H = total head above the crest, including the velocity head of approach, in feet (Fig. 1);
H_e = design head for a standard crest, including the velocity head of approach, in feet;
h = velocity head of approach, $v^2/2g$, in feet (Fig. 1);
L = spillway crest length, in feet;
P = depth of the approach channel, crest to river bed, in feet (Fig. 1(a));
Q = total discharge, in cubic feet per second;
v = average velocity of approach, in feet per second; and
X, Y = crest coordinates, in feet.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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TRANSACTIONS

Paper No. 2856

WATER CONTROL IN CENTRAL AND SOUTHERN FLORIDA

By Harold A. Scott,[1] M. ASCE

Synopsis

This paper describes the historical efforts made to provide drainage and water control for central and southern Florida. Distribution and utilization of water in the comprehensive plan for flood control and multiple purposes are described. The need for a secondary water-control plan is emphasized.

Introduction

The area described in this paper (Fig. 1) lies south of an east-west line through Lake Harney (about 35 miles north of Cocoa) in Florida in the St. Johns River basin and east of the ridge that extends through Haines City and Sebring. The ridge divides the waters which flow into the Atlantic Ocean and those which flow into the Gulf of Mexico. Water-control problems are quite common throughout the area, although there are a few variations in topography and soil. The area consists of approximately 15,000 sq miles of groveland, pastures, rich agricultural lands, lakes, and marshlands. Elevations range from approximately 7 ft in the vicinity of Miami and 15 ft around Lake Okeechobee to 80 ft in the area of the headwaters of the Kissimmee River basin. (All stages and elevations throughout this paper refer to mean sea level data.) However, the lands of a large part of the area are extremely flat, and natural water courses are not common. Except for the St. Johns River, the Kissimmee River, Fisheating Creek, and a few minor streams, most of the water control is accomplished by man-made canals and drainage districts. Soils in the area vary from sand to peat with a small amount of marl. The areas with higher elevations in the St. Johns and Kissimmee River basins consist of sand mixed with a small amount of organic material in the upper 6 in. to 12 in. In the low areas and marshes, deposits of peat of thicknesses ranging to several feet are found. The Everglades is covered with a layer of peat of thickness ranging to approximately 15 ft at Lake Okeechobee and gradually diminishing to zero at

Note.—Published, essentially as printed here, in October, 1954, as *Proceedings-Separate No. 521*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.
[1] Cons. Engr., Reynolds, Smith, and Hills, Jacksonville, Fla.

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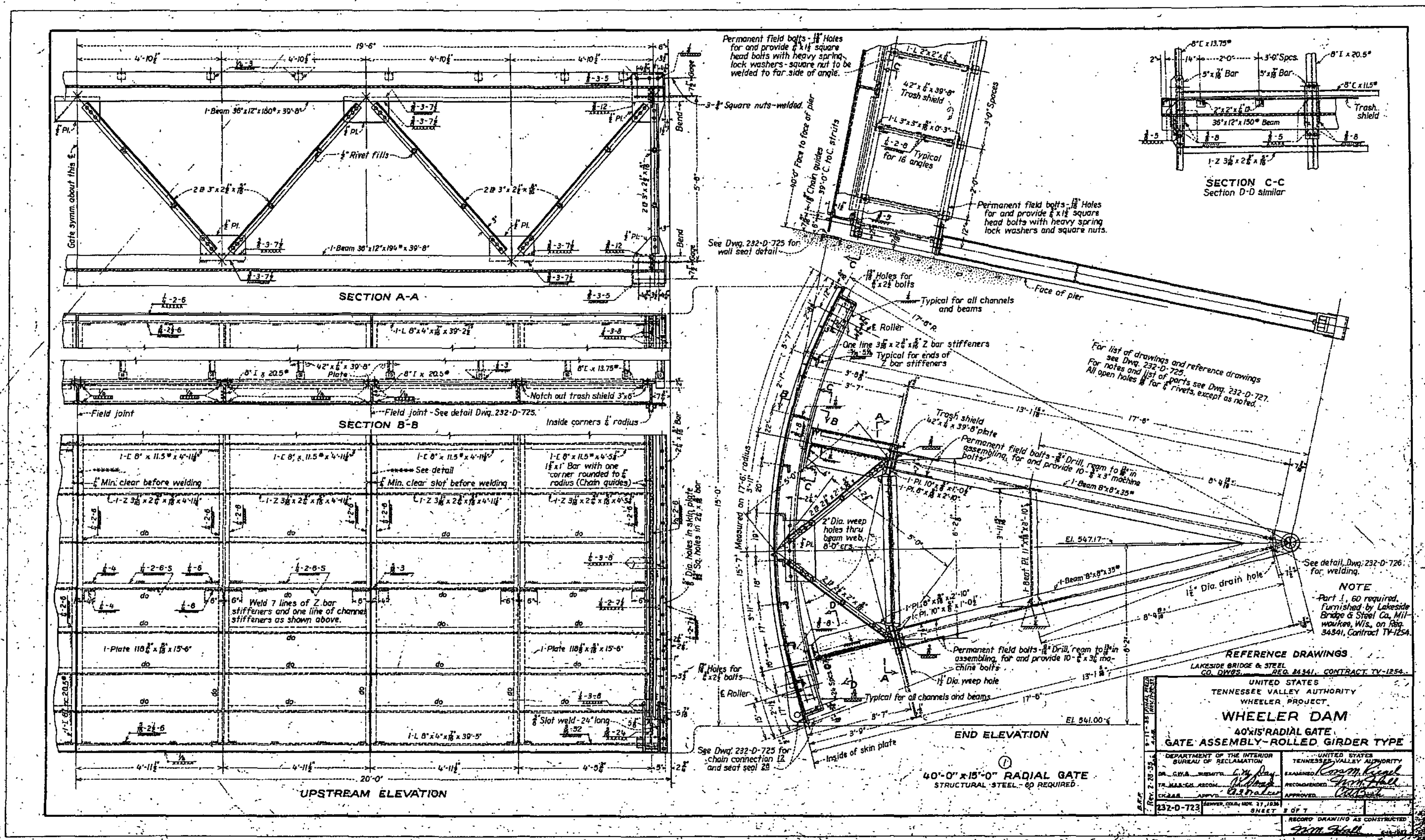
Attachment A2



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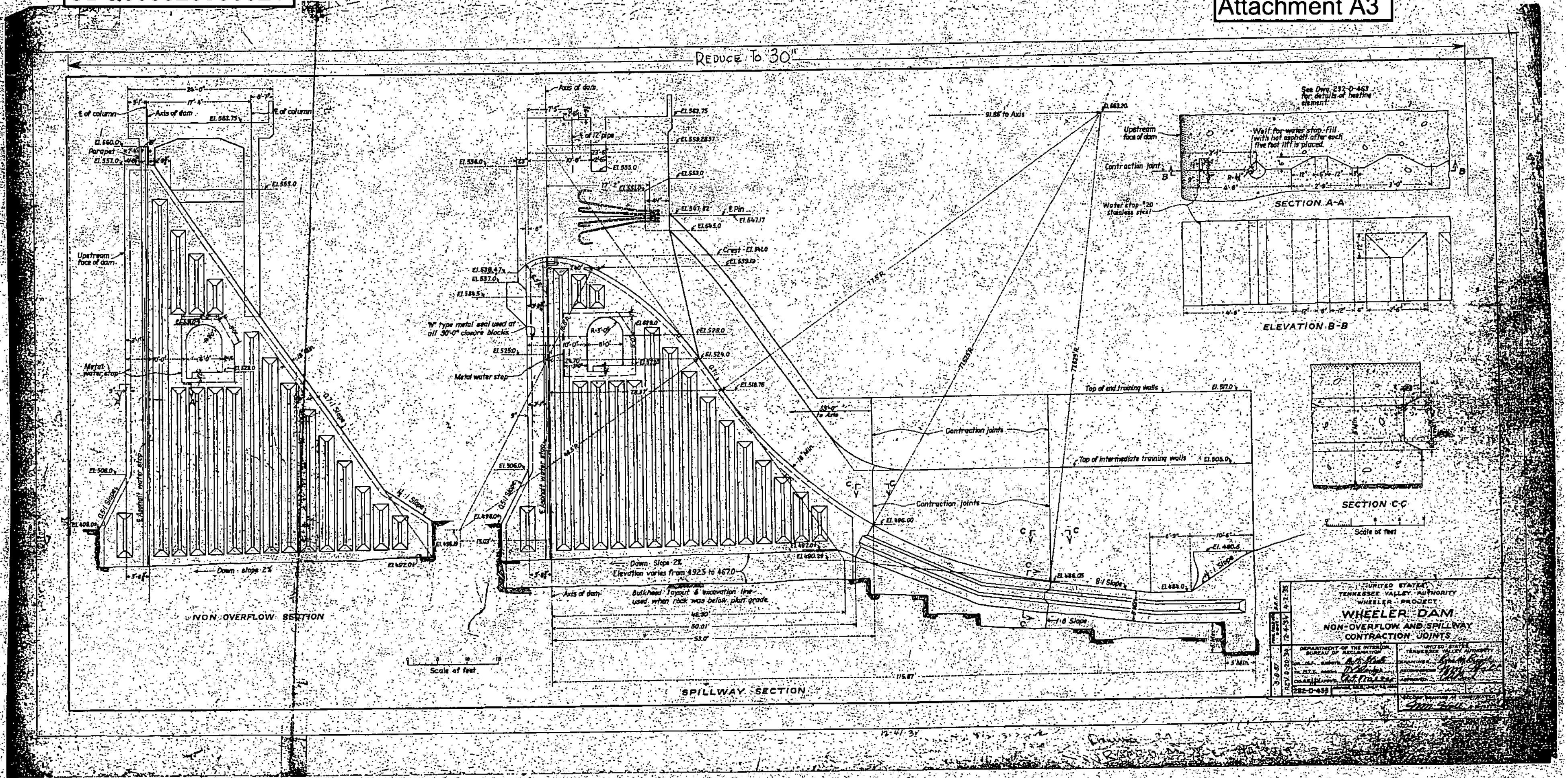

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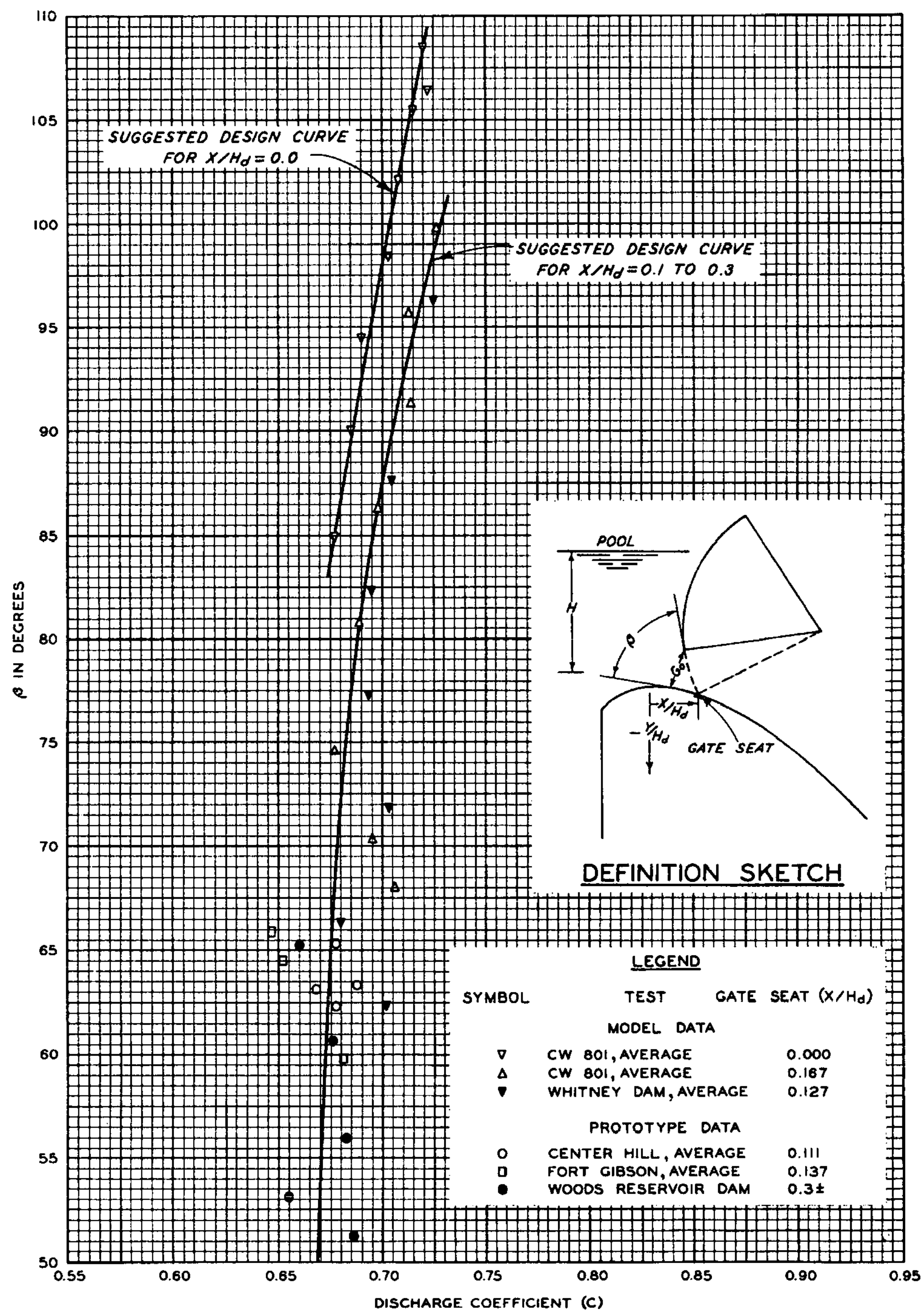

FORMULA

$Q = CG_oB\sqrt{2gH}$

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

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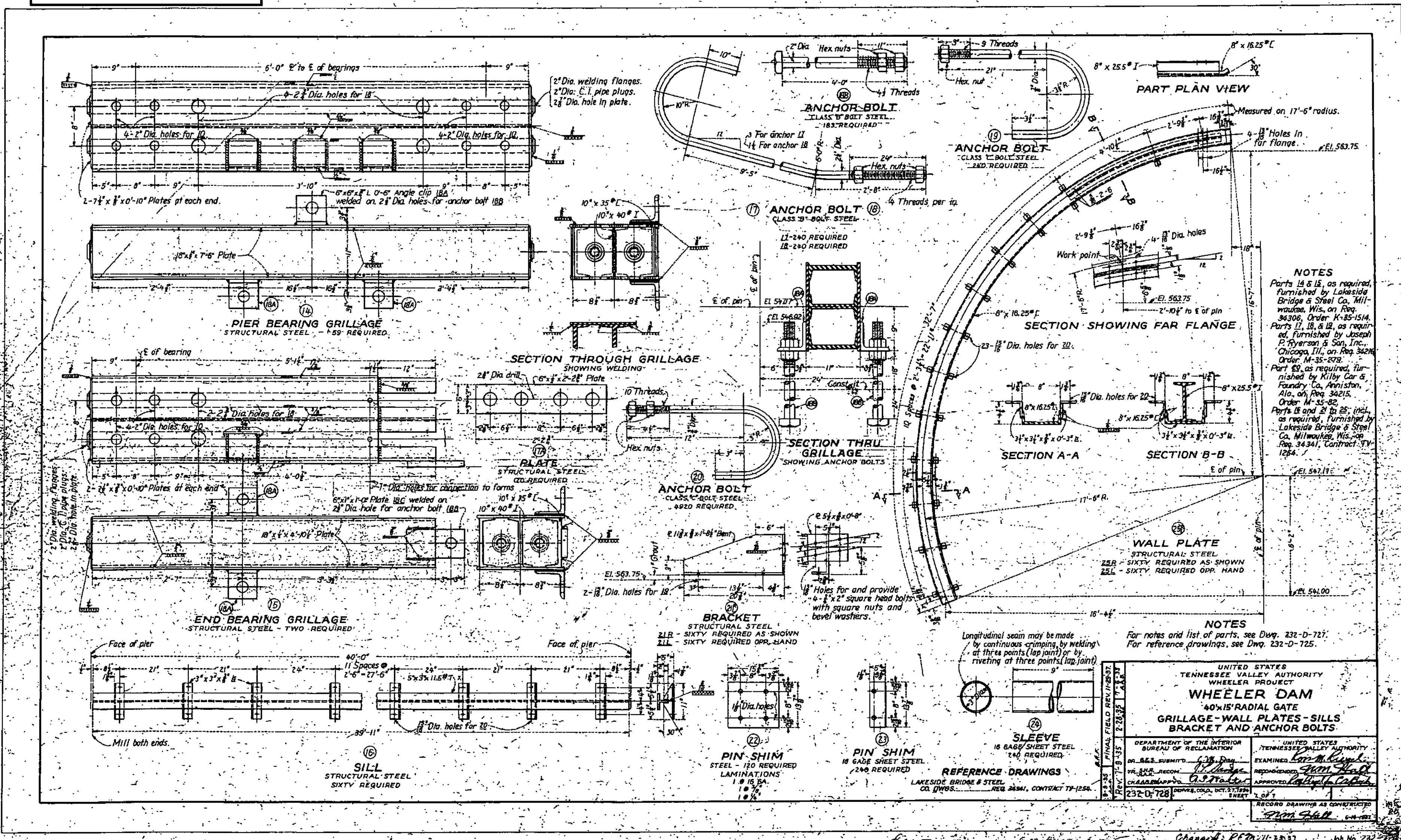
Attachment A5



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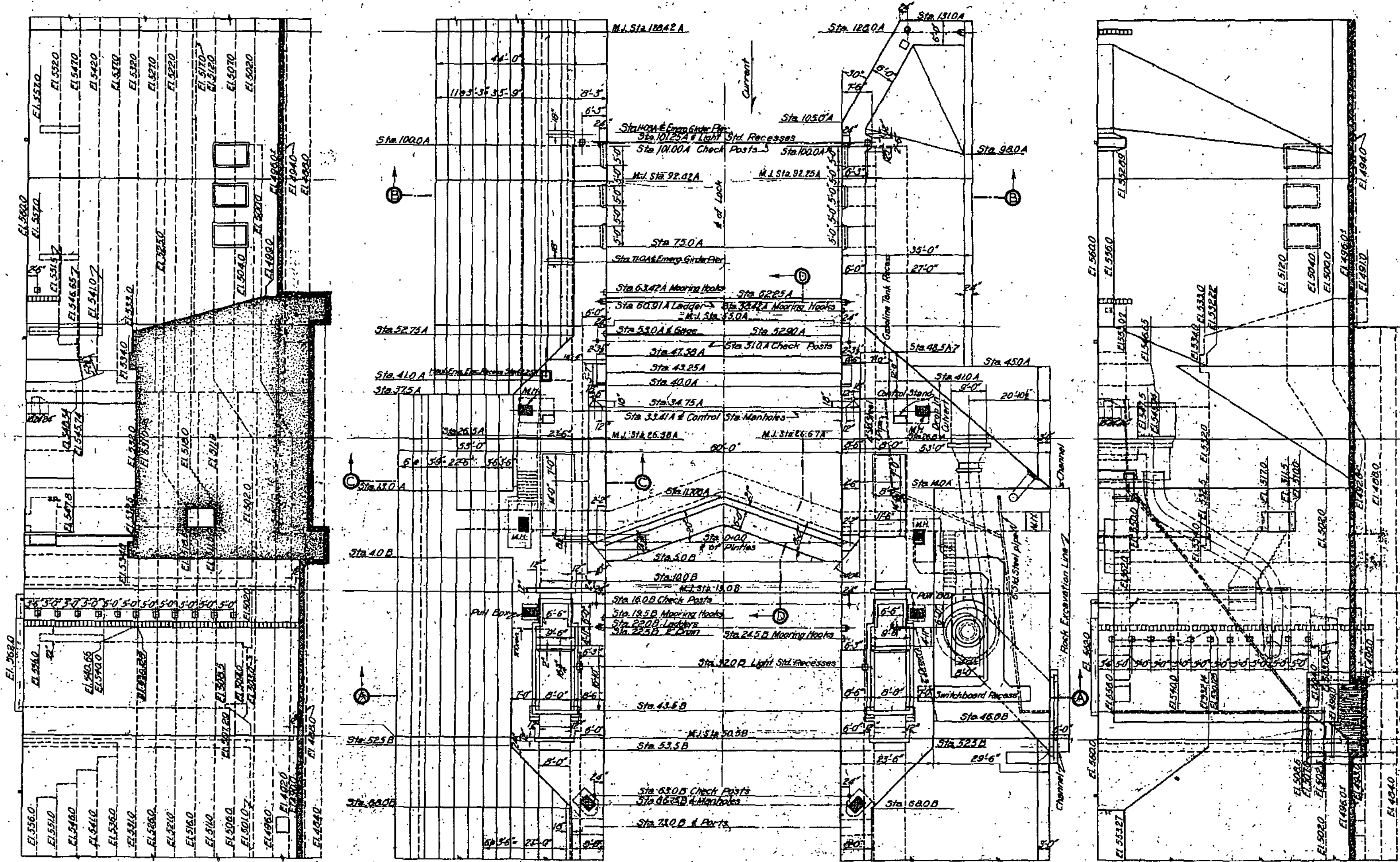
Attachment B1

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



REFERENCES

For location & details of manholes & electrical conduits see sheet 29/I-7
For details of ladders, mooring hooks, & ring bolts see sheet 20/12
For details & location of recess cover gratings see sheet 20/14.
For details of power house substructure see sheet 20/19
For details of tainter valves see sheets 20/15-16 & 25/I-10
For details of miter sill foundation see sheet 20/8
For details of lock gates see sheet 21/I-8
For sections thru upper bay see sheet 20/2A
For steel reinforcing see sheet 20/7

Note:
All elevations shown for bottom of walls are maximum only. All foundations shall be carried where necessary below these elevations to sound rock.

Revised and redrawn in Nashville Office.
Original St. Louis Office Dwg. No. 02-L3-20/2.3

TENNESSEE RIVER
LOCK & DAM NO. 3
LOCK
MASONRY – UPPER GATES

IN SHEETS SCALE 1/8"=1 FOOT SHEET NO.

U. S. ENGINEER OFFICE, NASHVILLE, TENN., NOVEMBER 28 1933

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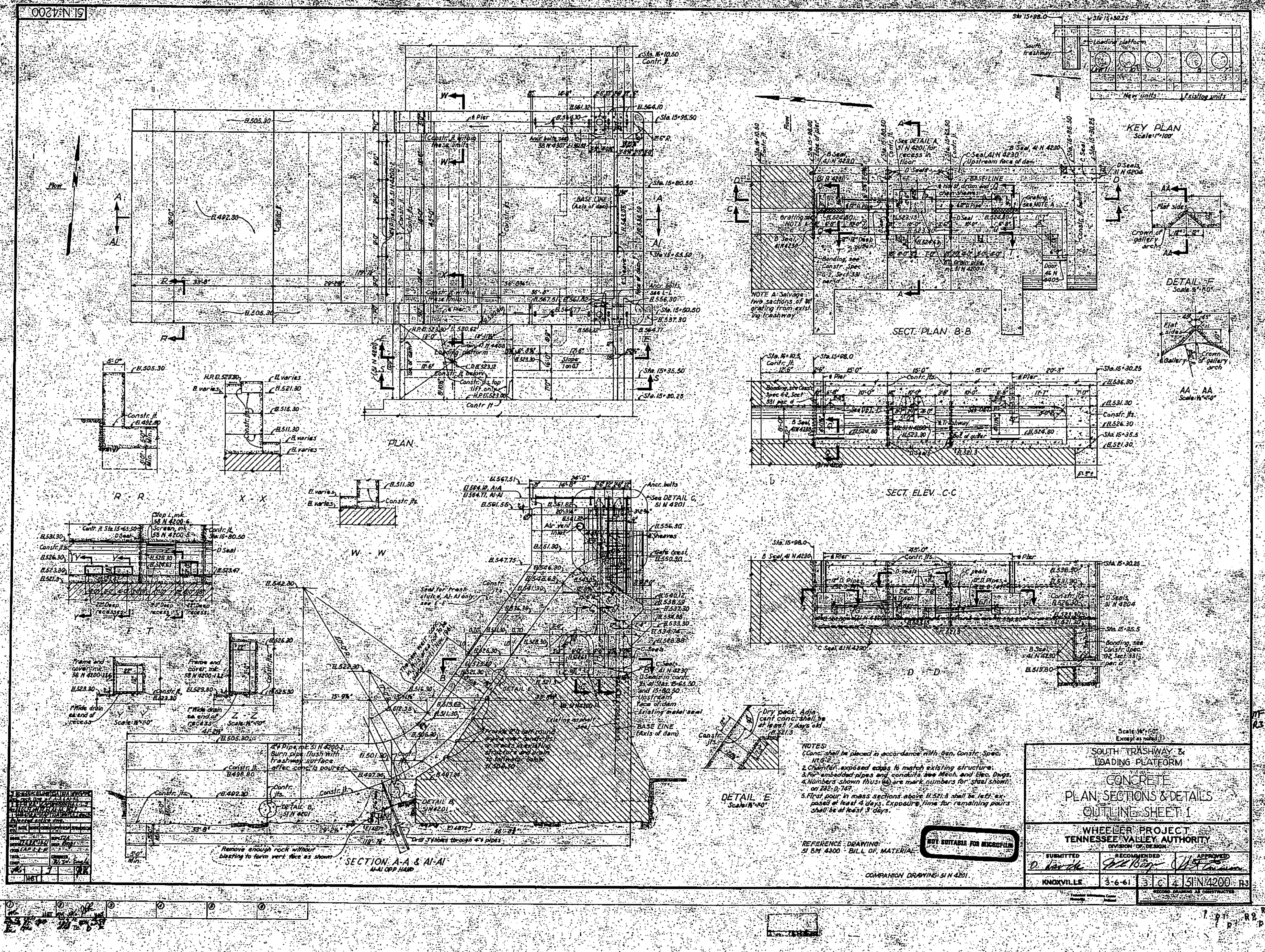
Attachment B2



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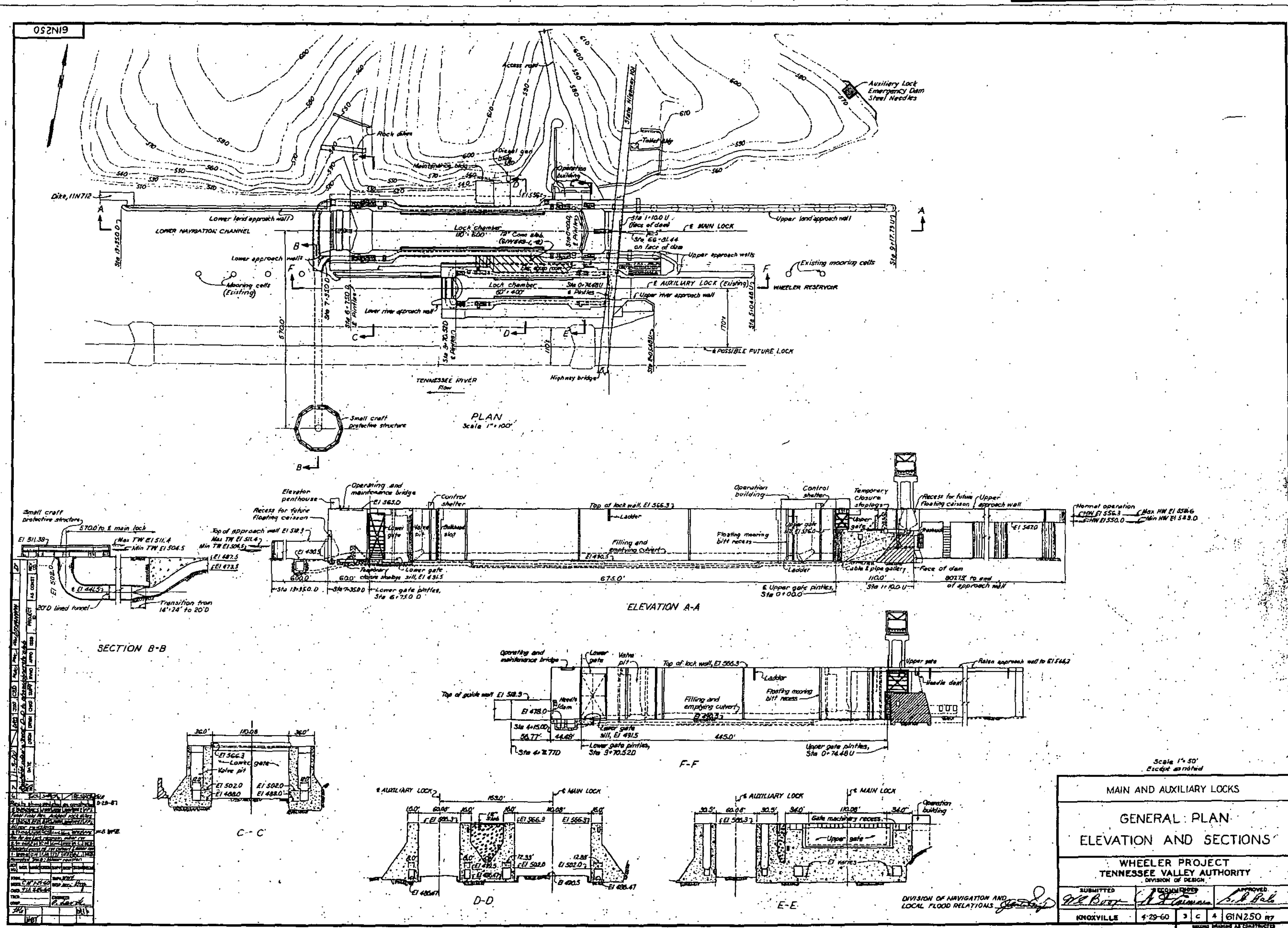

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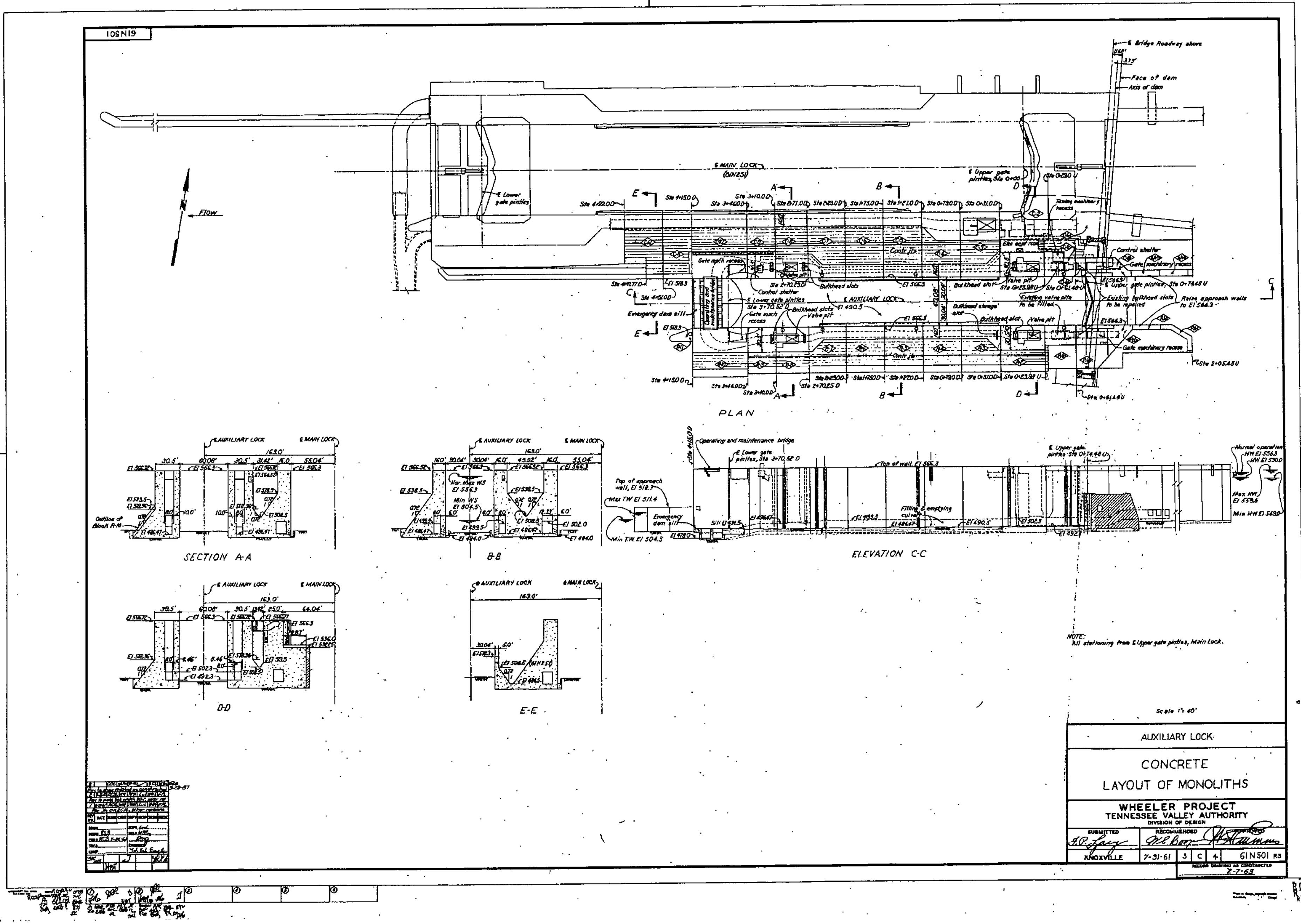

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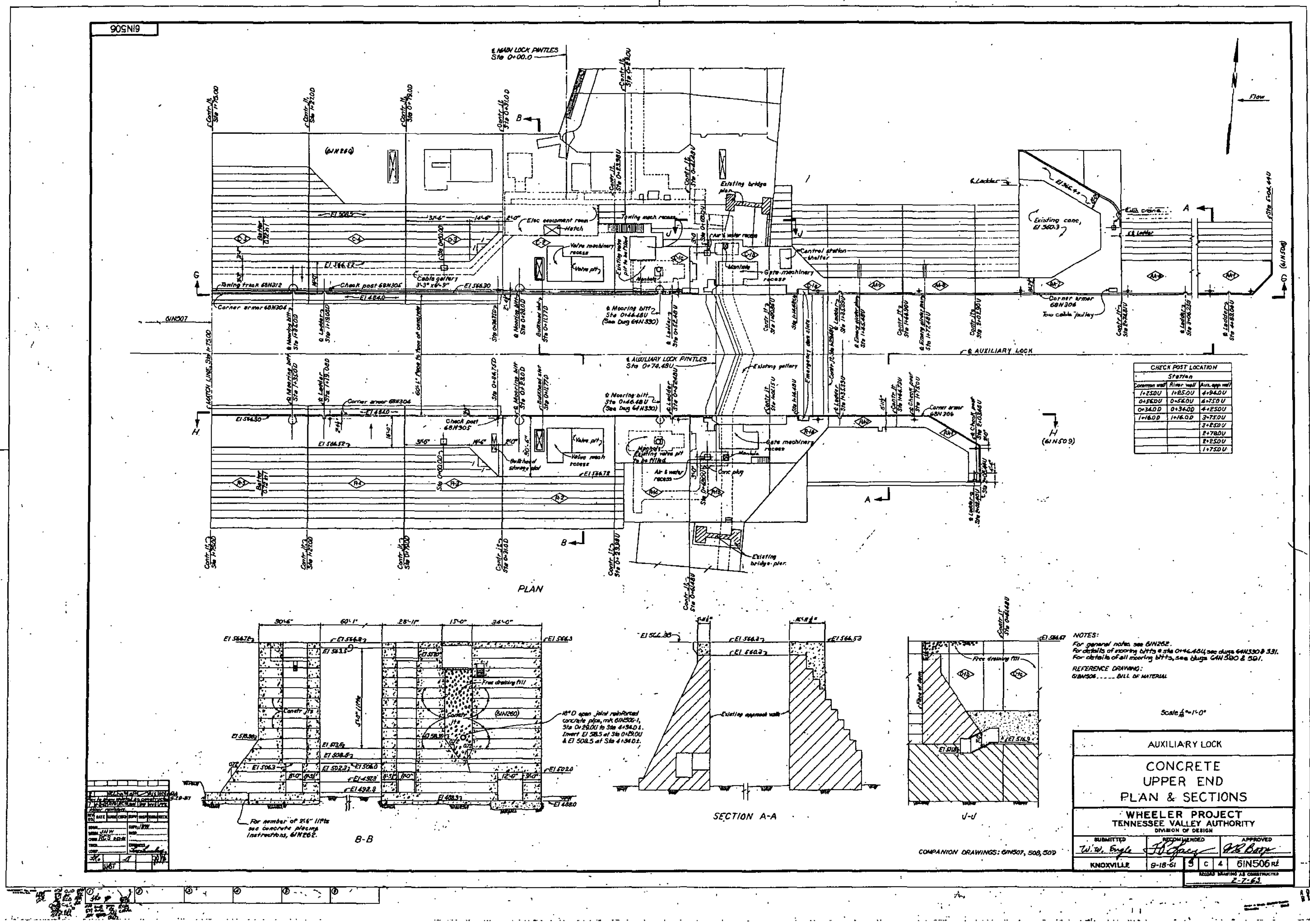

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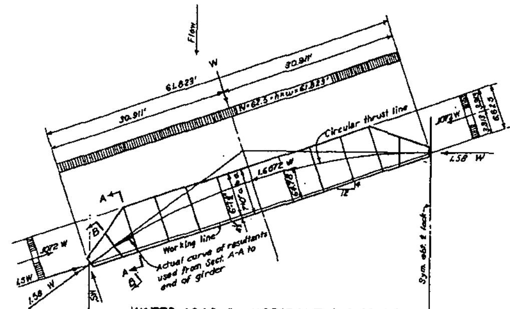
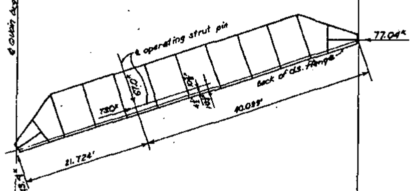
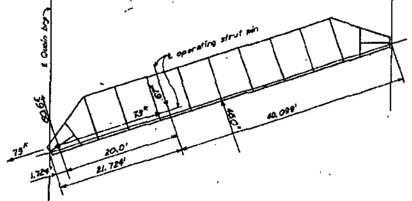


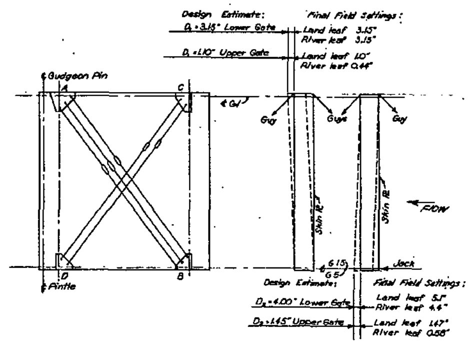
WATER LOAD ON HORIZONTAL GIRDERS



OPERATING STRUT THRUST-GIRDER G1 GATE MITERED



OPERATING STRUT THRUST & ANCHORAGE PULL GIRDER G1-GATE CLOSING



DOWNSTREAM ELEVATION

END ELEVATION

METHOD OF PRESTRESSING DIAGONALS

PRELIMINARY:

The leaf should be supported at its final elevation by the pintle at the quoin end and by jacks at the miter end. Cables with a minimum breaking strength of 200k shall be attached at the top and bottom of the miter end. The anchorage bars should be adjusted so that the quoin end is plumb. All sleeve nuts shall be well lubricated when tightening a diagonal. Diagonals should be tightened to the point that all the slack is removed and a very slight tension exists. Care must be taken that this tension is as small as possible. The slack shall be considered removed from a diagonal when it does not bow in or out from the leaf. No attempt shall be made to remove the slight vertical sag which will always exist in the diagonal due to its own dead weight. The pintle base must not be allowed to slip and the quoin end must be maintained plumb during the entire prestressing operation.

A positive deflection is defined as a twisting of the leaf such that the top of the miter end deflects upstream relative to the bottom.

PRESTRESSING INSTRUCTIONS:

① - Let the jacks at the miter end down slowly and gradually. The gate will then deflect in a negative direction under its own dead weight.

② - When the deflection due to ① above, reaches D1, hold the leaf firmly & tighten diagonals CD.

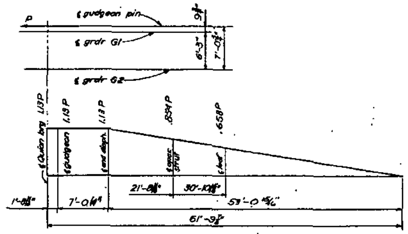
③ - Tighten diagonals AB and remove all jacks and guys. Do NOT change the adjustment of CD.

④ - Swing the leaf to the wall and tie it off at the top.

⑤ - Jack the bottom of the miter end away from the wall until the leaf is twisted to D_2. During this operation, strain gages should be used on diagonals CD to insure that the stress does not exceed 40,000 psi.

⑥ - Holding the leaf firmly in this position tighten diagonals AB.

⑦ - After tightening AB release all jacks and ties.



ASSUMED DISTRIBUTION OF ANCHORAGE PULL GIRDER G1

NOTES:

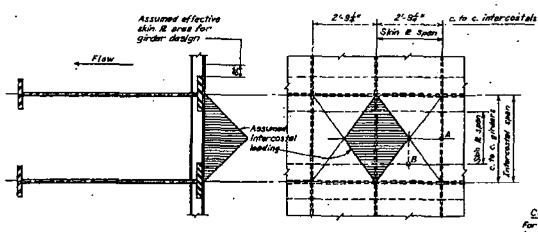
All welded construction, except as noted.
All welds not sized to be ¼" continuous.
Erection bolts to be ⅞" turned bolts as per section 31 of specification No. 7754.
Holes for field splices to be subdrilled & reamed with the entire gate leaf assembled in the shop.
All material to be low alloy steel ASTM A242-55, except as noted on the drawings.
End post sections to be stress relieved after all shop welding is complete.
All field welds to be made after complete erection and alignment of gate.

ALLOWABLE UNIT STRESSES: (lbs/sq in)
Low alloy steel ASTM 242-55

Yield point, min	45000.
Tension	24000.
Compression in extreme fibers of built up and rolled sections subject to bending, gross section l/b = 15 to 25	$24000 - 6.67\, l/b$
Compression in concentrically loaded columns l/r = 125 max	$20000 - .46\, l^2/r^2$
Shear in plate girder webs, gross section	15500.
Bearing on milled stiffeners & other parts in contact	36000.
Shear on bolts & pins in reamed or drilled holes	13500.
Bearing on pins subject to rotation	16000.
Tension in butt welds	20000.
Shear on fillet welds	15000
Bearing on bronze bushings	2500

OPERATIONAL RESTRICTIONS:

The region between the lower miter gate and the downstream stop logs shall not be unwatered when the water surface in the lock chamber is above El 5460



TYPICAL HORIZONTAL GIRDER SECTION

TYPICAL SKIN ℄ PANEL

The skin ℄ is designed using moment coefficients for plates with all edges fixed given by Westergaard and averaged as noted on page 143 of Seely's "Advanced Mechanics of Materials". No allowance is made for corrosion or wear of skin ℄.
The intercostals are designed as simple beams supported by the horizontal girders.

COMBINED STRESSES IN SKIN PLATE

For point A: The stress due to girder action is added to the skin ℄ stress and the total is limited by the critical buckling stress of the skin ℄. The entire width of skin ℄ is considered effective in computing the stress due to girder action.
For point B: The stress due to gdr action is added to .3 (Poisson's ratio) of the skin ℄ stress and the total is limited by the allowable 24,000 psi. (girder stress considered as per typical sections)

MAIN LOCK

UPPER & LOWER GATES
DESIGN DATA

WHEELER PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

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

KNOXVILLE	8-21-61	3	SH	4	64N201 R2

RECORD DRAWING AS CONSTRUCTED 2-8-63

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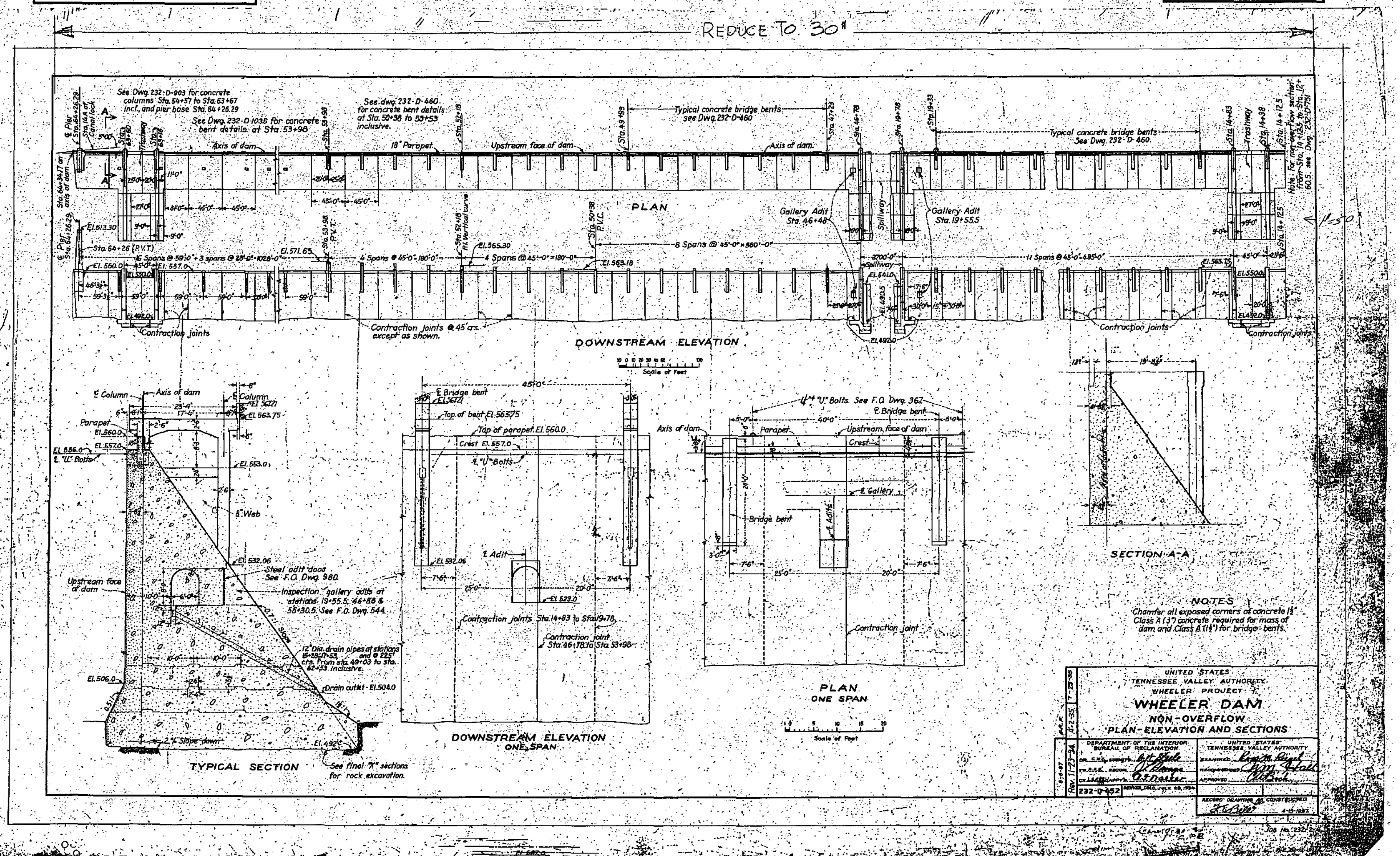
Attachment B7



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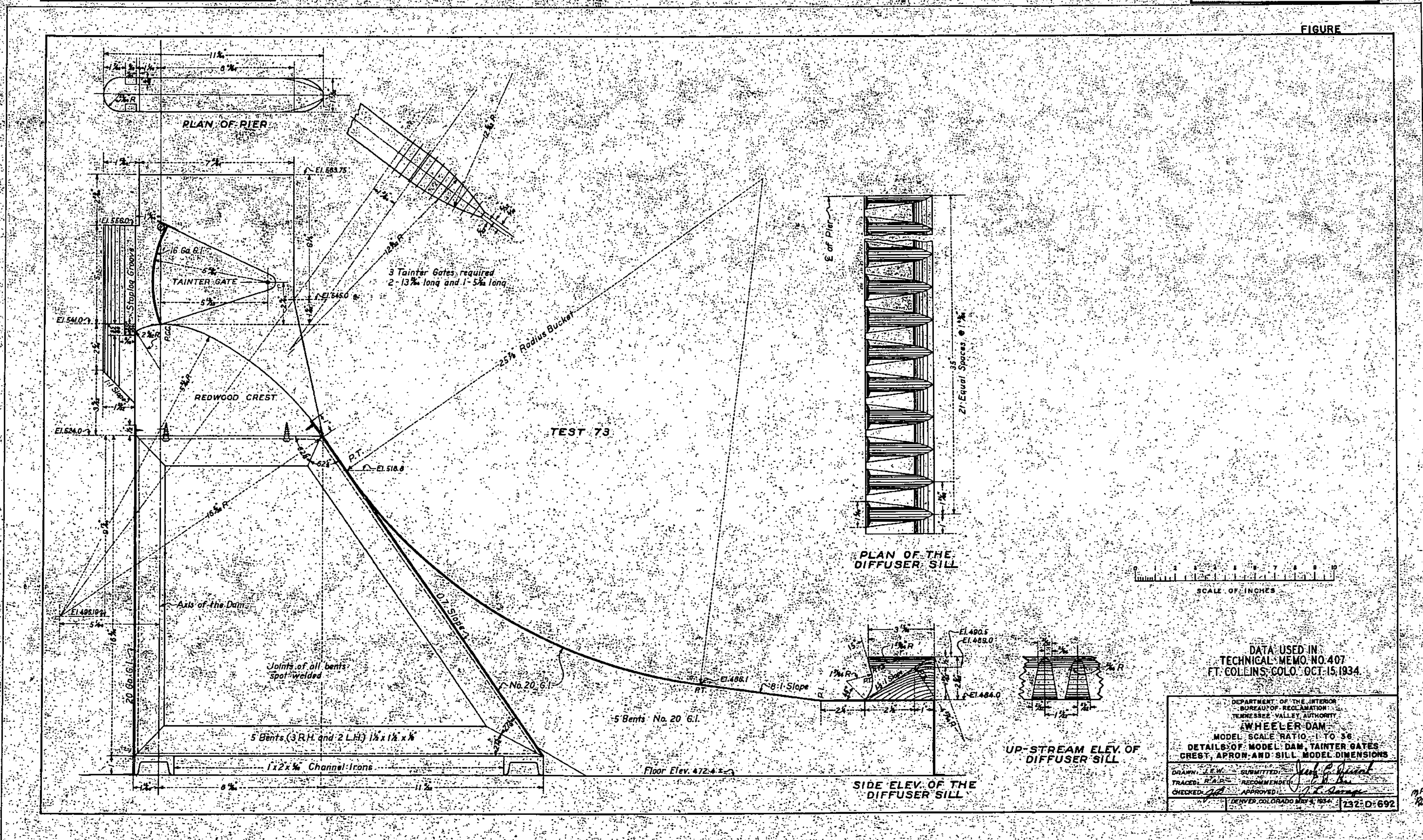

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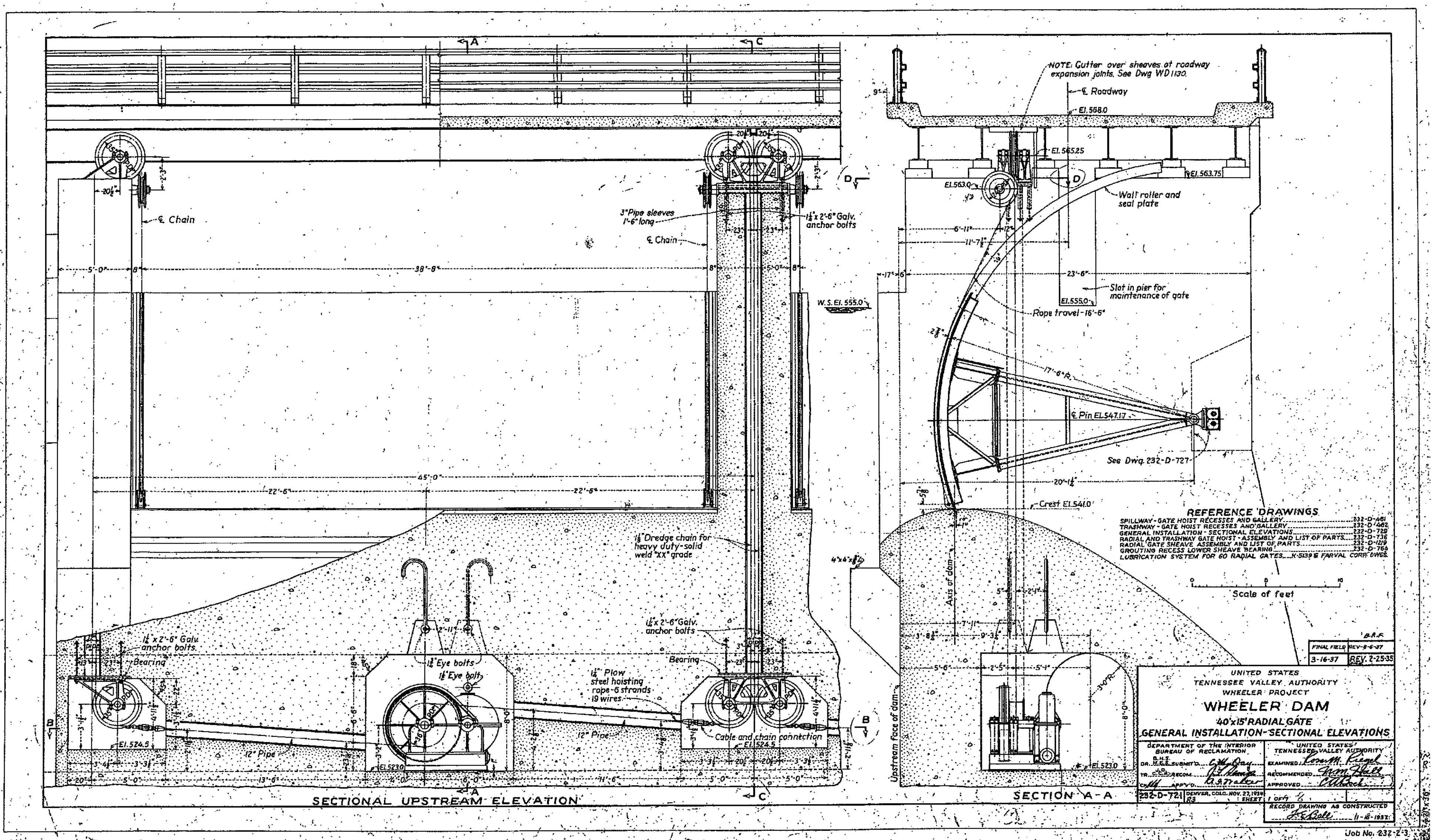

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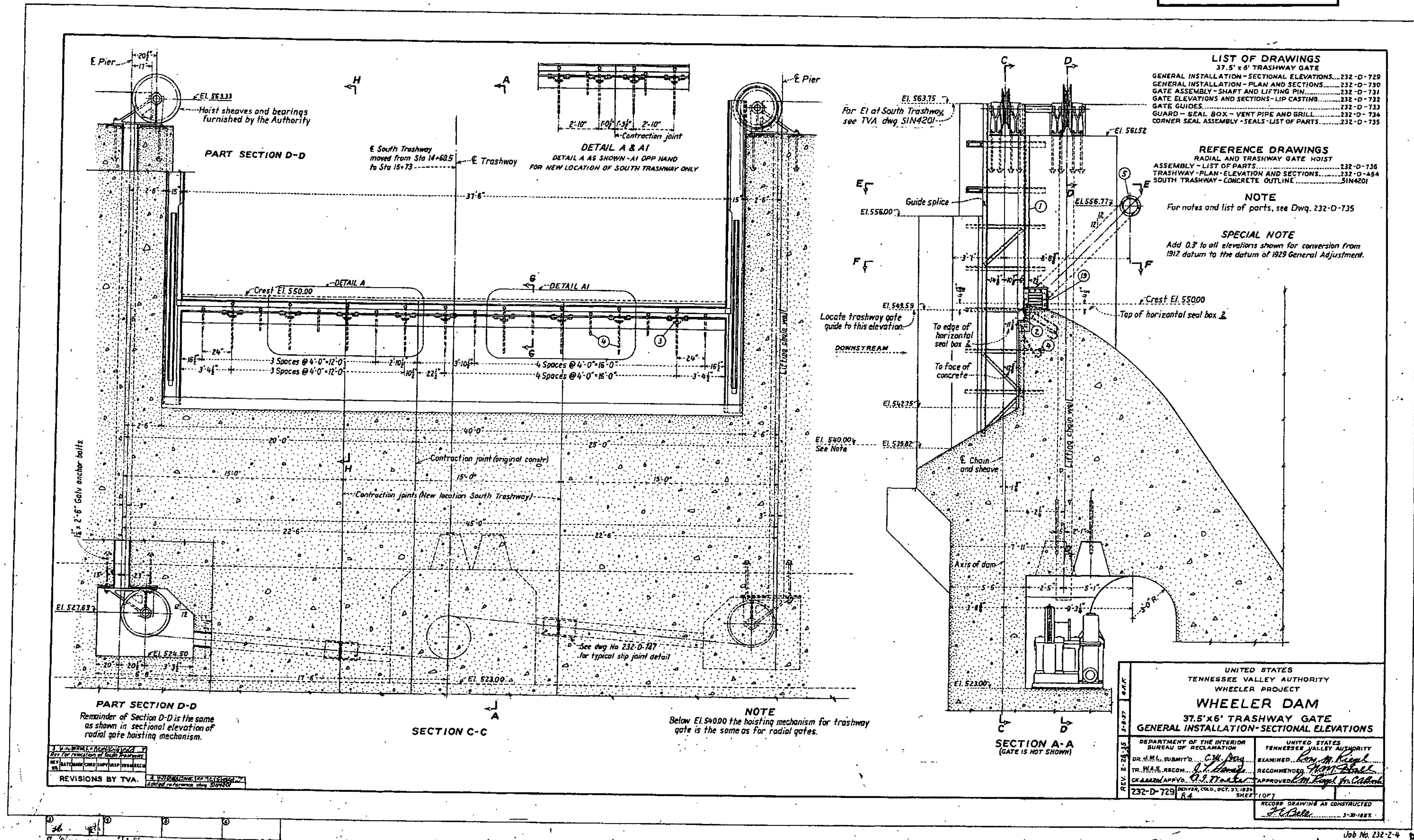

3. Free earth support analyses which compensate for toe fixity by including a bending moment reduction factor are liable to be misleading; fixed earth support methods should always be used.

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

AMERICAN SOCIETY OF CIVIL ENGINEERS
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TRANSACTIONS

Paper No. 2677 Vol. 119, 1954

RATING CURVES FOR FLOW OVER DRUM GATES

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

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

Synopsis

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

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

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

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

Introduction

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

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

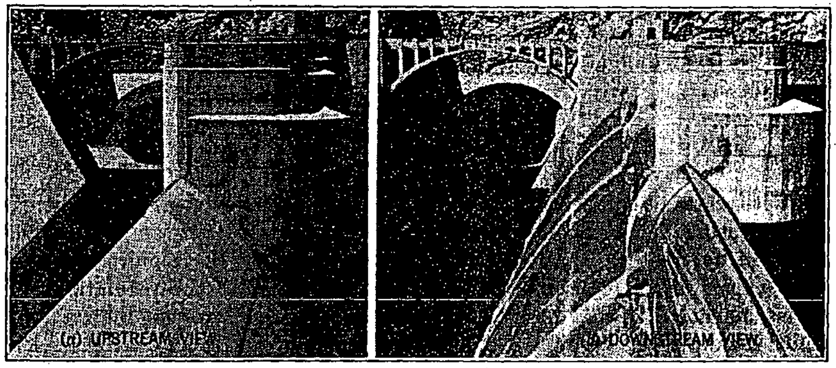


Fig. 1.—Drum Gate, 100 Ft by 16 Ft, at Hoover Dam (Arizona-Nevada)

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

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

[2] "Discha[illegible]efficients for Irregular Overfall Spillway Sections," by J. N. Bradley, *Engineering Monograph N*[illegible]*ureau* 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

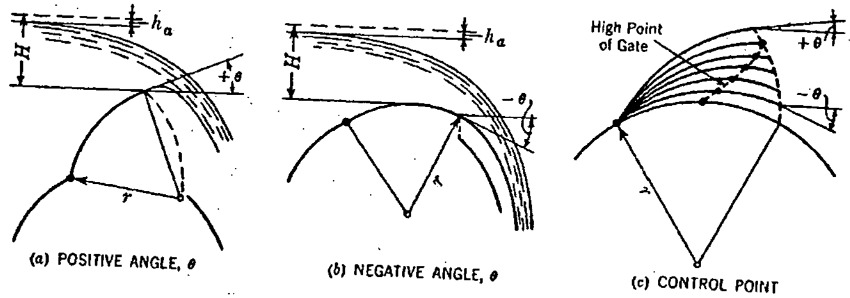


Fig. 2.—Drum-Gate Positions

gate involve a parabola; and C_q, the coefficient of discharge in $Q = C_q L H^{3/2}$, 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	400	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	10.0	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

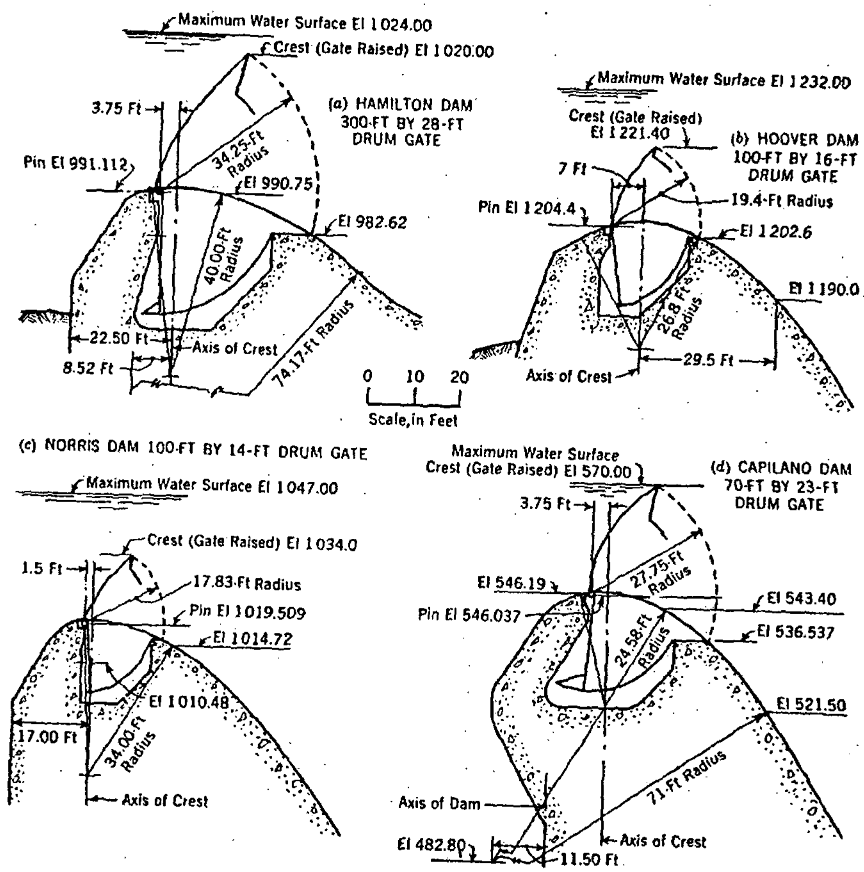


Fig. 3.—Examples of Drum-Gate Cross Sections

angle θ is also plotted with respect to C_q (in the expression, $Q = C_q L H^{3/2}$) in which H is the total head. *This latter expression will be used throughout the paper.*

By reference to Fig. 4 it can be observed (1) that the coefficient, C_q, varies only slightly with the observed head on the weir, (2) that there is a rather

[4] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. IX, No. 4, 1892, p. 316.)

TABLE 2.—DRUM-GATE COEFFICIENTS[a]

Grand Coulee Dam (Washington)		Bhakra Dam (India)		Shasta Dam (California)		Hamilton Dam (Texas)	
Reservoir elevation, in feet	Coefficient, C_q	Reservoir elevation, in feet	Coefficient, C_q	Reservoir elevation, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
Gate Elevation[b] 1260.0		Gate Elevation[b] 1552.0		Gate Elevation[b] 1037.0		Gate Elevation[b] 992.0	
1295	3.920	1580	3.680	1075	3.895	35	3.710
1290	3.842	1575	3.645	1070	3.835	30	3.645
1285	3.745	1570	3.550	1065	3.760	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_q	Reservoir elevation, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Reservoir elevation, in feet	Coefficient, C_q
Gate Elevation[b] 560.0		Gate Elevation[b] 1020.0		Gate Elevation[b] 232.0		Gate Elevation[b] 547.0	
580	3.650	1055	3.915	35	3.900	580	3.775
577	3.625	1050	3.845	30	3.770	575	3.705
574	3.550	1045	3.765	25	3.660	570	3.625
571	3.460	1040	3.670	20	3.560	565	3.530
568	3.340	1035	3.550	15	3.460	560	3.415
565	3.175	1030	3.390	10	3.365	555	3.250
562	2.965	1025	3.125	5	3.280		
Gate Elevation 561.5		Gate Elevation 1022.0		Gate Elevation 236.0		Gate Elevation 555.4	
580	3.340	1055	3.785	30	3.810	580	3.615
577	3.300	1050	3.725	25	3.750	577	3.580
574	3.250	1045	3.655	20	3.675	574	3.540
571	3.200	1040	3.570	15	3.590	571	3.485
568	3.125	1035	3.460	10	3.500	568	3.420
564	2.950	1030	3.300	5	3.410	565	3.320
		1025	3.000				
Gate Elevation 563.0		Gate Elevation 1024.0		Gate Elevation 240.0		Gate Elevation 561.1	
580	3.320	1055	3.760	30	3.960	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	3.895				
574	3.900	1035	3.920				
Gate Elevation 575.0		Gate Elevation 1034.0					
580	3.780	1055	3.815				
578	3.700	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	3.876	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.

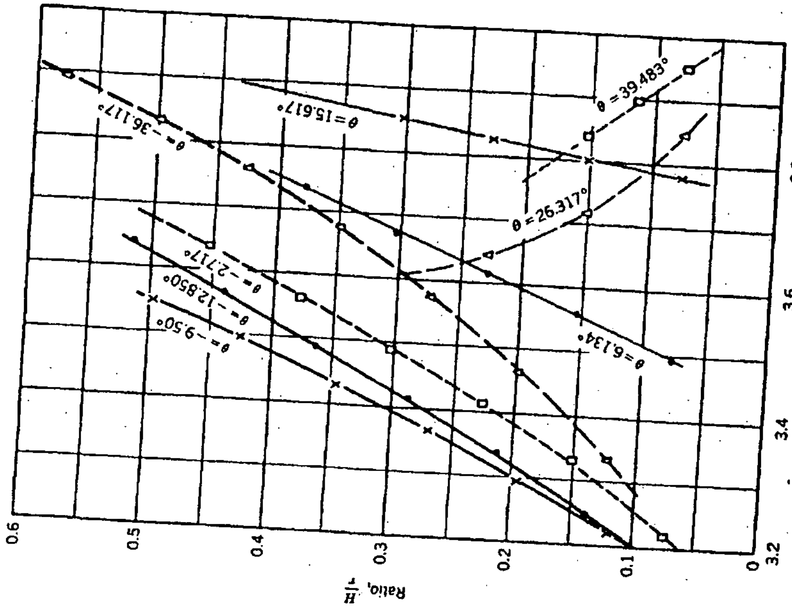


FIG. 5.—DIMENSIONLESS PLOTTING OF DATA FROM MODEL OF SHASTA DAM DRUM GATE

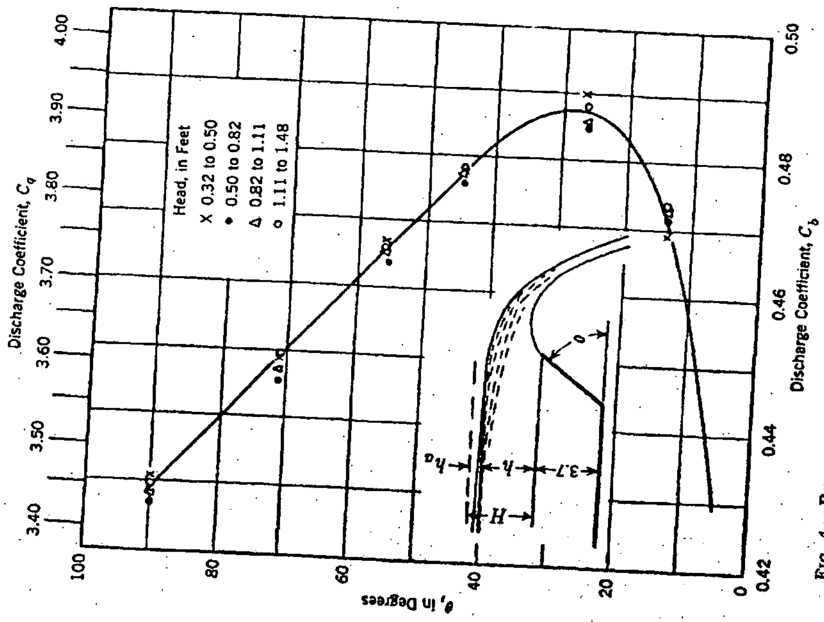


FIG. 4.—RESULTS OF BAZIN'S EXPERIMENTS ON SLOPING WEIRS

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

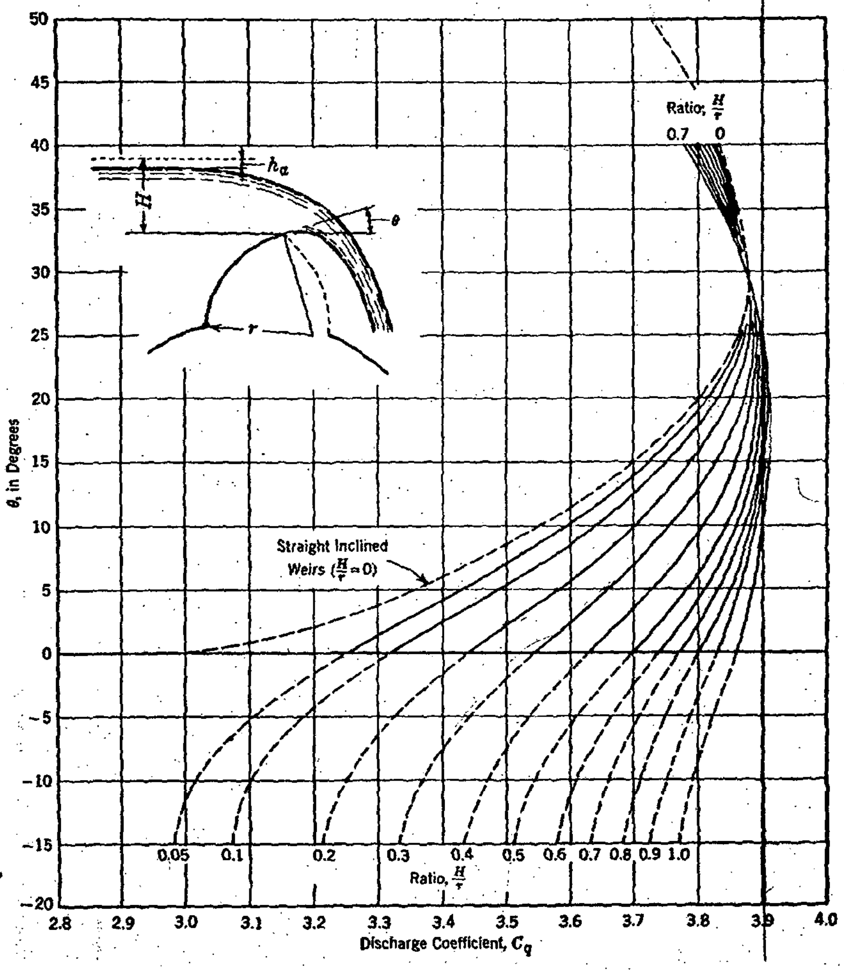


FIG. 6.—GENERAL CURVES FOR THE DETERMINATION OF DISCHARGE COEFFICIENTS

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_e and C_e are the designed head and the coefficient for the designed head, respectively. This chart was reproduced from a previous publication[2] and represents a curve well supported by tests of some fifty overfall spillway crests having wide variation in shape and operating conditions.

