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

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8B: Dam Rating Curve, Apalachia

(237 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58090128003	calculations(nuclear)	L58 091230 014

Calc Title: Dam Rating Curve, Apalachia

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080001	0	1	Entire calc ☒ Selected pages ☐
NEW								

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) N/A	CLASSIFICATION
*see note below		E

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

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

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

STATEMENT OF PROBLEM/ABSTRACT

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 headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents headwater rating curves for Apalachia Dam.

Note: The headwater rating curve provided in this calculation is limited in application to maximum PMF headwater elevation of 1295.00 feet (See Section 5.0 in the calculation for the basis of this limiting condition).

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

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

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

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS:LP4D-C
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NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.:	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 090128 003	calculations(nuclear)	N/A

Calc Title: Dam Rating Curve, Apalachia

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV
CURRENT	CN	NUC					
NEW	CN	NUC	GEN	CEB	CDQ000020080001	N/A	0

REVISION APPLICABILITY: Entire calc ☒ Selected pages ☐

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
C. SATTLER	632-6443	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
S. Martinez Sara Martinez; Clint Sattler	12-19-08	Chris Triplett	01/16/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Dr. L. Yu Lin	01/16/09	K.R. Spates	1/26/09

STATEMENT OF PROBLEM/ABSTRACT

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 headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents headwater rating curves for Apalachia Dam.

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

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080001	1

ALTERNATE CALCULATION IDENTIFICATION

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

CATEGORIES SR / LC

KEY NOUNS (A-add, D-delete)

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

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

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	EN	WBN	CEB	54018	
A	P	EN	SQN	CEB	22404	
D	S	CN	GEN	CEB	CDQ000020080054	
A	S	CN	GEN	CEB	CDQ000020080053	

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 CDQ000020080001

Title Dam Rating Curve, Apalachia

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue Total Pages – 78 Attachments 1, 5, 7-12, 22-25, A1-A4, A6 & A8-A14 - 1 Page Each Attachment 6 - 2 Pages Attachments 2, A5 & A7 - 5 Pages Each
1	This calculation was revised to address the following: • PER 203951-The verification of the original 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 those 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 2 through 5 and Page 7 with the forms from the NEDP-2 Revision in effect at the time of calculations issuance • Replaced Unverified Assumption 3.2.1 with Assumption 3.1.4, based on Technical Justification • Replaced Unverified Assumption 3.2.2 with Assumption 3.1.5 based on Ref. 15 and Appendix C. • Added Reference 15 • Additional Comments Rev 0 coversheet is page 1a Coversheet and CCRIS forms updated Added number of attachment pages to Table of Contents Rev 0 verification form is page 6a • Added Appendix C to evaluate the margin of forces on tainter gates Significant changes in Revision 1 are noted with a right margin revision bar. Administrative changes and typos are excluded. Pages Added: 1a, 6a, C1, C2, C3 Pages Replaced: 1-7, 10 – 12, 15-16, 18, 19, 21 Total pages of calculation hard copy for Revision 1= 82

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080001	Revision:	1

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	Attachments	
1	General plan, Apalachia Dam (Ref. 1)	1 page
2	Apalachia Powerhouse Tailwater Rating (Ref. 3)	5 pages
3	Intentionally Left Blank	
4	See listing of electronic attachments on page 7	N/A
5	Apalachia Tailwater Rating Curve; River Mile 66 (Ref. 3)	1 page
6	Hydraulic Design Charts 711 and 311-2/3 (Ref. 7)	2 pages
7	Spillway Intake and Non-Overflow Dam General Arrangement (Ref. 8)	1 page
8	Cut-Off Walls Outline and Reinforcement (Ref. 9)	1 page
9	Concrete Block 28 Outline and Reinforcement (Ref. 10)	1 page
10	Spillway Intake and Non-Overflow Dam Principal Features of Design (Ref. 11)	1 page
11	Curve Fit for Apalachia Tailwater Rating Curve; River Mile 66 (Ref. 3)	1 page
12	Flow over tops of wide-open tainter gates (From Ref. 12)	1 page
13-21	See listing of electronic attachments on page 7	N/A
22	Fit to Powerhouse Tailwater Curve (Ref. 3)	1 page
23	Operating Characteristics, Units 1 and 2 (Ref. 13)	1 page
24	Fit to Units 1 and 2 Discharge Curves (Ref. 13)	1 page

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080001	Revision:	1

TABLE OF CONTENTS

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26	See listing of electronic attachments on page 7	
Appendices		
A	Spillway Discharge Coefficients and Submergence Factors for Apalachia Dam from 1:28.72 Scale Model Test Data	21 pages
B	Overflow Parameters	8 pages
C	Hydraulic Loads on Spillway Tainter Gates	3 pages
	Appendix A Attachments	
A1	Location and numbering of spillway gates (From Ref. A1)	1 page
A2	Gate arrangements and gate openings (From Ref. A1)	1 page
A3	Measured gate openings, From Field Data	1 page
A4	Definition sketch for spillway discharge	1 page
A5	Tainter Gate Rating Model Data (From Ref. A3)	5 pages
A6	Pages 490 and 491 from Reference A5 (model scale ratios)	1 page
A7	Geometry for Flow Under an Open Tainter Gate	5 pages
A8	Radial Gate Arrangement (Ref. A6)	1 page
A9	Spillway Crest Details (Ref. A7)	1 page
A10	Point at which nappe touches bottoms of gates	1 page
A11	Free discharge coefficient	1 page
A12	Orifice discharge coefficient calculations	1 page
A13	Orifice discharge coefficient plot	1 page
A14	Orifice discharge coefficients on Hydraulic Design Criteria plot (From Ref. 5)	1 page
A15-A18	See listing of electronic attachments on page 7	N/A

Note: N/A indicates an electronic attached file(s).

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080001 Revision 1

Method of verification used:

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

Verifier L. Yu Lin Date 12/22/09

L. Lin

Comments:

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

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

The methodology used to justify the operability of the gates is based solely on the conclusions of the "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates." Appendix C 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 CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080001 Revision 0

Method of verification used:

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

David Hunt for Scott Zinkham per telecon
David Hunt

Verifier L. Lin Date 1/20/09
Dr. L Yu Lin

Comments:

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document CDQ000020080001	Rev. 1	Plant: GEN	

Subject:
Dam Rating Curve, Apalachia

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

There are no electronic inputs 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 4: High Resolution copy of Reference 13
Attachment 13: Complete PDF copy of Reference 2
Attachment 14: Complete PDF copy of Reference 4
Attachment 15: Complete PDF copy of Reference 12
Attachment 16: Spreadsheet, Attachment 16-Apalachia Headwater Rating Curve Rev 1.xls
Attachments 17-21, 26: High Resolution Copies of Reference 1, 8-11, 14.
Attachment A15: Spreadsheet, Attachment A15-Apalachia Model Data for Headwater Ratings.xls
Attachment A16-A17: High Resolution Copies of Reference A6, A7
Attachment A18: Complete PDF Copy of Reference A3

☐ Microfiche/eFiche

1. Purpose

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

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

BLN Unit 3 & 4 Combined Operating License Application (COLA) was submitted using data and analysis that was determined for the original BLN FSAR (Unit 1 and Unit 2) and was documented in a 1998 reassessment. In 1998, the analysis process and documentation was brought under the nuclear quality assurance process for the first time. A quality assurance audit conducted by NRC staff in early 2007 raised several questions related to 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 calculations are prepared, checked, verified, stored, and cross referenced in a goal to provide the highest quality nuclear design input and output possible.

Figure 1 is a plan and elevation view of Apalachia Dam (a portion of Reference 1). For headwaters in the normal operating range, discharge is passed through the turbines (located 12.4 river miles downstream) via two penstocks and the spillway. The spillway consists of ten spillway bays, each with a radial, or tainter, gate to control discharge. If, as during a probable maximum flood (PMF) event, headwater rises above the normal operating range, discharge may also pass over the non-overflow section, the tops of the open spillway gates, the tops of the spillway piers, and over the cutoff walls.

Rating curves are presented for the following two cases

Case 1 – Valid for rising headwaters and for falling headwaters as long as the tailwater elevation does not flood the powerhouse (TW<875')

Case 2 – Valid for falling headwaters after the powerhouse has been flooded.

These headwater rating curves are based on the configuration of Apalachia Dam as defined on the current design drawings. The purpose of this calculation does not evaluate the design loading conditions for the dam.

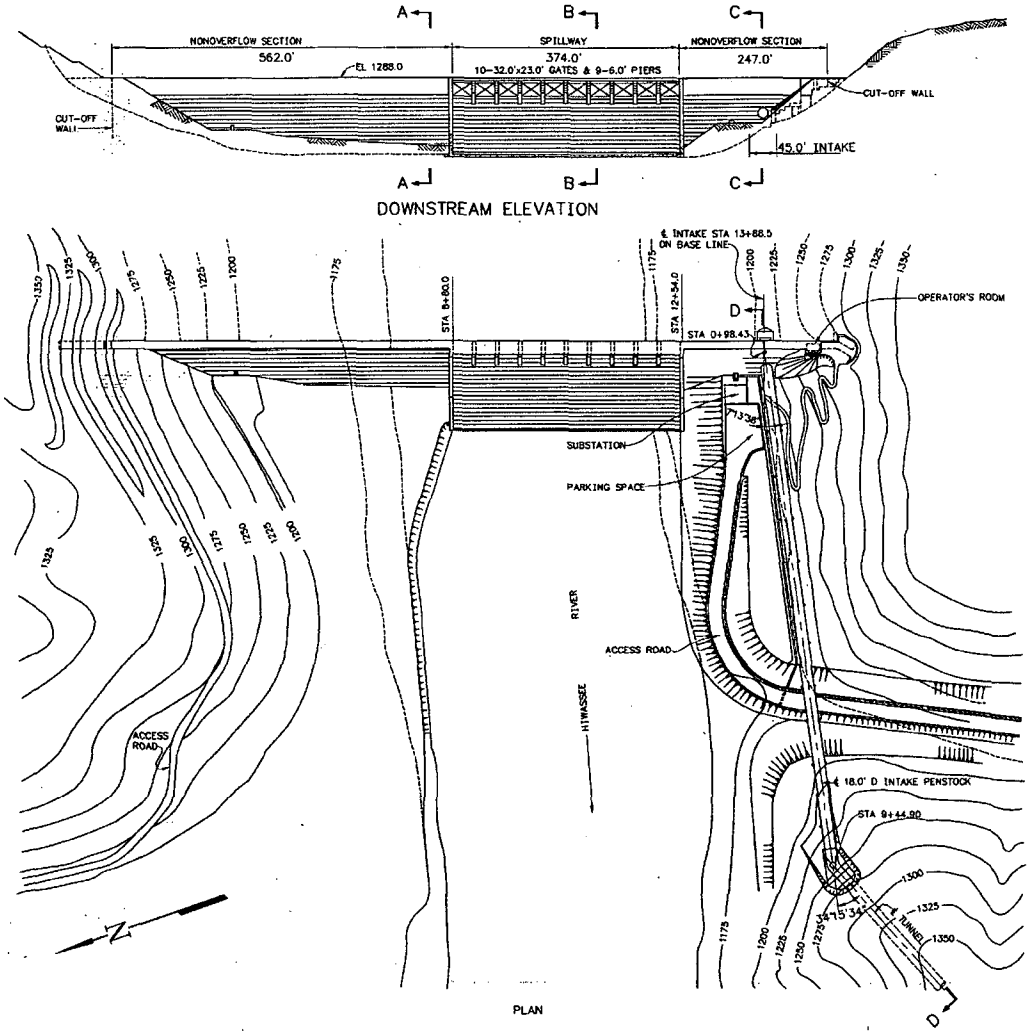


Figure 1 – Apalachia Dam, General Plan and Elevation (Ref. 1).

2. References

1. TVA drawing no: 10W200, R13 (Attachments 1 & 17)
2. TVA Water Control Project Manual (Blue Book) for Apalachia Dam, TVA River Operations, December, 1999 (Attachment 13)
3. TVA files, binder "River Scheduling: Tailwater Rating Curves by Projects."
4. "Apalachia Dam Spillway Discharge Tables", River Operations, Tennessee Valley Authority, 2004. EDMS# L58 081212 805 (Attachment 14)
5. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988.
6. Handbook of Hydraulics, E. F. Brater and H. W. King, Sixth Ed., McGraw Hill, 1976.
7. Hydraulic Design Chart 711 (HDC 711) from Reference 6 (Attachment 6)
8. TVA drawing no: 10N205, R4 (Attachments 7 & 18)
9. TVA drawing no: 21N201, R5 (Attachments 8 & 19)
10. TVA drawing no: 21N202, R4 (Attachments 9 & 20)
11. TVA drawing no: 10N206, R2 (Attachments 10 & 21)
12. "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 15)
13. TVA drawing no: 124K41, R4 (Attachments 4 and 23)
14. TVA drawing no: 46K208, R0 (Attachments 25 and 26)
15. TVA 2009: "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses", May 29, 2009 (EDMS No. L58090529800)

3. Assumptions & Methodology

The headwater rating curves developed in these calculations will be used in simulations of probable maximum flood events. 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: Power generation will continue during a PMF until the powerhouse is flooded.
Technical Justification: Power generation is assumed to stop when the addition of turbine discharge would lead to the tailwater reaching an elevation of 875 feet, at which point the tailwater will enter the powerhouse via the pilot door on the south side of the building (Attachment 25 Ref. 14). Accordingly, turbine discharge will be considered until the addition of discharge through the turbines would cause the tailwater to reach an elevation of 875 feet. After the powerhouse has been flooded, the generator will not be restarted as electrical components will be wet. Therefore, turbine discharge is not included as headwaters fall after flooding of the powerhouse.

3.1.2 Assumption: The tailwater curves given in Attachments 2-2 and 5 can be used to predict tailwater elevations at Apalachia Dam and its powerhouse.
Technical Justification: These tailwater rating curves are currently in use by TVA's River Operations Group to drive river management decisions during actual flooding events. The HEC-RAS tailwater rating curves attached to this calculation were generated by the TVA Flood Risk group within the last 4-5 years. As such, the HEC-RAS data is considered by TVA to be accurate information on tailwater elevations at Apalachia Dam. Even though it is not from a QA source, HEC-RAS data shows an acceptable level of agreement with tailwater curves generated from other sources, and is therefore considered valid as a confirmatory alternate analysis within the level of accuracy involved with this calculation (see 3.1.3 for justification of this). HEC-RAS data was generated by subject matter specialists within TVA, and access to this data is limited to these individuals. Where variation between older curves and more recent curves are encountered, the higher tailwater curve is used to quantify effects on discharge past the dam. Any variations in the tailwater rating curves, however, have little overall impact on the headwater rating curves (see 3.1.3).

3.1.3 Assumption: Tailwater effects on Apalachia Dam can be neglected
Technical Justification: Tailwater at the dam (rivermile 66) would have to rise another 38.4 feet from its maximum value to reach the crest elevation, which is the lowest elevation at which free discharge occurs (See Section 7, 1257'-1218.6'=38.4'). Tailwater effects can confidently be neglected for free/orifice discharge past the dam because of this margin for error between the predicted tailwater elevation and the crest elevation. Tailwater elevation at the powerhouse (rivermile 53.6) will affect turbine discharge in that tailwater determines the gross head driving the flow through the turbines as well as determining the point at which turbine operation will no longer be feasible (3.1.1). According to Reference 13, turbine discharge varies by less than 5% ([(3401cfs/3250 cfs)-1]*100%=4.6%) with a 40 foot variation in gross head (440'-400'=40'), therefore changes in turbine discharge due to head differential can be considered negligible. Beyond a headwater elevation of 1271', turbine discharge accounts for only a maximum of 9.96% of the total discharge past the dam (see Section 7, HW=1271',6616 cfs / 66440 cfs = 9.96%). Eliminating turbine discharge beyond this elevation would have a negligible impact on the overall rating curves, providing a relatively large margin for error in terms of when the turbines are shut down. Accordingly, the headwater rating curves are relatively insensitive to changes in either of the tailwater rating curves.

3.1.4 Assumption: Headwater elevation will not rise greater than 1296 feet.
Technical Justification: This PMF has been sufficient in all previous work. If a SOCH/TRBROUTE analysis requires a PMF Flood elevation higher than the maximum elevation considered, the change will be identified by the SOCH/TRBROUTE analyst and a revision to this dam rating curve calculation will be required.

3.1.5 Assumption: Spillway gates are considered fully operable and open to the maximum gate opening.
Technical Justification: For technical justification, see Reference 15, "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses", and Appendix C. 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 C1). Appendix C 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.

3.2 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 (References 5 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 ($ft^{0.5}$/sec), 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 need not be modified to account for tailwater submergence, as no portion of the dam which has free surface overflow will be submerged by tailwater (See Results Section)

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 5)

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

in which Q_g = orifice discharge (cfs), C_g = orifice discharge coefficient (dimensionless -- varies with gate opening and H_c), G_n = effective gate opening = minimum distance between the gate lip and the crest (ft), g = acceleration of gravity, and H_{mp} = vertical distance between the mid-point of G_n and the crest. This equation need not be modified to account for tailwater submergence, as tailwater elevation is never sufficiently high as to reach the crest elevation (See Results Section)

3.4 Methodology -- Spillway Discharge Calculations

The discharge coefficient, C_f, for free discharge over a spillway crest varies with head, H_c (References 5 and 6). For the Apalachia spillway crest, the relationships $H_{Lmin}(V)$ and $C_f(H_c)$ are available from model test data (Appendix A). The relationship between orifice discharge coefficient, C_g, and head, H_c, for each gate opening, V, is also available from the model test data. The crest length, L, and crest elevation, Z_c, are shown on TVA drawings (e.g., Reference 1). The parameters G_n and H_{mp} are determined from geometry (Appendix A).

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 (3.2.2), 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. According to Hydraulic Design Chart 111-3/2 (Attachment 6-2), end contraction losses effectively reduce the length of the overflowing spillway crest, L=320 ft (See Section 4), by $2*K_a*H_e$, in which K_a = abutment contraction coefficient (dimensionless), and $H_e = H_c$ =energy head on the crest (in ft.). The maximum possible value for $K_a = 0.2$ (Att.6-2), which means the maximum possible impact of abutment effects (calculated at maximum H_c , 25 ft, See Section 7, maximum elevation at which free discharge occurs) is equal to:

$$\left[1-\frac{L-2K_a(H_c)}{L}\right]*100\% = \left[1-\frac{320'-2(0.2)(25')}{320'}\right]*100\% = 3.1\%$$

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

Values of the discharge coefficient, C_f for flows over the non-overflow section, the tops of the open spillway gates, the tops of the spillway piers, and the area above the cutoff walls are estimated using Hydraulic Design Chart 711 (Reference 7) which is included as Attachment 6. Length, L, and crest elevation, Z_c, in each case is determined from TVA drawings (all relevant drawings are defined as References).

The upper plot of HDC 711 (Reference 7) shows that C_f is about 2.65 for very broad crests ($H_1/B < 0.4$ where $H_1 = H_c$ and B = streamwise length of the crest) and gradually increases to 3.1, the maximum value for a "broad-crested" weir, as H_1/B increases to about 1.2. As H_1/B increases above 1.2, C_f continues to increase as the weir transitions from broad-crested to sharp-crested at about $H_1/B = 2.0$. Since the estimation of discharge over the top of various sections of a dam and its embankments is an approximation, small variations in C_f with H_c are not modeled and the effects of end contractions are neglected. A single representative value for C_f within the range of its variation is used for all headwater elevations included in the rating. Neglecting minor variations in C_f values and end contractions has negligible impact on the dam rating curves.

4. Design Input

Sect.	Input Parameter	Source	Symbol	Value
4.1	Acceleration of gravity	Common knowledge, Ref. 5, sheet. 000-1 for example	g	32.2 ft/sec^2
4.2	**Spillway crest parameters**			
4.2.1	Crest length	10 32-foot wide bays, Ref. 1	L	320 feet
4.2.2	Crest elevation	Ref. 8	Z_c	1257.0 feet
4.2.3	Free discharge coefficient	Polynomial fit to model data given in Att. A5 and discussed in Appendix A	C_f	Equation A3
4.3	**Spillway gate parameters**			
4.3.1	Vertical opening	Extrapolation of data in Attachment A3	V	19.79 feet
4.3.2	Effective gate opening	Computed in Appendix A	G_n	20.381 feet
4.3.3	Mid-point elevation of G_n & Crest	Computed in Appendix A	H_{mp}	9.722 feet
4.3.4	Distance from spillway crest to point at which nappe touches gates	Estimated in Appendix A from data in Reference A3	H_{Lmin}	26.20 feet
4.3.5	Headwater elevation at which nappe touches gates	H_{Lmin} estimated in Appendix A	$H_{Lmin} + Z_c$	1283.20 feet
4.3.6	Orifice discharge coefficient	Extrapolated curve given in Att. A13 and Table A2 and discussed in Appendix A	$C_g(H_c)$	Interpolate between points in Table A2
4.4	**Spillway gate overflow**			
4.4.1	Overflow discharge coeff.	Justification in Appendix B	$C_o \equiv C_f$	3.1
4.4.2	Overflow elevation	Justification in Appendix A	$Z_o \equiv Z_c$	1288 feet
4.4.3	Overflow length	Same as spillway crest length, Ref. 1	L	320 feet
4.5	**Cutoff Walls**			
4.5.1	Discharge coefficient	Justification in Appendix B	C_f	2.75
4.5.2	Overflow elevation	Refs. 8, 9 and 10	Z_c	1287 feet
4.5.3	Overflow length	Determined in Appendix B	L	73.77 feet
4.6	**Non-overflow Sections (North and Middle)**			
4.6.1	Discharge coefficient	Justification in Appendix B	C_f	2.70
4.6.2	Overflow elevation	Refs. 8 and 11	Z_c	1288 feet
4.6.3	Overflow length	Determined in Appendix B	L	671.25
4.7	**Spillway Piers, Intake Structure and Op. Bldg.**			
4.7.1	Discharge coefficient	Justification in Appendix B	C_f	2.65
4.7.2	Overflow elevation	Refs. 10 and 11	Z_c	1288 feet
4.7.3	Overflow length	Determined in Appendix B	L	118.5
4.8	**South Section, Non-Overflow**			
4.8.1	Discharge coefficient	Justification in Appendix B	C_f	2.73
4.8.2	Overflow elevation	Refs. 10 and 11	Z_c	1287.83 feet
4.8.3	Overflow length	Determined in Appendix B	L	73.25 feet
4.9	**Tailwater Rating Curves**			
4.9.1	TW vs. total discharge, Q	Paragraph 4.12	TW(Q)	Equations 3.1 and 3.2

4.10	**Turbine Discharge**			
4.10.1	Q_t vs. Head on Turbine, H_t	Paragraph 4.14	Q_t (H_t)	Equation 4

4.11 Embankment Failure

The north and south embankments may be overtopped during a PMF event. The postulated failure of the embankments would result in the soil above the cutoff walls being washed away from elevation 1296 feet (the upper limit of this calculation) to elevation 1287 feet (the top of the north and south cutoff walls). Refer to Appendix B for failure sketches of the north embankment (page B1). The headwater rating curves for Apalachia Dam are calculated as if these failed sections of embankment do not exist. These failed sections are treated as a non-overflow section of the dam with a top elevation of 1287 feet (which is the top elevation of the cut-off walls underneath these sections).

4.12 Tailwater Rating Curves

The tailwater rating curve immediately downstream from the dam is shown in Attachment 5. Attachment 11 lists points scaled from this plot and shows a polynomial fit to the result. The polynomial indicated in Attachment 11 and repeated below is used for the headwater rating curve calculations (to determine submergence effects on free and orifice discharge past the dam).

$$TW_{dam} = 1169.48 + 0.547*Q - 4.00x10^{-3}Q^2 + 1.283x10^{-5}Q^3 \quad \text{for } Q \leq 150 \qquad (3.1a)$$
$$TW_{dam} = 0.104*Q + 1189.3 \quad \text{for } Q > 150 \qquad (3.1b)$$

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

Because calculated tailwater elevation immediately downstream from the dam (See Results Section) is less than the spillway crest elevation and overflow elevations for all headwaters in this calculation, tailwater effects on discharge (both free and orifice) can be neglected.

The tailwater rating curve at the powerhouse is shown in Attachment 2. Attachment 22 lists points scaled from the plot and shows a polynomial fit to the result. The polynomial indicated in Attachment 22 and repeated below is used for the headwater rating curve calculations (to determine turbine discharge).

$$TW_{ph} = 840.23 + 0.1886*Q - 8.0264x10^{-4}Q^2 + 1.0297x10^{-6}Q^3 \qquad (3.2)$$

Total flow past the powerhouse is a combination of flows past Apalachia Dam and runoff in the watershed between the dam and the powerhouse. Runoff will increase the flow, and thus the tailwater elevation at the powerhouse, however, as proven quantitatively in 3.1.3, the headwater rating curves are generally insensitive to changes in powerhouse tailwater elevation.

4.13 Upper Limit on Headwater Elevation Included in Rating Curves

The headwater rating curves need to include all headwater elevations that may occur during a PMF event. The headwater at Apalachia Dam is not expected to rise past 1296 feet. Although the headwater rating curve provided in this calculation extends to the elevation noted, Section 5.0 of this calculation limits the applicability of this curve to the headwater elevation defined in Section 5.0.

4.14 Discharge through Turbines

Discharge through the turbines, Q_t, was determined from Attachment 23 (Ref. 13) at 100% gate opening. Points were scaled from Reference 13 (100% gate curve) and a curve fit to turbine discharge versus gross head was developed in Attachment 24. The resulting polynomial is presented in Attachment 24 and repeated below.

$$Q_t = (3.7(H_t) + 1773) \quad (4)$$

in which Q_t = turbine discharge in cfs, and H_t = gross head on the turbine ($HW\text{-}TW_{ph}$) in feet. Because turbine discharge (Equation (4)) is a function of tailwater elevation, which itself is a function of all discharges past the dam (Equations (3.1) and (3.2)), an iterative process will be used to calculate tailwater elevation and turbine discharge in Case 1.

5.0 Special Requirements/Limiting Conditions

Calculations performed in Appendix C 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 headwaters no greater than 1295.00. If PMF headwater elevations at the Apalachia Dam exceed 1295.00, a revision of this calculation will be required.

6. Calculations

Case 1

The calculations consist of computing spillway, turbine and overflow discharges (from Equations 1, 2 and 4) for a list of headwater elevations ranging from the crest elevation, 1257 feet, up to 1296 feet, the upper limit of this calculation. The headwater rating curve is a plot of headwater elevation versus total dam discharge.

Discharge passes through the spillway section and turbines first and then the various overflow sections as headwater rises above the crest elevation. Total discharge, given in "1000 cfs", is the sum of all discharges in cfs past the dam divided by 1000.

Figure 2a shows the spreadsheet calculations for the headwater rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge.

The third and fourth columns (TW) give the tailwater elevations (at Apalachia Dam and at the powerhouse) associated with the "Total Discharge" from the tailwater rating curve polynomial fits [4.12]. Tailwater elevation at the dam is computed to verify that tailwater does not affect any of the discharges past the dam (free overflow or orifice flow). Tailwater elevation at the powerhouse is used to calculate the gross head on the turbines. Because the tailwater level varies with total dam discharge, an iterative process is used to determine turbine discharge. For the iterative process TW is assumed (red text column in Attachment 16), Q_{total} is calculated (using Qt calculated from $TW_{assumed}$), and $TW_{calculated}$ is calculated (based on Q_{total}). Iteration is done by varying $TW_{assumed}$ until the difference between $TW_{assumed}$ and $TW_{calculated}$ is equal to 0, within convergence tolerances. The convergence tolerance was set to $1*10^{-6}$. The average difference for converged solutions is $5*10^{-8}$ feet (Attachment 16).

Spillway discharge is computed in the seventh column. H_c, and $C_f|C_g$ are the parameters used to determine the spillway discharge, $Q_f|Q_g$. Free discharge occurs for elevations below 1283.20 feet [4.3.5] and orifice discharge occurs for headwaters above this elevation. The transition point is indicated by a horizontal line. Above the transition line, the listed discharge coefficient is C_f [4.2.3] and below the transition line the listed discharge coefficient is C_g [4.3.6].

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 five columns are overflow discharges in cfs for the various overflow sections of the dam. The first column calculates overflow discharge of the spillway gates. The next column calculates discharges over the north and south cutoff walls. The third column calculates discharges over the south section of the non-overflow dam. The fourth column determines discharge over the north and middle sections of the non overflow dam, and the fifth column calculates discharge over the piers, intake structure and operations building. The overflow discharge coefficient C_f ([4.4.1], [4.5.1], [4.6.1], [4.7.1] , [4.8.1]), elevation Z_c ([4.4.2], [4.5.2], [4.6.2], [4.7.2] , [4.8.2]), and length L ([4.4.3], [4.5.3], [4.6.3], [4.7.3], [4.8.3]) are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation (1). Since the tailwater elevation is below the overflow crest elevations for all headwater elevations included in the ratings, there are no tailwater effects on these discharges.

The final column contains the discharge past the turbines, Q_t in cfs, determined from the gross head on the turbine, H_t.

Case 2

The calculations consist of computing spillway and overflow discharges (from Equations 1 and 2) for a list of headwater elevations ranging from 1296 feet, the upper limit of this calculation, to the crest elevation, 1257 feet. The headwater rating curve is a plot of headwater elevation versus total dam discharge.

Figure 2 shows the spreadsheet calculations for the headwater rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge.

The third column (TW) gives the tailwater elevation (at Apalachia Dam) associated with the "Total Discharge" from the tailwater rating curve polynomial fits [4.12]. Tailwater elevation at the dam is computed to verify that tailwater does not affect any of the discharges past the dam (free overflow or orifice flow). Because no discharge past the dam is a function of tailwater elevation, an iterative process is not required to determine tailwater elevation in Case 2.

Spillway discharge is computed in the sixth column. H_c, and $C_f|C_g$ are the parameters used to determine the spillway discharge, $Q_f|Q_g$. Free discharge occurs for elevations below 1283.20 feet [4.3.5] and orifice discharge occurs for headwaters above this elevation. The transition point is indicated by a horizontal line. Above the transition line, the listed discharge coefficient is C_f [4.2.3] and below the transition line the listed discharge coefficient is C_g [4.3.6].

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 five columns are overflow discharges in cfs for the various overflow sections of the dam. The first column calculates overflow discharge of the spillway gates. The next column calculates discharges over the north and south cutoff walls. The third column calculates discharges over the south section of the non-overflow dam. The fourth column determines discharge over the north and middle sections of the non overflow dam, and the fifth column calculates discharge over the piers, intake structure and operations building. The overflow discharge coefficient C_f ([4.4.1], [4.5.1], [4.6.1], [4.7.1] , [4.8.1]), elevation Z_c ([4.4.2], [4.5.2], [4.6.2], [4.7.2] , [4.8.2]), and length L ([4.4.3], [4.5.3], [4.6.3], [4.7.3], [4.8.3]) are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation (1). Since the tailwater elevation is below the overflow crest elevations for all headwater elevations included in the ratings, there are no tailwater effects on these discharges.

7. Results/Conclusions

For convenience, the headwater rating results, separate from the calculation details provided above, are tabulated as total discharge in cfs vs. headwater elevation in feet in Figure 3. The headwater rating curves are plotted in Figure 4.

The headwater rating curves developed in this calculation provide total Apalachia Dam discharge vs. headwater elevation for use in TVA's SOCH and TRBROUTE models for simulation conditions satisfying the assumptions in Section 3. In particular, the spillway gates must all be fully raised and powerhouse gates open 100%.

As discussed in Section 5.0, the dam rating curves provided in Figures 2a and 2b are limited in applicability to headwater elevations no greater than 1295.00.

Apalachia Rating Curve, Case 1

g = 32.2 ft/s^2

Spillway Parameters
L = 320 feet
Z_c = 1257 feet
G_n = 20.381 feet
H_{mp} = 9.722 feet

HW feet	Q Total Discharge 1000 cfs	Mile 66 TW_{dam} feet	Mile 53.6 TW_{ph} feet	Spillway feet H_c	$C_f \mid C_g$	cfs $Q_f \mid Q_g$		Overflow Discharge, Q_f in cfs: Gate Overflow	Cutoff Section	South Section	Non-Over Dam	Piers Intake & Op Bldg	Turbine Dschg. At 100% Gate feet Ht	Qt cfs
							C_f =	3.1	2.75	2.73	2.7	2.65		
							Z_c =	1288	1287	1287.83	1288	1288		
							L =	320	73.77	73.25	671.25	118.5		
1257	3.31	1171.2	841.2	0	2.85	0		0	0	0	0	0	415.8	3312
1258	4.25	1171.7	841.4	1	2.93	938		0	0	0	0	0	416.6	3314
1261	11.37	1175.2	843.4	4	3.14	8047		0	0	0	0	0	417.6	3318
1263	18.64	1178.4	845.3	6	3.26	15318		0	0	0	0	0	417.7	3318
1265	27.60	1181.8	847.6	8	3.35	24280		0	0	0	0	0	417.4	3317
1267	38.08	1185.2	850.1	10	3.44	34761		0	0	0	0	0	416.9	3315
1269	49.95	1188.4	852.8	12	3.51	46636		0	0	0	0	0	416.2	3313
1270	56.38	1189.9	854.2	13	3.54	53071		0	0	0	0	0	415.8	3312
1271	63.14	1191.3	855.5	14	3.57	59827		0	0	0	0	0	415.5	3310
1272	70.21	1192.6	856.9	15	3.60	66902		0	0	0	0	0	415.1	3309
1274	85.32	1195.0	859.7	17	3.66	82015		0	0	0	0	0	414.3	3306
1275	93.37	1196.1	861.0	18	3.69	90062		0	0	0	0	0	414.0	3305
1276	101.75	1197.2	862.4	19	3.71	98450		0	0	0	0	0	413.6	3303
1278	119.61	1199.6	865.1	21	3.78	116311		0	0	0	0	0	412.9	3301
1279	129.12	1201.0	866.4	22	3.81	125825		0	0	0	0	0	412.6	3300
1281	149.45	1204.7	868.9	24	3.88	146154		0	0	0	0	0	412.1	3298
1282	160.33	1205.9	870.2	25	3.93	157038		0	0	0	0	0	411.8	3297
1283.2	173.00	1207.2	871.5	26.2	0.799	169700		0	0	0	0	0	411.7	3296
1284	172.18	1207.1	871.4	27	0.776	168876		0	0	0	0	0	412.6	3299
1285	170.70	1207.0	871.3	28	0.748	167401		0	0	0	0	0	413.7	3304
1286	168.76	1206.8	871.1	29	0.720	165456		0	0	0	0	0	414.9	3308
1287	172.22	1207.1	871.4	30	0.717	168907		0	0	0	0	0	415.6	3311
1287.83	175.13	1207.4	871.7	30.8	0.714	171664		0	153	0	0	0	416.1	3313
1288	175.75	1207.5	871.8	31	0.713	172217		0	203	14	0	0	416.2	3313
1289	182.65	1208.2	872.5	32	0.710	175394		992	574	253	1812	314	416.5	3314
1290	193.27	1209.3	873.5	33	0.711	179445		2806	1054	639	5126	888	416.5	3314
1291	205.69	1210.6	874.7	34	0.711	183420		5155	1623	1129	9417	1632	416.3	3313
1292	216.24	1211.7	875.6	35	0.712	187324		7936	2268	1703	14499	2512	416.4	0
1293	231.36	1213.3	876.9	36	0.713	191161		11091	2982	2351	20263	3511	416.1	0
1294	247.59	1215.0	878.2	37	0.713	194935		14579	3757	3065	26636	4615	415.8	0
1295	264.83	1216.7	879.6	38	0.714	198650		18372	4590	3839	33566	5816	415.4	0
1296	283.02	1218.6	881.0	39	0.714	202309		22446	5477	4670	41009	7106	415.0	0

Figure 2a – Calculations for Headwater Rating Curve, Case 1

Apalchia Rating Curve, Case 2

g = 32.2 ft/s^2

Spillway Parameters
L = 320 feet
Z_c = 1257 feet
G_n = 20.381 feet
H_{mp} = 9.722 feet

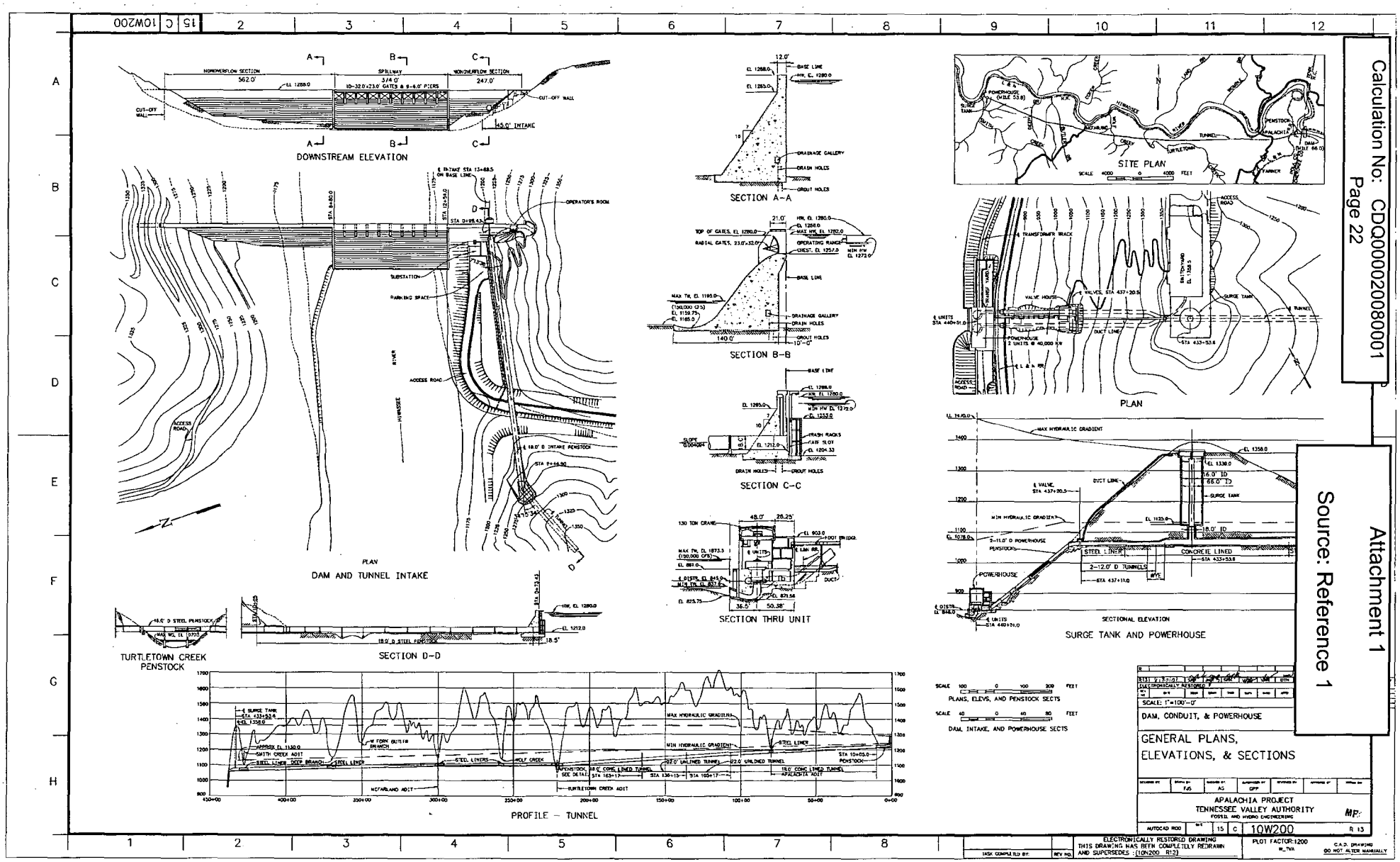
HW feet	Q Total Discharge 1000 cfs	Mile 66 TW$_{dam}$ feet	Spillway feet H_c	C_f | C_g	cfs Q_f | Q_g		Overflow Discharge, Q_f in cfs: Gate Overflow	Cutoff Section	South Section	Non-Over Dam	Piers Intake & Op Bldg
						C_f =	3.1	2.75	2.73	2.7	2.65
						Z_c =	1288	1287	1287.83	1288	1288
						L =	320	73.77	73.25	671.25	118.5
1257	**0.00**	1169.5	0	2.85	0		0	0	0	0	0
1258	**0.94**	1170.0	1	2.93	938		0	0	0	0	0
1261	**8.05**	1173.6	4	3.14	8047		0	0	0	0	0
1263	**15.32**	1177.0	6	3.26	15318		0	0	0	0	0
1265	**24.28**	1180.6	8	3.35	24280		0	0	0	0	0
1267	**34.76**	1184.2	10	3.44	34761		0	0	0	0	0
1269	**46.64**	1187.6	12	3.51	46636		0	0	0	0	0
1270	**53.07**	1189.2	13	3.54	53071		0	0	0	0	0
1271	**59.83**	1190.6	14	3.57	59827		0	0	0	0	0
1272	**66.90**	1192.0	15	3.60	66902		0	0	0	0	0
1274	**82.01**	1194.5	17	3.66	82015		0	0	0	0	0
1275	**90.06**	1195.7	18	3.69	90062		0	0	0	0	0
1276	**98.45**	1196.8	19	3.71	98450		0	0	0	0	0
1278	**116.31**	1199.2	21	3.78	116311		0	0	0	0	0
1279	**125.82**	1200.5	22	3.81	125825		0	0	0	0	0
1281	**146.15**	1204.0	24	3.88	146154		0	0	0	0	0
1282	**157.04**	1205.6	25	3.93	157038		0	0	0	0	0
1283.2	**169.81**	1206.9	26.2	0.799	169812		0	0	0	0	0
1284	**169.00**	1206.8	27	0.777	168995		0	0	0	0	0
1285	**167.53**	1206.7	28	0.749	167529		0	0	0	0	0
1286	**165.59**	1206.5	29	0.721	165594		0	0	0	0	0
1287	**168.93**	1206.8	30	0.717	168931		0	0	0	0	0
1287.83	**171.84**	1207.1	30.83	0.714	171689		0	153	0	0	0
1288	**172.46**	1207.2	31	0.713	172242		0	203	14	0	0
1289	**179.37**	1207.9	32	0.710	175420		992	574	253	1812	314
1290	**189.96**	1209.0	33	0.711	179445		2806	1054	639	5126	888
1291	**202.38**	1210.3	34	0.711	183420		5155	1623	1129	9417	1632
1292	**216.24**	1211.7	35	0.712	187324		7936	2268	1703	14499	2512
1293	**231.36**	1213.3	36	0.713	191161		11091	2982	2351	20263	3511
1294	**247.59**	1215.0	37	0.713	194935		14579	3757	3065	26636	4615
1295	**264.83**	1216.7	38	0.714	198650		18372	4590	3839	33566	5816
1296	**283.02**	1218.6	39	0.714	202309		22446	5477	4670	41009	7106

Figure 2b – Calculations for Headwater Rating Curve, Case 2

Apalachia Headwater Curves

2008 Rating Case 1		2008 Rating Case 2	
HW feet	Total Discharge 1000 cfs	HW feet	Total Discharge 1000 cfs
1257	3.31	1257	0.00
1258	4.25	1258	0.94
1261	11.37	1261	8.05
1263	18.64	1263	15.32
1265	27.60	1265	24.28
1267	38.08	1267	34.76
1269	49.95	1269	46.64
1270	56.38	1270	53.07
1271	63.14	1271	59.83
1272	70.21	1272	66.90
1274	85.32	1274	82.01
1275	93.37	1275	90.06
1276	101.75	1276	98.45
1278	119.61	1278	116.31
1279	129.12	1279	125.82
1281	149.45	1281	146.15
1282	160.33	1282	157.04
1283.2	173.00	1283.2	169.70
1284	172.18	1284	168.88
1285	170.70	1285	167.40
1286	168.76	1286	165.46
1287	172.22	1287	168.91
1287.83	175.13	1287.83	171.82
1288	175.75	1288	172.43
1289	182.65	1289	179.34
1290	193.27	1290	189.96
1291	205.69	1291	202.38
1292	216.24	1292	216.24
1293	231.36	1293	231.36
1294	247.59	1294	247.59
1295	264.83	1295	264.83
1296	283.02	1296	283.02

Figure 3 – Headwater Rating Results



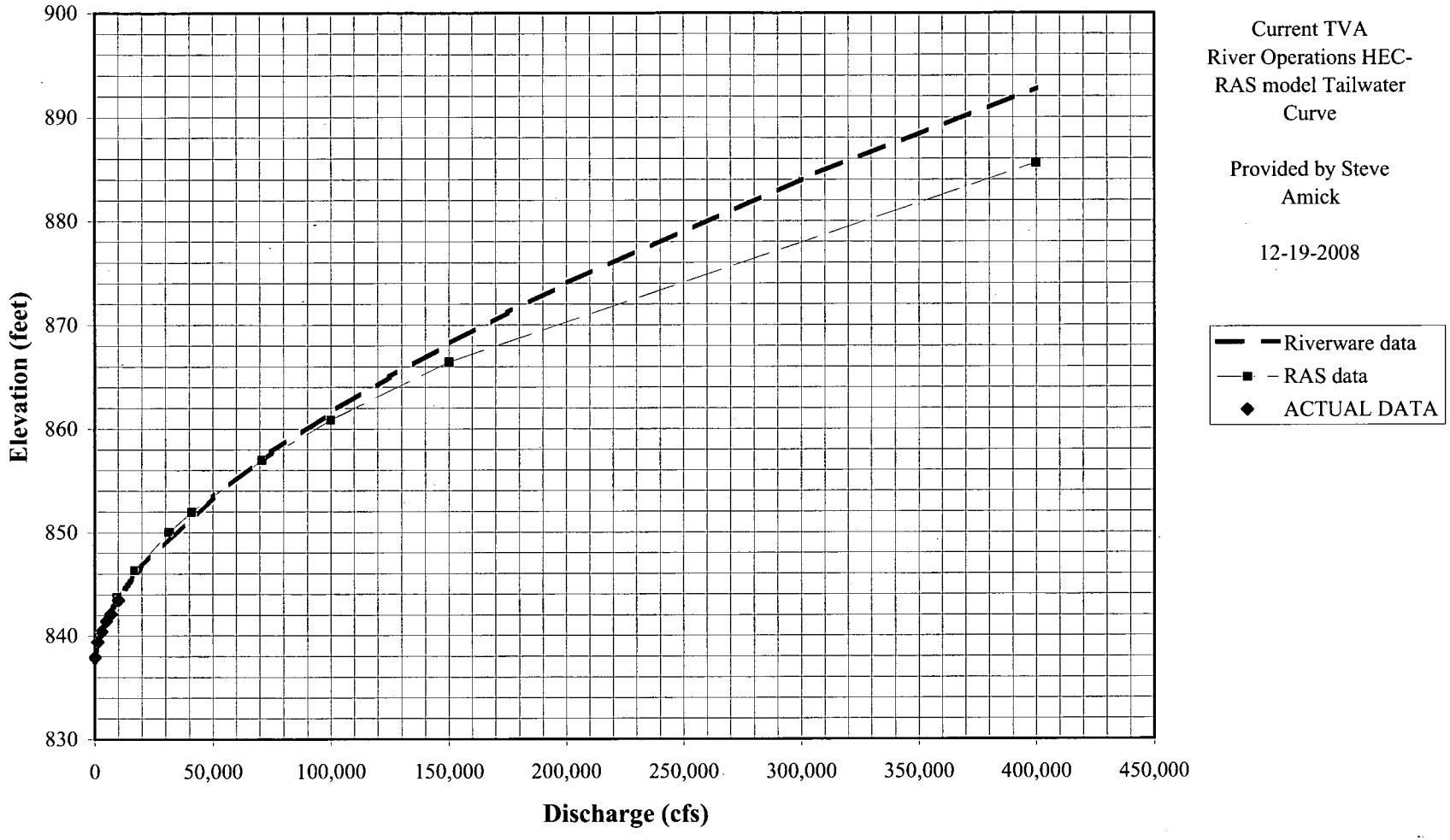
Attachment 1
Source: Reference 1

Tailwater Rating Curves

By Project

River Scheduling

Apalachia Powerhouse Tailwater Rating at mile 53.6



Apalachia Tailwater Rating
@ Powerhouse - Hiwassee River Mile 53.6
Riverware data

Q*1000	Q	Elevation
0	0	837.503
1	1,000	839.022
1.3	1,300	839.5
2	2,000	839.803
2.8	2,800	840.4
3	3,000	840.433
4	4,000	840.991
5	5,000	841.493
6	6,000	841.952
7	7,000	842.382
8	8,000	842.792
9	9,000	843.173
10	10,000	843.543
11	11,000	843.901
12	12,000	844.242
13	13,000	844.57
14	14,000	844.892
15	15,000	845.213
16	16,000	845.512
17	17,000	845.81
18	18,000	846.102
19	19,000	846.381
20	20,000	846.66
50	50,000	853.37
75	75,000	857.74
100	100,000	861.56
125	125,000	865
150	150,000	868.18
175	175,000	871.16
200	200,000	873.96
300	300,000	884.01
400	400,000	892.77

ACTUAL DATA

Dicharge	Elevation
0	837.9
1212	839.4
2860	840.4
4900	841.4
6920	842.1
10047	843.4

@ River Mile 66.0, 1941 Data
(Based on 1941 Channel)

Dicharge	Elevation
0	1167.5
10,000	1172.7
20,000	1175.5
40,000	1179.9
60,000	1183.4
80,000	1186.3
100,000	1189.2
120,000	1191.8
140,000	1194.2
150,000	1195.4

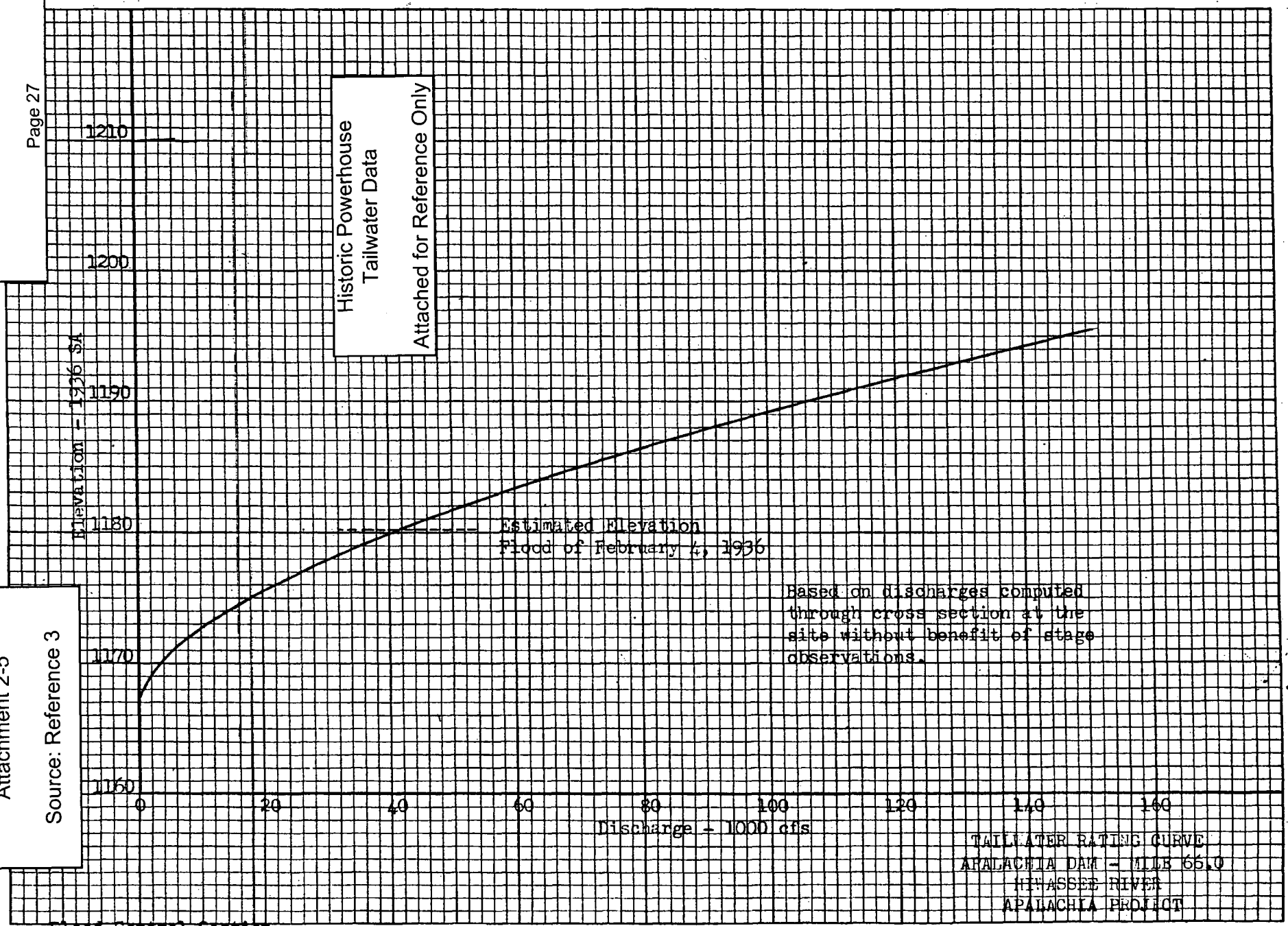
HEC-RAS Plan: finalHwFrqP River: RIVER-1 Reach: Reach-1

Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)
			RAS data	
	Rivermile 53.6		20	834.92
			2700	840.37
			9400	843.7
			17000	846.29
			31500	849.97
			41000	851.92
			71000	856.93
			100000	860.8
			150000	866.4
			400000	885.6
				RAS data
	Rivermile 66		20	1168.43
			2700	1171.47
			7000	1173.52
			15000	1177.29
			25000	1180.99
			29000	1182.27
			50000	1187.83
			100000	1197.3
			150000	1204.8
			400000	1230.7

KEUFFEL & ESSER CO., N. Y. NO. 359-8
10 X 10 to the inch, 10th lines heavy.
MADE IN U. S. A.

Calculation No: CDQ000020080001
Page 27

Historic Powerhouse
Tailwater Data
Attached for Reference Only

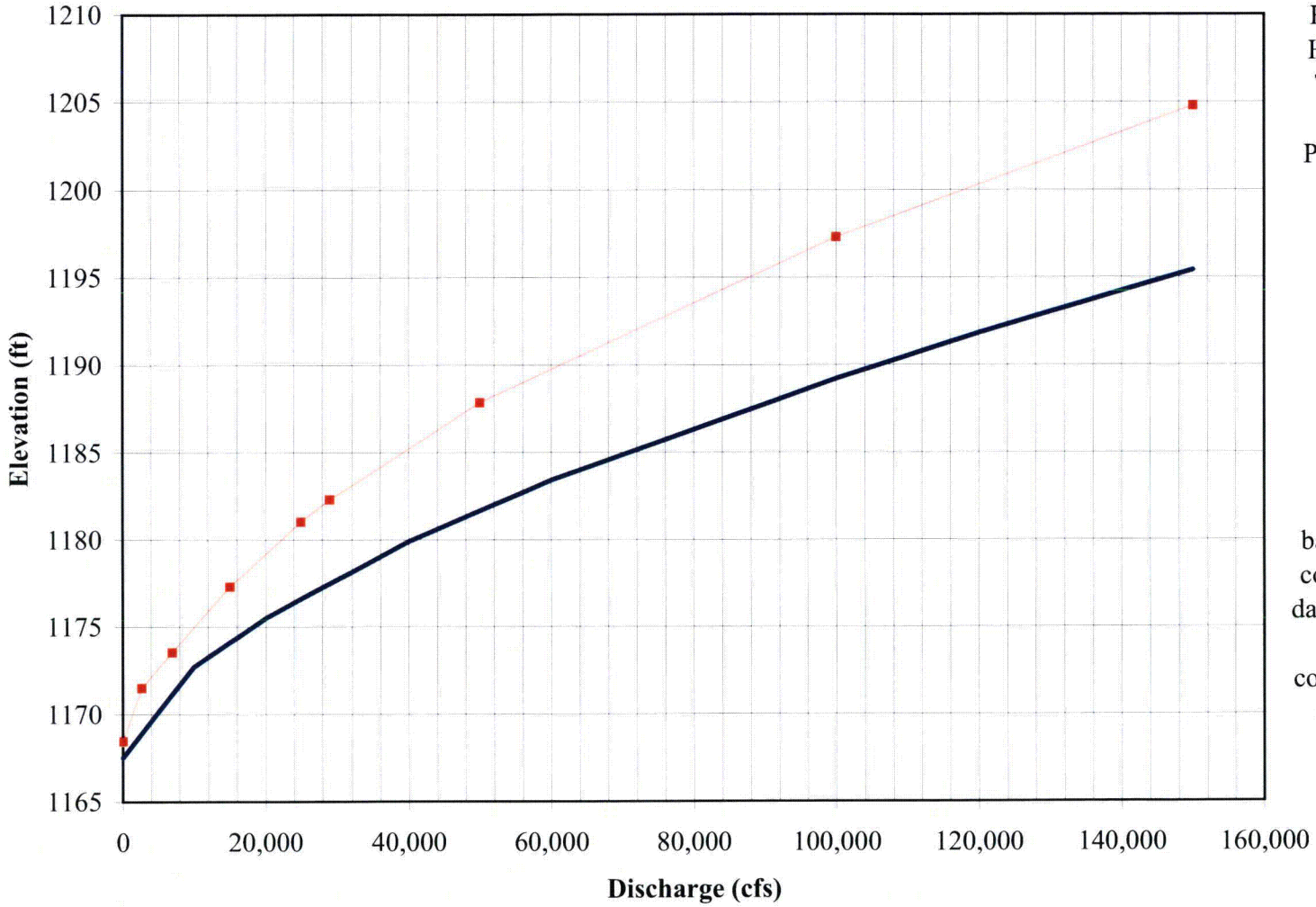


TAILWATER RATING CURVE
APALACHIA DAM - MILE 66.0
HIWASSEE RIVER
APALACHIA PROJECT

Attachment 2-5
Source: Reference 3

Flood Control Section
June 1941

Apalachia Tailwater Rating River Mile 66.0



Current TVA River Operations HEC-RAS model Tailwater Curve

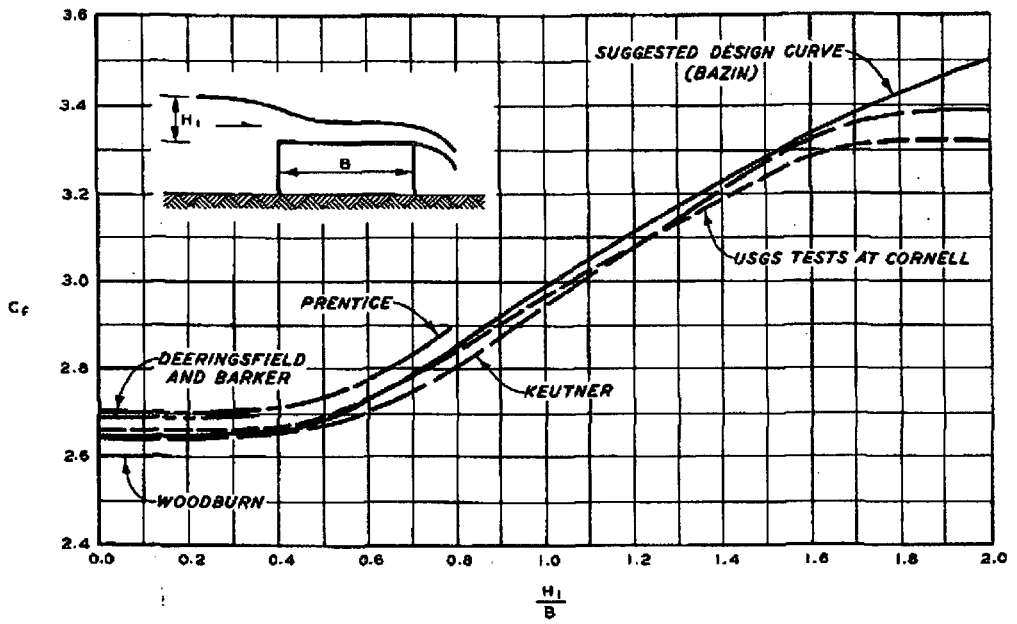
Provided by Steve Amick

12-19-2008

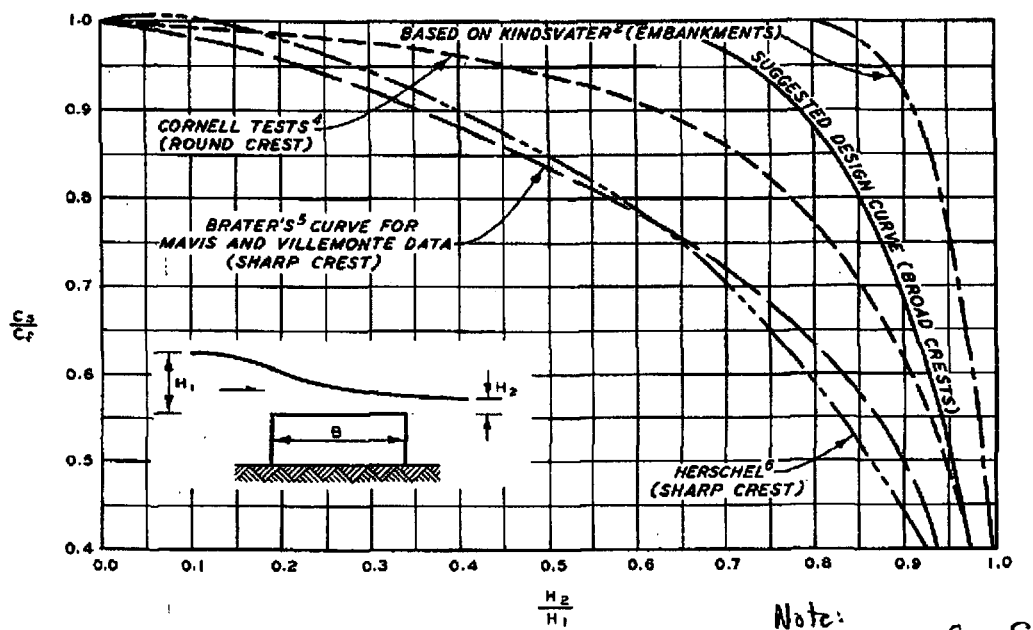
1941 Data

RAS data

1941 Data was based on channel conditions before dam closure. HEC-RAS data is corrected for more recent channel conditions (vegetation, deposition)



a. FREE FLOW



b. SUBMERGED FLOW

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

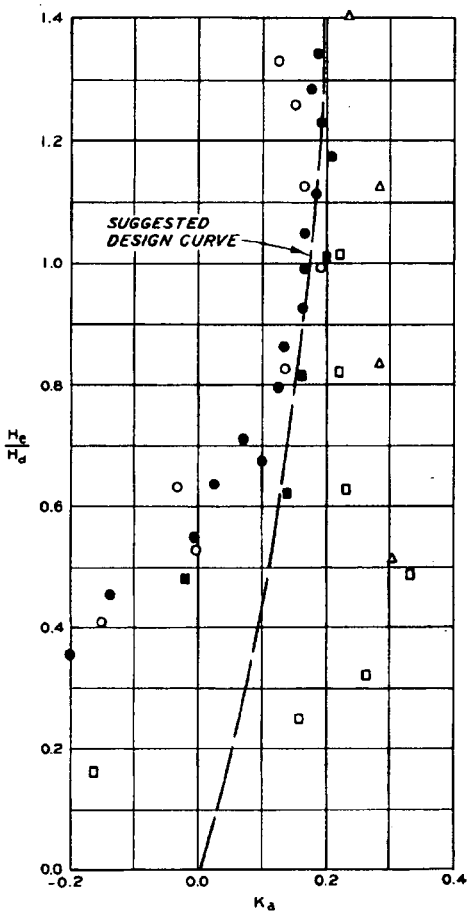
NOTE: C_f = FREE-FLOW COEFFICIENT
C_s = SUBMERGED-FLOW COEFFICIENT
NEGLIGIBLE VELOCITY OF APPROACH
RAISED NUMBERS ON SUBMERGED FLOW CHART ARE REFERENCE NUMBERS FROM TEXT.

LOW-MONOLITH DIVERSION
DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 711

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

WES 1-65



BASIC EQUATION

$$Q = C\left[L' - 2(NK_p + K_a)H_e\right]H_e^{3/2}$$

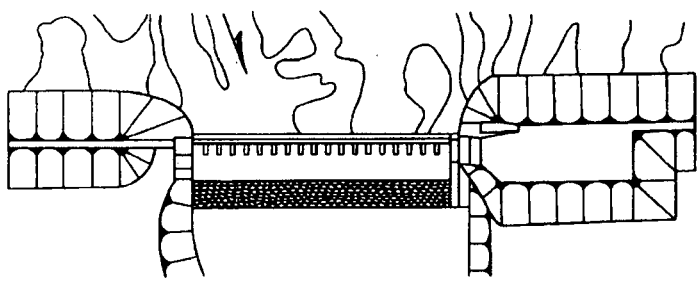
WHERE:
- Q = DISCHARGE, CFS
- C = DISCHARGE COEFFICIENT
- L' = NET LENGTH OF CREST, FT
- N = NUMBER OF PIERS
- K_p = PIER CONTRACTION COEFFICIENT
- K_a = ABUTMENT CONTRACTION COEFFICIENT
- H_e = ENERGY HEAD ON CREST, FT

LEGEND

SYMBOL	PROJECT	R	W/L	W/H
□	DORENA	2	5.60	10.7
■	DORENA	4	5.60	10.7
○	RED ROCK*	7.8	3.42	16.5
●	CARLYLE*	9	8.44	75.5
△	WALTER F. GEORGE*	4	5.44	55.3

*GATED SPILLWAY WITH PIERS

NOTE: R = RADIUS OF ABUTMENT, FT
W = WIDTH OF APPROACH REPRODUCED IN MODEL, FT
L = GROSS WIDTH OF SPILLWAY, FT
H = DEPTH OF APPROACH IN MODEL, FT
H_d = DESIGN HEAD ON CREST, FT



OVERFLOW SPILLWAY CREST WITH ADJACENT EMBANKMENT SECTIONS

ABUTMENT CONTRACTION COEFFICIENT

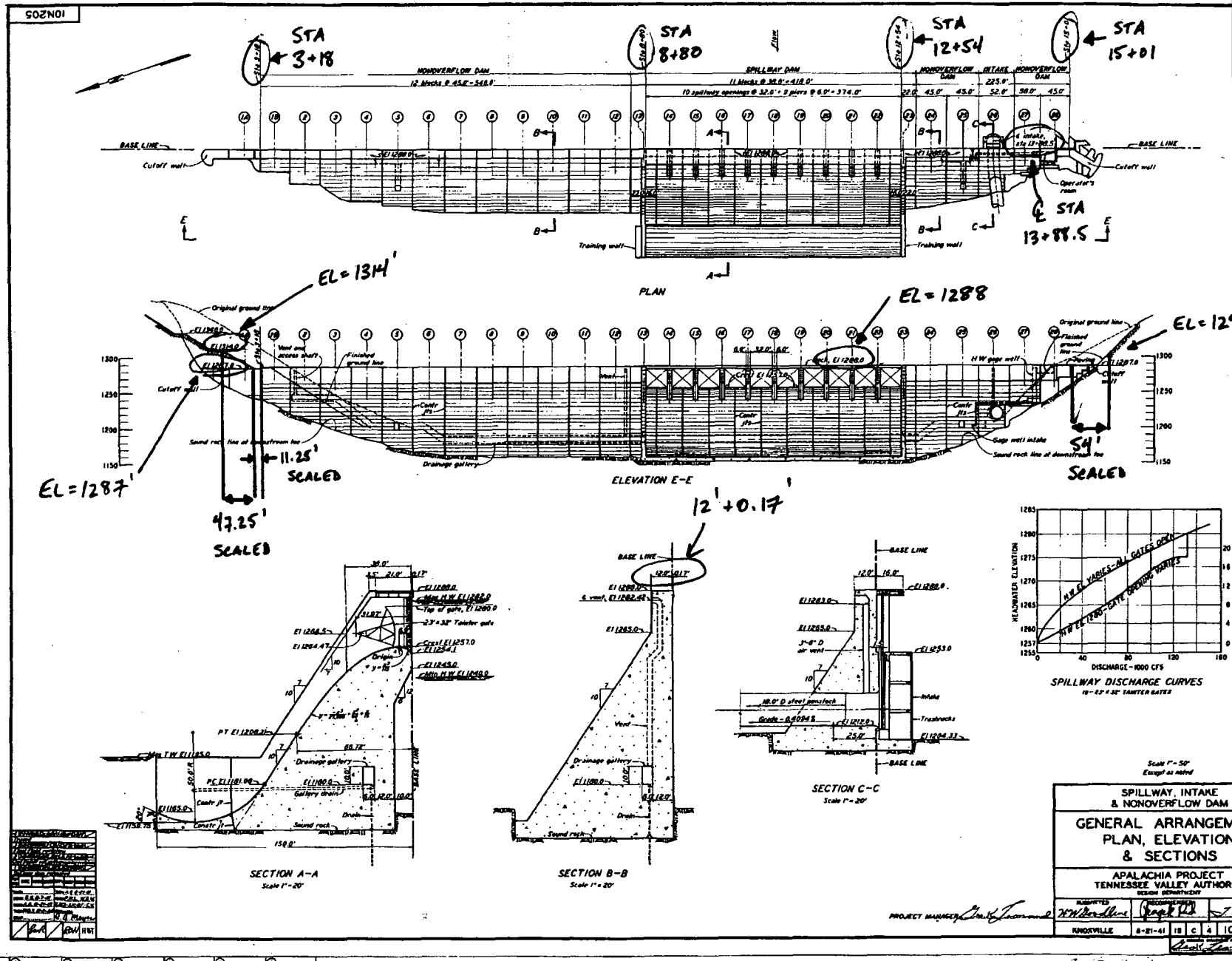
HYDRAULIC DESIGN CHART III-3/2

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

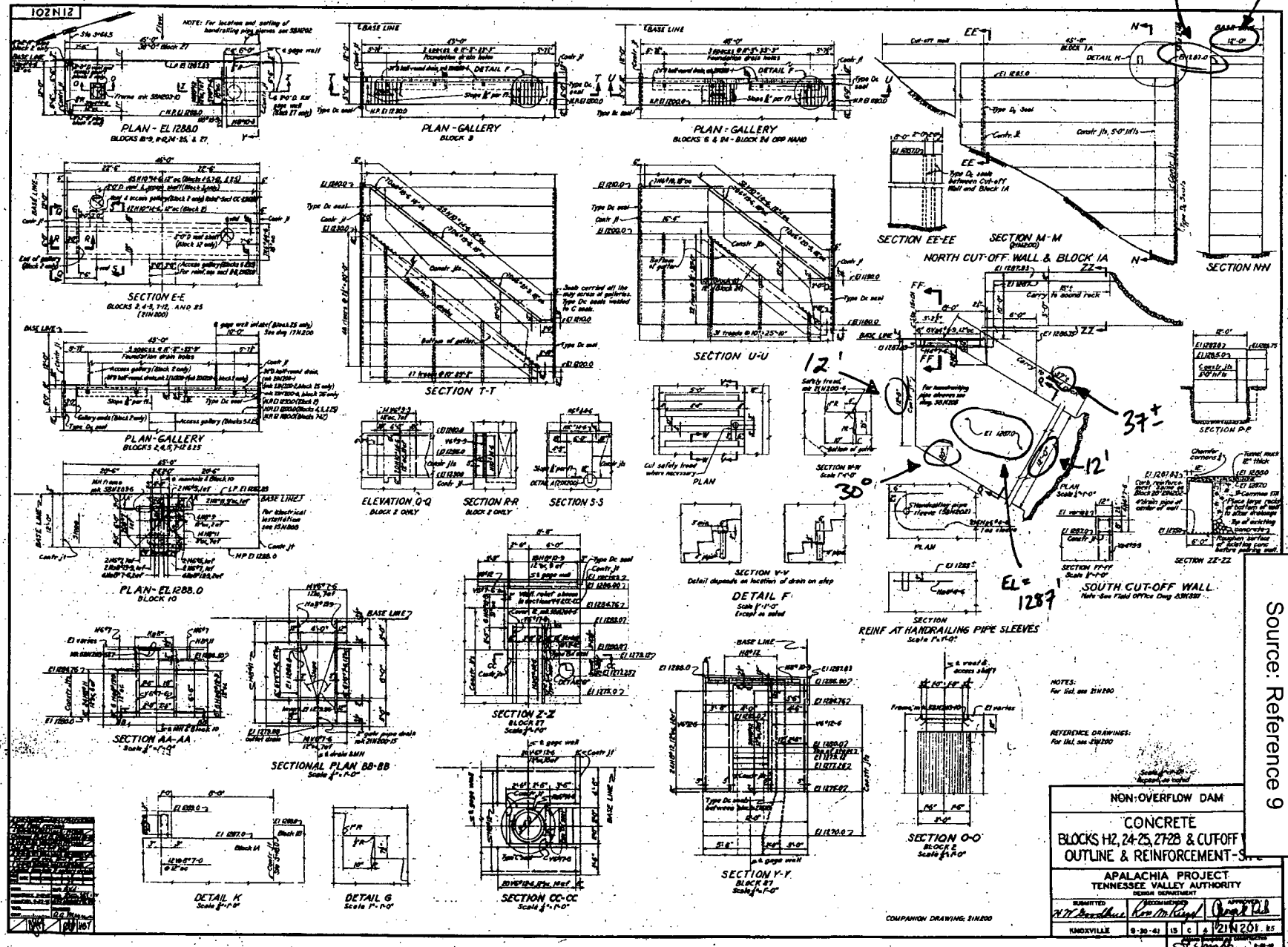
REV 1-64

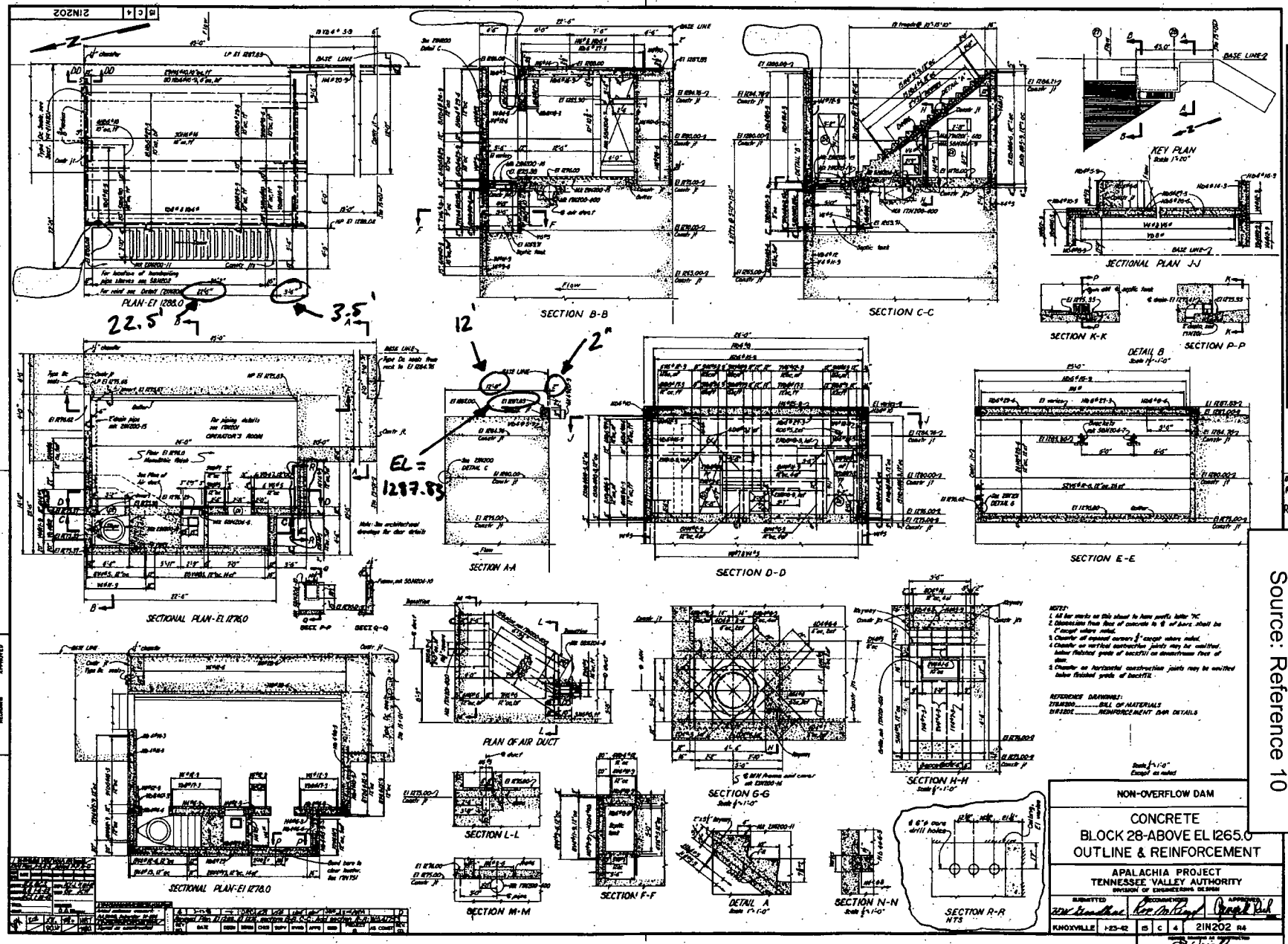
WES 8-60

Attachment 7
Source: Reference 8



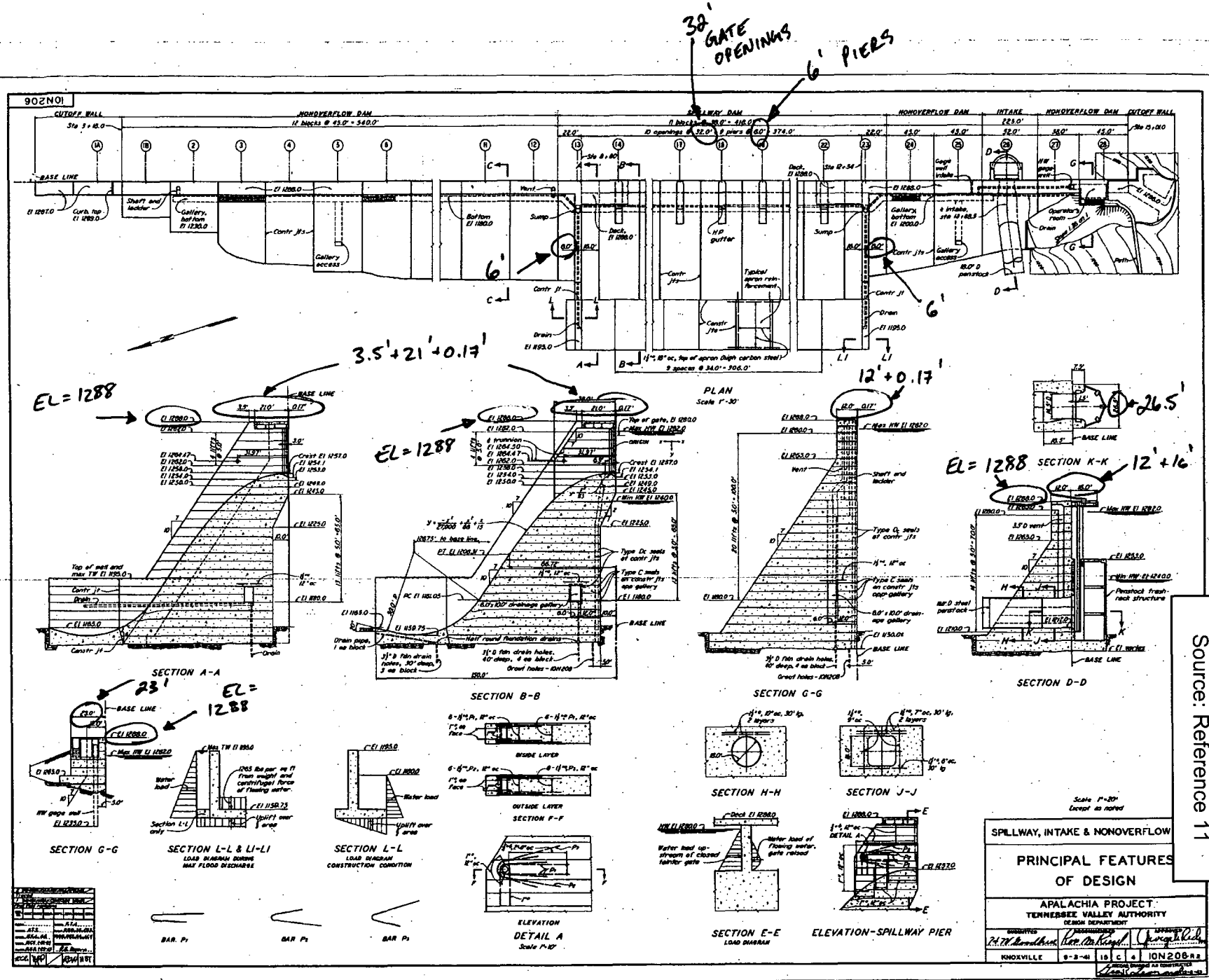
Calculation No: CDQ000020080001
Page 30


EL=1287.0'
12'
PLAN - EL 1288.0
PLAN - GALLERY
BLOCK 3
PLAN - GALLERY
SECTION EE-EE
SECTION M-M
NORTH CUT-OFF WALL & BLOCK 1A
SECTION NN
SECTION E-E
SECTION T-T
SECTION U-U
PLAN-GALLERY
SECTION P-P
37±
30°
ELEVATION Q-Q
SECTION R-R
SECTION S-S
PLAN
SECTION W-W
PLAN
SECTION TT-TT
SECTION ZZ-ZZ
SOUTH CUT-OFF WALL
PLAN-EL 1288.0
BLOCK 10
SECTION V-V
DETAIL F
REINF AT HANDRAILING PIPE SLEEVES
SECTION AA-AA
SECTIONAL PLAN BB-BB
SECTION Z-Z
BLOCK 27
SECTION Y-Y
BLOCK 27
SECTION O-O
BLOCK 2
DETAIL K
DETAIL G
SECTION CC-CC
NOTES:
REFERENCE DRAWINGS:
NON-OVERFLOW DAM
CONCRETE
BLOCKS H2, 24-25, 27-28 & CUTOFF
OUTLINE & REINFORCEMENT-S
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
COMPANION DRAWING: 21N200



Attachment 9

Source: Reference 10



Attachment 10
Source: Reference 11

Attachment 16-Apalachia Headwater Rating Curve Rev A.xls, Fit to Tailwater Curve

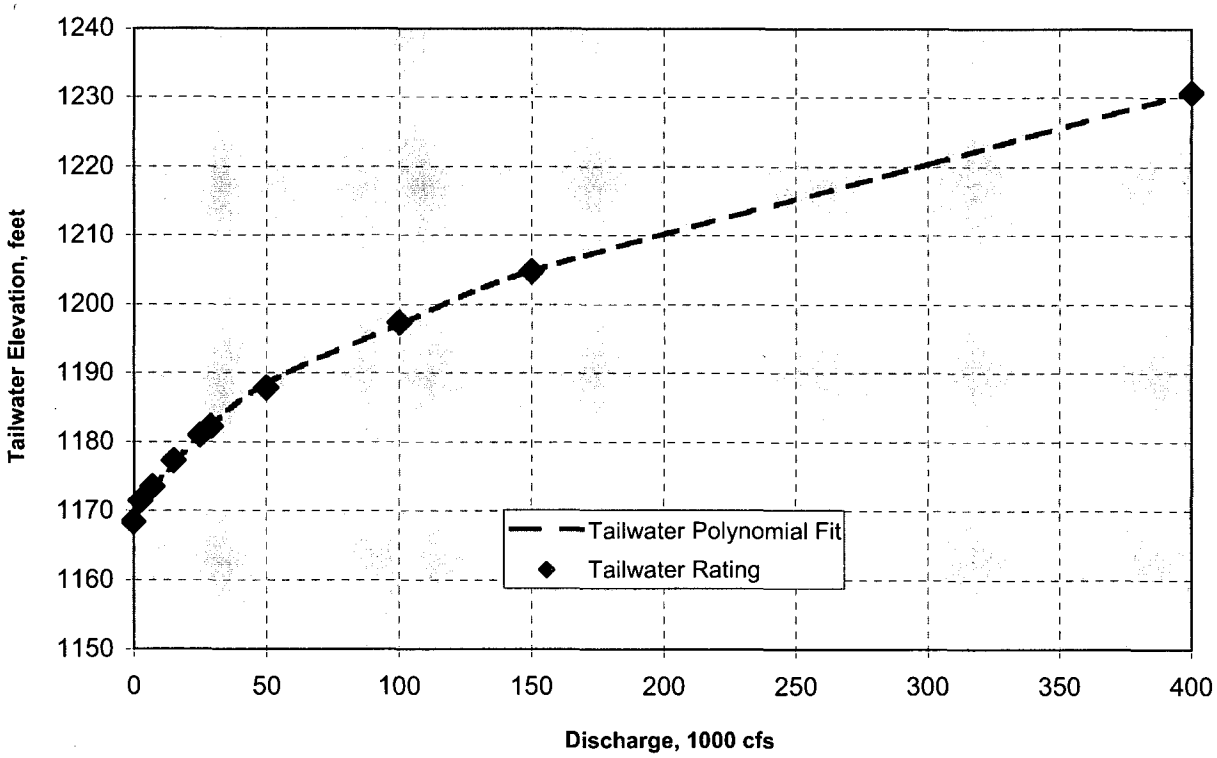
From River Mile 66
RAS model data

scale TW from plot

Discharge 1000 cfs	TW feet
0.02	1168.43
2.7	1171.47
7	1173.52
15	1177.29
25	1180.99
29	1182.27
50	1187.83
100	1197.3
150	1204.8
400	1230.7

from polynomial

Discharge 1000 cfs	TW feet
0.02	1169.49
2.7	1170.93
7	1173.12
15	1176.83
25	1180.86
29	1182.29
50	1188.43
100	1197.01
150	1204.83
300	1220.38
400	1230.74



Polynomial Curve Fit: $TW = 1169.48 + 0.547*Q - 4.00\times10^{-3}Q^2 + 1.283\times10^{-5}Q^3$ for $Q \leq 150$

$TW=0.104*Q+1189.3$ for $Q>150$

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

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

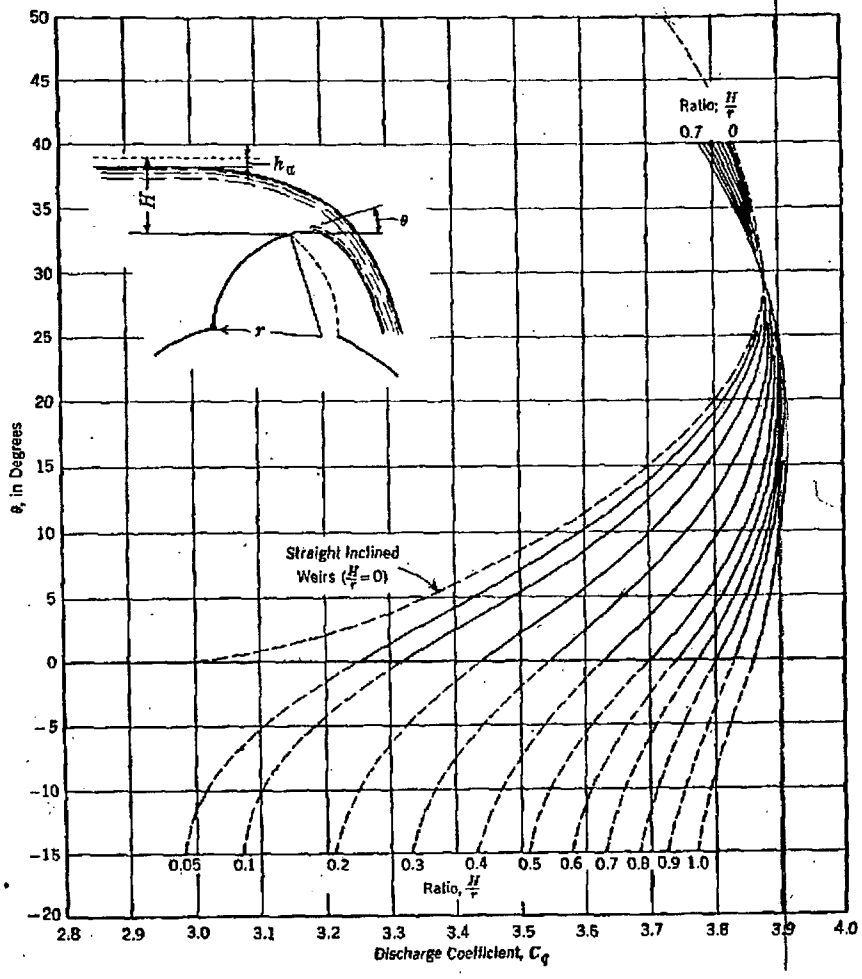


Fig. 6.—General Curves for the Determination of Discharge Coefficients

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.

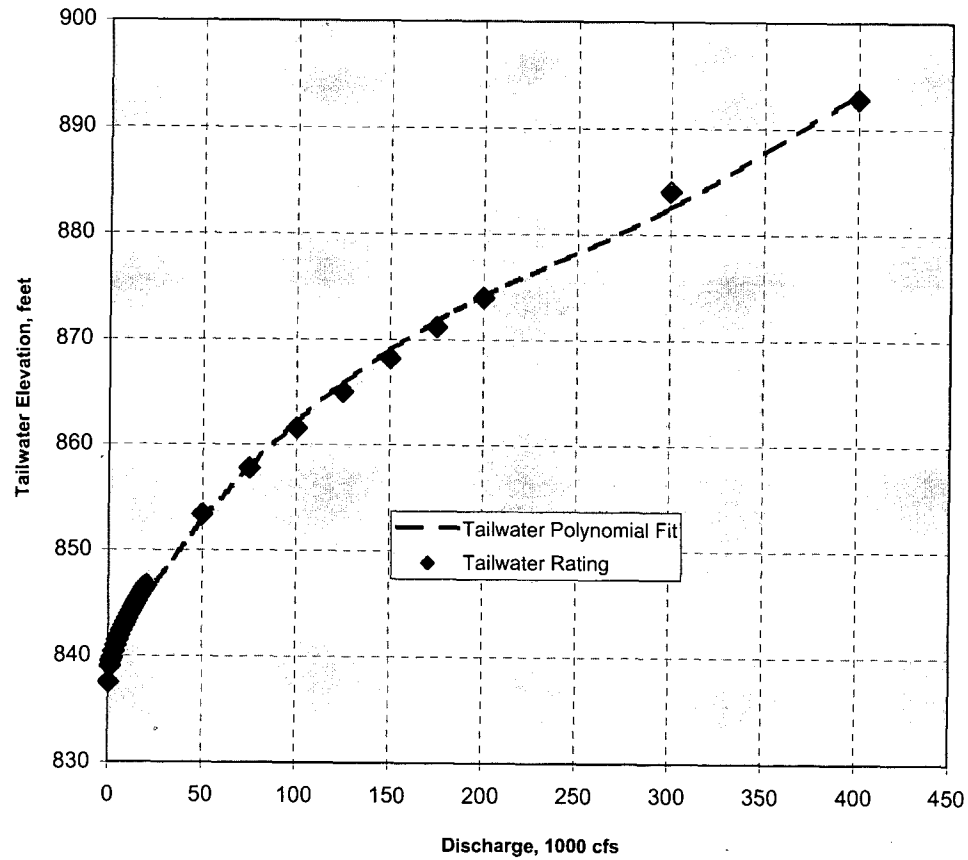
It must be assumed that the coefficient of discharge is known for at least one value of the head on the free crest (gate completely down) for the particular spillway under consideration. With the coefficient known for one or more heads, the complete coefficient curve for the free crest can be plotted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

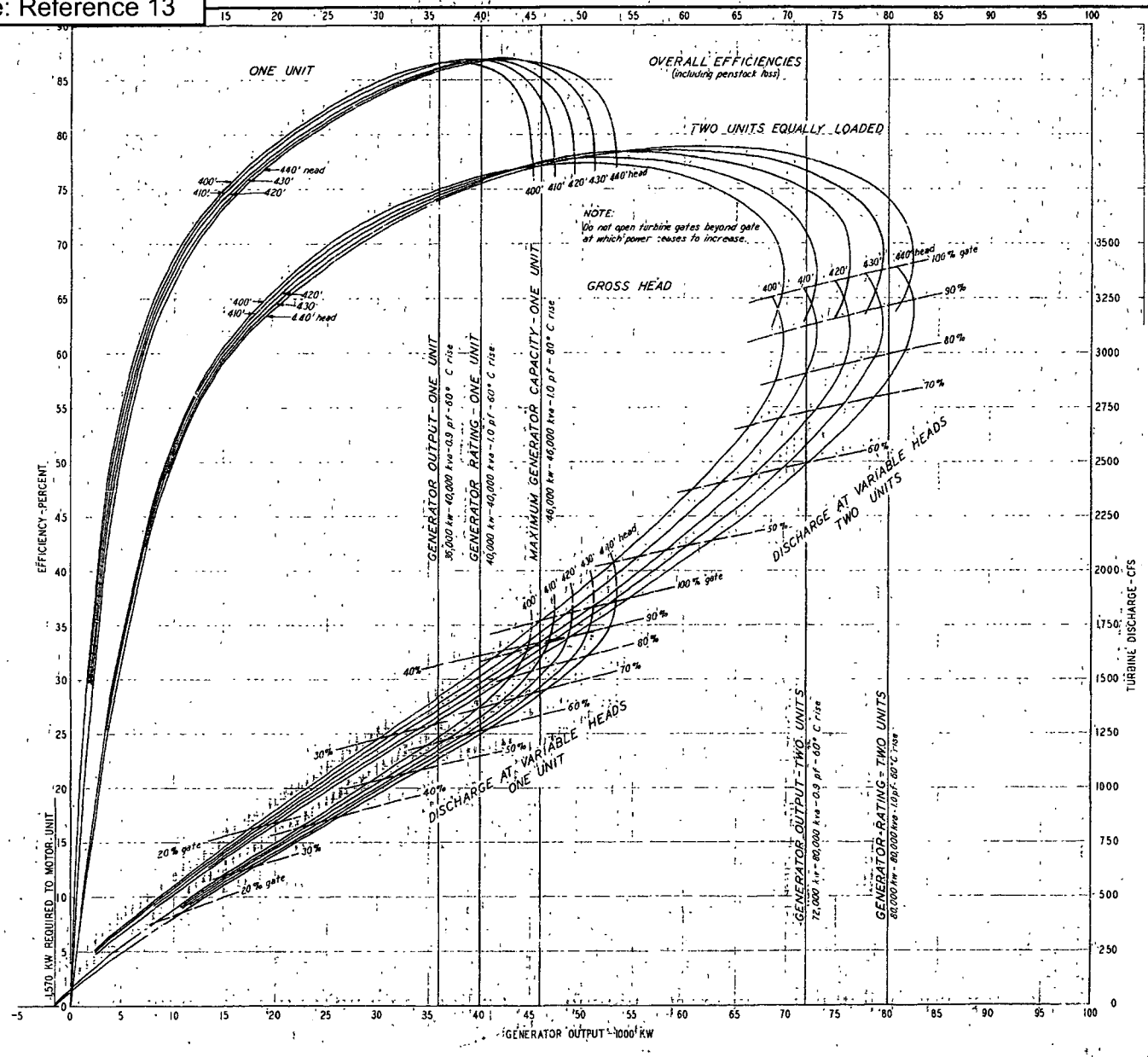
Riverware Data, Rivermile 53.6

Discharge 1000 cfs	TW Elevation At Powerhouse ft	Fit to TW ft
0	837.503	840.230
1	839.022	840.518
1.3	839.5	840.604
2	839.803	840.805
2.8	840.4	841.033
3	840.433	841.090
4	840.991	841.373
5	841.493	841.655
6	841.952	841.935
7	842.382	842.213
8	842.792	842.490
9	843.173	842.766
10	843.543	843.040
11	843.901	843.312
12	844.242	843.583
13	844.57	843.852
14	844.892	844.120
15	845.213	844.386
16	845.512	844.651
17	845.81	844.914
18	846.102	845.176
19	846.381	845.436
20	846.66	845.695
50	853.37	852.797
75	857.74	857.817
100	861.56	862.123
125	865	865.812
150	868.18	868.981
175	871.16	871.725
200	873.96	874.142
300	884.01	882.464
400	892.77	893.268

Polynomial Curve Fit: $TW = 840.23 + 0.2889*Q - 8.0264\times10^{-4}Q^2 + 1.0297\times10^{-6}Q^3$

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





NOTES:
Based on model-test curves furnished by Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia, Pennsylvania, and adjusted in accordance with index tests conducted 5-11, 12-44. Data should be revised to include field tests at other heads.
TURBINE RATED:
53,000 hp-360' net head-225 rpm-manufactured by Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia, Pennsylvania.
GENERATOR RATED:
40,000 kva-3 phase-60 cycle-13,800 volts-0.937 power factor-60°C rise-225 rpm-manufactured by Westinghouse Electric and Manufacturing Co., Pittsburgh, Pennsylvania.

