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

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8U: Dam Rating Curves, Watts Bar

(314 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 090224 002	Calculations (nuclear)	L58 091230 032

Calc Title: Initial Dam Rating Curves, Watts Bar

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080020	0	1	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes 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
C.J. GRACE	205.298.6074	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Chris Grace [signature]	12/21/2009	Bryant Bondurant [signature]	12/21/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Chris Triplett [signature]	12/21/09	K.R. Spates [signature]	12/23/09

STATEMENT OF PROBLEM/ABSTRACT

[initials] 12/21/09

Initial dam rating (headwater rating) curves are required as inputs to TVA's SOCH and TRBROUTE models, used in performing flood-routing calculations for the Tennessee River. The initial dam rating curves provide total dam discharge as a function of headwater elevation and are used to define the beginning conditions for the hydraulic analysis. The final dam rating curve is confirmed and documented in the SOCH Probable Maximum Flood model calculation by validating the headwater-tailwater relationship across the modeled dam configuration. This calculation presents initial dam rating curves for Watts Bar Dam for the condition of all spillway gates fully open. These initial rating curves are to be used for the purpose of computing water levels downstream from Watts Bar Dam during flood conditions.

EDCN – 22404A (SQN)
EDCN – 54018A (WBN)
EDCN – later (BFN)

Limiting Condition Note: The headwater rating curve provided in this calculation is limited in application to maximum PMF headwater elevation of 768.50 feet (See Section 5.0 in the calculation for the basis of this limiting condition).

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:

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 090224 002	Calculations (nuclear)	N/A

Calc Title: Dam Rating Curves, Watts Bar

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	CDQ000020080020	N/A	0	

ACTION	NEW ☒ REVISION ☐	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes 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
G. A. SCHOHL	632-3968	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Gerald A. Schohl	2/12/2009	Douglas W. Adams	2/12/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE** K.R. Spates	**DATE**
Frederick A. Locker	2/12/09	K.R. Spates	2-23-09

STATEMENT OF PROBLEM/ABSTRACT

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Watts Bar Dam for the condition of all spillway gates fully open. These rating curves are to be used for the purpose of computing water levels downstream from Watts Bar Dam during flood conditions.

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
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NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080020	1

ALTERNATE CALCULATION IDENTIFICATION

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

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	DW	GEN	CEB	54W200	R6
A	P	DW	GEN	CEB	51N205	R4
A	P	DW	GEN	CEB	10W222-1	R0
A	P	DN	SQN	CEB	22404	
A	P	DN	WBN	CEB	54018	
C	P	CN	GEN	CEB	CDQ000020080039	
A	S	CN	GEN	CEB	CDQ000020080041	
A	S	CN	GEN	CEB	CDQ000020080046	

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	CDQ000020080020
Title	Initial Dam Rating Curves, Watts Bar
Revision No.	DESCRIPTION OF REVISION
0	Initial issue Total pages: 117
1	This calculation was revised to address the following : • PER 203951- The verification of the previous 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 203951. The verification is inclusive of work completed prior to this revision. • PER 203872- Replace NEDP-2 forms on Pages 1 through 7 with the forms from the NEDP-2 Revision in effect at the time of calculations issuance. • UVA 3.2.1. Removed and replaced with Assumption 3.1.9 based on Reference 37. • UVA 3.2.2. Removed and replaced with Assumption 3.1.9 based on Reference 38. • UVA 3.2.3. Removed and replaced with: o Assumption 3.1.6 based on Reference 35 o Assumption 3.1.7 based on Appendix B. • UVA 3.2.4. Removed and replaced with Assumption 3.1.8 based on Reference 36. • Assumption 3.1.10 added based on Technical Justification. • Assumption 3.1.11 added based on Technical Justification. • Calculation was revised to address modification made to the east earth embankment. These modifications included the installation of three foot tall sand-filled HESCO baskets at the top of the embankment. These baskets effectively raise the overflow elevation of the east embankment from 767 feet to 770 feet. The headwater rating in Case 4 was consequently noted as not valid. • The upper lock gate overflow discharge coefficient (as listed in Section 4.9.1) was corrected from 3.0 to 3.3 to make it consistent with the supporting documentation found in Attachment 9 and the flow calculations. The correct coefficient value was used in the calculation in both the previous edition of this calculation (R0) and this version (R1). • Added Appendix B to evaluate the margin of forces on the spillway gates. Significant changes in Revision 1 are noted with a right margin revision bar. Administrative changes and typos are excluded. Pages deleted: Att. 3 Pages revised: 1-5, 7-9, 11-13, 16-20, 22-31, Att. 15-1, Att. 18 New pages added: 1a, 6 (NEDP 2-4), B1, B2, B3 Calculation header was revised (Title and Revision) on pages 1-31 and A1-A6 Total pages for Revision 1: 120

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080020	Revision: 1	

TABLE OF CONTENTS

NPG CALCULATION TABLE OF CONTENTS (CONTINUED)

Calculation Identifier: CDQ000020080020	Revision: 1	

TABLE OF CONTENTS

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080020	Revision 1
Method of verification used: 1. Design Review ☒ 2. Alternate Calculation ☐ 3. Qualification Test ☐	Verifier C. Triplett Date 12/21/09 [signature]

Comments:

This calculation entitled, "Initial Dam Rating Curves, Watts Bar," 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 east saddle dam's crest is at 770 feet, which was the original elevation of failure. Though the failure of the earthen embankment is expected soon after overtopping, it will not fail at the point water levels reach the dam's crest.

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 B 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 CDQ000020080020	Rev. 1	Plant: GEN	

Subject:
Initial Dam Rating Curves, Watts Bar

☐ 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 20: Watts Bar Rating Curves.xls
    Spreadsheet for dam rating curve calculations
Attachment 21: Watts Bar Area Topo.pdf
    A high-resolution PDF file of the topo map portion in Figure 2.
Attachment 22: Complete PDF copy of Reference 3 (also referenced as A1)
Attachment 23: Complete PDF copy of Reference 8
Attachment 24: Complete PDF copy of Reference 34
Attachments 25 through 49: Large resolution PDF files of References 1, 7, and 9-31
Attachment 50: Complete PDF copy of Reference 35
Attachment 51 Complete PDF copy of Reference 36
Attachment 52 Large resolution PDF file of Reference 39
Attachment A18: Watts Bar Model Data for Dam Ratings.xls
    Spreadsheet for model data calculations
Attachment A19: Complete PDF copy of Reference A3
Attachment A20: Complete PDF copy of Reference A4
Attachment A21: Large resolution PDF file of Reference A8
Attachment A22: Large resolution PDF file of Reference A9

☐ Microfiche/eFiche

1. Purpose

Initial dam rating (headwater rating) curves are required as inputs to TVA's SOCH and TRBROUTE models, used in performing flood-routing calculations for the Tennessee River. The initial dam rating curves provide total dam discharge as a function of headwater elevation and are used to define the beginning conditions for the hydraulic analysis. The final dam rating curve is confirmed and documented in the SOCH Probable Maximum Flood model calculation (Reference 38) by validating the headwater-tailwater relationship across the modeled dam configuration.

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 past work regarding design basis flood level determinations. This calculation supports a portion of the effort to improve the 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 calculation 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 Watts Bar dam (a portion of Attachment 1). For headwaters in the normal operating range, discharge is passed through the turbines, the spillway, or the trashway. The spillway consists of twenty spillway bays, each with a radial, or tainter, gate to control discharge (see Attachments 1, 7, A1, and A10). The trashway discharge is controlled by vertical lift gates (see Attachment 7). If, as during a probable maximum flood (PMF) event, headwater rises above the normal operating range, discharge may pass also over the nonoverflow section, the navigation lock, the tops of the open spillway gates, and the tops of the spillway piers. In addition, as indicated in Figure 2, discharge may also pass over an earth dike saddle dam (the "west saddle dam") that closes a low point in the reservoir rim west of the dam (see Attachment 2).

Rating curves are provided for four cases (Figure 8). All cases assume that all spillway gates remain fully open.

1. Pre-failure condition with turbine discharge -- west saddle dam (overflow elevation 757 feet [4.12.2]) and east embankment (overflow elevation 770 feet [4.11.2]) remain intact. For a rising hydrograph, this rating curve is used from the maximum headwater drawdown elevation (733 feet, see Attachment 1) and higher. If the headwater or tailwater rises far enough for water to enter the powerhouse (headwater elevation 752 feet [4.16.4] or tailwater elevation 740 feet [4.16.3]), turbine operation is suspended and this rating curve is no longer valid. The dam rating shifts to the Case 2 rating curve.
2. Pre-failure condition without turbine discharge -- west saddle dam and east embankment remain intact. This rating curve is used for both rising and falling headwaters after turbine operation has been suspended and before failure of the west saddle dam or east embankment. If the headwater rises far enough above the crest of the west saddle dam to cause its failure, this rating curve is no longer valid and the dam rating shifts to the Case 3 rating curve.
3. West saddle dam fails -- east embankment remains intact. For a rising hydrograph, this rating curve is used from the headwater elevation at which the west saddle dam fails and higher. The full curve is used for both rising and falling headwaters after failure of the west saddle dam. If the headwater rises far enough above the crest of the east

embankment to cause its failure, this rating curve is no longer valid and the dam rating shifts to the Case 4 rating curve.

4. East embankment fails -- west saddle dam previously failed. For a rising hydrograph, this rating curve is used from the elevation at which the east embankment fails and higher. The full curve is used for both rising and falling headwaters after failure of both the east embankment and west saddle dam.

The initial dam rating curves are based on the current configuration of Watts Bar Dam as defined on the current design drawings. The purpose of this calculation does not evaluate the design loading conditions for the dam or embankments.

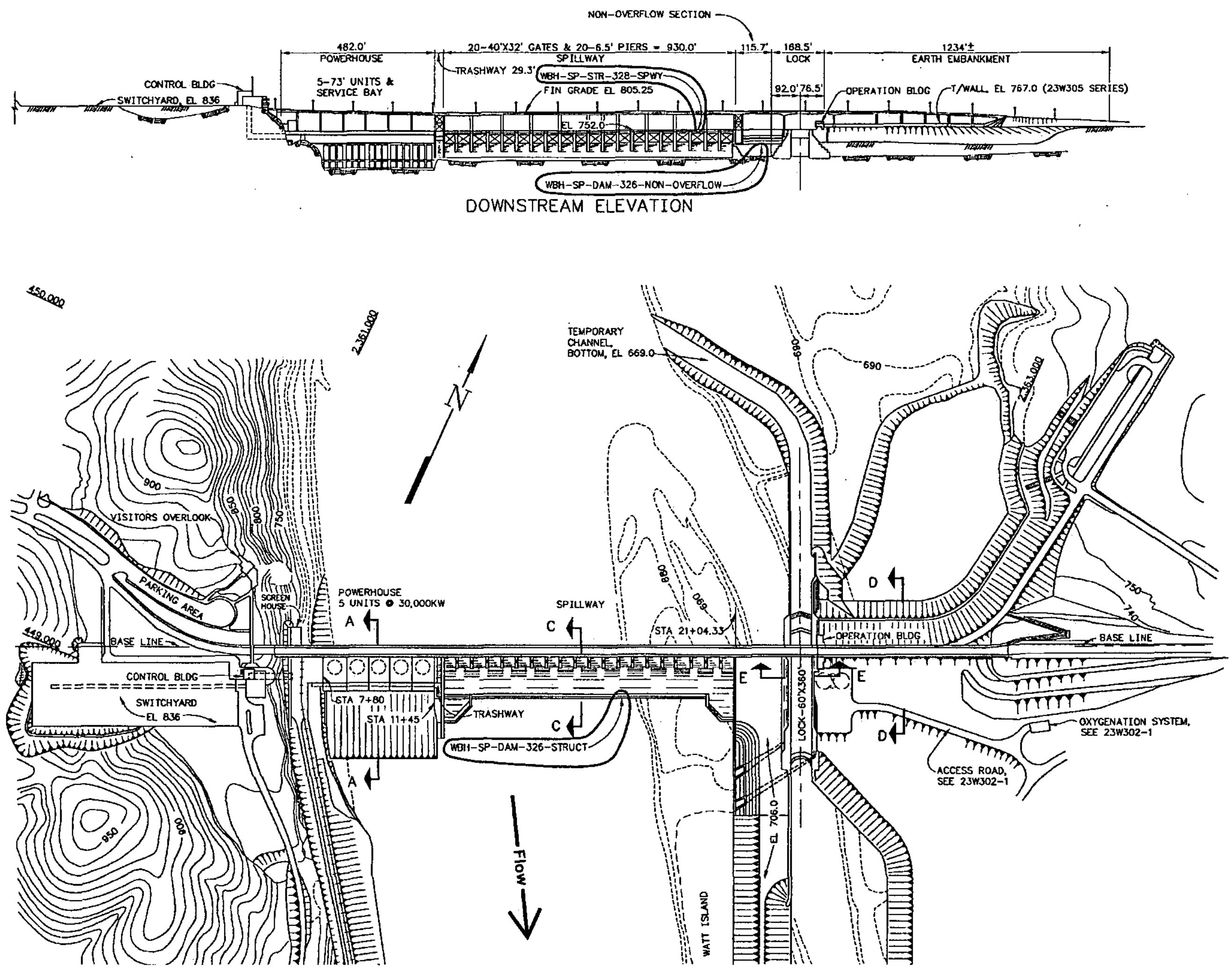


Figure 1 – Watts Bar Dam, General Plan and Elevation (Ref. 1; also refer to Attachments 15-4 to 15-8 for 1997 modifications to east embankment, as constructed, and Attachment 52 for 2009 modifications to east embankment, as proposed.).

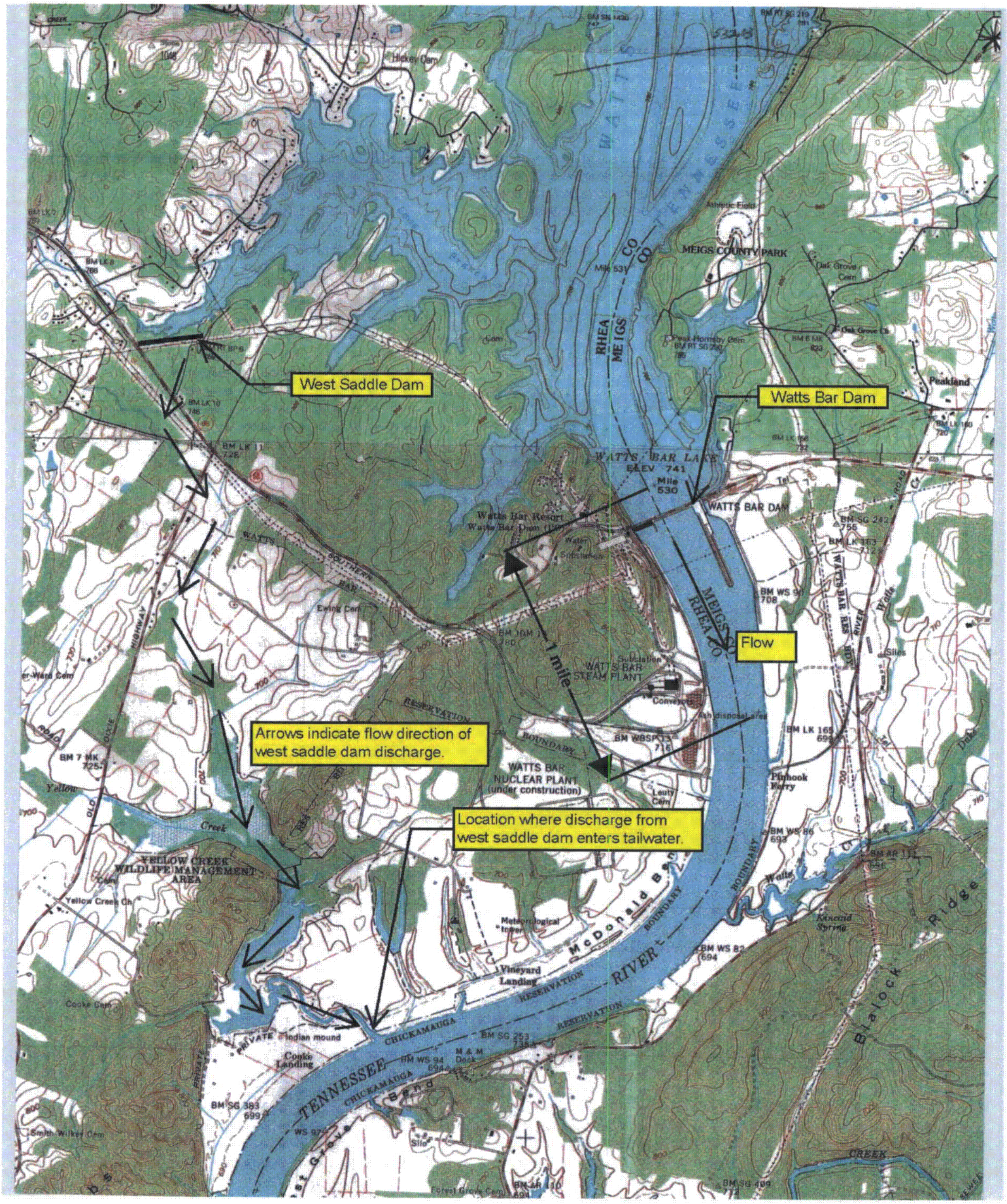


Figure 2 – Topo Map Showing West Saddle Dam (Ref. 32 and 33, Attachment 21).

2. References

1. TVA drawing no: 10W200, R11 (Attachments 1 and 25)
2. FSAR, Bellefonte Nuclear Plant, Units 1 and 2, Amendment 30, December 20, 1991 (Attachment 2).
3. "Watts Bar Dam Spillway Discharge Tables", River Operations, Tennessee Valley Authority, 2004, RIMS No. L58 081216 802 (Attachment 22).
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. TVA drawing no: 51N200, R4 (Attachments 7 and 26)
8. "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).
9. TVA drawing no: 41K17s, R0 (Attachments 10 and 27)
10. TVA drawing no: 66N200, R7 (Attachments 11-1 and 28)
11. TVA drawing no: 66N201, R9 (Attachments 11-2 and 29)
12. TVA drawing no: 66N202, R7 (Attachments 11-3 and 30)
13. TVA drawing no: 31N200, R2 (Attachments 12 and 31)
14. TVA drawing no: 61W225-1, R2 (Attachments 13 and 32)
15. TVA drawing no: 80H401, R2 (Attachments 14-2 and 33)
16. TVA drawing no: 80H415, R0 (Attachments 14-3 and 34)
17. TVA drawing no: 80H416, R0 (Attachments 14-4 and 35)
18. TVA drawing no: 80H418, R0 (Attachments 14-5 and 36)
19. TVA drawing no: 80H419, R0 (Attachments 14-6 and 37)
20. TVA drawing no: 80H420, R1 (Attachments 14-7 and 38)
21. TVA drawing no: 80H421, R0 (Attachments 14-8 and 39)
22. TVA drawing no: 80H422, R0 (Attachments 14-9 and 40)
23. TVA drawing no: 23W201, R7 (Attachments 15-3 and 41)
24. TVA drawing no: 23W300-1, R2 (Attachments 15-4 and 42)
25. TVA drawing no: 23W301-1, R1 (Attachments 15-5 and 43)
26. TVA drawing no: 23W301-2, R1 (Attachments 15-6 and 44)
27. TVA drawing no: 23W305-1, R1 (Attachments 15-7 and 45)
28. TVA drawing no: 23W305-2, R1 (Attachments 15-8 and 46)
29. TVA drawing no: 64W203-1, R0 (Attachments 9-5 and 47)
30. TVA drawing no: 47B903, R0 (Attachments 19-1 and 48)
31. TVA drawing no: 47B906, R0 (Attachments 19-2 and 49)
32. USGS - TVA, Topo. Map 118-NE, Spring City Quadrangle, 7.5 minute series, 35084-F7-TF-024, 1966, Limited Update 1190, DMA 4055 111 NE-SERIES V841
33. USGS - TVA, Topo. Map 118-SE, Decatur Quadrangle, 7.5 minute series, N 3530-W8445/7.5, 1973
34. TVA Water Control Project Manual (Blue Book) for Watts Bar Dam, TVA River Operations, August, 1999 (Attachment 24).
35. "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses," Tennessee Valley Authority, May 29, 2009 (EDMS No. L58 090529 800) (Attachment 50)
36. "Dam Lock Gate Technical Evaluation for the PMF," Tennessee Valley Authority, (EDMS No. L58 090908 001) (Attachment 51)
37. "SOCH Model Calibration, Chickamauga", Tennessee Valley Authority, CDQ000020080039 (EDMS No. L58 090804 001)
38. "PMF Determination for Tennessee River Watershed," Tennessee Valley Authority, CDQ000020080054
39. TVA drawing no: 10W222-1, R0 (Attachment 52)

3. Assumptions & Methodology

The initial dam rating curves developed in these calculations will be used in simulations of probable maximum flood events and other river operations evaluations. Consequently, the rating curves have been calculated well above the normal operating range and several feet above the top of the dam.

3.1 Assumptions

3.1.1 Assumption: Both gate leaves will be removed from the trashway.
Technical Justification: It is expected that the trashway gate leaves would be removed during a flood event large enough to require that all spillway gates are fully open. This assumption is conservative for predicting flood levels at the Bellefonte site since an open trashway increases the total dam discharge, but the added discharge due to the trashway is extremely small (less than 1 percent of the total dam discharge).

3.1.2 Assumption: If overtopped, the west saddle dam and east embankment of the main dam will fail to original ground elevation. The length of the failure section will be 750 feet.
Technical Justification: Original ground elevation represents the most probable extent to which the west saddle dam and east embankment would fail. They may erode less than this but would not be expected to erode further. The assumed length of the failure section is justified in paragraph 4.19.

3.1.3 Assumption: For calculating overflow discharge at the west saddle dam, the reservoir water elevation may be assumed to equal the headwater elevation at Watts Bar Dam.
Technical Justification: The west saddle dam is about two miles west of Watts Bar Dam at the end of a branch that connects to the main reservoir less than a mile upstream from the dam (see Figure 2). The differences between the water level at the west saddle dam and the Watts Bar headwater during flood flows up to and including a PMF event are not significant and will not impact the calculation results.

3.1.4 Assumption: The effect of tailwater elevations on the discharge from the west saddle dam may be neglected for computing tailwater effects on discharges.
Technical Justification: Discharge from the west saddle dam will enter the tailwater about three miles downstream from the dam (see Figure 2). This discharge will cause the Watts Bar tailwater elevation to be somewhat higher than if there were no west saddle dam discharge, but not as high as if the discharge entered the tailwater directly below the dam. Tailwater affects discharges at some headwaters for all four rating curve cases if the west saddle dam discharge is included in the tailwater determination. Neglect of the west saddle dam discharge for the tailwater calculations results in slightly lower tailwaters than expected and slightly high estimates of those discharges affected by tailwater. This is a conservative result since higher discharge past Watts Bar dam after the west saddle dam (Cases 3 and 4) and east embankment (Case 4) have failed will result in higher flood levels at the Bellefonte site downstream. The Case 1 and Case 2 rating curves are affected by tailwater only for headwater elevations above 767 feet (if saddle dam discharge is included in the tailwater determination), which will not be reached before the west saddle dam has failed.

3.1.5 Assumption: Turbine discharge is included in the rating curve for headwater and tailwater conditions under which generation is possible.
Technical Justification: Turbine discharge may or may not be coincident with the flood flows considered in this calculation. The Watts Bar hydro plant operators may operate the turbine-generators during a flood if they determine that it is safe to do so. Since this would add to the total discharge, a scenario is included in the calculation that includes turbine discharge. This is considered only for the pre-failure case (west saddle dam and east embankment intact), and only up to a headwater or tailwater elevation below the powerhouse deck. If operating, turbine-generator operation will be discontinued if the powerhouse is threatened with submergence. Existing performance data for the turbines does not extend into the zone of operating conditions that would exist during the floods contemplated in this calculation. Consequently, an estimate of the possible turbine discharge is used in the calculation, based on an extrapolation of the existing turbine performance curves. This estimate is undoubtedly high, but this

provides a conservative result since higher discharge past Watts Bar Dam will result in higher flood levels at TVA Nuclear plant sites downstream. The inclusion of a scenario that includes turbine discharge thus allows the calculation to bracket the exposure of the Bellefonte site to all conceivable flood flow conditions. (See paragraph 4.25 for further discussion).

3.1.6 Assumption: All spillway gates will be set to the maximum openings specified in the spillway discharge tables.
Technical Justification: For technical justification, see Reference 35, "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analysis"

3.1.7 Assumption: All spillway gates will remain operable in the closed position and in the maximum opened position as specified in the spillway discharge tables.
Technical Justification: 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 B1). Appendix B 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.

3.1.8 Assumption: The upper gates of the main and auxiliary navigation locks will not fail when overflowed.
Technical Justification: See Reference 36, "Dam Lock Gate Technical Evaluation for the PMF."

3.1.9 Assumption: The tailwater rating curve provided in Reference 37 is acceptable for use in development of the initial dam rating curve.
Technical Justification: The final tailwater curve is validated in the unsteady SOCH PMF calculation (Reference 38) by ensuring consistency with the headwater-tailwater relationship across the modeled dam configuration. This calculation provides the initial dam rating curve for the SOCH PMF calculation.

3.1.10 Assumption: The east earth embankment will remain intact and will not overflow at headwater elevations up to 770 feet.
Technical Justification: Recent improvements to the east earth embankment will effectively raise the overflow elevation to 770 feet during a PMF event. Reference 39 depicts the details of these improvements.

3.1.11 Assumption: The paved parking area will not be overtopped following the failure of the east embankment.
Technical Justification: The east embankment would fail near the peak of a major flood and would act as a fuse-plug spillway that lowers the headwater elevation and thereby prevents overtopping of the paved parking area. In addition, as evident in Att. 15-3, the natural topography under and around the parking area is considerably higher than the natural ground elevation of 700 feet under the earth embankment.

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):

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

in which Q_f = free discharge (cfs), C_f = free discharge coefficient ($ft^{0.5}/s$ -- may vary with HW), L = length of overflowing section (ft), H_c = head on crest (ft) = HW - Z_c, HW = headwater elevation (ft), and Z_c = top, or crest, elevation of overflowing section (ft). This equation is modified to account for tailwater submergence as follows:

$$Q_{fs} = Q_f S_f \qquad (2)$$

in which Q_{fs} = "corrected" free discharge (cfs) and S_f = tailwater submergence factor (dimensionless -- varies between 0 and 1). S_f varies with d/H_c where $d = TW - Z_c$ (ft) and TW = tailwater elevation (ft).

Flow over the nonoverflow section, the navigation lock, the tops of the open spillway gates, the tops of the spillway piers, the trashway, the east embankment, and the west saddle dam 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 using an orifice-type equation as follows (e.g., Reference 4, Hydraulic Design Chart 311-1):

$$Q_g = C_g G_n L\sqrt{2g(H_c - H_{mp})} \qquad (3)$$

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, and H_{mp} = vertical distance between the mid-point of G_n and the crest. This equation is modified to account for tailwater submergence as follows:

$$Q_{gs} = S_g Q_g \qquad (4)$$

in which Q_{gs} = "corrected" orifice discharge (cfs) and S_g = tailwater submergence factor (dimensionless -- varies with d/H_c and gate opening, G_n).

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 both provide this kind of data). For the Watts Bar spillway crest, the relationships $H_{Lmin}(V)$, $C_f(H_c)$, and $S_f(d/H_c)$ are available from model test data (Appendix A). The relationship between orifice discharge coefficient, C_g, and head, H_c, for various gate openings, V (up to V = 23.83 feet), is also available from the model test data. The crest length, L, and crest elevation, Z_c, are shown on TVA drawings (e.g., Attachment 1). The parameters G_n and H_{mp} are determined from geometry (Appendix A). Model data for Nickajack Dam and Tellico Dam are used to estimate $S_g(d/H_c,G_n)$ for Watts Bar Dam (Appendix A, Reference A6).

The physical model used to measure spillway discharge included several bays and the piers between them. Consequently, pier contraction effects are implicitly included in the discharge coefficients derived from the model test data.

Under the assumption that all spillway gates are fully open, the two end bays (first and last) are the only spillway bays subject to end contraction effects. These effects, which may reduce discharge through these two bays by a few percent, are neglected in this calculation. Neglecting this minor effect has negligible impact on the dam rating curve.

3.5 Methodology -- Discharge Coefficients and Submergence Factors for Overflow Sections

Values of the discharge coefficient, C_f, and the submergence factor, S_f, for flows over the nonoverflow section, the navigation lock, the tops of the spillway piers, the trashway, the east embankment, the west saddle dam, and the failed east embankment are estimated using Hydraulic Design Chart 711, 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 listed as References).

The upper plot of HDC 711 (Attachment 4) shows that C_f is about 2.65 for very broad crests ($H_l/B < 0.4$ where $H_l = H_c$ and B = streamwise length of the crest) and gradually increases to 3.1, the maximum value for a "broad-crested" weir, as H_l/B increases to about 1.2. As H_l/B increases above 1.2, C_f continues to increase as the weir transitions from broad-crested to sharp-crested at about $H_l/B = 2.0$. For the rating curve calculations, a single value for C_f is used based on the geometry of the overflow section and the range of H_l/B considered. Also, the effects of end contractions are neglected. Neglecting minor variations in C_f values and end contractions for overflow sections has negligible impact on the dam rating curve.

The lower plot of HDC 711 shows several curves of C_s/C_f (equivalent to S_f) versus H_2/H_l (equivalent to d/H_c). As illustrated in Attachment 5, the curve labeled "suggested for design (broad crests)" is well-represented by the following polynomial:

$$S_f = 1.0 + 0.023\sigma - 5.0259\sigma^2 + 18.266\sigma^3 - 44.658\sigma^4 \quad \text{for} \quad 0 \le \sigma \le 0.37 \quad \text{broad crest} \qquad (5)$$

in which $\sigma = d/H_c - 0.6$. According to this relationship, submergence affects discharge over a broad-crested weir for $d/H_c > 0.6$.

Values of the discharge coefficient, C_f, for flow over the tops of the open spillway gates are determined from experimental data (Reference 8) for drum gates, which present the same circular surface to overflow as the gate tops. Details are provided in Attachments 8-1 through 8-3. The tailwater elevation remains below the overflow elevation of the gate tops for all headwaters included in the rating curves (see results in section 6). Consequently, flow over the gate tops is not affected by tailwater submergence.

4. Design Input

Sect.	Input Parameter	Source	Symbol	Value
4.1	Acceleration of gravity	Common knowledge, e.g., Ref. 4, sheet. 000-1	g	32.2 ft/sec^2
4.2	**Spillway crest parameters**			
4.2.1	Crest length	20 40-foot wide bays; Att. 1 or Att. 7	L	800 feet
4.2.2	Crest elevation	Att. 1 or Att. 7	Z_c	713 feet
4.2.3	Free discharge coefficient	Polynomial fit to model data given in Att. A13 and discussed in Appendix A	$C_f(H_c)$	Equation A5
4.2.4	Submergence factor for free discharge	Curve fit to model data given in Att. A14 and discussed in Appendix A	$S_f(d/H_c)$	Equation A6
4.3	**Spillway gate parameters**			
4.3.1	Vertical opening	Average value from field measurements given in Att. A3 and discussed in Appendix A	V	28.92 feet
4.3.2	Effective gate opening	Computed in Appendix A	G_n	29.305 feet
4.3.3	Mid-point elevation of opening relative to crest	Computed in Appendix A	H_{mp}	14.371 feet
4.3.4	Headwater elevation at which nappe touches gates	H_{Lmin} estimated in Appendix A	$H_{Lmin} + Z_c$	749.64 feet
4.3.5	Orifice discharge coefficient	Extrapolated data listed in Table A3, plotted in Att. A16, and discussed in Appendix A	$C_g(H_c)$	Interpolate between points in Table A3
4.3.6	Submergence factors for orifice discharge	Family of curves developed in Ref. A6, given in Att. A5-3, and discussed in Appendix A	$S_g(d/H_c, H_c/G_n)$	Interpolate between points in Table A1
4.4	**Trashway**			
4.4.1	Free discharge coefficient	Justification in Att. 6	C_f	3.0
4.4.2	Crest elevation	Att. 7	Z_c	733 feet
4.4.3	Crest length	Att.7	L	16.33 feet
4.4.4	Submergence factor	Att. 4 and Att. 5. Justification in Att. 6	S_f	Equation 5
4.5	**Spillway gate overflow**	Symbol notation is defined in Att. 8-1		
4.5.1	Overflow discharge coeff.	Justification in Att. 8	C_o	3.4
4.5.2	Overflow elevation	Computed in Appendix A	Z_o	759.84 feet
4.5.3	Overflow length	Same as spillway crest, Att. 1 or Att. 7	L_o	800 feet
4.6	**Screen house overflow**			
4.6.1	Discharge coefficient	Justification in Att. 9	C_f	2.65
4.6.2	Overflow elevation	Att. 10	Z_c	767 feet

Sect.	Input Parameter	Source	Symbol	Value
4.6.3	Overflow length	Att. 10	L	40 feet
4.7	**Powerhouse and spillway piers overflow**			
4.7.1	Discharge coefficient	Justification in Att. 9	C_f	2.65
4.7.2	Overflow elevation	Att. 1 and Att. 7	Z_c	752 feet
4.7.3	Overflow length	Determined in Att. 9; see also paragraph 4.24	L	546.7 feet
4.8	**Nonoverflow and lock overflow**			
4.8.1	Discharge coefficient	Justification in Att. 9	C_f	3.0
4.8.2	Overflow elevation	Att. 1 and Att. 7	Z_c	752 feet
4.8.3	Overflow length	Determined in Att. 9; see also paragraph 4.24	L	211.5 feet
4.9	**Upper lock gate overflow**			
4.9.1	Discharge coefficient	Justification in Att. 9	C_f	3.3
4.9.2	Overflow elevation	Att. 9-5	Z_c	648.67 feet
4.9.3	Overflow length	Determined in Att. 9	L	60 feet
4.10	**East Emb. Floodwall**			
4.10.1	Discharge coefficient	Justification in Att. 15	C_f	3.0
4.10.2	Overflow elevation	Att. 15-7 and Att. 15-8	Z_c	767 feet
4.10.3	Overflow length	Determined in Att. 15	L	487.7 feet
4.11	**East Earth Emb.**			
4.11.1	Discharge coefficient	Justification in Att. 15	C_f	2.65
4.11.2	Overflow elevation	Att. 15-6 (justified in Att. 15-1 and Att. 15-2)	Z_c	770 feet
4.11.3	Overflow length	Determined in Att. 15-1 and Att. 15-2	L	1325.2 feet
4.12	**West Saddle Dam**			
4.12.1	Discharge coefficient	Att. 2 and Att. 4: $0 <= H_c = H_1 <= 770-757 = 13$ feet, B = 16 feet (Att. 2) $0 <= H_1/B <= 13/16 = 0.81$ $2.65 <= C_f <= 2.85$ Use $C_f = 2.75$ (average)	C_f	2.75
4.12.2	Overflow elevation	Attachment 2	Z_c	757 feet
4.12.3	Overflow length	Approx. length of "dike" in Att. 2	L	1300 feet
4.13	**East Earth Emb. Failure**			
4.13.1	Discharge coefficient	Paragraph 4.19	C_f	2.65
4.13.2	Overflow elevation	Paragraph 4.19	Z_c	700 feet
4.13.3	Overflow length	Paragraph 4.19	L	750 feet
4.13.4	Submergence factor	Paragraph 3.5	S_f	Equation 5
4.14	**Intact E. Emb. after Failure**			
4.14.1	Discharge coefficient	Paragraph 4.19	C_f	2.65
4.14.2	Overflow elevation	Paragraph 4.19	Z_c	770 feet
4.14.3	Overflow length	Paragraph 4.19	L	792 feet
4.15	**West Saddle Dam Failure**			
4.15.1	Rating curve, discharge, Q_{sd}, vs. headwater, HW	Paragraph 4.20	Q_{sd}(HW)	Interpolate between points in Table 1
4.16	**Turbine Discharge**			
4.16.1	Discharge, Case 1	Paragraph 4.25		40,000 cfs
4.16.2	Discharge, Case 2, 3, & 4	Paragraph 4.25		0
4.16.3	Maximum TW Elev.	Paragraph 4.25		740 feet
4.16.4	Maximum HW Elev..	Paragraph 4.25		752 feet
4.17	**Tailwater Rating Curve**			
4.17.1	TW vs. total discharge, Q	Paragraph 4.21	TW(Q)	Equation 6
4.18	Upper limit on headwater elevation for rating	Paragraph 4.22		770 feet

4.19 East Embankment Failure

Recent improvements to the east earth embankment have raised the overflow elevation from 767 feet to 770 feet. These improvements include the installation of sand-filled HESCO baskets along the top of the embankment. Three public access openings were left in place along public roads and parking areas. In the event of a probable maximum flood (PMF), additional cells will be added to close off these areas and create an impervious vertical extension of the embankment at an elevation of 770 feet. These improvements are further described in Reference 39 (Attachment 52).

However, should the east earth embankment overtop, it is expected to fail. Attachment 16 illustrates the postulated failure section which extends from the navigation lock to a streamwise line passing through station 135+00 at the edge of the paved parking area. The total length of 750 feet for the failure section was postulated in the FSAR for Bellefonte, Units 1 and 2 and is adopted here as a reasonable approximation of the extent of the failure. It is expected that the unpaved portion of the earth embankment would erode soon after overtopping, well before the paved parking area would be damaged, and once the earth embankment had eroded, the headwater level would soon drop below the level of the parking area. The concrete flood wall is included in the failure section because flow over top of it and around it will erode its foundation, leading to eventual failure. Similarly, the non-overflow section shown in Attachment 15-1 between the concrete flood wall and the earth embankment is included in the failure section because flow around it will undercut it leading to eventual failure. The after failure flow would initially be channeled between the lock and the east abutment of the highway bridge passing over the dam. The abutment and east roadway might fail under these conditions, but the extent would be limited because the natural ground slopes up to the east of the postulated failure section (see Attachments 15-3 and 15-4). The embankment is assumed [3.1.2] to fail to the original ground elevation under it, which is approximately 700 feet, estimated from topography contours (Att. 15-3).

For the purpose of the dam rating curve calculation the following parameter values are used for the failed portion of the east embankment: overflow elevation, Z_c = 700 feet; overflow length, L = 750 feet; and C_f = 2.65. A value for C_f of 2.65 is used in accordance with the data in Attachment 4 since the crest is broad compared to the depth of water flowing over it.

THIS SECTION NOT VALID

Attachment 16 also shows the overflow length for the paved parking area and remainder of the embankment to the east. For the dam rating curve calculation, this portion of the east embankment remains intact with overflow elevation, Z_c = 770 feet [4.11.2]; overflow length, L = 792 feet; and C_f = 2.65 [4.11.1], where Z_c and C_f are the same as determined for the embankment before failure.

4.20 West Saddle Dam Failure

Soon after overtopping, the west saddle dam is assumed to fail to the original ground elevation under it [3.1.2], which is at an elevation of approximately 750 feet. Critical flow through a cross-section near the saddle dam location will control the discharge through the gap but exactly which cross-section will act as the control is not obvious from the topography shown in Attachment 2 or in Figure 2. Discharge could be computed simply by using the broad-crested weir overflow equation (Equation 1) with C_f = 2.65 (wide crest compared to depth; see Att. 4), L =1300 feet (length of the failed saddle dam [4.12.3]), and Z_c = 750 feet. However, the topography around the saddle dam includes three small hills, or mounds, with top elevations of about 753, 757 and 760 feet, making it unlikely that the saddle dam cross-section would control the flow at headwaters below the tops of these hills. Given a choice of several cross-sections to consider as possible critical flow control sections, the cross-section that provides the smallest discharge will be the actual control. With this in mind, critical flow through a segmented cross section connecting the high points, as indicated in Attachment 2, was computed for a range of water levels as a possible rating curve for the failed saddle dam gap.

Attachment 17-1 lists the elevations and x-coordinates scaled off from Attachment 2 to define the segmented cross section and shows the calculation of top width, T, area, A, critical discharge, Q, and headwater elevation, HW for water level elevations ranging from 748 to 770 feet (the spreadsheet is included in electronic Attachment 20). Discharge for a broad-crested weir with C_f = 2.65, L =1300 feet, and Z_c = 750 feet is also computed in Attachment 17-1, for comparison. Attachment 17-2 includes a plot of the segmented cross-section as well as a headwater vs. discharge plot comparing the rating curves for the segmented cross section and broad-crested weir. The rating curve for the segmented cross-section passes less discharge for HW < 765 and more discharge for HW > 765. Because the section passing the least discharge is considered the control, the dam rating curve used for the failed saddle dam includes points from the curve labeled "Segmented Cross-Section" to HW = 765 and points from the curve labeled "Broad-Crested Weir" for HW >765. The resulting rating curve is tabulated in Table 1.

Table 1: Points Defining Initial Dam Rating Curve for Failed West Saddle Dam

HW, feet	Q_{sd}, cfs
748.0	0
749.3	100
750.4	653
752.7	6602
754.0	14317
756.8	39726
759.2	72793
760.6	97200
763.1	152522
765.0	200136
768.0	263086
770.0	308130

In determining elevations along the segmented cross section, the presence of the highway was ignored because elevations for its surface are not readily available. Since the highway crosses a very small portion of the cross section (about 6 to 7%), exclusion of the highway will have negligible effect on the rating curves.

The rating curve in Table 1 is not affected by tailwater submergence effects for the range of headwaters included in the Watts Bar dam rating curve calculations because d/H_c is always less than 0.6 [3.5].

4.21 Tailwater rating curve

The values used to create a tailwater rating curve for use in this calculation [3.1.9] are listed in Table 24 of Reference 37. Attachment 18 lists points taken from this table and shows a polynomial fit to the result that is also useful for extrapolation to discharges as high as 2,000,000 cfs. The polynomial indicated in Attachment 18 and repeated below is used in the dam rating curve calculations for all dam discharges: As noted previously, the dam rating curve, including the validated headwater-tailwater relationship, is confirmed and documented in Reference 38.

$$TW = 682.90 + 0.084671Q - 5.9075X10^{-5}Q^2 + 2.8568x10^{-8}Q^3 - 5.0597x10^{-12}Q^4 \quad (6)$$

in which Q = total discharge past the dam (not including the west saddle dam discharge [3.18] for Case 3 and Case 4) in cfs divided by 1000 ("1000 cfs").

4.22 Upper Limit on Headwater Elevation Included in Rating Curves

The dam rating curves need to include all headwater elevations that may occur during a major flood up to and including a PMF event. The 2009 improvements to the east embankment effectively raised the embankment top from an elevation of 767 feet to 770 feet. The west saddle dam (overflow elevation of 757 feet) is expected to fail soon after overtopping (as discussed in [4.20]). Therefore, the headwater elevation at Watts Bar Dam is not expected to rise past 770 feet. Users of this calculation should note that Section 5.0 limits the applicability of this curve to the headwater elevation defined in Section 5.0.

4.23 Highway Bridge over Dam

The overflow lengths for the powerhouse and spillway piers [4.7.3], nonoverflow and navigation lock [4.8.3], and east embankment floodwall [4.10.3] all reflect the presence of structural support columns for the highway bridge over the dam. The overflow blockage lengths associated with the support columns are determined in Attachment 14.

4.24 Lock Operations Building and Screen House

The overflow length [4.7.3] for the "powerhouse and spillway piers" does not include a portion blocked by the screen house at the west end of the dam. Similarly, the overflow length [4.8.3] for the "nonoverflow and lock" does not include a portion blocked by the lock operations building. Calculations showing that these two structures would survive the water levels and flows associated with the a major flood event are not available. However, the effect of these two structures on rating curve discharges is extremely small, less than 1 percent as shown below.

With reference to Attachment 9-1, the overflow elevation below the screen house and lock operations building is 752 feet. If these two building were to fail, the total overflow length for elevation 752 feet, which is 758.2 feet, would increase by 66 feet, 40 feet for the screen house and 26 feet for the lock operations building. The overflow discharge at elevation 752 feet is a larger percentage of the total discharge for the pre-failure cases 1 and 2, than for cases 3 and 4, so the effect of the screen house and lock operations building on discharge is largest in the pre-failure cases. Consider the Case 1 results in Figure 3 for headwater elevation 770 feet:

Total discharge, Q_{T1} = 1,456,640 cfs
Screen house overflow at elevation 767 feet, Q_{sh1} = 1185 cfs
Overflow at EL. 752, Q_{o1} = 129,581 + 56,751 = 186,332 cfs

If the screen house and lock operations building were removed:

Overflow at EL. 752, Q_{o2} = (758.2+66)/758.2*186,332 cfs = 202,552 cfs
Total discharge, $Q_{T2} = Q_{T1} - Q_{sh1} + (Q_{o2} - Q_{o1})$ = 1,471,675 cfs

in which the slight effect of submergence on the total discharge at headwater 770 feet is neglected. The percentage increase in discharge due to removal of the screen house and lock operations building is

(1,471,675 – 1,456,640)/1,456,640*100 = 1.03 percent.

The effect is largest at headwater elevation 770 feet.

4.25 Turbine Discharge

Watts Bar Dam has five turbines (see Attachment 1). The turbines will be operated during flood flow conditions ramping up to the 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 without complete performance characteristics so for the purpose of this calculation 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 rise 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 elevation is 836 feet, well above the upper headwater limit (770 feet [4.18]) for the rating curves. For tailwater elevations above 740 feet, water can enter the powerhouse as illustrated in Section A-A on Attachment 1. Therefore, the maximum tailwater elevation for turbine operation is 740 feet. For headwater elevations above 752 feet, water will flow over the intake deck and can enter the powerhouse as illustrated in Section A-A. Therefore, the maximum headwater elevation for turbine operation is 752 feet.

The results (see [6.1]) show that the headwater limit for turbine operation is reached long before the tailwater limit is reached. Because the headwater limit is 5 feet below the crest elevation of the saddle dam, turbine operation is suspended before the west saddle dam is overtopped. Consequently, the conclusion that the headwater limit is reached before the tailwater limit is reached is not affected by the neglect of west saddle dam discharge [3.1.4] in determining the tailwater elevation.

Turbine discharge is included for Case 1, but not for Cases 2, 3, or 4. The Case 2 rating curve is used when turbine discharge has been suspended before either the west saddle dam or east embankment has failed. The Case 3 and Case 4 rating curves are used only after the west saddle dam has failed (and the east embankment for Case 4), which occurs after the headwater elevation rises a few feet above its crest at 757 feet. Turbine generation would be suspended before the failure since water can enter the powerhouse for headwater elevations above 752 feet, 5 feet below the west saddle dam crest. As stated above, the units will not be restarted after water has threatened the electrical components until a thorough inspection indicates that all components are undamaged.

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 19-1 through 19-4. Attachments 19-1 and 19-2 are characteristics for Units 4 and 5 based on index tests conducted in 1944. Similar characteristics for Units 1, 2, and 3 are not available, but all five units are nominally identical (see Attachment 19-5). The turbines at Watts Bar are being rehabilitated and upgraded as described in Attachment 19-6. Currently, Units 1, 2, and 3 have been upgraded and Units 4 and 5 will be upgraded in the next few years. Attachments 19-3 and 19-4 are preliminary characteristics (not yet published but provided by TVA River Operations) based on index tests conducted in 2004 and 2003 for the upgraded Units 2 and 3, respectively.

Under high flood conditions, the turbines are expected to be operated for maximum capacity, with the wicket gates open as far as possible ("full gate" on Attachments 19-1 and 19-2 and 100% on Attachments 19-3 and 19-4). The lowest gross head included in the characteristics is 35 feet in Attachments 19-1 and 19-2 and 49 feet in Attachments 19-3 and 19-4. 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 35 feet are needed for the rating curves. The turbine discharges for lower values of gross head are estimated by linear extrapolation from the points given for maximum gate opening.

To determine the range of gross heads that would occur during a major flood, the pre-failure rating curve was computed first without turbine discharge (Case 2 [6.2]). For headwaters between the maximum headwater drawdown elevation (733 feet, see Attachment 1) and the maximum headwater elevation for turbine operation (752 feet), gross heads between 29.5 feet and 32.1 feet would occur. For the purpose of adding turbine discharge to the rating curve, a fixed gross head of 30 feet is used. This value is chosen rather than, say, 31 feet, since the turbine discharge will increase the tailwater elevation, resulting in slightly lower values of gross head than those with no turbine discharge. The results for Case 1 [6.1] verify that 30 feet is a good value to use for gross head. Use of a nominal gross head within the range of variation to estimate turbine discharge for all headwater elevations does not significantly affect the results since the turbine discharge is a small percentage of the total dam discharge.

Results determined by extrapolating turbine characteristics from $H_G = 35$ feet to $H_G = 30$ feet should be more reliable than results determined by extrapolating characteristics from $H_G = 49$ feet to $H_G = 30$ feet. Therefore, the data in Attachments 19-1 and 19-2 are used for the extrapolation, and the preliminary data in Attachments 19-3 and 19-4 are used only to estimate the difference in discharge between the upgraded units and the original units.

The procedure for estimating turbine discharge, Q_T, at gross head, $H_G = 30$ feet is as follows: Using linear extrapolation and linear interpolation, estimate Q_T at $H_G = 49$ feet and 30 feet from Attachments 19-1 and 19-2. Scale Q_T at $H_G = 49$ feet from Attachments 19-3 and 19-4. See Table 2 (following page) for results.

The average discharge from the original units at $H_G = 30$ feet is (7,800 + 7,630)/2 = 7,715 cfs per unit. The average increase in discharge through the upgraded units compared to the original units at $H_G = 49$ feet is [(9,560 + 9,670 - 9,240 - 9,260)/2 = 365 cfs per unit. Add this difference to the average discharge for the original units at $H_G = 30$ feet to obtain an estimate of the discharge through the updated units at $H_G = 30$ feet: 7,715 + 365 = 8,080 cfs per unit.

Table 2: Turbine Discharges from 1944, 2003, and 2004 Characteristics

Unit	Attachment	Q_{T49}, cfs (Q_T @ H_G=49')	Q_{T30}, cfs (Q_T @ H_G=30')
4	19-1	9,260	7,800
5	19-2	9,240	7,630
2	19-3	9,670	
3	19-4	9,560	

Based on this analysis, 40,000 cfs (5 times 8,080 cfs, rounded) is added to the rating curve discharges for headwater elevations between 733 feet and 752 feet, inclusive. Rounding the turbine discharge does not significantly affect the results since the turbine discharge is a small percentage of the total dam discharge.

This undoubtedly overstates the discharge by some amount. Actual efficiencies of the turbines at the lower net heads cannot be ascertained from these curves, but it is well known from typical turbine performance characteristics that efficiency will decline at the lower net heads, which will tend to reduce the flow. Consequently, the estimated values of flow used in the calculation are expected to be higher than would actually be experienced. This provides a conservative result since higher discharge past Watts Bar dam will result in higher flood levels at the Bellefonte site downstream.

5. Special Requirements/Limiting Conditions

Calculations performed in Appendix B demonstrate that the spillway gate PMF hydrostatic loads in the expected fully open position are comparable to the normal spillway gate design loads in the fully closed position. Although a detailed gate analysis could potentially demonstrate the capability of the gate to withstand higher headwater elevations, the applicability of this calculation is limited to headwater elevations no greater than 768.50 feet, the maximum expected headwater elevation for the PMF at the Watts Bar Dam. If PMF headwater elevations at the Watts Bar Dam exceed 768.50 feet, a revision of this calculation will be required.

6. Calculations

The calculations consist of computing spillway and overflow discharges (from Equations 1 through 4) for a list of headwater elevations ranging from the minimum for which discharge exceeds zero up to 770 feet [4.18], which the elevation of the top of the extended east embankment. Turbine discharge is added to the total discharge where applicable. Headwater values are terminated at an elevation of 770 feet. See Section 4.22 and Section 5.0 for further discussion. The dam rating curve for each case is a plot of headwater elevation versus total dam discharge. The spreadsheet in which the calculations were made is included as Attachment 20 (electronic attachment).

6.1 Case 1, Pre-Failure Condition with Turbine Discharge

For the pre-failure condition, discharges are computed for headwater elevations ranging from 713 feet, the spillway crest elevation, to 770 feet which is equal to the east embankment crest elevation (see Reference 39). Discharge passes through the spillway section, the trashway, and the various overflow sections as headwater rises above the crest elevations in each case. The turbines pass discharge for a limited range of headwater elevations between the maximum drawdown elevation (733 feet, see Attachment 1) and the maximum headwater elevation for turbine operation (752 feet [4.16.4]). Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 3 shows the spreadsheet calculations for the pre-failure dam rating curve (spreadsheet included as Attachment 20). 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" (not including the west saddle dam discharge) from the tailwater rating curve polynomial fit [4.17.1]. This is computed to check for tailwater submergence effects on the discharge.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, $S_f|S_g$ and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 749.6 feet [4.3.4] and orifice discharge occurs for headwater elevations above 749.6 feet. The transition point is indicated by a double horizontal line. Above the double horizontal line, the listed discharge coefficient is C_f [4.2.3] computed from Equation (A5) and the submergence factor is S_f [4.2.4]. Below this line, the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3 and the submergence factor is S_g [4.3.6] computed by bilinear interpolation between the points in Table A1. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 2 for free discharge and from Equation 4 for orifice discharge. Tailwater affects the discharge for HW elevations greater than 768 feet (indicated by horizontal line) for which $d/H_c > 0.40$ [4.2.4].

Turbine discharge [4.16.1] is listed in the column following the spillway discharge column. Turbine discharge is included only for headwaters between the maximum drawdown elevation and the elevation at which water would enter the powerhouse [4.16.4].

The next 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 nine columns are overflow discharges in cfs for the trash gate, spillway gates, screen house, powerhouse and spillway piers, nonoverflow and navigation lock sections, upper lock gate, east embankment flood wall, east embankment earth section, and west saddle dam. The overflow discharge coefficient C_f or C_o ([4.4.1], [4.5.1], [4.6.1], [4.7.1], [4.8.1], [4.9.1], [4.10.1], [4.11.1], [4.12.1]), elevation Z_c or Z_o ([4.4.2], [4.5.2], [4.6.2], [4.7.2], [4.8.2], [4.9.2], [4.10.2], [4.11.2], [4.12.2]), and length L or L_o ([4.4.3], [4.5.3], [4.6.3], [4.7.3], [4.8.3], [4.9.3], [4.10.3], [4.11.3], [4.12.3]) in each case is indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1.

The last column is d/H_c for the trash gate since the tailwater elevation is higher than its crest elevation for headwater elevations of 768 feet and above. The trash gate discharge is not affected by tailwater because $d/Hc < 0.6$ [3.5].

Pre-Failure with Turbine Discharge, West Saddle Dam and East Embankment Intact

g = 32.2 ft/s²

Spillway Parameters
L = 800 feet
Z_c = 713 feet
G_n = 29.305 feet
H_{mp} = 14.371 feet

HW	Q Total Discharge	TW[1]	Spillway[2] feet				cfs	Turbine Q		Overflow Discharge, Q_f in cfs: Trash Gate	Spill Gate Overflow	Screen House	P-house & Spill Piers	Nonover & Lock Walls	Upper Lock Gate	East Emb. Wall	East Emb. Earth	West Saddle Dam	Trash Gate
									C_f =	3.0	3.4	2.65	2.65	3.0	3.3	3.0	2.65	2.75	
									Z_c =	733	759.84	767	752	752	748.67	767	770	757	
feet	1000 cfs	feet	H_c	C_f | C_q	d/H_c	S_f | S_q	Q_f | Q_q	cfs	L =	16.33	800	40	546.7	211.5	60	487.7	1325.2	1300	d/H_c
713	**0.00**	682.90	0	3.090		1	0			0	0	0	0	0	0	0	0	0	
715	**7.22**	683.51	2	3.191		1	7221			0	0	0	0	0	0	0	0	0	
718	**29.65**	685.36	5	3.315		1	29651			0	0	0	0	0	0	0	0	0	
721	**61.76**	687.91	8	3.412		1	61764			0	0	0	0	0	0	0	0	0	
724	**101.84**	690.94	11	3.489		1	101845			0	0	0	0	0	0	0	0	0	
727	**148.92**	694.29	14	3.554		1	148918			0	0	0	0	0	0	0	0	0	
730	**202.40**	697.85	17	3.609		1	202398			0	0	0	0	0	0	0	0	0	
733	**301.97**	703.83	20	3.661		1	261970	40000		0	0	0	0	0	0	0	0	0	
734	**323.21**	705.00	21	3.678		1	283158	40000		49	0	0	0	0	0	0	0	0	
736	**367.78**	707.38	23	3.712		1	327523	40000		255	0	0	0	0	0	0	0	0	
738	**415.10**	709.76	25	3.746		1	374552	40000		548	0	0	0	0	0	0	0	0	
740	**465.17**	712.14	27	3.780		1	424262	40000		907	0	0	0	0	0	0	0	0	
742	**517.99**	714.51	29	3.815		1	476668	40000		1323	0	0	0	0	0	0	0	0	
744	**573.55**	716.87	31	3.851	0.125	1	531764	40000		1787	0	0	0	0	0	0	0	0	
746	**631.81**	719.21	33	3.887	0.188	1	589512	40000		2296	0	0	0	0	0	0	0	0	
748	**692.67**	721.53	35	3.923	0.244	1	649826	40000		2846	0	0	0	0	0	0	0	0	
749	**724.07**	722.69	36	3.940	0.269	1	680901	40000		3135	0	0	0	0	38	0	0	0	
750	**743.45**	723.39	37	0.782	0.281	1	699712	40000		3434	0	0	0	0	304	0	0	0	
752	**734.86**	723.08	39	0.739	0.258	1	689603	40000		4057	0	0	0	0	1203	0	0	0	
753	**691.15**	721.48	40	0.717	0.212	1	682901			4382	0	0	1449	635	1784	0	0	0	
755	**724.45**	722.70	42	0.713	0.231	1	705420			5055	0	0	7528	3297	3153	0	0	0	
757	**760.56**	724.00	44	0.710	0.250	1	726751			5760	0	0	16198	7094	4760	0	0	0	
759	**808.77**	725.34	46	0.706	0.268	1	747003			6495	0	0	26831	11751	6574	0	0	10112	
760	**839.03**	726.09	47	0.706	0.278	1	758719			6873	174	0	32782	14357	7551	0	0	18576	
761	**874.34**	726.95	48	0.706	0.291	1	770258			7258	3398	0	39116	17132	8573	0	0	28600	
762	**913.40**	727.88	49	0.706	0.304	1	781627			7651	8635	0	45814	20065	9636	0	0	39970	
763	**955.45**	728.86	50	0.706	0.317	1	792832			8050	15279	0	52855	23148	10741	0	0	52542	
764	**1000.11**	729.87	51	0.706	0.331	1	803881			8456	23079	0	60224	26376	11884	0	0	66210	
765	**1047.14**	730.92	52	0.706	0.345	1	814781			8868	31882	0	67906	29740	13066	0	0	80893	
766	**1096.35**	732.00	53	0.706	0.358	1	825536			9287	41585	0	75890	33237	14284	0	0	96525	
767	**1147.59**	733.11	54	0.706	0.372	1	836153			9712	52112	0	84165	36861	15538	0	0	113051	
768	**1202.33**	734.29	55	0.706	0.387	1	846637			10144	63402	106	92720	40608	16827	1463	0	130426	0.037
769	**1259.34**	735.51	56	0.706	0.402	0.999	856136			10582	75407	300	101547	44474	18150	4138	0	148610	0.070
770	**1319.43**	736.80	57	0.706	0.418	0.999	865999			11026	88087	551	110638	48455	19505	7602	0	167568	0.103

(1) Tailwater is computed using total discharge minus the discharge from the west saddle dam.
(2) Double horizontal line is boundary between free discharge (above the line) and orifice discharge (below the line).

Figure 3 – Calculations for Case 1, Pre-Failure Condition with Turbine Discharge

6.2 Case 2, Pre-Failure Condition without Turbine Discharge

The calculations for the Case 2 rating curve are identical to those for the Case 1 rating curve, except that turbine discharge is zero for all headwater elevations. Figure 4 shows the spreadsheet calculations.

Pre-Failure without Turbine Discharge, West Saddle Dam and East Embankment Intact

g = 32.2 ft/s²

Spillway Parameters
L = 800 feet
Z_c = 713 feet
G_n = 29.305 feet
H_{mp} = 14.371 feet

HW feet	Q Total Discharge 1000 cfs	TW[(1)] feet	Spillway[(2)] H_c feet	C_f | C_g	d/H_c	S_f | S_g	Q_f | Q_g cfs		Overflow Discharge, Q_f in cfs: Trash Gate	Spill Gate Overflow	Screen House	P-house & Spill Piers	Nonover & Lock Walls	Upper Lock Gate	East Emb. Wall	East Emb. Earth	West Saddle Dam	Trash Gate d/H_c
								C_f =	3.0	3.4	2.65	2.65	3.0	3.3	3.0	2.65	2.75	
								Z_c =	733	759.84	767	752	752	748.67	767	770	757	
								L =	16.33	800	40	546.7	211.5	60	487.7	1325.2	1300	
713	**0.00**	682.90	0	3.090		1	0		0	0	0	0	0	0	0	0	0	
715	**7.22**	683.51	2	3.191		1	7221		0	0	0	0	0	0	0	0	0	
718	**29.65**	685.36	5	3.315		1	29651		0	0	0	0	0	0	0	0	0	
721	**61.76**	687.91	8	3.412		1	61764		0	0	0	0	0	0	0	0	0	
724	**101.84**	690.94	11	3.489		1	101845		0	0	0	0	0	0	0	0	0	
727	**148.92**	694.29	14	3.554		1	148918		0	0	0	0	0	0	0	0	0	
730	**202.40**	697.85	17	3.609		1	202398		0	0	0	0	0	0	0	0	0	
733	**261.97**	701.52	20	3.661		1	261970		0	0	0	0	0	0	0	0	0	
734	**283.21**	702.76	21	3.678		1	283158		49	0	0	0	0	0	0	0	0	
736	**327.78**	705.25	23	3.712		1	327523		255	0	0	0	0	0	0	0	0	
738	**375.10**	707.76	25	3.746		1	374552		548	0	0	0	0	0	0	0	0	
740	**425.17**	710.25	27	3.780		1	424262		907	0	0	0	0	0	0	0	0	
742	**477.99**	712.73	29	3.815		1	476668		1323	0	0	0	0	0	0	0	0	
744	**533.55**	715.19	31	3.851	0.071	1	531764		1787	0	0	0	0	0	0	0	0	
746	**591.81**	717.62	33	3.887	0.140	1	589512		2296	0	0	0	0	0	0	0	0	
748	**652.67**	720.02	35	3.923	0.201	1	649826		2846	0	0	0	0	0	0	0	0	
749	**684.07**	721.21	36	3.940	0.228	1	680901		3135	0	0	0	0	38	0	0	0	
750	**703.45**	721.93	37	0.782	0.241	1	699712		3434	0	0	0	0	304	0	0	0	
752	**694.86**	721.62	39	0.739	0.221	1	689603		4057	0	0	0	0	1203	0	0	0	
753	**691.15**	721.48	40	0.717	0.212	1	682901		4382	0	0	1449	635	1784	0	0	0	
755	**724.45**	722.70	42	0.713	0.231	1	705420		5055	0	0	7528	3297	3153	0	0	0	
757	**760.56**	724.00	44	0.710	0.250	1	726751		5760	0	0	16198	7094	4760	0	0	0	
759	**808.77**	725.34	46	0.706	0.268	1	747003		6495	0	0	26831	11751	6574	0	0	10112	
760	**839.03**	726.09	47	0.706	0.278	1	758719		6873	174	0	32782	14357	7551	0	0	18576	
761	**874.34**	726.95	48	0.706	0.291	1	770258		7258	3398	0	39116	17132	8573	0	0	28600	
762	**913.40**	727.88	49	0.706	0.304	1	781627		7651	8635	0	45814	20065	9636	0	0	39970	
763	**955.45**	728.86	50	0.706	0.317	1	792832		8050	15279	0	52855	23148	10741	0	0	52542	
764	**1000.11**	729.87	51	0.706	0.331	1	803881		8456	23079	0	60224	26376	11884	0	0	66210	
765	**1047.14**	730.92	52	0.706	0.345	1	814781		8868	31882	0	67906	29740	13066	0	0	80893	
766	**1096.35**	732.00	53	0.706	0.358	1	825536		9287	41585	0	75890	33237	14284	0	0	96525	
767	**1147.59**	733.11	54	0.706	0.372	1	836153		9712	52112	0	84165	36861	15538	0	0	113051	
768	**1202.33**	734.29	55	0.706	0.387	1	846637		10144	63402	106	92720	40608	16827	1463	0	130426	0.037
769	**1259.34**	735.51	56	0.706	0.402	0.999	856136		10582	75407	300	101547	44474	18150	4138	0	148610	0.070
770	**1319.43**	736.80	57	0.706	0.418	0.999	865999		11026	88087	551	110638	48455	19505	7602	0	167568	0.103

(1) Tailwater is computed using total discharge minus the discharge from the west saddle dam.
(2) Double horizontal line is boundary between free discharge (above the line) and orifice discharge (below the line).

Figure 4 – Calculations for Case 2, Pre-Failure Condition without Turbine Discharge

6.3 Case 3, West Saddle Dam Failure

Figure 5 shows the spreadsheet calculations for the dam rating curve following failure of the west saddle dam. As for the pre-failure condition, discharges are computed for headwater elevations ranging from 713 feet to 770 feet. 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" (not including the west saddle dam discharge) from the tailwater rating curve polynomial fit [4.17.1]. Tailwater submergence reduces the spillway discharge for a headwater elevation of 770 feet. The tailwater and spillway discharges were determined by iteration for this headwater. The results are readily checked by computing all discharges and making sure that the listed tailwater and total discharge minus the saddle dam discharge agree with the tailwater rating curve.

In Figure 5, spillway discharge is computed in the five columns, H_c, $C_f|C_g$, d/H_c, $S_f|S_g$ and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 749.6 feet [4.3.4] and orifice discharge occurs for headwater elevations above 749.6 feet. Above the double horizontal line indicating the transition from free discharge to orifice discharge, the listed discharge coefficient is C_f [4.2.3] computed from Equation (A5) and the submergence factor is S_f [4.2.4]. Below this line, the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3 and the submergence factor is S_g [4.3.6] computed by bilinear interpolation between the points in Table A1. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 2 for free discharge and from Equation 4 for orifice discharge. Tailwater affects the discharge for HW elevations greater than 768 feet (indicated by horizontal line) for which $d/H_c > 0.40$ [4.2.4].

The column following the spillway 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 eight columns are overflow discharges in cfs for the trash gate, spillway gates, screen house, powerhouse and spillway piers, nonoverflow and navigation lock sections, upper lock gate, east embankment flood wall, and east embankment earth section. The overflow discharge coefficient C_f or C_o ([4.4.1], [4.5.1], [4.6.1], [4.7.1], [4.8.1], [4.9.1], [4.10.1], [4.11.1]), elevation Z_c or Z_o ([4.4.2], [4.5.2], [4.6.2], [4.7.2], [4.8.2], [4.9.2], [4.10.2], [4.11.2]), and length L or L_o ([4.4.3], [4.5.3], [4.6.3], [4.7.3], [4.8.3], [4.9.3], [4.10.3], [4.11.3]) in each case is indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflow discharges are the same as computed for the pre-failure case.

The second-to-last column is the discharge in cfs past the failed west saddle dam determined by linear interpolation from the rating curve developed for that purpose [4.15.1].

The last column is d/H_c for the trash gate since the tailwater elevation is higher than its crest elevation for headwater elevations of 764 feet and above. The trash gate discharge is not affected by tailwater because $d/Hc < 0.6$ [3.5].

After West Saddle Dam Failure

g = 32.2 ft/s²

Spillway Parameters
L = 800 feet
Z_c = 713 feet
G_n = 29.305 feet
H_{mp} = 14.371 feet

Overflow Discharge, Q_f in cfs

HW feet	Total Discharge 1000 cfs	TW(1) feet	Spillway(2) feet H_c	C_f | C_g	d/H_c	S_f | S_g	cfs Q_{fs} | Q_{gs}	Trash Gate	Spill Gate Overflow	Screen House	P-house & Spill Piers	Nonover & Lock Walls	Upper Lock Gate	East Emb. Wall	East Emb. Earth	Failed West Saddle Dam Q_f from rating curve	Trash Gate d/H_c
							C_f =	3.0	3.4	2.65	2.65	3.0	3.3	3.0	2.65		
							Z_c =	733	759.84	767	752	752	748.67	767	770		
							L =	16.33	800	40	546.7	211.5	60	487.7	1325.2		
713	**0.00**	682.90	0	3.090		1	0	0	0	0	0	0	0	0	0	0	
715	**7.22**	683.51	2	3.191		1	7221	0	0	0	0	0	0	0	0	0	
718	**29.65**	685.36	5	3.315		1	29651	0	0	0	0	0	0	0	0	0	
721	**61.76**	687.91	8	3.412		1	61764	0	0	0	0	0	0	0	0	0	
724	**101.84**	690.94	11	3.489		1	101845	0	0	0	0	0	0	0	0	0	
727	**148.92**	694.29	14	3.554		1	148918	0	0	0	0	0	0	0	0	0	
730	**202.40**	697.85	17	3.609		1	202398	0	0	0	0	0	0	0	0	0	
733	**261.97**	701.52	20	3.661		1	261970	0	0	0	0	0	0	0	0	0	
734	**283.21**	702.76	21	3.678		1	283158	49	0	0	0	0	0	0	0	0	
736	**327.78**	705.25	23	3.712		1	327523	255	0	0	0	0	0	0	0	0	
738	**375.10**	707.76	25	3.746		1	374552	548	0	0	0	0	0	0	0	0	
740	**425.17**	710.25	27	3.780		1	424262	907	0	0	0	0	0	0	0	0	
742	**477.99**	712.73	29	3.815		1	476668	1323	0	0	0	0	0	0	0	0	
744	**533.55**	715.19	31	3.851	0.071	1	531764	1787	0	0	0	0	0	0	0	0	
746	**591.81**	717.62	33	3.887	0.140	1	589512	2296	0	0	0	0	0	0	0	0	
748	**652.67**	720.02	35	3.923	0.201	1	649826	2846	0	0	0	0	0	0	0	0	
749	**684.15**	721.21	36	3.940	0.228	1	680901	3135	0	0	0	0	38	0	0	77	
750	**703.90**	721.93	37	0.782	0.241	1	699712	3434	0	0	0	0	304	0	0	452	
752	**699.65**	721.62	39	0.739	0.221	1	689603	4057	0	0	0	0	1203	0	0	4791	
753	**699.53**	721.48	40	0.717	0.212	1	682901	4382	0	0	1449	635	1784	0	0	8382	
755	**747.85**	722.70	42	0.713	0.231	1	705420	5055	0	0	7528	3297	3153	0	0	23392	
757	**803.04**	724.00	44	0.710	0.250	1	726751	5760	0	0	16198	7094	4760	0	0	42482	
759	**868.69**	725.34	46	0.706	0.268	1	747003	6495	0	0	26831	11751	6574	0	0	70037	
760	**907.20**	726.09	47	0.706	0.278	1	758719	6873	174	0	32782	14357	7551	0	0	86740	
761	**951.79**	726.95	48	0.706	0.291	1	770258	7258	3398	0	39116	17132	8573	0	0	106052	
762	**1001.61**	727.88	49	0.706	0.304	1	781627	7651	8635	0	45814	20065	9636	0	0	128180	
763	**1053.21**	728.86	50	0.706	0.317	1	792832	8050	15279	0	52855	23148	10741	0	0	150309	
764	**1108.98**	729.87	51	0.706	0.331	1	803881	8456	23079	0	60224	26376	11884	0	0	175076	
765	**1166.38**	730.92	52	0.706	0.345	1	814781	8868	31882	0	67906	29740	13066	0	0	200136	
766	**1220.94**	732.00	53	0.706	0.358	1	825536	9287	41585	0	75890	33237	14284	0	0	221119	
767	**1276.65**	733.11	54	0.706	0.372	1	836153	9712	52112	0	84165	36861	15538	0	0	242103	
768	**1334.99**	734.29	55	0.706	0.387	1	846637	10144	63402	106	92720	40608	16827	1463	0	263086	0.037
769	**1396.34**	735.51	56	0.706	0.402	0.999	856136	10582	75407	300	101547	44474	18150	4138	0	285608	0.070
770	**1459.99**	736.80	57	0.706	0.418	0.999	865999	11026	88087	551	110638	48455	19505	7602	0	308130	0.103

(1) Tailwater is computed using total discharge minus the discharge from the failed west saddle dam.
(2) Double horizontal line is boundary between free discharge (above the line) and orifice discharge (below the line).

Figure 5 – Calculations for Case 3, West Saddle Dam Failure

6.4 Case 4, East Embankment Failure

For the east embankment failure condition, discharges are computed for headwater elevations ranging from 700 feet, the overflow elevation of the failed embankment, to an elevation of 770 feet. Both the east embankment and the west saddle dam are treated as failed. The west saddle dam will fail first because its overflow elevation is 13 feet below the overflow elevation of the east embankment.

Figure 6 shows the spreadsheet calculations for the dam rating curve following failure of the east embankment. Tailwater submergence reduces the spillway, trash gate, and failed east embankment discharges for Case 4. Consequently, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.17.1]. Figure 6 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges (only spillway, trash gate, and east embankment are affected by tailwater), adding them up to compute total discharge, and then making sure the listed tailwater and total discharge minus the saddle dam discharge [4.20] agree with the tailwater rating curve.

In Figure 6, spillway discharge is computed in the five columns, H_c, $C_f|C_g$, d/H_c, $S_f|S_g$ and $Q_f|Q_g$. Above the double horizontal line indicating the transition from free discharge to orifice discharge, the listed discharge coefficient is C_f [4.2.3] and the submergence factor is S_f [4.2.4]. Below this line, the listed discharge coefficient is C_g [4.3.5] and the submergence factor is S_g [4.3.6]. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 2 for free discharge and from Equation 4 for orifice discharge. Tailwater affects the discharge for HW elevations greater than 734 feet (indicated by horizontal line) for which $d/H_c > 0.40$ [4.2.4].

The column following the spillway 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.

Trash gate discharge in cfs is computed in the next three columns. Tailwater affects the discharge for HW elevations greater than 763 feet, as indicated by the horizontal line. Discharges above the horizontal line are not affected by tailwater submergence. Discharges below the horizontal line are reduced (multiplied by S_f) by tailwater submergence.

The next six columns are overflow discharges in cfs for the spillway gates, screen house, powerhouse and spillway piers, nonoverflow and navigation lock sections, upper lock gate, and the non-failed portion of the east embankment. These discharges, all computed using Equation 1, are not affected by tailwater submergence. This is verified in the last column, which shows d/H_c remaining less than 0.6 [3.5] for the upper lock gate, which has the lowest overflow elevation of this group.

The failed east embankment overflow discharge is computed in the three columns following the "Intact East Emb" column. Tailwater affects the discharge for HW elevations greater than 733 feet, as indicated by the horizontal line. Discharges above the horizontal line are not affected by tailwater submergence. Discharges below the horizontal line are reduced (multiplied by S_f) by tailwater submergence.

The second-to-last column is the discharge past the failed west saddle dam determined by linear interpolation from the rating curve developed for that purpose [4.15.1].

After West Saddle Dam and East Embankment Failure

g = 32.2 ft/s²

Spillway Parameters
L = 800 feet
Z_c = 713 feet
G_n = 29.305 feet
H_{mp} = 14.371 feet

HW feet	Total Discharge 1000 cfs	TW(1) feet	Spillway(2) H_c feet	C_f | C_n	d/H_c	S_f | S_q	Q_{fs} | Q_{ns} cfs		Trash Gate d/H_c	Trash Gate S_f	Trash Gate Q_f	Spill Gate Overflow	Screen House	P-house & Spill Piers	Nonover & Lock Walls	Upper Lock Gate	Intact East Emb.	Failed East Embankment d/H_c	Failed East Embankment S_f	Failed East Embankment Q_f	Failed West Saddle Dam Q_f from rating curve	Upper Lock Gate d/H_c
								C_f =			3.0	3.4	2.65	2.65	3.0	3.3	2.65			2.65		
								Z_c =			733	759.84	767	752	752	748.67	770			700		
								L =			16.33	800	40	546.7	211.5	60	792			750		
700	0.00	682.90									0	0	0	0	0	0			1	0	0	
702	5.62	683.37									0	0	0	0	0	0			1	5621	0	
704	15.90	684.23									0	0	0	0	0	0			1	15900	0	
706	29.21	685.32									0	0	0	0	0	0			1	29210	0	
708	44.97	686.59									0	0	0	0	0	0			1	44972	0	
710	62.85	688.00									0	0	0	0	0	0			1	62850	0	
713	93.16	690.30	0	3.090		1	0				0	0	0	0	0	0			1	93158	0	
715	122.68	692.45	2	3.191		1	7221				0	0	0	0	0	0			1	115463	0	
718	181.43	696.48	5	3.315		1	29651				0	0	0	0	0	0			1	151780	0	
721	253.03	700.98	8	3.412		1	61764				0	0	0	0	0	0		0.047	1	191265	0	
724	335.53	705.67	11	3.489		1	101845				0	0	0	0	0	0		0.236	1	233681	0	
727	427.76	710.38	14	3.554		1	148918				0	0	0	0	0	0		0.384	1	278839	0	
730	528.98	714.99	17	3.609	0.117	1	202398				0	0	0	0	0	0		0.500	1	326580	0	
733	638.74	719.48	20	3.661	0.324	1	261970			1	0	0	0	0	0	0	0	0.590	1	376772	0	
734	676.90	720.94	21	3.678	0.378	1	283158			1	49	0	0	0	0	0	0	0.616	0.999	393693	0	
736	751.45	723.68	23	3.712	0.464	0.999	327214			1	255	0	0	0	0	0	0	0.658	0.988	423983	0	
738	826.03	726.28	25	3.746	0.531	0.997	373472			1	548	0	0	0	0	0	0	0.692	0.971	452006	0	
740	901.39	728.81	27	3.780	0.585	0.994	421515			1	907	0	0	0	0	0	0	0.720	0.953	478967	0	
742	977.44	731.28	29	3.815	0.630	0.988	470949			1	1323	0	0	0	0	0	0	0.745	0.934	505165	0	
744	1053.78	733.71	31	3.851	0.668	0.980	521378			1	1787	0	0	0	0	0	0	0.766	0.915	530615	0	
746	1129.97	736.12	33	3.887	0.700	0.971	572422		0.240	1	2296	0	0	0	0	0	0	0.785	0.895	555252	0	
748	1205.58	738.49	35	3.923	0.728	0.960	623713		0.366	1	2846	0	0	0	0	0	0	0.802	0.876	579018	0	
749	1243.14	739.66	36	3.940	0.741	0.954	649336		0.416	1	3135	0	0	0	0	38	0	0.809	0.866	590559	77	
750	1244.19	739.68	37	0.782	0.721	0.883	617536		0.393	1	3434	0	0	0	0	304	0	0.794	0.886	622469	452	
752	1287.92	740.92	39	0.739	0.716	0.887	611966		0.417	1	4057	0	0	0	0	1203	0	0.787	0.894	665904	4791	
753	1311.62	741.55	40	0.717	0.714	0.889	607338		0.428	1	4382	0	0	1449	635	1784	0	0.784	0.897	687658	8382	
755	1385.46	743.41	42	0.718	0.724	0.880	620759		0.473	1	5055	0	0	7528	3297	3153	0	0.789	0.891	722276	23392	
757	1462.15	745.23	44	0.710	0.732	0.864	628062		0.510	1	5760	0	0	16198	7094	4760	0	0.794	0.886	757794	42482	
759	1550.72	747.17	46	0.706	0.743	0.853	637489		0.545	1	6495	0	0	26831	11751	6574	0	0.800	0.879	791545	70037	
760	1586.15	747.77	47	0.706	0.740	0.820	622193		0.547	1	6873	174	0	32782	14357	7551	0	0.796	0.883	815484	86740	
761	1637.94	748.81	48	0.706	0.746	0.811	625018		0.565	1	7258	3398	0	39116	17132	8573	0	0.800	0.878	831395	106052	
762	1693.04	749.87	49	0.706	0.752	0.801	626148		0.582	1	7651	8635	0	45814	20065	9636	0	0.804	0.873	846908	128180	
763	1748.05	750.92	50	0.706	0.758	0.789	625300		0.597	1	8050	15279	0	52855	23148	10741	0	0.808	0.868	862366	150309	0.157
764	1806.26	752.00	51	0.706	0.765	0.776	623833		0.613	1.000	8451	23079	0	60224	26376	11884	0	0.812	0.862	877338	175076	0.217
765	1865.27	753.09	52	0.706	0.771	0.763	621852		0.628	0.997	8843	31882	0	67906	29740	13066	0	0.817	0.856	891843	200136	0.271
766	1920.66	754.19	53	0.706	0.777	0.750	619441		0.642	0.993	9224	41585	0	75890	33237	14284	0	0.821	0.850	905878	221119	0.319
767	1976.50	755.31	54	0.706	0.784	0.738	616674		0.656	0.988	9598	52112	0	84165	36861	15538	0	0.826	0.844	919447	242103	0.362
768	2032.85	756.44	55	0.706	0.790	0.725	613645		0.670	0.982	9965	63402	106	92720	40608	16827	0	0.830	0.837	932494	263086	0.402
769	2091.21	757.58	56	0.706	0.796	0.712	610323		0.683	0.976	10326	75407	300	101547	44474	18150	0	0.834	0.830	945073	285608	0.438
770	2150.00	758.72	57	0.706	0.802	0.700	606726		0.695	0.969	10682	88087	551	110638	48455	19505	0	0.839	0.822	957231	308130	0.471

Overflow Discharge, Q_f in cfs (columns Trash Gate through Upper Lock Gate)

(1) Tailwater is computed using total discharge minus the discharge from the failed west saddle dam.
(2) Double horizontal line is boundary between free discharge (above the line) and orifice discharge (below the line).

Figure 6 – Calculations for Case 4, East Embankment Failure

NOT VALID

7. Results/Conclusions

For convenience, the initial dam rating results, separate from the calculation details provided above, are tabulated as total discharge in cfs vs. headwater elevation in feet in Figure 7. The dam rating curves (along with the tailwater rating curve) are plotted in Figure 8.

The initial dam rating curves developed in this calculation provide Watts Bar total dam discharge vs. headwater elevation for use in TVA's SOCH and TRBROUTE models for simulation conditions satisfying the assumptions in [3.1], which apply to major floods up to and including the PMF which are of sufficient magnitude to require all of the spillway gates to be fully raised and both gate leaves to be removed from the trashway.

The Case 1 (pre-failure with turbine discharge) curve is used for both rising and falling headwaters until the headwater elevation rises above 752 feet at which time the turbines would be shut down. Then the Case 2 (pre-failure without turbine discharge) curve is used for both rising and falling headwaters until the west saddle dam is judged to fail, sometime after the headwater rises above its overflow elevation of 757 feet. Then the Case 3 (failed west saddle dam) curve is used for both rising and falling headwaters until up to an elevation of 770 feet, the top of the east earth embankment.

As discussed in Section 5.0, the dam rating curves provided in Figures 3, 4, 5, 7 and 8 are limited in applicability to headwater elevations no greater than 768.50 feet. The dam rating curve provided in Figure 6 is not valid for current conditions at Watts Bar Dam.

Case 1 Pre-Failure with Turbine Discharge		Case 2 Pre-Failure without Turbine Discharge		Case 3 Failed West Saddle Dam		Case 4 Failed W. Saddle Dam and East Embankment	
HW feet	Total Discharge 1000 cfs	HW feet	Total Discharge 1000 cfs	HW feet	Total Discharge 1000 cfs	HW feet	Total Discharge 1000 cfs
713	0.00	713	0.00	713	0.00	700	0.00
715	7.22	715	7.22	715	7.22	702	5.62
718	29.65	718	29.65	718	29.65	704	15.90
721	61.76	721	61.76	721	61.76	706	29.21
724	101.84	724	101.84	724	101.84	708	44.97
727	148.92	727	148.92	727	148.92	710	62.85
730	202.40	730	202.40	730	202.40	713	93.16
733	301.97	733	261.97	733	261.97	715	122.68
734	323.21	734	283.21	734	283.21	718	181.43
736	367.78	736	327.78	736	327.78	721	253.03
738	415.10	738	375.10	738	375.10	724	335.53
740	465.17	740	425.17	740	425.17	727	427.76
742	517.99	742	477.99	742	477.99	730	528.98
744	573.55	744	533.55	744	533.55	733	638.74
746	631.81	746	591.81	746	591.81	734	676.90
748	692.67	748	652.67	748	652.67	736	751.45
749	724.07	749	684.07	749	684.15	738	826.03
750	743.45	750	703.45	750	703.90	740	901.39
752	734.86	752	694.86	752	699.65	742	977.44
753	691.15	753	691.15	753	699.53	744	1053.78
755	724.45	755	724.45	755	747.85	746	1129.97
757	760.56	757	760.56	757	803.04	748	1205.58
759	808.77	759	808.77	759	868.69	749	1243.14
760	839.03	760	839.03	760	907.20	750	1244.19
761	874.34	761	874.34	761	951.79	752	1287.92
762	913.40	762	913.40	762	1001.61	753	1311.62
763	955.45	763	955.45	763	1053.21	755	1385.46
764	1000.11	764	1000.11	764	1108.98	757	1462.15
765	1047.14	765	1047.14	765	1166.38	759	1550.72
766	1096.35	766	1096.35	766	1220.94	760	1586.15
767	1147.59	767	1147.59	767	1276.65	761	1637.94
768	1202.33	768	1202.33	768	1334.99	762	1693.04
769	1259.34	769	1259.34	769	1396.34	763	1748.05
770	1319.43	770	1319.43	770	1459.99	764	1806.26
						765	1865.27
						766	1920.66
						767	1976.50
						768	2032.85
						769	2091.21
						770	2150.00

Figure 7 – Initial Dam Rating Results for Cases 1, 2, 3, and 4

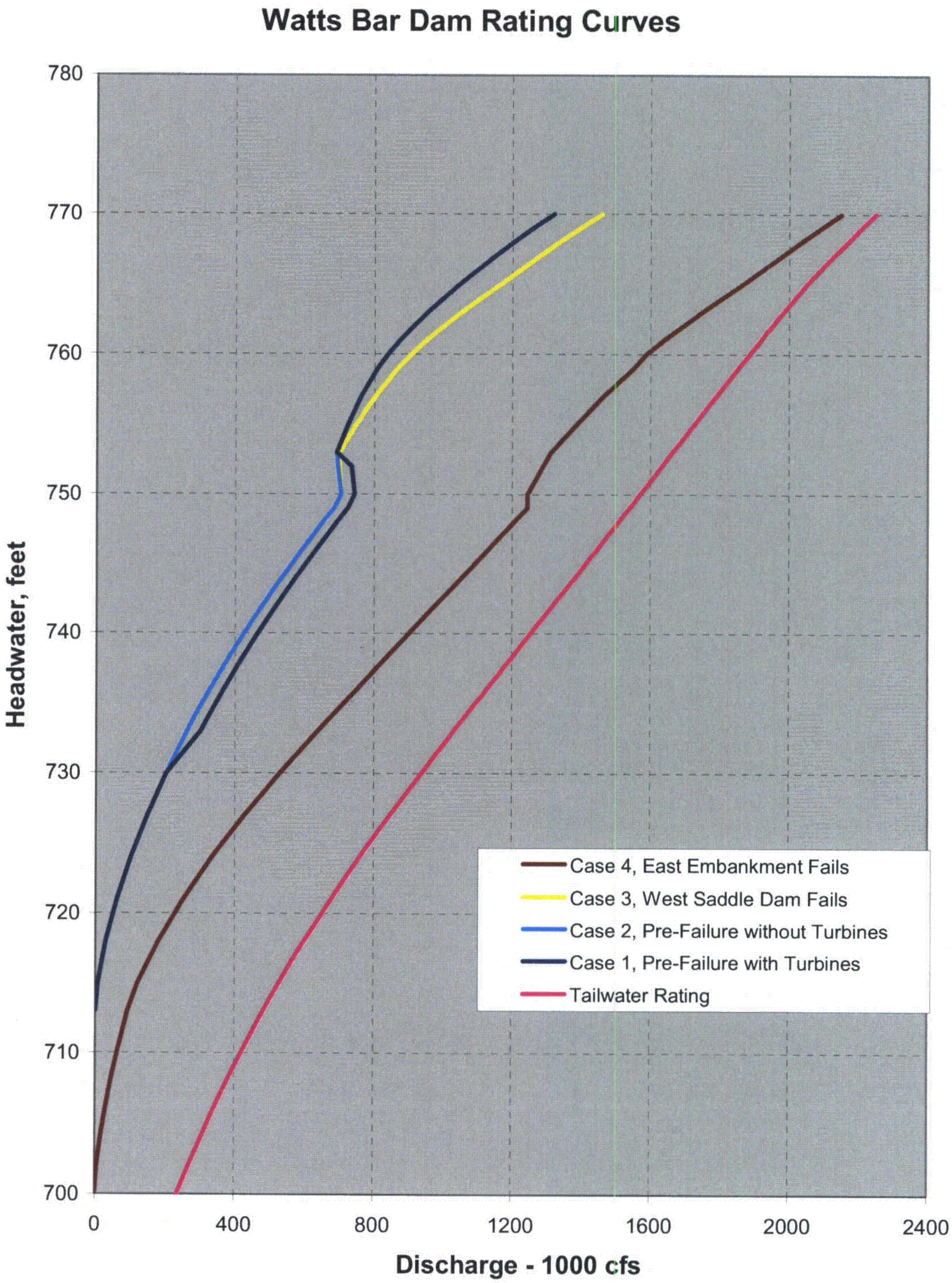


Figure 8 – Initial Dam Rating Curves for Cases 1, 2, 3, and 4

Appendix A: Spillway Discharge Coefficients and Submergence Factors for Watts Bar Dam from 1:35 Scale Model Test Data

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.

Watts Bar dam has twenty 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 included as Attachment A2. As shown in this table, the maximum opening corresponds to reading "UP" 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. For gate position indicator reading "UP" the average value of V for the twenty gates is 28.92 feet.

Test data from a 1:35 scale model (circa 1950) are available for free discharge conditions (Attachments A6-3, A6-4, and A7-6) and for orifice discharge conditions for nine different gate openings varying from V = 1.82 feet to V = 23.83 feet (Attachments A7-4 and A7-5). Orifice discharge data were not collected for gate openings as large as V = 28.92 feet, however, because under normal operating conditions the overflowing nappe will never touch the bottom of a gate open this far. But under certain high flood 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 = 28.92 feet.

Fort Loudoun, Douglas, and Cherokee Dams all have spillway gates and crests identical to Watts Bar 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. The free discharge relationships provided below apply to both Watts Bar and Fort Loudoun Dams because they have similar upstream depths, but not to Douglas and Cherokee Dams, which have greater upstream reservoir depths.

A.1 References

A1. "Watts Bar Dam Spillway Discharge Tables," River Operations, Tennessee Valley Authority, 2004 (Attachment 22).
A2. TVA Files, binder "Watts Bar , Spillway Rating, 1990" (Attachment A3)
A3. "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 A19)
A4. "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 A20)
A5. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988
A6: Dam Rating Curves, Nickajack, TVA Calculation CDQ 000020080014, Appendix A
A7. Open Channel Flow, F. M. Henderson, Macmillan, New York, 1966.
A8. TVA drawing no: 54W200, R6 (Attachments A10 and A21)
A9. TVA drawing no: 51N205, R4 (Attachments A11 and A22)
A10: Dam Rating Curves, Tellico, TVA Calculation CDQ 000020080018, Appendix A

A.2 Discharge Equations

Attachment A4 is a definition sketch for flow over the Watts Bar 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 $H_c \le H_{Lmin}$, and is computed using a weir equation (e.g., Reference A5):

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

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), and Z_c = top, or crest, elevation of overflowing section (ft). This equation is modified to account for tailwater submergence as follows:

$$Q_{fs} = Q_f S_f \quad \text{(A2)}$$

in which Q_{fs} = "corrected" free discharge (cfs), S_f = tailwater submergence factor (dimensionless -- varies with d / H_c), d = height of tailwater above crest (ft) = TW - Z_c, and TW = tailwater elevation (ft).

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 A5)

$$Q_g = C_g G_n L \sqrt{2g(H_c - H_{mp})} \quad \text{(A3)}$$

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 A5, sheet. 000-1 for example), and H_{mp} = vertical distance between the mid-point of G_n and the crest. This equation is modified to account for tailwater submergence as follows:

$$Q_{gs} = S_g Q_g \quad \text{(A4)}$$

in which in which Q_{gs} = "corrected" orifice discharge (cfs) and S_g = tailwater submergence factor (dimensionless -- varies with d / H_c and gate opening, V).

A.3 Model Test Data

The 1:35 scale Watts Bar model test data (Attachments A6 and A7) are used to determine

- $C_f(H_c)$ and $S_f(d/H_c)$
- H_{Lmin} and $C_g(H_c)$ for V = 28.92 ft.

The 1:35 scale Nickajack Dam model test data (Reference A6) and the 1:72 scale Tellico Dam model test data (Reference A10) are used to estimate

- $S_g(d/H_c)$ for V = 28.92 ft

Submergence effects on orifice discharge were not evaluated in the Watts Bar model study because under normal operating conditions the tailwater is never high enough to affect orifice discharge. Model data for estimating submergence effects on orifice discharge through radial gates on a spillway crest are available for the spillways at Nickajack Dam (Reference A6) and for the spillways at Tellico Dam (Reference A10). These spillways are similar to Watts Bar, both having radial gates controlling flow over a spillway crest. Their crest and gate parameters are somewhat different than those at Watts Bar, but the submergence data are normalized in a way that permits their use at any dam with radial gates on a spillway crest. Curve fits for $S_g(d/H_c, H_c/G_n)$ are included as Attachment A5-1 for Nickajack Dam and as Attachment A5-2 for Tellico Dam. One consequence of the parameter and geometry differences between Nickajack and Tellico Dams is that the value of the submergence ratio, d/H_c, at which submergence effects begins differs, being 0.6 for Nickajack and 0.2 for Tellico. Attachment A14 indicates that the value of d/H_c at which submergence effects begin at Watts Bar is 0.4. Because this value of d/H_c is halfway between the corresponding values for Nickajack and Tellico, an $S_g(d/H_c, H_c/G_n)$ relationship for Watts Bar was developed by averaging the values for Nickajack and Tellico Dams. The resulting curve fits are included as Attachment A5-3 and the coordinates defining the curve fits are given in Table A1.

Table A1: Points Defining Curves through averaged Nickajack and Tellico S_g data (Ref. A6, Ref. A10)

H_c/G_n =	1.35		H_c/G_n =	1.50		H_c/G_n =	1.70
d / H_c	S_g		d / H_c	S_g		d / H_c	S_g
0.00	1.000		0.00	1.000		0.00	1.000
0.40	1.000		0.40	1.000		0.40	1.000
0.45	0.990		0.45	0.990		0.45	0.988
0.50	0.984		0.50	0.984		0.50	0.978
0.55	0.973		0.55	0.973		0.55	0.967
0.60	0.961		0.60	0.960		0.60	0.951
0.65	0.938		0.65	0.938		0.65	0.920
0.70	0.902		0.70	0.898		0.70	0.875
0.75	0.856		0.75	0.846		0.75	0.806
0.80	0.794		0.80	0.766		0.80	0.704
0.85	0.697		0.85	0.651		0.85	0.598
0.90	0.570		0.90	0.523		0.90	0.482
0.96	0.350		0.95	0.358		0.94	0.363
H_c/G_n =	2.0		H_c/G_n =	2.30			
d / H_c	S_g		d / H_c	S_g			
0.00	1.000		0.00	1.000			
0.40	1.000		0.40	1.000			
0.45	0.986		0.45	0.980			
0.50	0.974		0.50	0.957			
0.55	0.953		0.55	0.929			
0.60	0.917		0.60	0.893			
0.65	0.877		0.65	0.828			
0.70	0.807		0.70	0.748			
0.75	0.714		0.75	0.668			
0.80	0.635		0.80	0.588			
0.85	0.545		0.85	0.505			
0.90	0.444		0.90	0.412			
0.93	0.367		0.92	0.365			

The Watts Bar model test results for $C_f(H_c)$ and $S_f(H_c)$ were published in graphical form in Reference A3. Reference A3 includes results also for orifice discharge but in terms of a different discharge coefficient than the coefficient C_g used here, and Reference A3 includes no information on the relationship between H_{Lmin} and gate opening. However, the model test data for both orifice and free discharge are tabulated in Reference A4 and these data are used in paragraphs A.5, A.6, and A.7 to estimate H_{Lmin} and $C_g(H_c)$ for V = 28.92 feet and to establish a curve fit for $C_f(H_c)$.

Attachment A6 provides the pages from Reference A3 that are relevant to these calculations. Attachment A7 provides the pages from Reference A4 that are relevant to these calculations. Reference A4 includes a few pages (Attachment A7-4, for example) with penciled corrections by the original author.

Model data are scaled to prototype values using the following scale ratios from Attachment A8:

- 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 Attachment A17) are computed from crest and gate geometry as described in Attachment A9. Table A2 gives the values of these parameters for V = 7.80, 11.83, 15.86, 19.84, 23.83, and 28.92 feet.

Table A2: 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	751.27	78.4
11.83	11.868	5.906	753.76	86.4
15.86	15.904	7.921	755.86	93.1
19.84	19.919	9.906	757.56	98.9
23.83	23.994	11.892	758.85	104.0
28.92	29.305	14.371	759.84	112.1

As an example, the procedure for computing the geometrical parameters for V = 28.92 feet is given here. From Attachment A10,

- R = 35 feet
- Z_c = 713 feet
- Z_{tr} = 725 feet
- z_1 = 725 - 712.636 = 12.364 feet
- z_2 =745 - 725 = 20.0 feet

where the parameters are defined in Attachment A9-2. Referring to Attachment A9:

Angle θ:

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

Angle α:

$$\alpha = \tan^{-1}\left(\frac{725-713-28.92}{\sqrt{35^2-(725-713-28.92)^2}}\right) = -28.910°$$

Overflow elevation Z_o:

$$Z_o = 725 + 35\sin[55.537 - (-28.910)] = 759.836 \text{ feet}$$

Gate lip y-coordinate:

$$y_\ell = 725 - 713 - 28.92 = -16.92 \text{ feet}$$

Gate lip x-coordinate:

$$x_\ell = \sqrt{35^2 - (-16.92)^2} = 30.6384 \text{ feet}$$

From Attachment A11, 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 $x_x^* = 43.708 - x_s$. In terms of y_s and x_s:

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

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}:

$$x_{sn} - 30.6384 + \left[25.4051 - 83.356\left(\frac{x_{sn}}{127}\right) + 127\left(\frac{x_{sn}}{127}\right)^2 - (-16.92)\right]\left[-0.65635 + \frac{x_{sn}}{63.5}\right] = 0$$

Solution:

- x_{sn} = 34.1076 feet (by iteration)
- $y_{sn} = 25.4051 - 83.356(34.1076/127) + 127(34.1076/127)^2 = 12.1788$
- $G_n = \sqrt{(34.1076 - 30.6384)^2 + (12.1788 - (-16.92))^2} = 29.305$ feet

and

- $H_{mp} = 28.92 - [12.1788 - (-16.92)]/2 = 14.371$ feet
- $\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{-16.92}{30.6384}\right) - \tan^{-1}\left(\frac{34.1076 - 30.6384}{12.1788 - (-16.92)}\right) = 90 - (-28.91) - 6.80 = 112.11°$

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

Attachment A12 shows the model test data (from Attachments A7-4 and A7-5) for H_{Lmin} and a polynomial curve fit to the data (spreadsheet included as Attachment A18). A value of H_{Lmin} for V = 28.92 feet is established by using the polynomial to extrapolate the data. The following is used for the dam rating curve calculations:

H_{Lmin} = 36.64 feet for V = 28.92 feet.

A.6 Determination of $C_f(H_c)$ and $S_f(d/H_c)$

Attachment A13 shows the model test data for free discharge (from Attachment A7-6) and a polynomial curve fit to the data. The "6.866" in the "Definition" was the length of the model crest in feet (Attachment A7-1). The polynomial indicated in Attachment A13 is used for the dam rating curve calculations:

$$C_f = 3.09 + 0.055033H_c - 0.0022844H_c^2 + 5.9044\text{x}10^{-5}H_c^3 - 5.507\text{x}10^{-7}H_c^4 \qquad \text{(A5)}$$

A plot of $C_s/C(S_f)$ vs. d/H(d/H_c) for Watts Bar Dam is provided in Attachment A6-4. The points listed in Attachment A14 were scaled off this plot and, as shown on the plot of S_f vs. d / H_c in Attachment A14, the following equation was fit to the scaled points:

$$S_f = \left[1 - \left(\frac{d}{H_c}\right)^{8.3}\right]^{0.55} \qquad \text{(A6)}$$

This equation is used for the dam rating calculations.

A.7 Determination of $C_g(H_c)$ for V = 28.92 feet

Attachment A15 shows the calculations and results for extrapolating $C_g(H_c)$ for V = 28.92 feet from the model data for other gate openings. The first column in Attachment A15 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 = 28.92 feet at $H_c = H_{Lmin}$ is the free discharge computed from Equation A1 using $C_f(H_c)$ from the polynomial in Attachment A13. 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 Attachments A7-4 and A7-5. 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 next column after the geometrical parameters lists the C_g values computed from the data. The last numerical column lists values used for drawing lines through the data points and extending them to H_c = 60 feet (Attachment A16). Values outside the data range that were estimated for extrapolation purposes are labeled as such to the right of the last column.

Attachment A16 shows C_g plotted against H_c for all gate openings. 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 = 28.92 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 = 28.92 feet is used for the dam rating calculations. Table A3 lists the points describing the extrapolated relationship.

Table A3: Points Defining Extrapolated Curve for $C_g(H_c)$ at V = 28.92 feet.

H_c, feet	C_g
36.64	0.790
40	0.717
46	0.706
60	0.706

As justification for the extrapolation, Attachment A17 shows the Watts Bar C_g values at H_c = 60 feet plotted against angle β on Hydraulic Design Chart 311-1 from Reference A5 showing U.S. Army Corps of Engineers data for tainter gates on standard crests. The value of X/H_d for Watts Bar is 0.15 (X = 3.43 feet, Attachment A10, and Hd = 23.5, Attachment A7-1). 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 = 0.706 at H_c = 60 feet and V = 28.92 feet (β = 112.1 degrees) is a satisfactory extrapolation of the Watts Bar data curve and that the Watts Bar curve is in excellent agreement with the trends exhibited by the Corps curves in HDC 311-1, particularly considering the overall scatter in the Corps experimental data.

Appendix B: Hydrostatic Loads on the Spillway Tainter Gates

The hydrostatic loads on the spillway tainter gates for Watts Bar Dam can be found in the following calculations.

B1 References

B1. "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates, pages 76-100" Tennessee Valley Authority, HEPE3WBHSQN-WBNBLNBFN.

B2. Calculations

Reference B1 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 (745 feet) and when the gates are completely open (FR_{open}) and the headwater elevation is at 768.50 feet. The margin is defined a the ration of FR_{open} to FR_{closed} . The calculation of these forces and the results of this comparison are shown in Figure B1.

Comparison of forces when gates are closed and HW is at 745 feet (top of gate) vs. when gates are fully open and HW at an elevation of 768.13 feet.

Attribute	Symbol	Value
top elev	Zo	745
trun elev	Ztr	725
sill elev	Zsill	712.64
radius	R	35
length	L	40
angle up	α2	34.85
angle lwr	α	20.69
angle tot	θ	55.54
area of lower slice	Aslice1	593.70
proj area	AProjected	1294.56
Desgn LdH	FRx	1307190.76
Result elv	Z1	723.42
Result ang deg		2.58
Result ang rad		0.05
Result Dsgn	Horiz	1305864.88
Area slice upper	Aslice2	372.55
Area triangle	Atriangle	287.23
project vert	x1	6.28
vert weight water	FRy	100392.74
Resultant load - Gates Closed	FR_{closed}	**1311040.20**
vert open fm calc	calc App A	28.92
max hw	calc	768.50
lwr lip elev	Z2	741.56
bot angle	α3	28.23
top elev	Zo	759.79
project area for h ld	AProjected	729.49
Flood LdH	FRx	811411.89
Height over gate	y1	8.71
Height ratio to orig		1.73
project vert	x2	27.04
Flood LdV1		587576.99
Flood lLdV2		393978.13
Total Flood LdV	FRy	981555.12
Resultant load - Gates Fully Open	FR_{open}	**1273514.71**
Margin	FR_{open}/FR_{closed}	0.97

Figure B1: Watts Bar Spillway Gate Margin Evaluation

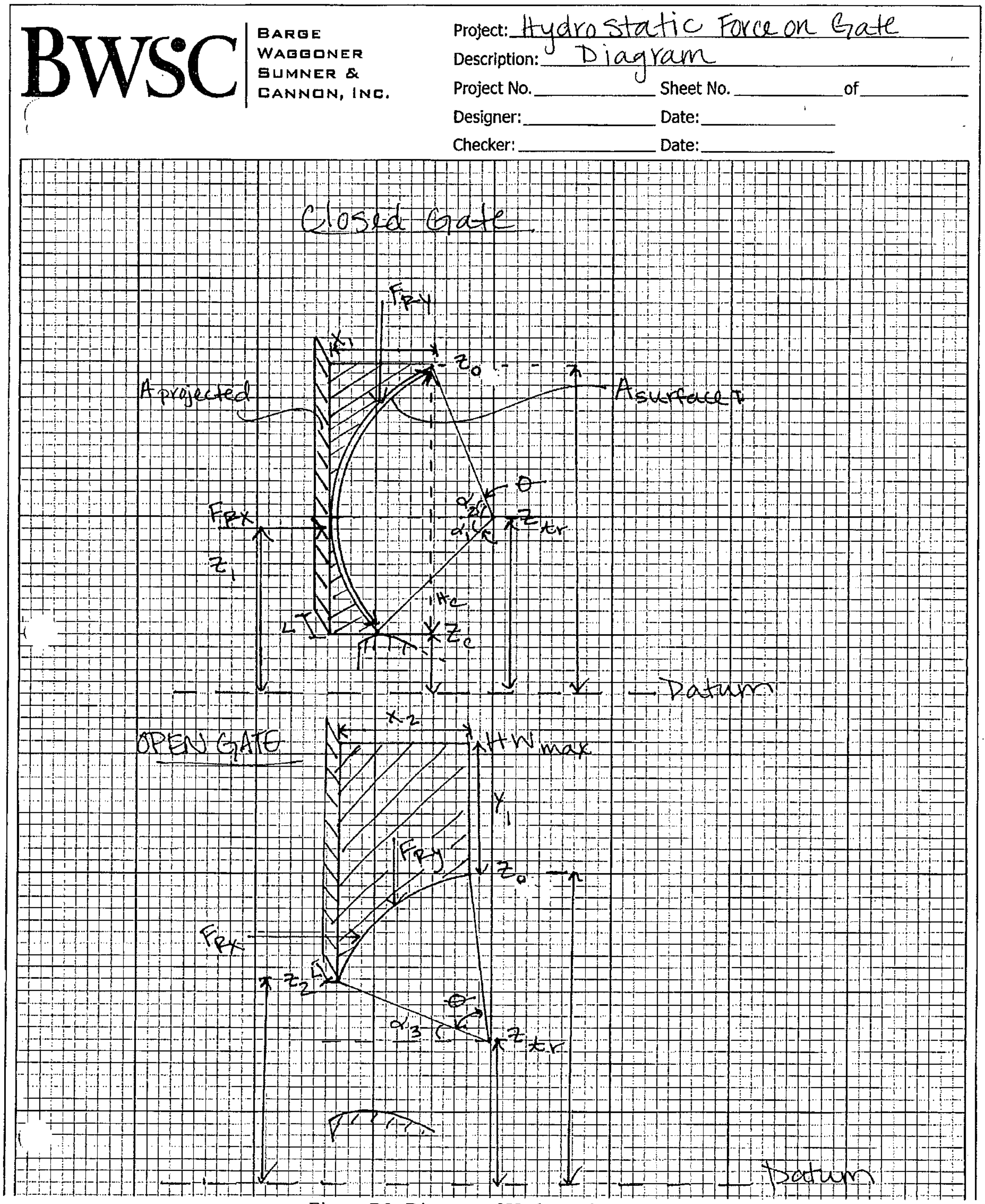
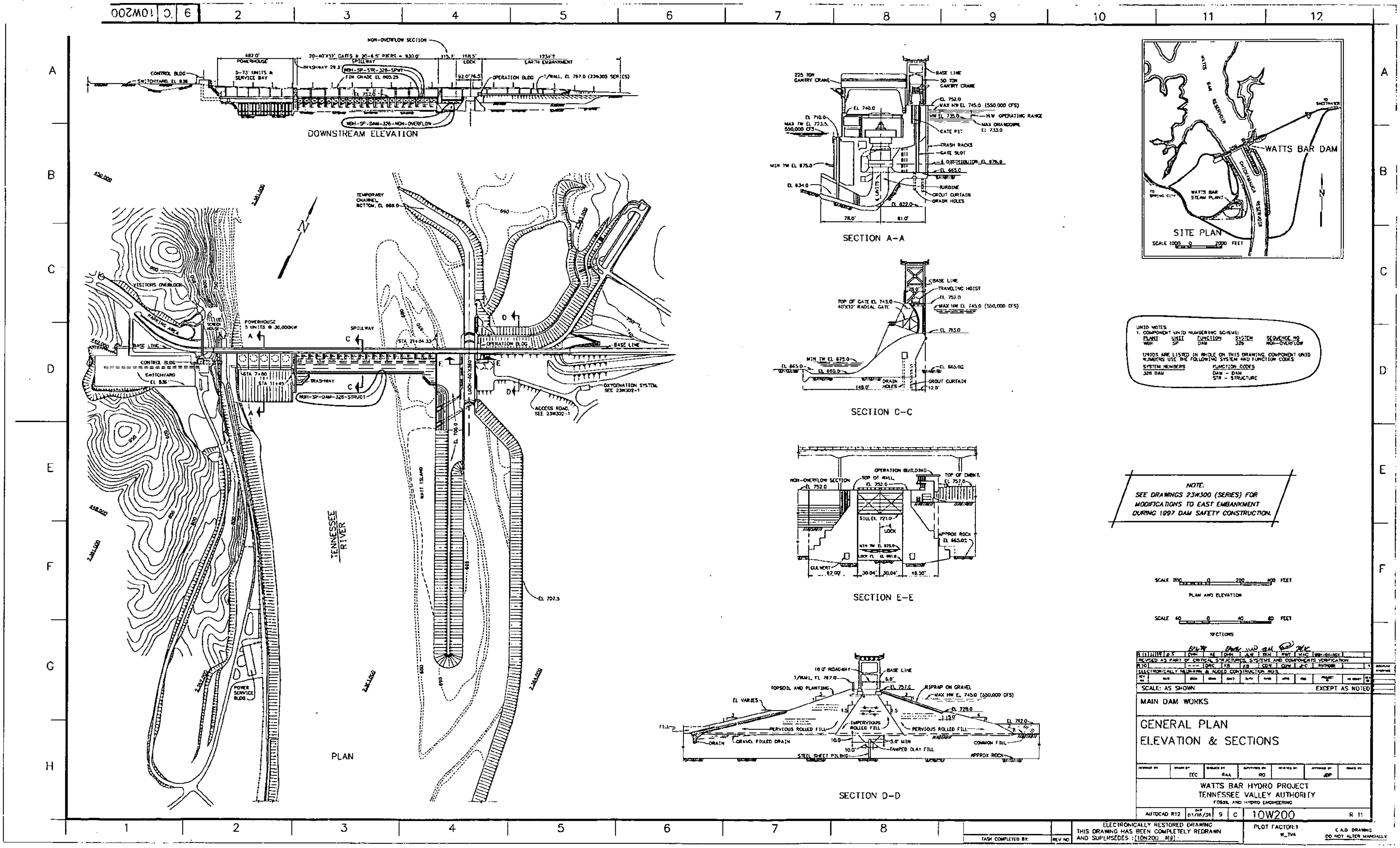


Figure B2: Diagram of Hydrostatic Forces

Attachment 1

Source: Reference 1

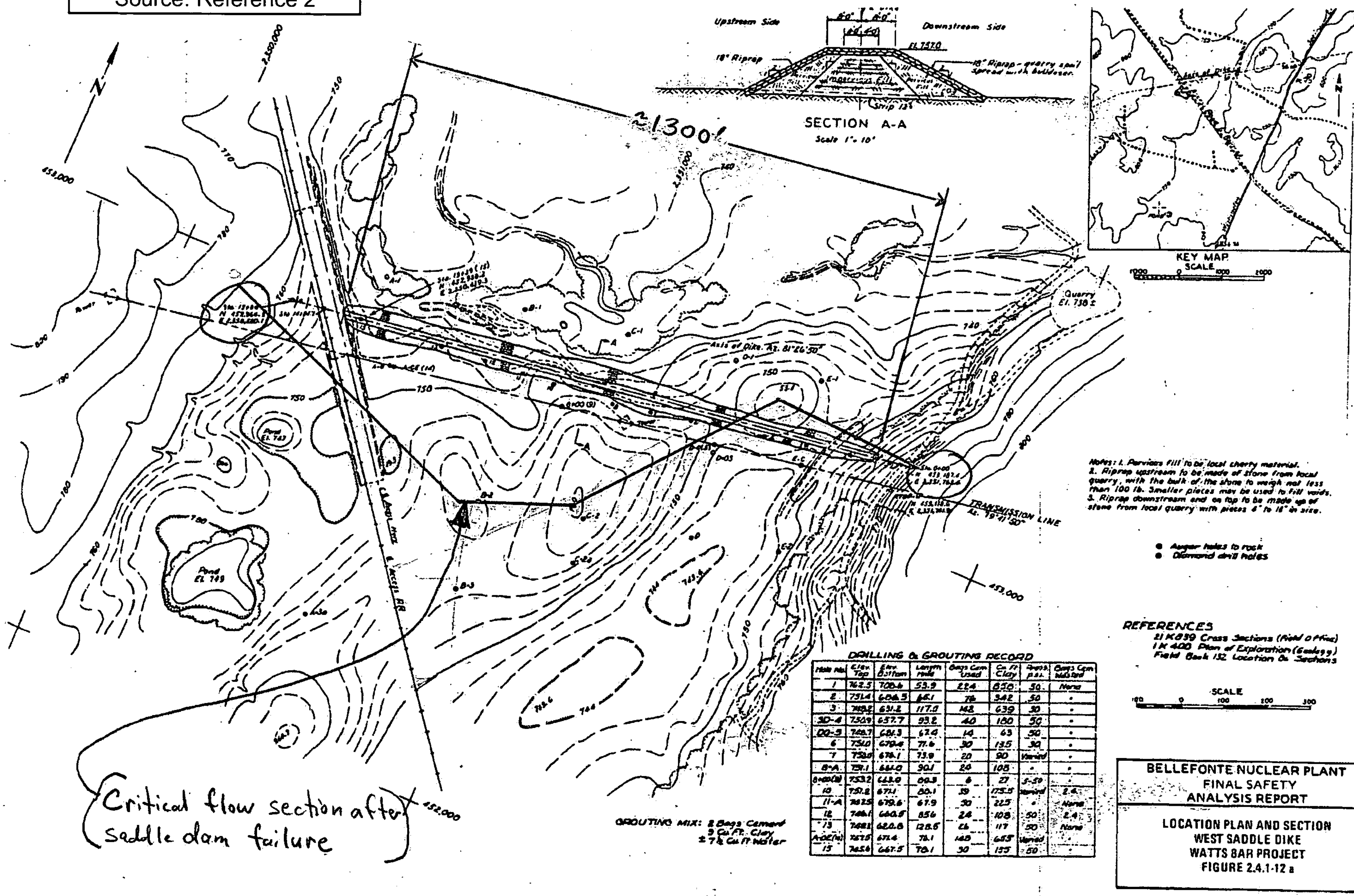
Calculation No: CDQ000020080020



Attachment 2

Source: Reference 2

Calculation No: CDQ000020080020



DRILLING & GROUTING RECORD

Hole No.	Elev. Top	Elev. Bottom	Length Hole	Bags Cem Used	Cu Ft Clay	Press. p.s.i.	Bags Cem Wasted
1	762.5	708.6	53.9	22.4	850	50	None
2	751.4	686.5	65.1	76	342	50	"
3	748.2	631.2	117.0	148	639	30	"
SD-4	750.9	657.7	93.2	40	180	50	"
DD-5	748.7	681.3	67.4	14	63	50	"
6	751.0	679.4	71.6	30	135	30	"
7	752.0	678.1	73.9	20	90	Varied	"
8-A	751.1	661.0	90.1	24	108	"	"
8+00(9)	753.2	663.0	90.3	6	27	5-50	"
10	751.2	671.1	80.1	39	175.5	Varied	2.4
11-A	748.5	679.6	67.9	30	225	"	None
12	746.1	660.5	85.6	24	108	50	2.4
13	748.1	620.6	128.6	26	117	50	None
A-OE(14)	747.5	671.4	76.1	148	655	Varied	"
15	745.6	667.5	78.1	30	135	50	"

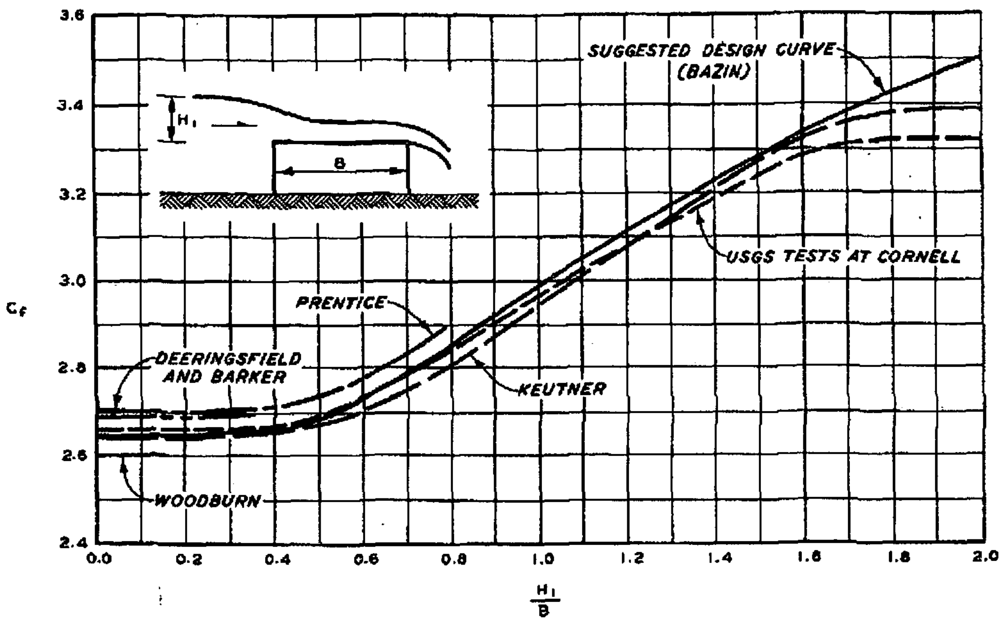
BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

LOCATION PLAN AND SECTION
WEST SADDLE DIKE
WATTS BAR PROJECT
FIGURE 2.4.1-12 a

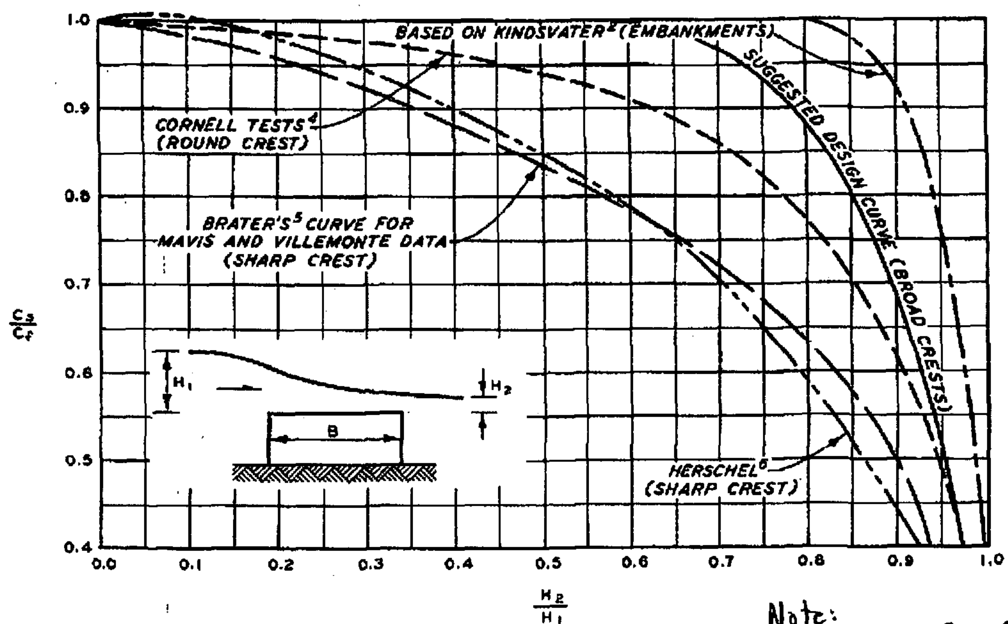
Attachment 4

Source: Reference 6

Calculation No: CDQ000020080020



a. FREE FLOW



b. SUBMERGED FLOW

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

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

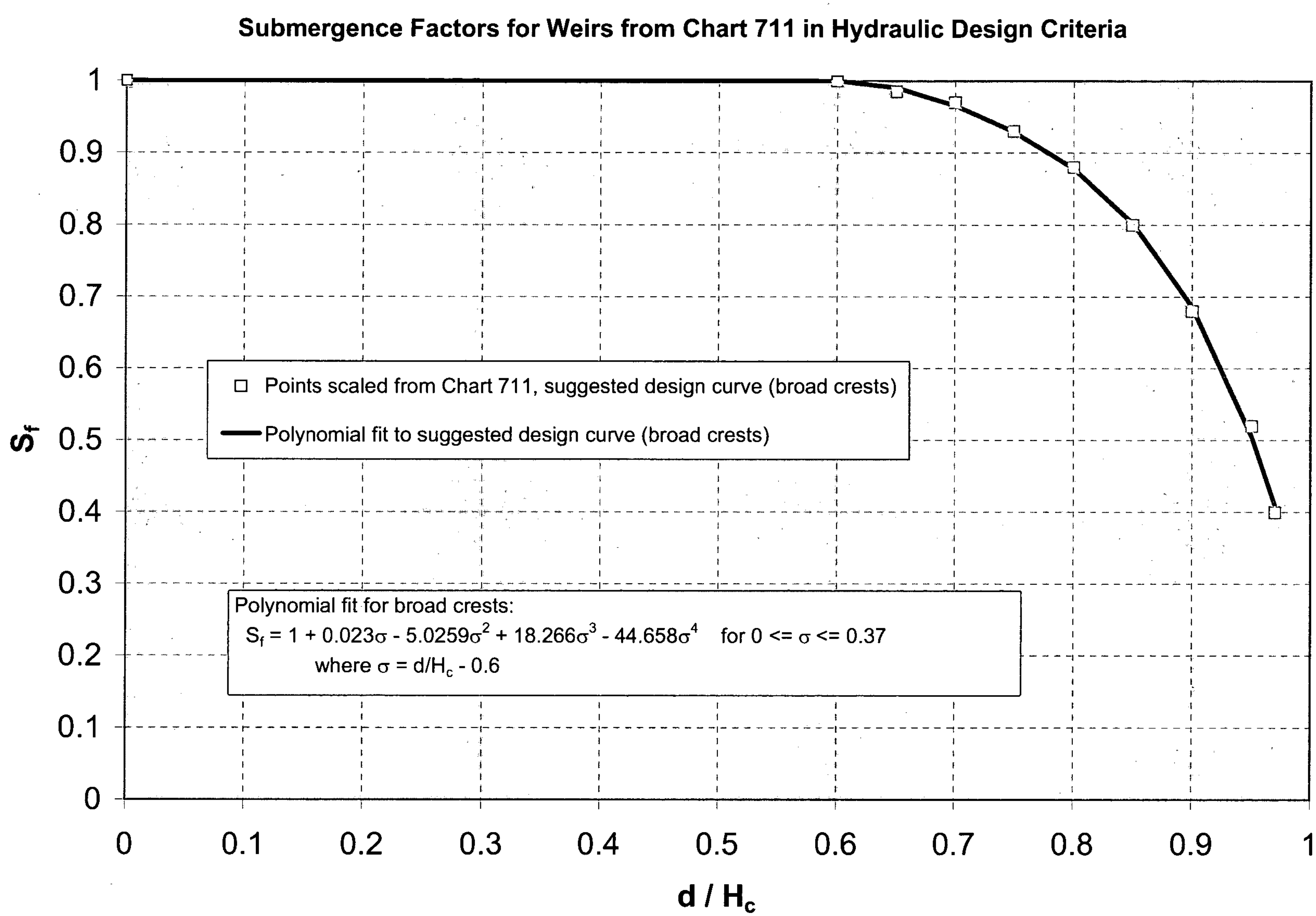
PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

WES 1-68

Attachment 5

Source: Reference 6

Calculation No: CDQ000020080020



Watts Bar Dam - Trashway

COMPUTED CAS DATE 9/8/2008

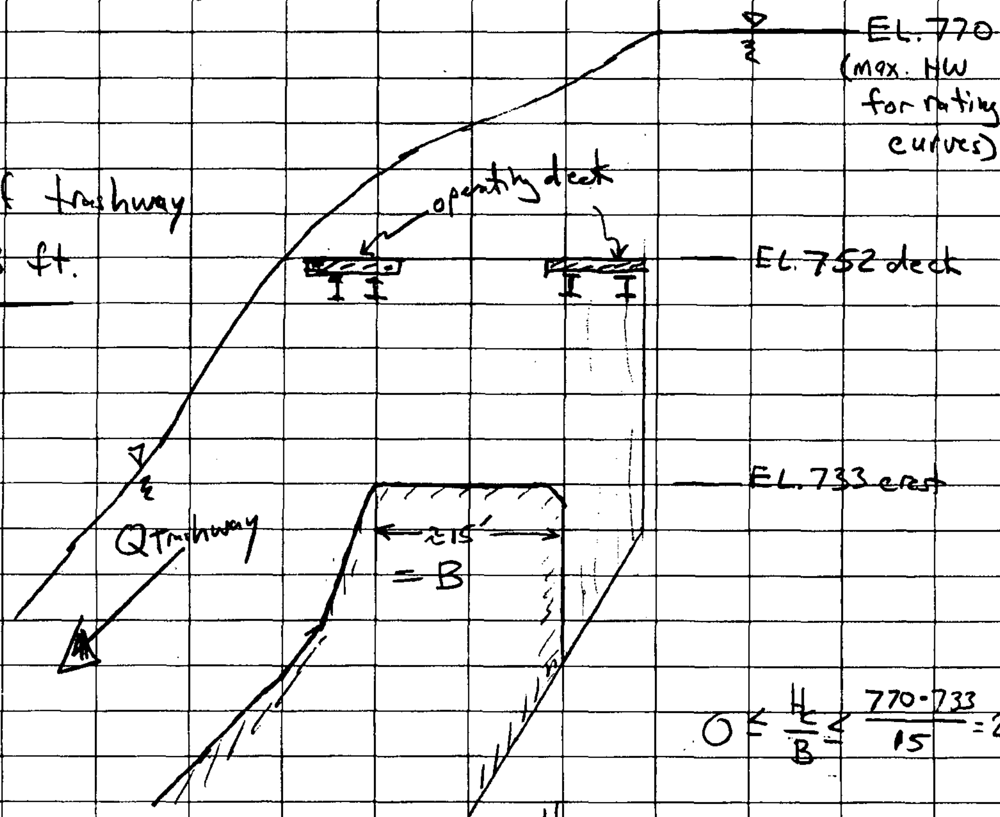
CHECKED ___ DATE ___

Sketch based on drawing no. 5 N200 R4 (Attachment 7, Ref. 7)

C_f & S_f from Hydraulic Design Chart 711 (Attachment 4, Ref. 6)

Clear width of trashway

$L_0 = 16.33$ ft.



$0 \le \frac{H_c}{B} \le \frac{770-733}{15} = 2.47$

$\frac{H_c}{B} = 1.2$ when $H_c = 1.2(15) = 18'$
$\Rightarrow HW = 751$ feet

Comments

(1) Trashway discharge < 1% of total dam discharge for rating curves
(2) Crest is broad for $H_c/B \le 1.2$ or $HW \le 751$
(3) Operating deck will interfere with flow for HW > a few feet above 752 feet - quantitative effect is unknown.