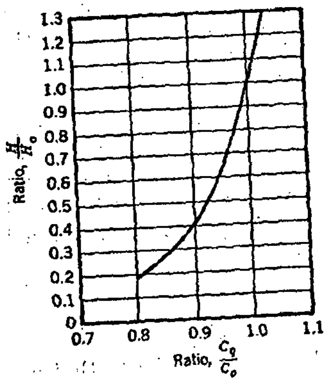


FIG. 7.—COEFFICIENTS OF DISCHARGE FOR OTHER THAN THE DESIGNED HEAD

APPLICATION OF RESULTS

From the plan and section of the Black Canyon Diversion Dam (Idaho), shown in Figs. 8 and 9, assume that it becomes necessary to compute and construct a rating curve for one drum gate for each 0.5 ft of gate elevation. The scale on the gate position indicator is calibrated to show the elevation of the high point of the gate, and the gate has a constant radius of 21.0 ft. The gate is 64 ft long. The coefficient of discharge for the free crest is $C_o = 3.48$ for the designed head (H_o) of 14.5 ft.

With the coefficient of discharge known for free flow at the designed head, the entire free-flow coefficient curve can be established by consulting Fig. 7. The free-flow coefficient curve for Black Canyon Dam spillway (for which $H_o = 14.5$ ft 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.

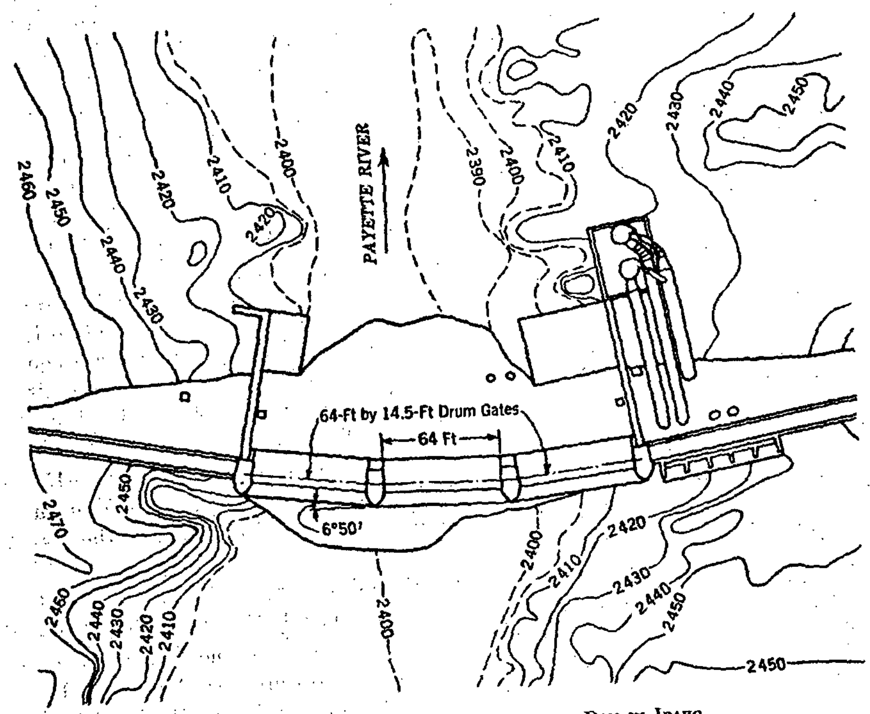


FIG. 8.—PLAN OF BLACK CANYON DIVERSION DAM IN IDAHO

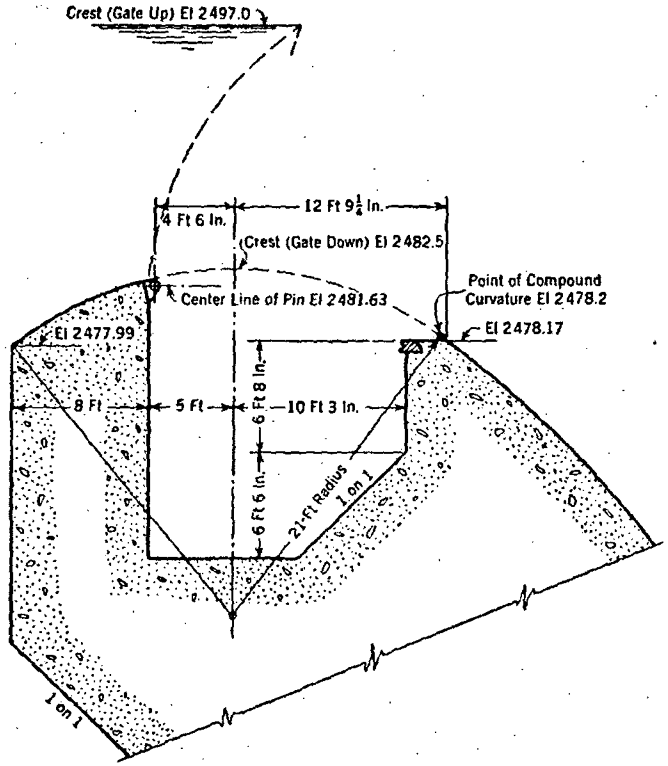


FIG. 9.—SPILLWAY CREST DETAIL, BLACK CANYON DAM IN IDAHO

TABLE 3.—HEAD AND DISCHARGE COMPUTATIONS FOR A FREE CREST (BLACK CANYON DAM IN IDAHO)

Total head, H, in ft (1)	Reservoir elevation, in ft (2)	Ratio,[a] H/H_o (3)	Ratio,[b] C_e/C_o (4)	Coefficient, C_e (5)	Q, in cu ft per sec[c] (6)
17	2499.5	1.172	1.020	3.55	15,950
16	2498.5	1.104	1.012	3.52	14,420
14.5	2497.0	1.0	1.0	3.48	12,298
12	2494.5	0.827	0.980	3.41	9,072
10	2492.5	0.690	0.960	3.34	6,759
8	2490.5	0.552	0.940	3.27	4,736
6	2488.5	0.414	0.905	3.135	2,949
4	2486.5	0.276	0.850	2.957	1,514
3	2485.5	0.207	0.815	2.835	943
2	2484.5	0.138	0.760	2.642	478

[a] $H_o = 14.5$ ft. [b] $C_o = 3.48$. [c] The discharge for one gate: $Q = C_e L H^{3/2}$, in which $L = 64.0$ ft.

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

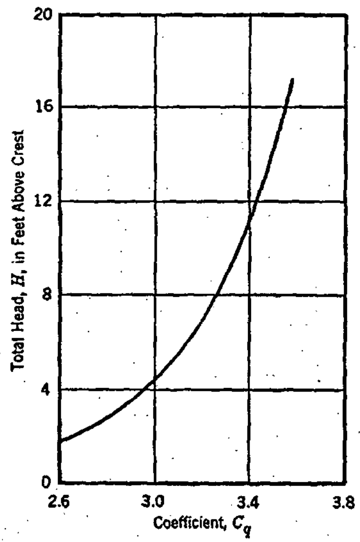


FIG. 10.—HEAD-COEFFICIENT CURVE, BLACK CANYON DAM, IN IDAHO

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

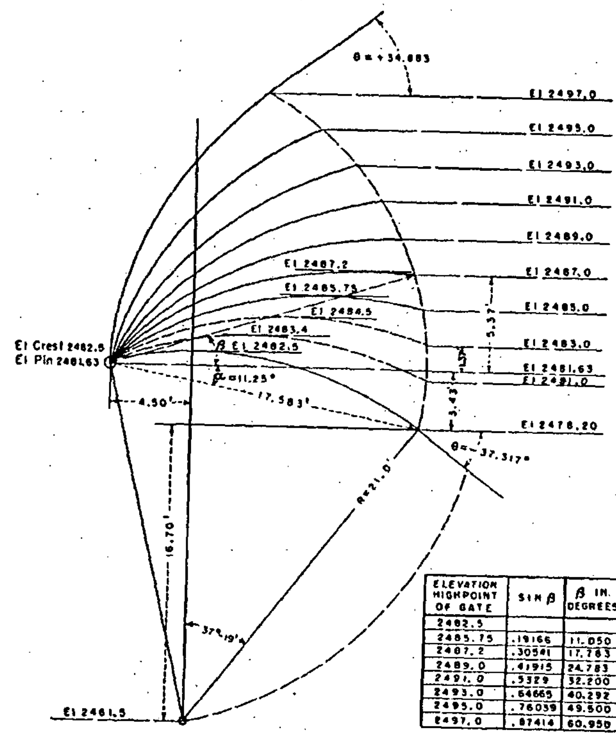
Entering the curves in Fig. 6 with the values in Col. 4, Table 4, for $\theta = +34.883°$, the discharge coefficients, listed in Col. 5 of the set of computations designated "A," are obtained. The remainder of the procedure outlined in Cols. 6 and 7, Table 4, consists of computing the discharge for one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

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

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

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

The intervals between the eight curves identified by points (Fig. 12) are too great for rating purposes, especially the gap between gate elevations, 2485.75 ft and 2482.5 ft. This is remedied by cross-plotting the eight curves for various constant values of the discharge as shown in Fig. 13. Fortunately, the result is a straight-line variation for any constant value of discharge. The lines in Fig. 13 are not quite parallel and there is no assurance that they will be straight for every drum gate. Nevertheless, this will not detract appreci-



ELEVATION HIGHPOINT OF GATE	SIN β	β IN DEGREES	θ IN DEGREES
2482.5			−37.317
2485.75	.19166	11.050	−15.017
2487.2	.30541	17.783	− 8.284
2489.0	.41915	24.783	− 1.284
2491.0	.5329	32.200	+ 6.133
2493.0	.64665	40.292	+14.225
2495.0	.76039	49.500	+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 calibrated, (2) the reservoir gage can be read to within 0.05 ft, (3) nearly atmospheric pressure exists under the sheet of water after it springs from the gate, and (4) all gates are set at approximately the same elevation.

TABLE 4.—Head and Discharge Computations for Drum Gates in Raised Positions

Set (1)	Reservoir elevation, in ft (2)	H, in ft[a] (3)	Ratio, $\frac{H}{r}$ (4)	Coefficients, C_e (5)	$H^{3/2}$, in ft (6)	Q, in cu ft per sec[b] (7)
Gate Elevation 2497.0; $\theta = +34.88°$						
A	2498.0	1	0.048	3.86	1	247
	2499.0	2	0.095	3.86	2.828	699
	2500.0	3	0.143	3.86	5.196	1.283
Gate Elevation 2495.0; $\theta = +23.43°$						
B	2496.0	1	0.048	3.85	1	246
	2497.0	2	0.095	3.86	2.828	698
	2498.0	3	0.143	3.87	5.196	1,284
	2499.0	4	0.190	3.87	8.00	1,979
	2500.0	5	0.238	3.88	11.18	2,770
Gate Elevation 2493.0; $\theta = +14.22°$						
C	2494.0	1	0.048	3.69	1	236
	2495.0	2	0.095	3.73	2.828	675
	2496.0	3	0.143	3.75	5.196	1,247
	2498.0	5	0.238	3.80	11.18	2,719
	2500.0	7	0.333	3.84	18.52	4,552
Gate Elevation 2491.0; $\theta = +6.13°$						
D	2492.0	1	0.048	3.47	1	222
	2493.0	2	0.095	3.51	2.828	635
	2494.0	3	0.143	3.57	5.196	1,187
	2496.0	5	0.235	3.63	11.18	2,597
	2498.0	7	0.333	3.70	18.52	4,386
	2500.0	9	0.429	3.77	27.00	6,515
Gate Elevation 2489.0; $\theta = -1.28°$						
E	2490.0	1	0.048	3.21	1	205
	2491.0	2	0.095	3.28	2.828	594
	2492.0	3	0.143	3.34	5.196	1,111
	2494.0	5	0.238	3.45	11.18	2,469
	2496.0	7	0.333	3.545	18.52	4,202
	2498.0	9	0.429	3.63	27.00	6.273
	2500.0	11	0.524	3.695	30.48	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: $Q = C_e L H^{3/2}$.

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.

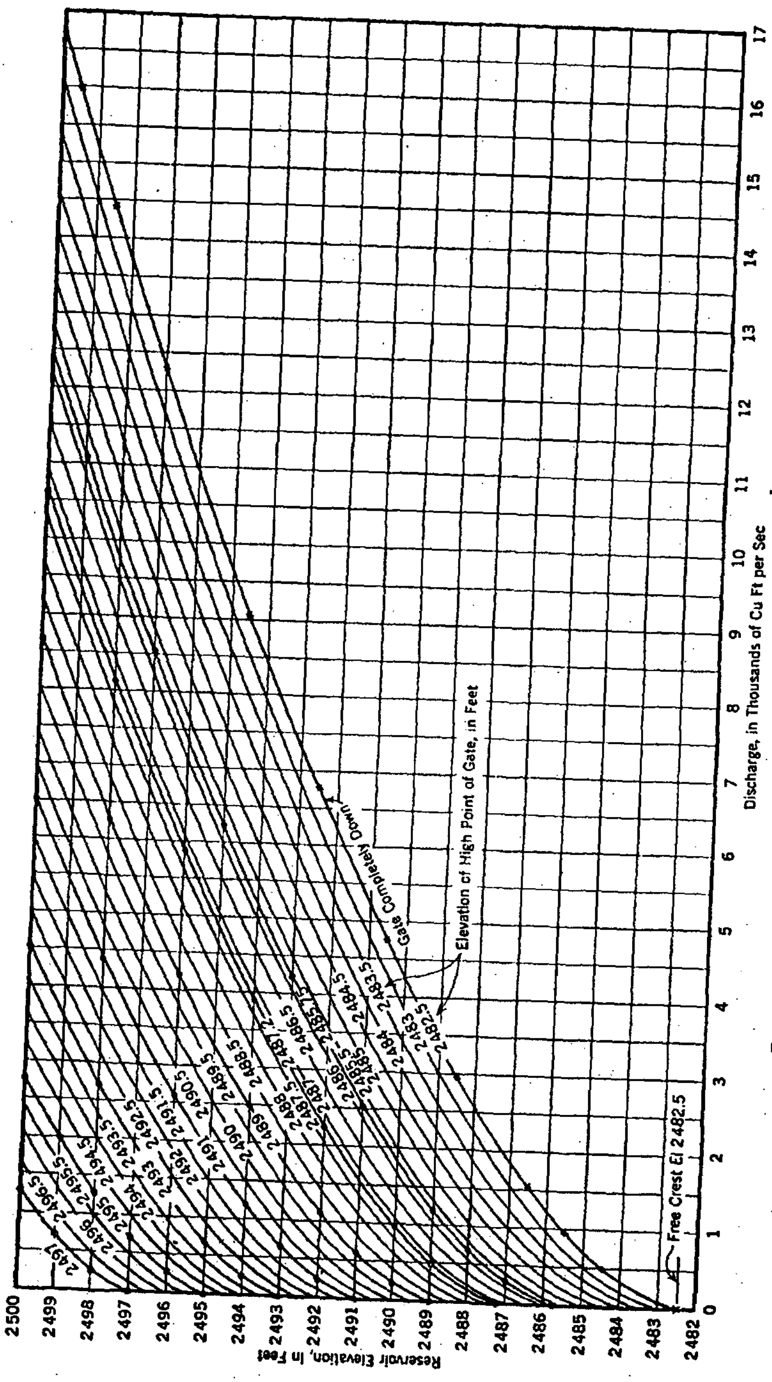


Fig. 12.—Rating Curves for Black Canyon Dam Drum-Gate Spillway in Idaho

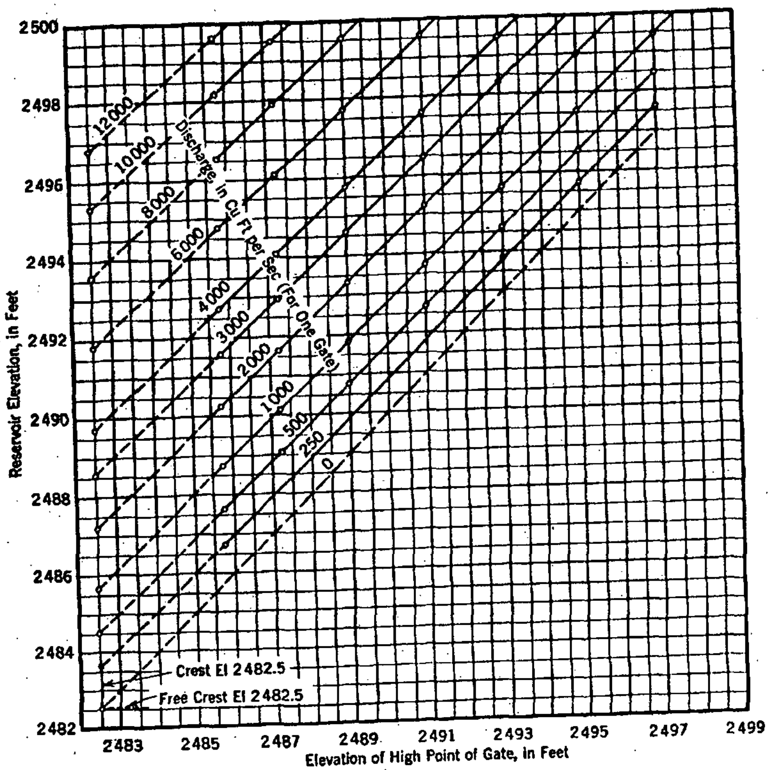


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

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 coefficient 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 $C_s = 3.48$. [c] C_s 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.

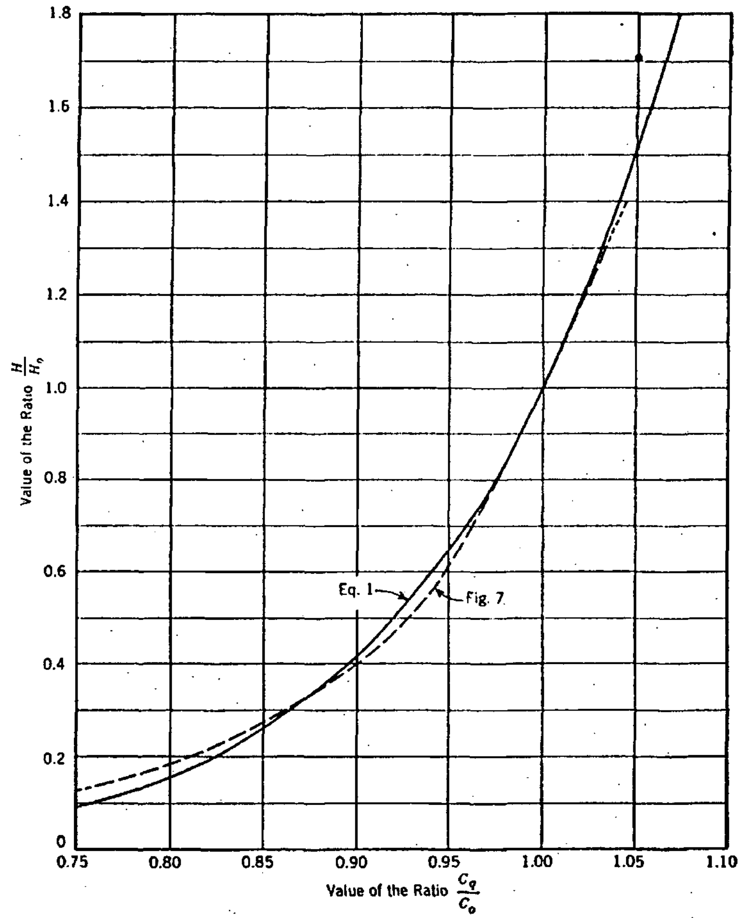

Fig. 14.—Comparison of Values Obtained from Fig. 7 and Eq. 1

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

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

and Eq. 1, from which

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

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

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

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

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

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

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

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

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

TABLE 6.—Comparison of Free-Flow Spillway Coefficients

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_q	Difference, in percent	C_q	Difference, in percent	C_q	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Grand Coulee Dam (Washington)							
35	3.920			3.914	− 0.15	3.902	−0.46
30	3.842			3.831	− 0.29	3.827	−0.39
25	3.745			3.745[a]	0	3.745[a]	0
20	3.635			3.655	+ 0.55	3.651	+0.44
15	3.510			3.550	+ 1.14	3.524	+0.40
10	3.352			3.370	+ 0.54	3.356	+0.12
5	3.220			3.138	− 2.54	3.168	−1.62
Bhakra Dam (India)							
28	3.680			3.736	+ 1.52	3.732	+1.41
23	3.645			3.645[a]	0	3.645[a]	0
18	3.550			3.547	− 0.08	3.543	−0.20
13	3.420			3.434	+ 0.41	3.404	−0.47
8	3.275			3.215	− 1.83	3.208	−2.04
3	3.120			2.748	−11.92	2.854	−8.53
Shasta Dam (California)							
38	3.895			3.910	+ 0.39	3.899	+0.10
33	3.835			3.839	+ 0.10	3.831	−0.10
28	3.760			3.760[a]	0	3.760[a]	0
23	3.675			3.677	+ 0.05	3.674	−0.03
18	3.575			3.591	+ 0.45	3.568	−0.20
13	3.465			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	3.716	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.635	+1.54	3.580[a]	0	3.580[a]	0
20	3.500	3.539	+1.11	3.494	− 0.17	3.490	−0.29
15	3.400	3.420	+0.59	3.394	− 0.18	3.369	−0.91
10	3.290	3.258	−0.97	3.222	− 2.07	3.208	−2.50
5	3.160	2.997	−5.16	3.000	− 5.06	3.029	−4.14
Friant Dam (California)							
20	3.650			3.717	+ 1.84	3.706	+1.53
17	3.625			3.639	+ 0.39	3.632	+0.19
14	3.550			3.550[a]	0	3.550[a]	0
11	3.460			3.458	− 0.06	3.452	−0.23
8	3.340			3.348	+ 0.24	3.319	−0.63
5	3.175			3.142	− 1.04	3.131	−1.38
2	2.965			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—(*Continued*)

Total head, in feet (1)	Coefficient obtained from model test (2)	Using Eq. 1: C_e (3)	Using Eq. 1: Difference, in percent (4)	Using Fig. 7: C_e (5)	Using Fig. 7: Difference, in percent (6)	Using Fig. 14: C_e (7)	Using Fig. 14: Difference, in percent (8)
Norris Dam (Tennessee) H_D = 35 Ft							
35	3.915	3.969	+1.38	3.934	+ 0.49	3.923	+0.20
30	3.845	3.897	+1.35	3.852	+ 0.18	3.848	+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	3.090	−5.81
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.

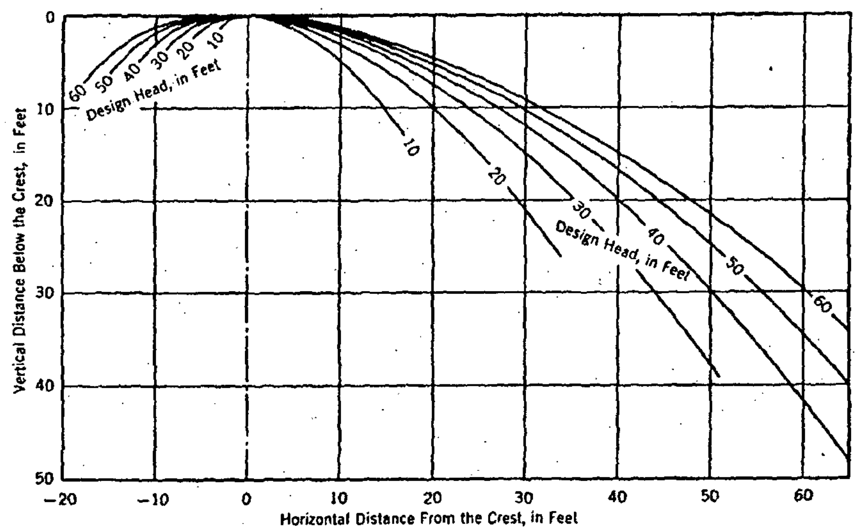

Fig. 15.—Standard Spillway Shapes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

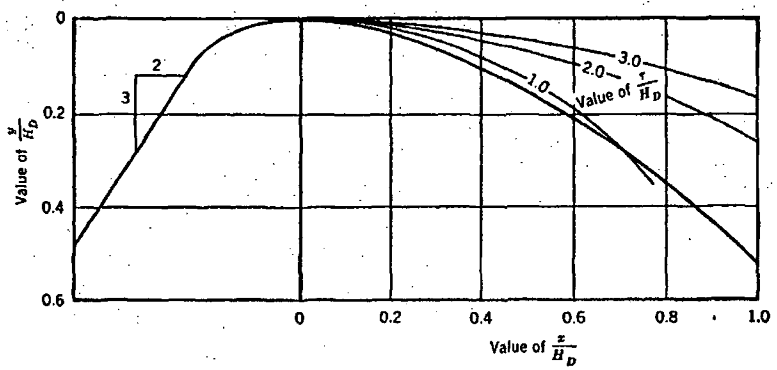

FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

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

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

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

Messrs. Campbell and McCool undertook to show that a definite relationship exists between the coefficient of discharge at the designed head and the ratio r/H_D for overflow shapes. This relationship is valid if the overflow shape can be approximated by an arc of a single radius and if the approach conditions are favorable—that is, if the approach depth below the crest is at least twice H_D. This method results in a coefficient of discharge for the designed head only. When overflow sections are encountered where a single radius does not approximate the overflow shape, or when the approach conditions are unusual, an engineering monograph[3] may prove helpful.

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

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

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

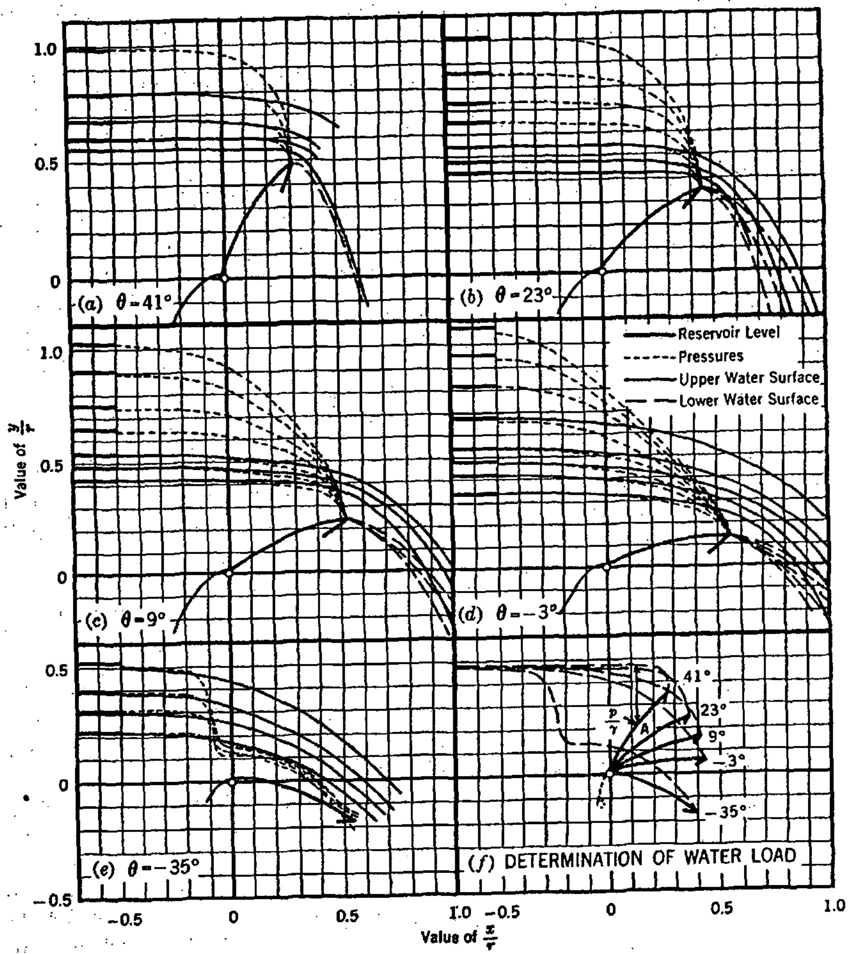

FIG. 17.—PRESSURE AND WATER-SURFACE PROFILES

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

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

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

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

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

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

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

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

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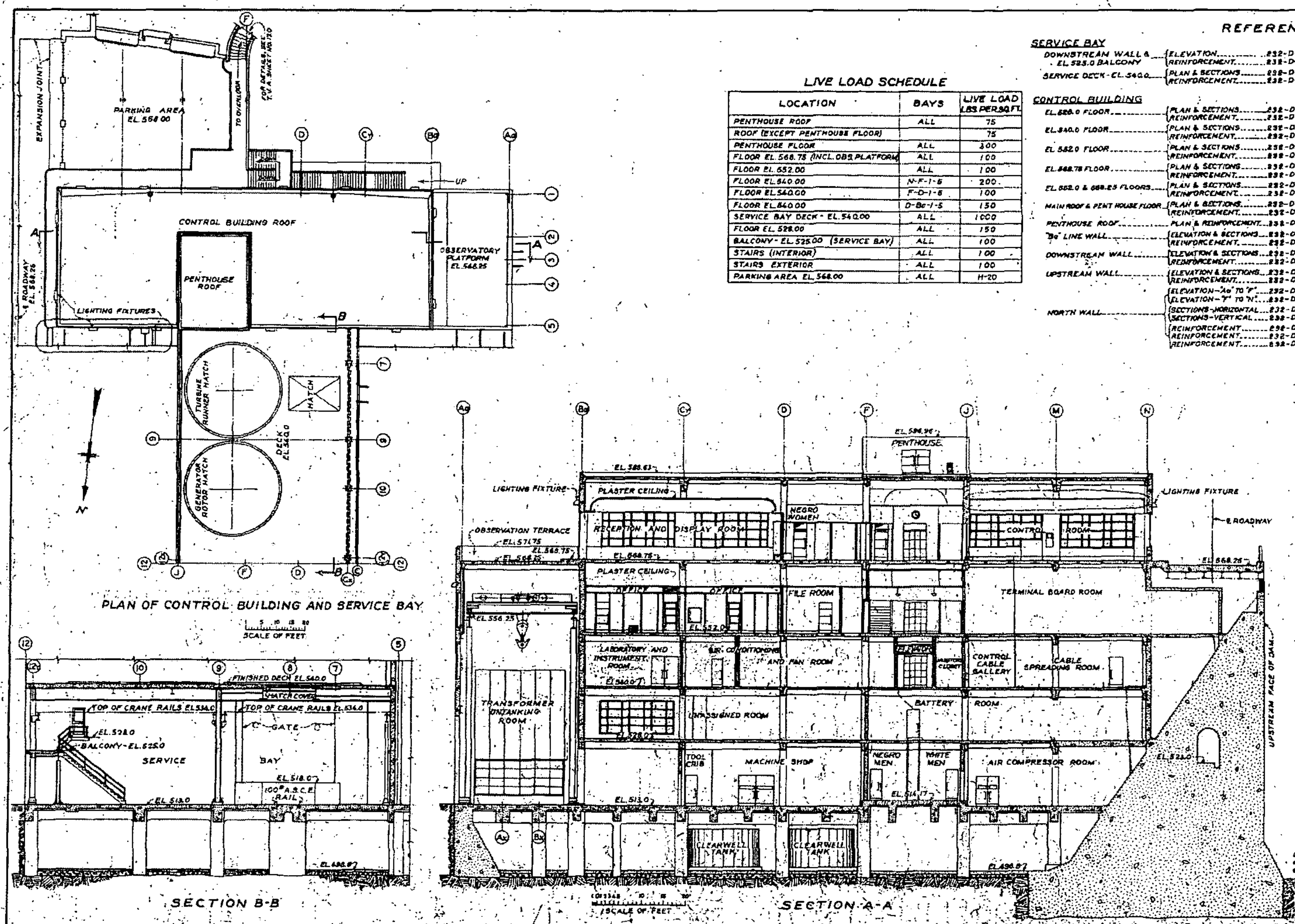
Attachment B12



LIVE LOAD SCHEDULE

LOCATION	BAYS	LIVE LOAD LBS. PER SQ. FT.
PENTHOUSE ROOF	ALL	75
ROOF (EXCEPT PENTHOUSE FLOOR)		75
PENTHOUSE FLOOR	ALL	300
FLOOR EL. 568.75 (INCL. OBS. PLATFORM)	ALL	100
FLOOR EL. 552.00	ALL	100
FLOOR EL. 540.00	N-F-1-6	200
FLOOR EL. 540.00	F-D-1-6	100
FLOOR EL. 540.00	D-Bc-1-5	150
SERVICE BAY DECK - EL. 540.00	ALL	1000
FLOOR EL. 528.00	ALL	150
BALCONY - EL. 525.00 (SERVICE BAY)	ALL	100
STAIRS (INTERIOR)	ALL	100
STAIRS EXTERIOR	ALL	100
PARKING AREA EL. 568.00	ALL	H-20

REFERENCE DRAWINGS

SERVICE BAY		
DOWNSTREAM WALL & EL. 525.0 BALCONY	ELEVATION	232-D-2112
	REINFORCEMENT	232-D-2113
SERVICE DECK - EL. 540.0	PLAN & SECTIONS	232-D-2114
	REINFORCEMENT	232-D-2115
CONTROL BUILDING		
EL. 528.0 FLOOR	PLAN & SECTIONS	232-D-2116
	REINFORCEMENT	232-D-2117
EL. 540.0 FLOOR	PLAN & SECTIONS	232-D-2118
	REINFORCEMENT	232-D-2119
EL. 552.0 FLOOR	PLAN & SECTIONS	232-D-2120
	REINFORCEMENT	232-D-2121
EL. 568.75 FLOOR	PLAN & SECTIONS	232-D-2122
	REINFORCEMENT	232-D-2123
EL. 552.0 & 568.25 FLOORS	PLAN & SECTIONS	232-D-2124
	REINFORCEMENT	232-D-2125
MAIN ROOF & PENT HOUSE FLOOR	PLAN & SECTIONS	232-D-2126
	REINFORCEMENT	232-D-2127
PENTHOUSE ROOF	PLAN & REINFORCEMENT	232-D-2128
"Bc" LINE WALL	ELEVATION & SECTIONS	232-D-2209
	REINFORCEMENT	232-D-2210
DOWNSTREAM WALL	ELEVATION & SECTIONS	232-D-2211
	REINFORCEMENT	232-D-2212
UPSTREAM WALL	ELEVATION & SECTIONS	232-D-2213
	REINFORCEMENT	232-D-2214
NORTH WALL	ELEVATION - "Aa" TO "F"	232-D-2215
	ELEVATION - "F" TO "N"	232-D-2216
	SECTIONS - HORIZONTAL	232-D-2217
	SECTIONS - VERTICAL	232-D-2218
	REINFORCEMENT	232-D-2219
	REINFORCEMENT	232-D-2220
	REINFORCEMENT	232-D-2221
CONTROL BUILDING - CONT'D		
SOUTH WALL	ELEVATION "F" LINE TO DAM	232-D-2222
	ELEVATION "F" LINE TO "Aa" LINE	232-D-2223
	SECTIONS & EXTERIOR ELEVATIONS	232-D-2224
	SECTIONS	232-D-2225
	REINFORCEMENT	232-D-2226
	REINFORCEMENT	232-D-2227
	REINFORCEMENT	232-D-2228
PENTHOUSE WALLS	ELEVATION & REINF.	232-D-2229
"D" AND "F" LINE WALLS	ELEVATION & REINF.	232-D-2230
COLUMNS	DETAIL & REINF.	232-D-2231
"J" LINE WALL	ELEVATION	232-D-2232
	REINFORCEMENT	232-D-2233
ROADWAY	EL. 568.0 - PLAN & SECTIONS	232-D-2234
	AND EXTERIOR STAIRS - SECTIONS	232-D-2235
	EL. 568.0 - REINFORCEMENT	232-D-2236
	EL. 568.0 - SECTIONS REINF.	232-D-2237
	GATE POSTS - EL. 568.0 - PLAN & REINFORCEMENT	LP&H 18.0
EXTERIOR STAIRS	LANDINGS & SECTIONS	232-D-2239
	LANDINGS & SECTIONS REIFORCEMENT	232-D-2240
	WALL & COLUMNS - ELEV.	232-D-2241
	WALL & COLUMNS - REINF.	232-D-2242
	STAIR & LANDINGS BELOW EL. 540.0 - PLAN & SECT.	232-D-2243
	STAIR & LANDINGS BELOW EL. 540.0 - REINF.	232-D-2244
INTERIOR STAIRS	STAIR LANDINGS	232-D-2245
WALLS AROUND ELEVATOR	ELEVATION & SECTIONS	232-D-2246
	REINFORCEMENT	232-D-2247
MISCELLANEOUS WALLS AT ELEVATION 513.0	EL. 513.0 - ELEVATION & REINF.	232-D-2248
MISCELLANEOUS WALL	ELEVATION & REINF.	232-D-2535
MISCELLANEOUS	ALUMINUM COPING DETAILS	232-D-1910
	WINDOW DETAILS	LP&H 10.3
	WINDOW DETAILS	LP&H 10.4
	WINDOW DETAILS AND OPERATORS	LP&H 10.5
		LP&H 10.6
	FOLDING DOORS: SERVICE BAY	232-D-2253
	UNTANKING ROOM - NORTH ELEVATION	232-D-2254
	UNTANKING ROOM - WEST ELEVATION	232-D-2255
	UNTANKING ROOM TO EL. 528.0 FLOOR	232-D-2256
	FRAME DETAILS	232-D-2257
	DOOR SCHEDULE	232-D-2258
	TOILET ROOM - EL. 513.0 FLOOR	232-D-2259
	REMOVABLE DOOR BRACE	232-D-2564
GENERAL	PLAN - EL. 513.0 FLOOR	232-D-2260
	PLAN - EL. 528.0 FLOOR	232-D-2261
	PLAN - EL. 540.0 FLOOR	232-D-2262
	PLAN - EL. 552.0 FLOOR	232-D-2263
	PLAN - EL. 568.75 FLOOR	232-D-2264

UNITED STATES
TENNESSEE VALLEY AUTHORITY
WHEELER PROJECT

WHEELER POWER PLANT

CONTROL BUILDING AND SERVICE BAY

GENERAL CONCRETE AND REINFORCEMENT DRAWINGS
KEY PLANS ABOVE ELEV. 513.0

DEPARTMENT OF THE INTERIOR — BUREAU OF RECLAMATION
UNITED STATES — TENNESSEE VALLEY AUTHORITY
EXAMINED / RECOMMENDED / APPROVED

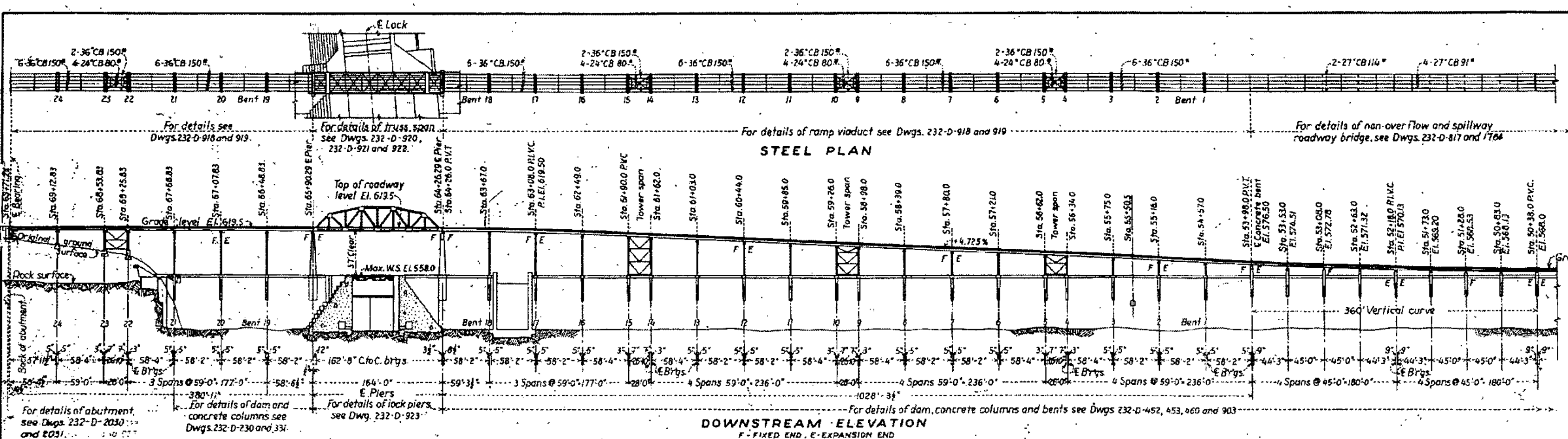
232-D-2111 — DENVER, COLO.

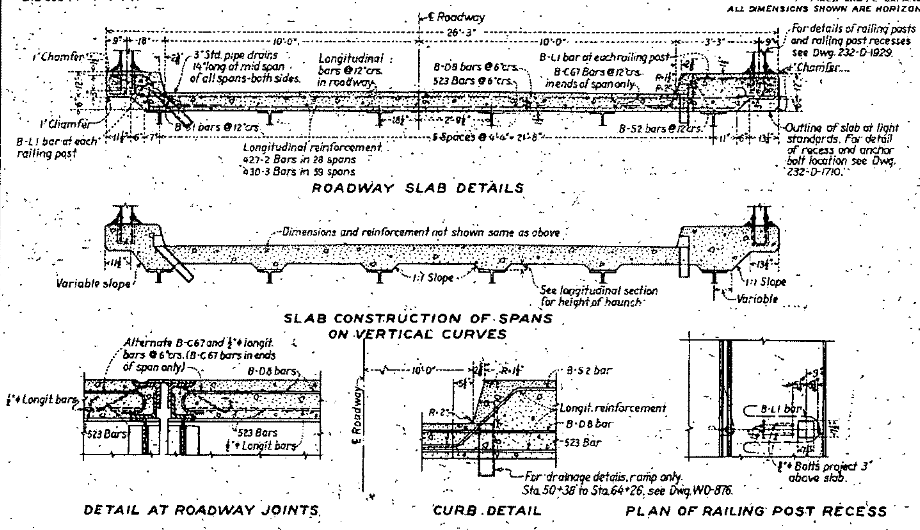
RECORD DRAWING AS CONSTRUCTED

36

CDQ000020080021

Attachment B13

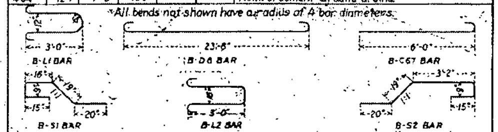




REINFORCEMENT BAR LIST

BAR NO.	SIZE	LENGTH	NUMBER REQUIRED TOTAL	ONE 59' SPAN	ONE 28' SPAN	LOCATION
B-D8	⅝"ϕ	25'-0"	2820	118	56	Top transverse reinforcement - Roadway
B-L1	⅝"ϕ	7'-10"	316			Railing post reinforcement
B-S1	⅝"ϕ	6'-6"	1388	58	28	Transverse reinforcement - Upstream curb
B-S2	⅝"ϕ	8'-3"	1388	58	28	Transverse reinforcement - Downstream curb
B-C67	⅝"ϕ	6'-8"	1300	50	50	Longitudinal reinforcement, each end of all spans
427-2	½"ϕ	27'-2"	220		55	Longitudinal reinforcement
430-3	½"ϕ	30'-3"	2420	110		Longitudinal reinforcement
523	⅝"ϕ	23'-0"	2820	118	56	Bottom transverse reinforcement - Roadway
B-L2	⅝"ϕ	9'-0"	22			Light Standard reinforcement
404	½"ϕ	4'-0	150			Reinforcement around drains

All bends not shown have a radius of 4 bar diameters.



NOTES

For plan, elevations and sections see Dwg. 232-D-638.

Bridge loading H20 as specified in "Standard Specifications of Highway Bridges and Incidental Structures," American Association of State Highway Officials, 1931 Edition. Unit stresses in steel, fs = 16000 lbs. per sq. inch for dead, live and impact loads.

Place Class "A" concrete in roadway slab, maximum size aggregate ¾".

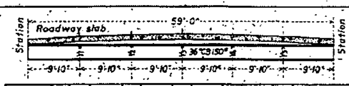
All reinforcement steel to be 1½" from concrete surfaces unless otherwise shown. Reinforcement bars lapped 40 diameters at all splices.

Where CB sections are shown, other sections of equal strength may be substitued. All rivets to be ⅞" dia. All welds to have a ⅜" bead and shall be made with the electric arc.

Structural steel furnished by McClintic-Marshall Corp. under req. 52434, cont. TV-1627.

REFERENCE DRAWINGS

McCLINTIC-MARSHALL CORP. DWGS. — REQ. 52434, CONT. TV-1627



STATION	Y1	Y2	Y3	Y4	Y5	STATION
61+90.0	⅝"	1"	1⅛"	1"	⅝"	62+49.0
62+49.0	⅝"	1"	1⅛"	1"	⅝"	63+08.0
63+08.0	⅝"	1"	1⅛"	1"	⅝"	63+67.0
63+67.0	⅝"	1"	1⅛"	1"	⅝"	64+26.0

LONGITUDINAL SECTION THRU SLABS ON VERTICAL CURVE SHOWING HEIGHT OF HAUNCH

UNITED STATES
TENNESSEE VALLEY AUTHORITY
WHEELER PROJECT

WHEELER DAM

RAMP VIADUCT LAYOUT AND SLAB DETAILS

DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION
DR. J.A.W. SUBMITTED [signature]
TR. R.E.B. RECOM. [signature]
CK. [illegible] APP'VD. [signature]

UNITED STATES TENNESSEE VALLEY AUTHORITY
EXAMINED [signature]
RECOMMENDED [signature]
APPROVED [signature]

232-D-917 DENVER, COLO. DEC. 19, 1934.

REV. 7-26-35. 8-7-35 8-30-35
FINAL FIELD REV. 11-8-37

RECORD DRAWING AS CONSTRUCTED [signature] 7-12-1937

Job No.

Corrected 12/11/44

CDQ000020080021

Attachment B14

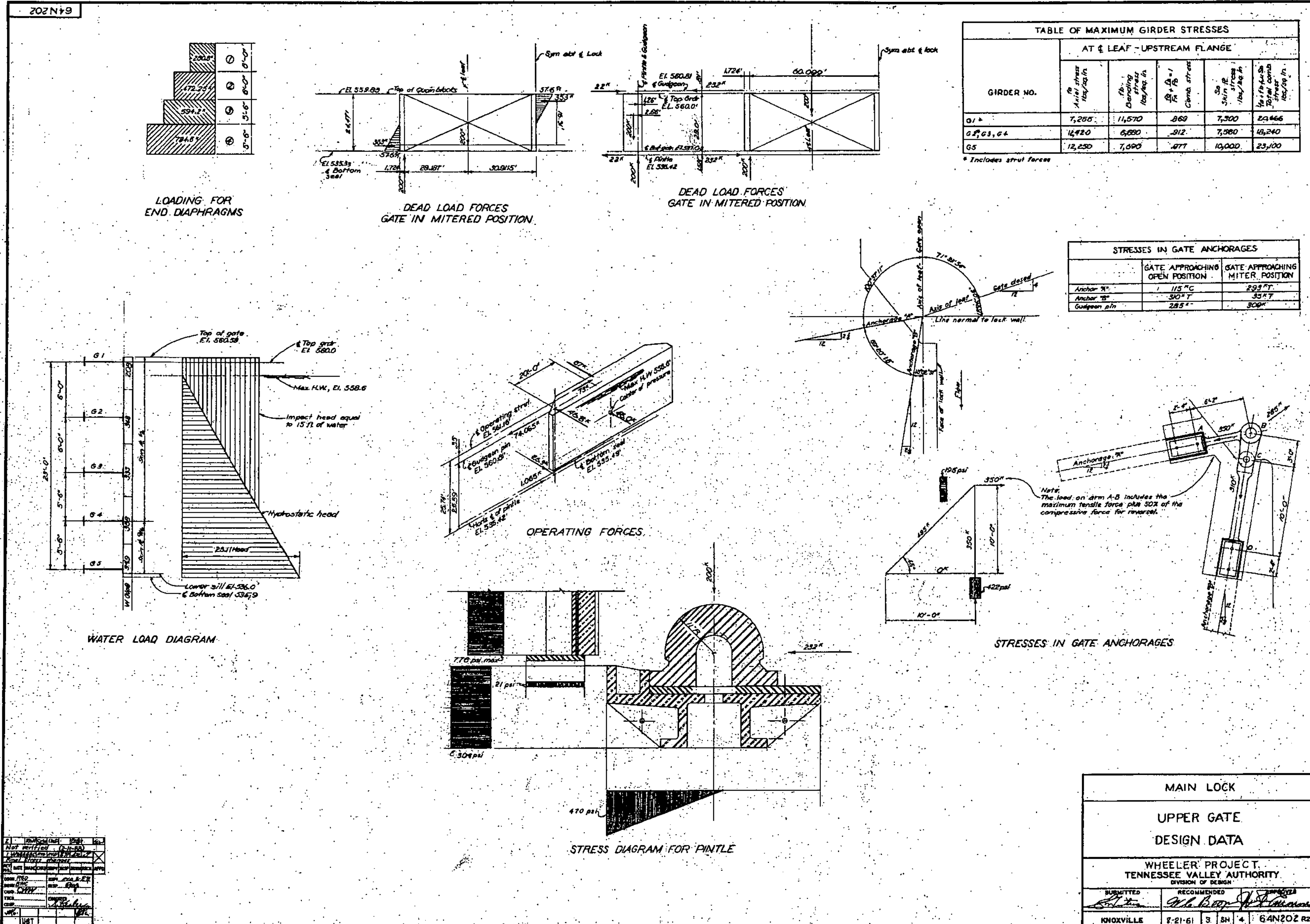


TABLE OF MAXIMUM GIRDER STRESSES					
GIRDER NO.	AT ℄ LEAF - UPSTREAM FLANGE				
	fa Axial stress lbs/sq.in.	fb Bending stress lbs/sq.in.	fa/Fa + fb/Fb = 1 Comb. stress	Sa Skin pl. stress lbs/sq.in.	½Sa + fb + fa Total comb. stress lbs/sq.in.
G1 *	7,256	11,570	.869	7,300	20,466
G2, G3, G4	12,420	6,680	.912	7,560	18,240
G5	12,250	7,690	.977	10,000	23,100

* Includes strut forces

STRESSES IN GATE ANCHORAGES		
	GATE APPROACHING OPEN POSITION	GATE APPROACHING MITER POSITION
Anchor "A"	115^K C	293^K T
Anchor "B"	310^K T	35^K T
Gudgeon pin	285^K	309^K

MAIN LOCK

UPPER GATE

DESIGN DATA

WHEELER PROJECT

TENNESSEE VALLEY AUTHORITY

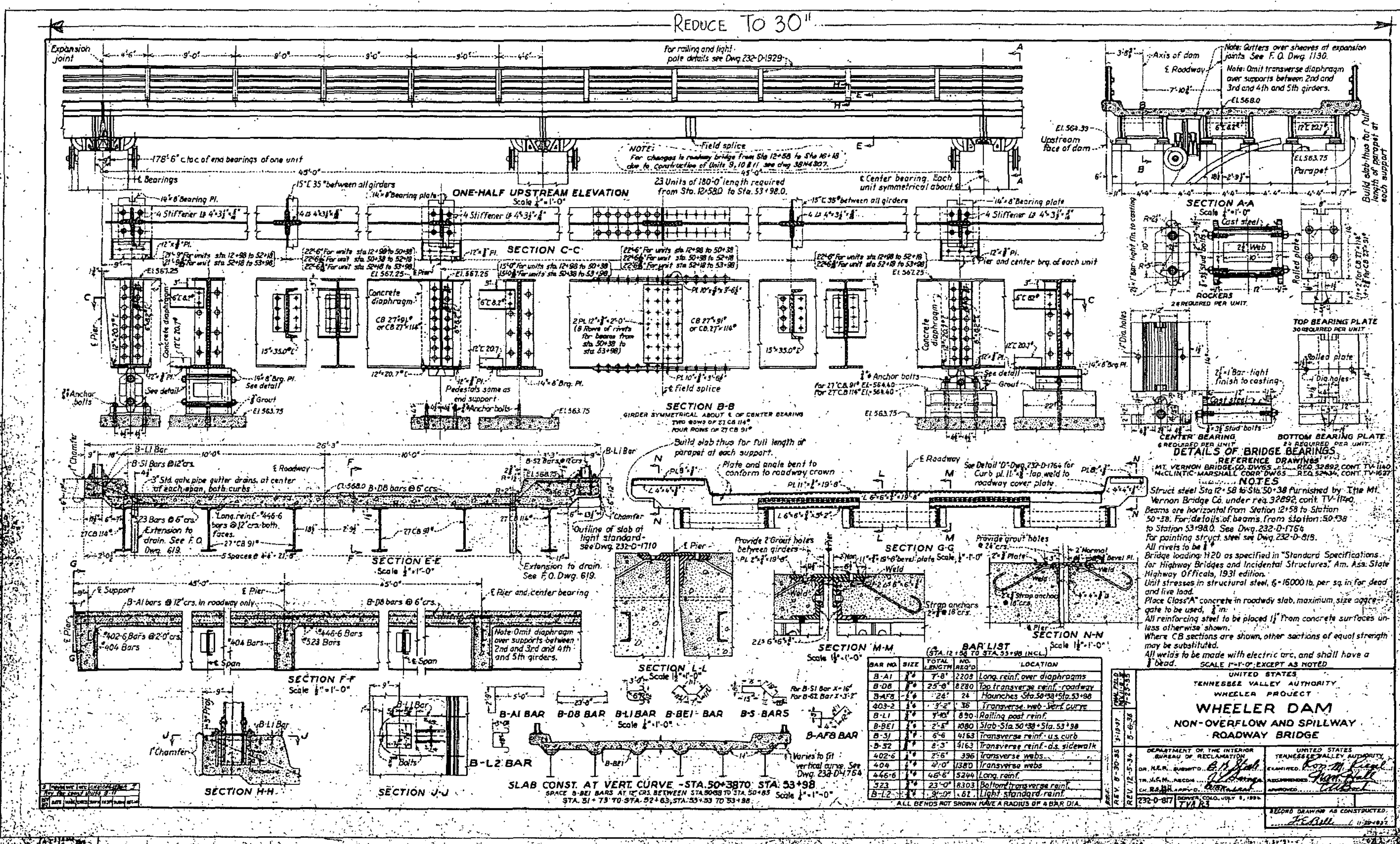
DIVISION OF DESIGN

SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 8-21-61 | 3 | SH 4 | 64N202 R2

CDQ000020080021

Attachment B15



REFERENCE DRAWINGS

MT. VERNON BRIDGE CO. DWGS ... REQ. 32892, CONT. TV-1140
McCLINTIC-MARSHALL CORP. DWGS ... REQ. 52434, CONT. TV-1637

NOTES

Struct. steel Sta 12+58 to Sta. 50+38 furnished by The Mt. Vernon Bridge Co. under req. 32892, cont. TV-1140.
Beams are horizontal from Station 12+58 to Station 50+38. For details of beams from station 50+38 to Station 53+98.0. See Dwg. 232-D-1764
For painting struct. steel see Dwg. 232-D-818.
All rivets to be ⅞"φ
Bridge loading: H20 as specified in "Standard Specifications for Highway Bridges and Incidental Structures," Am. Ass. State Highway Officals, 1931 edition.
Unit stresses in structural steel, f_s = 16000 lb. per sq. in for dead and live load.
Place Class "A" concrete in roadway slab, maximum size aggregate to be used, ¾ in.
All reinforcing steel to be placed 1½" from concrete surfaces unless otherwise shown.
Where CB sections are shown, other sections of equal strength may be substituted.
All welds to be made with electric arc, and shall have a ⅜" bead.

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

BAR LIST
(STA. 12+58 TO STA. 53+98 INCL.)

BAR NO.	SIZE	TOTAL LENGTH	NO. REQ'D	LOCATION
B-A1	[illegible]	7'-8"	2208	Long. reinf. over diaphragms
B-D8	[illegible]	25'-8"	8280	Top transverse reinf.-roadway
B-AF8	[illegible]	24"	24	Haunches Sta. 50+38 + Sta. 53+98
403-2	[illegible]	3'-2"	36	Transverse web - Vert. curve
B-L1	[illegible]	3'-10"	890	Railing post reinf.
B-BE1	[illegible]	2'-5"	1080	Slab - Sta. 50+38 + Sta. 53+98
B-S1	[illegible]	6'-6	4163	Transverse reinf. - u.s. curb
B-S2	[illegible]	8'-3"	4163	Transverse reinf. - d.s. sidewalk
402-6	[illegible]	2'-6"	396	Transverse webs
404	[illegible]	4'-0"	1380	Transverse webs
446-6	[illegible]	46'-6"	5244	Long. reinf.
523	[illegible]	23'-0"	8303	Bottom transverse reinf.
B-L2	[illegible]	9'-0"	62	Light standard reinf.

ALL BENDS NOT SHOWN HAVE A RADIUS OF 4 BAR DIA.

REV. 8-30-35
REV. 12-5-34
3-15-37
5-6-38
FINAL FIELD 7-25-35

UNITED STATES
TENNESSEE VALLEY AUTHORITY
WHEELER PROJECT

WHEELER DAM
NON-OVERFLOW AND SPILLWAY ROADWAY BRIDGE

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DR. H.E.R. SUBMIT'D B. H. Stah
TR. J.F.M. RECOM. J. L. Savage
CK. R.S. APP'D.

UNITED STATES
TENNESSEE VALLEY AUTHORITY
EXAMINED Ross M. Riegel
RECOMMENDED
APPROVED

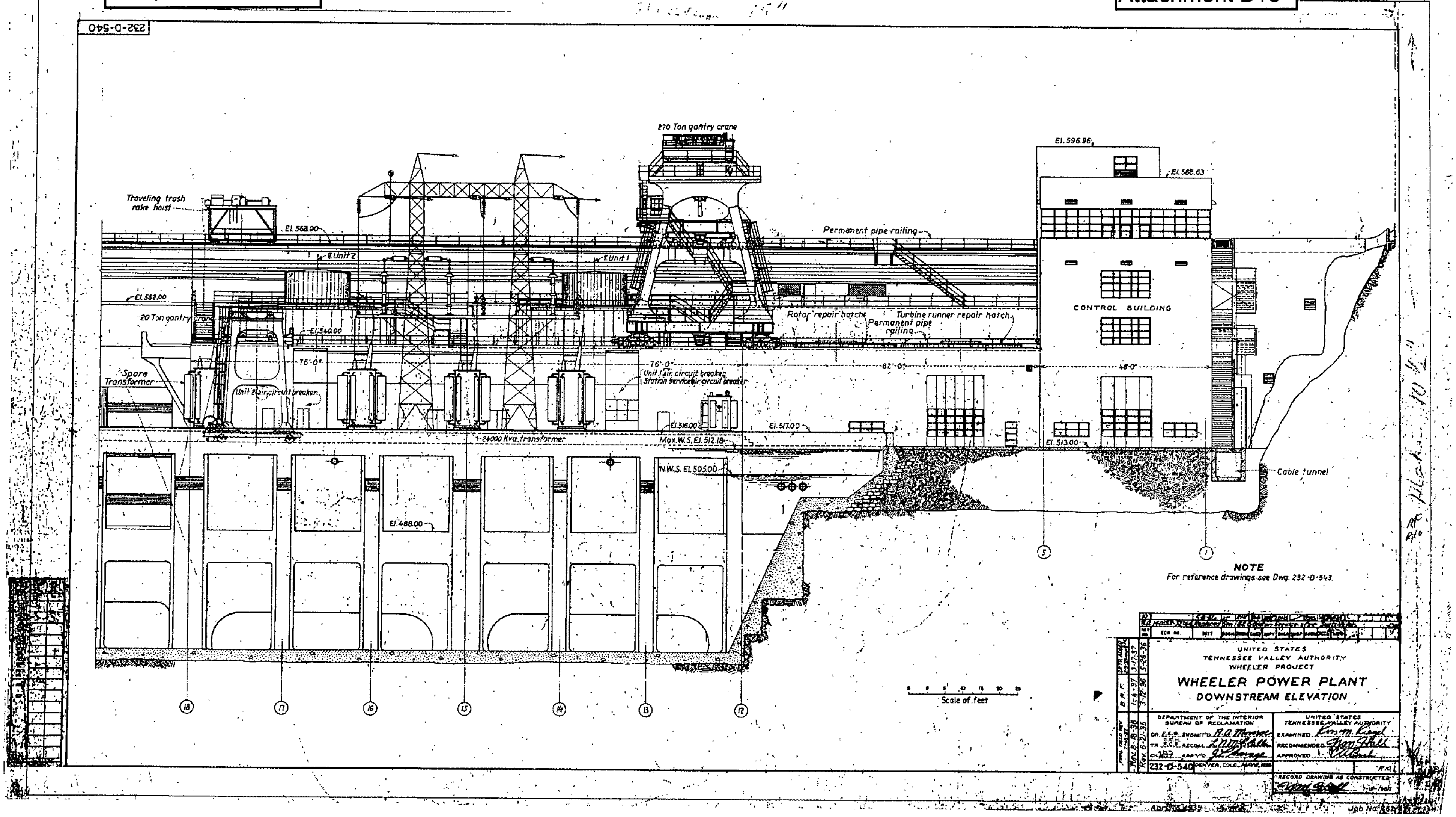
232-D-817
DENVER, COLO., JULY 8, 1934
TVA B3

RECORD DRAWING AS CONSTRUCTED
F. E. Bell 11-29-1937

Job No. 73

CDQ000020080021

Attachment B16



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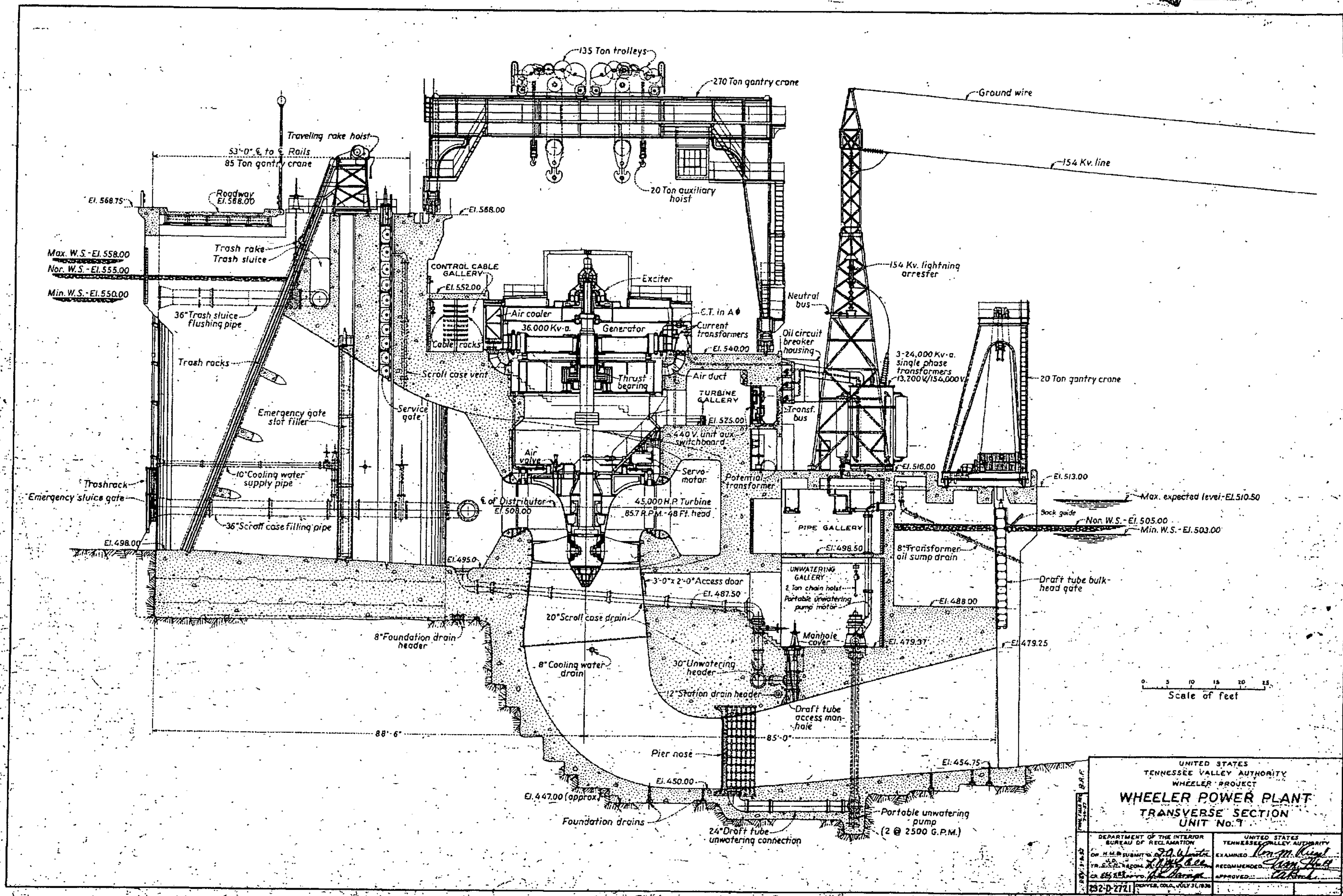
Attachment B17



ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-09C: CDQ000020080022, Rev. 0, Dam Rating Curve - Tims Ford

(179 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 091023 001	Calculations (nuclear)	N/A

Calc Title: Dam Rating Curve, Tims Ford

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC						Entire calc ☐ Selected pages ☐
NEW	CN	NUC	GEN	CEB	CDQ000020080022	NA	0	

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

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

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

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

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
Christopher J. Grace	205-298-6074	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Christopher J. Grace [signature]	10/16/2009	Bryant Bondurant [signature] Bryant Bondurant	10/16/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE** P. B. Selman	**DATE**
L.Y. Lin [signature] L. Lin	10/16/09	PB Selman for KRSpates	10/23/09

STATEMENT OF PROBLEM/ABSTRACT

A headwater rating curve for Tims Ford Dam is required as input to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations for the Tennessee River and its tributaries. The headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents a headwater rating curve for Tims Ford 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.

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

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

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CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080022	0

ALTERNATE CALCULATION IDENTIFICATION

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

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	Dam		
A	Curve		
A	Discharge		
A	Spillway		
A	PMF		

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	IO	GEN	CEB	Spillway Discharge Tables	
A	P	DW	GEN	CEB	10N200, R8	
A	P	DW	GEN	CEB	54W200, R5	
A	P	DW	GEN	CEB	51W202, R3	
A	P	DW	GEN	CEB	AEL99B104	
A	P	DW	GEN	CEB	AEL99B105	
A	P	DW	GEN	CEB	AEL99B115	
A	P	DW	GEN	CEB	AEL99B116	
A	P	DW	GEN	CEB	AEL99B117	
A	P	DW	GEN	CEB	AEL99B118	
A	P	DN	SQN	CEB	22404	
A	P	DN	WBN	CEB	54018	
A	S	CN	GEN	CEB	CDQ000020080053	
A	S	CN	GEN	CEB	CDQ000020080054	

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NPG CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER: CDQ000020080022	
Title	Dam Rating Curve, Tims Ford
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0	Initial issue: 38 Pages

NPG CALCULATION TABLE OF CONTENTS

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List of Acronyms

BLN	Bellefonte Nuclear Plant
BFN	Browns Ferry Nuclear Plant
COLA	Combined Operating License Application
FSAR	Final Safety Analysis Report
NEDP	TVA Standard Department Procedure
PMF	Probable Maximum Flood
SOCH	Simulated Open Channel Hydraulics
SQN	Sequoyah Nuclear Plant
TVA	Tennessee Valley Authority
TRBROUTE	Tributary Routing Model
WBN	Watts Bar Nuclear Plant

List of Variables

C_f	Free discharge coefficient
C_g	Orifice discharge coefficient
d	Height of water
g	Acceleration due to gravity
G	Effective gate opening
G_s	Orifice height
H_c	Head on crest
H_g	Minimum gross head
H_{Lmin}	Head at which the overflowing nappe first touches the bottoms of the open gates
H_{mp}	Vertical distance between the mid-point of G and the headwater elevation
H_o	Standard crest design head
HW	Headwater elevation
HW_{max}	Upper limit on headwater elevation for rating
L	Length of overflowing section
Q_f	Free discharge
Q_g	Orifice discharge
Q_{Tmax}	Maximum turbine discharge
S_g	Submergence factor for tailwater
TW	Tailwater elevation
V	Vertical opening of spillway gate
Z_c	Crest elevation of overflowing section

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STORAGE INFORMATION SHEET

Document CDQ000020080022	Rev. 0	Plant: GEN	

Subject: Dam Rating Curve, Tims Ford

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

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

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

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

Attachment 1: 10N200R8.pdf
Attachment 2: HDC711.pdf
Attachment 3: Method for Estimating Discharge.pdf
Attachment 4: TimsFordBlueBook.pdf
Attachment 5: TimsFordSpillwayDischargeTables.pdf
Attachment 6: TimsFord.xls
Attachment 7: DamsSpillwayGateOpenBasis Rev0.pdf
Attachment A1: HDC311.pdf
Attachment A2: 54W200R5.pdf
Attachment A3: 51W202R3.pdf
Attachment A4: HDC111-1 to 111-2-1.pdf
Attachment A5: AEL99B104.pdf
Attachment A6: "Design of Arch Dams", Fig. 9-21
Attachment A7: Tims Ford Model Data Summary
Attachment A8: Tims Ford Gate Opening Measurements
Attachment A9: AEL998105.pdf
Attachment A10: TVA Tims Ford Model Data and Cf_Hc Relationship.pdf
Attachment B1: Rating Curves for Flow over Drum Gates.pdf

☐ Microfiche/eFiche

1. Purpose

A headwater rating curve for Tims Ford Dam is required as input to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations for the Tennessee River and its tributaries. The headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents the headwater rating curves for Tims Ford Dam.

