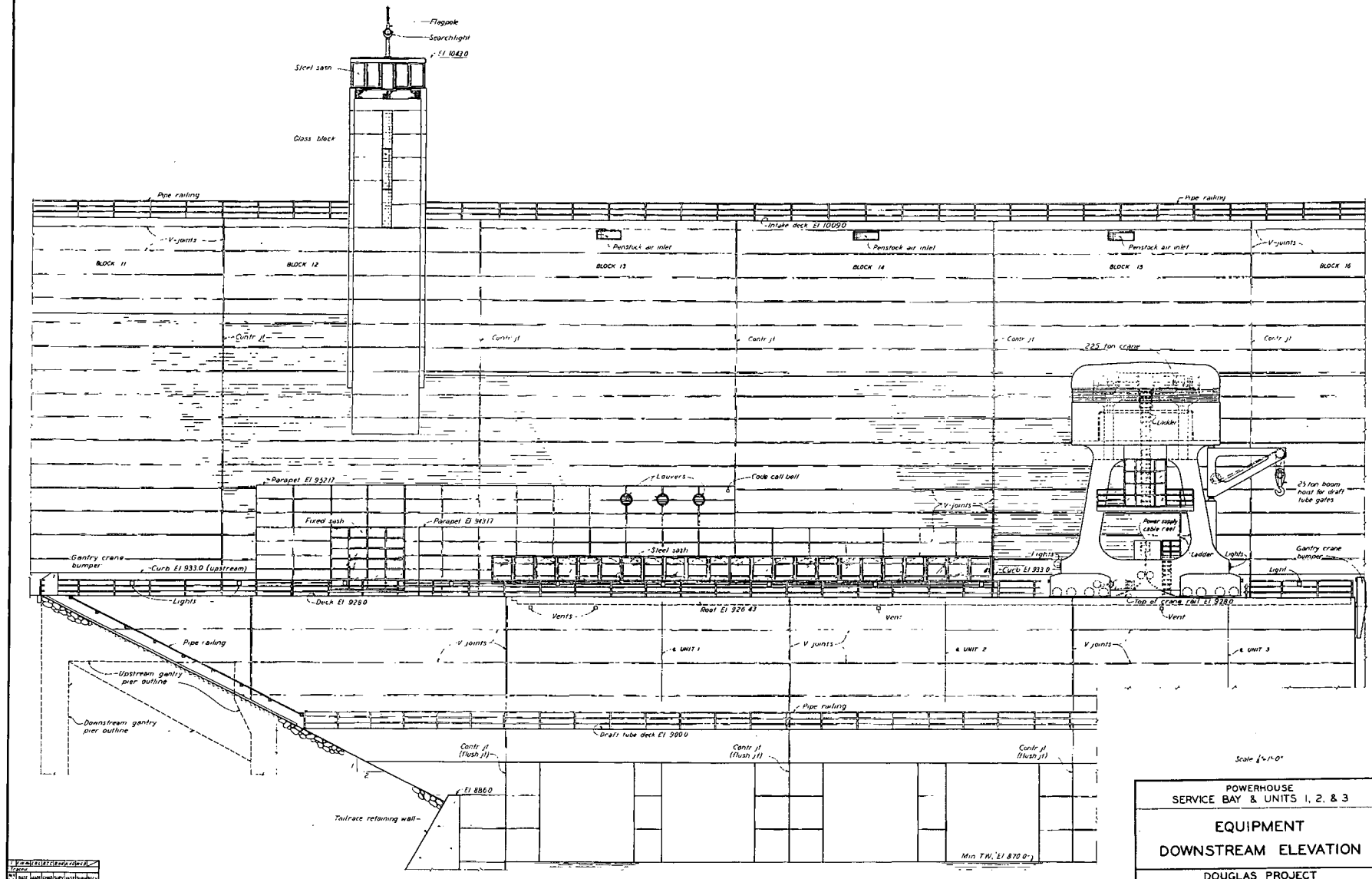
TASK COMPLETED BY	REV NO.	ELECTRONICALLY RESTORED DRAWING THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES (23W204 R6)	PLOT FACTOR:1200 W_TVA	C.A.D. DRAWING DO NOT ALTER MANUALLY

3IN211


DECK PLAN EL. 1009.0
ELEVATION A-A
ALL PENSTOCKS
SECTION H-H
PLAN CHAMBER EL. 999.0
DETAIL "B"
PLAN GATE HOIST FOUNDATION
SECTION B-B
ALL PENSTOCKS
DETAIL "D"
DETAIL "C"
SECTION C-C
ALL PENSTOCKS
SECTION D-D
SECTION E-E
ALL BLOCKS
SECTION F-F
SECTION G-G
TYPICAL CURB AROUND FLEET CONDUITS
PLAN EL. 987.0
SECTION J-J
SECTION K-K
DETAIL "A"
NOTES:
REFERENCE DRAWINGS:
INTAKE
CONCRETE
GATE HOIST CHAMBERS & DECK
OUTLINE
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
8-11-42
20-C 4 3IN211R1


31N218
INTAKE
CONCRETE
ELEVATOR TOWER
OUTLINE AND REINFORCEMENT
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
J.B. Lowell
KNOXVILLE
6-11-42
20
C
4
31N218 R1
RECORD DRAWING AS CONSTRUCTED
4-9-44
PLAN EL. 1009.00
PLAN EL. 1024.17
Showing Reinforcement
PLAN EL. 1024.17
Showing location of machinery supports and bearing areas
PLAN EL. 1033.50
SECTION A-A
SECTION B-B
ELEVATION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION J-J
SECTION P-P
SECTION R-R
SECTION L-L
SECTION K-K
SECTION M-M
SECTION N-N
DETAIL A
SECTION X-X
ANCHOR BOLT PLAN AT EL 1032.0
NOTES:
All bar marks to have prefix letter 'I'
REFERENCE DRAWINGS:
31R218 REINFORCEMENT BAR DETAILS
31BM218 BILL OF MATERIAL

46N200



Scale $\frac{1}{8}$"=1'-0"

POWERHOUSE
SERVICE BAY & UNITS 1, 2, & 3

EQUIPMENT
DOWNSTREAM ELEVATION

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

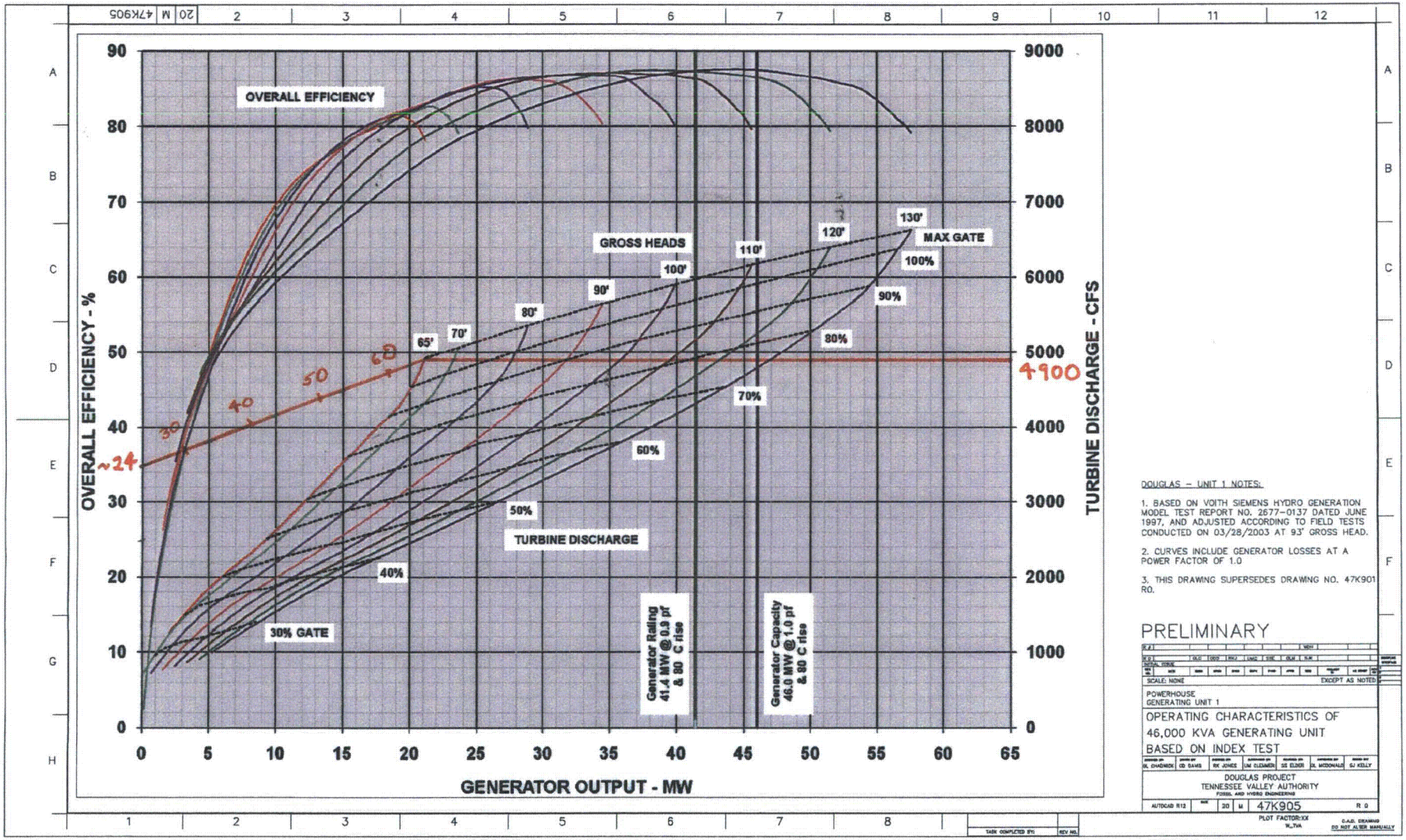
SUBMITTED	RECOMMENDED	APPROVED
Harry B. Jones	W. H. Wilson	B. A. Moore

KNOXVILLE	5-5-48	20	A	4	46N200R1

RECORD DRAWING AS CONSTRUCTED

Attachment A8-5
Reference 29, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 1 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677–0137 DATED JUNE 1997, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 03/28/2003 AT 93' GROSS HEAD.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K901 R0.

PRELIMINARY

SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 1

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DRAWN BY RL DWEMEN | CHECKED BY CD DAVIS | DESIGNED BY RK JONES | SUPERVISED BY LM CLEMMEN | RECOMMENDED BY SE ELDER | APPROVED BY RL MCDONALD | ISSUED BY GJ KELLY

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

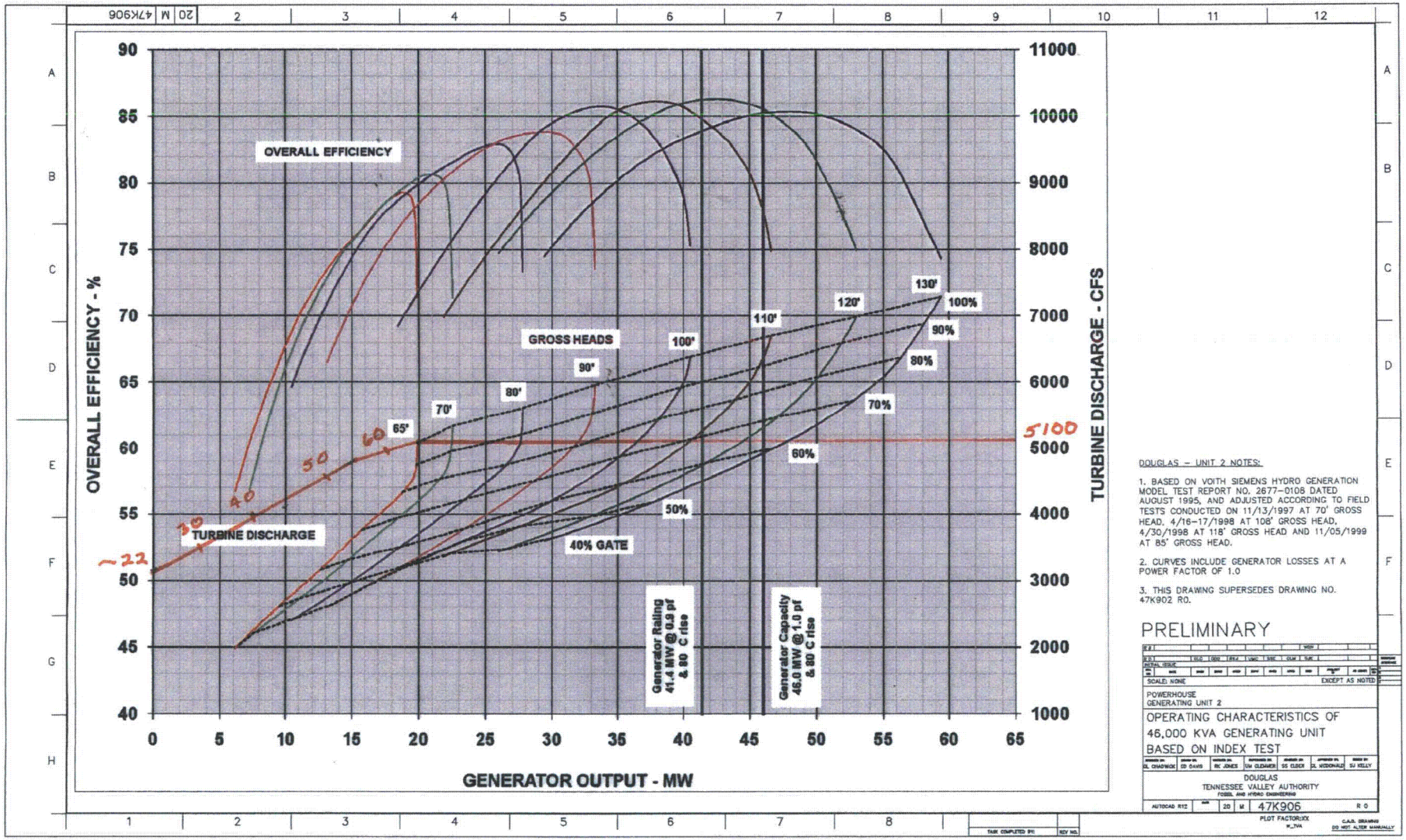
AUTOCAD R12 | SIZE D | M | 47K905 | R 0

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment A8-6
Reference 30, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 2 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0108 DATED AUGUST 1995, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 11/13/1997 AT 70' GROSS HEAD, 4/16-17/1998 AT 108' GROSS HEAD, 4/30/1998 AT 118' GROSS HEAD AND 11/05/1999 AT 85' GROSS HEAD.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K902 R0.

PRELIMINARY

SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 2

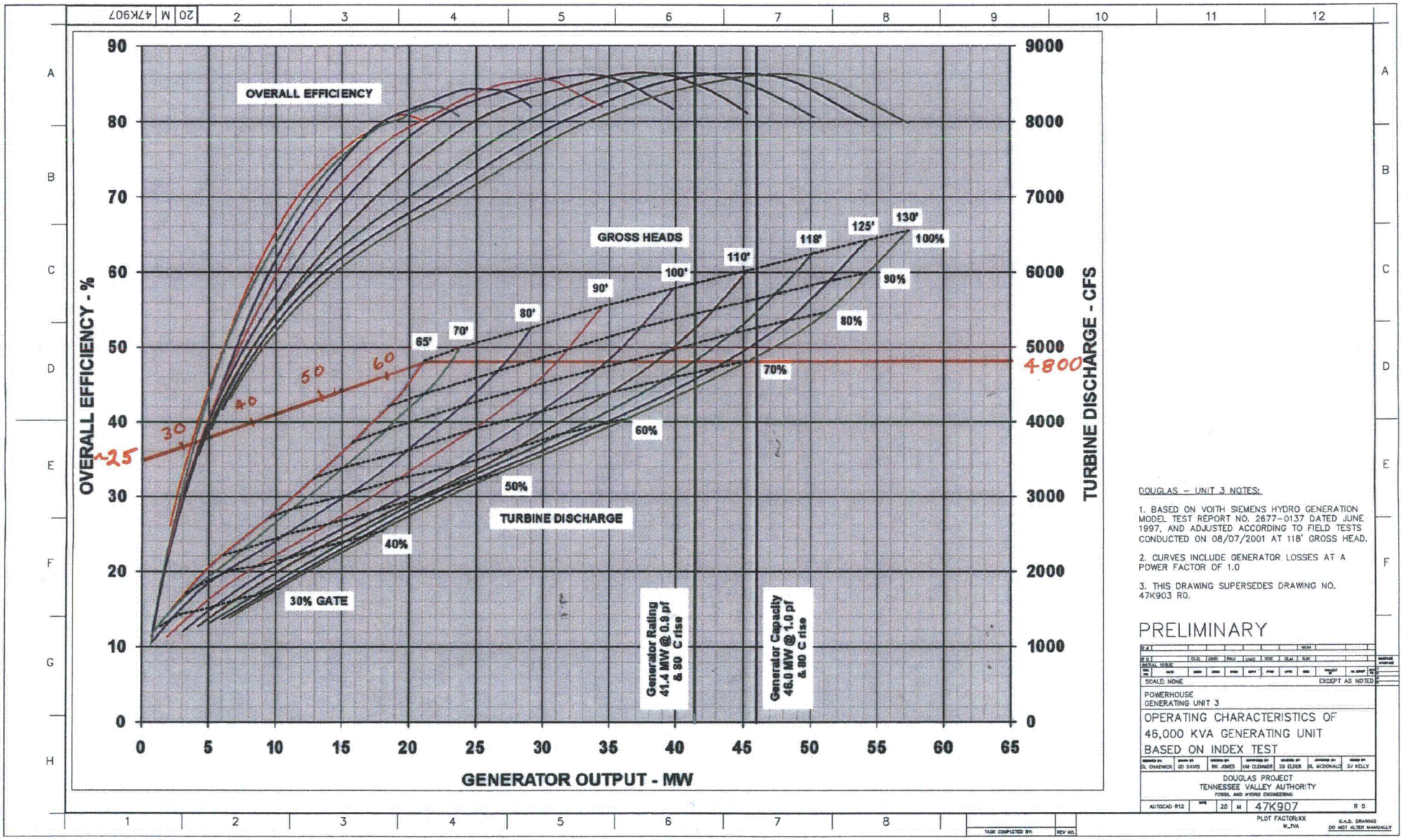
OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DOUGLAS
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | 20 | M | 47K906 | R 0

Attachment A8-7
Reference 31, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 3 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0137 DATED JUNE 1997, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 08/07/2001 AT 118' GROSS HEAD.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K903 R0.

PRELIMINARY

SCALE: NONE — EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 3

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

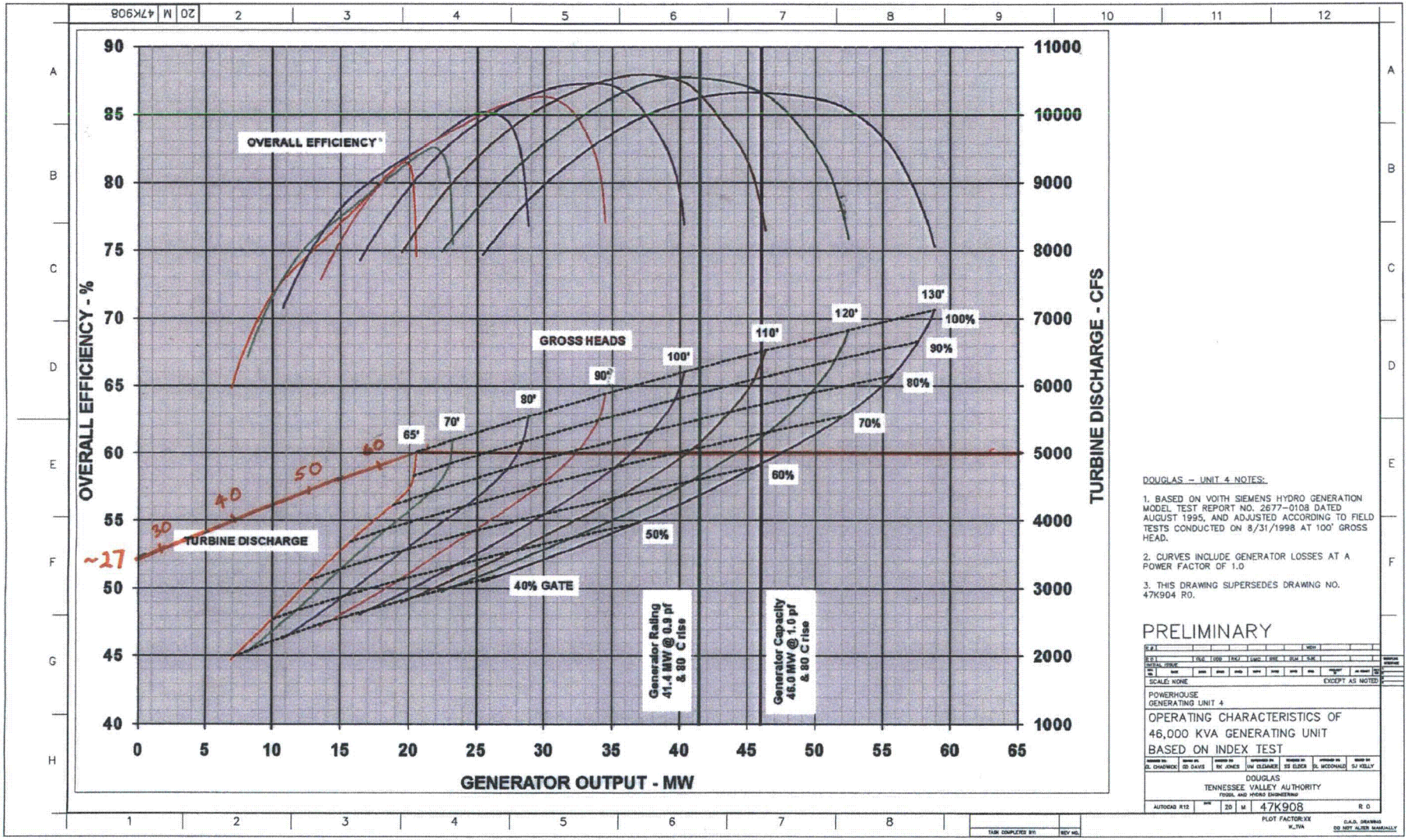
AUTOCAD R12 | 20 M 47K907 | R 0

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment A8-8
Reference 32, 38
Replaced for Rev 3

Calculation No: CDQ000020080007



DOUGLAS – UNIT 4 NOTES:

1. BASED ON VOITH SIEMENS HYDRO GENERATION MODEL TEST REPORT NO. 2677-0108 DATED AUGUST 1995, AND ADJUSTED ACCORDING TO FIELD TESTS CONDUCTED ON 8/31/1998 AT 100' GROSS HEAD.
2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 1.0
3. THIS DRAWING SUPERSEDES DRAWING NO. 47K904 R0.

PRELIMINARY

SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 4

OPERATING CHARACTERISTICS OF
46,000 KVA GENERATING UNIT
BASED ON INDEX TEST

DRAWN BY: D. CHADWICK | DESIGN BY: GD DAVIS | CHECKED BY: BK JONES | REVIEWED BY: HM ELDAKER | APPROVED BY: SS ELDER | APPROVED BY: DL MCDONALD | ISSUED BY: SJ KELLY

DOUGLAS
TENNESSEE VALLEY AUTHORITY
TODD, AND HYDRO ENGINEERING

AUTOCAD R12 | SIZE: D | NO: 47K908 | REV: R 0

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.

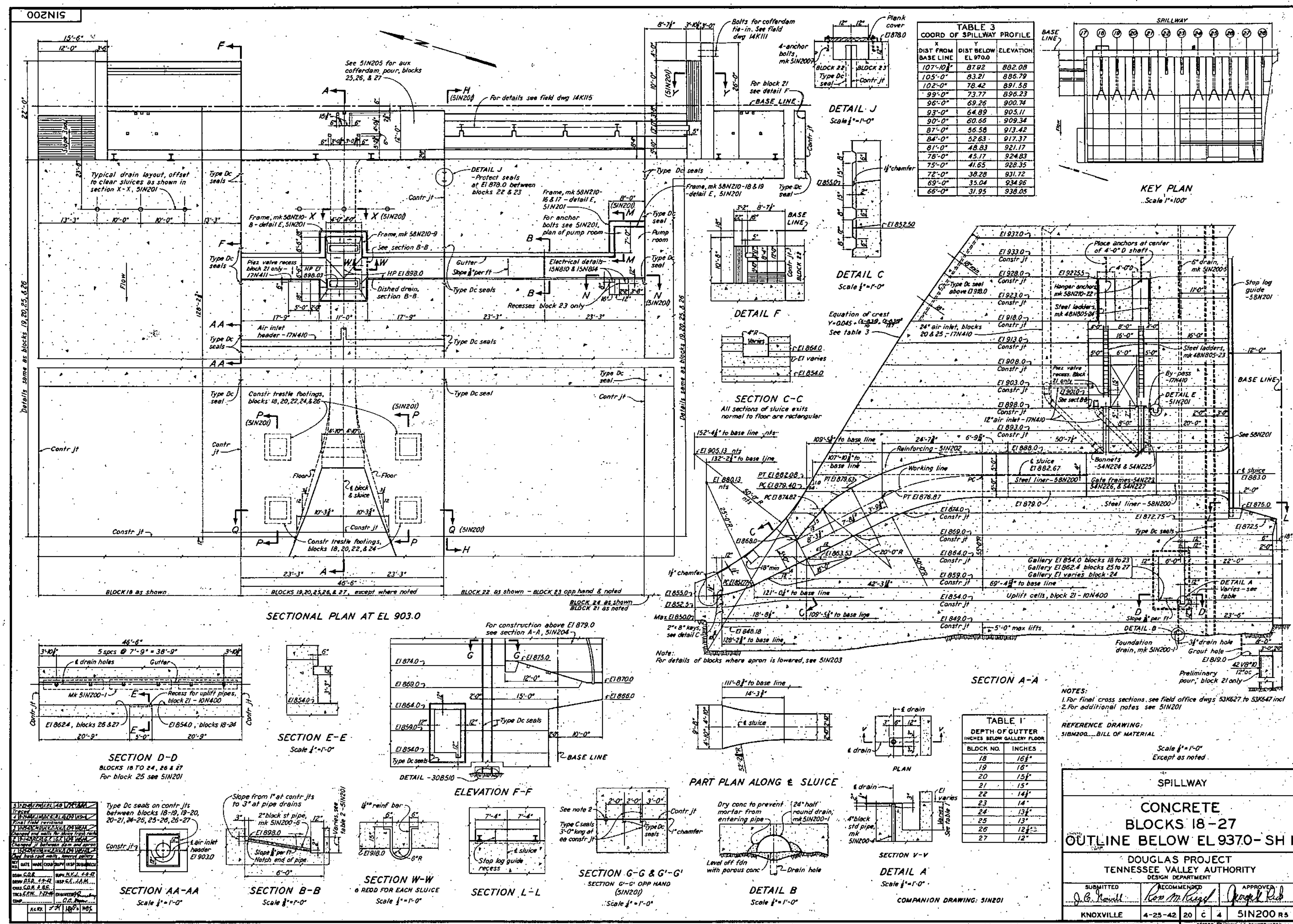


TABLE 3 COORD OF SPILLWAY PROFILE		
X DIST FROM BASE LINE	Y DIST BELOW EL 970.0	ELEVATION
107'-10 3/8"	87.92	882.08
105'-0"	83.21	886.79
102'-0"	78.42	891.58
99'-0"	73.77	896.23
96'-0"	69.26	900.74
93'-0"	64.89	905.11
90'-0"	60.66	909.34
87'-0"	56.58	913.42
84'-0"	52.63	917.37
81'-0"	48.83	921.17
78'-0"	45.17	924.83
75'-0"	41.65	928.35
72'-0"	38.28	931.72
69'-0"	35.04	934.96
66'-0"	31.95	938.05

TABLE 1 DEPTH OF GUTTER INCHES BELOW GALLERY FLOOR	
BLOCK NO.	INCHES
18	16 1/2"
19	16"
20	15 1/2"
21	15"
22	14 1/2"
23	14"
24	13 1/2"
25	13"
26	12 1/2"
27	12"

NOTES:
1. For final cross sections, see field office dwgs 53K627 to 53K647 incl
2. For additional notes see 5IN201

REFERENCE DRAWING:
5IBM200....BILL OF MATERIAL

Scale 1/8"=1'-0"
Except as noted

SPILLWAY

CONCRETE
BLOCKS 18-27
OUTLINE BELOW EL 937.0 - SH 1

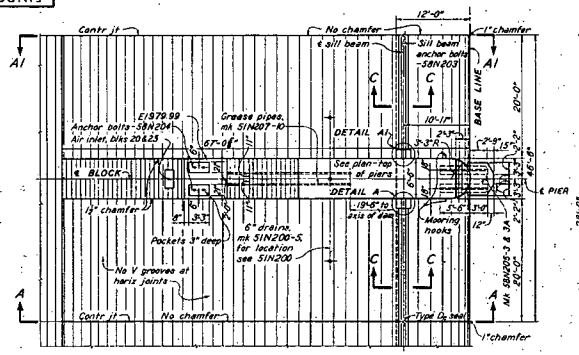
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
J. C. Novell	Ross M. Riegel	George R. Rich

KNOXVILLE	4-25-42	20	C	4	5IN200 R5

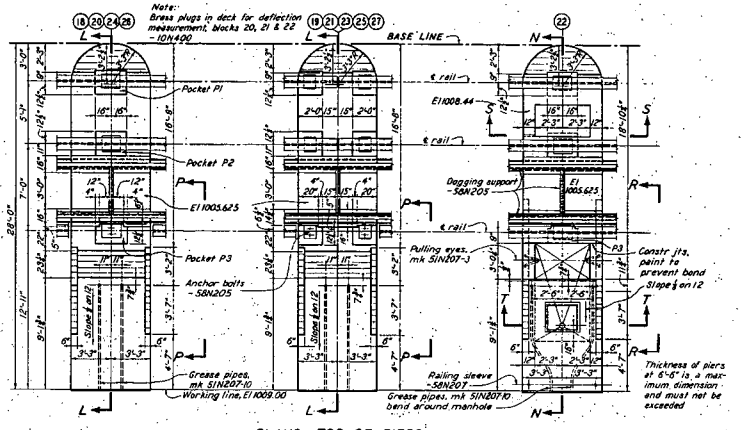
RECORD DRAWING AS CONSTRUCTED

SIN207

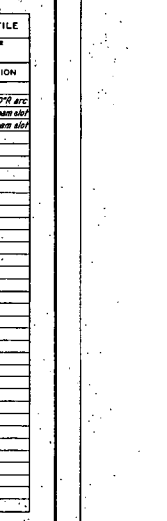


PLAN - BLOCKS 18 TO 27 INCL - ABOVE EL 937

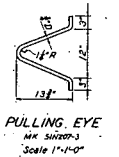
Scale ¼"-1'-0"



PLANS - TOP OF PIERS



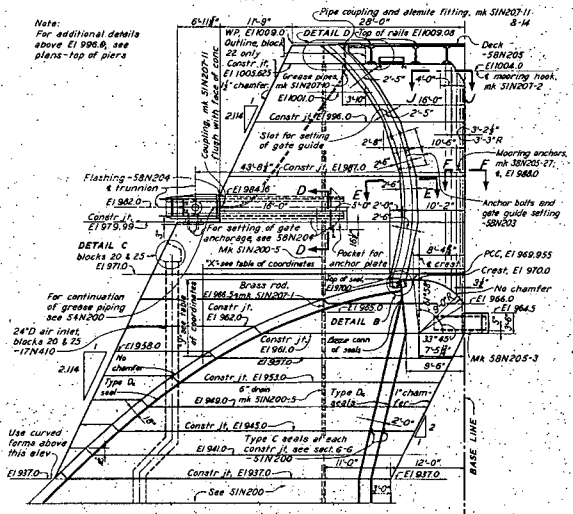
COORDINATES OF WEIR PROFILE $y = 0.045 + \frac{x-8.380}{10} + \frac{(x-8.380)^2}{127}$			
x	y	ELEV	DESCRIPTION
7.484	0.000	970.000	℄ of crest
8.380	0.045	969.955	PCC with 240'R arc
9.824	0.219	969.781	Edge of sill beam slot
11.904	0.495	969.505	Edge of sill beam slot
14.000	0.856	969.144	
16.000	1.264	968.735	
18.000	1.736	968.264	
20.000	2.270	967.730	
22.000	2.868	967.132	
24.000	3.528	966.472	
26.000	4.252	965.748	
28.000	5.038	964.962	
30.000	5.887	964.113	
32.000	6.800	963.200	
32.420	7.000	963.000	
34.000	7.775	962.225	
36.000	8.814	961.186	
38.000	9.915	960.085	
40.000	11.080	958.920	
42.000	12.307	957.693	
44.000	13.597	956.403	
46.000	14.951	955.049	
46.000	16.367	953.633	
48.866	17.000	953.000	
50.000	17.847	952.153	
52.000	18.389	950.611	
54.000	20.954	949.046	
56.000	22.653	947.337	
58.000	24.394	945.606	
58.683	25.000	945.000	
60.000	26.188	943.812	
62.000	28.046	941.954	
64.000	29.966	940.034	
66.000	31.950	938.050	
67.052	33.000	937.000	



PULLING EYE

MK SIN207-3

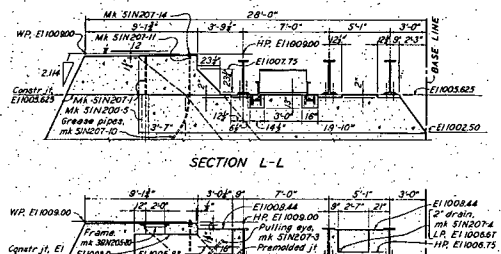
Scale 1"-1'-0"



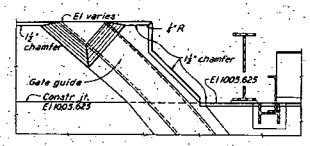
ELEVATION A-A & AI-AI

ELEVATION AI-AI OPPOSITE HAND

Scale ¼"-1'-0"



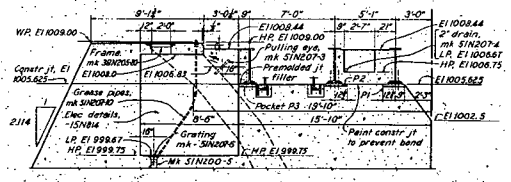
SECTION L-L



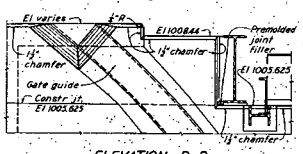
ELEVATION P-P

SHOWING FINISHED PIER FACE

Scale ¼"-1'-0"



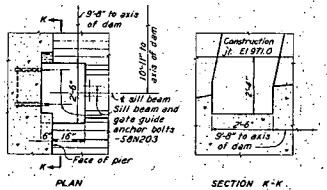
SECTION N-N



ELEVATION R-R

SHOWING FINISHED PIER FACE

Scale ¼"-1'-0"



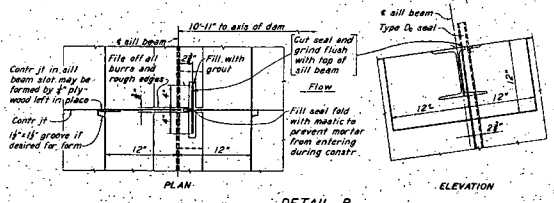
PLAN

SECTION K-K

DETAIL A & AI

DETAIL AI OPPOSITE HAND

Scale ¼"-1'-0"



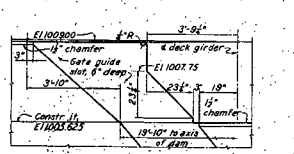
PLAN

ELEVATION

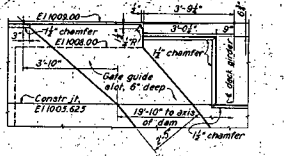
DETAIL B

SHOWING SEAL CONN TO SILL BEAM

Scale ½"-1'-0"



TYPICAL ELEV FOR ALL BLOCKS EXCEPT 22



ELEVATION FOR BLOCK 22

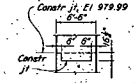
DETAIL D

Scale ¼"-1'-0"

NOTES:
1. For key plan see SIN200
2. In accordance with Construction Specification G-2, concrete shall be class A in piers and exterior surfaces of weirs.
3. For seal details and connections see 30B510.
4. For treatment of contraction joints see Construction Specification.
5. Exposed edges to be chamfered ¾" except as noted.

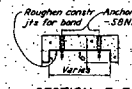
REFERENCE DRAWINGS:
SIBM207 - BILL OF MATERIAL

Scale ¼"-1'-0"
Except as noted



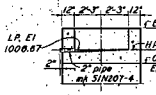
SECTION D-D

Scale ¼"-1'-0"

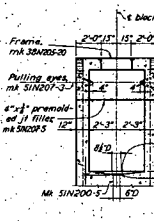


SECTION E-E

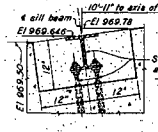
Scale ¼"-1'-0"



SECTION S-S

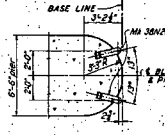


SECTION T-T

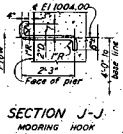


SECTION C-C

Scale ½"-1'-0"



SECTION F-F



SECTION J-J

MOORING HOOK FORGED STEEL MK SIN207-2

Scale ½"-1'-0"

SPILLWAY

CONCRETE

BLOCKS 18-27 - PIERS & CREST OUTLINE

DOUGLAS PROJECT

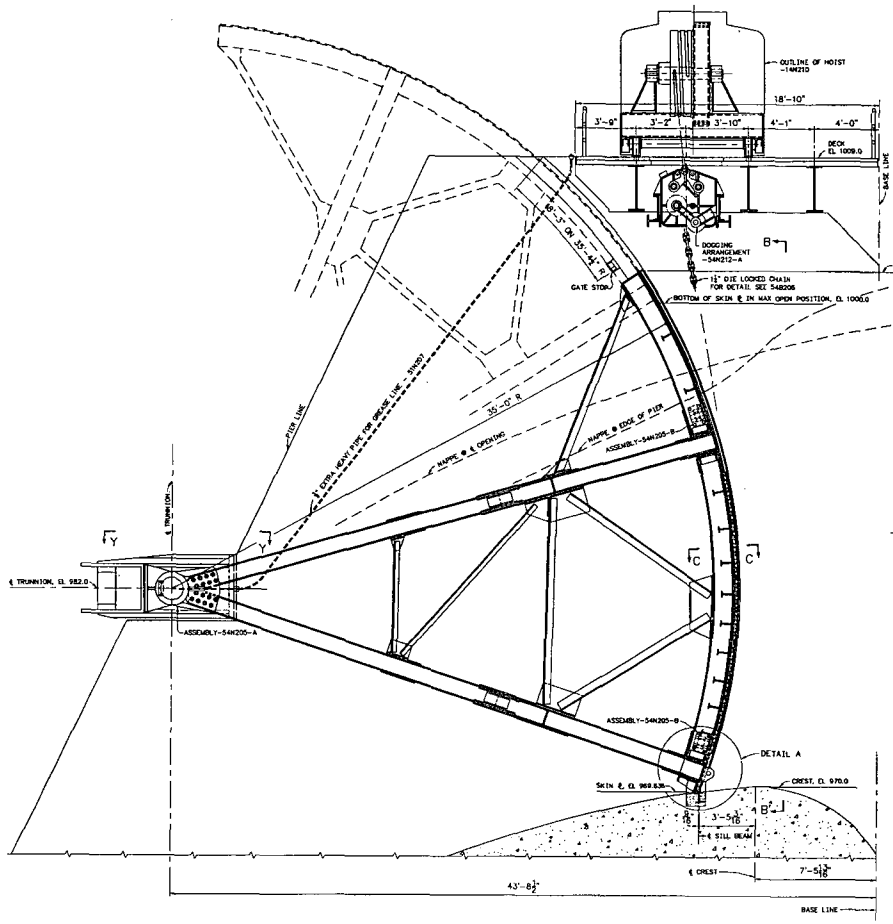
TENNESSEE VALLEY AUTHORITY

DESIGN DEPARTMENT

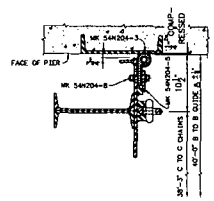
SUBMITTED	RECOMMENDED	APPROVED
J. G. Ewalt	Ken M. Kapp	George Reid
KNOXVILLE	5-2-42	20 C 4 SIN207R1

RECORD DRAWING AS CONSTRUCTED

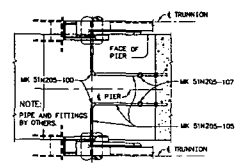
Rolls in Box No. 88



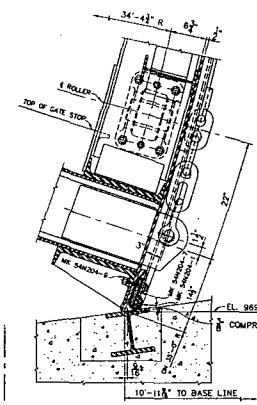
SECTION A~A



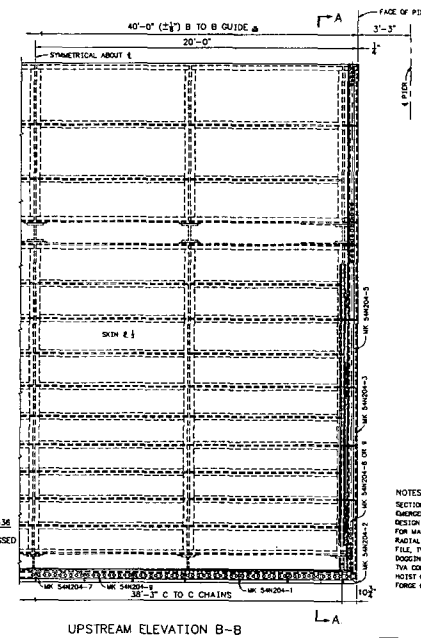
SECTION C-C
SCALE: 1½"=1'-0"



SECTION Y-Y



DETAIL A
SCALE: 1½"=1'-0"



UPSTREAM ELEVATION B~B

NOTES:
SECTIONS USED ARE THOSE AVAILABLE UNDER NATIONAL EMERGENCY ACT OF FEB 1, 1942, FOR ORIGINAL DESIGN SECTIONS, SEE CHEROKEE PROJECT.
FOR MANUFACTURER'S DETAILS OF:
RADIAL GATES, REFER TO LAKESIDE BRIDGE & STEEL CO. FILE, TVA CONTRACT NO. TV-88717.
DOGGING UNITS, REFER TO PHILLIPS & DAVIES, INC. FILE, TVA CONTRACT NO. TV-68784.
HOIST CHAINS, REFER TO BALDT ANCHOR CHAIN & FORGE CO. FILE, TVA CONTRACT NO. K-42-42630.

R								
R.E. 20 P	JAR	JAR	SRK	VAN	VAN	RWT	MAC	
ELECTRONICALLY RESTORED								

SCALE: ⅜"=1'-0" EXCEPT AS NOTED

SPILLWAY

GATES
GENERAL ARRANGEMENT

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
	C.O.P.	H.J.C.	W.L.M.			

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14	DATE 3-27-42	20	M	54W200	R 4

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES -(54N200 R3)

TASK COMPLETED BY: | REV NO.

PLOT FACTOR:32 W_TVA

C.A.D. DRAWING DO NOT ALTER MANUALLY

3. Free earth support analyses which compensate for toe fixity by including a bending moment reduction factor are liable to be misleading; fixed earth support methods should always be used.

4. Design analyses should be suitable for practical design use. In view of the approximations involved in "idealizing" geologic sections and assessing soil properties, design computations should not depend on arithmetical accuracy to several decimal places.

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

TRANSACTIONS

Paper No. 2677 Vol. 119, 1954

RATING CURVES FOR FLOW OVER DRUM GATES

By Joseph N. Bradley,[1] A. M. ASCE

With Discussion by Messrs. Guido Wyss; Sam Shulits; Bob Buehler; F. B. Campbell and A. A. McCool; and Joseph N. Bradley

Synopsis

With water becoming more valuable in the western states each year, there is an increasing demand for better methods of measurement and additional rating structures. This condition applies not only to the requirements for main canals and laterals of irrigation works but also to the regulation and measurement of flow at dams. In fact, the need has reached the point at which operators are desirous of metering the flow at nearly all control devices in irrigation systems, and in other water supply or control systems.

The primary purpose of this paper is to point out that there are numerous control structures in existence that will serve a dual purpose—that of a metering station as well as that of a regulating device. Examples of such structures include spillways, with or without gates; outlet works for dams using gates or valves; and canal regulating structures using gates. With the accumulation of information from hydraulic model studies made by the Bureau of Reclamation (USBR), United States Department of the Interior, it is now possible to prepare reasonably accurate rating curves for many such structures without the construction of models and without access to the prototypes. The method is especially useful for the rating of existing structures. This paper describes the method as it applies to the rating of drum gates and the paper is concluded with an engineering example. The method is also applicable to the rating of the Volet gate used in France, the bascule gate manufactured in the United States, and others in which the sector of a circle is hinged at or near the crest of a spillway.

Note.—Published, essentially as printed here, in February, 1953, as *Proceedings-Separate No. 169*. Positions and titles given are those in effect when the paper or discussion was received for publication.

[1] Hydr. Engr., Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo.

Introduction

The drum gate is a type of gate that floats in a chamber and is buoyed into position by regulating the water level in that chamber. A medium-sized gate of this type is shown in Fig. 1. To use drum gates as metering devices, it is essential that each gate be equipped with an accurate position indicator. This indicator may consist of an arm or pointer connected directly to one of the gate pins, and is usually located inside an adjacent pier. The scale, which commonly indicates "position of high point of gate," may be a cast-metal arc mounted on the wall under the pointer, or a scale painted on the wall.

This paper presents a method of computing rating curves for all positions of the gate with an accuracy comparable to that which can be obtained from an average current-meter traverse of the river. The information required for rating a drum gate consists of the over-all dimensions of the gate and overflow crest, the information contained in this paper, and the coefficient of discharge

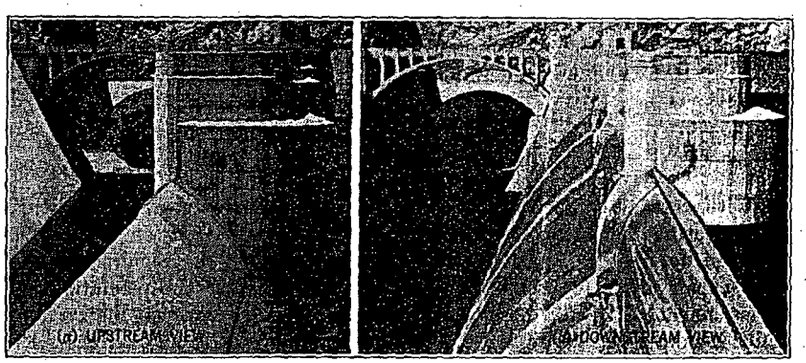


Fig. 1.—Drum Gate, 100 Ft by 16 Ft, at Hoover Dam (Arizona-Nevada)

for any appreciable head on the spillway with the gate in the completely lowered position. Should the coefficient data be lacking, the coefficient of discharge for the designed head can be estimated for nearly any overflow section by a method previously published.[2]

The method of rating described here is not intended to replace the measurements taken at river gaging stations. However, it has the following advantages: (1) The gates can be set in a few minutes to pass a desired discharge and (2) in time of flood, the gaging station may be out of order but the gate calibration is as accurate as usual. The flood that passed over Grand Coulee Dam (Washington) in 1948 is an example. The river gage, in the pier of a bridge downstream, was in error because of a drawdown in the water surface, adjacent to the pier, at the higher flows. Current-meter measurements were also attempted during the flood, but the swiftness of the current and other difficulties rendered these only partially successful. As a result, the discharge at the peak of the flood, which was finally estimated as 638,000

[2] "Discharge Coefficients for Irregular Overfall Spillway Sections," by J. N. Bradley, *Engineering Monograph No.* Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo., March, 1952.

sec-ft, is questionable. Measurement of the flow over the drum gates, which is now possible, would have afforded a continuous record and one that would be as accurate for floods as for normal flows.

Characteristics of the Drum Gate

As a measuring device, the drum gate resembles a sharp-crested weir with a curved upstream face over the greater part of its travel. With an adequate positioning indicator, the drum gate can serve as a very satisfactory metering device.

When the drum gate simulates a sharp-crested weir—that is, when a line drawn tangent to the downstream lip of the gate makes a positive angle with the horizontal, as in Fig. 2(*a*), four principal factors are involved. These factors are H, the total head above the high point of the gate; θ, the angle made by a line drawn tangent to the downstream lip of the gate and the horizontal; r, the radius of the gate or an equivalent radius, should the curvature of the

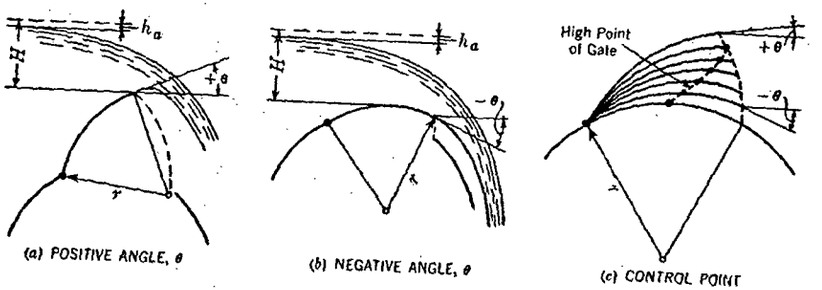


Fig. 2.—Drum-Gate Positions

gate involve a parabola; and C_q, the coefficient of discharge in $Q = C_q L H^{\frac{3}{2}}$, in which Q is the discharge in second-feet, and L is the length of the gate.

The depth of approach was not included as a variable because drum-gate installations studied were for medium and high dams at which approach effects were negligible. When the approach depth, measured below the high point of the gate, is equal to or greater than twice the head on the gate, it has been shown[3] that a further increase in approach depth produces very little increase in the coefficient of discharge. Most drum-gate installations satisfy this condition, especially when the gate is in a raised position. Therefore, with adequate approach depth the four variables H, θ, r, and C_q completely define the flow over this type of gate for positive angles of θ, Fig. 2(*a*).

For negative values of θ, Fig. 2(*b*), the downstream lip of the gate no longer controls the flow. Rather, the control point shifts upstream to the vicinity of the high point of the gate for each setting as illustrated in Fig. 2(*c*), and flow conditions gradually approach those of the free crest (as the gate is lowered). Although other factors enter the problem, the similitude also holds for this case down to an angle of approximately $-15°$.

[3] "Studies of Crests for Overfall Dams," *Bulletin No. 3*, Pt. VI, Boulder Canyon Final Reports, Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo., 1948.

Sources of Information

The data for this drum-gate study were obtained from hydraulic models of various sizes and scales. The experiments were performed over a period of about eighteen years. The spillway drum gates tested, the principal dimensions of each, the model scale, the laboratory where the tests were conducted, and other information are given in Table 1. Gates for the first three dams

TABLE 1.—Principal Dimensions of Drum Gates Tested

Dam	No. of gates	Length of gate, in ft	Height of gate, in ft	Radius of gate, in ft	Approach depth, in ft	Maximum head on crest,[a] in ft	Model scale	Hydraulic laboratory
Grand Coulee (Washington)	11	135	28	66.25	360	31.65	1:30	Fort Collins (Colo.)
Bhakra (India)	2	135	28	66.25	410	28	1:80	Customhouse (Denver, Colo.)
Shasta (California)	3	110	28	66.25	460	28	1:68	Customhouse
Hamilton (Texas)	1	300	28	74.17	50	32	1:30	Fort Collins
Hoover, Shape 4-M3[b] (Ariz.-Nev.)	4	100	16	26.8	50	26.6	1:20	Montrose, Colo.
Hoover, Shape 8-M5[b] (Ariz.-Nev.)	4	100	16	36.0	50	26.6	1:20	Montrose
Hoover, Shape 7-C4[b] (Ariz.-Nev.)	4	100	16	26.0	50	26.6	1:60	Fort Collins
Friant (California)	3	100	18	47.0	140	19.0	1:25	Fort Collins
Norris (Tennessee)	3	100	14	34.0	200	27.0	1:72	Fort Collins
Madden (Canal Zone)	4	100	18	30.0	120	30.0	1:72	Fort Collins
Capilano (British Columbia)	1	70	23	71.0	200	23.0	1:60	Denver Federal Center

[a] Gate down. [b] Refers to the shape of the spillway cross section.

listed in the table—Grand Coulee Dam (Washington), Bhakra Dam (India), and Shasta Dam (California)—are identical except for the length and number. The models of each were tested at different times by different personnel. The results of the tests are nearly identical, which fact indicates the consistency possible in this type of test. Although identical gates are of value in indicating the consistency of results, test results on dissimilar gates are desirable because they can give assurance that all factors involved in the establishment of similitude have been considered. The study includes only eleven gates (Table 1), but the dimensions of these vary over a fairly wide range, and the consistency indicated in compiling the results was quite satisfactory.

Cross sections of representative examples of the spillway overflow sections and drum gates listed in Table 1 are shown in Fig. 3. For Hoover Dam, Shape 4-M3 is shown. The data relating the coefficient, C_q, to the head for the model drum gates tested are tabulated in Table 2.

Results of Bazin on Straight Inclined Weirs

The straight inclined weir is comparable to a drum gate, having infinite radius, thus the results of Bazin serve as an introduction to this study.

Bazin, in his classical experiments, studied inclined sharp-crested weirs.[4] The angle of the weir was varied in increments from 14° to 90° with the horizontal, and each weir was 3.7 ft high (*vertical dimension*). The head on the crest of the weirs ranged from 0.32 ft to 1.48 ft. The results, presented in Fig. 4, show θ plotted against the Bazin coefficient, C_b (*in the formula*, $Q = C_b L h \sqrt{2 g h}$), in which h does not include the velocity head of approach (h_a). The

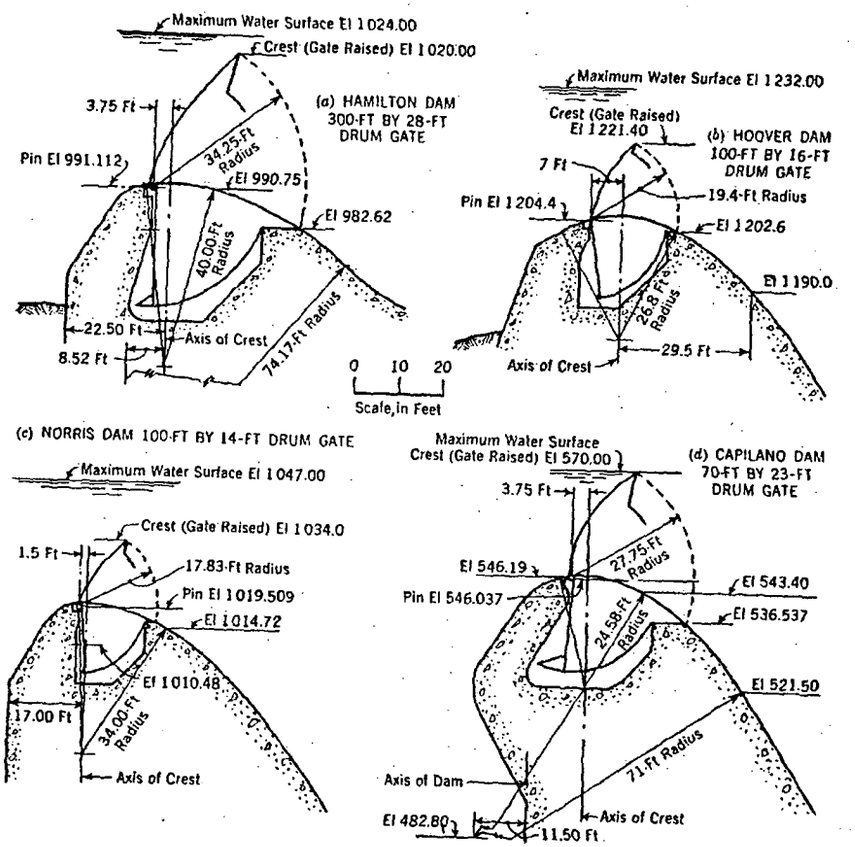


Fig. 3.—Examples of Drum-Gate Cross Sections

angle θ is also plotted with respect to C_q (in the expression, $Q = C_q L H^{\frac{3}{2}}$) in which H is the total head. This latter expression will be used throughout the paper.

By reference to Fig. 4 it can be observed (1) that the coefficient, C_q, varies only slightly with the observed head on the weir, (2) that there is a rather

[4] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. IX, No. 4, 1892, p. 316.)

TABLE 2.—DRUM-GATE COEFFICIENTS[a]

Grand Coulee Dam (Washington)		Bhakra Dam (India)		Shasta Dam (California)		Hamilton Dam (Texas)	
Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e
Gate Elevation[b] 1260.0		Gate Elevation[b] 1552.0		Gate Elevation[b] 1037.0		Gate Elevation[b] 992.0	
1295	3.920	1580	3.680	1075	3.895	35	3.710
1290	3.842	1575	3.645	1070	3.835	30	3.645
1285	3.745	1570	3.550	1065	3.760	25	3.580
1280	3.635	1565	3.420	1060	3.675	20	3.500
1275	3.510	1560	3.275	1055	3.575	15	3.400
1270	3.352	1555	3.120	1050	3.465	10	3.290
1265	3.220			1045	3.335	5	3.160
Gate Elevation 1263.51		Gate Elevation 1557.0		Gate Elevation 1039.0		Gate Elevation 995.52	
1295	3.530	1580	3.430	1075	3.637	30	3.400
1290	3.442	1575	3.380	1070	3.565	25	3.310
1285	3.360	1570	3.295	1065	3.490	20	3.223
1280	3.280	1565	3.170	1060	3.417	15	3.150
1275	3.220	1560	3.040	1055	3.340	10	3.085
1270	3.182			1050	3.250	5	3.010
Gate Elevation 1267.02		Gate Elevation 1562.0		Gate Elevation 1041.0		Gate Elevation 999.0	
1295	3.530	1580	3.550	1075	3.550	25	3.450
1290	3.457	1576	3.355	1070	3.494	20	3.390
1285	3.380	1572	3.290	1065	3.432	15	3.300
1280	3.300	1568	3.345	1060	3.365	10	3.195
1275	3.213	1564	3.465	1055	3.290	5	3.080
1270	3.120						
Gate Elevation 1270.48		Gate Elevation 1567.0		Gate Elevation 1045.0		Gate Elevation 1006.0	
1295	3.600	1580	3.665	1075	3.637	18	3.640
1290	3.530	1577	3.650	1070	3.565	15	3.635
1285	3.462	1573	3.600	1065	3.490	12	3.605
1280	3.410	1570	3.535	1060	3.415	9	3.560
1275	3.375			1055	3.330	6	3.505
				1050	3.220		
Gate Elevation 1274.01		Gate Elevation 1572.0		Gate Elevation 1050.0		Gate Elevation 1013.0	
1300	3.725	1580	3.780	1075	3.717	12	3.718
1295	3.695	1579	3.755	1070	3.670	10	3.690
1290	3.662	1578	3.690	1065	3.615	8	3.645
1285	3.630	1577	3.500	1060	3.560	6	3.595
1280	3.600	1576	3.150	1055	3.495	4	3.530
Gate Elevation 1277.50				Gate Elevation 1055.0		Gate Elevation 1020.0	
1295	3.750			1075	3.854	6	3.630
1290	3.738			1070	3.827	5	3.610
1285	3.740			1065	3.800	4	3.540
1280	3.765			1060	3.780	3.5	3.400
				1055	3.763		
Gate Elevation 1281.02				Gate Elevation 1060.0			
1295	3.730			1075	3.645		
1292	3.708			1072	3.683		
1288	3.705			1069	3.740		
1285	3.725			1066	3.815		
				1063	3.920		
Gate Elevation 1284.50				Gate Elevation 1065.0			
1300	3.840			1076	3.810		
1296	3.830			1074	3.865		
1292	3.875			1072	3.910		
1288	3.950			1070	3.950		
Gate Elevation 1288.0							
1296	3.750						
1294	3.720						
1292	3.670						
1290	3.580						

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Friant Dam (California)		Norris Dam (Tennessee)		Madden Dam (Canal Zone)		Capilano Dam (British Columbia)	
Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e
Gate Elevation[b] 560.0		Gate Elevation[b] 1020.0		Gate Elevation[b] 232.0		Gate Elevation[b] 547.0	
580	3.650	1055	3.915	35	3.900	580	3.775
577	3.625	1050	3.845	30	3.770	575	3.705
574	3.550	1045	3.765	25	3.660	570	3.625
571	3.460	1040	3.670	20	3.560	565	3.530
568	3.340	1035	3.550	15	3.460	560	3.415
565	3.175	1030	3.390	10	3.305	555	3.250
562	2.965	1025	3.125	5	3.280		
Gate Elevation 561.5		Gate Elevation 1022.0		Gate Elevation 236.0		Gate Elevation 555.4	
580	3.340	1055	3.785	30	3.810	580	3.615
577	3.300	1050	3.725	25	3.750	577	3.580
574	3.250	1045	3.655	20	3.675	574	3.540
571	3.200	1040	3.570	15	3.590	571	3.485
568	3.125	1035	3.460	10	3.500	568	3.420
564	2.950	1030	3.300	5	3.410	565	3.320
		1025	3.000				
Gate Elevation 563.0		Gate Elevation 1024.0		Gate Elevation 240.0		Gate Elevation 561.1	
580	3.320	1055	3.760	30	3.960	583	3.560
577	3.280	1050	3.720	25	3.890	580	3.530
574	3.240	1045	3.670	20	3.835	577	3.490
571	3.176	1040	3.605	15	3.800	574	3.435
568	3.080	1035	3.520	10	3.775	571	3.355
565	2.960	1030	3.380	5	3.740	568	3.130
		1025	3.000				
Gate Elevation 566.0		Gate Elevation 1026.0		Gate Elevation 245.0		Gate Elevation 568.5	
580	3.450	1055	3.835	25	3.900	583	3.785
577	3.410	1050	3.810	20	3.900	580	3.850
574	3.340	1045	3.780	15	3.890	577	3.890
571	3.240	1040	3.740	10	3.910	574	3.925
568	3.085	1035	3.685	5	3.935		
		1030	3.580				
Gate Elevation 569.0		Gate Elevation 1028.0		Gate Elevation 250.0			
580	3.625	1055	3.890	20	3.750		
578	3.605	1050	3.880	15	3.780		
576	3.575	1045	3.865	10	3.860		
574	3.550	1040	3.845	5	3.980		
572	3.500	1035	3.815				
570	3.400	1030	3.745				
Gate Elevation 572.0		Gate Elevation 1030.0					
580	3.725	1055	3.890				
578	3.720	1050	3.890				
576	3.680	1045	3.885				
574	3.620	1040	3.880				
		1035	3.875				
Gate Elevation 573.0		Gate Elevation 1032.0					
580	3.760	1055	3.870				
578	3.760	1050	3.875				
576	3.765	1045	3.880				
575	3.780	1040	3.895				
574	3.900	1035	3.920				
Gate Elevation 575.0		Gate Elevation 1034.0					
580	3.780	1055	3.815				
578	3.790	1050	3.835				
577	3.840	1045	3.855				
576	3.950	1040	3.885				
		1036	3.945				

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Hoover Dam (Arizona-Nevada) Shape 4-M3		Hoover Dam (Arizona-Nevada) Shape 8-M5		Hoover Dam (Arizona-Nevada) Shape 7-C4	
Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4	
26	3.670	28	3.735	26	3.665
22	3.605	25	3.705	22	3.615
18	3.540	20	3.650	18	3.540
14	3.472	15	3.565	14	3.450
10	3.405	10	3.460	10	3.360
6	3.338	5	3.335	6	3.200
Gate Elevation 1209.4		Gate Elevation 1209.4		Gate Elevation 1209.0	
20	3.675	24	3.590	23	3.725
17	3.645	20	3.540	19	3.650
14	3.615	16	3.492	15	3.580
11	3.585	12	3.428	11	3.508
8	3.555	8	3.330	7	3.415
Gate Elevation 1213.4		Gate Elevation 1213.4		Gate Elevation 1213.0	
20	3.880	20	3.765	19	3.800
17	3.875	16	3.765	16	3.845
14	3.875	12	3.725	13	3.825
11	3.870	8	3.668	10	3.750
8	3.870	4	3.600	7	3.640
Gate Elevation 1217.4		Gate Elevation 1217.4		Gate Elevation 1217.0	
14	3.960	15	3.900	15	3.960
12	3.980	12	3.890	13	3.930
10	4.010	9	3.900	11	3.935
8	4.075	6	3.930	9	3.970
				7	4.020
Gate Elevation 1221.4		Gate Elevation 1221.4		Gate Elevation 1221.4	
10	3.890	11	3.830	14	3.815
8	3.930	9	3.840	12	3.820
6	4.020	7	3.875	10	3.823
5	4.100	5	3.935	8	3.825

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

sharp reversal in the curve when the angle θ approaches 28°, and (3) that the coefficient of discharge is a maximum at this angle. As the angle θ is increased from 28° to 90°, contraction of the jet gradually reduces the coefficient to approximately 3.33, which occurs when the weir is vertical. As θ is decreased from 28° to 0° the coefficient is gradually reduced—either by approach conditions, friction, or both—to that for a broad-crested weir, which may be some value between 2.8 and 3.1. As the principal difference between the drum gate and the straight inclined weir lies in the curvature of the gate, the trends for the two should be similar.

An inconsistency exists in Fig. 4—namely, the coefficient of discharge for a vertical sharp-crested weir should approximate 3.33, but Fig. 4 shows that Bazin obtained 3.45. This conclusion is supported by the fact that the USBR, Ernest W. Schoder, M.ASCE, and Kenneth B. Turner,[5] and others have not

[5] "Precise Weir Measurements," by Ernest W. Schoder and Kenneth B. Turner, *Transactions*, ASCE, Vol. 93, 1929, p. 999.

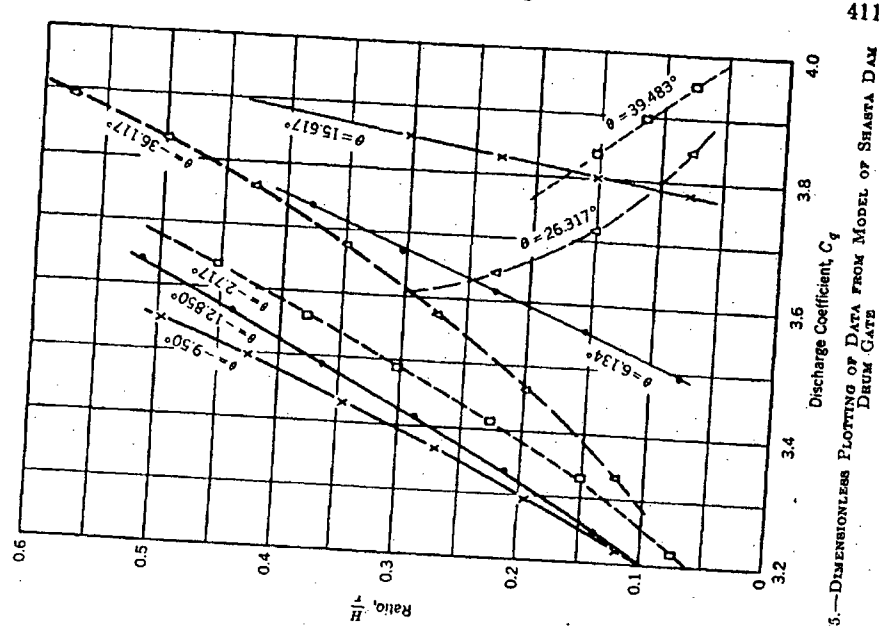


Fig. 5.—Dimensionless Plotting of Data from Model of Shasta Dam Drum Gate

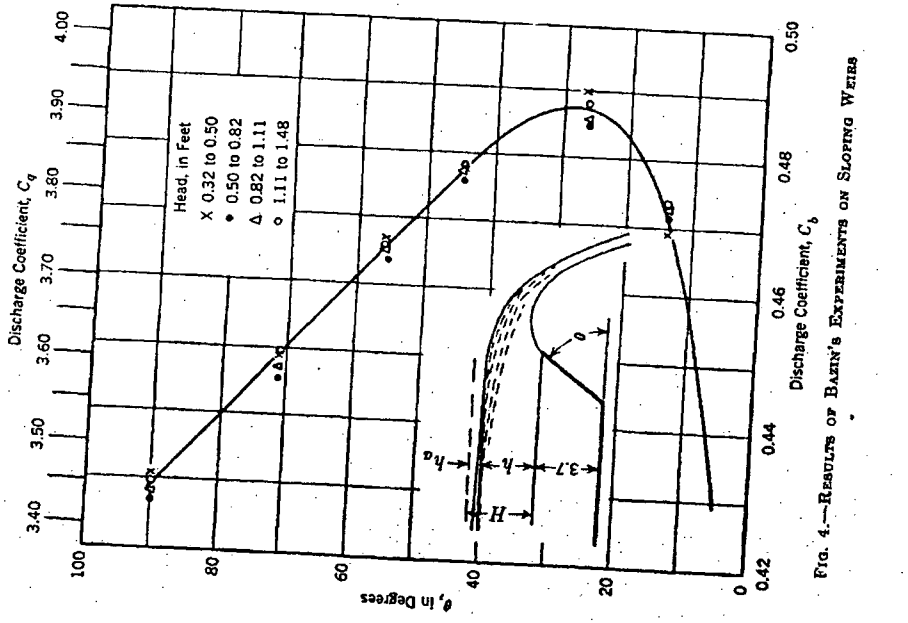


Fig. 4.—Results of Bazin's Experiments on Sloping Weirs

been able to check the discharge measurements of Bazin. However, the actual values are not so important for the case at hand as is the significance of the trend.

Method of Combining Test Results

The method for combining results from the eleven drum gates tested (Table 2) consisted of first plotting the coefficient of discharge data separately

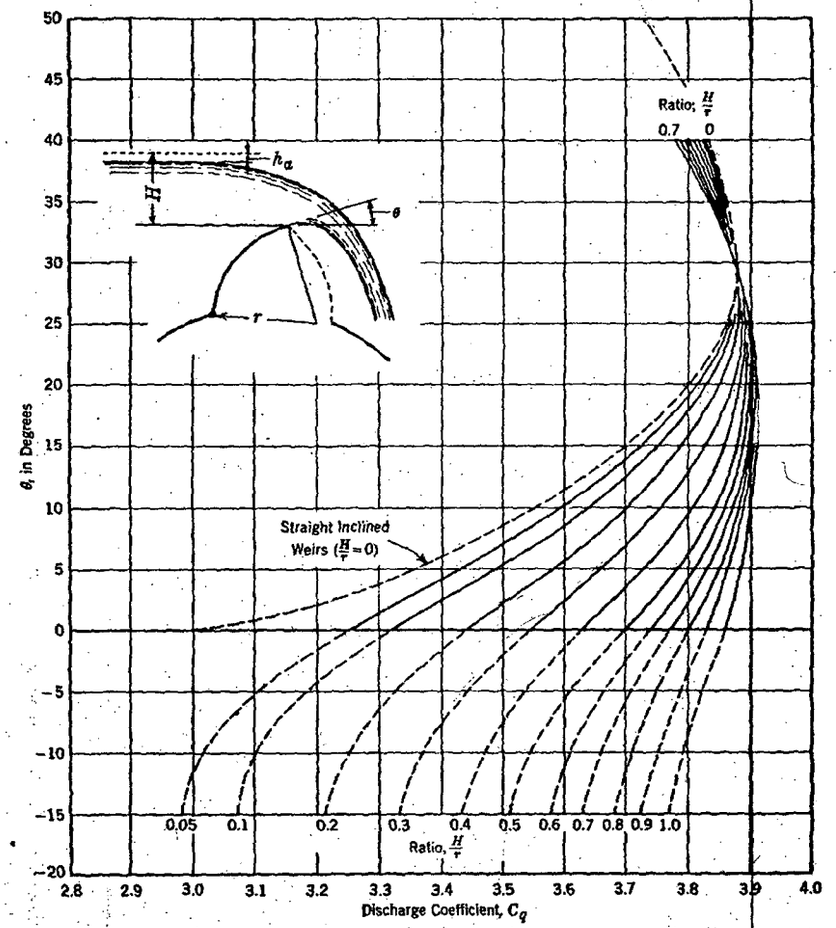


Fig. 6.—General Curves for the Determination of Discharge Coefficients

for each gate as illustrated by the sheet for the Shasta Dam gate (Fig. 5). With the coefficient of discharge as the abscissa and H/r as the ordinate, each curve in Fig. 5 represents a different gate angle θ, which the tangent to the downstream lip of the gate makes with the horizontal. In all cases, H is the

total head, including the velocity head of approach, *measured above the high point of the gate, and* r is the radius of the gate. In Fig. 5, C_q is based on the relationship, $Q = C_q L H^{\frac{1}{2}}$. For positive values of θ, the head was measured above the lip of the gate, whereas for negative angles it was observed above the high point, or crest, of the gate proper. The method of measuring the head is illustrated in Fig. 2.

Upon completion of a similar set of curves for each gate tested, the eleven sets of curves were replotted and combined into the chart exhibited as Fig. 6. The results from the various gates showed good general agreement; and the curves in Fig. 6 constitute the general experimental information needed for determining the discharge coefficients for gates in raised or partly raised positions. The supporting points are not shown in Fig. 6, but the individual information for each gate is listed in Table 2.

Analysis of Test Results

The curves in Fig. 6 show a tendency toward reversal, similar to that exhibited by the Bazin curve in Fig. 4, but the points of inflection vary from $\theta = 20°$ to $\theta = 30°$, depending on the value of H/r. Fig. 4 showed the coefficients to vary only slightly with the head, but in this case the coefficients definitely vary with the head.

A matter of significance is the reversal of the (H/r)-order which occurs at 29° (Fig. 6). The coefficient of discharge has but one value, 3.88, when θ approximates 29°; thus, it is insensitive to both the radius and the head on the gate for this angle. The curve for $H/r = 0$ approximates a drum gate of infinite radius and was obtained from the data of Bazin (Fig. 4) by applying a uniform adjustment.

As stated previously, similitude is valid for small negative angles of θ, as well as for positive angles up to 90°; thus, the curves in Fig. 6 are shown and recommended for use down to $\theta = -15°$. As the gate is lowered beyond this angle, the curves double back and converge, finally terminating in the free flow coefficient.

The discharge coefficients in the region between $\theta = -15°$ and the gate completely down are determined by graphical interpolation. Interpolation is accomplished by plotting head-discharge curves for several gate angles between $-15°$ and the maximum positive angle. Also the head-discharge curve is plotted for the free crest. This information is then cross-plotted to obtain values in the transition zone. The method will be explained in the example that follows. It will be discovered that negative angles greater than $-15°$ (with the exception of the free crest) are not particularly important from an operator's standpoint, as a change in gate position has little effect on the discharge in this range.

It must be assumed that the coefficient of discharge is known for at least one value of the head on the free crest (gate completely down) for the particular spillway under consideration. With the coefficient known for one or more heads, the complete coefficient curve for the free crest can be plotted by consulting Fig. 7, in which H_o and C_o are the designed head and the coefficient

for the designed head, respectively. This chart was reproduced from a previous publication[2] and represents a curve well supported by tests of some fifty overfall spillway crests having wide variation in shape and operating conditions.

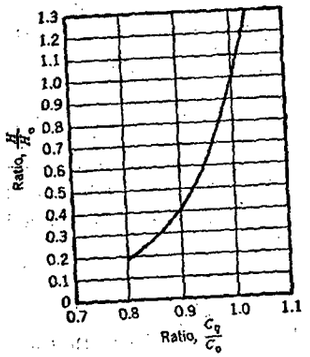


FIG. 7.—COEFFICIENTS OF DISCHARGE FOR OTHER THAN THE DESIGNED HEAD

APPLICATION OF RESULTS

From the plan and section of the Black Canyon Diversion Dam (Idaho), shown in Figs. 8 and 9, assume that it becomes necessary to compute and construct a rating curve for one drum gate for each 0.5 ft of gate elevation. The scale on the gate position indicator is calibrated to show the elevation of the high point of the gate, and the gate has a constant radius of 21.0 ft. The gate is 64 ft long. The coefficient of discharge for the free crest is $C_o = 3.48$ for the designed head (H_o) of 14.5 ft.

With the coefficient of discharge known for free flow at the designed head, the entire free-flow coefficient curve can be established by consulting Fig. 7. The free-flow coefficient curve for Black Canyon Dam spillway (for which $H_o = 14.5$ ft

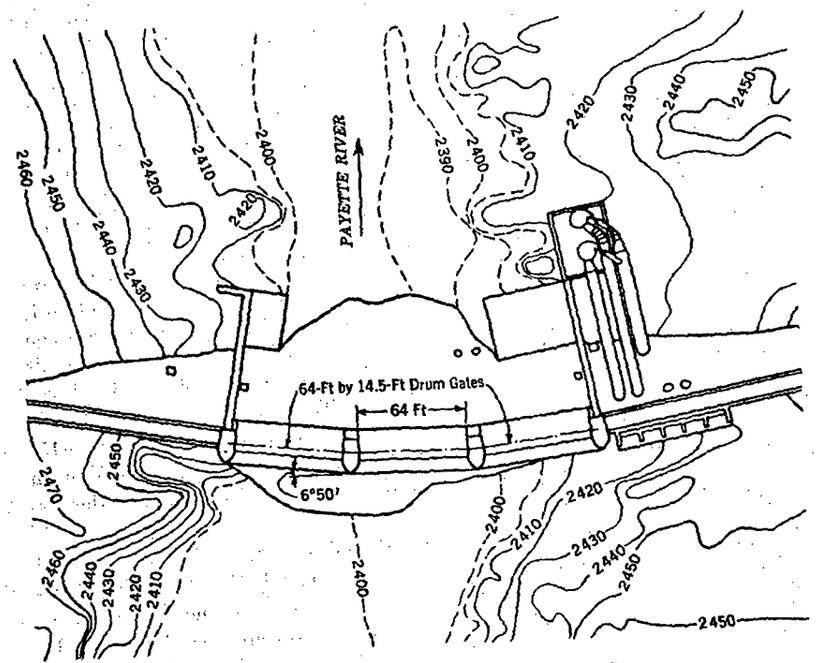


FIG. 8.—PLAN OF BLACK CANYON DIVERSION DAM IN IDAHO

and $C_o = 3.48$) is constructed by arbitrarily assuming several values of H/H_o and reading the corresponding values of C/C_o from Fig. 7. The method is illustrated in Table 3, and the head-coefficient curve for free flow (gate down), obtained in this manner, is shown in Fig. 10.

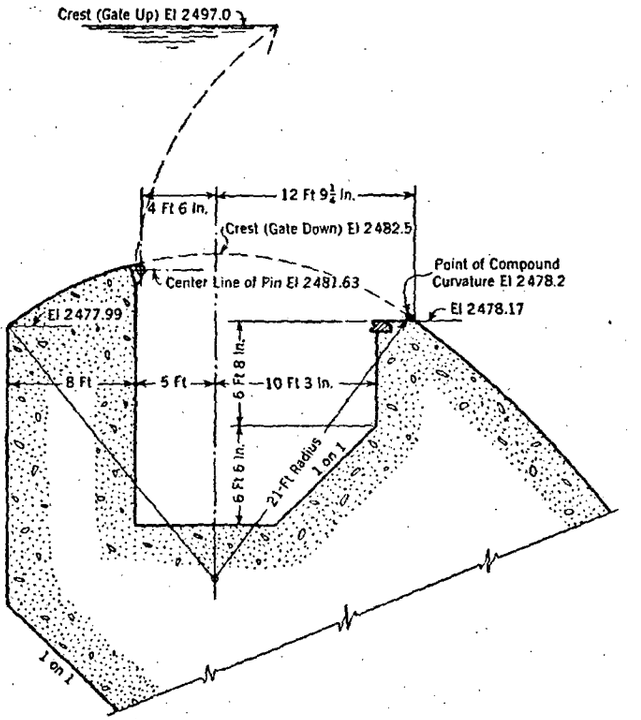


FIG. 9.—SPILLWAY CREST DETAIL, BLACK CANYON DAM IN IDAHO

TABLE 3.—HEAD AND DISCHARGE COMPUTATIONS FOR A FREE CREST (BLACK CANYON DAM IN IDAHO)

Total head, H, in ft (1)	Reservoir elevation, in ft (2)	Ratio,[a] H/H_o (3)	Ratio,[b] C_e/C_o (4)	Coefficient, C_e (5)	Q, in cu ft per sec[c] (6)
17	2499.5	1.172	1.020	3.55	15,950
16	2498.5	1.104	1.012	3.52	14,420
14.5	2497.0	1.0	1.0	3.48	12,296
12	2494.5	0.827	0.980	3.41	9,072
10	2492.5	0.690	0.960	3.34	6,759
8	2490.5	0.552	0.940	3.27	4,736
6	2488.5	0.414	0.905	3.135	2,949
4	2486.5	0.276	0.850	2.957	1,514
3	2485.5	0.207	0.815	2.835	943
2	2484.5	0.138	0.760	2.642	478

[a] $H_o = 14.5$ ft. [b] $C_o = 3.48$. [c] The discharge for one gate: $Q = C_e L H^{\frac{3}{2}}$, in which $L = 64.0$ ft.

Before considering the rating of the spillway with gates in raised positions, it is necessary to construct a diagram such as that shown in Fig. 11 to relate gate elevation to the angle θ for the Black Canyon Dam gate. The tabulation in Fig. 11 shows the angle θ for corresponding elevations of the downstream lip of the gate at intervals of 2 ft.

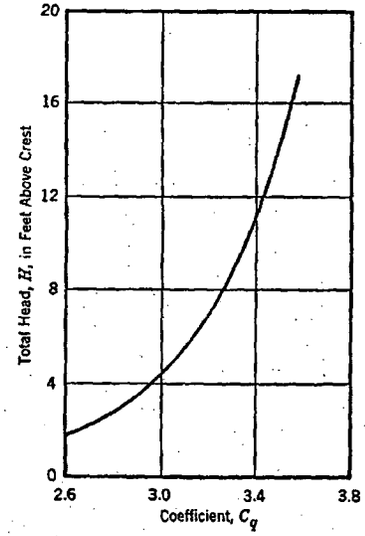


FIG. 10.—HEAD-COEFFICIENT CURVE, BLACK CANYON DAM, IN IDAHO

Beginning with the maximum positive angle of the gate, which is 34.883°, the computations may be begun by choosing a representative number of reservoir elevations as indicated in Col. 2, Table 4. The difference between the reservoir elevation and the high point of the gate (which is the downstream lip in this case) constitutes the total head on the gate, and values of head are recorded in Col. 3. Col. 4 shows these same heads divided by the radius of the gate, which is 21.0 ft.

Entering the curves in Fig. 6 with the values in Col. 4, Table 4, for $\theta = +34.883°$, the discharge coefficients, listed in Col. 5 of the set of computations designated "A," are obtained. The remainder of the procedure outlined in Cols. 6 and 7, Table 4, consists of computing the discharge for one gate from the expression, $Q = C_q L H^{\frac{3}{2}}$. A similar procedure of computation is repeated for other positive angles of θ as in sets B, C, and D of Table 4.

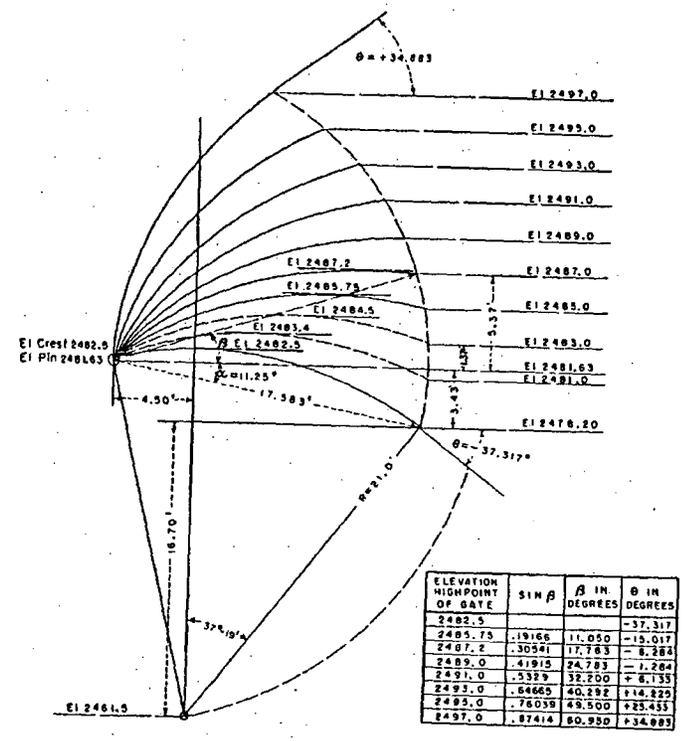
As the angle θ is given negative values, the procedure for determining the discharge remains the same for angles between 0 and $-15°$, except that the head on the gate is measured above the high point rather than above the lip. Discharge computations for negative angles of the gate down to $-15.017°$ are tabulated in E, F, and G of Table 4.

Plotting values of discharge, reservoir elevation, and gate elevation from Table 4 results in the seven curves in Fig. 12 for which the points are denoted by circles. The extreme lower curve, on which the points are identified by x-marks, represents the discharge of the free crest with the gate completely down. The latter values were obtained from Table 3.

The discharge values shown in Fig. 12 are for one gate only. When more than one gate is in operation, the discharges from the separate gates may be totaled providing the gates are each raised the same amount. The experimental models contained from one to four gates (with the exception of that of Grand Coulee Dam, which contained eleven) so a reasonable allowance for pier effect on the discharge is already present in the results.

The intervals between the eight curves identified by points (Fig. 12) are too great for rating purposes, especially the gap between gate elevations, 2485.75 ft and 2482.5 ft. This is remedied by cross-plotting the eight curves

for various constant values of the discharge as shown in Fig. 13. Fortunately, the result is a straight-line variation for any constant value of discharge. The lines in Fig. 13 are not quite parallel and there is no assurance that they will be straight for every drum gate. Nevertheless, this will not detract appreci-



ELEVATION HIGHPOINT OF GATE	SIN β	β IN DEGREES	θ IN DEGREES
2482.5			-37.317
2485.75	.19166	11.050	-15.017
2487.2	.30541	17.783	- 8.284
2489.0	.41915	24.783	- 1.284
2491.0	.5329	32.200	+ 6.133
2493.0	.64665	40.292	+14.225
2495.0	.76039	49.500	+23.433
2497.0	.87414	80.950	+34.883

FIG. 11.—RELATIONSHIP OF GATE ELEVATION TO ANGLE θ

ably from the accuracy obtained. Interpolated information from Fig. 13 is then utilized to construct the additional curves in Fig. 12. If all curves are considered, Fig. 12 shows the completed rating for the Black Canyon Dam spillway for 0.5-ft gate intervals. For intermediate values, straight-line interpolation is permissible.

CONCLUSIONS

This paper has demonstrated how an existing control structure, such as the Black Canyon Dam spillway, can also serve as a rating station. The accuracy of rating curves obtained by the method is estimated to approach that of an average current-meter traverse of the river providing that (1) the gate position indicators are made as large as possible and are accurately cali-

brated, (2) the reservoir gage can be read to within 0.05 ft, (3) nearly atmospheric pressure exists under the sheet of water after it springs from the gate, and (4) all gates are set at approximately the same elevation.

TABLE 4.—HEAD AND DISCHARGE COMPUTATIONS FOR DRUM GATES IN RAISED POSITIONS

Set	Reservoir elevation, in ft	H, in ft[a]	Ratio, $\frac{H}{r}$	Coefficients, C_e	$H^{\frac{1}{2}}$, in ft	Q, in cu ft per sec[b]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	GATE ELEVATION 2497.0; $\theta = +34.88°$					
A	2498.0	1	0.048	3.86	1	247
	2499.0	2	0.095	3.86	2.828	699
	2500.0	3	0.143	3.86	5.196	1,283
	GATE ELEVATION 2495.0; $\theta = +23.43°$					
B	2496.0	1	0.048	3.85	1	246
	2497.0	2	0.095	3.86	2.828	698
	2498.0	3	0.143	3.87	5.196	1,284
	2499.0	4	0.190	3.87	8.00	1,979
	2500.0	5	0.238	3.88	11.18	2,770
	GATE ELEVATION 2493.0; $\theta = +14.22°$					
C	2494.0	1	0.048	3.69	1	236
	2495.0	2	0.095	3.73	2.828	675
	2496.0	3	0.143	3.75	5.196	1,247
	2498.0	5	0.238	3.80	11.18	2,719
	2500.0	7	0.333	3.84	18.52	4,552
	GATE ELEVATION 2491.0; $\theta = +6.13°$					
D	2492.0	1	0.048	3.47	1	222
	2493.0	2	0.095	3.51	2.828	635
	2494.0	3	0.143	3.57	5.196	1,187
	2496.0	5	0.235	3.63	11.18	2,597
	2498.0	7	0.333	3.70	18.52	4,386
	2500.0	9	0.429	3.77	27.00	6,515
	GATE ELEVATION 2489.0; $\theta = -1.28°$					
E	2490.0	1	0.048	3.21	1	205
	2491.0	2	0.095	3.28	2.828	594
	2492.0	3	0.143	3.34	5.196	1,111
	2494.0	5	0.238	3.45	11.18	2,469
	2496.0	7	0.333	3.545	18.52	4,202
	2498.0	9	0.429	3.63	27.00	6,273
	2500.0	11	0.524	3.695	36.48	8,627
	GATE ELEVATION 2487.2; $\theta = -8.28°$					
F	2488.0	0.8	0.038	3.02	0.716	138
	2489.0	1.8	0.086	3.10	2.415	479
	2490.0	2.8	0.133	3.17	4.685	950
	2492.0	4.8	0.229	3.31	10.52	2,229
	2494.0	6.8	0.324	3.43	17.73	3,892
	2496.0	8.8	0.419	3.51	26.10	5,863
	2498.0	10.8	0.515	3.58	35.49	8,131
	2500.0	12.8	0.610	3.635	45.79	10,653
	GATE ELEVATION 2485.75; $\theta = -15.02°$					
G	2487.0	1.25	0.060	3.00	1.398	268
	2488.0	2.25	0.107	3.07	3.375	663
	2489.0	3.25	0.155	3.15	5.859	1,181
	2491.0	5.25	0.250	3.275	12.03	2,522
	2493.0	7.25	0.345	3.375	19.52	4,216
	2495.0	9.25	0.440	3.465	28.13	6,238
	2497.0	11.25	0.536	3.54	37.73	8,548
	2499.0	13.25	0.631	3.595	48.23	11,097

[a] H is the total head on the gate. [b] The discharge for one gate: $Q = C_e L H^{\frac{1}{2}}$.

In connection with provision (3), the blunt piers on the Black Canyon Dam spillway, Figs. 8 and 9, provide effective aeration under the overfalling sheet of water for all but very small heads with gate completely raised. In the case of provision (4), uniform operation of the gates is also most desirable from the standpoint of stilling basin operation for minimum erosion downstream.

Discharge measurements on the prototype are desirable whenever possible as a check on the accuracy of the foregoing method. Sufficient observations should be taken, however, to establish the fact that the prototype information is consistent and reliable.

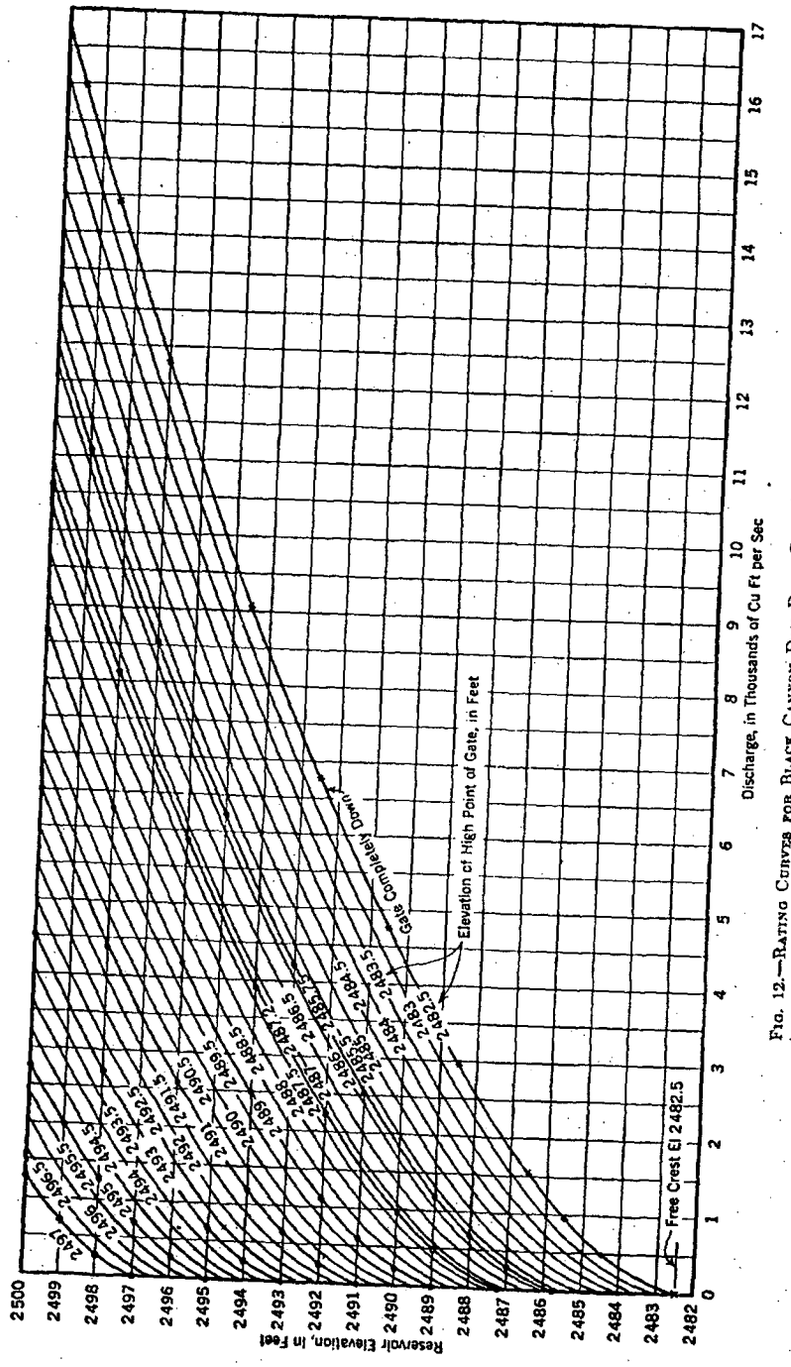


FIG. 12.—RATING CURVES FOR BLACK CANYON DAM DRUM-GATE SPILLWAY IN IDAHO

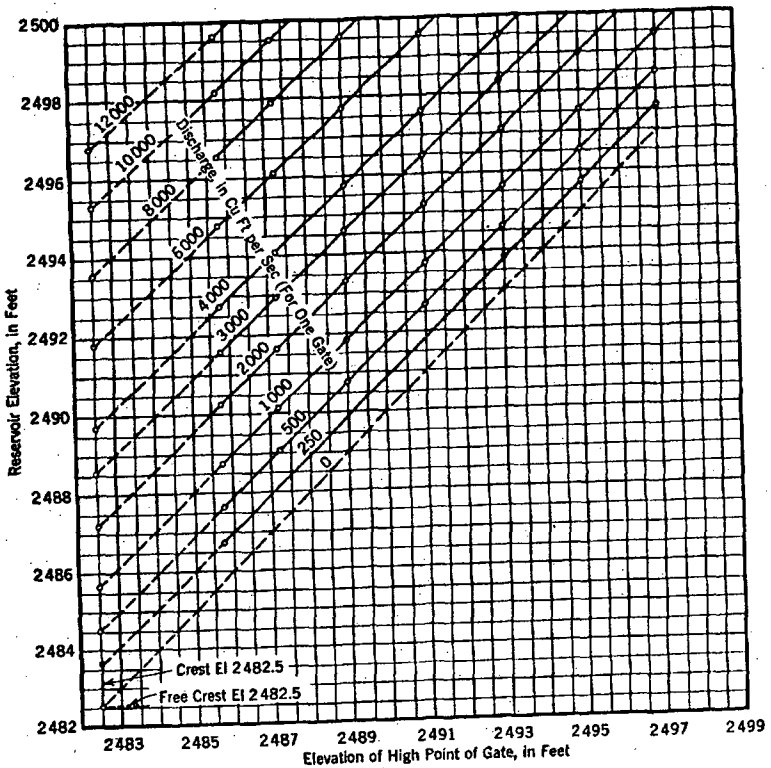


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

ACKNOWLEDGMENTS

The writer wishes to thank C. E. Blee, M. ASCE, chief engineer of the Tennessee Valley Authority for the use of the data on the Norris Dam Spillway; Hal Birkeland, M. ASCE, of the International Engineering Corporation, for obtaining permission to include the Bhakra and Capilano Dam spillways in the paper; and the chief engineer of the Panama Canal for use of the data on the Madden Dam spillway. The writer is also grateful to the Bureau of Reclamation for the use of the remainder of the experimental information. He also wishes to thank his engineering associates, H. M. Martin, M. ASCE, D. J. Hebert, and A. J. Peterka, A. M. ASCE, for their most helpful comments and suggestions.

DISCUSSION

GUIDO WYSS[6].—The information presented by Mr. Bradley is of utmost value for determining the quantities of discharge over drum gates under various heads for any gate position. This information will permit operators in the field to adjust the gate position from corresponding chart values in such a manner as to obtain the desired flow. The use of drum gates as an actual metering device for spillway quantity discharges is unique and the results obtained are more practicable and reliable than those obtained by stream gaging, especially when this gaging is conducted during periods of high floods.

It would have been interesting if the author had presented an investigation of the flow, profiles of the upper and lower nappe surfaces, as well as the actual water pressures on the upstream plate of the drum gate by use of charts. This would afford an opportunity to obtain the true loading conditions on the gate during the cycle of operation from fully-raised gate to fully-lowered gate. This information would be important in the determination of the buoyancy and loading criteria of the gate structure.

SAM SHULITS,[7] M. ASCE.—An outstanding contribution to the design and operation of drum gates has been presented in this report of the author's work at the USBR. The paper and its complement[2] fill a great need.

Since 1928, when the Freeman Scholarships were established, there has been a tremendous development of hydraulic model research in the laboratories of the United States. Although these laboratories are unexcelled in size and quality, many hydraulic engineers have pondered the procession of models (spillways, stilling pools, and river reaches) in the period from 1928 to 1953 with few, if any, summaries or proposals for design to reduce the dependence on models. In Mr. Bradley's work there is strong evidence that the laboratories will produce correlations and syntheses—not more models.

When it is realized that many of the most famous and productive laboratories in the United States did not exist prior to 1928, the lack of correlation and synthesis for general use is understandable. The hope is that other works of similar quality will be added to engineering literature.

BOB BUEHLER,[8] A. M. ASCE.—An interesting and clever use of data has resulted in a method by which records of gate settings at dams can be made a substitute for missing stream-flow records and can be used to augment existing records. The construction of a dam and reservoir often floods an established stream gage. Unless the gage is replaced below the dam or upstream from the reservoir, subsequent stream flow usually is not accurately known. Sometimes a series of dams (each causing the water to back up to the dam above) prevents continuing established gages at the strategic points where they had been

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located. The less accurate—and more costly—slope stations are not completely satisfactory alternatives to the single-line rating stations.

If the spillway of a dam can be rated with an accuracy comparable to the accuracy obtainable with a gage (as demonstrated by Mr. Bradley for certain spillway types), and if allowance is made for flow through other water outlets such as turbines, locks, and sluices, the structure is then superior in some respects to the gage. For example, the rating of the dam should be permanent, whereas the rating of a gage usually requires frequent checking.

Mr. Bradley's method for rating drum gates not only allows records for ordinary stream flow to be supplemented, but also probably gives a more accurate determination of extreme flood rates than do most gages. He has made an important contribution to the planning and design of drum-gated structures.

The author has presented a method for rating a spillway at all heads provided the coefficient for one appreciable head is known. He also states that a coefficient for the designed head can be estimated for most spillways by a method previously published.[2] The writer, on the other hand, offers a method by which an ogee spillway can be rated, provided its profile shape is known. The method is based on an equation derived by R. N. Brudenell, A. M. ASCE, incidental to studies made on radial gates.[2] Mr. Brudenell's equation is

$$Q = \frac{3.97\ L\ H^{1.62}}{H^{0.12}{}_D} \qquad (1)$$

in which Q is the spillway discharge, in cubic feet per second; L denotes the length of the spillway, in feet; H is the total head on the spillway crest, in feet; and H_D represents the design head in feet. The design head is that head which produces a standard lower nappe that agrees closely with the spillway profile.

TABLE 5.—Free Discharges for Black Canyon Dam in Idaho

Total head, in feet	Discharge, in cubic feet per second[a]	Using Eq. 1		Using Fig. 14	
		Discharge, in cubic feet per second	Difference, in percent	Discharge, in cubic feet per second	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)
17	15,950	15,847	−0.65	15,910	−0.25
16	14,420	14,363	−0.39	14,421	−0.01
14.5[b]	12,296	12,247[c]	−0.40	12,296	0
12	9,072	9,013	−0.65	9,049	−0.25
10	6,759	6,708	−0.75	6,735	−0.36
8	4,736	4,673	−1.33	4,692	−0.93
6	2,949	2,932	−0.58	2,944	−0.20
4	1,514	1,521	+0.46	1,527	+0.86
3	943	954	+1.17	958	+1.59
2	478	494	+3.35	496	+3.76

[a] From Col. 6, Table 3. [b] Head at which $C_e = 3.48$. [c] C_e would be 3.466 for this discharge.

[2] "Flow over Rounded Crests," by R. N. Brudenell, *Engineering News-Record*, July 18, 1935, p. 95.

Eq. 1 was intended to be used with heads greater than $H_D/4$, although the equation has been found to agree closely with model data for somewhat lower heads. Without knowing any coefficients, Eq. 1 gives discharges that agree closely with those obtained by Mr. Bradley for Black Canyon Dam. In the case of Black Canyon Dam, Mr. Bradley used one known coefficient and the curve of Fig. 7. Free-flow discharges computed by the two methods are shown in Cols. 2 and 3, Table 5. The procedure by which Eq. 1 was applied will be described subsequently.

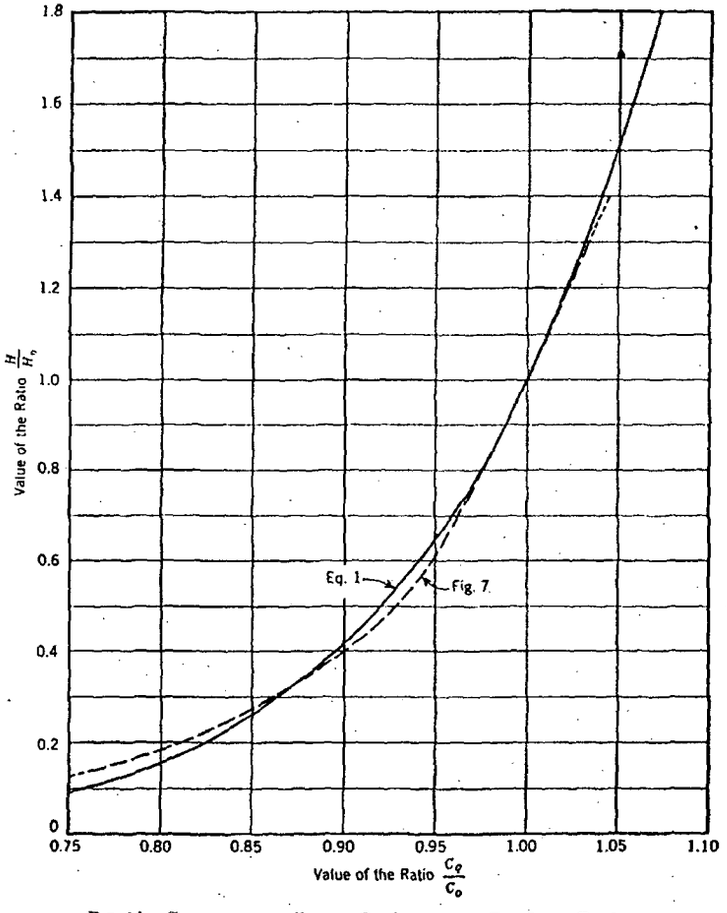


Fig. 14.—Comparison of Values Obtained from Fig. 7 and Eq. 1

It is assumed that in choosing Black Canyon Dam for his example, the author knew that his method would yield discharges close to known values. The good agreement for all except the low heads shows that, in this example, Eq. 1 (using only the shape of the spillway) also produces suitable results.

This good agreement suggests, too, that there must be a close relationship between the curve in Fig. 7 and a similar curve that can be derived from Eq. 1. To examine the relationship, theoretical discharge coefficients were computed by using

$$Q = C_q\, L\, H^{3/2} \qquad (2)$$

and Eq. 1, from which

$$C_q = \frac{3.97\ H^{1.62}}{H_D^{0.12}\ H^{3/2}} \qquad (3)$$

The design head, H_D, was found (by a method to be described subsequently) to be 45 ft for Black Canyon Dam, and this value was used in making the test. Thus, for $H_D = 45$ ft,

$$C_q = \frac{2.5143\ H^{1.62}}{H^{3/2}} \qquad (4)$$

For several assumed values of total head, H, varying from 2 ft to 58.5 ft, corresponding C_q-values were computed. The resulting C_q of 3.97 for a head of 45 ft (H_o) was taken arbitrarily as the known coefficient, C_o. Then the (H/H_o)-ratios and the (C_q/C_o)-ratios were computed for all other heads in the assumed range. The resulting curve is the solid line in Fig. 14. The dashed curve is from Fig. 7. The agreement is close—as expected. Still using H_D equal to 45 ft, the remainder of the process was repeated using the coefficient for the 25-ft head as C_o, and then using the coefficient for the 12-ft head as C_o. There was no discernible difference in the curves resulting from the three separate selections. A similar procedure, using H_D equal to 20 ft in Eq. 1, also showed no differences from Fig. 14. It can probably be proved that there should be no difference.

The curve derived from Eq. 1 then was applied to the Black Canyon Dam spillway, assuming (as did the author) that the coefficient is 3.48 at a 14.5-ft head. The resultant free discharges are shown in Col. 5, Table 5.

The free-flow coefficients in Table 2 invite further comparisons with Eq. 1 for the four projects for which spillway profiles are given in Fig. 3. It should be remembered that this comparison tests the use of only the spillway shape as a guide to free discharge for the entire range of heads. Col. 4, Table 6, shows that for appreciable heads the maximum error in the four cases is approximately 2% (Hamilton Dam). Observed coefficients in model tests often scatter as much.

The same coefficients permit testing the curve in Fig. 7 for all eleven spillways. This test is not as severe, however, because it is necessary to assume one known coefficient at which head agreement becomes perfect. At near-by higher and lower heads, large divergences would not be expected. Col. 6, Table 6, shows that for appreciable heads the maximum error is slightly greater than 2% (Hoover Dam, shape 8-M5). The base coefficient selected to obtain C_q from the (C_q/C_o)-ratios is designated by a footnote for each project. These arbitrary selections were made for medium high heads.

The solid-line curve in Fig. 14 also was tested in this manner. The same coefficient at each project was assumed to be known as when the curve in Fig. 7 was tested. Col. 8, Table 6, shows that for appreciable heads the maximum error is slightly more than 2% (Madden Dam).

These comparisons show that the direct application of Eq. 1, Fig. 7 (or Fig. 14) (derived from Eq. 1), all give highly accurate free-flow spillway dis-

TABLE 6.—COMPARISON OF FREE-FLOW SPILLWAY COEFFICIENTS

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_q	Difference, in percent	C_q	Difference, in percent	C_q	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Grand Coulee Dam (Washington)							
35	3.920			3.914	− 0.15	3.902	−0.46
30	3.842			3.831	− 0.29	3.827	−0.39
25	3.745			3.745[a]	0	3.745[a]	0
20	3.635			3.655	+ 0.55	3.651	+0.44
15	3.510			3.550	+ 1.14	3.524	+0.40
10	3.352			3.370	+ 0.54	3.356	+0.12
5	3.220			3.138	− 2.54	3.168	−1.62
Bhakra Dam (India)							
28	3.680			3.736	+ 1.52	3.732	+1.41
23	3.645			3.645[a]	0	3.645[a]	0
18	3.550			3.547	− 0.08	3.543	−0.20
13	3.420			3.434	+ 0.41	3.404	−0.47
8	3.275			3.215	− 1.83	3.208	−2.04
3	3.120			2.748	−11.92	2.854	−8.53
Shasta Dam (California)							
38	3.895			3.910	+ 0.39	3.899	+0.10
33	3.835			3.839	+ 0.10	3.831	−0.10
28	3.760			3.760[a]	0	3.760[a]	0
23	3.675			3.677	+ 0.05	3.674	−0.03
18	3.575			3.591	+ 0.45	3.568	−0.20
13	3.465			3.455	− 0.29	3.429	−1.04
8	3.335			3.215	− 3.60	3.230	−3.15
Hamilton Dam (Texas) H_D = 52 Ft							
35	3.710	3.785	+2.02	3.741	+ 0.84	3.730	+0.54
30	3.645	3.710	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.035	+1.54	3.580[a]	0	3.580[a]	0
20	3.500	3.539	+1.11	3.494	− 0.17	3.490	−0.29
15	3.400	3.420	+0.59	3.394	− 0.18	3.369	−0.91
10	3.290	3.258	−0.97	3.222	− 2.07	3.208	−2.50
5	3.160	2.997	−5.16	3.000	− 5.06	3.029	−4.14
Friant Dam (California)							
20	3.650			3.717	+ 1.84	3.706	+1.53
17	3.625			3.639	+ 0.39	3.632	+0.19
14	3.550			3.550[a]	0	3.550[a]	0
11	3.460			3.458	− 0.06	3.452	−0.23
8	3.340			3.348	+ 0.24	3.319	−0.63
5	3.175			3.142	− 1.04	3.131	−1.38
2	2.965			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—*(Continued)*

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_e	Difference, in percent	C_e	Difference, in percent	C_e	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Norris Dam (Tennessee) H_D = 35 Ft							
35	3.915	3.969	+1.38	3.934	+ 0.49	3.923	+0.20
30	3.845	3.897	+1.35	3.852	+ 0.18	3.848	+0.08
25	3.765	3.812	+1.25	3.765[a]	0	3.765[a]	0
20	3.670	3.711	+1.12	3.675	+ 0.14	3.671	+0.03
15	3.550	3.586	+1.01	3.569	+ 0.53	3.543	−0.20
10	3.390	3.416	+0.77	3.388	− 0.06	3.373	−0.50
5	3.125	3.143	+0.58	3.155	+ 0.96	3.185	+1.92
Madden Dam (Canal Zone)							
35	3.900			3.825	− 1.92	3.814	−2.20
30	3.770			3.744	− 0.69	3.740	−0.80
25	3.660			3.660[a]	0	3.660[a]	0
20	3.560			3.572	+ 0.34	3.568	+0.22
15	3.460			3.470	+ 0.29	3.444	−0.46
10	3.365			3.294	− 2.11	3.279	−2.55
5	3.280			3.067	− 6.49	3.096	−5.61
Capilano Dam (British Columbia) H_D = 48 Ft							
33	3.775	3.797	+0.58	3.783	+ 0.21	3.775	0
28	3.705	3.720	+0.40	3.705[a]	0	3.705[a]	0
23	3.625	3.634	+0.25	3.623	− 0.05	3.620	−0.14
18	3.530	3.529	−0.03	3.538	+ 0.23	3.516	−0.40
13	3.415	3.394	−0.62	3.405	− 0.29	3.379	−1.05
8	3.250	3.201	−1.51	3.168	− 2.52	3.183	−2.06
Hoover Dam (Arizona-Nevada) Shape 4-M3, H_D = 50 Ft							
26	3.670	3.670	0	3.681	+ 0.30	3.677	+0.19
22	3.605	3.597	−0.22	3.605[a]	0	3.605[a]	0
18	3.540	3.512	−0.79	3.526	− 0.40	3.522	−0.51
14	3.472	3.408	−1.84	3.439	− 0.95	3.414	−1.67
10	3.405	3.273	−3.88	3.306	− 2.91	3.280	−3.67
6	3.338	3.077	−7.82	3.064	− 8.21	3.082	−7.67
Hoover Dam Shape 8-M5							
28	3.735			3.814	+ 2.12	3.800	+1.74
25	3.705			3.752	+ 1.27	3.749	+1.19
20	3.650			3.650[a]	0	3.650[a]	0
15	3.565			3.537	− 0.78	3.530	−0.08
10	3.460			3.387	− 2.11	3.358	−2.94
5	3.335			3.059	− 8.28	3.088	−7.41
Hoover Dam Shape 7-C4							
26	3.665			3.691	+ 0.71	3.687	+0.60
22	3.615			3.615[a]	0	3.615[a]	0
18	3.540			3.535	− 0.14	3.532	−0.23
14	3.450			3.449	− 0.03	3.423	−0.78
10	3.360			3.315	− 1.34	3.290	−2.08
6	3.200			3.073	− 3.97	3.091	−3.41

charges for ogee dams at all but low heads. Eq. 1, applied directly to the spillway shape, has the advantage that no coefficients need be known or estimated in advance.

The comparisons in Table 6 show a tendency toward errors of some importance at low heads when Eq. 1 or its companion curve in Fig. 14 is used, as well as when Fig. 7 is used. In most cases the errors are negative. These errors are of little concern in planning the safety of a structure against extreme floods, or in considering most other operations such as emptying the reservoir. The errors nonetheless affect the analytical rating of drum gates in the lowered or slightly raised positions. The free-flow coefficients help to determine the direction of the general curves at the large negative angles shown in Fig. 6. Free discharges form the base curve of the rating curves in Fig. 12 and help define the curvature of the low ends of the cross-plot curves in Fig. 13. Low to ordinary heads, corresponding to normal stream flow, can exist for a large part of the time at dams whose reservoir capacities are small. Further study of data for low heads might lead to valuable refinements.

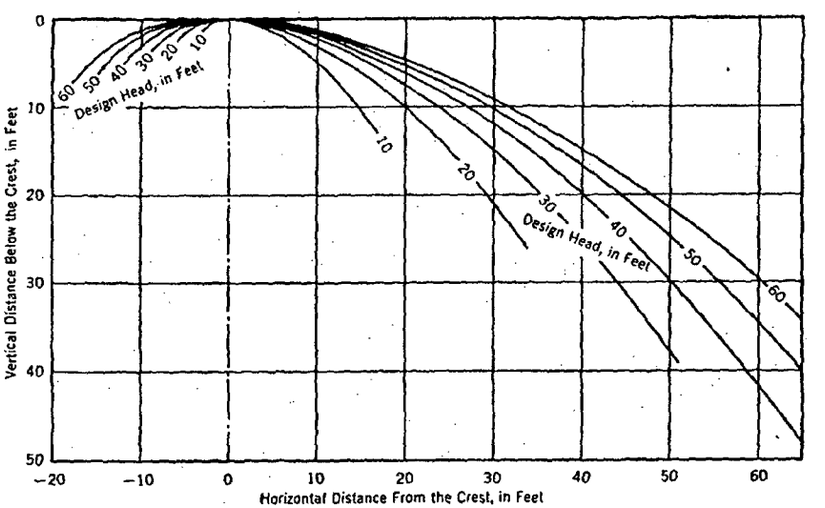


Fig. 15.—Standard Spillway Shapes

Application of Eq. 1.—Since the factor H_D in Eq. 1 represents the head at which a standard lower nappe shape is a reasonable approximation of the spillway shape (as designed or built), it is only necessary to find this head to apply the formula. Spillway coordinates for a standard crest having a vertical upstream face have been used to find this head.[10] These coordinates are shown in Table 7. The last column in Table 7 refers the horizontal (x) coordinates to the spillway crest because this form is the simplest to apply. In Table 7, y is the distance below the crest elevation.

Using these dimensionless coordinates, standard spillway shapes were plotted (Fig. 15) for values of H_D from 10 ft to 60 ft. In Fig. 15 negative

[10] "Hydroelectric Handbook," by William P. Creager and Joel D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950, p. 362.

horizontal distances indicate the distance upstream from the crest. The spillway shape as designed or built is then drawn on transparent paper. This paper is laid over Fig. 15, and the value of H_D which gives the best fit is selected. In deciding the best fit it may be found that the profile upstream from the crest indicates one value and the downstream profile indicates a different value. The higher of the two indicated values of H_D should be used. For example, the shape of Black Canyon Dam spillway upstream from the crest indicated a value of approximately 45 ft for H_D. The downstream shape indicated a value of approximately 25 ft. The larger value was used.

TABLE 7.—COORDINATES OF A STANDARD SPILLWAY CREST

Value of $\frac{x}{H_D}$	Value of $\frac{y}{H_D}$	Value of $\frac{x}{H_D}$ referred to crest
0	0.126	−0.3
0.1	0.036	−0.2
0.2	0.007	−0.1
0.3	0	0
0.4	0.007	0.1
0.6	0.063	0.3
0.8	0.153	0.5
1.0	0.267	0.7
1.2	0.410	0.9
1.4	0.590	1.1
1.7	0.920	1.4
2.0	1.31	1.7

The determination of the H_D-value which gives a reasonable fit requires a certain amount of judgment. When the profile upstream from the crest is the criterion, the lip of the dam will sometimes be the determinant. Sometimes, however, the lip droops sharply downward and indicates a lower value than other parts of the upstream profile. When the downstream shape is the criterion, good results have been obtained by assigning a value of H_D based on the average fit in the zone between points on the spillway where tangents range from 20° to 35° from the horizontal. The exact value of H_D is not too important. Since it enters Eq. 1 in the 0.12 power, a difference of 10% in its value affects the discharge by only 1.15%.

The writer's application of Eq. 1 has been limited to fairly high dams. Although the total head used in Eq. 1 should include the approach velocity, the accuracy of Eq. 1 when used for low dams, where approach velocity is large, has not been tested.

So far as is known, the application of standard nappe shapes (for which discharge coefficients are known) to actual spillways on a basis of reasonable best fit was first suggested by W. M. Borlund.[11] Mr. Borlund used a curve of observed C_e-value plotted against H/H_e. In 1942, C. E. Kindsvater, M. ASCE, suggested a similar procedure in which the curve of C_e versus H/H_e was derived from Eq. 1. Mr. Kindsvater's work (not published) should give results comparable to those obtained herein.

The material presented is regarded as an excellent check on that part of Mr. Bradley's work which relates to free discharge over an ogee spillway.

F. B. CAMPBELL,[12] M. ASCE, AND A. A. MCCOOL,[13] J. M. ASCE.—The experimental data on discharge coefficients for flow over drum gates are a welcome addition to the published information on flow over spillways, or the observation and recording of the flow of streams. A paper by Robert E. Horton has been a guide for the estimation of flows over spillways since its publication.[14] The basic information for the discharge over curved crests which fit the under side of a nappe from a sharp-crested weir can be deduced from investigations made by Bazin,[14,15] although the published record of these experiments has not been generally available to engineers in the United States. The investigations conducted by the USBR (proposed by E. W. Lane, M. ASCE) embraced and extended the scope of Bazin's work which is often used as the basis for overflow spillway shapes.[3] Although good estimates for discharge over free-overflow crests can be accomplished rather simply, the problem becomes complicated when flow through partly opened crest gates is involved.

The commonly used types of crest gates are vertical lift gates, tainter or radial gates, and drum gates. The coefficient for a partly opened vertical lift gate depends on the location of the plane of the skin plate or lip with respect to the axis of the curved crest. The discharge coefficient for tainter gates is affected by the radius of the skin plate, the elevation of the trunnion with respect to the crest, and the location of the gate seat with respect to the axis as well as the crest curvature. To complicate any investigations further, observers define the gate opening variously as (1) the length of the arc from the gate seat to the gate lip, (2) the vertical distance from the lip to the face, and (3) the distance from the lip to the face measured normal to the face. The last method is believed to give the proper dimension, whereas the foregoing considerations are geometrical. The effective head for a partly opened vertical lift or tainter gate depends on the pressures on the face of the concrete and the pressures within the issuing jet. The author has given a good outline of the geometrical variables and the head-measurement method for analyzing partly raised drum gates.

The drum gate has the very attractive feature of requiring no mechanical hoisting equipment for operation. Many of the dams constructed by the USBR have spillways controlled by drum gates. For example the Arrowrock Dam in Idaho (constructed in 1915) and the Tieton Dam in Washington (constructed in 1925) are both equipped with drum gates. B. F. Thomas and D. A. Watt credit H. M. Crittenden with the design of what is apparently the first drum gate.[17] The gates were installed in Dam No. 1 on the Osage River in Missouri in 1911. However, the refinements of the modern drum gate have been developed principally by the USBR.

The discharge coefficients presented by the author are based on model studies. There should be opportunity to check the coefficients for relatively low heads with partly raised gates in the prototype by current-meter measure-

[11] "Flow over Rounded Crest Weirs," by W. M. Borlund, thesis presented to the University of Colorado, at Boulder, Colo., in 1938, in partial fulfilment of the requirement for the degree of Master of Science.

[12] Chf. Hydr. Engr., Analysis Branch, Corps of Engrs., U. S. Waterways Experiment Station, Vicksburg, Miss.

[13] Hydr. [illegible], U. S. Waterways Experiment Station, Vicksburg, Miss.

[14] "Weir Experiments, Coefficients and Formulas," by Robert E. Horton, *Water Supply and Irrigation Paper No. 200*, Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington, D. C., 1907 (revision of Paper No. 150).

[15] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. VII, No. 5, 1890, p. 259.)

[16] *Ibid.*, Vol. IX, No. 3, 1892, p. 231.

[17] "The Improvement of Rivers," by B. F. Thomas and D. A. Watt, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1913.

ments. Only on rare occasions with large floods is it possible to verify the coefficients for high prototype heads over the drum gates in the lowered position. The author's mention of the failure to obtain discharge measurements during the 1948 flood over the Grand Coulee Dam spillway emphasizes the importance of this condition. The writers have studied the basic data for high heads over the drum gate in the lowered position.

It becomes evident from a study of Table 2 that the ratio of gate radius to maximum head has a wide range. The writers use the ratio r/H_D, in which H_D is the design head for the spillway. This is the inverse of the ratio used by Mr. Bradley, used so that circular arcs can be traced on dimensionless profiles of x/H_D and y/H_D.

A comparison has been made of the coefficients for various (r/H_D)-values with the gate down. Only the high-overflow sections with negligible velocity of approach were selected from Table 2 for a study of discharge coefficients. Table 8 shows the value of the discharge coefficients for the condition when the drum gate is down. The percentage difference of the coefficient from that of the Madden Dam coefficient is also shown. It is expected that the accuracy of the discharge measurements and thus the coefficient of discharge is less than 1%.

TABLE 8.—COMPARISON OF DISCHARGE COEFFICIENT WITH THE GATE DOWN

Dam	Radius of gate, in feet[a]	Maximum head on crest, in feet[a]	Ratio, $\frac{r}{H_D}$	Coefficient,[b] C_e	Difference, in percent, from Madden Dam
Madden (Canal Zone)	30.0	30.0	1.00	3.77	0.0
Norris (Tennessee)	34.0	27.0	1.26	3.80	0.8
Grand Coulee (Washington)	66.2	31.6	2.09	3.87	2.6
Shasta (California)	66.2	28.0	2.37	3.76	−0.3
Friant (California)	47.0	19.0	2.47	3.64	−3.5
Capilano (British Columbia)	71.0	23.0	3.08	3.62	−4.0

[a] From Table 1. [b] From Table 2.

The dams for which the data are listed in Table 8 are in the approximate chronological order of the time of their design conception.

Because of the increase in the ratio of r/H_D (Table 8), it is of interest to plot the profile for the lower surface of the nappe from a sharp-crested weir with an approach slope of 2 on 3 in terms of x/H_D and y/H_D and to superimpose on it the arcs of circles with radii of r/H_D equal to 1, 2, and 3, as is done in Fig. 16. The center of the radius is located on the axis of the crest. It can be seen that the arc represented by r/H_D equal to 1 is a fair approximation of the true nappe shape. The arcs of r/H_D equal to 2 and 3 indicate a very flat curvature in comparison to the shape of the nappe.

One is tempted to assume, for a crest with a ratio $r/H_D = 3$, that the coefficient would be that for one third the design head of a crest with $4/H_D = 1$.

Model studies for Madden Dam reported by Richard R. Randolph, Jr.,[18] indicate that the coefficient for such a condition is approximately 3.40. Such a coefficient is not in agreement with that for Capilano Dam with r/H_D equal to 3.62 at full head. The lack of agreement does not necessarily vitiate the initial assumption. The difference in the coefficient may be caused by the

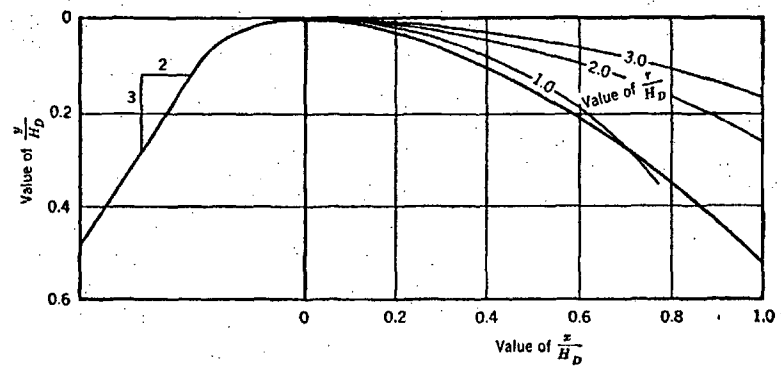


FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

difference in shape of the two crests upstream from the circular arc. Furthermore, the scale ratio of the Madden Dam model was only 1:78, and a 10-ft prototype head would be 0.128 ft on the model, which is near the lower limit of reliability for conformity of the discharge coefficient.

JOSEPH N. BRADLEY,[19] A.M. ASCE.—Mr. Shulits' statements regarding the lack of correlation in laboratory studies are well founded, and the writer is in complete agreement with his views.

Mr. Buehler's analysis for the determination of the designed head, H_D, for overflow sections formed by a single radius, or for a shape that conforms closely to a single radius, gives satisfactory results. The comparison of discharge coefficients for free flow over various dams, using Eq. 3 with the method offered in the paper, is gratifying. Mr. Buehler's method certainly has merit because following the determination of H_D, coefficients of discharge can be computed directly for all heads.

Messrs. Campbell and McCool undertook to show that a definite relationship exists between the coefficient of discharge at the designed head and the ratio r/H_D for overflow shapes. This relationship is valid if the overflow shape can be approximated by an arc of a single radius and if the approach conditions are favorable—that is, if the approach depth below the crest is at least twice H_D. This method results in a coefficient of discharge for the designed head only. When overflow sections are encountered where a single radius does not approximate the overflow shape, or when the approach conditions are unusual, an engineering monograph[2] may prove helpful.

[18] "Hydraulic Tests on the Spillway of the Madden Dam," by Richard R. Randolph, Jr., *Transactions*, ASCE, Vol. 103, 1938, p. 1091.

[19] Hydr. Engr., Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo.

Mr. Wyss suggested that pressures and water surfaces for drum gates at various positions and reservoir levels would be useful to designers in computing gate loadings. A limited amount of information is available, and this will be presented.