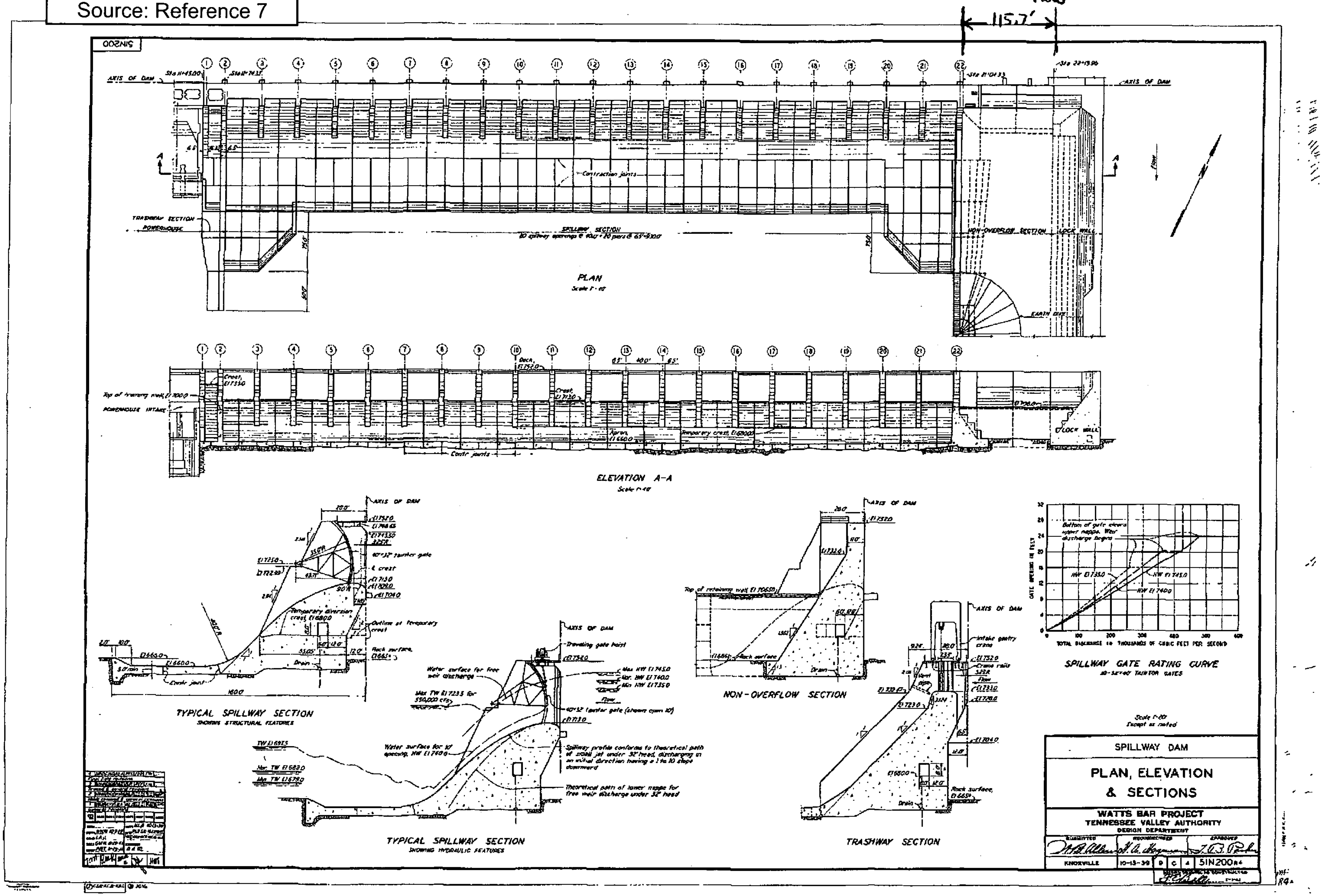
A simplistic approach is appropriate for this insignificant discharge. Use

- $C_f = 3.0$ (about midway in the overall range) for all HW's
- treat as broad-crested weir for submergence calculations

Attachment 7

Source: Reference 7

Calculation No: CDQ000020080020



Watts Bar - Flow over Tops of Wide-Open Tainter Gates

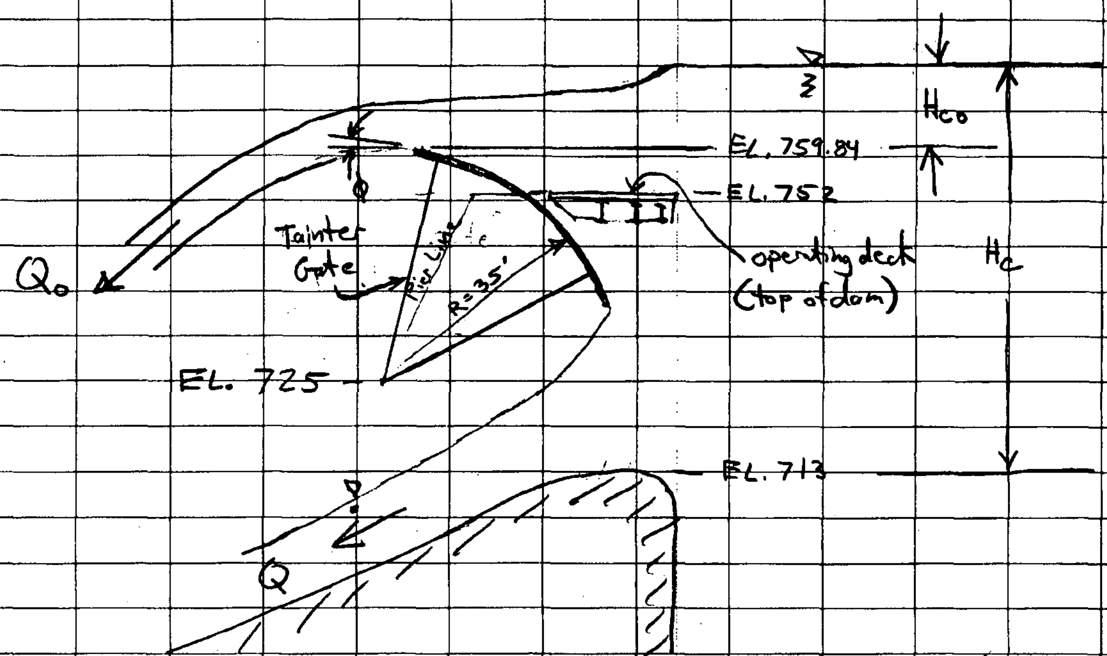
COMPUTED GAS DATE 9/5/2008

CHECKED DATE

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



Sketch based on drawing no. 54W200, R6 [Ref. A8, Attachment A9]

A reasonable 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 gate are available in Ref. 8, Fig. 6 as

$$C_q = C_q\left(\theta, \frac{H}{r}\right) \quad \sim \text{Attachment 8-3}$$

where
- C_q = same as C_o above
- θ = same as ϕ above
- H = same as H_{co} above
- r = gate radius = 35' (R above)

Angle Φ is computed as described in Attachment A8-3:

$$\Phi = \tan^{-1}\left(\frac{X_0}{Y_0}\right) \quad \text{with} \quad \begin{cases} X_0 = R\cos(\theta - \alpha) \\ Y_0 = 759.84' - 725' = 34.84' \end{cases}$$

From Appendix A:

$$R = 35', \quad \theta = 55.537^{\circ}, \quad \alpha = -28.910^{\circ}$$

$$\Rightarrow X_0 = 35\cos[55.537 - (-28.910)] = 3.387'$$

$$\Rightarrow \Phi = \tan^{-1}\left(\frac{3.387'}{34.84'}\right) = 5.55^{\circ}$$

Headwater rating curve computed to headwater elevation 770 ft

$$\Rightarrow \quad 0 \le H_{c0} \le 770 - 759.84 = 10.16 \text{ ft}$$

and

$$0 \le \frac{H}{r} \le \frac{10.16}{35} = 0.29$$

From Ref 8, $\Rightarrow$ $3.37 \lesssim C_q \lesssim 3.66$

For headwater rating use constant value near low end for all heads

* $C_0 = 3.4$ because uncertainties and the magnitude of the overflow discharge do not justify further refinement. Low end because overflow Q is probably less than drum gate Q. Reasoning:

- ~~total overflow discharge < 7% of total dam discharge (see results) so small variations in C_0 have negligible effect on total dam discharge (0.1 change in $C_0 \Rightarrow \frac{0.1}{3.4} \cdot 7\% = 0.2\%$)~~
- flow under gate causes significant drawdown in water level upstream from gate which should result is less overflow than predicted for an equivalent drumgate
- Operating deck may impede flow and reduce discharge

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

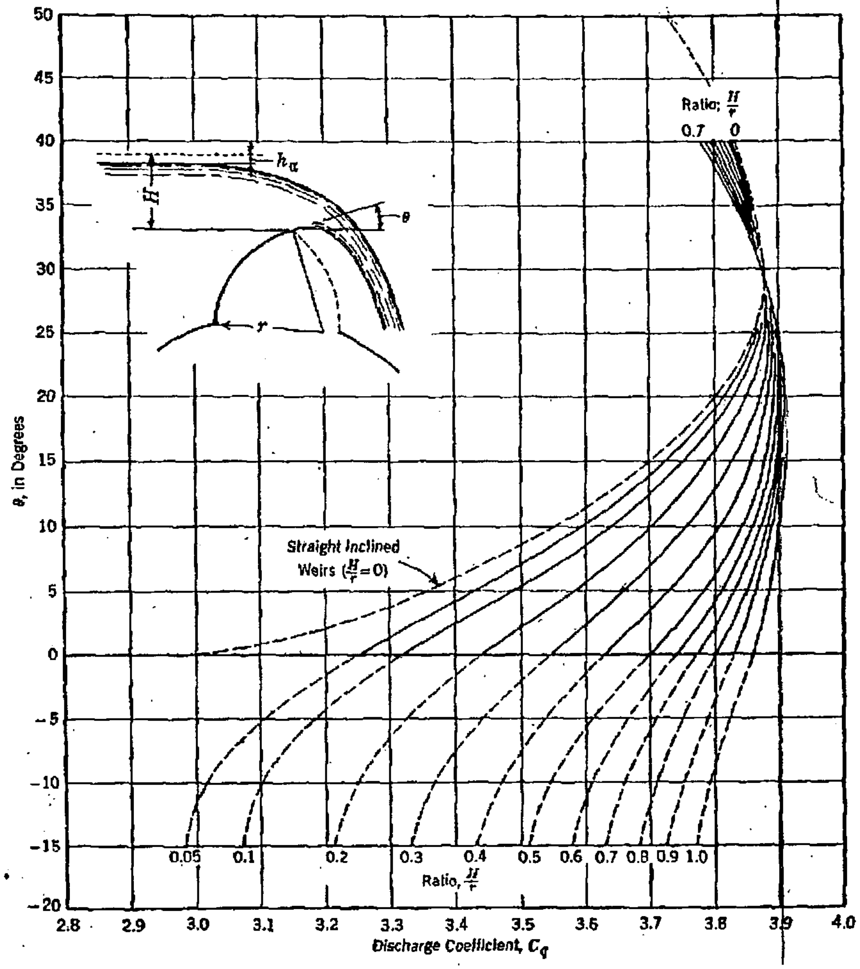


Fig. 6.—General Curves for the Determination of Discharge Coefficients

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 downstre 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, $Q = C_q L H^{\frac{3}{2}}$. 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_o and C_o are the designed head and the coefficient

Watts Bar — Dam Overflow

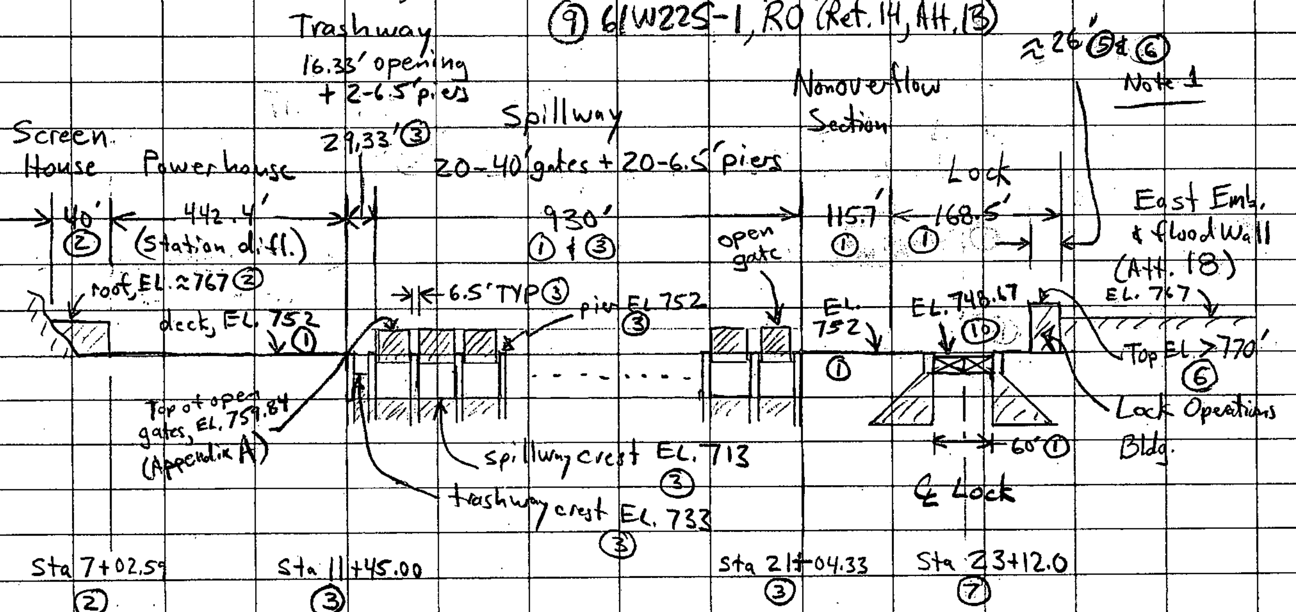
Powerhouse, spillway piers, nonoverflow section, lock

COMPUTED GAS DATE 9/9/2008

CHECKED DATE

Drawings

(10) 64W203-1, R0 (Ref. 29, Att. 9-5)
(1) 10W200, R1 (Ref. 1, Att. 1)
(2) 41K17s, R0 (Ref. 9, Att. 10)
(3) 51N200, R4 (Ref. 7, Att. 7)
(4) 66N200, R7 (Ref. 10, Att. 11-1)
(5) 66N201, R9 (Ref. 11, Att. 11-2)
(6) 66N202, R7 (Ref. 12, Att. 11-3)
(7) 23W300-1, R2 (Ref. 24, Att. 15-4)
(8) 31N200, R2 (Ref. 13, Att. 12)
(9) 61W225-1, R0 (Ref. 14, Att. 13)



Dam Profile Looking Upstream

Notes:

(1) Width of lock operations bldg. is 24.5' for elevations 752' → ≈761' (4) & (5) and 27.5' for elevations ≈761' → ≈772' (4) & (6). Use 26', which is the average, for all headwaters in rating curve.

(2) Highway bridge structural supports are not included in sketch above. The blockage length associated with these columns is identified in Attachment 14-1.

Overflow Length L

(Powerhouse; spill and trash piers; nonoverflow section; Lock section; Lock Ops. Bldg.; Lock gate)

Overflow elevation 752': L = 442.4' + 22*6.5' + 115.7' + 168.5' − 26' − 60'
− (15' + 23.7' + 4.2' + 2.5') + 20' = 758.2'

(bridge columns) (West lock Wall (see Att. 9-3))

Overflow elevation 767': L = 40' — screen house

~~Overflow elevation 748.67: L = 60' - upper lock gate~~ (neglect angle)

Overflow elevation 713': L = 20x40' = 800' – spillway crest

Overflow elevation 759.84': L = 20x40' = 800' – tops of open gates

Overflow elevation 733': L = 16.33' – trashway crest

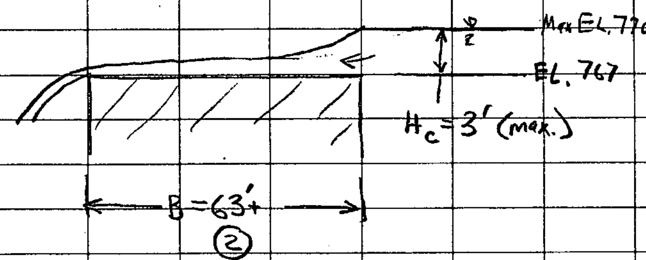
Discharge Coefficient, C_f

Refer to HDC 711 (Reference 6) for values of free discharge coefficient, C_f. Maximum headwater elevation used in this routing is 770'. See discussion in section 3.5.

Screen House Roof:

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{3'}{63'} = 0.05$

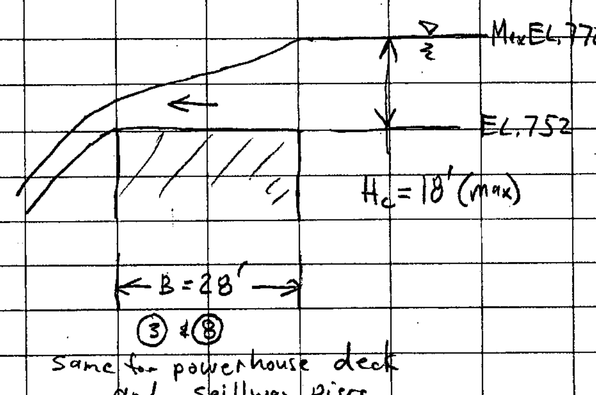
$\Rightarrow C_f = 2.65$ for all H_c



Powerhouse Section and Spillway Piers:

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{18}{28} = 0.64$

$\Rightarrow 2.65 \le C_f \le 2.72$



$C_f = 2.65$ for $0 \le \frac{H_1}{B} \le 0.4$

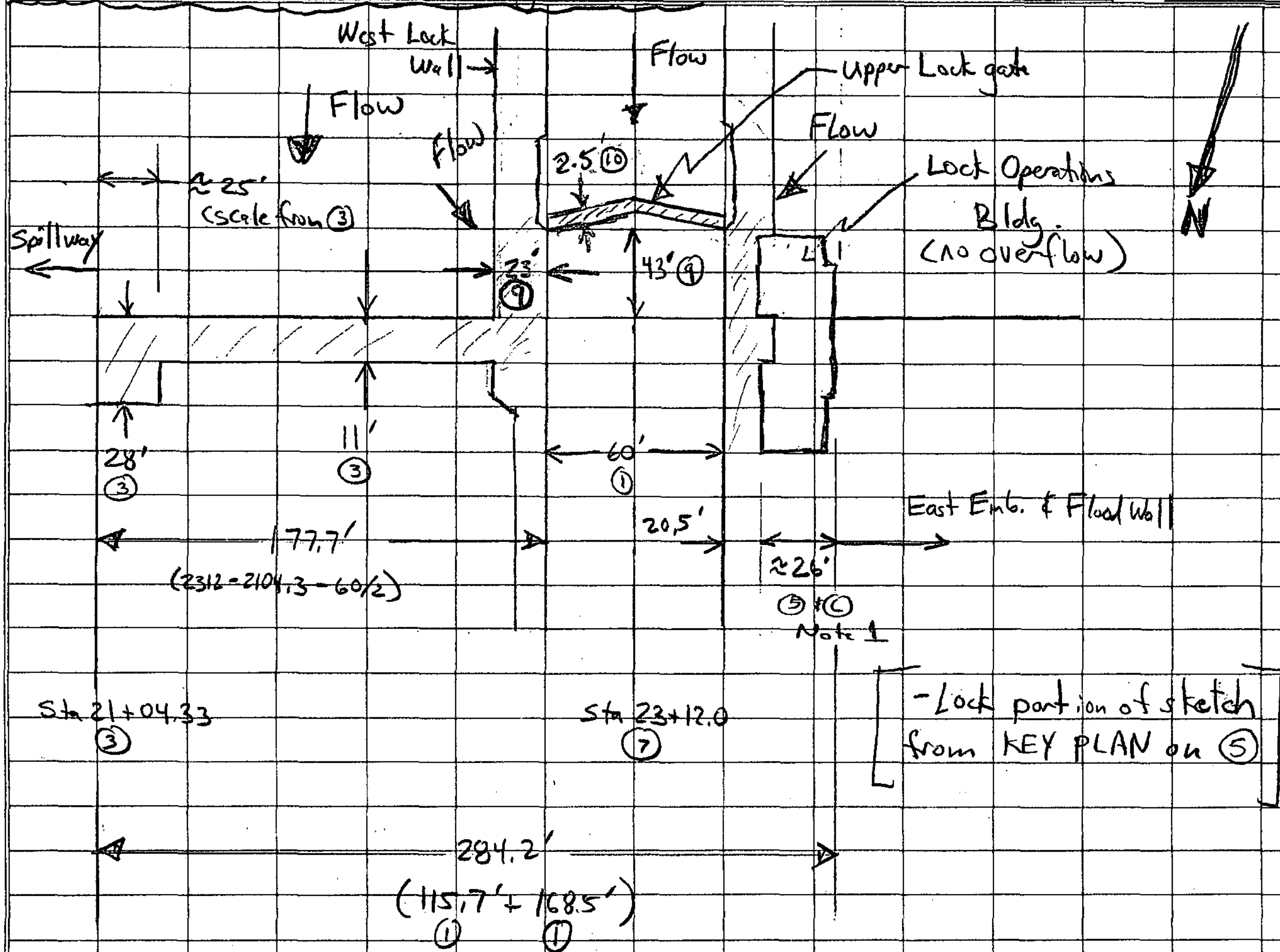
and we are neglecting the presence of handrails, equipment, etc. on top of the deck and spillway piers, which would reduce flow slightly. So, use value at low end of range

$C_f = 2.65$ for all H_c

Overflow length, $L = 442.4' + 22 * 6.5' - (15' + 23.7') = 546.7'$

(442.4' – Powerhouse; 22*6.5' – spillway and trashway piers; (15' + 23.7') – bridge columns)

Nonoverflow Section and Navigation Lock



The plan-view sketch above shows the overflow surfaces within the 284' length of the dam that includes the nonoverflow section and the navigation Lock. Sketch indicates that actual overflow length is

$$L = 284.2' - 26' - (4.2' + 2.5') - 23' + 43' - 60' = 211.5'$$

(26' = Lock Ops Bldg.; 4.2' + 2.5' = bridge columns; 23' = west lock wall width; 43' = west lock wall overflow length; 60' = upper lock gate)

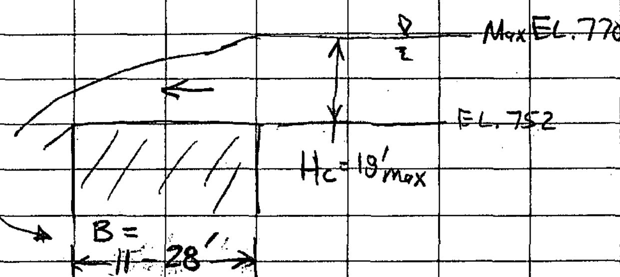
C_f Determination

$$0 < \frac{H_c}{B} = \frac{H_1}{B} < \frac{18}{11} \leftarrow \text{minimum}$$

$$\text{or } 0 \leq \frac{H_1}{B} \leq 1.64$$

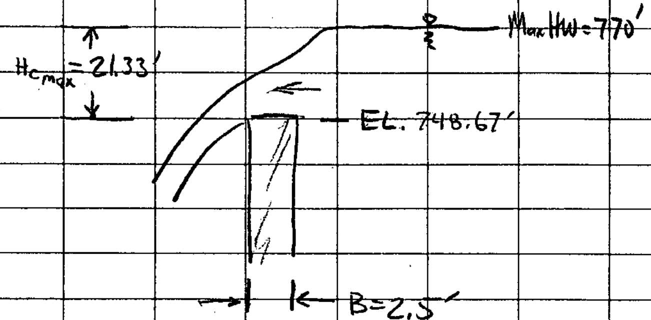
$$2.65 \leq C_f \leq \approx 3.3$$

Use $C_f = 3.0$ (approx. mid-point)



C_f Determination for Upper Lock Gate

$$0 \leq \frac{H_c}{B} = \frac{H_1}{B} \leq \frac{21.33}{2.5} = 8.5$$



$\Rightarrow C_f \approx 3.3$ (sharp-crested weir)

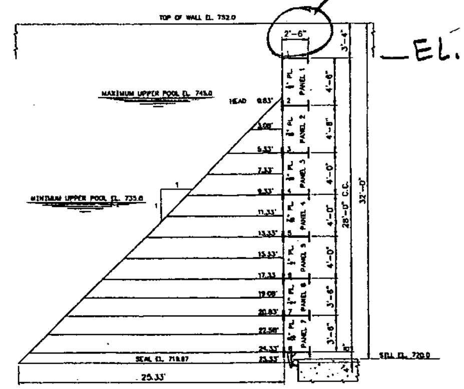
Summary

	Z_c (ft)	L (ft)	C_f
Screen House	767	40	2.65
Powerhouse & Spillway Piers	752	546.7	2.65
Nonoverflow and Lock Sections	752	211.5	3.0
Upper Lock Gate	748.67	60	3.3

Attachment 9-5

Source: Reference 29

Calculation No: CDQ000020080020



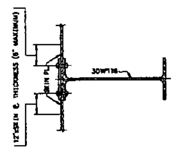
LOADING DIAGRAM

ALL GIRDERS 30WF116

HORIZONTAL GIRDER DESIGN

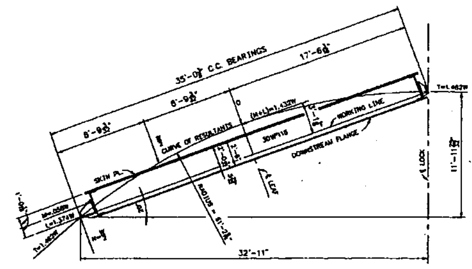
	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
GIRD NO.	CU. FT. WATER PER LIN. FT. OF GIRDER	W KIPS ①×35.03×62.5/1000	T KIPS ②×1.462	L KIPS ②×1.374	N KIPS ②×0.500	M KIPS ②×0.058	M+L KIPS ②×1.432	X ECCENT. INCHES	MOMENT (M+L)× IN.-KIPS	CROSS AREA SQ. IN.	CROSS I/IN	FIBER STRESS AT ℄ LEAF LBS/SQ IN + = TEN. − = COMP. UP-STREAM	DOWN-STREAM
1	0.02	0.044	0.064	0.06	0.02	0.00	0.06	USE 30WF 116 — SAME AS GIRDER 3					
2	4.71	10.31	15.07	14.17	5.16	0.60	14.77	"	"	"	"	"	"
3	22.10	48.38	70.73	66.47	24.19	2.81	69.28	25.92	1796	38.57	6002	−5730	+3359
4	37.33	81.89	119.43	112.24	40.85	4.74	116.98	25.65	3001	40.35	8133	−9301	+5589
5	53.32	116.72	170.64	160.37	58.36	6.77	167.14	24.04	4019	45.95	6986	−10482	+7248
6	64.50	141.19	206.42	194.00	70.60	8.19	202.18	23.82	4816	46.82	7109	−12244	+8575
7	72.90	159.58	233.31	219.26	79.79	9.26	228.52	23.71	5418	47.37	7184	−13610	+9724
8	65.87	144.19	210.81	198.12	72.19	8.36	208.48	24.02	4980	45.95	7912	−13771*	+8112*

* GIRDER NO.8 INCLUDES 619#/ft DUE TO DEAD LOAD MINUS BUOYANCY



SKIN PLATE ASSUMED AS GIRDER SECTION

SCALE: 1"=1'-0"

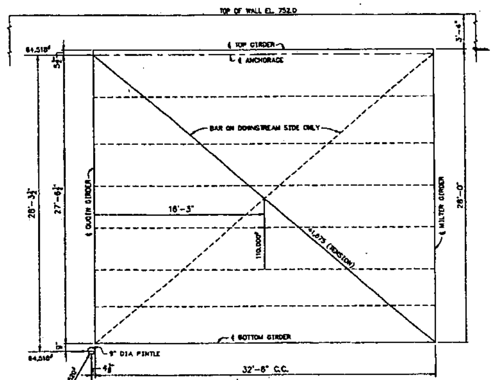


FORCES ACTING ON GIRDER

DESIGN DATA

ALLOWABLE STRESSES FOR EXTREME CONDITIONS

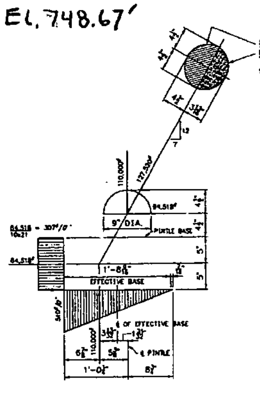
STRUCTURAL STEEL:	TENSION AND BENDING	18000 LBS./SQ. IN.
	COMPRESSION	18000−80 L/R (15000 MAX. −L/R 60)
	BEARING	24000 LBS./SQ. IN.
	SHEAR	10000 LBS./SQ. IN.
RIVETS:	SHEAR AND SINGLE BEARING	12000 LBS./SQ. IN.
	ENCLOSED BEARING	24000 LBS./SQ. IN.
PINTLE BUSHING:		3000 LBS./SQ. IN.
GUDGEON PIN BUSHING:		8000 LBS./SQ. IN.
PINS:	SHEAR	PER AISC LRFD 2nd EDITION
	BEARING	PER AISC LRFD 2nd EDITION
OTHER MATERIALS:		60% ELASTIC LIMIT
MINIMUM THICKNESS OF MAIN MEMBERS:	⅜"	
MAXIMUM BEARING ON CONCRETE:		800 LBS./SQ. IN.
RIVETS:	⅞"⌀	



DEAD LOAD STRESSES

1. LEAF SWINGING IN AIR.
2. SKIN PL. ON UPSTREAM FACE AND DIAGONAL ON DOWNSTREAM FACE EACH TAKE ½ STRESS.

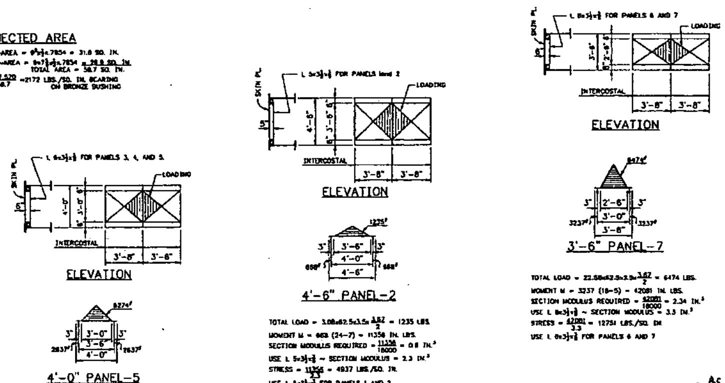
HORIZONTAL FORCE = 110,000 × 25.50/38.29 = 64,518 LBS.



PINTLE DESIGN

SCALE: 1½"=1'-0"

STRESS = 127,520/58.7 = 2172 LBS./SQ. IN. BEARING ON BRONZE BUSHING



4'-0" PANEL-5

TOTAL LOAD = 15.33×62.5×3.0×3.87/2 = 6274 LBS.

MOMENT M = 2637 (21-6) = 39,555 IN. LBS.

SECTION MODULUS REQUIRED = 39555/18000 = 2.19 IN.³

USE L 6×3½×⅜ ~ SECTION MODULUS = 3.30 IN.³

STRESS = 39555/3.3 = 11986 LBS./SQ. IN.

USE L 6×3½×⅜ FOR PANELS 3, 4, AND 5

4'-6" PANEL-2

TOTAL LOAD = 3.08×62.5×3.5×3.87/2 = 1235 LBS.

MOMENT M = 668 (24-7) = 11356 IN. LBS.

SECTION MODULUS REQUIRED = 11356/18000 = 0.6 IN.³

USE L 5×3½×⅜ ~ SECTION MODULUS = 2.3 IN.³

STRESS = 11356/2.3 = 4937 LBS./SO. IN.

USE L 5×3½×⅜ FOR PANELS 1 AND 2

3'-6" PANEL-7

TOTAL LOAD = 22.58×62.5×3.5×3.42/2 = 6474 LBS.

MOMENT M = 3237 (18-5) = 42081 IN. LBS.

SECTION MODULUS REQUIRED = 42081/18000 = 2.34 IN.³

USE L 6×3½×⅜ ~ SECTION MODULUS = 3.3 IN.³

STRESS = 42081/3.3 = 12751 LBS./SQ. IN.

USE L 6×3½×⅜ FOR PANELS 6 AND 7

*NOTE:
AS OF AUGUST 2000 THIS DRAWING HAS BEEN CONVERTED FROM CORPS OF ENGINEERING DRAWING TO TVA AUTOCAD FILE PER TVA/CORPS 1995 AGREEMENT.

0 | 3/11/04 | ELECTRONICALLY RESTORED DRAWING AS-BUILT

REV NO. | DATE | DSGN | DRWN | CHKD | SUPV | RVWD | APPD | LSSD | PROJECT ID | AS CONST

LOCK

UPPER LOCK GATE
DESIGN DATA

WATTS BAR HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
RIVER SYSTEMS OPERATIONS

DRAWN BY: A.L.R.
CHECKED BY: J.T.D. C.D.

US Army Corps of Engineers

THOMAS W. WATERS

21/1.3

SCALE: ½"=1'-0" | SHEET OF SHEETS

AUTOCAD R 00 | 9 | M | 64W203-1 | R 0

TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES 21/1.4

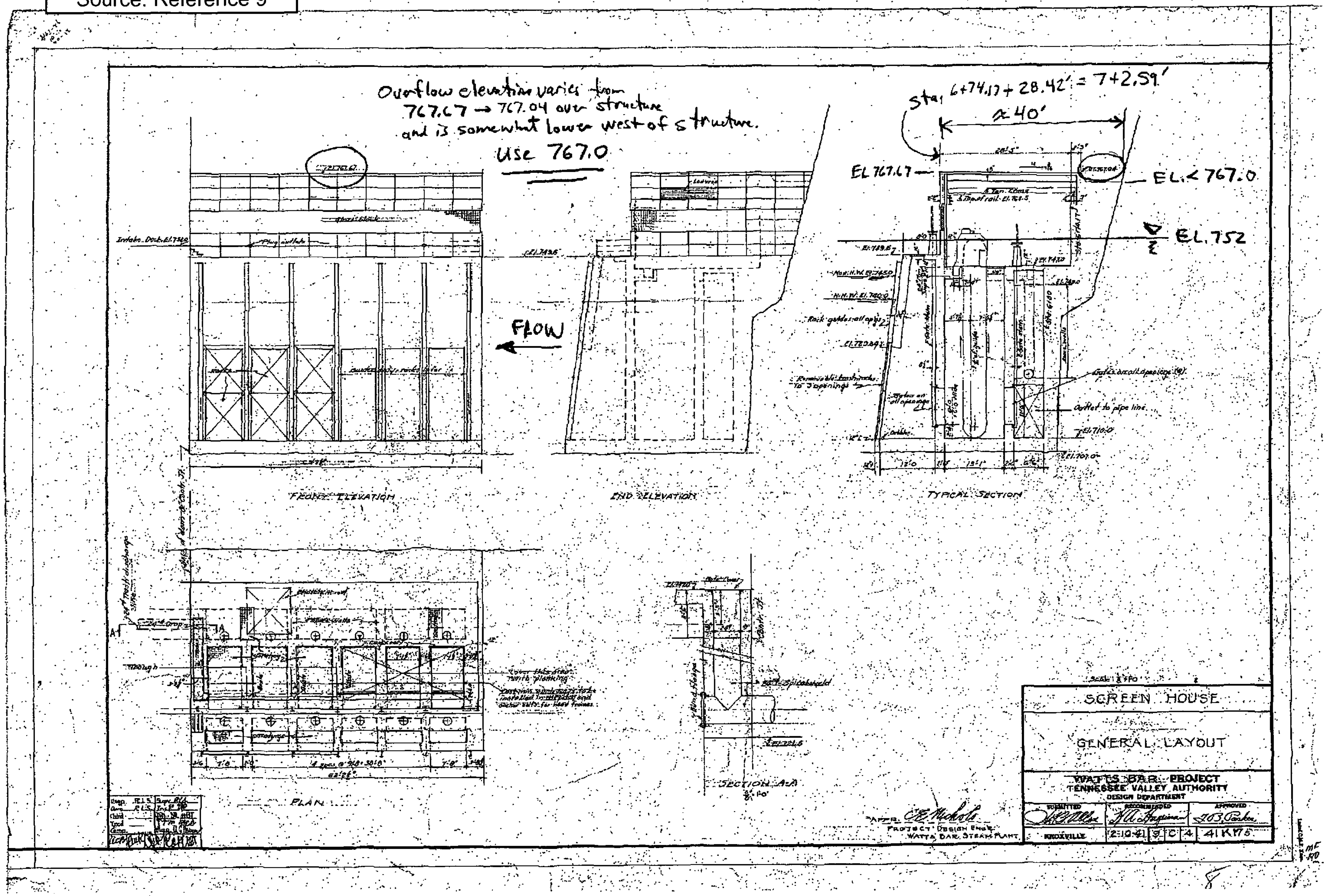
PLOT FACTOR: 48

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment 10

Source: Reference 9

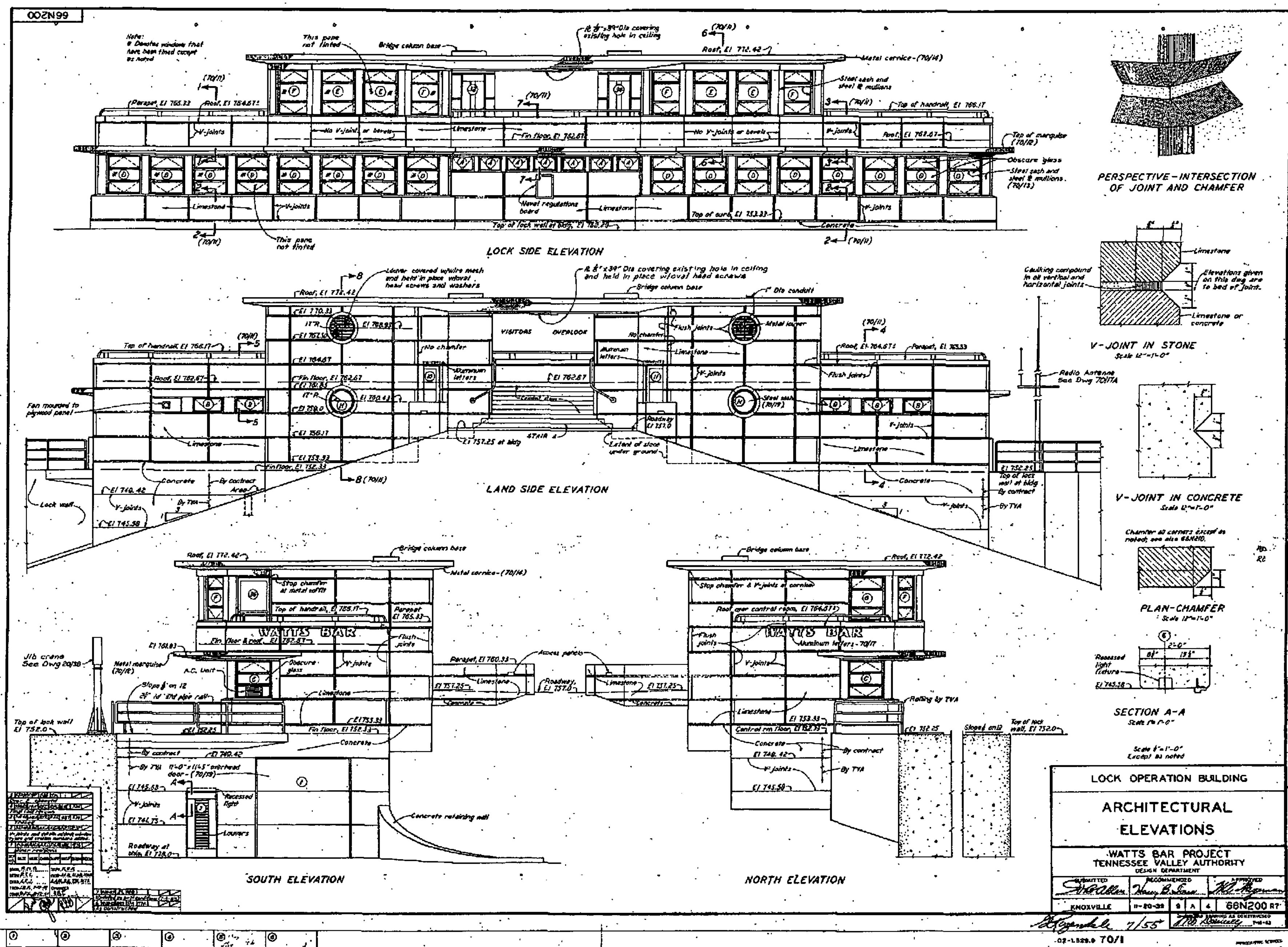
Calculation No: CDQ000020080020



Attachment 11-1

Source: Reference 10

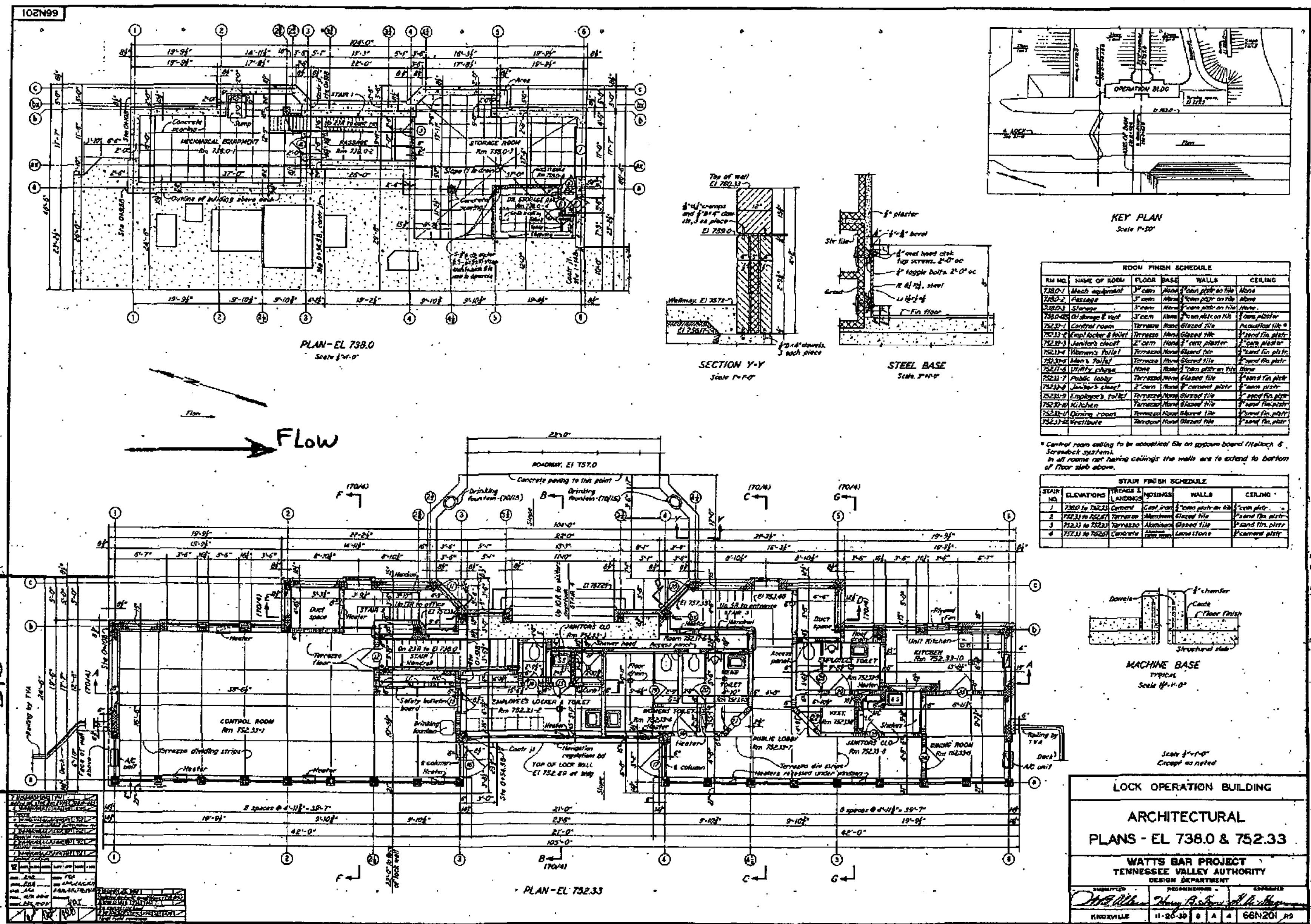
Calculation No: CDQ000020080020



Attachment 11-2

Source: Reference 11

Calculation No: CDQ000020080020



ROOM FINISH SCHEDULE

RM NO.	NAME OF ROOM	FLOOR	BASE	WALLS	CEILING
738.0-1	Mech equipment	3" cem	None	¾" cem plstr on tile	None
738.0-2	Passage	3" cem	None	¾" cem plstr on tile	None
738.0-3	Storage	3" cem	None	¾" cem plstr on tile	None
738.0-4&5	Oil storage & vest	3" cem	None	¾" cem plstr on tile	¾" cem plaster
752.33-1	Control room	Terrazzo	None	Glazed tile	Acoustical tile *
752.33-2	Empl locker & toilet	Terrazzo	None	Glazed tile	¾" sand fin. plstr
752.33-3	Janitor's closet	2" cem	None	¾" cem plaster	¾" cem plaster
752.33-4	Women's toilet	Terrazzo	None	Glazed tile	¾" sand fin plstr.
752.33-5	Men's Toilet	Terrazzo	None	Glazed tile	¾" sand fin plstr
752.17-6	Utility chase	None	None	¾" cem plstr on tile	None
752.33-7	Public lobby	Terrazzo	None	Glazed tile	¾" sand fin plstr
752.33-8	Janitor's closet	2" cem	None	¾" cement plstr	¾" cem plstr
752.33-9	Employee's toilet	Terrazzo	None	Glazed tile	¾" sand fin plstr
752.33-10	Kitchen	Terrazzo	None	Glazed tile	¾" sand fin plstr
752.33-11	Dining room	Terrazzo	None	Glazed tile	¾" sand fin. plstr
752.33-12	Vestibule	Terrazzo	None	Glazed tile	¾" sand fin. plstr

* Control room ceiling to be acoustical tile on gypsum board (Hollock & Screwlock systems).
In all rooms not having ceilings the walls are to extend to bottom of floor slab above.

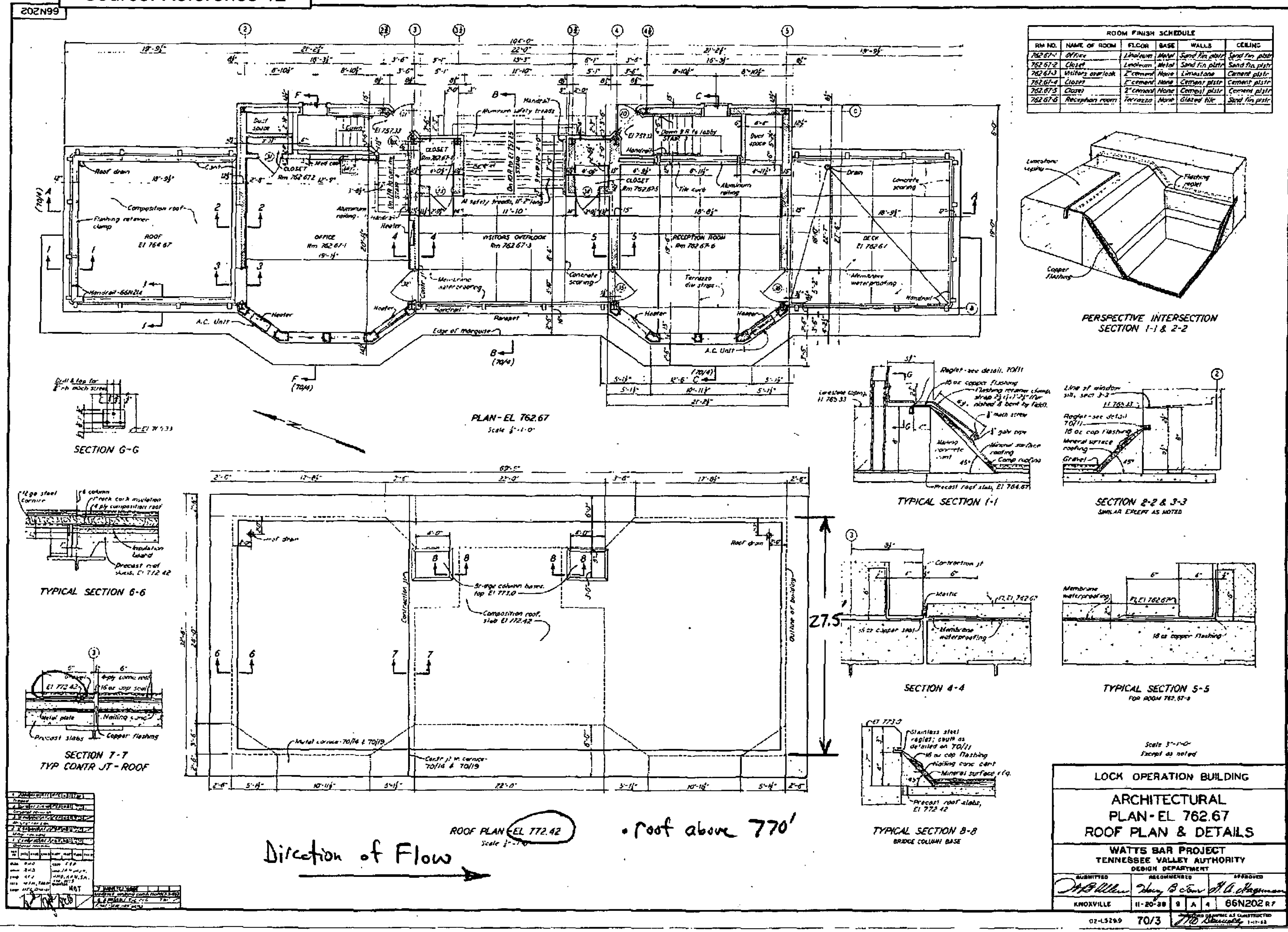
STAIR FINISH SCHEDULE

STAIR NO.	ELEVATIONS	TREADS & LANDINGS	NOSINGS	WALLS	CEILING
1	738.0 to 752.33	Cement	Cast iron	¾" cem plstr on tile	¾" cem plstr
2	752.33 to 762.67	Terrazzo	Aluminum	Glazed tile	¾" sand fin. plstr
3	752.33 to 757.33	Terrazzo	Aluminum	Glazed tile	¾" sand fin. plstr
4	757.33 to 762.67	Concrete	Aluminum	Limestone	¾" cement plstr

Attachment 11-3

Source: Reference 12

Calculation No: CDQ000020080020

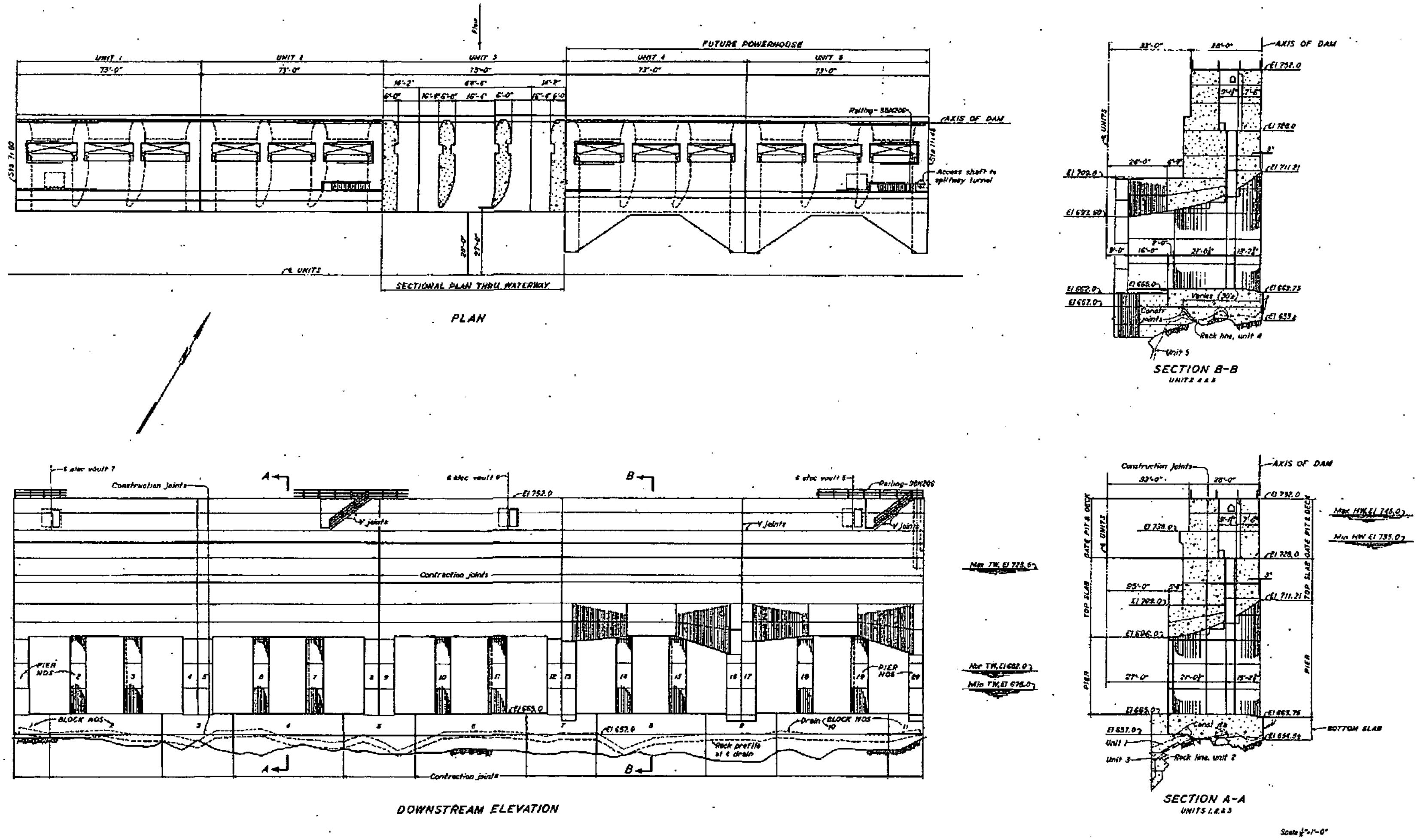


ROOM FINISH SCHEDULE					
RM NO.	NAME OF ROOM	FLOOR	BASE	WALLS	CEILING
762.67-1	Office	Linoleum	Metal	Sand fin plstr	Sand fin plstr
762.67-2	Closet	Linoleum	Metal	Sand fin plstr	Sand fin plstr
762.67-3	Visitors overlook	2" cement	None	Limestone	Cement plstr
762.67-4	Closet	2" cement	None	Cement plstr	Cement plstr
762.67-5	Closet	2" cement	None	Cement plstr	Cement plstr
762.67-6	Reception room	Terrazzo	None	Glazed tile	Sand fin plstr

Attachment 12

Source: Reference 13

Calculation No: CDQ000020080020



NOTES:

For class of concrete see construction specifications No. 62.
For treatment of contraction joints see construction specifications KC-571.
Chamfer all exposed corners ¾" unless otherwise noted.
For final rock lines see field office drawings 41K857.

POWERHOUSE INTAKE
CONCRETE GENERAL PLAN ELEVATION & SECTIONS
WATTS BAR PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE	8-13-40	9	C	4	31N200R2

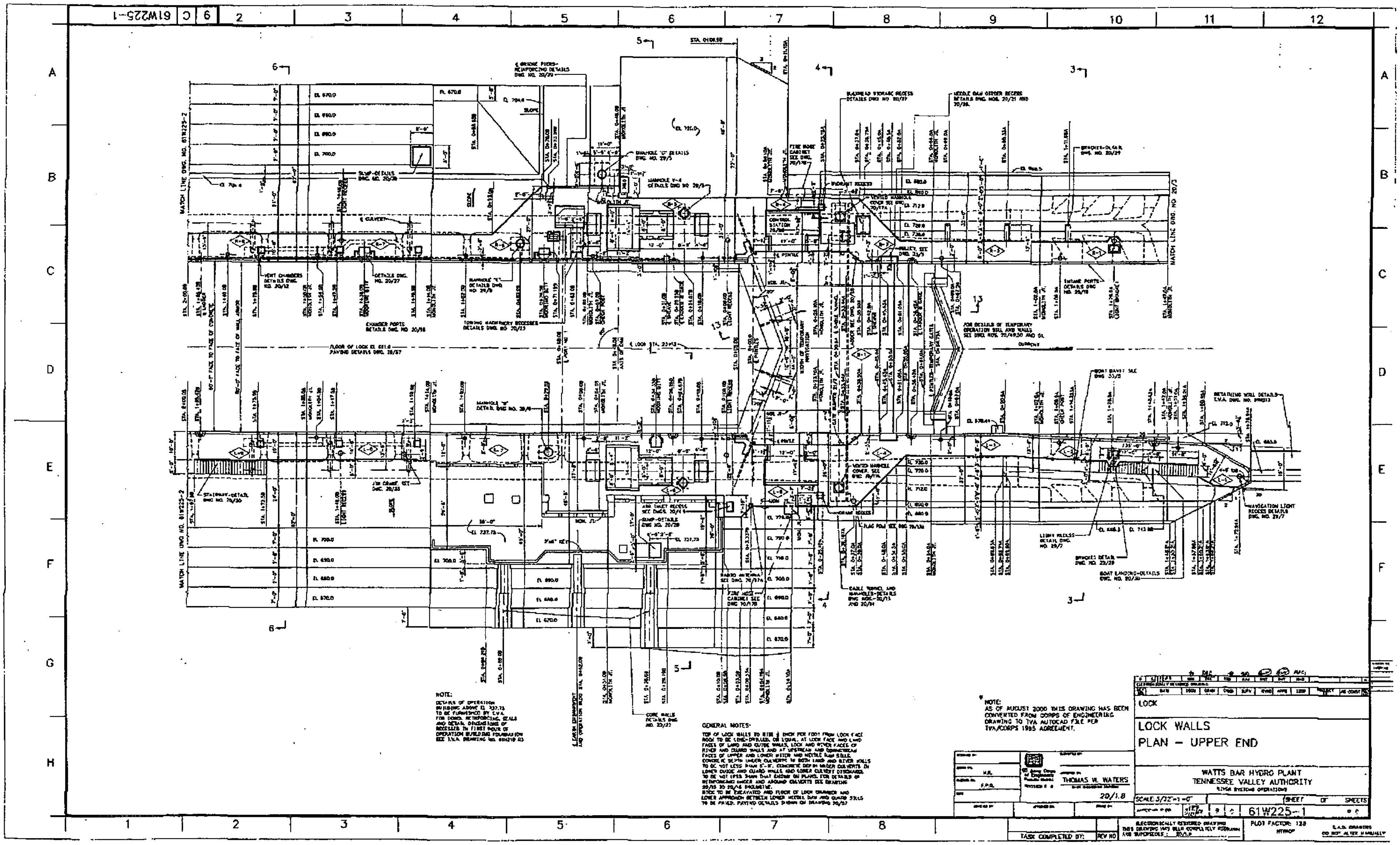
RECORD DRAWING AS CONSTRUCTED 12-2-42

31N500

Attachment 13

Source: Reference 14

Calculation No: CDQ000020080020



Watts Bar Dam Highway Bridge

COMPUTED GAS DATE 9/10/2008
CHECKED ___ DATE ___

Blockage associated with highway columns on dam

Drawings

1. 80H401, R2 (Ref. 15, Att. 14-2)
2. 80H415, R0 (Ref. 16, Att. 14-3)
3. 80H416, R0 (Ref. 17, Att. 14-4)
4. 80H418, R0 (Ref. 18, Att. 14-5)
5. 80H419, R0 (Ref. 19, Att. 14-6)
6. 80H420, R1 (Ref. 20, Att. 14-7)
7. 80H421, R0 (Ref. 21, Att. 14-8)
8. 80H422, R0 (Ref. 22, Att. 14-9)

Profile shown on (1). Structural columns are referred to as "bents" on drawings (2), (4), (7) and (8). Also have two structural "towers" with details on (3), (5) & (6).

- Bents D1 → D6 block flow over powerhouse deck. Columns are 2.5' wide in direction perpendicular to flow. (2)

  ⇒ blocked length = 6×2.5' = <u>15'</u>

- Tower DT1 and bents D7 → D15 are mounted on the spillway piers. DT1 includes two columns, each 2.5' wide (3). Bents D7 → D15 are 2.08' wide (4)

  ⇒ blocked length = 2*2.5' + 9*2.08' = <u>23.7'</u>

- Tower DT2 on nonoverflow section has two columns each 2.08' feet wide. (5) & (6)

  ⇒ blocked length = 2×2.08 ≃ <u>4.2'</u>

- Bent D16 on lock section is 2.5' wide (7)

  ⇒ blocked length <u>2.5'</u>

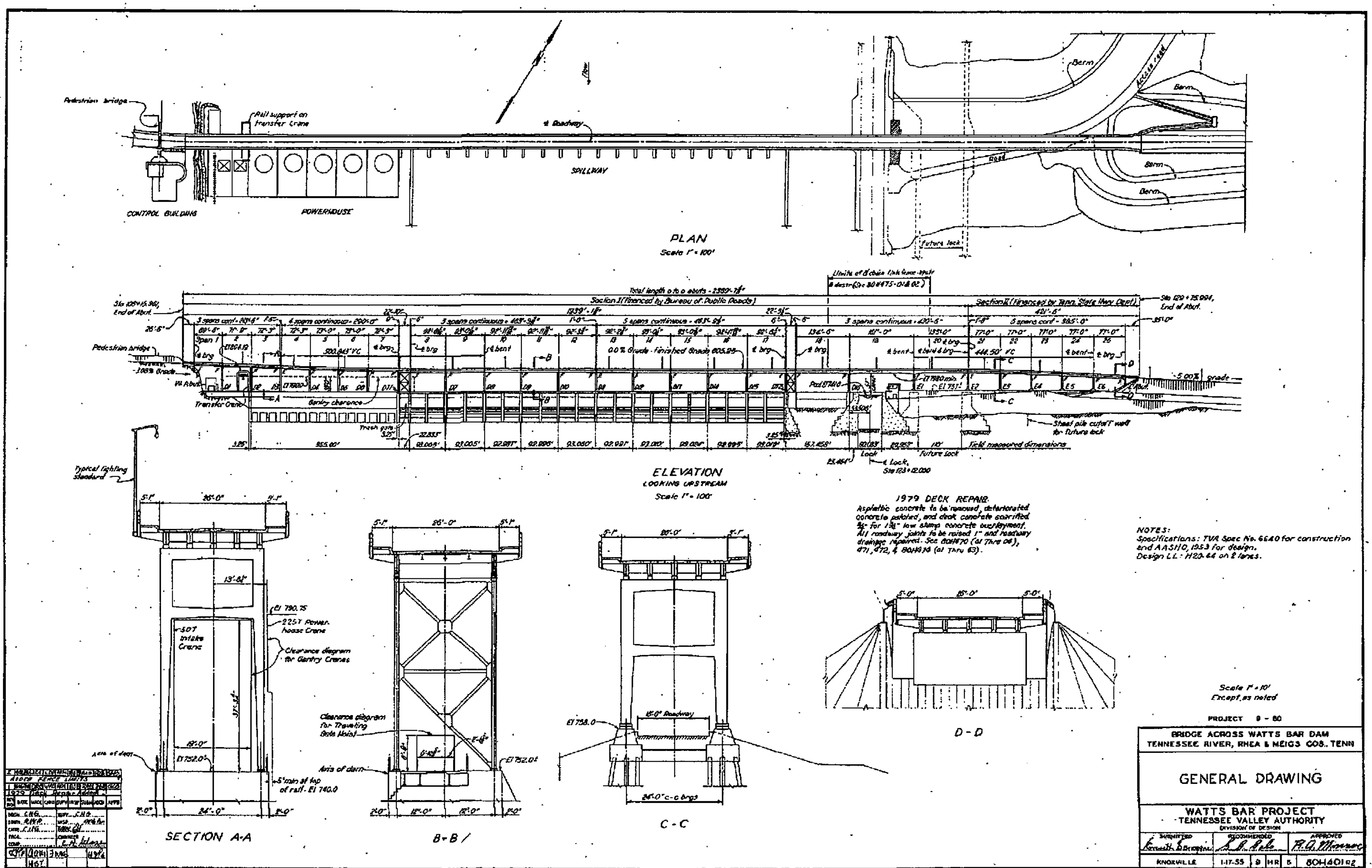
- Bents E1 → E6 are 2.5' wide (7) & (8) and block flow over the east embankment flood wall

  ⇒ blocked length = 6×2.5' = <u>15'</u>

Attachment 14-2

Source: Reference 15

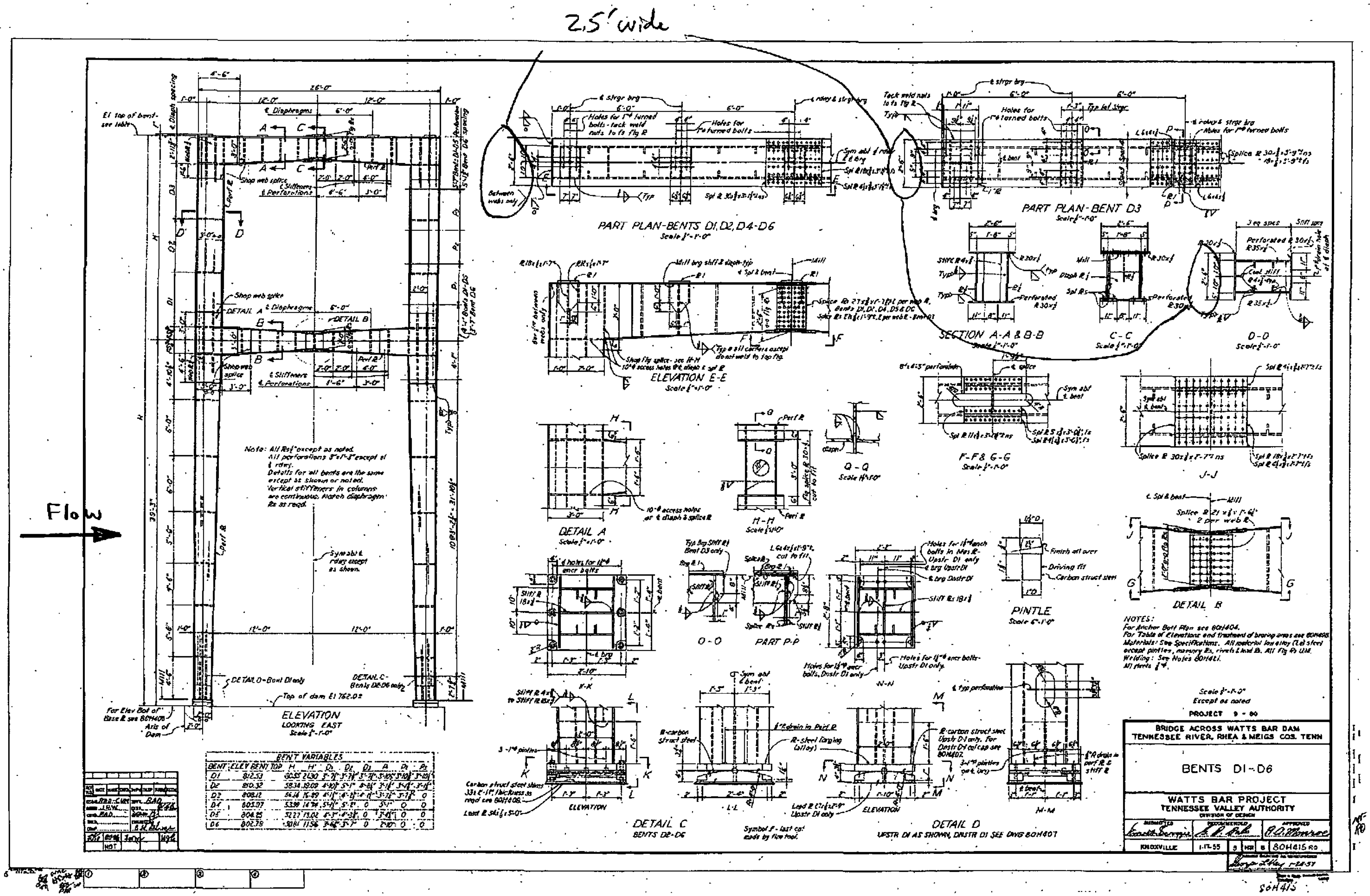
Calculation No: CDQ000020080020



Attachment 14-3

Source: Reference 16

Calculation No: CDQ000020080020



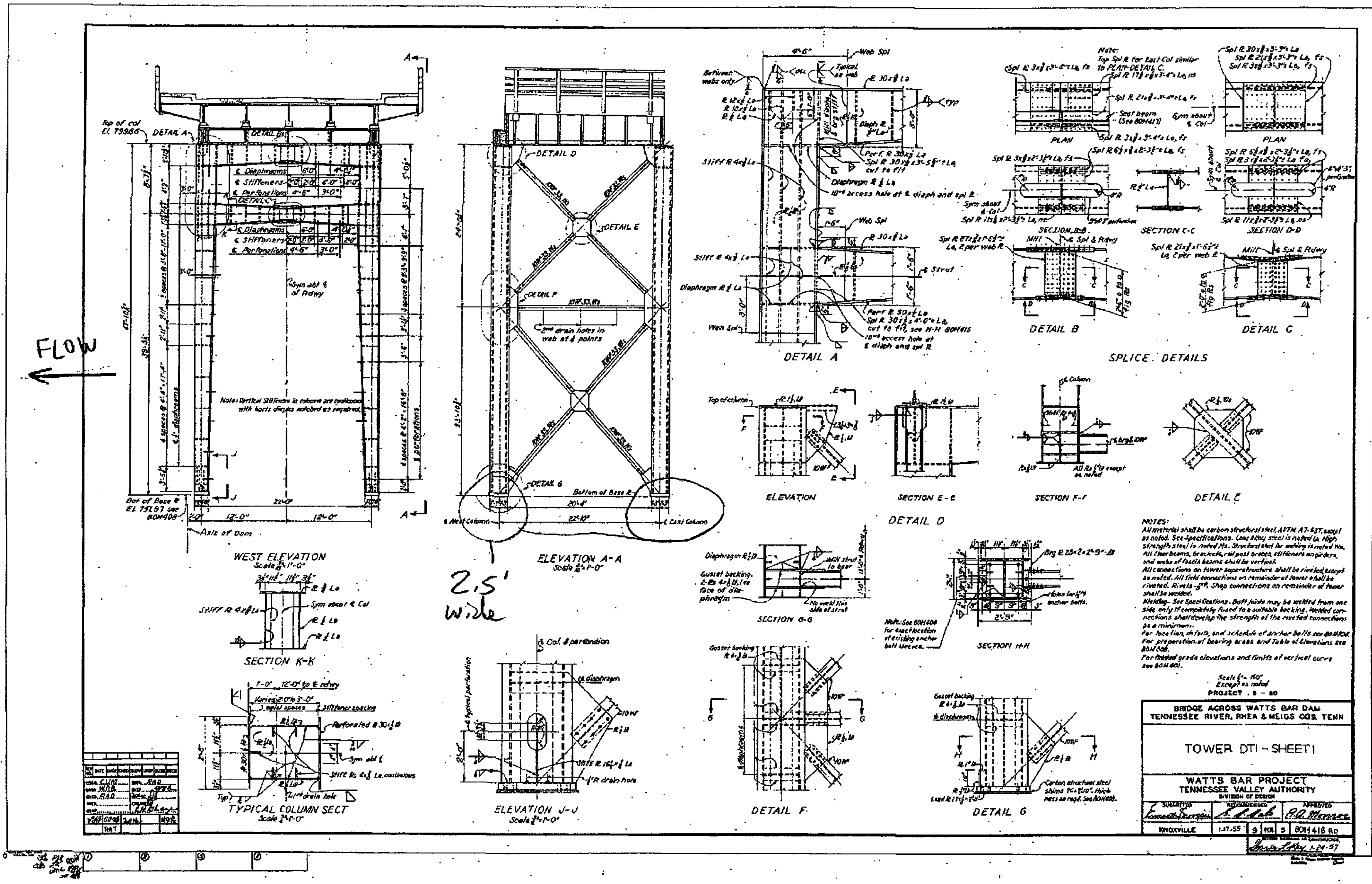
BENT VARIABLES

BENT	ELEV BENT TOP	H	H'	D1	D2	D3	A	P2	P3
D1	812.53	60.55	21.30	3'-7 1/2"	3'-7 1/2"	3'-7 1/2"	3'-10 1/2"	3'-10 1/2"	3'-10 1/2"
D2	810.32	58.34	19.09	4'-10 1/2"	5'-1"	4'-8 1/2"	3'-1 1/2"	3'-4 1/2"	3'-1 1/2"
D3	808.12	56.14	16.89	4'-1 1/2"	4'-2 1/2"	4'-11"	3'-7 1/2"	3'-7 1/2"	0
D4	805.97	53.98	14.74	5'-4 1/2"	5'-2"	0	5'-1"	0	0
D5	804.25	52.27	13.02	4'-3"	4'-3 1/2"	0	3'-4 1/2"	0	0
D6	802.79	50.81	11.56	3'-6 1/2"	3'-7"	0	2'-10"	0	0

Attachment 14-4

Source: Reference 17

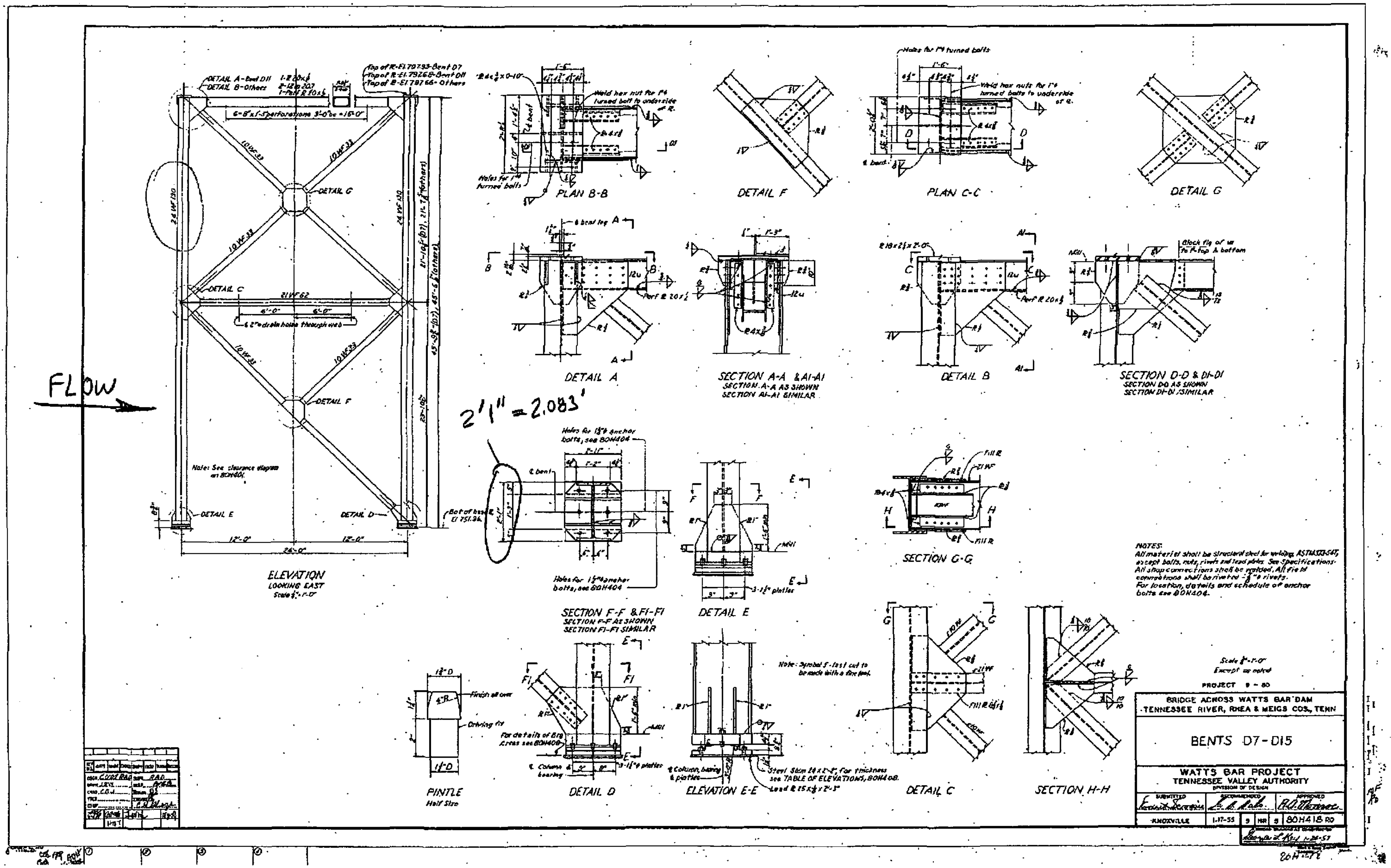
Calculation No: CDQ000020080020



Attachment 14-5

Source: Reference 18

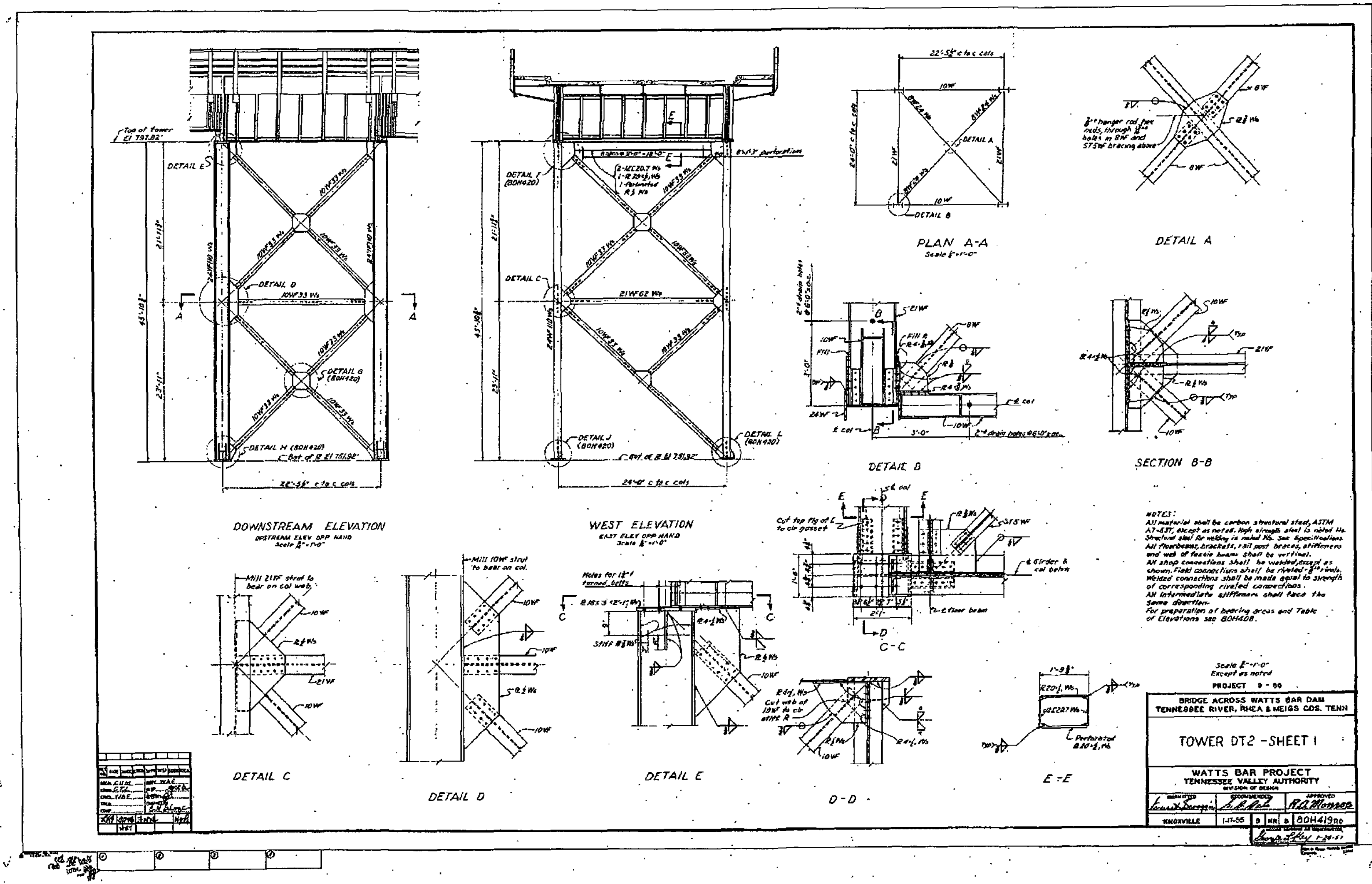
Calculation No: CDQ000020080020



Attachment 14-6

Source: Reference 19

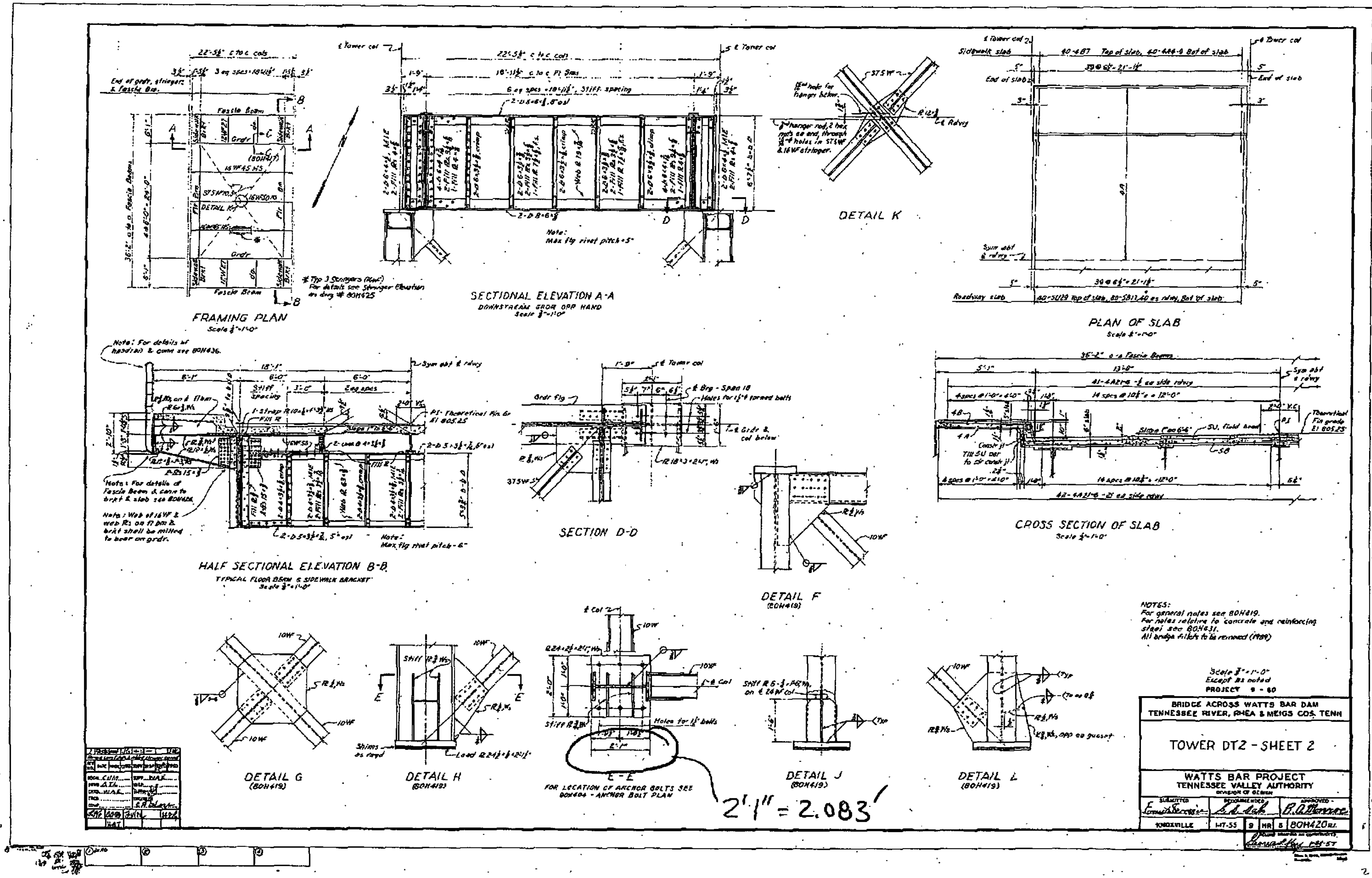
Calculation No: CDQ000020080020



Attachment 14-7

Source: Reference 20

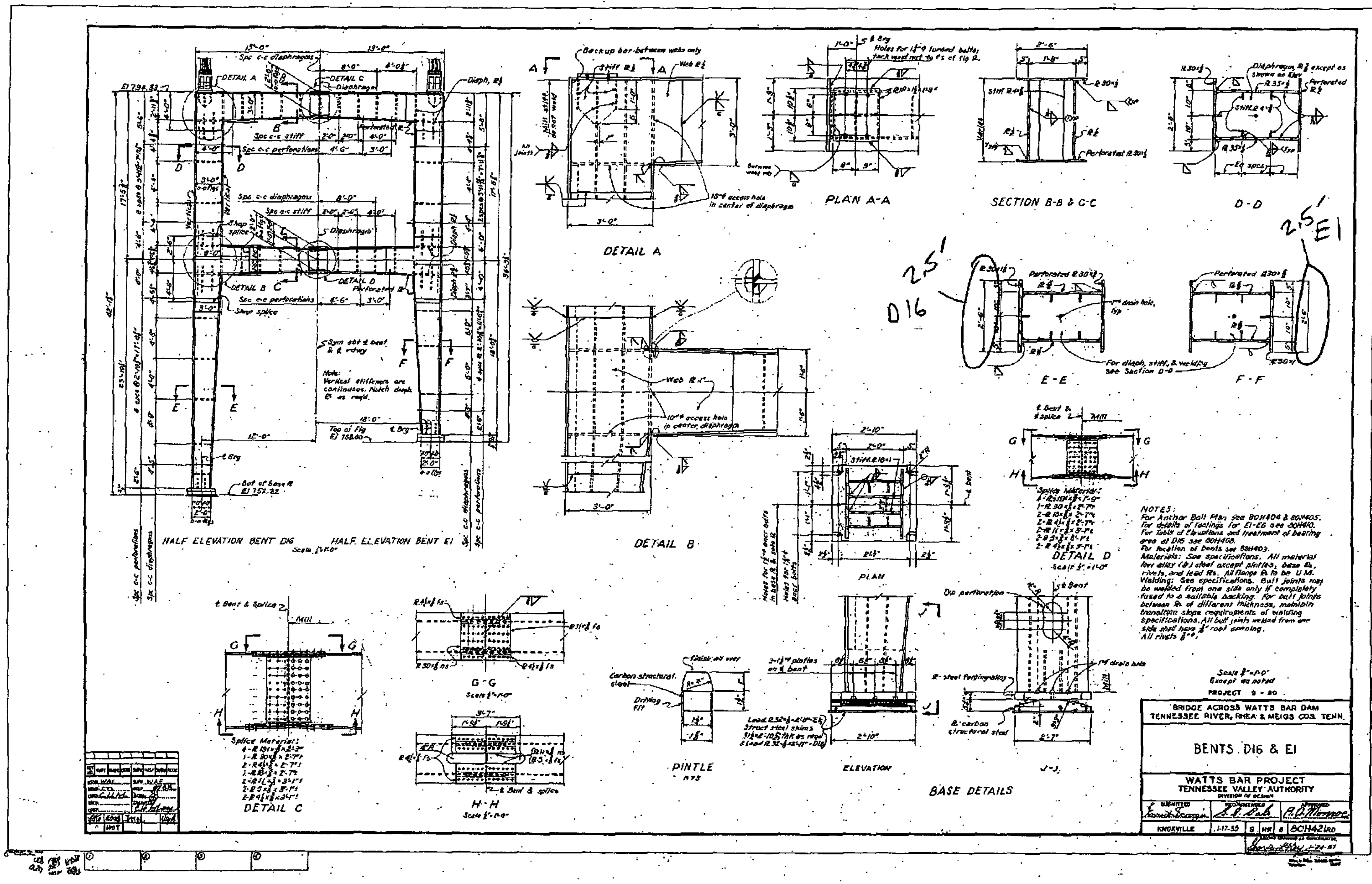
Calculation No: CDQ000020080020



Attachment 14-8

Source: Reference 21

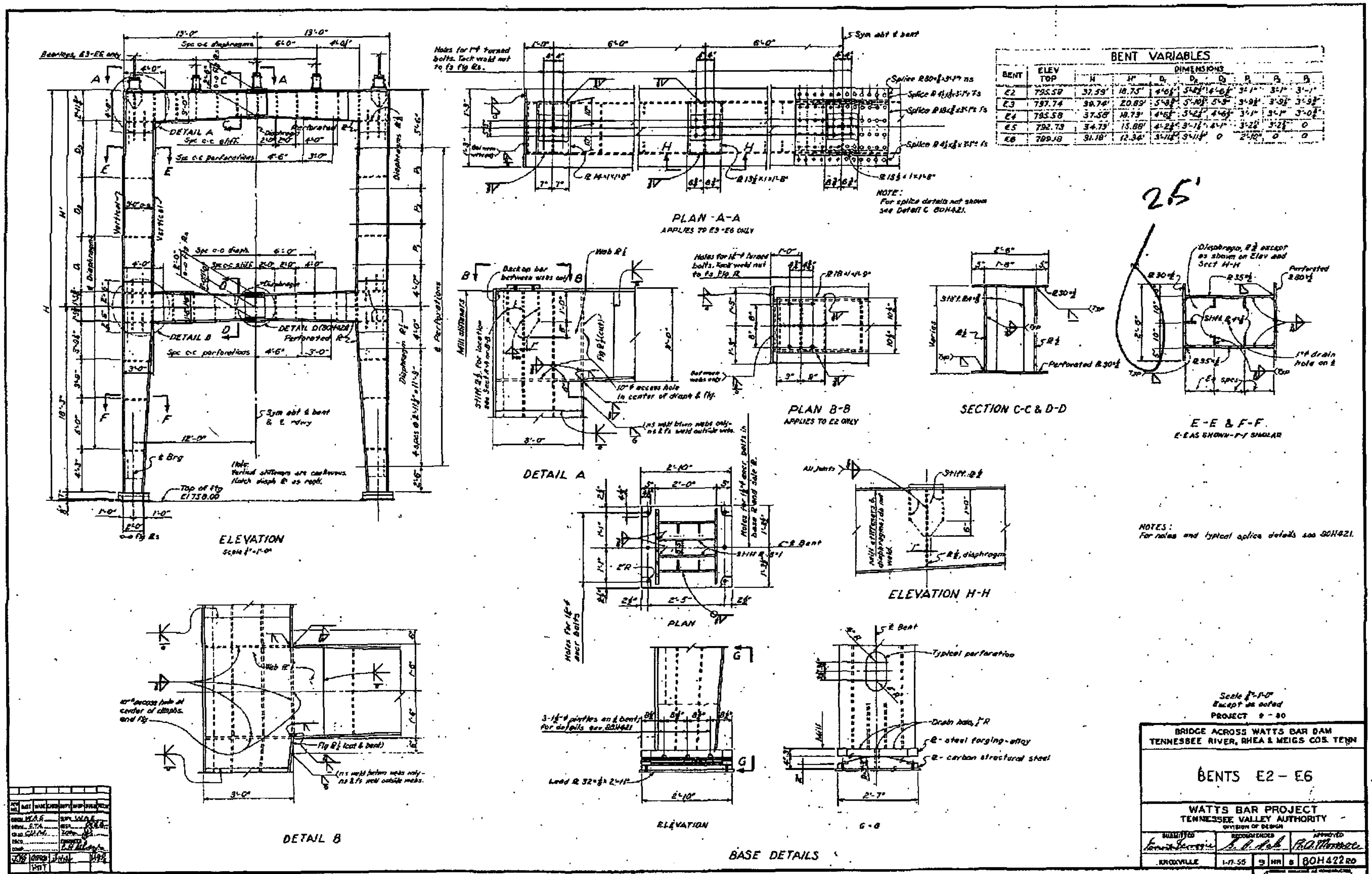
Calculation No: CDQ000020080020



Attachment 14-9

Source: Reference 22

Calculation No: CDQ000020080020



BENT VARIABLES

BENT	ELEV TOP	H	H'	D1	D2	D3	P1	P2	P3
E2	795.58	37.59'	18.75'	4'-6½"	5'-2½"	4'-6½"	3'-1"	3'-1"	3'-1"
E3	797.74	39.74'	20.89'	5'-8½"	5'-10½"	5'-5"	3'-9½"	3'-9½"	3'-9½"
E4	795.58	37.58'	18.73'	4'-6½"	5'-2½"	4'-6½"	3'-1"	3'-1"	3'-0½"
E5	792.73	34.73'	15.88'	4'-2¼"	3'-1½"	4'-1"	3'-2¼"	3'-2¼"	0
E6	789.18	31.18'	12.34'	3'-11½"	3'-11½"	0	2'-10"	0	0

BWSC Barge Waggoner Sumner & Cannon, Inc.

Attachment 15-1

Calculation No: CDQ000020080020

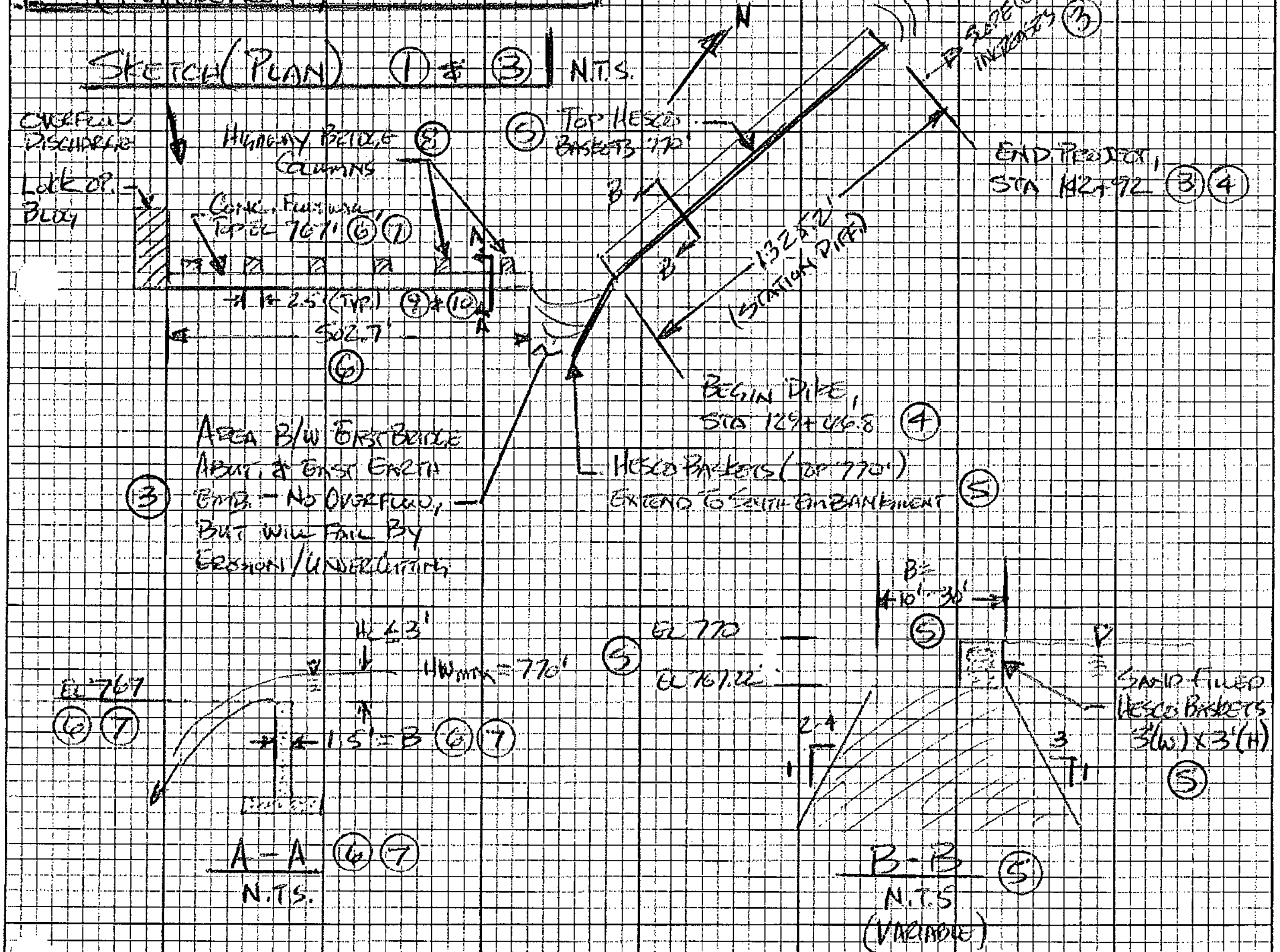
Project: Watts Bar DRC (Rev 1)
Description: East Embankment Overflow
Project No. ______ Sheet No. 1 of 2
Designer: CJG Date: 11/18/2009
Checker: ______ Date: ______

Drawings

① 10W200, R1 (Ref 1, Att 1)
② 23W201, R7 (Ref 23, Att 15-3)
③ 23W300-1, R2 (Ref 24, Att 15-4)
④ 23W301-1, R1 (Ref 25, Att 15-5)
⑤ 10W222-1, R0 (Ref 39, Att 52)
⑥ 23W305-1, R1 (Ref 27, Att 15-7)
⑦ 23W305-2, R1 (Ref 28, Att 15-8)
⑧ 80H401, R2 (Ref 15, Att 14-2)
⑨ 80H421, R0 (Ref 21, Att 14-8)
⑩ 80H422, R0 (Ref 22, Att 14-9)

Discharge Coefficients From HDC 711 (Reference 6)

Sketch (Plan) ① & ③ N.T.S.



Concrete Flood Wall

$0 \le \frac{H_c}{B} \le \frac{3}{1.5} = 2.0 \Rightarrow C_f$ varies from $\approx 2.65 \rightarrow 3.4$ (HDC 711)

The flood wall discharge will be less than 1% of the total discharge for the rating curve at HW = 770′ (see results). So simple approach is adequate.

Use: $C_f = 3.0$ ← mid-value
$Z_c = 767'$ for flood wall
$L = 502.7' - 6 * 2.5' = 487.7'$
(↑ Hwy Bridge Columns)

Earth Embankment

$0 \le \frac{H_c}{B} \le \frac{3}{10} = 0.3 \Rightarrow C_f \approx 2.65$ (HDC 711)

Drawing (5) shows highest elevation as 767.22′ at roadway crown but nominal elevation of 767′ is used for overflow calculations. This approximation has an insignificant impact on the calculations.

Use $C_f = 2.65$
$Z_c = 767'$ for earth embankment
$L = 1325.2'$ (before failure)

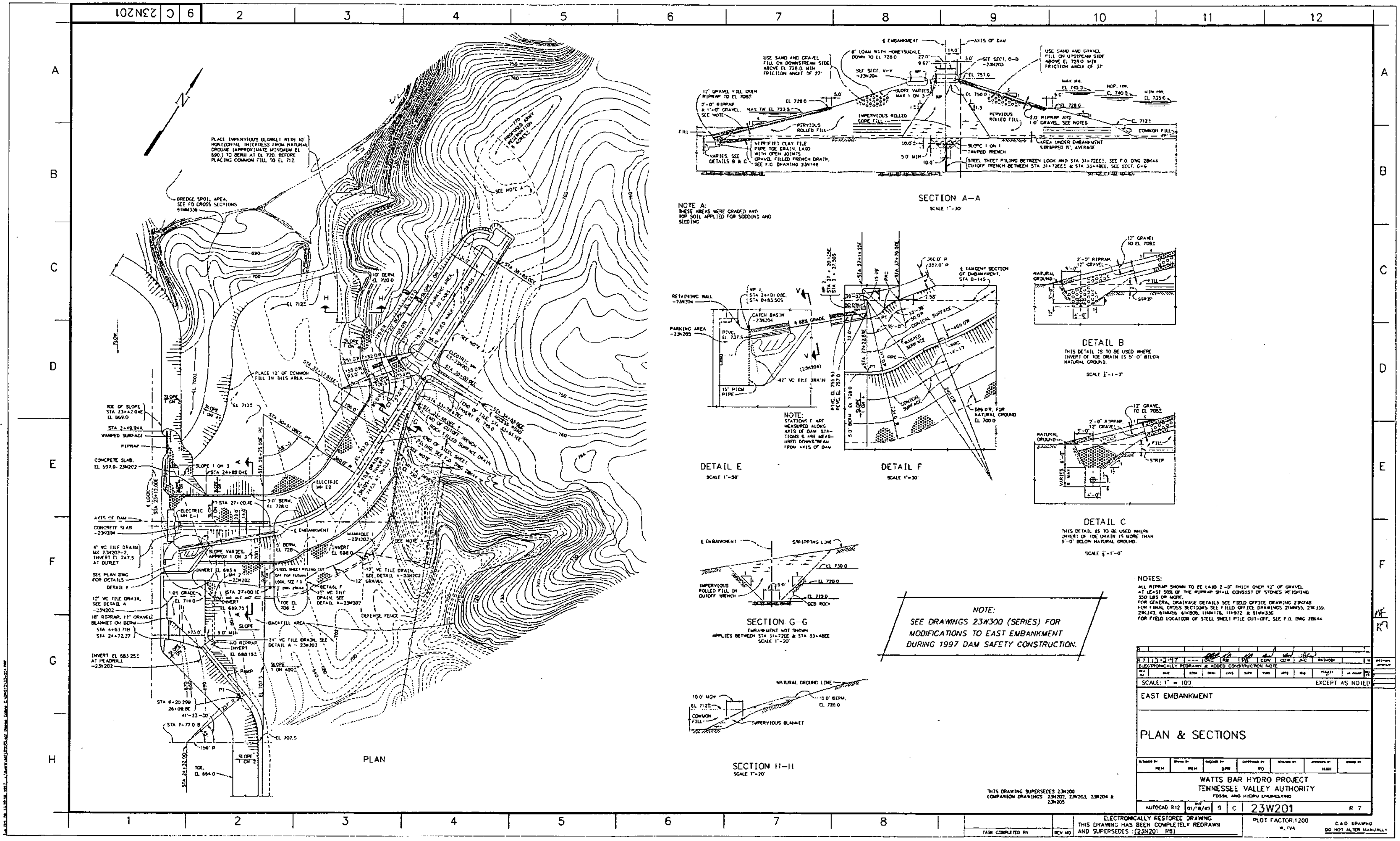
Submergence

The pre-failure east embankment overflow discharge is not affected by tailwater for the dam discharges determined in this calculation. See calculation results for verification.

Attachment 15-3

Source: Reference 23

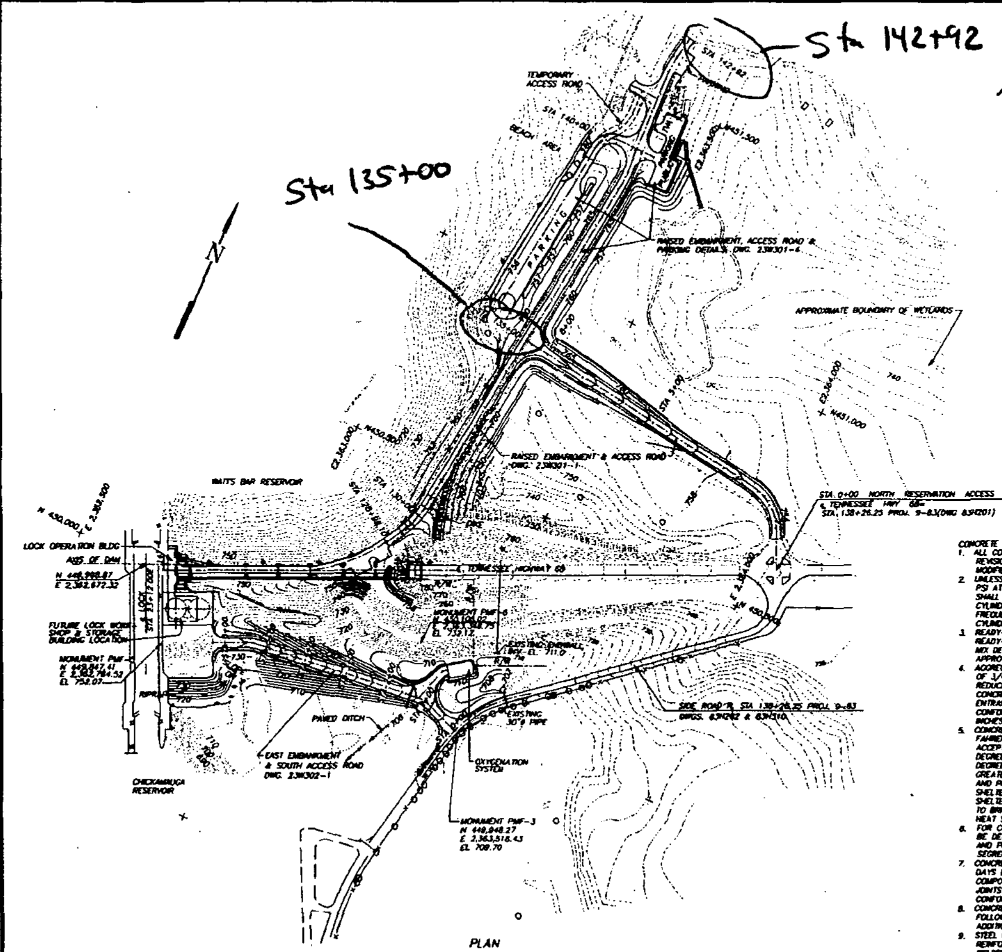
Calculation No: CDQ000020080020

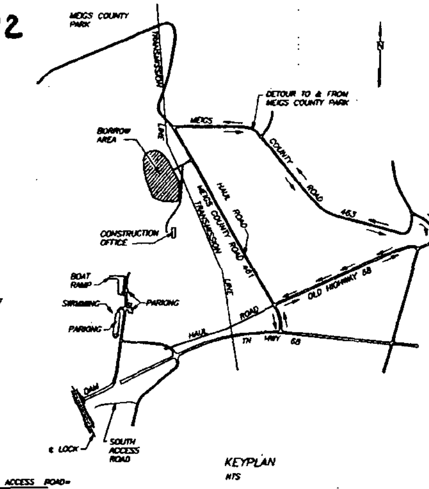


Attachment 15-4

Source: Reference 24

Calculation No: CDQ000020080020





CONCRETE NOTES:

1. ALL CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF ACI 301- (LATEST REVISION) SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS, EXCEPT AS MODIFIED BY THE SUPPLEMENTAL REQUIREMENTS THAT FOLLOW
2. UNLESS OTHERWISE NOTED, CONCRETE COMPRESSIVE STRENGTH SHALL BE 3000 PSI AT 28 DAYS. STRENGTH SHALL BE VERIFIED BY CYLINDER TESTS. CONCRETE SHALL BE SAMPLED FOR STRENGTH TESTING AT A MAXIMUM RATE OF ONE SET OF CYLINDERS FOR EVERY 50 CUBIC YARDS OR ON A DAILY BASIS, WHICHEVER IS MORE FREQUENT. 2 CYLINDERS SHALL BE BROKEN AT 3 DAYS, 2 CYLINDERS AT 7 DAYS, AND 2 CYLINDERS AT 28 DAYS.
3. READY-MIXED CONCRETE SHALL CONFORM TO DE-SPEC-96.08.10. READY-MIXED CONCRETE. THE READY-MIX SUPPLIER IS RESPONSIBLE FOR THE MIX DESIGN. THE MIX DESIGN SHALL BE SUBMITTED TO HYDRO ENGINEERING FOR APPROVAL PRIOR TO THE AWARDING OF THE CONTRACT.
4. AGGREGATE FOR CONCRETE SHALL CONFORM TO ASTM C-33 WITH A MAXIMUM SIZE OF 3/4". CEMENT SHALL CONFORM TO ASTM C-150, TYPE I OR TYPE II. A WATER REDUCING AGENT CONFORMING TO ASTM C-194 SHALL BE USED. AIR ENTRAINMENT OF CONCRETE SHALL BE BETWEEN 4% AND 7% BY VOLUME. ADMIXTURES USED FOR AIR ENTRAINMENT SHALL CONFORM TO ASTM C-260. THE MIX SHALL INCLUDE FLYASH CONFORMING TO ASTM C-618. SLUMP AT POINT OF DISCHARGE SHALL BE BETWEEN 2.0 INCHES AND 4.0 INCHES.
5. CONCRETE TEMPERATURE AT DISCHARGE SHALL BE BETWEEN 50 AND 85 DEGREES FAHRENHEIT. CONCRETE NOT MEETING THESE REQUIREMENTS WILL NOT BE ACCEPTABLE. CONCRETE PLACEMENT SHALL CEASE IF THE AIR TEMPERATURE IS 38 DEGREES AND FALLING. PLACEMENT MAY RESUME WHEN THE AIR TEMPERATURE IS 40 DEGREES AND RISING. CONCRETE SHALL BE MAINTAINED AT A TEMPERATURE GREATER THAN 50 DEGREES FOR THE FIRST THREE DAYS FOLLOWING PLACEMENT AND PROTECTED ABOVE FREEZING FOR AN ADDITIONAL 3 DAYS. HEATED PROTECTIVE SHELTERS MAY BE CONSTRUCTED TO ENCLOSE THE AREAS TO BE PLACED. THESE SHELTERS SHALL BE CONSTRUCTED IN ADVANCE OF PLACEMENT AND HEAT APPLIED TO BRING THE FORMWORK AND STEEL TO A MINIMUM OF 50 DEGREES. COMBUSTIVE HEAT SHALL NOT BE USED.
6. FOR CONTINUOUS VERTICAL PLACEMENT OF CONCRETE, THE RATE OF PLACEMENT WILL BE DETERMINED BY WEATHER CONDITIONS, CONCRETE TEMPERATURE PRIOR TO PLACING, AND PRESSURE CAPACITY OF FORMWORK. CARE SHALL BE TAKEN SO AS TO NOT SEGREGATE CONCRETE MIX DURING PLACEMENT.
7. CONCRETE SHALL BE PROTECTED FROM MOISTURE LOSS FOR A MINIMUM OF 14 DAYS BY EITHER KEEPING FORMWORK AND SURFACES WET OR APPLYING A CURING COMPOUND. CURING COMPOUNDS SHALL NOT BE APPLIED TO HORIZONTAL LIFT JOINTS WHICH ARE TO RECEIVE ADDITIONAL LIFTS. CURING COMPOUNDS SHALL CONFORM TO ASTM C-309.
8. CONCRETE FORMWORK SHALL REMAIN IN PLACE FOR A MINIMUM OF 24 HOURS FOLLOWING PLACEMENT. A MINIMUM OF 3 DAYS SHALL ELAPSE BEFORE PLACING ADDITIONAL LIFTS OR ADJACENT BLOCKS.
9. STEEL REINFORCEMENT SHALL MEET THE REQUIREMENTS OF ASTM A-615 REINFORCEMENT SHALL BE DEFORMED WITH A YIELD STRENGTH OF 60,000 PSI. WELDED WIRE FABRIC SHALL MEET THE REQUIREMENTS OF ASTM A-497 WITH A YIELD STRENGTH OF 60,000 PSI.
10. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4" UNLESS INDICATED OTHERWISE. ALL EXPOSED SURFACES SHALL HAVE A CLASS I RUBBED FINISH PER TVA-T1 SECTION 400.29.
11. CLEAR COVER FOR REINFORCEMENT SHALL BE 3 INCHES WHERE CONCRETE IS CAST AGAINST EARTH AND 2 INCHES AT ALL OTHER LOCATIONS UNLESS OTHERWISE INDICATED. ALL OTHER DIMENSIONS ARE TO THE CENTERLINE OR END OF BAR.
12. GROUT SHALL BE FIVE STAR MIXED AND APPLIED PER MANUFACTURER'S INSTRUCTIONS, OR AN APPROVED EQUAL.

NOTES:

1. ALL EARTHWORK SHALL BE DONE IN ACCORDANCE WITH TVA GENERAL CONSTRUCTION SPECIFICATION C-8. REFERENCES TO SECTION NUMBERS ARE FOR TVA GENERAL CONSTRUCTION SPECIFICATION NO. T-1.
2. LIGHT DASHED CONTOURS INDICATE EXISTING GROUND. HEAVY SOLID CONTOURS INDICATE FINISHED GRADING AND PAVING UNLESS OTHERWISE INDICATED.
3. UNLESS OTHERWISE INDICATED, FOUNDATION PREPARATION FOR ALL EMBANKMENTS SHALL CONSIST OF REMOVING ORGANIC TOPSOIL TO A DEPTH THAT WILL REMOVE ALL ROOTS AND EXCAVATION SHALL CONTINUE TO A DEPTH THAT WILL OBTAIN A FOUNDATION THAT WILL SUPPORT EARTHMOVING EQUIPMENT WITHOUT RUTTING INTO THE GROUND AND HEAVING THE GROUND SO AS TO REDUCE ITS STABILITY. CLEARING AND GRUBBING SHALL BE IN ACCORDANCE WITH SECTION 101.
4. AT THE BEGINNING OF GRADING OPERATIONS, ALL TOPSOIL THAT IS IN ACCORD WITH SECTION 130 SHALL BE STOCKPILED FOR FUTURE USE IN FINISHED AREAS.
5. IMPERVIOUS EARTHFILL MATERIAL IS TO BE OBTAINED FROM THE DESIGNATED BORROW AREA OR AN OFFSITE BORROW AREA APPROVED BY THE ENGINEER. RANDOM EARTHFILL MAY BE OBTAINED FROM EXCAVATIONS REQUIRED ON DRAWINGS.
6. CAREFULLY CONTROLLED EARTHFILLS SHALL BE PLACED IN EIGHT INCH THICK LAYERS. EACH LAYER SHALL BE COMPACTED TO AT LEAST 95% OF MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D698. MOISTURE CONTENT SHALL BE WITHIN 3% ABOVE OR BELOW THE OPTIMUM MOISTURE CONTENT. IN-PLACE DENSITY TESTS USING THE SAND CONE (ASTM D1556) OR RUBBER BALLOON (ASTM D 2167) TEST METHODS SHALL BE CONDUCTED AT A RATE OF AT LEAST ONE TEST PER EACH 2000 CY EARTHFILL PLACED OR A MINIMUM OF ONE PER DAY THAT EARTHFILL IS PLACED. IF NUCLEAR DENSITY METHODS ARE USED (ASTM D 2922), SUFFICIENT NUMBERS OF THE SAND CONE OR RUBBER BALLOON TESTS WILL BE REQUIRED TO CORRELATE AND VERIFY THE NUCLEAR GAUGE RESULTS. ALL TEST RESULTS SHALL BE PROMPTLY SUBMITTED TO HYDRO ENGINEERING.
7. COMMON FILLS SHALL BE UNCLASSIFIED MATERIAL AND SHALL BE PLACED IN APPROXIMATELY 8 INCH LAYERS AND COMPACTED WITH HAULING EQUIPMENT.
8. EXCAVATION AND BACKFILL FOR THE PIPE CULVERTS SHALL CONFORM TO SECTION 125.
9. THE CONNECTION OF PIPE TO ENDWALLS SHALL BE NEAT AND SECURE. WHERE ENTIRE END OF PIPE DOES NOT EXTEND TO FRONT FACE OF ENDWALL, THE BARREL OF THE CULVERT SHALL BE EXTENDED WITH SMOOTH, RIGID, CIRCULAR FORMS EXACTLY FITTING THE INNER CIRCUMFERENCE OF THE PIPE. UNLESS INDICATED OTHERWISE, WHERE A PORTION OF PIPE EXTENDS BEYOND THE REQUIRED FRONT FACE OF THE ENDWALL, IT SHALL BE CUT OFF SMOOTH AND FLUSH THEREWITH.
10. RIPRAP SHALL CONFORM TO SECTION 575. 50 PERCENT OF THE STONES SHALL WEIGH 200 LBS. OR GREATER WITH WITH A MAXIMUM STONE WEIGHT OF 800 LBS. NOT MORE THAN 5 PERCENT OF THE STONES BY WEIGHT IS TO PASS THE ONE INCH SIEVE. THE SIZE OF THE STONES IS TO BE REASONABLY WELL GRADED FROM THE SMALLER TO THE LARGER SIZE.
11. WHERE HAND-PLACED RIPRAP IS SPECIFIED OR ALLOWED, IT SHALL HAVE A MAXIMUM SIZE OF NINE INCHES WITH NOT MORE THAN 5% BY WEIGHT PASSING THE ONE INCH SIEVE. THE SIZE OF STONE IS TO BE WELL GRADED FROM SMALLEST TO LARGEST.
12. CRUSHED STONE FOR DRAINAGE SHALL CONFORM TO SECTION 1081. CRUSHED STONE PLACED BENEATH RIPRAP SHALL CONFORM TO SECTION 1081.
13. FILTER FABRIC SHALL CONFORM TO REQUIREMENTS OF SECTION 571, CLASS C. FABRIC IS TO BE PLACED IN ACCORDANCE WITH SECTION 571. MINIMUM OVERLAP TO BE 18 INCHES. DAMAGED MATERIAL TO BE REPAIRED BY PLACING A PIECE OF MATERIAL OVER THE DAMAGED AREA LARGE ENOUGH TO COVER THE DAMAGED AREA AND MEETING THE OVERLAP REQUIREMENT.
14. PAVEMENT SHALL BE THE FOLLOWING: EIGHT INCHES STABILIZED BASE PER SECTION 225, BITUMINOUS PRIME COAT PER SECTION 320, TWO INCHES BITUMINOUS LEVELING COURSE PER SECTION 335, AND ONE INCH ASPHALTIC CONCRETE SURFACE COURSE PER SECTION 345. CONCRETE CURB SHALL BE IN ACCORDANCE WITH SECTION 531. ALL EXPOSED EDGES OF CONCRETE SHALL BE CHAMFERED 3/4". ALL WORK PER GENERAL CONSTRUCTION SPECIFICATION NO. T-1.
15. CORRUGATED METAL PIPE SHALL BE 14 GA. CONFORMING TO 1271. REINFORCED CONCRETE PIPE SHALL BE CLASS III CONFORMING TO 1250. PERFORATED HIGH DENSITY POLYETHYLENE (HDPE) DRAIN PIPE SHALL CONFORM TO AASHTO M252. NON PERFORATED HDPE DRAIN PIPE SHALL CONFORM TO AASHTO M294 AND ASTM F667.
16. CAULKING FOR CONCRETE JOINTS SHALL BE SIKAFLEX-1A, COLOR LIMESTONE. AS MANUFACTURED BY SIKA CORPORATION OR AN APPROVED EQUAL. SURFACE PREPARATION & CAULK APPLICATION SHALL BE PER MANUFACTURE'S INSTRUCTION.
17. ALL SIGNS AND RELATED PAVEMENT MARKINGS SHALL CONFORM TO THE "MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES" PUBLISHED BY THE U. S. D.O.T., D6.1-1978 OR LATEST REVISION.
18. UNLESS OTHERWISE NOTED, SIGNS ARE TO BE FABRICATED FROM 0.08 INCH ALUMINUM SHEET CONFORMING TO ASTM B-209. FACINGS ARE TO BE ENGINEERING GRADE REFLECTIVE SHEETING (10 YEAR LIFE).
19. STANDARD U-POST TO BE GALVANIZED STEEL (50,000 PSI), 2.5 LB/FT. CONFORMING TO ASTM A-499. THE POST SHALL BE PREPUNCHED WITH 3/8 INCH DIAMETER HOLES ON ONE INCH CENTERS FOR THE ENTIRE LENGTH. GALVANIZING SHALL CONFORM TO ASTM A-525, DESIGNATION G-90.
20. ALL HARDWARE, EXCEPT WHERE OTHERWISE NOTED, SHALL CONFORM TO THE REQUIREMENTS OF ASTM A-307, CLASS A.
21. IF ROCK IS ENCOUNTERED DURING THE INSTALLATION OF POSTS, HOLES SHALL BE DRILLED TO PROVIDE THE 3'-0" MIN. DEPTH.
22. ALL REUSABLE SIGNS TO BE REMOVED & STORED DURING CONSTRUCTION AND RESET AFTER CONSTRUCTION IS COMPLETE.
23. PRECAST MANHOLES AND ACCESSORIES SHALL CONFORM TO ASTM C478.
24. CONSTRUCTION ACTIVITIES SHALL BE WELL PLANED TO AVOID DISRUPTING PUBLIC USE OF THE RECREATION AREA AND TO MINIMIZE IMPACTS ON CORPS OF ENGINEERS OPERATIONS.
25. FOR DESIGN CALCULATIONS AND FIELD INFORMATION, SEE RIMS NUMBER B92960508005.

PROJECT REVISION HISTORY

SCALE: 1" = 100' EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

GENERAL PLAN

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY

AUTOCAD R12 | 9 | C | 23W300-1 | R 2

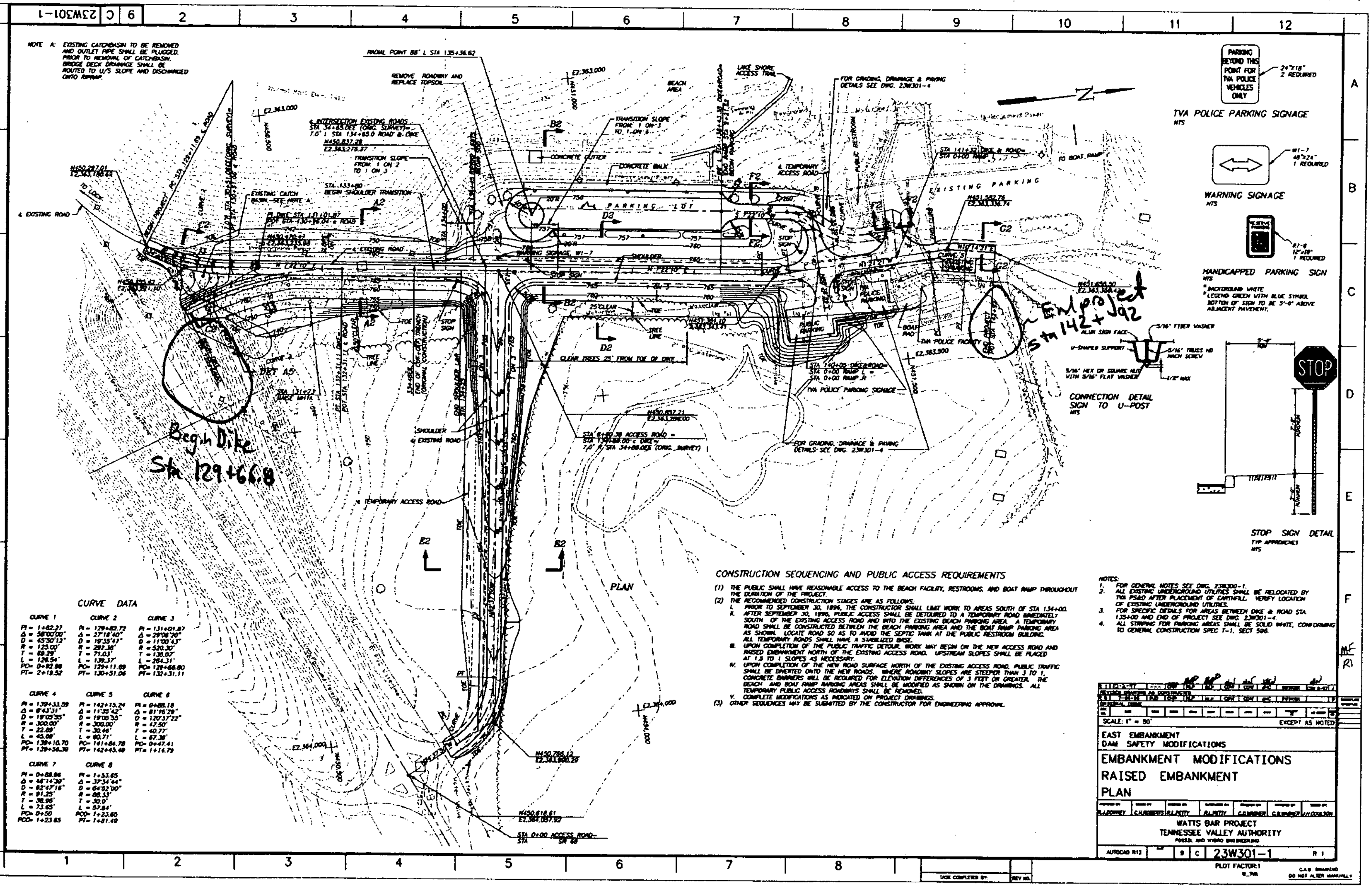
PLOT FACTOR:1

C.A.D. DRAWING DO NOT ALTER MANUALLY

Attachment 15-5

Source: Reference 25

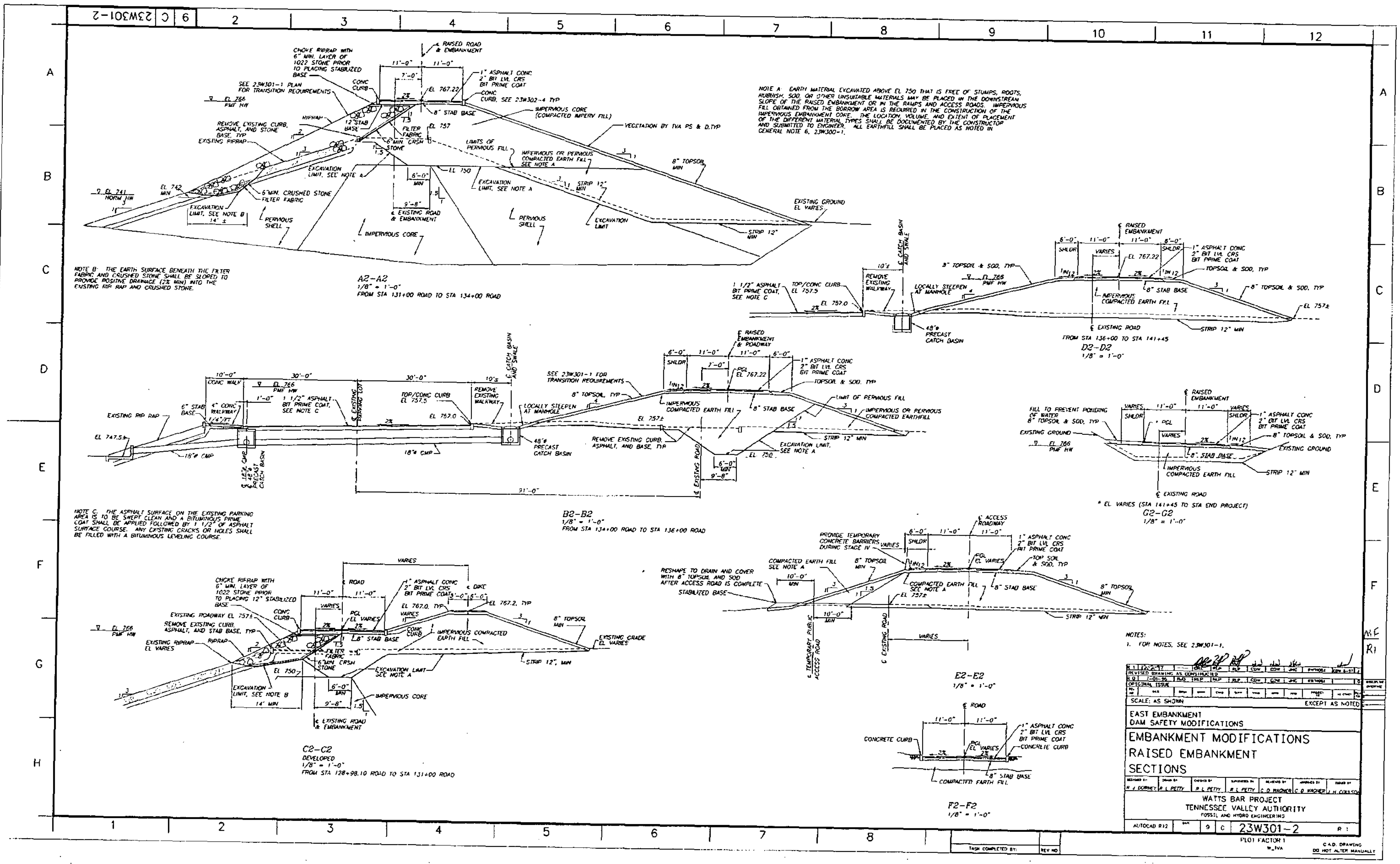
Calculation No: CDQ000020080020



Attachment 15-6

Source: Reference 26

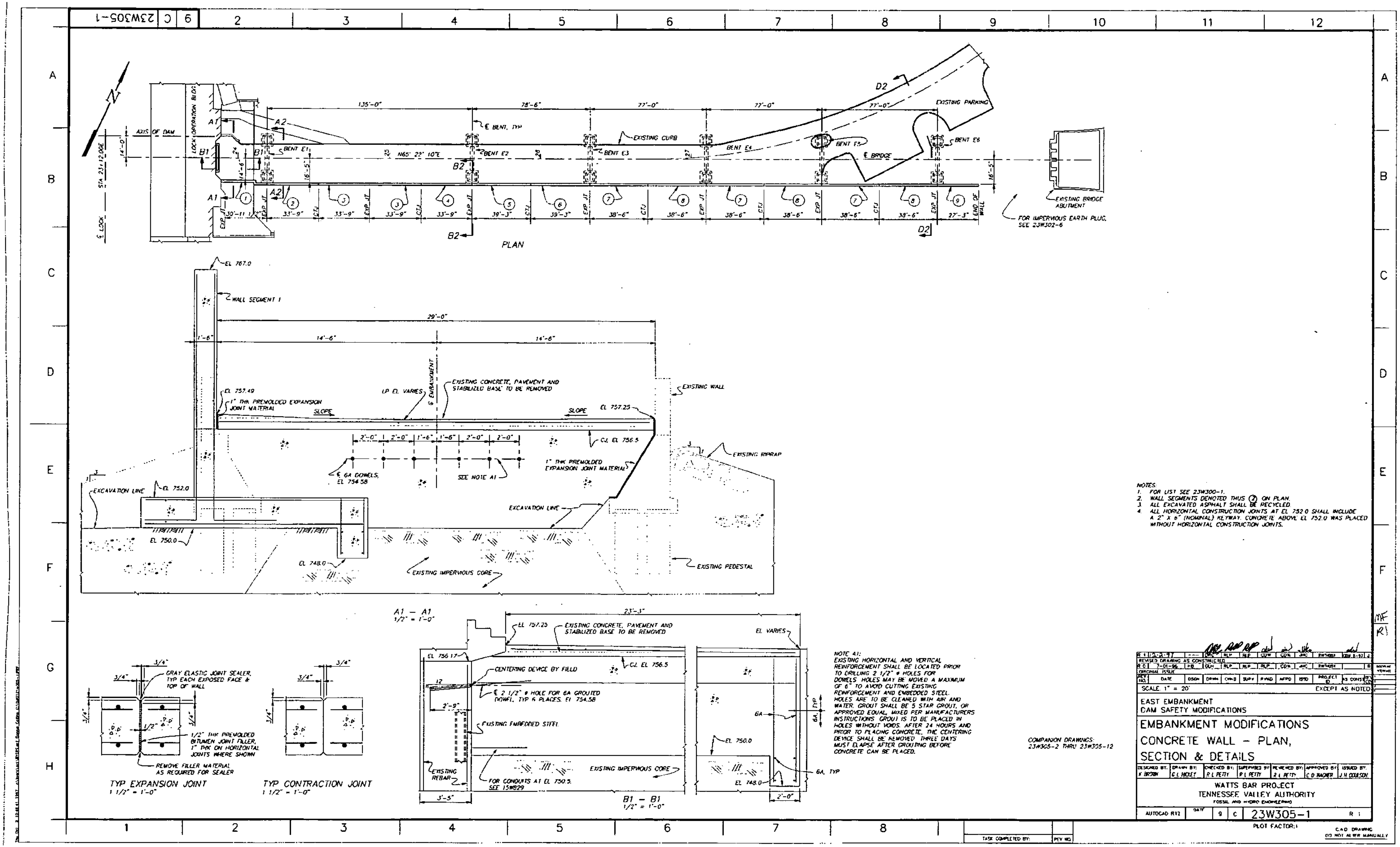
Calculation No: CDQ000020080020



Attachment 15-7

Source: Reference 27

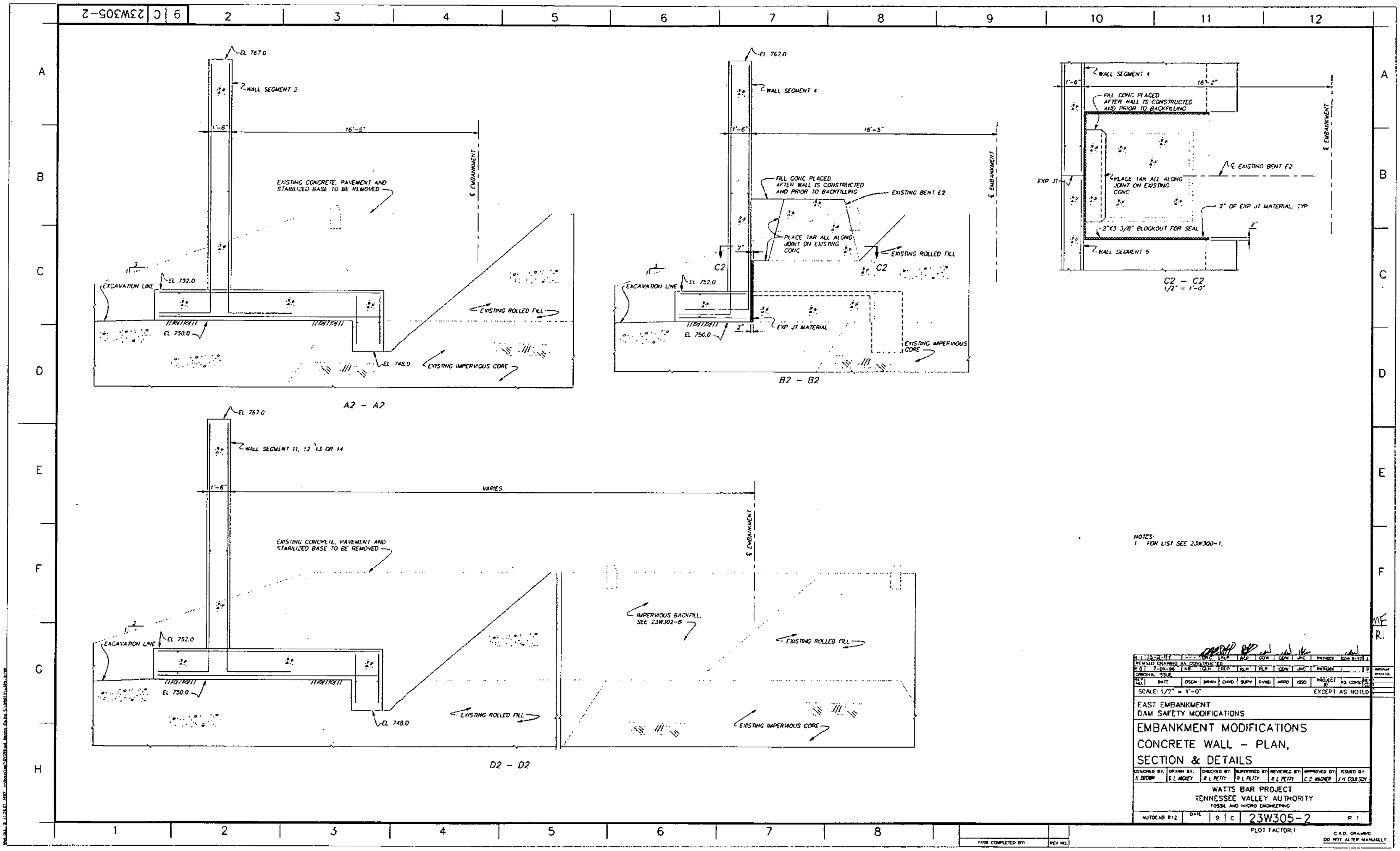
Calculation No: CDQ000020080020



Attachment 15-8

Source: Reference 28

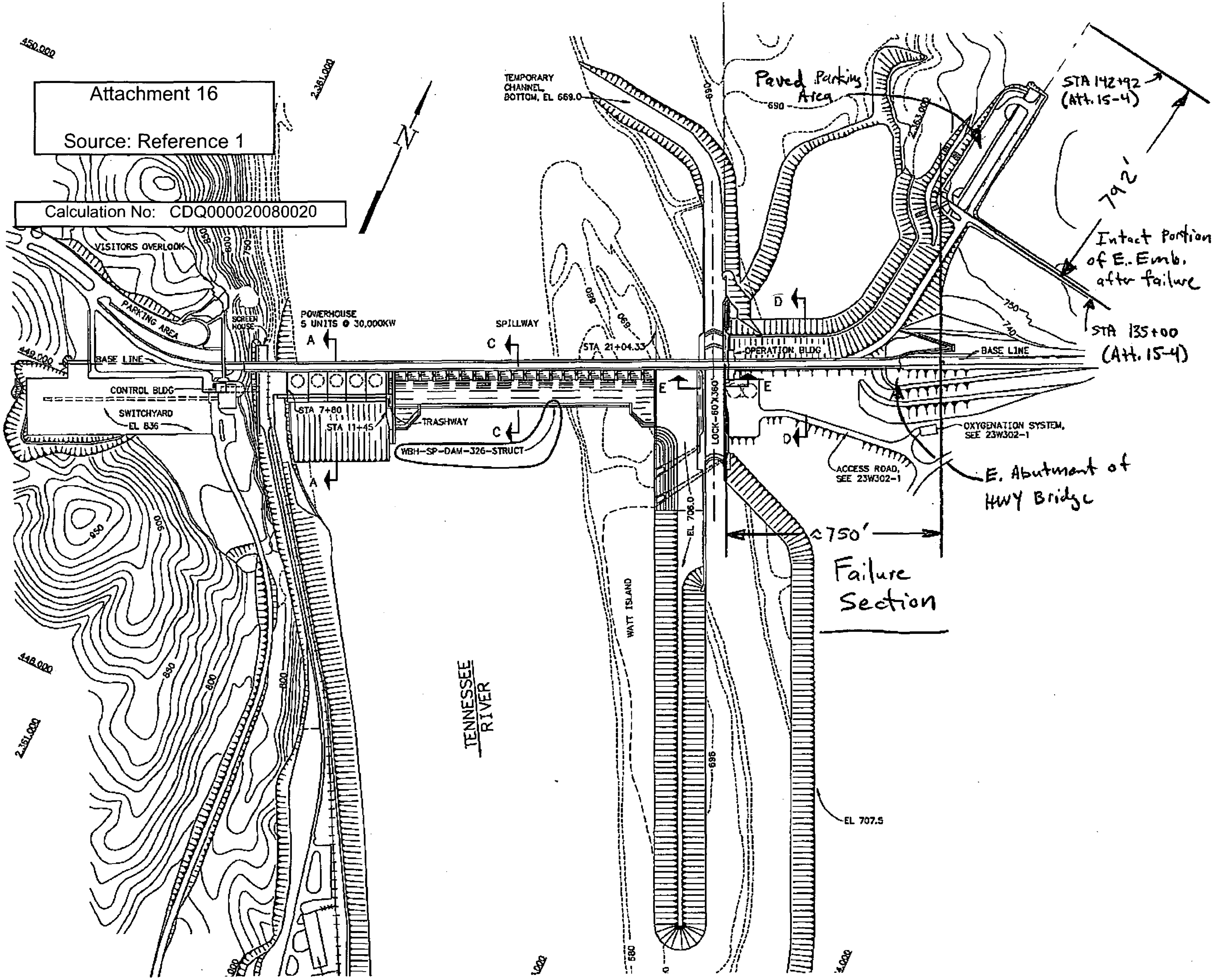
Calculation No: CDQ000020080020



Attachment 16

Source: Reference 1

Calculation No: CDQ000020080020



Distance along cross-section from west end x, ft	Ground Elevation z, ft
0	770
58	765
115	760
150	758
160	757
184	755
217	753
230	752
317	750
425	750
560	752
583	753
635	755
727	757
835	755
910	757
940	758
985	760
1015	760
1130	758
1160	757
1215	755
1260	753
1275	752
1345	750
1380	749
1420	750
1465	752
1535	753
1580	752
1622	750
1635	749
1660	748
1685	749
1700	750
1765	752
1780	753
1795	755
1805	757
1810	758
1830	760
1863	765
1895	770

g = 32.2 f/s2

Water level at critical section y feet	Top Width T feet	Area A feet^2	Critical Discharge Q cfs	Headwater HW feet
748	0	0	0	748.0
749	50	25	100	749.3
750	153	127	653	750.4
752	705	985	6602	752.7
753	886	1780	14317	754.0
755	1031	3697	39726	756.8
757	1395	6123	72793	759.2
758	1470	7556	97200	760.6
760	1715	10741	152522	763.1
762.5	1760	15084	250586	766.8
765	1805	19541	364832	770.4
770	1895	28791	636791	777.6

The x-coordinates were scaled from Attachment 5 using the distance between stations 0+00 and 15+00 along the saddle dam axis as 1500 feet.