TVA developed methods of analysis, procedures, and computer programs for determining design basis flood levels for nuclear plant sites in the 1970s. 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 Units 3 & 4 Combined Operating License Application (COLA) was submitted using data and analysis that was determined for the original BLN FSAR (Unit 1 and Unit 2) and was documented in a 1998 reassessment. In 1998, the analysis process and documentation was brought under the nuclear quality assurance process for the first time. A quality assurance audit conducted by NRC staff in early 2007 raised several questions related to the documentation of past work regarding design basis flood level determinations. This calculation supports a portion of the effort to improve this design basis documentation.

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

Figure 1 is a plan and elevation view of Tims Ford Dam (Reference 2.1). For headwaters in the normal operating range, discharge is passed through the turbines, sluice, and the spillway. The spillway consists of three (3) spillway bays, each with radial or tainter gates to control discharge. If headwater rises above the normal operating range, discharge may also pass over the non-overflow sections, and the top of the spillway piers. However, the probable maximum flood (PMF) event value provided in the Tims Ford Blue Book (Reference 2.4) is lower than both the top of the dam and the top of the tainter gates when fully raised. Therefore, the initial dam rating curve contained in this calculation does not consider the effects of these potential overflow points.

The initial dam rating curve is based on the current configuration of Tims Ford Dam as defined on the current design drawings. The purpose of this calculation does not evaluate the design loading conditions for the dam or embankments.

TVA

Calculation No. CDQ000020080022	Rev: 0	Plant: GEN	Page: 8
Subject: Dam Rating Curve, Tims Ford		Prepared	CJG
		Checked	WBB

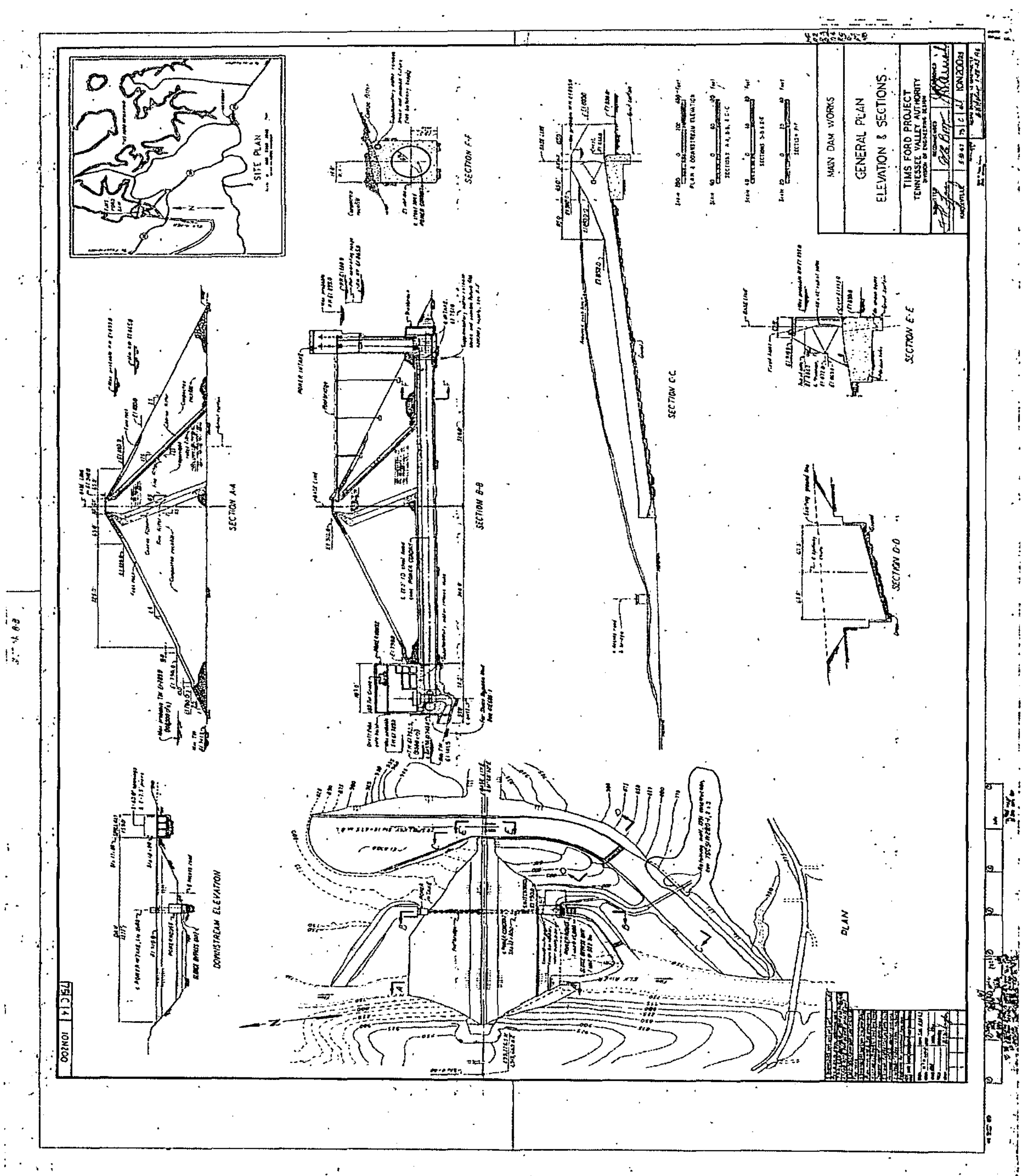


Figure 1 – Tims Ford Dam General Plan and Elevation (Reference 2.1)

2. References

2.1. TVA drawing no. 10N200R8 (Attachment 1).

2.2. "Hydraulic Design Criteria," Hydraulic Design Chart 711 (HDC 711), USACE (U.S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, Ms, 1988 (Attachment 2).

2.3. "Method for Estimating Discharge at Overflow Spillways with Curved Crests and Radial Gates," Tennessee Valley Authority, Office of Natural Resources and Economic Development, Report No. WR28-2-900-123, 1985 (Attachment 3).

2.4. TVA Water Control Project Manual (Blue Book) for Tims Ford Dam, TVA River Operations, July 1999 (Attachment 4).

2.5. "Tims Ford Dam Spillway and Sluice Discharge Tables," River Systems Operations, Tennessee Valley Authority, May 2008 (Attachment 5).

2.6. "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses," Tennessee Valley Authority, 2009, EDMS No. L58 090529 800 (Attachment 7).

2.7. US Bureau of Reclamation. *Design of Small Dams*, 3rd ed. U.S. Government Printing Office, Washington, D.C., 1987.

3. Assumptions & Methodology

The headwater rating curves developed in this calculation will be used in simulations of probable maximum flood events. Consequently, the rating curves have been calculated well above the normal operating range.

3.1 Assumptions

3.1.1 Assumption: Power generation will continue during a PMF event until the powerhouse is flooded.

Technical Justification: Power generation is assumed to stop when the tailwater reaches an elevation of 789.0 feet, at which point water will enter the powerhouse (Reference 2.1). Turbine discharge will be considered for rising headwaters until the tailwater reaches an elevation of 789.0 feet.

3.1.2 Assumption: The tailwater rating curve (Attachment 6) is sufficient for computing submergence effects on the headwater rating curve.

Technical Justification: The attached tailwater rating curve was provided in the TVA Blue Book for Tims Ford. The maximum estimated overflow represented in the tailwater curve is 110,000cfs which places the tailwater elevation at approximately 789.6 feet. Since the crest elevation is 853.0 feet, tailwater needs to rise another 63.4 feet from its maximum before impacting flow through the spillway.

3.1.3 Assumption: All spillway gates will be set to the maximum openings specified in the Spillway Discharge Tables (Reference 2.5).

Technical Justification: A TVA position paper justifying the operability of the gates in included as Reference 2.6.

3.1.4 Assumption: The sluice unit is only in operation when the main unit is not operational.

Technical Justification: The Tims Ford Blue Book (Reference 2.4) notes that the sluice unit was installed in 1986 to provide a minimum continuous flow of water and to improve the ecosystems downstream of Tims Ford Dam. The blue book further states that the sluice unit normally operates whenever the main unit is shut down. Even if the sluice was open during a PMF event, the magnitude of the discharge would be insignificant (< 0.5% of total discharge) compared to the combined spillway and turbine discharges.

3.1.5 Assumption: The maximum headwater assumed in 910 (top of the dam).

Technical Justification: Higher elevations, if required to support the SOCH/TRBROUTE hydraulic analysis, will be identified by the analyst and a revision to the calculation will be performed.

3.1.6 Assumption: The fully raised spillway tainter gates will remain in their open position and will not fail when flow passes over the spillway deck.

Technical Justification: Appendix C shows that the calculated load on a fully open gate at a headwater of 910 feet is less than the design load of the gate (headwater at the top of the gate).

3.2 Unverified Assumptions (UVA)

N/A

3.3 Methodology – Discharge Equations

Discharges past the dam are computed as either "free" discharge or "orifice" discharge. Free discharge refers to free surface overflow and is computed using a weir-type equation as follows (Reference 2.3 shows weir flow equations for overflow discharges):

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

in which variables are defined as follows:
Q_f = free discharge (cfs)
C_f = free discharge coefficient (may vary with HW)
L= length of overflowing section (ft)
H_c = head on crest (ft) = HW – Z_c
HW = headwater elevation (ft)
Z_c = top, or crest, elevation of overflowing section (ft)
This equation need not be modified to account for tailwater submergence, as no portion of the dam which has free surface overflow is expected to be submerged by tailwater.

Flow over the spillway crest is treated as free discharge for headwater elevations below $H_c = H_{Lmin}$, the head at which the overflowing nappe first touches the bottoms of the open gates (Appendix A). H_{Lmin} varies with gate opening, V, defined as the vertical distance between the bottom of the wide-open gate and the surface of the spillway crest directly below the gate lip.

For headwater elevations above $H_c = H_{Lmin}$ flow through the spillway gates is treated as orifice discharge. Orifice discharge refers to flow passing through a contracted opening and is computed using an orifice-type equation as follows (Reference 2.7):

$$Q_g = C_g GL\sqrt{2g(H_c - H_{mp})} \qquad \text{(Equation 2)}$$

in which variables are defined as follows:
Q_g = orifice discharge (cfs)
C_g = orifice discharge coefficient (varies with gate opening and H_c)
V = effective gate opening (ft)
L = length of overflowing section (ft)
g = acceleration due to gravity (ft/s^2)
H_c = head on crest
Values may be made dimensionless by dividing by the standard crest design head, H_o.

This equation need not be modified to account for tailwater submergence. Attachment 2 indicates tailwater effects are not significant until d/Hc (see Definition Sketch, Appendix A) approaches a value of 0.6. Calculation of d/Hc during headwater rating curve calculations confirms that tailwater effects can be neglected.

3.4 Methodology – Low Level outlet Discharges

The discharge from the low level outlet (sluice unit) will be neglected. The Tims Ford Blue Book (Reference 2.4, Attachment 4) states that the sluice unit normally operates when the main unit is not in operation in order to provide a minimum continuous flow for sustaining the downstream aquatic ecosystem. Additionally, the Tims Ford Spillway and Sluice Discharge Tables (Reference 2.5, Attachment 5) rate the maximum flow at a HW elevation of 900 feet at 250 cfs, which can be considered negligible against the spillway discharge at the same HW elevation.

3.5 Methodology – Spillway Discharge Calculations

The discharge coefficient, C_f, for free discharge over a spillway crest varies with head, H_c. For the Tims Ford spillway crest, limited model data is available to determine the relationships of $H_{Lmin}(G)$ and $C_f(H_c)$. The standard flow equation for free flow over a spillway is used to calculate these flows (Equation 1).

H_{Lmin} was determined by using the relationship between H_{Lmin}/H_o and G_v/H_o found in Attachment A9. An equation is derived for the straight-line portion of this graph. This is discussed in more detail in Appendix A.

Once H_c exceeds H_{Lmin}, gated discharge occurs. For gated discharge over the spillway crest, C_g also varies with head, H_c. For this calculation, the gated discharge equation published in Reference 2.7 was used (Equation 2).

Under the assumption that all three spillway gates are fully open, the two end bays are likely subject to end contraction and approach effects. These conditions, which reduce discharge through the three bays, are implicitly included in the model data.

3.6 Methodology – Discharge Coefficients

The value of the discharge coefficient, C_f, for flows over the open spillway bays are estimated using the available limited model data (Attachment A7 and A8). Only a small portion of this model test was conducted under free flow conditions. The relationship for C_f and head, H_c, is available from the free flow model test data for H_c>39 feet. Length, L, and crest elevation, Z_c, in each case are determined from TVA drawings (all relevant drawings are defined as References). A value of C_f for H_c=0 was assumed to be 3.0665. A polynomial was then fit from the cluster of model data to the assumed point. This process and the associated results are discussed and shown in Appendix A, Section A.6.

Once the headwater reaches an elevation which produces a nappe which touches the bottom of the radial tainter gates, the flow conditions warrant a different flow equation and likewise a different discharge coefficient. The limited model data was evaluated to determine a relationship between orifice discharge coefficient, C_g, and head, H_c, for various gate openings, V (up to V = 36.067 feet). From the eight data points representing the highest two gate openings (28 feet and 32 feet), C_g values were calculated. The results were scattered in a manner that a relationship could not be determined. In lieu of an equation, the results were averaged together to give a composite C_g value. This process is discussed in detail and results shown in Appendix A, Section A.7.

Although not used in this calculation, values of the discharge coefficient, C_f, for flows over the embankment, the tops of the spillway piers, and the tops of the spillway walls are estimated using Hydraulic Design Chart 711 (Reference 2.2) and can be found in Appendix B.

3.7 Methodology – Turbine Discharge

The elevation of the switchyard is such that the tailwater will not impede its operation until significant headwater or tailwater levels are reached (i.e. flows of over 110,000 cfs). It is assumed that the turbines may be in operation at the time of a flooding event and that the most efficient operation of the turbine will not be the highest priority. Therefore, the discharge values shown in the maximum sustainable column were chosen from the Reservoir and Power Data sheets from the Tims Ford Blue Book (Reference 2.4, Attachment 4). This value was chosen as the most conservative value from the data sheets and is assumed to be the maximum flow that the turbine discharge pipes can handle. The turbines will be inoperable after a tailwater elevation of 789.0 feet since the powerhouse would be flooded.

4. Design Input

Sect.	Input Parameter	Source	Symbol	Value
4.1	**Acceleration of Gravity**	Common Knowledge	g	32.2 ft/sec^2
4.2	**Spillway Crest Parameters**			
4.2.1	Crest Length	3, 40' wide bays, Reference 2.4	L	120 ft
4.2.2	Crest Elevation	Reference 2.4	Z_c	853.0 ft
4.2.3	Free Discharge Coefficient	Computed in Appendix A	$C_f(H_c)$	Eqn. A6
4.3	**Spillway Gate Parameters**			
4.3.1	Vertical Opening	Reference A3	V	36.07 ft
4.3.2	Effective Gate Opening	Computed in Appendix A	G	36.09 ft
4.3.3	Mid-point Elevation of Opening, relative to crest	Computed in Appendix A	H_{mp}	18.03 ft
4.3.4	Distance from spillway crest to point at which nappe touches gate	Computed in Appendix A	H_{Lmin}	44.24 ft
4.3.5	Headwater Elevation at which nappe touches gates		$H_{Lmin} + Z_c$	897.24 ft
4.3.6	Orifice Discharge Coefficient	Computed in Appendix A	$C_g(H_c)$	Eqn. A7
4.4	**Spillway Gate Overflow (Gates Fully Open)**			
4.4.1	Overflow Discharge Coefficient	Computed in Appendix B	C_f	3.12
4.4.2	Overflow Elevation	Computed in Appendix A	Z_c	912.99 ft
4.4.3	Overflow Length	3, 40' wide bays, Reference 2.4	L	120 ft
4.5	**Spillway Piers Overflow**			
4.5.1	Discharge Coefficient	Computed in Appendix B	C_f	2.65
4.5.2	Overflow Elevation	Computed in Appendix B	Z_c	910 ft
4.5.3	Overflow Length	2, 7.5' piers, Reference 2.4	L	15 ft
4.6	**Spillway Walls Overflow**			
4.6.1	Discharge Coefficient	Computed in Appendix B	C_f	2.65
4.6.2	Overflow Elevation	Computed in Appendix B	Z_c	910 ft
4.6.3	Overflow Length	Computed in Appendix B	L	24 ft
4.7	**Embankment Overflow**			
4.7.1	Discharge Coefficient	Computed in Appendix B	C_f	2.65
4.7.2	Overflow Elevation	Computed in Appendix B	Z_c	910 ft
4.7.3	Overflow Length	Reference 2.4	L	1421 ft
4.8	**Turbine Discharge**			
4.8.1	Maximum HW Elevation	Refer to Attachment 4		895 ft
4.8.2	Maximum TW Elevation	Refer to Section 4.13		789 feet
4.8.3	Minimum Gross Head	Reference 2.4, pg 32	H_g	111.2 ft
4.8.4	Maximum Discharge	Reference 2.4, pg 32	Q_{Tmax}	4000 cfs
4.9	**Tailwater Rating Curve**	Refer to Section 4.11	TW(Q)	Eqn. 3 &4
4.10	**Upper Limit on Headwater Elevation for Rating**	Refer to section 4.12	HW_{max}	910 feet

4.11 Tailwater Rating Curve

The tailwater rating curve used in this calculation is shown in Attachment 6. Attachment 6 lists points scaled from the tailwater plot (Reference 2.4), and shows a polynomial fit to the result. The polynomial indicated in Attachment 6 and repeated below is used for the headwater rating curve calculations.

$$TW = -9x10^{-8}Q^6 + 1x10^{-5}Q^5 - .0005Q^4 + 0.0133Q^3 - 0.1969Q^2 + 2.31Q + 744.5 \quad \text{for } 0 \leq Q \leq 30 \text{ cfs} \quad \text{(Equation 3)}$$

and

$$TW = 0.00001Q^3 - 0.0038Q^2 + 0.6264Q + 752.38 \quad \text{for } Q > 30 \text{ cfs} \quad \text{(Equation 4)}$$

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

4.12 Upper Limit on Headwater Elevation included in Rating Curve

The headwater rating curve needs to include all headwater elevations that may occur during a PMF event. The headwater at Tims Ford Dam is not expected to rise past 910 feet (rounding of value in Reference 2.4, see Assumption 3.2.1). The embankment, spillway piers and spillway walls are indicated at 910 feet (Reference 2.4). Therefore, they will not be overtopped and are not considered in this initial headwater rating curve.

5. Special Requirements/Limiting Conditions

N/A

6. Calculations

The calculations consist of computing spillway and overflow discharges (from Equations 1 and 2) for a list of headwater elevations ranging from 853 feet up to 910 feet [4.14], the assumed PMF elevation. The headwater rating curve is a plot of headwater elevation versus total dam discharge.

Below an elevation of 853 feet, no discharge passes through the dam spillway. Flow can be passed through the turbine in this case but at an inefficient rate in terms of kW/cfs until the headwater reaches an elevation of 860 feet per Reference 2.4. Beginning at 853 feet, the discharge passes through the spillway. Flows are calculated as outlined in section 3.8. Total discharge, given in "1000 cfs," is the sum of all discharges in cfs past the dam divided by 1000.

Table 1 shows the spreadsheet calculations for the headwater rating curve (spreadsheet included as Attachment 6). 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 associated with the "Total Discharge" from the tailwater rating curve polynomial fit [4.13]. This is computed to verify that tailwater does not affect discharge.

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 898.05 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 term G/H_c is computed to verify the absence of tailwater submergence effects on the spillway discharge ($G/H_c < 0.6$ – see Attachment 2). The values in this column demonstrate that the tailwater elevations are far below the crest elevation and therefore have no effect on the flow through the gates.

Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 2 for orifice discharge. Cells with zeros indicate that the data was not applicable for the given headwater elevation.

The column following the spillway discharge column shows the "Overflow Discharge" for the turbine flow. Zeros indicate that the flow is an assumed flow.

There are no overflow discharges for overflow of the embankment, open spillway gates, spillway piers, or spillway walls, therefore no columns including these items are shown. The calculation method of each column has been covered previously.

Table 1: Headwater Rating Curve Calculations for Tims Ford Dam

Spillway Parameters

L = 120 feet

Z_c = 853 feet

G = 36.088 feet

H_{mp} = 18.03 feet

Overflow Discharge, Q_f in cfs

C_f =

Z_c = feet

L = feet

HW	Q Total Discharge 1000 cfs	feet TW	Spillway feet H_c	Spillway C_f | C_g	Spillway G/H_c	Spillway d/H_c	Spillway cfs Q_f | Q_g	Turbine Flow	Sluice Flow	
853.0	**4.00**	751.32	0.0	3.067	0.00		0	4000	0	
854.0	**4.37**	751.78	1.0	3.083	36.09	101.22	370	4000	0	
856.0	**5.94**	753.51	3.0	3.114	12.03	33.16	1,941	4000	0	
858.0	**8.21**	755.63	5.0	3.142	7.22	19.47	4,215	4000	0	
860.0	**11.04**	757.95	7.0	3.167	5.16	13.58	7,038	4000	0	
862.0	**14.33**	760.49	9.0	3.189	4.01	10.28	10,334	4000	0	
864.0	**18.05**	763.23	11.0	3.210	3.28	8.16	14,052	4000	0	
866.0	**22.15**	765.93	13.0	3.228	2.78	6.70	18,155	4000	0	
868.0	**26.61**	767.92	15.0	3.244	2.41	5.67	22,613	4000	0	
870.0	**31.40**	768.61	17.0	3.258	2.12	4.96	27,401	4000	0	
872.0	**36.50**	770.67	19.0	3.270	1.90	4.33	32,498	4000	0	
874.0	**41.88**	772.68	21.0	3.281	1.72	3.82	37,884	4000	0	
876.0	**47.52**	774.64	23.0	3.290	1.57	3.41	43,543	3980	0	
878.0	**53.42**	776.52	25.0	3.297	1.44	3.06	49,461	3960	0	
880.0	**59.56**	778.32	27.0	3.304	1.34	2.77	55,624	3940	0	
882.0	**65.94**	780.03	29.0	3.309	1.24	2.52	62,020	3920	0	
884.0	**72.54**	781.64	31.0	3.314	1.16	2.30	68,640	3900	0	when TW hits
886.0	**79.36**	783.16	33.0	3.318	1.09	2.12	75,476	3880	0	powerhouse
888.0	**86.38**	784.58	35.0	3.321	1.03	1.95	82,520	3860	0	(EL. 789),
890.0	**93.59**	785.92	37.0	3.324	0.98	1.81	89,767	3820	0	turbines cut off
892.0	**100.99**	787.18	39.0	3.326	0.93	1.69	97,214	3780	0	
894.0	**108.60**	788.40	41.0	3.328	0.88	1.58	104,858	3740	0	
895.0	**112.47**	788.99	42.0	3.330	0.86	1.52	108,754	3720	0	
896.0	**116.42**	789.58	43.0	3.331	0.84	1.47	112,699	3720	0	
897.24	**117.66**	789.76	44.2	3.332	0.82	1.43	117,659	0	0	
898.0	**116.59**	789.61	45.0	0.646	0.80	1.41	116,590	0	0	
900.0	**120.82**	790.23	47.0	0.646	0.77	1.34	120,817	0	0	
902.0	**124.92**	790.82	49.0	0.646	0.74	1.27	124,917	0	0	
904.0	**128.89**	791.40	51.0	0.646	0.71	1.21	128,888	0	0	
906.0	**132.74**	791.96	53.0	0.646	0.68	1.15	132,739	0	0	
908.0	**136.48**	792.51	55.0	0.646	0.66	1.10	136,482	0	0	
909.0	**138.32**	792.78	56.0	0.646	0.64	1.08	138,316	0	0	
910.0	**140.13**	793.05	57.0	0.646	0.63	1.05	140,126	0	0	

7. Results/Conclusions

For convenience, the headwater rating results are shown in Table 2, separate from the calculation details provided in Table 1, are tabulated as total discharge in cfs versus headwater elevation in feet. The headwater rating curve is plotted in Figure 2.
In addition to the results shown below, a conclusion drawn from the calculation is that tailwater does not impact the calculation.

Note the discontinuity that appears in Figure 2 at headwater elevation of approximately 898 feet. This is the result of the flow transitioning from free flow over the spillway crest to orifice flow through the tainter gates. This discontinuity was anticipated and is typical for this type of flow transition.

Table 2: Headwater Rating Results

HW	Q 1000 cfs	TW
853	4.00	751.32
854	4.37	751.78
856	5.94	753.51
858	8.21	755.63
860	11.04	757.95
862	14.33	760.49
864	18.05	763.23
866	22.15	765.93
868	26.61	767.92
870	31.40	768.61
872	36.50	770.67
874	41.88	772.68
876	47.52	774.64
878	53.42	776.52
880	59.56	778.32
882	65.94	780.03
884	72.54	781.64
886	79.36	783.16
888	86.38	784.58
890	93.59	785.92
892	100.99	787.18
894	108.60	788.40
895	112.47	788.99
896	116.42	789.58
897.24	117.66	789.76
898	116.59	789.61
900	120.82	790.23
902	124.92	790.82
904	128.89	791.40
906	132.74	791.96
908	136.48	792.51
909	138.32	792.78
910	140.13	793.05

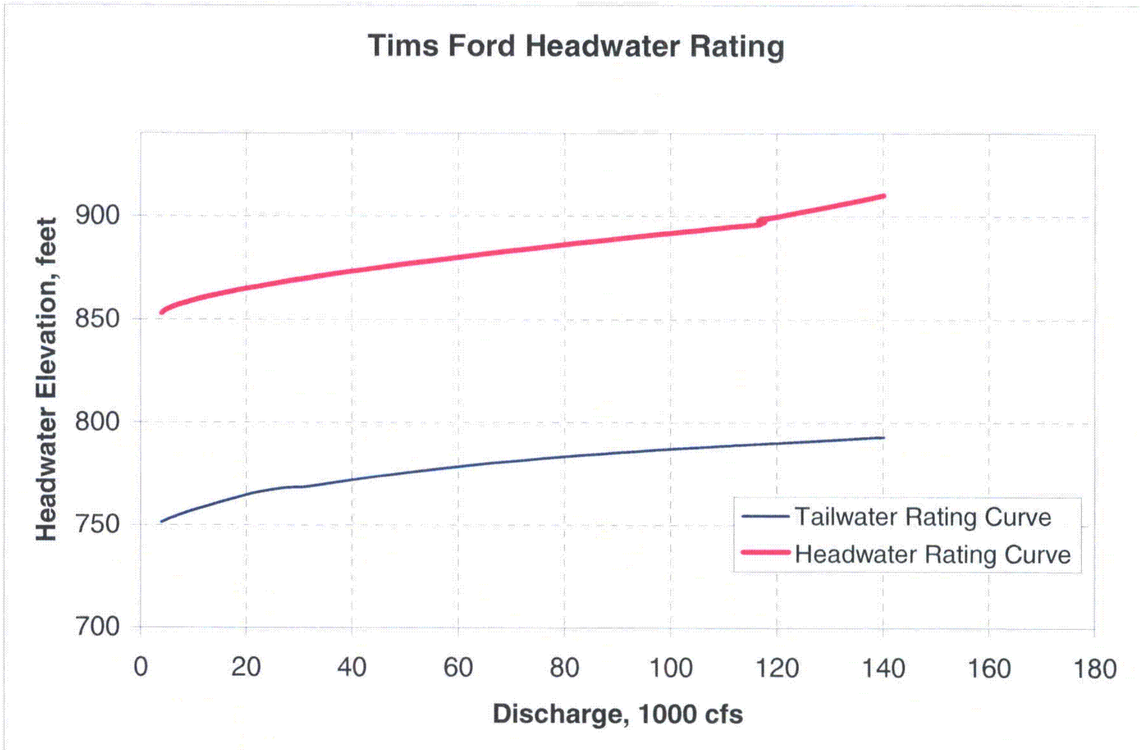


Figure 2: Headwater Rating Curve

Appendix A: Spillway Discharge Coefficients for Tims Ford Dam

TVA has model test data describing the relationships between discharge, headwater, tailwater, and gate opening for most of its spillways. These data 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.

Tims Ford Dam has three spillway bays, each controlled by a radial (tainter) gate as illustrated in Attachments A2 and A3 (References A3 and A2, respectively). 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 2.5 and included in the calculation as Attachment 5. As shown in this table, all three gates are set to their maximum opening position, indicator reading "30" for gate arrangement number 65. 1971 Field measurements (Attachment A8) relate gate opening (referenced from the crest elevation) to the indicator reading on the gate hoist. The average maximum gate opening, V, is 36.067 feet for gate indicator reading 30.

A.1 References

A1. "Hydraulic Design Criteria," Hydraulic Design Chart 711 (HDC 711), USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988 (Attachment 2).
A2. TVA drawing No: 51W202R3 (Attachment A3).
A3. TVA drawing No. 54W200R5(Attachment A2).
A4. "Hydraulic Design Criteria," Hydraulic Design Chart 311 (HDC 311), USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988 (Attachment A1).
A5. "Hydraulic Design Criteria," Hydraulic Design Chart 111-1 and 111-2/1, USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988 (Attachment A4).
A6. Drawing AEL99B104 (Attachment A5).
A7. "Design of Arch Dams," Figure 9-21. Coefficient of discharge for flow under a gate. (A Water Resources Technical Publication), Denver CO, 1977 (Attachment A6).
A8. TVA files, Tims Ford Model Data Summary. "Tims Ford 1:100 Spillway Model." Dated 2/27/1971 (Attachment A7)
A9. TVA files, Tims Ford Average Gate Opening Measurements. Dated 1/13/1971 (Attachment A8)
A10. Drawing AEL998105 (Attachment A9)
A11. TVA Tims Ford Model Data and Cf_Hc Relationship (Attachment A10)

A.2 Discharge Equations

Figure A2 is a definition sketch for flow over the Tims Ford 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 $H_c \leq H_{Lmin}$, and is computed using a weir equation (e.g., Reference A1):

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

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

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

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 A7):

$$Q_g = C_g GL\sqrt{2g(H_c - H_{mp})}$$ (Equation A2)

in which
Q_g = orifice discharge (cfs)
C_g = orifice discharge coefficient (varies with gate opening and H_c)
V = effective gate opening (ft)
L = length of overflowing section (ft)
g = acceleration due to gravity (ft/s^2)
H_c = head on crest

Values may be made dimensionless by dividing by the equivalent standard crest design head, H_o, which is approximated and verified in Section A.3. This equation need not be modified to account for tailwater submergence.

A.3 Determination of H_o

The equivalent standard crest design head, H_o, of the spillway must be determined. The referenced design head (H_o) is not readily available for the Tims Ford Spillway Crest. One method to determine this value is to compare the standard crest values to the known design values of the Tims Ford Crest. However, Reference A2 shows that the downstream spillway crest section for Tims Ford varies significantly from a standard crest after 3.391 feet. Beyond this point (PT) the spillway profile takes on a linear slope of 8:1. As a result of this configuration, a very limited data set is available for graphical comparison.

Along with the referenced data point, Reference A2 also includes a formula for both upstream and downstream crest line. The downstream crest line is shown here to be represented by the formula:

$$y = \frac{x^{1.8}}{38.25} \quad \text{for } 0 \le x \le 3.391$$ (Equation A3)

Whereas the downstream quadrant of a standard crest is represented as (Reference A5):

$$y = \frac{x^{1.85}}{2H_o^{0.85}}$$ (Equation A4)

where x = distance downstream from crest, y = vertical distance downstream of crest, and H_o = design head (H_d in Reference A4).

According to Reference 2.3, H_o corresponds to the head at which a free issuing jet of water will conform to the shape of the crest contour. TVA crests are nonstandard and therefore the deviation between the shape of a free issuing jet of water and the crest contour increase as the distance from the crest centerline increases. In order to justify using H_o = 40 feet for Tims Ford Dam, the coordinates for the upper third of the crest (x = 0 to x = 3.391 feet) were compared to the coordinates (calculated from Equation A4) for the standard crest at various design heads. It was found that H_o = 40 feet minimized the sum of square errors (i.e. (Tims Ford y coordinate – standard crest y coordinate) across the upper third of the dam's crest. Results of this analysis, as well as results for bracketing H_o values are listed in Table A1. A plot comparing the standard crest with H_o = 40 feet to the Tims Ford crest is contained in Figure A1.

Table A1: Coordinates of Tims Ford Crest and Standard Crest for H_o = 39, 40, and 41 feet

	Tims Ford Crest	Standard Crest, H_o=39		Standard Crest, H_o=40		Standard Crest, H_o=41	
x (ft)	y (ft)	y (ft)	Square Error (ft^2)	y (ft)	Square Error (ft^2)	y (ft)	Square Error (ft^2)
0	0	0.0000	0.0000	0	0.0000	0	0.0000
1.503	-0.054	-0.0450	0.0001	-0.0462	0.0001	-0.0452	0.0001
2	-0.091	-0.0764	0.0002	-0.0784	0.0002	-0.0767	0.0002
2.5	-0.136	-0.1155	0.0004	-0.1184	0.0003	-0.1160	0.0004
3.391	-0.235	-0.2029	0.0010	-0.2081	0.0007	-0.2038	0.0010
Sum of Square Error			0.0017		0.0013		0.0017

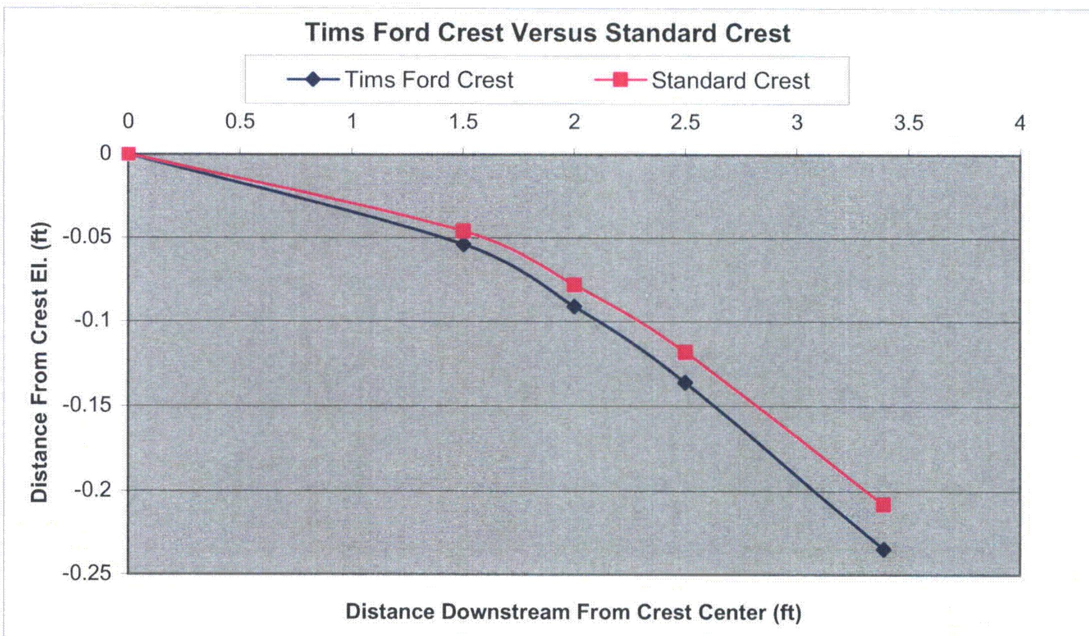


Figure A1: Standard Crest Versus Tims Ford Crest Profile

A.4 Geometry

Parameters G, H_{mp}, Z_o (gate overflow elevation), and β (angle plotted against discharge coefficient in Reference A1) are computed from crest and gate geometry as described in Figure A3. Table A2 gives the values for V = 5', 8', 12', 16', 20', 22', 24', 28', 32' and 36.067'.

Table A2: Geometrical Parameters for Relevant Gate Openings

V, feet	G, feet	H_{mp}, feet	Z_o, feet	β, deg.
5	5.001	2.499	899.43	69.39
8	8.001	3.999	901.69	74.69
12	12.010	5.996	904.36	81.19
16	16.020	7.993	906.68	87.28
20	20.021	9.993	908.64	92.87
22	22.018	10.994	909.50	95.52
24	24.014	11.995	910.27	98.10
28	28.004	13.999	911.53	103.18
32	32.000	16.000	912.43	108.50
36.067	36.088	18.030	912.93	113.04

As an example, the procedure for computing the geometrical parameters for V = 36.067 feet is given here. From Attachment A2 (Reference A3),

- R = 41.0 feet
- Z_c = 853 feet
- Z_{tr} = 872 feet
- Z_1 = 872' – 852.86' = 19.14 feet
- Z_2 = 895 – 872 = 23 feet

where the parameters are defined in Figure A4. Referring to Figure A5:

Angle θ: $$\theta = \sin^{-1}\left(\frac{23}{41}\right) + \sin^{-1}\left(\frac{19.14}{41}\right) = 61.952^\circ$$

Angle α: $$\alpha = \tan^{-1}\left(\frac{872 - 853 - 36.067}{\sqrt{41^2 - (872 - 853 - 36.067)^2}}\right) = -24.60^\circ$$

Overflow Elevation Zo: $Z_o = 872 + 41\sin[61.952 - (-24.60)] = 912.93\,feet$

Gate lip y-coordinate: $y_l = 872 - 853 - 36.067 = -17.07\,feet$

Gate lip x-coordinate: $x_l = \sqrt{41^2 - (-17.07)^2} = 37.28\,feet$

From Attachment A3 (Reference A2):

Upstream:

$$y = f(x) = \frac{x^3}{343} \text{ for } 0' < x \leq 12'$$

In which $y = y_s - 19'$ and $x = x_s - 38.76'$. In terms of x_s and y_s (From Figures A4 and A5):

$$y_s = 19 + \frac{(x_s - 38.76)^{1.8}}{343}, \text{ for } 38.76' < x_s \leq 50.76'$$

Downstream:

$$y = f(x) = \frac{x^{1.8}}{38.25} \text{ for } 0' < x \leq 3.391'$$

In which $y = y_s - 19'$ and $x = x_s - 38.76'$. In terms of x_s and y_s (From Figures A4 and A5):

$$y_s = 19 + \frac{(38.76 - x_s)^{1.8}}{38.25}, \text{ for } 35.369' < x_s \leq 38.76'$$

The downstream equation is used for V = 5' and 36.067'. The upstream equation is used for V = 8', 12', 16', 20', 22', 24', 28', and 32'. x_s and y_s values were found through a series of iterations.

Table A3: Spillway Values for Each Gate Opening

V, feet	x_s	y_s
5	38.592	19.001
8	39.462	19.001
12	40.184	19.008
16	40.477	19.015
20	40.473	19.015
22	40.383	19.012
24	40.236	19.009
28	39.756	19.003
32	38.879	19.000
36.067	38.258	19.008

To determine effective gate opening, G, at V = 36.067', calculate y_s for x_s = 38.258 feet:

$$y_s = f(x_s) = 19 + \frac{(38.76 - 36.067)^{1.8}}{38.25} = 19.008\,feet$$

G_n is calculated as follows:

- $G_n = \sqrt{(38.26 - 37.28)^2 + (19.008 - (-17.07))^2} = 36.09\,feet$

And

- $$H_{mp} = 36.067 - \frac{(19.008 - (-17.07))}{2} = 18.03\,feet$$
- $$\beta = \frac{\Pi}{2} - \tan^{-1}\left(\frac{-17.07}{37.28}\right) - \tan^{-1}\left(\frac{38.26 - 37.28}{19.008 - (-17.07)}\right) = 113.04^{\circ}$$

A.5 Determination of H_{Lmin}

The flow does not transform into orifice flow as soon as the water height reaches the elevation of the bottoms of the gates. There is a transition zone in which unknown behavior of the flow is anticipated. The relationship between normalized effective gate opening, G/H_o, and H_c/H_o shown on Attachment A9 was used to determine the value of H_{Lmin} at V = 36.067 feet when $H_c = H_{Lmin}$. The straight line portion of this curve is fit by:

$H_{Lmin}/H_o = 0.0414 + 1.18{*}G/H_o$. (Equation A5)

At V = 36.067 feet, H_{Lmin} = 44.24 feet.

A.6 Determination of $C_f(H_c)$

The equation for free flow was derived from 1:100 model data for H_o >39 feet by TVA. The portion of the model data for a free flow condition was used to calculate C_f values. This cluster of data was plotted and a value for C_f at H_o=0 was inserted to form a curve for values of C_f for H_c between 0 and 39 feet. The chosen value for C_f at H_o = 0 (3.0665) used to create the polynomial was derived from model data when creating the Tims Ford Spillway Discharge Tables (Attachment 5). This information is shown and discussed in Reference A11 (Attachment A10). The resulting polynomial is given and shown below in graphical form in Figure A2.

$C_f = 3.0665 + 1.6826E\text{-}2(H_c) - 3.8028E\text{-}4(H_c)^2 + 3.0666E\text{-}6(H_c)^3$ (Equation A6)

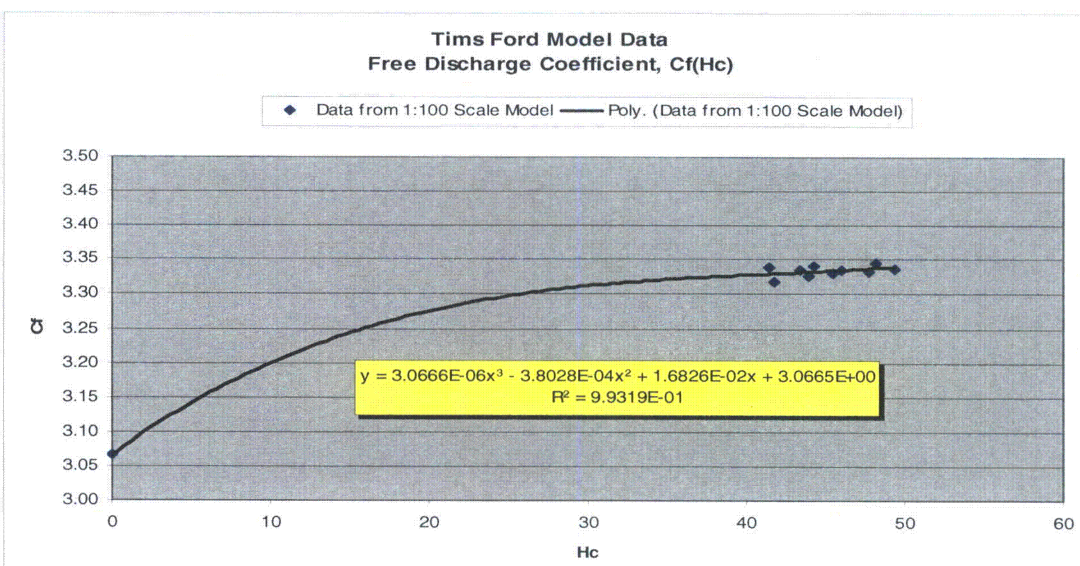


Figure A2: Tims Ford 1:100 Model Data, Calculated Cf vs. Ho

A.7 Determination of C_g (H_c)

As headwater rises, it eventually reaches a level at which the nappe touches the bottoms of the raised gates. For headwaters above that level, discharge is predicted using an orifice type equation. Reference A8 gives 1:100 scale model data for Tims Ford Dam for gated flows at different values of V in feet (5, 8, 12, 16, 20, 22, 24, 28, and 32). This data was evaluated to obtain a mathematical relationship between H_c and C_g. The data was limited in nature making it difficult to observe a definitive relationship.

The maximum gate opening (V) for Tims Ford spillway is 36.067 feet. Because no model data is available for this value of V, the two highest gate openings, V = 28 feet and 32 feet were used to establish a value of C_g. It was observed that the values of C_g stabilized somewhat at these two gate openings. However, the data did not occur in predictable patterns and subsequently an equation could not be generated. The average value of these eight data points was taken to determine a reasonable value of C_g. These results are shown below in Table A4.

Table A4: Summary of Model C_g Values for Large Gate Openings

Summary of Model Cg Values for Large Gate Openings		
V (ft)	Hc (ft)	Cg
28	37.72	0.643
	40.13	0.648
	41.92	0.642
	47.62	0.648
32	42.4	0.648
	45.42	0.644
	47.7	0.646
	49.02	0.649
Average Cg		0.646

All available model data for Tims Ford Dam provided in reference A8 is represented graphically in Figure A3.

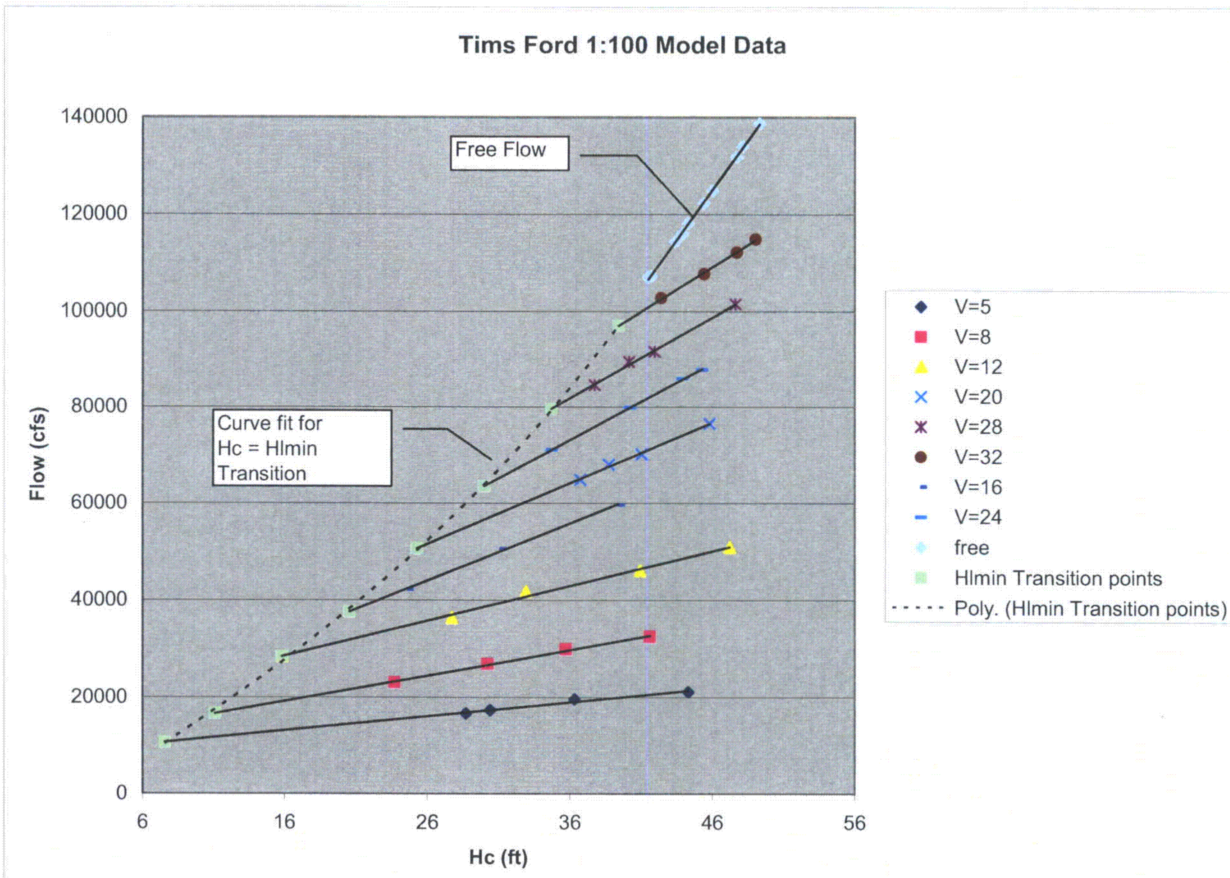


Figure A3: Graphical Summary of Tims Ford 1:100 Model Data

BWSC | Barge Waggoner Sumner & Cannon, Inc.

Project: Tims Ford Dam
Description: Spillway Gate Geometry
Project No. ______ Sheet No. ______ of ______
Designer: CJG Date: 7/29/09
Checker: ______ Date: ______

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 = effective gate opening

H_{mp} = vertical distance between mid-point of G and the headwater elevation

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

α = angle formed by the trunnion and the bottom of the gate

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

ϕ = angle formed by a vertical line and the line connecting the trunnion to the top of the gate

x, y = coordinates relative to the trunnion axis

x_s, x_y = coordinates of spillway surface defined as $y_s = f(x_s)$

x_g, y_g = coordinates of the gate lip relative to the trunnion axis

Note: for all coordinates, y is positive downward and coordinates are relative to the trunnion axis

x_o, y_o = coordinates of overflow elevation

Figure A4 – Variables for Spillway Gate Geometry

BARGE WAGGONER SUMNER & CANNON, INC.

Project: Tims Ford Dam
Description: Spillway Gate Geometry
Project No. ______ Sheet No. ______ of ______
Designer: CJG Date: 7/29/09
Checker: ______ Date: ______

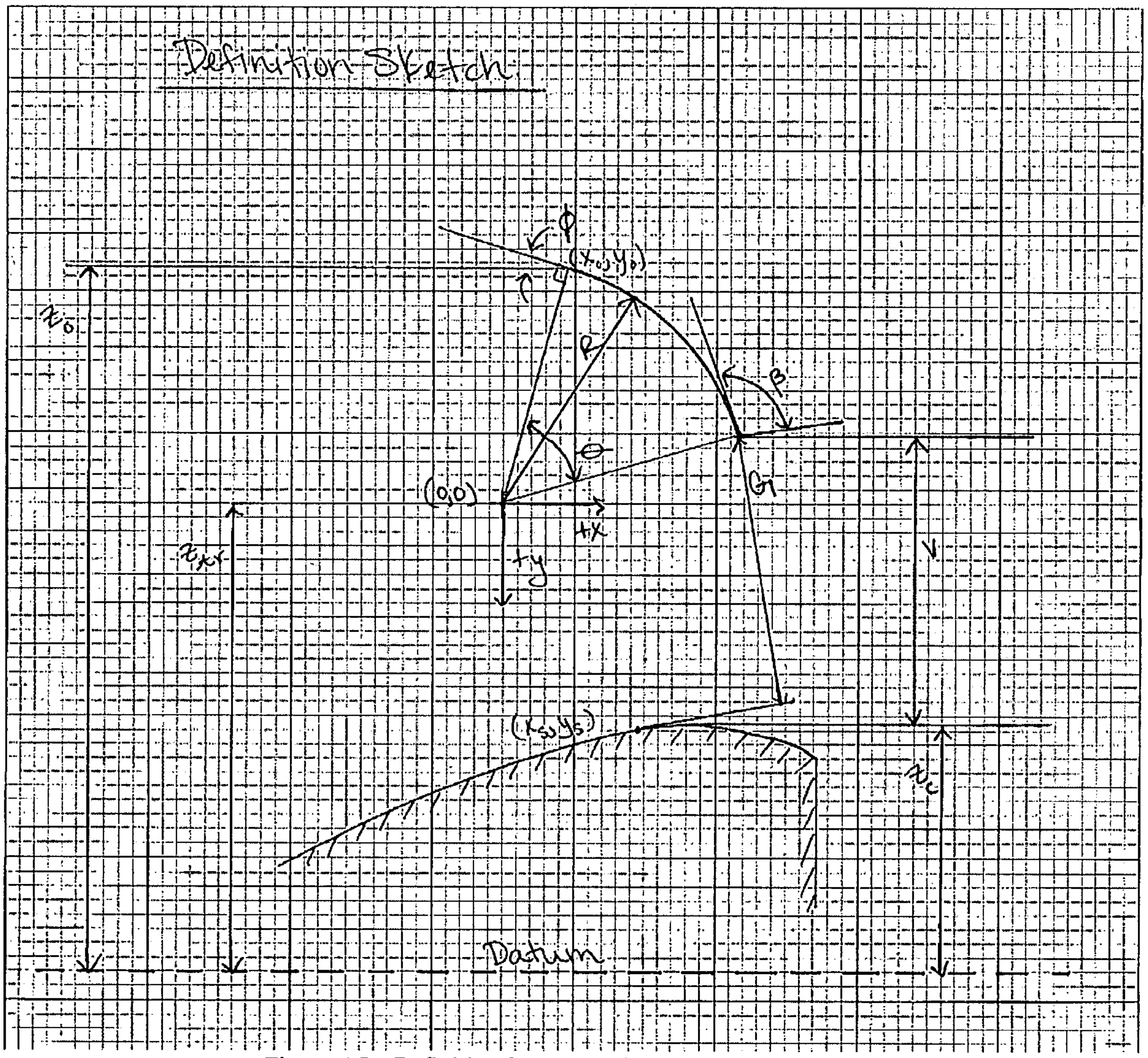
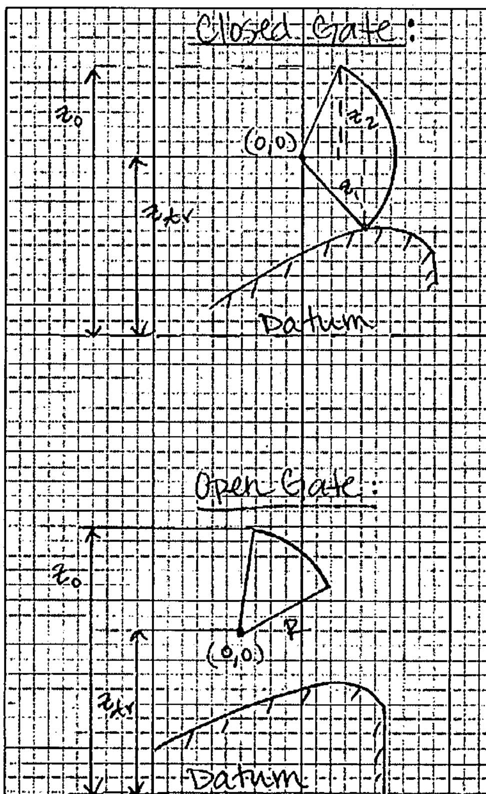


Figure A5 – Definition Sketch for Spillway Gate Geometry

BWSC Barge Waggoner Sumner & Cannon, Inc.

Project: Tims Ford Dam
Description: Spillway Gate Geometry
Project No. ______ Sheet No. ______ of ______
Designer: CJG Date: 7/29/09
Checker: ______ Date: ______



$$\theta = \sin^{-1}\left(\frac{z_2}{R}\right) + \sin^{-1}\left(\frac{z_1}{R}\right)$$

R, z_1, and z_2 are determined from drawings

$$z_0 = z_{tr} + R\sin(\theta - \alpha)$$

Figure A6 – Spillway Gate Geometry

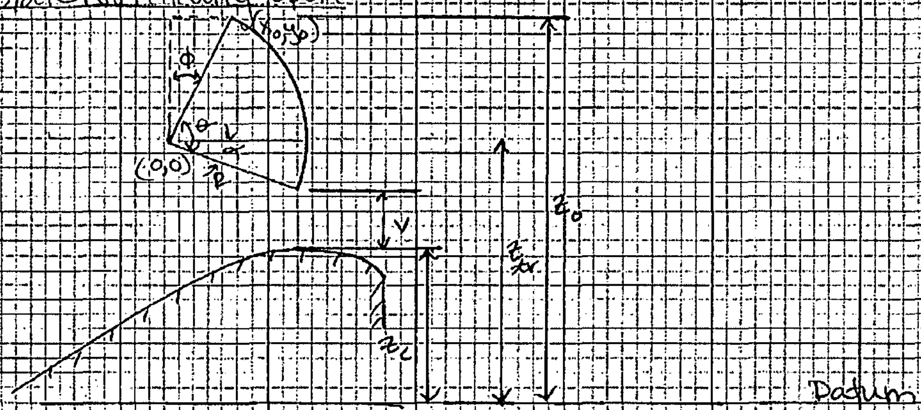
TVA

Calculation No. CDQ000020080022		Rev: 0	Plant: GEN	Page: A-12
Subject: Dam Rating Curve, Tims Ford			**Prepared**	CJG
Appendix A			**Checked**	WBB

BWSC — Barge Waggoner Sumner & Cannon, Inc.

Project: Tims Ford
Description: Spillway Gate Geometry
Project No. ______ Sheet No. ______ of ______
Designer: CJG Date: 7/29/09
Checker: ______ Date: ______

Gate Not Fully Open:

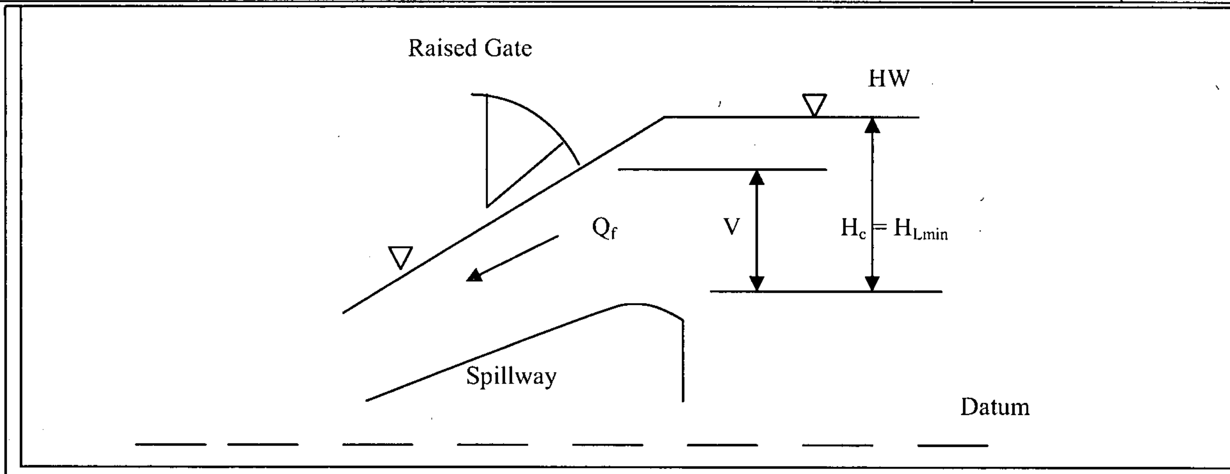


$$\alpha = \tan^{-1}\left(\frac{z_{tr} - (z_c + V)}{\sqrt{R^2 - (z_{tr} - z_c - V)^2}}\right)$$

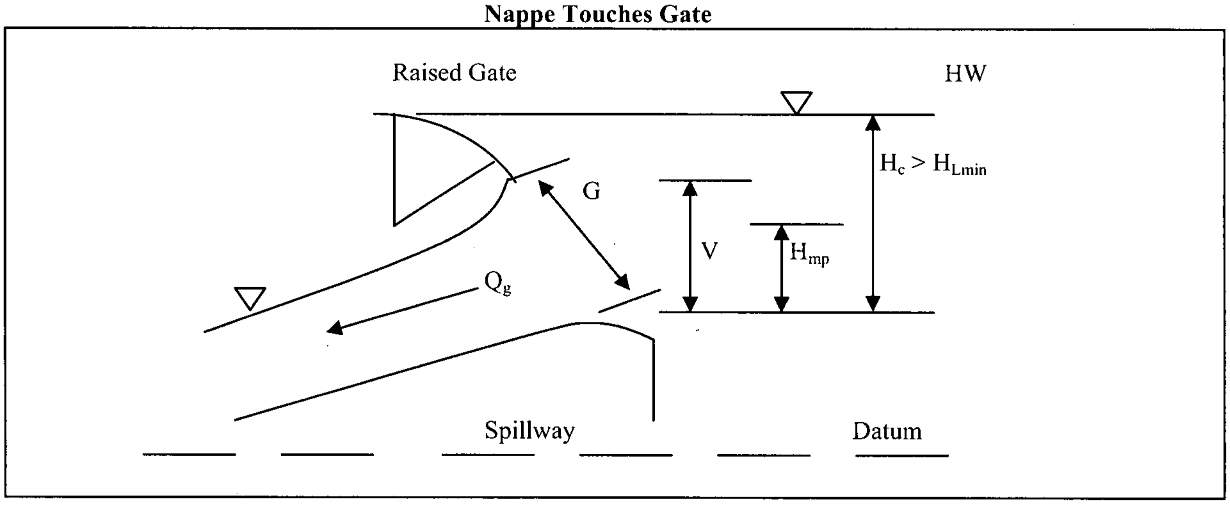
$$z_o = z_{tr} + R\sin(\theta - \alpha)$$

$$\Phi = \tan^{-1}\left(\frac{x_o}{y_o}\right) \text{ where } \begin{cases} x_o = R\cos(\theta - \alpha) \\ y_o = z_o - z_{tr} \end{cases}$$

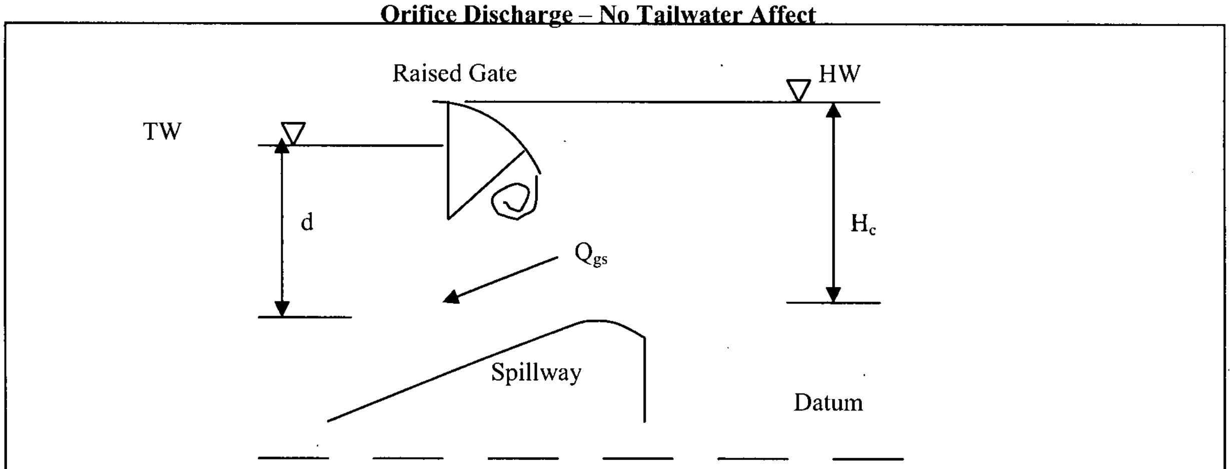
Figure A7 – Spillway Gate Geometry



Nappe Touches Gate

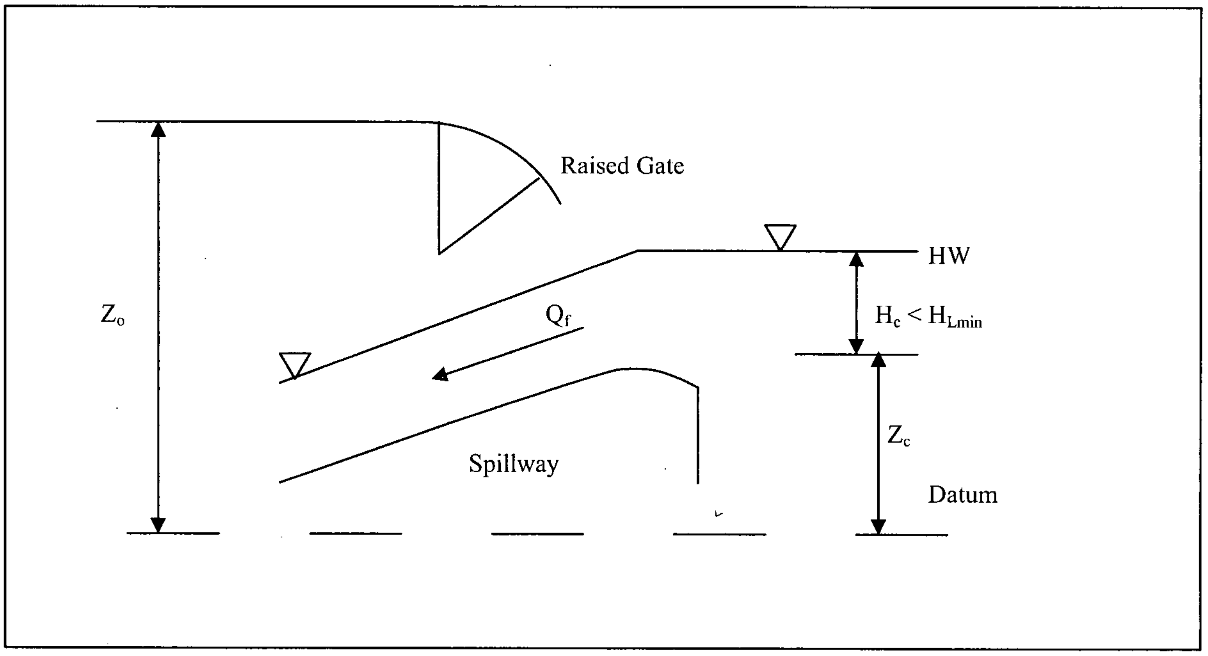


Orifice Discharge – No Tailwater Affect

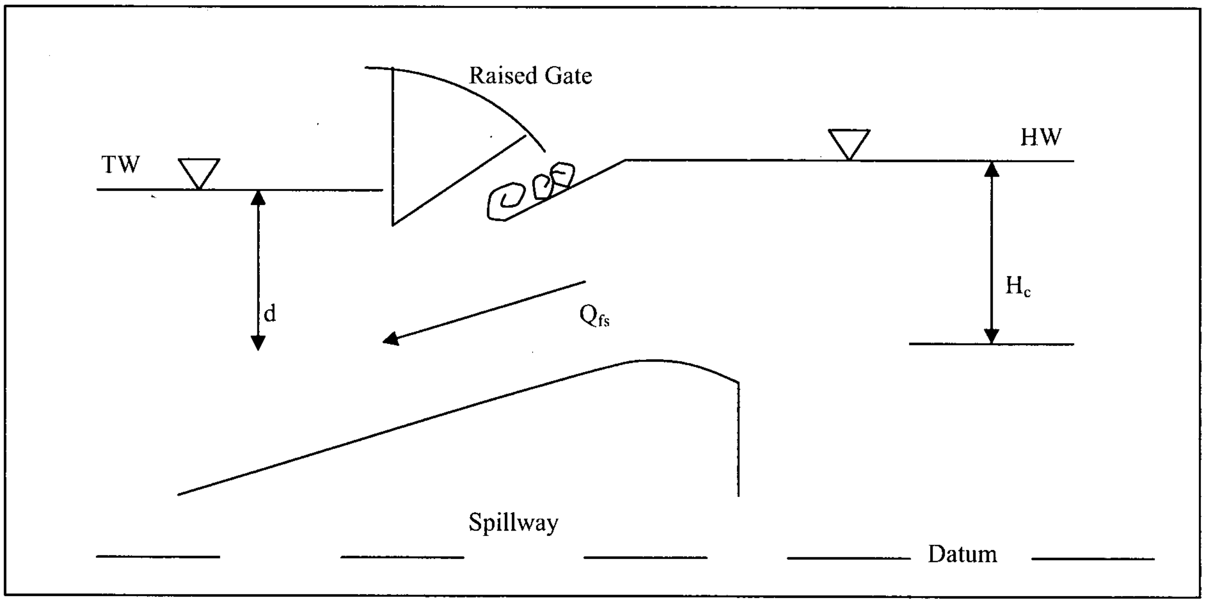


Orifice Discharge – Affected by Tailwater

Figure A8 – Definition Sketch for Spillway Discharge



Free Discharge – No Tailwater Affect



Free Discharge – Affected by Tailwater

Figure A8 Continued – Definition Sketch for Spillway Discharge

Appendix B: Overflow Parameters for Tims Ford Dam

Overflow parameters for each portion of the Tims Ford Dam can be found in the following calculations.

B.1 References

B1. "Rating Curves for Flow over Drum Gates," Joseph N. Bradley, Paper No. 2677, Transactions of the American Society of Civil Engineers, Vol. 119, p. 403 – 433, 1954 (Attachment B1).
B2. "Hydraulic Design Criteria," Design Chart 711, USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988 (Attachment 2).
B3. TVA Water Control Project Manual (Blue Book) for Tims Ford Dam, TVA River Systems Operations, July 1999 (Attachment 4).
B4. TVA drawing no: 10N200R3 (Attachment 1).
B5. TVA drawing no: 51W202R5 (Attachment A3).

B.2 Spillway Gate Overflow for Gates Fully Open

The following values are computed from Appendix A:

$\varphi = 3.449°$
R = 41.0 feet
$\theta = 61.952°$
$\alpha = -24.599°$
$Z_C = 912.93'$ (computed in Appendix A)
L = 120' (Reference B5)

Using Figure 6 on page 412 from Reference B1, C_f (called C_q) can be determined as follows:

$0 \leq H \leq 910' - 912.93' = -2.93'$
and $0 \leq H/r \leq -2.93'/41' = -0.0715 = 0$
therefore $3.28 \leq C_f \leq 3.28$
Use: $C_f = 3.28$

B.3 Spillway Piers Overflow

B = 29' (Reference B4)
$Z_C = 910'$ (Reference B4)
L = 2 x 7.5' = 15' (Reference B5)

$$0 \leq \frac{H}{B} \leq \frac{910' - 910'}{29'} = 0$$

Therefore, using Reference B2, $C_f = 2.65$.

B.4 Spillway Walls Overflow

B = 16 + 16 = 32' (Reference B4)
$Z_C = 910'$ (Reference B4)
L= 12 + 12 = 24'' (Reference B5)

$$0 \leq \frac{H}{B} \leq \frac{910' - 910'}{32'} = 0$$

Therefore, using Reference B2, $C_f = 2.65$.

B.5 Embankment Overflow
B = 32' (Reference B4)
Z_C = 910' (Reference B3)
L = 1421' (Reference B3)

$$0 \leq \frac{H}{B} \leq \frac{910' - 910'}{32'} = 0$$

Therefore, using Reference B2, C_f = 2.65.

Appendix C: Hydrostatic Loads on the Spillway Tainter Gates

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

C.1 References

C1. TimsFord.xls – Hydrostatic Forces tab (Attachment 6).
C2. "Engineering Fluid Mechanics," Clayton T. Crowe, John Wiley & Sons, Inc. 8th ed, p. 53-55, 2005.
C3. TVA drawing no: 54W200R5 (Attachment A2).
C4. TVA Water Control Project Manual (Blue Book) for Tims Ford Dam, TVA River Operations, July 1999 (Attachment 4).