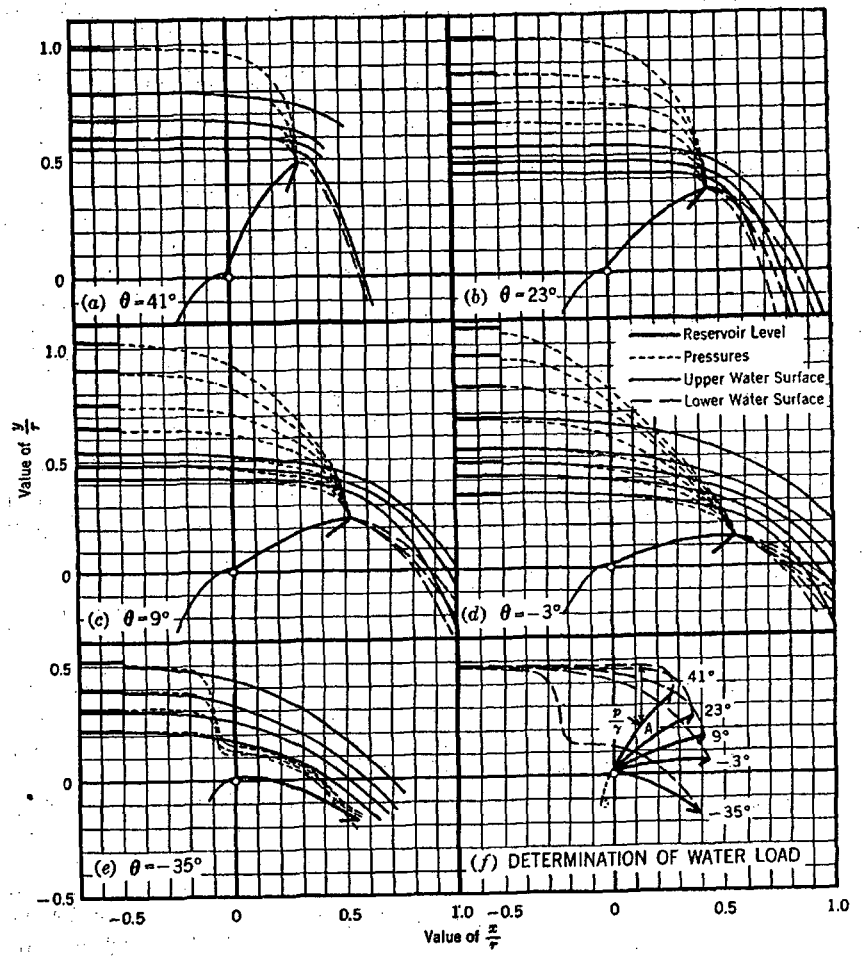


FIG. 17.—PRESSURE AND WATER-SURFACE PROFILES

Because there was good correlation among the discharge coefficients, it was reasoned that the pressures and related flow patterns would also be well correlated through the same variables.

Pressures and water-surface profiles are plotted in dimensionless coordinates (in terms of the radius of the gate) in Fig. 17. Five positions of the gate are shown for various reservoir levels producing flow over the gate. Pressures and water surfaces are shown for some levels whereas only pressures are

available for others. The broken lines represent pressure, measured vertically, for the reservoir levels indicated at the left of the charts. Upper water-surface profiles are shown by solid lines, and lower water-surface profiles are identified by dash lines. The charts represent a composite, in graphical form, of information from model tests performed on the Grand Coulee, Hamilton, Norris, Friant, and Hoover dams.

To determine graphically the most adverse water load on a particular gate, it is necessary to investigate the pressures for several gate positions. Assuming that the first position is $\theta = 41°$, the gate is drawn in this position on a piece of transparent paper to the same scale as that used in Fig. 17. The maximum expected reservoir is indicated for this gate position on the left side of the transparent sheet.

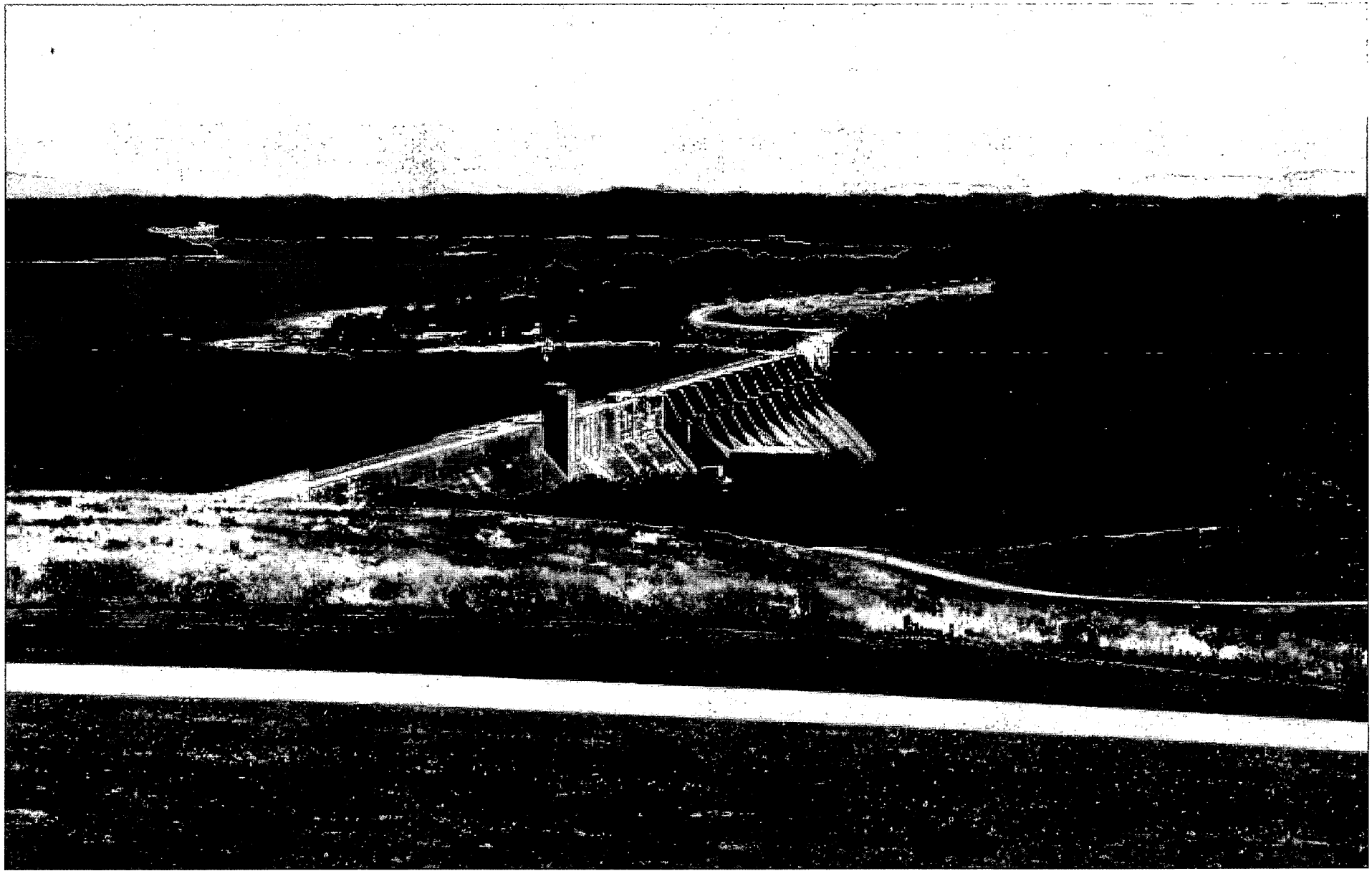
The transparent sheet is then placed over Fig. 17(*a*), disregarding the origin of coordinates, and matching only the downstream tips of the two gates. The downstream part of all drum gates, regardless of size or radius, will coincide for any given value of θ. The height of the gate, or length of arc, can be expected to vary; this will have a negligible effect on pressures or water-surface profiles in the majority of cases. Should the gate under investigation differ from the height shown in Fig. 17(*a*), a small increase or decrease in the approach-depth results.

Beginning with the chosen reservoir level, the pressure curve is traced from Fig. 17(*a*) onto the transparent paper. It may be necessary to interpolate between two of the pressure curves. The result will be similar to that shown in Fig. 17(*f*).

A similar procedure is then followed for gate positions of 23°, 9°, −3°, and −35°, utilizing Figs. 17(*b*), 17(*c*), 17(*d*), and 17(*e*), respectively. The result is a composite plot similar to that shown in Fig. 17(*f*). It should be noted that the pressures shown for negative angles of the gate are not as reliable as those for positive angles. Fortunately, the greater water loads occur for positive angles.

Water loads can be determined by scaling the pressures vertically over the gate as indicated by point A in Fig. 17(*f*). If a gate angle other than those shown is desired, interpolation can be made directly on the sheet corresponding to Fig. 17(*f*). Following the establishment of the maximum-pressure curve, values of x/r and y/r are scaled from the sheet corresponding to Fig. 17(*f*) and are transferred to dimensional values by multiplying by r. Should water-surface profiles be desired, the same method of tracing and scaling can be used.

D O U G L A S D A M



July 1998

RESERVOIR OPERATION OVERVIEW

Douglas is a multipurpose tributary storage project and is the only TVA project on the French Broad River. Like similar projects on other major Tennessee River tributaries, Douglas is operated for many purposes including flood control, augmentation of flows for navigation, hydropower production, water supply, recreation and aquatic ecology. Douglas has an annual pool level variation of about 55 feet during normal years. This fluctuation is necessary to provide for flood storage and for economical augmentation of flows during the drier seasons of the year.

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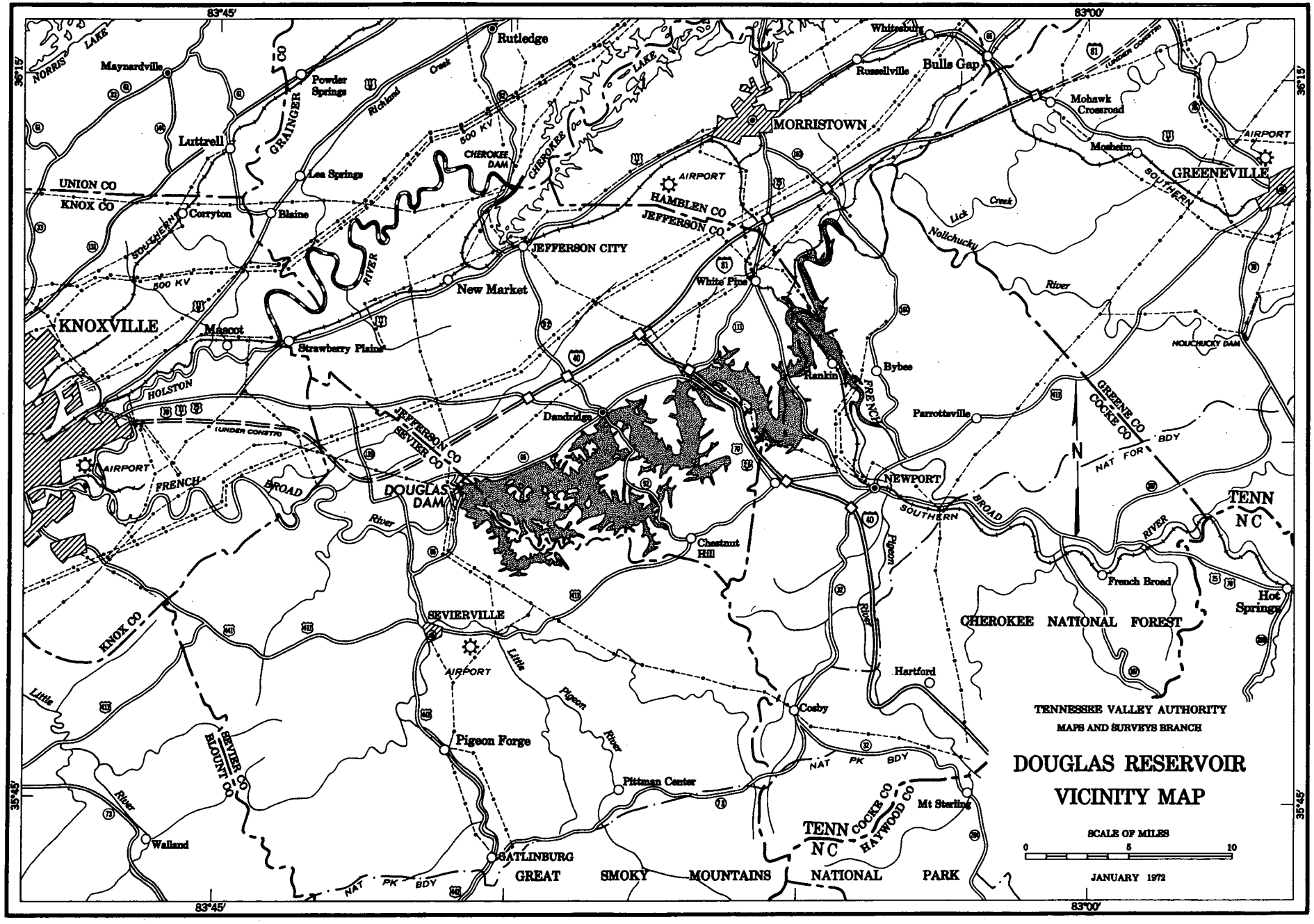
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83°45'
83°00'
36°15'
35°45'
NORRIS LAKE
Maynardville
Rutledge
Powder Springs
Richland Creek
GRAINGER CO
Luttrell
Lea Springs
CHEROKEE DAM
CHEROKEE LAKE
500 KV
UNION CO
KNOX CO
Corryton
Blaine
SOUTHERN
500 KV
RIVER
JEFFERSON CITY
New Market
KNOXVILLE
Mascot
Strawberry Plains
HOLSTON
UNDER CONSTR
AIRPORT
FRENCH
BROAD
River
JEFFERSON CO
SEVIER CO
DOUGLAS DAM
Dandridge
AIRPORT
HAMBLEN CO
JEFFERSON CO
MORRISTOWN
Whitesburg
Russellville
Bulls Gap
Mohawk Crossroad
Mosheim
AIRPORT
GREENEVILLE
SOUTHERN
Lick Creek
Nolichucky River
White Pine
Rankin
Bybee
FRENCH
Parrottsville
NOLICHUCKY DAM
GREENE CO
COCKE CO
NAT FOR BDY
N
NEWPORT
SOUTHERN
BROAD
River
Pigeon River
TENN
NC
French Broad
Hot Springs
CHEROKEE NATIONAL FOREST
Chestnut Hill
SEVIERVILLE
AIRPORT
KNOX CO
Little Pigeon River
Hartford
Cosby
Pigeon Forge
SEVIER CO
BLOUNT CO
Pittman Center
NAT PK BDY
Mt Sterling
TENN
NC
COCKE CO
HAYWOOD CO
Walland
GATLINBURG
GREAT SMOKY MOUNTAINS NATIONAL PARK
NAT PK BDY
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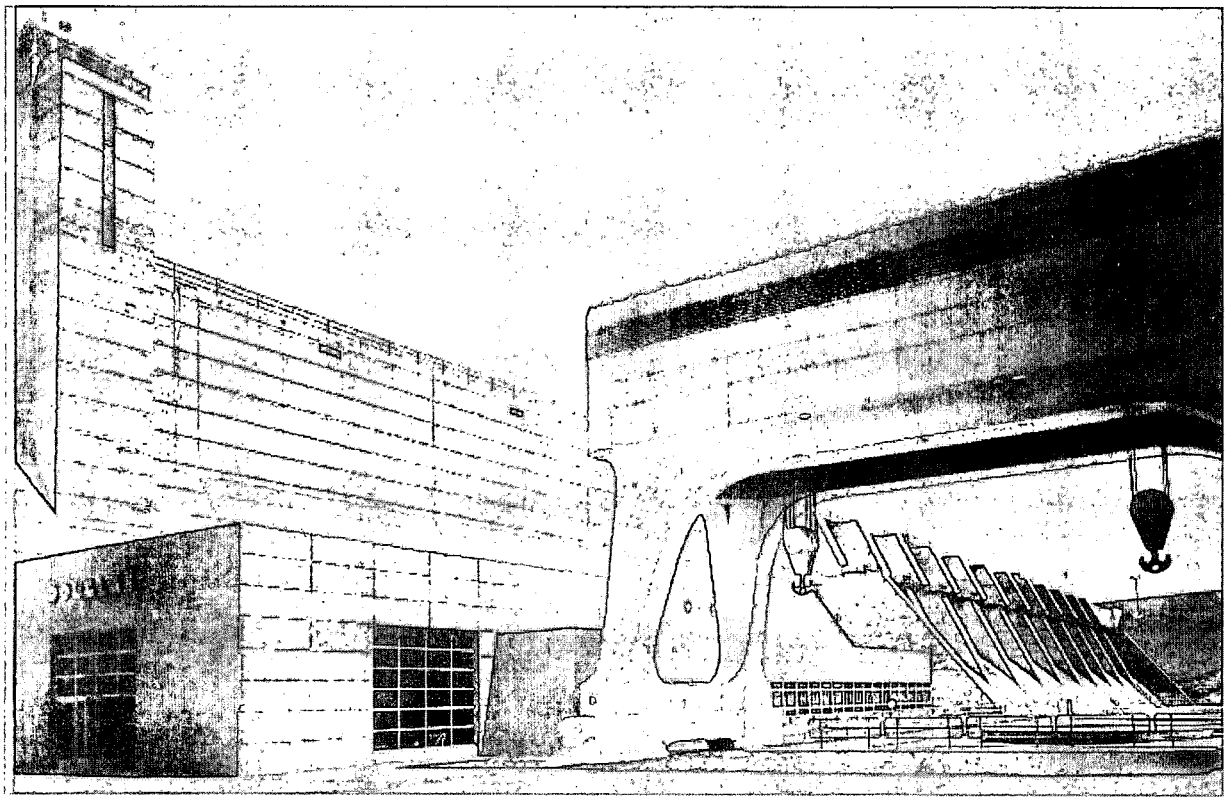


FIGURE 1 - View of Spillway through overhead crane, 1943

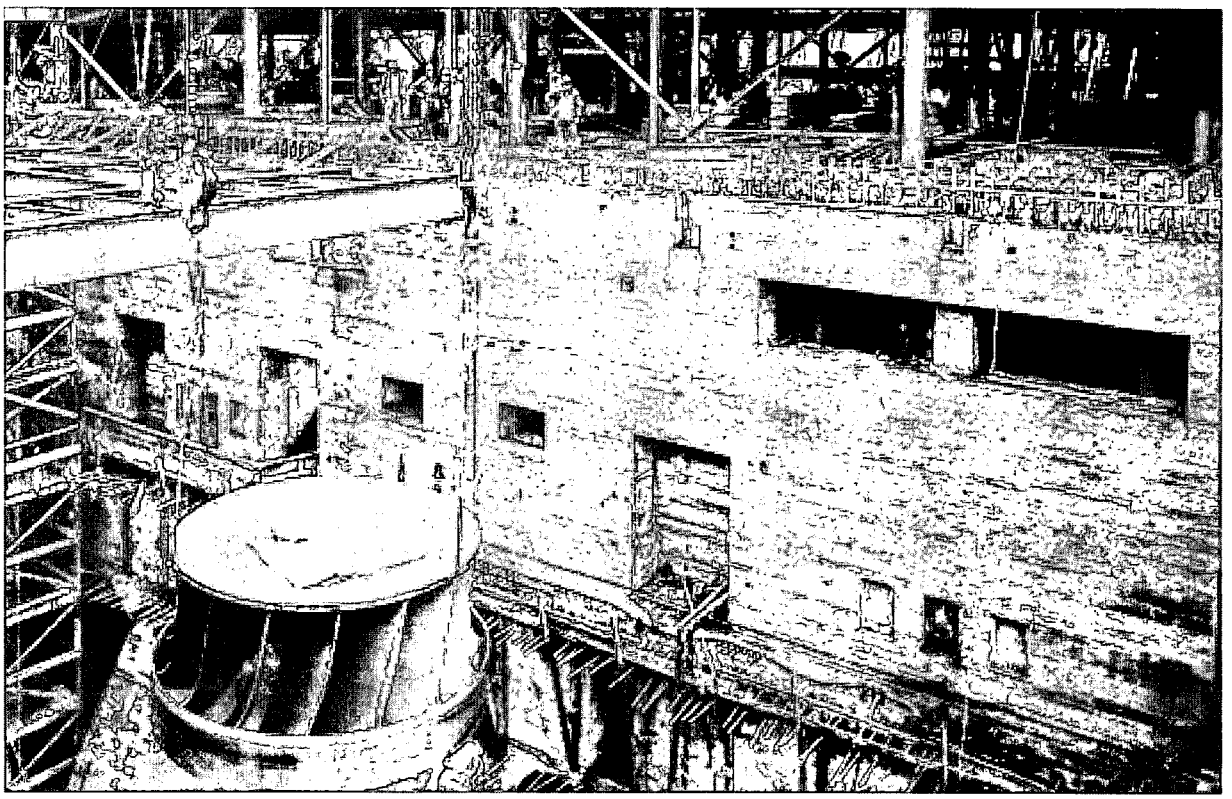


FIGURE 2 - Installation of turbine runner, 1943

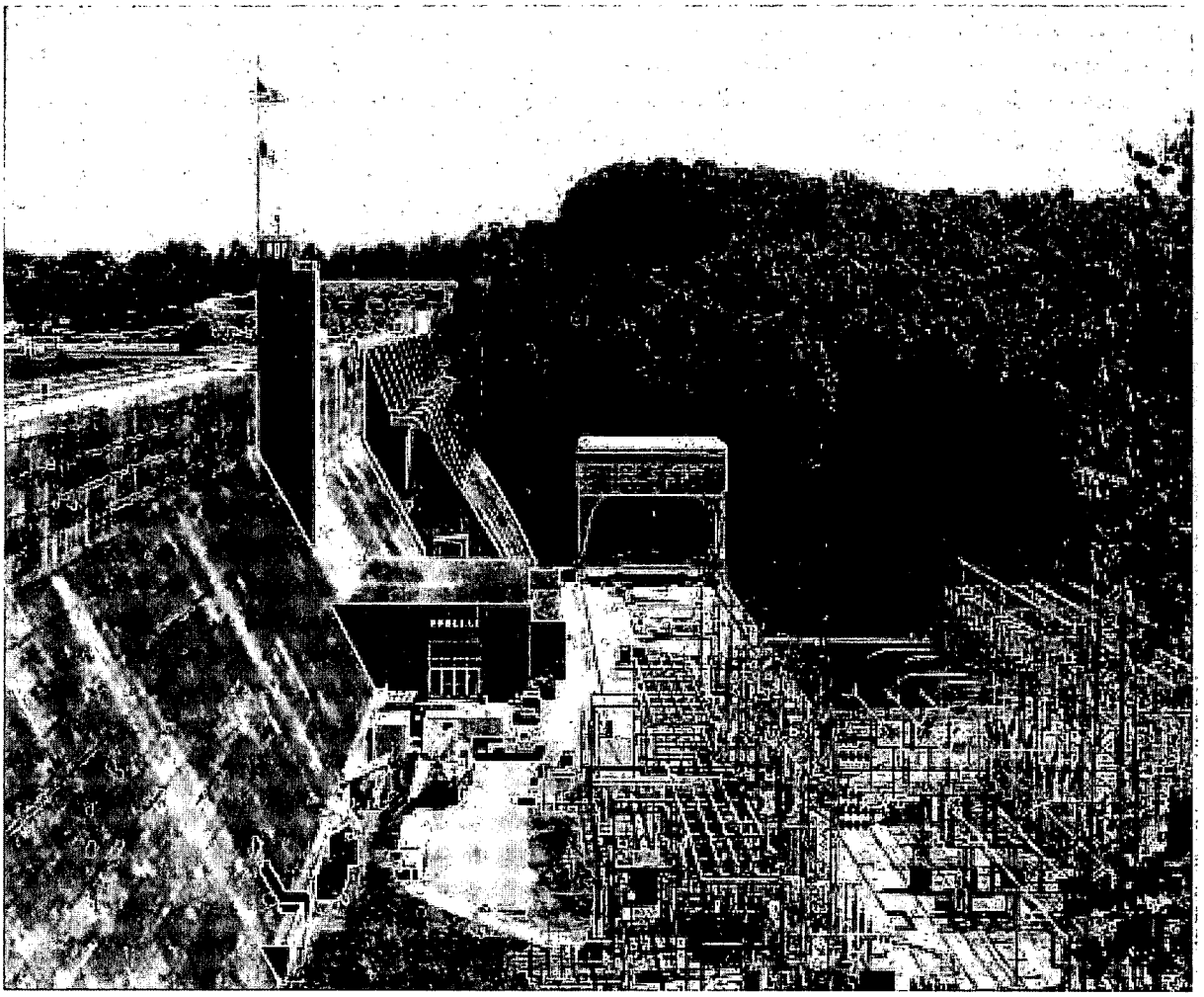
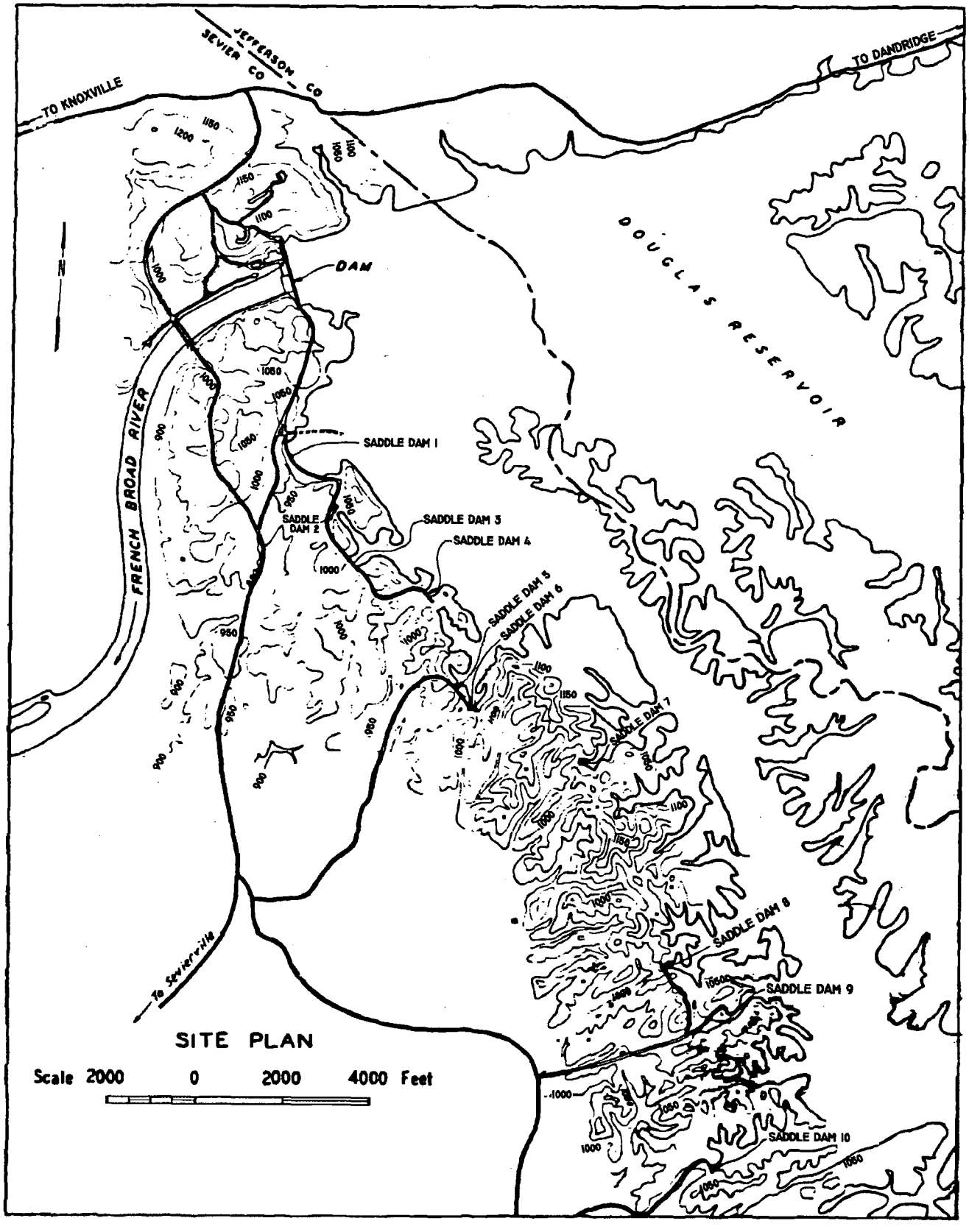
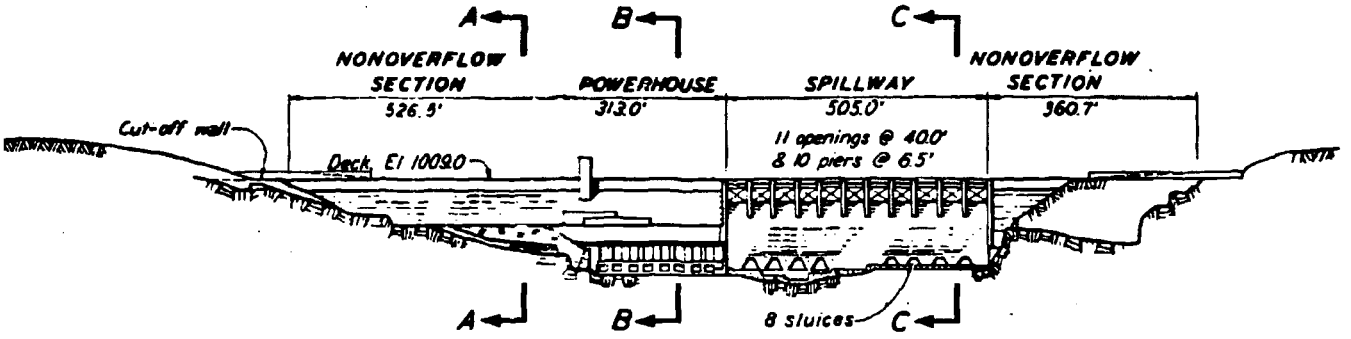


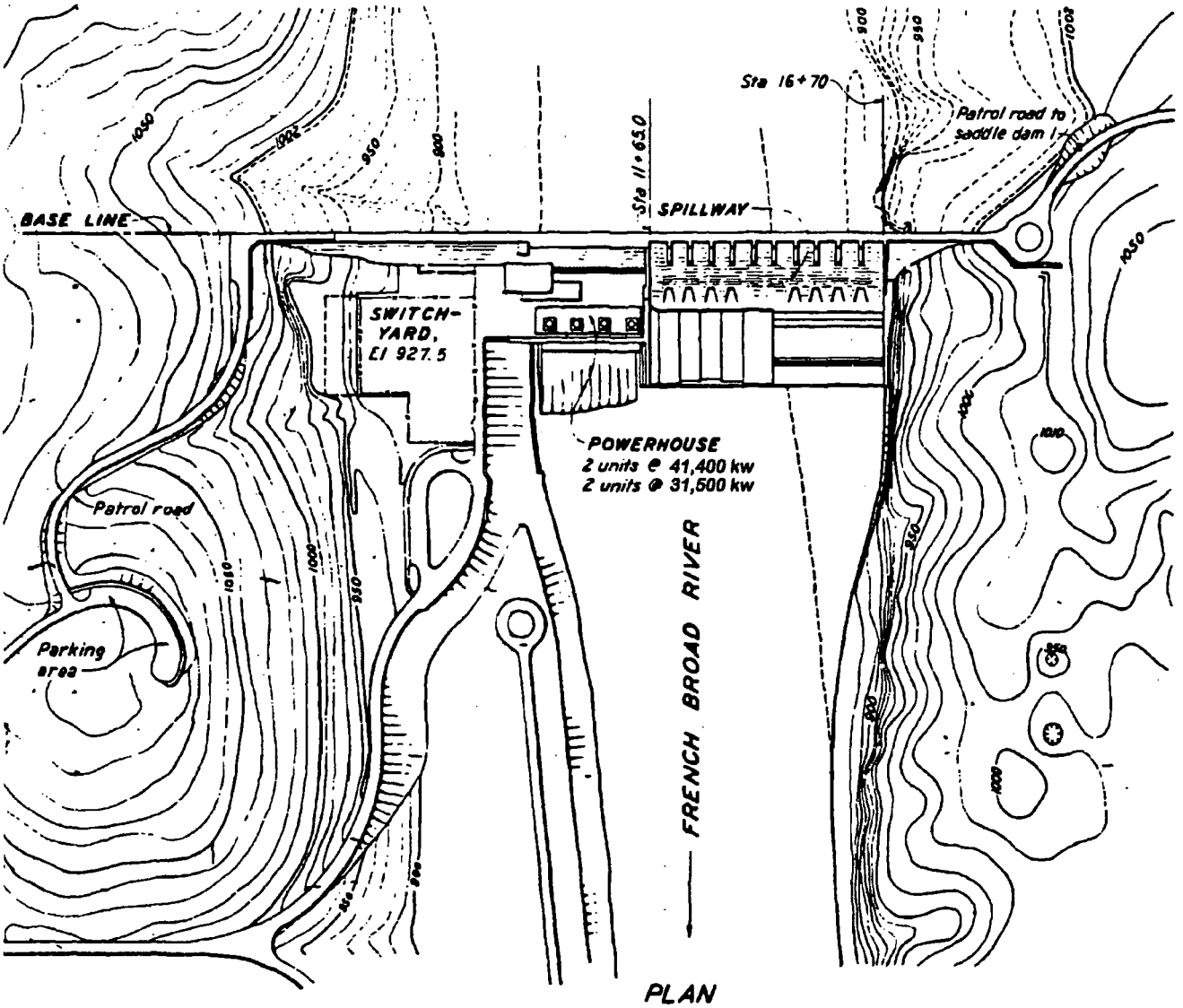
FIGURE 3 - Plant View Looking South, August 1998

FIGURE 4


JEFFERSON CO
SEVIER CO
TO KNOXVILLE
TO DANDRIDGE
DAM
DOUGLAS RESERVOIR
FRENCH BROAD RIVER
SADDLE DAM 1
SADDLE DAM 2
SADDLE DAM 3
SADDLE DAM 4
SADDLE DAM 5
SADDLE DAM 6
SADDLE DAM 7
SADDLE DAM 8
SADDLE DAM 9
SADDLE DAM 10
To Sevierville
SITE PLAN
Scale 2000 0 2000 4000 Feet

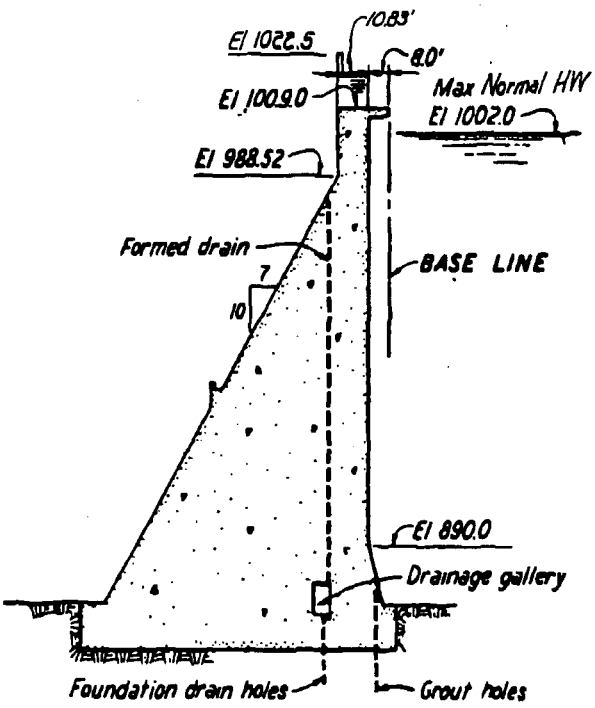


DOWNSTREAM ELEVATION

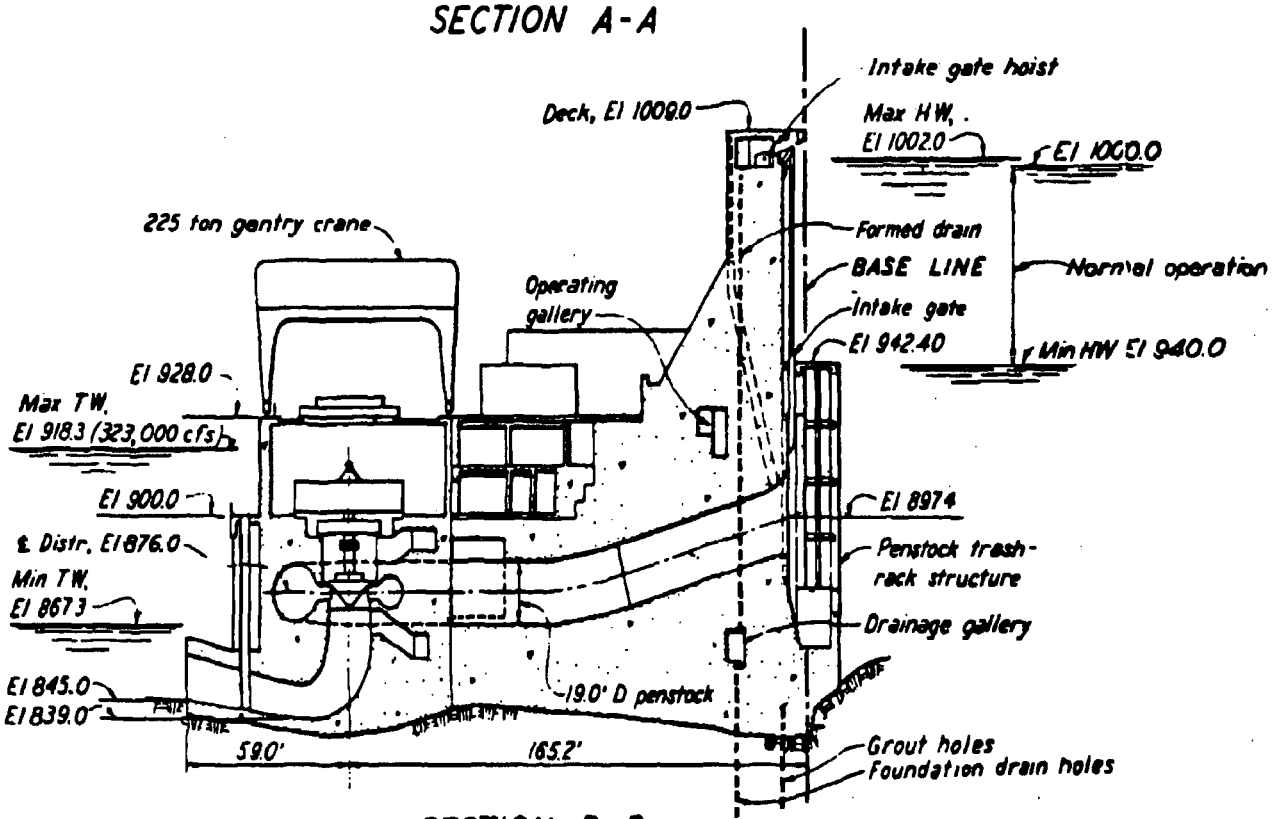


PLAN

FIGURE 5

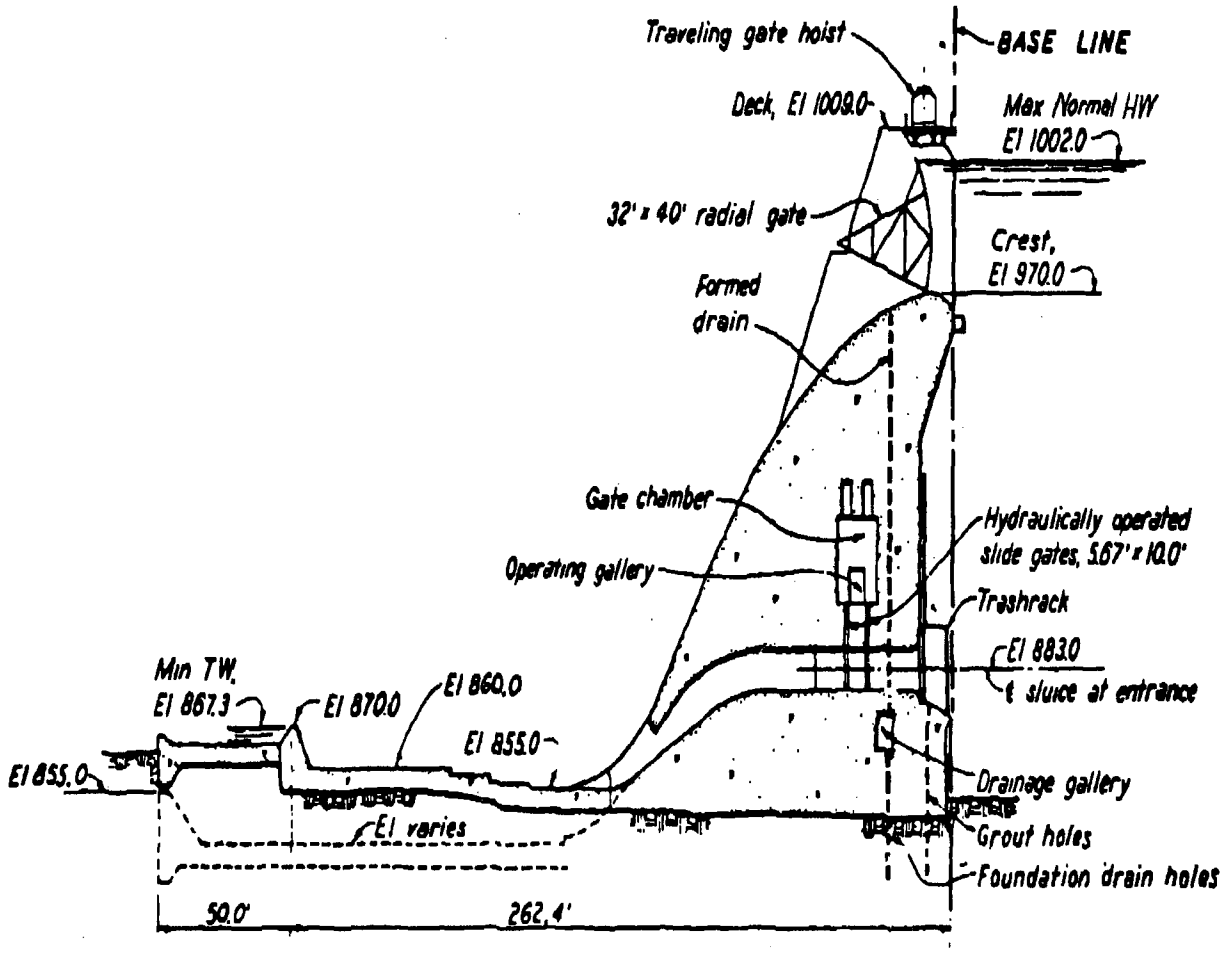


SECTION A-A



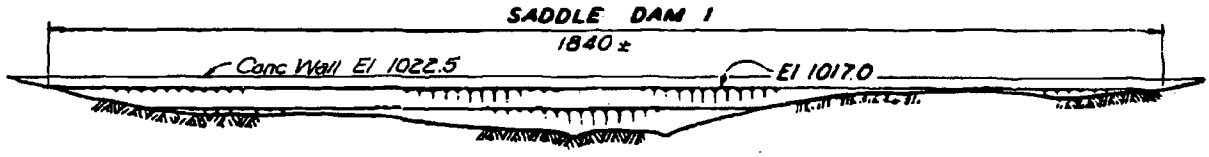
SECTION B-B

FIGURE 6

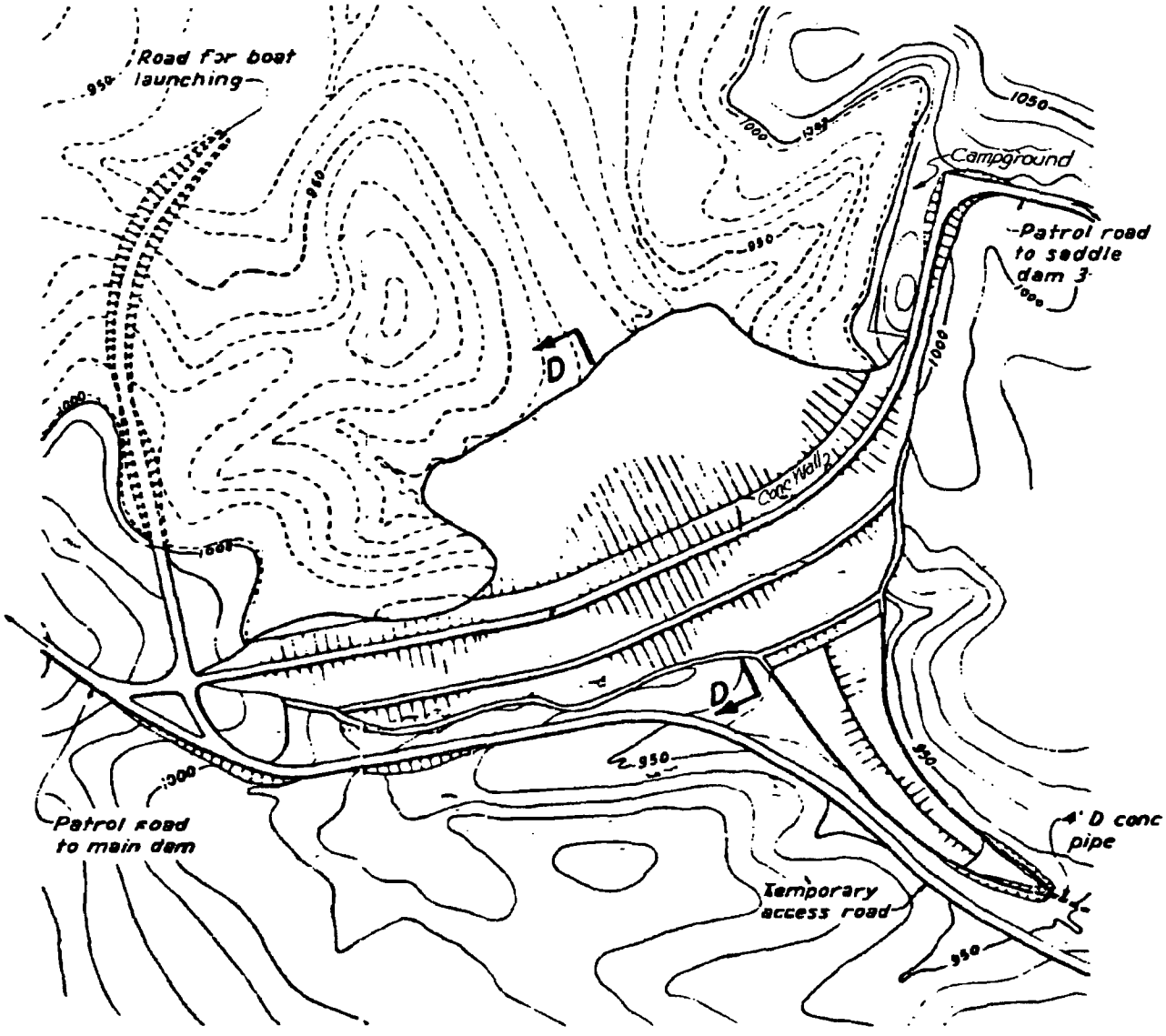


SECTION C-C

FIGURE 7



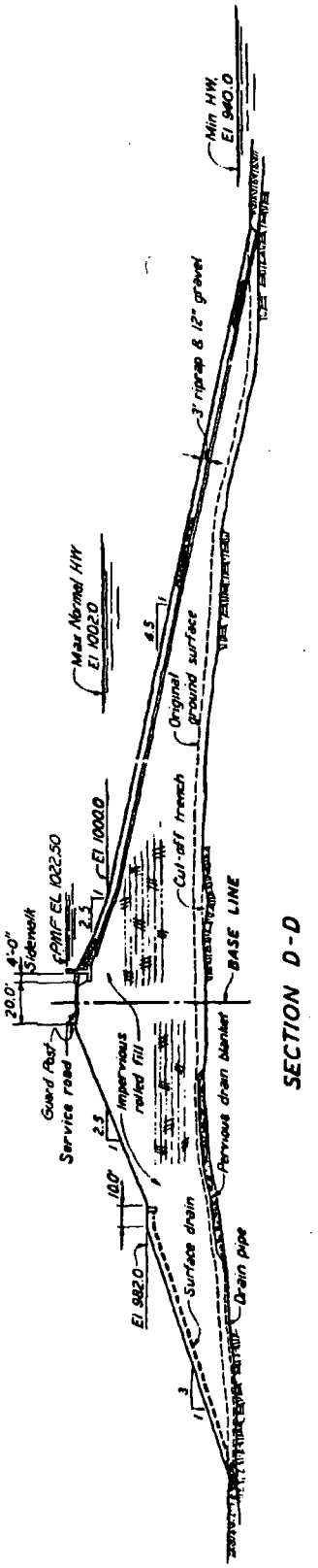
DOWNSTREAM ELEVATION



PLAN - SADDLE DAM 1

FIGURE 8

FIGURE 9
Saddle Dam 1



DOUGLAS PROJECT

SUMMARY OF PRINCIPAL FEATURES

LOCATION

On French Broad River at mile 32.3; in Sevier County, Tennessee; 6.6 air miles north of Sevierville; 21 air miles east of Knoxville.

Note

Elevations are based on the U.S.C. & G. S. 1936 Supplementary Adjustment.

CHRONOLOGY

Initial appropriation by Congress	January 30, 1942
Authorized by TVA Board of Directors	February 2, 1942
Construction started	February 2, 1942
Dam closure	February 19, 1943
First unit (No. 3) in commercial operation	March 21, 1943
Second unit (No. 1) in commercial operation	January 12, 1944
Installation of third unit (No. 2) started	September 11,1946
Third unit (No. 2) in commercial operation	May 22, 1949
Installation of fourth unit (No. 4) started	August 20, 1951
Fourth unit (No. 4) in commercial operation	August 3, 1954
Safety Modification for Probable Maximum Flood Construction completed	May 1987
Reservoir Release Improvements - completed	September 1996
Generator & Turbine Modernization Units 2 & 4 - completed	September 2, 1998

PROJECT COST

Initial project, including 2 units (1 & 3)	$40,244,349
Addition of unit 2	2,061,892
Addition of unit 4	2,946,952
Safety Modifications for Probable Maximum Flood	2,500,000
Reservoir Release Improvements	6,300,000
Generator & Turbine Modernization	18,882,000
Total, including switchyard	$72,935,193

STREAMFLOW

Drainage area at dam ..... 4,541 sq. miles
Maximum known flood at dam site:
Natural(1867) ..... 150,000 cfs
Regulated (May, 1984) ..... 54,000 cfs

RESERVOIR

Counties affected:
State of Tennessee ..... Sevier, Jefferson, Cocke, Hamblen
Reservoir land at June 1998:
Fee simple ..... 9,553 ac.
Easements ..... 23,074 ac.
Total ..... 32,627 ac.
Transferred ..... 195.5 ac.
Operating levels at dam:
Probable maximum flood elevation (PMF) ..... *el. 1022.5
500 year flood elevation ..... *el. 1003
100 year flood elevation ..... *el. 1002.6
Winter flood guide level ..... el. 940
Summer flood guide level ..... el. 994
Maximum used for design (337,000 cfs) ..... el. 1002
Top of gates (area 31,300 ac.) ..... el. 1002
Normal minimum pool ..... el. 940
Backwater, length at top of gates ..... 43.1 miles
Shoreline, length at top of gates:
Main shore ..... 454.9 miles
Islands ..... 57.6 miles
Total ..... 512.5 miles
Original river area (to el. 1002 crossing) ..... 3,170 ac.
Storage (flat pool assumption):
Total volume:
At top of gates (el. 1002) ..... 1,461,000 ac.-ft
At normal minimum pool (el. 940) ..... 210,000 ac.-ft
Reservation for flood control on:
January 1 (el. 1002-940) ..... 1,251,000 ac.-ft
March 15 (el. 1002-958) ..... 1,021,400 ac.-ft
June 1 (el. 1002-994) ..... 237,500 ac.-ft

**These elevations are valid at the dam and may change significantly upstream of the dam.*

TAILWATER

Maximum used for design (337,000 cfs)	el. 919
Minimum level	el.867.3

HEAD (Gross)

Maximum static (el. 1002-867.3)	134.7 ft
Maximum expected operating (el. 1002-871)	131 ft
Minimum operating (el. 910-874)	36 ft

RESERVOIR ADJUSTMENTS

Clearing	5,182 ac.
Drainage of isolated pools	15,549 cu. yd
Highways:	
Access	22.3 miles
State	5.3 miles
County and tertiary	52.1 miles
Total	79.7 miles
Railroads:	
Access	7.2 miles
Other	9.4 miles
Total	16.6 miles
Bridges (highway, 12; railroad, 2)	14
Concrete box culverts	54
Families relocated	525
Graves removed	2,449
Utility lines adjusted or constructed	204.3 miles

DAMS

MAIN DAM

Material and type	Concrete gravity nonoverflow dam and spillway
Lengths:	
Nonoverflow dam	887 ft
Spillway	505 ft
Powerhouse intake	313 ft
Total	1,705 ft
Maximum height, foundation to deck level	202 ft
Maximum width at base:	
Spillway section only	40 ft
Including apron	310 ft
Deck level	el. 1009.0
Outlet facilities:	
Spillway clear opening (11 openings at 40 ft)	440 ft
Spillway crest level	el. 970.0
Crest gates	11 radial gates, 40 ft wide, 32 ft high, separated by 6.5-ft-thick piers
Traveling hoists	Two 60-ton hoists
Sluices	Eight, 5 ft 8 in. wide, 10 ft high
Centerline of sluices	el. 883.0
Sluice gates	8 sets of two 5-ft-8-in. by 10-ft hydraulically operated slide gates
Discharge capacity:	
Spillway, HW el. 1002 (top of gates)	313,000 cfs
Sluices, HW el. 1002	29,000 cfs
Service road	17.5 ft wide, each side of spillway
Foundation	Knox dolomite

DAMS (CONT.)

SADDLE DAMS

Location ..... Left rim, No.1 at 0.8 mile and No.10 at 4.5 miles from main dam

Material and type ..... Impervious rolled earthfill embankments

Dam No.	1	2	3	4	5	6	7	8	9	10
Length, feet	1,918	20	650	65	228	130	20	125	295	322
*Maximum height, feet	101	10	39	32	32	25	15	25	25	25

*Top of embankments (except Saddle Dam 1) ..... el. 1023.5

*Top of concrete wall for Saddle Dam 1 ..... el. 1022.5

*Saddle Dams 2 and 7 (added for dam safety) ..... el. 1023.5

Total length all saddle dams, feet 3,733

Top width ..... 20 ft

Foundations ..... No. 1, Athens shale; others, earth

See Section on Safety Modification for Probable Maximum Flood. Saddle Dam heights were increased for dam safety.

POWER FACILITIES

INTAKES

Number 4

Dimensions of one rack opening ..... 14 ft 8 in. by 24 ft 4 in.

Gross area at rack (total per unit) ..... 1,780 sq. ft

Gates ..... Four 19-ft-wide by 26-ft-high structural steel gates with roller trains

Hoists ..... Four 60-ton stationary chain hoists

PENSTOCKS

Number 4

Type ..... Riveted steel lined

Diameter ..... 19 ft

Length ..... 123 ft

Air vents ..... One 30-in.-dia. for each unit

POWER FACILITIES (CONT.)

POWERHOUSE

Generating capacity, 4-unit total (Original Capacity) ..... 115,000 kW
Type of construction ..... Semioutdoor, reinforced concrete and structural steel
Principal dimensions, including
service bay ..... 313 ft long by 95 ft wide by 93 ft high
Service bay ..... 55 ft long by 134 ft wide
Draft tubes:
Type ..... Elbow, 2 openings
Horizontal length (centerline of turbine to downstream face) ..... 59 ft
Vertical distance from distributor centerline to draft tube floor ..... 37 ft
Net area at outlet opening (total per unit) ..... 592.5 sq. ft
Gates ..... One set of 2 slide gates, 20.33 ft clear opening by 13.42 ft high
Crane ..... 25-ton jib crane on gantry
Erecting crane ..... One 225-ton gantry, two 112-1/2-ton main hooks, two 25-ton auxiliary hooks, and one 25-ton jib crane

GENERATOR & TURBINE MODERNIZATION

Douglas Units 2 and 4 were modernized in the Spring/Summer of 1997 and 1998 respectively. The equipment replaced are the runner, wicket gates, wear rings, main transformers, neutral ground reactor, generator leads, generator switchgear, generator stator winding, pilot and main exciters, generator leads disconnect switch, neutral ground transformer, generator and transformer protective relays, generator CTs, transformer PTs, raw water strainer, generator air coolers, thrust bearing oil coolers, proportional valves, and thrust runner. Rehabilitated equipment includes the generator and turbine shafts, generator and turbine guide bearings, servo motors and shift ring, headcover, bottom ring, and the rotor poles reinsulated. New equipment added includes generator fans and baffles, deflectors on the runner, and discharge ring aeration system.

POWER FACILITIES (CONT.)

HYDRAULIC TURBINES

UNITS 1 AND 3

Number	2
Manufacturer(Original)	S. Morgan Smith Co. (now Allis-Chalmers Manufacturing Co.)
Type	Vertical Francis
Rated capacity (each)	41,500 hp at 100-ft net head
Rated speed	94.7 r/min
Maximum runaway speed	179 r/min
Specific speed at rating	61
Value of sigma at rating	0.29
Diameter of runner, intake	165 in.
Diameter of runner, discharge	177 in.
Centerline to bottom of runner	61 in.
Centerline to top of runner	28.437 in.
Diameter of guide vane circle	202 in.
Diameter of lower pit	19.0 ft
Spacing of turbines, center to center of units	61.0 ft
Governors	Woodward, cabinet actuator type
Weight of rotating parts	175,000 lb

UNITS 2 AND 4

Number	2
Manufacturer(Replacement)	Voith Hydro, Inc.
Type	Francis
Rated capacity (each)	63,365 hp at 120-ft net head
Rated speed	.90 r/min
Maximum runaway speed	189.2 r/min
Specific speed at rating	57.0
Tailwater safety factor	19.0 @ 72.0 tailwater elevation
Diameter of runner, intake	146.36 in. CL
Diameter of runner, discharge	183.28 in.
Centerline to bottom of runner	88.2 in.
Centerline to top of runner	36.4 in.
Diameter of guide vane circle	205.5 in.
Diameter of lower pit	19.92 ft
Spacing of turbines, center to center of units	61.0 ft
Governors	Woodward, cabinet actuator type
Weight of rotating parts (runner and turbine shaft)	163,264 lb

POWER FACILITIES (CONT.)

GENERATORS

Generating capacity - 4 unit total 145,800 kW
Number 4
Manufacturer ..... General Electric Co.
Type ..... Enclosed, water-cooled, vertical-shaft
Original rating:
Units 1, 3 ..... 33,333 kVA , 30, 000 kW, 1393 amp, 60 degrees C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Original capacity:
Units 1, 3 ..... 38,333, kVA , 34,500 kW, 1602 amp, 80 degrees C rise
Note: Units 1 and 3 rewound and rerated June 1, 1972, and July 1, 1971, respectively.
Rating:
Units 1, 3 ..... 35,000 kVA , 31,500 kW, 1464 A, 60 degrees C rise, 0.90 pf , 13.8 kV , 3 ph, 60 Hz
Original Rating:
Units 2, 4 ..... 33,333 kVA , 30,000 kW, 1393 amp, 60 degrees C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Original Capacity:
Units 2, 4 ..... 38,333 kVA, 34,500 kW, 1602 amp, 80 degrees C rise

Note:
Units 2 and 4 modernization completed September 2, 1998.

Rating:
Units 2,4 ..... 46,000 kVA, 41,400 Kw 1,925 A, 80 degrees C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Efficiency (guaranteed original values):
Units 1, 3:
At rated kVA 1.0 pf ..... 97.55 percent
At 75% kVA, 0.9 pf ..... 97.00 percent
Units 2, 4:
At rated kVA, 1.0 pf ..... 97.35 percent
At 75% kVA, O.9 pf ..... 96.80 percent
Flywheel effect:
Units 1, 3 ..... 45,000,000 lb-ft^2
Units 2, 4 ..... 44,000,000 lb-ft^2
Thrust bearing:
Units 1, 2, 3 ..... Kingsbury, dia. 89 in., max. load 1672 tons
Unit 4 ..... GE, dia. 75.5 in., max. load 1908 tons
Neutral reactor ..... equipment removed

POWER FACILITIES (CONT.)

Generators (Cont.)

Grounding transformer & resistor:
- Unit 2 ..... 13.8 kV; 240 volt; 0.47 ohms (resistor)
- Unit 4 ..... 13.8 kV; 240 volt; 0.36 ohms (resistor)

Exciters:
- Main ..... 450 kW, 325 V
- Pilot ..... equipment removed

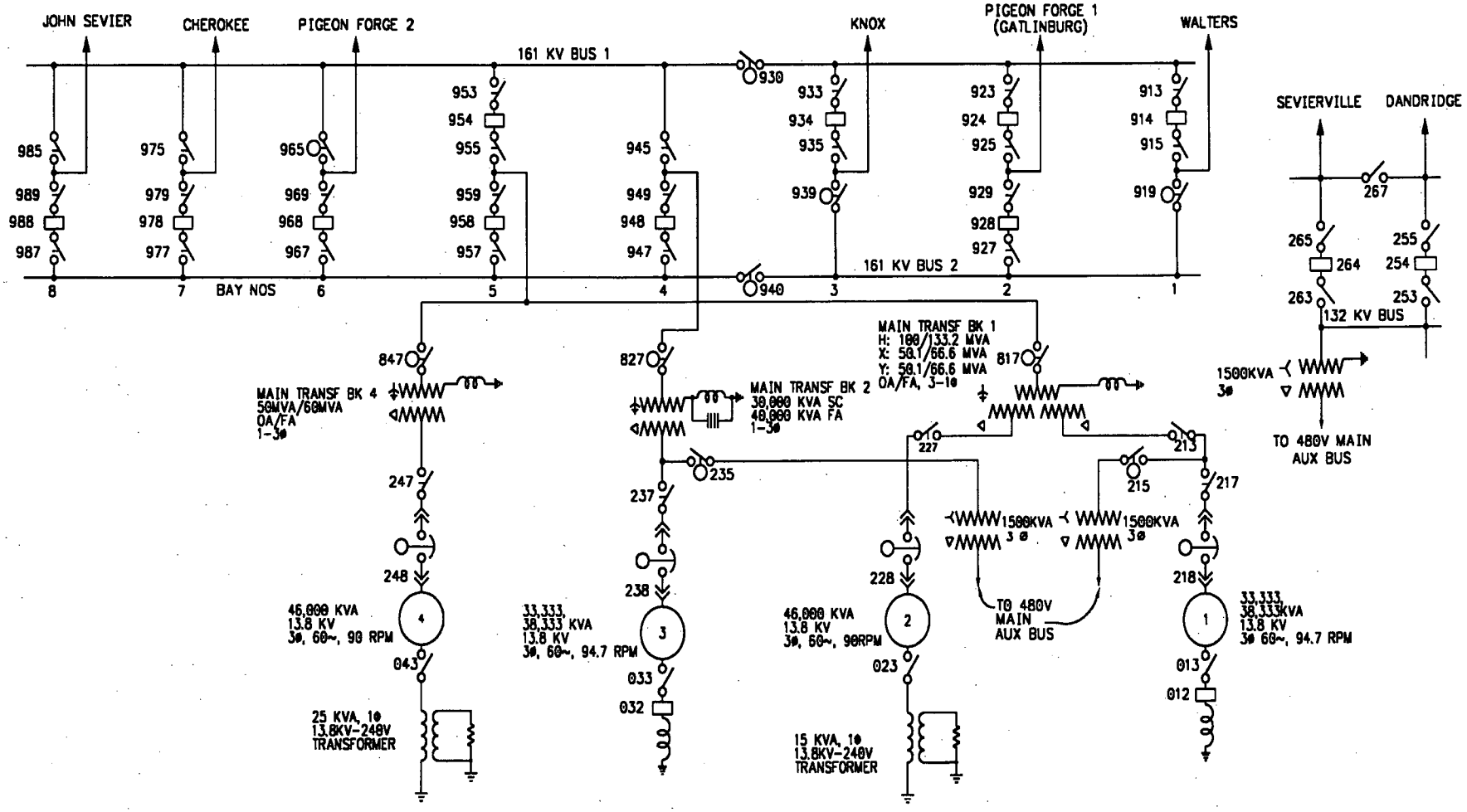
Weight of heaviest crane lift, rotor:
- Units 1, 3 ..... 185 tons
- Units 2, 4 ..... 173 tons

Diameter over air housing, less trim ..... 460 in.

Top of pilot exciter:
- Above stator soleplates ..... 175.25 in.
- Above generator floor ..... 165.25 in.

FIGURE 10

Single Line Diagram of Main Connections



PRESENT INSTALLATION

ELECTRIC CONTROLS

Generation may be controlled by one of three methods. Normally, the local automation computer system will receive generation schedules from the Hydro Dispatch Control Cell(HDCC) in the Power Business Center in Chattanooga and respond with automatic control of the units. All pertinent data such as electrical quantities, water levels, alarms, etc. are telemetered to the HDCC. If required, the production coordinator in the HDCC may take over control of the units from Chattanooga through traditional Supervisory Control and Data Acquisition(SCADA) communications. Controls for local operation are also provided in the Douglas control room. All switching is controlled either from the Power Business Center through traditional SCADA communications or locally from the control room at the plant.

TRANSMISSION PLANT

Step-up transformers: See Transmission Plant Data Spreadsheet.

Intersystem transformers: See Transmission Plant Data Spreadsheet.

161-kV circuit breakers;

4	1200 - A,	3.5 - MVA,	General	Electric
4	1200 - A,	5.0 - MVA,	General	Electric
2	1200 - A,	5.0 - MVA,	Westinghouse	

14.4-kV circuit breakers:

2	600 - A,	250,000 - kVA,	General Electric

Structures:

8	161-kV switchyard bays, 38 ft wide
2	12.5-kV switchyard bays, 12 ft wide
4	transformer banks

TRANSMISSION PLANT DATA

Plant	Location	Phase	Serial Number	MVA Rating		Voltage kV	Cooling	Tap Changer	Oil Preservation System
				55 degrees	65 degrees				
Douglas Hydro	Bank 1	A	70595C	33.34/44.45	37.34/49.78	161/13.8/13.8	OA/FA	DETC	Sealed Conservator
Douglas Hydro	Bank 1	B	70595B	33.34/44.45	37.34/49.78	161/13.8/13.8	OA/FA	DETC	Sealed Conservator
Douglas Hydro	Bank 1	C	70595A	33.34/44.45	37.34/49.78	161/13.8/13.8	OA/FA	DETC	Sealed Conservator
Douglas Hydro	Bank 2	1	862296	30/40		161/132.2	OA/FA	DETC	Gas-Blanketed
Douglas Hydro	Bank 3	3	97960319	50/66.5	56/74.5	161/13.8	OA/FA	DETC	Sealed Conservator
Douglas Hydro	Bank 4	3	907753	30/40		161/132.2	OA/FA	DETC	Gas-Blanketed

Plant	Location	Phase	Oil Volume gal.	Configuration	Impedance %			Contract Number	Manufacturer	Year of Manufacture
					H-X	H-Y	X-Y			
Douglas Hydro	Bank 1	A	6080	Wye/Delta/Delta	18.94	18.99	37.91	96P1E-163872-000	North American	1997
Douglas Hydro	Bank 1	B	6080	Wye/Delta/Delta	19.05	19.03	38.39	96P1E-163872-000	North American	1997
Douglas Hydro	Bank 1	C	6080	Wye/Delta/Delta	19.00	19.01	38.53	96P1E-163872-000	North American	1997
Douglas Hydro	Bank 2	1	11945	Wye/Delta				TV-94507	Westinghouse	1948
Douglas Hydro	Bank 3	3	8189	GRD Wye/Delta		N/A	N/A	96PFM-172321-000	Pauwels Canada	1998
Douglas Hydro	Bank 4	3	11954	Wye/Delta				C52-11033	Moloney	1952

RESERVOIR AND POWER DATA - DOUGLAS

					BEST EFFICIENCY			MAXIMUM SUSTAINABLE		
Pool Elevation (feet)	Area (acre *1000)	Volume (ac-ft *1000)	Potential EIS* (gWh)	Gross Head (feet)	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs
1002	30.75	1461.0	710.9	126.7	116.9	12,660	9.24	144.7	16,600	8.72
1001	30.52	1430.3	694.7	125.7	117.0	12,750	9.18	144.7	16,690	8.68
1000	30.28	1399.9	678.7	124.7	117.0	12,830	9.13	144.8	16,780	8.63
999	30.02	1369.8	662.8	123.6	117.1	12,910	9.07	144.8	16,870	8.58
998	29.74	1339.9	647.1	122.6	117.1	12,990	9.02	144.8	16,970	8.54
997	29.44	1310.3	631.6	121.6	117.1	13,070	8.96	144.8	17,060	8.49
996	29.12	1281.0	616.3	120.6	117.2	13,150	8.91	144.8	17,150	8.44
995	28.78	1252.1	601.1	119.5	117.2	13,260	8.84	144.5	17,240	8.38
994	28.42	1223.5	585.8	118.5	117.2	13,390	8.76	143.9	17,330	8.31
993	28.04	1195.2	570.8	117.5	117.2	13,520	8.68	143.3	17,420	8.23
992	27.64	1167.4	555.9	116.5	117.2	13,660	8.60	142.7	17,520	8.15
991	27.22	1140.0	541.4	115.5	117.2	13,790	8.52	142.1	17,610	8.08
990	26.77	1113.0	527.0	114.4	117.2	13,920	8.44	141.5	17,700	8.00
989	26.33	1086.4	513.0	113.4	117.2	14,050	8.35	140.9	17,790	7.92
988	25.89	1060.3	499.2	112.4	117.2	14,190	8.27	140.2	17,880	7.85
987	25.47	1034.6	485.7	111.4	117.2	14,320	8.19	139.6	17,980	7.77
986	25.06	1009.4	472.4	110.4	117.2	14,450	8.11	139.0	18,070	7.69
985	24.66	984.5	459.4	109.3	117.0	14,560	8.04	138.4	18,170	7.62
984	24.26	960.1	446.7	108.3	116.6	14,640	7.97	137.8	18,290	7.54
983	23.88	936.0	434.2	107.3	116.3	14,730	7.90	137.2	18,400	7.46
982	23.51	912.3	422.0	106.3	115.9	14,820	7.83	136.6	18,510	7.39
981	23.15	889.0	410.0	105.2	115.6	14,900	7.77	135.9	18,620	7.31
980	22.80	866.0	398.2	104.2	115.2	14,990	7.70	135.3	18,740	7.23
979	22.46	843.4	386.5	103.2	114.9	15,080	7.63	134.7	18,850	7.16
978	22.13	821.1	375.1	102.2	114.5	15,160	7.56	134.1	18,960	7.08
977	21.80	799.1	363.9	101.1	114.2	15,250	7.49	133.5	19,070	7.00
976	21.48	777.5	352.9	100.1	113.8	15,340	7.42	132.9	19,190	6.93
975	21.17	756.1	342.0	99.1	112.9	15,390	7.34	131.1	19,170	6.84
974	20.87	735.1	331.2	98.1	111.9	15,450	7.25	129.1	19,130	6.75
973	20.57	714.4	320.6	97.1	110.9	15,500	7.17	127.1	19,090	6.65
972	20.28	694.0	310.2	96.2	110.0	15,550	7.08	125.1	19,050	6.56
971	19.99	673.8	300.0	95.2	109.0	15,600	6.99	123.1	19,010	6.47
970	19.71	654.0	289.9	94.2	108.0	15,650	6.91	121.1	18,970	6.38
969	19.44	634.4	280.0	93.2	107.0	15,700	6.82	119.2	18,930	6.29
968	19.15	615.1	270.3	92.2	106.0	15,750	6.73	117.2	18,890	6.20
967	18.85	596.1	260.8	91.2	105.0	15,810	6.65	115.2	18,850	6.11
966	18.55	577.4	251.4	90.2	104.0	15,860	6.56	113.2	18,810	6.02
965	18.24	559.0	242.3	89.2	102.0	15,830	6.44	111.3	18,710	5.95
964	17.91	540.9	233.3	88.3	99.8	15,770	6.32	109.4	18,590	5.88
963	17.58	523.2	224.5	87.3	97.5	15,720	6.20	107.5	18,470	5.82
962	17.24	505.8	215.9	86.3	95.3	15,670	6.08	105.6	18,360	5.75

** EIS represents energy in storage, and includes production at Douglas and all downstream plants through Kentucky Dam.*

RESERVOIR AND POWER DATA - DOUGLAS (CONT.)

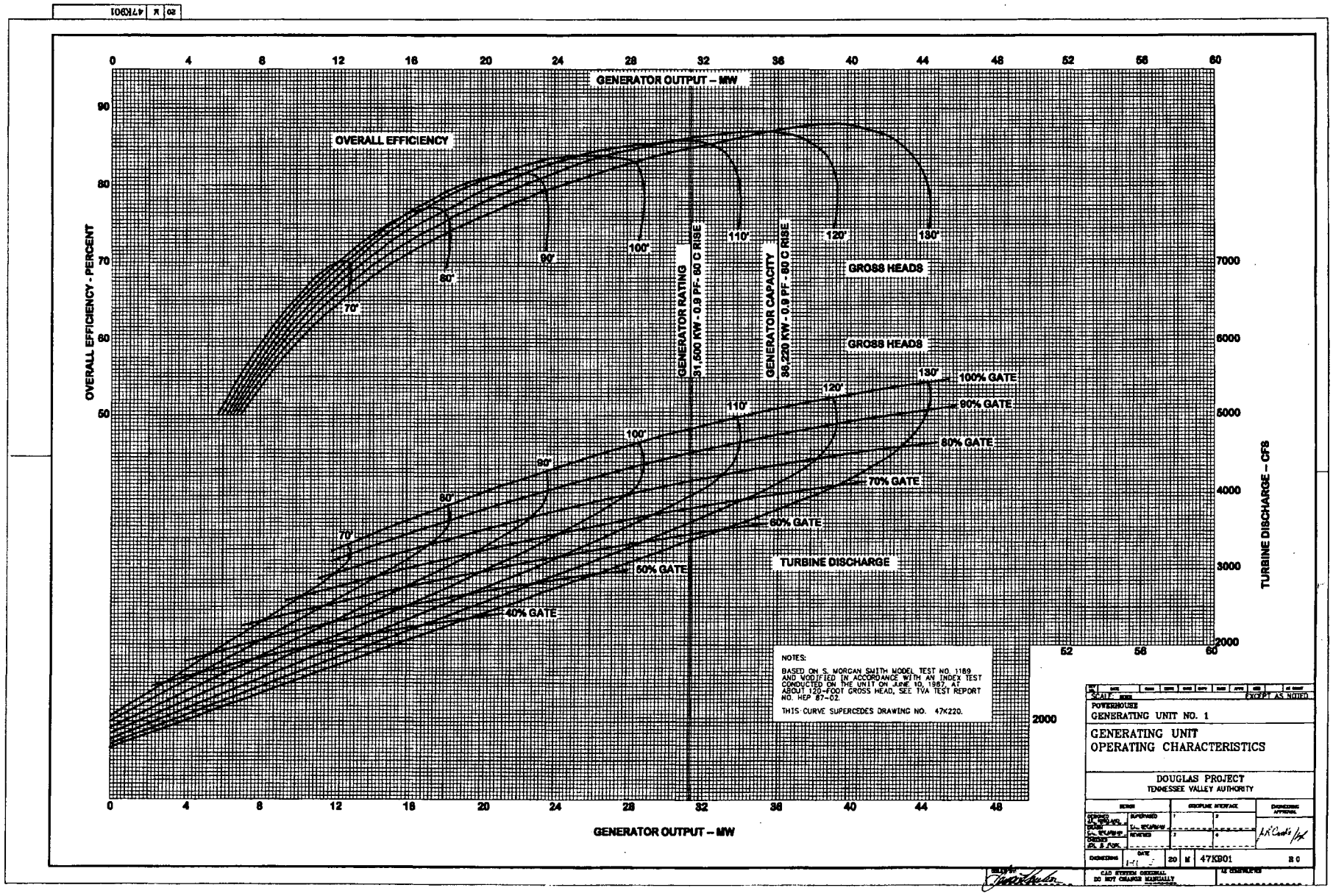
					BEST EFFICIENCY			MAXIMUM SUSTAINABLE		
Pool Elevation (feet)	Area (acre *1000)	Volume (ac-ft *1000)	Potential EIS* (gWh)	Gross Head (feet)	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs
961	16.90	488.7	207.5	85.3	93.1	15,620	5.96	103.7	18,240	5.69
960	16.54	472.0	199.2	84.4	91.4	15,530	5.88	101.8	18,120	5.62
959	16.18	455.6	191.4	83.4	90.0	15,410	5.84	99.9	18,010	5.54
958	15.83	439.6	183.7	82.4	88.6	15,300	5.79	97.9	17,890	5.47
957	15.47	424.0	176.3	81.4	87.2	15,190	5.74	96.0	17,770	5.40
956	15.13	408.7	169.0	80.5	85.8	15,080	5.69	94.0	17,650	5.33
955	14.78	393.7	161.9	79.5	84.2	14,940	5.62	92.1	17,490	5.26
954	14.44	379.1	154.9	78.5	82.2	14,790	5.54	90.2	17,290	5.21
953	14.11	364.8	148.1	77.6	80.3	14,630	5.47	88.2	17,090	5.15
952	13.78	350.9	141.5	76.6	78.3	14,480	5.39	86.3	16,890	5.09
951	13.45	337.3	135.1	75.7	76.4	14,320	5.31	84.4	16,690	5.04
950	13.13	324.0	128.8	74.7	74.4	14,170	5.23	82.5	16,490	4.98
949	12.80	311.0	122.7	73.8	72.5	14,010	5.15	80.6	16,290	4.93
948	12.47	298.4	116.8	72.8	70.5	13,860	5.07	78.6	16,090	4.87
947	12.13	286.1	111.0	71.9	68.6	13,700	4.99	76.7	15,890	4.82
946	11.78	274.1	105.5	70.9	66.6	13,550	4.91	74.8	15,690	4.76
945	11.43	262.5	100.0	70.0	64.7	13,390	4.83	72.9	15,490	4.70
944	11.07	251.3	94.8	69.0	62.7	13,200	4.74	70.9	15,300	4.62
943	10.70	240.4	89.7	68.0	60.8	13,010	4.65	68.8	15,110	4.54
942	10.33	229.9	84.8	67.1	58.8	12,820	4.55	66.8	14,920	4.45
941	9.95	219.8	80.1	66.1	56.8	12,630	4.46	64.8	14,730	4.37
940	9.56	210.0	75.6	65.2	54.9	12,440	4.37	62.8	14,540	4.29
939	9.18	200.6	71.2	64.2	52.9	12,250	4.28	60.8	14,350	4.20
938	8.81	191.6	67.1	63.3	50.9	12,050	4.19	58.7	14,150	4.12
937	8.47	183.0	63.1	62.3	49.0	11,860	4.10	56.7	13,960	4.04
936	8.14	174.7	59.3	61.4	47.0	11,670	4.01	54.7	13,770	3.95
935	7.83	166.7	55.7	60.4	45.1	11,480	3.91	52.7	13,580	3.87
934	7.53	159.0	52.2	59.5	43.6	11,290	3.83	51.1	13,390	3.79
933	7.26	151.7	48.8	58.5	42.4	11,100	3.76	49.8	13,200	3.72
932	7.00	144.5	45.6	57.6	41.3	10,910	3.69	48.5	13,010	3.65
931	6.76	137.6	42.6	56.6	40.1	10,720	3.61	47.3	12,820	3.57
930	6.54	131.0	39.6	55.7	39.0	10,530	3.54	46.0	12,630	3.50
929	6.33	124.6	36.7	54.7	37.9	10,340	3.46	44.7	12,440	3.43
928	6.12	118.3	34.0	53.8	36.7	10,150	3.39	43.4	12,250	3.36
927	5.90	112.3	31.3	52.8	35.6	9,960	3.32	42.2	12,060	3.28
926	5.70	106.5	28.7	51.9	34.5	9,770	3.24	40.9	11,870	3.21
925	5.49	100.9	26.3	50.9	33.3	9,580	3.17	39.6	11,680	3.14
924	5.28	95.6	23.9	50.0	32.2	9,390	3.09	38.4	11,490	3.07
923	5.07	90.4	21.6	49.0	31.1	9,200	3.02	37.1	11,300	2.99
922	4.86	85.4	19.5	48.1	29.9	9,010	2.95	35.8	11,110	2.92
921	4.66	80.7	17.4	47.1	28.8	8,820	2.87	34.5	10,920	2.85
920	4.45	76.1	15.4	46.2	27.7	8,640	2.80	33.3	10,740	2.78
919	4.26	71.7	13.6	45.2	26.5	8,450	2.73	32.0	10,550	2.71
918	4.07	67.6	11.8	44.3	25.4	8,260	2.65	30.7	10,360	2.63

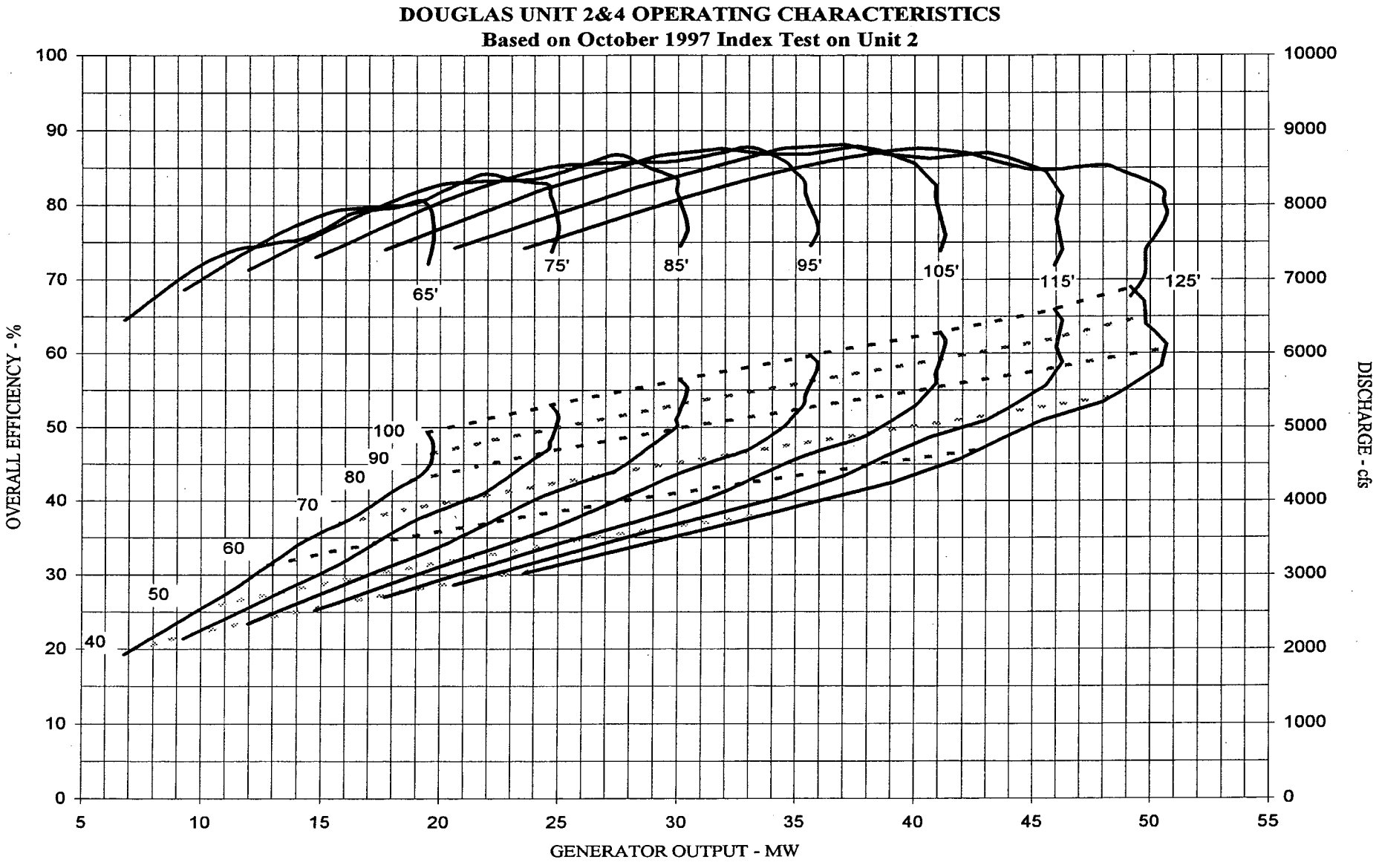
** EIS represents energy in storage, and includes production at Douglas and all downstream plants through Kentucky Dam.*

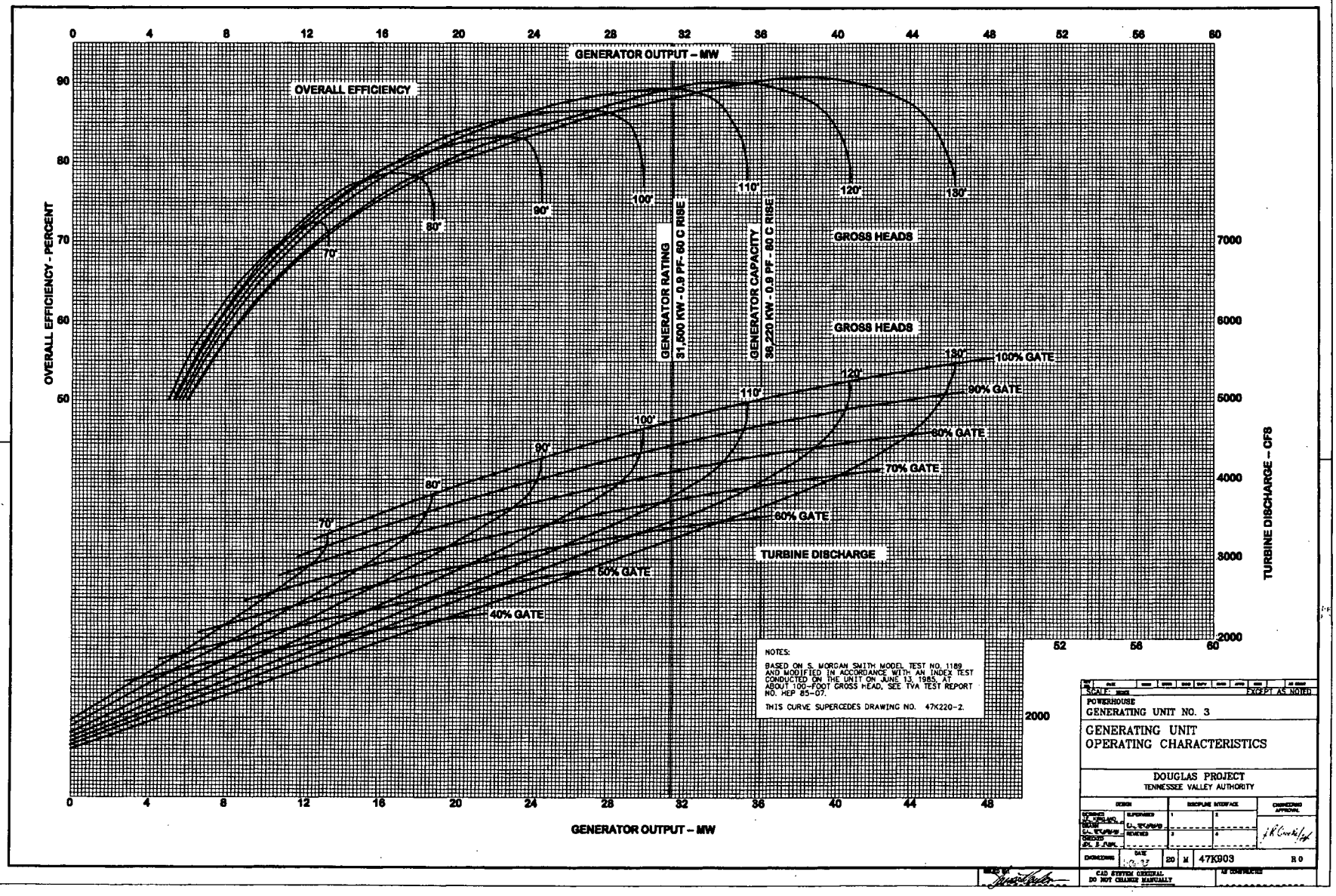
RESERVOIR AND POWER DATA - DOUGLAS (CONT.)

					BEST EFFICIENCY			MAXIMUM SUSTAINABLE		
Pool Elevation (feet)	Area (acre *1000)	Volume (ac-ft *1000)	Potential EIS* (gWh)	Gross Head (feet)	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs	Plant Output (MW)	Turbine Discharge (cfs)	kW/cfs
917	3.90	63.6	10.1	43.3	24.3	8,070	2.58	29.5	10,170	2.56
916	3.73	59.8	8.4	42.4	23.1	7,880	2.51	28.2	9,980	2.49
915	3.58	56.1	6.9	41.5	22.0	7,690	2.43	26.9	9,790	2.42
914	3.44	52.6	5.4	40.5	20.9	7,500	2.36	25.7	9,600	2.34
913	3.31	49.2	4.0	39.6	19.7	7,310	2.29	24.4	9,410	2.27
912	3.20	46.0	2.6	38.6	18.6	7,120	2.21	23.2	9,220	2.20
911	3.09	42.8	1.3	37.7	17.5	6,940	2.14	21.9	9,040	2.13
910	3.00	39.8	.0	36.7	16.4	6,750	2.07	20.6	8,850	2.06

- *EIS represents energy in storage, and includes production at Douglas and all downstream plants through Kentucky Dam.*


GENERATOR OUTPUT – MW
OVERALL EFFICIENCY
OVERALL EFFICIENCY - PERCENT
GENERATOR RATING
31,500 KW - 0.9 PF - 60 C RISE
GENERATOR CAPACITY
38,220 KW - 0.9 PF - 60 C RISE
GROSS HEADS
60'
70'
80'
90'
100'
110'
120'
130'
100% GATE
90% GATE
80% GATE
70% GATE
60% GATE
50% GATE
40% GATE
TURBINE DISCHARGE
TURBINE DISCHARGE – CFS
NOTES:
BASED ON S. MORGAN SMITH MODEL TEST NO. 1189 AND MODIFIED IN ACCORDANCE WITH AN INDEX TEST CONDUCTED ON THE UNIT ON June 10, 1987, AT ABOUT 120-FOOT GROSS HEAD, SEE TVA TEST REPORT NO. HEP 87-02.
THIS CURVE SUPERCEDES DRAWING NO. 47K220.
SCALE: EXCEPT AS NOTED
POWERHOUSE
GENERATING UNIT NO. 1
GENERATING UNIT
OPERATING CHARACTERISTICS
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
47K801
B 0


DOUGLAS UNIT 2&4 OPERATING CHARACTERISTICS
Based on October 1997 Index Test on Unit 2
OVERALL EFFICIENCY - %
DISCHARGE - cfs
GENERATOR OUTPUT - MW
65'
75'
85'
95'
105'
115'
125'
100
90
80
70
60
50
40
0
10
20
30
40
50
60
70
80
90
100
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
5
10
15
20
25
30
35
40
45
50
55


GENERATOR OUTPUT – MW
OVERALL EFFICIENCY
OVERALL EFFICIENCY - PERCENT
GENERATOR RATING
31,500 KW - 0.9 PF - 60 C RISE
GENERATOR CAPACITY
38,220 KW - 0.9 PF - 80 C RISE
GROSS HEADS
70'
80'
90'
100'
110'
120'
130'
100% GATE
90% GATE
80% GATE
70% GATE
60% GATE
50% GATE
40% GATE
TURBINE DISCHARGE
TURBINE DISCHARGE – CFS
NOTES:
BASED ON S. MORGAN SMITH MODEL TEST NO. 1189 AND MODIFIED IN ACCORDANCE WITH AN INDEX TEST CONDUCTED ON THE UNIT ON JUNE 13, 1985, AT ABOUT 100-FOOT GROSS HEAD. SEE TVA TEST REPORT NO. HEP 85-07.
THIS CURVE SUPERCEDES DRAWING NO. 47K220-2.
POWERHOUSE
GENERATING UNIT NO. 3
GENERATING UNIT
OPERATING CHARACTERISTICS
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
47K903
R 0

TVA - River System Operations Douglas Spill Compilation

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	Volumes are average daily in day-second-feet, except as shown. Maximum spill, date of maximum, and number of days of spill in each spill period, in this order. "Total Days" is for calendar year and does not always equal the sum of the days in periods because of extension of periods in to adjacent years. Water may be spilled through spillway and/or sluiceways. All unmarked spill was through the sluiceways. Maximum hourly average discharge to date was 53,847 cfs at 5 p.m. on 5/8/84. *Spillway #Spillway and sluiceways
1943	13905	7/25	12	116	7985---5/13---8; 4180---5/30---6; 2260---6/5&6---4; * 5810---7/18---7; #10280---7/25---5; 4300---7/29---3; *8600---8/31&9/1---19; 120---9/16---3; *2800---10/22---25; #3500---11/3---3; 6800---11/22---15; 3215---12/6---8
1944	25163	4/1	3	20	#11972---3/8---7; #24679---4/2---9; *5249---4/27---4
1945	18108	12/19	2	34	3387---3/7---12; 11489---12/19---29
1946	22257	2/24	4	60	15033---1/24---25; 15669---2/21---18; 6220---3/10&11---4; 3295---3/23&24---6
1947	23500	1/31	2	49	16914---1/30---19; 3885---12/7---17
1948	22900	12/31	7	64	2737---1/3---21; 2247---1/16---2; 5206---1/20---5; 1400---1/27---2; 2591---2/1---5; 12392---2/21---18; 16915---12/31---29
1949	22900	1/1	5	45	11391---1/12---10; 3055---2/12&13---4; 5659---2/22---7; *11105---7/21---6; 8088---12/28---13
1950	22900	2/12	3	25	9968---2/12---20; 3210---12/19---3; 3210---12/27---2
1951	22400	12/24	1	11	11438---12/24---11
1952	17100	2/6	1	10	6360---2/6---10
1953	24400	2/26	1	7	12021---2/26---7
1954	27600	1/26	2	13	4016---1/13---3; 15307---1/26---10
1955	17174	3/25	0	0	
1956	15489	2/20	1	23	8560---1/11---23
1957	33352	2/12	2	30	13960---2/12---21; 8460---12/27---10
1958	17258	5/14	0	1	
1959	16169	10/19	0	0	
1960	14967	2/23	0	0	
1961	34331	12/24	2	16	6502---3/11---4; 19232---12/23---12
1962	30497	3/4	2	16	7516---1/30---7; 13000---3/4---9
1963	32444	3/18	1	10	14061---3/17---10
1964	17344	10/27	1	2	3283---12/31---2

TVA - River System Operations Douglas Spill Compilation

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	Volumes are average daily in day-second-feet, except as shown. Maximum spill, date of maximum, and number of days of spill in each spill period, in this order. "Total Days" is for calendar year and does not always equal the sum of the days in periods because of extension of periods in to adjacent years. Water may be spilled through spillway and/or sluiceways. All unmarked spill was through the sluiceways. Maximum hourly average discharge to date was 53,847 cfs at 5 p.m. on 5/8/84.. *Spillway #Spillway and sluiceways
1965	24516	3/31	1	4	6880---3/31---4
1966	18181	3/7	0	0	
1967	16157	2/28	0	0	
1968	15596	6/12	0	0	
1969	14792	2/4	0	0	
1970	15258	1/3	0	0	
1971	16238	12/12	0	0	
1972	18817	12/27	0	0	
1973	30342	5/30	2	14	5988---3/27---6; 12819---5/30---8
1974	25204	1/13	2	20	6684---1/8---8; 7480---1/17---12
1975	24201	4/2	2	20	9561---3/27---10; 9130---4/2---10
1976	15724	1/5	0	0	
1977	18836	12/8	1	5	4550---4/8-10---5
1978	21644	1/31	1	4	4268---1/31---4
1979	25158	3/7	2	11	3980---3/2---3; 7435---3/8---8
1980	18244	3/26-27	0	0	
1981	11989	8/18	0	0	
1982	18858	2/7	2	11	4370---12/18---7; 4150---12/28---4
1983	17718	5/22	1	7	4660---5/24-26---7
1984	50022	5/9	2	7	#32068---5/9---6; 150---12/16---1
1985	16923	2/15	0	0	
1986	15916	12/20	1	1	66---9/19---1
1987	18348	3/10	0	0	

TVA - River System Operations Douglas Spill Compilation

Volumes are average daily in day-second-feet, except as shown.
Maximum spill, date of maximum, and number of days of spill in each spill period, in this order. "Total Days" is for calendar year and does not always equal the sum of the days in periods because of extension of periods in to adjacent years.
Water may be spilled through spillway and/or sluiceways. All unmarked spill was through the sluiceways.
Maximum hourly average discharge to date was 53,847 cfs at 5 p.m. on 5/8/84.
*Spillway #Spillway and sluiceways

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	
1988	11560	12/12	0	0	
1989	16668	3/9	1	1	173---8/11---1
1990	24429	2/26	2	18	5955---2/24---13; 3250---3/21---5
1991	19320	4/3	1	4	6300---4/2-3---4
1992	22497	12/27	1	6	6060---12/27---10
1993	18290	4/1	1	4	1963---1/1---10
1994	22636	4/1	6	28	4807---2/15---4; 3855---2/26---4; 6523---4/1---7; 5948---4/8---4; 5407---4/14---3; 5689---4/18---6
1995	22987	1/18	1	12	6695---1/18---12
1996	25173	2/1	3	22	5400---1/23---4; 8614---1/30---13; 6101---2/13---5
1997	16083	3/4	0	0	

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE
FROM DATE OF RESERVOIR CLOSURE THROUGH 1997

DOUGLAS

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	1002.45	1984	MAY	9	1	883.70	1956	JAN.	16
2	1001.79	1949	JULY	25	2	891.85 *	1943	FEB.	19
3	1001.44	1973	MAY	30	3	913.83	1954	JAN.	14
4	1001.14	1989	JUNE	24	4	916.17	1955	FEB.	4
5	1000.88	1944	MAY	8	5	920.24	1958	DEC.	22
6	999.67	1958	MAY	10	6	920.34	1966	FEB.	1
7	999.14	1979	JULY	25	7	921.08	1948	JAN.	27
8	999.05	1983	MAY	24	8	921.42	1957	JAN.	22
9	998.93	1959	JUNE	6	9	921.84	1962	DEC.	13
10	998.59	1964	MAY	8	10	924.46	1952	DEC.	29
11	998.56	1968	JUNE	10	11	924.72	1965	DEC.	14
12	998.50	1967	JULY	15	12	924.74	1953	JAN.	1
13	998.35	1943	JULY	16	13	924.96	1960	JAN.	26
14	998.30	1972	MAY	24	14	924.99	1968	DEC.	13
15	998.13	1950	SEP.	14	15	925.01	1961	JAN.	13
16	998.02	1976	JULY	9	16	925.11	1959	JAN.	12
17	996.98	1992	JUNE	13	17	925.25	1969	DEC.	29
18	996.74	1980	JUNE	2	18	925.27	1963	JAN.	12
19	996.59	1974	JUNE	12	19	925.52	1964	JAN.	1
20	996.32	1981	JUNE	15	20	925.99	1967	JAN.	25
21	996.22	1997	JULY	5	21	926.74	1970	DEC.	5
22	996.14	1990	MAY	30	22	926.84	1951	JAN.	12
23	996.08	1991	JUNE	27	23	929.18	1946	DEC.	19
24	995.38	1994	AUG.	21	24	929.76	1947	DEC.	31
25	995.32	1956	MAY	13	25	931.30	1971	JAN.	5
26	994.92	1996	JUNE	1	26	931.72	1950	JAN.	6
27	994.67	1961	JUNE	28	27	934.96	1949	DEC.	31
28	994.59	1995	JUNE	27	28	935.34	1977	FEB.	12
29	994.52	1993	JUNE	2	29	935.67	1945	DEC.	30
30	994.45	1965	JUNE	23	30	936.44	1981	JAN.	21
31	993.60	1946	JUNE	8	31	937.21 %	1994	JAN.	21
32	993.55	1975	JUNE	4	32	940.34 %	1997	FEB.	4

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE
FROM DATE OF RESERVOIR CLOSURE THROUGH 1997

DOUGLAS

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
33	993.34	1987	JUNE	8	33	940.48	1993	DEC.	22
34	993.10	1977	APR.	9	34	940.52	1995	JAN.	6
35	992.29	1962	APR.	17	35	940.60	1980	JAN.	6
36	991.42	1957	JULY	6	36	940.83	1973	JAN.	13
37	990.01	1951	MAY	7	37	941.01	1985	JAN.	22
38	989.92	1978	JUNE	19	38	941.25	1976	DEC.	29
39	989.69	1971	AUG.	9	39	941.36	1986	JAN.	29
40	989.31	1982	JUNE	7	40	941.54	1987	JAN.	9
41	986.40	1945	MAY	23	41	941.56	1972	JAN.	1
42	986.24	1969	JUNE	25	42	941.70	1978	JAN.	6
43	984.41	1954	MAY	24	43	941.95	1975	DEC.	25
44	984.02	1963	AUG.	5	44	941.97	1984	DEC.	28
45	983.38	1960	APR.	11	45	942.05	1979	DEC.	30
46	983.31	1952	JUNE	23	46	942.08	1996	NOV.	17
47	983.16	1955	MAY	2	47	942.47	1988	JAN.	15
48	982.61	1966	MAY	30	48	942.49	1992	JAN.	18
49	982.24	1970	MAY	12	49	942.72	1983	JAN.	22
50	976.85	1948	APR.	21	50	943.12	1982	JAN.	1
51	974.29	1953	MAY	29	51	943.46	1989	DEC.	25
52	973.67	1988	MAY	27	52	944.52	1944	FEB.	8
53	972.62	1947	JAN.	23	53	944.70	1974	DEC.	21
54	972.50	1985	MAY	28	54	945.74	1991	DEC.	28
55	970.43	1986	JUNE	16	55	946.09	1990	DEC.	22

* CLOSURE
% MIDNIGHT ELEVATION
TOP-OF-GATES ELEVATION 1002

MAXIMUM, MINIMIUM, MEDIAN, AND MEAN

Adjusted Flow by Weeks

Douglas
Years=1903-1997

WEEK ENDING	WEEK NO.	AVERAGE WEEKLY CFS MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
JAN 7	1	32,200	1937	1,600	1904	7,240	8,720
JAN 14	2	39,500	1946	1,400	1904	7,000	8,400
JAN 21	3	38,200	1995	2,110	1981	6,860	8,820
JAN 28	4	36,100	1954	2,050	1940	8,460	9,690
FEB 4	5	54,100	1957	1,860	1966	7,960	10,100
FEB 11	6	34,200	1957	2,600	1934	8,110	10,500
FEB 18	7	37,700	1966	2,200	1934	9,610	11,000
FEB 25	8	26,800	1953	2,300	1934	9,550	10,600
MAR 4	9	28,300	1962	2,660	1941	9,100	10,800
MAR 11	10	43,000	1917	4,310	1986	11,000	11,800
MAR 18	11	51,000	1963	4,070	1931	9,830	12,400
MAR 25	12	30,300	1980	3,100	1988	10,100	11,600
APR 1	13	51,700	1994	2,920	1988	10,800	12,700
APR 8	14	45,700	1920	3,100	1910	9,130	11,600
APR 15	15	39,400	1903	3,100	1910	8,820	10,100
APR 22	16	25,100	1956	2,740	1986	8,350	8,950
APR 29	17	18,300	1983	2,730	1986	8,080	8,190
MAY 6	18	21,000	1912	2,280	1986	7,100	8,080
MAY 13	19	49,300	1984	2,020	1986	6,600	8,040
MAY 20	20	15,200	1929	2,590	1941	5,800	6,960
MAY 27	21	18,400	1909	2,070	1941	5,700	6,640
JUN 3	22	25,600	1973	1,770	1988	5,570	6,580
JUN 10	23	23,400	1967	1,660	1988	5,000	6,170
JUN 17	24	16,500	1992	1,480	1988	4,700	5,620
JUN 24	25	17,500	1972	1,460	1988	4,920	5,370
JUL 1	26	18,100	1928	1,140	1988	4,500	4,990
JUL 8	27	15,000	1989	1,170	1988	4,280	4,830
JUL 15	28	22,400	1916	1,490	1970	4,220	5,200
JUL 22	29	42,000	1916	1,400	1986	3,970	5,510
JUL 29	30	17,900	1938	1,450	1925	4,000	4,640
AUG 5	31	13,400	1971	1,020	1986	3,780	4,570
AUG 12	32	11,400	1916	1,130	1925	3,800	4,370
AUG 19	33	32,200	1940	1,040	1925	3,720	5,060
AUG 26	34	12,200	1928	880	1925	3,390	4,300
SEP 2	35	29,500	1940	700	1925	2,960	4,360
SEP 9	36	25,000	1928	640	1925	3,150	4,000
SEP 16	37	10,700	1950	832	1954	2,840	3,330
SEP 23	38	14,700	1906	775	1963	2,710	3,290
SEP 30	39	14,300	1989	880	1954	2,800	3,470
OCT 7	40	27,000	1964	718	1993	2,600	4,130
OCT 14	41	13,300	1976	396	1987	2,570	3,320

MAXIMUM, MINIMIUM, MEDIAN, AND MEAN (CONT.)

Adjusted Flow by Weeks

Douglas
Years=1903-1997

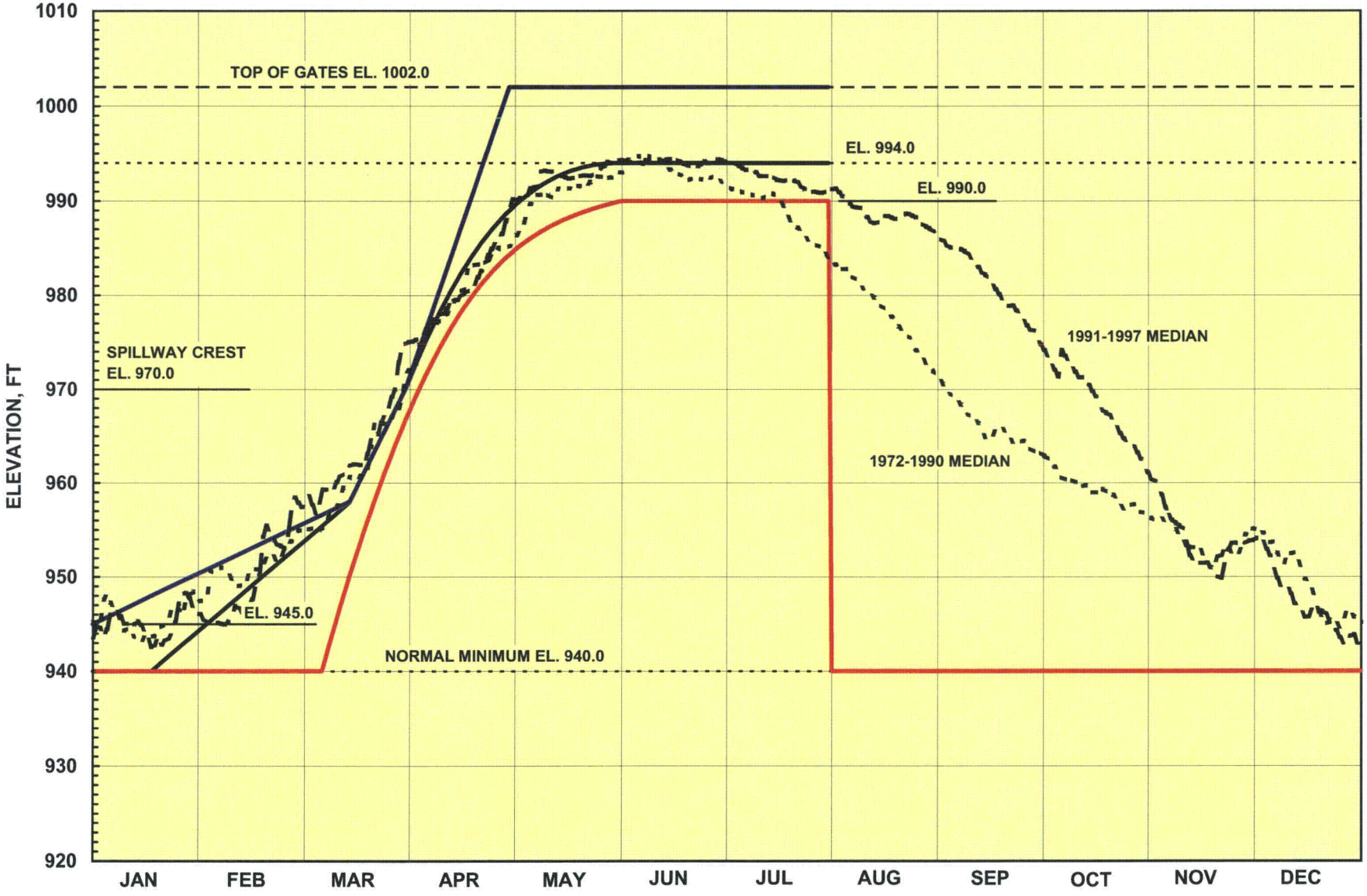
WEEK ENDING	WEEK NO.	AVERAGE WEEKLY CFS MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
OCT 21	42	21,800	1964	964	1963	2,600	3,810
OCT 28	43	15,400	1918	766	1993	2,880	3,790
NOV 4	44	35,300	1918	1,100	1904	2,900	4,150
NOV 11	45	34,600	1977	1,060	1953	2,890	4,000
NOV 18	46	12,100	1979	903	1953	3,200	3,990
NOV 25	47	28,500	1906	1,000	1910	3,890	4,690
DEC 2	48	22,900	1979	1,500	1912	3,990	5,050
DEC 9	49	22,300	1914	1,400	1903	4,410	5,800
DEC 16	50	32,200	1961	1,400	1903	5,430	6,340
DEC 23	51	29,300	1961	1,540	1943	4,790	6,240
DEC 31	52	31,000	1932	2,030	1965	6,420	7,650

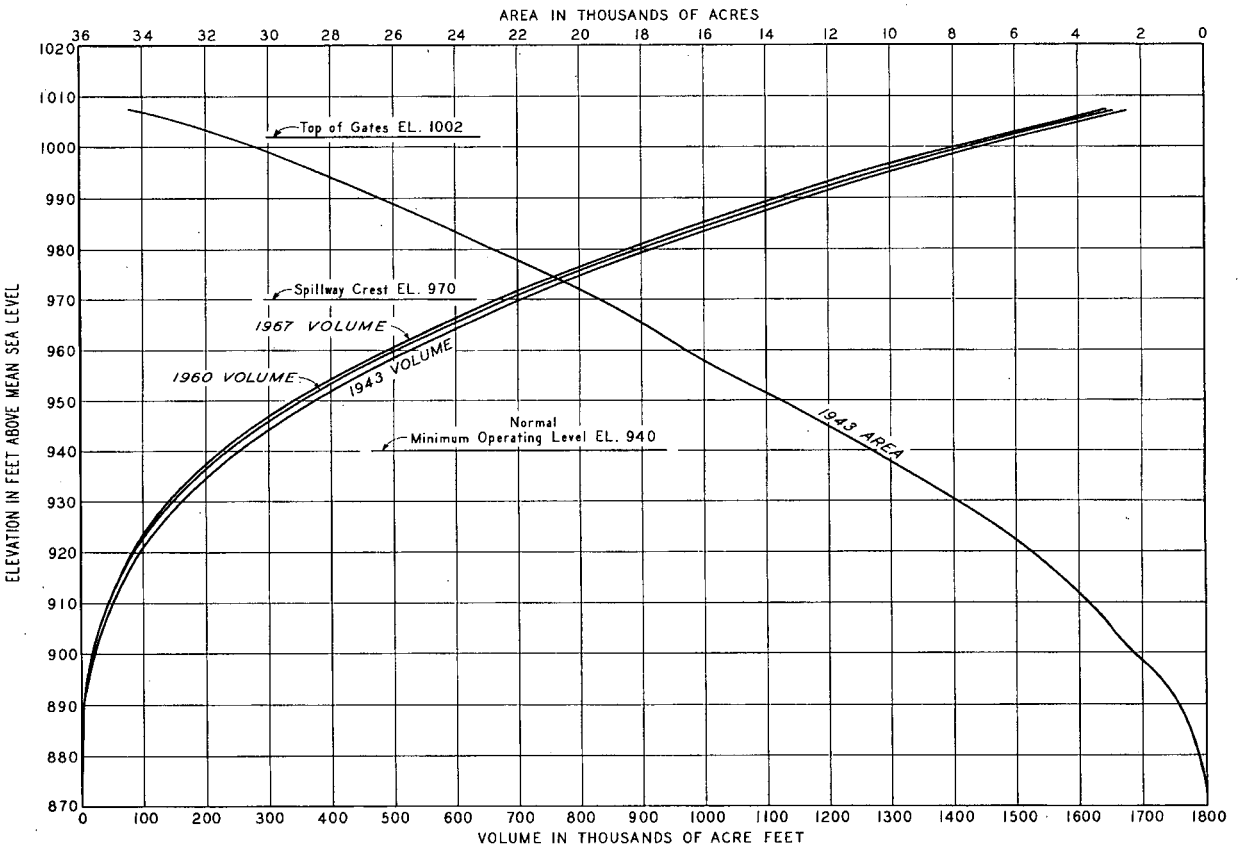
AVERAGE FLOW:1903 - 1997 = 6810 CFS RIVER SYSTEM OPERATIONS

ADJUSTED FLOWS COMPUTED BY:

1/1/03-9/30/18	Flows at Douglas computed from USGS streamflow records at Knoxville and Rogersville by: Douglas = 0.77 (Knoxville-Rogersville).
10/1/18-12/31/38	Natural flows at Douglas site were computed by increasing USGS daily flows at Dandridge in proportion to the drainage area. Drainage area: Dandridge 4446 sq. mi.
1/1/39-3/11/42	Flows were computed from USGS records of the At Dandridge, Tennessee, gage, corrected for storage changes in Walters Reservoir and then increased in proportion to the drainage areas.
3/12/42-12/31/56	Flows were computed from USGS records of the Below Douglas Dam, Tennessee, gage, drainage area 4,543 sq. mi., corrected for storage changes in Walters and Douglas Reservoirs.
1/1/57-current	Flows were computed by adjusting discharges at Douglas Dam, furnished by the TVA Division of Power Production, for storage changes in Walters and Douglas Reservoirs.

ANNUAL OPERATING CYCLE





ELEV FT	1943 AREA AC	VOLUME 1943 AC-FT	1949 AC-FT	1955 AC-FT	1960 AC-FT	1967 AC-FT
1,007	34,000	1,677,000	1,662,000	1,666,000	1,655,000	1,641,000
1,002	31,300	1,512,000	1,497,000	1,501,000	1,490,000	1,475,000
990	26,450	1,164,000	1,148,000	1,153,000	1,142,000	1,127,000
980	22,860	918,000	902,000	906,000	896,000	881,000
970	19,410	706,000	691,000	694,000	683,000	669,000
960	16,650	526,000	512,000	514,000	503,000	489,000
950	13,540	376,000	363,000	363,000	353,000	340,000
940	10,600	255,000	245,000	243,000	235,000	223,000
930	7,890	163,000	156,000	153,000	146,000	138,000
920	5,540	96,300	92,600	89,100	84,500	80,300
910	3,700	50,400	48,500	47,200	43,900	42,500
900	2,320	20,800	19,900	19,500	17,500	16,700
890	860	5,300	4,800	4,600	3,800	3,600
880	220	600	400	400	300	200
873	0	0	0	0	0	0

NOTES:

Reservoir areas were measured on a composite map prepared by the Hydraulic Data Branch with contours drawn at 10' intervals. The map was prepared from TVA land maps with contours at elevations 910, 930, 1002 & 1007. Contours were made to conform to elevations on TVA sediment range cross sections which are located at one to three mile intervals within the reservoir.

Elevations are referred to the 1936 Supplementary Adjustment of the U.S.C. & G.S.

Area of original river within reservoir at elevation 1002 = 3,170 acres.

Drainage area at dam = 4,541 square miles.

The 1949 and subsequent volumes were determined by the constant factor method for computing sediment.

Dam closure February 19, 1943.

REV NO	DATE	MADE	CHKD	SUPV	INSP
2	9-[illegible]	ANL			
CHANGE NOR MIN OPERATING LEVEL					
1	7-[illegible]	WHS		WHS	
ADD 1967 VOLUMES TO TABLE					

DRWN. COMPUTED
TRCD. ENGINEER
CHKD.

THIS DRAWING SUPERSEDES 20-DA-1-321G420R1

FRENCH BROAD RIVER - MILE 32.3

RESERVOIR AREAS AND VOLUMES

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Edwin B. McCain	Paul C. Epperly	Kenneth A. Smith

KNOXVILLE	12-28-62	20	DA	1	321N798RZ

NOTE: See pages 26-28 for latest volume data.

RESERVOIR RELEASE IMPROVEMENTS

These modifications and an operational change have been made to improve the quality of the aquatic environment downstream from the dam: (1) Surface water pumps (2) Oxygen diffuser system (3) Turbine venting (4) Turbine pulsing.

SURFACE WATER PUMPS

The purpose of the surface water pumps is to increase the dissolved oxygen (DO) in the turbine releases. To accomplish this, the pumps are floated on the surface at the upstream face of the dam. The pumps are operated to move large quantities of surface water, relatively high in dissolved oxygen (DO) content, down to the withdrawal zone of the hydroturbine units. This surface water mixed with the low DO subsurface water as it enters the hydroturbine unit, raises the average DO content of the release by approximately 2 mg/L.

There are a total of nine pumps mounted on triangular float assemblies (Figure 11). The assemblies are linked at the corners and attached to the dam via shock absorbing struts. To allow for varying headwater elevations, a trolley on the end of each strut runs on a vertical rail anchored to the face of the dam. Power for the pump motors and the navigation lights is provided via cable reels from the top of the dam. The pump shafts extend approximately 15 ft below the water surface and drive 15 ft diameter impellers. Eight of the nine surface water pumps have stainless steel impellers driven by 40 horsepower electric motors through 90° gear reduction units. Surface water pump number 2 has a composite impeller driven by a 60 horsepower electric motor through a 90° gear reduction unit. At the design point, the impellers rotate at approximately 21 RPM, and move 530 ft^3 of water per second. To provide flexibility in pump operation, the motors are driven by variable frequency drives located in the head gate gallery of the dam. When necessary, for example during periods of lower temperature stratification or lower headwater elevations, the impeller speed can be reduced to prevent bottom sediments from being disturbed.

OXYGEN DIFFUSER SYSTEM

The oxygen diffuser system for Douglas Hydro Plant is designed to provide a large instantaneous oxygen flowrate to help aerate the turbine water flow while the turbines are in operation. It is also designed to provide a smaller continuous flow rate to keep the forebay charged with high DO water which can be withdrawn when turbine operation begins.

RESERVOIR RELEASE IMPROVEMENTS (CONT.)

The oxygen diffuser system consists of sixteen diffuser frames and four line diffusers. The oxygen diffuser frames are located from 600-ft to 1600-ft upstream of the face of the dam. Each diffuser frame is approximately 100 ft by 120 ft and is positioned approximately 20 ft above the bottom of the reservoir. The diffuser frames are constructed from PVC pipe and support 80 porous hoses (garden soaker hoses), each 50 ft in length. Oxygen is supplied to the hoses by a 2 inch diameter header which runs across the middle of the frame. The diffuser hoses have an orifice at their point of connection to the central supply header to equalize flow and to minimize losses in the event of a hose break. The outer end of the hose is capped and connected to the diffuser frame with an elastic cord.

Each diffuser frame has its own supply line. These supply lines are constructed of 2 inch polyethylene to a point about 100 ft from the frame where EPDM hoses are used for the supply line and buoyancy control lines. The supply lines are constructed in a manner similar to the line diffuser design and can be raised individually from the shore to access the diffuser frame buoyancy line connections.

The four line diffusers differ in length, but add up to a total of 16,000 ft. The first line diffuser begins approximately 1700 ft upstream of the dam and extends about 1000 ft upstream. Each of the other three line diffusers begins approximately 2000 ft upstream of the dam and each extends about 5000 ft. All four line diffusers float approximately 3½ ft above the bottom of the reservoir. The line diffusers are constructed of polyethylene pipe that supplies oxygen to porous hoses (garden soaker hoses). In a manner similar to the frames, the diffuser hoses have an orifice at their point of connection to the supply pipe to equalize the flow and to minimize losses in the event of a hose break.

The oxygen diffuser frames and line diffusers are supplied with oxygen from a liquid oxygen storage facility located on the north bank. The storage facility equipment consists of a horizontal 20,000 gallon liquid oxygen storage tank, ten ambient air vaporizers, a solenoid operated emergency shut-off valve, a temperature switch for low temperature shut-off, a pressure gauge and transmitter, four remotely operated control valves, four flowmeters, and 20 pressure regulators. A separate supply line is used to feed each of the diffuser frames and line diffusers. Each supply line is equipped with an isolation valve and pressure regulator for flow control.

RESERVOIR RELEASE IMPROVEMENTS (CONT.)

TURBINE VENTING SYSTEM

The turbine venting system can be used to increase the dissolved oxygen content of the turbine releases up to about 1 mg/L depending upon wicket gate opening and headwater elevation. Because it is relatively inexpensive to operate, this system is the first aeration method to be utilized when the dissolved oxygen in the discharge drops below the target level.

Turbine venting utilizes the vacuum breaker ports on the turbine casing to induce air into the water flowing through the turbine. Baffles over the existing vacuum breaker ports and vacuum breaker system by-pass piping were added to increase air induction.

The by-pass system consists of an 8 in. diameter opening in the head-cover, to which is attached an 8 in. diameter pipe. This pipe is equipped with a check valve to prevent back flow, a butterfly valve for off-on flow control, and a bellmouth intake to reduce flow resistance and provide flow measurement. The by-pass system was installed below the walkway surrounding the turbine guide bearing. Holes were drilled in the deckplates to provide ventilation for the by-pass piping. To further increase suction through this piping, flat plate hub baffles were installed at the vacuum breaker outlets located on the turbine crown.

The combined operation of the surface water pumps, the oxygen diffuser system, and the turbine venting system, provides the target 4 mg/L in the release during periods of maximum dissolved oxygen deficit.

TURBINE PULSING

Turbine pulsing provides minimum downstream water levels with periodic releases through the hydro turbines during scheduled off hours.

RESERVOIR RELEASE IMPROVEMENTS(CONT.)

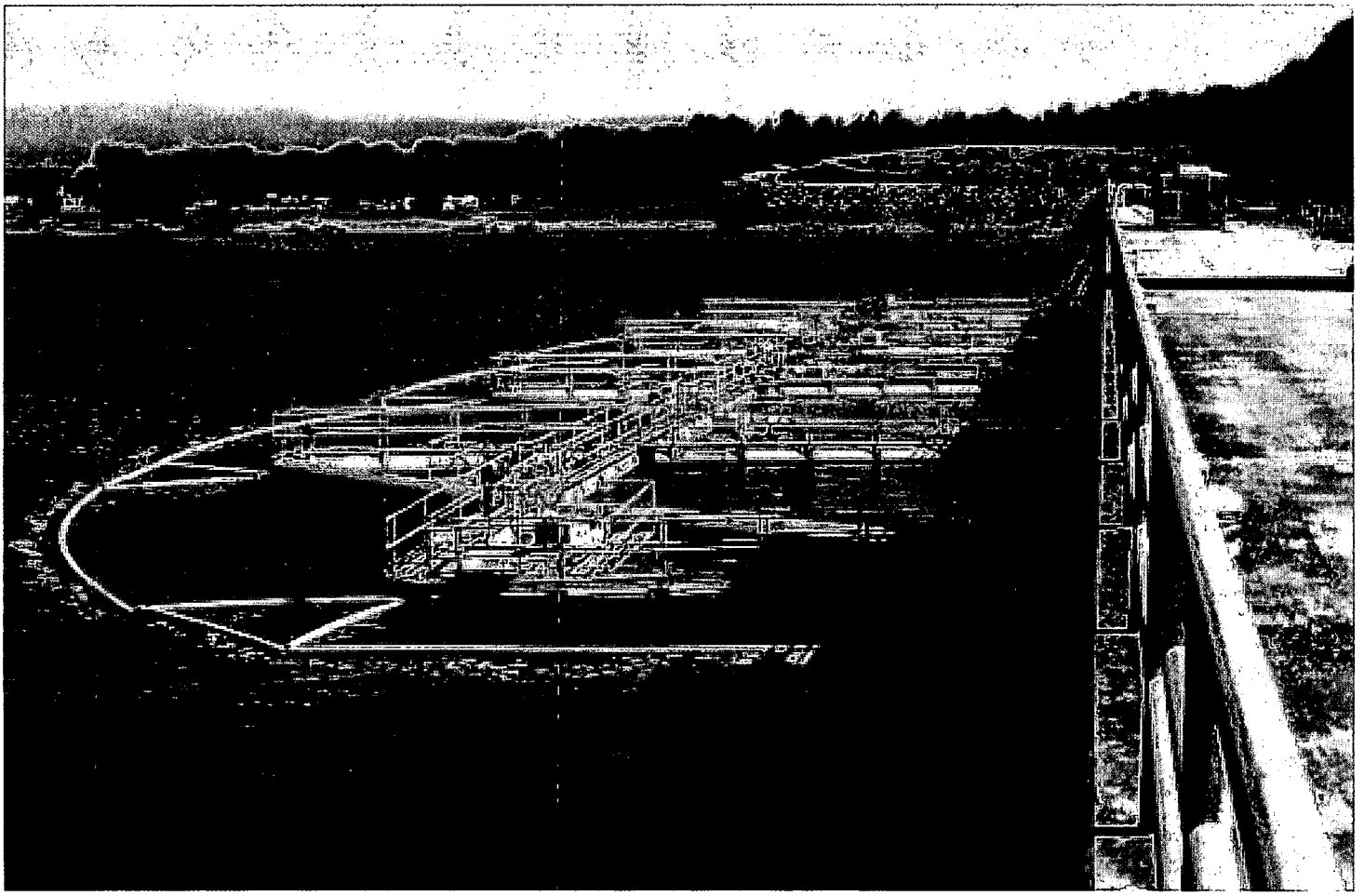


FIGURE 11

Surface Water Pumps, August 1998

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD

Chronology

Safety analysis studies for Douglas Dam for the Probable Maximum Flood were started at the beginning of fiscal year 1985 and were completed with the submittal of *DOUGLAS PROJECT DAM SAFETY ANALYSIS REPORT HEP-C85-1 BY MEMORANDUM FROM R. G. DOMER TO R. W. CANTRELL ON JUNE 17, 1985 (B66 850617 0001)*. Final design started in October 1985. Onsite construction began in March 1986 and was completed in May 1987.

Cost of Modification

Design costs for the capital safety modifications to Douglas Dam were approximately $403,000. This did not include costs for dam safety evaluation studies which resulted in the modifications, construction costs were approximately $1.8 million. The total project cost was approximately $2.5 million.

Controlling Features

Modifications for the PMF consisted of increasing the height of the north and south concrete nonoverflow dams and their earth abutments by 13.5 feet, increasing the height of saddle dam one by 5 feet and the remaining existing seven saddle dams by 6.5 feet, and adding two new saddle dams. These modifications will prevent overtopping and erosion of the embankment and saddle dams but would permit overtopping of the concrete dam spillway area with possible major damage to the powerhouse and switchyard. The elevation of the headwater for a PMF resulting from combined storage and discharge through the spillway and over the top of the concrete structures is 1022.5.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Concrete Dam Modifications

Stability of a typical nonoverflow block was investigated for the increased water loads resulting from a PMF. Stresses resulting from these increased loads were judged to be acceptable for this extreme loading conditions. The original stability analysis for the concrete structure is shown in an Appendix to the report referenced under Chronology.