THIS DRAWING SUPERSEDES 124K41R4

POWERHOUSE
UNITS 1 & 2

OPERATING CHARACTERISTICS
40,000 KVA UNIT

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED | RECOMMENDED | APPROVED

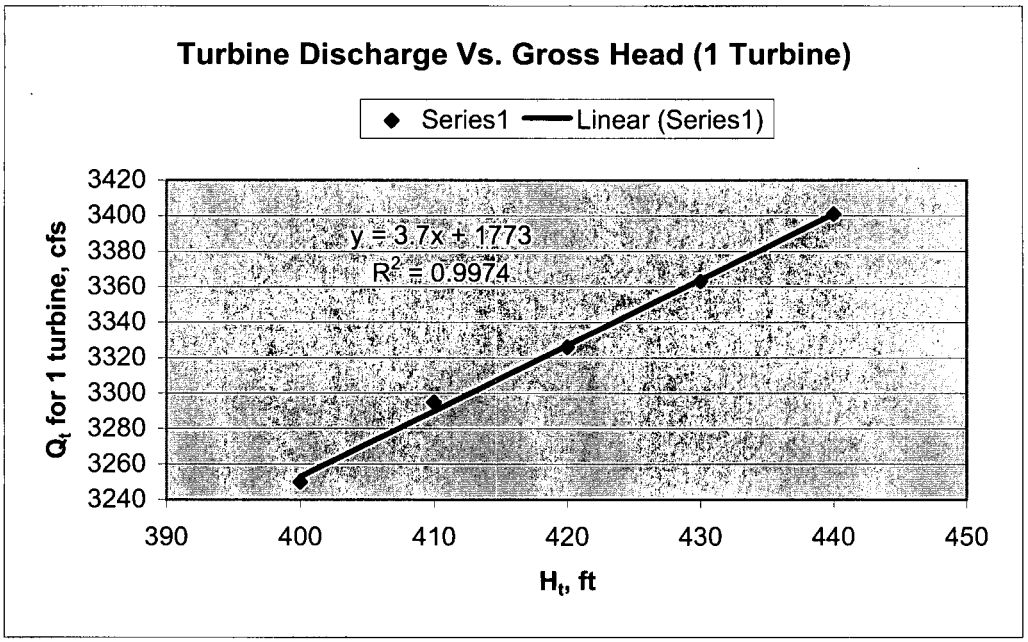
KNOXVILLE | 2-8-41 | 5 DD 4 | 124K41R4

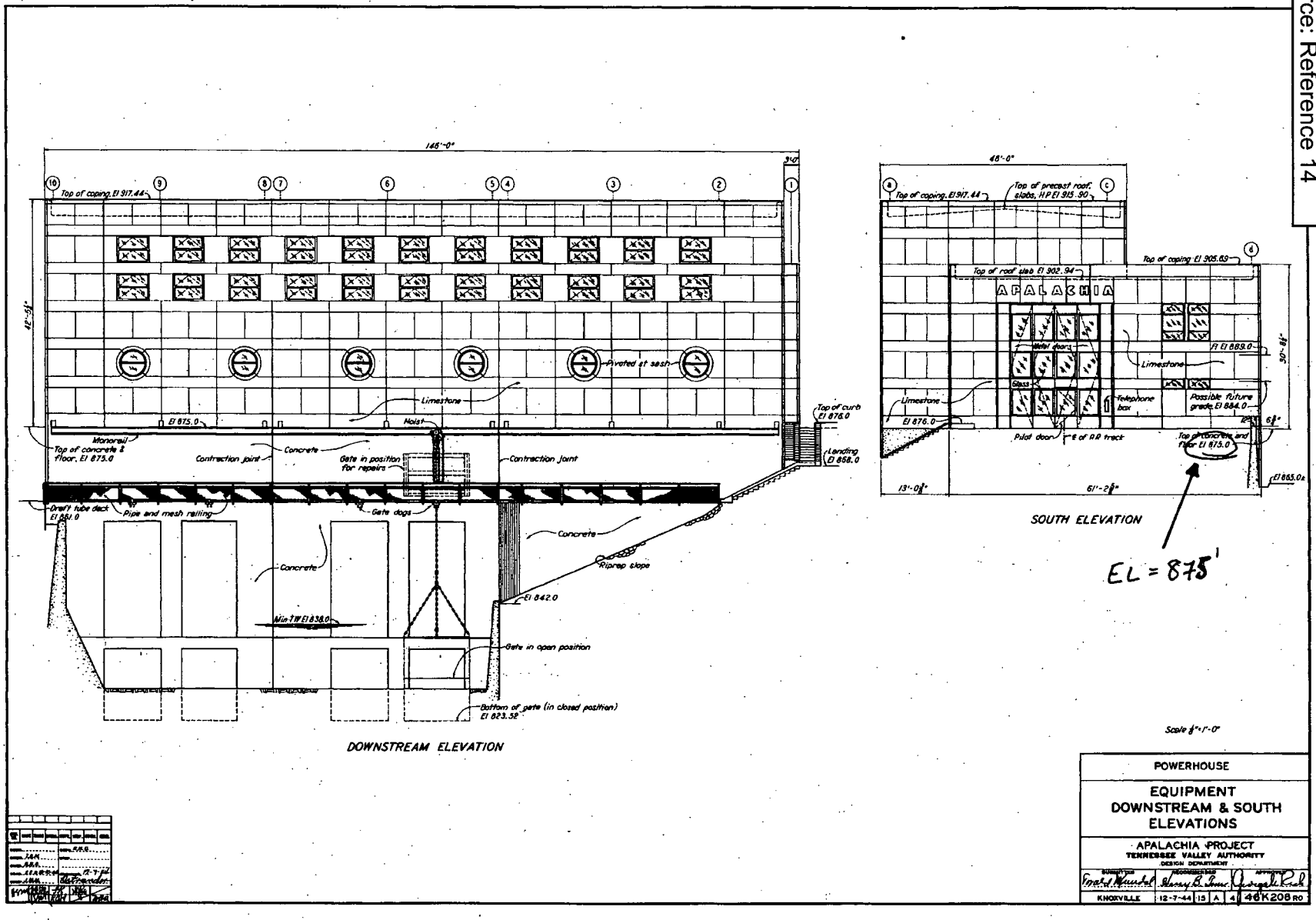
Attachment 24

Source: Reference 13

From Drawing 124K41

Gross Head ft	Discharge per Turbine cfs	Fit to Data cfs
400	3250	3253
410	3295	3290
420	3326	3327
430	3363	3364
440	3401	3401




146'-0"
Top of coping, El 917.44
Pivoted st sash
Limestone
El 875.0
Hoist
Monorail
Top of concrete & floor, El 875.0
Contraction joint
Concrete
Gate in position for repairs
Contraction joint
Top of curb El 876.0
Landing El 868.0
Draft tube deck El 861.0
Pipe and mesh railing
Gate dogs
Concrete
Concrete
Riprap slope
El 842.0
Min TW El 838.0
Gate in open position
Bottom of gate (in closed position) El 823.52
DOWNSTREAM ELEVATION
48'-0"
Top of coping, El 917.44
Top of precast roof slabs, HP El 915.90
Top of coping El 905.69
Top of roof slab El 902.94
APALACHIA
Metal doors
Limestone
Glass
Limestone
El 876.0
Telephone box
Ft El 889.0
Possible future grade El 884.0
Pilot door
℄ of RR track
Top of concrete and floor El 875.0
El 865.0±
13'-0⅜"
61'-2⅝"
SOUTH ELEVATION
EL = 875'
Scale ⅛"=1'-0"
POWERHOUSE
EQUIPMENT
DOWNSTREAM & SOUTH
ELEVATIONS
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
12-7-44
15
A
4
46K208 R0

Appendix A: Spillway Discharge Coefficients and Submergence Factors for Apalachia Dam from 1:28.72 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 headwater 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.

Apalachia Dam has ten spillway bays, each controlled by a radial (tainter) gate as illustrated in Attachment A1. For headwater rating curve calculations the gates are assumed to be open to their maximum opening position as specified in the Spillway Gate Arrangements table in Reference A1 and included as Attachment A2. As shown in this table, the maximum opening corresponds to reading "21" on the gate position indicators for the spillway. 1966 Field measurements of V, the vertical distance between the bottom lip of a raised spillway gate and the spillway crest, are summarized in Attachment A3 (from Reference A2). For gate position indicator reading "21" the average value of V for the ten gates is 19.79 feet.

Test data from a 1:28.72 scale model are available for free discharge conditions and for orifice discharge conditions for seven different gate openings varying from V = 1.53 feet to V = 16.30 feet (Reference A3). Orifice discharge data were not collected for gate openings as large as V = 19.79 feet, however, because under normal operating conditions the overflowing nappe will never touch the bottom of a gate open this far. But under the PMF conditions considered for the headwater rating curves the nappe will touch the gate in this position. Consequently, the data for gate openings V = 16.30, 13.04, 9.75, and 6.45 feet are used here to estimate orifice flow discharge characteristics for V = 19.79 feet.

A.1 References

A1. "Apalachia Dam Spillway Discharge Tables," River Operations, Tennessee Valley Authority, 2004, EDMS #L58 081212 805
A2. TVA Files, binder "SPILLQ Vol. 2: Projects, Apalachia through Chickamauga"
A3. "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 A18)
A4. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988
A5. Open Channel Flow, F. M. Henderson, Macmillan, New York, 1966.
A6. TVA drawing no: 54W200, R4 (Attachments A8 & A16)
A7. TVA drawing no: 51N201, R4 (Attachments A9 & A17)

A.2 Discharge Equations

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

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

in which Q_f = free discharge (cfs), C_f = free discharge coefficient ($ft^{0.5}/s$), 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).

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 A4)

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

in which Q_g = orifice discharge (cfs), C_g = orifice discharge coefficient (dimensionless -- varies with gate opening and H_c), G_n = effective gate opening = minimum distance between the gate lip and the crest (ft), g = acceleration of gravity (32.2 ft/s^2 -- common knowledge, Reference A4, sheet. 000-1 for example), and H_{mp} = vertical distance between the mid-point of G_n and the crest (in ft.).

A.3 Model Test Data

The 1:28.72 scale Apalachia model test data (Reference A3) are used to determine

- $C_f(H_c)$
- H_{Lmin} and $C_g(H_c)$ for V = 19.79 ft.

The model test data for both orifice and free discharge are tabulated in Reference A3 and these data are used below to estimate H_{Lmin} and $C_g(H_c)$ for V = 19.79 feet and to establish a curve fit for $C_f(H_c)$. Attachment A5 provides the pages from Reference A3 that are relevant to these calculations.

Model data are scaled to prototype values using the following scale ratios from Attachment A6 (Reference A5):

- V_p/V_m and $H_p/H_m = 28.72$
- $Q_p/Q_m = (28.72)^{2.5} = 4420.4$

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

A.4 Geometry

Parameters G_n, H_{mp}, Z_o (gate overflow elevation), and β (angle plotted against discharge coefficient in Reference A4) are computed from crest and gate geometry as described in Attachment A7. Table A1 gives the values of these parameters for V = 6.45, 9.74, 13.04, 16.30, and 19.79 feet.

Table A1: Geometrical Parameters for Relevant Gate Openings

V, feet	G_n, feet	H_{mp}, feet	Z_o, feet	β, deg.
6.45	6.677	3.129	1284.30	81.5
9.74	9.960	4.783	1285.64	90.3
13.04	13.301	6.424	1286.54	98.5
16.30	16.664	8.028	1286.95	106.2
19.79	20.381	9.722	1288	114.3

As an example, the procedure for computing the geometrical parameters for V = 19.79 feet is given here. From Attachment A8 (Reference A6),

- R = 22.5 feet
- Z_c = 1257 feet
- Z_{tr} = 1264.47 feet
- z_1 = 1264.47 - 1257 + 0.505 = 7.975 feet
- z_2 =1280 - 1264.47 = 15.53 feet

where the parameters are defined in Attachment A7-2. Referring to Attachment A7:

Angle θ: $$\theta = \sin^{-1}\left(\frac{15.53}{22.5}\right) + \sin^{-1}\left(\frac{7.975}{22.5}\right) = 64.407°$$

Angle α: $$\alpha = \tan^{-1}\left(\frac{1264.47 - 1257 - 19.79}{\sqrt{22.5^2 - (1264.47 - 1257 - 19.79)^2}}\right) = -33.199°$$

Overflow elevation Z_o: $$Z_o = 1264.47 + 22.5\sin[64.407 - (-33.017)] = 1286.77 \ feet$$

According to Attachment A8, very little clearance exists between the tainter gates and the concrete deck above the spillway when the gates are in the fully opened position. Because of this minimal clearance, it is assumed that gate overflow discharge will pass over the concrete deck before flowing over the top of the open gate. Accordingly, the overflow elevation used in calculation is equal to the top elevation of the concrete deck (1288 feet, Attachment A8).

Gate lip y-coordinate: $$y_\ell = 1264.47 - 1257 - 19.79 = -12.32 \ feet$$

Gate lip x-coordinate: $$x_\ell = \sqrt{22.5^2 - (-12.26)^2} = 18.827 \ feet$$

From Attachment A9 (Reference A7), the equation for the spillway crest is:

$$y_s^* = f(x_s^*) = -\frac{(x_s^*)^3}{27000} + \frac{(x_s^*)^2}{68} + \frac{x_s^*}{15} \quad \text{for } x_s^* \geq 0$$

This equation has been corrected to calculate y_s^* referenced from the crest centerline, which is 6.9 feet from the origin of the crest coordinates as given in Reference A6 (x_s^* - 6.9 + 6.9 = x_s^*)

in which $y_s^* = y_s - 7.47 \quad and \quad x_s^* = 25.073 - x_s$. In terms of y_s and x_s:

$$y_s = f(x_s) = 7.47 - \frac{(25.073 - x_s)^3}{27000} + \frac{(25.073 - x_s)^2}{68} + \frac{(25.073 - x_s)}{15} \quad \text{for} \quad x_s \leq 25.073 \text{ feet}$$

and

$$\frac{dy_s}{dx_s} = \frac{3(25.073 - x_s)^2}{27000} - \frac{2(25.073 - x_s)}{68} - \frac{1}{15}$$

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

$$x_{sn} - 18.827 + \left[7.47 - \frac{(25.073 - x_{sn})^3}{27000} + \frac{(25.073 - x_{sn})^2}{68} + \frac{(25.073 - x_{sn})}{15} - (-12.32)\right]\left[\frac{3(25.073 - x_{sn})^2}{27000} - \frac{2(25.073 - x_{sn})}{68} - \frac{1}{15}\right] = 0$$

Solution:

- x_{sn} = 21.9798 feet (by iteration)
- y_{sn} = 7.47 - (25.073-21.9798)^3/27000 + (25.073-21.9798)^2/68 + (25.073-21.9798)/15 = 7.816
- $G_n = \sqrt{(21.9798 - 18.827)^2 + (7.816 - (-12.32))^2} = 20.381 \; feet$

and

- H_{mp} = 19.79-[7.8115 - (-12.32)]/2 = 9.722 feet
- $\beta = 90° - \tan^{-1}\left(\frac{-12.32}{18.827}\right) - \tan^{-1}\left(\frac{21.9798 - 18.827}{7.816 - (-12.32)}\right) = 90° - (-33.20°) - 8.90° = 114.3°$

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

Attachment A10 shows the model test data (Attachment A5-4) for H_{Lmin} and a polynomial curve fit to the data (spreadsheet included as Attachment A15). A value of H_{Lmin} for V = 19.79 feet is established by using the polynomial to extrapolate the data. The following is used for the headwater rating curve calculations:

H_{Lmin} = 26.20 feet for V = 19.79 feet.

A.6 Determination of $C_f(H_c)$

Attachment A11 shows the model test data for free discharge (Attachment A5-5) and a polynomial curve fit to the data. The "6.684" in the "Definition" was the length of the model crest in feet (Attachment A5-1). The polynomial indicated in Attachment A11 is used for the headwater rating curve calculations:

$$C_f = 6.8700 \times 10^{-5} H_c^3 - 0.003436\, H_c^2 + 0.08600 * H_c + 2.85 \qquad \text{(A3)}$$

A.7 Determination of $C_g(H_c)$ for V = 19.79 feet

Attachment A12 shows the calculations and results for extrapolating $C_g(H_c)$ for V = 19.79 feet from the model data for other gate openings. The first column in Attachment A12 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 = 19.79 feet at $H_c = H_{Lmin}$ is the free discharge computed using $C_f(H_c)$ from equation A3. The first three numerical columns list the model data (scaled to prototype dimensions) for V = 6.45, 9.74, 13.04, and 16.3 feet as listed in Attachment A5-4. The rows that do not include values of discharge, Q, were added to extrapolate the data. The next two columns after the model data list prototype geometrical parameters. The last numerical column lists the C_g values computed from the data. Values that were "estimated" for extrapolation purposes are labeled as such to the right of the C_g column.

Attachment A13 shows C_g plotted against H_c for all gate openings. All curves include extrapolated segments to H_c = 40 feet. The estimated curve for V = 19.79 feet starts with the value for $H_c = H_{Lmin}$ and runs approximately parallel to the curve for V = 16.30 feet. Given the absence of data, this extrapolated line segment fit for $C_g(H_c)$ at V = 19.79 feet is used for the headwater rating calculations. Table A2 lists the points describing the extrapolated relationship.

Table A2: Points Defining Extrapolated Curve for $C_g(H_c)$ at V = 19.79 feet.

H_c, feet	C_g
26.12	0.801
29.00	0.720
32.00	0.710
40.00	0.715

As further justification for the extrapolation, Attachment A14 shows the Apalachia C_g values at large H_c plotted against angle β on Hydraulic Design Chart 311-1 from Reference A4 showing U.S. Army Corps of Engineers data for tainter gates on standard crests. The value of X/H_d for Apalachia is 0.17 (X = 3.99 feet, Attachment A8, and $H_d \equiv H_o$= 23.0, Attachment A5-1). Presumably because TVA's spillway crests are not standard, TVA data always lie to the left of the suggested design curves on this chart. Note that C_g = 0.715 at H_c = 40 feet and V = 19.79 feet (β = 114.3 degrees) is a very reasonable extrapolation of the Apalachia data curve and appears reasonable compared with the suggested design curves on the chart.

Attachment A1

Source: Reference A1

Calculation No: CDQ000020080001

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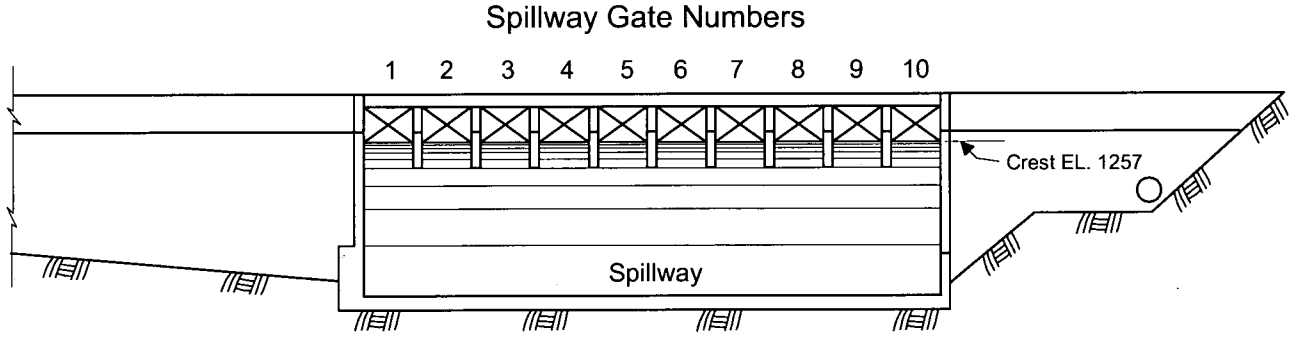
APALACHIA DAM

LOCATION OF SPILLWAY GATES



DOWNSTREAM ELEVATION

Attachment A2

Source: Reference A1

Calculation No: CDQ000020080001

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APALACHIA DAM

SPILLWAY GATE ARRANGEMENTS

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
1	0	0	0	1	0	0	0	0	0	0
2	0	0	0	1	0	0	1	0	0	0
3	0	1	0	1	0	0	1	0	0	0
4	0	1	0	1	0	0	1	0	1	0
5	0	1	0	1	1	0	1	0	1	0
6	0	1	0	1	1	1	1	0	1	0
7	1	1	0	1	1	1	1	0	1	0
8	1	1	0	1	1	1	1	0	1	1
9	1	1	1	1	1	1	1	0	1	1
10	1	1	1	1	1	1	1	1	1	1
11	1	1	1	2	1	1	1	1	1	1
12	1	1	1	2	1	1	2	1	1	1
13	1	2	1	2	1	1	2	1	1	1
14	1	2	1	2	1	1	2	1	2	1
15	1	2	1	2	2	1	2	1	2	1
16	1	2	1	2	2	2	2	1	2	1
17	2	2	1	2	2	2	2	1	2	1
18	2	2	1	2	2	2	2	1	2	2
19	2	2	2	2	2	2	2	1	2	2
20	2	2	2	2	2	2	2	2	2	2
21	2	2	2	3	2	2	2	2	2	2
22	2	2	2	3	2	2	3	2	2	2
23	2	3	2	3	2	2	3	2	2	2
24	2	3	2	3	2	2	3	2	3	2
25	2	3	2	3	3	2	3	2	3	2
26	2	3	2	3	3	3	3	2	3	2
27	3	3	2	3	3	3	3	2	3	2
28	3	3	2	3	3	3	3	2	3	3
29	3	3	3	3	3	3	3	2	3	3
30	3	3	3	3	3	3	3	3	3	3
31	3	3	3	4	3	3	3	3	3	3
32	3	3	3	4	3	3	4	3	3	3
33	3	4	3	4	3	3	4	3	3	3
34	3	4	3	4	3	3	4	3	4	3
35	3	4	3	4	4	3	4	3	4	3
36	3	4	3	4	4	4	4	3	4	3
37	4	4	3	4	4	4	4	3	4	3
38	4	4	3	4	4	4	4	3	4	4
39	4	4	4	4	4	4	4	3	4	4
40	4	4	4	4	4	4	4	4	4	4

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
41	4	4	4	5	4	4	4	4	4	4
42	4	4	4	5	4	4	5	4	4	4
43	4	5	4	5	4	4	5	4	4	4
44	4	5	4	5	4	4	5	4	5	4
45	4	5	4	5	5	4	5	4	5	4
46	4	5	4	5	5	5	5	4	5	4
47	5	5	4	5	5	5	5	4	5	4
48	5	5	4	5	5	5	5	4	5	5
49	5	5	5	5	5	5	5	4	5	5
50	5	5	5	5	5	5	5	5	5	5
51	5	5	5	6	5	5	5	5	5	5
52	5	5	5	6	5	5	6	5	5	5
53	5	6	5	6	5	5	6	5	5	5
54	5	6	5	6	5	5	6	5	6	5
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56	5	6	5	6	6	6	6	5	6	5
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66	6	8	6	8	8	8	8	6	8	6
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68	8	8	6	8	8	8	8	6	8	8
69	8	8	8	8	8	8	8	6	8	8
70	8	8	8	8	8	8	8	8	8	8
71	8	8	8	8	8	8	8	8	8	10
72	8	8	8	8	8	8	8	10	8	10
73	8	8	8	8	8	10	8	10	8	10
74	8	8	8	10	8	10	8	10	8	10
75	8	10	8	10	8	10	8	10	8	10
76	10	10	8	10	8	10	8	10	8	10
77	10	10	10	10	8	10	8	10	8	10
78	10	10	10	10	10	10	8	10	8	10
79	10	10	10	10	10	10	10	10	8	10
80	10	10	10	10	10	10	10	10	10	10

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
81	10	10	10	10	10	10	10	10	10	14
82	10	10	10	10	10	10	10	14	10	14
83	10	10	10	10	10	14	10	14	10	14
84	10	10	10	14	10	14	10	14	10	14
85	10	14	10	14	10	14	10	14	10	14
86	14	14	10	14	10	14	10	14	10	14
87	14	14	14	14	10	14	10	14	10	14
88	14	14	14	14	14	14	10	14	10	14
89	14	14	14	14	14	14	14	14	10	14
90	14	14	14	14	14	14	14	14	14	14
91	14	14	14	14	14	14	14	14	14	18
92	14	14	14	14	14	14	14	18	14	18
93	14	14	14	14	14	18	14	18	14	18
94	14	14	14	18	14	18	14	18	14	18
95	14	18	14	18	14	18	14	18	14	18
96	18	18	14	18	14	18	14	18	14	18
97	18	18	18	18	14	18	14	18	14	18
98	18	18	18	18	18	18	14	18	14	18
99	18	18	18	18	18	18	18	18	14	18
100	18	18	18	18	18	18	18	18	18	18
101	18	18	18	18	18	18	18	18	18	21
102	18	18	18	18	18	18	18	21	18	21
103	18	18	18	18	18	21	18	21	18	21
104	18	18	18	21	18	21	18	21	18	21
105	18	21	18	21	18	21	18	21	18	21
106	21	21	18	21	18	21	18	21	18	21
107	21	21	21	21	18	21	18	21	18	21
108	21	21	21	21	21	21	18	21	18	21
109	21	21	21	21	21	21	21	21	18	21
110	21	21	21	21	21	21	21	21	21	21

GATE OPENINGS

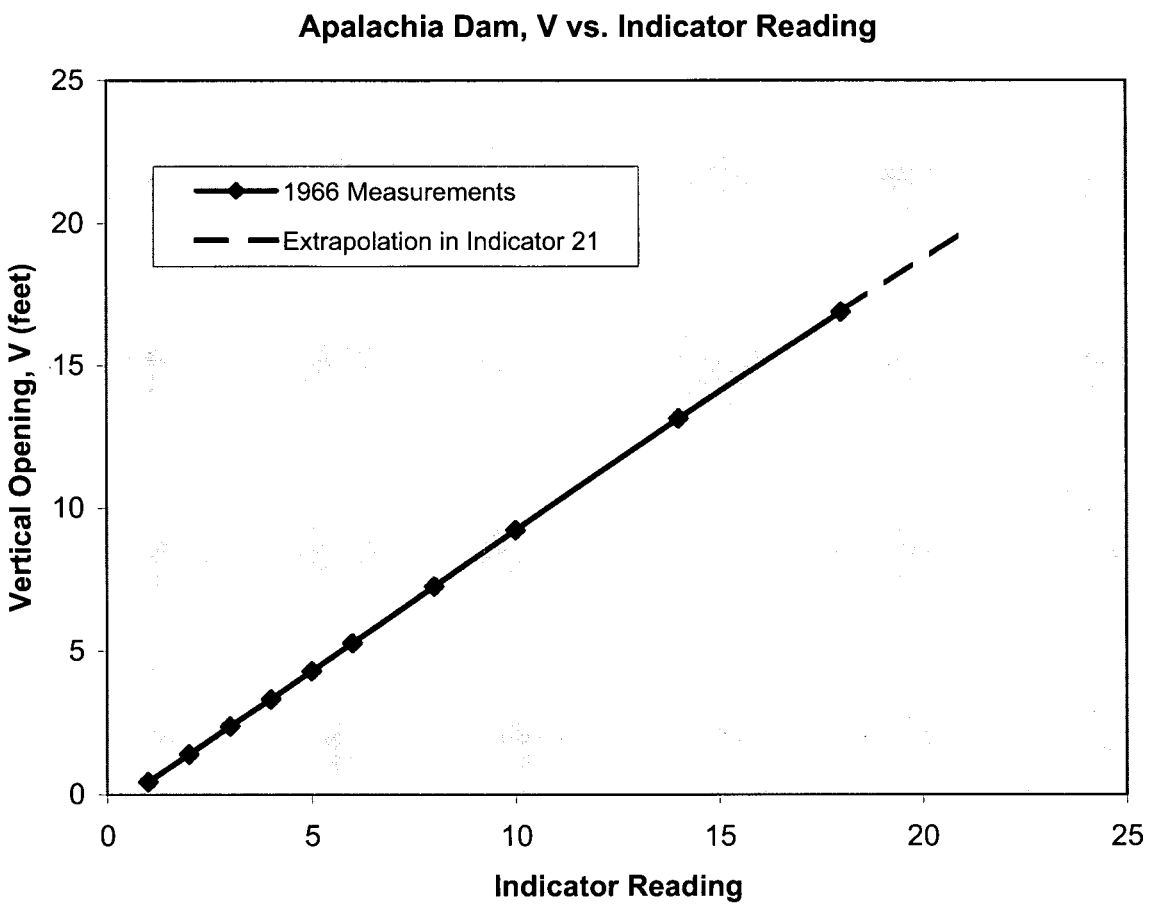
Figures in columns under each gate number refer to gate opening indicator readings.

Apalachia Dam

Vertical Openings (last measured in May 1966)

Indicator/Gate	1	2	3	4	5	6	7	8	9	10	
0											
1	0.44	0.41	0.39	0.35	0.34	0.38	0.3	0.31	0.42	0.31	
2	1.4	1.32	1.33	1.31	1.27	1.32	1.24	1.25	1.38	1.26	
3	2.38	2.32	2.29	2.3	2.23	2.3	2.24	2.22	2.34	2.23	
4	3.32	3.26	3.26	3.27	3.2	3.26	3.2	3.2	3.3	3.2	
5	4.3	4.24	4.24	4.26	4.22	4.26	4.2	4.17	4.28	4.19	
6	5.29	5.23	5.23	5.24	5.2	5.24	5.18	5.17	5.28	5.16	
8	7.26	7.2	7.22	7.25	7.22	7.22	7.18	7.19	7.26	7.14	
10	9.24	9.18	9.2	9.22	9.2	9.2	9.16	9.2	9.24	9.14	
14	13.15	13.08	13.13	13.16	13.18	13.12	13.1	13.17	13.18	13.02	
18	16.9	16.84	16.88	16.93	17.03	17.04	16.88	17.14	16.92	16.78	Average
21	19.71	19.66	19.69	19.76	19.92	19.98	19.72	20.12	19.73	19.60	19.79

Note: Vertical openings highlighted with yellow back ground are linearly extrapolated.

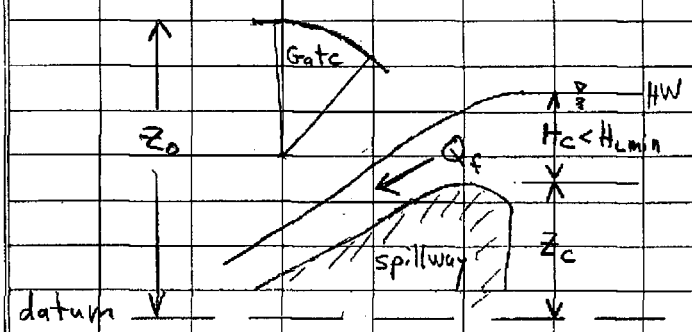


Definition Sketch for Spillway Discharge

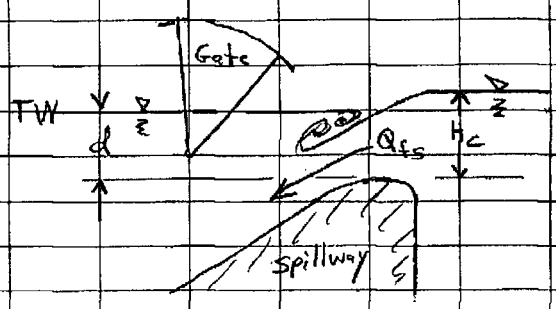
COMPUTED GAS DATE 8/12/2008

CHECKED ____ DATE ____

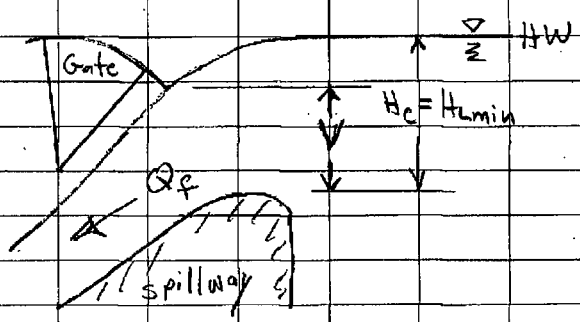
Free Discharge - No Tailwater effect



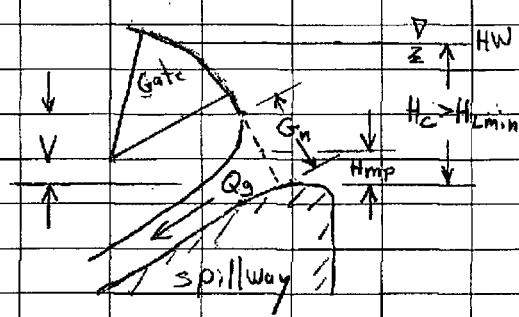
Free Discharge affected by Tailwater



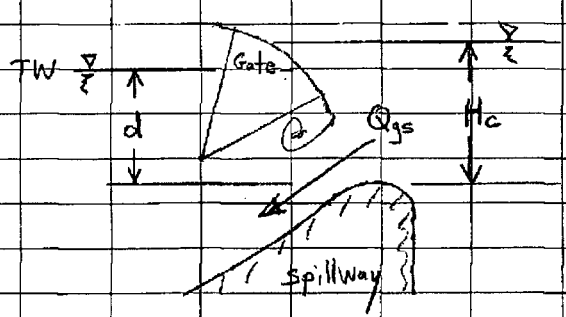
Nappe Touches Gate



Orifice Discharge - No Tailwater Effect



Orifice Discharge affected by Tailwater



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

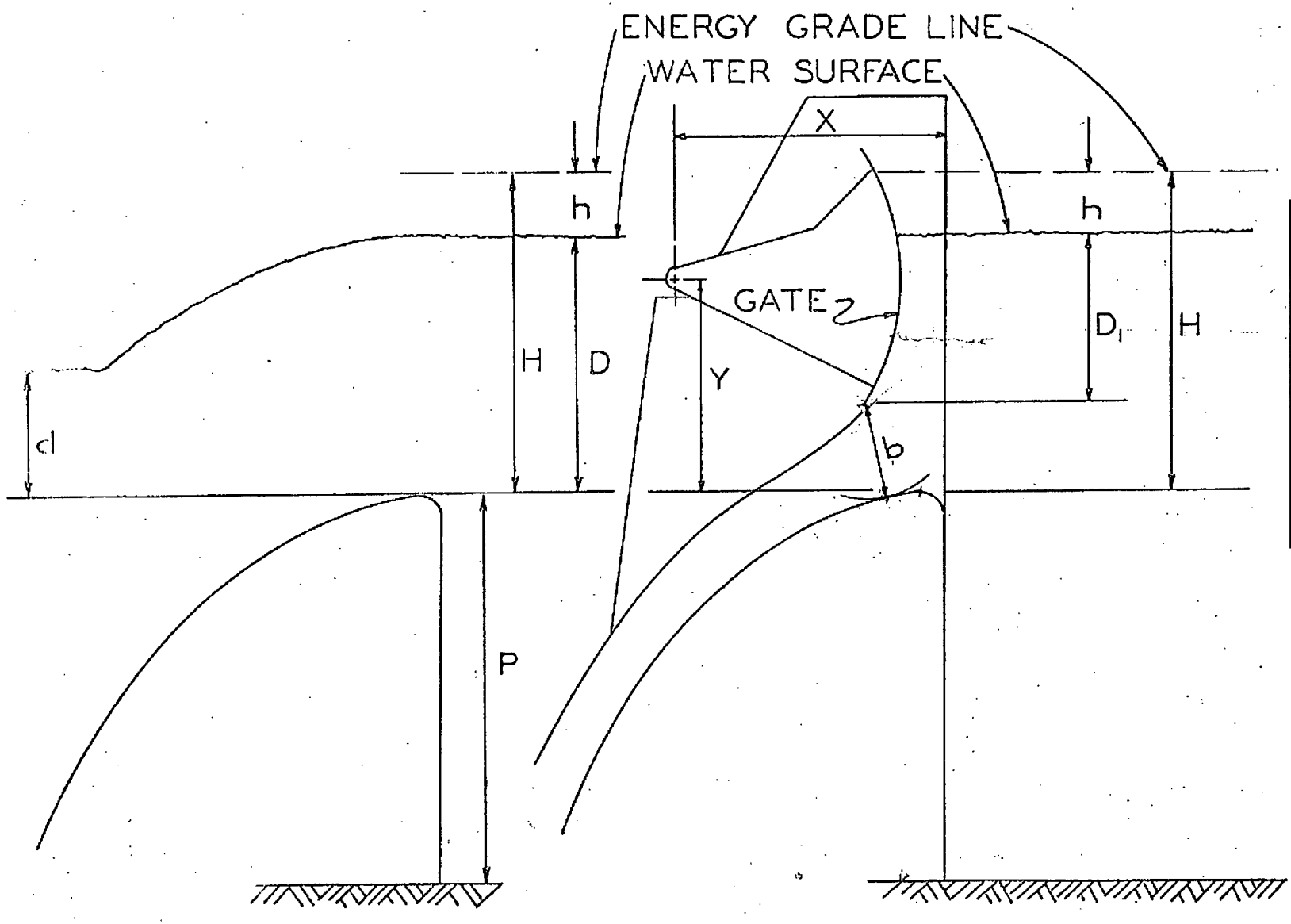
For flow under a gate:

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

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 1 [b]

Attachment A5-3
Source: Reference A3

Calculation No: CDQ000020080001
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Attachment A5-4

Source: Reference A3

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

Attachment A6

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,

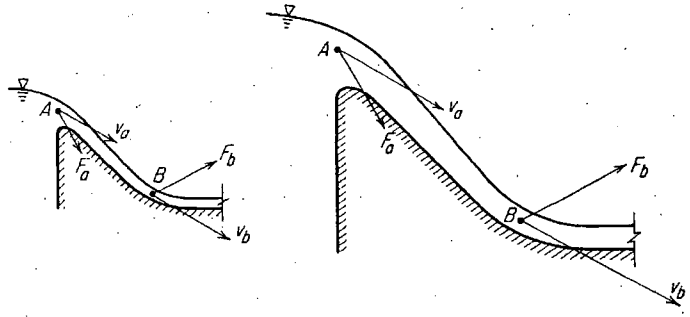

Figure 11-1. *Basic Model-Prototype Relationships*

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

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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

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

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

Spillway Discharge Calculations
Geometry for Flow Under an Open Tainter Gate

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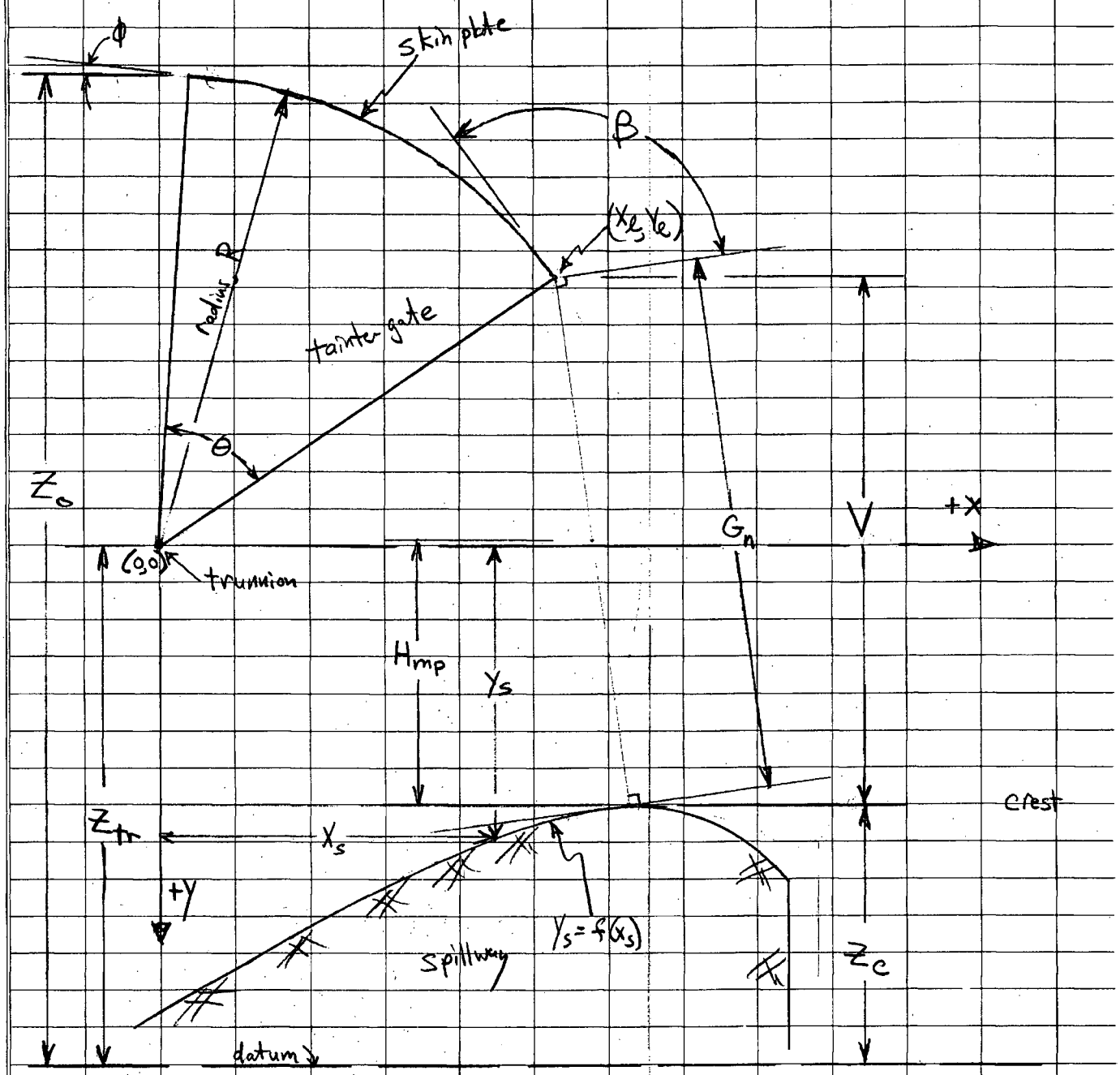
Definition Sketch



Spillway Gate Geometry

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Variables

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

Z_c = crest elevation

Z_{tr} = trunnion elevation

Z_o = overflow elevation

R = radius of the tainter gate

G_n = minimum distance between the gate lip and the crest

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

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

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

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

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

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

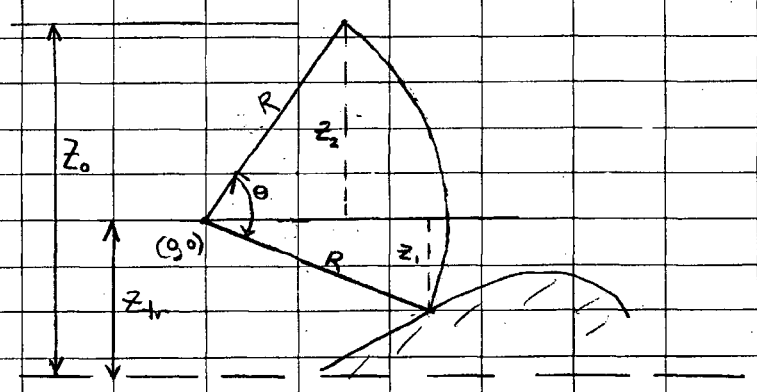
notes: Y positive downward for all coordinates
all coordinates relative to trunnion axis

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

Angle, Θ

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

Z_1 & Z_2 are determined from drawings



Closed Gate

Attachment A7-3

Spillway Gate Geometry

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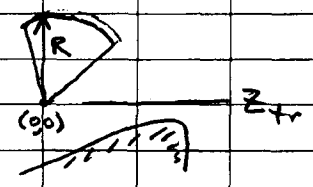
CHECKED DATE

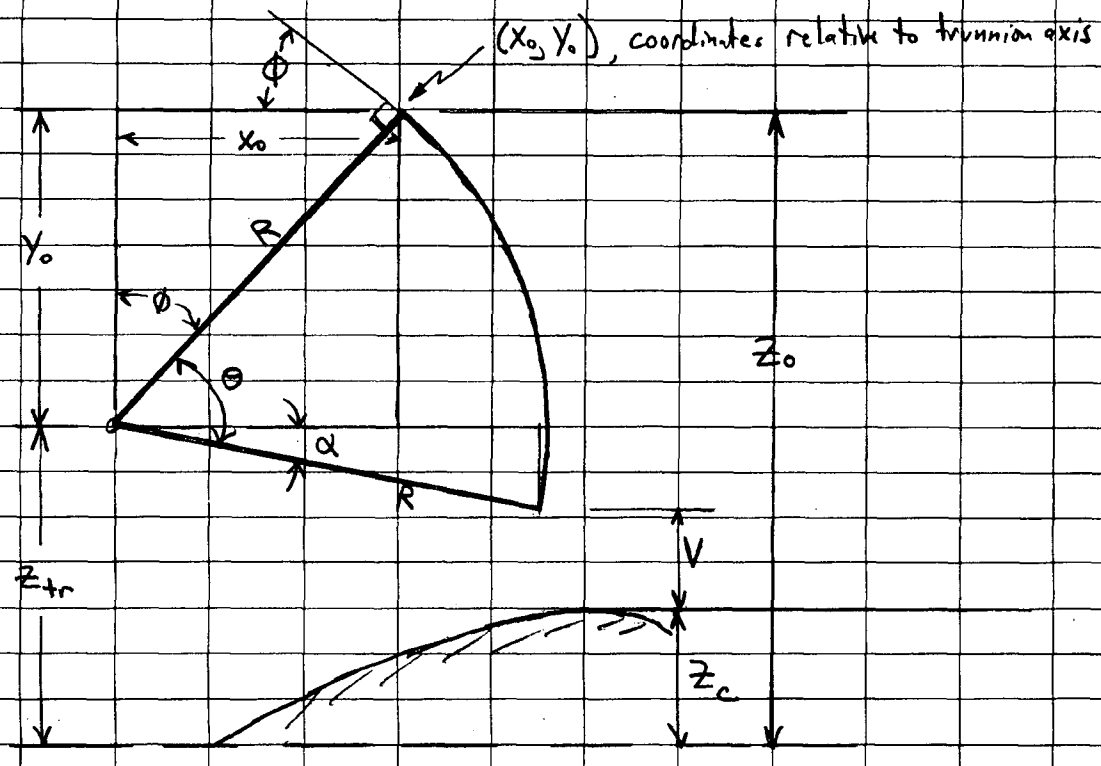
Overflow Elevation, Z_o and Angle, Φ

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

COMPUTED GAS DATE 8/11/2008

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Gate Opening, G_n

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

Distance between gate lip and any point on spillway surface is

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

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

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

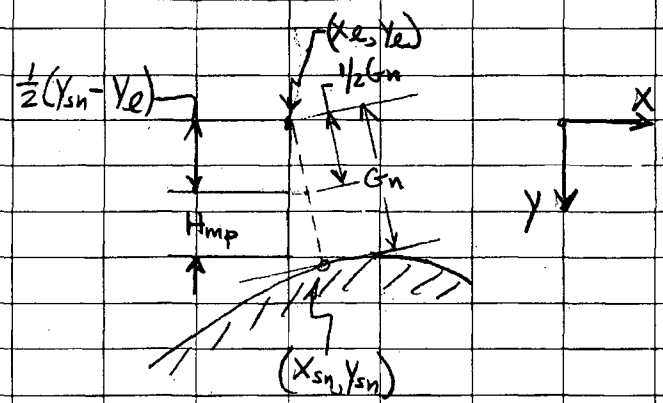
$$\Rightarrow 0 = \frac{(X_{sn} - X_\ell) + [f(X_{sn}) - Y_\ell]\frac{df(X_{sn})}{dX_s}}{\ell_{minimum}}$$

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}



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

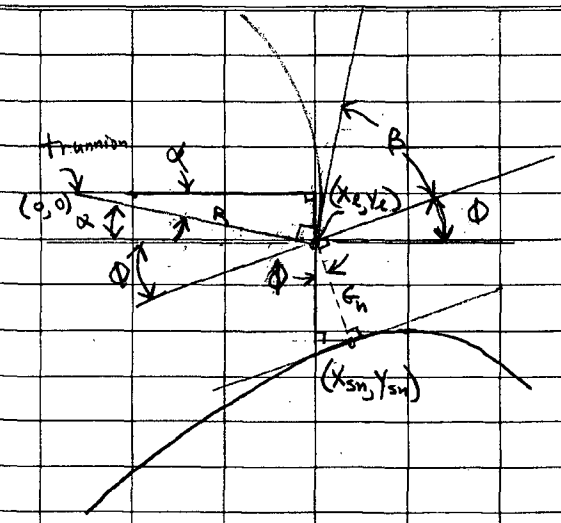
$$\Rightarrow \boxed{H_{mp} = V - \frac{1}{2}(Y_{sn} - Y_\ell)}$$

Spillway Gate Geometry

COMPUTED GAS DATE

CHECKED DATE

Angle, β



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

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

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

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

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

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

Attachment A8

Source: Reference A6

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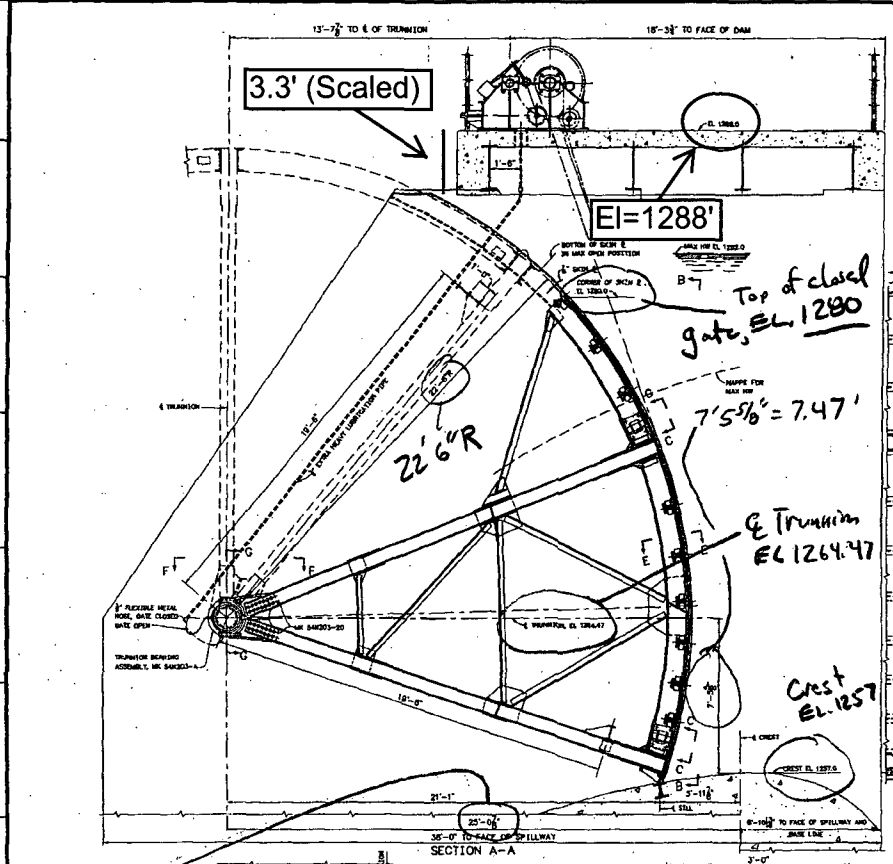
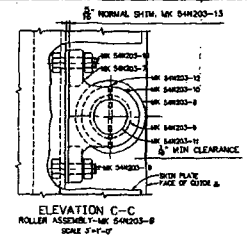
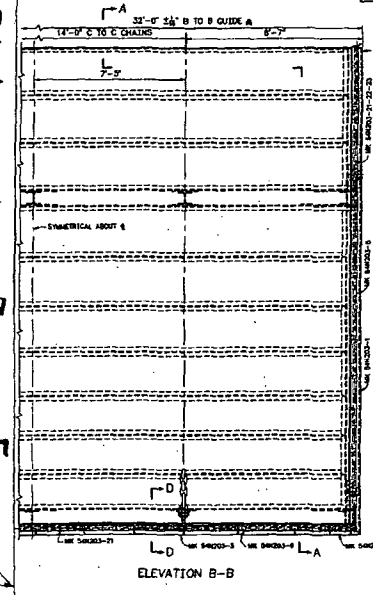
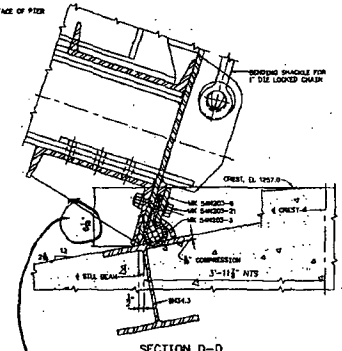








MATERIAL SPECIFICATIONS						
NO.	MATERIAL	ULTIMATE TENSION	YIELD POINT TENSION	% EL IN 2"	% RED AREA	SPECIFICATIONS
1	STR STEEL, 35,000 MIN YP	60-75,000	0.5 TENS	22		ASTM A-7-38
2	RIVET STEEL, 28,000 MIN YP	52-62,000	0.5 TENS			ASTM A-141-38
3	BOLT & NUT STEEL, GRADE 2B OR 22					ASTM A-107-40
4	STEEL CASTINGS, GRADE B	70,000	36,000	24	36	ASTM A-27-38
5	STEEL FORGINGS, CLASS E	70,000	0.5 TENS	20	33	ASTM A235-40T
6	STEEL FORGINGS, CLASS C	90,000	55,000	20.5	38	ASTM A235-40T
7	STEEL FORGINGS, CLASS D OR E	85,000	55,000	20	41	ASTM A237-40T
8	PHOS BRZ & GRAPHITE					M-SEE BELOW
9	BRASS ROD, FREE CUTTING *	44,000	18,000	25		ASTM B-16-39
10	CAST PHOS BRONZE	35,000	12,000	8		ASTM B-74-33T
11	ROLLED NAVAL BRASS	60,000	30,000	30		ASTM B-21-40T
12	STEEL					M-SEE BELOW
13	CAST IRON, CLASS 35	35,000				ASTM A-48-38
14	BRONZE					M-SEE BELOW
15	SPRING STEEL					M-SEE BELOW
16	WELDING FILLER METAL, GRADE 19					ASTM A-233-37T
17	RUBBER					M-SEE BELOW
18	GLASS					M-SEE BELOW

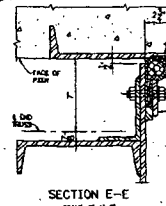
* PHYSICAL PROPERTIES FROM FED. SPECIFICATIONS QQ-B-611 COMP B.
M-MISCELLANEOUS MATERIALS SHALL BE HIGH CLASS COMMERCIAL GRADE.

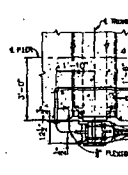
NOTES:

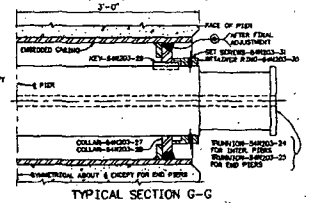
GATES TO BE ASSEMBLED AS COMPLETELY AS POSSIBLE & SECURELY BOLTED IN FIELD BEFORE RIVETING & WELDING. SEQUENCE OF RIVETING & WELDING TO BE SUCH AS TO PREVENT DISTORTION OF GATE.
HOLES OVER 1" SHALL BE PUNCHED.

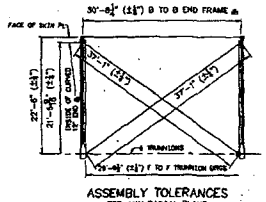
FIELD WELDING TO BE IN ACCORDANCE WITH THE CODE FOR FUSION WELDING & GAS CUTTING IN BUILDING CONSTR. 1937 EDITION OF AWS & AISC. GATES TO BE CORRECT ON TRUNNION PINS TO GIVE EQUAL COMPRESSION ON SIDE SEALS.

SEAL JOINTS & PLUGS TO BE CONCRETED.
CLEANING & PAINTING TO BE DONE BY FIELD FORCES.
GUIDE ROLLER ASSEMBLIES TO BE SHIMMED TO GIVE A" MIN CLEARANCE.
FOR MANUFACTURER'S DETAILS OF BASTIN GATES REFER TO AMERICAN BRIDGE CO FILE TVA CONTRACT NO. TV-80015.









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

SPILLWAY

RADIAL GATES
ARRANGEMENT

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
POSTAL AND HYDRO ENGINEERING

54W200

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES (DWG 54W200 R3)

PLOT FACTOR-24

C.A.D. DRAWING DO NOT ALTER MANUALLY

Attachment A9

Source: Reference A7

Calculation No: CDQ000020080001
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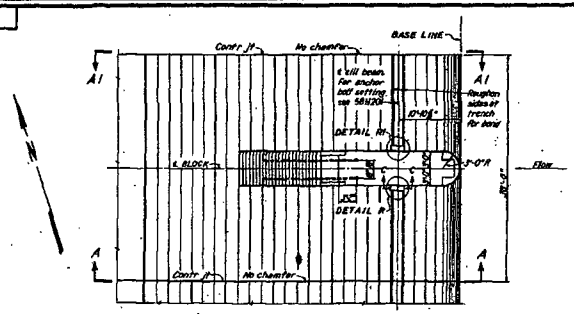
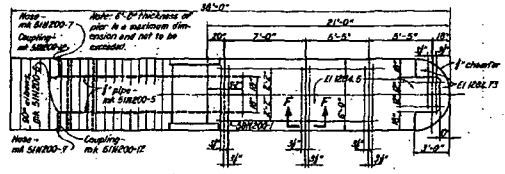
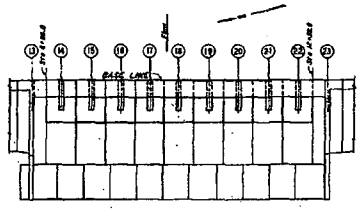
5IN201



PLAN—BLOCKS 14 TO 22 INL—ABOVE EL 1225.0
Scale 1/8"=1'-0"



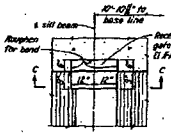
PLAN—TOP OF PIERS



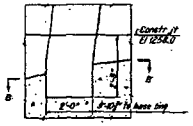
KEY PLAN
Scale 1"=60'

Crest Coordinate equations

COORDINATES OF WEIR PROFILE			
$Y = \frac{(6.8-X)^2}{115}$, From X=0 to X=6.8			
$Y = \frac{(X-6.8)^2}{2,000} + \frac{(X-6.8)}{68}$, From X=6.8 to Y=66.72			
X	Y	EL	DESCRIPTION
2.000	1.041	1255.959	
4.000	0.216	1256.784	
6.800	0.000	1257.000	6 of crest
8.800	0.182	1256.818	
9.906	0.331	1256.669	Edge of sill beam slot
11.875	0.691	1256.309	Edge of sill beam slot
14.000	1.201	1255.799	
16.000	1.797	1255.203	
18.000	2.601	1254.499	
20.000	3.314	1253.685	
22.000	4.213	1252.787	
24.000	5.255	1251.745	
26.000	6.380	1250.620	
28.000	7.606	1249.394	
30.000	8.930	1248.070	
32.000	10.352	1246.648	
34.000	11.810	1245.190	
36.000	13.480	1243.520	
38.000	15.183	1241.817	
40.000	16.976	1240.024	
42.000	18.856	1238.144	
44.000	20.823	1236.177	
46.000	22.875	1234.125	
48.000	25.010	1231.990	
50.000	27.226	1229.774	
52.000	29.521	1227.479	
54.000	31.894	1225.106	
56.000	34.342	1222.658	
58.000	36.865	1220.135	
60.000	39.460	1217.540	
62.000	42.124	1214.876	
64.000	44.859	1212.141	
66.720	48.594	1208.318	P.C.

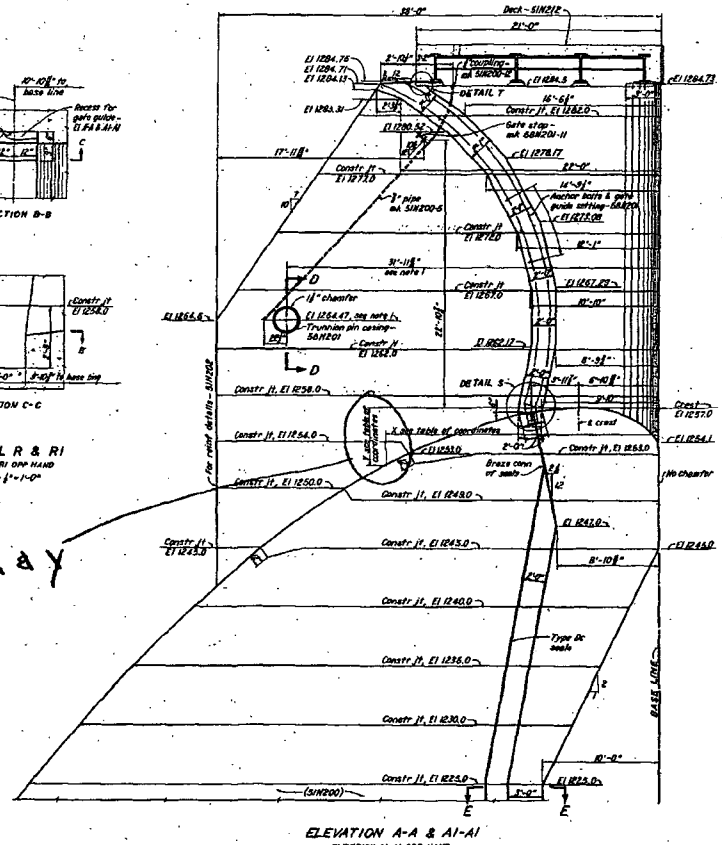


SECTION B-B

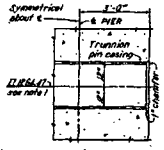


SECTION C-C

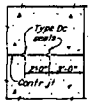
DETAIL R & R1
DETAIL R1 OPP HAND
Scale 1/8"=1'-0"



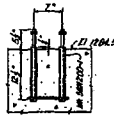
ELEVATION A-A & A1-A1
ELEVATION A1-A1 OPP HAND



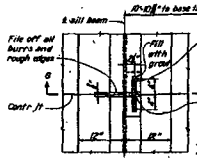
SECTION D-D
Scale 1/8"=1'-0"



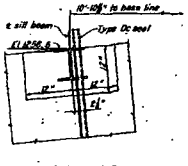
SECTION E-E



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

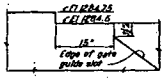


PLAN



ELEVATION G-G

DETAIL S
Scale 1"=1'-0"



DETAIL T
Scale 1"=1'-0"

NOTES:
1. Extreme care should be taken to set trunnion pin casing to exact dimensions and elevations shown.
2. Chamfer exposed corners 1/4" except as noted.

REFERENCE DRAWINGS:
5IN200... BILL OF MATERIAL
5IN201... SEALS

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

SPILLWAY

CONCRETE
BLOCKS 14 TO 22—ABOVE EL 1225.0
OUTLINE

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
W. W. Goodhouse	Roe M. Kiesel	Joseph K. Koch

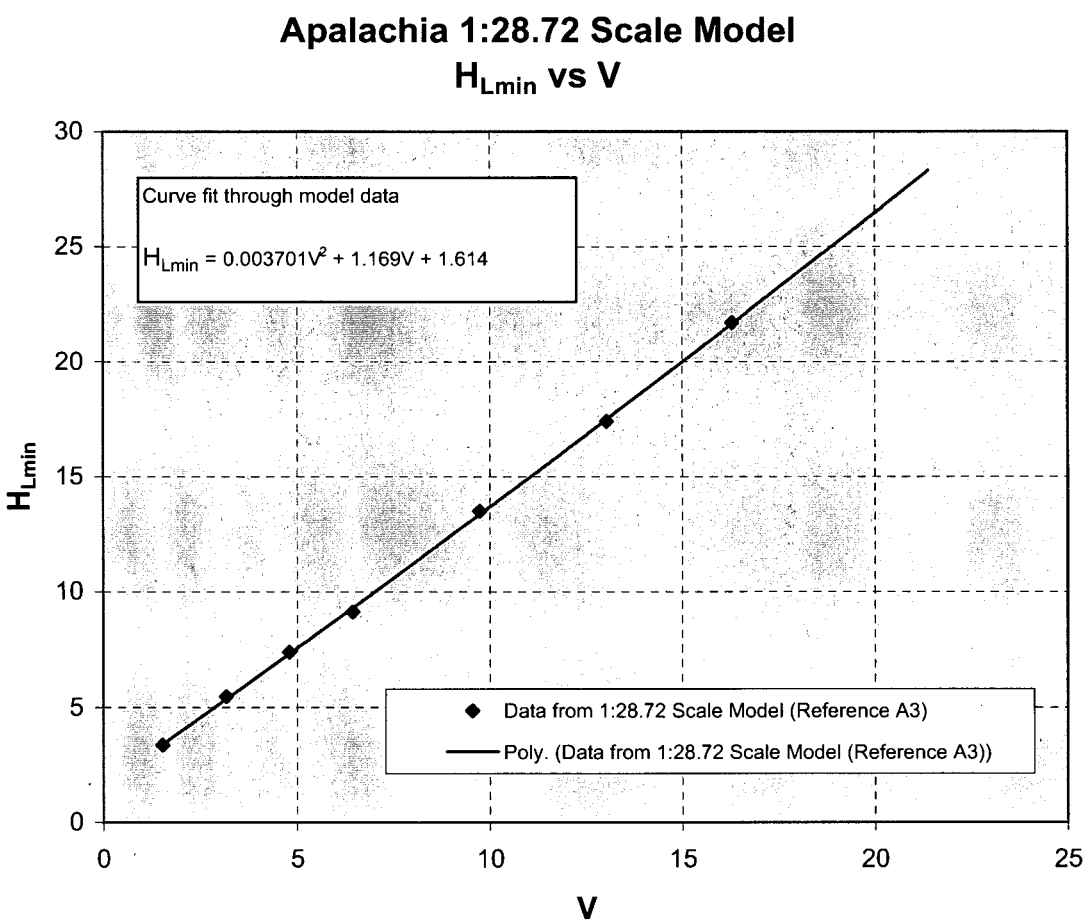
KNOXVILLE | 10-18-41 | 15 | C | 4 | 5IN201 | R4

CHIEF, DESIGN DEPARTMENT
C. J. Ley Jr. 5-21-48

CAP 0.0 REQ FOR DWR
1 2 3 4 5 6
3 of 11-30

Apalachia Project
Tainter Gates Partially Opened
Data from 1:28.72 scale model (Reference A3)
EQUIVALENT PROTOTYPE

V	H_{Lmin} (data)	H_{Lmin} (fit)	
feet	feet	feet	
1.53	3.36	3.41	
3.18	5.46	5.37	
4.81	7.38	7.32	
6.45	9.13	9.31	
9.74	13.5	13.35	
13.04	17.4	17.49	
16.30	21.68	21.65	
19.79		**26.20**	extrapolated using polynomial shown on plot



Apalachia

Tainter Gates Raised Above the Water Surface

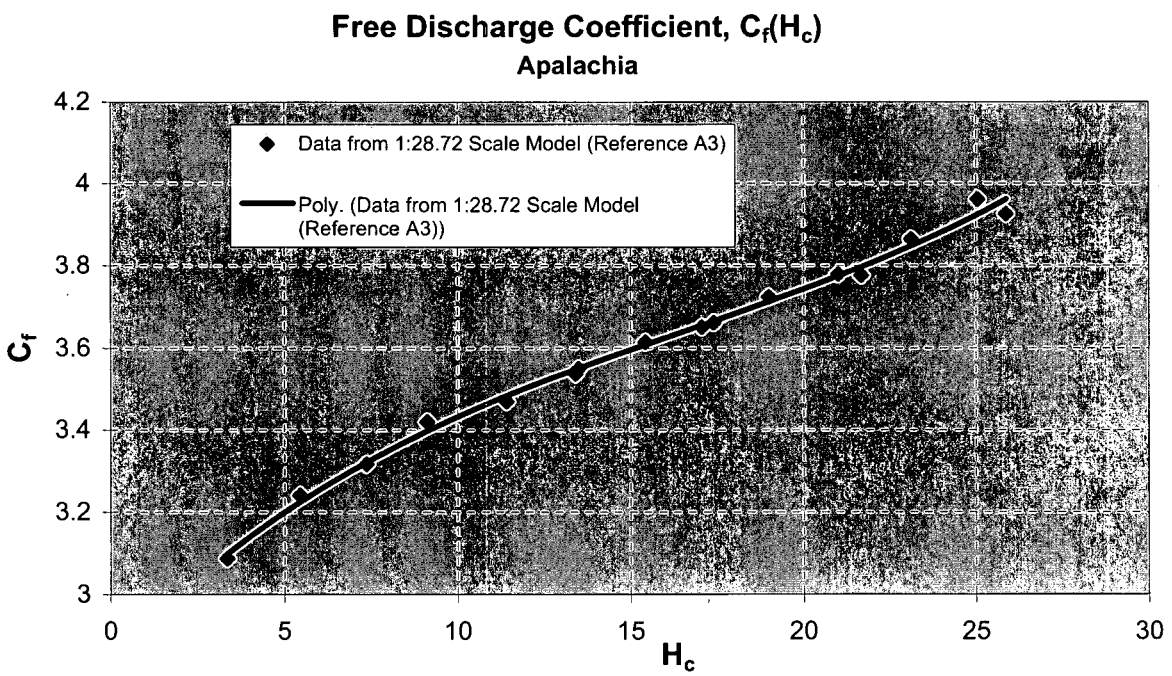
Data from 1:28.72 scale model (Reference A3)

(equivalent prototype)

H_c ft.	Q cfs	C_f
3.36	3,651	3.09
5.46	7,939	3.24
7.38	12,770	3.32
9.13	18,110	3.42
11.42	25,700	3.47
13.41	33,340	3.54
15.43	42,050	3.61
17.06	49,380	3.65
19.00	59,190	3.72
21.01	69,840	3.78
23.12	82,480	3.86
25.05	95,350	3.96
25.87	99,190	3.93
13.50	33,800	3.55
17.40	51,010	3.66
21.68	73,160	3.78

Definition: $C_f = Q/(28.72*6.684*H_c^{1.5})$

H_c ft.	3rd-order curve fit (see plot) C_f	
0	3.020	2.85
0.25	3.032	2.87
0.5	3.043	2.89
0.75	3.054	2.91
1	3.066	2.93
2	3.110	3.01
3	3.153	3.08
4	3.194	3.14
6	3.274	3.26
8	3.350	3.35
10	3.423	3.44
12	3.492	3.51
14	3.558	3.57
16	3.623	3.63
19	3.717	3.71
22	3.810	3.81
25	3.902	3.93
28	3.997	4.07



$C_f = 6.8700x^{-5}H_c^3 - .003436H_c^2 + .08600H_c + 2.85$

Apalachia Project, Tainter Gates Partially Opened
Data from 1:28.72 scale model as published in Reference A3
"Tainter Gate Rating Data Determined from Eight TVA Model Studies," Norris, Tennessee, March 1962

Model Scale = 28.72 g = 32.2 ft/s2

L_{model} = 6.684 ft Attachment A5-1

$L_{prototype}$ = 191.96 ft $28.72*L_{model}$

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
	ft	ft	cfs	ft	ft	
$H_c=H_{Lmin}$	6.45	9.13	18110	6.677	3.129	0.719
	6.45	10.45	18490	6.677	3.129	0.6644
	6.45	11.8	19450	6.677	3.129	0.6422
	6.45	13.24	21010	6.677	3.129	0.6424
	6.45	15.25	22900	6.677	3.129	0.639
	6.45	18.04	25380	6.677	3.129	0.639
	6.45	20.65	27510	6.677	3.129	0.639
	6.45	23.72	29930	6.677	3.129	0.641
	6.45	26.19	31730	6.677	3.129	0.642
	6.45	40.00				0.646 Estimated*
$H_c=H_{Lmin}$	9.74	13.50	33800	9.960	4.783	0.746
	9.74	15.14	33110	9.960	4.783	0.671
	9.74	16.51	34620	9.960	4.783	0.659
	9.74	18.15	36880	9.960	4.783	0.657
	9.74	20.62	40180	9.960	4.783	0.658
	9.74	23.61	43680	9.960	4.783	0.656
	9.74	26.42	46770	9.960	4.783	0.655
	9.74	40.00				0.665 Estimated*
$H_c=H_{Lmin}$	13.04	17.40	51010	13.301	6.424	0.751
	13.04	17.78	52340	13.301	6.424	0.758
	13.04	19.24	50480	13.301	6.424	0.688
	13.04	20.74	52340	13.301	6.424	0.675
	13.04	22.03	54550	13.301	6.424	0.674
	13.04	24.12	57910	13.301	6.424	0.679
	13.04	26.36	61180	13.301	6.424	0.683
	13.04	40.00				0.685 Estimated*
$H_c=H_{Lmin}$	16.30	21.68	73160	16.664	8.028	0.771
	16.30	23.52	71790	16.664	8.028	0.711
	16.30	24.50	73910	16.664	8.028	0.709
	16.30	25.82	75770	16.664	8.028	0.700
	16.30	40.00				0.700 Estimated*
$H_c=H_{Lmin}$	19.79	26.12	101839	20.381	9.722	0.801
	19.79	29.00				0.720 Estimated*
	19.79	32.00				0.710 Estimated*
	19.79	40.00				0.715 Estimated*

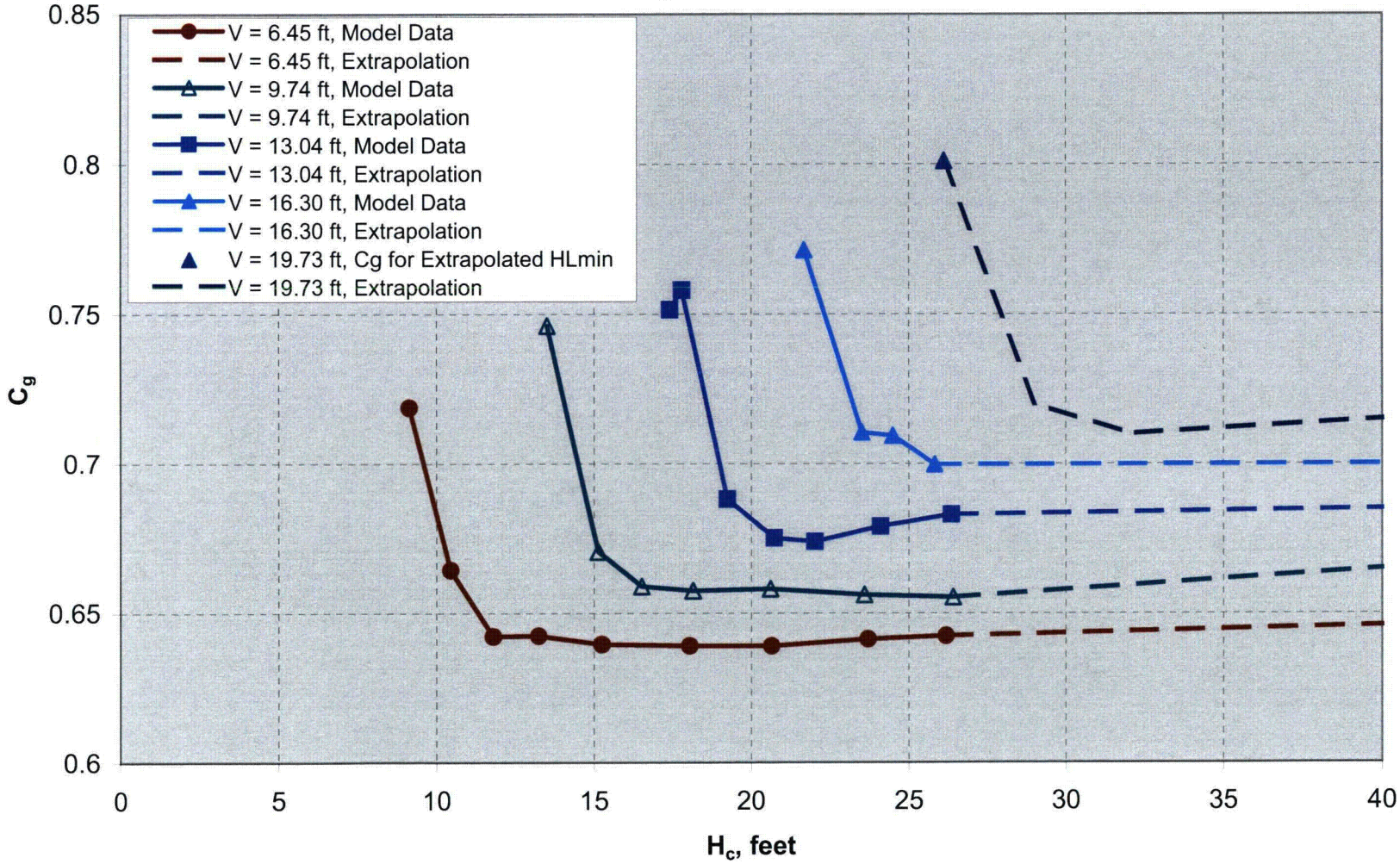
* Value of Cg is estimated; no model data, so no value for Q; geometrical parameters not needed

Attachment A13

Calculation No: CDQ000020080001

Page A27

Apalachia 1:28.72 Scale Model
C_g vs. Hc



Calculation No: CDQ000020080001

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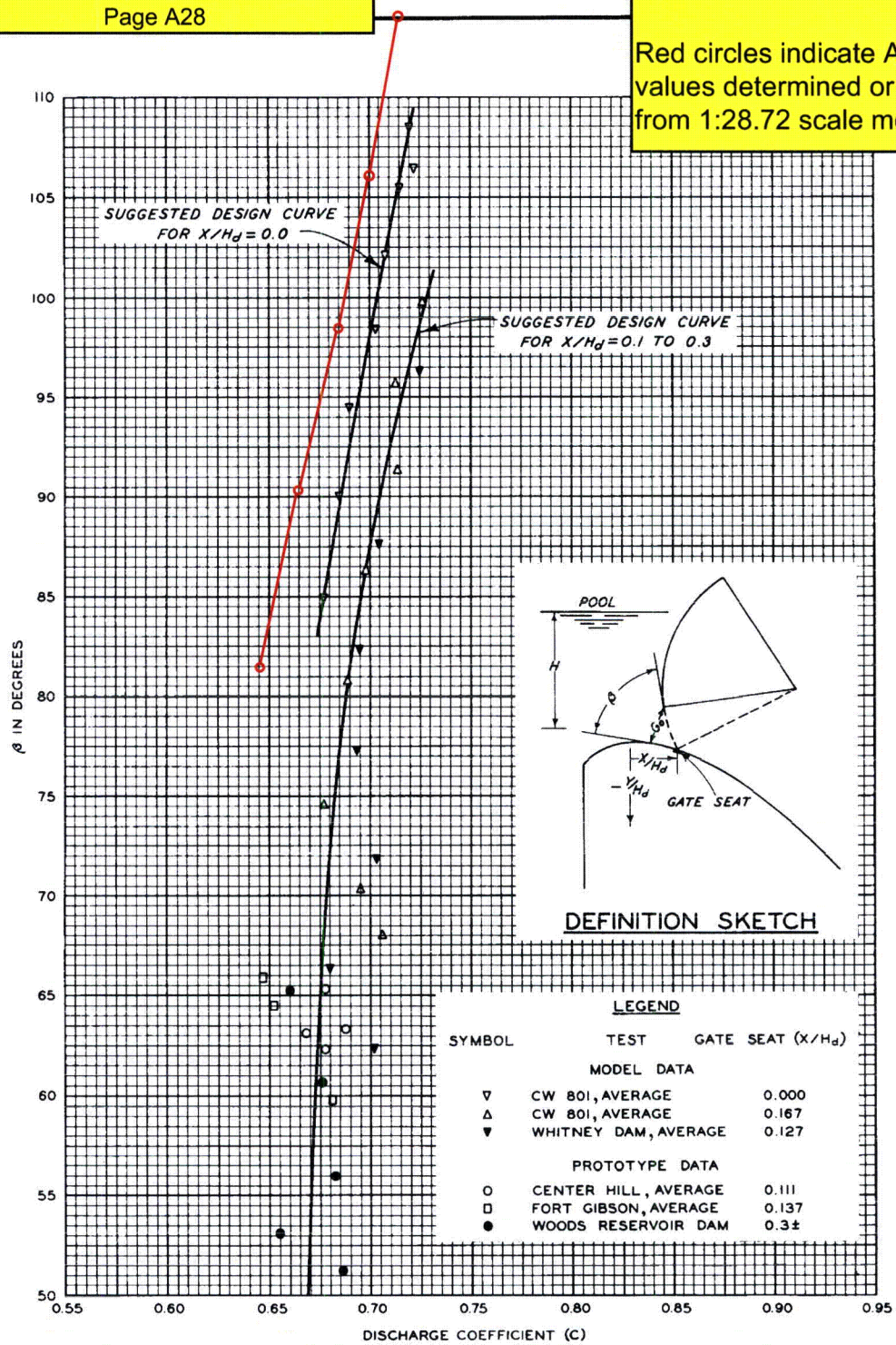
Attachment A14

Source: Reference A5

Red circles indicate Apalachia values determined or estimated from 1:28.72 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

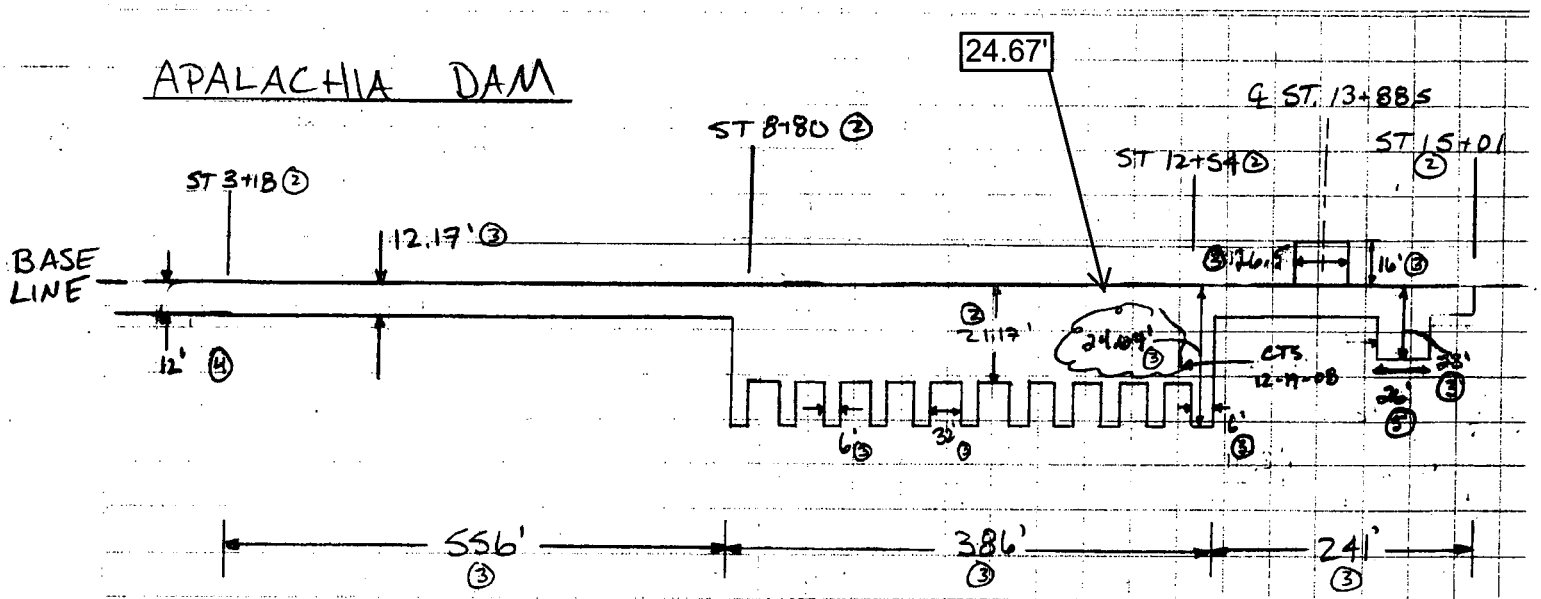
TVA 489H (EN DES-2-78) **TENNESSEE VALLEY AUTHORITY** SHEET B1 OF B8

DAM RATING CURVE - APALACHIA

SUBJECT OVERFLOW PARAMETERS APPENDIX B. PROJECT CDQ 0000200 80001

SEM	10-22-08	JCT	1/16/2009
COMPUTED BY	DATE	CHECKED BY	DATE

APALACHIA DAM

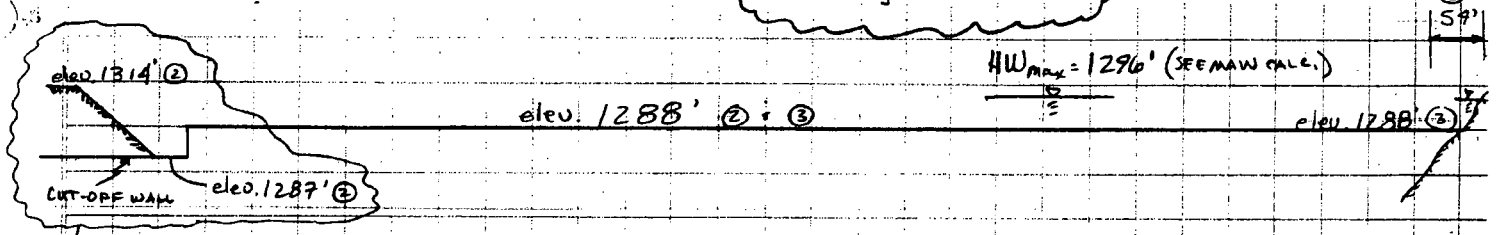


11 piers @ 6' = 66'

10 openings @ 32' = 320' ← CTS 12-19-2008

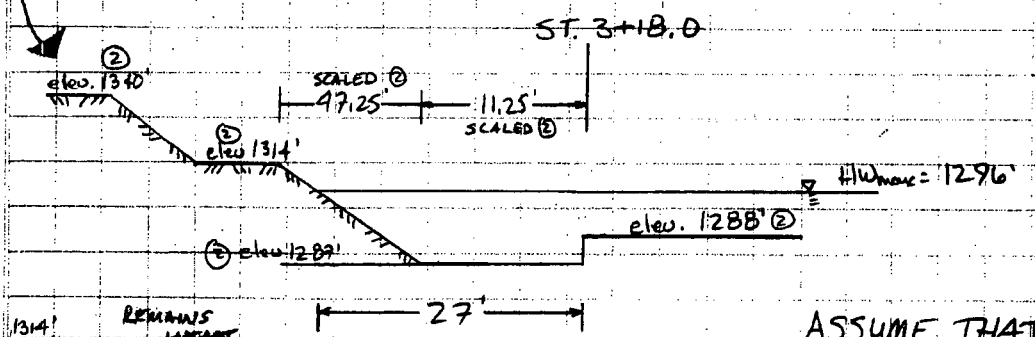
SCALED ③ 57'

HW_{max} = 1296' (SEE MAW CALC.)

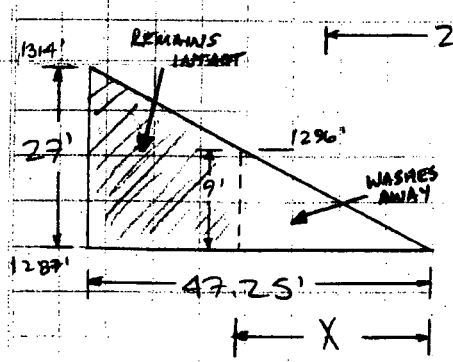


ELEVATION VIEW

NOT TO SCALE



* ANY VALUE WHICH HAS NO REFERENCE IS A CALCULATED VALUE.



(SIMILAR TRIANGLES)

$\frac{9}{27} = \frac{x}{47.25} \Rightarrow x = 15.75'$

15.75' + 11.25' = 27'

ASSUME THAT THE SOIL WASHES AWAY AT HW_{max} = 1296'. THE SOIL WILL BE CONSIDERED VERTICAL AT THIS POINT. THE CUTOFF WALL WIDTH WILL BE CONSIDERED TO CONTINUE.

DAM RATING CURVE - APALACHIA

APPENDIX B

CDQ00002008 0001

COMPUTED CTS DATE 11/19/2008

CHECKED JCT DATE 1/16/2009

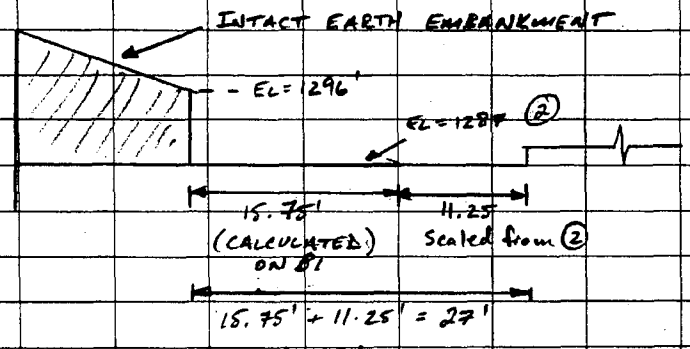
DISCHARGE COEFFICIENTS

REFER TO HCD 711 (REF 7, ATT 6) FOR VALUES OF FREE FLOW DISCHARGE COEFFICIENT, C_f. MAXIMUM HEADWATER ELEVATION USED IN THIS RATING IS 1296'

REFERENCE DRAWINGS

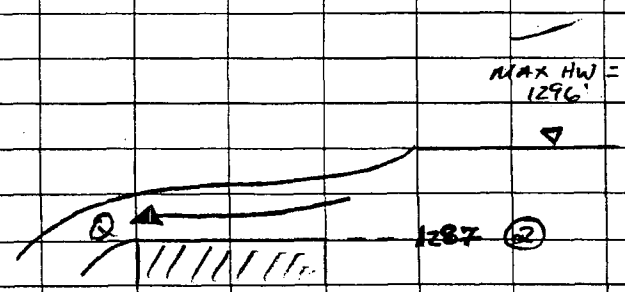
1. 10W200, R13 (REF 1, ATT 1)
2. 10N205, R4 (REF 8, ATT 7)
3. 10N206, R2 (REF 11, ATT 10)
4. 21N201 R5 (REF 9, ATT 8)
5. 21N202 R4 (REF 10, ATT 9)
6. 54N200 R4 (REF A6, ATT A8)

NORTH CUT OFF WALL (AFTER EMBANKMENT FAILURE)



$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{9'}{12'}$

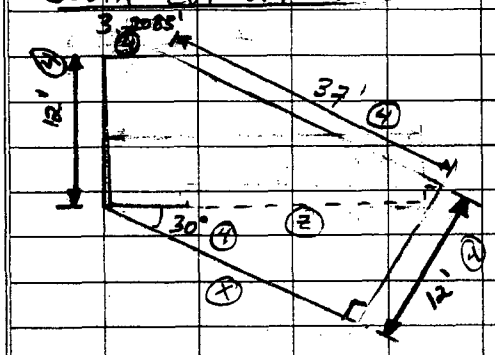
$0 \le \frac{H_c}{B} \le 0.75$



$2.65 \le C_f \le 2.81$ $L = 27'$ $B = 12'$ (SECTION N-N ON (4))

$H_c = 9'$

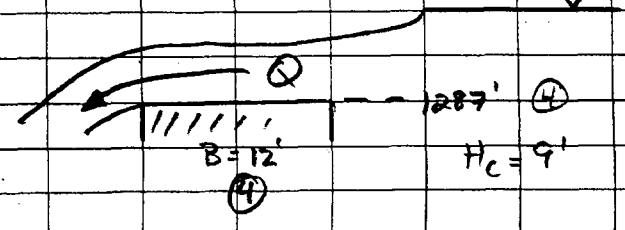
SOUTH CUT OFF WALL



$Z = 54'$ (SCALED FROM (2)) FROM STA 15+01 TO END OF PROPOSED FAILURE AREA ON SOUTH EMBANKMENT

$X =$ OVERFLOW $L = 54' \times \cos(30°)$

$L = 46.77'$



$H_c = 9'$

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{9}{12}$

$0 \le \frac{H_c}{B} \le 0.75$

$2.65 \le C_f \le 2.81$ $L = 46.77'$

DAM RATING CURVE - APALACHIA
APPENDIX B

CDQ 0000 20080001

COMPUTED CTS DATE 11/19/2008
CHECKED JCT DATE 1/16/2009

BOTH CUTOFF WALLS ARE COMBINED

$C_f = 2.75$ (Approx. Mid Pt of Range) $L = 46.77 + 27' = 73.77'$

NORTH SECTION NON-OVERFLOW DAM

THIS IS THE SECTION THAT RUNS BETWEEN THE NORTHERMOST SPILLWAY PIER (STA 8+80 ②) AND THE SOUTH END OF THE NORTH CUTOFF WALL (STA 3+18 ②). $L = (880 - 318) - 6 = 556'$

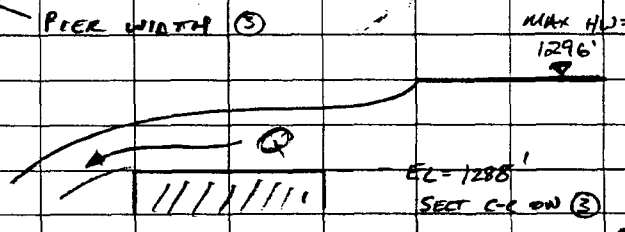
NON OVERFLOW DAM STA POINT CALC

PIER WIDTH ③

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{8'}{12.17'}$

$0 \le \frac{H_c}{B} \le 0.66$

$2.65 < C_f < 2.75$



$B = 12.17'$ → SECTION C-C ON ③

$H_c = 8'$

MIDDLE SECTION, NON OVERFLOW DAM

THIS SECTION EXTENDS FROM SOUTHERN MOST SPILLWAY PIER TO THE NORTHERN END OF THE INTAKE STRUCTURE

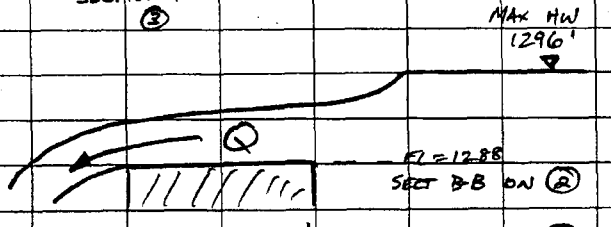
$L = 1388.5' - 1254' - 6' - \frac{1}{2}(26.5') = 115.25'$

SURVEY PT. INTAKE ℄ ③ — SURVEY PT SOUTH END OF SPILLWAY ③ — WIDTH OF SPILLWAY PIER ③ — HALF THE WIDTH OF THE INTAKE SECTION K-K ③

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{8'}{12.17'}$

$0 \le \frac{H_c}{B} \le 0.66$

$2.65 < C_f < 2.75$



$B = 12.17'$ SECT B-B ON ②

$H_c = 8'$

COMBINE THESE NON OVERFLOW SECTIONS

$L = 556' + 115.25' = 671.25'$

$C_f = 2.70$ (MID PT OF RANGE)

DAM RATING CURVE - APALACHIA
APPENDIX B

CDQ 0000 2008 0001

COMPUTED CTS DATE 11/19/2008
CHECKED JCT DATE 1/16/2009

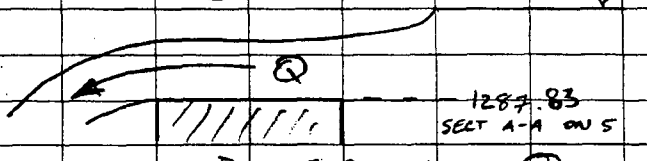
SOUTH SECTION, NON OVERFLOW DAM

THIS SECTION EXTENDS FROM THE SOUTH END OF THE INTAKE TO THE NORTH END OF THE SOUTH CUTOFF WALL

$L = 1501.0 - 1388.5 - \frac{1}{2}(26.5') - (22.5' + 3.5') = 73.25$

SURVEY PT CUTOFF WALL (2) — SURVEY PT INTAKE ℄ (2) — HALF OF WIDTH OF INTAKE (3) — WIDTH OF OPERATORS ROOM (5)

MAX HW 1296'



$B = 12.17$ SECT A-A ON (5)

$H_c = 9'$

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{9'}{12.17'}$

$0 \le H_c/B \le 0.74$

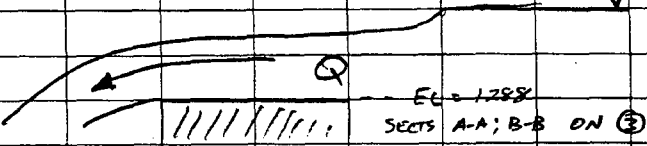
$2.65 \le C_f \le 2.81$

$C_f = 2.73$ (MID POINT OF RANGE)

SPILLWAY PIERS

$L = 11 \text{ piers} \times \frac{6 \text{ Foot}}{\text{Pier}} = 66 \text{ Feet}$

MAX HW 1296



$B = 3.5' + 21.0' + 0.17'$
$= 24.67'$ SECTS A-A & B-B ON (3)

$H_c = 8'$

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{8'}{24.67'} = 0.33$

$C_f = 2.65$ for all H_c

DAM RATING CURVE - APALACHIA
APPENDIX B

CDQ0000200800 01

COMPUTED CTS DATE 11/19/2008
CHECKED JCT DATE 1/16/2009

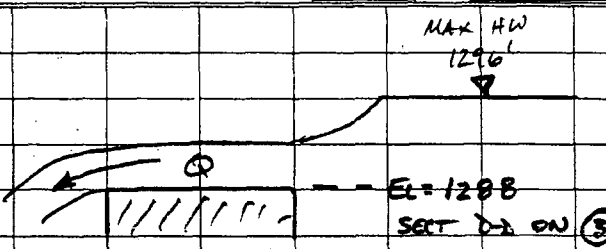
INTAKE STRUCTURE

$L = 26.5'$ (SECT K-K ON 3)

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{8'}{28'}$

$0 \le H_c/B \le 0.286$

$C_f = 2.65$ for all H_c



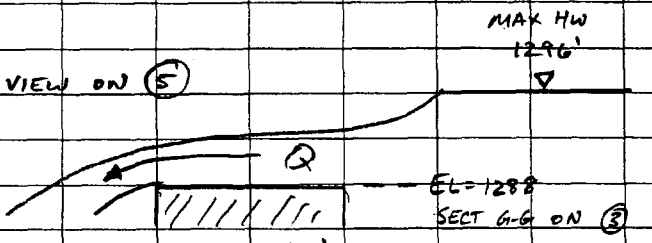
OPERATORS ROOM

$L = 22.5' + 3.5' = 26'$ PLAN VIEW ON 5

$0 \le \frac{H_c}{B} = \frac{H_1}{B} \le \frac{8'}{23'}$

$0 \le \frac{H_c}{B} \le 0.35$

$C_f = 2.65$ for all H_c



THESE SECTIONS ARE COMBINED WITH THE SPILLWAY PIERS

$C_f = 2.65$

$L = 26.5' + 26' + 66' = 118.5$

A 489 (EN DES-11-76)

DAM RATING CURVE - APALACHIA
APPENDIX B

CDQ 0000 2008 0001

COMPUTED CTS DATE 11/19/2008
CHECKED JCT DATE 1/16/2009

SUMMARY - OVERFLOW PARAMETERS

LOCATION	C_f	L	Z_c
CUTOFF WALLS	2.75	73.77'	1287.0'
NON OVERFLOW SECTIONS	2.70	671.25'	1288.0'
PIERS, INTAKE & OP BLDG	2.65	118.5'	1288.0'
SOUTH SECTION	2.73	73.25'	1287.85'

DAM RATING CURVE - APALACHIA

APPENDIX B

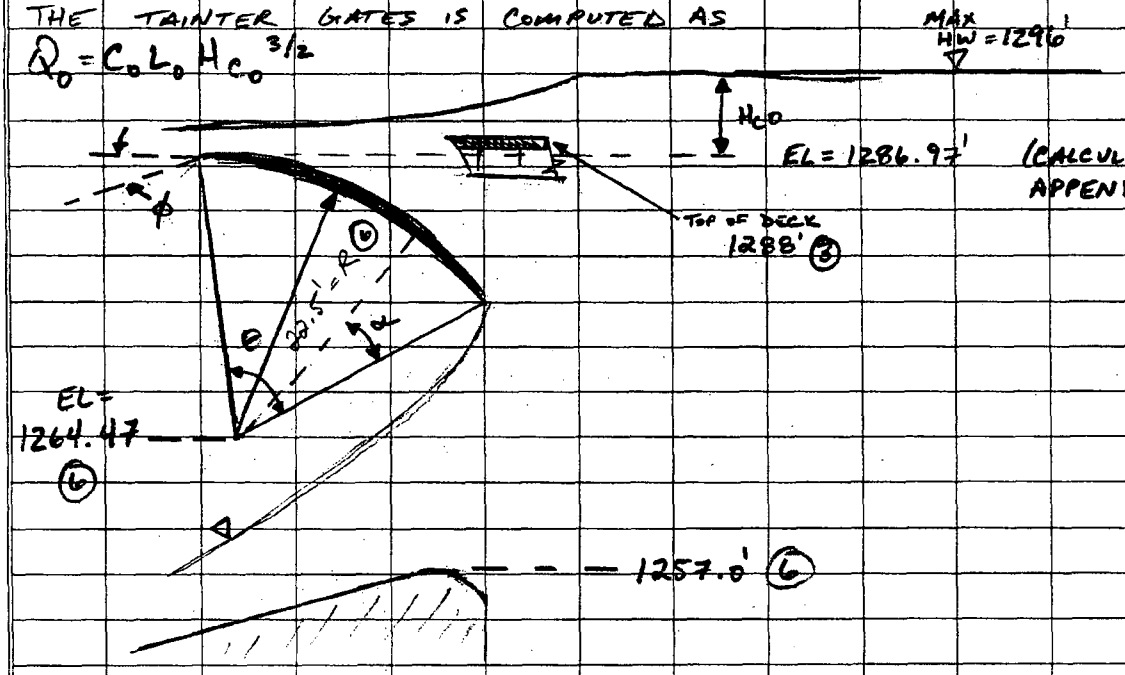
CDQ 0000 2008 0001

COMPUTED CTS DATE 11/19/2008

CHECKED JCT DATE 1/16/2009

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

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



A REASONABLE APPROACH TO SPECIFYING C_o IS TO USE DISCHARGE COEFFICIENT FOR DRUM GATES WHICH PRESENT THE SAME CIRCULAR SURFACE TO OVERFLOW. DISCHARGE COEFFICIENTS ARE AVAILABLE IN REF 12 FIG 6. (ATTACHMENT 12)

$$C_q = C_q\left(\theta, \frac{H}{r}\right) \quad \text{WHERE} \quad C_q = C_o$$

$\theta = \phi =$ (SEE BELOW)

$H = H_{c_o}$

$r = R = 22.5'$

HEADWATER RATING CURVE COMPUTED TO HW ELEV = 1296'

$$0 \le H_c \le 1296' - 1286.97' = 9.03'$$

$$0 \le H/r \le 9.03/22.5' = 0.40$$

$$\phi = \tan^{-1}\left(\frac{x_o}{y_o}\right) = \tan^{-1}\left[\frac{R\cos(\theta-\alpha)}{z_o - z_{TR}}\right] = \tan^{-1}\left[\frac{22.5\cos(64.407° + (-35.199°))}{1286.97 - 1264.47}\right]$$

$$\phi = -7.53°$$

REFER TO APPENDIX A FOR DEFINITION / CALCULATION OF θ, α, z_o, x_o & y_o

DAM RATING CURVE - APALACHIA
APPENDIX B

CDR 0000 2008 0001

COMPUTED CTS DATE 11/19/2008
CHECKED JCT DATE 1/16/2009

FROM REF. 12 ("RATING CURVES FOR FLOW OVER DRUM GATES")

FIG 6 ⇒ $3.05 \le C_q \le 3.5$ USE $\boxed{C_o = 3.1}$

$C_q \frac{H}{r} = 0.05$ $C_q \frac{H}{r} = 0.4$

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

- TOTAL OVERFLOW DISCHARGE IS < 10% of TOTAL DAM DISCHARGE (SEE RESULTS) SO SMALL VARIATIONS IN C_o HAVE NEGLIGIBLE EFFECTS ON TOTAL DAM DISCHARGE (10% CHANGE IN $C_o \Rightarrow \frac{0.10}{3.10}(10\%) = 0.3\%$)
- FLOW UNDER DRUM GATES CAUSES SIGNIFICANT DRAWDOWN IN WATER LEVEL UPSTREAM OF THE GATE WHICH SHOULD RESULT IN LESS OVERFLOW THAN PREDICTED FOR AN EQUIVALENT DRUM GATE
- OPERATING DECK MAY IMPEDE FLOW & REDUCE DISCHARGE

L = 10 32 FOOT OPENINGS = 320'

OVERFLOW DISCHARGE AS A % OF TOTAL DISCHARGE

CALCULATION AT MAXIMUM HEADWATER (EL = 1296', SEE SECTION 7)

$$\frac{\text{GATE OVERFLOW}}{\text{TOTAL DISCHARGE}} \times 100\% = \frac{26918 \text{ cfs}}{287420 \text{ cfs}} = 9.3\%$$

Appendix C: Hydrostatic Loads on the Spillway Tainter Gates

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

C1 References

C1. "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates, pages 76-100" Tennessee Valley Authority, HEPE3WBHSQN-WBNBLNBFN. (B25880520307)

C2 Calculations

Reference C1 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 (1280.00 feet) and when the gates are completely open (FR_{open}) and the headwater elevation is at 1295.00 feet. The margin is defined at the ratio of FR_{open} to FR_{closed}. The calculation of these forces and the results of this comparison are shown in Figure C1.