C.2 Calculations for Closed Gate when water level is at top of gate

The following is a summary of known values. The values are computed in Appendix A. The parameters are defined in Figure C1.

Table C1: Tainter Gate Parameters
(References C3 and C4)

Known Values	
Z_c	853 ft
Z_{tr}	872 ft
Z_o	895 ft
R	41 ft
L	40 ft

- $\alpha_1 = \sin^{-1}\left(\frac{Z_{tr} - Z_c}{R}\right)$
  $= \sin^{-1}\left(\frac{872' - 853'}{41'}\right)$
  $= \mathbf{27.61°}$
- $\alpha_2 = \sin^{-1}\left(\frac{Z_o - Z_{tr}}{R}\right)$
  $= \sin^{-1}\left(\frac{895' - 872'}{41'}\right)$
  $= \mathbf{34.12°}$
- $\theta = \alpha_1 + \alpha_2 = \mathbf{61.73°}$
- $A_{Projected} = L\,(Z_o - Z_c)$
  $= 40'\,(895' - 853')$
  $= \mathbf{1680.0\ sf}$
- $A_{Slice2} = \Pi R^2 (\alpha_2/360°)$
  $= \Pi * (41')^2 * (34.12° / 360°)$

= **500.567 sf**

- $F_{Rx} = \gamma h_c A_{Projected}$ (Reference C2)
  = (62.4 pcf) ((0.5) (895' – 853')) (1680 sf)
  = **2201.47 kip**

- $x_1 = R - \left(R * \cos\left(\sin^{-1}\left(\frac{(Z_o - Z_{tr})}{R} \right)\right)\right)$

  $= 41' - \left(41' * \cos\left(\sin^{-1}\left(\frac{(895' - 872')}{41'} \right)\right)\right)$

  = **7.059'**

- $F_{Ry} = \gamma Vol = \gamma L\left[(Z_0 - Z_{tr})x_1 - A_{Slice2} + 0.5(R - x_1)(Z_o - Z_{tr})\right]$ (Reference C2)
  = (62.4 pcf) (40')[(895' – 872')(7.059') - (500.567sf) + 0.5(41' – 7.059')(895' – 872')]
  = **130.06 kip**

- $Z_1 = Z_o - \left(\frac{2}{3}(Z_o - Z_c) \right)$

  $= 895' - \left(\frac{2}{3}(895' - 853') \right)$

  = **867.0'**

- $F_R = \sqrt{(130.06 kip)^2 + (2{,}201.47 kip)^2}$ (Reference C2)
  = **2,205.31 kip**

Table C2: Summary of Calculated Values for Closed Gate at PMF

Summary of Calculated Values			
α_1	27.61°	x_1	7.06 ft
α_2	34.12°	Z_1	867.0 ft
θ	61.73°	F_{Rx}	2,201.47 kip
$A_{Projected}$	1,680.0 sf	F_{Ry}	130.06 kip
A_{slice2}	500.57 sf	F_R	2,205.31 kip

C.3 Calculations for Open Gate when water is at Flood Level

Known values are computed in Appendix A. The parameters are defined in Figure C1.

- $Z_2 = V + Z_c$
  = 36.067' + 853'
  = **889.07'**

- $\alpha_3 = \sin^{-1}\left(\frac{Z_2 - Z_{tr}}{R}\right)$

  $= \sin^{-1}\left(\frac{889.067' - 872'}{41'}\right)$

  = 24.60°

- $\alpha_4 = \sin^{-1}\left(\frac{HW_{Max} - Z_{tr}}{R}\right) - \alpha_3$

  $= \sin^{-1}\left(\frac{910' - 872'}{41'}\right) - 24.60°$

  = 43.347°

- $Z_o = Z_{tr} + R \sin(\theta + \alpha_3)$
  $= 872' + 41' \sin(61.95° + 24.60°)$
  = 912.93'

- $A_{Projected} = L\,(HW_{max} - Z_2)$
  $= 40'\,(910' - 889.067')$
  = 837.32 sf

- $F_{Rx} = \gamma h_c A_{Projected} = \gamma\left(\frac{(HW_{Max} - Z_2)}{2}\right) A_{Projected}$

  $= (62.4\,pcf)(1/2)(910' - 889.067')(837.32\,sf)$

  =546.86 kip

- $x_2 = R\cos\alpha_3 - \sqrt{R^2 - (HW_{max} - Z_{tr})^2}$

  $= 41\cos 24.60° - \sqrt{41^2 - (910' - 872')^2}$

  = 21.88'

- $A_{Slice3} = \Pi R^2 (\alpha_4/360°)$
  $= \Pi * (41')^2 * (43.347° / 360°)$
  = 635.87 sf

- $A_{Triangle} = 0.5*(2*R*\sin(\alpha_4 / 2))*(R*\cos(\alpha_4 / 2))$
  $= 0.5 * (2)(41)(\sin(43.347° / 2))\,(41)(\cos(43.347° / 2))$
  = 576.93 sf

- $F_{Ry} = \gamma Vol = \gamma L\left[(HW_{max} - Z_2)(x_2) - 0.5(x_2)(HW_{max} - z_2) - A_{Slice3} + 0.5(2R\sin\frac{\alpha_4}{2})(R\cos(\frac{\alpha_4}{2}))\right]$

  $= (62.4\,pcf)(40')[(910' - 889.067')(21.88') - 0.5(21.88')(910' - 889.067') - 635.87\,sf +$
  $0.5(2)(41'\sin\frac{43.347°}{2})(41'\cos(\frac{43.347°}{2}))]$

= 424.58 kip

- $F_R = \sqrt{(546.86kip)^2 + (424.58kip)^2}$

  = 692.33 kip

Table C3 – Summary of Calculated Values for Open Gate at PMF

Summary of Calculated Values			
α_3	24.60°	$A_{triangle}$	576.93 sf
Z_2	889.07 ft	x_2	21.88 ft
Z_o	912.93 ft	F_{Rx}	546.86 kip
$A_{Projected}$	837.32 sf	F_{Ry}	424.58 kip
$A_{slice,3}$	635.87 sf	F_R	692.33 kip

C.4 Conclusion

The resultant force on the closed gate when water is at the PMF is 2,245.31 kip. The resultant force on the open gate when water is at the PMF is 644.92 kip. Therefore, the open radial gate will not fail when water is at the PMF.

BWSC — Barge Waggoner Sumner & Cannon, Inc.

Project: HydroStatic Force on Gate
Description: Diagram
Project No. ______ Sheet No. ______ of ______
Designer: ______ Date: ______
Checker: ______ Date: ______

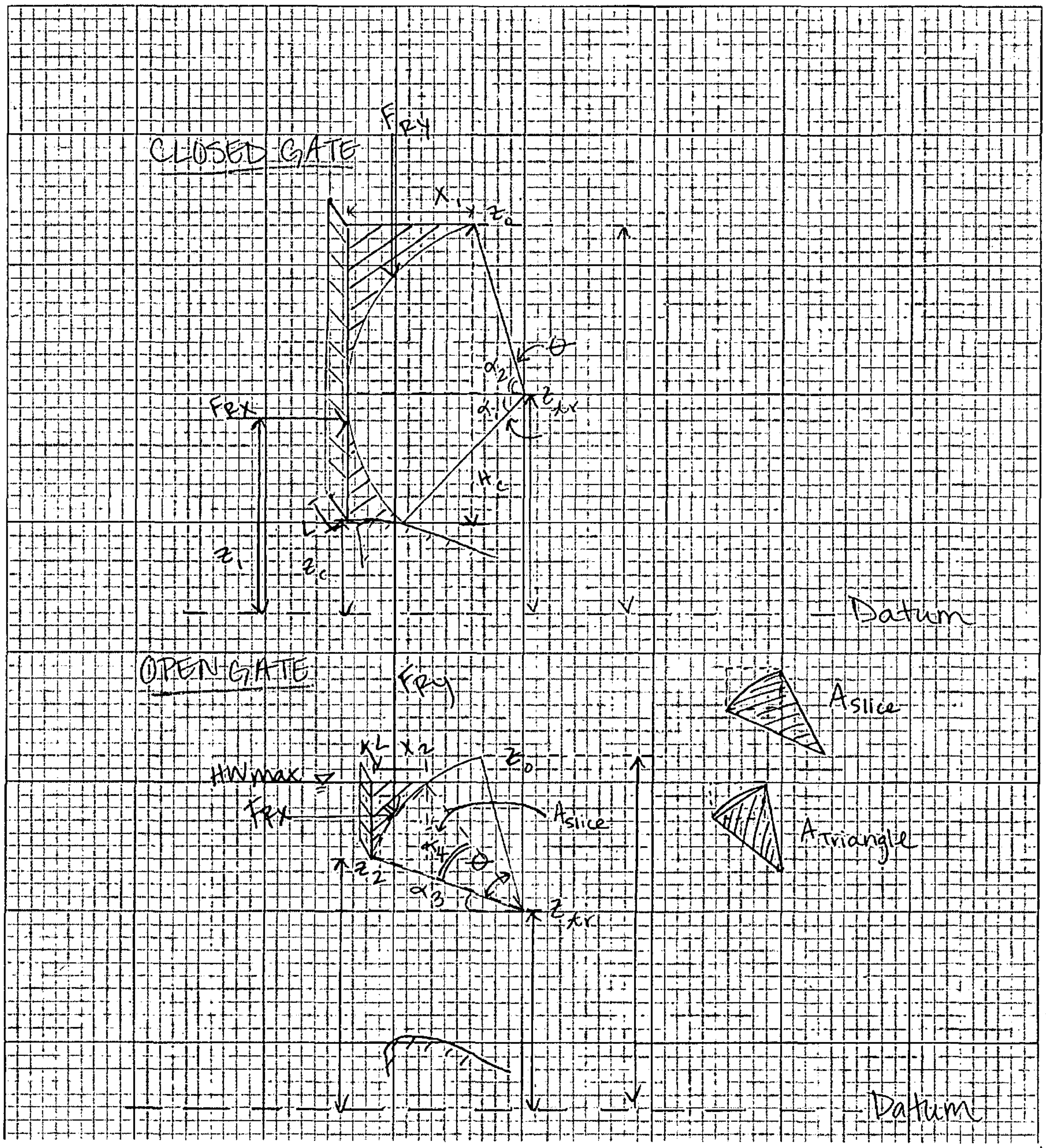
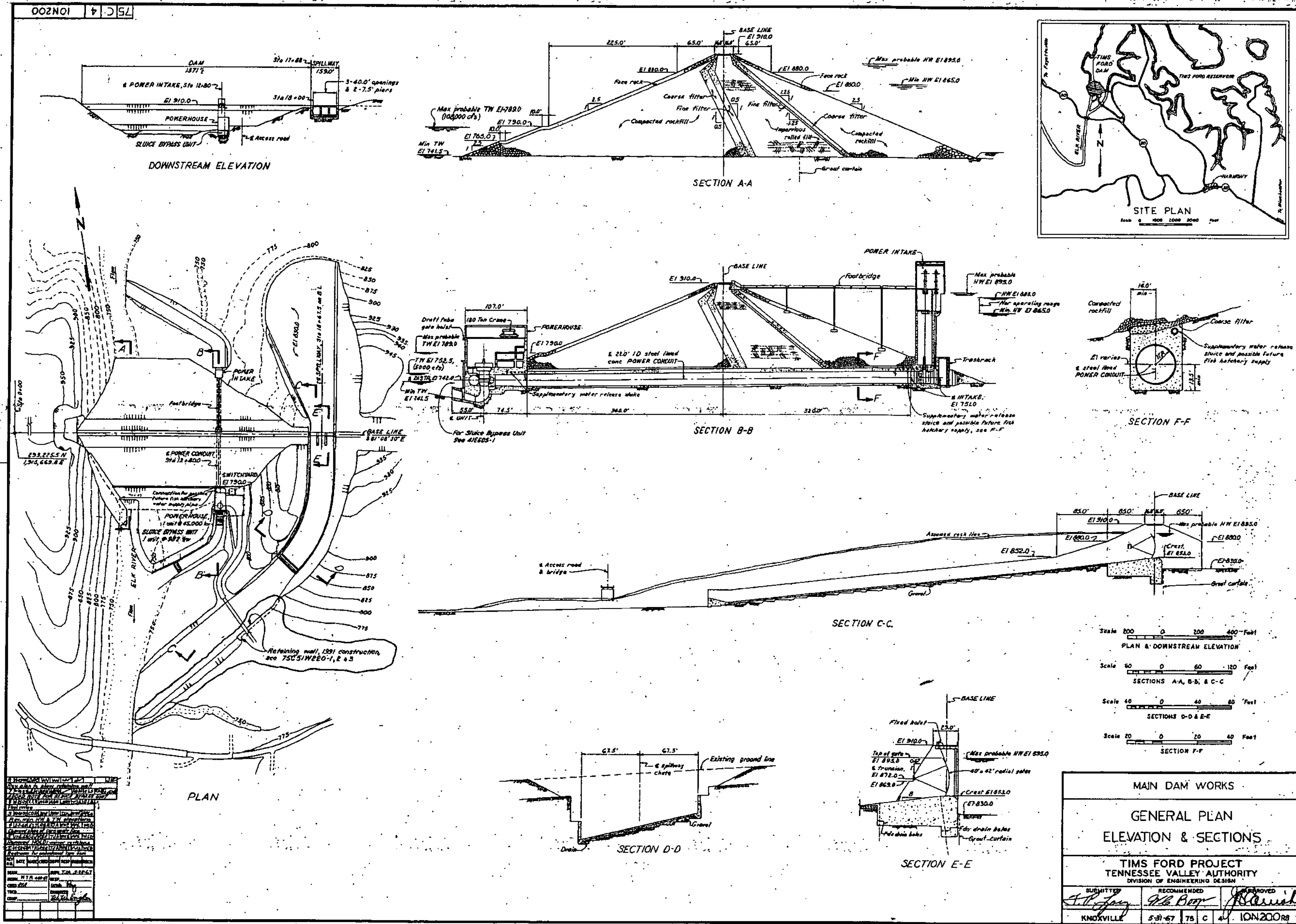


Figure C1: Definition Sketch for Hydrostatic Forces on Tainter Gates

Attachment 1



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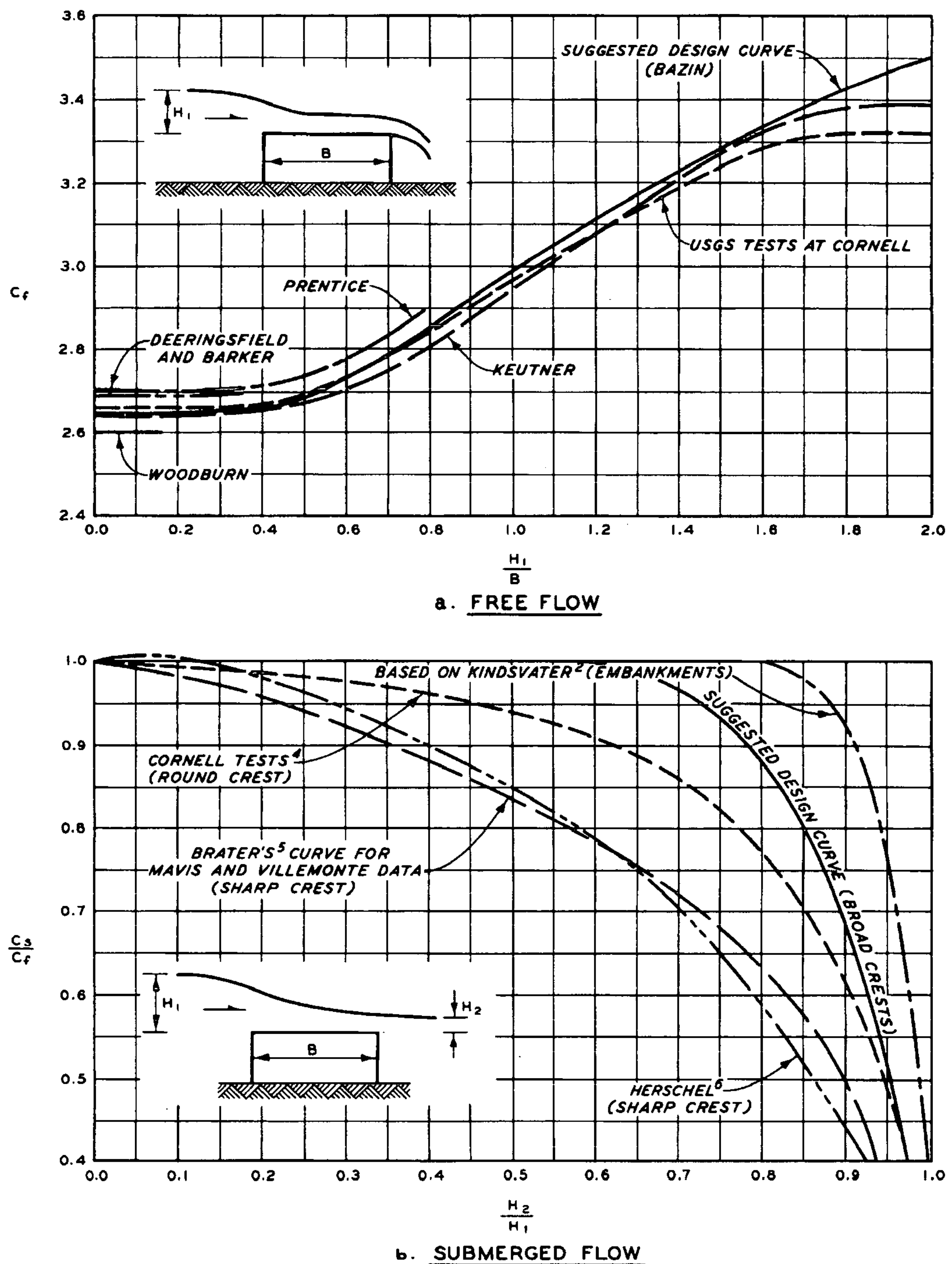

NOTE: C_f = FREE-FLOW COEFFICIENT
C_s = SUBMERGED-FLOW COEFFICIENT
NEGLIGIBLE VELOCITY OF APPROACH
RAISED NUMBERS ON SUBMERGED FLOW CHART ARE REFERENCE NUMBERS FROM TEXT.

LOW-MONOLITH DIVERSION

DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 711

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

WES 1-66

CDQ000020080022

Attachment 3

WR28-2-900-123

METHOD FOR ESTIMATING DISCHARGE AT OVERFLOW SPILLWAYS WITH CURVED CRESTS AND RADIAL GATES

TENNESSEE VALLEY AUTHORITY
OFFICE OF NATURAL RESOURCES AND ECONOMIC DEVELOPMENT
DIVISION OF AIR AND WATER RESOURCES
WATER SYSTEMS DEVELOPMENT BRANCH
NORRIS, TENNESSEE

Tennessee Valley Authority
Office of Natural Resources and Economic Development
Division of Air and Water Resources
Water Systems Development Branch

METHOD FOR ESTIMATING DISCHARGE AT OVERFLOW SPILLWAYS WITH CURVED CRESTS AND RADIAL GATES

Report No. WR28-2-900-123

Prepared by
E. Dean Harshbarger,
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Norris, Tennessee
January 1985

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INTRODUCTION

The discharge at overflow spillways is determined by the spillway width, spillway gate position, a representative head (or water depth), and a discharge coefficient. For rating purposes, the spillway width and head are usually specified and the discharge coefficient is determined from scale model tests. Most of the spillways for the Tennessee Valley Authority (TVA) dams were model tested at the TVA Engineering Laboratory.

The original development of specific TVA spillway discharge coefficients (Kirkpatrick, 1957; TVA, 1962) did not establish an orderly connection between the discharge characteristics of various spillways, and therefore, the data could not be directly applied to other installations. However, revised discharge coefficient curves which did establish usable relationships were developed (TVA, 1972) and were later augmented by additional model tests. Presently data from Apalachia, Boone, Fort Patrick Henry, Hales Bar, Hiwassee, Melton Hill, Nickajack, Watts Bar and Wheeler model tests are used to define discharge coefficients with respect to gate openings, headwater elevations and crest shapes. Using these relationships, the coefficients for installations of similar design may be obtained without model testing. Discharge coefficients for Normandy Dam (TVA, 1984) were determined in this manner.

This report describes the discharge coefficient relationships established by TVA and how they are used to compute spillway rating tables for similar spillway installations in lieu of model testing.

DISCHARGE CRITERIA

The major factors which influence the discharge coefficient are the position of the gate seal point with respect to the highest point of the spillway crest, the curvature (or shape) of the crest and the curvature of the gate. Although no systematic attempt has been made to determine the quantitative effect of these factors individually, the basic trend of the coefficient data has been established with respect to crest shape. The crest shapes were identified by their relative similarity to standard crests (Creager, 1950; Corps of Engineers, 1954; Bureau of Reclamation, 1960) which approximate closely the lower portion of a free jet issuing from a sharp-crested weir.

For each standard crest shape there is a corresponding head at which flow over the crest will not separate from the surface of the crest, but will conform exactly to the crest contours. This head is termed the "standard crest design head." The TVA spillway discharge coefficient relationships are based on normalized data from the nine spillway models tested, together with standard crest design heads determined by comparing the model crest shape with standard crests.

In given situations, if the flow over the spillway crest touches or impinges upon the gate, the discharge is computed using a formula for gated discharges. If the flow does not impinge upon the gate, the discharge is computed using a formula for free discharge.

Discharge coefficients were determined for gated and free discharge using spillway models consisting of three spillway bays placed across an open channel with uniform flow. The width of the channel corresponded to the distance between the centerlines of the end piers to include the effect of flow contraction around piers. These spillway crests approximate standard crests from a point near the upstream face of the spillway to a point downstream near the gate seal point. The gate seal point is usually located below the crest elevation on the downstream portion of the crest to prevent discharge jets from overshooting the spillway for small gate openings under high heads.

The discharge nappe was unrestricted due to low tailwater elevations in the model tests. Therefore, the spillway discharge coefficient relationships do not include the effects of tailwater submergence.

GATED DISCHARGE

At multipurpose reservoirs, spillway discharge is used to regulate reservoir water levels and downstream water flowrates.

Therefore various spillway gate positions are needed to provide a range of discharge rates for each headwater elevation. To release water, the gate is raised to a predetermined position which allows a prescribed discharge to pass over the spillway crest.

The gated discharge shown in Figure 1 is determined by the area of the opening under the gate, by the water velocity through the gate opening and by the discharge coefficient of the gate opening. The area is based on the vertical distance, G, between the gate bottom point and the spillway point directly below. The water velocity is a function of the acceleration due to gravity and the mean water depth over the gate opening, H_m, defined as the distance from the surface of the headwater to the gate opening mid-point.

The equation for gated discharge through one spillway bay is:

$$Q = C\,L\,G\sqrt{2g\,H_m} \qquad (1)$$

where

Q = discharge, ft^3/s

C = discharge coefficient, dimensionless

L = spillway bay width, ft

G = vertical gate opening, ft

g = acceleration due to gravity, ft/s^2

H_m = head on the vertical gate opening mid-point measured from the reservoir headwater elevation, ft

The discharge coefficients were developed as a function of vertical gate opening, standard crest design head, and headwater elevation as shown in Figures 2a and 2b. The general uncertainty of the gated discharge coefficient relationship is considered to be within ± 2 percent based on the maximum deviation from the average trend. At small vertical gate openings (i.e., less that two feet) the error may be greater (Kirkpatrick, 1972).

To use Figure 2a, the headwater elevation, HL_1, at which the spillway discharge touches, but does not impinge upon the spillway gate must be determined. Starting with the desired gate opening, G, and the standard crest design head, H_o, the ratio H_c/H_o can be determined from Figure 2b. Then HL_1 can be determined by using the equation:

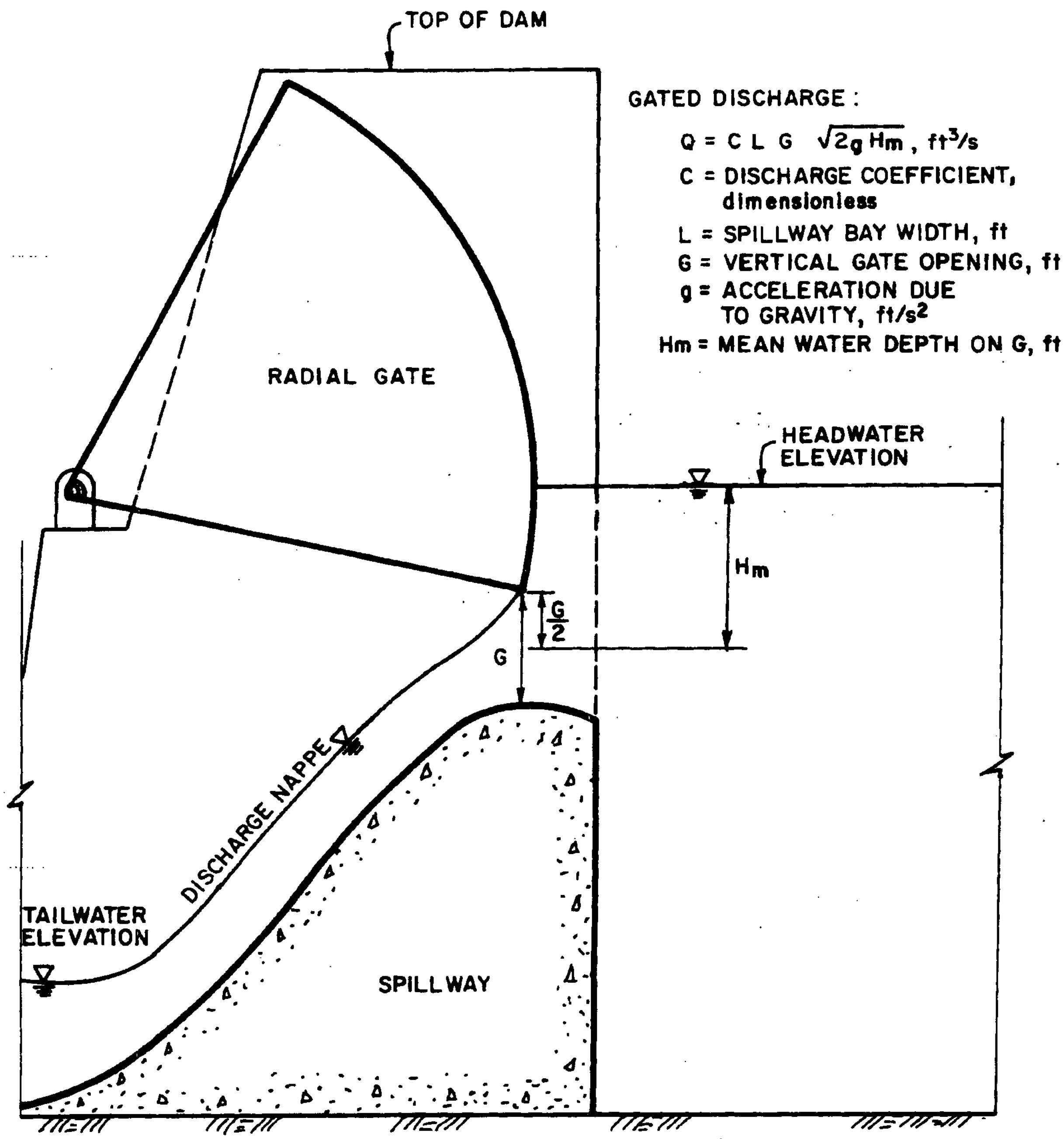

Figure 1: Gated Spillway Discharge

COEFFICIENTS

1. FOR $HL_1 \leq HL \leq HL_5$
   $C = f(G/H_o, HL)$
2. FOR $HL > HL_5$
   $C = f(G/H_o, HL_5)$

TRANSITION HEADWATER ELEVATIONS

$HL_1 = HL_{cr} + (H_c/H_o)\,H_o$
$HL_2 = HL_1 + 0.025\,H_o$
$HL_3 = HL_1 + 0.050\,H_o$
$HL_4 = HL_1 + 0.075\,H_o$
$HL_5 = HL_1 + 0.100\,H_o$

NOTE

HL_1 = HEADWATER ELEVATION AT WHICH SPILLWAY DISCHARGE TOUCHES BUT DOES NOT IMPINGE UPON THE GATE, ft
HL = HEADWATER ELEVATION, ft
H_o = STANDARD CREST DESIGN HEAD, ft
H_c = HEAD ON CREST, ft
HL_{cr} = CREST ELEVATION, ft
H_m = HEAD ON MID-POINT OF GATE OPENING, ft
G = VERTICAL GATE OPENING, ft
L = SPILLWAY BAY WIDTH, ft
g = ACCELERATION DUE TO GRAVITY, ft/s^2

REFERENCE DRAWINGS AEL 99 B105
AEL 99 B106

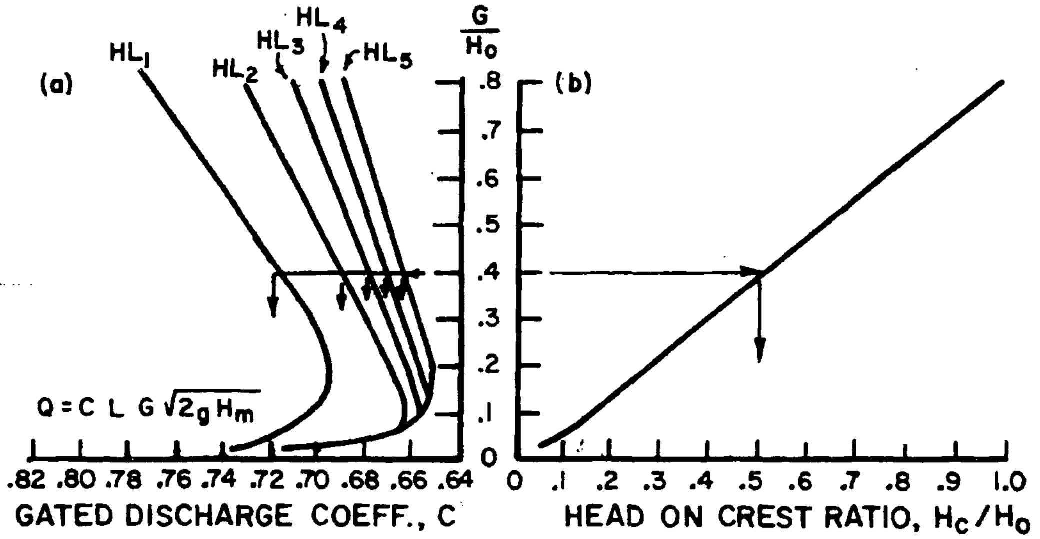

Figure 2: Gated Discharge Coefficients and Associated Headwater Elevations for Specified Gate Openings and Standard Crest Design Heads at Curved Spillways with Radial Gates

$$HL_1 = HL_{cr} + \frac{H_c}{H_o} H_o \qquad (2)$$

Where:

HL_1	=	headwater elevation at which spillway discharge touches but does not impinge upon the gate, ft
HL_{cr}	=	spillway crest elevation, ft
H_c	=	head on crest, ft
H_o	=	standard crest design head, ft
H_c/H_o	=	dimensionless ratio specified by G/H_o in Figure 2b

Once HL_1 is known, the discharge coefficients for higher headwater elevations can be determined as shown in Figure 2a. For transition headwater elevations HL_1 through HL_5 in Figure 2a, increased headwater elevation may not cause increased discharge and may even cause decreased flow because of flow contraction losses and friction losses resulting from increased water impingement upon the gate. At headwater elevations greater than HL_5 there is no significant increase in the various flow losses, and therefore the discharge coefficient is constant and equal to the discharge coefficient for headwater elevation HL_5. At small gate openings (say less than a foot), there may be little, or no transition and the discharge coefficients may be constant at some headwater elevation less than headwater elevation HL_5. The general uncertainty of the H_c/H_o vs G/H_o relationship is within ± 10 percent at small vertical gate openings and ± 2 percent at large openings based on the maximum deviations from the trend.

At headwater elevation HL_1, gated discharge is equal to free discharge described later in this report. However, due to the uncertainties of the discharge coefficient relationship and the H_c/H_o relationship to headwater elevation HL_1, either the gated discharge coefficient for headwater elevation HL_1 at large vertical gate openings or the headwater elevation HL_1 at small vertical gate openings may require adjustment as described later in this report to mathematically ensure gated discharge equivalent to free discharge.

In some cases, headwater elevation HL_1 may be the headwater elevation for maximum spillway discharge at the maximum vertical gate opening. This maximum spillway discharge elevation is critical in extreme flood control situations. Although the relationship between headwater HL_1 and the ratio H_c/H_o in Figures 2a and 2b is satisfactory for most spillway operations, deviations from the average trend are inherent due to variations in gate designs and locations. Other computation methods may have the same uncertainty because they require friction factors, kinetic energy factors, etc., that are best evaluated through individual model or prototype tests.

FREE DISCHARGE

Free spillway discharge occurs when water discharges freely through the vertical gate opening, as shown in Figure 3, without impinging on the gate. For each vertical gate opening, free discharge is limited by headwater elevation HL_1 previously described. The equation for free spillway discharge through a single spillway bay is:

$$Q = C\ L\ H_c^{3/2} \tag{3}$$

in which

Q = discharge, ft^3/s
C = discharge coefficient, dimensionless
L = spillway bay width, ft
H_c = head on crest measured from the reservoir headwater elevation, ft

This equation is similar to the general equation for weirs across open channels. The free discharge coefficient varies with the head on crest, H_c, shown in Figure 3, and with the standard crest design head. The relationship between discharge coefficients, head on crest, and the standard crest design head is shown in Figure 4. The uncertainty of the discharge coefficient relationship is within ± 1 percent based on the maximum deviation from the average trend (Kirkpatrick, 1972).

GATE ARRANGEMENTS AND IDENTIFICATION

Gate opening arrangement, or the pattern of open gates across the spillway is important at installations with several spillway bays and

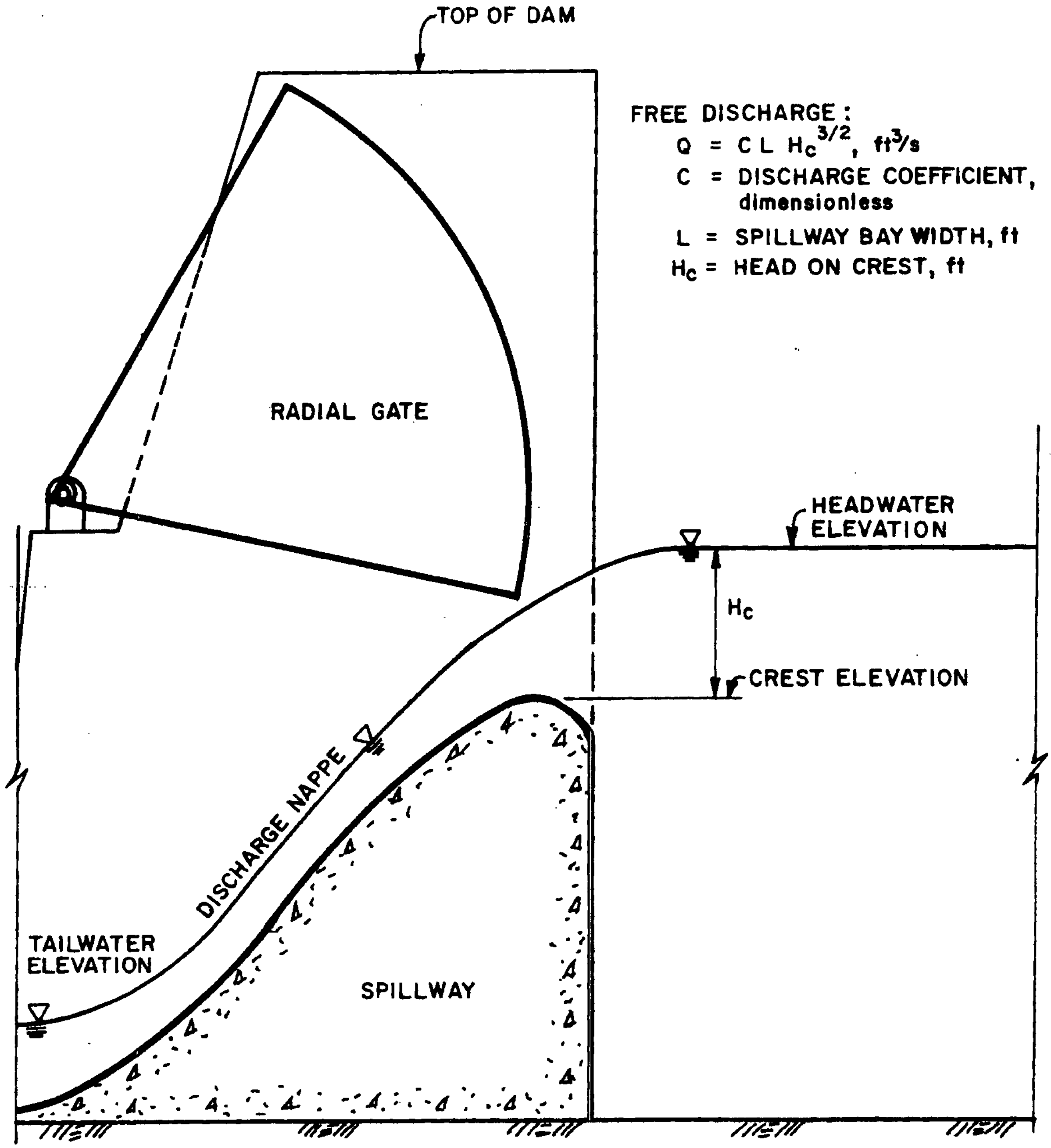

Figure 3: Free Spillway Discharge

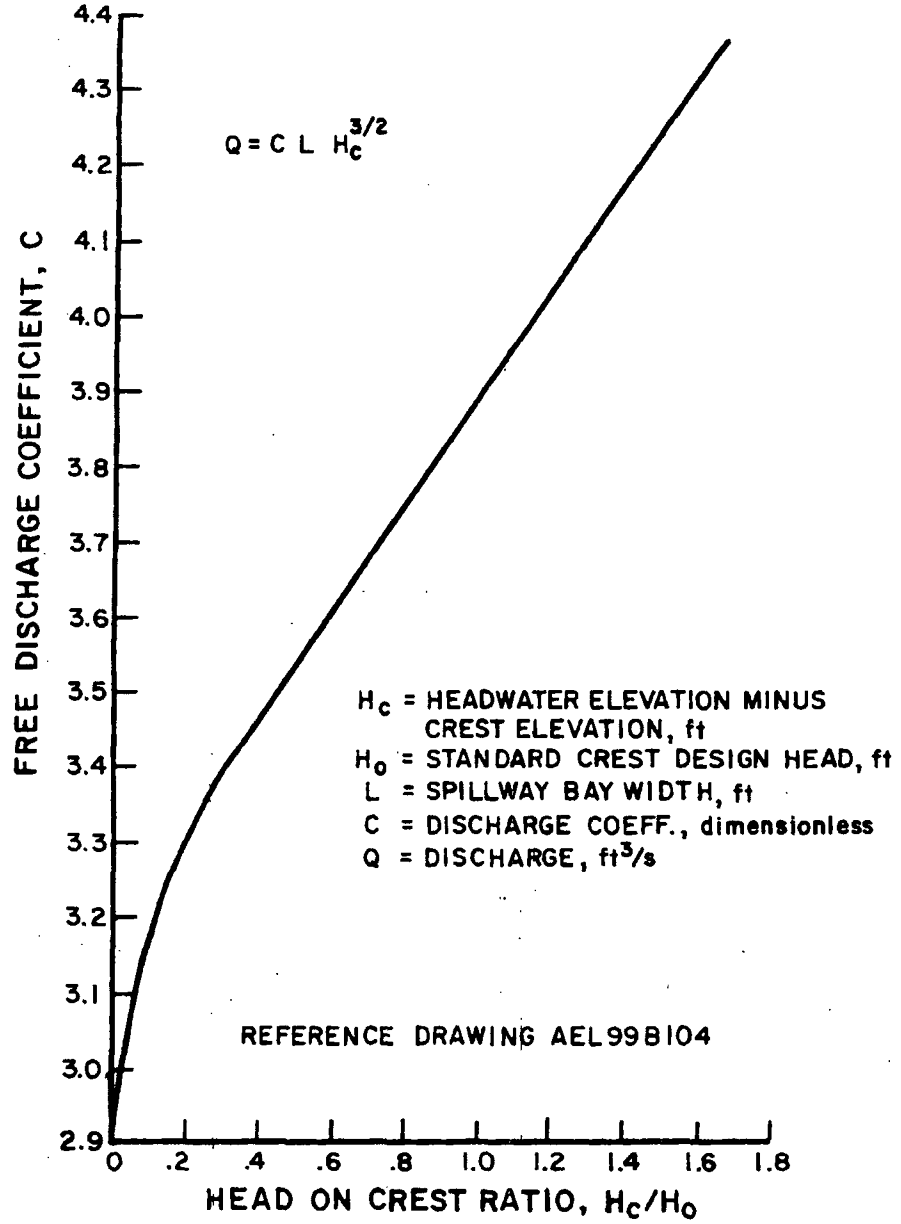

Figure 4: Free Discharge Coefficients for Specified Headwater Elevations and Standard Crest Design Heads at Curved Spillways

gates. Some gate opening arrangements will produce flow patterns in the stilling basin that are hazardous to the structural stability of the dam and stilling basin and to navigation downstream.

In practice, each gate is assigned an identification number and a diagram showing the spillway gate number and location is included in the spillway rating tables. For a given flow and headwater elevation, the gates to be opened and the required amount of opening to obtain the given flow are identified by a specific gate arrangement number. Increasing gate arrangement number indicates increasing flow.

RATING TABLES

Spillway rating tables are used for daily water control operations and water control planning. For each gate arrangement number, discharge rates are listed as a function of headwater elevation. At multiple gate spillways, the listed discharge represents the total discharge for the gate positions prescribed in the table of gate arrangements. The primary purpose of the spillway rating table is to determine the appropriate gate opening arrangements required to pass the listed discharge for the given headwater elevation. The alternate use is to determine the discharge for a given gate arrangement and headwater elevation.

Only discrete discharge rates are listed in the rating table. In the event that a preferred rate is not listed, the rate nearest to it should be used to minimize gate arrangement adjustments and to avoid using gate arrangements not authorized in the rating table.

The TVA discharge coefficient relationships can be used in lieu of calibration data to prepare rating tables for spillways that meet conditions of geometric similitude and have an established table of gate arrangements. Seven major parameters must be evaluated for each spillway rating.

1. <u>Standard crest design head</u>: determined by crest shape.
2. <u>Vertical gate openings</u>: determined by gate positions.
3. <u>Gated discharge headwater elevations</u>: determined for each gate opening by the relationships in Figures 2a and 2b for

transitional headwater elevations based on headwater elevation HL_1. Note adjustment listed in (4) below for headwater elevation HL_1.

4. Gated discharge coefficients: with minor adjustments, they are determined for each vertical gate opening and headwater elevation by the relationships in Figure 2a. At headwater elevation HL_1, the gated discharge must be equivalent to free discharge. However, due to the uncertainties of the discharge relationships, the gated and free discharge equations may not converge. In this case, the gated discharge coefficient is adjusted so that the gated discharge from equation (1) is equal to the free discharge from equation (3). Also the adjusted gated discharge coefficient at headwater elevation HL_1 must not be less than the constant gated discharge coefficient at headwater elevation HL_5. If the coefficient must be readjusted to be equal to the constant coefficient, headwater elevation HL_1 must be adjusted also by using equations (1) and (3) which are solved iteratively to establish headwater elevation HL_1 for equivalent discharges.

   After adjustment, the coefficients are plotted as a function of transitional headwater elevation. An average, monotonically-decreasing curve is drawn to pass through the maximum and minimum coefficient points to define interpolated coefficients in the transitional headwater range. For headwaters greater than the transitional headwaters, the discharge coefficient is constant and equal to the minimum coefficient. At small gate openings, the interpolated coefficients may be equal or they may become equal at some headwater within the transitional headwater range.

5. Free discharge coefficients: determined for each crest elevation and headwater elevations less than, or equal to headwater elevation HL_1, by the relationship in Figure 4.

6. Adjacent gate effect: the discharge coeffieients include the effect of flow contraction around spillway piers when the gate

openings for adjacent bays are equal. Although reduced discharge occurs due to contractions at piers between adjacent gates with dissimilar gate openings (Kirkpatrick, 1957), the reduction is not significant when compared with the accuracy of discharge coefficient relationships where interior adjacent gate openings do not vary more than one position. At end gates, the dam abutment may have the same effect as a closed gate. Where the abutment approximates one gate, the estimated end gate discharge reduction varies from one percent at median gate positions to three percent at the maximum gate position. If the approach channel corresponds to the spillway end piers, there is no discharge reduction.

7. Overtopping discharge: the spillway discharge coefficent relationships cannot be used to estimate discharge over the gates or over the dam. At small gate openings, the top of the gate elevation may be lower than the top of the dam elevation and, therefore, gated discharge headwater elevations must not exceed the top of the gate elevation in discharge calculations for small gate openings.

A representative discharge rating curve for one gate is shown in Figure 5. Some, or all, gates at a particular dam may have identical discharge characteristics at all gate positions and will have duplicate discharge rating curves. Discharge rates for each gate arrangement are determined by summing individual rates according to the prescribed gates, gate positions, and headwater elevations for each gate arrangement number. The spillway rating table normally lists discharge rates to the nearest 10 cubic feet per second for rates less than 100,000 and to the nearest 100 cubic feet per second at higher rates.

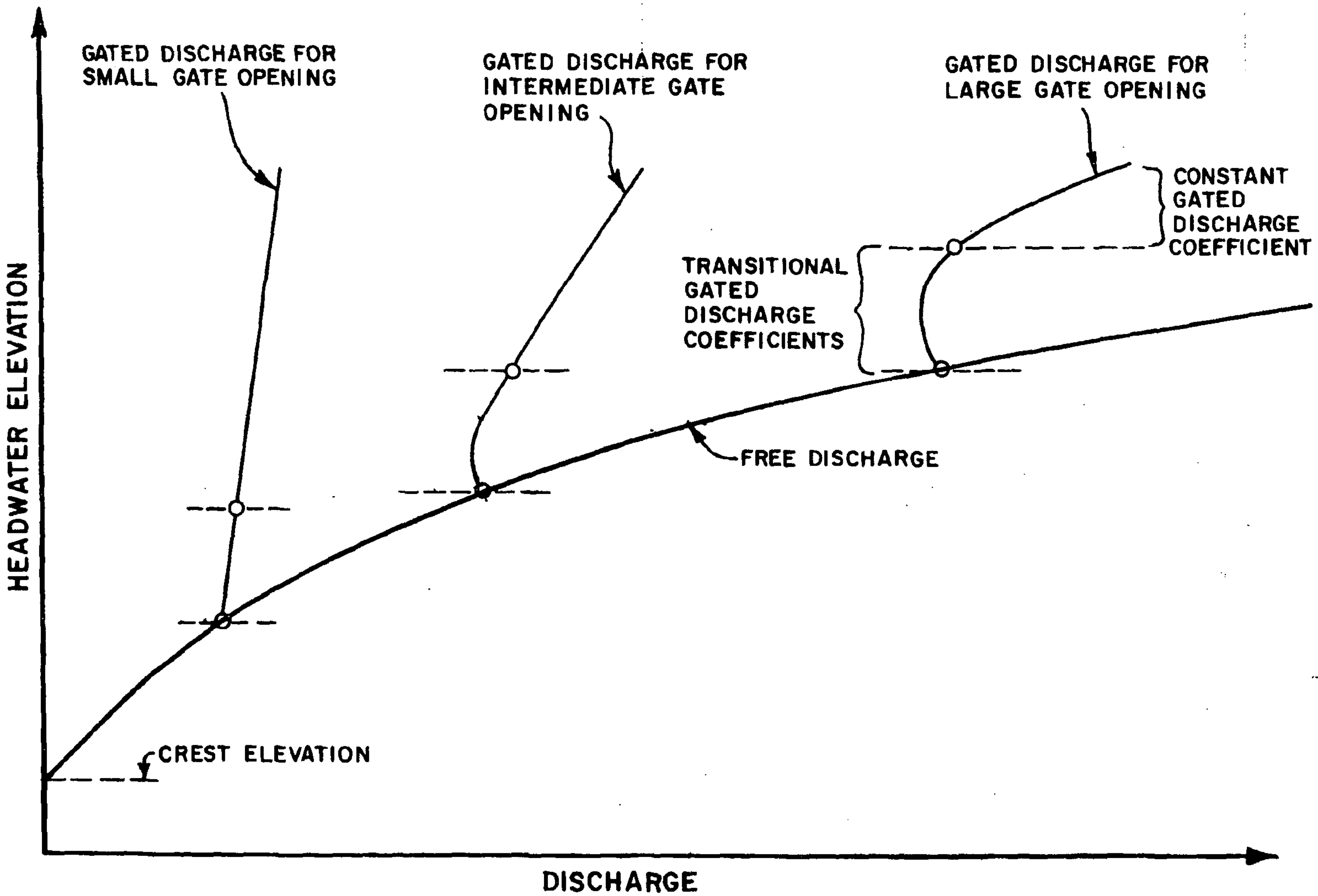

Figure 5: Representative Discharge Curve for a Radial Gate Over a Curved Spillway

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Attachment 4

TIMS FORD DAM

July 1999

RESERVOIR OPERATION OVERVIEW

Tims Ford is a multipurpose tributary project located on the Elk River in central Tennessee. Tims Ford provides flood protection for downstream locations on the Elk River, generates hydropower, and provides water supply. Part of the original authorization for Tims Ford was recreation, and to accommodate this objective, a minimum recreation pool is maintained through October 15 each year, and hydro operations during much of the year are adjusted to accommodate downstream recreation to the extent practicable. Tims Ford was also TVA's first hydroelectric facility retrofitted with a small generating unit for the purpose of maintaining instantaneous downstream minimum flows. The average annual planned pool fluctuation is about 18 feet.

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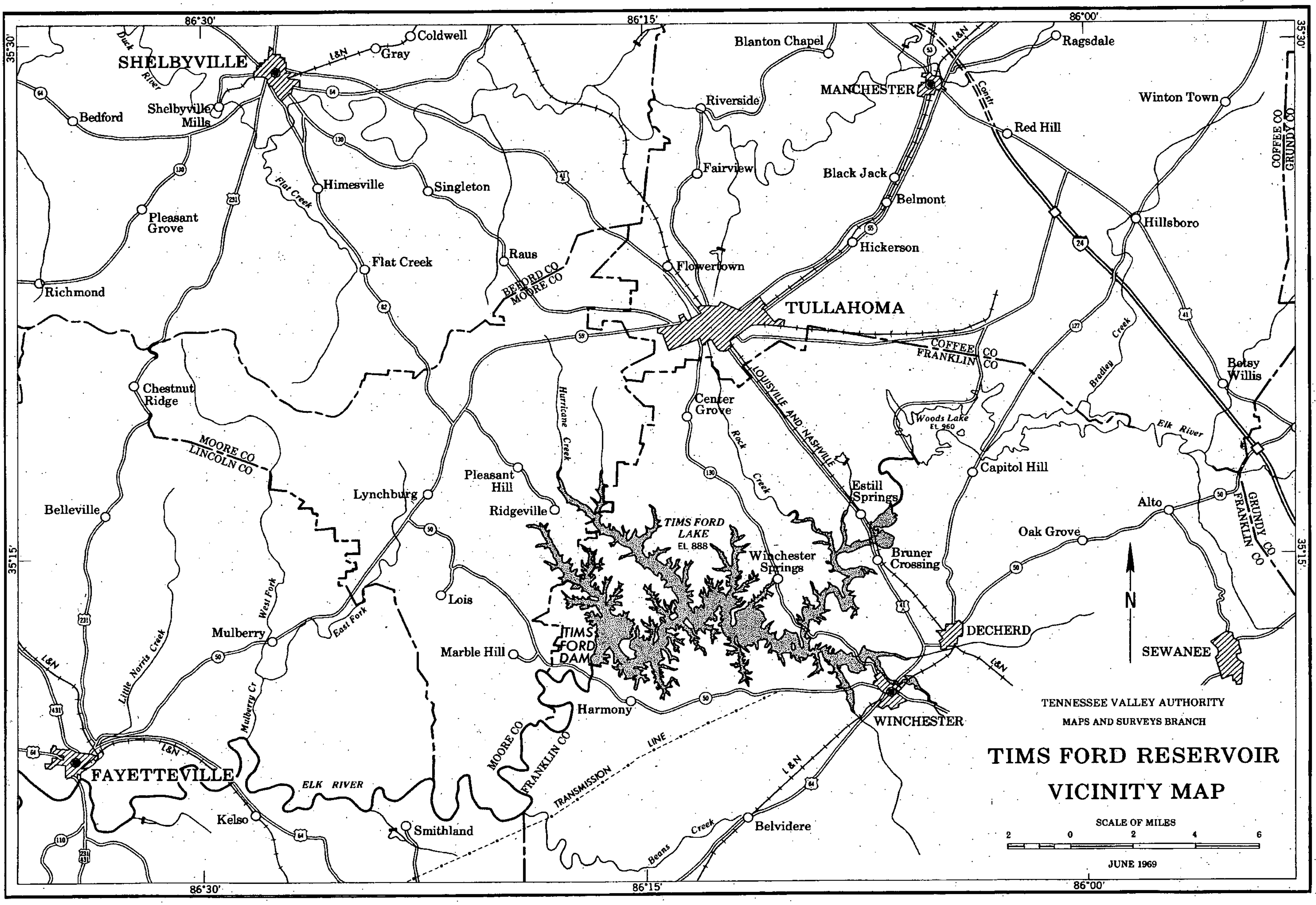

TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
TIMS FORD RESERVOIR
VICINITY MAP
SCALE OF MILES
2 0 2 4 6
JUNE 1969
SHELBYVILLE
TULLAHOMA
MANCHESTER
FAYETTEVILLE
WINCHESTER
DECHERD
SEWANEE
TIMS FORD LAKE
EL 888
TIMS FORD DAM
ELK RIVER
Elk River
Woods Lake
EL 960
TRANSMISSION LINE
LOUISVILLE AND NASHVILLE
BEDFORD CO
MOORE CO
LINCOLN CO
FRANKLIN CO
COFFEE CO
GRUNDY CO
Coldwell
Gray
Blanton Chapel
Ragsdale
Bedford
Shelbyville Mills
Riverside
Winton Town
Red Hill
Fairview
Black Jack
Belmont
Himesville
Singleton
Pleasant Grove
Hillsboro
Hickerson
Raus
Flowertown
Flat Creek
Richmond
Chestnut Ridge
Betsy Willis
Center Grove
Capitol Hill
Estill Springs
Pleasant Hill
Lynchburg
Ridgeville
Belleville
Alto
Oak Grove
Bruner Crossing
Winchester Springs
Lois
Mulberry
Marble Hill
Harmony
Kelso
Smithland
Belvidere
Hurricane Creek
Rock Creek
Bradley Creek
Beans Creek
Little Norris Creek
Mulberry Cr
West Fork
East Fork
Duck River
Flat Creek
N
86°30'
86°15'
86°00'
35°30'
35°15'

FIGURE 1 - Site Plan

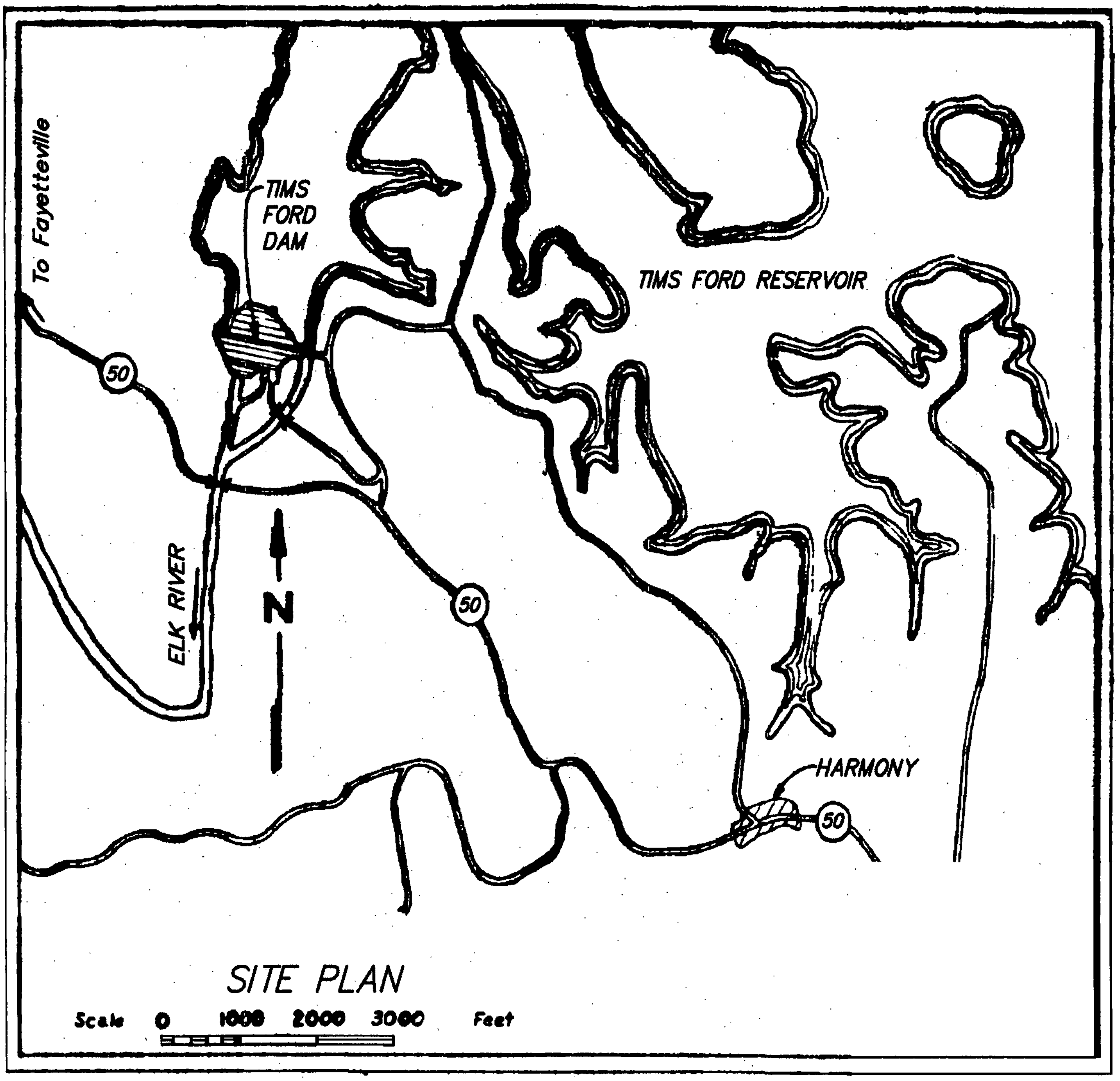


FIGURE 2 - Plan and Downstream Elevation

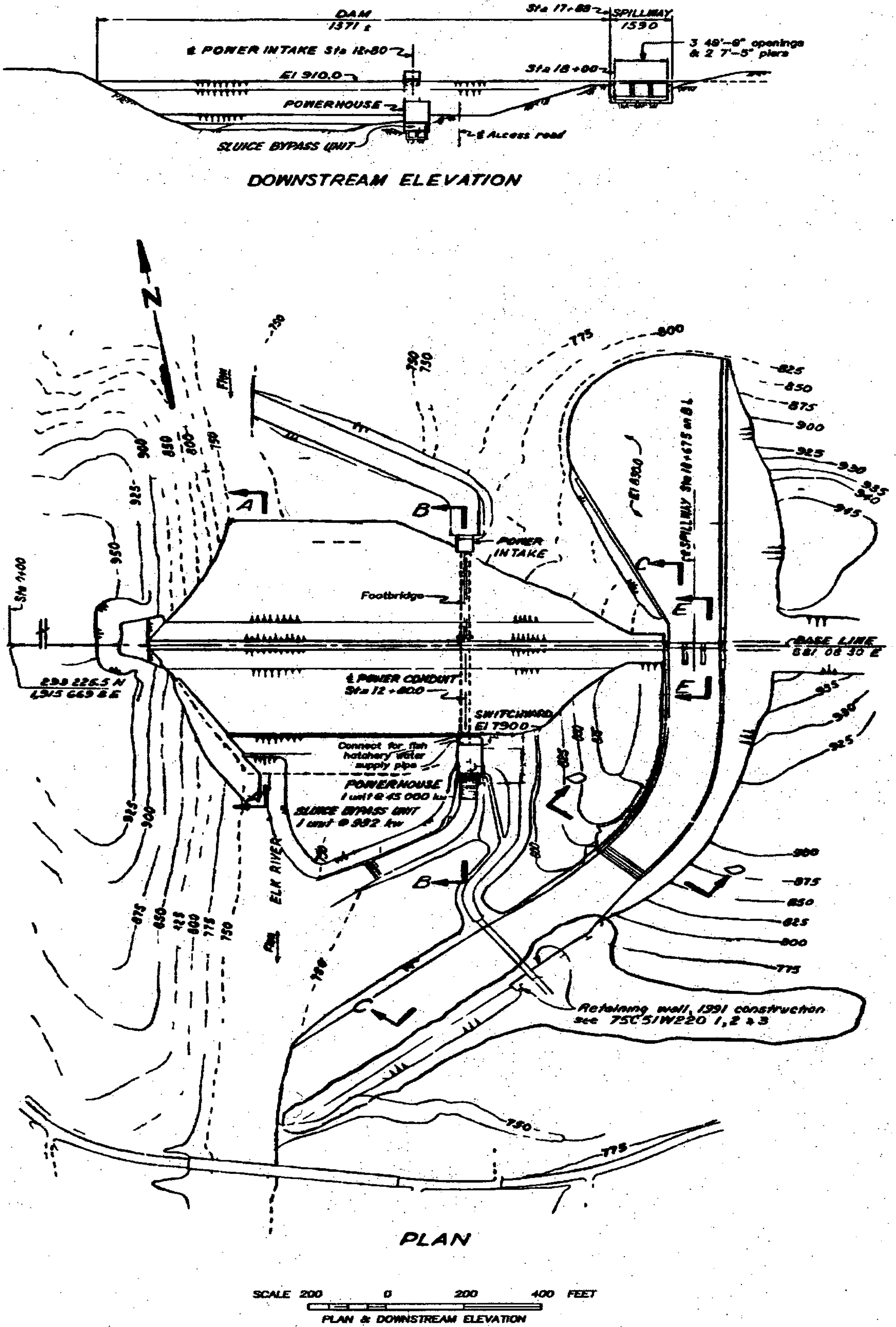


FIGURE 3 - Section A-A

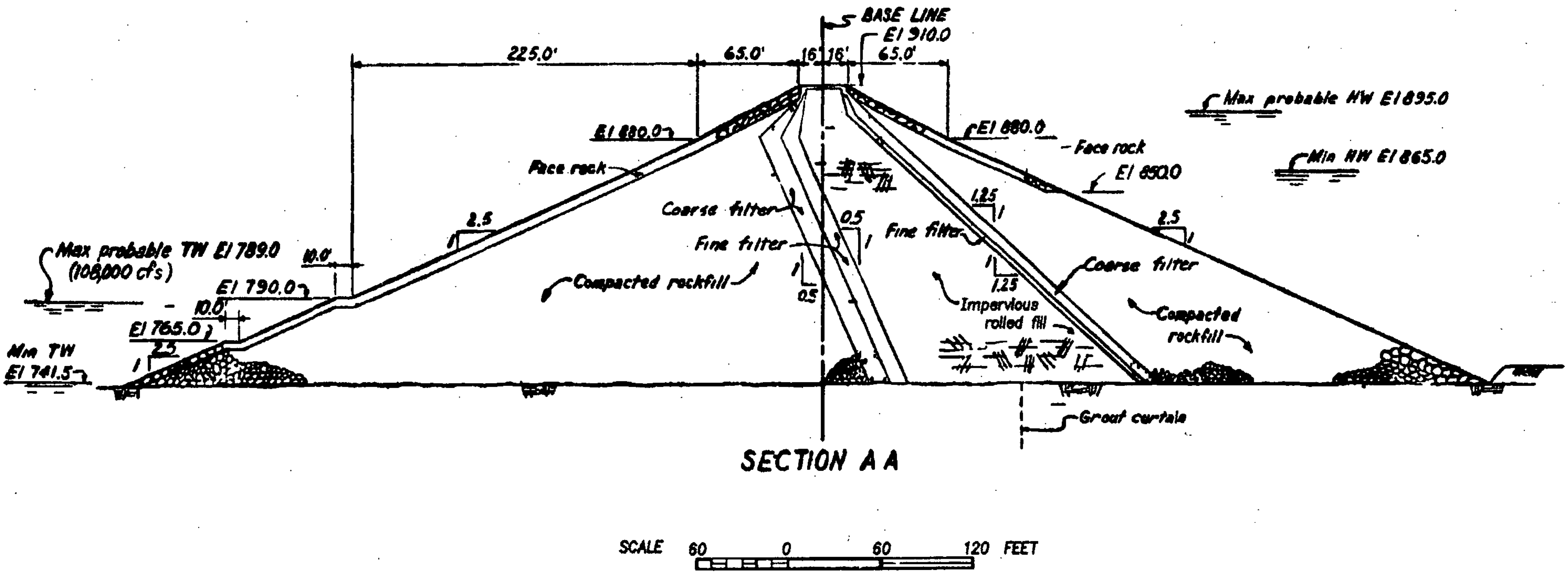


FIGURE 4 - Section B-B

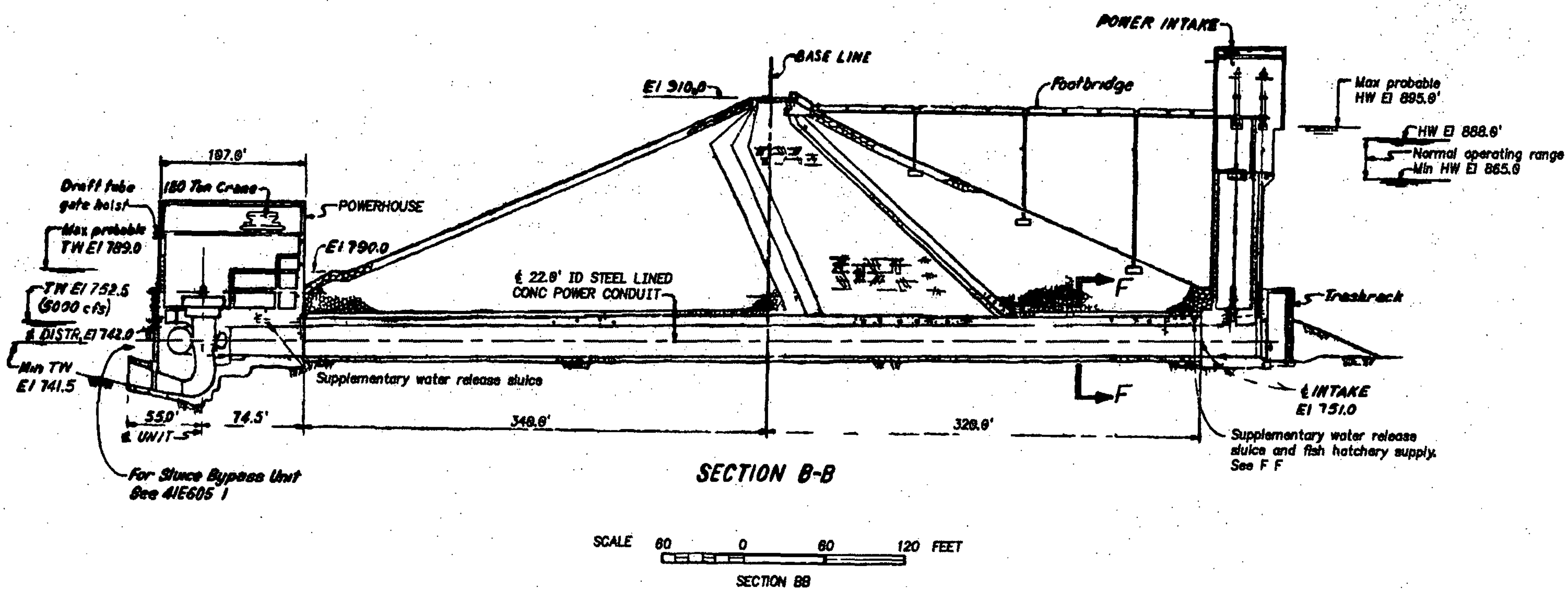
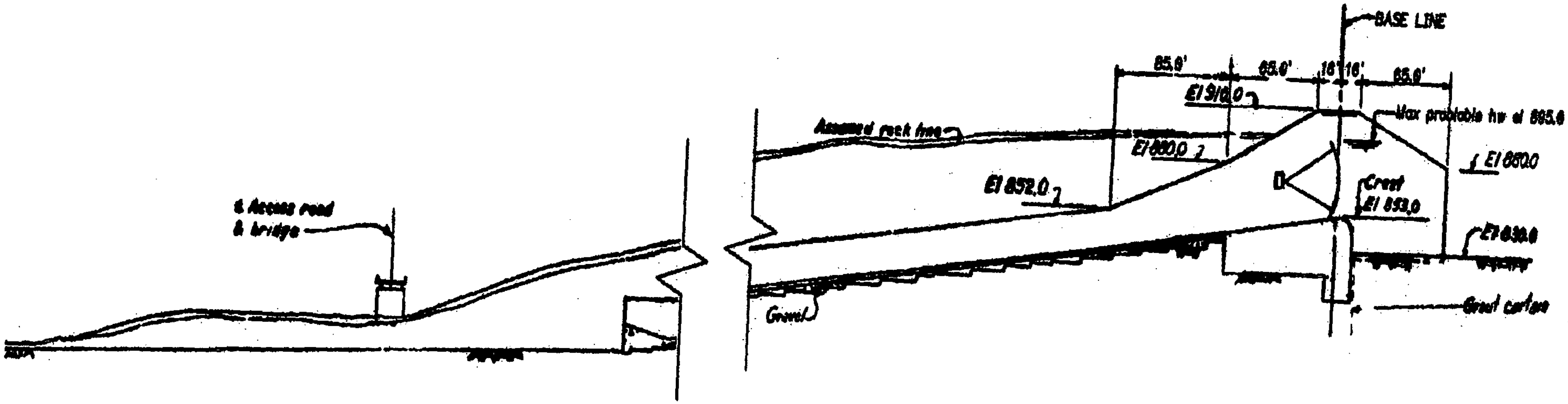


FIGURE 5 - Section C-C

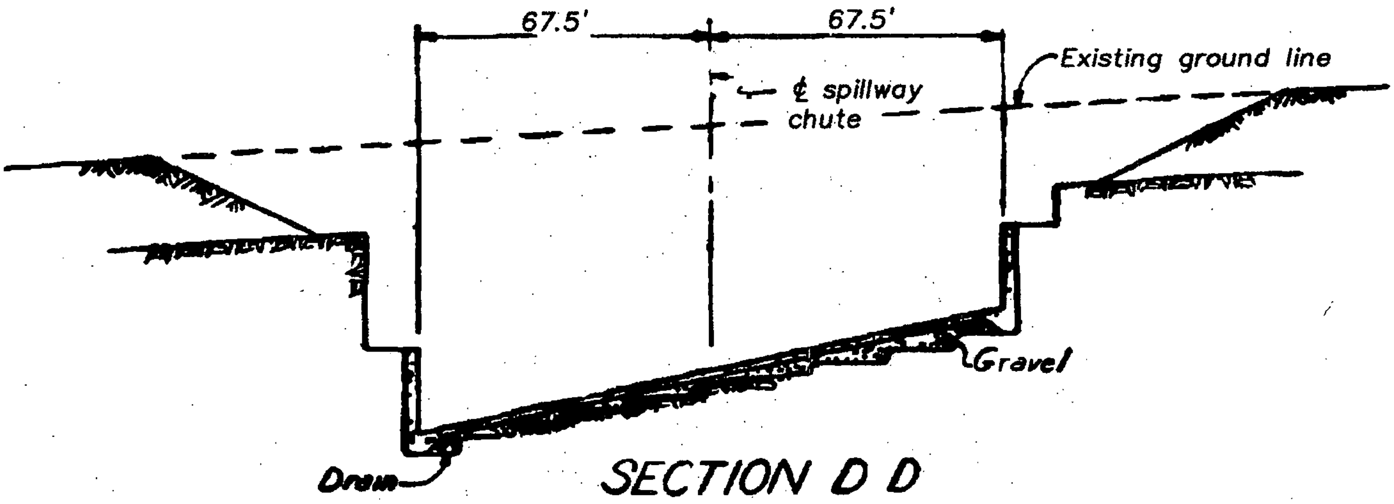


SECTION C C

SCALE 60 0 60 120 FEET

SECTION CC

FIGURE 6 - Sections D-D and E-E



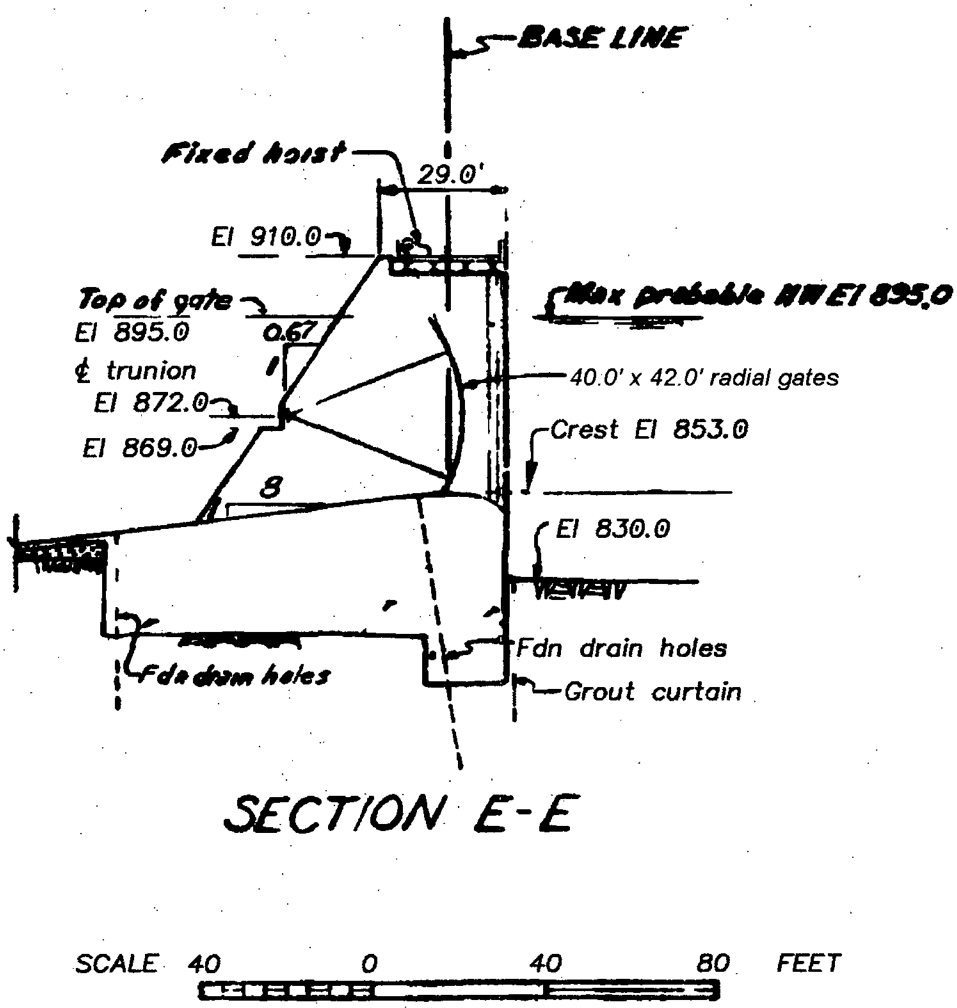
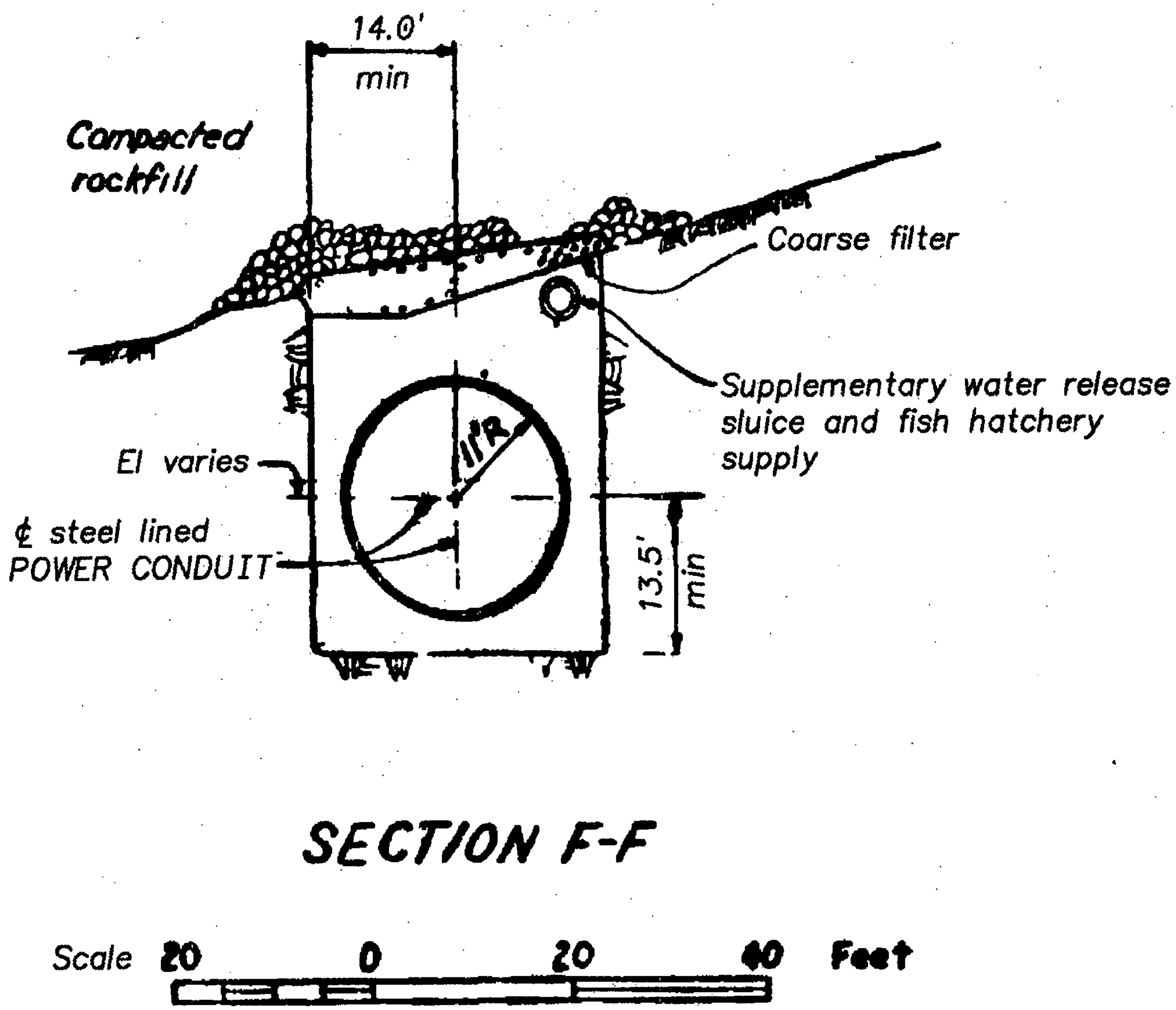


FIGURE 7 - Section F-F



TIMS FORD PROJECT

SUMMARY OF PRINCIPAL FEATURES

LOCATION

On Elk River at river mile 133.3, in Franklin County, Tennessee; 36.7 river miles downstream from Elk River Dam (AEDC); 10 air miles west of Winchester, Tennessee, and 17 air miles east of Fayetteville, Tennessee.