Nonoverflow blocks 1A through 3 and 28 through 32 were modified by placing concrete on top of the existing structures. This modification was primarily to enable vehicular access from the new top of embankment elevation 1018.5 to the spillway operating equipment at elevation 1009.0. Additionally, a 12-inch-think concrete wall with top elevation at 1022.5 was placed on the downstream side of blocks 1A through 3 and 28 through 32. Due to the increased hydrostatic loads on the additional concrete and wall, blocks 1 through 3 and 28 through 31 had to be strengthened by installing high strength dowels on the upstream side of the blocks. Details of the modification to the top of nonoverflow blocks 1A through 3 and 28 through 32 are shown on drawings 21E 205-1,2, and 3. Existing drain holes, wells, electrical manholes, equipment shaft, ladder, air vent, and access shaft were extended through the new concrete with new embedded frames where required. *FIGURES 12* and *13* at the end of this section are photos which show the key features of this modification.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

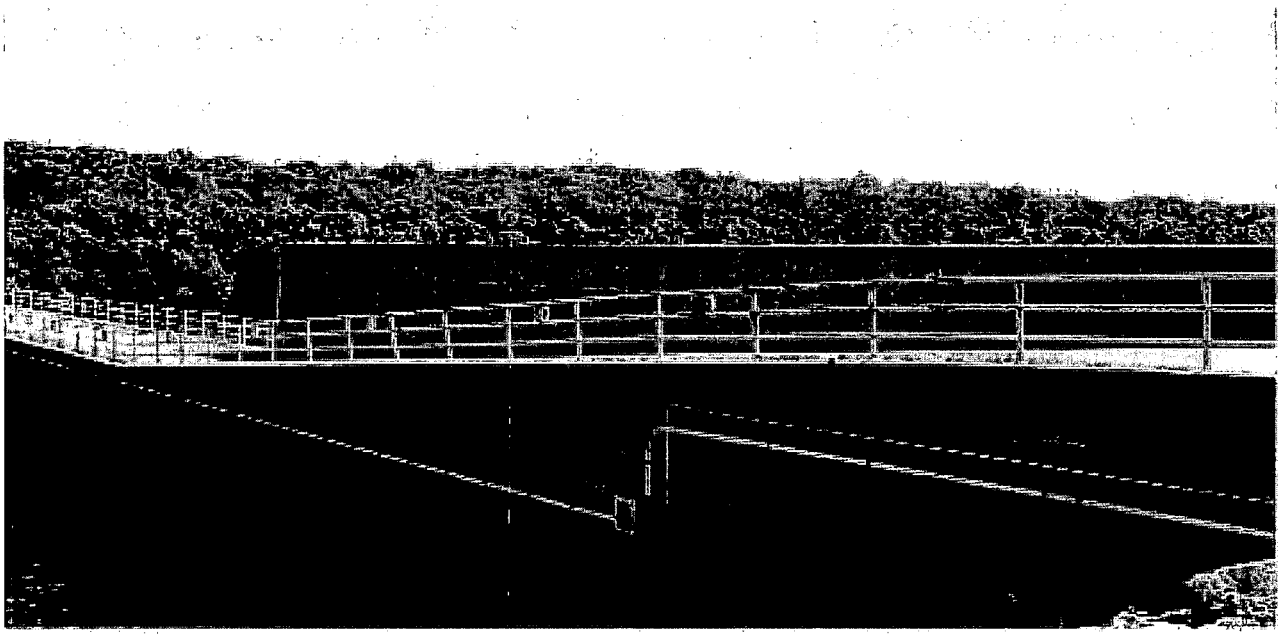


FIGURE 12
Access Ramp and Wall Atop Nonoverflow Blocks 1A through 3, August 1998

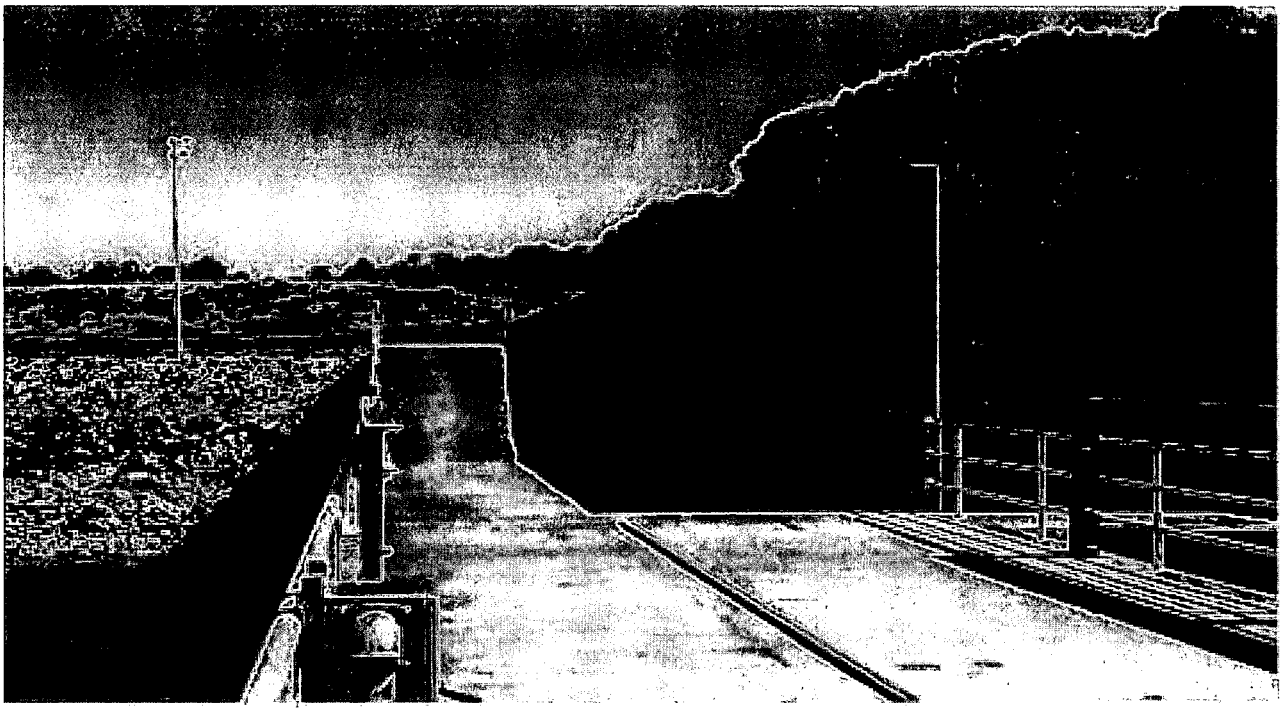


FIGURE 13
Access Ramp and Wall Atop Nonoverflow Blocks 28 through 32
August 1998

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

North and South Earth Abutment Modifications

The north and south earth abutments were stripped of pavement, curbs, and stabilized roadway base, and increased in height to elevation 1018.5 using impervious rolled earthfill, filter blanket, and riprap. A 12-inch-think concrete wall with top elevation at 1022.5 was placed on the north abutment, joined to the wall on the downstream side of nonoverflow block 1A, and extended along the river side of the patrol road to the 1022.5 contour. These walls, along with the walls on nonoverflow blocks 1A through 3 and 28 through 32, are for the purpose of diverting overtopping flow to the spillway and powerhouse portions of the dam. Details of these walls are shown on drawing 23E210-1.

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Saddle Dam 1 Modifications

A 12-inch-thick concrete wall with top elevation 1022.5 was placed 14 feet upstream of the centerline of saddle dam 1 roadway. The wall begins near the intersection of the boat launching road with saddle dam 1 and parallels the saddle dam roadway to the Sevier County campground on the south end of the dam. The wall then turns away from the roadway and is routed upstream of the campgound, approximately parallel to the roadway, until it intersects the 1022.5 contour. *FIGURE 14* at the end of this section is a photo which shows the location and configuration of saddle dam 1. Details of modified features for saddle dam 1 are shown on drawings 23E209-1, 2, and 3.

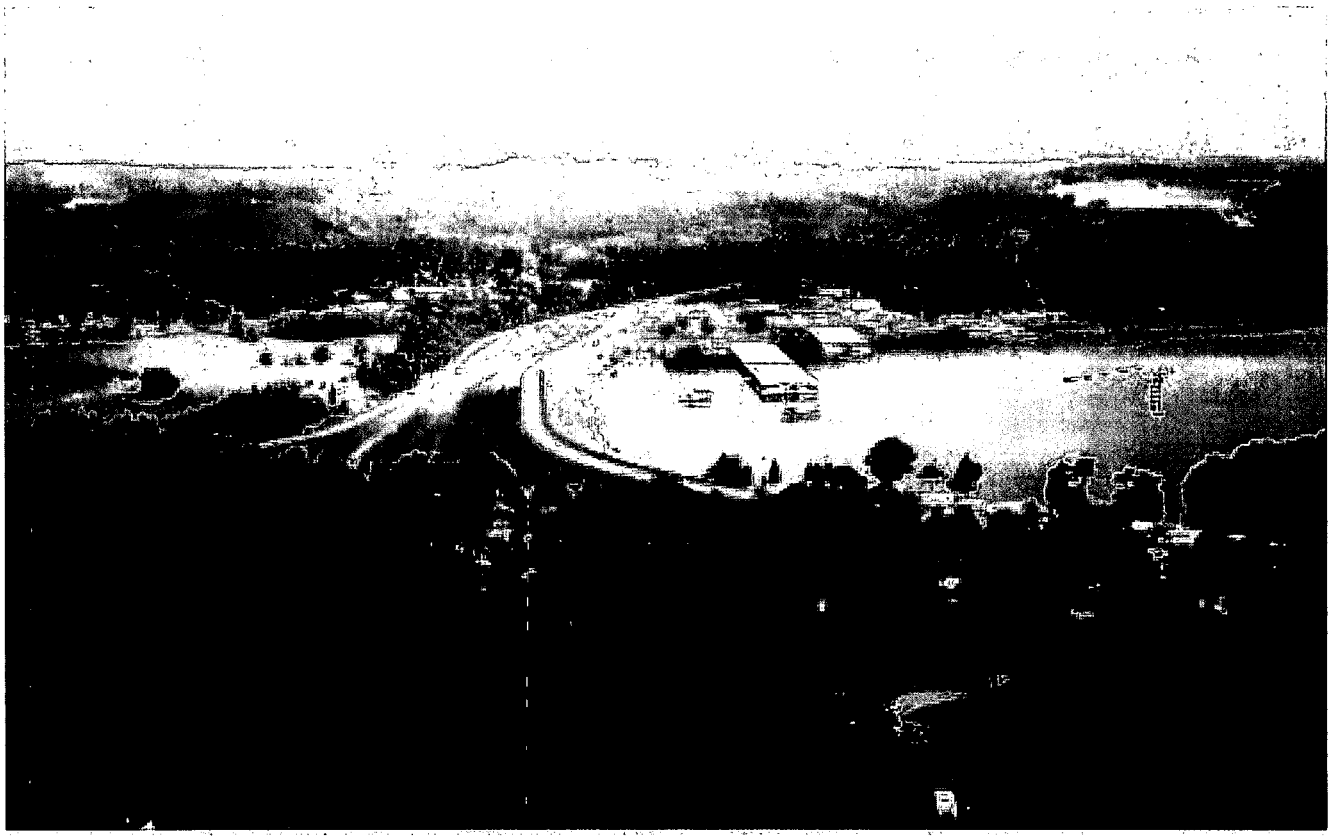


FIGURE 14

Saddle Dam 1, July 1998

SAFETY MODIFICATION FOR PROBABLE MAXIMUM FLOOD (CONT.)

Saddle Dams 3, 4, 5, 6, 8, 9, and 10 Modifications

Saddle dams 3, 4, 5, 6, 8, 9, and 10 were stripped of topsoil on the downstream side, the crushed stone was excavated from the roadway, and the saddle dams were raised 6.5 feet to elevation 1023.5 by placing impervious rolled earthfill, filter blanket, and riprap. A crushed stone roadway was constructed on top of each dam, topsoil was placed on disturbed areas, and the dams were seeded and mulched. Details for raising saddle dams 3, 4, 5, 6, 8, 9, and 10 are shown on drawings 23N203 and 23N204. *FIGURE 4* shows the location of these saddle dams.

Addition of Saddle Dams 2 and 7

In addition to the saddle dams previously described, two new saddle dams, numbers 2 and 7, were required at low areas which would be overtopped by a PMF. Since these areas were small, the saddle dams were constructed by stripping the topsoil, adding impervious rolled earthfill to elevation 1023.5, and seeding and mulching. Riprap was not required. Saddle dam 2 is located near the Sevier County campground just off the roadway between saddle dams 1 and 3. Borrow for saddle dam 2 was obtained from the adjacent borrow area previously described for saddle dam 3. Saddle dam 7 is located approximately halfway between saddle dams 6 and 8 on TVA property. Borrow for saddle dam 7 was obtained adjacent to the saddle dam. Details for saddle dam 2 and 7 are shown on drawings 23N203 and 23N204. *FIGURE 4* shows the location of these saddle dams.

Other Modifications

Other modifications that were made included: reinstalling handrail on the nonoverflow blocks of the dam retaining walls to retain embankment slopes; relocating parking areas and turnarounds, security fencing, and campground area modifications; and resurfacing the saddle dam roadway.

HOUSING FACILITIES

(Original Project)

Permanent houses built ..... None
Tents (40 total capacity) 4
Dormitories built:
- Men (528 total capacity) 6
- Women (26 rooms plus kitchen and dining room) 1

Family housing ..... 92-trailer village
Other camp buildings included a cafeteria 178 seats), community building, and hospital.

ORIGINAL CONSTRUCTION DATA

PERSONNEL

	Initial Project		Additions	
	Dam and Reservoir Construction	Dam Construction Only	3rd Unit (No. 2)	4th Unit (No. 4)
Peak employed	6,220	4,650	100	*110
Total man-hours	17,774,612	12,061,410	156,387	**175,000
Number of injuries	97	157	2	1
Days lost	50,599	34,649	58	16
Fatalities	6	4	0	0
Accident frequency	11.1	13.0	12.8	5.71
Accident severity	2,847	2,873	371	91

**Trades and labor hourly*

***Estimated*

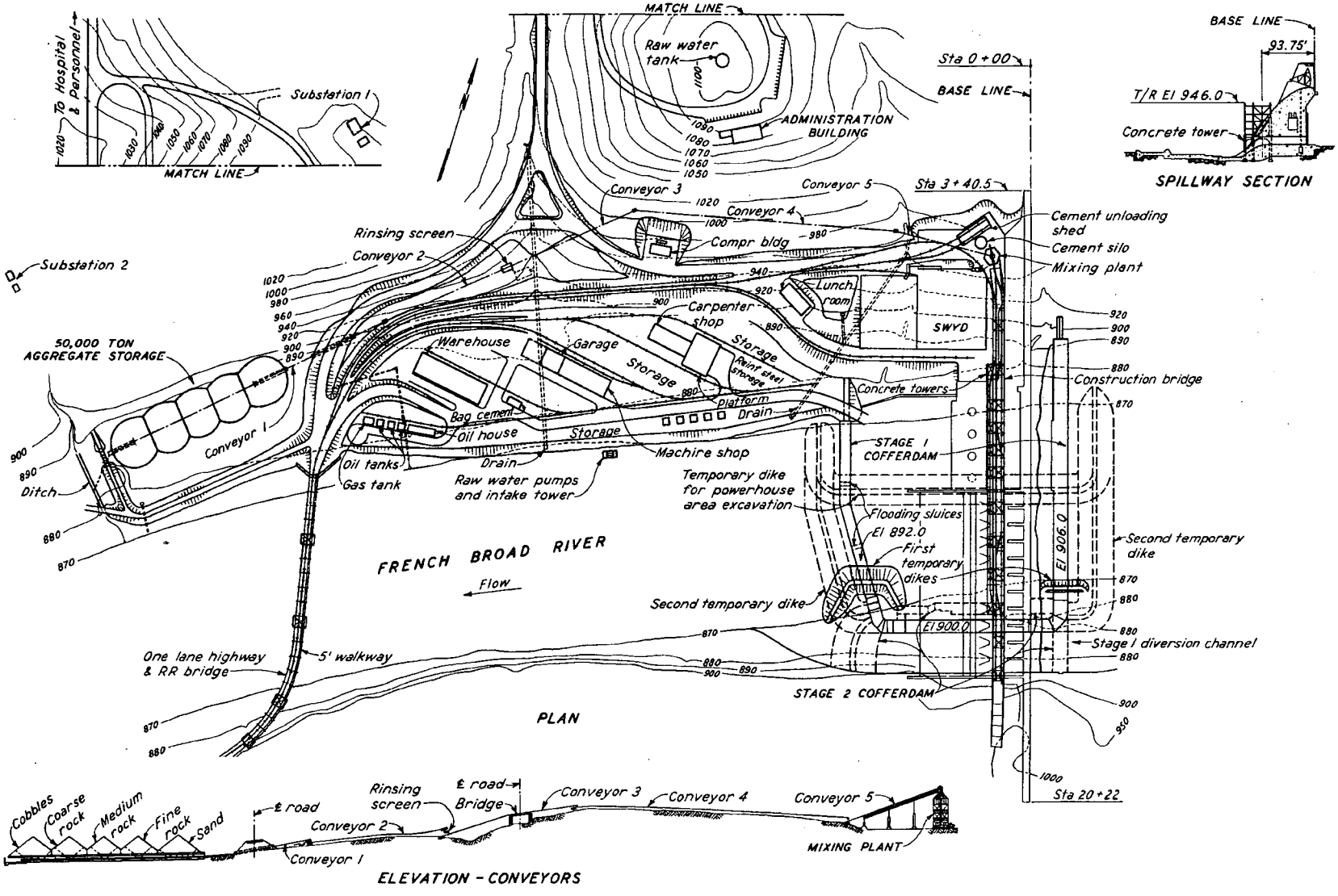
QUANTITIES

	Initial Project		Additions	
	Dam	Saddle Dams and Dike	3rd Unit (No. 2)	4th Unit (No. 4)
Dam and power facilities:				
Earth excavation, cu. yd.	172,300	113,500	-	-
Rock excavation, cu. yd.	332,800	4,100	-	1
Earthfill, cu. yd.	56,300	693,000	-	-
Rockfill, cu. yd.	60,000	15,200	-	-
Reinforcing steel, tons	3,500	-	30	148
Structural steel, tons	2,900	-	11	112
Concrete, cu. yd.	548,200	3,810	2,890	5,250
Formwork, sq. ft.	1,253,000	-	6,100	30,400
Riprap, cu. yd.	11,600	89,000	-	-
Highway and railroad:				
Excavation, cu. yd.	3,425,000	-	-	-

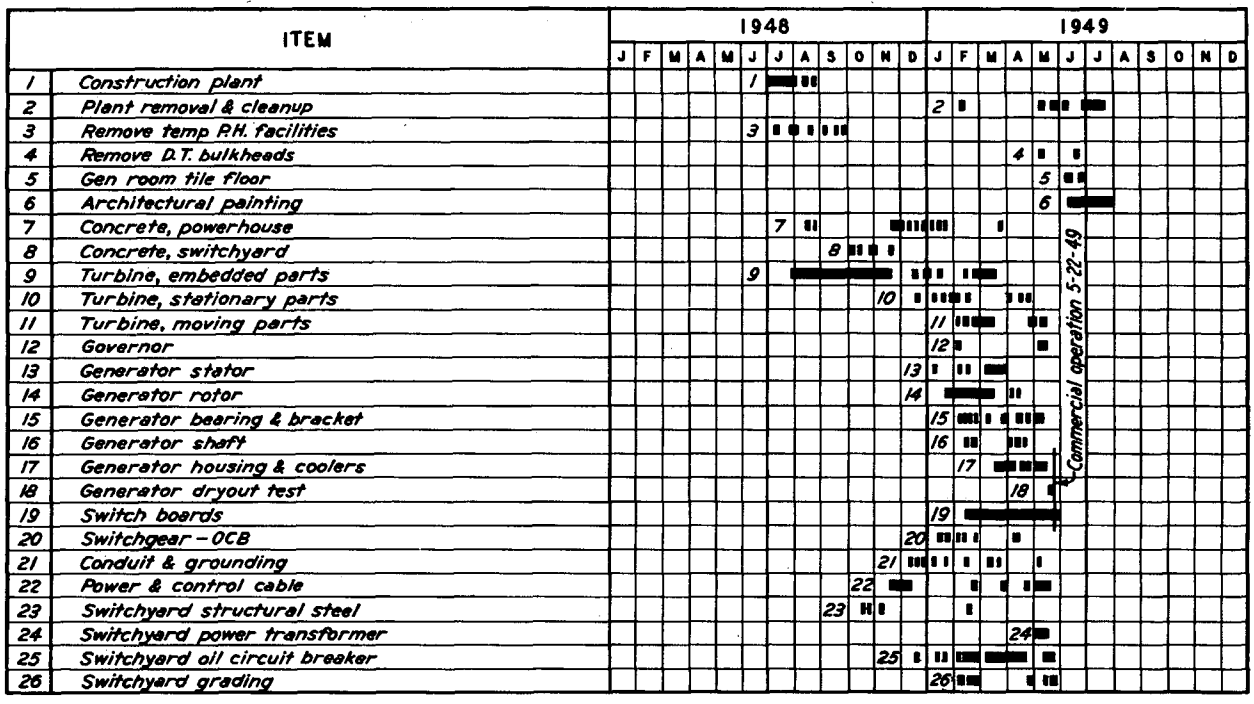
MODIFICATION FOR PROBABLE MAXIMUM FLOOD

QUANTITIES

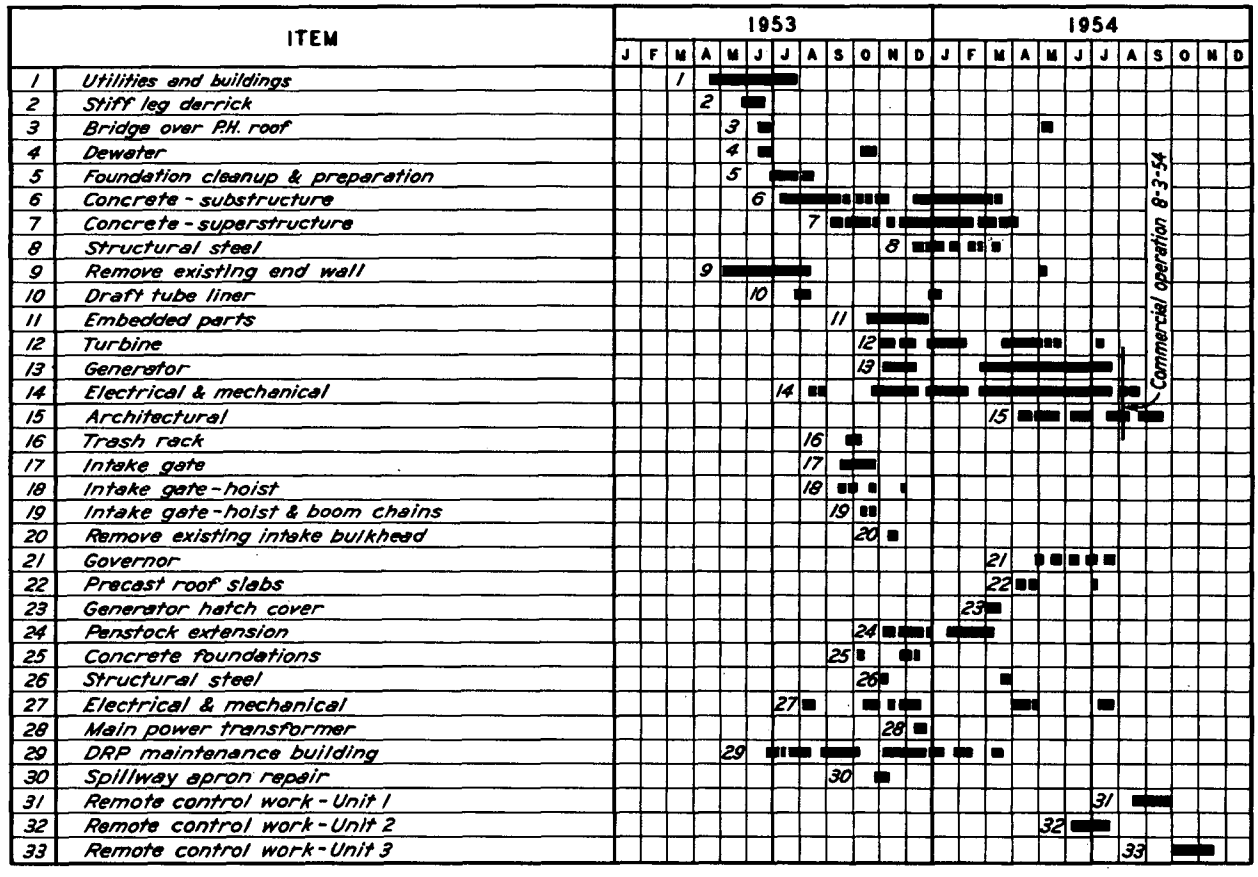
	Dam	Saddle Dams and Dike
Earthfill, cu. yd.	-	17,840
Riprap, cu. yd.	2,022	8,924
Concrete, cu. yd.	1,572	1,285
Reinforcing steel, tons	62	15
Formwork, sq. ft.	-	-



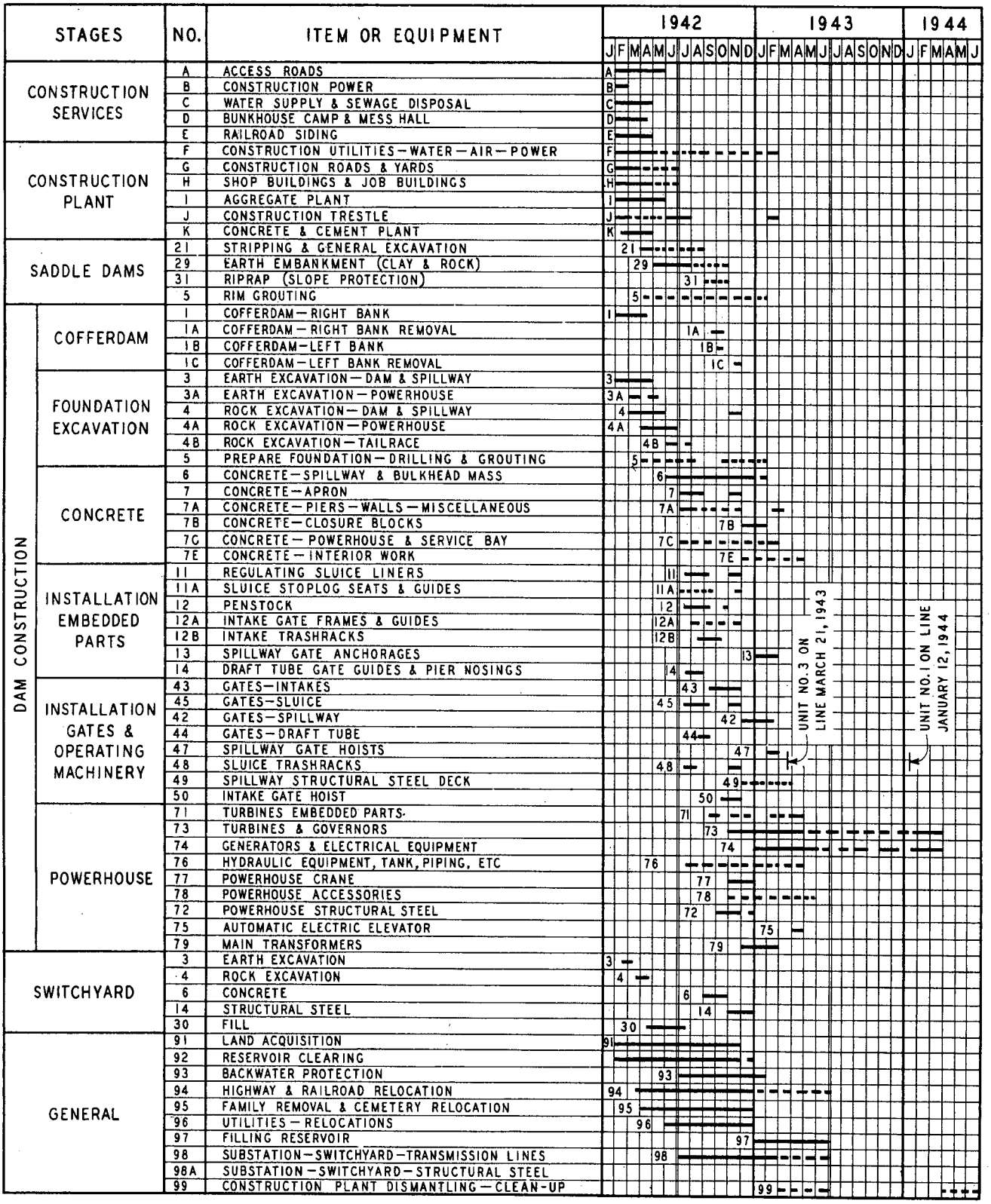
CONSTRUCTION PLANT LAYOUT



CONSTRUCTION SCHEDULE - UNIT 2



CONSTRUCTION SCHEDULE - UNIT 4



CONSTRUCTION SCHEDULE

L58 081211 802

TENNESSEE VALLEY AUTHORITY
RIVER SYSTEM OPERATIONS & ENVIRONMENT
RIVER OPERATIONS

DOUGLAS DAM

SPILLWAY AND SLUICE DISCHARGE TABLES

MARCH 1999

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PART 1

SPILLWAY DISCHARGE TABLES

MARCH 1999

INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables dated August 1973. The tables were revised to account for changes in gate openings produced by reversing the ends of the gate lifting chains and to increase the maximum headwater elevation covered in the tables from 1003 feet to 1007 feet. The computer code SPILLQ generated the tabulated discharges.

Whenever the gate lifting chains are replaced or their ends are reversed, the gate opening indicators must be reset, the opening heights under the spillway gates at every indicator position must be re-measured, and the spillway tables must be re-computed. As described below, the spillway gates at Douglas Dam are set by "dogging" the gate lifting chains at discrete positions marked by indicator pointers. When the chains are replaced, or the ends of the chains are reversed, the opening heights under the gates change for every indicator position and discharges computed assuming the previous opening heights are no longer correct. The gate openings on which these tables are based were measured in 1996.

2. Purpose of Tables

These tables provide a means for setting required spillway discharges and for determining the discharge when a specific arrangement of gates is in use. The tabulated discharges are based on test results from scale models

The specific gate arrangements in the tables were determined by considering erosion data obtained from spillway model studies together with incremental discharge values required for satisfactory spillway operation.

3. Range of Tables

The tables cover a discharge range from 0 to 391,000 cubic feet per second. Headwater elevations range from 970 feet to 1007 feet.

4. Arrangement of Tables

The tables show spillway discharges in cubic feet per second. Headwater elevations for each 0.1 foot of headwater elevation are shown at the top of each column. The headwater range is shown at the bottom of each page.

The discharge is tabulated under the headwater elevations for specific arrangements of gate openings, which are indicated by number in the left and right columns of each page. The numbered arrangements are defined in the table of Spillway Gate Arrangements on page 5. Reference to this table and to the drawing showing the location of the gates on page 4 will determine the gate opening to which each gate is to be set for any particular discharge given in the tables.

5. Discharge Intervals

The tables have been prepared so that the incremental discharge between the tabulated values for consecutive gate arrangements is generally less than 5 percent of the tabulated discharge. The incremental discharge between tabulated values of consecutive headwater elevations is generally less than 1 percent. These increments are exceeded in some cases near the extreme ends of the tables where operation is relatively infrequent. In general it is possible to set any required discharge within 2-1/2 percent and to know the actual discharge for any given set of conditions within 1 percent. These tolerances are considered acceptable and therefore it will not be necessary to interpolate between values given in these tables.

When the exact headwater elevation does not appear in the tables, the discharge for the headwater elevation closest to it should be used. For example, the column headed 991.2 should be used for actual headwater elevations between 991.15 feet and 991.24 feet inclusive. When the actual headwater elevation is exactly halfway between tabular values, the larger value is used.

6. Raising and Lowering Gates

The gates are raised and lowered by traveling hoists that lift the gates by chains attached to each end of the gates. Gate openings are set by dogging each chain by means of a dogging arrangement located just below the deck of the dam. Fastened to the dogging device is a gate opening indicator pointer that revolves as the gate is raised or lowered. This indicator pointer can be observed from either end of the traveling hoist. Gate opening positions have been marked on the gate opening indicator dials and correspond to the openings described in the tables of Spillway Gate Arrangements on page 5. Gate opening indicator readings do not represent gate opening in feet but only provide a gate opening position which will give the desired discharge when used with the table of Spillway Gate Arrangements. Gate opening indicator readings cannot be interchanged between gates since a given indicator reading on one gate will not necessarily give the same discharge as the same indicator reading on another gate.

7. Special Instruction – Preventing Flow Over Top of Spillway Gates When Headwater Elevation is Above 1002 feet

If the headwater elevation exceeds 1002 feet (actually, 1001.8 feet to provide a 0.2-foot margin of safety) the spillway gates must be set to one of the gate arrangements listed in the tables to prevent flow over the tops of the gates. The minimum gate openings are those corresponding to the lowest numbered gate arrangement for which a discharge value is provided in the tables.

8. Use of Tables

The tables can be used in two ways: (1) to determine the arrangement of gates needed to pass a required discharge at a given headwater elevation, and (2) to determine the discharge for a given arrangement of gates and headwater elevation.

Example 1 -- What gate arrangement is necessary to pass a discharge of 46,000 cubic feet per second with the headwater at elevation 980.82 feet?

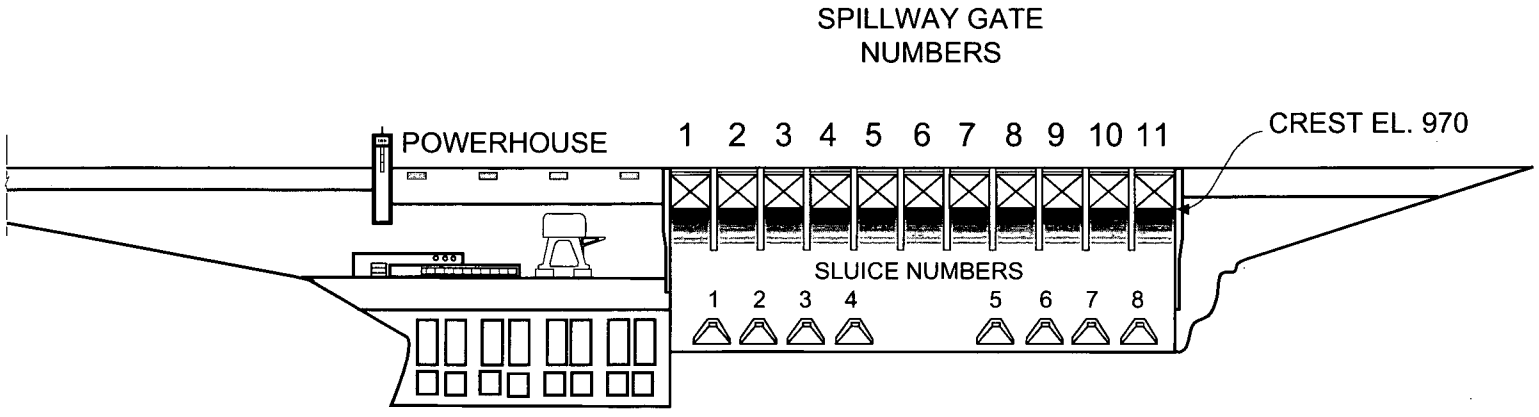
The first step is to find the table in which the headwater elevation appears. Referring to the contents page, we find that headwater elevations between 980 feet and 982 feet are found on page 12 (and continued on page 13). The headwater elevation closest to 980.82 feet is 980.8 feet. In the column headed 980.8 the discharge nearest to the required 46,000 cubic feet per second is 45,790 cubic feet per second located near the bottom of the page. By tracing the horizontal line in which 45,790 cubic feet per second appears, to either side of the page, we find that gate arrangement 49 is the one for producing the discharge closest to 46,000 cubic feet per second at headwater elevation 980.82 feet. Referring to page 5 it is found that the gates should be set with the gate opening indicators reading as follows: gates 1, 2, 4, 6, 8, and 10 at indicator reading 10; gates 3, 5, 7, 9, and 11 at indicator reading 14.

After all the gates are set, changes in the headwater elevation may require changes in the gate arrangement to maintain the desired discharge. For example, if the headwater should fall to 980.63 feet, the discharge will be found in the column headed 980.6. In this column the discharge closest to 46,000 cubic feet per second is 46,190 cubic feet per second for gate arrangement 50. To change to gate arrangement 50 from gate arrangement 49, gate 1 would be opened to an indicator reading of 14.

Example 2 -- Suppose the operating records show that the headwater is at elevation 982.95 feet, and gate arrangement 46 is in use. The headwater is found on page 14, which is marked "Headwater 982 to 984." The elevation given is exactly halfway between elevation 982.9 feet and 983.0 feet. The larger value, 983.0 feet, is used. In the column headed 983.0 opposite gate arrangement 46, the discharge is found to be 46,790 cubic feet per second.

DOUGLAS DAM

LOCATION OF SPILLWAY AND SLUICE GATES



DOWNSTREAM ELEVATION

DOUGLAS DAM

SPILLWAY GATE ARRANGEMENTS

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0	0	0	0	0	2	0	0
2	0	0	2	0	0	0	0	0	2	0	0
3	0	0	2	0	2	0	0	0	2	0	0
4	0	0	2	0	2	0	2	0	2	0	0
5	0	0	2	0	2	0	2	0	2	0	2
6	2	0	2	0	2	0	2	0	2	0	2
7	2	0	2	0	2	0	2	0	2	2	2
8	2	2	2	0	2	0	2	0	2	2	2
9	2	2	2	0	2	0	2	2	2	2	2
10	2	2	2	2	2	0	2	2	2	2	2
11	2	2	2	2	2	2	2	2	2	2	2
12	2	2	2	2	2	2	2	2	4	2	2
13	2	2	4	2	2	2	2	2	4	2	2
14	2	2	4	2	4	2	2	2	4	2	2
15	2	2	4	2	4	2	4	2	4	2	2
16	2	2	4	2	4	2	4	2	4	2	4
17	4	2	4	2	4	2	4	2	4	2	4
18	4	2	4	2	4	2	4	2	4	4	4
19	4	4	4	2	4	2	4	2	4	4	4
20	4	4	4	2	4	2	4	4	4	4	4
21	4	4	4	4	4	2	4	4	4	4	4
22	4	4	4	4	4	4	4	4	4	4	4
23	4	4	4	4	4	4	4	4	6	4	4
24	4	4	6	4	4	4	4	4	6	4	4
25	4	4	6	4	6	4	4	4	6	4	4
26	4	4	6	4	6	4	6	4	6	4	4
27	4	4	6	4	6	4	6	4	6	4	6
28	6	4	6	4	6	4	6	4	6	4	6
29	6	4	6	4	6	4	6	4	6	6	6
30	6	6	6	4	6	4	6	4	6	6	6
31	6	6	6	4	6	4	6	6	6	6	6
32	6	6	6	6	6	4	6	6	6	6	6
33	6	6	6	6	6	6	6	6	6	6	6
34	6	6	6	6	6	6	6	6	10	6	6
35	6	6	10	6	6	6	6	6	10	6	6
36	6	6	10	6	10	6	6	6	10	6	6
37	6	6	10	6	10	6	10	6	10	6	6
38	6	6	10	6	10	6	10	6	10	6	10
39	10	6	10	6	10	6	10	6	10	6	10
40	10	6	10	6	10	6	10	6	10	10	10

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
41	10	10	10	6	10	6	10	6	10	10	10
42	10	10	10	6	10	6	10	10	10	10	10
43	10	10	10	10	10	6	10	10	10	10	10
44	10	10	10	10	10	10	10	10	10	10	10
45	10	10	10	10	10	10	10	10	14	10	10
46	10	10	14	10	10	10	10	10	14	10	10
47	10	10	14	10	14	10	10	10	14	10	10
48	10	10	14	10	14	10	14	10	14	10	10
49	10	10	14	10	14	10	14	10	14	10	14
50	14	10	14	10	14	10	14	10	14	10	14
51	14	10	14	10	14	10	14	10	14	14	14
52	14	14	14	10	14	10	14	10	14	14	14
53	14	14	14	10	14	10	14	14	14	14	14
54	14	14	14	14	14	10	14	14	14	14	14
55	14	14	14	14	14	14	14	14	14	14	14
56	14	14	14	14	14	14	14	14	18	14	14
57	14	14	18	14	14	14	14	14	18	14	14
58	14	14	18	14	18	14	14	14	18	14	14
59	14	14	18	14	18	14	18	14	18	14	14
60	14	14	18	14	18	14	18	14	18	14	18
61	18	14	18	14	18	14	18	14	18	14	18
62	18	14	18	14	18	14	18	14	18	18	18
63	18	18	18	14	18	14	18	14	18	18	18
64	18	18	18	14	18	14	18	18	18	18	18
65	18	18	18	18	18	14	18	18	18	18	18
66	18	18	18	18	18	18	18	18	18	18	18
67	18	18	18	18	18	18	18	18	22	18	18
68	18	18	22	18	18	18	18	18	22	18	18
69	18	18	22	18	22	18	18	18	22	18	18
70	18	18	22	18	22	18	22	18	22	18	18
71	18	18	22	18	22	18	22	18	22	18	22
72	22	18	22	18	22	18	22	18	22	18	22
73	22	18	22	18	22	18	22	18	22	22	22
74	22	22	22	18	22	18	22	18	22	22	22
75	22	22	22	18	22	18	22	22	22	22	22
76	22	22	22	22	22	18	22	22	22	22	22
77	22	22	22	22	22	22	22	22	22	22	22
78	22	22	22	22	22	22	22	22	26	22	22
79	22	22	26	22	22	22	22	22	26	22	22
80	22	22	26	22	26	22	22	22	26	22	22

Arrangement Number	Gate Number										
	1	2	3	4	5	6	7	8	9	10	11
81	22	22	26	22	26	22	26	22	26	22	22
82	22	22	26	22	26	22	26	22	26	22	26
83	26	22	26	22	26	22	26	22	26	22	26
84	26	22	26	22	26	22	26	22	26	26	26
85	26	26	26	22	26	22	26	22	26	26	26
86	26	26	26	22	26	22	26	26	26	26	26
87	26	26	26	26	26	22	26	26	26	26	26
88	26	26	26	26	26	26	26	26	26	26	26
89	26	26	26	26	26	26	26	26	UP	26	26
90	26	26	UP	26	26	26	26	26	UP	26	26
91	26	26	UP	26	UP	26	26	26	UP	26	26
92	26	26	UP	26	UP	26	UP	26	UP	26	26
93	26	26	UP	26	UP	26	UP	26	UP	26	UP
94	UP	26	UP	26	UP	26	UP	26	UP	26	UP
95	UP	26	UP	26	UP	26	UP	26	UP	UP	UP
96	UP	UP	UP	26	UP	26	UP	26	UP	UP	UP
97	UP	UP	UP	26	UP	26	UP	UP	UP	UP	UP
98	UP	UP	UP	UP	UP	26	UP	UP	UP	UP	UP
99	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
100	UP	UP	UP	UP	UP	UP	UP	UP	X	UP	UP
101	UP	UP	X	UP	UP	UP	UP	UP	X	UP	UP
102	UP	UP	X	UP	X	UP	UP	UP	X	UP	UP
103	UP	UP	X	UP	X	UP	X	UP	X	UP	UP
104	UP	UP	X	UP	X	UP	X	UP	X	UP	X
105	X	UP	X	UP	X	UP	X	UP	X	UP	X
106	X	UP	X	UP	X	UP	X	UP	X	X	X
107	X	X	X	UP	X	UP	X	UP	X	X	X
108	X	X	X	UP	X	UP	X	X	X	X	X
109	X	X	X	X	X	UP	X	X	X	X	X
110	X	X	X	X	X	X	X	X	X	X	X

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator readings.

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	970.0	970.1	970.2	970.3	970.4	970.5	970.6	970.7	970.8	970.9	971.0	971.1	971.2	971.3	971.4	971.5	971.6	971.7	971.8	971.9	972.0	
1	0	5	10	20	30	45	60	75	90	110	130	140	170	190	210	230	260	280	310	330	360	1
2	0	10	20	40	65	90	120	150	180	210	250	290	330	370	420	460	510	560	610	660	720	2
3	0	10	35	60	95	130	170	220	270	320	380	430	500	560	630	700	770	840	920	1,000	1,080	3
4	0	15	45	80	130	180	230	290	360	430	500	580	660	750	840	930	1,020	1,120	1,220	1,330	1,440	4
5	0	20	55	100	160	220	290	370	450	530	630	720	830	930	1,040	1,160	1,280	1,400	1,530	1,660	1,800	5
6	0	25	65	120	190	260	350	440	540	640	750	870	990	1,120	1,250	1,390	1,530	1,680	1,840	1,990	2,160	6
7	0	25	80	140	220	310	410	510	630	750	880	1,010	1,160	1,310	1,460	1,620	1,790	1,970	2,140	2,330	2,520	7
8	0	30	90	160	250	350	460	590	720	860	1,000	1,160	1,320	1,500	1,670	1,860	2,050	2,250	2,450	2,660	2,880	8
9	0	35	100	180	280	400	520	660	810	960	1,130	1,310	1,490	1,680	1,880	2,090	2,310	2,530	2,760	3,000	3,240	9
10	0	40	110	200	310	440	580	730	900	1,070	1,260	1,450	1,660	1,870	2,090	2,330	2,570	2,810	3,070	3,330	3,610	10
11	0	45	120	220	350	480	640	810	990	1,180	1,380	1,600	1,820	2,060	2,300	2,560	2,820	3,100	3,380	3,670	3,970	11
12	0	45	120	220	350	480	640	810	990	1,180	1,380	1,600	1,820	2,060	2,300	2,560	2,820	3,100	3,380	3,670	3,970	12
13	0	45	120	220	350	480	640	810	990	1,180	1,380	1,600	1,820	2,060	2,300	2,560	2,820	3,100	3,380	3,670	3,970	13
14	0	45	120	220	350	480	640	810	990	1,180	1,380	1,600	1,820	2,060	2,300	2,560	2,820	3,100	3,380	3,670	3,970	14
15	0	45	120	220	350	480	640	810	990	1,180	1,380	1,600	1,820	2,060	2,300	2,560	2,820	3,100	3,380	3,670	3,970	15

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																				GATE ARRANGEMENT
	972.0	972.1	972.2	972.3	972.4	972.5	972.6	972.7	972.8	972.9	973.0	973.1	973.2	973.3	973.4	973.5	973.6	973.7	973.8	973.9	974.0	
1	360	390	420	440	470	470	460	460	450	440	450	450	460	470	470	480	490	500	500	510	520	1
2	720	770	830	890	940	930	910	900	880	870	890	900	910	930	940	950	970	980	1,000	1,010	1,030	2
3	1,080	1,160	1,250	1,320	1,370	1,350	1,330	1,310	1,290	1,290	1,310	1,330	1,350	1,370	1,390	1,410	1,430	1,450	1,470	1,490	1,520	3
4	1,440	1,550	1,660	1,770	1,830	1,810	1,780	1,750	1,730	1,720	1,750	1,770	1,800	1,820	1,850	1,880	1,910	1,940	1,970	2,000	2,020	4
5	1,800	1,930	2,080	2,210	2,300	2,290	2,260	2,230	2,190	2,180	2,200	2,240	2,270	2,300	2,340	2,370	2,410	2,450	2,480	2,520	2,550	5
6	2,160	2,320	2,490	2,640	2,720	2,710	2,670	2,630	2,590	2,590	2,620	2,660	2,700	2,740	2,780	2,820	2,860	2,910	2,950	2,990	3,030	6
7	2,520	2,710	2,910	3,060	3,140	3,120	3,080	3,030	3,000	2,990	3,030	3,080	3,120	3,170	3,220	3,270	3,320	3,370	3,420	3,470	3,520	7
8	2,880	3,100	3,330	3,490	3,560	3,540	3,490	3,430	3,400	3,410	3,450	3,500	3,550	3,610	3,660	3,720	3,780	3,840	3,890	3,950	4,000	8
9	3,240	3,490	3,750	3,940	4,040	4,010	3,950	3,890	3,850	3,850	3,900	3,960	4,020	4,080	4,140	4,200	4,270	4,330	4,400	4,460	4,520	9
10	3,610	3,880	4,170	4,390	4,510	4,480	4,420	4,340	4,300	4,290	4,350	4,420	4,480	4,550	4,610	4,690	4,760	4,830	4,900	4,970	5,040	10
11	3,970	4,280	4,590	4,840	4,990	4,950	4,880	4,810	4,750	4,730	4,800	4,870	4,950	5,020	5,090	5,170	5,250	5,330	5,410	5,490	5,570	11
12	3,970	4,280	4,590	4,840	4,990	4,990	4,960	4,920	4,900	4,930	5,020	5,120	5,220	5,330	5,430	5,540	5,650	5,760	5,870	5,980	6,090	12
13	3,970	4,280	4,590	4,840	5,000	5,040	5,040	5,040	5,070	5,130	5,250	5,380	5,510	5,640	5,780	5,920	6,060	6,200	6,350	6,490	6,630	13
14	3,970	4,280	4,590	4,850	5,050	5,120	5,160	5,200	5,270	5,350	5,500	5,660	5,820	5,980	6,140	6,320	6,490	6,660	6,840	7,010	7,190	14
15	3,970	4,280	4,590	4,850	5,060	5,170	5,250	5,330	5,440	5,560	5,730	5,920	6,110	6,300	6,490	6,690	6,900	7,100	7,310	7,510	7,720	15
16	3,970	4,280	4,590	4,850	5,060	5,190	5,300	5,420	5,570	5,730	5,950	6,160	6,370	6,590	6,820	7,050	7,280	7,520	7,750	7,990	8,240	16
17	3,970	4,280	4,590	4,870	5,120	5,280	5,430	5,590	5,770	5,960	6,200	6,440	6,690	6,940	7,190	7,450	7,710	7,980	8,250	8,520	8,800	17
18	3,970	4,280	4,590	4,890	5,180	5,380	5,570	5,770	5,970	6,190	6,460	6,730	7,000	7,280	7,570	7,860	8,150	8,450	8,750	9,060	9,370	18
19	3,970	4,280	4,590	4,910	5,240	5,470	5,700	5,940	6,180	6,420	6,720	7,020	7,320	7,630	7,940	8,260	8,580	8,910	9,250	9,590	9,930	19
20	3,970	4,280	4,590	4,910	5,240	5,510	5,780	6,060	6,340	6,620	6,940	7,270	7,600	7,940	8,280	8,630	8,990	9,350	9,710	10,090	10,460	20
21	3,970	4,280	4,590	4,910	5,250	5,550	5,860	6,170	6,490	6,820	7,170	7,520	7,880	8,250	8,620	9,000	9,390	9,780	10,180	10,580	10,990	21
22	3,970	4,280	4,590	4,910	5,250	5,580	5,930	6,280	6,650	7,010	7,390	7,770	8,160	8,560	8,960	9,370	9,790	10,210	10,640	11,080	11,520	22
23	3,970	4,280	4,590	4,910	5,250	5,580	5,930	6,280	6,650	7,010	7,390	7,770	8,160	8,560	8,960	9,370	9,790	10,210	10,640	11,080	11,520	23
24	3,970	4,280	4,590	4,910	5,250	5,580	5,930	6,280	6,650	7,010	7,390	7,770	8,160	8,560	8,960	9,370	9,790	10,210	10,640	11,080	11,520	24
25	3,970	4,280	4,590	4,910	5,250	5,580	5,930	6,280	6,650	7,010	7,390	7,770	8,160	8,560	8,960	9,370	9,790	10,210	10,640	11,080	11,520	25

MARCH 1999

HEADWATER 972 to 974

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	974.0	974.1	974.2	974.3	974.4	974.5	974.6	974.7	974.8	974.9	975.0	975.1	975.2	975.3	975.4	975.5	975.6	975.7	975.8	975.9	976.0	
1	520	530	530	540	550	550	560	570	570	580	580	590	600	600	610	620	620	630	630	640	640	1
2	1,030	1,040	1,050	1,070	1,080	1,090	1,110	1,120	1,130	1,150	1,160	1,170	1,180	1,200	1,210	1,220	1,230	1,240	1,250	1,270	1,280	2
3	1,520	1,540	1,560	1,580	1,600	1,620	1,630	1,650	1,670	1,690	1,710	1,730	1,750	1,760	1,780	1,800	1,820	1,830	1,850	1,870	1,890	3
4	2,020	2,050	2,080	2,100	2,130	2,160	2,180	2,210	2,230	2,260	2,280	2,310	2,330	2,360	2,380	2,400	2,430	2,450	2,470	2,490	2,520	4
5	2,550	2,590	2,620	2,650	2,690	2,720	2,750	2,790	2,820	2,850	2,880	2,910	2,940	2,970	3,000	3,030	3,060	3,090	3,120	3,150	3,180	5
6	3,030	3,080	3,120	3,160	3,190	3,230	3,270	3,310	3,350	3,390	3,420	3,460	3,500	3,530	3,570	3,600	3,640	3,670	3,710	3,740	3,770	6
7	3,520	3,560	3,610	3,660	3,700	3,750	3,790	3,840	3,880	3,920	3,970	4,010	4,050	4,090	4,130	4,170	4,210	4,250	4,290	4,330	4,370	7
8	4,000	4,060	4,110	4,160	4,210	4,270	4,320	4,370	4,420	4,470	4,510	4,560	4,610	4,660	4,700	4,750	4,800	4,840	4,890	4,930	4,980	8
9	4,520	4,580	4,640	4,700	4,760	4,820	4,880	4,930	4,990	5,050	5,100	5,160	5,210	5,260	5,320	5,370	5,420	5,470	5,520	5,570	5,620	9
10	5,040	5,110	5,180	5,240	5,310	5,370	5,440	5,500	5,570	5,630	5,690	5,750	5,810	5,870	5,930	5,990	6,040	6,100	6,160	6,210	6,270	10
11	5,570	5,640	5,710	5,790	5,860	5,930	6,000	6,070	6,140	6,210	6,280	6,350	6,410	6,480	6,540	6,610	6,670	6,740	6,800	6,860	6,920	11
12	6,090	6,200	6,310	6,420	6,510	6,570	6,630	6,690	6,750	6,810	6,880	6,940	7,010	7,070	7,140	7,210	7,280	7,350	7,420	7,490	7,560	12
13	6,630	6,770	6,920	7,060	7,150	7,200	7,250	7,290	7,340	7,400	7,470	7,530	7,600	7,660	7,730	7,810	7,890	7,970	8,050	8,120	8,200	13
14	7,190	7,360	7,540	7,700	7,780	7,820	7,860	7,890	7,930	7,990	8,060	8,120	8,190	8,250	8,330	8,420	8,500	8,590	8,670	8,750	8,840	14
15	7,720	7,930	8,150	8,350	8,420	8,450	8,470	8,500	8,520	8,580	8,650	8,710	8,770	8,840	8,930	9,020	9,110	9,200	9,290	9,380	9,470	15
16	8,240	8,480	8,730	8,960	9,030	9,050	9,060	9,070	9,080	9,140	9,210	9,270	9,340	9,400	9,490	9,590	9,690	9,790	9,880	9,980	10,070	16
17	8,800	9,080	9,360	9,600	9,660	9,670	9,670	9,670	9,670	9,730	9,800	9,860	9,920	9,990	10,090	10,200	10,300	10,410	10,510	10,610	10,710	17
18	9,370	9,680	10,000	10,250	10,290	10,290	10,280	10,260	10,260	10,320	10,390	10,450	10,520	10,590	10,690	10,810	10,920	11,030	11,140	11,250	11,360	18
19	9,930	10,280	10,630	10,880	10,920	10,910	10,880	10,850	10,850	10,910	10,980	11,040	11,100	11,180	11,290	11,410	11,530	11,650	11,770	11,880	12,000	19
20	10,460	10,840	11,230	11,520	11,560	11,530	11,500	11,460	11,440	11,500	11,560	11,630	11,690	11,760	11,880	12,010	12,140	12,260	12,390	12,510	12,630	20
21	10,990	11,410	11,830	12,150	12,190	12,160	12,110	12,060	12,030	12,080	12,150	12,210	12,270	12,350	12,470	12,610	12,740	12,870	13,000	13,130	13,260	21
22	11,520	11,970	12,420	12,780	12,830	12,790	12,730	12,660	12,620	12,670	12,740	12,800	12,860	12,930	13,060	13,200	13,340	13,480	13,620	13,750	13,890	22
23	11,520	11,970	12,420	12,780	12,850	12,850	12,840	12,830	12,830	12,930	13,040	13,140	13,240	13,350	13,520	13,700	13,870	14,050	14,220	14,400	14,570	23
24	11,520	11,970	12,420	12,780	12,890	12,940	12,980	13,010	13,070	13,200	13,350	13,490	13,630	13,790	14,000	14,210	14,420	14,630	14,840	15,060	15,270	24
25	11,520	11,970	12,420	12,800	12,950	13,050	13,140	13,220	13,330	13,500	13,690	13,870	14,050	14,250	14,490	14,740	14,990	15,240	15,490	15,730	15,980	25
26	11,520	11,970	12,420	12,800	12,990	13,130	13,270	13,410	13,560	13,780	14,000	14,230	14,450	14,690	14,970	15,250	15,540	15,820	16,110	16,400	16,680	26
27	11,520	11,970	12,420	12,800	13,030	13,220	13,400	13,590	13,800	14,050	14,310	14,580	14,850	15,130	15,440	15,760	16,080	16,400	16,720	17,050	17,370	27
28	11,520	11,970	12,420	12,820	13,100	13,340	13,570	13,810	14,060	14,350	14,660	14,960	15,270	15,590	15,930	16,290	16,640	17,000	17,360	17,730	18,090	28
29	11,520	11,970	12,420	12,850	13,180	13,460	13,750	14,030	14,330	14,660	15,000	15,350	15,700	16,060	16,440	16,830	17,220	17,610	18,010	18,410	18,820	29
30	11,520	11,970	12,420	12,880	13,250	13,590	13,920	14,260	14,600	14,970	15,360	15,740	16,130	16,530	16,940	17,370	17,800	18,230	18,670	19,110	19,530	30
31	11,520	11,970	12,420	12,880	13,290	13,670	14,050	14,440	14,830	15,240	15,670	16,090	16,530	16,960	17,410	17,870	18,340	18,810	19,280	19,760	20,230	31
32	11,520	11,970	12,420	12,880	13,320	13,750	14,180	14,620	15,060	15,510	15,980	16,440	16,920	17,400	17,880	18,380	18,880	19,390	19,900	20,420	20,920	32
33	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	33
34	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	34
35	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	35
36	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	36
37	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	37
38	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	38
39	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	39
40	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,610	40
41	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,630	41
42	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,630	42
43	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,630	43
44	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,630	44
45	11,520	11,970	12,420	12,880	13,350	13,830	14,310	14,790	15,280	15,780	16,280	16,790	17,310	17,830	18,350	18,890	19,420	19,970	20,510	21,070	21,630	45

DOUGLAS DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	976.0	976.1	976.2	976.3	976.4	976.5	976.6	976.7	976.8	976.9	977.0	977.1	977.2	977.3	977.4	977.5	977.6	977.7	977.8	977.9	978.0	
1	640	650	660	660	670	670	680	680	690	690	700	700	710	720	720	730	730	740	740	750	750	1
2	1,280	1,290	1,300	1,310	1,320	1,330	1,340	1,350	1,370	1,380	1,390	1,400	1,410	1,420	1,430	1,440	1,450	1,460	1,470	1,480	1,490	2
3	1,890	1,900	1,920	1,930	1,950	1,970	1,980	2,000	2,010	2,030	2,050	2,060	2,080	2,090	2,110	2,120	2,140	2,150	2,160	2,180	2,190	3
4	2,520	2,540	2,560	2,580	2,600	2,630	2,650	2,670	2,690	2,710	2,730	2,750	2,770	2,790	2,810	2,830	2,850	2,870	2,890	2,910	2,930	4
5	3,180	3,200	3,230	3,260	3,290	3,310	3,340	3,370	3,390	3,420	3,450	3,470	3,500	3,520	3,550	3,570	3,600	3,620	3,650	3,670	3,700	5
6	3,770	3,810	3,840	3,870	3,910	3,940	3,970	4,000	4,030	4,060	4,090	4,120	4,160	4,190	4,220	4,250	4,280	4,300	4,330	4,360	4,390	6
7	4,370	4,410	4,450	4,490	4,520	4,560	4,600	4,640	4,670	4,710	4,740	4,780	4,810	4,850	4,880	4,920	4,950	4,990	5,020	5,050	5,090	7
8	4,980	5,020	5,060	5,110	5,150	5,190	5,230	5,270	5,320	5,360	5,400	5,440	5,480	5,520	5,560	5,600	5,640	5,680	5,710	5,750	5,790	8
9	5,620	5,670	5,720	5,770	5,820	5,870	5,910	5,960	6,010	6,050	6,100	6,150	6,190	6,240	6,280	6,320	6,370	6,410	6,460	6,500	6,540	9
10	6,270	6,330	6,380	6,430	6,490	6,540	6,590	6,650	6,700	6,750	6,800	6,850	6,900	6,950	7,000	7,050	7,100	7,150	7,200	7,250	7,300	10
11	6,920	6,980	7,040	7,100	7,160	7,220	7,280	7,340	7,400	7,450	7,510	7,570	7,620	7,680	7,730	7,790	7,840	7,900	7,950	8,000	8,060	11
12	7,560	7,630	7,690	7,760	7,830	7,890	7,960	8,020	8,090	8,150	8,220	8,280	8,340	8,400	8,470	8,530	8,590	8,650	8,710	8,770	8,830	12
13	8,200	8,270	8,340	8,420	8,490	8,560	8,630	8,710	8,780	8,850	8,920	8,990	9,060	9,130	9,200	9,260	9,330	9,400	9,470	9,530	9,600	13
14	8,840	8,920	9,000	9,070	9,160	9,240	9,320	9,400	9,470	9,550	9,630	9,710	9,780	9,860	9,930	10,010	10,080	10,150	10,230	10,300	10,370	14
15	9,470	9,560	9,640	9,730	9,820	9,900	9,990	10,080	10,160	10,250	10,330	10,410	10,500	10,580	10,660	10,740	10,820	10,900	10,980	11,060	11,140	15
16	10,070	10,170	10,260	10,350	10,440	10,540	10,630	10,730	10,820	10,910	11,000	11,090	11,180	11,270	11,360	11,440	11,530	11,620	11,700	11,790	11,870	16
17	10,710	10,810	10,910	11,010	11,110	11,210	11,310	11,410	11,510	11,610	11,710	11,800	11,900	12,000	12,090	12,180	12,280	12,370	12,460	12,550	12,640	17
18	11,360	11,460	11,570	11,670	11,780	11,890	12,000	12,110	12,210	12,320	12,420	12,530	12,630	12,730	12,830	12,930	13,030	13,130	13,230	13,320	13,420	18
19	12,000	12,110	12,220	12,330	12,450	12,560	12,680	12,790	12,910	13,020	13,130	13,240	13,350	13,460	13,560	13,670	13,780	13,880	13,990	14,090	14,190	19
20	12,630	12,750	12,860	12,980	13,100	13,230	13,350	13,470	13,590	13,710	13,830	13,950	14,060	14,180	14,290	14,400	14,520	14,630	14,740	14,850	14,960	20
21	13,260	13,380	13,510	13,630	13,760	13,890	14,020	14,150	14,280	14,400	14,530	14,650	14,770	14,900	15,020	15,140	15,250	15,370	15,490	15,610	15,720	21
22	13,890	14,020	14,150	14,280	14,420	14,550	14,690	14,830	14,960	15,090	15,220	15,360	15,480	15,610	15,740	15,870	15,990	16,120	16,240	16,360	16,480	22
23	14,570	14,740	14,900	15,030	15,160	15,290	15,420	15,550	15,680	15,810	15,930	16,060	16,190	16,320	16,450	16,570	16,700	16,820	16,950	17,070	17,190	23
24	15,270	15,470	15,630	15,750	15,870	16,000	16,120	16,240	16,370	16,500	16,620	16,740	16,870	17,000	17,130	17,260	17,390	17,510	17,640	17,760	17,880	24
25	15,980	16,200	16,350	16,460	16,580	16,700	16,810	16,930	17,060	17,180	17,300	17,420	17,550	17,680	17,810	17,940	18,070	18,200	18,320	18,450	18,570	25
26	16,680	16,920	17,070	17,180	17,290	17,400	17,510	17,630	17,750	17,860	17,980	18,090	18,230	18,360	18,490	18,620	18,750	18,880	19,010	19,130	19,250	26
27	17,370	17,650	17,790	17,890	18,000	18,100	18,200	18,320	18,430	18,550	18,650	18,770	18,900	19,040	19,170	19,300	19,430	19,560	19,690	19,810	19,930	27
28	18,090	18,360	18,500	18,600	18,690	18,790	18,890	19,000	19,110	19,220	19,320	19,440	19,570	19,710	19,850	19,980	20,110	20,240	20,360	20,490	20,610	28
29	18,820	19,090	19,220	19,310	19,400	19,490	19,580	19,690	19,800	19,900	20,000	20,120	20,260	20,400	20,530	20,670	20,800	20,930	21,050	21,180	21,300	29
30	19,530	19,800	19,920	20,010	20,090	20,170	20,270	20,370	20,470	20,570	20,670	20,790	20,930	21,070	21,210	21,340	21,470	21,600	21,730	21,850	21,970	30
31	20,230	20,530	20,650	20,730	20,810	20,880	20,970	21,070	21,170	21,260	21,360	21,470	21,610	21,750	21,890	22,030	22,160	22,290	22,420	22,540	22,660	31
32	20,920	21,260	21,380	21,460	21,520	21,590	21,670	21,770	21,860	21,950	22,040	22,150	22,290	22,440	22,580	22,710	22,850	22,980	23,100	23,230	23,350	32
33	21,610	21,990	22,110	22,180	22,240	22,300	22,370	22,460	22,550	22,640	22,730	22,830	22,970	23,120	23,260	23,400	23,530	23,660	23,790	23,920	24,040	33
34	21,610	21,990	22,120	22,230	22,340	22,440	22,560	22,710	22,840	22,980	23,110	23,260	23,460	23,640	23,830	24,010	24,190	24,370	24,540	24,720	24,890	34
35	21,610	22,000	22,170	22,330	22,480	22,630	22,800	22,990	23,180	23,360	23,540	23,740	23,970	24,200	24,430	24,660	24,890	25,110	25,340	25,560	25,750	35
36	21,610	22,030	22,240	22,450	22,660	22,860	23,070	23,300	23,540	23,760	23,990	24,240	24,520	24,790	25,070	25,340	25,610	25,890	26,160	26,420	26,610	36
37	21,610	22,050	22,300	22,560	22,810	23,060	23,320	23,600	23,870	24,150	24,430	24,720	25,040	25,360	25,680	26,000	26,320	26,640	26,960	27,270	27,460	37
38	21,610	22,050	22,350	22,650	22,950	23,240	23,550	23,880	24,200	24,520	24,850	25,190	25,550	25,910	26,280	26,640	27,010	27,370	27,740	28,090	28,310	38
39	21,610	22,090	22,440	22,780	23,120	23,470	23,820	24,190	24,560	24,930	25,300	25,690	26,090	26,500	26,910	27,320	27,730	28,140	28,550	28,950	29,160	39
40	21,610	22,130	22,520	22,910	23,310	23,700	24,100	24,510	24,930	25,350	25,770	26,200	26,650	27,100	27,550	28,010	28,460	28,920	29,380	29,800	30,020	40
41	21,630	22,190	22,630	23,070	23,510	23,950	24,390	24,850	25,320	25,780	26,250	26,720	27,210	27,710	28,210	28,710	29,210	29,720	30,230	30,660	30,870	41
42	21,630	22,190	22,670	23,160	23,640	24,130	24,630	25,130	25,640	26,160	26,670	27,190	27,730	28,270	28,810	29,360	29,910	30,460	31,020	31,490	31,730	42
43	21,630	22,190	22,720	23,250	23,780	24,320	24,860	25,410	25,970	26,530	27,090	27,660	28,240	28,830	29,410	30,010	30,600	31,200	31,810	32,330	32,590	43
44	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,170	33,440	44
45	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,170	33,440	45
46	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,170	33,470	46
47	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,180	33,530	47
48	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,180	33,580	48
49	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,180	33,610	49
50	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,190	33,670	50
51	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,210	33,730	51
52	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,250	33,830	52
53	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,250	33,860	53
54	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,250	33,890	54
55	21,630	22,190	22,760	23,340	23,920	24,510	25,100	25,690	26,300	26,900	27,510	28,130	28,750	29,380	30,010	30,650	31,290	31,940	32,590	33,250	33,910	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	978.0	978.1	978.2	978.3	978.4	978.5	978.6	978.7	978.8	978.9	979.0	979.1	979.2	979.3	979.4	979.5	979.6	979.7	979.8	979.9	980.0	
1	750	760	760	770	770	780	780	780	790	790	800	800	810	810	820	820	830	830	840	840	840	1
2	1,490	1,500	1,510	1,520	1,530	1,540	1,540	1,550	1,560	1,570	1,580	1,590	1,600	1,610	1,620	1,630	1,640	1,650	1,650	1,660	1,670	2
3	2,190	2,210	2,220	2,240	2,250	2,260	2,280	2,290	2,310	2,320	2,330	2,350	2,360	2,370	2,390	2,400	2,410	2,430	2,440	2,450	2,470	3
4	2,930	2,950	2,970	2,990	3,010	3,020	3,040	3,060	3,080	3,100	3,120	3,130	3,150	3,170	3,190	3,200	3,220	3,240	3,260	3,270	3,290	4
5	3,700	3,720	3,750	3,770	3,790	3,820	3,840	3,860	3,890	3,910	3,930	3,960	3,980	4,000	4,020	4,050	4,070	4,090	4,110	4,130	4,150	5
6	4,390	4,420	4,450	4,480	4,510	4,530	4,560	4,590	4,620	4,640	4,670	4,700	4,730	4,750	4,780	4,810	4,830	4,860	4,880	4,910	4,940	6
7	5,090	5,120	5,150	5,190	5,220	5,250	5,280	5,320	5,350	5,380	5,410	5,440	5,470	5,500	5,540	5,570	5,600	5,630	5,660	5,690	5,720	7
8	5,790	5,830	5,870	5,900	5,940	5,980	6,010	6,050	6,090	6,120	6,160	6,190	6,230	6,260	6,300	6,330	6,370	6,400	6,440	6,470	6,510	8
9	6,540	6,590	6,630	6,670	6,710	6,750	6,800	6,840	6,880	6,920	6,960	7,000	7,040	7,080	7,120	7,160	7,200	7,240	7,270	7,310	7,350	9
10	7,300	7,340	7,390	7,440	7,490	7,530	7,580	7,620	7,670	7,720	7,760	7,810	7,850	7,890	7,940	7,980	8,030	8,070	8,110	8,160	8,200	10
11	8,060	8,110	8,160	8,210	8,260	8,320	8,370	8,420	8,470	8,520	8,570	8,620	8,670	8,720	8,760	8,810	8,860	8,910	8,960	9,000	9,050	11
12	8,830	8,890	8,950	9,000	9,060	9,120	9,180	9,230	9,290	9,350	9,400	9,460	9,510	9,570	9,620	9,680	9,730	9,780	9,840	9,890	9,940	12
13	9,600	9,660	9,730	9,790	9,860	9,920	9,980	10,040	10,110	10,170	10,230	10,290	10,350	10,410	10,470	10,530	10,590	10,650	10,710	10,770	10,830	13
14	10,370	10,440	10,510	10,580	10,650	10,720	10,790	10,860	10,930	11,000	11,060	11,130	11,200	11,260	11,330	11,400	11,460	11,530	11,590	11,660	11,720	14
15	11,140	11,220	11,290	11,370	11,440	11,520	11,600	11,670	11,740	11,820	11,890	11,960	12,040	12,110	12,180	12,250	12,320	12,400	12,470	12,540	12,610	15
16	11,870	11,950	12,040	12,120	12,200	12,280	12,360	12,440	12,520	12,600	12,680	12,760	12,840	12,910	12,990	13,070	13,150	13,220	13,300	13,380	13,450	16
17	12,640	12,730	12,820	12,910	13,000	13,080	13,170	13,260	13,340	13,430	13,510	13,600	13,680	13,760	13,850	13,930	14,010	14,100	14,180	14,260	14,340	17
18	13,420	13,520	13,610	13,710	13,800	13,890	13,990	14,080	14,170	14,260	14,350	14,440	14,530	14,620	14,710	14,800	14,890	14,980	15,060	15,150	15,240	18
19	14,190	14,300	14,400	14,500	14,600	14,700	14,790	14,890	14,990	15,090	15,180	15,280	15,370	15,470	15,560	15,660	15,750	15,850	15,940	16,040	16,130	19
20	14,960	15,070	15,170	15,280	15,390	15,490	15,600	15,700	15,800	15,910	16,010	16,110	16,210	16,310	16,410	16,510	16,610	16,710	16,810	16,910	17,010	20
21	15,720	15,840	15,950	16,060	16,170	16,290	16,400	16,510	16,610	16,720	16,830	16,940	17,040	17,150	17,260	17,360	17,470	17,580	17,680	17,790	17,890	21
22	16,480	16,600	16,720	16,840	16,960	17,080	17,190	17,310	17,420	17,540	17,650	17,770	17,880	17,990	18,100	18,220	18,330	18,440	18,550	18,660	18,770	22
23	17,190	17,310	17,440	17,560	17,690	17,810	17,940	18,060	18,180	18,300	18,420	18,540	18,660	18,780	18,900	19,020	19,140	19,260	19,370	19,490	19,610	23
24	17,880	18,000	18,130	18,270	18,400	18,530	18,660	18,790	18,920	19,050	19,180	19,300	19,430	19,550	19,680	19,800	19,930	20,050	20,180	20,300	20,420	24
25	18,570	18,690	18,830	18,970	19,110	19,250	19,390	19,520	19,660	19,790	19,930	20,060	20,190	20,320	20,460	20,590	20,720	20,850	20,980	21,110	21,240	25
26	19,250	19,380	19,520	19,670	19,820	19,960	20,110	20,250	20,390	20,530	20,680	20,810	20,950	21,090	21,230	21,370	21,500	21,640	21,780	21,910	22,050	26
27	19,930	20,060	20,210	20,370	20,520	20,670	20,830	20,980	21,130	21,270	21,420	21,570	21,710	21,860	22,000	22,150	22,290	22,430	22,570	22,710	22,850	27
28	20,610	20,750	20,900	21,070	21,230	21,390	21,540	21,700	21,860	22,010	22,170	22,320	22,470	22,620	22,770	22,920	23,070	23,220	23,370	23,510	23,660	28
29	21,300	21,440	21,610	21,780	21,940	22,110	22,270	22,440	22,600	22,760	22,920	23,080	23,240	23,400	23,560	23,710	23,870	24,020	24,180	24,330	24,480	29
30	21,970	22,120	22,300	22,470	22,650	22,820	22,990	23,160	23,330	23,500	23,670	23,830	24,000	24,160	24,320	24,490	24,650	24,810	24,970	25,130	25,280	30
31	22,660	22,810	22,990	23,180	23,360	23,540	23,720	23,890	24,070	24,250	24,420	24,590	24,760	24,930	25,100	25,270	25,440	25,600	25,770	25,930	26,100	31
32	23,350	23,500	23,690	23,880	24,070	24,260	24,440	24,630	24,810	24,990	25,170	25,350	25,530	25,710	25,880	26,060	26,230	26,400	26,570	26,740	26,910	32
33	24,040	24,190	24,380	24,580	24,780	24,970	25,160	25,350	25,540	25,730	25,920	26,110	26,290	26,470	26,660	26,840	27,020	27,200	27,370	27,550	27,720	33
34	24,890	25,060	25,250	25,440	25,630	25,810	26,000	26,190	26,370	26,560	26,740	26,920	27,110	27,300	27,480	27,660	27,850	28,030	28,210	28,380	28,560	34
35	25,750	25,920	26,100	26,280	26,460	26,640	26,820	27,010	27,190	27,370	27,550	27,740	27,930	28,110	28,300	28,490	28,670	28,850	29,030	29,210	29,400	35
36	26,610	26,770	26,950	27,120	27,290	27,470	27,650	27,820	28,000	28,170	28,360	28,550	28,740	28,940	29,120	29,310	29,500	29,680	29,860	30,050	30,240	36
37	27,460	27,620	27,790	27,960	28,120	28,290	28,470	28,640	28,810	28,980	29,170	29,360	29,560	29,750	29,940	30,130	30,320	30,510	30,690	30,870	31,070	37
38	28,310	28,470	28,630	28,790	28,940	29,110	29,280	29,450	29,610	29,770	29,960	30,160	30,360	30,550	30,750	30,940	31,130	31,320	31,500	31,690	31,890	38
39	29,160	29,320	29,470	29,620	29,770	29,930	30,090	30,260	30,420	30,580	30,770	30,970	31,170	31,370	31,560	31,760	31,950	32,140	32,330	32,510	32,720	39
40	30,020	30,170	30,310	30,450	30,590	30,750	30,910	31,070	31,230	31,390	31,580	31,780	31,990	32,190	32,390	32,580	32,780	32,970	33,160	33,350	33,570	40
41	30,870	31,010	31,150	31,280	31,420	31,570	31,730	31,880	32,030	32,190	32,390	32,600	32,800	33,000	33,210	33,400	33,600	33,790	33,980	34,180	34,410	41
42	31,730	31,870	32,000	32,120	32,250	32,400	32,550	32,700	32,850	33,000	33,200	33,410	33,610	33,820	34,020	34,220	34,420	34,620	34,810	35,010	35,240	42
43	32,590	32,720	32,850	32,960	33,080	33,220	33,370	33,520	33,660	33,810	34,000	34,220	34,430	34,640	34,840	35,040	35,240	35,440	35,630	35,840	36,070	43
44	33,440	33,580	33,700	33,800	33,920	34,050	34,200	34,340	34,470	34,620	34,810	35,030	35,240	35,450	35,660	35,860	36,060	36,260	36,460	36,660	36,900	44
45	33,440	33,610	33,780	33,940	34,100	34,290	34,480	34,670	34,860	35,060	35,300	35,570	35,830	36,080	36,340	36,590	36,840	37,090	37,330	37,590	37,880	45
46	33,470	33,690	33,910	34,120	34,330	34,570	34,820	35,060	35,300	35,550	35,840	36,150	36,450	36,760	37,060	37,360	37,660	37,950	38,250	38,550	38,890	46
47	33,530	33,800	34,070	34,330	34,600	34,890	35,180	35,470	35,760	36,060	36,400	36,760	37,110	37,460	37,810	38,160	38,500	38,850	39,200	39,550	39,930	47
48	33,580	33,900	34,210	34,530	34,850	35,190	35,530	35,870	36,210	36,570	36,950	37,350	37,750	38,140	38,540	38,940	39,330	39,730	40,130	40,530	40,960	48
49	33,610	33,970	34,340	34,710	35,080	35,470	35,860	36,250	36,640	37,050	37,480	37,920	38,360	38,810	39,250	39,690	40,140	40,580	41,030	41,480	41,960	49
50	33,670	34,080	34,500	34,920	35,340	35,780	36,220	36,660	37,100	37,560	38,030	38,520	39,010	39,500	39,990	40,480	40,970	41,460	41,960	42,460	42,980	50
51	33,730	34,200	34,670	35,140	35,610	36,100	36,590	37,080	37,580	38,080	38,600	39,130	39,670	40,200	40,740	41,280	41,820	42,370	42,910	43,460	44,030	51
52	33,830	34,350	34,870	35,390	35,910	36,450	36,990	37,530	38,080	38,630	39,190	39,770	40,350	40,930	41,520	42,110	42,700	43,290	43,890	44,490	45,100	52
53	33,860	34,420	35,000	35,570	36,140	36,730	37,320	37,920	38,510	39,110	39,730	40,350	40,980	41,610	42,240	42,880	43,520	44,160	44,810	45,460	46,120	53
54	33,890	34,500	35,120	35,750	36,380	37,010	37,650	38,300	38,950	39,600	40,260	40,930	41,600	42,280	42,960	43,650	44,340	45,030	45,720	46,420	47,130	54
55	33,910	34,580	35,250	35,930	36,610	37,300	37,990	38,680	39,380	40,090	40,800	41,510	42,230	42,950	43,680	44,410	45,150	45,890	46,640	47,390	48,150	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	978.0	978.1	978.2	978.3	978.4	978.5	978.6	978.7	978.8	978.9	979.0	979.1	979.2	979.3	979.4	979.5	979.6	979.7	979.8	979.9	980.0	
56	33, 910	34, 580	35, 250	35, 930	36, 610	37, 300	37, 990	38, 680	39, 380	40, 090	40, 800	41, 510	42, 230	42, 950	43, 680	44, 410	45, 150	45, 890	46, 640	47, 390	48, 150	56
57	33, 910	34, 580	35, 250	35, 930	36, 610	37, 300	37, 990	38, 680	39, 380	40, 090	40, 800	41, 510	42, 230	42, 950	43, 680	44, 410	45, 150	45, 890	46, 640	47, 390	48, 150	57
58	33, 910	34, 580	35, 250	35, 930	36, 610	37, 300	37, 990	38, 680	39, 380	40, 090	40, 800	41, 510	42, 230	42, 950	43, 680	44, 410	45, 150	45, 890	46, 640	47, 390	48, 150	58
59	33, 910	34, 580	35, 250	35, 930	36, 610	37, 300	37, 990	38, 680	39, 380	40, 090	40, 800	41, 510	42, 230	42, 950	43, 680	44, 410	45, 150	45, 890	46, 640	47, 390	48, 150	59
60	33, 910	34, 580	35, 250	35, 930	36, 610	37, 300	37, 990	38, 680	39, 380	40, 090	40, 800	41, 510	42, 230	42, 950	43, 680	44, 410	45, 150	45, 890	46, 640	47, 390	48, 150	60

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	980.0	980.1	980.2	980.3	980.4	980.5	980.6	980.7	980.8	980.9	981.0	981.1	981.2	981.3	981.4	981.5	981.6	981.7	981.8	981.9	982.0	
1	840	850	850	860	860	870	870	870	880	880	890	890	900	900	900	910	910	920	920	920	930	1
2	1,670	1,680	1,690	1,700	1,710	1,710	1,720	1,730	1,740	1,750	1,760	1,760	1,770	1,780	1,790	1,800	1,810	1,810	1,820	1,830	1,840	2
3	2,470	2,480	2,490	2,500	2,520	2,530	2,540	2,550	2,570	2,580	2,590	2,600	2,610	2,630	2,640	2,650	2,660	2,670	2,690	2,700	2,710	3
4	3,290	3,310	3,330	3,340	3,360	3,380	3,390	3,410	3,430	3,440	3,460	3,480	3,490	3,510	3,520	3,540	3,560	3,570	3,590	3,600	3,620	4
5	4,150	4,180	4,200	4,220	4,240	4,260	4,280	4,300	4,320	4,350	4,370	4,390	4,410	4,430	4,450	4,470	4,490	4,510	4,530	4,550	4,570	5
6	4,940	4,960	4,990	5,010	5,040	5,060	5,090	5,110	5,140	5,160	5,190	5,210	5,240	5,260	5,280	5,310	5,330	5,360	5,380	5,400	5,430	6
7	5,720	5,750	5,780	5,810	5,830	5,860	5,890	5,920	5,950	5,980	6,010	6,040	6,060	6,090	6,120	6,150	6,170	6,200	6,230	6,260	6,280	7
8	6,510	6,540	6,570	6,610	6,640	6,670	6,700	6,740	6,770	6,800	6,840	6,870	6,900	6,930	6,960	6,990	7,030	7,060	7,090	7,120	7,150	8
9	7,350	7,390	7,430	7,470	7,500	7,540	7,580	7,610	7,650	7,690	7,720	7,760	7,800	7,830	7,870	7,900	7,940	7,980	8,010	8,050	8,080	9
10	8,200	8,240	8,280	8,330	8,370	8,410	8,450	8,490	8,530	8,570	8,620	8,660	8,700	8,740	8,780	8,820	8,860	8,900	8,930	8,970	9,010	10
11	9,050	9,100	9,150	9,190	9,240	9,280	9,330	9,380	9,420	9,470	9,510	9,560	9,600	9,640	9,690	9,730	9,780	9,820	9,860	9,910	9,950	11
12	9,940	10,000	10,050	10,100	10,150	10,210	10,260	10,310	10,360	10,410	10,460	10,510	10,560	10,610	10,660	10,710	10,760	10,810	10,860	10,900	10,950	12
13	10,830	10,890	10,950	11,010	11,060	11,120	11,180	11,230	11,290	11,350	11,400	11,460	11,510	11,570	11,620	11,680	11,730	11,790	11,840	11,900	11,950	13
14	11,720	11,790	11,850	11,910	11,980	12,040	12,100	12,170	12,230	12,290	12,350	12,410	12,470	12,530	12,590	12,650	12,710	12,770	12,830	12,890	12,950	14
15	12,610	12,680	12,750	12,820	12,880	12,950	13,020	13,090	13,160	13,220	13,290	13,360	13,420	13,490	13,560	13,620	13,690	13,750	13,820	13,880	13,940	15
16	13,450	13,530	13,600	13,680	13,750	13,820	13,900	13,970	14,040	14,120	14,190	14,260	14,330	14,400	14,470	14,540	14,610	14,680	14,750	14,820	14,890	16
17	14,340	14,420	14,500	14,580	14,660	14,740	14,820	14,900	14,980	15,060	15,130	15,210	15,290	15,360	15,440	15,520	15,590	15,670	15,740	15,820	15,890	17
18	15,240	15,330	15,410	15,500	15,580	15,670	15,750	15,840	15,920	16,010	16,090	16,170	16,250	16,340	16,420	16,500	16,580	16,660	16,740	16,820	16,900	18
19	16,130	16,220	16,310	16,400	16,500	16,590	16,680	16,770	16,860	16,940	17,030	17,120	17,210	17,300	17,380	17,470	17,560	17,640	17,730	17,810	17,900	19
20	17,010	17,110	17,210	17,300	17,400	17,500	17,590	17,690	17,780	17,880	17,970	18,060	18,160	18,250	18,340	18,430	18,520	18,620	18,710	18,800	18,890	20
21	17,890	18,000	18,100	18,200	18,300	18,410	18,510	18,610	18,710	18,810	18,910	19,010	19,100	19,200	19,300	19,400	19,490	19,590	19,690	19,780	19,880	21
22	18,770	18,880	18,990	19,100	19,210	19,310	19,420	19,530	19,630	19,740	19,840	19,950	20,050	20,150	20,260	20,360	20,460	20,560	20,660	20,770	20,870	22
23	19,610	19,720	19,840	19,950	20,060	20,180	20,290	20,400	20,510	20,620	20,740	20,850	20,950	21,060	21,170	21,280	21,390	21,500	21,610	21,710	21,820	23
24	20,420	20,540	20,660	20,780	20,900	21,020	21,140	21,260	21,380	21,490	21,610	21,720	21,840	21,960	22,070	22,190	22,300	22,420	22,530	22,640	22,760	24
25	21,240	21,360	21,490	21,620	21,740	21,860	21,990	22,110	22,230	22,360	22,480	22,600	22,720	22,840	22,970	23,090	23,210	23,330	23,450	23,570	23,690	25
26	22,050	22,180	22,310	22,440	22,570	22,700	22,830	22,960	23,090	23,220	23,340	23,470	23,600	23,730	23,860	23,990	24,110	24,240	24,370	24,490	24,620	26
27	22,850	22,990	23,130	23,270	23,400	23,540	23,670	23,810	23,940	24,080	24,210	24,340	24,480	24,610	24,750	24,880	25,010	25,150	25,280	25,410	25,540	27
28	23,660	23,800	23,950	24,090	24,230	24,370	24,510	24,650	24,790	24,930	25,070	25,210	25,350	25,490	25,630	25,770	25,910	26,050	26,190	26,330	26,470	28
29	24,480	24,630	24,780	24,930	25,080	25,220	25,370	25,510	25,660	25,800	25,950	26,090	26,240	26,390	26,530	26,680	26,830	26,970	27,120	27,260	27,410	29
30	25,280	25,440	25,590	25,750	25,900	26,060	26,210	26,360	26,510	26,660	26,810	26,960	27,110	27,270	27,420	27,570	27,720	27,880	28,030	28,180	28,330	30
31	26,100	26,260	26,420	26,580	26,740	26,900	27,060	27,210	27,370	27,520	27,680	27,830	27,990	28,160	28,320	28,470	28,630	28,790	28,950	29,100	29,260	31
32	26,910	27,080	27,250	27,410	27,580	27,740	27,910	28,070	28,230	28,390	28,550	28,710	28,880	29,050	29,210	29,380	29,540	29,710	29,870	30,030	30,190	32
33	27,720	27,900	28,070	28,240	28,410	28,580	28,750	28,920	29,090	29,250	29,420	29,580	29,760	29,930	30,100	30,280	30,450	30,620	30,790	30,960	31,120	33
34	28,560	28,740	28,920	29,100	29,280	29,460	29,630	29,810	29,980	30,150	30,330	30,500	30,680	30,860	31,040	31,220	31,390	31,570	31,740	31,920	32,090	34
35	29,400	29,580	29,770	29,960	30,140	30,330	30,510	30,690	30,880	31,060	31,240	31,420	31,600	31,790	31,970	32,160	32,340	32,520	32,700	32,880	33,060	35
36	30,240	30,430	30,630	30,820	31,020	31,210	31,400	31,590	31,780	31,960	32,150	32,340	32,530	32,720	32,910	33,100	33,290	33,480	33,670	33,850	34,040	36
37	31,070	31,270	31,480	31,680	31,880	32,080	32,280	32,470	32,670	32,860	33,060	33,250	33,450	33,650	33,850	34,040	34,240	34,430	34,620	34,810	35,000	37
38	31,890	32,100	32,310	32,520	32,730	32,940	33,140	33,350	33,550	33,750	33,950	34,150	34,360	34,560	34,760	34,960	35,160	35,360	35,560	35,760	35,950	38
39	32,720	32,940	33,160	33,380	33,590	33,810	34,020	34,230	34,440	34,650	34,860	35,070	35,280	35,490	35,700	35,900	36,110	36,310	36,520	36,720	36,920	39
40	33,570	33,790	34,020	34,240	34,470	34,690	34,910	35,130	35,350	35,560	35,780	35,990	36,210	36,420	36,640	36,850	37,060	37,270	37,480	37,690	37,900	40
41	34,410	34,640	34,870	35,110	35,340	35,570	35,790	36,020	36,250	36,470	36,690	36,910	37,130	37,360	37,580	37,790	38,010	38,230	38,440	38,660	38,870	41
42	35,240	35,480	35,720	35,960	36,200	36,440	36,670	36,910	37,140	37,370	37,600	37,830	38,050	38,280	38,510	38,730	38,960	39,180	39,400	39,620	39,840	42
43	36,070	36,320	36,570	36,820	37,060	37,310	37,550	37,790	38,030	38,270	38,500	38,740	38,970	39,210	39,440	39,670	39,900	40,130	40,350	40,580	40,800	43
44	36,900	37,160	37,420	37,670	37,920	38,180	38,430	38,670	38,920	39,170	39,410	39,650	39,890	40,130	40,370	40,610	40,840	41,070	41,310	41,540	41,770	44
45	37,880	38,180	38,480	38,790	39,090	39,380	39,680	39,980	40,280	40,570	40,800	41,030	41,260	41,490	41,720	41,950	42,180	42,410	42,630	42,860	43,090	45
46	38,890	39,240	39,590	39,940	40,290	40,630	40,980	41,330	41,670	41,950	42,170	42,400	42,620	42,830	43,060	43,280	43,500	43,730	43,950	44,180	44,420	46
47	39,930	40,330	40,730	41,120	41,520	41,910	42,310	42,700	43,050	43,320	43,540	43,750	43,960	44,170	44,390	44,610	44,820	45,040	45,260	45,500	45,750	47
48	40,960	41,400	41,850	42,290	42,730	43,170	43,620	44,060	44,430	44,690	44,900	45,100	45,300	45,500	45,710	45,930	46,140	46,350	46,570	46,820	47,070	48
49	41,960	42,450	42,930	43,420	43,910	44,400	44,890	45,380	45,790	46,050	46,240	46,440	46,620	46,820	47,020	47,230	47,430	47,630	47,850	48,110	48,370	49
50	42,980	43,510	44,040	44,580	45,110	45,650	46,190	46,730	47,160	47,400	47,590	47,770	47,950	48,130	48,330	48,540	48,730	48,930	49,150	49,410	49,680	50
51	44,030	44,610	45,190	45,770	46,350	46,930	47,520	48,110	48,540	48,770	48,950	49,120	49,290	49,470	49,660	49,860	50,050	50,240	50,460	50,730	51,010	51
52	45,100	45,720	46,350	46,980	47,610	48,240	48,880	49,490	49,900	50,130	50,300	50,460	50,620	50,790	50,980	51,170	51,360	51,540	51,780	52,050	52,330	52
53	46,120	46,780	47,460	48,130	48,810	49,490	50,170	50,830	51,300	51,510	51,670	51,820	51,970	52,140	52,320	52,500	52,680	52,860	53,090	53,370	53,660	53
54	47,130	47,840	48,560	49,280	50,010	50,740	51,470	52,180	52,680	52,890	53,040	53,180	53,320	53,470	53,650	53,830	54,000	54,180	54,400	54,690	54,980	54
55	48,150	48,900	49,670	50,440	51,210	51,990	52,770	53,530	54,060	54,260	54,400	54,530	54,660	54,800	54,980	55,150	55,320	55,480	55,700	56,000	56,300	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	980.0	980.1	980.2	980.3	980.4	980.5	980.6	980.7	980.8	980.9	981.0	981.1	981.2	981.3	981.4	981.5	981.6	981.7	981.8	981.9	982.0	
56	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 060	54, 270	54, 460	54, 660	54, 850	55, 050	55, 290	55, 520	55, 740	55, 970	56, 250	56, 610	56, 960	56
57	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 070	54, 330	54, 590	54, 840	55, 090	55, 360	55, 660	55, 950	56, 230	56, 520	56, 860	57, 260	57, 670	57
58	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 110	54, 430	54, 750	55, 070	55, 380	55, 710	56, 060	56, 410	56, 760	57, 110	57, 500	57, 950	58, 400	58
59	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 140	54, 520	54, 900	55, 280	55, 650	56, 040	56, 450	56, 860	57, 270	57, 680	58, 120	58, 620	59, 120	59
60	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 150	54, 590	55, 020	55, 460	55, 900	56, 350	56, 810	57, 280	57, 740	58, 210	58, 720	59, 270	59, 810	60
61	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 180	54, 670	55, 170	55, 670	56, 160	56, 670	57, 200	57, 720	58, 240	58, 770	59, 330	59, 930	60, 520	61
62	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 530	54, 230	54, 780	55, 340	55, 900	56, 460	57, 030	57, 610	58, 190	58, 780	59, 370	59, 980	60, 620	61, 260	62
63	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 320	54, 930	55, 550	56, 170	56, 790	57, 420	58, 060	58, 700	59, 350	59, 990	60, 650	61, 340	62, 030	63
64	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 320	55, 000	55, 670	56, 360	57, 040	57, 730	58, 430	59, 130	59, 830	60, 540	61, 260	62, 000	62, 740	64
65	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 330	55, 060	55, 800	56, 540	57, 290	58, 040	58, 800	59, 560	60, 320	61, 090	61, 870	62, 660	63, 450	65
66	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 350	55, 140	55, 940	56, 740	57, 550	58, 360	59, 180	60, 000	60, 820	61, 650	62, 480	63, 320	64, 160	66
67	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 350	55, 140	55, 940	56, 740	57, 550	58, 360	59, 180	60, 000	60, 820	61, 650	62, 480	63, 320	64, 160	67
68	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 350	55, 140	55, 940	56, 740	57, 550	58, 360	59, 180	60, 000	60, 820	61, 650	62, 480	63, 320	64, 160	68
69	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 350	55, 140	55, 940	56, 740	57, 550	58, 360	59, 180	60, 000	60, 820	61, 650	62, 480	63, 320	64, 160	69
70	48, 150	48, 900	49, 670	50, 440	51, 210	51, 990	52, 770	53, 550	54, 350	55, 140	55, 940	56, 740	57, 550	58, 360	59, 180	60, 000	60, 820	61, 650	62, 480	63, 320	64, 160	70

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	982.0	982.1	982.2	982.3	982.4	982.5	982.6	982.7	982.8	982.9	983.0	983.1	983.2	983.3	983.4	983.5	983.6	983.7	983.8	983.9	984.0	
1	930	930	940	940	940	950	950	960	960	960	970	970	970	980	980	990	990	990	1,000	1,000	1,000	1
2	1,840	1,850	1,850	1,860	1,870	1,880	1,880	1,890	1,900	1,910	1,920	1,920	1,930	1,940	1,950	1,950	1,960	1,970	1,980	1,980	1,990	2
3	2,710	2,720	2,730	2,740	2,760	2,770	2,780	2,790	2,800	2,810	2,820	2,840	2,850	2,860	2,870	2,880	2,890	2,900	2,910	2,920	2,930	3
4	3,620	3,630	3,650	3,670	3,680	3,700	3,710	3,730	3,740	3,760	3,770	3,790	3,800	3,820	3,830	3,840	3,860	3,870	3,890	3,900	3,920	4
5	4,570	4,590	4,610	4,630	4,650	4,670	4,680	4,700	4,720	4,740	4,760	4,780	4,800	4,820	4,840	4,850	4,870	4,890	4,910	4,930	4,950	5
6	5,430	5,450	5,470	5,500	5,520	5,540	5,560	5,590	5,610	5,630	5,650	5,680	5,700	5,720	5,740	5,770	5,790	5,810	5,830	5,850	5,870	6
7	6,280	6,310	6,340	6,370	6,390	6,420	6,440	6,470	6,500	6,520	6,550	6,570	6,600	6,630	6,650	6,680	6,700	6,730	6,750	6,780	6,800	7
8	7,150	7,180	7,210	7,240	7,270	7,300	7,330	7,360	7,390	7,420	7,450	7,480	7,510	7,540	7,570	7,600	7,630	7,650	7,680	7,710	7,740	8
9	8,080	8,120	8,150	8,180	8,220	8,250	8,290	8,320	8,350	8,390	8,420	8,450	8,490	8,520	8,550	8,590	8,620	8,650	8,680	8,720	8,750	9
10	9,010	9,050	9,090	9,130	9,170	9,200	9,240	9,280	9,320	9,350	9,390	9,430	9,470	9,500	9,540	9,580	9,610	9,650	9,680	9,720	9,760	10
11	9,950	9,990	10,040	10,080	10,120	10,160	10,200	10,250	10,290	10,330	10,370	10,410	10,450	10,490	10,530	10,570	10,610	10,650	10,690	10,730	10,770	11
12	10,950	11,000	11,050	11,100	11,140	11,190	11,240	11,290	11,330	11,380	11,420	11,470	11,520	11,560	11,610	11,650	11,700	11,740	11,790	11,830	11,880	12
13	11,950	12,000	12,060	12,110	12,160	12,210	12,270	12,320	12,370	12,420	12,470	12,520	12,570	12,620	12,670	12,720	12,770	12,820	12,870	12,920	12,970	13
14	12,950	13,010	13,070	13,130	13,180	13,240	13,300	13,350	13,410	13,470	13,520	13,580	13,640	13,690	13,750	13,800	13,860	13,910	13,970	14,020	14,080	14
15	13,940	14,010	14,070	14,130	14,200	14,260	14,320	14,380	14,450	14,510	14,570	14,630	14,690	14,750	14,810	14,870	14,930	14,990	15,050	15,110	15,170	15
16	14,890	14,960	15,030	15,100	15,170	15,230	15,300	15,370	15,430	15,500	15,570	15,630	15,700	15,760	15,830	15,890	15,960	16,020	16,090	16,150	16,220	16
17	15,890	15,960	16,040	16,110	16,180	16,260	16,330	16,400	16,470	16,540	16,620	16,690	16,760	16,830	16,900	16,970	17,040	17,110	17,180	17,250	17,310	17
18	16,900	16,980	17,060	17,140	17,210	17,290	17,370	17,450	17,520	17,600	17,680	17,750	17,830	17,900	17,980	18,050	18,130	18,200	18,280	18,350	18,420	18
19	17,900	17,980	18,060	18,150	18,230	18,310	18,400	18,480	18,560	18,640	18,720	18,800	18,890	18,970	19,050	19,130	19,210	19,280	19,360	19,440	19,520	19
20	18,890	18,980	19,070	19,150	19,240	19,330	19,420	19,510	19,590	19,680	19,770	19,850	19,940	20,020	20,110	20,190	20,280	20,360	20,450	20,530	20,610	20
21	19,880	19,970	20,070	20,160	20,250	20,350	20,440	20,530	20,620	20,720	20,810	20,900	20,990	21,080	21,170	21,260	21,350	21,440	21,530	21,610	21,700	21
22	20,870	20,970	21,060	21,160	21,260	21,360	21,460	21,560	21,650	21,750	21,850	21,940	22,040	22,130	22,230	22,320	22,420	22,510	22,610	22,700	22,790	22
23	21,820	21,930	22,030	22,140	22,240	22,350	22,450	22,560	22,660	22,760	22,860	22,970	23,070	23,170	23,270	23,370	23,470	23,570	23,670	23,770	23,870	23
24	22,760	22,870	22,980	23,090	23,200	23,310	23,420	23,530	23,640	23,750	23,860	23,970	24,080	24,180	24,290	24,400	24,500	24,610	24,720	24,820	24,930	24
25	23,690	23,810	23,930	24,040	24,160	24,280	24,390	24,510	24,620	24,740	24,850	24,970	25,080	25,190	25,310	25,420	25,530	25,640	25,750	25,870	25,980	25
26	24,620	24,740	24,870	24,990	25,110	25,230	25,360	25,480	25,600	25,720	25,840	25,960	26,080	26,200	26,320	26,440	26,550	26,670	26,790	26,910	27,020	26
27	25,540	25,670	25,800	25,930	26,060	26,190	26,320	26,450	26,570	26,700	26,830	26,950	27,080	27,200	27,330	27,450	27,580	27,700	27,820	27,940	28,070	27
28	26,470	26,600	26,740	26,870	27,010	27,140	27,280	27,410	27,550	27,680	27,810	27,940	28,070	28,200	28,330	28,460	28,590	28,720	28,850	28,980	29,110	28
29	27,410	27,550	27,690	27,830	27,970	28,110	28,250	28,390	28,530	28,670	28,810	28,950	29,090	29,220	29,360	29,490	29,630	29,760	29,900	30,030	30,170	29
30	28,330	28,480	28,620	28,770	28,920	29,070	29,210	29,360	29,500	29,650	29,790	29,930	30,080	30,220	30,360	30,500	30,640	30,790	30,930	31,070	31,200	30
31	29,260	29,420	29,570	29,720	29,880	30,030	30,180	30,330	30,480	30,640	30,790	30,930	31,080	31,230	31,380	31,530	31,670	31,820	31,970	32,110	32,260	31
32	30,190	30,360	30,520	30,680	30,840	30,990	31,150	31,310	31,470	31,620	31,780	31,940	32,090	32,240	32,400	32,550	32,700	32,860	33,010	33,160	33,310	32
33	31,120	31,290	31,460	31,620	31,790	31,950	32,120	32,280	32,450	32,610	32,770	32,930	33,090	33,250	33,410	33,570	33,730	33,890	34,050	34,200	34,360	33
34	32,090	32,270	32,440	32,610	32,780	32,950	33,120	33,290	33,460	33,630	33,790	33,960	34,130	34,290	34,460	34,620	34,790	34,950	35,120	35,280	35,440	34
35	33,060	33,240	33,420	33,600	33,770	33,950	34,120	34,300	34,470	34,640	34,810	34,990	35,160	35,330	35,510	35,680	35,850	36,020	36,190	36,360	36,530	35
36	34,040	34,220	34,400	34,590	34,770	34,950	35,130	35,310	35,490	35,670	35,840	36,020	36,200	36,380	36,560	36,740	36,910	37,090	37,270	37,440	37,620	36
37	35,000	35,190	35,380	35,570	35,760	35,940	36,130	36,310	36,500	36,680	36,860	37,050	37,240	37,420	37,610	37,790	37,970	38,150	38,340	38,520	38,700	37
38	35,950	36,150	36,340	36,540	36,730	36,920	37,110	37,300	37,490	37,680	37,870	38,060	38,250	38,440	38,630	38,820	39,010	39,200	39,390	39,570	39,760	38
39	36,920	37,120	37,320	37,520	37,720	37,920	38,110	38,310	38,500	38,690	38,890	39,090	39,290	39,480	39,680	39,880	40,070	40,260	40,460	40,650	40,840	39
40	37,900	38,100	38,310	38,510	38,720	38,920	39,120	39,320	39,520	39,720	39,920	40,130	40,330	40,530	40,740	40,940	41,140	41,340	41,540	41,740	41,930	40
41	38,870	39,080	39,290	39,500	39,710	39,920	40,130	40,330	40,540	40,740	40,950	41,160	41,370	41,580	41,790	42,000	42,200	42,410	42,610	42,820	43,020	41
42	39,840	40,050	40,270	40,480	40,700	40,910	41,120	41,330	41,540	41,750	41,970	42,190	42,400	42,620	42,830	43,050	43,260	43,470	43,680	43,890	44,100	42
43	40,800	41,020	41,250	41,470	41,690	41,900	42,120	42,340	42,550	42,770	42,990	43,210	43,430	43,650	43,870	44,090	44,310	44,530	44,750	44,960	45,180	43
44	41,770	41,990	42,220	42,450	42,670	42,900	43,120	43,340	43,560	43,780	44,010	44,240	44,460	44,690	44,920	45,140	45,370	45,590	45,820	46,040	46,260	44
45	43,090	43,330	43,560	43,790	44,030	44,260	44,480	44,710	44,940	45,160	45,400	45,640	45,870	46,110	46,340	46,570	46,800	47,040	47,270	47,490	47,720	45
46	44,420	44,660	44,900	45,140	45,380	45,610	45,850	46,080	46,310	46,550	46,790	47,040	47,280	47,520	47,760	48,000	48,240	48,480	48,720	48,950	49,190	46
47	45,750	46,000	46,240	46,490	46,730	46,970	47,210	47,450	47,690	47,940	48,190	48,440	48,690	48,940	49,190	49,440	49,680	49,930	50,170	50,410	50,660	47
48	47,070	47,330	47,580	47,830	48,080	48,330	48,580	48,820	49,070	49,320	49,580	49,840	50,100	50,350	50,610	50,860	51,120	51,370	51,620	51,870	52,120	48
49	48,370	48,630	48,890	49,150	49,400	49,660	49,910	50,160	50,410	50,670	50,940	51,210	51,470	51,740	52,000	52,260	52,520	52,780	53,040	53,290	53,550	49
50	49,680	49,950	50,210	50,480	50,740	51,000	51,260	51,510	51,770	52,040	52,320	52,590	52,860	53,140	53,410	53,670	53,940	54,210	54,470	54,730	54,990	50
51	51,010	51,280	51,550	51,820	52,090	52,360	52,620	52,880	53,150	53,430	53,710	54,000	54,280	54,560	54,830	55,110	55,380	55,650	55,930	56,200	56,460	51
52	52,330	52,610	52,890	53,170	53,440	53,720	53,990	54,250	54,530	54,820	55,110	55,400	55,690	55,970	56,260	56,540	56,820	57,100	57,380	57,650	57,930	52
53	53,660	53,950	54,230	54,520	54,800	55,080	55,350	55,630	55,910	56,200	56,500	56,800	57,100	57,390	57,680	57,970	58,260	58,550	58,830	59,110	59,390	53
54	54,980	55,280	55,570	55,860	56,150	56,430	56,710	56,990	57,280	57,590	57,890	58,200	58,500	58,800	59,100	59,400	59,690	59,990	60,280	60,570	60,860	54
55	56,300	56,600	56,900	57,200	57,490	57,780	58,070	58,350	58,650	58,960	59,280	59,590	59,900	60,210	60,510	60,820	61,120	61,420	61,720	62,020	62,310	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	982.0	982.1	982.2	982.3	982.4	982.5	982.6	982.7	982.8	982.9	983.0	983.1	983.2	983.3	983.4	983.5	983.6	983.7	983.8	983.9	984.0	
56	56,960	57,310	57,660	58,010	58,350	58,690	59,030	59,370	59,720	60,090	60,460	60,820	61,180	61,540	61,900	62,260	62,620	62,970	63,330	63,680	64,030	56
57	57,670	58,070	58,470	58,860	59,260	59,650	60,050	60,440	60,840	61,260	61,680	62,100	62,510	62,930	63,340	63,750	64,170	64,580	64,990	65,400	65,810	57
58	58,400	58,850	59,300	59,750	60,200	60,640	61,090	61,530	61,990	62,460	62,930	63,400	63,870	64,340	64,810	65,270	65,740	66,210	66,680	67,140	67,610	58
59	59,120	59,620	60,120	60,620	61,120	61,620	62,120	62,620	63,130	63,650	64,170	64,690	65,220	65,740	66,260	66,780	67,310	67,830	68,350	68,880	69,400	59
60	59,810	60,360	60,910	61,460	62,010	62,560	63,110	63,660	64,220	64,790	65,360	65,940	66,510	67,080	67,660	68,240	68,810	69,390	69,970	70,550	71,120	60
61	60,520	61,120	61,720	62,310	62,910	63,510	64,120	64,720	65,330	65,950	66,570	67,200	67,820	68,450	69,080	69,710	70,330	70,970	71,600	72,230	72,870	61
62	61,260	61,910	62,560	63,210	63,860	64,510	65,170	65,820	66,490	67,160	67,830	68,510	69,190	69,870	70,550	71,230	71,920	72,610	73,300	73,990	74,680	62
63	62,030	62,730	63,430	64,130	64,830	65,540	66,250	66,960	67,670	68,390	69,120	69,850	70,580	71,320	72,050	72,790	73,530	74,280	75,020	75,770	76,520	63
64	62,740	63,490	64,230	64,990	65,740	66,500	67,260	68,020	68,790	69,570	70,340	71,130	71,910	72,700	73,490	74,280	75,080	75,880	76,680	77,480	78,290	64
65	63,450	64,240	65,040	65,850	66,650	67,460	68,280	69,090	69,910	70,740	71,570	72,410	73,240	74,080	74,930	75,780	76,630	77,480	78,340	79,200	80,070	65
66	64,160	65,010	65,860	66,710	67,570	68,430	69,300	70,170	71,040	71,920	72,800	73,690	74,580	75,480	76,370	77,280	78,180	79,090	80,010	80,930	81,850	66
67	64,160	65,010	65,860	66,710	67,570	68,430	69,300	70,170	71,040	71,920	72,800	73,690	74,580	75,480	76,370	77,280	78,180	79,090	80,010	80,930	81,850	67
68	64,160	65,010	65,860	66,710	67,570	68,430	69,300	70,170	71,040	71,920	72,800	73,690	74,580	75,480	76,370	77,280	78,180	79,090	80,010	80,930	81,850	68
69	64,160	65,010	65,860	66,710	67,570	68,430	69,300	70,170	71,040	71,920	72,800	73,690	74,580	75,480	76,370	77,280	78,180	79,090	80,010	80,930	81,850	69
70	64,160	65,010	65,860	66,710	67,570	68,430	69,300	70,170	71,040	71,920	72,800	73,690	74,580	75,480	76,370	77,280	78,180	79,090	80,010	80,930	81,850	70

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE OPENING-MENT	HEADWATER ELEVATION																					GATE OPENING-MENT
	984.0	984.1	984.2	984.3	984.4	984.5	984.6	984.7	984.8	984.9	985.0	985.1	985.2	985.3	985.4	985.5	985.6	985.7	985.8	985.9	986.0	
1	1,000	1,010	1,010	1,020	1,020	1,020	1,030	1,030	1,030	1,040	1,040	1,040	1,050	1,050	1,060	1,060	1,060	1,070	1,070	1,070	1,080	1
2	1,990	2,000	2,000	2,010	2,020	2,030	2,030	2,040	2,050	2,050	2,060	2,070	2,080	2,080	2,090	2,100	2,100	2,110	2,120	2,120	2,130	2
3	2,930	2,940	2,960	2,970	2,980	2,990	3,000	3,010	3,020	3,030	3,040	3,050	3,060	3,070	3,080	3,090	3,100	3,110	3,120	3,130	3,140	3
4	3,920	3,930	3,950	3,960	3,970	3,990	4,000	4,020	4,030	4,040	4,060	4,070	4,090	4,100	4,110	4,130	4,140	4,150	4,170	4,180	4,190	4
5	4,950	4,960	4,980	5,000	5,020	5,040	5,050	5,070	5,090	5,110	5,120	5,140	5,160	5,180	5,190	5,210	5,230	5,240	5,260	5,280	5,300	5
6	5,870	5,900	5,920	5,940	5,960	5,980	6,000	6,020	6,040	6,060	6,090	6,110	6,130	6,150	6,170	6,190	6,210	6,230	6,250	6,270	6,290	6
7	6,800	6,830	6,850	6,880	6,900	6,930	6,950	6,970	7,000	7,020	7,050	7,070	7,100	7,120	7,140	7,170	7,190	7,210	7,240	7,260	7,280	7
8	7,740	7,770	7,800	7,820	7,850	7,880	7,910	7,940	7,960	7,990	8,020	8,050	8,070	8,100	8,130	8,150	8,180	8,210	8,230	8,260	8,290	8
9	8,750	8,780	8,810	8,840	8,870	8,910	8,940	8,970	9,000	9,030	9,060	9,090	9,120	9,150	9,180	9,220	9,250	9,280	9,310	9,340	9,370	9
10	9,760	9,790	9,830	9,860	9,900	9,930	9,970	10,000	10,040	10,070	10,110	10,140	10,180	10,210	10,240	10,280	10,310	10,350	10,380	10,410	10,450	10
11	10,770	10,810	10,850	10,890	10,930	10,970	11,010	11,040	11,080	11,120	11,160	11,200	11,230	11,270	11,310	11,350	11,380	11,420	11,460	11,500	11,530	11
12	11,880	11,920	11,960	12,010	12,050	12,100	12,140	12,180	12,220	12,270	12,310	12,350	12,390	12,440	12,480	12,520	12,560	12,600	12,650	12,690	12,730	12
13	12,970	13,020	13,070	13,120	13,170	13,220	13,260	13,310	13,360	13,410	13,450	13,500	13,550	13,590	13,640	13,680	13,730	13,780	13,820	13,870	13,910	13
14	14,080	14,130	14,180	14,240	14,290	14,340	14,390	14,450	14,500	14,550	14,600	14,650	14,700	14,750	14,800	14,850	14,900	14,950	15,000	15,050	15,100	14
15	15,170	15,230	15,290	15,350	15,400	15,460	15,520	15,570	15,630	15,680	15,740	15,800	15,850	15,910	15,960	16,010	16,070	16,120	16,180	16,230	16,290	15
16	16,220	16,280	16,340	16,410	16,470	16,530	16,590	16,650	16,710	16,770	16,830	16,890	16,950	17,010	17,070	17,120	17,180	17,240	17,300	17,360	17,420	16
17	17,310	17,380	17,450	17,520	17,580	17,650	17,710	17,780	17,840	17,910	17,970	18,040	18,100	18,160	18,230	18,290	18,350	18,420	18,480	18,540	18,600	17
18	18,420	18,500	18,570	18,640	18,710	18,780	18,850	18,920	18,990	19,060	19,130	19,200	19,260	19,330	19,400	19,470	19,530	19,600	19,670	19,730	19,800	18
19	19,520	19,600	19,680	19,750	19,830	19,900	19,980	20,050	20,120	20,200	20,270	20,340	20,410	20,490	20,560	20,630	20,700	20,770	20,840	20,910	20,980	19
20	20,610	20,690	20,780	20,860	20,940	21,020	21,100	21,170	21,250	21,330	21,410	21,480	21,560	21,640	21,710	21,790	21,860	21,940	22,010	22,090	22,160	20
21	21,700	21,790	21,880	21,960	22,050	22,130	22,210	22,300	22,380	22,460	22,540	22,620	22,700	22,790	22,870	22,950	23,030	23,100	23,180	23,260	23,340	21
22	22,790	22,880	22,980	23,070	23,160	23,240	23,330	23,420	23,500	23,590	23,680	23,760	23,850	23,930	24,020	24,100	24,190	24,270	24,350	24,440	24,520	22
23	23,870	23,970	24,070	24,160	24,260	24,350	24,450	24,540	24,630	24,720	24,820	24,910	25,000	25,090	25,180	25,270	25,360	25,450	25,540	25,630	25,720	23
24	24,930	25,030	25,130	25,240	25,340	25,440	25,540	25,640	25,730	25,830	25,930	26,030	26,130	26,220	26,320	26,420	26,510	26,610	26,700	26,800	26,890	24
25	25,980	26,090	26,200	26,300	26,410	26,520	26,620	26,730	26,830	26,940	27,040	27,150	27,250	27,350	27,450	27,560	27,660	27,760	27,860	27,960	28,060	25
26	27,020	27,140	27,250	27,370	27,480	27,590	27,700	27,820	27,930	28,040	28,150	28,260	28,370	28,470	28,580	28,690	28,800	28,910	29,010	29,120	29,230	26
27	28,070	28,190	28,310	28,430	28,550	28,670	28,780	28,900	29,020	29,130	29,250	29,370	29,480	29,600	29,710	29,820	29,940	30,050	30,170	30,280	30,390	27
28	29,110	29,230	29,360	29,490	29,610	29,740	29,860	29,980	30,110	30,230	30,350	30,470	30,590	30,710	30,830	30,950	31,070	31,190	31,310	31,430	31,550	28
29	30,170	30,300	30,430	30,560	30,690	30,820	30,950	31,080	31,210	31,340	31,470	31,600	31,720	31,850	31,980	32,100	32,230	32,350	32,480	32,600	32,730	29
30	31,200	31,340	31,480	31,620	31,760	31,890	32,030	32,160	32,300	32,430	32,560	32,700	32,830	32,960	33,100	33,230	33,360	33,490	33,620	33,750	33,880	30
31	32,260	32,400	32,550	32,690	32,830	32,970	33,120	33,260	33,400	33,540	33,680	33,820	33,960	34,090	34,230	34,370	34,510	34,650	34,780	34,920	35,050	31
32	33,310	33,460	33,610	33,760	33,910	34,060	34,200	34,350	34,500	34,640	34,790	34,940	35,080	35,230	35,370	35,510	35,660	35,800	35,940	36,080	36,230	32
33	34,360	34,520	34,670	34,830	34,980	35,140	35,290	35,440	35,590	35,750	35,900	36,050	36,200	36,350	36,500	36,650	36,800	36,950	37,100	37,250	37,390	33
34	35,440	35,600	35,770	35,930	36,090	36,250	36,410	36,570	36,720	36,880	37,040	37,200	37,350	37,510	37,670	37,820	37,980	38,130	38,280	38,440	38,590	34
35	36,530	36,690	36,860	37,030	37,190	37,360	37,530	37,690	37,850	38,020	38,180	38,340	38,510	38,670	38,830	38,990	39,150	39,310	39,470	39,630	39,790	35
36	37,620	37,790	37,960	38,140	38,310	38,480	38,650	38,820	38,990	39,160	39,330	39,500	39,660	39,830	40,000	40,170	40,330	40,500	40,660	40,830	40,990	36
37	38,700	38,880	39,050	39,230	39,410	39,590	39,770	39,940	40,120	40,290	40,470	40,640	40,810	40,990	41,160	41,330	41,500	41,670	41,840	42,010	42,180	37
38	39,760	39,950	40,130	40,310	40,500	40,680	40,860	41,040	41,230	41,410	41,590	41,770	41,940	42,120	42,300	42,480	42,650	42,830	43,010	43,180	43,360	38
39	40,840	41,030	41,220	41,410	41,600	41,790	41,980	42,170	42,350	42,540	42,730	42,910	43,100	43,280	43,460	43,650	43,830	44,010	44,190	44,370	44,550	39
40	41,930	42,130	42,330	42,520	42,720	42,910	43,110	43,300	43,490	43,680	43,870	44,070	44,260	44,440	44,630	44,820	45,010	45,200	45,380	45,570	45,750	40
41	43,020	43,220	43,430	43,630	43,830	44,030	44,230	44,430	44,630	44,820	45,020	45,220	45,410	45,610	45,800	45,990	46,190	46,380	46,570	46,760	46,950	41
42	44,100	44,310	44,520	44,730	44,930	45,140	45,340	45,550	45,750	45,950	46,160	46,360	46,560	46,760	46,960	47,160	47,360	47,560	47,750	47,950	48,150	42
43	45,180	45,400	45,610	45,820	46,030	46,250	46,460	46,670	46,880	47,090	47,290	47,500	47,710	47,910	48,120	48,320	48,530	48,730	48,930	49,140	49,340	43
44	46,260	46,480	46,700	46,920	47,140	47,350	47,570	47,790	48,000	48,220	48,430	48,640	48,860	49,070	49,280	49,490	49,700	49,910	50,110	50,320	50,530	44
45	47,720	47,950	48,180	48,400	48,630	48,850	49,070	49,290	49,520	49,740	49,950	50,170	50,390	50,610	50,820	51,040	51,250	51,470	51,680	51,890	52,110	45
46	49,190	49,420	49,650	49,890	50,120	50,350	50,580	50,800	51,030	51,260	51,480	51,710	51,930	52,150	52,370	52,590	52,810	53,030	53,250	53,470	53,700	46
47	50,660	50,900	51,130	51,370	51,610	51,850	52,080	52,310	52,550	52,780	53,010	53,240	53,470	53,700	53,930	54,150	54,380	54,600	54,830	55,060	55,290	47
48	52,120	52,360	52,610	52,850	53,100	53,340	53,580	53,820	54,060	54,300	54,530	54,770	55,000	55,240	55,470	55,700	55,930	56,160	56,400	56,640	56,880	48
49	53,550	53,800	54,050	54,310	54,550	54,800	55,050	55,300	55,540	55,780	56,030	56,270	56,510	56,750	56,990	57,220	57,460	57,690	57,930	58,180	58,430	49
50	54,990	55,250	55,510	55,770	56,030	56,280	56,530	56,780	57,040	57,280	57,530	57,780	58,030	58,270	58,510	58,760	59,000	59,240	59,480	59,740	60,000	50
51	56,460	56,730	56,990	57,260	57,520	57,780	58,040	58,300	58,550	58,810	59,060	59,320	59,570	59,820	60,070	60,310	60,560	60,810	61,060	61,330	61,590	51
52	57,930	58,200	58,470	58,740	59,010	59,280	59,540	59,810	60,070	60,330	60,590	60,850	61,110	61,360	61,620	61,870	62,120	62,370	62,640	62,910	63,190	52
53	59,390	59,670	59,950	60,230	60,500	60,780	61,050	61,320	61,590	61,850	62,120	62,380	62,650	62,910	63,170	63,420	63,680	63,940	64,210	64,490	64,770	53
54	60,860	61,140	61,430	61,710	61,990	62,270	62,550	62,820	63,100	63,370	63,640	63,910	64,180	64,450	64,710	64,980	65,240	65,500	65,770	66,070	66,360	54
55	62,310	62,600	62,890	63,180	63,470	63,750	64,040	64,320	64,600	64,880	65,160	65,430	65,710	65,980	66,250	66,520	66,790	67,050	67,330	67,630	67,930	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	984.0	984.1	984.2	984.3	984.4	984.5	984.6	984.7	984.8	984.9	985.0	985.1	985.2	985.3	985.4	985.5	985.6	985.7	985.8	985.9	986.0	
56	64,030	64,380	64,730	65,080	65,430	65,770	66,110	66,460	66,800	67,080	67,340	67,600	67,860	68,120	68,380	68,640	68,900	69,160	69,430	69,730	70,030	56
57	65,810	66,210	66,620	67,030	67,430	67,840	68,240	68,650	68,980	69,240	69,490	69,740	69,980	70,230	70,480	70,730	70,980	71,230	71,510	71,810	72,110	57
58	67,610	68,080	68,540	69,010	69,470	69,940	70,400	70,820	71,140	71,390	71,620	71,860	72,090	72,330	72,570	72,820	73,060	73,300	73,580	73,880	74,180	58
59	69,400	69,930	70,450	70,970	71,500	72,030	72,550	72,990	73,290	73,530	73,750	73,970	74,190	74,420	74,660	74,890	75,120	75,370	75,650	75,950	76,250	59
60	71,120	71,710	72,290	72,870	73,450	74,030	74,620	75,120	75,410	75,630	75,840	76,040	76,250	76,470	76,700	76,920	77,140	77,380	77,660	77,960	78,270	60
61	72,870	73,500	74,140	74,780	75,420	76,060	76,710	77,230	77,510	77,720	77,920	78,100	78,300	78,510	78,730	78,950	79,160	79,390	79,670	79,980	80,280	61
62	74,680	75,370	76,070	76,770	77,470	78,170	78,870	79,410	79,680	79,880	80,050	80,230	80,410	80,620	80,830	81,030	81,240	81,470	81,750	82,060	82,360	62
63	76,520	77,270	78,030	78,790	79,550	80,310	81,040	81,560	81,810	82,000	82,160	82,320	82,500	82,700	82,900	83,100	83,300	83,530	83,820	84,120	84,420	63
64	78,290	79,100	79,920	80,730	81,550	82,380	83,160	83,740	83,980	84,150	84,300	84,450	84,610	84,800	84,990	85,180	85,370	85,600	85,890	86,190	86,500	64
65	80,070	80,940	81,810	82,690	83,560	84,450	85,300	85,940	86,170	86,320	86,460	86,590	86,740	86,920	87,100	87,280	87,460	87,680	87,970	88,280	88,580	65
66	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,110	88,330	88,470	88,590	88,710	88,850	89,020	89,190	89,360	89,540	89,750	90,040	90,350	90,650	66
67	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,110	88,330	88,530	88,730	88,930	89,140	89,390	89,640	89,880	90,130	90,420	90,790	91,160	91,530	67
68	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,110	88,400	88,680	88,960	89,230	89,520	89,850	90,170	90,480	90,810	91,170	91,600	92,040	92,470	68
69	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,160	88,530	88,880	89,230	89,580	89,950	90,350	90,740	91,130	91,530	91,960	92,460	92,950	93,450	69
70	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,200	88,640	89,070	89,500	89,930	90,370	90,840	91,310	91,770	92,250	92,740	93,300	93,860	94,420	70
71	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,200	88,710	89,220	89,720	90,220	90,740	91,280	91,820	92,360	92,900	93,470	94,090	94,720	95,340	71
72	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,230	88,810	89,390	89,970	90,550	91,140	91,750	92,360	92,970	93,590	94,230	94,910	95,590	96,270	72
73	81,850	82,780	83,710	84,640	85,580	86,520	87,430	88,280	88,940	89,590	90,250	90,910	91,570	92,250	92,940	93,620	94,310	95,020	95,760	96,510	97,250	73
74	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,390	89,130	89,860	90,590	91,320	92,060	92,820	93,570	94,330	95,090	95,860	96,670	97,470	98,280	74
75	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,400	89,210	90,020	90,830	91,640	92,450	93,280	94,110	94,940	95,780	96,620	97,490	98,360	99,230	75
76	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,400	89,280	90,160	91,050	91,930	92,830	93,730	94,630	95,540	96,450	97,370	98,300	99,230	100,200	76
77	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,420	89,380	90,330	91,300	92,260	93,230	94,210	95,180	96,170	97,150	98,140	99,130	100,100	101,100	77
78	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,420	89,380	90,330	91,300	92,260	93,230	94,210	95,180	96,170	97,150	98,140	99,130	100,100	101,100	78
79	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,420	89,380	90,330	91,300	92,260	93,230	94,210	95,180	96,170	97,150	98,140	99,130	100,100	101,100	79
80	81,850	82,780	83,710	84,640	85,580	86,520	87,470	88,420	89,380	90,330	91,300	92,260	93,230	94,210	95,180	96,170	97,150	98,140	99,130	100,100	101,100	80