Apalachia Hydrostatic Forces on Gates

Comparison of forces when gates are closed and HW is at 1280.00 feet (top of gate) vs. when gates are fully open and HW at an elevation of 1295.00 feet.

Attribute	Symbol	Value	Unit
top elev	Zo	1280.00	ft
trun elev	Ztr	1264.47	ft
sill elev	Zsill	1256.50	ft
radius	R	22.50	ft
length	L	32.00	ft
angle up	α2	43.65	deg
angle lwr	α	20.75	deg
angle tot	θ	64.39	deg
area of lower slice	Aslice1	284.48	ft^2
proj area	AProjected	752.00	ft^2
Desgn LdH	FRx	551366.40	lbs
Result elv	Z1	1264.33	ft
Result ang deg		0.35	deg
Result ang rad		0.01	rad
Result Dsgn	Horiz	551356.23	lbs
Area slice upper	Aslice2	192.83	ft^2
Area triangle	Atriangle	126.42	ft^2
project vert	x1	6.22	ft
vert weight water	FRy	60251.12	lbs
Resultant load - Gates Closed	FR_{closed}	**554648.63**	lbs
vert open fm calc	calc App A	19.79	ft
max hw	calc	1295.00	ft
lwr lip elev	Z2	1276.29	ft
bot angle	α3	31.69	deg
top elev	Zo	1286.84	ft
project area for h ld	AProjected	337.70	ft^2
Flood LdH	FRx	283078.10	lbs
Height over gate	y1	8.16	ft
Height ratio to orig		1.64	(ratio)
project vert	x2	21.53	ft
Flood LdV1		350666.02	lbs
Flood lLdV2		114591.84	lbs
Total Flood LdV	FRy	465257.86	lbs
Resultant load - Gates Fully Open	FR_{open}	**544608.19**	lbs
Margin	FR_{open}/FR_{closed}	**0.98**	(ratio)

Figure C1: Apalachia Spillway Gate Margin Evaluation

BWSC BARGE WAGGONER SUMNER & CANNON, INC.

Project: Hydrostatic Force on Gate
Description: Diagram
Project No. _____ Sheet No. _____ of _____
Designer: _____ Date: _____
Checker: _____ Date: _____

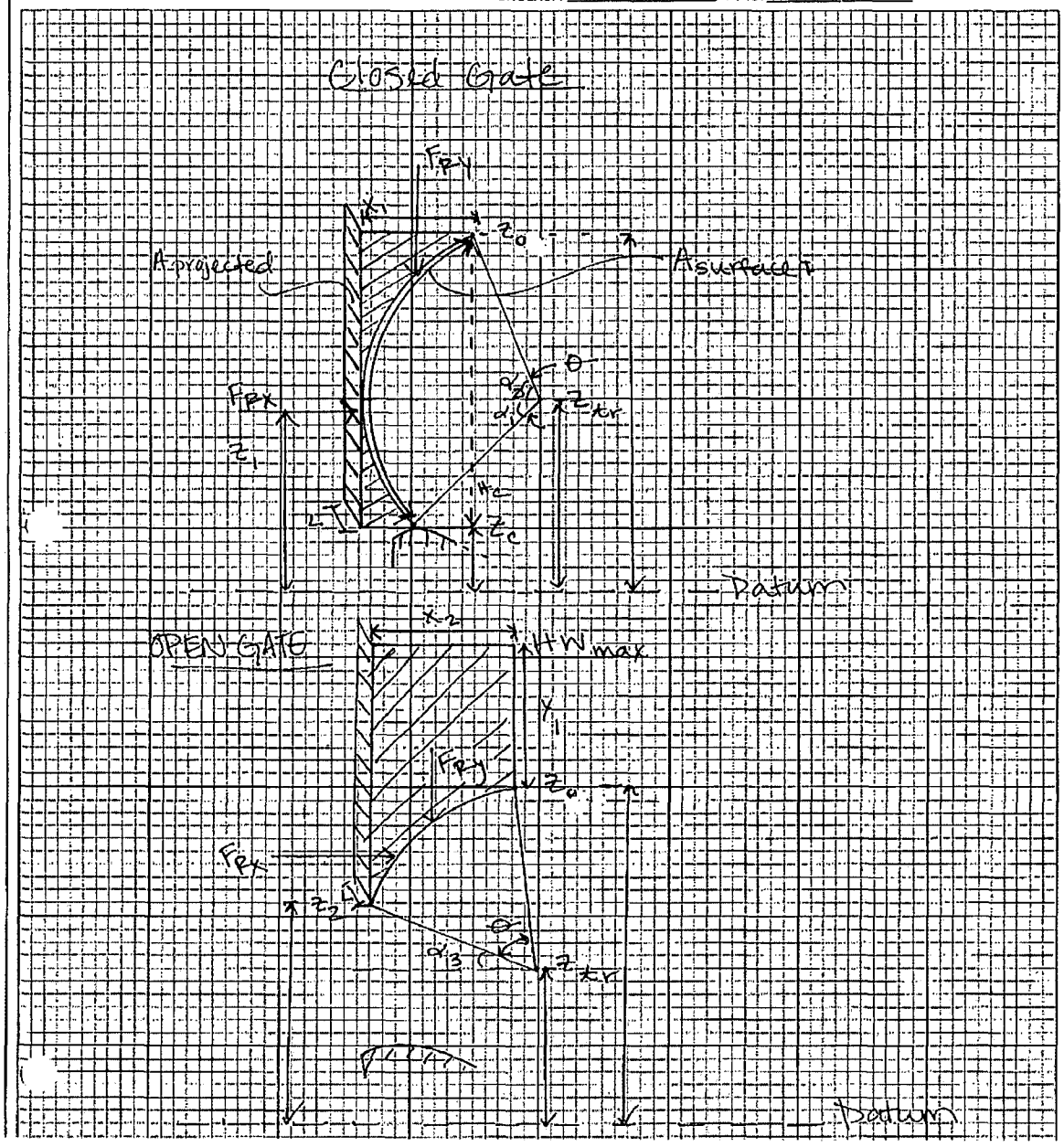
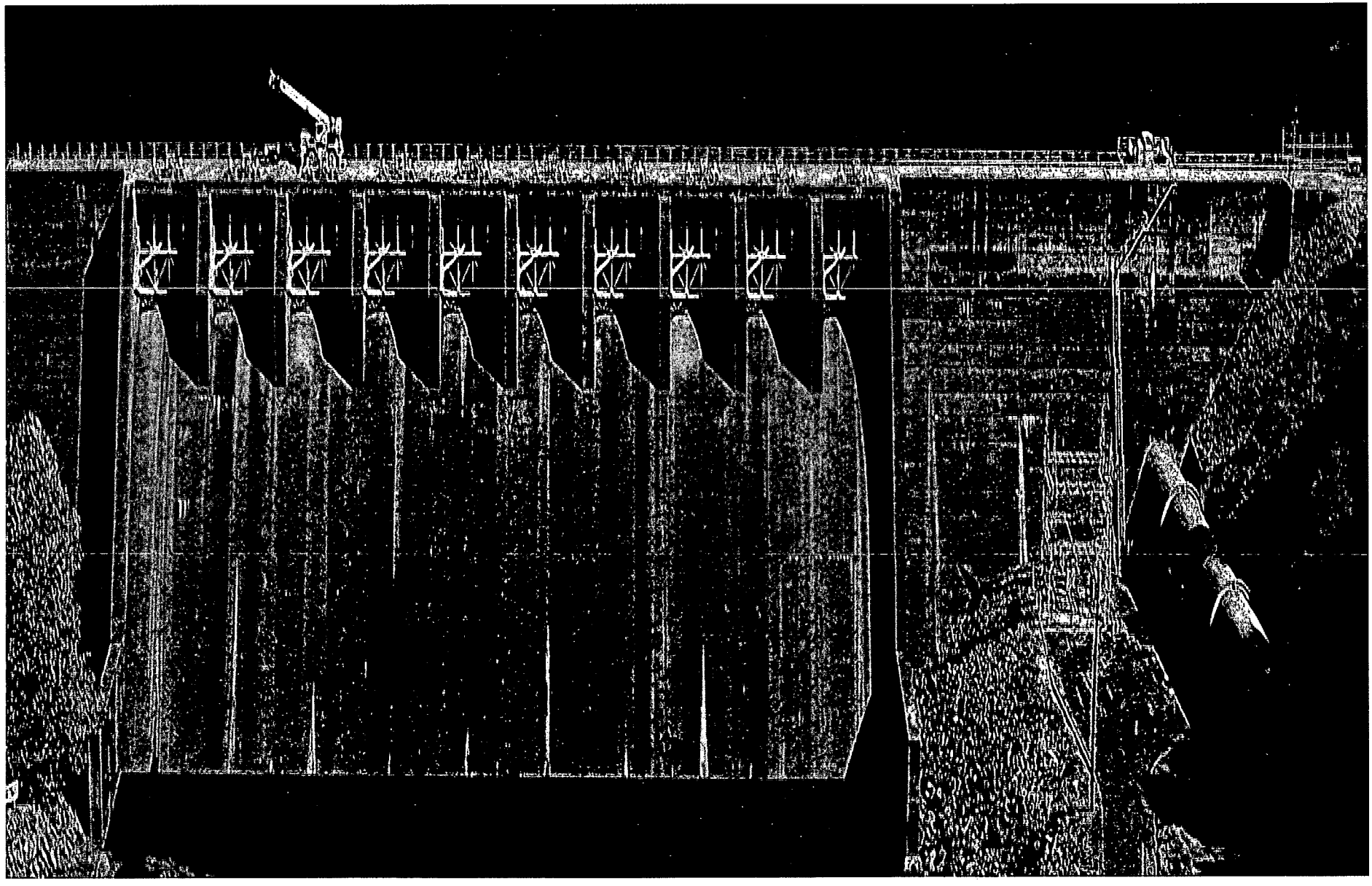


Figure C2: Diagram of Hydrostatic Forces

APALACHIA DAM

December 1999



RESERVOIR OPERATION OVERVIEW

Apalachia is one of four major TVA dams on the upper Hiwassee river system. Apalachia was constructed as a single purpose power reservoir, meaning that the funds for construction and operation were supplied from the sale of power. Apalachia has very limited storage in its normal 6 foot operating range (elevation 1272 to 1278) and is primarily a run-of-river project with its small storage used on a daily basis for power release shaping. Upstream seasonal storage is provided by Hiwassee, Chatuge, and Nottely Reservoirs. Apalachia Reservoir also serves as the tailpond for the pump-turbine unit located immediately upstream at Hiwassee Dam.

Although primarily a power project, Apalachia serves other purposes including recreation to a limited degree on the reservoir and seasonal whitewater rafting below the powerhouse. Apalachia receives unregulated inflow from its small local drainage area (50 square miles) in addition to regulated releases from Hiwassee Dam upstream.

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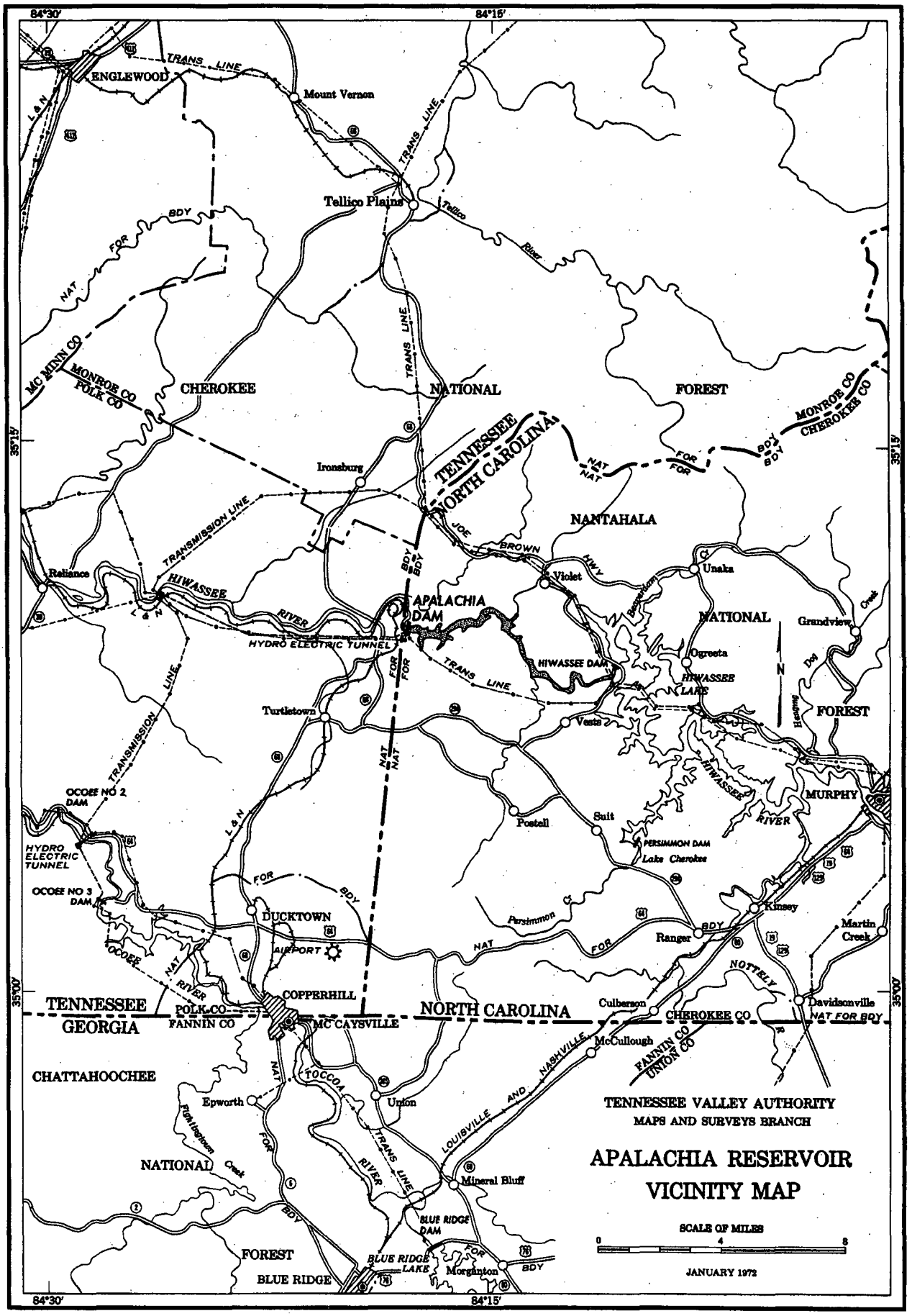
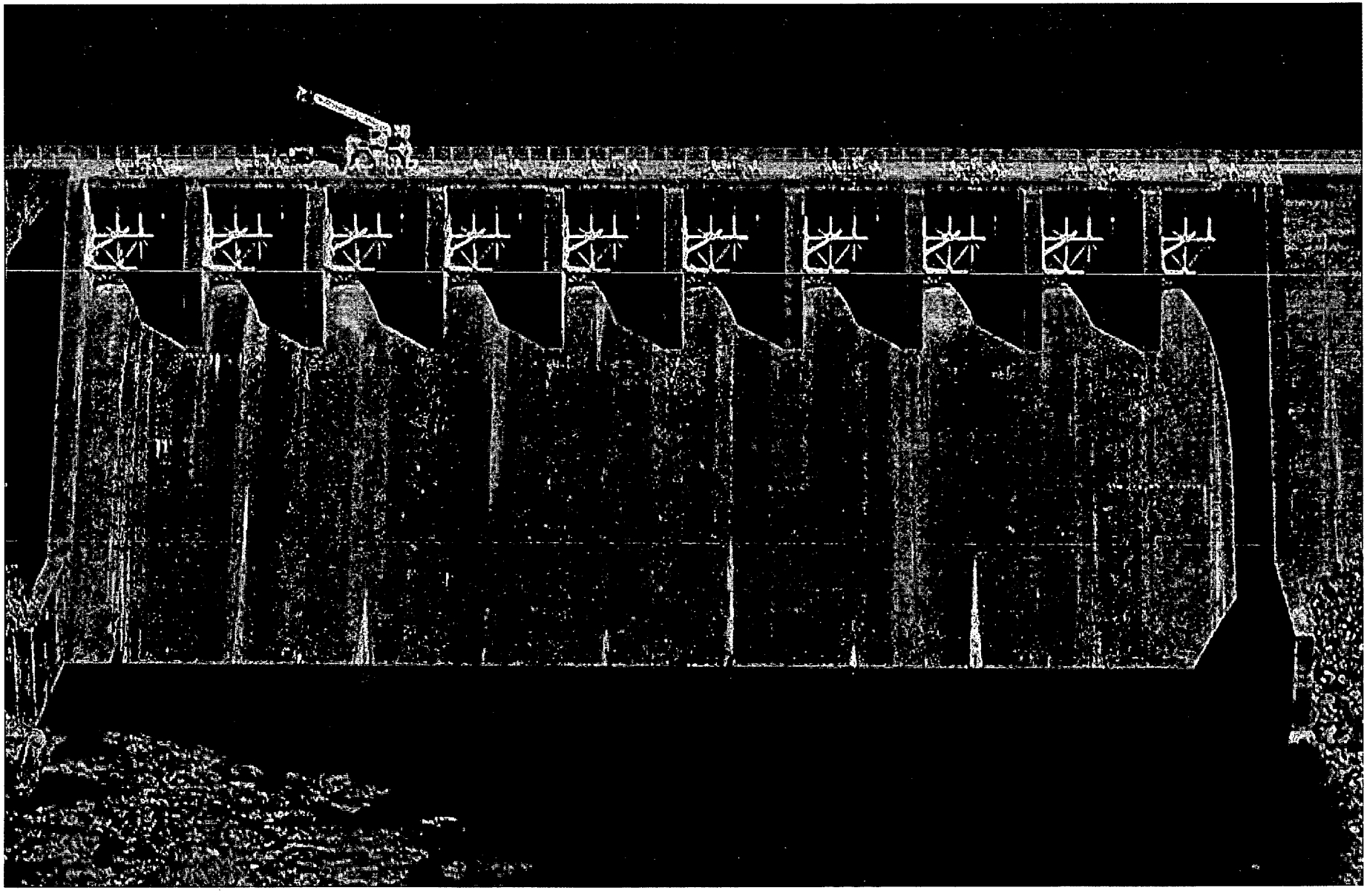

84°30'
84°15'
35°15'
35°00'
ENGLEWOOD
Mount Vernon
Tellico Plains
Tellico River
TRANS LINE
L & N
NAT FOR BDY
MC MINN CO
MONROE CO
POLK CO
CHEROKEE
NATIONAL
FOREST
TENNESSEE
NORTH CAROLINA
Ironsburg
NANTAHALA
JOE BROWN HWY
Violet
Unaka
Grandview
Reliance
TRANSMISSION LINE
HIWASSEE RIVER
APALACHIA DAM
HYDRO ELECTRIC TUNNEL
HIWASSEE DAM
HIWASSEE LAKE
Ogreeta
Turtletown
Vesta
OCOEE NO 2 DAM
HYDRO ELECTRIC TUNNEL
OCOEE NO 3 DAM
Postell
Suit
PERSIMMON DAM
Lake Cherokee
MURPHY
Kinsey
Ranger
Martin Creek
DUCKTOWN
AIRPORT
OCOEE RIVER
COPPERHILL
MC CAYSVILLE
TENNESSEE
GEORGIA
POLK CO
FANNIN CO
NORTH CAROLINA
Culberson
CHEROKEE CO
Davidsonville
NOTTELY
McCullough
FANNIN CO
UNION CO
LOUISVILLE AND NASHVILLE
CHATTAHOOCHEE
Epworth
TOCCOA RIVER
Union
Mineral Bluff
BLUE RIDGE DAM
BLUE RIDGE LAKE
Morganton
BLUE RIDGE
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
APALACHIA RESERVOIR
VICINITY MAP
SCALE OF MILES
0 4 8
JANUARY 1972

FIGURE 1 - Spillway Gates

December 1999



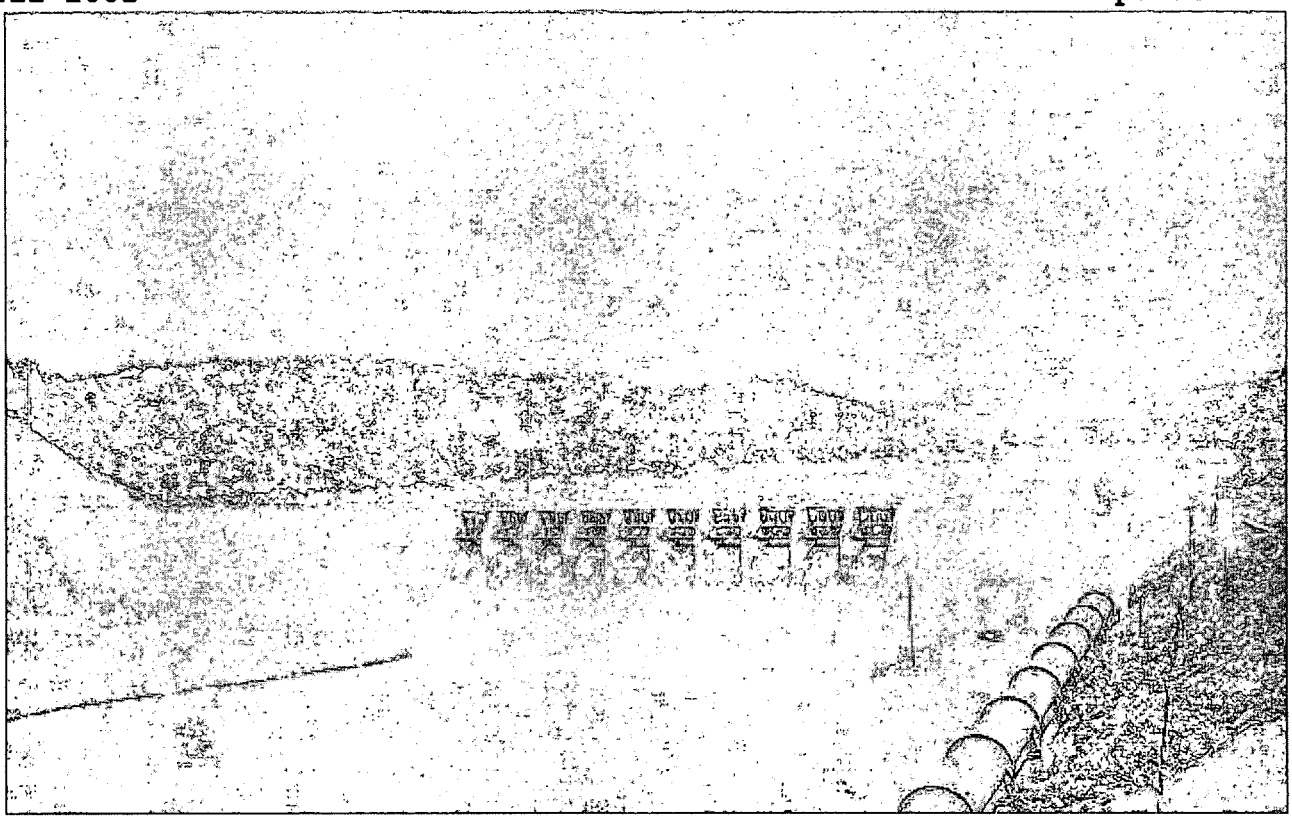


FIGURE 2 - Dam and penstock to eight-mile-long tunnel

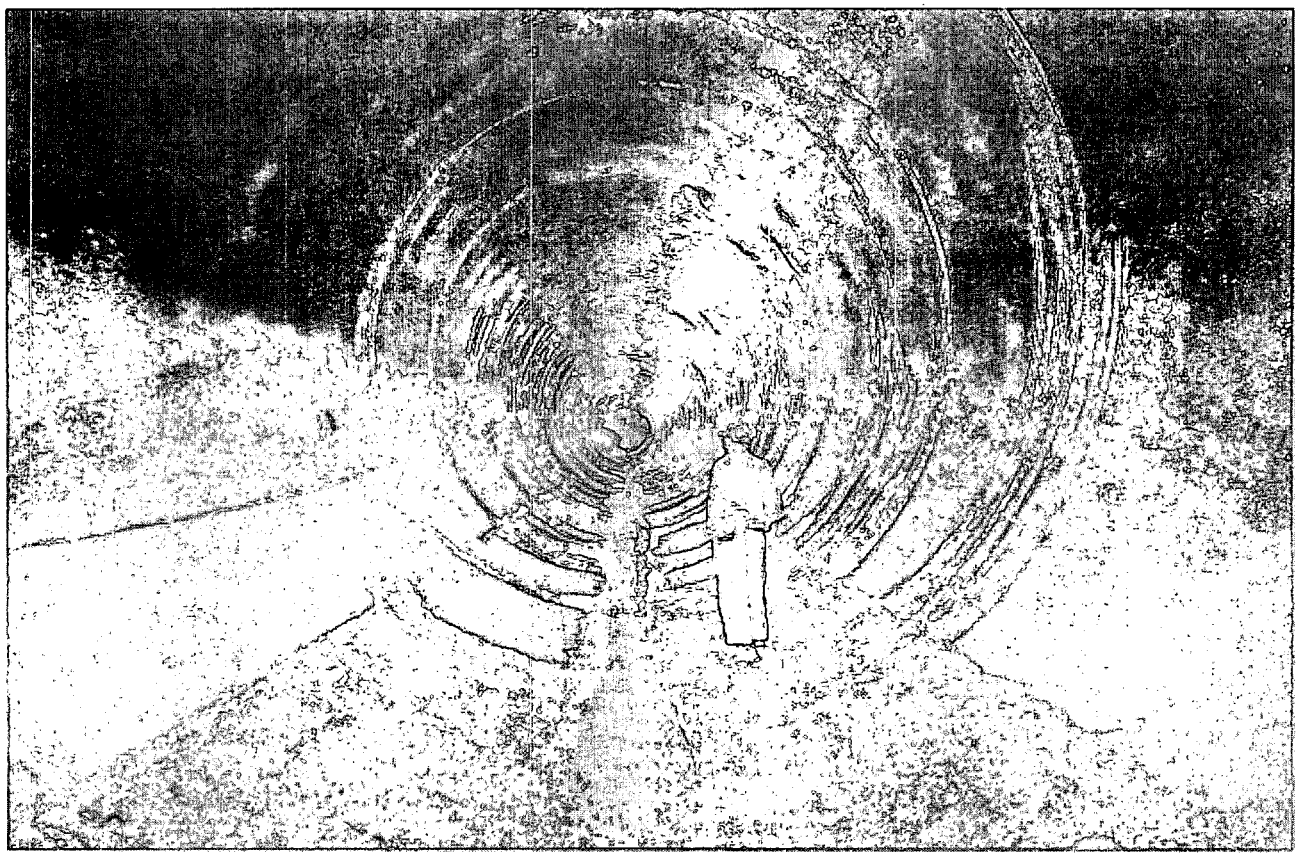


FIGURE 3 - Concrete-lined section of tunnel

FIGURE 4

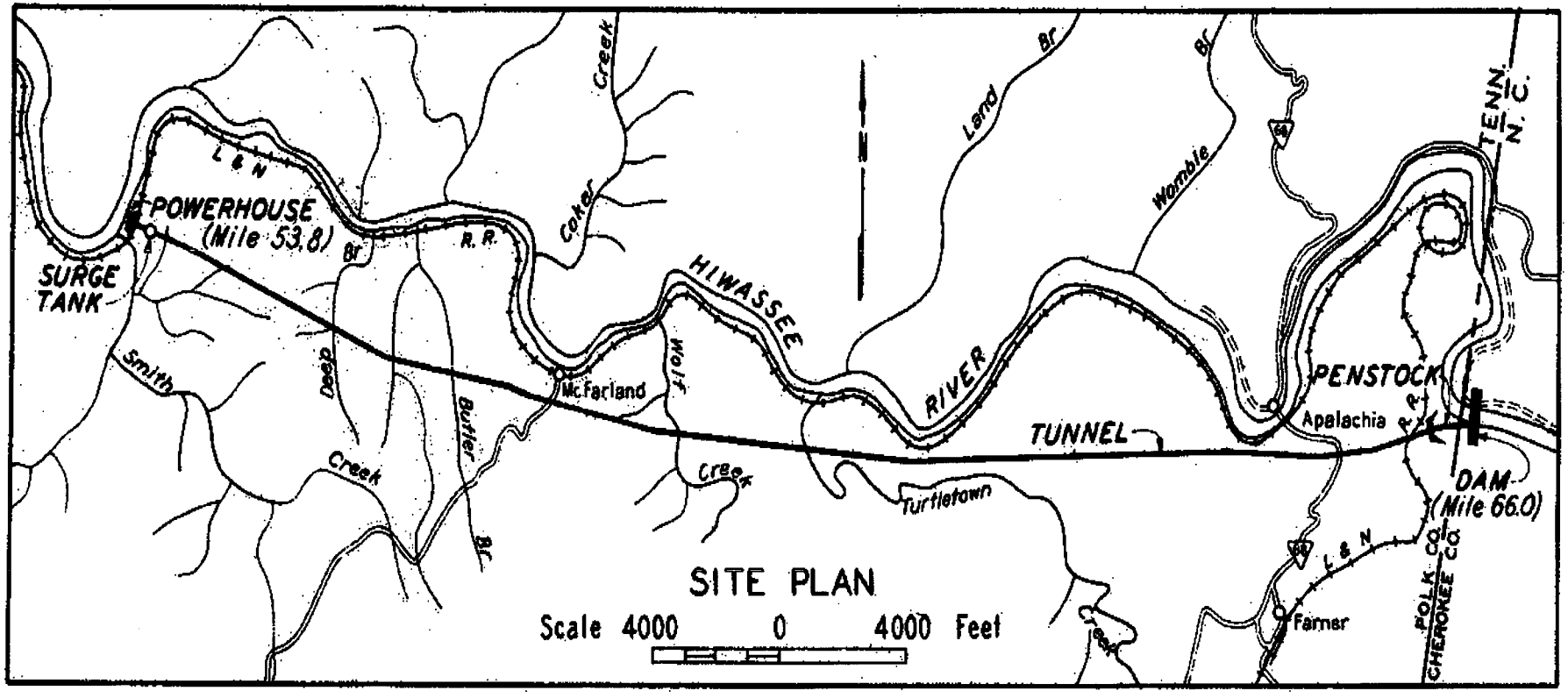

SITE PLAN
Scale 4000 0 4000 Feet
POWERHOUSE
(Mile 53.8)
SURGE TANK
L & N
R. R.
Br
Smith
Creek
Deep
Butler
Br
Coker
Creek
McFarland
Wolf
Creek
HIWASSEE
RIVER
TUNNEL
Turtletown
Creek
Land
Br
Womble
Br
PENSTOCK
Apalachia
R. R.
DAM
(Mile 66.0)
L & N
Farner
POLK CO.
CHEROKEE CO.
TENN.
N. C.

FIGURE 5

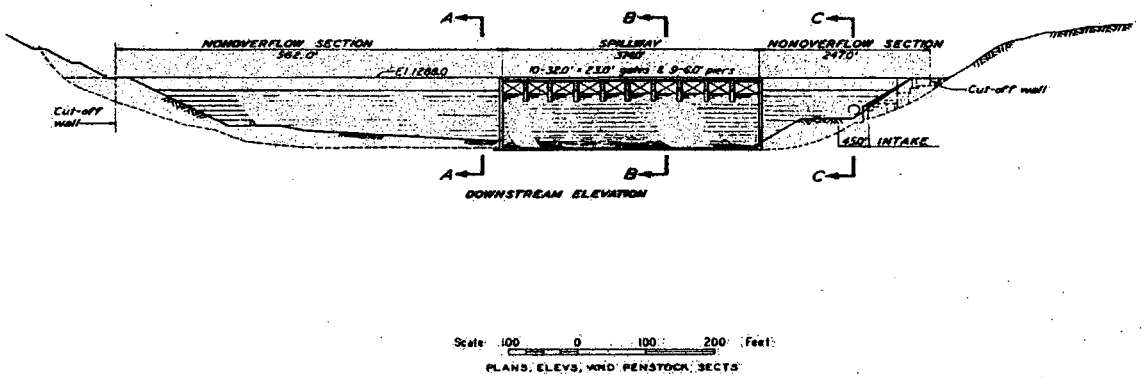


FIGURE 6

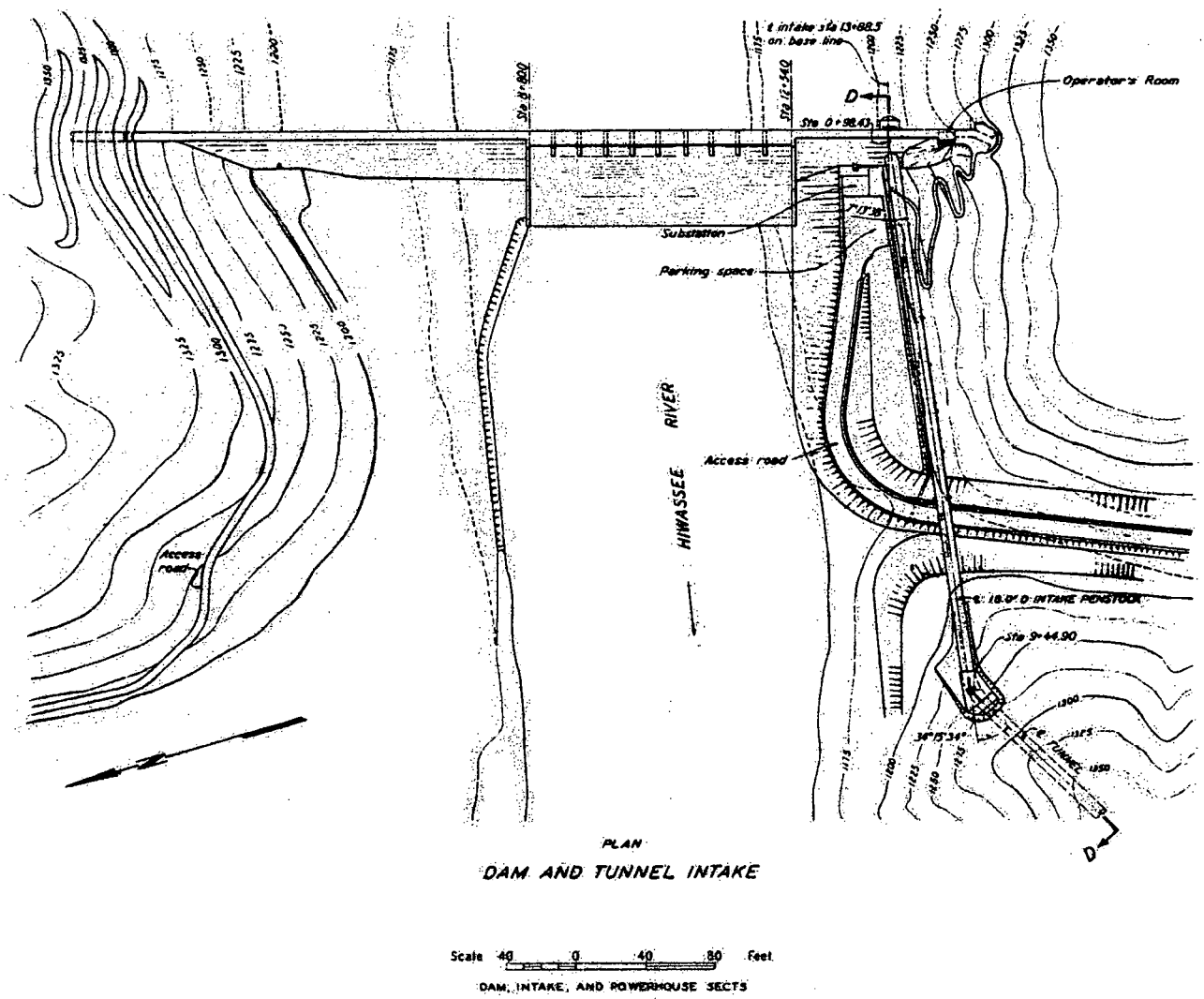
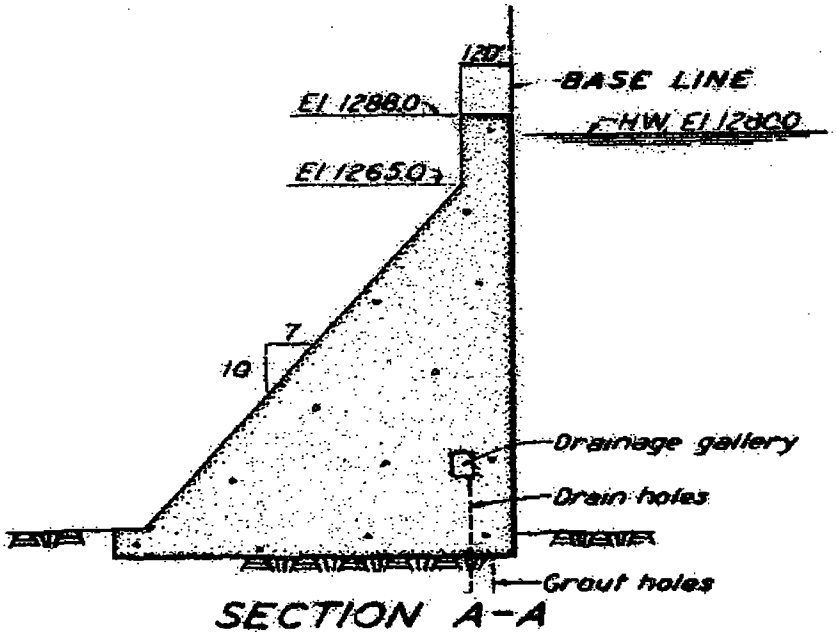


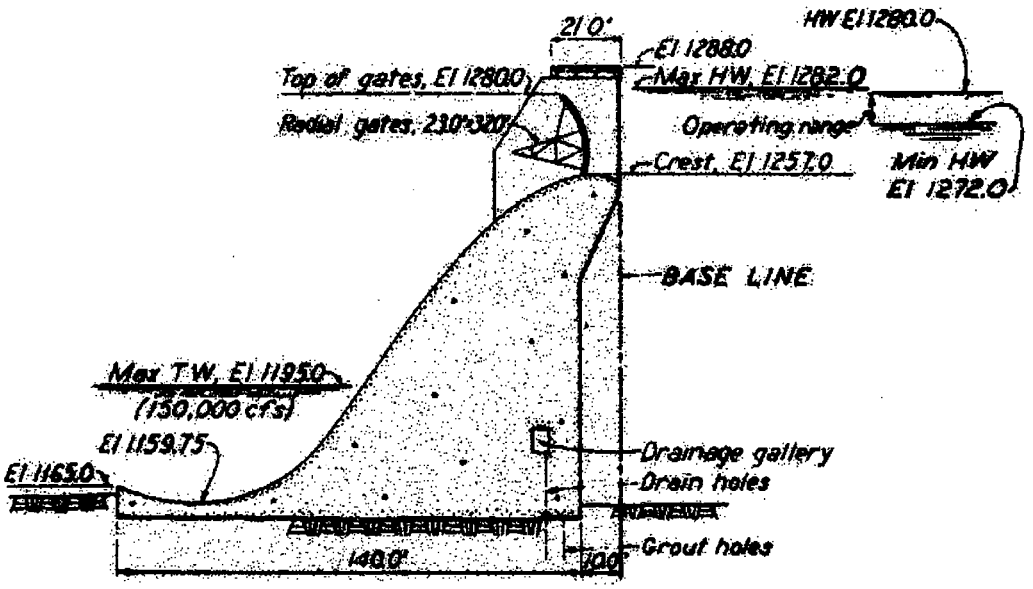
FIGURE 7



Scale 40 0 40 80 Feet

DAM, INTAKE, AND POWERHOUSE SECTS

FIGURE 8

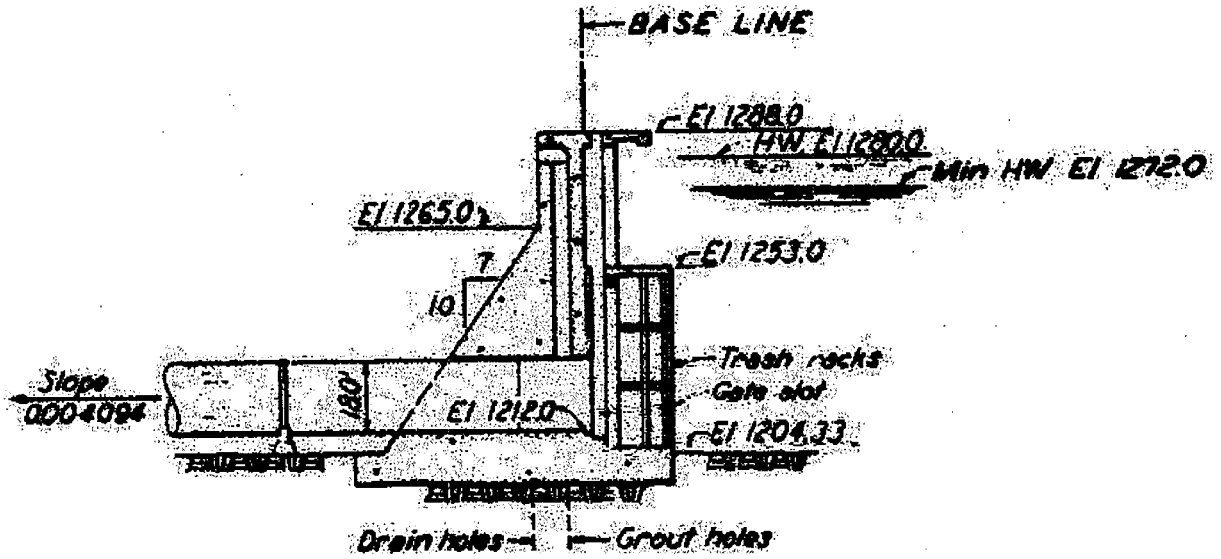


SECTION B-B

Scale 40 0 40 80 Feet

DAM, INTAKE, AND POWERHOUSE SECTS

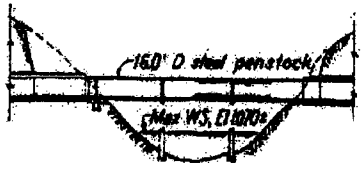
FIGURE 9



Scale 100 0 100 200 Feet

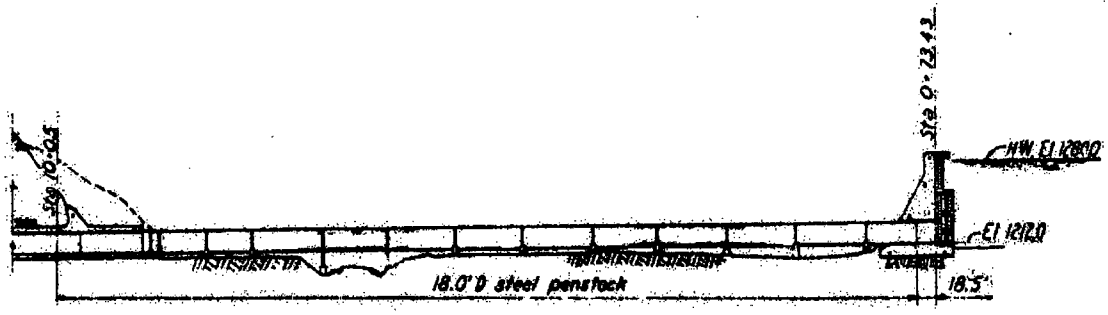
PLANS, ELEVS, AND PENSTOCK SECTS

FIGURE 10



TURTLETOWN CREEK PENSTOCK

FIGURE 11

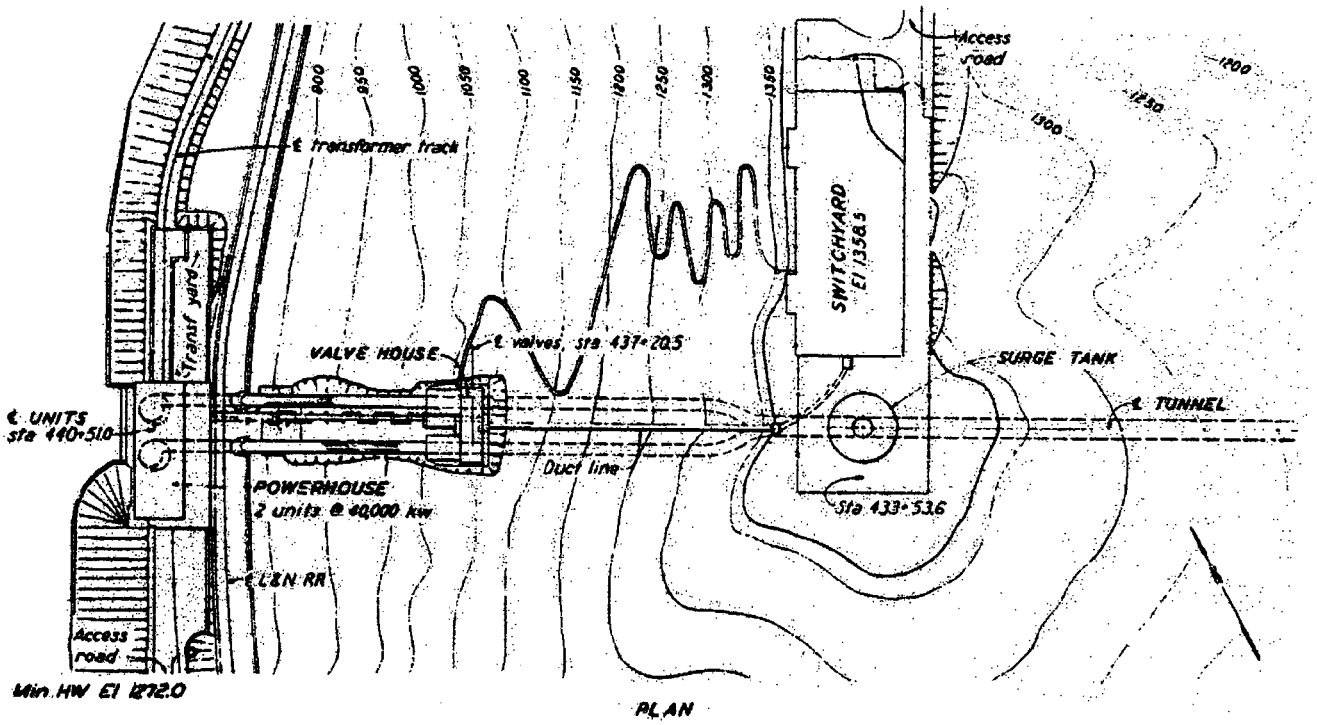


SECTION D-D

Scale 100 0 100 200 Feet

PLANS, ELEVS, AND PENSTOCK SECTS

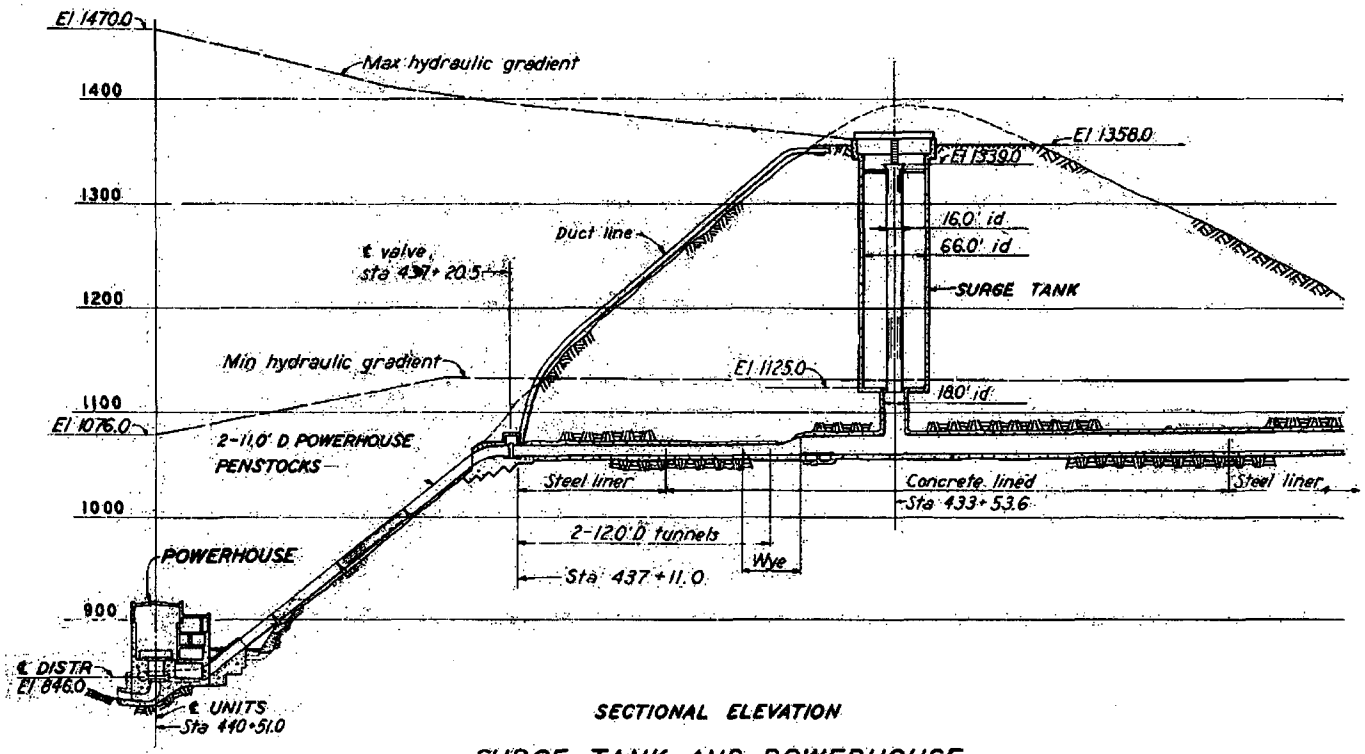
FIGURE 12



Scale 100 0 100 200 Feet

PLANS, ELEVS, AND PENSTOCK SECTS

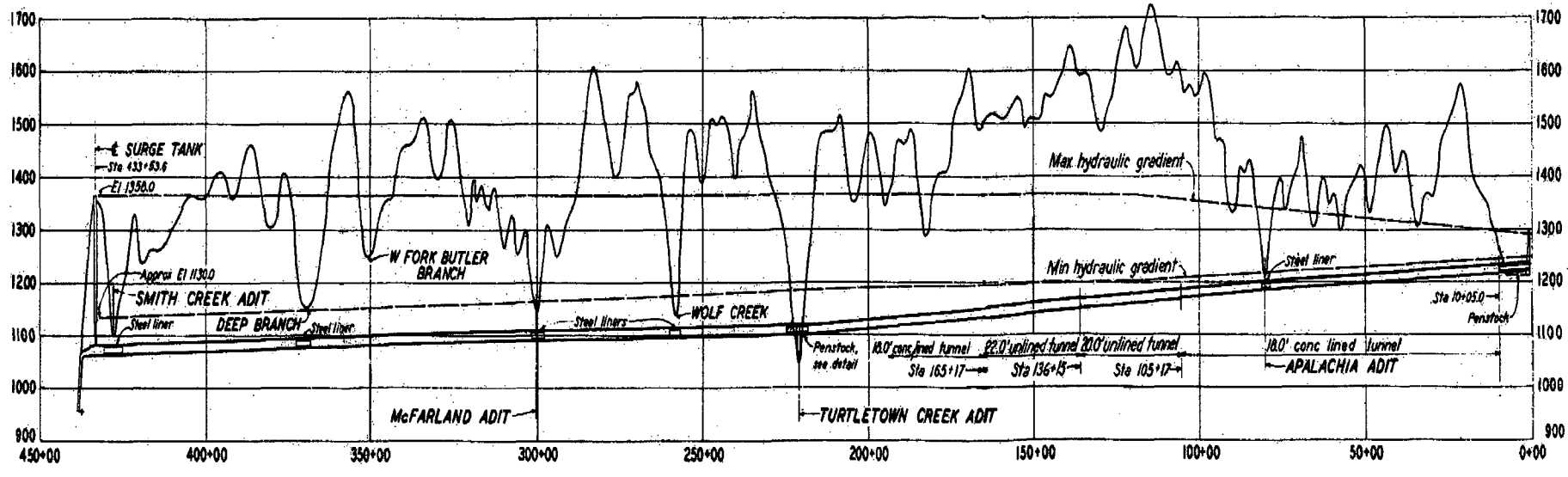
FIGURE 13



SECTIONAL ELEVATION

SURGE TANK AND POWERHOUSE

FIGURE 14



PROFILE - TUNNEL

APALACHIA

SUMMARY OF PRINCIPAL FEATURES

LOCATION

Dam - on Hiwassee River at river mile 66.0; in Cherokee County, North Carolina; 9.8 miles downstream from Hiwassee Dam; about 0.1 mile east of Tennessee State line; 1-1/2 miles northeast of Louisville and Nashville Railroad station at Farner, Tennessee; 3.6 miles from Louisville and Nashville Railroad station at Apalachia, Tennessee.

Powerhouse - on Hiwassee River at river mile 53.6; in Polk County, Tennessee; on Louisville and Nashville Railroad about midway between Hiwassee (deactivated) and McFarland stations. Distance from dam to powerhouse by road is about 18 miles.

CHRONOLOGY

Initial appropriation by Congress	July 16, 1941
Authorized by TVA Board of Directors	July 17, 1941
Construction started	July 17, 1941
First concrete placed	February 2, 1942
Closure	February 14, 1943
Unit 2 in commercial operation	September 22, 1943
Unit 1 in commercial operation	November 17, 1943

PROJECT COST

Initial project, including 2 units and switchyard	$23,762,118

STREAMFLOW

Drainage area at dam:	
Total	1,018 sq. miles
Uncontrolled (below Hiwassee Dam)	50 sq. miles
Gaging station discharge records:	
At Hiwassee Dam, North Carolina, September 1934 to September 1943; drainage area	968 sq. miles
Below Apalachia Dam, June 1941 to April 1946; drainage area	1,018 sq. miles

STREAMFLOW (Continued)

Near Apalachia, Tennessee, January 1914 to December 1922; drainage area ..... 1,038 sq. miles
Near McFarland, Tennessee, October 1942 to date; drainage area ..... 1,136 sq. miles
Reliance, Tennessee, August 1900 to December 1913, February 1919 to September 1926; drainage Area ..... 1,181 sq. miles
Near Reliance, Tennessee, October 1926 to September 1948; drainage area ..... 1,223 sq. miles
Maximum natural flow at dam site, (1898) ..... 82,000 cfs
Maximum regulated flood since closure (1973) ..... 39,200 cfs
Average unregulated flow at dam site, estimated (1903-2000) ..... 2,140 cfs
Minimum daily natural flow at dam site (1925), approx. ..... 150 cfs

RESERVOIR

Counties affected:
State of North Carolina ..... Cherokee
Reservoir land at May 31, 1996:
Fee simple ..... 1,708 ac.
Total ..... 1,708 ac.
Transferred ..... 10,395 ac.
Operating levels at dam:
Probable maximum flood elevation (PMF) ..... el. 1297.2
500-year flood elevation ..... el. 1283.0
100-year flood elevation ..... el. 1282.0
Winter flood guide level ..... el. 1272.0
Summer flood guide level ..... el. 1280.0
Maximum used for design (150,000 cfs) ..... el. 1282.0
Top of gates (area 1,100 ac.) ..... el. 1280.0
Backwater, length to Hiwassee Dam ..... 9.8 miles
Shoreline, length at normal maximum pool level:
Main shore ..... 31 miles
Original river area (to Hiwassee Dam ..... 80 ac.
Storage (flat pool assumption):
Total volume:
At top of gates (el. 1280) ..... 57,800 ac.-ft
At normal maximum pool (el. 1280) ..... 57,800 ac.-ft
At normal minimum pool (el. 1272) ..... 49,000 ac.-ft
Useful controlled storage (el. 1280-1272) ..... 8,800 ac.-ft
Volume for Hiwassee pump-turbine operation (el. 1280-1272) ..... 8,800 ac.-ft

TAILWATER

Maximum used for design (150,000 cfs):	
At dam	el. 1195.0
At powerhouse	el. 873.5
Maximum known flood at powerhouse (February 4, 1936)	el. 855.0
Full plant operation (2 units)	el. 842.7
One unit operating at best efficiency	el. 841.5
Minimum level at powerhouse	el. 837.6

HEAD (Gross)

Maximum static (el. 1280-837.6)	442.4 ft
Normal maximum operating (el. 1280-840)	440.0 ft
Average operating	436.0 ft
Minimum operating (el. 1282-873.5)	408.5 ft

RESERVOIR ADJUSTMENTS

Clearing	595 ac.
Highways:	
Access	4.8 miles
State	2.4 miles
Other	12.5 miles
Total	19.7 miles
Railroad	2.5 miles
Bridges (Highway)	1
Utilities adjusted	None
Families relocated	22
Graves	None

DAM

Material and type	Concrete gravity nonoverflow dam and spillway
Lengths:	
Nonoverflow dam	809 ft
Spillway	374 ft
Cutoff walls	125 ft
Total	1,308 ft
Maximum height, foundation to deck level	150 ft

DAM (Continued)

Maximum width at base:
- Spillway section only ..... 100 ft
- Including apron (bucket) ..... 140 ft

Deck level ..... el. 1288.0

Outlet facilities:
- Spillway clear opening (10 openings at 32 ft) ..... 320 ft
- Spillway crest level ..... el. 1257.0
- Crest gates ..... 10 radial gates, 32 ft wide, 23 ft high, separated by 6-ft-thick piers

Gate hoists ..... Ten 40-ton fixed hoists

Spillway capacity:
- HW el. 1282 (design level) ..... 156,600 cfs
- HW el. 1280 (top of gates) ..... 136,000 cfs

Foundation ..... Micaceous quartzite, mica schist, and mica slate

POWER FACILITIES

INTAKE

Location ..... Left abutment of dam nonoverflow section

Number 1

Dimensions of opening ..... 14.5 ft wide by 21.75 ft high

Gross area at racks ..... 1,365 sq. ft

Gate ..... One fixed roller lift gate, 14.5 by 22.28 ft clear opening

Hoist ..... One 50-ton-capacity stationary chain hoist

CONDUIT (See Figure 15)

(Intake to Powerhouse)

Type ..... Single penstock from intake to tunnel portal; single concrete-lined, unlined and steel-lined tunnel section branching into 2 concrete lined and steel-lined tunnel sections; 2 steel penstocks from valve house to powerhouse

POWER FACILITIES (Continued)

Size and length:	
Steel penstock, 18-ft-dia. (intake to tunnel)	913 ft
Tunnel:	
18-ft-dia., concrete-lined	33,850 ft
20-ft-dia., unlined	3,098 ft
22-ft-dia., unlined	2,902 ft
16-ft-dia., steel-lined	1,008 ft
16-ft-dia., penstock (Turtletown Creek)	647 ft
18-ft-dia., steel-lined	934 ft
Wye transition, concrete-lined	56 ft
12-ft-dia., concrete lined, 2	80 ft
12-ft-dia., steel-lined, 2	131 ft
Total tunnel	42,706 ft
Steel penstocks (valve house to powerhouse),	
11-ft-dia., 2	363 ft

FIGURE 15

December 1999

POWER FACILITIES (Continued)

SURGE TANK (See Figure 16)

Location	In rock bluff above powerhouse
Type	Differential, concrete-lined chamber excavated in rock with steel internal riser
Tank height	235.5 ft
Riser height	214 ft
Tank (inside diameter)	66 ft
Riser (inside diameter)	16 ft

Figure 16
December 1999

POWER FACILITIES (Continued)

VALVE HOUSE

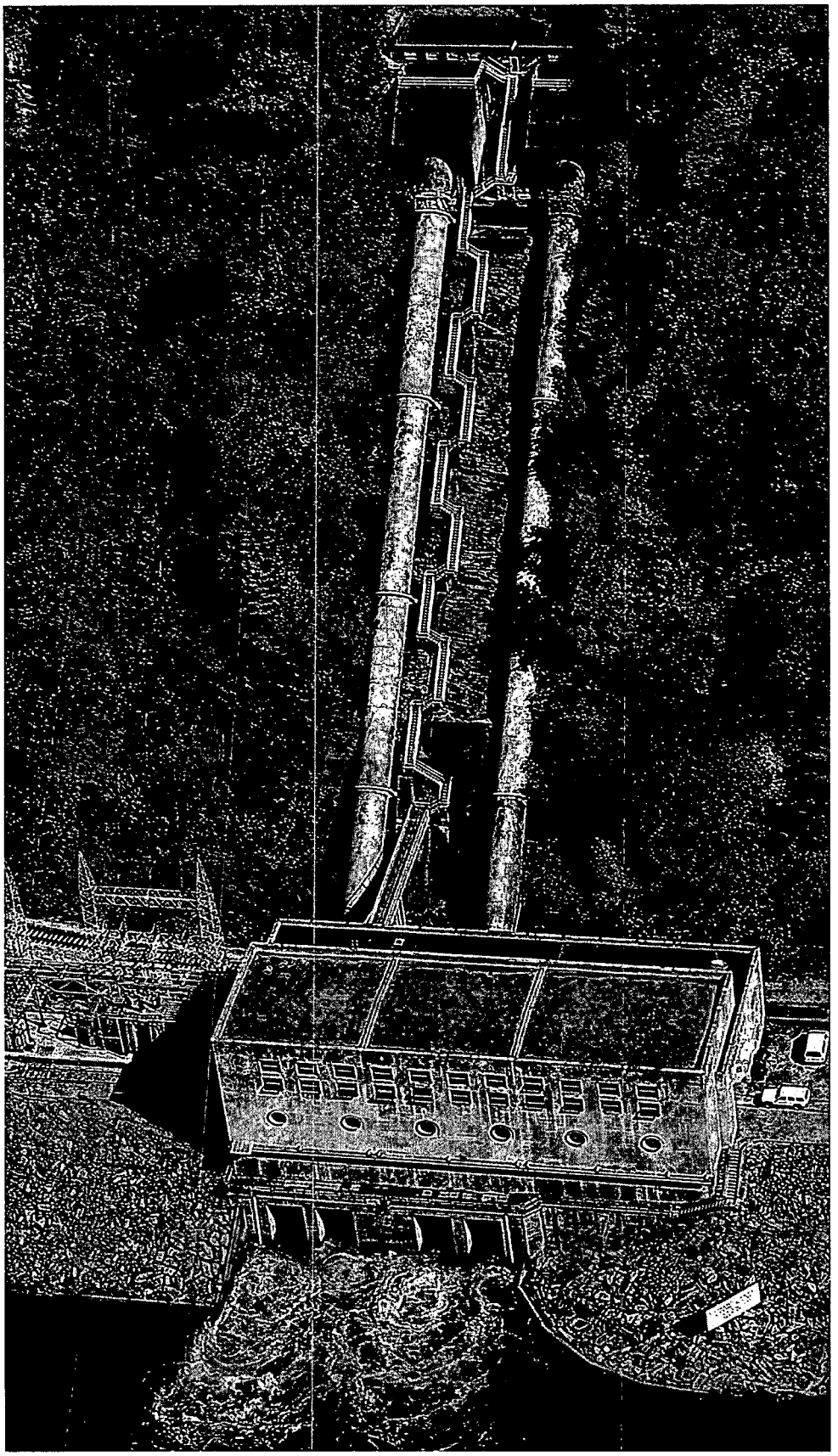
Location ..... At tunnel portal above powerhouse, el. 1053
Material ..... Reinforced concrete
Principal dimensions ..... 74 ft long by 20 ft wide by
..... 23 ft high
Butterfly valves ..... Two 12-ft-dia. Baldwin-Southwark
rated 300 ft head, to close within
300 seconds, 1500 cfs

POWERHOUSE (See Figure 17)

Location ..... On left bank of Hiwassee River
at river mile 53.6; 12.4 river
miles downstream from dam
Generating capacity, 2-unit total ..... 78,900 kW
Type of construction ..... Enclosed, reinforced concrete
and structural steel
Principal outside dimensions,
including service bay ..... 146 ft long by 87 ft wide
by 98 ft high
Service bay ..... 58 ft long by 76.75 ft wide
Draft tubes:
Type ..... Elbow, 2 openings
Vertical distance centerline of
distributor to draft tube floor ..... 24.4 ft
Horizontal length (centerline of turbine
to downstream face) ..... 36.5 ft
Net area of outlet opening, per unit ..... 210 sq. ft
Gates ..... One set of 2 slide gates, 11
ft clear opening by 8 ft high
Gate hoist ..... One 5-ton hand-operated monorail
Erecting crane ..... 13.0-ton overhead crane with
25-ton auxiliary hook.

FIGURE 17

December 1999



POWER FACILITIES (Continued)

HYDRAULIC TURBINES

Number 2
Manufacturer ..... Baldwin-Lima-Hamilton Corp.
Type ..... Vertical Francis
Rated capacity (each) ..... 53,000 hp at 360-ft net head
Head for best efficiency ..... 390 ft net
Rated speed ..... 225 r/min
Maximum runaway speed ..... 440 r/min
Specific speed at rating 33
Value of sigma at rating 0.073
Diameter of runner, intake ..... 118 in.
Diameter of runner, discharge ..... 103 in.
Centerline to bottom of runner ..... 36.125 in.
Centerline to top of runner ..... 9.625 in.
Diameter of guide vane circle ..... 138.5 in.
Diameter of lower pit ..... 15.0 ft
Spacing of turbines, center to center of units ..... 44 ft
Governors ..... Woodward, cabinet actuator type
Weight of rotating parts ..... 64,000 lb

GENERATORS

Number 2
Manufacturer ..... Westinghouse Electric Corp.
Type ..... Enclosed, water-cooled, vertical-shaft
Rating:
Unit 1, original rating
unit 2 ..... 40,000 kVA, 37,500 kW, 1675 A, 60 degrees C rise, 0.938 pf, 13.8 kV, 3 ph, 60 Hz
Capacity:
Unit 1, original capacity
unit 2 ..... 46,000 kVA, 43,100 kW, 1926 A, 80 degrees C rise
Efficiency (guaranteed original values):
At rated kVA, 1.0 pf ..... 97.6 percent
At 75% kVA, 0.9 pf ..... 97.0 percent
Note: Unit 2 rewound and rerated June 1, 1973.
Rating:
Unit 2 ..... 46,000 kVA, 41,400 kW,1925 A,60 degrees C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Flywheel 13,200,000 Ib-ft2
Thrust bearing ..... Kingsbury type, dia. 60 in., max. load 260 tons
Neutral reactor ..... 0.75 ohm, 5000 A, 1 min

POWER FACILITIES (Continued)

GENERATORS (continued)

Exciters:
- Main ..... 225 kW, 250 V
- Pilot ..... 5 kW, 250 V

Weight of heaviest crane lift, rotor ..... 130 tons
Diameter over air housing, less trim ..... 360 in.
Diameter of stator bore ..... 215.5 in.
Top of pilot exciter:
- Above stator soleplates ..... 135 in.
- Above generator floor ..... 159 in.

Generator & Turbine Modernization

This project will modernize the power train and involves replacing principal components such as the runners, main transformers, wicket gates, wicket gates seal system, switchgear, pilot exciter, generator air fans/baffles, generator air coolers, generator leads, protective relays, discharge ring extention, and winding (for unit 2). Components to be rehabilitated are the turbine/generator guide bearings and shaft, generator pole reinsulation, main exciter, distribution ring, headcover, bottom ring, and servo motors. Work on unit 1 is scheduled to start in September 2003 and complete in January 2004; unit 2 work should start in September 2004 and complete in January 2005.

ELECTRIC CONTROLS

Generation and switching are normally controlled from Hiwassee Dam by. means of supervisory equipment. Pertinent data such as electrical quantities, water levels, etc., and the annunciation of equipment conditions and operation are telemetered to Hiwassee also. Controls for local operation are provided in the Apalachia control room.

TRANSMISSION PLANT

Step-up transformers:
2 3-phase, 2-winding transformers, banks 1 and 2; each rated 13.2-161 kV, 36,000 kVA self-cooled, 48,000 kVA forced-air-cooled; Westinghouse

161-kV circuit breakers:
4 1200-A, 2,500,000-kVA, 8/60-Hz, pneu, Westinghouse
3 1200-A, 2,500,000-kVA, 8/35-Hz, pneu, Westinghouse
1 1200-A, 2,500,000-kVA, 5/35-Hz, pneu, Allis-Chalmers

Structures:
6 161-kV switchyard bays, 36 ft wide
2 transformer structures

FIGURE 18

SINGLE LINE DIAGRAM OF MAIN CONNECTIONS

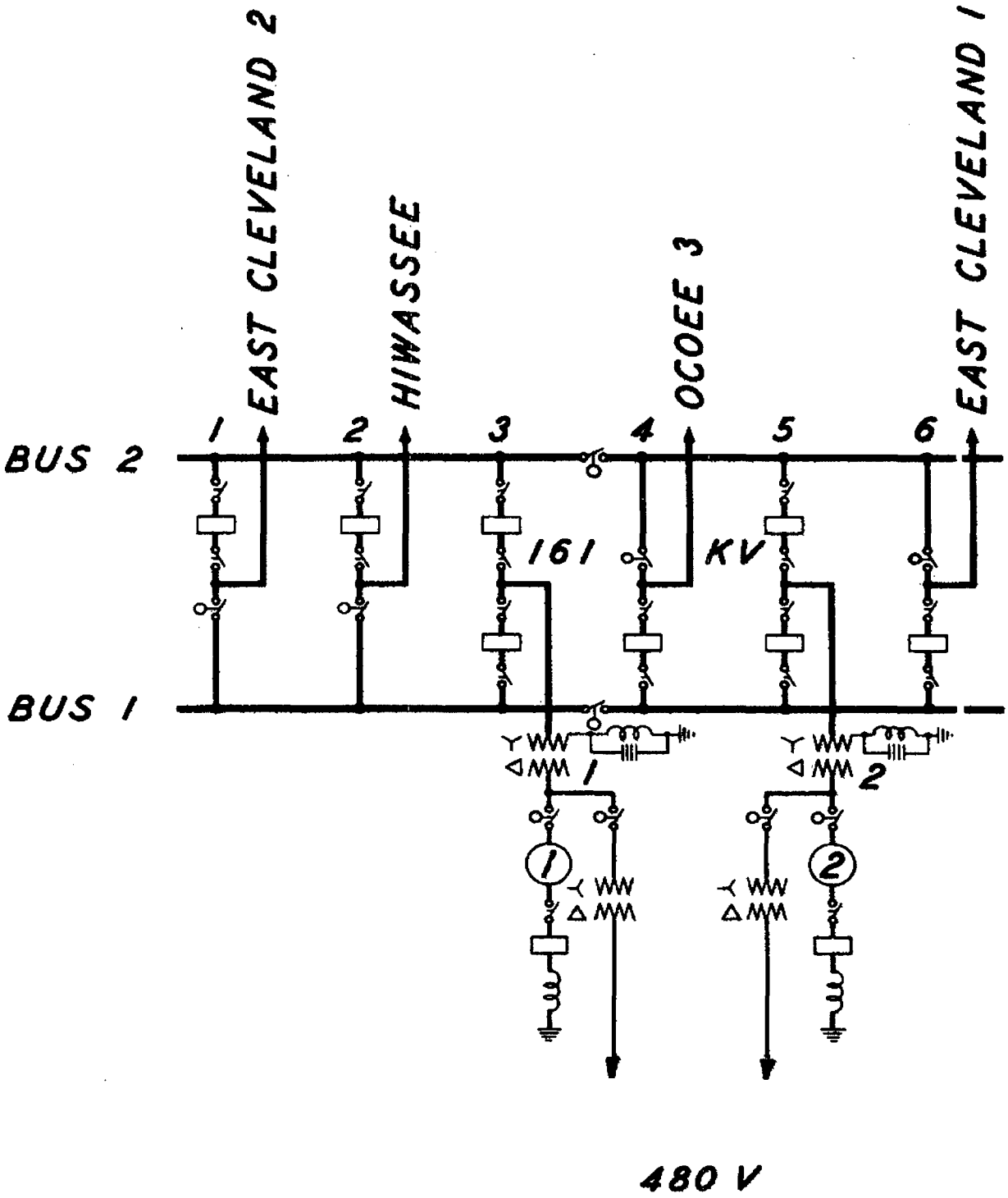
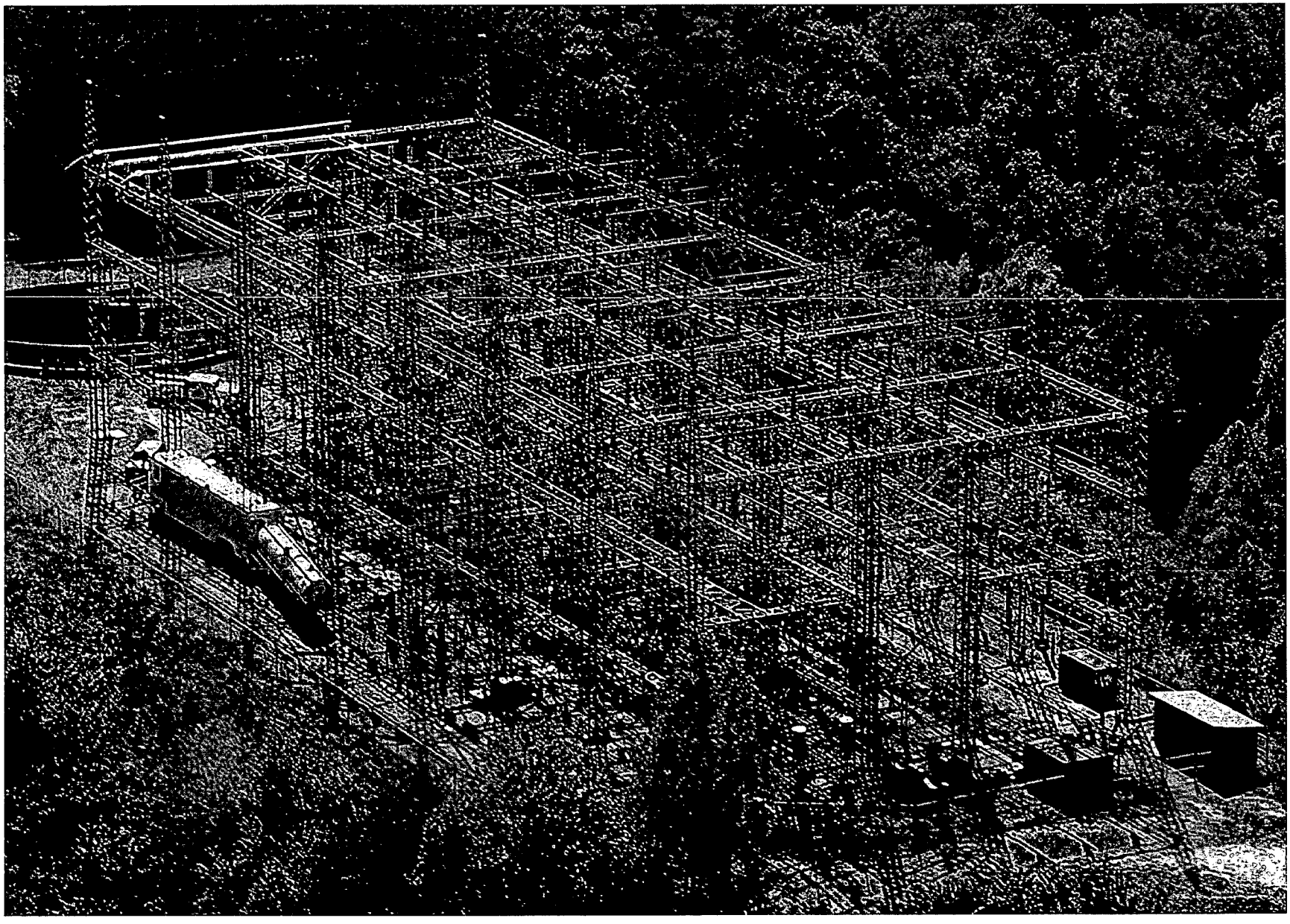


FIGURE 19

December 1999



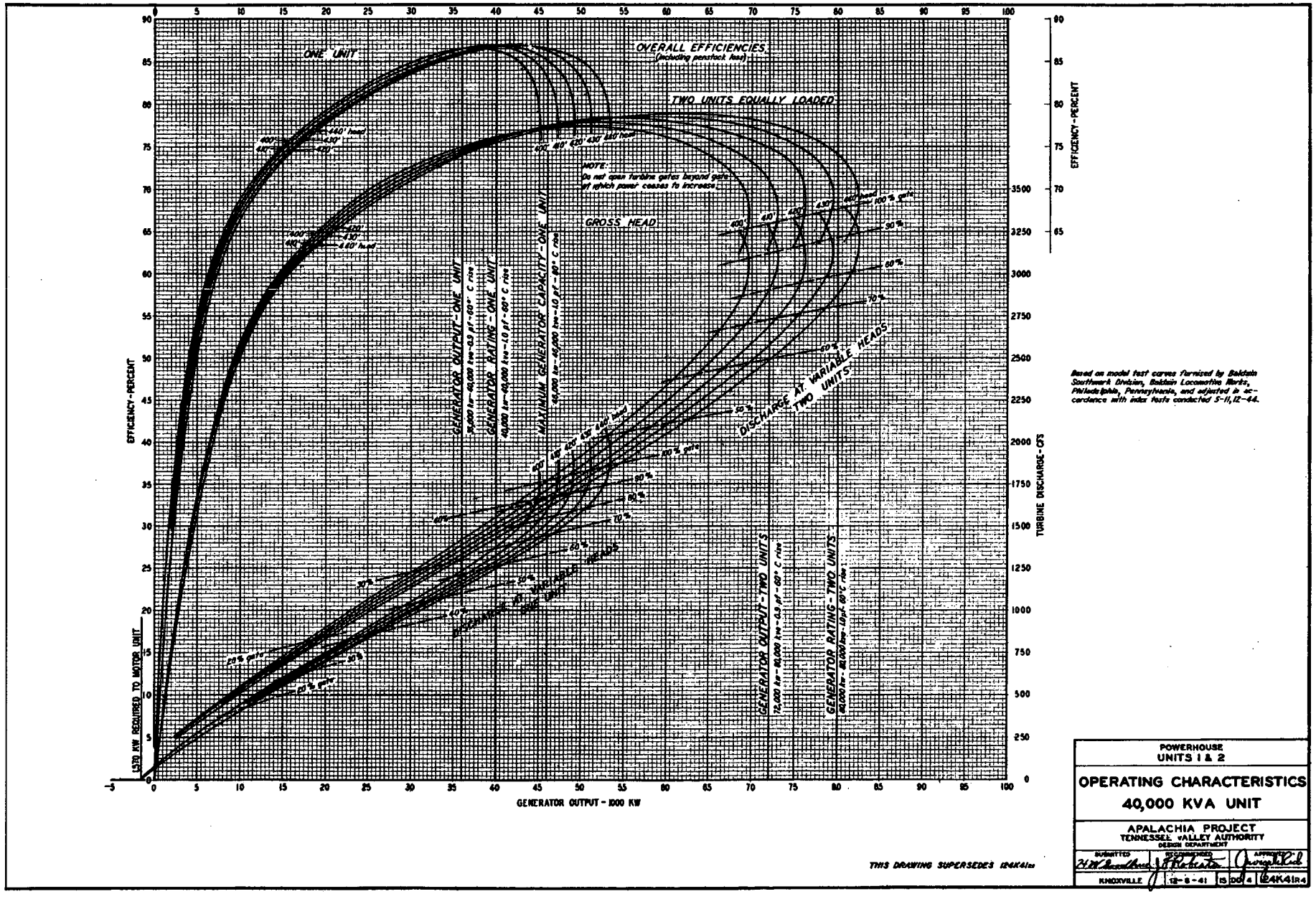
TRANSMISSION PLANT DATA

Plant	Location	Phase	Serial Number	MVA Rating		Voltage kV	Cooling	Tap Changer	Oil Preservation System	Oil Volume Gal.	Configuration	Impedance %			Contract Number	Manufacturer	Year of Manufacture
				55 degrees	65 degrees							H-X	H-Y	X-Y			
Appalachia Hydro	Bank 1	3	3111413	36/48	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	9784	Wye/Delta	10.82	N/A	N/A	TV-65786	Westinghouse	1942
Appalachia Hydro	Bank 2	3	3111412	36/48	N/A	161/13.2	OA/FA	DETC	Gas-Blanketed	9784	Wye/Delta	10.80	N/A	N/A	TV-65786	Westinghouse	1942

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

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1285	1.18	63.5	444.7	70.4	2,450	28.75	76.0	2,850	26.67
1284	1.16	62.4	443.7	70.4	2,450	28.75	76.0	2,850	26.67
1283	1.15	61.2	442.7	70.4	2,450	28.75	76.0	2,850	26.67
1282	1.14	60.1	441.7	70.4	2,450	28.75	76.0	2,850	26.67
1281	1.13	58.9	440.7	70.4	2,450	28.75	76.0	2,850	26.67
1280	1.12	57.8	439.7	70.4	2,450	28.73	75.9	2,850	26.65
1279	1.11	56.7	438.7	70.2	2,450	28.67	75.8	2,850	26.58
1278	1.10	55.6	437.7	70.1	2,450	28.60	75.6	2,850	26.52
1277	1.09	54.5	436.7	69.9	2,450	28.54	75.4	2,850	26.46
1276	1.08	53.4	435.7	69.8	2,450	28.48	75.2	2,850	26.40
1275	1.07	52.3	434.7	69.6	2,450	28.42	75.0	2,850	26.33
1274	1.06	51.3	433.7	69.5	2,450	28.35	74.9	2,850	26.27
1273	1.05	50.2	432.7	69.3	2,450	28.29	74.7	2,850	26.21
1272	1.04	49.2	431.7	69.2	2,450	28.23	74.5	2,850	26.15
1271	1.03	48.1	430.7	69.0	2,450	28.17	74.3	2,850	26.08
1270	1.02	47.1	429.7	68.8	2,450	28.10	74.2	2,850	26.02
1269	1.00	46.1	428.7	68.7	2,450	28.04	74.0	2,850	25.96
1268	.99	45.1	427.7	68.5	2,450	27.97	73.8	2,850	25.90
1267	.98	44.1	426.7	68.4	2,450	27.90	73.6	2,850	25.83
1266	.96	43.1	425.7	68.2	2,450	27.84	73.4	2,850	25.77
1265	.95	42.2	424.7	68.0	2,450	27.77	73.3	2,850	25.71
1264	.93	41.2	423.7	67.9	2,450	27.70	73.1	2,850	25.65
1263	.92	40.3	422.7	67.7	2,450	27.64	72.9	2,850	25.58
1262	.90	39.4	421.7	67.5	2,450	27.57	72.7	2,850	25.52
1261	.89	38.5	420.7	67.4	2,450	27.50	72.6	2,850	25.46
1260	.87	37.6	419.7	67.2	2,450	27.44	72.4	2,850	25.40
1259	.85	36.8	418.7	67.1	2,450	27.37	72.2	2,850	25.34
1258	.83	35.9	417.7	66.9	2,450	27.30	72.0	2,850	25.28
1257	.82	35.1	416.7	66.7	2,450	27.24	71.9	2,850	25.22
1256	.80	34.3	415.7	66.6	2,450	27.17	71.7	2,850	25.16
1255	.79	33.5	414.7	66.4	2,450	27.10	71.5	2,850	25.10

				Best Efficiency			Maximum Sustainable		
1254	.78	32.7	413.7	66.2	2,450	27.04	71.4	2,850	25.05
1253	.77	31.9	412.7	66.1	2,450	26.97	71.2	2,850	24.99
1252	.75	31.2	411.7	65.9	2,450	26.90	71.1	2,850	24.93
1251	.74	30.4	410.7	65.7	2,450	26.84	70.9	2,850	24.87
1250	.73	29.7	409.7	65.6	2,450	26.77	70.7	2,850	24.81
1249	.72	29.0	408.7	65.4	2,450	26.70	70.6	2,850	24.75
1248	.71	28.3	407.7	65.3	2,450	26.64	70.4	2,850	24.70
1247	.70	27.5	406.7	65.1	2,450	26.57	70.2	2,850	24.64
1246	.69	26.8	405.7	64.9	2,450	26.50	70.1	2,850	24.58
1245	.68	26.2	404.7	64.8	2,450	26.44	69.9	2,850	24.52
1244	.67	25.5	403.7	64.6	2,450	26.37	69.7	2,850	24.46
1243	.66	24.8	402.7	64.4	2,450	26.30	69.6	2,850	24.40
1242	.65	24.2	401.7	64.3	2,450	26.24	69.4	2,850	24.35
1241	.64	23.5	400.7	64.1	2,450	26.17	69.2	2,850	24.29
1240	.63	22.9	399.7	63.9	2,450	26.10	69.1	2,850	24.23
1239	.61	22.3	398.7	63.8	2,450	26.04	68.9	2,850	24.17
1238	.60	21.7	397.7	63.6	2,450	25.97	68.7	2,850	24.11
1237	.59	21.1	396.7	63.5	2,450	25.90	68.6	2,850	24.05
1236	.58	20.5	395.7	63.3	2,450	25.84	68.4	2,850	24.00
1235	.57	19.9	394.7	63.1	2,450	25.77	68.2	2,850	23.94


ONE UNIT
OVERALL EFFICIENCIES
(Including penstock loss)
TWO UNITS EQUALLY LOADED
NOTE:
Do not open turbine gates beyond gate at which power ceases to increase.
GROSS HEAD
DISCHARGE AT VARIABLE HEADS
TWO UNITS
GENERATOR OUTPUT-ONE UNIT
GENERATOR RATING-ONE UNIT
MAXIMUM GENERATOR CAPACITY-ONE UNIT
GENERATOR OUTPUT-TWO UNITS
GENERATOR RATING-TWO UNITS
EFFICIENCY-PERCENT
TURBINE DISCHARGE-CFS
GENERATOR OUTPUT-1000 KW
(570 KW REQUIRED TO MOTOR UNIT)
Based on model test curves furnished by Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia, Pennsylvania, and adjusted in accordance with index tests conducted 5-11,12-44.
THIS DRAWING SUPERSEDES 124K41R3
POWERHOUSE
UNITS 1 & 2
OPERATING CHARACTERISTICS
40,000 KVA UNIT
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
12-6-41
15
00
4
124K41R4

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 39,228 cfs at M., on 5/28/73.
1943	5090	7/26	6	232	4020---6/29---149; 5090---7/26---49; 4220---9/15---20; 1640---10/9---5; 100---11/18---4; 670---12/2---4
1944	7396	4/27	4	18	4700---3/28---9; 1300---4/17&18---3; 120---4/22---2; 4400---4/27---4
1945	7305	12/21	2	16	5890---12/21---14; 3790---12/27---2
1946	11818	2/12	6	46	110---1/2---2; 7130---1/10---16; 5290---1/31---5; 9790---2/12---18; 1610---2/27---2; 10445---3/10---3
1947	9537	1/24	1	9	6810---1/24---9
1948	9422	12/28	3	24	1184---11/30---2; 2154---12/9---2; 6480---12/28&29---20
1949	10125	1/13	5	72	7125---1/13---9; 6147---2/11---3; 4153---2/18---2; 1059---2/26---3; 6485---12/28---55
1950	5045	2/3	3	23	2082---2/3---8; 1409---2/17---6; 958---3/15---9
1951	4976	12/22	1	6	2084---12/22---6
1952	4976	6/13	2	8	1682---1/31---7; 2004---6/13---1
1953	2978	3/7	0	0	
1954	9547	1/26	1	8	6582---1/26---8
1955	2926	8/17	0	0	
1956	2795	3/18	0	0	
1957	8884	2/6	2	20	6080---2/6---12; 5198---12/27---8
1958	2808	2/12	2	2	10---11/28---1; 6---12/9---1
1959	2700	1/6	1	1	2---1/5---1
1960	2736	8/30	0	0	
1961	8530	12/21	3	19	5478---2/28---4; 6156---3/9---3; 5903---12/21---12
1962	8667	2/28	3	15	5958---1/30---7; 5973---2/28---3; 1955---3/3---5
1963	2898	8/3	0	0	
1964	7402	12/31	2	24	2373---12/7---9; 4191---12/31---15

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 was39,228 cfs at M., on 5/28/73.
1965	3213	1/4	0	0	
1966	3708	12/31	1	2	29---4/27---1
1967	8976	12/23	7	65	1350---1/1---3; 3231---8/27---5; 307---10/11---1; 1903---10/26---1; 2483---11/3---2; 5686---11/14---40; 5980---12/23---14
1968	9016	1/9	1	11	6003---1/9---11
1969	9508	2/5	1	6	6471---2/5---6
1970	4193	1/9	2	2	1100---1/9---1; 1---9/15---1
1971	5162	2/10	1	5	2062---2/10---5
1972	8879	1/12	1	21	5790---1/12---8
1973	25147	5/28	6	42	3816---1/2---19; 1580---2/13---8; 23781---5/28---15; 3752---6/7---4; 3288---6/17---7; 2784---12/10---2
1974	8338	1/11	2	56	5157---1/11---19; 4083---2/9---37
1975	7215	2/8	2	39	4213---2/8---30; 2095---4/6---9
1976	5572	7/7	2	10	432---6/13---1; 2487---7/7---9
1977	4390	12/28	6	39	338---1/11---3; 2572---4/14---21; 297---5/12---1; 1055---12/12---6; 981---12/22---3; 1562---12/28---9
1978	7179	1/27	4	29	1678---1/12---5; 4376---1/27---18; 568---11/28---1; 358---12/2---1
1979	7893	3/8	3	42	5016---3/8---9; 1337---3/23---2; 2226---12/10---31
1980	5136	3/28	3	18	2188---3/28---13; 295---10/23---1; 1541---12/20---4
1981	2800	1/31 thru 2/2	1	1	85---4/10---1
1982	8150	2/5	3	34	4922---1/11---4; 5305---2/5---13; 3102---12/22---17
1983	8434	12/25	3	23	1834---1/19---2; 4643---5/22---7; 5506---12/25---14
1984	10600	5/9	2	6	327---2/16---1; 7585---5/9---4
1985	2929	1/21	1	3	1542---12/25---3

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 39,228 cfs at M., on 5/28/73.
1986	2825	1/28	4	14	957---1/14---2; 1596---1/28---3; 100---7/24---3; 504---10/6---6
1987	2770	1/11	0	0	
1988	2711	11/30	0	0	
1989	13852	6/22	3	117	10972---6/22---14; 3470---7/7---16; 3277---12/23----87
1990	8633	2/20	2	90	5753---2/20---85; 3645---12/28---16
1991	5924	2/27	4	47	3121---1/3---16; 3124---2/27---8; 1547---5/7---5; 2222----12/19---33
1992	7534	12/30	2	42	1748---1/7---33; 4667---12/30---54
1993	7505	1/2	2	26	4635---1/2---54; 1618---1/28---4; 1014---4/5---25
1994	7377	4/9	9	79	1065---1/20---4; 3848---4/4---7; 4577---4/9---5; 3185---4/14---3; 3735---4/24---9; 3789---6/30---5; 1073---10/28---32; 2208---12/13---9; 2119---12/20---5
1995	7279	2/22	3	27	4359---2/22---12; 3129---3/2---3; 2236---11/30---12
1996	9276	1/29	2	38	6546---1/29---20; 1620---12/21---18
1997	6097	3/13	1	8	3277---3/13---8
1998	7037	2/1	3	17	4187---2/1---5; 3197---2/6---6; 1616---6/15---6
1999	2890	7/14	3	5	49---4/5---1; 154---4/14---2; 52---9/4---2
2000	2842	12/20	1	1	225---3/19---1

ANNUAL MAXIMUM AND MINIMUM ELEVATIONS IN ORDER OF MAGNITUDE

RIVER SCHEDULING
TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE FROM DATE OF RESERVOIR CLOSURE THROUGH 2000

APALACHIA

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	1281.40	1952	JUNE	13	1	1177.90 *	1943	FEB.	14
2	1281.25	1977	JAN.	11	2	1251.00	1971	APR.	25
3	1281.23	1946	FEB.	10	3	1251.19	1986	NOV.	30
4	1280.85	1943	DEC.	3	4	1251.73	1955	AUG.	28
5	1280.70	1994	MAR	30	5	1251.97	1966	APR.	15
6	1280.70	1999	APR.	5	6	1252.20	1989	APR.	16
7	1280.60	1983	DEC.	25	7	1252.70	1977	OCT.	31
8	1280.49	1990	JAN.	1	8	1252.73	1995	AUG.	16
9	1280.46	1961	MAR.	8	9	1254.36	1984	DEC.	14
10	1280.40	1944	APR.	22	10	1254.82	1969	APR.	5
11	1280.40	1945	DEC.	31	11	1255.21	1992	APR.	15
12	1280.39	1950	MAR.	13	12	1257.60	1980	NOV.	1
13	1280.32	1970	JAN.	9	13	1259.34	1979	MAR.	27
14	1280.29	1984	FEB.	16	14	1260.59	1954	APR.	18
15	1280.27	1949	JAN.	7	15	1264.25	1978	OCT.	25
16	1280.27	1951	FEB.	8	16	1264.61	1946	JULY	22
17	1280.27	1968	AUG.	7	17	1264.78	1985	SEP.	5
18	1280.26	1958	NOV.	28	18	1264.87	1945	DEC.	16
19	1280.25	1964	DEC.	19	19	1265.47	1947	JULY	13
20	1280.16	1957	APR.	2	20	1265.55	1944	OCT.	9
21	1280.14	1947	JAN.	23	21	1265.67	1948	JULY	12
22	1280.08	1959	JAN.	5	22	1265.81	1994	JULY	28
23	1280.05	1953	JULY	14	23	1266.31	1962	APR.	21
24	1280.04	1962	FEB.	21	24	1269.85	1950	APR.	24
25	1280.03	1960	JULY	28	25	1269.89	1949	JAN.	18
26	1280.00	1948	NOV.	29	26	1270.25	1952	JAN.	2
27	1280.00	1973	OCT.	10	27	1270.59	1959	DEC.	30
28	1280.00	1976	DEC.	9	28	1270.76	1953	JUNE	6
29	1280.00	1978	JAN.	12	29	1270.78	1956	JAN.	27
30	1280.00	1979	NOV.	8	30	1270.84	1973	FEB.	24
31	1280.00	1989	NOV.	15	31	1271.12	1951	DEC.	31
32	1280.00	2000	FEB.	4	32	1271.32	1975	FEB.	11
33	1279.99	1955	APR.	25	33	1271.33	1982	DEC.	19
34	1279.99	1956	FEB.	29	34	1271.38	1990	MAR.	3
35	1279.99	1963	JAN.	24	35	1271.57	1999	AUG.	3
36	1279.99	1969	JULY	15	36	1271.68	1996	FEB.	9
37	1279.99	1975	MAR.	31	37	1271.85	1968	APR.	7
38	1279.97	1980	MAR.	21	38	1271.90	1972	AUG.	23