CHRONOLOGY

Exploration of site started........................ September 5, 1963
Initial appropriation by Congress.................... October 28, 1965
Authorized by TVA Board of Directors................ December 16, 1965
Construction started.................................... March 28, 1966
Dam closure.. December 1, 1970
Power unit in commercial operation...................... March 1,1972
Reservoir Release Improvements completed.................. March 1992

PROJECT COST

Initial Project, Including 1 Unit and Switchyard.......... $52,277,635
Reservoir Release Improvements........................... $2,000,000
Total.. $54,277,635

STREAMFLOW

Drainage area at dam:
Total... 529 sq miles
Uncontrolled (below Elk River Dam).................. 266 sq miles
Gaging station discharge records (for complete records see Data Services Branch files):
Near Estill Springs, Tennessee, October 1966 to date;
drainage area....................................... 275 sq miles
At Estill Springs, Tennessee, October 1920 to June 1967;
drainage area....................................... 282 sq miles
At Tims Ford Dam, Tennessee, December 1967 to December 1970;
drainage area....................................... 529 sq miles
Below Tims Ford Dam, Tennessee, April 1966 to date;
drainage area....................................... 534 sq miles
Above Fayetteville, Tennessee, August 1934 to date;
drainage area....................................... 827 sq miles
Near Fayetteville, Tennessee, October 1925 to September 1934;
drainage area....................................... 897 sq miles
Maximum flood of record at dam site,
estimated (March 1929)................................ 30,000 cfs

STREAMFLOW (CONT.)

Maximum probable flood, regulated........................ 108,000 cfs
Average unregulated flow at dam site,
estimated (1921-1969).. 890 cfs
Minimum daily natural flow at dam site
(September 9, 1931), approx.................................. 62 cfs

RESERVOIR

Counties affected: State of Tennessee............ Moore and Franklin
Reservoir land at July 2, 1999:
Fee simple.. 14,584 ac
Easements.. 756 ac
Total *.. 15,340 ac
Transferred... 35 ac
Operating levels at dam:
Probable maximum flood elevation (PMF)................ El. 908.8
500 year flood elevation .... El. 894.2
100 year flood elevation .... El. 893.3
Winter flood guide level.............................. El. 860.0
Summer flood guide level.............................. El. 888.0
Maximum used for design .... El. 895.0
Backwater, length at El. 888:(normal max.) .... 34.2 miles
Shoreline, length at El. 888: Main shore.................... 241 miles
Islands........................ 5 miles
Total.......................... 246 miles
Original river area (El. 895).................................. 565 ac.
Storage (flat pool assumption):
Total volume :
At top of gates (El.895) .... 608,000 ac-ft
At normal maximum pool (El.888)................ 530,000 ac-ft
At normal minimum pool (El.865)................ 325,400 ac-ft
Reservation for flood control on:
January 1 (El. 895-873)........................ 219,600 ac-ft
March 15 (El. 895-879)......................... 167,300 ac-ft

* In addition, 15,572 acres are owned by the Tennessee Elk River Development Agency.

TAILWATER

Maximum level used for design (108,000 cfs)................ El. 789.0
Maximum probable flood, regulated.......................... El. 789.0
Maximum level of record prior to construction
of dam (March 1929).. El. 768.0
Average level with powerhouse operating.................... El. 752.0
Minimum operating level.................................... El. 751.0

Minimum level .... El. 740.3.0

HEAD (gross)

Maximum static (El. 895-744)	151 ft
Normal maximum operating (El. 888-751)	137 ft
Average operating	130 ft
Minimum operating (El. 895-789)	106 ft

RESERVOIR ADJUSTMENTS

Land required	21,383 ac
Land clearing	4085 ac
Highways adjusted:	
Access	1.6 miles
State	3.4 miles
County and tertiary	25.4 miles
City Streets	1.4 miles
Total	31.8 miles
Railroad adjustments:	
Slope protection	0.2 mile
Signal and communication lines	0.1 mile
Bridge , highway (8 in reservoir , 1 over spillway channel)	9
Concrete box culverts	9
Families relocated	215
Utilities adjusted or relocated	131 miles*
Graves	318

*Includes power, transmission, and telephone lines and water, sewer, and gas pipelines.

DAM

Material and type:	
Embankment	Compacted rock fill with upstream sloping impervious earth core
Spillway	Concrete
Lengths:	
Embankment	1421 ft
Spillway	159 ft
Total	1580 ft
Maximum height	175 ft, embankment section
Maximum width at base	897 ft, embankment section
Top of embankment	El. 910
Top width of embankment	32 ft
Roadway	For maintenance only

OUTLET FACILITIES

SPILLWAY

Location. Left side of main embankment near left abutment (See Fig. 8)
Type................ Concrete weir and chute with 3-bay gated spillway
Clear opening (3 openings at 40 ft)........................... 120 ft
Crest level.. El. 853.0
Crest gates........ 40 ft-wide by 42-ft-high radial gates (See Fig. 9)
Chute (curved):
    Length........................ 735 ft on centerline (See Fig. 10)
    Width... 135 ft
    Height... 20 ft
Gate hoists........................ Three 72-ton-capacity fixed hoists
Discharge capacity, HW El. 895........................... 108,000 cfs

RIGHT RIM LEAKAGE REPAIRS

The grouting of the Reservoir's right rim was completed in 1998. Hydro Engineering initiated a remedial project at the right rim to address increases in rim leakage. This remedial project, construction of a grout curtain along the right rim, successfully reduced rim leakage from nearly 8000 gallons per minute (gpm) to less than 300 gpm in 1998 (see attached graph on page 17).

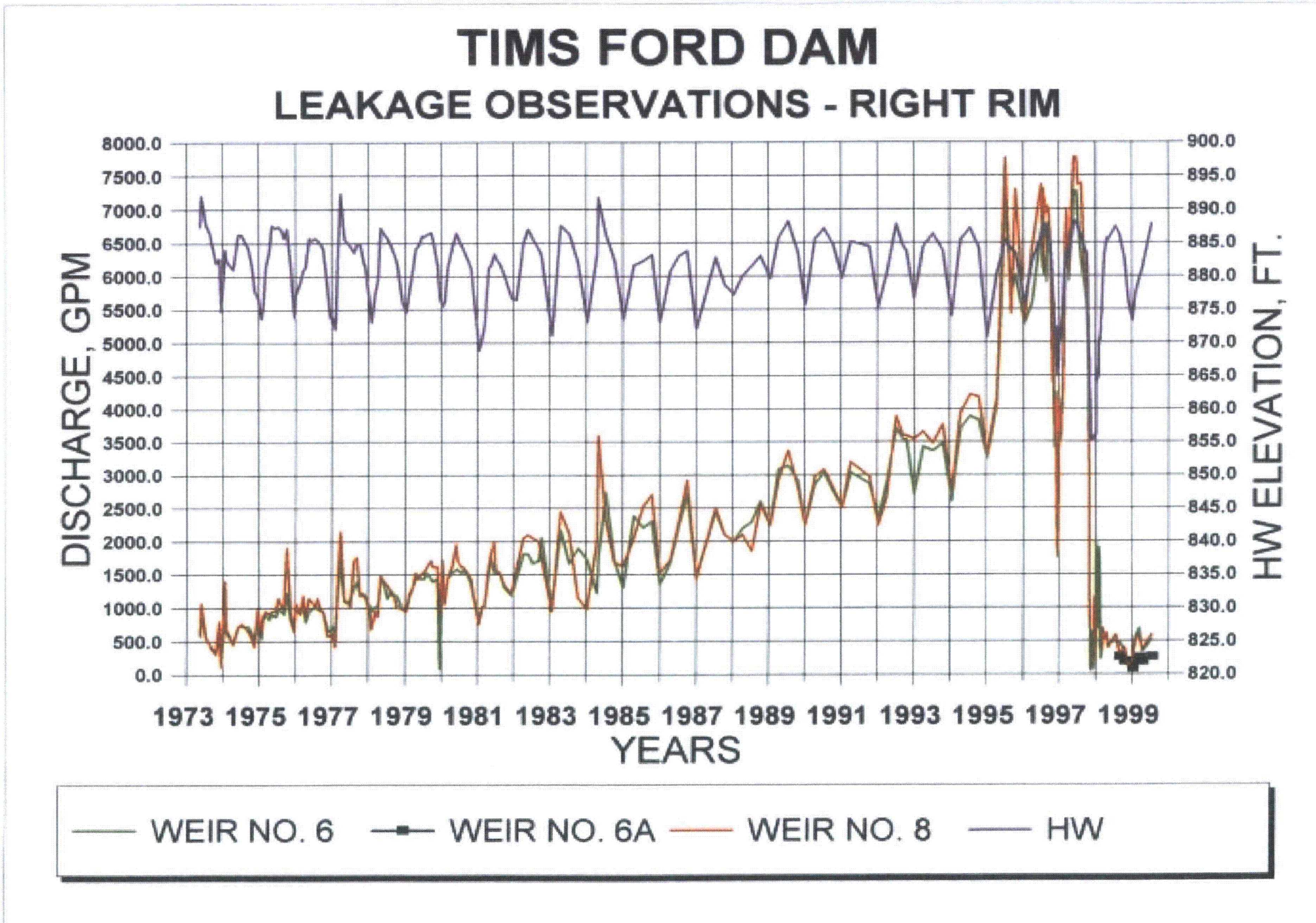

TIMS FORD DAM
LEAKAGE OBSERVATIONS - RIGHT RIM
DISCHARGE, GPM
8000.0
7500.0
7000.0
6500.0
6000.0
5500.0
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
HW ELEVATION, FT.
900.0
895.0
890.0
885.0
880.0
875.0
870.0
865.0
860.0
855.0
850.0
845.0
840.0
835.0
830.0
825.0
820.0
1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999
YEARS
WEIR NO. 6
WEIR NO. 6A
WEIR NO. 8
HW

FIGURE 8 - Spillway Gates Looking Downstream, July 1999

FIGURE 9 - Spillway - Upper End Looking Upstream, July 1999

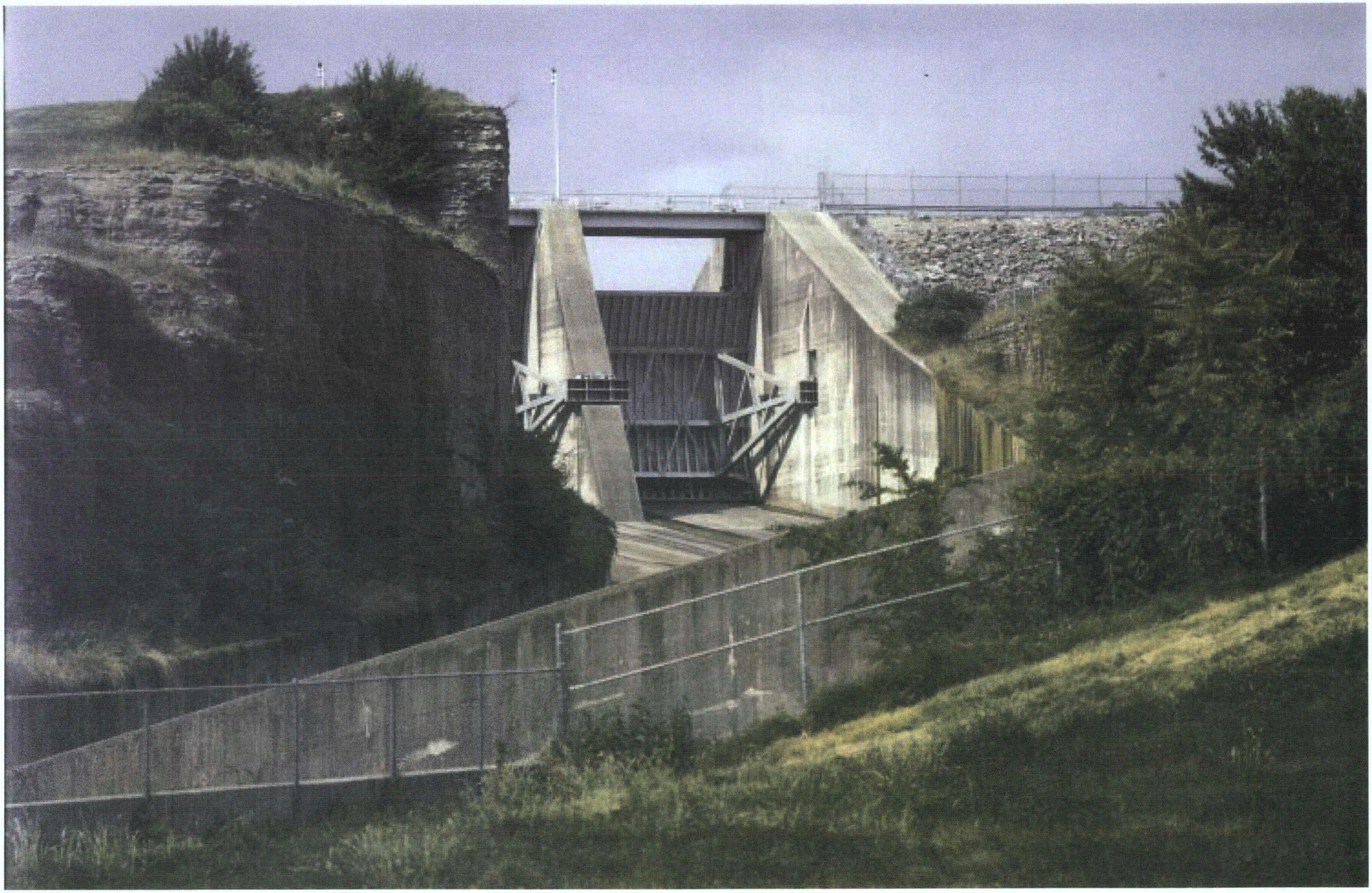


FIGURE 10 - Spillway - Lower End Looking Upstream, July 1999

OUTLET FACILITIES (CONT.)

SLUICEWAY

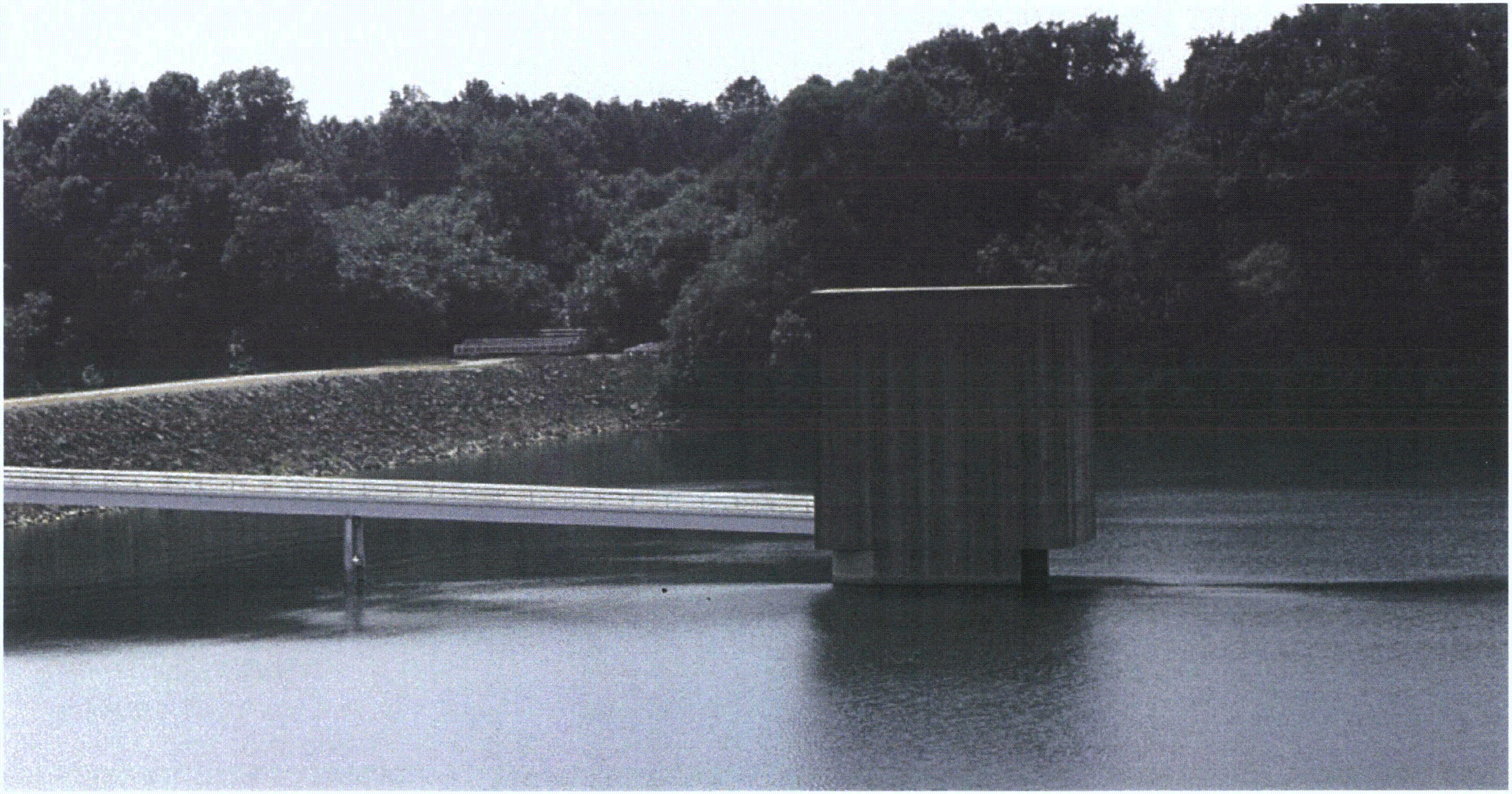
Number and type.............. 1; low-level supplementary water release sluice, 3-ft diameter pipe embedded in concrete of intake power conduit, controlled by 2-ft square slide gate installed in powerhouse service bay; intake in power intake tower, discharge into powerhouse tailrace
Centerline of sluiceway intake.............................. El. 771.5
Centerline of sluiceway discharge........................... El. 741.4
Entrance closure................. Hinged bulkhead, 4 ft 2 in. diameter by 8 in deep
Gate valve (in intake tower)........ 36 in., with bevel gear, manually operated
Sluice gate (in powerhouse)........... 24-in.-square opening, vertical lift gate, electric motor operated
Discharge capacity.................. HW El. 865, TW El. 741.5: 230 cfs (approx)
Sluice unit......................... HW El. 865, TW El. 741.5:75 cfs (approx)

POWER FACILITIES

INTAKE

Type................. Circular reinforced concrete tower (See Fig. 11)
Size:
Inside diameter......... 25 ft lower portion, 27 ft upper portion
Height, approx.. 211 ft
Dimensions at gate opening....... 17 ft 6 in. wide by 22 ft 0 in. high
Trashracks....................... 16 sections, 12 ft 2-1/8 in. wide by 13 ft 3 in. high
Gross area at racks.................................. 2100 sq ft
Service gate................ Roller train type, 21 ft 9 in. wide by 22 ft 8 in. high, hydraulically operated
Maintenance gate.......... Slide type, 22 ft 0 in. wide by 24 ft 7 in. high, hydraulically operated
Service hoists............... One 2-ton electric, one 24-ton manual on common bridge with 2-ton hoist

FIGURE 11 - Turbine Intake Structure, July 1999



POWER FACILITIES (CONT.)

CONDUIT

Type........................ Steel liner, concrete encased, in open cut trench excavated in rock
Diameter, inside.. 22 ft
Length.. 660 ft

POWERHOUSE

Generating capacity (1 unit).................. 45,000 kW (See Fig. 12)
Type of construction....... Indoor; cast-in-place reinforced concrete; precast concrete roof deck
Principal dimensions including
service bay................ 129 ft 6 in. long by 65 ft 6 in. wide by 134 ft high
Service bay................. 51 ft 0 in. by 65 ft 6 in. by 112 ft high
Draft tubes:
Type...................................... Elbow, 2 openings
Horizontal length (centerline of
turbine to downstream face)........................... 55 ft
Vertical distance from centerline of
distributor to floor of draft tube.................... 38 ft
Net area at outlet opening........................... 602 sq ft
Gates.......... One set of two slide-type gates, each 20 ft 1 in. wide by 12 ft 0-3/4 in. high
Hoist...................... One 20-ton monorail, electrically operated
Crane............ One 180-ton overhead traveling crane with two 90-ton main hooks and two 50-ton auxiliary hooks
Excavated tailrace channel:
Length, approx.. 430 ft
Width.................................. Varies from 54 to 64 ft
Depth.................................. Varies from 45 to 2 ft

Generator & Turbine Modernization

Tims Ford was the first plant to have the power train upgraded in the Hydro - Modernization Program . Major improvements included turbine replacement and auxiliary systems upgrades.

Schedule: October 16,1992 to June 8,1993

Outage length: 131 days

Total budget: $2.6 M

Net Capacity Gain: 8.7 mW

FIGURE 12 - Powerhouse and Discharge, July 1999

Sluice Unit

A sluice unit was installed in 1986 to provide a minimum continuous flow of water to improve aquatic ecosystems downstream of Tims Ford Dam. The sluice or " small" unit normally operates whenever the main unit is shut down. Typical discharge flow rate is 80 cfs. The sluice unit is actually a surplus motor/generator from a cancelled nuclear project - Hartsville.

Specifications :

Motor/Generator

Manufacturer	- Hitachi,Ltd.
Output	- 1250 hp
Phase	- 3
Speed	- 582
Voltage	- 6600 volts
Poles	- 12
Rated Frequency	- 60 Hz
Stator Insulation	- Type F
Weight	- Approx. 19,500 lb

Pump/Turbine

Manufacturer	- Hitachi,Ltd
Type	- Vertical shaft - semi-axial flow propeller
Size	- 36″

Sluice Unit commercial operation: Jan 14,1987

POWER FACILITIES (CONT.)

HYDRAULIC TURBINE

Number.. 1
Manufacturer.. Voith
Type.................................. Diagonal flow, fixed blade
Rated capacity.......................... 54,800 hp at 134-ft net head
Head for best efficiency.................................... 134 ft
Maximum head.. 138 ft
Minimum head.. 105 ft
Rated speed... 180 rpm
Maximum runaway speed....................................... 333 rpm
Specific speed at rating...................................... 113
Value of sigma at rating.................................... 0.376
Diameter of runner.. 150 in.
Diameter of guide vane circle............................... 180 in.
Diameter of lower pit....................................... 210 in.
Draft tubes (see Powerhouse)............................ Elbow type
Governors.......................... Woodward , cabinet actuator type
Heaviest assembly to be lifted by crane................. 125,000 lb

GENERATOR

Number.. 1
Manufacturer.. Hitachi, Ltd.
Type .... Enclosed, water-cooled, vertical-shaft
Rating.................. 50,000 kVA, 45,000 kW, 2092 Amp, 60° C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Capability...................... 57,500 kVA, 51,750 kW., 24,057 Amp, 80° C rise, 0.9 pf
Efficiency: At 115 percent rated kVA, 0.9 pf.......... 97.7 percent
At 100 percent rated kVA, 0.9 pf......... 97.65 percent
At 75 percent rated kVA, 0.9 pf........... 97.3 percent
Flywheel effect.......................21,500,000 lb-ft^2 (not including turbine runner)
Thrust bearing.... Kingsbury , pivotal-shoe type, jackscrew supported, pressurized lubrication for starting and stopping , max load 569.6 tons
Neutral transformer......................... 14.4 kV-240 V, 50 kVA
Exciters: Main......................... 270 kW, 250 V, 1080 Amp, d-c
Pilot............................ 15 kW , amplidyne type
Weight of heaviest crane lift................. 160 tons (rotor only)
Diameter of stator bore.............................. Not determined

STATION SERVICE TRANSFORMERS

Number and rating........ 2; 500 kVA, 13.8 kV-480 V, 3 ph, 55° C rise, 60 Hz (kVA subject to change). Replaced with dry type in 1999.

FIGURE 13 - Single Line Diagram of Main Connections
(from TVA drawing 45W502)

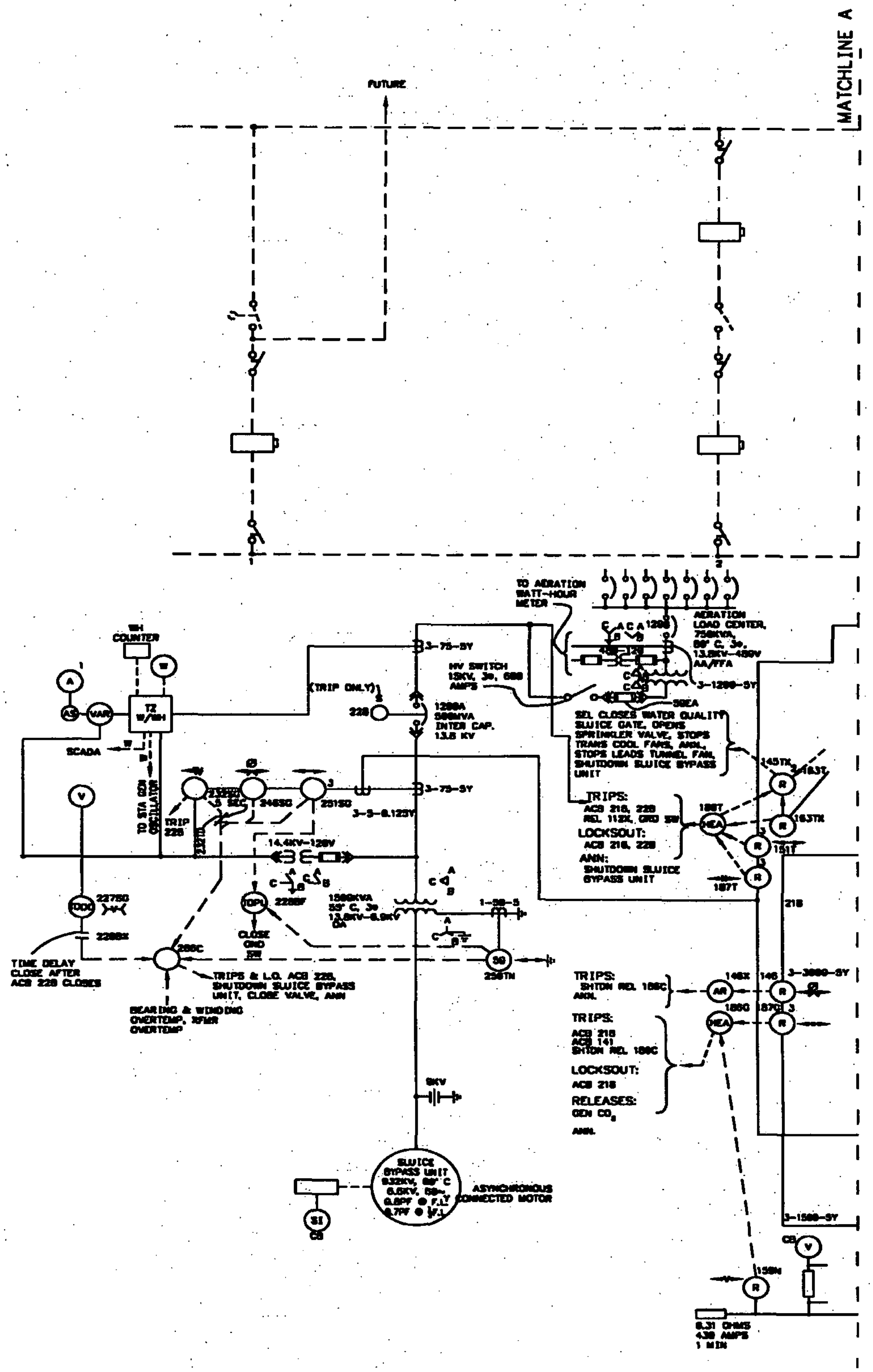


FIGURE 13 (CONT.)

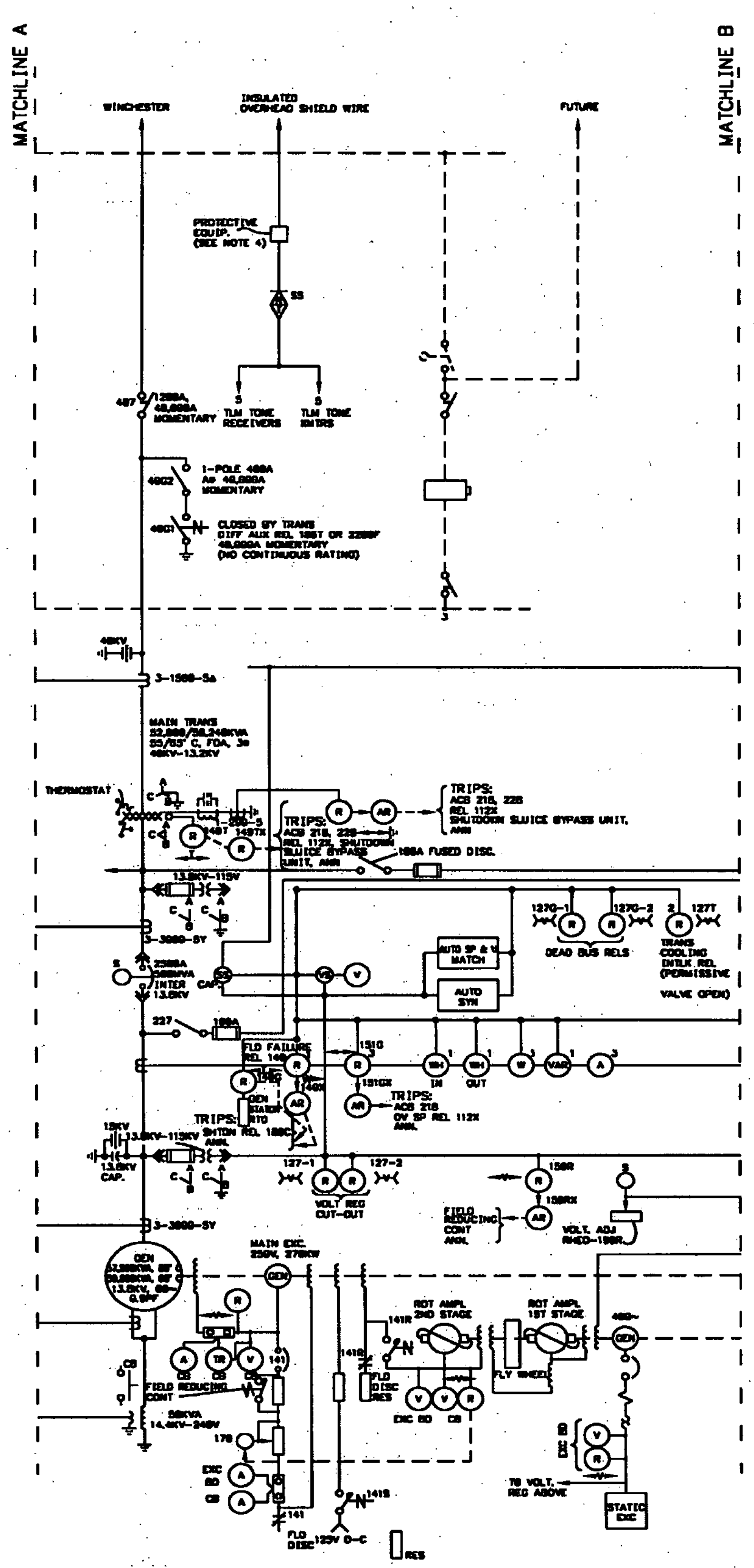
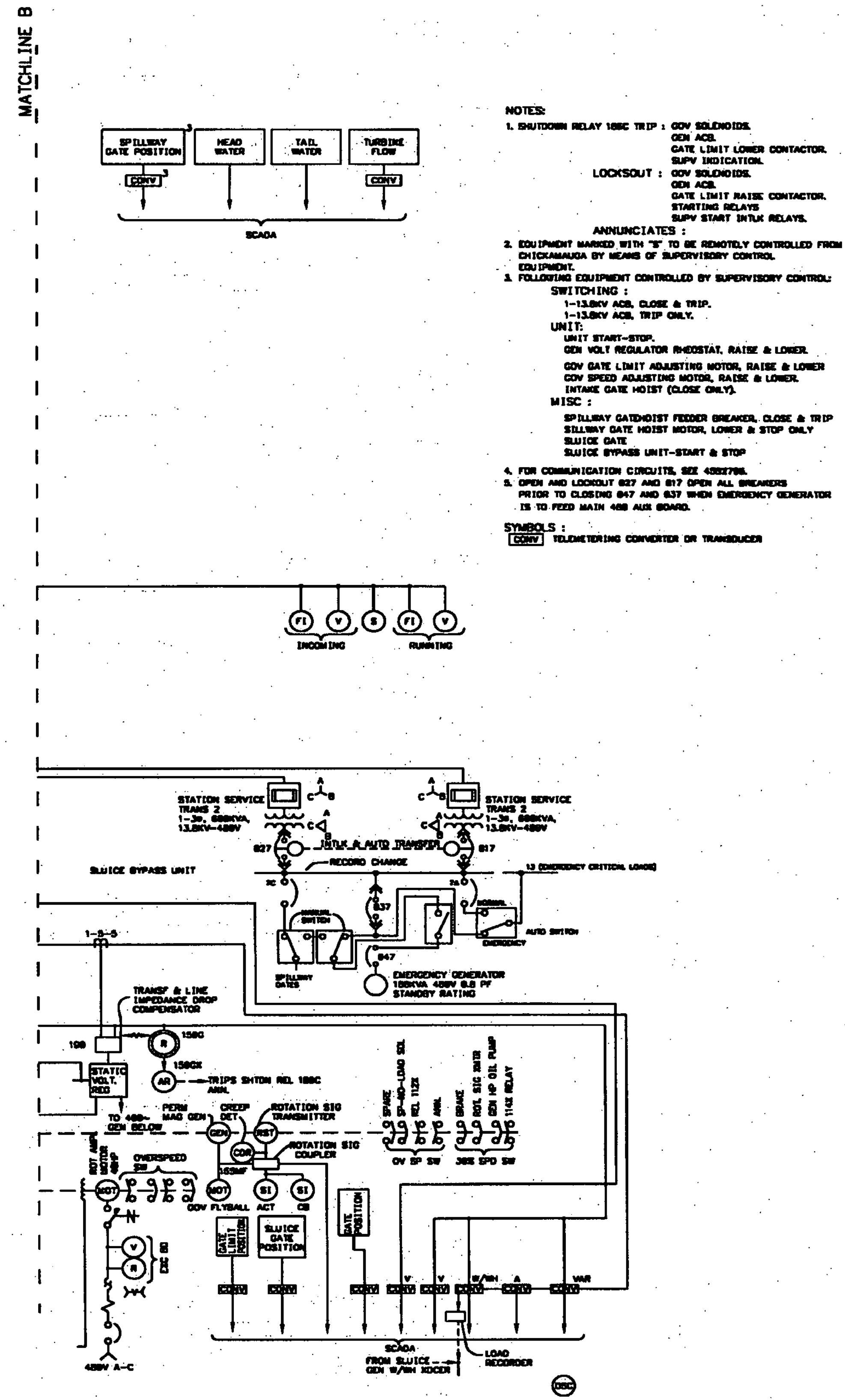


FIGURE 13 (CONT.)



POWER FACILITIES (CONT.)

ELECTRIC CONTROLS

Generation and switching are controlled with local facilities.

TRANSMISSION PLANT

Step-up transformers................................ One Main Step-up
1; 52,000 kVA (55° C rise), 46-13.2 kV, 3 ph, class FOA; (65° C rise rating 58,250 kVA); no load tap changer on high-voltage side; 2.5 percent voltage taps , 1 below and 3 above nominal

One for Sluice Unit; 1500 kva (55° C rise) 13.8 - 6.9 kv, 3 phase class OA

Power circuit breakers.. None
Transformer pulloff structure.. 1
Switching structure.................. Combined with pulloff structure

Emergency Station Service Power is provided by a caterpillar diesel generator model 3208 Engine and SR4 Generator.
Speed: 1800 kvA
kvA Rating: 188 kvA
Kilowatt Rating: 150 kw
Voltage: 480 vac 3 phase
Output Current: 226 amps
Fuel Consumption: 4-6 gph

The emergency diesel generator will automatically start (after a time delay) on loss of the offsite 46 kv powerline. Critical station power requirements will be met until offsite power is restored.

TRANSMISSION PLANT DATA

Plant	Location	Phase	Serial Number	MVA Rating		Voltage kV	Cooling	Tap Changer	Oil Preservation System	Oil Vol. Gal.	Configuration	Impedance %			Contract Number	Manufacturer	Yr of Manuf
				55 deg	65 deg							H-X	H-Y	X-Y			
Tims Ford	Bank 1	3	21531-1	52	58.24	46/13.2	FOA	DETC	N Blanket	2784	Wye/Delta	9.40			70C2-92351	Federal Pacific	1970
Tims Ford	Sluice Unit	3	*	1.5	-	13800/ 6900Y	OA	-	-	441	-	-	-	-	85kRB-83769	Ferranti-Packard	1986

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

* 0033006001

Tims Ford

Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Best Efficiency Plant Output (mW)	Best Efficiency Turbine Discharge (cfs)	Best Efficiency kW/CFS	Maximum Sustainable Plant Output (mW)	Maximum Sustainable Turbine Discharge (cfs)	Maximum Sustainable kW/CFS
895	11.48	608.0	103.4	146.6	40.0	3,420	11.70	41.0	3,720	11.02
894	11.41	596.5	99.4	145.5	40.0	3,440	11.62	40.9	3,740	10.95
893	11.33	585.2	95.5	144.5	40.0	3,460	11.55	40.9	3,760	10.89
892	11.23	573.9	91.6	143.5	40.0	3,480	11.48	41.0	3,780	10.84
891	11.11	562.7	87.8	142.5	39.9	3,500	11.41	41.0	3,800	10.79
890	10.98	551.7	84.1	141.5	39.9	3,520	11.35	41.0	3,820	10.74
889	10.84	540.8	80.4	140.4	39.9	3,540	11.28	41.1	3,840	10.69
888	10.68	530.0	76.7	139.4	39.8	3,560	11.20	41.0	3,860	10.62
887	10.51	519.4	73.1	138.4	39.6	3,570	11.12	40.7	3,870	10.53
886	10.34	509.0	69.6	137.4	39.4	3,580	11.03	40.5	3,880	10.45
885	10.17	498.7	66.1	136.4	39.2	3,590	10.95	40.3	3,890	10.36
884	10.00	488.6	62.7	135.4	39.1	3,600	10.86	40.1	3,900	10.28
883	9.83	478.7	59.4	134.4	38.9	3,610	10.78	39.9	3,910	10.20
882	9.66	469.0	56.1	133.3	38.7	3,620	10.69	39.7	3,920	10.13
881	9.49	459.4	53.0	132.3	38.5	3,630	10.61	39.5	3,930	10.05
880	9.32	450.0	49.9	131.3	38.3	3,640	10.53	39.3	3,940	9.97
879	9.16	440.8	46.9	130.3	38.1	3,650	10.44	39.1	3,950	9.90
878	9.00	431.7	43.9	129.3	37.9	3,660	10.36	38.9	3,960	9.82
877	8.85	422.7	41.0	128.3	37.7	3,670	10.27	38.7	3,970	9.75
876	8.71	414.0	38.2	127.3	37.5	3,680	10.19	38.5	3,980	9.67
875	8.57	405.3	35.4	126.3	37.3	3,690	10.10	38.3	3,990	9.59
874	8.44	396.8	32.7	125.2	37.0	3,700	10.02	38.0	4,000	9.52
873	8.32	388.5	30.0	124.2	36.7	3,700	9.92	37.7	4,000	9.42
872	8.20	380.2	27.4	123.2	36.3	3,700	9.82	37.3	4,000	9.32
871	8.10	372.0	24.8	122.2	36.0	3,700	9.72	36.9	4,000	9.22
870	8.00	364.0	22.3	121.2	35.6	3,690	9.62	36.5	4,000	9.12
869	7.90	356.0	19.8	120.2	35.2	3,690	9.52	36.1	4,000	9.02
868	7.79	348.2	17.4	119.2	34.8	3,690	9.42	35.7	4,000	8.92
867	7.67	340.5	15.0	118.2	34.4	3,690	9.31	35.3	4,000	8.82
866	7.54	332.9	12.7	117.2	34.0	3,690	9.20	34.9	4,000	8.72
865	7.41	325.4	10.4	116.2	33.6	3,690	9.09	34.5	4,000	8.62
864	7.27	318.1	8.2	115.2	33.2	3,690	8.98	34.1	4,000	8.52
863	7.14	310.9	6.1	114.2	32.8	3,690	8.88	33.7	4,000	8.42
862	7.01	303.8	4.0	113.2	32.4	3,690	8.77	33.3	4,000	8.32
861	6.89	296.8	2.0	112.2	31.9	3,680	8.66	32.9	4,000	8.22
860	6.78	290.0	.0	111.2	31.5	3,680	8.55	32.5	4,000	8.12

Tims Ford Spill Compilation

Tennessee Valley Authority
River System Operations

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. Water may be spilled through the spillway and/or sluiceway. All unmarked spill is through the sluiceway. Maximum hourly average discharge to date was 35,640 cfs at 9 p.m. and 10 p.m. on 12/23/90. *Spillway #Spillway and sluiceway
1970	11	12/12	1	2	11---12/12---2
1971	2655	12/17	6	228	2---3/15---1; #1830---5/15---13; 132---5/28---2; #1230---7/17---115; 244---9/25---11; *1190---10/23---27
1972	4700	3/18	9	68	*4480---1/11---84; *1550---1/30&31---15; *1050---2/15-17---5; 86---6/14---3; 122---7/13---4; 182---7/27---4; 243---8/15---9; *80---10/16---1; *1706---10/19---2
1973	15882	3/18	15	43	*11232---3/18---7; 33---6/23-24---2; 33---6/30-7/1---2; 33---7/7-8---2; 33---7/14-15---2; 13---7/28-29---2; 33---8/4-5---2; 33---8/11-12---2; 33---8/18-19---2; 13---8/21---1; 33---8/25-26---2; 33---9/2-3---2; 33---9/9---2; 24---9/15-16---2; 122---9/29-30---11
1974	8763	1/13	4	14	*278---1/2---1; *1651---1/5---5; *2963---1/13---7; 40---7/23---1
1975	7639	3/16	2	7	*1782---3/16---4; 61---6/11---1
1976	3050	2/1	23	93	*3000---1/4-6---16; *1550---1/18&19---12; *300---1/29---1; *3050---2/1---19; *1400---2/23-29---11; 61---6/6---2; 61---6/13---2; 61---6/20---2; 56---6/27---2; 61---7/4---2; 61---7/11---2; 61---7/18---2; 61---7/25---2; 61---8/1---2; 61---8/7&8---2; 81---8/15---1; 81---8/21&22---2; 61---8/29---2; 76---8/31---3; 81---9/4&5---2; 61---9/12---2; 81---9/18&19---2; 91---9/25---2
1977	6503	4/10	22	61	*652---4/7---6; 65---5/1---3; 61---5/30---2; 77---6/5---2; 77---6/12---2; 61---6/19---2; 61---6/26---2; 79---7/3---2; 77---7/10---3; 93---7/16---3; 121---7/23---3; 121---7/30---3; 121---8/6---3; 121---8/13---3; 91---8/21---2; 121---8/27---3; 121---9/3---3; 61---9/10-11---2; 61---9/18---2; 24---9/20---1; 61---9/25---3; 620---12/3---6
1978	3790	1/26	20	57	61---5/29---2; 61---6/4---2; 61---6/11---2; 61---6/18---2; 61---6/25---2; 61---7/2---2; 33---6/4---1; 61---7/9---2; 61---7/16---2; 61---7/23---2; 78---7/30---2; 108---8/6---4; 121---8/12-13---4; 121---8/19-20---4; 121---8/26-27---4; 241---9/4---4; 121---9/9-10---4; 121---9/16-17---4; 121---9/23-24---4; 121---9/30-10/1---4
1979	4759	3/7	19	42	61---5/27-28---3; 61---6/3---2; 61---6/10---2; 61---6/17---2; 61---6/24---2; 61---7/1---2; 33---7/4---1; 61---7/8---2; 108---7/15---3; 61---7/22---2; 61---7/29---2; 61---8/5---2; 61---8/12---2; 108---8/19---3; 108---8/26---3; 244---9/3---3; 61---9/9---2; 61---9/16---2; 61---9/23---2
1980	6545	3/25	21	77	*2040---1/24-25---25; *627---3/25---3; 61---5/25-26---3; 61---6/1---2; 61---6/8---2; 61---6/15---2; 61---6/22---2; 61---6/29---2; 61---7/6---2; 61---7/13---2; 61---7/20---2; 61---7/27---2; 61---8/3---2; 61---8/10---2; 88---8/17---4; 121---8/24---4; 180---9/1---4; 91---9/7---3; 91---9/14---3; 91---9/21---3; 91---9/28---3

Tims Ford Spill Compilation

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	Volumes are average daily in day-second-feet, except as shown. Maximum spill, date of maximum, and number of days of spill in each spill period, in this order. "Total Days" is for calendar years and does not always equal the sum of the days in periods because of extension of periods into adjacent years. Water may be spilled through the spillway and/or sluiceway. All unmarked spill is through the sluiceway. Maximum hourly average discharge to date was 35,640 cfs at 9 p.m. and 10 p.m. on 12/23/90. *Spillway #Spillway and sluiceway
1981	2967	12/17	19	49	61---5/24---2; 61---5/31---2; 61---6/7---2; 61---6/14---2; 61---6/21---2; 61---6/28---2; 121---7/4---3; 91---7/11-12---2; 121---7/18---3; 121---7/25---3; 121---8/1---2; 121---8/8---3; 121---8/15---3; 77---8/23---3; 121---8/29---3; 121---9/5---3; 121---9/12-13---3; 120---9/19-20---3; 120---9/26-27---3
1982	3912	1/26	16	37	62---5/30-31---3; 59---6/6---2; 61---6/13---2; 61---6/19-20---2; 107---6/27---3; 122---7/5---3; 91---7/11---2; 122---7/17-18---3; 61---7/25---2; 122---7/31-8/1---2; 61---8/8---2; 61---8/15---2; 61---8/22---2; 61---8/29---2; 122---9/6---3; 92---9/12---2
1983	5439	5/24	17	51	61---6/12---2; 61---6/19---2; 61---6/26---2; 122---7/4---3; 61---7/10---2; 92---7/17---3; 77---7/24---3; 77---7/31---3; 75---8/7---3; 77---8/14---3; 91---8/21---3; 121---8/27---2; 181---9/5---4; 121---9/10---3; 121---9/17---5; 77---9/25---3; 239---9/31-10/1---5
1984	5000	5/10&11	21	63	123---5/28---4; 62---6/3---2; 77---6/10---3; 77---6/17---3; 77---6/24---3; 80---7/1---3; 77---7/8---3; 77---7/15---3; 77---7/22---3; 77---7/29---3; 61---8/5---2; 61---8/12---2; 80---8/18-20---5; 77---8/26---3; 181---9/3---4; 128---9/9---3; 128---9/16---3; 121---9/22---3; 121---9/29---3; 80---11/3-4---4; 17---11/27---1
1985	3196	2/26	7	82	77---5/25-27---5; 79---6/1&2---4; 79---6/8---3; 79---6/15---3; 79---6/22---3; 79---6/29---3; 105---7/19---61
1986	3900	12/4	9	114	42---3/12---2; 90---5/24-27---40; 80---7/5-6---4; 80---7/12-13---4; 80---7/19-20---4; 107---7/31---48; 80---9/13-14---2; 80---9/16-17, 20-21---7; 80---9/27-28---3
1987	3900	3/2	4	74	68---1/25---6; 100---6/13---4; 100---6/29---62; 34---9/11---2
1988	3900	12/29	7	75	39---2/9---3; 9---4/5---1; 100---6/28---18; 100---7/21---3; 100---7/29---34; 100---9/2---13; 80---11/9---3
1989	6107	2/24	5	12	35---2/1---2; 80---2/11-12---6; 61---6/10---1; 61---8/12---1; 25---12/19---2
1990	25964	12/24	12	102	2---3/15---1; *4950---3/18---14; 43---4/2---5; 4---5/1---1; 60---6/16---1; 26---7/17---1; 60---7/21---1; 208---8/18---52; 122---9/15-16---4; 122---9/22-24, 26-30---11; 50---10/4---2; 22113---12/24---16
1991	6906	2/28	8	139	2500---1/3---16; 61---1/11---2; 6906---2/28---107; 30---5/29---1; 81---7/20---1; 60---8/17---1; 2856---12/4---18; 58---12/22---2
1992	3876	1/3	2	106	*854---7/15-16, 21-23---103; 89---11/4---4
1993	3765	5/5	4	7	2---6/7---1; 32---6/30---2; 24---7/19---1; 122---8/15---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. Water may be spilled through the spillway and/or sluiceway. All unmarked spill is through the sluiceway. Maximum hourly average discharge to date was 35,640 cfs at 9 p.m. and 10 p.m. on 12/23/90. *Spillway #Spillway and sluiceway
1994	7778	2/16	10	32	3---1/12---1; 46---1/26---2; 3792---2/15---7; 3631---2/26---5; 2611---3/30---8; 2499---4/8---3; 3155---4/14---3; 19---5/19---1; 23---6/7---1; 28---8/16---1
1995	3900	11/9, 14-17, 20-22	3	4	40---7/5---2; 28---8/23---1; 8---12/10---1
1996	3900	1/15,16; 2/6; 12/3-13	3	5	46---2/3---3; 17---8/19---1; 18---8/28---1
1997	3900	3/10; 6/11-12; 10/14-16, 22-23, 29-30; 11/2, 7-13	0	0	
1998	3900	1/9; 3/10-11; 6/11; 12/14	7	25	32---5/20---2; 114---6/19---1; 15---9/9---1; 241---9/19-20---4; 239---10/3-12---12; 239---10/17-18---4; 19---12/16---1

RIVER SYSTEM OPERATIONS

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

TIMS FORD

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	893.62	1990	DEC.	23	1	746.65 *	1970	DEC.	1
2	893.24	1973	MAR.	17	2	855.25	1997	DEC.	1
3	892.76	1977	APR.	6	3	856.01	1998	JAN.	1
4	892.67	1983	MAY	22	4	862.24	1972	OCT.	15
5	891.91	1984	MAY	9	5	864.87	1996	DEC.	16
6	891.69	1975	OCT.	19	6	868.87	1981	JAN.	22
7	891.67	1991	FEB.	23	7	869.98	1995	JAN.	5
8	891.18	1989	OCT.	3	8	870.10	1994	DEC.	27
9	890.33	1994	MAR.	29	9	870.64	1983	JAN.	20
10	890.14	1998	JUNE	7	10	870.67	1980	DEC.	31
11	889.91	1997	JUNE	10	11	871.38	1986	FEB.	4
12	889.78	1980	MAR.	24	12	871.48	1987	JAN.	14
13	889.15	1993	MAY	5	13	871.80	1985	JAN.	22
14	888.68	1979	SEP.	30	14	871.83	1974	DEC.	24
15	888.12	1971	JULY	9	15	871.93	1978	DEC.	29
16	888.07	1978	MAY	15	16	872.07	1977	FEB.	17
17	888.00	1995	OCT.	7	17	872.09	1975	DEC.	24
18	887.86	1974	JAN.	12	18	872.16	1973	JAN.	12
19	887.74	1992	JULY	8	19	872.56	1976	DEC.	24
20	887.67	1982	MAY	10	20	872.68	1979	JAN.	1
21	887.52	1972	JULY	30	21	872.72	1984	JAN.	22
22	887.43	1996	JUNE	13	22	872.74	1988	JAN.	14
23	886.93	1976	JULY	7	23	873.00	1989	DEC.	25
24	884.94	1985	SEP.	3	24	873.20	1971	DEC.	30
25	883.90	1986	NOV.	27	25	873.50	1982	JAN.	2
26	883.48	1988	NOV.	9	26	874.12	1990	JAN.	1
27	883.44	1981	JUNE	22	27	874.15	1993	DEC.	28
28	882.95	1987	JULY	13	28	875.46	1992	JAN.	22
29	809.70	1970	DEC.	31	29	876.36	1991	JAN.	24

* CLOSURE
TOP-OF-GATES ELEVATION 895

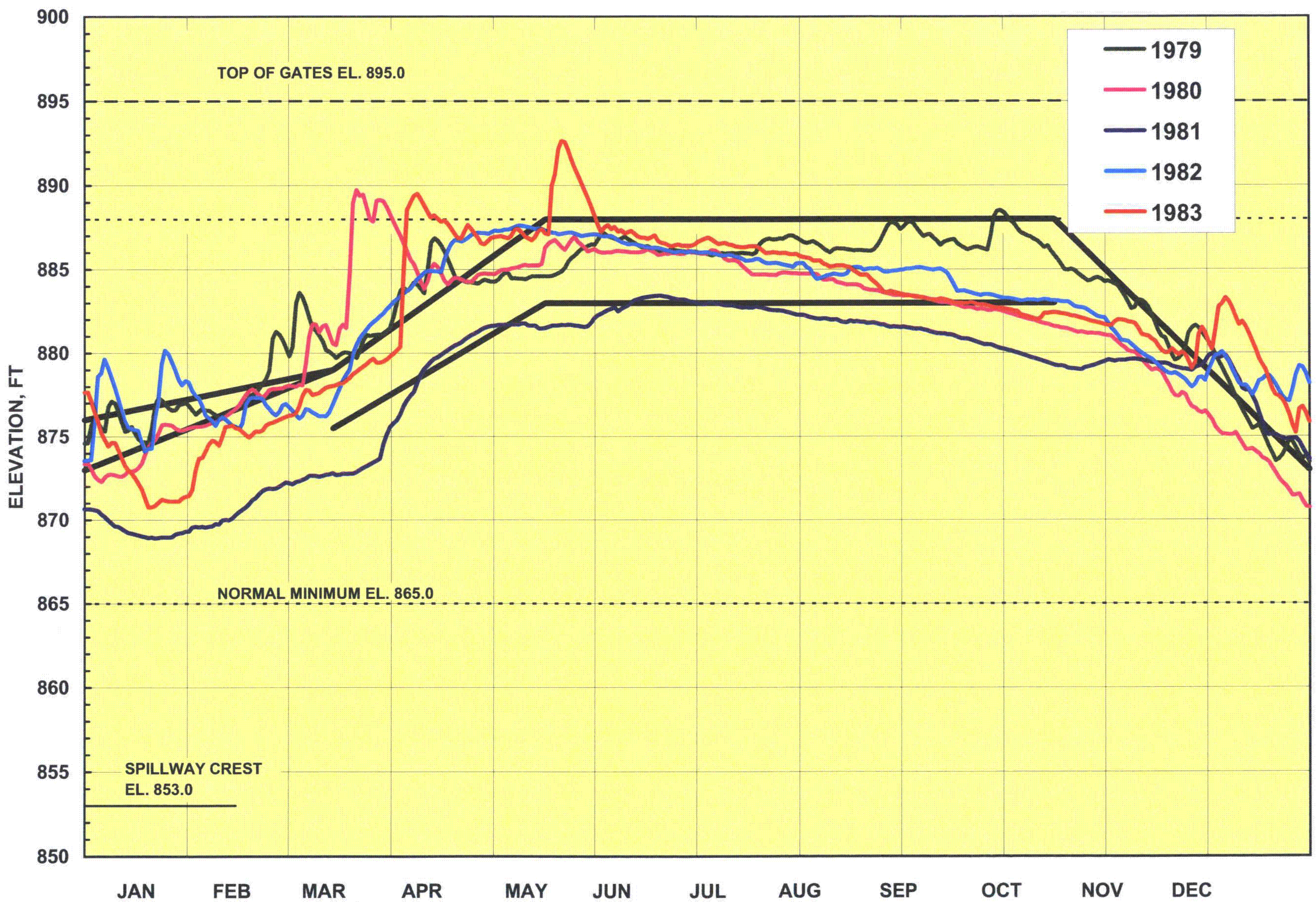
MAXIMUM, MINIMIUM, MEDIAN, AND MEAN
Adjusted Flow by Weeks
Tims Ford
Years=1971-1998

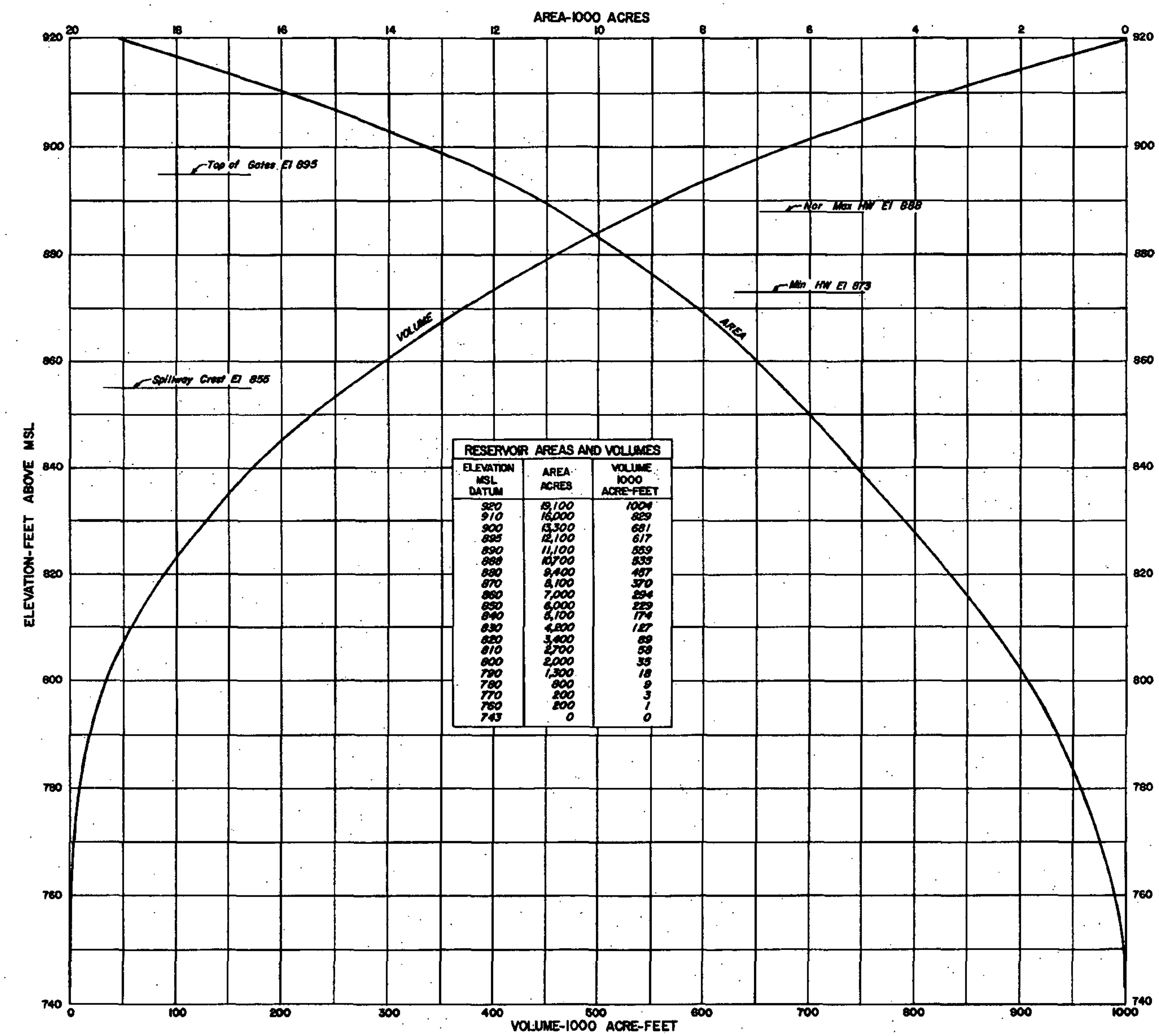
WEEK ENDING	WEEK NO.	MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
		AVERAGE WEEKLY CFS					
JAN 7	1	4,900	1982	136	1981	1,640	1,920
JAN 14	2	10,300	1974	84	1981	1,660	1,970
JAN 21	3	2,700	1988	166	1981	1,290	1,510
JAN 28	4	5,160	1974	237	1986	1,550	1,780
FEB 4	5	4,910	1990	279	1986	1,270	1,460
FEB 11	6	6,620	1994	391	1981	1,070	1,610
FEB 18	7	4,230	1974	508	1977	1,340	1,700
FEB 25	8	9,530	1991	447	1988	1,320	1,990
MAR 4	9	5,480	1997	318	1988	1,330	1,820
MAR 11	10	5,290	1989	369	1988	1,520	1,960
MAR 18	11	14,000	1973	343	1981	1,250	2,160
MAR 25	12	8,510	1980	288	1988	1,360	2,010
APR 1	13	8,890	1994	409	1986	1,250	1,960
APR 8	14	10,500	1977	341	1986	1,340	2,060
APR 15	15	4,310	1994	260	1986	932	1,310
APR 22	16	4,530	1998	264	1986	927	1,160
APR 29	17	1,750	1973	177	1986	892	913
MAY 6	18	5,620	1984	86	1986	755	1,080
MAY 13	19	3,890	1984	114	1986	818	984
MAY 20	20	4,200	1983	100	1986	612	896
MAY 27	21	4,500	1983	104	1988	501	804
JUN 3	22	4,200	1973	81	1988	498	712
JUN 10	23	4,350	1998	-26	1988	410	754
JUN 17	24	3,060	1989	-3	1988	339	583
JUN 24	25	2,690	1989	28	1988	279	448
JUL 1	26	1,240	1989	-46	1988	264	368
JUL 8	27	2,360	1989	24	1988	247	373
JUL 15	28	1,380	1989	54	1981	240	301
JUL 22	29	1,360	1973	14	1987	218	305
JUL 29	30	1,500	1972	-33	1987	222	325
AUG 5	31	1,240	1972	0	1986	142	250
AUG 12	32	886	1972	34	1990	220	274
AUG 19	33	905	1998	46	1976	169	243
AUG 26	34	1,030	1979	-24	1987	135	200
SEP 2	35	1,370	1979	-54	1987	137	193
SEP 9	36	800	1979	-9	1990	103	173
SEP 16	37	2,250	1989	0	1980	134	280
SEP 23	38	1,030	1975	-54	1991	149	260
SEP 30	39	2,670	1979	-50	1985	172	449
OCT 7	40	4,700	1989	-,145	1987	149	502
OCT 14	41	2,960	1975	-12	1987	176	381
OCT 21	42	4,780	1975	-8	1978	140	403
OCT 28	43	1,320	1976	10	1998	240	384
NOV 4	44	1,490	1995	11	1991	251	390
NOV 11	45	4,750	1995	-30	1991	321	646
NOV 18	46	2,580	1975	55	1971	322	544
NOV 25	47	4,030	1977	76	1981	660	793
DEC 2	48	5,000	1973	92	1998	1,070	1,490
DEC 9	49	5,200	1991	36	1987	845	1,250
DEC 16	50	7,060	1972	93	1987	747	1,220
DEC 23	51	15,600	1990	-1	1998	782	1,410
DEC 31	52	6,710	1973	163	1980	1,290	1,730

AVERAGE FLOW: 1971 - 1998 = 975 CFS

RIVER SYSTEM OPERATIONS

ANNUAL OPERATING CYCLE





RESERVOIR AREAS AND VOLUMES

ELEVATION MSL DATUM	AREA ACRES	VOLUME 1000 ACRE-FEET
920	19,100	1004
910	16,000	829
900	13,300	681
895	12,100	617
890	11,100	559
888	10,700	535
880	9,400	457
870	8,100	370
860	7,000	294
850	6,000	229
840	5,100	174
830	4,200	127
820	3,400	89
810	2,700	58
800	2,000	35
790	1,300	18
780	800	9
770	200	3
760	200	1
743	0	0

NOTES:
Areas obtained by planimeter from USGS-TVA maps, scale: 1"=2000'.
Drainage area at site=529 square miles.
Original river area within reservoir at El 895=480 acres.