Area, A: segment-by-segment for each water elevation, y

$A(y_2) = A(y_1) + .5*(T_1+T_2)*(y_2-y_1)$ for $y_2 > y_1$

Critical discharge, $Q^2 = gA^3/T$ (Ref. 29)

Headwater, $HW = y + Q^2 / (2gA^2)$ (Ref. 29)

Compute discharge for broad-crested weir at elevation 750 feet

C_f = 2.65

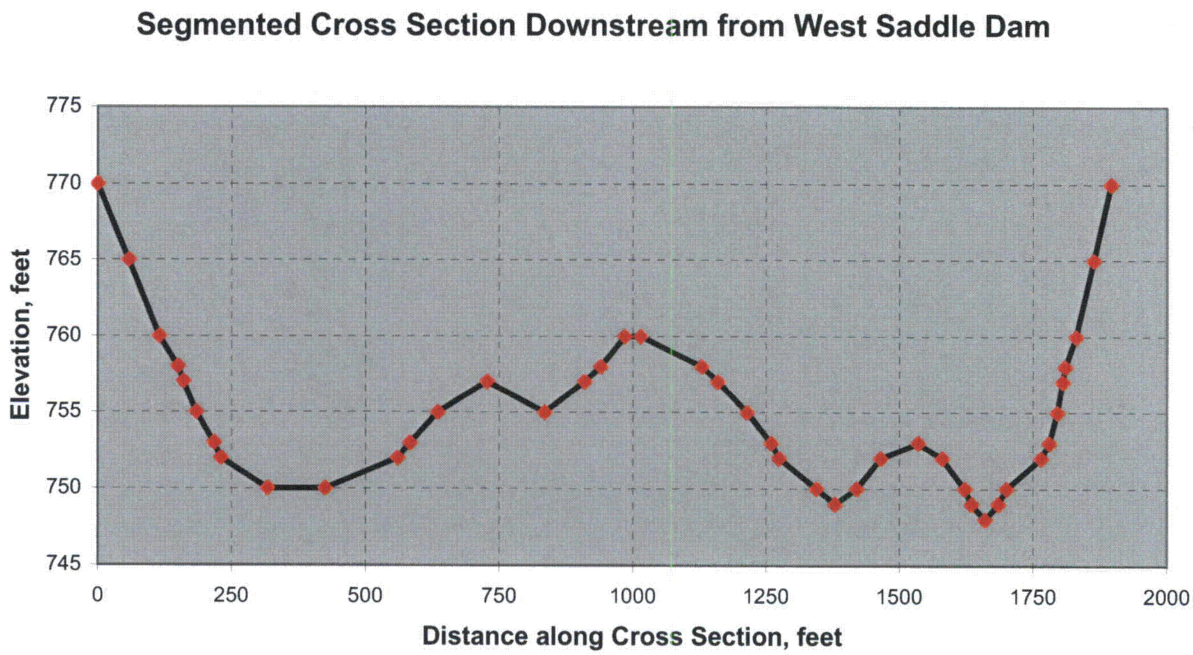
L = 1300

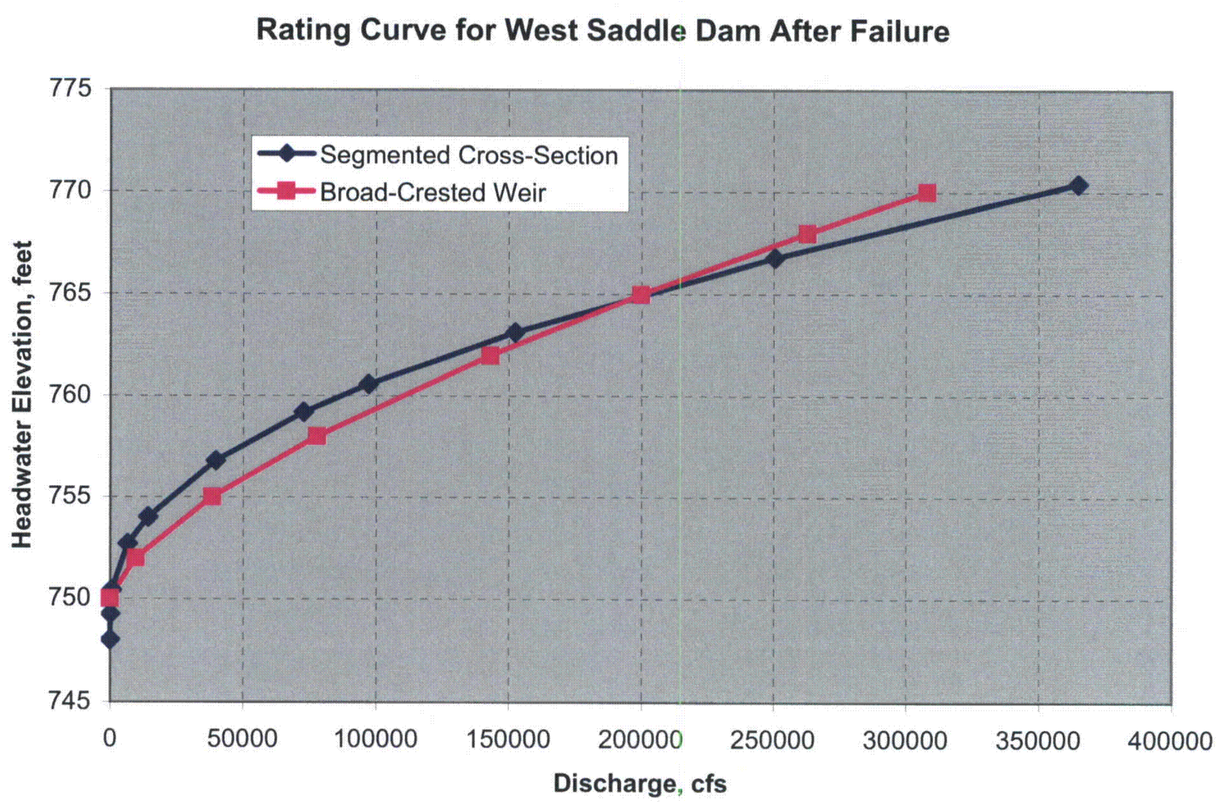
Z_c = 750

Discharge Q cfs	Headwater HW feet
0	750
9744	752
38516	755
77951	758
143206	762
200136	765
263086	768
308130	770

Attachment 17-2

Calculation No: CDQ000020080020





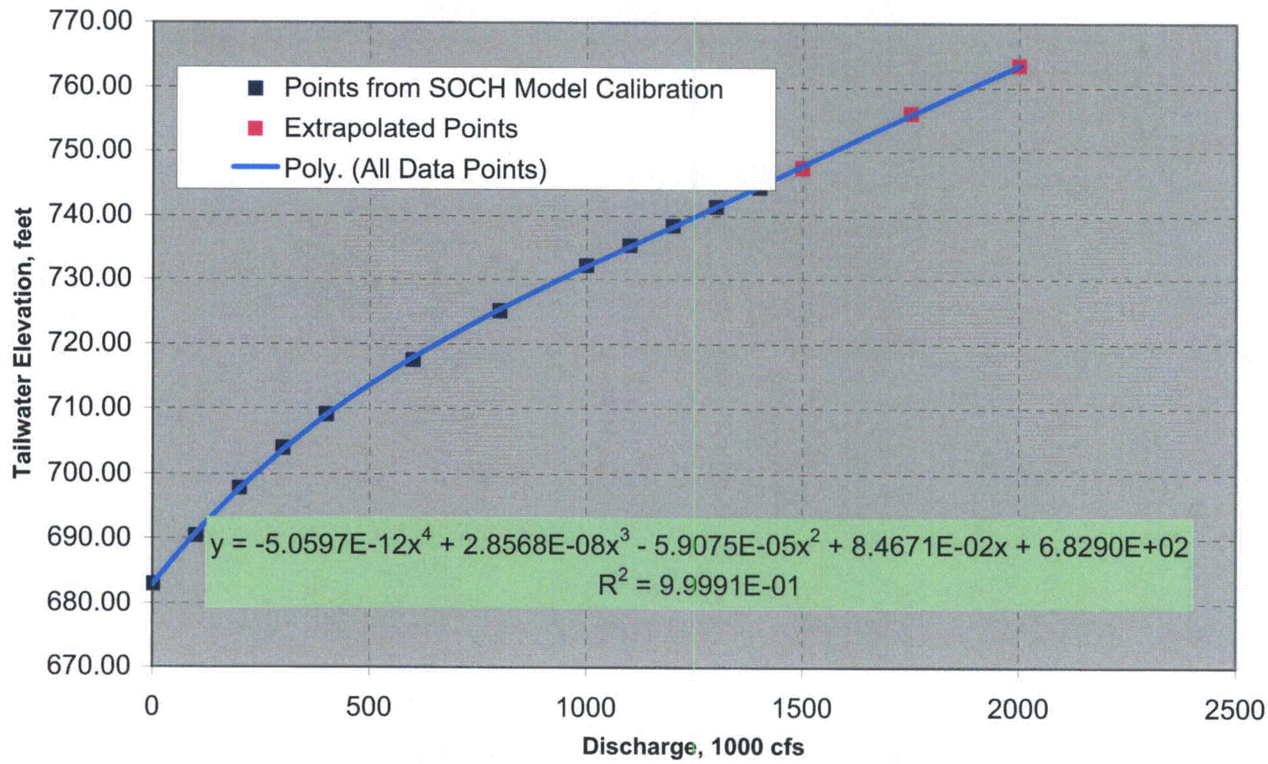
TW from SOCH

1000 cfs	TW feet
0	683.00
100	690.42
200	697.86
300	704.02
400	709.13
600	717.55
800	725.17
1000	732.20
1100	735.39
1200	738.50
1300	741.46
1400	744.44
1500	747.5 (1)
1750	756.0 (1)
2000	763.5 (1)

Polynomial Curve Fit: $TW = 682.90 + 0.084671Q - 5.9075\times10^{-5}Q^2 + 2.8568\times10^{-8}Q^3 - 5.0597\times10^{-12}Q^4$

where TW = tailwater elevation in feet and Q = discharge in 1000 cfs

(1) These estimated points are added to achieve a polynomial that fits the known points and can be used to extrapolate the curve for discharges above 1,400,000 cfs.

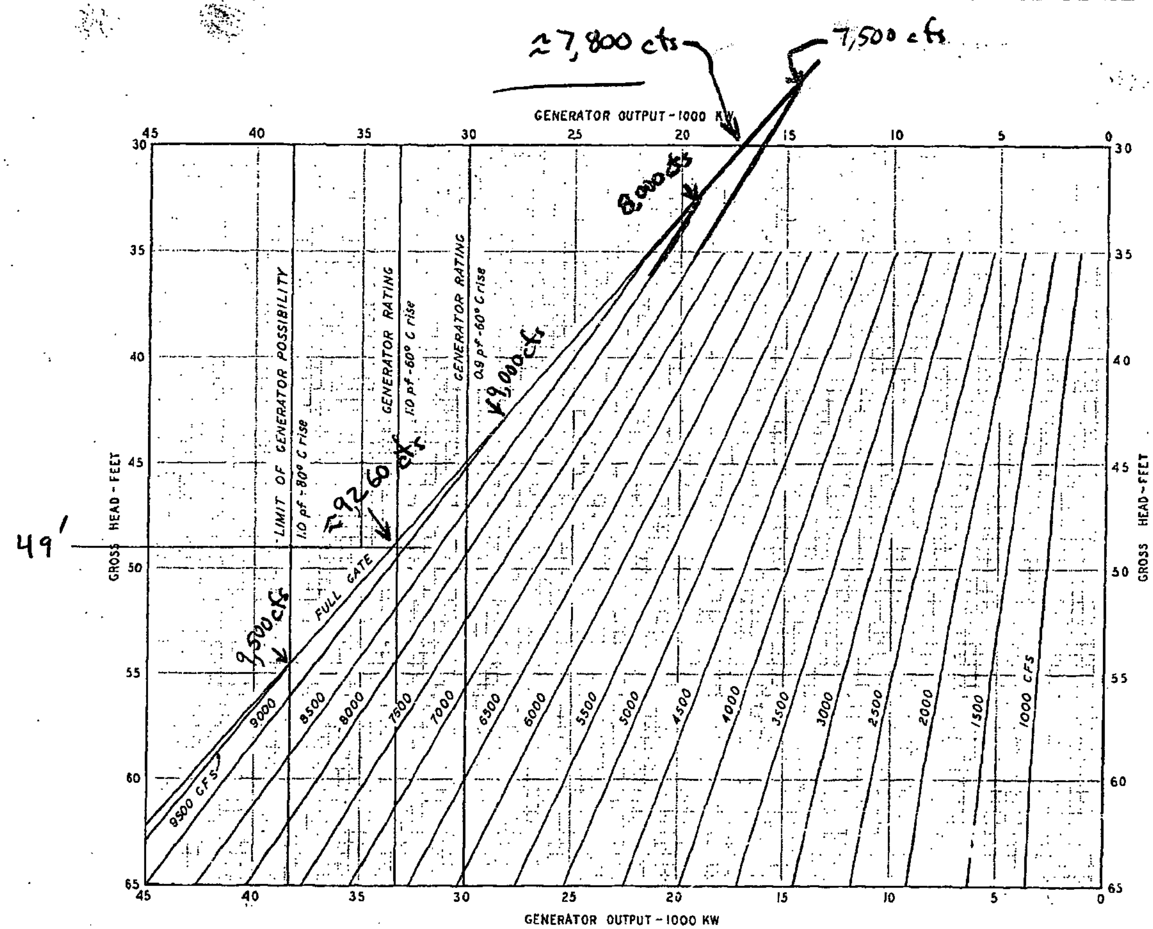


Attachment 19-1

Source: Reference 30

Calculation No: CDQ000020080020

EXHIBIT 3



NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 4-26-44. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV-65071 rated 42,000 hp, 52 ft. head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg. Co TV-65072 rated 33,333 kva, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

POWERHOUSE
UNIT 4

DISCHARGE CURVES
BASED ON INDEX TESTS

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED | RECOMMENDED | APPROVED

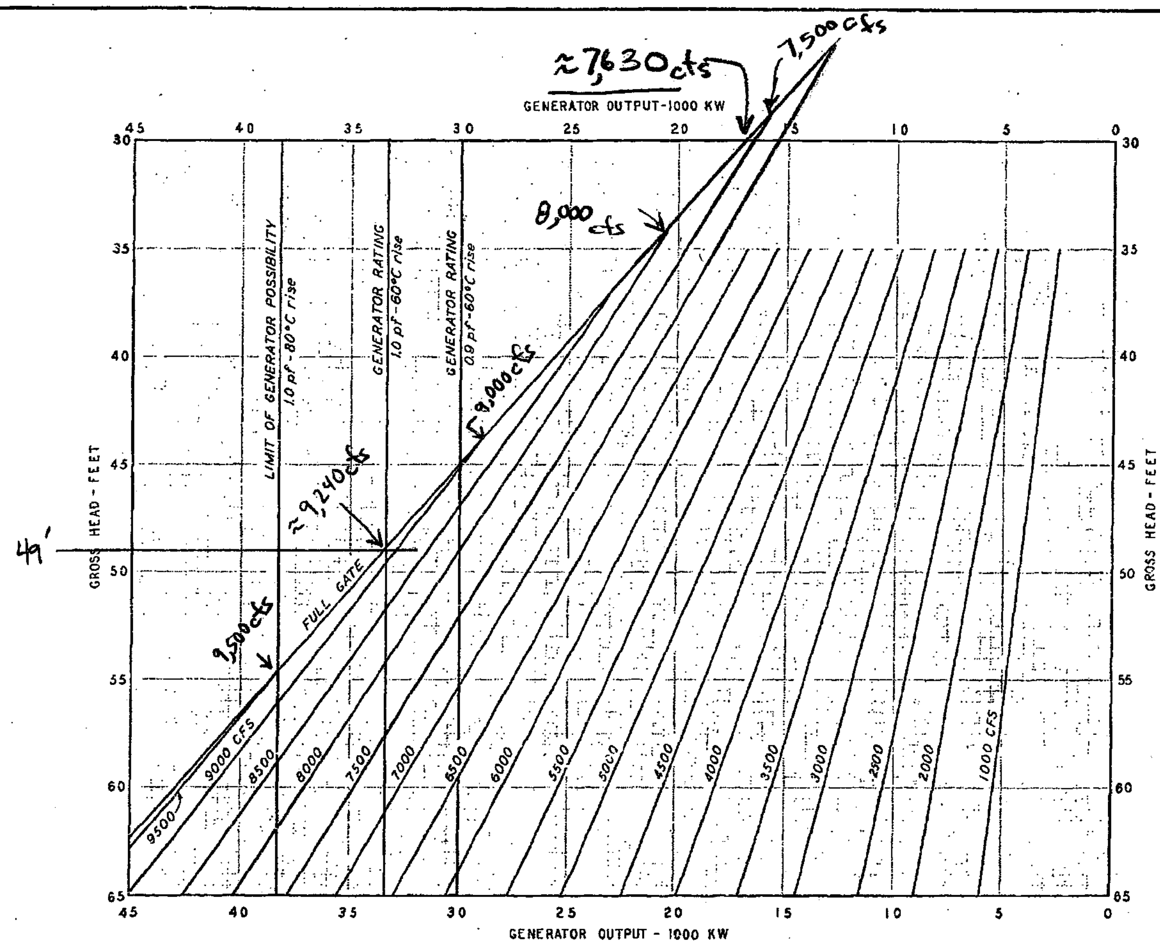
KNOXVILLE | 6-17-44 | 9 | M | 4 | 478903 R0

Attachment 19-2

Source: Reference 31

Calculation No: CDQ000020080020

EXHIBIT 6



NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory Test no. 845 modified in accordance with index test conducted at the plant on 4-27-44. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV-65071 rated 42,000 hp, 52 ft head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg Co. TV-65072 rated 33,333 kva, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

POWERHOUSE UNIT 5

DISCHARGE CURVES BASED ON INDEX TESTS

WATTS BAR PROJECT

TENNESSEE VALLEY AUTHORITY

DESIGN DEPARTMENT

SUBMITTED / RECOMMENDED / APPROVED

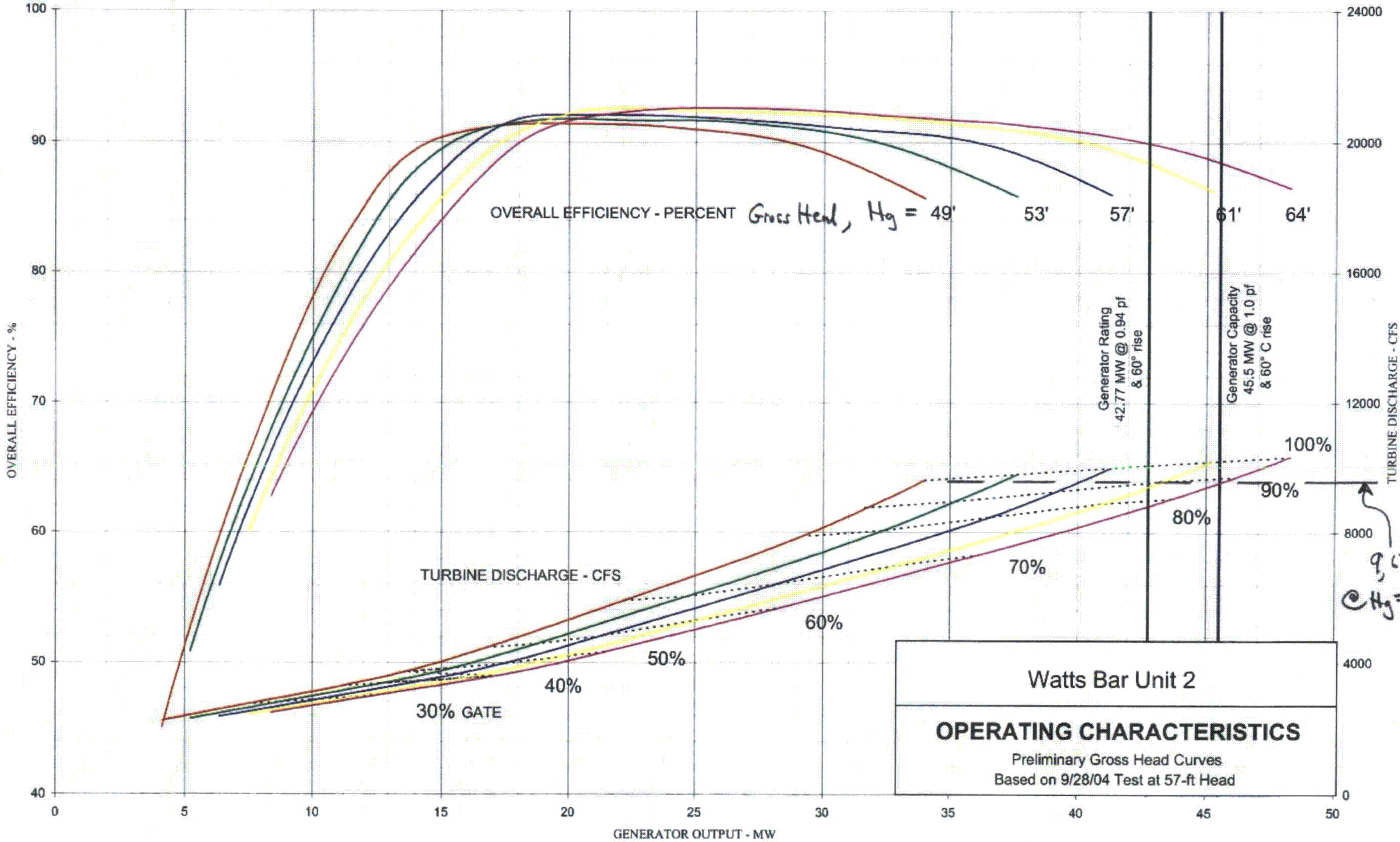
KNOXVILLE 6-17-44 | 8 | M | 4 | 47B906 R0

DSGN JRP SUPV CLN
DRWN JRP INSP
CHKD CLN
TRCD MCK ENGINEER

Attachment 19-3

Source: TVA River Operations

Calculation No: CDQ000020080020



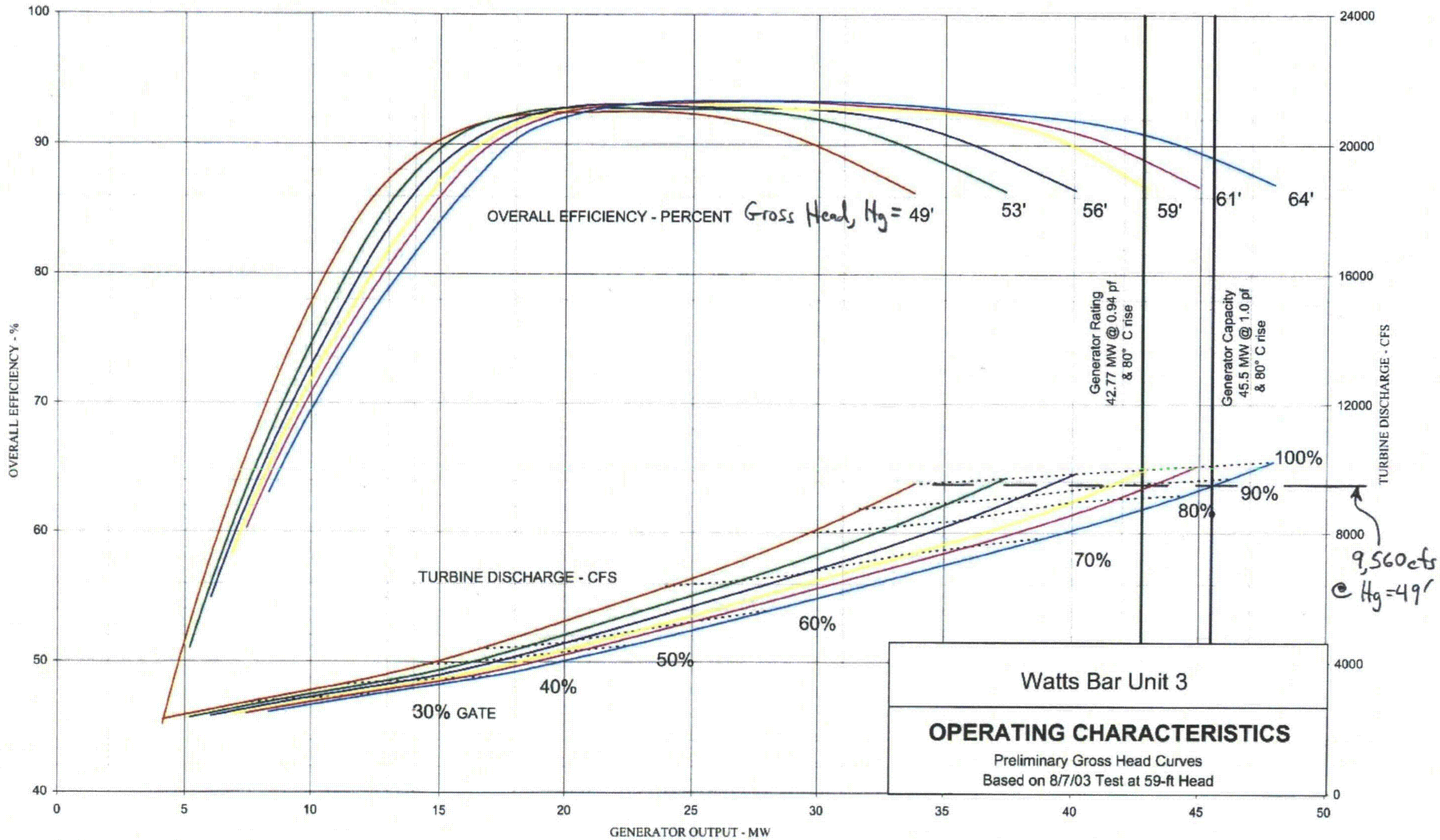
Issued 9/29/2005

WBH_HYPAS_prelim_U2_092804.xls

Attachment 19-4

Source: TVA River Operations

Calculation No: CDQ000020080020



POWER FACILITIES (CONT.)

HYDRAULIC TURBINES

Number	5
Manufacturer	Baldwin-Lima-Hamilton Corp.
Type	Kaplan adjustable-blade propeller
Rated capacity (each)	42,000 hp at 52-ft net head
Rated speed	94.7 r/min
Maximum runaway speed	243 r/min
Specific speed at rating	139
Value of sigma at rating	0.89
Diameter of runner	234 in.
Diameter of guide vane circle	276.5 in.
Diameter of lower pit	27.0 ft
Spacing of turbines, center to center of units	73 ft
Draft tubes (see Powerhouse)	Elbow type
Governors	Woodward, cabinet actuator type
Heaviest assembly to be lifted by crane	434,000 lb

POWER FACILITIES (CONT.)

CONTROL BUILDING

Location ....West of powerhouse, adjacent to switchyard
Type of construction ....Reinforced concrete, structural steel, limestone and brick
Floor area ....17,500 sq. ft
Volume ....181,500 cu. ft

GENERATOR AND TURBINE MODERNIZATION

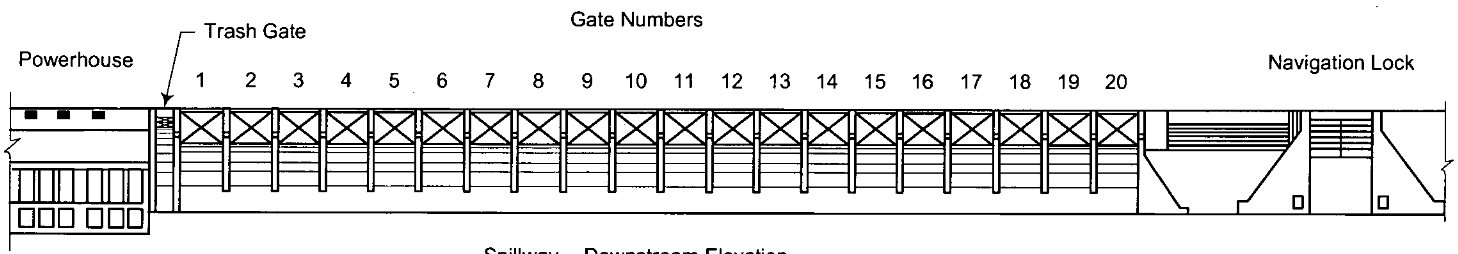
This project, scheduled to start in June 2003 and complete in September 2007, will modernize the power train. Principal components to be replaced are the existing runners, main transformers generator breakers (including addititon of a generator breaker to unit 3), pilot/main exciters, protective relays , current and potential transformers , generator leads, and critical components of the cooling water system including generator air coolers, thrust bearing oil coolers, proportioning valves, strainers, and manual valves. Principal components to be rehabilitated are the generator and turbine bearings and shafts, rotor poles, stator windings, and wicket gates.

Attachment A1

Source: Reference A1

WATTS BAR DAM

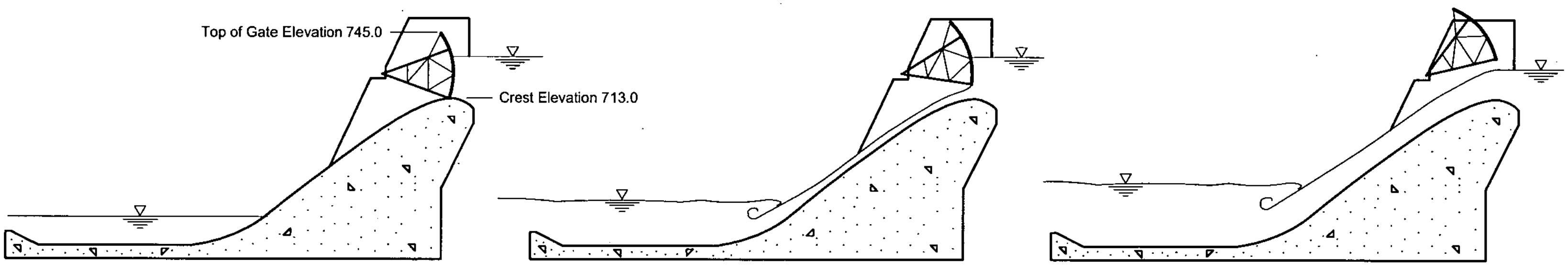
LOCATION OF SPILLWAY GATES



Spillway -- Downstream Elevation

KEY TO GATE ARRANGEMENT TABLE

Numbers Under Gate Operating Conditions Shown Below Refer To Numbers Marked On Gate Position Indicator And Used In Gate Arrangement Table, Pages 4 And 5



Gate Closed
Gate Position Indicated by Dash (-)

Headwater Above Bottom of Gate
Possible Gate Position Indicator Numbers
2, 6, 10, 14, 18, 22, 26, 30, or 34

Bottom of Gate Raised Above Water Surface
Possible Gate Position Indicator Numbers
26, 30, 34, or UP, Depending on Headwater Elevation

Attachment A2

Source: Reference A1

Calculation No: CDQ000020080020

WATTS BAR DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrangement	Gate Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
57	6	10	6	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
58	10	10	6	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
59	10	10	10	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
61	10	10	10	10	10	14	10	14	10	10	10	10	10	10	10	10	10	10	10	10
62	10	10	10	10	10	14	10	14	10	14	10	14	10	10	10	10	10	10	10	10
63	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	10	10	10	10
64	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	10	14	10	14
65	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	14	14	14	14
66	10	10	10	10	10	14	10	14	10	14	10	14	14	14	14	14	14	14	14	14
67	10	10	10	10	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14
68	10	10	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
69	14	14	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
71	14	14	14	14	18	14	18	14	14	14	14	14	14	14	14	14	14	14	14	14
72	14	14	14	14	18	14	18	14	18	14	18	14	14	14	14	14	14	14	14	14
73	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	14	14	14	14
74	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	18	14	18	14
75	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	18	18	18	18
76	14	14	14	14	18	14	18	14	18	14	18	14	18	18	18	18	18	18	18	18
77	14	14	14	14	18	14	18	14	18	18	18	18	18	18	18	18	18	18	18	18
78	14	14	14	18	18	14	18	18	18	18	18	18	18	18	18	18	18	18	18	18
79	14	14	14	18	18	22	18	18	18	18	18	18	18	18	18	18	18	18	18	18
80	14	14	14	18	18	22	18	22	18	22	18	18	18	18	18	18	18	18	18	18
81	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	18	18	18	18	18
82	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	22	18	22	18	18
83	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	22	18	22	22	22

Gate Arrangement	Gate Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
84	14	14	14	18	18	22	18	22	18	22	18	22	18	22	22	22	22	22	22	22
85	14	14	14	18	18	22	18	22	22	22	22	22	22	22	22	22	22	22	22	22
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89	14	14	14	22	26	22	26	22	26	22	26	22	26	22	26	22	26	22	26	26
90	14	14	14	22	26	22	26	22	26	22	26	22	26	26	26	26	26	26	26	26
91	14	14	14	22	26	22	26	26	26	26	26	26	26	26	26	26	26	26	26	26
92	14	14	14	26	26	30	26	26	26	26	26	26	26	26	26	26	26	26	26	26
93	14	14	14	26	26	30	26	30	26	30	26	30	26	26	26	26	26	26	26	26
94	14	14	14	26	26	30	26	30	26	30	26	30	26	30	26	30	26	30	26	30
95	14	14	14	26	26	30	26	30	26	30	26	30	30	30	30	30	30	30	30	30
96	14	14	14	30	26	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
97	14	14	14	30	34	30	34	30	34	30	30	30	30	30	30	30	30	30	30	30
98	14	14	14	30	34	30	34	30	34	30	34	30	34	30	34	30	34	30	34	30
99	14	14	14	30	34	30	34	30	34	30	34	34	34	34	34	34	34	34	34	34
100	14	14	14	34	34	UP	34	34	34	34	34	34	34	34	34	34	34	34	34	34
101	14	14	14	34	34	UP	34	UP	34	UP	34	UP	34	UP	34	34	34	34	34	34
102	14	14	14	34	34	UP	34	UP	34	UP	34	UP	34	UP	34	UP	34	UP	UP	UP
103	14	14	14	34	34	UP	34	UP	34	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
104	14	14	14	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
105	18	18	18	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
106	22	22	22	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
107	26	26	26	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
108	30	30	30	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
109	34	34	34	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
110	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate

Calculation No: CDQ000020080020	Attachment A3 Source: Reference A2	Watts Bar 1989 Measurements

Spillway Rating Table

COMPUTED LWS DATE 6-9-90

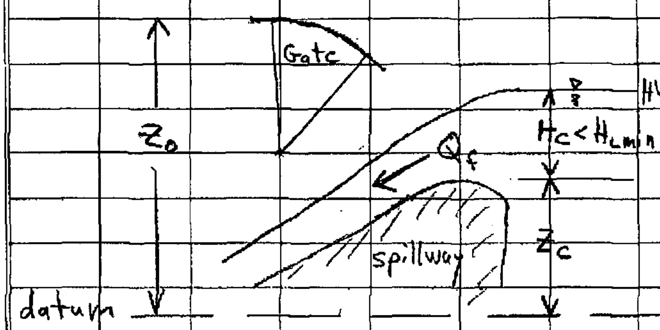
CHECKED ______ DATE ______

Chain-Link		0	4	8	14	20	28	36	44	52	60	72
Indicate		0.	2	6	10	14	18	22	26	30	34	Max
Gate			vertical distance in feet									
Number	1	0	.62	2.19	4.66	7.11	10.42	13.72	17.06	20.48	23.52	28.40
	2	0	.82	2.39	4.60	7.26	10.56	13.87	17.16	20.42	23.64	28.81
	4	0	.46	2.04	4.46	6.96	10.25	13.56	16.92	20.22	23.46	28.68
	3	0	.48	2.07	4.50	6.96	10.27	13.60	16.92	20.20	23.44	28.62
	5	0	.91	2.52	4.98	7.46	10.82	14.19	17.53	20.84	24.12	29.64
	6	0	.96	2.57	5.02	7.51	10.87	14.23	17.56	20.86	24.12	29.65
	7	0	.59	2.18	4.54	7.04	10.35	13.70	16.99	20.26	23.49	28.68
	8	0	.86	2.46	4.93	7.43	10.80	14.17	17.52	20.83	24.12	29.62
	9	0	.54	2.12	4.54	6.94	10.32	13.64	16.96	20.21	23.46	28.62
	10	0	.82	2.44	4.90	7.40	10.76	14.14	17.48	20.80	24.10	29.58
	11		.72	2.33	4.81	7.32	10.67	14.05	17.41	20.71	23.99	29.58
	12		.72	2.29	4.70	7.16	10.44	13.74	17.03	20.28	23.51	28.66
	13		.80	2.38	4.77	7.22	10.51	13.81	17.10	20.25	23.54	28.68
	14		.74	2.42	4.88	7.35	10.71	14.08	17.42	20.72	24.00	28.46
	15		.59	2.18	4.60	7.06	10.37	13.68	16.98	20.24	23.48	28.62
	16		.60	2.18	4.60	7.05	10.35	13.67	16.97	20.24	23.46	28.66
	17		.53	2.12	4.52	6.98	10.26	13.62	16.94	20.20	23.44	28.67
	18		.67	2.28	4.75	7.25	10.68	14.00	17.36	20.68	23.98	29.47
	19		.58	2.10	4.51	6.97	10.28	13.61	16.92	20.20	23.45	28.62
	20		.59	2.16	4.57	7.03	10.34	13.66	16.95	20.22	23.46	28.62

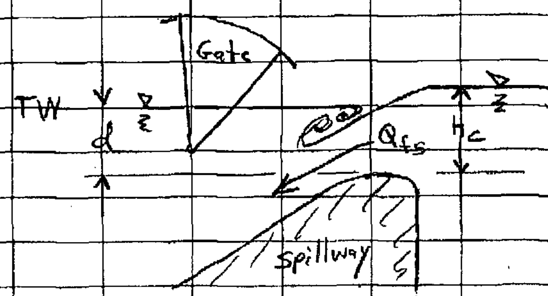
Definition Sketch for Spillway Discharge

COMPUTED GAS DATE 8/12/2008
CHECKED ____ DATE ____

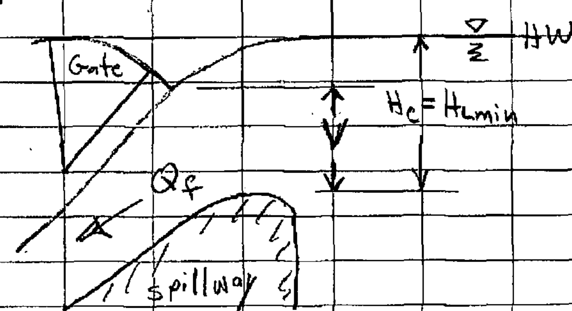
Free Discharge - No Tailwater effect



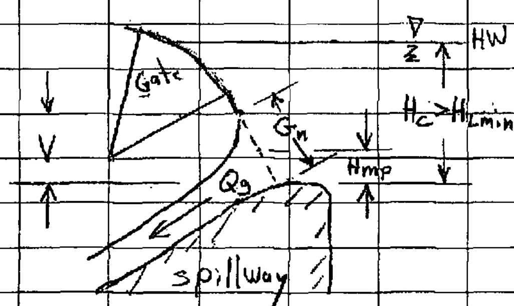
Free Discharge affected by Tailwater



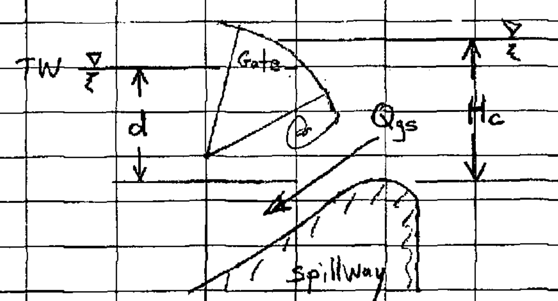
Nappe Touches Gate



Orifice Discharge - No Tailwater Effect



Orifice Discharge affected by Tailwater



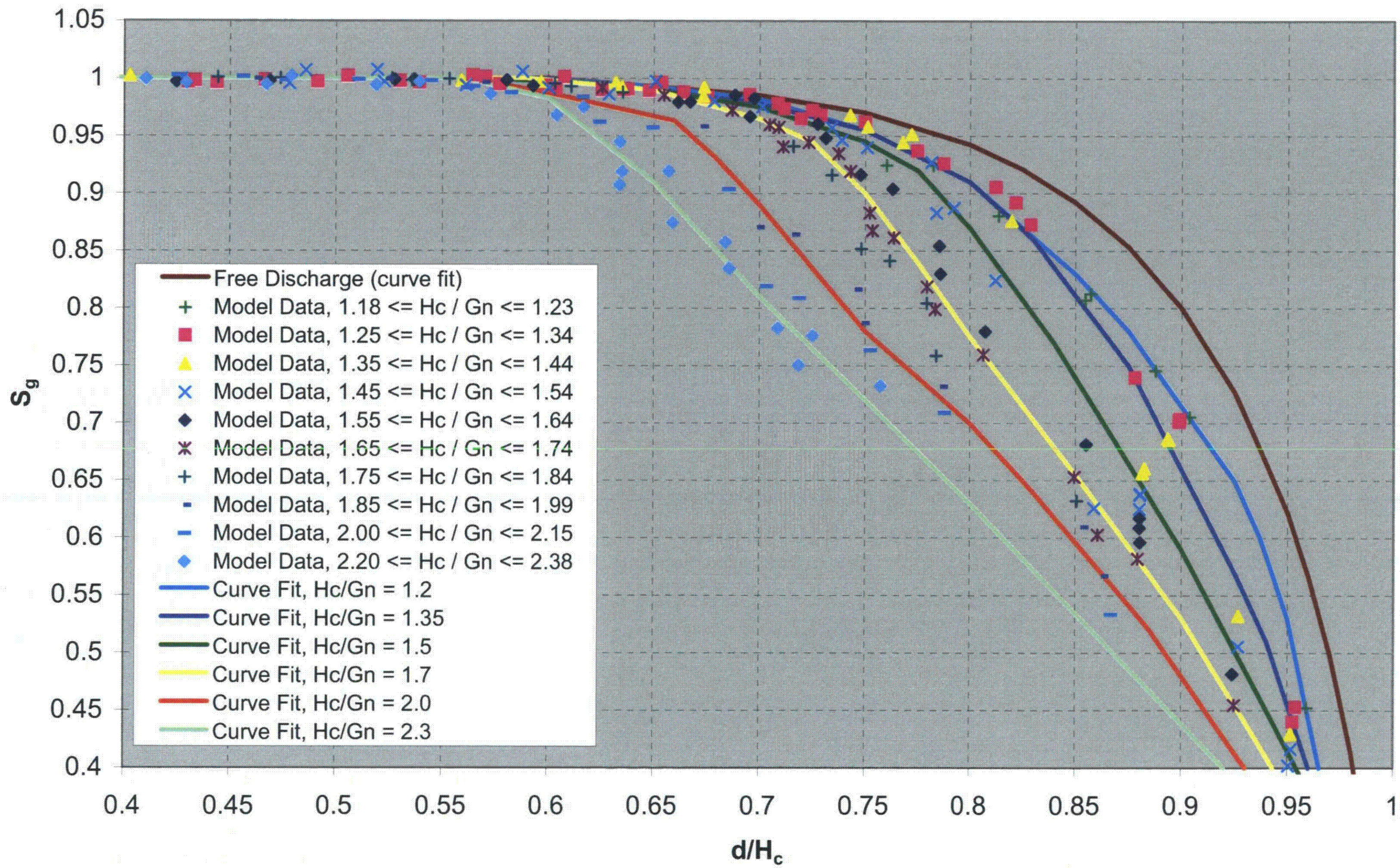
Attachment A5-1

Source: Reference A6

Calculation No: CDQ000020080020

Submergence Factors for Radial Gates on Spillway Crests

Nickajack Dam 1:35 scale model data

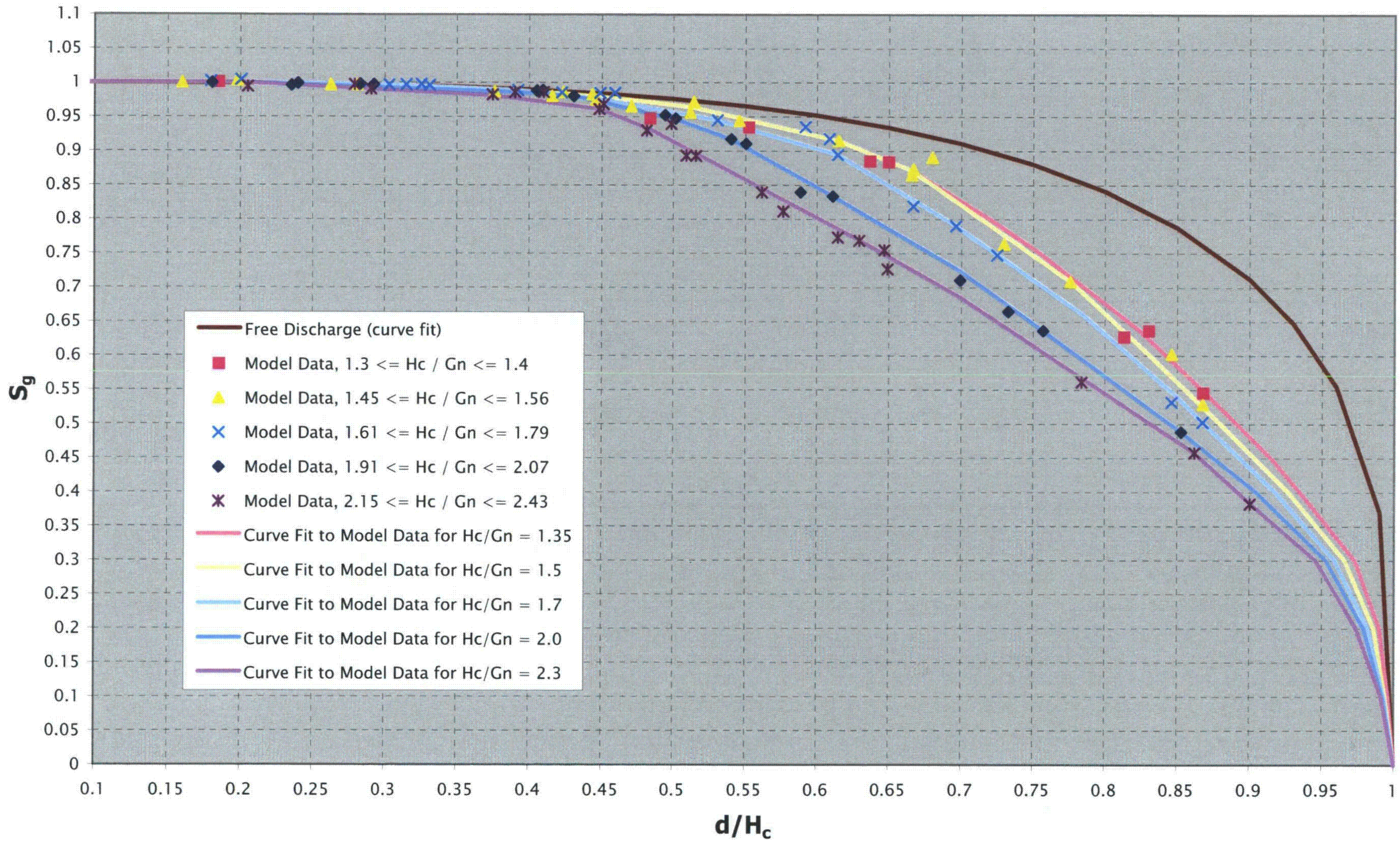


Submergence Factors for Radial Gates on Spillway Crests
Tellico Dam 1:72 scale model data

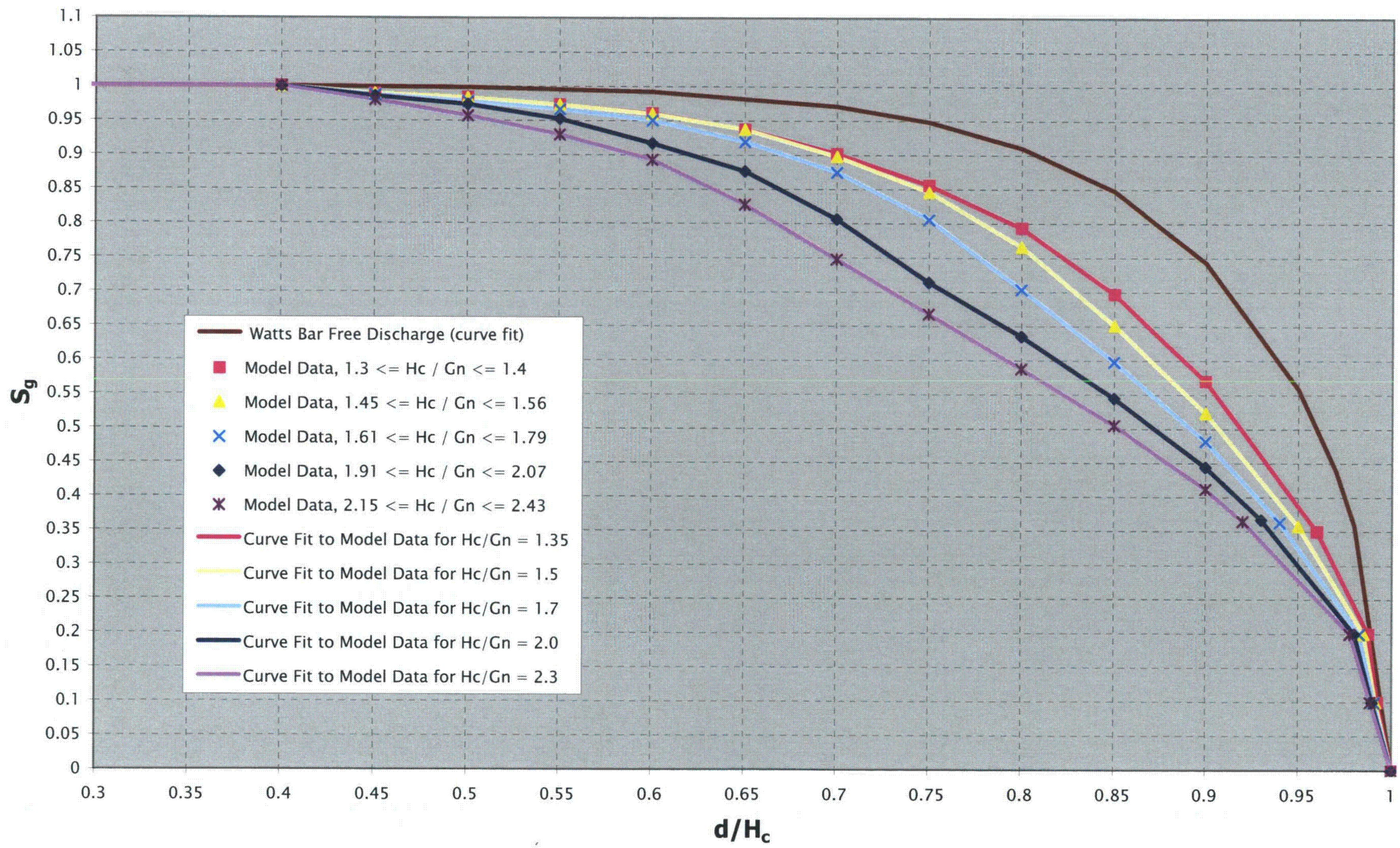
Attachment A5-2

Source: Reference A10

Calculation No: CDQ000020080020



Submergence Factors for Radial Gates on Spillway Crests Average Between Tellico Dam and Nickajack Model Data $d/H_c > .4$



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

AMERICAN SOCIETY OF CIVIL ENGINEERS

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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 A6-2

Source: Reference A3

Calculation No: CDQ000020080020

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,

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

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.

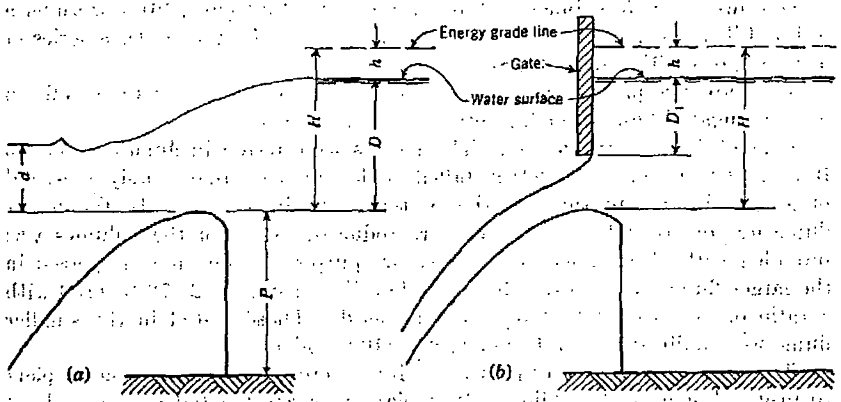


Fig. 1.—Spillway-Crest Diagram

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.

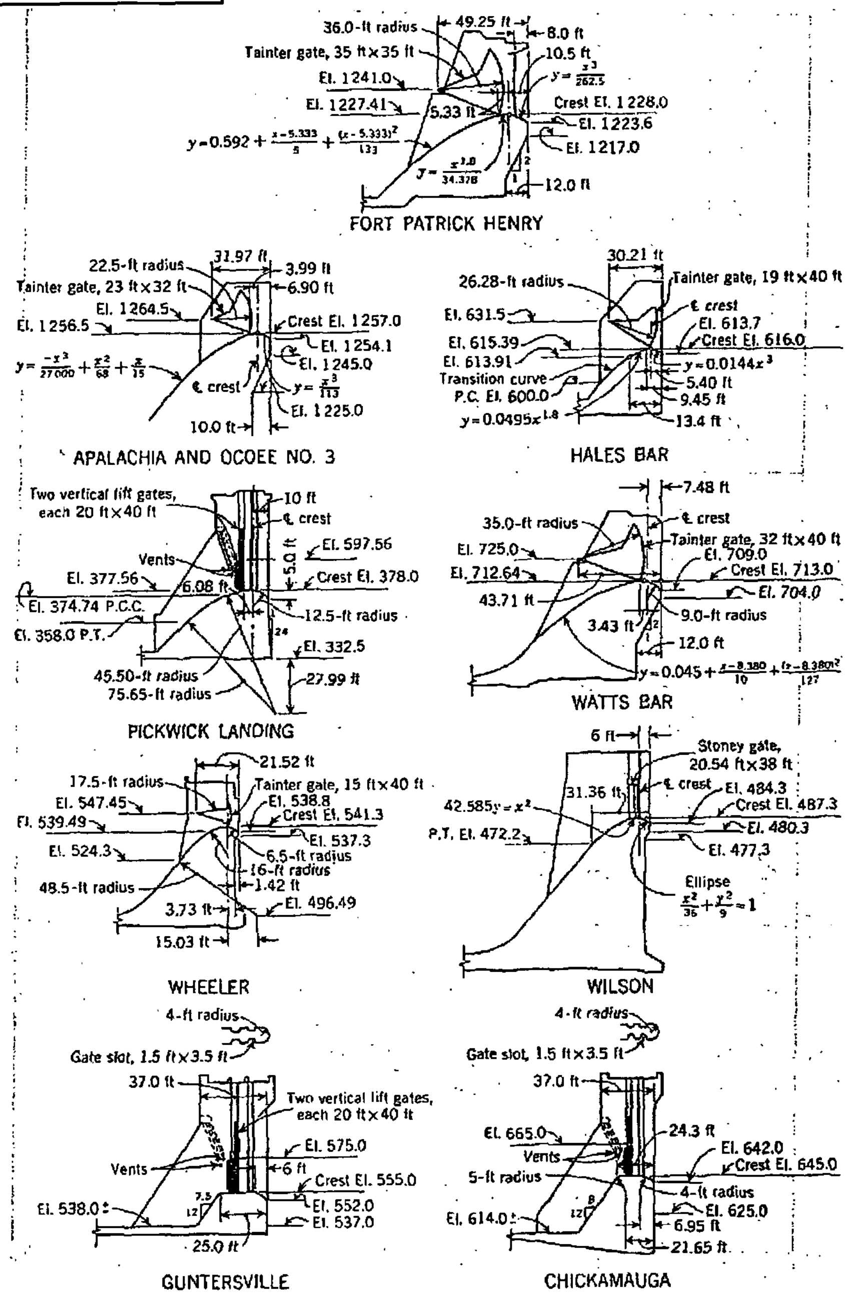


Fig. 2.—TVA Spillway Crests (Data in Fig. 3)

Attachment A6-3

Source: Reference A3

Calculation No: CDQ000020080020

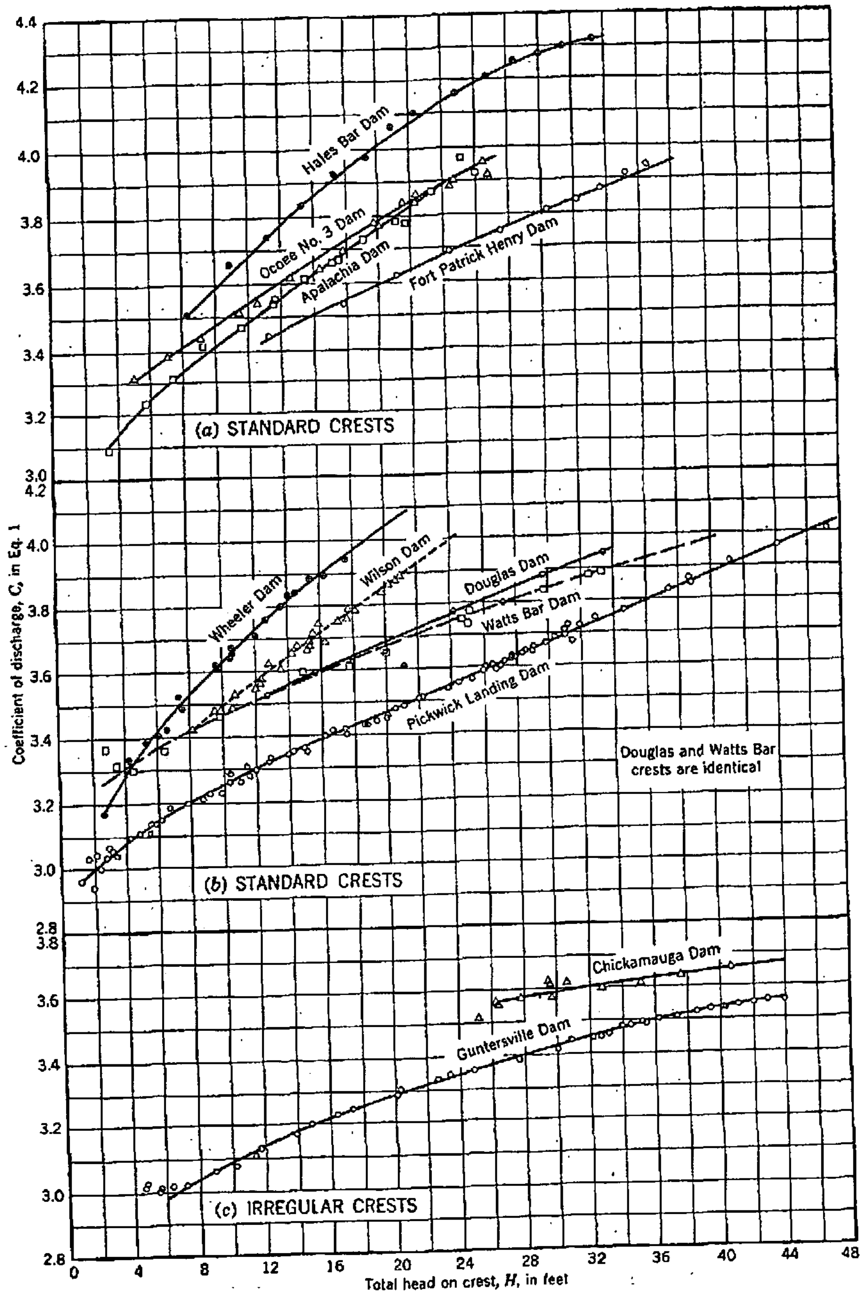


FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

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_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.

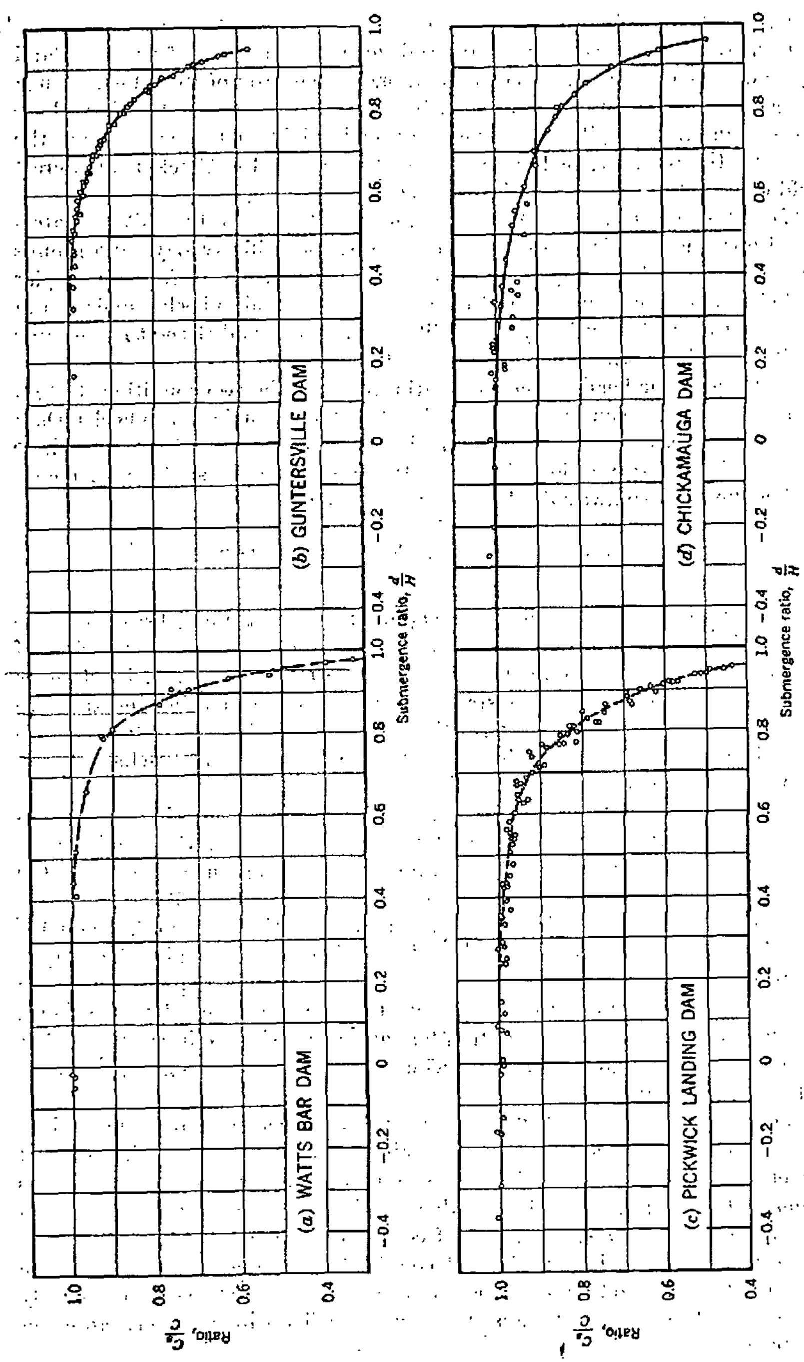


FIG. 7.—EFFECT OF SUBMERGENCE ON DISCHARGE COEFFICIENTS (C-VALUES FROM FIG. 3)

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.

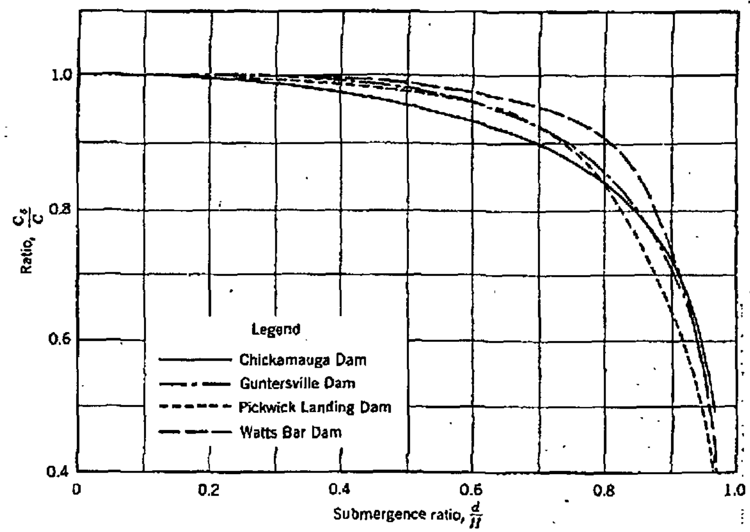


FIG. 8.—COMPARISON OF SUBMERGENCE EFFECTS FOR VARIOUS SPILLWAY CREST SHAPES

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.

Attachment A6-5

Source: Reference A3

Calculation No: CDQ000020080020

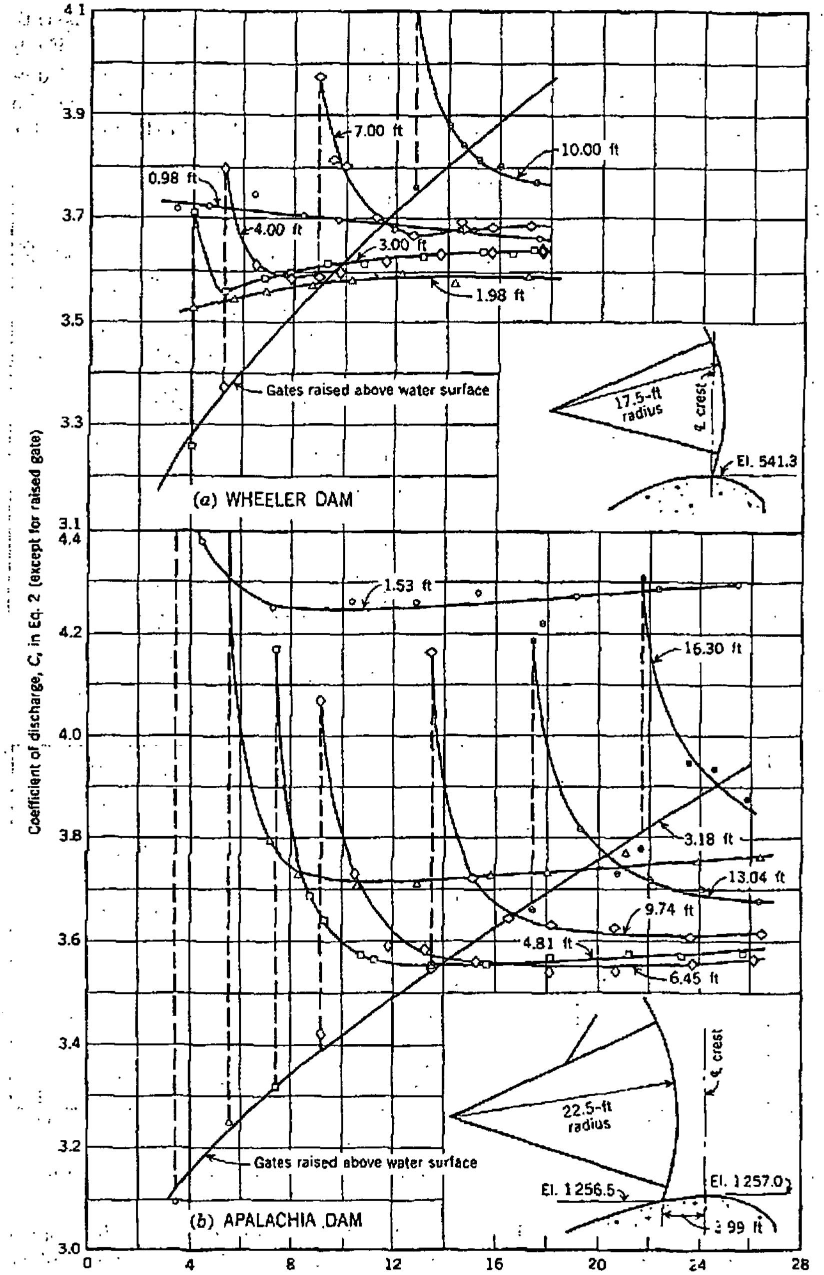


FIG. 12.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

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 coeffi-

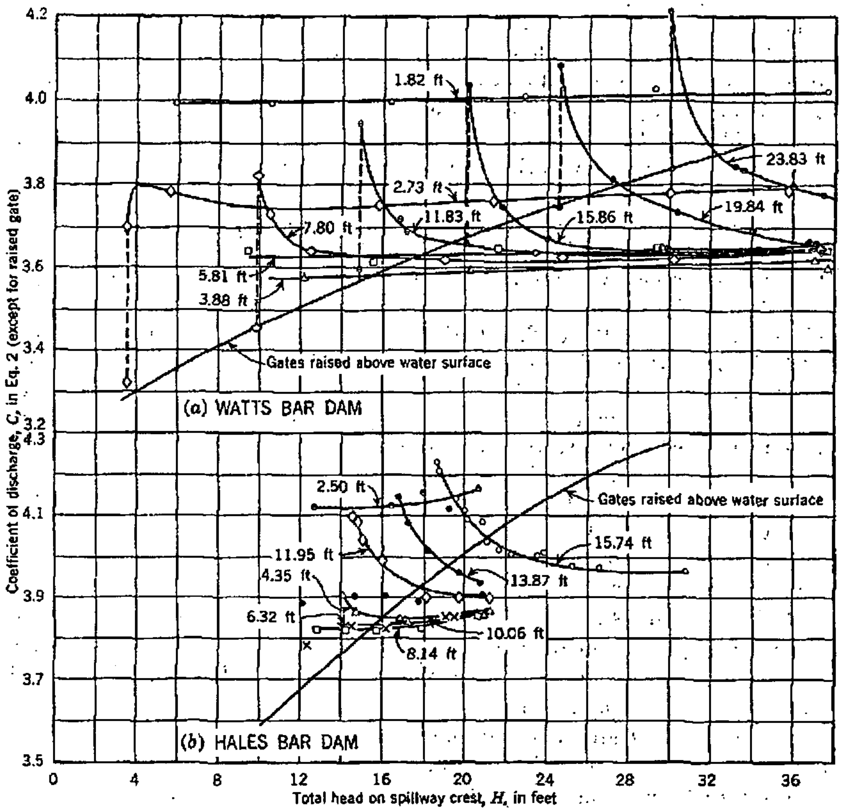


FIG. 13.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

cient 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.

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

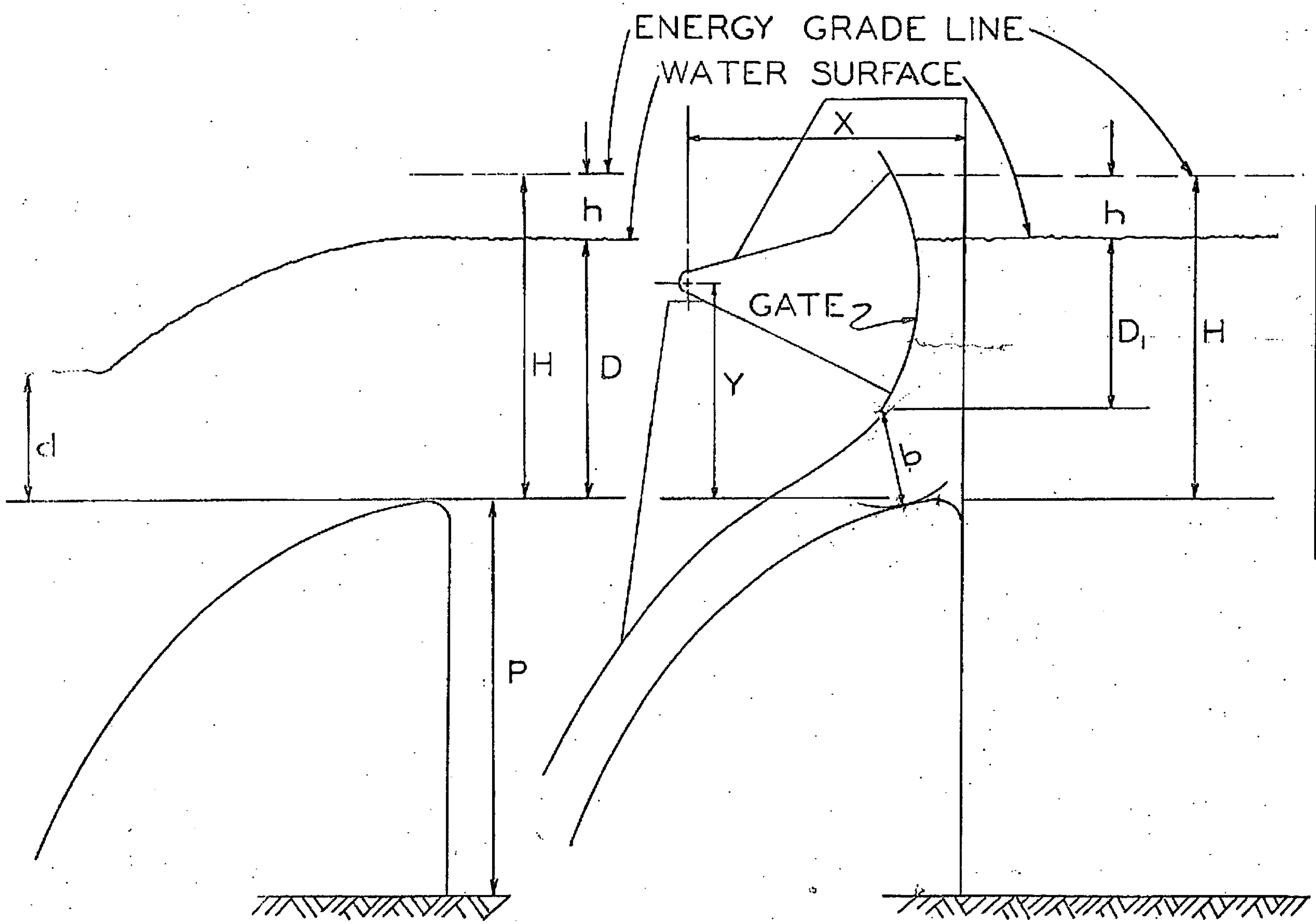
For flow under a gate:

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

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 I [b]

Attachment A7-3
Source: Reference A4

Calculation No: CDQ000020080020

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~~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 ft.	Q cfs	h ft.	H ft.	Q cfs	C
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

Attachment A8

Source: Reference A7

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,

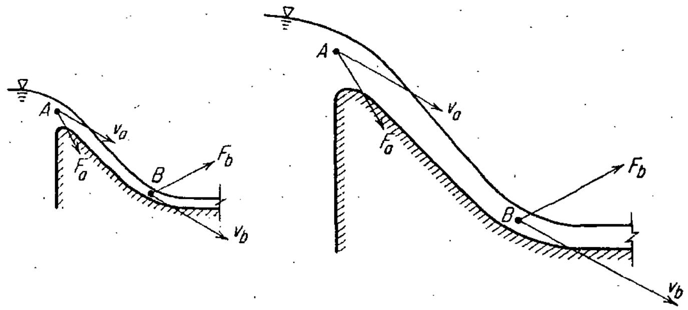


Figure 11-1. *Basic Model-Prototype Relationships*

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

Calculation No: CDQ000020080020

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

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

$\frac{Q_p}{Q_m}$ → Discharge

$$\left.\begin{array}{lll}
\text{Mass} & M_r & = \rho_r L_r^3 \\
\text{Length} & L_r & = L_r \\
\text{Velocity} & v_r & = L_r^{1/2} \\
\text{Time} & T_r = L_r v_r^{-1} & = L_r^{1/2} \\
\text{Discharge} & Q_r = v_r L_r^2 & = L_r^{2\frac{1}{2}} \\
\text{Force} & F_r = M_r L_r T_r^{-2} & = \rho_r L_r^3 \\
\text{Pressure} & p_r = F_r L_r^{-2} & = \rho_r L_r
\end{array}\right\} \tag{11-5}$$

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

Attachment A9-1

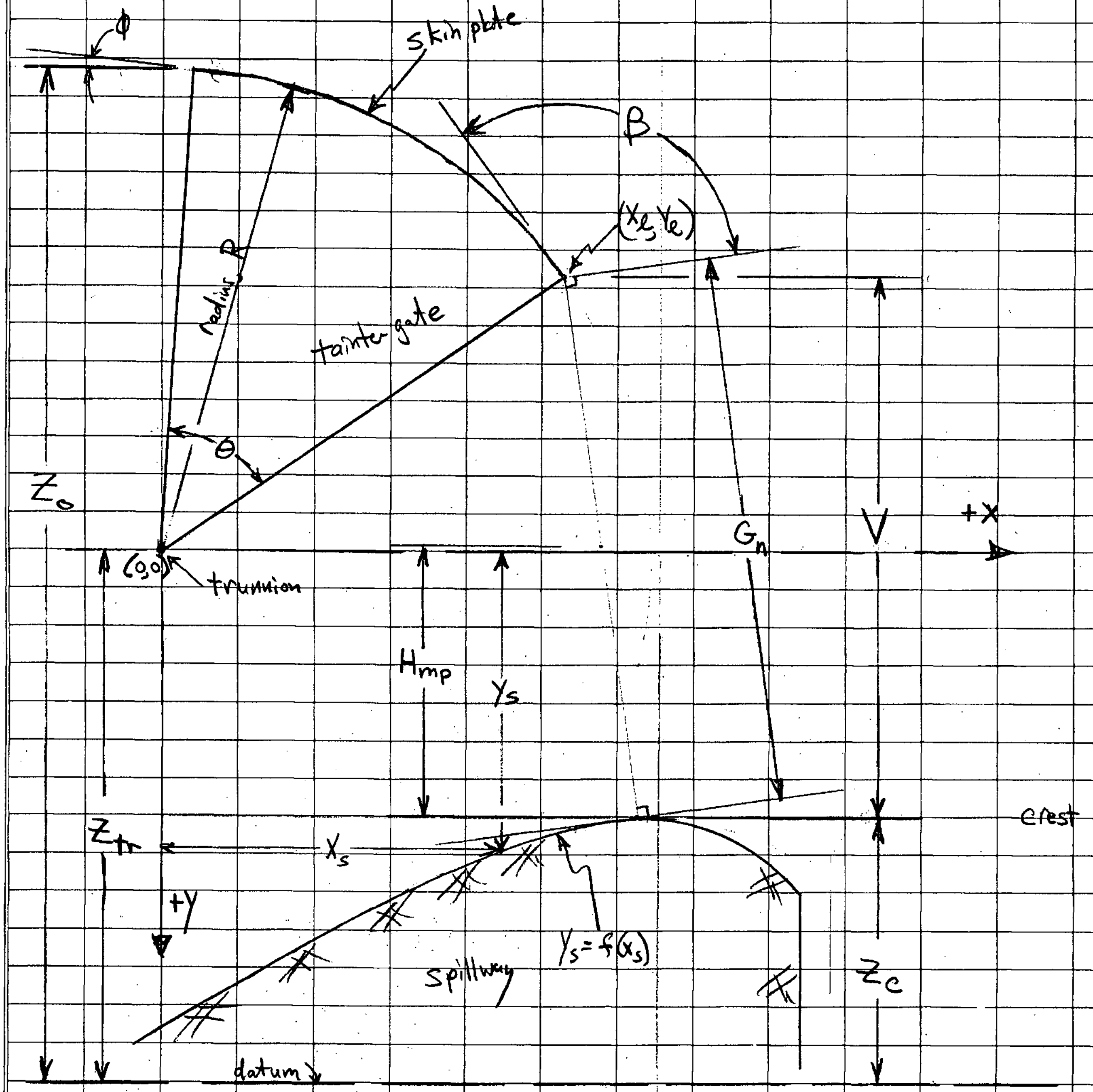
Spillway Discharge Calculations Geometry for Flow Under an Open Tainter Gate

Calculation No: CDQ000020080020

COMPUTED GAS DATE 8/11/2008

CHECKED ____ DATE ____

Definition Sketch



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_e, y_e = coordinates of the gate lip relative to trunnion axis

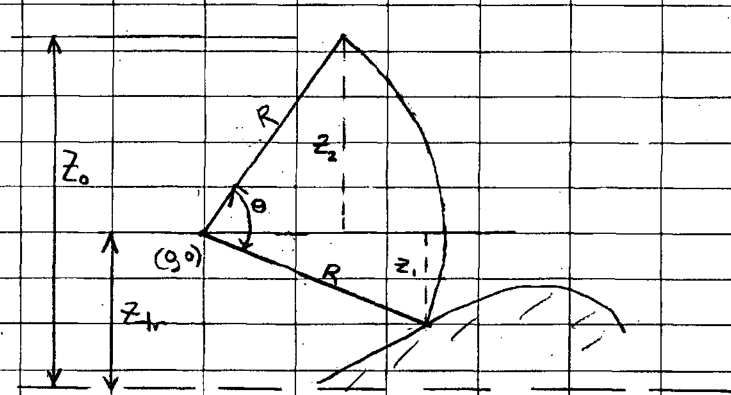
notes: { y positive downward for all coordinates; all coordinates relative to trunnion axis }

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

Spillway Gate Geometry

COMPUTED GAS DATE 8/11/2008

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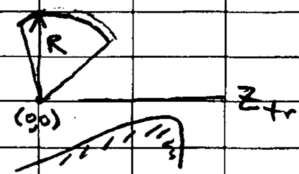
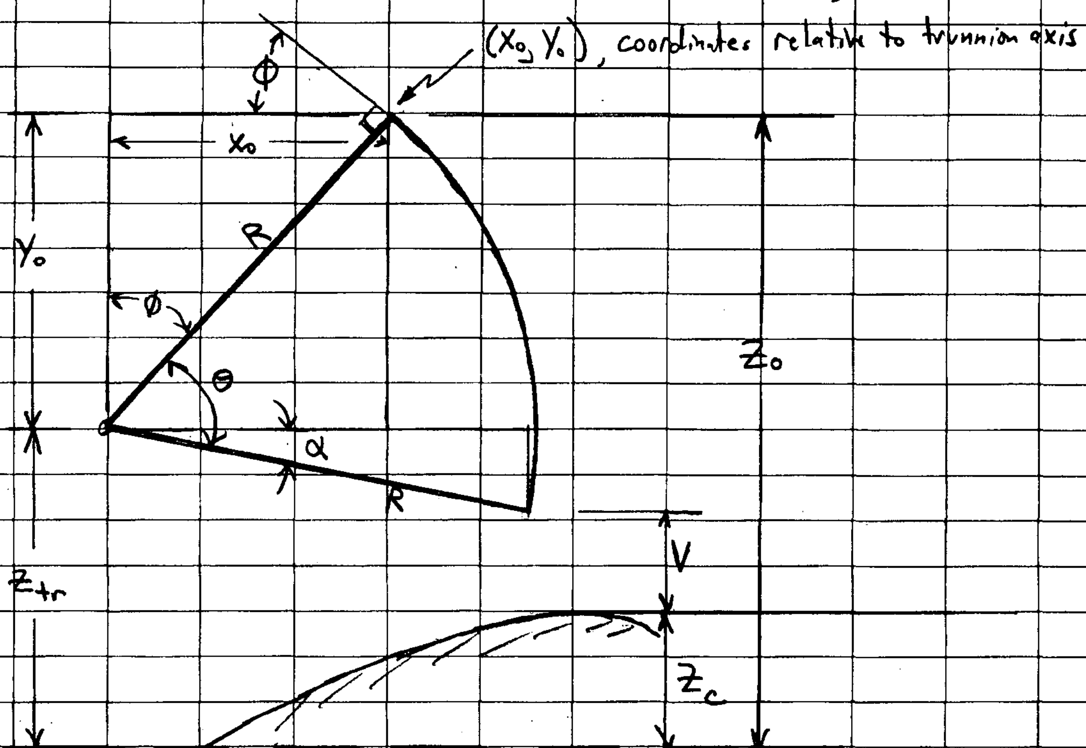
Overflow Elevation, Z_o and Angle, Φ

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 $\begin{cases} Y_o = Z_o - Z_{tr} \\ X_o = R\cos(\theta - \alpha) \end{cases}$

Spillway Gate Geometry

Gate Opening, G_n

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

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 $\frac{d\ell}{dX_s} = 0$

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

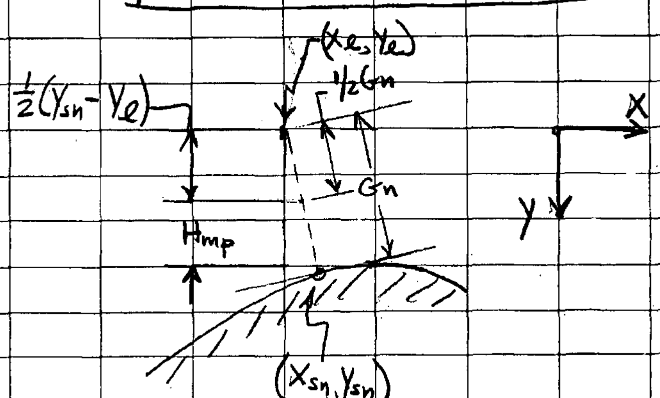
$$\Rightarrow 0 = \frac{(X_{sn} - X_\ell) + [f(X_{sn}) - Y_\ell]\frac{df(X_{sn})}{dX_s}}{\ell_{minimum}}$$

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

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

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

Mid-Point Head, H_{mp}



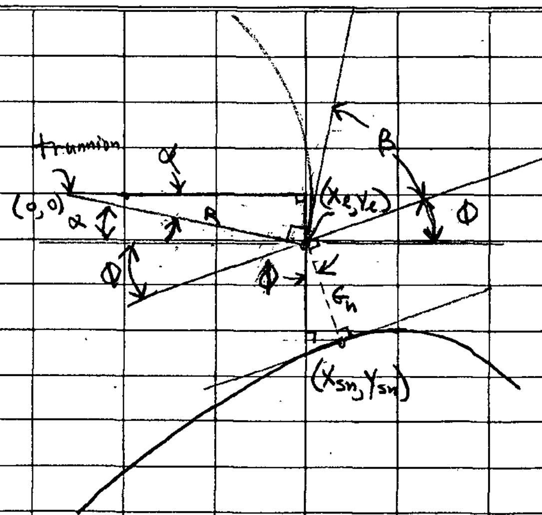
$$H_{mp} = Z_{tr} - Z_c - Y_\ell - \frac{1}{2}(Y_{sn} - Y_\ell)$$

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

Spillway Gate Geometry

COMPUTED GAS DATE
CHECKED DATE

Angle, B



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

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

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

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

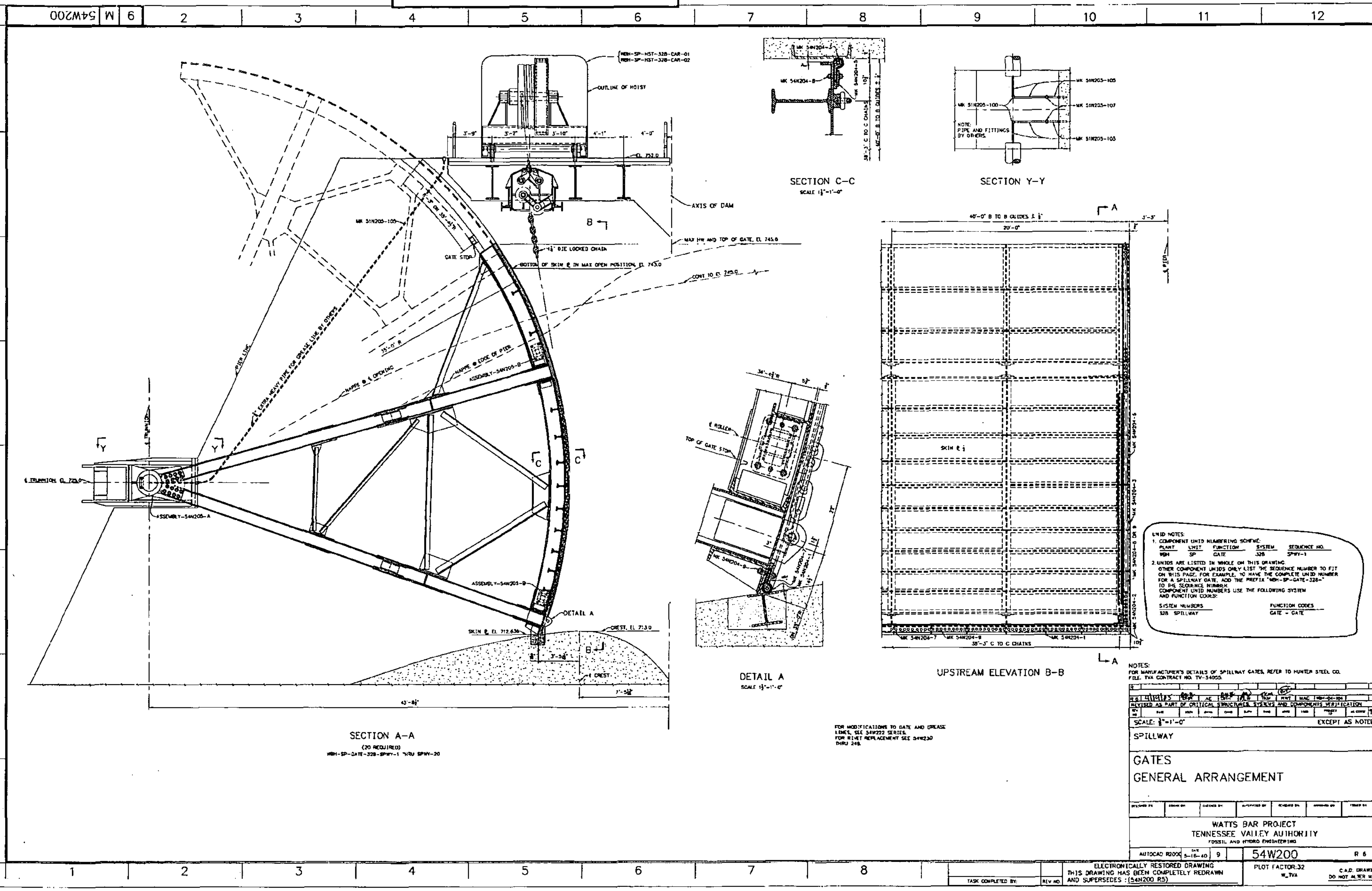
$$\phi = \tan^{-1}\left(\frac{X_{sn} - X_e}{Y_{sn} - Y_e}\right)$$

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

Attachment A10

Source: Reference A8

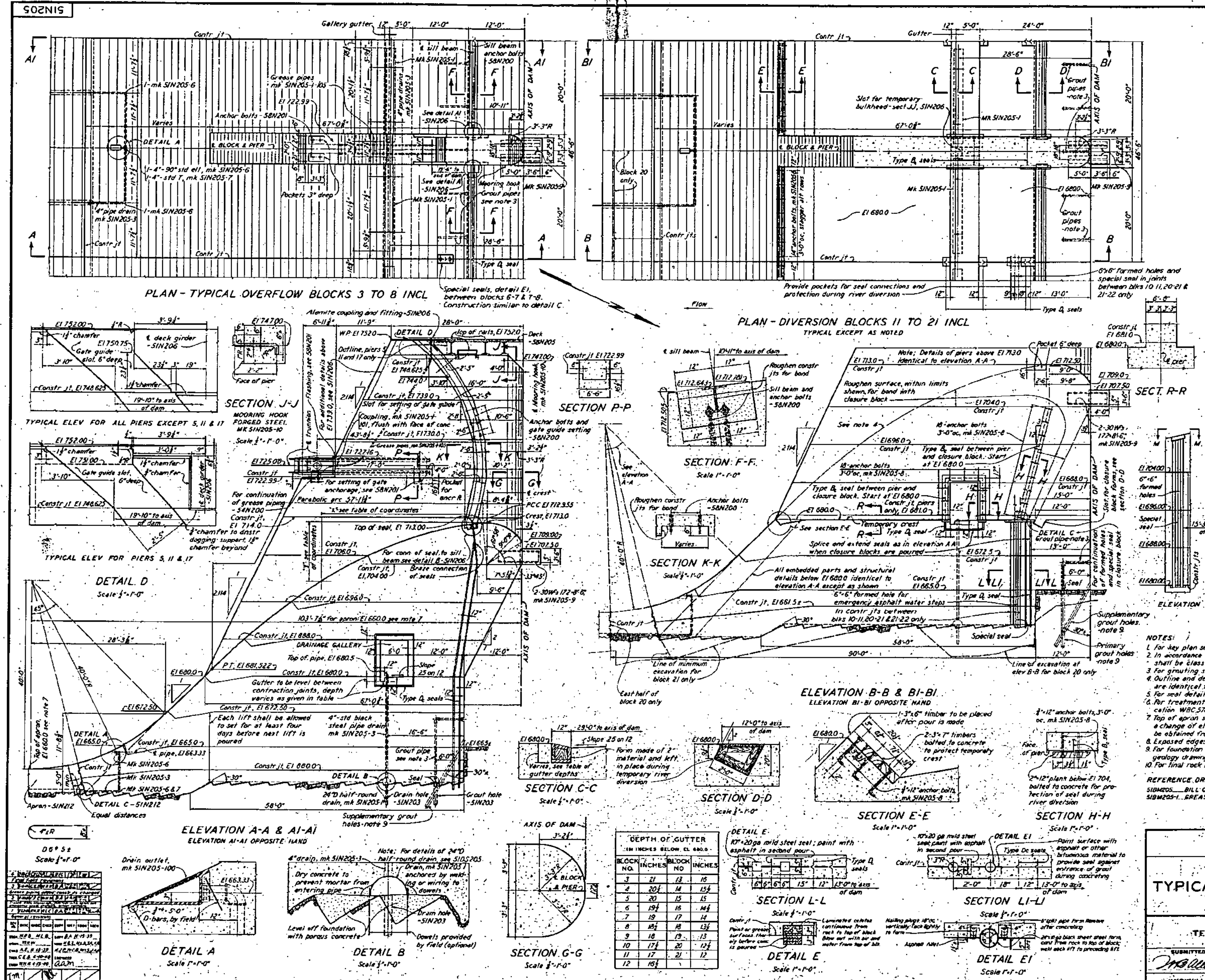
Calculation No: CDQ000020080020



Attachment A11

Source: Reference A9

Calculation No: CDQ000020080020



COORDINATES OF WEIR PROFILE			
$y = 0.045 + \frac{x - 8.380}{10} + \frac{(x - 8.380)^2}{127}$			
+ x	y	ELEV	DESCRIPTION
7.434	0.000	713.000	℄ of crest
8.380	0.045	712.955	PCC with 9'-0"R arc
9.924	0.219	712.781	Edge of sill beam slot
11.904	0.495	712.505	Edge of sill beam slot
14.000	0.856	712.144	
16.000	1.264	711.736	
18.000	1.736	711.264	
20.000	2.270	710.730	
22.000	2.858	710.132	
24.000	3.528	709.472	
26.000	4.252	708.748	
28.000	5.038	707.962	
30.000	5.887	707.113	
32.000	6.800	706.200	
32.420	7.000	706.000	Top of pour
34.000	7.775	705.225	
36.000	8.814	704.186	
38.000	9.915	703.085	
40.000	11.080	701.920	
42.000	12.307	700.693	
44.000	13.597	699.403	
46.000	14.951	698.049	
48.000	16.367	696.633	
48.866	17.000	696.000	Top of pour
50.000	17.847	695.153	
52.000	19.389	693.611	
54.000	20.994	692.006	
56.000	22.663	690.337	
58.000	24.394	688.606	
58.683	25.000	688.000	Top of pour
60.000	26.188	686.812	
62.000	28.046	684.954	
64.000	29.966	683.034	
65.530	31.478	681.522	PT with 1 on 1 slope
67.052	33.000	680.000	Top of pour

NOTES:

1. For key plan see 51N206
2. In accordance with Construction Specification G-2 concrete shall be class A in piers and exterior surfaces of weirs.
3. For grouting see instructions given on 51N203, note 5.
4. Outline and details of the wier closure block above El 680.00 are identical to those shown on elevation A-A, except as noted.
5. For seal details and connections see 308510.
6. For treatment of contraction joints see Construction Specification WBC 570.
7. Top of apron shall be at El 660.00. If rock conditions make a change of elevation desirable, additional instructions shall be obtained from the Design Department.
8. Exposed edges to be chamfered 1½" except as noted.
9. For foundation treatment and grout cutoff, see field office geology drawing 9 GE 4 1K327.
10. For final rock lines see field office dwgs 51K817-1 to 19 inclusive.

REFERENCE DRAWINGS:

51BM205 — BILL OF MATERIAL
51BM205-1 — GREASE PIPING BILL OF MATERIAL

Scale ⅛"=1'-0"
Except as noted

DEPTH OF GUTTER (IN INCHES BELOW EL 680.0)			
BLOCK NO.	INCHES	BLOCK NO	INCHES
3	21	13	16
4	20½	14	15½
5	20	15	15
6	19½	16	14½
7	19	17	14
8	18½	18	13½
9	18	19	13
10	17½	20	12½
11	17	21	12
12	16½		

SPILLWAY DAM

CONCRETE
TYPICAL SPILLWAY BLOCKS
OUTLINE

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

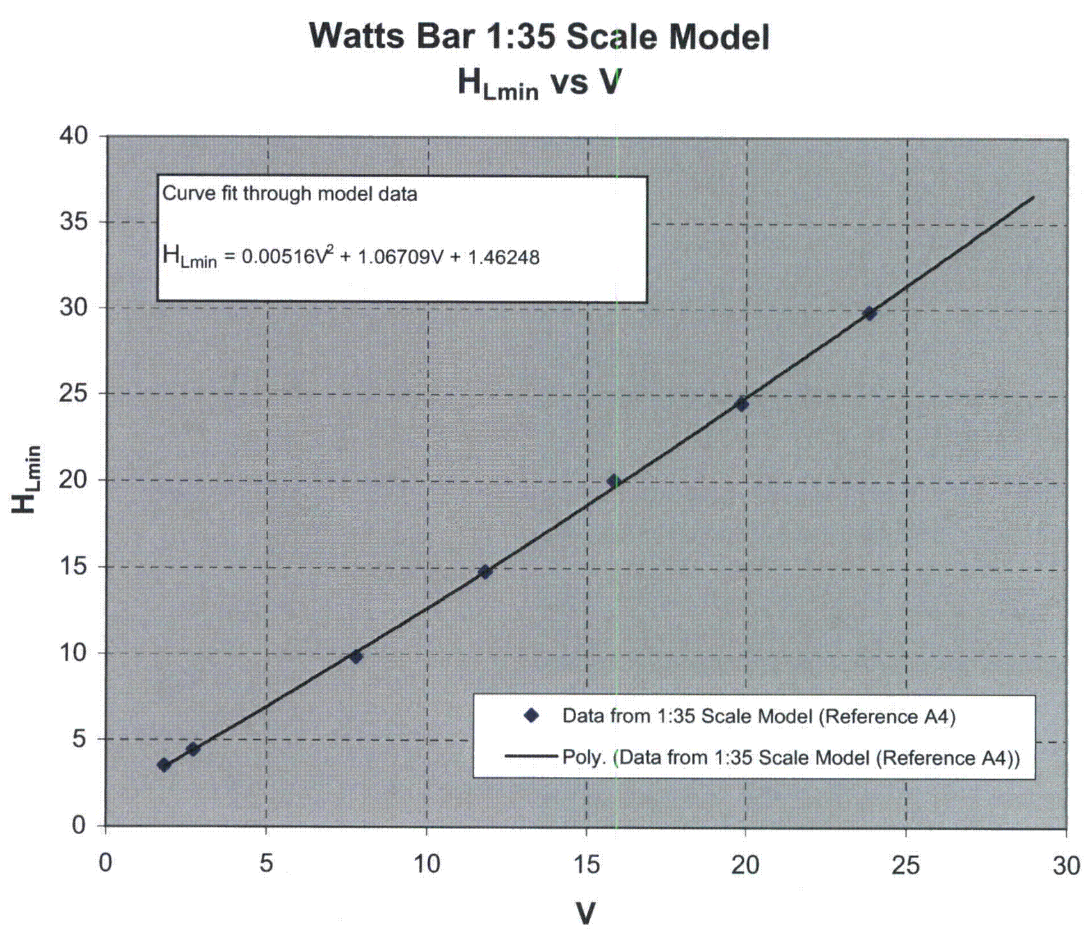
SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 11-15-39 | 9 | C | 4 | 51N205 R4

RECORD DRAWING AS CONSTRUCTED 6-1-43

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	
28.92		**36.64**	extrapolated using polynomial shown on plot



from: Watts Bar Model Data for Dam Ratings.xls, HLmin Determination

Watts Bar Project
Tainter Gates Raised Above the Water Surface
Data from 1:35 scale model (Reference A4)
(equivalent prototype)

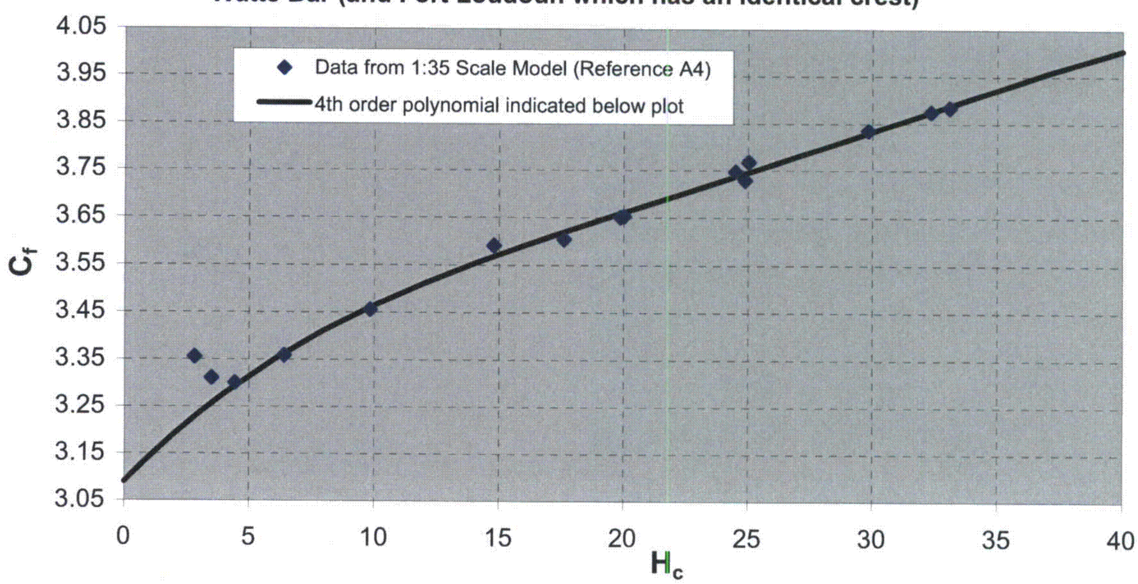
H_c ft.	Q cfs	C_f
2.82	3,819	3.36
3.50	5,211	3.31
4.44	7,421	3.30
6.40	13,070	3.36
9.84	25,640	3.46
14.80	49,140	3.59
17.61	64,010	3.60
19.88	77,760	3.65
20.02	78,630	3.65
24.50	109,200	3.75
24.88	111,200	3.73
25.02	113,300	3.77
29.82	150,100	3.84
32.34	171,300	3.88
33.08	177,600	3.88

Definition: $C_f = Q/(35*6.866*H_c^{1.5})$

4th-order curve fit (see plot)

H_c ft.	C_f
0	3.090
0.25	3.104
0.5	3.117
0.75	3.130
1	3.143
2	3.191
3	3.236
4	3.277
6	3.350
8	3.412
10	3.465
12	3.512
14	3.554
16	3.591
19	3.644
22	3.695
25	3.746
28	3.798
31	3.851
34	3.905
37	3.958
40	4.005

Free Discharge Coefficient, $C_f(H_c)$
Watts Bar (and Fort Loudoun which has an identical crest)



$C_f = -5.5070x10^{-7}H_c^4 + 5.9044x^{-5}H_c^3 - .0022844H_c^2 + .055033H_c + 3.09$

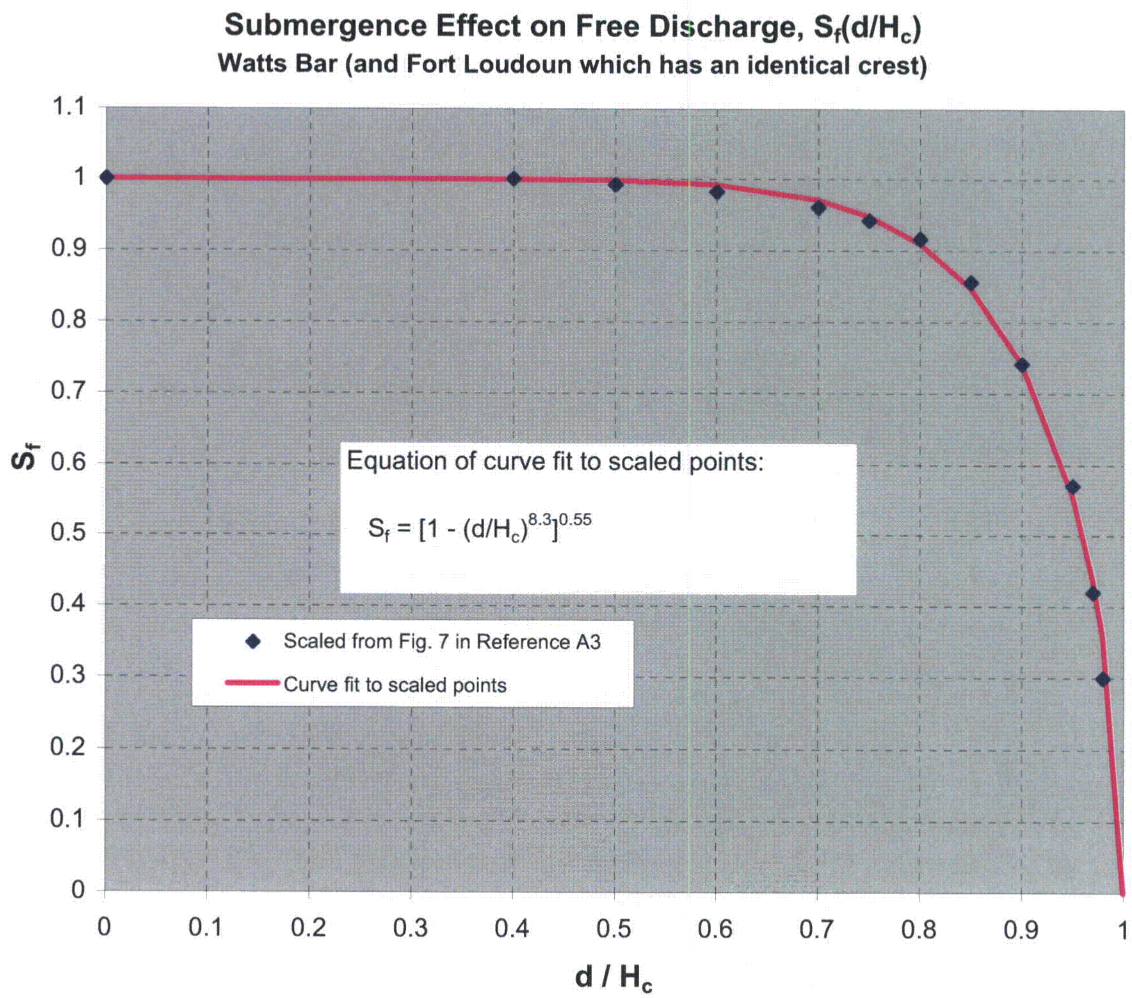
from: Watts Bar Model Data for Dam Ratings.xls, Free Discharge

Attachment A14

Calculation No: CDQ000020080020

Data Scaled from plot of Cs/C vs d/H in Reference A3

d / H_c	S_f	Curve fit to S_f	exponents (see chart)
0	1.000	1.000	8.3
0.4	1.000	1.000	0.55
0.5	0.992	0.998	
0.6	0.982	0.992	
0.7	0.961	0.971	
0.75	0.943	0.948	
0.8	0.917	0.910	
0.85	0.856	0.848	
0.9	0.742	0.743	
0.95	0.571	0.558	
0.97	0.420	0.439	
0.98	0.300	0.358	
1		0.000	



from: Watts Bar Model Data for Dam Ratings.xls, Free Discharge

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 $35*L_{model}$

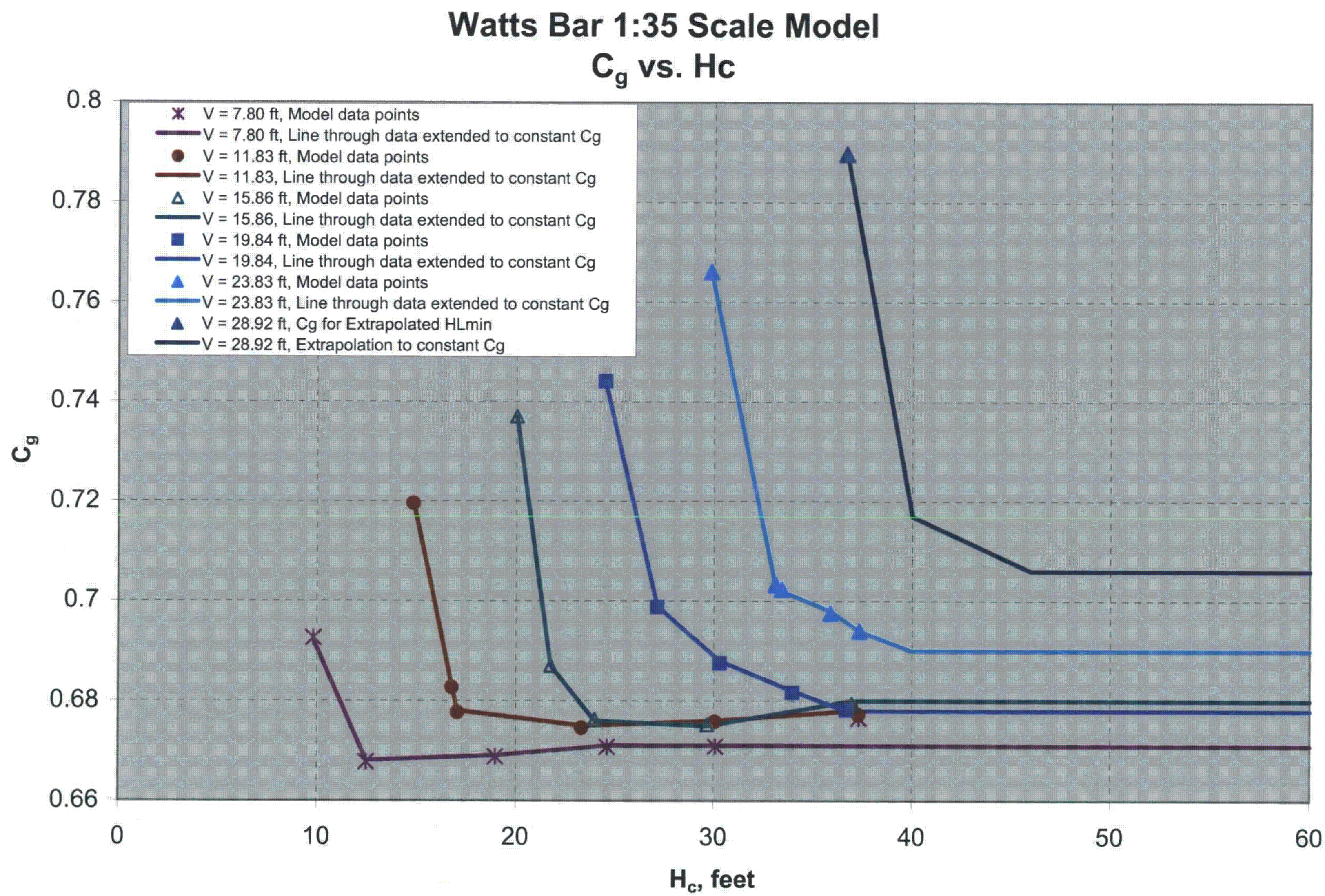
Definition: $C_g = Q / \{G_n*L*sqrt[2*g*(H_c-H_{mp})]\}$

	Model Test Data In Prototype Dimensions			Geometry			
	V	H_c	Q	G_n	H_{mp}	C_g	C_g 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)
$H_c=H_{Lmin}$	28.92	36.64	210600	29.305	14.371	0.790	0.790
	28.92	40					0.717 (1)
	28.92	46					0.706 (1)
	28.92	60					0.706 (1)

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

Attachment A16

Calculation No: CDQ000020080020



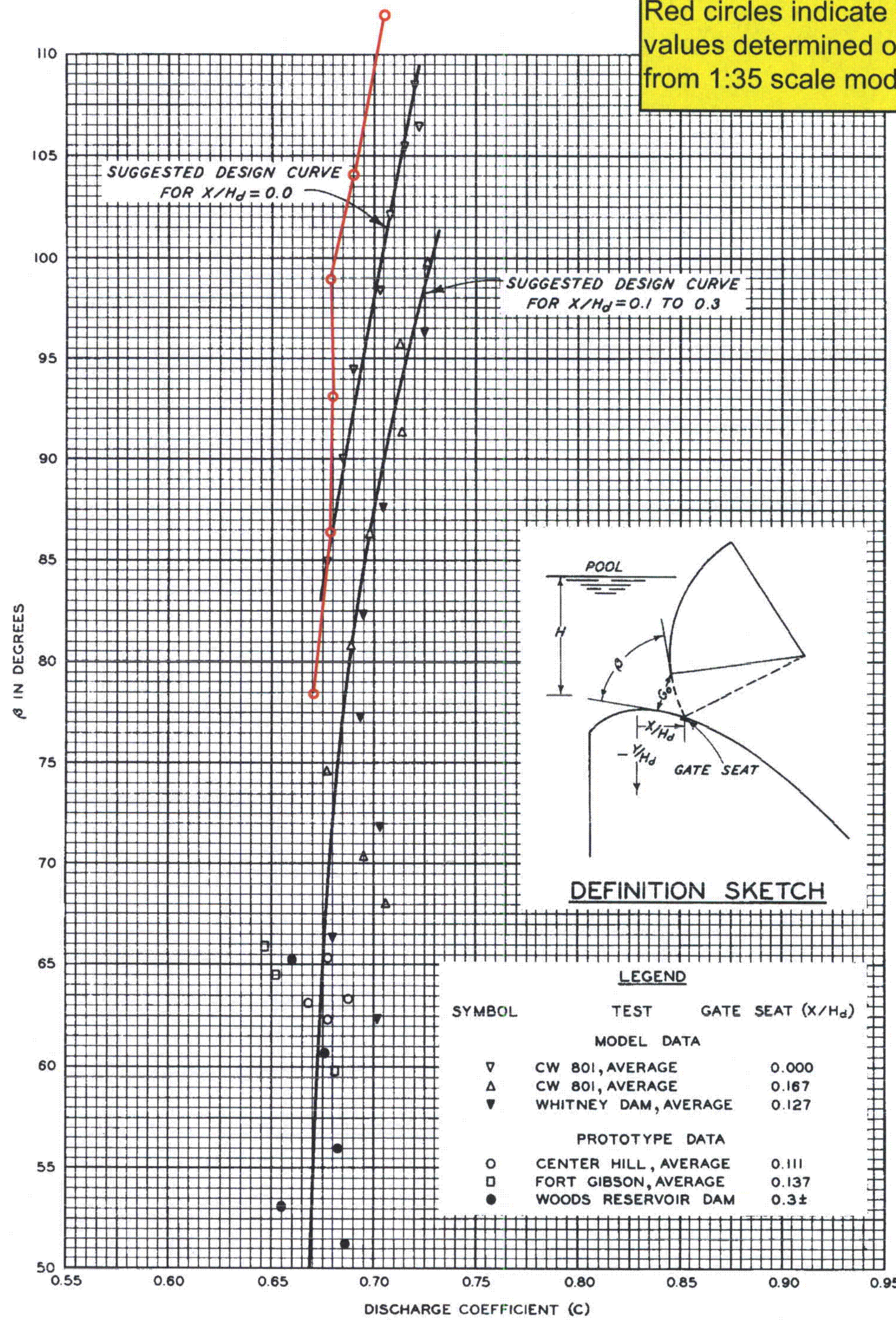
from: Watts Bar Model Data for Dam Ratings.xls, Cg vs. Hc-HLmin

Calculation No: CDQ000020080020

Attachment A17

Source: Reference A5

Red circles indicate Watts Bar 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

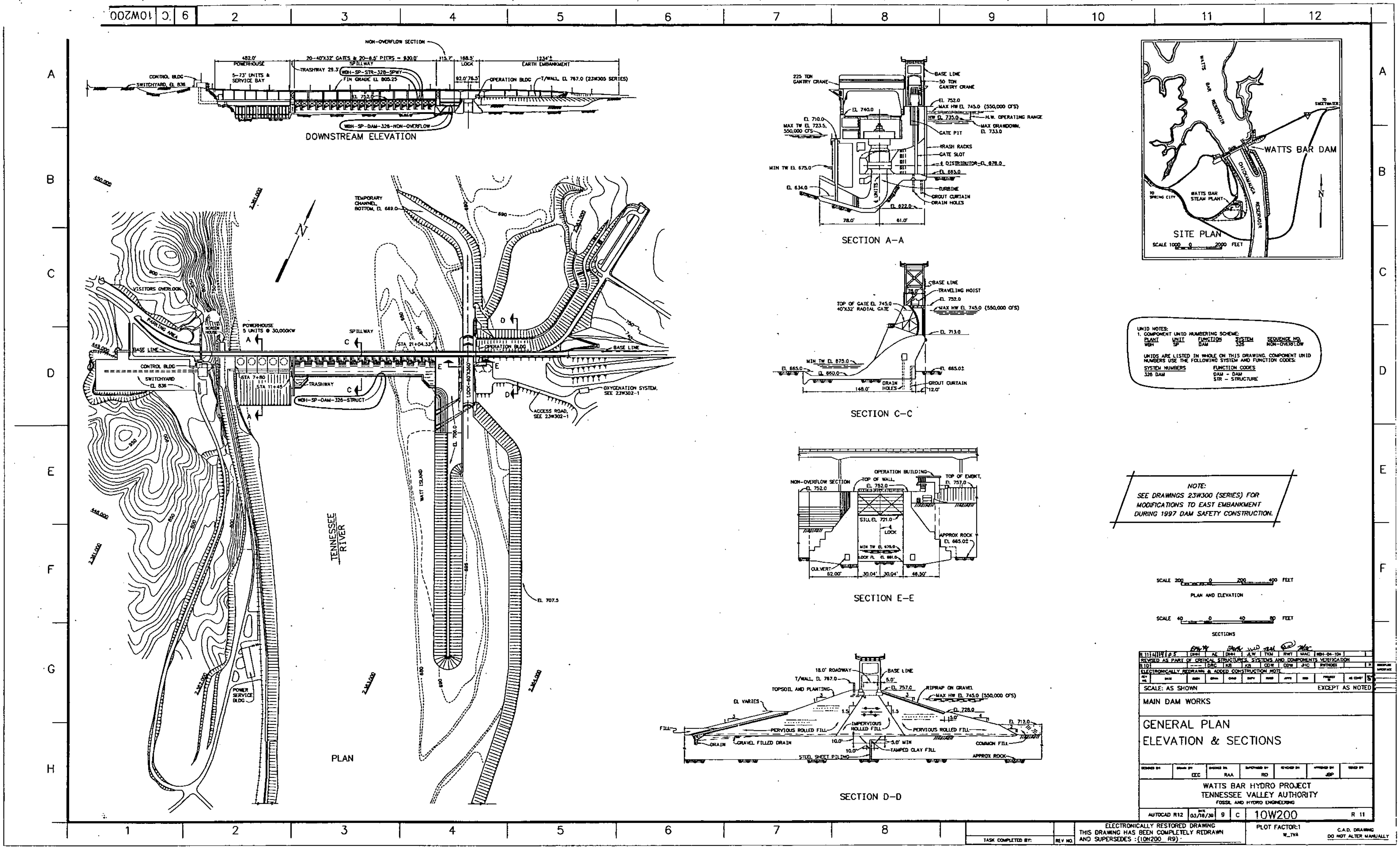
H = HEAD TO CENTER OF GATE OPENING

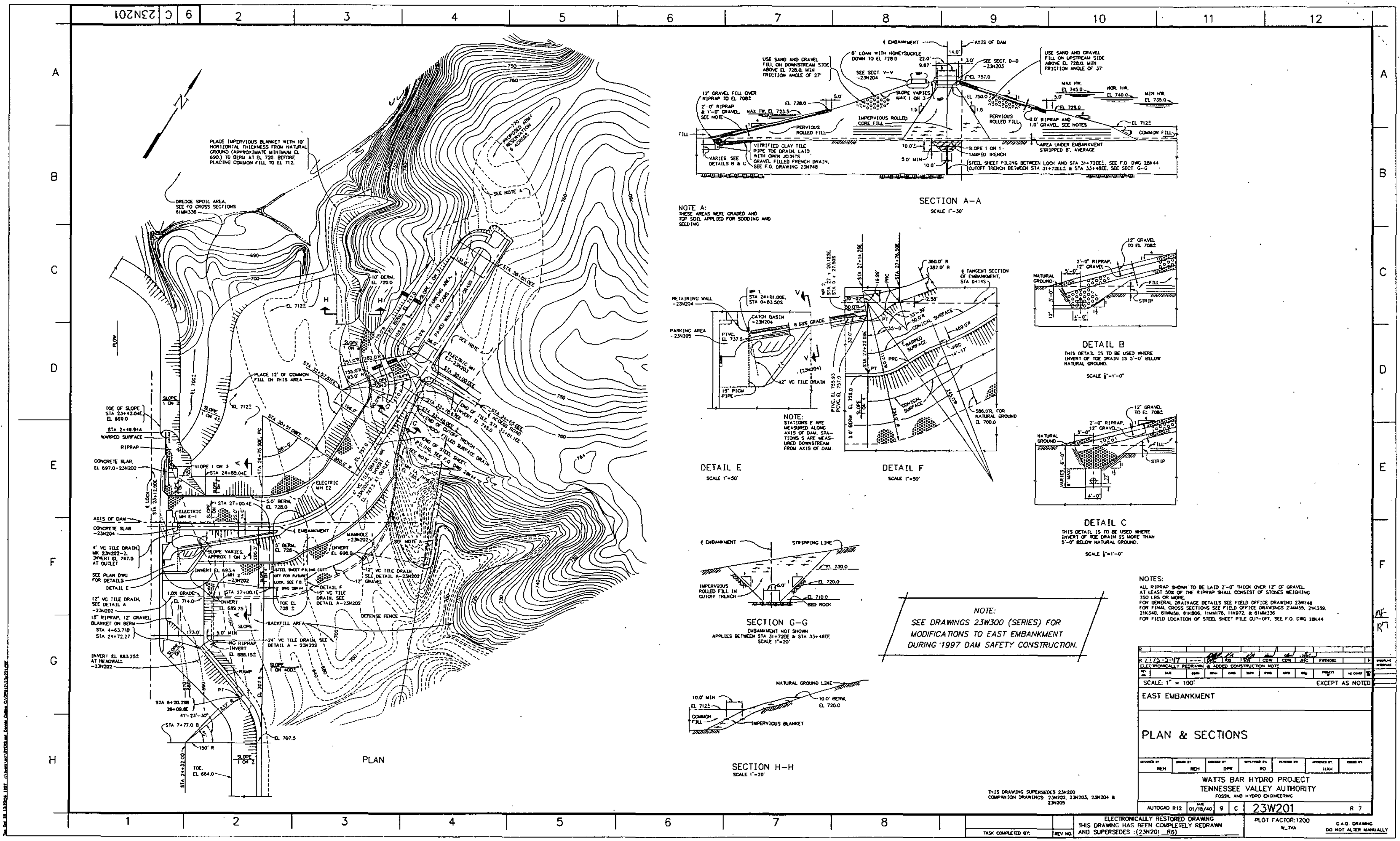
TAINTER GATES ON SPILLWAY CRESTS

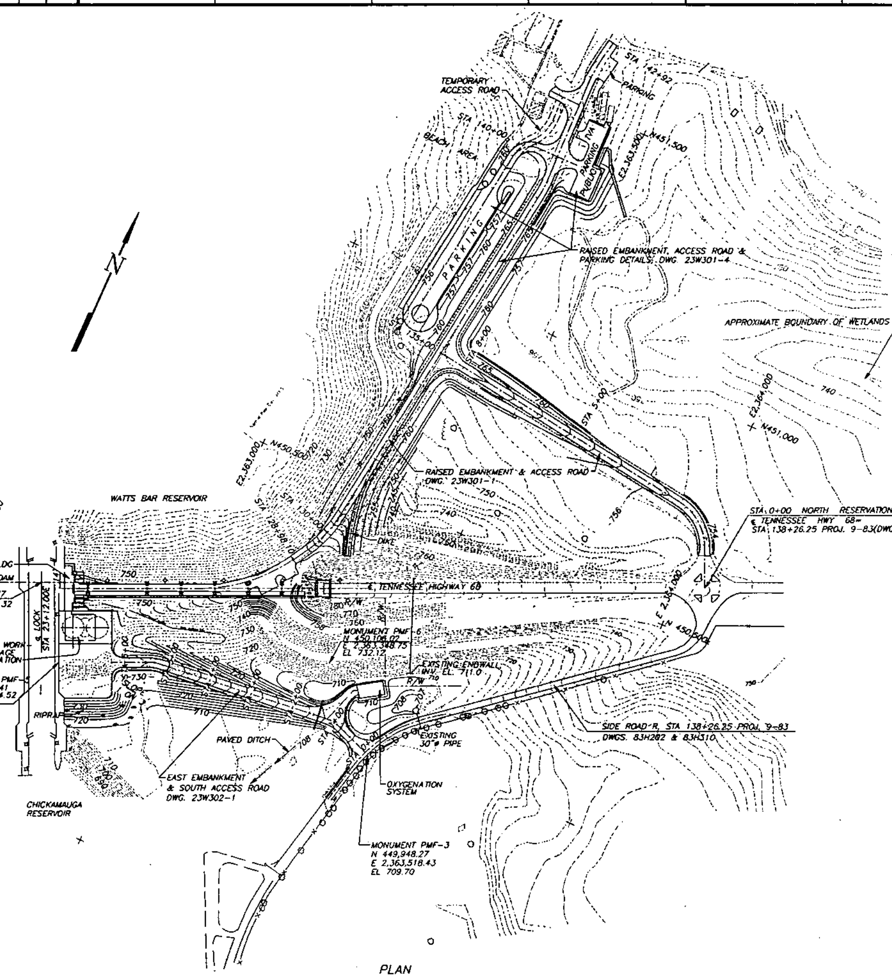
DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 311-1

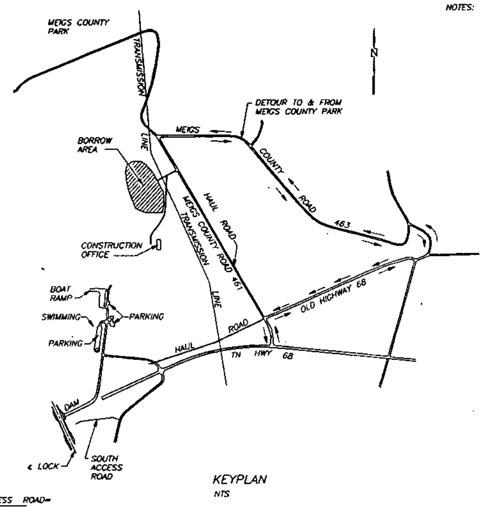
WES 3-56


DOWNSTREAM ELEVATION
NON-OVERFLOW SECTION
POWERHOUSE
5-73' UNITS & SERVICE BAY
SPILLWAY
20-40'X32' GATES & 20-6.5' PIERS = 930.0'
LOCK
EARTH EMBANKMENT
CONTROL BLDG
SWITCHYARD, EL 836
TRASHWAY
OPERATION BLDG
WBH-SP-STR-326-SPWY
WBH-SP-DAM-326-NON-OVERFLOW
PLAN
TENNESSEE RIVER
WATT ISLAND
VISITORS OVERLOOK
PARKING AREA
POWERHOUSE 5 UNITS @ 30,000KW
BASE LINE
WBH-SP-DAM-326-STRUCT
OXYGENATION SYSTEM, SEE 23W302-1
ACCESS ROAD, SEE 23W302-1
POWER SERVICE BLDG
TEMPORARY CHANNEL BOTTOM, EL 669.0
EL 707.5
SECTION A-A
SECTION C-C
SECTION E-E
SECTION D-D
SITE PLAN
WATTS BAR DAM
WATTS BAR STEAM PLANT
WATTS BAR RESERVOIR
CHICKAMAUGA RESERVOIR
UNID NOTES:
1. COMPONENT UNID NUMBERING SCHEME:
UNIDS ARE LISTED IN WHOLE ON THIS DRAWING. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:
NOTE:
SEE DRAWINGS 23W300 (SERIES) FOR MODIFICATIONS TO EAST EMBANKMENT DURING 1997 DAM SAFETY CONSTRUCTION.
SCALE 200 0 200 400 FEET
PLAN AND ELEVATION
SCALE 40 0 40 80 FEET
SECTIONS
REVISED AS PART OF CRITICAL STRUCTURES, SYSTEMS AND COMPONENTS VERIFICATION
ELECTRONICALLY REDRAWN & ADDED CONSTRUCTION NOTE
SCALE: AS SHOWN
EXCEPT AS NOTED
MAIN DAM WORKS
GENERAL PLAN
ELEVATION & SECTIONS
WATTS BAR HYDRO PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING
AUTOCAD R12
9
C
10W200
R 11
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(10N200 R9)
PLOT FACTOR:1
C.A.D. DRAWING
DO NOT ALTER MANUALLY


PLAN
SECTION A-A
SCALE 1"=30'
NOTE A:
THESE AREAS WERE GRADED AND TOP SOIL APPLIED FOR SODDING AND SEEDING
DETAIL E
SCALE 1"=50'
DETAIL F
SCALE 1"=50'
DETAIL B
THIS DETAIL IS TO BE USED WHERE INVERT OF TOE DRAIN IS 5'-0" BELOW NATURAL GROUND.
DETAIL C
THIS DETAIL IS TO BE USED WHERE INVERT OF TOE DRAIN IS MORE THAN 5'-0" BELOW NATURAL GROUND.
SECTION G-G
EMBANKMENT NOT SHOWN
APPLIES BETWEEN STA 31+72EE & STA 33+48EE
SCALE 1"=20'
SECTION H-H
SCALE 1"=20'
NOTE:
SEE DRAWINGS 23W300 (SERIES) FOR MODIFICATIONS TO EAST EMBANKMENT DURING 1997 DAM SAFETY CONSTRUCTION.
NOTES:
ALL RIPRAP SHOWN TO BE LAID 2'-0" THICK OVER 12" OF GRAVEL.
AT LEAST 50% OF THE RIPRAP SHALL CONSIST OF STONES WEIGHING 350 LBS OR MORE.
FOR GENERAL DRAINAGE DETAILS SEE FIELD OFFICE DRAWING 23N748
FOR FINAL CROSS SECTIONS SEE FIELD OFFICE DRAWINGS 21MM55, 21K339, 21K340, 61MM58, 61K806, 11MM178, 11K972, & 61MM336
FOR FIELD LOCATION OF STEEL SHEET PILE CUT-OFF, SEE F.O. DWG 28K44
THIS DRAWING SUPERSEDES 23N200
COMPANION DRAWINGS: 23N202, 23N203, 23N204 & 23N205
ELECTRONICALLY REDRAWN & ADDED CONSTRUCTION NOTE
SCALE: 1" = 100' EXCEPT AS NOTED
EAST EMBANKMENT
PLAN & SECTIONS
REH REH DPR RO HAH
WATTS BAR HYDRO PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING
AUTOCAD R12 01/18/40 9 C 23W201 R 7
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23N201 R6)
PLOT FACTOR:1200
W_TVA
C.A.D. DRAWING
DO NOT ALTER MANUALLY



PLAN



KEYPLAN

NTS

CONCRETE NOTES:

1. ALL CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF ACI 301- (LATEST REVISION) SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS, EXCEPT AS MODIFIED BY THE SUPPLEMENTAL REQUIREMENTS THAT FOLLOW.
2. UNLESS OTHERWISE NOTED, CONCRETE COMPRESSIVE STRENGTH SHALL BE 3000 PSI AT 28 DAYS. STRENGTH SHALL BE VERIFIED BY CYLINDER TESTS. CONCRETE SHALL BE SAMPLED FOR STRENGTH TESTING AT A MAXIMUM RATE OF ONE SET OF CYLINDERS FOR EVERY 50 CUBIC YARDS OR ON A DAILY BASIS, WHICHEVER IS MORE FREQUENT. 2 CYLINDERS SHALL BE BROKEN AT 3 DAYS, 2 CYLINDERS AT 7 DAYS, AND 2 CYLINDERS AT 28 DAYS.
3. READY-MIXED CONCRETE SHALL CONFORM TO CE-SPEC-96.06.10, READY-MIXED CONCRETE. THE READY-MIX SUPPLIER IS RESPONSIBLE FOR THE MIX DESIGN. THE MIX DESIGN SHALL BE SUBMITTED TO HYDRO ENGINEERING FOR APPROVAL PRIOR TO THE AWARDING OF THE CONTRACT.
4. AGGREGATE FOR CONCRETE SHALL CONFORM TO ASTM C-33 WITH A MAXIMUM SIZE OF 3/4". CEMENT SHALL CONFORM TO ASTM C-150, TYPE I OR TYPE II. A WATER REDUCING AGENT CONFORMING TO ASTM C-194 SHALL BE USED. AIR ENTRAINMENT OF CONCRETE SHALL BE BETWEEN 4% AND 7% BY VOLUME. ADMIXTURES USED FOR AIR ENTRAINMENT SHALL CONFORM TO ASTM C-260. THE MIX SHALL INCLUDE FLYASH CONFORMING TO ASTM C-618. SLUMP AT POINT OF DISCHARGE SHALL BE BETWEEN 2.0 INCHES AND 4.0 INCHES.
5. CONCRETE TEMPERATURE AT DISCHARGE SHALL BE BETWEEN 50 AND 85 DEGREES FAHRENHEIT. CONCRETE NOT MEETING THESE REQUIREMENTS WILL NOT BE ACCEPTABLE. CONCRETE PLACEMENT SHALL CEASE IF THE AIR TEMPERATURE IS 38 DEGREES AND FALLING. PLACEMENT MAY RESUME WHEN THE AIR TEMPERATURE IS 40 DEGREES AND RISING. CONCRETE SHALL BE MAINTAINED AT A TEMPERATURE GREATER THAN 50 DEGREES FOR THE FIRST THREE DAYS FOLLOWING PLACEMENT AND PROTECTED ABOVE FREEZING FOR AN ADDITIONAL 3 DAYS. HEATED PROTECTIVE SHELTERS MAY BE CONSTRUCTED TO ENCLOSE THE AREAS TO BE PLACED. THESE SHELTERS SHALL BE CONSTRUCTED IN ADVANCE OF PLACEMENT AND HEAT APPLIED TO BRING THE FORMWORK AND STEEL TO A MINIMUM OF 50 DEGREES. COMBUSTIVE HEAT SHALL NOT BE USED.
6. FOR CONTINUOUS VERTICAL PLACEMENT OF CONCRETE, THE RATE OF PLACEMENT WILL BE DETERMINED BY WEATHER CONDITIONS, CONCRETE TEMPERATURE PRIOR TO PLACING, AND PRESSURE CAPACITY OF FORMWORK. CARE SHALL BE TAKEN SO AS TO NOT SEGREGATE CONCRETE MIX DURING PLACEMENT.
7. CONCRETE SHALL BE PROTECTED FROM MOISTURE LOSS FOR A MINIMUM OF 14 DAYS BY EITHER KEEPING FORMWORK AND SURFACES WET OR APPLYING A CURING COMPOUND. CURING COMPOUNDS SHALL NOT BE APPLIED TO HORIZONTAL LIFT JOINTS WHICH ARE TO RECEIVE ADDITIONAL LIFTS. CURING COMPOUNDS SHALL CONFORM TO ASTM C-309.
8. CONCRETE FORMWORK SHALL REMAIN IN PLACE FOR A MINIMUM OF 24 HOURS FOLLOWING PLACEMENT. A MINIMUM OF 3 DAYS SHALL ELAPSE BEFORE PLACING ADDITIONAL LIFTS OR ADJACENT BLOCKS.
9. STEEL REINFORCEMENT SHALL MEET THE REQUIREMENTS OF ASTM A-615. REINFORCEMENT SHALL BE DEFORMED WITH A YIELD STRENGTH OF 60,000 PSI. WELDED WIRE FABRIC SHALL MEET THE REQUIREMENTS OF ASTM A-497 WITH A YIELD STRENGTH OF 60,000 PSI.
10. ALL EXPOSED EDGES SHALL BE CHAMFERED 3/4" UNLESS INDICATED OTHERWISE. ALL EXPOSED SURFACES SHALL HAVE A CLASS II RUBBED FINISH PER TVA-T1 SECTION 400.29.
11. CLEAR COVER FOR REINFORCEMENT SHALL BE 3 INCHES WHERE CONCRETE IS CAST AGAINST EARTH AND 2 INCHES AT ALL OTHER LOCATIONS UNLESS OTHERWISE INDICATED. ALL OTHER DIMENSIONS ARE TO THE CENTERLINE OR END OF BAR.
12. GROUT SHALL BE FIVE STAR MIXED AND APPLIED PER MANUFACTURER'S INSTRUCTIONS, OR AN APPROVED EQUAL.