ANNUAL MAXIMUM AND MINIMUM ELEVATIONS IN ORDER OF MAGNITUDE

RIVER SCHEDULING
TVA OPERATED RESERVOIR SYSTEM
ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE
FROM DATE OF RESERVOIR CLOSURE THROUGH 2000

APALACHIA

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
39	1279.96	1954	JAN.	22	39	1271.95	1983	MAY	24
40	1279.95	1971	MAY	26	40	1271.96	1960	JAN.	1
41	1279.95	1998	APR.	20	41	1271.97	1970	SEP.	7
42	1279.92	1967	DEC.	2	42	1272.00	1957	JAN.	8
43	1279.90	1974	JULY	15	43	1272.24	1987	MAY	22
44	1279.90	1993	JAN.	26	44	1272.25	1976	JUNE	2
45	1279.90	1996	MAY	20	45	1272.28	1991	AUG.	16
46	1279.89	1966	APR.	2	46	1272.29	2000	JUNE	8
47	1279.84	1997	OCT.	23	47	1272.44	1967	OCT.	3
48	1279.80	1965	MAY	31	48	1272.56	1961	DEC.	15
49	1279.80	1981	JUNE	4	49	1272.57	1958	MAR.	13
50	1279.80	1992	OCT.	21	50	1272.64	1988	FEB.	11
51	1279.80	1995	FEB.	16	51	1272.72	1981	DEC.	22
52	1279.75	1972	MAR.	24	52	1272.73	1964	JAN.	4
53	1279.61	1991	SEP.	14	53	1272.75	1974	OCT.	30
54	1279.60	1988	DEC.	13	54	1272.81	1965	MAR.	30
55	1279.48	1987	JUNE	3	55	1273.10	1993	JAN.	9
56	1279.21	1982	SEP.	13	56	1273.10	1997	MAR.	9
57	1279.04	1985	FEB.	16	57	1273.13	1963	DEC.	14
58	1278.93	1986	FEB.	18	58	1273.60	1998	DEC.	29

AVERAGE WEEKLY CFS

MAXIMUM, MINIMIUM, MEDIAN, AND MEAN
Adjusted Flow by Weeks
Apalachia
Years=1903-2002

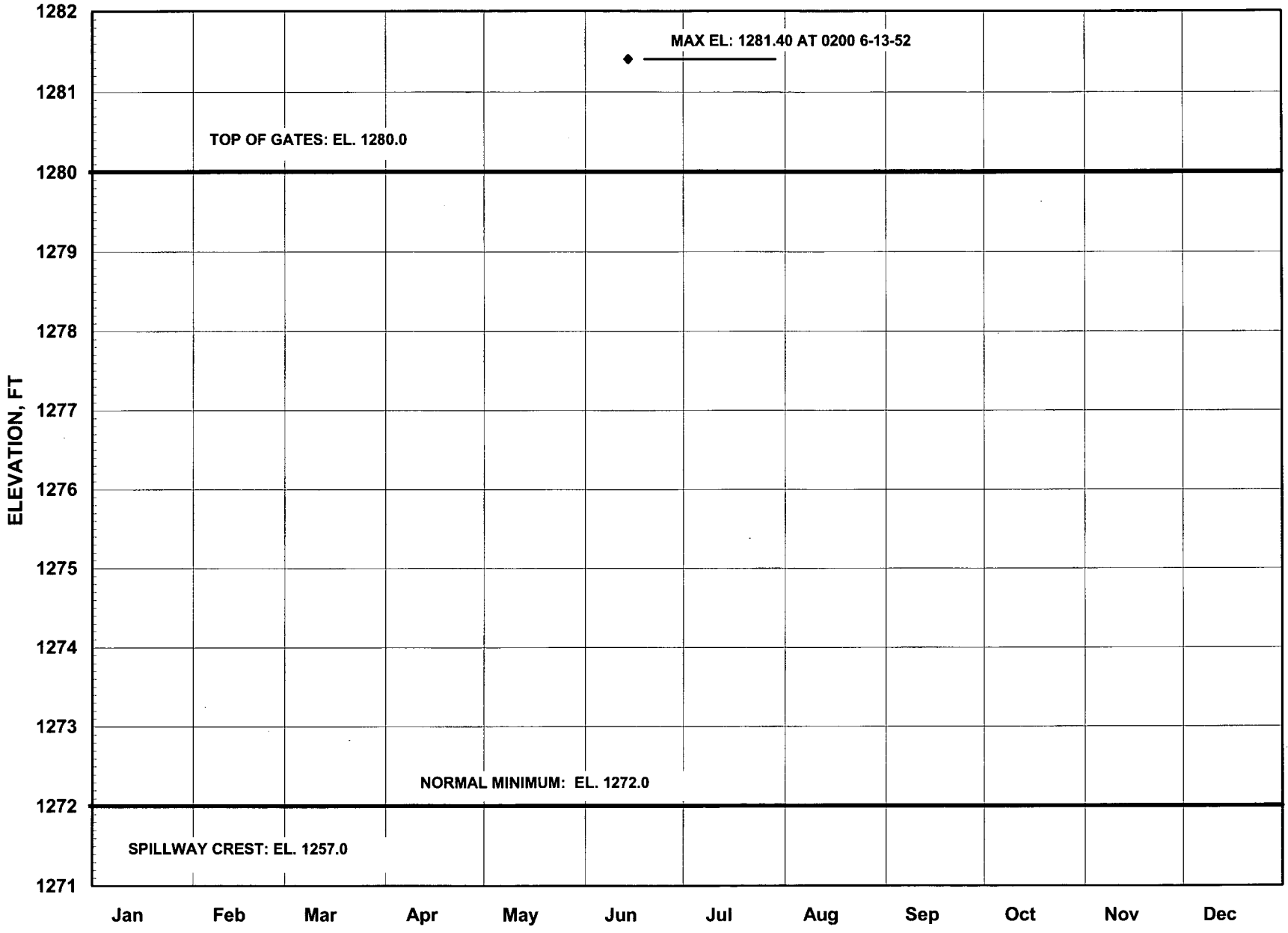
WEEK ENDING	WEEK NO.	AVERAGE WEEKLY CFS MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
JAN 7	1	8,400	1937	508	1940	2,300	2,740
JAN 14	2	7,950	1946	587	1956	2,250	2,640
JAN 21	3	14,000	1947	610	1914	2,460	2,960
JAN 28	4	9,890	1954	535	1940	2,800	3,110
FEB 4	5	15,300	1957	482	1940	2,710	3,150
FEB 11	6	11,400	1921	755	1934	2,730	3,270
FEB 18	7	14,800	1990	763	1934	2,940	3,520
FEB 25	8	11,300	1961	778	1941	2,780	3,300
MAR 4	9	12,800	1917	839	1941	2,930	3,380
MAR 11	10	11,800	1917	1,070	1914	3,010	3,510
MAR 18	11	13,300	1990	1,130	1981	2,810	3,660
MAR 25	12	12,400	1917	1,030	1988	2,970	3,510
APR 1	13	14,200	1994	1,030	1988	2,990	3,910
APR 8	14	18,900	1920	1,200	1986	3,100	3,690
APR 15	15	9,820	1979	1,040	1986	2,660	3,150
APR 22	16	7,070	1994	917	1986	2,750	2,860
APR 29	17	6,070	1958	880	1986	2,700	2,700
MAY 6	18	7,410	1984	707	1986	2,350	2,730
MAY 13	19	8,220	1984	721	1986	2,270	2,540
MAY 20	20	8,750	1976	687	2001	2,010	2,220
MAY 27	21	9,830	1909	529	1941	1,950	2,270
JUN 3	22	8,590	1973	436	1988	1,720	2,050
JUN 10	23	8,600	1909	312	1988	1,650	1,960
JUN 17	24	5,230	1989	236	1988	1,550	1,800
JUN 24	25	7,920	1989	431	1986	1,430	1,620
JUL 1	26	4,600	1994	316	1988	1,310	1,600
JUL 8	27	5,350	1989	418	1986	1,320	1,620
JUL 15	28	11,300	1916	334	1986	1,250	1,670
JUL 22	29	7,050	1906	314	1986	1,280	1,550
JUL 29	30	9,570	1938	381	1986	1,190	1,490
AUG 5	31	6,070	1971	239	1986	1,130	1,380
AUG 12	32	4,320	1938	301	1987	1,160	1,330
AUG 19	33	10,300	1920	309	1925	1,120	1,370
AUG 26	34	10,300	1967	255	1925	988	1,290
SEP 2	35	5,020	1967	180	1925	881	1,130
SEP 9	36	7,210	1928	146	1925	884	1,070
SEP 16	37	4,060	1920	155	1925	835	934
SEP 23	38	3,720	1906	169	1925	823	977
SEP 30	39	6,570	1989	280	1925	859	1,130
OCT 7	40	9,750	1964	290	1981	877	1,210
OCT 14	41	3,740	1906	280	2000	810	951
OCT 21	42	3,410	1906	240	1954	803	1,010
OCT 28	43	3,090	1997	290	1954	876	1,020
NOV 4	44	8,420	1918	270	1954	892	1,170
NOV 11	45	4,930	1977	376	1931	956	1,180
NOV 18	46	10,200	1929	396	1931	1,070	1,330
NOV 25	47	13,900	1906	516	1956	1,110	1,540
DEC 2	48	8,070	1948	496	1939	1,100	1,590
DEC 9	49	6,060	1983	494	1939	1,640	1,850
DEC 16	50	9,060	1932	455	1939	1,540	2,090
DEC 23	51	9,420	1961	485	1943	1,460	2,240
DEC 31	52	13,100	1932	582	1965	2,010	2,550

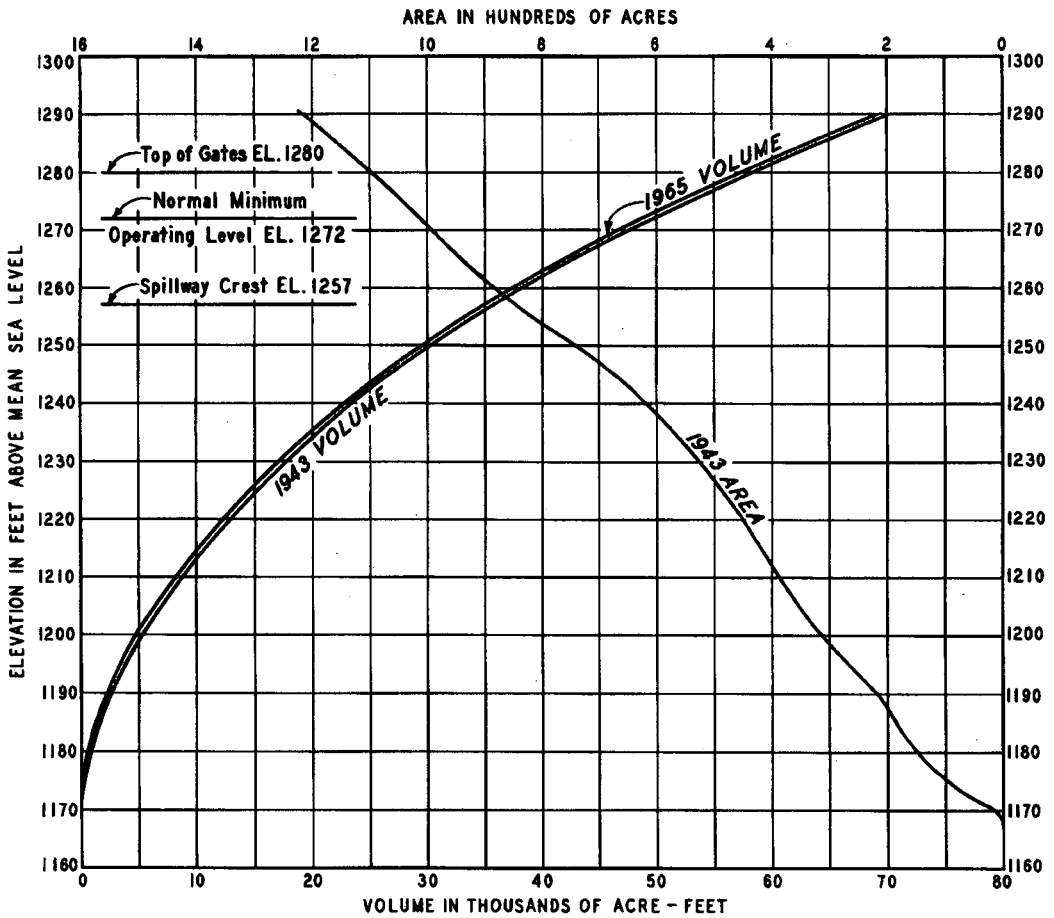
AVERAGE FLOW:1903 - 2002 = 2130 CFS

RIVER SYSTEM OPERATIONS

APALACHIA

ANNUAL OPERATING CYCLE





ELEV FT	1943 AREA AC	VOLUME 1943 AC-FT	1950 AC-FT	1960 AC-FT	1965 AC-FT
1,290	1,222	70,100	69,800	69,400	69,600
1,280	1,100	58,300	58,000	57,500	57,800
1,270	993	47,700	47,400	46,900	47,100
1,257	846	35,700	35,400	34,900	35,100
1,255	820	34,000	33,700	33,300	33,500
1,240	614	23,400	23,100	22,700	22,900
1,230	524	17,700	17,500	17,100	17,200
1,220	449	12,900	12,700	12,300	12,500
1,210	385	8,700	8,500	8,200	8,300
1,200	312	5,200	5,000	4,700	4,900
1,190	215	2,600	2,500	2,300	2,400
1,180	149	800	700	600	600
1,170	11	10	0	0	0
1,168	0	0	0	0	0

NOTES:

Reservoir areas were measured on a composite map prepared by the Hydraulic Data Branch with contours drawn at 10' intervals and scale 1"=500'. The map was prepared from TVA land maps with contours at elevations 1,255 & 1,280. Contours were made to conform to elevations on TVA sediment range cross sections located at one-mile intervals. The 1943 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.

Upstream limit of the reservoir is Hiwassee Dam at river mile 75.8.

Area of original river within reservoir = 80 acres.

Drainage area above Apalachia Dam = 1,018 square miles.

Drainage area between Apalachia and Hiwassee Dams = 50 square miles.

Dam closure February 14, 1943.

REV NO.	DATE	MADE	CHKD	SUPV	INSP
1	12-20-65	WMS	ITB	EHM	
ADDED 1965 VOLUME					

DRWN _____ COMPUTED _____
TRCD DCW _____ ENGINEER _____
CHKD _____

THIS DRAWING SUPERSEDES 15-DA-321G501RO

HIWASSEE RIVER - MILE 66.0

RESERVOIR AREAS AND VOLUMES

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Edwin K. McCain	Paul C. Spratt	Reed C. Elliott

KNOXVILLE | 12-28-62 | 15 | DA | 1 | 321G794R1

RESERVOIR RELEASE IMPROVEMENTS

Two improvements have been made to enhance the quality of the aquatic environment below the dam: 1) Turbine venting 2) Turbine pulsing.

TURBINE VENTING AERATION SYSTEM

The Apalachia turbine venting aeration system is used to improve the dissolved oxygen level of the turbine discharges by 2 mg/L depending on the operating conditions of wicket gate opening and headwater elevation. Because the turbine venting system is relatively inexpensive to operate, this is the first aeration alternative used when the dissolved oxygen level in the discharge drops below the target level.

Turbine venting aeration uses the vacuum breaker outlets on the turbine runner to induce air into the unit discharge. Modifications to increase the amount of air induced consist of the addition of hub baffles and vacuum breaker bypass conduits.

Hub baffles increase the amount of suction at the vacuum breaker outlets, whereas bypass conduits reduce the flow path and pressure losses for air entering the unit. Together these changes increase both the amount of air aspirated in the turbine and the amount of dissolved oxygen uptake. At Apalachia, six flat-plate-type hub baffles were installed on the turbine runners in 1993. The six-inch diameter vacuum breaker supply piping was modified in the wheel pit to admit air through a manually operated six-inch diameter butterfly isolation valve, a six-inch diameter low-loss check valve, and a bellmouth inlet with debris strainer. The vacuum breaker bypass system is located in the turbine wheel pit against the wheel pit liner near the existing vacuum breaker valve and piping where it is easily accessed by plant operators.

TURBINE PULSING

Turbine pulsing provides downstream water levels to be kept at minimum flow conditions by periodic hydro-turbine releases during scheduled non-generation times. At Apalachia, one unit is operated about thirty minutes every four hours to maintain minimum flow conditions.

CONSTRUCTION DATA

HOUSING FACILITIES

Built-in-place houses, cell-type 20
(All Apalachia housing has been removed.)
Demountable houses 51
Dormitories built:
Men (432 total capacity) 7
Women (6 total capacity) 2
Trailers 66
Tents (352 total capacity) 88
Washhouses 3
Public buildings constructed included a cafeteria (seating capacity 200), hospital (19 beds), community and recreation buildings (2).

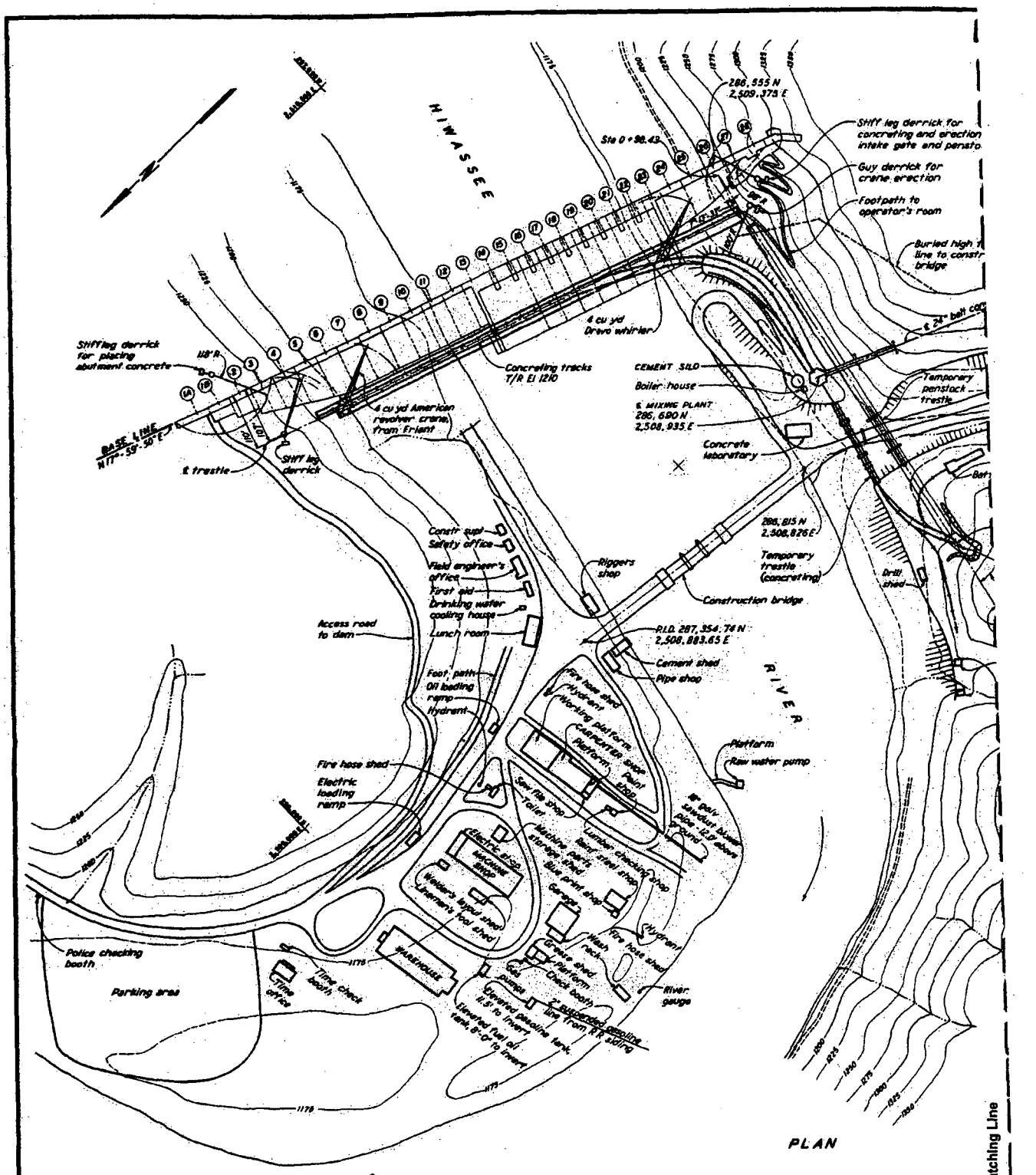
PERSONNEL

	Dam and Powerhouse	Tunnel
Peak employed	3,600 total on dam, powerhouse, and tunnel	
Total man hours	7,542,056	2,474,431
Number of injuries	95	173
Days lost	12,738	50,739
Fatalities	1	7
Accident frequency	12.6	69.9
Accident severity	1,689	20,505

QUANTITIES

Dam and power facilities:
Earth excavation ..... 102,700 cu. yd
Rock excavation (including 662,075 cu. yd in tunnel) ..... 756,800 cu. yd
Concrete (including 210,543 cu. yd in tunnel) ..... 448,349 cu. yd
Foundation grouting (at dam only), cement ..... 4,375 bags
Structural steel (tunnel liners, penstock, and surge tank riser) ..... 4,552 tons
Structural steel (dam, powerhouse, and switchyard) ..... 845 tons
Reinforcing steel ..... 1,422 tons
Highway and railroad:
Excavation ..... 250,000 cu. yd

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



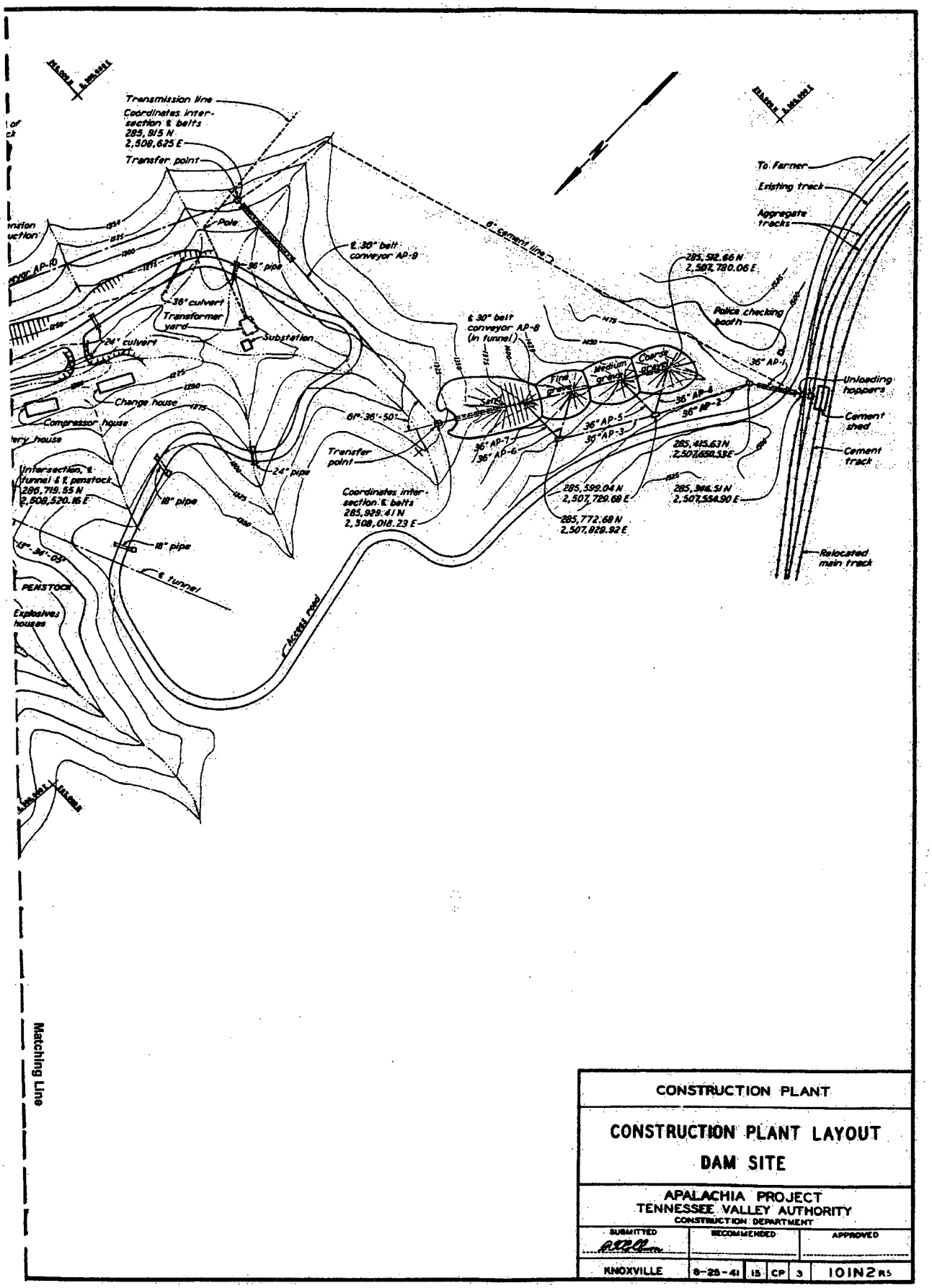
CONSTRUCTION PLANT

CONSTRUCTION PLANT LAYOUT
DAM SITE

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	8-25-41	15	CP	3	101N2 #5



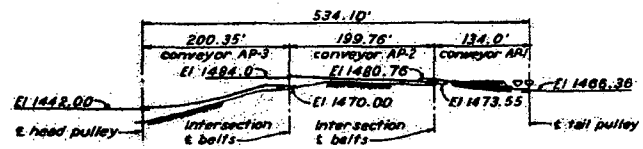
CONSTRUCTION PLANT

CONSTRUCTION PLANT LAYOUT
DAM SITE

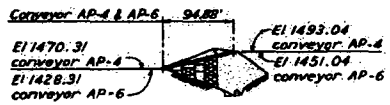
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

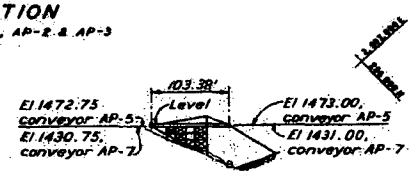
KNOXVILLE 8-25-41 15 CP 3 101N2 R5



ELEVATION
CONVEYORS AP-1, AP-2 & AP-3



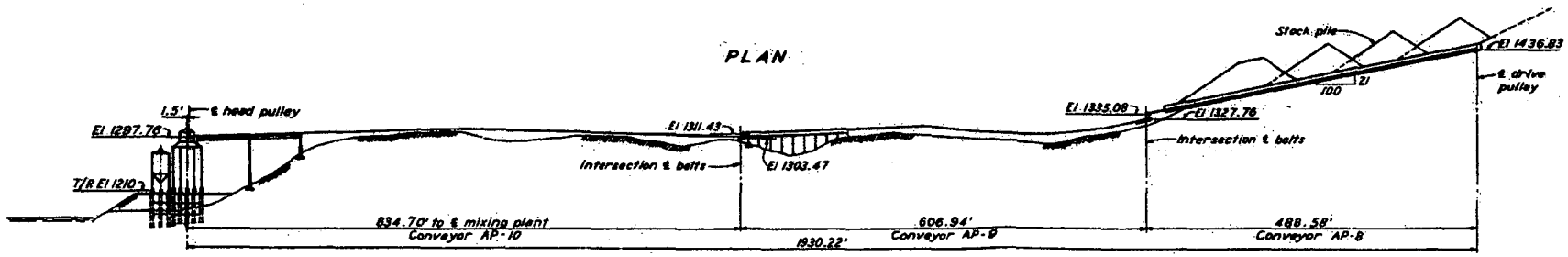
ELEVATION
CONVEYORS AP-4 & AP-6



ELEVATION
CONVEYORS AP-5 & AP-7

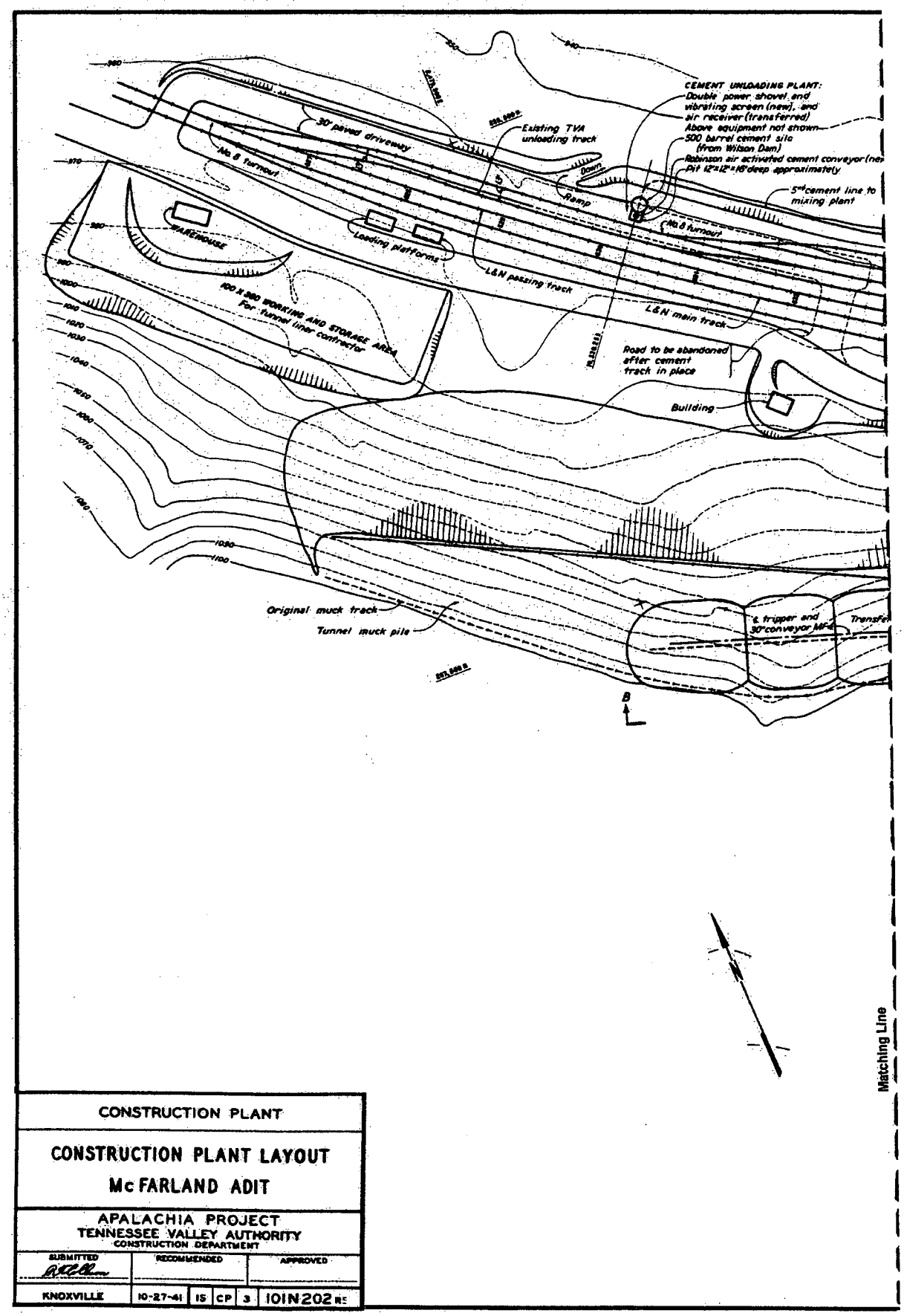
NOTES:
All elevations are to ℄ pulleys.
Elevations taken on ℄ conveyors.

PLAN



ELEVATION
CONVEYORS AP-8, AP-9 & AP-10

CONSTRUCTION PLANT					
CONSTRUCTION PLANT LAYOUT DAM SITE					
APALACHIA PROJECT TENNESSEE VALLEY AUTHORITY CONSTRUCTION DEPARTMENT					
SUBMITTED	RECOMMENDED			APPROVED	
KNOXVILLE	8-25-41	15	CP	3	101N2 R5



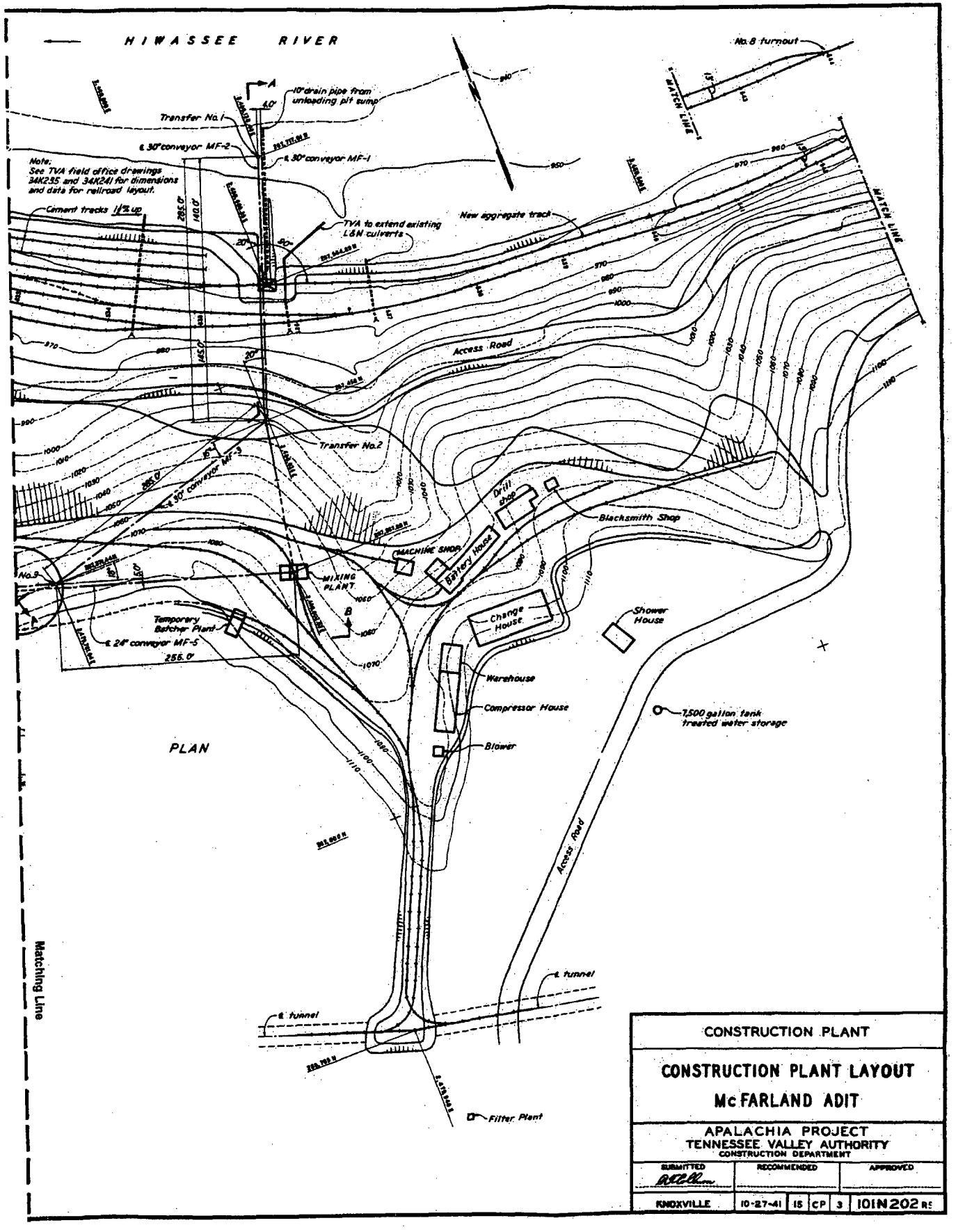
CONSTRUCTION PLANT

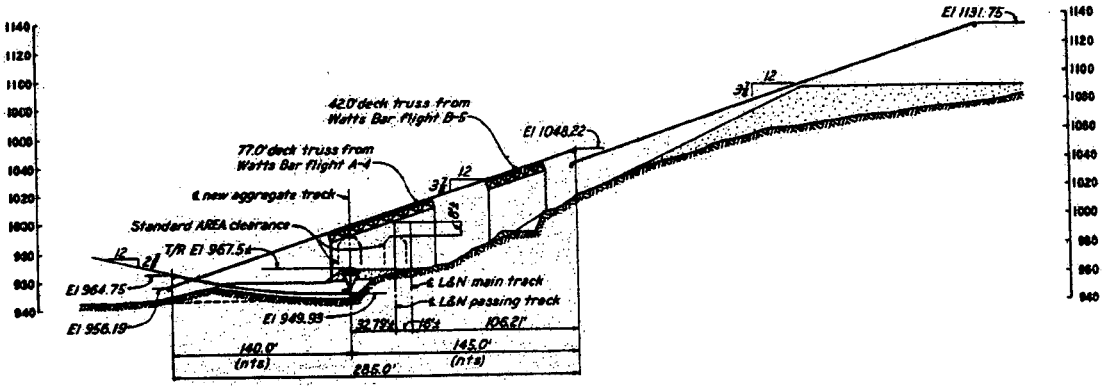
CONSTRUCTION PLANT LAYOUT
McFARLAND ADIT

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

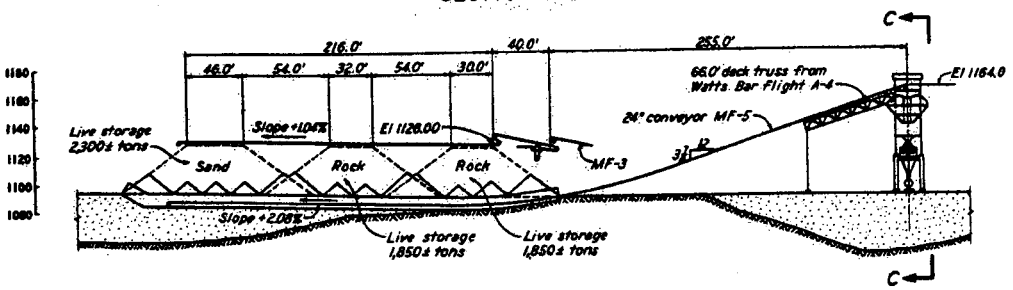
SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	10-27-41	15	CP	3	101N202 R5

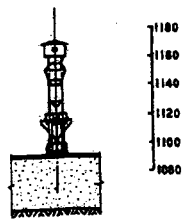

HIWASSEE RIVER
No.8 turnout
MATCH LINE
10" drain pipe from unloading pit sump
Transfer No.1
℄ 30" conveyor MF-2
℄ 30" conveyor MF-1
Note:
See TVA field office drawings 34K235 and 34K241 for dimensions and data for railroad layout.
Cement tracks 1½% up
TVA to extend existing L&N culverts
New aggregate track
Access Road
Transfer No.2
℄ 30" conveyor MF-3
Drill shop
Blacksmith Shop
MACHINE SHOP
Battery House
MIXING PLANT
No.9
Temporary Batcher Plant
℄ 24" conveyor MF-5
256.0'
Change House
Shower House
Warehouse
Compressor House
Blower
7,500 gallon tank treated water storage
PLAN
Access Road
℄ tunnel
Filter Plant
Matching Line
CONSTRUCTION PLANT
CONSTRUCTION PLANT LAYOUT
McFARLAND ADIT
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
10-27-41
15
CP
3
101N202 R5



SECTION A-A

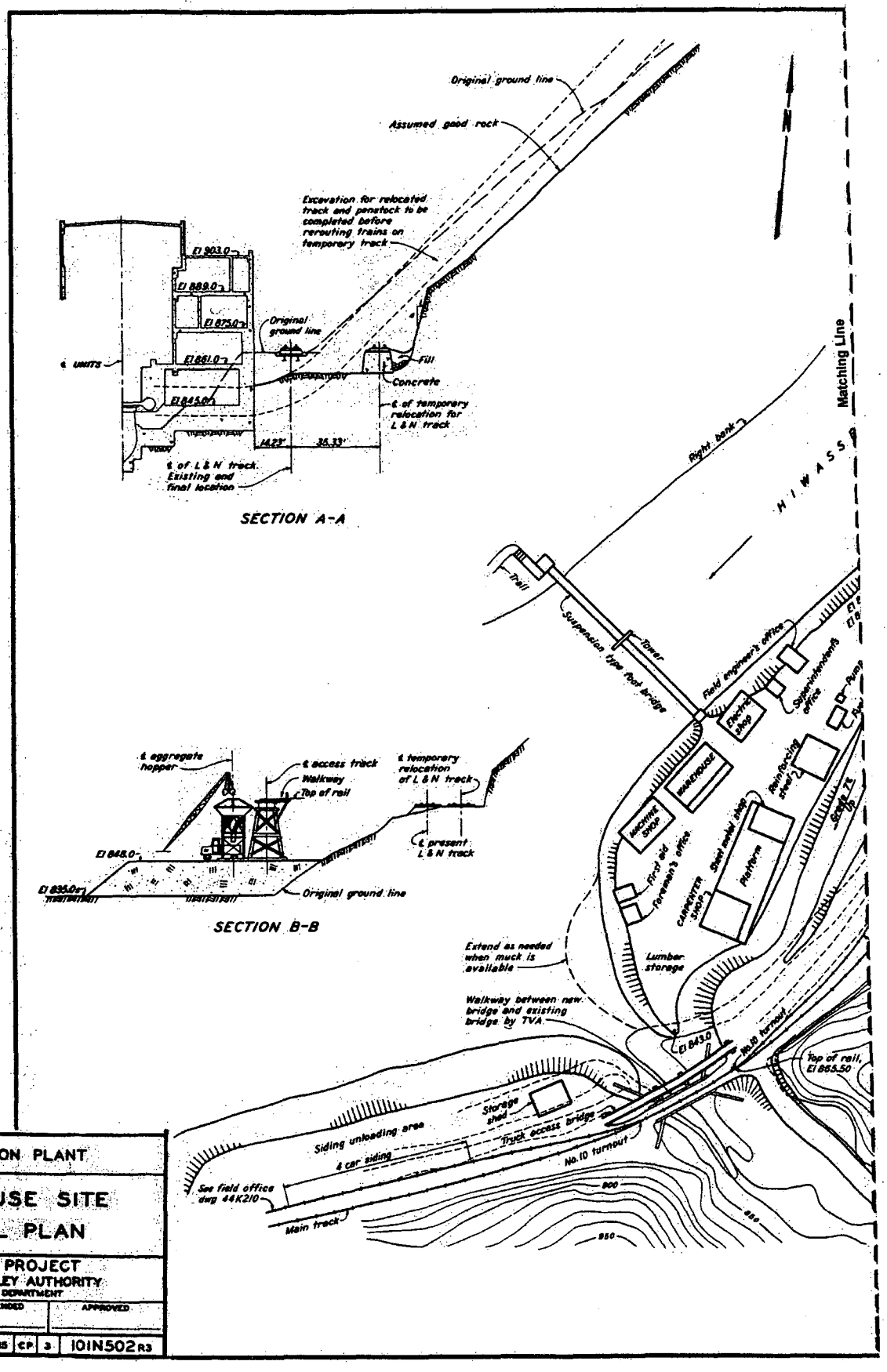


SECTION B-B

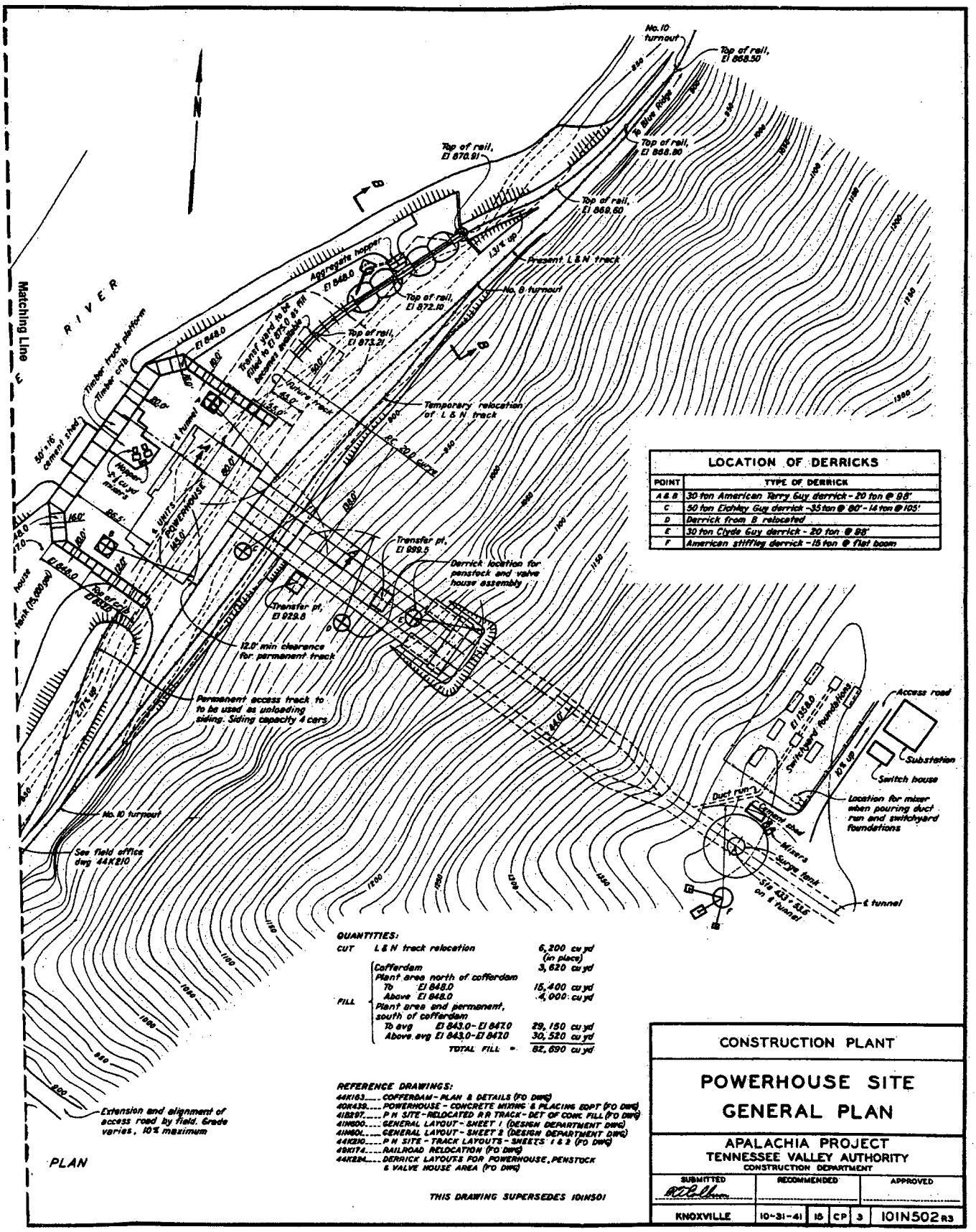


SECTION C-C

CONSTRUCTION PLANT					
CONSTRUCTION PLANT LAYOUT Mc FARLAND ADIT					
APALACHIA PROJECT TENNESSEE VALLEY AUTHORITY CONSTRUCTION DEPARTMENT					
SUBMITTED	RECOMMENDED			APPROVED	
KNOXVILLE	10-27-41	15	CP	3	101N202 RE



CONSTRUCTION PLANT					
POWERHOUSE SITE GENERAL PLAN					
APALACHIA PROJECT TENNESSEE VALLEY AUTHORITY CONSTRUCTION DEPARTMENT					
SUBMITTED	RECOMMENDED	APPROVED			
KNOXVILLE	10-31-41	15	CP	3	101N502 R3



LOCATION OF DERRICKS	
POINT	TYPE OF DERRICK
A & B	30 ton American Terry Guy derrick - 20 ton @ 98'
C	50 ton Eichleay Guy derrick - 35 ton @ 80' - 14 ton @ 105'
D	Derrick from B relocated
E	30 ton Clyde Guy derrick - 20 ton @ 98'
F	American stiffleg derrick - 15 ton @ flat boom

QUANTITIES:

CUT	L & N track relocation	6,200 cu yd (in place)
FILL	Cofferdam	3,620 cu yd
	Plant area north of cofferdam	
	To El 848.0	15,400 cu yd
	Above El 848.0	4,000 cu yd
	Plant area and permanent, south of cofferdam	
	To avg El 843.0 - El 847.0	29,150 cu yd
	Above avg El 843.0 - El 847.0	30,520 cu yd
	TOTAL FILL =	82,690 cu yd

REFERENCE DRAWINGS:

44K163 ____ COFFERDAM - PLAN & DETAILS (FO DWG)
40K439 ____ POWERHOUSE - CONCRETE MIXING & PLACING EQPT (FO DWG)
41B297 ____ P H SITE - RELOCATED R R TRACK - DET OF CONC FILL (FO DWG)
41N500 ____ GENERAL LAYOUT - SHEET 1 (DESIGN DEPARTMENT DWG)
41N501 ____ GENERAL LAYOUT - SHEET 2 (DESIGN DEPARTMENT DWG)
44K210 ____ P H SITE - TRACK LAYOUTS - SHEETS 1 & 2 (FO DWG)
49K174 ____ RAILROAD RELOCATION (FO DWG)
44K224 ____ DERRICK LAYOUTS FOR POWERHOUSE, PENSTOCK & VALVE HOUSE AREA (FO DWG)

THIS DRAWING SUPERSEDES 101N501

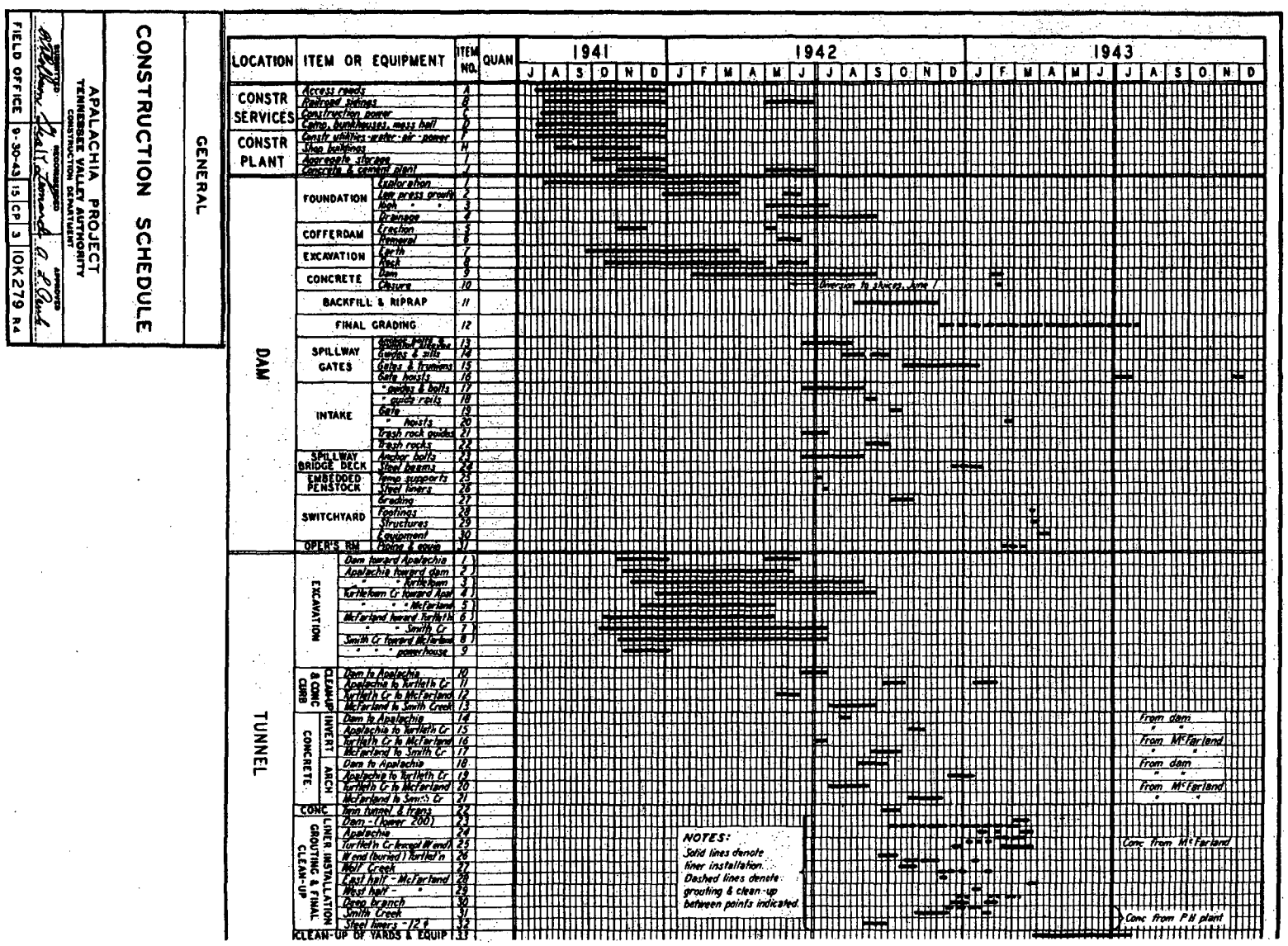
CONSTRUCTION PLANT

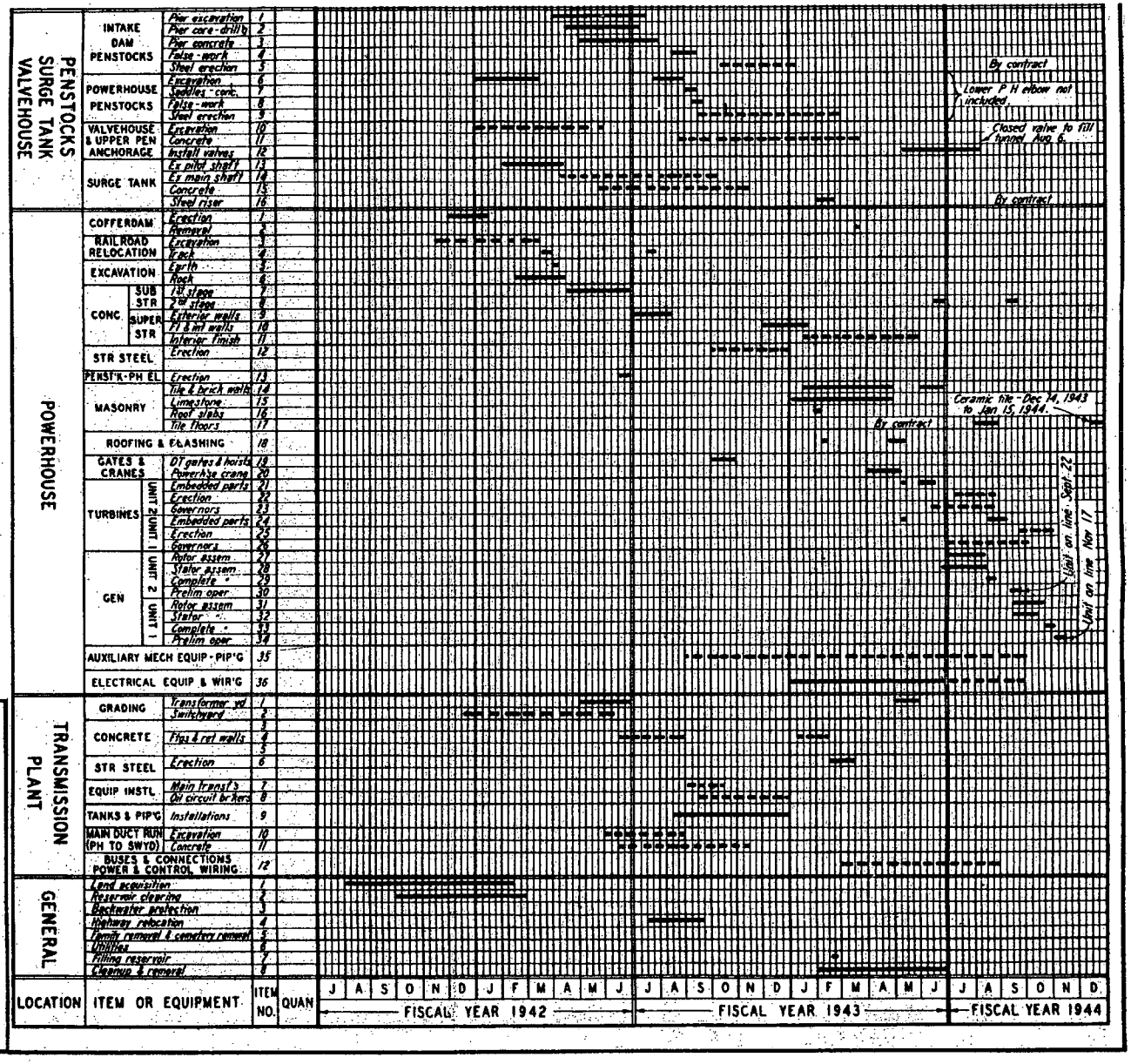
POWERHOUSE SITE
GENERAL PLAN

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	10-31-41	15	CP	3	101N502 R3


GENERAL
CONSTRUCTION SCHEDULE
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
FIELD OFFICE 9-30-43 15 CP 3 10K279 R4
LOCATION
ITEM OR EQUIPMENT
ITEM NO.
QUAN
1941
1942
1943
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
CONSTR SERVICES
Access roads A
Railroad sidings B
Construction power C
Camp, bunkhouses, mess hall D
CONSTR PLANT
Constr utilities-water-air-power F
Shop buildings H
Aggregate storage I
Concrete & cement plant J
DAM
FOUNDATION
Exploration 1
Low press grouting 2
High " " 3
Drainage 4
COFFERDAM
Erection 5
Removal 6
EXCAVATION
Earth 7
Rock 8
CONCRETE
Dam 9
Closure 10
Diversion to sluices, June 1
BACKFILL & RIPRAP 11
FINAL GRADING 12
SPILLWAY GATES
Guides & sills 14
Gates & trunions 15
Gate hoists 16
INTAKE
" guides & bolts 17
" guide rails 18
Gate 19
" hoists 20
Trash rock guides 21
Trash rocks 22
SPILLWAY BRIDGE DECK
Anchor bolts 23
Steel beams 24
EMBEDDED PENSTOCK
Temp supports 25
Steel liners 26
SWITCHYARD
Grading 27
Footings 28
Structures 29
Equipment 30
OPER'S RM
Piping & equip 31
TUNNEL
EXCAVATION
Dam toward Apalachia 1
Apalachia toward dam 2
" " Turtletown 3
Turtletown Cr toward Apal 4
" " " McFarland 5
McFarland toward Turtleth 6
" " Smith Cr 7
Smith Cr toward McFarland 8
" " " powerhouse 9
CLEAN-UP & CONC CURB
Dam to Apalachia 10
Apalachia to Turtleth Cr 11
Turtleth Cr to McFarland 12
McFarland to Smith Creek 13
CONCRETE
INVERT
Dam to Apalachia 14
Apalachia to Turtleth Cr 15
Turtleth Cr to McFarland 16
McFarland to Smith Cr 17
ARCH
Dam to Apalachia 18
Apalachia to Turtleth Cr 19
Turtleth Cr to McFarland 20
McFarland to Smith Cr 21
CONC
Twin tunnel & trans 22
LINER INSTALLATION GROUTING & FINAL CLEAN-UP
Dam - (lower 200) 23
Apalachia 24
Turtleth Cr (except W end) 25
W end (buried) Turtleth 26
Wolf Creek 27
East half - McFarland 28
West half - " 29
Deep branch 30
Smith Creek 31
Steel liners - 12 ϕ 32
CLEAN-UP OF YARDS & EQUIP 33
From dam
" "
From McFarland
" "
From dam
" "
From McFarland
" "
Conc from McFarland
Conc from PH plant
NOTES:
Solid lines denote liner installation.
Dashed lines denote grouting & clean-up between points indicated.


PENSTOCKS SURGE TANK VALVEHOUSE
INTAKE DAM PENSTOCKS
Pier excavation 1
Pier core-drill'g 2
Pier concrete 3
False-work 4
Steel erection 5
POWERHOUSE PENSTOCKS
Excavation 6
Saddles-conc. 7
False-work 8
Steel erection 9
VALVEHOUSE & UPPER PEN ANCHORAGE
Excavation 10
Concrete 11
Install valves 12
SURGE TANK
Ex pilot shaft 13
Ex main shaft 14
Concrete 15
Steel riser 16
By contract
Lower P H elbow not included.
Closed valve to fill turned Aug 6
By contract
POWERHOUSE
COFFERDAM
Erection 1
Removal 2
RAILROAD RELOCATION
Excavation 3
Track 4
EXCAVATION
Earth 5
Rock 6
CONC
SUB STR
1st stage 7
2nd stage 8
SUPER STR
Exterior walls 9
Pl & int walls 10
Interior finish 11
STR STEEL
Erection 12
PENST'K-PH EL
Erection 13
MASONRY
Tile & brick walls 14
Limestone 15
Roof slabs 16
Tile floors 17
ROOFING & FLASHING 18
GATES & CRANES
DT gates & hoists 19
Powerhse crane 20
TURBINES
UNIT 2
Embedded parts 21
Erection 22
Governors 23
UNIT 1
Embedded parts 24
Erection 25
Governors 26
GEN
UNIT 2
Rotor assem 27
Stator assem 28
Complete " 29
Prelim oper 30
UNIT 1
Rotor assem 31
Stator " 32
Complete " 33
Prelim oper 34
AUXILIARY MECH EQUIP-PIP'G 35
ELECTRICAL EQUIP & WIR'G 36
Ceramic tile-Dec 14, 1943 to Jan 15, 1944.
By contract
Unit on line Sept 22
Unit on line Nov 17
TRANSMISSION PLANT
GRADING
Transformer yd 1
Switchyard 2
CONCRETE
Ftgs & ret walls 3
4
5
STR STEEL
Erection 6
EQUIP INSTL
Main transf's 7
Oil circuit brkers 8
TANKS & PIP'G
Installations 9
MAIN DUCT RUN (PH TO SWYD)
Excavation 10
Concrete 11
BUSES & CONNECTIONS POWER & CONTROL WIRING 12
GENERAL
Land acquisition 1
Reservoir clearing 2
Backwater protection 3
Highway relocation 4
Family removal & cemetery removal 5
Utilities 6
Filling reservoir 7
Cleanup & removal 8
LOCATION
ITEM OR EQUIPMENT
ITEM NO.
QUAN
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
FISCAL YEAR 1942
FISCAL YEAR 1943
FISCAL YEAR 1944
GENERAL
CONSTRUCTION SCHEDULE
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
FIELD OFFICE
9-30-43
15
CP
3
10K279 R4

TENNESSEE VALLEY AUTHORITY
RIVER SYSTEM OPERATIONS & ENVIRONMENT
RIVER OPERATIONS

APALACHIA DAM

SPILLWAY DISCHARGE TABLES

MARCH 2004

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INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables issued in August 1971. The tables were revised to increase the maximum headwater elevation covered in the tables from 1282 feet to 1285 feet. The tables were revised also to reflect the discharge values obtained from SPILLQ, which is a computer code used in TVA software for monitoring spill discharges and determining gate arrangements.

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 164,400 cubic feet per second. Headwater elevations range from 1257 feet to 1285 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 table of Spillway Gate Arrangements on page 5. Reference to this table and to the drawing showing the location of the gates on page 4 will determine the gate opening to which each gate is to be set for any particular discharge given in the tables.

5. Discharge Intervals

The tables have been prepared so that the incremental discharge between the tabulated values for consecutive gate arrangements is generally less than 5 percent of the tabulated discharge. The incremental discharge between tabulated values of consecutive headwater elevations is generally less than 1 percent. These increments are exceeded in some cases near the extreme ends of the tables where operation is relatively infrequent. In general it is possible to set any required discharge within 2-1/2 percent and to know the actual discharge for any given set of conditions within 1 percent. These tolerances are considered acceptable and therefore <u>it will not be necessary to interpolate between values given in these tables</u>.

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 1262.2 is used for actual headwater elevations between 1262.15 feet and 1262.24 feet inclusive. When the actual headwater elevation is exactly halfway between tabular values, the larger value is used.

6. Raising and Lowering Gates

The operating mechanism for raising and lowering the spillway gates is located on the deck of the dam. The gates are raised individually by operating an electrical switch attached to the operating mechanism. As the gate is raised or lowered, the gate opening is indicated on a dial that is visible from the control switch. The gates may be stopped at any opening, but only the openings shown in the spillway gate arrangement table on page 5 may be used. Care should be taken to set each required position accurately.

7. Special Instruction – Preventing Flow Over Top of Spillway Gates When Headwater Elevation is Above 1280 feet

If the headwater elevation exceeds 1280 feet (actually, 1279.8 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 10,000 cubic feet per second with the headwater at elevation 1265.82 feet?

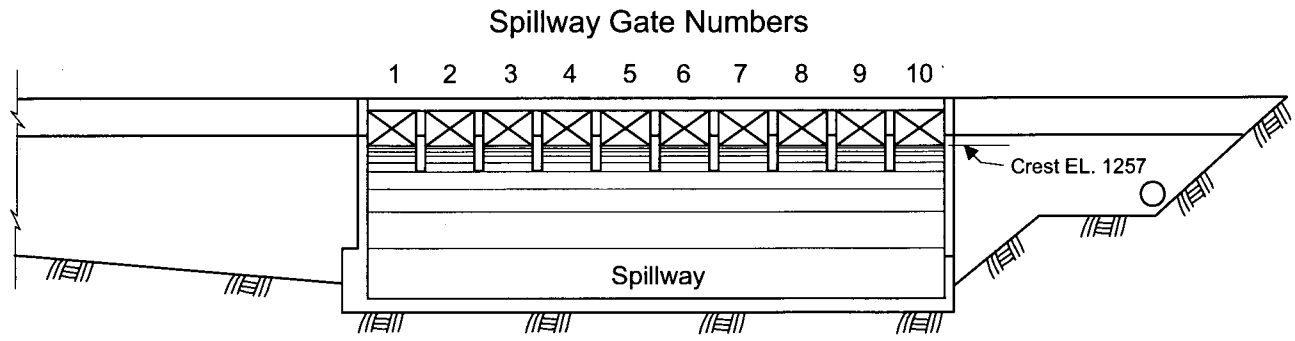
The first step is to find the table in which the headwater elevation appears. Referring to the contents page, we find that headwater elevations between 1265 feet and 1267 feet are found on page 12. The headwater elevation closest to 1265.82 feet is 1265.8 feet. In the column headed 1265.8 the discharge nearest to the required 10,000 cubic feet per second is 10,010 cubic feet per second located near the center of the page. By tracing the horizontal line in which 10,010 cubic feet per second appears, to either side of the page, we find that gate arrangement 26 is the one for producing the discharge closest to 10,000 cubic feet per second at headwater elevation 1265.8 feet. Referring to page 5 it is found that the gates should be set with the gate indicators reading as follows: gates 1, 3, 8, and 10 at indicator position 2; gates 2, 4, 5, 6, 7, and 9 at indicator position 3.

After 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 1265.42 feet, the discharge will be found in the column headed 1265.4. In this column the discharge closest to 10,000 cubic feet per second is 10,140 cubic feet per second for gate arrangement 27. To change from gate arrangement 26 to gate arrangement 27, gate 1 would be set to gate opening indicator position 3.

Example 2 -- Suppose the operating records show that the headwater is at elevation 1277.35 feet, and gate arrangement 91 is in use. The headwater is found on page 24 which is marked "Headwater 1277 to 1279." The elevation given is exactly halfway between elevation 1277.3 feet and 1277.4 feet. The larger value, 1277.4 feet, should be used. In the column headed 1277.4 opposite gate arrangement 91, the discharge is found to be 89,580 cubic feet per second.

APALACHIA DAM

LOCATION OF SPILLWAY GATES



DOWNSTREAM ELEVATION

APALACHIA DAM

SPILLWAY GATE ARRANGEMENTS

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
1	0	0	0	1	0	0	0	0	0	0
2	0	0	0	1	0	0	1	0	0	0
3	0	1	0	1	0	0	1	0	0	0
4	0	1	0	1	0	0	1	0	1	0
5	0	1	0	1	1	0	1	0	1	0
6	0	1	0	1	1	1	1	0	1	0
7	1	1	0	1	1	1	1	0	1	0
8	1	1	0	1	1	1	1	0	1	1
9	1	1	1	1	1	1	1	0	1	1
10	1	1	1	1	1	1	1	1	1	1
11	1	1	1	2	1	1	1	1	1	1
12	1	1	1	2	1	1	2	1	1	1
13	1	2	1	2	1	1	2	1	1	1
14	1	2	1	2	1	1	2	1	2	1
15	1	2	1	2	2	1	2	1	2	1
16	1	2	1	2	2	2	2	1	2	1
17	2	2	1	2	2	2	2	1	2	1
18	2	2	1	2	2	2	2	1	2	2
19	2	2	2	2	2	2	2	1	2	2
20	2	2	2	2	2	2	2	2	2	2
21	2	2	2	3	2	2	2	2	2	2
22	2	2	2	3	2	2	3	2	2	2
23	2	3	2	3	2	2	3	2	2	2
24	2	3	2	3	2	2	3	2	3	2
25	2	3	2	3	3	2	3	2	3	2
26	2	3	2	3	3	3	3	2	3	2
27	3	3	2	3	3	3	3	2	3	2
28	3	3	2	3	3	3	3	2	3	3
29	3	3	3	3	3	3	3	2	3	3
30	3	3	3	3	3	3	3	3	3	3
31	3	3	3	4	3	3	3	3	3	3
32	3	3	3	4	3	3	4	3	3	3
33	3	4	3	4	3	3	4	3	3	3
34	3	4	3	4	3	3	4	3	4	3
35	3	4	3	4	4	3	4	3	4	3
36	3	4	3	4	4	4	4	3	4	3
37	4	4	3	4	4	4	4	3	4	3
38	4	4	3	4	4	4	4	3	4	4
39	4	4	4	4	4	4	4	3	4	4
40	4	4	4	4	4	4	4	4	4	4

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
41	4	4	4	5	4	4	4	4	4	4
42	4	4	4	5	4	4	5	4	4	4
43	4	5	4	5	4	4	5	4	4	4
44	4	5	4	5	4	4	5	4	5	4
45	4	5	4	5	5	4	5	4	5	4
46	4	5	4	5	5	5	5	4	5	4
47	5	5	4	5	5	5	5	4	5	4
48	5	5	4	5	5	5	5	4	5	5
49	5	5	5	5	5	5	5	4	5	5
50	5	5	5	5	5	5	5	5	5	5
51	5	5	5	6	5	5	5	5	5	5
52	5	5	5	6	5	5	6	5	5	5
53	5	6	5	6	5	5	6	5	5	5
54	5	6	5	6	5	5	6	5	6	5
55	5	6	5	6	6	5	6	5	6	5
56	5	6	5	6	6	6	6	5	6	5
57	6	6	5	6	6	6	6	5	6	5
58	6	6	5	6	6	6	6	5	6	6
59	6	6	6	6	6	6	6	5	6	6
60	6	6	6	6	6	6	6	6	6	6
61	6	6	6	8	6	6	6	6	6	6
62	6	6	6	8	6	6	8	6	6	6
63	6	8	6	8	6	6	8	6	6	6
64	6	8	6	8	6	6	8	6	8	6
65	6	8	6	8	8	6	8	6	8	6
66	6	8	6	8	8	8	8	6	8	6
67	8	8	6	8	8	8	8	6	8	6
68	8	8	6	8	8	8	8	6	8	8
69	8	8	8	8	8	8	8	6	8	8
70	8	8	8	8	8	8	8	8	8	8
71	8	8	8	8	8	8	8	8	8	10
72	8	8	8	8	8	8	8	10	8	10
73	8	8	8	8	8	10	8	10	8	10
74	8	8	8	10	8	10	8	10	8	10
75	8	10	8	10	8	10	8	10	8	10
76	10	10	8	10	8	10	8	10	8	10
77	10	10	10	10	8	10	8	10	8	10
78	10	10	10	10	10	10	8	10	8	10
79	10	10	10	10	10	10	10	10	8	10
80	10	10	10	10	10	10	10	10	10	10

Arrangement Number	Gate Number									
	1	2	3	4	5	6	7	8	9	10
81	10	10	10	10	10	10	10	10	10	14
82	10	10	10	10	10	10	10	14	10	14
83	10	10	10	10	10	14	10	14	10	14
84	10	10	10	14	10	14	10	14	10	14
85	10	14	10	14	10	14	10	14	10	14
86	14	14	10	14	10	14	10	14	10	14
87	14	14	14	14	10	14	10	14	10	14
88	14	14	14	14	14	14	10	14	10	14
89	14	14	14	14	14	14	14	14	10	14
90	14	14	14	14	14	14	14	14	14	14
91	14	14	14	14	14	14	14	14	14	18
92	14	14	14	14	14	14	14	18	14	18
93	14	14	14	14	14	18	14	18	14	18
94	14	14	14	18	14	18	14	18	14	18
95	14	18	14	18	14	18	14	18	14	18
96	18	18	14	18	14	18	14	18	14	18
97	18	18	18	18	14	18	14	18	14	18
98	18	18	18	18	18	18	14	18	14	18
99	18	18	18	18	18	18	18	18	14	18
100	18	18	18	18	18	18	18	18	18	18
101	18	18	18	18	18	18	18	18	18	21
102	18	18	18	18	18	18	18	21	18	21
103	18	18	18	18	18	21	18	21	18	21
104	18	18	18	21	18	21	18	21	18	21
105	18	21	18	21	18	21	18	21	18	21
106	21	21	18	21	18	21	18	21	18	21
107	21	21	21	21	18	21	18	21	18	21
108	21	21	21	21	21	21	18	21	18	21
109	21	21	21	21	21	21	21	21	18	21
110	21	21	21	21	21	21	21	21	21	21

GATE OPENINGS

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

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APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1257.0	1257.1	1257.2	1257.3	1257.4	1257.5	1257.6	1257.7	1257.8	1257.9	1258.0	1258.1	1258.2	1258.3	1258.4	1258.5	1258.6	1258.7	1258.8	1258.9	1259.0	
1	0	5	15	20	30	40	55	65	80	95	110	120	140	160	180	180	190	180	180	180	180	1
2	5	15	25	45	65	85	110	130	160	190	220	250	280	320	350	350	360	350	350	350	360	2
3	5	20	40	65	95	130	160	200	240	280	330	370	420	470	520	550	560	560	560	550	560	3
4	5	25	55	85	130	170	210	260	320	370	430	500	560	630	700	740	770	770	760	760	760	4
5	10	35	70	110	160	210	270	330	400	470	540	620	700	790	870	930	950	950	940	940	940	5
6	10	40	80	130	190	250	320	400	480	560	650	750	850	950	1,050	1,120	1,140	1,140	1,140	1,130	1,140	6
7	15	50	95	150	220	290	370	460	560	660	760	870	990	1,110	1,230	1,310	1,360	1,350	1,350	1,350	1,350	7
8	15	55	110	170	250	340	430	530	640	750	870	1,000	1,130	1,270	1,400	1,490	1,530	1,530	1,520	1,520	1,520	8
9	15	60	120	200	280	380	480	590	720	840	980	1,120	1,270	1,420	1,570	1,680	1,730	1,720	1,720	1,710	1,720	9
10	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,850	1,900	1,900	1,890	1,880	1,890	10
11	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,860	1,930	1,950	1,960	1,980	2,000	11
12	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,890	1,970	2,010	2,050	2,080	2,130	12
13	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,890	1,980	2,040	2,100	2,150	2,220	13
14	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,890	1,990	2,070	2,140	2,220	2,320	14
15	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,900	2,020	2,120	2,220	2,320	2,430	15
16	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,900	2,040	2,160	2,280	2,400	2,540	16
17	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,750	1,900	2,040	2,180	2,320	2,460	2,620	17
18	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,920	2,080	2,240	2,400	2,570	2,740	18
19	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,920	2,100	2,270	2,460	2,650	2,850	19
20	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	20
21	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	21
22	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	22
23	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	23
24	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	24
25	20	70	140	220	310	420	540	660	790	940	1,090	1,240	1,410	1,580	1,760	1,950	2,140	2,340	2,540	2,750	2,970	25

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1259.0	1259.1	1259.2	1259.3	1259.4	1259.5	1259.6	1259.7	1259.8	1259.9	1260.0	1260.1	1260.2	1260.3	1260.4	1260.5	1260.6	1260.7	1260.8	1260.9	1261.0	
1	180	190	190	190	200	200	200	210	210	210	220	220	220	230	230	230	240	240	240	240	250	1
2	360	360	370	380	380	390	400	400	410	420	420	430	430	440	440	450	460	460	470	470	480	2
3	560	570	580	590	590	600	610	630	640	640	650	660	670	680	690	700	710	720	730	740	750	3
4	760	770	780	800	810	820	840	850	860	880	890	900	910	930	940	950	960	980	990	1,000	1,010	4
5	940	960	970	990	1,000	1,020	1,040	1,050	1,070	1,090	1,100	1,120	1,140	1,150	1,170	1,180	1,200	1,210	1,230	1,240	1,260	5
6	1,140	1,150	1,170	1,190	1,210	1,230	1,250	1,270	1,290	1,310	1,330	1,350	1,370	1,390	1,400	1,420	1,440	1,460	1,480	1,500	1,510	6
7	1,350	1,360	1,380	1,410	1,430	1,450	1,480	1,500	1,520	1,550	1,570	1,590	1,610	1,640	1,660	1,680	1,700	1,720	1,740	1,770	1,790	7
8	1,520	1,540	1,570	1,590	1,620	1,640	1,670	1,700	1,720	1,750	1,780	1,800	1,830	1,850	1,880	1,900	1,920	1,950	1,970	2,000	2,020	8
9	1,720	1,740	1,770	1,800	1,820	1,850	1,880	1,910	1,950	1,980	2,000	2,030	2,060	2,090	2,120	2,140	2,170	2,200	2,230	2,260	2,280	9
10	1,890	1,910	1,950	1,980	2,010	2,040	2,080	2,110	2,150	2,180	2,210	2,240	2,270	2,300	2,330	2,360	2,400	2,430	2,460	2,490	2,520	10
11	2,000	2,050	2,100	2,150	2,200	2,260	2,310	2,370	2,430	2,480	2,530	2,550	2,570	2,600	2,620	2,640	2,670	2,700	2,730	2,760	2,790	11
12	2,130	2,190	2,260	2,330	2,410	2,480	2,560	2,640	2,720	2,790	2,820	2,840	2,860	2,870	2,880	2,910	2,940	2,970	3,000	3,030	3,060	12
13	2,220	2,300	2,400	2,490	2,580	2,680	2,780	2,880	2,980	3,070	3,130	3,140	3,140	3,150	3,160	3,170	3,200	3,230	3,260	3,290	3,320	13
14	2,320	2,420	2,530	2,640	2,760	2,870	2,990	3,120	3,240	3,360	3,440	3,450	3,460	3,450	3,450	3,460	3,480	3,510	3,540	3,570	3,600	14
15	2,430	2,550	2,680	2,820	2,950	3,090	3,230	3,380	3,520	3,660	3,740	3,750	3,740	3,730	3,720	3,720	3,750	3,780	3,810	3,830	3,860	15
16	2,540	2,680	2,830	2,980	3,140	3,290	3,460	3,620	3,790	3,960	4,050	4,050	4,040	4,020	4,000	4,000	4,020	4,050	4,080	4,100	4,130	16
17	2,620	2,790	2,960	3,130	3,300	3,490	3,670	3,860	4,050	4,230	4,350	4,370	4,350	4,320	4,290	4,290	4,300	4,330	4,360	4,380	4,410	17
18	2,740	2,930	3,120	3,310	3,510	3,710	3,910	4,120	4,340	4,540	4,650	4,670	4,640	4,600	4,570	4,560	4,570	4,600	4,630	4,650	4,680	18
19	2,850	3,050	3,260	3,470	3,690	3,910	4,140	4,370	4,610	4,840	4,970	4,970	4,940	4,890	4,850	4,830	4,850	4,870	4,900	4,920	4,950	19
20	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,140	5,270	5,270	5,220	5,170	5,110	5,100	5,110	5,140	5,160	5,190	5,220	20
21	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,140	5,280	5,310	5,290	5,280	5,260	5,270	5,320	5,370	5,420	5,470	5,540	21
22	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,320	5,380	5,400	5,420	5,430	5,470	5,540	5,630	5,710	5,790	5,880	22
23	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,320	5,420	5,470	5,520	5,570	5,650	5,740	5,850	5,960	6,070	6,190	23
24	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,320	5,430	5,520	5,600	5,680	5,800	5,930	6,060	6,200	6,340	6,490	24
25	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,350	5,490	5,610	5,730	5,850	5,980	6,140	6,310	6,470	6,640	6,820	25
26	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,360	5,530	5,680	5,830	5,990	6,160	6,340	6,530	6,730	6,930	7,130	26
27	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,150	5,360	5,540	5,720	5,900	6,090	6,300	6,520	6,740	6,960	7,190	7,420	27
28	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,390	5,600	5,820	6,040	6,260	6,490	6,740	6,980	7,240	7,490	7,750	28
29	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,390	5,640	5,880	6,140	6,390	6,660	6,930	7,210	7,490	7,770	8,070	29
30	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	30
31	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	31
32	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	32
33	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	33
34	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	34
35	2,970	3,190	3,420	3,650	3,890	4,130	4,380	4,640	4,900	5,160	5,430	5,710	5,990	6,270	6,560	6,860	7,160	7,460	7,770	8,080	8,400	35

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1261.0	1261.1	1261.2	1261.3	1261.4	1261.5	1261.6	1261.7	1261.8	1261.9	1262.0	1262.1	1262.2	1262.3	1262.4	1262.5	1262.6	1262.7	1262.8	1262.9	1263.0	
1	250	250	250	260	260	260	260	270	270	270	280	280	280	280	290	290	290	290	300	300	300	1
2	480	490	490	500	500	510	510	520	520	530	540	540	550	550	560	560	570	570	580	580	590	2
3	750	750	760	770	780	790	800	810	810	820	830	840	850	860	860	870	880	890	890	900	910	3
4	1,010	1,030	1,040	1,050	1,060	1,070	1,080	1,100	1,110	1,120	1,130	1,140	1,150	1,160	1,170	1,190	1,200	1,210	1,220	1,230	1,240	4
5	1,260	1,270	1,290	1,300	1,320	1,330	1,350	1,360	1,370	1,390	1,400	1,420	1,430	1,440	1,460	1,470	1,480	1,500	1,510	1,520	1,540	5
6	1,510	1,530	1,550	1,570	1,590	1,600	1,620	1,640	1,650	1,670	1,690	1,710	1,720	1,740	1,750	1,770	1,790	1,800	1,820	1,830	1,850	6
7	1,790	1,810	1,830	1,850	1,870	1,890	1,910	1,930	1,950	1,970	1,990	2,010	2,030	2,050	2,070	2,090	2,110	2,130	2,150	2,170	2,180	7
8	2,020	2,050	2,070	2,100	2,120	2,140	2,160	2,190	2,210	2,230	2,260	2,280	2,300	2,320	2,350	2,370	2,390	2,410	2,430	2,450	2,470	8
9	2,280	2,310	2,340	2,360	2,390	2,420	2,440	2,470	2,490	2,520	2,550	2,570	2,600	2,620	2,650	2,670	2,690	2,720	2,740	2,770	2,790	9
10	2,520	2,550	2,580	2,610	2,640	2,670	2,690	2,720	2,750	2,780	2,810	2,840	2,860	2,890	2,920	2,950	2,970	3,000	3,020	3,050	3,080	10
11	2,790	2,830	2,860	2,890	2,920	2,950	2,980	3,010	3,040	3,070	3,100	3,130	3,160	3,190	3,220	3,250	3,280	3,310	3,340	3,370	3,400	11
12	3,060	3,100	3,130	3,160	3,200	3,230	3,260	3,290	3,320	3,360	3,390	3,420	3,460	3,490	3,520	3,560	3,590	3,620	3,650	3,680	3,710	12
13	3,320	3,360	3,390	3,430	3,460	3,500	3,530	3,570	3,600	3,630	3,670	3,700	3,740	3,770	3,810	3,850	3,880	3,910	3,950	3,980	4,020	13
14	3,600	3,640	3,670	3,710	3,750	3,780	3,820	3,850	3,890	3,920	3,960	3,990	4,030	4,070	4,110	4,150	4,190	4,220	4,260	4,300	4,330	14
15	3,860	3,900	3,940	3,980	4,020	4,060	4,090	4,130	4,170	4,200	4,240	4,280	4,320	4,370	4,410	4,450	4,490	4,530	4,570	4,610	4,650	15
16	4,130	4,170	4,220	4,260	4,300	4,340	4,370	4,410	4,450	4,480	4,520	4,570	4,610	4,660	4,700	4,750	4,790	4,830	4,870	4,920	4,960	16
17	4,410	4,450	4,490	4,540	4,580	4,620	4,660	4,700	4,740	4,770	4,810	4,860	4,910	4,960	5,000	5,050	5,100	5,140	5,190	5,230	5,280	17
18	4,680	4,720	4,770	4,820	4,860	4,900	4,940	4,980	5,020	5,060	5,110	5,150	5,210	5,260	5,310	5,360	5,400	5,450	5,500	5,550	5,600	18
19	4,950	5,000	5,040	5,090	5,140	5,180	5,220	5,260	5,300	5,340	5,390	5,440	5,500	5,550	5,600	5,650	5,710	5,760	5,810	5,860	5,910	19
20	5,220	5,270	5,320	5,370	5,410	5,460	5,500	5,550	5,590	5,630	5,680	5,730	5,790	5,850	5,900	5,960	6,010	6,070	6,120	6,170	6,230	20
21	5,540	5,610	5,690	5,730	5,770	5,810	5,840	5,880	5,920	5,960	6,000	6,050	6,110	6,160	6,220	6,280	6,330	6,390	6,440	6,490	6,550	21
22	5,880	5,980	6,050	6,080	6,120	6,150	6,170	6,210	6,240	6,280	6,320	6,370	6,420	6,480	6,540	6,600	6,650	6,710	6,760	6,820	6,870	22
23	6,190	6,320	6,420	6,450	6,480	6,500	6,520	6,540	6,580	6,610	6,650	6,690	6,740	6,800	6,860	6,920	6,970	7,030	7,090	7,140	7,200	23
24	6,490	6,640	6,770	6,810	6,830	6,840	6,850	6,870	6,900	6,930	6,970	7,000	7,050	7,110	7,170	7,230	7,290	7,340	7,400	7,450	7,510	24
25	6,820	7,000	7,120	7,150	7,160	7,170	7,170	7,180	7,210	7,240	7,270	7,310	7,350	7,410	7,470	7,530	7,590	7,650	7,710	7,760	7,820	25
26	7,130	7,340	7,490	7,510	7,510	7,510	7,500	7,510	7,540	7,570	7,590	7,620	7,660	7,730	7,790	7,850	7,910	7,970	8,030	8,080	8,140	26
27	7,420	7,660	7,830	7,880	7,880	7,870	7,850	7,850	7,870	7,890	7,920	7,950	7,980	8,040	8,110	8,170	8,230	8,290	8,350	8,400	8,460	27
28	7,750	8,020	8,190	8,230	8,220	8,200	8,170	8,170	8,180	8,210	8,230	8,250	8,290	8,350	8,410	8,480	8,540	8,600	8,660	8,720	8,770	28
29	8,070	8,360	8,550	8,580	8,560	8,530	8,500	8,490	8,500	8,520	8,550	8,560	8,600	8,660	8,720	8,790	8,850	8,910	8,970	9,030	9,090	29
30	8,400	8,720	8,900	8,920	8,900	8,860	8,820	8,810	8,820	8,840	8,850	8,870	8,900	8,960	9,030	9,100	9,160	9,220	9,280	9,340	9,400	30
31	8,400	8,720	8,900	8,960	8,970	8,970	8,970	9,000	9,040	9,100	9,150	9,190	9,270	9,360	9,450	9,510	9,560	9,610	9,660	9,710	9,760	31
32	8,400	8,720	8,930	9,030	9,070	9,110	9,150	9,210	9,290	9,380	9,460	9,540	9,650	9,770	9,850	9,900	9,940	9,980	10,020	10,060	10,110	32
33	8,400	8,720	8,930	9,060	9,140	9,220	9,290	9,390	9,500	9,620	9,740	9,860	10,000	10,150	10,260	10,290	10,330	10,360	10,380	10,420	10,460	33
34	8,400	8,720	8,930	9,080	9,200	9,310	9,430	9,560	9,710	9,870	10,020	10,170	10,350	10,530	10,670	10,710	10,730	10,750	10,760	10,780	10,820	34
35	8,400	8,720	8,970	9,150	9,310	9,460	9,610	9,780	9,960	10,150	10,340	10,530	10,730	10,950	11,080	11,100	11,110	11,120	11,120	11,140	11,180	35
36	8,400	8,720	8,970	9,190	9,380	9,570	9,760	9,970	10,180	10,410	10,630	10,860	11,100	11,340	11,490	11,500	11,510	11,500	11,490	11,500	11,540	36
37	8,400	8,720	8,970	9,200	9,420	9,650	9,880	10,120	10,380	10,630	10,890	11,150	11,430	11,710	11,890	11,910	11,900	11,890	11,870	11,870	11,890	37
38	8,400	8,720	9,000	9,260	9,530	9,790	10,060	10,340	10,630	10,920	11,210	11,510	11,810	12,130	12,290	12,310	12,290	12,260	12,230	12,230	12,250	38
39	8,400	8,720	9,010	9,310	9,610	9,910	10,220	10,530	10,850	11,180	11,510	11,840	12,180	12,520	12,710	12,710	12,680	12,650	12,610	12,590	12,610	39
40	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,120	13,110	13,070	13,030	12,970	12,950	12,970	40
41	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,120	13,160	13,160	13,160	13,150	13,180	13,230	41
42	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,170	13,240	13,290	13,330	13,370	13,430	13,520	42
43	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,180	13,300	13,380	13,470	13,550	13,660	13,790	43
44	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,180	13,330	13,460	13,590	13,710	13,870	14,040	44
45	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,220	13,410	13,580	13,760	13,930	14,120	14,330	45
46	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,230	13,460	13,680	13,900	14,110	14,350	14,590	46
47	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,230	13,480	13,740	14,000	14,260	14,540	14,830	47
48	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,270	13,570	13,870	14,170	14,480	14,800	15,130	48
49	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,280	13,620	13,960	14,310	14,660	15,030	15,390	49
50	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	50
51	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	51
52	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	52
53	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	53
54	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	54
55	8,400	8,720	9,050	9,380	9,720	10,060	10,400	10,750	11,110	11,470	11,830	12,190	12,570	12,940	13,320	13,700	14,090	14,480	14,880	15,280	15,680	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1263.0	1263.1	1263.2	1263.3	1263.4	1263.5	1263.6	1263.7	1263.8	1263.9	1264.0	1264.1	1264.2	1264.3	1264.4	1264.5	1264.6	1264.7	1264.8	1264.9	1265.0	
1	300	300	310	310	310	310	320	320	320	320	330	330	330	330	340	340	340	340	340	350	350	1
2	590	590	600	600	610	610	610	620	620	630	630	640	640	650	650	660	660	660	670	670	680	2
3	910	920	930	930	940	950	950	960	970	980	980	990	1,000	1,000	1,010	1,020	1,020	1,030	1,040	1,040	1,050	3
4	1,240	1,250	1,260	1,270	1,280	1,290	1,300	1,310	1,320	1,330	1,340	1,350	1,360	1,370	1,370	1,380	1,390	1,400	1,410	1,420	1,430	4
5	1,540	1,550	1,560	1,570	1,590	1,600	1,610	1,620	1,640	1,650	1,660	1,670	1,680	1,690	1,710	1,720	1,730	1,740	1,750	1,760	1,770	5
6	1,850	1,860	1,880	1,900	1,910	1,930	1,940	1,950	1,970	1,980	2,000	2,010	2,030	2,040	2,050	2,070	2,080	2,100	2,110	2,120	2,140	6
7	2,180	2,200	2,220	2,240	2,260	2,270	2,290	2,310	2,330	2,340	2,360	2,380	2,390	2,410	2,430	2,440	2,460	2,480	2,490	2,510	2,520	7
8	2,470	2,490	2,510	2,530	2,550	2,570	2,590	2,610	2,630	2,650	2,670	2,690	2,710	2,730	2,750	2,760	2,780	2,800	2,820	2,840	2,860	8
9	2,790	2,810	2,830	2,860	2,880	2,900	2,930	2,950	2,970	2,990	3,010	3,030	3,060	3,080	3,100	3,120	3,140	3,160	3,180	3,200	3,220	9
10	3,080	3,100	3,130	3,150	3,180	3,200	3,230	3,250	3,280	3,300	3,320	3,350	3,370	3,390	3,420	3,440	3,460	3,490	3,510	3,530	3,550	10
11	3,400	3,430	3,450	3,480	3,510	3,540	3,570	3,590	3,620	3,650	3,680	3,700	3,730	3,750	3,780	3,810	3,830	3,860	3,880	3,910	3,930	11
12	3,710	3,750	3,780	3,810	3,840	3,870	3,900	3,930	3,960	3,990	4,020	4,050	4,080	4,110	4,140	4,170	4,200	4,230	4,250	4,280	4,310	12
13	4,020	4,050	4,090	4,120	4,160	4,190	4,220	4,260	4,290	4,320	4,350	4,390	4,420	4,450	4,480	4,510	4,550	4,580	4,610	4,640	4,670	13
14	4,330	4,370	4,410	4,450	4,480	4,520	4,560	4,590	4,630	4,670	4,700	4,740	4,770	4,810	4,840	4,880	4,910	4,950	4,980	5,010	5,050	14
15	4,650	4,690	4,730	4,770	4,810	4,850	4,890	4,930	4,970	5,010	5,040	5,080	5,120	5,160	5,200	5,230	5,270	5,310	5,340	5,380	5,420	15
16	4,960	5,000	5,050	5,090	5,130	5,180	5,220	5,260	5,300	5,350	5,390	5,430	5,470	5,510	5,550	5,590	5,630	5,670	5,710	5,750	5,790	16
17	5,280	5,320	5,370	5,420	5,460	5,510	5,560	5,600	5,650	5,690	5,740	5,780	5,820	5,870	5,910	5,950	6,000	6,040	6,080	6,120	6,160	17
18	5,600	5,650	5,700	5,750	5,800	5,850	5,890	5,940	5,990	6,040	6,090	6,130	6,180	6,230	6,270	6,320	6,360	6,410	6,450	6,500	6,540	18
19	5,910	5,960	6,020	6,070	6,120	6,170	6,230	6,280	6,330	6,380	6,430	6,480	6,530	6,580	6,630	6,680	6,720	6,770	6,820	6,870	6,910	19
20	6,230	6,280	6,340	6,390	6,450	6,510	6,560	6,610	6,670	6,720	6,780	6,830	6,880	6,930	6,990	7,040	7,090	7,140	7,190	7,240	7,290	20
21	6,550	6,600	6,660	6,720	6,780	6,840	6,890	6,950	7,010	7,060	7,120	7,170	7,230	7,280	7,340	7,390	7,450	7,500	7,550	7,610	7,660	21
22	6,870	6,930	6,990	7,050	7,110	7,170	7,230	7,290	7,350	7,400	7,460	7,520	7,580	7,640	7,690	7,750	7,810	7,870	7,920	7,980	8,030	22
23	7,200	7,250	7,310	7,370	7,440	7,500	7,560	7,630	7,690	7,750	7,810	7,870	7,930	7,990	8,050	8,110	8,170	8,230	8,290	8,350	8,410	23
24	7,510	7,570	7,620	7,690	7,760	7,820	7,890	7,950	8,010	8,080	8,140	8,200	8,260	8,330	8,390	8,460	8,520	8,580	8,640	8,710	8,770	24
25	7,820	7,880	7,940	8,000	8,070	8,140	8,210	8,280	8,340	8,410	8,470	8,540	8,600	8,670	8,740	8,800	8,870	8,930	9,000	9,060	9,130	25
26	8,140	8,190	8,260	8,330	8,400	8,470	8,540	8,610	8,680	8,740	8,810	8,880	8,940	9,010	9,080	9,150	9,220	9,290	9,360	9,430	9,490	26
27	8,460	8,520	8,580	8,650	8,720	8,800	8,870	8,940	9,010	9,080	9,150	9,220	9,290	9,360	9,430	9,510	9,580	9,650	9,720	9,790	9,860	27
28	8,770	8,830	8,890	8,970	9,040	9,120	9,190	9,270	9,340	9,410	9,480	9,560	9,630	9,700	9,780	9,860	9,930	10,000	10,080	10,150	10,220	28
29	9,090	9,140	9,210	9,280	9,360	9,440	9,520	9,590	9,670	9,740	9,820	9,890	9,960	10,040	10,120	10,200	10,280	10,360	10,430	10,510	10,580	29
30	9,400	9,450	9,520	9,600	9,680	9,760	9,840	9,920	10,000	10,070	10,150	10,230	10,300	10,390	10,470	10,550	10,630	10,710	10,790	10,870	10,950	30
31	9,760	9,810	9,870	9,950	10,020	10,100	10,180	10,260	10,340	10,420	10,490	10,570	10,650	10,730	10,810	10,890	10,970	11,060	11,140	11,220	11,300	31
32	10,110	10,160	10,220	10,280	10,360	10,440	10,520	10,600	10,680	10,750	10,830	10,900	10,980	11,060	11,140	11,230	11,310	11,400	11,480	11,560	11,650	32
33	10,460	10,510	10,560	10,620	10,690	10,770	10,850	10,930	11,010	11,080	11,160	11,230	11,310	11,390	11,470	11,560	11,650	11,730	11,820	11,900	11,990	33
34	10,820	10,870	10,910	10,960	11,030	11,110	11,190	11,270	11,350	11,420	11,500	11,570	11,650	11,730	11,810	11,900	11,990	12,070	12,160	12,250	12,340	34
35	11,180	11,220	11,260	11,300	11,360	11,450	11,530	11,610	11,690	11,760	11,840	11,910	11,990	12,060	12,150	12,240	12,330	12,420	12,510	12,600	12,690	35
36	11,540	11,570	11,610	11,640	11,700	11,780	11,870	11,950	12,020	12,100	12,180	12,250	12,320	12,400	12,480	12,580	12,670	12,760	12,860	12,950	13,040	36
37	11,890	11,920	11,960	11,990	12,040	12,120	12,200	12,280	12,360	12,430	12,510	12,580	12,660	12,730	12,810	12,910	13,000	13,100	13,190	13,290	13,380	37
38	12,250	12,280	12,300	12,330	12,380	12,460	12,540	12,620	12,700	12,770	12,850	12,920	13,000	13,070	13,150	13,250	13,350	13,440	13,540	13,640	13,730	38
39	12,610	12,630	12,650	12,670	12,720	12,800	12,880	12,960	13,040	13,120	13,190	13,260	13,340	13,410	13,490	13,590	13,690	13,790	13,890	13,990	14,080	39
40	12,970	12,990	13,000	13,010	13,060	13,140	13,220	13,300	13,380	13,460	13,530	13,610	13,680	13,750	13,830	13,930	14,040	14,140	14,240	14,340	14,440	40
41	13,230	13,290	13,340	13,390	13,480	13,590	13,710	13,780	13,850	13,920	13,980	14,040	14,100	14,170	14,250	14,340	14,430	14,530	14,630	14,730	14,820	41
42	13,520	13,620	13,710	13,800	13,920	14,070	14,190	14,260	14,310	14,360	14,410	14,460	14,520	14,580	14,650	14,740	14,820	14,920	15,020	15,120	15,210	42
43	13,790	13,920	14,060	14,190	14,350	14,530	14,680	14,730	14,770	14,810	14,850	14,890	14,940	15,000	15,060	15,130	15,210	15,310	15,400	15,500	15,590	43
44	14,040	14,210	14,380	14,560	14,760	14,970	15,160	15,210	15,240	15,270	15,290	15,320	15,370	15,410	15,470	15,540	15,610	15,700	15,790	15,880	15,970	44
45	14,330	14,540	14,760	14,970	15,200	15,450	15,650	15,700	15,710	15,730	15,740	15,760	15,800	15,840	15,890	15,940	16,010	16,100	16,190	16,280	16,370	45
46	14,590	14,850	15,100	15,350	15,630	15,910	16,150	16,180	16,190	16,190	16,190	16,190	16,230	16,260	16,310	16,350	16,410	16,490	16,580	16,670	16,760	46
47	14,830	15,120	15,420	15,710	16,020	16,350	16,620	16,670	16,660	16,650	16,640	16,630	16,650	16,680	16,720	16,760	16,800	16,880	16,970	17,060	17,140	47
48	15,130	15,460	15,790	16,120	16,470	16,830	17,090	17,130	17,120	17,090	17,060	17,050	17,070	17,100	17,120	17,150	17,190	17,270	17,360	17,440	17,520	48
49	15,390	15,760	16,130	16,510	16,890	17,280	17,580	17,610	17,580	17,540	17,500	17,470	17,490	17,510	17,530	17,550	17,580	17,660	17,740	17,830	17,910	49
50	15,680	16,090	16,500	16,920	17,340	17,760	18,050	18,060	18,020	17,970	17,920	17,880	17,890	17,910	17,920	17,930	17,960	18,040	18,120	18,200	18,280	50
51	15,680	16,090	16,500	16,920	17,340	17,760	18,050	18,100	18,110	18,110	18,110	18,120	18,180	18,240	18,290	18,350	18,420	18,540	18,660	18,740	18,800	51
52	15,680	16,090	16,500	16,920	17,340	17,760	18,080	18,180	18,240	18,280	18,330	18,390	18,490	18,590	18,700	18,790	18,910	19,070	19,200	19,270	19,320	52
53	15,680	16,090	16,500	16,920	17,340	17,760	18,080	18,240	18,340	18,440	18,530	18,640	18,780	18,930	19,080	19,220	19,380	19,580	19,750	19,810	19,850	53
54	15,680	16,090	16,500	16,920	17,340	17,760	18,080	18,270	18,420	18,560	18,710	18,870	19,060	19,250	19,440	19,630	19,840	20,070	20,280	20,360	20,390	54
55	15,680	16,090	16,500	16,920	17,340	17,760	18,100	18,330	18,530	18,720	18,920	19,130	19,360	19,590	19,830	20,070	20,320	20,590	20,830	20,890	20,910	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1263.0	1263.1	1263.2	1263.3	1263.4	1263.5	1263.6	1263.7	1263.8	1263.9	1264.0	1264.1	1264.2	1264.3	1264.4	1264.5	1264.6	1264.7	1264.8	1264.9	1265.0	
56	15,680	16,090	16,500	16,920	17,340	17,760	18,100	18,370	18,620	18,860	19,110	19,370	19,640	19,920	20,200	20,480	20,780	21,090	21,370	21,430	21,430	56
57	15,680	16,090	16,500	16,920	17,340	17,760	18,100	18,390	18,690	18,980	19,270	19,580	19,900	20,230	20,550	20,880	21,220	21,580	21,890	21,990	21,980	57
58	15,680	16,090	16,500	16,920	17,340	17,760	18,140	18,480	18,820	19,160	19,500	19,860	20,220	20,590	20,960	21,330	21,720	22,110	22,420	22,500	22,480	58
59	15,680	16,090	16,500	16,920	17,340	17,760	18,150	18,530	18,920	19,310	19,700	20,110	20,520	20,930	21,340	21,760	22,190	22,620	22,970	23,050	23,010	59
60	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,520	23,580	23,530	60
61	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,520	23,620	23,620	61
62	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,540	23,700	23,760	62
63	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,540	23,750	23,860	63
64	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,540	23,760	23,930	64
65	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,560	23,830	24,050	65
66	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,560	23,870	24,140	66
67	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,560	23,880	24,210	67
68	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,600	23,980	24,350	68
69	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,600	24,030	24,460	69
70	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	70
71	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	71
72	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	72
73	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	73
74	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	74
75	15,680	16,090	16,500	16,920	17,340	17,760	18,190	18,620	19,060	19,500	19,940	20,390	20,840	21,300	21,760	22,220	22,690	23,160	23,640	24,110	24,600	75