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	986.0	986.1	986.2	986.3	986.4	986.5	986.6	986.7	986.8	986.9	987.0	987.1	987.2	987.3	987.4	987.5	987.6	987.7	987.8	987.9	988.0	
1	1,080	1,080	1,080	1,090	1,090	1,090	1,100	1,100	1,100	1,110	1,110	1,110	1,120	1,120	1,120	1,130	1,130	1,130	1,140	1,140	1,140	1
2	2,130	2,140	2,140	2,150	2,160	2,160	2,170	2,180	2,180	2,190	2,200	2,200	2,210	2,220	2,220	2,230	2,240	2,240	2,250	2,260	2,260	2
3	3,140	3,150	3,160	3,170	3,180	3,190	3,200	3,210	3,220	3,230	3,240	3,250	3,260	3,270	3,280	3,290	3,300	3,310	3,320	3,330	3,340	3
4	4,190	4,210	4,220	4,230	4,250	4,260	4,270	4,290	4,300	4,310	4,330	4,340	4,350	4,370	4,380	4,390	4,400	4,420	4,430	4,440	4,450	4
5	5,300	5,310	5,330	5,350	5,360	5,380	5,400	5,410	5,430	5,450	5,460	5,480	5,490	5,510	5,530	5,540	5,560	5,580	5,590	5,610	5,620	5
6	6,290	6,310	6,330	6,350	6,370	6,390	6,410	6,430	6,450	6,470	6,490	6,510	6,530	6,550	6,560	6,580	6,600	6,620	6,640	6,660	6,680	6
7	7,280	7,310	7,330	7,350	7,380	7,400	7,420	7,450	7,470	7,490	7,510	7,540	7,560	7,580	7,600	7,630	7,650	7,670	7,690	7,710	7,740	7
8	8,290	8,310	8,340	8,370	8,390	8,420	8,440	8,470	8,500	8,520	8,550	8,570	8,600	8,620	8,650	8,680	8,700	8,730	8,750	8,780	8,800	8
9	9,370	9,400	9,430	9,460	9,480	9,510	9,540	9,570	9,600	9,630	9,660	9,690	9,720	9,750	9,780	9,800	9,830	9,860	9,890	9,920	9,950	9
10	10,450	10,480	10,510	10,550	10,580	10,610	10,640	10,680	10,710	10,740	10,770	10,810	10,840	10,870	10,900	10,940	10,970	11,000	11,030	11,060	11,090	10
11	11,530	11,570	11,610	11,640	11,680	11,720	11,750	11,790	11,820	11,860	11,900	11,930	11,970	12,000	12,040	12,070	12,110	12,140	12,180	12,210	12,250	11
12	12,730	12,770	12,810	12,850	12,890	12,930	12,970	13,010	13,050	13,090	13,130	13,170	13,210	13,250	13,290	13,330	13,370	13,410	13,450	13,490	13,520	12
13	13,910	13,960	14,000	14,050	14,090	14,140	14,180	14,230	14,270	14,320	14,360	14,400	14,450	14,490	14,530	14,580	14,620	14,660	14,710	14,750	14,790	13
14	15,100	15,150	15,200	15,250	15,300	15,350	15,400	15,450	15,490	15,540	15,590	15,640	15,690	15,730	15,780	15,830	15,880	15,920	15,970	16,020	16,060	14
15	16,290	16,340	16,390	16,450	16,500	16,550	16,600	16,660	16,710	16,760	16,810	16,870	16,920	16,970	17,020	17,070	17,120	17,170	17,220	17,280	17,330	15
16	17,420	17,470	17,530	17,590	17,640	17,700	17,760	17,810	17,870	17,930	17,980	18,040	18,090	18,150	18,210	18,260	18,320	18,370	18,420	18,480	18,530	16
17	18,600	18,660	18,730	18,790	18,850	18,910	18,970	19,030	19,090	19,150	19,210	19,270	19,330	19,390	19,450	19,510	19,570	19,630	19,680	19,740	19,800	17
18	19,800	19,870	19,930	20,000	20,060	20,130	20,190	20,260	20,320	20,390	20,450	20,510	20,580	20,640	20,700	20,770	20,830	20,890	20,960	21,020	21,080	18
19	20,980	21,050	21,120	21,190	21,260	21,330	21,400	21,470	21,540	21,610	21,680	21,740	21,810	21,880	21,950	22,010	22,080	22,150	22,210	22,280	22,350	19
20	22,160	22,240	22,310	22,390	22,460	22,530	22,610	22,680	22,750	22,820	22,900	22,970	23,040	23,110	23,180	23,250	23,320	23,390	23,470	23,540	23,610	20
21	23,340	23,420	23,500	23,580	23,650	23,730	23,810	23,890	23,960	24,040	24,120	24,190	24,270	24,340	24,420	24,490	24,570	24,640	24,720	24,790	24,860	21
22	24,520	24,600	24,680	24,770	24,850	24,930	25,010	25,090	25,170	25,250	25,330	25,410	25,490	25,570	25,650	25,730	25,810	25,890	25,970	26,040	26,120	22
23	25,720	25,810	25,900	25,980	26,070	26,160	26,240	26,330	26,410	26,500	26,580	26,670	26,750	26,840	26,920	27,000	27,090	27,170	27,250	27,340	27,420	23
24	26,890	26,990	27,080	27,170	27,260	27,360	27,450	27,540	27,630	27,720	27,810	27,890	27,980	28,070	28,160	28,250	28,340	28,420	28,510	28,600	28,680	24
25	28,060	28,160	28,260	28,360	28,450	28,550	28,640	28,740	28,830	28,930	29,020	29,110	29,210	29,300	29,390	29,490	29,580	29,670	29,760	29,850	29,940	25
26	29,230	29,330	29,440	29,540	29,640	29,740	29,840	29,940	30,030	30,130	30,230	30,330	30,430	30,530	30,620	30,720	30,820	30,910	31,010	31,100	31,200	26
27	30,390	30,500	30,610	30,710	30,820	30,920	31,030	31,130	31,230	31,340	31,440	31,540	31,650	31,750	31,850	31,950	32,050	32,150	32,250	32,350	32,450	27
28	31,550	31,660	31,780	31,890	32,000	32,100	32,210	32,320	32,430	32,540	32,640	32,750	32,860	32,960	33,070	33,180	33,280	33,390	33,490	33,590	33,700	28
29	32,730	32,850	32,960	33,080	33,190	33,310	33,420	33,530	33,640	33,760	33,870	33,980	34,090	34,200	34,310	34,420	34,530	34,640	34,750	34,860	34,970	29
30	33,880	34,010	34,130	34,250	34,360	34,480	34,600	34,720	34,830	34,950	35,070	35,180	35,300	35,410	35,530	35,640	35,760	35,870	35,980	36,100	36,210	30
31	35,050	35,180	35,310	35,430	35,560	35,680	35,800	35,920	36,040	36,170	36,290	36,410	36,530	36,650	36,770	36,880	37,000	37,120	37,240	37,360	37,470	31
32	36,230	36,360	36,490	36,620	36,750	36,880	37,000	37,130	37,260	37,380	37,510	37,630	37,760	37,880	38,000	38,130	38,250	38,370	38,490	38,620	38,740	32
33	37,390	37,540	37,670	37,800	37,940	38,070	38,200	38,330	38,460	38,590	38,720	38,850	38,980	39,110	39,240	39,360	39,490	39,620	39,740	39,870	40,000	33
34	38,590	38,740	38,880	39,020	39,160	39,300	39,430	39,570	39,710	39,850	39,980	40,120	40,250	40,390	40,520	40,660	40,790	40,920	41,060	41,190	41,320	34
35	39,790	39,940	40,090	40,230	40,380	40,520	40,670	40,810	40,960	41,100	41,240	41,390	41,530	41,670	41,810	41,950	42,090	42,230	42,370	42,510	42,650	35
36	40,990	41,150	41,300	41,460	41,610	41,760	41,910	42,060	42,210	42,360	42,510	42,660	42,810	42,960	43,100	43,250	43,400	43,540	43,690	43,830	43,980	36
37	42,180	42,350	42,510	42,670	42,830	42,980	43,140	43,300	43,450	43,610	43,770	43,920	44,080	44,230	44,390	44,540	44,690	44,840	45,000	45,150	45,300	37
38	43,360	43,530	43,690	43,860	44,020	44,190	44,350	44,520	44,680	44,840	45,000	45,170	45,330	45,490	45,650	45,810	45,970	46,130	46,280	46,440	46,600	38
39	44,550	44,730	44,900	45,070	45,240	45,420	45,590	45,760	45,930	46,090	46,260	46,430	46,600	46,770	46,930	47,100	47,260	47,430	47,590	47,760	47,920	39
40	45,750	45,940	46,120	46,300	46,470	46,650	46,830	47,000	47,180	47,360	47,530	47,710	47,880	48,050	48,230	48,400	48,570	48,740	48,910	49,080	49,250	40
41	46,950	47,140	47,330	47,510	47,700	47,880	48,070	48,250	48,430	48,610	48,800	48,980	49,160	49,340	49,520	49,700	49,870	50,050	50,230	50,400	50,570	41
42	48,150	48,340	48,530	48,730	48,920	49,110	49,300	49,490	49,680	49,860	50,050	50,240	50,430	50,610	50,800	50,980	51,170	51,350	51,540	51,720	51,890	42
43	49,340	49,540	49,740	49,940	50,130	50,330	50,530	50,720	50,920	51,110	51,310	51,500	51,690	51,890	52,080	52,270	52,460	52,650	52,840	53,030	53,210	43
44	50,530	50,730	50,940	51,140	51,350	51,550	51,760	51,960	52,160	52,360	52,560	52,760	52,960	53,160	53,360	53,560	53,760	53,950	54,150	54,340	54,530	44
45	52,110	52,320	52,540	52,750	52,970	53,180	53,390	53,600	53,810	54,020	54,230	54,440	54,650	54,850	55,060	55,270	55,470	55,680	55,880	56,080	56,280	45
46	53,700	53,920	54,140	54,370	54,590	54,810	55,030	55,250	55,470	55,680	55,900	56,120	56,330	56,550	56,760	56,980	57,190	57,410	57,620	57,830	58,030	46
47	55,290	55,520	55,750	55,980	56,210	56,440	56,670	56,900	57,130	57,350	57,580	57,800	58,030	58,250	58,470	58,700	58,920	59,140	59,360	59,580	59,790	47
48	56,880	57,120	57,360	57,600	57,830	58,070	58,310	58,550	58,780	59,020	59,250	59,480	59,710	59,950	60,180	60,410	60,640	60,870	61,100	61,320	61,540	48
49	58,430	58,680	58,930	59,170	59,420	59,670	59,910	60,160	60,400	60,640	60,880	61,130	61,370	61,610	61,840	62,080	62,320	62,560	62,790	63,030	63,260	49
50	60,000	60,260	60,510	60,770	61,020	61,280	61,530	61,780	62,030	62,290	62,540	62,790	63,030	63,280	63,530	63,780	64,020	64,270	64,510	64,750	64,990	50
51	61,590	61,860	62,120	62,390	62,650	62,920	63,180	63,440	63,700	63,960	64,220	64,470	64,730	64,990	65,240	65,500	65,750	66,000	66,260	66,510	66,750	51
52	63,190	63,460	63,740	64,010	64,280	64,550	64,820	65,090	65,360	65,630	65,890	66,160	66,430	66,690	66,950	67,220	67,480	67,740	68,000	68,260	68,510	52
53	64,770	65,060	65,340	65,620	65,900	66,180	66,460	66,740	67,020	67,290	67,570	67,840	68,110	68,390	68,660	68,930	69,200	69,470	69,740	70,000	70,270	53
54	66,360	66,650	66,940	67,230	67,520	67,810	68,100	68,380	68,670	68,950	69,240	69,520	69,800	70,080	70,360	70,640	70,920	71,190	71,470	71,740	72,020	54
55	67,930	68,240	68,540	68,830	69,130	69,430	69,720	70,020	70,310	70,600	70,900	71,190	71,480	71,760	72,050	72,340	72,620	72,910	73,190	73,480	73,760	55

DOUGLAS DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	986.0	986.1	986.2	986.3	986.4	986.5	986.6	986.7	986.8	986.9	987.0	987.1	987.2	987.3	987.4	987.5	987.6	987.7	987.8	987.9	988.0	
56	70,030	70,330	70,630	70,930	71,220	71,520	71,810	72,110	72,400	72,700	73,000	73,300	73,600	73,890	74,190	74,480	74,780	75,070	75,360	75,650	75,940	56
57	72,110	72,410	72,710	73,010	73,300	73,600	73,890	74,180	74,480	74,790	75,100	75,410	75,710	76,020	76,320	76,620	76,920	77,220	77,520	77,820	78,120	57
58	74,180	74,480	74,780	75,080	75,380	75,670	75,960	76,260	76,570	76,880	77,200	77,520	77,830	78,140	78,450	78,760	79,070	79,380	79,690	79,990	80,300	58
59	76,250	76,550	76,850	77,150	77,440	77,740	78,030	78,330	78,640	78,970	79,290	79,620	79,940	80,260	80,580	80,900	81,210	81,530	81,840	82,160	82,470	59
60	78,270	78,570	78,870	79,160	79,460	79,750	80,040	80,340	80,660	81,000	81,330	81,660	81,990	82,320	82,650	82,970	83,290	83,620	83,940	84,260	84,580	60
61	80,280	80,580	80,880	81,180	81,470	81,760	82,050	82,350	82,680	83,020	83,370	83,710	84,040	84,380	84,710	85,050	85,380	85,710	86,040	86,360	86,690	61
62	82,360	82,660	82,960	83,260	83,550	83,840	84,130	84,430	84,780	85,130	85,470	85,820	86,170	86,510	86,850	87,190	87,530	87,870	88,210	88,540	88,870	62
63	84,420	84,730	85,020	85,320	85,610	85,900	86,190	86,510	86,860	87,220	87,570	87,930	88,280	88,640	88,990	89,330	89,680	90,030	90,370	90,710	91,050	63
64	86,500	86,800	87,090	87,390	87,680	87,970	88,260	88,580	88,930	89,300	89,670	90,030	90,390	90,750	91,110	91,470	91,820	92,170	92,520	92,870	93,220	64
65	88,580	88,880	89,180	89,480	89,770	90,050	90,340	90,660	91,030	91,400	91,770	92,150	92,520	92,880	93,250	93,610	93,980	94,340	94,690	95,050	95,400	65
66	90,650	90,950	91,250	91,540	91,840	92,120	92,410	92,730	93,100	93,490	93,870	94,250	94,630	95,000	95,380	95,750	96,120	96,480	96,850	97,210	97,570	66
67	91,530	91,890	92,250	92,610	92,970	93,320	93,680	94,060	94,510	94,950	95,390	95,830	96,270	96,710	97,150	97,580	98,010	98,440	98,870	99,300	99,730	67
68	92,470	92,900	93,320	93,750	94,170	94,590	95,020	95,470	95,970	96,480	96,980	97,480	97,980	98,480	98,980	99,470	99,970	100,500	101,000	101,500	101,900	68
69	93,450	93,940	94,440	94,930	95,420	95,900	96,390	96,910	97,470	98,040	98,600	99,160	99,720	100,300	100,800	101,400	102,000	102,500	103,100	103,600	104,200	69
70	94,420	94,980	95,540	96,100	96,650	97,210	97,770	98,340	98,970	99,590	100,200	100,800	101,500	102,100	102,700	103,300	103,900	104,600	105,200	105,800	106,400	70
71	95,340	95,960	96,580	97,200	97,820	98,440	99,060	99,700	100,400	101,100	101,700	102,400	103,100	103,800	104,500	105,200	105,800	106,500	107,200	107,900	108,600	71
72	96,270	96,950	97,640	98,320	99,000	99,690	100,400	101,100	101,800	102,600	103,300	104,000	104,800	105,500	106,300	107,000	107,700	108,500	109,200	110,000	110,700	72
73	97,250	98,000	98,750	99,500	100,200	101,000	101,800	102,500	103,300	104,100	104,900	105,700	106,500	107,300	108,100	108,900	109,700	110,500	111,400	112,200	113,000	73
74	98,280	99,100	99,910	100,700	101,500	102,400	103,200	104,000	104,900	105,700	106,600	107,400	108,300	109,200	110,000	110,900	111,800	112,700	113,500	114,400	115,300	74
75	99,230	100,100	101,000	101,900	102,800	103,600	104,500	105,400	106,300	107,300	108,200	109,100	110,000	110,900	111,900	112,800	113,700	114,700	115,600	116,600	117,500	75
76	100,200	101,100	102,100	103,000	104,000	104,900	105,900	106,800	107,800	108,800	109,800	110,700	111,700	112,700	113,700	114,700	115,700	116,700	117,700	118,700	119,700	76
77	101,100	102,100	103,100	104,200	105,200	106,200	107,200	108,200	109,300	110,300	111,400	112,400	113,400	114,500	115,600	116,600	117,700	118,700	119,800	120,900	122,000	77
78	101,100	102,100	103,100	104,200	105,200	106,200	107,200	108,200	109,300	110,300	111,400	112,400	113,400	114,500	115,600	116,600	117,700	118,700	119,800	120,900	122,000	78
79	101,100	102,100	103,100	104,200	105,200	106,200	107,200	108,200	109,300	110,300	111,400	112,400	113,400	114,500	115,600	116,600	117,700	118,700	119,800	120,900	122,000	79
80	101,100	102,100	103,100	104,200	105,200	106,200	107,200	108,200	109,300	110,300	111,400	112,400	113,400	114,500	115,600	116,600	117,700	118,700	119,800	120,900	122,000	80

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	988.0	988.1	988.2	988.3	988.4	988.5	988.6	988.7	988.8	988.9	989.0	989.1	989.2	989.3	989.4	989.5	989.6	989.7	989.8	989.9	990.0	
1	1,140	1,150	1,150	1,150	1,160	1,160	1,160	1,170	1,170	1,170	1,170	1,180	1,180	1,180	1,190	1,190	1,190	1,200	1,200	1,200	1,210	1
2	2,260	2,270	2,280	2,280	2,290	2,290	2,300	2,310	2,310	2,320	2,330	2,330	2,340	2,340	2,350	2,360	2,360	2,370	2,380	2,380	2,390	2
3	3,340	3,350	3,350	3,360	3,370	3,380	3,390	3,400	3,410	3,420	3,430	3,440	3,450	3,460	3,470	3,470	3,480	3,490	3,500	3,510	3,520	3
4	4,450	4,470	4,480	4,490	4,500	4,520	4,530	4,540	4,550	4,570	4,580	4,590	4,600	4,620	4,630	4,640	4,650	4,660	4,680	4,690	4,700	4
5	5,620	5,640	5,660	5,670	5,690	5,700	5,720	5,730	5,750	5,770	5,780	5,800	5,810	5,830	5,840	5,860	5,870	5,890	5,900	5,920	5,930	5
6	6,680	6,700	6,720	6,740	6,750	6,770	6,790	6,810	6,830	6,850	6,870	6,880	6,900	6,920	6,940	6,960	6,980	6,990	7,010	7,030	7,050	6
7	7,740	7,760	7,780	7,800	7,820	7,840	7,870	7,890	7,910	7,930	7,950	7,970	7,990	8,020	8,040	8,060	8,080	8,100	8,120	8,140	8,160	7
8	8,800	8,830	8,850	8,870	8,900	8,920	8,950	8,970	9,000	9,020	9,050	9,070	9,090	9,120	9,140	9,170	9,190	9,210	9,240	9,260	9,290	8
9	9,950	9,970	10,000	10,030	10,060	10,090	10,110	10,140	10,170	10,200	10,220	10,250	10,280	10,310	10,330	10,360	10,390	10,410	10,440	10,470	10,490	9
10	11,090	11,120	11,160	11,190	11,220	11,250	11,280	11,310	11,340	11,370	11,400	11,430	11,460	11,490	11,530	11,560	11,590	11,620	11,650	11,680	11,710	10
11	12,250	12,280	12,320	12,350	12,390	12,420	12,450	12,490	12,520	12,560	12,590	12,620	12,660	12,690	12,720	12,760	12,790	12,820	12,860	12,890	12,920	11
12	13,520	13,560	13,600	13,640	13,680	13,720	13,750	13,790	13,830	13,870	13,910	13,940	13,980	14,020	14,060	14,090	14,130	14,170	14,200	14,240	14,280	12
13	14,790	14,830	14,880	14,920	14,960	15,000	15,040	15,090	15,130	15,170	15,210	15,250	15,290	15,340	15,380	15,420	15,460	15,500	15,540	15,580	15,620	13
14	16,060	16,110	16,160	16,200	16,250	16,290	16,340	16,390	16,430	16,480	16,520	16,570	16,610	16,660	16,700	16,750	16,790	16,840	16,880	16,920	16,970	14
15	17,330	17,380	17,430	17,480	17,530	17,580	17,630	17,680	17,720	17,770	17,820	17,870	17,920	17,970	18,020	18,070	18,110	18,160	18,210	18,260	18,310	15
16	18,530	18,590	18,640	18,700	18,750	18,800	18,860	18,910	18,960	19,020	19,070	19,120	19,170	19,230	19,280	19,330	19,380	19,430	19,480	19,540	19,590	16
17	19,800	19,860	19,920	19,970	20,030	20,090	20,150	20,200	20,260	20,320	20,370	20,430	20,490	20,540	20,600	20,650	20,710	20,770	20,820	20,880	20,930	17
18	21,080	21,140	21,200	21,270	21,330	21,390	21,450	21,510	21,570	21,630	21,690	21,750	21,810	21,870	21,930	21,990	22,050	22,110	22,170	22,230	22,290	18
19	22,350	22,410	22,480	22,540	22,610	22,670	22,740	22,800	22,870	22,930	23,000	23,060	23,120	23,190	23,250	23,310	23,380	23,440	23,500	23,570	23,630	19
20	23,610	23,680	23,740	23,810	23,880	23,950	24,020	24,090	24,160	24,230	24,290	24,360	24,430	24,500	24,560	24,630	24,700	24,760	24,830	24,900	24,960	20
21	24,860	24,940	25,010	25,090	25,160	25,230	25,300	25,380	25,450	25,520	25,590	25,660	25,730	25,810	25,880	25,950	26,020	26,090	26,160	26,230	26,300	21
22	26,120	26,200	26,280	26,350	26,430	26,510	26,580	26,660	26,740	26,810	26,890	26,960	27,040	27,110	27,190	27,260	27,340	27,410	27,490	27,560	27,630	22
23	27,420	27,500	27,580	27,660	27,750	27,830	27,910	27,990	28,070	28,150	28,230	28,310	28,390	28,470	28,550	28,630	28,700	28,780	28,860	28,940	29,020	23
24	28,680	28,770	28,860	28,940	29,030	29,110	29,200	29,280	29,370	29,450	29,540	29,620	29,700	29,790	29,870	29,950	30,040	30,120	30,200	30,280	30,370	24
25	29,940	30,030	30,120	30,210	30,300	30,390	30,480	30,570	30,660	30,750	30,840	30,930	31,010	31,100	31,190	31,280	31,360	31,450	31,540	31,620	31,710	25
26	31,200	31,290	31,390	31,480	31,580	31,670	31,760	31,860	31,950	32,040	32,140	32,230	32,320	32,410	32,500	32,590	32,690	32,780	32,870	32,960	33,050	26
27	32,450	32,550	32,650	32,750	32,850	32,950	33,040	33,140	33,240	33,330	33,430	33,530	33,620	33,720	33,820	33,910	34,010	34,100	34,200	34,290	34,380	27
28	33,700	33,800	33,910	34,010	34,110	34,210	34,320	34,420	34,520	34,620	34,720	34,820	34,920	35,020	35,120	35,220	35,320	35,420	35,520	35,620	35,710	28
29	34,970	35,070	35,180	35,290	35,400	35,500	35,610	35,720	35,820	35,930	36,030	36,140	36,240	36,340	36,450	36,550	36,660	36,760	36,860	36,960	37,070	29
30	36,210	36,320	36,430	36,540	36,660	36,770	36,880	36,990	37,100	37,210	37,320	37,420	37,530	37,640	37,750	37,860	37,960	38,070	38,180	38,280	38,390	30
31	37,470	37,590	37,710	37,820	37,940	38,050	38,170	38,280	38,390	38,510	38,620	38,740	38,850	38,960	39,070	39,180	39,300	39,410	39,520	39,630	39,740	31
32	38,740	38,860	38,980	39,100	39,220	39,340	39,460	39,580	39,690	39,810	39,930	40,050	40,160	40,280	40,400	40,510	40,630	40,740	40,860	40,970	41,090	32
33	40,000	40,120	40,250	40,370	40,490	40,620	40,740	40,860	40,990	41,110	41,230	41,350	41,470	41,590	41,710	41,830	41,950	42,070	42,190	42,310	42,430	33
34	41,320	41,450	41,580	41,710	41,840	41,970	42,100	42,230	42,350	42,480	42,610	42,730	42,860	42,990	43,110	43,240	43,360	43,480	43,610	43,730	43,850	34
35	42,650	42,780	42,920	43,050	43,190	43,320	43,450	43,590	43,720	43,850	43,980	44,110	44,240	44,370	44,500	44,630	44,760	44,890	45,020	45,150	45,280	35
36	43,980	44,120	44,260	44,400	44,540	44,670	44,810	44,950	45,090	45,220	45,360	45,500	45,630	45,770	45,900	46,040	46,170	46,300	46,440	46,570	46,700	36
37	45,300	45,440	45,590	45,730	45,870	46,020	46,160	46,300	46,450	46,590	46,730	46,870	47,010	47,150	47,290	47,430	47,570	47,710	47,840	47,980	48,120	37
38	46,600	46,750	46,900	47,040	47,190	47,340	47,490	47,640	47,780	47,930	48,080	48,220	48,370	48,510	48,660	48,800	48,940	49,090	49,230	49,370	49,510	38
39	47,920	48,070	48,230	48,380	48,530	48,690	48,840	48,990	49,140	49,300	49,450	49,600	49,750	49,900	50,050	50,200	50,340	50,490	50,640	50,790	50,930	39
40	49,250	49,410	49,570	49,730	49,880	50,040	50,200	50,360	50,510	50,670	50,830	50,980	51,140	51,290	51,450	51,600	51,750	51,900	52,060	52,210	52,360	40
41	50,570	50,740	50,900	51,070	51,230	51,390	51,560	51,720	51,880	52,040	52,200	52,360	52,520	52,680	52,840	53,000	53,160	53,310	53,470	53,630	53,780	41
42	51,890	52,060	52,230	52,400	52,570	52,740	52,910	53,070	53,240	53,410	53,570	53,740	53,900	54,060	54,230	54,390	54,550	54,720	54,880	55,040	55,200	42
43	53,210	53,390	53,560	53,730	53,910	54,080	54,250	54,430	54,600	54,770	54,940	55,110	55,280	55,450	55,610	55,780	55,950	56,120	56,280	56,450	56,610	43
44	54,530	54,710	54,890	55,070	55,250	55,430	55,600	55,780	55,960	56,130	56,310	56,480	56,660	56,830	57,000	57,170	57,350	57,520	57,690	57,860	58,030	44
45	56,280	56,460	56,650	56,840	57,030	57,220	57,400	57,590	57,770	57,960	58,140	58,330	58,510	58,690	58,880	59,060	59,240	59,420	59,600	59,780	59,960	45
46	58,030	58,230	58,430	58,620	58,820	59,020	59,210	59,410	59,600	59,800	59,990	60,180	60,370	60,570	60,760	60,950	61,140	61,330	61,520	61,700	61,890	46
47	59,790	60,000	60,200	60,410	60,620	60,820	61,030	61,230	61,440	61,640	61,840	62,040	62,240	62,440	62,640	62,840	63,040	63,240	63,440	63,640	63,830	47
48	61,540	61,760	61,980	62,190	62,410	62,620	62,830	63,050	63,260	63,470	63,680	63,890	64,100	64,310	64,520	64,730	64,940	65,150	65,350	65,560	65,760	48
49	63,260	63,480	63,710	63,930	64,160	64,380	64,600	64,830	65,050	65,270	65,490	65,710	65,930	66,150	66,360	66,580	66,800	67,010	67,230	67,440	67,660	49
50	64,990	65,230	65,460	65,690	65,930	66,160	66,390	66,620	66,850	67,080	67,310	67,540	67,770	68,000	68,220	68,450	68,670	68,900	69,120	69,350	69,570	50
51	66,750	67,000	67,240	67,480	67,730	67,970	68,210	68,450	68,690	68,930	69,170	69,400	69,640	69,880	70,110	70,350	70,580	70,810	71,050	71,280	71,510	51
52	68,510	68,770	69,020	69,270	69,530	69,780	70,030	70,280	70,520	70,770	71,020	71,270	71,510	71,760	72,000	72,240	72,490	72,730	72,970	73,210	73,450	52
53	70,270	70,530	70,790	71,060	71,320	71,580	71,840	72,090	72,350	72,610	72,860	73,120	73,380	73,630	73,880	74,140	74,390	74,640	74,890	75,140	75,390	53
54	72,020	72,290	72,560	72,830	73,100	73,370	73,640	73,910	74,170	74,440	74,710	74,970	75,230	75,500	75,760	76,020	76,280	76,540	76,800	77,060	77,320	54
55	73,760	74,040	74,320	74,600	74,880	75,160	75,440	75,710	75,990	76,260	76,540	76,810	77,080	77,350	77,630	77,900	78,170	78,440	78,700	78,970	79,240	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	988.0	988.1	988.2	988.3	988.4	988.5	988.6	988.7	988.8	988.9	989.0	989.1	989.2	989.3	989.4	989.5	989.6	989.7	989.8	989.9	990.0	
56	75,940	76,230	76,520	76,800	77,090	77,370	77,660	77,940	78,220	78,510	78,790	79,070	79,340	79,620	79,900	80,180	80,450	80,730	81,000	81,280	81,550	56
57	78,120	78,410	78,710	79,000	79,300	79,590	79,880	80,170	80,460	80,740	81,030	81,320	81,600	81,890	82,170	82,450	82,730	83,010	83,300	83,580	83,870	57
58	80,300	80,600	80,900	81,200	81,500	81,800	82,100	82,390	82,690	82,980	83,280	83,570	83,860	84,150	84,440	84,720	85,010	85,300	85,600	85,890	86,190	58
59	82,470	82,780	83,090	83,390	83,700	84,000	84,310	84,610	84,910	85,210	85,510	85,810	86,110	86,400	86,700	86,990	87,280	87,580	87,890	88,190	88,500	59
60	84,580	84,890	85,210	85,520	85,840	86,150	86,460	86,770	87,070	87,380	87,690	87,990	88,290	88,590	88,890	89,190	89,490	89,790	90,110	90,430	90,750	60
61	86,690	87,010	87,330	87,650	87,970	88,290	88,610	88,920	89,240	89,550	89,860	90,170	90,480	90,790	91,090	91,400	91,700	92,010	92,340	92,670	93,000	61
62	88,870	89,200	89,530	89,860	90,190	90,510	90,840	91,160	91,480	91,800	92,110	92,430	92,740	93,060	93,370	93,680	93,990	94,310	94,650	94,990	95,330	62
63	91,050	91,390	91,720	92,060	92,390	92,720	93,050	93,380	93,710	94,030	94,360	94,680	95,000	95,320	95,630	95,950	96,270	96,600	96,950	97,300	97,650	63
64	93,220	93,560	93,910	94,250	94,590	94,930	95,260	95,600	95,930	96,260	96,590	96,920	97,250	97,570	97,890	98,220	98,540	98,880	99,230	99,590	99,960	64
65	95,400	95,760	96,110	96,450	96,800	97,150	97,490	97,830	98,170	98,510	98,840	99,180	99,510	99,840	100,200	100,500	100,800	101,200	101,500	101,900	102,300	65
66	97,570	97,930	98,290	98,650	99,000	99,350	99,700	100,000	100,400	100,700	101,100	101,400	101,800	102,100	102,400	102,800	103,100	103,400	103,800	104,200	104,600	66
67	99,730	100,200	100,600	101,000	101,400	101,800	102,300	102,700	103,100	103,500	103,900	104,300	104,700	105,100	105,600	106,000	106,400	106,800	107,200	107,700	108,000	67
68	101,900	102,400	102,900	103,400	103,900	104,400	104,900	105,400	105,800	106,300	106,800	107,300	107,800	108,300	108,700	109,200	109,700	110,200	110,600	111,000	111,300	68
69	104,200	104,800	105,300	105,900	106,400	107,000	107,500	108,100	108,600	109,200	109,800	110,300	110,900	111,400	112,000	112,500	113,100	113,600	114,000	114,400	114,600	69
70	106,400	107,100	107,700	108,300	108,900	109,600	110,200	110,800	111,400	112,100	112,700	113,300	113,900	114,600	115,200	115,800	116,400	117,000	117,400	117,700	118,000	70
71	108,600	109,300	110,000	110,600	111,300	112,000	112,700	113,400	114,100	114,800	115,500	116,200	116,900	117,600	118,300	119,000	119,700	120,300	120,700	121,000	121,200	71
72	110,700	111,500	112,200	113,000	113,700	114,500	115,300	116,000	116,800	117,500	118,300	119,100	119,800	120,600	121,300	122,100	122,900	123,600	123,900	124,200	124,400	72
73	113,000	113,800	114,600	115,400	116,300	117,100	117,900	118,700	119,600	120,400	121,200	122,100	122,900	123,700	124,600	125,400	126,300	127,000	127,300	127,500	127,700	73
74	115,300	116,200	117,100	117,900	118,800	119,700	120,600	121,500	122,400	123,300	124,200	125,100	126,000	126,900	127,900	128,800	129,700	130,400	130,700	130,900	131,000	74
75	117,500	118,500	119,400	120,400	121,300	122,300	123,200	124,200	125,200	126,200	127,100	128,100	129,100	130,100	131,000	132,000	133,000	133,800	134,000	134,200	134,300	75
76	119,700	120,700	121,800	122,800	123,800	124,800	125,900	126,900	127,900	129,000	130,000	131,100	132,100	133,200	134,200	135,300	136,400	137,200	137,400	137,600	137,600	76
77	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,600	140,800	140,900	141,000	77
78	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,600	140,800	141,000	141,100	78
79	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,600	140,900	141,100	141,400	79
80	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,700	141,000	141,400	141,700	80
81	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,700	141,200	141,600	142,100	81
82	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,700	141,200	141,800	142,300	82
83	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,700	141,400	142,000	142,700	83
84	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,700	141,500	142,200	143,000	84
85	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,800	141,700	142,500	143,400	85
86	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,800	141,800	142,700	143,700	86
87	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,800	141,900	142,900	144,000	87
88	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,900	142,000	143,200	144,300	88
89	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,900	142,000	143,200	144,300	89
90	122,000	123,000	124,100	125,200	126,300	127,400	128,500	129,600	130,700	131,800	132,900	134,100	135,200	136,300	137,400	138,600	139,700	140,900	142,000	143,200	144,300	90

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	990.0	990.1	990.2	990.3	990.4	990.5	990.6	990.7	990.8	990.9	991.0	991.1	991.2	991.3	991.4	991.5	991.6	991.7	991.8	991.9	992.0	
1	1,210	1,210	1,210	1,220	1,220	1,220	1,220	1,230	1,230	1,230	1,240	1,240	1,240	1,250	1,250	1,250	1,250	1,260	1,260	1,260	1,270	1
2	2,390	2,390	2,400	2,410	2,410	2,420	2,420	2,430	2,440	2,440	2,450	2,450	2,460	2,470	2,470	2,480	2,480	2,490	2,490	2,500	2,510	2
3	3,520	3,530	3,540	3,550	3,560	3,560	3,570	3,580	3,590	3,600	3,610	3,620	3,630	3,630	3,640	3,650	3,660	3,670	3,680	3,690	3,690	3
4	4,700	4,710	4,720	4,740	4,750	4,760	4,770	4,780	4,790	4,810	4,820	4,830	4,840	4,850	4,860	4,880	4,890	4,900	4,910	4,920	4,930	4
5	5,930	5,950	5,960	5,980	5,990	6,010	6,020	6,040	6,050	6,070	6,080	6,100	6,110	6,130	6,140	6,160	6,170	6,190	6,200	6,210	6,230	5
6	7,050	7,070	7,080	7,100	7,120	7,140	7,150	7,170	7,190	7,210	7,220	7,240	7,260	7,280	7,290	7,310	7,330	7,350	7,360	7,380	7,400	6
7	8,160	8,180	8,200	8,220	8,240	8,260	8,290	8,310	8,330	8,350	8,370	8,390	8,410	8,430	8,450	8,470	8,490	8,510	8,530	8,550	8,570	7
8	9,290	9,310	9,330	9,360	9,380	9,400	9,430	9,450	9,470	9,500	9,520	9,540	9,560	9,590	9,610	9,630	9,660	9,680	9,700	9,720	9,750	8
9	10,490	10,520	10,550	10,570	10,600	10,630	10,650	10,680	10,710	10,730	10,760	10,780	10,810	10,840	10,860	10,890	10,910	10,940	10,960	10,990	11,020	9
10	11,710	11,730	11,760	11,790	11,820	11,850	11,880	11,910	11,940	11,970	12,000	12,030	12,060	12,090	12,110	12,140	12,170	12,200	12,230	12,260	12,290	10
11	12,920	12,960	12,990	13,020	13,050	13,090	13,120	13,150	13,180	13,220	13,250	13,280	13,310	13,340	13,380	13,410	13,440	13,470	13,500	13,530	13,570	11
12	14,280	14,310	14,350	14,390	14,420	14,460	14,500	14,530	14,570	14,600	14,640	14,670	14,710	14,750	14,780	14,820	14,850	14,890	14,920	14,960	14,990	12
13	15,620	15,660	15,700	15,740	15,780	15,820	15,860	15,900	15,940	15,980	16,020	16,060	16,100	16,140	16,170	16,210	16,250	16,290	16,330	16,370	16,410	13
14	16,970	17,010	17,060	17,100	17,140	17,190	17,230	17,270	17,320	17,360	17,400	17,450	17,490	17,530	17,570	17,620	17,660	17,700	17,740	17,790	17,830	14
15	18,310	18,350	18,400	18,450	18,500	18,540	18,590	18,640	18,680	18,730	18,780	18,820	18,870	18,920	18,960	19,010	19,060	19,100	19,150	19,190	19,240	15
16	19,590	19,640	19,690	19,740	19,790	19,840	19,890	19,940	19,990	20,040	20,090	20,140	20,190	20,240	20,290	20,340	20,390	20,440	20,490	20,540	20,590	16
17	20,930	20,990	21,040	21,100	21,150	21,200	21,260	21,310	21,370	21,420	21,470	21,530	21,580	21,630	21,690	21,740	21,790	21,850	21,900	21,950	22,000	17
18	22,290	22,350	22,400	22,460	22,520	22,580	22,640	22,690	22,750	22,810	22,870	22,920	22,980	23,040	23,090	23,150	23,210	23,260	23,320	23,380	23,430	18
19	23,630	23,690	23,750	23,810	23,880	23,940	24,000	24,060	24,120	24,180	24,240	24,300	24,360	24,430	24,490	24,550	24,610	24,670	24,730	24,780	24,840	19
20	24,960	25,030	25,100	25,160	25,230	25,290	25,360	25,420	25,490	25,550	25,620	25,680	25,740	25,810	25,870	25,940	26,000	26,060	26,130	26,190	26,250	20
21	26,300	26,370	26,440	26,510	26,580	26,650	26,710	26,780	26,850	26,920	26,990	27,060	27,120	27,190	27,260	27,330	27,390	27,460	27,530	27,590	27,660	21
22	27,630	27,710	27,780	27,850	27,930	28,000	28,070	28,140	28,210	28,290	28,360	28,430	28,500	28,570	28,640	28,710	28,780	28,850	28,930	29,000	29,070	22
23	29,020	29,090	29,170	29,250	29,330	29,400	29,480	29,550	29,630	29,710	29,780	29,860	29,930	30,010	30,080	30,160	30,230	30,310	30,380	30,460	30,530	23
24	30,370	30,450	30,530	30,610	30,690	30,770	30,850	30,930	31,010	31,090	31,170	31,250	31,330	31,410	31,490	31,570	31,650	31,720	31,800	31,880	31,960	24
25	31,710	31,790	31,880	31,970	32,050	32,130	32,220	32,300	32,390	32,470	32,560	32,640	32,720	32,810	32,890	32,970	33,050	33,140	33,220	33,300	33,380	25
26	33,050	33,140	33,230	33,320	33,400	33,490	33,580	33,670	33,760	33,850	33,930	34,020	34,110	34,200	34,280	34,370	34,450	34,540	34,630	34,710	34,800	26
27	34,380	34,480	34,570	34,660	34,760	34,850	34,940	35,030	35,130	35,220	35,310	35,400	35,490	35,580	35,670	35,760	35,850	35,940	36,030	36,120	36,210	27
28	35,710	35,810	35,910	36,010	36,100	36,200	36,300	36,390	36,490	36,580	36,680	36,770	36,870	36,960	37,060	37,150	37,250	37,340	37,430	37,530	37,620	28
29	37,070	37,170	37,270	37,370	37,470	37,570	37,670	37,770	37,870	37,970	38,070	38,170	38,270	38,370	38,470	38,570	38,660	38,760	38,860	38,960	39,050	29
30	38,390	38,500	38,600	38,710	38,810	38,920	39,020	39,130	39,230	39,330	39,440	39,540	39,640	39,740	39,850	39,950	40,050	40,150	40,250	40,350	40,450	30
31	39,740	39,850	39,960	40,070	40,180	40,280	40,390	40,500	40,610	40,720	40,820	40,930	41,040	41,140	41,250	41,360	41,460	41,570	41,670	41,780	41,880	31
32	41,090	41,200	41,310	41,430	41,540	41,650	41,770	41,880	41,990	42,100	42,210	42,320	42,430	42,550	42,660	42,760	42,870	42,980	43,090	43,200	43,310	32
33	42,430	42,550	42,670	42,780	42,900	43,020	43,130	43,250	43,370	43,480	43,600	43,710	43,830	43,940	44,050	44,170	44,280	44,390	44,510	44,620	44,730	33
34	43,850	43,980	44,100	44,220	44,340	44,470	44,590	44,710	44,830	44,950	45,070	45,190	45,310	45,430	45,540	45,660	45,780	45,900	46,010	46,130	46,250	34
35	45,280	45,400	45,530	45,660	45,780	45,910	46,040	46,160	46,290	46,410	46,540	46,660	46,780	46,910	47,030	47,150	47,270	47,400	47,520	47,640	47,760	35
36	46,700	46,840	46,970	47,100	47,230	47,360	47,490	47,620	47,750	47,880	48,010	48,140	48,270	48,390	48,520	48,650	48,770	48,900	49,030	49,150	49,280	36
37	48,120	48,260	48,390	48,530	48,660	48,800	48,930	49,070	49,200	49,340	49,470	49,600	49,740	49,870	50,000	50,130	50,260	50,390	50,530	50,660	50,790	37
38	49,510	49,660	49,800	49,940	50,080	50,220	50,360	50,500	50,630	50,770	50,910	51,050	51,190	51,320	51,460	51,600	51,730	51,870	52,000	52,140	52,270	38
39	50,930	51,080	51,220	51,370	51,510	51,660	51,800	51,950	52,090	52,230	52,370	52,520	52,660	52,800	52,940	53,080	53,220	53,360	53,500	53,640	53,780	39
40	52,360	52,510	52,660	52,810	52,960	53,110	53,260	53,410	53,550	53,700	53,850	54,000	54,140	54,290	54,430	54,580	54,720	54,870	55,010	55,150	55,300	40
41	53,780	53,940	54,090	54,250	54,400	54,550	54,710	54,860	55,010	55,170	55,320	55,470	55,620	55,770	55,920	56,070	56,220	56,370	56,510	56,660	56,810	41
42	55,200	55,360	55,520	55,680	55,840	55,990	56,150	56,310	56,470	56,620	56,780	56,940	57,090	57,250	57,400	57,550	57,710	57,860	58,010	58,170	58,320	42
43	56,610	56,780	56,940	57,110	57,270	57,430	57,600	57,760	57,920	58,080	58,240	58,400	58,560	58,720	58,880	59,040	59,200	59,350	59,510	59,670	59,820	43
44	58,030	58,200	58,370	58,540	58,700	58,870	59,040	59,210	59,370	59,540	59,700	59,870	60,030	60,200	60,360	60,520	60,680	60,850	61,010	61,170	61,330	44
45	59,960	60,130	60,310	60,490	60,670	60,840	61,020	61,190	61,370	61,540	61,720	61,890	62,060	62,230	62,400	62,570	62,740	62,910	63,080	63,250	63,410	45
46	61,890	62,080	62,270	62,450	62,640	62,820	63,010	63,190	63,370	63,560	63,730	63,910	64,090	64,270	64,450	64,630	64,800	64,980	65,150	65,330	65,500	46
47	63,830	64,030	64,220	64,420	64,610	64,810	65,000	65,190	65,380	65,570	65,760	65,940	66,130	66,320	66,500	66,680	66,870	67,050	67,230	67,420	67,600	47
48	65,760	65,970	66,170	66,380	66,580	66,780	66,980	67,190	67,380	67,580	67,770	67,970	68,160	68,350	68,540	68,740	68,930	69,120	69,310	69,490	69,680	48
49	67,660	67,870	68,080	68,290	68,510	68,720	68,930	69,140	69,350	69,550	69,750	69,950	70,150	70,350	70,550	70,740	70,940	71,140	71,340	71,530	71,730	49
50	69,570	69,790	70,010	70,230	70,450	70,670	70,890	71,110	71,330	71,540	71,740	71,950	72,160	72,360	72,570	72,770	72,980	73,180	73,390	73,590	73,790	50
51	71,510	71,740	71,970	72,200	72,430	72,660	72,890	73,120	73,340	73,560	73,770	73,990	74,200	74,410	74,620	74,840	75,050	75,260	75,470	75,680	75,890	51
52	73,450	73,690	73,930	74,170	74,410	74,650	74,880	75,120	75,350	75,570	75,790	76,020	76,240	76,460	76,680	76,900	77,110	77,330	77,550	77,770	77,980	52
53	75,390	75,640	75,890	76,130	76,380	76,630	76,870	77,110	77,350	77,580	77,810	78,040	78,270	78,500	78,720	78,950	79,180	79,400	79,620	79,850	80,070	53
54	77,320	77,580	77,830	78,090	78,340	78,600	78,850	79,110	79,350	79,590	79,830	80,060	80,300	80,530	80,770	81,000	81,230	81,460	81,690	81,920	82,150	54
55	79,240	79,500	79,770	80,030	80,300	80,560	80,830	81,090	81,340	81,590	81,830	82,070	82,320	82,560	82,800	83,040	83,280	83,520	83,750	83,990	84,230	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGEMENT	990.0	990.1	990.2	990.3	990.4	990.5	990.6	990.7	990.8	990.9	991.0	991.1	991.2	991.3	991.4	991.5	991.6	991.7	991.8	991.9	992.0	GATE ARRANGEMENT
56	81,550	81,830	82,110	82,380	82,660	82,930	83,210	83,480	83,740	84,000	84,250	84,510	84,760	85,010	85,270	85,520	85,770	86,020	86,270	86,520	86,760	56
57	83,870	84,160	84,450	84,730	85,020	85,300	85,580	85,870	86,140	86,410	86,680	86,940	87,210	87,470	87,740	88,000	88,260	88,520	88,780	89,040	89,300	57
58	86,190	86,490	86,790	87,080	87,380	87,670	87,970	88,260	88,550	88,830	89,100	89,380	89,660	89,930	90,210	90,480	90,760	91,030	91,300	91,570	91,840	58
59	88,500	88,810	89,120	89,430	89,730	90,040	90,340	90,640	90,940	91,230	91,520	91,810	92,100	92,390	92,670	92,960	93,240	93,530	93,810	94,090	94,380	59
60	90,750	91,070	91,380	91,700	92,020	92,330	92,650	92,960	93,270	93,570	93,870	94,170	94,470	94,770	95,070	95,360	95,660	95,950	96,250	96,540	96,840	60
61	93,000	93,330	93,650	93,980	94,310	94,630	94,950	95,280	95,600	95,910	96,220	96,530	96,840	97,150	97,460	97,770	98,080	98,390	98,690	99,000	99,300	61
62	95,330	95,670	96,000	96,340	96,680	97,010	97,350	97,680	98,010	98,330	98,660	98,980	99,300	99,630	99,950	100,300	100,600	100,900	101,200	101,500	101,900	62
63	97,650	98,000	98,350	98,690	99,040	99,390	99,730	100,100	100,400	100,800	101,100	101,400	101,800	102,100	102,400	102,800	103,100	103,400	103,700	104,100	104,400	63
64	99,960	100,300	100,700	101,000	101,400	101,700	102,100	102,500	102,800	103,200	103,500	103,800	104,200	104,500	104,900	105,200	105,600	105,900	106,200	106,600	106,900	64
65	102,300	102,700	103,000	103,400	103,800	104,100	104,500	104,900	105,200	105,600	105,900	106,300	106,600	107,000	107,400	107,700	108,100	108,400	108,800	109,100	109,500	65
66	104,600	105,000	105,400	105,700	106,100	106,500	106,900	107,200	107,600	108,000	108,400	108,700	109,100	109,500	109,800	110,200	110,600	110,900	111,300	111,600	112,000	66
67	108,000	108,400	108,700	109,100	109,400	109,800	110,100	110,500	110,800	111,200	111,500	111,900	112,200	112,600	112,900	113,300	113,600	114,000	114,300	114,700	115,000	67
68	111,300	111,700	112,000	112,300	112,600	112,900	113,300	113,600	113,900	114,300	114,600	114,900	115,300	115,600	115,900	116,300	116,600	116,900	117,300	117,600	118,000	68
69	114,600	114,900	115,200	115,500	115,800	116,100	116,400	116,700	117,000	117,400	117,700	118,000	118,300	118,600	119,000	119,300	119,600	119,900	120,300	120,600	121,000	69
70	118,000	118,200	118,500	118,800	119,000	119,300	119,600	119,900	120,200	120,500	120,800	121,100	121,400	121,700	122,000	122,300	122,600	122,900	123,300	123,600	124,000	70
71	121,200	121,400	121,600	121,900	122,100	122,400	122,600	122,900	123,200	123,500	123,700	124,000	124,300	124,600	124,900	125,200	125,500	125,800	126,100	126,500	126,900	71
72	124,400	124,600	124,800	125,000	125,200	125,400	125,700	125,900	126,200	126,400	126,700	127,000	127,300	127,500	127,800	128,100	128,300	128,600	129,000	129,400	129,700	72
73	127,700	127,900	128,000	128,200	128,400	128,600	128,800	129,000	129,300	129,500	129,800	130,100	130,300	130,600	130,800	131,100	131,300	131,600	132,000	132,400	132,800	73
74	131,000	131,100	131,300	131,400	131,600	131,800	132,000	132,200	132,400	132,600	132,900	133,100	133,400	133,600	133,900	134,100	134,300	134,600	135,000	135,400	135,800	74
75	134,300	134,400	134,500	134,700	134,800	135,000	135,100	135,300	135,500	135,800	136,000	136,200	136,400	136,700	136,900	137,100	137,300	137,600	138,000	138,400	138,800	75
76	137,600	137,700	137,800	137,900	138,000	138,200	138,300	138,400	138,600	138,900	139,100	139,300	139,500	139,700	139,900	140,100	140,300	140,500	140,900	141,300	141,700	76
77	141,000	141,000	141,100	141,200	141,300	141,400	141,400	141,600	141,800	142,000	142,200	142,400	142,600	142,800	142,900	143,100	143,300	143,500	143,900	144,300	144,700	77
78	141,100	141,200	141,400	141,600	141,800	142,000	142,200	142,400	142,700	143,000	143,300	143,600	143,900	144,200	144,400	144,700	145,000	145,300	145,800	146,300	146,800	78
79	141,400	141,600	141,900	142,200	142,500	142,800	143,100	143,400	143,800	144,200	144,600	144,900	145,300	145,700	146,100	146,400	146,800	147,200	147,800	148,400	148,900	79
80	141,700	142,100	142,400	142,800	143,200	143,600	144,000	144,400	144,900	145,400	145,900	146,300	146,800	147,300	147,700	148,200	148,700	149,200	149,800	150,500	151,100	80
81	142,100	142,500	143,000	143,500	144,000	144,500	145,000	145,500	146,000	146,600	147,200	147,700	148,300	148,800	149,400	150,000	150,500	151,100	151,800	152,500	153,300	81
82	142,300	142,900	143,400	144,000	144,600	145,200	145,800	146,400	147,000	147,700	148,400	149,000	149,700	150,300	151,000	151,600	152,300	152,900	153,700	154,500	155,300	82
83	142,700	143,300	144,000	144,600	145,300	146,000	146,700	147,400	148,100	148,800	149,600	150,300	151,100	151,800	152,500	153,300	154,000	154,800	155,600	156,500	157,400	83
84	143,000	143,700	144,500	145,300	146,000	146,800	147,600	148,400	149,200	150,000	150,900	151,700	152,500	153,400	154,200	155,000	155,900	156,700	157,700	158,600	159,500	84
85	143,400	144,200	145,100	146,000	146,800	147,700	148,600	149,500	150,400	151,300	152,200	153,200	154,100	155,000	155,900	156,900	157,800	158,700	159,700	160,700	161,700	85
86	143,700	144,600	145,600	146,600	147,500	148,500	149,500	150,500	151,500	152,500	153,500	154,500	155,500	156,500	157,600	158,600	159,600	160,600	161,700	162,800	163,900	86
87	144,000	145,000	146,100	147,200	148,200	149,300	150,400	151,500	152,600	153,700	154,800	155,900	157,000	158,100	159,200	160,300	161,400	162,600	163,700	164,900	166,000	87
88	144,300	145,500	146,600	147,800	149,000	150,100	151,300	152,500	153,700	154,900	156,000	157,200	158,400	159,600	160,800	162,100	163,300	164,500	165,700	166,900	168,200	88
89	144,300	145,500	146,600	147,800	149,000	150,100	151,300	152,500	153,700	154,900	156,000	157,200	158,400	159,600	160,800	162,100	163,300	164,500	165,700	166,900	168,200	89
90	144,300	145,500	146,600	147,800	149,000	150,100	151,300	152,500	153,700	154,900	156,000	157,200	158,400	159,600	160,800	162,100	163,300	164,500	165,700	166,900	168,200	90

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	992.0	992.1	992.2	992.3	992.4	992.5	992.6	992.7	992.8	992.9	993.0	993.1	993.2	993.3	993.4	993.5	993.6	993.7	993.8	993.9	994.0	
1	1,270	1,270	1,270	1,270	1,280	1,280	1,280	1,290	1,290	1,290	1,290	1,300	1,300	1,300	1,310	1,310	1,310	1,310	1,320	1,320	1,320	1
2	2,510	2,510	2,520	2,520	2,530	2,540	2,540	2,550	2,550	2,560	2,560	2,570	2,580	2,580	2,590	2,590	2,600	2,600	2,610	2,610	2,620	2
3	3,690	3,700	3,710	3,720	3,730	3,740	3,750	3,750	3,760	3,770	3,780	3,790	3,800	3,800	3,810	3,820	3,830	3,840	3,850	3,850	3,860	3
4	4,930	4,950	4,960	4,970	4,980	4,990	5,000	5,010	5,020	5,040	5,050	5,060	5,070	5,080	5,090	5,100	5,110	5,120	5,130	5,150	5,160	4
5	6,230	6,240	6,260	6,270	6,290	6,300	6,310	6,330	6,340	6,360	6,370	6,390	6,400	6,410	6,430	6,440	6,460	6,470	6,480	6,500	6,510	5
6	7,400	7,410	7,430	7,450	7,470	7,480	7,500	7,520	7,530	7,550	7,570	7,580	7,600	7,620	7,630	7,650	7,670	7,680	7,700	7,720	7,730	6
7	8,570	8,590	8,610	8,630	8,650	8,670	8,680	8,700	8,720	8,740	8,760	8,780	8,800	8,820	8,840	8,860	8,880	8,900	8,920	8,930	8,950	7
8	9,750	9,770	9,790	9,810	9,840	9,860	9,880	9,900	9,920	9,950	9,970	9,990	10,010	10,030	10,060	10,080	10,100	10,120	10,140	10,170	10,190	8
9	11,020	11,040	11,070	11,090	11,120	11,140	11,170	11,190	11,220	11,240	11,270	11,290	11,320	11,340	11,370	11,390	11,420	11,440	11,460	11,490	11,510	9
10	12,290	12,310	12,340	12,370	12,400	12,430	12,460	12,480	12,510	12,540	12,570	12,590	12,620	12,650	12,680	12,700	12,730	12,760	12,790	12,810	12,840	10
11	13,570	13,600	13,630	13,660	13,690	13,720	13,750	13,780	13,810	13,840	13,870	13,910	13,940	13,970	14,000	14,030	14,060	14,090	14,120	14,150	14,180	11
12	14,990	15,030	15,060	15,100	15,130	15,170	15,200	15,230	15,270	15,300	15,340	15,370	15,400	15,440	15,470	15,510	15,540	15,570	15,610	15,640	15,670	12
13	16,410	16,450	16,480	16,520	16,560	16,600	16,640	16,670	16,710	16,750	16,790	16,820	16,860	16,900	16,940	16,970	17,010	17,050	17,080	17,120	17,160	13
14	17,830	17,870	17,910	17,950	17,990	18,040	18,080	18,120	18,160	18,200	18,240	18,280	18,320	18,360	18,400	18,450	18,490	18,530	18,570	18,610	18,650	14
15	19,240	19,280	19,330	19,370	19,420	19,460	19,510	19,550	19,600	19,640	19,690	19,730	19,780	19,820	19,860	19,910	19,950	20,000	20,040	20,080	20,130	15
16	20,590	20,640	20,690	20,730	20,780	20,830	20,880	20,930	20,970	21,020	21,070	21,120	21,170	21,210	21,260	21,310	21,350	21,400	21,450	21,490	21,540	16
17	22,000	22,060	22,110	22,160	22,210	22,260	22,310	22,370	22,420	22,470	22,520	22,570	22,620	22,670	22,720	22,770	22,820	22,870	22,920	22,980	23,030	17
18	23,430	23,490	23,540	23,600	23,650	23,710	23,760	23,820	23,870	23,930	23,980	24,040	24,090	24,150	24,200	24,250	24,310	24,360	24,420	24,470	24,520	18
19	24,840	24,900	24,960	25,020	25,080	25,140	25,200	25,260	25,310	25,370	25,430	25,490	25,550	25,600	25,660	25,720	25,780	25,830	25,890	25,950	26,000	19
20	26,250	26,320	26,380	26,440	26,500	26,560	26,630	26,690	26,750	26,810	26,870	26,930	27,000	27,060	27,120	27,180	27,240	27,300	27,360	27,420	27,480	20
21	27,660	27,730	27,790	27,860	27,920	27,990	28,050	28,120	28,190	28,250	28,320	28,380	28,440	28,510	28,570	28,640	28,700	28,770	28,830	28,890	28,960	21
22	29,070	29,130	29,200	29,270	29,340	29,410	29,480	29,550	29,620	29,690	29,760	29,820	29,890	29,960	30,030	30,090	30,160	30,230	30,300	30,360	30,430	22
23	30,530	30,600	30,680	30,750	30,820	30,900	30,970	31,040	31,110	31,190	31,260	31,330	31,400	31,470	31,550	31,620	31,690	31,760	31,830	31,900	31,970	23
24	31,960	32,040	32,110	32,190	32,270	32,340	32,420	32,500	32,570	32,650	32,730	32,800	32,880	32,950	33,030	33,100	33,180	33,250	33,330	33,400	33,480	24
25	33,380	33,460	33,540	33,620	33,710	33,790	33,870	33,950	34,030	34,110	34,190	34,270	34,340	34,420	34,500	34,580	34,660	34,740	34,820	34,890	34,970	25
26	34,800	34,880	34,970	35,050	35,140	35,220	35,310	35,390	35,470	35,560	35,640	35,720	35,810	35,890	35,970	36,060	36,140	36,220	36,300	36,380	36,460	26
27	36,210	36,300	36,390	36,480	36,570	36,660	36,740	36,830	36,920	37,010	37,090	37,180	37,270	37,350	37,440	37,530	37,610	37,700	37,780	37,870	37,950	27
28	37,620	37,710	37,810	37,900	37,990	38,080	38,170	38,270	38,360	38,450	38,540	38,630	38,720	38,810	38,900	38,990	39,080	39,170	39,260	39,350	39,440	28
29	39,050	39,150	39,250	39,340	39,440	39,530	39,630	39,720	39,820	39,910	40,010	40,100	40,200	40,290	40,380	40,480	40,570	40,660	40,760	40,850	40,940	29
30	40,450	40,560	40,660	40,760	40,850	40,950	41,050	41,150	41,250	41,350	41,450	41,550	41,640	41,740	41,840	41,940	42,030	42,130	42,230	42,320	42,420	30
31	41,880	41,990	42,090	42,190	42,300	42,400	42,500	42,610	42,710	42,810	42,910	43,020	43,120	43,220	43,320	43,420	43,520	43,620	43,720	43,820	43,920	31
32	43,310	43,420	43,530	43,630	43,740	43,850	43,950	44,060	44,170	44,270	44,380	44,490	44,590	44,700	44,800	44,900	45,010	45,110	45,220	45,320	45,420	32
33	44,730	44,840	44,960	45,070	45,180	45,290	45,400	45,510	45,620	45,730	45,840	45,950	46,060	46,170	46,280	46,380	46,490	46,600	46,710	46,810	46,920	33
34	46,250	46,360	46,480	46,600	46,710	46,830	46,940	47,060	47,170	47,290	47,400	47,510	47,630	47,740	47,850	47,970	48,080	48,190	48,300	48,410	48,520	34
35	47,760	47,880	48,000	48,120	48,240	48,360	48,480	48,600	48,720	48,840	48,960	49,070	49,190	49,310	49,430	49,540	49,660	49,780	49,890	50,010	50,120	35
36	49,280	49,400	49,530	49,650	49,780	49,900	50,030	50,150	50,270	50,400	50,520	50,640	50,760	50,880	51,000	51,130	51,250	51,370	51,490	51,610	51,730	36
37	50,790	50,920	51,040	51,170	51,300	51,430	51,560	51,690	51,810	51,940	52,070	52,190	52,320	52,450	52,570	52,700	52,820	52,950	53,070	53,200	53,320	37
38	52,270	52,400	52,540	52,670	52,800	52,940	53,070	53,200	53,330	53,460	53,600	53,730	53,860	53,990	54,120	54,250	54,370	54,500	54,630	54,760	54,890	38
39	53,780	53,920	54,060	54,190	54,330	54,470	54,600	54,740	54,880	55,010	55,150	55,280	55,420	55,550	55,680	55,820	55,950	56,080	56,220	56,350	56,480	39
40	55,300	55,440	55,580	55,720	55,870	56,010	56,150	56,290	56,430	56,570	56,710	56,850	56,990	57,130	57,260	57,400	57,540	57,680	57,810	57,950	58,090	40
41	56,810	56,960	57,100	57,250	57,400	57,540	57,690	57,830	57,980	58,120	58,270	58,410	58,550	58,690	58,840	58,980	59,120	59,260	59,400	59,540	59,680	41
42	58,320	58,470	58,620	58,770	58,920	59,070	59,220	59,370	59,520	59,670	59,820	59,960	60,110	60,260	60,410	60,550	60,700	60,840	60,990	61,130	61,280	42
43	59,820	59,980	60,140	60,290	60,450	60,600	60,750	60,910	61,060	61,210	61,370	61,520	61,670	61,820	61,970	62,120	62,270	62,420	62,570	62,720	62,870	43
44	61,330	61,490	61,650	61,810	61,970	62,130	62,290	62,440	62,600	62,760	62,920	63,070	63,230	63,380	63,540	63,690	63,850	64,000	64,160	64,310	64,460	44
45	63,410	63,580	63,750	63,910	64,080	64,250	64,410	64,580	64,740	64,900	65,070	65,230	65,390	65,560	65,720	65,880	66,040	66,200	66,360	66,520	66,680	45
46	65,500	65,680	65,850	66,020	66,200	66,370	66,540	66,710	66,880	67,050	67,220	67,390	67,560	67,730	67,900	68,070	68,240	68,400	68,570	68,740	68,900	46
47	67,600	67,780	67,960	68,140	68,320	68,500	68,680	68,850	69,030	69,210	69,390	69,560	69,740	69,910	70,090	70,260	70,440	70,610	70,790	70,960	71,130	47
48	69,680	69,870	70,060	70,250	70,430	70,620	70,800	70,990	71,170	71,360	71,540	71,720	71,910	72,090	72,270	72,450	72,630	72,810	72,990	73,170	73,350	48
49	71,730	71,920	72,120	72,310	72,500	72,690	72,890	73,080	73,270	73,460	73,650	73,840	74,030	74,220	74,410	74,590	74,780	74,970	75,150	75,340	75,530	49
50	73,790	73,990	74,190	74,390	74,590	74,790	74,990	75,190	75,390	75,580	75,780	75,980	76,170	76,370	76,560	76,760	76,950	77,140	77,340	77,530	77,720	50
51	75,890	76,100	76,300	76,510	76,720	76,920	77,130	77,330	77,540	77,740	77,950	78,150	78,350	78,550	78,760	78,960	79,160	79,360	79,560	79,750	79,950	51
52	77,980	78,200	78,410	78,630	78,840	79,050	79,260	79,480	79,690	79,900	80,110	80,320	80,530	80,740	80,940	81,150	81,360	81,560	81,770	81,970	82,180	52
53	80,070	80,290	80,510	80,740	80,960	81,180	81,390	81,610	81,830	82,050	82,270	82,480	82,700	82,910	83,130	83,340	83,550	83,770	83,980	84,190	84,400	53
54	82,150	82,380	82,610	82,840	83,070	83,290	83,520	83,740	83,970	84,190	84,420	84,640	84,860	85,080	85,310	85,530	85,750	85,970	86,180	86,400	86,620	54
55	84,230	84,460	84,700	84,930	85,170	85,400	85,630	85,870	86,100	86,330	86,560	86,790	87,020	87,250	87,470	87,700	87,930	88,150	88,380	88,600	88,830	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	992.0	992.1	992.2	992.3	992.4	992.5	992.6	992.7	992.8	992.9	993.0	993.1	993.2	993.3	993.4	993.5	993.6	993.7	993.8	993.9	994.0	
56	86,760	87,010	87,260	87,500	87,750	87,990	88,240	88,480	88,720	88,970	89,210	89,450	89,690	89,930	90,170	90,400	90,640	90,880	91,110	91,350	91,580	56
57	89,300	89,560	89,820	90,080	90,330	90,590	90,840	91,100	91,350	91,600	91,860	92,110	92,360	92,610	92,860	93,110	93,360	93,600	93,850	94,100	94,340	57
58	91,840	92,110	92,380	92,650	92,920	93,190	93,450	93,720	93,980	94,250	94,510	94,770	95,030	95,290	95,560	95,820	96,070	96,330	96,590	96,850	97,100	58
59	94,380	94,660	94,940	95,220	95,500	95,770	96,050	96,330	96,600	96,880	97,150	97,430	97,700	97,970	98,240	98,510	98,780	99,050	99,320	99,590	99,860	59
60	96,840	97,130	97,420	97,710	98,000	98,290	98,580	98,860	99,150	99,430	99,720	100,000	100,300	100,600	100,900	101,100	101,400	101,700	102,000	102,300	102,500	60
61	99,300	99,600	99,900	100,200	100,500	100,800	101,100	101,400	101,700	102,000	102,300	102,600	102,900	103,200	103,500	103,800	104,000	104,300	104,600	104,900	105,200	61
62	101,900	102,200	102,500	102,800	103,100	103,400	103,700	104,000	104,300	104,600	105,000	105,300	105,600	105,900	106,200	106,500	106,800	107,100	107,400	107,700	108,000	62
63	104,400	104,700	105,000	105,400	105,700	106,000	106,300	106,700	107,000	107,300	107,600	107,900	108,200	108,600	108,900	109,200	109,500	109,800	110,100	110,400	110,700	63
64	106,900	107,300	107,600	107,900	108,300	108,600	108,900	109,300	109,600	109,900	110,200	110,600	110,900	111,200	111,600	111,900	112,200	112,500	112,800	113,200	113,500	64
65	109,500	109,800	110,200	110,500	110,900	111,200	111,500	111,900	112,200	112,600	112,900	113,200	113,600	113,900	114,300	114,600	114,900	115,300	115,600	115,900	116,300	65
66	112,000	112,400	112,700	113,100	113,400	113,800	114,100	114,500	114,800	115,200	115,500	115,900	116,200	116,600	116,900	117,300	117,600	118,000	118,300	118,700	119,000	66
67	115,000	115,400	115,700	116,100	116,500	116,800	117,200	117,500	117,900	118,300	118,600	119,000	119,300	119,700	120,000	120,400	120,700	121,100	121,400	121,800	122,100	67
68	118,000	118,400	118,700	119,100	119,500	119,800	120,200	120,600	120,900	121,300	121,700	122,000	122,400	122,700	123,100	123,400	123,800	124,100	124,500	124,800	125,200	68
69	121,000	121,400	121,800	122,100	122,500	122,900	123,200	123,600	124,000	124,300	124,700	125,100	125,400	125,800	126,100	126,500	126,800	127,200	127,600	127,900	128,300	69
70	124,000	124,400	124,800	125,100	125,500	125,900	126,300	126,600	127,000	127,400	127,700	128,100	128,500	128,800	129,200	129,600	129,900	130,300	130,600	131,000	131,300	70
71	126,900	127,300	127,600	128,000	128,400	128,800	129,200	129,500	129,900	130,300	130,700	131,000	131,400	131,800	132,100	132,500	132,800	133,200	133,600	133,900	134,300	71
72	129,700	130,100	130,500	130,900	131,300	131,700	132,100	132,400	132,800	133,200	133,600	133,900	134,300	134,700	135,100	135,400	135,800	136,100	136,500	136,900	137,200	72
73	132,800	133,200	133,500	133,900	134,300	134,700	135,100	135,500	135,900	136,200	136,600	137,000	137,400	137,800	138,100	138,500	138,900	139,200	139,600	140,000	140,300	73
74	135,800	136,200	136,600	137,000	137,400	137,800	138,100	138,500	138,900	139,300	139,700	140,100	140,400	140,800	141,200	141,600	141,900	142,300	142,700	143,000	143,400	74
75	138,800	139,200	139,600	140,000	140,400	140,800	141,200	141,600	142,000	142,300	142,700	143,100	143,500	143,900	144,300	144,600	145,000	145,400	145,700	146,100	146,500	75
76	141,700	142,200	142,600	143,000	143,400	143,800	144,200	144,600	145,000	145,400	145,800	146,100	146,500	146,900	147,300	147,700	148,100	148,400	148,800	149,200	149,500	76
77	144,700	145,200	145,600	146,000	146,400	146,800	147,200	147,600	148,000	148,400	148,800	149,200	149,600	150,000	150,400	150,700	151,100	151,500	151,900	152,300	152,600	77
78	146,800	147,300	147,800	148,300	148,700	149,200	149,700	150,200	150,700	151,100	151,600	152,100	152,600	153,000	153,500	154,000	154,400	154,900	155,300	155,800	156,300	78
79	148,900	149,500	150,100	150,600	151,200	151,700	152,300	152,900	153,400	154,000	154,500	155,100	155,600	156,200	156,700	157,300	157,800	158,400	158,900	159,500	160,000	79
80	151,100	151,700	152,400	153,000	153,700	154,300	154,900	155,600	156,200	156,800	157,500	158,100	158,700	159,400	160,000	160,600	161,300	161,900	162,500	163,200	163,800	80
81	153,300	154,000	154,700	155,400	156,100	156,800	157,600	158,300	159,000	159,700	160,400	161,100	161,800	162,600	163,300	164,000	164,700	165,400	166,100	166,800	167,600	81
82	155,300	156,100	156,900	157,700	158,400	159,200	160,000	160,800	161,600	162,400	163,200	164,000	164,800	165,600	166,400	167,100	167,900	168,700	169,500	170,300	171,100	82
83	157,400	158,200	159,100	159,900	160,800	161,700	162,500	163,400	164,200	165,100	166,000	166,800	167,700	168,600	169,500	170,300	171,200	172,100	172,900	173,800	174,700	83
84	159,500	160,500	161,400	162,300	163,300	164,200	165,100	166,100	167,000	168,000	168,900	169,900	170,800	171,800	172,700	173,700	174,600	175,600	176,500	177,500	178,500	84
85	161,700	162,700	163,700	164,800	165,800	166,800	167,800	168,800	169,900	170,900	171,900	172,900	174,000	175,000	176,000	177,100	178,100	179,200	180,200	181,200	182,300	85
86	163,900	165,000	166,000	167,100	168,200	169,300	170,400	171,500	172,600	173,700	174,800	175,900	177,000	178,200	179,300	180,400	181,500	182,600	183,800	184,900	186,000	86
87	166,000	167,200	168,300	169,500	170,700	171,800	173,000	174,200	175,400	176,500	177,700	178,900	180,100	181,300	182,500	183,700	184,900	186,100	187,300	188,600	189,800	87
88	168,200	169,400	170,600	171,900	173,100	174,400	175,600	176,900	178,100	179,400	180,700	181,900	183,200	184,500	185,800	187,100	188,300	189,600	190,900	192,200	193,500	88
89	168,200	169,400	170,600	171,900	173,100	174,400	175,600	176,900	178,100	179,400	180,700	181,900	183,200	184,500	185,800	187,100	188,300	189,600	190,900	192,200	193,500	89
90	168,200	169,400	170,600	171,900	173,100	174,400	175,600	176,900	178,100	179,400	180,700	181,900	183,200	184,500	185,800	187,100	188,300	189,600	190,900	192,200	193,500	90

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	994.0	994.1	994.2	994.3	994.4	994.5	994.6	994.7	994.8	994.9	995.0	995.1	995.2	995.3	995.4	995.5	995.6	995.7	995.8	995.9	996.0	
1	1,320	1,330	1,330	1,330	1,330	1,340	1,340	1,340	1,350	1,350	1,350	1,350	1,360	1,360	1,360	1,360	1,370	1,370	1,370	1,380	1,380	1
2	2,620	2,630	2,630	2,640	2,640	2,650	2,650	2,660	2,660	2,670	2,670	2,680	2,690	2,690	2,700	2,700	2,710	2,710	2,720	2,720	2,730	2
3	3,860	3,870	3,880	3,890	3,890	3,900	3,910	3,920	3,930	3,930	3,940	3,950	3,960	3,970	3,970	3,980	3,990	4,000	4,010	4,010	4,020	3
4	5,160	5,170	5,180	5,190	5,200	5,210	5,220	5,230	5,240	5,250	5,260	5,280	5,290	5,300	5,310	5,320	5,330	5,340	5,350	5,360	5,370	4
5	6,510	6,520	6,540	6,550	6,570	6,580	6,590	6,610	6,620	6,630	6,650	6,660	6,670	6,690	6,700	6,710	6,730	6,740	6,750	6,770	6,780	5
6	7,730	7,750	7,760	7,780	7,800	7,810	7,830	7,850	7,860	7,880	7,890	7,910	7,930	7,940	7,960	7,970	7,990	8,000	8,020	8,040	8,050	6
7	8,950	8,970	8,990	9,010	9,030	9,050	9,070	9,090	9,100	9,120	9,140	9,160	9,180	9,200	9,220	9,230	9,250	9,270	9,290	9,310	9,320	7
8	10,190	10,210	10,230	10,250	10,270	10,290	10,310	10,340	10,360	10,380	10,400	10,420	10,440	10,460	10,480	10,500	10,530	10,550	10,570	10,590	10,610	8
9	11,510	11,540	11,560	11,590	11,610	11,630	11,660	11,680	11,710	11,730	11,750	11,780	11,800	11,830	11,850	11,870	11,900	11,920	11,940	11,970	11,990	9
10	12,840	12,870	12,900	12,920	12,950	12,980	13,000	13,030	13,060	13,080	13,110	13,140	13,160	13,190	13,220	13,240	13,270	13,290	13,320	13,350	13,370	10
11	14,180	14,210	14,240	14,270	14,300	14,330	14,360	14,390	14,420	14,440	14,470	14,500	14,530	14,560	14,590	14,620	14,650	14,680	14,710	14,740	14,770	11
12	15,670	15,710	15,740	15,770	15,810	15,840	15,870	15,910	15,940	15,970	16,000	16,040	16,070	16,100	16,130	16,170	16,200	16,230	16,260	16,300	16,330	12
13	17,160	17,190	17,230	17,270	17,300	17,340	17,380	17,410	17,450	17,490	17,520	17,560	17,590	17,630	17,660	17,700	17,740	17,770	17,810	17,840	17,880	13
14	18,650	18,690	18,730	18,770	18,810	18,850	18,890	18,930	18,960	19,000	19,040	19,080	19,120	19,160	19,200	19,240	19,280	19,320	19,350	19,390	19,430	14
15	20,130	20,170	20,210	20,260	20,300	20,340	20,390	20,430	20,470	20,510	20,560	20,600	20,640	20,680	20,730	20,770	20,810	20,850	20,890	20,930	20,980	15
16	21,540	21,590	21,630	21,680	21,730	21,770	21,820	21,870	21,910	21,960	22,000	22,050	22,090	22,140	22,180	22,230	22,280	22,320	22,370	22,410	22,450	16
17	23,030	23,080	23,120	23,170	23,220	23,270	23,320	23,370	23,420	23,470	23,520	23,570	23,620	23,670	23,710	23,760	23,810	23,860	23,910	23,960	24,000	17
18	24,520	24,580	24,630	24,680	24,730	24,790	24,840	24,890	24,950	25,000	25,050	25,100	25,150	25,210	25,260	25,310	25,360	25,410	25,460	25,520	25,570	18
19	26,000	26,060	26,120	26,170	26,230	26,290	26,340	26,400	26,450	26,510	26,560	26,620	26,680	26,730	26,790	26,840	26,900	26,950	27,000	27,060	27,110	19
20	27,480	27,540	27,600	27,660	27,720	27,780	27,840	27,900	27,960	28,020	28,070	28,130	28,190	28,250	28,310	28,370	28,420	28,480	28,540	28,600	28,660	20
21	28,960	29,020	29,080	29,150	29,210	29,270	29,330	29,400	29,460	29,520	29,580	29,640	29,710	29,770	29,830	29,890	29,950	30,010	30,070	30,140	30,200	21
22	30,430	30,500	30,560	30,630	30,700	30,760	30,830	30,890	30,960	31,020	31,090	31,160	31,220	31,290	31,350	31,410	31,480	31,540	31,610	31,670	31,740	22
23	31,970	32,040	32,110	32,180	32,250	32,320	32,390	32,460	32,530	32,600	32,670	32,740	32,810	32,880	32,940	33,010	33,080	33,150	33,220	33,280	33,350	23
24	33,480	33,550	33,620	33,700	33,770	33,840	33,920	33,990	34,060	34,140	34,210	34,280	34,350	34,430	34,500	34,570	34,640	34,710	34,790	34,860	34,930	24
25	34,970	35,050	35,130	35,210	35,280	35,360	35,440	35,510	35,590	35,670	35,740	35,820	35,890	35,970	36,050	36,120	36,200	36,270	36,350	36,420	36,500	25
26	36,460	36,550	36,630	36,710	36,790	36,870	36,950	37,030	37,110	37,190	37,270	37,350	37,430	37,510	37,590	37,670	37,740	37,820	37,900	37,980	38,060	26
27	37,950	38,040	38,120	38,210	38,290	38,380	38,460	38,550	38,630	38,710	38,800	38,880	38,960	39,040	39,130	39,210	39,290	39,370	39,460	39,540	39,620	27
28	39,440	39,520	39,610	39,700	39,790	39,880	39,960	40,050	40,140	40,230	40,310	40,400	40,490	40,570	40,660	40,740	40,830	40,920	41,000	41,090	41,170	28
29	40,940	41,030	41,130	41,220	41,310	41,400	41,490	41,580	41,670	41,770	41,860	41,950	42,040	42,130	42,220	42,300	42,390	42,480	42,570	42,660	42,750	29
30	42,420	42,510	42,610	42,710	42,800	42,900	42,990	43,080	43,180	43,270	43,370	43,460	43,550	43,650	43,740	43,830	43,930	44,020	44,110	44,200	44,300	30
31	43,920	44,020	44,120	44,220	44,320	44,420	44,510	44,610	44,710	44,810	44,910	45,000	45,100	45,200	45,290	45,390	45,490	45,580	45,680	45,770	45,870	31
32	45,420	45,530	45,630	45,730	45,840	45,940	46,040	46,140	46,240	46,340	46,440	46,550	46,650	46,750	46,850	46,950	47,050	47,150	47,250	47,340	47,440	32
33	46,920	47,030	47,130	47,240	47,350	47,450	47,560	47,660	47,770	47,870	47,980	48,080	48,190	48,290	48,390	48,500	48,600	48,700	48,810	48,910	49,010	33
34	48,520	48,640	48,750	48,860	48,970	49,080	49,190	49,300	49,410	49,510	49,620	49,730	49,840	49,950	50,060	50,160	50,270	50,380	50,480	50,590	50,700	34
35	50,120	50,240	50,350	50,470	50,580	50,700	50,810	50,920	51,040	51,150	51,260	51,380	51,490	51,600	51,710	51,820	51,930	52,050	52,160	52,270	52,380	35
36	51,730	51,850	51,970	52,080	52,200	52,320	52,440	52,560	52,670	52,790	52,910	53,020	53,140	53,260	53,370	53,490	53,600	53,720	53,830	53,950	54,060	36
37	53,320	53,440	53,570	53,690	53,810	53,930	54,060	54,180	54,300	54,420	54,540	54,660	54,780	54,900	55,020	55,140	55,260	55,380	55,500	55,620	55,740	37
38	54,890	55,020	55,140	55,270	55,400	55,520	55,650	55,780	55,900	56,030	56,150	56,280	56,400	56,520	56,650	56,770	56,900	57,020	57,140	57,260	57,390	38
39	56,480	56,610	56,750	56,880	57,010	57,140	57,270	57,400	57,530	57,660	57,790	57,910	58,040	58,170	58,300	58,430	58,550	58,680	58,810	58,940	59,060	39
40	58,090	58,220	58,360	58,490	58,630	58,760	58,900	59,030	59,170	59,300	59,430	59,570	59,700	59,830	59,960	60,090	60,230	60,360	60,490	60,620	60,750	40
41	59,680	59,830	59,960	60,100	60,240	60,380	60,520	60,660	60,800	60,930	61,070	61,210	61,350	61,480	61,620	61,750	61,890	62,020	62,160	62,290	62,430	41
42	61,280	61,420	61,570	61,710	61,850	62,000	62,140	62,280	62,420	62,560	62,710	62,850	62,990	63,130	63,270	63,410	63,550	63,690	63,830	63,960	64,100	42
43	62,870	63,020	63,170	63,310	63,460	63,610	63,760	63,900	64,050	64,190	64,340	64,480	64,630	64,770	64,920	65,060	65,200	65,350	65,490	65,630	65,770	43
44	64,460	64,610	64,770	64,920	65,070	65,220	65,370	65,520	65,670	65,820	65,970	66,120	66,270	66,420	66,570	66,710	66,860	67,010	67,160	67,300	67,450	44
45	66,080	66,840	67,000	67,160	67,310	67,470	67,630	67,790	67,940	68,100	68,250	68,410	68,560	68,720	68,870	69,030	69,180	69,340	69,490	69,640	69,790	45
46	68,900	69,070	69,230	69,400	69,560	69,730	69,890	70,050	70,220	70,380	70,540	70,700	70,870	71,030	71,190	71,350	71,510	71,670	71,830	71,980	72,140	46
47	71,130	71,300	71,480	71,650	71,820	71,990	72,160	72,330	72,500	72,670	72,830	73,000	73,170	73,340	73,500	73,670	73,840	74,000	74,170	74,330	74,500	47
48	73,350	73,530	73,710	73,880	74,060	74,240	74,420	74,590	74,770	74,940	75,120	75,290	75,470	75,640	75,810	75,990	76,160	76,330	76,500	76,670	76,840	48
49	75,530	75,710	75,900	76,080	76,260	76,450	76,630	76,810	76,990	77,170	77,360	77,540	77,720	77,900	78,070	78,250	78,430	78,610	78,790	78,970	79,140	49
50	77,720	77,910	78,100	78,290	78,480	78,670	78,860	79,050	79,240	79,430	79,610	79,800	79,990	80,170	80,360	80,540	80,730	80,910	81,100	81,280	81,460	50
51	79,950	80,150	80,350	80,540	80,740	80,940	81,130	81,330	81,520	81,720	81,910	82,100	82,300	82,490	82,680	82,870	83,060	83,250	83,440	83,630	83,820	51
52	82,180	82,380	82,590	82,790	82,990	83,200	83,400	83,600	83,800	84,000	84,200	84,400	84,600	84,800	85,000	85,190	85,390	85,590	85,780	85,980	86,170	52
53	84,400	84,610	84,820	85,030	85,240	85,450	85,660	85,870	86,080	86,280	86,490	86,690	86,900	87,100	87,310	87,510	87,720	87,920	88,120	88,320	88,520	53
54	86,620	86,840	87,060	87,270	87,490	87,700	87,920	88,130	88,340	88,560	88,770	88,980	89,190	89,400	89,620	89,830	90,030	90,240	90,450	90,660	90,870	54
55	88,830	89,050	89,270	89,500	89,720	89,940	90,160	90,380	90,600	90,820	91,040	91,260	91,480	91,690	91,910	92,130	92,340	92,560	92,770	92,990	93,200	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	994.0	994.1	994.2	994.3	994.4	994.5	994.6	994.7	994.8	994.9	995.0	995.1	995.2	995.3	995.4	995.5	995.6	995.7	995.8	995.9	996.0	
56	91, 580	91, 820	92, 050	92, 290	92, 520	92, 750	92, 980	93, 210	93, 440	93, 670	93, 900	94, 130	94, 360	94, 580	94, 810	95, 030	95, 260	95, 480	95, 710	95, 930	96, 150	56
57	94, 340	94, 590	94, 830	95, 080	95, 320	95, 560	95, 810	96, 050	96, 290	96, 520	96, 760	97, 000	97, 240	97, 470	97, 710	97, 940	98, 170	98, 410	98, 640	98, 870	99, 100	57
58	97, 100	97, 360	97, 620	97, 870	98, 120	98, 380	98, 630	98, 880	99, 130	99, 380	99, 630	99, 870	100, 100	100, 400	100, 600	100, 800	101, 100	101, 300	101, 600	101, 800	102, 100	58
59	99, 860	100, 100	100, 400	100, 700	100, 900	101, 200	101, 400	101, 700	102, 000	102, 200	102, 500	102, 700	103, 000	103, 200	103, 500	103, 700	104, 000	104, 300	104, 500	104, 800	105, 000	59
60	102, 500	102, 800	103, 100	103, 400	103, 600	103, 900	104, 200	104, 500	104, 700	105, 000	105, 300	105, 500	105, 800	106, 000	106, 300	106, 600	106, 800	107, 100	107, 300	107, 600	107, 900	60
61	105, 200	105, 500	105, 800	106, 100	106, 400	106, 600	106, 900	107, 200	107, 500	107, 800	108, 000	108, 300	108, 600	108, 800	109, 100	109, 400	109, 700	109, 900	110, 200	110, 500	110, 700	61
62	108, 000	108, 300	108, 600	108, 900	109, 200	109, 500	109, 800	110, 000	110, 300	110, 600	110, 900	111, 200	111, 500	111, 700	112, 000	112, 300	112, 600	112, 900	113, 100	113, 400	113, 700	62
63	110, 700	111, 100	111, 400	111, 700	112, 000	112, 300	112, 600	112, 900	113, 200	113, 500	113, 800	114, 100	114, 300	114, 600	114, 900	115, 200	115, 500	115, 800	116, 100	116, 400	116, 600	63
64	113, 500	113, 800	114, 100	114, 400	114, 800	115, 100	115, 400	115, 700	116, 000	116, 300	116, 600	116, 900	117, 200	117, 500	117, 800	118, 100	118, 400	118, 700	119, 000	119, 300	119, 600	64
65	116, 300	116, 600	116, 900	117, 200	117, 600	117, 900	118, 200	118, 500	118, 900	119, 200	119, 500	119, 800	120, 100	120, 400	120, 700	121, 000	121, 300	121, 600	121, 900	122, 200	122, 500	65
66	119, 000	119, 300	119, 700	120, 000	120, 400	120, 700	121, 000	121, 400	121, 700	122, 000	122, 300	122, 700	123, 000	123, 300	123, 600	123, 900	124, 200	124, 600	124, 900	125, 200	125, 500	66
67	122, 100	122, 500	122, 800	123, 100	123, 500	123, 800	124, 200	124, 500	124, 800	125, 100	125, 500	125, 800	126, 100	126, 500	126, 800	127, 100	127, 500	127, 800	128, 100	128, 500	128, 800	67
68	125, 200	125, 500	125, 900	126, 200	126, 600	126, 900	127, 200	127, 600	127, 900	128, 300	128, 600	129, 000	129, 300	129, 600	130, 000	130, 300	130, 700	131, 000	131, 400	131, 700	132, 000	68
69	128, 300	128, 600	129, 000	129, 300	129, 600	130, 000	130, 300	130, 700	131, 000	131, 400	131, 700	132, 100	132, 500	132, 800	133, 200	133, 600	133, 900	134, 300	134, 600	135, 000	135, 300	69
70	131, 300	131, 700	132, 000	132, 400	132, 700	133, 100	133, 400	133, 800	134, 100	134, 500	134, 900	135, 300	135, 600	136, 000	136, 400	136, 800	137, 100	137, 500	137, 900	138, 300	138, 600	70
71	134, 300	134, 600	135, 000	135, 300	135, 700	136, 000	136, 400	136, 700	137, 100	137, 500	137, 900	138, 300	138, 700	139, 100	139, 500	139, 800	140, 200	140, 600	141, 000	141, 400	141, 800	71
72	137, 200	137, 600	137, 900	138, 300	138, 600	139, 000	139, 300	139, 700	140, 100	140, 500	140, 900	141, 300	141, 700	142, 100	142, 500	142, 900	143, 300	143, 700	144, 100	144, 500	144, 900	72
73	140, 300	140, 700	141, 000	141, 400	141, 700	142, 100	142, 500	142, 800	143, 200	143, 600	144, 100	144, 500	144, 900	145, 300	145, 700	146, 100	146, 600	147, 000	147, 400	147, 800	148, 200	73
74	143, 400	143, 800	144, 100	144, 500	144, 900	145, 200	145, 600	145, 900	146, 400	146, 800	147, 200	147, 700	148, 100	148, 500	149, 000	149, 400	149, 800	150, 200	150, 700	151, 100	151, 500	74
75	146, 500	146, 900	147, 200	147, 600	147, 900	148, 300	148, 600	149, 000	149, 500	149, 900	150, 400	150, 800	151, 300	151, 700	152, 100	152, 600	153, 000	153, 500	153, 900	154, 400	154, 800	75
76	149, 500	149, 900	150, 300	150, 600	151, 000	151, 400	151, 700	152, 100	152, 600	153, 000	153, 500	153, 900	154, 400	154, 900	155, 300	155, 800	156, 200	156, 700	157, 200	157, 600	158, 100	76
77	152, 600	153, 000	153, 400	153, 700	154, 100	154, 500	154, 800	155, 200	155, 700	156, 100	156, 600	157, 100	157, 600	158, 000	158, 500	159, 000	159, 500	159, 900	160, 400	160, 900	161, 300	77
78	156, 300	156, 700	157, 200	157, 600	158, 100	158, 500	159, 000	159, 500	160, 000	160, 600	161, 100	161, 500	161, 900	162, 300	162, 700	163, 100	163, 600	164, 000	164, 400	164, 800	165, 300	78
79	160, 000	160, 500	161, 100	161, 600	162, 200	162, 700	163, 200	163, 800	164, 400	165, 000	165, 400	165, 800	166, 100	166, 500	166, 800	167, 200	167, 600	167, 900	168, 300	168, 700	169, 100	79
80	163, 800	164, 400	165, 000	165, 700	166, 300	166, 900	167, 600	168, 200	168, 900	169, 300	169, 700	170, 000	170, 300	170, 600	170, 900	171, 200	171, 500	171, 900	172, 200	172, 600	172, 900	80
81	167, 600	168, 300	169, 000	169, 700	170, 400	171, 100	171, 900	172, 600	173, 300	173, 700	174, 000	174, 200	174, 400	174, 700	174, 900	175, 200	175, 500	175, 800	176, 100	176, 400	176, 700	81
82	171, 100	171, 900	172, 700	173, 500	174, 300	175, 100	175, 900	176, 700	177, 500	177, 900	178, 200	178, 300	178, 400	178, 600	178, 800	179, 000	179, 300	179, 500	179, 800	180, 100	180, 400	82
83	174, 700	175, 600	176, 500	177, 300	178, 200	179, 100	180, 000	180, 900	181, 700	182, 100	182, 300	182, 300	182, 400	182, 500	182, 700	182, 900	183, 100	183, 300	183, 500	183, 700	184, 000	83
84	178, 500	179, 400	180, 400	181, 400	182, 300	183, 300	184, 300	185, 300	186, 200	186, 400	186, 600	186, 600	186, 600	186, 600	186, 800	186, 900	187, 100	187, 200	187, 400	187, 600	187, 800	84
85	182, 300	183, 300	184, 400	185, 400	186, 500	187, 600	188, 600	189, 700	190, 600	190, 800	190, 900	190, 800	190, 800	190, 700	190, 800	190, 900	191, 000	191, 100	191, 300	191, 500	191, 600	85
86	186, 000	187, 200	188, 300	189, 500	190, 600	191, 800	192, 900	194, 100	195, 000	195, 200	195, 200	195, 100	194, 900	194, 900	194, 900	195, 000	195, 000	195, 100	195, 200	195, 300	195, 500	86
87	189, 800	191, 000	192, 200	193, 500	194, 700	195, 900	197, 200	198, 400	199, 500	199, 600	199, 500	199, 300	199, 100	199, 000	199, 000	199, 000	199, 000	199, 000	199, 100	199, 200	199, 300	87
88	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	203, 900	203, 900	203, 800	203, 500	203, 300	203, 000	203, 000	203, 000	202, 900	202, 900	202, 900	203, 000	203, 100	88
89	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	203, 900	203, 900	203, 800	203, 700	203, 600	203, 500	203, 600	203, 700	203, 800	203, 900	204, 100	204, 300	204, 500	89
90	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	203, 900	204, 000	204, 100	204, 100	204, 100	204, 200	204, 400	204, 700	204, 900	205, 200	205, 400	205, 700	206, 100	90
91	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	203, 900	204, 200	204, 400	204, 600	204, 800	205, 000	205, 300	205, 700	206, 100	206, 400	206, 800	207, 300	207, 700	91
92	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 000	204, 400	204, 700	205, 000	205, 400	205, 700	206, 200	206, 700	207, 200	207, 700	208, 200	208, 800	209, 300	92
93	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 000	204, 500	204, 900	205, 400	205, 900	206, 400	207, 000	207, 600	208, 200	208, 800	209, 500	210, 100	210, 800	93
94	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 000	204, 600	205, 200	205, 800	206, 500	207, 100	207, 800	208, 600	209, 300	210, 000	210, 800	211, 600	212, 400	94
95	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 000	204, 800	205, 500	206, 300	207, 000	207, 800	208, 700	209, 500	210, 400	211, 300	212, 100	213, 000	214, 000	95
96	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 100	205, 000	205, 900	206, 800	207, 700	208, 600	209, 600	210, 600	211, 600	212, 600	213, 600	214, 600	215, 600	96
97	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 100	205, 100	206, 200	207, 200	208, 300	209, 400	210, 500	211, 600	212, 700	213, 800	214, 900	216, 100	217, 200	97
98	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 100	205, 300	206, 500	207, 700	208, 900	210, 100	211, 300	212, 600	213, 800	215, 000	216, 300	217, 600	218, 800	98
99	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 100	205, 500	206, 800	208, 200	209, 500	210, 900	212, 200	213, 600	215, 000	216, 300	217, 700	219, 100	220, 500	99
100	193, 500	194, 900	196, 200	197, 500	198, 800	200, 100	201, 500	202, 800	204, 100	205, 500	206, 800	208, 200	209, 500	210, 900	212, 200	213, 600	215, 000	216, 300	217, 700	219, 100	220, 500	100

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	996.0	996.1	996.2	996.3	996.4	996.5	996.6	996.7	996.8	996.9	997.0	997.1	997.2	997.3	997.4	997.5	997.6	997.7	997.8	997.9	998.0	
1	1,380	1,380	1,380	1,390	1,390	1,390	1,390	1,400	1,400	1,400	1,400	1,410	1,410	1,410	1,420	1,420	1,420	1,420	1,430	1,430	1,430	1
2	2,730	2,730	2,740	2,740	2,750	2,750	2,760	2,770	2,770	2,780	2,780	2,790	2,790	2,800	2,800	2,810	2,810	2,820	2,820	2,830	2,830	2
3	4,020	4,030	4,040	4,050	4,050	4,060	4,070	4,080	4,080	4,090	4,100	4,110	4,110	4,120	4,130	4,140	4,150	4,150	4,160	4,170	4,180	3
4	5,370	5,380	5,390	5,400	5,410	5,420	5,430	5,440	5,450	5,460	5,470	5,480	5,490	5,500	5,510	5,520	5,540	5,550	5,560	5,570	5,580	4
5	6,780	6,790	6,810	6,820	6,830	6,850	6,860	6,870	6,890	6,900	6,910	6,920	6,940	6,950	6,960	6,980	6,990	7,000	7,010	7,030	7,040	5
6	8,050	8,070	8,080	8,100	8,110	8,130	8,150	8,160	8,180	8,190	8,210	8,220	8,240	8,250	8,270	8,280	8,300	8,310	8,330	8,350	8,360	6
7	9,320	9,340	9,360	9,380	9,400	9,420	9,430	9,450	9,470	9,490	9,500	9,520	9,540	9,560	9,580	9,590	9,610	9,630	9,650	9,660	9,680	7
8	10,610	10,630	10,650	10,670	10,690	10,710	10,730	10,750	10,770	10,790	10,810	10,830	10,850	10,870	10,890	10,910	10,930	10,950	10,970	10,990	11,010	8
9	11,990	12,010	12,040	12,060	12,080	12,110	12,130	12,150	12,180	12,200	12,220	12,240	12,270	12,290	12,310	12,340	12,360	12,380	12,400	12,430	12,450	9
10	13,370	13,400	13,430	13,450	13,480	13,500	13,530	13,550	13,580	13,610	13,630	13,660	13,680	13,710	13,730	13,760	13,780	13,810	13,830	13,860	13,880	10
11	14,770	14,790	14,820	14,850	14,880	14,910	14,940	14,970	14,990	15,020	15,050	15,080	15,110	15,130	15,160	15,190	15,220	15,250	15,270	15,300	15,330	11
12	16,330	16,360	16,390	16,420	16,460	16,490	16,520	16,550	16,580	16,610	16,640	16,680	16,710	16,740	16,770	16,800	16,830	16,860	16,890	16,930	16,960	12
13	17,880	17,910	17,950	17,980	18,020	18,050	18,090	18,120	18,160	18,190	18,230	18,260	18,300	18,330	18,360	18,400	18,430	18,470	18,500	18,530	18,570	13
14	19,430	19,470	19,510	19,550	19,590	19,620	19,660	19,700	19,740	19,770	19,810	19,850	19,890	19,930	19,960	20,000	20,040	20,070	20,110	20,150	20,190	14
15	20,980	21,020	21,060	21,100	21,140	21,180	21,230	21,270	21,310	21,350	21,390	21,430	21,470	21,510	21,550	21,590	21,630	21,670	21,710	21,750	21,790	15
16	22,450	22,500	22,540	22,590	22,630	22,680	22,720	22,770	22,810	22,850	22,900	22,940	22,990	23,030	23,070	23,120	23,160	23,200	23,250	23,290	23,330	16
17	24,000	24,050	24,100	24,150	24,190	24,240	24,290	24,340	24,380	24,430	24,480	24,530	24,570	24,620	24,670	24,710	24,760	24,810	24,850	24,900	24,940	17
18	25,570	25,620	25,670	25,720	25,770	25,820	25,870	25,920	25,970	26,020	26,070	26,120	26,170	26,220	26,270	26,320	26,370	26,420	26,470	26,520	26,570	18
19	27,110	27,170	27,220	27,280	27,330	27,380	27,440	27,490	27,550	27,600	27,650	27,710	27,760	27,810	27,860	27,920	27,970	28,020	28,080	28,130	28,180	19
20	28,660	28,710	28,770	28,830	28,890	28,940	29,000	29,060	29,110	29,170	29,230	29,280	29,340	29,390	29,450	29,510	29,560	29,620	29,670	29,730	29,780	20
21	30,200	30,260	30,320	30,380	30,440	30,500	30,560	30,620	30,680	30,740	30,800	30,860	30,920	30,980	31,040	31,090	31,150	31,210	31,270	31,330	31,390	21
22	31,740	31,800	31,860	31,930	31,990	32,050	32,120	32,180	32,240	32,310	32,370	32,430	32,490	32,560	32,620	32,680	32,740	32,810	32,870	32,930	32,990	22
23	33,350	33,420	33,490	33,550	33,620	33,690	33,750	33,820	33,890	33,950	34,020	34,090	34,150	34,220	34,280	34,350	34,420	34,480	34,550	34,610	34,680	23
24	34,930	35,000	35,070	35,140	35,210	35,280	35,350	35,420	35,490	35,560	35,630	35,700	35,770	35,840	35,910	35,980	36,050	36,120	36,180	36,250	36,320	24
25	36,500	36,570	36,640	36,720	36,790	36,870	36,940	37,010	37,090	37,160	37,230	37,310	37,380	37,450	37,520	37,600	37,670	37,740	37,810	37,890	37,960	25
26	38,060	38,140	38,210	38,290	38,370	38,450	38,520	38,600	38,680	38,750	38,830	38,910	38,980	39,060	39,140	39,210	39,290	39,360	39,440	39,510	39,590	26
27	39,620	39,700	39,780	39,860	39,940	40,020	40,100	40,190	40,270	40,350	40,430	40,510	40,590	40,660	40,740	40,820	40,900	40,980	41,060	41,140	41,220	27
28	41,170	41,260	41,340	41,420	41,510	41,590	41,680	41,760	41,840	41,930	42,010	42,090	42,180	42,260	42,340	42,430	42,510	42,590	42,670	42,750	42,840	28
29	42,750	42,840	42,930	43,010	43,100	43,190	43,280	43,360	43,450	43,540	43,620	43,710	43,800	43,880	43,970	44,060	44,140	44,230	44,310	44,400	44,480	29
30	44,300	44,390	44,480	44,570	44,660	44,750	44,840	44,930	45,020	45,110	45,200	45,290	45,380	45,470	45,560	45,650	45,740	45,830	45,920	46,010	46,100	30
31	45,870	45,960	46,060	46,150	46,250	46,340	46,440	46,530	46,630	46,720	46,810	46,910	47,000	47,090	47,180	47,280	47,370	47,460	47,550	47,650	47,740	31
32	47,440	47,540	47,640	47,740	47,840	47,940	48,030	48,130	48,230	48,330	48,420	48,520	48,620	48,710	48,810	48,900	49,000	49,100	49,190	49,290	49,380	32
33	49,010	49,110	49,220	49,320	49,420	49,520	49,620	49,720	49,820	49,930	50,030	50,130	50,230	50,330	50,420	50,520	50,620	50,720	50,820	50,920	51,020	33
34	50,700	50,800	50,910	51,020	51,120	51,230	51,330	51,440	51,540	51,650	51,750	51,850	51,960	52,060	52,170	52,270	52,370	52,470	52,580	52,680	52,780	34
35	52,380	52,490	52,600	52,710	52,820	52,930	53,040	53,140	53,250	53,360	53,470	53,580	53,690	53,790	53,900	54,010	54,110	54,220	54,330	54,430	54,540	35
36	54,060	54,180	54,290	54,410	54,520	54,630	54,750	54,860	54,970	55,080	55,200	55,310	55,420	55,530	55,640	55,750	55,860	55,970	56,080	56,190	56,300	36
37	55,740	55,860	55,970	56,090	56,210	56,330	56,440	56,560	56,680	56,790	56,910	57,020	57,140	57,250	57,370	57,480	57,600	57,710	57,830	57,940	58,050	37
38	57,390	57,510	57,630	57,750	57,870	57,990	58,120	58,240	58,360	58,480	58,600	58,720	58,830	58,950	59,070	59,190	59,310	59,430	59,550	59,660	59,780	38
39	59,060	59,190	59,310	59,440	59,560	59,690	59,810	59,940	60,060	60,190	60,310	60,430	60,560	60,680	60,800	60,920	61,050	61,170	61,290	61,410	61,530	39
40	60,750	60,880	61,010	61,140	61,270	61,400	61,520	61,650	61,780	61,910	62,040	62,160	62,290	62,420	62,540	62,670	62,800	62,920	63,050	63,170	63,300	40
41	62,430	62,560	62,700	62,830	62,960	63,090	63,230	63,360	63,490	63,620	63,750	63,890	64,020	64,150	64,280	64,410	64,540	64,670	64,800	64,930	65,050	41
42	64,100	64,240	64,380	64,520	64,650	64,790	64,930	65,060	65,200	65,330	65,470	65,600	65,740	65,870	66,010	66,140	66,270	66,410	66,540	66,670	66,810	42
43	65,770	65,920	66,060	66,200	66,340	66,480	66,620	66,760	66,900	67,040	67,180	67,320	67,460	67,600	67,730	67,870	68,010	68,150	68,280	68,420	68,560	43
44	67,450	67,590	67,740	67,890	68,030	68,170	68,320	68,460	68,610	68,750	68,890	69,040	69,180	69,320	69,460	69,600	69,750	69,890	70,030	70,170	70,310	44
45	69,790	69,950	70,100	70,250	70,400	70,550	70,700	70,850	71,000	71,150	71,300	71,450	71,600	71,740	71,890	72,040	72,190	72,330	72,480	72,630	72,770	45
46	72,140	72,300	72,460	72,620	72,770	72,930	73,090	73,240	73,400	73,550	73,710	73,860	74,020	74,170	74,330	74,480	74,630	74,790	74,940	75,090	75,240	46
47	74,500	74,660	74,830	74,990	75,150	75,320	75,480	75,640	75,800	75,960	76,130	76,290	76,450	76,610	76,770	76,930	77,090	77,240	77,400	77,560	77,720	47
48	76,840	77,010	77,180	77,350	77,520	77,690	77,860	78,030	78,200	78,360	78,530	78,700	78,860	79,030	79,200	79,360	79,530	79,690	79,860	80,020	80,180	48
49	79,140	79,320	79,490	79,670	79,850	80,020	80,200	80,370	80,540	80,720	80,890	81,060	81,240	81,410	81,580	81,750	81,920	82,090	82,260	82,430	82,600	49
50	81,460	81,650	81,830	82,010	82,190	82,370	82,550	82,730	82,910	83,090	83,270	83,450	83,630	83,810	83,980	84,160	84,340	84,510	84,690	84,870	85,040	50
51	83,820	84,010	84,200	84,390	84,570	84,760	84,950	85,130	85,320	85,500	85,690	85,870	86,060	86,240	86,430	86,610	86,790	86,970	87,160	87,340	87,520	51
52	86,170	86,370	86,560	86,760	86,950	87,140	87,340	87,530	87,720	87,910	88,100	88,290	88,480	88,670	88,860	89,050	89,240	89,430	89,620	89,800	89,990	52
53	88,520	88,730	88,930	89,130	89,330	89,520	89,720	89,920	90,120	90,320	90,510	90,710	90,910	91,100	91,300	91,490	91,690	91,880	92,080	92,270	92,460	53
54	90,870	91,080	91,280	91,490	91,690	91,900	92,100	92,310	92,510	92,720	92,920	93,120	93,320	93,530	93,730	93,930	94,130	94,330	94,530	94,730	94,930	54
55	93,200	93,410	93,630	93,840	94,050	94,260	94,470	94,680	94,890	95,100	95,310	95,520	95,730	95,940	96,140	96,350	96,560	96,760	96,970	97,170	97,380	55

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGEMENT	996.0	996.1	996.2	996.3	996.4	996.5	996.6	996.7	996.8	996.9	997.0	997.1	997.2	997.3	997.4	997.5	997.6	997.7	997.8	997.9	998.0	GATE ARRANGEMENT
56	96,150	96,380	96,600	96,820	97,040	97,260	97,480	97,700	97,920	98,140	98,350	98,570	98,790	99,000	99,220	99,430	99,650	99,860	100,100	100,300	100,500	56
57	99,100	99,340	99,570	99,800	100,000	100,300	100,500	100,700	100,900	101,200	101,400	101,600	101,800	102,100	102,300	102,500	102,700	103,000	103,200	103,400	103,600	57
58	102,100	102,300	102,500	102,800	103,000	103,300	103,500	103,700	104,000	104,200	104,400	104,700	104,900	105,100	105,400	105,600	105,800	106,100	106,300	106,500	106,800	58
59	105,000	105,300	105,500	105,700	106,000	106,200	106,500	106,700	107,000	107,200	107,500	107,700	108,000	108,200	108,400	108,700	108,900	109,200	109,400	109,600	109,900	59
60	107,900	108,100	108,400	108,600	108,900	109,100	109,400	109,700	109,900	110,200	110,400	110,700	110,900	111,200	111,400	111,700	111,900	112,200	112,400	112,700	112,900	60
61	110,700	111,000	111,300	111,500	111,800	112,100	112,300	112,600	112,800	113,100	113,400	113,600	113,900	114,100	114,400	114,700	114,900	115,200	115,400	115,700	115,900	61
62	113,700	114,000	114,200	114,500	114,800	115,100	115,300	115,600	115,900	116,100	116,400	116,700	117,000	117,200	117,500	117,800	118,000	118,300	118,600	118,800	119,100	62
63	116,600	116,900	117,200	117,500	117,800	118,100	118,300	118,600	118,900	119,200	119,500	119,700	120,000	120,300	120,600	120,800	121,100	121,400	121,700	121,900	122,200	63
64	119,600	119,900	120,200	120,500	120,800	121,000	121,300	121,600	121,900	122,200	122,500	122,800	123,100	123,300	123,600	123,900	124,200	124,500	124,800	125,000	125,300	64
65	122,500	122,900	123,200	123,500	123,800	124,100	124,400	124,600	124,900	125,200	125,500	125,800	126,100	126,400	126,700	127,000	127,300	127,600	127,900	128,200	128,500	65
66	125,500	125,800	126,100	126,400	126,700	127,000	127,300	127,700	128,000	128,300	128,600	128,900	129,200	129,500	129,800	130,100	130,400	130,700	131,000	131,300	131,600	66
67	128,800	129,100	129,400	129,700	130,100	130,400	130,700	131,000	131,400	131,700	132,000	132,300	132,600	132,900	133,300	133,600	133,900	134,200	134,500	134,800	135,100	67
68	132,000	132,400	132,700	133,100	133,400	133,700	134,100	134,400	134,700	135,100	135,400	135,700	136,100	136,400	136,700	137,100	137,400	137,700	138,000	138,400	138,700	68
69	135,300	135,700	136,000	136,400	136,700	137,100	137,400	137,800	138,100	138,500	138,800	139,200	139,500	139,900	140,200	140,500	140,900	141,200	141,600	141,900	142,200	69
70	138,600	139,000	139,400	139,700	140,100	140,400	140,800	141,200	141,500	141,900	142,300	142,600	143,000	143,300	143,700	144,000	144,400	144,800	145,100	145,500	145,800	70
71	141,800	142,100	142,500	142,900	143,300	143,700	144,000	144,400	144,800	145,200	145,500	145,900	146,300	146,600	147,000	147,400	147,800	148,100	148,500	148,900	149,200	71
72	144,900	145,300	145,700	146,100	146,500	146,900	147,300	147,600	148,000	148,400	148,800	149,200	149,600	150,000	150,300	150,700	151,100	151,500	151,900	152,200	152,600	72
73	148,200	148,600	149,000	149,400	149,800	150,200	150,600	151,000	151,400	151,800	152,200	152,600	153,000	153,400	153,800	154,200	154,600	155,000	155,400	155,800	156,200	73
74	151,500	151,900	152,400	152,800	153,200	153,600	154,000	154,500	154,900	155,300	155,700	156,100	156,500	156,900	157,300	157,800	158,200	158,600	159,000	159,400	159,800	74
75	154,800	155,200	155,700	156,100	156,500	157,000	157,400	157,800	158,300	158,700	159,100	159,500	160,000	160,400	160,800	161,200	161,700	162,100	162,500	162,900	163,300	75
76	158,100	158,500	159,000	159,400	159,900	160,300	160,700	161,200	161,600	162,100	162,500	163,000	163,400	163,800	164,300	164,700	165,200	165,600	166,000	166,500	166,900	76
77	161,300	161,800	162,300	162,700	163,200	163,700	164,100	164,600	165,000	165,500	165,900	166,400	166,900	167,300	167,800	168,200	168,700	169,100	169,600	170,000	170,400	77
78	165,300	165,700	166,100	166,500	167,000	167,400	167,800	168,200	168,700	169,100	169,500	170,000	170,400	170,900	171,300	171,800	172,200	172,700	173,100	173,600	174,000	78
79	169,100	169,500	169,900	170,300	170,700	171,100	171,500	171,800	172,200	172,600	173,100	173,500	174,000	174,400	174,900	175,300	175,800	176,200	176,700	177,100	177,600	79
80	172,900	173,300	173,600	174,000	174,300	174,700	175,100	175,400	175,800	176,200	176,600	177,100	177,500	178,000	178,400	178,900	179,400	179,800	180,300	180,700	181,100	80
81	176,700	177,100	177,400	177,700	178,000	178,300	178,700	179,000	179,300	179,700	180,200	180,600	181,100	181,500	182,000	182,500	182,900	183,400	183,800	184,300	184,700	81
82	180,400	180,700	181,000	181,200	181,500	181,800	182,100	182,400	182,700	183,100	183,500	184,000	184,400	184,900	185,400	185,800	186,300	186,700	187,200	187,600	188,100	82
83	184,000	184,300	184,500	184,800	185,000	185,300	185,500	185,800	186,000	186,400	186,900	187,300	187,800	188,300	188,700	189,200	189,600	190,100	190,500	191,000	191,400	83
84	187,800	188,100	188,300	188,500	188,700	188,900	189,200	189,400	189,600	190,000	190,400	190,900	191,400	191,800	192,300	192,700	193,200	193,700	194,100	194,600	195,000	84
85	191,600	191,800	192,000	192,200	192,400	192,600	192,800	192,900	193,200	193,600	194,000	194,500	194,900	195,400	195,900	196,300	196,800	197,200	197,700	198,100	198,600	85
86	195,500	195,600	195,800	196,000	196,100	196,200	196,400	196,500	196,700	197,100	197,600	198,000	198,500	199,000	199,400	199,900	200,300	200,800	201,200	201,700	202,100	86
87	199,300	199,400	199,500	199,700	199,800	199,900	200,000	200,100	200,200	200,700	201,100	201,600	202,000	202,500	203,000	203,400	203,900	204,300	204,800	205,200	205,700	87
88	203,100	203,200	203,300	203,400	203,400	203,500	203,600	203,600	203,800	204,200	204,600	205,100	205,600	206,000	206,500	207,000	207,400	207,900	208,300	208,800	209,200	88
89	204,500	204,700	204,900	205,100	205,300	205,500	205,700	205,900	206,100	206,700	207,200	207,800	208,300	208,900	209,500	210,000	210,600	211,100	211,700	212,200	212,700	89
90	206,100	206,400	206,700	207,100	207,400	207,700	208,000	208,300	208,700	209,300	210,000	210,600	211,300	211,900	212,500	213,200	213,800	214,500	215,100	215,700	216,400	90
91	207,700	208,200	208,600	209,100	209,500	209,900	210,400	210,800	211,300	212,000	212,700	213,500	214,200	214,900	215,700	216,400	217,100	217,900	218,600	219,300	220,000	91
92	209,300	209,900	210,500	211,000	211,600	212,200	212,700	213,300	213,900	214,700	215,500	216,300	217,100	218,000	218,800	219,600	220,400	221,200	222,100	222,900	223,700	92
93	210,800	211,500	212,200	212,900	213,500	214,200	214,900	215,600	216,300	217,200	218,100	219,000	219,900	220,800	221,700	222,600	223,500	224,400	225,300	226,200	227,100	93
94	212,400	213,100	213,900	214,700	215,500	216,300	217,100	217,900	218,700	219,700	220,700	221,700	222,700	223,700	224,600	225,600	226,600	227,600	228,600	229,600	230,600	94
95	214,000	214,900	215,800	216,700	217,600	218,500	219,400	220,300	221,300	222,400	223,400	224,500	225,600	226,700	227,700	228,800	229,900	231,000	232,100	233,200	234,300	95
96	215,600	216,700	217,700	218,700	219,800	220,800	221,800	222,900	223,900	225,100	226,200	227,400	228,600	229,700	230,900	232,100	233,200	234,400	235,600	236,800	238,000	96
97	217,200	218,400	219,500	220,700	221,800	223,000	224,100	225,300	226,500	227,700	229,000	230,200	231,500	232,700	234,000	235,300	236,500	237,800	239,000	240,300	241,600	97
98	218,800	220,100	221,400	222,600	223,900	225,200	226,500	227,800	229,100	230,400	231,700	233,100	234,400	235,700	237,100	238,400	239,800	241,200	242,500	243,900	245,200	98
99	220,500	221,800	223,200	224,600	226,000	227,400	228,800	230,200	231,700	233,100	234,500	235,900	237,300	238,800	240,200	241,700	243,100	244,600	246,000	247,500	248,900	99
100	220,500	221,800	223,200	224,600	226,000	227,400	228,800	230,200	231,700	233,100	234,500	235,900	237,300	238,800	240,200	241,700	243,100	244,600	246,000	247,500	248,900	100

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	998.0	998.1	998.2	998.3	998.4	998.5	998.6	998.7	998.8	998.9	999.0	999.1	999.2	999.3	999.4	999.5	999.6	999.7	999.8	999.9	1000.0	
1	1,430	1,430	1,440	1,440	1,440	1,440	1,450	1,450	1,450	1,450	1,460	1,460	1,460	1,460	1,470	1,470	1,470	1,470	1,480	1,480	1,480	1
2	2,830	2,840	2,840	2,850	2,850	2,860	2,860	2,870	2,870	2,880	2,880	2,890	2,890	2,900	2,900	2,910	2,910	2,920	2,920	2,930	2,930	2
3	4,180	4,180	4,190	4,200	4,210	4,210	4,220	4,230	4,240	4,240	4,250	4,260	4,270	4,270	4,280	4,290	4,290	4,300	4,310	4,320	4,320	3
4	5,580	5,590	5,600	5,610	5,620	5,630	5,640	5,650	5,660	5,670	5,680	5,690	5,700	5,710	5,720	5,720	5,730	5,740	5,750	5,760	5,770	4
5	7,040	7,050	7,070	7,080	7,090	7,100	7,120	7,130	7,140	7,150	7,170	7,180	7,190	7,200	7,220	7,230	7,240	7,250	7,270	7,280	7,290	5
6	8,360	8,380	8,390	8,410	8,420	8,440	8,450	8,470	8,480	8,500	8,510	8,520	8,540	8,550	8,570	8,580	8,600	8,610	8,630	8,640	8,660	6
7	9,680	9,700	9,720	9,730	9,750	9,770	9,790	9,800	9,820	9,840	9,850	9,870	9,890	9,910	9,920	9,940	9,960	9,970	9,990	10,010	10,030	7
8	11,010	11,030	11,050	11,070	11,090	11,110	11,130	11,150	11,170	11,190	11,210	11,230	11,250	11,270	11,290	11,310	11,330	11,350	11,370	11,390	11,410	8
9	12,450	12,470	12,490	12,520	12,540	12,560	12,580	12,610	12,630	12,650	12,670	12,690	12,720	12,740	12,760	12,780	12,800	12,830	12,850	12,870	12,890	9
10	13,880	13,910	13,930	13,960	13,980	14,010	14,030	14,060	14,080	14,110	14,130	14,160	14,180	14,210	14,230	14,260	14,280	14,300	14,330	14,350	14,380	10
11	15,330	15,360	15,390	15,410	15,440	15,470	15,500	15,520	15,550	15,580	15,600	15,630	15,660	15,690	15,710	15,740	15,770	15,790	15,820	15,850	15,870	11
12	16,960	16,990	17,020	17,050	17,080	17,110	17,140	17,170	17,200	17,230	17,260	17,290	17,320	17,350	17,380	17,410	17,440	17,470	17,500	17,530	17,560	12
13	18,570	18,600	18,640	18,670	18,700	18,740	18,770	18,800	18,840	18,870	18,900	18,940	18,970	19,000	19,040	19,070	19,100	19,140	19,170	19,200	19,240	13
14	20,190	20,220	20,260	20,300	20,330	20,370	20,410	20,440	20,480	20,520	20,550	20,590	20,630	20,660	20,700	20,730	20,770	20,810	20,840	20,880	20,910	14
15	21,790	21,830	21,870	21,910	21,950	21,990	22,030	22,070	22,110	22,150	22,190	22,230	22,270	22,310	22,350	22,390	22,430	22,470	22,500	22,540	22,580	15
16	23,330	23,380	23,420	23,460	23,500	23,550	23,590	23,630	23,670	23,720	23,760	23,800	23,840	23,890	23,930	23,970	24,010	24,050	24,100	24,140	24,180	16
17	24,940	24,990	25,040	25,080	25,130	25,170	25,220	25,270	25,310	25,360	25,400	25,450	25,490	25,540	25,580	25,630	25,670	25,720	25,760	25,810	25,850	17
18	26,570	26,620	26,670	26,720	26,770	26,820	26,860	26,910	26,960	27,010	27,060	27,110	27,160	27,200	27,250	27,300	27,350	27,400	27,440	27,490	27,540	18
19	28,180	28,230	28,280	28,340	28,390	28,440	28,490	28,540	28,600	28,650	28,700	28,750	28,800	28,850	28,900	28,950	29,010	29,060	29,110	29,160	29,210	19
20	29,780	29,840	29,900	29,950	30,010	30,060	30,120	30,170	30,220	30,280	30,330	30,390	30,440	30,500	30,550	30,600	30,660	30,710	30,770	30,820	30,870	20
21	31,390	31,450	31,510	31,560	31,620	31,680	31,740	31,800	31,850	31,910	31,970	32,030	32,080	32,140	32,200	32,250	32,310	32,370	32,420	32,480	32,540	21
22	32,990	33,050	33,110	33,170	33,240	33,300	33,360	33,420	33,480	33,540	33,600	33,660	33,720	33,780	33,840	33,900	33,960	34,020	34,080	34,140	34,200	22
23	34,680	34,740	34,810	34,870	34,940	35,000	35,060	35,130	35,190	35,260	35,320	35,380	35,450	35,510	35,570	35,640	35,700	35,760	35,830	35,890	35,950	23
24	36,320	36,390	36,460	36,530	36,590	36,660	36,730	36,800	36,860	36,930	37,000	37,070	37,130	37,200	37,270	37,330	37,400	37,460	37,530	37,600	37,660	24
25	37,960	38,030	38,100	38,170	38,240	38,310	38,380	38,460	38,530	38,600	38,670	38,740	38,810	38,880	38,950	39,020	39,090	39,160	39,230	39,300	39,360	25
26	39,590	39,660	39,740	39,810	39,890	39,960	40,040	40,110	40,180	40,260	40,330	40,400	40,480	40,550	40,620	40,700	40,770	40,840	40,920	40,990	41,060	26
27	41,220	41,290	41,370	41,450	41,530	41,610	41,680	41,760	41,840	41,920	41,990	42,070	42,150	42,220	42,300	42,380	42,450	42,530	42,600	42,680	42,750	27
28	42,840	42,920	43,000	43,080	43,160	43,240	43,320	43,400	43,480	43,560	43,640	43,720	43,800	43,880	43,960	44,040	44,120	44,200	44,280	44,360	44,440	28
29	44,480	44,570	44,650	44,740	44,820	44,910	44,990	45,070	45,160	45,240	45,320	45,410	45,490	45,570	45,660	45,740	45,820	45,900	45,990	46,070	46,150	29
30	46,100	46,180	46,270	46,360	46,450	46,530	46,620	46,710	46,800	46,880	46,970	47,060	47,140	47,230	47,320	47,400	47,490	47,570	47,660	47,740	47,830	30
31	47,740	47,830	47,920	48,010	48,100	48,190	48,280	48,370	48,470	48,560	48,650	48,740	48,820	48,910	49,000	49,090	49,180	49,270	49,360	49,450	49,540	31
32	49,380	49,480	49,570	49,670	49,760	49,850	49,950	50,040	50,140	50,230	50,320	50,420	50,510	50,600	50,690	50,790	50,880	50,970	51,060	51,150	51,250	32
33	51,020	51,120	51,210	51,310	51,410	51,510	51,600	51,700	51,800	51,900	51,990	52,090	52,180	52,280	52,380	52,470	52,570	52,660	52,760	52,850	52,950	33
34	52,780	52,880	52,990	53,090	53,190	53,290	53,390	53,490	53,590	53,690	53,790	53,890	53,990	54,090	54,190	54,290	54,390	54,490	54,590	54,690	54,790	34
35	54,540	54,650	54,750	54,860	54,960	55,070	55,170	55,280	55,380	55,490	55,590	55,690	55,800	55,900	56,000	56,110	56,210	56,310	56,410	56,520	56,620	35
36	56,300	56,410	56,520	56,630	56,740	56,850	56,960	57,070	57,180	57,280	57,390	57,500	57,610	57,710	57,820	57,930	58,030	58,140	58,250	58,350	58,460	36
37	58,050	58,170	58,280	58,390	58,510	58,620	58,730	58,840	58,960	59,070	59,180	59,290	59,400	59,510	59,620	59,730	59,840	59,950	60,060	60,170	60,280	37
38	59,780	59,900	60,010	60,130	60,250	60,360	60,480	60,600	60,710	60,830	60,940	61,060	61,170	61,290	61,400	61,520	61,630	61,740	61,860	61,970	62,080	38
39	61,530	61,650	61,770	61,900	62,020	62,140	62,260	62,380	62,490	62,610	62,730	62,850	62,970	63,090	63,210	63,320	63,440	63,560	63,680	63,790	63,910	39
40	63,300	63,420	63,550	63,670	63,800	63,920	64,040	64,170	64,290	64,410	64,530	64,660	64,780	64,900	65,020	65,140	65,270	65,390	65,510	65,630	65,750	40
41	65,050	65,180	65,310	65,440	65,570	65,690	65,820	65,950	66,080	66,200	66,330	66,460	66,580	66,710	66,830	66,960	67,080	67,210	67,330	67,460	67,580	41
42	66,810	66,940	67,070	67,200	67,330	67,470	67,600	67,730	67,860	67,990	68,120	68,250	68,380	68,510	68,640	68,770	68,890	69,020	69,150	69,280	69,410	42
43	68,560	68,690	68,830	68,960	69,100	69,240	69,370	69,500	69,640	69,770	69,910	70,040	70,170	70,310	70,440	70,570	70,700	70,840	70,970	71,100	71,230	43
44	70,310	70,450	70,590	70,730	70,870	71,010	71,140	71,280	71,420	71,560	71,700	71,830	71,970	72,110	72,240	72,380	72,520	72,650	72,790	72,920	73,060	44
45	72,770	72,920	73,060	73,210	73,360	73,500	73,640	73,790	73,930	74,080	74,220	74,360	74,500	74,650	74,790	74,930	75,070	75,210	75,360	75,500	75,640	45
46	75,240	75,400	75,550	75,700	75,850	76,000	76,150	76,300	76,450	76,600	76,750	76,900	77,040	77,190	77,340	77,490	77,640	77,780	77,930	78,080	78,220	46
47	77,720	77,880	78,030	78,190	78,350	78,500	78,660	78,810	78,970	79,130	79,280	79,430	79,590	79,740	79,900	80,050	80,200	80,350	80,510	80,660	80,810	47
48	80,180	80,350	80,510	80,670	80,840	81,000	81,160	81,320	81,480	81,640	81,800	81,960	82,120	82,280	82,440	82,600	82,760	82,920	83,080	83,230	83,390	48
49	82,600	82,770	82,940	83,110	83,280	83,440	83,610	83,780	83,940	84,110	84,280	84,440	84,610	84,770	84,940	85,100	85,270	85,430	85,590	85,760	85,920	49
50	85,040	85,220	85,390	85,560	85,740	85,910	86,080	86,260	86,430	86,600	86,770	86,950	87,120	87,290	87,460	87,630	87,800	87,970	88,140	88,300	88,470	50
51	87,520	87,700	87,880	88,060	88,240	88,420	88,600	88,780	88,950	89,130	89,310	89,490	89,660	89,840	90,020	90,190	90,370	90,540	90,720	90,890	91,070	51
52	89,990	90,180	90,360	90,550	90,730	90,920	91,100	91,290	91,470	91,660	91,840	92,020	92,210	92,390	92,570	92,750	92,930	93,110	93,290	93,470	93,650	52
53	92,460	92,650	92,850	93,040	93,230	93,420	93,610	93,800	93,990	94,180	94,370	94,560	94,750	94,930	95,120	95,310	95,490	95,680	95,870	96,050	96,240	53
54	94,930	95,120	95,320	95,520	95,720	95,910	96,110	96,300	96,500	96,700	96,890	97,080	97,280	97,470	97,670	97,860	98,050	98,240	98,430	98,630	98,820	54
55	97,380	97,580	97,780	97,990	98,190	98,390	98,590	98,800	99,000	99,200	99,400	99,600	99,800	100,000	100,200	100,400	100,600	100,800	101,000	101,200	101,400	55