NOTES:

1. ALL EARTHWORK SHALL BE DONE IN ACCORDANCE WITH TVA GENERAL CONSTRUCTION SPECIFICATION G-9. REFERENCES TO SECTION NUMBERS ARE FOR TVA GENERAL CONSTRUCTION SPECIFICATION NO. T-1.
2. LIGHT DASHED CONTOURS INDICATE EXISTING GROUND. HEAVY SOLID CONTOURS INDICATE FINISHED GRADING AND PAVING UNLESS OTHERWISE INDICATED.
3. UNLESS OTHERWISE INDICATED, FOUNDATION PREPARATION FOR ALL EMBANKMENTS SHALL CONSIST OF REMOVING ORGANIC TOPSOIL TO A DEPTH THAT WILL REMOVE ALL ROOTS AND EXCAVATION SHALL CONTINUE TO A DEPTH THAT WILL OBTAIN A FOUNDATION THAT WILL SUPPORT EARTHMOVING EQUIPMENT WITHOUT RUTTING INTO THE GROUND AND HEAVING THE GROUND SO AS TO REDUCE ITS STABILITY. CLEARING AND GRUBBING SHALL BE IN ACCORDANCE WITH SECTION 101.
4. AT THE BEGINNING OF GRADING OPERATIONS, ALL TOPSOIL THAT IS IN ACCORD WITH SECTION 130 SHALL BE STOCKPILED FOR FUTURE USE IN FINISHED AREAS.
5. IMPERVIOUS EARTHFILL MATERIAL IS TO BE OBTAINED FROM THE DESIGNATED BORROW AREA OR AN OFFSITE BORROW AREA APPROVED BY THE ENGINEER. RANDOM EARTHFILL MAY BE OBTAINED FROM EXCAVATIONS REQUIRED ON DRAWINGS.
6. CAREFULLY CONTROLLED EARTHFILLS SHALL BE PLACED IN EIGHT INCH THICK LAYERS. EACH LAYER SHALL BE COMPACTED TO AT LEAST 95% OF MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D698. MOISTURE CONTENT SHALL BE WITHIN 3% ABOVE OR BELOW THE OPTIMUM MOISTURE CONTENT. IN-PLACE DENSITY TESTS USING THE SAND CONE (ASTM D1556) OR RUBBER BALLOON (ASTM D 2167) TEST METHODS SHALL BE CONDUCTED AT A RATE OF AT LEAST ONE TEST PER EACH 2000 CY EARTHFILL PLACED OR A MINIMUM OF ONE PER DAY THAT EARTHFILL IS PLACED. IF NUCLEAR DENSITY METHODS ARE USED (ASTM D 2922), SUFFICIENT NUMBERS OF THE SAND CONE OR RUBBER BALLOON TESTS WILL BE REQUIRED TO CORRELATE AND VERIFY THE NUCLEAR GAUGE RESULTS. ALL TEST RESULTS SHALL BE PROMPTLY SUBMITTED TO HYDRO ENGINEERING.
7. COMMON FILLS SHALL BE UNCLASSIFIED MATERIAL AND SHALL BE PLACED IN APPROXIMATELY 8 INCH LAYERS AND COMPACTED WITH HAULING EQUIPMENT.
8. EXCAVATION AND BACKFILL FOR THE PIPE CULVERTS SHALL CONFORM TO SECTION 125.
9. THE CONNECTION OF PIPE TO ENDWALLS SHALL BE NEAT AND SECURE. WHERE ENTIRE END OF PIPE DOES NOT EXTEND TO FRONT FACE OF ENDWALL, THE BARREL OF THE CULVERT SHALL BE EXTENDED WITH SMOOTH, RIGID, CIRCULAR FORMS EXACTLY FITTING THE INNER CIRCUMFERENCE OF THE PIPE. UNLESS INDICATED OTHERWISE, WHERE A PORTION OF PIPE EXTENDS BEYOND THE REQUIRED FRONT FACE OF THE ENDWALL, IT SHALL BE CUT OFF SMOOTH AND FLUSH THEREWITH.
10. RIPRAP SHALL CONFORM TO SECTION 575. 50 PERCENT OF THE STONES SHALL WEIGH 200 LBS. OR GREATER WITH WITH A MAXIMUM STONE WEIGHT OF 600 LBS. NOT MORE THAN 5 PERCENT OF THE STONES BY WEIGHT IS TO PASS THE ONE INCH SIEVE. THE SIZE OF THE STONES IS TO BE REASONABLY WELL GRADED FROM THE SMALLER TO THE LARGER SIZE.
11. WHERE HAND-PLACED RIPRAP IS SPECIFIED OR ALLOWED, IT SHALL HAVE A MAXIMUM SIZE OF NINE INCHES WITH NOT MORE THAN 5% BY WEIGHT PASSING THE ONE INCH SEIVE. THE SIZE OF STONE IS TO BE WELL GRADED FROM SMALLEST TO LARGEST.
12. CRUSHED STONE FOR DRAINAGE SHALL CONFORM TO SECTION 1081. CRUSHED STONE PLACED BENEATH RIPRAP SHALL CONFORM TO SECTION 1081.
13. FILTER FABRIC SHALL CONFORM TO REQUIREMENTS OF SECTION 571, CLASS C. FABRIC IS TO BE PLACED IN ACCORDANCE WITH SECTION 571. MINIMUM OVERLAP TO BE 18 INCHES. DAMAGED MATERIAL TO BE REPAIRED BY PLACING A PIECE OF MATERIAL OVER THE DAMAGED AREA LARGE ENOUGH TO COVER THE DAMAGED AREA AND MEETING THE OVERLAP REQUIREMENT.
14. PAVEMENT SHALL BE THE FOLLOWING: EIGHT INCHES STABILIZED BASE PER SECTION 225, BITUMINOUS PRIME COAT PER SECTION 320, TWO INCHES BITUMINOUS LEVELING COURSE PER SECTION 335, AND ONE INCH ASPHALTIC CONCRETE SURFACE COURSE PER SECTION 345. CONCRETE CURB SHALL BE IN ACCORDANCE WITH SECTION 521. ALL EXPOSED EDGES OF CONCRETE SHALL BE CHAMFERED 3/4". ALL WORK PER GENERAL CONSTRUCTION SPECIFICATION NO. T-1.
15. CORRUGATED METAL PIPE SHALL BE 14 GA. CONFORMING TO 1271. REINFORCED CONCRETE PIPE SHALL BE CLASS III CONFORMING TO 1250. PERFORATED HIGH DENSITY POLYETHYLENE (HDPE) DRAIN PIPE SHALL CONFORM TO AASHTO M252. NON PERFORATED HDPE DRAIN PIPE SHALL CONFORM TO AASHTO M294 AND ASTM F667.
16. CAULKING FOR CONCRETE JOINTS SHALL BE SIKAFLEX-1A, COLOR LIMESTONE, AS MANUFACTURED BY SIKA CORPORATION OR AN APPROVED EQUAL. SURFACE PREPARATION & CAULK APPLICATION SHALL BE PER MANUFACTURE'S INSTRUCTION.
17. ALL SIGNS AND RELATED PAVEMENT MARKINGS SHALL CONFORM TO THE "MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES" PUBLISHED BY THE U. S. D.O.T., D6.1-1978 OR LATEST REVISION.
18. UNLESS OTHERWISE NOTED, SIGNS ARE TO BE FABRICATED FROM 0.08 INCH ALUMINUM SHEET CONFORMING TO ASTM B-209. FACINGS ARE TO BE ENGINEERING GRADE REFLECTIVE SHEETING (10 YEAR LIFE).
19. STANDARD U-POST TO BE GALVANIZED STEEL (50,000 PSI), 2.5 LB/FT. CONFORMING TO ASTM A-499. THE POST SHALL BE PREPUNCHED WITH 3/8 INCH DIAMETER HOLES ON ONE INCH CENTERS FOR THE ENTIRE LENGTH. GALVANIZING SHALL CONFORM TO ASTM A-525, DESIGNATION G-90.
20. ALL HARDWARE, EXCEPT WHERE OTHERWISE NOTED, SHALL CONFORM TO THE REQUIREMENTS OF ASTM A-307, CLASS A.
21. IF ROCK IS ENCOUNTERED DURING THE INSTALLATION OF POSTS, HOLES SHALL BE DRILLED TO PROVDE THE 3'-0" MIN. DEPTH.
22. ALL REUSABLE SIGNS TO BE REMOVED & STORED DURING CONSTRUCTION AND RESET AFTER CONSTRUCTION IS COMPLETE.
23. PRECAST MANHOLES AND ACCESSORIES SHALL CONFORM TO ASTM C478.
24. CONSTRUCTION ACTIVITIES SHALL BE WELL PLANED TO AVOID DISRUPTING PUBLIC USE OF THE RECREATION AREA AND TO MINIMIZE IMPACTS ON CORPS OF ENGINEERS OPERATIONS.
25. FOR DESIGN CALCULATIONS AND FIELD INFORMATION, SEE RIMS NUMBER: B92960508005.

PROJECT REVISION HISTORY

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R2	[illegible]	---	[illegible]	[illegible]	[illegible]	CDW	CDW	JHC	RWTHOBX	CDW 8-97	J
REVISED DRAWING AS CONSTRUCTED											
R 1	9-24-96	RLP	CHR	RLP	RLP	CDW	CDW	JHC	RWTHOBX		D
RELEASE HOLD											
R 0	7-01-96	BSS	CHR	RLP	RLP	RLP	CDW	JHC	RWTHOBX		D
ORIGINAL ISSUE											

SCALE: 1" = 100' EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

GENERAL PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
B S SNIDER	DH ROBERTS	R L PETTY	R L PETTY	R L PETTY	C D WAGNER	J H COULSON

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

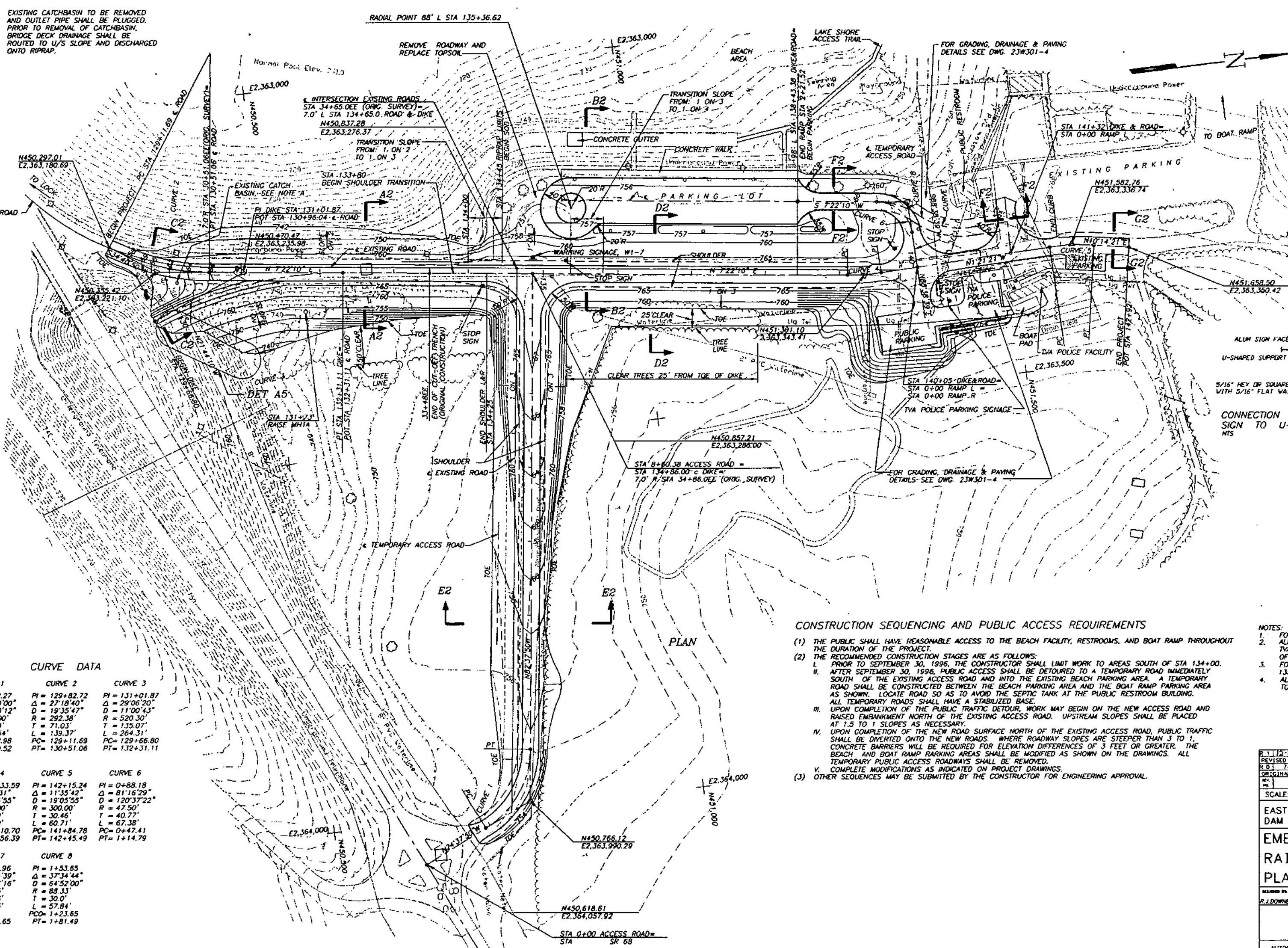
AUTOCAD R12 | DATE | 9 | C | 23W300-1 | R 2

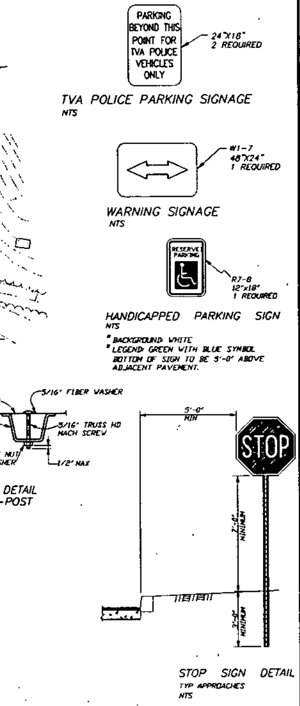
PLOT FACTOR:1

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.

NOTE A: EXISTING CATCHBASIN TO BE REMOVED AND OUTLET PIPE SHALL BE PLUGGED. PRIOR TO REMOVAL OF CATCHBASIN, BRIDGE DECK DRAINAGE SHALL BE ROUTED TO U/S SLOPE AND DISCHARGED ONTO RIPRAP.





CURVE DATA

CURVE 1	CURVE 2	CURVE 3
PI = 1+62.27	PI = 129+82.72	PI = 131+01.87
Δ = 58°00'00"	Δ = 27°18'40"	Δ = 29°06'20"
D = 45°50'12"	D = 19°35'47"	D = 11°00'43"
R = 125.00'	R = 292.38'	R = 520.30'
T = 69.29'	T = 71.03'	T = 135.07'
L = 126.54'	L = 139.37'	L = 264.31'
PC= 0+92.98	PC= 129+11.69	PC= 129+66.80
PT= 2+19.52	PT= 130+51.06	PT= 132+31.11

CURVE 4	CURVE 5	CURVE 6
PI = 139+33.59	PI = 142+15.24	PI = 0+88.18
Δ = 8°43'31"	Δ = 11°35'42"	Δ = 81°16'29"
D = 19°05'55"	D = 19°05'55"	D = 120°37'22"
R = 300.00'	R = 300.00'	R = 47.50'
T = 22.89'	T = 30.46'	T = 40.77'
L = 45.69'	L = 60.71'	L = 67.38'
PC= 139+10.70	PC= 141+84.78	PC= 0+47.41
PT= 139+56.39	PT= 142+45.49	PT= 1+14.79

CURVE 7	CURVE 8
PI = 0+88.96	PI = 1+53.65
Δ = 46°14'39"	Δ = 37°34'44"
D = 62°47'16"	D = 64°52'00"
R = 91.25'	R = 88.33'
T = 38.96'	T = 30.0'
L = 73.65'	L = 57.84'
PC= 0+50	PCC= 1+23.65
PCC= 1+23.65	PT= 1+81.49

CONSTRUCTION SEQUENCING AND PUBLIC ACCESS REQUIREMENTS

(1) THE PUBLIC SHALL HAVE REASONABLE ACCESS TO THE BEACH FACILITY, RESTROOMS, AND BOAT RAMP THROUGHOUT THE DURATION OF THE PROJECT.

(2) THE RECOMMENDED CONSTRUCTION STAGES ARE AS FOLLOWS:

I. PRIOR TO SEPTEMBER 30, 1996, THE CONSTRUCTOR SHALL LIMIT WORK TO AREAS SOUTH OF STA 134+00.

II. AFTER SEPTEMBER 30, 1996, PUBLIC ACCESS SHALL BE DETOURED TO A TEMPORARY ROAD IMMEDIATELY SOUTH OF THE EXISTING ACCESS ROAD AND INTO THE EXISTING BEACH PARKING AREA. A TEMPORARY ROAD SHALL BE CONSTRUCTED BETWEEN THE BEACH PARKING AREA AND THE BOAT RAMP PARKING AREA AS SHOWN. LOCATE ROAD SO AS TO AVOID THE SEPTIC TANK AT THE PUBLIC RESTROOM BUILDING. ALL TEMPORARY ROADS SHALL HAVE A STABILIZED BASE.

III. UPON COMPLETION OF THE PUBLIC TRAFFIC DETOUR, WORK MAY BEGIN ON THE NEW ACCESS ROAD AND RAISED EMBANKMENT NORTH OF THE EXISTING ACCESS ROAD. UPSTREAM SLOPES SHALL BE PLACED AT 1.5 TO 1 SLOPES AS NECESSARY.

IV. UPON COMPLETION OF THE NEW ROAD SURFACE NORTH OF THE EXISTING ACCESS ROAD, PUBLIC TRAFFIC SHALL BE DIVERTED ONTO THE NEW ROADS. WHERE ROADWAY SLOPES ARE STEEPER THAN 3 TO 1, CONCRETE BARRIERS WILL BE REQUIRED FOR ELEVATION DIFFERENCES OF 3 FEET OR GREATER. THE BEACH AND BOAT RAMP RARKING AREAS SHALL BE MODIFIED AS SHOWN ON THE DRAWINGS. ALL TEMPORARY PUBLIC ACCESS ROADWAYS SHALL BE REMOVED.

V. COMPLETE MODIFICATIONS AS INDICATED ON PROJECT DRAWINGS.

(3) OTHER SEQUENCES MAY BE SUBMITTED BY THE CONSTRUCTOR FOR ENGINEERING APPROVAL.

NOTES:

1. FOR GENERAL NOTES SEE DWG. 23W300-1.
2. ALL EXISTING UNDERGROUND UTILITIES SHALL BE RELOCATED BY TVA PS&D AFTER PLACEMENT OF EARTHFILL. VERIFY LOCATION OF EXISTING UNDERGROUND UTILITIES.
3. FOR SPECIFIC DETAILS FOR AREAS BETWEEN DIKE & ROAD STA 135+00 AND END OF PROJECT SEE DWG. 23W301-4.
4. ALL STRIPING FOR PARKING AREAS SHALL BE SOLID WHITE, CONFORMING TO GENERAL CONSTRUCTION SPEC T-1, SECT 596.

MF R1

R 1	12-2-97	---	CHR	RLP	RLP	CDW	CDW	JHC	RWTHOBX	CDW 8-97
REVISED DRAWING AS CONSTRUCTED										
R 0	7-01-96	RJD	CHR	RLP	RLP	CDW	CDW	JHC	RWTHOBX	
ORIGINAL ISSUE										

SCALE: 1" = 50' EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

EMBANKMENT MODIFICATIONS RAISED EMBANKMENT PLAN

R.J.DOWNEY	C.H.ROBERTS	R.L.PETTY	R.L.PETTY	C.D.WAGNER	C.D.WAGNER	J.H.COULSON

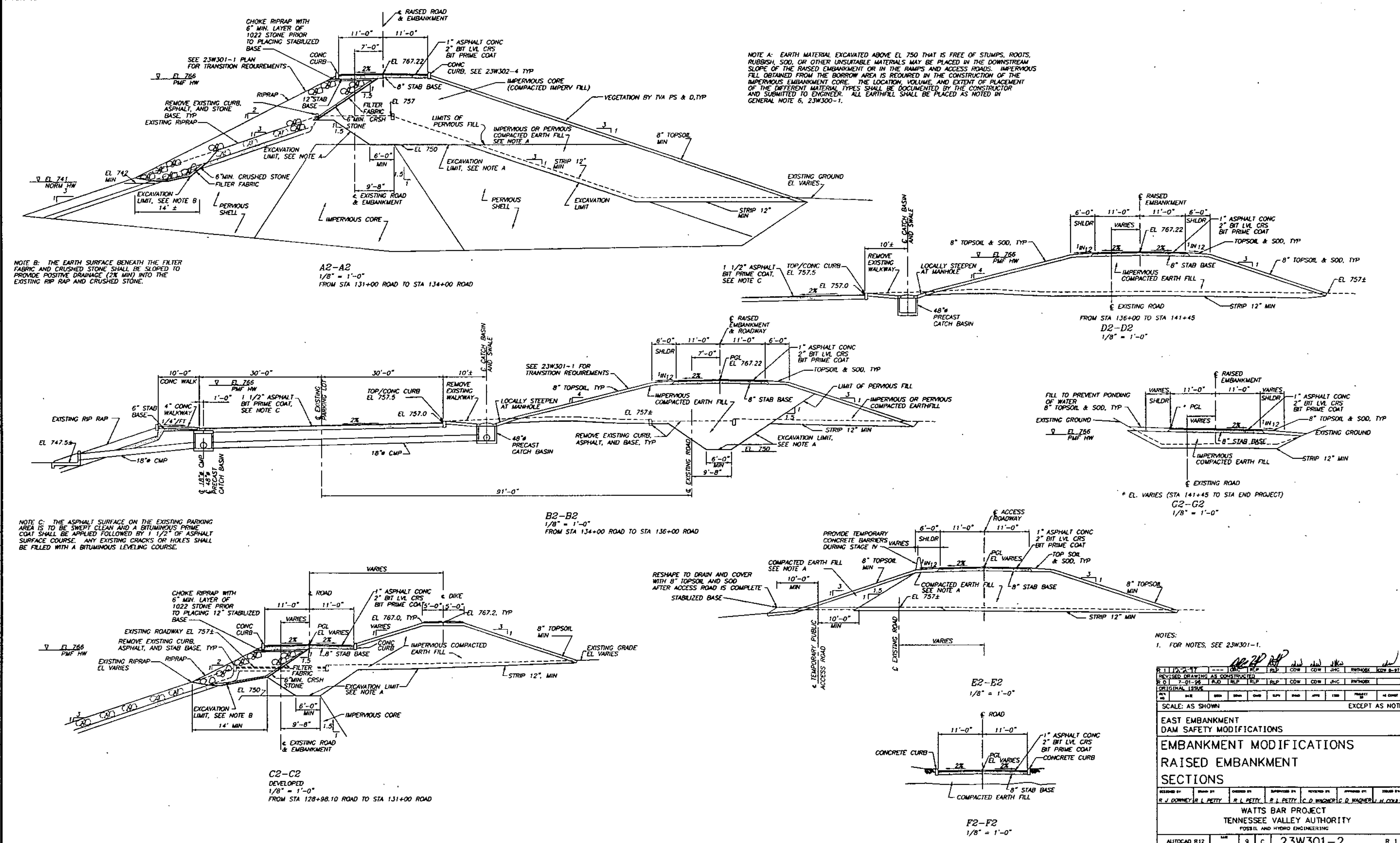
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | 9 | C | 23W301-1 | R 1

PLOT FACTOR:1
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: REV NO.



NOTE A: EARTH MATERIAL EXCAVATED ABOVE EL 750 THAT IS FREE OF STUMPS, ROOTS, RUBBISH, SOD, OR OTHER UNSUITABLE MATERIALS MAY BE PLACED IN THE DOWNSTREAM SLOPE OF THE RAISED EMBANKMENT OR IN THE RAMPS AND ACCESS ROADS. IMPERVIOUS FILL OBTAINED FROM THE BORROW AREA IS REQUIRED IN THE CONSTRUCTION OF THE IMPERVIOUS EMBANKMENT CORE. THE LOCATION, VOLUME, AND EXTENT OF PLACEMENT OF THE DIFFERENT MATERIAL TYPES SHALL BE DOCUMENTED BY THE CONSTRUCTOR AND SUBMITTED TO ENGINEER. ALL EARTHFILL SHALL BE PLACED AS NOTED IN GENERAL NOTE 6, 23W300-1.

NOTE B: THE EARTH SURFACE BENEATH THE FILTER FABRIC AND CRUSHED STONE SHALL BE SLOPED TO PROVIDE POSITIVE DRAINAGE (2% MIN) INTO THE EXISTING RIP RAP AND CRUSHED STONE.

NOTE C: THE ASPHALT SURFACE ON THE EXISTING PARKING AREA IS TO BE SWEPT CLEAN AND A BITUMINOUS PRIME COAT SHALL BE APPLIED FOLLOWED BY 1 1/2" OF ASPHALT SURFACE COURSE. ANY EXISTING CRACKS OR HOLES SHALL BE FILLED WITH A BITUMINOUS LEVELING COURSE.

NOTES:
1. FOR NOTES, SEE 23W301-1.

R 1	12-2-97	---	DRC	RLP	RLP	CDW	CDW	JHC	RWTHOBX	CDW 8-97	
REVISED DRAWING AS CONSTRUCTED											
R 0	7-01-96	RJD	RLP	RLP	RLP	CDW	CDW	JHC	RWTHOBX		D
ORIGINAL ISSUE											

SCALE: AS SHOWN EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

EMBANKMENT MODIFICATIONS RAISED EMBANKMENT SECTIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
R J DOWNEY	R L PETTY	R L PETTY	R L PETTY	C D WAGNER	C D WAGNER	J H COULSON

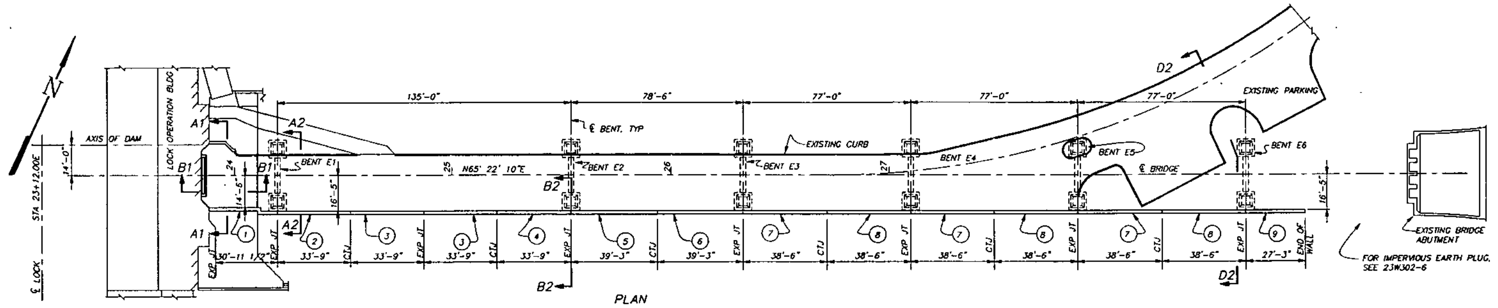
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R12 | 9 | C | 23W301-2 | R 1

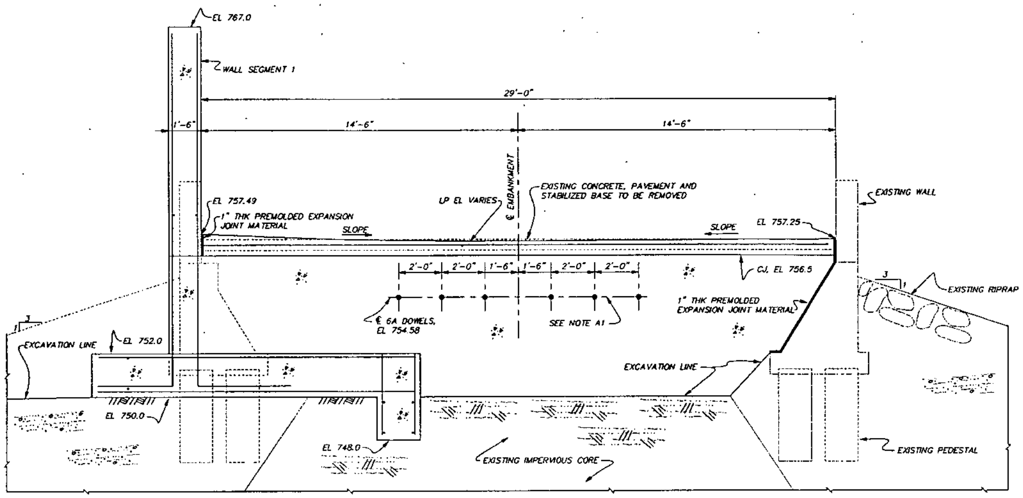
PLOT FACTOR:1
W_TVA

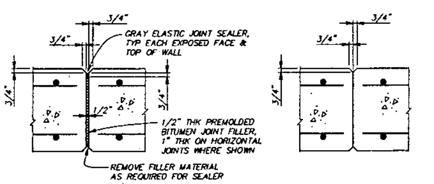
C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.



PLAN

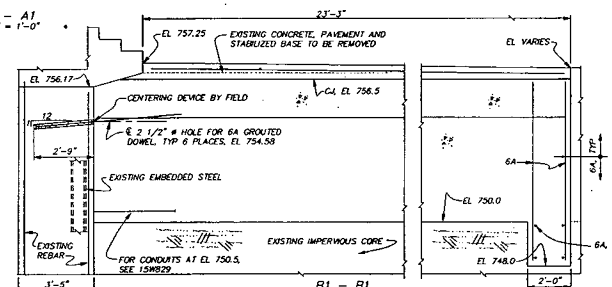




TYP EXPANSION JOINT
1 1/2" = 1'-0"

TYP CONTRACTION JOINT
1 1/2" = 1'-0"

A1 - A1
1/2" = 1'-0"



B1 - B1
1/2" = 1'-0"

NOTE A1:
EXISTING HORIZONTAL AND VERTICAL REINFORCEMENT SHALL BE LOCATED PRIOR TO DRILLING 2 1/2" ⌀ HOLES FOR DOWELS. HOLES MAY BE MOVED A MAXIMUM OF 6" TO AVOID CUTTING EXISTING REINFORCEMENT AND EMBEDDED STEEL. HOLES ARE TO BE CLEANED WITH AIR AND WATER. GROUT SHALL BE 5 STAR GROUT, OR APPROVED EQUAL, MIXED PER MANUFACTURERS INSTRUCTIONS. GROUT IS TO BE PLACED IN HOLES WITHOUT VOIDS. AFTER 24 HOURS AND PRIOR TO PLACING CONCRETE, THE CENTERING DEVICE SHALL BE REMOVED. THREE DAYS MUST ELAPSE AFTER GROUTING BEFORE CONCRETE CAN BE PLACED.

COMPANION DRAWINGS:
23W305-2 THRU 23W305-12

NOTES:
1. FOR LIST SEE 23W300-1.
2. WALL SEGMENTS DENOTED THUS (2) ON PLAN.
3. ALL EXCAVATED ASPHALT SHALL BE RECYCLED.
4. ALL HORIZONTAL CONSTRUCTION JOINTS AT EL 752.0 SHALL INCLUDE A 2" X 6" (NOMINAL) KEYWAY. CONCRETE ABOVE EL 752.0 WAS PLACED WITHOUT HORIZONTAL CONSTRUCTION JOINTS.

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST
R 1	12-2-97	---		RLP	RLP	CDW	CDW	JHC	RWHOOX	CDW 8-97
REVISED DRAWING AS CONSTRUCTED										
R 0	7-01-96	KB	GLH	RLP	RLP	RLP	CDW	JHC	RWHOOX	
ORIGINAL ISSUE										

SCALE: 1" = 20' EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

EMBANKMENT MODIFICATIONS CONCRETE WALL - PLAN, SECTION & DETAILS

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
K BROWN	G L HICKEY	R L PETTY	R L PETTY	R L PETTY	C D WAGNER	J H COULSON

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

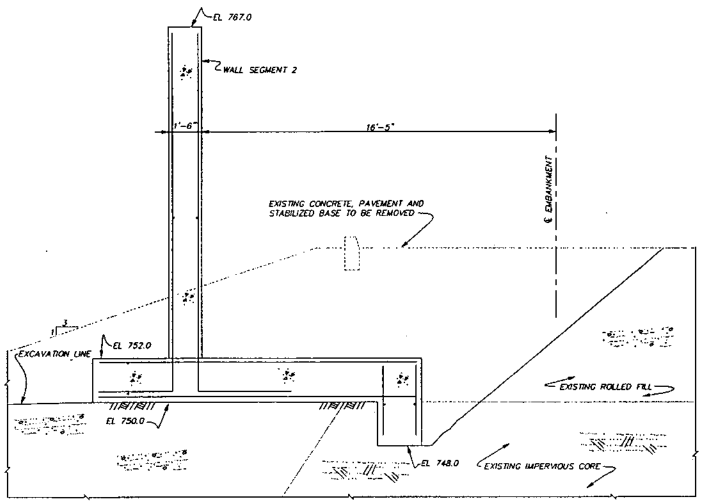
AUTOCAD R12 | DATE | 9 | C | 23W305-1 | R 1

PLOT FACTOR:1

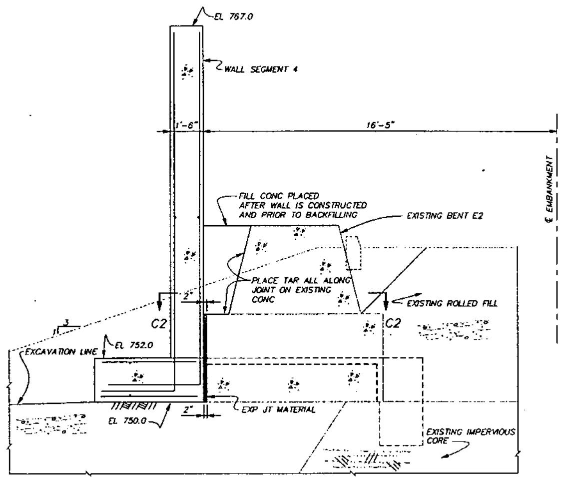
C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: REV NO.

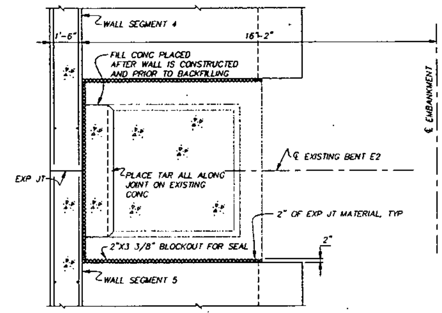
MF R1



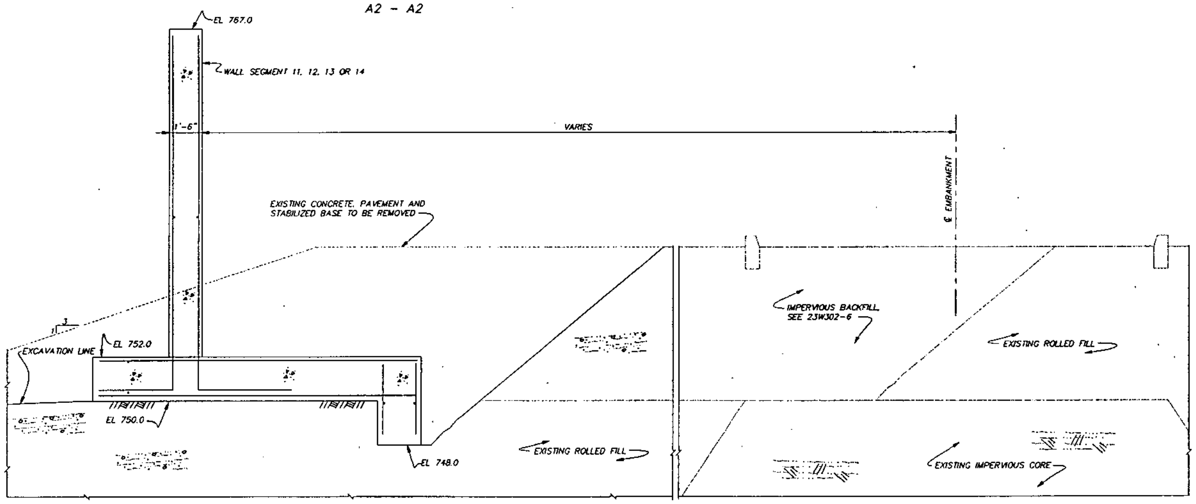
A2 - A2



B2 - B2



C2 - C2
1/2" = 1'-0"



D2 - D2

NOTES:
1. FOR LIST SEE 23W300-1.

MF
R1

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R 1	12-2-97	---	DRC	RLP	RLP	CDW	CDW	JHC	RWTHOBX	CDW 8-87	J
REVISED DRAWING AS CONSTRUCTED											
R 0	7-01-96	KB	GLH	RLP	RLP	RLP	CDW	JHC	RWTHOBX		D
ORIGINAL ISSUE											

SCALE: 1/2" = 1'-0" EXCEPT AS NOTED

EAST EMBANKMENT
DAM SAFETY MODIFICATIONS

EMBANKMENT MODIFICATIONS CONCRETE WALL - PLAN, SECTION & DETAILS

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
K BROWN	G L HICKEY	R L PETTY	R L PETTY	R L PETTY	C D WAGNER	J H COULSON

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

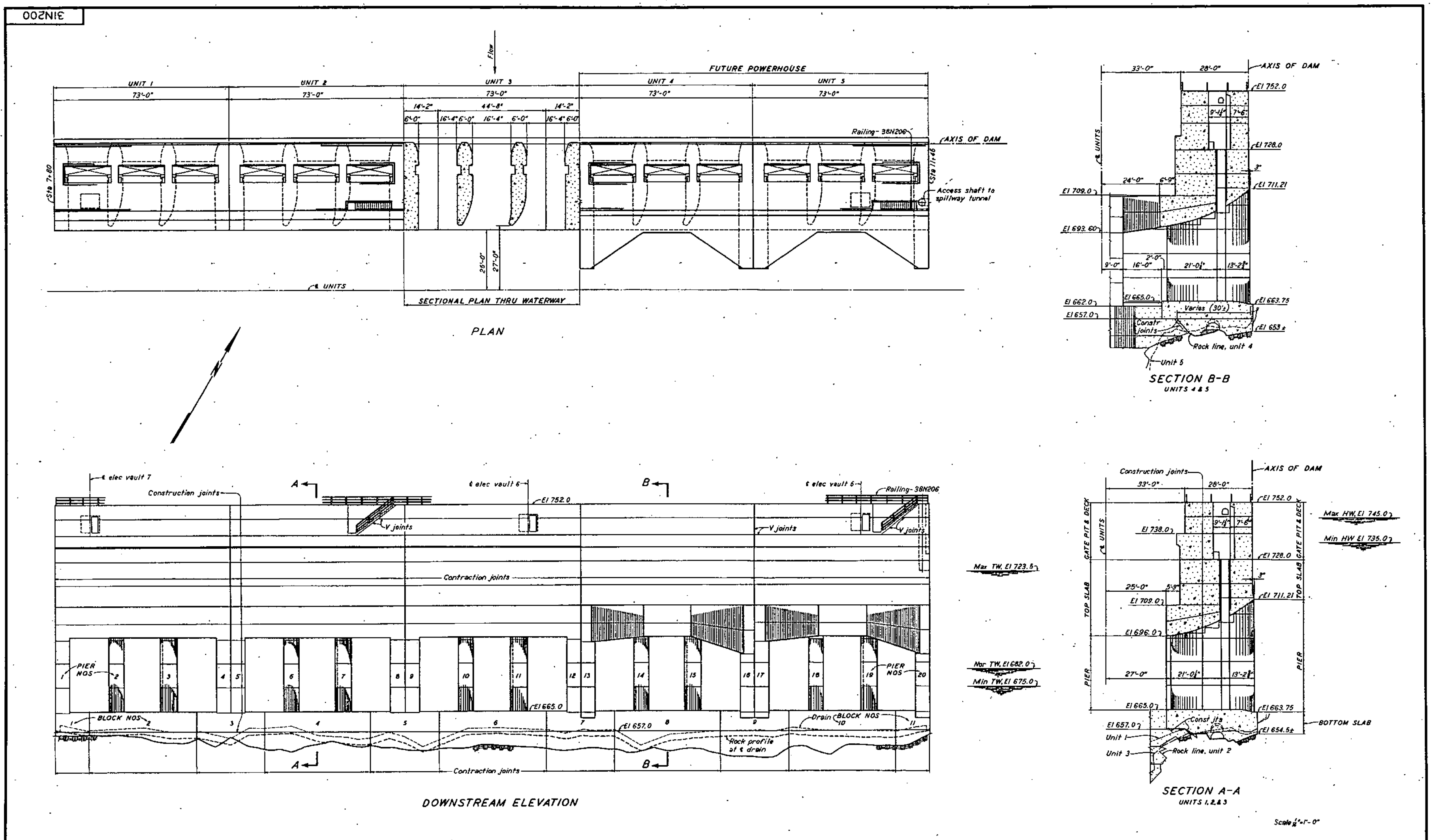
AUTOCAD R12 | DATE | 9 | C | 23W305-2 | R 1

PLOT FACTOR:1

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV NO.

9 C 23W305-2



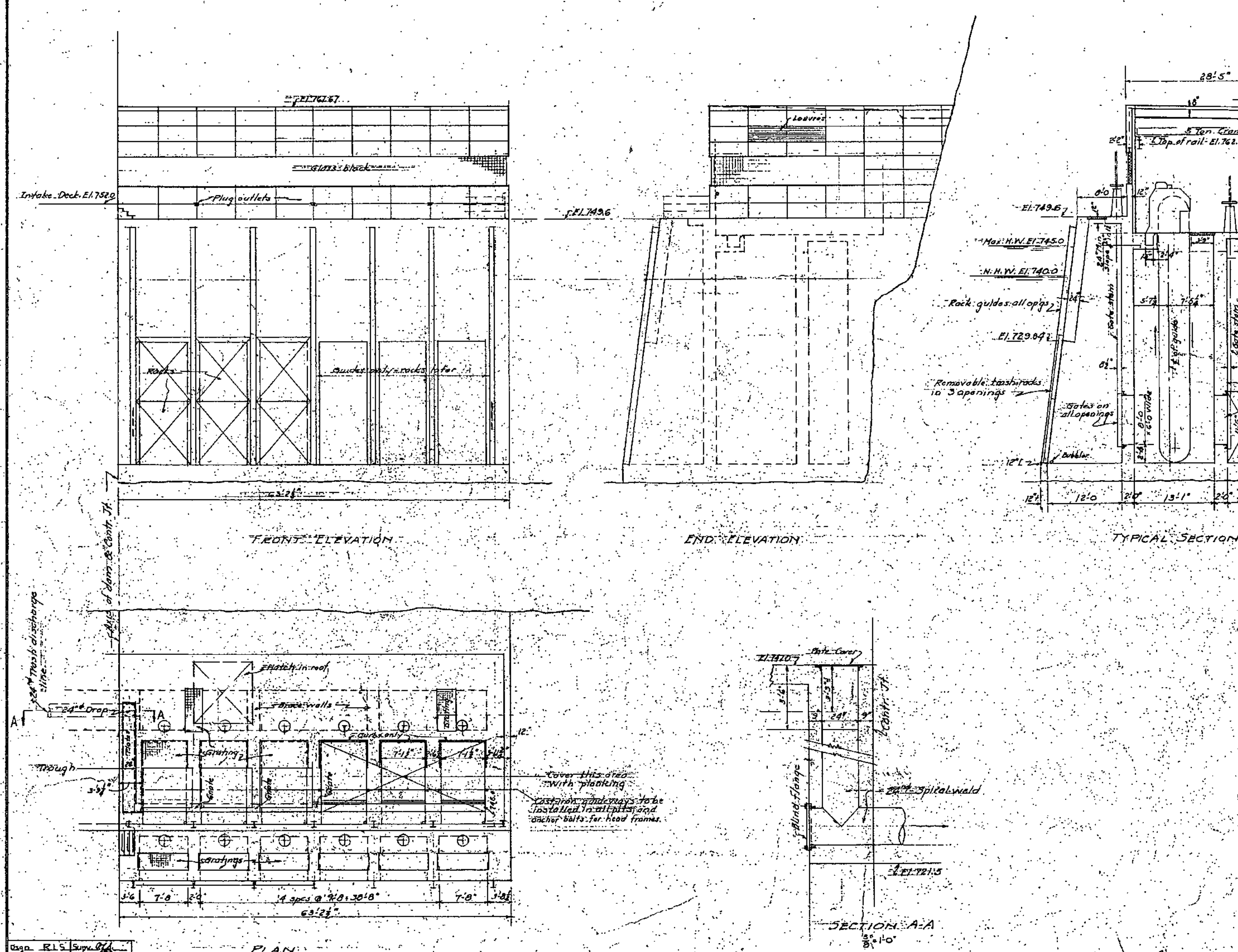
NOTES:

For class of concrete see construction specifications No. G2.
For treatment of contraction joints see construction specifications KC-571.
Chamfer all exposed corners 3/4" unless otherwise noted.
For final rock lines see field office drawings 41K857.

POWERHOUSE INTAKE
CONCRETE GENERAL PLAN ELEVATION & SECTIONS
WATTS BAR PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED				APPROVED
W. B. Allen	H. A. Hageman				T. B. Parker
KNOXVILLE	8-15-40	9	C	4	3IN200R2

RECORD DRAWING AS CONSTRUCTED 12-2-42



Scale 1/8" = 1'-0"

SCREEN HOUSE

GENERAL LAYOUT

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

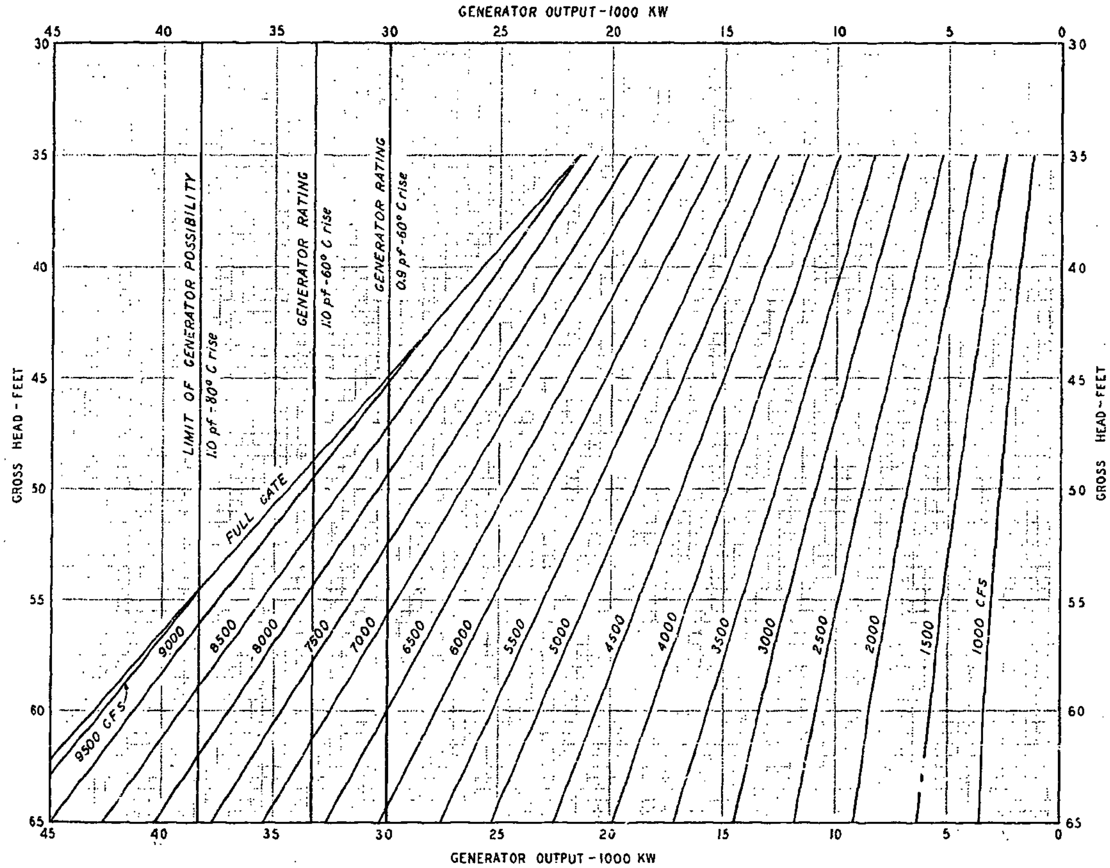
SUBMITTED	RECOMMENDED	APPROVED
W.B. Allen	H.A. Hageman	T.B. Parker

KNOXVILLE	2-10-41	9	C	4	41K175

APPR. C.E. Nichols
PROJECT DESIGN ENGR.
WATTS BAR STEAM PLANT

Dsgn.	R.L.S.	Supv.	
Drwn.	R.L.S.	Insp.	
Chkd.			
Trcd.			
Comp.			

EXHIBIT 3



NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 4-26-44. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV-65071 rated 42,000 hp, 52 ft. head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg. Co TV-65072 rated 33,333 kva, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

POWERHOUSE
UNIT 4

DISCHARGE CURVES BASED ON INDEX TESTS

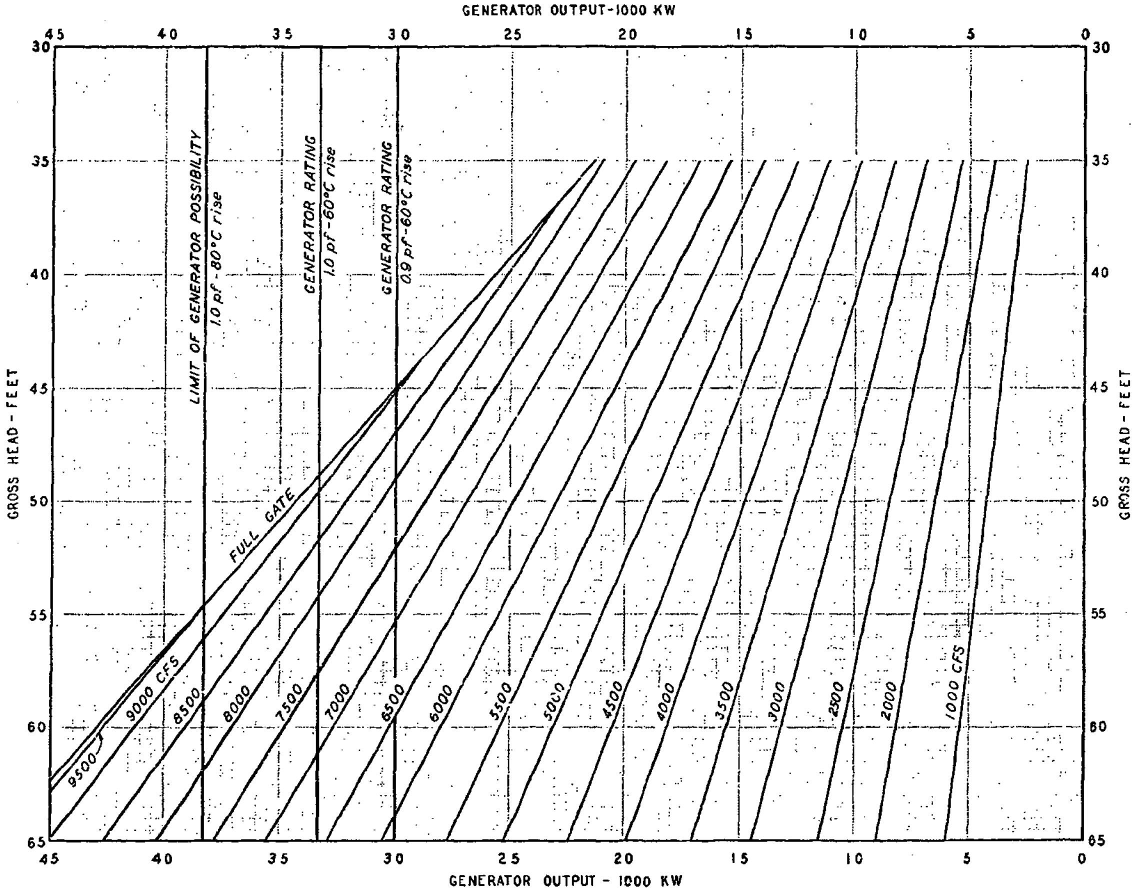
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE	6-17-44	9	M	4	478903 RO

DSGN. JRP	SUPV. CLN
DRFT. JRP	
CHKD. CLN	
TRCD. KLH	

EXHIBIT 6



NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test no. 645 modified in accordance with index test conducted at the plant on 4-27-44. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV-65071 rated 42,000 hp, 52 ft head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg Co. TV-65072 rated 33,333 kva, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

POWERHOUSE
UNIT 5

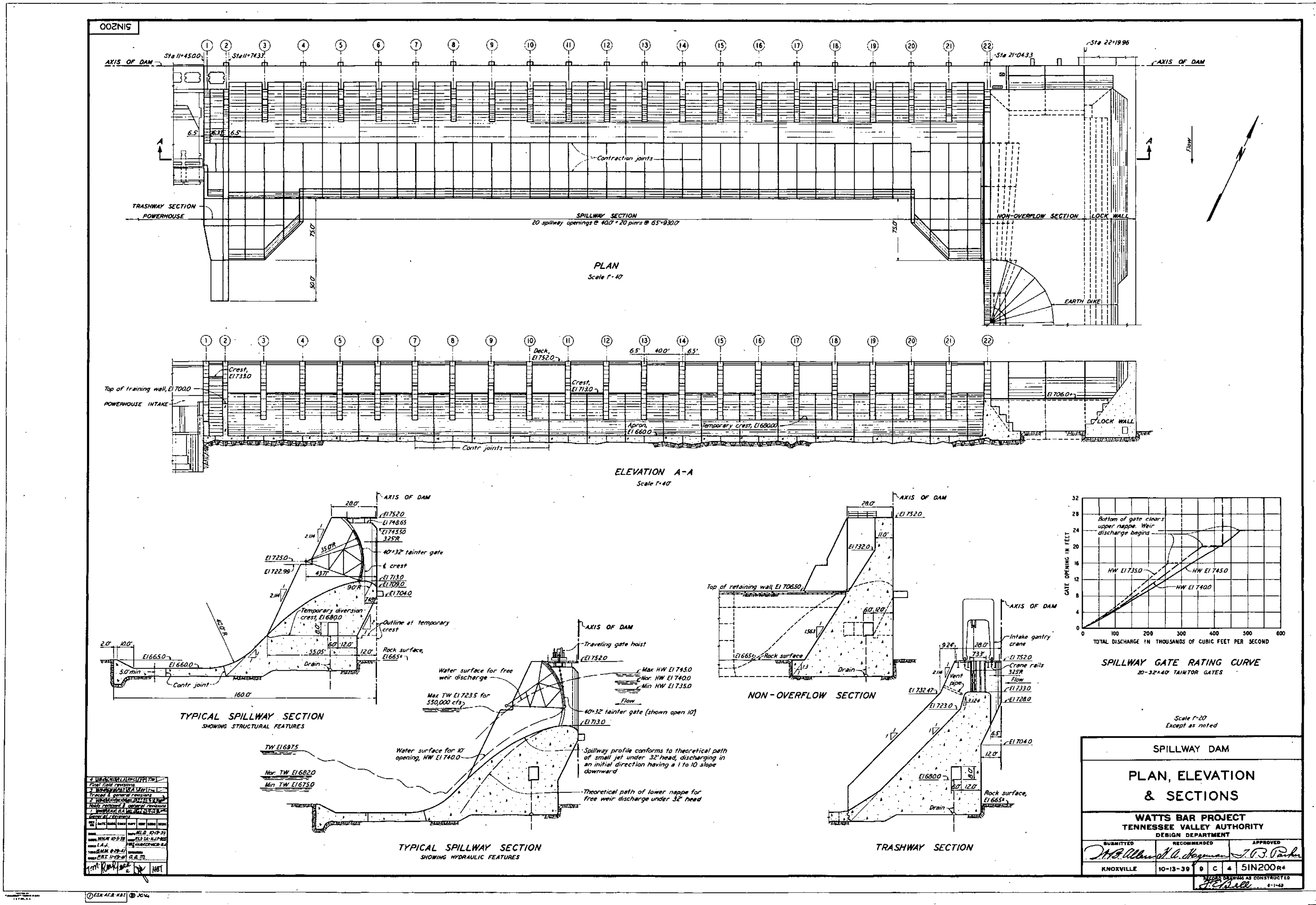
DISCHARGE CURVES
BASED ON INDEX TESTS

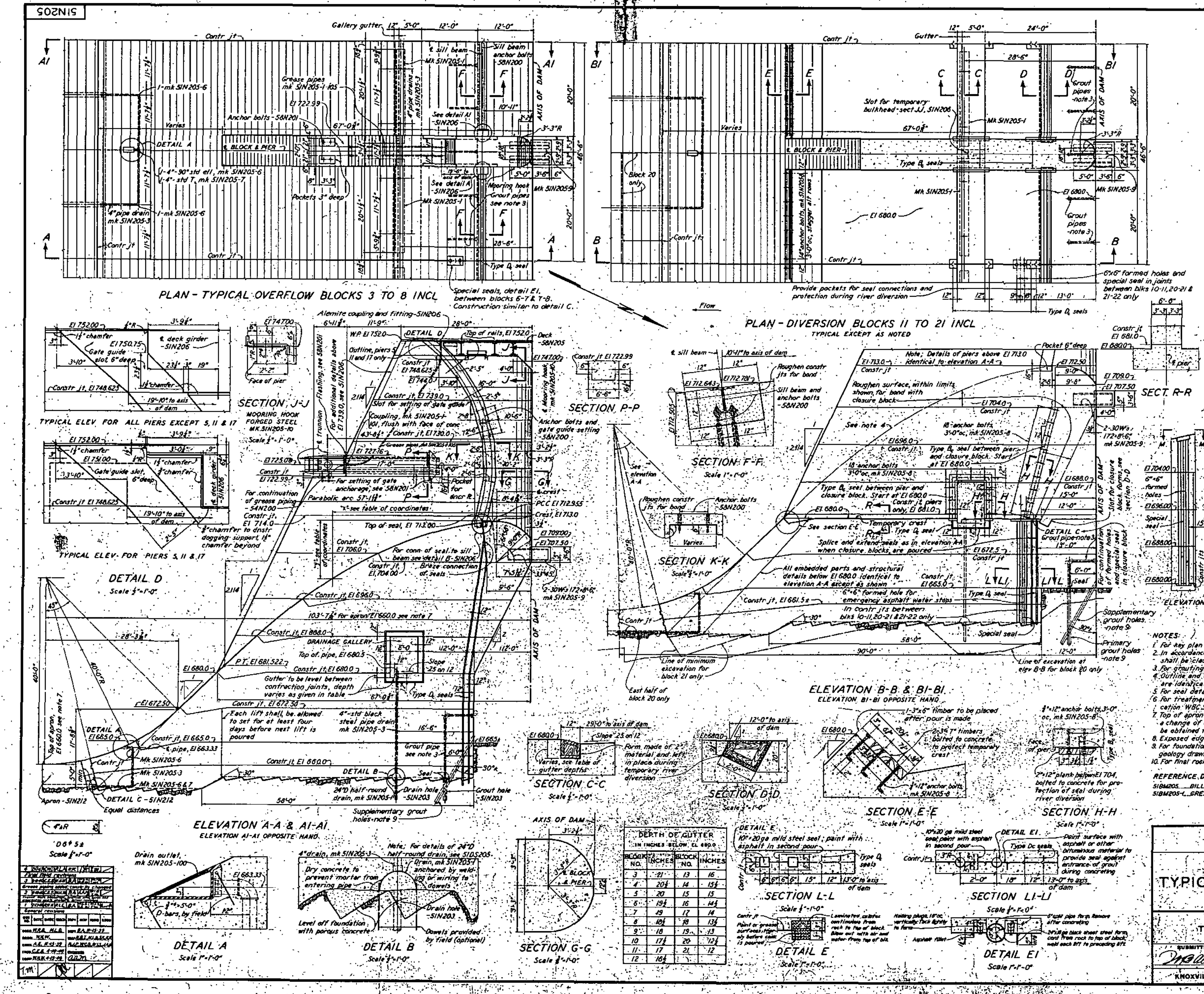
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
Tonald Munde	W. J. Petersen	George R. Rich

KNOXVILLE	6-17-44	9	M	4	47B906RO

DSGN JRP	SUPV CLN		
DRWN JRP	INSP		
CHKD CLN			
TRCD MCK	ENGINEER		
COMP.			


5IN200
AXIS OF DAM
Sta 11+450.0
Sta 11+743.3
Sta 21+043.3
Sta 22+19.96
Contraction joints
TRASHWAY SECTION
POWERHOUSE
SPILLWAY SECTION
20 spillway openings @ 40.0' + 20 piers @ 65' = 930.0'
NON-OVERFLOW SECTION
LOCK WALL
EARTH DIKE
PLAN
Scale 1"=40'
Flow
Deck, El 752.0
Crest, El 733.0
Crest, El 713.0
Top of training wall, El 700.0
POWERHOUSE INTAKE
El 706.0
Apron, El 660.0
Temporary crest, El 680.0
Contr joints
ELEVATION A-A
Scale 1"=40'
40'x32' tainter gate
Temporary diversion crest, El 680.0
Outline at temporary crest
Rock surface, El 665±
Drain
Contr joint
TYPICAL SPILLWAY SECTION
SHOWING STRUCTURAL FEATURES
Traveling gate hoist
Water surface for free weir discharge
Max TW El 723.5 for 550,000 cfs
Max HW El 745.0
Nor. HW El 740.0
Min HW El 735.0
40'x32' tainter gate (shown open 10')
TW El 687.5
Nor. TW El 682.0
Min. TW El 675.0
Water surface for 10' opening, HW El 740.0
Spillway profile conforms to theoretical path of small jet under 32' head, discharging in an initial direction having a 1 to 10 slope downward
Theoretical path of lower nappe for free weir discharge under 32' head
TYPICAL SPILLWAY SECTION
SHOWING HYDRAULIC FEATURES
Top of retaining wall, El 706.50
NON-OVERFLOW SECTION
Intake gantry crane
Crane rails
Vent pipe
TRASHWAY SECTION
Bottom of gate clears upper nappe. Weir discharge begins
HW El 735.0
HW El 745.0
HW El 740.0
GATE OPENING IN FEET
TOTAL DISCHARGE IN THOUSANDS OF CUBIC FEET PER SECOND
SPILLWAY GATE RATING CURVE
20-32'x40' TAINTOR GATES
Scale 1"=20'
Except as noted
SPILLWAY DAM
PLAN, ELEVATION & SECTIONS
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
10-13-39
5IN200 R4
RECORD DRAWING AS CONSTRUCTED



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	713.000	℄ of crest
8.380	-0.045	712.955	PCC with 9'-0"R arc
9.924	0.219	712.781	Edge of sill beam slot
11.904	0.495	712.505	Edge of sill beam slot
14.000	0.856	712.144	
16.000	1.264	711.736	
18.000	1.736	711.264	
20.000	2.270	710.730	
22.000	2.868	710.132	
24.000	3.528	709.472	
26.000	4.252	708.748	
28.000	5.038	707.962	
30.000	5.887	707.113	
32.000	6.800	706.200	
32.420	7.000	706.000	Top of pour
34.000	7.775	705.225	
36.000	8.814	704.186	
38.000	9.915	703.085	
40.000	11.080	701.920	
42.000	12.307	700.693	
44.000	13.597	699.403	
46.000	14.951	698.049	
48.000	16.367	696.633	
48.866	17.000	696.000	Top of pour
50.000	17.847	695.153	
52.000	19.389	693.611	
54.000	20.994	692.006	
56.000	22.663	690.337	
58.000	24.394	688.606	
58.683	25.000	688.000	Top of pour
60.000	26.188	686.812	
62.000	28.046	684.954	
64.000	29.966	683.034	
65.530	31.478	681.522	PT with 1 on 1 slope
67.052	33.000	680.000	Top of pour

DEPTH OF GUTTER IN INCHES BELOW EL 680.0			
BLOCK NO.	INCHES	BLOCK NO.	INCHES
3	21	13	16
4	20½	14	15½
5	20	15	15
6	19½	16	14½
7	19	17	14
8	18½	18	13½
9	18	19	13
10	17½	20	12½
11	17	21	12
12	16½		

NOTES:
1. For key plan see 5IN206.
2. In accordance with Construction Specification G-2 concrete shall be class A in piers and exterior surfaces of weirs.
3. For grouting see instructions given on 5IN203, note 5.
4. Outline and details of the wier closure block above El 680.00 are identical to those shown on elevation A-A, except as noted.
5. For seal details and connections see 30B510.
6. For treatment of contraction joints see Construction Specification WBC 570.
7. Top of apron shall be at El 660.00. If rock conditions make a change of elevation desirable, additional instructions shall be obtained from the Design Department.
8. Exposed edges to be chamfered 1½" except as noted.
9. For foundation treatment and grout cutoff, see field office geology drawing 9 GE 4 1K327.
10. For final rock lines see field office dwgs 5IK817-1 to 19 inclusive.

REFERENCE DRAWINGS:
5IBM205 — BILL OF MATERIAL
5IBM205-1 — GREASE PIPING BILL OF MATERIAL

Scale ⅛" = 1'-0"
Except as noted

SPILLWAY DAM

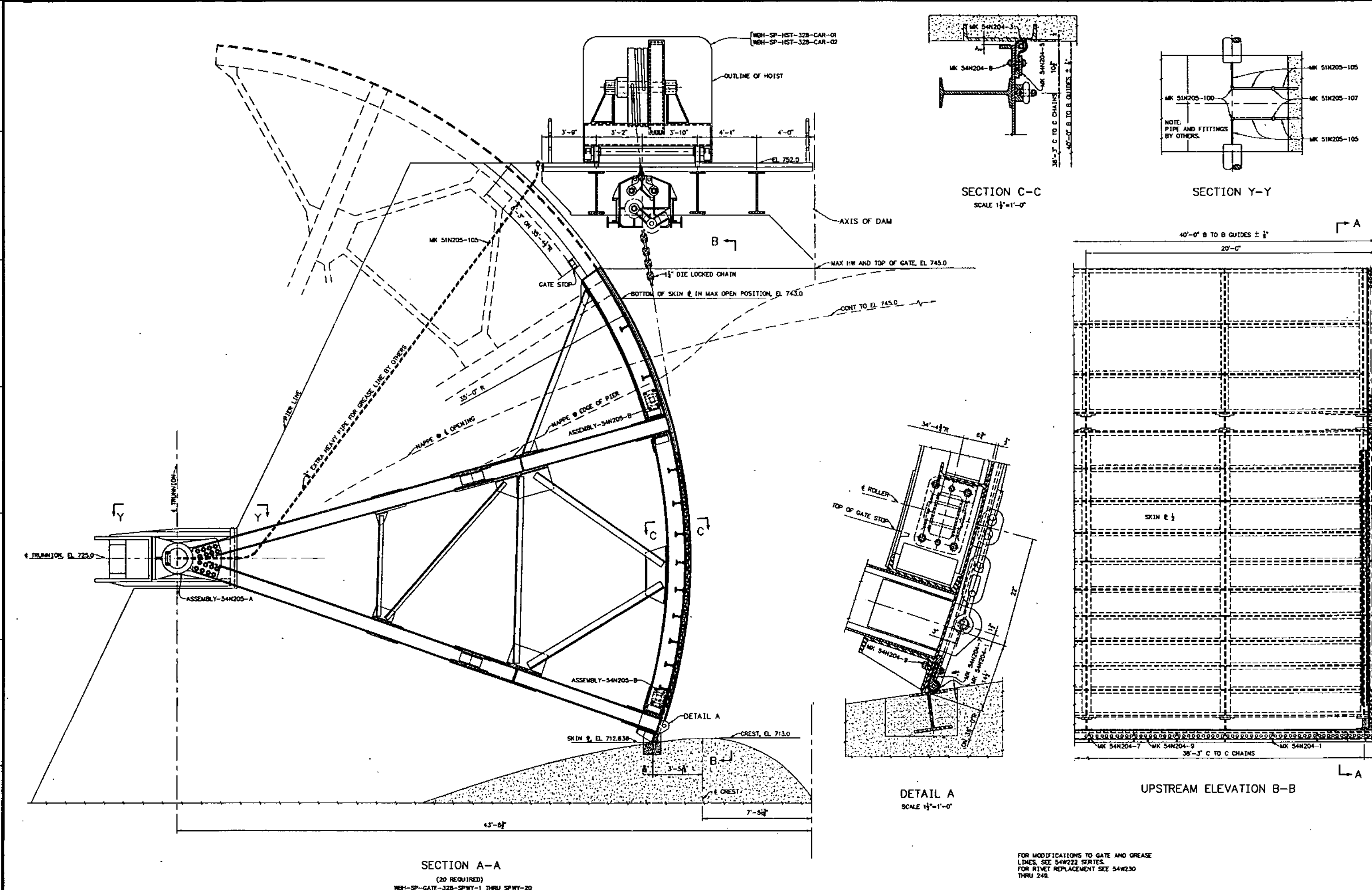
CONCRETE TYPICAL SPILLWAY BLOCKS OUTLINE

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE | 11-15-39 | 9 | C | 4 | 5IN205 R4

RECORD DRAWING AS CONSTRUCTED



UNID NOTES:

1. COMPONENT UNID NUMBERING SCHEME:

PLANT	UNIT	FUNCTION	SYSTEM	SEQUENCE NO.
WBH	SP	GATE	328	SPWY-1

2. UNIDS ARE LISTED IN WHOLE ON THIS DRAWING. OTHER COMPONENT UNIDS ONLY LIST THE SEQUENCE NUMBER TO FIT ON THIS PAGE. FOR EXAMPLE, TO HAVE THE COMPLETE UNID NUMBER FOR A SPILLWAY GATE, ADD THE PREFIX "WBH-SP-GATE-328-" TO THE SEQUENCE NUMBER. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS	FUNCTION CODES
328 SPILLWAY	GATE - GATE

NOTES:
FOR MANUFACTURER'S DETAILS OF SPILLWAY GATES, REFER TO HUNTER STEEL CO. FILE. TVA CONTRACT NO. TV-54055.

R6 4/19/05 — AC — RWT — MAC — WBH-04-104
REVISED AS PART OF CRITICAL STRUCTURES, SYSTEMS AND COMPONENTS VERIFICATION

SCALE: ⅜"=1'-0" EXCEPT AS NOTED

SPILLWAY

GATES
GENERAL ARRANGEMENT

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

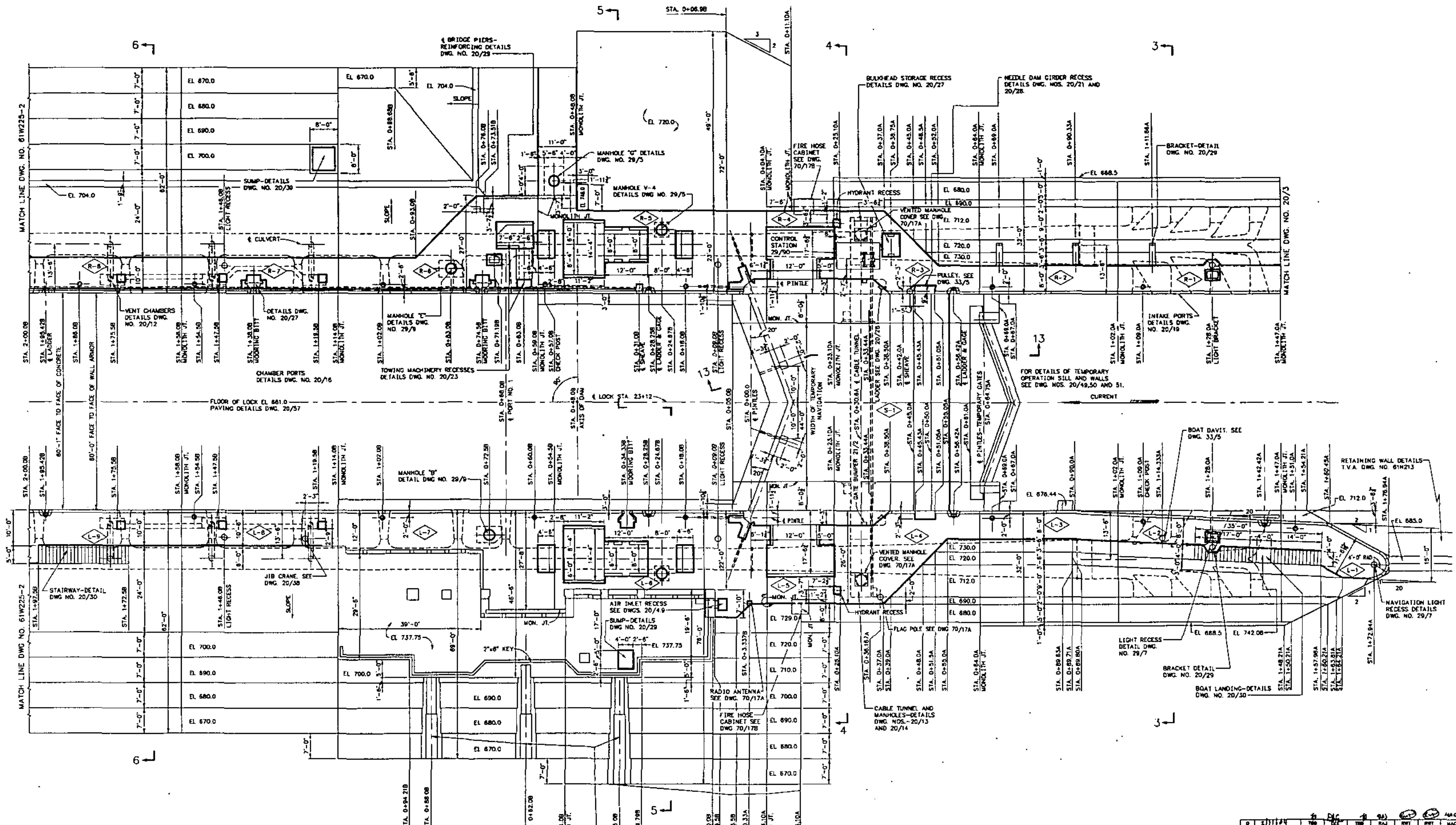
AUTOCAD R2000 | 5-16-40 | 9 | 54W200 | R 6

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES :(54N200 R5)

PLOT FACTOR:32
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: REV NO.



NOTE:
DETAILS OF OPERATION BUILDING ABOVE EL 737.75 TO BE FURNISHED BY T.V.A FOR DOWEL REINFORCING, SEALS AND DETAIL DIMENSIONS OF RECESSES IN FIRST POUR OF OPERATION BUILDING FOUNDATION SEE T.V.A. DRAWING NO. 61N218 R3

GENERAL NOTES:
TOP OF LOCK WALLS TO RISE 1/4 INCH PER FOOT FROM LOCK FACE.
ROCK TO BE LINE-DRILLED, OR EQUAL, AT LOCK FACE AND LAND FACES OF LAND AND GUIDE WALLS, LOCK AND RIVER FACES OF RIVER AND GUARD WALLS AND AT UPSTREAM AND DOWNSTREAM FACES OF UPPER AND LOWER MITER AND NEEDLE DAM SILLS.
CONCRETE DEPTH UNDER CULVERTS IN BOTH LAND AND RIVER WALLS TO BE NOT LESS THAN 5'-0". CONCRETE DEPTH UNDER CULVERTS IN LOWER GUIDE AND GUARD WALLS AND LOWER CULVERT DISCHARGE TO BE NOT LESS THAN THAT SHOWN ON PLANS. FOR DETAILS OF REINFORCING UNDER AND AROUND CULVERTS SEE DRAWING 20/15 TO 20/18 INCLUSIVE.
ROCK TO BE EXCAVATED AND FLOOR OF LOCK CHAMBER AND LOWER APPROACH BETWEEN LOWER NEEDLE DAM AND GUARD SILLS TO BE PAVED. PAVING DETAILS SHOWN ON DRAWING 20/57.

* NOTE:
AS OF AUGUST 2000 THIS DRAWING HAS BEEN CONVERTED FROM CORPS OF ENGINEERING DRAWING TO TVA AUTOCAD FILE PER TVA/CORPS 1995 AGREEMENT.

ELECTRONICALLY RESTORED DRAWING

LOCK

LOCK WALLS
PLAN - UPPER END

WATTS BAR HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
RIVER SYSTEMS OPERATIONS

US Army Corps of Engineers

M.R.
F.P.G.
THOMAS W. WATERS
20/1.8

SCALE: 3/32"=1'-0"
SHEET OF SHEETS
AUTOCAD R 00 | 9 | C | 61W225-1 | R 0

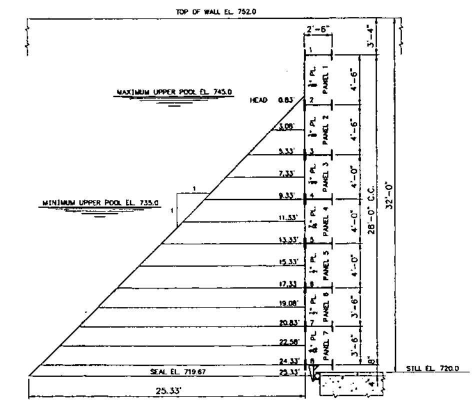
TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES: 20/1.9

PLOT FACTOR: 128
NTVAOP

C.A.D. DRAWING
DO NOT ALTER MANUALLY

61W225-1

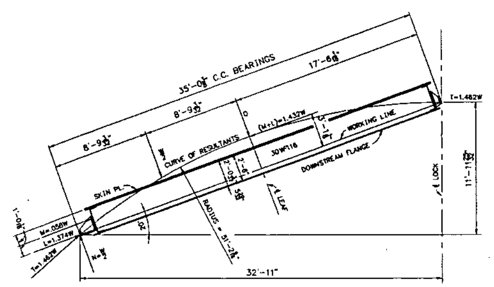


LOADING DIAGRAM
ALL GIRDERS 30W116

HORIZONTAL GIRDER DESIGN

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
GIRD NO.	CU. FT. WATER PER LIN. FT. OF GIRDER	W KIPS ①x35.03 x 62.5/1000	T KIPS ②x1.462	L KIPS ②x1.374	N KIPS ②x0.500	M KIPS ②x0.058	M+L KIPS ②x1.432	X ECCENT. INCHES	MOMENT (M+L) x IN.-KIPS	GROSS AREA SQ. IN.	GROSS 1/IN	FIBER STRESS AT ℄ LEAF LBS/SQ IN += TEN. −= COMP. UP-STREAM	DOWN-STREAM
1	0.02	0.044	0.064	0.06	0.02	0.00	0.06	USE 30WF 116 – SAME AS GIRDER 3					
2	4.71	10.31	15.07	14.17	5.16	0.60	14.77	"	"	"	"	"	"
3	22.10	48.38	70.73	66.47	24.19	2.81	69.28	25.92	1796	39.57	8002	−5730	+3359
4	37.32	81.69	119.43	112.24	40.85	4.74	116.98	25.65	3001	40.35	6135	−9301	+5586
5	53.32	116.72	170.64	160.37	58.38	6.77	167.14	24.04	4018	45.95	6998	−10482	+7248
6	64.50	141.19	206.42	194.00	70.60	8.19	202.18	23.82	4816	46.82	7109	−12244	+8675
7	72.90	159.58	233.31	219.26	79.79	9.26	228.52	23.71	5418	47.37	7184	−13610	+9724
8	65.87	144.19	210.81	198.12	72.10	8.36	206.48	24.02	4960	45.95	7012	−13771*	+8112*

* GIRDER NO.8 INCLUDES 818#/" DUE TO DEAD LOAD MINUS BUOYANCY

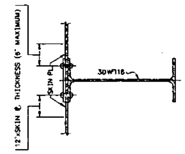


FORCES ACTING ON GIRDER

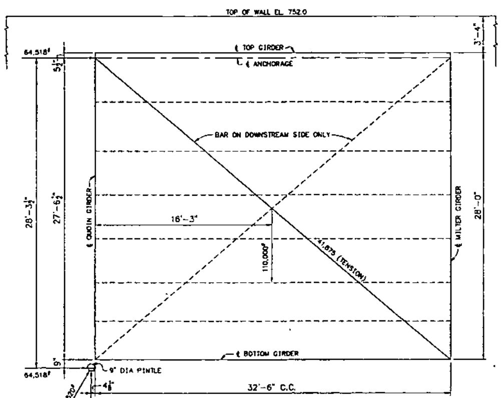
DESIGN DATA

ALLOWABLE STRESSES FOR EXTREME CONDITIONS

STRUCTURAL STEEL:	TENSION AND BENDING	18000 LBS./SQ. IN.
	COMPRESSION	18000–80 L/R (15000 MAX ~L/R <60)
	BEARING	24000 LBS./SQ. IN.
	SHEAR	10000 LBS./SQ. IN.
RIVETS:	SHEAR AND SINGLE BEARING	12000 LBS./SQ. IN.
	ENCLOSED BEARING	24000 LBS./SQ. IN.
PINTLE BUSHING		3000 LBS./SQ. IN.
GUDGEON PIN BUSHING		8000 LBS./SQ. IN.
PINS:	SHEAR	PER AISC LRFD 2nd EDITION
	BEARING	PER AISC LRFD 2nd EDITION
OTHER MATERIALS		60% ELASTIC LIMIT
MINIMUM THICKNESS OF MAIN MEMBERS		3/8"
MAXIMUM BEARING ON CONCRETE		800 LBS./SQ. IN.
RIVETS		7/8"Ø



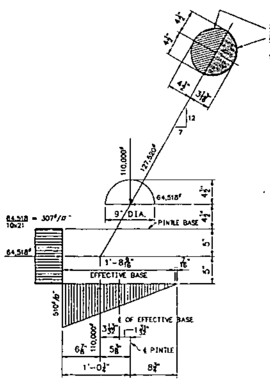
SKIN PLATE ASSUMED AS GIRDER SECTION
SCALE: 1"=1'-0"



DEAD LOAD STRESSES

1. LEAF SWINGING IN AIR.
2. SKIN PL. ON UPSTREAM FACE AND DIAGONAL ON DOWNSTREAM FACE EACH TAKE ½ STRESS.

HORIZONTAL FORCE = 110,000 x $\frac{16.59}{28.29}$ = 64,518 LBS.

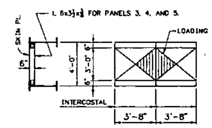


PROJECTED AREA

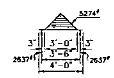
½ CIRCLE–AREA = 9²x½x.7854 = 31.8 SQ. IN.
½ ELLIPSE–AREA = 9x7⅛x½x.7854 = 26.9 SQ. IN.
TOTAL AREA = 58.7 SQ. IN.

STRESS $\frac{127,520}{58.7}$ = 2172 LBS./SQ. IN. BEARING ON BRONZE BUSHING

PINTLE DESIGN
SCALE: 1½"=1'-0"

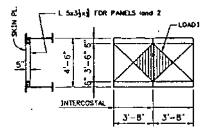


ELEVATION

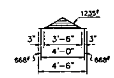


4'-0" PANEL-5

TOTAL LOAD = 15.33x62.5x3.0x $\frac{3.67}{2}$ = 5274 LBS
MOMENT M=2637 (21–6) = 39,555 IN. LBS.
SECTION MODULUS REQUIRED = $\frac{39555}{18000}$ = 2.19 IN.³
USE L 6x3½x⅜ ~ SECTION MODULUS = 3.30 IN.³
STRESS = $\frac{39555}{3.3}$ = 11986 LBS./SQ. IN.
USE L 6x3½x⅜ FOR PANELS 3, 4, AND 5

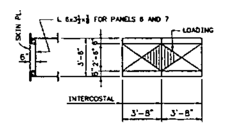


ELEVATION

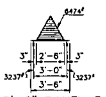


4'-6" PANEL-2

TOTAL LOAD = 3.08x62.5x3.5x $\frac{3.67}{2}$ = 1235 LBS.
MOMENT M = 668 (24–7) = 11356 IN. LBS.
SECTION MODULUS REQUIRED = $\frac{11356}{18000}$ = 0.6 IN.³
USE L 5x3½x⅜ ~ SECTION MODULUS = 2.3 IN.³
STRESS = $\frac{11356}{2.3}$ = 4937 LBS./SQ. IN.
USE L 5x3½x⅜ FOR PANELS 1 AND 2



ELEVATION



3'-6" PANEL-7

TOTAL LOAD = 22.58x62.5x2.5x $\frac{3.67}{2}$ = 6474 LBS.
MOMENT M = 3237 (18–5) = 42081 IN. LBS.
SECTION MODULUS REQUIRED = $\frac{42081}{18000}$ = 2.34 IN.³
USE L 6x3½x⅜ ~ SECTION MODULUS = 3.3 IN.³
STRESS = $\frac{42081}{3.3}$ = 12751 LBS./SQ. IN.
USE L 6x3½x⅜ FOR PANELS 6 AND 7

*NOTE:
AS OF AUGUST 2000 THIS DRAWING HAS BEEN CONVERTED FROM CORPS OF ENGINEERING DRAWING TO TVA AUTOCAD FILE PER TVA/CORPS 1995 AGREEMENT.

DRAWN BY: J.L.R.
CHECKED BY: J.T.D. C.D.
US Army Corps of Engineers Nashville District
APPROVED BY: THOMAS W. WATERS
REVISION # 3
21/1.3

ELECTRONICALLY RESTORED DRAWING, AS-BUILT

LOCK

UPPER LOCK GATE
DESIGN DATA

WATTS BAR HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
RIVER SYSTEMS OPERATIONS

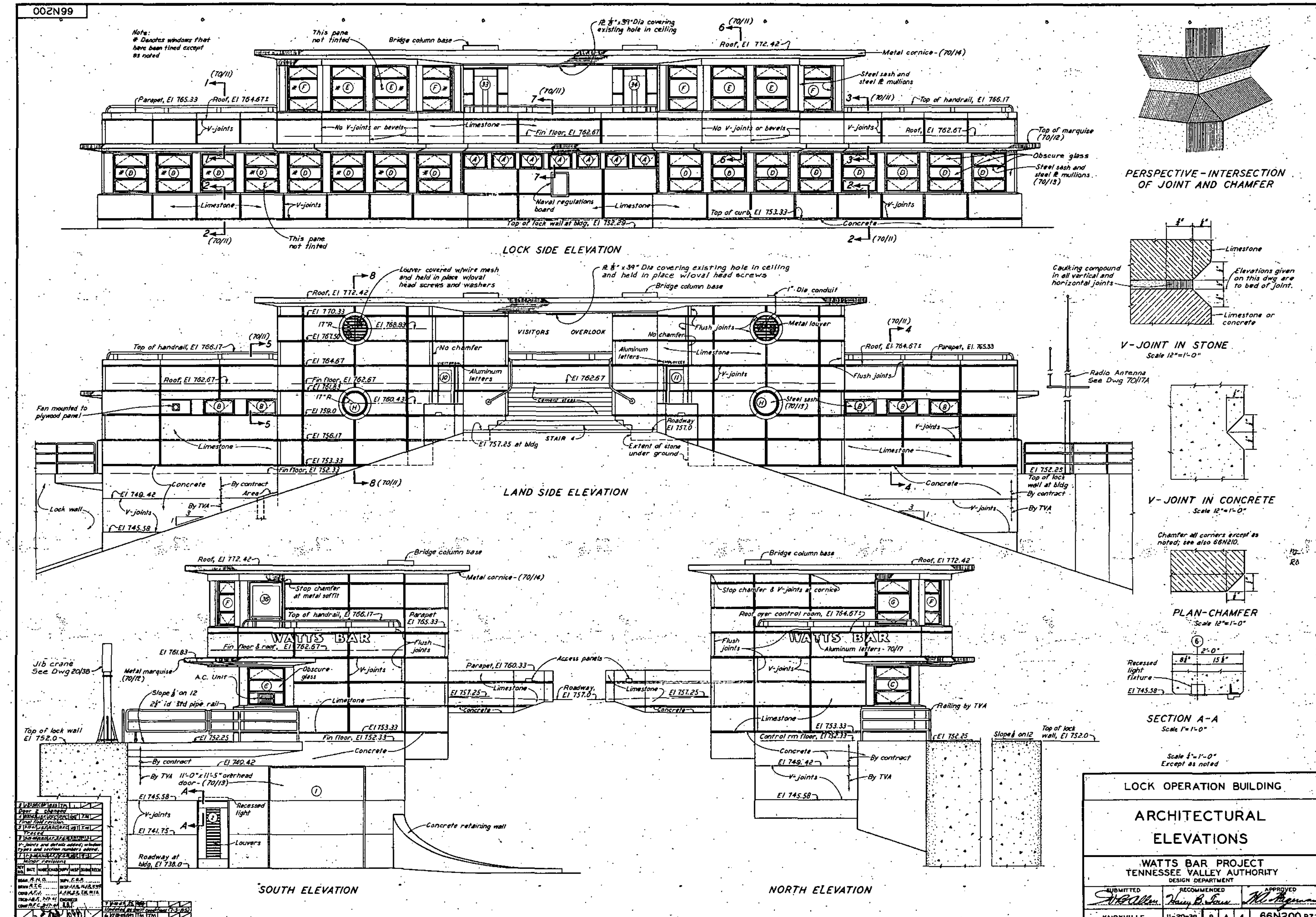
SCALE: ¼"=1'-0" | SHEET OF SHEETS
AUTOCAD R 00 | 9 | M | 64W203-1 | R 0

TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES 21/1.4

PLOT FACTOR: 48
NTVAOP

C.A.D. DRAWING
DO NOT ALTER MANUALLY



LOCK OPERATION BUILDING

ARCHITECTURAL ELEVATIONS

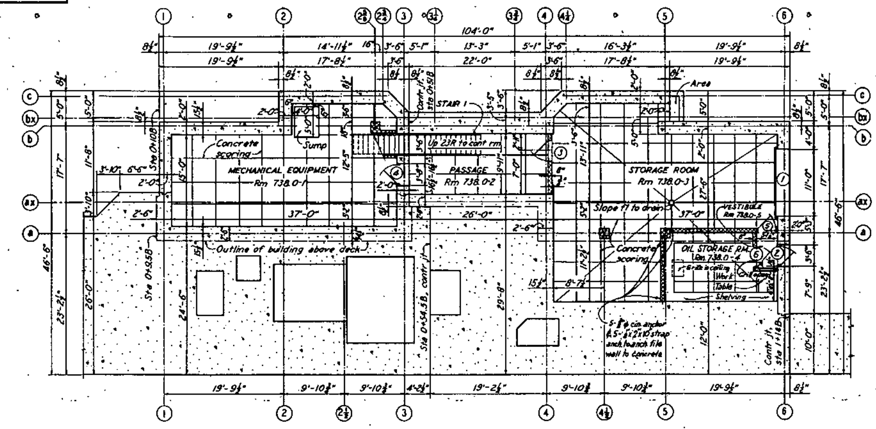
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED | RECOMMENDED | APPROVED

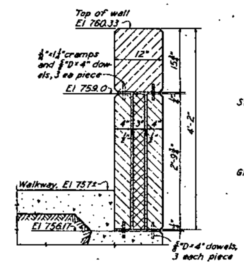
KNOXVILLE 11-20-39 9 A 4 66N200 R7

RECORD DRAWING AS CONSTRUCTED

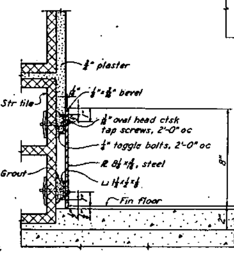
02-L529.9 70/1



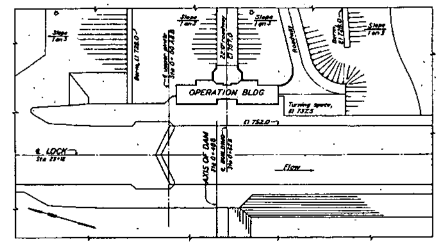
PLAN - EL 738.0
Scale 1/8"=1'-0"



SECTION Y-Y
Scale 1"=1'-0"



STEEL BASE
Scale 3"=1'-0"

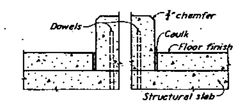


KEY PLAN
Scale 1"=50'

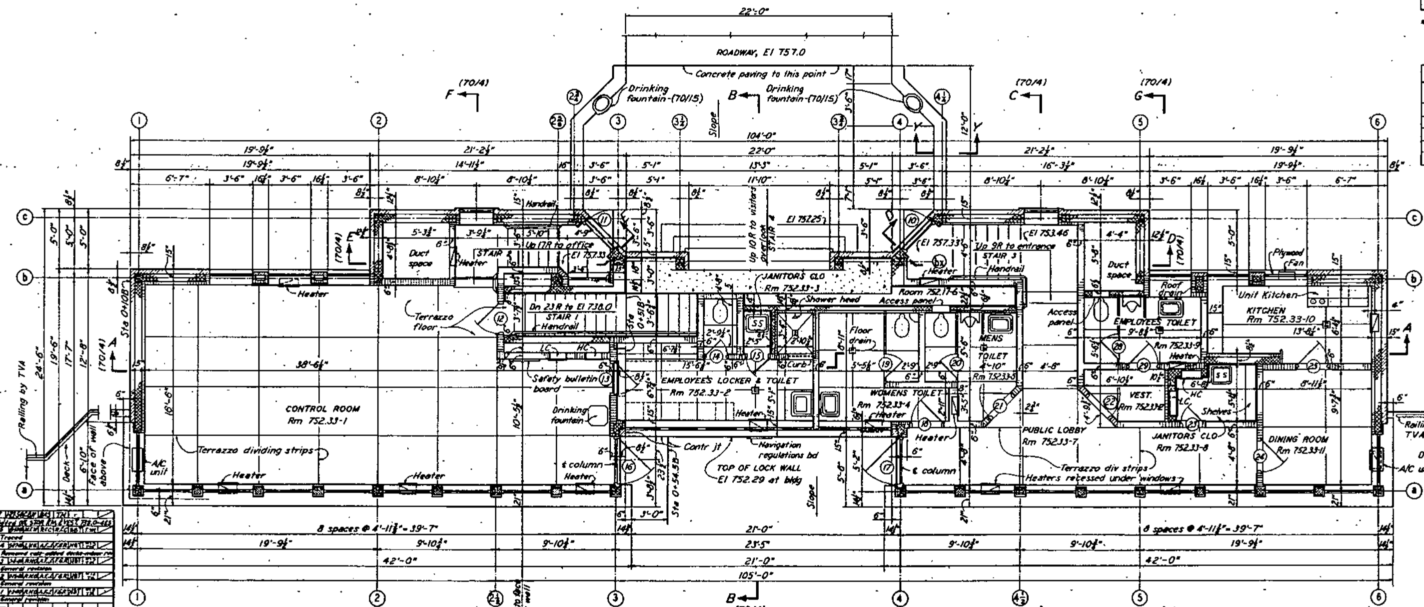
ROOM FINISH SCHEDULE					
RM NO.	NAME OF ROOM	FLOOR	BASE	WALLS	CEILING
738.0-1	Mech equipment	3" cem	None	3/4" cem plstr on tile	None
738.0-2	Passage	3" cem	None	3/4" cem plstr on tile	None
738.0-3	Storage	3" cem	None	3/4" cem plstr on tile	None.
738.0-4&5	Oil storage & Vent	3" cem	None	3/4" cem plstr. on tile	3/4 cem plaster
752.33-1	Control room	Terrazzo	None	Glazed tile	Acoustical tile *
752.33-2	Empl locker & toilet	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.33-3	Janitor's closet	2" cem	None	3/4" cem plaster	3/4" cem plaster
752.33-4	Women's toilet	Terrazzo	None	Glazed tile	3/4" sand fin. plstr.
752.33-5	Men's toilet	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.17-6	Utility chase	None	None	3/4" cem plstr on tile	None
752.33-7	Public lobby	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.33-8	Janitor's closet	2" cem	None	3/4" cement plstr	3/4" cem plstr
752.33-9	Employee's toilet	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.33-10	Kitchen	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.33-11	Dining room	Terrazzo	None	Glazed tile	3/4" sand fin. plstr
752.33-12	Vestibule	Terrazzo	None	Glazed tile	3/4" sand fin. plstr

* Control room ceiling to be acoustical tile on gypsum board (Nailock & Screwlock system).
In all rooms not having ceilings the walls are to extend to bottom of floor slab above.

STAIR FINISH SCHEDULE					
STAIR NO.	ELEVATIONS	TREADS & LANDINGS	NOSINGS	WALLS	CEILING
1	738.0 to 752.33	Cement	Cast iron	3/4" cem plstr on tile	3/4" cem plstr.
2	752.33 to 762.67	Terrazzo	Aluminum	Glazed tile	3/4" sand fin. plstr
3	752.33 to 757.33	Terrazzo	Aluminum	Glazed tile	3/4" sand fin. plstr
4	757.33 to 762.67	Concrete	Aluminum safety treads	Limestone	3/4" cement plstr



MACHINE BASE
TYPICAL
Scale 1½"=1'-0"



PLAN - EL 752.33

Scale 1/4"=1'-0"
Except as noted

LOCK OPERATION BUILDING

ARCHITECTURAL
PLANS - EL 738.0 & 752.33

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

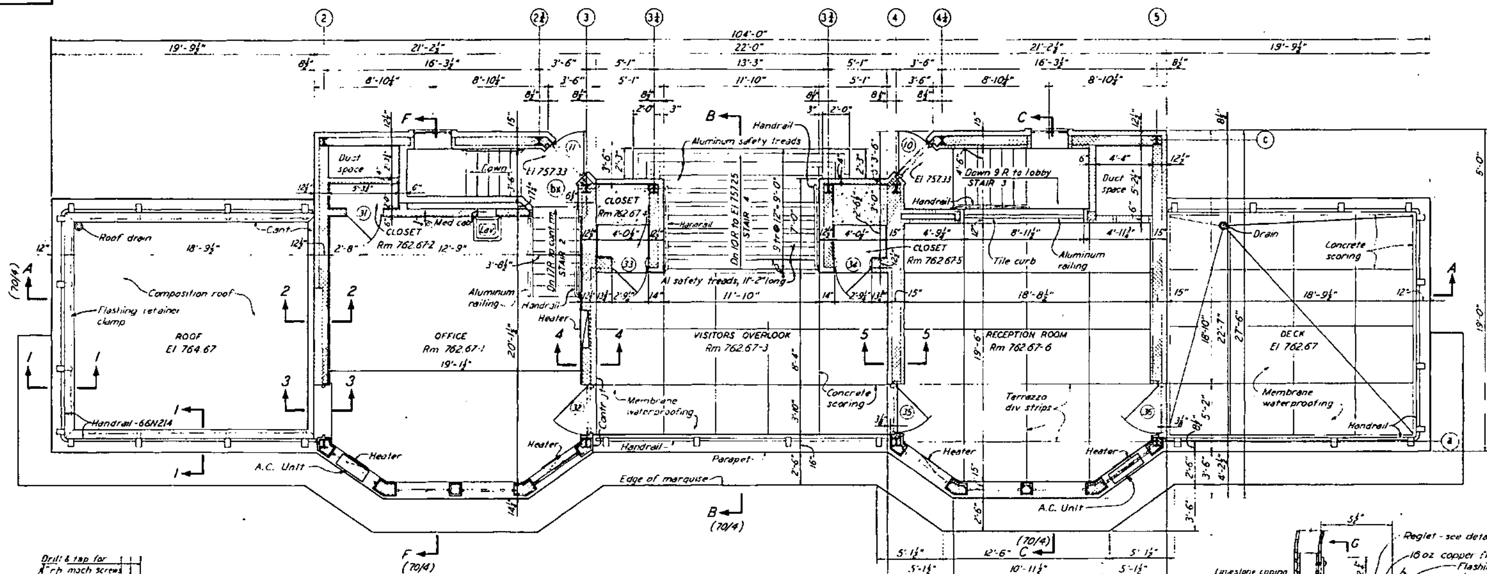
SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE	11-20-39	9	A	4	66N201 R9

RECORD DRAWING AS CONSTRUCTED

02-L529.9 70/2

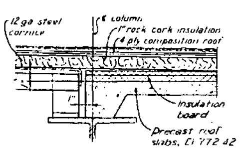
66N202



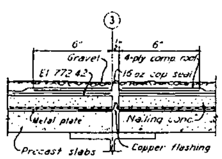
PLAN - EL 762.67

Scale 1/4"=1'-0"

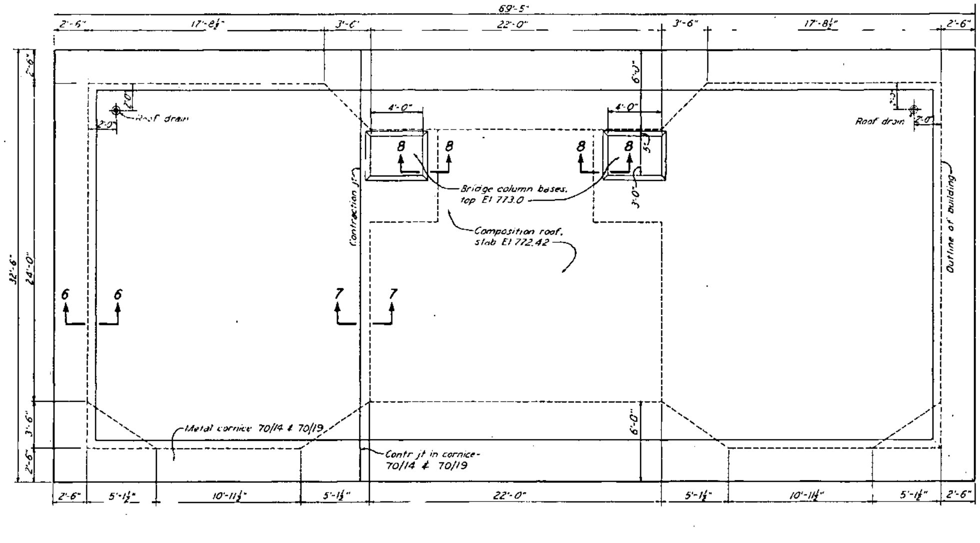
SECTION G-G



TYPICAL SECTION 6-6

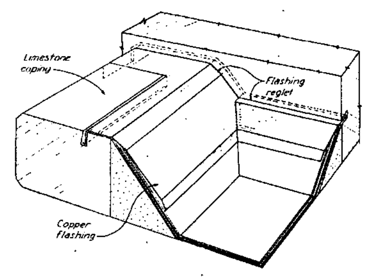


SECTION 7-7
TYP CONTR JT - ROOF

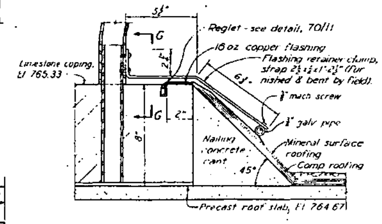


ROOF PLAN - EL 772.42

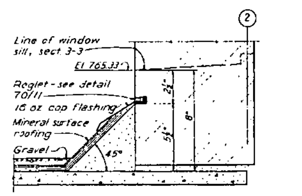
Scale 1/8"=1'-0"



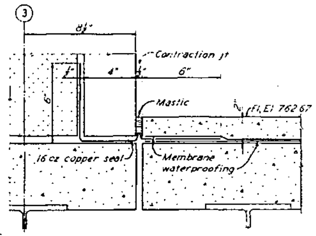
PERSPECTIVE INTERSECTION
SECTION 1-1 & 2-2



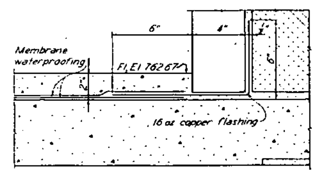
TYPICAL SECTION 1-1



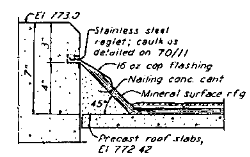
SECTION 2-2 & 3-3
SIMILAR EXCEPT AS NOTED



SECTION 4-4



TYPICAL SECTION 5-5
FOR ROOM 762.67-3



TYPICAL SECTION 8-8
BRIDGE COLUMN BASE

ROOM FINISH SCHEDULE					
RM NO.	NAME OF ROOM	FLOOR	BASE	WALLS	CEILING
762.67-1	Office	Linoleum	Metal	Sand fin plstr	Sand fin. plstr
762.67-2	Closet	Linoleum	Metal	Sand fin plstr	Sand fin. plstr
762.67-3	Visitors overlook	2" cement	None	Limestone	Cement plstr
762.67-4	Closet	2" cement	None	Cement plstr	Cement plstr
762.67-5	Closet	2" cement	None	Cement plstr	Cement plstr
762.67-6	Reception room	Terrazzo	None	Glazed tile	Sand fin plstr

Scale 3"=1'-0"
Except as noted

LOCK OPERATION BUILDING

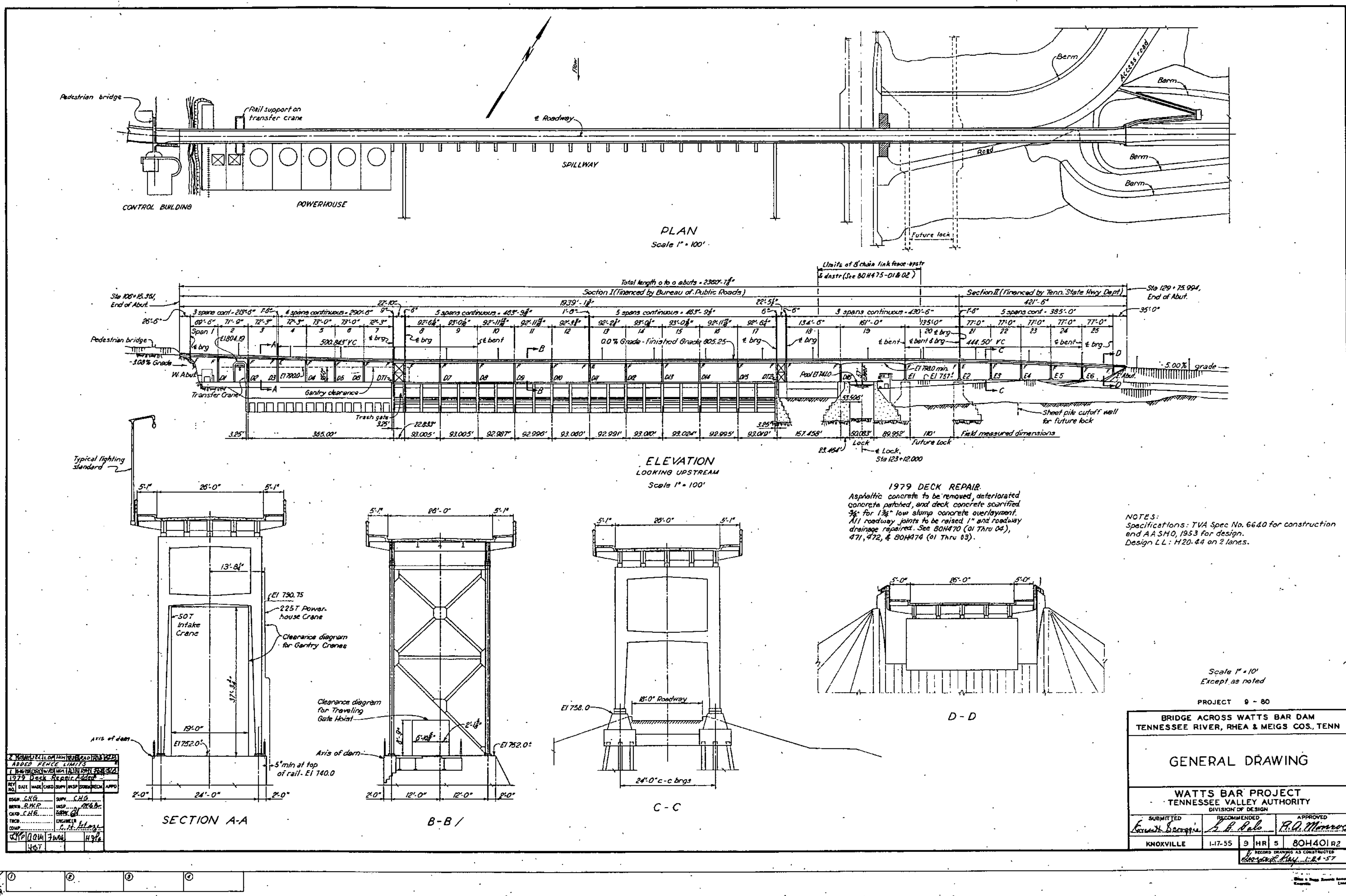
ARCHITECTURAL
PLAN - EL 762.67
ROOF PLAN & DETAILS

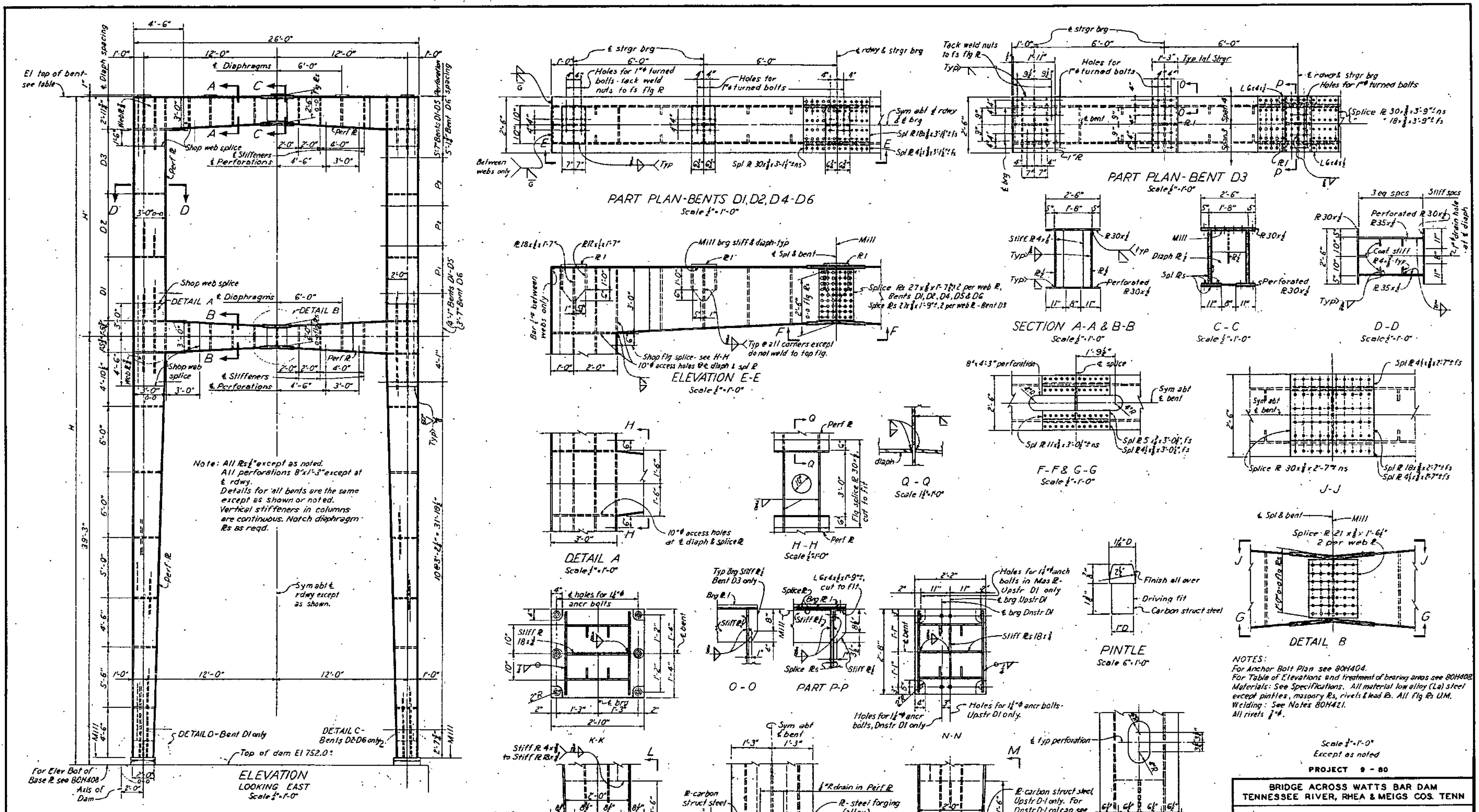
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
(signature)	Harry B. Tour	H. A. Hageman

KNOXVILLE | 11-20-39 | 9 | A | 4 | 66N202 R7

02-L529.9 70/3 RECORD DRAWING AS CONSTRUCTED 7-17-43


PLAN
Scale 1" = 100'
Pedestrian bridge
Rail support on transfer crane
℄ Roadway
Flow
SPILLWAY
CONTROL BUILDING
POWERHOUSE
Berm
Access road
Road
Future lock
Limits of 8' chain link fence - upstr & dnstr (See 80H475-01 & 02)
Total length o to o abuts = 2350'-7⅛"
Section I (Financed by Bureau of Public Roads)
Section II (Financed by Tenn. State Hwy Dept)
Sta 106+15.351, End of Abut.
Sta 129+75.994, End of Abut.
1939'-1⅞"
421'-6"
3 spans cont - 213'-6"
4 spans continuous - 290'-6"
5 spans continuous - 463'-9⅝"
5 spans continuous - 463'-9⅝"
3 spans continuous - 430'-6"
5 spans cont - 385'-0"
0.0% Grade - Finished Grade 805.25
500.845' VC
444.50' VC
-3.08% Grade
5.00% grade
W. Abut.
E. Abut.
Transfer Crane
Gantry clearance
Trash gate
Pool El 741.0
Sheet pile cutoff wall for future lock
Field measured dimensions
Lock
℄ Lock, Sta 123+12.000
Future lock
ELEVATION
LOOKING UPSTREAM
Scale 1" = 100'
Typical lighting standard
SECTION A-A
B-B
C-C
D-D
El 790.75
225T Powerhouse Crane
50T Intake Crane
Clearance diagram for Gantry Cranes
Clearance diagram for Traveling Gate Hoist
Axis of dam
5' min at top of rail - El 740.0
El 752.0
El 758.0
18'-0" Roadway
24'-0" c-c brgs
1979 DECK REPAIR
Asphaltic concrete to be removed, deteriorated concrete patched, and deck concrete scarified ¼" for 1¾" low slump concrete overlayment. All roadway joints to be raised 1" and roadway drainage repaired. See 80H470 (01 Thru 04), 471, 472, & 80H474 (01 Thru 03).
NOTES:
Specifications: TVA Spec No. 6640 for construction and AASHO, 1953 for design.
Design LL: H20-44 on 2 lanes.
Scale 1" = 10'
Except as noted
PROJECT 9 - 80
BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS., TENN
GENERAL DRAWING
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
1-17-55
9 HR 5 80H401 R2
RECORD DRAWING AS CONSTRUCTED
ADDED FENCE LIMITS
1979 Deck Repair Added



BENT VARIABLES									
BENT	ELEV BENT TOP	H	H'	D1	D2	D3	P1	P2	P3
D1	812.53	60.55	21.30	3'-7¼"	3'-7⅜"	3'-7¼"	3'-10¼"	3'-10⅜"	3'-10¼"
D2	810.32	58.34	19.09	4'-10¼"	5'-1"	4'-8⅜"	3'-1⅜"	3'-1⅜"	3'-1⅜"
D3	808.12	56.14	16.89	4'-1¼"	4'-2⅛"	4'-1¼"	3'-7¼"	3'-7⅜"	0
D4	805.97	53.99	14.74	5'-1½"	5'-2"	0	5'-1"	0	0
D5	804.25	52.27	13.02	4'-3"	4'-3½"	0	3'-4¼"	0	0
D6	802.79	50.81	11.56	3'-6¼"	3'-7"	0	2'-10"	0	0

NOTES:
For Anchor Bolt Plan see 80H404.
For Table of Elevations and treatment of bearing areas see 80H408.
Materials: See Specifications. All material low alloy (La) steel except pintles, masonry Rs, rivets & lead Rs. All flg Rs U.M.
Welding: See Notes 80H421.
All rivets ⅞"⌀.