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1265.0	1265.1	1265.2	1265.3	1265.4	1265.5	1265.6	1265.7	1265.8	1265.9	1266.0	1266.1	1266.2	1266.3	1266.4	1266.5	1266.6	1266.7	1266.8	1266.9	1267.0	
1	350	350	350	360	360	360	360	360	370	370	370	370	370	380	380	380	380	380	390	390	390	1
2	680	680	690	690	690	700	700	710	710	710	720	720	730	730	730	740	740	750	750	750	760	2
3	1,050	1,060	1,060	1,070	1,080	1,080	1,090	1,100	1,100	1,110	1,120	1,120	1,130	1,130	1,140	1,150	1,150	1,160	1,160	1,170	1,180	3
4	1,430	1,440	1,450	1,460	1,470	1,470	1,480	1,490	1,500	1,510	1,520	1,530	1,530	1,540	1,550	1,560	1,570	1,580	1,580	1,590	1,600	4
5	1,770	1,790	1,800	1,810	1,820	1,830	1,840	1,850	1,860	1,870	1,880	1,890	1,900	1,910	1,920	1,930	1,950	1,960	1,970	1,980	1,990	5
6	2,140	2,150	2,160	2,180	2,190	2,200	2,220	2,230	2,240	2,250	2,270	2,280	2,290	2,300	2,320	2,330	2,340	2,350	2,370	2,380	2,390	6
7	2,520	2,540	2,550	2,570	2,590	2,600	2,620	2,630	2,650	2,660	2,680	2,690	2,710	2,720	2,740	2,750	2,770	2,780	2,790	2,810	2,820	7
8	2,860	2,870	2,890	2,910	2,930	2,940	2,960	2,980	3,000	3,010	3,030	3,050	3,060	3,080	3,100	3,110	3,130	3,150	3,160	3,180	3,190	8
9	3,220	3,240	3,260	3,280	3,300	3,320	3,340	3,360	3,380	3,400	3,420	3,440	3,460	3,470	3,490	3,510	3,530	3,550	3,570	3,590	3,600	9
10	3,550	3,580	3,600	3,620	3,640	3,660	3,680	3,710	3,730	3,750	3,770	3,790	3,810	3,830	3,850	3,870	3,890	3,920	3,940	3,960	3,980	10
11	3,930	3,960	3,980	4,010	4,030	4,060	4,080	4,110	4,130	4,150	4,180	4,200	4,220	4,250	4,270	4,290	4,320	4,340	4,360	4,390	4,410	11
12	4,310	4,340	4,370	4,390	4,420	4,450	4,470	4,500	4,530	4,550	4,580	4,610	4,630	4,660	4,680	4,710	4,730	4,760	4,790	4,810	4,840	12
13	4,670	4,700	4,730	4,760	4,790	4,820	4,850	4,880	4,910	4,940	4,960	4,990	5,020	5,050	5,080	5,110	5,130	5,160	5,190	5,220	5,240	13
14	5,050	5,080	5,110	5,140	5,180	5,210	5,240	5,270	5,310	5,340	5,370	5,400	5,430	5,460	5,490	5,520	5,550	5,580	5,610	5,640	5,670	14
15	5,420	5,450	5,490	5,520	5,560	5,590	5,630	5,660	5,700	5,730	5,760	5,800	5,830	5,860	5,900	5,930	5,960	6,000	6,030	6,060	6,090	15
16	5,790	5,830	5,860	5,900	5,940	5,980	6,010	6,050	6,090	6,130	6,160	6,200	6,230	6,270	6,310	6,340	6,380	6,410	6,450	6,480	6,520	16
17	6,160	6,200	6,250	6,290	6,330	6,370	6,410	6,450	6,490	6,530	6,560	6,600	6,640	6,680	6,720	6,760	6,800	6,830	6,870	6,910	6,950	17
18	6,540	6,590	6,630	6,670	6,720	6,760	6,800	6,840	6,890	6,930	6,970	7,010	7,050	7,090	7,140	7,180	7,220	7,260	7,300	7,340	7,380	18
19	6,910	6,960	7,010	7,050	7,100	7,140	7,190	7,230	7,280	7,320	7,370	7,410	7,460	7,500	7,540	7,590	7,630	7,670	7,710	7,760	7,800	19
20	7,290	7,340	7,390	7,440	7,480	7,530	7,580	7,630	7,680	7,720	7,770	7,820	7,860	7,910	7,950	8,000	8,050	8,090	8,140	8,180	8,220	20
21	7,660	7,710	7,760	7,820	7,870	7,920	7,970	8,020	8,070	8,120	8,170	8,220	8,270	8,320	8,360	8,410	8,460	8,510	8,560	8,600	8,650	21
22	8,030	8,090	8,140	8,200	8,250	8,310	8,360	8,410	8,470	8,520	8,570	8,620	8,670	8,730	8,780	8,830	8,880	8,930	8,980	9,030	9,080	22
23	8,410	8,470	8,520	8,580	8,640	8,690	8,750	8,810	8,860	8,920	8,970	9,030	9,080	9,140	9,190	9,250	9,300	9,350	9,410	9,460	9,510	23
24	8,770	8,830	8,890	8,950	9,010	9,070	9,130	9,190	9,240	9,300	9,360	9,420	9,470	9,530	9,590	9,650	9,700	9,760	9,810	9,870	9,930	24
25	9,130	9,190	9,250	9,320	9,380	9,440	9,500	9,560	9,630	9,690	9,750	9,810	9,870	9,930	9,990	10,050	10,100	10,160	10,220	10,280	10,340	25
26	9,490	9,560	9,630	9,690	9,760	9,820	9,890	9,950	10,010	10,080	10,140	10,200	10,270	10,330	10,390	10,450	10,520	10,580	10,640	10,700	10,760	26
27	9,860	9,930	10,000	10,070	10,140	10,200	10,270	10,340	10,400	10,470	10,530	10,600	10,660	10,730	10,800	10,860	10,930	10,990	11,060	11,120	11,180	27
28	10,220	10,300	10,370	10,440	10,510	10,580	10,650	10,720	10,790	10,860	10,930	10,990	11,060	11,130	11,200	11,270	11,330	11,400	11,470	11,530	11,600	28
29	10,580	10,660	10,730	10,810	10,880	10,950	11,030	11,100	11,170	11,240	11,310	11,380	11,450	11,520	11,590	11,670	11,740	11,810	11,880	11,950	12,010	29
30	10,950	11,020	11,100	11,180	11,250	11,330	11,410	11,480	11,550	11,630	11,700	11,780	11,850	11,920	12,000	12,070	12,140	12,220	12,290	12,360	12,430	30
31	11,300	11,380	11,460	11,540	11,610	11,690	11,770	11,850	11,930	12,000	12,080	12,150	12,230	12,310	12,380	12,460	12,530	12,610	12,680	12,760	12,830	31
32	11,650	11,730	11,810	11,890	11,970	12,050	12,130	12,210	12,290	12,370	12,450	12,530	12,610	12,690	12,770	12,840	12,920	13,000	13,080	13,150	13,230	32
33	11,990	12,070	12,160	12,240	12,320	12,400	12,490	12,570	12,650	12,740	12,820	12,900	12,980	13,060	13,140	13,220	13,300	13,380	13,460	13,540	13,620	33
34	12,340	12,420	12,510	12,590	12,680	12,760	12,850	12,940	13,020	13,110	13,190	13,270	13,360	13,440	13,520	13,610	13,690	13,770	13,850	13,930	14,010	34
35	12,690	12,780	12,860	12,950	13,040	13,130	13,220	13,300	13,390	13,480	13,570	13,650	13,740	13,820	13,910	13,990	14,080	14,160	14,250	14,330	14,410	35
36	13,040	13,130	13,220	13,300	13,390	13,490	13,580	13,670	13,760	13,850	13,940	14,030	14,120	14,200	14,290	14,380	14,470	14,550	14,640	14,720	14,810	36
37	13,380	13,470	13,560	13,650	13,740	13,840	13,930	14,030	14,120	14,210	14,300	14,390	14,490	14,580	14,670	14,760	14,840	14,930	15,020	15,110	15,190	37
38	13,730	13,820	13,920	14,010	14,100	14,200	14,300	14,390	14,490	14,590	14,680	14,770	14,870	14,960	15,050	15,150	15,240	15,330	15,420	15,510	15,600	38
39	14,080	14,180	14,270	14,370	14,460	14,560	14,660	14,760	14,860	14,960	15,060	15,150	15,250	15,350	15,440	15,530	15,630	15,720	15,810	15,900	16,000	39
40	14,440	14,540	14,630	14,730	14,830	14,930	15,030	15,140	15,240	15,340	15,440	15,540	15,640	15,730	15,830	15,930	16,020	16,120	16,210	16,310	16,400	40
41	14,820	14,920	15,010	15,110	15,200	15,300	15,400	15,510	15,610	15,710	15,810	15,920	16,020	16,120	16,210	16,310	16,410	16,510	16,610	16,700	16,800	41
42	15,210	15,300	15,400	15,490	15,580	15,680	15,770	15,880	15,990	16,090	16,190	16,300	16,400	16,500	16,600	16,700	16,800	16,900	17,000	17,100	17,200	42
43	15,590	15,680	15,770	15,860	15,950	16,040	16,140	16,250	16,350	16,460	16,570	16,670	16,780	16,880	16,980	17,080	17,190	17,290	17,390	17,490	17,600	43
44	15,970	16,060	16,150	16,240	16,320	16,410	16,500	16,610	16,720	16,830	16,940	17,050	17,150	17,260	17,360	17,460	17,570	17,670	17,780	17,880	17,990	44
45	16,370	16,460	16,540	16,620	16,710	16,790	16,880	16,990	17,110	17,220	17,330	17,440	17,540	17,650	17,760	17,860	17,970	18,080	18,180	18,290	18,400	45
46	16,760	16,840	16,930	17,010	17,090	17,170	17,260	17,370	17,480	17,590	17,710	17,820	17,930	18,040	18,140	18,250	18,360	18,470	18,580	18,690	18,800	46
47	17,140	17,230	17,310	17,380	17,460	17,540	17,620	17,730	17,850	17,960	18,080	18,190	18,300	18,410	18,520	18,630	18,740	18,850	18,970	19,080	19,190	47
48	17,520	17,600	17,680	17,760	17,830	17,910	17,990	18,100	18,220	18,340	18,450	18,570	18,680	18,800	18,910	19,020	19,130	19,250	19,360	19,480	19,590	48
49	17,910	17,980	18,060	18,130	18,200	18,270	18,350	18,470	18,590	18,710	18,830	18,940	19,060	19,170	19,290	19,400	19,510	19,630	19,750	19,870	19,990	49
50	18,280	18,350	18,430	18,500	18,570	18,630	18,720	18,830	18,950	19,080	19,190	19,310	19,430	19,550	19,660	19,780	19,890	20,010	20,140	20,260	20,380	50
51	18,800	18,870	18,930	18,980	19,050	19,110	19,180	19,290	19,400	19,520	19,630	19,740	19,860	19,970	20,080	20,190	20,300	20,410	20,530	20,650	20,770	51
52	19,320	19,370	19,410	19,460	19,520	19,570	19,640	19,730	19,840	19,950	20,060	20,170	20,280	20,380	20,490	20,590	20,700	20,800	20,920	21,040	21,170	52
53	19,850	19,880	19,910	19,950	20,000	20,050	20,110	20,190	20,280	20,390	20,500	20,600	20,700	20,810	20,910	21,000	21,100	21,200	21,310	21,440	21,560	53
54	20,390	20,410	20,430	20,450	20,490	20,540	20,590	20,670	20,750	20,840	20,940	21,050	21,140	21,240	21,330	21,430	21,520	21,620	21,720	21,840	21,960	54
55	20,910	20,920	20,920	20,930	20,970	21,010	21,060	21,120	21,190	21,280	21,380	21,470	21,560	21,660	21,750	21,830	21,920	22,010	22,100	22,230	22,360	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1265.0	1265.1	1265.2	1265.3	1265.4	1265.5	1265.6	1265.7	1265.8	1265.9	1266.0	1266.1	1266.2	1266.3	1266.4	1266.5	1266.6	1266.7	1266.8	1266.9	1267.0	
56	21,430	21,430	21,420	21,420	21,440	21,480	21,520	21,570	21,630	21,720	21,810	21,900	21,990	22,080	22,160	22,240	22,330	22,410	22,500	22,620	22,750	56
57	21,980	21,960	21,940	21,920	21,930	21,970	22,000	22,050	22,090	22,170	22,260	22,340	22,430	22,510	22,590	22,660	22,740	22,820	22,900	23,020	23,150	57
58	22,480	22,450	22,410	22,390	22,400	22,420	22,450	22,480	22,520	22,590	22,680	22,760	22,840	22,920	22,990	23,060	23,130	23,200	23,280	23,400	23,540	58
59	23,010	22,960	22,910	22,870	22,880	22,900	22,920	22,940	22,970	23,040	23,120	23,190	23,270	23,340	23,410	23,480	23,540	23,600	23,680	23,800	23,940	59
60	23,530	23,470	23,410	23,360	23,360	23,380	23,390	23,390	23,410	23,480	23,550	23,630	23,690	23,760	23,830	23,890	23,940	24,000	24,070	24,200	24,340	60
61	23,620	23,620	23,610	23,620	23,670	23,730	23,790	23,850	23,920	24,030	24,150	24,270	24,380	24,500	24,610	24,720	24,820	24,930	25,050	25,220	25,400	61
62	23,760	23,810	23,860	23,920	24,010	24,130	24,240	24,340	24,460	24,610	24,780	24,940	25,100	25,260	25,420	25,580	25,730	25,890	26,050	26,260	26,480	62
63	23,860	23,960	24,070	24,180	24,330	24,490	24,650	24,810	24,980	25,170	25,380	25,590	25,800	26,000	26,210	26,410	26,620	26,820	27,040	27,280	27,550	63
64	23,930	24,090	24,240	24,420	24,620	24,830	25,040	25,240	25,460	25,710	25,960	26,210	26,470	26,720	26,970	27,220	27,470	27,730	27,990	28,290	28,590	64
65	24,050	24,260	24,480	24,700	24,950	25,210	25,470	25,720	25,990	26,280	26,580	26,880	27,180	27,470	27,770	28,070	28,370	28,670	28,990	29,320	29,670	65
66	24,140	24,410	24,680	24,960	25,260	25,570	25,870	26,180	26,500	26,840	27,180	27,520	27,860	28,210	28,560	28,900	29,250	29,600	29,960	30,340	30,730	66
67	24,210	24,530	24,850	25,190	25,540	25,900	26,250	26,610	26,980	27,370	27,750	28,140	28,530	28,920	29,310	29,710	30,100	30,500	30,920	31,340	31,770	67
68	24,350	24,730	25,110	25,500	25,900	26,300	26,710	27,120	27,530	27,960	28,390	28,820	29,260	29,700	30,140	30,580	31,020	31,470	31,930	32,400	32,870	68
69	24,460	24,890	25,320	25,760	26,210	26,670	27,120	27,580	28,050	28,520	28,990	29,470	29,950	30,440	30,920	31,410	31,910	32,400	32,910	33,420	33,930	69
70	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	70
71	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	71
72	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	72
73	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	73
74	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	74
75	24,600	25,080	25,570	26,070	26,560	27,060	27,570	28,080	28,590	29,110	29,630	30,150	30,680	31,210	31,740	32,280	32,820	33,370	33,910	34,470	35,020	75

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1267.0	1267.1	1267.2	1267.3	1267.4	1267.5	1267.6	1267.7	1267.8	1267.9	1268.0	1268.1	1268.2	1268.3	1268.4	1268.5	1268.6	1268.7	1268.8	1268.9	1269.0	
1	390	390	390	400	400	400	400	400	410	410	410	410	410	420	420	420	420	420	420	430	430	1
2	760	760	760	770	770	780	780	780	790	790	790	800	800	810	810	810	820	820	820	830	830	2
3	1,180	1,180	1,190	1,190	1,200	1,210	1,210	1,220	1,220	1,230	1,230	1,240	1,250	1,250	1,260	1,260	1,270	1,270	1,280	1,280	1,290	3
4	1,600	1,610	1,620	1,620	1,630	1,640	1,650	1,660	1,660	1,670	1,680	1,690	1,690	1,700	1,710	1,720	1,720	1,730	1,740	1,750	1,750	4
5	1,990	2,000	2,010	2,020	2,030	2,040	2,040	2,050	2,060	2,070	2,080	2,090	2,100	2,110	2,120	2,130	2,140	2,150	2,160	2,170	2,180	5
6	2,390	2,400	2,410	2,430	2,440	2,450	2,460	2,470	2,490	2,500	2,510	2,520	2,530	2,540	2,550	2,570	2,580	2,590	2,600	2,610	2,620	6
7	2,820	2,840	2,850	2,870	2,880	2,890	2,910	2,920	2,940	2,950	2,960	2,980	2,990	3,000	3,020	3,030	3,040	3,060	3,070	3,080	3,100	7
8	3,190	3,210	3,230	3,240	3,260	3,270	3,290	3,310	3,320	3,340	3,350	3,370	3,380	3,400	3,410	3,430	3,440	3,460	3,470	3,490	3,500	8
9	3,600	3,620	3,640	3,660	3,680	3,690	3,710	3,730	3,750	3,760	3,780	3,800	3,820	3,830	3,850	3,870	3,880	3,900	3,920	3,930	3,950	9
10	3,980	4,000	4,020	4,040	4,060	4,070	4,090	4,110	4,130	4,150	4,170	4,190	4,210	4,230	4,250	4,270	4,290	4,300	4,320	4,340	4,360	10
11	4,410	4,430	4,450	4,480	4,500	4,520	4,540	4,560	4,590	4,610	4,630	4,650	4,670	4,690	4,710	4,740	4,760	4,780	4,800	4,820	4,840	11
12	4,840	4,860	4,890	4,910	4,930	4,960	4,980	5,010	5,030	5,060	5,080	5,100	5,130	5,150	5,170	5,200	5,220	5,240	5,270	5,290	5,310	12
13	5,240	5,270	5,300	5,330	5,350	5,380	5,410	5,430	5,460	5,490	5,510	5,540	5,560	5,590	5,610	5,640	5,670	5,690	5,720	5,740	5,770	13
14	5,670	5,700	5,730	5,760	5,790	5,820	5,850	5,880	5,910	5,940	5,960	5,990	6,020	6,050	6,080	6,110	6,130	6,160	6,190	6,220	6,240	14
15	6,090	6,130	6,160	6,190	6,220	6,250	6,280	6,320	6,350	6,380	6,410	6,440	6,470	6,500	6,530	6,560	6,590	6,620	6,650	6,680	6,710	15
16	6,520	6,550	6,590	6,620	6,650	6,690	6,720	6,760	6,790	6,820	6,860	6,890	6,920	6,950	6,990	7,020	7,050	7,080	7,120	7,150	7,180	16
17	6,950	6,980	7,020	7,060	7,090	7,130	7,160	7,200	7,240	7,270	7,310	7,340	7,380	7,410	7,450	7,480	7,520	7,550	7,590	7,620	7,650	17
18	7,380	7,420	7,450	7,490	7,530	7,570	7,610	7,650	7,690	7,720	7,760	7,800	7,840	7,880	7,910	7,950	7,990	8,020	8,060	8,100	8,130	18
19	7,800	7,840	7,880	7,920	7,960	8,010	8,050	8,090	8,130	8,170	8,210	8,250	8,290	8,330	8,370	8,410	8,450	8,490	8,520	8,560	8,600	19
20	8,220	8,270	8,310	8,360	8,400	8,440	8,490	8,530	8,570	8,620	8,660	8,700	8,740	8,790	8,830	8,870	8,910	8,950	8,990	9,030	9,070	20
21	8,650	8,700	8,740	8,790	8,840	8,880	8,930	8,980	9,020	9,070	9,110	9,160	9,200	9,250	9,290	9,330	9,380	9,420	9,470	9,510	9,550	21
22	9,080	9,130	9,180	9,230	9,280	9,330	9,380	9,430	9,470	9,520	9,570	9,620	9,660	9,710	9,760	9,810	9,850	9,900	9,940	9,990	10,040	22
23	9,510	9,560	9,620	9,670	9,720	9,770	9,820	9,870	9,930	9,980	10,030	10,080	10,130	10,180	10,230	10,280	10,330	10,370	10,420	10,470	10,520	23
24	9,930	9,980	10,040	10,090	10,140	10,200	10,250	10,310	10,360	10,410	10,470	10,520	10,570	10,620	10,680	10,730	10,780	10,830	10,880	10,930	10,990	24
25	10,340	10,400	10,450	10,510	10,570	10,630	10,680	10,740	10,790	10,850	10,910	10,960	11,020	11,070	11,130	11,180	11,230	11,290	11,340	11,400	11,450	25
26	10,760	10,820	10,880	10,940	11,000	11,060	11,120	11,180	11,240	11,300	11,350	11,410	11,470	11,530	11,580	11,640	11,700	11,760	11,810	11,870	11,920	26
27	11,180	11,250	11,310	11,370	11,430	11,500	11,560	11,620	11,680	11,740	11,800	11,860	11,920	11,980	12,040	12,100	12,160	12,220	12,280	12,340	12,400	27
28	11,600	11,670	11,730	11,800	11,860	11,930	11,990	12,060	12,120	12,180	12,250	12,310	12,370	12,440	12,500	12,560	12,620	12,680	12,740	12,810	12,870	28
29	12,010	12,080	12,150	12,220	12,290	12,350	12,420	12,490	12,550	12,620	12,690	12,750	12,820	12,880	12,950	13,010	13,080	13,140	13,200	13,270	13,330	29
30	12,430	12,500	12,570	12,650	12,720	12,790	12,860	12,920	12,990	13,060	13,130	13,200	13,270	13,330	13,400	13,470	13,540	13,600	13,670	13,730	13,800	30
31	12,830	12,910	12,980	13,050	13,120	13,200	13,270	13,340	13,410	13,480	13,560	13,630	13,700	13,770	13,840	13,910	13,980	14,050	14,110	14,180	14,250	31
32	13,230	13,300	13,380	13,450	13,530	13,610	13,680	13,760	13,830	13,900	13,980	14,050	14,120	14,200	14,270	14,340	14,410	14,490	14,560	14,630	14,700	32
33	13,620	13,690	13,770	13,850	13,930	14,000	14,080	14,160	14,240	14,310	14,390	14,470	14,540	14,620	14,690	14,770	14,840	14,920	14,990	15,060	15,140	33
34	14,010	14,090	14,170	14,250	14,330	14,410	14,490	14,570	14,650	14,730	14,810	14,890	14,970	15,050	15,120	15,200	15,280	15,350	15,430	15,510	15,580	34
35	14,410	14,490	14,580	14,660	14,740	14,820	14,910	14,990	15,070	15,150	15,240	15,320	15,400	15,480	15,560	15,640	15,720	15,800	15,880	15,960	16,040	35
36	14,810	14,890	14,980	15,060	15,140	15,230	15,320	15,400	15,490	15,570	15,660	15,740	15,830	15,910	15,990	16,080	16,160	16,240	16,320	16,400	16,480	36
37	15,190	15,280	15,370	15,450	15,540	15,630	15,720	15,800	15,890	15,980	16,070	16,150	16,240	16,330	16,410	16,500	16,580	16,670	16,750	16,840	16,920	37
38	15,600	15,680	15,770	15,860	15,950	16,040	16,130	16,220	16,310	16,400	16,490	16,580	16,670	16,760	16,850	16,940	17,030	17,110	17,200	17,290	17,370	38
39	16,000	16,090	16,180	16,270	16,360	16,450	16,550	16,640	16,730	16,830	16,920	17,010	17,100	17,200	17,290	17,380	17,470	17,560	17,650	17,740	17,830	39
40	16,400	16,490	16,590	16,680	16,770	16,870	16,970	17,060	17,160	17,260	17,350	17,450	17,540	17,630	17,730	17,820	17,920	18,010	18,100	18,190	18,280	40
41	16,800	16,890	16,990	17,080	17,180	17,280	17,380	17,480	17,570	17,670	17,770	17,870	17,960	18,060	18,150	18,250	18,340	18,440	18,530	18,630	18,720	41
42	17,200	17,300	17,400	17,490	17,590	17,690	17,790	17,900	18,000	18,090	18,190	18,290	18,390	18,490	18,580	18,680	18,780	18,880	18,970	19,070	19,170	42
43	17,600	17,700	17,800	17,900	18,000	18,100	18,200	18,310	18,410	18,510	18,610	18,710	18,810	18,910	19,010	19,100	19,200	19,300	19,400	19,500	19,600	43
44	17,990	18,090	18,200	18,300	18,400	18,510	18,610	18,710	18,820	18,920	19,020	19,130	19,230	19,330	19,430	19,530	19,630	19,730	19,830	19,940	20,040	44
45	18,400	18,510	18,610	18,720	18,820	18,930	19,040	19,140	19,250	19,350	19,460	19,560	19,660	19,760	19,870	19,970	20,070	20,180	20,280	20,390	20,490	45
46	18,800	18,910	19,020	19,130	19,240	19,340	19,450	19,560	19,670	19,770	19,880	19,980	20,090	20,190	20,300	20,400	20,500	20,610	20,720	20,830	20,930	46
47	19,190	19,310	19,420	19,530	19,640	19,750	19,860	19,970	20,080	20,190	20,290	20,400	20,510	20,610	20,720	20,820	20,930	21,040	21,150	21,260	21,370	47
48	19,590	19,710	19,820	19,930	20,050	20,160	20,270	20,380	20,490	20,600	20,710	20,820	20,930	21,040	21,140	21,250	21,360	21,470	21,580	21,700	21,810	48
49	19,990	20,110	20,220	20,340	20,450	20,570	20,680	20,790	20,910	21,020	21,130	21,240	21,350	21,460	21,570	21,670	21,780	21,900	22,010	22,130	22,240	49
50	20,380	20,500	20,620	20,740	20,850	20,970	21,090	21,200	21,310	21,430	21,540	21,650	21,760	21,870	21,980	22,090	22,200	22,320	22,440	22,560	22,680	50
51	20,770	20,890	21,020	21,140	21,250	21,370	21,490	21,610	21,720	21,840	21,950	22,070	22,180	22,300	22,410	22,520	22,640	22,760	22,880	23,000	23,120	51
52	21,170	21,290	21,410	21,530	21,650	21,770	21,890	22,010	22,130	22,250	22,370	22,490	22,600	22,720	22,840	22,950	23,070	23,190	23,310	23,430	23,550	52
53	21,560	21,690	21,810	21,940	22,060	22,180	22,300	22,420	22,540	22,660	22,790	22,910	23,030	23,150	23,270	23,380	23,500	23,630	23,750	23,870	24,000	53
54	21,960	22,090	22,220	22,340	22,470	22,590	22,710	22,840	22,960	23,080	23,210	23,330	23,460	23,580	23,700	23,820	23,940	24,070	24,200	24,320	24,450	54
55	22,360	22,490	22,620	22,740	22,870	22,990	23,120	23,240	23,370	23,490	23,620	23,750	23,880	24,000	24,130	24,250	24,380	24,500	24,630	24,760	24,880	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1267.0	1267.1	1267.2	1267.3	1267.4	1267.5	1267.6	1267.7	1267.8	1267.9	1268.0	1268.1	1268.2	1268.3	1268.4	1268.5	1268.6	1268.7	1268.8	1268.9	1269.0	
56	22,750	22,880	23,010	23,140	23,270	23,400	23,520	23,650	23,770	23,900	24,040	24,170	24,300	24,420	24,550	24,680	24,810	24,940	25,070	25,200	25,320	56
57	23,150	23,280	23,420	23,550	23,680	23,800	23,930	24,060	24,190	24,320	24,450	24,590	24,720	24,850	24,980	25,110	25,240	25,380	25,510	25,640	25,770	57
58	23,540	23,670	23,810	23,940	24,070	24,200	24,330	24,460	24,590	24,720	24,860	25,000	25,140	25,270	25,400	25,540	25,670	25,810	25,940	26,070	26,200	58
59	23,940	24,070	24,210	24,340	24,480	24,610	24,740	24,870	25,000	25,140	25,280	25,420	25,560	25,700	25,830	25,970	26,110	26,240	26,380	26,510	26,650	59
60	24,340	24,480	24,610	24,750	24,890	25,020	25,150	25,280	25,420	25,560	25,700	25,850	25,990	26,130	26,270	26,410	26,550	26,680	26,820	26,960	27,090	60
61	25,400	25,580	25,760	25,940	26,060	26,170	26,290	26,400	26,510	26,640	26,770	26,900	27,030	27,150	27,280	27,410	27,540	27,670	27,800	27,920	28,050	61
62	26,480	26,710	26,930	27,100	27,200	27,300	27,390	27,480	27,580	27,700	27,810	27,930	28,040	28,160	28,280	28,400	28,520	28,640	28,760	28,870	28,990	62
63	27,550	27,810	28,080	28,260	28,340	28,420	28,490	28,570	28,650	28,750	28,850	28,950	29,050	29,150	29,270	29,380	29,490	29,600	29,700	29,810	29,910	63
64	28,590	28,900	29,210	29,430	29,500	29,560	29,620	29,670	29,740	29,820	29,910	29,990	30,080	30,170	30,270	30,370	30,470	30,570	30,670	30,770	30,860	64
65	29,670	30,020	30,370	30,610	30,670	30,710	30,750	30,780	30,830	30,900	30,970	31,040	31,110	31,190	31,280	31,380	31,470	31,560	31,650	31,730	31,810	65
66	30,730	31,120	31,520	31,780	31,820	31,840	31,860	31,870	31,900	31,960	32,020	32,080	32,130	32,190	32,280	32,360	32,450	32,530	32,600	32,680	32,750	66
67	31,770	32,210	32,640	32,950	32,970	32,980	32,980	32,970	32,980	33,030	33,070	33,110	33,150	33,200	33,280	33,350	33,420	33,490	33,560	33,630	33,690	67
68	32,870	33,340	33,800	34,080	34,090	34,080	34,060	34,040	34,030	34,070	34,100	34,120	34,150	34,190	34,250	34,320	34,380	34,440	34,500	34,550	34,610	68
69	33,930	34,450	34,950	35,260	35,250	35,210	35,180	35,130	35,110	35,130	35,150	35,160	35,170	35,190	35,250	35,310	35,360	35,410	35,460	35,510	35,550	69
70	35,020	35,580	36,120	36,430	36,400	36,350	36,290	36,230	36,200	36,200	36,200	36,200	36,190	36,210	36,260	36,310	36,350	36,390	36,430	36,470	36,500	70
71	35,020	35,580	36,140	36,510	36,550	36,560	36,560	36,560	36,580	36,640	36,700	36,760	36,810	36,880	36,990	37,090	37,190	37,290	37,380	37,480	37,560	71
72	35,020	35,580	36,140	36,560	36,650	36,720	36,790	36,860	36,940	37,060	37,180	37,290	37,410	37,530	37,690	37,850	38,010	38,170	38,320	38,470	38,620	72
73	35,020	35,580	36,140	36,580	36,730	36,870	37,000	37,130	37,280	37,450	37,630	37,810	37,980	38,170	38,380	38,600	38,810	39,020	39,240	39,450	39,650	73
74	35,020	35,580	36,140	36,580	36,790	36,990	37,190	37,380	37,590	37,830	38,060	38,300	38,530	38,780	39,050	39,320	39,590	39,860	40,130	40,400	40,670	74
75	35,020	35,580	36,140	36,610	36,890	37,150	37,410	37,670	37,940	38,230	38,530	38,830	39,120	39,430	39,750	40,080	40,410	40,730	41,060	41,390	41,720	75
76	35,020	35,580	36,140	36,610	36,940	37,270	37,590	37,910	38,240	38,600	38,950	39,300	39,660	40,020	40,400	40,790	41,170	41,550	41,940	42,320	42,710	76
77	35,020	35,580	36,140	36,630	37,030	37,410	37,800	38,180	38,580	38,990	39,400	39,820	40,230	40,660	41,090	41,530	41,970	42,410	42,850	43,300	43,740	77
78	35,020	35,580	36,140	36,660	37,110	37,560	38,010	38,460	38,920	39,380	39,860	40,330	40,800	41,290	41,780	42,270	42,770	43,270	43,770	44,270	44,780	78
79	35,020	35,580	36,140	36,710	37,220	37,730	38,250	38,760	39,280	39,810	40,340	40,870	41,410	41,950	42,490	43,040	43,600	44,150	44,710	45,270	45,840	79
80	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	80
81	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	81
82	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	82
83	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	83
84	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	84
85	35,020	35,580	36,140	36,710	37,280	37,850	38,420	39,000	39,590	40,170	40,760	41,360	41,950	42,550	43,150	43,760	44,370	44,990	45,600	46,220	46,850	85

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1269.0	1269.1	1269.2	1269.3	1269.4	1269.5	1269.6	1269.7	1269.8	1269.9	1270.0	1270.1	1270.2	1270.3	1270.4	1270.5	1270.6	1270.7	1270.8	1270.9	1271.0	
1	430	430	430	430	430	440	440	440	440	440	450	450	450	450	450	450	460	460	460	460	460	1
2	830	830	840	840	840	850	850	850	860	860	860	870	870	870	880	880	880	890	890	890	900	2
3	1,290	1,290	1,300	1,300	1,310	1,320	1,320	1,330	1,330	1,340	1,340	1,350	1,350	1,360	1,360	1,370	1,370	1,380	1,380	1,390	1,390	3
4	1,750	1,760	1,770	1,780	1,780	1,790	1,800	1,800	1,810	1,820	1,820	1,830	1,840	1,850	1,850	1,860	1,870	1,870	1,880	1,890	1,890	4
5	2,180	2,190	2,190	2,200	2,210	2,220	2,230	2,240	2,250	2,260	2,260	2,270	2,280	2,290	2,300	2,310	2,320	2,320	2,330	2,340	2,350	5
6	2,620	2,630	2,640	2,650	2,660	2,670	2,680	2,690	2,710	2,720	2,730	2,740	2,750	2,760	2,770	2,780	2,790	2,800	2,810	2,820	2,830	6
7	3,100	3,110	3,120	3,130	3,150	3,160	3,170	3,180	3,200	3,210	3,220	3,230	3,250	3,260	3,270	3,280	3,290	3,310	3,320	3,330	3,340	7
8	3,500	3,520	3,530	3,550	3,560	3,570	3,590	3,600	3,620	3,630	3,640	3,660	3,670	3,690	3,700	3,710	3,730	3,740	3,750	3,770	3,780	8
9	3,950	3,970	3,980	4,000	4,020	4,030	4,050	4,060	4,080	4,100	4,110	4,130	4,140	4,160	4,170	4,190	4,200	4,220	4,240	4,250	4,270	9
10	4,360	4,380	4,390	4,410	4,430	4,450	4,460	4,480	4,500	4,520	4,530	4,550	4,570	4,590	4,600	4,620	4,640	4,650	4,670	4,690	4,710	10
11	4,840	4,860	4,880	4,900	4,920	4,940	4,960	4,980	5,000	5,020	5,040	5,060	5,080	5,100	5,120	5,130	5,150	5,170	5,190	5,210	5,230	11
12	5,310	5,330	5,360	5,380	5,400	5,420	5,450	5,470	5,490	5,510	5,530	5,550	5,580	5,600	5,620	5,640	5,660	5,680	5,700	5,720	5,740	12
13	5,770	5,790	5,820	5,840	5,860	5,890	5,910	5,940	5,960	5,990	6,010	6,030	6,060	6,080	6,100	6,120	6,150	6,170	6,190	6,220	6,240	13
14	6,240	6,270	6,300	6,320	6,350	6,380	6,400	6,430	6,460	6,480	6,510	6,530	6,560	6,580	6,610	6,640	6,660	6,680	6,710	6,730	6,760	14
15	6,710	6,740	6,770	6,800	6,830	6,850	6,880	6,910	6,940	6,970	7,000	7,020	7,050	7,080	7,110	7,130	7,160	7,190	7,210	7,240	7,270	15
16	7,180	7,210	7,240	7,270	7,300	7,340	7,370	7,400	7,430	7,460	7,490	7,520	7,550	7,580	7,610	7,640	7,660	7,690	7,720	7,750	7,780	16
17	7,650	7,690	7,720	7,760	7,790	7,820	7,860	7,890	7,920	7,960	7,990	8,020	8,050	8,080	8,110	8,140	8,180	8,210	8,240	8,270	8,300	17
18	8,130	8,170	8,210	8,240	8,280	8,310	8,350	8,380	8,420	8,450	8,490	8,520	8,560	8,590	8,620	8,650	8,690	8,720	8,750	8,790	8,820	18
19	8,600	8,640	8,680	8,720	8,750	8,790	8,830	8,870	8,910	8,940	8,980	9,020	9,050	9,090	9,120	9,160	9,190	9,230	9,260	9,300	9,330	19
20	9,070	9,120	9,160	9,200	9,240	9,280	9,320	9,360	9,400	9,440	9,470	9,510	9,550	9,590	9,620	9,660	9,700	9,730	9,770	9,810	9,840	20
21	9,550	9,600	9,640	9,680	9,730	9,770	9,810	9,850	9,890	9,940	9,980	10,020	10,060	10,100	10,140	10,180	10,220	10,260	10,300	10,330	10,370	21
22	10,040	10,080	10,130	10,170	10,220	10,260	10,310	10,350	10,400	10,440	10,490	10,530	10,570	10,610	10,660	10,700	10,740	10,780	10,820	10,870	10,910	22
23	10,520	10,570	10,620	10,660	10,710	10,760	10,810	10,850	10,900	10,950	10,990	11,040	11,090	11,130	11,180	11,220	11,260	11,310	11,350	11,400	11,440	23
24	10,990	11,040	11,090	11,140	11,190	11,240	11,290	11,340	11,390	11,430	11,480	11,530	11,580	11,630	11,670	11,720	11,770	11,820	11,860	11,910	11,950	24
25	11,450	11,500	11,560	11,610	11,660	11,710	11,770	11,820	11,870	11,920	11,970	12,020	12,070	12,120	12,170	12,220	12,270	12,320	12,370	12,420	12,470	25
26	11,920	11,980	12,030	12,090	12,140	12,200	12,250	12,310	12,360	12,420	12,470	12,520	12,580	12,630	12,680	12,730	12,780	12,840	12,890	12,940	12,990	26
27	12,400	12,460	12,510	12,570	12,630	12,690	12,740	12,800	12,860	12,910	12,970	13,020	13,080	13,130	13,190	13,240	13,300	13,350	13,410	13,460	13,520	27
28	12,870	12,930	12,990	13,050	13,110	13,170	13,230	13,290	13,340	13,400	13,460	13,520	13,580	13,640	13,690	13,750	13,810	13,860	13,920	13,980	14,030	28
29	13,330	13,390	13,460	13,520	13,580	13,640	13,710	13,770	13,830	13,890	13,950	14,010	14,070	14,130	14,190	14,250	14,310	14,370	14,430	14,490	14,550	29
30	13,800	13,870	13,930	14,000	14,060	14,120	14,190	14,250	14,320	14,380	14,440	14,510	14,570	14,630	14,690	14,760	14,820	14,880	14,940	15,000	15,060	30
31	14,250	14,320	14,390	14,450	14,520	14,590	14,660	14,720	14,790	14,850	14,920	14,990	15,050	15,120	15,180	15,250	15,310	15,370	15,440	15,500	15,570	31
32	14,700	14,770	14,840	14,910	14,980	15,050	15,120	15,190	15,260	15,330	15,390	15,460	15,530	15,600	15,660	15,730	15,800	15,870	15,930	16,000	16,060	32
33	15,140	15,210	15,280	15,360	15,430	15,500	15,570	15,640	15,710	15,790	15,860	15,930	16,000	16,070	16,140	16,210	16,280	16,340	16,410	16,480	16,550	33
34	15,580	15,660	15,730	15,810	15,880	15,960	16,030	16,110	16,180	16,250	16,330	16,400	16,470	16,550	16,620	16,690	16,760	16,830	16,900	16,970	17,050	34
35	16,040	16,120	16,190	16,270	16,350	16,430	16,500	16,580	16,650	16,730	16,810	16,880	16,960	17,030	17,110	17,180	17,250	17,330	17,400	17,480	17,550	35
36	16,480	16,560	16,650	16,730	16,810	16,890	16,960	17,040	17,120	17,200	17,280	17,360	17,430	17,510	17,590	17,670	17,740	17,820	17,890	17,970	18,050	36
37	16,920	17,000	17,090	17,170	17,250	17,330	17,420	17,500	17,580	17,660	17,740	17,820	17,900	17,980	18,060	18,140	18,220	18,300	18,370	18,450	18,530	37
38	17,370	17,460	17,550	17,630	17,720	17,800	17,880	17,970	18,050	18,140	18,220	18,300	18,380	18,470	18,550	18,630	18,710	18,790	18,870	18,950	19,030	38
39	17,830	17,910	18,000	18,090	18,180	18,260	18,350	18,440	18,520	18,610	18,700	18,780	18,870	18,950	19,030	19,120	19,200	19,290	19,370	19,450	19,540	39
40	18,280	18,370	18,470	18,560	18,650	18,740	18,830	18,910	19,000	19,090	19,180	19,270	19,350	19,440	19,530	19,620	19,700	19,790	19,870	19,960	20,040	40
41	18,720	18,820	18,910	19,000	19,100	19,190	19,280	19,370	19,460	19,550	19,640	19,730	19,820	19,910	20,000	20,090	20,180	20,270	20,360	20,440	20,530	41
42	19,170	19,260	19,360	19,460	19,550	19,650	19,740	19,830	19,930	20,020	20,110	20,210	20,300	20,390	20,480	20,570	20,670	20,760	20,850	20,940	21,030	42
43	19,600	19,700	19,800	19,900	20,000	20,090	20,190	20,290	20,380	20,480	20,570	20,670	20,760	20,860	20,950	21,050	21,140	21,230	21,330	21,420	21,510	43
44	20,040	20,140	20,240	20,340	20,440	20,540	20,640	20,740	20,840	20,940	21,030	21,130	21,230	21,330	21,420	21,520	21,610	21,710	21,800	21,900	21,990	44
45	20,490	20,600	20,700	20,800	20,910	21,010	21,110	21,210	21,310	21,410	21,510	21,610	21,710	21,810	21,910	22,010	22,110	22,210	22,300	22,400	22,500	45
46	20,930	21,040	21,150	21,250	21,360	21,460	21,570	21,670	21,780	21,880	21,980	22,090	22,190	22,290	22,390	22,490	22,590	22,690	22,790	22,890	22,990	46
47	21,370	21,480	21,590	21,700	21,800	21,910	22,020	22,120	22,230	22,340	22,440	22,550	22,650	22,760	22,860	22,960	23,070	23,170	23,270	23,370	23,470	47
48	21,810	21,920	22,030	22,140	22,250	22,360	22,470	22,580	22,690	22,800	22,910	23,020	23,120	23,230	23,340	23,440	23,550	23,650	23,760	23,860	23,960	48
49	22,240	22,360	22,470	22,590	22,700	22,810	22,920	23,040	23,150	23,260	23,370	23,480	23,590	23,700	23,810	23,910	24,020	24,130	24,240	24,340	24,450	49
50	22,680	22,790	22,910	23,030	23,140	23,260	23,370	23,490	23,600	23,710	23,830	23,940	24,050	24,160	24,270	24,380	24,490	24,600	24,710	24,820	24,930	50
51	23,120	23,230	23,350	23,470	23,590	23,700	23,820	23,940	24,050	24,170	24,280	24,400	24,510	24,630	24,740	24,850	24,960	25,080	25,190	25,300	25,410	51
52	23,550	23,670	23,790	23,910	24,030	24,150	24,270	24,390	24,500	24,620	24,740	24,860	24,970	25,090	25,210	25,320	25,440	25,550	25,660	25,780	25,890	52
53	24,000	24,120	24,240	24,360	24,480	24,600	24,720	24,840	24,960	25,080	25,200	25,320	25,440	25,560	25,680	25,800	25,910	26,030	26,150	26,260	26,380	53
54	24,450	24,570	24,690	24,820	24,940	25,060	25,180	25,300	25,420	25,540	25,670	25,790	25,910	26,030	26,150	26,270	26,390	26,510	26,630	26,750	26,870	54
55	24,880	25,010	25,140	25,260	25,380	25,510	25,630	25,750	25,870	26,000	26,120	26,250	26,370	26,500	26,620	26,740	26,870	26,990	27,110	27,230	27,350	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1269.0	1269.1	1269.2	1269.3	1269.4	1269.5	1269.6	1269.7	1269.8	1269.9	1270.0	1270.1	1270.2	1270.3	1270.4	1270.5	1270.6	1270.7	1270.8	1270.9	1271.0	
56	25,320	25,450	25,580	25,700	25,830	25,950	26,080	26,200	26,320	26,450	26,580	26,710	26,840	26,960	27,090	27,210	27,340	27,460	27,590	27,710	27,830	56
57	25,770	25,900	26,030	26,150	26,280	26,410	26,530	26,660	26,780	26,910	27,040	27,170	27,300	27,430	27,560	27,690	27,820	27,940	28,070	28,200	28,320	57
58	26,200	26,330	26,460	26,590	26,720	26,850	26,980	27,100	27,230	27,360	27,490	27,630	27,760	27,890	28,020	28,150	28,280	28,410	28,540	28,670	28,800	58
59	26,650	26,780	26,910	27,040	27,170	27,300	27,430	27,560	27,690	27,820	27,960	28,090	28,230	28,360	28,490	28,630	28,760	28,890	29,020	29,150	29,280	59
60	27,090	27,230	27,360	27,490	27,620	27,760	27,890	28,010	28,150	28,280	28,420	28,560	28,700	28,830	28,970	29,110	29,240	29,380	29,510	29,640	29,780	60
61	28,050	28,170	28,290	28,420	28,550	28,690	28,820	28,950	29,090	29,230	29,370	29,510	29,650	29,780	29,930	30,070	30,210	30,350	30,480	30,620	30,760	61
62	28,990	29,100	29,210	29,330	29,470	29,610	29,750	29,880	30,020	30,160	30,310	30,450	30,590	30,730	30,880	31,020	31,170	31,310	31,460	31,600	31,740	62
63	29,910	30,020	30,120	30,240	30,380	30,520	30,660	30,800	30,940	31,090	31,230	31,370	31,520	31,660	31,820	31,970	32,120	32,260	32,410	32,560	32,710	63
64	30,860	30,950	31,040	31,150	31,290	31,440	31,580	31,730	31,870	32,020	32,160	32,310	32,450	32,600	32,760	32,910	33,070	33,220	33,370	33,530	33,680	64
65	31,810	31,890	31,970	32,080	32,220	32,370	32,520	32,670	32,810	32,960	33,110	33,260	33,410	33,560	33,720	33,880	34,040	34,200	34,350	34,510	34,670	65
66	32,750	32,820	32,890	32,980	33,140	33,290	33,440	33,590	33,740	33,890	34,040	34,190	34,340	34,490	34,660	34,830	34,990	35,150	35,320	35,480	35,640	66
67	33,690	33,750	33,800	33,890	34,040	34,200	34,350	34,510	34,660	34,810	34,970	35,120	35,270	35,420	35,590	35,760	35,930	36,100	36,270	36,430	36,600	67
68	34,610	34,650	34,700	34,790	34,950	35,110	35,270	35,430	35,580	35,740	35,890	36,050	36,200	36,360	36,540	36,710	36,880	37,060	37,230	37,400	37,570	68
69	35,550	35,580	35,620	35,710	35,870	36,030	36,190	36,350	36,510	36,670	36,830	36,980	37,140	37,300	37,480	37,660	37,840	38,020	38,200	38,370	38,550	69
70	36,500	36,520	36,550	36,630	36,800	36,970	37,130	37,290	37,460	37,620	37,780	37,930	38,090	38,260	38,440	38,630	38,810	38,990	39,180	39,360	39,540	70
71	37,560	37,650	37,730	37,860	38,070	38,290	38,500	38,660	38,810	38,940	39,080	39,220	39,360	39,500	39,670	39,830	40,000	40,160	40,330	40,500	40,670	71
72	38,620	38,770	38,910	39,090	39,350	39,610	39,870	40,080	40,210	40,330	40,440	40,560	40,670	40,800	40,950	41,090	41,240	41,380	41,540	41,690	41,840	72
73	39,650	39,860	40,070	40,300	40,610	40,910	41,220	41,490	41,600	41,700	41,790	41,880	41,980	42,090	42,210	42,340	42,460	42,590	42,730	42,870	43,010	73
74	40,670	40,940	41,200	41,500	41,850	42,210	42,560	42,880	42,990	43,070	43,140	43,210	43,280	43,380	43,480	43,590	43,690	43,800	43,920	44,050	44,170	74
75	41,720	42,040	42,370	42,720	43,120	43,520	43,930	44,280	44,380	44,430	44,480	44,530	44,580	44,650	44,740	44,830	44,910	44,990	45,110	45,220	45,330	75
76	42,710	43,090	43,480	43,890	44,340	44,790	45,240	45,640	45,750	45,790	45,810	45,840	45,870	45,920	45,990	46,060	46,120	46,190	46,280	46,380	46,470	76
77	43,740	44,190	44,640	45,100	45,600	46,090	46,590	47,040	47,140	47,150	47,160	47,160	47,170	47,210	47,260	47,300	47,350	47,390	47,470	47,560	47,640	77
78	44,780	45,280	45,790	46,310	46,860	47,400	47,950	48,440	48,530	48,520	48,510	48,490	48,470	48,490	48,520	48,550	48,570	48,600	48,660	48,730	48,800	78
79	45,840	46,400	46,970	47,550	48,130	48,730	49,320	49,840	49,910	49,880	49,840	49,800	49,760	49,760	49,770	49,780	49,780	49,790	49,840	49,900	49,950	79
80	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,220	51,310	51,260	51,200	51,140	51,080	51,060	51,050	51,040	51,020	51,010	51,040	51,090	51,130	80
81	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,270	51,420	51,440	51,450	51,460	51,470	51,520	51,580	51,630	51,680	51,730	51,830	51,930	52,040	81
82	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,270	51,490	51,580	51,660	51,740	51,820	51,940	52,060	52,190	52,310	52,430	52,590	52,760	52,930	82
83	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,270	51,550	51,710	51,870	52,020	52,170	52,360	52,550	52,750	52,930	53,130	53,350	53,590	53,820	83
84	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,270	51,600	51,830	52,050	52,280	52,510	52,760	53,030	53,290	53,550	53,810	54,100	54,400	54,700	84
85	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,280	51,680	51,980	52,280	52,580	52,880	53,200	53,530	53,860	54,190	54,520	54,880	55,240	55,610	85
86	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,280	51,700	52,070	52,440	52,810	53,180	53,580	53,970	54,370	54,770	55,170	55,590	56,020	56,440	86
87	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,280	51,770	52,210	52,650	53,090	53,540	54,000	54,460	54,930	55,390	55,870	56,350	56,840	57,340	87
88	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,280	51,830	52,340	52,850	53,370	53,890	54,420	54,950	55,490	56,020	56,560	57,110	57,670	58,230	88
89	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,930	52,510	53,100	53,680	54,270	54,870	55,470	56,080	56,680	57,290	57,910	58,530	59,150	89
90	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	90
91	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	91
92	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	92
93	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	93
94	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	94
95	46,850	47,470	48,100	48,740	49,370	50,010	50,660	51,310	51,960	52,610	53,270	53,930	54,590	55,260	55,930	56,600	57,280	57,960	58,640	59,330	60,020	95

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1271.0	1271.1	1271.2	1271.3	1271.4	1271.5	1271.6	1271.7	1271.8	1271.9	1272.0	1272.1	1272.2	1272.3	1272.4	1272.5	1272.6	1272.7	1272.8	1272.9	1273.0	
1	460	460	470	470	470	470	470	470	470	480	480	480	480	480	480	490	490	490	490	490	490	1
2	900	900	900	910	910	910	910	920	920	920	930	930	930	940	940	940	950	950	950	950	960	2
3	1,390	1,400	1,400	1,410	1,410	1,420	1,420	1,430	1,430	1,440	1,440	1,450	1,450	1,450	1,460	1,460	1,470	1,470	1,480	1,480	1,490	3
4	1,890	1,900	1,910	1,910	1,920	1,930	1,930	1,940	1,950	1,950	1,960	1,970	1,970	1,980	1,990	1,990	2,000	2,000	2,010	2,020	2,020	4
5	2,350	2,360	2,370	2,370	2,380	2,390	2,400	2,410	2,420	2,420	2,430	2,440	2,450	2,460	2,460	2,470	2,480	2,490	2,500	2,500	2,510	5
6	2,830	2,840	2,850	2,860	2,870	2,880	2,890	2,900	2,910	2,920	2,930	2,940	2,950	2,960	2,970	2,980	2,990	2,990	3,000	3,010	3,020	6
7	3,340	3,350	3,370	3,380	3,390	3,400	3,410	3,420	3,440	3,450	3,460	3,470	3,480	3,490	3,500	3,520	3,530	3,540	3,550	3,560	3,570	7
8	3,780	3,790	3,810	3,820	3,830	3,850	3,860	3,870	3,890	3,900	3,910	3,930	3,940	3,950	3,960	3,980	3,990	4,000	4,020	4,030	4,040	8
9	4,270	4,280	4,300	4,310	4,330	4,340	4,360	4,370	4,390	4,400	4,410	4,430	4,440	4,460	4,470	4,490	4,500	4,520	4,530	4,540	4,560	9
10	4,710	4,720	4,740	4,760	4,770	4,790	4,800	4,820	4,840	4,850	4,870	4,890	4,900	4,920	4,930	4,950	4,970	4,980	5,000	5,010	5,030	10
11	5,230	5,250	5,270	5,280	5,300	5,320	5,340	5,360	5,380	5,390	5,410	5,430	5,450	5,470	5,480	5,500	5,520	5,540	5,560	5,570	5,590	11
12	5,740	5,760	5,790	5,810	5,830	5,850	5,870	5,890	5,910	5,930	5,950	5,970	5,990	6,010	6,030	6,050	6,070	6,090	6,100	6,120	6,140	12
13	6,240	6,260	6,280	6,310	6,330	6,350	6,370	6,390	6,420	6,440	6,460	6,480	6,500	6,530	6,550	6,570	6,590	6,610	6,630	6,650	6,670	13
14	6,760	6,780	6,810	6,830	6,860	6,880	6,900	6,930	6,950	6,980	7,000	7,020	7,050	7,070	7,090	7,120	7,140	7,160	7,190	7,210	7,230	14
15	7,270	7,290	7,320	7,350	7,370	7,400	7,420	7,450	7,480	7,500	7,530	7,550	7,580	7,600	7,630	7,650	7,680	7,700	7,730	7,750	7,780	15
16	7,780	7,810	7,840	7,860	7,890	7,920	7,950	7,980	8,000	8,030	8,060	8,090	8,110	8,140	8,170	8,190	8,220	8,250	8,270	8,300	8,330	16
17	8,300	8,330	8,360	8,390	8,420	8,450	8,480	8,510	8,540	8,570	8,600	8,630	8,660	8,680	8,710	8,740	8,770	8,800	8,830	8,860	8,890	17
18	8,820	8,850	8,880	8,910	8,950	8,980	9,010	9,040	9,070	9,110	9,140	9,170	9,200	9,230	9,260	9,290	9,320	9,350	9,380	9,410	9,440	18
19	9,330	9,360	9,400	9,430	9,470	9,500	9,530	9,570	9,600	9,630	9,670	9,700	9,730	9,770	9,800	9,830	9,860	9,900	9,930	9,960	9,990	19
20	9,840	9,880	9,920	9,950	9,990	10,020	10,060	10,100	10,130	10,170	10,200	10,240	10,270	10,310	10,340	10,370	10,410	10,440	10,480	10,510	10,550	20
21	10,370	10,410	10,450	10,490	10,530	10,560	10,600	10,640	10,680	10,710	10,750	10,790	10,830	10,860	10,900	10,940	10,970	11,010	11,040	11,080	11,120	21
22	10,910	10,950	10,990	11,030	11,070	11,110	11,150	11,190	11,230	11,270	11,310	11,350	11,390	11,420	11,460	11,500	11,540	11,580	11,620	11,660	11,690	22
23	11,440	11,490	11,530	11,570	11,610	11,660	11,700	11,740	11,780	11,820	11,860	11,910	11,950	11,990	12,030	12,070	12,110	12,150	12,190	12,230	12,270	23
24	11,950	12,000	12,050	12,090	12,140	12,180	12,220	12,270	12,310	12,360	12,400	12,440	12,490	12,530	12,570	12,610	12,660	12,700	12,740	12,780	12,830	24
25	12,470	12,520	12,560	12,610	12,660	12,700	12,750	12,800	12,840	12,890	12,930	12,980	13,020	13,070	13,110	13,160	13,200	13,250	13,290	13,340	13,380	25
26	12,990	13,040	13,090	13,140	13,190	13,240	13,290	13,340	13,380	13,430	13,480	13,530	13,570	13,620	13,670	13,710	13,760	13,810	13,850	13,900	13,940	26
27	13,520	13,570	13,620	13,670	13,720	13,770	13,830	13,880	13,930	13,980	14,020	14,070	14,120	14,170	14,220	14,270	14,320	14,370	14,420	14,460	14,510	27
28	14,030	14,090	14,140	14,200	14,250	14,300	14,360	14,410	14,460	14,510	14,560	14,620	14,670	14,720	14,770	14,820	14,870	14,920	14,970	15,020	15,070	28
29	14,550	14,610	14,660	14,720	14,770	14,830	14,880	14,940	14,990	15,040	15,100	15,150	15,210	15,260	15,310	15,360	15,420	15,470	15,520	15,570	15,630	29
30	15,060	15,130	15,190	15,240	15,300	15,360	15,410	15,470	15,530	15,580	15,640	15,690	15,750	15,800	15,860	15,910	15,970	16,020	16,080	16,130	16,180	30
31	15,570	15,630	15,690	15,750	15,810	15,870	15,930	15,990	16,050	16,110	16,170	16,220	16,280	16,340	16,400	16,450	16,510	16,570	16,620	16,680	16,740	31
32	16,060	16,130	16,190	16,260	16,320	16,380	16,440	16,510	16,570	16,630	16,690	16,750	16,810	16,870	16,930	16,990	17,050	17,110	17,170	17,220	17,280	32
33	16,550	16,620	16,690	16,750	16,820	16,880	16,950	17,010	17,070	17,140	17,200	17,270	17,330	17,390	17,450	17,510	17,580	17,640	17,700	17,760	17,820	33
34	17,050	17,120	17,190	17,250	17,320	17,390	17,460	17,520	17,590	17,660	17,720	17,790	17,860	17,920	17,990	18,050	18,110	18,180	18,240	18,300	18,360	34
35	17,550	17,620	17,690	17,760	17,840	17,910	17,980	18,050	18,110	18,180	18,250	18,320	18,390	18,460	18,530	18,590	18,660	18,720	18,790	18,850	18,910	35
36	18,050	18,120	18,190	18,270	18,340	18,410	18,490	18,560	18,630	18,700	18,780	18,850	18,920	18,990	19,060	19,130	19,190	19,260	19,330	19,390	19,460	36
37	18,530	18,610	18,680	18,760	18,840	18,910	18,990	19,060	19,140	19,210	19,290	19,360	19,430	19,510	19,580	19,650	19,720	19,790	19,860	19,930	19,990	37
38	19,030	19,110	19,190	19,270	19,350	19,430	19,510	19,580	19,660	19,740	19,820	19,890	19,970	20,050	20,120	20,190	20,260	20,330	20,410	20,480	20,550	38
39	19,540	19,620	19,700	19,780	19,860	19,940	20,020	20,100	20,180	20,260	20,340	20,420	20,500	20,580	20,660	20,730	20,810	20,880	20,950	21,030	21,100	39
40	20,040	20,130	20,210	20,300	20,380	20,470	20,550	20,630	20,710	20,800	20,880	20,960	21,040	21,130	21,200	21,280	21,360	21,430	21,510	21,580	21,660	40
41	20,530	20,620	20,710	20,790	20,880	20,970	21,050	21,140	21,220	21,310	21,390	21,480	21,560	21,640	21,720	21,800	21,880	21,960	22,040	22,120	22,190	41
42	21,030	21,120	21,210	21,290	21,380	21,470	21,560	21,650	21,730	21,820	21,910	22,000	22,080	22,170	22,250	22,330	22,420	22,500	22,580	22,660	22,740	42
43	21,510	21,600	21,690	21,790	21,880	21,970	22,060	22,150	22,240	22,330	22,420	22,500	22,590	22,680	22,770	22,850	22,940	23,020	23,100	23,190	23,270	43
44	21,990	22,090	22,180	22,280	22,370	22,460	22,550	22,650	22,740	22,830	22,920	23,010	23,100	23,190	23,280	23,370	23,460	23,540	23,630	23,710	23,800	44
45	22,500	22,590	22,690	22,790	22,880	22,980	23,070	23,170	23,260	23,360	23,450	23,540	23,640	23,730	23,820	23,910	24,000	24,090	24,180	24,270	24,350	45
46	22,990	23,090	23,190	23,290	23,390	23,480	23,580	23,680	23,770	23,870	23,970	24,060	24,160	24,250	24,350	24,440	24,530	24,620	24,710	24,800	24,900	46
47	23,470	23,580	23,680	23,780	23,880	23,980	24,080	24,180	24,270	24,370	24,470	24,570	24,670	24,760	24,860	24,950	25,050	25,140	25,240	25,330	25,430	47
48	23,960	24,070	24,170	24,270	24,380	24,480	24,580	24,680	24,780	24,880	24,980	25,080	25,180	25,280	25,380	25,480	25,580	25,670	25,770	25,870	25,960	48
49	24,450	24,550	24,660	24,760	24,870	24,970	25,080	25,180	25,280	25,390	25,490	25,590	25,690	25,800	25,900	26,000	26,100	26,200	26,300	26,400	26,500	49
50	24,930	25,040	25,140	25,250	25,360	25,470	25,570	25,680	25,780	25,890	25,990	26,100	26,200	26,310	26,410	26,510	26,610	26,720	26,820	26,920	27,020	50
51	25,410	25,520	25,630	25,740	25,850	25,960	26,070	26,180	26,280	26,390	26,500	26,610	26,710	26,820	26,920	27,030	27,130	27,240	27,340	27,450	27,550	51
52	25,890	26,000	26,120	26,230	26,340	26,450	26,560	26,670	26,780	26,890	27,000	27,110	27,220	27,330	27,440	27,540	27,650	27,760	27,870	27,970	28,080	52
53	26,380	26,490	26,610	26,720	26,840	26,950	27,060	27,180	27,290	27,400	27,510	27,630	27,740	27,850	27,960	28,070	28,180	28,290	28,390	28,500	28,610	53
54	26,870	26,990	27,110	27,220	27,340	27,460	27,570	27,690	27,800	27,920	28,030	28,140	28,260	28,370	28,480	28,590	28,710	28,820	28,930	29,040	29,150	54
55	27,350	27,470	27,590	27,710	27,830	27,950	28,070	28,180	28,300	28,420	28,530	28,650	28,770	28,880	29,000	29,110	29,220	29,340	29,450	29,560	29,680	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1271.0	1271.1	1271.2	1271.3	1271.4	1271.5	1271.6	1271.7	1271.8	1271.9	1272.0	1272.1	1272.2	1272.3	1272.4	1272.5	1272.6	1272.7	1272.8	1272.9	1273.0	
56	27,830	27,960	28,080	28,200	28,320	28,440	28,560	28,680	28,800	28,920	29,040	29,160	29,280	29,390	29,510	29,630	29,740	29,860	29,970	30,090	30,200	56
57	28,320	28,450	28,570	28,700	28,820	28,940	29,070	29,190	29,310	29,430	29,550	29,670	29,790	29,910	30,030	30,150	30,270	30,390	30,500	30,620	30,740	57
58	28,800	28,930	29,050	29,180	29,300	29,430	29,560	29,680	29,800	29,930	30,050	30,170	30,300	30,420	30,540	30,660	30,780	30,900	31,020	31,140	31,260	58
59	29,280	29,410	29,540	29,670	29,800	29,930	30,060	30,180	30,310	30,440	30,560	30,690	30,810	30,940	31,060	31,180	31,310	31,430	31,550	31,670	31,790	59
60	29,780	29,910	30,040	30,170	30,300	30,430	30,560	30,690	30,820	30,950	31,080	31,200	31,330	31,460	31,580	31,710	31,830	31,960	32,080	32,210	32,330	60
61	30,760	30,900	31,030	31,170	31,310	31,440	31,570	31,710	31,840	31,970	32,110	32,240	32,370	32,500	32,630	32,760	32,890	33,020	33,150	33,280	33,410	61
62	31,740	31,880	32,020	32,160	32,300	32,440	32,580	32,720	32,860	33,000	33,130	33,270	33,400	33,540	33,680	33,810	33,950	34,080	34,220	34,350	34,480	62
63	32,710	32,850	33,000	33,140	33,290	33,430	33,580	33,720	33,860	34,000	34,140	34,280	34,420	34,560	34,700	34,840	34,990	35,130	35,270	35,400	35,540	63
64	33,680	33,830	33,980	34,130	34,280	34,420	34,570	34,720	34,860	35,010	35,160	35,300	35,440	35,590	35,730	35,880	36,030	36,170	36,320	36,460	36,610	64
65	34,670	34,820	34,980	35,130	35,290	35,440	35,590	35,740	35,890	36,040	36,190	36,340	36,490	36,640	36,790	36,940	37,090	37,240	37,390	37,540	37,690	65
66	35,640	35,800	35,960	36,120	36,270	36,430	36,590	36,740	36,900	37,050	37,210	37,360	37,510	37,660	37,820	37,980	38,140	38,290	38,450	38,600	38,760	66
67	36,600	36,770	36,930	37,090	37,250	37,420	37,580	37,740	37,900	38,050	38,210	38,370	38,520	38,680	38,850	39,010	39,170	39,330	39,490	39,650	39,810	67
68	37,570	37,740	37,910	38,080	38,240	38,410	38,570	38,740	38,900	39,060	39,230	39,390	39,550	39,710	39,880	40,050	40,210	40,380	40,540	40,710	40,870	68
69	38,550	38,720	38,890	39,060	39,240	39,410	39,580	39,740	39,910	40,080	40,250	40,410	40,580	40,740	40,920	41,090	41,260	41,430	41,600	41,770	41,940	69
70	39,540	39,720	39,890	40,070	40,250	40,420	40,590	40,770	40,940	41,110	41,280	41,450	41,620	41,790	41,970	42,150	42,330	42,500	42,680	42,850	43,030	70
71	40,670	40,830	40,990	41,160	41,320	41,480	41,630	41,800	41,970	42,140	42,310	42,480	42,640	42,810	42,990	43,160	43,340	43,520	43,700	43,880	44,050	71
72	41,840	41,990	42,140	42,290	42,440	42,580	42,720	42,870	43,040	43,210	43,380	43,540	43,710	43,880	44,050	44,220	44,390	44,560	44,750	44,930	45,110	72
73	43,010	43,140	43,280	43,410	43,540	43,670	43,800	43,930	44,100	44,260	44,430	44,590	44,760	44,920	45,090	45,260	45,420	45,600	45,780	45,970	46,160	73
74	44,170	44,290	44,410	44,530	44,650	44,760	44,870	44,990	45,150	45,320	45,480	45,640	45,800	45,970	46,130	46,290	46,460	46,620	46,810	47,000	47,200	74
75	45,330	45,440	45,540	45,650	45,750	45,850	45,940	46,050	46,200	46,370	46,530	46,690	46,850	47,010	47,170	47,330	47,490	47,660	47,850	48,040	48,240	75
76	46,470	46,570	46,660	46,750	46,830	46,920	47,000	47,090	47,240	47,400	47,560	47,720	47,870	48,030	48,190	48,350	48,500	48,660	48,850	49,050	49,250	76
77	47,640	47,720	47,790	47,870	47,940	48,010	48,070	48,150	48,290	48,450	48,610	48,770	48,920	49,080	49,230	49,390	49,540	49,690	49,890	50,090	50,300	77
78	48,800	48,870	48,930	48,990	49,040	49,100	49,150	49,210	49,350	49,510	49,660	49,820	49,970	50,120	50,270	50,420	50,570	50,730	50,930	51,130	51,340	78
79	49,950	50,010	50,050	50,100	50,140	50,180	50,210	50,260	50,400	50,560	50,710	50,860	51,020	51,160	51,310	51,460	51,600	51,760	51,960	52,170	52,390	79
80	51,130	51,170	51,200	51,230	51,260	51,280	51,300	51,330	51,460	51,610	51,770	51,920	52,070	52,210	52,360	52,500	52,640	52,790	53,000	53,210	53,430	80
81	52,040	52,140	52,240	52,330	52,420	52,510	52,600	52,690	52,870	53,080	53,290	53,500	53,700	53,910	54,110	54,310	54,510	54,720	54,970	55,240	55,510	81
82	52,930	53,100	53,260	53,420	53,580	53,740	53,900	54,060	54,300	54,570	54,830	55,100	55,360	55,630	55,890	56,150	56,410	56,670	56,980	57,310	57,630	82
83	53,820	54,060	54,290	54,520	54,750	54,970	55,200	55,430	55,730	56,050	56,370	56,700	57,020	57,340	57,670	57,990	58,310	58,630	59,000	59,380	59,750	83
84	54,700	55,000	55,300	55,600	55,890	56,190	56,480	56,780	57,140	57,520	57,900	58,290	58,670	59,050	59,430	59,810	60,200	60,580	61,000	61,430	61,870	84
85	55,610	55,970	56,340	56,700	57,070	57,430	57,800	58,170	58,580	59,020	59,460	59,900	60,340	60,780	61,220	61,660	62,110	62,550	63,030	63,510	64,000	85
86	56,440	56,870	57,300	57,730	58,160	58,590	59,020	59,460	59,940	60,430	60,920	61,420	61,920	62,410	62,910	63,410	63,910	64,420	64,950	65,490	66,030	86
87	57,340	57,830	58,330	58,830	59,320	59,820	60,320	60,830	61,370	61,910	62,470	63,020	63,570	64,130	64,690	65,250	65,810	66,380	66,960	67,560	68,150	87
88	58,230	58,790	59,350	59,920	60,480	61,050	61,620	62,200	62,790	63,400	64,010	64,620	65,230	65,850	66,470	67,090	67,710	68,340	68,980	69,620	70,270	88
89	59,150	59,780	60,410	61,040	61,680	62,310	62,950	63,600	64,250	64,910	65,570	66,240	66,920	67,590	68,270	68,950	69,630	70,320	71,010	71,710	72,410	89
90	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	90
91	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	91
92	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	92
93	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	93
94	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	94
95	60,020	60,710	61,410	62,100	62,810	63,510	64,220	64,930	65,650	66,370	67,090	67,820	68,550	69,280	70,020	70,760	71,510	72,250	73,010	73,760	74,520	95

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1273.0	1273.1	1273.2	1273.3	1273.4	1273.5	1273.6	1273.7	1273.8	1273.9	1274.0	1274.1	1274.2	1274.3	1274.4	1274.5	1274.6	1274.7	1274.8	1274.9	1275.0	
1	490	500	500	500	500	500	500	500	510	510	510	510	510	510	510	520	520	520	520	520	520	1
2	960	960	960	970	970	970	970	980	980	980	990	990	990	990	1,000	1,000	1,000	1,010	1,010	1,010	1,010	2
3	1,490	1,490	1,500	1,500	1,510	1,510	1,510	1,520	1,520	1,530	1,530	1,540	1,540	1,550	1,550	1,560	1,560	1,560	1,570	1,570	1,580	3
4	2,020	2,030	2,040	2,040	2,050	2,050	2,060	2,070	2,070	2,080	2,090	2,090	2,100	2,100	2,110	2,120	2,120	2,130	2,130	2,140	2,150	4
5	2,510	2,520	2,530	2,530	2,540	2,550	2,560	2,570	2,570	2,580	2,590	2,600	2,600	2,610	2,620	2,630	2,630	2,640	2,650	2,660	2,660	5
6	3,020	3,030	3,040	3,050	3,060	3,070	3,080	3,090	3,100	3,110	3,120	3,130	3,130	3,140	3,150	3,160	3,170	3,180	3,190	3,200	3,210	6
7	3,570	3,580	3,590	3,600	3,620	3,630	3,640	3,650	3,660	3,670	3,680	3,690	3,700	3,710	3,720	3,730	3,750	3,760	3,770	3,780	3,790	7
8	4,040	4,050	4,070	4,080	4,090	4,100	4,120	4,130	4,140	4,150	4,160	4,180	4,190	4,200	4,210	4,230	4,240	4,250	4,260	4,270	4,290	8
9	4,560	4,570	4,590	4,600	4,620	4,630	4,640	4,660	4,670	4,690	4,700	4,710	4,730	4,740	4,750	4,770	4,780	4,790	4,810	4,820	4,830	9
10	5,030	5,040	5,060	5,080	5,090	5,110	5,120	5,140	5,150	5,170	5,180	5,200	5,210	5,230	5,240	5,260	5,270	5,290	5,300	5,320	5,330	10
11	5,590	5,610	5,630	5,640	5,660	5,680	5,690	5,710	5,730	5,750	5,760	5,780	5,800	5,810	5,830	5,850	5,860	5,880	5,900	5,910	5,930	11
12	6,140	6,160	6,180	6,200	6,220	6,240	6,260	6,280	6,300	6,320	6,330	6,350	6,370	6,390	6,410	6,430	6,450	6,460	6,480	6,500	6,520	12
13	6,670	6,700	6,720	6,740	6,760	6,780	6,800	6,820	6,840	6,860	6,880	6,900	6,920	6,940	6,960	6,980	7,000	7,020	7,040	7,060	7,080	13
14	7,230	7,260	7,280	7,300	7,320	7,350	7,370	7,390	7,410	7,440	7,460	7,480	7,500	7,530	7,550	7,570	7,590	7,610	7,630	7,660	7,680	14
15	7,780	7,800	7,830	7,850	7,880	7,900	7,930	7,950	7,970	8,000	8,020	8,050	8,070	8,090	8,120	8,140	8,170	8,190	8,210	8,240	8,260	15
16	8,330	8,350	8,380	8,410	8,430	8,460	8,490	8,510	8,540	8,560	8,590	8,620	8,640	8,670	8,690	8,720	8,740	8,770	8,790	8,820	8,840	16
17	8,890	8,910	8,940	8,970	9,000	9,030	9,050	9,080	9,110	9,140	9,170	9,190	9,220	9,250	9,270	9,300	9,330	9,360	9,380	9,410	9,440	17
18	9,440	9,470	9,500	9,530	9,560	9,590	9,620	9,650	9,680	9,710	9,740	9,770	9,800	9,830	9,860	9,890	9,920	9,940	9,970	10,000	10,030	18
19	9,990	10,020	10,060	10,090	10,120	10,150	10,180	10,210	10,250	10,280	10,310	10,340	10,370	10,400	10,430	10,460	10,490	10,520	10,550	10,580	10,610	19
20	10,550	10,580	10,610	10,650	10,680	10,710	10,750	10,780	10,810	10,850	10,880	10,910	10,940	10,980	11,010	11,040	11,070	11,110	11,140	11,170	11,200	20
21	11,120	11,150	11,190	11,220	11,260	11,290	11,330	11,370	11,400	11,440	11,470	11,500	11,540	11,570	11,610	11,640	11,680	11,710	11,750	11,780	11,810	21
22	11,690	11,730	11,770	11,810	11,840	11,880	11,920	11,960	11,990	12,030	12,070	12,100	12,140	12,180	12,210	12,250	12,280	12,320	12,360	12,390	12,430	22
23	12,270	12,310	12,350	12,390	12,430	12,470	12,510	12,550	12,590	12,620	12,660	12,700	12,740	12,780	12,820	12,860	12,890	12,930	12,970	13,010	13,050	23
24	12,830	12,870	12,910	12,950	12,990	13,030	13,070	13,120	13,160	13,200	13,240	13,280	13,320	13,360	13,400	13,440	13,480	13,520	13,560	13,600	13,640	24
25	13,380	13,420	13,470	13,510	13,550	13,600	13,640	13,680	13,730	13,770	13,810	13,850	13,900	13,940	13,980	14,020	14,060	14,110	14,150	14,190	14,230	25
26	13,940	13,990	14,040	14,080	14,130	14,170	14,220	14,260	14,310	14,350	14,400	14,440	14,490	14,530	14,570	14,620	14,660	14,700	14,750	14,790	14,830	26
27	14,510	14,560	14,610	14,650	14,700	14,750	14,800	14,840	14,890	14,940	14,980	15,030	15,080	15,120	15,170	15,210	15,260	15,300	15,350	15,400	15,440	27
28	15,070	15,120	15,170	15,220	15,270	15,320	15,370	15,420	15,460	15,510	15,560	15,610	15,660	15,710	15,750	15,800	15,850	15,900	15,940	15,990	16,040	28
29	15,630	15,680	15,730	15,780	15,830	15,880	15,930	15,980	16,030	16,090	16,140	16,190	16,240	16,290	16,330	16,380	16,430	16,480	16,530	16,580	16,630	29
30	16,180	16,240	16,290	16,350	16,400	16,450	16,500	16,560	16,610	16,660	16,710	16,770	16,820	16,870	16,920	16,970	17,020	17,070	17,130	17,180	17,230	30
31	16,740	16,790	16,850	16,900	16,960	17,010	17,070	17,120	17,180	17,230	17,290	17,340	17,390	17,450	17,500	17,550	17,610	17,660	17,710	17,770	17,820	31
32	17,280	17,340	17,400	17,460	17,510	17,570	17,630	17,680	17,740	17,800	17,850	17,910	17,960	18,020	18,080	18,130	18,190	18,240	18,300	18,350	18,410	32
33	17,820	17,880	17,940	18,000	18,060	18,110	18,170	18,230	18,290	18,350	18,410	18,460	18,520	18,580	18,640	18,690	18,750	18,810	18,870	18,920	18,980	33
34	18,360	18,420	18,490	18,550	18,610	18,670	18,730	18,790	18,850	18,910	18,970	19,030	19,090	19,150	19,210	19,270	19,330	19,390	19,450	19,500	19,560	34
35	18,910	18,980	19,040	19,110	19,170	19,230	19,300	19,360	19,420	19,480	19,550	19,610	19,670	19,730	19,790	19,850	19,910	19,970	20,040	20,100	20,160	35
36	19,460	19,530	19,590	19,660	19,720	19,790	19,850	19,920	19,980	20,050	20,110	20,180	20,240	20,300	20,370	20,430	20,490	20,550	20,620	20,680	20,740	36
37	19,990	20,060	20,130	20,200	20,260	20,330	20,400	20,470	20,530	20,600	20,660	20,730	20,800	20,860	20,930	20,990	21,060	21,120	21,190	21,250	21,310	37
38	20,550	20,620	20,690	20,760	20,830	20,890	20,960	21,030	21,100	21,170	21,240	21,310	21,370	21,440	21,510	21,570	21,640	21,710	21,770	21,840	21,910	38
39	21,100	21,170	21,240	21,310	21,390	21,460	21,530	21,600	21,670	21,740	21,810	21,880	21,950	22,020	22,090	22,160	22,230	22,290	22,360	22,430	22,500	39
40	21,660	21,730	21,800	21,880	21,950	22,030	22,100	22,170	22,240	22,320	22,390	22,460	22,530	22,600	22,670	22,750	22,820	22,890	22,960	23,030	23,100	40
41	22,190	22,270	22,350	22,420	22,500	22,580	22,650	22,730	22,800	22,880	22,950	23,020	23,100	23,170	23,240	23,320	23,390	23,460	23,540	23,610	23,680	41
42	22,740	22,820	22,900	22,980	23,050	23,130	23,210	23,290	23,370	23,440	23,520	23,590	23,670	23,750	23,820	23,900	23,970	24,050	24,120	24,190	24,270	42
43	23,270	23,350	23,430	23,510	23,600	23,680	23,760	23,840	23,920	24,000	24,070	24,150	24,230	24,310	24,390	24,460	24,540	24,620	24,690	24,770	24,850	43
44	23,800	23,880	23,970	24,050	24,140	24,220	24,300	24,390	24,470	24,550	24,630	24,710	24,790	24,870	24,950	25,030	25,110	25,190	25,260	25,340	25,420	44
45	24,350	24,440	24,530	24,620	24,700	24,790	24,880	24,960	25,040	25,130	25,210	25,290	25,370	25,460	25,540	25,620	25,700	25,780	25,860	25,940	26,020	45
46	24,900	24,990	25,080	25,170	25,260	25,350	25,430	25,520	25,610	25,690	25,780	25,860	25,940	26,030	26,110	26,200	26,280	26,360	26,440	26,530	26,610	46
47	25,430	25,520	25,610	25,700	25,800	25,890	25,980	26,070	26,160	26,240	26,330	26,420	26,500	26,590	26,680	26,760	26,850	26,930	27,020	27,100	27,180	47
48	25,960	26,060	26,160	26,250	26,350	26,440	26,530	26,620	26,710	26,800	26,890	26,980	27,070	27,160	27,250	27,330	27,420	27,510	27,600	27,680	27,770	48
49	26,500	26,590	26,690	26,790	26,890	26,990	27,080	27,170	27,270	27,360	27,450	27,540	27,630	27,720	27,810	27,900	27,990	28,080	28,170	28,260	28,340	49
50	27,020	27,120	27,230	27,330	27,430	27,530	27,620	27,720	27,810	27,910	28,000	28,090	28,190	28,280	28,370	28,460	28,550	28,640	28,740	28,830	28,920	50
51	27,550	27,650	27,760	27,860	27,960	28,060	28,170	28,260	28,360	28,460	28,550	28,650	28,740	28,840	28,930	29,030	29,120	29,210	29,310	29,400	29,490	51
52	28,080	28,180	28,290	28,390	28,500	28,600	28,700	28,800	28,900	29,000	29,100	29,200	29,300	29,400	29,490	29,590	29,690	29,780	29,880	29,970	30,070	52
53	28,610	28,720	28,830	28,930	29,040	29,150	29,250	29,350	29,460	29,560	29,660	29,760	29,860	29,960	30,060	30,160	30,260	30,360	30,460	30,550	30,650	53
54	29,150	29,260	29,370	29,480	29,590	29,700	29,800	29,910	30,010	30,120	30,220	30,320	30,430	30,530	30,630	30,730	30,840	30,940	31,040	31,140	31,240	54
55	29,680	29,790	29,900	30,010	30,120	30,230	30,340	30,450	30,560	30,670	30,770	30,880	30,980	31,090	31,190	31,300	31,400	31,510	31,610	31,710	31,810	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1273.0	1273.1	1273.2	1273.3	1273.4	1273.5	1273.6	1273.7	1273.8	1273.9	1274.0	1274.1	1274.2	1274.3	1274.4	1274.5	1274.6	1274.7	1274.8	1274.9	1275.0	
56	30,200	30,320	30,430	30,550	30,660	30,770	30,880	30,990	31,100	31,210	31,320	31,430	31,540	31,650	31,760	31,860	31,970	32,080	32,180	32,290	32,390	56
57	30,740	30,860	30,970	31,090	31,200	31,320	31,430	31,540	31,660	31,770	31,880	31,990	32,100	32,210	32,320	32,430	32,540	32,650	32,760	32,870	32,970	57
58	31,260	31,380	31,500	31,610	31,730	31,850	31,970	32,080	32,200	32,310	32,420	32,540	32,650	32,770	32,880	32,990	33,100	33,210	33,330	33,430	33,540	58
59	31,790	31,910	32,030	32,150	32,270	32,390	32,510	32,630	32,750	32,860	32,980	33,100	33,210	33,330	33,440	33,560	33,670	33,790	33,900	34,010	34,120	59
60	32,330	32,450	32,580	32,700	32,820	32,940	33,060	33,180	33,300	33,420	33,540	33,660	33,780	33,900	34,020	34,130	34,250	34,370	34,480	34,600	34,710	60
61	33,410	33,540	33,670	33,790	33,920	34,050	34,170	34,300	34,420	34,550	34,670	34,800	34,920	35,040	35,170	35,290	35,410	35,530	35,650	35,770	35,890	61
62	34,480	34,620	34,750	34,880	35,020	35,150	35,280	35,410	35,540	35,670	35,800	35,930	36,050	36,180	36,310	36,440	36,560	36,690	36,820	36,940	37,060	62
63	35,540	35,680	35,820	35,960	36,090	36,230	36,370	36,500	36,640	36,770	36,910	37,040	37,170	37,300	37,440	37,570	37,700	37,830	37,960	38,090	38,220	63
64	36,610	36,750	36,890	37,030	37,180	37,320	37,460	37,600	37,740	37,880	38,020	38,160	38,290	38,430	38,570	38,710	38,840	38,980	39,110	39,250	39,380	64
65	37,690	37,840	37,990	38,140	38,280	38,430	38,570	38,720	38,870	39,010	39,150	39,300	39,440	39,580	39,720	39,870	40,010	40,150	40,290	40,430	40,560	65
66	38,760	38,910	39,060	39,210	39,370	39,520	39,670	39,820	39,970	40,120	40,270	40,410	40,560	40,710	40,860	41,000	41,150	41,290	41,440	41,580	41,720	66
67	39,810	39,970	40,130	40,280	40,440	40,600	40,750	40,910	41,060	41,220	41,370	41,520	41,680	41,830	41,980	42,130	42,280	42,430	42,580	42,730	42,880	67
68	40,870	41,040	41,200	41,360	41,520	41,690	41,850	42,010	42,170	42,320	42,480	42,640	42,800	42,950	43,110	43,270	43,420	43,580	43,730	43,880	44,040	68
69	41,940	42,110	42,280	42,450	42,610	42,780	42,950	43,110	43,270	43,440	43,600	43,760	43,930	44,090	44,250	44,410	44,570	44,730	44,890	45,050	45,200	69
70	43,030	43,200	43,380	43,550	43,720	43,890	44,060	44,230	44,400	44,570	44,740	44,910	45,070	45,240	45,410	45,570	45,740	45,900	46,060	46,230	46,390	70
71	44,050	44,230	44,410	44,590	44,760	44,940	45,110	45,280	45,460	45,630	45,800	45,970	46,140	46,310	46,480	46,650	46,820	46,990	47,160	47,330	47,490	71
72	45,110	45,300	45,480	45,660	45,840	46,020	46,200	46,370	46,550	46,730	46,900	47,080	47,250	47,430	47,600	47,770	47,940	48,110	48,290	48,460	48,640	72
73	46,160	46,340	46,530	46,710	46,900	47,080	47,260	47,450	47,630	47,810	47,990	48,160	48,340	48,520	48,700	48,870	49,050	49,220	49,400	49,580	49,760	73
74	47,200	47,390	47,580	47,760	47,950	48,140	48,330	48,510	48,700	48,880	49,060	49,250	49,430	49,610	49,790	49,970	50,150	50,330	50,510	50,690	50,880	74
75	48,240	48,430	48,630	48,820	49,010	49,200	49,390	49,580	49,770	49,960	50,150	50,330	50,520	50,700	50,890	51,070	51,250	51,430	51,620	51,810	52,000	75
76	49,250	49,450	49,650	49,850	50,040	50,240	50,430	50,620	50,820	51,010	51,200	51,390	51,580	51,770	51,950	52,140	52,320	52,510	52,700	52,900	53,090	76
77	50,300	50,500	50,700	50,900	51,100	51,300	51,500	51,700	51,890	52,090	52,280	52,480	52,670	52,860	53,050	53,240	53,430	53,620	53,820	54,020	54,220	77
78	51,340	51,550	51,750	51,960	52,160	52,370	52,570	52,770	52,970	53,170	53,370	53,560	53,760	53,950	54,150	54,340	54,530	54,730	54,930	55,140	55,340	78
79	52,390	52,600	52,810	53,020	53,220	53,430	53,640	53,840	54,040	54,250	54,450	54,650	54,850	55,050	55,250	55,440	55,640	55,840	56,050	56,260	56,470	79
80	53,430	53,650	53,860	54,070	54,280	54,490	54,700	54,910	55,120	55,330	55,530	55,740	55,940	56,140	56,340	56,540	56,740	56,940	57,160	57,370	57,590	80
81	55,510	55,780	56,040	56,310	56,580	56,840	57,110	57,370	57,630	57,900	58,160	58,420	58,680	58,940	59,200	59,400	59,570	59,750	59,930	60,120	60,310	81
82	57,630	57,950	58,280	58,600	58,920	59,240	59,570	59,890	60,210	60,530	60,850	61,170	61,490	61,810	62,130	62,390	62,630	62,780	62,940	63,100	63,260	82
83	59,750	60,130	60,510	60,890	61,270	61,650	62,020	62,400	62,780	63,160	63,540	63,920	64,300	64,680	65,060	65,380	65,640	65,770	65,900	66,020	66,160	83
84	61,870	62,300	62,730	63,170	63,600	64,040	64,470	64,910	65,350	65,780	66,220	66,660	67,100	67,540	67,980	68,370	68,680	68,790	68,880	68,980	69,090	84
85	64,000	64,490	64,980	65,470	65,960	66,450	66,940	67,440	67,930	68,430	68,930	69,420	69,920	70,430	70,930	71,370	71,660	71,740	71,810	71,870	71,950	85
86	66,030	66,570	67,110	67,650	68,200	68,740	69,290	69,840	70,390	70,950	71,500	72,060	72,610	73,170	73,730	74,230	74,570	74,620	74,660	74,700	74,750	86
87	68,150	68,740	69,340	69,940	70,540	71,150	71,750	72,360	72,970	73,580	74,190	74,810	75,420	76,040	76,660	77,220	77,590	77,620	77,630	77,640	77,650	87
88	70,270	70,920	71,570	72,230	72,890	73,550	74,210	74,870	75,540	76,210	76,880	77,560	78,230	78,910	79,590	80,220	80,650	80,670	80,650	80,630	80,620	88
89	72,410	73,120	73,830	74,540	75,250	75,970	76,690	77,410	78,140	78,870	79,600	80,330	81,070	81,810	82,550	83,230	83,660	83,650	83,610	83,560	83,510	89
90	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,200	86,690	86,680	86,610	86,530	86,450	90
91	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,840	86,910	86,930	86,930	86,940	91
92	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,840	86,990	87,090	87,190	87,290	92
93	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,880	87,120	87,310	87,500	87,690	93
94	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,880	87,210	87,490	87,770	88,050	94
95	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,960	87,380	87,750	88,120	88,490	95
96	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	86,970	87,480	87,940	88,390	88,850	96
97	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,010	87,600	88,150	88,690	89,240	97
98	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,010	87,660	88,300	88,940	89,580	98
99	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,820	88,540	89,270	90,000	99
100	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	100
101	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	101
102	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	102
103	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	103
104	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	104
105	74,520	75,280	76,040	76,810	77,580	78,350	79,130	79,910	80,690	81,480	82,270	83,060	83,850	84,650	85,460	86,260	87,070	87,880	88,700	89,520	90,340	105