ELK RIVER-MILE 133.3

RESERVOIR AREAS AND VOLUMES

TIMS FORD PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

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

KNOXVILLE	2-14-62	W	PP	1	321K771R3

NOTE: See page 29 for latest volume data

RESERVOIR RELEASE IMPROVEMENTS

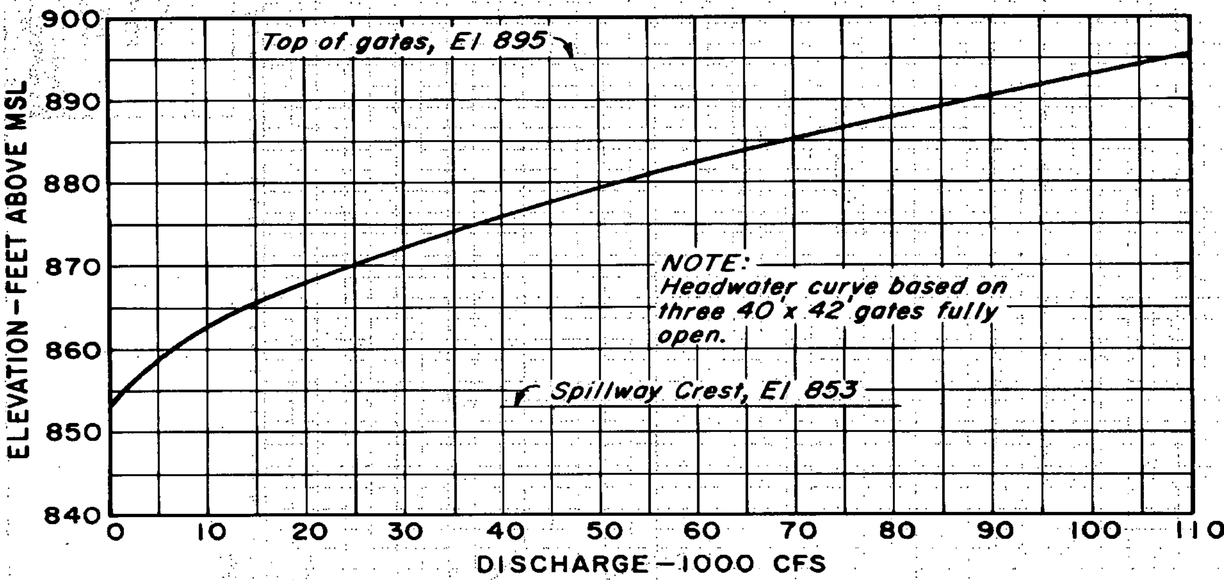
The aeration equipment at Tims Ford Dam is part of the implementation of TVA's Lake Improvement Plan (LIP) approved by the Board of Directors in 1991. One of the goals of the Lake Improvement Plan is to improve the dissolved oxygen (DO) levels and minimum flows of the release of 16 dams. Minimum flow releases of 85 cfs at Tims Ford were obtained by the installation of a small hydroturbine unit which is operated whenever the main unit is off. At Tims Ford testing showed the target minimum DO content of the release (6 mg/L) to be best achieved by the installation of air and oxygen injection equipment. Blower and compressor systems inject air at the large and small hydroturbines respectively. An oxygen injection system supplies oxygen to the penstock for the large unit and to the sluice line for the small unit.

Oxygen Injection System - The oxygen injection system for Tims Ford Hydro Plant is designed to supply pure oxygen to the penstock to increase the DO content of the tailwater by 3 mg/L. The diffusers are supplied with oxygen from a liquid oxygen storage facility located near the powerhouse. The storage facility equipment consists of a horizontal 6000 gallon liquid oxygen storage tank, two ambient air vaporizers, a solenoid-operated emergency shut-off valve, a temperature switch for low temperature shut-off, a pressure gauge and transmitter, a remote-operated control valve, a flowmeter, and a pressure regulator. The tubing to the penstock is made of copper. Inside the penstock, copper tubing supplies stainless steel headers anchored along the wall. These headers distribute the oxygen to diffuser (garden soaker) hoses. (Reference TVA Drawing 47W405-05).

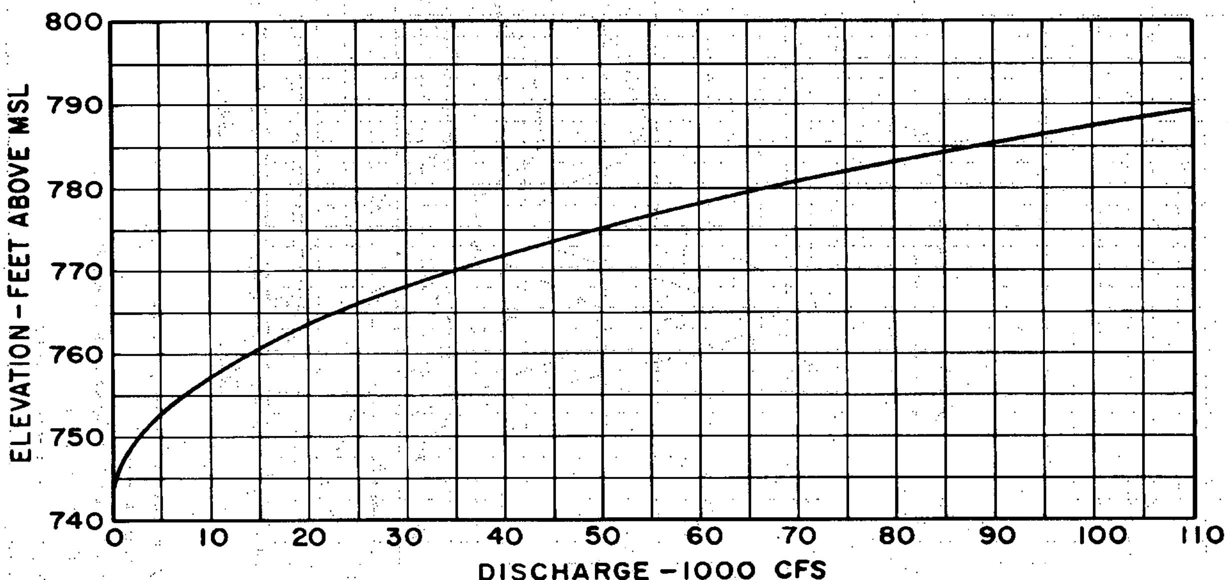
The system also includes tubing to feed oxygen is injected into the sluice line upstream of the unit (at the corner of the powerhouse). A remote-operated valve and a pressure regulator control the oxygen flow to the small unit. The oxygen flow meter includes a low flow scale to meter the flow to the small sluice unit.

Blower System - The blower system consists of two blowers, controls, piping, and valves designed to inject air into the water flow through the large unit. The smaller blower is sized at 200 hp, 3000 SCFM, and the larger blower is sized at 350 hp, 4000 SCFM, and the large blower discharge piping is arranged such that with the proper valve alignment either blower can feed the headcover and/or the draft tube.

Air Compressor System - The air compressor system consists of three air compressors, controls, piping, and valves designed to inject air into the flow through the small unit. Compressors designated No.1 and No.2 are rated at 25 hp. The compressor designated No.3 is rated at 40 hp. The discharge piping is tied together and valved such that any combination of compressors may be used to supply the required air flow.



HEADWATER RATING CURVE



TAILWATER RATING CURVE

TIMS FORD DAM

CONSTRUCTION DATA

QUANTITIES (ESTIMATED)

Dam, spillway, and power facilities:

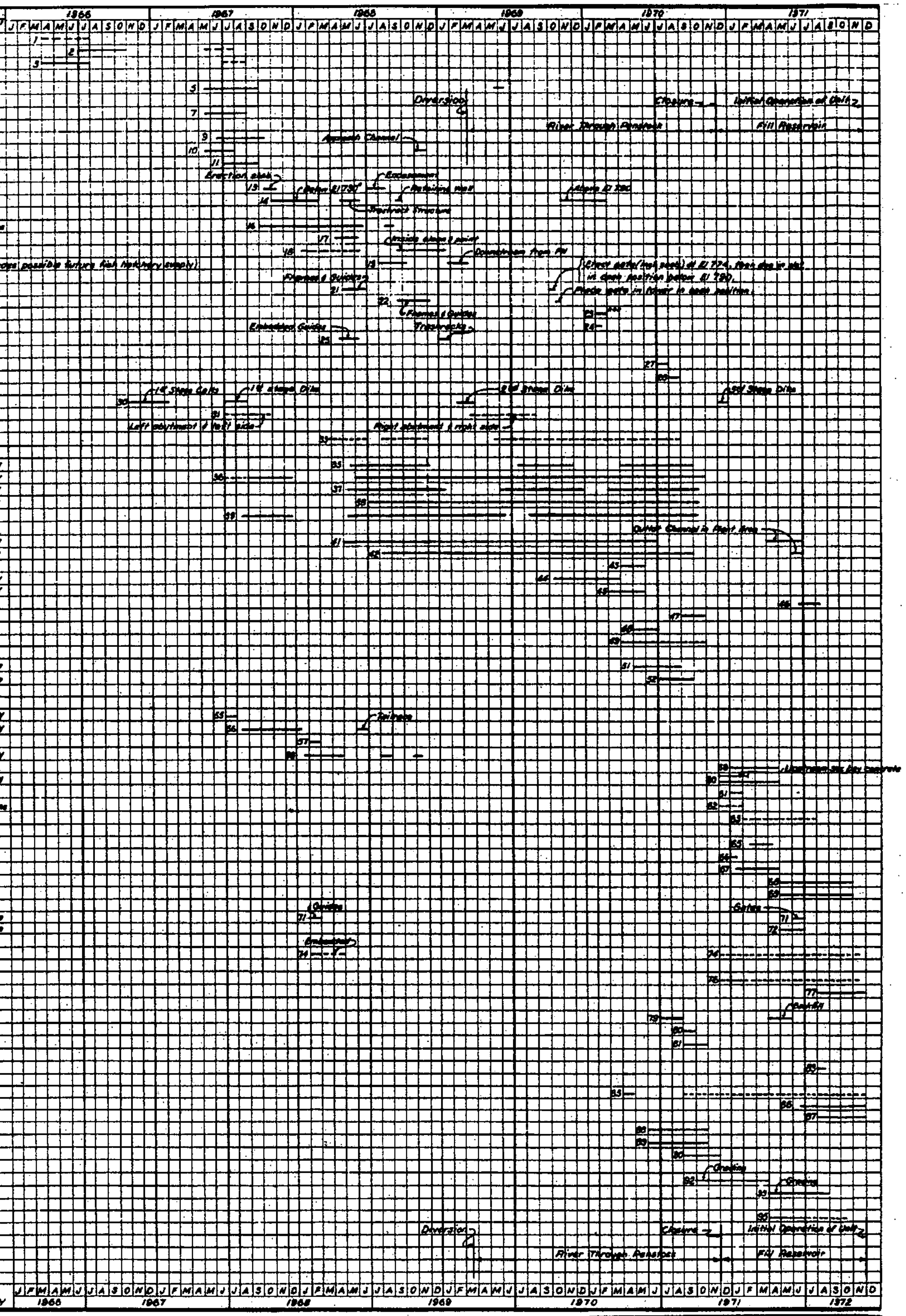
Excavation:

Earth and unclassified	1,321,000 cu yd
Earth, borrow	450,000 cu yd
Rock, features	638,000 cu yd
Rock, borrow	1,008,000 cu yd
Impervious rolled fill	505,000 cu yd
Rock fill	1,660,000 cu yd
Filter material	477,000 cu yd
Concrete	85,400 cu yd

Highway and railroad adjustments:

Excavation	1,565,000 cu yd

FEATURES	NO	ITEM	QUANT	UNIT
CONSTR PLANT	1	Clearing		
	2	Grading Plant Site		
	3	Roads		
	4			
	5	Temporary Buildings		
	6			
	7	Utilities		
	8			
	9	Concrete Mixing Plant		
INTAKE	10	Excavation - Earth		
	11	- Rock	35,600	CY
	12			
	13	Concrete - Penstock Encasement	17,370	CY
	14	- Intake Structure	5,800	CY
	15			
	16	Steel Penstock - Field Fabrication & Installation	4,160	Tons
	17	- Testing		
	18	- Painting		
	19	Supplementary Sluice Pipe (Encased with penstock & Includes possible future fish hatchery supply)		
	20			
	21	Maintenance Gate	1	Ea
	22	Service Gate	1	Ea
	23	Gate Hoisting Equipment	2	Ea
	24	Overhead Crane		
	25	Trashracks		
	26			
	27	Access Bridge - Foundations		
	28	- Structural		
	29			
DAM	30	Cofferdam		
	31	Excavation - Earth		
	32			
	33	Foundation Treatment		
	34			
	35	Embankment - Earth	303,000	CY
	36	- Rock Fill	1,550,000	CY
	37	- Filter	258,000	CY
	38	- Rock Face	110,000	CY
	39	Rock Fill Quarry Operation (U.S. Spillway Approach)		
	40			
SPILLWAY	41	Excavation - Earth	843,000	CY
	42	- Rock	800,000	CY
	43	Foundation Treatment		
	44	Concrete - Weir & Piers	30,000	CY
	45	- Chute	18,800	CY
	46	Riprap Outlet Channel Slopes		
	47	Riprap Upstream Slopes		
	48	Operating Bridge - Str. Steel & Concrete		
	49	Backfill		
	50			
	51	Gates - Installation	3	Ea
	52	- Operating Equipment	3	Ea
	53			
	54			
POWERHOUSE AND SERVICE BAY	55	Excavation - Earth	30,000	CY
	56	- Rock	28,800	CY
	57	Foundation Treatment		
	58	Concrete - First Stage	10,000	CY
	59	- Second Stage		
	60	- Superstructure	Later	CY
	61	Penstock Transition & Expansion Joint		
	62	Structural Steel	Later	Tons
	63	Architectural (Including Roof)		
	64			
	65	Turbine Room Crane		
	66	Turbine Erection - Draft Tube Liner		
	67	- Spiral Case, Emb. Parts		
	68	- Internal Parts		
	69	Generator Erection		
	70			
	71	Draft Tube Gates	2	Ea
	72	Draft Tube Gate Monorail Hoist	1	Ea
	73			
	74	Air, Oil & Water Lines		
	75			
	76	Electrical Equipment		
	77	Communication Equipment		
	78			
SWITCHYARD	79	Excavation and Backfill		
	80	Concrete - Cable Tunnel		
	81	- Foundations		
	82			
	83	Structural Steel		
	84			
	85	Conduit and Grounding		
	86	Install Equipment		
	87	Carrier Current Equipment		
GENERAL YARD IMPROVEMENT	88	Grading		
	89	Roads & Parking Areas		
	90	Powerhouse Access Bridge		
	91			
	92	Visitors Building		
	93	DRP Maintenance Building		
	94			
MISC.	95	Rim Treatment		
	96			
	97			
	98			
	99			
	100			

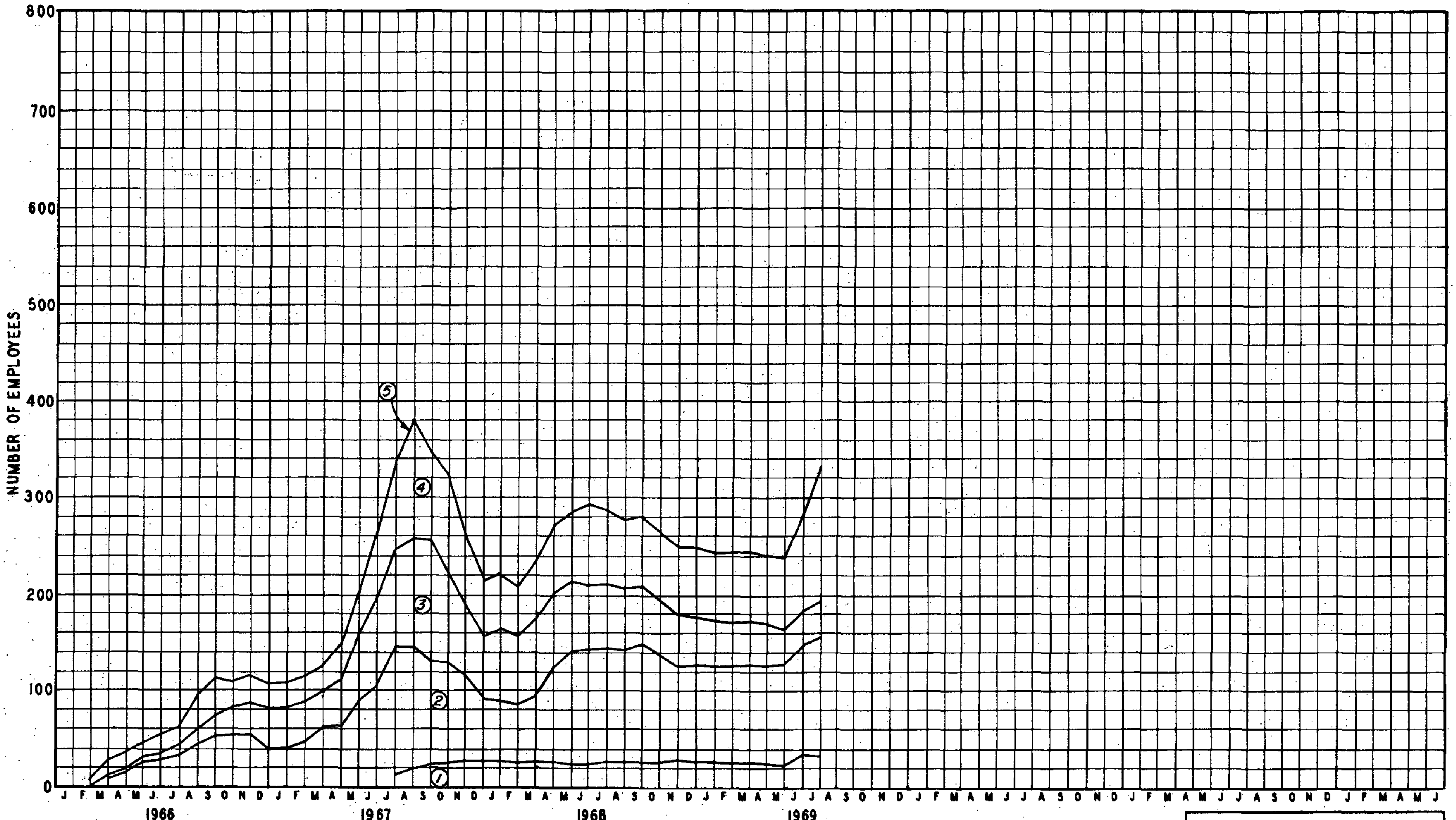


* Build intake structure to El 790. Resume construction of tower after maintenance and service gates have been placed in tower in open position.

** Bottom section of maintenance gate hoisting stem should be delivered prior to July 1969 so it can be installed on gate before placing in dogged position.

NOTE:
This schedule supersedes drawing 102N10001 prepared initially for construction of a concrete dam.

GENERAL				
DETAILED CONSTRUCTION SCHEDULE				
TIMS FORD PROJECT TENNESSEE VALLEY AUTHORITY DIVISION OF CONSTRUCTION				
SUBMITTED [signature]	RECOMMENDED [signature]	APPROVED [signature]		
FIELD OFFICE	7-7-67	75	PC	3	102N10003 R2



SYMBOLS:

① - - - Office and Engineers, Clerks, Stenographers, etc.

② - - - Plant and Equipment Operators.

③ - - - Other skilled labor, - Carpenters, Riggers, Electricians; Masons, etc.

④ - - - Laborers, - Construction, Unclassified.

⑤ - - - Total on Payroll, including reservoir activities

CONSTRUCTION FORCE REPORT
TIMS FORD PROJECT TENNESSEE VALLEY AUTHORITY
SUBMITTED F.C. [signature] / RECOMMENDED / APPROVED
KNOXVILLE / 10-22-69 / 75 / C5 / 3 / 10284

CDQ000020080022

Attachment 5

TENNESSEE VALLEY AUTHORITY
RIVER OPERATIONS

TIMS FORD DAM

SPILLWAY AND SLUICE DISCHARGE TABLES

MAY 2008

CONTENTS

PART 1

SPILLWAY DISCHARGE TABLES

MAY 2008

INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables dated March 2004. The tables were revised to include eight new gate settings for providing minimum flows. The additional gate settings are specified in eight new gate arrangements at the beginning of the gate arrangement table with the result that all previously available gate arrangements have been renumbered. The discharges in these tables for the previously available arrangements are unchanged from those provided in the 2004 tables. The computer code SPILLQ generated the tabulated discharges.

The accuracy of these tables depends on properly set zero indicator positions for each of the spillway gates. The tabulated discharges are based on known gate openings for each indicator position. The known gate openings and, therefore, the tabulated discharges are accurate only when the zero indicator settings are properly set.

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 a scale model.

The specific gate arrangements in the tables were determined by considering data obtained from spillway model studies together with incremental discharge values required for satisfactory spillway operation.

3. Range of Tables

The tables cover a discharge range from 0 to 121,500 cubic feet per second. Headwater elevations range from 860 feet to 890 feet.

4. Arrangement of Tables

The tables show spillway discharges in cubic feet per second. Headwater elevations for each 0.1 foot of headwater elevation are shown at the top of each column. The headwater range is shown at the bottom of each page.

The discharge is tabulated under the headwater elevations for specific arrangements of gate openings, which are indicated by number in the left and right columns of each page. The numbered arrangements are defined in the table of Spillway Gate Arrangements on page 5. Reference to this table and to the drawing showing the location of the gates on page 4 will determine the gate opening to which each gate is to be set for any particular discharge given in the tables.

5. Discharge Intervals

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

When the exact headwater elevation does not appear in the tables, the discharge for the headwater elevation closest to it is used. For example, the column headed 892.2 is used for actual headwater elevations between 892.15 feet and 892.24 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 arrangements table on page 5 may be used because these are the only openings for which discharges are given in the tables. 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 895 feet

If the headwater elevation exceeds 895 feet (actually, 894.8 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 8000 cubic feet per second with the headwater at elevation 877.72 feet?

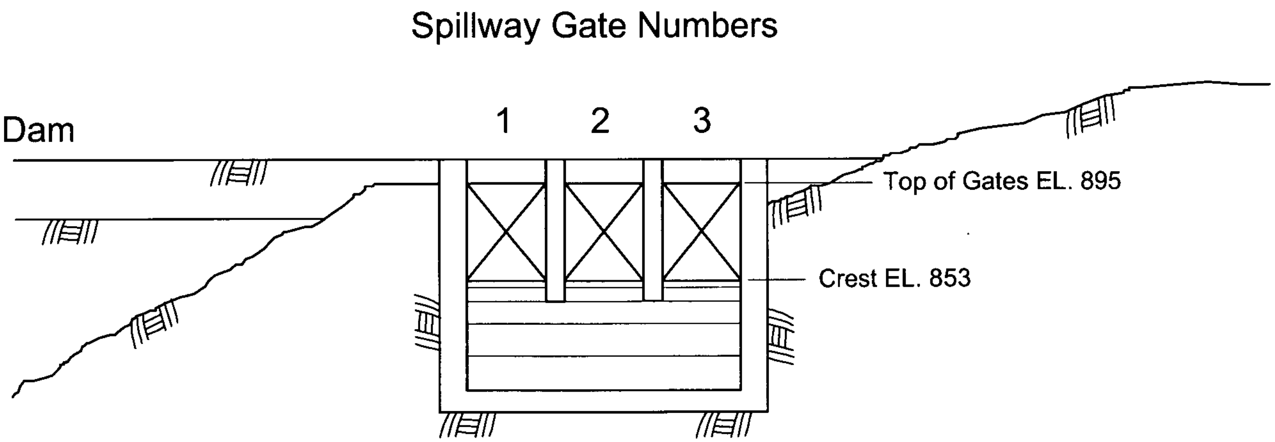
The first step is to find the table in which the headwater elevation appears. Referring to the contents page, we find that headwater elevations between 876 feet and 878 feet are found on page 14. The headwater elevation closest to 877.72 feet is 877.7 feet. In the column headed 877.7 the discharge nearest to the required 8,000 cubic feet per second is 7,700 cubic feet per second. By tracing the horizontal line in which 7,700 cubic feet per second appears, to either side of the page, we find that gate arrangement 10 is the one for producing the discharge closest to 8,000 cubic feet per second at headwater elevation 877.72 feet. Referring to page 5 it is found that the gates should be set with the gate opening indicators reading as follows: gates 1 and 2 at indicator reading 2.0 and gate 3 at indicator reading 3.0.

After all the gates are set, changes in the headwater elevation may require changes in the gate arrangement to maintain the desired discharge. For example, if the headwater should fall to 876.22 feet, the discharge will be found in the column headed 876.2. In this column the discharge closest to 8,000 cubic feet per second is 8,520 cubic feet per second for gate arrangement 11. To change to gate arrangement 11 from gate arrangement 10, gate 2 would be opened to indicator reading 3.0.

Example 2 -- Suppose the operating records show that the headwater is at elevation 888.35 feet, and gate arrangement 47 is in use. The headwater is found on page 20, which is marked "Headwater 888 to 890." The elevation given is exactly halfway between elevation 888.3 feet and 888.4 feet. The larger value, 888.4 feet, should be used. In the column headed 888.4 opposite gate arrangement 47, the discharge is found to be 70,520 cubic feet per second.

TIMS FORD DAM

LOCATION OF SPILLWAY GATES



DOWNSTREAM ELEVATION

TIMS FORD DAM

SPILLWAY GATE ARRANGEMENTS

Arrangement Number	Gate Number		
	1	2	3
1	0	0.1	0
2	0	0.2	0
3	0	0.3	0
4	0	0.4	0
5	0	0.5	0
6	0	0.6	0
7	0	0.7	0
8	0	0.8	0
9	0	0.9	0
10	0	0.5	0.5
11	0.5	0.5	0.5
12	0.5	1.0	0.5
13	0.5	1.0	1.0
14	1.0	1.0	1.0
15	1.0	1.0	2.0
16	1.0	2.0	2.0
17	2.0	2.0	2.0
18	2.0	2.0	3.0
19	2.0	3.0	3.0
20	3.0	3.0	3.0
21	3.0	3.0	4.0
22	3.0	4.0	4.0
23	4.0	4.0	4.0
24	4.0	4.0	5.0
25	4.0	5.0	5.0
26	5.0	5.0	5.0
27	5.0	5.0	6.0
28	5.0	6.0	6.0
29	6.0	6.0	6.0
30	6.0	6.0	7.0
31	6.0	7.0	7.0
32	7.0	7.0	7.0
33	7.0	7.0	8.0
34	7.0	8.0	8.0
35	8.0	8.0	8.0

Arrangement Number	Gate Number		
	1	2	3
36	8.0	8.0	9.0
37	8.0	9.0	9.0
38	9.0	9.0	9.0
39	9.0	9.0	10.0
40	9.0	10.0	10.0
41	10.0	10.0	10.0
42	10.0	10.0	12.0
43	10.0	12.0	12.0
44	12.0	12.0	12.0
45	12.0	12.0	14.0
46	12.0	14.0	14.0
47	14.0	14.0	14.0
48	14.0	14.0	16.0
49	14.0	16.0	16.0
50	16.0	16.0	16.0
51	16.0	16.0	18.0
52	16.0	18.0	18.0
53	18.0	18.0	18.0
54	18.0	18.0	20.0
55	18.0	20.0	20.0
56	20.0	20.0	20.0
57	20.0	20.0	22.0
58	20.0	22.0	22.0
59	22.0	22.0	22.0
60	22.0	22.0	24.0
61	22.0	24.0	24.0
62	24.0	24.0	24.0
63	24.0	24.0	30.0
64	24.0	30.0	30.0
65	30.0	30.0	30.0

Figures in columns under each gate number refer to gate opening indicator reading

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	860.0	860.1	860.2	860.3	860.4	860.5	860.6	860.7	860.8	860.9	861.0	861.1	861.2	861.3	861.4	861.5	861.6	861.7	861.8	861.9	862.0	
1	50	50	50	50	50	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	60	1
2	100	100	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	120	120	120	120	2
3	160	160	160	160	160	160	160	170	170	170	170	170	170	170	170	170	170	180	180	180	180	3
4	210	220	220	220	220	220	220	220	230	230	230	230	230	230	230	240	240	240	240	240	240	4
5	270	270	270	280	280	280	280	280	290	290	290	290	290	290	300	300	300	300	300	310	310	5
6	330	330	330	330	340	340	340	340	350	350	350	350	360	360	360	360	360	370	370	370	370	6
7	390	390	390	390	400	400	400	410	410	410	410	420	420	420	420	430	430	430	430	440	440	7
8	440	450	450	450	460	460	460	470	470	470	480	480	480	490	490	490	490	500	500	500	510	8
9	500	510	510	510	520	520	530	530	530	540	540	540	550	550	550	560	560	560	570	570	570	9
10	540	540	550	550	560	560	560	570	570	570	580	580	590	590	590	600	600	600	610	610	610	10
11	810	820	820	830	830	840	840	850	860	860	870	870	880	880	890	890	900	900	910	920	920	11
12	1,100	1,110	1,120	1,130	1,130	1,140	1,150	1,160	1,170	1,170	1,180	1,190	1,200	1,200	1,210	1,220	1,230	1,230	1,240	1,250	1,250	12
13	1,390	1,400	1,410	1,420	1,430	1,440	1,450	1,460	1,470	1,480	1,490	1,500	1,510	1,520	1,530	1,540	1,550	1,560	1,570	1,580	1,590	13
14	1,680	1,700	1,710	1,720	1,730	1,750	1,760	1,770	1,780	1,800	1,810	1,820	1,830	1,840	1,850	1,870	1,880	1,890	1,900	1,910	1,920	14
15	2,230	2,250	2,270	2,280	2,300	2,320	2,330	2,350	2,370	2,380	2,400	2,420	2,430	2,450	2,470	2,480	2,500	2,510	2,530	2,550	2,560	15
16	2,780	2,800	2,820	2,840	2,870	2,890	2,910	2,930	2,950	2,970	2,990	3,020	3,040	3,060	3,080	3,100	3,120	3,140	3,160	3,180	3,200	16
17	3,320	3,350	3,380	3,400	3,430	3,460	3,480	3,510	3,540	3,560	3,590	3,610	3,640	3,660	3,690	3,710	3,740	3,760	3,790	3,810	3,840	17
18	3,900	3,890	3,880	3,910	3,940	3,970	4,010	4,040	4,070	4,100	4,130	4,160	4,190	4,220	4,250	4,280	4,310	4,340	4,370	4,400	4,430	18
19	4,490	4,430	4,380	4,420	4,450	4,490	4,530	4,570	4,600	4,640	4,670	4,710	4,740	4,780	4,810	4,850	4,880	4,920	4,950	4,980	5,020	19
20	5,070	4,960	4,880	4,920	4,970	5,010	5,050	5,090	5,140	5,180	5,220	5,260	5,300	5,340	5,380	5,420	5,460	5,490	5,530	5,570	5,610	20
21	5,710	5,690	5,680	5,760	5,840	5,920	6,000	6,090	6,170	6,250	6,330	6,360	6,350	6,330	6,320	6,300	6,280	6,260	6,230	6,210	6,190	21
22	6,340	6,410	6,480	6,600	6,720	6,840	6,960	7,080	7,200	7,320	7,440	7,460	7,400	7,330	7,250	7,180	7,100	7,020	6,940	6,850	6,760	22
23	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,570	8,450	8,320	8,190	8,060	7,920	7,780	7,640	7,490	7,340	23
24	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,620	8,590	8,560	8,530	8,500	8,460	8,430	8,390	8,350	8,300	24
25	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,670	8,740	8,810	8,870	8,940	9,010	9,070	9,140	9,210	9,270	25
26	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,720	8,880	9,050	9,210	9,380	9,550	9,720	9,890	10,060	10,240	26
27	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,720	8,880	9,050	9,210	9,380	9,550	9,720	9,890	10,060	10,240	27
28	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,720	8,880	9,050	9,210	9,380	9,550	9,720	9,890	10,060	10,240	28
29	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,720	8,880	9,050	9,210	9,380	9,550	9,720	9,890	10,060	10,240	29
30	6,980	7,130	7,290	7,440	7,600	7,750	7,910	8,070	8,230	8,390	8,550	8,720	8,880	9,050	9,210	9,380	9,550	9,720	9,890	10,060	10,240	30

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	862.0	862.1	862.2	862.3	862.4	862.5	862.6	862.7	862.8	862.9	863.0	863.1	863.2	863.3	863.4	863.5	863.6	863.7	863.8	863.9	864.0	
1	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	65	65	65	65	65	1
2	120	120	120	120	120	120	120	120	120	120	120	120	130	130	130	130	130	130	130	130	130	2
3	180	180	180	180	180	180	180	190	190	190	190	190	190	190	190	190	190	200	200	200	200	3
4	240	240	250	250	250	250	250	250	250	250	260	260	260	260	260	260	260	260	270	270	270	4
5	310	310	310	310	310	320	320	320	320	320	320	330	330	330	330	330	330	330	340	340	340	5
6	370	370	380	380	380	380	380	390	390	390	390	400	400	400	400	400	400	410	410	410	410	6
7	440	440	440	450	450	450	450	460	460	460	460	470	470	470	470	480	480	480	480	480	490	7
8	510	510	510	510	520	520	520	530	530	530	530	540	540	540	550	550	550	550	560	560	560	8
9	570	580	580	580	590	590	590	600	600	600	610	610	610	620	620	620	620	630	630	630	640	9
10	610	620	620	620	630	630	630	640	640	640	650	650	650	660	660	660	670	670	670	680	680	10
11	920	930	930	940	940	950	950	960	960	970	970	980	980	990	990	1,000	1,000	1,000	1,010	1,010	1,020	11
12	1,250	1,260	1,270	1,280	1,280	1,290	1,300	1,300	1,310	1,320	1,320	1,330	1,340	1,350	1,350	1,360	1,370	1,370	1,380	1,380	1,390	12
13	1,590	1,600	1,610	1,620	1,630	1,630	1,640	1,650	1,660	1,670	1,680	1,690	1,700	1,700	1,710	1,720	1,730	1,740	1,750	1,760	1,760	13
14	1,920	1,930	1,950	1,960	1,970	1,980	1,990	2,000	2,010	2,020	2,030	2,040	2,050	2,060	2,070	2,080	2,100	2,110	2,120	2,130	2,140	14
15	2,560	2,580	2,590	2,610	2,620	2,640	2,650	2,670	2,680	2,700	2,710	2,730	2,740	2,750	2,770	2,780	2,800	2,810	2,830	2,840	2,850	15
16	3,200	3,220	3,240	3,260	3,280	3,300	3,310	3,330	3,350	3,370	3,390	3,410	3,430	3,450	3,460	3,480	3,500	3,520	3,540	3,550	3,570	16
17	3,840	3,860	3,880	3,910	3,930	3,950	3,980	4,000	4,020	4,050	4,070	4,090	4,110	4,140	4,160	4,180	4,200	4,220	4,250	4,270	4,290	17
18	4,430	4,460	4,480	4,510	4,540	4,570	4,600	4,620	4,650	4,680	4,700	4,730	4,760	4,780	4,810	4,840	4,860	4,890	4,910	4,940	4,970	18
19	5,020	5,050	5,080	5,120	5,150	5,180	5,210	5,250	5,280	5,310	5,340	5,370	5,400	5,430	5,460	5,490	5,520	5,550	5,580	5,610	5,640	19
20	5,610	5,650	5,680	5,720	5,760	5,800	5,830	5,870	5,900	5,940	5,980	6,010	6,050	6,080	6,120	6,150	6,190	6,220	6,250	6,290	6,320	20
21	6,190	6,200	6,240	6,280	6,320	6,360	6,410	6,450	6,490	6,530	6,570	6,610	6,650	6,690	6,730	6,770	6,810	6,840	6,880	6,920	6,960	21
22	6,760	6,740	6,790	6,840	6,890	6,930	6,980	7,020	7,070	7,120	7,160	7,210	7,250	7,290	7,340	7,380	7,420	7,470	7,510	7,550	7,600	22
23	7,340	7,290	7,350	7,400	7,450	7,500	7,550	7,600	7,650	7,700	7,750	7,800	7,850	7,900	7,950	8,000	8,040	8,090	8,140	8,190	8,230	23
24	8,300	8,330	8,430	8,520	8,610	8,710	8,800	8,890	8,970	8,950	8,930	8,910	8,890	8,870	8,840	8,810	8,790	8,760	8,740	8,790	8,840	24
25	9,270	9,370	9,510	9,640	9,780	9,910	10,050	10,180	10,290	10,200	10,110	10,020	9,930	9,830	9,730	9,630	9,530	9,420	9,340	9,400	9,450	25
26	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,600	11,450	11,290	11,130	10,970	10,800	10,630	10,450	10,270	10,090	9,940	10,000	10,060	26
27	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,620	11,580	11,540	11,490	11,440	11,390	11,340	11,280	11,230	11,170	11,130	11,240	11,340	27
28	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,640	11,710	11,780	11,850	11,920	11,980	12,050	12,120	12,180	12,250	12,330	12,480	12,620	28
29	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	29
30	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	30
31	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	31
32	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	32
33	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	33
34	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	34
35	10,240	10,410	10,580	10,760	10,940	11,120	11,300	11,480	11,660	11,840	12,020	12,210	12,390	12,580	12,760	12,950	13,140	13,330	13,520	13,710	13,900	35

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	864.0	864.1	864.2	864.3	864.4	864.5	864.6	864.7	864.8	864.9	865.0	865.1	865.2	865.3	865.4	865.5	865.6	865.7	865.8	865.9	866.0	
1	65	65	65	65	65	65	65	65	65	65	65	65	65	65	70	70	70	70	70	70	70	1
2	130	130	130	130	130	130	130	130	130	140	140	140	140	140	140	140	140	140	140	140	140	2
3	200	200	200	200	200	200	200	200	210	210	210	210	210	210	210	210	210	210	210	210	220	3
4	270	270	270	270	270	270	280	280	280	280	280	280	280	280	280	290	290	290	290	290	290	4
5	340	340	340	340	350	350	350	350	350	350	350	360	360	360	360	360	360	370	370	370	370	5
6	410	410	420	420	420	420	420	430	430	430	430	430	430	440	440	440	440	440	450	450	450	6
7	490	490	490	490	500	500	500	500	500	510	510	510	510	520	520	520	520	520	530	530	530	7
8	560	560	570	570	570	570	580	580	580	580	590	590	590	590	600	600	600	600	610	610	610	8
9	640	640	640	650	650	650	650	660	660	660	670	670	670	670	680	680	680	690	690	690	690	9
10	680	680	690	690	690	690	700	700	700	710	710	710	720	720	720	720	730	730	730	740	740	10
11	1,020	1,020	1,030	1,030	1,040	1,040	1,050	1,050	1,060	1,060	1,060	1,070	1,070	1,080	1,080	1,090	1,090	1,100	1,100	1,100	1,110	11
12	1,390	1,400	1,400	1,410	1,420	1,420	1,430	1,440	1,440	1,450	1,450	1,460	1,470	1,470	1,480	1,490	1,490	1,500	1,500	1,510	1,520	12
13	1,760	1,770	1,780	1,790	1,800	1,800	1,810	1,820	1,830	1,840	1,840	1,850	1,860	1,870	1,880	1,880	1,890	1,900	1,910	1,910	1,920	13
14	2,140	2,150	2,160	2,170	2,180	2,190	2,200	2,210	2,220	2,220	2,230	2,240	2,250	2,260	2,270	2,280	2,290	2,300	2,310	2,320	2,330	14
15	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	3,050	3,070	3,080	3,090	3,110	3,120	15
16	3,570	3,590	3,610	3,620	3,640	3,660	3,680	3,690	3,710	3,730	3,740	3,760	3,780	3,790	3,810	3,830	3,840	3,860	3,880	3,890	3,910	16
17	4,290	4,310	4,330	4,350	4,370	4,390	4,420	4,440	4,460	4,480	4,500	4,520	4,540	4,560	4,580	4,600	4,620	4,640	4,660	4,680	4,700	17
18	4,970	4,990	5,020	5,040	5,070	5,090	5,120	5,140	5,170	5,190	5,210	5,240	5,260	5,290	5,310	5,330	5,360	5,380	5,410	5,430	5,450	18
19	5,640	5,670	5,700	5,730	5,760	5,790	5,820	5,850	5,880	5,900	5,930	5,960	5,990	6,020	6,040	6,070	6,100	6,130	6,150	6,180	6,210	19
20	6,320	6,350	6,390	6,420	6,450	6,490	6,520	6,550	6,580	6,620	6,650	6,680	6,710	6,740	6,780	6,810	6,840	6,870	6,900	6,930	6,960	20
21	6,960	7,000	7,030	7,070	7,110	7,150	7,180	7,220	7,260	7,290	7,330	7,360	7,400	7,440	7,470	7,510	7,540	7,580	7,610	7,650	7,680	21
22	7,600	7,640	7,680	7,720	7,760	7,800	7,850	7,890	7,930	7,970	8,010	8,050	8,090	8,130	8,170	8,210	8,250	8,280	8,320	8,360	8,400	22
23	8,230	8,280	8,330	8,370	8,420	8,460	8,510	8,550	8,600	8,640	8,690	8,730	8,780	8,820	8,860	8,910	8,950	8,990	9,030	9,080	9,120	23
24	8,840	8,890	8,950	9,000	9,050	9,100	9,150	9,200	9,250	9,300	9,340	9,390	9,440	9,490	9,540	9,580	9,630	9,680	9,730	9,770	9,820	24
25	9,450	9,510	9,570	9,620	9,680	9,730	9,790	9,840	9,890	9,950	10,000	10,050	10,110	10,160	10,210	10,260	10,310	10,370	10,420	10,470	10,520	25
26	10,060	10,120	10,190	10,250	10,310	10,360	10,420	10,480	10,540	10,600	10,660	10,710	10,770	10,830	10,890	10,940	11,000	11,050	11,110	11,160	11,220	26
27	11,340	11,450	11,550	11,660	11,750	11,730	11,720	11,700	11,680	11,660	11,640	11,610	11,590	11,560	11,550	11,610	11,670	11,730	11,790	11,850	11,910	27
28	12,620	12,770	12,920	13,070	13,190	13,100	13,010	12,920	12,820	12,720	12,620	12,510	12,410	12,300	12,210	12,270	12,340	12,410	12,470	12,540	12,600	28
29	13,900	14,100	14,290	14,490	14,640	14,470	14,310	14,140	13,960	13,780	13,600	13,410	13,220	13,030	12,870	12,940	13,010	13,080	13,150	13,220	13,290	29
30	13,900	14,100	14,290	14,490	14,650	14,610	14,560	14,520	14,470	14,410	14,360	14,300	14,250	14,190	14,150	14,260	14,380	14,500	14,610	14,630	14,620	30
31	13,900	14,100	14,290	14,490	14,670	14,750	14,820	14,900	14,970	15,050	15,120	15,200	15,270	15,340	15,420	15,580	15,750	15,910	16,070	16,030	15,950	31
32	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,440	17,290	32
33	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,540	17,510	33
34	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,640	17,730	34
35	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	35
36	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	36
37	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	37
38	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	38
39	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	39
40	13,900	14,100	14,290	14,490	14,690	14,880	15,080	15,280	15,480	15,680	15,880	16,090	16,290	16,490	16,700	16,910	17,110	17,320	17,530	17,740	17,950	40

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	866.0	866.1	866.2	866.3	866.4	866.5	866.6	866.7	866.8	866.9	867.0	867.1	867.2	867.3	867.4	867.5	867.6	867.7	867.8	867.9	868.0	
1	70	70	70	70	70	70	70	70	70	70	70	70	70	75	75	75	75	75	75	75	75	1
2	140	140	140	140	140	140	140	140	150	150	150	150	150	150	150	150	150	150	150	150	150	2
3	220	220	220	220	220	220	220	220	220	220	220	220	220	230	230	230	230	230	230	230	230	3
4	290	290	290	300	300	300	300	300	300	300	300	300	310	310	310	310	310	310	310	310	310	4
5	370	370	370	370	380	380	380	380	380	380	380	390	390	390	390	390	390	390	390	400	400	5
6	450	450	450	450	460	460	460	460	460	460	470	470	470	470	470	470	480	480	480	480	480	6
7	530	530	530	540	540	540	540	540	550	550	550	550	550	560	560	560	560	560	570	570	570	7
8	610	610	620	620	620	620	630	630	630	630	640	640	640	640	640	650	650	650	650	660	660	8
9	690	700	700	700	700	710	710	710	720	720	720	720	730	730	730	730	740	740	740	740	750	9
10	740	740	740	750	750	750	760	760	760	760	770	770	770	780	780	780	780	790	790	790	790	10
11	1,110	1,110	1,120	1,120	1,130	1,130	1,130	1,140	1,140	1,150	1,150	1,160	1,160	1,160	1,170	1,170	1,180	1,180	1,180	1,190	1,190	11
12	1,520	1,520	1,530	1,530	1,540	1,540	1,550	1,560	1,560	1,570	1,570	1,580	1,590	1,590	1,600	1,600	1,610	1,610	1,620	1,620	1,630	12
13	1,920	1,930	1,940	1,940	1,950	1,960	1,970	1,970	1,980	1,990	2,000	2,000	2,010	2,020	2,030	2,030	2,040	2,050	2,050	2,060	2,070	13
14	2,330	2,340	2,350	2,360	2,370	2,370	2,380	2,390	2,400	2,410	2,420	2,430	2,440	2,450	2,460	2,460	2,470	2,480	2,490	2,500	2,510	14
15	3,120	3,130	3,140	3,160	3,170	3,180	3,190	3,210	3,220	3,230	3,240	3,260	3,270	3,280	3,290	3,300	3,320	3,330	3,340	3,350	3,360	15
16	3,910	3,920	3,940	3,960	3,970	3,990	4,000	4,020	4,040	4,050	4,070	4,080	4,100	4,110	4,130	4,140	4,160	4,170	4,190	4,200	4,220	16
17	4,700	4,720	4,740	4,760	4,780	4,800	4,810	4,830	4,850	4,870	4,890	4,910	4,930	4,950	4,960	4,980	5,000	5,020	5,040	5,060	5,070	17
18	5,450	5,480	5,500	5,520	5,540	5,570	5,590	5,610	5,640	5,660	5,680	5,700	5,720	5,750	5,770	5,790	5,810	5,830	5,860	5,880	5,900	18
19	6,210	6,230	6,260	6,290	6,310	6,340	6,370	6,390	6,420	6,440	6,470	6,500	6,520	6,550	6,570	6,600	6,620	6,650	6,670	6,700	6,720	19
20	6,960	6,990	7,020	7,050	7,080	7,110	7,140	7,170	7,200	7,230	7,260	7,290	7,320	7,350	7,380	7,400	7,430	7,460	7,490	7,520	7,550	20
21	7,680	7,710	7,750	7,780	7,820	7,850	7,880	7,920	7,950	7,980	8,020	8,050	8,080	8,110	8,150	8,180	8,210	8,240	8,280	8,310	8,340	21
22	8,400	8,440	8,480	8,510	8,550	8,590	8,630	8,660	8,700	8,740	8,770	8,810	8,850	8,880	8,920	8,950	8,990	9,030	9,060	9,100	9,130	22
23	9,120	9,160	9,200	9,240	9,290	9,330	9,370	9,410	9,450	9,490	9,530	9,570	9,610	9,650	9,690	9,730	9,770	9,810	9,850	9,890	9,930	23
24	9,820	9,870	9,910	9,960	10,000	10,050	10,090	10,140	10,180	10,230	10,270	10,320	10,360	10,400	10,450	10,490	10,530	10,580	10,620	10,660	10,710	24
25	10,520	10,570	10,620	10,670	10,720	10,770	10,820	10,870	10,920	10,960	11,010	11,060	11,110	11,160	11,200	11,250	11,300	11,350	11,390	11,440	11,490	25
26	11,220	11,270	11,330	11,380	11,440	11,490	11,540	11,600	11,650	11,700	11,750	11,810	11,860	11,910	11,960	12,010	12,060	12,120	12,170	12,220	12,270	26
27	11,910	11,970	12,030	12,090	12,150	12,200	12,260	12,320	12,380	12,430	12,490	12,550	12,600	12,660	12,720	12,770	12,830	12,880	12,940	12,990	13,050	27
28	12,600	12,660	12,730	12,790	12,850	12,920	12,980	13,040	13,100	13,160	13,230	13,290	13,350	13,410	13,470	13,530	13,590	13,650	13,710	13,770	13,820	28
29	13,290	13,360	13,430	13,490	13,560	13,630	13,700	13,760	13,830	13,900	13,960	14,030	14,090	14,160	14,220	14,290	14,350	14,410	14,480	14,540	14,600	29
30	14,620	14,620	14,610	14,600	14,590	14,580	14,570	14,550	14,540	14,590	14,660	14,730	14,800	14,870	14,940	15,010	15,080	15,150	15,220	15,280	15,350	30
31	15,950	15,870	15,790	15,700	15,620	15,530	15,430	15,340	15,240	15,290	15,370	15,440	15,520	15,590	15,670	15,740	15,810	15,880	15,960	16,030	16,100	31
32	17,290	17,130	16,970	16,810	16,640	16,470	16,300	16,130	15,950	15,990	16,070	16,150	16,230	16,310	16,390	16,460	16,540	16,620	16,700	16,770	16,850	32
33	17,510	17,470	17,440	17,400	17,360	17,320	17,280	17,240	17,190	17,290	17,420	17,540	17,650	17,650	17,640	17,630	17,620	17,610	17,600	17,590	17,580	33
34	17,730	17,820	17,910	18,000	18,080	18,170	18,260	18,350	18,430	18,590	18,760	18,940	19,070	18,980	18,890	18,800	18,710	18,610	18,510	18,410	18,300	34
35	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,490	20,320	20,150	19,970	19,790	19,600	19,420	19,220	19,030	35
36	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,510	20,470	20,430	20,390	20,340	20,290	20,240	20,190	20,140	36
37	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,530	20,620	20,710	20,800	20,890	20,980	21,070	21,160	21,240	37
38	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	38
39	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	39
40	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	40
41	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	41
42	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	42
43	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	43
44	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	44
45	17,950	18,160	18,380	18,590	18,810	19,020	19,240	19,450	19,670	19,890	20,110	20,330	20,550	20,770	21,000	21,220	21,450	21,670	21,900	22,120	22,350	45

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	868.0	868.1	868.2	868.3	868.4	868.5	868.6	868.7	868.8	868.9	869.0	869.1	869.2	869.3	869.4	869.5	869.6	869.7	869.8	869.9	870.0	
1	75	75	75	75	75	75	75	75	75	75	75	75	75	80	80	80	80	80	80	80	80	1
2	150	150	150	150	150	150	150	160	160	160	160	160	160	160	160	160	160	160	160	160	160	2
3	230	230	230	230	230	230	240	240	240	240	240	240	240	240	240	240	240	240	240	250	250	3
4	310	310	320	320	320	320	320	320	320	320	320	320	330	330	330	330	330	330	330	330	330	4
5	400	400	400	400	400	400	410	410	410	410	410	410	410	410	420	420	420	420	420	420	420	5
6	480	480	490	490	490	490	490	490	500	500	500	500	500	500	510	510	510	510	510	510	510	6
7	570	570	570	580	580	580	580	580	590	590	590	590	590	590	600	600	600	600	600	610	610	7
8	660	660	660	660	670	670	670	670	680	680	680	680	680	690	690	690	690	700	700	700	700	8
9	750	750	750	750	760	760	760	760	770	770	770	770	780	780	780	780	790	790	790	790	800	9
10	790	800	800	800	810	810	810	810	820	820	820	820	830	830	830	830	840	840	840	840	850	10
11	1,190	1,200	1,200	1,200	1,210	1,210	1,220	1,220	1,220	1,230	1,230	1,230	1,240	1,240	1,250	1,250	1,250	1,260	1,260	1,270	1,270	11
12	1,630	1,640	1,640	1,650	1,650	1,660	1,660	1,670	1,670	1,680	1,680	1,690	1,700	1,700	1,710	1,710	1,720	1,720	1,730	1,730	1,740	12
13	2,070	2,080	2,080	2,090	2,100	2,100	2,110	2,120	2,120	2,130	2,140	2,150	2,150	2,160	2,170	2,170	2,180	2,190	2,190	2,200	2,210	13
14	2,510	2,520	2,520	2,530	2,540	2,550	2,560	2,570	2,580	2,580	2,590	2,600	2,610	2,620	2,630	2,630	2,640	2,650	2,660	2,670	2,670	14
15	3,360	3,370	3,390	3,400	3,410	3,420	3,430	3,440	3,460	3,470	3,480	3,490	3,500	3,510	3,520	3,540	3,550	3,560	3,570	3,580	3,590	15
16	4,220	4,230	4,250	4,260	4,280	4,290	4,310	4,320	4,340	4,350	4,370	4,380	4,390	4,410	4,420	4,440	4,450	4,470	4,480	4,490	4,510	16
17	5,070	5,090	5,110	5,130	5,150	5,160	5,180	5,200	5,220	5,240	5,250	5,270	5,290	5,310	5,320	5,340	5,360	5,370	5,390	5,410	5,430	17
18	5,900	5,920	5,940	5,960	5,980	6,000	6,030	6,050	6,070	6,090	6,110	6,130	6,150	6,170	6,190	6,210	6,230	6,250	6,270	6,290	6,310	18
19	6,720	6,750	6,770	6,800	6,820	6,850	6,870	6,890	6,920	6,940	6,970	6,990	7,010	7,040	7,060	7,080	7,110	7,130	7,150	7,180	7,200	19
20	7,550	7,570	7,600	7,630	7,660	7,690	7,710	7,740	7,770	7,800	7,820	7,850	7,880	7,900	7,930	7,960	7,980	8,010	8,040	8,060	8,090	20
21	8,340	8,370	8,400	8,430	8,460	8,500	8,530	8,560	8,590	8,620	8,650	8,680	8,710	8,740	8,770	8,800	8,830	8,860	8,890	8,920	8,950	21
22	9,130	9,170	9,200	9,240	9,270	9,310	9,340	9,380	9,410	9,440	9,480	9,510	9,550	9,580	9,610	9,650	9,680	9,710	9,740	9,780	9,810	22
23	9,930	9,960	10,000	10,040	10,080	10,120	10,160	10,190	10,230	10,270	10,310	10,340	10,380	10,420	10,450	10,490	10,530	10,560	10,600	10,640	10,670	23
24	10,710	10,750	10,790	10,830	10,870	10,920	10,960	11,000	11,040	11,080	11,120	11,160	11,200	11,240	11,290	11,330	11,370	11,410	11,450	11,490	11,520	24
25	11,490	11,530	11,580	11,620	11,670	11,720	11,760	11,810	11,850	11,900	11,940	11,980	12,030	12,070	12,120	12,160	12,200	12,250	12,290	12,330	12,380	25
26	12,270	12,320	12,370	12,420	12,470	12,510	12,560	12,610	12,660	12,710	12,760	12,810	12,850	12,900	12,950	13,000	13,040	13,090	13,140	13,180	13,230	26
27	13,050	13,100	13,150	13,210	13,260	13,310	13,370	13,420	13,470	13,530	13,580	13,630	13,680	13,730	13,780	13,840	13,890	13,940	13,990	14,040	14,090	27
28	13,820	13,880	13,940	14,000	14,060	14,110	14,170	14,230	14,280	14,340	14,400	14,450	14,510	14,570	14,620	14,680	14,730	14,790	14,840	14,890	14,950	28
29	14,600	14,670	14,730	14,790	14,850	14,910	14,970	15,040	15,100	15,160	15,220	15,280	15,340	15,400	15,460	15,520	15,570	15,630	15,690	15,750	15,810	29
30	15,350	15,420	15,490	15,550	15,620	15,680	15,750	15,820	15,880	15,950	16,010	16,070	16,140	16,200	16,270	16,330	16,390	16,460	16,520	16,580	16,640	30
31	16,100	16,170	16,240	16,320	16,390	16,460	16,530	16,600	16,670	16,730	16,800	16,870	16,940	17,010	17,080	17,140	17,210	17,280	17,350	17,410	17,480	31
32	16,850	16,930	17,000	17,080	17,150	17,230	17,300	17,380	17,450	17,520	17,600	17,670	17,740	17,820	17,890	17,960	18,030	18,100	18,170	18,240	18,310	32
33	17,580	17,560	17,560	17,640	17,720	17,800	17,880	17,950	18,030	18,110	18,190	18,260	18,340	18,410	18,490	18,570	18,640	18,720	18,790	18,870	18,940	33
34	18,300	18,200	18,120	18,200	18,280	18,370	18,450	18,530	18,610	18,690	18,770	18,850	18,930	19,010	19,090	19,170	19,250	19,330	19,410	19,490	19,560	34
35	19,030	18,830	18,670	18,760	18,850	18,930	19,020	19,110	19,190	19,280	19,360	19,450	19,530	19,610	19,700	19,780	19,860	19,950	20,030	20,110	20,190	35
36	20,140	20,080	20,050	20,190	20,320	20,460	20,550	20,550	20,540	20,530	20,530	20,520	20,510	20,500	20,480	20,470	20,490	20,570	20,660	20,740	20,830	36
37	21,240	21,330	21,430	21,610	21,800	21,980	22,080	21,990	21,890	21,790	21,690	21,590	21,490	21,380	21,270	21,160	21,110	21,200	21,290	21,380	21,470	37
38	22,350	22,580	22,810	23,040	23,270	23,500	23,610	23,430	23,240	23,050	22,860	22,660	22,460	22,260	22,050	21,850	21,730	21,820	21,920	22,010	22,110	38
39	22,350	22,580	22,810	23,040	23,270	23,500	23,650	23,610	23,560	23,510	23,460	23,410	23,360	23,300	23,250	23,190	23,190	23,330	23,480	23,620	23,710	39
40	22,350	22,580	22,810	23,040	23,270	23,500	23,690	23,790	23,880	23,980	24,070	24,160	24,260	24,350	24,440	24,530	24,650	24,840	25,040	25,230	25,310	40
41	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	26,920	41
42	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	26,970	42
43	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,030	43
44	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	44
45	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	45
46	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	46
47	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	47
48	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	48
49	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	49
50	22,350	22,580	22,810	23,040	23,270	23,500	23,740	23,970	24,210	24,440	24,680	24,910	25,150	25,390	25,630	25,870	26,110	26,350	26,590	26,840	27,080	50

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	870.0	870.1	870.2	870.3	870.4	870.5	870.6	870.7	870.8	870.9	871.0	871.1	871.2	871.3	871.4	871.5	871.6	871.7	871.8	871.9	872.0	
1	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	85	85	85	85	85	85	1
2	160	160	160	160	160	160	160	160	170	170	170	170	170	170	170	170	170	170	170	170	170	2
3	250	250	250	250	250	250	250	250	250	250	250	250	250	260	260	260	260	260	260	260	260	3
4	330	330	340	340	340	340	340	340	340	340	340	340	350	350	350	350	350	350	350	350	350	4
5	420	420	430	430	430	430	430	430	430	430	440	440	440	440	440	440	440	440	450	450	450	5
6	510	520	520	520	520	520	520	530	530	530	530	530	530	530	540	540	540	540	540	540	540	6
7	610	610	610	610	610	620	620	620	620	620	630	630	630	630	630	630	640	640	640	640	640	7
8	700	700	710	710	710	710	710	720	720	720	720	720	730	730	730	730	730	740	740	740	740	8
9	800	800	800	800	810	810	810	810	820	820	820	820	820	830	830	830	830	840	840	840	840	9
10	850	850	850	850	860	860	860	860	870	870	870	870	880	880	880	880	890	890	890	890	890	10
11	1,270	1,270	1,280	1,280	1,280	1,290	1,290	1,300	1,300	1,300	1,310	1,310	1,310	1,320	1,320	1,320	1,330	1,330	1,340	1,340	1,340	11
12	1,740	1,740	1,750	1,750	1,760	1,760	1,770	1,770	1,780	1,780	1,790	1,790	1,800	1,800	1,810	1,810	1,820	1,820	1,830	1,830	1,840	12
13	2,210	2,210	2,220	2,230	2,230	2,240	2,250	2,250	2,260	2,260	2,270	2,280	2,280	2,290	2,300	2,300	2,310	2,320	2,320	2,330	2,330	13
14	2,670	2,680	2,690	2,700	2,710	2,710	2,720	2,730	2,740	2,750	2,750	2,760	2,770	2,780	2,780	2,790	2,800	2,810	2,820	2,820	2,830	14
15	3,590	3,600	3,610	3,620	3,630	3,650	3,660	3,670	3,680	3,690	3,700	3,710	3,720	3,730	3,740	3,750	3,760	3,770	3,780	3,790	3,810	15
16	4,510	4,520	4,540	4,550	4,560	4,580	4,590	4,610	4,620	4,630	4,650	4,660	4,670	4,690	4,700	4,710	4,730	4,740	4,750	4,770	4,780	16
17	5,430	5,440	5,460	5,480	5,490	5,510	5,530	5,540	5,560	5,580	5,590	5,610	5,630	5,640	5,660	5,670	5,690	5,710	5,720	5,740	5,750	17
18	6,310	6,330	6,350	6,370	6,390	6,410	6,430	6,450	6,470	6,490	6,510	6,530	6,550	6,570	6,590	6,610	6,630	6,650	6,660	6,680	6,700	18
19	7,200	7,220	7,250	7,270	7,290	7,320	7,340	7,360	7,380	7,410	7,430	7,450	7,470	7,500	7,520	7,540	7,560	7,580	7,610	7,630	7,650	19
20	8,090	8,120	8,140	8,170	8,190	8,220	8,250	8,270	8,300	8,320	8,350	8,370	8,400	8,420	8,450	8,470	8,500	8,520	8,550	8,570	8,600	20
21	8,950	8,980	9,010	9,040	9,070	9,100	9,130	9,150	9,180	9,210	9,240	9,270	9,300	9,330	9,350	9,380	9,410	9,440	9,470	9,490	9,520	21
22	9,810	9,840	9,880	9,910	9,940	9,970	10,010	10,040	10,070	10,100	10,130	10,160	10,200	10,230	10,260	10,290	10,320	10,350	10,380	10,410	10,440	22
23	10,670	10,710	10,740	10,780	10,810	10,850	10,890	10,920	10,960	10,990	11,030	11,060	11,090	11,130	11,160	11,200	11,230	11,270	11,300	11,330	11,370	23
24	11,520	11,560	11,600	11,640	11,680	11,720	11,760	11,800	11,840	11,870	11,910	11,950	11,990	12,030	12,060	12,100	12,140	12,180	12,210	12,250	12,290	24
25	12,380	12,420	12,460	12,510	12,550	12,590	12,630	12,680	12,720	12,760	12,800	12,840	12,880	12,920	12,970	13,010	13,050	13,090	13,130	13,170	13,210	25
26	13,230	13,280	13,320	13,370	13,420	13,460	13,510	13,550	13,600	13,640	13,690	13,730	13,780	13,820	13,870	13,910	13,950	14,000	14,040	14,090	14,130	26
27	14,090	14,140	14,190	14,240	14,290	14,340	14,390	14,440	14,490	14,540	14,580	14,630	14,680	14,730	14,780	14,830	14,870	14,920	14,970	15,010	15,060	27
28	14,950	15,000	15,060	15,110	15,160	15,220	15,270	15,320	15,380	15,430	15,480	15,530	15,580	15,640	15,690	15,740	15,790	15,840	15,890	15,940	15,990	28
29	15,810	15,870	15,920	15,980	16,040	16,090	16,150	16,210	16,260	16,320	16,380	16,430	16,490	16,540	16,600	16,650	16,710	16,760	16,820	16,870	16,930	29
30	16,640	16,700	16,770	16,830	16,890	16,950	17,010	17,070	17,130	17,190	17,250	17,310	17,370	17,430	17,490	17,550	17,610	17,670	17,720	17,780	17,840	30
31	17,480	17,540	17,610	17,680	17,740	17,810	17,870	17,930	18,000	18,060	18,130	18,190	18,250	18,320	18,380	18,440	18,510	18,570	18,630	18,690	18,750	31
32	18,310	18,380	18,450	18,520	18,590	18,660	18,730	18,800	18,870	18,930	19,000	19,070	19,140	19,200	19,270	19,340	19,400	19,470	19,540	19,600	19,670	32
33	18,940	19,010	19,090	19,160	19,230	19,300	19,380	19,450	19,520	19,590	19,660	19,730	19,810	19,880	19,950	20,020	20,090	20,160	20,220	20,290	20,360	33
34	19,560	19,640	19,720	19,800	19,870	19,950	20,020	20,100	20,180	20,250	20,330	20,400	20,470	20,550	20,620	20,690	20,770	20,840	20,910	20,990	21,060	34
35	20,190	20,270	20,350	20,430	20,510	20,590	20,670	20,750	20,830	20,910	20,990	21,060	21,140	21,220	21,300	21,370	21,450	21,530	21,600	21,680	21,750	35
36	20,830	20,910	21,000	21,080	21,170	21,250	21,330	21,420	21,500	21,580	21,660	21,750	21,830	21,910	21,990	22,070	22,150	22,230	22,310	22,390	22,470	36
37	21,470	21,560	21,650	21,730	21,820	21,910	22,000	22,080	22,170	22,260	22,340	22,430	22,510	22,600	22,680	22,770	22,850	22,940	23,020	23,100	23,190	37
38	22,110	22,200	22,290	22,380	22,480	22,570	22,660	22,750	22,840	22,930	23,020	23,110	23,200	23,290	23,380	23,470	23,550	23,640	23,730	23,810	23,900	38
39	23,710	23,730	23,760	23,780	23,800	23,820	23,830	23,850	23,860	23,880	23,930	24,020	24,120	24,210	24,310	24,400	24,490	24,590	24,680	24,770	24,860	39
40	25,310	25,270	25,220	25,170	25,120	25,060	25,010	24,950	24,890	24,830	24,840	24,940	25,040	25,140	25,240	25,330	25,430	25,530	25,630	25,720	25,820	40
41	26,920	26,800	26,680	26,560	26,440	26,310	26,180	26,050	25,910	25,770	25,750	25,850	25,960	26,060	26,160	26,270	26,370	26,470	26,580	26,680	26,780	41
42	26,970	26,980	26,980	26,980	26,980	26,980	26,970	26,970	26,960	26,950	27,020	27,170	27,330	27,480	27,640	27,790	27,940	28,100	28,250	28,410	28,560	42
43	27,030	27,150	27,280	27,400	27,520	27,640	27,770	27,890	28,010	28,130	28,290	28,490	28,700	28,900	29,110	29,310	29,520	29,720	29,930	30,130	30,340	43
44	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	44
45	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	45
46	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	46
47	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	47
48	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	48
49	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	49
50	27,080	27,330	27,570	27,820	28,070	28,310	28,560	28,810	29,060	29,310	29,560	29,820	30,070	30,320	30,580	30,830	31,090	31,350	31,600	31,860	32,120	50