Scale ½"=1'-0"
Except as noted

PROJECT 9 - 80

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN

BENTS D1-D6

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	R.O. Monroe

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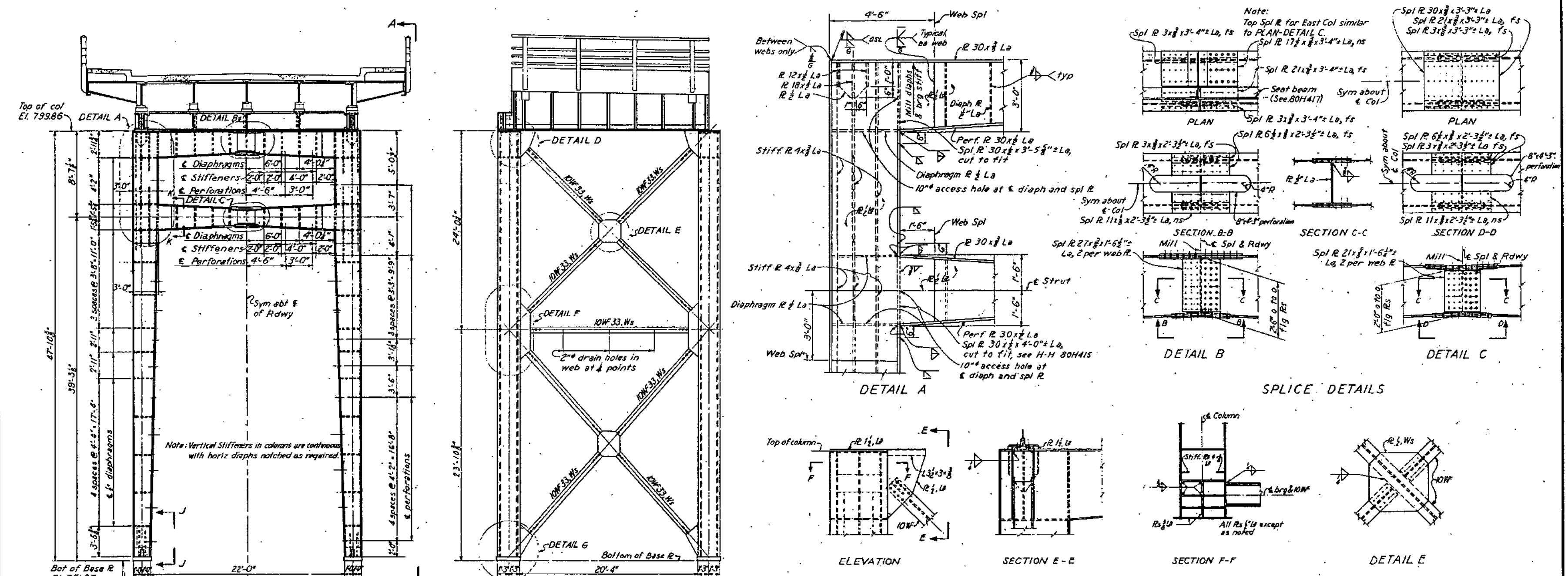
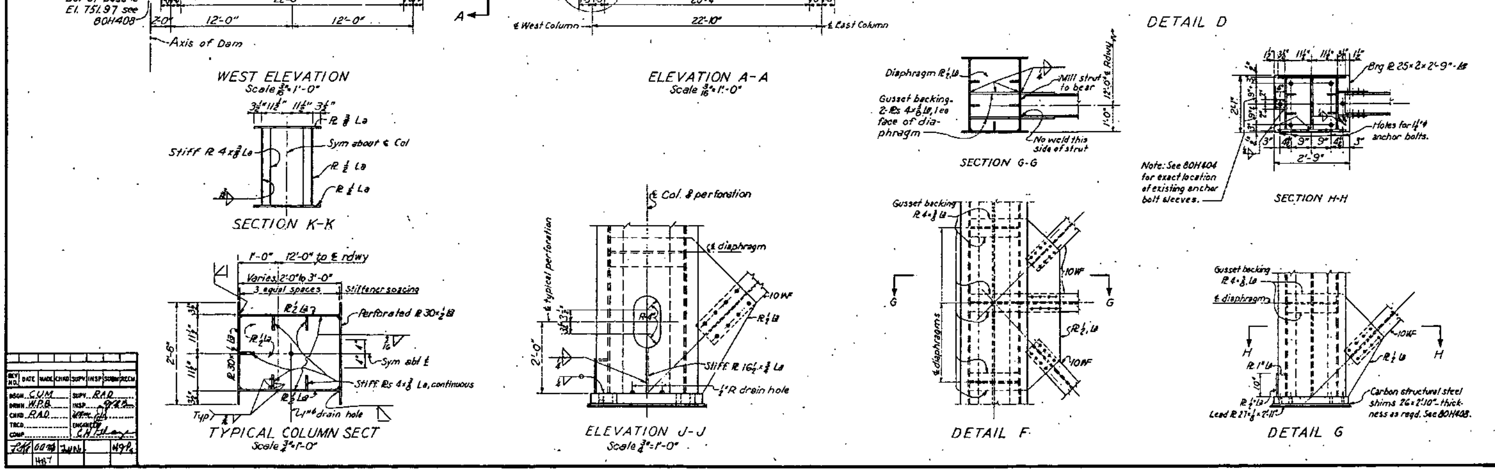
RECORD DRAWING AS CONSTRUCTED
George L. Key 1-24-57

80H415





NOTES:
All material shall be carbon structural steel, ASTM A7-53T, except as noted. See Specifications. Low Alloy steel is noted La. High strength steel is noted Hs. Structural steel for welding is noted Ws. All floorbeams, brackets, rail post braces, stiffeners on girders, and webs of fascia beams shall be vertical.
All connections on tower superstructure shall be riveted, except as noted. All field connections on remainder of tower shall be riveted. Rivets - 7/8"ø. Shop connections on remainder of tower shall be welded.
Welding - See Specifications - Butt joints may be welded from one side only if completely fused to a suitable backing. Welded connections shall develop the strength of the riveted connections as a minimum.
For location, details, and schedule of anchor bolts see 80H404.
For preparation of bearing areas and Table of Elevations see 80H408.
For finished grade elevations and limits of vertical curve see 80H401.

Scale 1/2"=1'-0"
Except as noted

PROJECT 9 - 80

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN

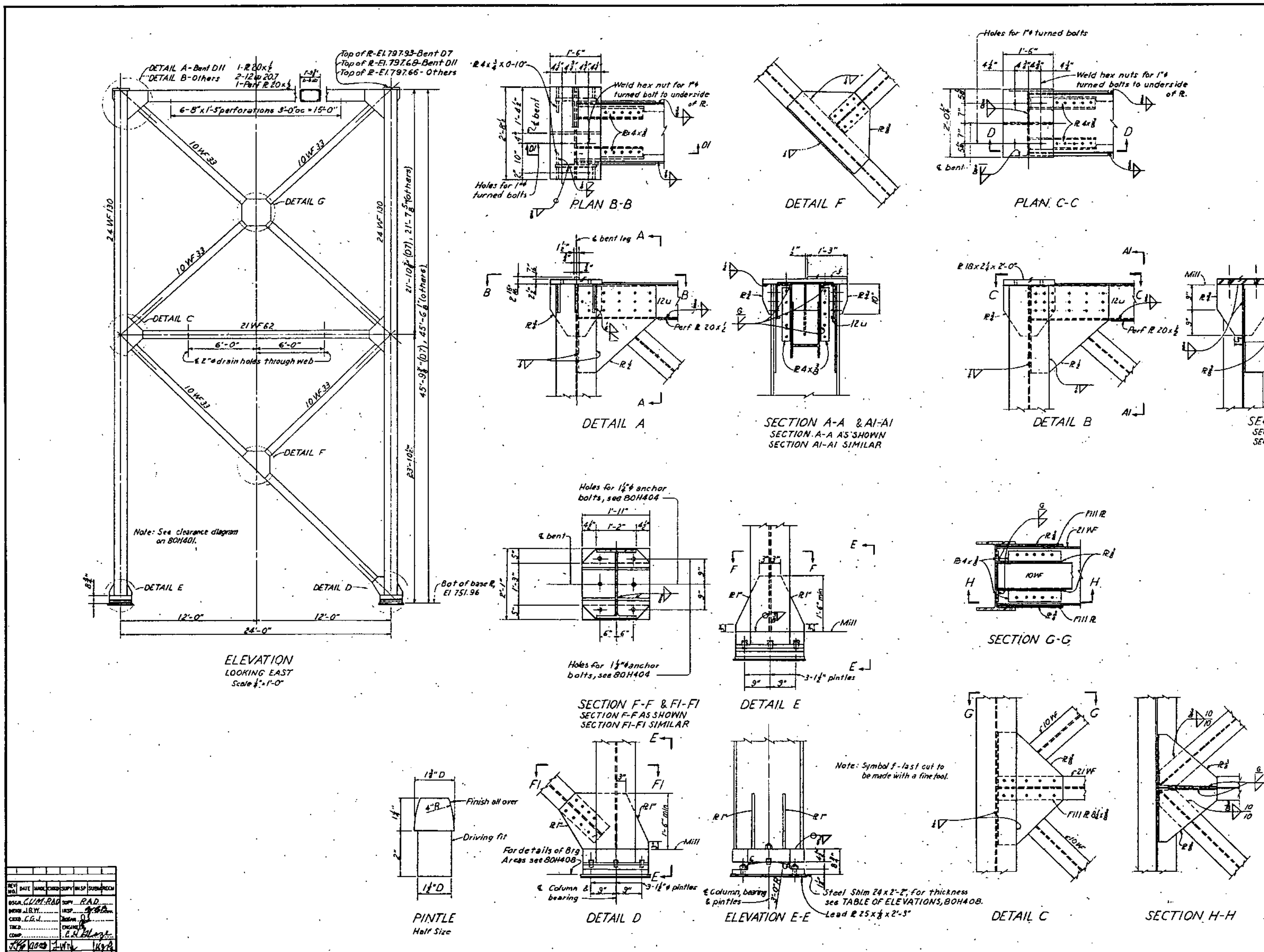
TOWER DT1 - SHEET 1

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED | RECOMMENDED | APPROVED
R.A. Monroe

KNOXVILLE 1-17-55 9 HR 8 80H416 R0

RECORD DRAWING AS CONSTRUCTED 1-24-57



NOTES:
All material shall be structural steel for welding, ASTM A373-54T, except bolts, nuts, rivets and lead plates. See Specifications.
All shop connections shall be welded. All field connections shall be riveted - 7/8"φ rivets.
For location, details and schedule of anchor bolts see 80H404.

Scale 3/4"=1'-0"
Except as noted

PROJECT 9 - 80

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS., TENN

BENTS D7 - D15

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

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[signature]	[signature]	R.A. Monroe
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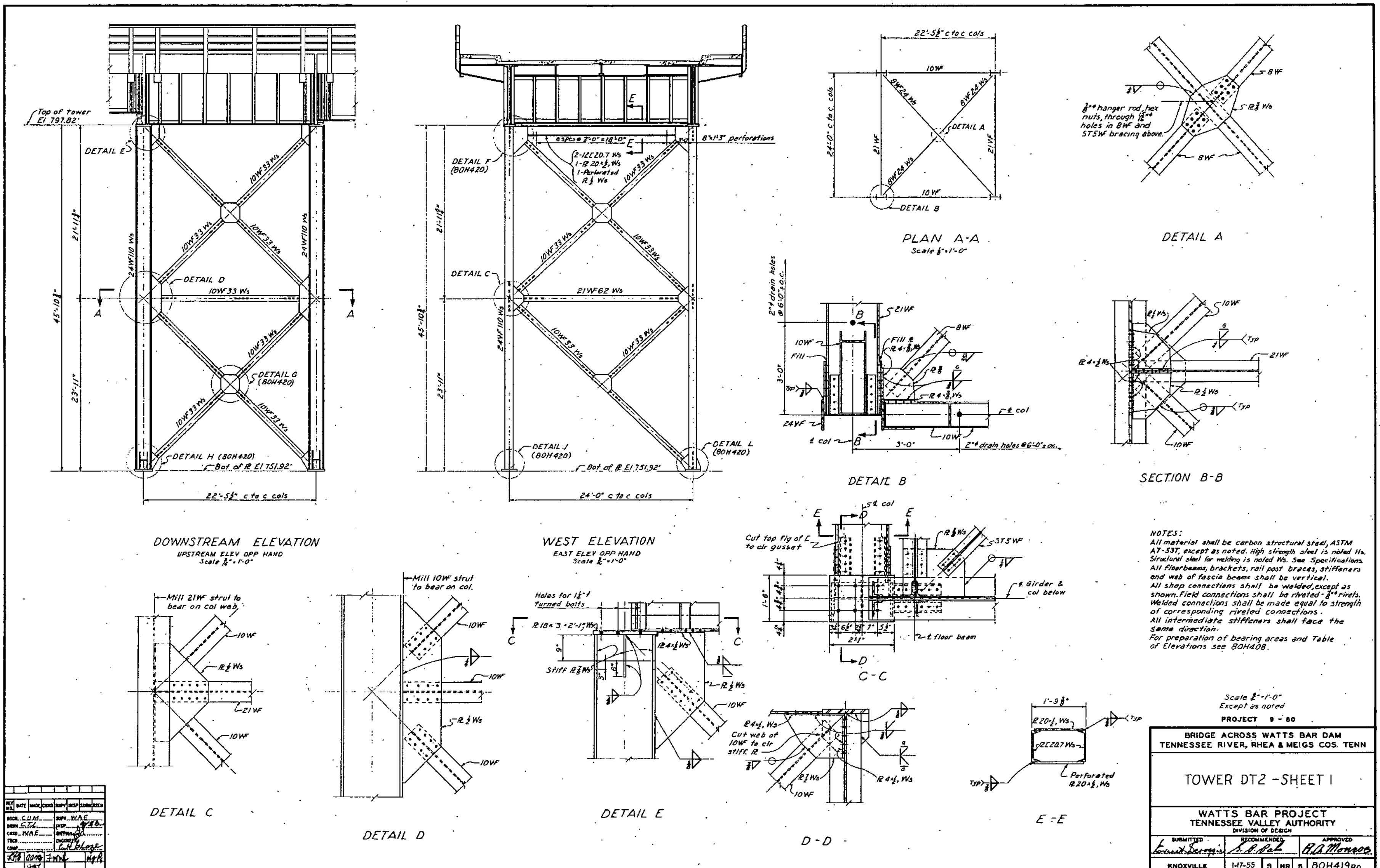

NOTES:
All material shall be carbon structural steel, ASTM A7-53T, except as noted. High strength steel is noted Hs. Structural steel for welding is noted Ws. See Specifications.
All floorbeams, brackets, rail post braces, stiffeners and web of fascia beams shall be vertical.
All shop connections shall be welded, except as shown. Field connections shall be riveted - ⅞" rivets. Welded connections shall be made equal to strength of corresponding riveted connections.
All intermediate stiffeners shall face the same direction.
For preparation of bearing areas and Table of Elevations see 80H408.

Scale ¼"-1'-0"
Except as noted

PROJECT 9 - 80

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN

TOWER DT2 - SHEET 1

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

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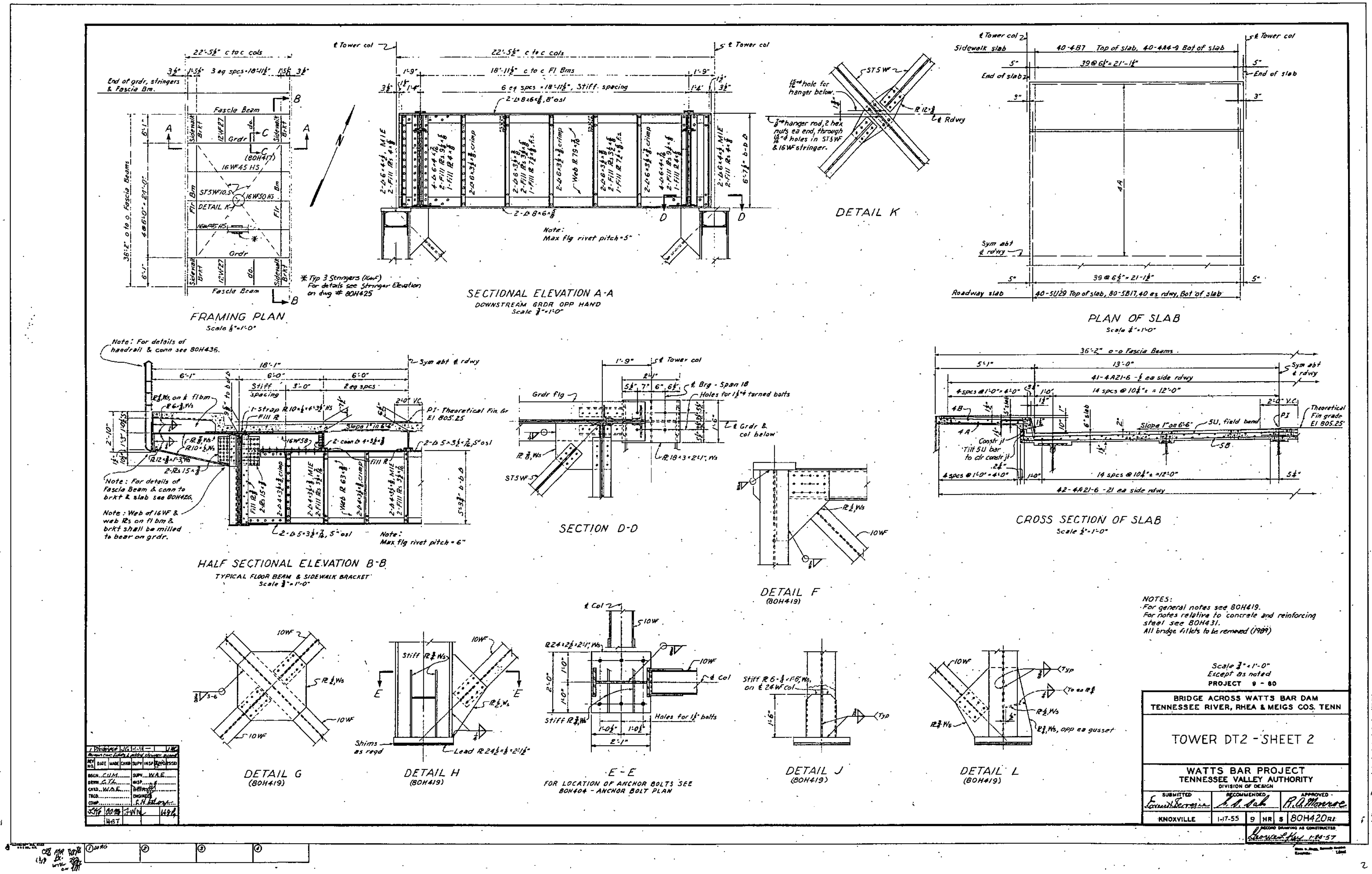
RECORD DRAWING AS CONSTRUCTED
George L. Key 1-24-57



FRAMING PLAN
Scale 1/8"=1'-0"
SECTIONAL ELEVATION A-A
DOWNSTREAM GRDR OPP HAND
Scale 3/8"=1'-0"
Note: Max flg rivet pitch = 5"
DETAIL K
PLAN OF SLAB
Scale 1/4"=1'-0"
HALF SECTIONAL ELEVATION B-B
TYPICAL FLOOR BEAM & SIDEWALK BRACKET
Scale 3/8"=1'-0"
Note: For details of handrail & conn see 80H436.
Note: For details of Fascia Beam & conn to brkt & slab see 80H426.
Note: Web of 16WF & web Pls on fl bm & brkt shall be milled to bear on grdr.
Note: Max flg rivet pitch = 6"
SECTION D-D
DETAIL F
(80H419)
CROSS SECTION OF SLAB
Scale 1/2"=1'-0"
DETAIL G
(80H419)
DETAIL H
(80H419)
E-E
FOR LOCATION OF ANCHOR BOLTS SEE 80H404 - ANCHOR BOLT PLAN
DETAIL J
(80H419)
DETAIL L
(80H419)
* Typ 3 Stringers (16WF) For details see Stringer Elevation on dwg # 80H425
NOTES:
For general notes see 80H419.
For notes relative to concrete and reinforcing steel see 80H431.
All bridge fillets to be removed (1989)
Scale 3/4"=1'-0"
Except as noted
PROJECT 9-80
BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN
TOWER DT2 - SHEET 2
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
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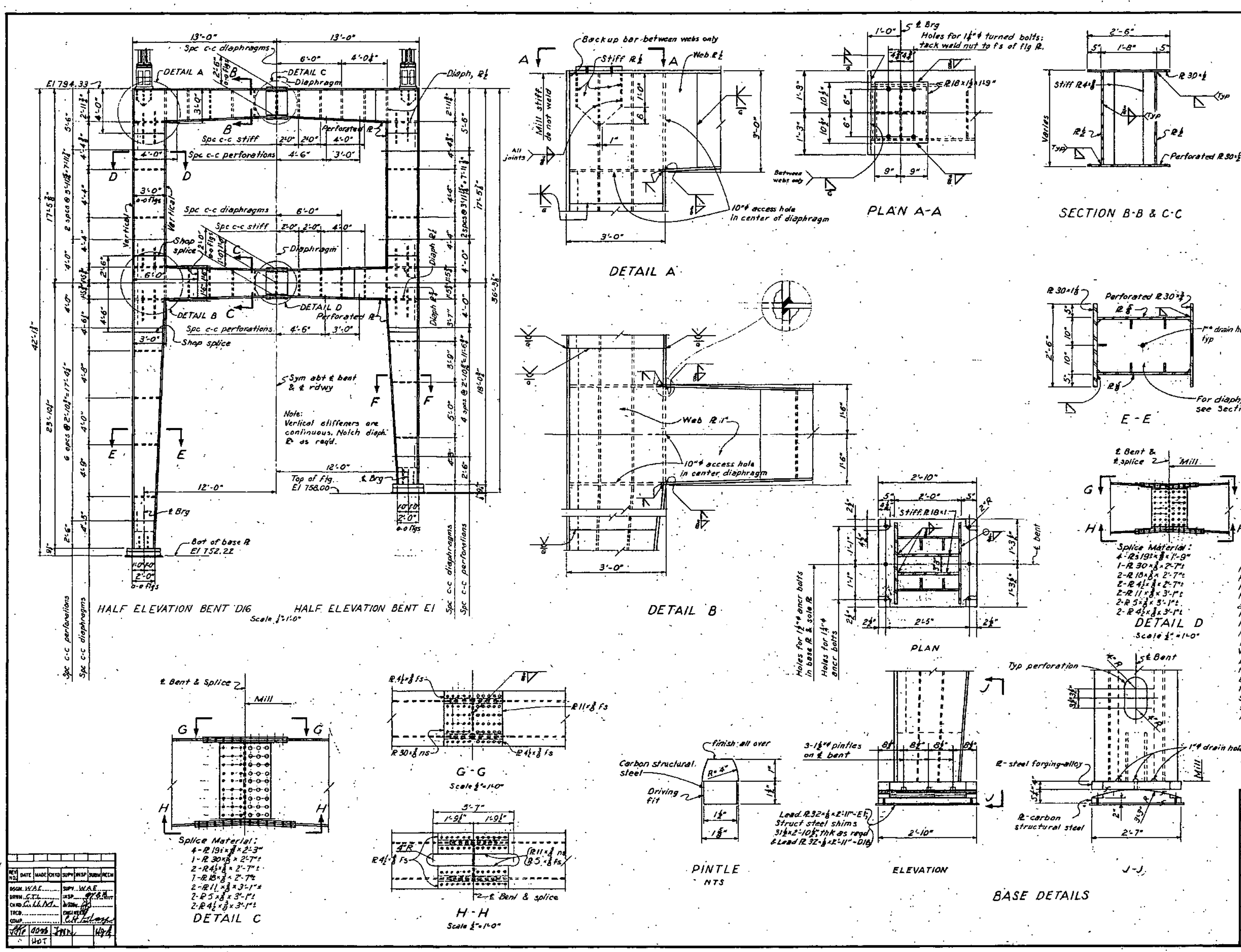
80H420



NOTES:
For Anchor Bolt Plan see 80H404 & 80H405.
For details of footings for E1-E6 see 80H410.
For Table of Elevations and treatment of bearing area at D16 see 80H408.
For location of bents see 80H403.
Materials: See specifications. All material low alloy (B) steel except pintles, base Ps, rivets, and lead Ps. All flange Ps to be U M.
Welding: See specifications. Butt joints may be welded from one side only if completely fused to a suitable backing. For butt joints between Ps of different thickness, maintain transition slope requirements of welding specifications. All butt joints welded from one side shall have 3/16" root opening.
All rivets 7/8"φ.

Scale 3/4"=1'-0"
Except as noted

PROJECT 9 - 80

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN.

BENTS D16 & E1

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
Everett Scroggie	S. B. Bale	R. A. Monroe

KNOXVILLE | 1-17-55 | 9 | HR | 8 | 80H421R0

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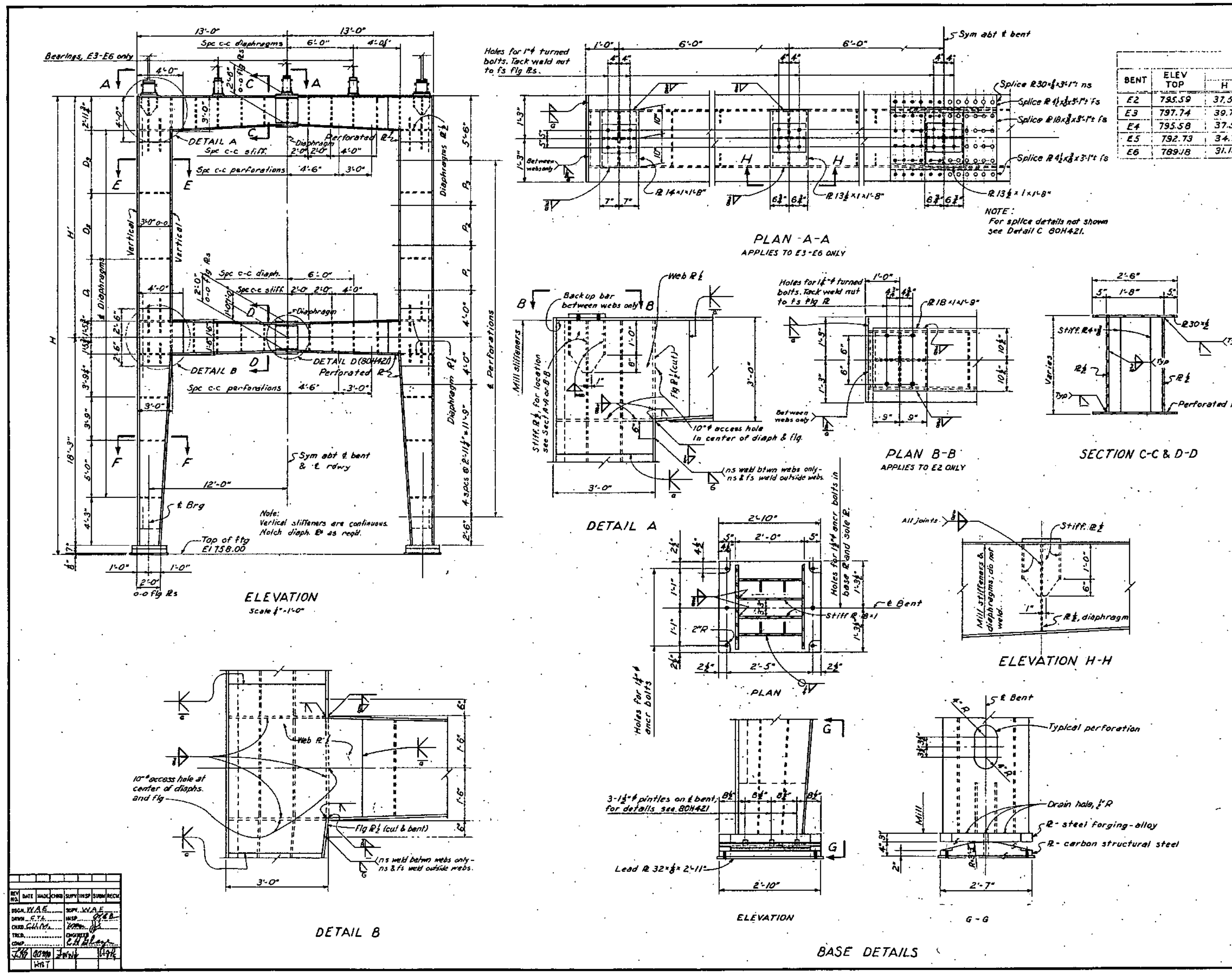
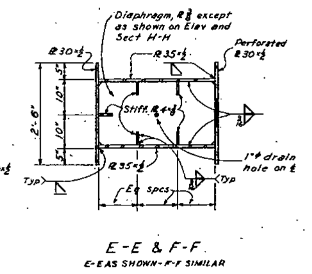
George L. Key 1-24-57



BENT	ELEV TOP	H	H'	D_1	D_2	D_3	P_1	P_2	P_3
		DIMENSIONS							
E2	795.59	37.59'	18.75'	4'-6½"	5'-2½"	4'-6½"	3'-1"	3'-1"	3'-1"
E3	797.74	39.74'	20.89'	5'-3¾"	5'-10½"	5'-3"	3'-9½"	3'-9½"	3'-9½"
E4	795.58	37.58'	18.73'	4'-6½"	5'-2¼"	4'-6½"	3'-1"	3'-1"	3'-0¾"
E5	792.73	34.73'	15.88'	4'-2¼"	3'-1⅞"	4'-1"	3'-2¼"	3'-2⅜"	0
E6	789.18	31.18'	12.34'	3'-11¼"	3'-11¼"	0	2'-10"	0	0

BENT VARIABLES



NOTES:
For notes and typical splice details see 80H421.

Scale 3/8"=1'-0" Except as noted

PROJECT 9-60

BRIDGE ACROSS WATTS BAR DAM
TENNESSEE RIVER, RHEA & MEIGS COS. TENN

BENTS E2 - E6

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

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80H422

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

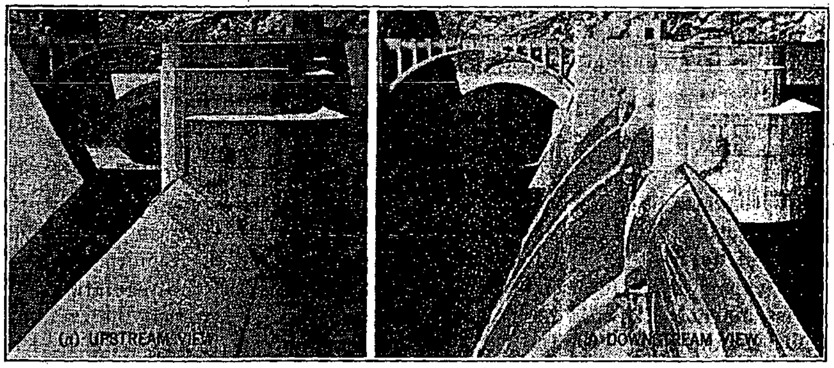


Fig. 1.—Drum Gate, 100 Ft by 16 Ft, at Hoover Dam (Arizona-Nevada)

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.[3]

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

[3] "Discha[illegible]oefficients for Irregular Overfall Spillway Sections," by J. N. Bradley, *Engineering Monograph N*[illegible] 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

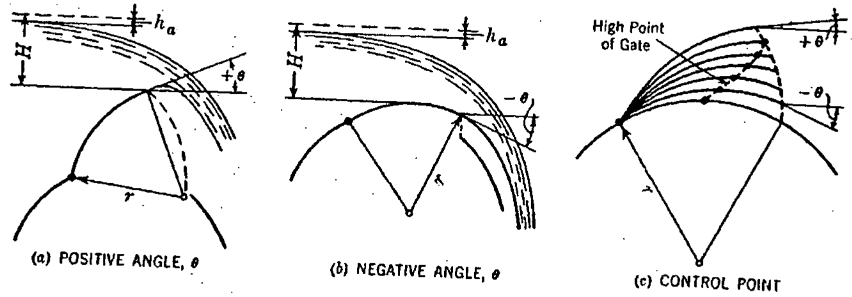


Fig. 2.—Drum-Gate Positions

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

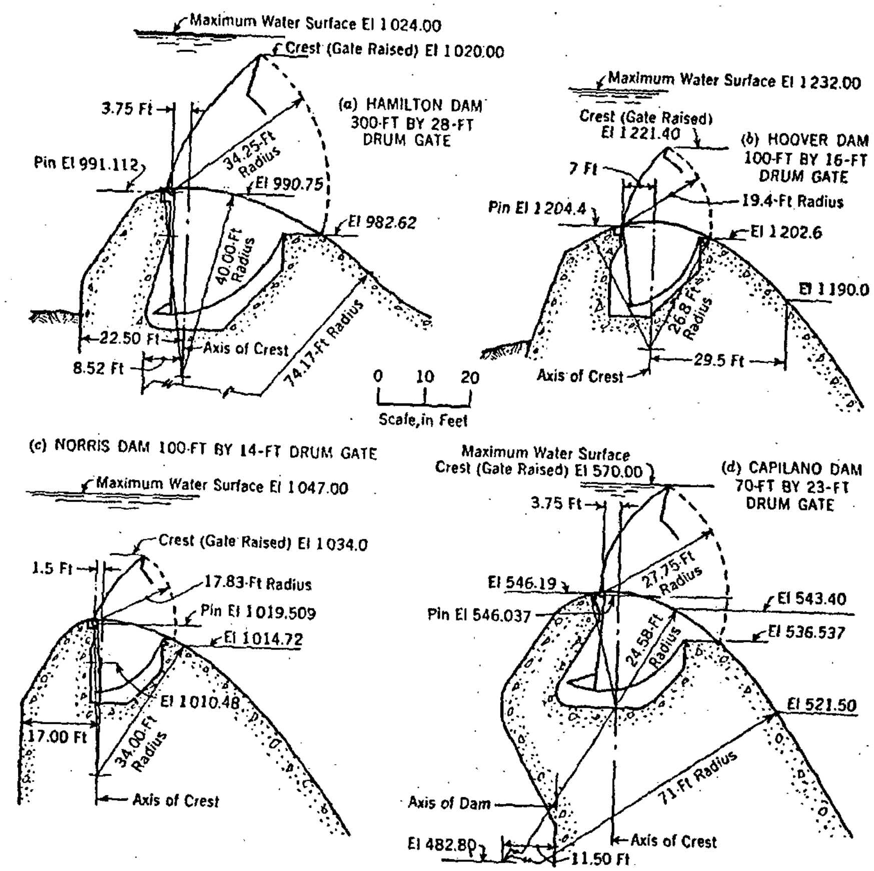


Fig. 3.—Examples of Drum-Gate Cross Sections

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_q	Reservoir elevation, in feet	Coefficient, C_q	Reservoir elevation, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
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	3.700	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_q	Reservoir elevation, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Reservoir elevation, in feet	Coefficient, C_q
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	3.365	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	3.900	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	3.175	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	3.800		
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	3.300
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	3.050
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.

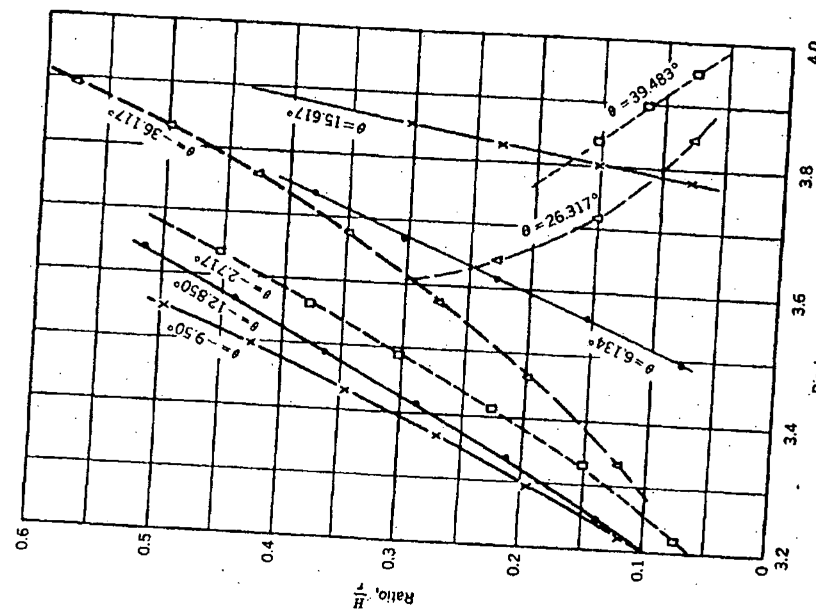


FIG. 5.—DIMENSIONLESS PLOTTING OF DATA FROM MODEL OF SHASTA DAM DRUM GATE

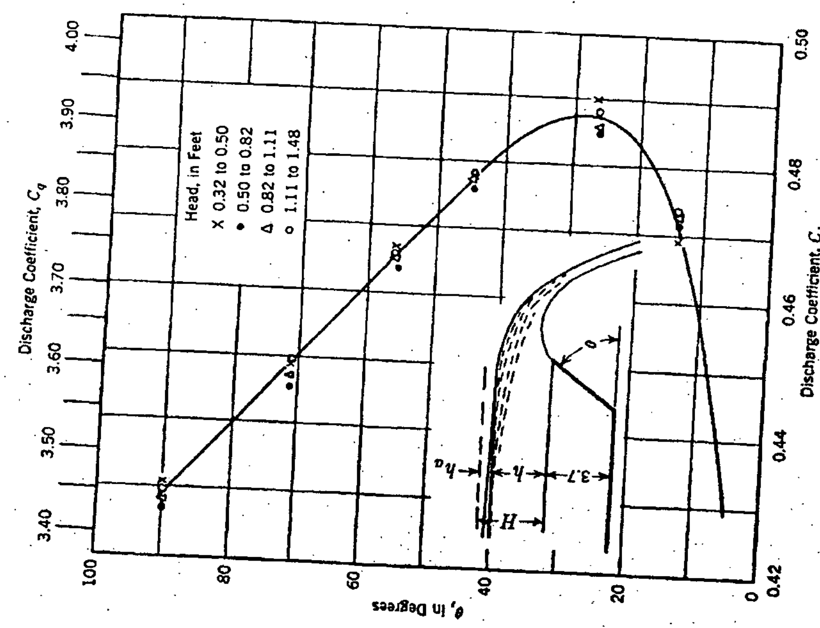


FIG. 4.—RESULTS OF BAZIN'S EXPERIMENTS ON SLOPING WEIRS

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

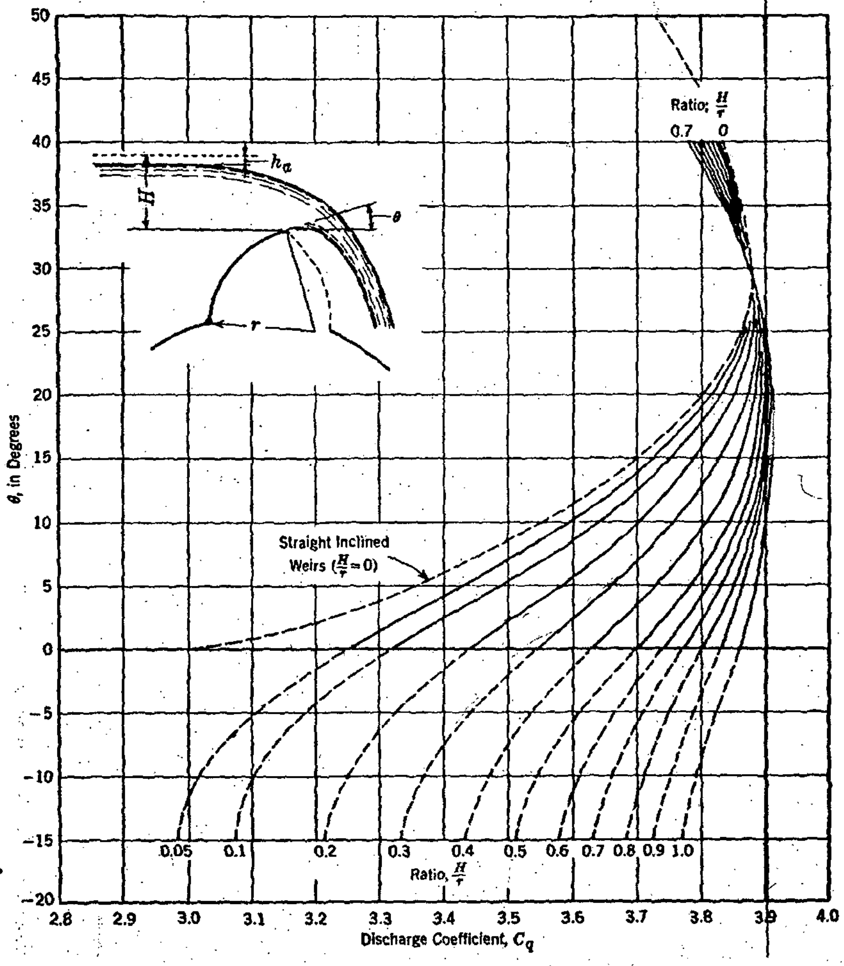


FIG. 6.—GENERAL CURVES FOR THE DETERMINATION OF DISCHARGE COEFFICIENTS

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, $Q = C_q L H^{3/2}$. 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 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.

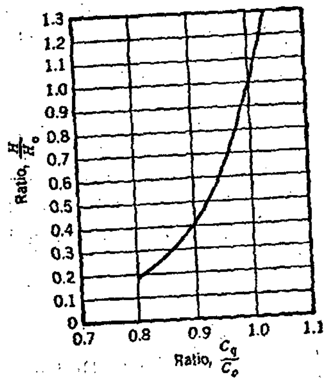


FIG. 7.—COEFFICIENTS OF DISCHARGE FOR OTHER THAN THE DESIGNED HEAD

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

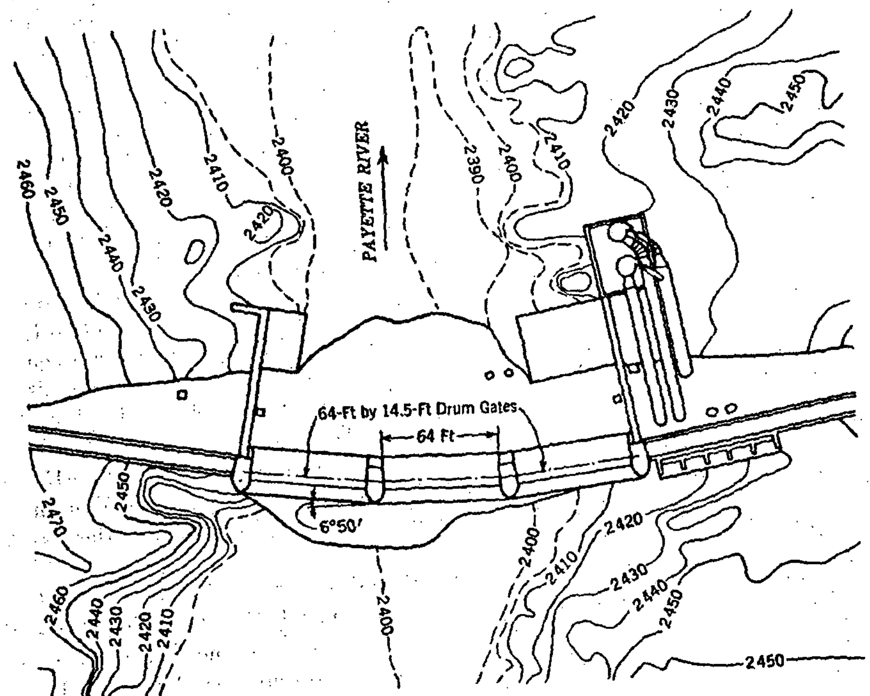


FIG. 8.—PLAN OF BLACK CANYON DIVERSION DAM IN IDAHO

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.

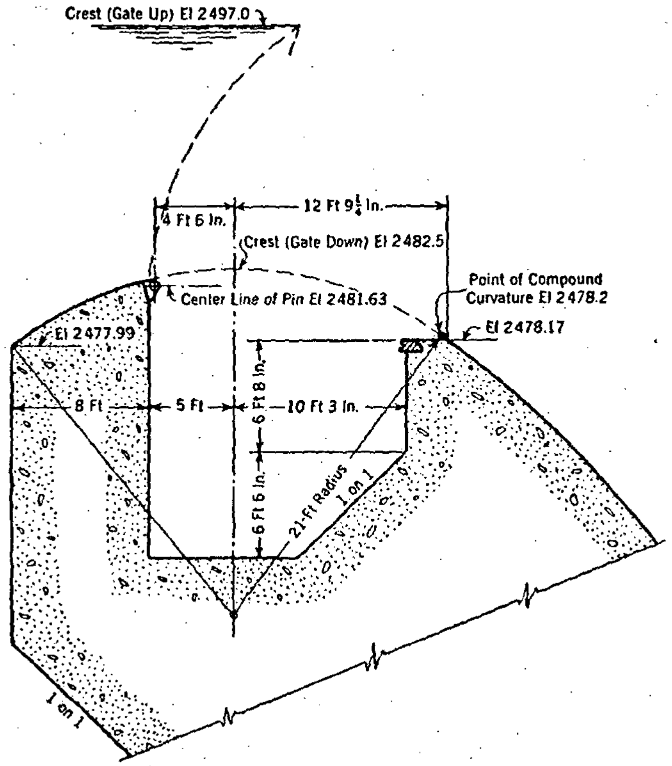


FIG. 9.—SPILLWAY CREST DETAIL, BLACK CANYON DAM IN IDAHO

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_q/C_o (4)	Coefficient, C_q (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: $Q = C_q L H^{3/2}$, 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.

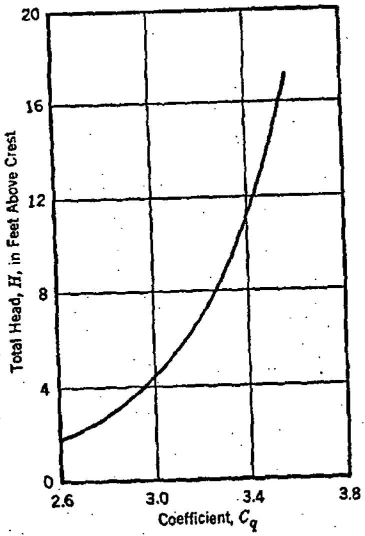


FIG. 10.—HEAD-COEFFICIENT CURVE, BLACK CANYON DAM, IN IDAHO

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.

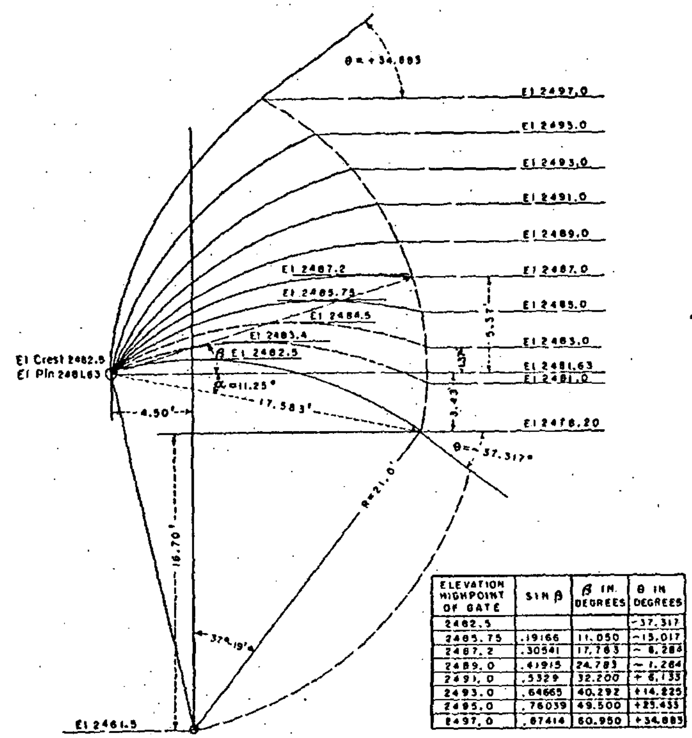
As the angle θ is given negative values, the procedure for determining the discharge remains the same for angles between 0 and −15°, except that the head on the gate is measured above the high point rather than above the lip. Discharge computations for negative angles of the gate down to −15.017° are 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 appreciably 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.



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	+25.433
2497.0	.87414	60.950	+34.883

FIG. 11.—RELATIONSHIP OF GATE ELEVATION TO ANGLE θ

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 calibrated, (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 (1)	Reservoir elevation, in ft (2)	H, in ft[a] (3)	Ratio, $\frac{H}{r}$ (4)	Coefficients, C_q (5)	$H^{3/2}$, in ft (6)	Q, in cu ft per sec[b] (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	0.000	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: $Q = C_q L H^{3/2}$.

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.

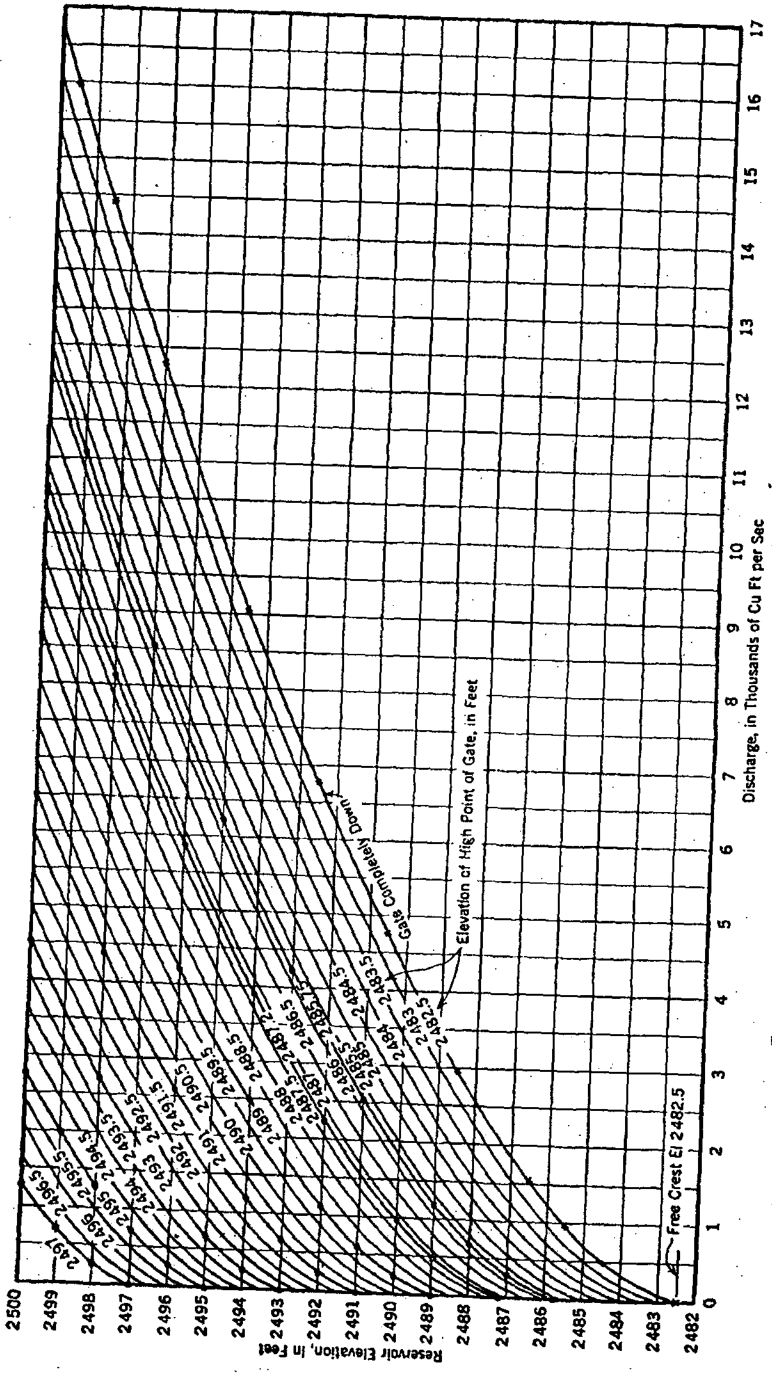


FIG. 12.—RATING CURVES FOR BLACK CANYON DAM DRUM-GATE SPILLWAY IN IDAHO

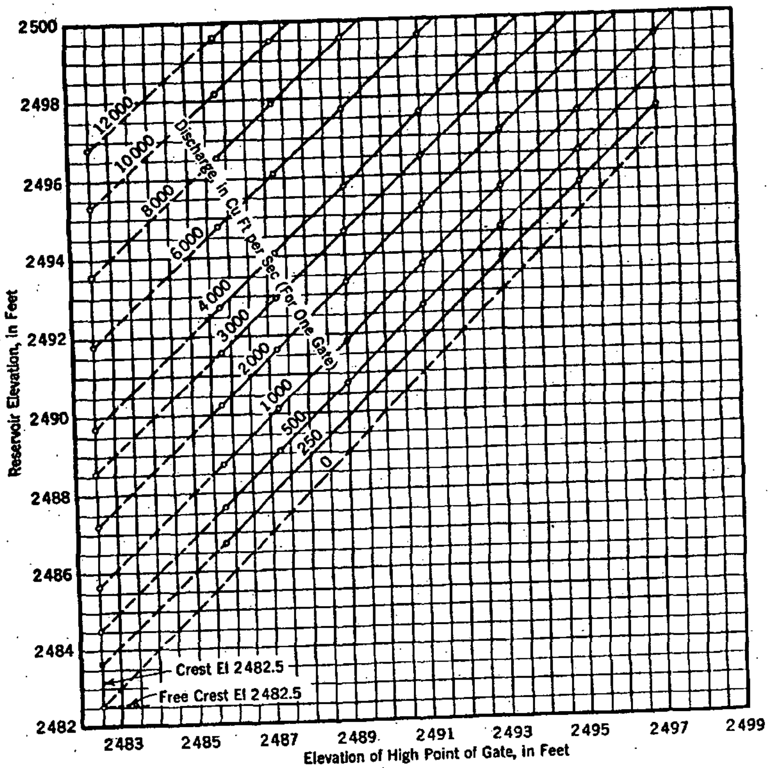


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

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.[9] Mr. Brudenell's equation is

$$Q = \frac{3.97\ L\ H^{1.62}}{H^{0.12}{}_D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

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;

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	1,4363	−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 $C_q = 3.48$. [c] C_q would be 3.466 for this discharge.

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.

[9] "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.

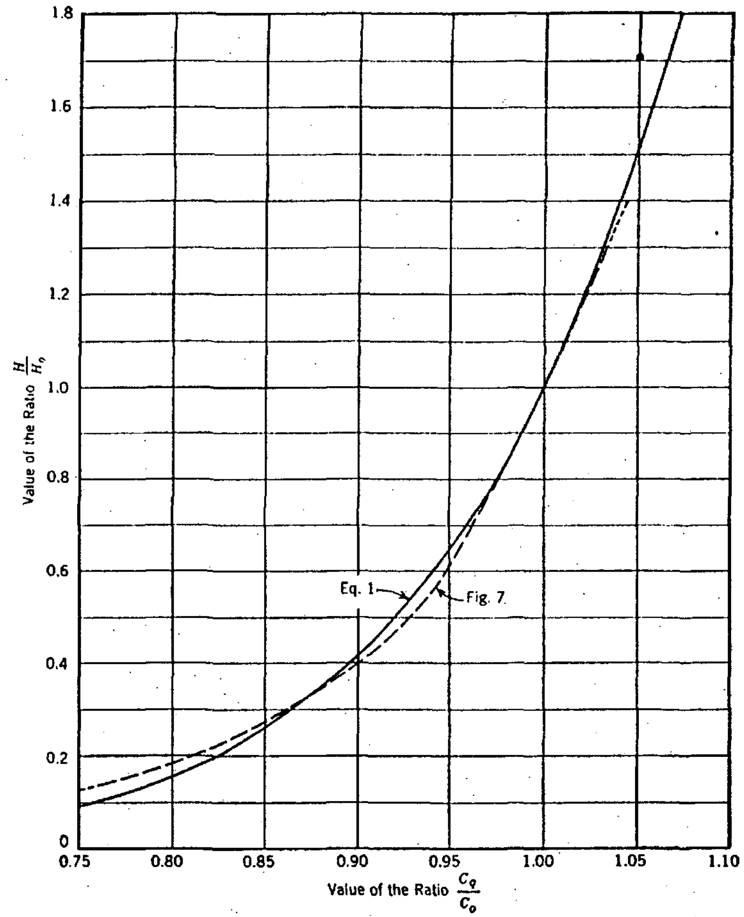

FIG. 14.—COMPARISON OF VALUES OBTAINED FROM FIG. 7 AND EQ. 1

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

$$Q = C_q L H^{3/2} \ldots\ldots (2)$$

and Eq. 1, from which

$$C_q = \frac{3.97 \; H^{1.62}}{H^{0.12}_D \; H^{3/2}} \ldots\ldots (3)$$

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,

$$C_q = \frac{2.5143 \; H^{1.62}}{H^{3/2}} \ldots\ldots (4)$$

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	3.405			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	3.716	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.635	+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	2.905			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—(*Continued*)

Total head, in feet (1)	Coefficient obtained from model test (2)	Using Eq. 1: C_e (3)	Using Eq. 1: Difference, in percent (4)	Using Fig. 7: C_e (5)	Using Fig. 7: Difference, in percent (6)	Using Fig. 14: C_e (7)	Using Fig. 14: Difference, in percent (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	3.818	+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	3.508	+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	−5.01
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	− 2.01	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	−0.98
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.

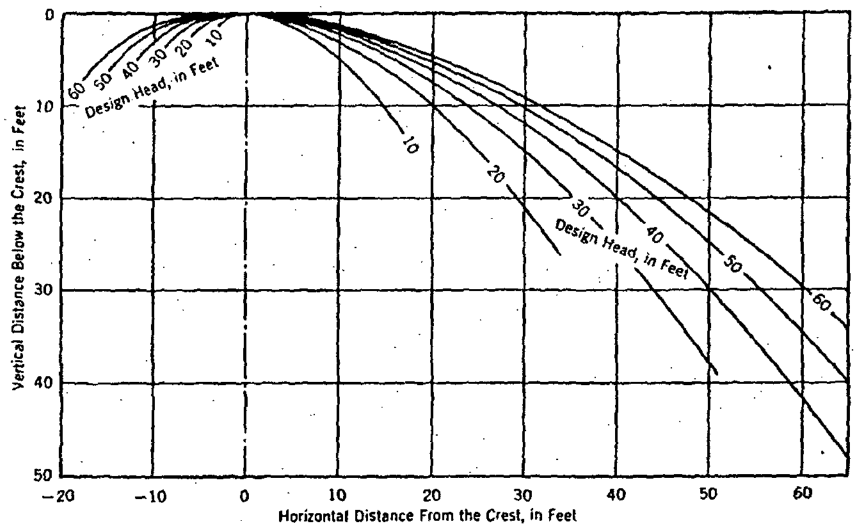

Fig. 15.—Standard Spillway Shapes

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.[19] 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

[19] "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_q-value plotted against H/H_o. In 1942, C. E. Kindsvater, M. ASCE, suggested a similar procedure in which the curve of C_q versus H/H_o 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,[15,16] 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.

[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.

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-

[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, 1902, 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_q	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

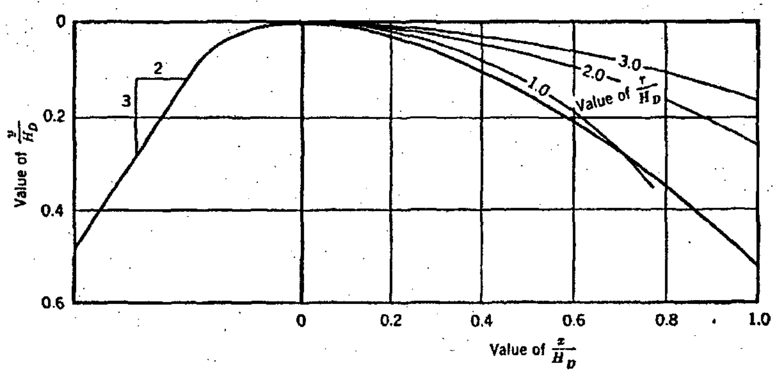

FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

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[3] 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.

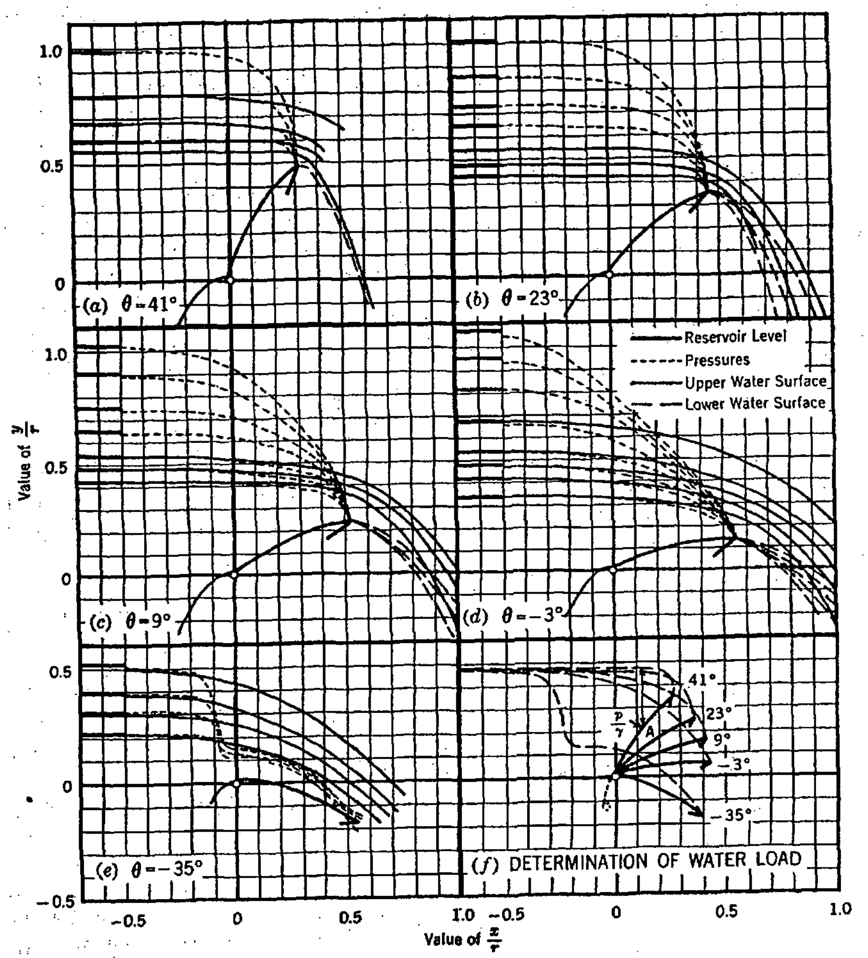

FIG. 17.—PRESSURE AND WATER-SURFACE PROFILES

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.

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Bellefonte Nuclear Units 3&4

Hydrology Project

Basis for
Dam Spillway Gate/Outlet Open Configuration
for Flood Analyses

Tennessee Valley Authority

Revision 0 - May 29, 2009

Basis for
Dam Spillway Gate/Outlet Open Configuration
for Flood Analyses

Issue

TVA maintains that all discharge outlets (spillway gates, sluice gates, and valves) for projects in the reservoir system can be placed in the fully open position for the passage of water when and as needed. The specific language contained in the Final Safety Analysis Report (FSAR) for the operating plants (WBN, SQN, and BFN) and for the BLN COLA is - "All gates were determined to be operable without failures during the flood." This evaluation provides the rationale and justification for this position.

Background

The TVA reservoir system consists of 48 dams located within the Tennessee River Basin. There are a total of 424 spillway gates at the 28 dams with gates. The spillway gates consist of a variety of types including: radial, vertical lift, fixed-roller lift, fixed-wheel lift, slide, drum, hinge, and Stoney. There are also several projects which have sluice gates and valves for discharge of water from the dam.

Basis for the All Gates/Outlets Open

1. Inspection of TVA dams is an integral part of TVA's dam safety program to ensure their safe and reliable operation. Plant operations staff is tasked to perform monthly walk-through inspections on high and significant hazard dams. Low hazard dams are performed on a quarterly basis. Most of the larger dams are classified as high hazard, 10 dams are classified significant hazard and 3 dams are classified low hazard. Inspections are scheduled and tracked in the TVA wide maintenance database (EMPAC) and a checklist is utilized to ensure a complete inspection. The inspection includes all civil, mechanical and electrical features. Special inspections are also completed after significant earthquake or severe flood events. A "Dam Safety Awareness Course" is provided to inspectors and site personnel as part of their training.

   These inspections provide confidence that observable issues which could impact the ability to fully open gates/outlets when needed are identified and are prioritized for resolution commensurate with the potential impact of the deficiencies on dam safety.

2. The Dam Safety Engineering staff performs comprehensive inspections of TVA dams every 5 years which are consistent with the formal inspection described in the Federal Guidelines for Dam Safety. Preparation for these inspections includes reviewing previous inspection reports, status of previous recommendations, history of the project, and a review of available instrumentation data and analysis results. An intermediate walk through inspection is performed every 15 months for high and

significant hazard dams. For the low hazard dams the intermediate inspection is performed every 2 1/2 years. Special unscheduled inspections are also performed when needed to resolve problems or deficiencies identified at TVA dams. Rope access for close-up inspection of spillway gates and decks, downstream faces of the dams and sloped sections of penstocks and tunnels are a part of TVA's inspection. Remote operated vehicle (ROV) inspections of toe drains, upstream face of dams, sluice gates and exterior lock walls are also employed.

All inspections are documented in a report, issued and archived in TVA Electronic Data Management System (EDMS) and Business Support Library (BSL). The Dam Safety Engineering staff serve as emergency technical contacts available on a 24 hour basis for emergency situations that could affect the integrity of a dam. Follow-up maintenance associated with the issues identified from these inspections is prioritized commensurate with the potential impact of the deficiencies on dam safety.

These thorough engineering inspections and subsequent maintenance provide confidence that existing and potentially eminent issues associated with gate/outlet functionality are identified and are prioritized for resolution.

3. Emergency Action Plans (EAP) are prepared by TVA-River Operations for each project to minimize life and property loss by defining responsibilities and providing emergency notification guidelines for TVA personnel to follow upon indication of possible, impending, or actual failure of a TVA dam. The EAP is designed to provide TVA personnel with the information needed for a quick and effective response to a TVA dam safety emergency.

   In a dam safety emergency the River Operations Emergency Operations Center (REOC) and the Knoxville Emergency Operations Center (KEOC) would be activated to coordinate overall emergency operations. Once the emergency operations centers are activated, clearly defined organizational responsibilities and resources from across the TVA agency are available to deal with the emergency. The EAP clearly defines indicators of potential or actual emergency conditions that warrant special attention and immediate evaluation. Among these indicators are mechanical or electrical malfunctions which include: cranes, spillway gates, sluice gates, valves, spillway and sluice gate operating machinery and generators (primary or emergency). During such emergencies on-site TVA staff is authorized to contact any and all sources deemed necessary to procure emergency equipment, materials and labor to prevent or lessen the magnitude of the impending emergency.

   TVA's staff is maintained in a readiness condition by being knowledgeable of EAP and procedure requirements through a comprehensive training and exercise program. The Dam Safety Exercise Program consists of four types of activities: Orientation Seminar, Drills, Tabletop Exercises, and Functional Exercises. Orientation seminars, drills and tabletop exercises are used to train both TVA staff and outside organizations that would be involved with a TVA dam safety emergency. Seminars, drills, and tabletop exercises are developed and held as needed, and generally target specific groups or organizations with specific training needs. Typically, one or two functional exercises are held each year. Each functional exercise focuses on one dam in the TVA system and uses a scenario designed specifically for that project. An exercise critique is held after each exercise to provide participants with the opportunity to comment on the exercise and to identify improvements/changes needed in the EAP, the notification procedures, and the exercise process.

4. In the event that flooding conditions arise that have the potential to impact any of the three TVA operating nuclear plants, operations, maintenance and engineering Nuclear Power Group condition response teams would be assembled at the nuclear plants and corporate offices to assist in the identification and direction of resources required to address and resolve issues such as non-functional gates/outlets and crane malfunctions as well as to develop contingency plans to mitigate impacts. In addition to the normal contingency of TVA maintenance and operational personnel located at dam sites, TVA has substantial additional internal resources, including the Power Services Shops, the Heavy Equipment Division and River Operations Engineering Support Services as well as external vendors, which would be applied as needed to resolve any issues that could impact gate/outlet function.

   These TVA internal resources and external vendors have the requisite experience, expertise and equipment to accomplish any needed maintenance, repairs or workarounds to provide a high level of confidence that issues that may prevent gates from opening will be resolved.

Conclusion

The TVA plant personnel periodic inspections, the intermediate and 5-year dam safety engineering inspections and the significant capability of the emergency response teams to direct and manage resources to address issues potentially impacting gate/outlet functionality provide a high level of confidence that the all gates/outlets open configuration used in the flood analysis is reasonable and valid.

Prepared: for Greg Lowe Date: 5/28/09

Concurrence: Charles L Bach Date: 5/28/09

Approved: for K.R. Spates Date: 5/29/09

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

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.

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,

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

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.

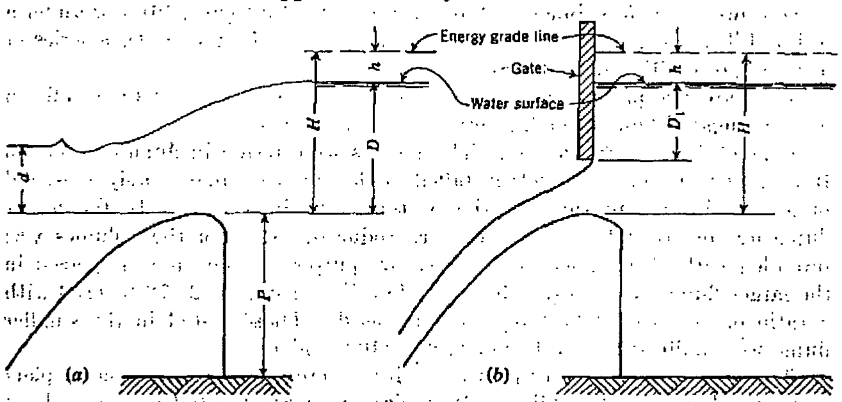

FIG. 1.—SPILLWAY-CREST DIAGRAM

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.[3] 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.

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

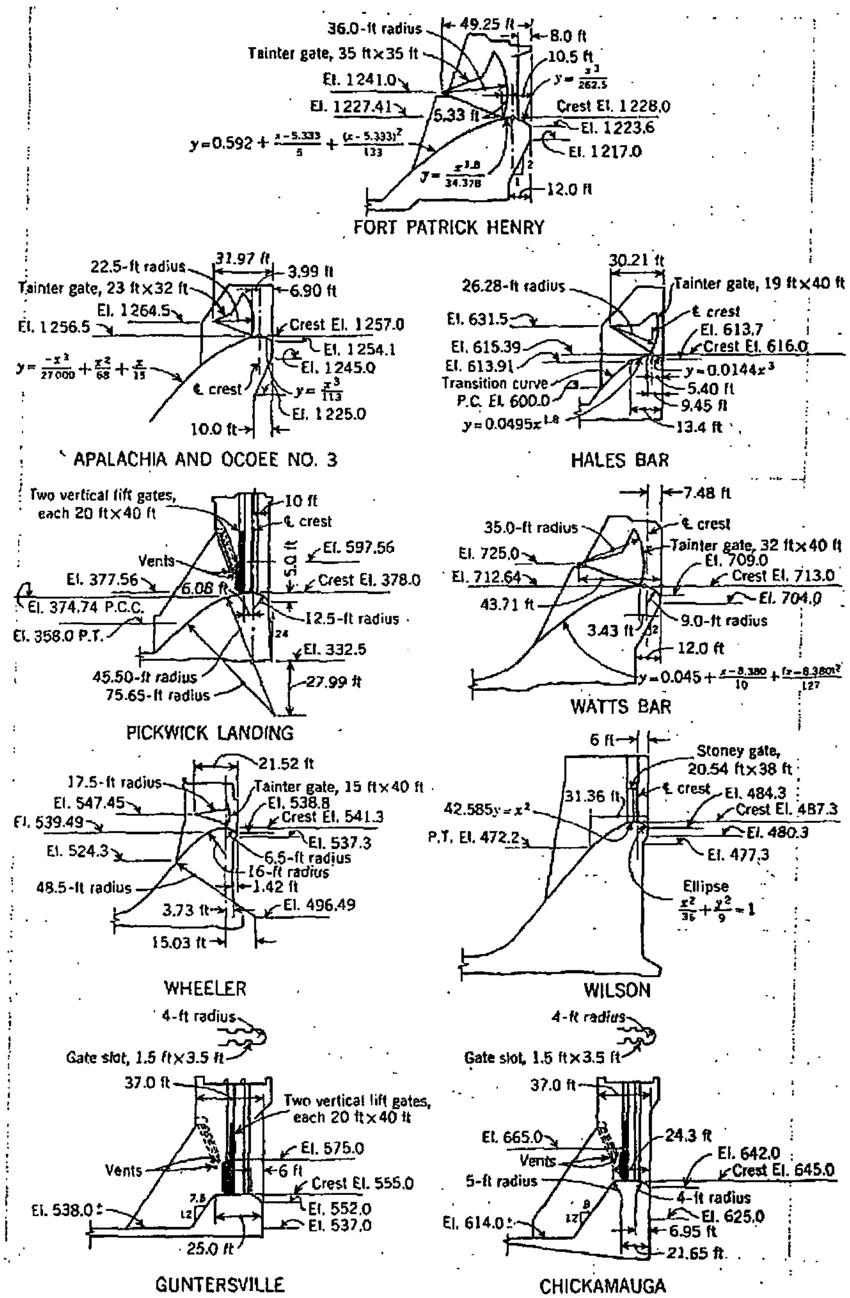

FIG. 2.—TVA SPILLWAY CRESTS (DATA IN FIG. 3)

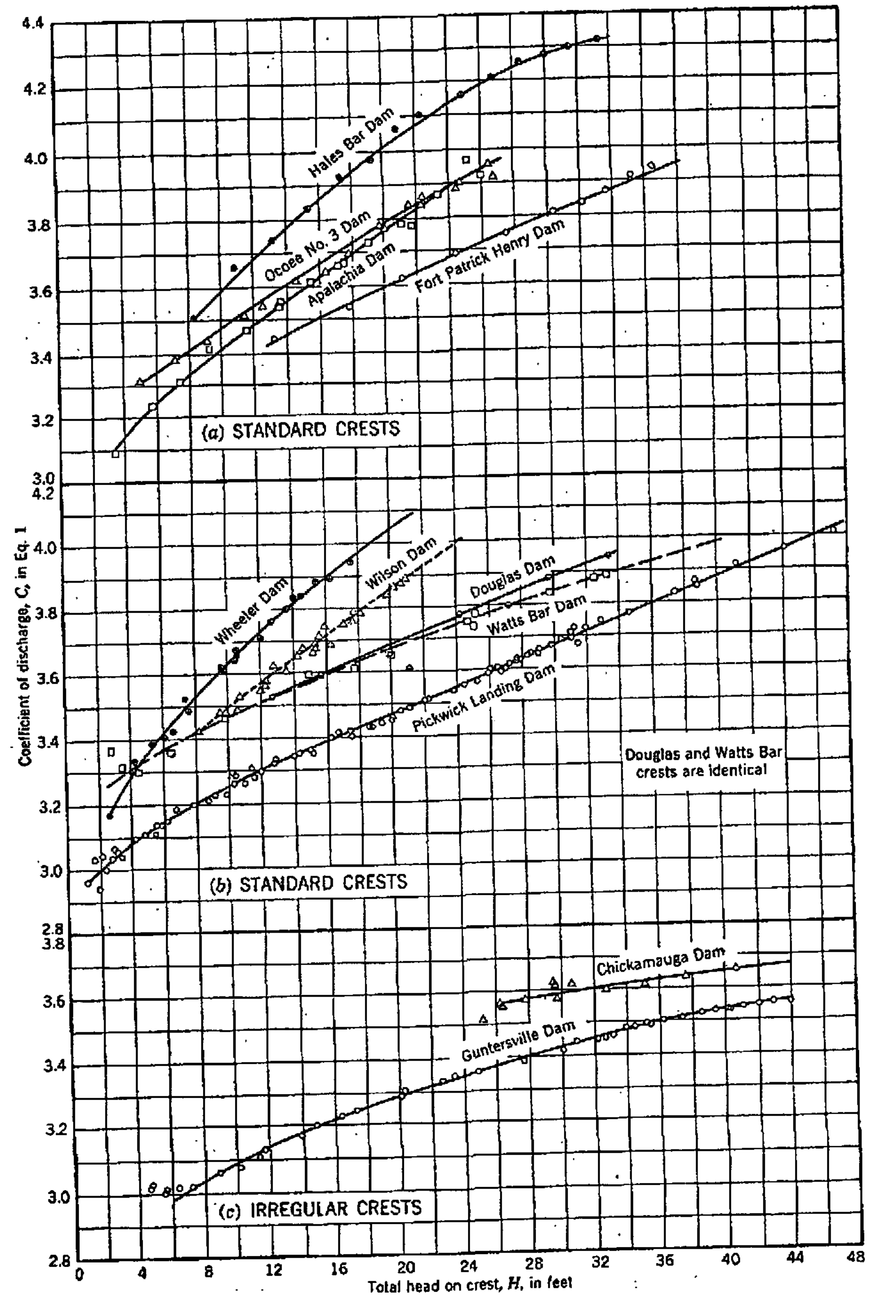

FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

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_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.

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.

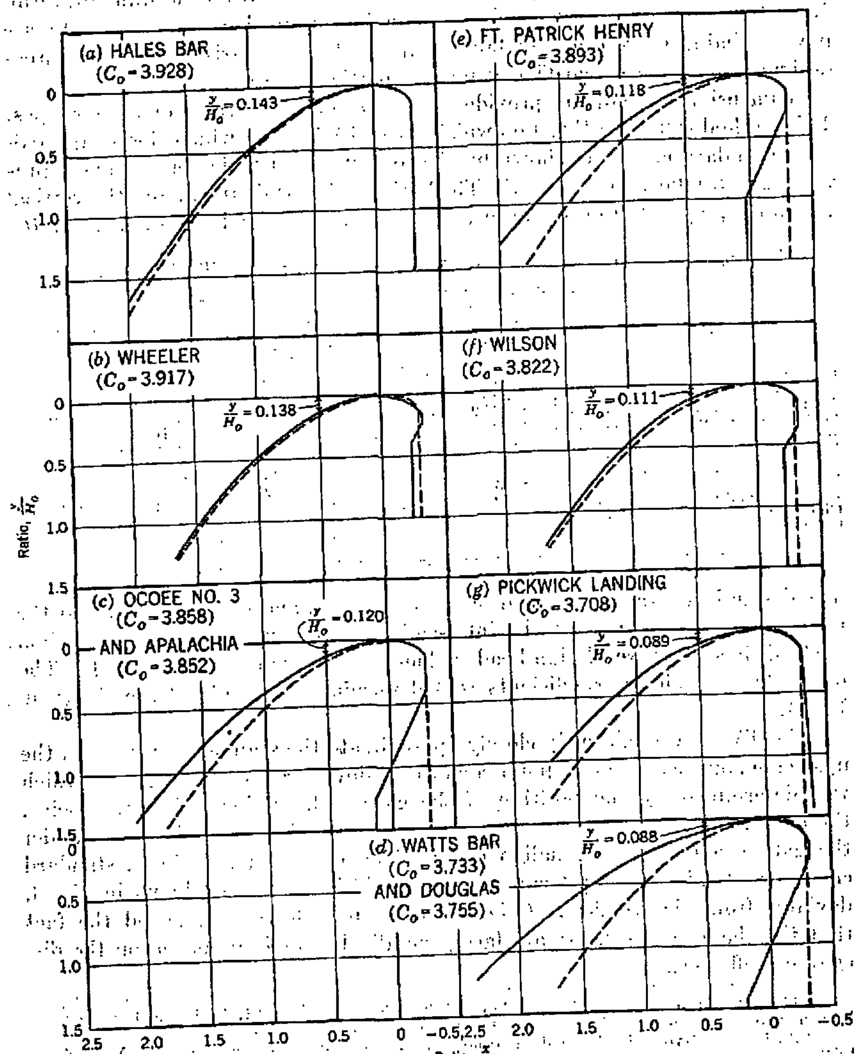

Fig. 4.—Comparative Crests (H_o/P Shown in Table 1)

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

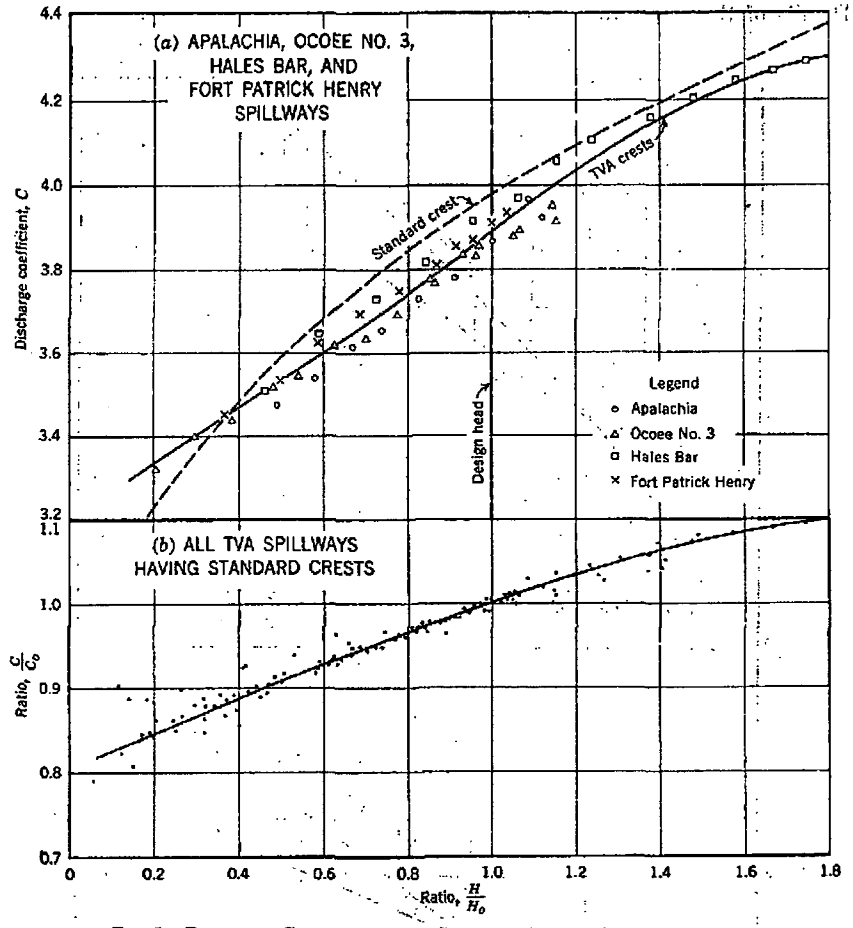

Fig. 5.—Discharge Coefficients for Spillways Having Standard Crests

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

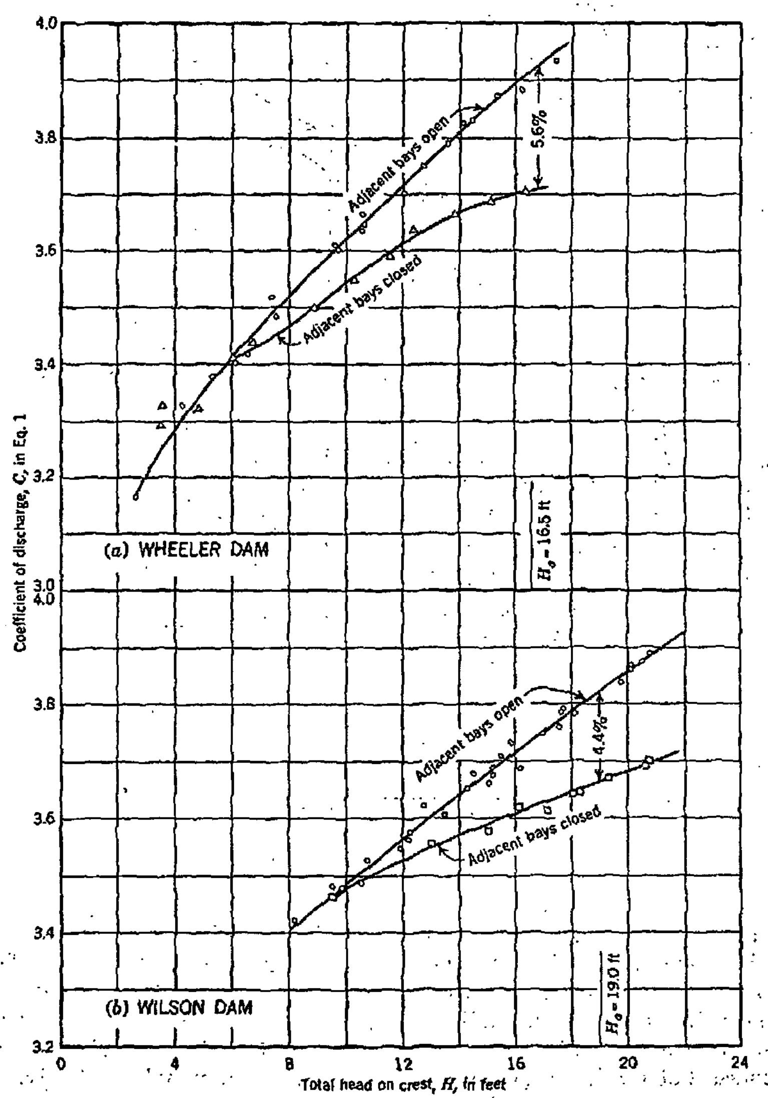

FIG. 6.—EFFECT OF OPERATION OF ADJACENT SPILLWAY BAYS

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.

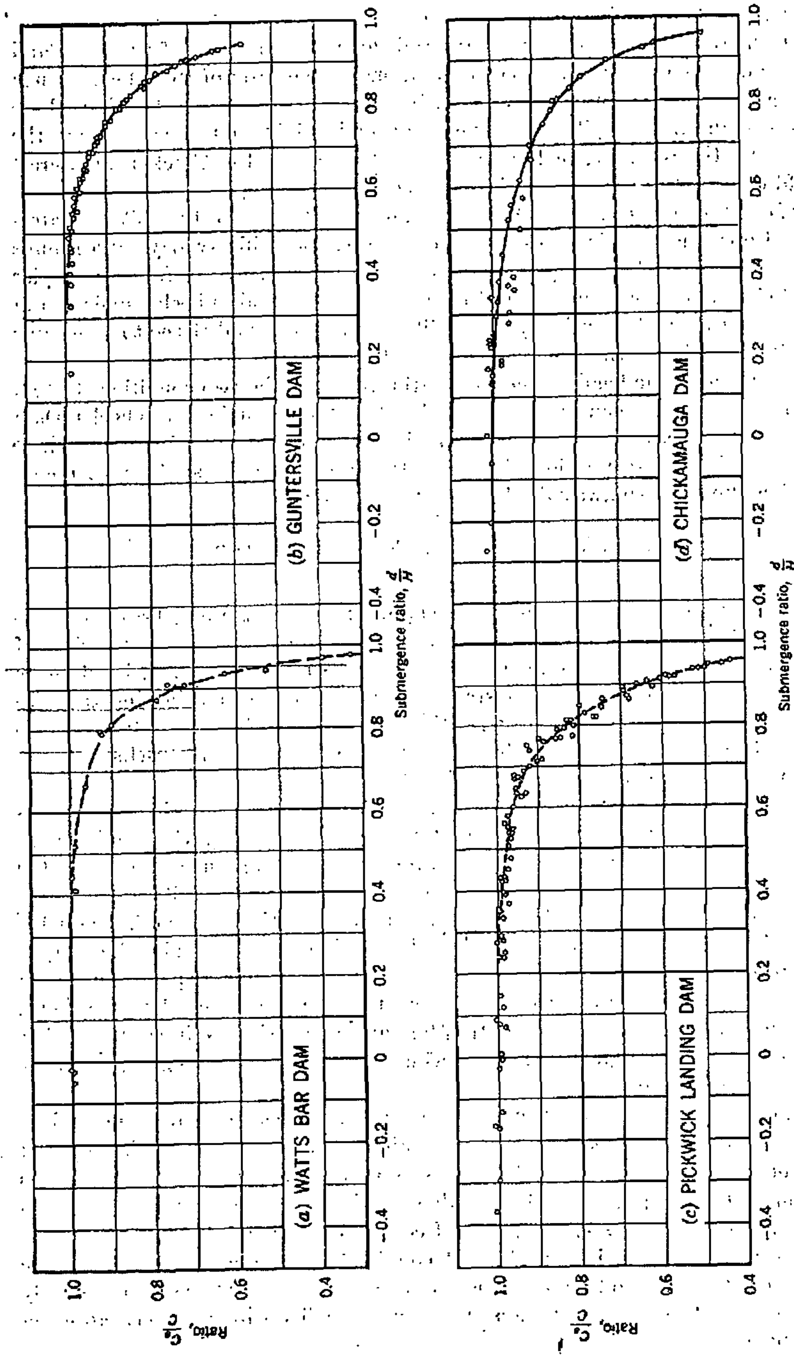

Fig. 7.—Effect of Submergence on Discharge Coefficients (C-Values from Fig. 3)

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.

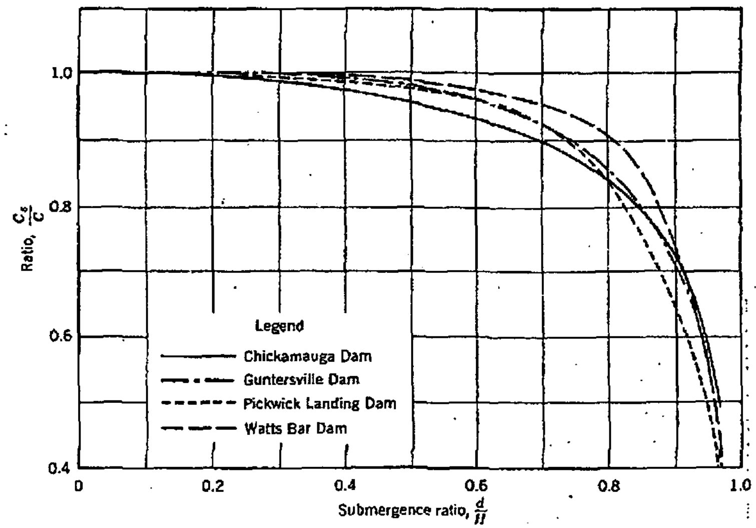

Fig. 8.—Comparison of Submergence Effects for Various Spillway Crest Shapes

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.

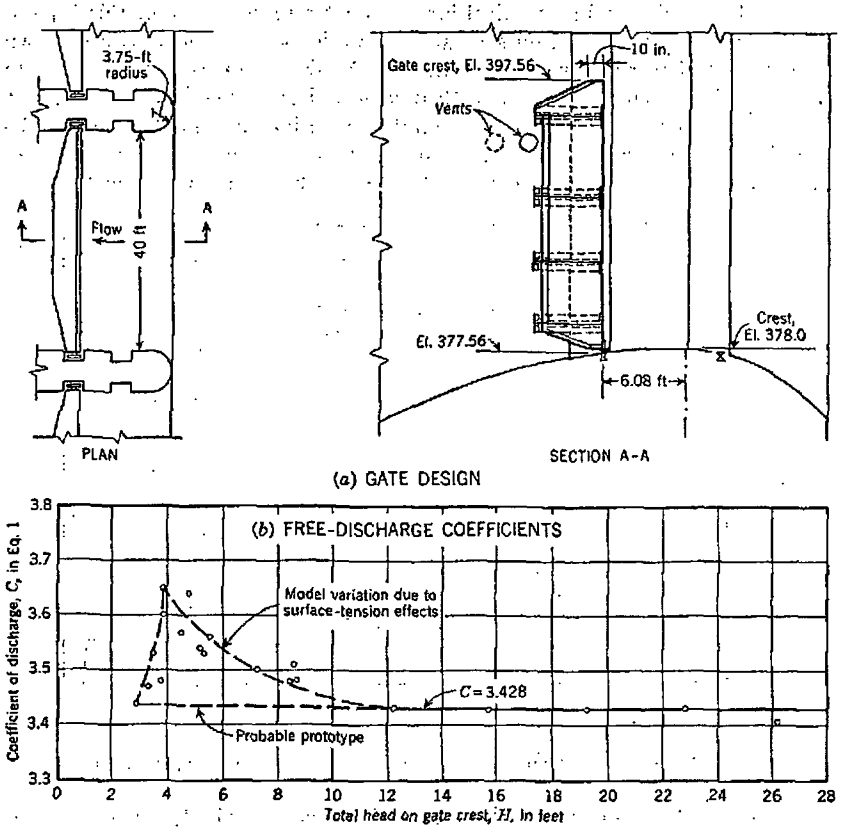

FIG. 9.—VERTICAL LIFT GATE, PICKWICK LANDING DAM

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

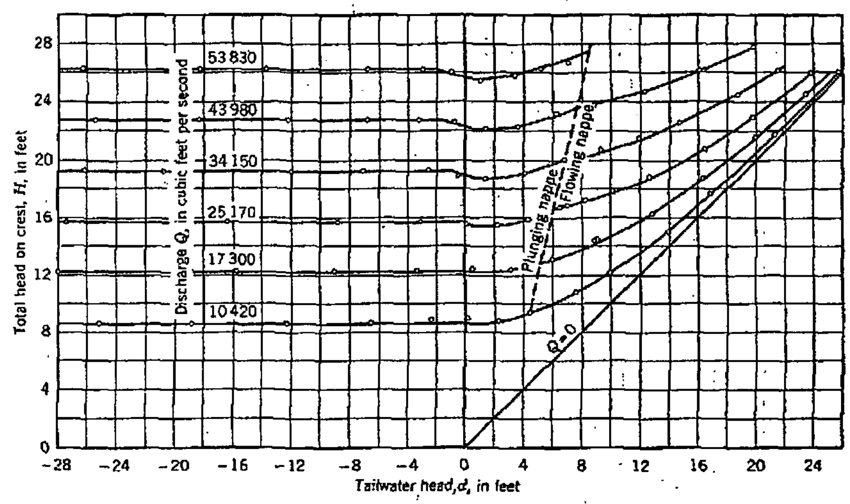

FIG. 10.—HEADWATER-TAILWATER RELATIONS FOR FLOW OVER A VERTICAL LIFT GATE (PROFILE SKETCH IN FIG. 11)

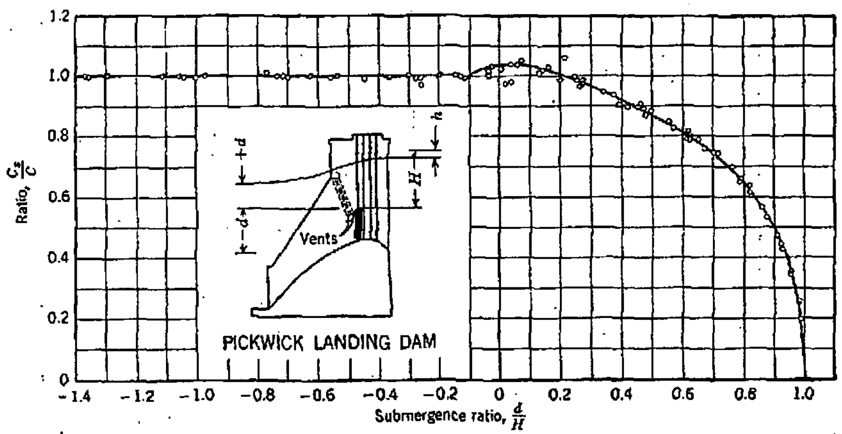

FIG. 11.—SUBMERGENCE EFFECT FOR FLOW OVER A VERTICAL LIFT SPILLWAY GATE ($C = 2.428$)

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

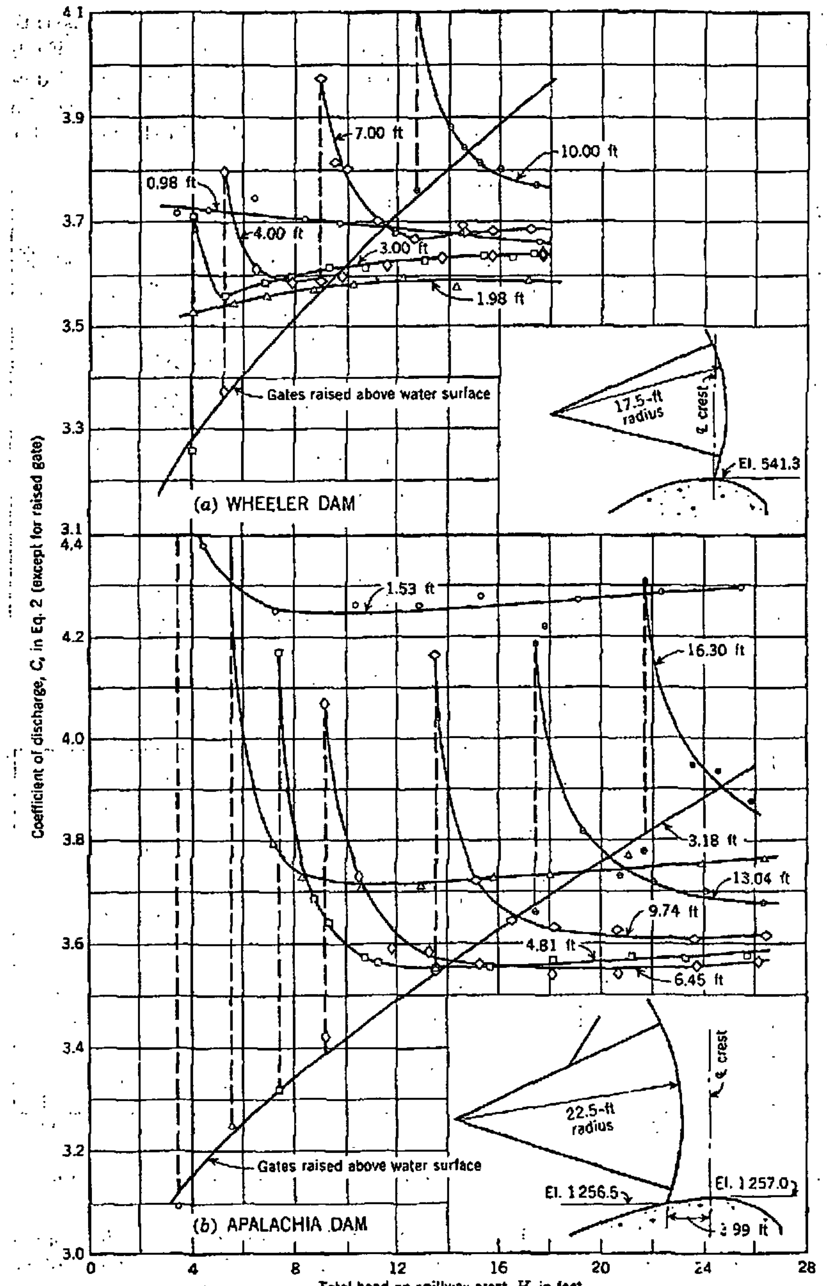

FIG. 12.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

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 coeffi-

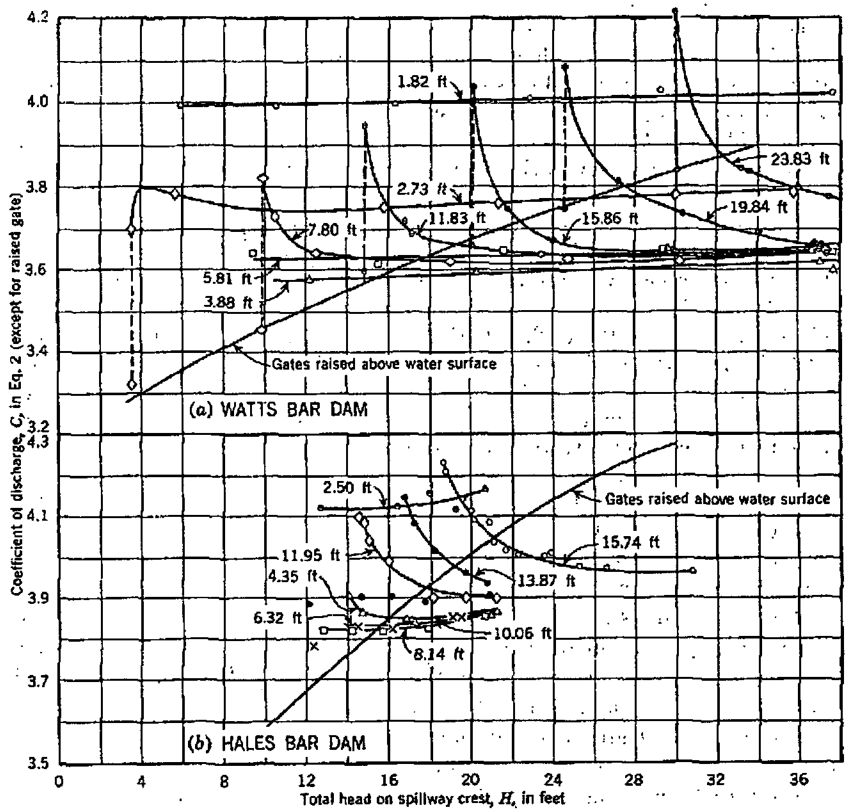

FIG. 13.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

cient 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.

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 relationships 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

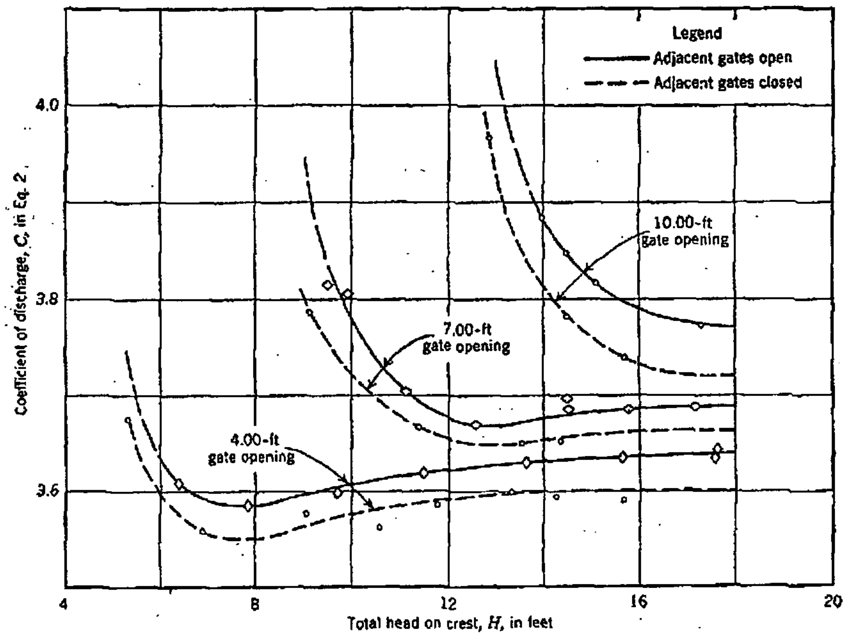

Fig. 14.—Tainter-Gate Discharge Coefficients, C, Wheeler Dam

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.

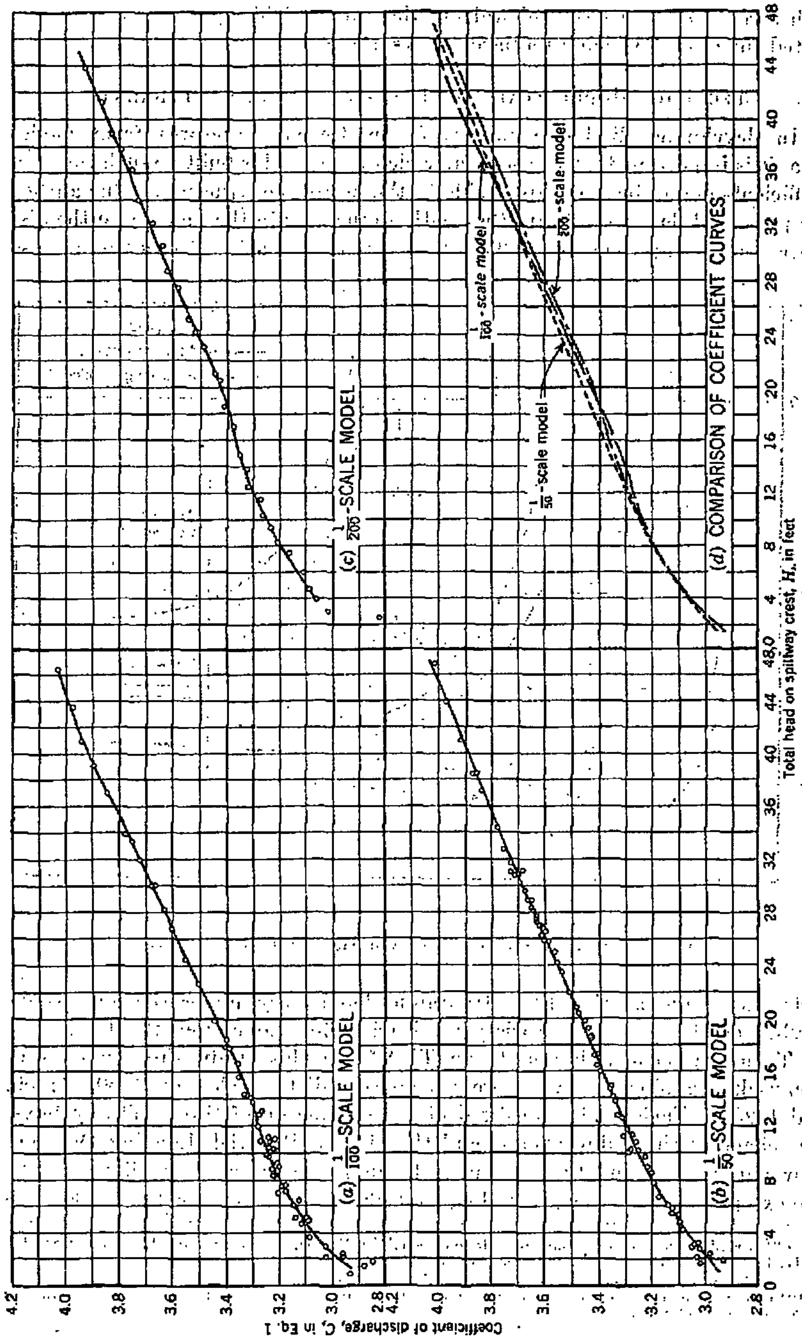

FIG. 15.—EFFECT OF MODEL SCALE ON DISCHARGE COEFFICIENTS, FLOW OVER PICKWICK LANDING SPILLWAY CREST

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_e = 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.

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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. 521*. 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.

GAS

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

CONTENTS

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:

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

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.

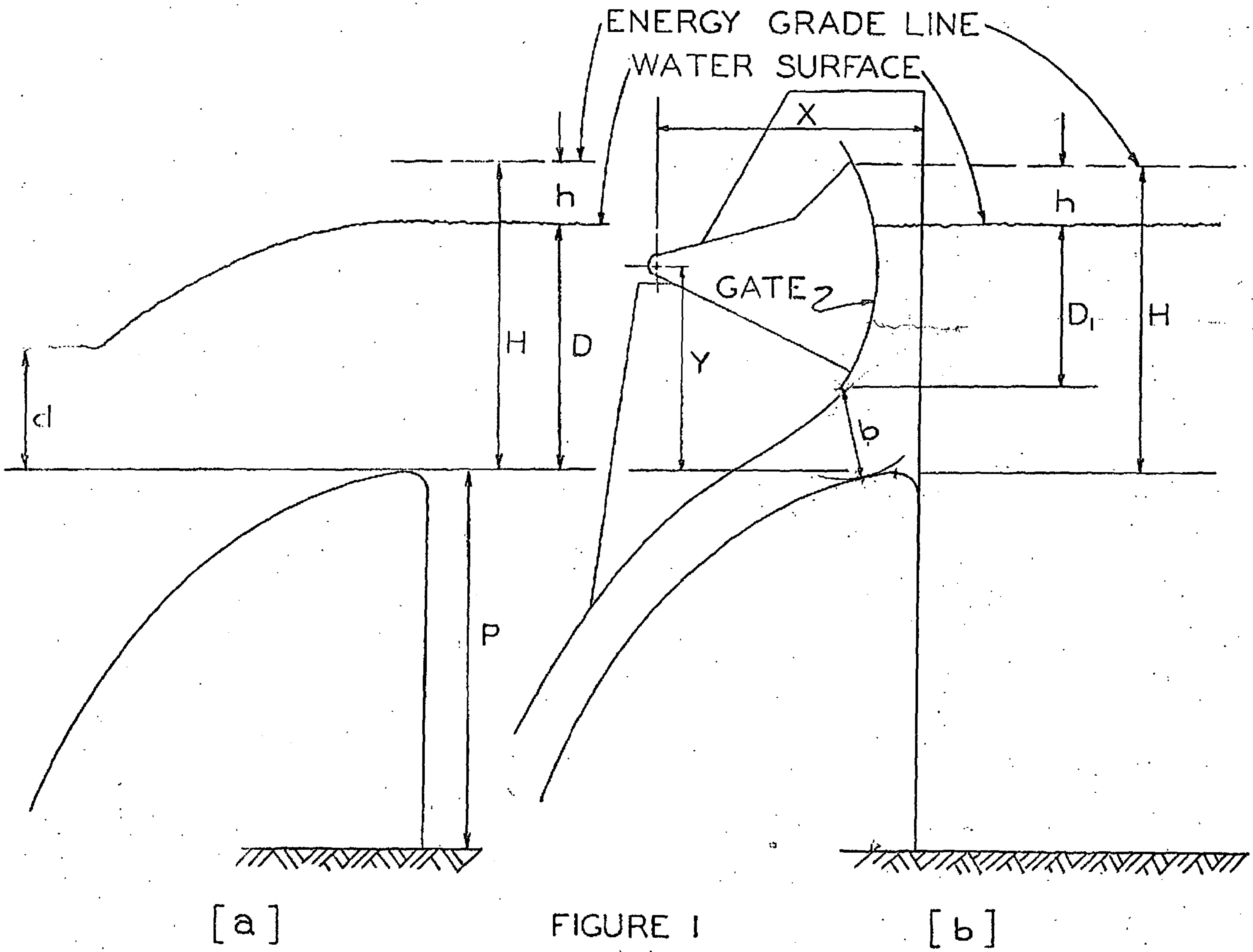


FIGURE 1

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.	D	Q	h	G.O.	H	Q	C
ft.	ft.	cfs	ft.	ft.	ft.	cfs	
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			34.00	116,600	3.92
	0.721	6.715	Negligible		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 ft.	Q cfs	h ft.	H ft.	Q cfs	C
0.323	2.312	Negligible	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		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 ft.	L ft.	x ft.	y ft.	D ft.	h ft.	Q 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

b	L	Trunnion Locations x	Trunnion Locations 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

b ft.	L ft.	Trunnion Locations x ft.	y ft.	D ft.	h ft.	Q 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

b ft.	L ft.	Trunnion Locations x ft.	y ft.	D ft.	h ft.	Q 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

b ft.	L ft.	Trunnion Locations x ft.	y ft.	D ft.	h ft.	Q 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

b ft.	L ft.	Trunnion Locations x ft.	Trunnion Locations y ft.	D ft.	h ft.	Q 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.	D	Q	h	G.O.	H	Q	C
ft.	ft.	cfs	ft.	ft.	ft.	cfs	
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 ft.	Q cfs	h ft.	H ft.	Q cfs	C
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	Negligible	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			~~1.71~~ 17.05	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			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	Negligible	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		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 ft.	Q cfs	h ft.	H ft.	Q cfs	C
0.199	1.224	Negligible	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		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		36.58	~~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.	D	Q	h	G.O.	H	Q	C
ft.	ft.	cfs	ft.	ft.	ft.	cfs	
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		14.81	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 ft.	Q cfs	h ft.	H ft.	Q cfs	C
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

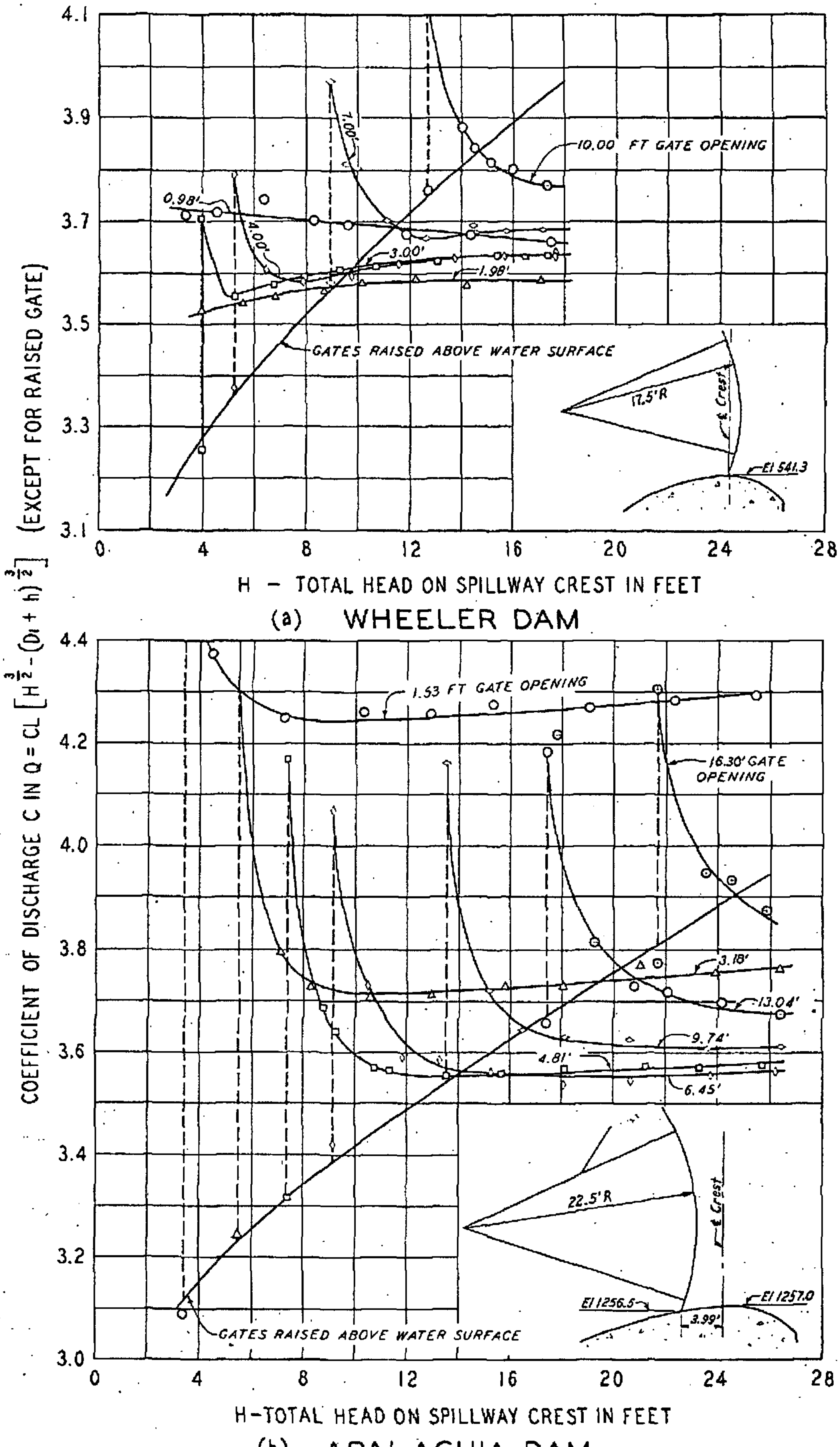
*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

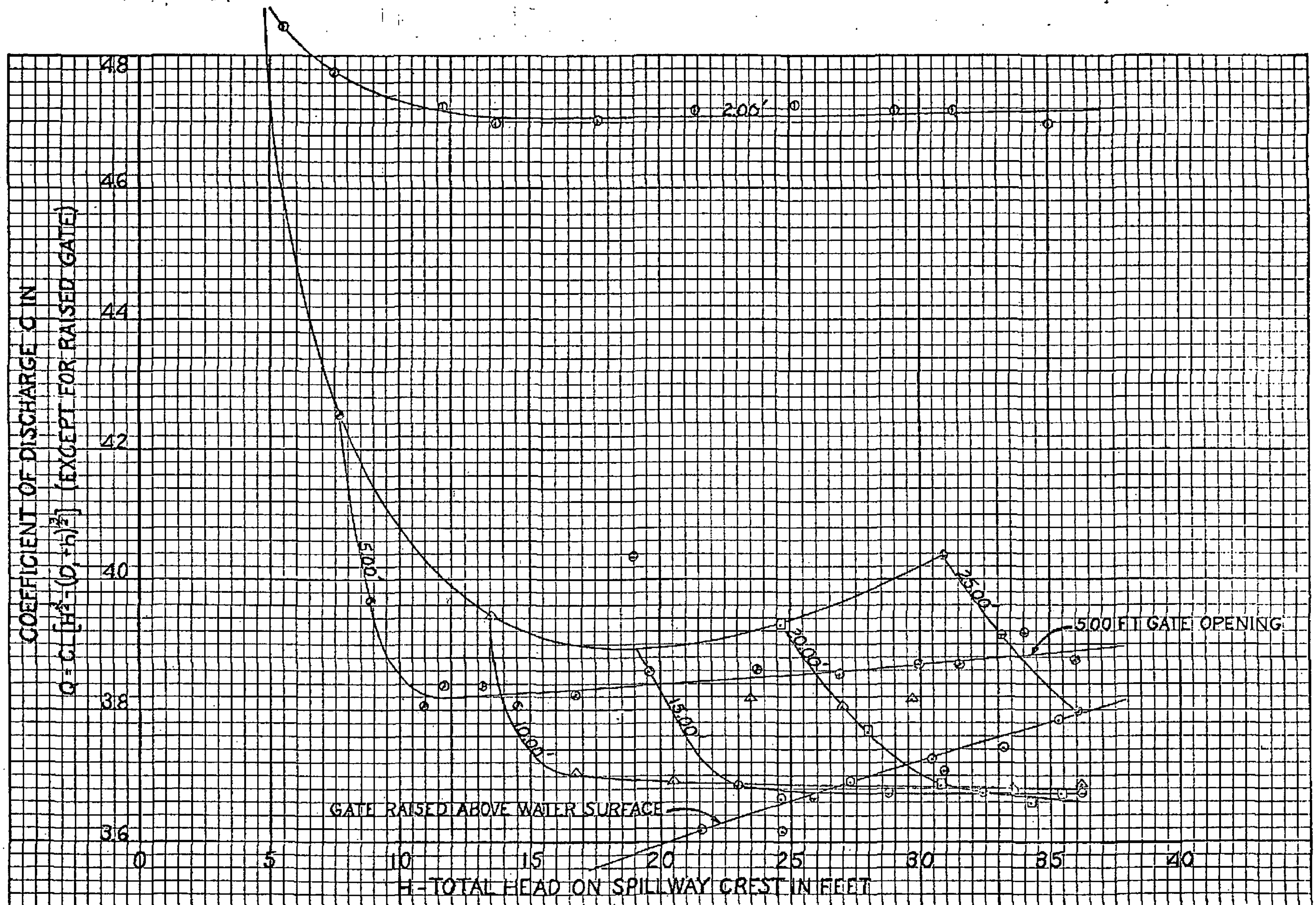
Wheeler Project

Tainter Gates Raised Above Water Surface

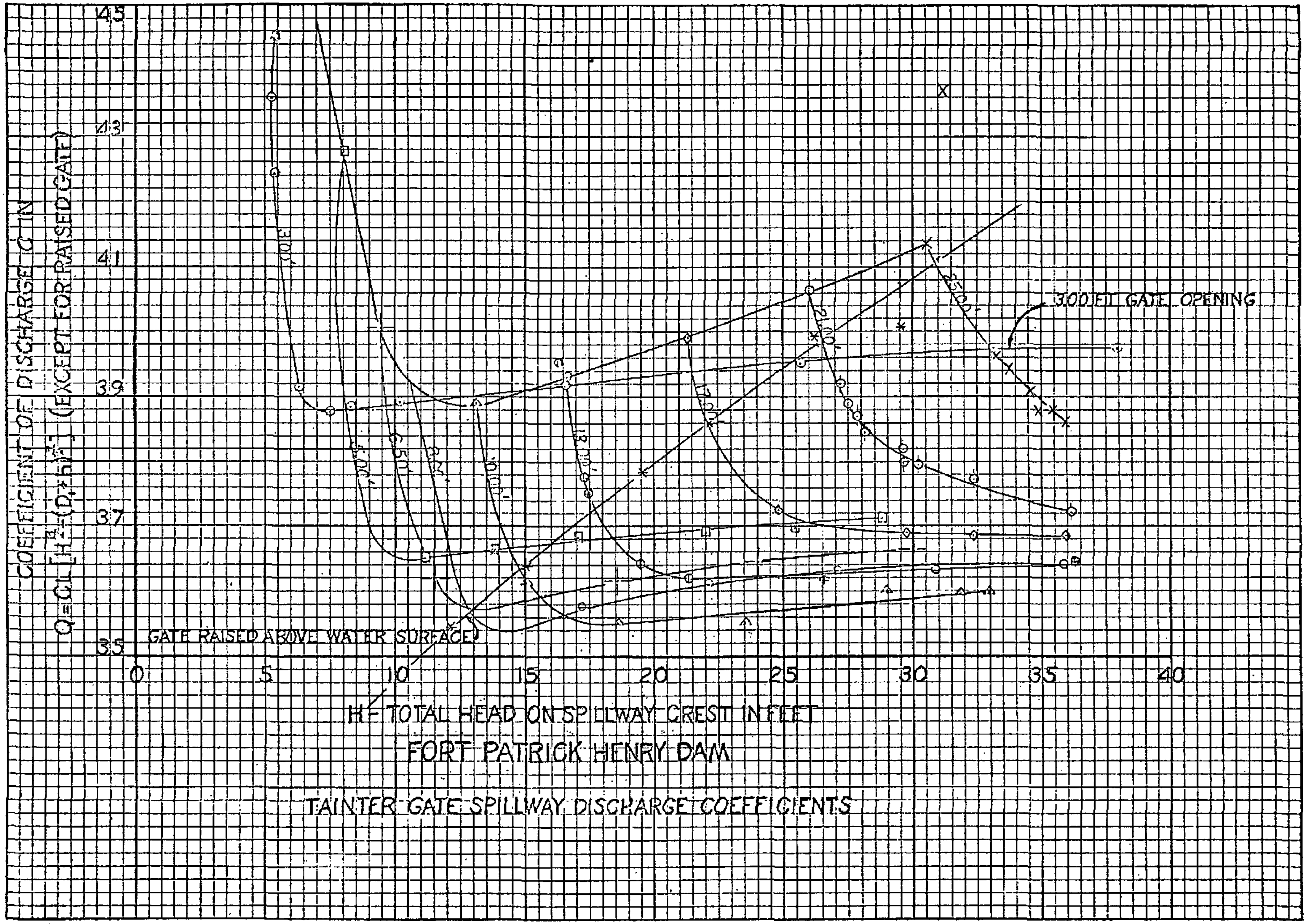
MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.178	1.786	0.000	6.11	12,350	3.41
0.214	2.444	0.001	7.39	16,900	3.51
0.281	3.788	0.002	9.72	26,200	3.60
0.307	4.386	0.002	10.58	30,330	3.67
0.347	5,348	0.003	12.02	36,980	3.70
0.390	6.559	0.004	13.53	45,360	3.80
0.440	8,038	0.006	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

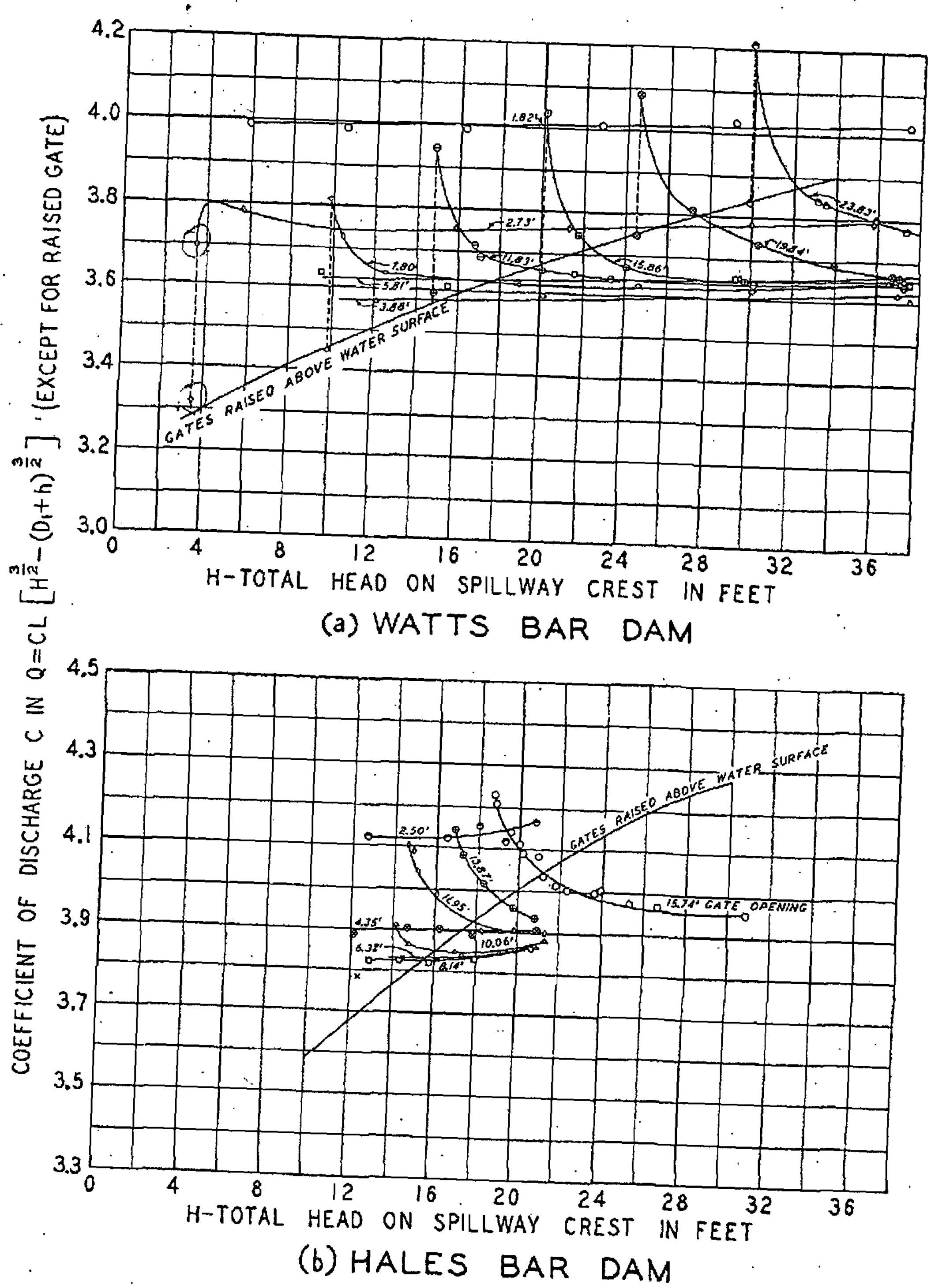


TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

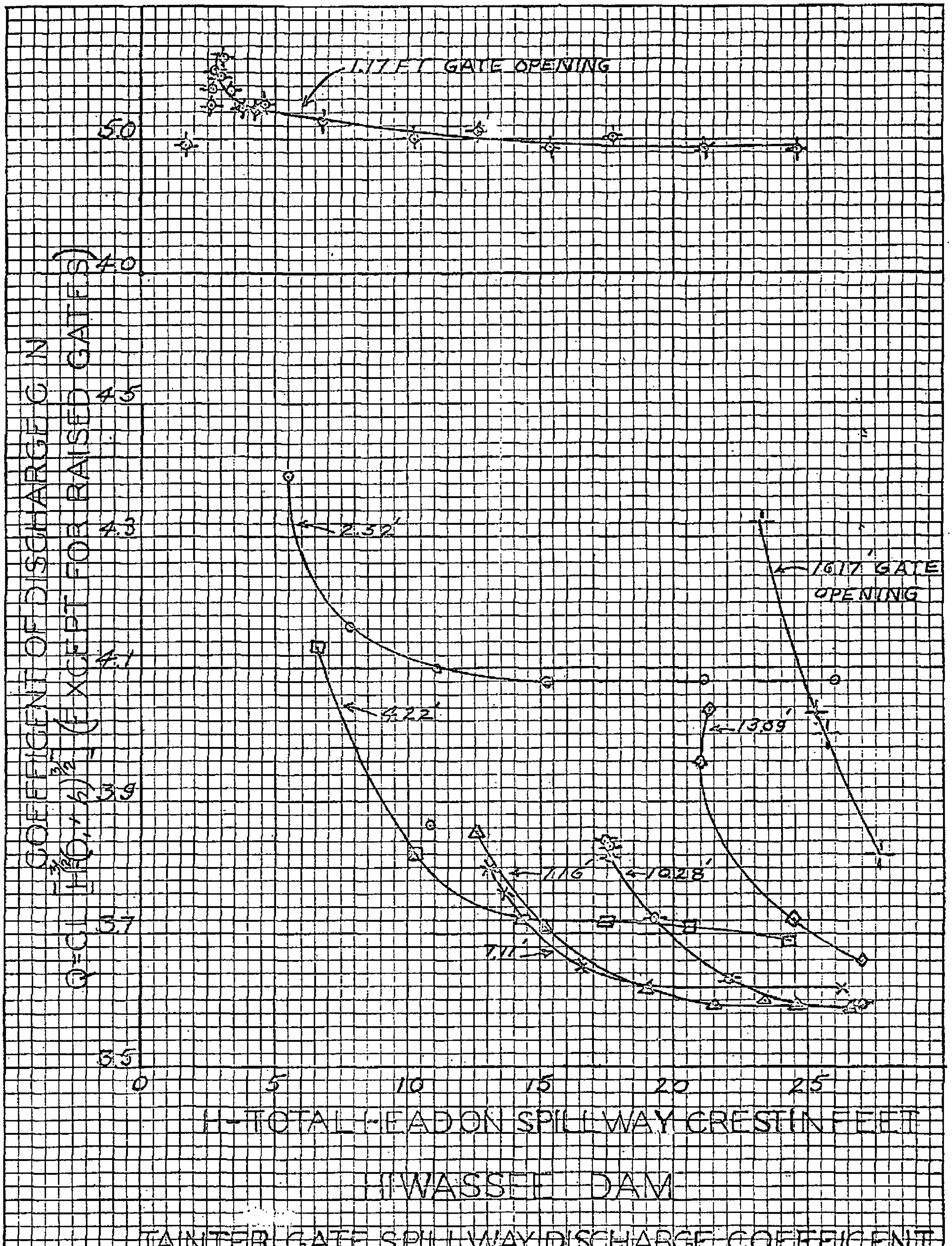


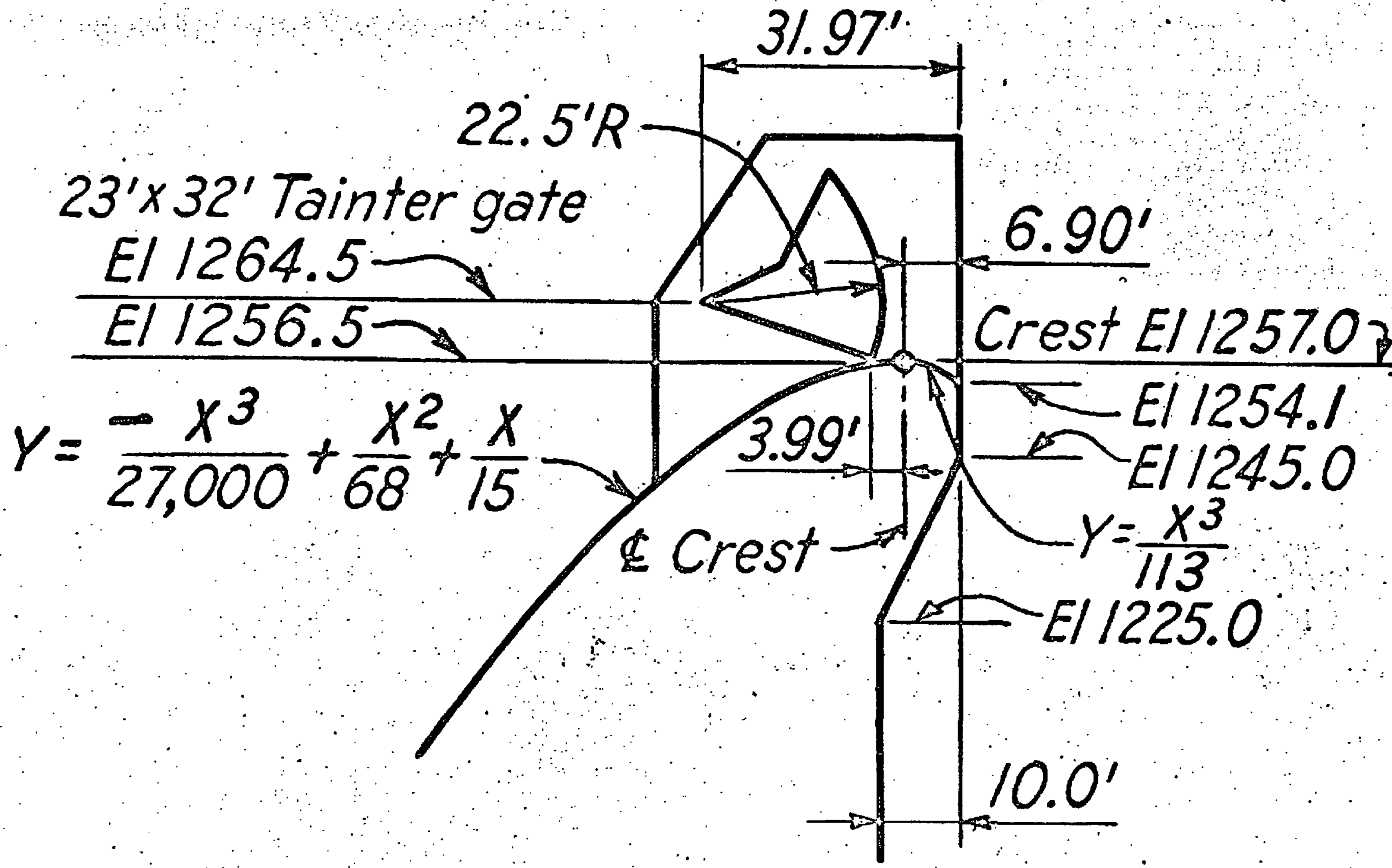
BOONE DAM
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENT