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1275.0	1275.1	1275.2	1275.3	1275.4	1275.5	1275.6	1275.7	1275.8	1275.9	1276.0	1276.1	1276.2	1276.3	1276.4	1276.5	1276.6	1276.7	1276.8	1276.9	1277.0	
1	520	530	530	530	530	530	530	530	540	540	540	540	540	540	540	540	550	550	550	550	550	1
2	1,010	1,020	1,020	1,020	1,030	1,030	1,030	1,030	1,040	1,040	1,040	1,050	1,050	1,050	1,050	1,060	1,060	1,060	1,060	1,070	1,070	2
3	1,580	1,580	1,590	1,590	1,590	1,600	1,600	1,610	1,610	1,620	1,620	1,620	1,630	1,630	1,640	1,640	1,650	1,650	1,650	1,660	1,660	3
4	2,150	2,150	2,160	2,160	2,170	2,180	2,180	2,190	2,190	2,200	2,200	2,210	2,220	2,220	2,230	2,230	2,240	2,240	2,250	2,260	2,260	4
5	2,660	2,670	2,680	2,680	2,690	2,700	2,710	2,710	2,720	2,730	2,740	2,740	2,750	2,760	2,760	2,770	2,780	2,790	2,790	2,800	2,810	5
6	3,210	3,210	3,220	3,230	3,240	3,250	3,260	3,270	3,280	3,280	3,290	3,300	3,310	3,320	3,330	3,340	3,340	3,350	3,360	3,370	3,380	6
7	3,790	3,800	3,810	3,820	3,830	3,840	3,850	3,860	3,870	3,880	3,890	3,900	3,910	3,920	3,930	3,940	3,950	3,960	3,970	3,980	3,990	7
8	4,290	4,300	4,310	4,320	4,330	4,340	4,360	4,370	4,380	4,390	4,400	4,410	4,430	4,440	4,450	4,460	4,470	4,480	4,490	4,500	4,520	8
9	4,830	4,850	4,860	4,870	4,890	4,900	4,910	4,930	4,940	4,950	4,970	4,980	4,990	5,010	5,020	5,030	5,040	5,060	5,070	5,080	5,100	9
10	5,330	5,350	5,360	5,380	5,390	5,410	5,420	5,430	5,450	5,460	5,480	5,490	5,510	5,520	5,540	5,550	5,560	5,580	5,590	5,610	5,620	10
11	5,930	5,950	5,960	5,980	6,000	6,010	6,030	6,040	6,060	6,080	6,090	6,110	6,130	6,140	6,160	6,170	6,190	6,200	6,220	6,240	6,250	11
12	6,520	6,540	6,550	6,570	6,590	6,610	6,630	6,640	6,660	6,680	6,700	6,720	6,730	6,750	6,770	6,790	6,800	6,820	6,840	6,860	6,870	12
13	7,080	7,100	7,120	7,140	7,160	7,180	7,200	7,220	7,240	7,260	7,280	7,300	7,320	7,340	7,360	7,380	7,390	7,410	7,430	7,450	7,470	13
14	7,680	7,700	7,720	7,740	7,760	7,790	7,810	7,830	7,850	7,870	7,890	7,910	7,930	7,950	7,980	8,000	8,020	8,040	8,060	8,080	8,100	14
15	8,260	8,280	8,310	8,330	8,350	8,370	8,400	8,420	8,440	8,470	8,490	8,510	8,530	8,560	8,580	8,600	8,620	8,650	8,670	8,690	8,710	15
16	8,840	8,870	8,890	8,920	8,940	8,970	8,990	9,020	9,040	9,070	9,090	9,110	9,140	9,160	9,190	9,210	9,230	9,260	9,280	9,310	9,330	16
17	9,440	9,460	9,490	9,520	9,540	9,570	9,600	9,620	9,650	9,670	9,700	9,730	9,750	9,780	9,800	9,830	9,860	9,880	9,910	9,930	9,960	17
18	10,030	10,060	10,090	10,120	10,140	10,170	10,200	10,230	10,260	10,280	10,310	10,340	10,370	10,390	10,420	10,450	10,480	10,500	10,530	10,560	10,580	18
19	10,610	10,640	10,670	10,700	10,730	10,760	10,790	10,820	10,850	10,880	10,910	10,940	10,970	11,000	11,030	11,060	11,090	11,120	11,140	11,170	11,200	19
20	11,200	11,230	11,270	11,300	11,330	11,360	11,390	11,420	11,450	11,490	11,520	11,550	11,580	11,610	11,640	11,670	11,700	11,730	11,760	11,790	11,820	20
21	11,810	11,850	11,880	11,910	11,950	11,980	12,010	12,050	12,080	12,110	12,150	12,180	12,210	12,240	12,280	12,310	12,340	12,370	12,410	12,440	12,470	21
22	12,430	12,460	12,500	12,540	12,570	12,610	12,640	12,680	12,710	12,750	12,780	12,810	12,850	12,880	12,920	12,950	12,990	13,020	13,050	13,090	13,120	22
23	13,050	13,080	13,120	13,160	13,190	13,230	13,270	13,310	13,340	13,380	13,420	13,450	13,490	13,530	13,560	13,600	13,630	13,670	13,710	13,740	13,780	23
24	13,640	13,680	13,720	13,760	13,800	13,830	13,870	13,910	13,950	13,990	14,030	14,070	14,100	14,140	14,180	14,220	14,260	14,290	14,330	14,370	14,410	24
25	14,230	14,270	14,310	14,350	14,390	14,430	14,480	14,520	14,560	14,600	14,640	14,680	14,720	14,760	14,800	14,840	14,880	14,910	14,950	14,990	15,030	25
26	14,830	14,880	14,920	14,960	15,010	15,050	15,090	15,130	15,180	15,220	15,260	15,300	15,340	15,380	15,430	15,470	15,510	15,550	15,590	15,630	15,670	26
27	15,440	15,490	15,530	15,570	15,620	15,660	15,710	15,750	15,800	15,840	15,880	15,930	15,970	16,010	16,060	16,100	16,140	16,190	16,230	16,270	16,320	27
28	16,040	16,080	16,130	16,180	16,220	16,270	16,320	16,360	16,410	16,450	16,500	16,540	16,590	16,640	16,680	16,730	16,770	16,820	16,860	16,900	16,950	28
29	16,630	16,680	16,730	16,780	16,820	16,870	16,920	16,970	17,010	17,060	17,110	17,160	17,200	17,250	17,300	17,340	17,390	17,440	17,480	17,530	17,580	29
30	17,230	17,280	17,330	17,380	17,430	17,480	17,530	17,580	17,630	17,680	17,720	17,770	17,820	17,870	17,920	17,970	18,020	18,070	18,110	18,160	18,210	30
31	17,820	17,870	17,920	17,980	18,030	18,080	18,130	18,180	18,230	18,280	18,340	18,390	18,440	18,490	18,540	18,590	18,640	18,690	18,740	18,790	18,840	31
32	18,410	18,460	18,510	18,570	18,620	18,680	18,730	18,780	18,840	18,890	18,940	18,990	19,050	19,100	19,150	19,200	19,260	19,310	19,360	19,410	19,460	32
33	18,980	19,030	19,090	19,150	19,200	19,260	19,310	19,370	19,420	19,480	19,530	19,590	19,640	19,700	19,750	19,800	19,860	19,910	19,970	20,020	20,070	33
34	19,560	19,620	19,680	19,740	19,790	19,850	19,910	19,970	20,020	20,080	20,140	20,190	20,250	20,310	20,360	20,420	20,470	20,530	20,580	20,640	20,690	34
35	20,160	20,220	20,280	20,340	20,400	20,450	20,510	20,570	20,630	20,690	20,750	20,810	20,870	20,920	20,980	21,040	21,100	21,150	21,210	21,270	21,330	35
36	20,740	20,800	20,870	20,930	20,990	21,050	21,110	21,170	21,230	21,290	21,350	21,410	21,470	21,530	21,590	21,650	21,710	21,770	21,830	21,890	21,950	36
37	21,310	21,380	21,440	21,500	21,570	21,630	21,690	21,760	21,820	21,880	21,940	22,010	22,070	22,130	22,190	22,250	22,310	22,370	22,440	22,500	22,560	37
38	21,910	21,970	22,040	22,100	22,170	22,230	22,300	22,360	22,430	22,490	22,560	22,620	22,680	22,750	22,810	22,870	22,940	23,000	23,060	23,130	23,190	38
39	22,500	22,570	22,630	22,700	22,770	22,840	22,900	22,970	23,030	23,100	23,170	23,230	23,300	23,360	23,430	23,490	23,560	23,620	23,690	23,750	23,820	39
40	23,100	23,170	23,240	23,310	23,380	23,440	23,510	23,580	23,650	23,720	23,790	23,850	23,920	23,990	24,060	24,120	24,190	24,260	24,320	24,390	24,450	40
41	23,680	23,750	23,820	23,890	23,970	24,040	24,110	24,180	24,250	24,320	24,390	24,460	24,530	24,600	24,660	24,730	24,800	24,870	24,940	25,010	25,080	41
42	24,270	24,340	24,420	24,490	24,560	24,640	24,710	24,780	24,850	24,930	25,000	25,070	25,140	25,210	25,280	25,350	25,420	25,490	25,560	25,630	25,700	42
43	24,850	24,920	25,000	25,070	25,150	25,220	25,300	25,370	25,450	25,520	25,590	25,670	25,740	25,810	25,890	25,960	26,030	26,100	26,180	26,250	26,320	43
44	25,420	25,500	25,580	25,650	25,730	25,810	25,880	25,960	26,040	26,110	26,190	26,260	26,340	26,410	26,490	26,560	26,640	26,710	26,790	26,860	26,930	44
45	26,020	26,100	26,180	26,260	26,340	26,420	26,500	26,580	26,650	26,730	26,810	26,890	26,960	27,040	27,120	27,200	27,270	27,350	27,420	27,500	27,580	45
46	26,610	26,690	26,770	26,850	26,940	27,020	27,100	27,180	27,260	27,340	27,420	27,500	27,580	27,660	27,740	27,810	27,890	27,970	28,050	28,130	28,200	46
47	27,180	27,270	27,350	27,440	27,520	27,600	27,680	27,770	27,850	27,930	28,010	28,090	28,180	28,260	28,340	28,420	28,500	28,580	28,660	28,740	28,820	47
48	27,770	27,850	27,940	28,030	28,110	28,200	28,280	28,360	28,450	28,530	28,620	28,700	28,780	28,870	28,950	29,030	29,110	29,200	29,280	29,360	29,440	48
49	28,340	28,430	28,520	28,610	28,690	28,780	28,870	28,960	29,040	29,130	29,210	29,300	29,380	29,470	29,550	29,640	29,720	29,810	29,890	29,970	30,060	49
50	28,920	29,010	29,100	29,190	29,270	29,360	29,450	29,540	29,630	29,720	29,800	29,890	29,980	30,070	30,150	30,240	30,320	30,410	30,500	30,580	30,670	50
51	29,490	29,580	29,680	29,770	29,860	29,950	30,040	30,130	30,220	30,310	30,400	30,490	30,580	30,670	30,760	30,850	30,930	31,020	31,110	31,200	31,280	51
52	30,070	30,160	30,260	30,350	30,440	30,540	30,630	30,720	30,810	30,910	31,000	31,090	31,180	31,270	31,360	31,450	31,540	31,630	31,720	31,810	31,900	52
53	30,650	30,750	30,840	30,940	31,030	31,130	31,220	31,320	31,410	31,510	31,600	31,690	31,790	31,880	31,970	32,070	32,160	32,250	32,340	32,430	32,520	53
54	31,240	31,340	31,430	31,530	31,630	31,730	31,830	31,920	32,020	32,110	32,210	32,310	32,400	32,500	32,590	32,690	32,780	32,870	32,970	33,060	33,160	54
55	31,810	31,910	32,010	32,110	32,210	32,310	32,410	32,510	32,610	32,710	32,810	32,910	33,000	33,100	33,200	33,290	33,390	33,490	33,580	33,680	33,770	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1275.0	1275.1	1275.2	1275.3	1275.4	1275.5	1275.6	1275.7	1275.8	1275.9	1276.0	1276.1	1276.2	1276.3	1276.4	1276.5	1276.6	1276.7	1276.8	1276.9	1277.0	
56	32,390	32,490	32,600	32,700	32,800	32,900	33,000	33,100	33,200	33,300	33,400	33,500	33,600	33,700	33,800	33,900	34,000	34,100	34,200	34,290	34,390	56
57	32,970	33,080	33,180	33,290	33,390	33,490	33,600	33,700	33,800	33,910	34,010	34,110	34,210	34,310	34,420	34,520	34,620	34,720	34,820	34,920	35,020	57
58	33,540	33,650	33,760	33,860	33,970	34,070	34,180	34,280	34,390	34,490	34,600	34,700	34,810	34,910	35,010	35,120	35,220	35,320	35,420	35,520	35,620	58
59	34,120	34,230	34,340	34,450	34,560	34,670	34,770	34,880	34,990	35,100	35,200	35,310	35,410	35,520	35,620	35,730	35,830	35,940	36,040	36,150	36,250	59
60	34,710	34,820	34,930	35,040	35,150	35,260	35,370	35,480	35,590	35,700	35,810	35,920	36,030	36,130	36,240	36,350	36,450	36,560	36,670	36,770	36,880	60
61	35,890	36,000	36,120	36,240	36,350	36,470	36,580	36,700	36,810	36,920	37,040	37,150	37,260	37,380	37,490	37,600	37,710	37,820	37,930	38,040	38,150	61
62	37,060	37,180	37,300	37,430	37,550	37,670	37,790	37,910	38,020	38,140	38,260	38,380	38,500	38,610	38,730	38,850	38,960	39,080	39,200	39,310	39,430	62
63	38,220	38,340	38,470	38,600	38,720	38,850	38,970	39,100	39,220	39,340	39,470	39,590	39,710	39,830	39,960	40,080	40,200	40,320	40,440	40,560	40,680	63
64	39,380	39,510	39,640	39,770	39,900	40,030	40,160	40,290	40,420	40,550	40,680	40,800	40,930	41,060	41,180	41,310	41,440	41,560	41,690	41,810	41,940	64
65	40,560	40,700	40,840	40,970	41,110	41,240	41,380	41,510	41,650	41,780	41,910	42,040	42,180	42,310	42,440	42,570	42,700	42,830	42,960	43,090	43,220	65
66	41,720	41,870	42,010	42,150	42,290	42,430	42,570	42,710	42,850	42,980	43,120	43,260	43,400	43,530	43,670	43,810	43,940	44,080	44,210	44,350	44,480	66
67	42,880	43,020	43,170	43,310	43,460	43,600	43,750	43,890	44,040	44,180	44,320	44,470	44,610	44,750	44,890	45,030	45,170	45,310	45,450	45,590	45,730	67
68	44,040	44,190	44,340	44,490	44,640	44,790	44,940	45,090	45,240	45,390	45,530	45,680	45,830	45,970	46,120	46,260	46,410	46,550	46,700	46,840	46,980	68
69	45,200	45,360	45,520	45,670	45,830	45,980	46,140	46,290	46,440	46,600	46,750	46,900	47,050	47,200	47,360	47,510	47,650	47,800	47,950	48,100	48,250	69
70	46,390	46,550	46,710	46,870	47,030	47,190	47,350	47,510	47,670	47,830	47,990	48,140	48,300	48,450	48,610	48,770	48,920	49,070	49,230	49,380	49,530	70
71	47,490	47,660	47,830	47,990	48,160	48,320	48,490	48,650	48,820	48,980	49,140	49,300	49,470	49,630	49,790	49,950	50,110	50,270	50,420	50,580	50,740	71
72	48,640	48,810	48,980	49,150	49,320	49,490	49,660	49,830	50,000	50,170	50,340	50,500	50,670	50,840	51,000	51,170	51,330	51,490	51,660	51,820	51,980	72
73	49,760	49,940	50,110	50,290	50,470	50,640	50,820	50,990	51,170	51,340	51,510	51,680	51,860	52,030	52,200	52,370	52,540	52,710	52,870	53,040	53,210	73
74	50,880	51,060	51,240	51,430	51,610	51,790	51,970	52,150	52,330	52,500	52,680	52,860	53,030	53,210	53,390	53,560	53,740	53,910	54,080	54,260	54,430	74
75	52,000	52,190	52,380	52,570	52,750	52,940	53,120	53,310	53,490	53,670	53,860	54,040	54,220	54,400	54,580	54,760	54,940	55,120	55,300	55,480	55,650	75
76	53,090	53,290	53,480	53,670	53,860	54,050	54,240	54,430	54,620	54,810	55,000	55,190	55,370	55,560	55,740	55,930	56,110	56,300	56,480	56,660	56,840	76
77	54,220	54,420	54,610	54,810	55,010	55,200	55,400	55,590	55,790	55,980	56,170	56,370	56,560	56,750	56,940	57,130	57,320	57,510	57,700	57,880	58,070	77
78	55,340	55,550	55,750	55,950	56,150	56,350	56,560	56,750	56,950	57,150	57,350	57,550	57,740	57,940	58,140	58,330	58,520	58,720	58,910	59,100	59,290	78
79	56,470	56,680	56,880	57,090	57,300	57,510	57,710	57,920	58,120	58,320	58,530	58,730	58,930	59,130	59,330	59,530	59,730	59,930	60,130	60,320	60,520	79
80	57,590	57,800	58,020	58,230	58,440	58,650	58,870	59,080	59,290	59,490	59,700	59,910	60,120	60,320	60,530	60,730	60,940	61,140	61,340	61,540	61,750	80
81	60,310	60,500	60,700	60,890	61,080	61,280	61,470	61,670	61,860	62,050	62,240	62,430	62,620	62,810	62,990	63,180	63,370	63,560	63,750	63,930	64,120	81
82	63,260	63,430	63,600	63,770	63,940	64,120	64,290	64,470	64,640	64,820	64,990	65,160	65,340	65,500	65,670	65,840	66,010	66,190	66,360	66,530	66,700	82
83	66,160	66,300	66,450	66,600	66,760	66,910	67,060	67,230	67,380	67,540	67,700	67,850	68,000	68,160	68,300	68,460	68,610	68,770	68,930	69,080	69,240	83
84	69,090	69,200	69,330	69,460	69,600	69,730	69,860	70,010	70,150	70,290	70,430	70,570	70,700	70,830	70,960	71,100	71,230	71,380	71,520	71,660	71,800	84
85	71,950	72,040	72,150	72,270	72,380	72,490	72,610	72,740	72,860	72,990	73,110	73,230	73,340	73,460	73,570	73,680	73,800	73,930	74,060	74,190	74,310	85
86	74,750	74,810	74,900	75,000	75,090	75,180	75,280	75,390	75,500	75,610	75,710	75,810	75,910	76,000	76,100	76,190	76,290	76,410	76,530	76,640	76,750	86
87	77,650	77,690	77,760	77,840	77,910	77,980	78,060	78,160	78,250	78,340	78,420	78,510	78,590	78,670	78,740	78,820	78,900	79,000	79,100	79,200	79,300	87
88	80,620	80,620	80,670	80,730	80,780	80,830	80,890	80,970	81,040	81,120	81,190	81,250	81,310	81,370	81,430	81,490	81,550	81,640	81,730	81,810	81,890	88
89	83,510	83,490	83,530	83,560	83,600	83,630	83,670	83,730	83,790	83,840	83,890	83,940	83,990	84,030	84,070	84,110	84,160	84,230	84,300	84,370	84,430	89
90	86,450	86,400	86,420	86,430	86,440	86,450	86,470	86,520	86,560	86,600	86,630	86,660	86,690	86,710	86,730	86,750	86,780	86,840	86,900	86,950	87,000	90
91	86,940	86,970	87,060	87,160	87,250	87,340	87,430	87,560	87,680	87,790	87,910	88,020	88,130	88,230	88,340	88,430	88,540	88,680	88,820	88,950	89,080	91
92	87,290	87,410	87,580	87,760	87,940	88,110	88,290	88,490	88,690	88,890	89,090	89,280	89,480	89,670	89,850	90,040	90,230	90,450	90,670	90,890	91,110	92
93	87,690	87,900	88,150	88,410	88,670	88,930	89,190	89,470	89,760	90,040	90,320	90,590	90,870	91,140	91,420	91,690	91,970	92,270	92,570	92,870	93,170	93
94	88,050	88,350	88,690	89,030	89,370	89,710	90,050	90,420	90,780	91,140	91,510	91,870	92,230	92,590	92,940	93,300	93,670	94,050	94,440	94,820	95,210	94
95	88,490	88,880	89,290	89,720	90,140	90,570	90,990	91,440	91,880	92,330	92,770	93,220	93,660	94,100	94,550	94,990	95,440	95,910	96,380	96,840	97,310	95
96	88,850	89,320	89,820	90,320	90,820	91,330	91,840	92,360	92,880	93,400	93,930	94,450	94,980	95,500	96,030	96,550	97,090	97,630	98,180	98,730	99,280	96
97	89,240	89,800	90,380	90,960	91,550	92,140	92,730	93,330	93,930	94,540	95,150	95,750	96,360	96,970	97,580	98,190	98,810	99,440	100,100	100,700	101,300	97
98	89,580	90,230	90,890	91,560	92,230	92,900	93,570	94,260	94,940	95,630	96,320	97,010	97,700	98,390	99,090	99,790	100,500	101,200	101,900	102,600	103,300	98
99	90,000	90,740	91,480	92,230	92,980	93,740	94,490	95,260	96,020	96,790	97,560	98,340	99,110	99,890	100,700	101,500	102,200	103,000	103,800	104,600	105,400	99
100	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	100
101	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	101
102	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	102
103	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	103
104	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	104
105	90,340	91,160	91,990	92,820	93,660	94,500	95,340	96,180	97,030	97,880	98,730	99,590	100,500	101,300	102,200	103,100	103,900	104,800	105,700	106,600	107,400	105

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1277.0	1277.1	1277.2	1277.3	1277.4	1277.5	1277.6	1277.7	1277.8	1277.9	1278.0	1278.1	1278.2	1278.3	1278.4	1278.5	1278.6	1278.7	1278.8	1278.9	1279.0	
1	550	550	550	560	560	560	560	560	560	560	570	570	570	570	570	570	570	570	580	580	580	1
2	1,070	1,070	1,070	1,080	1,080	1,080	1,090	1,090	1,090	1,090	1,100	1,100	1,100	1,100	1,110	1,110	1,110	1,110	1,120	1,120	1,120	2
3	1,660	1,670	1,670	1,670	1,680	1,680	1,690	1,690	1,690	1,700	1,700	1,710	1,710	1,720	1,720	1,720	1,730	1,730	1,730	1,740	1,740	3
4	2,260	2,270	2,270	2,280	2,280	2,290	2,300	2,300	2,310	2,310	2,320	2,320	2,330	2,330	2,340	2,340	2,350	2,360	2,360	2,370	2,370	4
5	2,810	2,810	2,820	2,830	2,830	2,840	2,850	2,860	2,860	2,870	2,880	2,880	2,890	2,900	2,900	2,910	2,920	2,920	2,930	2,940	2,940	5
6	3,380	3,390	3,400	3,400	3,410	3,420	3,430	3,440	3,450	3,450	3,460	3,470	3,480	3,490	3,490	3,500	3,510	3,520	3,530	3,540	3,540	6
7	3,990	4,000	4,010	4,020	4,030	4,040	4,050	4,060	4,070	4,080	4,090	4,100	4,110	4,120	4,130	4,140	4,150	4,160	4,170	4,180	4,190	7
8	4,520	4,530	4,540	4,550	4,560	4,570	4,580	4,590	4,610	4,620	4,630	4,640	4,650	4,660	4,670	4,680	4,690	4,700	4,710	4,730	4,740	8
9	5,100	5,110	5,120	5,130	5,150	5,160	5,170	5,180	5,200	5,210	5,220	5,230	5,250	5,260	5,270	5,280	5,290	5,310	5,320	5,330	5,340	9
10	5,620	5,630	5,650	5,660	5,680	5,690	5,700	5,720	5,730	5,740	5,760	5,770	5,790	5,800	5,810	5,830	5,840	5,850	5,870	5,880	5,890	10
11	6,250	6,270	6,280	6,300	6,310	6,330	6,340	6,360	6,380	6,390	6,410	6,420	6,440	6,450	6,470	6,480	6,500	6,510	6,530	6,540	6,560	11
12	6,870	6,890	6,910	6,920	6,940	6,960	6,980	6,990	7,010	7,030	7,040	7,060	7,080	7,090	7,110	7,130	7,140	7,160	7,180	7,190	7,210	12
13	7,470	7,490	7,510	7,530	7,550	7,560	7,580	7,600	7,620	7,640	7,660	7,670	7,690	7,710	7,730	7,750	7,770	7,780	7,800	7,820	7,840	13
14	8,100	8,120	8,140	8,160	8,180	8,200	8,220	8,240	8,260	8,280	8,300	8,320	8,340	8,360	8,380	8,400	8,420	8,440	8,460	8,480	8,500	14
15	8,710	8,730	8,760	8,780	8,800	8,820	8,840	8,870	8,890	8,910	8,930	8,950	8,970	8,990	9,020	9,040	9,060	9,080	9,100	9,120	9,140	15
16	9,330	9,350	9,380	9,400	9,420	9,450	9,470	9,490	9,520	9,540	9,560	9,590	9,610	9,630	9,660	9,680	9,700	9,720	9,750	9,770	9,790	16
17	9,960	9,980	10,010	10,030	10,060	10,080	10,110	10,130	10,160	10,180	10,210	10,230	10,260	10,280	10,310	10,330	10,360	10,380	10,400	10,430	10,450	17
18	10,580	10,610	10,640	10,670	10,690	10,720	10,750	10,770	10,800	10,830	10,850	10,880	10,900	10,930	10,960	10,980	11,010	11,030	11,060	11,090	11,110	18
19	11,200	11,230	11,260	11,290	11,320	11,340	11,370	11,400	11,430	11,460	11,480	11,510	11,540	11,570	11,600	11,620	11,650	11,680	11,710	11,730	11,760	19
20	11,820	11,850	11,880	11,910	11,940	11,970	12,000	12,030	12,060	12,090	12,120	12,150	12,180	12,210	12,240	12,270	12,300	12,330	12,360	12,380	12,410	20
21	12,470	12,500	12,530	12,570	12,600	12,630	12,660	12,690	12,720	12,760	12,790	12,820	12,850	12,880	12,910	12,940	12,970	13,000	13,030	13,060	13,090	21
22	13,120	13,160	13,190	13,220	13,260	13,290	13,320	13,360	13,390	13,420	13,460	13,490	13,520	13,550	13,590	13,620	13,650	13,690	13,720	13,750	13,780	22
23	13,780	13,810	13,850	13,880	13,920	13,950	13,990	14,020	14,060	14,090	14,130	14,160	14,200	14,230	14,270	14,300	14,330	14,370	14,400	14,440	14,470	23
24	14,410	14,440	14,480	14,520	14,550	14,590	14,630	14,660	14,700	14,740	14,770	14,810	14,850	14,880	14,920	14,960	14,990	15,030	15,060	15,100	15,130	24
25	15,030	15,070	15,110	15,150	15,190	15,230	15,260	15,300	15,340	15,380	15,420	15,460	15,490	15,530	15,570	15,610	15,640	15,680	15,720	15,760	15,790	25
26	15,670	15,710	15,750	15,800	15,840	15,880	15,920	15,960	16,000	16,040	16,080	16,120	16,160	16,200	16,230	16,270	16,310	16,350	16,390	16,430	16,470	26
27	16,320	16,360	16,400	16,440	16,490	16,530	16,570	16,610	16,650	16,690	16,740	16,780	16,820	16,860	16,900	16,940	16,980	17,020	17,070	17,110	17,150	27
28	16,950	16,990	17,040	17,080	17,130	17,170	17,210	17,260	17,300	17,340	17,390	17,430	17,470	17,520	17,560	17,600	17,640	17,690	17,730	17,770	17,810	28
29	17,580	17,620	17,670	17,710	17,760	17,810	17,850	17,900	17,940	17,990	18,030	18,080	18,120	18,170	18,210	18,250	18,300	18,340	18,390	18,430	18,480	29
30	18,210	18,260	18,300	18,350	18,400	18,450	18,490	18,540	18,590	18,630	18,680	18,730	18,770	18,820	18,870	18,910	18,960	19,000	19,050	19,100	19,140	30
31	18,840	18,890	18,940	18,990	19,040	19,090	19,130	19,180	19,230	19,280	19,330	19,380	19,430	19,470	19,520	19,570	19,620	19,660	19,710	19,760	19,810	31
32	19,460	19,510	19,570	19,620	19,670	19,720	19,770	19,820	19,870	19,920	19,970	20,020	20,070	20,120	20,170	20,220	20,270	20,320	20,370	20,420	20,470	32
33	20,070	20,130	20,180	20,230	20,280	20,340	20,390	20,440	20,490	20,550	20,600	20,650	20,700	20,750	20,800	20,860	20,910	20,960	21,010	21,060	21,110	33
34	20,690	20,750	20,800	20,860	20,910	20,970	21,020	21,080	21,130	21,180	21,240	21,290	21,340	21,400	21,450	21,500	21,560	21,610	21,660	21,720	21,770	34
35	21,330	21,380	21,440	21,500	21,550	21,610	21,660	21,720	21,780	21,830	21,890	21,940	22,000	22,050	22,110	22,160	22,220	22,270	22,330	22,380	22,430	35
36	21,950	22,010	22,070	22,120	22,180	22,240	22,300	22,360	22,410	22,470	22,530	22,580	22,640	22,700	22,750	22,810	22,870	22,920	22,980	23,040	23,090	36
37	22,560	22,620	22,680	22,740	22,800	22,860	22,920	22,980	23,040	23,090	23,150	23,210	23,270	23,330	23,390	23,450	23,500	23,560	23,620	23,680	23,730	37
38	23,190	23,250	23,310	23,370	23,440	23,500	23,560	23,620	23,680	23,740	23,800	23,860	23,920	23,980	24,040	24,100	24,160	24,220	24,280	24,340	24,400	38
39	23,820	23,880	23,940	24,010	24,070	24,140	24,200	24,260	24,320	24,390	24,450	24,510	24,570	24,640	24,700	24,760	24,820	24,880	24,940	25,010	25,070	39
40	24,450	24,520	24,590	24,650	24,720	24,780	24,850	24,910	24,980	25,040	25,100	25,170	25,230	25,300	25,360	25,420	25,490	25,550	25,610	25,680	25,740	40
41	25,080	25,140	25,210	25,280	25,350	25,410	25,480	25,550	25,610	25,680	25,740	25,810	25,880	25,940	26,010	26,070	26,140	26,200	26,270	26,330	26,400	41
42	25,700	25,770	25,840	25,910	25,980	26,050	26,120	26,190	26,260	26,320	26,390	26,460	26,530	26,600	26,660	26,730	26,800	26,860	26,930	27,000	27,060	42
43	26,320	26,390	26,460	26,530	26,600	26,680	26,750	26,820	26,890	26,960	27,030	27,100	27,170	27,240	27,300	27,370	27,440	27,510	27,580	27,650	27,720	43
44	26,930	27,010	27,080	27,150	27,230	27,300	27,370	27,440	27,520	27,590	27,660	27,730	27,800	27,870	27,950	28,020	28,090	28,160	28,230	28,300	28,370	44
45	27,580	27,650	27,730	27,800	27,880	27,950	28,030	28,100	28,170	28,250	28,320	28,390	28,470	28,540	28,610	28,690	28,760	28,830	28,900	28,980	29,050	45
46	28,200	28,280	28,360	28,440	28,510	28,590	28,660	28,740	28,820	28,890	28,970	29,040	29,120	29,190	29,270	29,340	29,420	29,490	29,570	29,640	29,710	46
47	28,820	28,900	28,980	29,060	29,130	29,210	29,290	29,370	29,450	29,520	29,600	29,680	29,760	29,830	29,910	29,980	30,060	30,140	30,210	30,290	30,360	47
48	29,440	29,520	29,600	29,680	29,760	29,840	29,920	30,000	30,080	30,160	30,240	30,320	30,400	30,480	30,560	30,640	30,710	30,790	30,870	30,950	31,020	48
49	30,060	30,140	30,220	30,300	30,390	30,470	30,550	30,630	30,710	30,800	30,880	30,960	31,040	31,120	31,200	31,280	31,360	31,440	31,520	31,600	31,680	49
50	30,670	30,750	30,840	30,920	31,000	31,090	31,170	31,260	31,340	31,420	31,510	31,590	31,670	31,750	31,830	31,920	32,000	32,080	32,160	32,240	32,320	50
51	31,280	31,370	31,460	31,540	31,630	31,720	31,800	31,890	31,970	32,060	32,140	32,230	32,310	32,400	32,480	32,560	32,650	32,730	32,810	32,900	32,980	51
52	31,900	31,990	32,080	32,170	32,250	32,340	32,430	32,520	32,610	32,690	32,780	32,870	32,950	33,040	33,120	33,210	33,290	33,380	33,460	33,550	33,630	52
53	32,520	32,620	32,710	32,800	32,890	32,980	33,070	33,160	33,240	33,330	33,420	33,510	33,600	33,690	33,780	33,860	33,950	34,040	34,120	34,210	34,300	53
54	33,160	33,250	33,340	33,430	33,530	33,620	33,710	33,800	33,890	33,980	34,070	34,160	34,250	34,340	34,430	34,520	34,610	34,700	34,790	34,880	34,970	54
55	33,770	33,870	33,960	34,060	34,150	34,240	34,340	34,430	34,520	34,620	34,710	34,800	34,890	34,990	35,080	35,170	35,260	35,350	35,440	35,530	35,620	55

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1277.0	1277.1	1277.2	1277.3	1277.4	1277.5	1277.6	1277.7	1277.8	1277.9	1278.0	1278.1	1278.2	1278.3	1278.4	1278.5	1278.6	1278.7	1278.8	1278.9	1279.0	
56	34,390	34,490	34,580	34,680	34,780	34,870	34,970	35,060	35,160	35,250	35,350	35,440	35,540	35,630	35,720	35,820	35,910	36,000	36,100	36,190	36,280	56
57	35,020	35,110	35,210	35,310	35,410	35,510	35,610	35,700	35,800	35,900	35,990	36,090	36,190	36,280	36,380	36,470	36,570	36,660	36,760	36,850	36,940	57
58	35,620	35,730	35,830	35,930	36,030	36,130	36,230	36,330	36,420	36,520	36,620	36,720	36,820	36,920	37,010	37,110	37,210	37,300	37,400	37,500	37,590	58
59	36,250	36,350	36,450	36,560	36,660	36,760	36,860	36,960	37,060	37,170	37,270	37,370	37,470	37,570	37,660	37,760	37,860	37,960	38,060	38,160	38,260	59
60	36,880	36,980	37,090	37,190	37,300	37,400	37,500	37,610	37,710	37,810	37,910	38,020	38,120	38,220	38,320	38,420	38,520	38,620	38,720	38,820	38,920	60
61	38,150	38,260	38,370	38,480	38,590	38,700	38,810	38,920	39,020	39,130	39,240	39,340	39,450	39,560	39,660	39,770	39,870	39,980	40,080	40,190	40,290	61
62	39,430	39,540	39,650	39,770	39,880	39,990	40,110	40,220	40,330	40,440	40,550	40,660	40,770	40,890	41,000	41,100	41,210	41,320	41,430	41,540	41,650	62
63	40,680	40,800	40,920	41,030	41,150	41,270	41,390	41,500	41,620	41,730	41,850	41,970	42,080	42,190	42,310	42,420	42,540	42,650	42,760	42,880	42,990	63
64	41,940	42,060	42,180	42,310	42,430	42,550	42,670	42,790	42,910	43,030	43,150	43,270	43,390	43,510	43,630	43,750	43,860	43,980	44,100	44,220	44,330	64
65	43,220	43,350	43,480	43,610	43,730	43,860	43,980	44,110	44,230	44,360	44,480	44,610	44,730	44,850	44,980	45,100	45,220	45,340	45,460	45,580	45,710	65
66	44,480	44,610	44,750	44,880	45,010	45,140	45,270	45,400	45,530	45,660	45,790	45,910	46,040	46,170	46,300	46,420	46,550	46,670	46,800	46,930	47,050	66
67	45,730	45,870	46,000	46,140	46,280	46,410	46,540	46,680	46,810	46,940	47,080	47,210	47,340	47,470	47,610	47,740	47,870	48,000	48,130	48,260	48,390	67
68	46,980	47,130	47,270	47,410	47,550	47,690	47,830	47,970	48,100	48,240	48,380	48,520	48,650	48,790	48,920	49,060	49,190	49,330	49,460	49,600	49,730	68
69	48,250	48,400	48,540	48,690	48,830	48,980	49,120	49,260	49,410	49,550	49,690	49,830	49,970	50,110	50,250	50,390	50,530	50,670	50,810	50,940	51,080	69
70	49,530	49,690	49,840	49,990	50,140	50,290	50,430	50,580	50,730	50,870	51,020	51,160	51,310	51,450	51,600	51,740	51,880	52,030	52,170	52,310	52,450	70
71	50,740	50,900	51,050	51,210	51,360	51,520	51,670	51,820	51,970	52,120	52,270	52,420	52,570	52,720	52,870	53,020	53,170	53,320	53,460	53,610	53,760	71
72	51,980	52,150	52,310	52,470	52,630	52,780	52,940	53,100	53,260	53,410	53,570	53,720	53,880	54,030	54,190	54,340	54,490	54,650	54,800	54,950	55,100	72
73	53,210	53,380	53,540	53,710	53,870	54,030	54,200	54,360	54,520	54,680	54,840	55,000	55,160	55,320	55,480	55,640	55,800	55,960	56,110	56,270	56,430	73
74	54,430	54,600	54,770	54,940	55,110	55,280	55,450	55,610	55,780	55,950	56,110	56,280	56,440	56,610	56,770	56,930	57,100	57,260	57,420	57,580	57,740	74
75	55,650	55,830	56,010	56,180	56,360	56,530	56,700	56,870	57,050	57,220	57,390	57,560	57,730	57,900	58,060	58,230	58,400	58,570	58,730	58,900	59,070	75
76	56,840	57,030	57,210	57,390	57,560	57,740	57,920	58,100	58,270	58,450	58,630	58,800	58,980	59,150	59,320	59,500	59,670	59,840	60,010	60,180	60,350	76
77	58,070	58,260	58,440	58,630	58,810	58,990	59,180	59,360	59,540	59,720	59,900	60,080	60,260	60,440	60,620	60,800	60,970	61,150	61,330	61,500	61,680	77
78	59,290	59,490	59,680	59,870	60,050	60,240	60,430	60,620	60,800	60,990	61,180	61,360	61,550	61,730	61,910	62,100	62,280	62,460	62,640	62,820	63,000	78
79	60,520	60,720	60,910	61,110	61,300	61,490	61,690	61,880	62,070	62,260	62,450	62,640	62,830	63,020	63,210	63,400	63,580	63,770	63,960	64,140	64,330	79
80	61,750	61,950	62,150	62,350	62,540	62,740	62,940	63,140	63,330	63,530	63,730	63,920	64,120	64,310	64,500	64,690	64,890	65,080	65,270	65,460	65,650	80
81	64,120	64,300	64,490	64,670	64,850	65,050	65,260	65,460	65,670	65,870	66,070	66,270	66,470	66,680	66,880	67,070	67,270	67,470	67,670	67,870	68,060	81
82	66,700	66,870	67,040	67,210	67,380	67,560	67,750	67,960	68,170	68,380	68,590	68,800	69,010	69,210	69,420	69,630	69,830	70,040	70,240	70,450	70,650	82
83	69,240	69,390	69,550	69,700	69,850	70,020	70,200	70,420	70,640	70,850	71,070	71,290	71,500	71,720	71,930	72,150	72,360	72,570	72,780	73,000	73,210	83
84	71,800	71,940	72,080	72,220	72,350	72,500	72,670	72,890	73,120	73,340	73,570	73,790	74,020	74,240	74,460	74,680	74,900	75,120	75,340	75,560	75,770	84
85	74,310	74,440	74,560	74,680	74,800	74,930	75,110	75,340	75,570	75,810	76,040	76,270	76,500	76,730	76,960	77,190	77,410	77,640	77,870	78,090	78,310	85
86	76,750	76,860	76,960	77,070	77,170	77,290	77,450	77,690	77,930	78,170	78,410	78,650	78,880	79,120	79,360	79,590	79,820	80,060	80,290	80,520	80,750	86
87	79,300	79,390	79,480	79,570	79,650	79,750	79,910	80,150	80,400	80,650	80,900	81,140	81,390	81,630	81,870	82,120	82,360	82,600	82,840	83,070	83,310	87
88	81,890	81,970	82,040	82,110	82,180	82,270	82,410	82,650	82,910	83,170	83,420	83,680	83,930	84,180	84,430	84,680	84,930	85,170	85,420	85,660	85,910	88
89	84,430	84,490	84,550	84,610	84,660	84,730	84,870	85,130	85,390	85,650	85,920	86,180	86,440	86,700	86,950	87,210	87,460	87,720	87,970	88,220	88,470	89
90	87,000	87,050	87,090	87,130	87,170	87,220	87,350	87,600	87,880	88,150	88,420	88,680	88,950	89,220	89,480	89,740	90,010	90,270	90,530	90,780	91,040	90
91	89,080	89,210	89,340	89,460	89,580	89,700	89,880	90,200	90,540	90,870	91,200	91,530	91,860	92,190	92,510	92,840	93,170	93,490	93,820	94,140	94,460	91
92	91,110	91,320	91,530	91,740	91,950	92,150	92,420	92,810	93,210	93,600	94,000	94,400	94,790	95,190	95,580	95,980	96,370	96,770	97,160	97,550	97,950	92
93	93,170	93,470	93,770	94,070	94,360	94,650	95,000	95,450	95,910	96,380	96,840	97,300	97,760	98,230	98,690	99,150	99,610	100,100	100,500	101,000	101,500	93
94	95,210	95,590	95,970	96,350	96,740	97,120	97,550	98,060	98,590	99,120	99,650	100,200	100,700	101,200	101,800	102,300	102,800	103,400	103,900	104,400	105,000	94
95	97,310	97,780	98,250	98,720	99,190	99,660	100,200	100,700	101,300	101,900	102,500	103,100	103,700	104,300	104,900	105,500	106,100	106,700	107,300	107,900	108,500	95
96	99,280	99,830	100,400	100,900	101,500	102,000	102,600	103,200	103,900	104,600	105,200	105,900	106,500	107,200	107,800	108,500	109,200	109,800	110,500	111,200	111,800	96
97	101,300	102,000	102,600	103,200	103,900	104,500	105,200	105,900	106,600	107,300	108,000	108,800	109,500	110,200	110,900	111,700	112,400	113,100	113,900	114,600	115,300	97
98	103,300	104,100	104,800	105,500	106,200	107,000	107,700	108,500	109,300	110,000	110,800	111,600	112,400	113,200	114,000	114,800	115,600	116,400	117,200	118,000	118,800	98
99	105,400	106,200	107,000	107,900	108,700	109,500	110,300	111,100	112,000	112,800	113,700	114,500	115,400	116,300	117,100	118,000	118,900	119,700	120,600	121,500	122,400	99
100	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	100
101	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	101
102	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	102
103	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	103
104	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	104
105	107,400	108,300	109,200	110,100	111,000	111,900	112,800	113,700	114,600	115,600	116,500	117,400	118,300	119,300	120,200	121,100	122,100	123,000	123,900	124,900	125,800	105

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1279.0	1279.1	1279.2	1279.3	1279.4	1279.5	1279.6	1279.7	1279.8	1279.9	1280.0	1280.1	1280.2	1280.3	1280.4	1280.5	1280.6	1280.7	1280.8	1280.9	1281.0	
1	580	580	580	580	580	590	590	590														1
2	1,120	1,120	1,130	1,130	1,130	1,130	1,140	1,140														2
3	1,740	1,750	1,750	1,750	1,760	1,760	1,770	1,770														3
4	2,370	2,380	2,380	2,390	2,390	2,400	2,400	2,410														4
5	2,940	2,950	2,960	2,960	2,970	2,980	2,980	2,990														5
6	3,540	3,550	3,560	3,570	3,580	3,580	3,590	3,600														6
7	4,190	4,200	4,200	4,210	4,220	4,230	4,240	4,250														7
8	4,740	4,750	4,760	4,770	4,780	4,790	4,800	4,810														8
9	5,340	5,360	5,370	5,380	5,390	5,400	5,420	5,430														9
10	5,890	5,910	5,920	5,930	5,950	5,960	5,970	5,990	6,000	6,010	6,030	6,040	6,050	6,060								10
11	6,560	6,570	6,590	6,600	6,620	6,630	6,650	6,660	6,680	6,690	6,700	6,720	6,730	6,750								11
12	7,210	7,230	7,240	7,260	7,280	7,290	7,310	7,320	7,340	7,360	7,370	7,390	7,410	7,420								12
13	7,840	7,860	7,870	7,890	7,910	7,930	7,950	7,960	7,980	8,000	8,020	8,030	8,050	8,070								13
14	8,500	8,520	8,540	8,560	8,580	8,600	8,620	8,630	8,650	8,670	8,690	8,710	8,730	8,750								14
15	9,140	9,160	9,190	9,210	9,230	9,250	9,270	9,290	9,310	9,330	9,350	9,370	9,390	9,410								15
16	9,790	9,820	9,840	9,860	9,880	9,900	9,930	9,950	9,970	9,990	10,020	10,040	10,060	10,080								16
17	10,450	10,480	10,500	10,520	10,550	10,570	10,600	10,620	10,640	10,670	10,690	10,710	10,740	10,760								17
18	11,110	11,140	11,160	11,190	11,210	11,240	11,260	11,290	11,320	11,340	11,370	11,390	11,420	11,440								18
19	11,760	11,790	11,810	11,840	11,870	11,900	11,920	11,950	11,980	12,000	12,030	12,060	12,080	12,110								19
20	12,410	12,440	12,470	12,500	12,530	12,560	12,580	12,610	12,640	12,670	12,700	12,730	12,750	12,780	12,810	12,840	12,870	12,890	12,920	12,950	12,980	20
21	13,090	13,130	13,160	13,190	13,220	13,250	13,280	13,310	13,340	13,370	13,400	13,430	13,460	13,490	13,510	13,540	13,570	13,600	13,630	13,660	13,690	21
22	13,780	13,810	13,850	13,880	13,910	13,940	13,970	14,010	14,040	14,070	14,100	14,130	14,160	14,190	14,230	14,260	14,290	14,320	14,350	14,380	14,410	22
23	14,470	14,500	14,540	14,570	14,610	14,640	14,670	14,710	14,740	14,770	14,810	14,840	14,870	14,910	14,940	14,970	15,000	15,040	15,070	15,100	15,130	23
24	15,130	15,170	15,200	15,240	15,280	15,310	15,350	15,380	15,420	15,450	15,490	15,520	15,550	15,590	15,620	15,660	15,690	15,730	15,760	15,790	15,830	24
25	15,790	15,830	15,870	15,910	15,940	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	16,490	16,520	25
26	16,470	16,510	16,550	16,590	16,620	16,660	16,700	16,740	16,780	16,820	16,850	16,890	16,930	16,970	17,000	17,040	17,080	17,120	17,150	17,190	17,230	26
27	17,150	17,190	17,230	17,270	17,310	17,350	17,390	17,430	17,470	17,510	17,550	17,590	17,630	17,670	17,710	17,740	17,780	17,820	17,860	17,900	17,940	27
28	17,810	17,860	17,900	17,940	17,980	18,020	18,060	18,110	18,150	18,190	18,230	18,270	18,310	18,350	18,390	18,440	18,480	18,520	18,560	18,600	18,640	28
29	18,480	18,520	18,560	18,610	18,650	18,690	18,740	18,780	18,820	18,870	18,910	18,950	18,990	19,040	19,080	19,120	19,160	19,210	19,250	19,290	19,330	29
30	19,140	19,190	19,230	19,280	19,320	19,370	19,410	19,460	19,500	19,550	19,590	19,640	19,680	19,720	19,770	19,810	19,860	19,900	19,940	19,990	20,030	30
31	19,810	19,850	19,900	19,950	19,990	20,040	20,090	20,130	20,180	20,230	20,270	20,320	20,370	20,410	20,460	20,500	20,550	20,590	20,640	20,680	20,730	31
32	20,470	20,510	20,560	20,610	20,660	20,710	20,760	20,810	20,850	20,900	20,950	21,000	21,040	21,090	21,140	21,190	21,230	21,280	21,330	21,380	21,420	32
33	21,110	21,160	21,210	21,260	21,310	21,360	21,410	21,460	21,510	21,560	21,610	21,660	21,710	21,760	21,810	21,860	21,900	21,950	22,000	22,050	22,100	33
34	21,770	21,820	21,870	21,920	21,980	22,030	22,080	22,130	22,180	22,230	22,280	22,340	22,390	22,440	22,490	22,540	22,590	22,640	22,690	22,740	22,790	34
35	22,430	22,490	22,540	22,600	22,650	22,700	22,760	22,810	22,860	22,910	22,970	23,020	23,070	23,130	23,180	23,230	23,280	23,330	23,390	23,440	23,490	35
36	23,090	23,150	23,200	23,260	23,310	23,370	23,420	23,480	23,530	23,590	23,640	23,700	23,750	23,810	23,860	23,910	23,970	24,020	24,070	24,130	24,180	36
37	23,730	23,790	23,850	23,910	23,960	24,020	24,080	24,130	24,190	24,250	24,300	24,360	24,410	24,470	24,530	24,580	24,640	24,690	24,750	24,800	24,860	37
38	24,400	24,460	24,520	24,580	24,640	24,700	24,750	24,810	24,870	24,930	24,990	25,040	25,100	25,160	25,220	25,270	25,330	25,390	25,440	25,500	25,560	38
39	25,070	25,130	25,190	25,250	25,310	25,370	25,430	25,490	25,550	25,610	25,670	25,730	25,790	25,850	25,900	25,960	26,020	26,080	26,140	26,200	26,260	39
40	25,740	25,800	25,860	25,930	25,990	26,050	26,110	26,170	26,240	26,300	26,360	26,420	26,480	26,540	26,600	26,660	26,720	26,780	26,840	26,900	26,960	40
41	26,400	26,460	26,530	26,590	26,650	26,720	26,780	26,840	26,910	26,970	27,030	27,100	27,160	27,220	27,280	27,350	27,410	27,470	27,530	27,590	27,660	41
42	27,060	27,130	27,200	27,260	27,330	27,390	27,460	27,520	27,590	27,650	27,720	27,780	27,850	27,910	27,980	28,040	28,100	28,170	28,230	28,300	28,360	42
43	27,720	27,780	27,850	27,920	27,990	28,050	28,120	28,190	28,260	28,320	28,390	28,450	28,520	28,590	28,650	28,720	28,780	28,850	28,920	28,980	29,050	43
44	28,370	28,440	28,510	28,580	28,650	28,710	28,780	28,850	28,920	28,990	29,060	29,130	29,190	29,260	29,330	29,400	29,460	29,530	29,600	29,670	29,730	44
45	29,050	29,120	29,190	29,260	29,330	29,400	29,470	29,540	29,620	29,690	29,760	29,830	29,900	29,960	30,030	30,100	30,170	30,240	30,310	30,380	30,450	45
46	29,710	29,790	29,860	29,930	30,010	30,080	30,150	30,220	30,300	30,370	30,440	30,510	30,580	30,650	30,720	30,800	30,870	30,940	31,010	31,080	31,150	46
47	30,360	30,440	30,510	30,590	30,660	30,740	30,810	30,890	30,960	31,030	31,110	31,180	31,250	31,330	31,400	31,470	31,550	31,620	31,690	31,760	31,830	47
48	31,020	31,100	31,180	31,250	31,330	31,410	31,480	31,560	31,630	31,710	31,790	31,860	31,940	32,010	32,090	32,160	32,230	32,310	32,380	32,460	32,530	48
49	31,680	31,750	31,830	31,910	31,990	32,070	32,150	32,220	32,300	32,380	32,460	32,530	32,610	32,690	32,760	32,840	32,910	32,990	33,070	33,140	33,220	49
50	32,320	32,400	32,480	32,560	32,640	32,720	32,800	32,880	32,960	33,040	33,120	33,200	33,280	33,350	33,430	33,510	33,590	33,670	33,740	33,820	33,900	50
51	32,980	33,060	33,140	33,230	33,310	33,390	33,470	33,550	33,630	33,710	33,790	33,880	33,960	34,040	34,120	34,200	34,270	34,350	34,430	34,510	34,590	51
52	33,630	33,720	33,800	33,890	33,970	34,050	34,140	34,220	34,300	34,390	34,470	34,550	34,630	34,710	34,800	34,880	34,960	35,040	35,120	35,200	35,280	52
53	34,300	34,380	34,470	34,560	34,640	34,730	34,810	34,900	34,980	35,070	35,150	35,230	35,320	35,400	35,490	35,570	35,650	35,730	35,820	35,900	35,980	53
54	34,970	35,060	35,140	35,230	35,320	35,410	35,490	35,580	35,670	35,750	35,840	35,930	36,010	36,100	36,180	36,270	36,350	36,440	36,520	36,610	36,690	54
55	35,620	35,710	35,800	35,890	35,980	36,070	36,160	36,250	36,340	36,430	36,510	36,600	36,690	36,780	36,860	36,950	37,040	37,120	37,210	37,300	37,380	55

See special instruction for preventing gate overflow on page 3.

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1279.0	1279.1	1279.2	1279.3	1279.4	1279.5	1279.6	1279.7	1279.8	1279.9	1280.0	1280.1	1280.2	1280.3	1280.4	1280.5	1280.6	1280.7	1280.8	1280.9	1281.0	
56	36,280	36,370	36,460	36,560	36,650	36,740	36,830	36,920	37,010	37,100	37,190	37,280	37,370	37,460	37,550	37,640	37,720	37,810	37,900	37,990	38,080	56
57	36,940	37,040	37,130	37,230	37,320	37,410	37,500	37,600	37,690	37,780	37,870	37,960	38,060	38,150	38,240	38,330	38,420	38,510	38,600	38,690	38,780	57
58	37,590	37,690	37,780	37,880	37,970	38,070	38,160	38,260	38,350	38,450	38,540	38,630	38,730	38,820	38,910	39,000	39,100	39,190	39,280	39,370	39,460	58
59	38,260	38,350	38,450	38,550	38,640	38,740	38,840	38,930	39,030	39,130	39,220	39,320	39,410	39,510	39,600	39,690	39,790	39,880	39,980	40,070	40,160	59
60	38,920	39,020	39,120	39,220	39,320	39,420	39,520	39,620	39,710	39,810	39,910	40,010	40,100	40,200	40,290	40,390	40,490	40,580	40,680	40,770	40,870	60
61	40,290	40,390	40,500	40,600	40,700	40,810	40,910	41,010	41,110	41,210	41,320	41,420	41,520	41,620	41,720	41,820	41,920	42,020	42,120	42,220	42,320	61
62	41,650	41,760	41,860	41,970	42,080	42,190	42,290	42,400	42,500	42,610	42,720	42,820	42,930	43,030	43,140	43,240	43,340	43,450	43,550	43,650	43,760	62
63	42,990	43,100	43,210	43,320	43,430	43,550	43,660	43,770	43,880	43,990	44,100	44,210	44,310	44,420	44,530	44,640	44,750	44,860	44,960	45,070	45,180	63
64	44,330	44,450	44,560	44,680	44,800	44,910	45,030	45,140	45,250	45,370	45,480	45,600	45,710	45,820	45,930	46,050	46,160	46,270	46,380	46,490	46,600	64
65	45,710	45,830	45,950	46,070	46,190	46,300	46,420	46,540	46,660	46,780	46,900	47,010	47,130	47,250	47,360	47,480	47,600	47,710	47,830	47,940	48,060	65
66	47,050	47,180	47,300	47,420	47,550	47,670	47,790	47,920	48,040	48,160	48,280	48,400	48,530	48,650	48,770	48,890	49,010	49,130	49,250	49,370	49,490	66
67	48,390	48,510	48,640	48,770	48,900	49,030	49,150	49,280	49,410	49,530	49,660	49,780	49,910	50,030	50,160	50,280	50,410	50,530	50,650	50,780	50,900	67
68	49,730	49,860	49,990	50,130	50,260	50,390	50,520	50,650	50,780	50,910	51,040	51,170	51,300	51,430	51,560	51,690	51,820	51,940	52,070	52,200	52,320	68
69	51,080	51,220	51,360	51,490	51,630	51,760	51,900	52,030	52,170	52,300	52,440	52,570	52,700	52,840	52,970	53,100	53,230	53,370	53,500	53,630	53,760	69
70	52,450	52,600	52,740	52,880	53,020	53,160	53,300	53,440	53,580	53,710	53,850	53,990	54,130	54,260	54,400	54,540	54,670	54,810	54,940	55,080	55,210	70
71	53,760	53,900	54,050	54,190	54,340	54,480	54,630	54,770	54,920	55,060	55,200	55,340	55,480	55,630	55,770	55,910	56,050	56,190	56,330	56,470	56,610	71
72	55,100	55,250	55,400	55,550	55,700	55,850	56,000	56,150	56,300	56,450	56,590	56,740	56,890	57,030	57,180	57,320	57,470	57,610	57,760	57,900	58,040	72
73	56,430	56,580	56,740	56,890	57,050	57,200	57,350	57,510	57,660	57,810	57,960	58,110	58,270	58,420	58,570	58,710	58,860	59,010	59,160	59,310	59,460	73
74	57,740	57,900	58,060	58,220	58,380	58,540	58,700	58,860	59,010	59,170	59,330	59,480	59,640	59,790	59,950	60,100	60,250	60,410	60,560	60,710	60,860	74
75	59,070	59,230	59,400	59,560	59,730	59,890	60,050	60,220	60,380	60,540	60,700	60,860	61,020	61,180	61,340	61,490	61,650	61,810	61,970	62,120	62,280	75
76	60,350	60,520	60,690	60,860	61,030	61,200	61,370	61,540	61,700	61,870	62,030	62,190	62,360	62,520	62,690	62,850	63,010	63,170	63,330	63,490	63,650	76
77	61,680	61,850	62,030	62,200	62,370	62,550	62,720	62,890	63,060	63,230	63,400	63,570	63,740	63,910	64,070	64,240	64,410	64,570	64,740	64,900	65,070	77
78	63,000	63,180	63,360	63,540	63,720	63,900	64,070	64,250	64,420	64,600	64,770	64,950	65,120	65,290	65,460	65,630	65,800	65,970	66,140	66,310	66,480	78
79	64,330	64,510	64,700	64,880	65,060	65,240	65,430	65,610	65,790	65,970	66,140	66,320	66,500	66,680	66,850	67,030	67,200	67,380	67,550	67,730	67,900	79
80	65,650	65,840	66,030	66,220	66,400	66,590	66,780	66,960	67,150	67,330	67,510	67,700	67,880	68,060	68,240	68,420	68,600	68,780	68,960	69,130	69,310	80
81	68,060	68,260	68,450	68,650	68,840	69,040	69,230	69,430	69,620	69,810	70,000	70,190	70,380	70,570	70,750	70,940	71,130	71,310	71,500	71,690	71,870	81
82	70,650	70,850	71,060	71,260	71,460	71,660	71,860	72,060	72,260	72,460	72,660	72,860	73,050	73,250	73,450	73,640	73,840	74,030	74,230	74,420	74,610	82
83	73,210	73,410	73,620	73,830	74,040	74,250	74,450	74,660	74,870	75,080	75,290	75,490	75,700	75,900	76,110	76,310	76,510	76,710	76,920	77,120	77,320	83
84	75,770	75,990	76,210	76,420	76,630	76,850	77,060	77,280	77,500	77,710	77,930	78,140	78,350	78,570	78,780	78,990	79,200	79,410	79,620	79,830	80,040	84
85	78,310	78,540	78,760	78,980	79,200	79,420	79,640	79,870	80,090	80,320	80,540	80,760	80,980	81,200	81,420	81,640	81,860	82,080	82,300	82,510	82,730	85
86	80,750	80,980	81,210	81,430	81,660	81,890	82,120	82,350	82,580	82,810	83,040	83,270	83,500	83,730	83,960	84,190	84,410	84,640	84,860	85,090	85,310	86
87	83,310	83,550	83,780	84,010	84,250	84,480	84,720	84,960	85,200	85,440	85,680	85,920	86,150	86,390	86,630	86,860	87,090	87,330	87,560	87,790	88,020	87
88	85,910	86,150	86,390	86,630	86,870	87,110	87,350	87,600	87,850	88,100	88,350	88,590	88,840	89,080	89,330	89,570	89,810	90,050	90,290	90,530	90,770	88
89	88,470	88,720	88,970	89,220	89,460	89,710	89,960	90,220	90,470	90,730	90,990	91,240	91,490	91,750	92,000	92,250	92,500	92,750	93,000	93,240	93,490	89
90	91,040	91,300	91,550	91,810	92,060	92,310	92,570	92,830	93,100	93,360	93,630	93,890	94,150	94,410	94,670	94,930	95,190	95,450	95,700	95,960	96,210	90
91	94,460	94,760	94,970	95,190	95,400	95,620	95,840	96,080	96,320	96,560	96,790	97,030	97,280	97,520	97,760	98,000	98,230	98,470	98,710	98,940	99,180	91
92	97,950	98,310	98,600	98,870	99,040	99,220	99,400	99,600	99,800	100,000	100,200	100,400	100,700	100,900	101,100	101,300	101,500	101,700	102,000	102,200	102,400	92
93	101,500	101,900	102,300	102,500	102,600	102,800	102,900	103,100	103,200	103,400	103,600	103,800	104,000	104,200	104,400	104,600	104,800	105,000	105,200	105,400	105,600	93
94	105,000	105,500	105,900	106,100	106,200	106,300	106,400	106,600	106,700	106,900	107,000	107,200	107,300	107,500	107,700	107,900	108,100	108,200	108,400	108,600	108,700	94
95	108,500	109,100	109,500	109,700	109,800	109,800	109,900	110,000	110,100	110,200	110,400	110,500	110,600	110,800	111,000	111,100	111,300	111,400	111,600	111,700	111,900	95
96	111,800	112,500	113,000	113,200	113,200	113,200	113,200	113,300	113,400	113,500	113,600	113,700	113,800	113,900	114,100	114,200	114,400	114,500	114,600	114,800	114,900	96
97	115,300	116,100	116,600	116,800	116,800	116,800	116,700	116,700	116,800	116,900	117,000	117,000	117,100	117,200	117,400	117,500	117,600	117,700	117,800	118,000	118,100	97
98	118,800	119,600	120,200	120,500	120,500	120,500	120,400	120,400	120,400	120,400	120,500	120,500	120,600	120,700	120,800	120,900	121,000	121,100	121,200	121,300	121,400	98
99	122,400	123,200	123,900	124,100	124,100	124,000	123,900	123,800	123,800	123,800	123,900	123,900	123,900	124,000	124,100	124,200	124,300	124,300	124,400	124,500	124,500	99
100	125,800	126,800	127,500	127,700	127,700	127,600	127,400	127,300	127,300	127,300	127,300	127,300	127,300	127,300	127,400	127,400	127,500	127,600	127,600	127,700	127,700	100
101	125,800	126,800	127,700	128,000	128,000	128,000	128,000	127,900	128,000	128,100	128,200	128,300	128,400	128,500	128,700	128,800	129,000	129,100	129,300	129,400	129,500	101
102	125,800	126,800	127,700	128,000	128,200	128,300	128,300	128,400	128,600	128,800	129,000	129,200	129,300	129,600	129,800	130,100	130,300	130,600	130,800	131,000	131,300	102
103	125,800	126,800	127,700	128,100	128,400	128,600	128,800	129,000	129,200	129,500	129,800	130,100	130,400	130,700	131,100	131,400	131,800	132,100	132,400	132,800	133,100	103
104	125,800	126,800	127,700	128,200	128,600	128,900	129,200	129,500	129,800	130,200	130,600	131,000	131,400	131,800	132,300	132,700	133,100	133,600	134,000	134,400	134,900	104
105	125,800	126,800	127,700	128,300	128,800	129,200	129,700	130,100	130,500	131,000	131,500	132,000	132,500	133,000	133,500	134,100	134,600	135,100	135,700	136,200	136,700	105
106	125,800	126,800	127,700	128,400	129,000	129,500	130,100	130,600	131,100	131,700	132,300	132,900	133,500	134,100	134,700	135,300	135,900	136,600	137,200	137,800	138,400	106
107	125,800	126,800	127,700	128,500	129,200	129,900	130,500	131,100	131,800	132,500	133,200	133,900	134,500	135,200	135,900	136,700	137,400	138,100	138,800	139,500	140,300	107
108	125,800	126,800	127,700	128,500	129,300	130,000	130,800	131,500	132,300	133,100	133,800	134,600	135,400	136,200	137,000	137,800	138,600	139,500	140,300	141,100	141,900	108
109	125,800	126,800	127,700	128,600	129,500	130,300	131,200	132,100	132,900	133,800	134,700	135,600	136,500	137,400	138,300	139,200	140,100	141,000	141,900	142,800	143,700	109
110	125,800	126,800	127,700	128,700	129,700	130,600	131,600	132,600	133,500	134,500	135,500	136,500	137,500	138,500	139,500	140,500	141,500	142,500	143,500	144,500	145,500	110

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1281.0	1281.1	1281.2	1281.3	1281.4	1281.5	1281.6	1281.7	1281.8	1281.9	1282.0	1282.1	1282.2	1282.3	1282.4	1282.5	1282.6	1282.7	1282.8	1282.9	1283.0	
16																						16
17																						17
18																						18
19																						19
20	12, 980																					20
21	13, 690																					21
22	14, 410																					22
23	15, 130																					23
24	15, 830																					24
25	16, 520																					25
26	17, 230																					26
27	17, 940																					27
28	18, 640																					28
29	19, 330																					29
30	20, 030	20, 070	20, 120	20, 160	20, 200	20, 250	20, 290															30
31	20, 730	20, 770	20, 820	20, 860	20, 910	20, 950	21, 000															31
32	21, 420	21, 470	21, 520	21, 560	21, 610	21, 650	21, 700															32
33	22, 100	22, 150	22, 200	22, 240	22, 290	22, 340	22, 390															33
34	22, 790	22, 840	22, 890	22, 940	22, 990	23, 040	23, 090															34
35	23, 490	23, 540	23, 590	23, 640	23, 700	23, 750	23, 800															35
36	24, 180	24, 230	24, 290	24, 340	24, 390	24, 450	24, 500															36
37	24, 860	24, 910	24, 970	25, 020	25, 080	25, 130	25, 180															37
38	25, 560	25, 610	25, 670	25, 730	25, 780	25, 840	25, 890															38
39	26, 260	26, 310	26, 370	26, 430	26, 490	26, 540	26, 600															39
40	26, 960	27, 020	27, 080	27, 140	27, 200	27, 260	27, 320	27, 380	27, 440	27, 500	27, 550	27, 610	27, 670	27, 730								40
41	27, 660	27, 720	27, 780	27, 840	27, 900	27, 960	28, 020	28, 080	28, 140	28, 200	28, 260	28, 330	28, 390	28, 440								41
42	28, 360	28, 420	28, 480	28, 550	28, 610	28, 670	28, 740	28, 800	28, 860	28, 920	28, 980	29, 050	29, 110	29, 170								42
43	29, 050	29, 110	29, 180	29, 240	29, 300	29, 370	29, 430	29, 500	29, 560	29, 620	29, 690	29, 750	29, 810	29, 880								43
44	29, 730	29, 800	29, 860	29, 930	30, 000	30, 060	30, 130	30, 190	30, 260	30, 330	30, 390	30, 460	30, 520	30, 590								44
45	30, 450	30, 520	30, 580	30, 650	30, 720	30, 790	30, 860	30, 920	30, 990	31, 060	31, 120	31, 190	31, 260	31, 320								45
46	31, 150	31, 220	31, 290	31, 360	31, 430	31, 500	31, 570	31, 640	31, 700	31, 770	31, 840	31, 910	31, 980	32, 050								46
47	31, 830	31, 910	31, 980	32, 050	32, 120	32, 190	32, 260	32, 330	32, 400	32, 470	32, 540	32, 620	32, 690	32, 750								47
48	32, 530	32, 600	32, 680	32, 750	32, 820	32, 900	32, 970	33, 040	33, 110	33, 180	33, 260	33, 330	33, 400	33, 470								48
49	33, 220	33, 290	33, 370	33, 440	33, 520	33, 590	33, 660	33, 740	33, 810	33, 890	33, 960	34, 030	34, 110	34, 180								49
50	33, 900	33, 970	34, 050	34, 130	34, 200	34, 280	34, 360	34, 430	34, 510	34, 580	34, 660	34, 730	34, 810	34, 880	34, 960	35, 030	35, 110	35, 180	35, 250			50
51	34, 590	34, 670	34, 750	34, 830	34, 900	34, 980	35, 060	35, 140	35, 210	35, 290	35, 370	35, 450	35, 520	35, 600	35, 680	35, 750	35, 830	35, 900	35, 980			51
52	35, 280	35, 360	35, 440	35, 520	35, 600	35, 680	35, 760	35, 840	35, 920	36, 000	36, 080	36, 160	36, 240	36, 310	36, 390	36, 470	36, 550	36, 630	36, 700			52
53	35, 980	36, 060	36, 150	36, 230	36, 310	36, 390	36, 470	36, 550	36, 640	36, 720	36, 800	36, 880	36, 960	37, 040	37, 120	37, 200	37, 280	37, 360	37, 430			53
54	36, 690	36, 780	36, 860	36, 940	37, 030	37, 110	37, 190	37, 280	37, 360	37, 440	37, 520	37, 610	37, 690	37, 770	37, 850	37, 930	38, 010	38, 090	38, 180			54
55	37, 380	37, 470	37, 550	37, 640	37, 730	37, 810	37, 900	37, 980	38, 060	38, 150	38, 230	38, 320	38, 400	38, 480	38, 570	38, 650	38, 730	38, 820	38, 900			55
56	38, 080	38, 160	38, 250	38, 340	38, 430	38, 510	38, 600	38, 690	38, 770	38, 860	38, 940	39, 030	39, 120	39, 200	39, 290	39, 370	39, 460	39, 540	39, 620			56
57	38, 780	38, 870	38, 960	39, 050	39, 140	39, 220	39, 310	39, 400	39, 490	39, 580	39, 660	39, 750	39, 840	39, 930	40, 010	40, 100	40, 190	40, 270	40, 360			57
58	39, 460	39, 550	39, 650	39, 740	39, 830	39, 920	40, 010	40, 100	40, 190	40, 280	40, 370	40, 450	40, 540	40, 630	40, 720	40, 810	40, 900	40, 990	41, 070			58
59	40, 160	40, 260	40, 350	40, 440	40, 530	40, 630	40, 720	40, 810	40, 900	40, 990	41, 080	41, 170	41, 270	41, 360	41, 450	41, 540	41, 630	41, 720	41, 810			59
60	40, 870	40, 960	41, 060	41, 150	41, 250	41, 340	41, 430	41, 530	41, 620	41, 710	41, 810	41, 900	41, 990	42, 080	42, 180	42, 270	42, 360	42, 450	42, 540	42, 630	42, 720	60
61	42, 320	42, 420	42, 510	42, 610	42, 710	42, 810	42, 910	43, 000	43, 100	43, 200	43, 290	43, 390	43, 490	43, 580	43, 680	43, 780	43, 870	43, 970	44, 060	44, 160	44, 250	61
62	43, 760	43, 860	43, 960	44, 070	44, 170	44, 270	44, 370	44, 470	44, 570	44, 670	44, 770	44, 870	44, 980	45, 080	45, 170	45, 270	45, 370	45, 470	45, 570	45, 670	45, 770	62
63	45, 180	45, 280	45, 390	45, 500	45, 600	45, 710	45, 810	45, 920	46, 020	46, 130	46, 230	46, 340	46, 440	46, 540	46, 650	46, 750	46, 850	46, 960	47, 060	47, 160	47, 260	63
64	46, 600	46, 710	46, 820	46, 930	47, 040	47, 150	47, 260	47, 370	47, 480	47, 590	47, 700	47, 810	47, 910	48, 020	48, 130	48, 240	48, 340	48, 450	48, 560	48, 660	48, 770	64
65	48, 060	48, 170	48, 290	48, 400	48, 520	48, 630	48, 740	48, 860	48, 970	49, 080	49, 190	49, 300	49, 420	49, 530	49, 640	49, 750	49, 860	49, 970	50, 080	50, 190	50, 300	65
66	49, 490	49, 600	49, 720	49, 840	49, 960	50, 080	50, 190	50, 310	50, 430	50, 540	50, 660	50, 770	50, 890	51, 010	51, 120	51, 230	51, 350	51, 460	51, 580	51, 690	51, 800	66
67	50, 900	51, 020	51, 150	51, 270	51, 390	51, 510	51, 630	51, 750	51, 870	51, 990	52, 110	52, 230	52, 350	52, 470	52, 590	52, 710	52, 830	52, 940	53, 060	53, 180	53, 300	67
68	52, 320	52, 450	52, 580	52, 700	52, 830	52, 950	53, 080	53, 200	53, 330	53, 450	53, 580	53, 700	53, 820	53, 950	54, 070	54, 190	54, 310	54, 430	54, 560	54, 680	54, 800	68
69	53, 760	53, 890	54, 020	54, 150	54, 280	54, 410	54, 540	54, 660	54, 790	54, 920	55, 050	55, 180	55, 300	55, 430	55, 560	55, 680	55, 810	55, 930	56, 060	56, 180	56, 310	69
70	55, 210	55, 350	55, 480	55, 620	55, 750	55, 880	56, 020	56, 150	56, 280	56, 410	56, 540	56, 670	56, 810	56, 940	57, 070	57, 200	57, 330	57, 460	57, 580	57, 710	57, 840	70

See special instruction for preventing gate overflow on page 3.

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1281.0	1281.1	1281.2	1281.3	1281.4	1281.5	1281.6	1281.7	1281.8	1281.9	1282.0	1282.1	1282.2	1282.3	1282.4	1282.5	1282.6	1282.7	1282.8	1282.9	1283.0	
71	56,610	56,740	56,880	57,020	57,160	57,300	57,430	57,570	57,710	57,840	57,980	58,110	58,250	58,380	58,520	58,650	58,780	58,920	59,050	59,180	59,320	71
72	58,040	58,190	58,330	58,470	58,610	58,750	58,890	59,040	59,180	59,320	59,460	59,600	59,740	59,870	60,010	60,150	60,290	60,430	60,560	60,700	60,840	72
73	59,460	59,600	59,750	59,900	60,040	60,190	60,340	60,480	60,630	60,770	60,910	61,060	61,200	61,340	61,490	61,630	61,770	61,910	62,050	62,200	62,340	73
74	60,860	61,020	61,170	61,320	61,470	61,620	61,770	61,920	62,070	62,210	62,360	62,510	62,660	62,810	62,950	63,100	63,250	63,390	63,540	63,680	63,830	74
75	62,280	62,430	62,590	62,750	62,900	63,050	63,210	63,360	63,520	63,670	63,820	63,970	64,120	64,280	64,430	64,580	64,730	64,880	65,030	65,180	65,330	75
76	63,650	63,810	63,970	64,130	64,290	64,450	64,610	64,770	64,920	65,080	65,240	65,390	65,550	65,700	65,860	66,010	66,170	66,320	66,480	66,630	66,780	76
77	65,070	65,230	65,400	65,560	65,720	65,890	66,050	66,210	66,370	66,530	66,690	66,850	67,010	67,170	67,330	67,490	67,650	67,810	67,970	68,120	68,280	77
78	66,480	66,650	66,820	66,990	67,160	67,320	67,490	67,660	67,820	67,990	68,150	68,320	68,480	68,640	68,810	68,970	69,130	69,300	69,460	69,620	69,780	78
79	67,900	68,070	68,240	68,420	68,590	68,760	68,930	69,100	69,270	69,440	69,610	69,780	69,950	70,110	70,280	70,450	70,620	70,780	70,950	71,110	71,280	79
80	69,310	69,490	69,670	69,840	70,020	70,190	70,370	70,540	70,720	70,890	71,070	71,240	71,410	71,580	71,750	71,930	72,100	72,270	72,440	72,610	72,780	80
81	71,870	72,060	72,240	72,420	72,610	72,790	72,970	73,150	73,330	73,510	73,690	73,870	74,050	74,230	74,410	74,590	74,770	74,940	75,120	75,300	75,470	81
82	74,610	74,810	75,000	75,190	75,380	75,570	75,760	75,950	76,140	76,320	76,510	76,700	76,890	77,070	77,260	77,440	77,630	77,810	77,990	78,180	78,360	82
83	77,320	77,520	77,720	77,920	78,110	78,310	78,510	78,710	78,900	79,100	79,290	79,490	79,680	79,870	80,070	80,260	80,450	80,640	80,830	81,020	81,210	83
84	80,040	80,250	80,450	80,660	80,870	81,070	81,270	81,480	81,680	81,880	82,090	82,290	82,490	82,690	82,890	83,090	83,290	83,490	83,680	83,880	84,080	84
85	82,730	82,940	83,160	83,370	83,590	83,800	84,010	84,220	84,430	84,640	84,850	85,060	85,270	85,480	85,680	85,890	86,090	86,300	86,500	86,710	86,910	85
86	85,310	85,530	85,750	85,980	86,200	86,420	86,630	86,850	87,070	87,290	87,500	87,720	87,930	88,150	88,360	88,580	88,790	89,000	89,210	89,420	89,630	86
87	88,020	88,250	88,480	88,710	88,940	89,170	89,390	89,620	89,840	90,070	90,290	90,510	90,740	90,960	91,180	91,400	91,620	91,840	92,050	92,270	92,490	87
88	90,770	91,010	91,250	91,480	91,720	91,950	92,190	92,420	92,650	92,880	93,120	93,350	93,580	93,800	94,030	94,260	94,490	94,710	94,940	95,160	95,390	88
89	93,490	93,740	93,980	94,230	94,470	94,710	94,950	95,190	95,430	95,670	95,910	96,150	96,380	96,620	96,860	97,090	97,320	97,560	97,790	98,020	98,250	89
90	96,210	96,460	96,720	96,970	97,220	97,470	97,720	97,970	98,210	98,460	98,710	98,950	99,190	99,440	99,680	99,920	100,200	100,400	100,600	100,900	101,100	90
91	99,180	99,410	99,650	99,900	100,100	100,400	100,600	100,900	101,100	101,300	101,600	101,800	102,000	102,300	102,500	102,800	103,000	103,300	103,500	103,700	104,000	91
92	102,400	102,600	102,800	103,000	103,300	103,500	103,700	104,000	104,200	104,400	104,600	104,900	105,100	105,300	105,600	105,800	106,100	106,300	106,600	106,800	107,000	92
93	105,600	105,700	105,900	106,200	106,400	106,600	106,800	107,000	107,300	107,500	107,700	107,900	108,100	108,400	108,600	108,800	109,100	109,300	109,600	109,800	110,100	93
94	108,700	108,900	109,100	109,300	109,500	109,700	109,900	110,100	110,300	110,500	110,700	110,900	111,200	111,400	111,600	111,900	112,100	112,400	112,600	112,900	113,100	94
95	111,900	112,100	112,200	112,400	112,600	112,800	113,000	113,200	113,400	113,600	113,800	114,000	114,200	114,400	114,700	114,900	115,200	115,400	115,700	115,900	116,100	95
96	114,900	115,000	115,200	115,400	115,500	115,700	115,900	116,100	116,300	116,500	116,600	116,800	117,000	117,300	117,500	117,800	118,000	118,300	118,500	118,800	119,000	96
97	118,100	118,200	118,300	118,500	118,600	118,800	119,000	119,200	119,300	119,500	119,700	119,900	120,000	120,300	120,500	120,800	121,000	121,300	121,500	121,800	122,000	97
98	121,400	121,400	121,500	121,700	121,900	122,000	122,200	122,400	122,500	122,700	122,800	123,000	123,200	123,400	123,600	123,900	124,200	124,400	124,700	124,900	125,200	98
99	124,500	124,600	124,700	124,800	125,000	125,100	125,300	125,400	125,600	125,700	125,900	126,000	126,200	126,400	126,700	126,900	127,200	127,400	127,700	128,000	128,200	99
100	127,700	127,800	127,800	127,900	128,100	128,200	128,400	128,500	128,700	128,800	128,900	129,100	129,200	129,400	129,700	130,000	130,200	130,500	130,700	131,000	131,200	100
101	129,500	129,700	129,800	130,000	130,200	130,500	130,700	130,900	131,200	131,400	131,600	131,800	132,100	132,400	132,700	133,000	133,300	133,500	133,700	134,000	134,200	101
102	131,300	131,500	131,800	132,100	132,400	132,700	133,000	133,300	133,700	134,000	134,300	134,600	134,900	135,300	135,700	136,100	136,500	136,800	137,100	137,300	137,400	102
103	133,100	133,400	133,800	134,200	134,600	135,000	135,400	135,800	136,200	136,600	137,000	137,400	137,900	138,300	138,800	139,300	139,800	140,100	140,400	140,500	140,600	103
104	134,900	135,300	135,700	136,200	136,700	137,200	137,700	138,200	138,700	139,200	139,700	140,200	140,700	141,300	141,900	142,500	143,000	143,400	143,700	143,800	143,900	104
105	136,700	137,300	137,800	138,400	139,000	139,500	140,100	140,700	141,300	141,900	142,500	143,100	143,700	144,300	145,000	145,700	146,300	146,700	146,900	147,000	147,000	105
106	138,400	139,100	139,700	140,300	141,000	141,700	142,400	143,000	143,700	144,400	145,100	145,800	146,500	147,200	147,900	148,600	149,300	149,800	150,000	150,000	150,000	106
107	140,300	141,000	141,700	142,500	143,200	144,000	144,700	145,500	146,300	147,100	147,800	148,600	149,400	150,200	151,000	151,800	152,600	153,100	153,300	153,200	153,200	107
108	141,900	142,700	143,600	144,400	145,300	146,100	147,000	147,800	148,700	149,600	150,400	151,300	152,200	153,000	154,000	154,900	155,700	156,300	156,600	156,600	156,600	108
109	143,700	144,700	145,600	146,500	147,500	148,400	149,300	150,300	151,200	152,200	153,200	154,100	155,100	156,100	157,000	158,000	159,000	159,700	159,900	159,900	159,800	109
110	145,500	146,500	147,600	148,600	149,600	150,600	151,700	152,700	153,800	154,800	155,900	156,900	158,000	159,000	160,100	161,200	162,200	163,000	163,100	163,100	163,000	110

APALACHIA DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	1283.0	1283.1	1283.2	1283.3	1283.4	1283.5	1283.6	1283.7	1283.8	1283.9	1284.0	1284.1	1284.2	1284.3	1284.4	1284.5	1284.6	1284.7	1284.8	1284.9	1285.0	
56																						56
57																						57
58																						58
59																						59
60	42, 720	42, 820	42, 910	43, 000	43, 090																	60
61	44, 250	44, 350	44, 440	44, 530	44, 630																	61
62	45, 770	45, 870	45, 970	46, 060	46, 160																	62
63	47, 260	47, 370	47, 470	47, 570	47, 670																	63
64	48, 770	48, 870	48, 980	49, 080	49, 190																	64
65	50, 300	50, 410	50, 520	50, 630	50, 740																	65
66	51, 800	51, 920	52, 030	52, 140	52, 260																	66
67	53, 300	53, 410	53, 530	53, 650	53, 760																	67
68	54, 800	54, 920	55, 040	55, 160	55, 280																	68
69	56, 310	56, 430	56, 560	56, 680	56, 800																	69
70	57, 840	57, 970	58, 100	58, 230	58, 350	58, 480	58, 610	58, 730	58, 860	58, 990	59, 110	59, 240	59, 360	59, 490								70
71	59, 320	59, 450	59, 580	59, 710	59, 840	59, 980	60, 110	60, 240	60, 370	60, 500	60, 630	60, 760	60, 890	61, 010	61, 140							71
72	60, 840	60, 970	61, 110	61, 250	61, 380	61, 520	61, 650	61, 790	61, 920	62, 050	62, 190	62, 320	62, 460	62, 590	62, 720							72
73	62, 340	62, 480	62, 620	62, 760	62, 900	63, 040	63, 170	63, 310	63, 450	63, 590	63, 730	63, 860	64, 000	64, 140	64, 280							73
74	63, 830	63, 970	64, 120	64, 260	64, 400	64, 550	64, 690	64, 830	64, 970	65, 120	65, 260	65, 400	65, 540	65, 680	65, 820							74
75	65, 330	65, 470	65, 620	65, 770	65, 920	66, 070	66, 210	66, 360	66, 510	66, 650	66, 800	66, 940	67, 090	67, 230	67, 380							75
76	66, 780	66, 940	67, 090	67, 240	67, 390	67, 540	67, 690	67, 840	67, 990	68, 140	68, 290	68, 440	68, 590	68, 740	68, 890							76
77	68, 280	68, 440	68, 590	68, 750	68, 910	69, 060	69, 220	69, 370	69, 520	69, 680	69, 830	69, 990	70, 140	70, 290	70, 440							77
78	69, 780	69, 940	70, 100	70, 260	70, 420	70, 580	70, 740	70, 900	71, 060	71, 210	71, 370	71, 530	71, 680	71, 840	72, 000							78
79	71, 280	71, 440	71, 610	71, 770	71, 940	72, 100	72, 260	72, 420	72, 590	72, 750	72, 910	73, 070	73, 230	73, 390	73, 550							79
80	72, 780	72, 950	73, 110	73, 280	73, 450	73, 620	73, 780	73, 950	74, 120	74, 280	74, 450	74, 610	74, 780	74, 940	75, 110	75, 270	75, 430	75, 600	75, 760	75, 920	76, 080	80
81	75, 470	75, 650	75, 820	76, 000	76, 170	76, 340	76, 520	76, 690	76, 860	77, 030	77, 210	77, 380	77, 550	77, 720	77, 890	78, 060	78, 230	78, 400	78, 570	78, 740	78, 910	81
82	78, 360	78, 540	78, 720	78, 910	79, 090	79, 270	79, 450	79, 630	79, 810	79, 980	80, 160	80, 340	80, 520	80, 690	80, 870	81, 050	81, 230	81, 410	81, 580	81, 760	81, 940	82
83	81, 210	81, 400	81, 590	81, 780	81, 960	82, 150	82, 340	82, 520	82, 710	82, 890	83, 080	83, 260	83, 450	83, 630	83, 810	84, 000	84, 180	84, 370	84, 560	84, 750	84, 930	83
84	84, 080	84, 270	84, 470	84, 660	84, 860	85, 050	85, 250	85, 440	85, 630	85, 820	86, 010	86, 200	86, 390	86, 580	86, 770	86, 960	87, 150	87, 350	87, 550	87, 740	87, 940	84
85	86, 910	87, 110	87, 320	87, 520	87, 720	87, 920	88, 120	88, 320	88, 520	88, 720	88, 910	89, 110	89, 310	89, 500	89, 700	89, 900	90, 100	90, 300	90, 500	90, 710	90, 910	85
86	89, 630	89, 840	90, 050	90, 260	90, 460	90, 670	90, 880	91, 080	91, 290	91, 490	91, 700	91, 900	92, 100	92, 300	92, 510	92, 710	92, 920	93, 130	93, 340	93, 550	93, 760	86
87	92, 490	92, 710	92, 920	93, 140	93, 350	93, 560	93, 780	93, 990	94, 200	94, 410	94, 620	94, 830	95, 040	95, 250	95, 460	95, 670	95, 880	96, 100	96, 320	96, 540	96, 760	87
88	95, 390	95, 610	95, 830	96, 050	96, 270	96, 490	96, 710	96, 930	97, 150	97, 370	97, 590	97, 800	98, 020	98, 230	98, 450	98, 660	98, 880	99, 110	99, 340	99, 570	99, 800	88
89	98, 250	98, 480	98, 710	98, 940	99, 170	99, 390	99, 620	99, 850	100, 100	100, 300	100, 500	100, 700	101, 000	101, 200	101, 400	101, 600	101, 900	102, 100	102, 300	102, 600	102, 800	89
90	101, 100	101, 400	101, 600	101, 800	102, 100	102, 300	102, 500	102, 800	103, 000	103, 200	103, 500	103, 700	103, 900	104, 100	104, 400	104, 600	104, 800	105, 100	105, 300	105, 600	105, 800	90
91	104, 000	104, 200	104, 500	104, 700	104, 900	105, 200	105, 400	105, 600	105, 900	106, 100	106, 300	106, 500	106, 800	107, 000	107, 300	107, 500	107, 700	108, 000	108, 200	108, 500	108, 800	91
92	107, 000	107, 300	107, 500	107, 700	108, 000	108, 200	108, 500	108, 700	108, 900	109, 200	109, 400	109, 600	109, 900	110, 100	110, 300	110, 600	110, 800	111, 100	111, 400	111, 600	111, 900	92
93	110, 100	110, 300	110, 500	110, 800	111, 000	111, 300	111, 500	111, 700	112, 000	112, 200	112, 400	112, 700	112, 900	113, 100	113, 400	113, 700	113, 900	114, 200	114, 500	114, 700	115, 000	93
94	113, 100	113, 400	113, 600	113, 800	114, 100	114, 300	114, 500	114, 800	115, 000	115, 200	115, 500	115, 700	116, 000	116, 200	116, 500	116, 700	117, 000	117, 300	117, 600	117, 800	118, 100	94
95	116, 100	116, 400	116, 600	116, 900	117, 100	117, 300	117, 600	117, 800	118, 100	118, 300	118, 500	118, 800	119, 000	119, 300	119, 500	119, 800	120, 100	120, 400	120, 700	120, 900	121, 200	95
96	119, 000	119, 300	119, 500	119, 700	120, 000	120, 200	120, 500	120, 700	120, 900	121, 200	121, 400	121, 600	121, 900	122, 100	122, 400	122, 700	123, 000	123, 300	123, 600	123, 900	124, 100	96
97	122, 000	122, 300	122, 500	122, 800	123, 000	123, 200	123, 500	123, 700	124, 000	124, 200	124, 400	124, 700	124, 900	125, 200	125, 500	125, 800	126, 100	126, 400	126, 700	127, 000	127, 300	97
98	125, 200	125, 400	125, 600	125, 900	126, 100	126, 400	126, 600	126, 800	127, 100	127, 300	127, 600	127, 800	128, 000	128, 300	128, 600	128, 900	129, 200	129, 500	129, 800	130, 100	130, 400	98
99	128, 200	128, 500	128, 700	128, 900	129, 200	129, 400	129, 700	129, 900	130, 100	130, 400	130, 600	130, 800	131, 100	131, 400	131, 700	132, 000	132, 300	132, 600	132, 900	133, 300	133, 600	99
100	131, 200	131, 500	131, 700	132, 000	132, 200	132, 500	132, 700	132, 900	133, 200	133, 400	133, 600	133, 900	134, 100	134, 400	134, 700	135, 100	135, 400	135, 700	136, 000	136, 300	136, 700	100
101	134, 200	134, 400	134, 600	134, 800	135, 100	135, 300	135, 500	135, 700	136, 000	136, 200	136, 400	136, 600	136, 900	137, 100	137, 400	137, 700	138, 000	138, 300	138, 600	138, 900	139, 200	101
102	137, 400	137, 600	137, 800	138, 000	138, 200	138, 400	138, 600	138, 800	139, 000	139, 200	139, 400	139, 600	139, 900	140, 100	140, 400	140, 700	140, 900	141, 200	141, 500	141, 800	142, 100	102
103	140, 600	140, 800	140, 900	141, 100	141, 300	141, 400	141, 600	141, 800	142, 000	142, 200	142, 400	142, 600	142, 800	143, 000	143, 300	143, 500	143, 800	144, 100	144, 300	144, 600	144, 900	103
104	143, 900	143, 900	144, 100	144, 200	144, 400	144, 500	144, 700	144, 900	145, 100	145, 200	145, 400	145, 600	145, 800	146, 000	146, 200	146, 500	146, 700	146, 900	147, 200	147, 400	147, 700	104
105	147, 000	147, 100	147, 200	147, 300	147, 400	147, 600	147, 700	147, 900	148, 000	148, 200	148, 400	148, 600	148, 700	148, 900	149, 100	149, 300	149, 500	149, 700	150, 000	150, 200	150, 500	105
106	150, 000	150, 000	150, 100	150, 200	150, 300	150, 400	150, 600	150, 700	150, 900	151, 000	151, 200	151, 300	151, 500	151, 700	151, 800	152, 000	152, 200	152, 400	152, 600	152, 800	153, 100	106
107	153, 200	153, 200	153, 200	153, 300	153, 400	153, 500	153, 600	153, 700	153, 900	154, 000	154, 100	154, 300	154, 400	154, 600	154, 700	154, 900	155, 000	155, 200	155, 400	155, 600	155, 800	107
108	156, 600	156, 500	156, 500	156, 500	156, 600	156, 700	156, 800	156, 900	157, 000	157, 100	157, 300	157, 400	157, 500	157, 600	157, 800	157, 900	158, 100	158, 200	158, 400	158, 600	158, 800	108
109	159, 800	159, 700	159, 600	159, 600	159, 700	159, 800	159, 800	159, 900	160, 000	160, 100	160, 300	160, 400	160, 500	160, 600	160, 700	160, 800	160, 900	161, 100	161, 200	161, 400	161, 600	109
110	163, 000	162, 800	162, 700	162, 700	162, 800	162, 800	162, 900	162, 900	163, 000	163, 100	163, 200	163, 300	163, 400	163, 500	163, 600	163, 700	163, 800	163, 900	164, 100	164, 200	164, 400	110

See special instruction for preventing gate overflow on page 3.

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.

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TRANSACTIONS

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RATING CURVES FOR FLOW OVER DRUM GATES

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

With Discussion by Messrs. Guido Wyss; Sam Shulits; Bob Buehler; F. B. Campbell and A. A. McCool; and Joseph N. Bradley

Synopsis

With water becoming more valuable in the western states each year, there is an increasing demand for better methods of measurement and additional rating structures. This condition applies not only to the requirements for main canals and laterals of irrigation works but also to the regulation and measurement of flow at dams. In fact, the need has reached the point at which operators are desirous of metering the flow at nearly all control devices in irrigation systems, and in other water supply or control systems.

The primary purpose of this paper is to point out that there are numerous control structures in existence that will serve a dual purpose—that of a metering station as well as that of a regulating device. Examples of such structures include spillways, with or without gates; outlet works for dams using gates or valves; and canal regulating structures using gates. With the accumulation of information from hydraulic model studies made by the Bureau of Reclamation (USBR), United States Department of the Interior, it is now possible to prepare reasonably accurate rating curves for many such structures without the construction of models and without access to the prototypes. The method is especially useful for the rating of existing structures. This paper describes the method as it applies to the rating of drum gates and the paper is concluded with an engineering example. The method is also applicable to the rating of the Volet gate used in France, the bascule gate manufactured in the United States, and others in which the sector of a circle is hinged at or near the crest of a spillway.

Note.—Published, essentially as printed here, in February, 1953, as *Proceedings-Separate No. 169*. Positions and titles given are those in effect when the paper or discussion was received for publication.

[1] Hydr. Engr., Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo.

Introduction

The drum gate is a type of gate that floats in a chamber and is buoyed into position by regulating the water level in that chamber. A medium-sized gate of this type is shown in Fig. 1. To use drum gates as metering devices, it is essential that each gate be equipped with an accurate position indicator. This indicator may consist of an arm or pointer connected directly to one of the gate pins, and is usually located inside an adjacent pier. The scale, which commonly indicates "position of high point of gate," may be a cast-metal arc mounted on the wall under the pointer, or a scale painted on the wall.