DOUGLAS DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGEMENT	998.0	998.1	998.2	998.3	998.4	998.5	998.6	998.7	998.8	998.9	999.0	999.1	999.2	999.3	999.4	999.5	999.6	999.7	999.8	999.9	1000.0	GATE ARRANGEMENT
56	100,500	100,700	100,900	101,100	101,400	101,600	101,800	102,000	102,200	102,400	102,600	102,800	103,000	103,200	103,400	103,600	103,900	104,100	104,300	104,500	104,700	56
57	103,600	103,900	104,100	104,300	104,500	104,700	105,000	105,200	105,400	105,600	105,800	106,000	106,300	106,500	106,700	106,900	107,100	107,300	107,500	107,800	108,000	57
58	106,800	107,000	107,200	107,400	107,700	107,900	108,100	108,400	108,600	108,800	109,000	109,300	109,500	109,700	109,900	110,200	110,400	110,600	110,800	111,000	111,300	58
59	109,900	110,100	110,400	110,600	110,800	111,100	111,300	111,500	111,800	112,000	112,200	112,500	112,700	112,900	113,200	113,400	113,600	113,900	114,100	114,300	114,500	59
60	112,900	113,200	113,400	113,600	113,900	114,100	114,400	114,600	114,900	115,100	115,300	115,600	115,800	116,100	116,300	116,500	116,800	117,000	117,300	117,500	117,700	60
61	115,900	116,200	116,500	116,700	117,000	117,200	117,500	117,700	118,000	118,200	118,500	118,700	119,000	119,200	119,500	119,700	119,900	120,200	120,400	120,700	120,900	61
62	119,100	119,300	119,600	119,900	120,100	120,400	120,700	120,900	121,200	121,400	121,700	121,900	122,200	122,500	122,700	123,000	123,200	123,500	123,700	124,000	124,200	62
63	122,200	122,500	122,800	123,000	123,300	123,600	123,800	124,100	124,400	124,600	124,900	125,200	125,400	125,700	126,000	126,200	126,500	126,700	127,000	127,300	127,500	63
64	125,300	125,600	125,900	126,200	126,400	126,700	127,000	127,300	127,500	127,800	128,100	128,400	128,600	128,900	129,200	129,500	129,700	130,000	130,300	130,500	130,800	64
65	128,500	128,700	129,000	129,300	129,600	129,900	130,200	130,500	130,700	131,000	131,300	131,600	131,900	132,200	132,400	132,700	133,000	133,300	133,600	133,800	134,100	65
66	131,600	131,900	132,200	132,500	132,800	133,100	133,300	133,600	133,900	134,200	134,500	134,800	135,100	135,400	135,700	136,000	136,200	136,500	136,800	137,100	137,400	66
67	135,100	135,400	135,800	136,100	136,400	136,700	137,000	137,300	137,600	137,900	138,200	138,500	138,800	139,100	139,400	139,700	140,000	140,300	140,600	140,900	141,200	67
68	138,700	139,000	139,300	139,700	140,000	140,300	140,600	140,900	141,300	141,600	141,900	142,200	142,500	142,800	143,200	143,500	143,800	144,100	144,400	144,700	145,000	68
69	142,200	142,600	142,900	143,300	143,600	143,900	144,300	144,600	144,900	145,300	145,600	145,900	146,200	146,600	146,900	147,200	147,600	147,900	148,200	148,500	148,800	69
70	145,800	146,200	146,500	146,900	147,200	147,600	147,900	148,300	148,600	148,900	149,300	149,600	150,000	150,300	150,700	151,000	151,300	151,700	152,000	152,300	152,700	70
71	149,200	149,600	149,900	150,300	150,700	151,000	151,400	151,700	152,100	152,500	152,800	153,200	153,500	153,900	154,200	154,600	154,900	155,300	155,600	156,000	156,300	71
72	152,600	153,000	153,400	153,800	154,100	154,500	154,900	155,200	155,600	156,000	156,400	156,700	157,100	157,500	157,800	158,200	158,600	158,900	159,300	159,600	160,000	72
73	156,200	156,600	157,000	157,400	157,800	158,100	158,500	158,900	159,300	159,700	160,100	160,500	160,800	161,200	161,600	162,000	162,400	162,700	163,100	163,500	163,800	73
74	159,800	160,200	160,600	161,000	161,400	161,800	162,200	162,600	163,000	163,400	163,800	164,200	164,600	165,000	165,400	165,800	166,200	166,500	166,900	167,300	167,700	74
75	163,300	163,800	164,200	164,600	165,000	165,400	165,800	166,200	166,700	167,100	167,500	167,900	168,300	168,700	169,100	169,500	169,900	170,300	170,700	171,100	171,500	75
76	166,900	167,300	167,700	168,200	168,600	169,000	169,500	169,900	170,300	170,700	171,200	171,600	172,000	172,400	172,800	173,300	173,700	174,100	174,500	174,900	175,300	76
77	170,400	170,900	171,300	171,800	172,200	172,700	173,100	173,500	174,000	174,400	174,800	175,300	175,700	176,200	176,600	177,000	177,400	177,900	178,300	178,700	179,100	77
78	174,000	174,500	174,900	175,400	175,800	176,200	176,700	177,100	177,600	178,000	178,400	178,900	179,300	179,700	180,200	180,600	181,000	181,400	181,900	182,300	182,700	78
79	177,600	178,000	178,500	178,900	179,400	179,800	180,200	180,700	181,100	181,600	182,000	182,400	182,900	183,300	183,700	184,100	184,600	185,000	185,400	185,800	186,200	79
80	181,100	181,600	182,000	182,500	182,900	183,400	183,800	184,200	184,700	185,100	185,500	186,000	186,400	186,800	187,300	187,700	188,100	188,500	189,000	189,400	189,800	80
81	184,700	185,200	185,600	186,000	186,500	186,900	187,400	187,800	188,200	188,700	189,100	189,500	190,000	190,400	190,800	191,200	191,700	192,100	192,500	192,900	193,400	81
82	188,100	188,500	189,000	189,400	189,800	190,300	190,700	191,200	191,600	192,000	192,500	192,900	193,300	193,700	194,200	194,600	195,000	195,400	195,900	196,300	196,800	82
83	191,400	191,900	192,300	192,800	193,200	193,600	194,100	194,500	195,000	195,400	195,800	196,200	196,700	197,100	197,500	198,000	198,400	198,800	199,200	199,700	200,100	83
84	195,000	195,500	195,900	196,300	196,800	197,200	197,700	198,100	198,500	199,000	199,400	199,800	200,200	200,700	201,100	201,500	201,900	202,400	202,800	203,200	203,700	84
85	198,600	199,000	199,500	199,900	200,400	200,800	201,200	201,700	202,100	202,500	203,000	203,400	203,800	204,200	204,700	205,100	205,500	205,900	206,300	206,800	207,300	85
86	202,100	202,600	203,000	203,500	203,900	204,400	204,800	205,200	205,700	206,100	206,500	206,900	207,400	207,800	208,200	208,600	209,000	209,500	209,900	210,400	210,900	86
87	205,700	206,100	206,600	207,000	207,500	207,900	208,300	208,800	209,200	209,600	210,100	210,500	210,900	211,300	211,800	212,200	212,600	213,000	213,400	213,900	214,400	87
88	209,200	209,700	210,100	210,600	211,000	211,400	211,900	212,300	212,700	213,200	213,600	214,000	214,400	214,900	215,300	215,700	216,100	216,500	217,000	217,500	218,000	88
89	212,700	213,300	213,800	214,400	214,900	215,400	216,000	216,500	217,000	217,500	218,100	218,600	219,100	219,600	220,100	220,700	221,200	221,700	222,200	222,800	223,500	89
90	216,400	217,000	217,600	218,300	218,900	219,500	220,200	220,800	221,400	222,000	222,700	223,300	223,900	224,500	225,100	225,800	226,400	227,000	227,600	228,300	229,000	90
91	220,000	220,800	221,500	222,200	223,000	223,700	224,400	225,100	225,900	226,600	227,300	228,000	228,700	229,500	230,200	230,900	231,600	232,300	233,100	233,900	234,600	91
92	223,700	224,500	225,400	226,200	227,000	227,800	228,600	229,500	230,300	231,100	231,900	232,700	233,600	234,400	235,200	236,000	236,800	237,700	238,500	239,400	240,100	92
93	227,100	228,100	229,000	229,900	230,800	231,700	232,600	233,500	234,400	235,300	236,300	237,200	238,100	239,000	239,900	240,800	241,700	242,700	243,600	244,600	245,400	93
94	230,600	231,600	232,600	233,600	234,600	235,600	236,600	237,600	238,600	239,600	240,600	241,600	242,600	243,600	244,600	245,700	246,700	247,700	248,700	249,800	250,700	94
95	234,300	235,300	236,400	237,500	238,600	239,700	240,800	241,900	243,000	244,100	245,200	246,300	247,400	248,500	249,700	250,800	251,900	253,000	254,100	255,300	256,300	95
96	238,000	239,100	240,300	241,500	242,700	243,900	245,100	246,300	247,500	248,700	249,900	251,100	252,300	253,500	254,700	255,900	257,100	258,400	259,600	260,800	261,800	96
97	241,600	242,900	244,100	245,400	246,700	248,000	249,300	250,600	251,900	253,200	254,500	255,800	257,100	258,400	259,700	261,000	262,300	263,700	265,000	266,300	267,400	97
98	245,200	246,600	248,000	249,400	250,700	252,100	253,500	254,900	256,300	257,700	259,100	260,500	261,900	263,300	264,700	266,100	267,600	269,000	270,400	271,900	273,000	98
99	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,500	99
100	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,500	100
101	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,500	101
102	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,600	102
103	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,700	103
104	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,700	104
105	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,700	105
106	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,700	106
107	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,800	107
108	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,800	108
109	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,800	109
110	248,900	250,400	251,800	253,300	254,800	256,300	257,800	259,200	260,700	262,200	263,700	265,200	266,700	268,300	269,800	271,300	272,800	274,300	275,900	277,400	278,900	110

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	1000.0	1000.1	1000.2	1000.3	1000.4	1000.5	1000.6	1000.7	1000.8	1000.9	1001.0	1001.1	1001.2	1001.3	1001.4	1001.5	1001.6	1001.7	1001.8	1001.9	1002.0	
1	1,480	1,480	1,490	1,490	1,490	1,490	1,500	1,500	1,500	1,500	1,510	1,510	1,510	1,510	1,520	1,520	1,520	1,520	1,530			1
2	2,930	2,940	2,940	2,950	2,950	2,960	2,960	2,970	2,970	2,980	2,980	2,990	2,990	3,000	3,000	3,010	3,010	3,020	3,020			2
3	4,320	4,330	4,340	4,350	4,350	4,360	4,370	4,370	4,380	4,390	4,400	4,400	4,410	4,420	4,420	4,430	4,440	4,450	4,450			3
4	5,770	5,780	5,790	5,800	5,810	5,820	5,830	5,840	5,850	5,860	5,870	5,880	5,890	5,900	5,910	5,920	5,930	5,940	5,950			4
5	7,290	7,300	7,310	7,330	7,340	7,350	7,360	7,380	7,390	7,400	7,410	7,420	7,440	7,450	7,460	7,470	7,480	7,500	7,510			5
6	8,660	8,670	8,690	8,700	8,720	8,730	8,740	8,760	8,770	8,790	8,800	8,820	8,830	8,850	8,860	8,870	8,890	8,900	8,920			6
7	10,030	10,040	10,060	10,080	10,090	10,110	10,130	10,140	10,160	10,180	10,190	10,210	10,230	10,240	10,260	10,280	10,290	10,310	10,330			7
8	11,410	11,420	11,440	11,460	11,480	11,500	11,520	11,540	11,560	11,580	11,600	11,620	11,630	11,650	11,670	11,690	11,710	11,730	11,750			8
9	12,890	12,910	12,930	12,960	12,980	13,000	13,020	13,040	13,060	13,080	13,110	13,130	13,150	13,170	13,190	13,210	13,230	13,260	13,280			9
10	14,380	14,400	14,430	14,450	14,470	14,500	14,520	14,550	14,570	14,590	14,620	14,640	14,670	14,690	14,710	14,740	14,760	14,780	14,810			10
11	15,870	15,900	15,930	15,950	15,980	16,010	16,030	16,060	16,090	16,110	16,140	16,170	16,190	16,220	16,250	16,270	16,300	16,320	16,350	16,380	16,400	11
12	17,560	17,590	17,620	17,650	17,680	17,710	17,740	17,770	17,800	17,830	17,860	17,890	17,920	17,950	17,970	18,000	18,030	18,060	18,090	18,120	18,150	12
13	19,240	19,270	19,300	19,330	19,370	19,400	19,430	19,460	19,500	19,530	19,560	19,590	19,620	19,660	19,690	19,720	19,750	19,780	19,820	19,850	19,880	13
14	20,910	20,950	20,990	21,020	21,060	21,090	21,130	21,160	21,200	21,230	21,270	21,300	21,340	21,370	21,410	21,440	21,480	21,510	21,550	21,580	21,620	14
15	22,580	22,620	22,660	22,700	22,740	22,770	22,810	22,850	22,890	22,930	22,970	23,000	23,040	23,080	23,120	23,160	23,190	23,230	23,270	23,310	23,340	15
16	24,180	24,220	24,260	24,300	24,340	24,390	24,430	24,470	24,510	24,550	24,590	24,630	24,670	24,710	24,750	24,790	24,830	24,870	24,910	24,960	25,000	16
17	25,850	25,890	25,940	25,980	26,030	26,070	26,120	26,160	26,200	26,250	26,290	26,340	26,380	26,420	26,470	26,510	26,550	26,600	26,640	26,680	26,730	17
18	27,540	27,590	27,630	27,680	27,730	27,770	27,820	27,870	27,920	27,960	28,010	28,060	28,100	28,150	28,200	28,240	28,290	28,330	28,380	28,430	28,470	18
19	29,210	29,260	29,310	29,360	29,410	29,460	29,510	29,560	29,610	29,660	29,710	29,760	29,810	29,860	29,910	29,960	30,000	30,050	30,100	30,150	30,200	19
20	30,870	30,930	30,980	31,030	31,090	31,140	31,190	31,240	31,300	31,350	31,400	31,450	31,510	31,560	31,610	31,660	31,720	31,770	31,820	31,870	31,920	20
21	32,540	32,590	32,650	32,710	32,760	32,820	32,870	32,930	32,980	33,040	33,100	33,150	33,210	33,260	33,320	33,370	33,430	33,480	33,540	33,590	33,650	21
22	34,200	34,260	34,320	34,380	34,440	34,490	34,550	34,610	34,670	34,730	34,790	34,850	34,900	34,960	35,020	35,080	35,140	35,190	35,250	35,310	35,370	22
23	35,950	36,020	36,080	36,140	36,200	36,260	36,330	36,390	36,450	36,510	36,570	36,640	36,700	36,760	36,820	36,880	36,940	37,000	37,060	37,120	37,190	23
24	37,660	37,730	37,790	37,860	37,930	37,990	38,060	38,120	38,190	38,250	38,320	38,380	38,450	38,510	38,570	38,640	38,700	38,770	38,830	38,900	38,960	24
25	39,360	39,430	39,500	39,570	39,640	39,710	39,780	39,850	39,910	39,980	40,050	40,120	40,180	40,250	40,320	40,390	40,450	40,520	40,590	40,660	40,720	25
26	41,060	41,130	41,200	41,280	41,350	41,420	41,490	41,560	41,630	41,710	41,780	41,850	41,920	41,990	42,060	42,130	42,200	42,270	42,340	42,410	42,480	26
27	42,750	42,830	42,910	42,980	43,060	43,130	43,210	43,280	43,350	43,430	43,500	43,580	43,650	43,720	43,800	43,870	43,950	44,020	44,090	44,170	44,240	27
28	44,440	44,520	44,600	44,670	44,750	44,830	44,910	44,990	45,060	45,140	45,220	45,300	45,370	45,450	45,530	45,600	45,680	45,760	45,830	45,910	45,990	28
29	46,150	46,230	46,310	46,400	46,480	46,560	46,640	46,720	46,800	46,880	46,960	47,040	47,120	47,200	47,280	47,360	47,440	47,520	47,600	47,680	47,760	29
30	47,830	47,910	48,000	48,080	48,170	48,250	48,340	48,420	48,500	48,590	48,670	48,750	48,840	48,920	49,000	49,090	49,170	49,250	49,340	49,420	49,500	30
31	49,540	49,620	49,710	49,800	49,890	49,980	50,060	50,150	50,240	50,320	50,410	50,500	50,580	50,670	50,760	50,840	50,930	51,020	51,100	51,190	51,270	31
32	51,250	51,340	51,430	51,520	51,610	51,700	51,790	51,880	51,970	52,060	52,150	52,240	52,330	52,420	52,510	52,600	52,690	52,780	52,870	52,960	53,040	32
33	52,950	53,040	53,140	53,230	53,330	53,420	53,510	53,610	53,700	53,790	53,890	53,980	54,070	54,170	54,260	54,350	54,440	54,530	54,630	54,720	54,810	33
34	54,790	54,890	54,980	55,080	55,180	55,280	55,370	55,470	55,570	55,670	55,760	55,860	55,960	56,050	56,150	56,240	56,340	56,440	56,530	56,630	56,720	34
35	56,620	56,720	56,820	56,920	57,030	57,130	57,230	57,330	57,430	57,530	57,630	57,730	57,830	57,930	58,030	58,130	58,230	58,330	58,430	58,530	58,630	35
36	58,460	58,560	58,670	58,770	58,880	58,980	59,090	59,190	59,300	59,400	59,510	59,610	59,710	59,820	59,920	60,020	60,130	60,230	60,330	60,430	60,540	36
37	60,280	60,390	60,500	60,610	60,720	60,830	60,940	61,040	61,150	61,260	61,370	61,470	61,580	61,690	61,800	61,900	62,010	62,110	62,220	62,330	62,430	37
38	62,080	62,200	62,310	62,420	62,530	62,640	62,760	62,870	62,980	63,090	63,200	63,310	63,420	63,530	63,640	63,750	63,860	63,970	64,080	64,190	64,300	38
39	63,910	64,030	64,140	64,260	64,370	64,490	64,600	64,720	64,840	64,950	65,060	65,180	65,290	65,410	65,520	65,630	65,750	65,860	65,970	66,090	66,200	39
40	65,750	65,870	65,990	66,110	66,230	66,350	66,470	66,580	66,700	66,820	66,940	67,060	67,180	67,290	67,410	67,530	67,640	67,760	67,880	67,990	68,110	40
41	67,580	67,700	67,830	67,950	68,070	68,200	68,320	68,440	68,560	68,690	68,810	68,930	69,050	69,170	69,290	69,410	69,530	69,650	69,770	69,890	70,010	41
42	69,410	69,530	69,660	69,790	69,910	70,040	70,170	70,290	70,420	70,540	70,670	70,800	70,920	71,040	71,170	71,290	71,420	71,540	71,660	71,790	71,910	42
43	71,230	71,360	71,490	71,620	71,750	71,880	72,010	72,140	72,270	72,400	72,530	72,660	72,790	72,920	73,040	73,170	73,300	73,430	73,550	73,680	73,810	43
44	73,060	73,190	73,330	73,460	73,590	73,730	73,860	73,990	74,130	74,260	74,390	74,520	74,660	74,790	74,920	75,050	75,180	75,310	75,440	75,570	75,700	44
45	75,640	75,780	75,920	76,060	76,200	76,340	76,470	76,610	76,750	76,890	77,030	77,170	77,300	77,440	77,580	77,710	77,850	77,990	78,120	78,260	78,390	45
46	78,220	78,370	78,510	78,660	78,800	78,950	79,090	79,240	79,380	79,530	79,670	79,810	79,960	80,100	80,240	80,380	80,520	80,670	80,810	80,950	81,090	46
47	80,810	80,960	81,110	81,260	81,420	81,570	81,720	81,870	82,020	82,160	82,310	82,460	82,610	82,760	82,910	83,050	83,200	83,350	83,500	83,640	83,790	47
48	83,390	83,550	83,700	83,860	84,020	84,170	84,330	84,480	84,640	84,790	84,950	85,100	85,260	85,410	85,560	85,720	85,870	86,020	86,170	86,330	86,480	48
49	85,920	86,080	86,240	86,410	86,570	86,730	86,890	87,050	87,210	87,370	87,530	87,690	87,850	88,010	88,170	88,330	88,490	88,640	88,800	88,960	89,120	49
50	88,470	88,640	88,810	88,980	89,140	89,310	89,480	89,640	89,810	89,970	90,140	90,310	90,470	90,630	90,800	90,960	91,130	91,290	91,450	91,610	91,780	50
51	91,070	91,240	91,410	91,590	91,760	91,930	92,100	92,270	92,450	92,620	92,790	92,960	93,130	93,300	93,470	93,640	93,810	93,980	94,140	94,310	94,480	51
52	93,650	93,830	94,010	94,190	94,370	94,550	94,720	94,900	95,080	95,250	95,430	95,610	95,780	95,960	96,130	96,310	96,480	96,660	96,830	97,000	97,180	52
53	96,240	96,420	96,610	96,790	96,980	97,160	97,340	97,520	97,710	97,890	98,070	98,250	98,430	98,610	98,800	98,980	99,160	99,330	99,510	99,690	99,870	53
54	98,820	99,010	99,200	99,390	99,580	99,760	99,950	100,100	100,300	100,500	100,700	100,900	101,100	101,300	101,500	101,600	101,800	102,000	102,200	102,400	102,600	54
55	101,400	101,600	101,800	102,000	102,200	102,400	102,600	102,700	102,900	103,100	103,300	103,500	103,700	103,900	104,100	104,300	104,500	104,700	104,900	105,000	105,200	55

See special instruction for preventing gate overflow on page 3.

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	1000.0	1000.1	1000.2	1000.3	1000.4	1000.5	1000.6	1000.7	1000.8	1000.9	1001.0	1001.1	1001.2	1001.3	1001.4	1001.5	1001.6	1001.7	1001.8	1001.9	1002.0	
56	104,700	104,900	105,100	105,300	105,500	105,700	105,900	106,100	106,300	106,500	106,700	106,900	107,100	107,300	107,500	107,700	107,900	108,100	108,300	108,500	108,700	56
57	108,000	108,200	108,400	108,600	108,800	109,000	109,200	109,400	109,700	109,900	110,100	110,300	110,500	110,700	110,900	111,100	111,300	111,500	111,700	111,900	112,100	57
58	111,300	111,500	111,700	111,900	112,100	112,400	112,600	112,800	113,000	113,200	113,400	113,700	113,900	114,100	114,300	114,500	114,700	114,900	115,200	115,400	115,600	58
59	114,500	114,800	115,000	115,200	115,500	115,700	115,900	116,100	116,400	116,600	116,800	117,000	117,300	117,500	117,700	117,900	118,100	118,400	118,600	118,800	119,000	59
60	117,700	118,000	118,200	118,400	118,700	118,900	119,100	119,400	119,600	119,800	120,100	120,300	120,500	120,800	121,000	121,200	121,500	121,700	121,900	122,100	122,400	60
61	120,900	121,200	121,400	121,700	121,900	122,100	122,400	122,600	122,900	123,100	123,300	123,600	123,800	124,100	124,300	124,500	124,800	125,000	125,200	125,500	125,700	61
62	124,200	124,500	124,700	125,000	125,200	125,500	125,700	126,000	126,200	126,500	126,700	127,000	127,200	127,500	127,700	128,000	128,200	128,500	128,700	128,900	129,200	62
63	127,500	127,800	128,000	128,300	128,600	128,800	129,100	129,300	129,600	129,800	130,100	130,400	130,600	130,900	131,100	131,400	131,600	131,900	132,100	132,400	132,600	63
64	130,800	131,100	131,300	131,600	131,900	132,100	132,400	132,700	132,900	133,200	133,500	133,700	134,000	134,200	134,500	134,800	135,000	135,300	135,600	135,800	136,100	64
65	134,100	134,400	134,700	134,900	135,200	135,500	135,800	136,000	136,300	136,600	136,800	137,100	137,400	137,700	137,900	138,200	138,500	138,700	139,000	139,300	139,500	65
66	137,400	137,700	138,000	138,200	138,500	138,800	139,100	139,400	139,600	139,900	140,200	140,500	140,800	141,000	141,300	141,600	141,900	142,100	142,400	142,700	143,000	66
67	141,200	141,500	141,800	142,100	142,400	142,700	143,000	143,300	143,600	143,900	144,100	144,400	144,700	145,000	145,300	145,600	145,900	146,200	146,400	146,700	147,000	67
68	145,000	145,300	145,600	145,900	146,200	146,600	146,900	147,200	147,500	147,800	148,100	148,400	148,700	149,000	149,300	149,600	149,900	150,200	150,400	150,700	151,000	68
69	148,800	149,200	149,500	149,800	150,100	150,400	150,700	151,100	151,400	151,700	152,000	152,300	152,600	152,900	153,200	153,500	153,800	154,200	154,500	154,800	155,100	69
70	152,700	153,000	153,300	153,700	154,000	154,300	154,600	155,000	155,300	155,600	155,900	156,200	156,600	156,900	157,200	157,500	157,800	158,200	158,500	158,800	159,100	70
71	156,300	156,700	157,000	157,300	157,700	158,000	158,400	158,700	159,000	159,400	159,700	160,000	160,400	160,700	161,000	161,300	161,700	162,000	162,300	162,700	163,000	71
72	160,000	160,300	160,700	161,000	161,400	161,700	162,100	162,400	162,800	163,100	163,500	163,800	164,100	164,500	164,800	165,200	165,500	165,800	166,200	166,500	166,800	72
73	163,800	164,200	164,500	164,900	165,300	165,600	166,000	166,300	166,700	167,000	167,400	167,800	168,100	168,500	168,800	169,200	169,500	169,900	170,200	170,600	170,900	73
74	167,700	168,000	168,400	168,800	169,200	169,500	169,900	170,300	170,600	171,000	171,400	171,700	172,100	172,400	172,800	173,200	173,500	173,900	174,300	174,600	175,000	74
75	171,500	171,900	172,200	172,600	173,000	173,400	173,800	174,100	174,500	174,900	175,300	175,700	176,000	176,400	176,800	177,100	177,500	177,900	178,300	178,600	179,000	75
76	175,300	175,700	176,100	176,500	176,900	177,200	177,600	178,000	178,400	178,800	179,200	179,600	180,000	180,300	180,700	181,100	181,500	181,900	182,300	182,600	183,000	76
77	179,100	179,500	179,900	180,300	180,700	181,100	181,500	181,900	182,300	182,700	183,100	183,500	183,900	184,300	184,700	185,100	185,500	185,900	186,300	186,700	187,000	77
78	182,700	183,100	183,500	183,900	184,300	184,700	185,200	185,600	186,000	186,400	186,800	187,200	187,600	188,000	188,400	188,800	189,200	189,600	190,000	190,400	190,800	78
79	186,200	186,700	187,100	187,500	187,900	188,400	188,800	189,200	189,600	190,000	190,500	190,900	191,300	191,700	192,100	192,500	193,000	193,400	193,800	194,200	194,600	79
80	189,800	190,300	190,700	191,100	191,600	192,000	192,400	192,900	193,300	193,700	194,100	194,600	195,000	195,400	195,900	196,300	196,700	197,100	197,500	198,000	198,400	80
81	193,400	193,800	194,300	194,700	195,200	195,600	196,100	196,500	196,900	197,400	197,800	198,300	198,700	199,100	199,600	200,000	200,400	200,900	201,300	201,700	202,200	81
82	196,800	197,200	197,700	198,100	198,600	199,000	199,500	199,900	200,400	200,800	201,300	201,700	202,200	202,600	203,100	203,500	204,000	204,400	204,800	205,300	205,700	82
83	200,100	200,600	201,100	201,500	202,000	202,500	202,900	203,400	203,800	204,300	204,800	205,200	205,700	206,100	206,600	207,000	207,500	207,900	208,400	208,800	209,300	83
84	203,700	204,200	204,700	205,100	205,600	206,100	206,600	207,000	207,500	208,000	208,500	208,900	209,400	209,900	210,300	210,800	211,200	211,700	212,200	212,600	213,100	84
85	207,300	207,800	208,300	208,800	209,300	209,700	210,200	210,700	211,200	211,700	212,200	212,600	213,100	213,600	214,100	214,500	215,000	215,500	215,900	216,400	216,900	85
86	210,900	211,400	211,900	212,400	212,900	213,400	213,900	214,400	214,800	215,300	215,800	216,300	216,800	217,300	217,800	218,300	218,700	219,200	219,700	220,200	220,700	86
87	214,400	214,900	215,500	216,000	216,500	217,000	217,500	218,000	218,500	219,000	219,500	220,000	220,500	221,000	221,500	222,000	222,500	223,000	223,500	223,900	224,400	87
88	218,000	218,500	219,000	219,500	220,100	220,600	221,100	221,600	222,100	222,600	223,200	223,700	224,200	224,700	225,200	225,700	226,200	226,700	227,200	227,700	228,200	88
89	223,500	224,100	224,700	225,100	225,500	226,000	226,400	226,800	227,200	227,700	228,100	228,600	229,000	229,400	229,900	230,300	230,800	231,200	231,700	232,100	232,600	89
90	229,000	229,600	230,100	230,400	230,800	231,100	231,400	231,800	232,100	232,500	232,900	233,300	233,600	234,000	234,400	234,800	235,200	235,600	236,000	236,400	236,800	90
91	234,600	235,000	235,500	235,700	235,900	236,200	236,400	236,700	237,000	237,300	237,600	237,900	238,300	238,600	239,000	239,300	239,600	240,000	240,300	240,600	241,000	91
92	240,100	240,500	240,800	241,000	241,100	241,300	241,500	241,700	241,900	242,100	242,400	242,600	242,900	243,200	243,500	243,800	244,000	244,300	244,600	244,900	245,200	92
93	245,400	245,700	246,000	246,000	246,100	246,100	246,200	246,400	246,500	246,700	246,900	247,100	247,300	247,500	247,800	248,000	248,200	248,500	248,700	248,900	249,200	93
94	250,700	250,900	251,100	251,000	251,000	251,000	251,000	251,100	251,200	251,300	251,400	251,500	251,700	251,900	252,100	252,200	252,400	252,600	252,700	252,900	253,100	94
95	256,300	256,400	256,500	256,400	256,200	256,100	256,100	256,100	256,100	256,100	256,100	256,200	256,400	256,500	256,600	256,700	256,900	257,000	257,100	257,200	257,300	95
96	261,800	261,900	261,900	261,600	261,400	261,200	261,100	261,000	261,000	260,900	260,900	260,900	261,000	261,100	261,200	261,200	261,300	261,300	261,400	261,400	261,600	96
97	267,400	267,400	267,200	266,900	266,600	266,300	266,100	266,000	265,900	265,700	265,600	265,600	265,600	265,700	265,700	265,700	265,700	265,700	265,700	265,800	265,800	97
98	273,000	272,900	272,600	272,200	271,800	271,400	271,200	271,000	270,800	270,600	270,400	270,300	270,300	270,300	270,200	270,200	270,100	270,100	270,000	270,000	270,000	98
99	278,500	278,300	278,000	277,500	277,000	276,500	276,200	275,900	275,600	275,400	275,100	275,000	274,900	274,800	274,700	274,600	274,500	274,400	274,300	274,200	274,200	99
100	278,500	278,300	278,000	277,700	277,400	277,100	277,000	276,900	276,800	276,700	276,600	276,700	276,700	276,800	276,900	276,900	277,000	277,000	277,100	277,100	277,300	100
101	278,500	278,500	278,400	278,200	278,100	278,000	278,100	278,100	278,200	278,300	278,400	278,600	278,800	279,000	279,300	279,500	279,700	279,900	280,100	280,300	280,600	101
102	278,600	278,800	278,800	278,900	278,900	279,000	279,300	279,500	279,700	280,000	280,200	280,600	281,000	281,400	281,700	282,100	282,500	282,800	283,200	283,500	284,000	102
103	278,700	279,000	279,300	279,500	279,800	280,000	280,400	280,800	281,200	281,600	282,100	282,600	283,100	283,700	284,200	284,700	285,200	285,700	286,300	286,800	287,400	103
104	278,700	279,200	279,600	280,000	280,400	280,900	281,400	282,000	282,600	283,100	283,700	284,400	285,100	285,700	286,400	287,100	287,800	288,400	289,100	289,800	290,500	104
105	278,700	279,300	279,900	280,500	281,100	281,800	282,500	283,200	283,900	284,600	285,400	286,200	287,000	287,900	288,700	289,500	290,300	291,100	291,900	292,800	293,600	105
106	278,700	279,500	280,300	281,100	281,900	282,700	283,600	284,500	285,400	286,300	287,200	288,200	289,100	290,100	291,100	292,000	293,000	294,000	295,000	295,900	297,000	106
107	278,800	279,800	280,800	281,700	282,700	283,700	284,800	285,800	286,900	288,000	289,000	290,200	291,300	292,400	293,600	294,700	295,800	296,900	298,100	299,200	300,400	107
108	278,800	280,000	281,200	282,300	283,500	284,700	285,900	287,200	288,400	289,600	290,900	292,100	293,400	294,700	296,000	297,300	298,600	299,800	301,100	302,400	303,700	108
109	278,800	280,200	281,600	282,900	284,300	285,700	287,000	288,400	289,800	291,200	292,700	294,100	295,500	297,000	298,400	299,800	301,300	302,700	304,200	305,600	307,100	109
110	278,900	280,500	282,000	283,600	285,100	286,700	288,200	289,800	291,400	292,900	294,500	296,100	297,700	299,300	300,900	302,500	304,100	305,700	307,300	308,900	310,500	110

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE OPENING	HEADWATER ELEVATION																					GATE OPENING
	1002.0	1002.1	1002.2	1002.3	1002.4	1002.5	1002.6	1002.7	1002.8	1002.9	1003.0	1003.1	1003.2	1003.3	1003.4	1003.5	1003.6	1003.7	1003.8	1003.9	1004.0	
11	16,400	16,430	16,450	16,480	16,500	16,530	16,560	16,580	16,610													11
12	18,150	18,180	18,210	18,230	18,260	18,290	18,320	18,350	18,380													12
13	19,880	19,910	19,940	19,970	20,010	20,040	20,070	20,100	20,130													13
14	21,620	21,650	21,690	21,720	21,750	21,790	21,820	21,860	21,890													14
15	23,340	23,380	23,420	23,460	23,490	23,530	23,570	23,600	23,640													15
16	25,000	25,040	25,080	25,120	25,160	25,200	25,240	25,280	25,310													16
17	26,730	26,770	26,810	26,850	26,900	26,940	26,980	27,030	27,070													17
18	28,470	28,520	28,560	28,610	28,660	28,700	28,750	28,790	28,840													18
19	30,200	30,250	30,300	30,350	30,390	30,440	30,490	30,540	30,590	30,640												19
20	31,920	31,980	32,030	32,080	32,130	32,180	32,230	32,280	32,330	32,390												20
21	33,650	33,700	33,750	33,810	33,860	33,920	33,970	34,030	34,080	34,130												21
22	35,370	35,420	35,480	35,540	35,600	35,650	35,710	35,770	35,820	35,880	35,940	35,990	36,050	36,100	36,160	36,220	36,270	36,330	36,380	36,440	36,500	22
23	37,190	37,250	37,310	37,370	37,430	37,490	37,550	37,610	37,670	37,730	37,790	37,850	37,910	37,960	38,020	38,080	38,140	38,200	38,260	38,320	38,380	23
24	38,960	39,020	39,090	39,150	39,210	39,280	39,340	39,400	39,470	39,530	39,590	39,650	39,720	39,780	39,840	39,900	39,970	40,030	40,090	40,150	40,210	24
25	40,720	40,790	40,860	40,920	40,990	41,060	41,120	41,190	41,250	41,320	41,390	41,450	41,520	41,580	41,650	41,710	41,780	41,840	41,910	41,970	42,040	25
26	42,480	42,550	42,620	42,690	42,760	42,830	42,900	42,970	43,040	43,110	43,180	43,240	43,310	43,380	43,450	43,520	43,590	43,650	43,720	43,790	43,860	26
27	44,240	44,310	44,380	44,460	44,530	44,600	44,670	44,750	44,820	44,890	44,960	45,030	45,110	45,180	45,250	45,320	45,390	45,460	45,530	45,600	45,670	27
28	45,990	46,060	46,140	46,210	46,290	46,360	46,440	46,510	46,590	46,660	46,740	46,810	46,890	46,960	47,040	47,110	47,190	47,260	47,330	47,410	47,480	28
29	47,760	47,840	47,920	48,000	48,080	48,160	48,230	48,310	48,390	48,470	48,550	48,620	48,700	48,780	48,860	48,930	49,010	49,090	49,160	49,240	49,320	29
30	49,500	49,580	49,660	49,750	49,830	49,910	49,990	50,070	50,150	50,230	50,320	50,400	50,480	50,560	50,640	50,720	50,800	50,880	50,960	51,040	51,120	30
31	51,270	51,360	51,440	51,530	51,610	51,700	51,780	51,870	51,950	52,030	52,120	52,200	52,290	52,370	52,450	52,540	52,620	52,700	52,780	52,870	52,950	31
32	53,040	53,130	53,220	53,310	53,400	53,480	53,570	53,660	53,750	53,830	53,920	54,010	54,090	54,180	54,270	54,350	54,440	54,530	54,610	54,700	54,780	32
33	54,810	54,900	54,990	55,080	55,170	55,270	55,360	55,450	55,540	55,630	55,720	55,810	55,900	55,990	56,080	56,170	56,260	56,340	56,430	56,520	56,610	33
34	56,720	56,820	56,910	57,010	57,100	57,190	57,290	57,380	57,480	57,570	57,660	57,760	57,850	57,940	58,040	58,130	58,220	58,310	58,410	58,500	58,590	34
35	58,630	58,720	58,820	58,920	59,020	59,120	59,210	59,310	59,410	59,510	59,600	59,700	59,800	59,890	59,990	60,090	60,180	60,280	60,370	60,470	60,560	35
36	60,540	60,640	60,740	60,840	60,940	61,040	61,140	61,250	61,350	61,450	61,550	61,650	61,750	61,850	61,950	62,050	62,150	62,250	62,350	62,450	62,540	36
37	62,430	62,540	62,640	62,750	62,850	62,960	63,060	63,170	63,270	63,380	63,480	63,580	63,690	63,790	63,890	64,000	64,100	64,200	64,300	64,410	64,510	37
38	64,300	64,410	64,520	64,630	64,740	64,850	64,950	65,060	65,170	65,280	65,380	65,490	65,600	65,700	65,810	65,920	66,020	66,130	66,240	66,340	66,450	38
39	66,200	66,310	66,420	66,540	66,650	66,760	66,870	66,980	67,090	67,210	67,320	67,430	67,540	67,650	67,760	67,870	67,980	68,090	68,200	68,310	68,410	39
40	68,110	68,230	68,340	68,460	68,570	68,690	68,800	68,920	69,030	69,150	69,260	69,380	69,490	69,600	69,720	69,830	69,940	70,060	70,170	70,280	70,390	40
41	70,010	70,130	70,250	70,370	70,490	70,610	70,730	70,850	70,960	71,080	71,200	71,320	71,430	71,550	71,670	71,780	71,900	72,020	72,130	72,250	72,370	41
42	71,910	72,030	72,160	72,280	72,400	72,520	72,650	72,770	72,890	73,010	73,130	73,250	73,370	73,490	73,610	73,730	73,850	73,970	74,090	74,210	74,330	42
43	73,810	73,930	74,060	74,190	74,310	74,440	74,560	74,690	74,810	74,940	75,060	75,190	75,310	75,440	75,560	75,680	75,810	75,930	76,050	76,170	76,300	43
44	75,700	75,830	75,960	76,090	76,220	76,350	76,480	76,610	76,740	76,870	76,990	77,120	77,250	77,380	77,500	77,630	77,760	77,880	78,010	78,140	78,260	44
45	78,390	78,530	78,670	78,800	78,930	79,070	79,200	79,340	79,470	79,600	79,740	79,870	80,000	80,140	80,270	80,400	80,530	80,670	80,800	80,930	81,060	45
46	81,090	81,230	81,370	81,510	81,650	81,790	81,930	82,070	82,210	82,350	82,490	82,630	82,760	82,900	83,040	83,180	83,310	83,450	83,590	83,720	83,860	46
47	83,790	83,940	84,080	84,230	84,370	84,520	84,660	84,810	84,950	85,100	85,240	85,380	85,530	85,670	85,810	85,960	86,100	86,240	86,380	86,520	86,670	47
48	86,480	86,630	86,780	86,930	87,080	87,230	87,380	87,530	87,680	87,830	87,980	88,130	88,280	88,430	88,580	88,720	88,870	89,020	89,170	89,310	89,460	48
49	89,120	89,270	89,430	89,590	89,740	89,900	90,050	90,210	90,360	90,520	90,670	90,830	90,980	91,130	91,290	91,440	91,590	91,740	91,900	92,050	92,200	49
50	91,780	91,940	92,100	92,260	92,420	92,580	92,750	92,910	93,070	93,230	93,390	93,540	93,700	93,860	94,020	94,180	94,340	94,490	94,650	94,810	94,970	50
51	94,480	94,650	94,810	94,980	95,150	95,310	95,480	95,650	95,810	95,980	96,140	96,310	96,470	96,630	96,800	96,960	97,120	97,290	97,450	97,610	97,770	51
52	97,180	97,350	97,520	97,690	97,870	98,040	98,210	98,380	98,550	98,720	98,890	99,060	99,230	99,400	99,570	99,740	99,910	100,100	100,200	100,400	100,600	52
53	99,870	100,000	100,200	100,400	100,600	100,800	100,900	101,100	101,300	101,500	101,600	101,800	102,000	102,200	102,300	102,500	102,700	102,900	103,000	103,200	103,400	53
54	102,600	102,700	102,900	103,100	103,300	103,500	103,700	103,800	104,000	104,200	104,400	104,600	104,700	104,900	105,100	105,300	105,500	105,600	105,800	106,000	106,200	54
55	105,200	105,400	105,600	105,800	106,000	106,200	106,400	106,500	106,700	106,900	107,100	107,300	107,500	107,700	107,800	108,000	108,200	108,400	108,600	108,800	108,900	55
56	108,700	108,900	109,100	109,300	109,500	109,700	109,900	110,100	110,300	110,400	110,600	110,800	111,000	111,200	111,400	111,600	111,800	112,000	112,200	112,400	112,600	56
57	112,100	112,300	112,500	112,700	113,000	113,200	113,400	113,600	113,800	114,000	114,200	114,400	114,600	114,800	115,000	115,200	115,400	115,600	115,800	116,000	116,200	57
58	115,600	115,800	116,000	116,200	116,400	116,600	116,900	117,100	117,300	117,500	117,700	117,900	118,100	118,300	118,500	118,700	118,900	119,100	119,300	119,600	119,800	58
59	119,000	119,200	119,500	119,700	119,900	120,100	120,300	120,600	120,800	121,000	121,200	121,400	121,600	121,900	122,100	122,300	122,500	122,700	122,900	123,100	123,300	59
60	122,400	122,600	122,800	123,100	123,300	123,500	123,700	124,000	124,200	124,400	124,600	124,800	125,100	125,300	125,500	125,700	126,000	126,200	126,400	126,600	126,800	60
61	125,700	126,000	126,200	126,400	126,700	126,900	127,100	127,400	127,600	127,800	128,000	128,300	128,500	128,700	129,000	129,200	129,400	129,700	129,900	130,100	130,300	61
62	129,200	129,400	129,700	129,900	130,200	130,400	130,600	130,900	131,100	131,300	131,600	131,800	132,100	132,300	132,500	132,800	133,000	133,200	133,500	133,700	133,900	62
63	132,600	132,900	133,100	133,400	133,600	133,900	134,100	134,400	134,600	134,900	135,100	135,400	135,600	135,800	136,100	136,300	136,600	136,800	137,100	137,300	137,500	63
64	136,100	136,300	136,600	136,800	137,100	137,400	137,600	137,900	138,100	138,400	138,600	138,900	139,100	139,400	139,600	139,900	140,100	140,400	140,600	140,900	141,100	64
65	139,500	139,800	140,100	140,300	140,600	140,900	141,100	141,400	141,600	141,900	142,200	142,400	142,700	142,900	143,200	143,500	143,700	144,000	144,200	144,500	144,700	65

See special instruction for preventing gate overflow on page 3.

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	1002.0	1002.1	1002.2	1002.3	1002.4	1002.5	1002.6	1002.7	1002.8	1002.9	1003.0	1003.1	1003.2	1003.3	1003.4	1003.5	1003.6	1003.7	1003.8	1003.9	1004.0	
66	143,000	143,200	143,500	143,800	144,100	144,300	144,600	144,900	145,100	145,400	145,700	145,900	146,200	146,500	146,700	147,000	147,300	147,500	147,800	148,100	148,300	66
67	147,000	147,300	147,600	147,900	148,100	148,400	148,700	149,000	149,300	149,500	149,800	150,100	150,400	150,700	150,900	151,200	151,500	151,800	152,000	152,300	152,600	67
68	151,000	151,300	151,600	151,900	152,200	152,500	152,800	153,100	153,400	153,700	154,000	154,200	154,500	154,800	155,100	155,400	155,700	156,000	156,300	156,500	156,800	68
69	155,100	155,400	155,700	156,000	156,300	156,600	156,900	157,200	157,500	157,800	158,100	158,400	158,700	159,000	159,300	159,600	159,900	160,200	160,500	160,800	161,100	69
70	159,100	159,400	159,700	160,100	160,400	160,700	161,000	161,300	161,600	161,900	162,200	162,500	162,900	163,200	163,500	163,800	164,100	164,400	164,700	165,000	165,300	70
71	163,000	163,300	163,600	164,000	164,300	164,600	164,900	165,200	165,600	165,900	166,200	166,500	166,800	167,200	167,500	167,800	168,100	168,400	168,700	169,100	169,400	71
72	166,800	167,200	167,500	167,900	168,200	168,500	168,900	169,200	169,500	169,800	170,200	170,500	170,800	171,200	171,500	171,800	172,100	172,500	172,800	173,100	173,400	72
73	170,900	171,200	171,600	171,900	172,300	172,600	173,000	173,300	173,700	174,000	174,300	174,700	175,000	175,400	175,700	176,000	176,400	176,700	177,000	177,400	177,700	73
74	175,000	175,300	175,700	176,000	176,400	176,700	177,100	177,500	177,800	178,200	178,500	178,900	179,200	179,600	179,900	180,200	180,600	180,900	181,300	181,600	182,000	74
75	179,000	179,400	179,700	180,100	180,500	180,800	181,200	181,600	181,900	182,300	182,600	183,000	183,400	183,700	184,100	184,400	184,800	185,100	185,500	185,900	186,200	75
76	183,000	183,400	183,800	184,100	184,500	184,900	185,300	185,600	186,000	186,400	186,800	187,100	187,500	187,900	188,200	188,600	189,000	189,300	189,700	190,100	190,400	76
77	187,000	187,400	187,800	188,200	188,600	189,000	189,400	189,700	190,100	190,500	190,900	191,300	191,700	192,000	192,400	192,800	193,200	193,500	193,900	194,300	194,700	77
78	190,800	191,200	191,600	192,000	192,400	192,800	193,200	193,600	194,000	194,400	194,800	195,200	195,500	195,900	196,300	196,700	197,100	197,500	197,900	198,300	198,600	78
79	194,600	195,000	195,400	195,800	196,200	196,600	197,000	197,400	197,800	198,200	198,600	199,000	199,400	199,800	200,200	200,600	201,000	201,400	201,800	202,200	202,600	79
80	198,400	198,800	199,200	199,600	200,000	200,500	200,900	201,300	201,700	202,100	202,500	202,900	203,300	203,700	204,200	204,600	205,000	205,400	205,800	206,200	206,600	80
81	202,200	202,600	203,000	203,400	203,900	204,300	204,700	205,100	205,600	206,000	206,400	206,800	207,200	207,700	208,100	208,500	208,900	209,300	209,700	210,100	210,500	81
82	205,700	206,200	206,600	207,000	207,500	207,900	208,300	208,800	209,200	209,600	210,100	210,500	210,900	211,300	211,800	212,200	212,600	213,000	213,400	213,900	214,300	82
83	209,300	209,700	210,200	210,600	211,100	211,500	212,000	212,400	212,800	213,300	213,700	214,100	214,600	215,000	215,500	215,900	216,300	216,700	217,200	217,600	218,000	83
84	213,100	213,500	214,000	214,500	214,900	215,400	215,800	216,300	216,700	217,200	217,600	218,000	218,500	218,900	219,400	219,800	220,300	220,700	221,100	221,600	222,000	84
85	216,900	217,400	217,800	218,300	218,700	219,200	219,700	220,100	220,600	221,000	221,500	222,000	222,400	222,900	223,300	223,800	224,200	224,700	225,100	225,600	226,000	85
86	220,700	221,100	221,600	222,100	222,600	223,000	223,500	224,000	224,400	224,900	225,400	225,800	226,300	226,800	227,200	227,700	228,200	228,600	229,100	229,500	230,000	86
87	224,400	224,900	225,400	225,900	226,400	226,800	227,300	227,800	228,300	228,800	229,200	229,700	230,200	230,700	231,100	231,600	232,100	232,500	233,000	233,500	233,900	87
88	228,200	228,700	229,200	229,700	230,200	230,700	231,100	231,600	232,100	232,600	233,100	233,600	234,100	234,500	235,000	235,500	236,000	236,500	236,900	237,400	237,900	88
89	232,600	233,000	233,400	233,900	234,400	234,900	235,400	235,900	236,400	236,900	237,300	237,800	238,300	238,800	239,300	239,700	240,200	240,700	241,200	241,600	242,100	89
90	236,800	237,200	237,600	238,100	238,600	239,100	239,600	240,100	240,600	241,100	241,500	242,000	242,500	243,000	243,400	243,900	244,400	244,900	245,300	245,800	246,300	90
91	241,000	241,400	241,900	242,300	242,800	243,300	243,800	244,300	244,800	245,300	245,700	246,200	246,700	247,200	247,600	248,100	248,600	249,000	249,500	250,000	250,400	91
92	245,200	245,600	246,100	246,500	247,000	247,500	248,000	248,500	249,000	249,400	249,900	250,400	250,900	251,300	251,800	252,300	252,800	253,200	253,700	254,100	254,600	92
93	249,200	249,600	250,000	250,500	251,000	251,500	251,900	252,400	252,900	253,400	253,900	254,300	254,800	255,300	255,700	256,200	256,700	257,100	257,600	258,000	258,500	93
94	253,100	253,500	254,000	254,400	254,900	255,400	255,900	256,400	256,800	257,300	257,800	258,300	258,700	259,200	259,700	260,100	260,600	261,000	261,500	262,000	262,400	94
95	257,300	257,700	258,200	258,700	259,200	259,600	260,100	260,600	261,100	261,500	262,000	262,500	262,900	263,400	263,900	264,300	264,800	265,200	265,700	266,100	266,600	95
96	261,600	262,000	262,400	262,900	263,400	263,900	264,300	264,800	265,300	265,700	266,200	266,700	267,100	267,600	268,100	268,500	269,000	269,400	269,900	270,300	270,800	96
97	265,800	266,200	266,600	267,100	267,600	268,000	268,500	269,000	269,500	269,900	270,400	270,900	271,300	271,800	272,200	272,700	273,100	273,600	274,000	274,500	274,900	97
98	270,000	270,400	270,800	271,300	271,800	272,300	272,700	273,200	273,700	274,100	274,600	275,100	275,500	276,000	276,400	276,900	277,300	277,800	278,200	278,700	279,100	98
99	274,200	274,600	275,000	275,500	276,000	276,500	276,900	277,400	277,900	278,300	278,800	279,300	279,700	280,200	280,600	281,100	281,500	282,000	282,400	282,800	283,300	99
100	277,300	277,800	278,400	279,000	279,600	280,200	280,700	281,300	281,900	282,500	283,000	283,600	284,200	284,700	285,300	285,900	286,400	287,000	287,500	288,100	288,600	100
101	280,600	281,300	282,000	282,700	283,300	284,000	284,700	285,400	286,100	286,800	287,400	288,100	288,800	289,500	290,200	290,800	291,500	292,200	292,800	293,500	294,200	101
102	284,000	284,800	285,600	286,400	287,100	287,900	288,700	289,500	290,300	291,100	291,900	292,700	293,500	294,300	295,100	295,800	296,600	297,400	298,200	299,000	299,800	102
103	287,400	288,200	289,100	290,100	291,000	291,900	292,800	293,700	294,600	295,500	296,400	297,300	298,200	299,100	300,000	300,900	301,800	302,700	303,600	304,500	305,300	103
104	290,500	291,500	292,500	293,500	294,500	295,500	296,500	297,500	298,500	299,500	300,500	301,500	302,500	303,500	304,500	305,500	306,500	307,500	308,500	309,500	310,500	104
105	293,600	294,700	295,800	296,900	298,000	299,100	300,200	301,300	302,400	303,500	304,600	305,700	306,800	308,000	309,100	310,200	311,300	312,400	313,500	314,600	315,700	105
106	297,000	298,200	299,400	300,600	301,800	303,000	304,200	305,400	306,600	307,800	309,100	310,300	311,500	312,700	313,900	315,100	316,400	317,600	318,800	320,000	321,300	106
107	300,400	301,700	303,000	304,300	305,600	306,900	308,200	309,600	310,900	312,200	313,500	314,800	316,200	317,500	318,800	320,200	321,500	322,800	324,200	325,500	326,900	107
108	303,700	305,200	306,600	308,000	309,400	310,800	312,200	313,700	315,100	316,500	318,000	319,400	320,800	322,300	323,700	325,200	326,600	328,100	329,500	331,000	332,400	108
109	307,100	308,600	310,100	311,600	313,200	314,700	316,200	317,800	319,300	320,800	322,400	323,900	325,500	327,000	328,600	330,100	331,700	333,300	334,800	336,400	338,000	109
110	310,500	312,100	313,700	315,400	317,000	318,600	320,300	321,900	323,500	325,200	326,800	328,500	330,100	331,800	333,500	335,100	336,800	338,500	340,200	341,900	343,600	110

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE OPENING	HEADWATER ELEVATION																					GATE OPENING
	1004.0	1004.1	1004.2	1004.3	1004.4	1004.5	1004.6	1004.7	1004.8	1004.9	1005.0	1005.1	1005.2	1005.3	1005.4	1005.5	1005.6	1005.7	1005.8	1005.9	1006.0	
21																						21
22	36, 500	36, 550																				22
23	38, 380	38, 440																				23
24	40, 210	40, 270																				24
25	42, 040	42, 100																				25
26	43, 860	43, 930																				26
27	45, 670	45, 750																				27
28	47, 480	47, 560																				28
29	49, 320	49, 390																				29
30	51, 120	51, 200	51, 280																			30
31	52, 950	53, 030	53, 120																			31
32	54, 780	54, 870	54, 960																			32
33	56, 610	56, 700	56, 790	56, 880	56, 960	57, 050	57, 140	57, 230	57, 320	57, 400	57, 490	57, 580	57, 660	57, 750	57, 840							33
34	58, 590	58, 680	58, 780	58, 870	58, 960	59, 050	59, 140	59, 230	59, 320	59, 410	59, 500	59, 590	59, 690	59, 780	59, 870							34
35	60, 560	60, 660	60, 760	60, 850	60, 950	61, 040	61, 130	61, 230	61, 320	61, 420	61, 510	61, 610	61, 700	61, 790	61, 890							35
36	62, 540	62, 640	62, 740	62, 840	62, 940	63, 040	63, 130	63, 230	63, 330	63, 430	63, 520	63, 620	63, 720	63, 820	63, 910							36
37	64, 510	64, 610	64, 710	64, 820	64, 920	65, 020	65, 120	65, 220	65, 320	65, 420	65, 520	65, 620	65, 720	65, 820	65, 920							37
38	66, 450	66, 550	66, 660	66, 760	66, 870	66, 970	67, 080	67, 180	67, 290	67, 390	67, 490	67, 600	67, 700	67, 810	67, 910							38
39	68, 410	68, 520	68, 630	68, 740	68, 850	68, 960	69, 060	69, 170	69, 280	69, 390	69, 490	69, 600	69, 710	69, 820	69, 920							39
40	70, 390	70, 510	70, 620	70, 730	70, 840	70, 950	71, 060	71, 180	71, 290	71, 400	71, 510	71, 620	71, 730	71, 840	71, 950							40
41	72, 370	72, 480	72, 600	72, 710	72, 830	72, 940	73, 060	73, 170	73, 290	73, 400	73, 510	73, 630	73, 740	73, 850	73, 970	74, 080						41
42	74, 330	74, 450	74, 570	74, 690	74, 810	74, 930	75, 040	75, 160	75, 280	75, 400	75, 510	75, 630	75, 750	75, 860	75, 980	76, 100						42
43	76, 300	76, 420	76, 540	76, 660	76, 790	76, 910	77, 030	77, 150	77, 270	77, 390	77, 510	77, 630	77, 750	77, 870	77, 990	78, 110						43
44	78, 260	78, 390	78, 510	78, 640	78, 770	78, 890	79, 010	79, 140	79, 260	79, 390	79, 510	79, 640	79, 760	79, 880	80, 010	80, 130	80, 250	80, 370	80, 500	80, 620	80, 740	44
45	81, 060	81, 190	81, 320	81, 450	81, 580	81, 710	81, 840	81, 970	82, 100	82, 230	82, 360	82, 490	82, 620	82, 750	82, 870	83, 000	83, 130	83, 260	83, 380	83, 510	83, 640	45
46	83, 860	84, 000	84, 130	84, 270	84, 400	84, 540	84, 670	84, 810	84, 940	85, 080	85, 210	85, 350	85, 480	85, 610	85, 750	85, 880	86, 010	86, 150	86, 280	86, 410	86, 540	46
47	86, 670	86, 810	86, 950	87, 090	87, 230	87, 370	87, 510	87, 650	87, 790	87, 930	88, 070	88, 210	88, 350	88, 480	88, 620	88, 760	88, 900	89, 040	89, 170	89, 310	89, 450	47
48	89, 460	89, 610	89, 750	89, 900	90, 040	90, 190	90, 330	90, 480	90, 620	90, 770	90, 910	91, 060	91, 200	91, 350	91, 490	91, 630	91, 780	91, 920	92, 060	92, 200	92, 340	48
49	92, 200	92, 350	92, 500	92, 650	92, 810	92, 960	93, 110	93, 260	93, 410	93, 560	93, 700	93, 850	94, 000	94, 150	94, 300	94, 450	94, 600	94, 740	94, 890	95, 040	95, 190	49
50	94, 970	95, 120	95, 280	95, 440	95, 590	95, 750	95, 900	96, 060	96, 210	96, 370	96, 520	96, 680	96, 830	96, 980	97, 140	97, 290	97, 440	97, 600	97, 750	97, 900	98, 050	50
51	97, 770	97, 940	98, 100	98, 260	98, 420	98, 580	98, 740	98, 900	99, 060	99, 220	99, 380	99, 540	99, 700	99, 860	100, 000	100, 200	100, 300	100, 500	100, 600	100, 800	101, 000	51
52	100, 600	100, 700	100, 900	101, 100	101, 200	101, 400	101, 600	101, 700	101, 900	102, 100	102, 200	102, 400	102, 600	102, 700	102, 900	103, 100	103, 200	103, 400	103, 500	103, 700	103, 900	52
53	103, 400	103, 500	103, 700	103, 900	104, 100	104, 200	104, 400	104, 600	104, 700	104, 900	105, 100	105, 300	105, 400	105, 600	105, 800	105, 900	106, 100	106, 300	106, 400	106, 600	106, 800	53
54	106, 200	106, 300	106, 500	106, 700	106, 900	107, 100	107, 200	107, 400	107, 600	107, 800	107, 900	108, 100	108, 300	108, 500	108, 600	108, 800	109, 000	109, 100	109, 300	109, 500	109, 700	54
55	108, 900	109, 100	109, 300	109, 500	109, 700	109, 900	110, 000	110, 200	110, 400	110, 600	110, 800	110, 900	111, 100	111, 300	111, 500	111, 700	111, 800	112, 000	112, 200	112, 400	112, 500	55
56	112, 600	112, 700	112, 900	113, 100	113, 300	113, 500	113, 700	113, 900	114, 100	114, 300	114, 400	114, 600	114, 800	115, 000	115, 200	115, 400	115, 600	115, 700	115, 900	116, 100	116, 300	56
57	116, 200	116, 400	116, 500	116, 700	116, 900	117, 100	117, 300	117, 500	117, 700	117, 900	118, 100	118, 300	118, 500	118, 700	118, 900	119, 100	119, 300	119, 500	119, 700	119, 800	120, 000	57
58	119, 800	120, 000	120, 200	120, 400	120, 600	120, 800	121, 000	121, 200	121, 400	121, 600	121, 800	122, 000	122, 200	122, 400	122, 600	122, 800	123, 000	123, 200	123, 400	123, 600	123, 800	58
59	123, 300	123, 600	123, 800	124, 000	124, 200	124, 400	124, 600	124, 800	125, 000	125, 200	125, 400	125, 700	125, 900	126, 100	126, 300	126, 500	126, 700	126, 900	127, 100	127, 300	127, 500	59
60	126, 800	127, 100	127, 300	127, 500	127, 700	127, 900	128, 100	128, 400	128, 600	128, 800	129, 000	129, 200	129, 400	129, 700	129, 900	130, 100	130, 300	130, 500	130, 700	130, 900	131, 200	60
61	130, 300	130, 600	130, 800	131, 000	131, 200	131, 500	131, 700	131, 900	132, 100	132, 400	132, 600	132, 800	133, 000	133, 200	133, 500	133, 700	133, 900	134, 100	134, 400	134, 600	134, 800	61
62	133, 900	134, 200	134, 400	134, 600	134, 900	135, 100	135, 300	135, 600	135, 800	136, 000	136, 300	136, 500	136, 700	137, 000	137, 200	137, 400	137, 600	137, 900	138, 100	138, 300	138, 500	62
63	137, 500	137, 800	138, 000	138, 300	138, 500	138, 700	139, 000	139, 200	139, 500	139, 700	139, 900	140, 200	140, 400	140, 700	140, 900	141, 100	141, 400	141, 600	141, 800	142, 100	142, 300	63
64	141, 100	141, 400	141, 600	141, 900	142, 100	142, 400	142, 600	142, 900	143, 100	143, 400	143, 600	143, 800	144, 100	144, 300	144, 600	144, 800	145, 100	145, 300	145, 500	145, 800	146, 000	64
65	144, 700	145, 000	145, 300	145, 500	145, 800	146, 000	146, 300	146, 500	146, 800	147, 000	147, 300	147, 500	147, 800	148, 000	148, 300	148, 500	148, 800	149, 000	149, 300	149, 500	149, 800	65
66	148, 300	148, 600	148, 900	149, 100	149, 400	149, 600	149, 900	150, 200	150, 400	150, 700	150, 900	151, 200	151, 500	151, 700	152, 000	152, 200	152, 500	152, 700	153, 000	153, 300	153, 500	66
67	152, 600	152, 900	153, 100	153, 400	153, 700	154, 000	154, 200	154, 500	154, 800	155, 000	155, 300	155, 600	155, 800	156, 100	156, 400	156, 600	156, 900	157, 200	157, 400	157, 700	158, 000	67
68	156, 800	157, 100	157, 400	157, 700	157, 900	158, 200	158, 500	158, 800	159, 100	159, 400	159, 600	159, 900	160, 200	160, 500	160, 700	161, 000	161, 300	161, 600	161, 800	162, 100	162, 400	68
69	161, 100	161, 400	161, 600	161, 900	162, 200	162, 500	162, 800	163, 100	163, 400	163, 700	164, 000	164, 300	164, 500	164, 800	165, 100	165, 400	165, 700	166, 000	166, 300	166, 500	166, 800	69
70	165, 300	165, 600	165, 900	166, 200	166, 500	166, 800	167, 100	167, 400	167, 700	168, 000	168, 300	168, 600	168, 900	169, 200	169, 500	169, 800	170, 100	170, 400	170, 700	171, 000	171, 300	70
71	169, 400	169, 700	170, 000	170, 300	170, 600	170, 900	171, 200	171, 600	171, 900	172, 200	172, 500	172, 800	173, 100	173, 400	173, 700	174, 000	174, 300	174, 600	174, 900	175, 200	175, 500	71
72	173, 400	173, 800	174, 100	174, 400	174, 700	175, 000	175, 400	175, 700	176, 000	176, 300	176, 600	177, 000	177, 300	177, 600	177, 900	178, 200	178, 500	178, 900	179, 200	179, 500	179, 800	72
73	177, 700	178, 000	178, 400	178, 700	179, 000	179, 400	179, 700	180, 000	180, 300	180, 700	181, 000	181, 300	181, 700	182, 000	182, 300	182, 600	183, 000	183, 300	183, 600	183, 900	184, 200	73
74	182, 000	182, 300	182, 700	183, 000	183, 300	183, 700	184, 000	184, 400	184, 700	185, 000	185, 400	185, 700	186, 100	186, 400	186, 700	187, 100	187, 400	187, 700	188, 100	188, 400	188, 700	74
75	186, 200	186, 600	186, 900	187, 300	187, 600	188, 000	188, 300	188, 700	189, 000	189, 400	189, 700	190, 100	190, 400	190, 700	191, 100	191, 400	191, 800	192, 100	192, 500	192, 800	193, 200	75

See special instruction for preventing gate overflow on page 3.

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	1004.0	1004.1	1004.2	1004.3	1004.4	1004.5	1004.6	1004.7	1004.8	1004.9	1005.0	1005.1	1005.2	1005.3	1005.4	1005.5	1005.6	1005.7	1005.8	1005.9	1006.0	
76	190,400	190,800	191,200	191,500	191,900	192,200	192,600	193,000	193,300	193,700	194,000	194,400	194,700	195,100	195,500	195,800	196,200	196,500	196,900	197,200	197,600	76
77	194,700	195,000	195,400	195,800	196,200	196,500	196,900	197,300	197,600	198,000	198,400	198,700	199,100	199,500	199,800	200,200	200,600	200,900	201,300	201,600	202,000	77
78	198,600	199,000	199,400	199,800	200,200	200,500	200,900	201,300	201,700	202,000	202,400	202,800	203,200	203,600	203,900	204,300	204,700	205,100	205,400	205,800	206,200	78
79	202,600	203,000	203,400	203,800	204,200	204,500	204,900	205,300	205,700	206,100	206,500	206,900	207,300	207,600	208,000	208,400	208,800	209,200	209,600	210,000	210,300	79
80	206,600	207,000	207,400	207,800	208,200	208,600	209,000	209,400	209,800	210,200	210,600	211,000	211,300	211,700	212,100	212,500	212,900	213,300	213,700	214,100	214,500	80
81	210,500	211,000	211,400	211,800	212,200	212,600	213,000	213,400	213,800	214,200	214,600	215,000	215,400	215,800	216,200	216,700	217,100	217,500	217,900	218,300	218,700	81
82	214,300	214,700	215,100	215,500	216,000	216,400	216,800	217,200	217,600	218,000	218,400	218,900	219,300	219,700	220,100	220,500	221,000	221,400	221,800	222,200	222,600	82
83	218,000	218,500	218,900	219,300	219,700	220,200	220,600	221,000	221,400	221,900	222,300	222,700	223,100	223,600	224,000	224,400	224,900	225,300	225,700	226,100	226,600	83
84	222,000	222,500	222,900	223,300	223,800	224,200	224,600	225,000	225,500	225,900	226,400	226,800	227,200	227,700	228,100	228,600	229,000	229,400	229,900	230,300	230,700	84
85	226,000	226,500	226,900	227,300	227,800	228,200	228,700	229,100	229,500	230,000	230,400	230,900	231,400	231,800	232,300	232,700	233,200	233,600	234,000	234,500	234,900	85
86	230,000	230,400	230,900	231,300	231,800	232,200	232,700	233,100	233,600	234,000	234,500	235,000	235,400	235,900	236,400	236,800	237,300	237,700	238,200	238,600	239,100	86
87	233,900	234,400	234,900	235,300	235,800	236,200	236,700	237,200	237,600	238,100	238,600	239,000	239,500	240,000	240,400	240,900	241,400	241,900	242,300	242,800	243,300	87
88	237,900	238,400	238,800	239,300	239,800	240,200	240,700	241,200	241,600	242,100	242,600	243,100	243,600	244,000	244,500	245,000	245,500	246,000	246,500	246,900	247,400	88
89	242,100	242,600	243,000	243,500	244,000	244,400	244,900	245,400	245,800	246,300	246,800	247,300	247,700	248,200	248,700	249,200	249,700	250,200	250,700	251,100	251,600	89
90	246,300	246,700	247,200	247,700	248,100	248,600	249,000	249,500	250,000	250,400	250,900	251,400	251,900	252,400	252,900	253,300	253,800	254,300	254,800	255,300	255,800	90
91	250,400	250,900	251,400	251,800	252,300	252,700	253,200	253,600	254,100	254,600	255,000	255,500	256,000	256,500	257,000	257,500	258,000	258,500	259,000	259,500	260,000	91
92	254,600	255,100	255,500	256,000	256,400	256,900	257,300	257,800	258,200	258,700	259,200	259,700	260,100	260,600	261,100	261,600	262,100	262,600	263,100	263,600	264,100	92
93	258,500	259,000	259,400	259,900	260,300	260,800	261,200	261,700	262,100	262,600	263,000	263,500	264,000	264,500	265,000	265,500	266,000	266,500	267,000	267,500	268,000	93
94	262,400	262,900	263,300	263,800	264,200	264,700	265,100	265,500	266,000	266,400	266,900	267,400	267,900	268,400	268,900	269,400	269,900	270,400	270,900	271,400	271,900	94
95	266,600	267,000	267,500	267,900	268,400	268,800	269,300	269,700	270,100	270,600	271,000	271,500	272,000	272,600	273,100	273,600	274,100	274,600	275,100	275,600	276,100	95
96	270,800	271,200	271,700	272,100	272,600	273,000	273,400	273,900	274,300	274,700	275,200	275,700	276,200	276,700	277,200	277,700	278,300	278,800	279,300	279,800	280,300	96
97	274,900	275,400	275,800	276,300	276,700	277,100	277,600	278,000	278,400	278,800	279,300	279,800	280,300	280,800	281,400	281,900	282,400	282,900	283,400	284,000	284,500	97
98	279,100	279,600	280,000	280,400	280,900	281,300	281,700	282,100	282,600	283,000	283,400	283,900	284,500	285,000	285,500	286,000	286,600	287,100	287,600	288,100	288,700	98
99	283,300	283,700	284,100	284,600	285,000	285,400	285,900	286,300	286,700	287,100	287,500	288,100	288,600	289,100	289,700	290,200	290,700	291,300	291,800	292,300	292,800	99
100	288,600	289,200	289,700	290,300	290,800	291,400	291,900	292,500	293,000	293,500	294,100	294,700	295,400	296,000	296,700	297,300	298,000	298,600	299,200	299,900	300,500	100
101	294,200	294,900	295,500	296,200	296,800	297,500	298,200	298,800	299,500	300,100	300,800	301,600	302,300	303,100	303,800	304,600	305,300	306,100	306,900	307,600	308,400	101
102	299,800	300,600	301,300	302,100	302,900	303,700	304,500	305,200	306,000	306,800	307,600	308,400	309,300	310,200	311,000	311,900	312,800	313,600	314,500	315,400	316,200	102
103	305,300	306,200	307,100	308,000	308,900	309,800	310,700	311,600	312,500	313,400	314,300	315,300	316,300	317,300	318,200	319,200	320,200	321,200	322,200	323,100	324,100	103
104	310,500	311,500	312,500	313,500	314,500	315,600	316,600	317,600	318,600	319,600	320,600	321,700	322,800	323,800	324,900	326,000	327,100	328,200	329,200	330,300	331,400	104
105	315,700	316,800	317,900	319,100	320,200	321,300	322,400	323,500	324,600	325,800	326,900	328,100	329,300	330,400	331,600	332,800	334,000	335,200	336,400	337,500	338,700	105
106	321,300	322,500	323,700	324,900	326,200	327,400	328,600	329,900	331,100	332,400	333,600	334,900	336,200	337,500	338,800	340,100	341,400	342,700	344,000	345,300	346,600	106
107	326,900	328,200	329,500	330,900	332,200	333,600	334,900	336,300	337,700	339,000	340,400	341,800	343,200	344,600	346,000	347,400	348,800	350,200	351,600	353,100	354,500	107
108	332,400	333,900	335,300	336,800	338,300	339,700	341,200	342,700	344,200	345,600	347,100	348,600	350,200	351,700	353,200	354,700	356,200	357,700	359,300	360,800	362,300	108
109	338,000	339,500	341,100	342,700	344,300	345,900	347,500	349,100	350,700	352,300	353,900	355,500	357,100	358,700	360,400	362,000	363,600	365,300	366,900	368,500	370,200	109
110	343,600	345,200	346,900	348,600	350,300	351,800	353,300	354,800	356,300	357,800	359,300	360,800	362,300	363,800	365,400	366,900	368,500	370,100	371,600	373,200	374,800	110

DOUGLAS DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	1006.0	1006.1	1006.1	1006.1	1006.2	1006.2	1006.3	1006.3	1006.4	1006.4	1006.5	1006.5	1006.6	1006.6	1006.7	1006.7	1006.8	1006.8	1006.9	1006.9	1007.0	
41																						41
42																						42
43																						43
44	80, 740	80, 800	80, 860	80, 920	80, 980	81, 050	81, 110	81, 170	81, 230	81, 290	81, 350	81, 410	81, 470	81, 530								44
45	83, 640	83, 700	83, 770	83, 830	83, 890	83, 960	84, 020	84, 080	84, 150	84, 210	84, 270	84, 330	84, 400	84, 460								45
46	86, 540	86, 610	86, 670	86, 740	86, 810	86, 870	86, 940	87, 000	87, 070	87, 130	87, 200	87, 270	87, 330	87, 400								46
47	89, 450	89, 520	89, 590	89, 650	89, 720	89, 790	89, 860	89, 930	90, 000	90, 060	90, 130	90, 200	90, 270	90, 330								47
48	92, 340	92, 420	92, 490	92, 560	92, 630	92, 700	92, 770	92, 840	92, 910	92, 980	93, 050	93, 120	93, 190	93, 260								48
49	95, 190	95, 260	95, 330	95, 410	95, 480	95, 550	95, 620	95, 700	95, 770	95, 840	95, 920	95, 990	96, 060	96, 140								49
50	98, 050	98, 130	98, 200	98, 280	98, 350	98, 430	98, 510	98, 580	98, 660	98, 730	98, 810	98, 880	98, 960	99, 030								50
51	101, 000	101, 000	101, 100	101, 200	101, 300	101, 400	101, 400	101, 500	101, 600	101, 700	101, 700	101, 800	101, 900	102, 000								51
52	103, 900	103, 900	104, 000	104, 100	104, 200	104, 300	104, 300	104, 400	104, 500	104, 600	104, 700	104, 800	104, 800	104, 900	105, 000	105, 100						52
53	106, 800	106, 900	106, 900	107, 000	107, 100	107, 200	107, 300	107, 400	107, 400	107, 500	107, 600	107, 700	107, 800	107, 800	107, 900	108, 000						53
54	109, 700	109, 700	109, 800	109, 900	110, 000	110, 100	110, 200	110, 300	110, 300	110, 400	110, 500	110, 600	110, 700	110, 800	110, 900	110, 900						54
55	112, 500	112, 600	112, 700	112, 800	112, 900	113, 000	113, 100	113, 200	113, 200	113, 300	113, 400	113, 500	113, 600	113, 700	113, 800	113, 900	113, 900	114, 000	114, 100	114, 200	114, 300	55
56	116, 300	116, 400	116, 500	116, 600	116, 700	116, 800	116, 800	116, 900	117, 000	117, 100	117, 200	117, 300	117, 400	117, 500	117, 600	117, 700	117, 800	117, 800	117, 900	118, 000	118, 100	56
57	120, 000	120, 100	120, 200	120, 300	120, 400	120, 500	120, 600	120, 700	120, 800	120, 900	121, 000	121, 100	121, 200	121, 300	121, 400	121, 500	121, 600	121, 700	121, 700	121, 800	121, 900	57
58	123, 800	123, 900	124, 000	124, 100	124, 200	124, 300	124, 400	124, 500	124, 600	124, 700	124, 800	124, 900	125, 000	125, 100	125, 200	125, 300	125, 400	125, 500	125, 600	125, 700	125, 800	58
59	127, 500	127, 600	127, 700	127, 800	127, 900	128, 000	128, 100	128, 200	128, 300	128, 400	128, 500	128, 600	128, 700	128, 800	128, 900	129, 000	129, 200	129, 300	129, 400	129, 500	129, 600	59
60	131, 200	131, 300	131, 400	131, 500	131, 600	131, 700	131, 800	131, 900	132, 000	132, 100	132, 200	132, 300	132, 400	132, 500	132, 600	132, 700	132, 800	132, 900	133, 000	133, 200	133, 300	60
61	134, 800	134, 900	135, 000	135, 100	135, 200	135, 300	135, 400	135, 600	135, 700	135, 800	135, 900	136, 000	136, 100	136, 200	136, 300	136, 400	136, 500	136, 600	136, 700	136, 900	137, 000	61
62	138, 500	138, 700	138, 800	138, 900	139, 000	139, 100	139, 200	139, 300	139, 500	139, 600	139, 700	139, 800	139, 900	140, 000	140, 100	140, 200	140, 300	140, 500	140, 600	140, 700	140, 800	62
63	142, 300	142, 400	142, 500	142, 600	142, 800	142, 900	143, 000	143, 100	143, 200	143, 300	143, 500	143, 600	143, 700	143, 800	143, 900	144, 000	144, 100	144, 300	144, 400	144, 500	144, 600	63
64	146, 000	146, 100	146, 300	146, 400	146, 500	146, 600	146, 700	146, 900	147, 000	147, 100	147, 200	147, 300	147, 500	147, 600	147, 700	147, 800	147, 900	148, 100	148, 200	148, 300	148, 400	64
65	149, 800	149, 900	150, 000	150, 200	150, 300	150, 400	150, 500	150, 600	150, 800	150, 900	151, 000	151, 100	151, 300	151, 400	151, 500	151, 600	151, 700	151, 900	152, 000	152, 100	152, 200	65
66	153, 500	153, 600	153, 800	153, 900	154, 000	154, 200	154, 300	154, 400	154, 500	154, 700	154, 800	154, 900	155, 000	155, 200	155, 300	155, 400	155, 500	155, 700	155, 800	155, 900	156, 000	66
67	158, 000	158, 100	158, 200	158, 400	158, 500	158, 600	158, 800	158, 900	159, 000	159, 200	159, 300	159, 400	159, 500	159, 700	159, 800	159, 900	160, 100	160, 200	160, 300	160, 500	160, 600	67
68	162, 400	162, 500	162, 700	162, 800	162, 900	163, 100	163, 200	163, 400	163, 500	163, 600	163, 800	163, 900	164, 000	164, 200	164, 300	164, 400	164, 600	164, 700	164, 800	165, 000	165, 100	68
69	166, 800	167, 000	167, 100	167, 300	167, 400	167, 500	167, 700	167, 800	168, 000	168, 100	168, 200	168, 400	168, 500	168, 700	168, 800	168, 900	169, 100	169, 200	169, 400	169, 500	169, 600	69
70	171, 300	171, 400	171, 600	171, 700	171, 900	172, 000	172, 200	172, 300	172, 400	172, 600	172, 700	172, 900	173, 000	173, 200	173, 300	173, 500	173, 600	173, 800	173, 900	174, 000	174, 200	70
71	175, 500	175, 700	175, 800	176, 000	176, 100	176, 300	176, 400	176, 600	176, 700	176, 900	177, 000	177, 200	177, 300	177, 500	177, 600	177, 800	177, 900	178, 100	178, 200	178, 400	178, 500	71
72	179, 800	179, 900	180, 100	180, 300	180, 400	180, 600	180, 700	180, 900	181, 000	181, 200	181, 300	181, 500	181, 700	181, 800	182, 000	182, 100	182, 300	182, 400	182, 600	182, 700	182, 900	72
73	184, 200	184, 400	184, 600	184, 700	184, 900	185, 100	185, 200	185, 400	185, 500	185, 700	185, 900	186, 000	186, 200	186, 300	186, 500	186, 600	186, 800	187, 000	187, 100	187, 300	187, 400	73
74	188, 700	188, 900	189, 100	189, 200	189, 400	189, 500	189, 700	189, 900	190, 000	190, 200	190, 400	190, 500	190, 700	190, 900	191, 000	191, 200	191, 400	191, 500	191, 700	191, 800	192, 000	74
75	193, 200	193, 300	193, 500	193, 700	193, 800	194, 000	194, 200	194, 300	194, 500	194, 700	194, 800	195, 000	195, 200	195, 400	195, 500	195, 700	195, 900	196, 000	196, 200	196, 400	196, 500	75
76	197, 600	197, 700	197, 900	198, 100	198, 300	198, 400	198, 600	198, 800	199, 000	199, 100	199, 300	199, 500	199, 700	199, 800	200, 000	200, 200	200, 400	200, 500	200, 700	200, 900	201, 000	76
77	202, 000	202, 200	202, 400	202, 500	202, 700	202, 900	203, 100	203, 300	203, 400	203, 600	203, 800	204, 000	204, 200	204, 300	204, 500	204, 700	204, 900	205, 000	205, 200	205, 400	205, 600	77
78	206, 200	206, 400	206, 500	206, 700	206, 900	207, 100	207, 300	207, 500	207, 600	207, 800	208, 000	208, 200	208, 400	208, 600	208, 700	208, 900	209, 100	209, 300	209, 500	209, 700	209, 800	78
79	210, 300	210, 500	210, 700	210, 900	211, 100	211, 300	211, 500	211, 700	211, 900	212, 000	212, 200	212, 400	212, 600	212, 800	213, 000	213, 200	213, 400	213, 600	213, 700	213, 900	214, 100	79
80	214, 500	214, 700	214, 900	215, 100	215, 300	215, 500	215, 700	215, 900	216, 100	216, 300	216, 500	216, 700	216, 800	217, 000	217, 200	217, 400	217, 600	217, 800	218, 000	218, 200	218, 400	80
81	218, 700	218, 900	219, 100	219, 300	219, 500	219, 700	219, 900	220, 100	220, 300	220, 500	220, 700	220, 900	221, 100	221, 300	221, 500	221, 700	221, 900	222, 100	222, 300	222, 500	222, 700	81
82	222, 600	222, 800	223, 000	223, 200	223, 400	223, 600	223, 800	224, 100	224, 300	224, 500	224, 700	224, 900	225, 100	225, 300	225, 500	225, 700	225, 900	226, 100	226, 300	226, 500	226, 700	82
83	226, 600	226, 800	227, 000	227, 200	227, 400	227, 600	227, 800	228, 000	228, 200	228, 400	228, 700	228, 900	229, 100	229, 300	229, 500	229, 700	229, 900	230, 100	230, 300	230, 500	230, 700	83
84	230, 700	231, 000	231, 200	231, 400	231, 600	231, 800	232, 000	232, 300	232, 500	232, 700	232, 900	233, 100	233, 300	233, 500	233, 800	234, 000	234, 200	234, 400	234, 600	234, 800	235, 000	84
85	234, 900	235, 200	235, 400	235, 600	235, 800	236, 000	236, 300	236, 500	236, 700	236, 900	237, 100	237, 400	237, 600	237, 800	238, 000	238, 200	238, 500	238, 700	238, 900	239, 100	239, 300	85
86	239, 100	239, 300	239, 600	239, 800	240, 000	240, 200	240, 500	240, 700	240, 900	241, 100	241, 400	241, 600	241, 800	242, 000	242, 300	242, 500	242, 700	242, 900	243, 200	243, 400	243, 600	86
87	243, 300	243, 500	243, 700	244, 000	244, 200	244, 400	244, 700	244, 900	245, 100	245, 300	245, 600	245, 800	246, 000	246, 300	246, 500	246, 700	247, 000	247, 200	247, 400	247, 600	247, 900	87
88	247, 400	247, 600	247, 900	248, 100	248, 400	248, 600	248, 800	249, 100	249, 300	249, 500	249, 800	250, 000	250, 200	250, 500	250, 700	250, 900	251, 200	251, 400	251, 700	251, 900	252, 100	88
89	251, 600	251, 900	252, 100	252, 300	252, 600	252, 800	253, 100	253, 300	253, 500	253, 800	254, 000	254, 200	254, 500	254, 700	255, 000	255, 200	255, 400	255, 700	255, 900	256, 100	256, 400	89
90	255, 800	256, 000	256, 300	256, 500	256, 800	257, 000	257, 200	257, 500	257, 700	258, 000	258, 200	258, 400	258, 700	258, 900	259, 200	259, 400	259, 600	259, 900	260, 100	260, 300	260, 600	90
91	260, 000	260, 200	260, 500	260, 700	260, 900	261, 200	261, 400	261, 700	261, 900	262, 200	262, 400	262, 600	262, 900	263, 100	263, 400	263, 600	263, 800	264, 100	264, 300	264, 600	264, 800	91
92	264, 100	264, 400	264, 600	264, 900	265, 100	265, 400	265, 600	265, 900	266, 100	266, 300	266, 600	266, 800	267, 100	267, 300	267, 600	267, 800	268, 000	268, 300	268, 500	268, 800	269, 000	92
93	268, 000	268, 300	268, 500	268, 800	269, 000	269, 300	269, 500	269, 800	270, 000	270, 300	270, 500	270, 700	271, 000	271, 200	271, 500	271, 700	272, 000	272, 200	272, 500	272, 700	272, 900	93
94	271, 900	272, 200	272, 400	272, 700	272, 900	273, 200	273, 400	273, 700	273, 900	274, 200	274, 400	274, 700	274, 900	275, 200	275, 400	275, 700	275, 900	276, 100	276, 400	276, 600	276, 900	94
95	276, 100	276, 400	276, 600	276, 900	277, 100	277, 400	277, 600	277, 900	278, 100	278, 400	278, 600	278, 900	279, 100	279, 400	279, 600	279, 900	280, 100	280, 400	280, 600	280, 900	281, 100	95

See special instruction for preventing gate overflow on page 3.

DOUGLAS DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																				
	1006.0	1006.1	1006.1	1006.1	1006.2	1006.2	1006.3	1006.3	1006.4	1006.4	1006.5	1006.5	1006.6	1006.6	1006.7	1006.7	1006.8	1006.8	1006.9	1006.9	1007.0
96	280, 300	280, 600	280, 800	281, 100	281, 300	281, 600	281, 800	282, 100	282, 300	282, 600	282, 800	283, 100	283, 300	283, 600	283, 800	284, 100	284, 300	284, 600	284, 800	285, 100	285, 300
97	284, 500	284, 700	285, 000	285, 200	285, 500	285, 800	286, 000	286, 300	286, 500	286, 800	287, 000	287, 300	287, 500	287, 800	288, 000	288, 300	288, 500	288, 800	289, 000	289, 300	289, 500
98	288, 700	288, 900	289, 200	289, 400	289, 700	289, 900	290, 200	290, 500	290, 700	291, 000	291, 200	291, 500	291, 700	292, 000	292, 200	292, 500	292, 800	293, 000	293, 300	293, 500	293, 800
99	292, 800	293, 100	293, 400	293, 600	293, 900	294, 100	294, 400	294, 600	294, 900	295, 200	295, 400	295, 700	295, 900	296, 200	296, 400	296, 700	297, 000	297, 200	297, 500	297, 700	298, 000
100	300, 500	300, 800	301, 100	301, 500	301, 800	302, 100	302, 400	302, 700	303, 000	303, 400	303, 700	304, 000	304, 300	304, 600	304, 900	305, 300	305, 600	305, 900	306, 200	306, 500	306, 800
101	308, 400	308, 700	309, 100	309, 500	309, 900	310, 200	310, 600	311, 000	311, 400	311, 700	312, 100	312, 500	312, 800	313, 200	313, 600	314, 000	314, 300	314, 700	315, 100	315, 500	315, 800
102	316, 200	316, 700	317, 100	317, 500	318, 000	318, 400	318, 800	319, 300	319, 700	320, 100	320, 600	321, 000	321, 400	321, 900	322, 300	322, 700	323, 100	323, 600	324, 000	324, 400	324, 900
103	324, 100	324, 600	325, 100	325, 600	326, 100	326, 600	327, 100	327, 500	328, 000	328, 500	329, 000	329, 500	330, 000	330, 500	331, 000	331, 500	332, 000	332, 400	332, 900	333, 400	333, 900
104	331, 400	332, 000	332, 500	333, 000	333, 600	334, 100	334, 700	335, 200	335, 800	336, 300	336, 800	337, 400	337, 900	338, 500	339, 000	339, 600	340, 100	340, 700	341, 200	341, 700	342, 300
105	338, 700	339, 300	339, 900	340, 500	341, 100	341, 700	342, 300	342, 900	343, 500	344, 100	344, 700	345, 300	345, 900	346, 500	347, 100	347, 700	348, 300	348, 900	349, 500	350, 100	350, 700
106	346, 600	347, 200	347, 900	348, 500	349, 200	349, 800	350, 500	351, 100	351, 800	352, 500	353, 100	353, 800	354, 400	355, 100	355, 700	356, 400	357, 000	357, 700	358, 400	359, 000	359, 700
107	354, 500	355, 200	355, 900	356, 600	357, 300	358, 000	358, 700	359, 400	360, 200	360, 900	361, 600	362, 300	363, 000	363, 700	364, 400	365, 200	365, 900	366, 600	367, 300	368, 000	368, 700
108	362, 300	363, 100	363, 900	364, 600	365, 400	366, 200	366, 900	367, 700	368, 500	369, 300	370, 000	370, 800	371, 600	372, 300	373, 100	373, 900	374, 700	375, 400	376, 200	377, 000	377, 800
109	370, 200	371, 000	371, 800	372, 700	373, 500	374, 300	375, 100	376, 000	376, 800	377, 600	378, 400	379, 300	380, 100	380, 900	381, 800	382, 600	383, 400	384, 300	385, 100	385, 900	386, 800
110	374, 800	375, 600	376, 300	377, 100	377, 900	378, 700	379, 500	380, 300	381, 100	381, 900	382, 700	383, 600	384, 400	385, 200	386, 100	386, 900	387, 700	388, 500	389, 400	390, 200	391, 000

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PART 2

SLUICE DISCHARGE TABLES

MARCH 1999

INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables dated October 1962 in the August 1973 issue of the Spillway and Sluice Discharge Tables. The tables were revised to increase the maximum headwater elevation covered in the tables from 1003 feet to 1007 feet. The revised discharges were generated using the computer code SPILLQ and, except for the lowest gate openings, are only slightly different from those in the 1962 tables.

2. Purpose of Tables

These tables provide a means of setting up or determining the discharge through the sluices in Douglas Dam. They give the total discharge in cubic feet per second through all eight sluices when the headwater elevation and sluice gate openings are known. The discharges are based on the results of field measurements.

The tables have been prepared to permit simultaneous operation of all eight sluices shown on page 4. Past operating experience has shown that this type of operation should be used to minimize apron, bank, riprap, and sluice-conduit wear.

3. Range of Tables

The tables cover a discharge range from 0 to 31,200 cubic feet per second. Headwater elevations range from 890 feet to 1007 feet. Sluice gate openings range from 0.2 foot to the maximum opening of 10 feet.

4. Arrangement of Tables

The sluice discharge tables show discharges in cubic feet per second for all sluices set at identical openings. Gate opening positions in 0.2-foot increments are listed in the left and right columns. Headwater elevations for each foot of headwater elevation are shown at the top of each column. The headwater range is shown at the bottom of each page.

Discharges are recorded to the nearest 10 cubic feet per second since the accuracy of the field measurements does not warrant greater refinement. For this reason, there should be no interpolation between values given in these tables.

5. Gate Opening Indicator

The gate opening indicator consists of an indicating device and scale graduated in 0.01-foot increments between 0 and 10 feet. The indicator is plainly visible from the gate opening control valves, which makes it relatively easy to accurately set a required gate opening position.

6. Use of Tables

The use of the tables is best illustrated by an example.

Example 1 -- With the headwater elevation at 954.52 feet what sluice gate settings are necessary to pass 11,000 cubic feet per second? The headwater elevation closest to 954.52 feet is 955 feet, which is found on page 46. In the column headed 955 the discharge closest to 11,000 cubic feet per second is found near the middle of the column and is 11,090 cubic feet per second. By following the horizontal line containing this discharge to the left or right columns of the page, it is found that all eight sluice gates should be opened to position 4.8 feet.

Suppose the headwater elevation should rise from elevation 954.52 feet to 955.52 feet. The headwater elevation closest to 955.52 feet is 956 feet. In the column headed 956 the discharge is found to be 11,160 cubic feet per second.

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	
0.2	200	210	220	230	230	240	250	260	260	270	270	280	290	290	300	300	310	320	320	330	330	0.2
0.4	400	420	430	450	460	480	490	510	520	530	540	560	570	580	590	600	610	620	640	650	660	0.4
0.6	600	620	640	670	690	710	730	750	770	790	810	820	840	860	880	890	910	930	940	960	970	0.6
0.8	780	820	850	880	910	930	960	990	1,010	1,040	1,060	1,090	1,110	1,130	1,150	1,180	1,200	1,220	1,240	1,260	1,280	0.8
1.0	970	1,010	1,040	1,080	1,120	1,150	1,180	1,220	1,250	1,280	1,310	1,340	1,370	1,400	1,420	1,450	1,480	1,500	1,530	1,550	1,580	1.0
1.2	1,140	1,190	1,240	1,280	1,320	1,360	1,400	1,440	1,480	1,510	1,550	1,590	1,620	1,650	1,690	1,720	1,750	1,780	1,810	1,840	1,870	1.2
1.4	1,320	1,370	1,420	1,470	1,520	1,570	1,610	1,660	1,700	1,740	1,780	1,820	1,860	1,900	1,940	1,980	2,010	2,050	2,080	2,120	2,150	1.4
1.6	1,490	1,550	1,610	1,660	1,720	1,770	1,820	1,870	1,920	1,970	2,010	2,060	2,100	2,150	2,190	2,230	2,270	2,310	2,350	2,390	2,430	1.6
1.8	1,650	1,720	1,790	1,850	1,910	1,970	2,030	2,080	2,140	2,190	2,240	2,290	2,340	2,390	2,430	2,480	2,530	2,570	2,610	2,660	2,700	1.8
2.0	1,820	1,890	1,960	2,030	2,100	2,160	2,230	2,290	2,350	2,410	2,460	2,520	2,570	2,620	2,680	2,730	2,780	2,830	2,870	2,920	2,970	2.0
2.2	1,980	2,060	2,140	2,220	2,290	2,360	2,430	2,490	2,560	2,620	2,680	2,740	2,800	2,860	2,920	2,970	3,030	3,080	3,130	3,190	3,240	2.2
2.4	2,150	2,230	2,320	2,400	2,480	2,550	2,630	2,700	2,770	2,840	2,910	2,970	3,030	3,100	3,160	3,220	3,280	3,340	3,390	3,450	3,500	2.4
2.6	2,310	2,400	2,500	2,580	2,670	2,750	2,830	2,910	2,980	3,060	3,130	3,200	3,270	3,330	3,400	3,470	3,530	3,590	3,650	3,710	3,770	2.6
2.8	2,480	2,580	2,680	2,770	2,860	2,950	3,030	3,120	3,200	3,280	3,350	3,430	3,500	3,580	3,650	3,720	3,780	3,850	3,920	3,980	4,050	2.8
3.0	2,650	2,750	2,860	2,960	3,060	3,150	3,240	3,330	3,420	3,500	3,580	3,660	3,740	3,820	3,900	3,970	4,040	4,110	4,190	4,250	4,320	3.0
3.2	2,820	2,940	3,050	3,150	3,260	3,360	3,450	3,550	3,640	3,730	3,820	3,900	3,990	4,070	4,150	4,230	4,310	4,380	4,460	4,530	4,610	3.2
3.4	3,000	3,120	3,240	3,350	3,460	3,570	3,670	3,770	3,870	3,970	4,060	4,150	4,240	4,330	4,410	4,500	4,580	4,660	4,740	4,820	4,900	3.4
3.6	3,180	3,310	3,430	3,550	3,670	3,780	3,890	4,000	4,100	4,210	4,310	4,400	4,500	4,590	4,680	4,770	4,860	4,940	5,030	5,110	5,190	3.6
3.8	3,370	3,500	3,640	3,760	3,890	4,010	4,120	4,240	4,350	4,450	4,560	4,660	4,760	4,860	4,960	5,050	5,140	5,230	5,320	5,410	5,500	3.8
4.0	3,560	3,700	3,840	3,980	4,110	4,240	4,360	4,480	4,590	4,710	4,820	4,930	5,030	5,140	5,240	5,340	5,440	5,530	5,630	5,720	5,810	4.0
4.2	3,760	3,910	4,060	4,200	4,340	4,470	4,600	4,730	4,850	4,970	5,090	5,200	5,310	5,420	5,530	5,630	5,740	5,840	5,940	6,040	6,130	4.2
4.4	3,960	4,120	4,270	4,420	4,570	4,710	4,850	4,980	5,110	5,240	5,360	5,480	5,600	5,710	5,830	5,940	6,050	6,150	6,260	6,360	6,460	4.4
4.6	4,160	4,330	4,500	4,660	4,810	4,960	5,100	5,240	5,380	5,510	5,640	5,770	5,890	6,010	6,130	6,250	6,360	6,470	6,590	6,690	6,800	4.6
4.8	4,380	4,560	4,730	4,890	5,050	5,210	5,360	5,510	5,650	5,790	5,930	6,060	6,190	6,320	6,440	6,560	6,690	6,800	6,920	7,030	7,150	4.8
5.0	4,590	4,780	4,960	5,130	5,300	5,470	5,620	5,780	5,930	6,080	6,220	6,360	6,490	6,630	6,760	6,890	7,020	7,140	7,260	7,380	7,500	5.0
5.2	4,810	5,010	5,200	5,380	5,560	5,730	5,890	6,060	6,210	6,370	6,520	6,660	6,810	6,950	7,080	7,220	7,350	7,480	7,610	7,730	7,860	5.2
5.4	5,040	5,240	5,440	5,630	5,810	5,990	6,170	6,340	6,500	6,660	6,820	6,970	7,120	7,270	7,410	7,550	7,690	7,830	7,960	8,090	8,220	5.4
5.6	5,260	5,480	5,680	5,880	6,070	6,260	6,440	6,620	6,790	6,960	7,120	7,280	7,440	7,590	7,740	7,890	8,040	8,180	8,320	8,460	8,590	5.6
5.8	5,490	5,710	5,930	6,140	6,340	6,530	6,720	6,910	7,090	7,260	7,430	7,600	7,760	7,920	8,080	8,230	8,380	8,530	8,680	8,820	8,960	5.8
6.0	5,720	5,950	6,180	6,390	6,600	6,810	7,000	7,200	7,380	7,560	7,740	7,920	8,090	8,250	8,420	8,580	8,730	8,890	9,040	9,190	9,340	6.0
6.2	5,950	6,190	6,420	6,650	6,870	7,080	7,280	7,480	7,680	7,870	8,050	8,230	8,410	8,590	8,760	8,920	9,090	9,250	9,400	9,560	9,710	6.2
6.4	6,180	6,430	6,670	6,910	7,130	7,350	7,570	7,770	7,980	8,170	8,370	8,550	8,740	8,920	9,090	9,270	9,440	9,600	9,770	9,930	10,090	6.4
6.6	6,410	6,670	6,920	7,160	7,400	7,630	7,850	8,060	8,270	8,480	8,680	8,870	9,060	9,250	9,430	9,610	9,790	9,960	10,130	10,300	10,460	6.6
6.8	6,640	6,910	7,170	7,420	7,660	7,900	8,130	8,350	8,570	8,780	8,990	9,190	9,390	9,580	9,770	9,960	10,140	10,320	10,490	10,670	10,840	6.8
7.0	6,860	7,140	7,410	7,670	7,930	8,170	8,410	8,640	8,860	9,080	9,290	9,500	9,710	9,910	10,100	10,300	10,480	10,670	10,850	11,030	11,210	7.0
7.2	7,090	7,380	7,660	7,920	8,180	8,440	8,680	8,920	9,150	9,380	9,600	9,810	10,020	10,230	10,430	10,630	10,830	11,020	11,210	11,390	11,580	7.2
7.4	7,310	7,610	7,900	8,170	8,440	8,700	8,950	9,200	9,440	9,670	9,900	10,120	10,340	10,550	10,760	10,960	11,170	11,360	11,560	11,750	11,940	7.4
7.6	7,530	7,840	8,130	8,420	8,690	8,960	9,220	9,470	9,720	9,960	10,190	10,420	10,650	10,870	11,080	11,290	11,500	11,700	11,900	12,100	12,290	7.6
7.8	7,740	8,060	8,360	8,660	8,940	9,210	9,480	9,740	9,990	10,240	10,480	10,720	10,950	11,170	11,400	11,610	11,830	12,030	12,240	12,440	12,640	7.8
8.0	7,950	8,280	8,590	8,890	9,180	9,460	9,740	10,000	10,260	10,520	10,760	11,010	11,240	11,480	11,700	11,930	12,140	12,360	12,570	12,780	12,980	8.0
8.2	8,150	8,490	8,810	9,120	9,420	9,700	9,990	10,260	10,530	10,790	11,040	11,290	11,530	11,770	12,000	12,230	12,450	12,680	12,890	13,110	13,310	8.2
8.4	8,350	8,690	9,020	9,340	9,640	9,940	10,230	10,510	10,780	11,050	11,310	11,560	11,810	12,050	12,290	12,530	12,760	12,980	13,200	13,420	13,640	8.4
8.6	8,540	8,890	9,220	9,550	9,860	10,160	10,460	10,750	11,020	11,300	11,560	11,820	12,080	12,330	12,570	12,810	13,040	13,280	13,500	13,730	13,940	8.6
8.8	8,720	9,080	9,420	9,750	10,070	10,380	10,680	10,970	11,260	11,540	11,810	12,070	12,330	12,590	12,840	13,080	13,320	13,560	13,790	14,020	14,240	8.8
9.0	8,890	9,250	9,600	9,940	10,270	10,580	10,890	11,190	11,480	11,760	12,040	12,310	12,570	12,830	13,090	13,340	13,580	13,820	14,060	14,290	14,520	9.0
9.2	9,050	9,420	9,770	10,120	10,450	10,770	11,080	11,390	11,680	11,970	12,250	12,530	12,800	13,060	13,320	13,570	13,820	14,070	14,310	14,540	14,780	9.2
9.4	9,190	9,570	9,930	10,280	10,620	10,940	11,260	11,570	11,870	12,160	12,450	12,730	13,000	13,270	13,530	13,790	14,040	14,290	14,540	14,780	15,010	9.4
9.6	9,320	9,700	10,070	10,420	10,760	11,100	11,420	11,730	12,030	12,330	12,620	12,910	13,180	13,460	13,720	13,980	14,240	14,490	14,740	14,980	15,220	9.6
9.8	9,430	9,820	10,190	10,540	10,890	11,230	11,550	11,870	12,180	12,480	12,770	13,060	13,340	13,610	13,880	14,150	14,410	14,660	14,910	15,160	15,400	9.8
10.0	9,520	9,910	10,280	10,640	10,990	11,330	11,660	11,970	12,290	12,590	12,890	13,180	13,460	13,740	14,010	14,280	14,540	14,790	15,050	15,300	15,540	10.0

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	
0.2	330	340	340	350	350	360	360	370	370	370	380	380	390	390	400	400	410	410	410	420	420	0.2
0.4	660	670	680	690	700	710	710	720	730	740	750	760	770	780	790	790	800	810	820	830	840	0.4
0.6	970	990	1,000	1,020	1,030	1,050	1,060	1,070	1,090	1,100	1,110	1,130	1,140	1,150	1,170	1,180	1,190	1,200	1,220	1,230	1,240	0.6
0.8	1,280	1,300	1,320	1,340	1,360	1,380	1,400	1,410	1,430	1,450	1,470	1,480	1,500	1,520	1,540	1,550	1,570	1,580	1,600	1,620	1,630	0.8
1.0	1,580	1,600	1,630	1,650	1,680	1,700	1,720	1,740	1,770	1,790	1,810	1,830	1,850	1,870	1,890	1,910	1,930	1,950	1,970	1,990	2,010	1.0
1.2	1,870	1,900	1,930	1,960	1,980	2,010	2,040	2,060	2,090	2,120	2,140	2,170	2,190	2,220	2,240	2,270	2,290	2,310	2,340	2,360	2,380	1.2
1.4	2,150	2,190	2,220	2,250	2,280	2,310	2,350	2,380	2,410	2,440	2,470	2,500	2,520	2,550	2,580	2,610	2,640	2,660	2,690	2,720	2,740	1.4
1.6	2,430	2,470	2,500	2,540	2,580	2,610	2,650	2,680	2,720	2,750	2,780	2,820	2,850	2,880	2,910	2,940	2,970	3,010	3,040	3,070	3,100	1.6
1.8	2,700	2,740	2,780	2,820	2,860	2,900	2,940	2,980	3,020	3,060	3,090	3,130	3,170	3,200	3,240	3,270	3,310	3,340	3,380	3,410	3,440	1.8
2.0	2,970	3,020	3,060	3,110	3,150	3,190	3,240	3,280	3,320	3,360	3,400	3,440	3,480	3,520	3,560	3,600	3,640	3,670	3,710	3,750	3,780	2.0
2.2	3,240	3,290	3,340	3,380	3,430	3,480	3,530	3,570	3,620	3,660	3,710	3,750	3,790	3,840	3,880	3,920	3,960	4,000	4,050	4,090	4,130	2.2
2.4	3,500	3,560	3,610	3,660	3,720	3,770	3,820	3,870	3,920	3,970	4,010	4,060	4,110	4,150	4,200	4,250	4,290	4,340	4,380	4,420	4,470	2.4
2.6	3,770	3,830	3,890	3,950	4,000	4,060	4,110	4,170	4,220	4,270	4,320	4,370	4,420	4,470	4,520	4,570	4,620	4,670	4,720	4,760	4,810	2.6
2.8	4,050	4,110	4,170	4,230	4,290	4,350	4,410	4,470	4,520	4,580	4,630	4,690	4,740	4,800	4,850	4,900	4,950	5,010	5,060	5,110	5,160	2.8
3.0	4,320	4,390	4,460	4,520	4,580	4,650	4,710	4,770	4,830	4,890	4,950	5,010	5,070	5,130	5,180	5,240	5,290	5,350	5,400	5,460	5,510	3.0
3.2	4,610	4,680	4,750	4,820	4,880	4,950	5,020	5,080	5,150	5,210	5,280	5,340	5,400	5,460	5,520	5,580	5,640	5,700	5,760	5,810	5,870	3.2
3.4	4,900	4,970	5,050	5,120	5,190	5,260	5,330	5,400	5,470	5,540	5,610	5,670	5,740	5,800	5,870	5,930	6,000	6,060	6,120	6,180	6,240	3.4
3.6	5,190	5,270	5,350	5,430	5,510	5,580	5,660	5,730	5,810	5,880	5,950	6,020	6,090	6,160	6,230	6,290	6,360	6,430	6,490	6,550	6,620	3.6
3.8	5,500	5,580	5,670	5,750	5,830	5,910	5,990	6,070	6,150	6,220	6,300	6,370	6,450	6,520	6,590	6,660	6,730	6,800	6,870	6,940	7,010	3.8
4.0	5,810	5,900	5,990	6,080	6,160	6,250	6,330	6,420	6,500	6,580	6,660	6,740	6,810	6,890	6,970	7,040	7,120	7,190	7,260	7,340	7,410	4.0
4.2	6,130	6,230	6,320	6,410	6,500	6,590	6,680	6,770	6,860	6,940	7,030	7,110	7,190	7,270	7,350	7,430	7,510	7,590	7,670	7,740	7,820	4.2
4.4	6,460	6,560	6,660	6,760	6,860	6,950	7,040	7,130	7,230	7,320	7,400	7,490	7,580	7,660	7,750	7,830	7,920	8,000	8,080	8,160	8,240	4.4
4.6	6,800	6,910	7,010	7,110	7,210	7,310	7,410	7,510	7,600	7,700	7,790	7,880	7,980	8,070	8,150	8,240	8,330	8,420	8,500	8,590	8,670	4.6
4.8	7,150	7,260	7,370	7,470	7,580	7,690	7,790	7,890	7,990	8,090	8,190	8,280	8,380	8,480	8,570	8,660	8,750	8,840	8,930	9,020	9,110	4.8
5.0	7,500	7,620	7,730	7,840	7,950	8,060	8,170	8,280	8,380	8,490	8,590	8,690	8,790	8,890	8,990	9,090	9,190	9,280	9,370	9,470	9,560	5.0
5.2	7,860	7,980	8,100	8,220	8,340	8,450	8,560	8,680	8,790	8,900	9,000	9,110	9,210	9,320	9,420	9,520	9,620	9,720	9,820	9,920	10,020	5.2
5.4	8,220	8,350	8,480	8,600	8,720	8,840	8,960	9,080	9,190	9,310	9,420	9,530	9,640	9,750	9,860	9,970	10,070	10,180	10,280	10,380	10,480	5.4
5.6	8,590	8,720	8,860	8,980	9,110	9,240	9,360	9,480	9,610	9,720	9,840	9,960	10,070	10,190	10,300	10,410	10,520	10,630	10,740	10,850	10,950	5.6
5.8	8,960	9,100	9,240	9,370	9,510	9,640	9,770	9,900	10,020	10,150	10,270	10,390	10,510	10,630	10,750	10,860	10,980	11,090	11,200	11,320	11,430	5.8
6.0	9,340	9,480	9,620	9,770	9,900	10,040	10,180	10,310	10,440	10,570	10,700	10,820	10,950	11,070	11,200	11,320	11,440	11,550	11,670	11,790	11,900	6.0
6.2	9,710	9,860	10,010	10,160	10,300	10,440	10,580	10,720	10,860	10,990	11,130	11,260	11,390	11,520	11,650	11,770	11,900	12,020	12,140	12,260	12,380	6.2
6.4	10,090	10,250	10,400	10,550	10,700	10,850	10,990	11,140	11,280	11,420	11,560	11,700	11,830	11,960	12,100	12,230	12,360	12,480	12,610	12,740	12,860	6.4
6.6	10,460	10,630	10,790	10,940	11,100	11,250	11,400	11,550	11,700	11,850	11,990	12,130	12,270	12,410	12,550	12,680	12,820	12,950	13,080	13,210	13,340	6.6
6.8	10,840	11,010	11,170	11,330	11,500	11,650	11,810	11,960	12,120	12,270	12,420	12,560	12,710	12,850	12,990	13,130	13,270	13,410	13,550	13,680	13,820	6.8
7.0	11,210	11,380	11,550	11,720	11,890	12,050	12,210	12,370	12,530	12,690	12,840	12,990	13,140	13,290	13,440	13,580	13,730	13,870	14,010	14,150	14,290	7.0
7.2	11,580	11,750	11,930	12,110	12,280	12,450	12,610	12,780	12,940	13,100	13,260	13,420	13,570	13,730	13,880	14,030	14,180	14,320	14,470	14,610	14,760	7.2
7.4	11,940	12,120	12,300	12,480	12,660	12,840	13,010	13,180	13,350	13,510	13,680	13,840	14,000	14,160	14,310	14,470	14,620	14,770	14,920	15,070	15,220	7.4
7.6	12,290	12,480	12,670	12,860	13,040	13,220	13,400	13,570	13,740	13,910	14,080	14,250	14,410	14,580	14,740	14,900	15,060	15,210	15,370	15,520	15,670	7.6
7.8	12,640	12,840	13,030	13,220	13,410	13,590	13,780	13,960	14,130	14,310	14,480	14,650	14,820	14,990	15,160	15,320	15,480	15,640	15,800	15,960	16,120	7.8
8.0	12,980	13,180	13,380	13,580	13,770	13,960	14,150	14,330	14,520	14,700	14,870	15,050	15,220	15,400	15,570	15,730	15,900	16,070	16,230	16,390	16,550	8.0
8.2	13,310	13,520	13,720	13,920	14,120	14,320	14,510	14,700	14,890	15,070	15,250	15,430	15,610	15,790	15,960	16,140	16,310	16,480	16,640	16,810	16,970	8.2
8.4	13,640	13,850	14,060	14,260	14,460	14,660	14,860	15,050	15,250	15,430	15,620	15,810	15,990	16,170	16,350	16,530	16,700	16,870	17,050	17,210	17,380	8.4
8.6	13,940	14,160	14,370	14,580	14,790	14,990	15,200	15,390	15,590	15,780	15,980	16,160	16,350	16,540	16,720	16,900	17,080	17,260	17,430	17,600	17,780	8.6
8.8	14,240	14,460	14,680	14,890	15,100	15,310	15,520	15,720	15,920	16,120	16,310	16,510	16,700	16,890	17,070	17,260	17,440	17,620	17,800	17,980	18,150	8.8
9.0	14,520	14,740	14,960	15,180	15,400	15,610	15,820	16,030	16,230	16,430	16,630	16,830	17,020	17,220	17,410	17,590	17,780	17,970	18,150	18,330	18,510	9.0
9.2	14,780	15,010	15,230	15,450	15,670	15,890	16,100	16,310	16,520	16,730	16,930	17,130	17,330	17,520	17,720	17,910	18,100	18,290	18,470	18,660	18,840	9.2
9.4	15,010	15,250	15,480	15,700	15,920	16,140	16,360	16,570	16,790	16,990	17,200	17,400	17,600	17,800	18,000	18,190	18,390	18,580	18,770	18,950	19,140	9.4
9.6	15,220	15,460	15,690	15,920	16,150	16,370	16,590	16,810	17,020	17,230	17,440	17,650	17,850	18,050	18,250	18,450	18,640	18,840	19,030	19,220	19,410	9.6
9.8	15,400	15,640	15,870	16,110	16,330	16,560	16,780	17,000	17,220	17,430	17,640	17,850	18,060	18,260	18,460	18,660	18,860	19,060	19,250	19,440	19,630	9.8
10.0	15,540	15,780	16,020	16,250	16,480	16,710	16,940	17,160	17,380	17,590	17,800	18,010	18,220	18,430	18,630	18,830	19,030	19,230	19,430	19,620	19,810	10.0

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	
0.2	420	430	430	430	440	440	450	450	450	460	460	460	470	470	480	480	480	490	490	490	500	0.2
0.4	840	840	850	860	870	880	880	890	900	910	910	920	930	930	940	950	960	960	970	980	980	0.4
0.6	1,240	1,250	1,260	1,280	1,290	1,300	1,310	1,320	1,330	1,340	1,350	1,360	1,380	1,390	1,400	1,410	1,420	1,430	1,440	1,450	1,460	0.6
0.8	1,630	1,650	1,660	1,680	1,690	1,710	1,720	1,740	1,750	1,770	1,780	1,800	1,810	1,830	1,840	1,850	1,870	1,880	1,890	1,910	1,920	0.8
1.0	2,010	2,030	2,050	2,070	2,090	2,110	2,130	2,140	2,160	2,180	2,200	2,220	2,230	2,250	2,270	2,290	2,300	2,320	2,340	2,350	2,370	1.0
1.2	2,380	2,410	2,430	2,450	2,470	2,500	2,520	2,540	2,560	2,580	2,600	2,620	2,640	2,660	2,690	2,710	2,730	2,750	2,770	2,780	2,800	1.2
1.4	2,740	2,770	2,800	2,820	2,850	2,870	2,900	2,920	2,950	2,970	3,000	3,020	3,040	3,070	3,090	3,110	3,140	3,160	3,180	3,210	3,230	1.4
1.6	3,100	3,130	3,160	3,180	3,210	3,240	3,270	3,300	3,330	3,350	3,380	3,410	3,430	3,460	3,490	3,510	3,540	3,570	3,590	3,620	3,640	1.6
1.8	3,440	3,480	3,510	3,540	3,570	3,600	3,640	3,670	3,700	3,730	3,760	3,790	3,820	3,850	3,880	3,910	3,940	3,970	3,990	4,020	4,050	1.8
2.0	3,780	3,820	3,860	3,890	3,930	3,960	4,000	4,030	4,070	4,100	4,130	4,170	4,200	4,230	4,260	4,300	4,330	4,360	4,390	4,420	4,450	2.0
2.2	4,130	4,160	4,200	4,240	4,280	4,320	4,360	4,390	4,430	4,470	4,500	4,540	4,580	4,610	4,650	4,680	4,720	4,750	4,790	4,820	4,850	2.2
2.4	4,470	4,510	4,550	4,590	4,630	4,680	4,720	4,760	4,800	4,840	4,880	4,920	4,950	4,990	5,030	5,070	5,110	5,140	5,180	5,220	5,260	2.4
2.6	4,810	4,860	4,900	4,950	4,990	5,040	5,080	5,120	5,170	5,210	5,250	5,290	5,340	5,380	5,420	5,460	5,500	5,540	5,580	5,620	5,660	2.6
2.8	5,160	5,210	5,250	5,300	5,350	5,400	5,450	5,490	5,540	5,590	5,630	5,680	5,720	5,770	5,810	5,850	5,900	5,940	5,980	6,030	6,070	2.8
3.0	5,510	5,560	5,610	5,670	5,720	5,770	5,820	5,870	5,920	5,970	6,020	6,060	6,110	6,160	6,210	6,250	6,300	6,350	6,390	6,440	6,480	3.0
3.2	5,870	5,930	5,980	6,040	6,090	6,150	6,200	6,250	6,310	6,360	6,410	6,460	6,510	6,560	6,610	6,660	6,710	6,760	6,810	6,860	6,910	3.2
3.4	6,240	6,300	6,360	6,420	6,480	6,530	6,590	6,650	6,700	6,760	6,810	6,870	6,920	6,980	7,030	7,080	7,140	7,190	7,240	7,290	7,340	3.4
3.6	6,620	6,680	6,740	6,810	6,870	6,930	6,990	7,050	7,110	7,170	7,230	7,290	7,340	7,400	7,460	7,510	7,570	7,620	7,680	7,730	7,790	3.6
3.8	7,010	7,070	7,140	7,210	7,270	7,340	7,400	7,460	7,530	7,590	7,650	7,710	7,770	7,830	7,900	7,950	8,010	8,070	8,130	8,190	8,250	3.8
4.0	7,410	7,480	7,550	7,620	7,690	7,760	7,820	7,890	7,960	8,020	8,090	8,150	8,220	8,280	8,350	8,410	8,470	8,530	8,590	8,660	8,720	4.0
4.2	7,820	7,890	7,970	8,040	8,110	8,190	8,260	8,330	8,400	8,470	8,540	8,610	8,670	8,740	8,810	8,870	8,940	9,010	9,070	9,140	9,200	4.2
4.4	8,240	8,320	8,400	8,470	8,550	8,630	8,700	8,780	8,850	8,920	9,000	9,070	9,140	9,210	9,280	9,350	9,420	9,490	9,560	9,630	9,690	4.4
4.6	8,670	8,750	8,840	8,920	9,000	9,080	9,160	9,240	9,310	9,390	9,470	9,540	9,620	9,690	9,770	9,840	9,910	9,990	10,060	10,130	10,200	4.6
4.8	9,110	9,200	9,280	9,370	9,450	9,540	9,620	9,700	9,790	9,870	9,950	10,030	10,110	10,190	10,260	10,340	10,420	10,490	10,570	10,650	10,720	4.8
5.0	9,560	9,650	9,740	9,830	9,920	10,010	10,100	10,180	10,270	10,350	10,440	10,520	10,610	10,690	10,770	10,850	10,930	11,010	11,090	11,170	11,250	5.0
5.2	10,020	10,110	10,210	10,300	10,400	10,490	10,580	10,670	10,760	10,850	10,940	11,030	11,110	11,200	11,290	11,370	11,460	11,540	11,620	11,710	11,790	5.2
5.4	10,480	10,580	10,680	10,780	10,880	10,970	11,070	11,170	11,260	11,350	11,450	11,540	11,630	11,720	11,810	11,900	11,990	12,070	12,160	12,250	12,330	5.4
5.6	10,950	11,060	11,160	11,260	11,370	11,470	11,570	11,670	11,760	11,860	11,960	12,050	12,150	12,240	12,340	12,430	12,520	12,620	12,710	12,800	12,890	5.6
5.8	11,430	11,540	11,640	11,750	11,860	11,960	12,070	12,170	12,270	12,380	12,480	12,580	12,680	12,770	12,870	12,970	13,070	13,160	13,260	13,350	13,440	5.8
6.0	11,900	12,020	12,130	12,240	12,350	12,460	12,570	12,680	12,790	12,890	13,000	13,100	13,210	13,310	13,410	13,510	13,610	13,710	13,810	13,910	14,010	6.0
6.2	12,380	12,500	12,620	12,730	12,850	12,960	13,080	13,190	13,300	13,410	13,520	13,630	13,740	13,840	13,950	14,050	14,160	14,260	14,370	14,470	14,570	6.2
6.4	12,860	12,980	13,110	13,230	13,350	13,470	13,580	13,700	13,820	13,930	14,040	14,160	14,270	14,380	14,490	14,600	14,710	14,820	14,920	15,030	15,130	6.4
6.6	13,340	13,470	13,590	13,720	13,840	13,970	14,090	14,210	14,330	14,450	14,570	14,680	14,800	14,910	15,030	15,140	15,250	15,370	15,480	15,590	15,700	6.6
6.8	13,820	13,950	14,080	14,210	14,340	14,460	14,590	14,720	14,840	14,960	15,090	15,210	15,330	15,450	15,560	15,680	15,800	15,910	16,030	16,140	16,260	6.8
7.0	14,290	14,420	14,560	14,690	14,830	14,960	15,090	15,220	15,350	15,480	15,600	15,730	15,850	15,970	16,100	16,220	16,340	16,460	16,580	16,700	16,810	7.0
7.2	14,760	14,900	15,040	15,180	15,310	15,450	15,580	15,720	15,850	15,980	16,110	16,240	16,370	16,500	16,620	16,750	16,870	17,000	17,120	17,240	17,360	7.2
7.4	15,220	15,360	15,510	15,650	15,790	15,930	16,070	16,210	16,350	16,480	16,620	16,750	16,880	17,010	17,140	17,270	17,400	17,530	17,650	17,780	17,910	7.4
7.6	15,670	15,820	15,970	16,120	16,260	16,410	16,550	16,690	16,830	16,970	17,110	17,250	17,380	17,520	17,650	17,790	17,920	18,050	18,180	18,310	18,440	7.6
7.8	16,120	16,270	16,420	16,570	16,720	16,870	17,020	17,170	17,310	17,450	17,600	17,740	17,880	18,020	18,160	18,290	18,430	18,560	18,700	18,830	18,960	7.8
8.0	16,550	16,710	16,870	17,020	17,170	17,330	17,480	17,630	17,780	17,930	18,070	18,220	18,360	18,500	18,650	18,790	18,930	19,060	19,200	19,340	19,470	8.0
8.2	16,970	17,140	17,300	17,460	17,610	17,770	17,930	18,080	18,230	18,380	18,530	18,680	18,830	18,980	19,120	19,270	19,410	19,550	19,690	19,830	19,970	8.2
8.4	17,380	17,550	17,710	17,880	18,040	18,200	18,360	18,520	18,670	18,830	18,980	19,130	19,280	19,430	19,580	19,730	19,880	20,020	20,170	20,310	20,450	8.4
8.6	17,780	17,950	18,110	18,280	18,450	18,610	18,770	18,940	19,090	19,250	19,410	19,570	19,720	19,870	20,030	20,180	20,330	20,480	20,620	20,770	20,920	8.6
8.8	18,150	18,330	18,500	18,670	18,840	19,000	19,170	19,340	19,500	19,660	19,820	19,980	20,140	20,290	20,450	20,600	20,760	20,910	21,060	21,210	21,360	8.8
9.0	18,510	18,680	18,860	19,030	19,210	19,380	19,550	19,710	19,880	20,040	20,210	20,370	20,530	20,690	20,850	21,010	21,160	21,320	21,470	21,630	21,780	9.0
9.2	18,840	19,020	19,200	19,370	19,550	19,720	19,890	20,060	20,230	20,400	20,570	20,730	20,900	21,060	21,220	21,380	21,540	21,700	21,860	22,010	22,170	9.2
9.4	19,140	19,320	19,500	19,680	19,860	20,040	20,210	20,390	20,560	20,730	20,900	21,070	21,230	21,400	21,560	21,720	21,890	22,050	22,210	22,360	22,520	9.4
9.6	19,410	19,590	19,780	19,960	20,140	20,320	20,490	20,670	20,840	21,020	21,190	21,360	21,530	21,700	21,860	22,030	22,190	22,350	22,510	22,680	22,830	9.6
9.8	19,630	19,820	20,010	20,190	20,370	20,550	20,730	20,910	21,090	21,260	21,440	21,610	21,780	21,950	22,120	22,280	22,450	22,610	22,780	22,940	23,100	9.8
10.0	19,810	20,000	20,190	20,370	20,560	20,740	20,920	21,100	21,280	21,460	21,630	21,810	21,980	22,150	22,320	22,490	22,650	22,820	22,980	23,150	23,310	10.0