COEFFICIENT OF DISCHARGE C IN
Q=CL[H^3/2-(D+.5)^3/2] (EXCEPT FOR RAISED GATE)
4.5
4.3
4.1
3.9
3.7
3.5
0
5
10
15
20
25
30
35
40
3.00'
6.50'
30.00 FT GATE OPENING
GATE RAISED ABOVE WATER SURFACE
H= TOTAL HEAD ON SPILLWAY CREST IN FEET
FORT PATRICK HENRY DAM
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

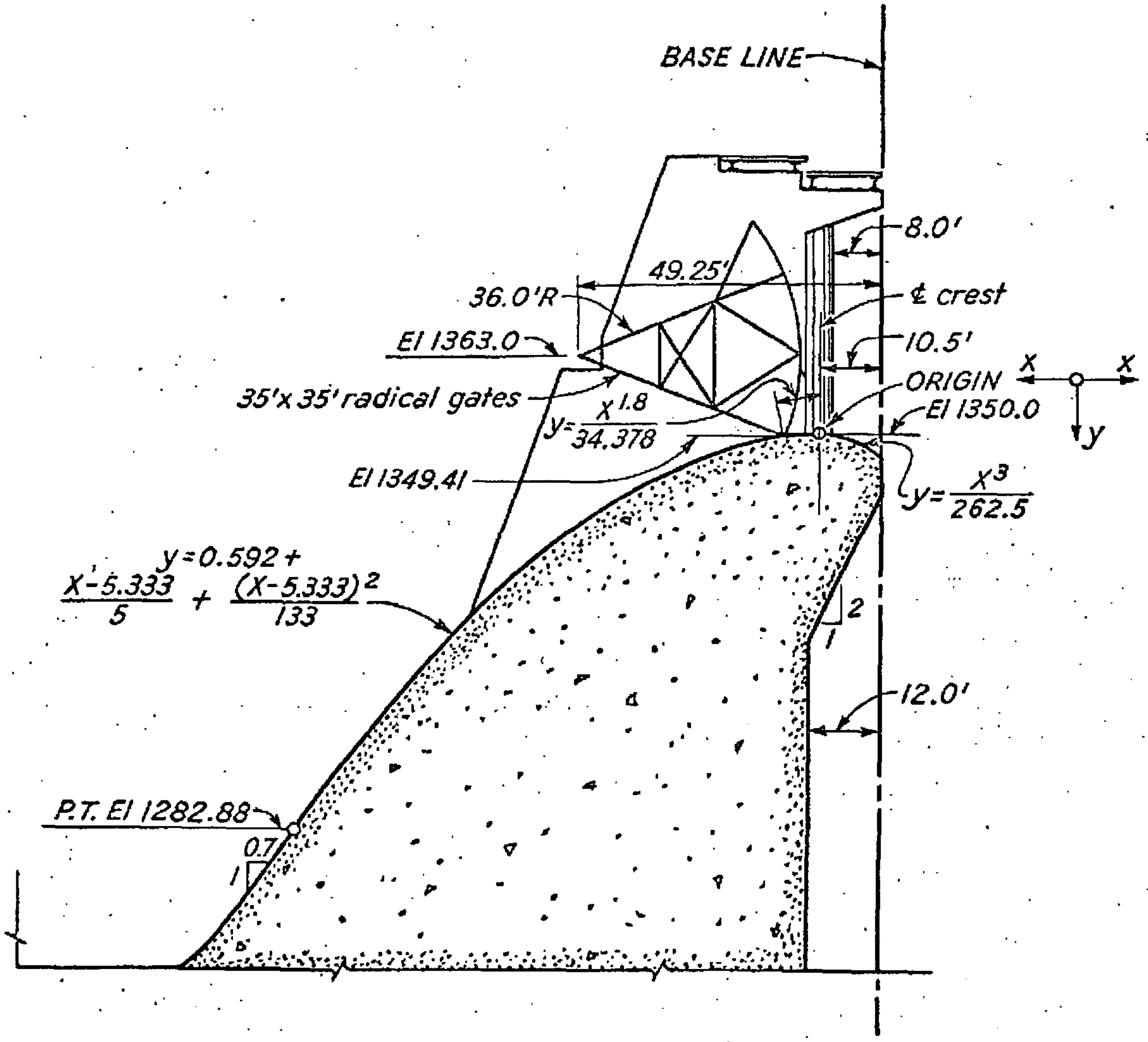


TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

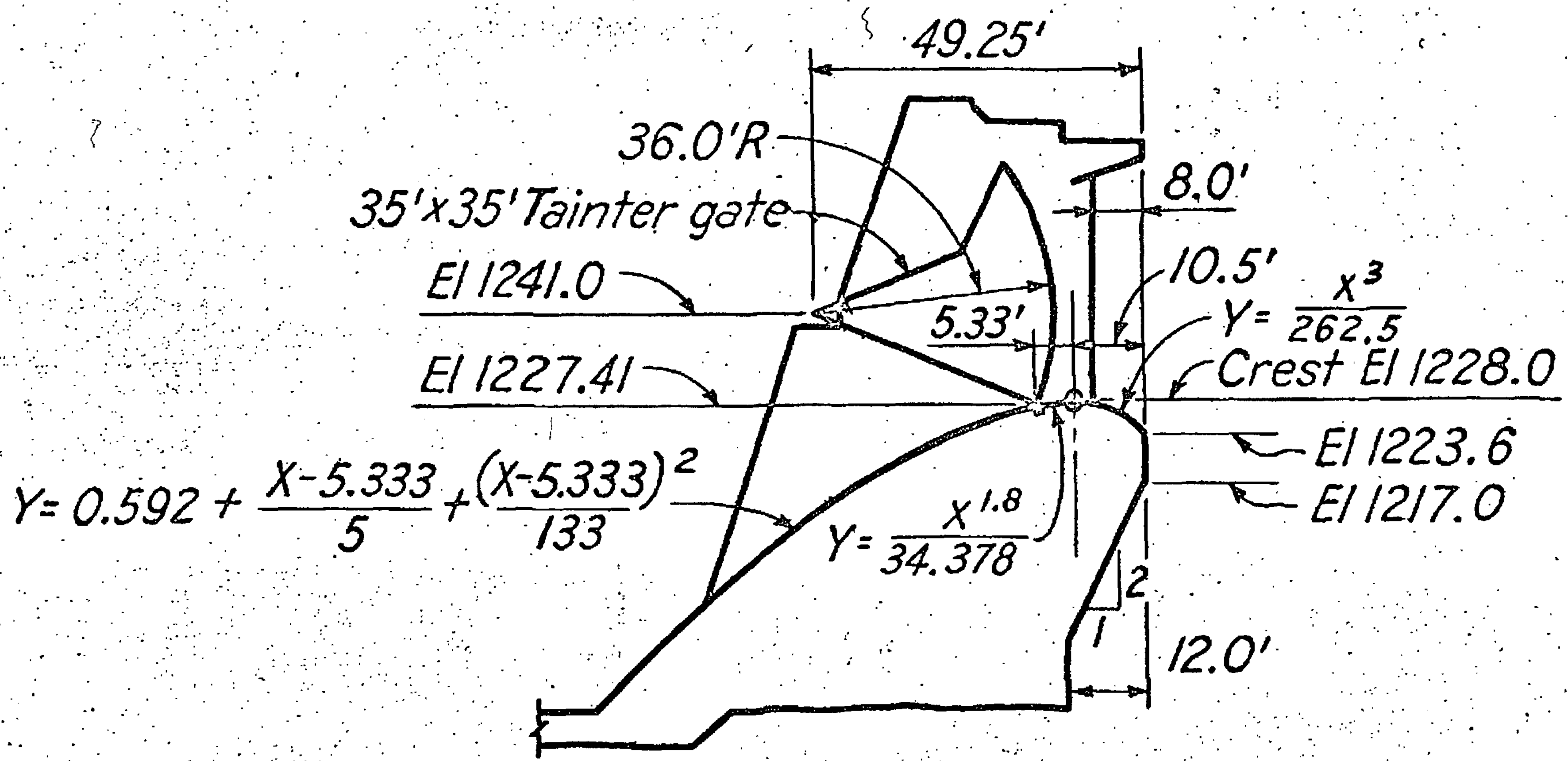

1.17 FT GATE OPENING
5.0
4.0
4.5
4.3
4.1
3.9
3.7
3.5
2.32'
4.22'
16.17' GATE OPENING
13.89'
7.16'
10.28'
7.11'
0
5
10
15
20
25
COEFFICIENT OF DISCHARGE C IN
Q=CL H$^{3/2}$ (EXCEPT FOR RAISED GATES)
H - TOTAL HEAD ON SPILLWAY CREST IN FEET
HIWASSEE DAM
TAINTER GATE SPILLWAY DISCHARGE COEFFICENT



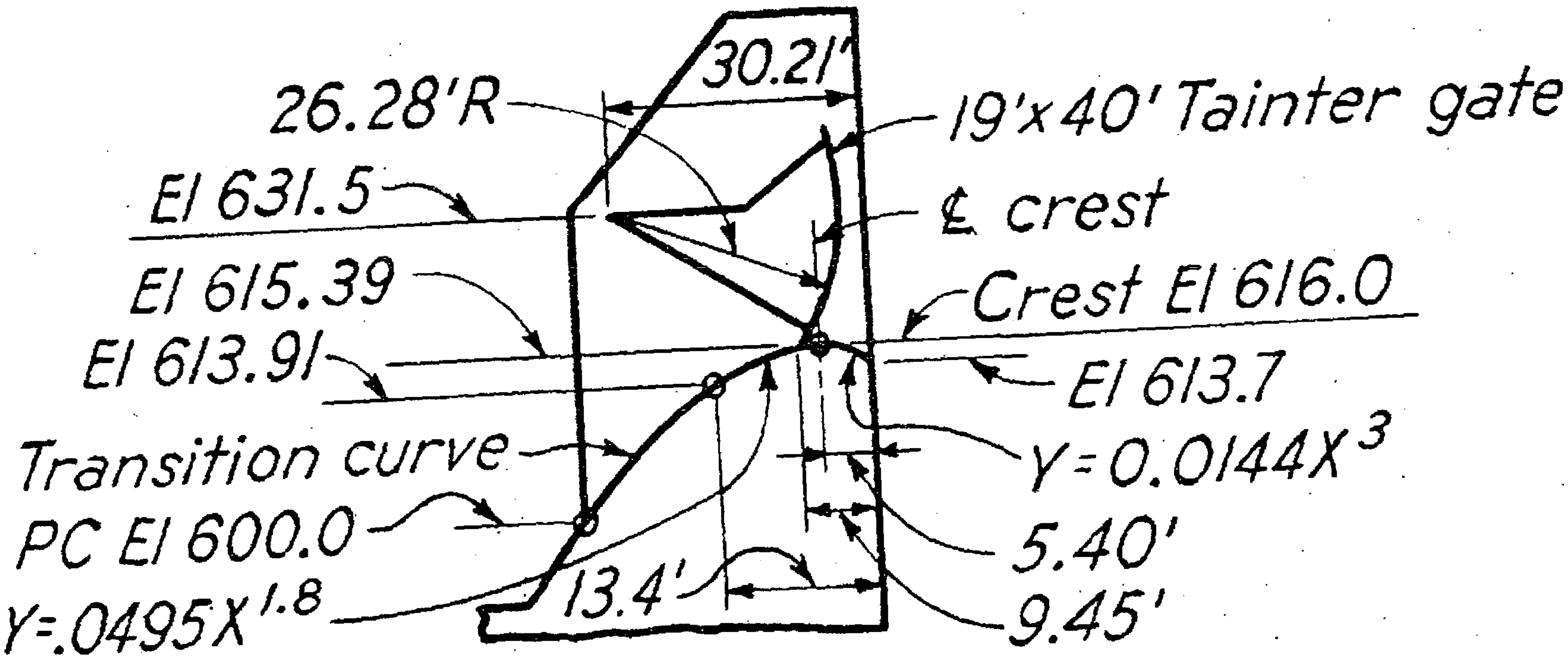
APALACHIA PROJECT



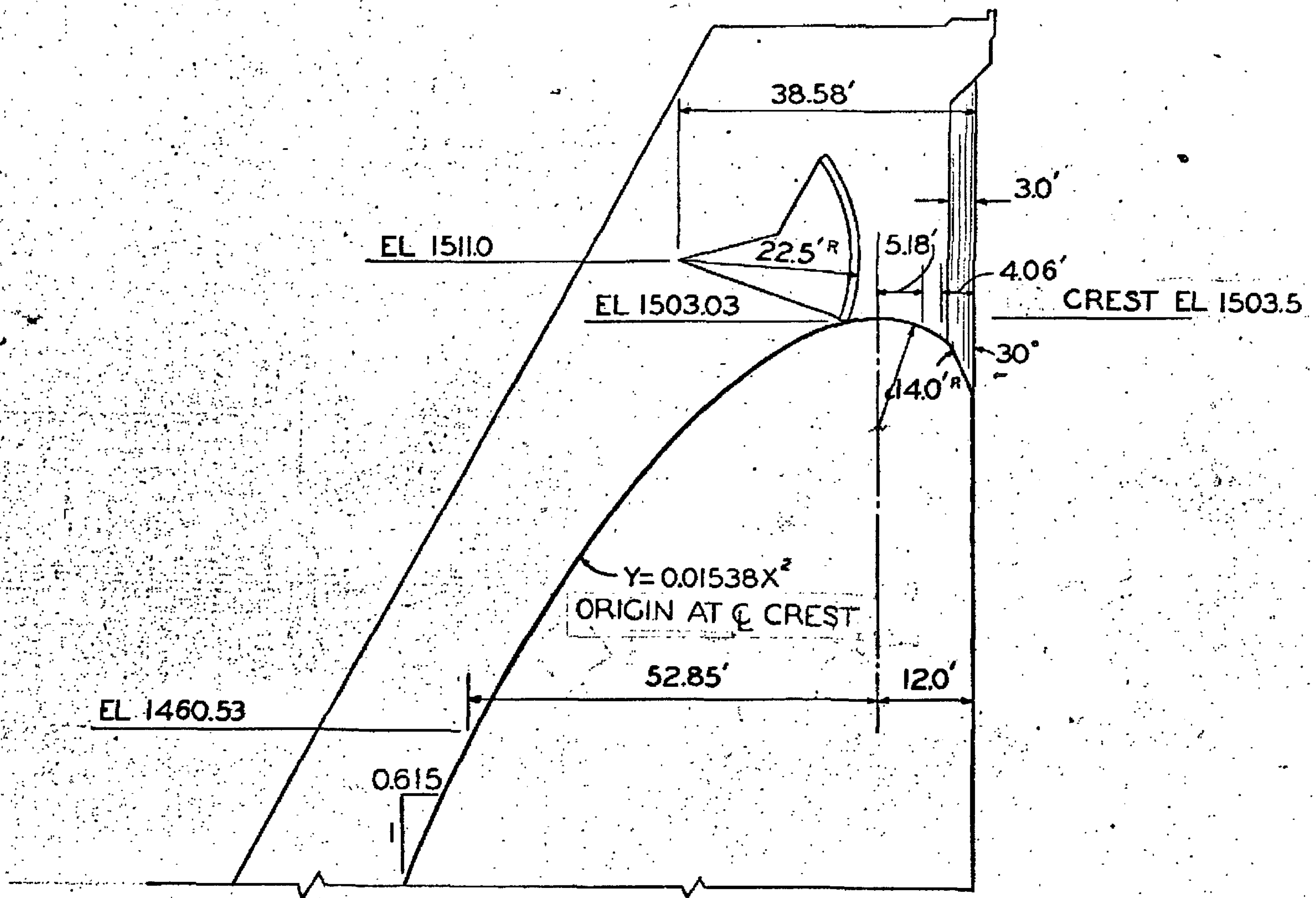
BOONE PROJECT



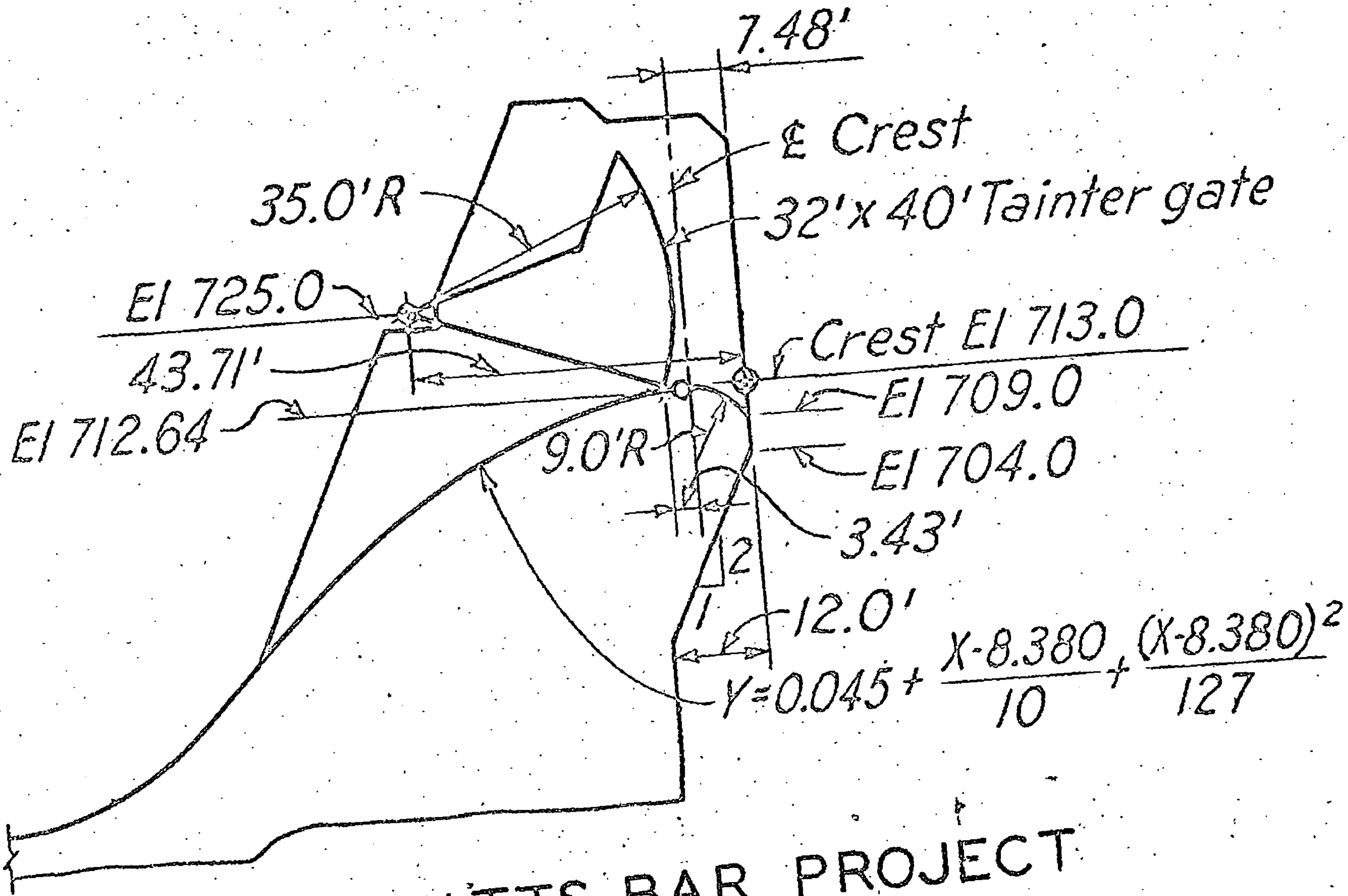
FORT PATRICK HENRY PROJECT



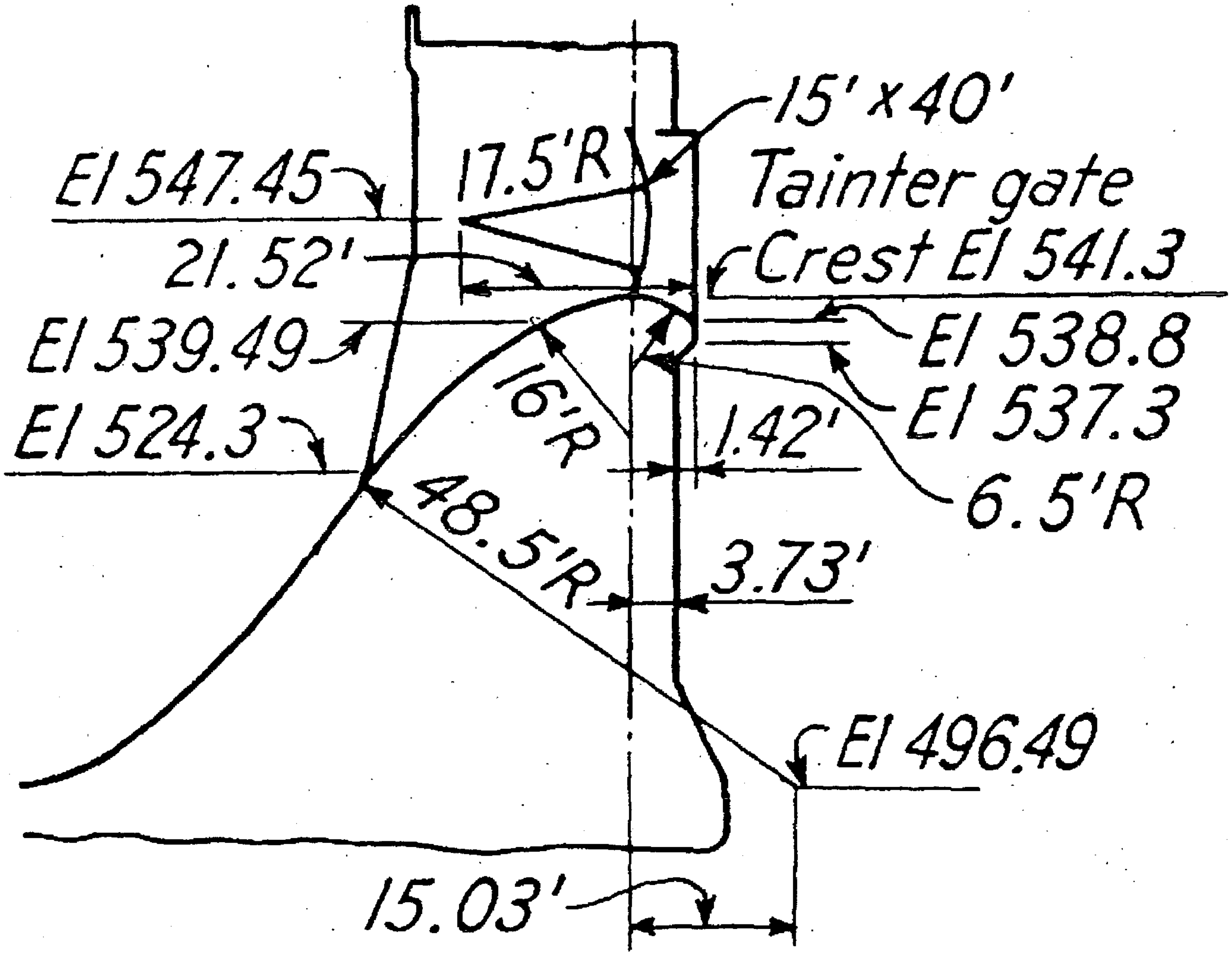
HALES BAR PROJECT



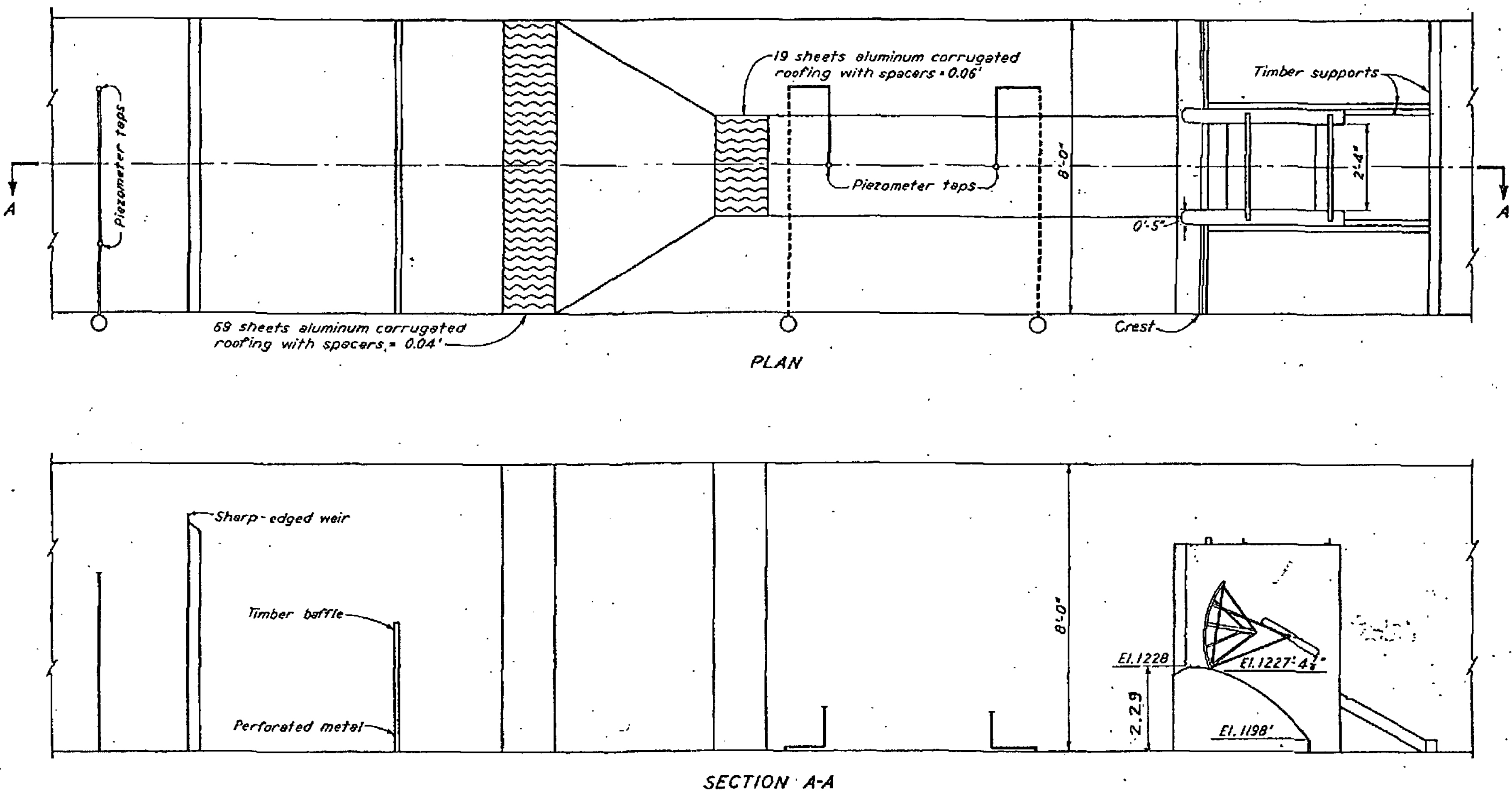
HIWASSEE PROJECT



WATTS BAR PROJECT



WHEELER PROJECT



Scales

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

EDMS No.

L58 090908 001

Bellefonte Nuclear Units 3&4

Hydrology Project

Dam Lock Gate Technical Evaluation for the PMF

Tennessee Valley Authority

Revision 0

March 26, 2008

Prepared: [signature] Date: 3/26/09

Checked: J. V. Peyton Date: 3-26-2009

RO Concurrence: Russell W. Tompkins Date: 8-24-09

NPG Approval: [signature] Date: 9-4-09

[initials] 9/2/09 PBS 8/31/09

Background

During the course of preparing the Dam Rating Curves (DRC) for the TVA Nuclear Probable Maximum Flood (PMF) documentation, the continued stability of the dam lock gates under PMF conditions was documented in the DRC calculations as an Unverified Assumption (UVA). While the initial design of the lock gates considered loading conditions that are typical of normal operations (including barge impact loading), most cases neglected the significantly increased headwater conditions that would be encountered in a PMF. The purpose of this evaluation is to document the basis for maintaining the lock gates in a stable configuration for the range of headwater elevations considered for the PMF and to support removal of the UVA from the DRC calculations.

Assumptions

For the purpose of this evaluation, the following assumptions are made:

1. <u>Assumption</u>: *The original gate design allowable stresses were based on the Allowable Stress Design (ASD) method as provided in the Army Corps of Engineers (COE) Design of Hydraulic Steel Structures and the 1989 AISC 9th edition ASD Manual.*

   Although the 1989 AISC manual post-dates the lock gate design, the concepts and factors utilized from this manual have not changed. In addition, allowable stresses as shown on Watts Bar Dam drawing 64W203-1 (Design Data) are consistent with the allowable stresses provided in the design manuals.

2. <u>Assumption</u>: *The lock gates are designed for a hydrostatic impact loading of 15 feet of water applied to the top 15 feet of the lock gate in addition to the hydrostatic load due to design maximum headwater conditions.*

   This impact loading is required by the Army Corps of Engineers Lock Gate and Operating Equipment Design Manual (Section 1-9(b)) and is typically shown in the Water Load Diagram on the Lock Gate Design Data drawings (e.g., 64N202, R0). During PMF conditions, navigation on the rivers will cease and barges are not likely to be moored above the dams for barge operational safety considerations. In addition, at the PMF headwater elevation considered, a large cushion of water exists between the water surface and the top of the gates (e.g., Watts Bar and Melton Hill have PMF elevations approximately 20 feet over the top of the gates considered in this evaluation). As a result, major gate impacts from river borne objects are not expected during the PMF[1]. Since major impacts are not expected, the design

[1] Impact loads were considered additive to design hydrostatic pressure loads up to approximately 5 feet over the top of the gate (see Attachment 1). When the flood headwater is higher than 5 feet over the lock gate, impact loads are not considered.

margin built into the gate design for impact loading can be utilized to off-set the increased lock gate stresses due to the hydrostatic loads from the PMF.

3. Assumption: *The headwater and tailwater elevations from the TVA Hydrology Project DRC calculations can be utilized to determine the differential loading on the lock gates.*

   These calculations are independently documented as a QA record under the calculations identifiers CDQ000020080001 through CDQ000020080020 and are retrievable from EDMS. (Note: Following completion of the SOCH PMF analysis and inclusion of the "loop tailwater rating effect", the headwater and tailwater elevations used in this evaluation will be verified to be technically acceptable.)

4. Assumption: *The operability of the gates a PMF is not a requirement.*

   Although lock gate operability is obviously a river navigational objective following a PMF, no credit is taken in the Nuclear Plant safety analysis for river navigation capability post-PMF. Inelastic but stable gate configurations are acceptable.

5. Assumption: *The auxiliary gates at Nickajack are adequate since the gates were analyzed and modified for PMF conditions.*

   The analysis of these gates is documented in River Operations Group calculation, *Upper Miter Gate Analysis for Probable Maximum Flood.* (Letter from G. L. Wimberly to J. H. Coulson, dated March 19, 1991, RIMS No. B65910322176)

6. Assumption: Downstream lock gates are assumed open for this evaluation

   During a PMF, the upstream lock gates will be in their normal operational configuration.

Evaluation

The cause of the overloading of the gates in a PMF event is the differential in headwater and tailwater elevations. Once the elevation of the tailwater is above the sill of the gate, the tailwater effectively cancels out some of the loading. All loads are treated as a static hydrostatic loading which is justified in the TVA Report "Nickajack Auxiliary Lock: Forces on Upstream Miter gate Due to Overflow during Probable Maximum Flood."

The impact loadings are added to the design load as shown on relevant TVA Upper Lock Gate Design Data drawings. This load is considered a portion of the design capacity in accordance with the second assumption noted above.[2]

The gates are evaluated by comparing PMF Design Margin Ratios for each dam. The PMF Design Margin Ratio is defined in this evaluation as (Original Hydrostatic Lateral Design Load + Impact Load)/ (PMF Critical Lateral Load). The PMF Critical Horizontal Load is the combination of PMF headwater and tailwater (from the DRC calculations) that creates the highest hydrostatic load on the lock gate (Note: A summary of the results of this evaluation is provided in Attachment 1). ASD design limits stress to 60% of the specified yield strength of the steel. As defined in Chapter 3 of the Sequoyah and Watts Bar Nuclear Plant FSARs, the limiting stress can be increased by 50% to a total of 90% of the yield capacity for extreme environmental load conditions such as severe seismic events, tornados and internal/external flooding events as well as for severe accident pressurization. In other words, this allows the numerator of the PMF Design Margin Ratio to be multiplied by 1.5. Reduction in allowable bending stresses due to compression flange buckling is not required due to the lateral support the gate skin plate and adjacent structural members provide the compression flange in areas of large compressive bending moment stresses.

The increase in allowable stress and the additional capacity for impact load shows that all the lock gates except for the gates at Melton Hill and Watts Bar have a PMF Design Margin Ratio greater than one (see Table 1). The PMF Design Margin Ratios at these two dams are 0.73 and 0.81, respectively. These low margins occur due to the height of the dams and the rate at which the tailwater elevation rises.

The geometry of the gates adds a significant amount of load carrying capacity not considered in these PMF Design Margin Ratios. The miter design will put large amounts of compression into the gates. This compression reduces the tension due to bending moments in the gate along the strong axis of the girders. The concrete lock wall has a large capacity to absorb these forces. Also, even with the increase in design strength of 50%, the actual stress is still 10% less than the specified yield strength of the steel. Due to these factors, it is not uncommon for structures to carry loads much larger than the loads for which the structures were designed. While there may be local failures such as skin plate yielding or localized buckling, it is not expected that the gates will fail catastrophically.

[2] As shown in Attachment 1, combining the hydrostatic water pressure load from the rising flood headwater up to approximately 5 feet over the top of the gate with the design impact load will not result in lock gate failure. For this condition, lock gate stresses are expected to be less than material yield strength.

Table 1: Summary - PMF Design Margin Ratio

TVA Dam	Adjusted PMF Design Margin Ratio
Guntersville (main)	2.03
Guntersville (auxiliary)	2.26
Fort Loudon	1.16
Melton Hill	0.73
Watts Bar	0.81
Chickamauga	2.10

To analyze the gates at Watts Bar and Melton Hill in more detail, the operational stress analysis drawings were utilized at both dams to obtain the existing calculated design stresses in the upper lock gates. Using these originally calculated stresses, the design stresses from the PMF loading scenarios can be extrapolated.

Analysis of the Watts Bar Lock gates was performed using the original loading considerations and the lock gate stress analysis results provided on drawing 64W203-1, R0. The maximum stress for the highest loaded lock gate structural component (bottom girder in the lock gate) is 27.92 ksi. Other component stresses provided on the drawing are less in magnitude than the lock gate girder stress. In addition, concrete stresses can be increased by a factor greater than that permitted for structural steel stresses. Since there is at least a 2 ksi margin to steel yielding, the lock gates will continue to function for the PMF elevations considered in the DRC calculation.

The lock gates at the Melton Hill dam are more difficult to analyze since the stresses developed during the PMF are closer to the steel yield stress. The original design basis analysis for the PMF assumed that the total Melton Hill dam structure failed at an elevation of 805 feet. As shown in Attachment 1 (for Melton Hill), for the PMF elevations at 809.27 feet and below, the allowable stresses in the structural steel gates will remain less than 0.9 x Fy, demonstrating that elastic response of the gate material and small deflections will be maintained for the original FSAR Nuclear Plant PMF analysis. Using the original loading considerations and the lock gate stress analysis results provided on drawing 64N202, R0, the stress at the maximum elevation of the dam rating curve of 820 feet for the highest loaded lock gate girder (bottom girder in the lock gate) is 29.4 ksi (Ref: CDQ000020080013, EDMS No. L58090210002), slightly less than the 32 ksi yield strength of the A373 girder steel. The stress in the skin plate and the girder/skin plate combination (22.73 ksi and 38.6 ksi, respectively) indicates that some localized buckling may occur in the skin plate at the 820 feet elevation.

The localized buckling in the skin plate of the Melton Hill lock gate for the 820 feet elevation will not result in functional failure of the gate structure. The impact of the localized buckling (caused by skin plate compression resulting from Poisson's ration of the flexural tension in the skin plate) is limited due to restrained conditions provided by the intercostal supports and the girder flanges and due to the localized nature of the skin plate high stressed regions. The localized skin plate buckling would increase the calculated 29.4

ksi elastic stress of the composite girder/plate section due to the reduced flexural effectiveness of the skin plate, potentially increasing the composite section stress slightly above the 32 ksi yield stress. Since the ultimate strength of the A373 steel is at least a factor of 1.8 higher than yield strength, the expected result will be a stable, functional gate with some increased deflection at the gate centerline and at the mitered joint with the adjacent gate.

The other main problem encountered is the weight of the water flowing over the gates. Lock gates are not designed to take this type of load. The expected result is that the weight of the water above the gate will further compress the 1.5 inch rubber seal at the bottom of the lock gate into the embedded steel plate on the concrete sill until the vertical weight of the water head over the gate and the weight of the gate is equalized by the resistance of the compressed rubber seal and concrete sill. Although the downward deflection is self-limiting, the navigational functionality of the lock gates may be impaired. As noted previously in Assumption 4, post-PMF navigational functionality is not required to mitigate the consequences of the PMF event at the TVA Nuclear sites.

Conclusion

While the upper lock gates in this evaluation may have increased leakage and minor localized skin pate buckling or yielding, it can be stated with a reasonable degree of engineering judgment that the gates will not fail catastrophically during a PMF event. The upper lock gates will potentially be inoperable at the conclusion of the PMF from the excessive deflection the gates are likely to undergo.

Attachment 1

Dam	Adjusted FOS
Guntersville (main)	2.03
Guntersville (aux)	2.26
Ft. Loudoun	1.16
Melton Hill	0.73
Watts Bar	0.81
Chickamauga	2.10

Summary of Gate Dimensions and Loading

Lock	Design HW (ft)	Top of Gate (ft)	Gate Sill (ft)	Gate Height (ft)	Design Load (lb/ft)	Impact Load (lb/ft)	Total Design Load (lb/ft)	50% increase (lb/ft)	Critical Load (lb/ft)	Design Margin Ratio
Guntersville - Main	595	599.38	578	21.38	9017	11120	20136	30205	14889	2.03
Guntersville - Aux	595	597.11	570	27.11	19500	8995	28495	42742	18879	2.26
Ft. Loudoun	815	818.67	777	41.67	45053	10455	55508	83262	71862	1.16
Melton Hill	795	800.44	776.75	23.69	10392	12112	22503	33755	45979	0.73
Watts Bar	745	748.67	719.67	29	20018	10455	30473	45710	56410	0.81
Chickamauga	682.5	689.17	662	27.17	13112	13263	26375	39562	18820	2.10
									Impact Ld + Design Ld 5ft Cover	**%FY**
Guntersville - Main					9017	11120	20136	30205	20462	0.61
Guntersville - Aux					19500	8995	28495	42742	20179	0.42
Ft. Loudoun					45053	10455	55508	83262	78488	0.85
Melton Hill					10392	12112	22503	33755	23296	0.62
Nickajack - Aux					7661	12243	19904	29856	30252	0.91
Watts Bar					20018	10455	30473	45710	48091	0.95
Chickamauga					13112	13263	26375	39562	31275	0.71

Guntersville Main Lock

Top of Gate*	599.38
Gate Sill*	578
HW Design*	595

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	DS-US (lb/ft)			
A	595	-	-	9017	0	9017	Design Condition		
C	600	593.77	6.23	15089	7759	7330			
C	602.5	595.86	6.64	18424	9952	8472			
C	605	597.95	7.05	21759	12418	9342			
D	607	599.64	7.36	24428	14609	9819			
D	608.8	601.19	7.61	26829	16676	10153			
D	611	602.67	8.33	29764	18651	11113			
D	613	604	9	32432	20425	12007			
D	615	605.33	9.67	35100	22200	12901			
D	617.5	607.01	10.49	38436	24441	13995			
D	619	608.18	10.82	40437	26002	14435			
D	620	609.04	10.96	41771	27149	14622			
D	622	610.88	11.12	44439	29604	14835			
D	624	612.84	11.16	47107	32219	14889		FOS=	0.605614

* Source: TVA Drawing 64N202, R0

Guntersville Auxiliary Lock

Top of Gate	597.11
Gate Sill	570
HW Design	595

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	DS-US (lb/ft)			
A	595	-	-	19500	0	19500	Design Condition		
C	600	593.77	6.23	27819	17628	10191			
C	602.5	595.86	6.64	32049	20865	11184			
D	605	597.95	7.05	36278	24352	11926			
D	607	599.64	7.36	39661	27210	12451			
D	608.8	601.19	7.61	42706	29832	12874			
D	611	602.67	8.33	46428	32336	14092			
D	613	604	9	49811	34586	15225			
D	615	605.33	9.67	53194	36836	16358			
D	617.5	607.01	10.49	57424	39678	17746			
D	619	608.18	10.82	59961	41657	18304			
D	620	609.04	10.96	61653	43112	18541			
D	622	610.88	11.12	65036	46225	18811			
D	624	612.84	11.16	68419	49540	18879		FOS=	1.032895

* Source: Miscellaneous TVA Sources

Ft. Loudoun Lock

Case 1

Top of Gate*	818.67
Gate Sill*	777
HW Design*	815

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	Impact Load (lb/ft)	DS-US (lb/ft)			
A	815	-	-	45053	0	10455	55508	Design Condition		
C	819	799.4	19.62	55033	15627	-	39406			
C	820	800.7	19.327	57634	17485	-	40149			
C	821	802.3	18.729	60234	19925	-	40309			
C	822	803.3	18.71	62834	21564	-	41270			
C	823	804.4	18.569	65434	23477	-	41957			
C	824	805.7	18.337	68034	25633	-	42402			
C	825	807.0	18.048	70635	27990	-	42644		FOS=	1.301645
C	826	808.7	17.313	73235	31327	-	41908			
C	827	810.5	16.507	75835	35000	-	40835			
C	828	812.3	15.75	78435	38768	-	39667			
C	829	813.9	15.092	81035	42501	-	38535			
C	830	815.6	14.414	83636	46453	-	37183			
C	831	817.8	13.205	86236	51924	-	34312			
D	832	820.3	11.654	88836	58533	-	30303			
D	833	822.9	10.057	91436	65286	-	26150			
D	834	825.7	8.337	94037	72359	-	21678			
D	835	828.6	6.378	96637	80053	-	16584			
D	836	831.6	4.433	99237	87710	-	11527			
D	837	834.3	2.739	101837	94715	-	7122			

Case 2

Top of Gate*	818.67
Gate Sill*	777
HW Design*	815

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	Impact Load (lb/ft)	DS-US (lb/ft)			
A	815	-	-	45053	0	10455	55508	Design Condition		
B	819	766.5	52.458	55033	0	-	55033			
B	820	768.9	51.054	57634	0	-	57634			
B	821	771.1	49.912	60234	0	-	60234			
B	822	773.7	48.313	62834	0	-	62834			
B	823	773.7	49.254	65434	0	-	65434			
C	824	777.2	46.789	68034	1	-	68033			
C	825	780.8	44.197	70635	451	-	70183			
C	826	784.4	41.574	73235	1721	-	71514			
C	827	788.3	38.715	75835	3973	-	71862		FOS=	0.772427
C	828	791.9	36.139	78435	6890	-	71545			
C	829	795.3	33.66	81035	10494	-	70541			
C	830	798.7	31.337	83636	14642	-	68994			
C	831	802.9	28.105	86236	20921	-	65315			
C	832	807.6	24.43	88836	29157	-	59679			
C	833	812.3	20.743	91436	38783	-	52653			
C	834	817.1	16.859	94037	50273	-	43764			
D	835	822.3	12.741	96637	63507	-	33129			
D	836	827.3	8.693	99237	76633	-	22604			
D	837	832.0	5.003	101837	88828	-	13009			

No Failure Case will control since the head differential is too low

* Source: TVA Drawing 64W204, R0

Melton Hill Lock

Top of Gate*	800.44
Gate Sill*	776.75
HW Design*	795

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	Impact Load (lb/ft)	DS-US (lb/ft)	
A	795	-	-	10392	0	12112	33755	Design Condition
B	800.44	765.4	35.1	17510	0	-	17510	
B	802	765.9	36.1	19816	0	-	19816	
B	803	766.3	36.7	21294	0	-	21294	
B	804	766.9	37.1	22773	0	-	22773	
B	804.95	767.6	37.4	24177	0	-	24177	
B	805	767.6	37.4	24251	0	-	24251	
B	805.48	768.0	37.5	24960	0	-	24960	
B	806	768.4	37.6	25729	0	-	25729	
B	807	769.2	37.8	27207	0	-	27207	
B	808	770.2	37.8	28686	0	-	28686	
B	809	771.1	37.9	30164	0	-	30164	
B	810	772.1	37.9	31642	0	-	31642	
B	811	773.2	37.8	33120	0	-	33120	
B	811.7	773.9	37.8	34155	0	-	34155	
B	812	774.2	37.8	34599	0	-	34599	
B	813	773.1	39.9	36077	0	-	36077	
B	814	774.3	39.7	37555	0	-	37555	
B	815	775.5	39.5	39033	0	-	39033	
B	816	776.7	39.3	40512	0	-	40512	
C	816.46	777.2	39.2	41192	7	-	41185	
C	818	778.9	39.1	43468	138	-	43330	
C	819	779.8	39.2	44946	284	-	44662	
C	820	780.5	39.5	46425	445	-	45979	

* Source: TVA Drawing 64N202, R0

Alternative Analysis

Design HW*	795 ft
Hydrostatic Head on Highest Stressed Girder*	17.25 ft
Critical Combined Girder Stress	15.76 ksi
Critical Skin Plate Stress	9.28 ksi
Critical Combined Girder/Plate Stress	12.98 ksi
Maximum Girder Stress*	15.76 ksi
Allowable Steel Stress*	19.2 ksi
Maximum PMF Elevation**	820 ft

For PMF considerations, it is typical to increase the load carrying capacity of the steel by 50%.***
Therefore, Fy=28.8 ksi in this analysis.

This input produces a rough equation for estimating the headwater at which Fy will be exceeded.

[17.25ft+(PMFelev-795)]*(15.76ksi/17.25ft)=28.8 ksi

Solving this equation results in a PMF elevation of 809.27'.

The maximum stress (girder + skin plate)

[17.25ft+(820-795)]*(15.76ksi/17.25ft)=38.6 ksi at HW of 820'

Maximum Stress (girder)

[17.25ft+(820-795)]*(11.98ksi/17.25ft)=29.4 ksi at HW of 820'

Maximum Stress (plate)

[17.25ft+(820-795)]*(15.76ksi/17.25ft)=22.73 ksi at HW of 820'

See whitepaper for conclusions.

* Source: TVA Drawing 64N202, R0
**Source: TVA Calculation CDQ000020080013
***Source: WBN and SQN FSAR, Section 3.8.4.3.2

Watts Bar Lock

Top of Gate*	748.67
Gate Sill*	719.67
HW Design*	745

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstream Force (lb/ft)	Upstream Force (lb/ft)	Impact Load (lb/ft)	DS-US (lb/ft)			
A	745	-	-	20018	0	10455	30473	Design Condition		
B	**749**	719.49	29.5	26836	0	-	26836			
C	**750**	720.23	29.8	28646	10	-	28636			
C	**752**	719.90	32.1	32265	2	-	32263			
C	**753**	719.76	33.2	34075	0	-	34075			
C	**755**	721.03	34.0	37694	58	-	37636			
C	**757**	722.38	34.6	41313	229	-	41084			
C	**759**	723.78	35.2	44932	527	-	44405			
C	**760**	724.57	35.4	46742	749	-	45993			
C	**761**	725.47	35.5	48552	1050	-	47501			
C	**762**	726.45	35.6	50361	1433	-	48928			
C	**763**	727.47	35.5	52171	1900	-	50271			
C	**764**	728.53	35.5	53980	2451	-	51529			
C	**765**	729.62	35.4	55790	3091	-	52699			
C	**766**	730.74	35.3	57600	3821	-	53778			
C	**767**	731.87	35.1	59409	4643	-	54766			
C	**768**	733.18	34.8	61219	5691	-	55527			
C	**769**	734.62	34.4	63028	6973	-	56055			
C	**770**	736.11	33.9	64838	8428	-	56410		FOS=	0.540215

* Source: TVA Drawing 64W203-1, R0

Alternative Analysis

Design HW*	745 ft
Hydrostatic Head on Highest Stressed Girder*	24.33 ft
Maximum Girder Stress*	13.77 ksi
Allowable Steel Stress*	18 ksi
Maximum PMF Elevation**	770 ft

For PMF considerations, it is typical to increase the load carrying capacity of the steel by 50%.***
Therefore, Fy=27 ksi in this analysis.

This input produces a rough equation for estimating the headwater at which Fy will be exceeded.

[24.33ft+(PMFelev-745)]*(13.77ksi/24.33ft)=27 ksi

At a PMF elevation of 770 feet, the stress in the girder is 27.92 ksi

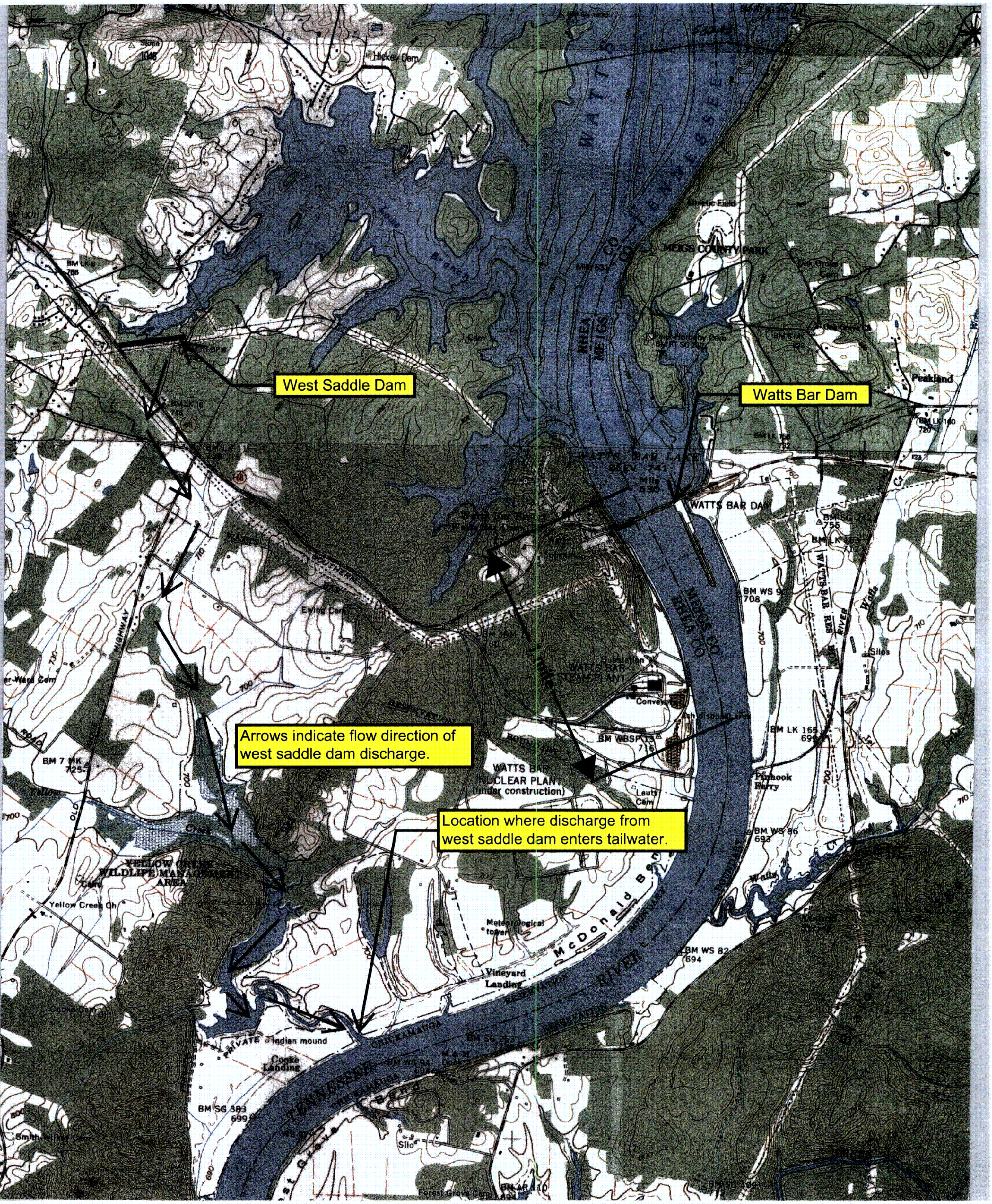
* Source: TVA Drawing 64W203-1, R0
**Source: TVA Calculation CDQ000020080020
***Source: WBN and SQN FSAR, Section 3.8.4.3.2

Chickamauga Main Lock

Top of Gate*	689.17
Gate Sill*	662
HW Design*	682.5

Load Condition	HW Elev (ft)	TW Elev (ft)	HW-TW (ft)	Downstrean Force (lb/ft)	Upstream Force (lb/ft)	Impact Load (lb/ft)	DS-US (lb/ft)			
A	682.5	-	-	13112	0	13263	13112	Design Condition		
C	690	678.553	11.447	24439	8549	-	15890			
C	692	680.524	11.476	27830	10706	-	17124			
C	694	682.576	11.424	31221	13209	-	18012			
C	696	684.676	11.324	34612	16043	-	18569			
C	698	686.796	11.204	38003	19183	-	18820		FOS=	0.696713
C	700	688.943	11.057	41393	22649	-	18745			
D	702	691.181	10.819	44784	26442	-	18343			
D	704	693.512	10.488	48175	30394	-	17781			
D	704.8	694.474	10.326	49531	32025	-	17507			
D	706	695.499	10.501	51566	33762	-	17803			
D	708	697.619	10.381	54957	37357	-	17600			
D	710	700.347	9.653	58347	41982	-	16366			
D	712	703.414	8.586	61738	47182	-	14557			
D	714	706.704	7.296	65129	52759	-	12370			
D	716	710.073	5.927	68520	58471	-	10049			
D	718	713.43	4.57	71911	64163	-	7748			
D	720	716.391	3.609	75302	69183	-	6119			
D	722	719.038	2.962	78692	73671	-	5022			
D	724	721.511	2.489	82083	77863	-	4220			
D	726	723.858	2.142	85474	81842	-	3632			

* Source: Miscellaneous TVA Sources



West Saddle Dam
Watts Bar Dam
Arrows indicate flow direction of west saddle dam discharge.
Location where discharge from west saddle dam enters tailwater.
MEIGS COUNTY PARK
Peakland
WATTS BAR DAM
WATTS BAR NUCLEAR PLANT (under construction)
YELLOW CREEK WILDLIFE MANAGEMENT AREA
Yellow Creek Ch
Vineyard Landing
Cooke Landing
Indian mound
Pinhook Ferry
McDonald Bend

TENNESSEE VALLEY AUTHORITY
RIVER SYSTEM OPERATIONS & ENVIRONMENT
RIVER OPERATIONS

WATTS BAR DAM

SPILLWAY DISCHARGE TABLES

NOVEMBER 2004

CONTENTS

INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables dated September 1996. They differ from those tables only in a few minor details. The September 1996 tables superseded the tables dated March 1991. Those tables were revised to increase the maximum headwater elevation covered in the tables from 747 feet to 750 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 Watts Bar 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 1989.

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 for satisfactory spillway operation.

3. Range of Tables

The tables cover a discharge range from 0 to 690,300 cubic feet per second. Headwater elevations range from 732 feet to 750 feet. The tailwater does not affect the discharges from this spillway.

4. Arrangement of Tables

The tables show spillway discharges in cubic feet per second. Headwater elevations in 0.1-foot increments 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 tables of Spillway Gate Arrangements on pages 4 and 5. Reference to these tables and to the drawing showing the location of the gates on page 3 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 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 is used. For example, the column headed 742.2 is used for actual headwater elevations between 742.15 feet and 742.24 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 pages 4 and 5. Gate opening indicator readings do not represent gate opening in feet but only provide a gate opening position that will give the desired discharge when used with the tables 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 745 feet

If the headwater elevation exceeds 745 feet (actually, 744.8 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 80,000 cubic feet per second with the headwater at elevation 740.82 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 740 feet and 742 feet are found on pages 14 and 15. The headwater elevation closest to 740.82 feet is 740.8 feet. In the column headed 740.8 the discharge nearest to the required 80,000 cubic feet per second is 80,200 cubic feet per second located near the bottom of page 14. By tracing the horizontal line in which 80,200 cubic feet per second appears, to either side of the page, we find that gate arrangement 50 is the one for producing the discharge closest to 80,000 cubic feet per second at headwater elevation 740.82 feet. Referring to page 4 it is found that the gates should be set with the gate opening indicators reading as follows: Gates 1-4, 6, 8, 10, 12, 14, and 16 at indicator reading 6; gates; Gates 5, 7, 9, 11, 13, 15, and 17-20 at indicator reading 10.

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 rise to 741.98 feet, the discharge will be found in the column headed 742.0. In this column the discharge closest to 80,000 cubic feet per second is 79,500 cubic feet per second for gate arrangement 49. To change to gate arrangement 49 from gate arrangement 50, gate 18 would be set to an indicator reading of 6.

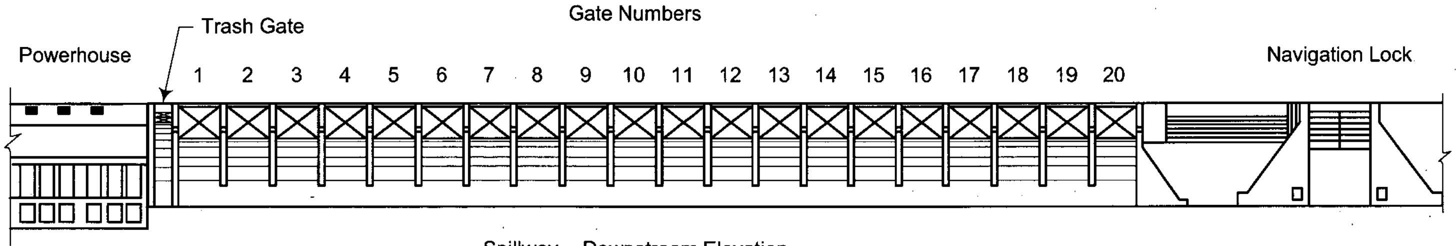
Example 2 -- Suppose the operating records show that the headwater is at elevation 736.35 feet, and gate arrangement 97 is in use. The headwater is found on pages 10 and 11, which are marked "Headwater 736 to 738." The elevation given is exactly halfway between elevation 736.3 feet and 736.4 feet. The larger value, 736.4 feet, is used. In the column headed 736.4 opposite gate arrangement 97, the discharge is found to be 304,100 cubic feet per second.

9. Trash Gate

The trash gate is located at the right end of the spillway between the spillway and the powerhouse. It consists of two vertical leaves that can be raised when necessary to pass trash. The top of the upper leaf is at elevation 745 feet. Should the headwater exceed 745 feet with the leaves closed, or when either the upper or lower gate leaf is raised, the discharge through this gate must be added to the spillway discharge taken from pages 6 through 22. Page 23 gives the discharge to be added at any headwater elevation.

WATTS BAR DAM

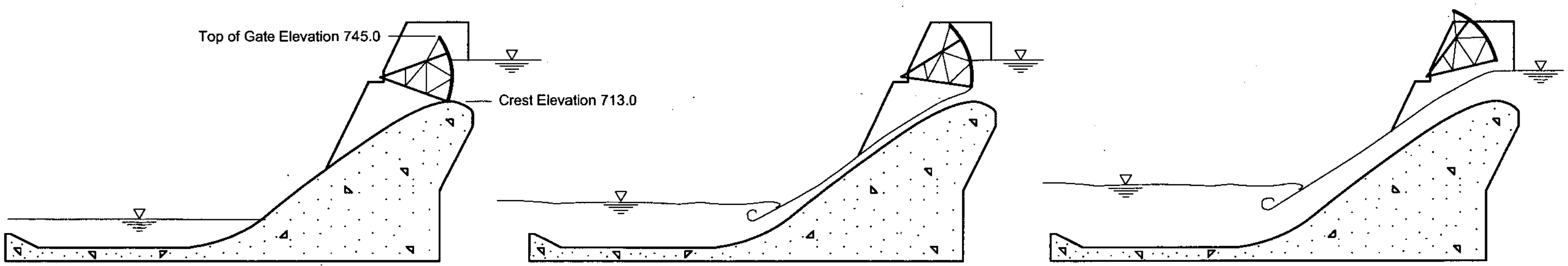
LOCATION OF SPILLWAY GATES



Spillway -- Downstream Elevation

KEY TO GATE ARRANGEMENT TABLE

Numbers Under Gate Operating Conditions Shown Below Refer To Numbers Marked On Gate Position Indicator And Used In Gate Arrangement Table, Pages 4 And 5



Gate Closed
Gate Position Indicated by Dash (-)

Headwater Above Bottom of Gate
Possible Gate Position Indicator Numbers
2, 6, 10, 14, 18, 22, 26, 30, or 34

Bottom of Gate Raised Above Water Surface
Possible Gate Position Indicator Numbers
26, 30, 34, or UP, Depending on Headwater Elevation

WATTS BAR DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrangement	Gate Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	6	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	6	-	6	-	2	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	6	-	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	6	-	6	-	6	-	2	-	-	-	-	-	-	-	-	-	-
8	-	-	-	6	-	6	-	6	-	6	-	-	-	-	-	-	-	-	-	-
9	-	-	-	6	-	6	-	6	-	6	-	2	-	-	-	-	-	-	-	-
10	-	-	-	6	-	6	-	6	-	6	-	6	-	-	-	-	-	-	-	-
11	-	-	-	6	-	6	-	6	-	6	-	6	-	2	-	-	-	-	-	-
12	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	-	-	-	-	-
13	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	2	-	-	-	-
14	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	-	-	-
15	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	2	-	-
16	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	-
17	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	2
18	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6
19	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6	2	6
20	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	-	6	6	6
21	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	2	6	6	6
22	-	-	-	6	-	6	-	6	-	6	-	6	-	6	-	6	6	6	6	6
23	-	-	-	6	-	6	-	6	-	6	-	6	-	6	2	6	6	6	6	6
24	-	-	-	6	-	6	-	6	-	6	-	6	-	6	6	6	6	6	6	6
25	-	-	-	6	-	6	-	6	-	6	-	6	2	6	6	6	6	6	6	6
26	-	-	-	6	-	6	-	6	-	6	-	6	6	6	6	6	6	6	6	6
27	-	-	-	6	-	6	-	6	-	6	2	6	6	6	6	6	6	6	6	6
28	-	-	-	6	-	6	-	6	-	6	6	6	6	6	6	6	6	6	6	6

Gate Arrangement	Gate Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
29	-	-	-	6	-	6	-	6	2	6	6	6	6	6	6	6	6	6	6	6
30	-	-	-	6	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6
31	-	-	-	6	-	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6
32	-	-	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
33	-	2	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
34	-	6	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
35	2	6	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
36	6	6	-	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
37	6	6	2	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
38	6	6	6	6	-	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
39	6	6	6	6	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
40	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
41	6	6	6	6	10	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
42	6	6	6	6	10	6	10	6	6	6	6	6	6	6	6	6	6	6	6	6
43	6	6	6	6	10	6	10	6	10	6	6	6	6	6	6	6	6	6	6	6
44	6	6	6	6	10	6	10	6	10	6	10	6	6	6	6	6	6	6	6	6
45	6	6	6	6	10	6	10	6	10	6	10	6	10	6	6	6	6	6	6	6
46	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	6	6	6	6	6
47	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	6	10	6	6	6
48	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	6	10	6	10	6
49	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	6	10	6	10	10
50	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	6	10	10	10	10
51	6	6	6	6	10	6	10	6	10	6	10	6	10	6	10	10	10	10	10	10
52	6	6	6	6	10	6	10	6	10	6	10	6	10	10	10	10	10	10	10	10
53	6	6	6	6	10	6	10	6	10	6	10	10	10	10	10	10	10	10	10	10
54	6	6	6	6	10	6	10	6	10	10	10	10	10	10	10	10	10	10	10	10
55	6	6	6	6	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
56	6	6	6	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate

WATTS BAR DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrangement	Gate Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
57	6	10	6	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
58	10	10	6	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
59	10	10	10	10	10	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
61	10	10	10	10	10	14	10	14	10	10	10	10	10	10	10	10	10	10	10	10
62	10	10	10	10	10	14	10	14	10	14	10	14	10	10	10	10	10	10	10	10
63	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	10	10	10	10
64	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	10	14	10	14
65	10	10	10	10	10	14	10	14	10	14	10	14	10	14	10	14	14	14	14	14
66	10	10	10	10	10	14	10	14	10	14	10	14	14	14	14	14	14	14	14	14
67	10	10	10	10	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14
68	10	10	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
69	14	14	10	14	10	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
71	14	14	14	14	18	14	18	14	14	14	14	14	14	14	14	14	14	14	14	14
72	14	14	14	14	18	14	18	14	18	14	18	14	14	14	14	14	14	14	14	14
73	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	14	14	14	14
74	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	18	14	18	14
75	14	14	14	14	18	14	18	14	18	14	18	14	18	14	18	14	18	18	18	18
76	14	14	14	14	18	14	18	14	18	14	18	14	18	18	18	18	18	18	18	18
77	14	14	14	14	18	14	18	14	18	18	18	18	18	18	18	18	18	18	18	18
78	14	14	14	18	18	14	18	18	18	18	18	18	18	18	18	18	18	18	18	18
79	14	14	14	18	18	22	18	18	18	18	18	18	18	18	18	18	18	18	18	18
80	14	14	14	18	18	22	18	22	18	22	18	18	18	18	18	18	18	18	18	18
81	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	18	18	18	18	18
82	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	22	18	22	18	18
83	14	14	14	18	18	22	18	22	18	22	18	22	18	22	18	22	18	22	22	22

Gate Arrangement	Gate Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
84	14	14	14	18	18	22	18	22	18	22	18	22	18	22	22	22	22	22	22	22
85	14	14	14	18	18	22	18	22	22	22	22	22	22	22	22	22	22	22	22	22
86	14	14	14	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
87	14	14	14	22	26	22	26	22	26	22	22	22	22	22	22	22	22	22	22	22
88	14	14	14	22	26	22	26	22	26	22	26	22	26	22	26	22	22	22	22	22
89	14	14	14	22	26	22	26	22	26	22	26	22	26	22	26	22	26	22	26	26
90	14	14	14	22	26	22	26	22	26	22	26	22	26	26	26	26	26	26	26	26
91	14	14	14	22	26	22	26	26	26	26	26	26	26	26	26	26	26	26	26	26
92	14	14	14	26	26	30	26	26	26	26	26	26	26	26	26	26	26	26	26	26
93	14	14	14	26	26	30	26	30	26	30	26	30	26	26	26	26	26	26	26	26
94	14	14	14	26	26	30	26	30	26	30	26	30	26	30	26	30	26	30	26	30
95	14	14	14	26	26	30	26	30	26	30	26	30	30	30	30	30	30	30	30	30
96	14	14	14	30	26	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
97	14	14	14	30	34	30	34	30	34	30	30	30	30	30	30	30	30	30	30	30
98	14	14	14	30	34	30	34	30	34	30	34	30	34	30	34	30	34	30	34	30
99	14	14	14	30	34	30	34	30	34	30	34	34	34	34	34	34	34	34	34	34
100	14	14	14	34	34	UP	34	34	34	34	34	34	34	34	34	34	34	34	34	34
101	14	14	14	34	34	UP	34	UP	34	UP	34	UP	34	UP	34	34	34	34	34	34
102	14	14	14	34	34	UP	34	UP	34	UP	34	UP	34	UP	34	UP	34	UP	UP	UP
103	14	14	14	34	34	UP	34	UP	34	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
104	14	14	14	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
105	18	18	18	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
106	22	22	22	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
107	26	26	26	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
108	30	30	30	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
109	34	34	34	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP
110	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP	UP

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	732.0	732.1	732.2	732.3	732.4	732.5	732.6	732.7	732.8	732.9	733.0	733.1	733.2	733.3	733.4	733.5	733.6	733.7	733.8	733.9	734.0	
1	720	720	730	730	730	730	730	740	740	740	740	740	740	750	750	750	750	750	760	760	760	1
2	2,020	2,030	2,030	2,040	2,040	2,050	2,050	2,060	2,070	2,070	2,080	2,080	2,090	2,090	2,100	2,100	2,110	2,110	2,120	2,120	2,130	2
3	3,130	3,140	3,150	3,160	3,170	3,180	3,180	3,190	3,200	3,210	3,220	3,230	3,230	3,240	3,250	3,260	3,270	3,280	3,280	3,290	3,300	3
4	4,430	4,440	4,450	4,460	4,480	4,490	4,500	4,510	4,530	4,540	4,550	4,560	4,570	4,590	4,600	4,610	4,620	4,630	4,640	4,660	4,670	4
5	5,460	5,480	5,490	5,510	5,520	5,540	5,550	5,570	5,580	5,590	5,610	5,620	5,640	5,650	5,670	5,680	5,700	5,710	5,730	5,740	5,750	5
6	6,760	6,780	6,790	6,810	6,830	6,850	6,870	6,890	6,910	6,920	6,940	6,960	6,980	7,000	7,020	7,030	7,050	7,070	7,090	7,110	7,120	6
7	7,790	7,810	7,830	7,850	7,880	7,900	7,920	7,940	7,960	7,980	8,000	8,020	8,050	8,070	8,090	8,110	8,130	8,150	8,170	8,190	8,210	7
8	9,090	9,110	9,140	9,160	9,190	9,210	9,240	9,260	9,290	9,310	9,340	9,360	9,390	9,410	9,430	9,460	9,480	9,510	9,530	9,560	9,580	8
9	10,020	10,050	10,070	10,100	10,130	10,160	10,180	10,210	10,240	10,270	10,290	10,320	10,350	10,370	10,400	10,430	10,460	10,480	10,510	10,540	10,560	9
10	11,320	11,350	11,390	11,420	11,450	11,480	11,510	11,540	11,570	11,600	11,630	11,670	11,700	11,730	11,760	11,790	11,820	11,850	11,880	11,910	11,940	10
11	12,310	12,350	12,380	12,420	12,450	12,480	12,520	12,550	12,580	12,620	12,650	12,680	12,720	12,750	12,780	12,820	12,850	12,880	12,920	12,950	12,980	11
12	13,630	13,670	13,700	13,740	13,780	13,820	13,860	13,890	13,930	13,970	14,000	14,040	14,080	14,120	14,150	14,190	14,220	14,260	14,300	14,330	14,370	12
13	14,450	14,490	14,530	14,570	14,610	14,650	14,690	14,730	14,770	14,810	14,850	14,890	14,930	14,970	15,010	15,040	15,080	15,120	15,160	15,200	15,240	13
14	15,740	15,790	15,830	15,880	15,920	15,960	16,010	16,050	16,090	16,130	16,180	16,220	16,260	16,310	16,350	16,390	16,430	16,470	16,520	16,560	16,600	14
15	16,640	16,680	16,730	16,770	16,820	16,860	16,910	16,960	17,000	17,050	17,090	17,140	17,180	17,230	17,270	17,320	17,360	17,400	17,450	17,490	17,540	15
16	17,940	17,990	18,040	18,090	18,140	18,190	18,240	18,290	18,340	18,390	18,440	18,480	18,530	18,580	18,630	18,680	18,730	18,770	18,820	18,870	18,920	16
17	18,770	18,820	18,870	18,920	18,970	19,020	19,080	19,130	19,180	19,230	19,280	19,330	19,380	19,430	19,480	19,530	19,580	19,630	19,680	19,730	19,780	17
18	20,060	20,110	20,170	20,220	20,280	20,330	20,390	20,440	20,500	20,550	20,610	20,660	20,720	20,770	20,830	20,880	20,930	20,990	21,040	21,090	21,150	18
19	20,900	20,950	21,010	21,070	21,130	21,180	21,240	21,300	21,360	21,410	21,470	21,530	21,580	21,640	21,690	21,750	21,810	21,860	21,920	21,970	22,030	19
20	22,150	22,210	22,280	22,340	22,400	22,460	22,520	22,580	22,640	22,700	22,760	22,820	22,880	22,940	23,000	23,060	23,120	23,180	23,240	23,300	23,350	20
21	22,960	23,030	23,090	23,150	23,220	23,280	23,340	23,400	23,470	23,530	23,590	23,650	23,720	23,780	23,840	23,900	23,960	24,020	24,080	24,140	24,210	21
22	24,260	24,330	24,400	24,470	24,530	24,600	24,670	24,730	24,800	24,860	24,930	25,000	25,060	25,130	25,190	25,260	25,320	25,390	25,450	25,520	25,580	22
23	25,110	25,180	25,250	25,320	25,390	25,460	25,530	25,600	25,660	25,730	25,800	25,870	25,940	26,000	26,070	26,140	26,210	26,270	26,340	26,410	26,470	23
24	26,420	26,490	26,570	26,640	26,710	26,790	26,860	26,930	27,000	27,070	27,150	27,220	27,290	27,360	27,430	27,500	27,570	27,640	27,710	27,780	27,850	24
25	27,450	27,530	27,610	27,680	27,760	27,830	27,910	27,980	28,060	28,130	28,210	28,280	28,360	28,430	28,500	28,580	28,650	28,720	28,800	28,870	28,940	25
26	28,750	28,830	28,910	28,990	29,070	29,150	29,220	29,300	29,380	29,460	29,540	29,620	29,690	29,770	29,850	29,920	30,000	30,080	30,150	30,230	30,310	26
27	29,710	29,790	29,870	29,950	30,040	30,120	30,200	30,280	30,360	30,440	30,520	30,600	30,680	30,760	30,840	30,920	31,000	31,080	31,160	31,240	31,320	27
28	31,030	31,110	31,200	31,290	31,370	31,460	31,540	31,630	31,710	31,800	31,880	31,960	32,050	32,130	32,210	32,300	32,380	32,460	32,550	32,630	32,710	28
29	31,840	31,930	32,020	32,100	32,190	32,280	32,370	32,450	32,540	32,630	32,710	32,800	32,890	32,970	33,060	33,140	33,230	33,310	33,400	33,480	33,560	29
30	33,140	33,230	33,330	33,420	33,510	33,600	33,690	33,780	33,870	33,960	34,050	34,140	34,230	34,320	34,410	34,500	34,590	34,680	34,760	34,850	34,940	30
31	33,990	34,090	34,180	34,280	34,370	34,460	34,560	34,650	34,740	34,830	34,930	35,020	35,110	35,200	35,290	35,380	35,470	35,560	35,650	35,740	35,830	31
32	35,300	35,400	35,500	35,590	35,690	35,790	35,890	35,980	36,080	36,170	36,270	36,370	36,460	36,560	36,650	36,750	36,840	36,930	37,030	37,120	37,210	32
33	36,310	36,410	36,510	36,610	36,710	36,810	36,910	37,010	37,110	37,210	37,300	37,400	37,500	37,600	37,700	37,790	37,890	37,990	38,080	38,180	38,270	33
34	37,580	37,690	37,790	37,900	38,000	38,100	38,210	38,310	38,410	38,510	38,620	38,720	38,820	38,920	39,020	39,120	39,220	39,320	39,420	39,520	39,620	34
35	38,450	38,550	38,660	38,770	38,870	38,980	39,080	39,190	39,290	39,400	39,500	39,600	39,710	39,810	39,910	40,020	40,120	40,220	40,320	40,430	40,530	35
36	39,730	39,840	39,950	40,060	40,170	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	41,680	41,780	41,890	36
37	40,480	40,590	40,700	40,810	40,920	41,040	41,150	41,260	41,370	41,480	41,590	41,700	41,810	41,920	42,020	42,130	42,240	42,350	42,460	42,560	42,670	37
38	41,790	41,910	42,020	42,140	42,250	42,370	42,480	42,600	42,710	42,830	42,940	43,050	43,160	43,280	43,390	43,500	43,610	43,720	43,830	43,950	44,060	38
39	42,930	43,050	43,170	43,290	43,410	43,520	43,640	43,760	43,880	43,990	44,110	44,220	44,340	44,460	44,570	44,690	44,800	44,910	45,030	45,140	45,260	39
40	44,240	44,370	44,490	44,610	44,730	44,860	44,980	45,100	45,220	45,340	45,460	45,580	45,700	45,820	45,940	46,050	46,170	46,290	46,410	46,530	46,640	40
41	46,230	46,360	46,480	46,610	46,740	46,870	47,000	47,120	47,250	47,380	47,500	47,630	47,760	47,880	48,010	48,130	48,260	48,380	48,500	48,630	48,750	41
42	48,150	48,290	48,420	48,560	48,690	48,820	48,960	49,090	49,230	49,360	49,490	49,620	49,750	49,890	50,020	50,150	50,280	50,410	50,540	50,670	50,800	42
43	50,820	50,970	51,110	51,250	51,400	51,540	51,680	51,820	51,970	52,110	52,250	52,390	52,530	52,670	52,810	52,950	53,090	53,220	53,360	53,500	53,640	43
44	52,810	52,970	53,120	53,270	53,420	53,560	53,710	53,860	54,010	54,160	54,300	54,450	54,600	54,740	54,890	55,030	55,180	55,320	55,470	55,610	55,760	44
45	54,740	54,890	55,050	55,210	55,360	55,520	55,670	55,830	55,980	56,140	56,290	56,440	56,590	56,750	56,900	57,050	57,200	57,350	57,500	57,650	57,800	45
46	56,660	56,830	56,990	57,150	57,310	57,470	57,640	57,800	57,960	58,120	58,270	58,430	58,590	58,750	58,910	59,060	59,220	59,380	59,530	59,690	59,840	46
47	59,330	59,510	59,680	59,850	60,020	60,190	60,360	60,530	60,700	60,870	61,030	61,200	61,370	61,530	61,700	61,870	62,030	62,200	62,360	62,520	62,690	47
48	61,250	61,430	61,610	61,790	61,960	62,140	62,310	62,490	62,660	62,840	63,010	63,190	63,360	63,530	63,700	63,870	64,040	64,220	64,390	64,560	64,720	48
49	63,160	63,340	63,520	63,710	63,890	64,070	64,250	64,440	64,620	64,800	64,980	65,160	65,330	65,510	65,690	65,870	66,040	66,220	66,400	66,570	66,750	49
50	65,140	65,330	65,520	65,710	65,900	66,080	66,270	66,460	66,650	66,830	67,020	67,200	67,390	67,570	67,760	67,940	68,120	68,310	68,490	68,670	68,850	50
51	67,060	67,260	67,450	67,650	67,850	68,040	68,230	68,430	68,620	68,810	69,000	69,200	69,390	69,580	69,770	69,960	70,150	70,330	70,520	70,710	70,900	51
52	69,040	69,250	69,450	69,650	69,850	70,050	70,250	70,450	70,650	70,850	71,050	71,250	71,440	71,640	71,840	72,030	72,230	72,420	72,620	72,810	73,000	52
53	71,030	71,240	71,450	71,660	71,870	72,080	72,280	72,490	72,700	72,900	73,110	73,310	73,510	73,720	73,920	74,120	74,320	74,520	74,720	74,920	75,120	53
54	73,020	73,240	73,450	73,670	73,880	74,100	74,310	74,520	74,730	74,950	75,160	75,370	75,580	75,790	75,990	76,200	76,410	76,620	76,820	77,030	77,230	54
55	75,010	75,230	75,450	75,680	75,900	76,120	76,340	76,560	76,770	76,990	77,210	77,420	77,640	77,860	78,070	78,280	78,500	78,710	78,920	79,140	79,350	55

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	732.0	732.1	732.2	732.3	732.4	732.5	732.6	732.7	732.8	732.9	733.0	733.1	733.2	733.3	733.4	733.5	733.6	733.7	733.8	733.9	734.0	
56	76,940	77,170	77,400	77,620	77,850	78,080	78,300	78,530	78,750	78,970	79,200	79,420	79,640	79,860	80,080	80,300	80,520	80,740	80,960	81,180	81,400	56
57	78,860	79,100	79,330	79,560	79,800	80,030	80,260	80,490	80,720	80,950	81,180	81,410	81,640	81,870	82,090	82,320	82,540	82,770	82,990	83,220	83,440	57
58	80,810	81,060	81,300	81,540	81,780	82,010	82,250	82,490	82,730	82,960	83,200	83,430	83,670	83,900	84,130	84,360	84,600	84,830	85,060	85,290	85,510	58
59	82,740	82,990	83,240	83,480	83,730	83,970	84,220	84,460	84,700	84,950	85,190	85,430	85,670	85,910	86,150	86,380	86,620	86,860	87,090	87,330	87,560	59
60	84,730	84,980	85,230	85,490	85,740	85,990	86,240	86,490	86,740	86,990	87,230	87,480	87,730	87,970	88,220	88,460	88,700	88,950	89,190	89,430	89,670	60
61	88,600	88,870	89,140	89,410	89,680	89,950	90,220	90,480	90,750	91,010	91,270	91,530	91,790	92,050	92,310	92,570	92,830	93,080	93,340	93,600	93,850	61
62	92,510	92,800	93,090	93,380	93,660	93,950	94,230	94,520	94,800	95,070	95,350	95,620	95,900	96,170	96,450	96,720	96,990	97,260	97,530	97,800	98,070	62
63	96,390	96,700	97,010	97,310	97,620	97,920	98,220	98,520	98,810	99,100	99,390	99,680	99,970	100,300	100,500	100,800	101,100	101,400	101,700	102,000	102,300	63
64	100,300	100,700	101,000	101,300	101,600	101,900	102,300	102,600	102,900	103,200	103,500	103,800	104,100	104,400	104,700	105,000	105,300	105,600	105,900	106,200	106,500	64
65	103,500	103,900	104,200	104,500	104,900	105,200	105,500	105,800	106,200	106,500	106,800	107,100	107,400	107,700	108,100	108,400	108,700	109,000	109,300	109,600	109,900	65
66	107,400	107,800	108,100	108,500	108,800	109,200	109,500	109,800	110,200	110,500	110,800	111,200	111,500	111,800	112,200	112,500	112,800	113,100	113,400	113,800	114,100	66
67	110,600	111,000	111,300	111,700	112,100	112,400	112,800	113,100	113,500	113,800	114,100	114,500	114,800	115,200	115,500	115,800	116,200	116,500	116,900	117,200	117,500	67
68	114,500	114,900	115,300	115,700	116,100	116,400	116,800	117,200	117,500	117,900	118,200	118,600	118,900	119,300	119,700	120,000	120,400	120,700	121,100	121,400	121,700	68
69	118,400	118,800	119,200	119,600	120,000	120,400	120,700	121,100	121,500	121,900	122,200	122,600	123,000	123,300	123,700	124,100	124,400	124,800	125,200	125,500	125,900	69
70	122,300	122,700	123,100	123,500	123,900	124,300	124,700	125,100	125,500	125,900	126,300	126,700	127,100	127,400	127,800	128,200	128,600	129,000	129,300	129,700	130,100	70
71	126,800	127,300	127,700	128,200	128,600	129,000	129,400	129,900	130,300	130,700	131,100	131,500	131,900	132,300	132,700	133,100	133,500	133,900	134,300	134,700	135,100	71
72	131,400	131,900	132,400	132,800	133,300	133,700	134,200	134,600	135,000	135,500	135,900	136,300	136,800	137,200	137,600	138,000	138,500	138,900	139,300	139,700	140,100	72
73	136,000	136,500	137,000	137,400	137,900	138,400	138,800	139,300	139,800	140,200	140,700	141,100	141,600	142,000	142,500	142,900	143,400	143,800	144,300	144,700	145,200	73
74	140,600	141,100	141,600	142,100	142,600	143,100	143,600	144,100	144,500	145,000	145,500	146,000	146,400	146,900	147,400	147,900	148,300	148,800	149,300	149,700	150,200	74
75	145,100	145,600	146,100	146,700	147,200	147,700	148,200	148,700	149,200	149,700	150,200	150,700	151,200	151,700	152,200	152,700	153,200	153,700	154,200	154,700	155,200	75
76	149,700	150,200	150,800	151,300	151,900	152,400	152,900	153,500	154,000	154,500	155,000	155,600	156,100	156,600	157,100	157,600	158,200	158,700	159,200	159,700	160,200	76
77	154,300	154,900	155,400	156,000	156,600	157,100	157,700	158,200	158,800	159,300	159,900	160,400	161,000	161,500	162,100	162,600	163,100	163,700	164,200	164,700	165,300	77
78	158,900	159,500	160,100	160,700	161,300	161,900	162,400	163,000	163,600	164,200	164,700	165,300	165,900	166,400	167,000	167,600	168,100	168,700	169,200	169,800	170,300	78
79	163,500	164,100	164,700	165,300	165,900	166,500	167,100	167,600	168,200	168,800	169,400	170,000	170,600	171,200	171,700	172,300	172,900	173,500	174,100	174,600	175,200	79
80	168,100	168,700	169,300	169,900	170,400	171,000	171,500	172,100	172,700	173,300	173,900	174,500	175,100	175,700	176,300	176,900	177,500	178,100	178,700	179,200	179,800	80
81	172,800	173,300	173,900	174,400	175,000	175,500	176,100	176,700	177,300	177,900	178,500	179,100	179,700	180,300	180,900	181,500	182,100	182,700	183,300	183,900	184,500	81
82	177,300	177,800	178,400	178,900	179,400	180,000	180,600	181,200	181,800	182,400	183,000	183,700	184,300	184,900	185,500	186,100	186,700	187,300	187,900	188,500	189,100	82
83	181,600	182,100	182,700	183,300	183,800	184,400	185,000	185,600	186,200	186,900	187,500	188,100	188,700	189,400	190,000	190,600	191,200	191,800	192,400	193,000	193,600	83
84	186,000	186,600	187,100	187,700	188,300	188,800	189,400	190,100	190,700	191,400	192,000	192,600	193,300	193,900	194,500	195,200	195,800	196,400	197,000	197,600	198,300	84
85	190,500	191,100	191,700	192,200	192,800	193,400	194,000	194,600	195,300	195,900	196,600	197,200	197,900	198,500	199,100	199,800	200,400	201,000	201,700	202,300	202,900	85
86	197,300	197,800	198,400	199,000	199,500	200,100	200,700	201,400	202,000	202,700	203,400	204,000	204,700	205,400	206,000	206,700	207,300	207,900	208,600	209,200	209,900	86
87	201,500	202,300	203,100	203,900	204,600	205,400	206,200	207,100	208,000	208,900	209,700	210,600	211,500	212,300	213,200	214,100	214,900	215,800	216,600	217,500	218,300	87
88	208,000	209,000	210,000	211,000	211,900	212,900	214,000	215,000	216,100	217,200	218,300	219,400	220,400	221,500	222,600	223,700	224,800	225,800	226,900	228,000	229,100	88
89	212,700	213,900	215,100	216,200	217,400	218,600	219,800	221,100	222,400	223,700	225,000	226,200	227,500	228,800	230,100	231,400	232,700	234,000	235,300	236,600	237,800	89
90	216,800	218,200	219,600	221,000	222,400	223,800	225,200	226,700	228,200	229,700	231,100	232,600	234,100	235,600	237,100	238,600	240,100	241,600	243,100	244,600	246,100	90
91	220,300	222,000	223,600	225,300	226,900	228,500	230,200	231,900	233,500	235,200	236,900	238,600	240,300	242,000	243,700	245,400	247,100	248,800	250,600	252,300	254,000	91
92	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	92
93	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	93
94	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	94
95	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	95
96	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	96
97	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	97
98	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	98
99	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	99
100	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	100
101	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	101
102	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	102
103	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	103
104	223,100	224,800	226,600	228,400	230,200	232,000	233,800	235,600	237,400	239,200	241,100	242,900	244,700	246,600	248,400	250,300	252,100	254,000	255,800	257,700	259,600	104
105	229,800	231,600	233,500	235,300	237,100	238,900	240,800	242,600	244,500	246,300	248,200	250,000	251,900	253,800	255,700	257,500	259,400	261,300	263,200	265,100	267,000	105
106	236,400	238,200	240,000	241,800	243,700	245,500	247,400	249,200	251,100	253,000	254,800	256,700	258,600	260,500	262,400	264,300	266,200	268,100	270,000	271,900	273,800	106
107	240,900	242,900	244,900	247,000	249,000	251,000	253,100	255,100	257,200	259,300	261,400	263,400	265,500	267,600	269,700	271,800	273,900	276,100	278,200	280,300	282,500	107
108	240,900	242,900	244,900	247,000	249,000	251,000	253,100	255,100	257,200	259,300	261,400	263,400	265,500	267,600	269,700	271,800	273,900	276,100	278,200	280,300	282,500	108
109	240,900	242,900	244,900	247,000	249,000	251,000	253,100	255,100	257,200	259,300	261,400	263,400	265,500	267,600	269,700	271,800	273,900	276,100	278,200	280,300	282,500	109
110	240,900	242,900	244,900	247,000	249,000	251,000	253,100	255,100	257,200	259,300	261,400	263,400	265,500	267,600	269,700	271,800	273,900	276,100	278,200	280,300	282,500	110

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	734.0	734.1	734.2	734.3	734.4	734.5	734.6	734.7	734.8	734.9	735.0	735.1	735.2	735.3	735.4	735.5	735.6	735.7	735.8	735.9	736.0	
1	760	760	760	760	770	770	770	770	770	780	780	780	780	780	780	790	790	790	790	790	790	1
2	2,130	2,140	2,140	2,150	2,150	2,160	2,160	2,170	2,170	2,180	2,180	2,190	2,190	2,200	2,200	2,210	2,210	2,220	2,220	2,230	2,230	2
3	3,300	3,310	3,320	3,320	3,330	3,340	3,350	3,360	3,360	3,370	3,380	3,390	3,400	3,400	3,410	3,420	3,430	3,440	3,440	3,450	3,460	3
4	4,670	4,680	4,690	4,700	4,710	4,730	4,740	4,750	4,760	4,770	4,780	4,790	4,810	4,820	4,830	4,840	4,850	4,860	4,870	4,890	4,900	4
5	5,750	5,770	5,780	5,800	5,810	5,830	5,840	5,850	5,870	5,880	5,900	5,910	5,920	5,940	5,950	5,970	5,980	5,990	6,010	6,020	6,030	5
6	7,120	7,140	7,160	7,180	7,200	7,210	7,230	7,250	7,270	7,280	7,300	7,320	7,340	7,350	7,370	7,390	7,400	7,420	7,440	7,460	7,470	6
7	8,210	8,230	8,250	8,270	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	8,590	8,610	7
8	9,580	9,600	9,630	9,650	9,680	9,700	9,720	9,750	9,770	9,790	9,820	9,840	9,870	9,890	9,910	9,930	9,960	9,980	10,000	10,030	10,050	8
9	10,560	10,590	10,610	10,640	10,670	10,690	10,720	10,740	10,770	10,800	10,820	10,850	10,870	10,900	10,930	10,950	10,980	11,000	11,030	11,050	11,080	9
10	11,940	11,970	12,000	12,030	12,060	12,090	12,120	12,150	12,180	12,210	12,230	12,260	12,290	12,320	12,350	12,380	12,410	12,440	12,470	12,490	12,520	10
11	12,980	13,010	13,050	13,080	13,110	13,140	13,170	13,210	13,240	13,270	13,300	13,330	13,360	13,400	13,430	13,460	13,490	13,520	13,550	13,580	13,620	11
12	14,370	14,410	14,440	14,480	14,510	14,550	14,580	14,620	14,660	14,690	14,730	14,760	14,800	14,830	14,870	14,900	14,940	14,970	15,010	15,040	15,070	12
13	15,240	15,270	15,310	15,350	15,390	15,430	15,460	15,500	15,540	15,580	15,610	15,650	15,690	15,720	15,760	15,800	15,840	15,870	15,910	15,940	15,980	13
14	16,600	16,640	16,680	16,720	16,770	16,810	16,850	16,890	16,930	16,970	17,010	17,050	17,090	17,130	17,170	17,210	17,250	17,290	17,330	17,370	17,410	14
15	17,540	17,580	17,620	17,670	17,710	17,750	17,800	17,840	17,880	17,930	17,970	18,010	18,060	18,100	18,140	18,180	18,230	18,270	18,310	18,350	18,390	15
16	18,920	18,960	19,010	19,060	19,110	19,150	19,200	19,250	19,290	19,340	19,390	19,430	19,480	19,520	19,570	19,620	19,660	19,710	19,750	19,800	19,840	16
17	19,780	19,830	19,880	19,930	19,980	20,030	20,080	20,130	20,170	20,220	20,270	20,320	20,370	20,420	20,460	20,510	20,560	20,610	20,650	20,700	20,750	17
18	21,150	21,200	21,250	21,300	21,360	21,410	21,460	21,510	21,570	21,620	21,670	21,720	21,770	21,820	21,880	21,930	21,980	22,030	22,080	22,130	22,180	18
19	22,030	22,080	22,140	22,190	22,250	22,300	22,360	22,410	22,460	22,520	22,570	22,630	22,680	22,730	22,790	22,840	22,890	22,950	23,000	23,050	23,100	19
20	23,350	23,410	23,470	23,530	23,590	23,650	23,700	23,760	23,820	23,880	23,930	23,990	24,050	24,100	24,160	24,220	24,270	24,330	24,390	24,440	24,500	20
21	24,210	24,270	24,330	24,390	24,450	24,510	24,570	24,630	24,690	24,740	24,800	24,860	24,920	24,980	25,040	25,100	25,160	25,210	25,270	25,330	25,390	21
22	25,580	25,640	25,710	25,.770	25,830	25,900	25,960	26,020	26,090	26,150	26,210	26,280	26,340	26,400	26,460	26,520	26,590	26,650	26,710	26,770	26,830	22
23	26,470	26,540	26,600	26,670	26,740	26,800	26,870	26,930	27,000	27,060	27,130	27,190	27,250	27,320	27,380	27,450	27,510	27,570	27,640	27,700	27,760	23
24	27,850	27,920	27,990	28,060	28,130	28,200	28,270	28,340	28,400	28,470	28,540	28,610	28,680	28,750	28,810	28,880	28,950	29,010	29,080	29,150	29,210	24
25	28,940	29,010	29,090	29,160	29,230	29,300	29,370	29,440	29,510	29,590	29,660	29,730	29,800	29,870	29,940	30,010	30,080	30,150	30,220	30,290	30,350	25
26	30,310	30,380	30,460	30,530	30,610	30,680	30,760	30,830	30,910	30,980	31,060	31,130	31,200	31,280	31,350	31,420	31,500	31,570	31,640	31,720	31,790	26
27	31,320	31,390	31,470	31,550	31,630	31,710	31,780	31,860	31,940	32,010	32,090	32,170	32,240	32,320	32,390	32,470	32,550	32,620	32,700	32,770	32,850	27
28	32,710	32,790	32,870	32,960	33,040	33,120	33,200	33,280	33,360	33,440	33,520	33,600	33,680	33,760	33,840	33,920	34,000	34,080	34,150	34,230	34,310	28
29	33,560	33,650	33,730	33,820	33,900	33,980	34,060	34,150	34,230	34,310	34,390	34,480	34,560	34,640	34,720	34,800	34,880	34,960	35,040	35,120	35,200	29
30	34,940	35,030	35,110	35,200	35,290	35,370	35,460	35,550	35,630	35,720	35,800	35,890	35,970	36,060	36,140	36,230	36,310	36,400	36,480	36,560	36,650	30
31	35,830	35,920	36,010	36,100	36,190	36,280	36,370	36,460	36,540	36,630	36,720	36,810	36,890	36,980	37,070	37,150	37,240	37,330	37,410	37,500	37,580	31
32	37,210	37,310	37,400	37,490	37,590	37,680	37,770	37,860	37,950	38,040	38,140	38,230	38,320	38,410	38,500	38,590	38,680	38,770	38,860	38,950	39,030	32
33	38,270	38,370	38,470	38,560	38,660	38,750	38,840	38,940	39,030	39,130	39,220	39,310	39,410	39,500	39,590	39,690	39,780	39,870	39,960	40,050	40,140	33
34	39,620	39,720	39,820	39,920	40,020	40,110	40,210	40,310	40,410	40,510	40,600	40,700	40,800	40,890	40,990	41,080	41,180	41,270	41,370	41,460	41,560	34
35	40,530	40,630	40,730	40,830	40,930	41,030	41,130	41,230	41,330	41,430	41,530	41,630	41,730	41,830	41,920	42,020	42,120	42,220	42,310	42,410	42,510	35
36	41,890	41,990	42,100	42,200	42,300	42,410	42,510	42,610	42,720	42,820	42,920	43,020	43,130	43,230	43,330	43,430	43,530	43,630	43,730	43,830	43,930	36
37	42,670	42,780	42,880	42,990	43,090	43,200	43,310	43,410	43,520	43,620	43,720	43,830	43,930	44,040	44,140	44,240	44,350	44,450	44,550	44,650	44,750	37
38	44,060	44,170	44,280	44,390	44,500	44,600	44,710	44,820	44,930	45,040	45,150	45,250	45,360	45,470	45,570	45,680	45,790	45,890	46,000	46,100	46,210	38
39	45,260	45,370	45,480	45,590	45,710	45,820	45,930	46,040	46,150	46,260	46,370	46,480	46,590	46,700	46,810	46,920	47,030	47,140	47,250	47,360	47,470	39
40	46,640	46,760	46,880	46,990	47,110	47,220	47,340	47,450	47,570	47,680	47,800	47,910	48,020	48,140	48,250	48,360	48,480	48,590	48,700	48,810	48,920	40
41	48,750	48,870	49,000	49,120	49,240	49,360	49,480	49,600	49,720	49,850	49,970	50,090	50,200	50,320	50,440	50,560	50,680	50,800	50,920	51,030	51,150	41
42	50,800	50,920	51,050	51,180	51,310	51,440	51,560	51,690	51,820	51,940	52,070	52,190	52,320	52,440	52,570	52,690	52,820	52,940	53,060	53,190	53,310	42
43	53,640	53,770	53,910	54,050	54,180	54,320	54,450	54,590	54,720	54,860	54,990	55,120	55,260	55,390	55,520	55,660	55,790	55,920	56,050	56,180	56,310	43
44	55,760	55,900	56,040	56,180	56,320	56,470	56,610	56,750	56,890	57,030	57,170	57,310	57,450	57,590	57,720	57,860	58,000	58,140	58,270	58,410	58,550	44
45	57,800	57,950	58,100	58,250	58,390	58,540	58,690	58,830	58,980	59,130	59,270	59,420	59,560	59,710	59,850	59,990	60,140	60,280	60,420	60,570	60,710	45
46	59,840	60,000	60,150	60,310	60,460	60,610	60,770	60,920	61,070	61,220	61,370	61,520	61,670	61,820	61,970	62,120	62,270	62,420	62,570	62,720	62,870	46
47	62,690	62,850	63,010	63,170	63,340	63,500	63,660	63,820	63,980	64,140	64,300	64,460	64,610	64,770	64,930	65,090	65,240	65,400	65,560	65,710	65,870	47
48	64,720	64,890	65,060	65,230	65,400	65,560	65,730	65,900	66,060	66,230	66,390	66,560	66,720	66,880	67,050	67,210	67,370	67,530	67,700	67,860	68,020	48
49	66,750	66,920	67,090	67,270	67,440	67,610	67,790	67,960	68,130	68,300	68,470	68,640	68,810	68,980	69,150	69,320	69,490	69,650	69,820	69,990	70,150	49
50	68,850	69,030	69,210	69,390	69,570	69,750	69,930	70,100	70,280	70,460	70,640	70,810	70,990	71,160	71,340	71,510	71,680	71,860	72,030	72,200	72,380	50
51	70,900	71,080	71,270	71,450	71,640	71,820	72,010	72,190	72,370	72,560	72,740	72,920	73,100	73,280	73,460	73,640	73,820	74,000	74,180	74,360	74,530	51
52	73,000	73,190	73,390	73,580	73,770	73,960	74,150	74,340	74,530	74,720	74,900	75,090	75,280	75,460	75,650	75,840	76,020	76,210	76,390	76,570	76,760	52
53	75,120	75,320	75,520	75,710	75,910	76,110	76,300	76,500	76,690	76,890	77,080	77,270	77,470	77,660	77,850	78,040	78,230	78,430	78,620	78,800	78,990	53
54	77,230	77,440	77,640	77,850	78,050	78,250	78,450	78,650	78,850	79,060	79,260	79,450	79,650	79,850	80,050	80,250	80,440	80,640	80,840	81,030	81,230	54
55	79,350	79,560	79,770	79,980	80,190	80,390	80,600	80,810	81,020	81,220	81,430	81,630	81,840	82,040	82,250	82,450	82,650	82,860	83,060	83,260	83,460	55

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	734.0	734.1	734.2	734.3	734.4	734.5	734.6	734.7	734.8	734.9	735.0	735.1	735.2	735.3	735.4	735.5	735.6	735.7	735.8	735.9	736.0	
56	81,400	81,610	81,830	82,040	82,260	82,470	82,690	82,900	83,110	83,320	83,530	83,750	83,960	84,170	84,380	84,580	84,790	85,000	85,210	85,410	85,620	56
57	83,440	83,660	83,880	84,110	84,330	84,550	84,770	84,980	85,200	85,420	85,640	85,850	86,070	86,290	86,500	86,720	86,930	87,140	87,360	87,570	87,780	57
58	85,510	85,740	85,970	86,200	86,420	86,650	86,880	87,100	87,320	87,550	87,770	87,990	88,220	88,440	88,660	88,880	89,100	89,320	89,530	89,750	89,970	58
59	87,560	87,800	88,030	88,260	88,500	88,730	88,960	89,190	89,420	89,650	89,880	90,100	90,330	90,560	90,790	91,010	91,240	91,460	91,690	91,910	92,130	59
60	89,670	89,910	90,150	90,390	90,630	90,870	91,100	91,340	91,580	91,810	92,050	92,280	92,510	92,750	92,980	93,210	93,440	93,670	93,900	94,130	94,360	60
61	93,850	94,100	94,360	94,610	94,860	95,110	95,370	95,620	95,860	96,110	96,360	96,610	96,860	97,100	97,350	97,590	97,840	98,080	98,320	98,570	98,810	61
62	98,070	98,340	98,610	98,870	99,140	99,400	99,670	99,930	100,200	100,500	100,700	101,000	101,200	101,500	101,800	102,000	102,300	102,500	102,800	103,000	103,300	62
63	102,300	102,500	102,800	103,100	103,400	103,700	103,900	104,200	104,500	104,800	105,000	105,300	105,600	105,900	106,100	106,400	106,700	106,900	107,200	107,500	107,700	63
64	106,500	106,800	107,100	107,400	107,700	108,000	108,300	108,600	108,800	109,100	109,400	109,700	110,000	110,300	110,600	110,800	111,100	111,400	111,700	112,000	112,300	64
65	109,900	110,200	110,500	110,800	111,100	111,400	111,700	112,000	112,300	112,600	112,900	113,200	113,500	113,800	114,100	114,400	114,700	115,000	115,300	115,600	115,900	65
66	114,100	114,400	114,700	115,100	115,400	115,700	116,000	116,300	116,600	116,900	117,300	117,600	117,900	118,200	118,500	118,800	119,100	119,400	119,700	120,000	120,300	66
67	117,500	117,800	118,200	118,500	118,800	119,200	119,500	119,800	120,100	120,500	120,800	121,100	121,400	121,800	122,100	122,400	122,700	123,000	123,400	123,700	124,000	67
68	121,700	122,100	122,400	122,800	123,100	123,500	123,800	124,100	124,500	124,800	125,200	125,500	125,800	126,200	126,500	126,800	127,200	127,500	127,800	128,200	128,500	68
69	125,900	126,200	126,600	127,000	127,300	127,700	128,000	128,400	128,700	129,100	129,400	129,800	130,100	130,500	130,800	131,200	131,500	131,800	132,200	132,500	132,900	69
70	130,100	130,500	130,800	131,200	131,600	131,900	132,300	132,700	133,000	133,400	133,800	134,100	134,500	134,900	135,200	135,600	135,900	136,300	136,600	137,000	137,300	70
71	135,100	135,500	135,900	136,300	136,700	137,100	137,500	137,900	138,200	138,600	139,000	139,400	139,800	140,200	140,500	140,900	141,300	141,700	142,100	142,400	142,800	71
72	140,100	140,600	141,000	141,400	141,800	142,200	142,600	143,000	143,500	143,900	144,300	144,700	145,100	145,500	145,900	146,300	146,700	147,100	147,500	147,900	148,300	72
73	145,200	145,600	146,000	146,500	146,900	147,300	147,800	148,200	148,600	149,100	149,500	149,900	150,400	150,800	151,200	151,600	152,100	152,500	152,900	153,300	153,700	73
74	150,200	150,700	151,100	151,600	152,000	152,500	152,900	153,400	153,900	154,300	154,800	155,200	155,700	156,100	156,600	157,000	157,400	157,900	158,300	158,800	159,200	74
75	155,200	155,600	156,100	156,600	157,100	157,600	158,000	158,500	159,000	159,500	160,000	160,400	160,900	161,400	161,800	162,300	162,800	163,200	163,700	164,200	164,600	75
76	160,200	160,700	161,200	161,700	162,200	162,700	163,200	163,700	164,200	164,700	165,200	165,700	166,200	166,700	167,200	167,700	168,200	168,600	169,100	169,600	170,100	76
77	165,300	165,800	166,300	166,900	167,400	167,900	168,400	169,000	169,500	170,000	170,500	171,000	171,500	172,100	172,600	173,100	173,600	174,100	174,600	175,100	175,600	77
78	170,300	170,900	171,500	172,000	172,600	173,100	173,600	174,200	174,700	175,300	175,800	176,400	176,900	177,400	178,000	178,500	179,000	179,600	180,100	180,600	181,100	78
79	175,200	175,800	176,300	176,900	177,500	178,000	178,600	179,100	179,700	180,300	180,800	181,400	181,900	182,500	183,000	183,600	184,100	184,700	185,200	185,800	186,300	79
80	179,800	180,400	181,000	181,500	182,100	182,700	183,200	183,800	184,400	184,900	185,500	186,100	186,600	187,200	187,700	188,300	188,800	189,400	190,000	190,500	191,100	80
81	184,500	185,100	185,700	186,200	186,800	187,400	188,000	188,500	189,100	189,700	190,300	190,800	191,400	191,900	192,500	193,100	193,600	194,200	194,800	195,400	196,000	81
82	189,100	189,700	190,300	190,900	191,500	192,000	192,600	193,200	193,800	194,400	194,900	195,500	196,100	196,700	197,200	197,800	198,400	199,000	199,600	200,200	200,900	82
83	193,600	194,200	194,800	195,400	196,000	196,600	197,200	197,800	198,400	198,900	199,500	200,100	200,700	201,300	201,900	202,500	203,100	203,800	204,400	205,000	205,700	83
84	198,300	198,900	199,500	200,100	200,700	201,300	201,900	202,500	203,000	203,600	204,200	204,800	205,500	206,100	206,700	207,300	207,900	208,600	209,200	209,900	210,600	84
85	202,900	203,500	204,100	204,800	205,400	206,000	206,600	207,200	207,800	208,400	209,000	209,600	210,200	210,900	211,500	212,100	212,800	213,400	214,100	214,800	215,500	85
86	209,900	210,500	211,100	211,700	212,400	213,000	213,600	214,200	214,800	215,400	216,000	216,700	217,300	218,000	218,600	219,300	220,000	220,700	221,400	222,100	222,800	86
87	218,300	219,100	219,700	220,400	221,000	221,700	222,300	222,900	223,500	224,100	224,600	225,200	225,800	226,300	226,900	227,500	228,100	228,700	229,400	230,000	230,600	87
88	229,100	230,000	230,800	231,500	232,200	232,900	233,500	234,100	234,600	235,100	235,500	236,000	236,600	237,100	237,600	238,100	238,600	239,200	239,800	240,300	240,900	88
89	237,800	238,800	239,500	240,200	240,800	241,400	242,000	242,500	242,900	243,300	243,700	244,100	244,500	245,000	245,400	245,900	246,300	246,800	247,300	247,800	248,300	89
90	246,100	247,300	248,100	248,900	249,600	250,400	251,000	251,500	251,800	252,100	252,400	252,800	253,200	253,500	253,900	254,300	254,600	255,000	255,500	255,900	256,300	90
91	254,000	255,400	256,400	257,400	258,400	259,300	260,200	260,800	261,100	261,400	261,600	261,900	262,100	262,400	262,700	263,000	263,300	263,600	264,000	264,300	264,700	91
92	259,600	261,000	262,100	263,200	264,200	265,200	266,100	266,700	267,100	267,400	267,700	268,000	268,300	268,700	269,000	269,400	269,700	270,100	270,500	270,900	271,300	92
93	259,600	261,000	262,100	263,200	264,200	265,200	266,100	266,800	267,500	268,100	268,600	269,300	269,900	270,600	271,300	271,900	272,600	273,300	274,000	274,700	275,400	93
94	259,600	261,000	262,200	263,400	264,500	265,600	266,700	267,700	268,700	269,600	270,500	271,400	272,400	273,300	274,300	275,300	276,300	277,200	278,200	279,200	280,200	94
95	259,600	261,200	262,700	264,200	265,700	267,200	268,700	270,200	271,500	272,900	274,200	275,500	276,900	278,200	279,600	280,900	282,300	283,700	285,100	286,400	287,800	95
96	259,600	261,400	263,200	265,000	266,800	268,600	270,500	272,300	274,100	275,800	277,500	279,300	281,000	282,800	284,500	286,300	288,000	289,800	291,600	293,400	295,200	96
97	259,600	261,400	263,200	265,000	266,800	268,600	270,500	272,300	274,100	275,900	277,800	279,600	281,400	283,300	285,200	287,000	288,900	290,800	292,700	294,500	296,400	97
98	259,600	261,400	263,200	265,000	266,800	268,600	270,500	272,300	274,100	275,900	277,800	279,600	281,400	283,300	285,200	287,000	288,900	290,800	292,700	294,500	296,400	98
99	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	99
100	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	100
101	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	101
102	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	102
103	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	103
104	259,600	261,500	263,400	265,300	267,200	269,100	271,000	272,900	274,800	276,700	278,700	280,600	282,500	284,500	286,400	288,400	290,400	292,300	294,300	296,300	298,300	104
105	267,000	269,000	270,900	272,800	274,700	276,700	278,600	280,600	282,500	284,500	286,400	288,400	290,400	292,400	294,300	296,300	298,300	300,300	302,300	304,400	306,400	105
106	273,800	275,800	277,700	279,600	281,600	283,500	285,500	287,400	289,400	291,400	293,300	295,300	297,300	299,300	301,400	303,400	305,400	307,400	309,500	311,500	313,600	106
107	282,500	284,500	286,500	288,400	290,300	292,100	294,000	295,900	297,800	299,700	301,600	303,500	305,400	307,300	309,300	311,200	313,200	315,200	317,100	319,100	321,100	107
108	282,500	284,600	286,800	288,900	291,100	293,300	295,400	297,600	299,800	302,000	304,200	306,400	308,600	310,900	313,100	315,300	317,600	319,800	322,100	324,400	326,600	108
109	282,500	284,600	286,800	288,900	291,100	293,300	295,400	297,600	299,800	302,000	304,200	306,400	308,600	310,900	313,100	315,300	317,600	319,800	322,100	324,400	326,600	109
110	282,500	284,600	286,800	288,900	291,100	293,300	295,400	297,600	299,800	302,000	304,200	306,400	308,600	310,900	313,100	315,300	317,600	319,800	322,100	324,400	326,600	110

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	736.0	736.1	736.2	736.3	736.4	736.5	736.6	736.7	736.8	736.9	737.0	737.1	737.2	737.3	737.4	737.5	737.6	737.7	737.8	737.9	738.0	
1	790	800	800	800	800	800	810	810	810	810	810	810	820	820	820	820	820	820	830	830	830	1
2	2,230	2,240	2,240	2,250	2,250	2,260	2,260	2,270	2,270	2,280	2,280	2,290	2,290	2,300	2,300	2,310	2,310	2,320	2,320	2,330	2,330	2
3	3,460	3,470	3,470	3,480	3,490	3,500	3,510	3,510	3,520	3,530	3,540	3,540	3,550	3,560	3,570	3,570	3,580	3,590	3,600	3,600	3,610	3
4	4,900	4,910	4,920	4,930	4,940	4,950	4,960	4,970	4,980	5,000	5,010	5,020	5,030	5,040	5,050	5,060	5,070	5,080	5,090	5,100	5,110	4
5	6,030	6,050	6,060	6,080	6,090	6,100	6,120	6,130	6,140	6,160	6,170	6,180	6,200	6,210	6,220	6,240	6,250	6,260	6,280	6,290	6,300	5
6	7,470	7,490	7,510	7,520	7,540	7,560	7,570	7,590	7,610	7,630	7,640	7,660	7,680	7,690	7,710	7,720	7,740	7,760	7,770	7,790	7,810	6
7	8,610	8,630	8,650	8,670	8,690	8,710	8,730	8,750	8,770	8,790	8,800	8,820	8,840	8,860	8,880	8,900	8,920	8,940	8,960	8,980	8,990	7
8	10,050	10,070	10,100	10,120	10,140	10,160	10,190	10,210	10,230	10,250	10,280	10,300	10,320	10,340	10,370	10,390	10,410	10,430	10,460	10,480	10,500	8
9	11,080	11,100	11,130	11,150	11,180	11,200	11,230	11,250	11,280	11,300	11,330	11,350	11,380	11,400	11,420	11,450	11,470	11,500	11,520	11,550	11,570	9
10	12,520	12,550	12,580	12,610	12,640	12,670	12,690	12,720	12,750	12,780	12,810	12,830	12,860	12,890	12,920	12,950	12,970	13,000	13,030	13,060	13,080	10
11	13,620	13,650	13,680	13,710	13,740	13,770	13,800	13,830	13,860	13,890	13,920	13,950	13,980	14,010	14,040	14,070	14,100	14,130	14,160	14,190	14,220	11
12	15,070	15,110	15,140	15,180	15,210	15,250	15,280	15,310	15,350	15,380	15,410	15,450	15,480	15,520	15,550	15,580	15,620	15,650	15,680	15,710	15,750	12
13	15,980	16,020	16,050	16,090	16,130	16,160	16,200	16,230	16,270	16,310	16,340	16,380	16,410	16,450	16,480	16,520	16,550	16,590	16,620	16,660	16,690	13
14	17,410	17,450	17,490	17,530	17,570	17,610	17,650	17,690	17,730	17,770	17,810	17,840	17,880	17,920	17,960	18,000	18,040	18,080	18,110	18,150	18,190	14
15	18,390	18,440	18,480	18,520	18,560	18,600	18,640	18,680	18,730	18,770	18,810	18,850	18,890	18,930	18,970	19,010	19,050	19,090	19,130	19,170	19,210	15
16	19,840	19,890	19,930	19,980	20,020	20,070	20,110	20,160	20,200	20,250	20,290	20,330	20,380	20,420	20,470	20,510	20,550	20,600	20,640	20,680	20,730	16
17	20,750	20,800	20,840	20,890	20,940	20,980	21,030	21,080	21,120	21,170	21,220	21,260	21,310	21,350	21,400	21,450	21,490	21,540	21,580	21,630	21,670	17
18	22,180	22,230	22,280	22,330	22,380	22,430	22,480	22,530	22,580	22,630	22,680	22,730	22,780	22,830	22,880	22,930	22,980	23,020	23,070	23,120	23,170	18
19	23,100	23,160	23,210	23,260	23,310	23,370	23,420	23,470	23,520	23,570	23,620	23,680	23,730	23,780	23,830	23,880	23,930	23,980	24,030	24,080	24,130	19
20	24,500	24,550	24,610	24,660	24,720	24,770	24,830	24,880	24,940	24,990	25,050	25,100	25,160	25,210	25,270	25,320	25,370	25,430	25,480	25,540	25,590	20
21	25,390	25,450	25,500	25,560	25,620	25,680	25,730	25,790	25,850	25,900	25,960	26,020	26,070	26,130	26,180	26,240	26,300	26,350	26,410	26,460	26,520	21
22	26,830	26,890	26,950	27,010	27,070	27,130	27,200	27,260	27,320	27,380	27,440	27,490	27,550	27,610	27,670	27,730	27,790	27,850	27,910	27,970	28,030	22
23	27,760	27,830	27,890	27,950	28,020	28,080	28,140	28,200	28,270	28,330	28,390	28,450	28,510	28,570	28,640	28,700	28,760	28,820	28,880	28,940	29,000	23
24	29,210	29,280	29,350	29,410	29,480	29,550	29,610	29,680	29,740	29,810	29,870	29,940	30,000	30,070	30,130	30,200	30,260	30,320	30,390	30,450	30,520	24
25	30,350	30,420	30,490	30,560	30,630	30,700	30,770	30,830	30,900	30,970	31,040	31,100	31,170	31,240	31,310	31,370	31,440	31,510	31,570	31,640	31,710	25
26	31,790	31,860	31,930	32,010	32,080	32,150	32,220	32,290	32,360	32,430	32,500	32,580	32,650	32,720	32,790	32,860	32,930	33,000	33,070	33,140	33,210	26
27	32,850	32,920	32,990	33,070	33,140	33,220	33,290	33,360	33,440	33,510	33,580	33,660	33,730	33,800	33,880	33,950	34,020	34,090	34,160	34,240	34,310	27
28	34,310	34,390	34,470	34,540	34,620	34,700	34,780	34,850	34,930	35,010	35,080	35,160	35,240	35,310	35,390	35,460	35,540	35,610	35,690	35,760	35,840	28
29	35,200	35,280	35,360	35,440	35,520	35,600	35,680	35,760	35,840	35,920	36,000	36,080	36,150	36,230	36,310	36,390	36,460	36,540	36,620	36,700	36,770	29
30	36,650	36,730	36,810	36,900	36,980	37,060	37,150	37,230	37,310	37,390	37,470	37,550	37,640	37,720	37,800	37,880	37,960	38,040	38,120	38,200	38,280	30
31	37,580	37,670	37,760	37,840	37,930	38,010	38,090	38,180	38,260	38,350	38,430	38,510	38,600	38,680	38,760	38,850	38,930	39,010	39,090	39,180	39,260	31
32	39,030	39,120	39,210	39,300	39,390	39,480	39,560	39,650	39,740	39,830	39,910	40,000	40,090	40,170	40,260	40,350	40,430	40,520	40,600	40,690	40,770	32
33	40,140	40,240	40,330	40,420	40,510	40,600	40,690	40,780	40,870	40,960	41,050	41,140	41,230	41,310	41,400	41,490	41,580	41,670	41,760	41,840	41,930	33
34	41,560	41,650	41,750	41,840	41,940	42,030	42,120	42,220	42,310	42,400	42,500	42,590	42,680	42,770	42,860	42,960	43,050	43,140	43,230	43,320	43,410	34
35	42,510	42,600	42,700	42,800	42,890	42,990	43,080	43,180	43,280	43,370	43,460	43,560	43,650	43,750	43,840	43,940	44,030	44,120	44,210	44,310	44,400	35
36	43,930	44,030	44,130	44,230	44,330	44,430	44,530	44,630	44,730	44,830	44,920	45,020	45,120	45,220	45,310	45,410	45,510	45,600	45,700	45,800	45,890	36
37	44,750	44,860	44,960	45,060	45,160	45,260	45,360	45,460	45,560	45,660	45,760	45,860	45,960	46,060	46,160	46,260	46,350	46,450	46,550	46,650	46,750	37
38	46,210	46,320	46,420	46,520	46,630	46,730	46,840	46,940	47,040	47,150	47,250	47,350	47,460	47,560	47,660	47,760	47,860	47,960	48,070	48,170	48,270	38
39	47,470	47,570	47,680	47,790	47,900	48,000	48,110	48,220	48,320	48,430	48,530	48,640	48,740	48,850	48,950	49,060	49,160	49,270	49,370	49,470	49,580	39
40	48,920	49,030	49,150	49,260	49,370	49,480	49,590	49,700	49,810	49,920	50,030	50,130	50,240	50,350	50,460	50,570	50,670	50,780	50,890	51,000	51,100	40
41	51,150	51,270	51,380	51,500	51,620	51,730	51,850	51,960	52,080	52,200	52,310	52,420	52,540	52,650	52,770	52,880	52,990	53,110	53,220	53,330	53,440	41
42	53,310	53,430	53,550	53,680	53,800	53,920	54,040	54,160	54,280	54,400	54,520	54,640	54,760	54,880	55,000	55,120	55,240	55,360	55,470	55,590	55,710	42
43	56,310	56,440	56,570	56,700	56,830	56,960	57,090	57,220	57,350	57,470	57,600	57,730	57,860	57,980	58,110	58,240	58,360	58,490	58,610	58,740	58,870	43
44	58,550	58,680	58,820	58,960	59,090	59,230	59,360	59,490	59,630	59,760	59,900	60,030	60,160	60,290	60,430	60,560	60,690	60,820	60,950	61,080	61,210	44
45	60,710	60,850	60,990	61,130	61,270	61,410	61,550	61,690	61,830	61,970	62,110	62,250	62,390	62,520	62,660	62,800	62,940	63,070	63,210	63,350	63,480	45
46	62,870	63,010	63,160	63,310	63,450	63,600	63,740	63,890	64,030	64,180	64,320	64,470	64,610	64,750	64,900	65,040	65,180	65,320	65,470	65,610	65,750	46
47	65,870	66,020	66,180	66,330	66,490	66,640	66,790	66,950	67,100	67,250	67,400	67,550	67,710	67,860	68,010	68,160	68,310	68,460	68,610	68,750	68,900	47
48	68,020	68,180	68,340	68,500	68,660	68,820	68,980	69,130	69,290	69,450	69,610	69,760	69,920	70,080	70,230	70,390	70,540	70,700	70,850	71,010	71,160	48
49	70,150	70,320	70,480	70,650	70,810	70,980	71,140	71,310	71,470	71,630	71,800	71,960	72,120	72,280	72,440	72,600	72,760	72,920	73,080	73,240	73,400	49
50	72,380	72,550	72,720	72,890	73,060	73,230	73,400	73,570	73,740	73,910	74,070	74,240	74,410	74,580	74,740	74,910	75,080	75,240	75,410	75,570	75,740	50
51	74,530	74,710	74,890	75,060	75,240	75,420	75,590	75,770	75,940	76,110	76,290	76,460	76,630	76,810	76,980	77,150	77,320	77,490	77,660	77,830	78,000	51
52	76,760	76,940	77,120	77,310	77,490	77,670	77,850	78,030	78,210	78,390	78,570	78,750	78,930	79,100	79,280	79,460	79,640	79,810	79,990	80,160	80,340	52
53	78,990	79,180	79,370	79,560	79,750	79,930	80,120	80,310	80,490	80,680	80,860	81,050	81,230	81,410	81,600	81,780	81,960	82,140	82,330	82,510	82,690	53
54	81,230	81,420	81,620	81,810	82,000	82,190	82,390	82,580	82,770	82,960	83,150	83,340	83,530	83,720	83,910	84,100	84,290	84,470	84,660	84,850	85,030	54
55	83,460	83,660	83,860	84,060	84,260	84,460	84,650	84,850	85,050	85,240	85,440	85,640	85,830	86,030	86,220	86,410	86,610	86,800	86,990	87,190	87,380	55