This paper presents a method of computing rating curves for all positions of the gate with an accuracy comparable to that which can be obtained from an average current-meter traverse of the river. The information required for rating a drum gate consists of the over-all dimensions of the gate and overflow crest, the information contained in this paper, and the coefficient of discharge

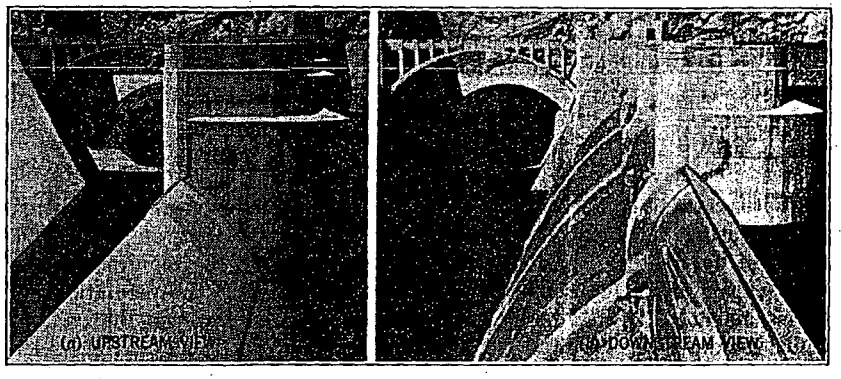


Fig. 1.—Drum Gate, 100 Ft by 16 Ft, at Hoover Dam (Arizona-Nevada)

for any appreciable head on the spillway with the gate in the completely lowered position. Should the coefficient data be lacking, the coefficient of discharge for the designed head can be estimated for nearly any overflow section by a method previously published.[2]

The method of rating described here is not intended to replace the measurements taken at river gaging stations. However, it has the following advantages: (1) The gates can be set in a few minutes to pass a desired discharge and (2) in time of flood, the gaging station may be out of order but the gate calibration is as accurate as usual. The flood that passed over Grand Coulee Dam (Washington) in 1948 is an example. The river gage, in the pier of a bridge downstream, was in error because of a drawdown in the water surface, adjacent to the pier, at the higher flows. Current-meter measurements were also attempted during the flood, but the swiftness of the current and other difficulties rendered these only partially successful. As a result, the discharge at the peak of the flood, which was finally estimated as 638,000

[2] "Discha[illegible]efficients 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

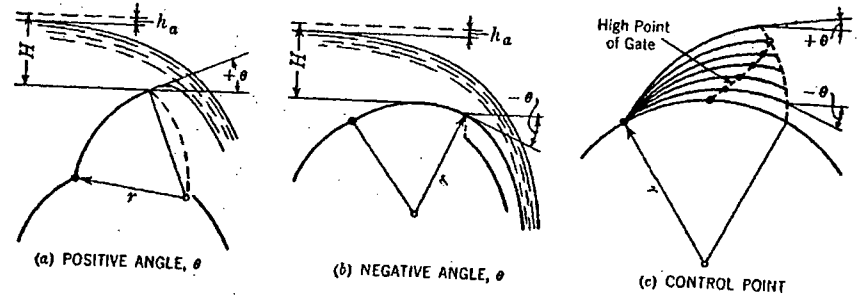


Fig. 2.—Drum-Gate Positions

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

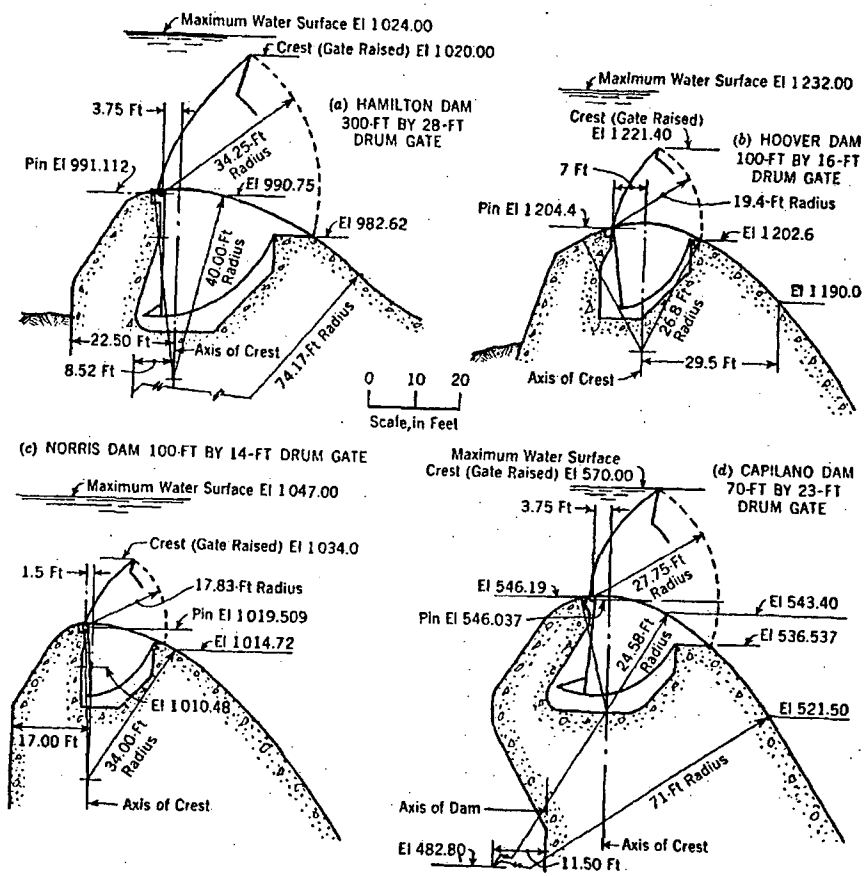


Fig. 3.—Examples of Drum-Gate Cross Sections

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_e	Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e
Gate Elevation[b] 1260.0		Gate Elevation[b] 1552.0		Gate Elevation[b] 1037.0		Gate Elevation[b] 992.0	
1295	3.920	1580	3.680	1075	3.895	35	3.710
1290	3.842	1575	3.645	1070	3.835	30	3.645
1285	3.745	1570	3.550	1065	3.760	25	3.580
1280	3.635	1565	3.420	1060	3.675	20	3.500
1275	3.510	1560	3.275	1055	3.575	15	3.400
1270	3.352	1555	3.120	1050	3.465	10	3.290
1265	3.220			1045	3.335	5	3.160
Gate Elevation 1263.51		Gate Elevation 1557.0		Gate Elevation 1039.0		Gate Elevation 995.52	
1295	3.530	1580	3.430	1075	3.637	30	3.400
1290	3.442	1575	3.380	1070	3.565	25	3.310
1285	3.360	1570	3.295	1065	3.490	20	3.223
1280	3.280	1565	3.170	1060	3.417	15	3.150
1275	3.220	1560	3.040	1055	3.340	10	3.085
1270	3.182			1050	3.250	5	3.010
Gate Elevation 1267.02		Gate Elevation 1562.0		Gate Elevation 1041.0		Gate Elevation 999.0	
1295	3.530	1580	3.550	1075	3.550	25	3.450
1290	3.457	1576	3.355	1070	3.494	20	3.390
1285	3.380	1572	3.290	1065	3.432	15	3.300
1280	3.300	1568	3.345	1060	3.365	10	3.195
1275	3.213	1564	3.465	1055	3.290	5	3.080
1270	3.120						
Gate Elevation 1270.48		Gate Elevation 1567.0		Gate Elevation 1045.0		Gate Elevation 1006.0	
1295	3.600	1580	3.665	1075	3.637	18	3.640
1290	3.530	1577	3.650	1070	3.565	15	3.635
1285	3.462	1573	3.600	1065	3.490	12	3.605
1280	3.410	1570	3.535	1060	3.415	9	3.560
1275	3.375			1055	3.330	6	3.505
				1050	3.220		
Gate Elevation 1274.01		Gate Elevation 1572.0		Gate Elevation 1050.0		Gate Elevation 1013.0	
1300	3.725	1580	3.780	1075	3.717	12	3.718
1295	3.695	1579	3.755	1070	3.670	10	3.690
1290	3.662	1578	3.690	1065	3.615	8	3.645
1285	3.630	1577	3.500	1060	3.560	6	3.595
1280	3.600	1576	3.150	1055	3.495	4	3.530
Gate Elevation 1277.50				Gate Elevation 1055.0		Gate Elevation 1020.0	
1295	3.750			1075	3.854	6	3.630
1290	3.738			1070	3.827	5	3.610
1285	3.740			1065	3.800	4	3.540
1280	3.765			1060	3.780	3.5	3.400
				1055	3.763		
Gate Elevation 1281.02				Gate Elevation 1060.0			
1295	3.730			1075	3.645		
1292	3.708			1072	3.683		
1288	3.705			1069	3.740		
1285	3.725			1066	3.815		
				1063	3.920		
Gate Elevation 1284.50				Gate Elevation 1065.0			
1300	3.840			1076	3.810		
1296	3.830			1074	3.865		
1292	3.875			1072	3.910		
1288	3.950			1070	3.950		
Gate Elevation 1288.0							
1296	3.750						
1294	3.720						
1292	3.670						
1290	3.580						

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Friant Dam (California)		Norris Dam (Tennessee)		Madden Dam (Canal Zone)		Capilano Dam (British Columbia)	
Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e
Gate Elevation[b] 560.0		Gate Elevation[b] 1020.0		Gate Elevation[b] 232.0		Gate Elevation[b] 547.0	
580	3.650	1055	3.915	35	3.900	580	3.775
577	3.625	1050	3.845	30	3.770	575	3.705
574	3.550	1045	3.765	25	3.660	570	3.625
571	3.460	1040	3.670	20	3.560	565	3.530
568	3.340	1035	3.550	15	3.460	560	3.415
565	3.175	1030	3.390	10	3.365	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	3.960	583	3.560
577	3.280	1050	3.720	25	3.890	580	3.530
574	3.240	1045	3.670	20	3.835	577	3.490
571	3.175	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	3.860		
574	3.550	1040	3.845	5	3.980		
572	3.500	1035	3.815				
570	3.400	1030	3.745				
Gate Elevation 572.0		Gate Elevation 1030.0					
580	3.725	1055	3.890				
578	3.720	1050	3.890				
576	3.680	1045	3.885				
574	3.620	1040	3.880				
		1035	3.875				
Gate Elevation 573.0		Gate Elevation 1032.0					
580	3.760	1055	3.870				
578	3.760	1050	3.875				
576	3.765	1045	3.880				
575	3.780	1040	3.896				
574	3.900	1035	3.920				
Gate Elevation 575.0		Gate Elevation 1034.0					
580	3.780	1055	3.815				
578	3.790	1050	3.835				
577	3.840	1045	3.855				
576	3.950	1040	3.885				
		1036	3.945				

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Hoover Dam (Arizona-Nevada) Shape 4-M3		Hoover Dam (Arizona-Nevada) Shape 8-M5		Hoover Dam (Arizona-Nevada) Shape 7-C4	
Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4	
26	3.670	28	3.735	26	3.665
22	3.605	25	3.705	22	3.615
18	3.540	20	3.650	18	3.540
14	3.472	15	3.565	14	3.450
10	3.405	10	3.460	10	3.360
6	3.338	5	3.335	6	3.200
Gate Elevation 1209.4		Gate Elevation 1209.4		Gate Elevation 1209.0	
20	3.675	24	3.590	23	3.725
17	3.645	20	3.540	19	3.650
14	3.615	16	3.492	15	3.580
11	3.585	12	3.428	11	3.508
8	3.555	8	3.330	7	3.415
Gate Elevation 1213.4		Gate Elevation 1213.4		Gate Elevation 1213.0	
20	3.880	20	3.765	19	3.800
17	3.875	16	3.765	16	3.845
14	3.875	12	3.725	13	3.825
11	3.870	8	3.668	10	3.750
8	3.870	4	3.600	7	3.640
Gate Elevation 1217.4		Gate Elevation 1217.4		Gate Elevation 1217.0	
14	3.960	15	3.900	15	3.960
12	3.980	12	3.890	13	3.930
10	4.010	9	3.900	11	3.935
8	4.075	6	3.930	9	3.970
				7	4.020
Gate Elevation 1221.4		Gate Elevation 1221.4		Gate Elevation 1221.4	
10	3.890	11	3.830	14	3.815
8	3.930	9	3.840	12	3.820
6	4.020	7	3.875	10	3.823
5	4.100	5	3.935	8	3.825

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

sharp reversal in the curve when the angle θ approaches 28°, and (3) that the coefficient of discharge is a maximum at this angle. As the angle θ is increased from 28° to 90°, contraction of the jet gradually reduces the coefficient to approximately 3.33, which occurs when the weir is vertical. As θ is decreased from 28° to 0° the coefficient is gradually reduced—either by approach conditions, friction, or both—to that for a broad-crested weir, which may be some value between 2.8 and 3.1. As the principal difference between the drum gate and the straight inclined weir lies in the curvature of the gate, the trends for the two should be similar.

An inconsistency exists in Fig. 4—namely, the coefficient of discharge for a vertical sharp-crested weir should approximate 3.33, but Fig. 4 shows that Bazin obtained 3.45. This conclusion is supported by the fact that the USBR, Ernest W. Schoder, M.ASCE, and Kenneth B. Turner,[5] and others have not

[5] "Precise Weir Measurements," by Ernest W. Schoder and Kenneth B. Turner, *Transactions*, ASCE, Vol. 93, 1929, p. 999.

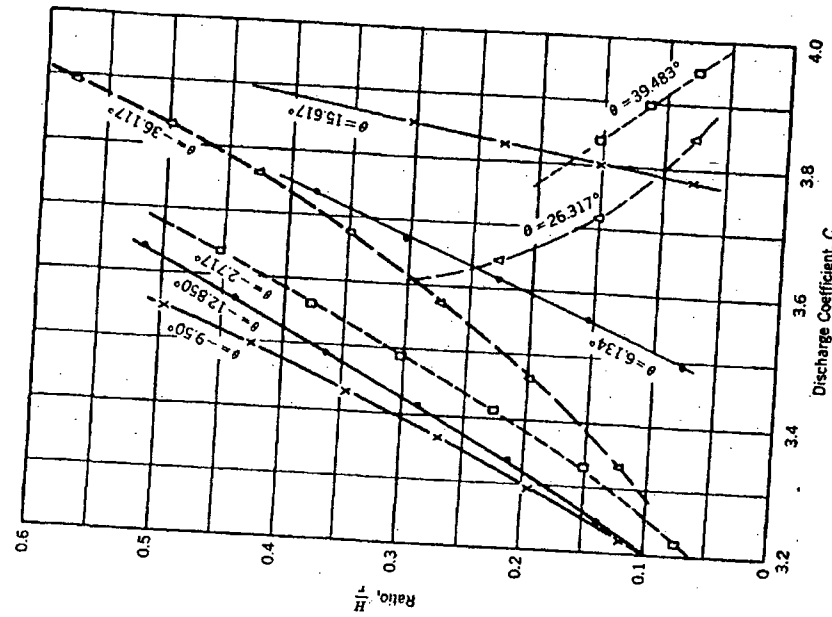


Fig. 5.—Dimensionless Plotting of Data from Model of Shasta Dam Drum Gate

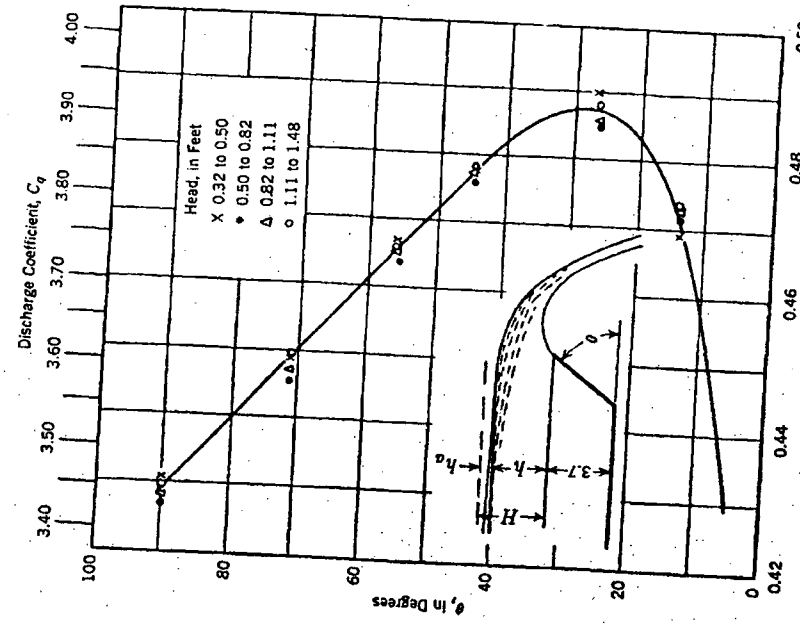


Fig. 4.—Results of Bazin's Experiments on Sloping Weirs

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

Method of Combining Test Results

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

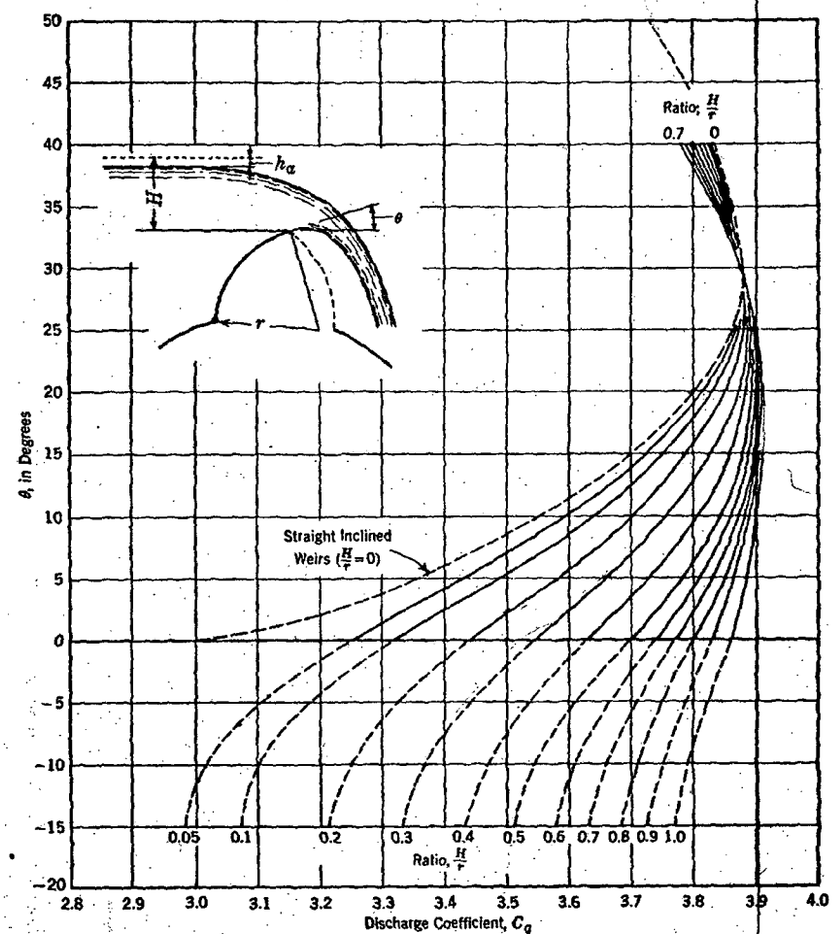


Fig. 6.—General Curves for the Determination of Discharge Coefficients

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

total head, including the velocity head of approach, measured above the high point of the gate, and r is the radius of the gate. In Fig. 5, C_q is based on the relationship, $Q = C_q L H^{\frac{3}{2}}$. 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

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.

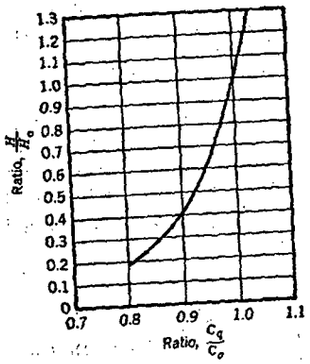


Fig. 7.—Coefficients of Discharge for Other Than the Designed Head

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

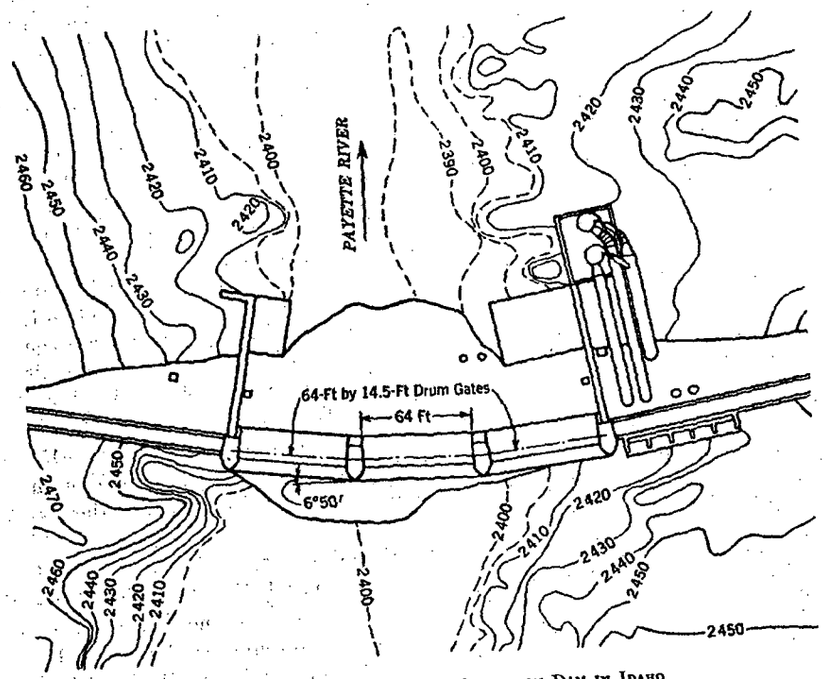


Fig. 8.—Plan of Black Canyon Diversion Dam in Idaho

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.

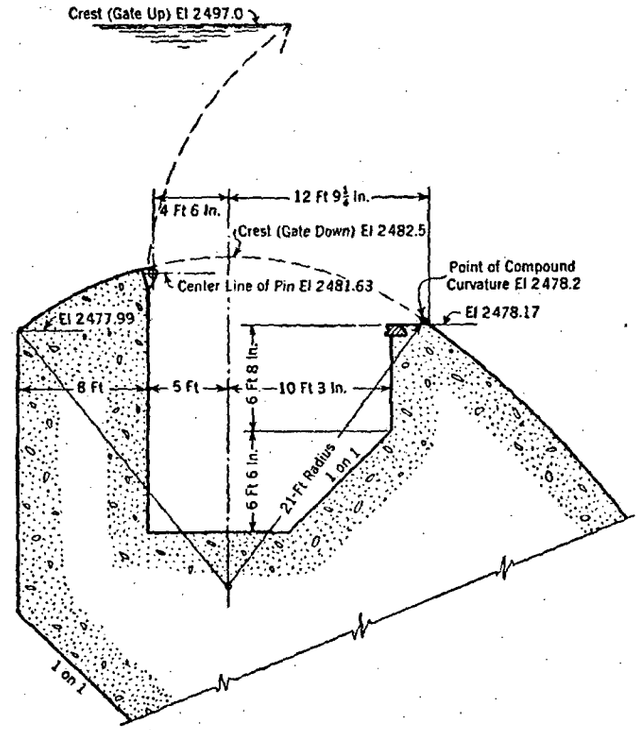


Fig. 9.—Spillway Crest Detail, Black Canyon Dam in Idaho

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: $Q = C_q L H^{\frac{3}{2}}$, in which $L = 64.0$ ft.

Before considering the rating of the spillway with gates in raised positions, it is necessary to construct a diagram such as that shown in Fig. 11 to relate gate elevation to the angle θ for the Black Canyon Dam gate. The tabulation in Fig. 11 shows the angle θ for corresponding elevations of the downstream lip of the gate at intervals of 2 ft.

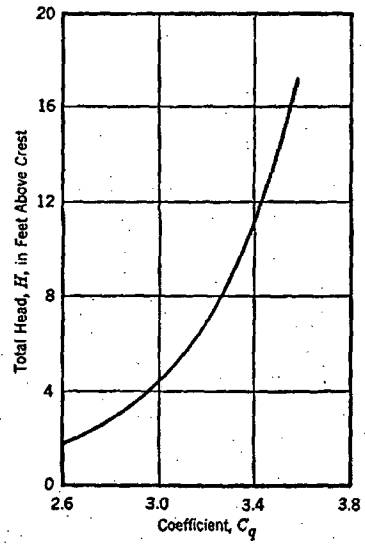


FIG. 10.—HEAD-COEFFICIENT CURVE, BLACK CANYON DAM, IN IDAHO

Beginning with the maximum positive angle of the gate, which is 34.883°, the computations may be begun by choosing a representative number of reservoir elevations as indicated in Col. 2, Table 4. The difference between the reservoir elevation and the high point of the gate (which is the downstream lip in this case) constitutes the total head on the gate, and values of head are recorded in Col. 3. Col. 4 shows these same heads divided by the radius of the gate, which is 21.0 ft.

Entering the curves in Fig. 6 with the values in Col. 4, Table 4, for $\theta = +34.883°$, the discharge coefficients, listed in Col. 5 of the set of computations designated "A," are obtained. The remainder of the procedure outlined in Cols. 6 and 7, Table 4, consists of computing the discharge for one gate from the expression, $Q = C_q L H^{\frac{3}{2}}$. A similar procedure of computation is repeated for other positive angles of θ as in sets B, C, and D of Table 4.

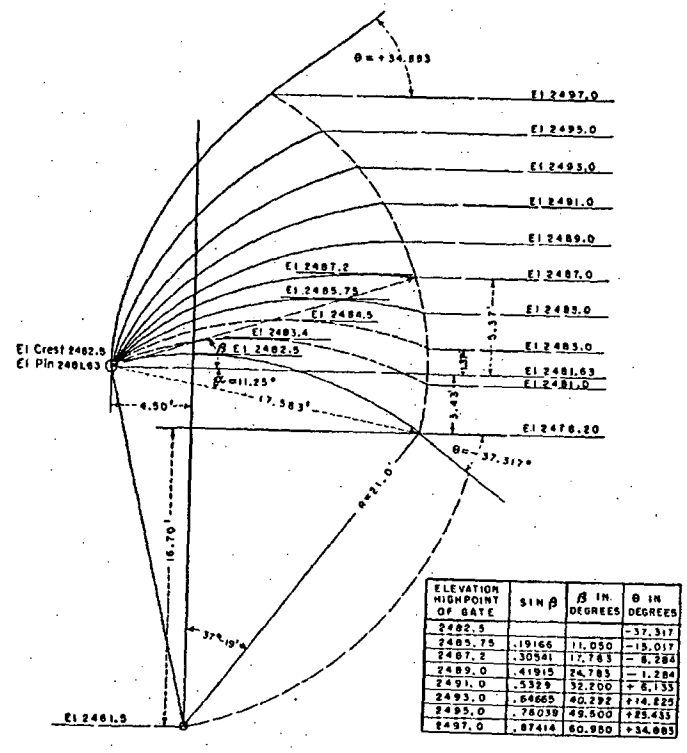
As the angle θ is given negative values, the procedure for determining the discharge remains the same for angles between 0 and $-15°$, except that the head on the gate is measured above the high point rather than above the lip. Discharge computations for negative angles of the gate down to $-15.017°$ are tabulated in E, F, and G of Table 4.

Plotting values of discharge, reservoir elevation, and gate elevation from Table 4 results in the seven curves in Fig. 12 for which the points are denoted by circles. The extreme lower curve, on which the points are identified by x-marks, represents the discharge of the free crest with the gate completely down. The latter values were obtained from Table 3.

The discharge values shown in Fig. 12 are for one gate only. When more than one gate is in operation, the discharges from the separate gates may be totaled providing the gates are each raised the same amount. The experimental models contained from one to four gates (with the exception of that of Grand Coulee Dam, which contained eleven) so a reasonable allowance for pier effect on the discharge is already present in the results.

The intervals between the eight curves identified by points (Fig. 12) are too great for rating purposes, especially the gap between gate elevations, 2485.75 ft and 2482.5 ft. This is remedied by cross-plotting the eight curves

for various constant values of the discharge as shown in Fig. 13. Fortunately, the result is a straight-line variation for any constant value of discharge. The lines in Fig. 13 are not quite parallel and there is no assurance that they will be straight for every drum gate. Nevertheless, this will not detract appreci-



ELEVATION HIGHPOINT OF GATE	SIN β	β IN DEGREES	θ IN DEGREES
2482.5			−37.317
2485.75	.19166	11.050	−15.017
2487.2	.30541	17.783	− 8.284
2489.0	.41915	24.783	− 1.284
2491.0	.5329	32.200	+ 6.133
2493.0	.64665	40.292	+14.825
2495.0	.76039	49.500	+25.433
2497.0	.87414	60.950	+34.883

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

ably from the accuracy obtained. Interpolated information from Fig. 13 is then utilized to construct the additional curves in Fig. 12. If all curves are considered, Fig. 12 shows the completed rating for the Black Canyon Dam spillway for 0.5-ft gate intervals. For intermediate values, straight-line interpolation is permissible.

CONCLUSIONS

This paper has demonstrated how an existing control structure, such as the Black Canyon Dam spillway, can also serve as a rating station. The accuracy of rating curves obtained by the method is estimated to approach that of an average current-meter traverse of the river providing that (1) the gate position indicators are made as large as possible and are accurately cali-

brated, (2) the reservoir gage can be read to within 0.05 ft, (3) nearly atmospheric pressure exists under the sheet of water after it springs from the gate, and (4) all gates are set at approximately the same elevation.

TABLE 4.—HEAD AND DISCHARGE COMPUTATIONS FOR DRUM GATES IN RAISED POSITIONS

Set (1)	Reservoir elevation, in ft (2)	H, in ft[a] (3)	Ratio, $\frac{H}{r}$ (4)	Coefficients, C_e (5)	$H^{\frac{3}{2}}$, 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	240
	2497.0	2	0.095	3.86	2.828	698
	2498.0	3	0.143	3.87	5.196	1,284
	2499.0	4	0.190	3.87	8.00	1,979
	2500.0	5	0.238	3.88	11.18	2,770
Gate Elevation 2493.0; $\theta = +14.22°$						
C	2494.0	1	0.048	3.69	1	236
	2495.0	2	0.095	3.73	2.828	675
	2496.0	3	0.143	3.75	5.196	1,247
	2498.0	5	0.238	3.80	11.18	2,719
	2500.0	7	0.333	3.84	18.52	4,552
Gate Elevation 2491.0; $\theta = +6.13°$						
D	2492.0	1	0.048	3.47	1	222
	2493.0	2	0.095	3.51	2.828	635
	2494.0	3	0.143	3.57	5.196	1,187
	2496.0	5	0.235	3.63	11.18	2,597
	2498.0	7	0.333	3.70	18.52	4,386
	2500.0	9	0.429	3.77	27.00	6,515
Gate Elevation 2489.0; $\theta = -1.28°$						
E	2490.0	1	0.048	3.21	1	205
	2491.0	2	0.095	3.28	2.828	594
	2492.0	3	0.143	3.34	5.196	1,111
	2494.0	5	0.238	3.45	11.18	2,469
	2496.0	7	0.333	3.545	18.52	4,202
	2498.0	9	0.429	3.63	27.00	6,273
	2500.0	11	0.524	3.695	36.48	8,627
Gate Elevation 2487.2; $\theta = -8.28°$						
F	2488.0	0.8	0.038	3.02	0.716	138
	2489.0	1.8	0.086	3.10	2.415	479
	2490.0	2.8	0.133	3.17	4.685	950
	2492.0	4.8	0.229	3.31	10.52	2,229
	2494.0	6.8	0.324	3.43	17.73	3,892
	2496.0	8.8	0.419	3.51	26.10	5,863
	2498.0	10.8	0.515	3.58	35.49	8,131
	2500.0	12.8	0.610	3.635	45.79	10,653
Gate Elevation 2485.75; $\theta = -15.02°$						
G	2487.0	1.25	0.060	3.00	1.398	268
	2488.0	2.25	0.107	3.07	3.375	663
	2489.0	3.25	0.155	3.15	5.859	1,181
	2491.0	5.25	0.250	3.275	12.03	2,522
	2493.0	7.25	0.345	3.375	19.52	4,216
	2495.0	9.25	0.440	3.465	28.13	6,238
	2497.0	11.25	0.536	3.54	37.73	8,548
	2499.0	13.25	0.631	3.595	48.23	11,097

[a] H is the total head on the gate. [b] The discharge for one gate: $Q = C_e L H^{\frac{3}{2}}$.

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.

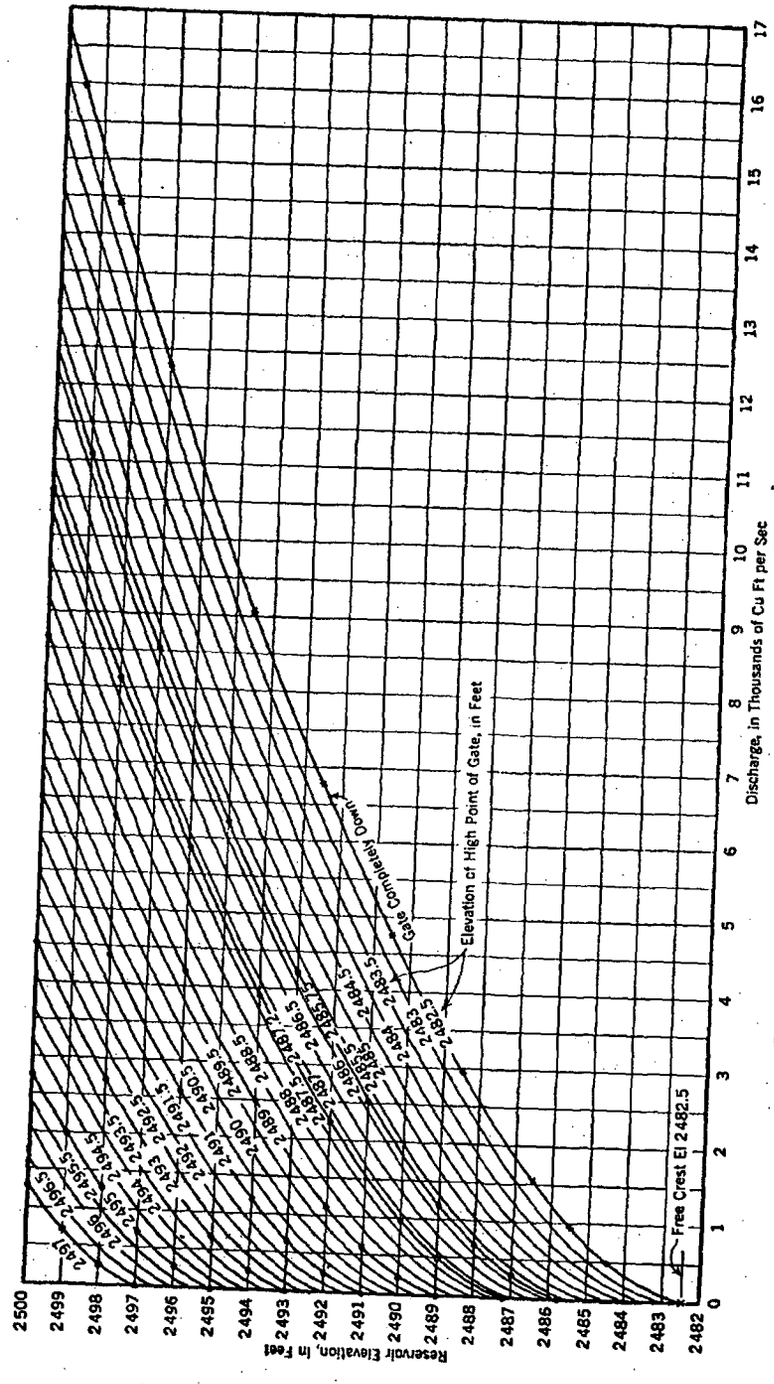


FIG. 12.—RATING CURVES FOR BLACK CANYON DAM DRUM-GATE SPILLWAY IN IDAHO

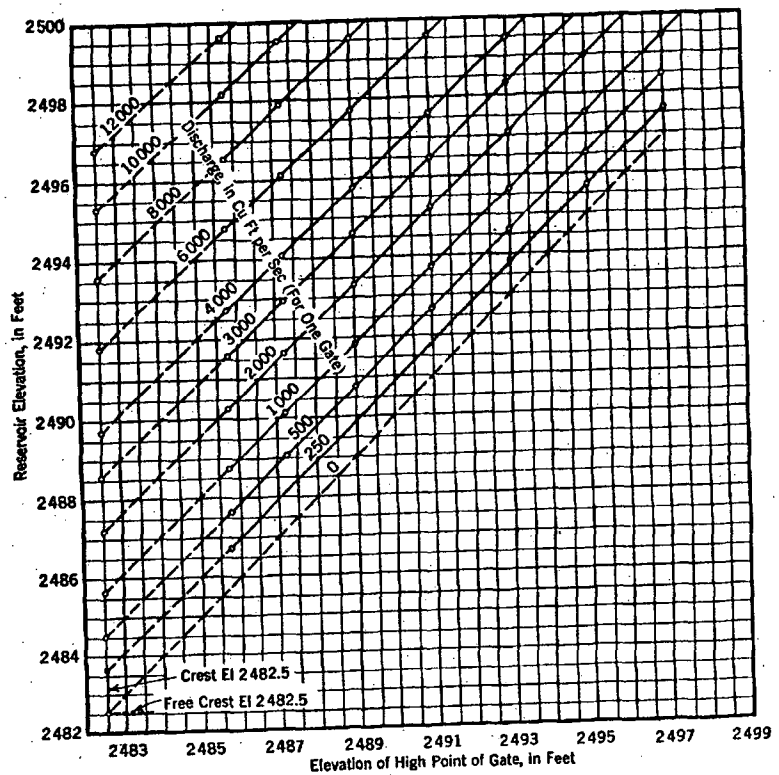


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

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.[8] 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

$$Q = \frac{3.97\, L\, H^{1.62}}{H^{0.12}{}_{D}} \qquad (1)$$

in which Q is the spillway discharge, in cubic feet per second; L denotes the length of the spillway, in feet; H is the total head on the spillway crest, in feet;

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.

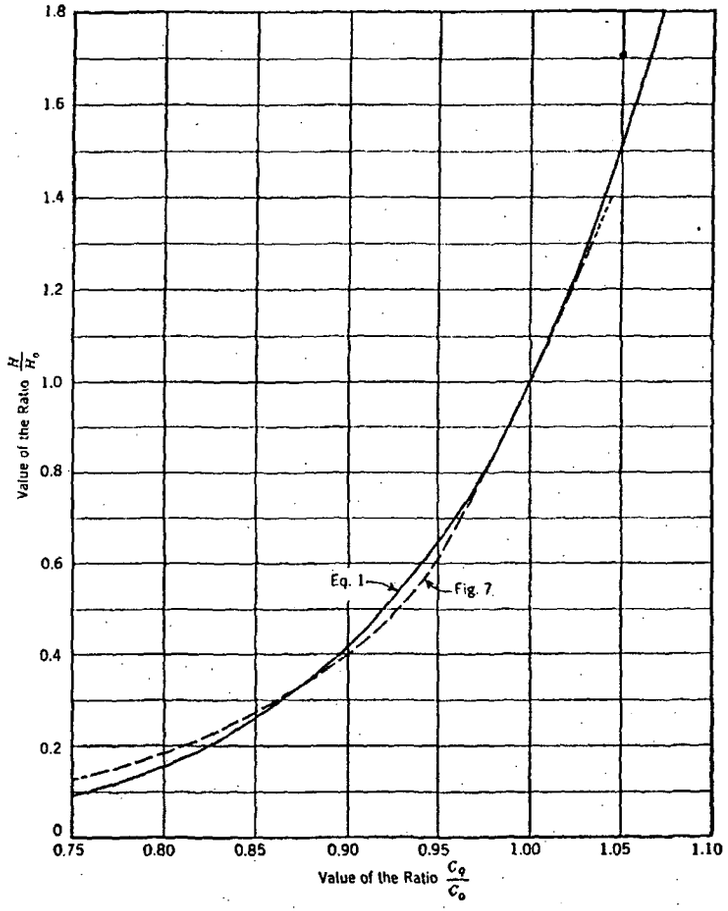

FIG. 14.—COMPARISON OF VALUES OBTAINED FROM FIG. 7 AND EQ. 1

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

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

and Eq. 1, from which

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

The design head, H_D, was found (by a method to be described subsequently) to be 45 ft for Black Canyon Dam, and this value was used in making the test. Thus, for $H_D = 45$ ft,

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

For several assumed values of total head, H, varying from 2 ft to 58.5 ft, corresponding C_q-values were computed. The resulting C_q of 3.97 for a head of 45 ft (H_o) was taken arbitrarily as the known coefficient, C_o. Then the (H/H_o)-ratios and the (C_q/C_o)-ratios were computed for all other heads in the assumed range. The resulting curve is the solid line in Fig. 14. The dashed curve is from Fig. 7. The agreement is close—as expected. Still using H_D equal to 45 ft, the remainder of the process was repeated using the coefficient for the 25-ft head as C_o, and then using the coefficient for the 12-ft head as C_o. There was no discernible difference in the curves resulting from the three separate selections. A similar procedure, using H_D equal to 20 ft in Eq. 1, also showed no differences from Fig. 14. It can probably be proved that there should be no difference.

The curve derived from Eq. 1 then was applied to the Black Canyon Dam spillway, assuming (as did the author) that the coefficient is 3.48 at a 14.5-ft head. The resultant free discharges are shown in Col. 5, Table 5.

The free-flow coefficients in Table 2 invite further comparisons with Eq. 1 for the four projects for which spillway profiles are given in Fig. 3. It should be remembered that this comparison tests the use of only the spillway shape as a guide to free discharge for the entire range of heads. Col. 4, Table 6, shows that for appreciable heads the maximum error in the four cases is approximately 2% (Hamilton Dam). Observed coefficients in model tests often scatter as much.

The same coefficients permit testing the curve in Fig. 7 for all eleven spillways. This test is not as severe, however, because it is necessary to assume one known coefficient at which head agreement becomes perfect. At near-by higher and lower heads, large divergences would not be expected. Col. 6, Table 6, shows that for appreciable heads the maximum error is slightly greater than 2% (Hoover Dam, shape 8-M5). The base coefficient selected to obtain C_q from the (C_q/C_o)-ratios is designated by a footnote for each project. These arbitrary selections were made for medium high heads.

The solid-line curve in Fig. 14 also was tested in this manner. The same coefficient at each project was assumed to be known as when the curve in Fig. 7 was tested. Col. 8, Table 6, shows that for appreciable heads the maximum error is slightly more than 2% (Madden Dam).

These comparisons show that the direct application of Eq. 1, Fig. 7 (or Fig. 14) (derived from Eq. 1), all give highly accurate free-flow spillway dis-

TABLE 6.—COMPARISON OF FREE-FLOW SPILLWAY COEFFICIENTS

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_q	Difference, in percent	C_q	Difference, in percent	C_q	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Grand Coulee Dam (Washington)							
35	3.920			3.914	− 0.15	3.902	−0.46
30	3.842			3.831	− 0.29	3.827	−0.39
25	3.745			3.745[a]	0	3.745[a]	0
20	3.635			3.655	+ 0.55	3.651	+0.44
15	3.510			3.550	+ 1.14	3.524	+0.40
10	3.352			3.370	+ 0.54	3.356	+0.12
5	3.220			3.138	− 2.54	3.168	−1.62
Bhakra Dam (India)							
28	3.680			3.736	+ 1.52	3.732	+1.41
23	3.645			3.645[a]	0	3.645[a]	0
18	3.550			3.547	− 0.08	3.543	−0.20
13	3.420			3.434	+ 0.41	3.404	−0.47
8	3.275			3.215	− 1.83	3.208	−2.04
3	3.120			2.748	−11.92	2.854	−8.53
Shasta Dam (California)							
38	3.895			3.910	+ 0.39	3.899	+0.10
33	3.835			3.839	+ 0.10	3.831	−0.10
28	3.760			3.760[a]	0	3.760[a]	0
23	3.675			3.677	+ 0.05	3.674	−0.03
18	3.575			3.591	+ 0.45	3.568	−0.20
13	3.465			3.455	− 0.29	3.429	−1.04
8	3.335			3.215	− 3.60	3.230	−3.15
Hamilton Dam (Texas) H_D = 52 Ft							
35	3.710	3.785	+2.02	3.741	+ 0.84	3.730	+0.54
30	3.645	3.710	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.635	+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	2.965			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—(*Continued*)

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_e	Difference, in percent	C_e	Difference, in percent	C_e	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Norris Dam (Tennessee) H_D = 35 Ft							
35	3.915	3.969	+1.38	3.934	+ 0.49	3.923	+0.20
30	3.845	3.897	+1.35	3.852	+ 0.18	3.848	+0.08
25	3.765	3.812	+1.25	3.765[a]	0	3.765[a]	0
20	3.670	3.711	+1.12	3.675	+ 0.14	3.671	+0.03
15	3.550	3.586	+1.01	3.569	+ 0.53	3.543	−0.20
10	3.390	3.416	+0.77	3.388	− 0.06	3.373	−0.50
5	3.125	3.143	+0.58	3.155	+ 0.96	3.185	+1.92
Madden Dam (Canal Zone)							
35	3.900			3.825	− 1.92	3.814	−2.20
30	3.770			3.744	− 0.69	3.740	−0.80
25	3.660			3.660[a]	0	3.660[a]	0
20	3.560			3.572	+ 0.34	3.568	+0.22
15	3.460			3.470	+ 0.29	3.444	−0.46
10	3.365			3.294	− 2.11	3.279	−2.55
5	3.280			3.067	− 6.49	3.096	−5.61
Capilano Dam (British Columbia) H_D = 48 Ft							
33	3.775	3.797	+0.58	3.783	+ 0.21	3.775	0
28	3.705	3.720	+0.40	3.705[a]	0	3.705[a]	0
23	3.625	3.634	+0.25	3.623	− 0.05	3.620	−0.14
18	3.530	3.529	−0.03	3.538	+ 0.23	3.516	−0.40
13	3.415	3.394	−0.62	3.405	− 0.29	3.379	−1.05
8	3.250	3.201	−1.51	3.168	− 2.52	3.183	−2.06
Hoover Dam (Arizona-Nevada) Shape 4-M3, H_D = 50 Ft							
26	3.670	3.670	0	3.681	+ 0.30	3.677	+0.19
22	3.605	3.597	−0.22	3.605[a]	0	3.605[a]	0
18	3.540	3.512	−0.79	3.526	− 0.40	3.522	−0.51
14	3.472	3.408	−1.84	3.439	− 0.95	3.414	−1.67
10	3.405	3.273	−3.88	3.306	− 2.91	3.280	−3.67
6	3.338	3.077	−7.82	3.064	− 8.21	3.082	−7.67
Hoover Dam Shape 8-M5							
28	3.735			3.814	+ 2.12	3.800	+1.74
25	3.705			3.752	+ 1.27	3.749	+1.19
20	3.650			3.650[a]	0	3.650[a]	0
15	3.565			3.537	− 0.78	3.530	−0.98
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.

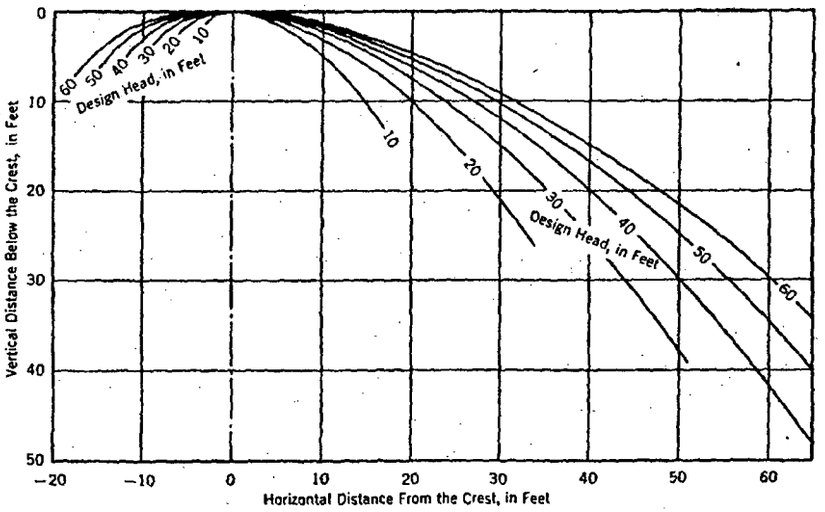

Fig. 15.—Standard Spillway Shapes

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.[10] These coordinates are shown in Table 7. The last column in Table 7 refers the horizontal (x) coordinates to the spillway crest because this form is the simplest to apply. In Table 7, y is the distance below the crest elevation.

Using these dimensionless coordinates, standard spillway shapes were plotted (Fig. 15) for values of H_D from 10 ft to 60 ft. In Fig. 15 negative

[10] "Hydroelectric Handbook," by William P. Creager and Joel D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950, p. 362.

horizontal distances indicate the distance upstream from the crest. The spillway shape as designed or built is then drawn on transparent paper. This paper is laid over Fig. 15, and the value of H_D which gives the best fit is selected. In deciding the best fit it may be found that the profile upstream from the crest indicates one value and the downstream profile indicates a different value. The higher of the two indicated values of H_D should be used. For example, the shape of Black Canyon Dam spillway *upstream from* the crest indicated a value of approximately 45 ft for H_D. The downstream shape indicated a value of approximately 25 ft. The larger value was used.

TABLE 7.—COORDINATES OF A STANDARD SPILLWAY CREST

Value of $\frac{x}{H_D}$	Value of $\frac{y}{H_D}$	Value of $\frac{x}{H_D}$ referred to crest
0	0.126	−0.3
0.1	0.036	−0.2
0.2	0.007	−0.1
0.3	0	0
0.4	0.007	0.1
0.6	0.063	0.3
0.8	0.153	0.5
1.0	0.267	0.7
1.2	0.410	0.9
1.4	0.590	1.1
1.7	0.920	1.4
2.0	1.31	1.7

The determination of the H_D-value which gives a reasonable fit requires a certain amount of judgment. When the profile upstream from the crest is the criterion, the lip of the dam will sometimes be the determinant. Sometimes, however, the lip droops sharply downward and indicates a lower value than other parts of the upstream profile. When the downstream shape is the criterion, good results have been obtained by assigning a value of H_D based on the average fit in the zone between points on the spillway where tangents range from 20° to 35° from the horizontal. The exact value of H_D is not too important. Since it enters Eq. 1 in the 0.12 power, a difference of 10% in its value affects the discharge by only 1.15%.

The writer's application of Eq. 1 has been limited to fairly high dams. Although the total head used in Eq. 1 should include the approach velocity, the accuracy of Eq. 1 when used for low dams, where approach velocity is large, has not been tested.

So far as is known, the application of standard nappe shapes (for which discharge coefficients are known) to actual spillways on a basis of reasonable best fit was first suggested by W. M. Borlund.[11] Mr. Borlund used a curve of observed C_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.

The commonly used types of crest gates are vertical lift gates, tainter or radial gates, and drum gates. The coefficient for a partly opened vertical lift gate depends on the location of the plane of the skin plate or lip with respect to the axis of the curved crest. The discharge coefficient for tainter gates is affected by the radius of the skin plate, the elevation of the trunnion with respect to the crest, and the location of the gate seat with respect to the axis as well as the crest curvature. To complicate any investigations further, observers define the gate opening variously as (1) the length of the arc from the gate seat to the gate lip, (2) the vertical distance from the lip to the face, and (3) the distance from the lip to the face measured normal to the face. The last method is believed to give the proper dimension, whereas the foregoing considerations are geometrical. The effective head for a partly opened vertical lift or tainter gate depends on the pressures on the face of the concrete and the pressures within the issuing jet. The author has given a good outline of the geometrical variables and the head-measurement method for analyzing partly raised drum gates.

The drum gate has the very attractive feature of requiring no mechanical hoisting equipment for operation. Many of the dams constructed by the USBR have spillways controlled by drum gates. For example the Arrowrock Dam in Idaho (constructed in 1915) and the Tieton Dam in Washington (constructed in 1925) are both equipped with drum gates. B. F. Thomas and D. A. Watt credit H. M. Crittenden with the design of what is apparently the first drum gate.[17] The gates were installed in Dam No. 1 on the Osage River in Missouri in 1911. However, the refinements of the modern drum gate have been developed principally by the USBR.

The discharge coefficients presented by the author are based on model studies. There should be opportunity to check the coefficients for relatively low heads with partly raised gates in the prototype by current-meter measure-

[11] "Flow over Rounded Crest Weirs," by W. M. Borlund, thesis presented to the University of Colorado, at Boulder, Colo., in 1938, in partial fulfilment of the requirement for the degree of Master of Science.

[12] Chf. Hydr. Engr., Analysis Branch, Corps of Engrs., U. S. Waterways Experiment Station, Vicksburg, Miss.

[13] Hydr. [illegible] U. S. Waterways Experiment Station, Vicksburg, Miss.

[14] "Weir Experiments, Coefficients and Formulas," by Robert E. Horton, *Water Supply and Irrigation Paper No. 200*, Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington, D. C., 1907 (revision of Paper No. 150).

[15] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. VII, No. 5, 1890, p. 259.)

[16] *Ibid.*, Vol. IX, No. 3, 1892, p. 231.

[17] "The Improvement of Rivers," by B. F. Thomas and D. A. Watt, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1913.

ments. Only on rare occasions with large floods is it possible to verify the coefficients for high prototype heads over the drum gates in the lowered position. The author's mention of the failure to obtain discharge measurements during the 1948 flood over the Grand Coulee Dam spillway emphasizes the importance of this condition. The writers have studied the basic data for high heads over the drum gate in the lowered position.

It becomes evident from a study of Table 2 that the ratio of gate radius to maximum head has a wide range. The writers use the ratio r/H_D, in which H_D is the design head for the spillway. This is the inverse of the ratio used by Mr. Bradley, used so that circular arcs can be traced on dimensionless profiles of x/H_D and y/H_D.

A comparison has been made of the coefficients for various (r/H_D)-values with the gate down. Only the high-overflow sections with negligible velocity of approach were selected from Table 2 for a study of discharge coefficients. Table 8 shows the value of the discharge coefficients for the condition when the drum gate is down. The percentage difference of the coefficient from that of the Madden Dam coefficient is also shown. It is expected that the accuracy of the discharge measurements and thus the coefficient of discharge is less than 1%.

TABLE 8.—COMPARISON OF DISCHARGE COEFFICIENT WITH THE GATE DOWN

Dam	Radius of gate, in feet[a]	Maximum head on crest, in feet[a]	Ratio, $\frac{r}{H_D}$	Coefficient,[b] C_d	Difference, in percent, from Madden Dam
Madden (Canal Zone)	30.0	30.0	1.00	3.77	0.0
Norris (Tennessee)	34.0	27.0	1.26	3.80	0.8
Grand Coulee (Washington)	66.2	31.6	2.09	3.87	2.6
Shasta (California)	66.2	28.0	2.37	3.76	−0.3
Friant (California)	47.0	19.0	2.47	3.64	−3.5
Capilano (British Columbia)	71.0	23.0	3.08	3.62	−4.0

[a] From Table 1. [b] From Table 2.

The dams for which the data are listed in Table 8 are in the approximate chronological order of the time of their design conception.

Because of the increase in the ratio of r/H_D (Table 8), it is of interest to plot the profile for the lower surface of the nappe from a sharp-crested weir with an approach slope of 2 on 3 in terms of x/H_D and y/H_D and to superimpose on it the arcs of circles with radii of r/H_D equal to 1, 2, and 3, as is done in Fig. 16. The center of the radius is located on the axis of the crest. It can be seen that the arc represented by r/H_D equal to 1 is a fair approximation of the true nappe shape. The arcs of r/H_D equal to 2 and 3 indicate a very flat curvature in comparison to the shape of the nappe.

One is tempted to assume, for a crest with a ratio $r/H_D = 3$, that the coefficient would be that for one third the design head of a crest with $4/H_D = 1$.

Model studies for Madden Dam reported by Richard R. Randolph, Jr.,[18] indicate that the coefficient for such a condition is approximately 3.40. Such a coefficient is not in agreement with that for Capilano Dam with r/H_D equal to 3.62 at full head. The lack of agreement does not necessarily vitiate the initial assumption. The difference in the coefficient may be caused by the

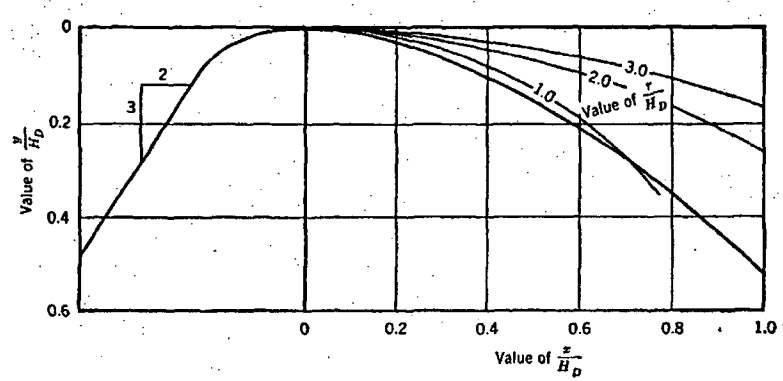

FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

difference in shape of the two crests upstream from the circular arc. Furthermore, the scale ratio of the Madden Dam model was only 1:78, and a 10-ft prototype head would be 0.128 ft on the model, which is near the lower limit of reliability for conformity of the discharge coefficient.

JOSEPH N. BRADLEY,[19] A.M. ASCE.—Mr. Shulits' statements regarding the lack of correlation in laboratory studies are well founded, and the writer is in complete agreement with his views.

Mr. Buehler's analysis for the determination of the designed head, H_D, for overflow sections formed by a single radius, or for a shape that conforms closely to a single radius, gives satisfactory results. The comparison of discharge coefficients for free flow over various dams, using Eq. 3 with the method offered in the paper, is gratifying. Mr. Buehler's method certainly has merit because following the determination of H_D, coefficients of discharge can be computed directly for all heads.

Messrs. Campbell and McCool undertook to show that a definite relationship exists between the coefficient of discharge at the designed head and the ratio r/H_D for overflow shapes. This relationship is valid if the overflow shape can be approximated by an arc of a single radius and if the approach conditions are favorable—that is, if the approach depth below the crest is at least twice H_D. This method results in a coefficient of discharge for the designed head only. When overflow sections are encountered where a single radius does not approximate the overflow shape, or when the approach conditions are unusual, an engineering monograph[2] may prove helpful.

[18] "Hydraulic Tests on the Spillway of the Madden Dam," by Richard R. Randolph, Jr., *Transactions*, ASCE, Vol. 103, 1938, p. 1091.

[19] Hydr. Engr., Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo.

Mr. Wyss suggested that pressures and water surfaces for drum gates at various positions and reservoir levels would be useful to designers in computing gate loadings. A limited amount of information is available, and this will be presented.

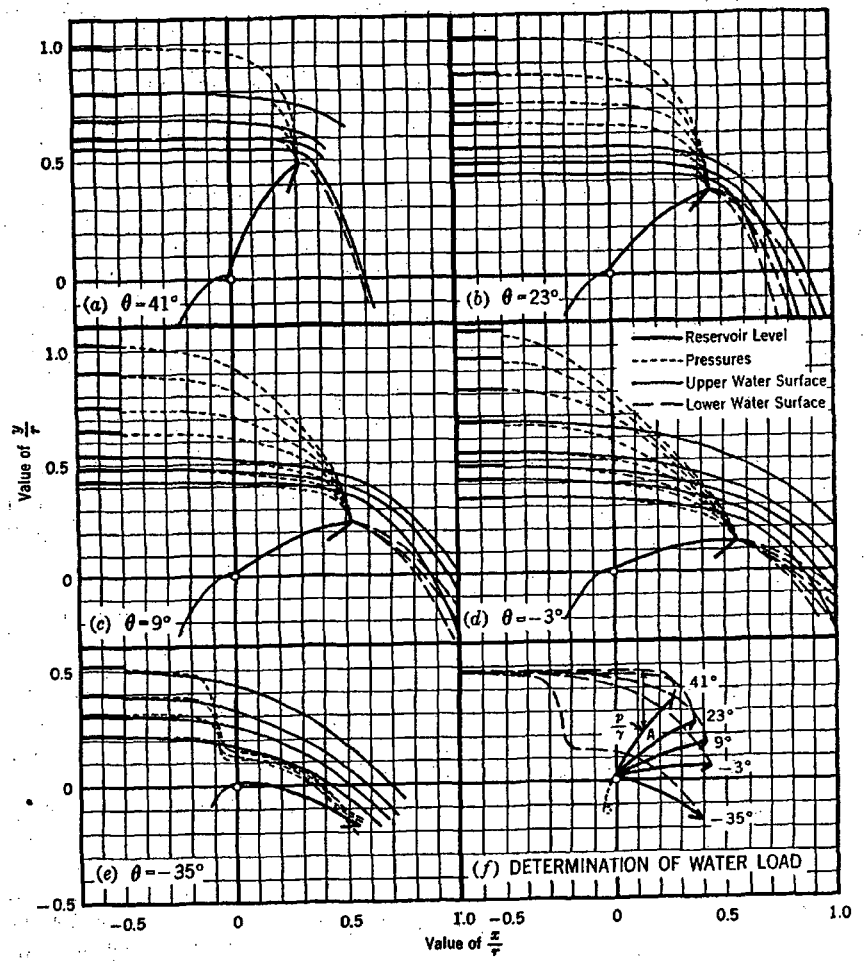

Fig. 17.—Pressure and Water-Surface Profiles

Because there was good correlation among the discharge coefficients, it was reasoned that the pressures and related flow patterns would also be well correlated through the same variables.

Pressures and water-surface profiles are plotted in dimensionless coordinates (in terms of the radius of the gate) in Fig. 17. Five positions of the gate are shown for various reservoir levels producing flow over the gate. Pressures and water surfaces are shown for some levels whereas only pressures are

available for others. The broken lines represent pressure, measured vertically, for the reservoir levels indicated at the left of the charts. Upper water-surface profiles are shown by solid lines, and lower water-surface profiles are identified by dash lines. The charts represent a composite, in graphical form, of information from model tests performed on the Grand Coulee, Hamilton, Norris, Friant, and Hoover dams.

To determine graphically the most adverse water load on a particular gate, it is necessary to investigate the pressures for several gate positions. Assuming that the first position is $\theta = 41°$, the gate is drawn in this position on a piece of transparent paper to the same scale as that used in Fig. 17. The maximum expected reservoir is indicated for this gate position on the left side of the transparent sheet.

The transparent sheet is then placed over Fig. 17(*a*), disregarding the origin of coordinates, and matching only the downstream tips of the two gates. The downstream part of all drum gates, regardless of size or radius, will coincide for any given value of θ. The height of the gate, or length of arc, can be expected to vary; this will have a negligible effect on pressures or water-surface profiles in the majority of cases. Should the gate under investigation differ from the height shown in Fig. 17(*a*), a small increase or decrease in the approach-depth results.

Beginning with the chosen reservoir level, the pressure curve is traced from Fig. 17(*a*) onto the transparent paper. It may be necessary to interpolate between two of the pressure curves. The result will be similar to that shown in Fig. 17(*f*).

A similar procedure is then followed for gate positions of 23°, 9°, −3°, and −35°, utilizing Figs. 17(*b*), 17(*c*), 17(*d*), and 17(*e*), respectively. The result is a composite plot similar to that shown in Fig. 17(*f*). It should be noted that the pressures shown for negative angles of the gate are not as reliable as those for positive angles. Fortunately, the greater water loads occur for positive angles.

Water loads can be determined by scaling the pressures vertically over the gate as indicated by point A in Fig. 17(*f*). If a gate angle other than those shown is desired, interpolation can be made directly on the sheet corresponding to Fig. 17(*f*). Following the establishment of the maximum-pressure curve, values of x/r and y/r are scaled from the sheet corresponding to Fig. 17(*f*) and are transferred to dimensional values by multiplying by r. Should water-surface profiles be desired, the same method of tracing and scaling can be used.

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Tennessee Valley Authority
Division of Water Control Planning
Engineering Laboratory

TAINTER GATE RATING DATA
DETERMINED FROM EIGHT TVA MODEL STUDIES

Norris, Tennessee
March 1962

TAINTER GATE RATING DATA

DETERMINED FROM EIGHT TVA MODEL STUDIES

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Tainter Gate Ratings

Basic Model and Prototype Data

	MODEL					PROTOTYPE		
Project	Model Scale	No. of 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.

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Definition of Symbols

Q = Total discharge in cubic feet per second.

D = Depth of flow above crest in feet.+

D_1 = Depth, bottom of gate to water surface.*

H = Total head above crest, including velocity head of approach in feet.*

H_o = Design head for standard crest, including velocity head of approach, in feet.

h = Velocity head of approach in feet.*

C = Coefficient of discharge for any head.

G.O. = Gate opening - vertical distance above spillway crest in feet.

b = Shortest distance between spillway surface and gate lip in feet.*

L = Length of spillway crest in feet.

P = Depth of model approach channel, crest to river bed, in feet.+

W = Width of model approach in feet.

x = Horizontal distance from upstream face of dam in feet.*

y = Vertical distance above spillway crest in feet.*

Discharge Equations

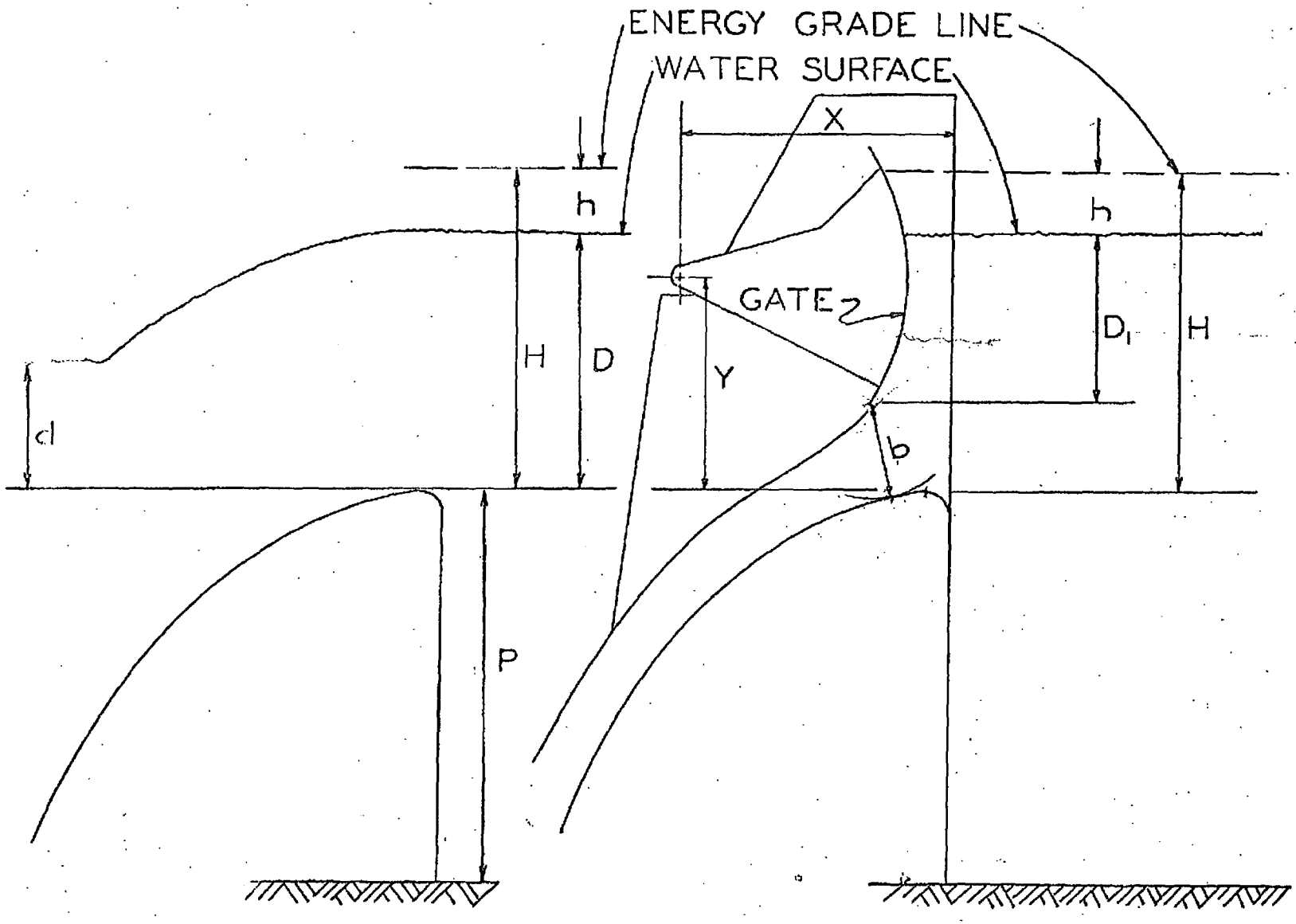
For flow under a gate:

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

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 1 [b]

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Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0532	0.117	0.826	0.000	1.53	3.36	3,650	3.09+ 5.19*
	0.154	0.828	0.000		4.42	3,660	4.38
	0.251	1.071	0.000		7.21	4,734	4.25
	0.358	1.305	0.000		10.28	5,769	4.26
	0.449	1.472	0.000		12.90	6,507	4.26
	0.533	1.618	0.000		15.31	7,152	4.28
	0.663	1.812	0.000		19.04	8,010	4.27
	0.778	1.973	0.000		22.34	8,721	4.28
	0.886	2.115	0.000		25.45	9,349	4.29
0.1107	0.190	1.796	0.000	3.18	5.46	7,939	3.25+ 4.43*
	0.246	1.838	0.000		7.07	8,125	3.80
	0.287	1.994	0.000		8.24	8,814	3.73
	0.367	2.302	0.000		10.54	10,180	3.71
	0.450	2.595	0.000		12.92	11,470	3.72
	0.549	2.916	0.000		15.77	12,890	3.73
	0.627	3.137	0.000		18.01	13,870	3.73
	0.732	3.451	0.000		21.02	15,250	3.77
	0.831	3.681	0.000		23.87	16,270	3.76
	0.917	3.888	0.000		26.34	17,190	3.76
0.1676	0.257	2.888	0.000	4.81	7.38	12,770	3.32+ 4.17*
	0.303	2.890	0.000		8.70	12,770	3.69
	0.393	3.330	0.000		11.29	14,720	3.57
	0.469	3.709	0.000		13.47	16,400	3.57
	0.545	4.066	0.000		15.65	17,970	3.56
	0.631	4.444	0.000		18.12	19,640	3.57
	0.739	4.866	0.000		21.22	21,510	3.57
	0.373	3.221	0.000		10.71	14,240	3.57
	0.322	2.977	0.000		9.25	13,160	3.64
	0.811	5.124	0.000		23.29	22,650	3.57
	0.894	5.418	0.000		25.68	23,950	3.58

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

Tennessee Valley Authority

Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2247	0.364	4.184	0.000	6.45	10.45	18,490	3.73
	0.318	4.098	0.000		9.13	18,110	3.42+ 4.08*
	0.411	4.399	0.000		11.80	19,450	3.59
	0.461	4.752	0.000		13.24	21,010	3.58
	0.531	5.181	0.000		15.25	22,900	3.56
	0.627	5.742	0.001		18.04	25,380	3.54
	0.718	6.224	0.001		20.65	27,510	3.55
	0.825	6.771	0.001		23.72	29,930	3.56
	0.911	7.179	0.001		26.19	31,730	3.56
0.3393	0.469	7.647	0.001	9.74	13.50	33,800	3.55+ 4.16*
	0.526	7.490	0.001		15.14	33,110	3.72
	0.574	7.832	0.001		16.51	34,620	3.65
	0.631	8.344	0.001		18.15	36,880	3.63
	0.717	9.089	0.001		20.62	40,180	3.63
	0.821	9.882	0.001		23.61	43,680	3.61
	0.919	10.58	0.002		26.42	46,770	3.62
0.4541	0.604	11.54	0.002	13.04	17.40	51,010	3.66+ 4.19*
	0.617	11.84	0.002		17.78	52,340	4.22
	0.720	11.84	0.002		20.74	52,340	3.73
	0.668	11.42	0.002		19.24	50,480	3.81
	0.765	12.34	0.002		22.03	54,550	3.72
	0.838	13.10	0.002		24.12	57,910	3.70
	0.915	13.84	0.003		26.36	61,180	3.68
0.5677	0.751	16.55	0.004	16.30	21.68	73,160	3.77+ 4.31*
	0.895	17.14	0.004		25.82	75,770	3.87
	0.849	16.72	0.004		24.50	73,910	3.94
	0.815	16.24	0.004		23.52	71,790	3.95

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

Tennessee Valley Authority

Apalachia Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.117	0.826	0.000	3.36	3,651	3.09
0.190	1.796	0.000	5.46	7,939	3.25
0.257	2.888	0.000	7.38	12,770	3.32
0.318	4.098	0.000	9.13	18,110	3.42
0.397	5.813	0.001	11.42	25,700	3.46
0.466	7.542	0.001	13.41	33,340	3.54
0.536	9.512	0.001	15.43	42,050	3.62
0.592	11.17	0.002	17.06	49,380	3.65
0.659	13.39	0.003	19.00	59,190	3.72
0.728	15.80	0.004	21.01	69,840	3.77
0.800	18.66	0.005	23.12	82,480	3.86
0.866	21.57	0.006	25.05	95,350	3.96
0.894	22.44	0.007	25.87	99,190	3.93
0.469	7.647	0.001	13.50	33,800	3.55
0.604	11.54	0.002	17.40	51,010	3.66
0.751	16.55	0.004	21.68	73,160	3.77

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.040	0.085	0.2810		2.00	4.25	4,968	3.26+ 5.28*
	0.149	0.3552			7.45	6,279	4.74
	0.234	0.4567			11.70	8,073	4.72
	0.274	0.4937			13.70	8,727	4.70
	0.351	0.5661			17.55	10,010	4.70
	0.428	0.6285			21.40	11,110	4.72
	0.504	0.6857			25.20	12,120	4.73
	0.581	0.7385			29.05	13,050	4.72
	0.626	0.7663			31.30	13,550	4.71
	0.700	0.8087			35.00	14,300	4.69
	0.110	0.3020			5.50	5,339	4.82
0.500	0.617	6.250		25.00	30.85	110,500	3.70+ 4.04*
	0.680	6.598	Negligible		34.00	116,600	3.92
	0.721	6.715			36.03	118,700	3.80
	0.633	6.456			33.15	114,100	3.91
0.400	0.493	4.355		20.00	24.65	76,990	3.61+ 3.93*
	0.558	4.638			27.90	81,990	3.77
	0.615	4.906			30.75	86,730	3.69
	0.685	5.279			34.25	93,320	3.66
	0.708	5.425			35.40	95,900	3.67
0.300	0.379	2.964		15.00	18.95	52,400	3.65+ 4.04*
	0.459	3.175			22.95	56,130	3.68
	0.517	3.453			25.85	61,040	3.67
	0.575	3.726			28.75	65,870	3.67
	0.648	4.044			32.40	71,490	3.67
	0.724	4.344			36.20	76,790	3.67

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

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.200	0.270	1.672		10.00	13.50	29,560	3.42+ 3.94*
	0.334	1.856			16.70	32,810	3.71
	0.409	2.133			20.45	37,710	3.69
	0.469	2.413			23.45	42,660	3.82
	0.539	2.626			26.95	46,420	3.80
	0.592	2.790			29.60	49,320	3.82
	0.670	2.896			33.50	51,200	3.68
	0.723	3.035			36.15	53,650	3.69
0.100	0.152	0.7015	Negligible	5.00	7.60	12,400	3.40+ 4.25*
	0.218	0.8119			10.90	14,350	3.81
	0.264	0.9232			13.20	16,320	3.83
	0.334	1.061			16.70	18,760	3.82
	0.391	1.174			19.55	20,750	3.86
	0.474	1.311			23.70	23,180	3.86
	0.599	1.496			29.95	26,450	3.87
	0.537	1.403			26.85	24,800	3.85
	0.630	1.537			31.50	27,170	3.87
	0.719	1.654			35.95	29,240	3.87
	0.177	0.7320			8.85	12,940	3.96
	0.234	0.8555			11.70	15,120	3.84
	0.299	0.9897			14.95	17,500	3.81

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

Tennessee Valley Authority

Boone Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.323	2.312	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

b	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.200	2.325	2.486	1.430	3.069	0.001	4.388
				3.048	0.001	4.374
				2.124	0.001	3.605
				1.282	0.001	2.734
				0.577	0.001	1.700
				0.283	0.000	0.999
0.203	2.325	2.808	0.550	0.601	0.001	1.714
				1.361	0.001	2.757
				2.240	0.001	3.600
				2.771	0.001	4.016
0.200	2.325	2.808	0.550	0.217	0.000	0.745
				0.402	0.001	1.309
				0.934	0.001	2.210
				1.882	0.001	3.244
				2.720	0.001	3.912
0.200	2.325	2.822	-0.077	1.389	0.001	2.652
				2.444	0.001	3.590
				1.945	0.001	3.180
				0.539	0.001	1.556
0.701	2.320	2.410	1.924	2.959	0.017	15.14
				2.374	0.017	13.27
				1.856	0.015	11.32
				0.970	0.009	6.688
				1.393	0.013	9.186
0.700	2.320	2.732	1.044	0.952	0.008	6.469
				1.525	0.012	9.396
				2.189	0.015	11.95
				3.047	0.015	14.52
0.700	2.320	2.746	0.417	0.795	0.007	5.691
				0.893	0.008	6.140
				1.488	0.012	9.080
				2.150	0.014	11.50
				2.727	0.014	13.25
1.199	2.320	2.333	2.418	1.305	0.027	12.94
				1.434	0.029	13.97
				1.641	0.035	16.00
				2.117	0.043	20.00
				2.765	0.048	24.40

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
1.199	2.320	2.655	1.538	2.746	0.045	23.29
				2.337	0.042	20.77
				1.787	0.036	16.90
				1.444	0.028	13.89
1.199	2.320	2.669	0.911	1.500	0.030	14.34
				1.803	0.036	16.92
				2.389	0.042	20.84
				2.851	0.043	23.43
1.698	2.320	2.579	2.032	1.926	0.065	23.58
				2.173	0.073	26.47
				2.465	0.080	29.47
1.701	2.320	2.593	1.405	1.798	0.063	22.55
				1.978	0.067	24.25
				2.278	0.076	27.62
				2.456	0.080	29.49
0.199	2.328	2.397	1.897	0.546	0.001	1.699
				1.129	0.001	2.698
				1.944	0.002	3.668
				2.949	0.002	4.594
0.199	2.328	2.917	1.118	2.835	0.001	4.102
				2.103	0.001	3.501
				1.276	0.001	2.661
				0.620	0.001	1.731
0.197	2.329	3.100	0.200	0.651	0.001	1.703
				1.461	0.001	2.693
				2.470	0.001	3.565
				3.099	0.001	4.013
0.198	2.329	3.018	-0.421	0.570	0.001	1.583
				1.439	0.001	2.645
				1.950	0.001	3.112
				2.549	0.001	3.534
0.200	2.328	3.018	-0.421	0.298	0.000	1.219
				0.424	0.001	1.346
				1.022	0.001	2.217

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

b	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.699	2.328	2.397	2.397	1.000	0.010	7.197
				1.338	0.013	9.270
				1.623	0.016	10.78
				2.074	0.018	12.86
				2.547	0.019	14.64
				2.862	0.019	15.71
0.699	2.328	2.917	1.618	1.007	0.010	7.094
				1.585	0.014	9.894
				2.199	0.016	12.31
				2.848	0.017	14.48
0.699	2.328	3.100	0.700	0.923	0.010	7.094
				1.036	0.010	7.133
				1.619	0.013	9.609
				2.163	0.014	11.60
				2.894	0.015	13.76
0.701	2.328	3.018	0.079	1.028	0.010	7.107
				1.663	0.012	9.609
				2.234	0.013	11.46
				2.911	0.014	13.52
1.199	2.328	2.917	2.118	1.628	0.035	16.08
				1.944	0.040	18.41
				2.349	0.044	21.30
				2.804	0.046	24.13
1.198	2.328	3.100	1.200	1.641	0.034	15.90
				1.972	0.036	18.05
				2.323	0.040	20.31
				2.797	0.042	22.93
1.200	2.328	3.018	0.579	1.483	0.036	15.88
				1.629	0.034	15.87
				2.001	0.037	18.08
				2.292	0.039	19.86
				2.571	0.040	21.43
1.699	2.328	2.917	2.618	2.016	0.083	27.31
				2.158	0.078	27.28
				2.217	0.079	27.83

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b ft.	L ft.	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

Trunnion Locations						
b ft.	L ft.	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	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.700	2.334	4.053	0.556	1.495	0.015	10.34
				2.064	0.016	12.28
				2.457	0.017	13.45
				2.838	0.017	14.59
0.697	2.334	3.890	-0.366	1.208	0.021	11.16
				1.530	0.014	10.10
				1.911	0.015	11.31
				2.208	0.015	12.06
				2.602	0.015	13.12
1.199	2.334	4.033	1.936	1.825	0.065	22.95
				2.071	0.054	22.37
				2.210	0.055	23.16
				2.404	0.055	24.20
				2.585	0.056	25.33
				2.731	0.056	26.10
1.198	2.334	4.235	1.022	1.924	0.051	21.00
				2.020	0.051	21.22
				2.225	0.050	22.02
				2.467	0.050	23.22
				2.704	0.050	24.42
1.199	2.334	4.072	0.100	2.141	0.046	21.14
				2.260	0.048	21.83
				2.577	0.046	23.06
				2.797	0.046	23.94
0.199	2.338	4.101	0.677	0.518	0.001	2.247
				1.082	0.002	3.019
				1.928	0.002	3.914
				2.748	0.002	4.626
0.200	2.338	4.233	-0.250	0.492	0.002	2.673
				0.512	0.001	2.118
				1.293	0.002	3.054
				2.007	0.002	3.692
				2.678	0.002	4.247

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.4529	0.595	11.53	0.014	15.74	21.17	82,140	4.04
	0.666	12.52	0.015		23.67	89,190	4.00
	0.869	15.01	0.018		30.83	106,900	3.96
	0.527	10.81	0.014		18.81	77,010	4.21
	0.561	11.17	0.014		19.99	79,570	4.11
	0.526	10.84	0.014		18.77	77,220	4.23
	0.612	11.74	0.014		21.76	83,630	4.02
	0.548	11.02	0.014		19.54	78,500	4.14
	0.588	11.55	0.014		20.93	82,280	4.08
	0.565	11.18	0.014		20.13	79,640	4.09
	0.669	12.59	0.016		23.81	89,700	4.01
	0.628	11.97	0.015		22.35	85,270	4.01
	0.712	13.10	0.016		25.31	93,320	3.98
	0.751	13.59	0.016		26.66	96,810	3.97
0.3991	0.588	10.18	0.011	13.87	20.82	72,520	3.94
	0.558	9.824	0.011		19.78	69,980	3.96
	0.517	9.346	0.010		18.32	66,580	4.02
	0.486	8.994	0.010		17.24	64,070	4.08
	0.475	8.946	0.010		16.86	63,730	4.14
0.3438	0.604	9.169	0.009	11.95	21.31	65,320	3.90
	0.562	8.706	0.008		19.81	62,020	3.90
	0.518	8.191	0.008		18.28	58,350	3.90
	0.457	7.560	0.007		16.13	53,850	3.99
	0.430	7.269	0.007		15.19	51,780	4.04
	0.414	7.135	0.007		14.63	50,830	4.10
	0.422	7.235	0.007		14.91	51,540	4.09
0.2894	0.483	6.723	0.006	10.06	17.00	47,890	3.85
	0.605	7.928	0.007		21.27	56,480	3.88
	0.403	5.938	0.005		14.18	42,300	3.91
	0.493	6.809	0.006		17.35	48,500	3.84
	0.419	6.049	0.005		14.74	43,090	3.86
	0.592	7.776	0.007		20.82	55,390	3.86

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.1818	0.354	3.650	0.002	6.319	12.37	26,000	3.78
	0.547	4.915	0.003		19.12	35,010	3.86
	0.462	4.393	0.002		16.13	31,290	3.83
	0.413	4.096	0.002		14.43	29,180	3.83
	0.488	4.574	0.003		17.07	32,580	3.85
	0.580	5.095	0.003		20.27	36,290	3.86
	0.559	4.972	0.003		19.54	35,420	3.85
0.2342	0.410	5.019	0.003	8.141	14.36	35,750	3.83
	0.368	4.636	0.003		12.90	33,020	3.83
	0.450	5.354	0.004		15.78	38,140	3.82
	0.590	6.461	0.004		20.65	46,030	3.86
0.1251	0.601	3.719	0.002	4.348	20.96	26,490	3.91
	0.512	3.382	0.001		17.83	24,090	3.89
	0.422	3.034	0.001		14.70	21,610	3.90
	0.348	2.693	0.001		12.13	19,180	3.89
	0.466	3.215	0.001		16.23	22,900	3.90
0.0720	0.475	2.039	0.000	2.503	16.51	14,530	4.12
	0.555	2.216	0.001		19.33	15,790	4.12
	0.596	2.330	0.001		20.75	16,600	4.17
	0.518	2.153	0.001		18.04	15,340	4.16
	0.365	1.762	0.000		12.69	12,550	4.12

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Raised Above the Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.896	27.80	0.058	33.16	198,000	4.32
0.851	25.43	0.051	31.35	181,100	4.30
0.817	23.66	0.046	30.00	168,500	4.27
0.775	21.62	0.040	28.33	154,000	4.26
0.731	19.44	0.034	26.59	138,500	4.21
0.684	17.26	0.028	24.75	122,900	4.16
0.579	12.93	0.018	20.75	92,100	4.06
0.537	11.24	0.015	19.19	80,060	3.97
0.617	14.47	0.022	22.21	103,100	4.10
0.483	9.387	0.011	17.17	66,870	3.92
0.430	7.647	0.008	15.22	54,470	3.82
0.372	5.957	0.005	13.10	42,400	3.72
0.306	4.321	0.003	10.74	30,780	3.64
0.242	2.919	0.002	8.48	20,790	3.51
0.654	15.88	0.025	23.60	113,100	4.11
0.568	12.39	0.017	20.33	88,260	4.01

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0213	0.280	0.3292		1.17	15.40	7,385	4.96
	0.185	0.2692			10.18	6,039	5.03
	0.070	0.1636			3.85	3,670	5.24
	0.310	0.3456			17.05 ~~1.71~~	7,753	4.96
	0.449	0.4161			24.70	9,335	4.92
	0.385	0.3849			21.18	8,635	4.92
	0.048	0.1296			2.64	2,907	5.25
	0.051	0.1372			2.80	3,078	5.38
	0.052	0.1415			2.86	3.174	5.46
	0.051	0.1404			2.80	3,150	5.51
	0.056	0.1520			3.08	3,410	5.61
	0.063	0.1568			3.46	3,518	5.37
	0.077	0.1725			4.24	3,870	5.20
	0.084	0.1812			4.62	4,065	5.27
	0.124	0.2188			6.82	4,909	5.15
	0.229	0.3010	Negligible		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		7.16	12.60	27,410	3.85
	0.277	1.344			15.24	30,150	3.71
	0.389	1.612			21.40	36,160	3.59
	0.447	1.751			24.59	39,280	3.59
	0.483	1.833			26.57	41,120	3.59
	0.425	1.703			23.38	38,210	3.60
	0.346	1.512			19.03	33,920	3.62
0.1293	0.300	1.382		7.11	16.50	31,000	3.65
	0.347	1.505			19.08	33,760	3.62
	0.477	1.817			26.24	40,760	3.62
	0.237	1.229			13.04	27,570	3.80
	0.248	1.255			13.64	28,150	3.76
0.187	0.402	2.282	Negligible	10.28	22.11	51,190	3.63
	0.350	2.130			19.25	47,780	3.72
	0.320	2.057			17.60	46,150	3.83
	0.452	2.438			24.86	54,690	3.59
	0.491	2.563			27.00	57,500	3.59
0.186	0.317	2.041		10.23	17.44	45,790	3.84
	0.320	2.037			17.60	45,700	3.81
0.238	0.445	3.051		13.09	24.48	68,450	3.72
	0.491	3.213			27.00	72,080	3.66
	0.381	2.908			20.96	65,240	3.96
	0.388	2.909			21.34	65,260	4.04
0.294	0.501	4.033		16.17	27.56	90,480	3.82
	0.422	3.993			23.21	89,580	4.32
	0.422	3.989			23.21	89,490	4.31
	0.460	3.989			25.30	89,490	4.03
	0.465	3.989			25.58	89,490	4.00

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.199	1.224		10.94	27,460	3.40
0.238	1.616		13.09	36,250	3.44
0.303	2.348		16.66	52,680	3.48
0.353	3.002		19.42	67,350	3.54
0.463	4.673		25.46	104,800	3.66
0.083	0.3053		4.56	6,849	3.15
0.081	0.2932		4.46	6,578	3.13
0.150	0.7790		8.25	17,480	3.31
0.113	0.4982		6.22	11,180	3.24
0.147	0.7553		8.08	16,940	3.31
0.157	0.8340		8.64	18,710	3.31
0.217	1.404	Negligible	11.94	31,500	3.43
0.252	1.769		13.86	39,690	3.45
0.283	2.116		15.56	47,470	3.47
0.293	2.244		16.12	50,340	3.49
0.319	2.548		17.54	57,160	3.49
0.371	3.254		20.40	73,000	3.56
0.289	2.200		15.90	49,350	3.50
0.498	5.274		27.39	118,300	3.71
0.314	2.498		17.27	56,040	3.50
0.426	4.059		23.43	91,060	3.60
0.054	0.1572		2.97	3,527	3.11
0.120	0.5475		6.60	12,280	3.25
0.347	2.893		19.08	64,900	3.49
0.347	2.911		19.08	65,310	3.52
0.422	3.993		23.21	89,580	3.60
0.280	2.082		15.40	46,710	3.47
0.048	0.1296		2.64	2,907	3.05
0.081	0.2886		4.46	6,474	3.08

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

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

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

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.338	1.061	11.98	0.005	11.83	37.28	86,820	3.64
	0.854	10.49	0.005		30.06	76,020	3.64
	0.663	8.894	0.004		23.34	64,460	3.64
	0.484	7.141	0.003		17.04	51,750	3.68
	0.420	6.781	0.003		14.8	49,140	3.59+ 3.95*
	0.476	7.102	0.003		16.76	51,470	3.70
	1.050	11.94	0.005		36.92	86,530	3.65
0.453	0.616	10.82	0.006	15.86	21.77	78,410	3.74
	0.565	10.85	0.007		20.02	78,630	3.65+ 4.04*
	0.679	11.48	0.007		24.01	83,200	3.67
	0.840	13.33	0.008		29.68	96,600	3.65
	1.047	15.50	0.009		36.96	112,300	3.66
0.567	0.688	15.07	0.012	19.84	24.50	109,200	3.75+ 4.09*
	0.765	15.39	0.011		27.16	111,500	3.81
	0.854	16.46	0.012		30.31	119,300	3.73
	0.957	17.72	0.013		33.95	128,400	3.69
	1.035	18.60	0.013		36.68	134,800	3.67
0.681	0.833	20.71	0.019	23.83	29.82	150,100	3.84+ 4.21*
	0.937	20.81	0.018		33.42	150,800	3.84
	1.007	21.82	0.018		35.88	158,100	3.80
	1.048	22.36	0.019		37.34	162,000	3.78
	0.928	20.69	0.018		33.11	149,900	3.85

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

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.100	0.717	0.000	3.50	5,211	3.31
0.183	1.803	0.000	6.40	13,070	3.35
0.280	3.538	0.001	9.84	25,640	3.46
0.420	6.781	0.003	14.80	49,140	3.59
0.565	10.85	0.007	20.02	78,630	3.65
0.688	15.07	0.012	24.50	109,200	3.75
0.833	20.71	0.019	29.82	150,100	3.84
0.920	24.51	0.025	33.08	177,600	3.89
0.561	10.73	0.007	19.88	77,760	3.65
0.703	15.63	0.012	25.02	113,300	3.77
0.127	10.24	0.000	4.44	7,421	3.30
0.900	23.64	0.024	32.34	171,300	3.88
0.699	15.34	0.012	24.88	111,200	3.73
0.498	8.833	0.005	17.61	64,010	3.61
0.080	0.527	0.000	2.82	3,819	3.40

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G. O. ft.	H ft.	Q cfs	C
0.0286	0.096	0.3164	0.000	0.98	3.30	2,188	3.71
	0.131	0.3794	0.000		4.50	2,624	3.72
	0.240	0.5280	0.000		8.24	3,651	3.71
	0.279	0.5704	0.000		9.58	3,945	3.70
	0.417	0.6987	0.000		14.32	4,832	3.68
	0.344	0.6346	0.000		11.82	4,389	3.70
	0.184	0.4629	0.000		6.32	3,201	3.74
	0.508	0.7730	0.000		17.45	5,346	3.66
0.0575	0.160	0.7723	0.000	1.98	5.50	5,341	3.54
	0.197	0.8797	0.000		6.77	6,083	3.56
	0.114	0.6192	0.000		3.92	4,282	3.53
	0.251	1.015	0.000		8.62	7,019	3.57
	0.294	1.112	0.000		10.10	7,690	3.59
	0.355	1.235	0.000		12.19	8,541	3.59
	0.412	1.338	0.000		14.15	9,253	3.58
	0.497	1.480	0.000		17.07	10,230	3.59
0.0875	0.116	0.8990	0.000	3.00	3.98	6,220	3.26+ 3.71*
	0.151	1.061	0.000		5.19	7,340	3.56
	0.195	1.273	0.000		6.70	8,803	3.58
	0.229	1.416	0.000		7.87	9,792	3.59
	0.269	1.568	0.000		9.24	10,840	3.61
	0.310	1.706	0.000		10.65	11,800	3.61
	0.379	1.922	0.000		13.02	13,290	3.63
	0.447	2.116	0.000		15.35	14,630	3.64
	0.478	2.196	0.000		16.42	15,190	3.64
	0.504	2.261	0.000		17.31	15,640	3.64
0.1166	0.151	1.385	0.000	4.00	5.19	9,578	3.38+ 3.79*
	0.186	1.560	0.000		6.39	10,790	3.61
	0.228	1.796	0.000		7.83	12,420	3.59
	0.283	2.080	0.000		9.72	14,380	3.60
	0.334	2.320	0.001		11.51	16,040	3.62
	0.396	2.576	0.001		13.64	17,810	3.63
	0.454	2.793	0.001		15.63	19,310	3.64
	0.512	2.997	0.001		17.62	20,730	3.64
	0.511	2.990	0.001		17.59	20,680	3.64

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

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2037	0.258	3.299	0.001	7.00	8.90	22,810	3.58+ 3.98*
	0.276	3.358	0.001		9.51	23,220	3.82
	0.288	3.467	0.001		9.93	23,980	3.80
	0.322	3.684	0.001		11.10	25,480	3.70
	0.365	4.007	0.002		12.61	27,710	3.67
	0.418	4.430	0.002		14.43	30,640	3.70
	0.456	4.677	0.002		15.73	32,340	3.68
	0.497	4.945	0.002		17.14	34,200	3.69
	0.421	4.434	0.002		14.53	30,660	3.68
0.2912	0.365	5.866	0.003	10.00	12.64	40,570	3.76+ 4.16*
	0.404	5.977	0.003		13.98	41,330	3.88
	0.418	6.081	0.003		14.46	42,050	3.85
	0.436	6.243	0.003		15.08	43,170	3.82
	0.461	6.502	0.004		15.97	44,960	3.81
	0.500	6.841	0.004		17.31	47,310	3.77

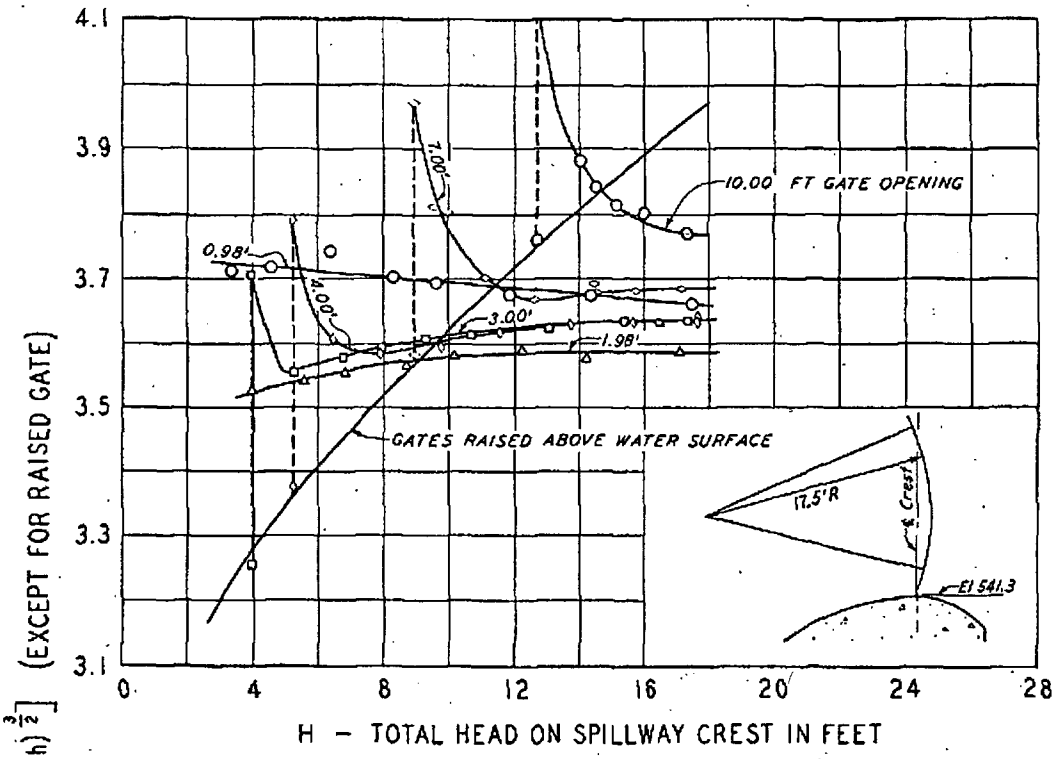
*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

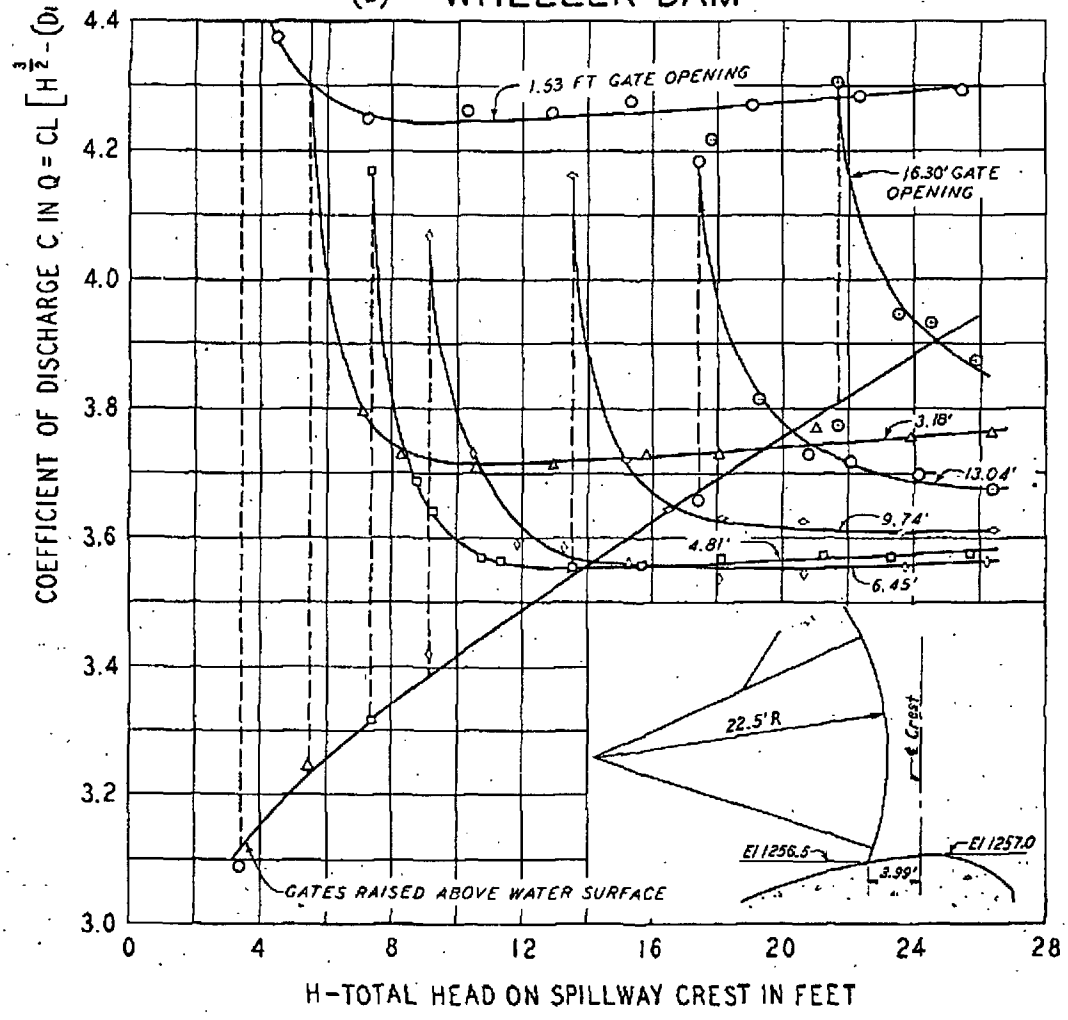
Wheeler Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.178	1.786	0.000	6.11	12,350	3.41
0.214	2.444	0.001	7.39	16,900	3.51
0.281	3.788	0.002	9.72	26,200	3.60
0.307	4.386	0.002	10.58	30,330	3.67
0.347	5,348	0.003	12.02	36,980	3.70
0.390	6.559	0.004	13.53	45,360	3.80
0.440	8,038	0.006	15.32	55,590	3.86
0.405	6.998	0.004	14.05	48,400	3.83
0.366	5.892	0.003	12.68	40,750	3.76
0.191	1.996	0.000	6.56	13,800	3.42
0.218	2.490	0.001	7.52	17,220	3.48
0.279	3.742	0.002	9.65	25,880	3.60
0.306	4.366	0.002	10.58	30,190	3.66
0.416	7.316	0.005	14.46	50,590	3.83
0.465	8.775	0.006	16.18	60,680	3.89
0.499	9.914	0.009	17.45	68,560	3.92
0.305	4.314	0.002	10.55	29,830	3.63
0.076	0.464	0.000	2.61	3,209	3.16
0.123	1.004	0.000	4.23	6,943	3.34
0.155	1.444	0.000	5.32	9,986	3.39
0.116	0.8990	0.000	3.98	6,220	3.26
0.151	1.385	0.000	5.19	9,578	3.38
0.258	3.299	0.001	8.90	22,810	3.58
0.365	5.866	0.003	12.64	40,570	3.76



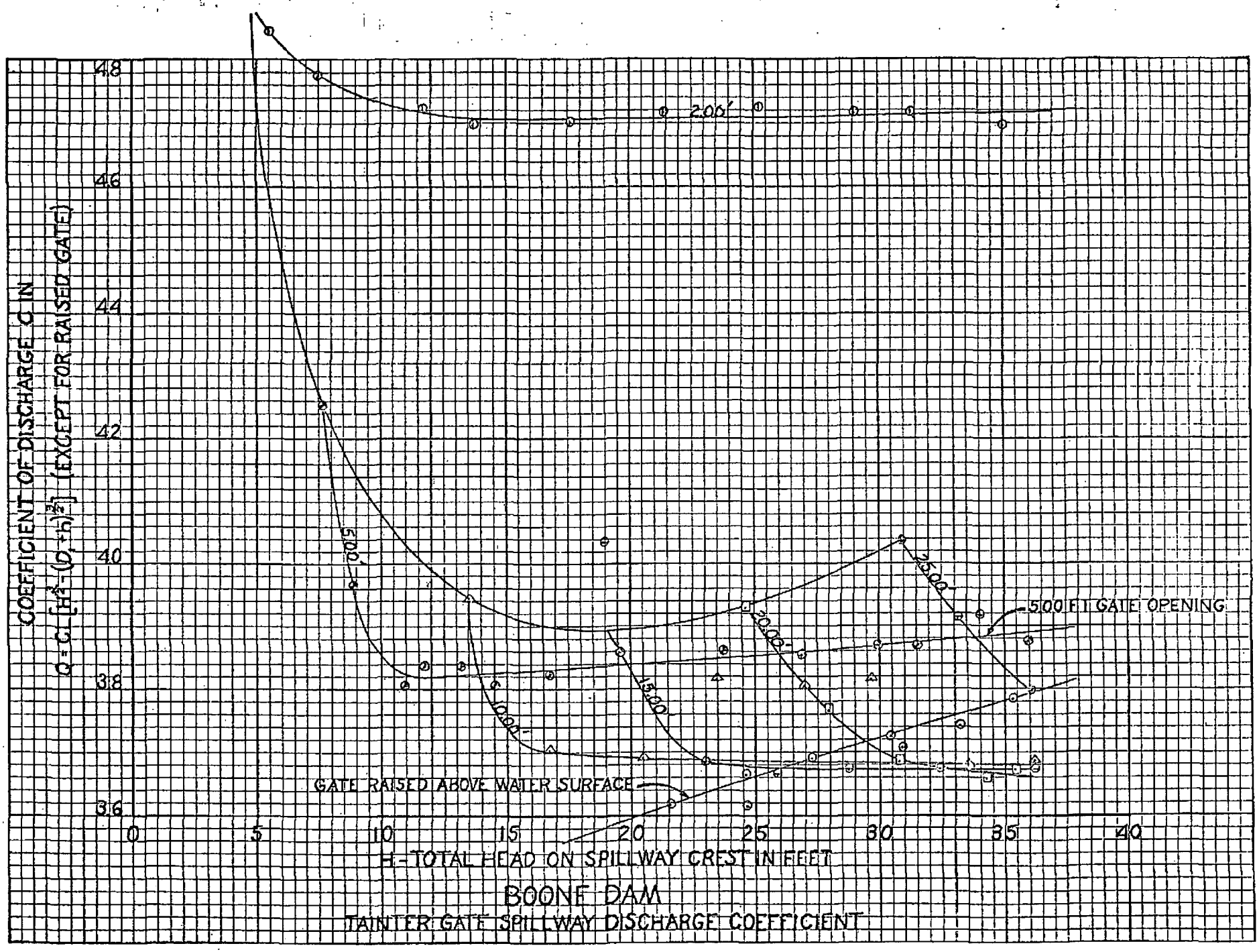
(a) WHEELER DAM



(b) APALACHIA DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

K+E 10 X 10 TO THE INCH 359-5
KEUFFEL & ESSER CO. MADE IN U.S.A.