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	
0.2	500	500	500	510	510	510	520	520	520	530	530	530	540	540	540	550	550	550	560	560	560	0.2
0.4	980	990	1,000	1,000	1,010	1,020	1,020	1,030	1,040	1,040	1,050	1,060	1,060	1,070	1,080	1,080	1,090	1,090	1,100	1,110	1,110	0.4
0.6	1,460	1,470	1,480	1,490	1,500	1,510	1,520	1,530	1,540	1,550	1,560	1,570	1,580	1,590	1,590	1,600	1,610	1,620	1,630	1,640	1,650	0.6
0.8	1,920	1,930	1,950	1,960	1,970	1,990	2,000	2,010	2,020	2,040	2,050	2,060	2,070	2,090	2,100	2,110	2,120	2,140	2,150	2,160	2,170	0.8
1.0	2,370	2,390	2,400	2,420	2,430	2,450	2,470	2,480	2,500	2,510	2,530	2,540	2,560	2,570	2,590	2,600	2,620	2,630	2,650	2,660	2,680	1.0
1.2	2,800	2,820	2,840	2,860	2,880	2,900	2,920	2,940	2,960	2,970	2,990	3,010	3,030	3,050	3,070	3,080	3,100	3,120	3,140	3,150	3,170	1.2
1.4	3,230	3,250	3,270	3,300	3,320	3,340	3,360	3,380	3,400	3,420	3,450	3,470	3,490	3,510	3,530	3,550	3,570	3,590	3,610	3,630	3,650	1.4
1.6	3,640	3,670	3,690	3,720	3,740	3,770	3,790	3,820	3,840	3,860	3,890	3,910	3,940	3,960	3,980	4,000	4,030	4,050	4,070	4,100	4,120	1.6
1.8	4,050	4,080	4,110	4,130	4,160	4,190	4,220	4,240	4,270	4,300	4,320	4,350	4,380	4,400	4,430	4,450	4,480	4,500	4,530	4,550	4,580	1.8
2.0	4,450	4,480	4,520	4,550	4,580	4,610	4,640	4,670	4,690	4,720	4,750	4,780	4,810	4,840	4,870	4,900	4,920	4,950	4,980	5,010	5,030	2.0
2.2	4,850	4,890	4,920	4,950	4,990	5,020	5,050	5,080	5,120	5,150	5,180	5,210	5,240	5,270	5,310	5,340	5,370	5,400	5,430	5,460	5,490	2.2
2.4	5,260	5,290	5,330	5,360	5,400	5,430	5,470	5,500	5,540	5,570	5,610	5,640	5,680	5,710	5,740	5,780	5,810	5,840	5,880	5,910	5,940	2.4
2.6	5,660	5,700	5,740	5,780	5,810	5,850	5,890	5,930	5,970	6,000	6,040	6,080	6,110	6,150	6,180	6,220	6,260	6,290	6,330	6,360	6,400	2.6
2.8	6,070	6,110	6,150	6,190	6,230	6,280	6,320	6,360	6,400	6,440	6,480	6,510	6,550	6,590	6,630	6,670	6,710	6,750	6,780	6,820	6,860	2.8
3.0	6,480	6,530	6,570	6,620	6,660	6,700	6,750	6,790	6,830	6,880	6,920	6,960	7,000	7,040	7,090	7,130	7,170	7,210	7,250	7,290	7,330	3.0
3.2	6,910	6,960	7,000	7,050	7,100	7,140	7,190	7,240	7,280	7,330	7,370	7,420	7,460	7,510	7,550	7,590	7,640	7,680	7,720	7,770	7,810	3.2
3.4	7,340	7,390	7,440	7,490	7,540	7,590	7,640	7,690	7,740	7,790	7,840	7,880	7,930	7,980	8,020	8,070	8,120	8,160	8,210	8,250	8,300	3.4
3.6	7,790	7,840	7,900	7,950	8,000	8,050	8,110	8,160	8,210	8,260	8,310	8,360	8,410	8,460	8,510	8,560	8,610	8,660	8,710	8,760	8,800	3.6
3.8	8,250	8,300	8,360	8,420	8,470	8,530	8,580	8,640	8,690	8,750	8,800	8,850	8,910	8,960	9,010	9,060	9,120	9,170	9,220	9,270	9,320	3.8
4.0	8,720	8,780	8,840	8,900	8,960	9,010	9,070	9,130	9,190	9,250	9,300	9,360	9,410	9,470	9,530	9,580	9,640	9,690	9,750	9,800	9,850	4.0
4.2	9,200	9,260	9,330	9,390	9,450	9,510	9,570	9,640	9,700	9,760	9,820	9,880	9,940	10,000	10,050	10,110	10,170	10,230	10,290	10,340	10,400	4.2
4.4	9,690	9,760	9,830	9,890	9,960	10,030	10,090	10,150	10,220	10,280	10,350	10,410	10,470	10,530	10,600	10,660	10,720	10,780	10,840	10,900	10,960	4.4
4.6	10,200	10,270	10,340	10,410	10,480	10,550	10,620	10,690	10,750	10,820	10,890	10,950	11,020	11,080	11,150	11,210	11,280	11,340	11,410	11,470	11,530	4.6
4.8	10,720	10,790	10,870	10,940	11,010	11,090	11,160	11,230	11,300	11,370	11,440	11,510	11,580	11,650	11,720	11,780	11,850	11,920	11,990	12,050	12,120	4.8
5.0	11,250	11,330	11,400	11,480	11,560	11,630	11,710	11,780	11,860	11,930	12,010	12,080	12,150	12,220	12,290	12,370	12,440	12,510	12,580	12,650	12,720	5.0
5.2	11,790	11,870	11,950	12,030	12,110	12,190	12,270	12,350	12,430	12,500	12,580	12,660	12,730	12,810	12,880	12,960	13,030	13,110	13,180	13,250	13,320	5.2
5.4	12,330	12,420	12,500	12,590	12,670	12,760	12,840	12,920	13,000	13,080	13,160	13,240	13,320	13,400	13,480	13,560	13,640	13,710	13,790	13,870	13,940	5.4
5.6	12,890	12,980	13,060	13,150	13,240	13,330	13,410	13,500	13,580	13,670	13,750	13,840	13,920	14,000	14,080	14,170	14,250	14,330	14,410	14,490	14,570	5.6
5.8	13,440	13,540	13,630	13,720	13,810	13,900	13,990	14,080	14,170	14,260	14,350	14,440	14,520	14,610	14,690	14,780	14,860	14,950	15,030	15,120	15,200	5.8
6.0	14,010	14,100	14,200	14,300	14,390	14,480	14,580	14,670	14,760	14,860	14,950	15,040	15,130	15,220	15,310	15,400	15,480	15,570	15,660	15,750	15,830	6.0
6.2	14,570	14,670	14,770	14,870	14,970	15,070	15,160	15,260	15,360	15,450	15,550	15,640	15,740	15,830	15,920	16,020	16,110	16,200	16,290	16,380	16,470	6.2
6.4	15,130	15,240	15,340	15,450	15,550	15,650	15,750	15,850	15,950	16,050	16,150	16,250	16,350	16,440	16,540	16,640	16,730	16,830	16,920	17,010	17,110	6.4
6.6	15,700	15,810	15,910	16,020	16,130	16,230	16,340	16,440	16,550	16,650	16,750	16,850	16,950	17,060	17,160	17,250	17,350	17,450	17,550	17,650	17,740	6.6
6.8	16,260	16,370	16,480	16,590	16,700	16,810	16,920	17,030	17,140	17,240	17,350	17,450	17,560	17,660	17,770	17,870	17,970	18,070	18,180	18,280	18,380	6.8
7.0	16,810	16,930	17,040	17,160	17,270	17,390	17,500	17,610	17,720	17,830	17,940	18,050	18,160	18,270	18,370	18,480	18,590	18,690	18,800	18,900	19,000	7.0
7.2	17,360	17,480	17,600	17,720	17,840	17,960	18,070	18,190	18,300	18,420	18,530	18,640	18,750	18,870	18,980	19,090	19,200	19,300	19,410	19,520	19,630	7.2
7.4	17,910	18,030	18,150	18,270	18,400	18,520	18,640	18,760	18,870	18,990	19,110	19,220	19,340	19,450	19,570	19,680	19,800	19,910	20,020	20,130	20,240	7.4
7.6	18,440	18,570	18,690	18,820	18,940	19,070	19,190	19,310	19,440	19,560	19,680	19,800	19,920	20,040	20,150	20,270	20,390	20,500	20,620	20,730	20,840	7.6
7.8	18,960	19,090	19,220	19,350	19,480	19,610	19,740	19,860	19,990	20,110	20,240	20,360	20,480	20,600	20,720	20,840	20,960	21,080	21,200	21,320	21,440	7.8
8.0	19,470	19,610	19,740	19,880	20,010	20,140	20,270	20,400	20,530	20,660	20,780	20,910	21,030	21,160	21,280	21,410	21,530	21,650	21,770	21,890	22,010	8.0
8.2	19,970	20,110	20,250	20,380	20,520	20,650	20,790	20,920	21,050	21,180	21,310	21,440	21,570	21,700	21,830	21,950	22,080	22,210	22,330	22,450	22,580	8.2
8.4	20,450	20,600	20,740	20,880	21,010	21,150	21,290	21,430	21,560	21,690	21,830	21,960	22,090	22,220	22,350	22,480	22,610	22,740	22,870	22,990	23,120	8.4
8.6	20,920	21,060	21,210	21,350	21,490	21,630	21,770	21,910	22,050	22,190	22,320	22,460	22,590	22,730	22,860	22,990	23,130	23,260	23,390	23,520	23,640	8.6
8.8	21,360	21,510	21,650	21,800	21,940	22,090	22,230	22,370	22,510	22,660	22,790	22,930	23,070	23,210	23,340	23,480	23,610	23,750	23,880	24,010	24,140	8.8
9.0	21,780	21,930	22,080	22,230	22,370	22,520	22,670	22,810	22,950	23,100	23,240	23,380	23,520	23,660	23,800	23,940	24,080	24,210	24,350	24,480	24,620	9.0
9.2	22,170	22,320	22,470	22,620	22,770	22,920	23,070	23,220	23,360	23,510	23,650	23,800	23,940	24,080	24,220	24,370	24,500	24,640	24,780	24,920	25,060	9.2
9.4	22,520	22,680	22,830	22,980	23,140	23,290	23,440	23,590	23,740	23,890	24,030	24,180	24,320	24,470	24,610	24,750	24,900	25,040	25,180	25,320	25,460	9.4
9.6	22,830	22,990	23,150	23,310	23,460	23,610	23,770	23,920	24,070	24,220	24,370	24,520	24,660	24,810	24,960	25,100	25,240	25,390	25,530	25,670	25,810	9.6
9.8	23,100	23,260	23,420	23,580	23,730	23,890	24,040	24,200	24,350	24,500	24,650	24,800	24,950	25,100	25,250	25,390	25,540	25,680	25,830	25,970	26,110	9.8
10.0	23,310	23,470	23,630	23,790	23,950	24,110	24,260	24,420	24,570	24,730	24,880	25,030	25,180	25,330	25,480	25,620	25,770	25,920	26,060	26,210	26,350	10.0

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	
0.2	560	560	570	570	570	580	580	580	590	590	590	590	600	600	600	610	610	610	610	620	620	0.2
0.4	1,110	1,120	1,120	1,130	1,140	1,140	1,150	1,150	1,160	1,170	1,170	1,180	1,180	1,190	1,190	1,200	1,210	1,210	1,220	1,220	1,230	0.4
0.6	1,650	1,660	1,670	1,680	1,680	1,690	1,700	1,710	1,720	1,730	1,740	1,750	1,750	1,760	1,770	1,780	1,790	1,800	1,800	1,810	1,820	0.6
0.8	2,170	2,180	2,190	2,210	2,220	2,230	2,240	2,250	2,260	2,270	2,290	2,300	2,310	2,320	2,330	2,340	2,350	2,360	2,370	2,380	2,400	0.8
1.0	2,680	2,690	2,710	2,720	2,740	2,750	2,760	2,780	2,790	2,810	2,820	2,830	2,850	2,860	2,870	2,890	2,900	2,910	2,930	2,940	2,950	1.0
1.2	3,170	3,190	3,200	3,220	3,240	3,260	3,270	3,290	3,310	3,320	3,340	3,350	3,370	3,390	3,400	3,420	3,430	3,450	3,470	3,480	3,500	1.2
1.4	3,650	3,670	3,690	3,710	3,730	3,750	3,770	3,790	3,800	3,820	3,840	3,860	3,880	3,900	3,920	3,940	3,950	3,970	3,990	4,010	4,030	1.4
1.6	4,120	4,140	4,160	4,180	4,210	4,230	4,250	4,270	4,290	4,320	4,340	4,360	4,380	4,400	4,420	4,440	4,460	4,480	4,500	4,520	4,540	1.6
1.8	4,580	4,600	4,630	4,650	4,680	4,700	4,730	4,750	4,770	4,800	4,820	4,850	4,870	4,890	4,920	4,940	4,960	4,980	5,010	5,030	5,050	1.8
2.0	5,030	5,060	5,090	5,120	5,140	5,170	5,200	5,220	5,250	5,270	5,300	5,330	5,350	5,380	5,400	5,430	5,450	5,480	5,500	5,530	5,550	2.0
2.2	5,490	5,520	5,550	5,580	5,610	5,630	5,660	5,690	5,720	5,750	5,780	5,810	5,830	5,860	5,890	5,920	5,950	5,970	6,000	6,030	6,050	2.2
2.4	5,940	5,970	6,000	6,040	6,070	6,100	6,130	6,160	6,190	6,220	6,260	6,290	6,320	6,350	6,380	6,410	6,440	6,470	6,500	6,530	6,550	2.4
2.6	6,400	6,430	6,470	6,500	6,530	6,570	6,600	6,640	6,670	6,700	6,740	6,770	6,800	6,830	6,870	6,900	6,930	6,960	6,990	7,030	7,060	2.6
2.8	6,860	6,900	6,930	6,970	7,010	7,040	7,080	7,120	7,150	7,190	7,220	7,260	7,290	7,330	7,360	7,400	7,430	7,470	7,500	7,530	7,570	2.8
3.0	7,330	7,370	7,410	7,450	7,490	7,530	7,560	7,600	7,640	7,680	7,720	7,750	7,790	7,830	7,870	7,900	7,940	7,980	8,010	8,050	8,090	3.0
3.2	7,810	7,850	7,890	7,930	7,980	8,020	8,060	8,100	8,140	8,180	8,220	8,260	8,300	8,340	8,380	8,420	8,460	8,500	8,540	8,580	8,620	3.2
3.4	8,300	8,340	8,390	8,430	8,480	8,520	8,570	8,610	8,650	8,700	8,740	8,780	8,820	8,870	8,910	8,950	8,990	9,030	9,080	9,120	9,160	3.4
3.6	8,800	8,850	8,900	8,950	8,990	9,040	9,090	9,130	9,180	9,220	9,270	9,320	9,360	9,410	9,450	9,490	9,540	9,580	9,630	9,670	9,710	3.6
3.8	9,320	9,370	9,420	9,470	9,520	9,570	9,620	9,670	9,720	9,770	9,810	9,860	9,910	9,960	10,010	10,050	10,100	10,150	10,190	10,240	10,280	3.8
4.0	9,850	9,910	9,960	10,010	10,060	10,120	10,170	10,220	10,270	10,320	10,370	10,430	10,480	10,530	10,580	10,630	10,680	10,720	10,770	10,820	10,870	4.0
4.2	10,400	10,460	10,510	10,570	10,620	10,680	10,730	10,790	10,840	10,900	10,950	11,000	11,060	11,110	11,160	11,210	11,270	11,320	11,370	11,420	11,470	4.2
4.4	10,960	11,020	11,080	11,140	11,190	11,250	11,310	11,370	11,430	11,480	11,540	11,600	11,650	11,710	11,760	11,820	11,870	11,930	11,980	12,040	12,090	4.4
4.6	11,530	11,590	11,660	11,720	11,780	11,840	11,900	11,960	12,020	12,080	12,140	12,200	12,260	12,320	12,380	12,440	12,490	12,550	12,610	12,670	12,720	4.6
4.8	12,120	12,180	12,250	12,310	12,380	12,440	12,510	12,570	12,630	12,700	12,760	12,820	12,880	12,950	13,010	13,070	13,130	13,190	13,250	13,310	13,370	4.8
5.0	12,720	12,790	12,850	12,920	12,990	13,060	13,120	13,190	13,260	13,320	13,390	13,460	13,520	13,590	13,650	13,710	13,780	13,840	13,900	13,970	14,030	5.0
5.2	13,320	13,400	13,470	13,540	13,610	13,680	13,750	13,820	13,890	13,960	14,030	14,100	14,170	14,240	14,300	14,370	14,440	14,500	14,570	14,640	14,700	5.2
5.4	13,940	14,020	14,090	14,170	14,240	14,320	14,390	14,460	14,540	14,610	14,680	14,750	14,820	14,890	14,970	15,040	15,110	15,180	15,250	15,310	15,380	5.4
5.6	14,570	14,650	14,720	14,800	14,880	14,960	15,030	15,110	15,190	15,260	15,340	15,410	15,490	15,560	15,640	15,710	15,780	15,860	15,930	16,000	16,070	5.6
5.8	15,200	15,280	15,360	15,440	15,520	15,610	15,690	15,770	15,840	15,920	16,000	16,080	16,160	16,240	16,310	16,390	16,470	16,540	16,620	16,690	16,770	5.8
6.0	15,830	15,920	16,000	16,090	16,170	16,260	16,340	16,420	16,510	16,590	16,670	16,750	16,830	16,910	16,990	17,070	17,150	17,230	17,310	17,390	17,470	6.0
6.2	16,470	16,560	16,650	16,740	16,820	16,910	17,000	17,080	17,170	17,260	17,340	17,430	17,510	17,590	17,680	17,760	17,840	17,930	18,010	18,090	18,170	6.2
6.4	17,110	17,200	17,290	17,380	17,480	17,570	17,660	17,750	17,840	17,920	18,010	18,100	18,190	18,280	18,360	18,450	18,540	18,620	18,710	18,790	18,880	6.4
6.6	17,740	17,840	17,940	18,030	18,130	18,220	18,310	18,410	18,500	18,590	18,680	18,770	18,870	18,960	19,050	19,140	19,220	19,310	19,400	19,490	19,580	6.6
6.8	18,380	18,480	18,580	18,670	18,770	18,870	18,970	19,060	19,160	19,250	19,350	19,440	19,540	19,630	19,730	19,820	19,910	20,000	20,090	20,190	20,280	6.8
7.0	19,000	19,110	19,210	19,310	19,410	19,510	19,610	19,710	19,810	19,910	20,010	20,110	20,210	20,300	20,400	20,500	20,590	20,690	20,780	20,880	20,970	7.0
7.2	19,630	19,730	19,840	19,940	20,050	20,150	20,260	20,360	20,460	20,560	20,670	20,770	20,870	20,970	21,070	21,170	21,260	21,360	21,460	21,560	21,660	7.2
7.4	20,240	20,350	20,460	20,570	20,680	20,780	20,890	21,000	21,100	21,210	21,310	21,420	21,520	21,620	21,730	21,830	21,930	22,030	22,130	22,230	22,330	7.4
7.6	20,840	20,960	21,070	21,180	21,290	21,400	21,510	21,620	21,730	21,840	21,950	22,050	22,160	22,270	22,370	22,480	22,580	22,690	22,790	22,900	23,000	7.6
7.8	21,440	21,550	21,670	21,780	21,900	22,010	22,120	22,240	22,350	22,460	22,570	22,680	22,790	22,900	23,010	23,120	23,220	23,330	23,440	23,550	23,650	7.8
8.0	22,010	22,130	22,250	22,370	22,490	22,600	22,720	22,840	22,950	23,070	23,180	23,290	23,410	23,520	23,630	23,740	23,850	23,960	24,070	24,180	24,290	8.0
8.2	22,580	22,700	22,820	22,940	23,060	23,180	23,300	23,420	23,540	23,650	23,770	23,890	24,000	24,120	24,230	24,350	24,460	24,570	24,690	24,800	24,910	8.2
8.4	23,120	23,250	23,370	23,490	23,620	23,740	23,860	23,980	24,110	24,230	24,350	24,460	24,580	24,700	24,820	24,930	25,050	25,170	25,280	25,400	25,510	8.4
8.6	23,640	23,770	23,900	24,030	24,150	24,280	24,400	24,530	24,650	24,770	24,900	25,020	25,140	25,260	25,380	25,500	25,620	25,740	25,850	25,970	26,090	8.6
8.8	24,140	24,280	24,410	24,540	24,660	24,790	24,920	25,050	25,170	25,300	25,420	25,550	25,670	25,790	25,920	26,040	26,160	26,280	26,400	26,520	26,640	8.8
9.0	24,620	24,750	24,880	25,010	25,150	25,280	25,410	25,540	25,660	25,790	25,920	26,050	26,170	26,300	26,420	26,550	26,670	26,790	26,920	27,040	27,160	9.0
9.2	25,060	25,190	25,330	25,460	25,590	25,730	25,860	25,990	26,120	26,250	26,380	26,510	26,640	26,770	26,890	27,020	27,150	27,270	27,400	27,520	27,650	9.2
9.4	25,460	25,590	25,730	25,870	26,000	26,140	26,270	26,410	26,540	26,670	26,800	26,940	27,070	27,200	27,320	27,450	27,580	27,710	27,840	27,960	28,090	9.4
9.6	25,810	25,950	26,090	26,230	26,370	26,500	26,640	26,780	26,910	27,040	27,180	27,310	27,440	27,580	27,710	27,840	27,970	28,100	28,220	28,350	28,480	9.6
9.8	26,110	26,250	26,400	26,540	26,670	26,810	26,950	27,090	27,220	27,360	27,500	27,630	27,760	27,900	28,030	28,160	28,290	28,420	28,550	28,680	28,810	9.8
10.0	26,350	26,490	26,640	26,780	26,920	27,060	27,200	27,330	27,470	27,610	27,750	27,880	28,020	28,150	28,280	28,420	28,550	28,680	28,810	28,940	29,070	10.0

DOUGLAS DAM

DISCHARGE FOR ALL SLUICES AT IDENTICAL OPENINGS

IN CUBIC FEET PER SECOND

GATE OPENING IN FEET	HEADWATER ELEVATION																					GATE OPENING IN FEET
	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	
0.2	620	620	630	630	630	630	640	640	640	640	650	650	650	650	660	660	660	660				0.2
0.4	1,230	1,230	1,240	1,240	1,250	1,250	1,260	1,260	1,270	1,280	1,280	1,290	1,290	1,300	1,300	1,310	1,310	1,320				0.4
0.6	1,820	1,830	1,840	1,840	1,850	1,860	1,870	1,880	1,880	1,890	1,900	1,910	1,910	1,920	1,930	1,940	1,950	1,950				0.6
0.8	2,400	2,410	2,420	2,430	2,440	2,450	2,460	2,470	2,480	2,490	2,500	2,510	2,520	2,530	2,540	2,550	2,560	2,570				0.8
1.0	2,950	2,970	2,980	2,990	3,010	3,020	3,030	3,050	3,060	3,070	3,080	3,100	3,110	3,120	3,130	3,150	3,160	3,170				1.0
1.2	3,500	3,510	3,530	3,540	3,560	3,580	3,590	3,610	3,620	3,640	3,650	3,670	3,680	3,700	3,710	3,720	3,740	3,750				1.2
1.4	4,030	4,040	4,060	4,080	4,100	4,120	4,130	4,150	4,170	4,190	4,200	4,220	4,240	4,250	4,270	4,290	4,300	4,320				1.4
1.6	4,540	4,560	4,580	4,600	4,620	4,640	4,660	4,680	4,700	4,720	4,740	4,760	4,780	4,800	4,820	4,840	4,860	4,880				1.6
1.8	5,050	5,070	5,100	5,120	5,140	5,160	5,190	5,210	5,230	5,250	5,270	5,290	5,320	5,340	5,360	5,380	5,400	5,420				1.8
2.0	5,550	5,580	5,600	5,630	5,650	5,680	5,700	5,730	5,750	5,770	5,800	5,820	5,840	5,870	5,890	5,920	5,940	5,960				2.0
2.2	6,050	6,080	6,110	6,140	6,160	6,190	6,210	6,240	6,270	6,290	6,320	6,340	6,370	6,400	6,420	6,450	6,470	6,500				2.2
2.4	6,550	6,580	6,610	6,640	6,670	6,700	6,730	6,760	6,780	6,810	6,840	6,870	6,900	6,920	6,950	6,980	7,010	7,030				2.4
2.6	7,060	7,090	7,120	7,150	7,180	7,210	7,240	7,280	7,310	7,340	7,370	7,400	7,430	7,460	7,490	7,520	7,550	7,570				2.6
2.8	7,570	7,600	7,640	7,670	7,700	7,740	7,770	7,800	7,830	7,870	7,900	7,930	7,960	8,000	8,030	8,060	8,090	8,120				2.8
3.0	8,090	8,120	8,160	8,190	8,230	8,260	8,300	8,340	8,370	8,410	8,440	8,470	8,510	8,540	8,580	8,610	8,640	8,680				3.0
3.2	8,620	8,650	8,690	8,730	8,770	8,810	8,840	8,880	8,920	8,960	8,990	9,030	9,070	9,100	9,140	9,170	9,210	9,250				3.2
3.4	9,160	9,200	9,240	9,280	9,320	9,360	9,400	9,440	9,480	9,520	9,560	9,600	9,640	9,670	9,710	9,750	9,790	9,830				3.4
3.6	9,710	9,760	9,800	9,840	9,890	9,930	9,970	10,010	10,050	10,100	10,140	10,180	10,220	10,260	10,300	10,340	10,380	10,420				3.6
3.8	10,280	10,330	10,380	10,420	10,470	10,510	10,560	10,600	10,650	10,690	10,730	10,780	10,820	10,870	10,910	10,950	10,990	11,040				3.8
4.0	10,870	10,920	10,970	11,020	11,060	11,110	11,160	11,210	11,250	11,300	11,350	11,390	11,440	11,480	11,530	11,580	11,620	11,670				4.0
4.2	11,470	11,520	11,580	11,630	11,680	11,730	11,780	11,830	11,880	11,930	11,970	12,020	12,070	12,120	12,170	12,220	12,270	12,310				4.2
4.4	12,090	12,150	12,200	12,250	12,310	12,360	12,410	12,460	12,520	12,570	12,620	12,670	12,720	12,770	12,820	12,880	12,930	12,980				4.4
4.6	12,720	12,780	12,840	12,890	12,950	13,000	13,060	13,120	13,170	13,230	13,280	13,330	13,390	13,440	13,500	13,550	13,600	13,660				4.6
4.8	13,370	13,430	13,490	13,550	13,610	13,670	13,720	13,780	13,840	13,900	13,950	14,010	14,070	14,130	14,180	14,240	14,290	14,350				4.8
5.0	14,030	14,090	14,160	14,220	14,280	14,340	14,400	14,460	14,520	14,580	14,640	14,700	14,760	14,820	14,880	14,940	15,000	15,060				5.0
5.2	14,700	14,770	14,830	14,900	14,960	15,030	15,090	15,150	15,220	15,280	15,340	15,410	15,470	15,530	15,590	15,660	15,720	15,780				5.2
5.4	15,380	15,450	15,520	15,590	15,660	15,720	15,790	15,860	15,920	15,990	16,060	16,120	16,190	16,250	16,320	16,380	16,450	16,510				5.4
5.6	16,070	16,140	16,220	16,290	16,360	16,430	16,500	16,570	16,640	16,710	16,770	16,840	16,910	16,980	17,050	17,120	17,180	17,250				5.6
5.8	16,770	16,840	16,920	16,990	17,070	17,140	17,210	17,280	17,360	17,430	17,500	17,570	17,640	17,720	17,790	17,860	17,930	18,000				5.8
6.0	17,470	17,550	17,620	17,700	17,780	17,850	17,930	18,010	18,080	18,160	18,230	18,310	18,380	18,460	18,530	18,600	18,680	18,750				6.0
6.2	18,170	18,250	18,330	18,410	18,490	18,570	18,650	18,730	18,810	18,890	18,970	19,040	19,120	19,200	19,270	19,350	19,430	19,500				6.2
6.4	18,880	18,960	19,040	19,130	19,210	19,290	19,370	19,460	19,540	19,620	19,700	19,780	19,860	19,940	20,020	20,100	20,180	20,260				6.4
6.6	19,580	19,660	19,750	19,840	19,920	20,010	20,090	20,180	20,260	20,350	20,430	20,520	20,600	20,680	20,760	20,850	20,930	21,010				6.6
6.8	20,280	20,370	20,460	20,550	20,630	20,720	20,810	20,900	20,990	21,070	21,160	21,250	21,330	21,420	21,510	21,590	21,680	21,760				6.8
7.0	20,970	21,060	21,160	21,250	21,340	21,430	21,520	21,610	21,700	21,800	21,890	21,970	22,060	22,150	22,240	22,330	22,420	22,500				7.0
7.2	21,660	21,750	21,850	21,940	22,040	22,130	22,230	22,320	22,420	22,510	22,600	22,690	22,790	22,880	22,970	23,060	23,150	23,240				7.2
7.4	22,330	22,430	22,530	22,630	22,730	22,820	22,920	23,020	23,120	23,210	23,310	23,400	23,500	23,590	23,690	23,780	23,870	23,970				7.4
7.6	23,000	23,100	23,200	23,300	23,410	23,510	23,610	23,710	23,810	23,900	24,000	24,100	24,200	24,300	24,390	24,490	24,590	24,680				7.6
7.8	23,650	23,760	23,860	23,970	24,070	24,170	24,280	24,380	24,480	24,580	24,680	24,790	24,890	24,990	25,090	25,190	25,280	25,380				7.8
8.0	24,290	24,400	24,500	24,610	24,720	24,830	24,930	25,040	25,140	25,250	25,350	25,450	25,560	25,660	25,760	25,860	25,970	26,070				8.0
8.2	24,910	25,020	25,130	25,240	25,350	25,460	25,570	25,680	25,780	25,890	26,000	26,100	26,210	26,320	26,420	26,530	26,630	26,730				8.2
8.4	25,510	25,620	25,740	25,850	25,960	26,070	26,190	26,300	26,410	26,520	26,630	26,730	26,840	26,950	27,060	27,170	27,270	27,380				8.4
8.6	26,090	26,200	26,320	26,440	26,550	26,660	26,780	26,890	27,000	27,120	27,230	27,340	27,450	27,560	27,670	27,780	27,890	28,000				8.6
8.8	26,640	26,760	26,880	26,990	27,110	27,230	27,340	27,460	27,580	27,690	27,800	27,920	28,030	28,140	28,260	28,370	28,480	28,590				8.8
9.0	27,160	27,280	27,400	27,520	27,640	27,760	27,880	28,000	28,110	28,230	28,350	28,460	28,580	28,690	28,810	28,920	29,040	29,150				9.0
9.2	27,650	27,770	27,890	28,010	28,130	28,260	28,380	28,500	28,620	28,730	28,850	28,970	29,090	29,210	29,320	29,440	29,550	29,670				9.2
9.4	28,090	28,210	28,340	28,460	28,580	28,710	28,830	28,950	29,070	29,190	29,310	29,430	29,550	29,670	29,790	29,910	30,030	30,140				9.4
9.6	28,480	28,610	28,730	28,860	28,980	29,110	29,230	29,360	29,480	29,600	29,720	29,850	29,970	30,090	30,210	30,330	30,450	30,560				9.6
9.8	28,810	28,940	29,070	29,200	29,320	29,450	29,570	29,700	29,820	29,950	30,070	30,190	30,320	30,440	30,560	30,680	30,800	30,920				9.8
10.0	29,070	29,200	29,330	29,460	29,590	29,720	29,840	29,970	30,090	30,220	30,340	30,470	30,590	30,710	30,840	30,960	31,080	31,200				10.0

HEADWATER 990 to 1010

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DISCHARGE COEFFICIENTS FOR SPILLWAYS AT TVA DAMS

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SYNOPSIS

Spillway ratings derived from model studies have been used in the preparation of spillway rating tables for the Tennessee Valley Authority dams. As a result of these studies, discharge coefficients for eleven of the Tennessee Valley Authority dams are given in this paper. Coefficients for both submerged and free discharge conditions are presented for discharges over standard spillway crests, irregular spillway crests, and a vertical-lift spillway gate. Discharge coefficients for Tainter gates placed on curved spillway crests are also given for various gate openings under free discharge conditions. In addition, data on the effect of model scale on the discharge coefficient and the effect of closing adjacent spillway bays and gates are presented. The coefficient relationships are shown in a form that may be used by designers as a guide in making determinations of the discharges for future spillways.

NOTATION

The letter symbols adopted for use in this paper are defined where they first appear, in the illustrations or in the text, and are arranged alphabetically, for convenience of reference, in the Appendix.

INTRODUCTION

The Tennessee Valley Authority (TVA) operates a system of nine dams on the Tennessee River and twenty-three on the tributary rivers. The successful operation of such a system requires accurate discharge ratings for each structure. Although enough water is seldom available to make complete ratings for most spillways from measurements conducted on the prototype structure, ratings can be determined from scale model tests. Therefore, the necessary ratings for the TVA spillways have been determined by this means. Model studies have been made at the TVA Hydraulic Laboratory at Norris, Tenn.,

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on nine different spillway crest shapes equipped with three types of control gates.

Seven of the nine crests were curved sections which approximated the shape of the lower nappe of a sharp-crested weir. The other two crests were flat. The two flat-crested weirs and one of the curved crests were equipped with double-leaf vertical lift gates. Five of the curved crests were equipped with Tainter gates and the other with vertical lift gates.

Data Presented.—Data are presented for the following conditions: (1) Free, ungated flow through a series of spillway bays; (2) submerged, ungated flow through a series of spillway bays; (3) free, ungated flow through a series of spillway bays, with adjacent bays fully open or closed; (4) free flow over a vertical lift gate; (5) submerged flow over a vertical lift gate; (6) flow under a series of Tainter gates set with equal openings; and (7) flow under a series of Tainter gates with adjacent gates closed.

Data are also presented to show the effect of model scale for the condition of free, ungated flow through a series of spillway bays.

General Model Arrangement.—The models were tested in flumes either 3.5 ft wide or 8 ft wide. Models installed in the smaller flume usually consisted of a reproduction of three of the prototype spillway bays. In the larger flume five or six spillway bays were reproduced. Each of these flumes was provided with glass panels for observation purposes. The models placed in the larger flume were constructed at scale ratios of from 1:28.72 to 1:50 with a ratio of approximately 1:35 generally used. Those tested in the smaller flume were built at scale ratios of 1:50, 1:100, and 1:200.

The models were usually provided with concrete crests and concrete piers to insure dimensional stability. Half piers were constructed on the ends of each model. If the model did not completely fill the flume one side was placed against the glass side of the flume and the other against a false wall. The river bed upstream and downstream from the model was reproduced at the elevation of the prototype river bed. Suitable baffling was provided to obtain a uniform distribution of flow in the spillway approach channel. The tailwater level was controlled at the end of the flumes by means of slat gates. Model discharges were determined from readings of a carefully calibrated diaphragm orifice located in the water supply line.

Headwater heights were measured at two piezometers at distances equal to approximately 5 and 8 times the design head upstream from the spillway crest. Tailwater heights were obtained at 2 piezometers at distances equal to approximately 9 and 12 times the design head downstream from the spillway crest—in all cases, sufficiently far enough downstream to eliminate the effect of the spillway apron.

In most studies the headwater and tailwater levels were determined by means of hook gages reading to 0.001 ft. For the 1/200-scale model the heads were measured with a micrometer point gage reading to 0.0001 ft.

Discharge Equations.—The model data have been reduced by the use of two commonly accepted discharge equations. For both free and submerged flow over a spillway crest the equation,

$$Q = C\,L\,H^{3/2} \qquad (1)$$

was used, in which Q is the discharge in cubic feet per second, C is the coefficient of discharge determined from the model tests, L is the length of the crest, and H is the total head as shown in Fig. 1(*a*). Use was made of the same equation in the reduction of the data for free and submerged flows over a vertical gate with D, H, d, and P (Fig. 1(*a*)) being measured from the top of the gate.

For flow under a gate the equation for a rectangular orifice under low head,

$$Q = C\,L\,[H^{3/2} - (D_1 + h)^{3/2}] \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

was used, in which D_1 is the depth of water to the bottom of the gate as defined in Fig. 1(*b*) and h is the approach velocity head.

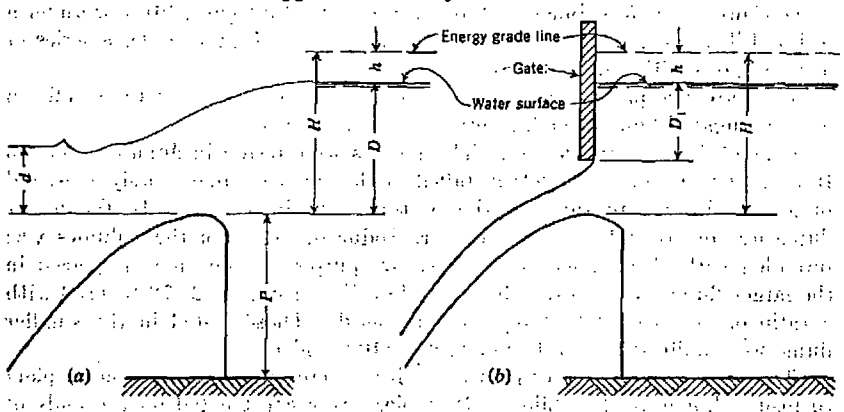


FIG. 1.—SPILLWAY-CREST DIAGRAM

FREE-DISCHARGE COEFFICIENTS, FLOW OVER SPILLWAY CRESTS

It is common practice for engineers to design spillway crests to approximate closely the shape of the lower portion of a jet issuing from a sharp-crested weir, and this type of crest is designated a standard crest.[2] Because the shape of the jet changes with the head on the weir, some particular head must be used for each design. This head for which a particular crest is designed is termed the design head. At this head, pressures approximating atmospheric pressure are developed at the spillway surface. At smaller heads, pressures are greater than atmospheric. Seven of the nine TVA crests for which data are available approximate standard crests in shape whereas the other two crests, which are flat, do not. Fig. 2 shows the basic details and dimensions of each of these crests. Fig. 3 presents the coefficient data obtained on the crests of Fig. 2. Pertinent design data concerning each crest, together with the scale to which each was modeled, appear in Table 1. Eleven spillways are also listed in Table 1. Two pairs of these, the Ocoee No. 3-Apalachia set, and the Douglas-Watts Bar set, both in Tennessee, have crest shapes that are identical within the pair but which were tested for different values of the approach depth, P.

[2] "Hydroelectric Handbook," by W. P. Creager and J. D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950.

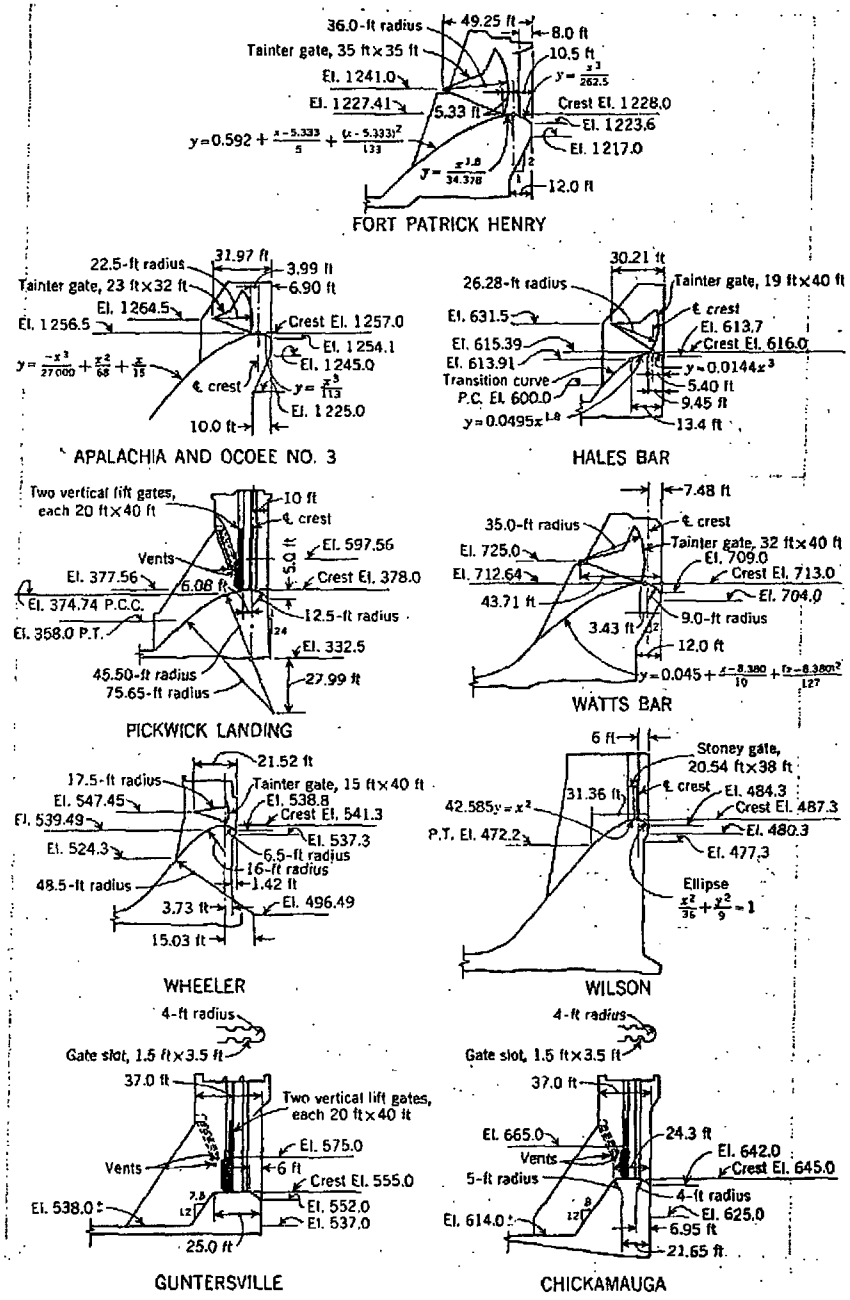


FIG. 2.—TVA SPILLWAY CRESTS (DATA IN FIG. 3)

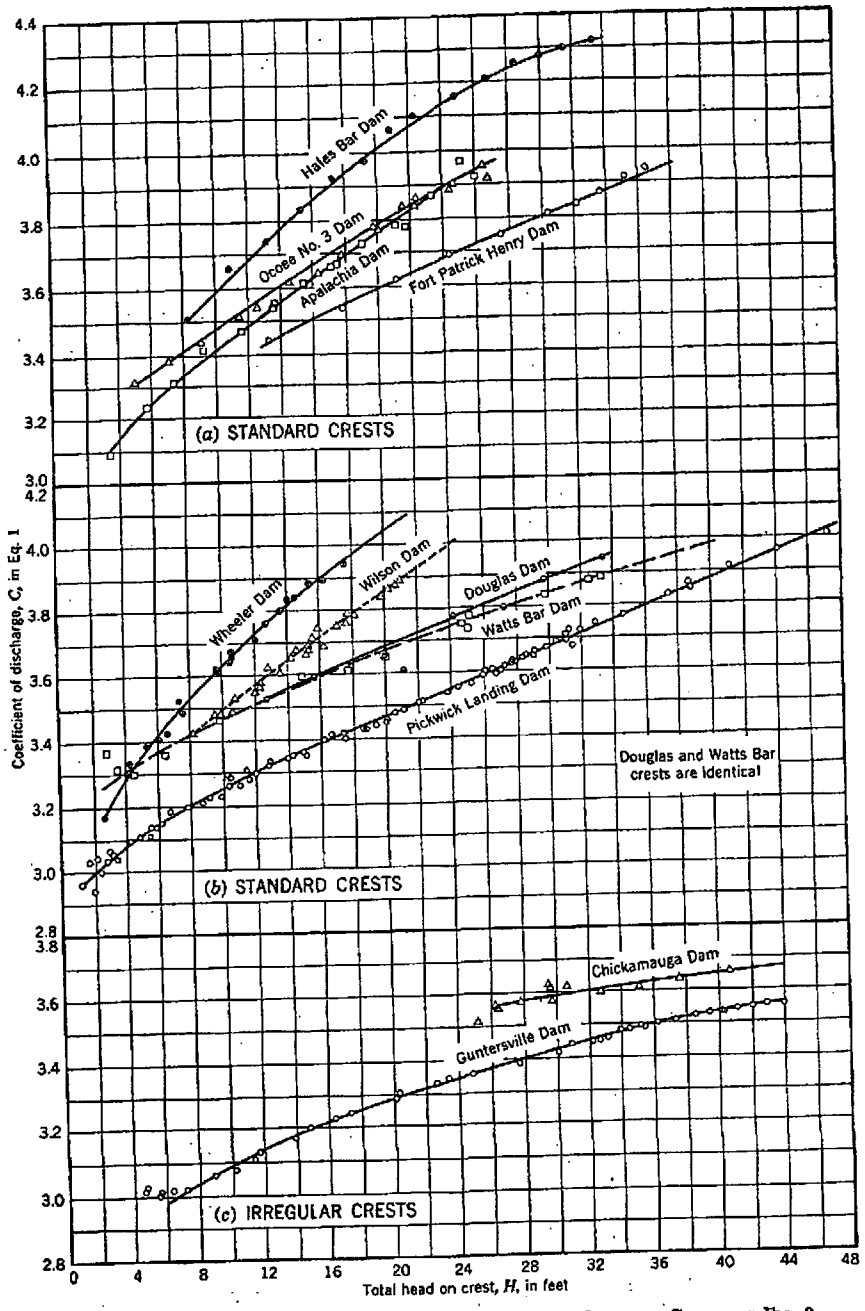


FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

The accuracy of the data is evidenced by the plotting of the data points in Fig. 3. Except in some cases at low heads, the deviation of any plotted point from the coefficient curve does not exceed 0.5%.

Standard Crests.—It has been shown by various authors that the discharge coefficients for all standard crests can be related to each other and that, conversely, the coefficients to be used for a new design can be taken from previous test data.[2,3,4,5] Unfortunately, in most crest designs, due to other design considerations, it is necessary that the shape be varied from the standard form. Nevertheless, satisfactory coefficients can be obtained as sufficient data are now available on a range of crest shapes. By comparison of crest shapes designers may select a coefficient for any particular crest.

Dimensionless plotting provides a means for comparison of crest shapes. This method is used in Fig. 4 on which seven TVA crests which closely approximate standard crests are shown by the solid lines, with the dashed line representing a standard crest shape.[2] The horizontal coordinate, x, and the vertical coordinate, y, of the crest curve have been divided by the design head, H_e.

TABLE 1.—DESIGN DATA FOR ELEVEN MODELS OF TVA SPILLWAYS

Project	Model scale	Design head, H_e, in feet	Upstream depth, P, in feet	$\frac{H_e}{P}$	Pier nose radius, in feet
Hales Bar	1:34.76	18	32	0.56	3.00
Ocoee No. 3	1:28.72	23	67	0.35	3.00
Apalachia	1:28.72	23	97	0.24	3.00
Fort Patrick Henry	1:50	35	43	0.81	3.25
Wheeler	1:34.35	16.5	43	0.38	2.50
Wilson	1:39.4	19	75	0.25	4.00
Douglas	1:35	23.5	133	0.18	3.25
Watts Bar	1:35	23.5	52	0.45	3.25
Pickwick Landing	1:50	31.5	32	0.98	3.75
Chickamauga	1:50		20		4.00
Guntersville	1:50		18		4.00

The design head was determined by fitting the real and standard curves at the crest point ($x = 0$) and at the intersection of the curve with the upstream vertical face. These design-head values are presented in Table 1. The design-head discharge coefficients (C_o) determined from Fig. 3 are shown in Fig. 4.

The TVA crests all fairly closely approximate the standard curve from the upstream spillway face to a point somewhere downstream from the crest which was determined by the position of the gate seal. Below this latter point, the crest shape was modified to fit the trajectory of a jet issuing from under the gate when set at a small opening. The upstream face for a standard crest is vertical. The upstream face of the TVA crests, as shown in Fig. 4, deviates from the vertical. Other experimenters have established the fact that the shape of the upstream face generally has little influence on the discharge coefficient.[3]

[2] "Final Reports of Boulder Canyon Project," *Bulletin No. 3*, Part VI, Hydraulic Investigations, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1947.

[4] "Engineering Hydraulics," edited by Hunter Rouse, John Wiley & Sons, Inc., New York, N. Y., 1950.

[5] "Discharge Coefficients for Irregular Overfall Spillways," by J. N. Bradley, *Engineering Monograph No. 9*, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1952.

Fig. 4 indicates that the shape of the curve from the crest to a point somewhere in the neighborhood of $x/H_o = 0.5$ materially affects the coefficient. As the curve is raised above the standard curve, the coefficient is decreased. This can be seen by comparing the (y/H_o)-values at $x/H_o = 0.5$ with C_o. The comparative crests in Fig. 4 have been placed in the order of decreasing (Y/H_o)-values. No reasonable correlation of C_o with either upstream shape of H_o/P can be determined.

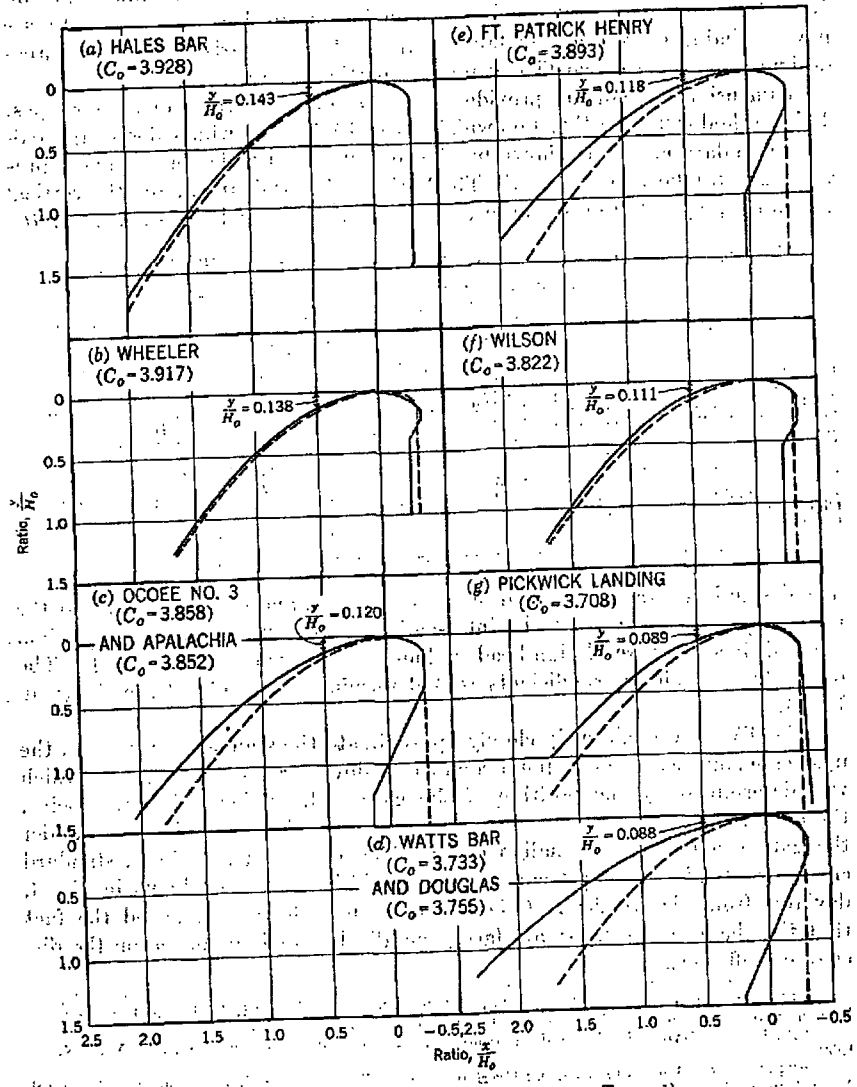


Fig. 4.—Comparative Crests (H_o/P Shown in Table 1)

The relationships between the discharge coefficient and the ratio of any head to the design head, H/H_o, are shown in Fig. 5. In Fig. 5(*a*) the value of C is plotted against H/H_o for the four crests—Apalachia, Ocoee No. 3, Hales Bar (Tennessee), and Fort Patrick Henry (Tennesse)—that most closely follow the standard crest shape. The maximum variation of the individual points from

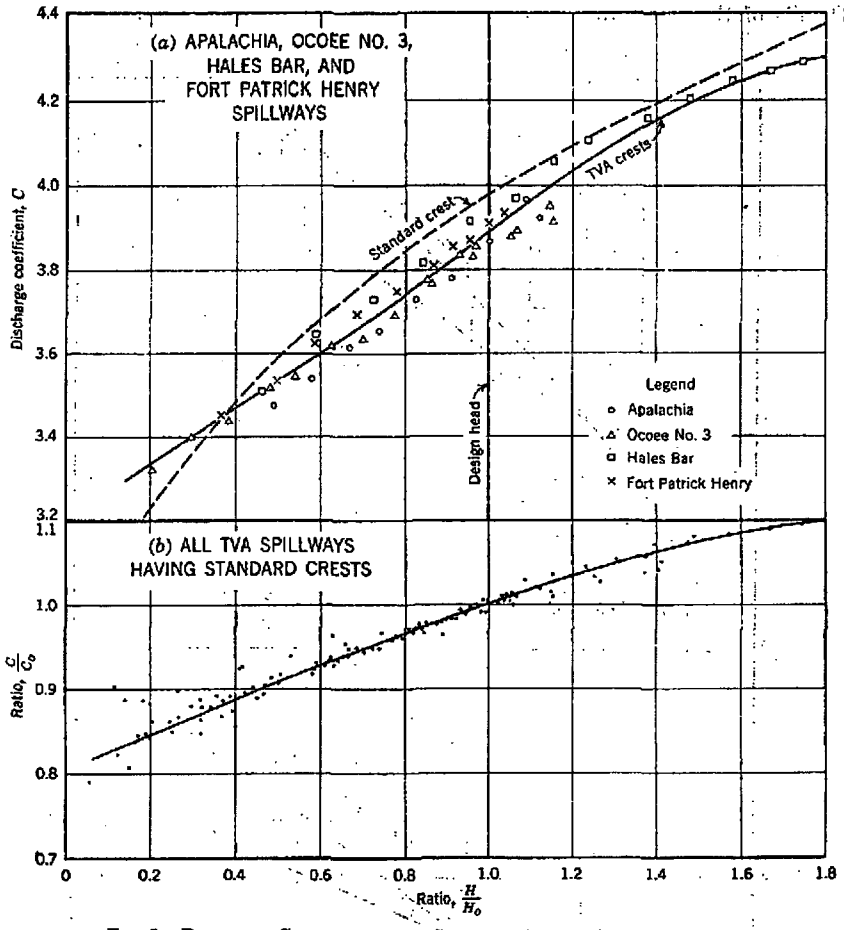


Fig. 5.—Discharge Coefficients for Spillways Having Standard Crests

the average curve for TVA crests is 0.5%. The standard-crest curve shown by the dashed line in Fig. 5 is that of W. P. Creager and J. D. Justin.[2] This curve is approximately 2% higher than the TVA curve. Fig. 5(*b*) is a dimensionless plot of the data from Figs. 3(*a*) and 3(*b*). The deviation of the points from the average curve is greater than in Fig. 5(*a*) because all crests are included, but for design purposes the curve should be useful. Actually, the

curve is more firmly established than it may appear because the curve itself obliterates several test points.

Irregular Spillway Crests.—The designation "irregular spillway crests" is used to distinguish between standard spillway crests and other crest forms. Only two of the TVA spillways, those at Chickamauga, Tenn., and Guntersville, Ala., have irregular spillway crests. Both are trapezoidal in cross section. Details of these spillway crests and the discharge coefficients computed using

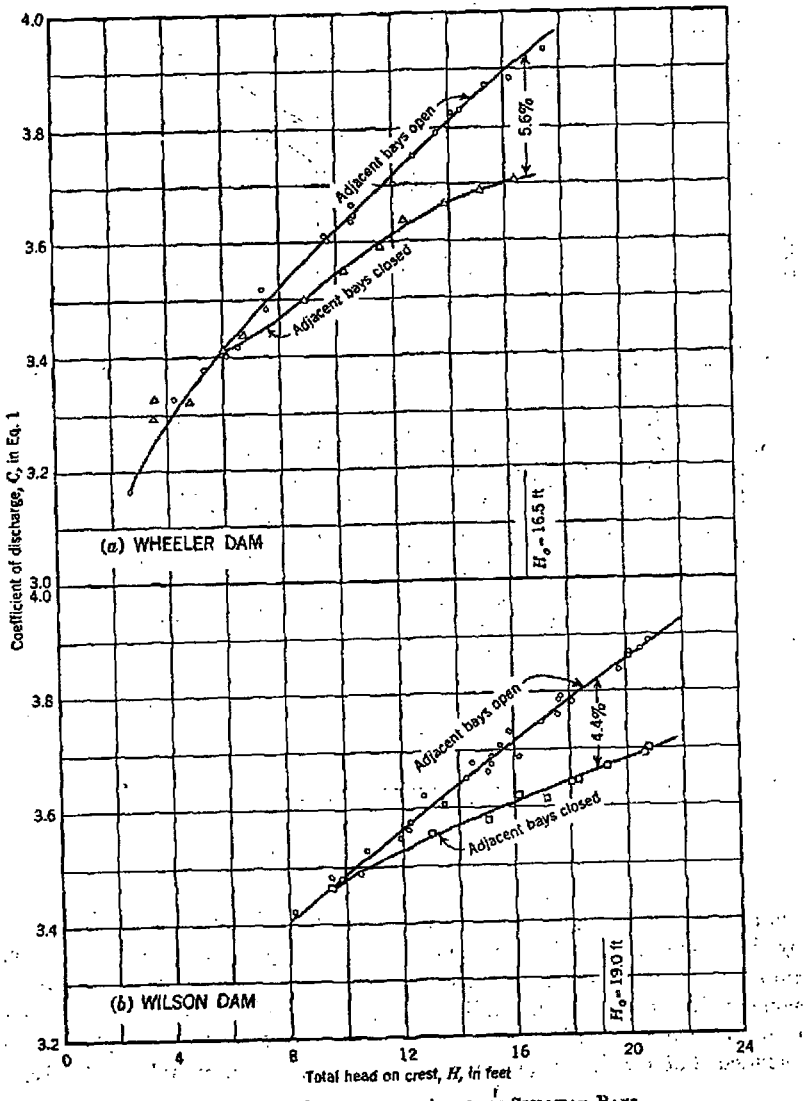


FIG. 6.—EFFECT OF OPERATION OF ADJACENT SPILLWAY BAYS

Eq. 1 from the model-study data are shown in Fig. 3(*c*). The two crests differ chiefly in the shape of the upstream and downstream edges of the crest and the height above the apron. Over the range of the tests of the Chickamauga spillway the coefficients are consistently from 3% to 5% greater than those for the Guntersville spillway. The additional height of the crest above the apron and the rounding of the near upstream edge of the Chickamauga crest would operate to increase the discharge coefficients.

The Effect of Operating Adjacent Spillway Bays.—In the TVA water-control operations, it is necessary to operate single spillway bays and groups of consecutive spillway bays. Because a greater contraction forms at a pier situated next to a closed bay, models of the Wilson and Wheeler spillways in Tennessee were tested with adjacent spillway bays open and closed to determine the difference in contraction effects at the piers.

Fig. 6 shows the head-coefficient relationships for the two conditions tested. The discharge coefficient at the design head was 5.6% higher at Wheeler Dam with adjacent bays opened and 4.4% higher at Wilson Dam than with these bays closed. These relationships show the importance of spillway pier contraction effects in spillway discharge determinations.

SUBMERGENCE DISCHARGE COEFFICIENTS FOR FLOW OVER SPILLWAY CRESTS

Chickamauga Dam, Guntersville Dam, Pickwick Landing Dam (Tennessee), and Watts Bar Dam are subject to submergence of the crest at periods of high discharge. To determine the effect of this submergence model tests were conducted by establishing a constant rate of discharge and varying the tailwater elevation to determine the relationship between the headwater and tailwater elevations. This procedure was repeated for several discharge rates covering the operating range at the dam.

Two flow conditions were observed in the model tests which are characterized as "plunging nappe" and "flowing nappe." In the condition of plunging nappe the discharge issuing from the spillway plunges down into the tailwater and appears to follow the boundary surface of the spillway.

In the condition of flowing nappe the flow is nearly horizontal, producing an undulating surface flow in the tailrace channel. The plunging nappe usually occurs with low submergence whereas the flowing nappe occurs with high submergence. When the headwater and tailwater head relationship at a constant rate of discharge was plotted for each series of tests, it was found that the change from plunging nappe to flowing nappe had no apparent effect on the discharge coefficient.

The results from these tests on the four spillways have been plotted in Fig. 7 in the dimensionless form, d/H, against C_s/C, in which d is the depth of submergence and H is the total head above the crest. The coefficient, C_s, was computed from Eq. 1 using the H-value for the submerged conditions; C was determined using the H-value for the free-flow condition.

No systematic variation of C_s/C could be determined for any variable except the (d/H)-ratio for any of the conditions tested. However, no relatively low discharges were tested because in practice the TVA installations can never be submerged at low discharges.

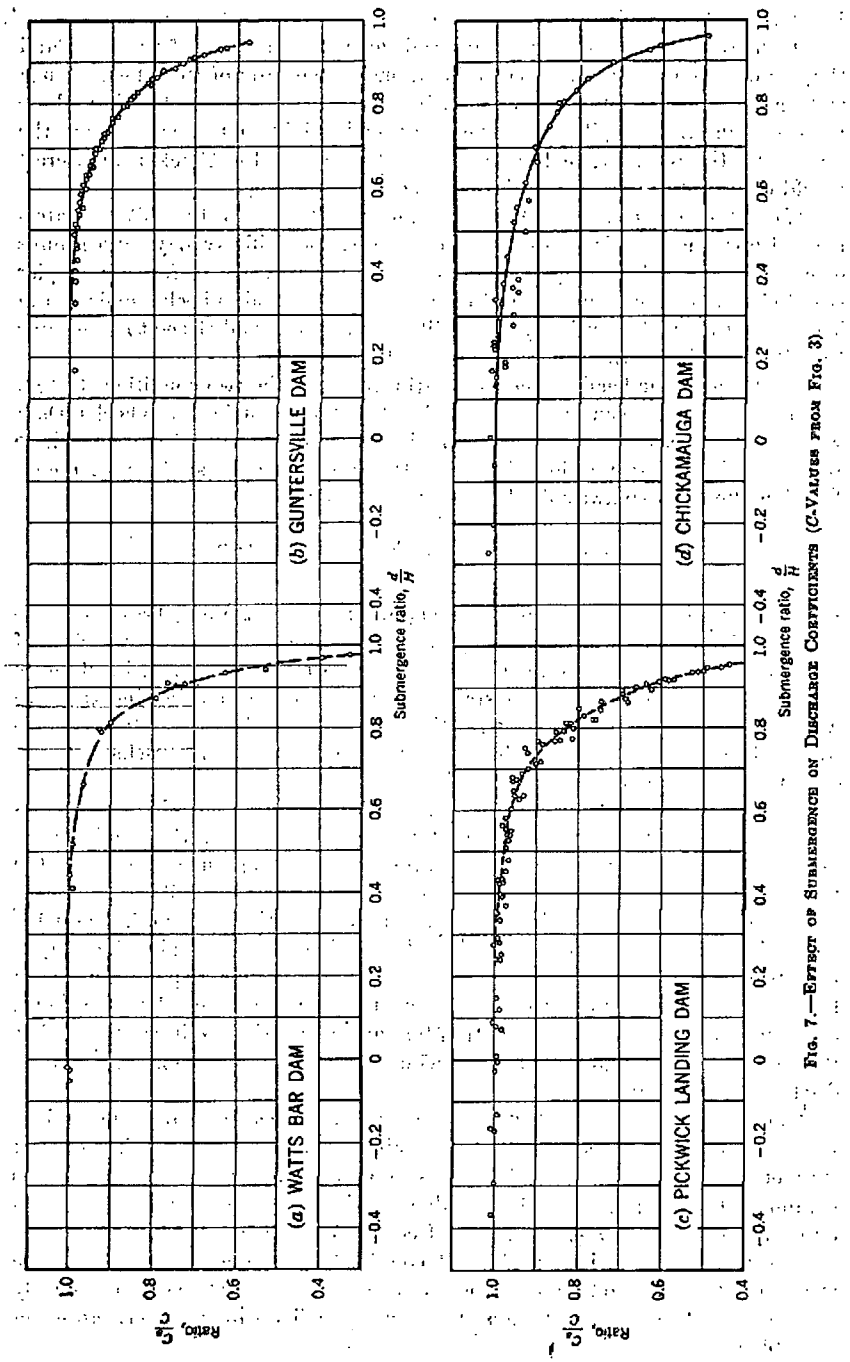


FIG. 7.—EFFECT OF SUBMERGENCE ON DISCHARGE COEFFICIENTS (C-VALUES FROM FIG. 3).

In Fig. 8 the four curves of Fig. 7 are shown on a single plot. Although the maximum spread between curves is about 10%, this is to be expected considering the wide range of crest shapes used in the tests.

FREE-DISCHARGE COEFFICIENTS FOR FLOW OVER VERTICAL LIFT GATES

The Pickwick Landing vertical lift gates are representative of this type of gate, which has been used on several TVA projects. In Fig. 9(*a*) are shown details of the lower spillway gate leaf. For heads greater than 2 ft, this gate is essentially a sharp-crested weir 40 ft long and 20 ft high with piers 7.5 ft thick at each end of the gate. Air intakes were installed in the sides of the piers just below the top of the gate to ventilate the underside of the nappe.[6] Model tests were conducted with the 1/50-scale, 3-bay spillway model.

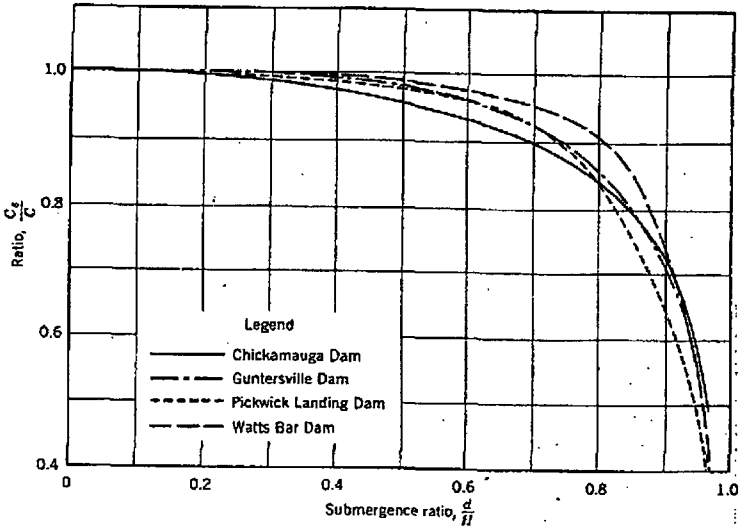


FIG. 8.—COMPARISON OF SUBMERGENCE EFFECTS FOR VARIOUS SPILLWAY CREST SHAPES

In Fig. 9(*b*) is shown the head-coefficient relationship for flow over the crest of the spillway gate. The coefficient, C, was computed from Eq. 1 using the top of the gate as crest elevation. The points define the head-coefficient relationship for heads between 3 ft and 28 ft. Each point was determined from the average of from 3 to 5 separate tests. A constant value of C equal to 3.428 is shown for heads in excess of 12 ft. For heads of from 12 ft to about 4 ft the model test curve shows a gradual rise in the coefficient, with an abrupt drop-off when the heads are approximately 4 ft and less. This curve takes the characteristic form for the coefficients of a sharp-crested weir, the rise and fall in the coefficient curve being due to the nappe clinging to the surface of the weir. This phenomenon is a function of the absolute head. Therefore, similarity between the model and prototype did not exist for prototype heads

[6] "Aeration of Spillways," by G. H. Hickox, *Transactions*, ASCE, Vol. 109, p. 537.

of less than 12 ft. Because the gate has a 10-in.-wide flat top, at low heads the prototype can be expected to exhibit discharge characteristics similar to those of the model. However, for a head in excess of about 2 ft the prototype can be expected to act similarly to a sharp-crested weir and to have a flat coefficient curve.

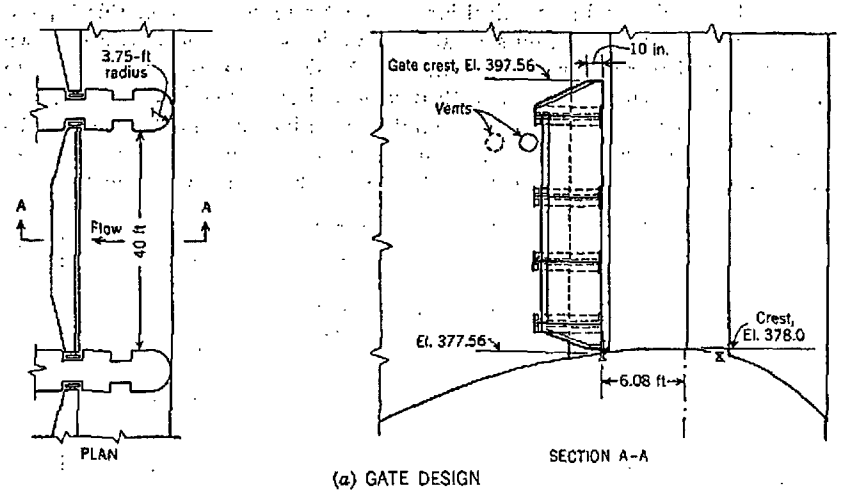


FIG. 9.—VERTICAL LIFT GATE, PICKWICK LANDING DAM

SUBMERGENCE DISCHARGE COEFFICIENTS FOR FLOW OVER A VERTICAL LIFT GATE

To obtain data on the effect of the submergence of flow over vertical-lift gates, model tests were conducted in a manner similar to that used in determining submergence effects on spillway crests. The coefficient, C_s, was computed from Eq. 1 in a manner similar to that used for the spillway crest data but using the top of gate as the crest elevation. Fig. 10 shows a plot of the headwater-tailwater relationships that have been determined. The data presented in Fig. 10 represent the rating of a three-bay, 1/50-scale model of the Pickwick Landing Dam. The total equivalent prototype crest width was

117.8 ft. The discharge was for three spillway bays. These curves illustrate the characteristic flow phenomena associated with this type of gate. Each constant-discharge curve begins with a horizontal line where the head-discharge relationship is not affected by the tailwater level. Just before the tailwater elevation reaches the gate crest level there is a drop in the headwater

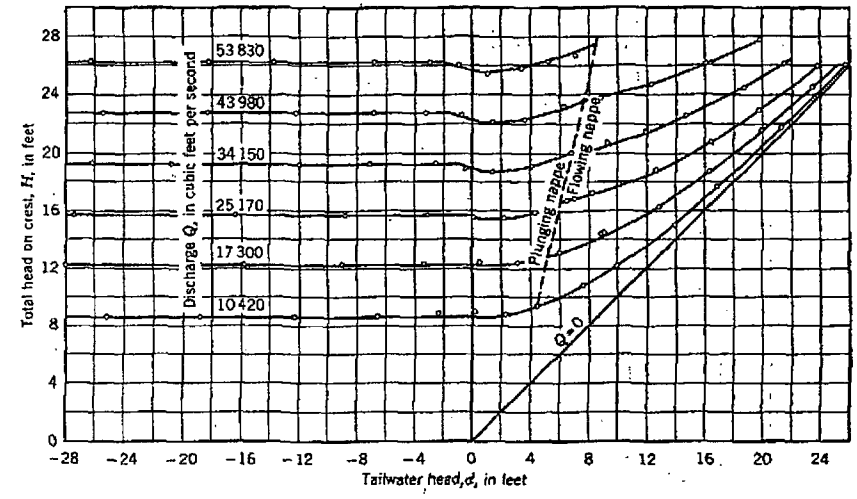


FIG. 10.—HEADWATER-TAILWATER RELATIONS FOR FLOW OVER A VERTICAL LIFT GATE (PROFILE SKETCH IN FIG. 11)

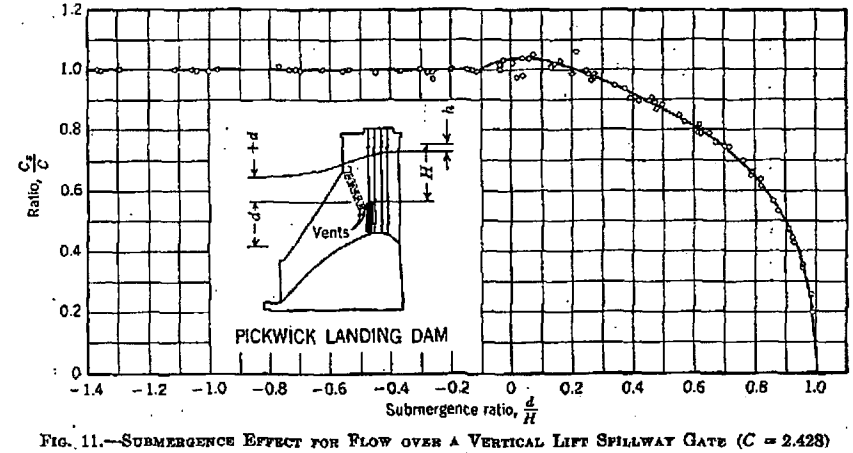


FIG. 11.—SUBMERGENCE EFFECT FOR FLOW OVER A VERTICAL LIFT SPILLWAY GATE ($C = 2.428$)

level for an increase in the tailwater level. Observations of the model operation showed that at this point the air vents, located in the sides of the piers just below the crest of the spillway gate, became submerged by the tailwater, reducing the contraction of the lower nappe issuing from the gate crest. The

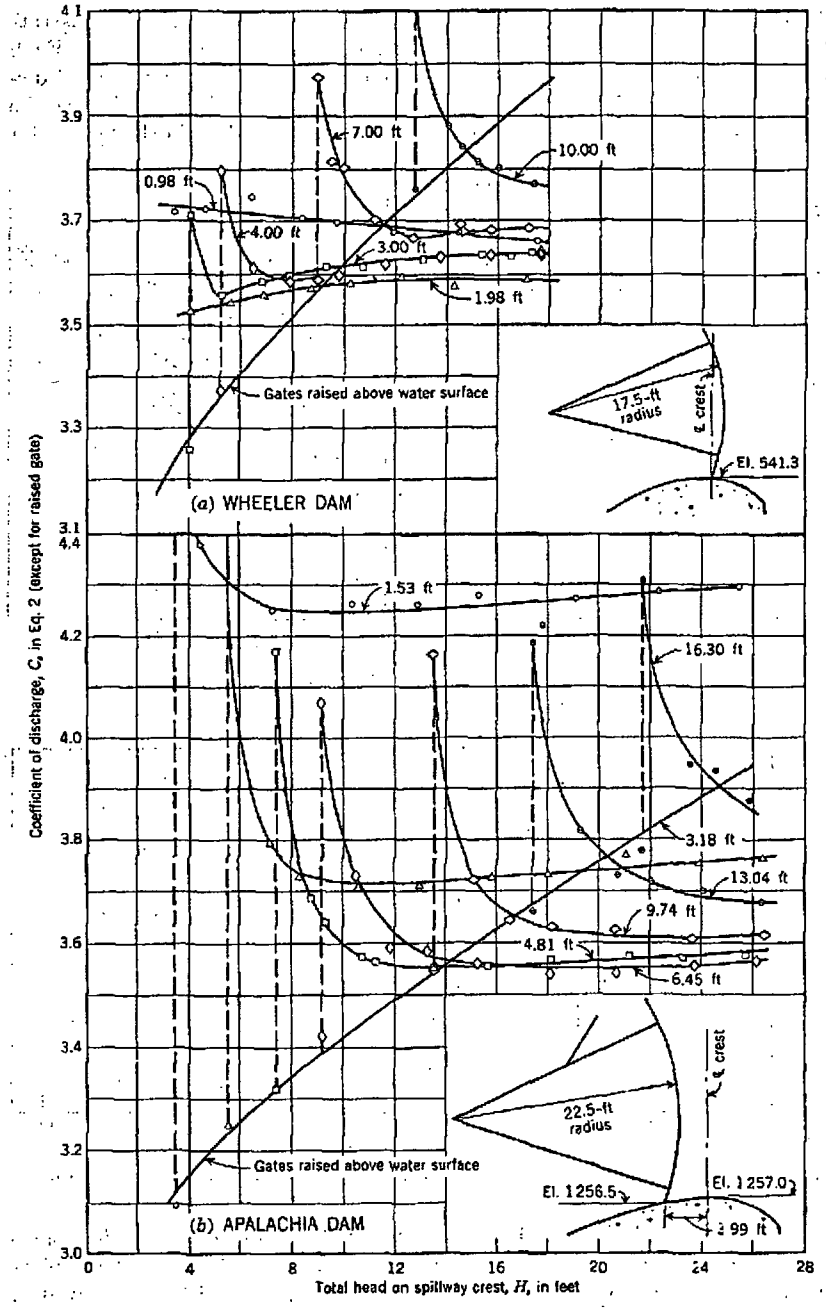


FIG. 12.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS ... (DIMENSIONS ON CURVES ARE GATE OPENINGS)

discharge over the gate was thus increased with a consequent lowering of the headwater level.

The flow conditions of plunging nappe and flowing nappe, previously described, also occurred in this type of flow. In this case the change from one to the other is apparent in the data. The dashed line in Fig. 10 indicates the approximate location of the change. At these points the curves show a definite discontinuity in shape. The data of Fig. 10 can be reduced in coefficient form to the single-curve representation shown in Fig. 11. In this illustration, a constant value of C, equal to 3.428, was used in computing the ratio of C_s/C.

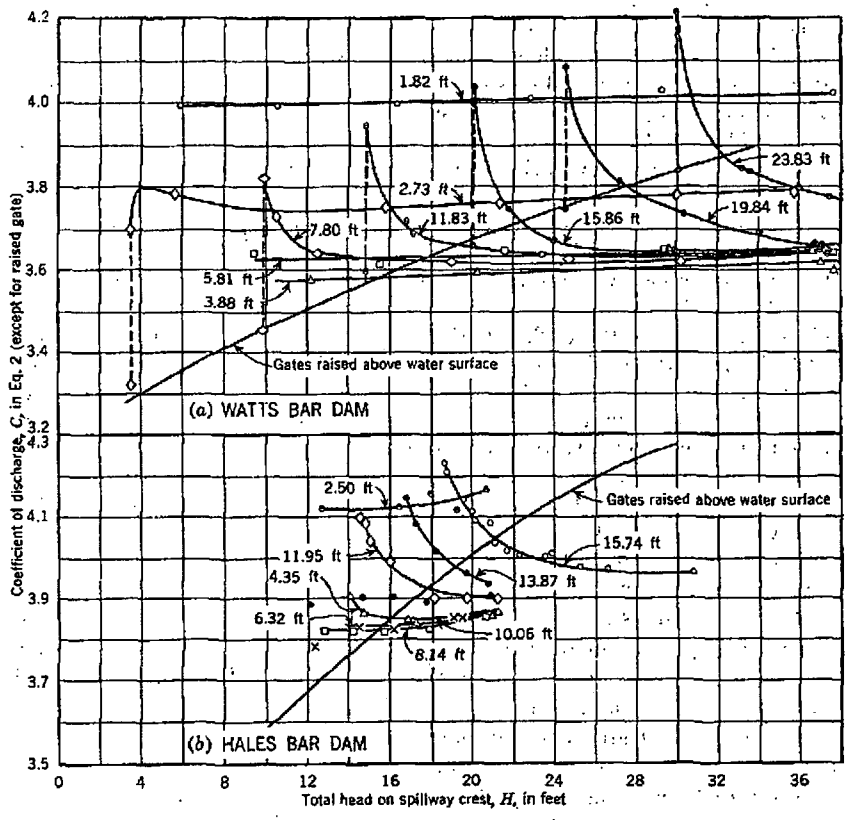


FIG. 13.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

DISCHARGE COEFFICIENTS FOR FLOW UNDER TAINTER GATES

The flow under Tainter gates mounted on curved crests is controlled by the geometry of three interrelated variables—the crest shape, the gate, and the gate setting. The major factors which influence the discharge relation-

ships are the position of the gate seal point with respect to the highest point of the spillway crest and the curvature of the upstream face of the gate. In obtaining the model data on the various TVA Tainter-gate installations no attempt has been made to determine the quantitative effect of these factors taken individually. The data presented in Figs. 12 and 13 for the gate settings at Wheeler Dam, Apalachia Dam, Watts Bar Dam, and Hales Bar Dam are not, therefore, applicable to other installations unless the several variables involved are similar.

Data on Tainter-gate coefficients previously published have, in most cases, been based on flow along a horizontal surface although many of these gates are installed on curved crests. The tests reported herein are for Tainter gates mounted on curved spillway crests where the pressure distribution differs considerably from that in a horizontal channel. The coefficients obtained from tests on a horizontal channel are not applicable to installations on curved crests.

The discharge coefficients for Figs. 12 and 13 were computed using Eq. 2, with the heads measured above the crest elevation. The curves designated "Gates raised above water surface" are the free-discharge curves taken from Figs. 3(*a*) and 3(*b*) for which *C*-values were computed using Eq. 1. The points connected by the dashed lines represent the point at which the water touched the bottom edge of the gate. The difference in the *C*-values is, of course, due to the use of Eq. 2 for the gate curve. The Hales Bar tests were not conducted in a manner that allowed the determination of the point of contact of the gate with the free water surface.

The gate opening was measured as the vertical distance above the crest. This definition leads to the somewhat peculiar variation in the coefficients for small gate openings. In Fig. 12(*a*) the data for Wheeler Dam are presented. The Wheeler gate was positioned, as shown in the insert, with the seal at the high point on the crest. With this design, except at the smallest opening, the coefficient curves for each gate position followed the general pattern of an increase in *C* for an increase in gate opening. In Fig. 12(*b*) the data for Apalachia Dam indicate that, when the gate seal is 3.99 ft downstream and 0.50 ft below the highest point on the crest, the coefficients for gate openings of less than 6.45 ft are increased materially with a decrease in gate opening. This is caused by an arbitrary use in Eq. 2 of an *H*-value as measured above the crest rather than as measured above the elevation of the spillway surface below the gate. Thus, although the *H*-value is consistently too small at the smaller gate openings, the effect becomes more appreciable and results in the increase in *C*.

Tainter-Gate Discharge Coefficients with Adjacent Gates Opened or Closed

The results of tests on the six-spillway-bay model of Wheeler Dam with one gate in operation and with six gates in operation are shown in Fig. 14. In operating with all six gates the contraction effect of the end piers was the same as that for the intermediate piers because the model was constructed with half piers against the sidewalls of the flume. This operation thus represented the case in which all adjacent bays are open.

Effect of Model Scale on Free-Discharge Coefficients

In developing discharge ratings for prototype structures from model data, it is important that the scale at which the model is built be such that the coefficients determined are applicable to the prototype structure. One author has presented data to indicate that with an increase in the model size the discharge coefficients increase.[7] To study this relationship, a series of precise

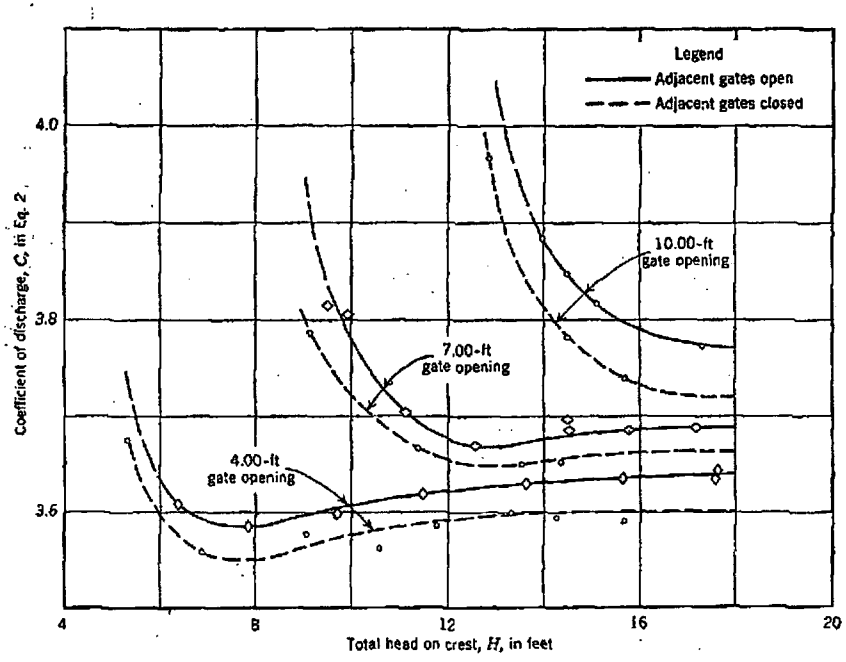


Fig. 14.—Tainter-Gate Discharge Coefficients, *C*, Wheeler Dam

tests was made at the TVA Hydraulic Laboratory under the joint sponsorship of the American Society for Engineering Education, the University of Tennessee (Knoxville) and the TVA.[8] In this study three models of Pickwick Landing spillway were constructed to scales of 1:50, 1:100, and 1:200. Each model consisted of a reproduction of three spillway bays. The shape of the spillway crest and the piers of Pickwick Landing Dam are shown in Figs. 2 and 9(*a*). Similar techniques were used in all tests with one exception. Hook gages reading to 0.0001 ft were used for the 1/200-scale

[7] "Überfallversuche in Berschiedener Modellgrosse," by F. Eisner, The Prussian Experiment Station for Hydraulic Structures and Shipbuilding, Berlin, 1933.

[8] "A Study of the Effect of Model Size on Spillway Coefficients," by C. R. Ownbey, thesis presented in 1949 to the University of Tennessee at Knoxville, in partial fulfilment of the requirements for the degree of Master of Science.

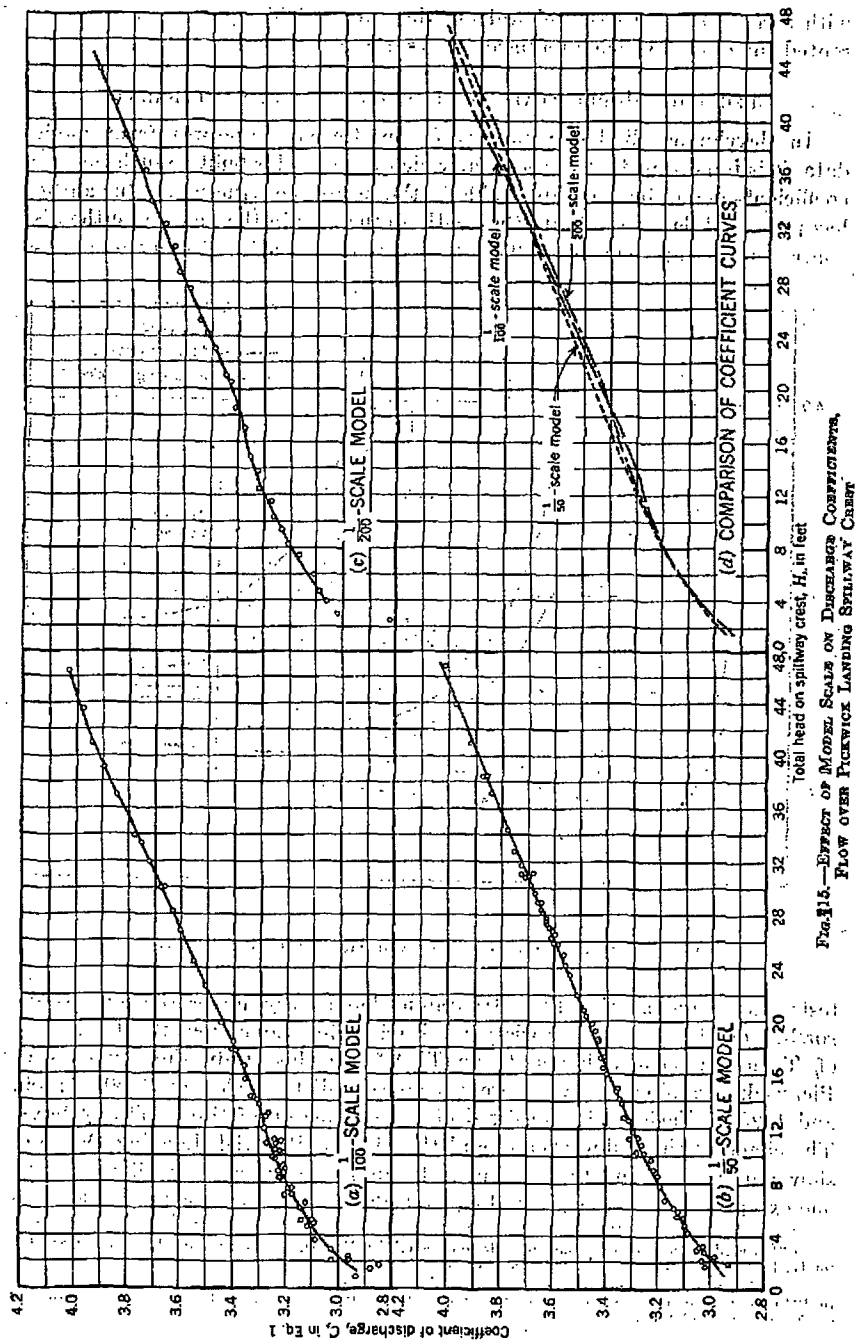


FIG. 15.—EFFECT OF MODEL SCALE ON DISCHARGE COEFFICIENTS, FLOW OVER PUCKWICK LANDING SPILLWAY CREST

tests, and gages reading to 0.001 ft were used in the 1/50-scale tests and 1/100-scale tests.

Discharge coefficients for free flow over the crest of each model are shown in Figs. 15(*a*), 15(*b*), and 15(*c*). The coefficients of discharge were computed using Eq. 1. Each curve was drawn through the average of the plotted points.

A comparison of the three coefficient curves is shown in Fig. 15(*d*). The maximum spread of the curves does not exceed 2%. For prototype heads between 2 ft and 8 ft, the three coefficient curves are almost identical. At 13 ft the coefficient curve for the 1/100-scale model is approximately 1% lower than those for the 1/50-scale model and the 1/200-scale model. At 43 ft the curve for the 1/100-scale model is 1% higher than the data for the 1/50-scale model, and that of the 1/200-scale model is 1% lower than that of the 1/50-scale model. Because there is no consistent relationship between the coefficient curves, it is logical to conclude that these variations are merely the result of experimental error and that the model scale did not affect the stage-coefficient relationship. The close agreement of the coefficient curves at the three scales supports the validity of the preparation of prototype ratings based on model tests.

ACKNOWLEDGMENTS

The model studies were made under the general direction of Albert S. Fry, M. ASCE, chief of the Hydraulic Data Branch of the TVA, and under the immediate supervision of G. H. Hickox, M. ASCE, former head of the TVA Hydraulic Laboratory, and Rex A. Elder, M. ASCE, head of the TVA Hydraulic Laboratory. The assistance of Jack C. Jones, J. M. ASCE, is acknowledged in making the computations and preparing the illustrations in this paper. The writer also acknowledges the many helpful suggestions made by Mr. Hickox and Mr. Elder.

APPENDIX. NOTATION

The following letter symbols, adopted for use in the paper and for the guidance of discussers, conform essentially with American Standard Letter Symbols for Hydraulics (ASA-Z10.2-1942), prepared by a committee of the American Standards Association with Society representation, and approved by the Association in 1942:

C = coefficient of discharge for any head:
C_o = coefficient of discharge for the design head;
C_s = coefficient of discharge for submerged flow;
D = depth of flow above the crest, in feet (Fig. 1(*a*));
D_1 = depth, bottom of gate to water surface, in feet (Fig. 1(*b*));
d = submergence tailwater, measured above the crest, in feet (Fig. 1(*a*));
g = acceleration due to gravity, in feet per second per second;

H = total head above the crest, including the velocity head of approach, in feet (Fig. 1);
H_o = design head for a standard crest, including the velocity head of approach, in feet;
h = velocity head of approach, $v^2/2g$, in feet (Fig. 1);
L = spillway crest length, in feet;
P = depth of the approach channel, crest to river bed, in feet (Fig. 1(a));
Q = total discharge, in cubic feet per second;
v = average velocity of approach, in feet per second; and
X, Y = crest coordinates, in feet.

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

TRANSACTIONS

Paper No. 2856

WATER CONTROL IN CENTRAL AND SOUTHERN FLORIDA

BY HAROLD A. SCOTT,[1] M. ASCE

SYNOPSIS

This paper describes the historical efforts made to provide drainage and water control for central and southern Florida. Distribution and utilization of water in the comprehensive plan for flood control and multiple purposes are described. The need for a secondary water-control plan is emphasized.

INTRODUCTION

The area described in this paper (Fig. 1) lies south of an east-west line through Lake Harney (about 35 miles north of Cocoa) in Florida in the St. Johns River basin and east of the ridge that extends through Haines City and Sebring. The ridge divides the waters which flow into the Atlantic Ocean and those which flow into the Gulf of Mexico. Water-control problems are quite common throughout the area, although there are a few variations in topography and soil. The area consists of approximately 15,000 sq miles of groveland, pastures, rich agricultural lands, lakes, and marshlands. Elevations range from approximately 7 ft in the vicinity of Miami and 15 ft around Lake Okeechobee to 80 ft in the area of the headwaters of the Kissimmee River basin. (All stages and elevations throughout this paper refer to mean sea level data.) However, the lands of a large part of the area are extremely flat, and natural water courses are not common. Except for the St. Johns River, the Kissimmee River, Fisheating Creek, and a few minor streams, most of the water control is accomplished by man-made canals and drainage districts. Soils in the area vary from sand to peat with a small amount of marl. The areas with higher elevations in the St. Johns and Kissimmee River basins consist of sand mixed with a small amount of organic material in the upper 6 in. to 12 in. In the low areas and marshes, deposits of peat of thicknesses ranging to several feet are found. The Everglades is covered with a layer of peat of thickness ranging to approximately 15 ft at Lake Okeechobee and gradually diminishing to zero at

NOTE.—Published, essentially as printed here, in October, 1954, as *Proceedings-Separate No. 581*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.
[1] Cons. Engr., Reynolds, Smith, and Hills, Jacksonville, Fla.

Tennessee Valley Authority
Division of Water Control Planning
Engineering Laboratory

NORRIS DAM

DISCHARGE RATINGS

FOR ASSUMED DAM FAILURES

DURING AN EARTHQUAKE

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Advance Report No. 1

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Norris, Tennessee
January 1974

Report No. 2-633

NORRIS DAM
DISCHARGE RATINGS
FOR ASSUMED DAM FAILURES
DURING AN EARTHQUAKE

INTRODUCTION

At the request of the Flood Control Branch, Division of Water Control Planning, a study was conducted by the Engineering Laboratory to establish discharge rating curves for various debris configurations resulting from a failure of Norris Dam. This study was authorized by the Project Management Corporation, Clinch River Breeder Reactor. The study was made to supply flow data to be used in the determinations of the necessary flood protection works for the Clinch River Breeder Reactor. Six failure cases detailed on Plate 1 were tested. The discharge ratings for the six cases are shown on Plates 2 and 3.

THE MODEL

A 1:150 scale model of Norris Dam duplicating the failure section and the topography immediately upstream from the dam and a 2400-foot reach downstream from the dam was installed in the eight-foot laboratory flume. A general view of the model with failure Case A installed is shown in Figure 1. The topography both upstream and downstream from the dam was obtained from drawing 232-D-264 shown on Plate 4. Model discharges were obtained from readings of a carefully calibrated diaphragm orifice located in the water supply line or a calibrated eight-foot sharp crested weir located at the upstream end of the eight-foot flume. The eight-foot weir was used whenever the discharge exceeded 2,000,000 cfs. Headwater heights were measured at two piezometers located 1200 and 1800 feet upstream from the dam. The headwater levels were determined by means of hook gages reading to .001 foot. Tailwater heights were taken from a staff gage located 1300 feet downstream from the dam. The tailwater level was controlled at the end of the flume by means of slot gates.

TEST PROCEDURE

During each discharge rating test a constant discharge was set up using the appropriate tailwater level shown on Plate 5. Recordings were then made of the headwater elevation, tailwater elevation and the discharge. The test procedure was repeated at other constant flows so that sufficient information was obtained to establish a discharge rating curve of headwater elevation vs. discharge for each case tested.

TEST CASES

Six failure schemes designated as cases A, B, C, D, E and F_{1-5} were rated. Details of the schemes are shown on Plate 1. The existing topography both upstream and downstream from the dam was duplicated in the model from contours given on Plate 4. The debris configuration was assumed to be as shown on Plate 1 for each case.

Case E was identical to case A except that the sideflow to the left and right of the debris was prevented by constructing sheet metal walls as shown on Plate 1. The difference between the discharge of case A and E at any headwater elevation will give the discharge not going over the top of the debris.

Four tests labeled No TW Effect on Plate 2 were conducted with the tailwater level lowered so that it would have no influence on the headwater level. At near maximum test Q the headwater level was reduced 5.4, 5.3 and 7.6 feet for cases A, B and D, respectively, by eliminating the tailwater effect.

For case F_{1-5} the remains of the dam, assumed broken off at elevation 970, was moved to five different positions as shown on Plate 1. A discharge rating was obtained for each location so that data would be available to estimate discharge coefficients which might be applicable to failures at other dams.

TEST RESULTS

The discharge rating curves for each case are shown on Plates 2 and 3. Tabulations of the rating data are given on Tables 1 to 10. A summary of the discharges at headwater elevations 970 and 1035 is given on Table 11 to show the spread in discharge between the various cases tested.

Photographs of the dry and operating model are shown on Figures 1 to 22 for each scheme. Additional photographs and color slides of the model operation are available at the TVA Engineering Laboratory.

TABLES

Table

1 Data Tabulations, Case A

2 Data Tabulations, Case B

3 Data Tabulations, Case C

4 Data Tabulations, Case D

5 Data Tabulations, Case E

6 Data Tabulations, Case F_1

7 Data Tabulations, Case F_2

8 Data Tabulations, Case F_3

9 Data Tabulations, Case F_4

10 Data Tabulations, Case F_5

11 Summary of Discharge, H.W. 970 and 1035

FIGURES

Figure

1 Case A, Dry Model

2 Case A, Dry Model

3 Case A, Discharge - 2,709.400

4 Case B, Dry Model

5 Case B, Discharge - 3,010,000

6 Case C, Discharge - 2,824,000

7 Case D, Dry Model

8 Case D, Discharge - 388,100

9 Case D, Discharge - 2,196,500

10 Case E, Dry Model

Figure

11 Case E, Discharge - 1,569,600

12 Case F_1, Dry Model

13 Case F_2, Discharge - 98,500

14 Case F_3, Discharge - 1,994,200

15 Case F_4, Discharge - 2,409,000

16 Case F_5, Discharge - 3,014,700

PLATES

Plate

1 Details of Cases

2 Discharge Rating, Case A to E

3 Discharge Rating, Case F_1 to F_5

4 Topography

5 Tailwater Curve

TABLE 1

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE A

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
1A	965.42	421,800	
2A	982.75	656,500	
3A	992.97	920,300	919.0
4A	1001.80	1,181,200	932.5
5A	1011.85	1,520,300	948.0
6A	1019.65	1,805,500	959.5
7A	1028.80	2,119,400	970.2
8A	1036.60	2,436,300	981.5
9A	1045.63	2,709,400	990.0
10A	1040.20	2,709,400	T.W. Low
11A	1030.45	2,196,100	973.0
12A	912.86	95,100	
13A	925.45	141,500	
14A	939.70	214,800	
15A	1037.03	2,462,700	982.0

TABLE 2

NORRIS DAM FAILURE STUDY
SUMMARY OF TESTS RESULTS
DISCHARGE RATING
CASE B

Test No.	H. W. Elev.	Q cfs	T.W. Elev.
26B	955.53	397,000	885.0
27B	966.18	625,300	902.0
28B	973.08	800,800	913.0
29B	980.13	1,004,000	923.0
30B	986.28	1,197,000	934.0
31B	991.98	1,377,000	942.0
32B	998.43	1,597,000	950.0
33B	1004.58	1,802,000	959.0
33B	1003.38	1,802,000	Low T.W.
34B	1010.28	2,003,000	967.0
35B	1017.03	2,203,000	974.0
36B	1022.43	2,413,000	981.0
37B	1028.13	2,594,000	987.0
38B	1033.38	2,799,000	993.0
39B	1038.27	3,010,000	999.0
39B	1032.93	3,009,000	Low T.W.
40B	949.83	293,800	875.0
41B	937.68	194,900	865.0

TABLE 3

NORRIS DAM FAILURE STUDY
SUMMARY OF TESTS RESULTS
DISCHARGE RATING
CASE C

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
59C	942.23	100,900	853.0
60C	960.11	192,000	864.0
61C	973.52	295,200	876.0
62C	978.62	389,800	885.0
63C	984.62	508,700	894.5
64C	991.82	692,900	906.5
65C	998.27	901,900	918.5
66C	1004.12	1,103,000	928.5
67C	1009.67	1,295,000	938.0
68C	1014.77	1,493,000	946.5
69C	1019.42	1,686,000	954.0
70C	1024.67	1,889,000	962.5
71C	1029.47	2,095,000	969.8
72C	1033.67	2,291,000	976.0
73C	1038.50	2,493,000	983.0
74C	1043.42	2,703,000	990.0
75C	1045.79	2,824,000	994.0
76C	1043.27	2,824,000	Low T.W.
77C	930.47	57,600	845.0
78C	909.62	20,700	839.0

TABLE 4

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE D

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
42D	888.48	99,800	851.00
43D	907.15	192,800	865.00
44D	920.20	296,100	876.00
45D	929.35	388,100	885.5
46D	941.80	591,000	900.5
47D	950.13	756,200	910.5
48D	959.53	952,900	921.0
49D	971.05	1,199,800	933.0
50D	982.00	1,418,700	943.0
51D	991.00	1,599,100	951.0
52D	1000.15	1,806,400	959.0
53D	1009.60	1,996,900	966.5
54D	1018.60	2,196,500	973.5
55D	1028.05	2,421,100	981.0
56D	1035.62	2,589,800	986.5
57D	1043.20	2,778,300	993.0
58D	1027.90	2,784,900	Low T.W.

TABLE 5

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE E

Test No.	H.W. Elev.	Q cfs	T.W.(1) Elev.
16E	979.00	68,400	
17E	987.25	170,300	
18E	993.70	271,000	
19E	998.95	367,200	
20E	1010.20	601,200	900.8
21E	1018.09	781,400	912.8
22E	1025.95	979,400	923.0
23E	1033.19	1,175,600	932.2
24E	1040.80	1,386,300	942.5
25E	1046.50	1,569,600	949.8

(1) No tailwater effect

TABLE 6

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE F_1

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
81	1007.35	384,100	885.0
82	1018.63	596,600	900.5
83	1027.25	801,300	912.7
84	1035.85	997,000	923.4
85	1043.15	1,207,100	933.5
86	1049.65	1,401,700	943.0
87	1055.80	1,598,700	951.0
88[1]	983.80	96,800	851.5
89[1]	992.80	198,700	865.0
90[1]	1000.00	296,700	875.5

[1]Model flow was unstable because of the small head on the crest. Test classified as unreliable.

TABLE 7

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE F_2

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
91[1]	982.45	98,500	851.0
92[1]	991.15	199,600	864.5
93[1]	997.90	295,700	876.0
94	1004.20	392,000	885.5
95	1014.70	594,400	900.5
96	1023.85	796,400	912.5
97	1031.65	997,100	923.0
98	1038.70	1,192,900	933.0
99	1045.42	1,400,400	942.5
100	1051.90	1,604,900	951.3

[1]Model flow was unstable because of the small head on the crest. Test classified as unreliable.

TABLE 8

NORRIS DAM FAILURE STUDY
SUMMARY OF TESTS RESULTS
DISCHARGE RATING
CASE F_3

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
101	1037.65	1,609,300	951.5
102	1042.98	1,797,000	959.0
103	1048.45	1,994,200	966.0
104	1031.17	1,397,600	942.5
105	1024.65	1,196,800	933.0
106	1017.85	998,400	923.0
107	1009.90	796,100	912.50
108	1001.20	602,700	901.0
109	990.22	396,100	885.5
110	954.13	100,500	859.0
111	975.42	198,100	864.5
112	983.35	295,600	876.0

TABLE 9

NORRIS DAM FAILURE STUDY
SUMMARY OF TEST DATA
DISCHARGE RATING
CASE F_4

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
113	919.35	100,100	851.5
114	943.00	200,100	865.0
115	959.95	297,400	876.0
116	972.85	388,300	885.0
117	985.45	590,000	900.5
118	995.50	797,800	912.5
119	1003.75	994,400	923.0
120	1011.10	1,191,700	933.0
121	1017.85	1,395,000	942.5
122	1024.00	1,594,500	951.0
123	1030.22	1,807,200	959.0
124	1035.70	2,003,700	966.5
125	1041.25	2,197,500	973.5
126	1046.35	2,409,000	980.5

TABLE 10

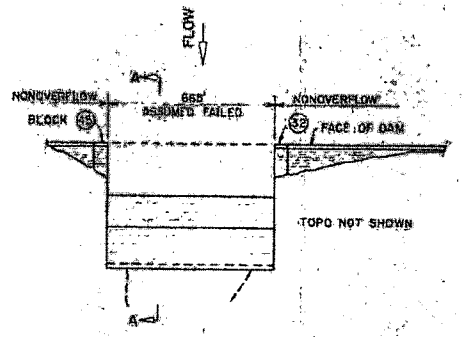
NORRIS DAM FAILURE STUDY
SUMMARY OF TEST RESULTS
DISCHARGE RATING
CASE F_5

Test No.	H.W. Elev.	Q cfs	T.W. Elev.
127	1042.68	2,598,000	987.00
128	1037.65	2,399,600	980.00
129	1047.77	2,797,700	993.00
130	1054.47	3,014,700	999.00
131	1033.09	2,190,300	973.00
132	1028.65	2,007,200	966.50
133	1023.03	1,797,200	959.00
134	1016.80	1,594,400	951.00
135	1010.20	1,394,000	942.50
136	1003.30	1,196,000	933.00
137	995.98	998,500	923.40
138	987.40	799,700	912.50
139	977.65	604.300	900.50
140	959.50	393,700	885.50
141	911.35	102,100	852.00
142	931.00	199,400	864.50
143	946.00	296,200	876.00

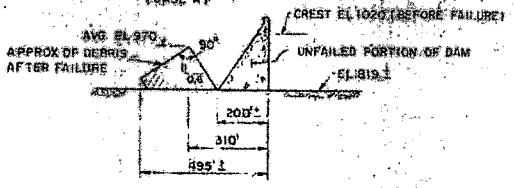
TABLE 11
SUMMARY OF DISCHARGE
CASE A THRU F_1-F_5
HEADWATER ELEVATIONS 970 & 1035

CASE	H.W. ELEV.	Q CFS	H.W. ELEV.	Q CFS
A	970	475,000	1035	2,370,000
B	970	740,000	1035	2,880,000
C	970	260,000	1035	2,310,000
D	970	1,180,000	1035	2,590,000
E	970	0	1035	1,230,000
F_1	970	0	1035	970,000
F_2	970	0	1035	1,105,000
F_3	970	165,000	1035	1,510,000
F_4	970	378,000	1035	1,980,000
F_5	970	505,000	1035	2,270,000

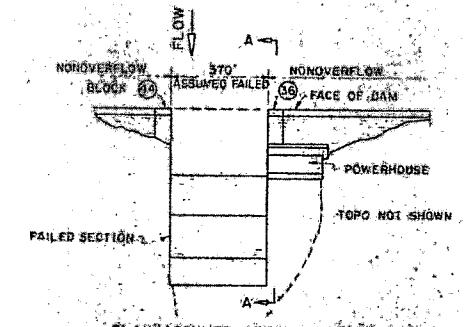
PLATE



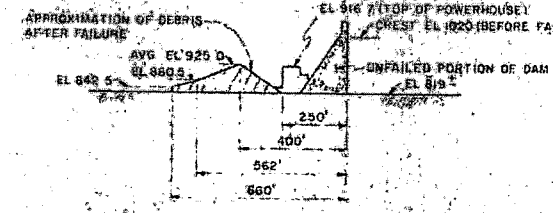
PLAN (ASSUMED AFTER FAILURE)
(CASE A)



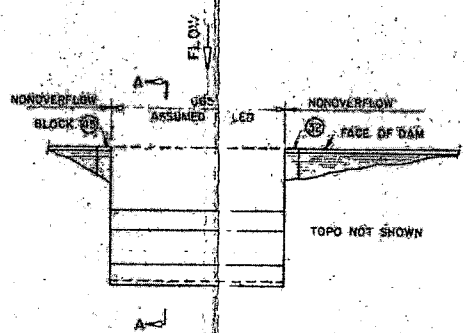
SECTION A-A



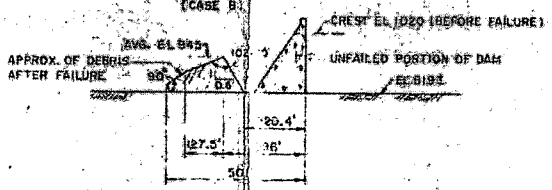
PLAN (ASSUMED AFTER FAILURE)
(CASE D)



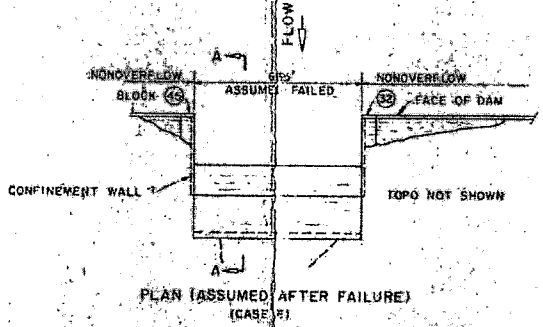
SECTION A-A



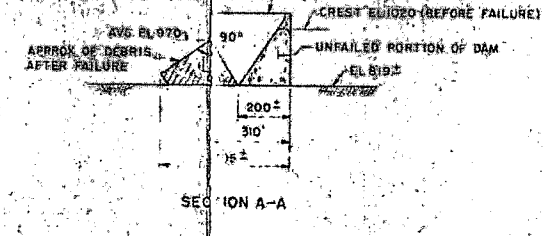
PLAN (ASSUMED AFTER FAILURE)
(CASE B)



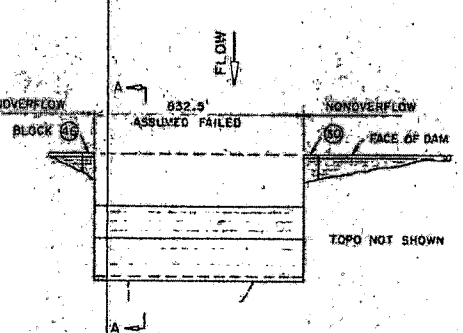
SECTION A-A



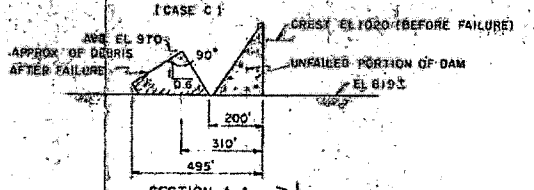
PLAN (ASSUMED AFTER FAILURE)
(CASE E)



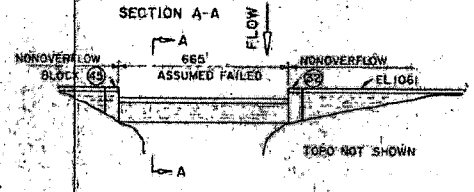
SECTION A-A



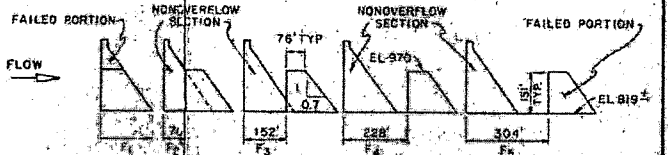
PLAN (ASSUMED AFTER FAILURE)
(CASE C)



SECTION A-A



PLAN (ASSUMED AFTER FAILURE)
(CASE F)



SECTION A-A

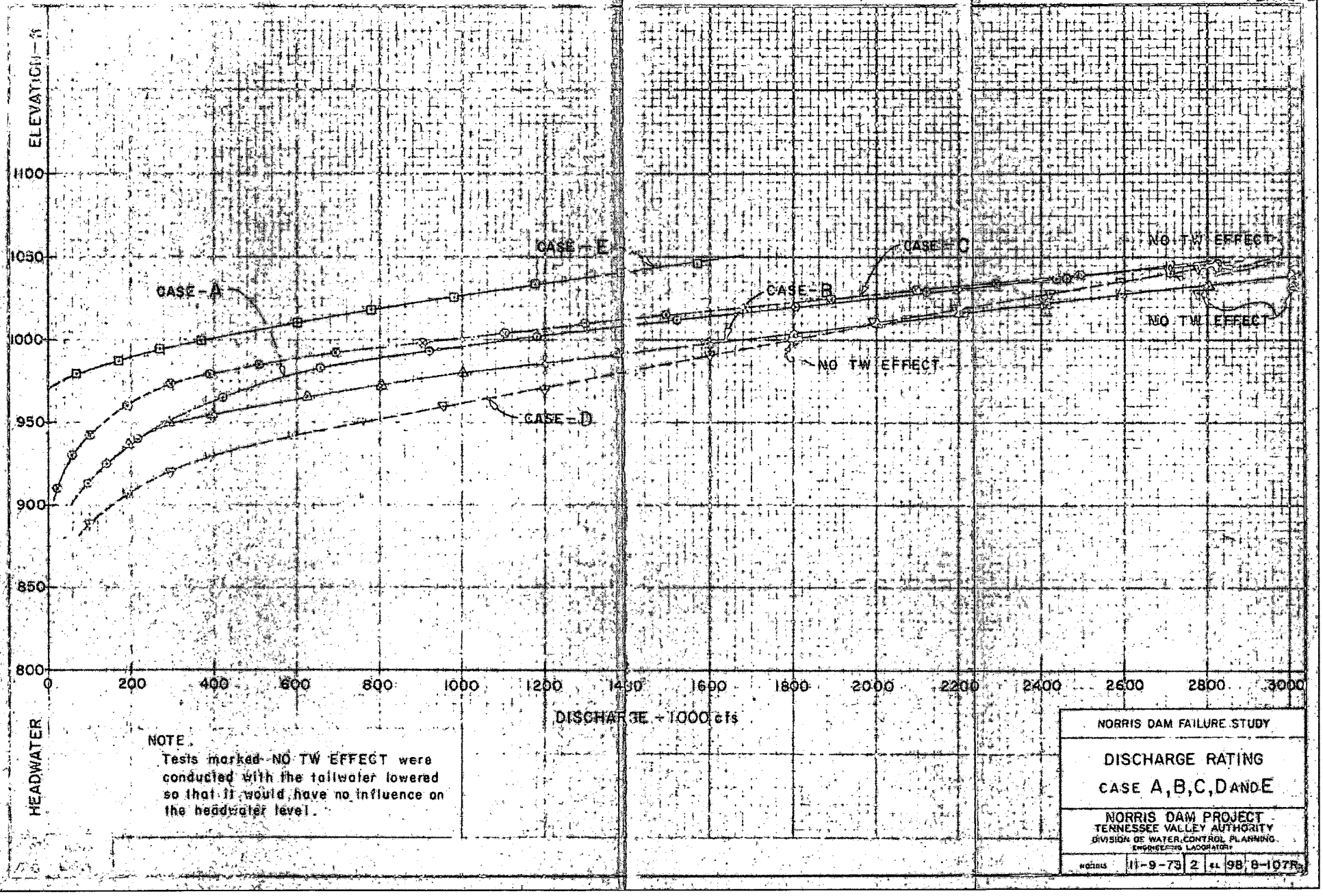
NORRIS DAM FAILURE STUDY

DETAILS OF CASES A, B, C, D, E, & F 1 TO 5

NORRIS DAM PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY, DENVER

12-18-73 | 2-EL-98-K-109

PLATE 2



NOTE.
Tests marked NO TW EFFECT were conducted with the tailwater lowered so that it would have no influence on the headwater level.

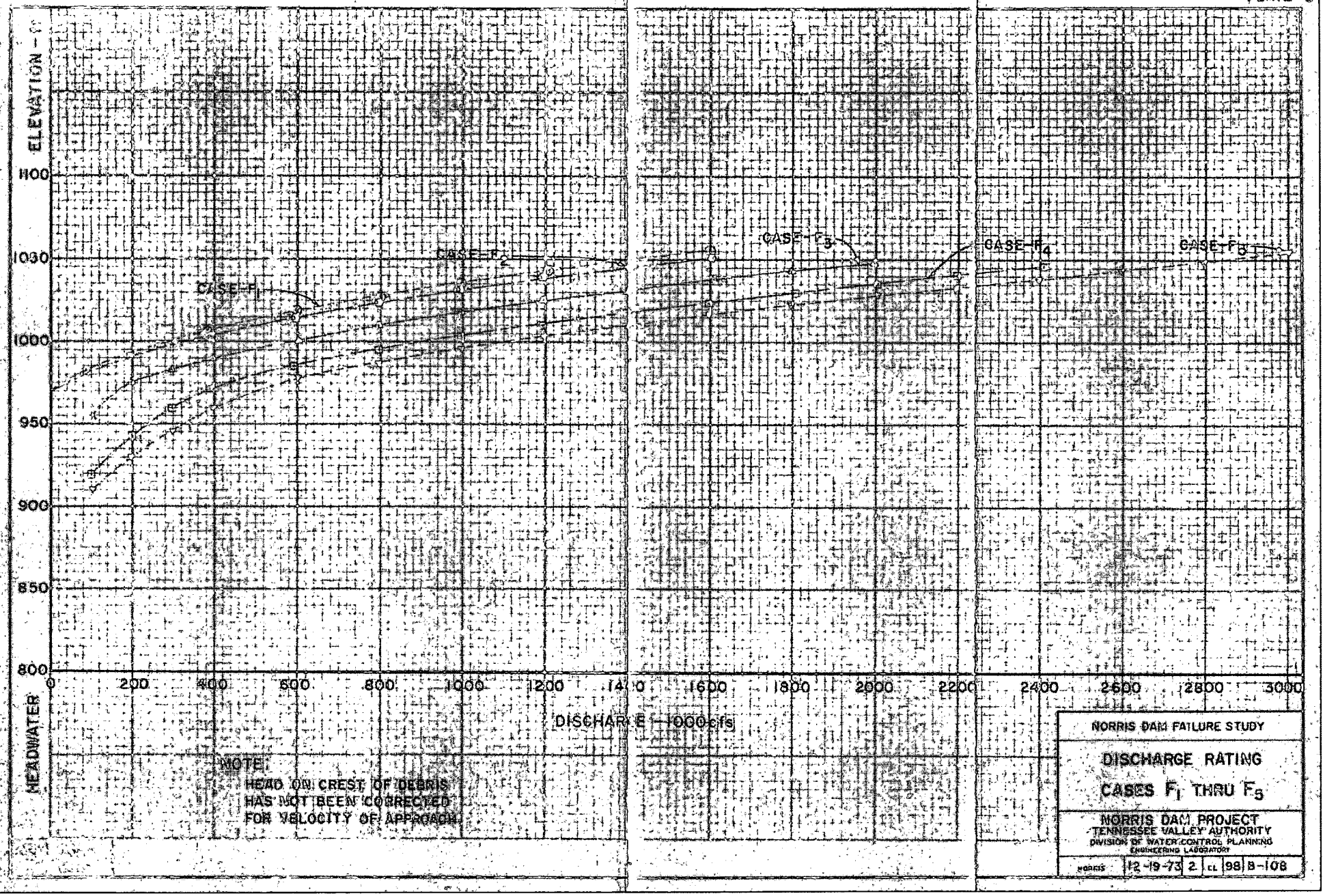
NORRIS DAM FAILURE STUDY

DISCHARGE RATING
CASE A, B, C, D AND E

NORRIS DAM PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN	DATE	CHECKED	DATE	APPROVED	DATE
	11-9-73	2	11 98	8-107R	

PLATE 5



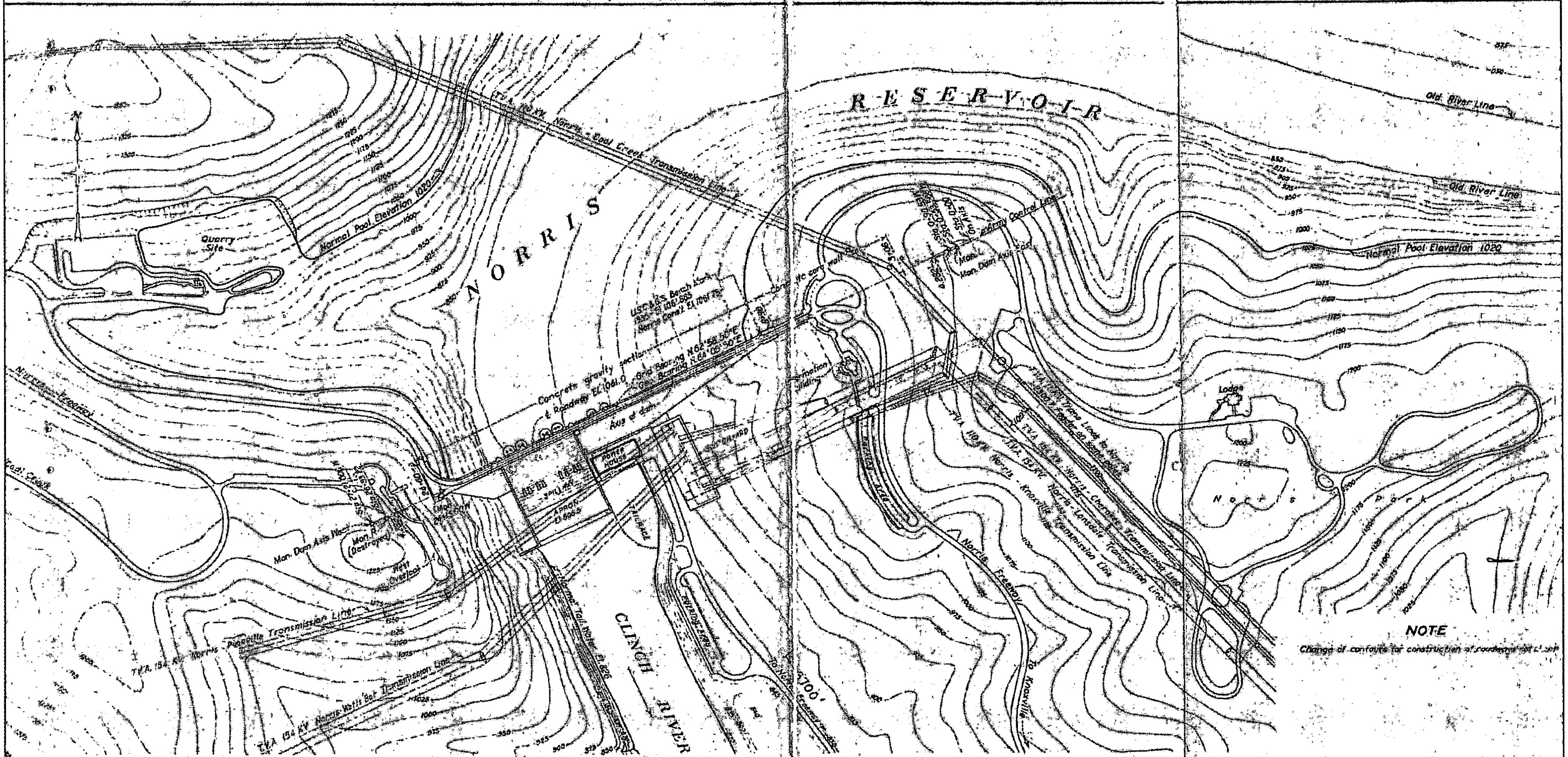
NORRIS DAM FAILURE STUDY

DISCHARGE RATING

CASES F_1 THRU F_5

NORRIS DAM PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	12-19-73	2	CL	98	B-108



Scale: 1/2400

200 0 200 400 600 800 1000 FEET

CONTOUR INTERVAL 25 FEET
DATUM IS MEAN SEA LEVEL

MONUMENT	CO-ORDINATES Tennessee Lambert Proj.	GEOGRAPHIC POSITION	ELEVATION Mean Sea Level Datum U.S.C.&G.S. 1912 Adj.	ELEVATION U.S.C. & G.S. 1936
L	E = 2,584,254.47 N = 673,249.76	Lat. 36°13'35.03" Long 84°05'12.87"	1153.401	
R Destroyed	E = 2,581,902.93 N = 672,050.58	Lat. 36°13'23.63" Long 84°05'41.85"	1199.476	
DAM AXIS EAST	E = 2,584,219.60 N = 673,236.77		1149.325	
U.S.C.&G.S. B.M. 1936			1061.75	1061.885
24+15.00 R	E = 2,582,148.84 N = 672,180.78		1061.797	
DAM AXIS WEST	E = 2,581,876.24 N = 672,041.77		1206.218	

UNITED STATES
TENNESSEE VALLEY AUTHORITY
NORRIS PROJECT

NORRIS DAM
GENERAL LAYOUT

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DR. ____ SUBMITTED B.K. Stele
TR. ____ RECOM. J.L. Savage
CK. ____ APPR'D. R.F. Walter

UNITED STATES
TENNESSEE VALLEY AUTHORITY

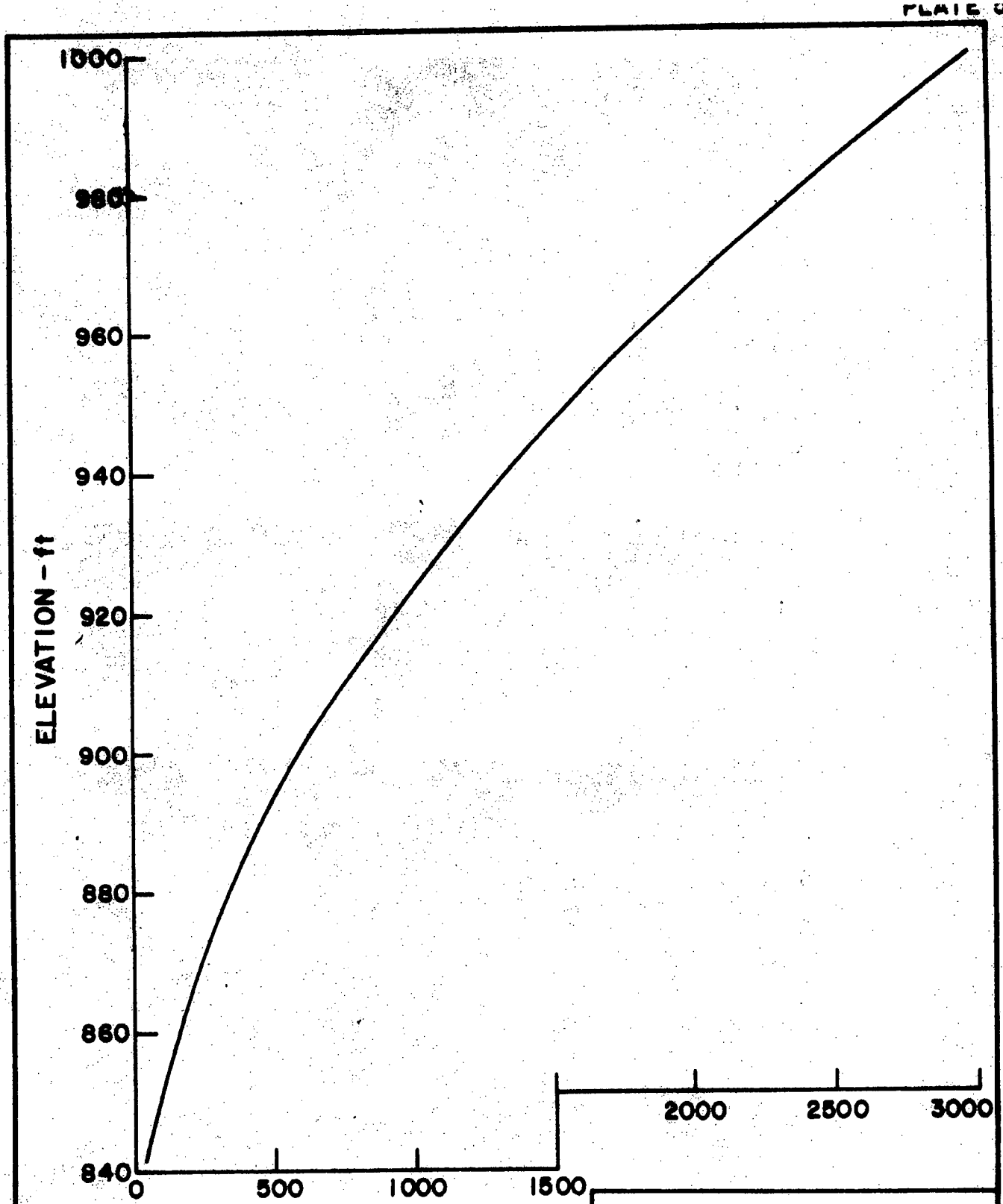
SUBMITTED Roy M. ...
RECOMMENDED ...
APPROVED ...

232-D-264 DENVER COLO. JUNE 1934

Rev. 1-11-46
Rev. 11-15-37

RECORD DRAWING AS CONSTRUCTED
C. M. ...