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	872.0	872.1	872.2	872.3	872.4	872.5	872.6	872.7	872.8	872.9	873.0	873.1	873.2	873.3	873.4	873.5	873.6	873.7	873.8	873.9	874.0	
1	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	90	90	90	1
2	170	170	170	170	170	170	170	170	170	170	180	180	180	180	180	180	180	180	180	180	180	2
3	260	260	260	260	260	260	260	260	270	270	270	270	270	270	270	270	270	270	270	270	270	3
4	350	350	350	360	360	360	360	360	360	360	360	360	360	360	370	370	370	370	370	370	370	4
5	450	450	450	450	450	450	450	460	460	460	460	460	460	460	460	460	470	470	470	470	470	5
6	540	550	550	550	550	550	550	550	560	560	560	560	560	560	560	570	570	570	570	570	570	6
7	640	640	650	650	650	650	650	650	660	660	660	660	660	660	670	670	670	670	670	670	680	7
8	740	740	750	750	750	750	750	760	760	760	760	760	770	770	770	770	770	780	780	780	780	8
9	840	840	850	850	850	850	860	860	860	860	860	870	870	870	870	880	880	880	880	880	890	9
10	890	900	900	900	900	910	910	910	910	920	920	920	920	930	930	930	930	930	940	940	940	10
11	1, 340	1, 350	1, 350	1, 350	1, 360	1, 360	1, 360	1, 370	1, 370	1, 370	1, 380	1, 380	1, 380	1, 390	1, 390	1, 390	1, 400	1, 400	1, 400	1, 410	1, 410	11
12	1, 840	1, 840	1, 850	1, 850	1, 860	1, 860	1, 870	1, 870	1, 880	1, 880	1, 890	1, 890	1, 900	1, 900	1, 910	1, 910	1, 920	1, 920	1, 920	1, 930	1, 930	12
13	2, 330	2, 340	2, 350	2, 350	2, 360	2, 370	2, 370	2, 380	2, 380	2, 390	2, 400	2, 400	2, 410	2, 410	2, 420	2, 430	2, 430	2, 440	2, 440	2, 450	2, 460	13
14	2, 830	2, 840	2, 850	2, 850	2, 860	2, 870	2, 880	2, 880	2, 890	2, 900	2, 910	2, 910	2, 920	2, 930	2, 940	2, 940	2, 950	2, 960	2, 960	2, 970	2, 980	14
15	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	4, 000	4, 010	15
16	4, 780	4, 790	4, 810	4, 820	4, 830	4, 850	4, 860	4, 870	4, 880	4, 900	4, 910	4, 920	4, 940	4, 950	4, 960	4, 970	4, 990	5, 000	5, 010	5, 020	5, 040	16
17	5, 750	5, 770	5, 790	5, 800	5, 820	5, 830	5, 850	5, 870	5, 880	5, 900	5, 910	5, 930	5, 940	5, 960	5, 970	5, 990	6, 010	6, 020	6, 040	6, 050	6, 070	17
18	6, 700	6, 720	6, 740	6, 760	6, 780	6, 800	6, 810	6, 830	6, 850	6, 870	6, 890	6, 910	6, 930	6, 940	6, 960	6, 980	7, 000	7, 020	7, 030	7, 050	7, 070	18
19	7, 650	7, 670	7, 690	7, 720	7, 740	7, 760	7, 780	7, 800	7, 820	7, 840	7, 870	7, 890	7, 910	7, 930	7, 950	7, 970	7, 990	8, 010	8, 030	8, 050	8, 070	19
20	8, 600	8, 620	8, 650	8, 670	8, 700	8, 720	8, 740	8, 770	8, 790	8, 820	8, 840	8, 870	8, 890	8, 910	8, 940	8, 960	8, 980	9, 010	9, 030	9, 060	9, 080	20
21	9, 520	9, 550	9, 580	9, 600	9, 630	9, 660	9, 690	9, 710	9, 740	9, 770	9, 790	9, 820	9, 850	9, 880	9, 900	9, 930	9, 960	9, 980	10, 010	10, 030	10, 060	21
22	10, 440	10, 480	10, 510	10, 540	10, 570	10, 600	10, 630	10, 660	10, 690	10, 720	10, 750	10, 780	10, 810	10, 840	10, 870	10, 900	10, 930	10, 960	10, 980	11, 010	11, 040	22
23	11, 370	11, 400	11, 440	11, 470	11, 500	11, 540	11, 570	11, 600	11, 640	11, 670	11, 700	11, 730	11, 770	11, 800	11, 830	11, 860	11, 900	11, 930	11, 960	11, 990	12, 030	23
24	12, 290	12, 330	12, 360	12, 400	12, 440	12, 470	12, 510	12, 550	12, 580	12, 620	12, 650	12, 690	12, 730	12, 760	12, 800	12, 830	12, 870	12, 900	12, 940	12, 970	13, 010	24
25	13, 210	13, 250	13, 290	13, 330	13, 370	13, 410	13, 450	13, 490	13, 530	13, 570	13, 610	13, 650	13, 680	13, 720	13, 760	13, 800	13, 840	13, 880	13, 920	13, 950	13, 990	25
26	14, 130	14, 170	14, 220	14, 260	14, 300	14, 350	14, 390	14, 430	14, 470	14, 520	14, 560	14, 600	14, 640	14, 680	14, 730	14, 770	14, 810	14, 850	14, 890	14, 930	14, 970	26
27	15, 060	15, 110	15, 160	15, 200	15, 250	15, 300	15, 340	15, 390	15, 430	15, 480	15, 530	15, 570	15, 620	15, 660	15, 710	15, 750	15, 800	15, 840	15, 890	15, 930	15, 980	27
28	15, 990	16, 040	16, 100	16, 150	16, 200	16, 250	16, 290	16, 340	16, 390	16, 440	16, 490	16, 540	16, 590	16, 640	16, 690	16, 740	16, 780	16, 830	16, 880	16, 930	16, 980	28
29	16, 930	16, 980	17, 030	17, 090	17, 140	17, 190	17, 250	17, 300	17, 350	17, 410	17, 460	17, 510	17, 560	17, 620	17, 670	17, 720	17, 770	17, 820	17, 870	17, 930	17, 980	29
30	17, 840	17, 900	17, 960	18, 010	18, 070	18, 130	18, 180	18, 240	18, 300	18, 350	18, 410	18, 470	18, 520	18, 580	18, 630	18, 690	18, 740	18, 800	18, 850	18, 910	18, 960	30
31	18, 750	18, 820	18, 880	18, 940	19, 000	19, 060	19, 120	19, 180	19, 240	19, 300	19, 360	19, 420	19, 480	19, 540	19, 600	19, 660	19, 710	19, 770	19, 830	19, 890	19, 950	31
32	19, 670	19, 730	19, 800	19, 860	19, 930	19, 990	20, 060	20, 120	20, 180	20, 250	20, 310	20, 370	20, 440	20, 500	20, 560	20, 620	20, 690	20, 750	20, 810	20, 870	20, 930	32
33	20, 360	20, 430	20, 500	20, 570	20, 640	20, 700	20, 770	20, 840	20, 900	20, 970	21, 040	21, 100	21, 170	21, 240	21, 300	21, 370	21, 430	21, 500	21, 560	21, 630	21, 690	33
34	21, 060	21, 130	21, 200	21, 270	21, 340	21, 410	21, 490	21, 560	21, 630	21, 700	21, 770	21, 840	21, 900	21, 970	22, 040	22, 110	22, 180	22, 250	22, 320	22, 380	22, 450	34
35	21, 750	21, 830	21, 900	21, 980	22, 050	22, 130	22, 200	22, 270	22, 350	22, 420	22, 490	22, 570	22, 640	22, 710	22, 780	22, 860	22, 930	23, 000	23, 070	23, 140	23, 210	35
36	22, 470	22, 550	22, 630	22, 710	22, 780	22, 860	22, 940	23, 020	23, 090	23, 170	23, 250	23, 320	23, 400	23, 470	23, 550	23, 620	23, 700	23, 770	23, 850	23, 920	24, 000	36
37	23, 190	23, 270	23, 350	23, 430	23, 510	23, 600	23, 680	23, 760	23, 840	23, 920	24, 000	24, 080	24, 160	24, 240	24, 320	24, 390	24, 470	24, 550	24, 630	24, 710	24, 780	37
38	23, 900	23, 990	24, 070	24, 160	24, 240	24, 330	24, 410	24, 500	24, 580	24, 670	24, 750	24, 830	24, 920	25, 000	25, 080	25, 160	25, 250	25, 330	25, 410	25, 490	25, 570	38
39	24, 860	24, 950	25, 040	25, 130	25, 220	25, 310	25, 400	25, 490	25, 580	25, 670	25, 760	25, 850	25, 930	26, 020	26, 110	26, 200	26, 280	26, 370	26, 450	26, 540	26, 630	39
40	25, 820	25, 920	26, 010	26, 110	26, 200	26, 300	26, 390	26, 490	26, 580	26, 670	26, 770	26, 860	26, 950	27, 040	27, 130	27, 230	27, 320	27, 410	27, 500	27, 590	27, 680	40
41	26, 780	26, 880	26, 980	27, 080	27, 180	27, 280	27, 380	27, 480	27, 580	27, 680	27, 770	27, 870	27, 970	28, 060	28, 160	28, 260	28, 350	28, 450	28, 540	28, 640	28, 730	41
42	28, 560	28, 710	28, 870	29, 020	29, 180	29, 330	29, 480	29, 640	29, 740	29, 790	29, 850	29, 900	29, 950	30, 000	30, 050	30, 100	30, 140	30, 190	30, 260	30, 370	30, 470	42
43	30, 340	30, 550	30, 760	30, 960	31, 170	31, 380	31, 590	31, 800	31, 910	31, 910	31, 920	31, 930	31, 930	31, 930	31, 930	31, 930	31, 930	31, 930	31, 980	32, 100	32, 210	43
44	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 070	34, 030	33, 990	33, 950	33, 910	33, 870	33, 820	33, 770	33, 720	33, 670	33, 700	33, 830	33, 950	44
45	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 120	34, 180	34, 250	34, 310	34, 370	34, 430	34, 490	34, 550	34, 600	34, 660	34, 770	34, 950	35, 120	45
46	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 170	34, 340	34, 500	34, 660	34, 830	34, 990	35, 160	35, 320	35, 490	35, 650	35, 840	36, 060	36, 290	46
47	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	47
48	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	48
49	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	49
50	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	50
51	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	51
52	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	52
53	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	53
54	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	54
55	32, 120	32, 380	32, 640	32, 900	33, 170	33, 430	33, 690	33, 960	34, 220	34, 490	34, 750	35, 020	35, 290	35, 560	35, 830	36, 100	36, 370	36, 640	36, 910	37, 180	37, 460	55

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	874.0	874.1	874.2	874.3	874.4	874.5	874.6	874.7	874.8	874.9	875.0	875.1	875.2	875.3	875.4	875.5	875.6	875.7	875.8	875.9	876.0	GATE ARRANGE-MENT
	HEADWATER ELEVATION																					
1	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	1
2	180	180	180	180	180	180	180	180	180	180	180	180	180	180	190	190	190	190	190	190	190	2
3	270	270	270	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	290	290	290	3
4	370	370	370	370	370	380	380	380	380	380	380	380	380	380	380	380	390	390	390	390	390	4
5	470	470	470	470	480	480	480	480	480	480	480	480	480	480	490	490	490	490	490	490	490	5
6	570	570	580	580	580	580	580	580	580	580	590	590	590	590	590	590	590	600	600	600	600	6
7	680	680	680	680	680	680	690	690	690	690	690	690	700	700	700	700	700	700	700	710	710	7
8	780	780	780	790	790	790	790	790	800	800	800	800	800	810	810	810	810	810	810	820	820	8
9	890	890	890	890	900	900	900	900	900	910	910	910	910	910	920	920	920	920	920	930	930	9
10	940	940	950	950	950	950	950	960	960	960	960	970	970	970	970	970	980	980	980	980	990	10
11	1,410	1,420	1,420	1,420	1,430	1,430	1,430	1,440	1,440	1,440	1,450	1,450	1,450	1,450	1,460	1,460	1,460	1,470	1,470	1,470	1,480	11
12	1,930	1,940	1,940	1,950	1,950	1,960	1,960	1,970	1,970	1,980	1,980	1,980	1,990	1,990	2,000	2,000	2,010	2,010	2,020	2,020	2,030	12
13	2,460	2,460	2,470	2,470	2,480	2,490	2,490	2,500	2,500	2,510	2,520	2,520	2,530	2,530	2,540	2,540	2,550	2,560	2,560	2,570	2,570	13
14	2,980	2,990	2,990	3,000	3,010	3,020	3,020	3,030	3,040	3,040	3,050	3,060	3,060	3,070	3,080	3,090	3,090	3,100	3,110	3,110	3,120	14
15	4,010	4,020	4,030	4,040	4,050	4,060	4,070	4,080	4,090	4,100	4,110	4,120	4,120	4,130	4,140	4,150	4,160	4,170	4,180	4,190	4,200	15
16	5,040	5,050	5,060	5,070	5,090	5,100	5,110	5,120	5,140	5,150	5,160	5,170	5,190	5,200	5,210	5,220	5,230	5,250	5,260	5,270	5,280	16
17	6,070	6,080	6,100	6,110	6,130	6,140	6,160	6,170	6,190	6,200	6,220	6,230	6,250	6,260	6,270	6,290	6,300	6,320	6,330	6,350	6,360	17
18	7,070	7,090	7,110	7,120	7,140	7,160	7,180	7,190	7,210	7,230	7,250	7,260	7,280	7,300	7,320	7,330	7,350	7,370	7,390	7,400	7,420	18
19	8,070	8,090	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	19
20	9,080	9,100	9,130	9,150	9,170	9,190	9,220	9,240	9,260	9,290	9,310	9,330	9,350	9,380	9,400	9,420	9,450	9,470	9,490	9,510	9,530	20
21	10,060	10,090	10,110	10,140	10,170	10,190	10,220	10,240	10,270	10,290	10,320	10,350	10,370	10,400	10,420	10,450	10,470	10,500	10,520	10,550	10,570	21
22	11,040	11,070	11,100	11,130	11,160	11,190	11,220	11,240	11,270	11,300	11,330	11,360	11,390	11,410	11,440	11,470	11,500	11,530	11,550	11,580	11,610	22
23	12,030	12,060	12,090	12,120	12,150	12,180	12,220	12,250	12,280	12,310	12,340	12,370	12,400	12,430	12,460	12,500	12,530	12,560	12,590	12,620	12,650	23
24	13,010	13,040	13,080	13,110	13,150	13,180	13,220	13,250	13,290	13,320	13,350	13,390	13,420	13,460	13,490	13,520	13,560	13,590	13,620	13,660	13,690	24
25	13,990	14,030	14,070	14,110	14,140	14,180	14,220	14,260	14,290	14,330	14,370	14,400	14,440	14,480	14,510	14,550	14,590	14,620	14,660	14,700	14,730	25
26	14,970	15,020	15,060	15,100	15,140	15,180	15,220	15,260	15,300	15,340	15,380	15,420	15,460	15,500	15,540	15,580	15,620	15,660	15,700	15,740	15,770	26
27	15,980	16,020	16,060	16,110	16,150	16,200	16,240	16,280	16,330	16,370	16,410	16,460	16,500	16,540	16,580	16,630	16,670	16,710	16,750	16,800	16,840	27
28	16,980	17,020	17,070	17,120	17,170	17,210	17,260	17,310	17,350	17,400	17,450	17,490	17,540	17,580	17,630	17,680	17,720	17,770	17,810	17,860	17,900	28
29	17,980	18,030	18,080	18,130	18,180	18,230	18,280	18,330	18,380	18,430	18,480	18,530	18,580	18,630	18,680	18,720	18,770	18,820	18,870	18,920	18,970	29
30	18,960	19,020	19,070	19,120	19,180	19,230	19,290	19,340	19,390	19,450	19,500	19,550	19,600	19,660	19,710	19,760	19,810	19,870	19,920	19,970	20,020	30
31	19,950	20,010	20,060	20,120	20,180	20,240	20,290	20,350	20,410	20,460	20,520	20,580	20,630	20,690	20,740	20,800	20,850	20,910	20,960	21,020	21,070	31
32	20,930	21,000	21,060	21,120	21,180	21,240	21,300	21,360	21,420	21,480	21,540	21,600	21,660	21,720	21,780	21,840	21,890	21,950	22,010	22,070	22,130	32
33	21,690	21,760	21,820	21,890	21,950	22,010	22,080	22,140	22,200	22,270	22,330	22,390	22,450	22,520	22,580	22,640	22,700	22,760	22,820	22,890	22,950	33
34	22,450	22,520	22,590	22,650	22,720	22,790	22,850	22,920	22,990	23,050	23,120	23,180	23,250	23,310	23,380	23,440	23,510	23,570	23,640	23,700	23,760	34
35	23,210	23,280	23,350	23,420	23,490	23,560	23,630	23,700	23,770	23,840	23,910	23,970	24,040	24,110	24,180	24,250	24,310	24,380	24,450	24,520	24,580	35
36	24,000	24,070	24,150	24,220	24,290	24,360	24,440	24,510	24,580	24,650	24,730	24,800	24,870	24,940	25,010	25,080	25,150	25,220	25,290	25,360	25,430	36
37	24,780	24,860	24,940	25,020	25,090	25,170	25,240	25,320	25,400	25,470	25,550	25,620	25,700	25,770	25,850	25,920	25,990	26,070	26,140	26,210	26,290	37
38	25,570	25,650	25,730	25,810	25,890	25,970	26,050	26,130	26,210	26,290	26,370	26,440	26,520	26,600	26,680	26,760	26,830	26,910	26,990	27,060	27,140	38
39	26,630	26,710	26,800	26,880	26,960	27,050	27,130	27,220	27,300	27,380	27,470	27,550	27,630	27,710	27,790	27,880	27,960	28,040	28,120	28,200	28,280	39
40	27,680	27,770	27,860	27,950	28,040	28,120	28,210	28,300	28,390	28,480	28,560	28,650	28,740	28,820	28,910	29,000	29,080	29,170	29,250	29,340	29,420	40
41	28,730	28,830	28,920	29,020	29,110	29,200	29,290	29,390	29,480	29,570	29,660	29,750	29,840	29,940	30,030	30,120	30,210	30,300	30,380	30,470	30,560	41
42	30,470	30,570	30,680	30,780	30,880	30,980	31,090	31,190	31,290	31,390	31,490	31,590	31,690	31,790	31,890	31,980	32,080	32,180	32,280	32,380	32,470	42
43	32,210	32,320	32,430	32,550	32,660	32,770	32,880	32,990	33,100	33,210	33,310	33,420	33,530	33,640	33,750	33,850	33,960	34,070	34,170	34,280	34,380	43
44	33,950	34,070	34,190	34,310	34,430	34,550	34,670	34,790	34,910	35,020	35,140	35,260	35,370	35,490	35,610	35,720	35,840	35,950	36,070	36,180	36,290	44
45	35,120	35,290	35,460	35,630	35,810	35,980	36,150	36,320	36,490	36,670	36,840	37,010	37,180	37,350	37,520	37,700	37,830	37,910	37,990	38,070	38,150	45
46	36,290	36,510	36,730	36,960	37,180	37,410	37,630	37,860	38,080	38,310	38,530	38,760	38,990	39,210	39,440	39,670	39,830	39,880	39,920	39,970	40,010	46
47	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,830	41,840	41,850	41,860	41,870	47
48	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,860	41,970	42,070	42,170	42,270	48
49	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,900	42,090	42,280	42,480	42,670	49
50	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	50
51	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	51
52	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	52
53	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	53
54	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	54
55	37,460	37,730	38,010	38,280	38,560	38,830	39,110	39,390	39,670	39,950	40,230	40,510	40,790	41,080	41,360	41,640	41,930	42,210	42,500	42,790	43,070	55

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	876.0	876.1	876.2	876.3	876.4	876.5	876.6	876.7	876.8	876.9	877.0	877.1	877.2	877.3	877.4	877.5	877.6	877.7	877.8	877.9	878.0	
1	90	90	90	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	1
2	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	200	200	2
3	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	300	300	300	300	300	300	3
4	390	390	390	390	390	390	390	390	400	400	400	400	400	400	400	400	400	400	400	400	410	4
5	490	490	490	500	500	500	500	500	500	500	500	500	510	510	510	510	510	510	510	510	510	5
6	600	600	600	600	600	610	610	610	610	610	610	610	610	620	620	620	620	620	620	620	630	6
7	710	710	710	710	710	720	720	720	720	720	720	720	730	730	730	730	730	730	740	740	740	7
8	820	820	820	820	830	830	830	830	830	830	840	840	840	840	840	840	850	850	850	850	850	8
9	930	930	930	930	940	940	940	940	940	950	950	950	950	950	960	960	960	960	960	970	970	9
10	990	990	990	990	990	1,000	1,000	1,000	1,000	1,000	1,010	1,010	1,010	1,010	1,010	1,020	1,020	1,020	1,020	1,030	1,030	10
11	1,480	1,480	1,480	1,490	1,490	1,490	1,500	1,500	1,500	1,510	1,510	1,510	1,520	1,520	1,520	1,530	1,530	1,530	1,530	1,540	1,540	11
12	2,030	2,030	2,030	2,040	2,040	2,050	2,050	2,060	2,060	2,070	2,070	2,070	2,080	2,080	2,090	2,090	2,100	2,100	2,100	2,110	2,110	12
13	2,570	2,580	2,580	2,590	2,600	2,600	2,610	2,610	2,620	2,620	2,630	2,630	2,640	2,650	2,650	2,660	2,660	2,670	2,670	2,680	2,680	13
14	3,120	3,130	3,130	3,140	3,150	3,150	3,160	3,170	3,180	3,180	3,190	3,200	3,200	3,210	3,220	3,220	3,230	3,240	3,240	3,250	3,260	14
15	4,200	4,210	4,220	4,230	4,240	4,250	4,260	4,270	4,280	4,290	4,290	4,300	4,310	4,320	4,330	4,340	4,350	4,360	4,370	4,380	4,390	15
16	5,280	5,290	5,310	5,320	5,330	5,340	5,350	5,360	5,380	5,390	5,400	5,410	5,420	5,430	5,450	5,460	5,470	5,480	5,490	5,500	5,520	16
17	6,360	6,380	6,390	6,410	6,420	6,430	6,450	6,460	6,480	6,490	6,510	6,520	6,530	6,550	6,560	6,580	6,590	6,600	6,620	6,630	6,650	17
18	7,420	7,440	7,450	7,470	7,490	7,500	7,520	7,540	7,560	7,570	7,590	7,610	7,620	7,640	7,650	7,670	7,690	7,700	7,720	7,740	7,750	18
19	8,480	8,500	8,520	8,540	8,560	8,570	8,590	8,610	8,630	8,650	8,670	8,690	8,710	8,730	8,750	8,770	8,790	8,810	8,820	8,840	8,860	19
20	9,530	9,560	9,580	9,600	9,620	9,650	9,670	9,690	9,710	9,730	9,750	9,780	9,800	9,820	9,840	9,860	9,880	9,910	9,930	9,950	9,970	20
21	10,570	10,600	10,620	10,650	10,670	10,700	10,720	10,750	10,770	10,790	10,820	10,840	10,870	10,890	10,920	10,940	10,960	10,990	11,010	11,040	11,060	21
22	11,610	11,640	11,670	11,690	11,720	11,750	11,770	11,800	11,830	11,860	11,880	11,910	11,940	11,960	11,990	12,020	12,040	12,070	12,100	12,120	12,150	22
23	12,650	12,680	12,710	12,740	12,770	12,800	12,830	12,860	12,890	12,920	12,950	12,980	13,010	13,040	13,070	13,100	13,120	13,150	13,180	13,210	13,240	23
24	13,690	13,720	13,760	13,790	13,820	13,860	13,890	13,920	13,950	13,990	14,020	14,050	14,080	14,120	14,150	14,180	14,210	14,240	14,280	14,310	14,340	24
25	14,730	14,770	14,800	14,840	14,880	14,910	14,950	14,980	15,020	15,050	15,090	15,120	15,160	15,190	15,230	15,260	15,300	15,330	15,370	15,400	15,440	25
26	15,770	15,810	15,850	15,890	15,930	15,970	16,010	16,050	16,080	16,120	16,160	16,200	16,240	16,270	16,310	16,350	16,390	16,420	16,460	16,500	16,540	26
27	16,840	16,880	16,920	16,960	17,010	17,050	17,090	17,130	17,170	17,210	17,250	17,300	17,340	17,380	17,420	17,460	17,500	17,540	17,580	17,620	17,660	27
28	17,900	17,950	17,990	18,040	18,080	18,130	18,170	18,220	18,260	18,310	18,350	18,390	18,440	18,480	18,520	18,570	18,610	18,660	18,700	18,740	18,790	28
29	18,970	19,020	19,060	19,110	19,160	19,210	19,260	19,300	19,350	19,400	19,440	19,490	19,540	19,590	19,630	19,680	19,720	19,770	19,820	19,860	19,910	29
30	20,020	20,070	20,120	20,180	20,230	20,280	20,330	20,380	20,430	20,480	20,530	20,580	20,630	20,680	20,730	20,780	20,830	20,880	20,930	20,980	21,030	30
31	21,070	21,130	21,180	21,240	21,290	21,350	21,400	21,450	21,510	21,560	21,620	21,670	21,720	21,780	21,830	21,880	21,930	21,990	22,040	22,090	22,140	31
32	22,130	22,190	22,240	22,300	22,360	22,420	22,470	22,530	22,590	22,650	22,700	22,760	22,810	22,870	22,930	22,980	23,040	23,090	23,150	23,210	23,260	32
33	22,950	23,010	23,070	23,130	23,190	23,250	23,310	23,370	23,430	23,490	23,550	23,610	23,670	23,730	23,780	23,840	23,900	23,960	24,020	24,080	24,130	33
34	23,760	23,830	23,890	23,950	24,020	24,080	24,140	24,210	24,270	24,330	24,390	24,460	24,520	24,580	24,640	24,700	24,760	24,830	24,890	24,950	25,010	34
35	24,580	24,650	24,720	24,780	24,850	24,910	24,980	25,040	25,110	25,170	25,240	25,300	25,370	25,430	25,500	25,560	25,630	25,690	25,750	25,820	25,880	35
36	25,430	25,500	25,570	25,640	25,710	25,780	25,850	25,920	25,990	26,050	26,120	26,190	26,260	26,330	26,390	26,460	26,530	26,590	26,660	26,730	26,790	36
37	26,290	26,360	26,430	26,500	26,580	26,650	26,720	26,790	26,860	26,940	27,010	27,080	27,150	27,220	27,290	27,360	27,430	27,500	27,570	27,640	27,710	37
38	27,140	27,210	27,290	27,370	27,440	27,520	27,590	27,670	27,740	27,820	27,890	27,960	28,040	28,110	28,180	28,260	28,330	28,400	28,480	28,550	28,620	38
39	28,280	28,360	28,440	28,520	28,600	28,680	28,760	28,840	28,920	28,990	29,070	29,150	29,230	29,310	29,380	29,460	29,540	29,610	29,690	29,770	29,840	39
40	29,420	29,510	29,590	29,670	29,760	29,840	29,920	30,010	30,090	30,170	30,250	30,340	30,420	30,500	30,580	30,660	30,740	30,820	30,910	30,990	31,070	40
41	30,560	30,650	30,740	30,830	30,920	31,000	31,090	31,180	31,260	31,350	31,440	31,520	31,610	31,700	31,780	31,870	31,950	32,040	32,120	32,200	32,290	41
42	32,470	32,570	32,670	32,760	32,860	32,950	33,050	33,140	33,240	33,330	33,430	33,520	33,620	33,710	33,800	33,900	33,990	34,080	34,170	34,270	34,360	42
43	34,380	34,490	34,590	34,700	34,800	34,910	35,010	35,110	35,210	35,320	35,420	35,520	35,620	35,730	35,830	35,930	36,030	36,130	36,230	36,330	36,430	43
44	36,290	36,410	36,520	36,630	36,740	36,860	36,970	37,080	37,190	37,300	37,410	37,520	37,630	37,740	37,850	37,960	38,070	38,170	38,280	38,390	38,500	44
45	38,150	38,230	38,300	38,380	38,460	38,530	38,620	38,740	38,860	38,980	39,100	39,210	39,330	39,450	39,570	39,680	39,800	39,920	40,030	40,150	40,260	45
46	40,010	40,050	40,090	40,130	40,170	40,200	40,270	40,400	40,530	40,660	40,780	40,910	41,030	41,160	41,290	41,410	41,530	41,660	41,780	41,910	42,030	46
47	41,870	41,870	41,870	41,880	41,880	41,880	41,920	42,060	42,200	42,330	42,470	42,600	42,740	42,870	43,000	43,140	43,270	43,400	43,530	43,660	43,790	47
48	42,270	42,370	42,470	42,560	42,660	42,760	42,890	43,070	43,260	43,450	43,640	43,830	44,010	44,200	44,390	44,580	44,770	44,950	45,140	45,330	45,520	48
49	42,670	42,860	43,060	43,250	43,440	43,640	43,850	44,090	44,330	44,570	44,810	45,050	45,290	45,540	45,780	46,020	46,260	46,510	46,750	46,990	47,240	49
50	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	50
51	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	51
52	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	52
53	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	53
54	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	54
55	43,070	43,360	43,650	43,940	44,230	44,520	44,810	45,100	45,390	45,690	45,980	46,280	46,570	46,870	47,160	47,460	47,760	48,060	48,360	48,660	48,960	55

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	878.0	878.1	878.2	878.3	878.4	878.5	878.6	878.7	878.8	878.9	879.0	879.1	879.2	879.3	879.4	879.5	879.6	879.7	879.8	879.9	880.0	
1	95	95	95	95	95	95	95	95	95	100	100	100	100	100	100	100	100	100	100	100	100	1
2	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	2
3	300	300	300	300	300	300	300	300	300	300	300	310	310	310	310	310	310	310	310	310	310	3
4	410	410	410	410	410	410	410	410	410	410	410	410	410	420	420	420	420	420	420	420	420	4
5	510	510	520	520	520	520	520	520	520	520	520	520	530	530	530	530	530	530	530	530	530	5
6	630	630	630	630	630	630	630	630	640	640	640	640	640	640	640	640	640	650	650	650	650	6
7	740	740	740	740	740	750	750	750	750	750	750	750	760	760	760	760	760	760	760	770	770	7
8	850	850	860	860	860	860	860	870	870	870	870	870	870	880	880	880	880	880	880	890	890	8
9	970	970	970	970	980	980	980	980	980	990	990	990	990	990	1,000	1,000	1,000	1,000	1,000	1,010	1,010	9
10	1,030	1,030	1,030	1,030	1,040	1,040	1,040	1,040	1,040	1,050	1,050	1,050	1,050	1,050	1,060	1,060	1,060	1,060	1,060	1,070	1,070	10
11	1,540	1,540	1,550	1,550	1,550	1,560	1,560	1,560	1,570	1,570	1,570	1,570	1,580	1,580	1,580	1,590	1,590	1,590	1,600	1,600	1,600	11
12	2,110	2,120	2,120	2,130	2,130	2,130	2,140	2,140	2,150	2,150	2,150	2,160	2,160	2,170	2,170	2,180	2,180	2,180	2,190	2,190	2,200	12
13	2,680	2,690	2,700	2,700	2,710	2,710	2,720	2,720	2,730	2,730	2,740	2,740	2,750	2,750	2,760	2,760	2,770	2,780	2,780	2,790	2,790	13
14	3,260	3,260	3,270	3,280	3,280	3,290	3,300	3,300	3,310	3,310	3,320	3,330	3,330	3,340	3,350	3,350	3,360	3,370	3,370	3,380	3,390	14
15	4,390	4,390	4,400	4,410	4,420	4,430	4,440	4,450	4,460	4,470	4,480	4,480	4,490	4,500	4,510	4,520	4,530	4,540	4,550	4,550	4,560	15
16	5,520	5,530	5,540	5,550	5,560	5,570	5,580	5,590	5,610	5,620	5,630	5,640	5,650	5,660	5,670	5,680	5,700	5,710	5,720	5,730	5,740	16
17	6,650	6,660	6,670	6,690	6,700	6,710	6,730	6,740	6,760	6,770	6,780	6,800	6,810	6,820	6,840	6,850	6,860	6,880	6,890	6,900	6,920	17
18	7,750	7,770	7,790	7,800	7,820	7,830	7,850	7,870	7,880	7,900	7,920	7,930	7,950	7,960	7,980	7,990	8,010	8,030	8,040	8,060	8,070	18
19	8,860	8,880	8,900	8,920	8,940	8,960	8,970	8,990	9,010	9,030	9,050	9,070	9,080	9,100	9,120	9,140	9,160	9,180	9,190	9,210	9,230	19
20	9,970	9,990	10,010	10,030	10,050	10,080	10,100	10,120	10,140	10,160	10,180	10,200	10,220	10,240	10,260	10,280	10,310	10,330	10,350	10,370	10,390	20
21	11,060	11,080	11,110	11,130	11,160	11,180	11,200	11,230	11,250	11,270	11,300	11,320	11,340	11,370	11,390	11,410	11,440	11,460	11,480	11,500	11,530	21
22	12,150	12,180	12,200	12,230	12,260	12,280	12,310	12,330	12,360	12,390	12,410	12,440	12,460	12,490	12,520	12,540	12,570	12,590	12,620	12,640	12,670	22
23	13,240	13,270	13,300	13,330	13,360	13,390	13,410	13,440	13,470	13,500	13,530	13,560	13,580	13,610	13,640	13,670	13,700	13,730	13,750	13,780	13,810	23
24	14,340	14,370	14,400	14,430	14,470	14,500	14,530	14,560	14,590	14,620	14,650	14,680	14,720	14,750	14,780	14,810	14,840	14,870	14,900	14,930	14,960	24
25	15,440	15,470	15,510	15,540	15,570	15,610	15,640	15,680	15,710	15,740	15,780	15,810	15,850	15,880	15,910	15,950	15,980	16,010	16,050	16,080	16,110	25
26	16,540	16,570	16,610	16,650	16,680	16,720	16,760	16,790	16,830	16,870	16,900	16,940	16,980	17,010	17,050	17,080	17,120	17,160	17,190	17,230	17,260	26
27	17,660	17,700	17,740	17,780	17,820	17,860	17,900	17,940	17,980	18,020	18,060	18,100	18,140	18,170	18,210	18,250	18,290	18,330	18,370	18,410	18,450	27
28	18,790	18,830	18,870	18,910	18,960	19,000	19,040	19,080	19,130	19,170	19,210	19,250	19,290	19,340	19,380	19,420	19,460	19,500	19,540	19,590	19,630	28
29	19,910	19,960	20,000	20,050	20,090	20,140	20,180	20,230	20,270	20,320	20,360	20,410	20,450	20,500	20,540	20,590	20,630	20,680	20,720	20,770	20,810	29
30	21,030	21,080	21,120	21,170	21,220	21,270	21,320	21,370	21,420	21,460	21,510	21,560	21,610	21,660	21,700	21,750	21,800	21,850	21,890	21,940	21,990	30
31	22,140	22,200	22,250	22,300	22,350	22,400	22,450	22,510	22,560	22,610	22,660	22,710	22,760	22,810	22,860	22,910	22,960	23,010	23,060	23,110	23,160	31
32	23,260	23,320	23,370	23,430	23,480	23,540	23,590	23,640	23,700	23,750	23,810	23,860	23,920	23,970	24,020	24,080	24,130	24,180	24,240	24,290	24,340	32
33	24,130	24,190	24,250	24,310	24,370	24,420	24,480	24,540	24,590	24,650	24,710	24,760	24,820	24,880	24,930	24,990	25,040	25,100	25,160	25,210	25,270	33
34	25,010	25,070	25,130	25,190	25,250	25,310	25,370	25,430	25,490	25,550	25,610	25,670	25,720	25,780	25,840	25,900	25,960	26,020	26,080	26,130	26,190	34
35	25,880	25,940	26,010	26,070	26,130	26,200	26,260	26,320	26,380	26,440	26,510	26,570	26,630	26,690	26,750	26,810	26,870	26,940	27,000	27,060	27,120	35
36	26,790	26,860	26,930	26,990	27,060	27,120	27,190	27,250	27,320	27,380	27,450	27,510	27,580	27,640	27,710	27,770	27,830	27,900	27,960	28,020	28,090	36
37	27,710	27,780	27,850	27,910	27,980	28,050	28,120	28,190	28,260	28,320	28,390	28,460	28,530	28,590	28,660	28,730	28,790	28,860	28,930	28,990	29,060	37
38	28,620	28,690	28,760	28,840	28,910	28,980	29,050	29,120	29,190	29,260	29,330	29,400	29,470	29,540	29,610	29,680	29,750	29,820	29,890	29,960	30,030	38
39	29,840	29,920	29,990	30,070	30,150	30,220	30,300	30,370	30,450	30,520	30,590	30,670	30,740	30,820	30,890	30,960	31,040	31,110	31,180	31,260	31,330	39
40	31,070	31,150	31,230	31,310	31,380	31,460	31,540	31,620	31,700	31,780	31,860	31,930	32,010	32,090	32,170	32,240	32,320	32,400	32,470	32,550	32,630	40
41	32,290	32,370	32,460	32,540	32,620	32,710	32,790	32,870	32,950	33,040	33,120	33,200	33,280	33,360	33,440	33,520	33,610	33,690	33,770	33,850	33,930	41
42	34,360	34,450	34,540	34,630	34,720	34,810	34,900	34,990	35,080	35,170	35,260	35,350	35,440	35,530	35,620	35,710	35,790	35,880	35,970	36,060	36,140	42
43	36,430	36,530	36,630	36,720	36,820	36,920	37,020	37,120	37,210	37,310	37,410	37,500	37,600	37,700	37,790	37,890	37,980	38,080	38,170	38,270	38,360	43
44	38,500	38,600	38,710	38,820	38,920	39,030	39,130	39,240	39,340	39,450	39,550	39,660	39,760	39,860	39,970	40,070	40,170	40,270	40,380	40,480	40,580	44
45	40,260	40,380	40,490	40,610	40,720	40,830	40,950	41,060	41,170	41,280	41,400	41,510	41,620	41,730	41,840	41,950	42,060	42,170	42,280	42,390	42,500	45
46	42,030	42,150	42,270	42,400	42,520	42,640	42,760	42,880	43,000	43,120	43,240	43,360	43,480	43,600	43,710	43,830	43,950	44,070	44,180	44,300	44,420	46
47	43,790	43,930	44,060	44,190	44,310	44,440	44,570	44,700	44,830	44,960	45,080	45,210	45,340	45,460	45,590	45,710	45,840	45,960	46,090	46,210	46,340	47
48	45,520	45,700	45,890	46,080	46,260	46,340	46,410	46,470	46,530	46,590	46,650	46,710	46,770	46,820	46,880	47,000	47,140	47,270	47,400	47,530	47,660	48
49	47,240	47,480	47,730	47,970	48,210	48,240	48,240	48,230	48,230	48,220	48,220	48,210	48,200	48,180	48,170	48,290	48,430	48,570	48,710	48,850	48,980	49
50	48,960	49,260	49,560	49,860	50,170	50,140	50,070	50,000	49,930	49,860	49,780	49,700	49,620	49,540	49,460	49,580	49,730	49,870	50,020	50,160	50,310	50
51	48,960	49,260	49,560	49,860	50,170	50,250	50,310	50,360	50,410	50,470	50,520	50,570	50,620	50,670	50,720	50,900	51,100	51,300	51,500	51,700	51,900	51
52	48,960	49,260	49,560	49,860	50,170	50,360	50,540	50,720	50,900	51,080	51,260	51,440	51,620	51,790	51,970	52,220	52,480	52,730	52,990	53,240	53,500	52
53	48,960	49,260	49,560	49,860	50,170	50,470	50,770	51,080	51,380	51,690	52,000	52,300	52,610	52,920	53,230	53,540	53,850	54,160	54,470	54,790	55,100	53
54	48,960	49,260	49,560	49,860	50,170	50,470	50,770	51,080	51,380	51,690	52,000	52,300	52,610	52,920	53,230	53,540	53,850	54,160	54,470	54,790	55,100	54
55	48,960	49,260	49,560	49,860	50,170	50,470	50,770	51,080	51,380	51,690	52,000	52,300	52,610	52,920	53,230	53,540	53,850	54,160	54,470	54,790	55,100	55

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	880.0	880.1	880.2	880.3	880.4	880.5	880.6	880.7	880.8	880.9	881.0	881.1	881.2	881.3	881.4	881.5	881.6	881.7	881.8	881.9	882.0	
1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1
2	200	200	200	200	200	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	210	2
3	310	310	310	310	310	310	310	310	310	320	320	320	320	320	320	320	320	320	320	320	320	3
4	420	420	420	420	420	430	430	430	430	430	430	430	430	430	430	430	430	430	430	440	440	4
5	530	530	540	540	540	540	540	540	540	540	540	540	550	550	550	550	550	550	550	550	550	5
6	650	650	650	650	650	660	660	660	660	660	660	660	660	670	670	670	670	670	670	670	670	6
7	770	770	770	770	770	770	780	780	780	780	780	780	780	790	790	790	790	790	790	790	800	7
8	890	890	890	890	890	900	900	900	900	900	900	910	910	910	910	910	910	910	920	920	920	8
9	1,010	1,010	1,010	1,010	1,010	1,020	1,020	1,020	1,020	1,020	1,030	1,030	1,030	1,030	1,030	1,040	1,040	1,040	1,040	1,040	1,040	9
10	1,070	1,070	1,070	1,070	1,080	1,080	1,080	1,080	1,080	1,090	1,090	1,090	1,090	1,090	1,100	1,100	1,100	1,100	1,100	1,100	1,110	10
11	1,600	1,600	1,610	1,610	1,610	1,620	1,620	1,620	1,630	1,630	1,630	1,630	1,640	1,640	1,640	1,650	1,650	1,650	1,650	1,660	1,660	11
12	2,200	2,200	2,200	2,210	2,210	2,220	2,220	2,230	2,230	2,230	2,240	2,240	2,250	2,250	2,250	2,260	2,260	2,270	2,270	2,270	2,280	12
13	2,790	2,800	2,800	2,810	2,810	2,820	2,820	2,830	2,830	2,840	2,840	2,850	2,850	2,860	2,860	2,870	2,870	2,880	2,880	2,890	2,890	13
14	3,390	3,390	3,400	3,400	3,410	3,420	3,420	3,430	3,440	3,440	3,450	3,460	3,460	3,470	3,470	3,480	3,490	3,490	3,500	3,500	3,510	14
15	4,560	4,570	4,580	4,590	4,600	4,610	4,610	4,620	4,630	4,640	4,650	4,660	4,670	4,670	4,680	4,690	4,700	4,710	4,720	4,720	4,730	15
16	5,740	5,750	5,760	5,770	5,780	5,790	5,810	5,820	5,830	5,840	5,850	5,860	5,870	5,880	5,890	5,900	5,910	5,920	5,930	5,940	5,960	16
17	6,920	6,930	6,940	6,960	6,970	6,980	7,000	7,010	7,020	7,040	7,050	7,060	7,070	7,090	7,100	7,110	7,130	7,140	7,150	7,170	7,180	17
18	8,070	8,090	8,100	8,120	8,140	8,150	8,170	8,180	8,200	8,210	8,230	8,240	8,260	8,270	8,290	8,310	8,320	8,340	8,350	8,370	8,380	18
19	9,230	9,250	9,270	9,280	9,300	9,320	9,340	9,360	9,370	9,390	9,410	9,430	9,440	9,460	9,480	9,500	9,510	9,530	9,550	9,570	9,580	19
20	10,390	10,410	10,430	10,450	10,470	10,490	10,510	10,530	10,550	10,570	10,590	10,610	10,630	10,650	10,670	10,690	10,710	10,730	10,750	10,770	10,790	20
21	11,530	11,550	11,570	11,600	11,620	11,640	11,660	11,690	11,710	11,730	11,750	11,780	11,800	11,820	11,840	11,870	11,890	11,910	11,930	11,960	11,980	21
22	12,670	12,690	12,720	12,740	12,770	12,790	12,820	12,840	12,870	12,890	12,920	12,940	12,970	12,990	13,020	13,040	13,070	13,090	13,120	13,140	13,170	22
23	13,810	13,840	13,860	13,890	13,920	13,950	13,980	14,000	14,030	14,060	14,080	14,110	14,140	14,170	14,190	14,220	14,250	14,270	14,300	14,330	14,350	23
24	14,960	14,990	15,020	15,050	15,080	15,110	15,140	15,170	15,200	15,230	15,260	15,290	15,320	15,350	15,380	15,410	15,440	15,470	15,500	15,530	15,560	24
25	16,110	16,140	16,180	16,210	16,240	16,280	16,310	16,340	16,370	16,410	16,440	16,470	16,500	16,540	16,570	16,600	16,630	16,660	16,700	16,730	16,760	25
26	17,260	17,300	17,330	17,370	17,410	17,440	17,480	17,510	17,550	17,580	17,620	17,650	17,690	17,720	17,760	17,790	17,820	17,860	17,890	17,930	17,960	26
27	18,450	18,480	18,520	18,560	18,600	18,640	18,670	18,710	18,750	18,790	18,830	18,860	18,900	18,940	18,980	19,010	19,050	19,090	19,120	19,160	19,200	27
28	19,630	19,670	19,710	19,750	19,790	19,830	19,870	19,910	19,950	19,990	20,040	20,080	20,120	20,160	20,200	20,240	20,280	20,320	20,360	20,400	20,430	28
29	20,810	20,850	20,900	20,940	20,980	21,030	21,070	21,120	21,160	21,200	21,240	21,290	21,330	21,370	21,420	21,460	21,500	21,540	21,590	21,630	21,670	29
30	21,990	22,030	22,080	22,130	22,170	22,220	22,270	22,310	22,360	22,410	22,450	22,500	22,540	22,590	22,630	22,680	22,730	22,770	22,820	22,860	22,910	30
31	23,160	23,210	23,260	23,310	23,360	23,410	23,460	23,510	23,560	23,610	23,660	23,710	23,760	23,800	23,850	23,900	23,950	24,000	24,050	24,090	24,140	31
32	24,340	24,390	24,450	24,500	24,550	24,600	24,660	24,710	24,760	24,810	24,860	24,920	24,970	25,020	25,070	25,120	25,170	25,220	25,270	25,330	25,380	32
33	25,270	25,320	25,380	25,430	25,490	25,540	25,600	25,650	25,710	25,760	25,810	25,870	25,920	25,980	26,030	26,080	26,140	26,190	26,240	26,300	26,350	33
34	26,190	26,250	26,310	26,370	26,420	26,480	26,540	26,590	26,650	26,710	26,760	26,820	26,880	26,930	26,990	27,050	27,100	27,160	27,210	27,270	27,330	34
35	27,120	27,180	27,240	27,300	27,360	27,420	27,480	27,540	27,600	27,660	27,720	27,770	27,830	27,890	27,950	28,010	28,070	28,130	28,180	28,240	28,300	35
36	28,090	28,150	28,210	28,280	28,340	28,400	28,460	28,530	28,590	28,650	28,710	28,770	28,840	28,900	28,960	29,020	29,080	29,140	29,200	29,260	29,320	36
37	29,060	29,120	29,190	29,260	29,320	29,390	29,450	29,520	29,580	29,650	29,710	29,780	29,840	29,900	29,970	30,030	30,100	30,160	30,220	30,290	30,350	37
38	30,030	30,100	30,170	30,230	30,300	30,370	30,440	30,510	30,570	30,640	30,710	30,780	30,840	30,910	30,980	31,040	31,110	31,180	31,240	31,310	31,370	38
39	31,330	31,400	31,470	31,540	31,620	31,690	31,760	31,830	31,900	31,970	32,040	32,120	32,190	32,260	32,330	32,400	32,470	32,540	32,610	32,680	32,750	39
40	32,630	32,700	32,780	32,860	32,930	33,010	33,080	33,160	33,230	33,310	33,380	33,460	33,530	33,600	33,680	33,750	33,830	33,900	33,970	34,040	34,120	40
41	33,930	34,010	34,090	34,170	34,250	34,320	34,400	34,480	34,560	34,640	34,720	34,800	34,870	34,950	35,030	35,110	35,180	35,260	35,340	35,410	35,490	41
42	36,140	36,230	36,320	36,400	36,490	36,580	36,660	36,750	36,830	36,920	37,010	37,090	37,180	37,260	37,340	37,430	37,510	37,600	37,680	37,760	37,850	42
43	38,360	38,460	38,550	38,640	38,740	38,830	38,920	39,020	39,110	39,200	39,290	39,390	39,480	39,570	39,660	39,750	39,840	39,930	40,020	40,110	40,200	43
44	40,580	40,680	40,780	40,880	40,980	41,080	41,180	41,280	41,380	41,480	41,580	41,680	41,780	41,880	41,980	42,070	42,170	42,270	42,370	42,460	42,560	44
45	42,500	42,610	42,720	42,820	42,930	43,040	43,150	43,250	43,360	43,470	43,570	43,680	43,780	43,890	44,000	44,100	44,210	44,310	44,410	44,520	44,620	45
46	44,420	44,530	44,650	44,760	44,880	44,990	45,110	45,220	45,340	45,450	45,560	45,680	45,790	45,900	46,010	46,130	46,240	46,350	46,460	46,570	46,680	46
47	46,340	46,460	46,580	46,700	46,830	46,950	47,070	47,190	47,310	47,430	47,560	47,680	47,800	47,910	48,030	48,150	48,270	48,390	48,510	48,630	48,740	47
48	47,660	47,790	47,920	48,050	48,180	48,310	48,430	48,560	48,690	48,820	48,940	49,070	49,200	49,320	49,450	49,570	49,700	49,820	49,950	50,070	50,200	48
49	48,980	49,120	49,260	49,390	49,530	49,660	49,800	49,930	50,070	50,200	50,330	50,470	50,600	50,730	50,860	51,000	51,130	51,260	51,390	51,520	51,650	49
50	50,310	50,450	50,590	50,740	50,880	51,020	51,160	51,300	51,440	51,580	51,720	51,860	52,000	52,140	52,280	52,420	52,560	52,690	52,830	52,970	53,100	50
51	51,900	52,100	52,300	52,500	52,700	52,900	53,100	53,300	53,500	53,700	53,900	54,100	54,300	54,410	54,470	54,520	54,580	54,630	54,690	54,740	54,790	51
52	53,500	53,760	54,020	54,270	54,530	54,790	55,050	55,310	55,560	55,820	56,080	56,340	56,600	56,680	56,650	56,630	56,600	56,570	56,540	56,510	56,480	52
53	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	58,940	58,840	58,730	58,620	58,510	58,400	58,290	58,170	53
54	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,040	59,070	59,110	59,150	59,180	59,210	59,240	59,280	54
55	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,130	59,310	59,490	59,670	59,850	60,030	60,200	60,380	55
56	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,220	59,550	59,870	60,190	60,510	60,840	61,160	61,490	56
57	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,220	59,550	59,870	60,190	60,510	60,840	61,160	61,490	57
58	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,220	59,550	59,870	60,190	60,510	60,840	61,160	61,490	58
59	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,220	59,550	59,870	60,190	60,510	60,840	61,160	61,490	59
60	55,100	55,410	55,730	56,040	56,360	56,670	56,990	57,310	57,620	57,940	58,260	58,580	58,900	59,220	59,550	59,870	60,190	60,510	60,840	61,160	61,490	60

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGE-MENT	882.0	882.1	882.2	882.3	882.4	882.5	882.6	882.7	882.8	882.9	883.0	883.1	883.2	883.3	883.4	883.5	883.6	883.7	883.8	883.9	884.0	GATE ARRANGE-MENT
1	100	100	100	100	100	100	100	100	100	100	110	110	110	110	110	110	110	110	110	110	110	1
2	210	210	210	210	210	210	210	210	210	210	210	210	220	220	220	220	220	220	220	220	220	2
3	320	320	320	320	320	320	320	330	330	330	330	330	330	330	330	330	330	330	330	330	330	3
4	440	440	440	440	440	440	440	440	440	440	440	440	450	450	450	450	450	450	450	450	450	4
5	550	550	560	560	560	560	560	560	560	560	560	560	560	570	570	570	570	570	570	570	570	5
6	670	670	680	680	680	680	680	680	680	680	690	690	690	690	690	690	690	690	690	700	700	6
7	800	800	800	800	800	800	800	810	810	810	810	810	810	810	810	820	820	820	820	820	820	7
8	920	920	920	920	930	930	930	930	930	930	940	940	940	940	940	940	940	950	950	950	950	8
9	1,040	1,050	1,050	1,050	1,050	1,050	1,060	1,060	1,060	1,060	1,060	1,060	1,070	1,070	1,070	1,070	1,070	1,080	1,080	1,080	1,080	9
10	1,110	1,110	1,110	1,110	1,110	1,120	1,120	1,120	1,120	1,120	1,130	1,130	1,130	1,130	1,130	1,140	1,140	1,140	1,140	1,140	1,140	10
11	1,660	1,660	1,670	1,670	1,670	1,670	1,680	1,680	1,680	1,690	1,690	1,690	1,690	1,700	1,700	1,700	1,710	1,710	1,710	1,710	1,720	11
12	2,280	2,280	2,290	2,290	2,290	2,300	2,300	2,300	2,310	2,310	2,320	2,320	2,320	2,330	2,330	2,340	2,340	2,340	2,350	2,350	2,360	12
13	2,890	2,900	2,900	2,910	2,910	2,920	2,920	2,930	2,930	2,940	2,940	2,950	2,950	2,960	2,960	2,970	2,970	2,980	2,980	2,990	2,990	13
14	3,510	3,520	3,520	3,530	3,540	3,540	3,550	3,550	3,560	3,570	3,570	3,580	3,580	3,590	3,600	3,600	3,610	3,610	3,620	3,630	3,630	14
15	4,730	4,740	4,750	4,760	4,770	4,770	4,780	4,790	4,800	4,810	4,820	4,820	4,830	4,840	4,850	4,860	4,870	4,870	4,880	4,890	4,900	15
16	5,960	5,970	5,980	5,990	6,000	6,010	6,020	6,030	6,040	6,050	6,060	6,070	6,080	6,090	6,100	6,110	6,120	6,130	6,140	6,150	6,160	16
17	7,180	7,190	7,200	7,220	7,230	7,240	7,250	7,270	7,280	7,290	7,300	7,320	7,330	7,340	7,360	7,370	7,380	7,390	7,410	7,420	7,430	17
18	8,380	8,400	8,410	8,430	8,440	8,460	8,470	8,490	8,500	8,520	8,530	8,550	8,560	8,580	8,590	8,600	8,620	8,630	8,650	8,660	8,680	18
19	9,580	9,600	9,620	9,640	9,650	9,670	9,690	9,710	9,720	9,740	9,760	9,770	9,790	9,810	9,830	9,840	9,860	9,880	9,890	9,910	9,930	19
20	10,790	10,810	10,830	10,850	10,870	10,890	10,910	10,930	10,940	10,960	10,980	11,000	11,020	11,040	11,060	11,080	11,100	11,120	11,140	11,160	11,170	20
21	11,980	12,000	12,020	12,040	12,060	12,090	12,110	12,130	12,150	12,170	12,200	12,220	12,240	12,260	12,280	12,300	12,320	12,350	12,370	12,390	12,410	21
22	13,170	13,190	13,210	13,240	13,260	13,290	13,310	13,340	13,360	13,380	13,410	13,430	13,460	13,480	13,500	13,530	13,550	13,570	13,600	13,620	13,650	22
23	14,350	14,380	14,410	14,430	14,460	14,490	14,510	14,540	14,570	14,590	14,620	14,650	14,670	14,700	14,720	14,750	14,780	14,800	14,830	14,850	14,880	23
24	15,560	15,590	15,620	15,640	15,670	15,700	15,730	15,760	15,790	15,820	15,850	15,880	15,900	15,930	15,960	15,990	16,020	16,050	16,070	16,100	16,130	24
25	16,760	16,790	16,820	16,850	16,890	16,920	16,950	16,980	17,010	17,040	17,070	17,100	17,140	17,170	17,200	17,230	17,260	17,290	17,320	17,350	17,380	25
26	17,960	18,000	18,030	18,060	18,100	18,130	18,170	18,200	18,230	18,270	18,300	18,330	18,370	18,400	18,430	18,470	18,500	18,530	18,570	18,600	18,630	26
27	19,200	19,240	19,270	19,310	19,350	19,380	19,420	19,450	19,490	19,530	19,560	19,600	19,640	19,670	19,710	19,740	19,780	19,820	19,850	19,890	19,920	27
28	20,430	20,470	20,510	20,550	20,590	20,630	20,670	20,710	20,750	20,790	20,830	20,870	20,900	20,940	20,980	21,020	21,060	21,100	21,140	21,170	21,210	28
29	21,670	21,710	21,760	21,800	21,840	21,880	21,920	21,970	22,010	22,050	22,090	22,130	22,170	22,210	22,260	22,300	22,340	22,380	22,420	22,460	22,500	29
30	22,910	22,950	23,000	23,040	23,090	23,130	23,180	23,220	23,260	23,310	23,350	23,400	23,440	23,480	23,530	23,570	23,620	23,660	23,700	23,750	23,790	30
31	24,140	24,190	24,240	24,280	24,330	24,380	24,430	24,470	24,520	24,570	24,620	24,660	24,710	24,760	24,800	24,850	24,900	24,940	24,990	25,030	25,080	31
32	25,380	25,430	25,480	25,530	25,580	25,630	25,680	25,730	25,780	25,830	25,880	25,930	25,980	26,030	26,080	26,120	26,170	26,220	26,270	26,320	26,370	32
33	26,350	26,400	26,460	26,510	26,560	26,610	26,670	26,720	26,770	26,820	26,880	26,930	26,980	27,030	27,080	27,140	27,190	27,240	27,290	27,340	27,390	33
34	27,330	27,380	27,440	27,490	27,550	27,600	27,660	27,710	27,770	27,820	27,870	27,930	27,980	28,040	28,090	28,150	28,200	28,250	28,310	28,360	28,410	34
35	28,300	28,360	28,420	28,470	28,530	28,590	28,650	28,700	28,760	28,820	28,870	28,930	28,990	29,040	29,100	29,160	29,210	29,270	29,320	29,380	29,440	35
36	29,320	29,390	29,450	29,510	29,570	29,630	29,690	29,750	29,810	29,860	29,920	29,980	30,040	30,100	30,160	30,220	30,280	30,340	30,400	30,450	30,510	36
37	30,350	30,410	30,480	30,540	30,600	30,660	30,730	30,790	30,850	30,910	30,970	31,040	31,100	31,160	31,220	31,280	31,340	31,410	31,470	31,530	31,590	37
38	31,370	31,440	31,510	31,570	31,640	31,700	31,770	31,830	31,900	31,960	32,030	32,090	32,150	32,220	32,280	32,350	32,410	32,470	32,540	32,600	32,660	38
39	32,750	32,820	32,880	32,950	33,020	33,090	33,160	33,230	33,300	33,360	33,430	33,500	33,570	33,640	33,700	33,770	33,840	33,900	33,970	34,040	34,100	39
40	34,120	34,190	34,260	34,340	34,410	34,480	34,550	34,620	34,700	34,770	34,840	34,910	34,980	35,050	35,120	35,190	35,260	35,340	35,410	35,480	35,550	40
41	35,490	35,570	35,640	35,720	35,790	35,870	35,950	36,020	36,100	36,170	36,250	36,320	36,400	36,470	36,540	36,620	36,690	36,770	36,840	36,910	36,990	41
42	37,850	37,930	38,010	38,100	38,180	38,260	38,340	38,420	38,510	38,590	38,670	38,750	38,830	38,910	38,990	39,070	39,160	39,240	39,320	39,400	39,480	42
43	40,200	40,290	40,380	40,470	40,560	40,650	40,740	40,830	40,920	41,010	41,090	41,180	41,270	41,360	41,440	41,530	41,620	41,710	41,790	41,880	41,970	43
44	42,560	42,660	42,750	42,850	42,950	43,040	43,140	43,230	43,330	43,420	43,520	43,610	43,710	43,800	43,890	43,990	44,080	44,180	44,270	44,360	44,450	44
45	44,620	44,730	44,830	44,930	45,030	45,140	45,240	45,340	45,440	45,550	45,650	45,750	45,850	45,950	46,050	46,150	46,250	46,350	46,450	46,550	46,650	45
46	46,680	46,790	46,900	47,010	47,120	47,230	47,340	47,450	47,560	47,670	47,780	47,880	47,990	48,100	48,210	48,310	48,420	48,530	48,630	48,740	48,840	46
47	48,740	48,860	48,980	49,100	49,210	49,330	49,440	49,560	49,670	49,790	49,900	50,020	50,130	50,250	50,360	50,480	50,590	50,700	50,810	50,930	51,040	47
48	50,200	50,320	50,440	50,570	50,690	50,810	50,930	51,060	51,180	51,300	51,420	51,540	51,660	51,780	51,900	52,020	52,140	52,260	52,380	52,490	52,610	48
49	51,650	51,780	51,910	52,040	52,170	52,300	52,420	52,550	52,680	52,810	52,930	53,060	53,190	53,310	53,440	53,560	53,690	53,810	53,940	54,060	54,190	49
50	53,100	53,240	53,380	53,510	53,650	53,780	53,910	54,050	54,180	54,320	54,450	54,580	54,710	54,850	54,980	55,110	55,240	55,370	55,500	55,630	55,760	50
51	54,790	54,840	54,890	55,010	55,150	55,290	55,430	55,570	55,710	55,850	55,990	56,130	56,270	56,410	56,550	56,690	56,820	56,960	57,100	57,240	57,370	51
52	56,480	56,450	56,410	56,500	56,650	56,800	56,950	57,090	57,240	57,390	57,540	57,680	57,830	57,970	58,120	58,260	58,410	58,550	58,700	58,840	58,980	52
53	58,170	58,050	57,930	58,000	58,150	58,310	58,460	58,620	58,770	58,930	59,080	59,230	59,390	59,540	59,690	59,840	59,990	60,140	60,290	60,440	60,590	53
54	59,280	59,310	59,330	59,490	59,700	59,910	60,130	60,340	60,550	60,760	60,980	61,190	61,400	61,610	61,830	62,040	62,250	62,460	62,680	62,890	62,960	54
55	60,380	60,560	60,740	60,980	61,250	61,520	61,790	62,060	62,330	62,600	62,870	63,150	63,420	63,690	63,960	64,240	64,510	64,780	65,060	65,330	65,320	55
56	61,490	61,810	62,140	62,470	62,790	63,120	63,450	63,780	64,110	64,440	64,770	65,100	65,440	65,770	66,100	66,440	66,770	67,110	67,440	67,780	67,680	56
57	61,490	61,810	62,140	62,470	62,790	63,120	63,450	63,780	64,110	64,440	64,770	65,100	65,440	65,770	66,100	66,440	66,770	67,110	67,440	67,780	67,830	57
58	61,490	61,810	62,140	62,470	62,790	63,120	63,450	63,780	64,110	64,440	64,770	65,100	65,440	65,770	66,100	66,440	66,770	67,110	67,440	67,780	67,970	58
59	61,490	61,810	62,140	62,470	62,790	63,120	63,450	63,780	64,110	64,440	64,770	65,100	65,440	65,770	66,100	66,440	66,770	67,110	67,440	67,780	68,110	59
60	61,490	61,810	62,140	62,470	62,790	63,120	63,450	63,780	64,110	64,440	64,770	65,100	65,440	65,770	66,100	66,440	66,770	67,110	67,440	67,780	68,110	60

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGE-MENT	884.0	884.1	884.2	884.3	884.4	884.5	884.6	884.7	884.8	884.9	885.0	885.1	885.2	885.3	885.4	885.5	885.6	885.7	885.8	885.9	886.0	GATE ARRANGE-MENT
1	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	1
2	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	2
3	330	330	330	330	330	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	3
4	450	450	450	450	450	450	460	460	460	460	460	460	460	460	460	460	460	460	460	460	470	4
5	570	570	570	580	580	580	580	580	580	580	580	580	580	580	590	590	590	590	590	590	590	5
6	700	700	700	700	700	700	700	700	710	710	710	710	710	710	710	710	710	720	720	720	720	6
7	820	820	830	830	830	830	830	830	830	830	840	840	840	840	840	840	840	850	850	850	850	7
8	950	950	950	960	960	960	960	960	960	960	970	970	970	970	970	970	980	980	980	980	980	8
9	1,080	1,080	1,080	1,090	1,090	1,090	1,090	1,090	1,090	1,100	1,100	1,100	1,100	1,100	1,100	1,110	1,110	1,110	1,110	1,110	1,120	9
10	1,140	1,150	1,150	1,150	1,150	1,150	1,160	1,160	1,160	1,160	1,160	1,160	1,170	1,170	1,170	1,170	1,170	1,180	1,180	1,180	1,180	10
11	1,720	1,720	1,720	1,730	1,730	1,730	1,730	1,740	1,740	1,740	1,740	1,750	1,750	1,750	1,760	1,760	1,760	1,760	1,770	1,770	1,770	11
12	2,360	2,360	2,360	2,370	2,370	2,370	2,380	2,380	2,390	2,390	2,390	2,400	2,400	2,400	2,410	2,410	2,420	2,420	2,420	2,430	2,430	12
13	2,990	3,000	3,000	3,010	3,010	3,020	3,020	3,030	3,030	3,040	3,040	3,050	3,050	3,060	3,060	3,070	3,070	3,080	3,080	3,080	3,090	13
14	3,630	3,640	3,640	3,650	3,660	3,660	3,670	3,670	3,680	3,680	3,690	3,700	3,700	3,710	3,710	3,720	3,730	3,730	3,740	3,740	3,750	14
15	4,900	4,910	4,910	4,920	4,930	4,940	4,950	4,950	4,960	4,970	4,980	4,990	4,990	5,000	5,010	5,020	5,030	5,030	5,040	5,050	5,060	15
16	6,160	6,170	6,180	6,190	6,200	6,210	6,220	6,230	6,250	6,260	6,270	6,280	6,290	6,300	6,310	6,320	6,330	6,340	6,350	6,360	6,370	16
17	7,430	7,440	7,450	7,470	7,480	7,490	7,500	7,520	7,530	7,540	7,550	7,560	7,580	7,590	7,600	7,610	7,630	7,640	7,650	7,660	7,670	17
18	8,680	8,690	8,710	8,720	8,740	8,750	8,770	8,780	8,790	8,810	8,820	8,840	8,850	8,870	8,880	8,890	8,910	8,920	8,940	8,950	8,970	18
19	9,930	9,940	9,960	9,980	9,990	10,010	10,030	10,040	10,060	10,080	10,090	10,110	10,130	10,140	10,160	10,180	10,190	10,210	10,220	10,240	10,260	19
20	11,170	11,190	11,210	11,230	11,250	11,270	11,290	11,310	11,330	11,340	11,360	11,380	11,400	11,420	11,440	11,460	11,470	11,490	11,510	11,530	11,550	20
21	12,410	12,430	12,450	12,470	12,490	12,520	12,540	12,560	12,580	12,600	12,620	12,640	12,660	12,680	12,700	12,730	12,750	12,770	12,790	12,810	12,830	21
22	13,650	13,670	13,690	13,720	13,740	13,760	13,790	13,810	13,830	13,860	13,880	13,900	13,920	13,950	13,970	13,990	14,020	14,040	14,060	14,090	14,110	22
23	14,880	14,910	14,930	14,960	14,980	15,010	15,030	15,060	15,090	15,110	15,140	15,160	15,190	15,210	15,240	15,260	15,290	15,310	15,340	15,360	15,390	23
24	16,130	16,160	16,190	16,220	16,240	16,270	16,300	16,330	16,360	16,380	16,410	16,440	16,470	16,490	16,520	16,550	16,580	16,600	16,630	16,660	16,690	24
25	17,380	17,410	17,440	17,470	17,500	17,530	17,570	17,600	17,630	17,660	17,690	17,720	17,750	17,780	17,810	17,840	17,870	17,900	17,920	17,950	17,980	25
26	18,630	18,670	18,700	18,730	18,770	18,800	18,830	18,860	18,900	18,930	18,960	18,990	19,030	19,060	19,090	19,120	19,150	19,190	19,220	19,250	19,280	26
27	19,920	19,960	19,990	20,030	20,060	20,100	20,130	20,170	20,210	20,240	20,280	20,310	20,340	20,380	20,410	20,450	20,480	20,520	20,550	20,590	20,620	27
28	21,210	21,250	21,290	21,330	21,360	21,400	21,440	21,480	21,510	21,550	21,590	21,630	21,660	21,700	21,740	21,780	21,810	21,850	21,890	21,920	21,960	28
29	22,500	22,540	22,580	22,620	22,660	22,700	22,740	22,780	22,820	22,860	22,900	22,940	22,980	23,020	23,060	23,100	23,140	23,180	23,220	23,260	23,300	29
30	23,790	23,830	23,880	23,920	23,960	24,010	24,050	24,090	24,140	24,180	24,220	24,260	24,310	24,350	24,390	24,430	24,470	24,520	24,560	24,600	24,640	30
31	25,080	25,130	25,170	25,220	25,260	25,310	25,350	25,400	25,450	25,490	25,540	25,580	25,630	25,670	25,720	25,760	25,810	25,850	25,900	25,940	25,990	31
32	26,370	26,420	26,470	26,520	26,560	26,610	26,660	26,710	26,760	26,800	26,850	26,900	26,950	27,000	27,040	27,090	27,140	27,190	27,230	27,280	27,330	32
33	27,390	27,440	27,490	27,540	27,600	27,650	27,700	27,750	27,800	27,850	27,900	27,950	28,000	28,050	28,100	28,150	28,200	28,250	28,300	28,350	28,390	33
34	28,410	28,470	28,520	28,570	28,630	28,680	28,730	28,780	28,840	28,890	28,940	28,990	29,050	29,100	29,150	29,200	29,250	29,310	29,360	29,410	29,460	34
35	29,440	29,490	29,550	29,600	29,660	29,710	29,770	29,820	29,880	29,930	29,990	30,040	30,100	30,150	30,200	30,260	30,310	30,370	30,420	30,470	30,530	35
36	30,510	30,570	30,630	30,690	30,740	30,800	30,860	30,920	30,970	31,030	31,090	31,150	31,200	31,260	31,320	31,370	31,430	31,490	31,540	31,600	31,650	36
37	31,590	31,650	31,710	31,770	31,830	31,890	31,950	32,010	32,070	32,130	32,190	32,250	32,310	32,370	32,430	32,490	32,540	32,600	32,660	32,720	32,780	37
38	32,660	32,730	32,790	32,850	32,920	32,980	33,040	33,100	33,170	33,230	33,290	33,350	33,410	33,480	33,540	33,600	33,660	33,720	33,780	33,840	33,900	38
39	34,100	34,170	34,240	34,300	34,370	34,440	34,500	34,570	34,630	34,700	34,760	34,830	34,890	34,960	35,020	35,090	35,150	35,220	35,280	35,350	35,410	39
40	35,550	35,620	35,690	35,750	35,820	35,890	35,960	36,030	36,100	36,170	36,240	36,310	36,380	36,440	36,510	36,580	36,650	36,720	36,780	36,850	36,920	40
41	36,990	37,060	37,130	37,210	37,280	37,350	37,420	37,500	37,570	37,640	37,710	37,780	37,860	37,930	38,000	38,070	38,140	38,210	38,280	38,350	38,430	41
42	39,480	39,560	39,630	39,710	39,790	39,870	39,950	40,030	40,110	40,190	40,270	40,340	40,420	40,500	40,580	40,650	40,730	40,810	40,890	40,960	41,040	42
43	41,970	42,050	42,140	42,220	42,310	42,390	42,480	42,560	42,650	42,730	42,820	42,900	42,990	43,070	43,160	43,240	43,320	43,410	43,490	43,570	43,660	43
44	44,450	44,550	44,640	44,730	44,820	44,920	45,010	45,100	45,190	45,280	45,370	45,460	45,550	45,640	45,730	45,820	45,910	46,000	46,090	46,180	46,270	44
45	46,650	46,750	46,850	46,950	47,040	47,140	47,240	47,340	47,440	47,530	47,630	47,730	47,820	47,920	48,020	48,110	48,210	48,310	48,400	48,500	48,590	45
46	48,840	48,950	49,050	49,160	49,260	49,370	49,470	49,580	49,680	49,790	49,890	49,990	50,100	50,200	50,300	50,400	50,510	50,610	50,710	50,810	50,910	46
47	51,040	51,150	51,260	51,370	51,490	51,600	51,710	51,820	51,930	52,040	52,150	52,260	52,370	52,480	52,590	52,690	52,800	52,910	53,020	53,130	53,240	47
48	52,610	52,730	52,850	52,970	53,080	53,200	53,320	53,430	53,550	53,660	53,780	53,900	54,010	54,130	54,240	54,350	54,470	54,580	54,700	54,810	54,920	48
49	54,190	54,310	54,430	54,560	54,680	54,800	54,920	55,050	55,170	55,290	55,410	55,530	55,650	55,770	55,890	56,010	56,130	56,250	56,370	56,490	56,610	49
50	55,760	55,890	56,020	56,150	56,280	56,410	56,530	56,660	56,790	56,920	57,040	57,170	57,300	57,420	57,550	57,670	57,800	57,920	58,050	58,170	58,300	50
51	57,370	57,510	57,640	57,780	57,910	58,050	58,180	58,320	58,450	58,590	58,720	58,850	58,990	59,120	59,250	59,380	59,510	59,640	59,780	59,910	60,040	51
52	58,980	59,130	59,270	59,410	59,550	59,690	59,830	59,980	60,120	60,260	60,400	60,540	60,670	60,810	60,950	61,090	61,230	61,370	61,500	61,640	61,780	52
53	60,590	60,740	60,890	61,040	61,190	61,340	61,490	61,630	61,780	61,930	62,070	62,220	62,360	62,510	62,650	62,800	62,940	63,090	63,230	63,370	63,520	53
54	62,960	63,020	63,090	63,160	63,220	63,280	63,350	63,410	63,470	63,530	63,680	63,840	63,990	64,140	64,290	64,440	64,590	64,740	64,890	65,040	65,190	54
55	65,320	65,310	65,290	65,270	65,250	65,230	65,210	65,190	65,160	65,130	65,290	65,450	65,610	65,770	65,930	66,090	66,250	66,400	66,560	66,720	66,870	55