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	736.0	736.1	736.2	736.3	736.4	736.5	736.6	736.7	736.8	736.9	737.0	737.1	737.2	737.3	737.4	737.5	737.6	737.7	737.8	737.9	738.0	
56	85,620	85,830	86,030	86,240	86,440	86,640	86,850	87,050	87,250	87,460	87,660	87,860	88,060	88,260	88,460	88,660	88,860	89,050	89,250	89,450	89,650	56
57	87,780	87,990	88,200	88,410	88,620	88,830	89,040	89,250	89,460	89,660	89,870	90,080	90,280	90,490	90,690	90,900	91,100	91,310	91,510	91,710	91,910	57
58	89,970	90,190	90,400	90,620	90,840	91,050	91,260	91,480	91,690	91,900	92,120	92,330	92,540	92,750	92,960	93,170	93,380	93,590	93,800	94,010	94,220	58
59	92,130	92,350	92,580	92,800	93,020	93,240	93,460	93,680	93,900	94,120	94,330	94,550	94,770	94,980	95,200	95,410	95,630	95,840	96,060	96,270	96,480	59
60	94,360	94,590	94,820	95,040	95,270	95,500	95,720	95,950	96,170	96,390	96,620	96,840	97,060	97,280	97,510	97,730	97,950	98,170	98,390	98,610	98,820	60
61	98,810	99,050	99,290	99,530	99,770	100,000	100,200	100,500	100,700	101,000	101,200	101,400	101,700	101,900	102,100	102,400	102,600	102,800	103,100	103,300	103,500	61
62	103,300	103,600	103,800	104,100	104,300	104,600	104,800	105,100	105,300	105,600	105,800	106,100	106,300	106,600	106,800	107,100	107,300	107,500	107,800	108,000	108,300	62
63	107,700	108,000	108,300	108,500	108,800	109,100	109,300	109,600	109,900	110,100	110,400	110,700	110,900	111,200	111,400	111,700	111,900	112,200	112,500	112,700	113,000	63
64	112,300	112,500	112,800	113,100	113,400	113,700	113,900	114,200	114,500	114,800	115,000	115,300	115,600	115,900	116,100	116,400	116,700	116,900	117,200	117,500	117,700	64
65	115,900	116,200	116,500	116,800	117,100	117,300	117,600	117,900	118,200	118,500	118,800	119,100	119,300	119,600	119,900	120,200	120,500	120,700	121,000	121,300	121,600	65
66	120,300	120,600	120,900	121,200	121,500	121,900	122,200	122,500	122,700	123,000	123,300	123,600	123,900	124,200	124,500	124,800	125,100	125,400	125,700	126,000	126,300	66
67	124,000	124,300	124,600	124,900	125,200	125,500	125,900	126,200	126,500	126,800	127,100	127,400	127,700	128,000	128,300	128,600	128,900	129,200	129,500	129,800	130,100	67
68	128,500	128,800	129,100	129,500	129,800	130,100	130,400	130,800	131,100	131,400	131,700	132,000	132,400	132,700	133,000	133,300	133,600	133,900	134,300	134,600	134,900	68
69	132,900	133,200	133,600	133,900	134,200	134,600	134,900	135,200	135,600	135,900	136,200	136,600	136,900	137,200	137,600	137,900	138,200	138,500	138,900	139,200	139,500	69
70	137,300	137,700	138,100	138,400	138,800	139,100	139,500	139,800	140,100	140,500	140,800	141,200	141,500	141,900	142,200	142,600	142,900	143,200	143,600	143,900	144,200	70
71	142,800	143,200	143,600	143,900	144,300	144,700	145,000	145,400	145,800	146,100	146,500	146,900	147,200	147,600	147,900	148,300	148,700	149,000	149,400	149,700	150,100	71
72	148,300	148,700	149,100	149,500	149,900	150,200	150,600	151,000	151,400	151,800	152,200	152,600	152,900	153,300	153,700	154,100	154,400	154,800	155,200	155,600	155,900	72
73	153,700	154,200	154,600	155,000	155,400	155,800	156,200	156,600	157,000	157,400	157,800	158,200	158,600	159,000	159,400	159,800	160,200	160,600	161,000	161,400	161,700	73
74	159,200	159,600	160,100	160,500	160,900	161,400	161,800	162,200	162,600	163,000	163,500	163,900	164,300	164,700	165,100	165,500	165,900	166,400	166,800	167,200	167,600	74
75	164,600	165,100	165,500	166,000	166,400	166,900	167,300	167,700	168,200	168,600	169,100	169,500	169,900	170,400	170,800	171,200	171,600	172,100	172,500	172,900	173,400	75
76	170,100	170,600	171,000	171,500	172,000	172,400	172,900	173,400	173,800	174,300	174,700	175,200	175,600	176,100	176,500	177,000	177,400	177,900	178,300	178,800	179,200	76
77	175,600	176,100	176,600	177,100	177,600	178,100	178,600	179,000	179,500	180,000	180,500	180,900	181,400	181,900	182,300	182,800	183,300	183,700	184,200	184,700	185,100	77
78	181,100	181,700	182,200	182,700	183,200	183,700	184,200	184,700	185,200	185,700	186,200	186,700	187,100	187,600	188,100	188,600	189,100	189,600	190,100	190,500	191,000	78
79	186,300	186,800	187,400	187,900	188,400	189,000	189,500	190,000	190,500	191,000	191,500	192,100	192,600	193,100	193,600	194,100	194,600	195,100	195,600	196,100	196,600	79
80	191,100	191,700	192,200	192,800	193,300	193,900	194,400	195,000	195,500	196,000	196,600	197,100	197,600	198,200	198,700	199,200	199,700	200,300	200,800	201,300	201,800	80
81	196,000	196,600	197,200	197,700	198,300	198,900	199,400	200,000	200,600	201,100	201,700	202,200	202,800	203,300	203,900	204,400	205,000	205,500	206,100	206,600	207,200	81
82	200,900	201,500	202,100	202,600	203,200	203,800	204,400	205,000	205,600	206,200	206,800	207,300	207,900	208,500	209,100	209,600	210,200	210,800	211,400	211,900	212,500	82
83	205,700	206,300	206,900	207,500	208,100	208,700	209,400	210,000	210,600	211,200	211,800	212,400	213,000	213,600	214,200	214,800	215,400	216,000	216,600	217,100	217,700	83
84	210,600	211,200	211,800	212,500	213,100	213,800	214,400	215,000	215,700	216,300	216,900	217,500	218,200	218,800	219,400	220,000	220,600	221,200	221,900	222,500	223,100	84
85	215,500	216,100	216,800	217,500	218,100	218,800	219,400	220,100	220,700	221,400	222,000	222,700	223,300	224,000	224,600	225,300	225,900	226,500	227,200	227,800	228,400	85
86	222,800	223,500	224,200	224,900	225,600	226,300	227,000	227,600	228,300	229,000	229,700	230,400	231,100	231,700	232,400	233,100	233,800	234,400	235,100	235,800	236,400	86
87	230,600	231,300	232,000	232,600	233,300	234,000	234,600	235,300	236,000	236,700	237,300	238,000	238,700	239,400	240,100	240,700	241,400	242,100	242,800	243,400	244,100	87
88	240,900	241,500	242,100	242,800	243,400	244,100	244,700	245,400	246,100	246,800	247,500	248,200	248,900	249,600	250,300	251,000	251,700	252,300	253,000	253,700	254,400	88
89	248,300	248,900	249,500	250,200	250,900	251,500	252,200	252,900	253,500	254,200	254,900	255,600	256,300	257,000	257,700	258,400	259,100	259,800	260,500	261,100	261,800	89
90	256,300	256,800	257,400	258,000	258,600	259,200	259,900	260,500	261,200	261,900	262,700	263,400	264,100	264,700	265,400	266,100	266,800	267,500	268,200	268,900	269,500	90
91	264,700	265,100	265,600	266,100	266,700	267,200	267,700	268,400	269,100	269,800	270,500	271,200	271,900	272,600	273,300	274,000	274,600	275,300	276,000	276,700	277,400	91
92	271,300	271,800	272,400	273,000	273,600	274,200	274,800	275,500	276,300	277,100	277,900	278,600	279,400	280,200	281,000	281,700	282,500	283,300	284,000	284,800	285,600	92
93	275,400	276,200	277,100	278,000	278,900	279,800	280,700	281,700	282,700	283,800	284,800	285,800	286,800	287,800	288,800	289,900	290,900	291,900	292,900	293,900	294,900	93
94	280,200	281,300	282,500	283,700	284,900	286,100	287,300	288,500	289,700	291,000	292,200	293,500	294,700	296,000	297,300	298,500	299,800	301,000	302,300	303,500	304,800	94
95	287,800	289,300	290,800	292,300	293,800	295,300	296,800	298,400	299,900	301,500	303,000	304,600	306,200	307,800	309,400	310,900	312,500	314,100	315,700	317,300	318,900	95
96	295,200	297,000	298,800	300,600	302,500	304,300	306,100	308,000	309,800	311,700	313,600	315,500	317,400	319,300	321,200	323,100	325,000	327,000	328,900	330,800	332,800	96
97	296,400	298,300	300,300	302,200	304,100	306,100	308,000	310,000	311,900	313,900	315,900	317,800	319,800	321,800	323,800	325,800	327,800	329,800	331,800	333,800	335,800	97
98	296,400	298,300	300,300	302,200	304,100	306,100	308,000	310,000	311,900	313,900	315,900	317,800	319,800	321,800	323,800	325,800	327,800	329,800	331,800	333,800	335,800	98
99	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	99
100	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	100
101	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	101
102	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	102
103	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	103
104	298,300	300,300	302,300	304,300	306,300	308,300	310,300	312,300	314,400	316,400	318,400	320,500	322,500	324,600	326,700	328,700	330,800	332,900	335,000	337,100	339,200	104
105	306,400	308,400	310,400	312,500	314,500	316,500	318,600	320,600	322,700	324,800	326,800	328,900	331,000	333,100	335,100	337,200	339,300	341,500	343,600	345,700	347,800	105
106	313,600	315,600	317,700	319,700	321,800	323,900	326,000	328,100	330,200	332,200	334,300	336,500	338,600	340,700	342,800	344,900	347,100	349,200	351,400	353,500	355,700	106
107	321,100	323,100	325,100	327,200	329,200	331,300	333,400	335,500	337,600	339,700	341,800	343,900	346,000	348,100	350,300	352,400	354,500	356,700	358,800	361,000	363,100	107
108	326,600	328,900	331,200	333,500	335,800	338,100	340,400	342,700	345,000	347,400	349,700	352,100	354,400	356,800	359,100	361,500	363,900	366,300	368,600	371,000	373,400	108
109	326,600	328,900	331,200	333,500	335,800	338,100	340,400	342,700	345,000	347,400	349,700	352,100	354,400	356,800	359,100	361,500	363,900	366,300	368,600	371,000	373,400	109
110	326,600	328,900	331,200	333,500	335,800	338,100	340,400	342,700	345,000	347,400	349,700	352,100	354,400	356,800	359,100	361,500	363,900	366,300	368,600	371,000	373,400	110

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	738.0	738.1	738.2	738.3	738.4	738.5	738.6	738.7	738.8	738.9	739.0	739.1	739.2	739.3	739.4	739.5	739.6	739.7	739.8	739.9	740.0	
1	830	830	830	830	840	840	840	840	840	840	850	850	850	850	850	850	850	860	860	860	860	1
2	2,330	2,340	2,340	2,350	2,350	2,360	2,360	2,370	2,370	2,380	2,380	2,390	2,390	2,390	2,400	2,400	2,410	2,410	2,420	2,420	2,430	2
3	3,610	3,620	3,630	3,630	3,640	3,650	3,660	3,660	3,670	3,680	3,680	3,690	3,700	3,710	3,710	3,720	3,730	3,740	3,740	3,750	3,760	3
4	5,110	5,130	5,140	5,150	5,160	5,170	5,180	5,190	5,200	5,210	5,220	5,230	5,240	5,250	5,260	5,270	5,280	5,290	5,300	5,310	5,320	4
5	6,300	6,310	6,330	6,340	6,350	6,370	6,380	6,390	6,410	6,420	6,430	6,440	6,460	6,470	6,480	6,490	6,510	6,520	6,530	6,550	6,560	5
6	7,810	7,820	7,840	7,860	7,870	7,890	7,900	7,920	7,940	7,950	7,970	7,980	8,000	8,020	8,030	8,050	8,060	8,080	8,100	8,110	8,130	6
7	8,990	9,010	9,030	9,050	9,070	9,090	9,110	9,120	9,140	9,160	9,180	9,200	9,220	9,230	9,250	9,270	9,290	9,310	9,320	9,340	9,360	7
8	10,500	10,520	10,540	10,560	10,590	10,610	10,630	10,650	10,670	10,690	10,720	10,740	10,760	10,780	10,800	10,820	10,840	10,870	10,890	10,910	10,930	8
9	11,570	11,590	11,620	11,640	11,670	11,690	11,710	11,740	11,760	11,790	11,810	11,830	11,860	11,880	11,900	11,930	11,950	11,970	12,000	12,020	12,040	9
10	13,080	13,110	13,140	13,160	13,190	13,220	13,250	13,270	13,300	13,330	13,350	13,380	13,410	13,430	13,460	13,490	13,510	13,540	13,570	13,590	13,620	10
11	14,220	14,250	14,280	14,310	14,340	14,370	14,400	14,430	14,460	14,490	14,510	14,540	14,570	14,600	14,630	14,660	14,690	14,720	14,750	14,770	14,800	11
12	15,750	15,780	15,810	15,850	15,880	15,910	15,940	15,980	16,010	16,040	16,070	16,110	16,140	16,170	16,200	16,230	16,270	16,300	16,330	16,360	16,390	12
13	16,690	16,730	16,760	16,800	16,830	16,870	16,900	16,940	16,970	17,000	17,040	17,070	17,110	17,140	17,170	17,210	17,240	17,280	17,310	17,340	17,380	13
14	18,190	18,230	18,270	18,300	18,340	18,380	18,420	18,450	18,490	18,530	18,570	18,600	18,640	18,680	18,710	18,750	18,790	18,830	18,860	18,900	18,940	14
15	19,210	19,250	19,290	19,330	19,370	19,410	19,450	19,490	19,530	19,570	19,610	19,650	19,690	19,730	19,770	19,810	19,840	19,880	19,920	19,960	20,000	15
16	20,730	20,770	20,810	20,860	20,900	20,940	20,990	21,030	21,070	21,110	21,160	21,200	21,240	21,280	21,330	21,370	21,410	21,450	21,490	21,540	21,580	16
17	21,670	21,720	21,760	21,810	21,850	21,900	21,940	21,990	22,030	22,080	22,120	22,170	22,210	22,250	22,300	22,340	22,390	22,430	22,470	22,520	22,560	17
18	23,170	23,220	23,270	23,320	23,360	23,410	23,460	23,510	23,550	23,600	23,650	23,700	23,740	23,790	23,840	23,890	23,930	23,980	24,030	24,070	24,120	18
19	24,130	24,180	24,230	24,280	24,330	24,380	24,430	24,480	24,530	24,580	24,630	24,680	24,730	24,780	24,830	24,880	24,930	24,970	25,020	25,070	25,120	19
20	25,590	25,640	25,700	25,750	25,800	25,850	25,910	25,960	26,010	26,070	26,120	26,170	26,220	26,270	26,330	26,380	26,430	26,480	26,530	26,580	26,640	20
21	26,520	26,570	26,630	26,680	26,740	26,790	26,850	26,900	26,960	27,010	27,070	27,120	27,170	27,230	27,280	27,330	27,390	27,440	27,500	27,550	27,600	21
22	28,030	28,080	28,140	28,200	28,260	28,320	28,380	28,430	28,490	28,550	28,610	28,660	28,720	28,780	28,830	28,890	28,950	29,000	29,060	29,120	29,170	22
23	29,000	29,060	29,120	29,180	29,240	29,300	29,360	29,420	29,480	29,540	29,600	29,660	29,720	29,780	29,830	29,890	29,950	30,010	30,070	30,130	30,190	23
24	30,520	30,580	30,640	30,710	30,770	30,830	30,900	30,960	31,020	31,080	31,150	31,210	31,270	31,330	31,390	31,460	31,520	31,580	31,640	31,700	31,760	24
25	31,710	31,770	31,840	31,900	31,970	32,030	32,100	32,160	32,230	32,290	32,360	32,420	32,490	32,550	32,620	32,680	32,750	32,810	32,870	32,940	33,000	25
26	33,210	33,270	33,340	33,410	33,480	33,550	33,620	33,690	33,760	33,820	33,890	33,960	34,030	34,090	34,160	34,230	34,300	34,360	34,430	34,500	34,560	26
27	34,310	34,380	34,450	34,520	34,590	34,660	34,730	34,800	34,870	34,950	35,020	35,090	35,160	35,230	35,290	35,360	35,430	35,500	35,570	35,640	35,710	27
28	35,840	35,910	35,990	36,060	36,140	36,210	36,290	36,360	36,430	36,510	36,580	36,650	36,730	36,800	36,870	36,940	37,020	37,090	37,160	37,230	37,310	28
29	36,770	36,850	36,920	37,000	37,080	37,150	37,230	37,300	37,380	37,460	37,530	37,610	37,680	37,760	37,830	37,900	37,980	38,050	38,130	38,200	38,270	29
30	38,280	38,360	38,440	38,520	38,600	38,680	38,760	38,840	38,910	38,990	39,070	39,150	39,230	39,310	39,380	39,460	39,540	39,620	39,690	39,770	39,850	30
31	39,260	39,340	39,420	39,500	39,580	39,660	39,750	39,830	39,910	39,990	40,070	40,150	40,230	40,310	40,390	40,470	40,550	40,630	40,700	40,780	40,860	31
32	40,770	40,860	40,940	41,030	41,110	41,200	41,280	41,360	41,450	41,530	41,610	41,700	41,780	41,860	41,950	42,030	42,110	42,190	42,280	42,360	42,440	32
33	41,930	42,020	42,110	42,190	42,280	42,370	42,450	42,540	42,620	42,710	42,800	42,880	42,970	43,050	43,140	43,220	43,310	43,390	43,480	43,560	43,640	33
34	43,410	43,500	43,590	43,680	43,770	43,860	43,950	44,040	44,130	44,220	44,310	44,400	44,480	44,570	44,660	44,750	44,840	44,920	45,010	45,100	45,190	34
35	44,400	44,490	44,590	44,680	44,770	44,860	44,950	45,040	45,140	45,230	45,320	45,410	45,500	45,590	45,680	45,770	45,860	45,950	46,040	46,130	46,220	35
36	45,890	45,990	46,080	46,180	46,270	46,370	46,460	46,560	46,650	46,750	46,840	46,930	47,030	47,120	47,210	47,310	47,400	47,490	47,580	47,680	47,770	36
37	46,750	46,840	46,940	47,040	47,130	47,230	47,330	47,420	47,520	47,620	47,710	47,810	47,900	48,000	48,090	48,190	48,280	48,380	48,470	48,560	48,660	37
38	48,270	48,370	48,470	48,570	48,670	48,770	48,870	48,970	49,070	49,170	49,260	49,360	49,460	49,560	49,660	49,760	49,850	49,950	50,050	50,140	50,240	38
39	49,580	49,680	49,780	49,890	49,990	50,090	50,190	50,300	50,400	50,500	50,600	50,700	50,800	50,900	51,000	51,100	51,200	51,300	51,400	51,500	51,600	39
40	51,100	51,210	51,320	51,420	51,530	51,630	51,740	51,840	51,950	52,050	52,160	52,260	52,370	52,470	52,570	52,680	52,780	52,890	52,990	53,090	53,190	40
41	53,440	53,560	53,670	53,780	53,890	54,000	54,110	54,220	54,330	54,440	54,550	54,660	54,770	54,880	54,990	55,100	55,210	55,320	55,430	55,530	55,640	41
42	55,710	55,830	55,940	56,060	56,180	56,290	56,410	56,530	56,640	56,760	56,870	56,990	57,100	57,220	57,330	57,440	57,560	57,670	57,780	57,900	58,010	42
43	58,870	58,990	59,110	59,240	59,360	59,490	59,610	59,730	59,860	59,980	60,100	60,220	60,350	60,470	60,590	60,710	60,830	60,950	61,070	61,190	61,310	43
44	61,210	61,340	61,470	61,600	61,730	61,860	61,990	62,120	62,250	62,380	62,500	62,630	62,760	62,890	63,010	63,140	63,270	63,390	63,520	63,640	63,770	44
45	63,480	63,620	63,750	63,890	64,020	64,160	64,290	64,420	64,560	64,690	64,820	64,960	65,090	65,220	65,350	65,490	65,620	65,750	65,880	66,010	66,140	45
46	65,750	65,890	66,030	66,170	66,310	66,450	66,590	66,730	66,870	67,000	67,140	67,280	67,420	67,560	67,690	67,830	67,970	68,100	68,240	68,370	68,510	46
47	68,900	69,050	69,200	69,350	69,490	69,640	69,790	69,930	70,080	70,230	70,370	70,520	70,660	70,810	70,950	71,090	71,240	71,380	71,520	71,670	71,810	47
48	71,160	71,310	71,470	71,620	71,770	71,920	72,080	72,230	72,380	72,530	72,680	72,830	72,980	73,130	73,280	73,430	73,580	73,730	73,870	74,020	74,170	48
49	73,400	73,560	73,720	73,880	74,030	74,190	74,350	74,510	74,660	74,820	74,970	75,130	75,280	75,440	75,590	75,750	75,900	76,050	76,210	76,360	76,510	49
50	75,740	75,900	76,060	76,230	76,390	76,550	76,710	76,880	77,040	77,200	77,360	77,520	77,680	77,840	78,000	78,160	78,320	78,480	78,640	78,800	78,950	50
51	78,000	78,170	78,340	78,510	78,680	78,840	79,010	79,180	79,350	79,510	79,680	79,840	80,010	80,170	80,340	80,500	80,670	80,830	81,000	81,160	81,320	51
52	80,340	80,510	80,690	80,860	81,040	81,210	81,380	81,550	81,730	81,900	82,070	82,240	82,410	82,580	82,750	82,920	83,090	83,260	83,430	83,600	83,770	52
53	82,690	82,870	83,050	83,230	83,410	83,580	83,760	83,940	84,120	84,300	84,470	84,650	84,830	85,000	85,180	85,350	85,530	85,700	85,880	86,050	86,220	53
54	85,030	85,220	85,400	85,590	85,770	85,960	86,140	86,330	86,510	86,690	86,870	87,050	87,240	87,420	87,600	87,780	87,960	88,140	88,320	88,500	88,680	54
55	87,380	87,570	87,760	87,950	88,140	88,330	88,520	88,710	88,900	89,090	89,270	89,460	89,650	89,830	90,020	90,210	90,390	90,580	90,760	90,940	91,130	55

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	738.0	738.1	738.2	738.3	738.4	738.5	738.6	738.7	738.8	738.9	739.0	739.1	739.2	739.3	739.4	739.5	739.6	739.7	739.8	739.9	740.0	
56	89,650	89,840	90,040	90,240	90,430	90,630	90,820	91,010	91,210	91,400	91,590	91,790	91,980	92,170	92,360	92,550	92,740	92,930	93,120	93,310	93,500	56
57	91,910	92,120	92,320	92,520	92,720	92,920	93,120	93,320	93,520	93,720	93,910	94,110	94,310	94,510	94,700	94,900	95,090	95,290	95,480	95,680	95,870	57
58	94,220	94,420	94,630	94,840	95,040	95,250	95,450	95,660	95,860	96,060	96,270	96,470	96,670	96,870	97,080	97,280	97,480	97,680	97,880	98,080	98,280	58
59	96,480	96,700	96,910	97,120	97,330	97,540	97,750	97,960	98,170	98,380	98,590	98,800	99,000	99,210	99,420	99,620	99,830	100,000	100,200	100,400	100,600	59
60	98,820	99,040	99,260	99,480	99,690	99,910	100,100	100,300	100,600	100,800	101,000	101,200	101,400	101,600	101,800	102,000	102,300	102,500	102,700	102,900	103,100	60
61	103,500	103,800	104,000	104,200	104,400	104,700	104,900	105,100	105,400	105,600	105,800	106,000	106,300	106,500	106,700	106,900	107,200	107,400	107,600	107,800	108,000	61
62	108,300	108,500	108,800	109,000	109,200	109,500	109,700	110,000	110,200	110,400	110,700	110,900	111,200	111,400	111,600	111,900	112,100	112,300	112,600	112,800	113,000	62
63	113,000	113,200	113,500	113,700	114,000	114,200	114,500	114,700	115,000	115,200	115,500	115,700	116,000	116,200	116,500	116,700	117,000	117,200	117,500	117,700	118,000	63
64	117,700	118,000	118,300	118,500	118,800	119,100	119,300	119,600	119,900	120,100	120,400	120,700	120,900	121,200	121,400	121,700	122,000	122,200	122,500	122,700	123,000	64
65	121,600	121,900	122,100	122,400	122,700	123,000	123,200	123,500	123,800	124,100	124,300	124,600	124,900	125,100	125,400	125,700	125,900	126,200	126,500	126,700	127,000	65
66	126,300	126,600	126,900	127,100	127,400	127,700	128,000	128,300	128,600	128,900	129,100	129,400	129,700	130,000	130,300	130,600	130,800	131,100	131,400	131,700	131,900	66
67	130,100	130,400	130,700	131,000	131,300	131,600	131,900	132,200	132,500	132,800	133,100	133,400	133,700	134,000	134,300	134,600	134,800	135,100	135,400	135,700	136,000	67
68	134,900	135,200	135,500	135,800	136,100	136,400	136,700	137,000	137,400	137,700	138,000	138,300	138,600	138,900	139,200	139,500	139,800	140,100	140,400	140,700	141,000	68
69	139,500	139,800	140,200	140,500	140,800	141,100	141,400	141,800	142,100	142,400	142,700	143,000	143,400	143,700	144,000	144,300	144,600	144,900	145,200	145,500	145,900	69
70	144,200	144,600	144,900	145,300	145,600	145,900	146,300	146,600	146,900	147,200	147,600	147,900	148,200	148,600	148,900	149,200	149,500	149,900	150,200	150,500	150,800	70
71	150,100	150,400	150,800	151,100	151,500	151,900	152,200	152,600	152,900	153,200	153,600	153,900	154,300	154,600	155,000	155,300	155,700	156,000	156,300	156,700	157,000	71
72	155,900	156,300	156,700	157,000	157,400	157,800	158,200	158,500	158,900	159,200	159,600	160,000	160,300	160,700	161,100	161,400	161,800	162,100	162,500	162,800	163,200	72
73	161,700	162,100	162,500	162,900	163,300	163,700	164,100	164,400	164,800	165,200	165,600	166,000	166,400	166,700	167,100	167,500	167,900	168,200	168,600	169,000	169,400	73
74	167,600	168,000	168,400	168,800	169,200	169,600	170,000	170,400	170,800	171,200	171,600	172,000	172,400	172,800	173,200	173,600	174,000	174,400	174,800	175,100	175,500	74
75	173,400	173,800	174,200	174,600	175,000	175,500	175,900	176,300	176,700	177,100	177,500	178,000	178,400	178,800	179,200	179,600	180,000	180,400	180,800	181,200	181,600	75
76	179,200	179,600	180,100	180,500	181,000	181,400	181,800	182,300	182,700	183,100	183,600	184,000	184,400	184,900	185,300	185,700	186,100	186,600	187,000	187,400	187,800	76
77	185,100	185,600	186,000	186,500	186,900	187,400	187,900	188,300	188,800	189,200	189,700	190,100	190,600	191,000	191,400	191,900	192,300	192,800	193,200	193,700	194,100	77
78	191,000	191,500	192,000	192,400	192,900	193,400	193,900	194,300	194,800	195,300	195,700	196,200	196,700	197,100	197,600	198,100	198,500	199,000	199,400	199,900	200,300	78
79	196,600	197,100	197,600	198,100	198,600	199,100	199,600	200,000	200,500	201,000	201,500	202,000	202,500	203,000	203,400	203,900	204,400	204,900	205,400	205,800	206,300	79
80	201,800	202,400	202,900	203,400	203,900	204,400	204,900	205,500	206,000	206,500	207,000	207,500	208,000	208,500	209,000	209,500	210,000	210,500	211,000	211,500	212,000	80
81	207,200	207,700	208,300	208,800	209,300	209,900	210,400	211,000	211,500	212,000	212,600	213,100	213,600	214,100	214,700	215,200	215,700	216,200	216,800	217,300	217,800	81
82	212,500	213,000	213,600	214,200	214,700	215,300	215,900	216,400	217,000	217,500	218,100	218,600	219,200	219,700	220,300	220,800	221,400	221,900	222,500	223,000	223,500	82
83	217,700	218,300	218,900	219,500	220,100	220,700	221,200	221,800	222,400	223,000	223,500	224,100	224,700	225,300	225,800	226,400	227,000	227,500	228,100	228,600	229,200	83
84	223,100	223,700	224,300	224,900	225,500	226,100	226,700	227,300	227,900	228,500	229,100	229,700	230,300	230,900	231,500	232,100	232,700	233,200	233,800	234,400	235,000	84
85	228,400	229,100	229,700	230,300	231,000	231,600	232,200	232,800	233,500	234,100	234,700	235,300	235,900	236,500	237,200	237,800	238,400	239,000	239,600	240,200	240,800	85
86	236,400	237,100	237,800	238,400	239,100	239,700	240,400	241,100	241,700	242,400	243,000	243,700	244,300	245,000	245,600	246,300	246,900	247,500	248,200	248,800	249,400	86
87	244,100	244,800	245,400	246,100	246,700	247,400	248,000	248,700	249,300	250,000	250,600	251,300	252,000	252,600	253,300	254,000	254,600	255,300	255,900	256,600	257,300	87
88	254,400	255,000	255,700	256,400	257,100	257,700	258,400	259,000	259,700	260,400	261,000	261,700	262,400	263,000	263,700	264,400	265,100	265,800	266,500	267,200	267,900	88
89	261,800	262,500	263,100	263,800	264,500	265,100	265,800	266,500	267,100	267,800	268,400	269,100	269,800	270,500	271,200	272,000	272,700	273,400	274,100	274,900	275,600	89
90	269,500	270,200	270,900	271,500	272,200	272,800	273,500	274,200	274,800	275,400	276,100	276,800	277,500	278,200	278,900	279,700	280,400	281,200	281,900	282,700	283,400	90
91	277,400	278,000	278,700	279,400	280,000	280,700	281,300	282,000	282,600	283,300	283,900	284,600	285,300	286,000	286,700	287,500	288,200	288,900	289,700	290,500	291,300	91
92	285,600	286,300	287,100	287,800	288,500	289,300	290,000	290,800	291,500	292,200	292,900	293,500	294,200	294,900	295,600	296,300	297,000	297,700	298,400	299,200	300,000	92
93	294,900	295,900	296,900	297,900	298,900	299,900	300,900	301,900	302,800	303,700	304,300	304,800	305,400	305,900	306,500	307,100	307,600	308,200	308,800	309,400	310,100	93
94	304,800	306,100	307,300	308,400	309,500	310,700	311,800	312,900	313,900	314,700	315,100	315,500	316,000	316,400	316,800	317,300	317,700	318,200	318,700	319,200	319,700	94
95	318,900	320,500	321,900	323,000	323,900	324,900	325,800	326,800	327,700	328,300	328,600	328,800	329,100	329,400	329,700	330,000	330,300	330,600	330,900	331,200	331,600	95
96	332,800	334,700	336,200	337,300	338,200	339,100	340,100	341,000	341,800	342,200	342,400	342,500	342,500	342,700	342,800	343,000	343,100	343,300	343,400	343,600	343,800	96
97	335,800	337,800	339,500	340,900	342,200	343,500	344,700	346,000	347,200	348,000	348,500	348,800	349,300	349,700	350,200	350,700	351,200	351,600	352,100	352,600	353,200	97
98	335,800	337,800	339,700	341,500	343,300	345,100	346,900	348,700	350,400	351,800	352,900	353,900	355,000	356,100	357,100	358,200	359,300	360,400	361,500	362,600	363,700	98
99	339,200	341,300	343,300	345,300	347,300	349,300	351,300	353,300	355,300	357,300	359,100	360,700	362,300	364,000	365,700	367,300	369,000	370,700	372,300	374,000	375,700	99
100	339,200	341,300	343,400	345,500	347,600	349,700	351,900	354,000	356,100	358,300	360,400	362,600	364,800	366,900	369,100	371,300	373,500	375,700	377,900	380,100	382,300	100
101	339,200	341,300	343,400	345,500	347,600	349,700	351,900	354,000	356,100	358,300	360,400	362,600	364,800	366,900	369,100	371,300	373,500	375,700	377,900	380,100	382,300	101
102	339,200	341,300	343,400	345,500	347,600	349,700	351,900	354,000	356,100	358,300	360,400	362,600	364,800	366,900	369,100	371,300	373,500	375,700	377,900	380,100	382,300	102
103	339,200	341,300	343,400	345,500	347,600	349,700	351,900	354,000	356,100	358,300	360,400	362,600	364,800	366,900	369,100	371,300	373,500	375,700	377,900	380,100	382,300	103
104	339,200	341,300	343,400	345,500	347,600	349,700	351,900	354,000	356,100	358,300	360,400	362,600	364,800	366,900	369,100	371,300	373,500	375,700	377,900	380,100	382,300	104
105	347,800	349,900	352,100	354,200	356,300	358,500	360,700	362,800	365,000	367,200	369,300	371,500	373,700	375,900	378,100	380,300	382,500	384,700	387,000	389,200	391,400	105
106	355,700	357,800	360,000	362,200	364,300	366,500	368,700	370,900	373,100	375,300	377,500	379,700	382,000	384,200	386,400	388,600	390,900	393,100	395,400	397,600	399,900	106
107	363,100	365,300	367,400	369,600	371,800	374,000	376,100	378,300	380,500	382,700	384,900	387,200	389,400	391,600	393,900	396,200	398,400	400,700	403,000	405,300	407,600	107
108	373,400	375,900	378,200	380,500	382,700	384,800	386,900	389,000	391,000	393,100	395,200	397,300	399,400	401,500	403,700	405,800	408,000	410,100	412,300	414,500	416,700	108
109	373,400	375,900	378,300	380,700	383,100	385,600	388,000	390,500	392,900	395,400	397,800	400,300	402,800	405,300	407,800	410,300	412,800	415,300	417,800	420,400	422,900	109
110	373,400	375,900	378,300	380,700	383,100	385,600	388,000	390,500	392,900	395,400	397,800	400,300	402,800	405,300	407,800	410,300	412,800	415,300	417,800	420,400	422,900	110

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	740.0	740.1	740.2	740.3	740.4	740.5	740.6	740.7	740.8	740.9	741.0	741.1	741.2	741.3	741.4	741.5	741.6	741.7	741.8	741.9	742.0	
1	860	860	860	870	870	870	870	870	870	880	880	880	880	880	880	890	890	890	890	890	890	1
2	2,430	2,430	2,440	2,440	2,450	2,450	2,460	2,460	2,460	2,470	2,470	2,480	2,480	2,490	2,490	2,500	2,500	2,510	2,510	2,510	2,520	2
3	3,760	3,760	3,770	3,780	3,790	3,790	3,800	3,810	3,810	3,820	3,830	3,830	3,840	3,850	3,860	3,860	3,870	3,880	3,880	3,890	3,900	3
4	5,320	5,330	5,340	5,350	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	5,530	4
5	6,560	6,570	6,580	6,600	6,610	6,620	6,630	6,650	6,660	6,670	6,680	6,690	6,710	6,720	6,730	6,740	6,760	6,770	6,780	6,790	6,800	5
6	8,130	8,140	8,160	8,170	8,190	8,200	8,220	8,240	8,250	8,270	8,280	8,300	8,310	8,330	8,340	8,360	8,370	8,390	8,400	8,420	8,430	6
7	9,360	9,380	9,400	9,410	9,430	9,450	9,470	9,490	9,500	9,520	9,540	9,560	9,570	9,590	9,610	9,630	9,640	9,660	9,680	9,700	9,710	7
8	10,930	10,950	10,970	10,990	11,010	11,030	11,060	11,080	11,100	11,120	11,140	11,160	11,180	11,200	11,220	11,240	11,260	11,280	11,300	11,320	11,340	8
9	12,040	12,070	12,090	12,110	12,140	12,160	12,180	12,200	12,230	12,250	12,270	12,300	12,320	12,340	12,360	12,390	12,410	12,430	12,450	12,480	12,500	9
10	13,620	13,650	13,670	13,700	13,720	13,750	13,780	13,800	13,830	13,850	13,880	13,900	13,930	13,960	13,980	14,010	14,030	14,060	14,080	14,110	14,130	10
11	14,800	14,830	14,860	14,890	14,920	14,940	14,970	15,000	15,030	15,060	15,080	15,110	15,140	15,170	15,200	15,220	15,250	15,280	15,310	15,330	15,360	11
12	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	16,920	16,950	16,980	17,010	12
13	17,380	17,410	17,440	17,480	17,510	17,540	17,580	17,610	17,640	17,670	17,710	17,740	17,770	17,810	17,840	17,870	17,900	17,940	17,970	18,000	18,030	13
14	18,940	18,970	19,010	19,040	19,080	19,120	19,150	19,190	19,230	19,260	19,300	19,330	19,370	19,400	19,440	19,480	19,510	19,550	19,580	19,620	19,650	14
15	20,000	20,040	20,080	20,110	20,150	20,190	20,230	20,270	20,300	20,340	20,380	20,420	20,460	20,490	20,530	20,570	20,610	20,640	20,680	20,720	20,750	15
16	21,580	21,620	21,660	21,700	21,740	21,780	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	16
17	22,560	22,600	22,650	22,690	22,730	22,780	22,820	22,860	22,900	22,950	22,990	23,030	23,080	23,120	23,160	23,200	23,240	23,290	23,330	23,370	23,410	17
18	24,120	24,170	24,210	24,260	24,300	24,350	24,400	24,440	24,490	24,530	24,580	24,630	24,670	24,720	24,760	24,810	24,850	24,900	24,940	24,990	25,030	18
19	25,120	25,170	25,220	25,260	25,310	25,360	25,410	25,460	25,500	25,550	25,600	25,650	25,690	25,740	25,790	25,840	25,880	25,930	25,980	26,020	26,070	19
20	26,640	26,690	26,740	26,790	26,840	26,890	26,940	26,990	27,040	27,090	27,140	27,200	27,250	27,300	27,350	27,400	27,450	27,500	27,540	27,590	27,640	20
21	27,600	27,650	27,710	27,760	27,810	27,870	27,920	27,970	28,020	28,080	28,130	28,180	28,230	28,280	28,340	28,390	28,440	28,490	28,540	28,590	28,640	21
22	29,170	29,230	29,290	29,340	29,400	29,450	29,510	29,560	29,620	29,670	29,730	29,780	29,840	29,890	29,950	30,000	30,060	30,110	30,170	30,220	30,280	22
23	30,190	30,240	30,300	30,360	30,420	30,470	30,530	30,590	30,650	30,700	30,760	30,820	30,870	30,930	30,990	31,040	31,100	31,160	31,210	31,270	31,330	23
24	31,760	31,830	31,890	31,950	32,010	32,070	32,130	32,190	32,250	32,310	32,370	32,430	32,490	32,550	32,610	32,670	32,730	32,790	32,850	32,910	32,960	24
25	33,000	33,060	33,130	33,190	33,250	33,320	33,380	33,440	33,500	33,570	33,630	33,690	33,750	33,820	33,880	33,940	34,000	34,060	34,120	34,190	34,250	25
26	34,560	34,630	34,700	34,760	34,830	34,900	34,960	35,030	35,090	35,160	35,220	35,290	35,350	35,420	35,480	35,550	35,610	35,680	35,740	35,810	35,870	26
27	35,710	35,780	35,850	35,920	35,980	36,050	36,120	36,190	36,260	36,320	36,390	36,460	36,520	36,590	36,660	36,730	36,790	36,860	36,930	36,990	37,060	27
28	37,310	37,380	37,450	37,520	37,590	37,660	37,730	37,810	37,880	37,950	38,020	38,090	38,160	38,230	38,300	38,370	38,440	38,510	38,580	38,650	38,720	28
29	38,270	38,350	38,420	38,500	38,570	38,640	38,710	38,790	38,860	38,930	39,000	39,080	39,150	39,220	39,290	39,360	39,440	39,510	39,580	39,650	39,720	29
30	39,850	39,920	40,000	40,080	40,150	40,230	40,300	40,380	40,460	40,530	40,610	40,680	40,760	40,830	40,910	40,980	41,060	41,130	41,200	41,280	41,350	30
31	40,860	40,940	41,020	41,100	41,180	41,250	41,330	41,410	41,490	41,560	41,640	41,720	41,790	41,870	41,950	42,020	42,100	42,180	42,250	42,330	42,410	31
32	42,440	42,520	42,600	42,680	42,770	42,850	42,930	43,010	43,090	43,170	43,250	43,330	43,410	43,490	43,570	43,650	43,730	43,810	43,890	43,970	44,040	32
33	43,640	43,730	43,810	43,900	43,980	44,060	44,150	44,230	44,310	44,390	44,480	44,560	44,640	44,720	44,800	44,890	44,970	45,050	45,130	45,210	45,290	33
34	45,190	45,270	45,360	45,450	45,530	45,620	45,710	45,790	45,880	45,960	46,050	46,130	46,220	46,300	46,390	46,470	46,560	46,640	46,730	46,810	46,890	34
35	46,220	46,300	46,390	46,480	46,570	46,660	46,750	46,830	46,920	47,010	47,100	47,180	47,270	47,360	47,440	47,530	47,620	47,700	47,790	47,880	47,960	35
36	47,770	47,860	47,950	48,040	48,130	48,230	48,320	48,410	48,500	48,590	48,680	48,770	48,860	48,950	49,040	49,130	49,220	49,310	49,400	49,490	49,570	36
37	48,660	48,750	48,840	48,940	49,030	49,120	49,220	49,310	49,400	49,490	49,580	49,680	49,770	49,860	49,950	50,040	50,130	50,220	50,310	50,400	50,500	37
38	50,240	50,340	50,430	50,530	50,630	50,720	50,820	50,910	51,010	51,100	51,200	51,290	51,390	51,480	51,580	51,670	51,770	51,860	51,950	52,050	52,140	38
39	51,600	51,700	51,800	51,900	52,000	52,100	52,200	52,290	52,390	52,490	52,590	52,680	52,780	52,880	52,980	53,070	53,170	53,260	53,360	53,460	53,550	39
40	53,190	53,300	53,400	53,500	53,600	53,700	53,800	53,910	54,010	54,110	54,210	54,310	54,410	54,510	54,610	54,710	54,810	54,910	55,010	55,110	55,200	40
41	55,640	55,750	55,860	55,960	56,070	56,180	56,280	56,390	56,500	56,600	56,710	56,810	56,920	57,030	57,130	57,240	57,340	57,440	57,550	57,650	57,760	41
42	58,010	58,120	58,240	58,350	58,460	58,570	58,680	58,790	58,910	59,020	59,130	59,240	59,350	59,460	59,570	59,680	59,790	59,900	60,010	60,110	60,220	42
43	61,310	61,430	61,550	61,670	61,790	61,910	62,030	62,150	62,260	62,380	62,500	62,620	62,730	62,850	62,970	63,080	63,200	63,320	63,430	63,550	63,660	43
44	63,770	63,890	64,020	64,140	64,270	64,390	64,510	64,640	64,760	64,880	65,010	65,130	65,250	65,380	65,500	65,620	65,740	65,860	65,980	66,100	66,220	44
45	66,140	66,270	66,400	66,530	66,660	66,790	66,920	67,050	67,170	67,300	67,430	67,560	67,680	67,810	67,940	68,070	68,190	68,320	68,440	68,570	68,700	45
46	68,510	68,640	68,780	68,910	69,050	69,180	69,320	69,450	69,580	69,720	69,850	69,980	70,110	70,250	70,380	70,510	70,640	70,770	70,900	71,030	71,160	46
47	71,810	71,950	72,090	72,240	72,380	72,520	72,660	72,800	72,940	73,080	73,220	73,360	73,500	73,640	73,780	73,920	74,050	74,190	74,330	74,470	74,600	47
48	74,170	74,320	74,460	74,610	74,760	74,900	75,050	75,190	75,340	75,480	75,630	75,770	75,920	76,060	76,210	76,350	76,490	76,630	76,780	76,920	77,060	48
49	76,510	76,660	76,820	76,970	77,120	77,270	77,420	77,570	77,720	77,870	78,020	78,170	78,320	78,470	78,620	78,760	78,910	79,060	79,210	79,350	79,500	49
50	78,950	79,110	79,270	79,420	79,580	79,740	79,890	80,050	80,200	80,360	80,510	80,670	80,820	80,980	81,130	81,280	81,440	81,590	81,740	81,890	82,040	50
51	81,320	81,480	81,650	81,810	81,970	82,130	82,290	82,450	82,610	82,770	82,930	83,090	83,250	83,410	83,570	83,730	83,880	84,040	84,200	84,350	84,510	51
52	83,770	83,930	84,100	84,270	84,430	84,600	84,770	84,930	85,100	85,260	85,430	85,590	85,760	85,920	86,080	86,250	86,410	86,570	86,730	86,900	87,060	52
53	86,220	86,400	86,570	86,740	86,910	87,080	87,250	87,430	87,600	87,770	87,940	88,110	88,280	88,440	88,610	88,780	88,950	89,120	89,280	89,450	89,620	53
54	88,680	88,850	89,030	89,210	89,390	89,560	89,740	89,920	90,090	90,270	90,440	90,620	90,790	90,960	91,140	91,310	91,490	91,660	91,830	92,000	92,170	54
55	91,130	91,310	91,500	91,680	91,860	92,040	92,220	92,410	92,590	92,770	92,950	93,130	93,310	93,490	93,660	93,840	94,020	94,200	94,380	94,550	94,730	55

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	740.0	740.1	740.2	740.3	740.4	740.5	740.6	740.7	740.8	740.9	741.0	741.1	741.2	741.3	741.4	741.5	741.6	741.7	741.8	741.9	742.0	
56	93, 500	93, 690	93, 880	94, 060	94, 250	94, 440	94, 630	94, 810	95, 000	95, 180	95, 370	95, 550	95, 740	95, 920	96, 110	96, 290	96, 470	96, 650	96, 840	97, 020	97, 200	56
57	95, 870	96, 070	96, 260	96, 450	96, 640	96, 840	97, 030	97, 220	97, 410	97, 600	97, 790	97, 980	98, 170	98, 360	98, 550	98, 740	98, 920	99, 110	99, 300	99, 490	99, 670	57
58	98, 280	98, 480	98, 670	98, 870	99, 070	99, 270	99, 460	99, 660	99, 850	100, 100	100, 200	100, 400	100, 600	100, 800	101, 000	101, 200	101, 400	101, 600	101, 800	102, 000	102, 200	58
59	100, 600	100, 900	101, 100	101, 300	101, 500	101, 700	101, 900	102, 100	102, 300	102, 500	102, 700	102, 900	103, 100	103, 300	103, 500	103, 700	103, 900	104, 100	104, 300	104, 500	104, 600	59
60	103, 100	103, 300	103, 500	103, 700	103, 900	104, 100	104, 300	104, 600	104, 800	105, 000	105, 200	105, 400	105, 600	105, 800	106, 000	106, 200	106, 400	106, 600	106, 800	107, 000	107, 200	60
61	108, 000	108, 300	108, 500	108, 700	108, 900	109, 100	109, 400	109, 600	109, 800	110, 000	110, 200	110, 400	110, 700	110, 900	111, 100	111, 300	111, 500	111, 700	111, 900	112, 200	112, 400	61
62	113, 000	113, 300	113, 500	113, 700	114, 000	114, 200	114, 400	114, 700	114, 900	115, 100	115, 300	115, 600	115, 800	116, 000	116, 200	116, 500	116, 700	116, 900	117, 100	117, 400	117, 600	62
63	118, 000	118, 200	118, 500	118, 700	118, 900	119, 200	119, 400	119, 700	119, 900	120, 100	120, 400	120, 600	120, 900	121, 100	121, 300	121, 600	121, 800	122, 100	122, 300	122, 500	122, 800	63
64	123, 000	123, 200	123, 500	123, 700	124, 000	124, 300	124, 500	124, 800	125, 000	125, 300	125, 500	125, 800	126, 000	126, 300	126, 500	126, 800	127, 000	127, 300	127, 500	127, 800	128, 000	64
65	127, 000	127, 300	127, 500	127, 800	128, 100	128, 300	128, 600	128, 900	129, 100	129, 400	129, 600	129, 900	130, 200	130, 400	130, 700	130, 900	131, 200	131, 500	131, 700	132, 000	132, 200	65
66	131, 900	132, 200	132, 500	132, 800	133, 100	133, 300	133, 600	133, 900	134, 100	134, 400	134, 700	135, 000	135, 200	135, 500	135, 800	136, 000	136, 300	136, 600	136, 800	137, 100	137, 400	66
67	136, 000	136, 300	136, 600	136, 900	137, 100	137, 400	137, 700	138, 000	138, 300	138, 600	138, 800	139, 100	139, 400	139, 700	140, 000	140, 200	140, 500	140, 800	141, 100	141, 300	141, 600	67
68	141, 000	141, 300	141, 600	141, 900	142, 200	142, 500	142, 800	143, 100	143, 400	143, 600	143, 900	144, 200	144, 500	144, 800	145, 100	145, 400	145, 700	146, 000	146, 300	146, 500	146, 800	68
69	145, 900	146, 200	146, 500	146, 800	147, 100	147, 400	147, 700	148, 000	148, 300	148, 600	148, 900	149, 200	149, 500	149, 800	150, 100	150, 400	150, 700	151, 000	151, 300	151, 600	151, 900	69
70	150, 800	151, 100	151, 500	151, 800	152, 100	152, 400	152, 700	153, 100	153, 400	153, 700	154, 000	154, 300	154, 600	155, 000	155, 300	155, 600	155, 900	156, 200	156, 500	156, 800	157, 100	70
71	157, 000	157, 400	157, 700	158, 000	158, 400	158, 700	159, 000	159, 400	159, 700	160, 000	160, 400	160, 700	161, 000	161, 400	161, 700	162, 000	162, 300	162, 700	163, 000	163, 300	163, 700	71
72	163, 200	163, 600	163, 900	164, 300	164, 600	165, 000	165, 300	165, 700	166, 000	166, 400	166, 700	167, 100	167, 400	167, 800	168, 100	168, 500	168, 800	169, 100	169, 500	169, 800	170, 200	72
73	169, 400	169, 700	170, 100	170, 500	170, 800	171, 200	171, 600	171, 900	172, 300	172, 700	173, 000	173, 400	173, 800	174, 100	174, 500	174, 800	175, 200	175, 600	175, 900	176, 300	176, 600	73
74	175, 500	175, 900	176, 300	176, 700	177, 100	177, 500	177, 800	178, 200	178, 600	179, 000	179, 400	179, 800	180, 100	180, 500	180, 900	181, 300	181, 600	182, 000	182, 400	182, 800	183, 100	74
75	181, 600	182, 000	182, 400	182, 800	183, 300	183, 700	184, 100	184, 500	184, 900	185, 200	185, 600	186, 000	186, 400	186, 800	187, 200	187, 600	188, 000	188, 400	188, 800	189, 200	189, 600	75
76	187, 800	188, 300	188, 700	189, 100	189, 500	189, 900	190, 400	190, 800	191, 200	191, 600	192, 000	192, 400	192, 800	193, 200	193, 700	194, 100	194, 500	194, 900	195, 300	195, 700	196, 100	76
77	194, 100	194, 500	195, 000	195, 400	195, 800	196, 300	196, 700	197, 100	197, 600	198, 000	198, 400	198, 900	199, 300	199, 700	200, 100	200, 600	201, 000	201, 400	201, 800	202, 300	202, 700	77
78	200, 300	200, 800	201, 300	201, 700	202, 200	202, 600	203, 100	203, 500	204, 000	204, 400	204, 800	205, 300	205, 700	206, 200	206, 600	207, 100	207, 500	207, 900	208, 400	208, 800	209, 300	78
79	206, 300	206, 800	207, 300	207, 700	208, 200	208, 700	209, 200	209, 600	210, 100	210, 500	211, 000	211, 500	211, 900	212, 400	212, 900	213, 300	213, 800	214, 200	214, 700	215, 100	215, 600	79
80	212, 000	212, 500	213, 000	213, 500	214, 000	214, 500	215, 000	215, 500	215, 900	216, 400	216, 900	217, 400	217, 900	218, 300	218, 800	219, 300	219, 800	220, 200	220, 700	221, 200	221, 700	80
81	217, 800	218, 300	218, 800	219, 300	219, 900	220, 400	220, 900	221, 400	221, 900	222, 400	222, 900	223, 400	223, 900	224, 400	224, 900	225, 400	225, 900	226, 400	226, 800	227, 300	227, 800	81
82	223, 500	224, 100	224, 600	225, 100	225, 700	226, 200	226, 700	227, 300	227, 800	228, 300	228, 800	229, 300	229, 800	230, 400	230, 900	231, 400	231, 900	232, 400	232, 900	233, 400	233, 900	82
83	229, 200	229, 800	230, 300	230, 900	231, 400	232, 000	232, 500	233, 100	233, 600	234, 100	234, 700	235, 200	235, 700	236, 300	236, 800	237, 300	237, 900	238, 400	238, 900	239, 400	240, 000	83
84	235, 000	235, 600	236, 100	236, 700	237, 300	237, 800	238, 400	239, 000	239, 500	240, 100	240, 600	241, 200	241, 700	242, 300	242, 800	243, 400	243, 900	244, 500	245, 000	245, 600	246, 100	84
85	240, 800	241, 400	242, 000	242, 600	243, 200	243, 800	244, 300	244, 900	245, 500	246, 100	246, 600	247, 200	247, 800	248, 300	248, 900	249, 500	250, 000	250, 600	251, 100	251, 700	252, 300	85
86	249, 400	250, 100	250, 700	251, 300	251, 900	252, 500	253, 200	253, 800	254, 400	255, 000	255, 600	256, 200	256, 700	257, 300	257, 900	258, 500	259, 100	259, 700	260, 300	260, 900	261, 500	86
87	257, 300	257, 900	258, 600	259, 200	259, 900	260, 500	261, 200	261, 800	262, 400	263, 100	263, 700	264, 300	264, 900	265, 600	266, 200	266, 800	267, 400	268, 100	268, 700	269, 300	269, 900	87
88	267, 900	268, 600	269, 300	270, 000	270, 700	271, 400	272, 100	272, 700	273, 400	274, 100	274, 700	275, 400	276, 100	276, 800	277, 400	278, 100	278, 700	279, 400	280, 100	280, 700	281, 400	88
89	275, 600	276, 300	277, 000	277, 800	278, 500	279, 200	279, 900	280, 600	281, 300	282, 000	282, 700	283, 400	284, 100	284, 800	285, 500	286, 200	286, 900	287, 600	288, 300	289, 000	289, 700	89
90	283, 400	284, 200	284, 900	285, 700	286, 500	287, 200	287, 900	288, 700	289, 400	290, 200	290, 900	291, 600	292, 400	293, 100	293, 800	294, 500	295, 300	296, 000	296, 700	297, 400	298, 200	90
91	291, 300	292, 100	292, 900	293, 700	294, 400	295, 200	296, 000	296, 800	297, 500	298, 300	299, 100	299, 800	300, 600	301, 400	302, 100	302, 900	303, 600	304, 400	305, 100	305, 900	306, 600	91
92	300, 000	300, 700	301, 500	302, 300	303, 000	303, 800	304, 500	305, 300	306, 000	306, 800	307, 500	308, 300	309, 100	309, 900	310, 700	311, 400	312, 200	313, 000	313, 800	314, 500	315, 300	92
93	310, 100	310, 700	311, 400	312, 000	312, 600	313, 300	313, 900	314, 500	315, 200	315, 800	316, 600	317, 400	318, 200	318, 900	319, 700	320, 500	321, 200	322, 000	322, 800	323, 500	324, 300	93
94	319, 700	320, 200	320, 700	321, 300	321, 900	322, 400	323, 000	323, 500	324, 100	324, 700	325, 500	326, 300	327, 100	327, 800	328, 600	329, 400	330, 100	330, 900	331, 700	332, 400	333, 200	94
95	331, 600	331, 900	332, 400	332, 900	333, 500	334, 000	334, 500	335, 100	335, 700	336, 300	337, 100	337, 800	338, 600	339, 400	340, 100	340, 900	341, 600	342, 400	343, 200	343, 900	344, 600	95
96	343, 800	344, 000	344, 400	344, 800	345, 300	345, 800	346, 300	346, 800	347, 400	348, 000	348, 800	349, 500	350, 300	351, 100	351, 800	352, 600	353, 300	354, 100	354, 800	355, 500	356, 300	96
97	353, 200	353, 700	354, 300	355, 100	355, 800	356, 600	357, 300	358, 100	358, 900	359, 800	360, 800	361, 800	362, 900	363, 900	364, 900	366, 000	367, 000	368, 000	369, 000	370, 000	371, 100	97
98	363, 700	364, 900	366, 100	367, 300	368, 600	369, 800	371, 000	372, 300	373, 500	374, 900	376, 300	377, 800	379, 300	380, 800	382, 200	383, 700	385, 200	386, 700	388, 200	389, 700	391, 200	98
99	375, 700	377, 500	379, 200	381, 000	382, 800	384, 500	386, 300	388, 100	389, 900	391, 700	393, 500	395, 500	397, 400	399, 300	401, 200	403, 200	405, 100	407, 000	409, 000	410, 900	412, 900	99
100	382, 300	384, 500	386, 700	388, 900	391, 200	393, 400	395, 600	397, 900	400, 100	402, 400	404, 700	406, 900	409, 200	411, 500	413, 800	416, 100	418, 400	420, 700	423, 000	425, 300	427, 600	100
101	382, 300	384, 500	386, 700	388, 900	391, 200	393, 400	395, 600	397, 900	400, 100	402, 400	404, 700	406, 900	409, 200	411, 500	413, 800	416, 100	418, 400	420, 700	423, 000	425, 300	427, 600	101
102	382, 300	384, 500	386, 700	388, 900	391, 200	393, 400	395, 600	397, 900	400, 100	402, 400	404, 700	406, 900	409, 200	411, 500	413, 800	416, 100	418, 400	420, 700	423, 000	425, 300	427, 600	102
103	382, 300	384, 500	386, 700	388, 900	391, 200	393, 400	395, 600	397, 900	400, 100	402, 400	404, 700	406, 900	409, 200	411, 500	413, 800	416, 100	418, 400	420, 700	423, 000	425, 300	427, 600	103
104	382, 300	384, 500	386, 700	388, 900	391, 200	393, 400	395, 600	397, 900	400, 100	402, 400	404, 700	406, 900	409, 200	411, 500	413, 800	416, 100	418, 400	420, 700	423, 000	425, 300	427, 600	104
105	391, 400	393, 600	395, 900	398, 100	400, 400	402, 700	404, 900	407, 200	409, 500	411, 800	414, 000	416, 300	418, 600	420, 900	423, 200	425, 600	427, 900	430, 200	432, 500	434, 900	437, 200	105
106	399, 900	402, 200	404, 500	406, 700	409, 000	411, 300	413, 600	415, 900	418, 200	420, 500	422, 800	425, 100	427, 500	429, 800	432, 100	434, 500	436, 800	439, 200	441, 500	443, 900	446, 300	106
107	407, 600	409, 900	412, 200	414, 500	416, 800	419, 100	421, 400	423, 800	426, 100	428, 400	430, 800	433, 100	435, 500	437, 900	440, 200	442, 600	445, 000	447, 400	449, 800	452, 100	454, 500	107
108	416, 700	418, 800	421, 100	423, 300	425, 600	427, 800	430, 200	432, 500	434, 800	437, 200	439, 500	441, 900	444, 200	446, 600	448, 900	451, 300	453, 700	456, 000	458, 400	460, 800	463, 200	108
109	422, 900	425, 500	428, 000	430, 600	433, 100	435, 700	438, 300	440, 900	443, 400	446, 000	448, 600	451, 300	453, 900	456, 500	459, 100	461, 800	464, 400	467, 100	469, 700	472, 400	475, 000	109
110	422, 900	425, 500	428, 000	430, 600	433, 100	435, 700	438, 300	440, 900	443, 400	446, 000	448, 600	451, 300	453, 900	456, 500	459, 100	461, 800	464, 400	467, 100	469, 700	472, 400	475, 000	110

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	742.0	742.1	742.2	742.3	742.4	742.5	742.6	742.7	742.8	742.9	743.0	743.1	743.2	743.3	743.4	743.5	743.6	743.7	743.8	743.9	744.0	
1	890	890	900	900	900	900	900	900	910	910	910	910	910	910	910	920	920	920	920	920	920	1
2	2,520	2,520	2,530	2,530	2,540	2,540	2,550	2,550	2,550	2,560	2,560	2,570	2,570	2,580	2,580	2,590	2,590	2,590	2,600	2,600	2,610	2
3	3,900	3,900	3,910	3,920	3,920	3,930	3,940	3,940	3,950	3,960	3,970	3,970	3,980	3,990	3,990	4,000	4,010	4,010	4,020	4,030	4,030	3
4	5,530	5,540	5,550	5,560	5,560	5,570	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	4
5	6,800	6,820	6,830	6,840	6,850	6,870	6,880	6,890	6,900	6,910	6,920	6,940	6,950	6,960	6,970	6,980	7,000	7,010	7,020	7,030	7,040	5
6	8,430	8,450	8,460	8,480	8,490	8,510	8,520	8,540	8,550	8,570	8,580	8,600	8,610	8,630	8,640	8,660	8,670	8,690	8,700	8,720	8,730	6
7	9,710	9,730	9,750	9,770	9,780	9,800	9,820	9,830	9,850	9,870	9,890	9,900	9,920	9,940	9,950	9,970	9,990	10,000	10,020	10,040	10,050	7
8	11,340	11,360	11,380	11,400	11,420	11,440	11,460	11,490	11,510	11,530	11,550	11,570	11,580	11,600	11,620	11,640	11,660	11,680	11,700	11,720	11,740	8
9	12,500	12,520	12,540	12,560	12,590	12,610	12,630	12,650	12,680	12,700	12,720	12,740	12,760	12,790	12,810	12,830	12,850	12,870	12,890	12,920	12,940	9
10	14,130	14,160	14,190	14,210	14,240	14,260	14,290	14,310	14,340	14,360	14,390	14,410	14,440	14,460	14,480	14,510	14,530	14,560	14,580	14,610	14,630	10
11	15,360	15,390	15,420	15,440	15,470	15,500	15,530	15,550	15,580	15,610	15,630	15,660	15,690	15,710	15,740	15,770	15,800	15,820	15,850	15,870	15,900	11
12	17,010	17,040	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	17,520	17,550	17,580	17,610	12
13	18,030	18,070	18,100	18,130	18,160	18,190	18,230	18,260	18,290	18,320	18,350	18,380	18,420	18,450	18,480	18,510	18,540	18,570	18,600	18,640	18,670	13
14	19,650	19,690	19,720	19,760	19,790	19,830	19,860	19,900	19,930	19,970	20,000	20,040	20,070	20,100	20,140	20,170	20,210	20,240	20,280	20,310	20,340	14
15	20,750	20,790	20,830	20,870	20,900	20,940	20,980	21,010	21,050	21,090	21,120	21,160	21,200	21,230	21,270	21,300	21,340	21,380	21,410	21,450	21,480	15
16	22,390	22,430	22,470	22,510	22,550	22,590	22,630	22,670	22,710	22,750	22,790	22,830	22,870	22,910	22,950	22,990	23,030	23,070	23,100	23,140	23,180	16
17	23,410	23,450	23,500	23,540	23,580	23,620	23,660	23,700	23,750	23,790	23,830	23,870	23,910	23,950	23,990	24,030	24,070	24,110	24,150	24,200	24,240	17
18	25,030	25,080	25,120	25,170	25,210	25,250	25,300	25,340	25,390	25,430	25,480	25,520	25,560	25,610	25,650	25,700	25,740	25,780	25,830	25,870	25,910	18
19	26,070	26,120	26,160	26,210	26,260	26,300	26,350	26,390	26,440	26,490	26,530	26,580	26,620	26,670	26,710	26,760	26,800	26,850	26,900	26,940	26,990	19
20	27,640	27,690	27,740	27,790	27,840	27,890	27,940	27,990	28,040	28,090	28,130	28,180	28,230	28,280	28,330	28,380	28,420	28,470	28,520	28,570	28,620	20
21	28,640	28,700	28,750	28,800	28,850	28,900	28,950	29,000	29,050	29,100	29,150	29,200	29,250	29,300	29,350	29,400	29,450	29,500	29,550	29,600	29,650	21
22	30,280	30,330	30,380	30,440	30,490	30,550	30,600	30,650	30,710	30,760	30,810	30,870	30,920	30,970	31,020	31,080	31,130	31,180	31,240	31,290	31,340	22
23	31,330	31,380	31,440	31,490	31,550	31,600	31,660	31,710	31,770	31,830	31,880	31,940	31,990	32,040	32,100	32,150	32,210	32,260	32,320	32,370	32,430	23
24	32,960	33,020	33,080	33,140	33,200	33,260	33,320	33,370	33,430	33,490	33,550	33,610	33,660	33,720	33,780	33,840	33,890	33,950	34,010	34,070	34,120	24
25	34,250	34,310	34,370	34,430	34,490	34,550	34,610	34,670	34,730	34,790	34,850	34,910	34,970	35,030	35,090	35,150	35,210	35,270	35,330	35,390	35,450	25
26	35,870	35,930	36,000	36,060	36,130	36,190	36,250	36,320	36,380	36,440	36,510	36,570	36,630	36,700	36,760	36,820	36,880	36,950	37,010	37,070	37,130	26
27	37,060	37,120	37,190	37,260	37,320	37,390	37,450	37,520	37,580	37,650	37,710	37,780	37,840	37,910	37,970	38,040	38,100	38,170	38,230	38,300	38,360	27
28	38,720	38,790	38,850	38,920	38,990	39,060	39,130	39,200	39,270	39,330	39,400	39,470	39,540	39,610	39,670	39,740	39,810	39,880	39,940	40,010	40,080	28
29	39,720	39,790	39,860	39,930	40,000	40,070	40,140	40,220	40,290	40,360	40,420	40,490	40,560	40,630	40,700	40,770	40,840	40,910	40,980	41,050	41,120	29
30	41,350	41,430	41,500	41,570	41,650	41,720	41,790	41,870	41,940	42,010	42,090	42,160	42,230	42,300	42,380	42,450	42,520	42,590	42,660	42,730	42,810	30
31	42,410	42,480	42,560	42,630	42,710	42,780	42,860	42,930	43,010	43,080	43,160	43,230	43,310	43,380	43,450	43,530	43,600	43,670	43,750	43,820	43,890	31
32	44,040	44,120	44,200	44,280	44,360	44,440	44,510	44,590	44,670	44,750	44,830	44,900	44,980	45,060	45,130	45,210	45,290	45,360	45,440	45,520	45,590	32
33	45,290	45,370	45,450	45,530	45,620	45,700	45,780	45,860	45,940	46,020	46,090	46,170	46,250	46,330	46,410	46,490	46,570	46,650	46,730	46,800	46,880	33
34	46,890	46,980	47,060	47,150	47,230	47,310	47,400	47,480	47,560	47,640	47,730	47,810	47,890	47,970	48,050	48,140	48,220	48,300	48,380	48,460	48,540	34
35	47,960	48,050	48,130	48,220	48,300	48,390	48,470	48,560	48,640	48,730	48,810	48,900	48,980	49,060	49,150	49,230	49,310	49,400	49,480	49,560	49,650	35
36	49,570	49,660	49,750	49,840	49,930	50,020	50,100	50,190	50,280	50,370	50,450	50,540	50,630	50,710	50,800	50,890	50,970	51,060	51,140	51,230	51,320	36
37	50,500	50,590	50,680	50,770	50,850	50,940	51,030	51,120	51,210	51,300	51,390	51,480	51,570	51,650	51,740	51,830	51,920	52,010	52,090	52,180	52,270	37
38	52,140	52,230	52,330	52,420	52,510	52,600	52,700	52,790	52,880	52,970	53,060	53,160	53,250	53,340	53,430	53,520	53,610	53,700	53,790	53,880	53,970	38
39	53,550	53,650	53,740	53,840	53,930	54,030	54,120	54,220	54,310	54,410	54,500	54,600	54,690	54,780	54,880	54,970	55,060	55,160	55,250	55,340	55,430	39
40	55,200	55,300	55,400	55,500	55,600	55,700	55,790	55,890	55,990	56,090	56,180	56,280	56,380	56,470	56,570	56,670	56,760	56,860	56,950	57,050	57,140	40
41	57,760	57,860	57,960	58,070	58,170	58,270	58,380	58,480	58,580	58,680	58,790	58,890	58,990	59,090	59,190	59,290	59,390	59,490	59,600	59,700	59,800	41
42	60,220	60,330	60,440	60,550	60,660	60,760	60,870	60,980	61,090	61,190	61,300	61,410	61,510	61,620	61,730	61,830	61,940	62,040	62,150	62,250	62,360	42
43	63,660	63,780	63,900	64,010	64,120	64,240	64,350	64,470	64,580	64,700	64,810	64,920	65,040	65,150	65,260	65,370	65,490	65,600	65,710	65,820	65,930	43
44	66,220	66,340	66,460	66,580	66,700	66,820	66,940	67,060	67,180	67,300	67,420	67,540	67,650	67,770	67,890	68,010	68,120	68,240	68,360	68,480	68,590	44
45	68,700	68,820	68,950	69,070	69,200	69,320	69,440	69,570	69,690	69,810	69,940	70,060	70,180	70,310	70,430	70,550	70,670	70,790	70,920	71,040	71,160	45
46	71,160	71,290	71,420	71,550	71,680	71,810	71,940	72,070	72,200	72,320	72,450	72,580	72,710	72,840	72,960	73,090	73,220	73,340	73,470	73,600	73,720	46
47	74,600	74,740	74,880	75,010	75,150	75,290	75,420	75,560	75,690	75,830	75,960	76,100	76,230	76,360	76,500	76,630	76,770	76,900	77,030	77,160	77,300	47
48	77,060	77,200	77,340	77,490	77,630	77,770	77,910	78,050	78,190	78,330	78,470	78,610	78,750	78,880	79,020	79,160	79,300	79,440	79,570	79,710	79,850	48
49	79,500	79,650	79,790	79,940	80,090	80,230	80,380	80,520	80,670	80,810	80,950	81,100	81,240	81,390	81,530	81,670	81,810	81,960	82,100	82,240	82,380	49
50	82,040	82,200	82,350	82,500	82,650	82,800	82,950	83,100	83,250	83,400	83,550	83,700	83,840	83,990	84,140	84,290	84,440	84,580	84,730	84,880	85,020	50
51	84,510	84,670	84,820	84,980	85,130	85,290	85,440	85,600	85,750	85,910	86,060	86,220	86,370	86,520	86,670	86,830	86,980	87,130	87,280	87,430	87,580	51
52	87,060	87,220	87,380	87,540	87,700	87,860	88,020	88,180	88,340	88,500	88,660	88,820	88,980	89,130	89,290	89,450	89,610	89,760	89,920	90,070	90,230	52
53	89,620	89,780	89,950	90,120	90,280	90,450	90,610	90,780	90,940	91,100	91,270	91,430	91,590	91,760	91,920	92,080	92,240	92,410	92,570	92,730	92,890	53
54	92,170	92,350	92,520	92,690	92,860	93,030	93,200	93,370	93,540	93,710	93,870	94,040	94,210	94,380	94,550	94,710	94,880	95,050	95,210	95,380	95,540	54
55	94,730	94,910	95,080	95,260	95,430	95,610	95,780	95,960	96,130	96,310	96,480	96,650	96,830	97,000	97,170	97,340	97,520	97,690	97,860	98,030	98,200	55

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	742.0	742.1	742.2	742.3	742.4	742.5	742.6	742.7	742.8	742.9	743.0	743.1	743.2	743.3	743.4	743.5	743.6	743.7	743.8	743.9	744.0	
56	97,200	97,380	97,560	97,740	97,920	98,100	98,280	98,460	98,640	98,820	99,000	99,180	99,350	99,530	99,710	99,890	100,100	100,200	100,400	100,600	100,800	56
57	99,670	99,860	100,000	100,200	100,400	100,600	100,800	101,000	101,200	101,300	101,500	101,700	101,900	102,100	102,200	102,400	102,600	102,800	103,000	103,200	103,300	57
58	102,200	102,400	102,600	102,700	102,900	103,100	103,300	103,500	103,700	103,900	104,100	104,300	104,400	104,600	104,800	105,000	105,200	105,400	105,600	105,700	105,900	58
59	104,600	104,800	105,000	105,200	105,400	105,600	105,800	106,000	106,200	106,400	106,600	106,800	107,000	107,200	107,400	107,500	107,700	107,900	108,100	108,300	108,500	59
60	107,200	107,400	107,600	107,800	108,000	108,200	108,400	108,600	108,800	109,000	109,200	109,400	109,600	109,800	110,000	110,200	110,400	110,600	110,800	111,000	111,100	60
61	112,400	112,600	112,800	113,000	113,200	113,400	113,600	113,900	114,100	114,300	114,500	114,700	114,900	115,100	115,300	115,500	115,700	115,900	116,100	116,300	116,500	61
62	117,600	117,800	118,000	118,300	118,500	118,700	118,900	119,200	119,400	119,600	119,800	120,000	120,300	120,500	120,700	120,900	121,100	121,300	121,600	121,800	122,000	62
63	122,800	123,000	123,200	123,500	123,700	123,900	124,200	124,400	124,600	124,900	125,100	125,300	125,500	125,800	126,000	126,200	126,500	126,700	126,900	127,100	127,400	63
64	128,000	128,300	128,500	128,700	129,000	129,200	129,500	129,700	130,000	130,200	130,400	130,700	130,900	131,200	131,400	131,600	131,900	132,100	132,400	132,600	132,800	64
65	132,200	132,500	132,700	133,000	133,200	133,500	133,700	134,000	134,300	134,500	134,800	135,000	135,300	135,500	135,800	136,000	136,200	136,500	136,700	137,000	137,200	65
66	137,400	137,600	137,900	138,200	138,400	138,700	139,000	139,200	139,500	139,800	140,000	140,300	140,500	140,800	141,100	141,300	141,600	141,800	142,100	142,400	142,600	66
67	141,600	141,900	142,200	142,400	142,700	143,000	143,300	143,500	143,800	144,100	144,400	144,600	144,900	145,200	145,400	145,700	146,000	146,200	146,500	146,800	147,000	67
68	146,800	147,100	147,400	147,700	148,000	148,300	148,500	148,800	149,100	149,400	149,700	150,000	150,200	150,500	150,800	151,100	151,400	151,600	151,900	152,200	152,500	68
69	151,900	152,200	152,500	152,800	153,100	153,400	153,700	154,000	154,300	154,600	154,900	155,200	155,500	155,800	156,000	156,300	156,600	156,900	157,200	157,500	157,800	69
70	157,100	157,400	157,800	158,100	158,400	158,700	159,000	159,300	159,600	159,900	160,200	160,500	160,800	161,100	161,400	161,700	162,000	162,300	162,600	162,900	163,200	70
71	163,700	164,000	164,300	164,600	164,900	165,300	165,600	165,900	166,200	166,600	166,900	167,200	167,500	167,800	168,100	168,500	168,800	169,100	169,400	169,700	170,000	71
72	170,200	170,500	170,800	171,200	171,500	171,900	172,200	172,500	172,900	173,200	173,500	173,900	174,200	174,500	174,900	175,200	175,500	175,900	176,200	176,500	176,900	72
73	176,600	177,000	177,300	177,700	178,100	178,400	178,800	179,100	179,500	179,800	180,200	180,500	180,900	181,200	181,600	181,900	182,300	182,600	182,900	183,300	183,600	73
74	183,100	183,500	183,900	184,200	184,600	185,000	185,400	185,700	186,100	186,500	186,800	187,200	187,500	187,900	188,300	188,600	189,000	189,400	189,700	190,100	190,400	74
75	189,600	190,000	190,300	190,700	191,100	191,500	191,900	192,300	192,600	193,000	193,400	193,800	194,200	194,500	194,900	195,300	195,700	196,100	196,400	196,800	197,200	75
76	196,100	196,500	196,900	197,300	197,700	198,100	198,500	198,900	199,300	199,700	200,100	200,500	200,900	201,300	201,700	202,100	202,400	202,800	203,200	203,600	204,000	76
77	202,700	203,100	203,500	203,900	204,400	204,800	205,200	205,600	206,000	206,400	206,800	207,300	207,700	208,100	208,500	208,900	209,300	209,700	210,100	210,500	210,900	77
78	209,300	209,700	210,100	210,600	211,000	211,400	211,900	212,300	212,700	213,100	213,600	214,000	214,400	214,900	215,300	215,700	216,100	216,500	217,000	217,400	217,800	78
79	215,600	216,000	216,500	216,900	217,400	217,800	218,300	218,700	219,200	219,600	220,100	220,500	221,000	221,400	221,800	222,300	222,700	223,200	223,600	224,000	224,500	79
80	221,700	222,100	222,600	223,100	223,500	224,000	224,500	224,900	225,400	225,900	226,300	226,800	227,200	227,700	228,200	228,600	229,100	229,500	230,000	230,400	230,900	80
81	227,800	228,300	228,800	229,300	229,800	230,300	230,700	231,200	231,700	232,200	232,700	233,100	233,600	234,100	234,600	235,000	235,500	236,000	236,500	236,900	237,400	81
82	233,900	234,400	234,900	235,400	235,900	236,400	236,900	237,400	237,900	238,400	238,900	239,400	239,900	240,400	240,900	241,400	241,900	242,400	242,900	243,300	243,800	82
83	240,000	240,500	241,000	241,500	242,000	242,500	243,100	243,600	244,100	244,600	245,100	245,600	246,100	246,700	247,200	247,700	248,200	248,700	249,200	249,700	250,200	83
84	246,100	246,600	247,200	247,700	248,200	248,800	249,300	249,800	250,400	250,900	251,400	252,000	252,500	253,000	253,500	254,100	254,600	255,100	255,600	256,100	256,700	84
85	252,300	252,800	253,400	253,900	254,500	255,000	255,600	256,100	256,700	257,200	257,800	258,300	258,900	259,400	260,000	260,500	261,000	261,600	262,100	262,600	263,200	85
86	261,500	262,000	262,600	263,200	263,800	264,400	264,900	265,500	266,100	266,700	267,200	267,800	268,400	268,900	269,500	270,100	270,600	271,200	271,800	272,300	272,900	86
87	269,900	270,500	271,100	271,700	272,400	273,000	273,600	274,200	274,800	275,400	276,000	276,600	277,200	277,800	278,400	279,000	279,600	280,200	280,800	281,300	281,900	87
88	281,400	282,000	282,700	283,300	284,000	284,600	285,300	285,900	286,600	287,200	287,800	288,500	289,100	289,800	290,400	291,000	291,700	292,300	292,900	293,600	294,200	88
89	289,700	290,400	291,100	291,700	292,400	293,100	293,800	294,500	295,100	295,800	296,500	297,100	297,800	298,500	299,100	299,800	300,500	301,100	301,800	302,500	303,100	89
90	298,200	298,900	299,600	300,300	301,000	301,700	302,400	303,100	303,800	304,500	305,300	306,000	306,700	307,300	308,000	308,700	309,400	310,100	310,800	311,500	312,200	90
91	306,600	307,400	308,100	308,900	309,600	310,400	311,100	311,800	312,600	313,300	314,000	314,800	315,500	316,200	317,000	317,700	318,400	319,100	319,900	320,600	321,300	91
92	315,300	316,100	316,800	317,600	318,400	319,100	319,900	320,600	321,400	322,100	322,900	323,600	324,400	325,100	325,900	326,600	327,400	328,100	328,800	329,600	330,300	92
93	324,300	325,100	325,800	326,600	327,300	328,100	328,800	329,600	330,300	331,100	331,800	332,600	333,300	334,000	334,800	335,500	336,200	336,900	337,700	338,400	339,200	93
94	333,200	333,900	334,700	335,400	336,200	336,900	337,600	338,400	339,100	339,900	340,600	341,300	342,000	342,800	343,500	344,200	345,000	345,700	346,400	347,200	348,000	94
95	344,600	345,400	346,100	346,900	347,600	348,300	349,100	349,800	350,500	351,200	351,900	352,600	353,400	354,100	354,900	355,600	356,400	357,200	357,900	358,700	359,500	95
96	356,300	357,000	357,700	358,500	359,200	359,900	360,600	361,300	362,000	362,700	363,400	364,100	364,900	365,600	366,400	367,200	368,000	368,700	369,500	370,300	371,200	96
97	371,100	372,100	373,100	374,100	374,900	375,600	376,300	377,000	377,700	378,400	379,100	379,800	380,500	381,100	381,700	382,300	382,900	383,500	384,100	384,700	385,400	97
98	391,200	392,600	394,100	395,600	396,700	397,400	398,000	398,600	399,200	399,800	400,300	400,800	401,200	401,400	401,700	402,100	402,400	402,700	403,000	403,400	403,800	98
99	412,900	414,800	416,800	418,700	420,100	421,000	421,800	422,600	423,400	424,100	424,900	425,200	425,300	425,300	425,300	425,400	425,400	425,500	425,500	425,500	425,600	99
100	427,600	429,900	432,300	434,600	436,200	437,400	438,500	439,500	440,500	441,500	442,400	443,000	443,300	443,200	443,200	443,200	443,200	443,200	443,200	443,100	443,100	100
101	427,600	429,900	432,300	434,600	436,200	437,400	438,500	439,500	440,500	441,500	442,400	443,200	443,800	444,300	444,900	445,600	446,200	446,800	447,400	448,000	448,700	101
102	427,600	429,900	432,300	434,600	436,500	438,100	439,600	441,000	442,500	443,900	445,400	446,700	448,000	449,100	450,300	451,500	452,700	453,900	455,100	456,400	457,600	102
103	427,600	429,900	432,300	434,600	436,700	438,600	440,500	442,400	444,300	446,200	448,100	450,000	451,900	453,700	455,500	457,300	459,100	460,900	462,700	464,600	466,400	103
104	427,600	429,900	432,300	434,600	436,900	439,300	441,600	444,000	446,400	448,700	451,100	453,500	455,900	458,300	460,700	463,100	465,500	467,900	470,300	472,700	475,200	104
105	437,200	439,600	441,900	444,300	446,700	449,000	451,400	453,800	456,200	458,600	461,000	463,400	465,800	468,200	470,600	473,000	475,500	477,900	480,400	482,800	485,300	105
106	446,300	448,600	451,000	453,400	455,800	458,200	460,600	463,000	465,400	467,800	470,200	472,700	475,100	477,600	480,000	482,400	484,900	487,400	489,800	492,300	494,800	106
107	454,500	457,000	459,400	461,800	464,200	466,600	469,100	471,500	473,900	476,400	478,800	481,300	483,800	486,200	488,700	491,200	493,700	496,200	498,700	501,200	503,700	107
108	463,200	465,600	468,000	470,400	472,800	475,200	477,700	480,100	482,500	485,000	487,400	489,900	492,300	494,800	497,300	499,800	502,300	504,800	507,300	509,800	512,400	108
109	475,000	477,700	480,400	483,100	485,700	488,100	490,400	492,700	495,000	497,200	499,500	501,800	504,100	506,300	508,600	511,000	513,300	515,700	518,000	520,400	522,800	109
110	475,000	477,700	480,400	483,100	485,800	488,500	491,200	493,900	496,600	499,400	502,100	504,800	507,600	510,300	513,100	515,900	518,700	521,400	524,200	527,000	529,800	110

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	744.0	744.1	744.2	744.3	744.4	744.5	744.6	744.7	744.8	744.9	745.0	745.1	745.2	745.3	745.4	745.5	745.6	745.7	745.8	745.9	746.0	
1	920	920	930	930	930	930	930	930	930													1
2	2, 610	2, 610	2, 620	2, 620	2, 620	2, 630	2, 630	2, 640	2, 640													2
3	4, 030	4, 040	4, 050	4, 050	4, 060	4, 070	4, 070	4, 080	4, 090													3
4	5, 720	5, 730	5, 740	5, 750	5, 760	5, 770	5, 780	5, 790	5, 800													4
5	7, 040	7, 050	7, 070	7, 080	7, 090	7, 100	7, 110	7, 120	7, 140													5
6	8, 730	8, 750	8, 760	8, 780	8, 790	8, 800	8, 820	8, 830	8, 850													6
7	10, 050	10, 070	10, 090	10, 100	10, 120	10, 140	10, 150	10, 170	10, 190													7
8	11, 740	11, 760	11, 780	11, 800	11, 820	11, 840	11, 860	11, 880	11, 900													8
9	12, 940	12, 960	12, 980	13, 000	13, 020	13, 040	13, 070	13, 090	13, 110													9
10	14, 630	14, 660	14, 680	14, 710	14, 730	14, 750	14, 780	14, 800	14, 830													10
11	15, 900	15, 930	15, 950	15, 980	16, 010	16, 030	16, 060	16, 090	16, 110													11
12	17, 610	17, 640	17, 670	17, 700	17, 730	17, 760	17, 790	17, 820	17, 850													12
13	18, 670	18, 700	18, 730	18, 760	18, 790	18, 820	18, 850	18, 880	18, 910													13
14	20, 340	20, 380	20, 410	20, 450	20, 480	20, 510	20, 550	20, 580	20, 610													14
15	21, 480	21, 520	21, 560	21, 590	21, 630	21, 660	21, 700	21, 730	21, 770													15
16	23, 180	23, 220	23, 260	23, 300	23, 340	23, 370	23, 410	23, 450	23, 490													16
17	24, 240	24, 280	24, 320	24, 360	24, 400	24, 440	24, 480	24, 520	24, 560													17
18	25, 910	25, 960	26, 000	26, 040	26, 080	26, 130	26, 170	26, 210	26, 260													18
19	26, 990	27, 030	27, 080	27, 120	27, 170	27, 210	27, 250	27, 300	27, 340													19
20	28, 620	28, 660	28, 710	28, 760	28, 810	28, 850	28, 900	28, 950	29, 000													20
21	29, 650	29, 700	29, 750	29, 800	29, 850	29, 900	29, 950	30, 000	30, 040													21
22	31, 340	31, 390	31, 440	31, 500	31, 550	31, 600	31, 650	31, 700	31, 760													22
23	32, 430	32, 480	32, 530	32, 590	32, 640	32, 700	32, 750	32, 800	32, 860													23
24	34, 120	34, 180	34, 240	34, 290	34, 350	34, 410	34, 460	34, 520	34, 580													24
25	35, 450	35, 510	35, 570	35, 630	35, 680	35, 740	35, 800	35, 860	35, 920													25
26	37, 130	37, 190	37, 260	37, 320	37, 380	37, 440	37, 500	37, 560	37, 620													26
27	38, 360	38, 420	38, 490	38, 550	38, 620	38, 680	38, 740	38, 810	38, 870													27
28	40, 080	40, 140	40, 210	40, 280	40, 340	40, 410	40, 480	40, 540	40, 610													28
29	41, 120	41, 190	41, 250	41, 320	41, 390	41, 460	41, 530	41, 590	41, 660													29
30	42, 810	42, 880	42, 950	43, 020	43, 090	43, 160	43, 230	43, 300	43, 370													30
31	43, 890	43, 970	44, 040	44, 110	44, 190	44, 260	44, 330	44, 400	44, 480													31
32	45, 590	45, 670	45, 740	45, 820	45, 900	45, 970	46, 050	46, 120	46, 200													32
33	46, 880	46, 960	47, 040	47, 120	47, 190	47, 270	47, 350	47, 430	47, 500													33
34	48, 540	48, 620	48, 700	48, 790	48, 870	48, 950	49, 030	49, 110	49, 190													34
35	49, 650	49, 730	49, 810	49, 890	49, 980	50, 060	50, 140	50, 220	50, 300													35
36	51, 320	51, 400	51, 490	51, 570	51, 660	51, 740	51, 830	51, 910	52, 000													36
37	52, 270	52, 360	52, 440	52, 530	52, 620	52, 700	52, 790	52, 880	52, 960													37
38	53, 970	54, 060	54, 150	54, 240	54, 330	54, 420	54, 510	54, 600	54, 690													38
39	55, 430	55, 530	55, 620	55, 710	55, 800	55, 890	55, 990	56, 080	56, 170	56, 260	56, 350	56, 440	56, 530	56, 620	56, 710	56, 800	56, 890	56, 980	57, 070	57, 160		39
40	57, 140	57, 240	57, 340	57, 430	57, 530	57, 620	57, 710	57, 810	57, 900	58, 000	58, 090	58, 180	58, 280	58, 370	58, 460	58, 560	58, 650	58, 740	58, 840	58, 930	59, 020	40
41	59, 800	59, 900	60, 000	60, 100	60, 200	60, 300	60, 390	60, 490	60, 590	60, 690	60, 790	60, 890	60, 990	61, 090	61, 180	61, 280	61, 380	61, 480	61, 570	61, 670	61, 770	41
42	62, 360	62, 460	62, 570	62, 670	62, 780	62, 880	62, 980	63, 090	63, 190	63, 300	63, 400	63, 500	63, 600	63, 710	63, 810	63, 910	64, 010	64, 120	64, 220	64, 320	64, 420	42
43	65, 930	66, 050	66, 160	66, 270	66, 380	66, 490	66, 600	66, 710	66, 820	66, 930	67, 040	67, 150	67, 260	67, 370	67, 480	67, 590	67, 690	67, 800	67, 910	68, 020	68, 130	43
44	68, 590	68, 710	68, 820	68, 940	69, 060	69, 170	69, 290	69, 400	69, 520	69, 630	69, 750	69, 860	69, 970	70, 090	70, 200	70, 320	70, 430	70, 540	70, 660	70, 770	70, 880	44
45	71, 160	71, 280	71, 400	71, 520	71, 640	71, 760	71, 880	72, 000	72, 120	72, 240	72, 360	72, 480	72, 600	72, 720	72, 830	72, 950	73, 070	73, 190	73, 310	73, 420	73, 540	45
46	73, 720	73, 850	73, 970	74, 100	74, 220	74, 350	74, 470	74, 600	74, 720	74, 840	74, 970	75, 090	75, 210	75, 340	75, 460	75, 580	75, 710	75, 830	75, 950	76, 070	76, 190	46
47	77, 300	77, 430	77, 560	77, 690	77, 820	77, 950	78, 090	78, 220	78, 350	78, 480	78, 610	78, 740	78, 870	79, 000	79, 130	79, 260	79, 380	79, 510	79, 640	79, 770	79, 900	47
48	79, 850	79, 980	80, 120	80, 260	80, 390	80, 530	80, 670	80, 800	80, 940	81, 070	81, 210	81, 340	81, 470	81, 610	81, 740	81, 880	82, 010	82, 140	82, 280	82, 410	82, 540	48
49	82, 380	82, 520	82, 660	82, 810	82, 950	83, 090	83, 230	83, 370	83, 510	83, 650	83, 790	83, 920	84, 060	84, 200	84, 340	84, 480	84, 620	84, 750	84, 890	85, 030	85, 170	49
50	85, 020	85, 170	85, 310	85, 460	85, 610	85, 750	85, 900	86, 040	86, 190	86, 330	86, 470	86, 620	86, 760	86, 900	87, 050	87, 190	87, 330	87, 470	87, 620	87, 760	87, 900	50
51	87, 580	87, 740	87, 890	88, 040	88, 190	88, 340	88, 490	88, 640	88, 780	88, 930	89, 080	89, 230	89, 380	89, 530	89, 670	89, 820	89, 970	90, 110	90, 260	90, 410	90, 550	51
52	90, 230	90, 390	90, 540	90, 700	90, 850	91, 010	91, 160	91, 320	91, 470	91, 620	91, 780	91, 930	92, 080	92, 230	92, 390	92, 540	92, 690	92, 840	92, 990	93, 140	93, 300	52
53	92, 890	93, 050	93, 210	93, 370	93, 530	93, 690	93, 850	94, 010	94, 170	94, 320	94, 480	94, 640	94, 800	94, 960	95, 110	95, 270	95, 430	95, 580	95, 740	95, 890	96, 050	53
54	95, 540	95, 710	95, 880	96, 040	96, 200	96, 370	96, 530	96, 700	96, 860	97, 020	97, 190	97, 350	97, 510	97, 670	97, 840	98, 000	98, 160	98, 320	98, 480	98, 640	98, 800	54
55	98, 200	98, 370	98, 540	98, 710	98, 880	99, 050	99, 220	99, 390	99, 550	99, 720	99, 890	100, 100	100, 200	100, 400	100, 600	100, 700	100, 900	101, 100	101, 200	101, 400	101, 600	55

See special instruction for preventing gate overflow on page 2.

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	744.0	744.1	744.2	744.3	744.4	744.5	744.6	744.7	744.8	744.9	745.0	745.1	745.2	745.3	745.4	745.5	745.6	745.7	745.8	745.9	746.0	
56	100,800	100,900	101,100	101,300	101,500	101,600	101,800	102,000	102,200	102,300	102,500	102,700	102,800	103,000	103,200	103,400	103,500	103,700	103,900	104,000	104,200	56
57	103,300	103,500	103,700	103,900	104,000	104,200	104,400	104,600	104,800	104,900	105,100	105,300	105,500	105,600	105,800	106,000	106,200	106,300	106,500	106,700	106,900	57
58	105,900	106,100	106,300	106,500	106,700	106,900	107,000	107,200	107,400	107,600	107,800	107,900	108,100	108,300	108,500	108,700	108,800	109,000	109,200	109,400	109,600	58
59	108,500	108,700	108,900	109,100	109,300	109,400	109,600	109,800	110,000	110,200	110,400	110,600	110,700	110,900	111,100	111,300	111,500	111,700	111,900	112,000	112,200	59
60	111,100	111,300	111,500	111,700	111,900	112,100	112,300	112,500	112,700	112,900	113,100	113,300	113,500	113,600	113,800	114,000	114,200	114,400	114,600	114,800	115,000	60
61	116,500	116,800	117,000	117,200	117,400	117,600	117,800	118,000	118,200	118,400	118,600	118,800	119,000	119,200	119,400	119,600	119,800	120,000	120,200	120,400	120,600	61
62	122,000	122,200	122,400	122,600	122,900	123,100	123,300	123,500	123,700	123,900	124,100	124,300	124,600	124,800	125,000	125,200	125,400	125,600	125,800	126,000	126,200	62
63	127,400	127,600	127,800	128,100	128,300	128,500	128,700	128,900	129,200	129,400	129,600	129,800	130,100	130,300	130,500	130,700	130,900	131,200	131,400	131,600	131,800	63
64	132,800	133,100	133,300	133,500	133,800	134,000	134,300	134,500	134,700	135,000	135,200	135,400	135,700	135,900	136,100	136,400	136,600	136,800	137,000	137,300	137,500	64
65	137,200	137,500	137,700	138,000	138,200	138,500	138,700	138,900	139,200	139,400	139,700	139,900	140,200	140,400	140,600	140,900	141,100	141,400	141,600	141,800	142,100	65
66	142,600	142,900	143,100	143,400	143,600	143,900	144,100	144,400	144,700	144,900	145,200	145,400	145,700	145,900	146,200	146,400	146,700	146,900	147,200	147,400	147,700	66
67	147,000	147,300	147,600	147,800	148,100	148,400	148,600	148,900	149,100	149,400	149,700	149,900	150,200	150,400	150,700	151,000	151,200	151,500	151,700	152,000	152,200	67
68	152,500	152,700	153,000	153,300	153,600	153,800	154,100	154,400	154,700	154,900	155,200	155,500	155,700	156,000	156,300	156,600	156,800	157,100	157,400	157,600	157,900	68
69	157,800	158,100	158,400	158,600	158,900	159,200	159,500	159,800	160,100	160,300	160,600	160,900	161,200	161,500	161,700	162,000	162,300	162,600	162,900	163,100	163,400	69
70	163,200	163,500	163,800	164,100	164,400	164,700	165,000	165,300	165,600	165,900	166,100	166,400	166,700	167,000	167,300	167,600	167,900	168,200	168,500	168,800	169,000	70
71	170,000	170,300	170,700	171,000	171,300	171,600	171,900	172,200	172,500	172,800	173,100	173,400	173,700	174,000	174,400	174,700	175,000	175,300	175,600	175,900	176,200	71
72	176,900	177,200	177,500	177,800	178,200	178,500	178,800	179,100	179,500	179,800	180,100	180,400	180,700	181,100	181,400	181,700	182,000	182,300	182,700	183,000	183,300	72
73	183,600	184,000	184,300	184,700	185,000	185,300	185,700	186,000	186,400	186,700	187,000	187,400	187,700	188,000	188,400	188,700	189,000	189,400	189,700	190,000	190,400	73
74	190,400	190,800	191,100	191,500	191,900	192,200	192,600	192,900	193,300	193,600	194,000	194,300	194,700	195,000	195,400	195,700	196,100	196,400	196,800	197,100	197,500	74
75	197,200	197,500	197,900	198,300	198,700	199,000	199,400	199,800	200,100	200,500	200,900	201,200	201,600	202,000	202,300	202,700	203,100	203,400	203,800	204,100	204,500	75
76	204,000	204,400	204,800	205,200	205,600	205,900	206,300	206,700	207,100	207,500	207,900	208,200	208,600	209,000	209,400	209,800	210,100	210,500	210,900	211,300	211,600	76
77	210,900	211,300	211,700	212,100	212,500	212,900	213,300	213,700	214,100	214,500	214,900	215,300	215,700	216,100	216,500	216,900	217,300	217,700	218,100	218,500	218,800	77
78	217,800	218,200	218,600	219,100	219,500	219,900	220,300	220,700	221,100	221,500	222,000	222,400	222,800	223,200	223,600	224,000	224,400	224,800	225,200	225,600	226,000	78
79	224,500	224,900	225,300	225,800	226,200	226,600	227,100	227,500	227,900	228,400	228,800	229,200	229,600	230,100	230,500	230,900	231,300	231,800	232,200	232,600	233,000	79
80	230,900	231,300	231,800	232,200	232,700	233,100	233,600	234,000	234,500	234,900	235,400	235,800	236,200	236,700	237,100	237,600	238,000	238,400	238,900	239,300	239,700	80
81	237,400	237,900	238,300	238,800	239,300	239,700	240,200	240,700	241,100	241,600	242,000	242,500	243,000	243,400	243,900	244,300	244,800	245,200	245,700	246,100	246,600	81
82	243,800	244,300	244,800	245,300	245,800	246,200	246,700	247,200	247,700	248,200	248,600	249,100	249,600	250,100	250,500	251,000	251,500	251,900	252,400	252,900	253,300	82
83	250,200	250,700	251,200	251,700	252,200	252,700	253,200	253,700	254,200	254,700	255,100	255,600	256,100	256,600	257,100	257,600	258,100	258,600	259,100	259,500	260,000	83
84	256,700	257,200	257,700	258,200	258,700	259,200	259,800	260,300	260,800	261,300	261,800	262,300	262,800	263,300	263,800	264,300	264,800	265,300	265,800	266,300	266,800	84
85	263,200	263,700	264,200	264,800	265,300	265,800	266,400	266,900	267,400	267,900	268,500	269,000	269,500	270,000	270,600	271,100	271,600	272,100	272,600	273,100	273,700	85
86	272,900	273,400	274,000	274,600	275,100	275,700	276,200	276,800	277,300	277,900	278,400	279,000	279,500	280,100	280,600	281,100	281,700	282,200	282,800	283,300	283,800	86
87	281,900	282,500	283,100	283,700	284,300	284,900	285,400	286,000	286,600	287,200	287,700	288,300	288,900	289,500	290,000	290,600	291,200	291,700	292,300	292,900	293,400	87
88	294,200	294,800	295,400	296,100	296,700	297,300	297,900	298,500	299,100	299,700	300,400	301,000	301,600	302,200	302,800	303,400	304,000	304,600	305,200	305,800	306,400	88
89	303,100	303,800	304,400	305,100	305,700	306,300	307,000	307,600	308,300	308,900	309,500	310,200	310,800	311,400	312,100	312,700	313,300	313,900	314,600	315,200	315,800	89
90	312,200	312,900	313,600	314,200	314,900	315,600	316,200	316,900	317,600	318,200	318,900	319,600	320,200	320,900	321,500	322,200	322,800	323,500	324,100	324,800	325,400	90
91	321,300	322,000	322,700	323,400	324,100	324,800	325,500	326,200	326,900	327,600	328,300	329,000	329,600	330,300	331,000	331,700	332,400	333,100	333,700	334,400	335,100	91
92	330,300	331,000	331,800	332,500	333,200	334,000	334,700	335,400	336,100	336,800	337,500	338,300	339,000	339,700	340,400	341,100	341,800	342,500	343,200	343,900	344,600	92
93	339,200	339,900	340,700	341,400	342,200	342,900	343,700	344,400	345,100	345,900	346,600	347,300	348,100	348,800	349,500	350,300	351,000	351,700	352,400	353,100	353,900	93
94	348,000	348,700	349,500	350,300	351,000	351,800	352,600	353,300	354,100	354,900	355,600	356,400	357,100	357,900	358,600	359,400	360,100	360,900	361,600	362,300	363,100	94
95	359,500	360,300	361,100	361,900	362,700	363,500	364,300	365,100	365,900	366,700	367,500	368,200	369,000	369,800	370,600	371,400	372,100	372,900	373,700	374,500	375,200	95
96	371,200	372,000	372,800	373,700	374,500	375,300	376,100	377,000	377,800	378,600	379,400	380,200	381,000	381,800	382,700	383,500	384,300	385,100	385,900	386,700	387,500	96
97	385,400	386,100	386,700	387,400	388,100	388,900	389,700	390,400	391,200	391,900	392,700	393,500	394,200	395,000	395,800	396,600	397,400	398,200	399,000	399,800	400,600	97
98	403,800	404,100	404,500	404,900	405,500	406,100	406,800	407,500	408,200	408,900	409,600	410,300	411,000	411,800	412,600	413,400	414,200	415,000	415,700	416,500	417,300	98
99	425,600	425,700	425,800	425,900	426,200	426,700	427,300	427,800	428,300	428,800	429,300	430,000	430,700	431,500	432,300	433,100	433,800	434,600	435,400	436,100	436,900	99
100	443,100	443,000	443,000	443,100	443,400	443,900	444,400	444,900	445,400	445,900	446,400	447,000	447,700	448,600	449,400	450,300	451,200	452,000	452,900	453,700	454,600	100
101	448,700	449,300	449,900	450,600	451,500	452,500	453,700	454,800	455,900	457,000	458,100	459,300	460,500	461,800	463,100	464,400	465,600	466,900	468,200	469,500	470,700	101
102	457,600	458,800	460,000	461,300	462,700	464,200	465,700	467,300	468,900	470,400	472,000	473,600	475,200	476,900	478,600	480,300	482,000	483,600	485,300	487,000	488,700	102
103	466,400	468,200	470,000	471,900	473,800	475,800	477,900	479,900	481,900	483,900	485,900	488,000	490,000	492,100	494,200	496,300	498,400	500,500	502,600	504,700	506,800	103
104	475,200	477,600	480,100	482,500	485,000	487,400	489,900	492,400	494,800	497,300	499,800	502,300	504,800	507,300	509,800	512,300	514,800	517,300	519,900	522,400	525,000	104
105	485,300	487,700	490,200	492,600	495,100	497,600	500,100	502,600	505,100	507,600	510,100	512,600	515,100	517,600	520,200	522,700	525,300	527,800	530,300	532,900	535,500	105
106	494,800	497,300	499,800	502,200	504,700	507,300	509,800	512,300	514,800	517,300	519,900	522,400	524,900	527,500	530,000	532,600	535,200	537,700	540,300	542,900	545,500	106
107	503,700	506,200	508,700	511,200	513,800	516,300	518,800	521,400	523,900	526,500	529,000	531,600	534,200	536,700	539,300	541,900	544,500	547,100	549,700	552,300	554,900	107
108	512,400	514,900	517,400	520,000	522,500	525,100	527,600	530,200	532,800	535,300	537,900	540,500	543,100	545,700	548,300	550,900	553,500	556,100	558,700	561,400	564,000	108
109	522,800	525,100	527,500	529,900	532,300	534,800	537,300	539,900	542,400	545,000	547,600	550,200	552,700	555,300	557,900	560,500	563,100	565,700	568,300	570,900	573,500	109
110	529,800	532,600	535,400	538,300	541,100	543,900	546,800	549,600	552,500	555,300	558,200	561,100	564,000	566,800	569,700	572,600	575,500	578,400	581,400	584,300	587,200	110

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	746.0	746.1	746.2	746.3	746.4	746.5	746.6	746.7	746.8	746.9	747.0	747.1	747.2	747.3	747.4	747.5	747.6	747.7	747.8	747.9	748.0	
36																						36
37																						37
38																						38
39																						39
40	59,020	59,110	59,210	59,300	59,390	59,480	59,570	59,660	59,760													40
41	61,770	61,870	61,960	62,060	62,160	62,250	62,350	62,440	62,540													41
42	64,420	64,520	64,620	64,730	64,830	64,930	65,030	65,130	65,230													42
43	68,130	68,230	68,340	68,450	68,560	68,660	68,770	68,880	68,980													43
44	70,880	70,990	71,110	71,220	71,330	71,440	71,550	71,660	71,780													44
45	73,540	73,660	73,770	73,890	74,010	74,120	74,240	74,360	74,470													45
46	76,190	76,310	76,440	76,560	76,680	76,800	76,920	77,040	77,160													46
47	79,900	80,030	80,150	80,280	80,410	80,540	80,660	80,790	80,920													47
48	82,540	82,670	82,810	82,940	83,070	83,200	83,330	83,460	83,590													48
49	85,170	85,300	85,440	85,570	85,710	85,850	85,980	86,120	86,250													49
50	87,900	88,040	88,180	88,320	88,460	88,610	88,750	88,890	89,030													50
51	90,550	90,700	90,850	90,990	91,140	91,280	91,430	91,570	91,710													51
52	93,300	93,450	93,600	93,750	93,900	94,050	94,200	94,340	94,490													52
53	96,050	96,200	96,360	96,510	96,670	96,820	96,980	97,130	97,280													53
54	98,800	98,960	99,120	99,280	99,440	99,600	99,760	99,920	100,100													54
55	101,600	101,700	101,900	102,000	102,200	102,400	102,500	102,700	102,900													55
56	104,200	104,400	104,500	104,700	104,900	105,100	105,200	105,400	105,600													56
57	106,900	107,000	107,200	107,400	107,600	107,700	107,900	108,100	108,200													57
58	109,600	109,700	109,900	110,100	110,300	110,400	110,600	110,800	111,000													58
59	112,200	112,400	112,600	112,800	112,900	113,100	113,300	113,500	113,700	113,900	114,000	114,200	114,400									59
60	115,000	115,200	115,300	115,500	115,700	115,900	116,100	116,300	116,500	116,600	116,800	117,000	117,200	117,400	117,600	117,700	117,900	118,100	118,300	118,500	118,700	60
61	120,600	120,800	121,000	121,200	121,400	121,600	121,800	122,000	122,100	122,300	122,500	122,700	122,900	123,100	123,300	123,500	123,700	123,900	124,100	124,300	124,500	61
62	126,200	126,400	126,600	126,900	127,100	127,300	127,500	127,700	127,900	128,100	128,300	128,500	128,700	128,900	129,100	129,300	129,500	129,700	129,900	130,100	130,300	62
63	131,800	132,000	132,300	132,500	132,700	132,900	133,100	133,300	133,600	133,800	134,000	134,200	134,400	134,600	134,900	135,100	135,300	135,500	135,700	135,900	136,100	63
64	137,500	137,700	138,000	138,200	138,400	138,600	138,900	139,100	139,300	139,600	139,800	140,000	140,200	140,500	140,700	140,900	141,100	141,300	141,600	141,800	142,000	64
65	142,100	142,300	142,500	142,800	143,000	143,300	143,500	143,700	144,000	144,200	144,400	144,700	144,900	145,100	145,400	145,600	145,800	146,100	146,300	146,500	146,700	65
66	147,700	147,900	148,200	148,400	148,600	148,900	149,100	149,400	149,600	149,900	150,100	150,400	150,600	150,800	151,100	151,300	151,600	151,800	152,100	152,300	152,500	66
67	152,200	152,500	152,800	153,000	153,300	153,500	153,800	154,000	154,300	154,500	154,800	155,000	155,300	155,500	155,800	156,000	156,300	156,500	156,800	157,000	157,300	67
68	157,900	158,200	158,400	158,700	159,000	159,200	159,500	159,700	160,000	160,300	160,500	160,800	161,100	161,300	161,600	161,800	162,100	162,400	162,600	162,900	163,100	68
69	163,400	163,700	164,000	164,200	164,500	164,800	165,100	165,300	165,600	165,900	166,200	166,400	166,700	167,000	167,200	167,500	167,800	168,100	168,300	168,600	168,900	69
70	169,000	169,300	169,600	169,900	170,200	170,500	170,800	171,000	171,300	171,600	171,900	172,200	172,500	172,700	173,000	173,300	173,600	173,900	174,100	174,400	174,700	70
71	176,200	176,500	176,800	177,100	177,400	177,700	178,000	178,300	178,600	178,900	179,200	179,500	179,800	180,100	180,300	180,600	180,900	181,200	181,500	181,800	182,100	71
72	183,300	183,600	183,900	184,200	184,600	184,900	185,200	185,500	185,800	186,100	186,400	186,700	187,100	187,400	187,700	188,000	188,300	188,600	188,900	189,200	189,500	72
73	190,400	190,700	191,000	191,400	191,700	192,000	192,300	192,700	193,000	193,300	193,600	194,000	194,300	194,600	194,900	195,300	195,600	195,900	196,200	196,600	196,900	73
74	197,500	197,800	198,200	198,500	198,800	199,200	199,500	199,900	200,200	200,500	200,900	201,200	201,600	201,900	202,200	202,600	202,900	203,200	203,600	203,900	204,300	74
75	204,500	204,900	205,200	205,600	205,900	206,300	206,600	207,000	207,400	207,700	208,100	208,400	208,800	209,100	209,500	209,800	210,200	210,500	210,900	211,200	211,600	75
76	211,600	212,000	212,400	212,800	213,100	213,500	213,900	214,200	214,600	215,000	215,300	215,700	216,100	216,400	216,800	217,200	217,500	217,900	218,300	218,600	219,000	76
77	218,800	219,200	219,600	220,000	220,400	220,800	221,200	221,600	221,900	222,300	222,700	223,100	223,500	223,800	224,200	224,600	225,000	225,400	225,700	226,100	226,500	77
78	226,000	226,400	226,800	227,200	227,600	228,000	228,400	228,800	229,200	229,600	230,000	230,400	230,800	231,200	231,600	232,000	232,400	232,800	233,200	233,600	234,000	78
79	233,000	233,400	233,900	234,300	234,700	235,100	235,500	235,900	236,300	236,800	237,200	237,600	238,000	238,400	238,800	239,200	239,600	240,000	240,400	240,800	241,300	79
80	239,700	240,200	240,600	241,000	241,500	241,900	242,300	242,800	243,200	243,600	244,100	244,500	244,900	245,300	245,800	246,200	246,600	247,000	247,500	247,900	248,300	80
81	246,600	247,000	247,500	247,900	248,400	248,800	249,300	249,700	250,200	250,600	251,100	251,500	251,900	252,400	252,800	253,300	253,700	254,100	254,600	255,000	255,500	81
82	253,300	253,800	254,300	254,700	255,200	255,700	256,100	256,600	257,100	257,500	258,000	258,400	258,900	259,300	259,800	260,300	260,700	261,200	261,600	262,100	262,500	82
83	260,000	260,500	261,000	261,500	261,900	262,400	262,900	263,400	263,800	264,300	264,800	265,300	265,700	266,200	266,700	267,200	267,600	268,100	268,600	269,000	269,500	83
84	266,800	267,300	267,800	268,300	268,800	269,300	269,800	270,300	270,800	271,300	271,800	272,200	272,700	273,200	273,700	274,200	274,700	275,200	275,600	276,100	276,600	84
85	273,700	274,200	274,700	275,200	275,700	276,200	276,700	277,200	277,700	278,200	278,700	279,300	279,800	280,300	280,800	281,300	281,800	282,300	282,800	283,300	283,700	85
86	283,800	284,400	284,900	285,500	286,000	286,500	287,100	287,600	288,100	288,600	289,200	289,700	290,200	290,700	291,300	291,800	292,300	292,800	293,400	293,900	294,400	86
87	293,400	294,000	294,600	295,100	295,700	296,200	296,800	297,300	297,900	298,500	299,000	299,600	300,100	300,700	301,200	301,800	302,300	302,900	303,400	303,900	304,500	87
88	306,400	307,000	307,600	308,200	308,800	309,300	309,900	310,500	311,100	311,700	312,300	312,900	313,500	314,000	314,600	315,200	315,800	316,400	316,900	317,500	318,100	88
89	315,800	316,400	317,100	317,700	318,300	318,900	319,500	320,100	320,800	321,400	322,000	322,600	323,200	323,800	324,400	325,000	325,600	326,200	326,800	327,400	328,000	89
90	325,400	326,100	326,700	327,400	328,000	328,700	329,300	329,900	330,600	331,200	331,900	332,500	333,100	333,700	334,400	335,000	335,600	336,300	336,900	337,500	338,100	90

See special instruction for preventing gate overflow on page 2.

WATTS BAR DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	746.0	746.1	746.2	746.3	746.4	746.5	746.6	746.7	746.8	746.9	747.0	747.1	747.2	747.3	747.4	747.5	747.6	747.7	747.8	747.9	748.0	
91	335, 100	335, 800	336, 400	337, 100	337, 800	338, 400	339, 100	339, 800	340, 400	341, 100	341, 800	342, 400	343, 100	343, 700	344, 400	345, 000	345, 700	346, 300	347, 000	347, 600	348, 300	91
92	344, 600	345, 300	346, 000	346, 700	347, 400	348, 100	348, 800	349, 400	350, 100	350, 800	351, 500	352, 200	352, 900	353, 500	354, 200	354, 900	355, 600	356, 300	356, 900	357, 600	358, 300	92
93	353, 900	354, 600	355, 300	356, 000	356, 700	357, 400	358, 100	358, 900	359, 600	360, 300	361, 000	361, 700	362, 400	363, 100	363, 800	364, 500	365, 200	365, 800	366, 500	367, 200	367, 900	93
94	363, 100	363, 800	364, 600	365, 300	366, 000	366, 800	367, 500	368, 200	368, 900	369, 700	370, 400	371, 100	371, 800	372, 500	373, 300	374, 000	374, 700	375, 400	376, 100	376, 800	377, 500	94
95	375, 200	376, 000	376, 700	377, 500	378, 300	379, 000	379, 800	380, 500	381, 300	382, 000	382, 800	383, 500	384, 300	385, 000	385, 800	386, 500	387, 300	388, 000	388, 700	389, 500	390, 200	95
96	387, 500	388, 200	389, 000	389, 800	390, 600	391, 400	392, 200	393, 000	393, 700	394, 500	395, 300	396, 100	396, 800	397, 600	398, 400	399, 200	399, 900	400, 700	401, 400	402, 200	403, 000	96
97	400, 600	401, 400	402, 200	403, 000	403, 700	404, 500	405, 300	406, 100	406, 800	407, 600	408, 400	409, 100	409, 900	410, 700	411, 400	412, 200	413, 000	413, 800	414, 500	415, 300	416, 100	97
98	417, 300	418, 000	418, 800	419, 600	420, 300	421, 100	421, 800	422, 600	423, 300	424, 100	424, 800	425, 600	426, 300	427, 000	427, 800	428, 600	429, 400	430, 200	431, 000	431, 800	432, 500	98
99	436, 900	437, 600	438, 400	439, 100	439, 900	440, 600	441, 400	442, 100	442, 800	443, 500	444, 300	445, 000	445, 700	446, 400	447, 200	448, 000	448, 800	449, 600	450, 400	451, 100	451, 900	99
100	454, 600	455, 400	456, 300	457, 100	457, 900	458, 800	459, 600	460, 400	461, 200	462, 100	462, 900	463, 700	464, 500	465, 300	466, 200	467, 100	468, 000	468, 900	469, 800	470, 600	471, 500	100
101	470, 700	472, 000	473, 300	474, 500	475, 800	477, 100	478, 300	479, 600	480, 800	482, 100	483, 400	484, 600	485, 900	487, 100	488, 400	489, 800	491, 100	492, 500	493, 800	495, 200	496, 600	101
102	488, 700	490, 400	492, 100	493, 800	495, 500	497, 200	498, 800	500, 500	502, 200	503, 900	505, 600	507, 300	509, 000	510, 700	512, 500	514, 200	516, 000	517, 800	519, 600	521, 300	523, 100	102
103	506, 800	508, 900	511, 100	513, 200	515, 300	517, 400	519, 600	521, 700	523, 800	526, 000	528, 100	530, 300	532, 400	534, 600	536, 800	539, 000	541, 200	543, 400	545, 600	547, 800	550, 000	103
104	525, 000	527, 500	530, 000	532, 600	535, 200	537, 700	540, 300	542, 900	545, 500	548, 100	550, 600	553, 200	555, 800	558, 500	561, 100	563, 700	566, 300	568, 900	571, 600	574, 200	576, 900	104
105	535, 500	538, 000	540, 600	543, 200	545, 800	548, 400	550, 900	553, 500	556, 100	558, 800	561, 400	564, 000	566, 600	569, 200	571, 900	574, 500	577, 200	579, 800	582, 500	585, 100	587, 800	105
106	545, 500	548, 100	550, 700	553, 300	555, 900	558, 500	561, 100	563, 700	566, 300	569, 000	571, 600	574, 200	576, 900	579, 500	582, 200	584, 900	587, 500	590, 200	592, 900	595, 600	598, 300	106
107	554, 900	557, 500	560, 100	562, 700	565, 400	568, 000	570, 700	573, 300	576, 000	578, 600	581, 300	583, 900	586, 600	589, 300	592, 000	594, 700	597, 300	600, 000	602, 700	605, 400	608, 200	107
108	564, 000	566, 600	569, 300	571, 900	574, 600	577, 200	579, 900	582, 600	585, 200	587, 900	590, 600	593, 300	596, 000	598, 700	601, 400	604, 100	606, 800	609, 500	612, 200	614, 900	617, 700	108
109	573, 500	576, 200	578, 800	581, 400	584, 100	586, 700	589, 400	592, 000	594, 700	597, 300	600, 000	602, 700	605, 300	608, 000	610, 700	613, 400	616, 100	618, 900	621, 600	624, 400	627, 100	109
110	587, 200	590, 200	593, 100	596, 100	599, 000	602, 000	604, 900	607, 900	610, 900	613, 900	616, 900	619, 900	622, 900	625, 900	628, 900	631, 900	635, 000	638, 000	641, 000	644, 100	647, 100	110

WATTS BAR DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	748.0	748.1	748.2	748.3	748.4	748.5	748.6	748.7	748.8	748.9	749.0	749.1	749.2	749.3	749.4	749.5	749.6	749.7	749.8	749.9	750.0	
56																						56
57																						57
58																						58
59																						59
60	118,700	118,800	119,000	119,200	119,400	119,600	119,700	119,900														60
61	124,500	124,700	124,900	125,000	125,200	125,400	125,600	125,800														61
62	130,300	130,500	130,700	130,900	131,100	131,300	131,500	131,700														62
63	136,100	136,300	136,600	136,800	137,000	137,200	137,400	137,600														63
64	142,000	142,200	142,500	142,700	142,900	143,100	143,300	143,600														64
65	146,700	147,000	147,200	147,400	147,700	147,900	148,100	148,300														65
66	152,500	152,800	153,000	153,300	153,500	153,700	154,000	154,200														66
67	157,300	157,500	157,800	158,000	158,300	158,500	158,800	159,000														67
68	163,100	163,400	163,700	163,900	164,200	164,400	164,700	164,900														68
69	168,900	169,100	169,400	169,700	169,900	170,200	170,500	170,700														69
70	174,700	175,000	175,300	175,500	175,800	176,100	176,400	176,600	176,900	177,200	177,500	177,700	178,000	178,300	178,500	178,800	179,100	179,400	179,600	179,900	180,200	70
71	182,100	182,400	182,700	183,000	183,300	183,600	183,900	184,100	184,400	184,700	185,000	185,300	185,600	185,900	186,200	186,400	186,700	187,000	187,300	187,600	187,900	71
72	189,500	189,800	190,100	190,400	190,700	191,000	191,300	191,600	191,900	192,200	192,600	192,900	193,200	193,500	193,800	194,100	194,300	194,600	194,900	195,200	195,500	72
73	196,900	197,200	197,500	197,800	198,100	198,500	198,800	199,100	199,400	199,700	200,000	200,400	200,700	201,000	201,300	201,600	201,900	202,200	202,500	202,900	203,200	73
74	204,300	204,600	204,900	205,300	205,600	205,900	206,200	206,600	206,900	207,200	207,600	207,900	208,200	208,500	208,900	209,200	209,500	209,800	210,200	210,500	210,800	74
75	211,600	211,900	212,300	212,600	213,000	213,300	213,600	214,000	214,300	214,700	215,000	215,400	215,700	216,000	216,400	216,700	217,100	217,400	217,700	218,100	218,400	75
76	219,000	219,300	219,700	220,100	220,400	220,800	221,100	221,500	221,900	222,200	222,600	222,900	223,300	223,600	224,000	224,300	224,700	225,100	225,400	225,800	226,100	76
77	226,500	226,900	227,200	227,600	228,000	228,400	228,700	229,100	229,500	229,900	230,200	230,600	231,000	231,300	231,700	232,100	232,400	232,800	233,200	233,500	233,900	77
78	234,000	234,400	234,700	235,100	235,500	235,900	236,300	236,700	237,100	237,500	237,800	238,200	238,600	239,000	239,400	239,700	240,100	240,500	240,900	241,300	241,600	78
79	241,300	241,700	242,100	242,500	242,900	243,300	243,700	244,100	244,500	244,900	245,300	245,700	246,100	246,500	246,900	247,300	247,600	248,000	248,400	248,800	249,200	79
80	248,300	248,700	249,100	249,600	250,000	250,400	250,800	251,200	251,600	252,000	252,500	252,900	253,300	253,700	254,100	254,500	254,900	255,300	255,700	256,200	256,600	80
81	255,500	255,900	256,300	256,800	257,200	257,600	258,100	258,500	258,900	259,300	259,800	260,200	260,600	261,100	261,500	261,900	262,300	262,800	263,200	263,600	264,000	81
82	262,500	263,000	263,400	263,900	264,300	264,800	265,200	265,700	266,100	266,500	267,000	267,400	267,900	268,300	268,800	269,200	269,600	270,100	270,500	270,900	271,400	82
83	269,500	270,000	270,400	270,900	271,300	271,800	272,300	272,700	273,200	273,600	274,100	274,600	275,000	275,500	275,900	276,400	276,800	277,300	277,700	278,200	278,600	83
84	276,600	277,100	277,600	278,000	278,500	279,000	279,500	279,900	280,400	280,900	281,400	281,800	282,300	282,800	283,200	283,700	284,200	284,600	285,100	285,600	286,000	84
85	283,700	284,200	284,700	285,200	285,700	286,200	286,700	287,200	287,700	288,200	288,700	289,100	289,600	290,100	290,600	291,100	291,600	292,100	292,500	293,000	293,500	85
86	294,400	294,900	295,400	295,900	296,500	297,000	297,500	298,000	298,500	299,000	299,500	300,000	300,600	301,100	301,600	302,100	302,600	303,100	303,600	304,100	304,600	86
87	304,500	305,000	305,600	306,100	306,700	307,200	307,700	308,300	308,800	309,300	309,900	310,400	310,900	311,500	312,000	312,500	313,000	313,600	314,100	314,600	315,200	87
88	318,100	318,700	319,200	319,800	320,400	320,900	321,500	322,100	322,600	323,200	323,800	324,300	324,900	325,500	326,000	326,600	327,100	327,700	328,300	328,800	329,400	88
89	328,000	328,600	329,200	329,800	330,400	331,000	331,600	332,200	332,800	333,400	333,900	334,500	335,100	335,700	336,300	336,900	337,500	338,000	338,600	339,200	339,800	89
90	338,100	338,800	339,400	340,000	340,600	341,200	341,900	342,500	343,100	343,700	344,300	344,900	345,500	346,100	346,800	347,400	348,000	348,600	349,200	349,800	350,400	90
91	348,300	348,900	349,600	350,200	350,900	351,500	352,200	352,800	353,400	354,100	354,700	355,400	356,000	356,600	357,300	357,900	358,500	359,100	359,800	360,400	361,000	91
92	358,300	358,900	359,600	360,300	360,900	361,600	362,300	362,900	363,600	364,200	364,900	365,600	366,200	366,900	367,500	368,200	368,900	369,500	370,200	370,800	371,500	92
93	367,900	368,600	369,300	370,000	370,700	371,300	372,000	372,700	373,400	374,100	374,700	375,400	376,100	376,800	377,500	378,200	378,800	379,500	380,200	380,900	381,600	93
94	377,500	378,200	378,900	379,600	380,400	381,100	381,800	382,500	383,200	383,900	384,600	385,300	386,000	386,700	387,400	388,100	388,800	389,500	390,200	390,900	391,600	94
95	390,200	390,900	391,700	392,400	393,100	393,900	394,600	395,300	396,100	396,800	397,600	398,300	399,100	399,800	400,500	401,300	402,000	402,800	403,500	404,200	405,000	95
96	403,000	403,700	404,500	405,200	406,000	406,800	407,600	408,300	409,100	409,900	410,600	411,400	412,200	413,000	413,800	414,500	415,300	416,100	416,800	417,600	418,400	96
97	416,100	416,800	417,600	418,400	419,200	420,000	420,800	421,500	422,300	423,100	423,900	424,700	425,500	426,300	427,100	427,900	428,700	429,500	430,200	431,000	431,800	97
98	432,500	433,300	434,100	434,900	435,700	436,500	437,300	438,100	438,900	439,700	440,600	441,400	442,200	443,000	443,800	444,600	445,400	446,200	447,000	447,800	448,600	98
99	451,900	452,700	453,600	454,400	455,200	456,100	456,900	457,700	458,600	459,400	460,200	461,000	461,900	462,700	463,500	464,300	465,200	466,000	466,800	467,600	468,400	99
100	471,500	472,500	473,400	474,400	475,300	476,300	477,200	478,200	479,100	480,100	481,000	482,000	482,900	483,900	484,800	485,800	486,700	487,600	488,600	489,500	490,400	100
101	496,600	497,900	499,300	500,700	502,100	503,500	504,900	506,200	507,600	509,000	510,400	511,600	512,800	514,000	515,200	516,400	517,600	518,800	519,900	521,100	522,200	101
102	523,100	524,900	526,700	528,500	530,300	532,100	533,900	535,700	537,600	539,400	541,200	542,800	544,500	545,900	547,000	548,100	549,100	550,200	551,200	552,200	553,100	102
103	550,000	552,200	554,400	556,700	558,900	561,100	563,400	565,600	567,900	570,100	572,400	574,500	576,600	578,300	579,500	580,500	581,400	582,400	583,300	584,000	584,800	103
104	576,900	579,500	582,200	584,800	587,500	590,200	592,800	595,500	598,200	600,900	603,600	606,100	608,600	610,700	611,700	612,600	613,500	614,300	615,100	615,600	616,200	104
105	587,800	590,500	593,100	595,800	598,500	601,200	603,900	606,600	609,300	612,000	614,700	617,300	619,800	621,900	622,900	623,900	624,700	625,600	626,400	627,000	627,500	105
106	598,300	600,900	603,600	606,300	609,100	611,800	614,500	617,200	619,900	622,700	625,400	628,000	630,500	632,600	633,700	634,600	635,500	636,400	637,200	637,800	638,400	106
107	608,200	610,900	613,600	616,300	619,100	621,800	624,500	627,300	630,000	632,800	635,500	638,100	640,700	642,800	643,900	644,900	645,800	646,700	647,500	648,200	648,800	107
108	617,700	620,400	623,100	625,900	628,600	631,400	634,200	636,900	639,700	642,500	645,300	647,900	650,500	652,600	653,800	654,800	655,700	656,600	657,500	658,200	658,800	108
109	627,100	629,900	632,600	635,400	638,100	640,900	643,700	646,500	649,200	652,000	654,800	657,500	660,100	662,200	663,300	664,300	665,300	666,200	667,100	667,700	668,400	109
110	647,100	650,200	653,300	656,300	659,400	662,500	665,600	668,700	671,800	674,900	677,900	680,700	683,500	685,700	686,800	687,600	688,300	689,000	689,600	689,900	690,300	110

See special instruction for preventing gate overflow on page 2.

WATTS BAR DAM

TRASH GATE DISCHARGE

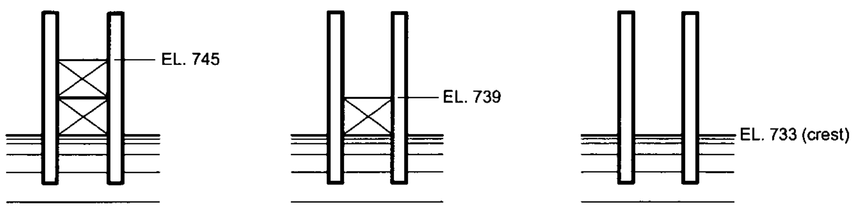
IN CUBIC FEET PER SECOND

TOP SECTION REMOVED					
HEADWATER ELEVATION	0	02	.4	.6	.8
739	0	10	15	30	40
740	60	75	95	110	140
741	160	180	210	240	260
742	290	320	350	380	420
743	450	480	520	550	590
744	630	660	700	740	780
745	820	870	910	950	990
746	1040	1080	1130	1180	1220
747	1270	1320	1370	1410	1460
748	1510	1570	1620	1670	1720
749	1770	1830	1880	1940	1990
750	2050				

TOP & BOTTOM SECTIONS INSTALLED					
HEADWATER ELEVATION	0	.2	.4	.6	.8
745	0	10	15	30	40
746	60	75	95	110	140
747	160	180	210	240	260
748	290	320	350	380	420
749	450	480	520	550	590
750	630				

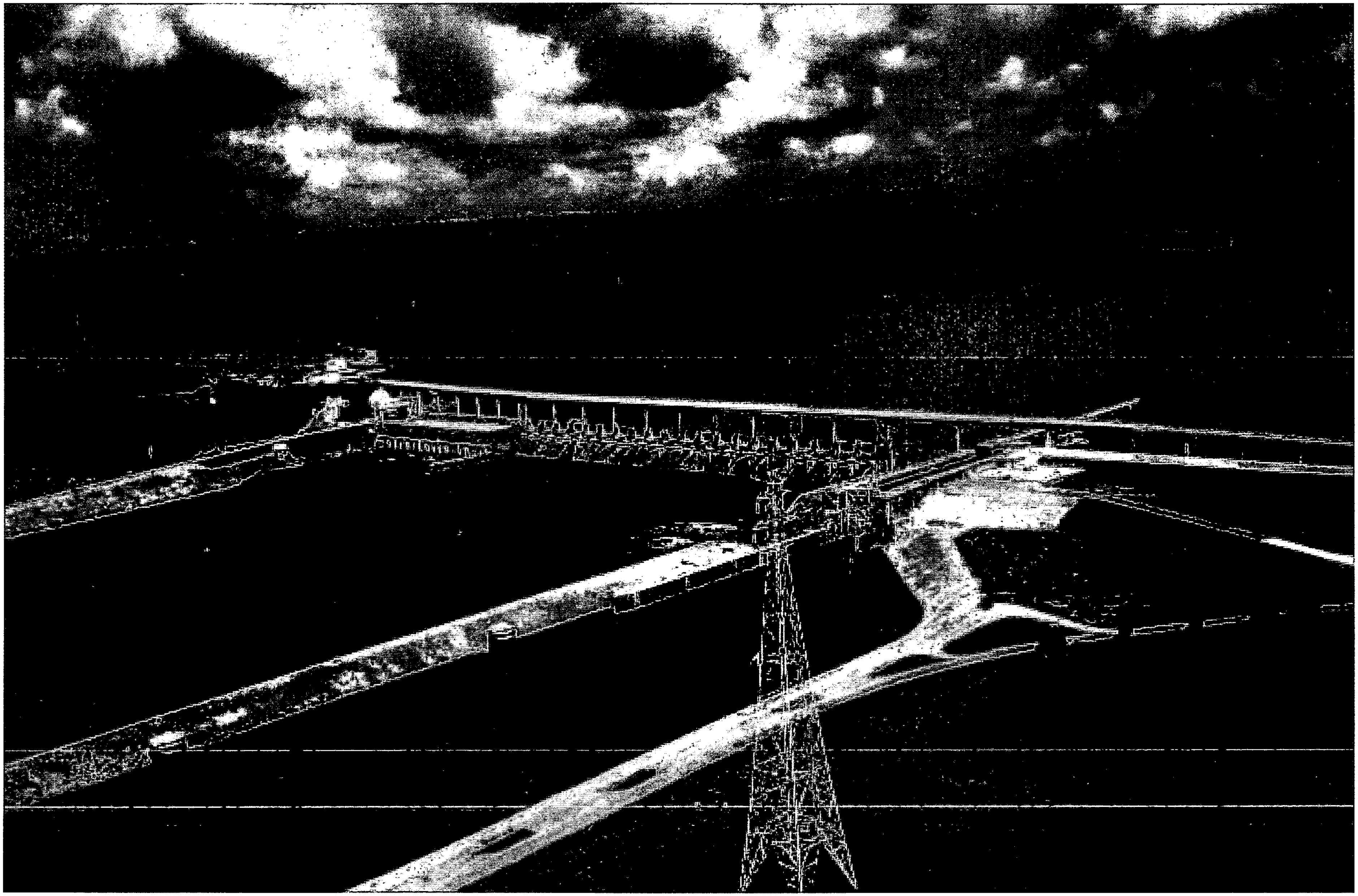
TOP & BOTTOM SECTIONS REMOVED					
HEADWATER ELEVATION	0	.2	.4	.6	.8
733	0	5	10	20	30
734	40	60	70	90	100
735	120	140	160	180	200
736	220	250	270	300	320
737	340	370	400	430	450
738	480	510	540	570	600
739	630	660	700	730	760
740	800	830	870	900	940
741	970	1010	1050	1080	1120
742	1160	1200	1240	1280	1320
743	1360	1400	1440	1480	1520
744	1570	1610	1650	1700	1740
745	1780	1830	1880	1920	1970
746	2010	2060	2110	2160	2200
747	2250	2300	2350	2400	2450
748	2500	2550	2600	2650	2700
749	2750	2800	2850	2900	2960
750	3010				

KEY



Top & Bottom Sections Installed — Top Section Removed — Top & Bottom Sections Removed

WATTS BAR DAM



July 1998

RESERVOIR OPERATION OVERVIEW

Watts Bar Dam is a multipurpose main river project, one of 9 such projects located on the Tennessee River which provide a navigable water way from the mouth of the river at Paducah, Kentucky, to the source of the river above Knoxville, Tennessee, some 652 river miles apart. Construction started in July, 1939, with the final hydroelectric unit being completed nearly 5 years later. In addition to serving as a vital navigation link on the Tennessee River, Watts Bar provides significant flood reduction benefits for downstream locations including Chattanoga, Tennessee, and also contributes hydroelectric generation.

Watts Bar lake is fed by releases from TVA's Fort Loudoun Dam and Melton Hill Dam , and on rare occasions, by spillway releases from TVA's Tellico Dam, in addition to unregulated inflows from the 1,790 square mile local drainage area.