PLATE 3



NORRIS DAM FAILURE STUDY

TAILWATER RATING CURVE

NORRIS DAM
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN	ENGINEER	CHECKED	APPROVED
GPO	KWK	AS	EED

NORRIS	1-18-74	2	EL	98	A-110

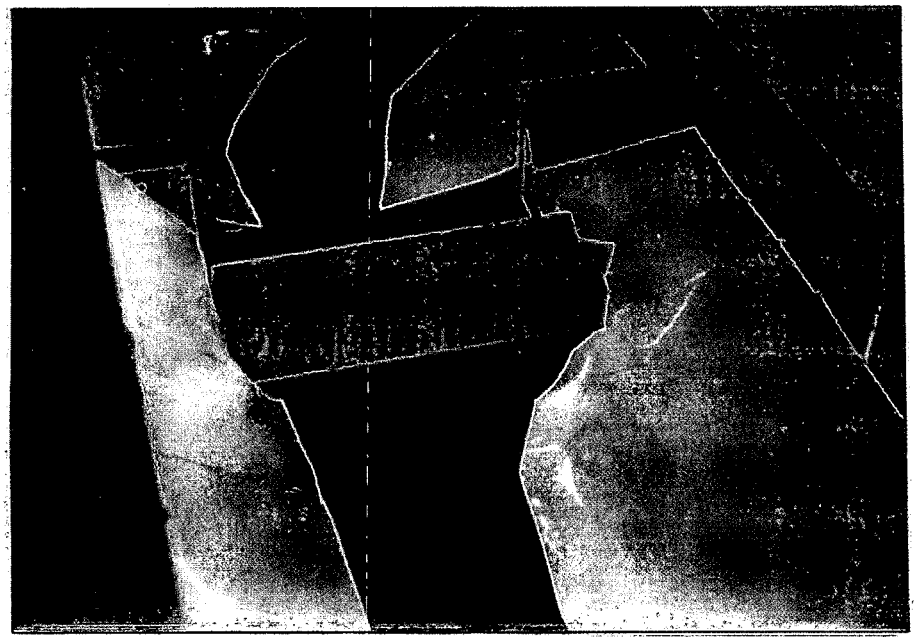


Figure 1 - General view of model
Case A - Looking upstream

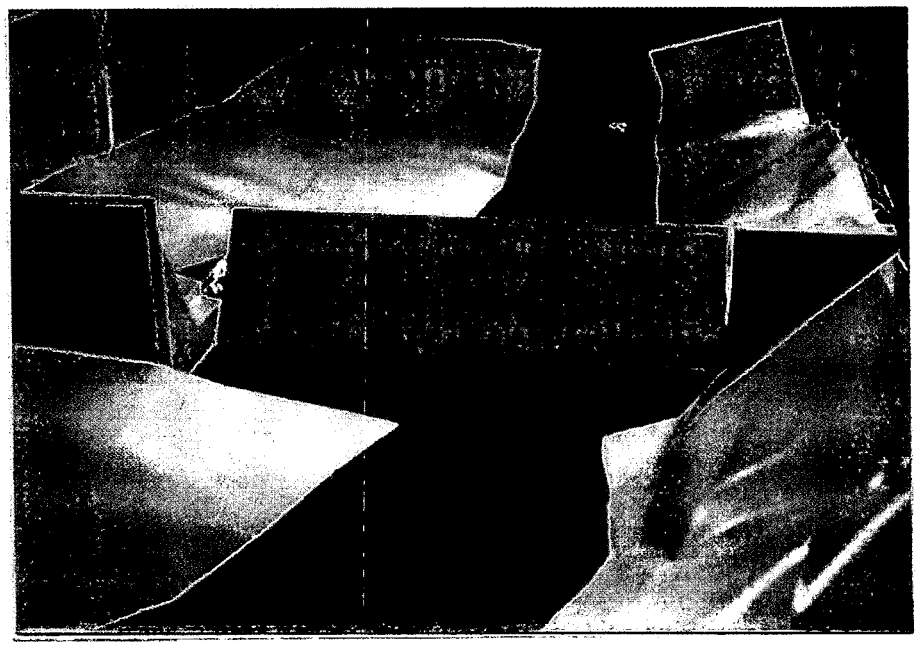


Figure 2 - General view of model
Case A - Looking downstream

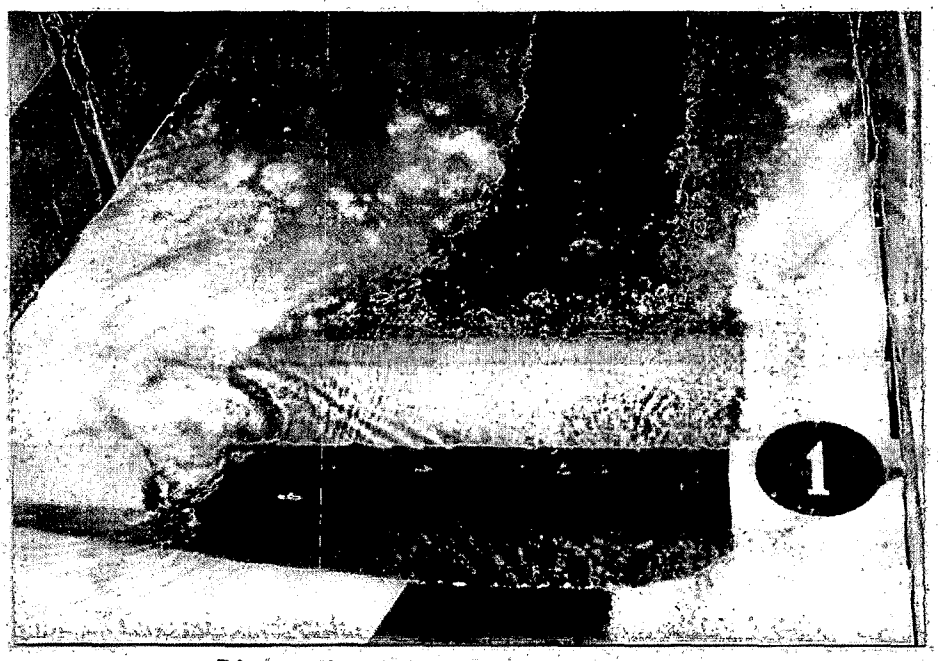


Figure 3 - H.W. El. - 1045.63
Case A - T.W. El. - 990.0
Test No. 9

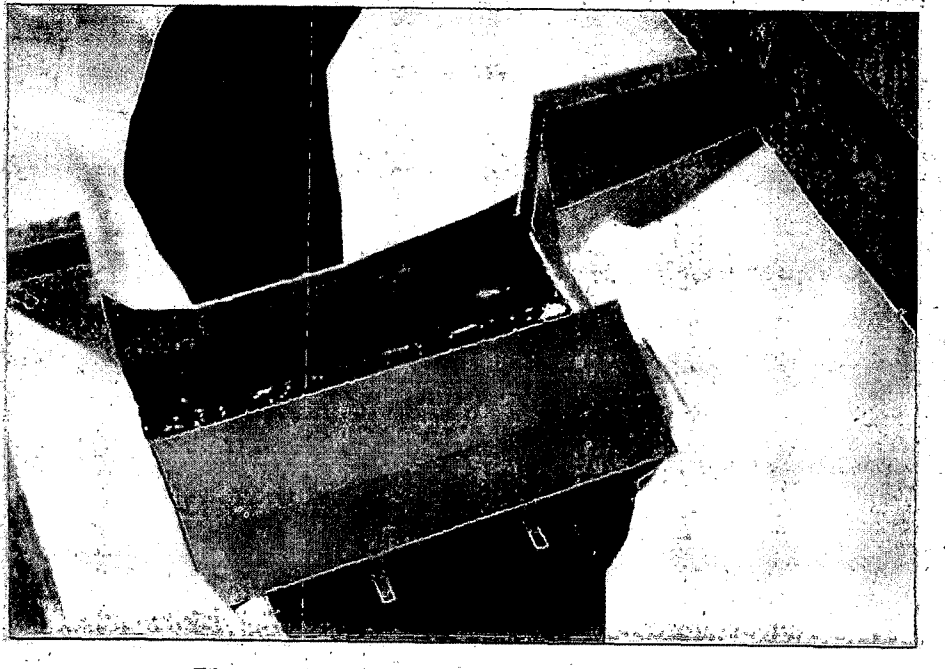


Figure 4 - General view of model
Case B - Looking upstream



Figure 5 - H.W. El. - 1038.27
Case B - T.W. El. - 999.00
Test No. 39

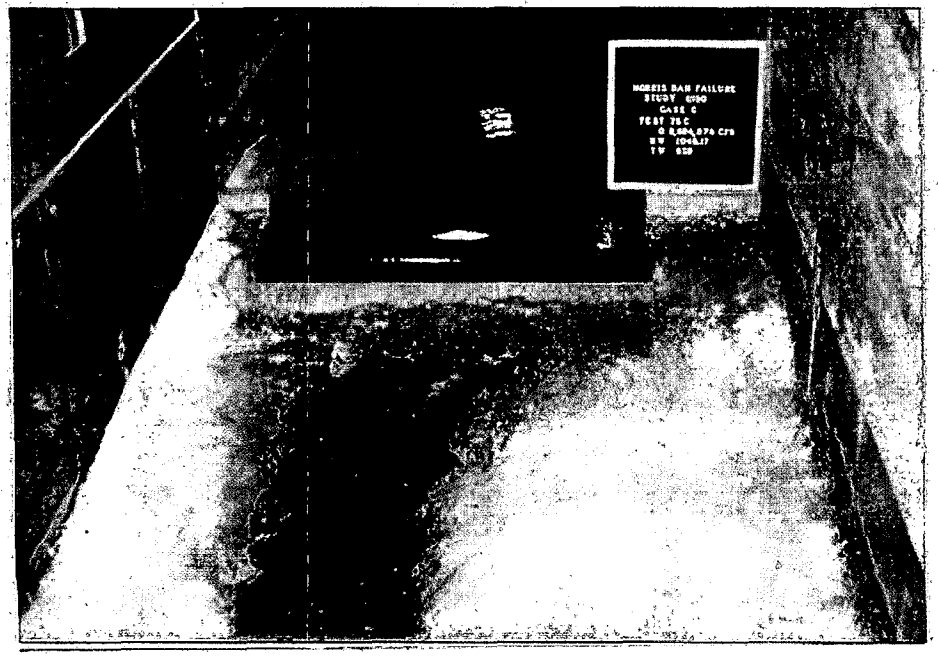


Figure 6 - H.W. El. - 1045.79
Case C - T.W. El. - 994.00
Test No. 75



Figure 7 - General view of model
Case D - Looking upstream

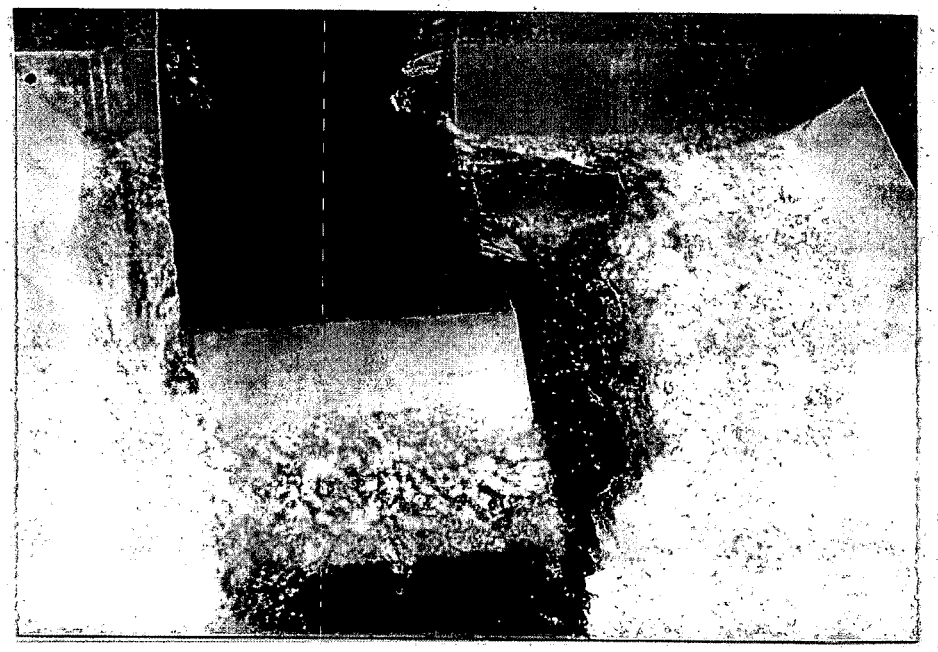


Figure 8 - H.W. El. - 929.35
Case D - T.W. El. - 885.50
Test No. 45

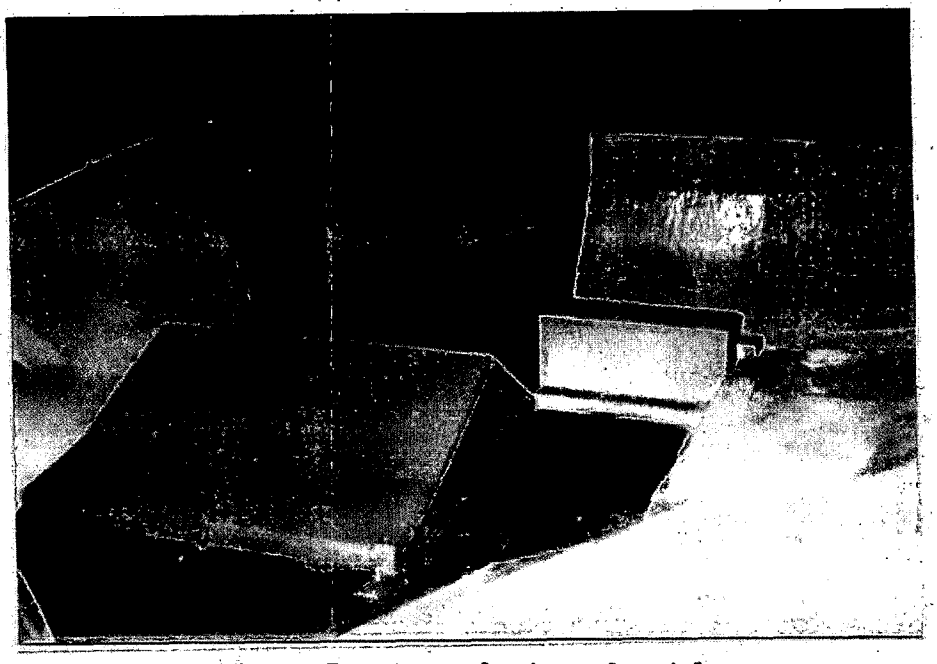


Figure 7 - General view of model
Case D - Looking upstream

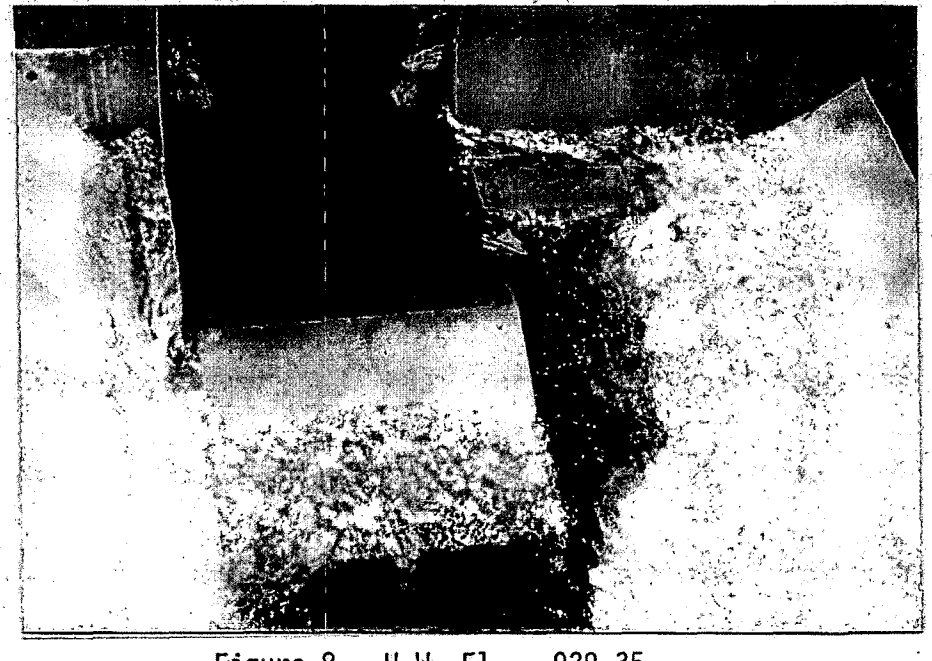


Figure 8 - H.W. El. - 929.35
Case D - T.W. El. - 885.50
Test No. 45



Figure 9 - H.W. El. - 1018.60
Case D - T.W. El. - 973.50
Test No. 54

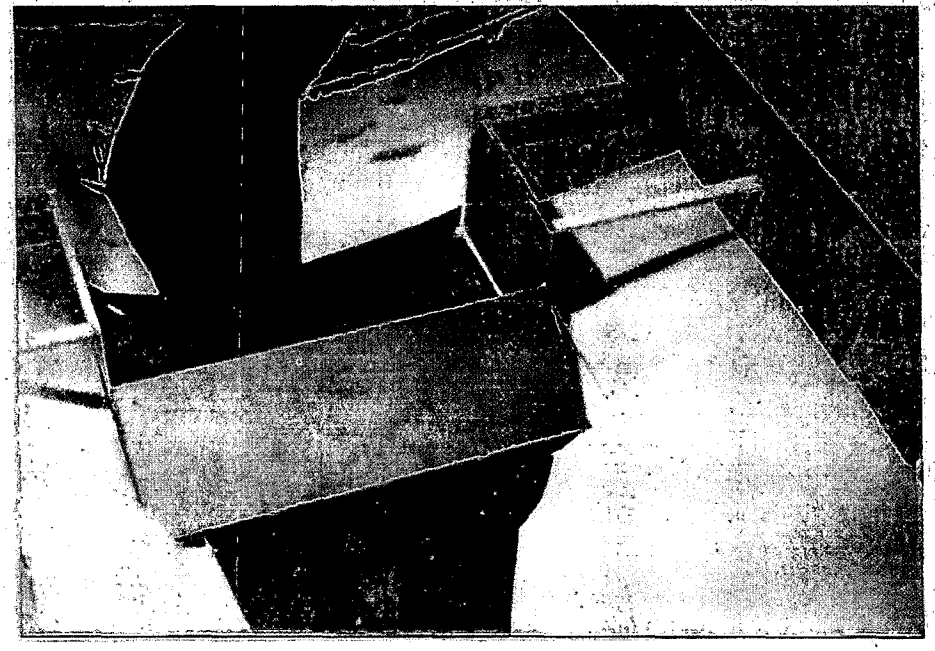


Figure 10 - General view of model
Case E - Looking upstream

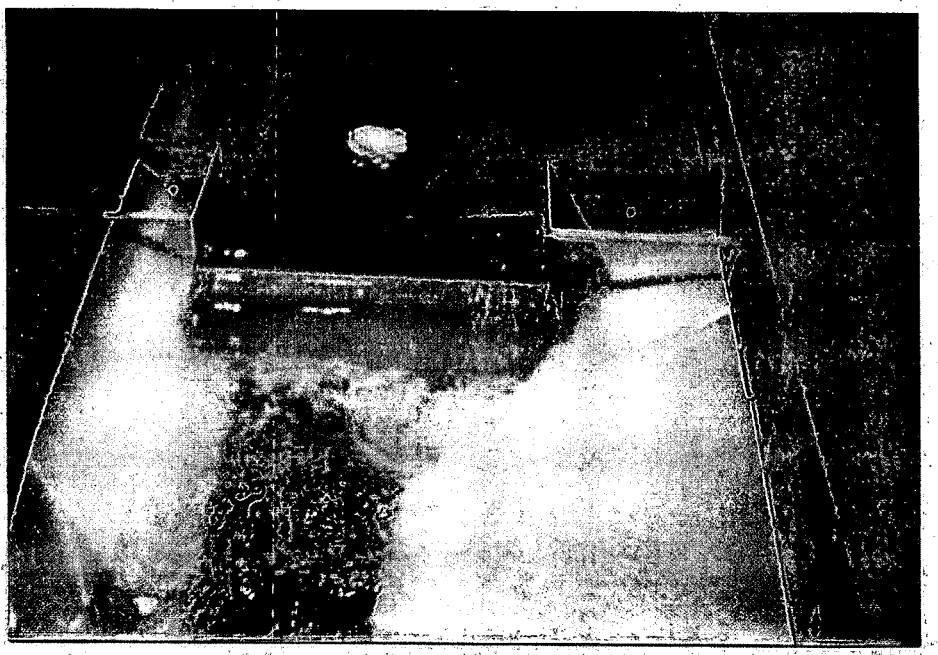


Figure 11 - H.W. El. - 1046.50
Case E - T.W. El. - 949.80
Test No. 25

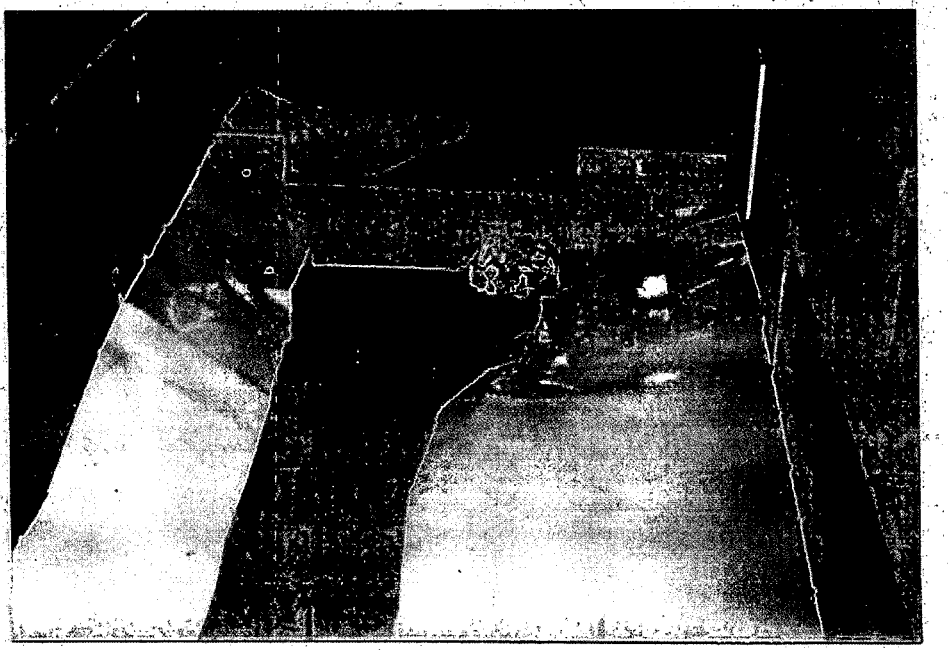


Figure 12 - General view of model
Case F_1 - Looking upstream

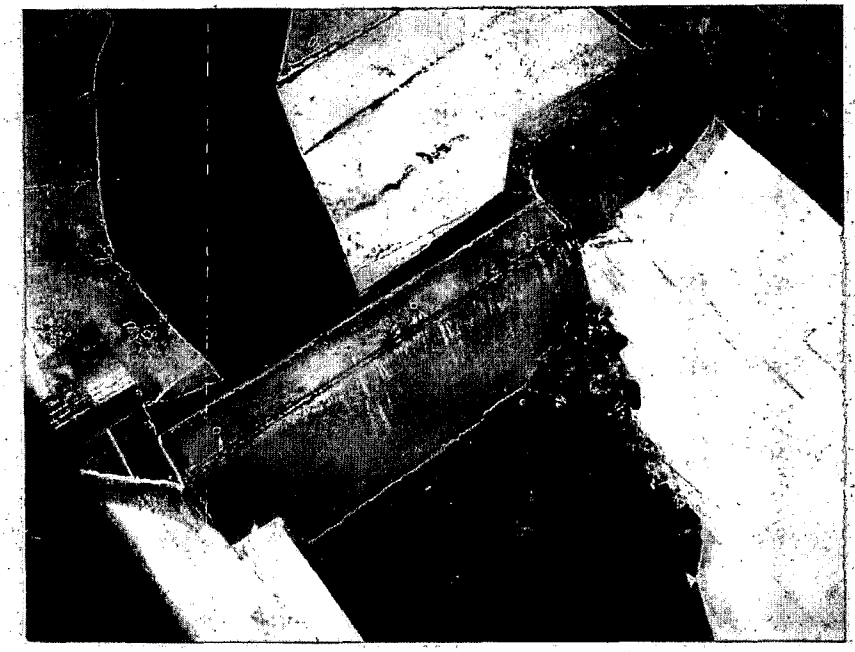


Figure 13 - H.W. El. - 982.45
Case F_2 - T.W. El. - 851.00
Test No. 91

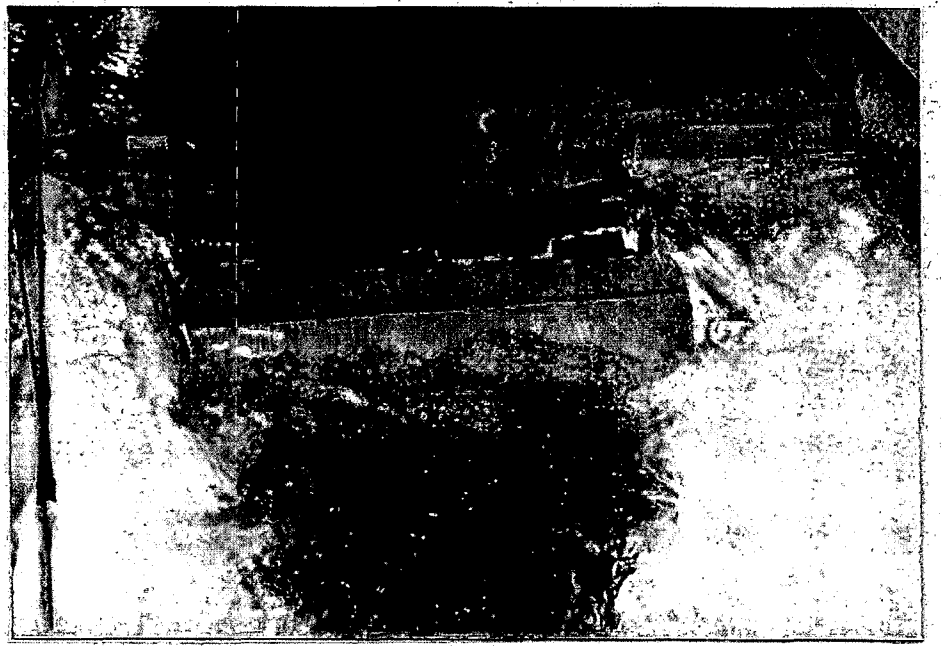


Figure 14 - H.W. El. - 1048.45
Case F_3 - T.W. El. - 966.00
Test No. 103

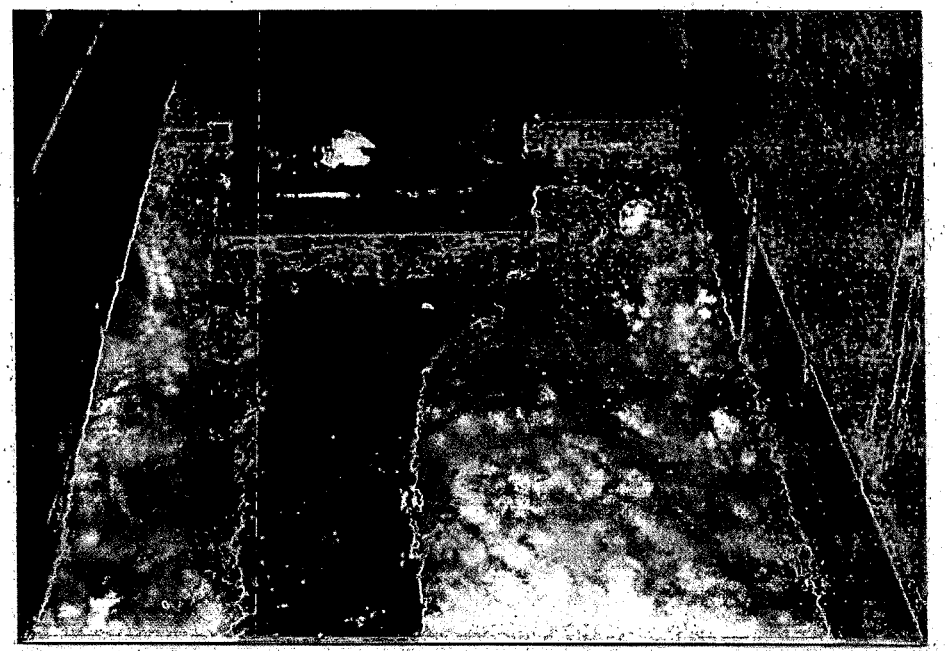


Figure 15 - H.W. El. - 1046.35
Case F_4 - T.W. El. - 980.50
Test No. 126



Figure 16 - H.W. El. - 1054.47
Case F_5 - T.W. El. - 999.00
Test No. 130

TVA 10697 (DNE 6-86)

DNE CALCULATIONS

TITLE: Douglas Dam - Concrete Stability Analysis For ½ SSE + ½ PMF	PLANT/UNIT: SQN, WBN, BLN, BFN
PREPARING ORGANIZATION: DE&C	KEY NOUNS (Consult RIMS DESCRIPTORS LIST): Sequoyah NP, Douglas Dam, Concrete Stability Analysis, ½ SSE + ½ PMF
BRANCH/PROJECT IDENTIFIERS: HEPES DGH SQN WBN BLN BFN ESSENT. CALCS A 5	Each time these calculations are issued, preparers must ensure that the original (R0) RIMS accession number is filled in.
APPLICABLE DESIGN DOCUMENT(S)	Rev (for RIMS' use) — RIMS accession number
	R0 8704150029 (65) B66 '870316 002
	R1 8806060001 (71) B25 '88 0520 308
SAR SECTION(S) / UNID SYSTEM(S)	R_
	R_

	Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable)	N/A	N/A		
Prepared	L. F. Schlomer	C.D. Wagner		
Checked	C. D. Wagner	L.F. Schlomer		
Reviewed	Archie J. Dean	Archie J. Dean		
Approved	W. C. Buttrey	C.M. Johnson /S		
Date	3/23/87	5/20/88		
List all pages added by this revision.		ii, 52		
List all pages deleted by this revision.		—		
List all pages changed by this revision.		2-11, 14, 17, 26-35, 41, 44, 50, 51		

Safety-related? Yes ☒ No ☐

Statement of Problem:

Determine effect of seismic event concurrent with major flood on typical nonoverflow and spillway blocks. Analyze for ½ SSE + ½ PMF.

Abstract

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒

Concrete stability analysis on typical nonoverflow and spillway blocks for ½ SSE + ½ PMF

Note:

These calculations were accomplished over a period from 1972 through 1977 in support of the Sequoyah Nuclear Plant FSAR. At the request of DNE in March of 1987, they have been reviewed, verified, and put into RIMS to satisfy the nuclear calculation verification program.

☐ Microfilm and store calculations in RIMS Service Center. Microfilm and destroy. ☐

☑ Microfilm and return calculations to L. F. Schlomer Address: W3 C17.3 C-K

cc: RIMS, SL 26 C-K

0 0 0 1

THIS SHT. ADDED PER REV. 1

SHEET 18.2 OF 18

BRIDGE ACROSS WATTS BAR DAM SQN

SEISMIC ANALYSIS FOR OBE (VESSE) & DBE (SSE)

COMPUTED _____ DATE _____

CHECKED _____ DATE _____

THIS IS THE LAST PAGE OF THE CALCULATION

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

HEPESDGHSQNWBNBLWBFN — Calculation No.

1 — Revision

Method of design verification (independent review) used (check method used):

1. Design Review ✓
2. Alternate Calculation
3. Qualification Test

Justification (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

There were no revisions to calculations. This revision corrects a RIMS reference number used on several pages in these calculations that was furnished by CEB concerning seismic analysis. This review addresses this R1 revision only.

Harold C. Bulley — Design Verifier (Independent Reviewer)

4/19/88 — Date

0003

HFPE5DGHSQN-WBNBLNBFN

TVA

Title: Douglas Dam - Concrete Stability Analysis for ½ SSE + ½ PMF

REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved
1	Changed RIMS reference number to Cals reference number.	5/20/88

TVA 10534 (EN DES-4-78)

A

DOUGLAS DAM - SEISMIC ANALYSES

HEPE5DGHSQN-WBNBLNBFN

INDEX

SHEET	
1	Summary of Mode of Failure
2 - 20	Stability Analysis Nonoverflow Block, ½ SSE + ½ PMF - Base EL 860
19 - 20	Summary of Stability Analysis Nonoverflow Block, ½ SSE + ½ PMF - Base EL 860
21 - 25	Stability Analysis Nonoverflow Block, ½ SSE + ½ PMF - Base EL 899
25	Summary of Stability Analysis Nonoverflow Block, ½ SSE + ½ PMF - Base EL 899
26 - 49	Stability Analysis Spillway Block, ½ SSE + ½ PMF, Gates Open - Base EL 815
46 - 48	Summary of Stability Analysis Spillway Block, ½ SSE + ½ PMF, Gates Open - Base EL 815
49	Summary of stability Analysis Spillway and Nonoverflow Blocks, ½ SSE + ½ PMF.

0 0 0 4

SHEET B OF

DOUGLAS DAM - SEISMIC ANALYSES

HEPESDGHSON-WBNBLNBEN

INDEX

COMPUTED DATE

CHECKED DATE

SHEET

50 Summary of Slip Circle Analysis Saddle Dam No. 1, ½ SSE + ½ PMF - Foundation EL 915.

51 Figure Showing Assumed Condition of Dam After Failure - ½ SSE + ½ PMF.

TVA 11030 (WX)-7-75)

Douglas - Summary of Mode of failure

B

HEPESDGHSQN-WBNBLNBFN

Re-evaluated By: LFS 3-7-87

CDW 3-9-87

Saddle Dam: The Saddle dam has Factor of safety of 1 and was judged not to fail since more thorough analysis including soil test to determine the soil constants more accurately would improve the F.S.

Nonoverflow:

The nonoverflow section at Douglas (above el 890) is identical to Cherokee and is assumed to fail at a point corresponding to failure at Cherokee (ie Swithyard Elevation 927.5). This is a judgment on the conservative side since Douglas is not as high as Cherokee and amplification of ground acceleration is slightly less.

Douglas is also similar to Tellico. Analysis of 110' high section (rock foundation) at Tellico showed that it could resist the OBE + ½ Max probable flood. Analysis 110' high section at Douglas showed that it was borderline failure (77 psi tension; resultant 1' outside base), the main difference being the difference in tailwater between the two projects. From this it was judged that an 80' high section at Douglas would resist the OBE + ½ Max probable flood without failure. OK

Spillway:

The spillway at Douglas is identical to the Spillway at Cherokee above the break point where failure occurs at Cherokee. Douglas is 5' higher than Cherokee but the amplification of ground acceleration is almost identical. Therefore it was judged that Douglas would fail at an elevation corresponding to failure at Cherokee (ie. Douglas Spillway judged to fail at el 937).

Intake:

The intake at Douglas is more massive than the nonoverflow section and is backed up by the powerhouse. The increased rigidity was judged to reduce amplification. Therefore the Intake was judged Not to fail.

Remark: All debris is assumed to be below el 937 / 927.5

TVA 489G (DES.1-83) TENNESSEE VALLEY AUTHORITY SHEET 1 OF 2

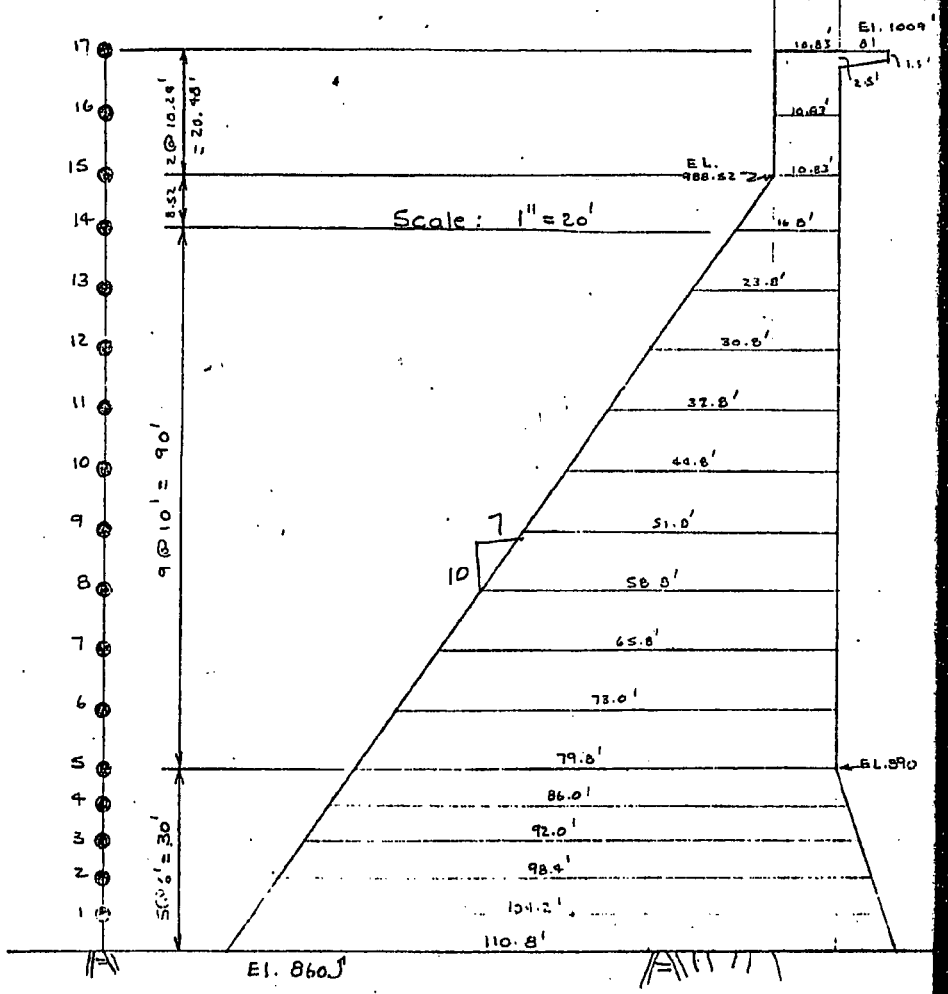
SUBJECT DOUGLAS DAM HEPE5DGHSQN-WBNBLNBFN PROJECT WBNP

SEISMIC ANALYSIS OF 1' SECTION

COMPUTED BY STONE DATE CHECKED BY DATE

DATA: $f_c' = 4000$; $E_c = 5.515 \times 10^8$ PSF

$E_r =$



Scale: 1" = 20'

ECF DAM CCR REPLACEMENT

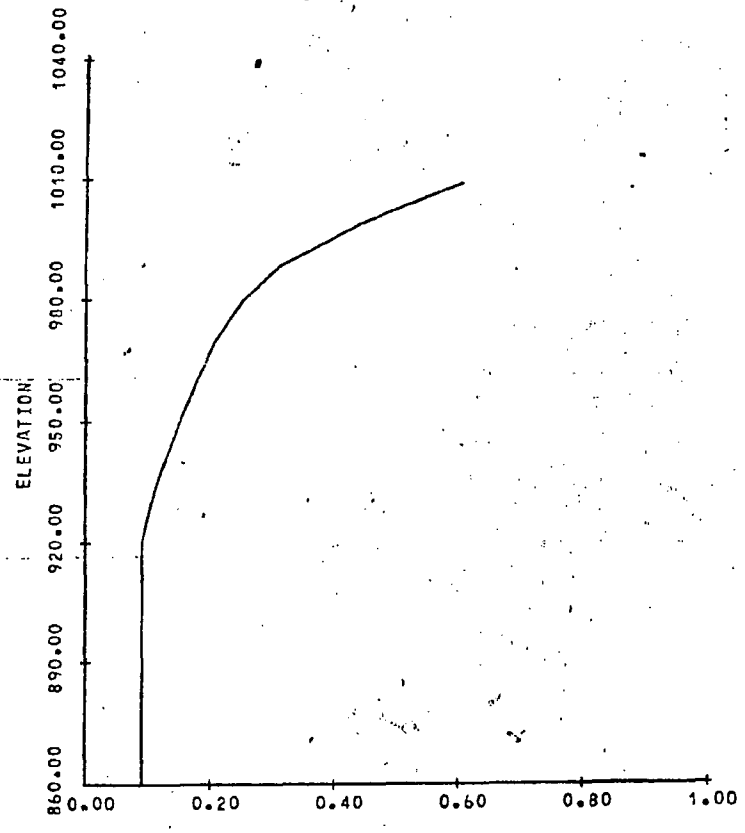
SEE CALCS - NO. CSG-87-017 LPS 9-11-89 CDH 9-15-89

sheet 3

HEPE5DGHSQN-WBNBLNBFN

04/17/72

TENNESSEE VALLEY AUTHORITY
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
NONOVERFLOW SECTION — 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL ACCELERATION



KEY RMX LHK BLØHDKIAA

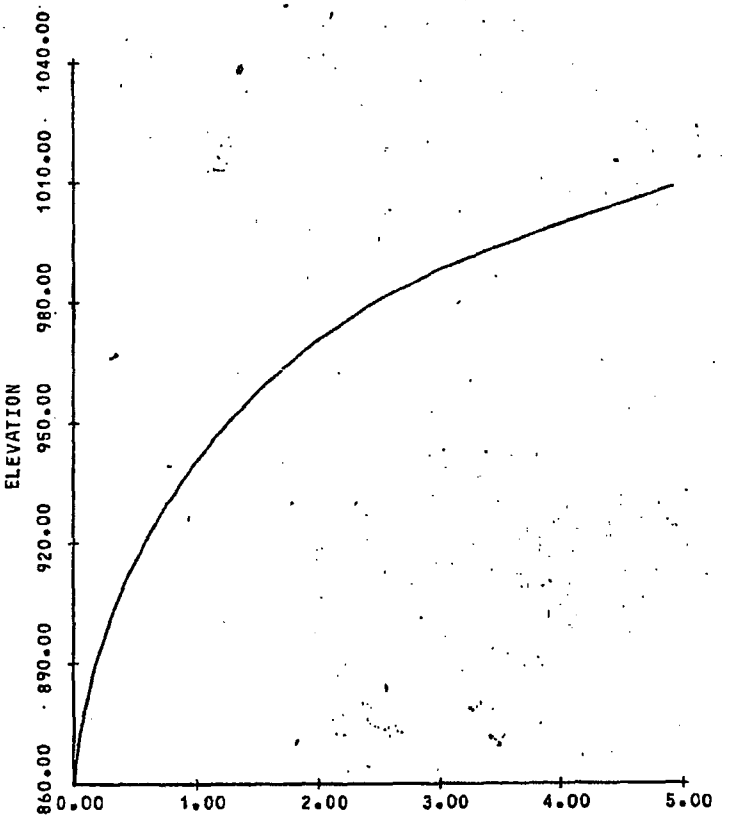
SEE CALCS - NO. CSG-87-017 LFS 4-11-88 CDW 4-15-88

Sheet 4

HEPE5DGHSQN-WBNBLNBFN

04/17/72

TENNESSEE VALLEY AUTHORITY
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
NONOVERFLOW SECTION — 7 10 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL DISPLACEMENT

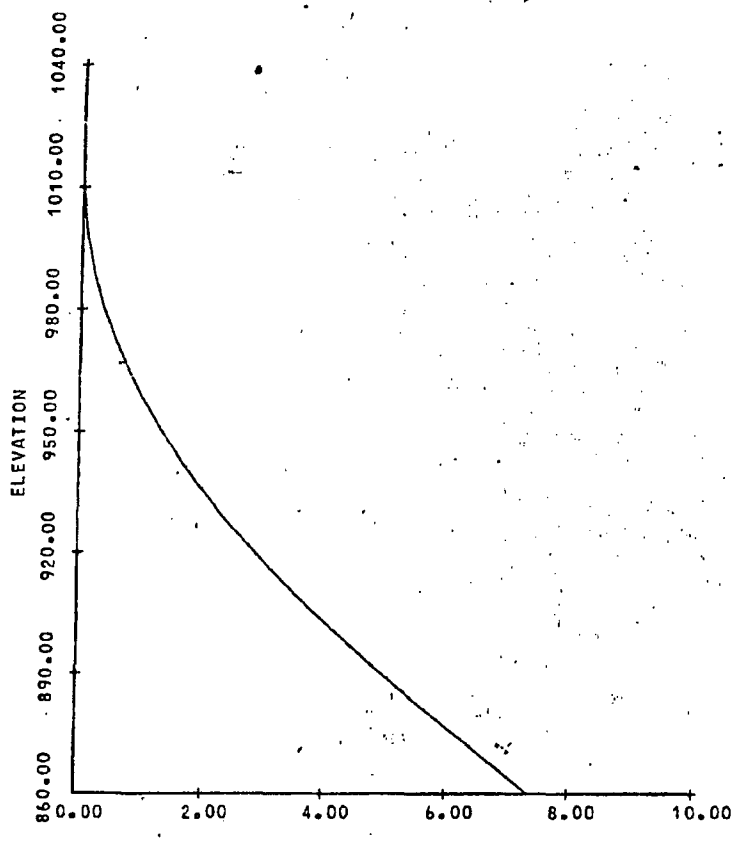


SEE CALCS - NO. CSG-87-017 LFS 4-11-88 EDW 4-15-88

Sheet 5

TENNESSEE VALLEY AUTHORITY HEPE5DGHSQN·WBNBLNBFN 04/17/72

DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
NONOVERFLOW SECTION — 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONTE
5.0 PERCENT DAMPING
HORIZONTAL BENDING MOMENT

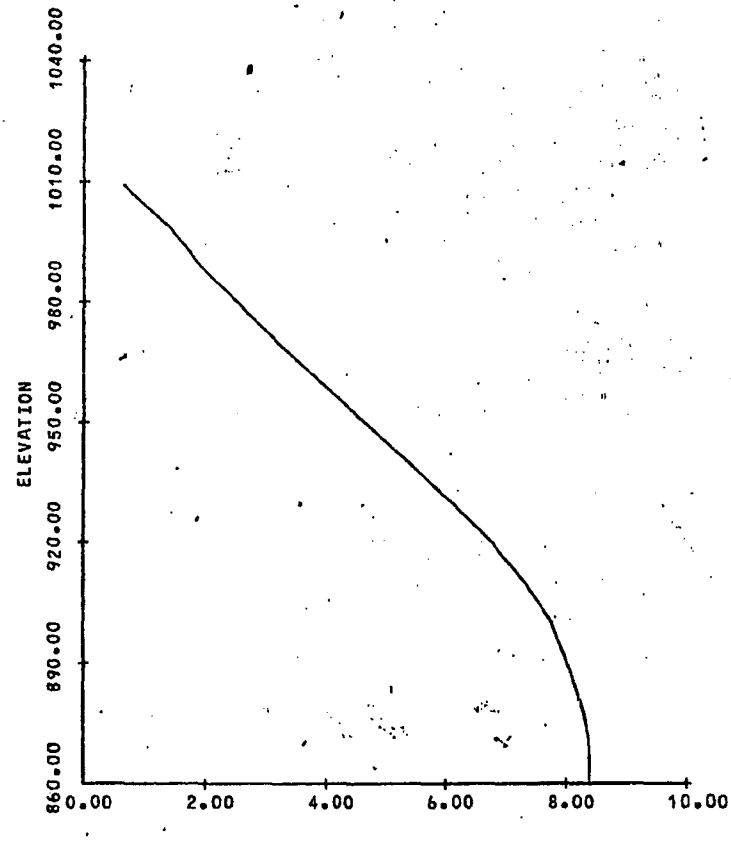


HEPE5DGHSQN·WBNBLNBFN

SEE CALCS - NO. CSG-87-017 LFS 4-11-88 EDN 4-15-88

Sheet 6

TENNESSEE VALLEY AUTHORITY 04/17/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
NONOVERFLOW SECTION - 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL SHEAR

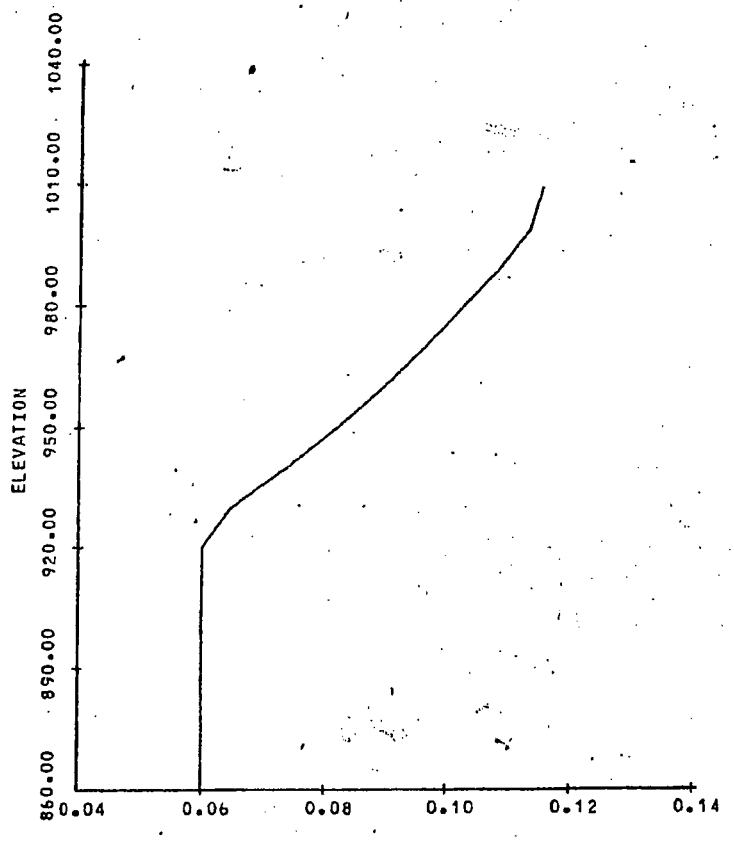


HEPESDQHSQN-WBNBLNBFN

REF HMB CRB 7/21/72 AAH
SEE CALCS - NO. CSG-87-017 LFS 4-11-88
EDMS 4-15-88

Sheet 7

TENNESSEE VALLEY AUTHORITY 04/17/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
NONOVERFLOW SECTION — 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL ACCELERATION

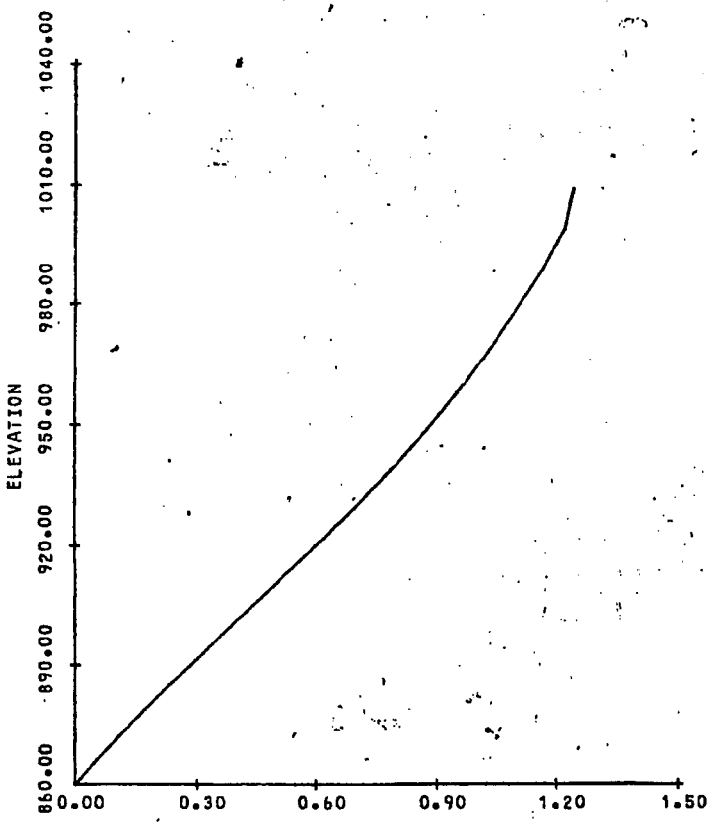


HEPE5DGHSQN-WBNBLNBFN

SEE CALCS - NO. CSG-87-017 LFS 4-11-88 GOJ 4-15-88

sheet 8

TENNESSEE VALLEY AUTHORITY 04/17/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
NONOVERFLOW SECTION — 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL DISPLACEMENT

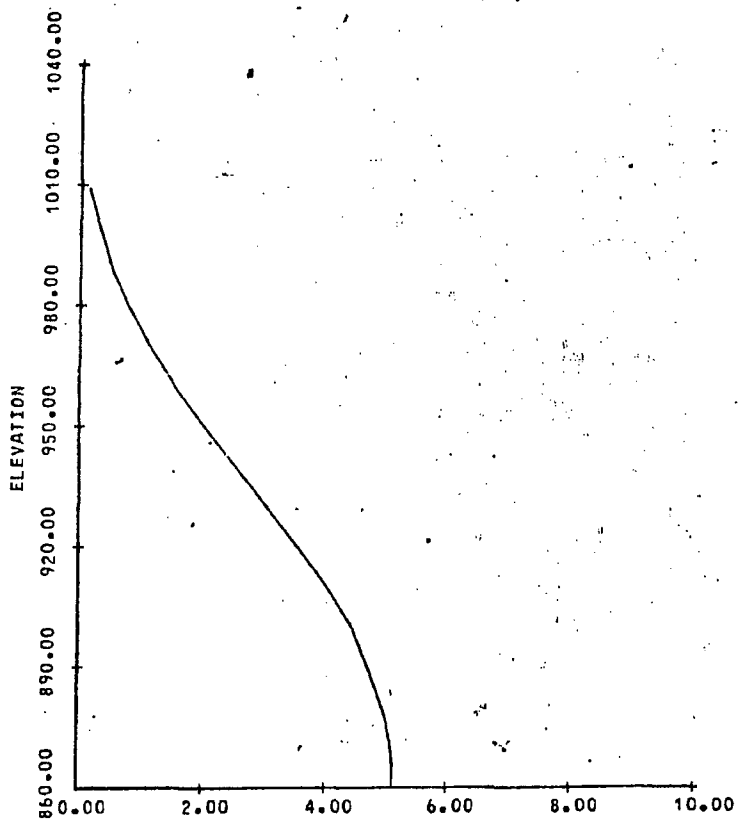


HEPE5DGHSQN-WBNBLNBFN

SEE KIMZ CLK 8201102444
SEE CALCS - NO. CSG-87-017 LFS-9-11-88 CDJ 9-15-88

Sheet 9

TENNESSEE VALLEY AUTHORITY 04/17/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATIOG BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
NONOVERFLOW SECTION — 7 TO 10 SLOPE
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL LOAD



HEPESDGHSQN-WBNBLNBFN

KEY PLAN LOCATION APPROX

SEE CALCS - NO. CSG-87-017 LFS 4-11-88 CSG 4-15-88

HEPE5DGHSQN-WBNBLNBFN

DOUGLAS DAM SEISMIC ANALYSIS
GROUND ACCELERATION = 0.09G

OPERATING BASIS EARTHQUAKE
NONOVERFLOW SECTION - 7 TO 10 SLOPE

Horizontal
R-M-S R-E-S-P-O-N-S-E

DAMPING= 5.00%

MASS POINT	DEFLECTION	SHEAR	MOMENT	ACCELERATION
BASE	0.0	0.84069E 05	0.73791E 07	0.90000E-01
1	0.23499E-04	0.84069E 05	0.68859E 07	0.90000E-01
2	0.52872E-04	0.83710E 05	0.63969E 07	0.90000E-01
3	0.88695E-04	0.82968E 05	0.59128E 07	0.90000E-01
4	0.13163E-03	0.81818E 05	0.54371E 07	0.90000E-01
5	0.18261E-03	0.80258E 05	0.49715E 07	0.90000E-01
6	0.24697E-03	0.77687E 05	0.42232E 07	0.90000E-01
7	0.41667E-03	0.73218E 05	0.35200E 07	0.90000E-01
8	0.57450E-03	0.67646E 05	0.28716E 07	0.90000E-01
9	0.76373E-03	0.61170E 05	0.22856E 07	0.10462E 00
10	0.98884E-03	0.54038E 05	0.17670E 07	0.12692E 00
11	0.12561E-02	0.46567E 05	0.13181E 07	0.15078E 00
12	0.15755E-02	0.39069E 05	0.93884E 06	0.17705E 00
13	0.19637E-02	0.31843E 05	0.62678E 06	0.20832E 00
14	0.24551E-02	0.25134E 05	0.37816E 06	0.25153E 00
15	0.30141E-02	0.19433E 05	0.21337E 06	0.31181E 00
16	0.39083E-02	0.14161E 05	0.68563E 05	0.43751E 00
17	0.49177E-02	0.66955E 04	0.0	0.60458E 00

ZZZ RMS ZZZ XBØØØR ØØØ

SEE CALCS - NO. CSG-87-017 LFS-4-11-88
CDW 4-15-88

WBNBLNBFN

EARTHQUAKE

TION - 7 TO 10 SLOPE 04/17/72

MENT	ACCELERATION
791E 07	0.90000E-01
859E 07	0.90000E-01
969E 07	0.90000E-01
128E 07	0.90000E-01
371E 07	0.90000E-01
715E 07	0.90000E-01
232E 07	0.90000E-01
200E 07	0.90000E-01
716E 07	0.90000E-01
856E 07	0.10462E 00
670E 07	0.12692E 00
181E 07	0.15078E 00
884E 06	0.17705E 00
678E 06	0.20832E 00
816E 06	0.25153E 00
337E 06	0.31181E 00
563E 05	0.43751E 00
	0.60458E 00

2

2 4 1 L R 004

-017 LFS-4-11-88
CDW 4-15-88

3

(2)

HEPE5DGHSQN-WBNBLN-BFN

DOUGLAS DAM SEISMIC ANALYSIS
GROUND ACCELERATION = 0.06G

OPERATING BASIS EARTHQUAKE
NONOVERFLOW SECTION - 7 TO 10 SLOPE

Vertical

R M S R E S P O N S E

DAMPING= 5.00%

MASS POINT	DEFLECTION	VERTICAL LOAD	ACCELERATION
BASE	0.0	0.51311E 05	0.60000E-01
1	0.51929E-05	0.51311E 05	0.60000E-01
2	0.10653E-04	0.50844E 05	0.60000E-01
3	0.16361E-04	0.49944E 05	0.60000E-01
4	0.22294E-04	0.48645E 05	0.60000E-01
5	0.28461E-04	0.46994E 05	0.60000E-01
6	0.39004E-04	0.44419E 05	0.60000E-01
7	0.49543E-04	0.40340E 05	0.60000E-01
8	0.59922E-04	0.35660E 05	0.60000E-01
9	0.69958E-04	0.30607E 05	0.64746E-01
10	0.79496E-04	0.25408E 05	0.73573E-01
11	0.88408E-04	0.20299E 05	0.81822E-01
12	0.96604E-04	0.15505E 05	0.89407E-01
13	0.10407E-03	0.11237E 05	0.96315E-01
14	0.11093E-03	0.76838E 04	0.10267E 00
15	0.11667E-03	0.51318E 04	0.10798E 00
16	0.12219E-03	0.32185E 04	0.11308E 00
17	0.12437E-03	0.12747E 04	0.11511E 00

ZZZ XXX ZZZ 77777 XXX

SEE CALCS - NO. CSG-87-017 LFS 4-11-88
CDW 4-15-88

NBFN

THQUAKE
- 7 TO 10 SLOPE 04/17/72

ATION

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11/1/18

LFS 4-11-89
CDW 4-15-89

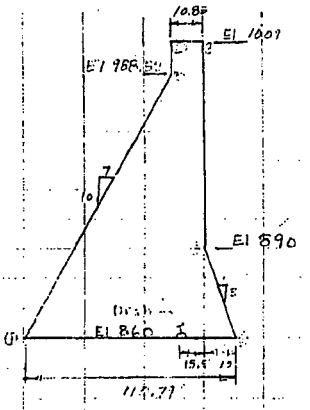
2

HEPE9DGHSQN-WBNBLNBFN SHEET X/12 OF

Douglas Nonoverflow - S.E. Stability
Base El 860, HW El 1002, TW El 919
One foot Section will be analyzed

Douglas Nonoverflow
O.B.E. Stability

COMPUTED GHK DATE 5-10-72
CHECKED REK DATE



DL. Coordinates:

①	0, 0	
②	89.96, 128.52	V
③	89.96, 141	0 S
④	130.71, 141	0 S
⑤	130.71, 30	89.96 S
⑥	110.79, 0	128.52 S
⑦	0, 0	89.96 S
		149 S
		100.79 S
		149 S
		100.79 S
		30 S
		110.79 S
		0 S
		Y

A = 7544.4996 DO
$\bar{X}$ = 68.4230 AO
$\bar{Y}$ = 48.9587 AO

7544.4996 I
0.15 X
DL = 1131.6749 AO

DL = 1132
X = -13.03
M = -14,752 K

HW: Horizontal
F = $\frac{1}{2}$ (.0625)(112)^2 = 630 K
a = 47.33
M = +29,800 K

HW: Vertical
F = (Chains) $\frac{1}{2}$ (144 + 112)(10) = 1284 K
$\bar{x}$ = 55.39 - $\frac{\frac{1}{2}(970)(\frac{4}{3}) + 15(112)(\frac{1}{2})}{970 + 15(112)}$
= 55.39 - 4.76 = 50.63'
M = -1020 K

$X = -68.42 - 55.39 = -13.03'$

TW: Horizontal
F = $\frac{1}{2}$ (.0625)(59)^2 = -109 K
a = 19.67
M = -2140 K

TW: Vertical
F = $\frac{1}{2}$ (59)(41.3)(.0625) = 762 K
X = +41.62
M = +317.5 K

HEPESDGHSQN-WBNBLNBFN

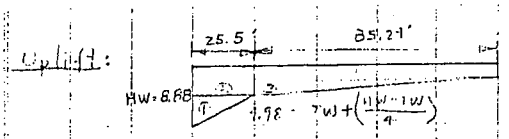
SHEET 13 OF

Douglas Newcastle - OBE Stability
HW = 11.88, HW El 1865, TW El 1819
One foot section

Douglas Newcastle
OBE Stability

COMPUTED GNA DATE 5-10-72
CHECKED [illegible] DATE [illegible]

Uplift:



	Force	arm	Moment
①	½(8.19)(25.5) = -49.75	-16.87'	2335
②	(1.29)(85.29) = -32.90	-12.64' ✓	1405
③	½(1.29)(85.29) = -55.00	-26.96' 1.47'	~~1452~~ 81
④	(3.69)(110.79) = -408.81	0	0
	-541.46	(-9.56)	5222
		4.98	+ 3219

Horizontal Earthquake Forces:

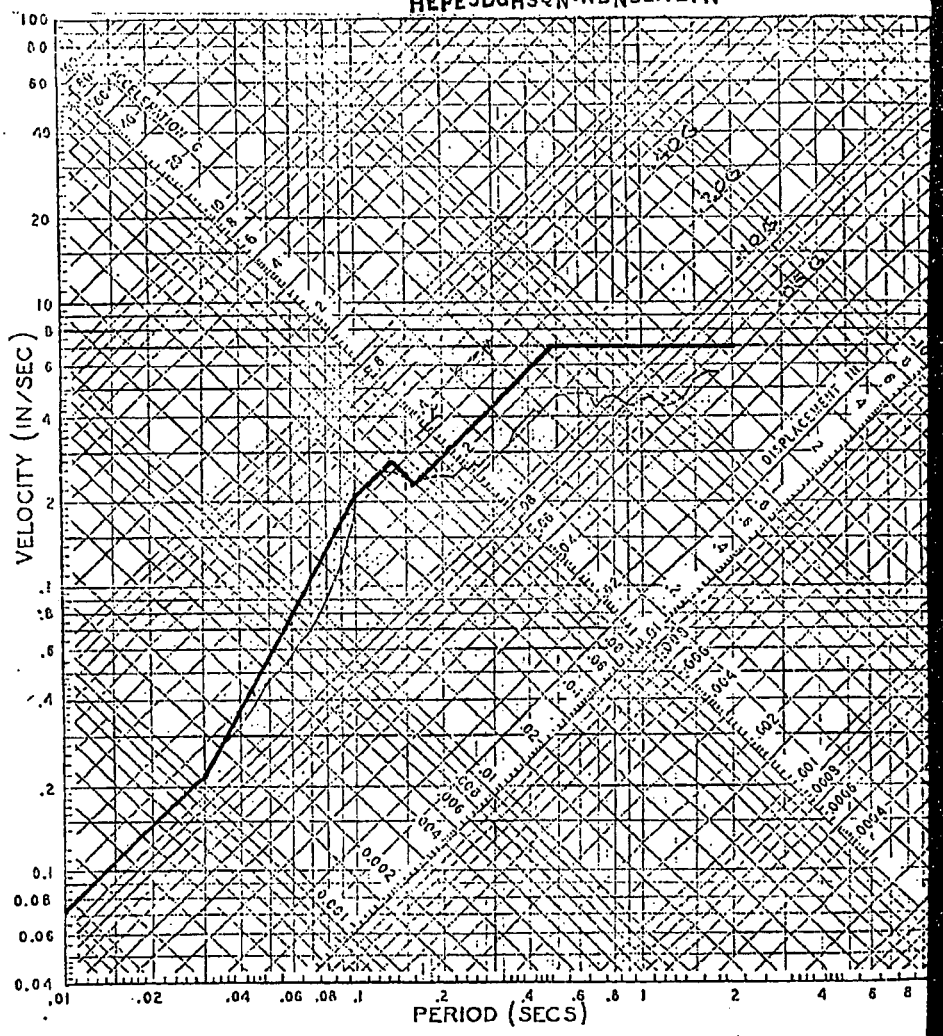
F = 81.07 K
M = 7379 K'

Vertical Earthquake Forces:

Mass Pt	Force	arm	Moment	
1	0.47	1.79	0.84	0.84
2	0.79	2.69	2.12	1.28
3	1.30	3.89	5.06	2.94
4	1.65	4.89	8.05	7.14
5	2.07	5.19 ✓	14.10	13.11
6	4.07	8.89 ✓	36.20	35.21
7	4.68	12.19 ✓	56.10	55.11
8	5.06	15.19 ✓	81.00	80.01
9	5.20	19.49 ✓	101.30	101.39
10	5.10	22.99 ✓	117.00	117.49
11	4.79	26.49 ✓	126.80	126.49
12	4.27	29.99 ✓	128.00	128.06
13	3.56	33.49 ✓	119.20	119.32
14	2.55	36.99 ✓	94.30	94.36
15	1.91	40.49 ✓	76.30	76.49
16	1.95 ✓	44.19 ✓	77.70	77.27
17	1.27	47.17	59.70	59.93
	-51.50 K		1077.50	1076.33

Sheet 14

HEPE5DGHSQN-WBNBLNBFN



DOUGLAS DAM - 7:10 SLOPE
HYDRODYNAMIC SPECTRUM
OPERATING BASIS EARTHQUAKE

~~E. HH CE: CS~~ CE'D LFS 4-15-88

SEE CALS - NO. CSG-87-017 aDW 4-13-88

SHEET 15 OF

HEPE5DGHSQN-WBNBLNBFN DOUGLAS

CHECK AVG ACCELERATION OF DAM

COMPUTED RBR DATE 6-2-72

CHECKED RNA DATE 6-1-72

POINT	WT	ACCEL	WT x ACCEL	ARM	MOMENT
1	97.09	0.09	8.74	6.0	52.43
2	91.57	0.09	8.22	12.0	98.68
3	85.75	0.09	7.72	18.0	138.92
4	80.03	0.09	7.20	24.0	172.86
5	97.76	0.09	8.80	30.0	263.95
6	113.00	0.09	10.17	40.0	406.80
7	102.07	0.09	9.19	50.0	459.32
8	91.14	0.09	8.20	60.0	492.16
9	80.29	0.10462	8.40	70.0	588.00
10	69.44	0.12692	8.81	80.0	705.07
11	58.59	0.15078	8.85	92.0	796.44
12	47.74	0.17705	8.45	100.0	845.00
13	36.89	0.20832	7.68	110.0	845.37
14	24.86	0.25153	6.25	120.0	750.36
15	17.72	0.31181	5.53	128.52	711.11
16	17.19	0.43751	7.52	138.76	1043.59
17	11.08	0.60458	6.70	149.00	998.11
		Σ	136.43		9368.14

$\bar{q} = 9368.14 \div 136.43 = 68.67$

@ $\bar{q} = 70'$ Accel = 0.105 g

HEPE5DGHSQN-WBNBLNBFN SHEET 16 OF

Douglas Dam - OBE.
Base El 943, HW 1602, TW 919

Douglas Dam
OBE Stability

COMPUTED RBK DATE 5-31-72
CHECKED G.A.B DATE 6-1-72

Hydrodynamic Force: (HW)

n = 1 $T_1 = \frac{4(142)}{4720} = 0.12$

$S_1' = 0.34$

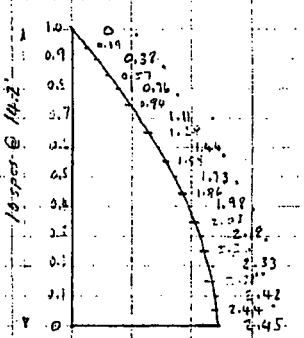
n = 2 $T_2 = 0.24$

$S_2^2 = (0.115)^2$

IGNORE 2ND MODE. THIS TERM APPROACHES 0

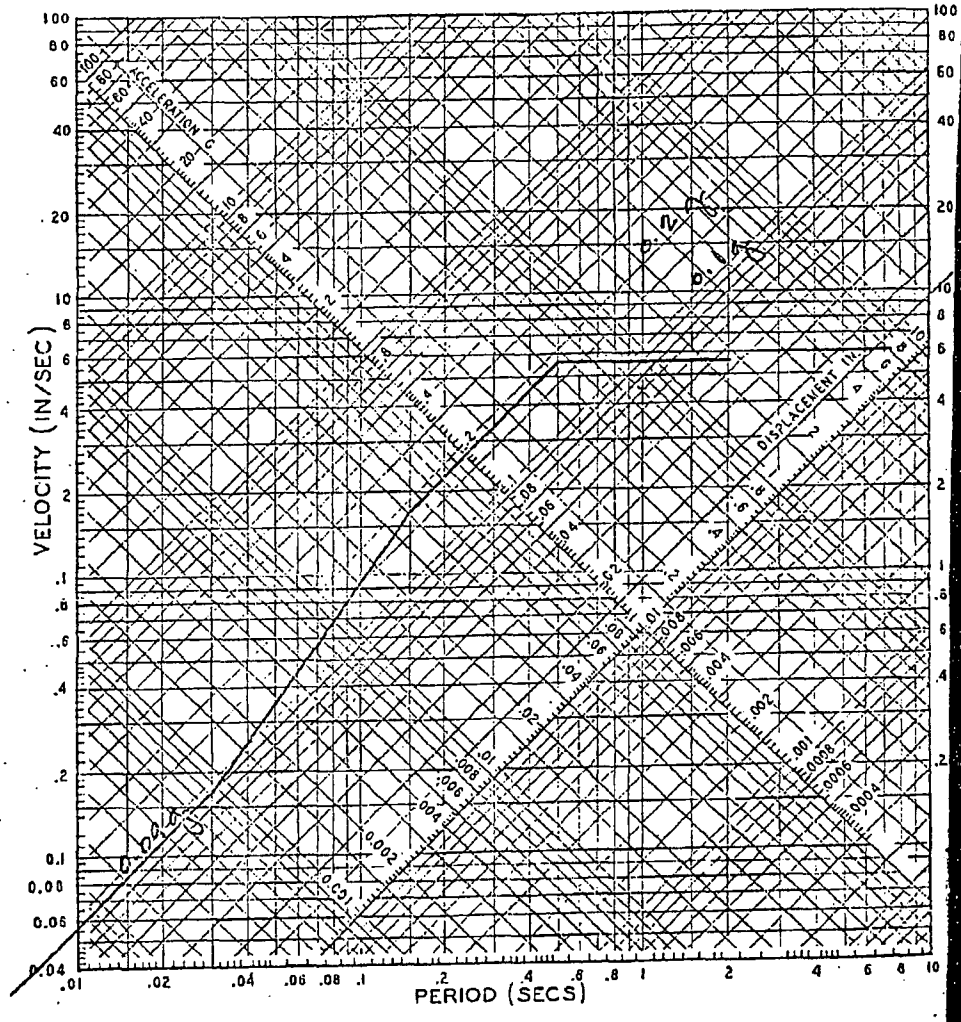
@ $Y/H = 0$ $P = \frac{(0.0625)(142)(2)}{\pi^2}(1)(0.34) = 2.45$

Y/H = 0.1	P = 2.45 (0.988) =	2.42
0.2	" (0.951) =	2.33
0.3	" (0.891) =	2.18
0.4	" (0.809) =	1.98
0.5	" (0.707) =	1.73
0.6	" (0.588) =	1.44
0.7	" (0.454) =	1.11
0.8	" (0.309) =	0.76
0.9	" (0.156) =	0.38
1.0	" (0) =	0



	Force	Arm	Moment
14.2 (2.40) =	34.65	7.1	246.00
14.2 (2.38) =	33.80	21.3	719.85
14.2 (2.26) =	32.09	35.5	1139.27
14.2 (2.08) =	29.54	49.7	1467.94
14.2 (1.86) =	26.41	63.9	1687.73
14.2 (1.59) =	22.58	78.1	1763.34
14.2 (1.28) =	18.18	92.3	1677.64
14.2 (0.94) =	13.35	106.5	1421.56
14.2 (0.57) =	8.09	120.7	976.95
14.2 (0.19) =	2.70	134.9	363.96
	221.39		11464.24

Sheet 17



OPERATING BASIS EARTHQUAKE
HYDRODYNAMIC SPECTRUM

HEPE5DGHSQN-WBNBLNBFN

SEE CALS - No. CSG-87-017

CDW 4-15-88
LFS 4-15-88

NSM DEGREDW DRY STABILITY DAT DOUGLAS

SHEET #18 OF

HW LL 1222 TW EL 919

BASE EL 860

HEPE5DGHSQN-WBNBLNBFN

COMPUTED RBR DATE 5-31-72

CHECKED GNA DATE 6-1-72

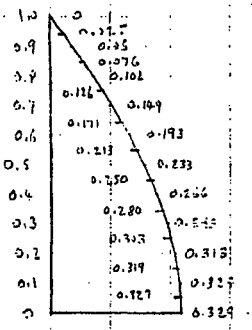
HYDRODYNAMIC FORCE (TW)

$T_1 = \frac{4(59)}{4720.} = 0.05$ FROM HYDRODYNAMIC SPECTRUM $S = 0.11$

IGNORE MODE 2

@ $Y/H = 0$ $P = \frac{0.0625(59)(8)(1)(0.11)}{\pi^2} = 0.329$

@ Y/H =	0.1	P = 0.329	(0.988) =	0.325
"	0.2	"	(0.951) =	0.313
"	0.3	"	(0.891) =	0.293
"	0.4	"	(0.809) =	0.266
"	0.5	"	(0.707) =	0.233
"	0.6	"	(0.589) =	0.193
"	0.7	"	(0.454) =	0.149
"	0.8	"	(0.309) =	0.102
"	0.9	"	(0.156) =	0.05
"	1.0	"	(0) =	0



	FORCE	ARM	MOMENT
5.9 (0.327) =	1.93	2.95	5.69
5.9 (0.319) =	1.88	8.85	16.66
5.9 (0.303) =	1.79	14.75	26.37
5.9 (0.280) =	1.65	20.65	34.11
5.9 (0.250) =	1.48	26.55	39.16
5.9 (0.213) =	1.26	32.45	40.78
5.9 (0.171) =	1.01	38.35	38.69
5.9 (0.126) =	0.74	44.25	32.96
5.9 (0.076) =	0.45	50.15	22.49
5.9 (0.025) =	0.15	56.05	8.27
	12.34		265.12

SHEET 819 OF

NON-OVERFLOW DAM STABILITY OBE DOUGLAS

HWY 61 1002 TWEL 919

BASE EL 860

COMPUTED BY RAK DATE 6-1-72

CHECKED BY HEPE5DGHSQN-WBNBLNBFN DATE

SUMMATION OF NON EARTHQUAKE FORCES

(+)

ITEM		H	V	ARM	MOMENT ABT CG
DL			↓ 1132'		− 14750'
HW (VERT)	1 SQ		↓ 79.4'		− 4017'
" (HORIZ)		← 630'			+ 29800'
TW (VERT)			↓ 76.2'		+ 3170'
(HORIZ)		→ 109'			− 2140'
UPLIFT	54 =		↑ 546.5'		+ 3819'
		← 521'	↓ 741.1'		+ 15882'

$ECCENTRICITY_{CG} = 15882 \div 741.1 = 21.43'$

$f = \frac{741.1}{110.79}\left(1 \pm \frac{6(21.43)}{110.79}\right) = 6.69(1 \pm 1.16)$

$f_U = -1.07\ KSF = 7.4\ psi\ TENSION$

$f_D = 14.45\ KSF = 100.4\ psi\ COMPR$

SUMMATION OF ALL FORCES

(+)

ITEM	H	V	MOMENT ABT CG
NON-EARTHQUAKE FORCES	← 521	↓ 741	+ 15882'
EARTHQUAKE FORCES			
DYNAMIC (HORIZ)	← 84'		+ 7379'
" (VERT)		↑ 51'	+ 1096'
HYDRODYNAMIC (HW)	← 221'		+ 11424'
" (TW)	← 12		+ 225'
	← 838	↓ 690	+ 36086'

$ECCENTRICITY_{CG} = 36086 \div 690 = 52.30'$ RESULTANT IS 5819 − 52.30 = 3.09' INSIDE BASE

$f = \frac{690}{110.79}\left(1 \pm \frac{6(52.30)}{110.79}\right) = 6.23(1 \pm 2.83)$

$f_U = -11.4\ KSF = 79.2\ psi\ TENSION$

$f_D = 23.5\ KSF = 165.7\ psi\ COMPR$

SHEET 820 OF

NON-OVERFLOW DAMS STABILITY OBS DOUGLAS
NWRR 1038 TVA 22 919
CASE 22 850

COMPUTED RKP DATE 5-1-72
CHECKED CNR DATE 6 4 72

HEPE5DGHSQN-WBNBLNBFN

$\frac{\Sigma H}{\Sigma V} = \frac{838}{690} = 1.21$

$Q = \frac{1411 + 150}{838} = 5.3$

$\frac{\Sigma H}{A} = \frac{838}{110.79} = 7.56$ KSF = 52.5 psi

MAX $f = \frac{2(690)}{3(3.09)} = .149$ KSF = 1035 psi (ASSUMING BASE CRACKS & NO UPLIFT CHANGE)

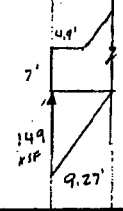
$Q = \frac{0.65(690) + 150}{838} = \frac{598}{838} = 0.535$ (ASSUMING NO FRICTION DEVELOPED ON BASE).

FOR Q=1 SHEAR = $\frac{838 - 448}{110.79} = \frac{390}{110.79} = 3.52$ KSF = 24.4 psi

FACTOR OF SAFETY AGAINST OVERTURNING ABOUT TOE

ITEM	FORCE	ARM	OT MOMENT	RESISTING MOM
DL	1137	62.42		71451
NW (VERT)	79.4	105.99		8416
" (HORIZ)	630	47.33	29800	
TW (VERT)	76.2	13.77		1049
" (HORIZ)	109	19.67		2140
UPLIFT	546.5	62.37	34085	
DYNAMIC FORCE (HORIZ)	84		7379	
" (VERT)	51.3	76.76	3938	
HYDRODYNAMIC " (UW)	221		11464	
" " (TW)	12		265	
			86931	89056

$F.S. = \frac{89056}{86931} = 1.02$



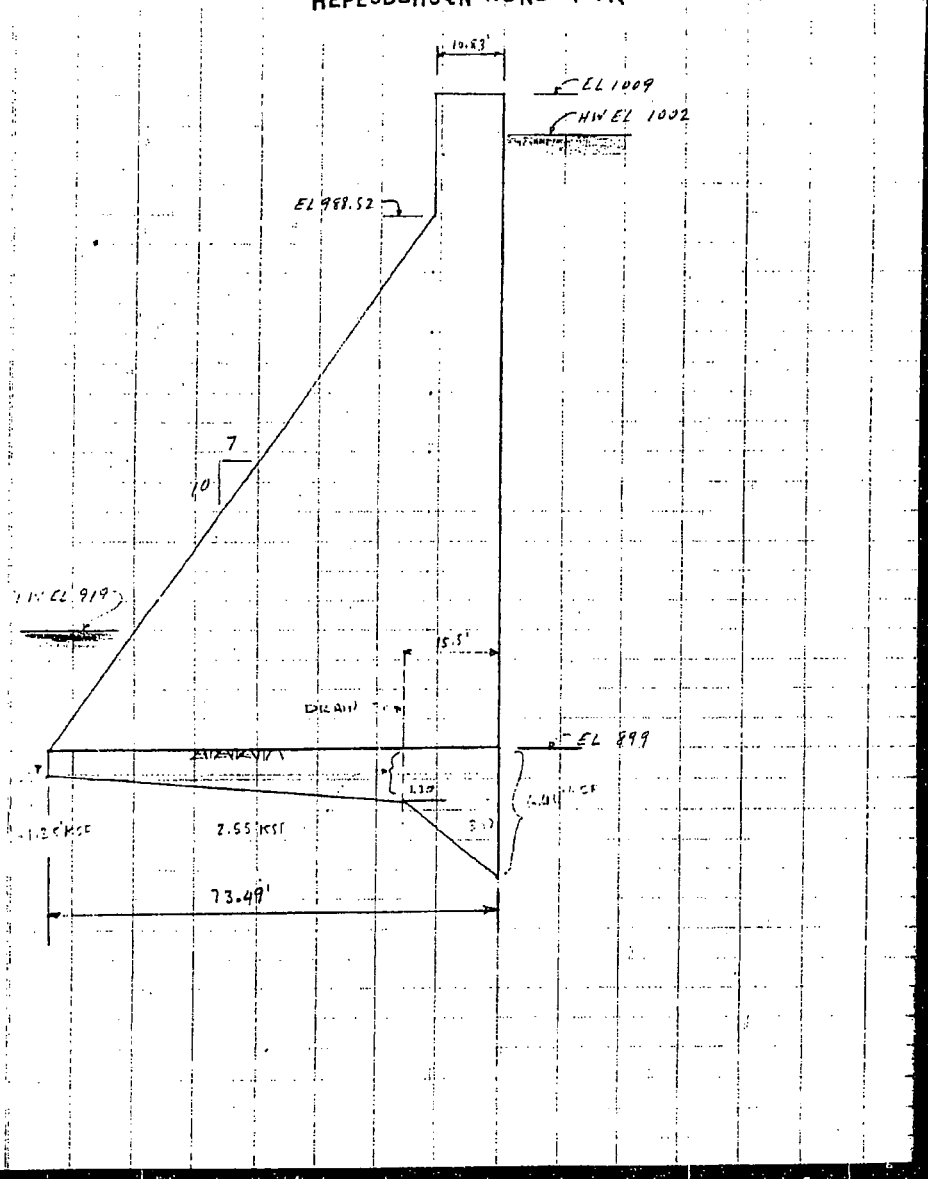
BOUYANT WT OF CONC = $[7(9.27) + \frac{1}{2}(4.37)(4.24)](0.0975) = 6.9^{K}$ say 7

NET UPLIFT = 690 − 7 = 683 K

SHEAR = $\frac{683}{13.24}$ = 51.6 KSF = 358 psi

BASE EL. 899 (ON ROCK)

HEPE5DGHSQN-WBNBLNBFN



TVA 483 (REV. 9-57)

SHEET 122 OF

NOR OVERFLOW DAM . STABILITY . SBE

COMPUTED REV DATE 8-1-72

RW EL 1002 TW EL 919

CHECKED CNA DATE 8-2-72

RRTS EL 899

HEPESDGHSQN-WBNBLNBFN

SUMMATION OF FORCES (NON EARTHQUAKE)

ITEM		H	V	ARM	MOMENT ABT HEEL	
D.L.	(10.83)(110)(0.15)		↓ 179'	5.92'	970'	C
	½(62.66)(89.13)(0.15)		↓ 830'	44.71'	17,500'	C
UPLIFT	(6.33)(73.84)		↑ 91.8'	36.75'	3380'	CW
	½(1.3)(33.0)		↑ 17.2'	39.83'	1315'	CW
	(1.3)(15.5)		↑ 20.2'	7.75'	156'	CW
	½(3.29)(15.5)		↑ 30.1'	5.17'	1156'	CW
HW	½(2.44)(103)	← 332'		24.53'	11,900'	C
TW	½(1.25)(25)	→ 12.5		3.27'	84'	CW
	½(2.44)(10)(60.25)		↓ 8.8'	62.82	605'	C
		← 319.7'	↓ 478.0'	(59.2')	28,366'	C

e_{CG} = 59.2 - 36.75 = 22.45' DIST'R OF C'G

RESULTANT IS 14.3' INSIDE MATE

$f = \frac{478}{73.5}\left(1 \pm \frac{6 \times 22.45}{73.5}\right) = 6.82\left(1 \pm 1.83\right)$

$f_{up} = -4.83$ KSF = 33.7 psi TENSION

$f_{dn} = 18.5$ KSF = 119 psi COMPR

SHEET 123

NUMMEDAL DRAG COEFFICIENT = 0.66
NW 21 1007 TW 22 977
DATE 22 899

COMPUTED ROK DATE 8-2-72
CHECKED GNA DATE 8-2-72

HEPE5DGHSQN-WBNBLNBFN

FOR DYNAMIC FORCES USE SAME AS FOR TELLICO
(VARY DT CENTERLINE HT ON ROCK)

HORIZ FORCE = 36 K
HORIZ MOM = 2383 K'

VERT FORCE = 22 K
VERT MOM = 34.5 K' (MAY NEED)

FIGURE HYDRODYNAMIC FORCES & MOMENTS USING TELLICO SPECTRA

H:W

$T_1 = \frac{4(103)}{4720} = 0.87$; 5 + 0.19

@ Y/H = 0 $P = \frac{0.0075(103)(8)(1)(0.19)}{32.2} = 0.494$

Y/H	P = 0.494 (0.98?) =	0.982	0.958
0.1	(0.951) =	0.965	0.934
0.2	(0.891) =	0.925	0.915
0.3	(0.809) =	0.864	0.845
0.4	(0.707) =	0.792	0.753
0.5	(0.588) =	0.695	0.608
0.6	(0.454) =	0.575	0.510
0.7	(0.309) =	0.450	0.379
0.8	(0.157) =	0.301	0.237
0.9	0 =	0.155	0.078
1.0		0	

	FORCE	ARM	MOMENT
10.2 (0.958)	10.2	5.15	52.5
(0.934)	9.95	15.45	153.5
(0.915)	9.05	25.75	243
(0.845)	8.7	36.05	314
(0.753)	7.75	46.35	359
(0.608)	6.34	56.65	177
(0.510)	5.34	66.95	357
(0.379)	3.9	77.25	302
0.237	2.39	87.55	209
0.078	.7	97.95	70
	Σ 70.39		2444

TVA 869 (REV. 9-51)

SHEET 24 OF

NON OVER FLOW DAM - STABILITY - DBE

DOUGLAS

NIVEL 1002 TW EL 719

BASE EL 697

COMPUTED RBV DATE 8-2-72

CHECKED [illegible] DATE 8-2-72

HEPE5DGHSQN·WBNBLNBFN

HYDRODYNAMIC FORCE (TW)

$n = 1$ $T_1 = \frac{4(20)}{4720} = 0.017$ $S_1 = 0.09$

@ $Y/H = 0$ $P = \frac{0.0625(20.0)(2)(1)(0.09)}{\pi} = 0.0915$

Y/H				
0.2	$P = 0.0915$	(0.951)	$= 0.087$	0.092
0.4		(0.809)	$= 0.074$	0.085
0.6		(0.522)	$= 0.050$	0.064
0.8		(0.209)	$= 0.028$	0.041
1.0	"	(0)	$= 0$	0.010

$4 \cdot (0.092)$	0.357	2'	0.714
(0.085)	0.322	6'	1.932
(0.064)	0.256	12'	2.56
(0.041)	0.154	18'	2.7
(0.010)	0.056	18'	1.01
	1.155		9.586 K

SHEET 125 OF

DOUGLAS

NOR. VERTICAL DAM - STABILITY - DAS

FM EL 1225 TW EL 915

BASE EL 555 (ON ROCK)

COMPUTED BY BR DATE 8-2-72

CHECKED BY DATE

HEPESDGHSQN-WBNBLNBFN

SUMMATION OF ALL FORCES

ITEM		H	V	MOMENT ARM	MOMENT
FROM SK 2	→	319.5'	↓ 428.0	25.385'	8107
DYNAMIC FORCES	→	36'		2.383'	86
			↑ 22'	15.345'	338
HYDRODYNAMIC FORCES:	→	65'		2.444'	159
	→	1'		9'	9
	→	422'	↓ 406'		8699'

$e_{CG} = \left(\frac{29\,674}{406}\right) - 36.75 = 36.85'$ DNSTR OF C.G.

RESULTANT IS 0.1' OUTSIDE BASE

$f = \frac{406}{73.5}\left(1 \pm \frac{6 \times 36.85}{73.5}\right) = 5.52(1 \pm 3.01')$

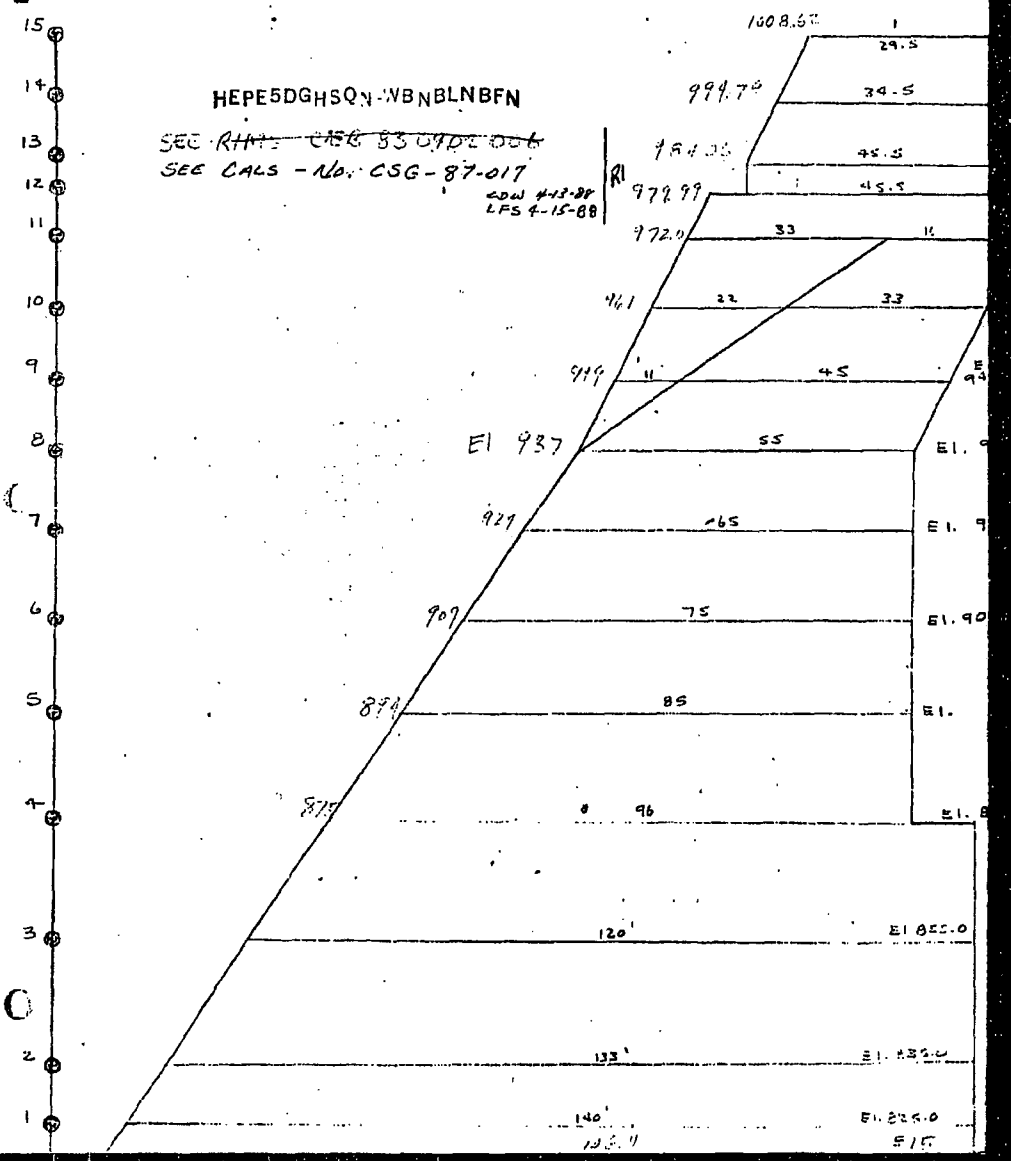
$f_U = -11.1\ KSF = 77.3\ psi$ TENSION

$f_D = 22.2\ KSF = 154\ psi$ COMPR.

$\frac{\Sigma H}{\Sigma V} = \frac{0.2}{406} = 1.0K'$

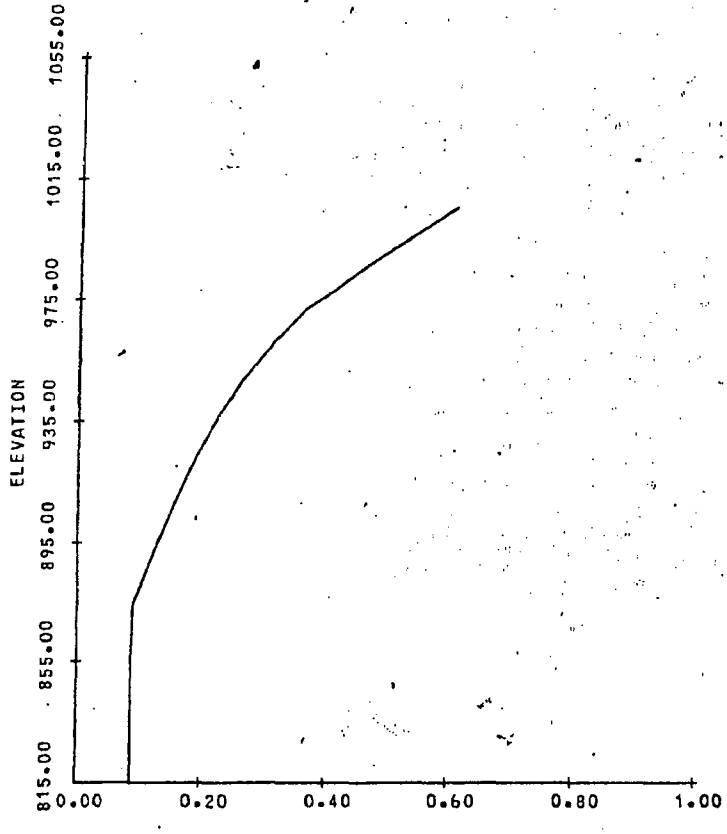
Sheet 26

LUMPED MASS MODEL
DOUGLAS SPILLWAY



Sheet 27

TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL ACCELERATION



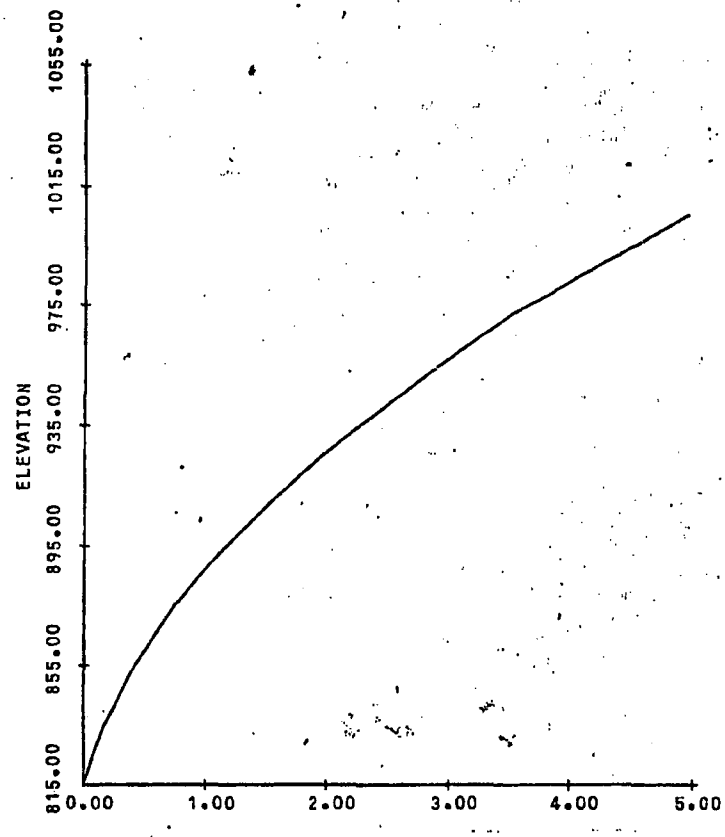
HEPE5DGHSQN-WBNBLNBFN

~~SEE RIM: CER. 7501702 006~~
SEE CALS - NO. CSG-87-017
EDW 4-13-88
CFS 4-15-88

R1

Sheet 28

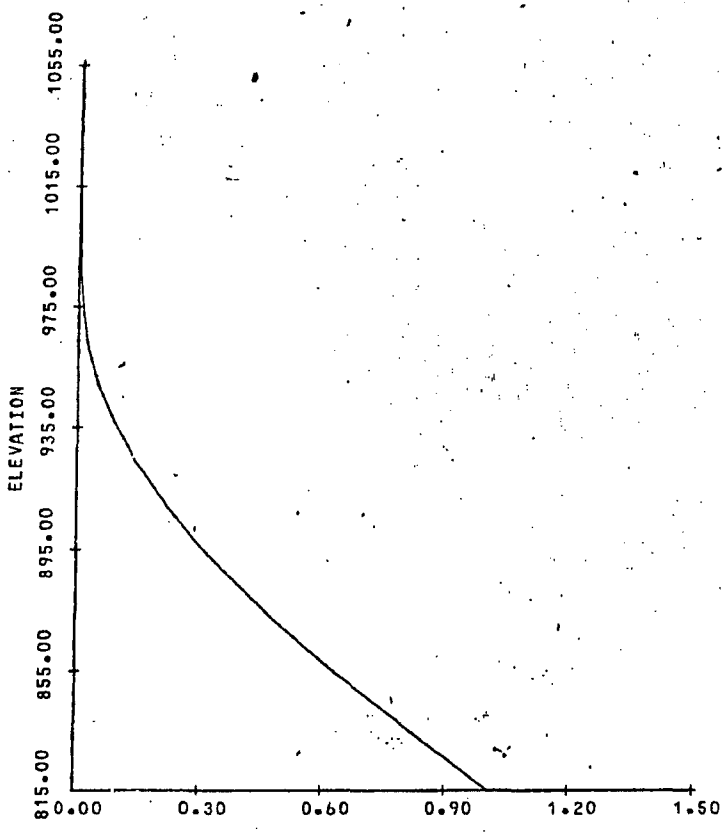
TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL DISPLACEMENT



HEPE5DGHSQN-WBNBLN BFN

~~SEE RIMS CES 830102006~~
SEE CALS - No. CSG-87-017
ADW 4-13-88
LFS 4-15-88

TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.096
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL BENDING MOMENT

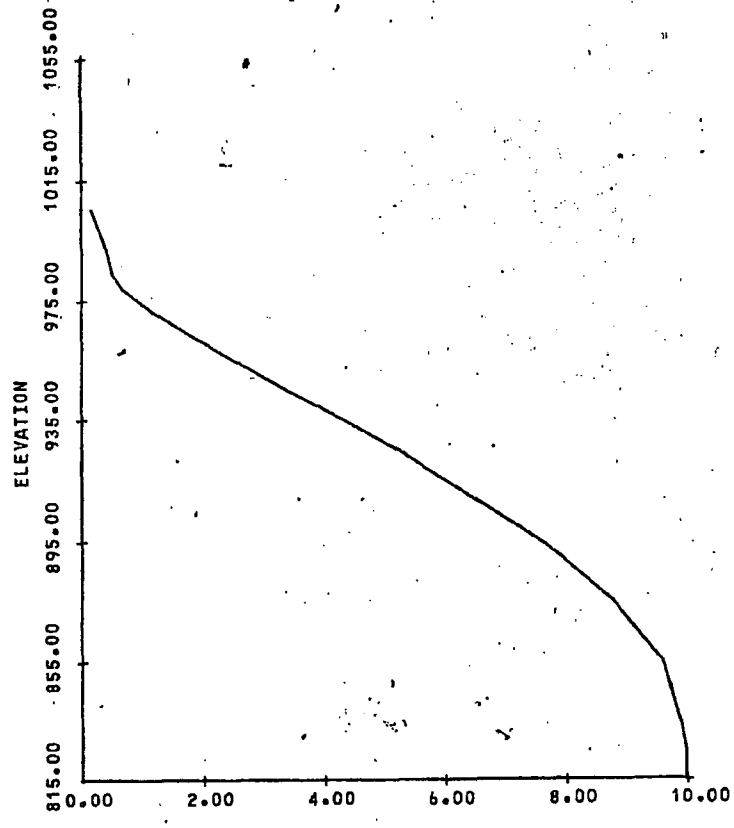


HEPE5DGHSQN-WBNBLNBFN

~~SEE RIMS CCB 551702 006~~
SEE CALS - No. CSG - 87-017
CDW 4-15-88
CFS 4-15-88

R1

TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.09G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
HORIZONTAL SHEAR

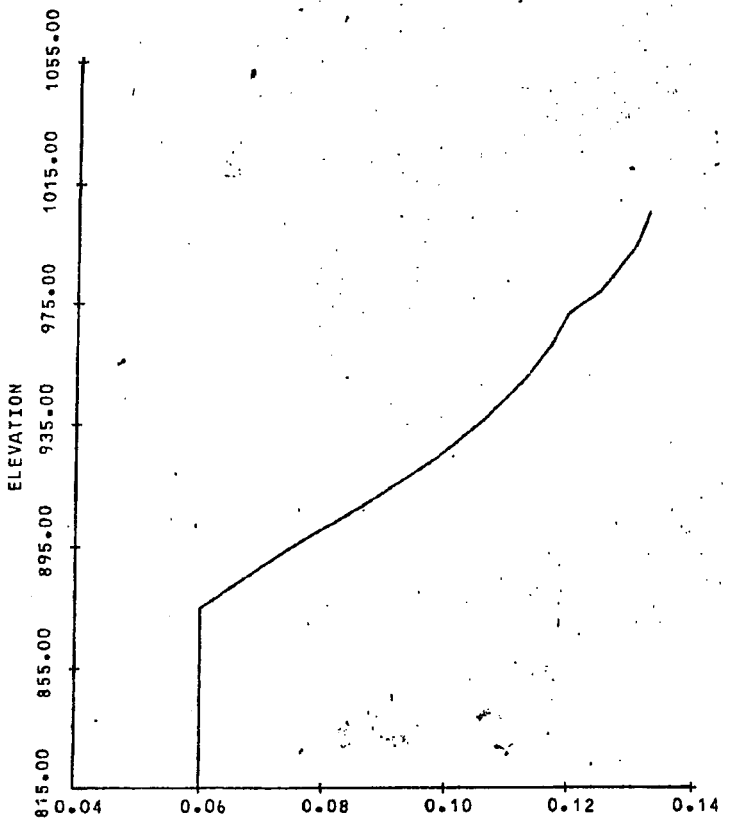


HEPE5DGHSQN-WBNBLNBFN

~~SEE RIMS CEB 830702006~~
SEE CALS- No. CSG-87-017
CDW 4-13-88
LFS 4-15-89

R1

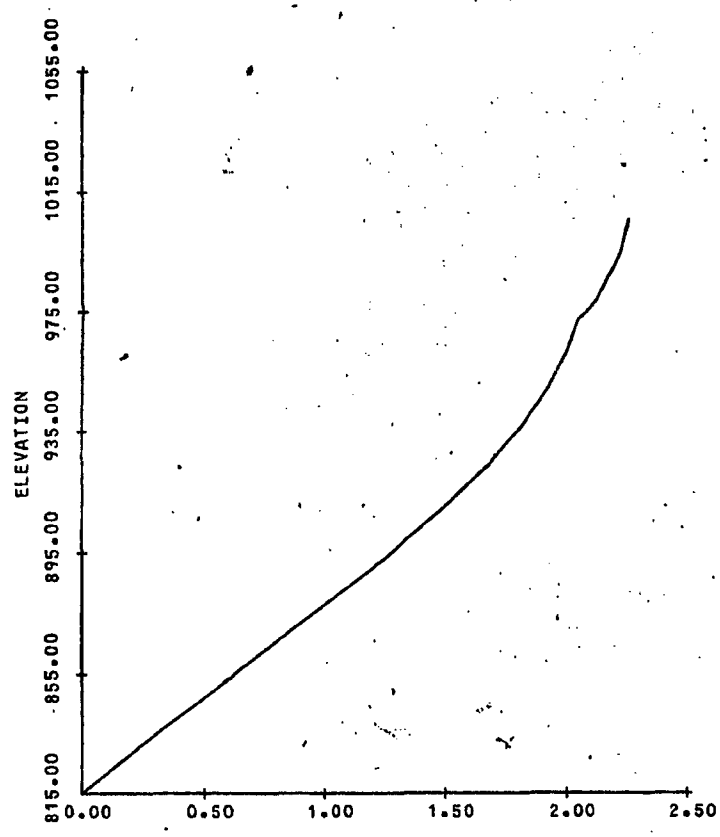
TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL ACCELERATION



HEPE5DGHSQN-WBNBLNBFN

~~SEE RMS - EB 830402 006~~
SEE CALS - NO. CSG-87-017
EDW 4-15-87
CFS 4-15-87

TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL DISPLACEMENT



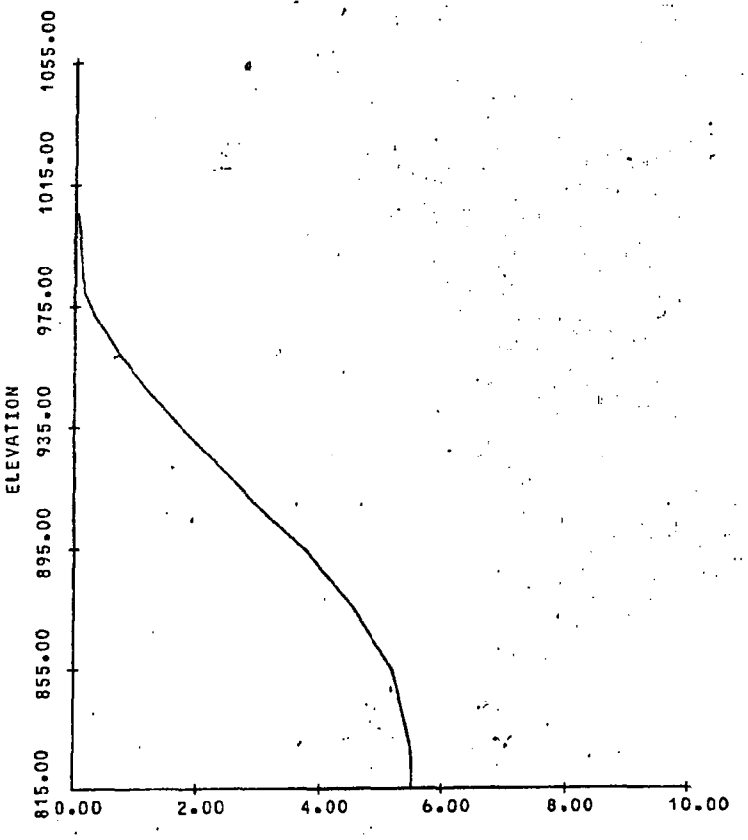
HEPE5DGHSQN-WBNBLNBFN

~~SEE RIMS .CEC F30702 006~~
SEE CALS - No. CSG-87-017
CDW 4-13-87
LFS 4-15-87

R1

Sheet 33

TENNESSEE VALLEY AUTHORITY 04/20/72
DOUGLAS DAM SEISMIC ANALYSIS
OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G
SPILLWAY SECTION
SPECTRAL EARTHQUAKE RESPONSE
5.0 PERCENT DAMPING
VERTICAL LOAD



NEPESDGHSQN-WBNBLNBFN

~~SEE XHM: CEB 73-04[illegible]~~

SEE CALS - No. CSG-87-017

CDW 4-15-88
LFS 4-15-88

R1

DOUGLAS DAM SEISMIC ANALYSIS
GROUND ACCELERATION = 0.096

OPERATING BASIS EARTHQUAKE
SPILLWAY SECTION

RMS RESPONSE

DAMPING= 5.00%

MASS POINT	DEFLECTION	SHEAR	MOMENT	ACCELERATION
BASE	0.0	0.99783E 07	0.10112E 10	0.90000E-01
1	0.75544E-04	0.99783E 07	0.91325E 09	0.90000E-01
2	0.16918E-03	0.98815E 07	0.81647E 09	0.90000E-01
3	0.41303E-03	0.95892E 07	0.62929E 09	0.90000E-01
4	0.74149E-03	0.87868E 07	0.45774E 09	0.93947E-01
5	0.11421E-02	0.76893E 07	0.31470E 09	0.12895E 00
6	0.15140E-02	0.65016E 07	0.21887E 09	0.15821E 00
7	0.19326E-02	0.53388E 07	0.13988E 09	0.19161E 00
8	0.23286E-02	0.41506E 07	0.86512E 08	0.22649E 00
9	0.27180E-02	0.30591E 07	0.50136E 08	0.26549E 00
10	0.31286E-02	0.20355E 07	0.25887E 08	0.31257E 00
11	0.35205E-02	0.11504E 07	0.13285E 08	0.36341E 00
12	0.38650E-02	0.67914E 06	0.78660E 07	0.41675E 00
13	0.40429E-02	0.50837E 06	0.57479E 07	0.44595E 00
14	0.45043E-02	0.37016E 06	0.17770E 07	0.52620E 00
15	0.49542E-02	0.16561E 06	0.0	0.60675E 00

HEPE5DGHSQN-WBNBLNBFN

~~SEE RIMS CEC330702 006~~

SEE CALS - No. CSG-87-017

GDW 4-15-88
LFS 4-15-88

IQUAKE

04/20/72

ACCELERATION

10	0.90000E-01
09	0.90000E-01
09	0.90000E-01
09	0.90000E-01
09	0.93947E-01
09	0.12895E 00
09	0.15821E 00
09	0.19161E 00
08	0.22649E 00
08	0.26549E 00
08	0.31257E 00
08	0.36341E 00
07	0.41675E 00
07	0.44595E 00
07	0.52620E 00
	0.60675E 00

SQN-WBNBLNBFN

~~20702 DOE~~

17-017

CDW 4-15-88
LFS 4-15-88

RI

2

DOUGLAS DAM SEISMIC ANALYSIS — OPERATING BASIS EARTHQUAKE
GROUND ACCELERATION = 0.06G — SPILLWAY SECTION

R M S R E S P O N S E

DAMPING= 5.00%

MASS POINT	DEFLECTION	VERTICAL LOAD	ACCELERATION
BASE	0.0	0.55197E 07	0.60000E-01
1	0.15021E-04	0.55197E 07	0.60000E-01
2	0.30536E-04	0.54308E 07	0.60000E-01
3	0.62471E-04	0.51795E 07	0.60000E-01
4	0.95403E-04	0.45608E 07	0.60000E-01
5	0.12634E-03	0.37788E 07	0.74063E-01
6	0.14827E-03	0.29996E 07	0.86920E-01
7	0.16745E-03	0.22950E 07	0.98161E-01
8	0.18137E-03	0.16476E 07	0.10632E 00
9	0.19165E-03	0.11153E 07	0.11235E 00
10	0.19940E-03	0.67167E 06	0.11689E 00
11	0.20448E-03	0.33542E 06	0.11987E 00
12	0.21287E-03	0.17795E 06	0.12479E 00
13	0.21610E-03	0.12645E 06	0.12668E 00
14	0.22261E-03	0.86946E 05	0.13050E 00
15	0.22599E-03	0.36161E 05	0.13248E 00

HEPE5DGHSQN-WBNBLNBFN

~~SEE RIMS CEE 02 702 006~~

SEE CALS - No. CSG - 87-017
CDW 4-13-88
LFS 4-15-88

RI

QUAKE

04/20/72

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VBNBLNBFN

~~2 006~~

17
W 4-13-88
S 4-15-88

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3

(3)

TVA 489 (REV 9-57)

SHEET X 36

Douglas Spillway [illegible]
[illegible] Elev 911 [illegible]
4.5:1 slope [illegible]
Level El 770

Douglas Spillway
O.B.E. Stability

COMPUTED JNA DATE 5-11-72
CHECKED [illegible] DATE [illegible]

HEPE5DGHSQN-WBNBLNBFN

D.L. above El 815 = 100,9?0K
x = 146.10 − 55.41 = 17??

Data for Douglas Spillway
by M.M. Ross, 7/31/36, Sht 12E

HW: horizontal
F = ½ (187)² (.0625)(146.5) = 50,750 K
d = 62.33'
M = 3,160,000 'K

Outward quantity for [illegible]

F = ½ (?0)² (.0625)(146) = −1280 K
d = 125.67'
M = −12,000 'K

HW: Vertical

Force	arm	Moment
(.0625)½(2.45)(?0) = 0.735	2.83	2.15
(.0625)(62)(?0) = 33.75	5.0	11.3.75
(.0625)(?)(?0) = 15??	[illegible]	50.00
51.1??	4.52	246.20

F = 51?(146.5) = 2550 K M = (−73.25+11.52)(2550) = −173,500 'K

TW: horizontal
F = ½ (104)² (.0625)(146.5) = −15,750 K
d = 69.67'
M = −546,000 'K

TW: Vertical
F = ½ (104)(104)(.0625)(.0625)(146.5) = 4,775 K
x = 73.05 − 65.?? = 5.11'
M = +510,000 'K

Douglas Spillway - O.B.E. Stability
Base El 3[illegible], HW [illegible], TW [illegible]

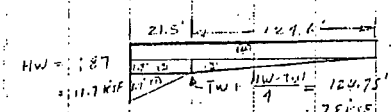
SHEET 137

Douglas Spillway
O.B.E. - Stability

COMPUTED RBK DATE 6-8-72
CHECKED CNA DATE 6-12-72

HEPE5DGHSQN-WBNBLNBFN

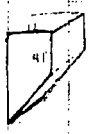
Uplift:



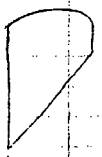
ITEM	FORCE	ARM	MOMENT$_{CG}$
① ½(3.9)(21.5)(46.5)	1950	65.89	128 453
② (1.3)(21.5)(46.5)	1300	62.3	80 970
③ ½(1.3)(124.6)(46.5)	3766	10.02	37 736
④ (6.5)(146.1)(46.5)	44 159	0	
Σ	51175	(4.83)	247 159

BOUYANT FORCES ON UPSTR SECTION

PIER



		FORCE	ARM	MOMENT$_{CG}$
½ (12)(65+41)(6.5)(0.0625) =		251	68.5	17,100
[½ (9+33)(12) − ½ (4.8)(3.1)](6.0625)(60) =		610	67.95	41450



SHEET 38 OF

DOUGLAS

SPILLWAY. STABILITY ANALYSIS . OBE

HW EL 1002 TW EL 919 GATES OPEN

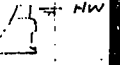
BASE EL 815

COMPUTED ROR DATE 6-2-72

CHECKED MM DATE

HEPE5DGHSQN-WBNBLNBFN

SUMMATION OF NON-EARTHQUAKE FORCES



ITEM	H	V	Mcg
DEAD LOAD		↓ 100970'	- 1176975'
UPLIFT		↑ 51175'	+ 247159'
HW ON HEEL		↓ 2127'	- 145295'
HW (HORIZ)	← 50750'		+ 3160000'
" "	→ 1280'		- 212000'
BOUYANT FORCES ON UPSTR SECTION		↑ 258'	+ 17709
		↑ 610'	+ 41450'
TW (HORIZ)	→ 15717'		- 544856'
" (VERT)		↓ 9949'	+ 508493'
	← 32753'	↓ 61003'	+ 1305676'

ECCENTRICITY = $\frac{1305676'}{61003'}$ = 21.40' DNSTR OF C.G.

$$f = \frac{61003'}{(46.5)(146.1)}\left(1 \pm \frac{6(21.4)}{146.1}\right) = 8.98'(1 \pm 0.88)$$

f_u = 1.08' KSF = 7.5' psi COMPR

f_D = 16.88' KSF = 117.2' psi COMPR

SHEET 439
DOUGLAS

CHECK AVG ACCEL OF SPILLWAY — COMPUTED RBR DATE 6-2-72
HEPE5DGHSQN-WBNBLNBFN — CHECKED NF DATE 6-12-72

POINT	WT	ACCEL	WT x ACCEL	ARM	MOMENT
1	10083	0.09	907.47	10.0	9074.70
2	14036	0.09	1263.24	20.0	25264.80
3	16901	0.09	1521.09	40.0	60843.60
4	13980	0.093947	1313.38	60.0	78802.74
5	10521	0.12895	1356.68	79.0	107177.94
6	8108.4	0.15821	1282.83	94.0	120586.01
7	6599.9	0.19161	1263.65	109.0	137737.70
8	5006.7	0.22649	1133.97	122.0	138344.02
9	3948.8	0.26549	1048.37	134.0	140481.16
10	2876.6	0.31257	899.14	146.0	131274.27
11	1313.8	0.36341	477.45	157.0	74959.34
12	412.76	0.41675	172.02	164.99	28381.21
13	311.80	0.44595	139.05	169.16	23521.23
14	389.18	0.52620	204.79	179.89	36839.05
15	272.97	0.60675	165.62	190.62	31571.35
			13148.75		1144859.12

$\bar{y}$ = 144859.12 ÷ 13148.75 = 87.07

@ $\bar{y}$ = 94' ACCEL = 0.15821

" " = 87.07' " = ?

" " = 79' " = 0.12895

BY INTERPOLATION AVG ACCEL = 0.14469 ok

SHEET B 40

SPILLWAY - STABILITY ANALYSIS - OBE

DESIGN

HW EL 1002 TW EL 919 GATES OPEN

BASE EL 815

COMPUTED RBR DATE 6.5.72

HEPE5DGHSQN-WBNBLNBFN

CHECKED [illegible] DATE [illegible]

EARTHQUAKE FORCES:

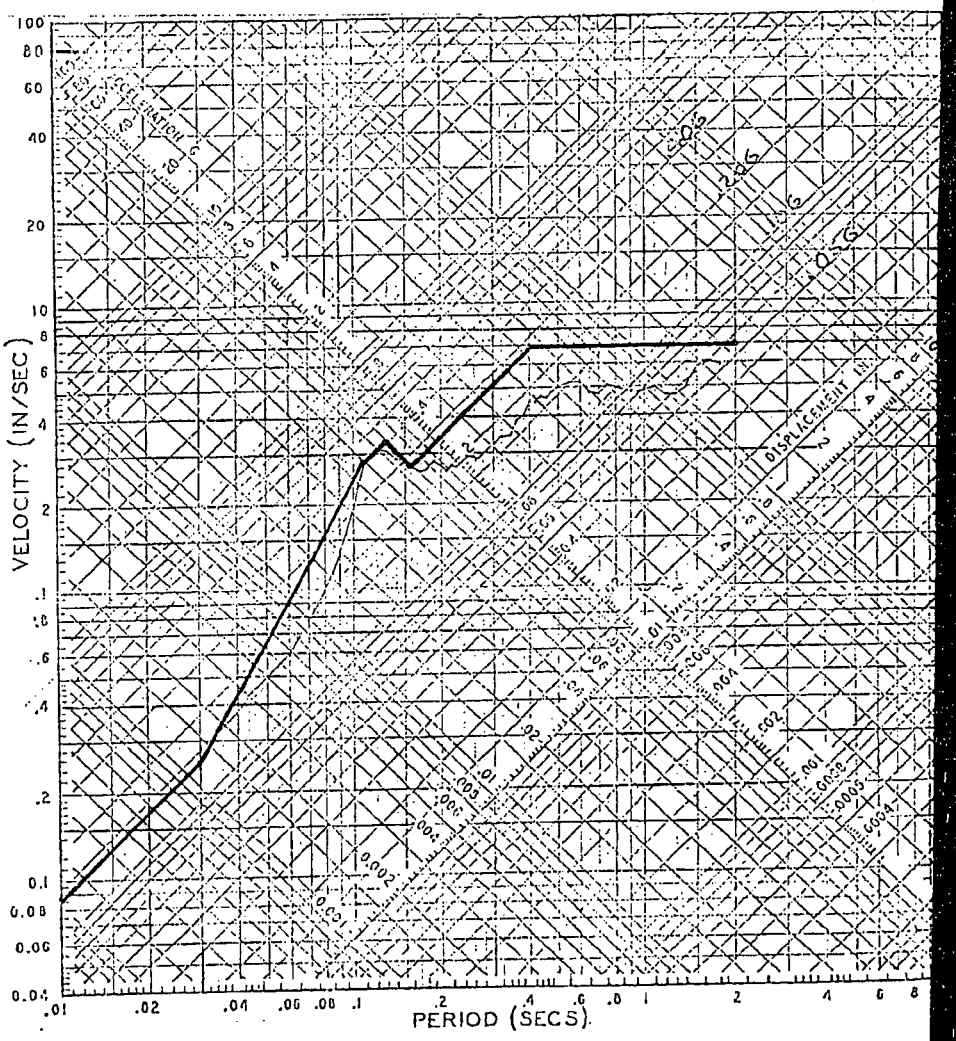
DYNAMIC (HORIZ)

FORCE = 9976.3 K MOMENT = 1,011,200 FT K

DYNAMIC (VERT)

MASS PT	FORCE	ARM	MOMENT CG
1	88.9	3.05	271.15
2	251.3	6.55	1646.02
3	618.7	13.05	8074.04
4	782.9	15.05	11769.10
5	779.2	20.55	16012.56
6	709.6	25.55	18002.53
7	649.4	30.55	19776.07
8	532.3	35.55	18923.27
9	443.63	41.05	18211.01
10	336.25	47.55	15988.69
11	157.47	50.55	7960.11
12	51.50	52.30	2693.45
13	39.50	52.30	2065.85
14	50.79	57.80	2935.66
15	36.16	60.30	2180.45
	5519.7	(26.54)	146 511.96

Sheet 41



DOUGLAS DAM - SPILLWAY SECTION
HYDRODYNAMIC SPECTRUM
OPERATING BASIS EARTHQUAKE

FOR HW

HEPE5DGHSQN-WBNBLNBFN

~~SEE RIM: CCB 53 0101 0.0.0.~~

SEE CALS-No. CSG-87-017 CL'D CFS 4-15-88
CDW 4-13-88

SHEET K 42

SPILLWAY - STABILITY ANALYSIS . OBE DOUGLAS

HW EL 1002 TW EL 919 GATES OPEN

BASE EL 815

COMPUTED RBR DATE 6-5-72

CHECKED ENA DATE 6-21-72

HEPE5DGHSQN-WBNBLNBFN

HYDRODYNAMIC FORCES (NW)

$T_1 = \frac{4(187)}{4720} = 0.1585'$

FROM HYDRODYNAMIC SPECTRUM $S_1 = 0.28'$

$T_2 = 0.0528'$ $S_2 = 0.22$

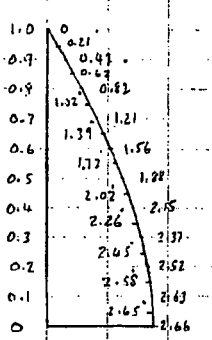
@ $Y/H = 0$; $P = \frac{\gamma H(g)}{\pi^2}\sqrt{\Sigma\left[\frac{\cos\left[(2n-1)\frac{\pi}{2}\frac{Y}{H}\right]}{(2n-1)^2}S_n\right]^2}$

FOR FIRST TWO MODES

$P = \frac{0.0625(187)(g)}{\pi^2}\sqrt{\left[\frac{1(0.28)}{1}\right]^2 + \left[\frac{1(0.22)}{9}\right]^2}$

Y/H		P
0		2.66
0.1	(0.992)(2.66)	2.63
0.2	(0.971)(2.66)	2.52
0.3	(0.939)(2.66)	2.37
0.4	(0.896)(2.66)	2.15
0.5	(0.707)(2.66)	1.88
0.6	(0.586)(2.66)	1.56
0.7	(0.459)(2.66)	1.21
0.8	(0.319)(2.66)	0.82
0.9	(0.164)(2.66)	0.42
1.0	(0)(2.66)	0

10 SPCS @ 18.7'



X 43

SPILLWAY - STABILITY ANALYSIS - OBE — DOUGLAS

HW EL 1002 TW EL 919 GATES OPEN

BASE EL 815

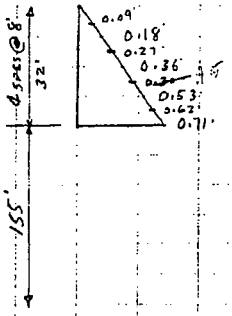
CHECKED RSH DATE 6-5-72

HEPE5DGHSQN-WBNBLNBFN CHECKED NA DATE

	FORCE	ARM	MOMENT
18.7 (2.45) =	49.56	9.35	463.34
18.7 (2.58) =	48.25	28.05	1353.30
18.7 (2.95) =	45.82	46.75	2141.85
18.7 (2.36) =	42.26	65.45	2766.05
18.7 (2.02) =	37.77	~~81.15~~	~~3065.56~~
18.7 (1.72) =	32.16	102.85	3308.07
18.7 (1.39) =	25.99	121.55	3159.45
18.7 (1.02) =	19.07	140.25	2675.13
18.7 (0.82) =	11.59	158.95	1842.87
18.7 (0.21) =	3.93	177.65	697.63
			~~21562.5~~
Σ =	316.40		21473.05 OK
Σ × 46.5 =	14713		CHECKED 998497 OK

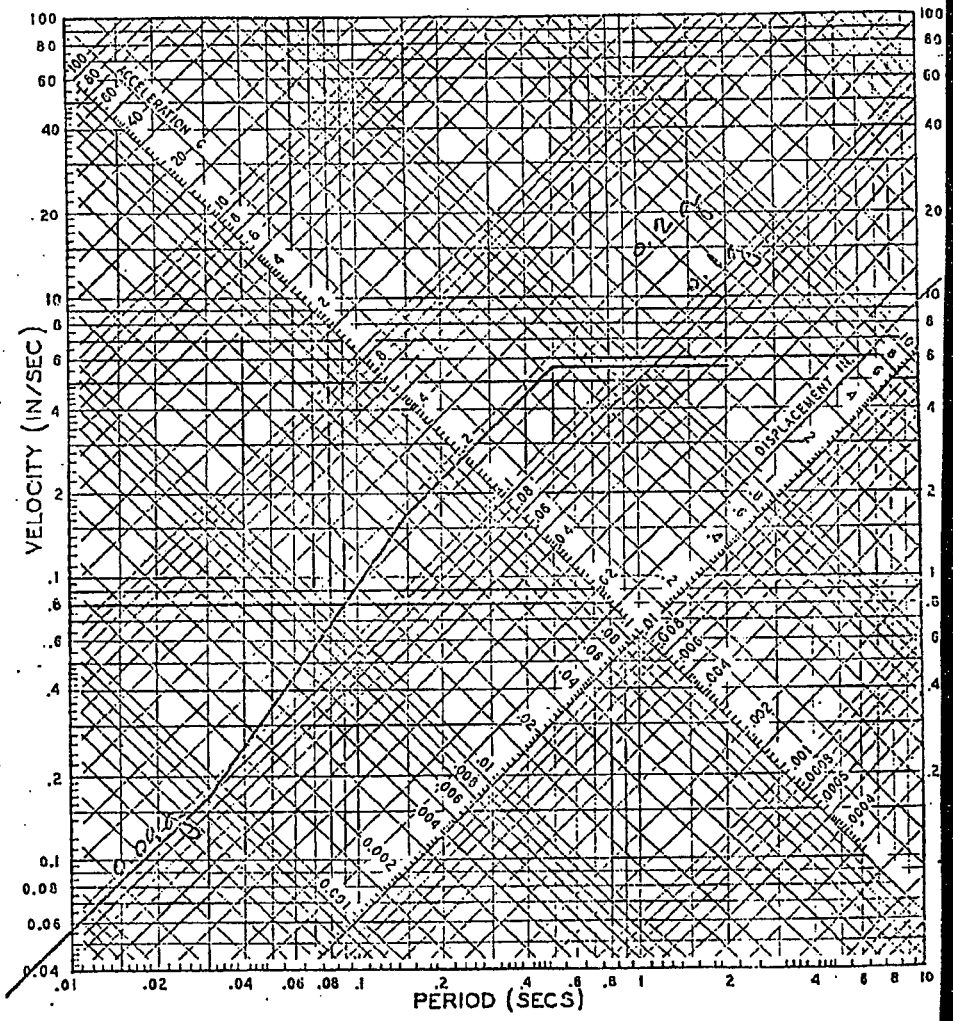
DEDUCT FOR OPEN GATES

Y/H	ANGLE	COS ANGLE	P
187/187	90°	0	0
179/187	86.13°	0.06714	0.18
171/187	82.30°	0.13399	0.36
163/187	78.45°	0.20022	0.53
155/187	74.60°	0.26556	0.71



	FORCE		ARM		MOMENT
8(0.62) =	4.96	×	159	=	788.64
8(0.30) =	~~2.4~~	×	167	=	~~400.8~~
8(0.27) =	2.16	×	175	=	378.0
8(0.09) =	0.72	×	183	=	131.76
Σ	10.24				~~1842.20~~
Σ × 46.5 =	~~476.16~~ 532				79012.8

Sheet 44



OPERATING BASIS EARTHQUAKE
HYDRODYNAMIC SPECTRUM

HEPE5DGHSQN-WBNBLNBFN

FJS TW

~~EC RIM: CEC 03/02 Dc1~~

SEG CALC No. CSG-97-017 CE'D LFS 4-15-98
CDW 4-13-98

SHEET # 45

SPILLWAY - STABILITY ANALYSIS - OBE — DOUGLAS

HWEL 1002 TW EL 719 GATES OPEN

BASE EL 815

COMPUTED PRR DATE 6-5-72

CHECKED HEPESDGHSQN-WBNBLNBFN DATE

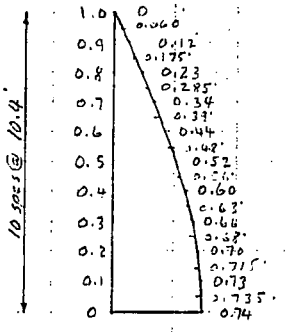
HYDRODYNAMIC FORCES (TW)

$T_1 = \frac{4(104)}{472.0} = 0.088$ — FROM HYDRODYNAMIC SPECTRUM $S_1 = 0.14$ (ASSUMING NO AMPLIFICATION)

$T_2 = 0.03$ $S_2 = 0.09$ IGNORE 2ND MODE THIS TERM APPROACHES 0

② $Y_H = 0$ $P = \frac{2.0625(104)(8)}{\pi^2}(1)(0.14) = 0.74$

Y_H		P
0		0.74
0.1	(0.955)(0.74) =	0.73
0.2	(0.951)(0.74) =	0.70
0.3	(0.891)(0.74) =	0.66
0.4	(0.809)(0.74) =	0.60
0.5	(0.707)(0.74) =	0.52
0.6	(0.588)(0.74) =	0.44
0.7	(0.454)(0.74) =	0.34
0.8	(0.309)(0.74) =	0.23
0.9	(0.156)(0.74) =	0.12
1.0	(0)(0.74) =	0



		FORCE	ARM	MOMENT
10.4 (0.735)	=	7.64	5.2	39.75
10.4 (0.715)	=	7.44	15.6	116.0
10.4 (0.680)	=	7.07	26.0	183.87
10.4 (0.630)	=	6.55	36.4	238.49
10.4 (0.560)	=	5.82	46.8	272.56
10.4 (0.480)	=	4.99	57.2	285.54
10.4 (0.390)	=	4.06	67.6	274.19
10.4 (0.285)	=	2.96	78.0	231.19
10.4 (0.175)	=	1.82	88.4	160.89
10.4 (0.060)	=	0.62	98.8	61.65
	Σ =	48.97		1864.13
$\Sigma \times 46.5$	=	2277.11		86682.05

SHEET 46 OF

SPILLWAY - STABILITY ANALYSIS - OBE — DOUGLAS

HW EL 1002 TW EL 919 GATES OPEN

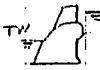
BASE EL 815

COMPUTED RBR DATE 6-6-72

CHECKED ELH DATE 6-21-72

HEPE5DGHSQN-WBNBLNBFN

SUMMATION OF ALL FORCES



ITEM	H	V	MOMENT$_{CG}$
NON-EARTHQUAKE FORCES	← 33753	↓ 61003	+ 1 305 676
DYNAMIC FORCES (HORIZ)	← 9978		+ 1 011 200
(VERT)		↑ 5520	+ 146 512
HYDRODYNAMIC FORCES			
HW	← 14713		+ 998 497
HW	→ 976		− 79 013
TWI	← 2277		+ 86 682
	← 60245	↓ 55483	+ 3 469 554

ECCENTRICITY$_{CG}$ = 3469 554 ÷ 55483 = 62.53' DNSTR OF C.G.