BOONE DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENT

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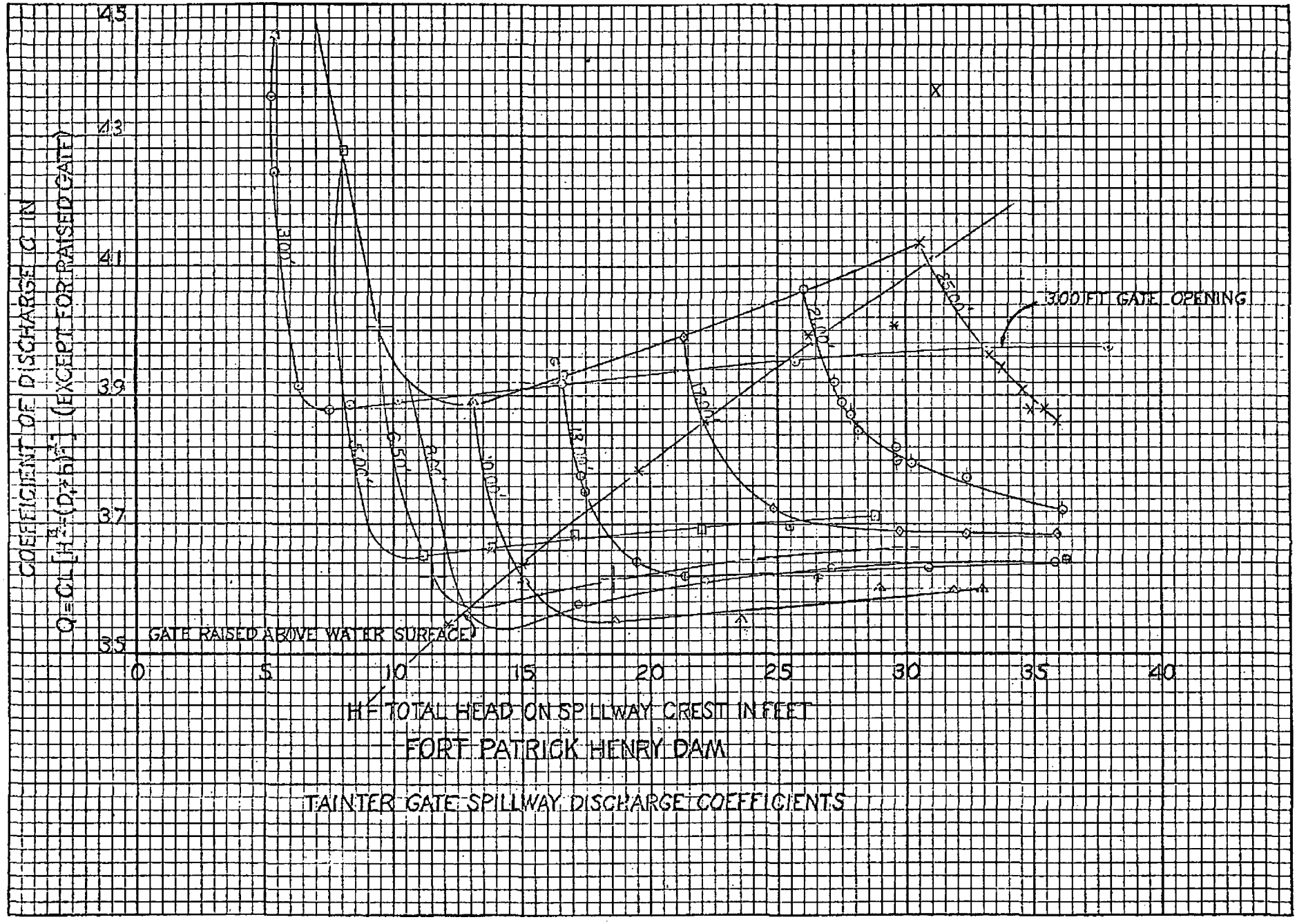
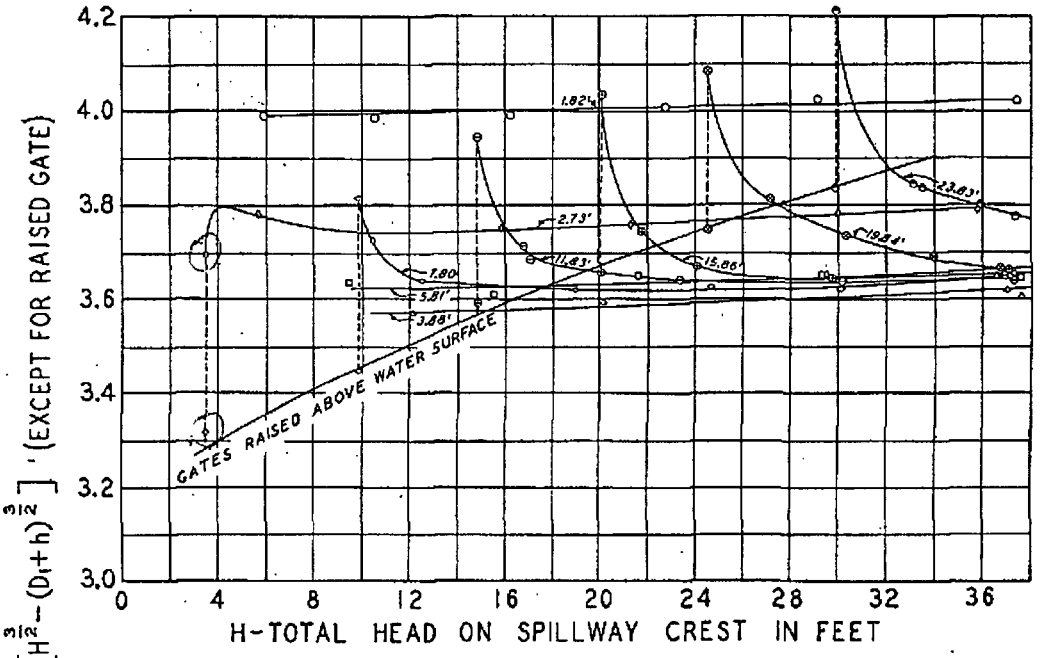
KEUFFEL & ESSER CO. MADE IN U.S.A.

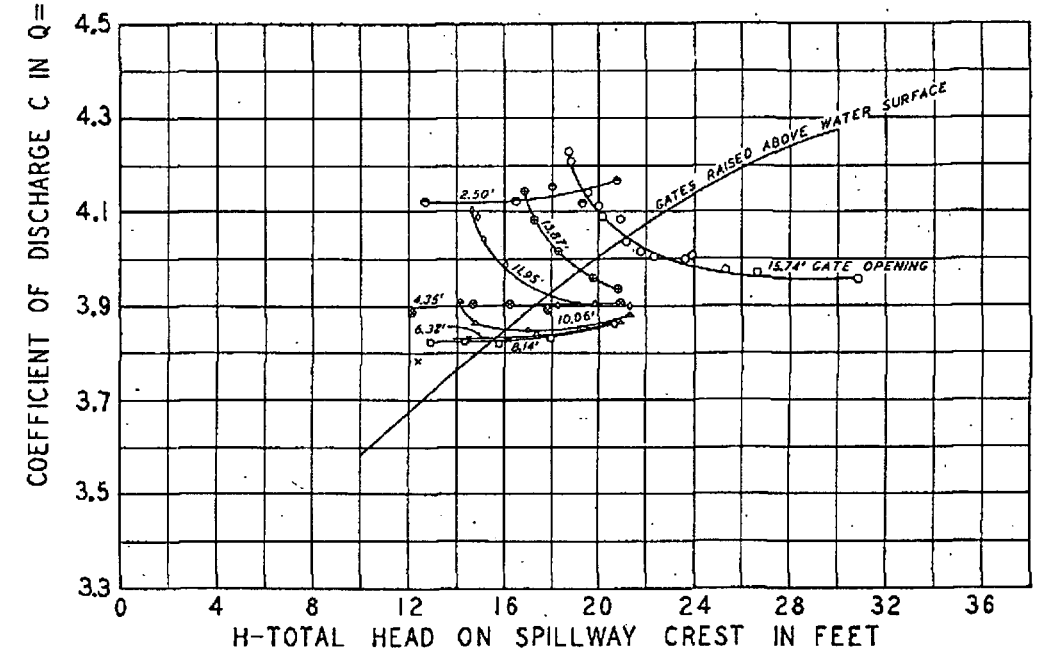


FORT PATRICK HENRY DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

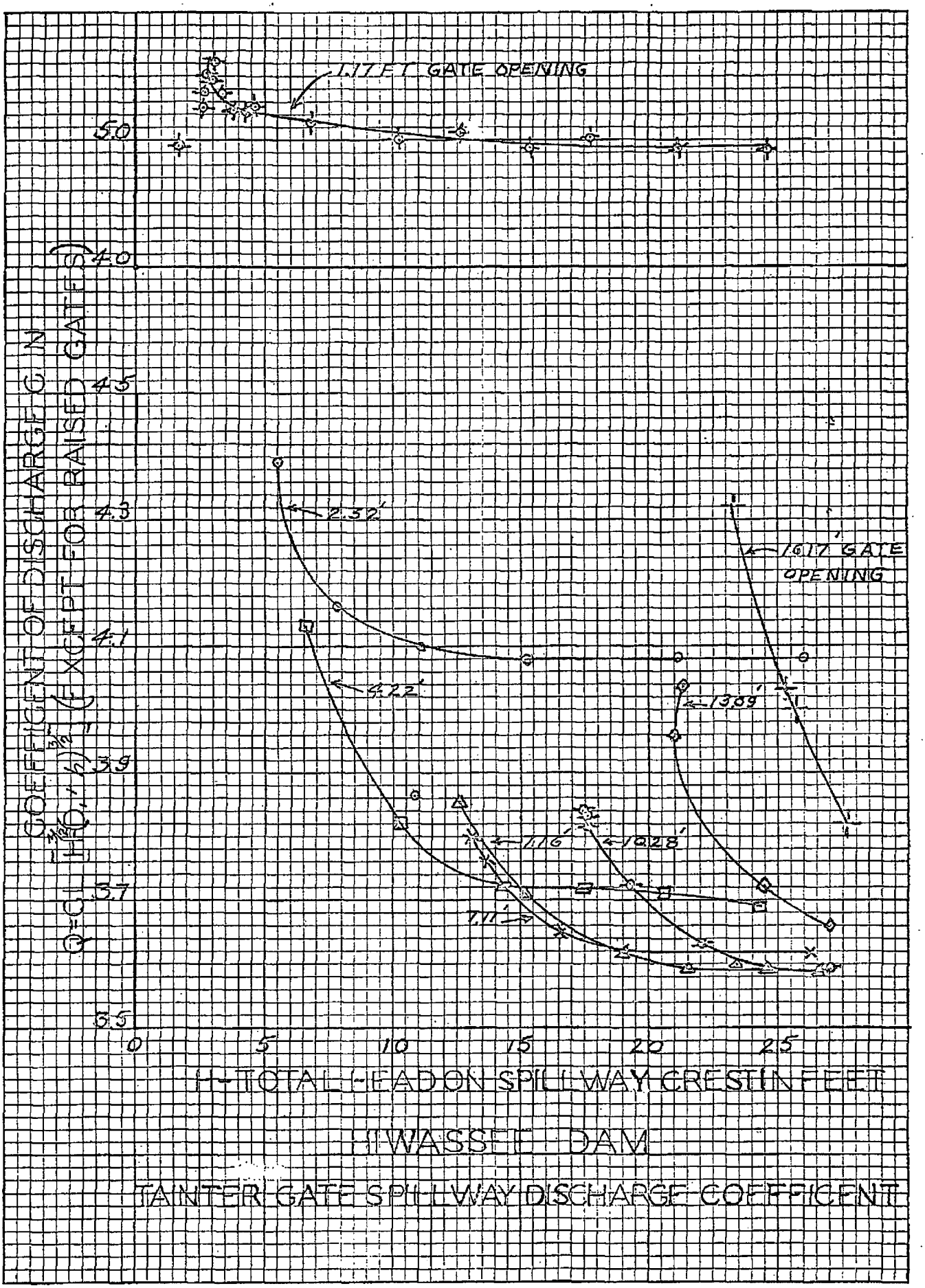


(a) WATTS BAR DAM

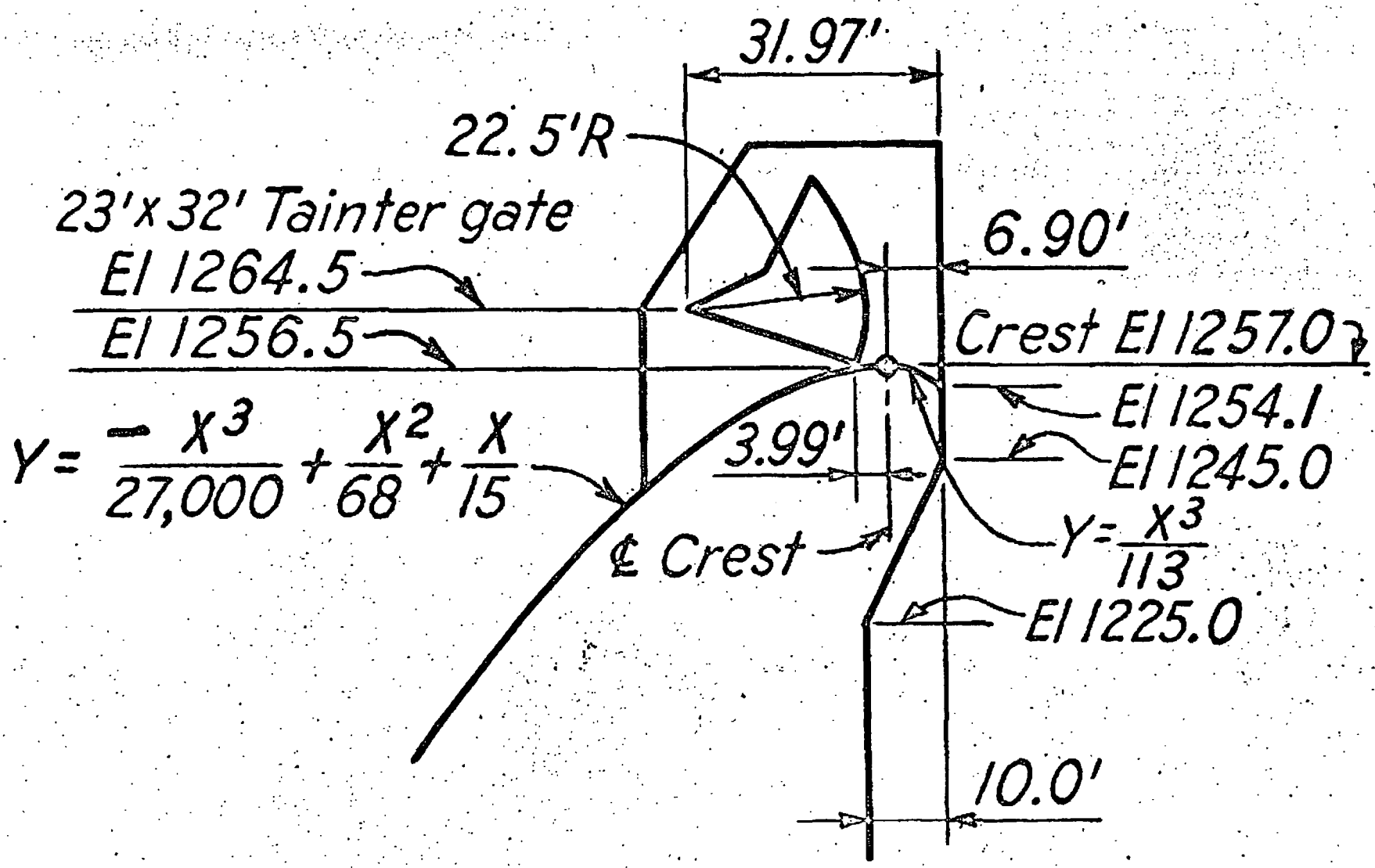


(b) HALES BAR DAM

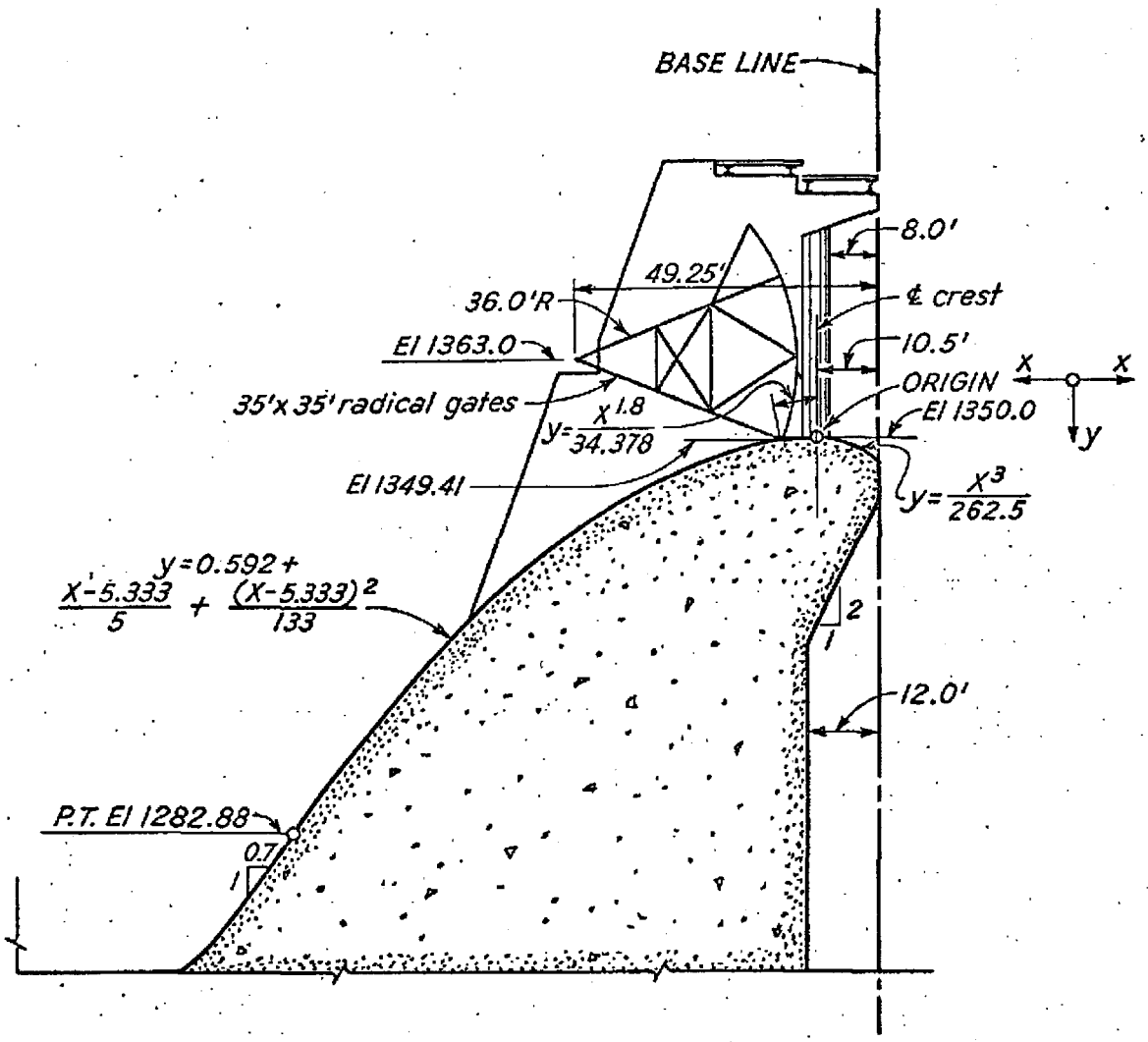
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS



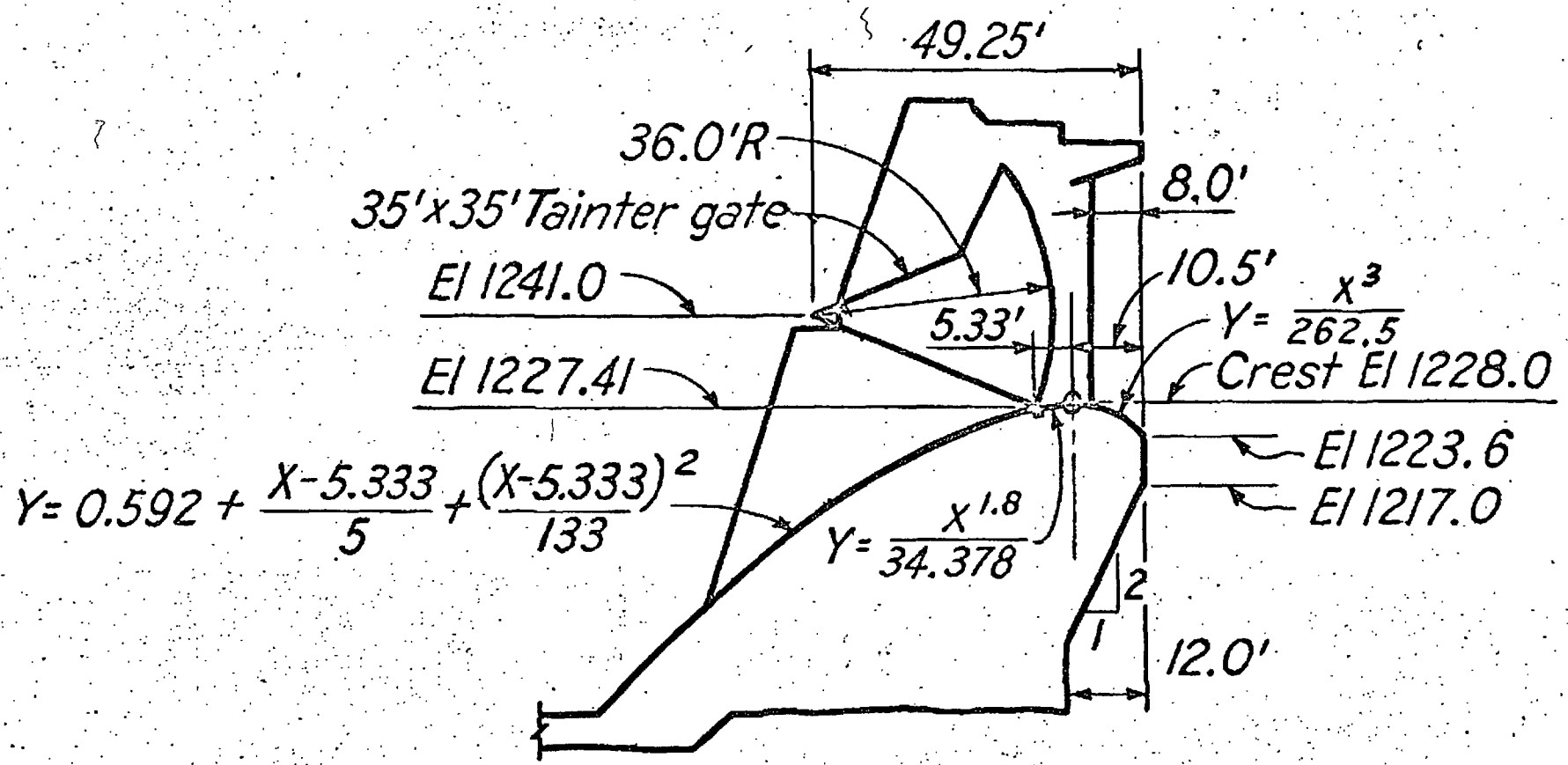
K+E 10 X 10 TO THE INCH 359-5 KEUFFEL & ESSER CO. MADE IN U.S.A.



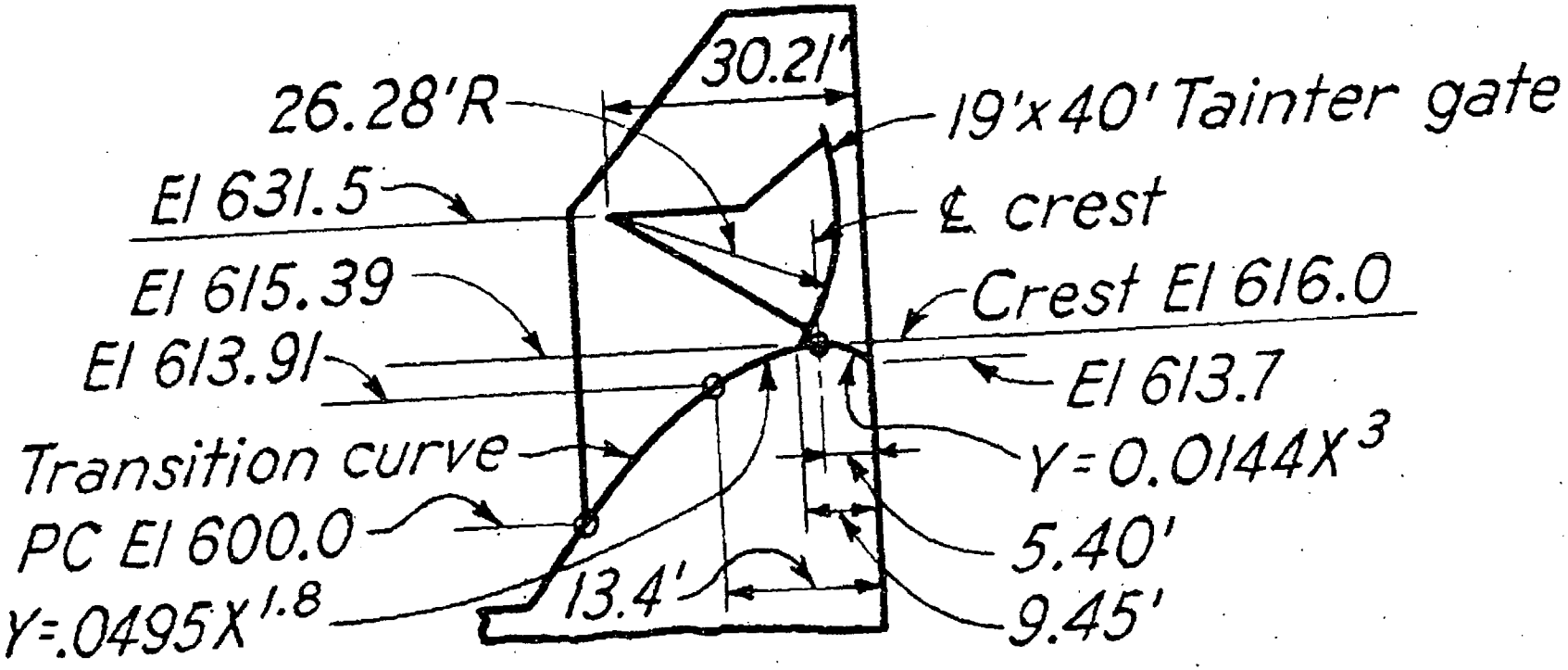
APALACHIA PROJECT



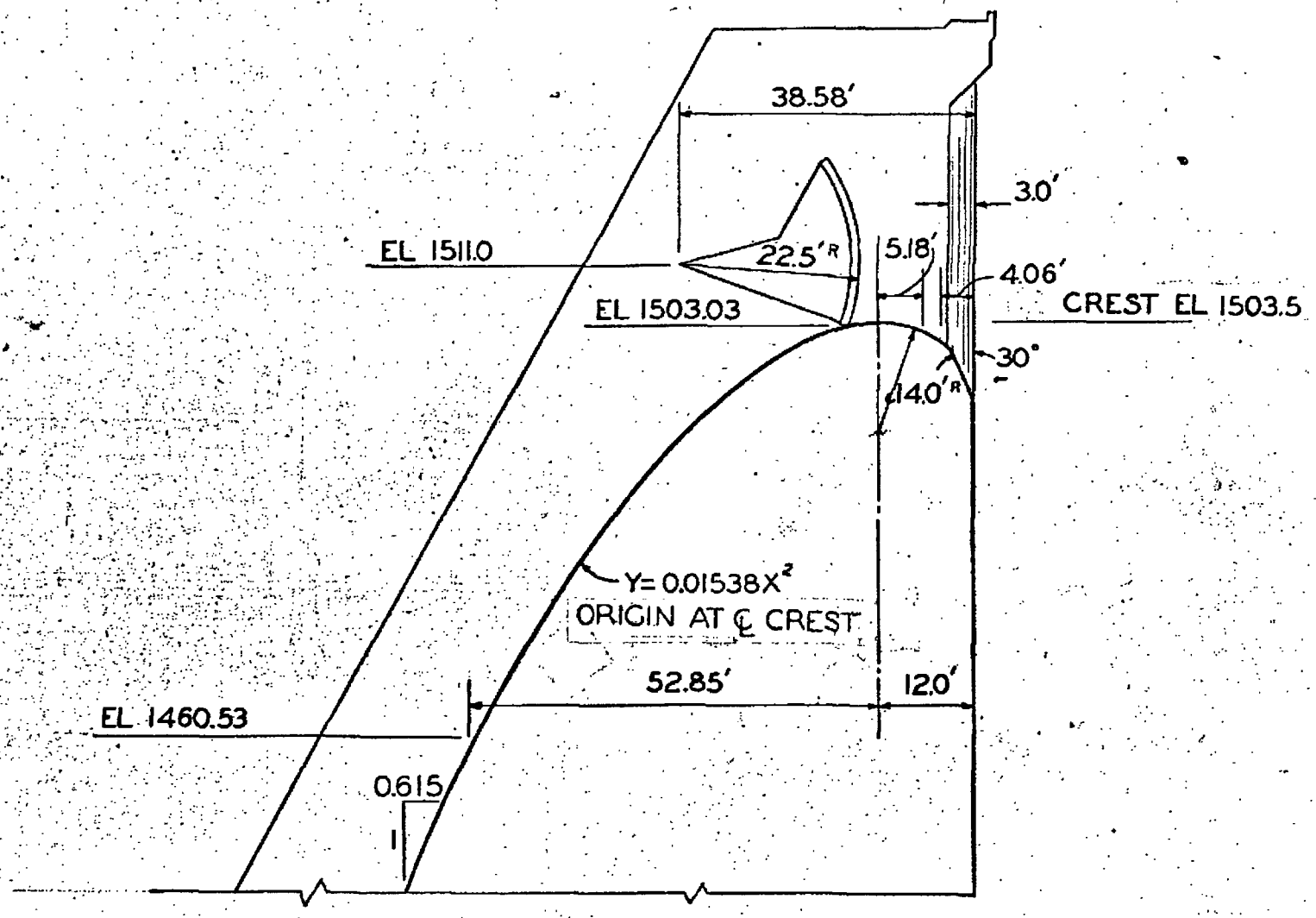
BOONE PROJECT



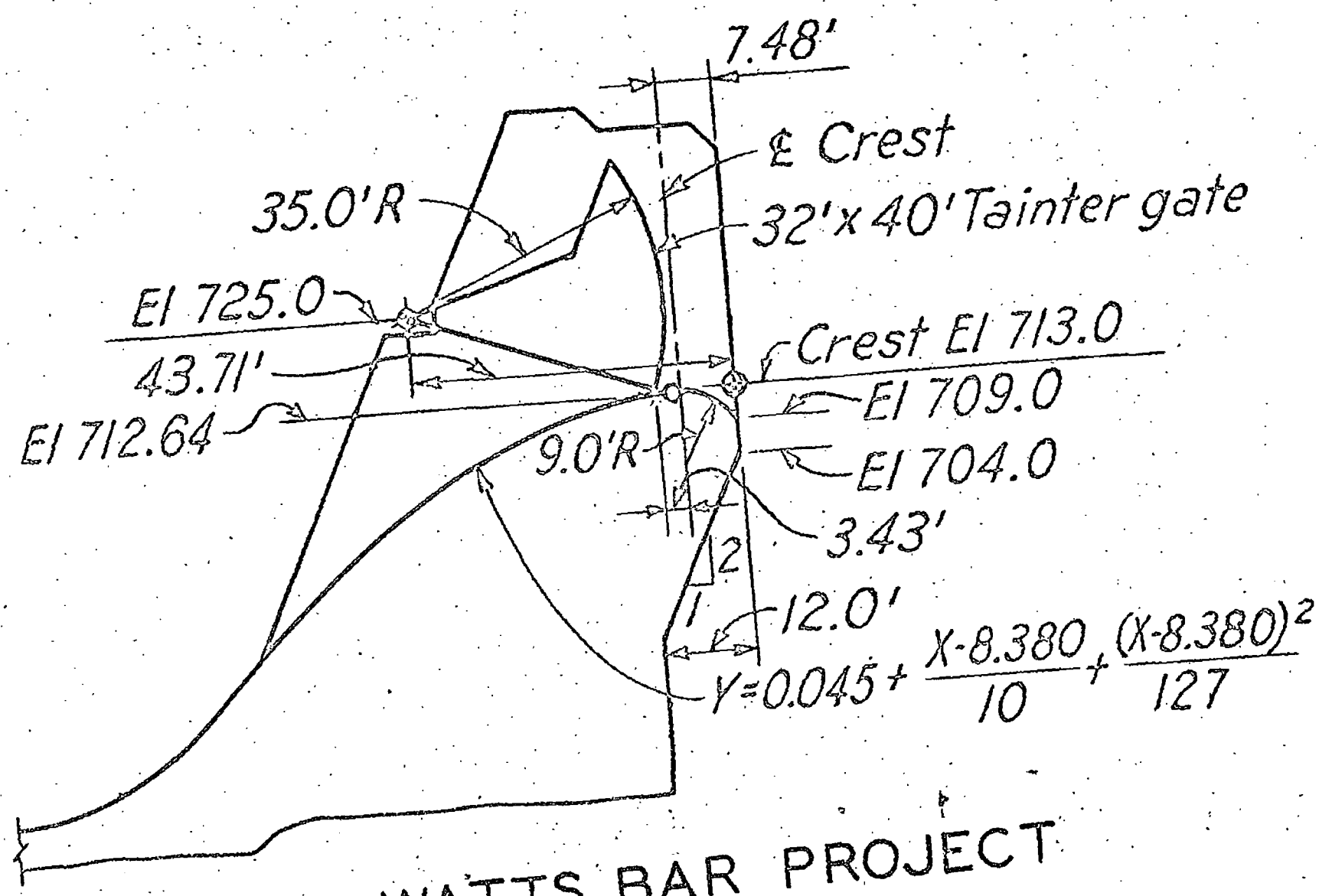
FORT PATRICK HENRY PROJECT



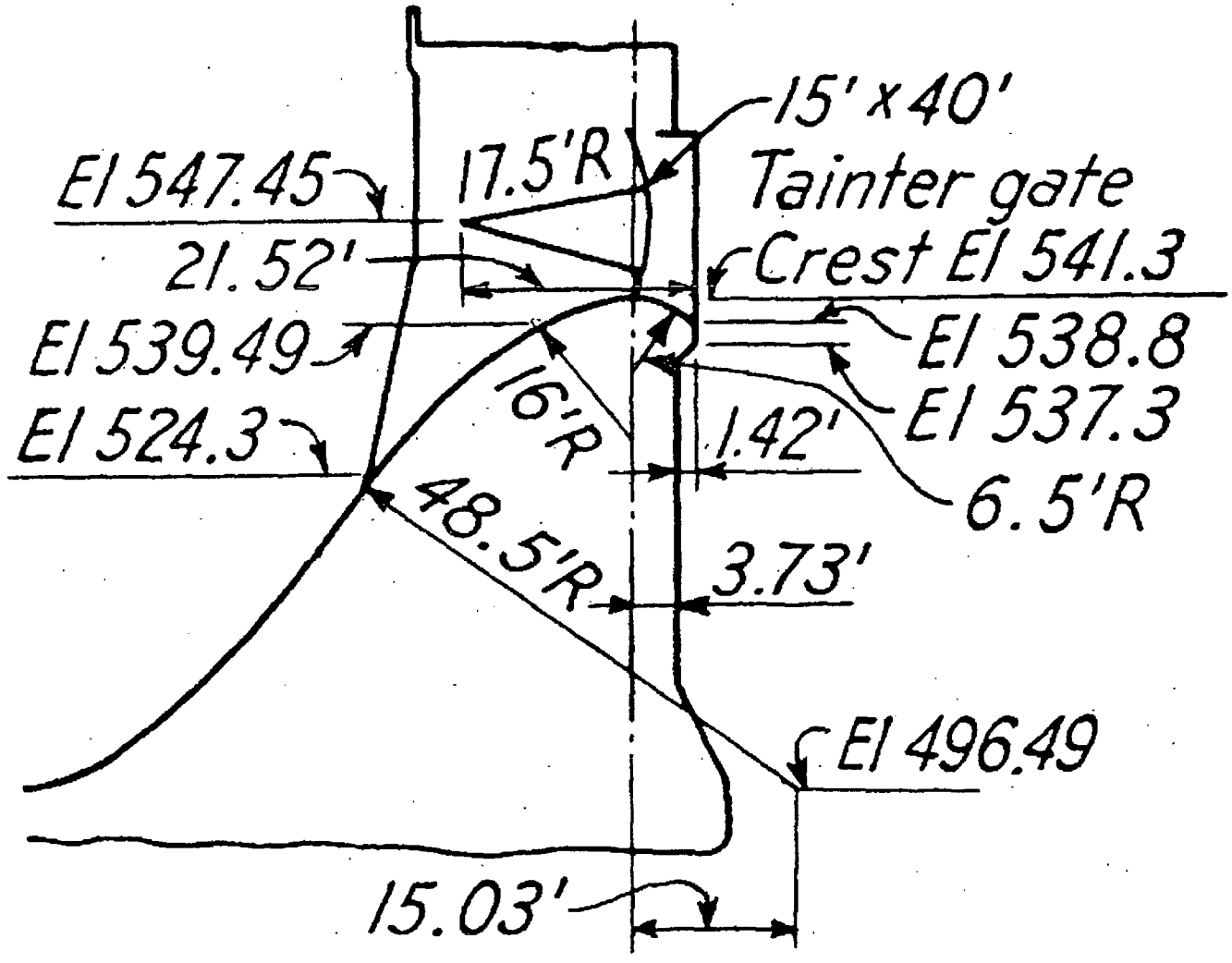
HALES BAR PROJECT



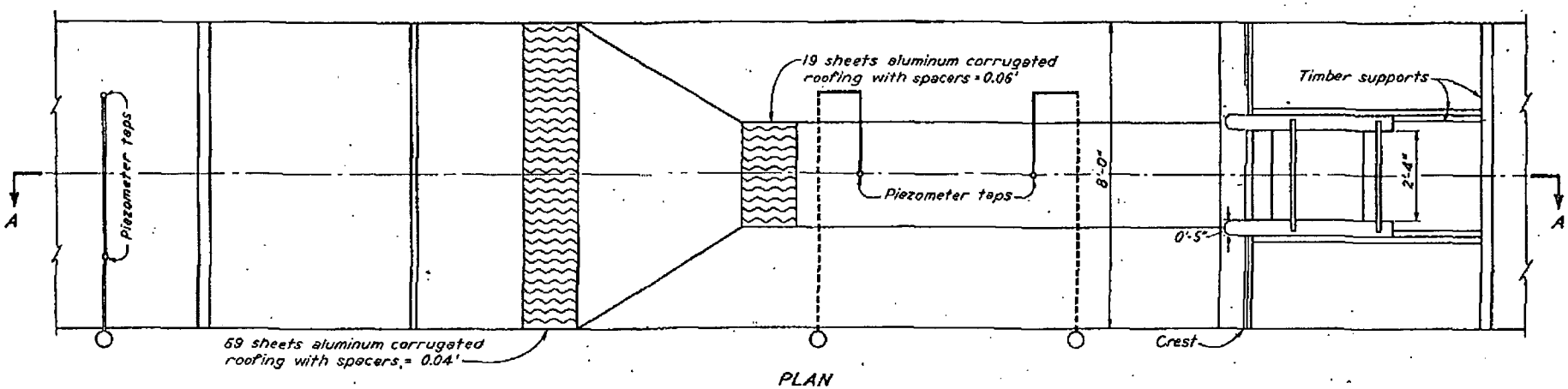
HIWASSEE PROJECT



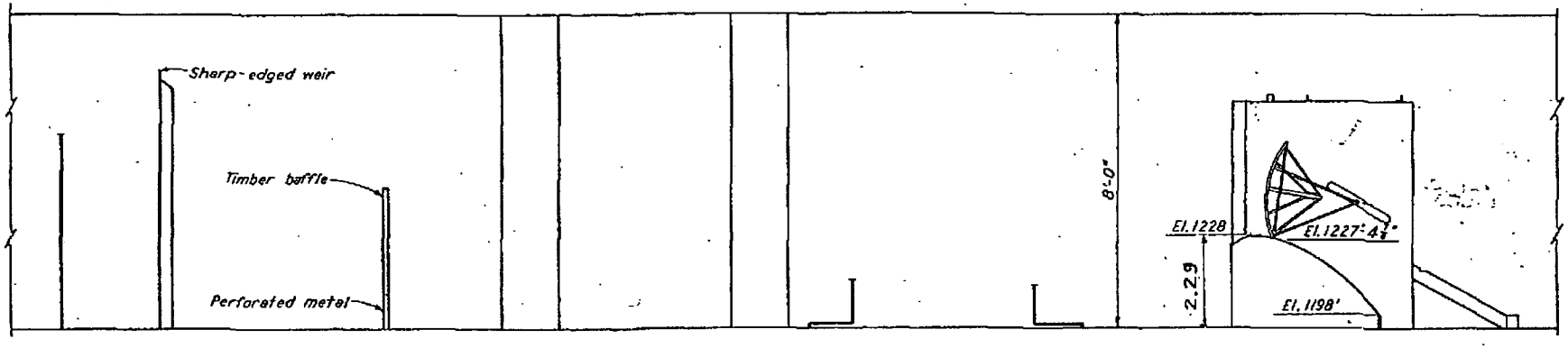
WATTS BAR PROJECT



WHEELER PROJECT



PLAN



SECTION A-A

Scales

1 Model 0 1 2 3 4 5 6 7 8 9 10 Feet

Prototype 0 20 40 60 80 100 Feet

NOTE:

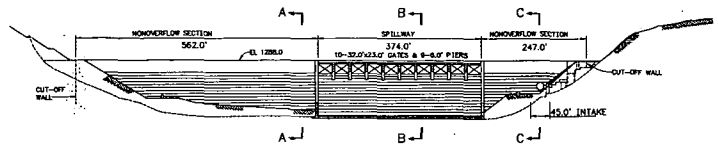
Elevations refer to the prototype.
Dimensions refer to the model.

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

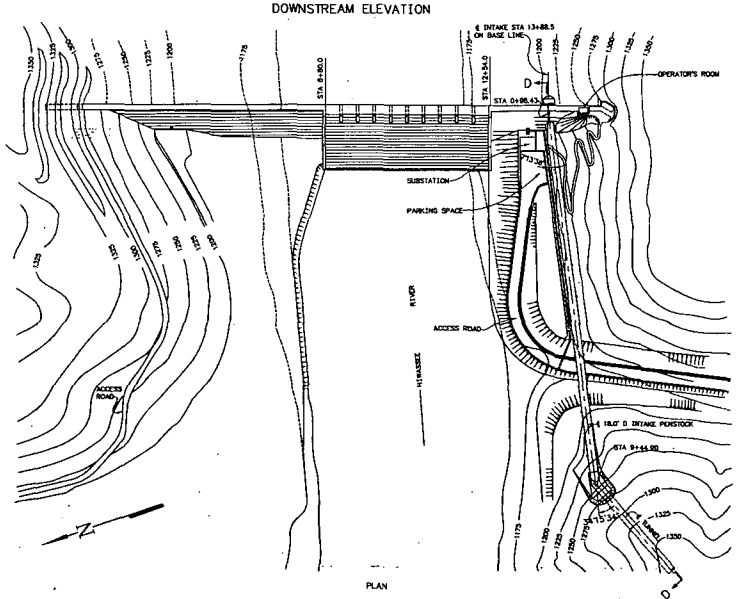
FORT PATRICK HENRY PROJECT
HYDRAULIC MODEL STUDIES

1:15 SCALE MODEL LAYOUT

44

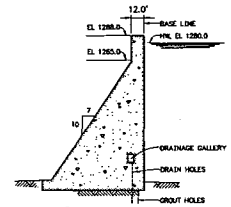


DOWNSTREAM ELEVATION

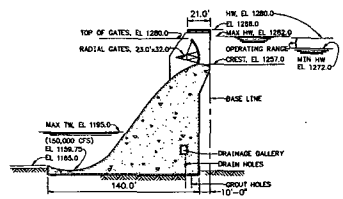


PLAN

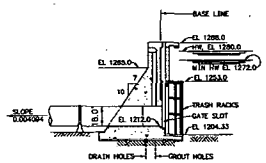
DAM AND TUNNEL INTAKE



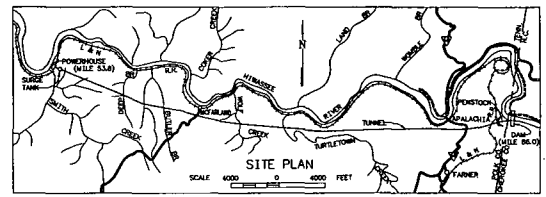
SECTION A–A



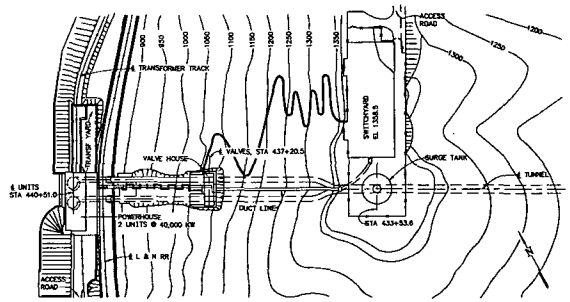
SECTION B–B



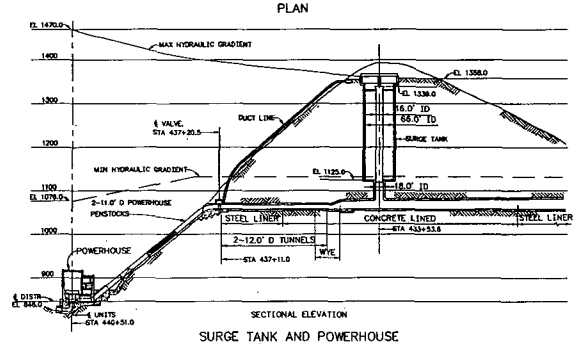
SECTION C–C



SITE PLAN

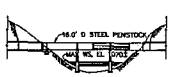


PLAN

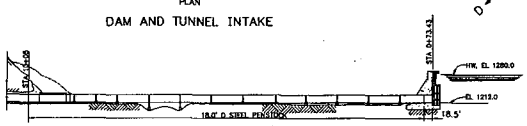


SECTIONAL ELEVATION

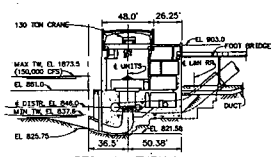
SURGE TANK AND POWERHOUSE



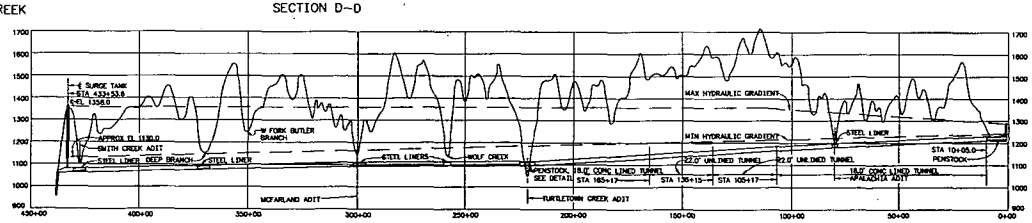
TURTLETOWN CREEK PENSTOCK



SECTION D–D



SECTION THRU UNIT



PROFILE – TUNNEL

SCALE 100 0 100 200 FEET

PLANS, ELEVS, AND PENSTOCK SECTS

SCALE 40 0 40 80 FEET

DAM, INTAKE, AND POWERHOUSE SECTS

R13 5/13/01 ELECTRONICALLY RESTORED

SCALE: 1"=100'-0" EXCEPT AS NOTED

DAM, CONDUIT, & POWERHOUSE

GENERAL PLANS, ELEVATIONS, & SECTIONS

DESIGNED BY FJS | DRAWN BY AG | CHECKED BY GPP

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

MP

AUTOCAD R00 | 15 | C | 10W200 | R 13

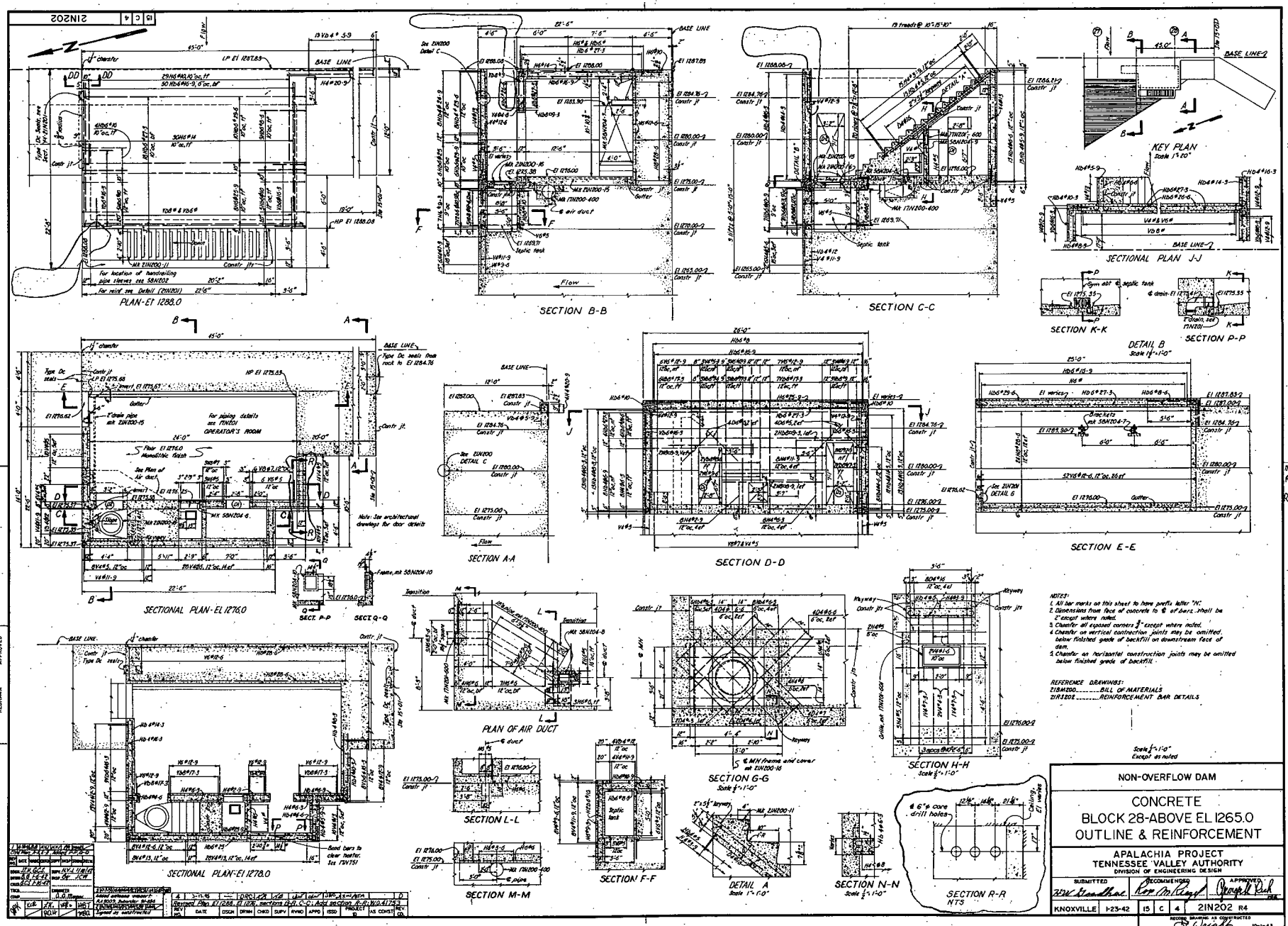
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(10N200 R12)

TASK COMPLETED BY: | REV NO.

PLOT FACTOR:1200
R_TVA

C.A.D. DRAWING DO NOT ALTER MANUALLY

15 C 10W200



NOTES:
1. All bar marks on this sheet to have prefix letter "N".
2. Dimensions from face of concrete to ℄ of bars shall be 2" except where noted.
3. Chamfer all exposed corners ¾" except where noted.
4. Chamfer on vertical contraction joints may be omitted below finished grade of backfill on downstream face of dam.
5. Chamfer on horizontal construction joints may be omitted below finished grade of backfill.

REFERENCE DRAWINGS:
21BM200 ..... BILL OF MATERIALS
21RS202 ..... REINFORCEMENT BAR DETAILS

Scale ¼"=1'-0"
Except as noted

NON-OVERFLOW DAM

CONCRETE
BLOCK 28-ABOVE EL 1265.0
OUTLINE & REINFORCEMENT

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED: H.W. Goodhue
RECOMMENDED: Roy M. Kiesel
APPROVED: George H. Fish

KNOXVILLE | 1-23-42 | 15 | C | 4 | 21N202 R4

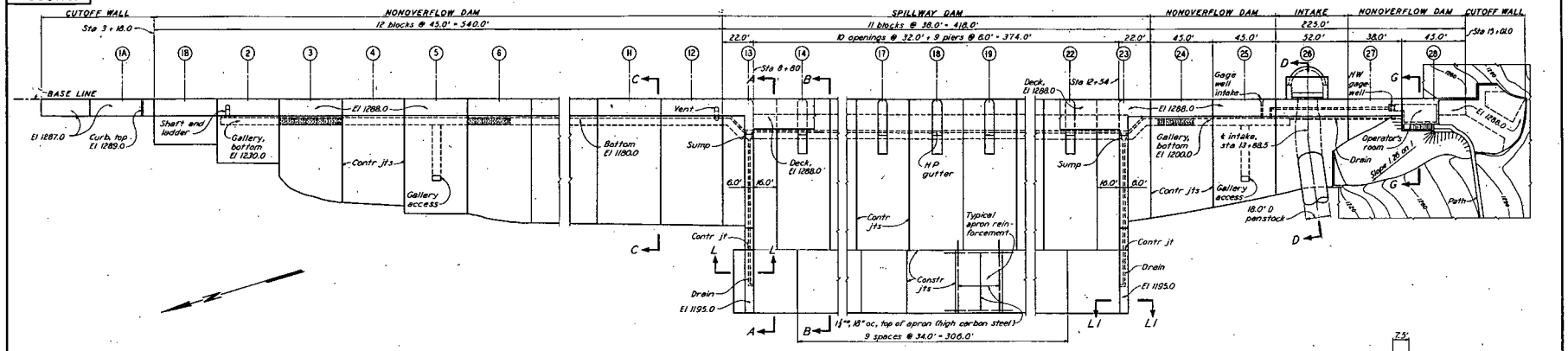
RECORD DRAWING AS CONSTRUCTED
D. Wright 10-1-43

THIS DRAWING HAS BEEN REDRAWN ORIGINAL DESTROYED DATE / INITIAL
3-9-76 / W.E. 1-26-76 / LER RCS 4-26-77
REDRAWN APPROVED

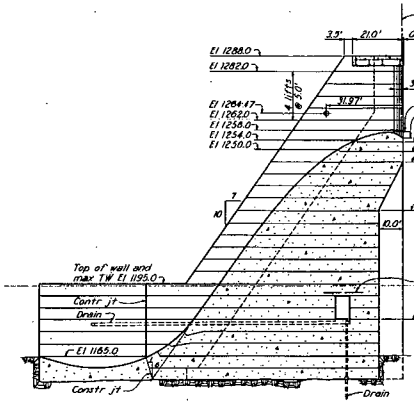
REV NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
4	3-11-76	—	DRC	JRS	JRS	JRS	JRS	JRS			D

Revised Plan El 1288, El 1276, sections B-B, C-C; Add section R-R; W.O. 41753

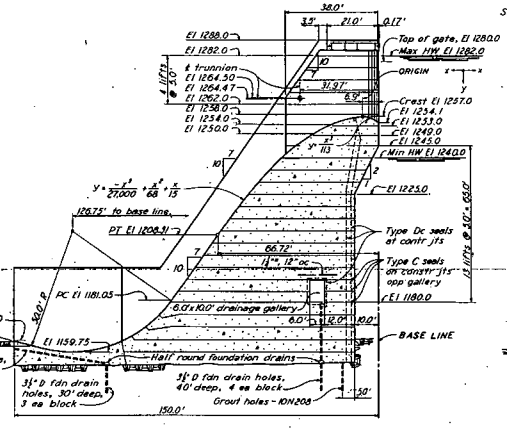
10N206



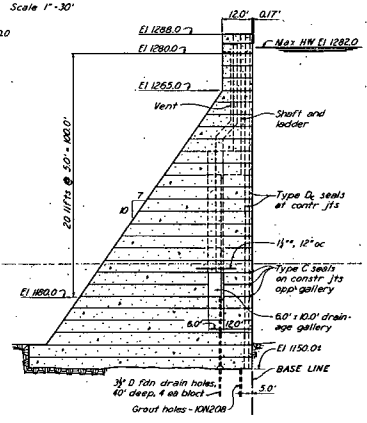
PLAN
Scale 1" = 30'



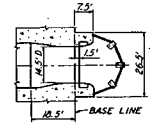
SECTION A-A



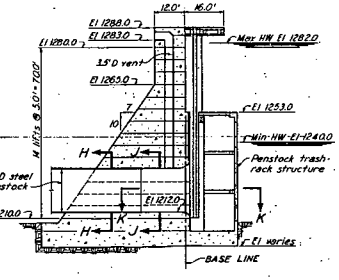
SECTION B-B



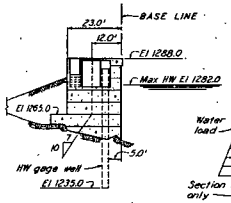
SECTION G-G



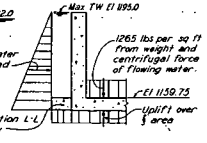
SECTION K-K



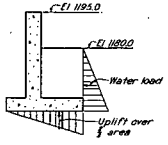
SECTION D-D



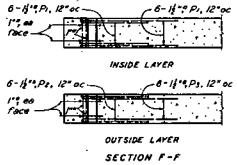
SECTION G-G



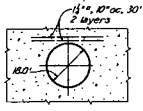
SECTION L-L & LI-LI
LOAD DIAGRAM DURING MAX FLOOD DISCHARGE



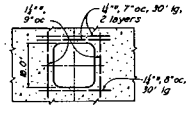
SECTION L-L
LOAD DIAGRAM
CONSTRUCTION CONDITION



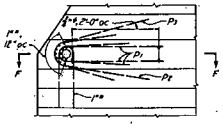
SECTION F-F



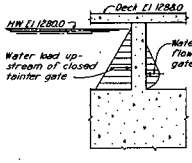
SECTION H-H



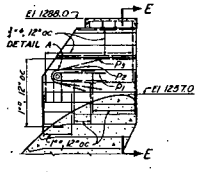
SECTION J-J



ELEVATION
DETAIL A
Scale 1" = 10'



SECTION E-E
LOAD DIAGRAM



ELEVATION-SPILLWAY PIER

BAR P1 BAR P2 BAR P3

Scale 1" = 20'
Except as noted

SPILLWAY, INTAKE & NONOVERFLOW DAM

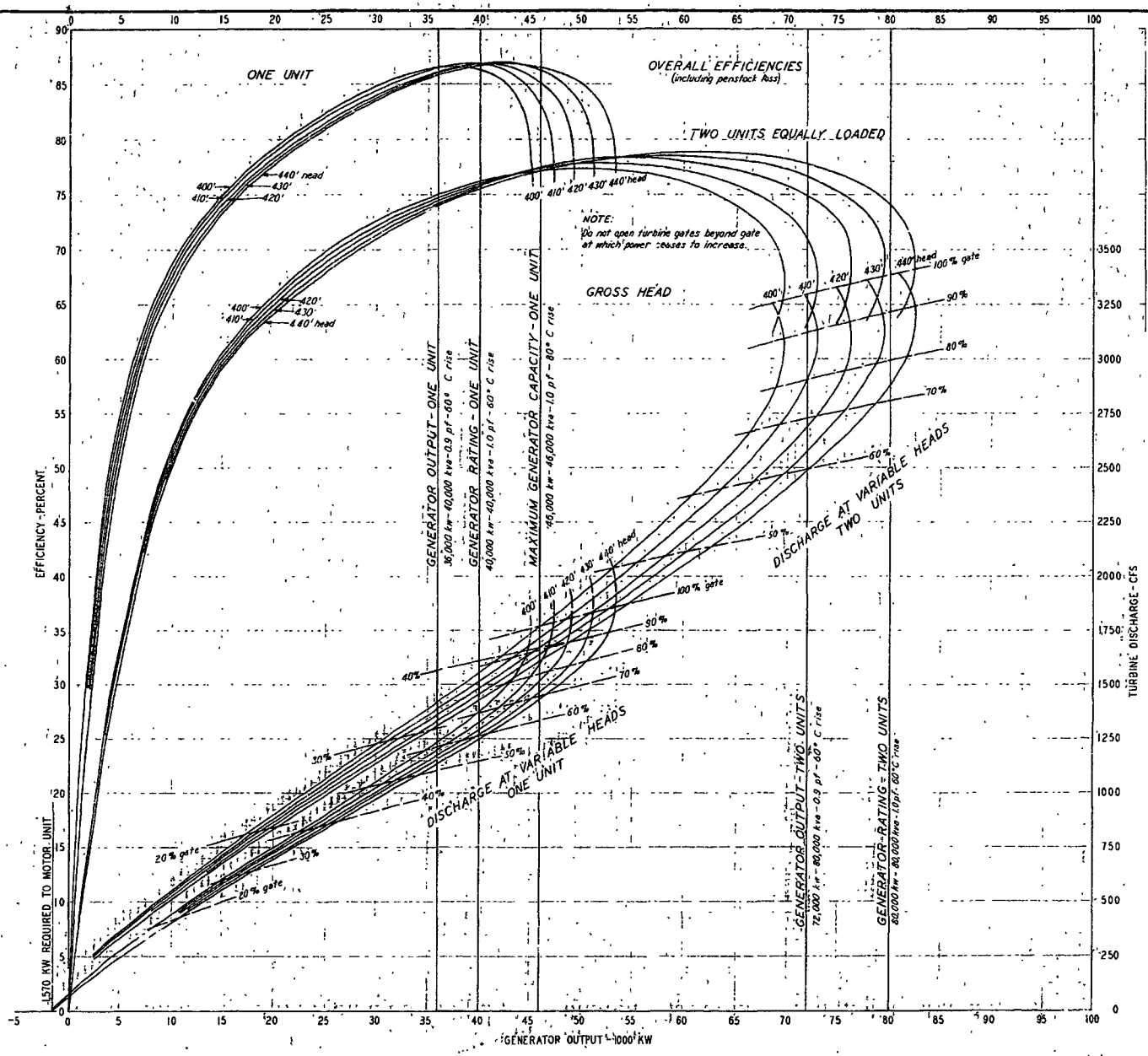
PRINCIPAL FEATURES OF DESIGN

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
T. T. Woodhouse	Roy M. Kluge	George L. Rich

KNOXVILLE 9-3-41 15 C 4 10N206 R2

RECORD DRAWING AS CONSTRUCTED



NOTES:

Based on model test curves furnished by Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia, Pennsylvania, and adjusted in accordance with index tests conducted 5-11, 12-44. Data should be revised to include field tests at other heads.

TURBINE RATED:

53,000 hp - 36' net head - 225 rpm - manufactured by Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia, Pennsylvania.

GENERATOR RATED:

40,000 kva - 3 phase - 60 cycle - 13,800 volts - 0.937 power factor - 60°C rise - 225 rpm - manufactured by Westinghouse Electric and Manufacturing Co., Pittsburgh, Pennsylvania.

THIS DRAWING SUPERSEDES 124K41100

POWERHOUSE
UNITS 1 & 2

OPERATING CHARACTERISTICS
40,000 KVA UNIT

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

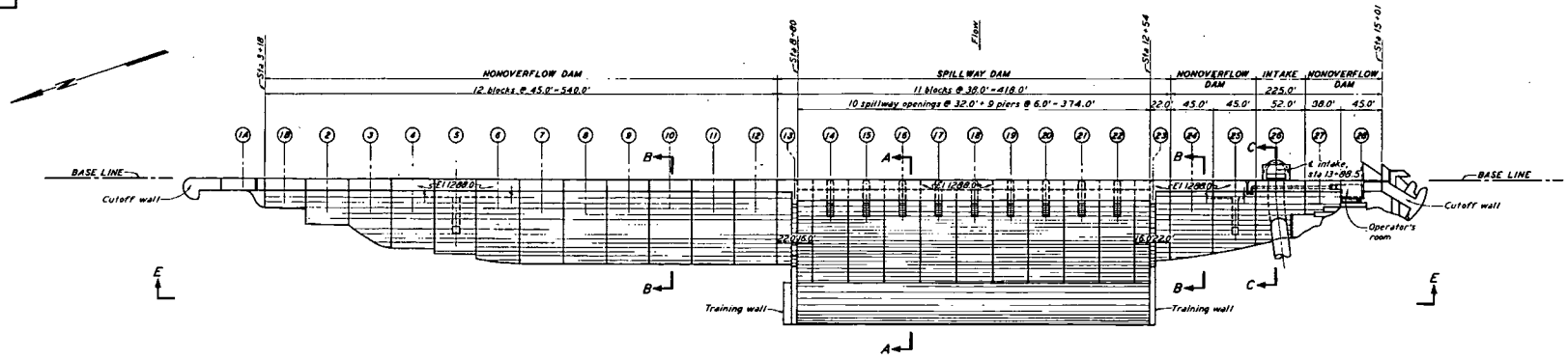
SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE 1-8-41 A DD 4 124K41R4

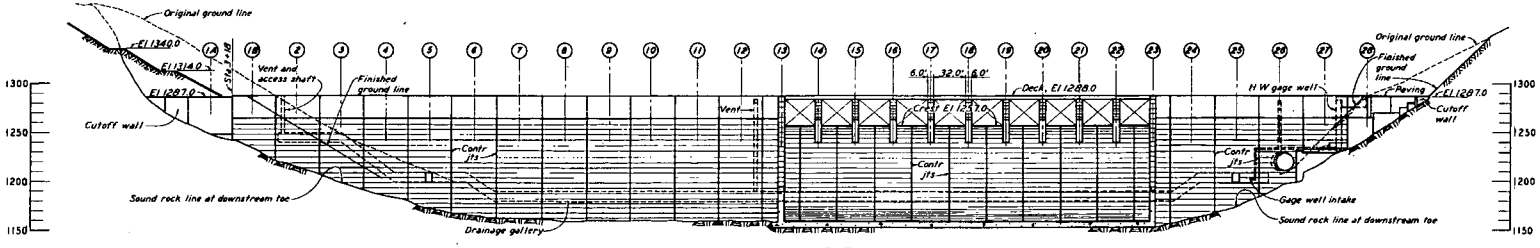
REV. NO.	DATE	DRAWN	CHECKED	SUPV	DISP	SUBM	RECM
4	1-15-44	WSM					
Lettering added to title.							
3	10-15-43	LCW	GLP				
Minor revisions							
2	9-24-42	TCM	CLN		TCM		
Double and curves revised							
1	7-24-42	TCM	CLN		WSM		
Revised to include index tests							

DSGN CLN SUPV JFR
DRWN CLN DISP
CHKD JFR
TRCD MCM RECORDED
COMP CLN

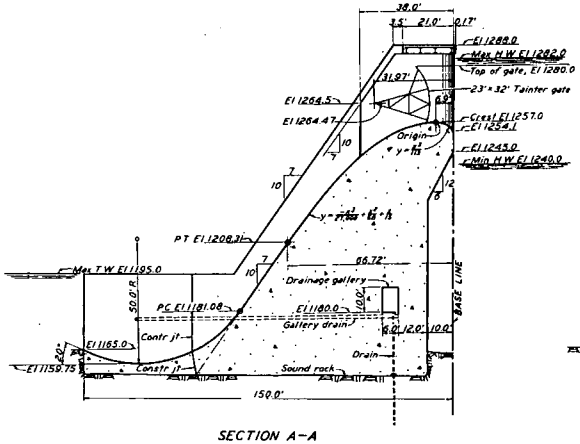
10N205



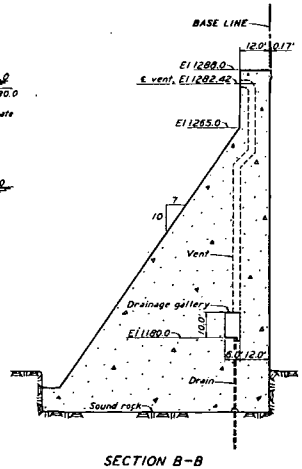
PLAN



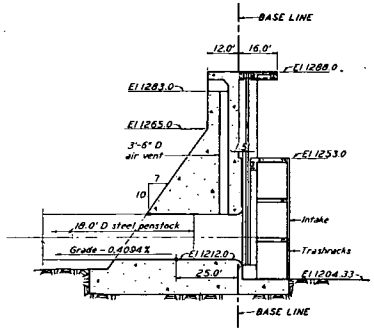
ELEVATION E-E



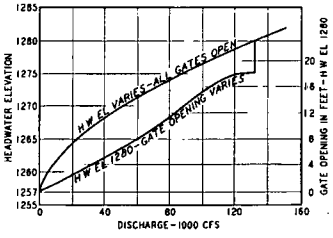
SECTION A-A
Scale 1" = 20'



SECTION B-B
Scale 1" = 20'



SECTION C-C
Scale 1" = 20'



SPILLWAY DISCHARGE CURVES
10 - 23' × 32' TAINTER GATES

Scale 1" = 50'
Except as noted

SPILLWAY, INTAKE & NONOVERFLOW DAM

GENERAL ARRANGEMENT PLAN, ELEVATION & SECTIONS

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

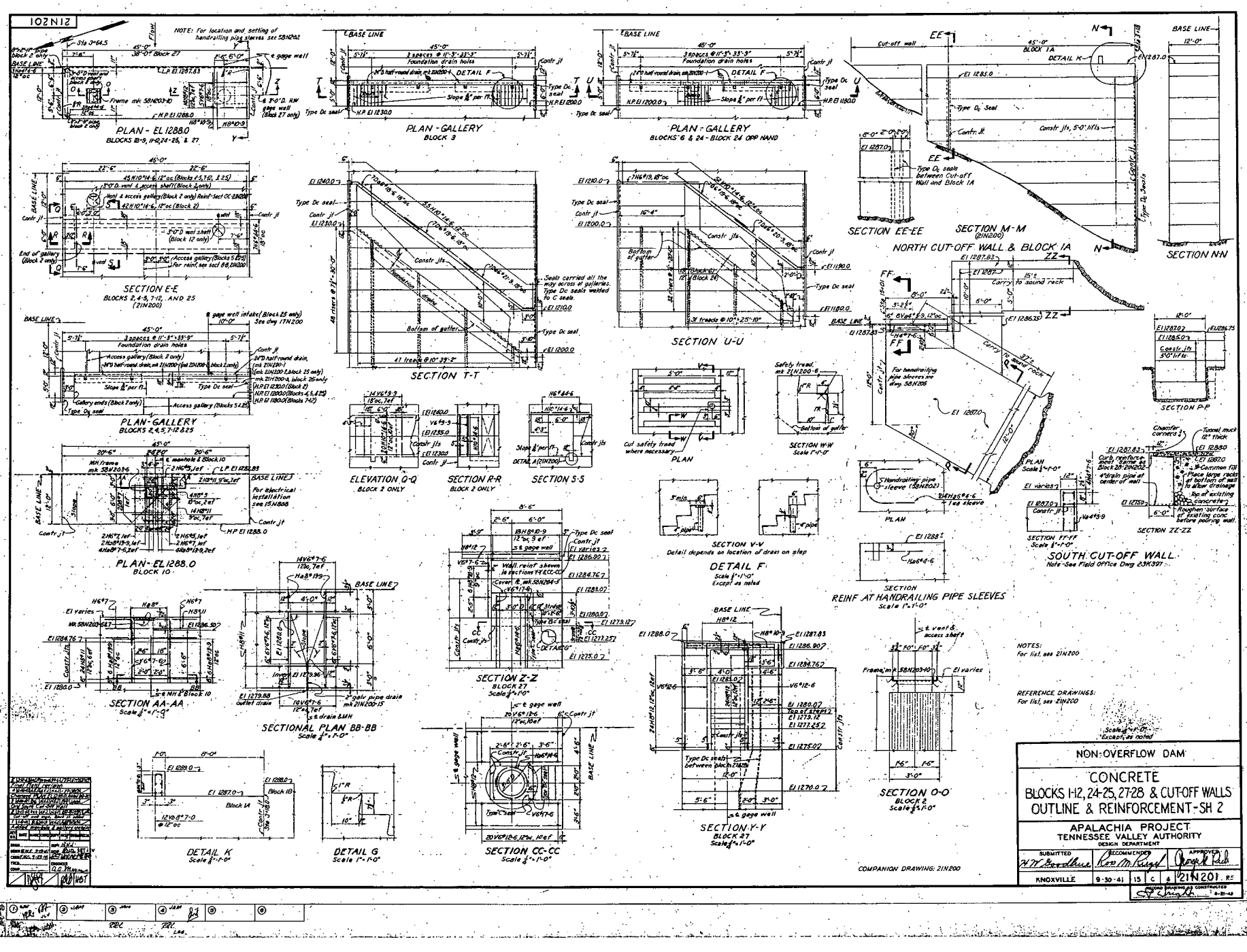
SUBMITTED	RECOMMENDED	APPROVED
N.W. Bordline	Joseph Ash	T.O. Parker

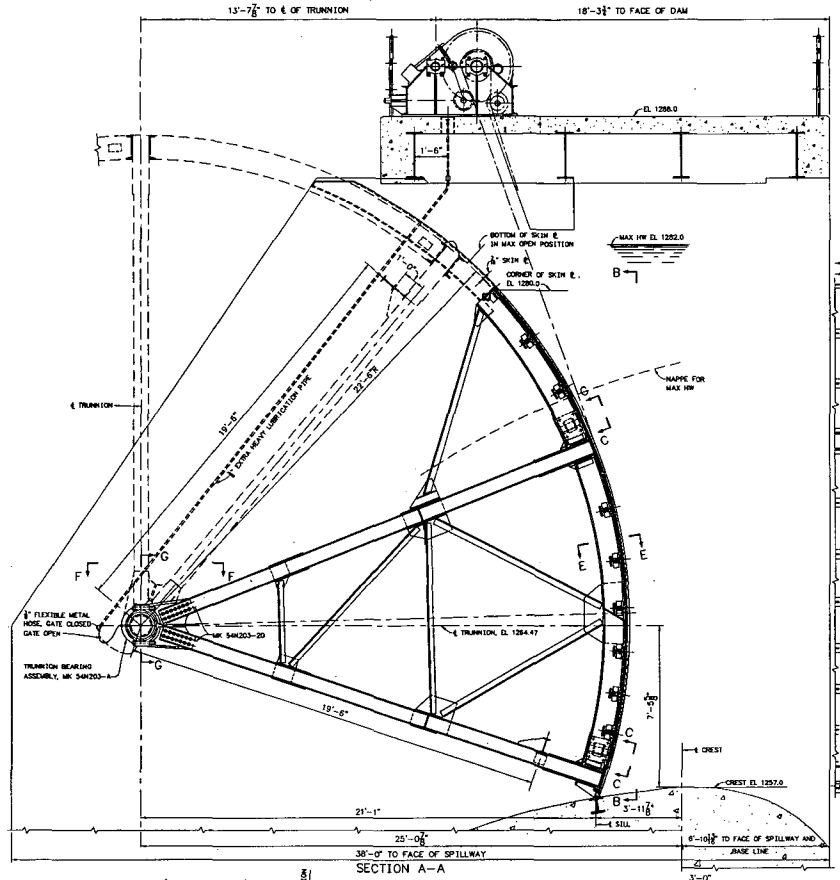
PROJECT MANAGER

KNOXVILLE	8-21-41	15	C	4	10N205	R4

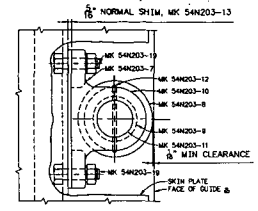
RECORD DRAWING AS CONSTRUCTED 12-6-43

21N201

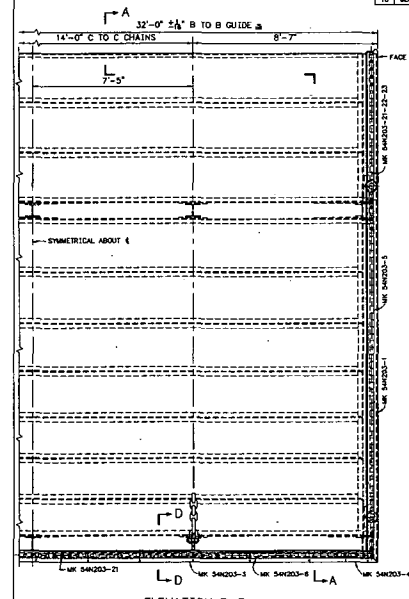

PLAN - EL 1288.0
BLOCKS 18-9, 11-12, 24-25, & 27
PLAN - GALLERY
BLOCK 3
PLAN - GALLERY
BLOCKS 6 & 24 - BLOCK 24 OPP HAND
SECTION E-E
BLOCKS 2, 4-5, 7-12, AND 25
(21N200)
SECTION T-T
SECTION U-U
SECTION EE-EE
SECTION M-M
(21N200)
NORTH CUT-OFF WALL & BLOCK 1A
SECTION N-N
PLAN-GALLERY
BLOCKS 2, 4, 5, 7-12 & 25
ELEVATION Q-Q
BLOCK 2 ONLY
SECTION R-R
BLOCK 2 ONLY
SECTION S-S
PLAN
SECTION W-W
Scale 1"=1'-0"
SECTION P-P
PLAN
SECTION ZZ-ZZ
SECTION FF-FF
Scale 1"=1'-0"
SOUTH CUT-OFF WALL
Note-See Field Office Dwg 63K397
SECTION V-V
Detail depends on location of drain on step
DETAIL F
Scale 1/4"=1'-0"
Except as noted
SECTION
REINF AT HANDRAILING PIPE SLEEVES
Scale 1"=1'-0"
PLAN-EL 1288.0
BLOCK 10
SECTION AA-AA
Scale 1/4"=1'-0"
SECTIONAL PLAN BB-BB
Scale 1/4"=1'-0"
SECTION Z-Z
BLOCK 27
Scale 1/4"=1'-0"
SECTION CC-CC
Scale 1/4"=1'-0"
SECTION Y-Y
BLOCK 27
Scale 1/4"=1'-0"
SECTION O-O
BLOCK 2
Scale 1/4"=1'-0"
DETAIL K
Scale 1/8"=1'-0"
DETAIL G
Scale 1"=1'-0"
NOTES:
For list, see 21N200
REFERENCE DRAWINGS:
For list, see 21N200
Scale 1"=1'-0"
Except as noted
COMPANION DRAWING: 21N200
NON-OVERFLOW DAM
CONCRETE
BLOCKS 1-12, 24-25, 27-28 & CUT-OFF WALLS
OUTLINE & REINFORCEMENT - SH 2
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
9-30-41
15
C
4
21N201
RS



SECTION A-A



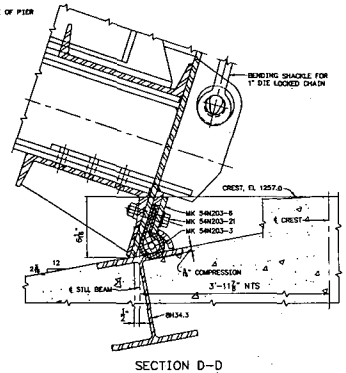
ELEVATION C-C
ROLLER ASSEMBLY-MK 54N203-B
SCALE 3"=1'-0"



ELEVATION B-B

MATERIAL SPECIFICATIONS						
NO.	MATERIAL	ULTIMATE TENSION	YIELD POINT TENSION	% EL IN 2"	% RED AREA	SPECIFICATIONS
1	STR STEEL, 33,000 MIN YP	60/72,000	0.5 TENS	22		ASTM A-7-39
2	RIVET STEEL, 28,000 MIN YP	52/62,000	0.5 TENS			ASTM A-141-39
3	BOLT & NUT STEEL, GRADE 2; OR 22					ASTM A-107-40
4	STEEL CASTINGS, GRADE B	70,000	38,000	24	36	ASTM A-27-38
5	STEEL FORGINGS, CLASS E	75,000	0.5 TENS	20	33	ASTM A235-40T
6	STEEL FORGINGS, CLASS G	90,000	55,000	20.5	38	ASTM A235-40T
7	STEEL FORGINGS, CLASS D OR E	85,000	55,000	20	41	ASTM A237-40T
8	PHOS BRZ & GRAPHITE					M-SEE BELOW
9	BRASS ROD, FREE CUTTING *	44,000	18,000	25		ASTM B-16-29
10	CAST PHOS BRONZE	25,000	12,000	8		ASTM B-74-32T
11	ROLLED NAVAL BRASS	60,000	30,000	30		ASTM B-21-40T
12	STEEL					M-SEE BELOW
13	CAST IRON, CLASS 35	35,000				ASTM A-48-38
14	BRONZE					M-SEE BELOW
15	SPRING STEEL					M-SEE BELOW
16	WELDING FILLER METAL, GRADE 10					ASTM A-205-37T
17	RUBBER					M-SEE BELOW
18	GLASS					M-SEE BELOW

* PHYSICAL PROPERTIES FROM FED. SPECIFICATIONS QQ-B-611 COMP B.
M-MISCELLANEOUS MATERIALS SHALL BE HIGH CLASS COMMERCIAL GRADES.



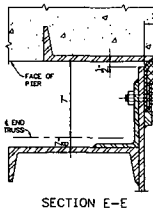
SECTION D-D
SCALE: 3"=1'-0"

NOTES:

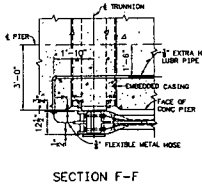
GATES TO BE ASSEMBLED AS COMPLETELY AS POSSIBLE & SECURELY BOLTED IN FIELD BEFORE RIVETING & WELDING. SEQUENCE OF RIVETING & WELDING TO BE SUCH AS TO PREVENT DISTORTION OF GATE.
WELDS OVER 1/4" SHALL BE PEENED.

FIELD WELDING TO BE IN ACCORDANCE WITH THE CODE FOR FUSION WELDING & GAS CUTTING IN BUILDING CONSTR. 1937 EDITION OF THE A.W.S.
GATES TO BE CENTERED ON TRUNNION PINS TO GIVE EQUAL COMPRESSION ON SIDE SEALS.

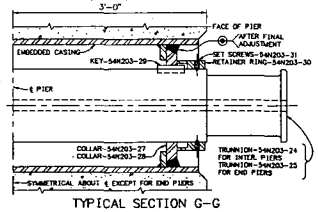
SEAL JOINTS & PLUGS TO BE CEMENTED.
CLEANING & PAINTING TO BE DONE BY FIELD FORCES.
GUIDE ROLLER ASSEMBLIES TO BE SHIMMED TO GIVE 1/4" MIN CLEARANCE.
FOR MANUFACTURER'S DETAILS OF RADIAL GATES REFER TO AMERICAN BRIDGE CO FILE. TVA CONTRACT NO. TV-85070.



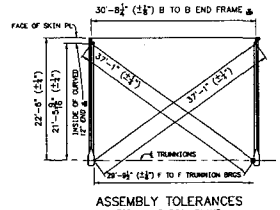
SECTION E-E
SCALE: 3"=1'-0"



SECTION F-F



TYPICAL SECTION G-G
TRUNNION ASSEMBLY
SCALE: 1 1/2"=1'-0"



ASSEMBLY TOLERANCES
FOR ANY RADIAL PLANE
SCALE: 3/8"=1'-0"

REV NO.	REVISIONS	DRAWN	DESIGN	CHKD	SUPV	CHKD	APPR	CHKD	PROJECT ENGR	AS CONST
R.4	6-24-0 REDRAWN TO AUTOCAD FORMAT									

SCALE: 3/8"=1'-0" EXCEPT AS NOTED

SPILLWAY

RADIAL GATES ARRANGEMENT

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
I.B.A., S.A.H.	C.O.W.	W.L.M.	R.B.B.			

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | DATE 9-12-41 | 15 | M | 54W200 | R 4

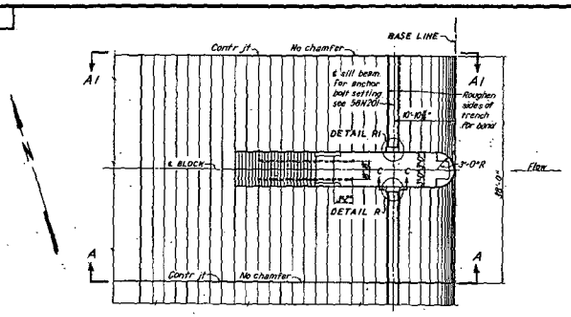
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (54W200 R3)

TASK COMPLETED BY: | REV NO.

PLOT FACTOR:24
W_TVA

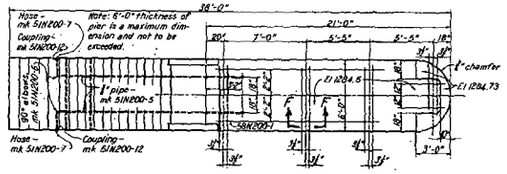
C.A.D. DRAWING
DO NOT ALTER MANUALLY

5IN201

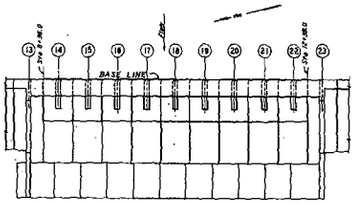


PLAN—BLOCKS 14 TO 22 INL—ABOVE EL 1225.0

Scale ½"=1'-0"



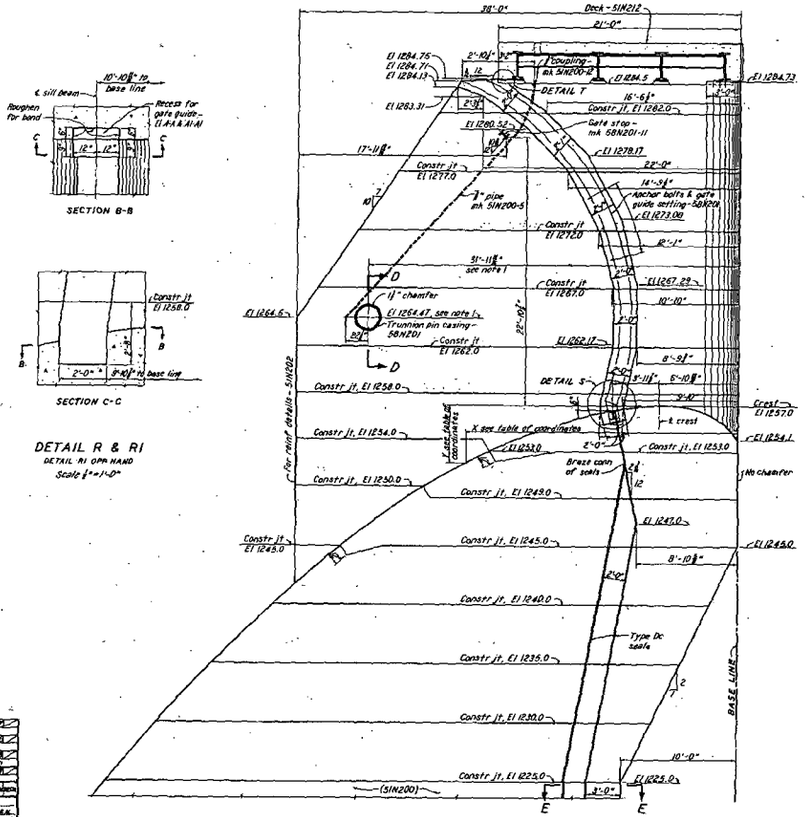
PLAN—TOP OF PIERS



KEY PLAN

Scale 1"=60'

COORDINATES OF WEIR PROFILE			
$Y = \frac{(6.9-X)^2}{113}$, from X=0 to X=6.9			
$Y = \frac{(X-6.9)^2}{27.08} + \frac{(X-6.9)^2}{68} + \frac{X-6.9}{15}$, from X=6.9 to X=66.72			
X	Y	EL	DESCRIPTION
2.000	1.041	1255.959	
4.000	0.216	1256.784	
6.900	0.000	1257.000	℄ of crest
8.900	0.192	1256.808	
9.906	0.331	1256.669	Edge of sill beam slot
11.875	0.691	1256.309	Edge of sill beam slot
14.000	1.201	1255.799	
16.000	1.797	1255.203	
18.000	2.501	1254.499	
20.000	3.314	1253.685	
22.000	4.233	1252.767	
24.000	5.255	1251.745	
26.000	6.380	1250.620	
28.000	7.606	1249.394	
30.000	8.930	1248.070	
32.000	10.352	1246.648	
34.000	11.870	1245.130	
36.000	13.480	1243.520	
38.000	15.183	1241.817	
40.000	16.976	1240.024	
42.000	18.856	1238.144	
44.000	20.823	1236.177	
46.000	22.875	1234.125	
48.000	25.010	1231.990	
50.000	27.326	1229.774	
52.000	29.521	1227.479	
54.000	31.894	1225.106	
56.000	34.342	1222.658	
58.000	36.865	1220.135	
60.000	39.460	1217.540	
62.000	42.124	1214.876	
64.000	44.859	1212.141	
66.720	48.684	1208.316	P.C.



ELEVATION A-A & A1-A1

ELEVATION A1-A1 OPP HAND

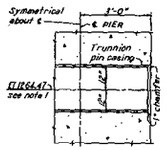
SECTION B-B

SECTION C-C

DETAIL R & R1

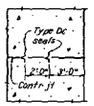
DETAIL R1 OPP HAND

Scale ½"=1'-0"

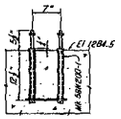


SECTION D-D

Scale ½"=1'-0"

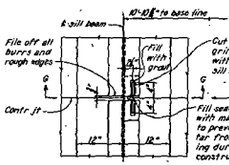


SECTION E-E

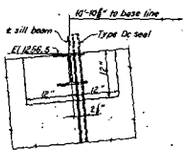


SECTION F-F

Scale 1"=1'-0"



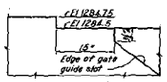
PLAN



ELEVATION G-G

DETAIL S

Scale 1"=1'-0"



DETAIL T

Scale 1"=1'-0"

NOTES:

1. Extreme care should be taken to set trunnion pin casing to exact dimensions and elevations shown.
2. Chamfer exposed corners 1" except as noted.

REFERENCE DRAWINGS:

5IBM200 — BILL OF MATERIAL

30B510 — SEALS

Scale ½"=1'-0"
Except as noted

SPILLWAY

CONCRETE

BLOCKS 14 TO 22—ABOVE EL 1225.0

OUTLINE

APALACHIA PROJECT

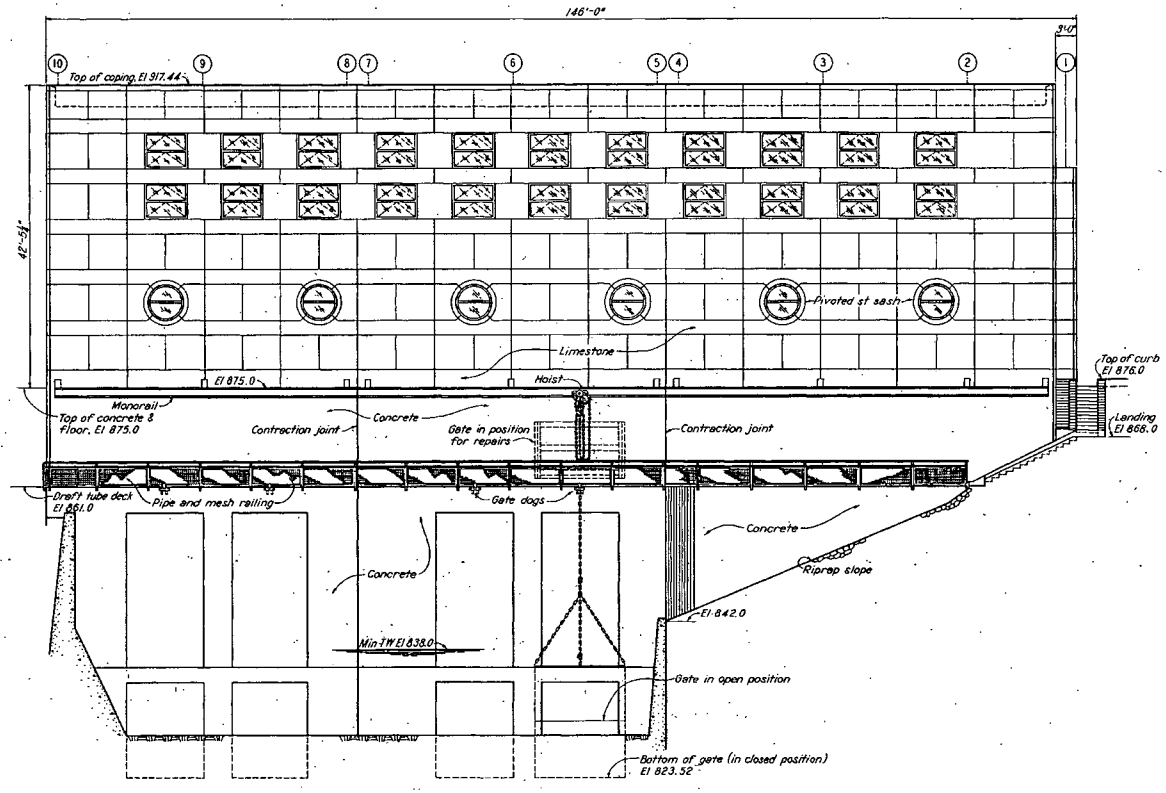
TENNESSEE VALLEY AUTHORITY

DESIGN DEPARTMENT

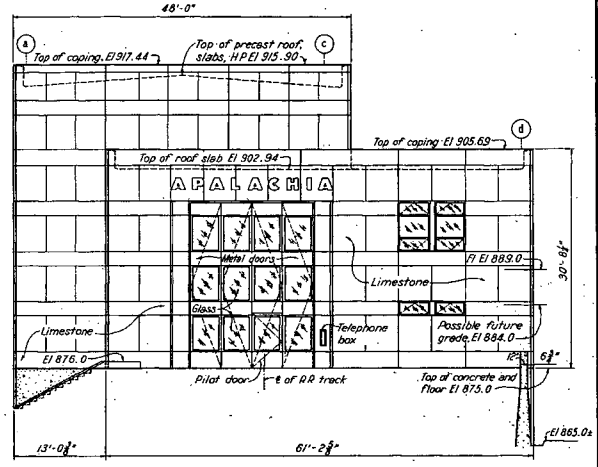
SUBMITTED	RECOMMENDED	APPROVED
H. W. Goodbee	Roe M. Fiegel	Joseph Koch

KNOXVILLE	10-18-41	15	C	4	5IN201	R4

RECORD DRAWING AS CONSTRUCTED C. F. Wright 6-21-43



DOWNSTREAM ELEVATION



SOUTH ELEVATION

Scale ⅛"=1'-0"

POWERHOUSE

EQUIPMENT
DOWNSTREAM & SOUTH
ELEVATIONS

APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
Ernest Mundel	Henry B. Tour	George Rich

KNOXVILLE	12-7-44	15	A	4	46K208 R0