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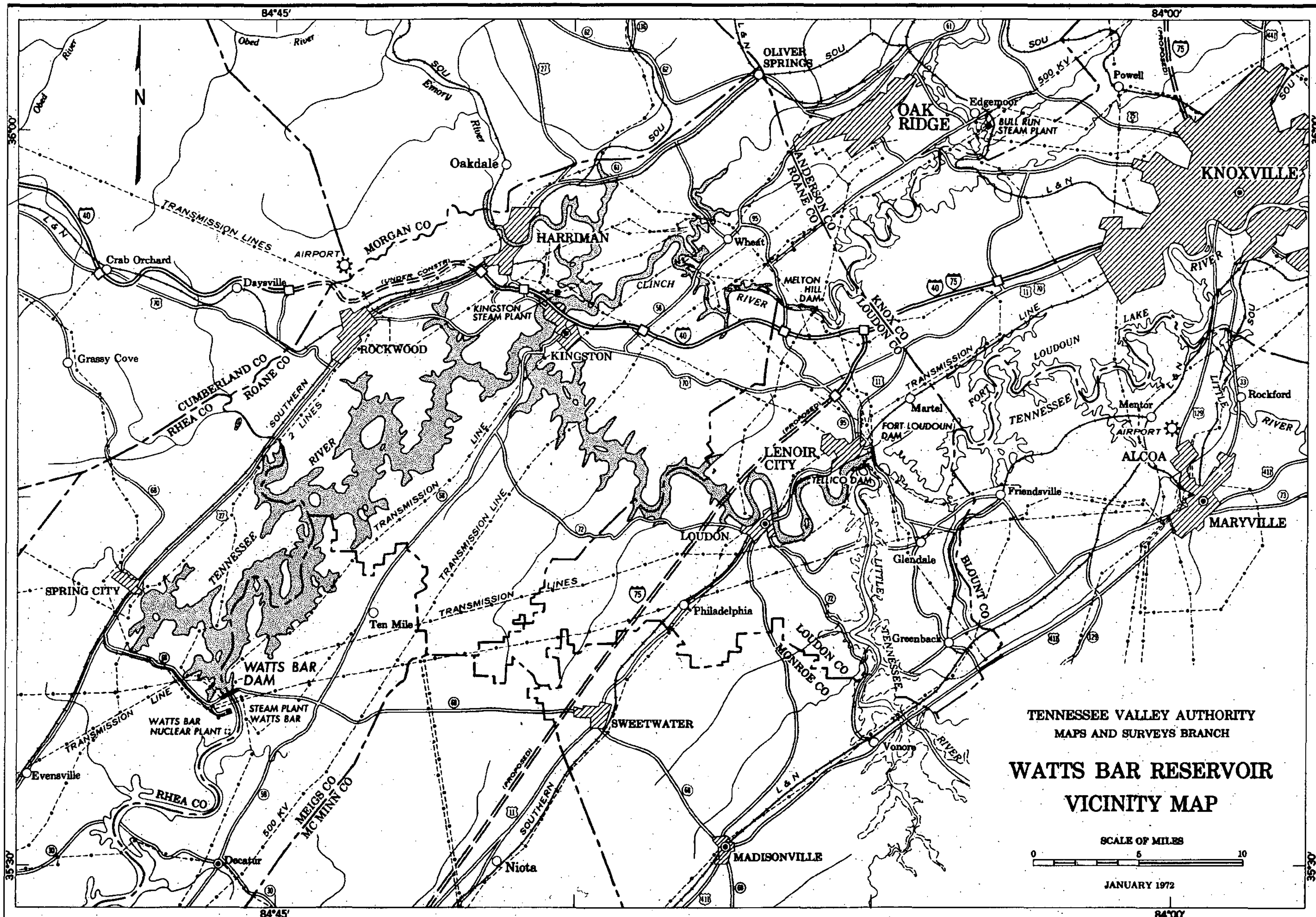

TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
WATTS BAR RESERVOIR
VICINITY MAP
SCALE OF MILES
JANUARY 1972
KNOXVILLE
OAK RIDGE
HARRIMAN
ROCKWOOD
KINGSTON
LENOIR CITY
LOUDON
MARYVILLE
ALCOA
SWEETWATER
MADISONVILLE
SPRING CITY
WATTS BAR DAM
WATTS BAR NUCLEAR PLANT
STEAM PLANT WATTS BAR
KINGSTON STEAM PLANT
BULL RUN STEAM PLANT
MELTON HILL DAM
FORT LOUDOUN DAM
TELLICO DAM
OLIVER SPRINGS
Oakdale
Crab Orchard
Daysville
Grassy Cove
Wheat
Edgemoor
Powell
Martel
Mentor
Rockford
Friendsville
Glendale
Greenback
Philadelphia
Ten Mile
Vonore
Niota
Decatur
Evensville
TRANSMISSION LINES
AIRPORT
MORGAN CO
CUMBERLAND CO
RHEA CO
ROANE CO
ANDERSON CO
KNOX CO
LOUDON CO
BLOUNT CO
MONROE CO
MEIGS CO
MC MINN CO
TENNESSEE RIVER
CLINCH RIVER
LITTLE TENNESSEE
LITTLE RIVER
FORT LOUDOUN LAKE
84°45′
84°00′
36°00′
35°30′

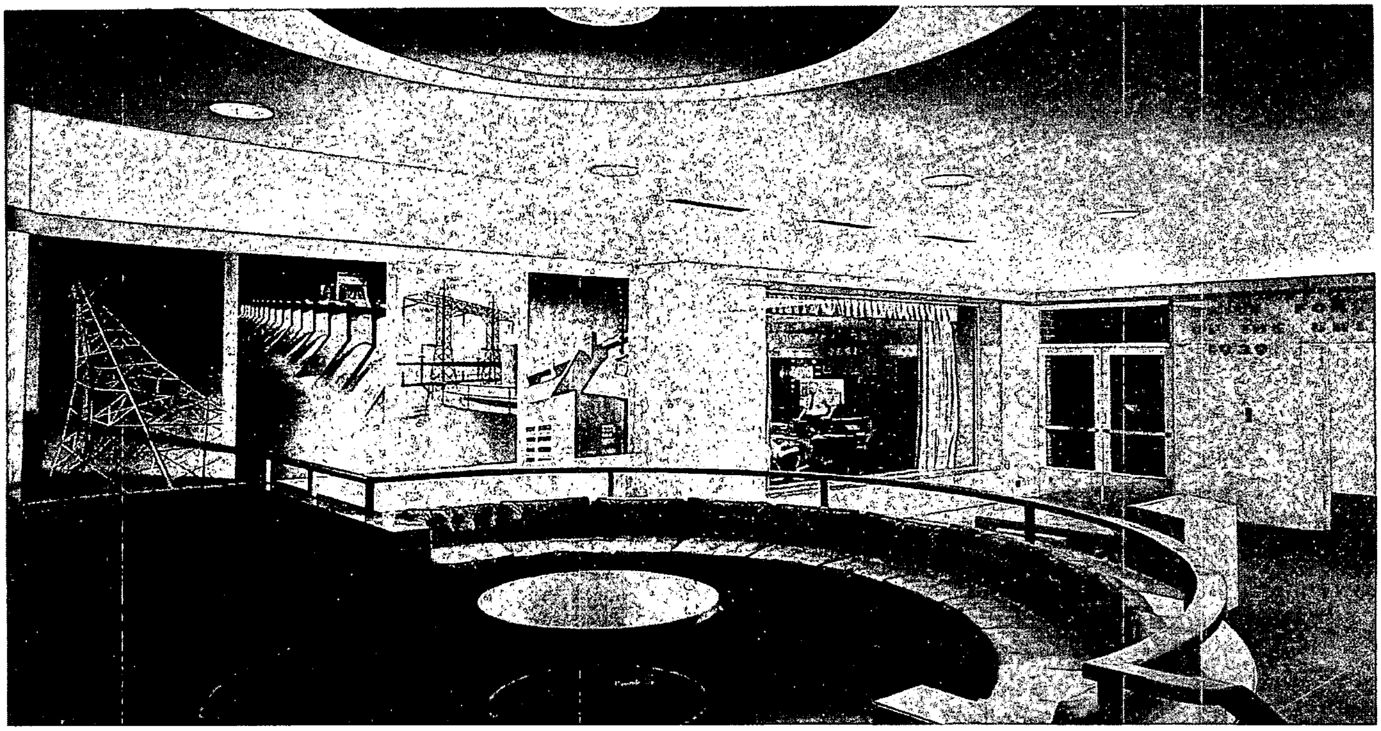


FIGURE 1: Visitors Reception Room in Control Building, 1944

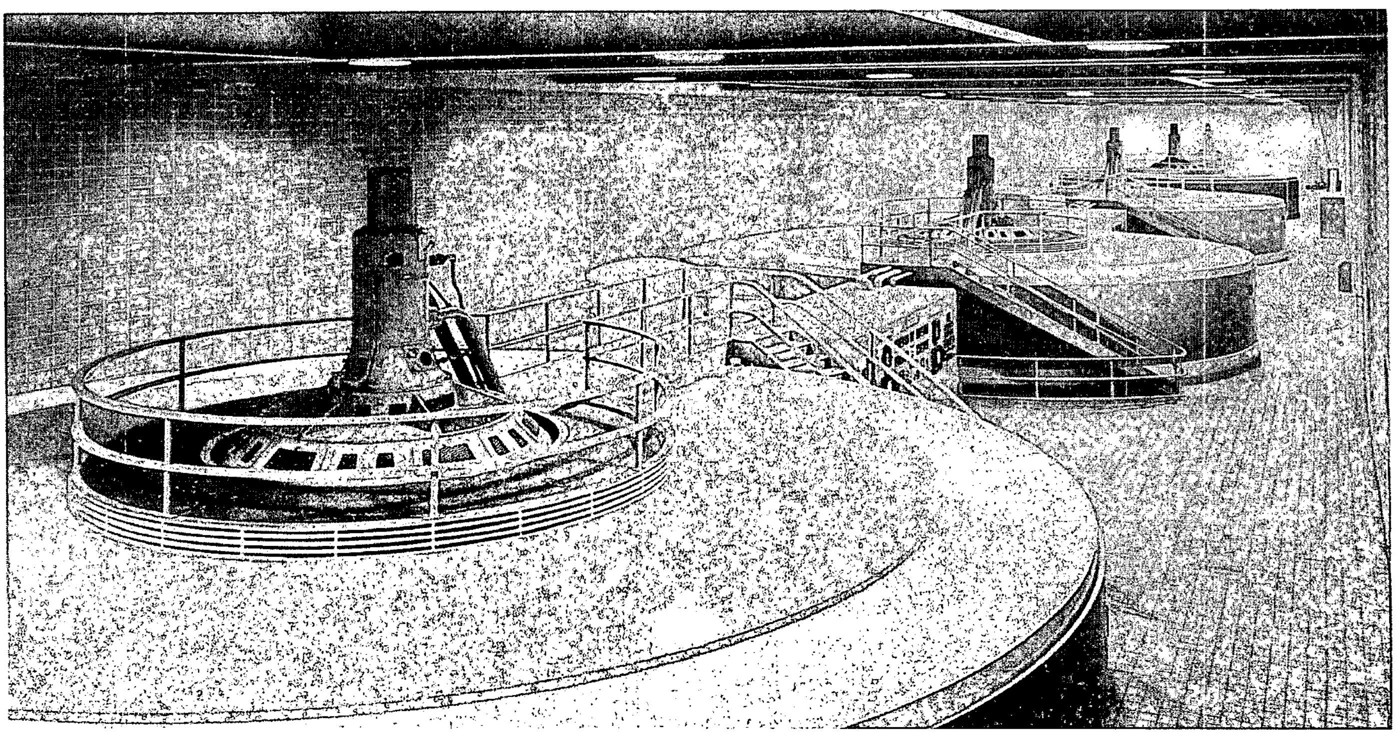


FIGURE 2: Generator Room, 1944

FIGURE 3: Plan and Downstream Elevation

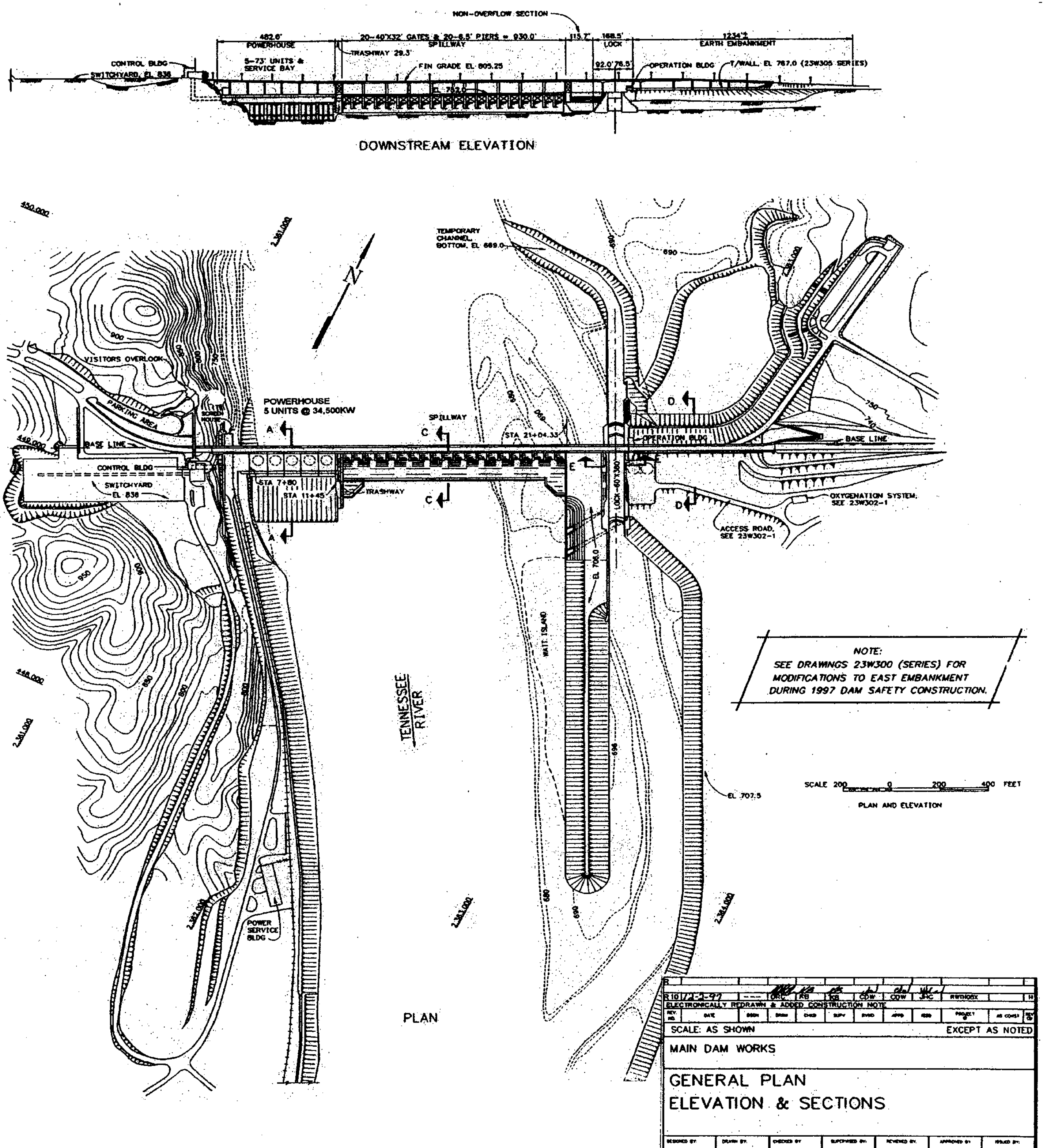


FIGURE 4: Sections A-A, C-C, D-D, and Site Plan

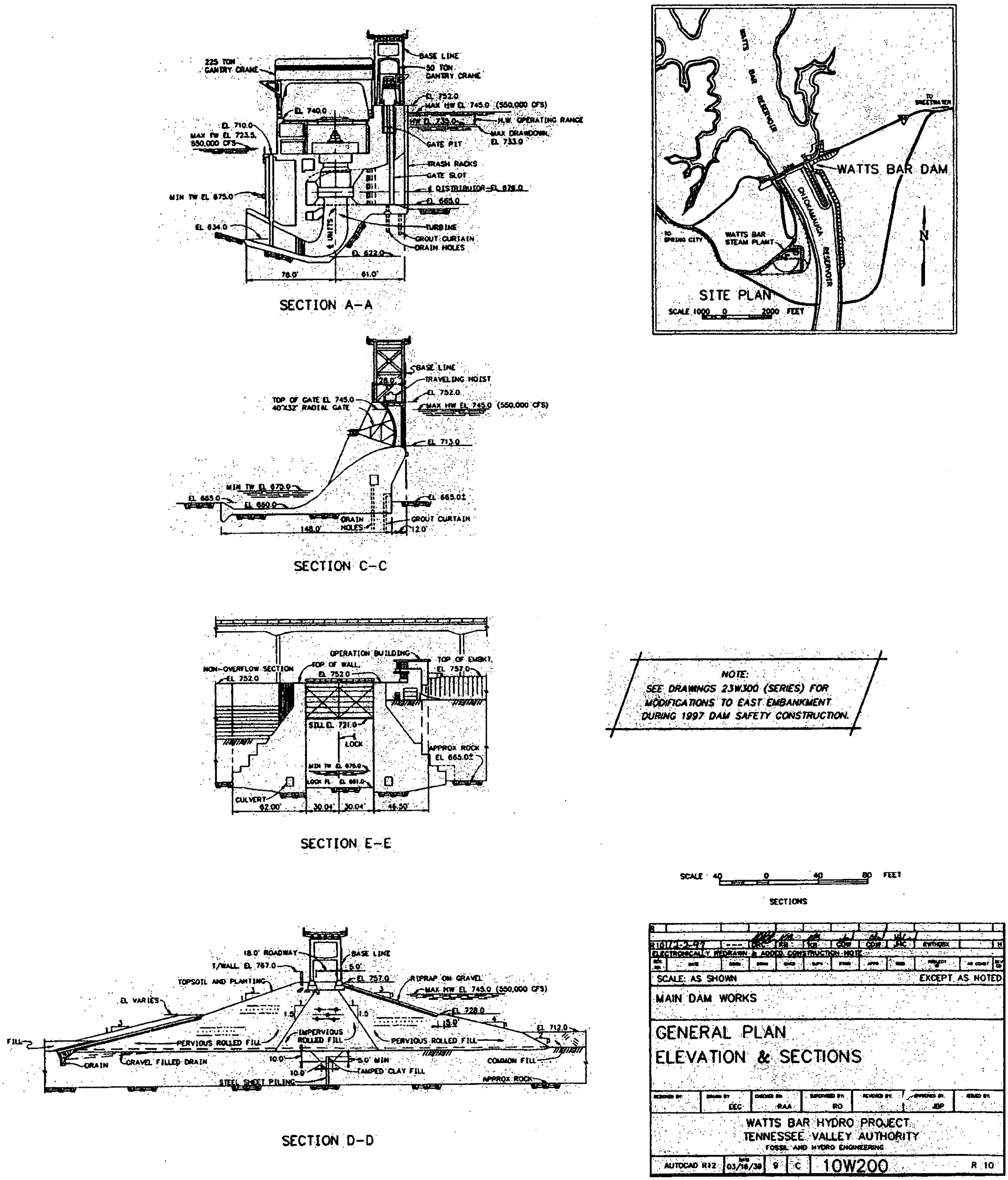
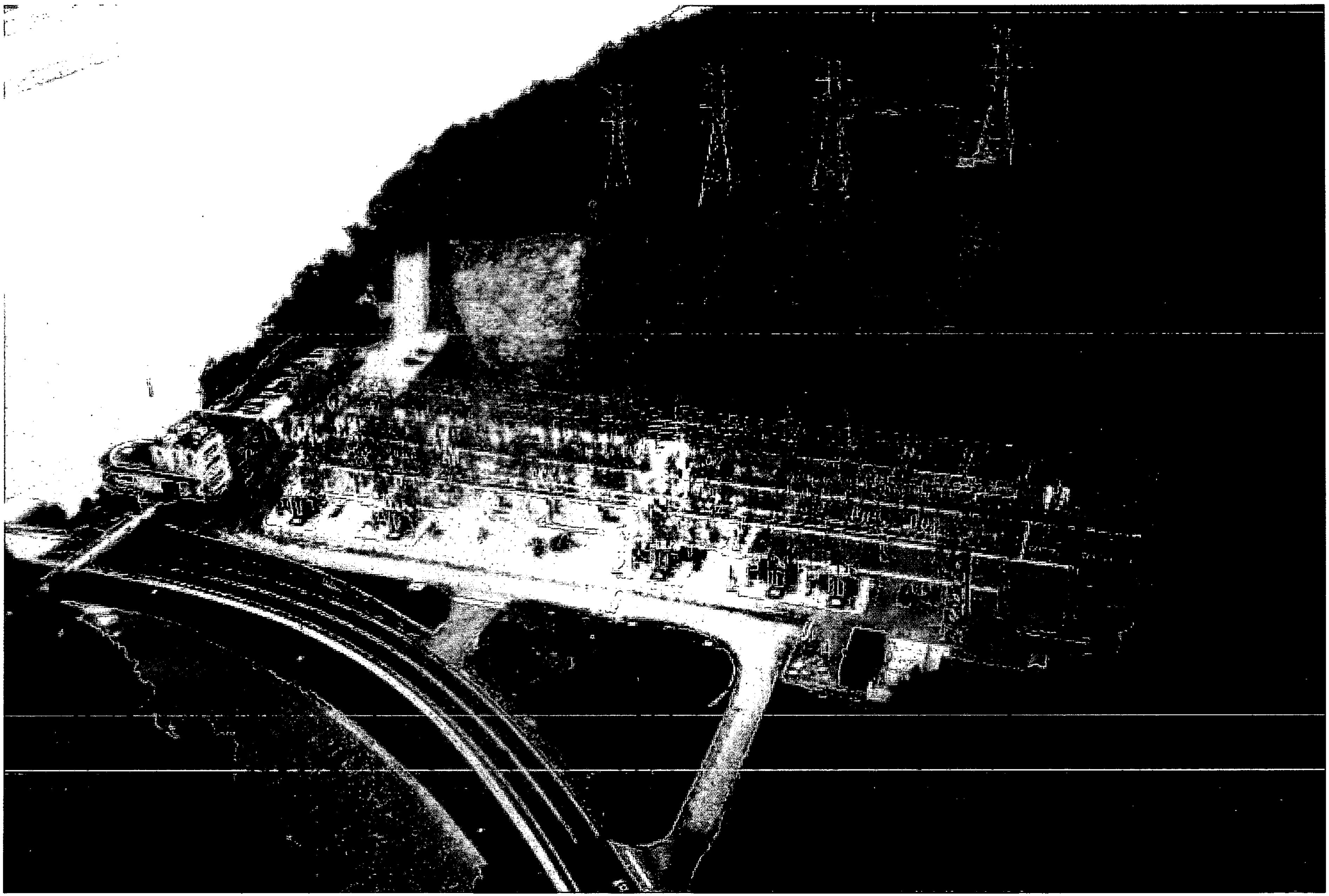


FIGURE 5: Watts Bar Control Building and Switchyard



WATTS BAR PROJECT
SUMMARY OF PRINCIPAL FEATURES

LOCATION

On Tennessee River at river mile 529.9; in Meigs and Rhea Counties, Tennessee; 72.4 miles downstream from Fort Loudoun Dam ; 58.9 miles upstream from Chickamauga Dam ; 10 miles from Spring City and the Southern Railway; 2.5 miles downstream from mouth of Piney River; 37.8 miles downstream from mouth of the Clinch River .

CHRONOLOGY

Initial appropriation by Congress	March 16, 1939
Authorized by TVA Board of Directors	May 3,1939
Construction started	July 1,1939
Started first cofferdam	July 27,1939
First excavation	August 1,1939
First concrete in permanent structures	February 28,1940
Lock placed in temporary operation	March 6,1941
Dam closure	January 1,1942
Unit 3 in commercial operation	February 11,1942
Lock placed in permanent operation	February 19,1942
Unit 2 in commercial operation	April 6,1942
Unit 1 in commercial operation	July 23,1942
Unit 5 in commercial operation	March 12,1944
Unit 4 in commercial operation	April 24,1944
Highway bridge across dam :	
Started	April 1955
Opened to traffic	September 28,1956
Safety Modifications for PMF - completed	Mid FY 1998
Reservoir Release Improvements - completed	June , 1996

PROJECT COST

Initial project:	
Including lock, 5 units, and switchyard	$35,231,729
Reservoir Release Improvements	1,515,000
Safety Modifications for Probable Maximum Flood	3,434,893
Total	$40,181,622

STREAMFLOW

Drainage area at dam:
 Total ....17,310 sq.miles
 Uncontrolled (below Fort Loudoun,
  Melton Hill, and Tellico Dams) ....1,790 sq.miles
Gaging station discharge records (for complete
 records see Data Services Branch files):
 Loudoun, Tennessee, October 1929 to July 1955;
 drainage area ....12,220 sq.miles
Near Loudon ,Tennessee , October 1922 to
 September 1929; drainage area ....12,230 sq.miles
 Breedenton, Tennessee February 1934 to
 February 1940; drainage area ....17,460 sq.miles
Maximum known flood at dam site:
 Natural (1867) ....463,000 cfs
 Regulated (May 1984) ....214,000 cfs
Average unregulated flow at dam site,
 estimated (1903-1998) ....27,400 cfs
Minimum daily natural flow at dam site
 (1987), approx ....1,530 cfs

RESERVOIR

Counties affected :
 State of Tennessee ....Meigs, Rhea, Roane, Anderson
 Loudon, Morgan
Reservoir land at May ,1999:
 Fee simple ....16,923 ac.
 Easements ....3,890 ac.
 Transferred ....1,345 ac.
 Total ....22,158 ac.
Operating levels at dam:
 Probable Maximum flood elevation (PMF) el.766.1
 500 year flood elevation el.747.1
 100 year flood elevation el.746.5
 Winter flood guide level el.735.0
 Summer flood guide level el.741.0
 Maximum used for design (550,000 cfs) el.745.0
 Top of gates (area 43,190 acres) el.745.0
 Normal minimum pool (area 32,400 ac.) el.735.0
Backwater, length at normal maximum pool level:
Tennessee River to Fort Loudoun Dam ....72.4 miles

RESERVOIR(CONT.)

Clinch River to Melton Hill Dam	23.1 miles
Total	95.5 miles
Shoreline, length at normal maximum pool level:	
Main shore	697 miles
Islands	86 miles
Total	783 miles
Original river area (to Fort Loudoun Dam)	10,343 ac.
Storage (flat pool assumption):	
Total volume :	
At top of gates (el.745)	1,175,000 ac.-ft
At normal maximum pool (el.741)	1,010,000 ac.-ft
At normal minimum pool (el.735)	796,000 ac.-ft
Controlled flood storage, January 1 to April 1,(el.745-735)	379,000 ac.-ft

TAILWATER

Maximum used for design (550,000 cfs)	el.723.5
Maximum known flood (1867)	el.717.6
Full plant operation (5 units)	el.680.0
One unit operating at best efficiency	el.676.1
Minimum level	el.675.0

HEAD (Gross)

Maximum static (el.745-675)	70 ft
Normal operating range	45 to 61 ft
Average operating	58 ft

RESERVOIR ADJUSTMENTS

Clearing	7,305 ac.
Drainage of isolated pools	200,000 cu.yd.
Preparation of sailing line	1,506 ac.
Highways:	
Access (dam to Tennessee Highway 29); bituminous surface on stabilized chert base	3.1 miles
State	19.9 miles
County and tertiary	100.7 miles
Total	123.7 miles
Railroads :	
Access	9.0 miles
Other	8.7 miles
Total	17.7 miles

RESERVOIR ADJUSTMENTS (CONT.)

Bridge adjustments (highway 7,506 ft; railroad 700 ft) ....40 bridges
Concrete box culverts 152
Families relocated 832
Graves ....1,102 agreements; 591 removals
Utilities adjusted or constructed ....58.6 miles

NAVIGATION FACILITIES

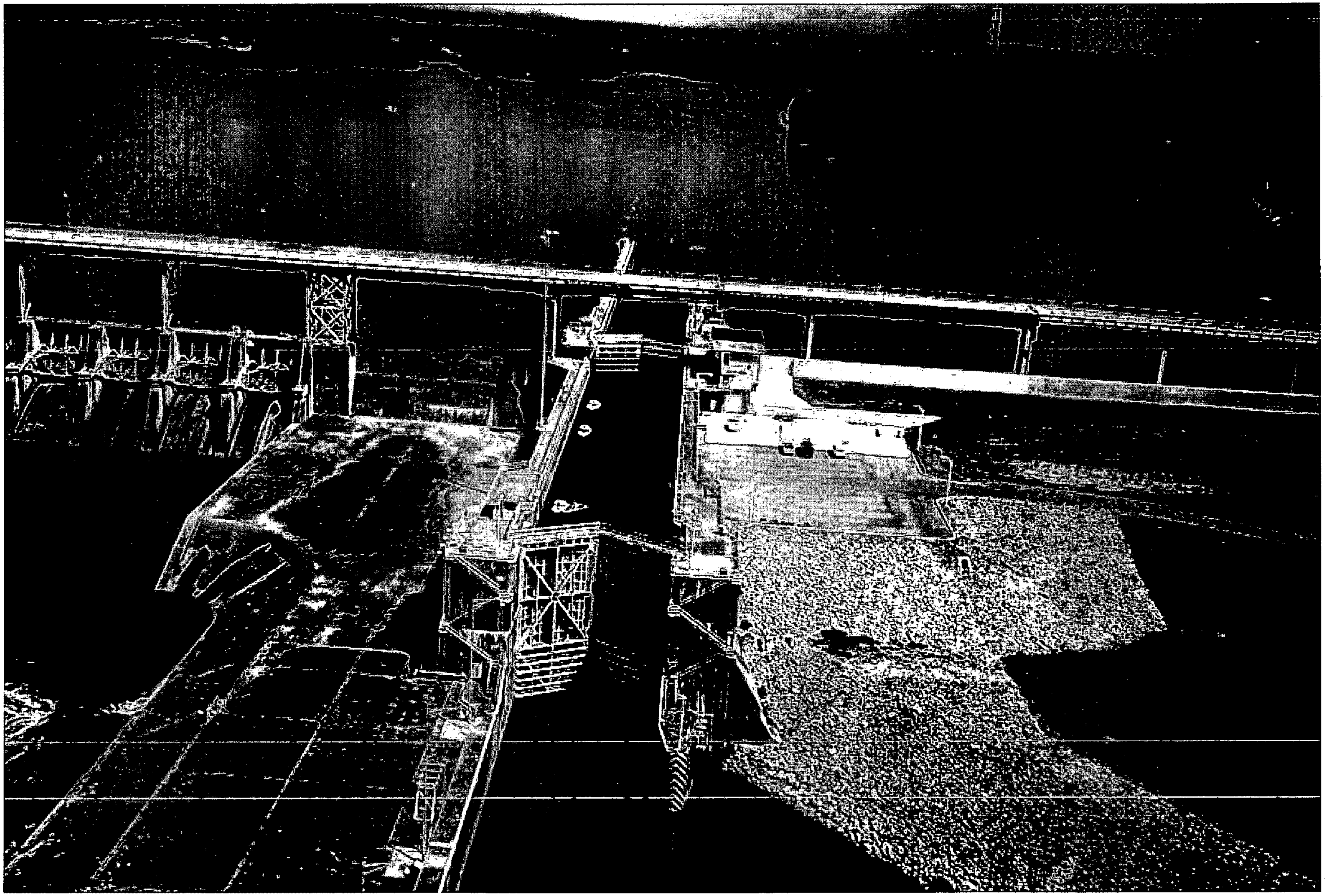
NAVIGATION CHANNEL

Length of channel for 9-ft navigable depth (to Fort Loudoun Dam) ....62.7 sailing miles
Length of dredged navigable channel :
 Below lock ....5.9 miles
 Upper end of pool to ....6.3 miles
Minimum flat pool to maintain 9-ft navigable depth el.735.0

NAVIGATION LOCK

Location (See Figure 6) ....At left (east)bank
Lock chamber, clear ....60 by 360 ft
Lift :
 Maximum (el.675-745) ....70 ft
 Normal (el.683-741) ....58 ft
Gate sills ....Upper, el.721.0; lower, el.663.2
Minimum depth over sills ....Upper, 12.0 ft; lower, 11.8 ft
Top of upper approach walls el.752.0
Top of chamber walls el.752.0
Top of lower approach walls el.706.2
Estimated lockage time (checking to regaining speed) ....40 min
Vertical clearance under bridge (min.) ....57 ft
Lock gate top ....Upper, el.749.11; lower, el.749.02
Lock gate height ....Upper, 29.44 ft; lower, 86.35 ft
Provision for future lock ....Space available for 110 by 600 ft lock to left (east) of present lock

FIGURE 6: Navigation Lock



DAM

Material and type .... Concrete gravity nonoverflow dam and spillway; concrete powerhouse intake; navigation lock; zoned rolled earthfill embankment

Lengths:
- Nonoverflow dam .... 116 ft
- Spillway .... 930 ft
- Trashway .... 29 ft
- Powerhouse intake and service bay .... 482 ft
- Navigation lock .... 169 ft
- Earth embankment .... 1,234 ft
- Total .... 2,960 ft

Maximum height, foundation to deck level .... 112 ft

Maximum width at base:
- Spillway section only .... 90 ft
- Including apron .... 148 ft

Deck level el.752.0

Top of earth embankment el.757.0

Outlet facilities :
- Spillway clear opening (20 openings at 40 ft) .... 800 ft
- Spillway crest level el.713.0
- Crest gates .... 20 radial gates, 40 ft wide, 32 ft high, separated by 6.5-ft-thick piers
- Traveling hoists .... Two 60-ton hoists
- Trashway crest level el.733.0
- Trash gate .... One fixed-wheel lift gate, 16.3 ft wide, 12 ft high, in 2 sections, operated by gantry
- Spillway capacity, HW el.745 (top of gates) .... 560,000 cfs

Highway .... 26 ft wide, on bridge over dam

Foundation .... Interbedded shale and sandstone

POWER FACILITIES

INTAKES

Number ....5 (each with 3 bays)
Dimensions of one rack
 opening ....21.08 ft wide by 47.46 ft high
Gross area at racks ....2 sets of 3 wheel gates, 40 ft 7-1/2 in. high by 16 ft 4 in. clear opening in 2 sections
Crane ....One 50-ton gantry and lifting beam
Transfer crane ....One 20-ton traveling trolley on fixed runway

POWERHOUSE

Generating capacity, 5-unit total ....172,500 kW
Type of construction ....Semioutdoor, reinforced concrete and structural steel
Principal outside dimensions
 including service bay ....470 ft long by 139 ft wide by by 133 ft high
Service bay ....106 ft long by 139 ft wide
Draft tubes:
 Type ....Elbow,3 openings
 Horizontal length (centerline of
  turbine to downstream face) ....78.0 ft
Vertical distance centerline of
 distributor to draft tube floor ....54.0 ft
Net area at outlet opening
 (total per unit) ....1,036 sq ft
Gates ....1 set of 3 sliding type,16 ft clear opening by 17 ft 1-3/4 in.high
 Crane ....25-ton jib crane on powerhouse gantry
Erecting crane ....225-ton gantry with two 112.5-ton main hooks and two 25-ton auxiliary hooks

POWER FACILITIES (CONT.)

CONTROL BUILDING

Location ....West of powerhouse, adjacent to switchyard
Type of construction ....Reinforced concrete, structural steel, limestone and brick
Floor area ....17,500 sq. ft
Volume ....181,500 cu. ft

GENERATOR AND TURBINE MODERNIZATION

This project, scheduled to start in June 2003 and complete in September 2007, will modernize the power train. Principal components to be replaced are the existing runners, main transformers generator breakers (including addititon of a generator breaker to unit 3), pilot/main exciters, protective relays , current and potential transformers , generator leads, and critical components of the cooling water system including generator air coolers, thrust bearing oil coolers, proportioning valves, strainers, and manual valves. Principal components to be rehabilitated are the generator and turbine bearings and shafts, rotor poles, stator windings, and wicket gates.

POWER FACILITIES (CONT.)

GENERATORS

Number 5
Manufacturer .... Westinghouse Electric Corp.
Type .... Enclosed, water-cooled, vertical-shaft
Rating:
 Units 1,3,4,5; original
  rating unit 2 .... 33,333 kVA, 30,000 kW, 1393 A,
  60 degrees C rise, 0.9 pf,
  13.8 kV, 3 phase, 60 Hz
Capacity :
 Units 1,3,4,5; original
  capacity unit 2 .... 38,333 kVA, 34,500 kW, 1602 A,
  80 degrees C rise

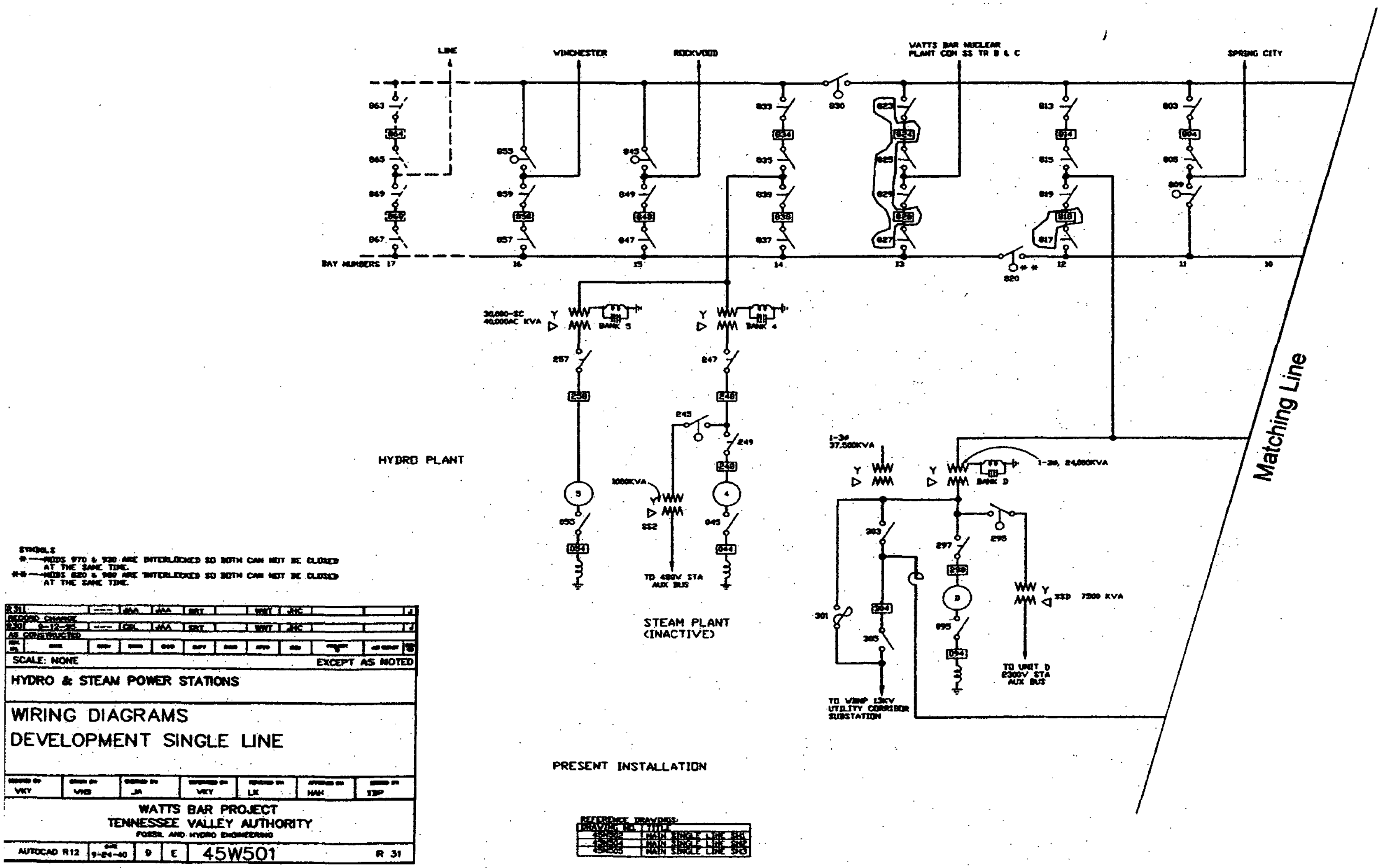
Note : Unit 2 rewound and rerated April 25,1974.
Unit 5 rewound and rerated May 20,1977.
Unit 1 rewound and rerated June 3,1978.
Unit 3 rewound and rerated Dec. 2,1978.
Unit 4 rewound and rerated May 28,1979.
 New Rating :
 All Units .... 36 MVA, 33.48 MV @ 0.93 pf,
  1506 A, 60 degrees C rise,
  13.8 kV, 3 phase, 60 Hz
Flywheel effect .... 45,000,000 lb-ft^2
Thrust bearing .... Kingsbury type, dia.92 in.,
  max. load 935 tons
Natural reactor .... 0.75 ohm, 4000 A, 1 min
Exiters:
 Main .... 225 kW, 250 V
 Pilot .... 10 kW,250 V
Weight of heaviest crane lift, rotor .... 189 tons
Diameter over air housing, less trim .... 474 in.
Top of pilot exciter:
 Above stator soleplates .... 139,625 in.
 Above generator floor .... 142,125 in.

POWER FACILITIES (CONT.)

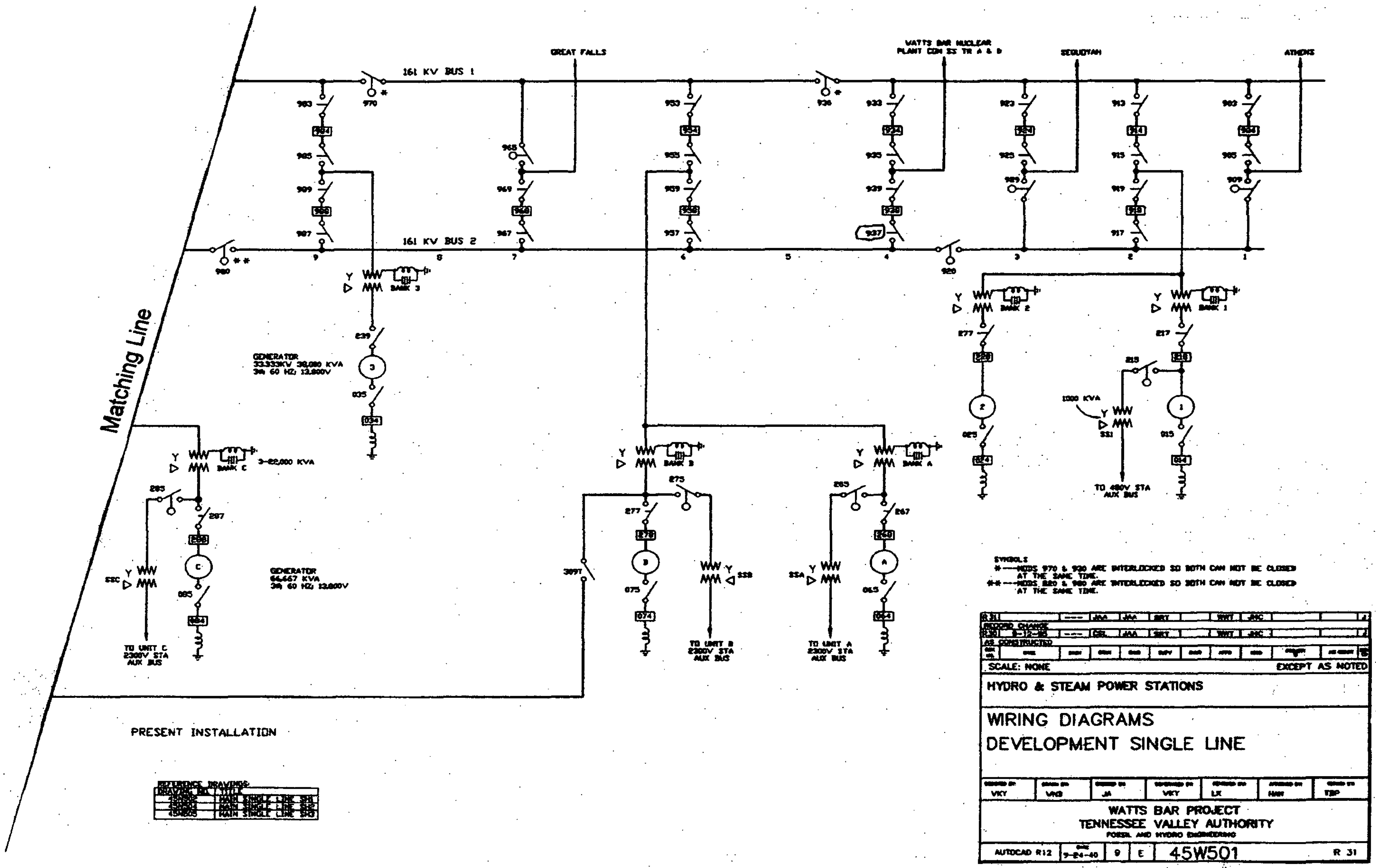
HYDRAULIC TURBINES

Number	5
Manufacturer	Baldwin-Lima-Hamilton Corp.
Type	Kaplan adjustable-blade propeller
Rated capacity (each)	42,000 hp at 52-ft net head
Rated speed	94.7 r/min
Maximum runaway speed	243 r/min
Specific speed at rating	139
Value of sigma at rating	0.89
Diameter of runner	234 in.
Diameter of guide vane circle	276.5 in.
Diameter of lower pit	27.0 ft
Spacing of turbines, center to center of units	73 ft
Draft tubes (see Powerhouse)	Elbow type
Governors	Woodward, cabinet actuator type
Heaviest assembly to be lifted by crane	434,000 lb

FIGURE 7: SINGLE LINE DIAGRAM OF MAIN CONNECTIONS



SINGLE LINE DIAGRAM OF MAIN CONNECTIONS (CONT.)



POWER FACILITIES (CONT.)

ELECTRIC CONTROLS

From control room in powerhouse:
Watts Bar hydro and steam plant generators, transformer, switchyard, sources of auxiliary power, hydro unit auxiliaries, and starting of hydro turbines by direct control

TRANSMISSION PLANT

Step-up transformers:
5 transformers, 3-phase, 2-winding, banks 1 to 5; each rated 13.2-161 kV, 30,000 kVA self-cooled, 40,000 kVA forced-air-cooled; Westinghouse
161-kV circuit breakers:
22 1200 A, 10,000,000 kVA, 3/20 Hz, pneu, Westinghouse (includes 4 circuit breakers for Watts Bar Steam Plant)
Structures (includes 2 switchyard bays for Watts Bar Steam Plant)
5 transformer structures
16 161 kV switchyard bays, 38 ft wide

TRANSMISSION PLANT DATA

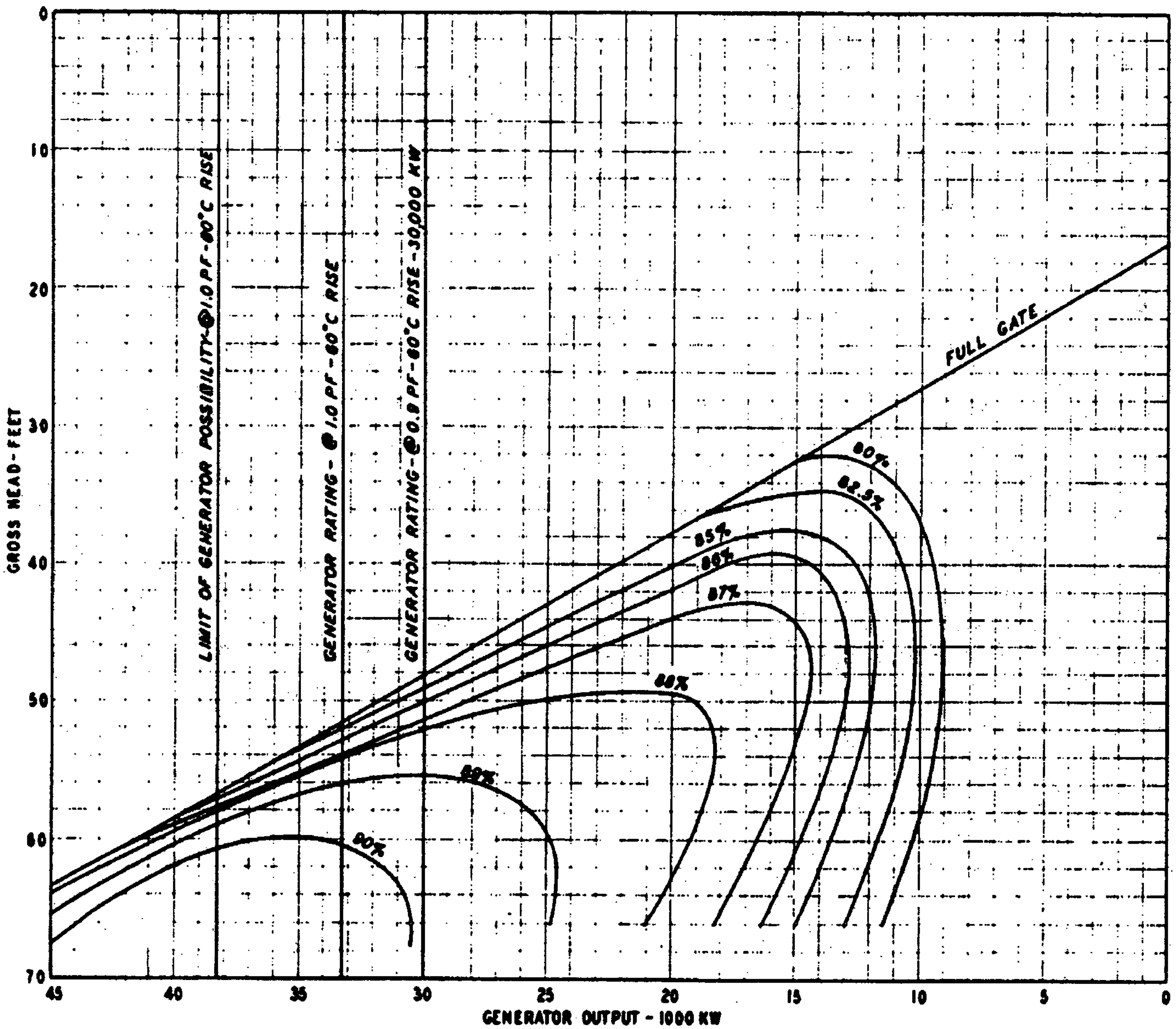
Plant	Loc	Phase	Serial Number	MVA Rating		Voltage kV	Cooling	Tap Changer	Oil Preservation System	Oil Vol Gal.	Configuration	Impedance %			Contract Number	Manufacturer	Year of Manuf
				55 deg	65 deg							H-X	H-Y	X-Y			
Watts Bar	Bank 1	3	2821306	30/40	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	8930	Wye/Delta	10.79	N/A	N/A	TV-58211	Westinghouse	1940
Watts Bar	Bank 2	3	2821305	30/40	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	8930	Wye/Delta	10.87	N/A	N/A	TV-58211	Westinghouse	1940
Watts Bar	Bank 3	3	2821304	30/40	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	8930	Wye/Delta	10.72	N/A	N/A	TV-58211	Westinghouse	1940
Watts Bar	Bank 4	3	3110675	30/40	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	8930	Wye/Delta	10.75	N/A	N/A	TV-58211	Westinghouse	1942
Watts Bar	Bank 5	3	3110676	30/40	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	8930	Wye/Delta	10.68	N/A	N/A	TV-58211	Westinghouse	1942

Note: H=High voltage winding
Y=Tertiary winding
X=Low voltage winding

Watts Bar

Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Best Efficiency Plant Output (mW)	Best Efficiency Turbine Discharge (cfs)	Best Efficiency kW/CFS	Maximum Sustainable Plant Output (mW)	Maximum Sustainable Turbine Discharge (cfs)	Maximum Sustainable kW/CFS
745	681	43.19	1175.0	128.1	64.0	140.2	29,000	4.84	193.4	40,700	4.76
744	681	42.29	1132.2	113.3	63.0	140.4	29,500	4.77	193.5	41,400	4.68
743	681	41.31	1090.4	99.0	62.0	140.5	30,000	4.69	193.7	42,100	4.61
742	681	40.24	1049.7	85.0	61.0	140.7	30,500	4.62	193.8	42,800	4.53
741	681	39.09	1010.0	71.5	60.0	140.8	31,000	4.54	193.9	43,500	4.46
740	681	37.91	971.5	58.5	59.0	141.4	31,740	4.46	192.4	44,000	4.38
739	681	36.75	934.2	45.9	58.0	142.0	32,480	4.38	190.9	44,500	4.29
738	681	35.63	898.0	33.8	57.0	142.6	33,220	4.29	189.4	45,000	4.21
737	681	34.53	862.9	22.1	56.0	138.7	33,110	4.19	184.7	45,000	4.10
736	681	33.45	828.9	10.8	55.0	134.8	33,000	4.08	180.0	45,000	4.00
735	681	32.40	796.0	.0	54.0	131.2	32,640	4.02	176.0	44,740	3.93

Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Best Efficiency Plant Output (mW)	Best Efficiency Turbine Discharge (cfs)	Best Efficiency kW/CFS	Maximum Sustainable Plant Output (mW)	Maximum Sustainable Turbine Discharge (cfs)	Maximum Sustainable kW/CFS
745	685	43.19	1175.0	126.7	60.0	140.8	31,000	4.54	193.9	43,500	4.46
744	685	42.29	1132.2	112.1	59.0	141.4	31,740	4.46	192.4	44,000	4.38
743	685	41.31	1090.4	97.8	58.0	142.0	32,480	4.38	190.9	44,500	4.29
742	685	40.24	1049.7	84.0	57.0	142.6	33,220	4.29	189.4	45,000	4.21
741	685	39.09	1010.0	70.6	56.0	138.7	33,110	4.19	184.7	45,000	4.10
740	685	37.91	971.5	57.7	55.0	134.8	33,000	4.08	180.0	45,000	4.00
739	685	36.75	934.2	45.3	54.0	131.2	32,640	4.02	176.0	44,740	3.93
738	685	35.63	898.0	33.4	53.0	127.7	32,280	3.95	172.1	44,480	3.87
737	685	34.53	862.9	21.8	52.0	124.1	31,920	3.88	168.1	44,220	3.80
736	685	33.45	828.9	10.7	51.0	120.6	31,560	3.82	164.2	43,960	3.73
735	685	32.40	796.0	.0	50.0	117.0	31,200	3.75	160.2	43,700	3.67



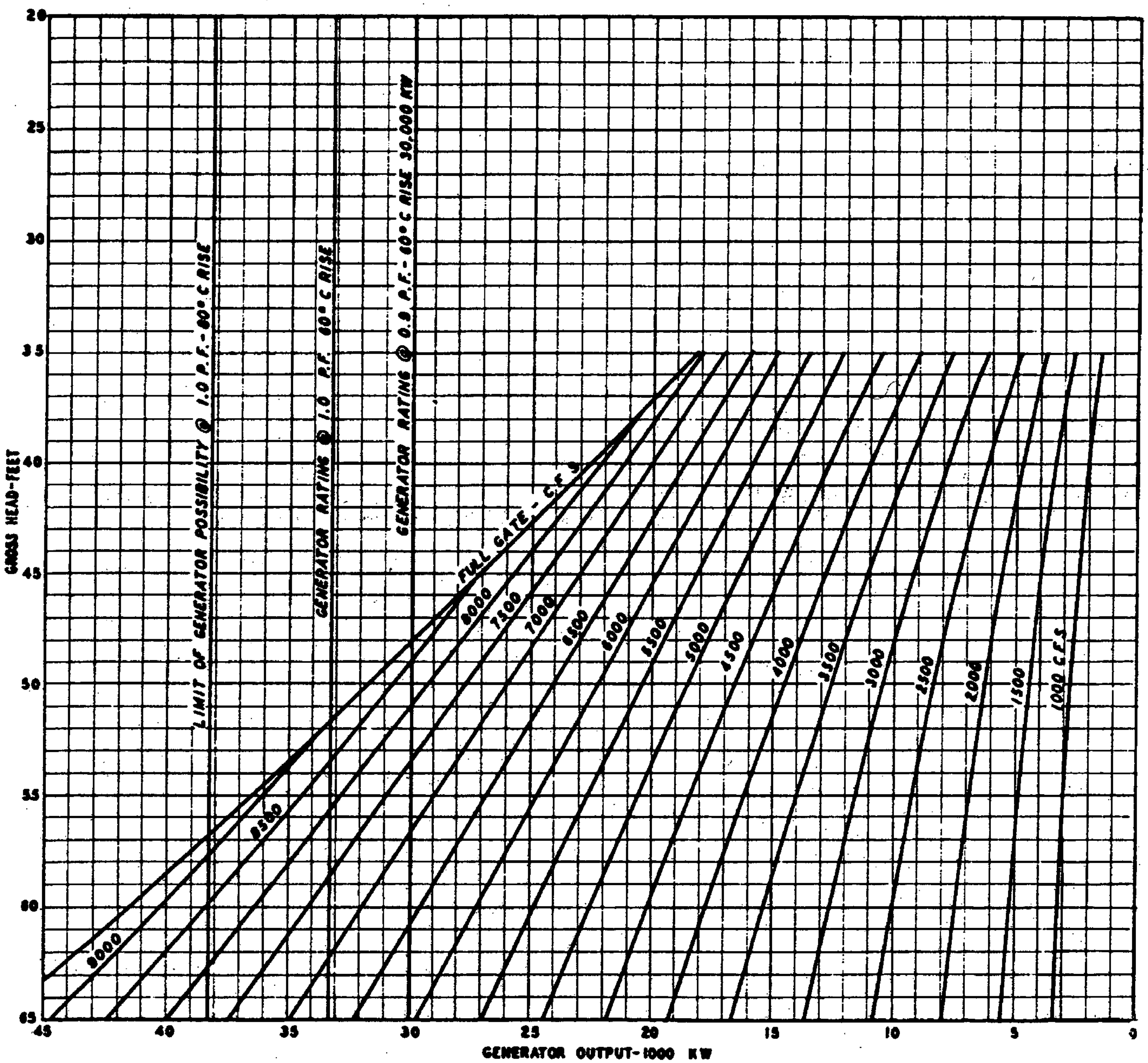
These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 11-20-42.

POWERHOUSE
UNITS 1, 2, & 3

OPERATING CHARACTERISTICS
OF 33,333 KVA
GENERATING UNIT

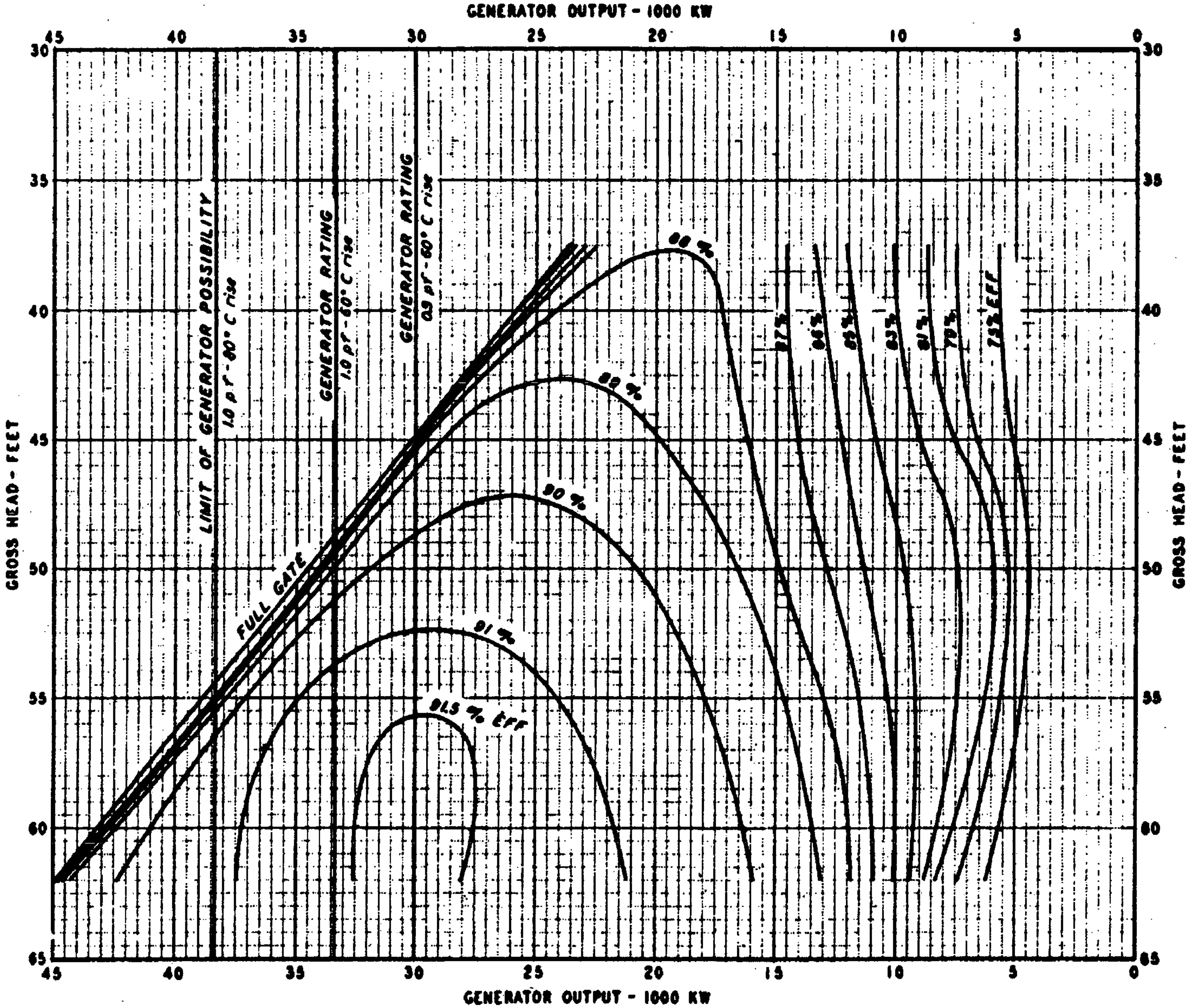
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY

KNOXVILLE 47?900



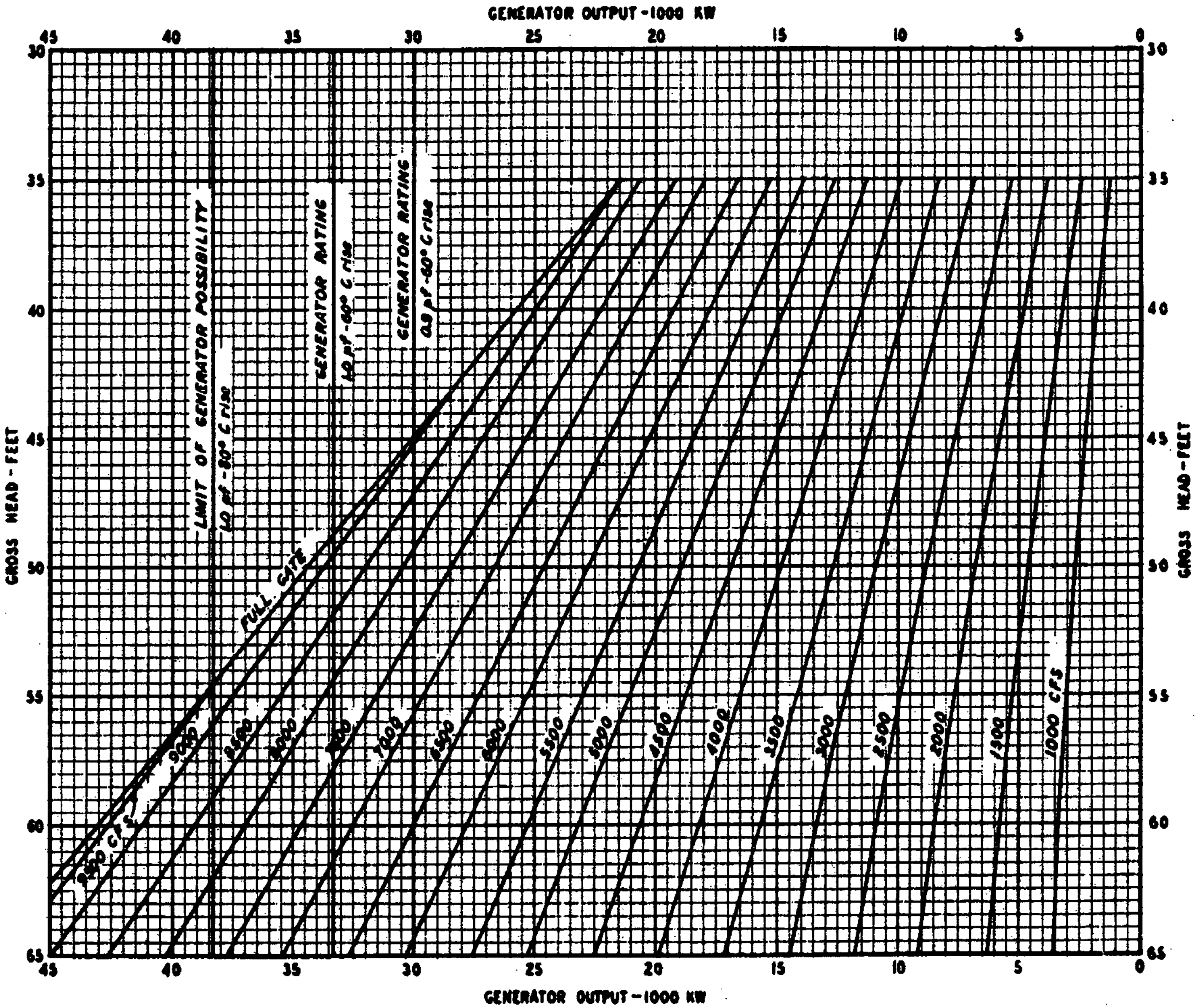
These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 11-20-42

POWERHOUSE
UNITS 1, 2, AND 3
DISCHARGE CURVES
BASED ON INDEX TESTS
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
KNOXVILLE



These performance curves are based on performance of 11" model runner tested in Baldwin - Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 4-26-44.

POWERHOUSE
UNIT 4
OPERATING CHARACTERISTICS OF 33,333 KVA GENERATING UNIT
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE 478904



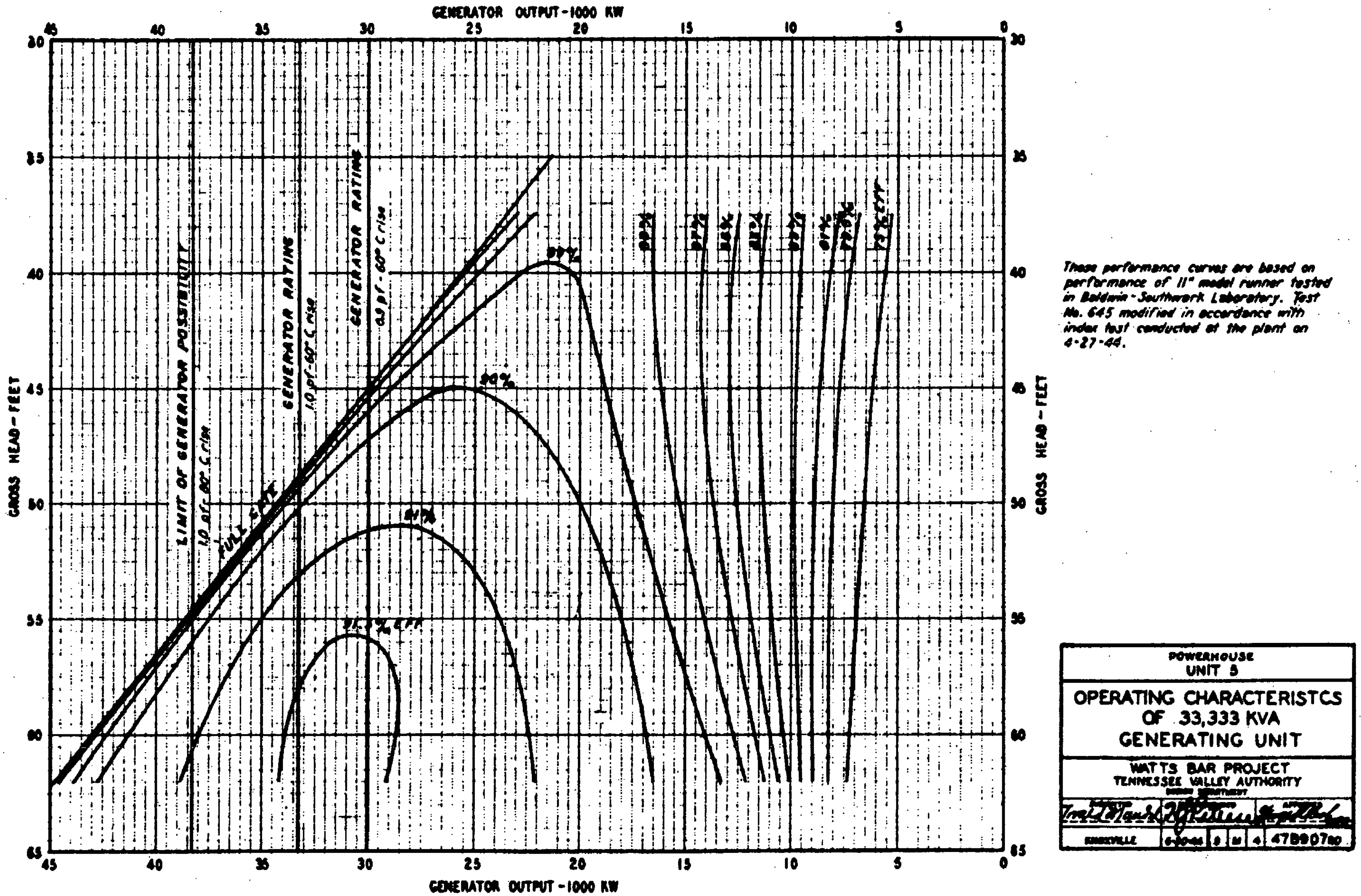
These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 4-26-44.

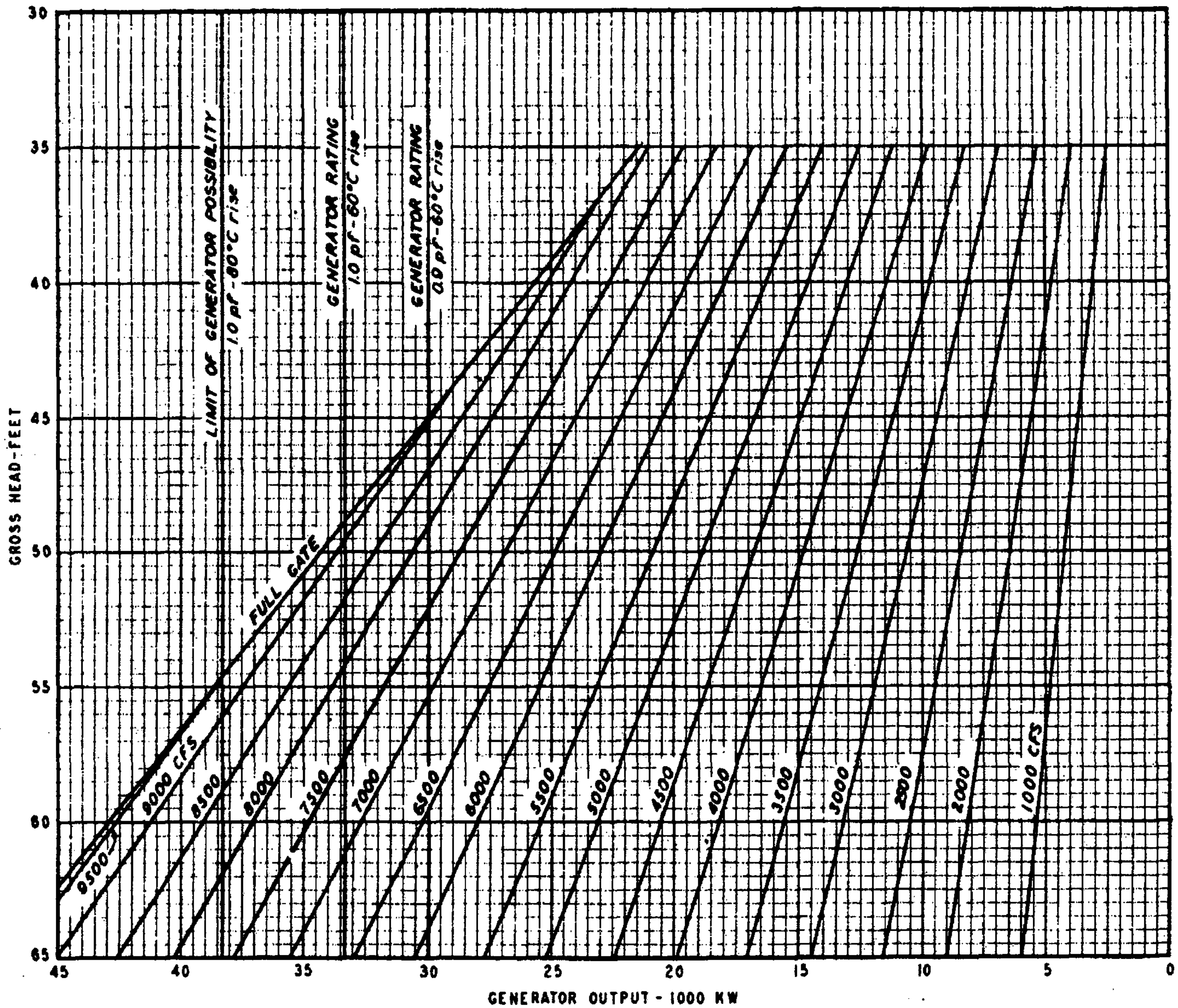
POWERHOUSE
UNIT 4

DISCHARGE CURVES
BASED ON INDEX TESTS

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY

KNOXVILLE | 6-17-44 | F | M | 4 | 47W903 R0


GENERATOR OUTPUT-1000 KW
GROSS HEAD-FEET
LIMIT OF GENERATOR POSSIBILITY 1.0 pf 60° C rise
GENERATOR RATING 1.0 pf-60° C rise
GENERATOR RATING 0.9 pf-60° C rise
FULL GATE
89%
90%
91%
91.5% EFF
These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 4-27-44.
POWERHOUSE
UNIT 5
OPERATING CHARACTERISTCS
OF 33,333 KVA
GENERATING UNIT
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
47B907



These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test no. 645 modified in accordance with index test conducted at the plant on 4-27-44.

POWERHOUSE
UNIT 5

DISCHARGE CURVES
BASED ON INDEX TESTS

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY

6-17-44 | 4 | 478906RO

Watts Bar 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 years and does not always equal the sum of the days in periods because of extension of periods into adjacent years. All spill is through the spillway. Maximum hourly average discharge to date was 214,000 cfs at 11 a.m. on 5/8/84. Includes steam plant use, if any.
1942	186956	12/30	12	164	1500---1/30---31; 23855---2/24---3; 64960---3/10---36; 18800---5/24---7; 1500---6/2---2; 14987---7/12---6; 23004---8/11---5; 43954---8/25---14; 6957---9/15---4; 10258---11/1---21; 1455---11/25---4; 159785---12/30---80
1943	123769	2/6	6	85	47193---3/22---14; 26073---4/25---10; 2020---5/4---3; 13327---5/13---5; 8576---7/27---2; 10137---7/31---2
1944	123289	3/29	9	64	12814---2/11---2; 4487---2/15---2; 55106---2/19---26; 30080---3/21---6; 84868---3/29---9; 28489---4/13---10; 20273---4/27---4; 42296---9/30---2; 17763---12/30---4
1945	84168	2/18	5	20	15785---2/14---3; 45539---2/18---4; 11215---2/24---3; 12915---2/28---2; 43256---3/6---7
1946	139008	1/9	8	72	115562---1/9---50; 26943---2/1---5; 78894---2/11---21; 1513---2/27---2; 20335---3/11---7; 17328---3/17---3; 23602---5/16---3; 2538---8/22---3
1947	113870	1/20	3	27	31250---1/3---5; 70474---1/20---20; 2613---3/8---7
1948	175396	2/14	3	32	127825---2/14---6; 7200---3/24---2; 81174---11/29---6
1949	109722	1/6	9	79	65368---1/6---33; 24633---1/22---3; 17892---2/2---6; 39393---7/18---5; 10867---7/22---2; 34772---11/2---7; 2830---11/11-14---8; 10131---12/14---13; 34800---12/27---20
1950	149388	2/1	7	55	27000---1/7---4; 7275---1/14---2; 33863---1/20---6; 102970---2/9---31; 34689---3/14---4; 11540---5/16---3; 15000---12/8---5
1951	107300	2/2	4	27	61984---2/2---5; 6953---2/23---2; 18950---3/30---3; 53800---12/23---17
1952	76100	2/1	2	14	29300---2/1---11; 16200---3/11---3
1953	65500	2/24	2	10	19200---2/22---7; 13200---3/6---3
1954	120900	1/22	3	14	57200---1/17---3; 74600---1/22---9; 7900---12/31---2
1955	95900	3/23	1	10	48900---3/23---10
1956	97700	2/4	4	14	51700---2/4---5; 23000---2/19---3; 25700---3/16---3; 35500---12/15---3
1957	156600	2/2	2	75	111700---2/2---30; 93700---11/19---47
1958	68600	1/1	3	22	22900---4/30---3; 25200---5/20---5; 5700---5/26---12
1959	93100	12/20	3	15	26900---1/23---3; 6400---12/14---5; 47000---12/20---7
1960	46300	3/4	0	0	

Tennessee Valley Authority
River System Operations

Watts Bar 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 years and does not always equal the sum of the days in periods because of extension of periods into adjacent years. All spill is through the spillway. Maximum hourly average discharge to date was 214,000 cfs at 11 a.m. on 5/8/84. Includes steam plant use, if any.
1961	136000	3/9	4	37	59800---2/24---11; 95400---3/9---9; 48000---12/13---3; 81500---12/19---14
1962	131600	2/28	4	46	12700---1/30---15; 86100---2/28---24; 19900---3/23---5; 17200---4/13---2
1963	161300	3/13	2	23	117400---3/13---22;100---4/29---1
1964	73500	3/16	3	8	29400---3/16---3; 27200---4/8---3; 5600---12/30---2
1965	123900	3/27	2	17	26000---1/12---5; 79700---3/27---12
1966	72000	2/14	2	7	25800---2/14---5; 10000---12/31---4
1967	105800	12/24	5	32	45100---3/8---8; 18900---7/8---3; 11900---7/12---3; 2800---7/30---2; 61200---12/24---32
1968	96000	1/6	0	18	
1969	157200	12/31	3	10	26000---2/3---4; 4900---2/8---4; 121100---12/31---12
1970	133500	1/1	1	14	51600---4/28---4
1971	59900	2/7	2	5	13900---2/7---3; 9600---5/13---2
1972	135600	12/11	5	68	23500---1/11&12---14; 9600---1/23---13; 39700---2/28---11; 6600---11/25---7; 90700---12/11---34
1973	180400	3/17	6	96	17600---2/10---8; 135800---3/17---19; 16000---5/1---9; 3500---5/8---2; 116500---5/28---13; 93200---11/28---8
1974	142700	1/11	10	107	105700---1/11---89; 6200---3/18&19---2; 38600---3/22---6; 24300---4/5---15; 8600---5/21---3; 18700---6/1---3; 7600---7/6---2; 9200---7/10---7; 7400---7/20---4; 2800---9/7---1
1975	135800	3/14	3	69	39600---2/5---34; 12800---2/26---5; 89900---3/14---30
1976	45400	1/10	0	0	
1977	161200	4/5	2	56	123100---4/5---12; 29800---12/6-7---44
1978	79500	1/28	2	16	20600---1/12---5; 32900---1/28---11
1979	110600	3/9	7	61	22600---1/9---6; 30300---1/22---13; 63300---3/9---20; 4700---6/1---2; 28700---7/22---9; 8200---11/13---4; 15100---11/27---7;
1980	79100	3/21	2	26	17100---1/26---11; 33100---3/21---15
1981	41000	8/14	0	0	

Tennessee Valley Authority
River System Operations

Watts Bar 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 years and does not always equal the sum of the days in periods because of extension of periods into adjacent years. All spill is through the spillway. Maximum hourly average discharge to date was 214,000 cfs at 11 a.m. on 5/8/84. Includes steam plant use, if any.
1982	77100	2/12	5	79	17200---1/13---15; 9000---1/25-26---9; 30700---2/11-13---23; 5400---3/19---2; 30200---12/17-18---36
1983	84500	5/23	9	67	3300---1/12---3; 5900---2/12---9; 16700---4/7---4; 7000---4/25---2; 47300---5/23---19; 5300---8/24---3; 18700---12/4---8; 5800---12/14---5; 13000---12/30-31---9
1984	208400	5/8	1	16	163600---5/8---15
1985	54892	2/2	1	3	9875---2/2---3
1986	38671	12/24	1	1	675---6/26---1
1987	70433	2/28	1	7	26320---2/28---7
1988	43933	1/21	0	0	
1989	108596	6/21	9	92	24883---1/18---7; 5100---2/24---4; 15900---3/7---4; 11212---5/11---5; 73917---6/21---35; 35166---10/2---8; 15508---11/17---16; 5850---12/5---8; 16883---12/23---5
1990	113679	2/19	5	68	20825---1/10---11; 14230---1/25---3; 70116---2/19---37; 39559---3/20---8; 56479---12/24---13
1991	125625	12/3	5	7	38388---1/1---13; 5971---1/13---10; 72209---2/20---21; 25037---4/2---5; 81333---12/3---31
1992	83363	12/28	2	19	32246---1/6---7; 38900---12/27---33
1993	100938	3/24	3	38	23229---1/1---33; 56734---3/24---10; 23996---12/7---7
1994	133917	2/12	4	82	13387---1/13---12; 10800---1/29---6; 89963---2/12---33; 87500---4/1---31
1995	84575	1/17	4	28	40525---1/17---10; 2587---1/28---2; 10700---2/22-23---8; 19904---3/10---8
1996	98617	1/30	4	59	8000---1/9---3; 54279---1/30---31; 39171---12/2---13; 20783---12/16---12
1997	90775	3/4	6	44	24617---1/10---7; 15625---2/1---9; 4366---2/7---1; 46675---3/4---20; 11833---6/2---2; 40291---6/15---5
1998	156329	4/20	4	63	26408---2/6---20; 112737---4/20---33; 31200---6/11---8; 3294---12/15---2

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE
FROM DATE OF RESERVOIR CLOSURE THROUGH 1998

WATTS BAR

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	746.48	1984	MAY	10	1	701.80 *	1942	JAN.	1
2	745.40 #	1973	MAR.	17	2	733.44	1945	MAR.	20
3	745.28	1994	MAR.	29	3	734.02	1963	FEB.	25
4	745.12	1942	MAR.	9	4	734.37	1949	DEC.	29
5	745.03	1989	JUNE	20	5	734.50	1951	DEC.	31
6	744.90	1950	MAY	15	6	734.56	1947	FEB.	3
7	744.89	1998	APR.	20	7	734.61	1962	MAR.	18
8	744.71	1949	MAY	2	8	734.68	1950	DEC.	18
9	744.57	1959	APR.	23	9	734.69	1952	JAN.	1
10	744.57	1970	APR.	28	10	734.69	1968	JAN.	19
11	744.51	1977	APR.	5	11	734.70	1964	JAN.	13
12	744.45	1957	NOV.	19	12	734.77	1967	DEC.	26
13	744.43	1963	MAY	2	13	734.80	1970	MAR.	11
14	744.40	1958	APR.	27	14	734.80	1971	MAR.	2
15	744.19	1953	MAY	2	15	734.80	1976	JAN.	24
16	743.88	1966	MAY	3	16	734.81	1954	FEB.	23
17	743.84	1990	DEC.	23	17	734.81	1958	JAN.	3
18	743.82	1967	JULY	7	18	734.82	1944	JAN.	24
19	743.60	1964	APR.	15	19	734.82	1959	JAN.	3
20	743.55	1948	APR.	26	20	734.82	1973	JAN.	8
21	743.46	1956	APR.	17	21	734.83	1977	JAN.	31
22	743.42	1969	DEC.	31	22	734.84	1946	DEC.	20
23	743.23	1965	APR.	29	23	734.84	1960	JAN.	23
24	743.17	1971	MAY	13	24	734.85	1966	FEB.	13
25	743.05	1972	APR.	23	25	734.85	1972	MAR.	16
26	743.03 %	1943	APR.	24	26	734.86	1969	JAN.	31
27	743.03	1983	MAY	22	27	734.87	1948	JAN.	19
28	743.00	1976	MAY	17	28	734.89	1953	JAN.	6
29	742.97	1979	JULY	22	29	734.89	1974	MAR.	12
30	742.93	1997	JUNE	15	30	734.90	1975	DEC.	30
31	742.89	1996	DEC.	1	31	734.92	1978	FEB.	13
32	742.80	1975	MAR.	14	32	734.93	1965	JAN.	8
33	742.75	1946	MAY	15	33	734.95	1955	FEB.	5
34	742.75	1954	DEC.	30	34	734.95	1961	DEC.	16
35	742.62	1968	MAY	11	35	734.98	1956	DEC.	24
36	742.56	1952	MAY	2	36	735.00	1980	FEB.	23
37	742.54	1960	MAY	11	37	735.00	1982	DEC.	11
38	742.54	1961	APR.	18	38	735.00	1983	FEB.	1
39	742.53	1991	DEC.	3	39	735.00	1984	MAR.	14
40	742.51	1981	JUNE	11	40	735.00	1998	DEC.	22
41	742.50	1951	MAY	6	41	735.02	1943	JAN.	8
42	742.44	1962	APR.	12	42	735.02	1979	JAN.	17
43	742.40	1978	JUNE	9	43	735.05	1957	JAN.	11
44	742.18	1988	JULY	18	44	735.08	1991	JAN.	28
45	742.13	1947	MAY	23	45	735.08	1992	JAN.	17
46	742.10	1955	MAY	31	46	735.10	1988	JAN.	28
47	741.97	1974	MAY	25	47	735.11	1985	JAN.	12
48	741.88	1987	APR.	26	48	735.15	1997	JAN.	22
49	741.84	1944	APR.	12	49	735.19	1981	FEB.	7
50	741.80	1992	JULY	4	50	735.20	1987	JAN.	13
51	741.78	1982	SEP.	2	51	735.22	1994	MAR.	10
52	741.77	1985	AUG.	18	52	735.26	1993	FEB.	11
53	741.45	1980	MAY	24	53	735.27	1986	MAR.	7
54	741.45	1993	MAY	5	54	735.33	1989	MAR.	31
55	741.37	1995	OCT.	6	55	735.35	1996	DEC.	26
56	741.18	1986	OCT.	4	56	735.37	1990	FEB.	2

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE
FROM DATE OF RESERVOIR CLOSURE THROUGH 1998

WATTS BAR

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
57	740.74 #	1945	APR.	25	57	735.44	1995	FEB.	15

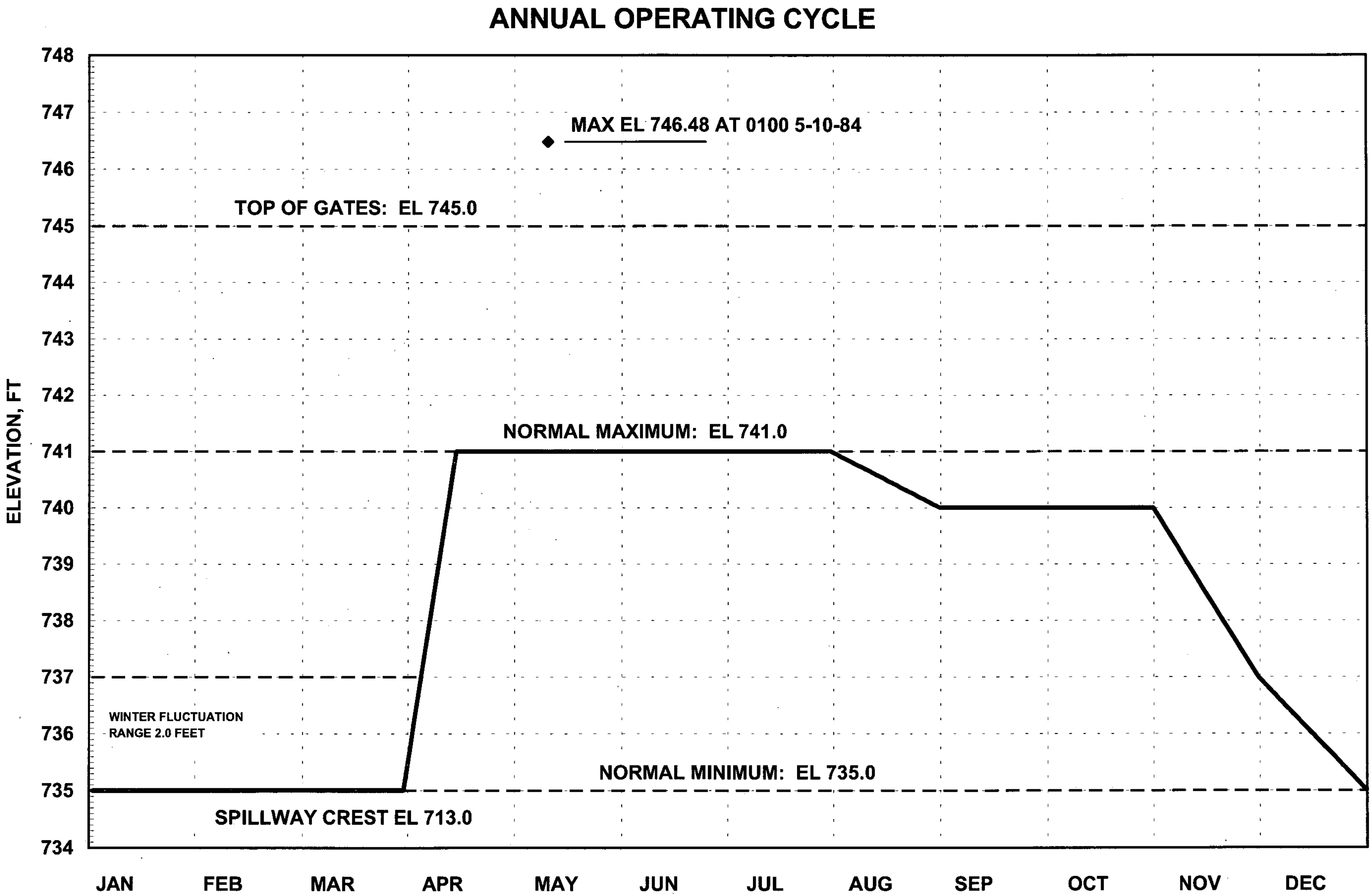
* MIDNIGHT ELEVATION ON CLOSURE DATE
# ESTIMATED
% MIDNIGHT ELEVATION
TOP-OF-GATES ELEVATION 745

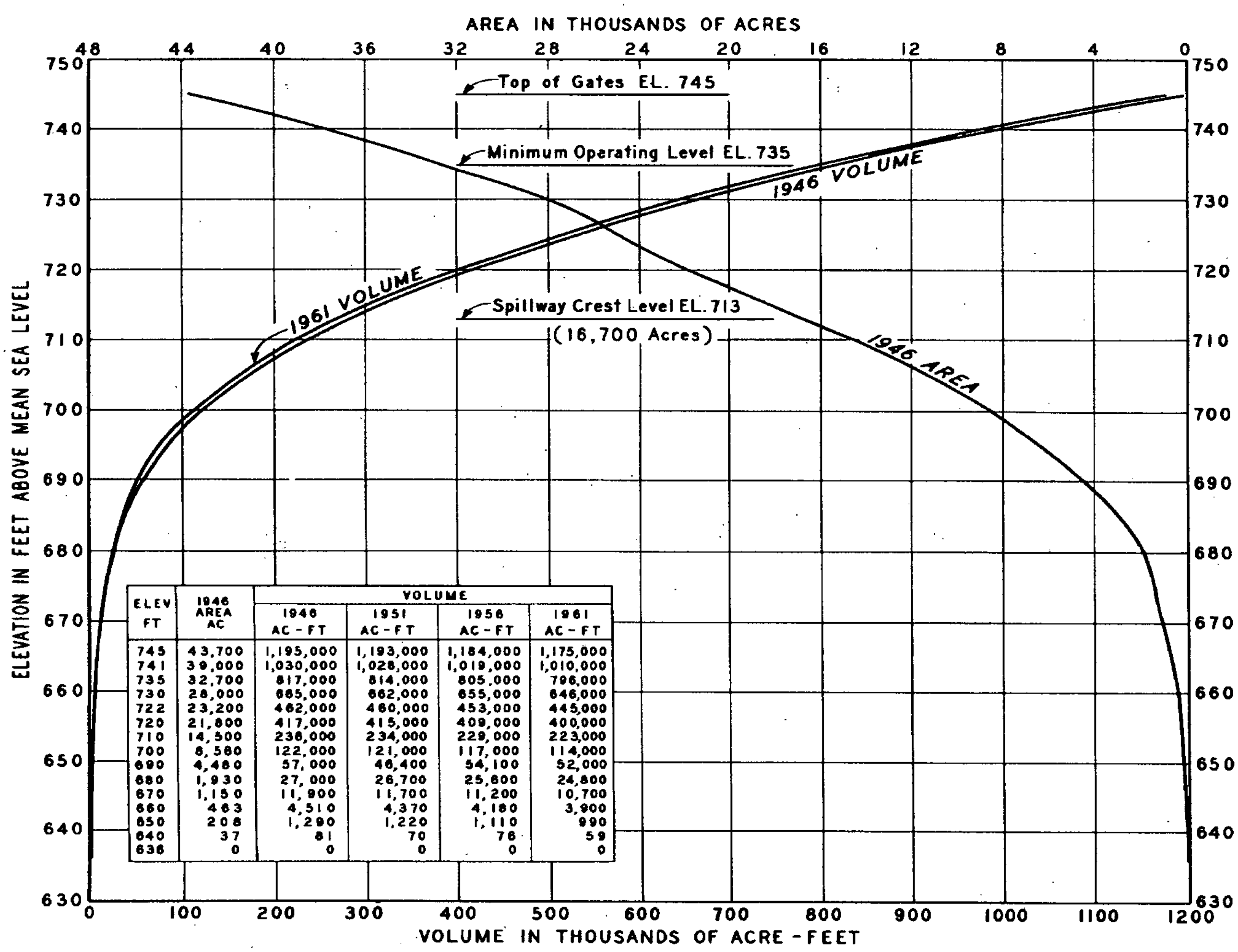
MAXIMUM, MINIMIUM, MEDIAN, AND MEAN
Adjusted Flow by Weeks
Watts Bar
Years=1928-1998

WEEK ENDING	WEEK NO.	MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
		AVERAGE WEEKLY CFS					
JAN 7	1	133,000	1937	5,370	1940	31,900	39,700
JAN 14	2	175,000	1946	5,780	1981	31,300	39,900
JAN 21	3	207,000	1947	6,790	1981	32,800	39,500
JAN 28	4	137,000	1954	5,380	1940	40,600	45,300
FEB 4	5	294,000	1957	4,900	1940	34,000	47,700
FEB 11	6	157,000	1957	8,380	1934	36,200	48,700
FEB 18	7	189,000	1948	7,190	1934	41,600	51,700
FEB 25	8	140,000	1961	6,830	1934	44,100	49,400
MAR 4	9	158,000	1962	8,130	1941	38,500	47,800
MAR 11	10	161,000	1963	13,700	1931	48,300	51,800
MAR 18	11	237,000	1963	12,300	1931	40,900	53,900
MAR 25	12	158,000	1980	12,300	1988	44,500	52,500
APR 1	13	241,000	1994	11,100	1988	40,200	55,500
APR 8	14	247,000	1977	12,800	1986	39,700	49,300
APR 15	15	145,000	1994	10,500	1986	37,100	42,500
APR 22	16	217,000	1998	9,730	1986	31,600	36,800
APR 29	17	96,200	1958	8,420	1986	31,000	34,300
MAY 6	18	92,900	1958	6,570	1986	26,900	32,300
MAY 13	19	235,000	1984	7,110	1986	25,100	32,900
MAY 20	20	66,100	1950	8,120	1941	24,000	27,900
MAY 27	21	87,600	1983	5,430	1941	21,100	24,900
JUN 3	22	107,000	1973	5,110	1988	18,500	23,600
JUN 10	23	67,600	1967	3,850	1988	16,000	21,300
JUN 17	24	83,400	1989	3,360	1988	16,100	19,800
JUN 24	25	82,500	1989	2,930	1988	16,400	17,600
JUL 1	26	86,200	1928	3,320	1988	13,600	16,300
JUL 8	27	58,000	1967	2,100	1988	13,800	16,400
JUL 15	28	60,300	1967	4,550	1970	13,000	16,200
JUL 22	29	85,700	1949	3,380	1986	11,600	15,500
JUL 29	30	66,100	1938	3,270	1952	12,500	15,200
AUG 5	31	58,400	1971	1,970	1986	12,000	15,100
AUG 12	32	48,900	1942	3,540	1957	11,900	13,700
AUG 19	33	66,200	1940	2,630	1954	11,300	14,300
AUG 26	34	44,600	1942	2,330	1987	9,760	12,400
SEP 2	35	50,000	1940	2,560	1953	9,340	11,700
SEP 9	36	85,800	1928	2,140	1954	8,570	11,100
SEP 16	37	30,500	1928	1,850	1998	8,430	9,830
SEP 23	38	36,400	1989	3,200	1955	8,020	9,680
SEP 30	39	59,000	1989	2,650	1998	7,730	10,800
OCT 7	40	74,900	1989	2,220	1952	7,430	12,300
OCT 14	41	42,500	1976	1,530	1987	7,990	10,000
OCT 21	42	48,100	1964	1,850	1952	7,340	11,000
OCT 28	43	37,400	1971	2,580	1998	8,930	11,100
NOV 4	44	72,900	1949	2,570	1954	9,560	12,800
NOV 11	45	93,800	1977	2,000	1953	9,830	14,500
NOV 18	46	78,600	1957	2,710	1953	10,500	15,400
NOV 25	47	90,000	1957	4,830	1998	15,200	18,500
DEC 2	48	125,000	1973	4,120	1953	16,400	24,200
DEC 9	49	100,000	1991	4,110	1987	16,500	25,200
DEC 16	50	164,000	1972	4,630	1939	19,900	28,100
DEC 23	51	136,000	1961	4,820	1958	19,700	28,100
DEC 31	52	124,000	1932	6,250	1963	29,700	35,100

AVERAGE FLOW:1928 - 1998 = 27300 CFS

RIVER SYSTEM OPERATIONS


ANNUAL OPERATING CYCLE
ELEVATION, FT
748
747
746
745
744
743
742
741
740
739
738
737
736
735
734
MAX EL 746.48 AT 0100 5-10-84
TOP OF GATES: EL 745.0
NORMAL MAXIMUM: EL 741.0
WINTER FLUCTUATION
RANGE 2.0 FEET
NORMAL MINIMUM: EL 735.0
SPILLWAY CREST EL 713.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC



ELEV FT	1946 AREA AC	VOLUME 1946 AC-FT	1951 AC-FT	1956 AC-FT	1961 AC-FT
745	43,700	1,195,000	1,193,000	1,184,000	1,175,000
741	39,000	1,030,000	1,028,000	1,019,000	1,010,000
735	32,700	817,000	814,000	805,000	796,000
730	28,000	665,000	662,000	655,000	646,000
722	23,200	462,000	460,000	453,000	445,000
720	21,800	417,000	415,000	409,000	400,000
710	14,500	238,000	234,000	229,000	223,000
700	8,580	122,000	121,000	117,000	114,000
690	4,480	57,000	46,400	54,100	52,000
680	1,930	27,000	26,700	25,800	24,800
670	1,150	11,900	11,700	11,200	10,700
660	463	4,510	4,370	4,180	3,900
650	208	1,290	1,220	1,110	990
640	37	81	70	78	59
636	0	0	0	0	0

NOTES:

Reservoir areas at elevation 720 and below were measured on a composite map prepared by the Hydraulic Data Branch with contours drawn at 10' intervals. The map was prepared from Tennessee River Survey Maps made by the U.S. Army Engineers, with contours at 690, 700, 710 and 720. Contours were made to conform to elevations on TVA sediment range cross sections located at one to five mile intervals. Areas above elevation 720 were measured on TVA navigation maps with contours at elevations 722, 730, 735, 741 and 745, scale 1" = ½ mile. The areas at these elevations check with areas at the same elevations previously measured on TVA land maps. The 1946 volume was computed by the contour method. Volumes of sediment on succeeding dates were computed by the constant factor method.

Elevations are referred to the USC & GS 1936 Supplementary Adjustment.

Area of original river within reservoir = 10,343 acres.

Drainage area at dam = 17,310 square miles.

Dam closure January 1, 1942.

RESERVOIR RELEASE IMPROVEMENTS

Oxygen Diffuser System--The oxygen diffuser system for Watts Bar Hydro Plant is designed to provide a large instantaneous oxygen flowrate to aerate the water flow from the turbine units while the turbines are in operation and to provide a smaller continuous flowrate to keep the forebay charged with high DO water. The continuous oxygen flowrate should be sufficient to meet the background DO demands of the reservoir in the forebay.

The oxygen diffuser system is designed to diffuse enough oxygen into the withdrawal zone for the hydroturbines to increase the DO content to 4 mg/L. The system uses eight line diffusers to supply oxygen to the units and to keep the forebay charged with high DO water.

Six 2,000-foot long line diffusers are located between 200 and 2,200 feet upstream of the plant intake and are located approximately 100 feet apart. Two 8,000-foot long line diffusers are located between 3,000 and 11,000 feet upstream of the plant intake. Their distance apart varies as they follow the channel upstream. All eight line diffusers float approximately three feet off the bottom of the reservoir. The line diffusers are constructed from polyethylene pipe which supplies oxygen to porous hoses. 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 diffusers are supplied with oxygen from a liquid oxygen storage facility located downstream of the dam along the access road to the navigation lock. The storage facility equipment consists of a horizontal 15,000-gallon liquid oxygen storage tank, four ambient air vaporizers, two ice racks, a solenoid-operated emergency shut-off valve, a temperature switch for low temperature shut-off, a pressure gauge and transmitter, a manually operated off/on flow valve, a flowmeter, and pressure regulators. The vaporizers are equipped with solenoid-operated valves and a timer to alternate flow through one-half of the vaporizers at a time to allow for a freeze/thaw cycle.

Oxygen for the line diffusers passes through a manually-operated control valve and a flow meter into a supply header. From this header, four supply lines feed the diffusers. The two long diffusers each have an individual supply line. The six shorter diffusers are fed by two supply lines which each feeds three diffusers. The supply lines are constructed from polyethylene pipe and are equipped with a valve and pressure regulator for flow control.

SAFETY MODIFICATIONS FOR PROBABLE MAXIMUM FLOOD

CHRONOLOGY

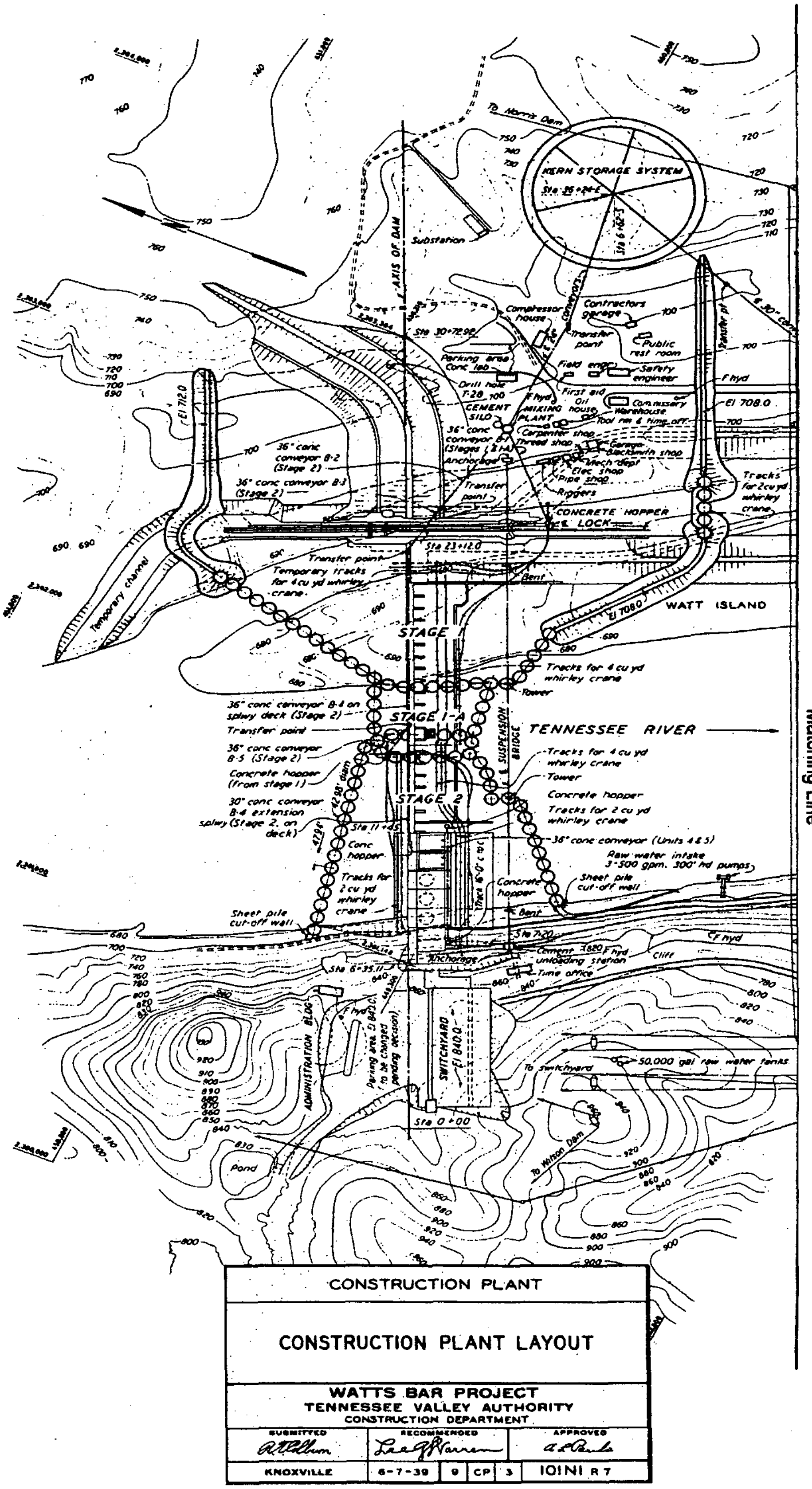
Safety analysis studies for Watts Bar to evaluate the safety hydrologic deficiencies caused by a Probable Maximum Flood (PMF) were essentially completed in fiscal year (FY) 1987. However , the study concentrated mainly on the new 110′ x 600′ lock being constructed concurrently with the hydrologic modifications. A new summary was performed in FY 1994 with two new alternatives assuming no new lock. The new recommended proposal was to pour a reinforced concrete retaining wall immediately downstream of the existing bridge bents that spans from the lock operations building almost to the bridge abutment. An earthen plug was utilized to connect the bridge abutment with the end of the retaining wall. Construction mobilization began at the end of FY 1994 and was completed in mid FY 1998.

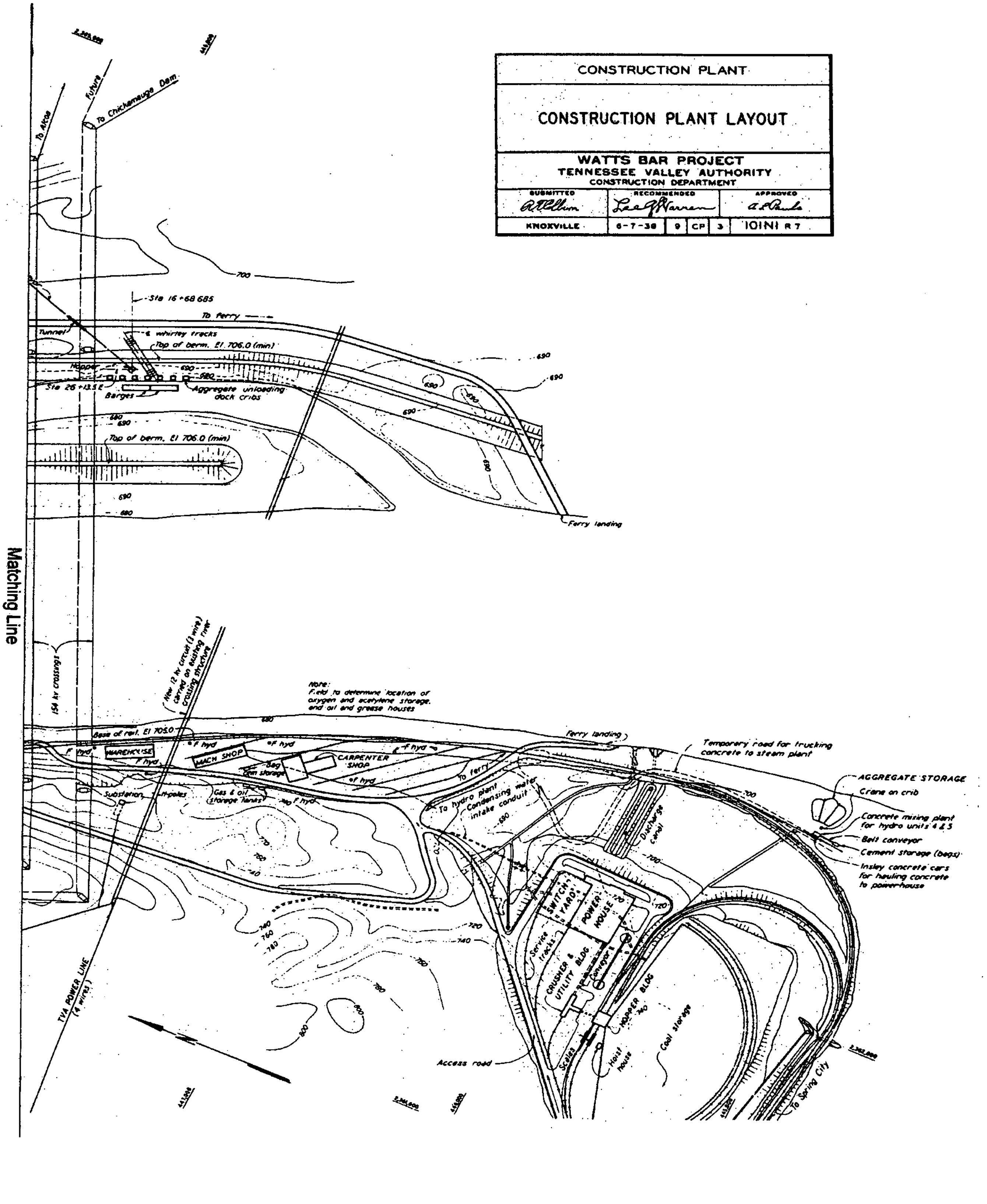
COST OF MODIFICATIONS

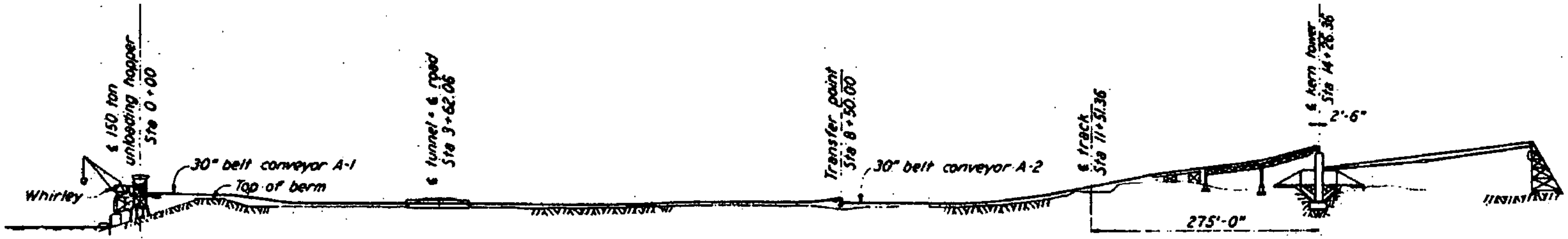
Engineering and Design cost for the safety modifications to Watts Bar Dam were $507,536.56. The construction costs were $2,927,356.93. The total project cost was $3,434,893.49.

CONTROLLING FEATURES

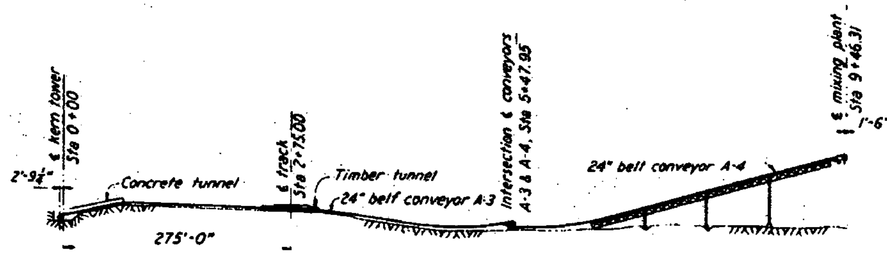
Modifications for the PMF consisted of a concrete retaining wall immediately downstream of the existing bridge bents that spans from the lock operations building almost to the bridge abutment. An earthen plug was utilized at the bridge abutment to tie the end of the wall into the compacted fill of the bridge abutment with the top of both at elevation 767.0. Reinforced concrete slabs were use for localized scour protection on the upstream and downstream slopes adjacent to lock.


KERN STORAGE SYSTEM
To Norris Dam
Substation
AXIS OF DAM
Compressor house
Contractors garage
Transfer point
Public rest room
Parking area
Conc lab
Field engr
Safety engineer
CEMENT SILO
MIXING PLANT
First aid
Oil house
Commissary Warehouse
Tool rm & time off
Carpenter shop
Thread shop
Garage
Blacksmith shop
Mech dept
Elec shop
Pipe shop
Riggers
CONCRETE HOPPER
LOCK
Temporary channel
Transfer point
Temporary tracks for 4 cu yd whirley crane
STAGE 1
WATT ISLAND
Tracks for 4 cu yd whirley crane
Tower
STAGE 1-A
TENNESSEE RIVER
SUSPENSION BRIDGE
STAGE 2
Concrete hopper
36" conc conveyor (Units 4 & 5)
Raw water intake
Sheet pile cut-off wall
Anchorage
Cement unloading station
Time office
Cliff
ADMINISTRATION BLDG
SWITCHYARD
To switchyard
50,000 gal raw water tanks
To Wilson Dam
Pond
Matching Line
CONSTRUCTION PLANT
CONSTRUCTION PLANT LAYOUT
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-7-39
9
CP
3
101N1 R 7


CONSTRUCTION PLANT
CONSTRUCTION PLANT LAYOUT
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-7-38
9
CP
3
10IN1 R7
Matching Line
To Alcoa
Future
To Chickamauga Dam
To ferry
Tunnel
Hopper
Barges
Aggregate unloading dock cribs
Top of berm. El. 706.0 (min)
Ferry landing
154 kv crossings
TVA POWER LINE (4 wires)
Base of rail El 705.0
WAREHOUSE
MACH SHOP
CARPENTER SHOP
Substation
Gas & oil storage tanks
Ferry landing
Temporary road for trucking concrete to steam plant
AGGREGATE STORAGE
Crane on crib
Concrete mixing plant for hydro units 4 & 5
Belt conveyor
Cement storage (bags)
Insley concrete cars for hauling concrete to power-house
To hydro plant
Condensing water intake conduit
Discharge canal
SWITCH YARD
POWER HOUSE
CRUSHER & UTILITY BLDG
HOPPER BLDG
Coal storage
Hoist house
Scales
Service tracks
Access road
To Spring City

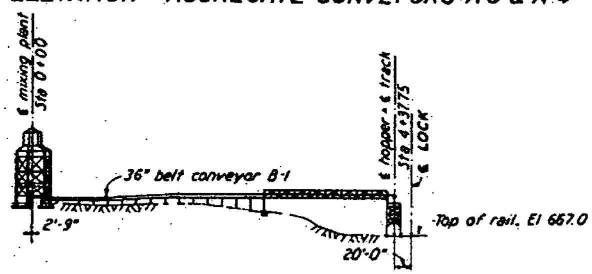


ELEVATION – AGGREGATE CONVEYORS A-1 & A-2

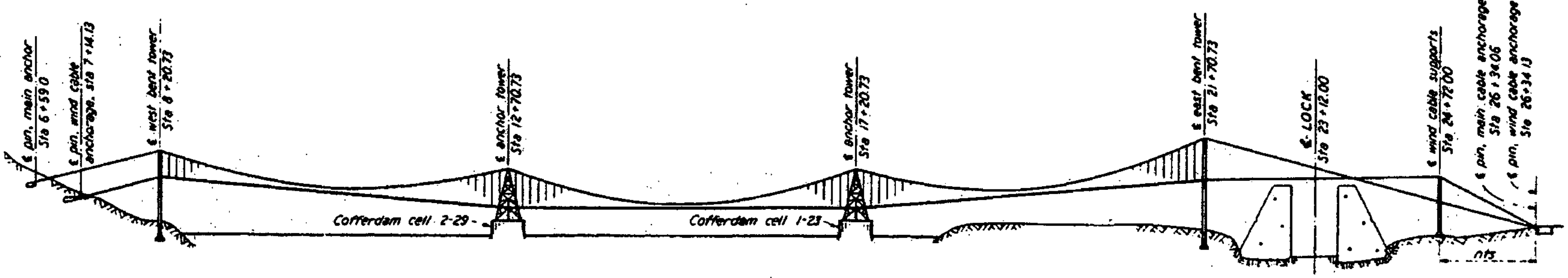


ELEVATION – AGGREGATE CONVEYORS A-3 & A-4

CONSTRUCTION PLANT					
CONSTRUCTION PLANT LAYOUT					
WATTS BAR PROJECT TENNESSEE VALLEY AUTHORITY CONSTRUCTION DEPARTMENT					
SUBMITTED	RECOMMENDED			APPROVED	
[signature]	[signature]			[signature]	
KNOXVILLE	6-7-39	9	CP	3	101N1 R.7



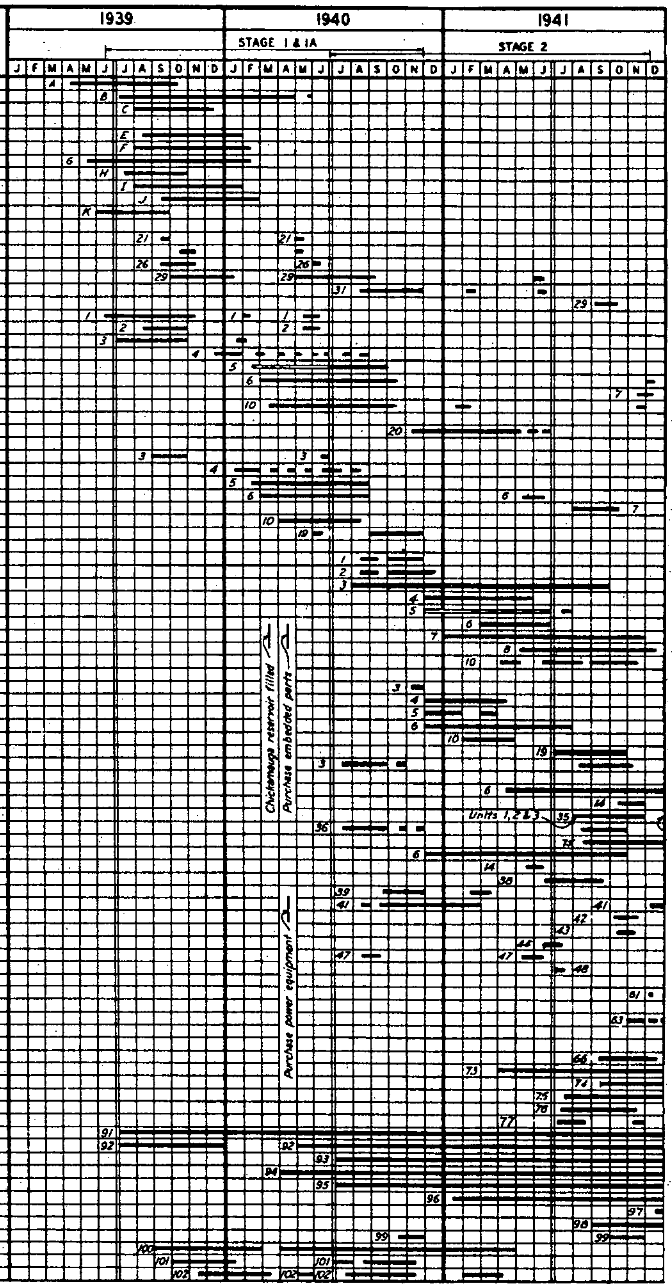
ELEVATION – CONCRETE CONVEYOR B-1



ELEVATION – SUSPENSION BRIDGE

LOOKING UPSTREAM

STAGES		NO.	ITEM OR EQUIPMENT	QUANTITY	UNIT	AVERAGE MONTHLY QUANTITY
CONSTRUCTION SERVICES		A	Access roads and railroad relocation			
		B	Camp and village buildings			
		C	Water supply and sewage disposal			
		D				
CONSTRUCTION PLANT		E	Railroad facilities			
		F	Construction utilities - water, air, power			
		G	Construction road and bridge			
		H	Shop building			
		I	Aggregate plant			
		J	Concrete and cement plant			
		K	Miscellaneous buildings			
EAST EMBANKMENT		21	Stripping and grubbing			
		22	Trench excavation			
		26	Cut-off wall sheet piling			
		29	Earth embankment and blanket			
		31	Riprap and gravel			
WEST SADDLE DIKE		29	Earth embankment (Rip rap 4,000 cu yds)(Earth 13,700 cu yds)			
STAGE 1 & 1A	LOCK	1	Cofferdam erection (5,650 tons - including cut-off walls)			
		2	Cofferdam fill - earth (including dikes and berms)			
		3	Foundation excavation - earth cleanup			
		4	Foundation excavation - rock			
		5	Prepare and grout foundation			
		6	Concrete			
		7	Concrete - upper miter sill closure			
		10	Installation of embedded parts			
		20	Operation building			
	13½ BAYS OF SPILLWAY & NON-OVERFLOW SECTION	3	Foundation excavation - earth cleanup			
		4	Foundation excavation - rock			
		5	Prepare and grout foundation			
		6	Concrete			
		7	Concrete closure blocks			
		10	Installation of embedded parts			
		19	Removal of cofferdam			
STAGE 2	POWER-HOUSE	1	Cofferdam erection (3,428 tons)			
		2	Cofferdam fill			
		3	Foundation excavation - earth & unclassified cleanup			
		4	Foundation excavation - rock			
		5	Prepare and grout foundation			
		6	Concrete - intake			
		7	Concrete - substructure - service bay & turbines			
		8	Concrete - superstructure			
		10	Installation of embedded parts			
	6½ BAYS OF SPILLWAY & TRASHWAY	3	Foundation excavation - earth cleanup			
		4	Foundation excavation - rock			
		5	Prepare and grout foundation			
		6	Concrete			
		10	Installation of embedded parts			
		19	Removal of cofferdam			
SWITCHYARD		3	Unclassified excavation			
		6	Concrete			
		14	Structural steel			
		35	Equipment			
		36	Earth and rock fill			
CONTROL BUILDING		75	Switchboards			
		6	Concrete			
		14	Structural steel			
		38	Superstructure (stone)			
		39	Shaft and tunnel (Rock excavation)			
INSTALLATION GATES AND MACHINERY		41	Lock gates and operating mechanism			
		42	Gates - spillway			
		43	Gates - intake			
		44	Gates - draft tube			
		47	Spillway deck girders			
		48	Trash racks			
INSTALLATION CRANES		61	Hoist—spillway			
		62	Crane - intake			
		63	Crane - powerhouse			
		64	Transfer crane			
ELEVATORS		66	Powerhouse and control building			
INSTALLATION POWERHOUSE MACHINERY		73	Turbines			
		74	Generators			
		75	Switchboard			
		76	Mechanical equipment			
		77	Powerhouse structural steel			
GENERAL		91	Land acquisition			
		92	Reservoir clearing			
		93	Backwater protection			
		94	Highway and railroad relocation			
		95	Family removal and cemetery relocation			
		96	Utilities			
		97	Filling reservoir			
		98	Switching structure transmission line			
		99	Cleanup and removal			
		100	Channel excavation (hydraulic and dry)			
		101	Earth embankment (navigation channel dikes)			
		102	Riprap and gravel (navigation channel dikes)			



*Includes trashway concrete.
**Includes 12,700 cu yd of channel improvement concrete.
***At elevation 680.
****Includes shaft and tunnel concrete

Revised to completion

[signature] PROJECT MANAGER.

GENERAL					
CONSTRUCTION SCHEDULE					
WATTS BAR PROJECT TENNESSEE VALLEY AUTHORITY CONSTRUCTION DEPARTMENT					
SUBMITTED	RECOMMENDED				APPROVED
[signature] 1-4-39	[signature]				[signature]
KNOXVILLE	3-28-39	9	CP	3	102N1R7

STAGES		NO.	ITEM OR EQUIPMENT	QUANTITY	UNIT	AVERAGE MONTHLY QUANTITY	1942	1943
CONSTRUCTION SERVICES		A	Access roads and railroad relocation					
		B	Camp and village buildings					
		C	Water supply and sewage disposal					
		D						
CONSTRUCTION PLANT		E	Railroad facilities					
		F	Construction utilities - water, air, power					
		G	Construction road and bridge					
		H	Shop building					
		I	Aggregate plant					
		J	Concrete and cement plant					
		K	Miscellaneous buildings					
EAST EMBANKMENT		21	Stripping and grubbing					
		22	Trench excavation					
		26	Cut-off wall sheet piling					
		29	Earth embankment and blanket					
		31	Riprap and gravel					
WEST SADDLE DIKE		29	Earth embankment (Rip rap 4,000 cu yds)(Earth 13,700 cu yds)					
STAGE 1 & 1A	LOCK	1	Cofferdam erection (5,650 tons - including cut-off walls)					
		2	Cofferdam fill - earth (including dikes and berms)					
		3	Foundation excavation - earth cleanup					
		4	Foundation excavation - rock					
		5	Prepare and grout foundation					
		6	Concrete					
		7	Concrete - upper miter sill closure					
		10	Installation of embedded parts					
		20	Operation building					
	13½ BAYS OF SPILLWAY & NON-OVERFLOW SECTION	3	Foundation excavation - earth cleanup					
		4	Foundation excavation - rock					
		5	Prepare and grout foundation					
		6	Concrete					
		7	Concrete closure blocks					
		10	Installation of embedded parts					
		19	Removal of cofferdam					
STAGE 2	POWER-HOUSE	1	Cofferdam erection (3,428 tons)					
		2	Cofferdam fill					
		3	Foundation excavation - earth & unclassified cleanup					
		4	Foundation excavation - rock					
		5	Prepare and grout foundation					
		6	Concrete - intake					
		7	Concrete - substructure - service bay & turbines					
		8	Concrete - superstructure					
		10	Installation of embedded parts					
	6½ BAYS OF SPILLWAY & TRASHWAY	3	Foundation excavation - earth cleanup					
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		6	Concrete					
		10	Installation of embedded parts					
		19	Removal of cofferdam					
SWITCHYARD		3	Unclassified excavation					
		6	Concrete					
		14	Structural steel					
		35	Equipment					
		36	Earth and rock fill					
		75	Switchboards					
CONTROL BUILDING		6	Concrete					
		14	Structural steel					
		38	Superstructure (stone)					
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INSTALLATION GATES AND MACHINERY		41	Lock gates and operating mechanism					
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		48	Trash racks					
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		64	Transfer crane					
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INSTALLATION POWERHOUSE MACHINERY		73	Turbines					
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		76	Mechanical equipment					
		77	Powerhouse structural steel					
GENERAL		91	Land acquisition					
		92	Reservoir clearing					
		93	Backwater protection					
		94	Highway and railroad relocation					
		95	Family removal and cemetery relocation					
		96	Utilities					
		97	Filling reservoir					
		98	Switching structure transmission line					
		99	Cleanup and removal					
		100	Channel excavation (hydraulic and dry)					
		101	Earth embankment (navigation channel dikes					
		102	Riprap and gravel (navigation channel dikes)					

*Includes trashway concrete.
**Includes 12,700 cu yd of channel improvement concrete.
***At elevation 680.
****Includes shaft and tunnel concrete

Revised to completion

PROJECT MANAGER

GENERAL

CONSTRUCTION SCHEDULE

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
KNOXVILLE	3-28-39 9 CP 3	102N1R7

STAGES		NO.	ITEM OR EQUIPMENT	QUANTITY	UNIT	AVERAGE MONTHLY QUANTITY
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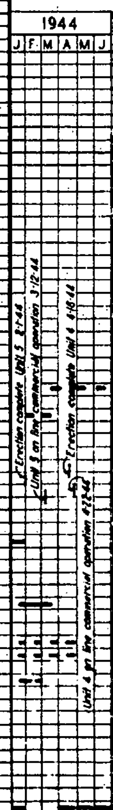

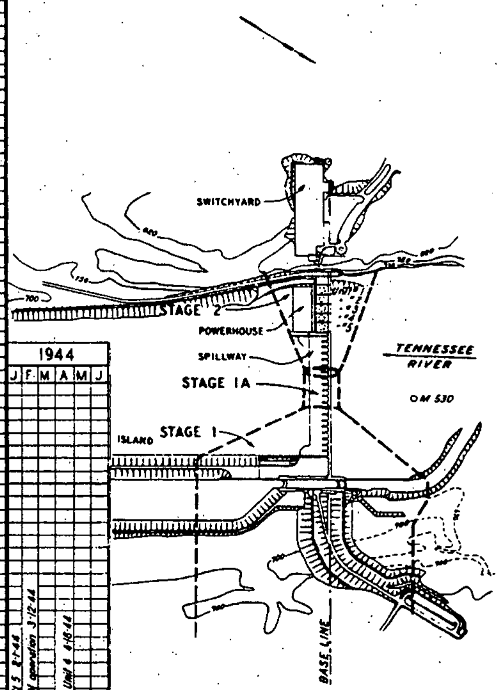

PLAN

Scale 400 0 400 800 Feet

Revised to completion

F.L.D. Clemmer
PROJECT MANAGER

GENERAL

CONSTRUCTION SCHEDULE

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
R.T.B. Olson 4-6-39	Lee Warren	A. E. Pauls
KNOXVILLE	3-28-39 | 9 | CP | 3	102N1R7

CONSTRUCTION DATA

PERSONNEL

	Total	Dam Construction Only
Peak employed.....	3,200	2,680
Total man-hours...	13,881,053	8,111,581
Number of injuries.........	178	108
Days lost.........	35,008	26,992
Fatalities........	3	2
Accident frequency........	12.9	13.5
Accident severity.........	2,522	3,328

QUANTITIES
(Initial Project)

Dam,lock,and power facilities:		
Earth excavation	1,630,500	cu.yd
Rock excavation	261,200	cu.yd
Unclassified excavation	206,300	cu.yd
Earthfill	1,050,000	cu.yd
Rockfill	160,000	cu.yd
Concrete	480,200	cu.yd
Reinforcing steel	6,360	tons
Structural steel, powerhouse	900	tons
Formwork	1,925,000	sq.ft
Foundation grouting cement	5,600	bags
Highway and railroad Excavation	3,060,000	cu.yd

CONSTRUCTION DATA (CONT.)

HOUSING FACILITIES

Permanent houses built .... None
Low-cost houses built 45
Dormitories built:
Men (420 total capacity) 7
Women (24 total capacity) 2
Public buildings constructed included a cafeteria (192 seats), hospital (16 beds), two community and recreation buildings, and gas station.

NOTE

Elevations are based on the U.S.C. & G.S. 1936 Supplementary Adjustment.