RESULTANT OF FORCES IS $\frac{146.1}{2}$ - 62.53 = 10.52' INSIDE BASE

$f = \frac{55483}{(46.5)(146.1)}\left(1 \pm \frac{6(62.53)}{146.1}\right) = 8.17(1 \pm 2.57)$

f_u = - 12.83 KSF = 89 PSI TENSION

f_D = 29.17 KSF = 203 PSI COMPR

$\frac{\Sigma H}{\Sigma V} = \frac{60245}{55483} = 1.09$

$\frac{\Sigma H}{A} = \frac{60245}{(46.5)(146.1)} = 8.87$ KSF = 61.58 PSI

MAX $f = \frac{2(55483)}{3(10.32)(46.5)} = 75.6$ KSF = 525 PSI

$Q = \frac{0.65(55483)}{60245} = 0.60$ ~~0.60~~ = 1.47

FOR Q = 1 SLIDING $= \frac{60245 - 0.65(55483)}{(46.5)(146.1)} = 3.56$ KSF = 24.7 PSI

[illegible] = 4.5 KSF = 171 PSI ✓

TVA 4HN 1OEV.9 72

SHEET 47

SPILLWAY - STABILITY ANALYSIS - OBE
HW EL 1002 TW EL 919 GATES OPEN
BASE EL 815

DOUGLAS

PSK DATE 6-6-72

HEPE5DGHSQN-WBNBLNBFN CHECKED ENA DATE 6-21-72

FACTOR OF SAFETY AGAINST OVERTURNING ABOUT TOE

ITEM	FORCE	ARM	OT MOMENT	RESISTING MOM.
DL	100970	90.55		9142834
UPLIFT	51175	77.88	3985509	
HW (VERT)	2127	141.36		300673
HW (HORIZ)	50750	62.33	3160000	
" "	1280	165.67	- 212000	
BOUYANT FORCES ON UPSTR SECTION	258	141.65	36546	
	610	141.0	86010	
TW (HORIZ)	15717	34.67		544856
TW (VERT)	9949	21.94		218281
DYNAMIC FORCES (HORIZ)	9978	-	1011200	
" " (VERT)	5520	99.59	549737	
HYDRODYNAMIC FORCES (HW)	14713	-	998097	
" " (HW)	476	-	- 79013	
" " (TW)	2077	-	86682	
			9623168	10206644

$$FS = \frac{10206644}{9623168} = 1.06$$

SHEET # 48

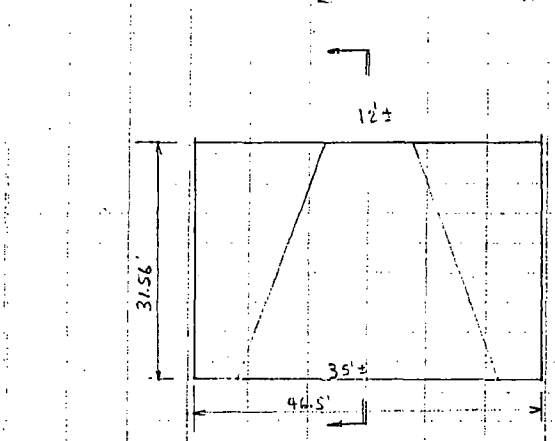
SPILLWAY - STABILITY ANALYSIS - ONE — DOUGLAS

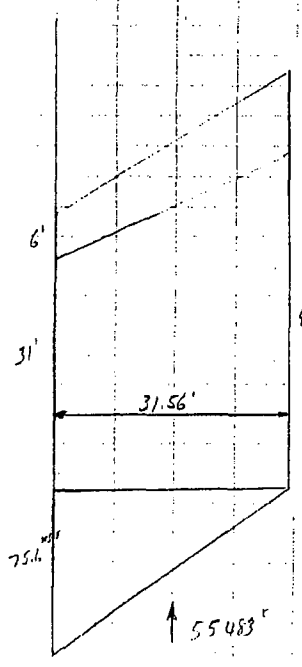
NW EL 1002 TW EL 919 GATES OPEN

BASE EL 815

COMPUTED RBR DATE 6-6-72

HEPESDGHSQN-WBNBLNBFN CHECKED [illegible] DATE 6-7-72





BOUYANT WT OF CONC.

$\frac{1}{2}(37+56)(46.5)(31.56) = 68100$

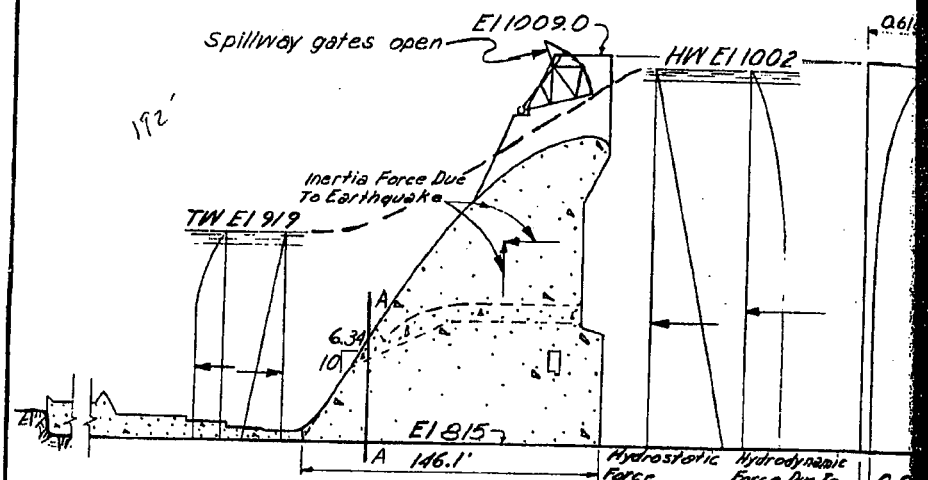
LESS $[(12)(11)+(35)(6)]\left(\frac{1}{2}\right)(31.56) = -5400$

$\Sigma = 62700$

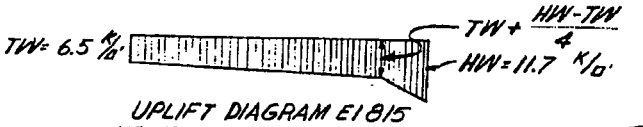
$\Sigma \times 0.0885 = 5490^{K}$

AREA $= 46.5(53) - 12(11) = 2473$ sq ft

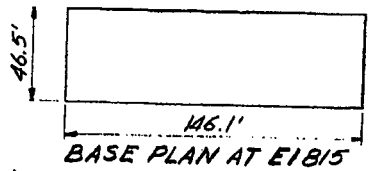
SHEAR $= \frac{55483}{2473} = 22.5$ KSF $= 156$ psi



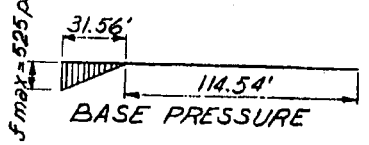
TYPICAL SPILLWAY SECTION



UPLIFT DIAGRAM EI 815
UPLIFT PRESSURES ASSUMED TO ACT ON 100 % OF BASE AREA



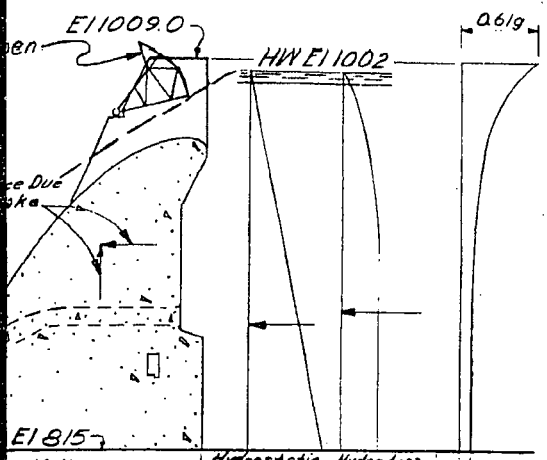
BASE PLAN AT EI 815



BASE PRESSURE

* Shear, s, that is reqd
calculated from shear
formula, $Q = \frac{0.65\Sigma V + S}{\Sigma H}$
assumed to be entire
** Shear stress, s, reqd
considering portion
compression instead
base area.

ΣV	ΣH	ΣH/ΣV	Avg Shear, s	s Reqd For Q=1	f max	FS=ΣMR/ΣMO	Vertical Shear on Plane A-A
55,483K	60,245K	1.09	61.6 psi (entire base)	25 psi* (170 psi)**	525 psi	1.06	156 psi



SPILLWAY SECTION

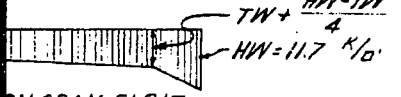
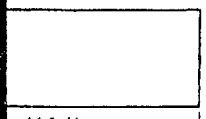
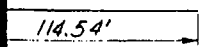


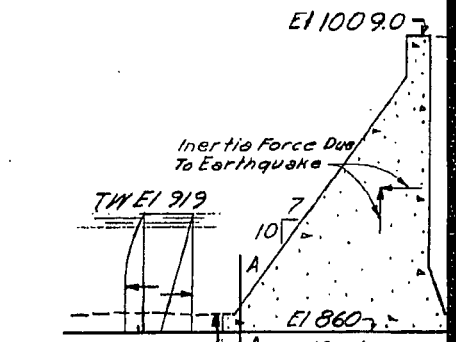
DIAGRAM EL 815
ESSURES ASSUMED
00 % OF BASE AREA



LAN AT EL 815



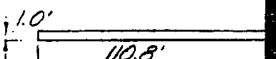
PRESSURE



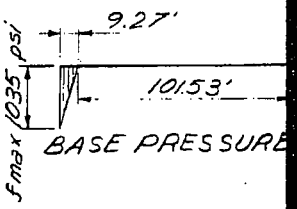
TYPICAL NONOVERFLOW S



UPLIFT DIAGRAM EL 86
UPLIFT PRESSURES ASSU
TO ACT ON 100 % OF BASE



BASE PLAN AT EL 8



BASE PRESSURE

* Shear, s, that is reqd for Q=1 is calculated from shear-friction formula, $Q = \frac{0.65\Sigma V + SA}{\Sigma H}$, A is assumed to be entire area.

** Shear stress, s, reqd for Q=1 considering portion of base in compression instead of entire base area.

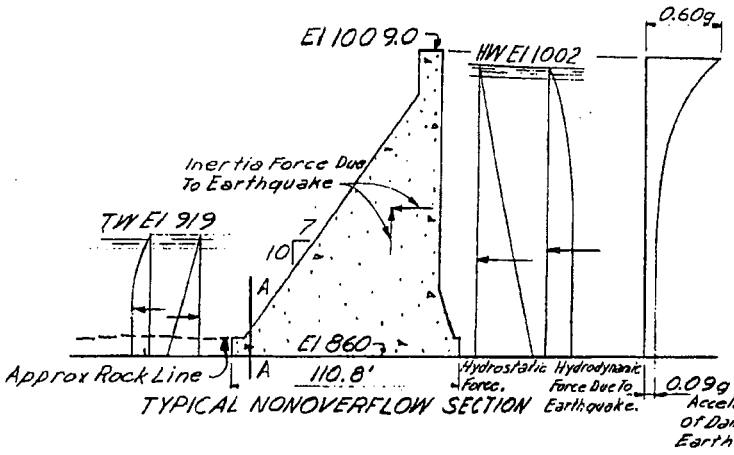
2

Avg Shear, S	S Reqd For Q=1	f max	F.S. $\frac{\Sigma MR}{\Sigma Mo}$	Vertical Shear on Plane A-A
61.6 psi (entire base)	25 psi * (170 psi) **	525 psi	1.06	156 psi

ΣV	ΣH	$\frac{\Sigma H}{\Sigma V}$	Avg Shear, S	S Reqd for Q=1	f max	F.S. $\frac{\Sigma M}{\Sigma Mo}$
690 K	838 K	1.21	52.5 psi (entire base)	24.4 psi * (292 psi) **	1035 psi	1.02

Sheet 49

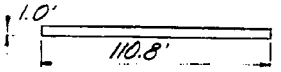
HEPE5DGHSQN-WBNBLNBFN



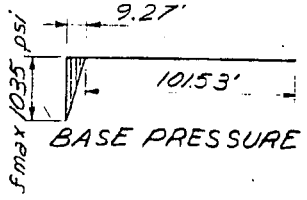
TYPICAL NONOVERFLOW SECTION



UPLIFT DIAGRAM EL 860
UPLIFT PRESSURES ASSUMED
TO ACT ON 100% OF BASE AREA



BASE PLAN AT EL 860



BASE PRESSURE

NOTES:

1. Vertical acceleration of nonoverflow and spillway at base assumed to be 0.06g. By dynamic analysis, amplification of acceleration above the base was determined to be 0.12g at the top for the nonoverflow section and 0.13g at the top for the spillway.
2. Horizontal acceleration of nonoverflow and spillway at base assumed to be 0.09g. By dynamic analysis, amplification of acceleration above the base was determined to be 0.60g at the top for the nonoverflow section and 0.61g at the top for the spillway.
3. Spillway gates assumed open for this analysis.

Scale 1"=60'

	ΣH	ΣH/ΣV	Avg Shear, S	S Reqd For Q=1	f max	F.S. ΣMR/ΣMo	Vertical Shear on Plane A-A
K	838 K	1.21	52.5 psi (entire base)	24.4 psi* (292 psi)**	1035 psi	1.02	958 psi

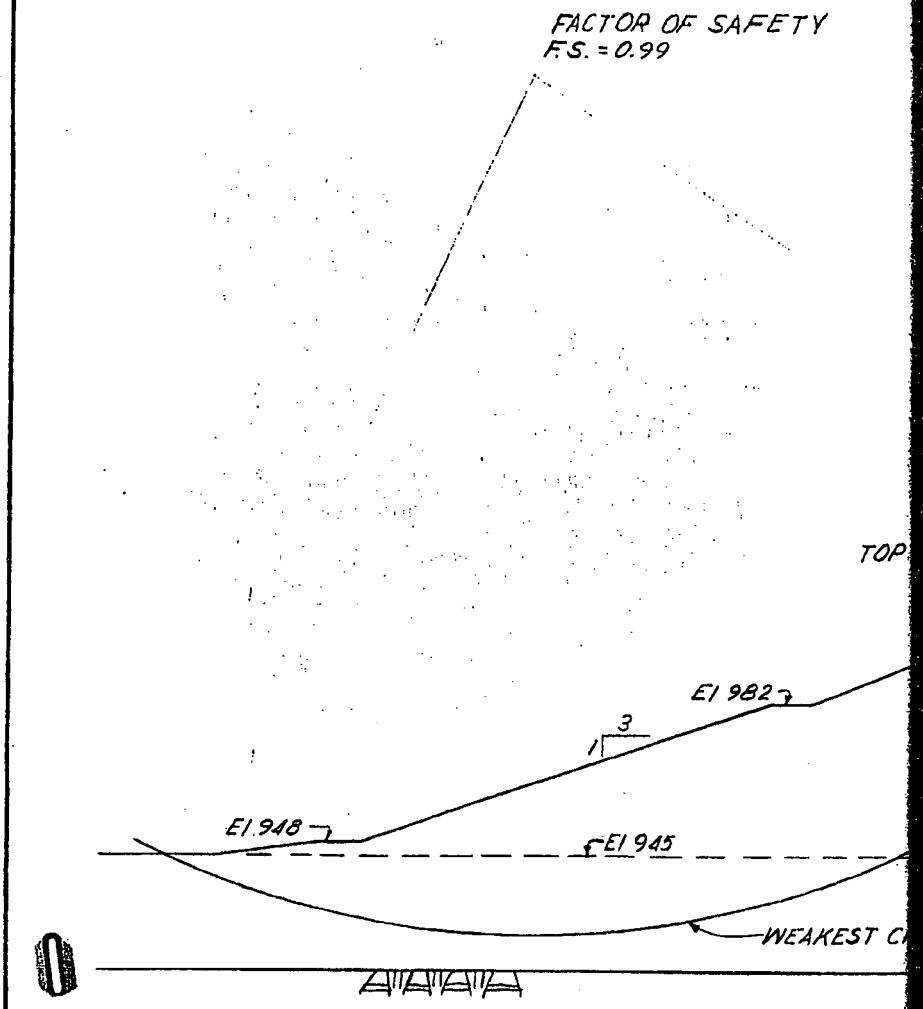
SPILLWAY & NONOVERFLOW

RESULTS OF ANALYSIS FOR OPERATING BASIS EARTHQUAKE

DOUGLAS DAM
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED

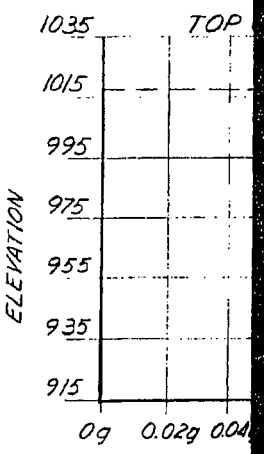
KNOXVILLE

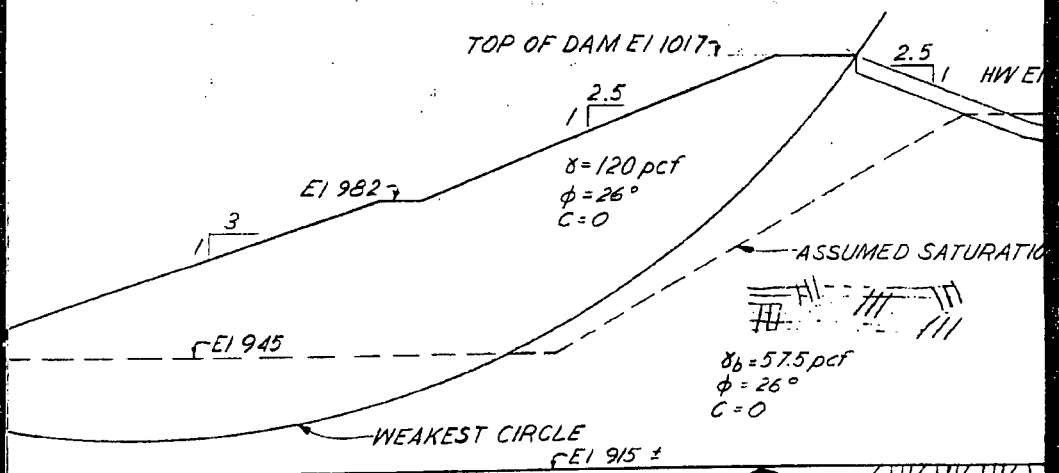


For Analyses See calcs - No, ~~Calcs 866 870317 002~~ SADDLE DAM No: HEPE

LFS 3-16-87
CDW 4-15-88
CKD LFS 4-15-88

FACTOR OF SAFETY
F.S. = 0.99



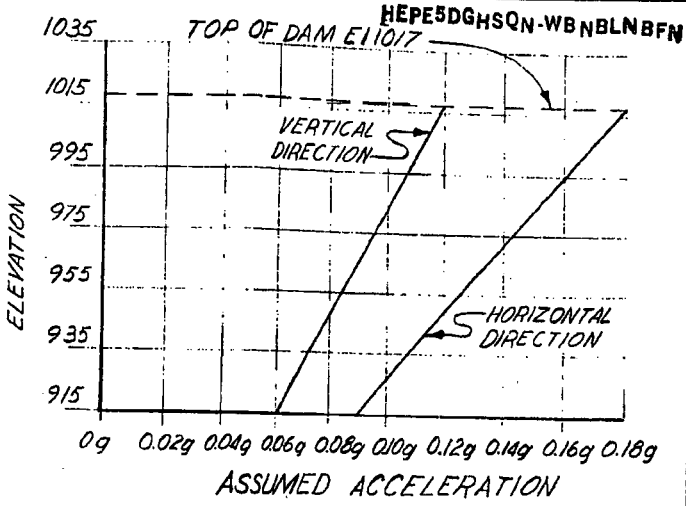


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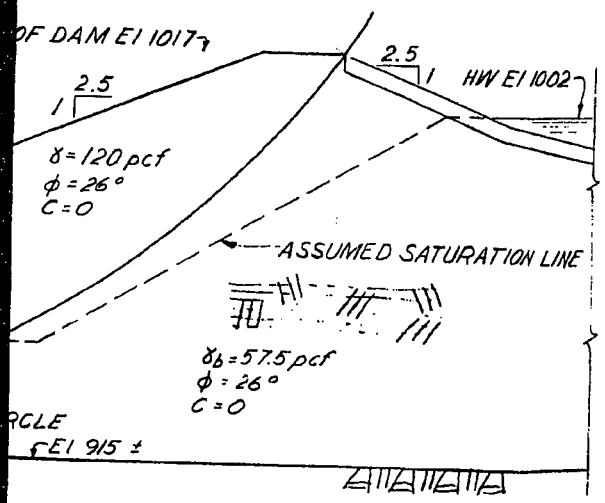
SADDLE DAM No. 1

CALCS - NO,
pe ~~Lotus 866 870317 002~~ HEPESDHESON-WBNBLNBFN
8-16-87
9-15-88
4-15-88

HEPE5DGHSQN-WBNBLNBFN



NOTES:
1. Analysis was made using the standard slip circle method.
2. Shear strengths of materials same as used in original analysis.



3

Scale 1" = 30'

SADDLE DAM No. 1

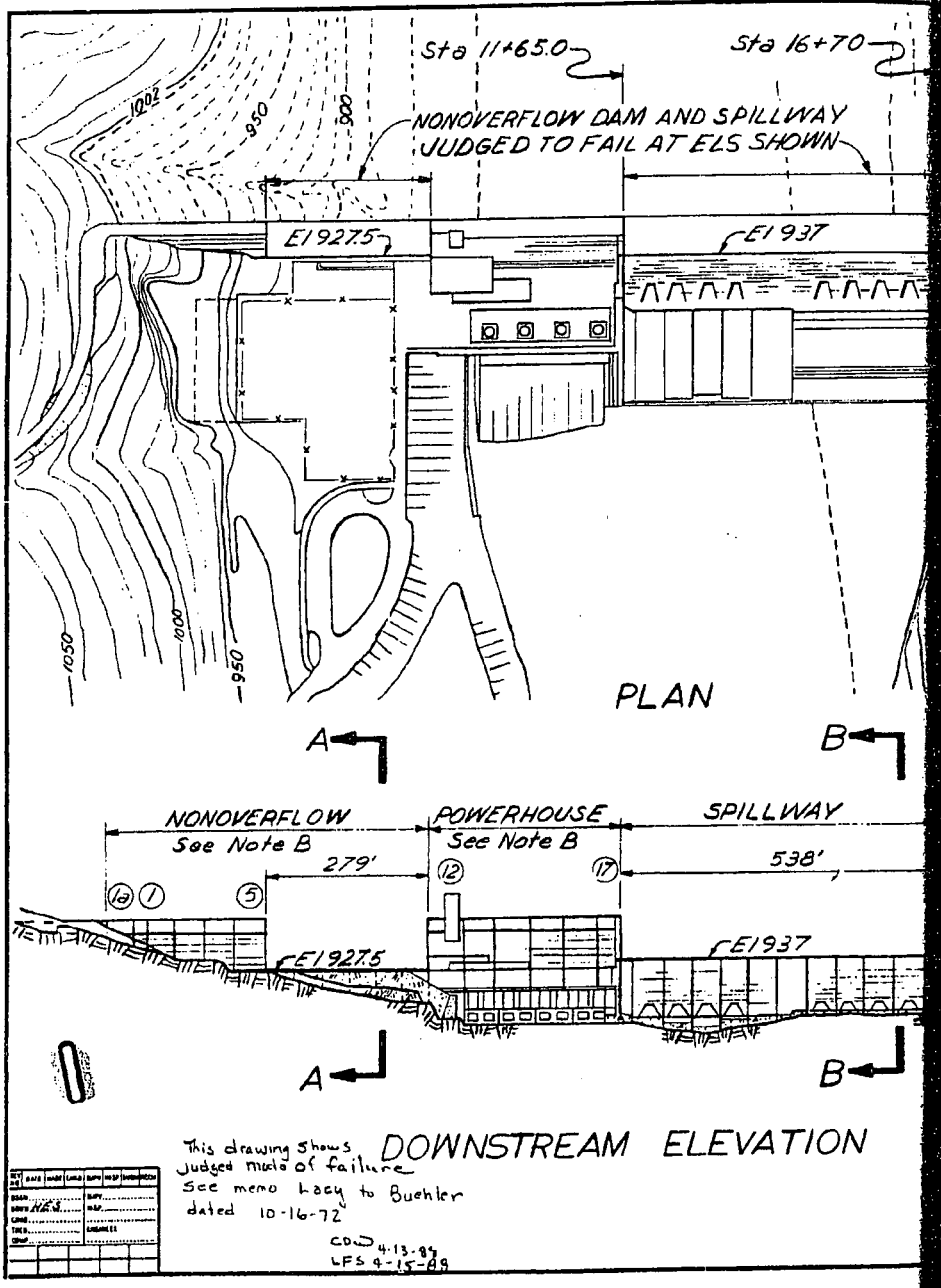
RESULTS OF ANALYSIS FOR OPERATING BASIS EARTHQUAKE

DOUGLAS DAM
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED
KNOXVILLE		

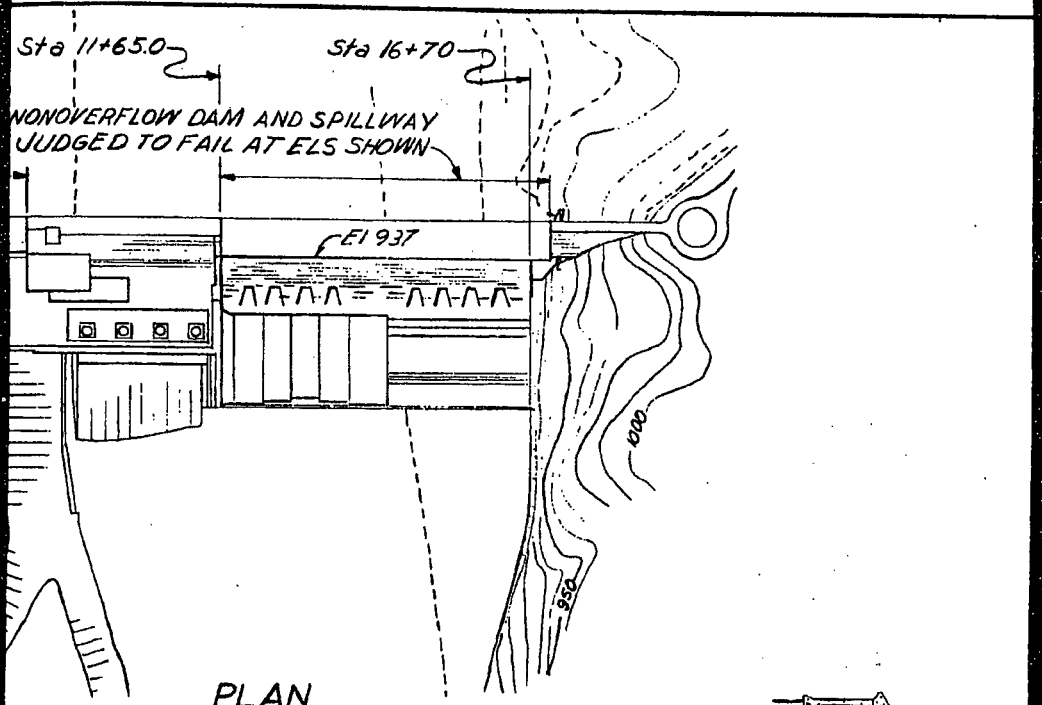
R1

5DHE SQN-WBN BLN BFN



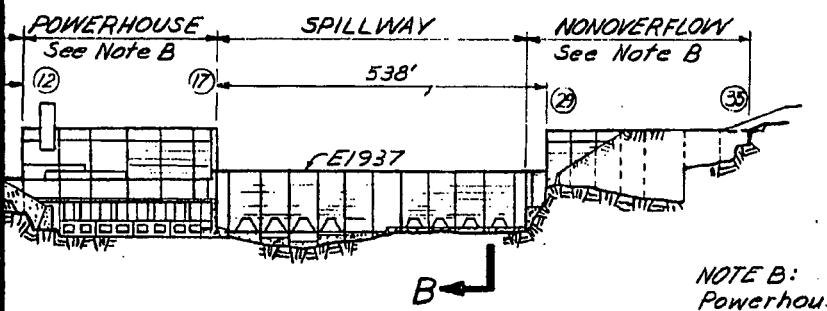
This drawing shows Judged mode of failure
See memo Lacy to Buehler dated 10-16-72

CDW 4-13-89
LFS 9-15-89



PLAN

B



B

DOWNSTREAM ELEVATION

NOTE A:
All debris
of dam ju
failure el

NOTE B:
Powerhouse Intake blocks
and Nonoverflow Dam bloc
and 29 - 35 judged to rem
original position.

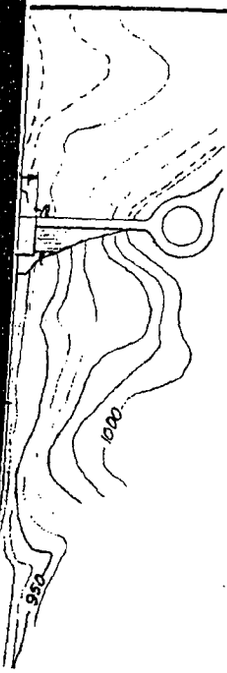
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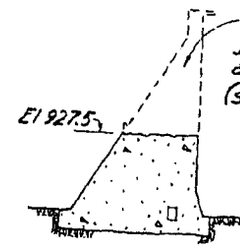
ehler

33
-88

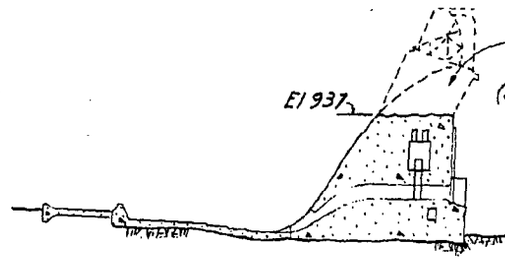
Sheet 51

HEPE5DGHSQN-WBNBLNBFN

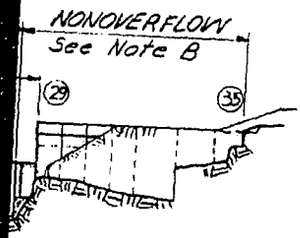




SECTION A-A



B-B



NOTE A:
All debris from failed portion of dam judged to be below failure elevations.

NOTE B:
Powerhouse Intake blocks 12-17 and Nonoverflow Dam blocks 1 to -5 and 29 -35 judged to remain in original position.

1" = 200'
PLAN & ELEVATION
1" = 80'
SECTIONS

DOUGLAS DAM
ASSUMED CONDITION OF DAM AFTER FAILURE- OBE AND ONE HALF MAX POSSIBLE FLOOD
DOUGLAS PROJECT TENNESSEE VALLEY AUTHORITY DIVISION OF ENGINEERING DESIGN
SUBMITTED / RECOMMENDED / APPROVED
KNOXVILLE

R1

Douglas Dam - Concrete Stability Analysis SQN, WBN, BLN, BFN
For ½ SSE + ½ PMF HEPE5DGHSQN-WBNBLNBFN

COMPUTED DATE

CHECKED DATE

THIS IS THE LAST PAGE OF THE CALCULATION

TVA 1142 (08-92)

GAS

L58 080821 001

Tennessee Valley Authority
Division of Water Control Planning
Engineering Laboratory

TAINTER GATE RATING DATA
DETERMINED FROM EIGHT TVA MODEL STUDIES

Norris, Tennessee
March 1962

TAINTER GATE RATING DATA

DETERMINED FROM EIGHT TVA MODEL STUDIES

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Tainter Gate Ratings
Basic Model and Prototype Data

	MODEL					PROTOTYPE		
Project	Model Scale	No. of Spillway Bays	Crest Length L	Approach Width W	Upstream Depth P	Crest Elev.	Design Head H_o	Pier Nose Radius R
Apalachia	1:28.72	6	6.684	8.00	3.38	1257.0	23.0	3.00
Boone	1:50	5	3.480	(1)	(1)	1350.0	35.0	12.75(2) 11.25(3) 3.50(4)
Ft. Patrick Henry	1:15	1	2.333(5)	2.77(5)	2.29	1228.0	35.0	3.25
Hales Bar	1:34.76	6	6.908(6) 6.905(7)	7.94	0.921	616.0	18.0	3.00
Hiwassee	1:55	7	4.050	8.00	6.35	1503.5		3.00
Watts Bar	1:35	6	6.866	8.00	1.5	713.0	23.5	3.25
Wheeler	1:34.35	6	6.984	7.97	1.253	541.3	16.5	2.50

(1) Variable because approach was reproduced in model.

(2) Right end pier.

(3) Left end pier.

(4) Intermediate piers.

(5) Except as noted on data tabulations.

(6) Gates partially opened.

(7) Gates raised above water surface.

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Definition of Symbols

Q	=	Total discharge in cubic feet per second.
D	=	Depth of flow above crest in feet.+
D_1	=	Depth, bottom of gate to water surface.*
H	=	Total head above crest, including velocity head of approach in feet.*
H_o	=	Design head for standard crest, including velocity head of approach, in feet.
h	=	Velocity head of approach in feet.*
C	=	Coefficient of discharge for any head.
G.O.	=	Gate opening - vertical distance above spillway crest in feet.
b	=	Shortest distance between spillway surface and gate lip in feet.*
L	=	Length of spillway crest in feet.
P	=	Depth of model approach channel, crest to river bed, in feet.+
W	=	Width of model approach in feet.
x	=	Horizontal distance from upstream face of dam in feet.*
y	=	Vertical distance above spillway crest in feet.*

Discharge Equations

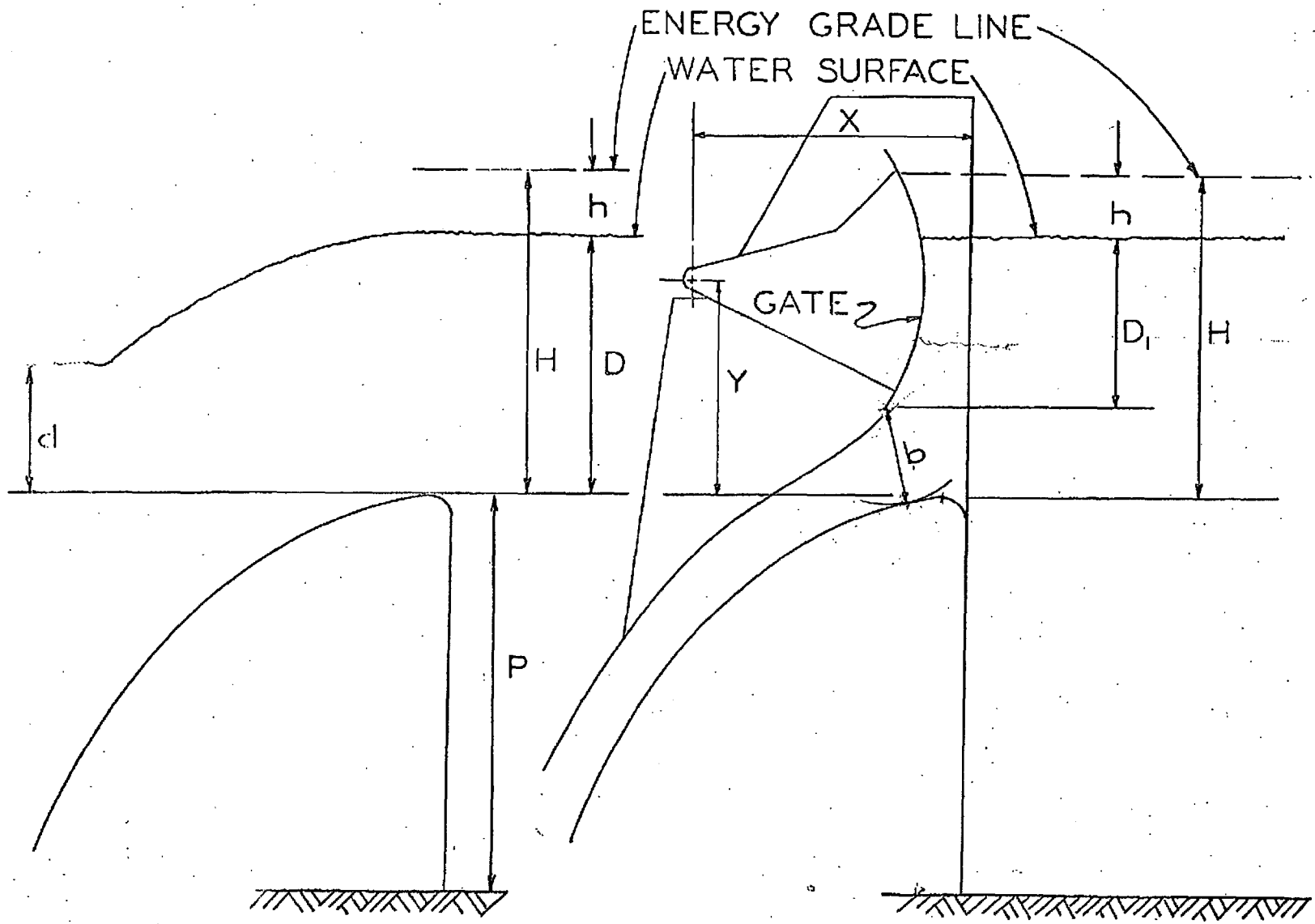
For flow under a gate:

$$Q = CL\ [H^{3/2} - (D_1 + h)^{3/2}] \qquad (A)$$

For flow over a spillway crest with the spillway gate raised above the water surface:

$$Q = CLH^{3/2} \qquad (B)$$

+See Figure 1(a) on page 4.
*See Figure 1(b) on page 4.



[a] FIGURE 1 [b]

Tennessee Valley Authority

Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0532	0.117	0.826	0.000	1.53	3.36	3,650	3.09+ 5.19*
	0.154	0.828	0.000		4.42	3,660	4.38
	0.251	1.071	0.000		7.21	4,734	4.25
	0.358	1.305	0.000		10.28	5,769	4.26
	0.449	1.472	0.000		12.90	6,507	4.26
	0.533	1.618	0.000		15.31	7,152	4.28
	0.663	1.812	0.000		19.04	8,010	4.27
	0.778	1.973	0.000		22.34	8,721	4.28
	0.886	2.115	0.000		25.45	9,349	4.29
0.1107	0.190	1.796	0.000	3.18	5.46	7,939	3.25+ 4.43*
	0.246	1.838	0.000		7.07	8,125	3.80
	0.287	1.994	0.000		8.24	8,814	3.73
	0.367	2.302	0.000		10.54	10,180	3.71
	0.450	2.595	0.000		12.92	11,470	3.72
	0.549	2.916	0.000		15.77	12,890	3.73
	0.627	3.137	0.000		18.01	13,870	3.73
	0.732	3.451	0.000		21.02	15,250	3.77
	0.831	3.681	0.000		23.87	16,270	3.76
	0.917	3.888	0.000		26.34	17,190	3.76
0.1676	0.257	2.888	0.000	4.81	7.38	12,770	3.32+ 4.17*
	0.303	2.890	0.000		8.70	12,770	3.69
	0.393	3.330	0.000		11.29	14,720	3.57
	0.469	3.709	0.000		13.47	16,400	3.57
	0.545	4.066	0.000		15.65	17,970	3.56
	0.631	4.444	0.000		18.12	19,640	3.57
	0.739	4.866	0.000		21.22	21,510	3.57
	0.373	3.221	0.000		10.71	14,240	3.57
	0.322	2.977	0.000		9.25	13,160	3.64
	0.811	5.124	0.000		23.29	22,650	3.57
	0.894	5.418	0.000		25.68	23,950	3.58

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2247	0.364	4.184	0.000	6.45	10.45	18,490	3.73
	0.318	4.098	0.000		9.13	18,110	3.42+ 4.08*
	0.411	4.399	0.000		11.80	19,450	3.59
	0.461	4.752	0.000		13.24	21,010	3.58
	0.531	5.181	0.000		15.25	22,900	3.56
	0.627	5.742	0.001		18.04	25,380	3.54
	0.718	6.224	0.001		20.65	27,510	3.55
	0.825	6.771	0.001		23.72	29,930	3.56
	0.911	7.179	0.001		26.19	31,730	3.56
0.3393	0.469	7.647	0.001	9.74	13.50	33,800	3.55+ 4.16*
	0.526	7.490	0.001		15.14	33,110	3.72
	0.574	7.832	0.001		16.51	34,620	3.65
	0.631	8.344	0.001		18.15	36,880	3.63
	0.717	9.089	0.001		20.62	40,180	3.63
	0.821	9.882	0.001		23.61	43,680	3.61
	0.919	10.58	0.002		26.42	46,770	3.62
0.4541	0.604	11.54	0.002	13.04	17.40	51,010	3.66+ 4.19*
	0.617	11.84	0.002		17.78	52,340	4.22
	0.720	11.84	0.002		20.74	52,340	3.73
	0.668	11.42	0.002		19.24	50,480	3.81
	0.765	12.34	0.002		22.03	54,550	3.72
	0.838	13.10	0.002		24.12	57,910	3.70
	0.915	13.84	0.003		26.36	61,180	3.68
0.5677	0.751	16.55	0.004	16.30	21.68	73,160	3.77+ 4.31*
	0.895	17.14	0.004		25.82	75,770	3.87
	0.849	16.72	0.004		24.50	73,910	3.94
	0.815	16.24	0.004		23.52	71,790	3.95

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Apalachia Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.117	0.826	0.000	3.36	3,651	3.09
0.190	1.796	0.000	5.46	7,939	3.25
0.257	2.888	0.000	7.38	12,770	3.32
0.318	4.098	0.000	9.13	18,110	3.42
0.397	5.813	0.001	11.42	25,700	3.46
0.466	7.542	0.001	13.41	33,340	3.54
0.536	9.512	0.001	15.43	42,050	3.62
0.592	11.17	0.002	17.06	49,380	3.65
0.659	13.39	0.003	19.00	59,190	3.72
0.728	15.80	0.004	21.01	69,840	3.77
0.800	18.66	0.005	23.12	82,480	3.86
0.866	21.57	0.006	25.05	95,350	3.96
0.894	22.44	0.007	25.87	99,190	3.93
0.469	7.647	0.001	13.50	33,800	3.55
0.604	11.54	0.002	17.40	51,010	3.66
0.751	16.55	0.004	21.68	73,160	3.77

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.040	0.085	0.2810		2.00	4.25	4,968	3.26+ 5.28*
	0.149	0.3552			7.45	6,279	4.74
	0.234	0.4567			11.70	8,073	4.72
	0.274	0.4937			13.70	8,727	4.70
	0.351	0.5661			17.55	10,010	4.70
	0.428	0.6285			21.40	11,110	4.72
	0.504	0.6857			25.20	12,120	4.73
	0.581	0.7385			29.05	13,050	4.72
	0.626	0.7663			31.30	13,550	4.71
	0.700	0.8087			35.00	14,300	4.69
	0.110	0.3020			5.50	5,339	4.82
0.500	0.617	6.250		25.00	30.85	110,500	3.70+ 4.04*
	0.680	6.598	Negligible		34.00	116,600	3.92
	0.721	6.715			36.03	118,700	3.80
	0.633	6.456			33.15	114,100	3.91
0.400	0.493	4.355		20.00	24.65	76,990	3.61+ 3.93*
	0.558	4.638			27.90	81,990	3.77
	0.615	4.906			30.75	86,730	3.69
	0.685	5.279			34.25	93,320	3.66
	0.708	5.425			35.40	95,900	3.67
0.300	0.379	2.964		15.00	18.95	52,400	3.65+ 4.04*
	0.459	3.175			22.95	56,130	3.68
	0.517	3.453			25.85	61,040	3.67
	0.575	3.726			28.75	65,870	3.67
	0.648	4.044			32.40	71,490	3.67
	0.724	4.344			36.20	76,790	3.67

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.200	0.270	1.672		10.00	13.50	29,560	3.42+ 3.94*
	0.334	1.856			16.70	32,810	3.71
	0.409	2.133			20.45	37,710	3.69
	0.469	2.413			23.45	42,660	3.82
	0.539	2.626			26.95	46,420	3.80
	0.592	2.790			29.60	49,320	3.82
	0.670	2.896			33.50	51,200	3.68
	0.723	3.035			36.15	53,650	3.69
0.100	0.152	0.7015	Negligible	5.00	7.60	12,400	3.40+ 4.25*
	0.218	0.8119			10.90	14,350	3.81
	0.264	0.9232			13.20	16,320	3.83
	0.334	1.061			16.70	18,760	3.82
	0.391	1.174			19.55	20,750	3.86
	0.474	1.311			23.70	23,180	3.86
	0.599	1.496			29.95	26,450	3.87
	0.537	1.403			26.85	24,800	3.85
	0.630	1.537			31.50	27,170	3.87
	0.719	1.654			35.95	29,240	3.87
	0.177	0.7320			8.85	12,940	3.96
	0.234	0.8555			11.70	15,120	3.84
	0.299	0.9897			14.95	17,500	3.81

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Boone Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.323	2.312		16.15	40,870	3.62
0.367	2.928		18.35	51,760	3.79
0.432	3.575		21.60	63,200	3.62
0.492	4.399		24.60	77,770	3.66
0.545	5.166		27.25	91,320	3.69
0.609	6.155		30.45	108,800	3.72
0.664	7.044		33.20	124.500	3.74
0.706	7.809	Negligible	35.30	138,000	3.78
0.252	1.522		12.60	26,910	3.46
0.190	0.9783		9.50	17,290	3.39
0.135	0.5736		6.75	10,140	3.33
0.088	0.2952		4.40	5,220	3.25
0.048	0.1170		2.40	2,068	3.21

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.200	2.214	4.040	0.000	3.00	33.21	3,520	3.97
	2.530	4.332	0.000		37.95	3,775	3.97
	1.714	3.511	0.000		25.71	3,060	3.95
	1.412	3.156	0.000		21.18	2,750	3.94
	1.110	2.755	0.000		16.65	2,401	3.92
	0.683	2.076	0.000		10.24	1,809	3.89
	0.556	1.831	0.000		8.34	1,596	3.88
	0.500	1.711	0.000		7.50	1,491	3.88
	0.424	1.552	0.000		6.36	1,352	3.91
	0.350	1.515	0.000		5.25	1,320	4.36
	0.362	1.510	0.000		5.43	1,316	4.24
	0.360	1.578	0.000		5.40	1,375	4.45
0.333	1.464	4.895	0.003	5.00	22.00	4,266	3.69
	1.133	4.218	0.003		17.04	3,676	3.68
	0.917	3.692	0.003		13.80	3,217	3.66
	0.742	3.217	0.002		11.16	2,803	3.65
	1.692	5.331	0.004		25.44	4,646	3.70
	1.913	5.716	0.004		28.76	4,981	3.71
0.667	1.226	7.822	0.010	10.00	18.54	6,816	3.55
	2.108	11.21	0.013		31.82	9,768	3.60
	1.556	9.169	0.012		23.52	7,990	3.55
	1.915	10.59	0.013		28.92	9,230	3.60
	0.995	6.828	0.009		15.06	5,950	3.61
	2.186	11.46	0.013		32.99	9,986	3.60
1.133	1.625	15.23	0.030	17.00	24.83	13,270	3.73
	1.947	17.28	0.034		29.72	15,060	3.69
	2.124	18.33	0.035		32.39	15,970	3.68
	2.361	19.68	0.036		35.96	17,150	3.68
1.400	1.966	21.05	0.049	21.00	30.22	18,340	3.79
	2.105	22.08	0.051		32.34	19,240	3.77
	2.359	23.67	0.052		36.16	20,630	3.72
	1.925	20.72	0.049		29.61	18,060	3.80
	1.925	20.83	0.049		29.61	18,150	3.82
	1.828	20.11	0.048		28.14	17,520	3.84
	1.807	20.03	0.048		27.82	17,460	3.87
	1.786	19.94	0.048		27.51	17,380	3.89
	1.766	19.92	0.049		27.22	17,360	3.92

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
1.667	2.326	27.84	0.073	25.00	35.98	24,260	3.86
	2.296	27.65	0.073		35.49	24,100	3.88
	2.253	27.40	0.073		34.89	23,880	3.89
	2.233	27.26	0.073		34.59	23,760	3.91
	2.179	26.96	0.073		33.78	23,493	3.94
	2.144	26.74	0.073		33.26	23,300	3.96
	1.995	27.89	0.086		31.22	24,304	4.37
0.867	2.396	15.55	0.022	13.00	36.27	13,550	3.65
	2.036	13.99	0.021		30.86	12,190	3.63
	1.756	12.66	0.020		26.64	11,030	3.62
	1.408	10.85	0.018		21.39	9,455	3.62
	1.281	10.15	0.016		19.46	8,845	3.64
	1.070	9.504	0.016		16.29	8,282	3.96
	1.149	9.582	0.016		17.48	8,350	3.75
	1.136	9.548	0.016		17.28	8,320	3.77
0.533	1.141	6.240	0.007	8.00	17.22	5,438	3.58
	1.466	7.389	0.008		22.11	6,439	3.61
	1.797	8.391	0.008		27.08	7,312	3.63
	2.378	9.885	0.009		35.80	8,614	3.64
0.433	1.991	7.402	0.006	6.50	29.96	6,450	3.66
	1.595	6.497	0.006		24.02	5,662	3.65
	1.238	5.544	0.005		18.64	4,831	3.62
	0.765	4.036	0.004		11.54	3,517	3.61

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
1.274	13.09	0.027	19.52	11,410	3.78
1.440	16.17	0.038	22.17	14,090	3.86
1.691	21.55	0.059	26.25	18,780	3.99
1.890	26.26	0.080	29.55	22,880	4.07
1.972	28.34	0.090	30.93	24,700	4.10
0.9916	8.551	0.014	15.09	7,451	3.63
0.8044	6.045	0.008	12.18	5,268	3.54
0.5831	3.578	0.003	8.79	3,118	3.42
0.3610	1.673	0.001	5.43	1,458	3.29

This is for special 1:15 model tests in which Fort Pat crest was replaced with a standard crest for comparison purposes.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.200	2.325	2.486	1.430	3.069	0.001	4.388
				3.048	0.001	4.374
				2.124	0.001	3.605
				1.282	0.001	2.734
				0.577	0.001	1.700
				0.283	0.000	0.999
0.203	2.325	2.808	0.550	0.601	0.001	1.714
				1.361	0.001	2.757
				2.240	0.001	3.600
				2.771	0.001	4.016
0.200	2.325	2.808	0.550	0.217	0.000	0.745
				0.402	0.001	1.309
				0.934	0.001	2.210
				1.882	0.001	3.244
				2.720	0.001	3.912
0.200	2.325	2.822	-0.077	1.389	0.001	2.652
				2.444	0.001	3.590
				1.945	0.001	3.180
				0.539	0.001	1.556
0.701	2.320	2.410	1.924	2.959	0.017	15.14
				2.374	0.017	13.27
				1.856	0.015	11.32
				0.970	0.009	6.688
				1.393	0.013	9.186
0.700	2.320	2.732	1.044	0.952	0.008	6.469
				1.525	0.012	9.396
				2.189	0.015	11.95
				3.047	0.015	14.52
0.700	2.320	2.746	0.417	0.795	0.007	5.691
				0.893	0.008	6.140
				1.488	0.012	9.080
				2.150	0.014	11.50
				2.727	0.014	13.25
1.199	2.320	2.333	2.418	1.305	0.027	12.94
				1.434	0.029	13.97
				1.641	0.035	16.00
				2.117	0.043	20.00
				2.765	0.048	24.40

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
1.199	2.320	2.655	1.538	2.746	0.045	23.29
				2.337	0.042	20.77
				1.787	0.036	16.90
				1.444	0.028	13.89
1.199	2.320	2.669	0.911	1.500	0.030	14.34
				1.803	0.036	16.92
				2.389	0.042	20.84
				2.851	0.043	23.43
1.698	2.320	2.579	2.032	1.926	0.065	23.58
				2.173	0.073	26.47
				2.465	0.080	29.47
1.701	2.320	2.593	1.405	1.798	0.063	22.55
				1.978	0.067	24.25
				2.278	0.076	27.62
				2.456	0.080	29.49
0.199	2.328	2.397	1.897	0.546	0.001	1.699
				1.129	0.001	2.698
				1.944	0.002	3.668
				2.949	0.002	4.594
0.199	2.328	2.917	1.118	2.835	0.001	4.102
				2.103	0.001	3.501
				1.276	0.001	2.661
				0.620	0.001	1.731
0.197	2.329	3.100	0.200	0.651	0.001	1.703
				1.461	0.001	2.693
				2.470	0.001	3.565
				3.099	0.001	4.013
0.198	2.329	3.018	-0.421	0.570	0.001	1.583
				1.439	0.001	2.645
				1.950	0.001	3.112
				2.549	0.001	3.534
0.200	2.328	3.018	-0.421	0.298	0.000	1.219
				0.424	0.001	1.346
				1.022	0.001	2.217

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.699	2.328	2.397	2.397	1.000	0.010	7.197
				1.338	0.013	9.270
				1.623	0.016	10.78
				2.074	0.018	12.86
				2.547	0.019	14.64
				2.862	0.019	15.71
0.699	2.328	2.917	1.618	1.007	0.010	7.094
				1.585	0.014	9.894
				2.199	0.016	12.31
				2.848	0.017	14.48
0.699	2.328	3.100	0.700	0.923	0.010	7.094
				1.036	0.010	7.133
				1.619	0.013	9.609
				2.163	0.014	11.60
				2.894	0.015	13.76
0.701	2.328	3.018	0.079	1.028	0.010	7.107
				1.663	0.012	9.609
				2.234	0.013	11.46
				2.911	0.014	13.52
1.199	2.328	2.917	2.118	1.628	0.035	16.08
				1.944	0.040	18.41
				2.349	0.044	21.30
				2.804	0.046	24.13
1.198	2.328	3.100	1.200	1.641	0.034	15.90
				1.972	0.036	18.05
				2.323	0.040	20.31
				2.797	0.042	22.93
1.200	2.328	3.018	0.579	1.483	0.036	15.88
				1.629	0.034	15.87
				2.001	0.037	18.08
				2.292	0.039	19.86
				2.571	0.040	21.43
1.699	2.328	2.917	2.618	2.016	0.083	27.31
				2.158	0.078	27.28
				2.217	0.079	27.83

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.200	2.333	3.115	1.451	0.415	0.001	1.557
				1.081	0.001	2.723
				1.882	0.002	3.677
				3.083	0.002	4.760
0.200	2.333	3.456	0.578	0.471	0.001	1.594
				1.164	0.001	2.630
				1.905	0.001	3.417
				2.679	0.001	4.084
0.198	2.333	3.437	-0.357	0.497	0.001	1.587
				0.923	0.001	2.201
				1.692	0.001	3.010
				2.584	0.001	3.737
0.194	2.333	3.224	-0.946	0.379	0.001	1.745
				0.620	0.001	1.733
				1.002	0.001	2.201
				1.550	0.001	2.727
				2.047	0.001	3.150
0.697	2.333	3.222	-1.940	1.372	0.015	9.915
				1.947	0.018	12.53
				2.472	0.019	14.44
				3.039	0.019	16.29
0.700	2.333	3.563	1.067	1.382	0.014	9.453
				1.976	0.016	11.74
				2.462	0.016	13.39
				2.983	0.017	14.93
0.697	2.333	3.544	0.132	1.086	0.016	9.420
				1.467	0.013	9.439
				1.940	0.014	11.09
				2.459	0.015	12.60
				2.972	0.015	14.07
0.701	2.333	3.331	-0.457	1.345	0.013	8.977
				1.739	0.014	10.31
				2.232	0.014	11.86
				2.497	0.014	12.57

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
1.200	2.333	3.329	2.428	1.886	0.048	20.08
				2.113	0.050	21.53
				2.332	0.052	23.08
				2.666	0.054	25.26
1.198	2.333	3.670	1.555	1.863	0.045	19.30
				2.134	0.046	20.66
				2.402	0.047	22.31
				2.784	0.048	24.40
1.199	2.333	3.651	0.620	1.881	0.043	18.94
				2.192	0.043	20.46
				2.514	0.044	22.19
				2.816	0.045	23.85
1.201	2.333	3.438	0.031	1.698	0.053	20.27
				2.010	0.043	19.44
				2.234	0.043	20.61
				2.548	0.043	22.13
				2.837	0.043	23.40
1.990	2.335	3.670	1.004	0.441	0.001	1.877
				0.442	0.001	2.247
				0.949	0.001	2.695
				1.779	0.002	3.678
				2.959	0.002	4.741
0.199	2.335	3.872	0.090	0.512	0.001	1.880
				1.156	0.001	2.735
				2.046	0.001	3.614
				2.860	0.001	4.279
0.198	2.335	3.709	-0.832	0.443	0.001	1.705
				0.834	0.001	2.233
				1.289	0.001	2.726
				2.138	0.001	3.473
0.701	2.334	3.851	1.470	1.409	0.018	10.65
				1.510	0.018	11.05
				1.795	0.019	12.16
				2.417	0.019	14.41
				2.962	0.019	16.10

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.700	2.334	4.053	0.556	1.495	0.015	10.34
				2.064	0.016	12.28
				2.457	0.017	13.45
				2.838	0.017	14.59
0.697	2.334	3.890	-0.366	1.208	0.021	11.16
				1.530	0.014	10.10
				1.911	0.015	11.31
				2.208	0.015	12.06
				2.602	0.015	13.12
1.199	2.334	4.033	1.936	1.825	0.065	22.95
				2.071	0.054	22.37
				2.210	0.055	23.16
				2.404	0.055	24.20
				2.585	0.056	25.33
				2.731	0.056	26.10
1.198	2.334	4.235	1.022	1.924	0.051	21.00
				2.020	0.051	21.22
				2.225	0.050	22.02
				2.467	0.050	23.22
				2.704	0.050	24.42
1.199	2.334	4.072	0.100	2.141	0.046	21.14
				2.260	0.048	21.83
				2.577	0.046	23.06
				2.797	0.046	23.94
0.199	2.338	4.101	0.677	0.518	0.001	2.247
				1.082	0.002	3.019
				1.928	0.002	3.914
				2.748	0.002	4.626
0.200	2.338	4.233	-0.250	0.492	0.002	2.673
				0.512	0.001	2.118
				1.293	0.002	3.054
				2.007	0.002	3.692
				2.678	0.002	4.247

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.4529	0.595	11.53	0.014	15.74	21.17	82,140	4.04
	0.666	12.52	0.015		23.67	89,190	4.00
	0.869	15.01	0.018		30.83	106,900	3.96
	0.527	10.81	0.014		18.81	77,010	4.21
	0.561	11.17	0.014		19.99	79,570	4.11
	0.526	10.84	0.014		18.77	77,220	4.23
	0.612	11.74	0.014		21.76	83,630	4.02
	0.548	11.02	0.014		19.54	78,500	4.14
	0.588	11.55	0.014		20.93	82,280	4.08
	0.565	11.18	0.014		20.13	79,640	4.09
	0.669	12.59	0.016		23.81	89,700	4.01
	0.628	11.97	0.015		22.35	85,270	4.01
	0.712	13.10	0.016		25.31	93,320	3.98
	0.751	13.59	0.016		26.66	96,810	3.97
0.3991	0.588	10.18	0.011	13.87	20.82	72,520	3.94
	0.558	9.824	0.011		19.78	69,980	3.96
	0.517	9.346	0.010		18.32	66,580	4.02
	0.486	8.994	0.010		17.24	64,070	4.08
	0.475	8.946	0.010		16.86	63,730	4.14
0.3438	0.604	9.169	0.009	11.95	21.31	65,320	3.90
	0.562	8.706	0.008		19.81	62,020	3.90
	0.518	8.191	0.008		18.28	58,350	3.90
	0.457	7.560	0.007		16.13	53,850	3.99
	0.430	7.269	0.007		15.19	51,780	4.04
	0.414	7.135	0.007		14.63	50,830	4.10
	0.422	7.235	0.007		14.91	51,540	4.09
0.2894	0.483	6.723	0.006	10.06	17.00	47,890	3.85
	0.605	7.928	0.007		21.27	56,480	3.88
	0.403	5.938	0.005		14.18	42,300	3.91
	0.493	6.809	0.006		17.35	48,500	3.84
	0.419	6.049	0.005		14.74	43,090	3.86
	0.592	7.776	0.007		20.82	55,390	3.86

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.1818	0.354	3.650	0.002	6.319	12.37	26,000	3.78
	0.547	4.915	0.003		19.12	35,010	3.86
	0.462	4.393	0.002		16.13	31,290	3.83
	0.413	4.096	0.002		14.43	29,180	3.83
	0.488	4.574	0.003		17.07	32,580	3.85
	0.580	5.095	0.003		20.27	36,290	3.86
	0.559	4.972	0.003		19.54	35,420	3.85
0.2342	0.410	5.019	0.003	8.141	14.36	35,750	3.83
	0.368	4.636	0.003		12.90	33,020	3.83
	0.450	5.354	0.004		15.78	38,140	3.82
	0.590	6.461	0.004		20.65	46,030	3.86
0.1251	0.601	3.719	0.002	4.348	20.96	26,490	3.91
	0.512	3.382	0.001		17.83	24,090	3.89
	0.422	3.034	0.001		14.70	21,610	3.90
	0.348	2.693	0.001		12.13	19,180	3.89
	0.466	3.215	0.001		16.23	22,900	3.90
0.0720	0.475	2.039	0.000	2.503	16.51	14,530	4.12
	0.555	2.216	0.001		19.33	15,790	4.12
	0.596	2.330	0.001		20.75	16,600	4.17
	0.518	2.153	0.001		18.04	15,340	4.16
	0.365	1.762	0.000		12.69	12,550	4.12

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Raised Above the Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.896	27.80	0.058	33.16	198,000	4.32
0.851	25.43	0.051	31.35	181,100	4.30
0.817	23.66	0.046	30.00	168,500	4.27
0.775	21.62	0.040	28.33	154,000	4.26
0.731	19.44	0.034	26.59	138,500	4.21
0.684	17.26	0.028	24.75	122,900	4.16
0.579	12.93	0.018	20.75	92,100	4.06
0.537	11.24	0.015	19.19	80,060	3.97
0.617	14.47	0.022	22.21	103,100	4.10
0.483	9.387	0.011	17.17	66,870	3.92
0.430	7.647	0.008	15.22	54,470	3.82
0.372	5.957	0.005	13.10	42,400	3.72
0.306	4.321	0.003	10.74	30,780	3.64
0.242	2.919	0.002	8.48	20,790	3.51
0.654	15.88	0.025	23.60	113,100	4.11
0.568	12.39	0.017	20.33	88,260	4.01

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0213	0.280	0.3292		1.17	15.40	7,385	4.96
	0.185	0.2692			10.18	6,039	5.03
	0.070	0.1636			3.85	3,670	5.24
	0.310	0.3456		17.05	~~1.71~~	7,753	4.96
	0.449	0.4161			24.70	9,335	4.92
	0.385	0.3849			21.18	8,635	4.92
	0.048	0.1296			2.64	2,907	5.25
	0.051	0.1372			2.80	3,078	5.38
	0.052	0.1415			2.86	3.174	5.46
	0.051	0.1404			2.80	3,150	5.51
	0.056	0.1520			3.08	3,410	5.61
	0.063	0.1568			3.46	3,518	5.37
	0.077	0.1725			4.24	3,870	5.20
	0.084	0.1812			4.62	4,065	5.27
	0.124	0.2188			6.82	4,909	5.15
	0.229	0.3010			12.60	6,753	5.06
	0.322	0.3555	Negligible		17.71	7,975	5.01
0.0421	0.142	0.3687		2.32	7.81	8,271	4.16
	0.100	0.3133			5.50	7,029	4.39
	0.196	0.4123			10.78	9,250	3.86
	0.277	0.5273			15.24	11,830	4.08
	0.385	0.6276			21.18	14,080	4.08
	0.473	0.6983			26.02	15,670	4.08
	0.203	0.4465			11.16	10,020	4.10
0.0767	0.120	0.5475		4.22	6.60	12,280	4.13
	0.188	0.6886			10.34	15,450	3.82
	0.261	0.8201			14.36	18,400	3.72
	0.318	0.9188			17.49	20,610	3.72
	0.374	1.003			20.57	22,500	3.71
	0.440	1.094			24.20	24,540	3.69
0.0762	0.172	0.6546		4.19	9.46	14,690	3.88
	0.203	0.7079			11.16	15,880	3.78

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.1302	0.229	1.222		7.16	12.60	27,410	3.85
	0.277	1.344			15.24	30,150	3.71
	0.389	1.612			21.40	36,160	3.59
	0.447	1.751			24.59	39,280	3.59
	0.483	1.833			26.57	41,120	3.59
	0.425	1.703			23.38	38,210	3.60
	0.346	1.512			19.03	33,920	3.62
0.1293	0.300	1.382		7.11	16.50	31,000	3.65
	0.347	1.505			19.08	33,760	3.62
	0.477	1.817			26.24	40,760	3.62
	0.237	1.229			13.04	27,570	3.80
	0.248	1.255			13.64	28,150	3.76
0.187	0.402	2.282	Negligible	10.28	22.11	51,190	3.63
	0.350	2.130			19.25	47,780	3.72
	0.320	2.057			17.60	46,150	3.83
	0.452	2.438			24.86	54,690	3.59
	0.491	2.563			27.00	57,500	3.59
0.186	0.317	2.041		10.23	17.44	45,790	3.84
	0.320	2.037			17.60	45,700	3.81
0.238	0.445	3.051		13.09	24.48	68,450	3.72
	0.491	3.213			27.00	72,080	3.66
	0.381	2.908			20.96	65,240	3.96
	0.388	2.909			21.34	65,260	4.04
0.294	0.501	4.033		16.17	27.56	90,480	3.82
	0.422	3.993			23.21	89,580	4.32
	0.422	3.989			23.21	89,490	4.31
	0.460	3.989			25.30	89,490	4.03
	0.465	3.989			25.58	89,490	4.00

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.199	1.224		10.94	27,460	3.40
0.238	1.616		13.09	36,250	3.44
0.303	2.348		16.66	52,680	3.48
0.353	3.002		19.42	67,350	3.54
0.463	4.673		25.46	104,800	3.66
0.083	0.3053		4.56	6,849	3.15
0.081	0.2932		4.46	6,578	3.13
0.150	0.7790		8.25	17,480	3.31
0.113	0.4982		6.22	11,180	3.24
0.147	0.7553		8.08	16,940	3.31
0.157	0.8340		8.64	18,710	3.31
0.217	1.404	Negligible	11.94	31,500	3.43
0.252	1.769		13.86	39,690	3.45
0.283	2.116		15.56	47,470	3.47
0.293	2.244		16.12	50,340	3.49
0.319	2.548		17.54	57,160	3.49
0.371	3.254		20.40	73,000	3.56
0.289	2.200		15.90	49,350	3.50
0.498	5.274		27.39	118,300	3.71
0.314	2.498		17.27	56,040	3.50
0.426	4.059		23.43	91,060	3.60
0.054	0.1572		2.97	3,527	3.11
0.120	0.5475		6.60	12,280	3.25
0.347	2.893		19.08	64,900	3.49
0.347	2.911		19.08	65,310	3.52
0.422	3.993		23.21	89,580	3.60
0.280	2.082		15.40	46,710	3.47
0.048	0.1296		2.64	2,907	3.05
0.081	0.2886		4.46	6,474	3.08

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.052	0.168	0.803	0.000	1.82	5.88	5,819	3.99
	0.301	1.119	0.000		10.54	8,110	3.99
	0.463	1.411	0.000		16.20	10,230	3.99
	0.650	1.695	0.000		22.75	12,280	4.01
	0.831	1.932	0.000		29.08	14,000	4.03
	1.068	2,198	0.000		37.38	15,930	4.02
~~0.078~~	0.100	0.719	0.000	~~2.73~~	3.50	5,211	3.31+ ~~3.70~~* 4.96
0.078	1.023	3.024	0.000	2.73	35.80	21,920	3.79
	0.608	2.278	0.000		21.28	16,510	3.76
	0.856	2.746	0.000		29.96	19,900	3.78
	0.451	1.932	0.000		15.78	14,000	3.75
	0.165	1.072	0.000		5.78	7,769	3.78
	0.299 0.127	1.523 1.025	0.000 0.000		10.46 4.44	11,040 7,428	3.72 3.30+ 4.34*
0.111	0.346	2.196	0.000	3.88	12.11	15,910	3.57
	0.576	2.962	0.000		20.16	21,470	3.59
	0.842	3.703	0.001		29.50	26,840	3.65
	1.074	4.161	0.001		37.62	30,160	3.61
	1.056	4.140	0.001		37.00	30,000	3.62
	~~0.183~~ 1.044	~~1.803~~ 4.149	0.0001		~~36.46~~ 36.58	~~13,070~~ 30,070	~~3.35+~~ 3.65
~~0.166~~	~~1.044~~	~~4.149~~	~~0.001~~	~~5.81~~	~~36.58~~	~~30,070~~	~~3.65~~
0.166	0.271	2.679	0.001	5.81	9.52	19,420	3.63
	1.068	6.182	0.001		37.42	44,800	3.64
	0.837	5.417	0.001		29.33	39,260	3.65
	0.616	4.552	0.001		21.60	32,990	3.65
	0.441	3.688	0.001		15.47	26,730	3.61
0.223	0.280	3.538	0.001	7.80	9.84	25,640	3.46+ 3.82*
	0.356	4.102	0.001		12.50	29,730	3.64
	0.540	5.436	0.002		18.97	39,400	3.62
	0.702	6.396	0.002		24.64	46,350	3.62
	0.858	7.189	0.002		30.10	52,100	3.62
	1.064	8.186	0.002		37.31	59,330	3.65

+Gate lip touching nappe C from Equation B.
*Gate lip touching nappe C from Equation A.

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.338	1.061	11.98	0.005	11.83	37.28	86,820	3.64
	0.854	10.49	0.005		30.06	76,020	3.64
	0.663	8.894	0.004		23.34	64,460	3.64
	0.484	7.141	0.003		17.04	51,750	3.68
	0.420	6.781	0.003		14.80	49,140	3.59+ 3.95*
	0.476	7.102	0.003		16.76	51,470	3.70
	1.050	11.94	0.005		36.92	86,530	3.65
0.453	0.616	10.82	0.006	15.86	21.77	78,410	3.74
	0.565	10.85	0.007		20.02	78,630	3.65+ 4.04*
	0.679	11.48	0.007		24.01	83,200	3.67
	0.840	13.33	0.008		29.68	96,600	3.65
	1.047	15.50	0.009		36.96	112,300	3.66
0.567	0.688	15.07	0.012	19.84	24.50	109,200	3.75+ 4.09*
	0.765	15.39	0.011		27.16	111,500	3.81
	0.854	16.46	0.012		30.31	119,300	3.73
	0.957	17.72	0.013		33.95	128,400	3.69
	1.035	18.60	0.013		36.68	134,800	3.67
0.681	0.833	20.71	0.019	23.83	29.82	150,100	3.84+ 4.21*
	0.937	20.81	0.018		33.42	150,800	3.84
	1.007	21.82	0.018		35.88	158,100	3.80
	1.048	22.36	0.019		37.34	162,000	3.78
	0.928	20.69	0.018		33.11	149,900	3.85

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.100	0.717	0.000	3.50	5,211	3.31
0.183	1.803	0.000	6.40	13,070	3.35
0.280	3.538	0.001	9.84	25,640	3.46
0.420	6.781	0.003	14.80	49,140	3.59
0.565	10.85	0.007	20.02	78,630	3.65
0.688	15.07	0.012	24.50	109,200	3.75
0.833	20.71	0.019	29.82	150,100	3.84
0.920	24.51	0.025	33.08	177,600	3.89
0.561	10.73	0.007	19.88	77,760	3.65
0.703	15.63	0.012	25.02	113,300	3.77
0.127	10.24	0.000	4.44	7,421	3.30
0.900	23.64	0.024	32.34	171,300	3.88
0.699	15.34	0.012	24.88	111,200	3.73
0.498	8.833	0.005	17.61	64,010	3.61
0.080	0.527	0.000	2.82	3,819	3.40

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G. O. ft.	H ft.	Q cfs	C
0.0286	0.096	0.3164	0.000	0.98	3.30	2,188	3.71
	0.131	0.3794	0.000		4.50	2,624	3.72
	0.240	0.5280	0.000		8.24	3,651	3.71
	0.279	0.5704	0.000		9.58	3,945	3.70
	0.417	0.6987	0.000		14.32	4,832	3.68
	0.344	0.6346	0.000		11.82	4,389	3.70
	0.184	0.4629	0.000		6.32	3,201	3.74
	0.508	0.7730	0.000		17.45	5,346	3.66
0.0575	0.160	0.7723	0.000	1.98	5.50	5,341	3.54
	0.197	0.8797	0.000		6.77	6,083	3.56
	0.114	0.6192	0.000		3.92	4,282	3.53
	0.251	1.015	0.000		8.62	7,019	3.57
	0.294	1.112	0.000		10.10	7,690	3.59
	0.355	1.235	0.000		12.19	8,541	3.59
	0.412	1.338	0.000		14.15	9,253	3.58
	0.497	1.480	0.000		17.07	10,230	3.59
0.0875	0.116	0.8990	0.000	3.00	3.98	6,220	3.26+ 3.71*
	0.151	1.061	0.000		5.19	7,340	3.56
	0.195	1.273	0.000		6.70	8,803	3.58
	0.229	1.416	0.000		7.87	9,792	3.59
	0.269	1.568	0.000		9.24	10,840	3.61
	0.310	1.706	0.000		10.65	11,800	3.61
	0.379	1.922	0.000		13.02	13,290	3.63
	0.447	2.116	0.000		15.35	14,630	3.64
	0.478	2.196	0.000		16.42	15,190	3.64
	0.504	2.261	0.000		17.31	15,640	3.64
0.1166	0.151	1.385	0.000	4.00	5.19	9,578	3.38+ 3.79*
	0.186	1.560	0.000		6.39	10,790	3.61
	0.228	1.796	0.000		7.83	12,420	3.59
	0.283	2.080	0.000		9.72	14,380	3.60
	0.334	2.320	0.001		11.51	16,040	3.62
	0.396	2.576	0.001		13.64	17,810	3.63
	0.454	2.793	0.001		15.63	19,310	3.64
	0.512	2.997	0.001		17.62	20,730	3.64
	0.511	2.990	0.001		17.59	20,680	3.64

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2037	0.258	3.299	0.001	7.00	8.90	22,810	3.58+ 3.98*
	0.276	3.358	0.001		9.51	23,220	3.82
	0.288	3.467	0.001		9.93	23,980	3.80
	0.322	3.684	0.001		11.10	25,480	3.70
	0.365	4.007	0.002		12.61	27,710	3.67
	0.418	4.430	0.002		14.43	30,640	3.70
	0.456	4.677	0.002		15.73	32,340	3.68
	0.497	4.945	0.002		17.14	34,200	3.69
	0.421	4.434	0.002		14.53	30,660	3.68
0.2912	0.365	5.866	0.003	10.00	12.64	40,570	3.76+ 4.16*
	0.404	5.977	0.003		13.98	41,330	3.88
	0.418	6.081	0.003		14.46	42,050	3.85
	0.436	6.243	0.003		15.08	43,170	3.82
	0.461	6.502	0.004		15.97	44,960	3.81
	0.500	6.841	0.004		17.31	47,310	3.77

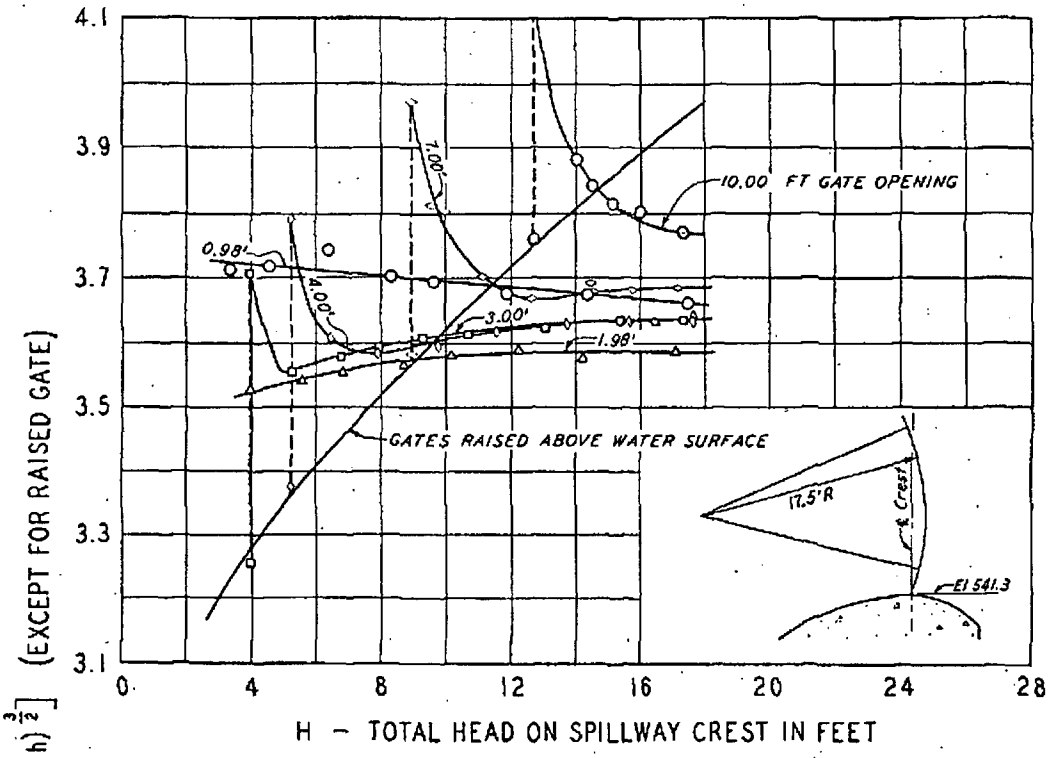
*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

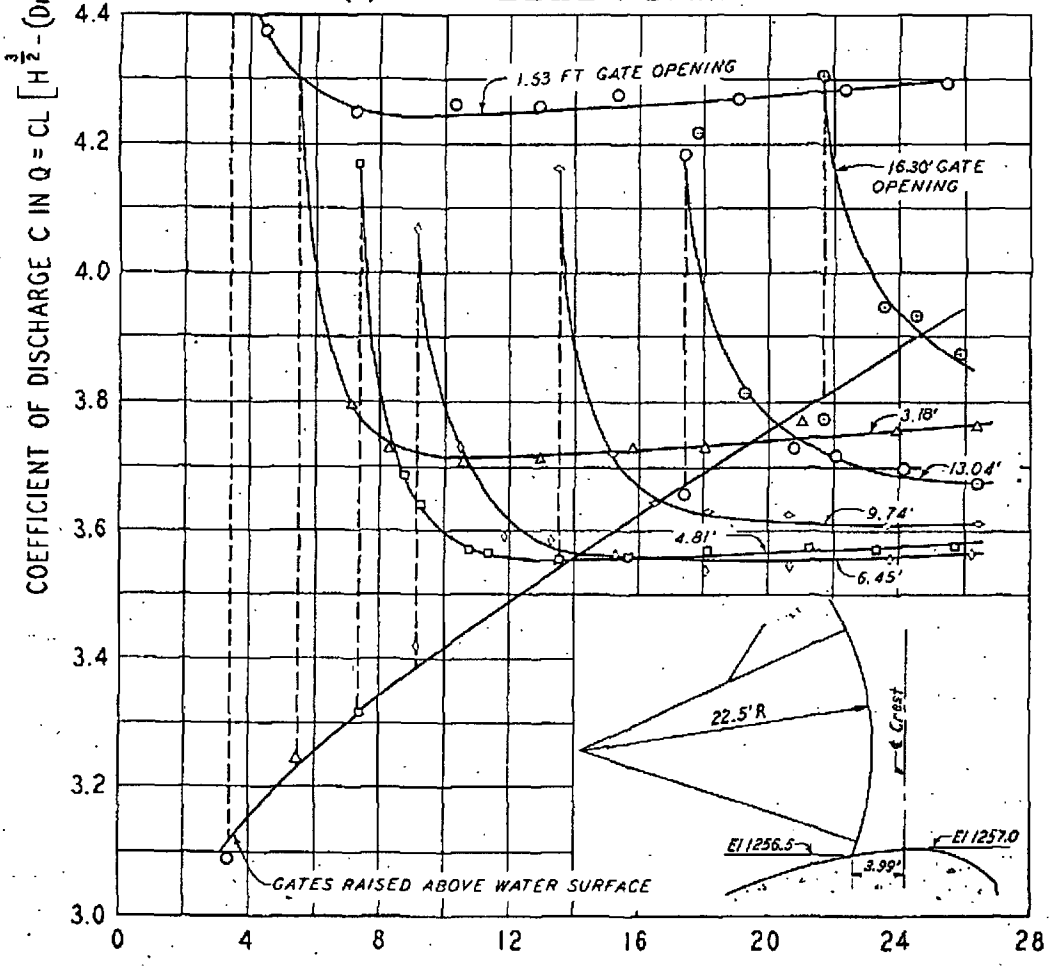
Wheeler Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.178	1.786	0.000	6.11	12,350	3.41
0.214	2.444	0.001	7.39	16,900	3.51
0.281	3.788	0.002	9.72	26,200	3.60
0.307	4.386	0.002	10.58	30,330	3.67
0.347	5,348	0.003	12.02	36,980	3.70
0.390	6.559	0.004	13.53	45,360	3.80
0.440	8,038	0.006	15.32	55,590	3.86
0.405	6.998	0.004	14.05	48,400	3.83
0.366	5.892	0.003	12.68	40,750	3.76
0.191	1.996	0.000	6.56	13,800	3.42
0.218	2.490	0.001	7.52	17,220	3.48
0.279	3.742	0.002	9.65	25,880	3.60
0.306	4.366	0.002	10.58	30,190	3.66
0.416	7.316	0.005	14.46	50,590	3.83
0.465	8.775	0.006	16.18	60,680	3.89
0.499	9.914	0.009	17.45	68,560	3.92
0.305	4.314	0.002	10.55	29,830	3.63
0.076	0.464	0.000	2.61	3,209	3.16
0.123	1.004	0.000	4.23	6,943	3.34
0.155	1.444	0.000	5.32	9,986	3.39
0.116	0.8990	0.000	3.98	6,220	3.26
0.151	1.385	0.000	5.19	9,578	3.38
0.258	3.299	0.001	8.90	22,810	3.58
0.365	5.866	0.003	12.64	40,570	3.76



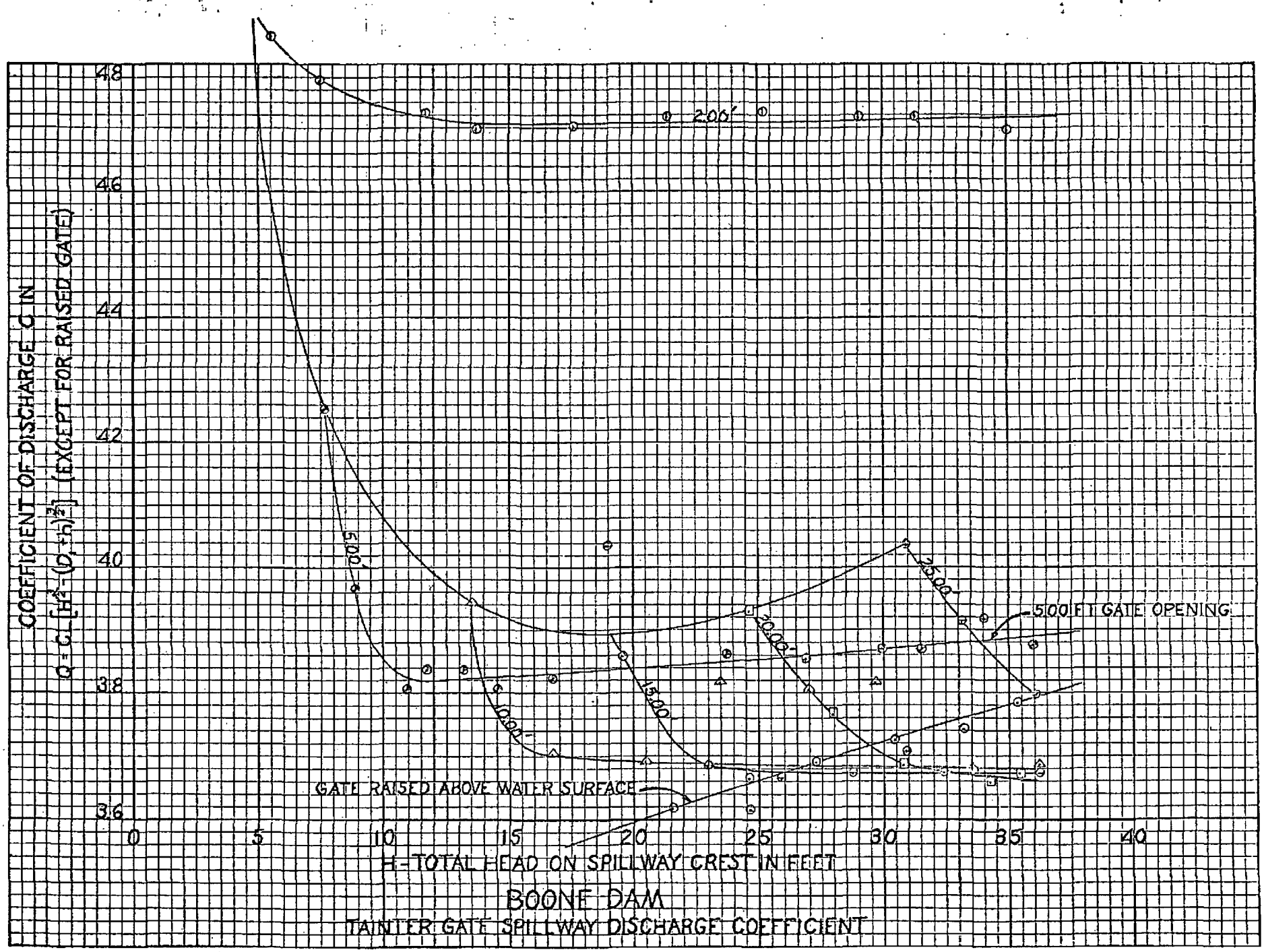
(a) WHEELER DAM



(b) APALACHIA DAM

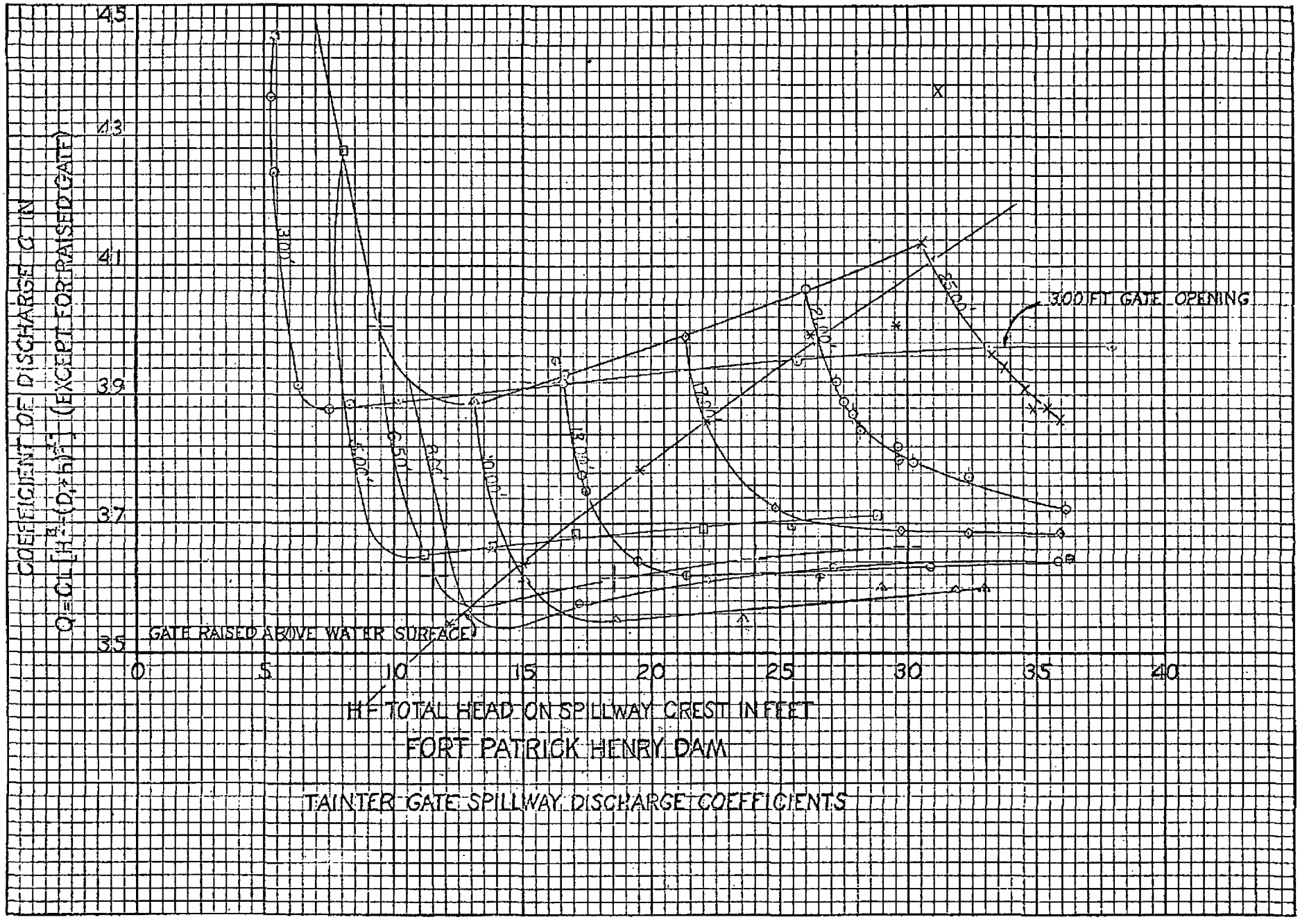
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

K&E 10 X 10 TO THE INCH 359-5
KEUFFEL & ESSER CO. MADE IN U.S.A.



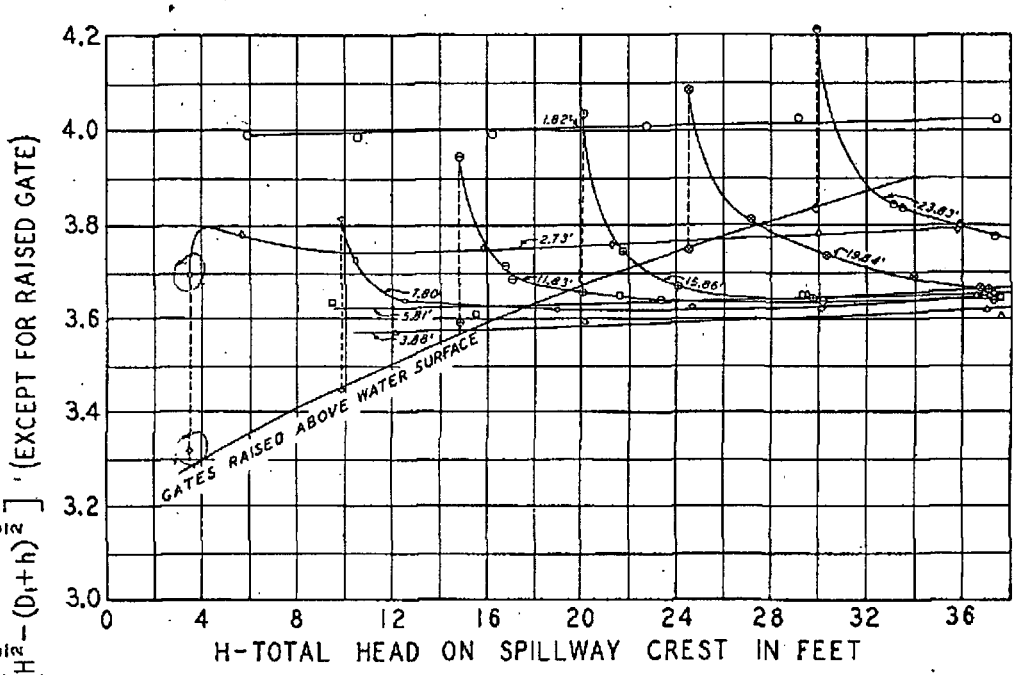
BOONE DAM
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENT

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KEUFFEL & ESSER CO. MADE IN U.S.A.

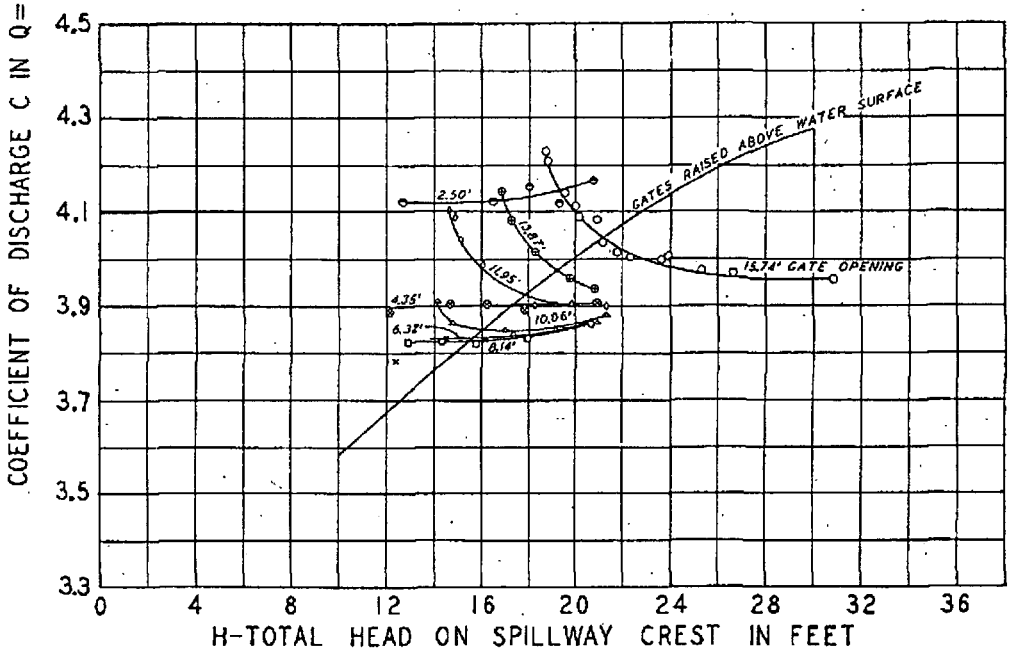


FORT PATRICK HENRY DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

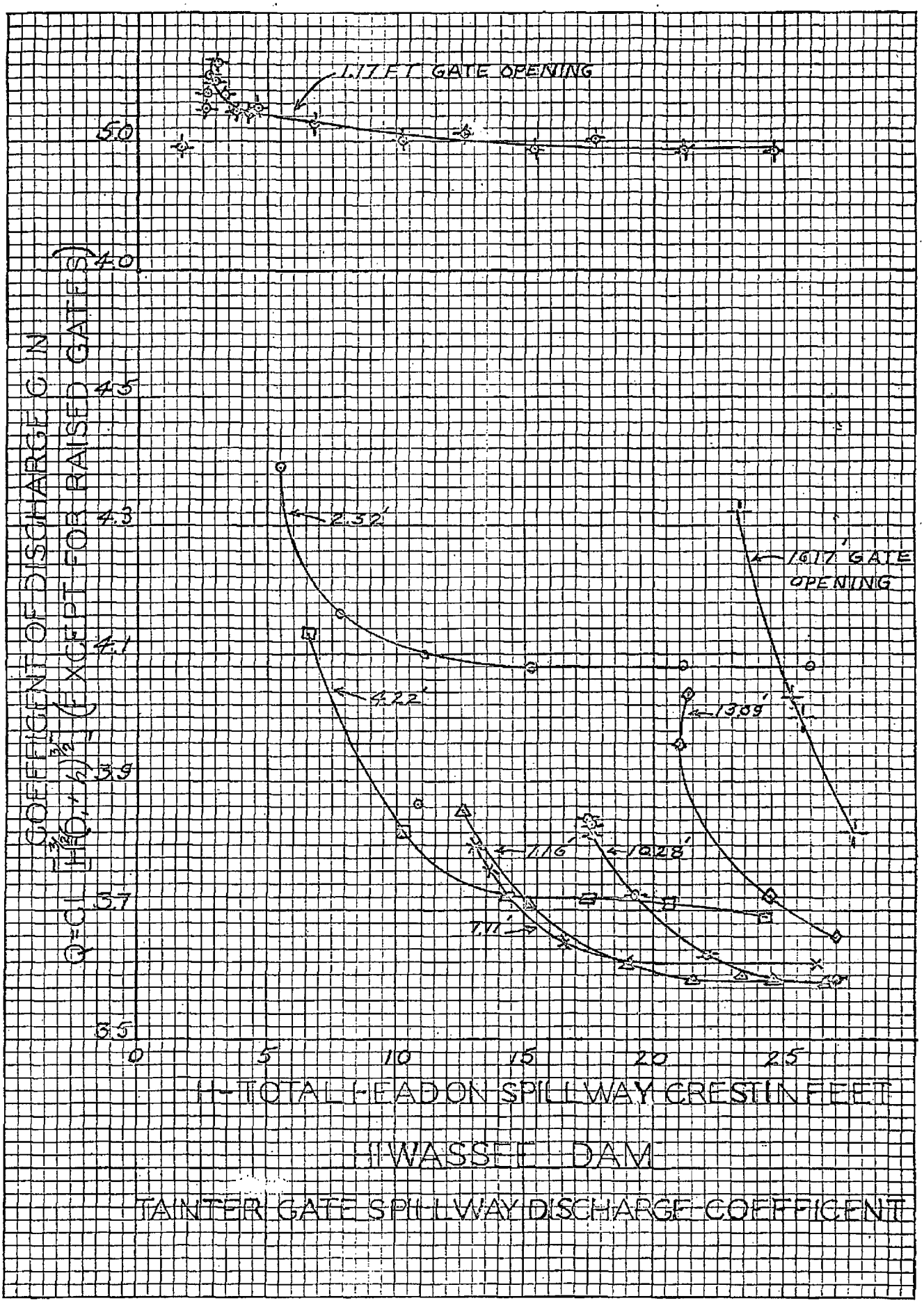


(a) WATTS BAR DAM



(b) HALES BAR DAM

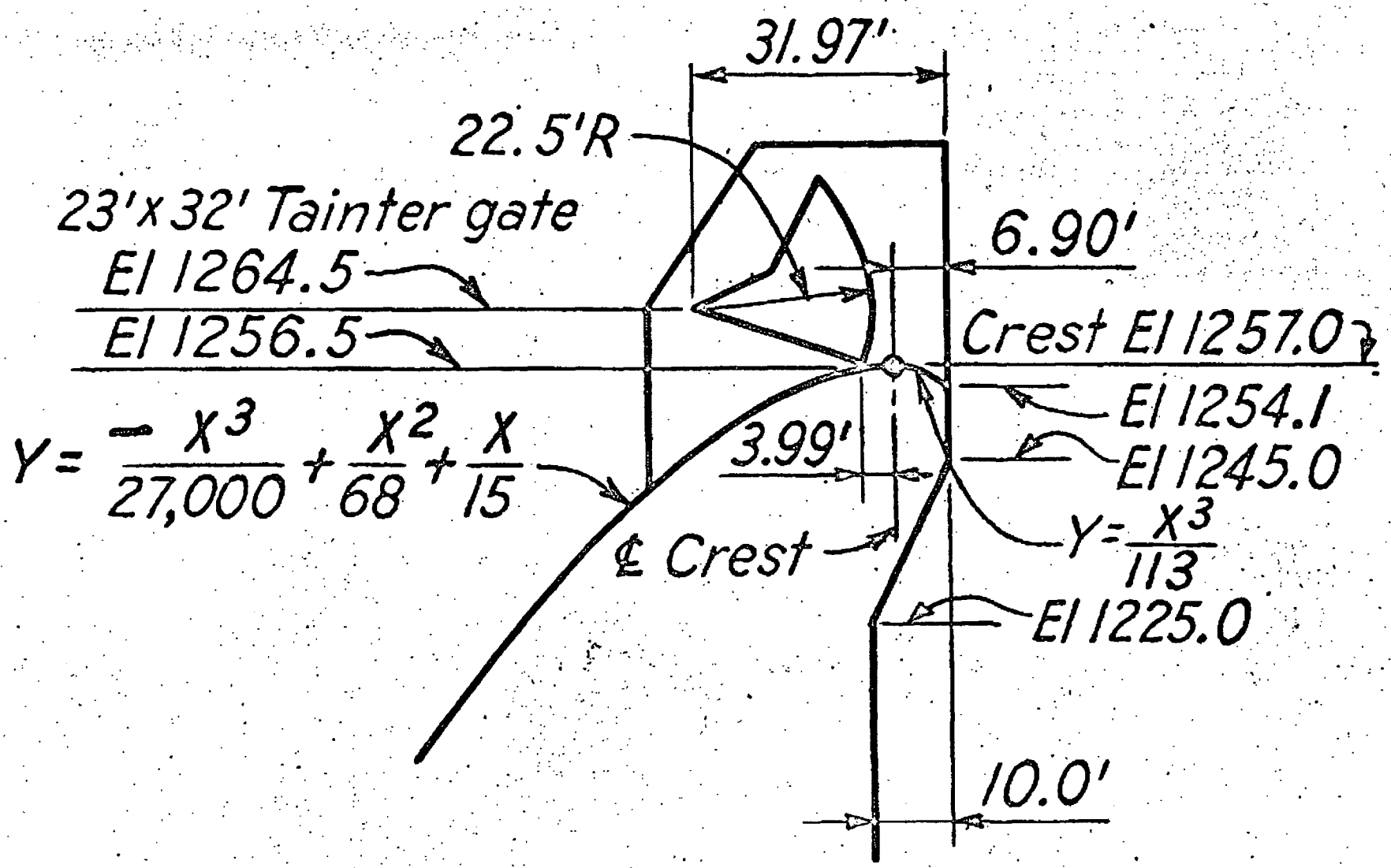
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS



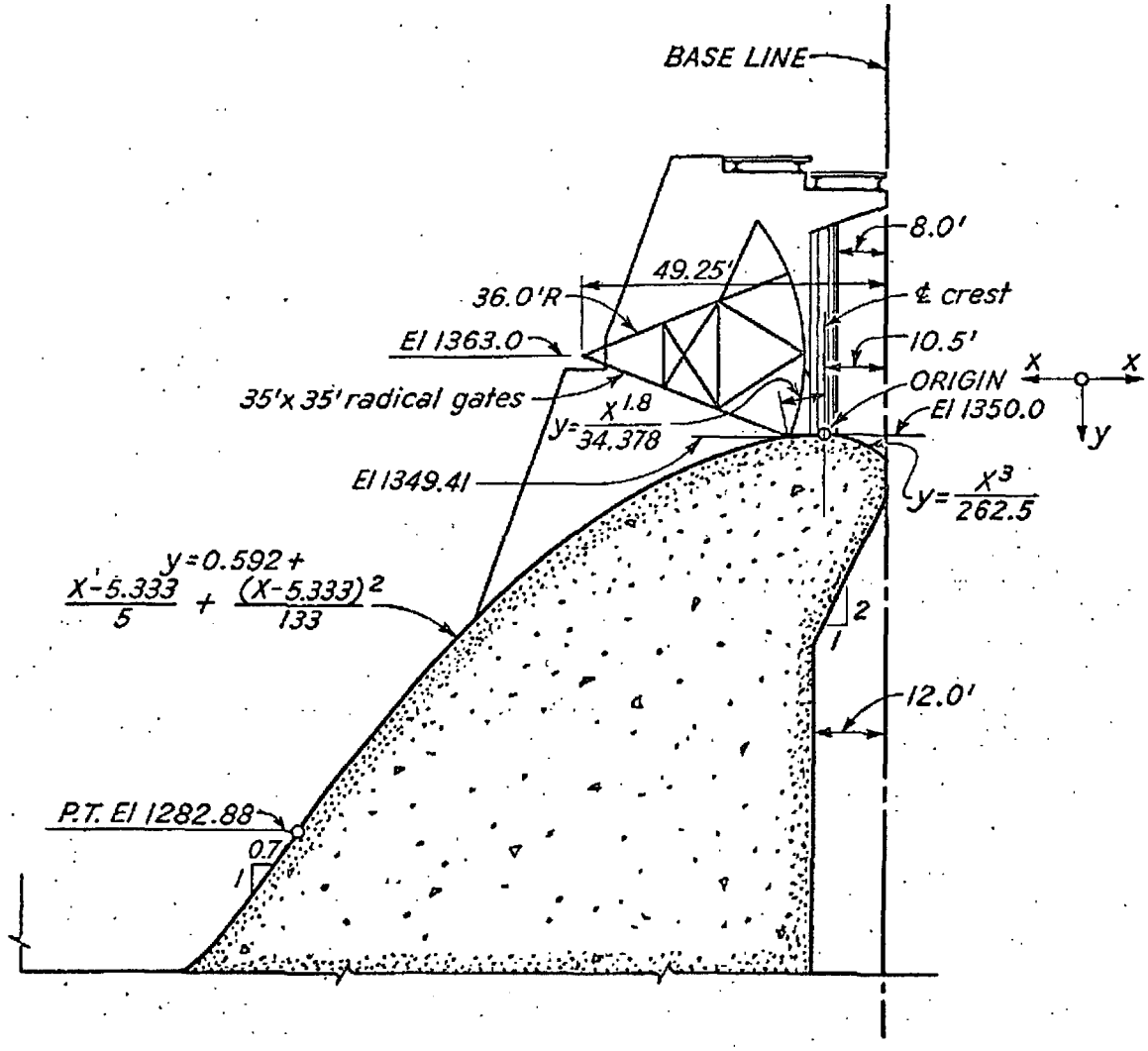
HIWASSEE DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICENT

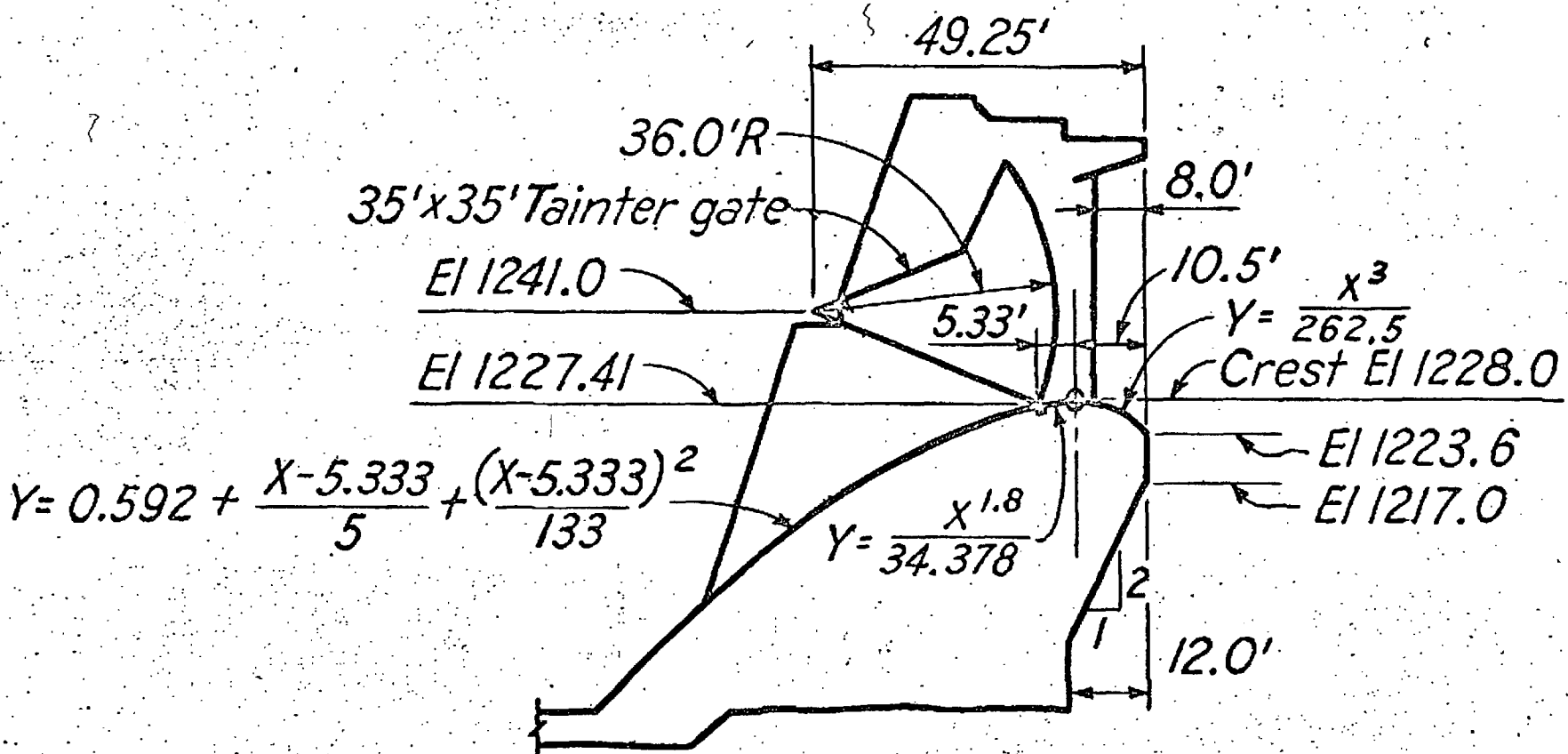
K&E 10 X 10 TO THE INCH 359-5 KEUFFEL & ESSER CO. MADE IN U.S.A.



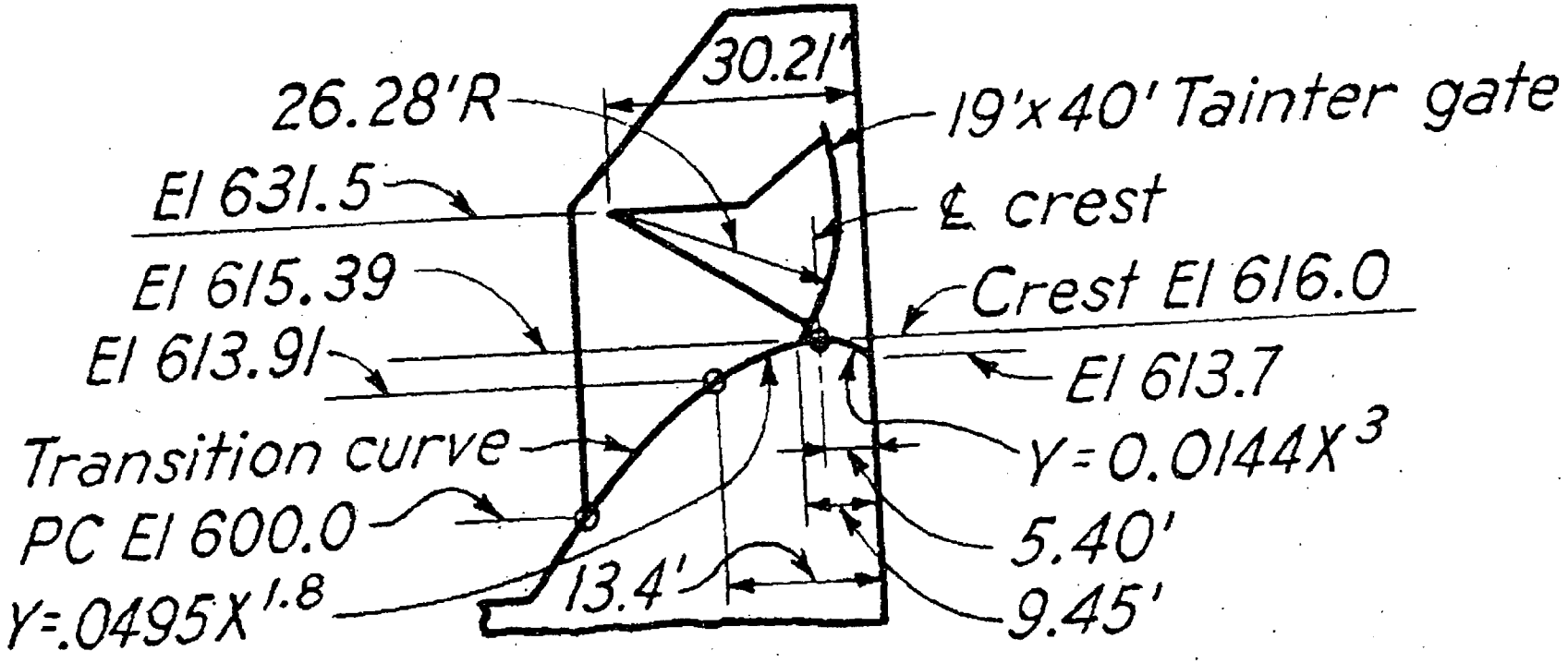
APALACHIA PROJECT



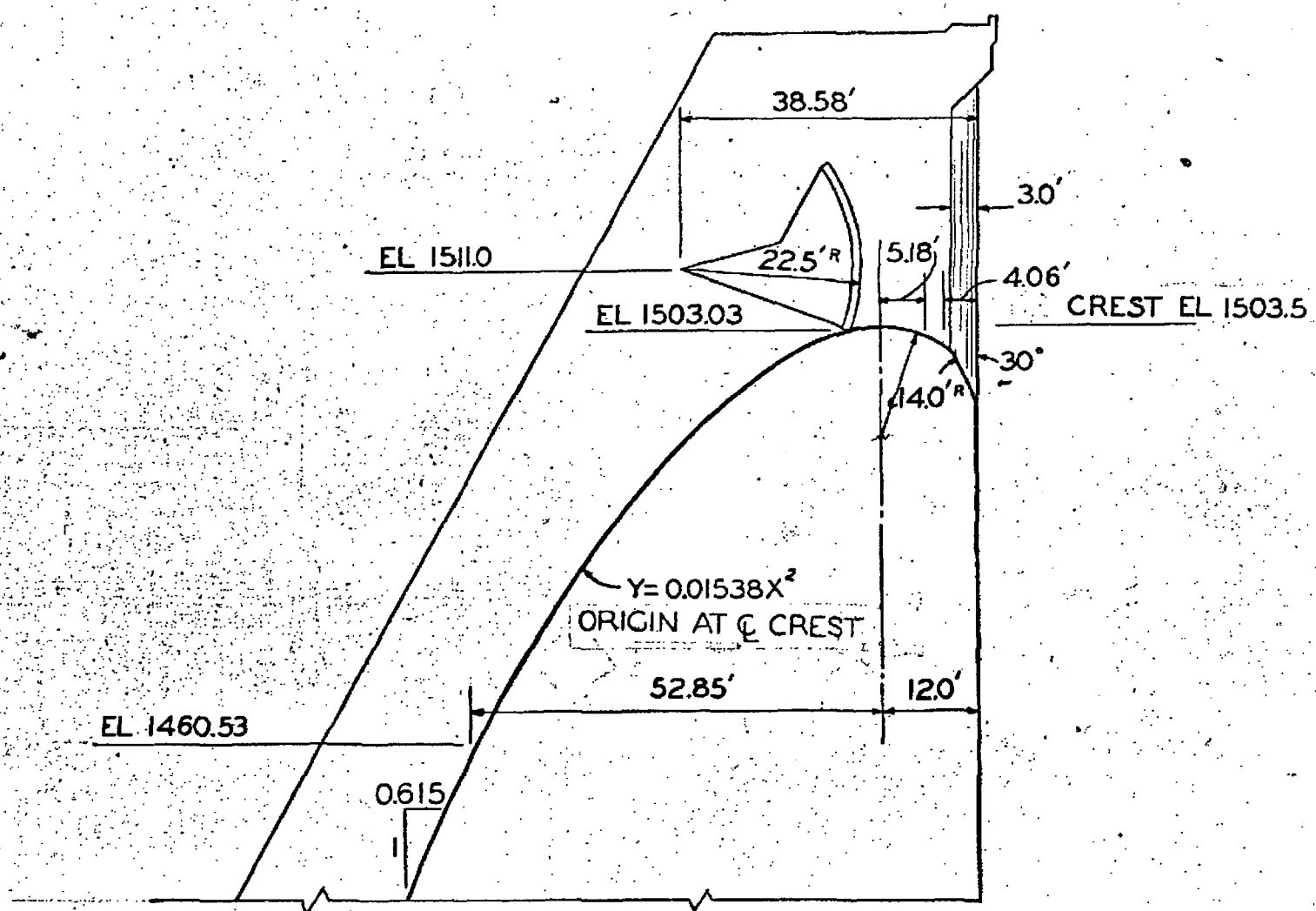
BOONE PROJECT



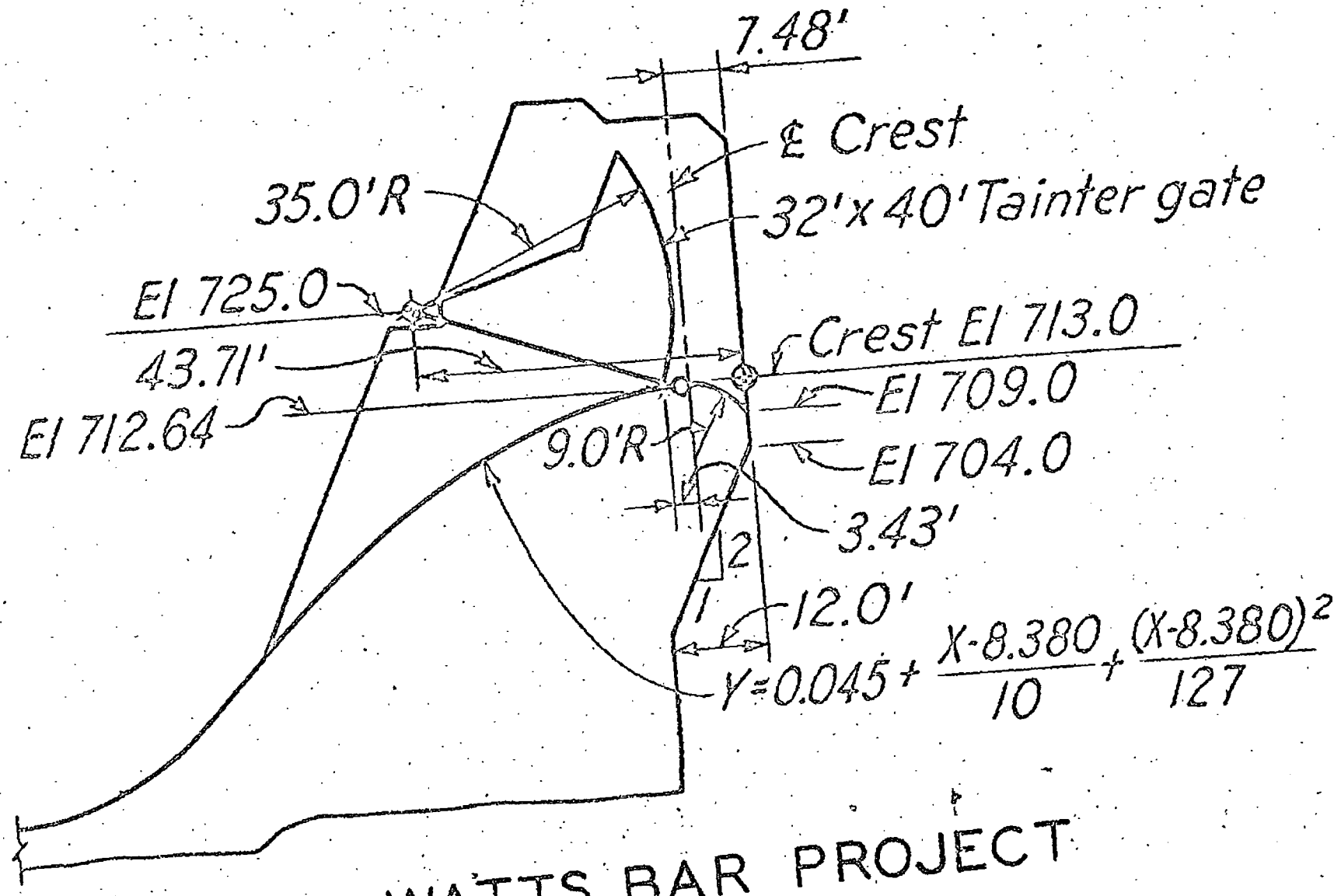
FORT PATRICK HENRY PROJECT



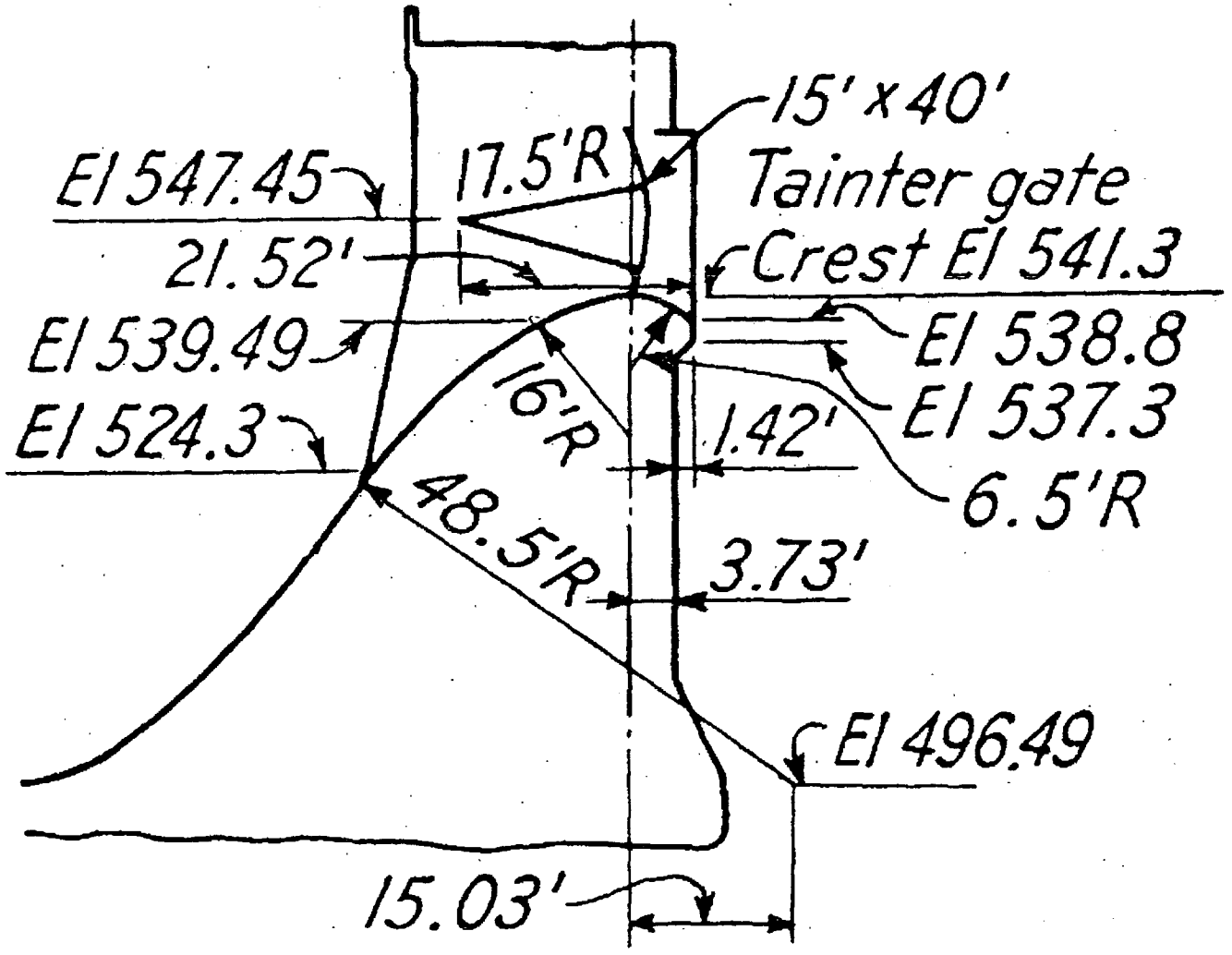
HALES BAR PROJECT



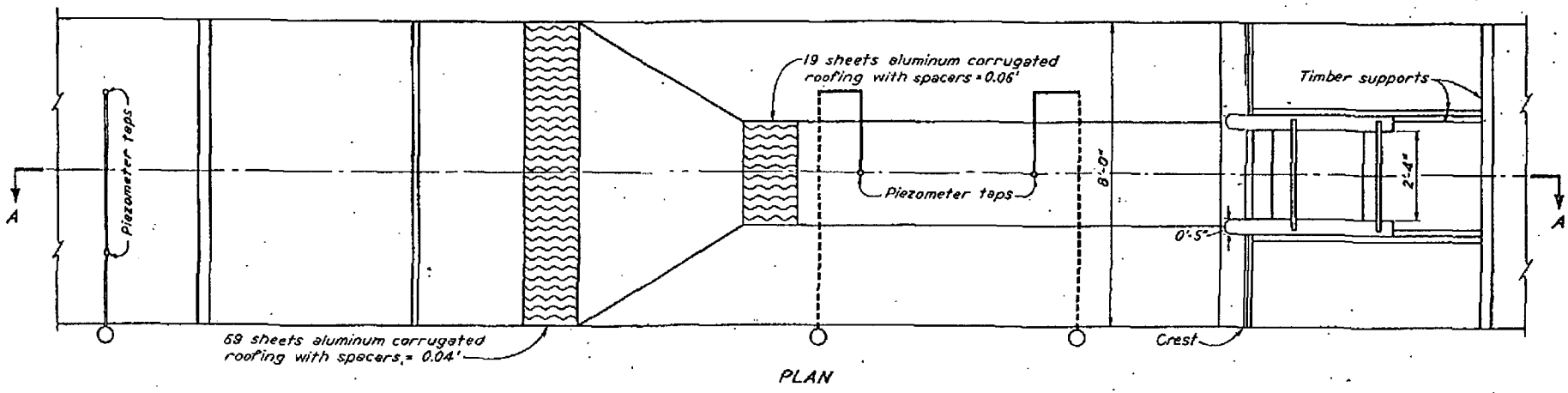
HIWASSEE PROJECT



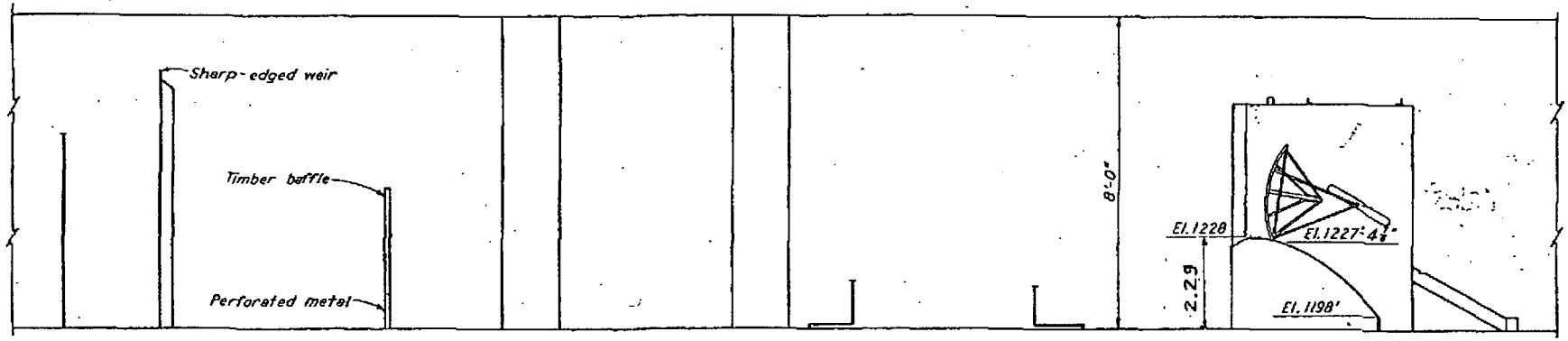
WATTS BAR PROJECT



WHEELER PROJECT



PLAN



SECTION A-A

Scales

1 Model 0 1 2 3 4 5 6 7 8 9 10 Feet

Prototype 0 20 40 60 80 100 Feet

NOTE:

Elevations refer to the prototype.
Dimensions refer to the model.

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

FORT PATRICK HENRY PROJECT
HYDRAULIC MODEL STUDIES

1:15 SCALE MODEL LAYOUT

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