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	884.0	884.1	884.2	884.3	884.4	884.5	884.6	884.7	884.8	884.9	885.0	885.1	885.2	885.3	885.4	885.5	885.6	885.7	885.8	885.9	886.0	
56	67, 680	67, 590	67, 490	67, 390	67, 280	67, 180	67, 070	66, 960	66, 850	66, 740	66, 900	67, 070	67, 240	67, 400	67, 570	67, 730	67, 900	68, 060	68, 220	68, 390	68, 550	56
57	67, 830	67, 880	67, 920	67, 970	68, 010	68, 050	68, 100	68, 140	68, 180	68, 220	68, 440	68, 670	68, 890	69, 120	69, 340	69, 570	69, 790	70, 020	70, 240	70, 470	70, 690	57
58	67, 970	68, 160	68, 360	68, 550	68, 740	68, 930	69, 120	69, 310	69, 500	69, 690	69, 980	70, 260	70, 550	70, 830	71, 120	71, 400	71, 690	71, 970	72, 260	72, 540	72, 830	58
59	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	59
60	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	60
61	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	61
62	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	62
63	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	63
64	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	64
65	68, 110	68, 450	68, 790	69, 130	69, 470	69, 810	70, 150	70, 490	70, 830	71, 170	71, 510	71, 860	72, 200	72, 550	72, 890	73, 240	73, 580	73, 930	74, 280	74, 620	74, 970	65

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGEMENT	HEADWATER ELEVATION																					GATE ARRANGEMENT
	886.0	886.1	886.2	886.3	886.4	886.5	886.6	886.7	886.8	886.9	887.0	887.1	887.2	887.3	887.4	887.5	887.6	887.7	887.8	887.9	888.0	
1	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	1
2	220	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	2
3	340	340	340	340	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	3
4	470	470	470	470	470	470	470	470	470	470	470	470	470	470	480	480	480	480	480	480	480	4
5	590	590	590	590	590	600	600	600	600	600	600	600	600	600	600	600	600	610	610	610	610	5
6	720	720	720	720	720	720	730	730	730	730	730	730	730	730	730	740	740	740	740	740	740	6
7	850	850	850	850	850	860	860	860	860	860	860	860	860	870	870	870	870	870	870	870	870	7
8	980	980	980	990	990	990	990	990	990	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,010	1,010	1,010	1,010	1,010	8
9	1,120	1,120	1,120	1,120	1,120	1,120	1,130	1,130	1,130	1,130	1,130	1,130	1,140	1,140	1,140	1,140	1,140	1,140	1,150	1,150	1,150	9
10	1,180	1,180	1,180	1,190	1,190	1,190	1,190	1,190	1,200	1,200	1,200	1,200	1,200	1,200	1,210	1,210	1,210	1,210	1,210	1,210	1,220	10
11	1,770	1,770	1,780	1,780	1,780	1,790	1,790	1,790	1,790	1,800	1,800	1,800	1,800	1,810	1,810	1,810	1,810	1,820	1,820	1,820	1,820	11
12	2,430	2,430	2,440	2,440	2,450	2,450	2,450	2,460	2,460	2,460	2,470	2,470	2,470	2,480	2,480	2,490	2,490	2,490	2,500	2,500	2,500	12
13	3,090	3,090	3,100	3,100	3,110	3,110	3,120	3,120	3,130	3,130	3,140	3,140	3,150	3,150	3,160	3,160	3,160	3,170	3,170	3,180	3,180	13
14	3,750	3,750	3,760	3,770	3,770	3,780	3,780	3,790	3,790	3,800	3,810	3,810	3,820	3,820	3,830	3,830	3,840	3,840	3,850	3,860	3,860	14
15	5,060	5,060	5,070	5,080	5,090	5,100	5,100	5,110	5,120	5,130	5,130	5,140	5,150	5,160	5,170	5,170	5,180	5,190	5,200	5,200	5,210	15
16	6,370	6,380	6,380	6,390	6,400	6,410	6,420	6,430	6,440	6,450	6,460	6,470	6,480	6,490	6,500	6,510	6,520	6,530	6,540	6,550	6,560	16
17	7,670	7,690	7,700	7,710	7,720	7,730	7,750	7,760	7,770	7,780	7,790	7,800	7,820	7,830	7,840	7,850	7,860	7,870	7,890	7,900	7,910	17
18	8,970	8,980	8,990	9,010	9,020	9,040	9,050	9,060	9,080	9,090	9,110	9,120	9,130	9,150	9,160	9,170	9,190	9,200	9,220	9,230	9,240	18
19	10,260	10,270	10,290	10,310	10,320	10,340	10,350	10,370	10,390	10,400	10,420	10,430	10,450	10,470	10,480	10,500	10,510	10,530	10,550	10,560	10,580	19
20	11,550	11,570	11,590	11,600	11,620	11,640	11,660	11,680	11,690	11,710	11,730	11,750	11,770	11,790	11,800	11,820	11,840	11,860	11,870	11,890	11,910	20
21	12,830	12,850	12,870	12,890	12,910	12,930	12,950	12,970	12,990	13,010	13,030	13,050	13,070	13,090	13,110	13,130	13,150	13,170	13,190	13,210	13,230	21
22	14,110	14,130	14,150	14,180	14,200	14,220	14,240	14,270	14,290	14,310	14,330	14,360	14,380	14,400	14,420	14,450	14,470	14,490	14,510	14,530	14,560	22
23	15,390	15,410	15,440	15,460	15,490	15,510	15,540	15,560	15,590	15,610	15,640	15,660	15,680	15,710	15,730	15,760	15,780	15,810	15,830	15,850	15,880	23
24	16,690	16,710	16,740	16,770	16,790	16,820	16,850	16,880	16,900	16,930	16,960	16,980	17,010	17,040	17,060	17,090	17,120	17,140	17,170	17,200	17,220	24
25	17,980	18,010	18,040	18,070	18,100	18,130	18,160	18,190	18,220	18,250	18,280	18,310	18,340	18,360	18,390	18,420	18,450	18,480	18,510	18,540	18,570	25
26	19,280	19,310	19,350	19,380	19,410	19,440	19,470	19,500	19,540	19,570	19,600	19,630	19,660	19,690	19,720	19,750	19,790	19,820	19,850	19,880	19,910	26
27	20,620	20,660	20,690	20,720	20,760	20,790	20,830	20,860	20,890	20,930	20,960	21,000	21,030	21,060	21,100	21,130	21,160	21,200	21,230	21,260	21,300	27
28	21,960	22,000	22,030	22,070	22,110	22,140	22,180	22,220	22,250	22,290	22,330	22,360	22,400	22,430	22,470	22,510	22,540	22,580	22,610	22,650	22,690	28
29	23,300	23,340	23,380	23,420	23,460	23,500	23,540	23,570	23,610	23,650	23,690	23,730	23,770	23,810	23,840	23,880	23,920	23,960	24,000	24,040	24,070	29
30	24,640	24,680	24,730	24,770	24,810	24,850	24,890	24,930	24,980	25,020	25,060	25,100	25,140	25,180	25,220	25,260	25,300	25,340	25,390	25,430	25,470	30
31	25,990	26,030	26,070	26,120	26,160	26,210	26,250	26,290	26,340	26,380	26,430	26,470	26,510	26,560	26,600	26,640	26,690	26,730	26,770	26,820	26,860	31
32	27,330	27,370	27,420	27,470	27,510	27,560	27,610	27,650	27,700	27,750	27,790	27,840	27,890	27,930	27,980	28,020	28,070	28,120	28,160	28,210	28,250	32
33	28,390	28,440	28,490	28,540	28,590	28,640	28,690	28,740	28,790	28,830	28,880	28,930	28,980	29,030	29,080	29,120	29,170	29,220	29,270	29,320	29,360	33
34	29,460	29,510	29,560	29,620	29,670	29,720	29,770	29,820	29,870	29,920	29,970	30,020	30,070	30,120	30,170	30,220	30,270	30,320	30,370	30,420	30,470	34
35	30,530	30,580	30,640	30,690	30,740	30,800	30,850	30,900	30,950	31,010	31,060	31,110	31,170	31,220	31,270	31,320	31,380	31,430	31,480	31,530	31,580	35
36	31,650	31,710	31,770	31,820	31,880	31,930	31,990	32,040	32,100	32,150	32,210	32,270	32,320	32,370	32,430	32,480	32,540	32,590	32,650	32,700	32,760	36
37	32,780	32,840	32,900	32,950	33,010	33,070	33,130	33,190	33,240	33,300	33,360	33,420	33,470	33,530	33,590	33,650	33,700	33,760	33,820	33,870	33,930	37
38	33,900	33,970	34,030	34,090	34,150	34,210	34,270	34,330	34,390	34,450	34,510	34,570	34,630	34,690	34,750	34,810	34,870	34,930	34,980	35,040	35,100	38
39	35,410	35,480	35,540	35,600	35,670	35,730	35,790	35,860	35,920	35,980	36,050	36,110	36,170	36,240	36,300	36,360	36,420	36,490	36,550	36,610	36,670	39
40	36,920	36,990	37,050	37,120	37,190	37,250	37,320	37,390	37,450	37,520	37,590	37,650	37,720	37,780	37,850	37,920	37,980	38,050	38,110	38,180	38,240	40
41	38,430	38,500	38,570	38,640	38,710	38,780	38,850	38,920	38,990	39,060	39,120	39,190	39,260	39,330	39,400	39,470	39,540	39,610	39,680	39,740	39,810	41
42	41,040	41,120	41,190	41,270	41,350	41,420	41,500	41,570	41,650	41,720	41,800	41,880	41,950	42,030	42,100	42,180	42,250	42,320	42,400	42,470	42,550	42
43	43,660	43,740	43,820	43,900	43,990	44,070	44,150	44,230	44,310	44,390	44,480	44,560	44,640	44,720	44,800	44,880	44,960	45,040	45,120	45,200	45,280	43
44	46,270	46,360	46,450	46,540	46,620	46,710	46,800	46,890	46,980	47,060	47,150	47,240	47,330	47,410	47,500	47,590	47,670	47,760	47,850	47,930	48,020	44
45	48,590	48,690	48,780	48,880	48,970	49,070	49,160	49,250	49,350	49,440	49,530	49,630	49,720	49,810	49,910	50,000	50,090	50,180	50,280	50,370	50,460	45
46	50,910	51,010	51,120	51,220	51,320	51,420	51,520	51,620	51,720	51,820	51,920	52,020	52,120	52,210	52,310	52,410	52,510	52,610	52,710	52,800	52,900	46
47	53,240	53,340	53,450	53,560	53,660	53,770	53,880	53,980	54,090	54,190	54,300	54,410	54,510	54,620	54,720	54,820	54,930	55,030	55,140	55,240	55,340	47
48	54,920	55,040	55,150	55,260	55,370	55,480	55,600	55,710	55,820	55,930	56,040	56,150	56,260	56,370	56,480	56,590	56,700	56,810	56,920	57,030	57,140	48
49	56,610	56,730	56,850	56,960	57,080	57,200	57,320	57,430	57,550	57,670	57,780	57,900	58,010	58,130	58,250	58,360	58,480	58,590	58,700	58,820	58,930	49
50	58,300	58,420	58,540	58,670	58,790	58,910	59,040	59,160	59,280	59,400	59,520	59,650	59,770	59,890	60,010	60,130	60,250	60,370	60,490	60,610	60,730	50
51	60,040	60,170	60,300	60,430	60,560	60,680	60,810	60,940	61,070	61,200	61,330	61,450	61,580	61,710	61,830	61,960	62,090	62,210	62,340	62,460	62,590	51
52	61,780	61,910	62,050	62,180	62,320	62,460	62,590	62,720	62,860	62,990	63,130	63,260	63,390	63,530	63,660	63,790	63,920	64,050	64,190	64,320	64,450	52
53	63,520	63,660	63,800	63,940	64,080	64,230	64,370	64,510	64,650	64,790	64,930	65,070	65,210	65,350	65,480	65,620	65,760	65,900	66,040	66,170	66,310	53
54	65,190	65,340	65,490	65,640	65,790	65,940	66,080	66,230	66,380	66,520	66,670	66,820	66,960	67,110	67,250	67,400	67,540	67,690	67,830	67,970	68,120	54
55	66,870	67,030	67,180	67,340	67,490	67,650	67,800	67,960	68,110	68,260	68,410	68,570	68,720	68,870	69,020	69,170	69,320	69,470	69,620	69,770	69,920	55

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	886.0	886.1	886.2	886.3	886.4	886.5	886.6	886.7	886.8	886.9	887.0	887.1	887.2	887.3	887.4	887.5	887.6	887.7	887.8	887.9	888.0	
56	68, 550	68, 710	68, 870	69, 040	69, 200	69, 360	69, 520	69, 680	69, 840	70, 000	70, 160	70, 320	70, 470	70, 630	70, 790	70, 950	71, 100	71, 260	71, 420	71, 570	71, 730	56
57	70, 690	70, 920	71, 140	71, 360	71, 590	71, 810	72, 040	72, 260	72, 490	72, 640	72, 720	72, 790	72, 860	72, 940	73, 010	73, 080	73, 150	73, 220	73, 290	73, 410	73, 570	57
58	72, 830	73, 120	73, 400	73, 690	73, 980	74, 270	74, 550	74, 840	75, 130	75, 280	75, 270	75, 260	75, 250	75, 240	75, 230	75, 220	75, 200	75, 190	75, 170	75, 240	75, 410	58
59	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	77, 920	77, 830	77, 740	77, 640	77, 550	77, 450	77, 350	77, 250	77, 150	77, 040	77, 070	77, 250	59
60	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	77, 990	78, 050	78, 100	78, 160	78, 220	78, 270	78, 320	78, 370	78, 420	78, 470	78, 610	78, 850	60
61	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	78, 060	78, 270	78, 470	78, 680	78, 880	79, 090	79, 290	79, 500	79, 700	79, 900	80, 150	80, 450	61
62	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	78, 130	78, 480	78, 840	79, 190	79, 550	79, 910	80, 260	80, 620	80, 980	81, 330	81, 690	82, 050	62
63	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	78, 130	78, 480	78, 840	79, 190	79, 550	79, 910	80, 260	80, 620	80, 980	81, 330	81, 690	82, 050	63
64	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	78, 130	78, 480	78, 840	79, 190	79, 550	79, 910	80, 260	80, 620	80, 980	81, 330	81, 690	82, 050	64
65	74, 970	75, 320	75, 670	76, 020	76, 370	76, 720	77, 070	77, 430	77, 780	78, 130	78, 480	78, 840	79, 190	79, 550	79, 910	80, 260	80, 620	80, 980	81, 330	81, 690	82, 050	65

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGE-MENT	888.0	888.1	888.2	888.3	888.4	888.5	888.6	888.7	888.8	888.9	889.0	889.1	889.2	889.3	889.4	889.5	889.6	889.7	889.8	889.9	890.0	GATE ARRANGE-MENT
1	110	110	110	110	110	110	110	110	110	110	120	120	120	120	120	120	120	120	120	120	120	1
2	230	230	230	230	230	230	230	230	230	230	230	240	240	240	240	240	240	240	240	240	240	2
3	350	350	350	350	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	3
4	480	480	480	480	480	480	480	480	490	490	490	490	490	490	490	490	490	490	490	490	490	4
5	610	610	610	610	610	610	610	610	620	620	620	620	620	620	620	620	620	620	620	620	630	5
6	740	740	740	740	740	750	750	750	750	750	750	750	750	750	760	760	760	760	760	760	760	6
7	870	880	880	880	880	880	880	880	880	890	890	890	890	890	890	890	890	900	900	900	900	7
8	1,010	1,010	1,010	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,030	1,030	1,030	1,030	1,030	1,030	1,030	1,040	1,040	1,040	1,040	8
9	1,150	1,150	1,150	1,150	1,160	1,160	1,160	1,160	1,160	1,160	1,170	1,170	1,170	1,170	1,170	1,170	1,170	1,180	1,180	1,180	1,180	9
10	1,220	1,220	1,220	1,220	1,220	1,230	1,230	1,230	1,230	1,230	1,230	1,240	1,240	1,240	1,240	1,240	1,240	1,250	1,250	1,250	1,250	10
11	1,820	1,830	1,830	1,830	1,840	1,840	1,840	1,840	1,850	1,850	1,850	1,850	1,860	1,860	1,860	1,860	1,870	1,870	1,870	1,870	1,880	11
12	2,500	2,510	2,510	2,510	2,520	2,520	2,530	2,530	2,530	2,540	2,540	2,540	2,550	2,550	2,550	2,560	2,560	2,560	2,570	2,570	2,570	12
13	3,180	3,190	3,190	3,200	3,200	3,210	3,210	3,210	3,220	3,220	3,230	3,230	3,240	3,240	3,250	3,250	3,260	3,260	3,260	3,270	3,270	13
14	3,860	3,870	3,870	3,880	3,880	3,890	3,900	3,900	3,910	3,910	3,920	3,920	3,930	3,930	3,940	3,940	3,950	3,960	3,960	3,970	3,970	14
15	5,210	5,220	5,230	5,230	5,240	5,250	5,260	5,260	5,270	5,280	5,290	5,290	5,300	5,310	5,320	5,320	5,330	5,340	5,350	5,350	5,360	15
16	6,560	6,570	6,580	6,590	6,600	6,610	6,620	6,630	6,640	6,650	6,660	6,670	6,670	6,680	6,690	6,700	6,710	6,720	6,730	6,740	6,750	16
17	7,910	7,920	7,930	7,940	7,960	7,970	7,980	7,990	8,000	8,010	8,030	8,040	8,050	8,060	8,070	8,080	8,090	8,110	8,120	8,130	8,140	17
18	9,240	9,260	9,270	9,280	9,300	9,310	9,330	9,340	9,350	9,370	9,380	9,390	9,410	9,420	9,430	9,450	9,460	9,470	9,490	9,500	9,510	18
19	10,580	10,590	10,610	10,620	10,640	10,660	10,670	10,690	10,700	10,720	10,730	10,750	10,760	10,780	10,800	10,810	10,830	10,840	10,860	10,870	10,890	19
20	11,910	11,930	11,950	11,960	11,980	12,000	12,020	12,030	12,050	12,070	12,090	12,110	12,120	12,140	12,160	12,180	12,190	12,210	12,230	12,240	12,260	20
21	13,230	13,250	13,270	13,290	13,310	13,330	13,350	13,370	13,390	13,410	13,430	13,450	13,470	13,490	13,510	13,530	13,550	13,570	13,590	13,610	13,630	21
22	14,560	14,580	14,600	14,620	14,640	14,670	14,690	14,710	14,730	14,750	14,780	14,800	14,820	14,840	14,860	14,880	14,910	14,930	14,950	14,970	14,990	22
23	15,880	15,900	15,930	15,950	15,980	16,000	16,020	16,050	16,070	16,100	16,120	16,140	16,170	16,190	16,210	16,240	16,260	16,290	16,310	16,330	16,360	23
24	17,220	17,250	17,280	17,300	17,330	17,350	17,380	17,410	17,430	17,460	17,480	17,510	17,540	17,560	17,590	17,610	17,640	17,670	17,690	17,720	17,740	24
25	18,570	18,590	18,620	18,650	18,680	18,710	18,740	18,770	18,790	18,820	18,850	18,880	18,910	18,930	18,960	18,990	19,020	19,050	19,070	19,100	19,130	25
26	19,910	19,940	19,970	20,000	20,030	20,060	20,090	20,120	20,160	20,190	20,220	20,250	20,280	20,310	20,340	20,370	20,400	20,430	20,460	20,490	20,520	26
27	21,300	21,330	21,360	21,400	21,430	21,460	21,500	21,530	21,560	21,600	21,630	21,660	21,690	21,730	21,760	21,790	21,820	21,860	21,890	21,920	21,950	27
28	22,690	22,720	22,760	22,790	22,830	22,860	22,900	22,930	22,970	23,000	23,040	23,070	23,110	23,140	23,180	23,210	23,250	23,280	23,320	23,350	23,390	28
29	24,070	24,110	24,150	24,190	24,230	24,260	24,300	24,340	24,380	24,410	24,450	24,490	24,530	24,560	24,600	24,640	24,670	24,710	24,750	24,790	24,820	29
30	25,470	25,510	25,550	25,590	25,630	25,670	25,710	25,750	25,790	25,830	25,870	25,910	25,950	25,990	26,030	26,070	26,110	26,150	26,190	26,230	26,260	30
31	26,860	26,900	26,950	26,990	27,030	27,070	27,120	27,160	27,200	27,240	27,290	27,330	27,370	27,410	27,460	27,500	27,540	27,580	27,620	27,660	27,710	31
32	28,250	28,300	28,340	28,390	28,430	28,480	28,520	28,570	28,610	28,660	28,700	28,750	28,790	28,840	28,880	28,930	28,970	29,020	29,060	29,100	29,150	32
33	29,360	29,410	29,460	29,510	29,550	29,600	29,650	29,690	29,740	29,790	29,840	29,880	29,930	29,980	30,020	30,070	30,120	30,160	30,210	30,250	30,300	33
34	30,470	30,520	30,570	30,620	30,670	30,720	30,770	30,820	30,870	30,920	30,970	31,020	31,060	31,110	31,160	31,210	31,260	31,310	31,360	31,400	31,450	34
35	31,580	31,640	31,690	31,740	31,790	31,840	31,890	31,940	32,000	32,050	32,100	32,150	32,200	32,250	32,300	32,350	32,400	32,450	32,500	32,550	32,600	35
36	32,760	32,810	32,860	32,920	32,970	33,030	33,080	33,130	33,190	33,240	33,290	33,350	33,400	33,450	33,510	33,560	33,610	33,670	33,720	33,770	33,820	36
37	33,930	33,990	34,040	34,100	34,150	34,210	34,270	34,320	34,380	34,430	34,490	34,550	34,600	34,660	34,710	34,770	34,820	34,880	34,930	34,990	35,040	37
38	35,100	35,160	35,220	35,280	35,340	35,400	35,450	35,510	35,570	35,630	35,690	35,740	35,800	35,860	35,920	35,970	36,030	36,090	36,150	36,200	36,260	38
39	36,670	36,730	36,800	36,860	36,920	36,980	37,040	37,100	37,160	37,230	37,290	37,350	37,410	37,470	37,530	37,590	37,650	37,710	37,770	37,830	37,890	39
40	38,240	38,310	38,370	38,440	38,500	38,570	38,630	38,690	38,760	38,820	38,890	38,950	39,010	39,080	39,140	39,210	39,270	39,330	39,390	39,460	39,520	40
41	39,810	39,880	39,950	40,020	40,080	40,150	40,220	40,290	40,350	40,420	40,490	40,550	40,620	40,690	40,750	40,820	40,890	40,950	41,020	41,090	41,150	41
42	42,550	42,620	42,690	42,770	42,840	42,920	42,990	43,060	43,130	43,210	43,280	43,350	43,430	43,500	43,570	43,640	43,710	43,790	43,860	43,930	44,000	42
43	45,280	45,360	45,440	45,520	45,600	45,680	45,760	45,840	45,920	46,000	46,070	46,150	46,230	46,310	46,390	46,460	46,540	46,620	46,700	46,780	46,850	43
44	48,020	48,100	48,190	48,270	48,360	48,440	48,530	48,610	48,700	48,780	48,870	48,950	49,040	49,120	49,200	49,290	49,370	49,450	49,540	49,620	49,700	44
45	50,460	50,550	50,640	50,730	50,820	50,920	51,010	51,100	51,190	51,280	51,370	51,460	51,550	51,640	51,730	51,820	51,910	51,990	52,080	52,170	52,260	45
46	52,900	53,000	53,100	53,190	53,290	53,390	53,480	53,580	53,680	53,770	53,870	53,960	54,060	54,160	54,250	54,350	54,440	54,530	54,630	54,720	54,820	46
47	55,340	55,450	55,550	55,650	55,760	55,860	55,960	56,060	56,170	56,270	56,370	56,470	56,570	56,670	56,770	56,870	56,980	57,080	57,180	57,280	57,380	47
48	57,140	57,250	57,360	57,460	57,570	57,680	57,790	57,890	58,000	58,110	58,210	58,320	58,430	58,530	58,640	58,750	58,850	58,960	59,060	59,170	59,270	48
49	58,930	59,050	59,160	59,270	59,390	59,500	59,610	59,720	59,840	59,950	60,060	60,170	60,280	60,400	60,510	60,620	60,730	60,840	60,950	61,060	61,170	49
50	60,730	60,850	60,970	61,080	61,200	61,320	61,440	61,560	61,670	61,790	61,910	62,020	62,140	62,260	62,370	62,490	62,600	62,720	62,830	62,950	63,060	50
51	62,590	62,710	62,840	62,960	63,090	63,210	63,330	63,460	63,580	63,700	63,830	63,950	64,070	64,190	64,310	64,440	64,560	64,680	64,800	64,920	65,040	51
52	64,450	64,580	64,710	64,840	64,970	65,100	65,230	65,360	65,490	65,620	65,740	65,870	66,000	66,130	66,250	66,380	66,510	66,640	66,760	66,890	67,010	52
53	66,310	66,450	66,580	66,720	66,850	66,990	67,120	67,260	67,390	67,530	67,660	67,800	67,930	68,060	68,200	68,330	68,460	68,590	68,730	68,860	68,990	53
54	68,120	68,260	68,400	68,540	68,690	68,830	68,970	69,110	69,250	69,390	69,530	69,670	69,810	69,950	70,090	70,230	70,370	70,500	70,640	70,780	70,920	54
55	69,920	70,070	70,220	70,370	70,520	70,660	70,810	70,960	71,110	71,250	71,400	71,540	71,690	71,840	71,980	72,130	72,270	72,410	72,560	72,700	72,850	55

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	888.0	888.1	888.2	888.3	888.4	888.5	888.6	888.7	888.8	888.9	889.0	889.1	889.2	889.3	889.4	889.5	889.6	889.7	889.8	889.9	890.0	
56	71, 730	71, 880	72, 040	72, 190	72, 350	72, 500	72, 660	72, 810	72, 960	73, 110	73, 270	73, 420	73, 570	73, 720	73, 870	74, 020	74, 170	74, 320	74, 470	74, 620	74, 770	56
57	73, 570	73, 730	73, 890	74, 060	74, 220	74, 380	74, 540	74, 700	74, 860	75, 020	75, 180	75, 340	75, 500	75, 660	75, 810	75, 970	76, 130	76, 290	76, 440	76, 600	76, 760	57
58	75, 410	75, 580	75, 750	75, 920	76, 090	76, 260	76, 420	76, 590	76, 760	76, 920	77, 090	77, 260	77, 420	77, 590	77, 750	77, 920	78, 080	78, 250	78, 410	78, 570	78, 740	58
59	77, 250	77, 430	77, 600	77, 780	77, 960	78, 130	78, 310	78, 480	78, 660	78, 830	79, 000	79, 180	79, 350	79, 520	79, 690	79, 870	80, 040	80, 210	80, 380	80, 550	80, 720	59
60	78, 850	79, 090	79, 330	79, 560	79, 800	80, 040	80, 280	80, 520	80, 750	80, 990	81, 230	81, 460	81, 700	81, 940	82, 180	82, 410	82, 650	82, 740	82, 820	82, 910	82, 990	60
61	80, 450	80, 750	81, 050	81, 350	81, 650	81, 950	82, 250	82, 550	82, 850	83, 150	83, 450	83, 750	84, 050	84, 360	84, 660	84, 960	85, 260	85, 270	85, 270	85, 270	85, 260	61
62	82, 050	82, 410	82, 770	83, 130	83, 490	83, 860	84, 220	84, 580	84, 950	85, 310	85, 670	86, 040	86, 410	86, 770	87, 140	87, 510	87, 870	87, 800	87, 710	87, 620	87, 530	62
63	82, 050	82, 410	82, 770	83, 130	83, 490	83, 860	84, 220	84, 580	84, 950	85, 310	85, 670	86, 040	86, 410	86, 770	87, 140	87, 510	87, 870	87, 950	88, 010	88, 080	88, 140	63
64	82, 050	82, 410	82, 770	83, 130	83, 490	83, 860	84, 220	84, 580	84, 950	85, 310	85, 670	86, 040	86, 410	86, 770	87, 140	87, 510	87, 870	88, 090	88, 310	88, 530	88, 750	64
65	82, 050	82, 410	82, 770	83, 130	83, 490	83, 860	84, 220	84, 580	84, 950	85, 310	85, 670	86, 040	86, 410	86, 770	87, 140	87, 510	87, 870	88, 240	88, 610	88, 980	89, 350	65

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	890.0	890.1	890.2	890.3	890.4	890.5	890.6	890.7	890.8	890.9	891.0	891.1	891.2	891.3	891.4	891.5	891.6	891.7	891.8	891.9	892.0	
1	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	1
2	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	2
3	360	360	360	360	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	3
4	490	490	490	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	510	510	510	4
5	630	630	630	630	630	630	630	630	630	630	630	630	640	640	640	640	640	640	640	640	640	5
6	760	760	760	760	770	770	770	770	770	770	770	770	770	770	780	780	780	780	780	780	780	6
7	900	900	900	900	900	910	910	910	910	910	910	910	910	920	920	920	920	920	920	920	920	7
8	1,040	1,040	1,040	1,040	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,070	1,070	1,070	8
9	1,180	1,180	1,180	1,190	1,190	1,190	1,190	1,190	1,190	1,200	1,200	1,200	1,200	1,200	1,200	1,210	1,210	1,210	1,210	1,210	1,210	9
10	1,250	1,250	1,250	1,260	1,260	1,260	1,260	1,260	1,260	1,270	1,270	1,270	1,270	1,270	1,270	1,280	1,280	1,280	1,280	1,280	1,280	10
11	1,880	1,880	1,880	1,880	1,890	1,890	1,890	1,890	1,900	1,900	1,900	1,900	1,910	1,910	1,910	1,910	1,920	1,920	1,920	1,920	1,930	11
12	2,570	2,580	2,580	2,590	2,590	2,590	2,600	2,600	2,600	2,610	2,610	2,610	2,620	2,620	2,620	2,630	2,630	2,630	2,640	2,640	2,640	12
13	3,270	3,280	3,280	3,290	3,290	3,300	3,300	3,300	3,310	3,310	3,320	3,320	3,330	3,330	3,340	3,340	3,340	3,350	3,350	3,360	3,360	13
14	3,970	3,980	3,980	3,990	3,990	4,000	4,000	4,010	4,020	4,020	4,030	4,030	4,040	4,040	4,050	4,050	4,060	4,060	4,070	4,070	4,080	14
15	5,360	5,370	5,380	5,380	5,390	5,400	5,410	5,410	5,420	5,430	5,430	5,440	5,450	5,460	5,460	5,470	5,480	5,490	5,490	5,500	5,510	15
16	6,750	6,760	6,770	6,780	6,790	6,800	6,810	6,820	6,820	6,830	6,840	6,850	6,860	6,870	6,880	6,890	6,900	6,910	6,920	6,930	6,930	16
17	8,140	8,150	8,160	8,170	8,180	8,200	8,210	8,220	8,230	8,240	8,250	8,260	8,270	8,280	8,300	8,310	8,320	8,330	8,340	8,350	8,360	17
18	9,510	9,530	9,540	9,550	9,570	9,580	9,590	9,610	9,620	9,630	9,650	9,660	9,670	9,680	9,700	9,710	9,720	9,740	9,750	9,760	9,780	18
19	10,890	10,900	10,920	10,930	10,950	10,960	10,980	10,990	11,010	11,020	11,040	11,050	11,070	11,080	11,100	11,120	11,130	11,140	11,160	11,170	11,190	19
20	12,260	12,280	12,300	12,310	12,330	12,350	12,370	12,380	12,400	12,420	12,430	12,450	12,470	12,490	12,500	12,520	12,540	12,550	12,570	12,590	12,600	20
21	13,630	13,650	13,670	13,680	13,700	13,720	13,740	13,760	13,780	13,800	13,820	13,840	13,860	13,880	13,900	13,910	13,930	13,950	13,970	13,990	14,010	21
22	14,990	15,010	15,030	15,060	15,080	15,100	15,120	15,140	15,160	15,180	15,200	15,220	15,250	15,270	15,290	15,310	15,330	15,350	15,370	15,390	15,410	22
23	16,360	16,380	16,400	16,430	16,450	16,470	16,500	16,520	16,540	16,570	16,590	16,610	16,640	16,660	16,680	16,700	16,730	16,750	16,770	16,800	16,820	23
24	17,740	17,770	17,790	17,820	17,850	17,870	17,900	17,920	17,950	17,970	18,000	18,020	18,050	18,070	18,100	18,120	18,150	18,170	18,200	18,220	18,250	24
25	19,130	19,160	19,190	19,210	19,240	19,270	19,300	19,320	19,350	19,380	19,410	19,430	19,460	19,490	19,520	19,540	19,570	19,600	19,620	19,650	19,680	25
26	20,520	20,550	20,580	20,610	20,640	20,670	20,700	20,730	20,760	20,790	20,820	20,850	20,870	20,900	20,930	20,960	20,990	21,020	21,050	21,080	21,110	26
27	21,950	21,990	22,020	22,050	22,080	22,110	22,150	22,180	22,210	22,240	22,270	22,310	22,340	22,370	22,400	22,430	22,460	22,490	22,530	22,560	22,590	27
28	23,390	23,420	23,460	23,490	23,530	23,560	23,590	23,630	23,660	23,700	23,730	23,770	23,800	23,830	23,870	23,900	23,930	23,970	24,000	24,040	24,070	28
29	24,820	24,860	24,900	24,930	24,970	25,010	25,040	25,080	25,120	25,150	25,190	25,230	25,260	25,300	25,330	25,370	25,410	25,440	25,480	25,510	25,550	29
30	26,260	26,300	26,340	26,380	26,420	26,460	26,500	26,540	26,580	26,620	26,650	26,690	26,730	26,770	26,810	26,850	26,890	26,920	26,960	27,000	27,040	30
31	27,710	27,750	27,790	27,830	27,870	27,910	27,960	28,000	28,040	28,080	28,120	28,160	28,200	28,240	28,280	28,330	28,370	28,410	28,450	28,490	28,530	31
32	29,150	29,190	29,240	29,280	29,320	29,370	29,410	29,460	29,500	29,540	29,590	29,630	29,670	29,720	29,760	29,800	29,850	29,890	29,930	29,970	30,020	32
33	30,300	30,350	30,390	30,440	30,480	30,530	30,580	30,620	30,670	30,710	30,760	30,800	30,850	30,890	30,940	30,990	31,030	31,080	31,120	31,170	31,210	33
34	31,450	31,500	31,550	31,600	31,640	31,690	31,740	31,790	31,840	31,880	31,930	31,980	32,030	32,070	32,120	32,170	32,210	32,260	32,310	32,360	32,400	34
35	32,600	32,660	32,710	32,760	32,810	32,860	32,900	32,950	33,000	33,050	33,100	33,150	33,200	33,250	33,300	33,350	33,400	33,450	33,500	33,550	33,590	35
36	33,820	33,880	33,930	33,980	34,030	34,080	34,140	34,190	34,240	34,290	34,340	34,400	34,450	34,500	34,550	34,600	34,650	34,700	34,760	34,810	34,860	36
37	35,040	35,100	35,150	35,210	35,260	35,310	35,370	35,420	35,480	35,530	35,580	35,640	35,690	35,750	35,800	35,850	35,910	35,960	36,010	36,070	36,120	37
38	36,260	36,320	36,370	36,430	36,490	36,540	36,600	36,660	36,710	36,770	36,820	36,880	36,940	36,990	37,050	37,100	37,160	37,220	37,270	37,330	37,380	38
39	37,890	37,950	38,010	38,070	38,130	38,190	38,250	38,310	38,370	38,430	38,490	38,540	38,600	38,660	38,720	38,780	38,840	38,900	38,950	39,010	39,070	39
40	39,520	39,580	39,650	39,710	39,770	39,830	39,900	39,960	40,020	40,080	40,150	40,210	40,270	40,330	40,390	40,450	40,520	40,580	40,640	40,700	40,760	40
41	41,150	41,220	41,280	41,350	41,410	41,480	41,540	41,610	41,680	41,740	41,810	41,870	41,930	42,000	42,060	42,130	42,190	42,260	42,320	42,390	42,450	41
42	44,000	44,070	44,140	44,220	44,290	44,360	44,430	44,500	44,570	44,640	44,710	44,780	44,850	44,920	44,990	45,060	45,130	45,200	45,270	45,340	45,410	42
43	46,850	46,930	47,010	47,080	47,160	47,240	47,310	47,390	47,470	47,540	47,620	47,690	47,770	47,850	47,920	48,000	48,070	48,150	48,220	48,300	48,370	43
44	49,700	49,790	49,870	49,950	50,030	50,120	50,200	50,280	50,360	50,440	50,530	50,610	50,690	50,770	50,850	50,930	51,010	51,090	51,170	51,250	51,330	44
45	52,260	52,350	52,440	52,530	52,610	52,700	52,790	52,880	52,960	53,050	53,140	53,230	53,310	53,400	53,490	53,570	53,660	53,740	53,830	53,920	54,000	45
46	54,820	54,910	55,010	55,100	55,190	55,290	55,380	55,470	55,570	55,660	55,750	55,840	55,940	56,030	56,120	56,210	56,300	56,400	56,490	56,580	56,670	46
47	57,380	57,480	57,570	57,670	57,770	57,870	57,970	58,070	58,170	58,270	58,360	58,460	58,560	58,660	58,760	58,850	58,950	59,050	59,140	59,240	59,340	47
48	59,270	59,380	59,480	59,590	59,690	59,790	59,900	60,000	60,100	60,210	60,310	60,410	60,520	60,620	60,720	60,820	60,920	61,030	61,130	61,230	61,330	48
49	61,170	61,280	61,390	61,500	61,610	61,710	61,820	61,930	62,040	62,150	62,260	62,360	62,470	62,580	62,690	62,790	62,900	63,010	63,110	63,220	63,320	49
50	63,060	63,180	63,290	63,410	63,520	63,630	63,750	63,860	63,970	64,090	64,200	64,310	64,430	64,540	64,650	64,760	64,870	64,980	65,100	65,210	65,320	50
51	65,040	65,160	65,280	65,400	65,520	65,640	65,760	65,880	65,990	66,110	66,230	66,350	66,470	66,580	66,700	66,820	66,940	67,050	67,170	67,290	67,400	51
52	67,010	67,140	67,270	67,390	67,520	67,640	67,760	67,890	68,010	68,140	68,260	68,380	68,510	68,630	68,750	68,880	69,000	69,120	69,240	69,360	69,490	52
53	68,990	69,120	69,250	69,380	69,510	69,640	69,770	69,900	70,030	70,160	70,290	70,420	70,550	70,680	70,800	70,930	71,060	71,190	71,320	71,440	71,570	53
54	70,920	71,050	71,190	71,330	71,460	71,600	71,740	71,870	72,010	72,140	72,280	72,410	72,550	72,680	72,810	72,950	73,080	73,210	73,350	73,480	73,610	54
55	72,850	72,990	73,130	73,270	73,420	73,560	73,700	73,840	73,980	74,120	74,260	74,400	74,540	74,680	74,820	74,960	75,100	75,240	75,380	75,520	75,660	55

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	890.0	890.1	890.2	890.3	890.4	890.5	890.6	890.7	890.8	890.9	891.0	891.1	891.2	891.3	891.4	891.5	891.6	891.7	891.8	891.9	892.0	
56	74, 770	74, 920	75, 070	75, 220	75, 370	75, 520	75, 660	75, 810	75, 960	76, 100	76, 250	76, 400	76, 540	76, 690	76, 830	76, 980	77, 120	77, 270	77, 410	77, 550	77, 700	56
57	76, 760	76, 910	77, 070	77, 220	77, 380	77, 530	77, 690	77, 840	77, 990	78, 150	78, 300	78, 450	78, 610	78, 760	78, 910	79, 060	79, 210	79, 360	79, 510	79, 660	79, 810	57
58	78, 740	78, 900	79, 060	79, 220	79, 390	79, 550	79, 710	79, 870	80, 030	80, 190	80, 350	80, 510	80, 670	80, 830	80, 990	81, 140	81, 300	81, 460	81, 620	81, 770	81, 930	58
59	80, 720	80, 890	81, 060	81, 230	81, 400	81, 560	81, 730	81, 900	82, 070	82, 230	82, 400	82, 570	82, 730	82, 900	83, 060	83, 230	83, 390	83, 560	83, 720	83, 880	84, 050	59
60	82, 990	83, 070	83, 160	83, 240	83, 320	83, 400	83, 470	83, 650	83, 820	83, 990	84, 170	84, 340	84, 510	84, 680	84, 860	85, 030	85, 200	85, 370	85, 540	85, 710	85, 880	60
61	85, 260	85, 260	85, 250	85, 250	85, 240	85, 230	85, 220	85, 390	85, 570	85, 750	85, 930	86, 110	86, 290	86, 470	86, 650	86, 830	87, 000	87, 180	87, 360	87, 530	87, 710	61
62	87, 530	87, 440	87, 350	87, 250	87, 160	87, 060	86, 960	87, 140	87, 330	87, 510	87, 700	87, 890	88, 070	88, 260	88, 440	88, 630	88, 810	88, 990	89, 180	89, 360	89, 540	62
63	88, 140	88, 200	88, 260	88, 320	88, 380	88, 440	88, 500	88, 750	88, 990	89, 240	89, 490	89, 740	89, 990	90, 240	90, 490	90, 740	90, 990	91, 240	91, 480	91, 730	91, 980	63
64	88, 750	88, 960	89, 180	89, 390	89, 610	89, 830	90, 040	90, 350	90, 660	90, 970	91, 290	91, 600	91, 910	92, 220	92, 540	92, 850	93, 160	93, 480	93, 790	94, 110	94, 420	64
65	89, 350	89, 720	90, 090	90, 460	90, 840	91, 210	91, 580	91, 950	92, 330	92, 700	93, 080	93, 450	93, 830	94, 210	94, 590	94, 960	95, 340	95, 720	96, 100	96, 480	96, 860	65

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	892.0	892.1	892.2	892.3	892.4	892.5	892.6	892.7	892.8	892.9	893.0	893.1	893.2	893.3	893.4	893.5	893.6	893.7	893.8	893.9	894.0	
1	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	1
2	240	240	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	2
3	370	370	370	370	370	380	380	380	380	380	380	380	380	380	380	380	380	380	380	380	380	3
4	510	510	510	510	510	510	510	510	510	510	510	510	510	510	520	520	520	520	520	520	520	4
5	640	640	640	640	650	650	650	650	650	650	650	650	650	650	650	650	660	660	660	660	660	5
6	780	780	780	780	790	790	790	790	790	790	790	790	790	790	800	800	800	800	800	800	800	6
7	920	920	930	930	930	930	930	930	930	930	940	940	940	940	940	940	940	940	940	950	950	7
8	1,070	1,070	1,070	1,070	1,070	1,070	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,100	8
9	1,210	1,210	1,220	1,220	1,220	1,220	1,220	1,220	1,230	1,230	1,230	1,230	1,230	1,230	1,240	1,240	1,240	1,240	1,240	1,240	1,240	9
10	1,280	1,290	1,290	1,290	1,290	1,290	1,290	1,300	1,300	1,300	1,300	1,300	1,300	1,310	1,310	1,310	1,310	1,310	1,310	1,320	1,320	10
11	1,930	1,930	1,930	1,930	1,940	1,940	1,940	1,940	1,950	1,950	1,950	1,950	1,960	1,960	1,960	1,960	1,970	1,970	1,970	1,970	1,980	11
12	2,640	2,650	2,650	2,650	2,660	2,660	2,660	2,670	2,670	2,670	2,680	2,680	2,680	2,690	2,690	2,690	2,700	2,700	2,700	2,710	2,710	12
13	3,360	3,370	3,370	3,370	3,380	3,380	3,390	3,390	3,400	3,400	3,400	3,410	3,410	3,420	3,420	3,430	3,430	3,430	3,440	3,440	3,450	13
14	4,080	4,080	4,090	4,090	4,100	4,110	4,110	4,120	4,120	4,130	4,130	4,140	4,140	4,150	4,150	4,160	4,160	4,170	4,170	4,180	4,180	14
15	5,510	5,510	5,520	5,530	5,540	5,540	5,550	5,560	5,560	5,570	5,580	5,590	5,590	5,600	5,610	5,610	5,620	5,630	5,630	5,640	5,650	15
16	6,930	6,940	6,950	6,960	6,970	6,980	6,990	7,000	7,010	7,020	7,020	7,030	7,040	7,050	7,060	7,070	7,080	7,090	7,100	7,110	7,110	16
17	8,360	8,370	8,380	8,400	8,410	8,420	8,430	8,440	8,450	8,460	8,470	8,480	8,490	8,500	8,510	8,530	8,540	8,550	8,560	8,570	8,580	17
18	9,780	9,790	9,800	9,810	9,830	9,840	9,850	9,870	9,880	9,890	9,900	9,920	9,930	9,940	9,960	9,970	9,980	9,990	10,010	10,020	10,030	18
19	11,190	11,200	11,220	11,230	11,250	11,260	11,280	11,290	11,310	11,320	11,340	11,350	11,370	11,380	11,400	11,410	11,430	11,440	11,450	11,470	11,480	19
20	12,600	12,620	12,640	12,650	12,670	12,690	12,700	12,720	12,740	12,750	12,770	12,790	12,800	12,820	12,840	12,850	12,870	12,890	12,900	12,920	12,940	20
21	14,010	14,030	14,050	14,070	14,080	14,100	14,120	14,140	14,160	14,180	14,200	14,210	14,230	14,250	14,270	14,290	14,310	14,330	14,340	14,360	14,380	21
22	15,410	15,430	15,460	15,480	15,500	15,520	15,540	15,560	15,580	15,600	15,620	15,640	15,660	15,680	15,700	15,720	15,740	15,760	15,780	15,800	15,820	22
23	16,820	16,840	16,860	16,890	16,910	16,930	16,960	16,980	17,000	17,020	17,050	17,070	17,090	17,110	17,140	17,160	17,180	17,200	17,220	17,250	17,270	23
24	18,250	18,270	18,300	18,320	18,350	18,370	18,400	18,420	18,450	18,470	18,500	18,520	18,550	18,570	18,590	18,620	18,640	18,670	18,690	18,720	18,740	24
25	19,680	19,710	19,730	19,760	19,790	19,810	19,840	19,870	19,890	19,920	19,950	19,970	20,000	20,030	20,050	20,080	20,110	20,130	20,160	20,190	20,210	25
26	21,110	21,140	21,170	21,200	21,230	21,250	21,280	21,310	21,340	21,370	21,400	21,430	21,460	21,480	21,510	21,540	21,570	21,600	21,630	21,660	21,680	26
27	22,590	22,620	22,650	22,680	22,710	22,750	22,780	22,810	22,840	22,870	22,900	22,930	22,960	22,990	23,020	23,050	23,090	23,120	23,150	23,180	23,210	27
28	24,070	24,100	24,140	24,170	24,200	24,240	24,270	24,300	24,340	24,370	24,400	24,440	24,470	24,500	24,540	24,570	24,600	24,630	24,670	24,700	24,730	28
29	25,550	25,590	25,620	25,660	25,690	25,730	25,760	25,800	25,840	25,870	25,910	25,940	25,980	26,010	26,050	26,080	26,120	26,150	26,190	26,220	26,260	29
30	27,040	27,080	27,120	27,150	27,190	27,230	27,270	27,310	27,340	27,380	27,420	27,460	27,490	27,530	27,570	27,610	27,640	27,680	27,720	27,760	27,790	30
31	28,530	28,570	28,610	28,650	28,690	28,730	28,770	28,810	28,850	28,890	28,930	28,970	29,010	29,050	29,090	29,130	29,170	29,210	29,250	29,290	29,330	31
32	30,020	30,060	30,100	30,150	30,190	30,230	30,270	30,320	30,360	30,400	30,440	30,490	30,530	30,570	30,610	30,650	30,700	30,740	30,780	30,820	30,860	32
33	31,210	31,250	31,300	31,340	31,390	31,430	31,480	31,520	31,570	31,610	31,660	31,700	31,740	31,790	31,830	31,880	31,920	31,960	32,010	32,050	32,090	33
34	32,400	32,450	32,500	32,540	32,590	32,640	32,680	32,730	32,770	32,820	32,870	32,910	32,960	33,010	33,050	33,100	33,140	33,190	33,230	33,280	33,330	34
35	33,590	33,640	33,690	33,740	33,790	33,840	33,890	33,930	33,980	34,030	34,080	34,130	34,180	34,220	34,270	34,320	34,370	34,410	34,460	34,510	34,560	35
36	34,860	34,910	34,960	35,010	35,060	35,110	35,160	35,210	35,260	35,310	35,360	35,410	35,460	35,510	35,560	35,610	35,660	35,710	35,760	35,810	35,860	36
37	36,120	36,170	36,230	36,280	36,330	36,380	36,440	36,490	36,540	36,590	36,650	36,700	36,750	36,800	36,860	36,910	36,960	37,010	37,060	37,110	37,170	37
38	37,380	37,440	37,490	37,550	37,600	37,660	37,710	37,770	37,820	37,880	37,930	37,980	38,040	38,090	38,150	38,200	38,260	38,310	38,360	38,420	38,470	38
39	39,070	39,130	39,190	39,240	39,300	39,360	39,420	39,480	39,530	39,590	39,650	39,700	39,760	39,820	39,880	39,930	39,990	40,050	40,100	40,160	40,220	39
40	40,760	40,820	40,880	40,940	41,000	41,060	41,120	41,180	41,250	41,310	41,370	41,430	41,490	41,550	41,610	41,660	41,720	41,780	41,840	41,900	41,960	40
41	42,450	42,510	42,580	42,640	42,700	42,770	42,830	42,890	42,960	43,020	43,080	43,150	43,210	43,270	43,330	43,400	43,460	43,520	43,580	43,650	43,710	41
42	45,410	45,480	45,550	45,620	45,690	45,760	45,820	45,890	45,960	46,030	46,100	46,170	46,240	46,300	46,370	46,440	46,510	46,570	46,640	46,710	46,780	42
43	48,370	48,450	48,520	48,600	48,670	48,740	48,820	48,890	48,970	49,040	49,110	49,190	49,260	49,330	49,410	49,480	49,550	49,630	49,700	49,770	49,850	43
44	51,330	51,410	51,490	51,570	51,650	51,730	51,810	51,890	51,970	52,050	52,130	52,210	52,290	52,370	52,440	52,520	52,600	52,680	52,760	52,840	52,910	44
45	54,000	54,090	54,170	54,260	54,340	54,430	54,510	54,600	54,680	54,770	54,850	54,940	55,020	55,100	55,190	55,270	55,360	55,440	55,520	55,610	55,690	45
46	56,670	56,760	56,850	56,940	57,030	57,120	57,210	57,300	57,390	57,480	57,570	57,660	57,750	57,840	57,930	58,020	58,110	58,200	58,290	58,370	58,460	46
47	59,340	59,430	59,530	59,630	59,720	59,820	59,910	60,010	60,100	60,200	60,290	60,390	60,480	60,580	60,670	60,770	60,860	60,960	61,050	61,140	61,240	47
48	61,330	61,430	61,530	61,630	61,730	61,830	61,940	62,040	62,140	62,240	62,330	62,430	62,530	62,630	62,730	62,830	62,930	63,030	63,130	63,220	63,320	48
49	63,320	63,430	63,540	63,640	63,750	63,850	63,960	64,060	64,170	64,270	64,380	64,480	64,580	64,690	64,790	64,890	65,000	65,100	65,200	65,310	65,410	49
50	65,320	65,430	65,540	65,650	65,760	65,870	65,980	66,090	66,200	66,310	66,420	66,520	66,630	66,740	66,850	66,960	67,070	67,170	67,280	67,390	67,500	50
51	67,400	67,520	67,630	67,750	67,860	67,980	68,090	68,210	68,320	68,440	68,550	68,670	68,780	68,890	69,010	69,120	69,230	69,350	69,460	69,570	69,680	51
52	69,490	69,610	69,730	69,850	69,970	70,090	70,210	70,330	70,450	70,570	70,690	70,810	70,930	71,050	71,160	71,280	71,400	71,520	71,640	71,750	71,870	52
53	71,570	71,700	71,820	71,950	72,070	72,200	72,330	72,450	72,580	72,700	72,820	72,950	73,070	73,200	73,320	73,440	73,570	73,690	73,810	73,940	74,060	53
54	73,610	73,740	73,880	74,010	74,140	74,270	74,400	74,530	74,660	74,790	74,920	75,050	75,180	75,310	75,440	75,570	75,700	75,830	75,960	76,080	76,210	54
55	75,660	75,790	75,930	76,070	76,200	76,340	76,480	76,610	76,750	76,890	77,020	77,160	77,290	77,430	77,560	77,700	77,830	77,960	78,100	78,230	78,360	55

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	892.0	892.1	892.2	892.3	892.4	892.5	892.6	892.7	892.8	892.9	893.0	893.1	893.2	893.3	893.4	893.5	893.6	893.7	893.8	893.9	894.0	
56	77, 700	77, 840	77, 980	78, 130	78, 270	78, 410	78, 550	78, 700	78, 840	78, 980	79, 120	79, 260	79, 400	79, 540	79, 680	79, 820	79, 960	80, 100	80, 240	80, 380	80, 520	56
57	79, 810	79, 960	80, 110	80, 260	80, 410	80, 560	80, 710	80, 860	81, 010	81, 150	81, 300	81, 450	81, 600	81, 740	81, 890	82, 030	82, 180	82, 330	82, 470	82, 620	82, 760	57
58	81, 930	82, 090	82, 240	82, 400	82, 550	82, 710	82, 860	83, 020	83, 170	83, 330	83, 480	83, 640	83, 790	83, 940	84, 090	84, 250	84, 400	84, 550	84, 700	84, 850	85, 000	58
59	84, 050	84, 210	84, 370	84, 540	84, 700	84, 860	85, 020	85, 180	85, 340	85, 500	85, 660	85, 820	85, 980	86, 140	86, 300	86, 460	86, 620	86, 780	86, 930	87, 090	87, 250	59
60	85, 880	86, 050	86, 220	86, 390	86, 550	86, 720	86, 890	87, 060	87, 220	87, 390	87, 560	87, 720	87, 890	88, 050	88, 220	88, 380	88, 550	88, 710	88, 880	89, 040	89, 200	60
61	87, 710	87, 890	88, 060	88, 240	88, 410	88, 590	88, 760	88, 930	89, 110	89, 280	89, 450	89, 630	89, 800	89, 970	90, 140	90, 310	90, 480	90, 650	90, 820	90, 990	91, 160	61
62	89, 540	89, 720	89, 910	90, 090	90, 270	90, 450	90, 630	90, 810	90, 990	91, 170	91, 350	91, 530	91, 700	91, 880	92, 060	92, 240	92, 410	92, 590	92, 770	92, 940	93, 120	62
63	91, 980	92, 230	92, 480	92, 730	92, 980	93, 220	93, 470	93, 720	93, 970	94, 210	94, 460	94, 710	94, 960	95, 210	95, 450	95, 700	95, 950	96, 200	96, 440	96, 690	96, 940	63
64	94, 420	94, 740	95, 050	95, 370	95, 680	96, 000	96, 310	96, 630	96, 940	97, 260	97, 580	97, 890	98, 210	98, 530	98, 850	99, 160	99, 480	99, 800	100, 100	100, 400	100, 800	64
65	96, 860	97, 240	97, 620	98, 000	98, 390	98, 770	99, 150	99, 540	99, 920	100, 300	100, 700	101, 100	101, 500	101, 900	102, 200	102, 600	103, 000	103, 400	103, 800	104, 200	104, 600	65

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	894.0	894.1	894.2	894.3	894.4	894.5	894.6	894.7	894.8	894.9	895.0	895.1	895.2	895.3	895.4	895.5	895.6	895.7	895.8	895.9	896.0	
1	120	120	120	120	120	120	120	120	120													1
2	250	250	250	250	250	250	250	250	250													2
3	380	380	380	380	380	380	390	390	390													3
4	520	520	520	520	520	520	520	520	520													4
5	660	660	660	660	660	660	660	660	660													5
6	800	800	800	800	810	810	810	810	810													6
7	950	950	950	950	950	950	950	960	960													7
8	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,110													8
9	1,240	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,260													9
10	1,320	1,320	1,320	1,320	1,320	1,330	1,330	1,330	1,330													10
11	1,980	1,980	1,980	1,980	1,990	1,990	1,990	1,990	1,990	2,000	2,000	2,000	2,000									11
12	2,710	2,710	2,720	2,720	2,720	2,730	2,730	2,730	2,740	2,740	2,740	2,750	2,750									12
13	3,450	3,450	3,460	3,460	3,460	3,470	3,470	3,480	3,480	3,490	3,490	3,490	3,500									13
14	4,180	4,190	4,190	4,200	4,200	4,210	4,210	4,220	4,220	4,230	4,230	4,240	4,240	4,250	4,250	4,260	4,270	4,270				14
15	5,650	5,660	5,660	5,670	5,680	5,680	5,690	5,700	5,700	5,710	5,720	5,730	5,730	5,740	5,750	5,750	5,760	5,770				15
16	7,110	7,120	7,130	7,140	7,150	7,160	7,170	7,180	7,180	7,190	7,200	7,210	7,220	7,230	7,240	7,250	7,250	7,260				16
17	8,580	8,590	8,600	8,610	8,620	8,630	8,640	8,650	8,660	8,680	8,690	8,700	8,710	8,720	8,730	8,740	8,750	8,760	8,770	8,780	8,790	17
18	10,030	10,040	10,060	10,070	10,080	10,090	10,110	10,120	10,130	10,140	10,160	10,170	10,180	10,190	10,210	10,220	10,230	10,240	10,260	10,270	10,280	18
19	11,480	11,500	11,510	11,530	11,540	11,560	11,570	11,590	11,600	11,610	11,630	11,640	11,660	11,670	11,690	11,700	11,710	11,730	11,740	11,760	11,770	19
20	12,940	12,950	12,970	12,990	13,000	13,020	13,030	13,050	13,070	13,080	13,100	13,120	13,130	13,150	13,160	13,180	13,200	13,210	13,230	13,240	13,260	20
21	14,380	14,400	14,420	14,440	14,450	14,470	14,490	14,510	14,530	14,540	14,560	14,580	14,600	14,620	14,640	14,650	14,670	14,690	14,710	14,730	14,740	21
22	15,820	15,850	15,870	15,890	15,910	15,930	15,950	15,970	15,990	16,010	16,030	16,050	16,070	16,090	16,110	16,130	16,150	16,170	16,190	16,210	16,230	22
23	17,270	17,290	17,310	17,340	17,360	17,380	17,400	17,420	17,450	17,470	17,490	17,510	17,530	17,560	17,580	17,600	17,620	17,640	17,670	17,690	17,710	23
24	18,740	18,770	18,790	18,810	18,840	18,860	18,890	18,910	18,930	18,960	18,980	19,010	19,030	19,050	19,080	19,100	19,130	19,150	19,170	19,200	19,220	24
25	20,210	20,240	20,260	20,290	20,320	20,340	20,370	20,400	20,420	20,450	20,470	20,500	20,530	20,550	20,580	20,600	20,630	20,650	20,680	20,710	20,730	25
26	21,680	21,710	21,740	21,770	21,800	21,820	21,850	21,880	21,910	21,940	21,970	21,990	22,020	22,050	22,080	22,100	22,130	22,160	22,190	22,220	22,240	26
27	23,210	23,240	23,270	23,300	23,330	23,360	23,390	23,420	23,450	23,480	23,510	23,540	23,570	23,600	23,630	23,660	23,690	23,720	23,750	23,780	23,810	27
28	24,730	24,770	24,800	24,830	24,860	24,900	24,930	24,960	24,990	25,030	25,060	25,090	25,120	25,150	25,190	25,220	25,250	25,280	25,310	25,350	25,380	28
29	26,260	26,290	26,330	26,360	26,400	26,430	26,470	26,500	26,530	26,570	26,600	26,640	26,670	26,710	26,740	26,780	26,810	26,840	26,880	26,910	26,950	29
30	27,790	27,830	27,870	27,900	27,940	27,980	28,010	28,050	28,090	28,120	28,160	28,200	28,230	28,270	28,310	28,340	28,380	28,420	28,450	28,490	28,530	30
31	29,330	29,370	29,410	29,450	29,480	29,520	29,560	29,600	29,640	29,680	29,720	29,760	29,800	29,840	29,870	29,910	29,950	29,990	30,030	30,070	30,100	31
32	30,860	30,900	30,950	30,990	31,030	31,070	31,110	31,150	31,190	31,240	31,280	31,320	31,360	31,400	31,440	31,480	31,520	31,560	31,600	31,640	31,680	32
33	32,090	32,140	32,180	32,220	32,270	32,310	32,350	32,400	32,440	32,480	32,530	32,570	32,610	32,660	32,700	32,740	32,780	32,830	32,870	32,910	32,950	33
34	33,330	33,370	33,420	33,460	33,510	33,550	33,600	33,640	33,690	33,730	33,780	33,820	33,870	33,910	33,960	34,000	34,050	34,090	34,130	34,180	34,220	34
35	34,560	34,600	34,650	34,700	34,750	34,790	34,840	34,890	34,930	34,980	35,030	35,070	35,120	35,170	35,210	35,260	35,310	35,350	35,400	35,450	35,490	35
36	35,860	35,910	35,960	36,010	36,060	36,110	36,160	36,210	36,260	36,300	36,350	36,400	36,450	36,500	36,550	36,600	36,640	36,690	36,740	36,790	36,840	36
37	37,170	37,220	37,270	37,320	37,370	37,420	37,470	37,530	37,580	37,630	37,680	37,730	37,780	37,830	37,880	37,930	37,980	38,030	38,080	38,130	38,180	37
38	38,470	38,520	38,580	38,630	38,680	38,740	38,790	38,840	38,900	38,950	39,000	39,060	39,110	39,160	39,210	39,270	39,320	39,370	39,430	39,480	39,530	38
39	40,220	40,270	40,330	40,390	40,440	40,500	40,550	40,610	40,670	40,720	40,780	40,830	40,890	40,940	41,000	41,050	41,110	41,170	41,220	41,280	41,330	39
40	41,960	42,020	42,080	42,140	42,200	42,260	42,320	42,380	42,430	42,490	42,550	42,610	42,670	42,730	42,780	42,840	42,900	42,960	43,020	43,070	43,130	40
41	43,710	43,770	43,830	43,890	43,960	44,020	44,080	44,140	44,200	44,260	44,320	44,390	44,450	44,510	44,570	44,630	44,690	44,750	44,810	44,870	44,930	41
42	46,780	46,840	46,910	46,980	47,050	47,110	47,180	47,250	47,310	47,380	47,450	47,510	47,580	47,640	47,710	47,780	47,840	47,910	47,970	48,040	48,100	42
43	49,850	49,920	49,990	50,060	50,130	50,210	50,280	50,350	50,420	50,490	50,570	50,640	50,710	50,780	50,850	50,920	50,990	51,060	51,140	51,210	51,280	43
44	52,910	52,990	53,070	53,150	53,220	53,300	53,380	53,460	53,530	53,610	53,690	53,760	53,840	53,920	53,990	54,070	54,150	54,220	54,300	54,370	54,450	44
45	55,690	55,770	55,850	55,940	56,020	56,100	56,180	56,270	56,350	56,430	56,510	56,590	56,680	56,760	56,840	56,920	57,000	57,080	57,160	57,240	57,330	45
46	58,460	58,550	58,640	58,730	58,810	58,900	58,990	59,080	59,160	59,250	59,340	59,430	59,510	59,600	59,690	59,770	59,860	59,940	60,030	60,120	60,200	46
47	61,240	61,330	61,420	61,520	61,610	61,700	61,800	61,890	61,980	62,070	62,160	62,260	62,350	62,440	62,530	62,620	62,710	62,810	62,900	62,990	63,080	47
48	63,320	63,420	63,520	63,620	63,710	63,810	63,910	64,010	64,100	64,200	64,300	64,390	64,490	64,580	64,680	64,780	64,870	64,970	65,060	65,160	65,250	48
49	65,410	65,510	65,610	65,720	65,820	65,920	66,020	66,120	66,220	66,330	66,430	66,530	66,630	66,730	66,830	66,930	67,030	67,130	67,230	67,330	67,430	49
50	67,500	67,600	67,710	67,820	67,920	68,030	68,140	68,240	68,350	68,450	68,560	68,660	68,770	68,870	68,980	69,080	69,190	69,290	69,400	69,500	69,610	50
51	69,680	69,800	69,910	70,020	70,130	70,240	70,350	70,460	70,580	70,690	70,800	70,910	71,020	71,130	71,240	71,350	71,460	71,570	71,680	71,780	71,890	51
52	71,870	71,990	72,110	72,220	72,340	72,460	72,570	72,690	72,800	72,920	73,030	73,150	73,270	73,380	73,500	73,610	73,720	73,840	73,950	74,070	74,180	52
53	74,060	74,180	74,300	74,430	74,550	74,670	74,790	74,910	75,030	75,150	75,270	75,390	75,510	75,630	75,750	75,870	75,990	76,110	76,230	76,350	76,470	53
54	76,210	76,340	76,470	76,590	76,720	76,850	76,970	77,100	77,230	77,350	77,480	77,600	77,730	77,850	77,980	78,100	78,230	78,350	78,480	78,600	78,730	54
55	78,360	78,500	78,630	78,760	78,900	79,030	79,160	79,290	79,420	79,550	79,680	79,820	79,950	80,080	80,210	80,340	80,470	80,600	80,720	80,850	80,980	55

See special instruction for preventing gate overflow on page 3.

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	894.0	894.1	894.2	894.3	894.4	894.5	894.6	894.7	894.8	894.9	895.0	895.1	895.2	895.3	895.4	895.5	895.6	895.7	895.8	895.9	896.0	
56	80, 520	80, 660	80, 790	80, 930	81, 070	81, 210	81, 340	81, 480	81, 620	81, 750	81, 890	82, 030	82, 160	82, 300	82, 430	82, 570	82, 700	82, 840	82, 970	83, 110	83, 240	56
57	82, 760	82, 910	83, 050	83, 190	83, 340	83, 480	83, 620	83, 770	83, 910	84, 050	84, 200	84, 340	84, 480	84, 620	84, 760	84, 900	85, 040	85, 180	85, 330	85, 470	85, 610	57
58	85, 000	85, 150	85, 310	85, 460	85, 610	85, 760	85, 900	86, 050	86, 200	86, 350	86, 500	86, 650	86, 800	86, 940	87, 090	87, 240	87, 390	87, 530	87, 680	87, 820	87, 970	58
59	87, 250	87, 400	87, 560	87, 720	87, 870	88, 030	88, 190	88, 340	88, 500	88, 650	88, 800	88, 960	89, 110	89, 270	89, 420	89, 570	89, 730	89, 880	90, 030	90, 180	90, 330	59
60	89, 200	89, 370	89, 530	89, 690	89, 850	90, 020	90, 180	90, 340	90, 500	90, 660	90, 820	90, 980	91, 140	91, 300	91, 460	91, 620	91, 780	91, 940	92, 090	92, 250	92, 410	60
61	91, 160	91, 330	91, 500	91, 670	91, 840	92, 000	92, 170	92, 340	92, 510	92, 670	92, 840	93, 000	93, 170	93, 340	93, 500	93, 670	93, 830	93, 990	94, 160	94, 320	94, 490	61
62	93, 120	93, 290	93, 470	93, 640	93, 820	93, 990	94, 160	94, 340	94, 510	94, 680	94, 860	95, 030	95, 200	95, 370	95, 540	95, 710	95, 880	96, 050	96, 220	96, 390	96, 560	62
63	96, 940	97, 180	97, 430	97, 680	97, 930	98, 170	98, 420	98, 670	98, 910	99, 160	99, 410	99, 650	99, 900	100, 100	100, 400	100, 600	100, 900	101, 100	101, 400	101, 600	101, 900	63
64	100, 800	101, 100	101, 400	101, 700	102, 000	102, 400	102, 700	103, 000	103, 300	103, 600	104, 000	104, 300	104, 600	104, 900	105, 200	105, 600	105, 900	106, 200	106, 500	106, 900	107, 200	64
65	104, 600	105, 000	105, 400	105, 800	106, 100	106, 500	106, 900	107, 300	107, 700	108, 100	108, 500	108, 900	109, 300	109, 700	110, 100	110, 500	110, 900	111, 300	111, 700	112, 100	112, 500	65

TIMS FORD DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

HEADWATER ELEVATION

GATE ARRANGE-MENT	896.0	896.1	896.2	896.3	896.4	896.5	896.6	896.7	896.8	896.9
11										
12										
13										
14										
15										
16										
17	8,790	8,800	8,810	8,820	8,830	8,840	8,850	8,860		
18	10,280	10,290	10,310	10,320	10,330	10,340	10,350	10,370		
19	11,770	11,780	11,800	11,810	11,830	11,840	11,860	11,870		
20	13,260	13,280	13,290	13,310	13,320	13,340	13,360	13,370	13,390	13,400
21	14,740	14,760	14,780	14,800	14,810	14,830	14,850	14,870	14,890	14,900
22	16,230	16,250	16,270	16,290	16,300	16,320	16,340	16,360	16,380	16,400
23	17,710	17,730	17,750	17,770	17,800	17,820	17,840	17,860	17,880	17,900
24	19,220	19,240	19,270	19,290	19,310	19,340	19,360	19,390	19,410	19,430
25	20,730	20,760	20,780	20,810	20,830	20,860	20,890	20,910	20,940	20,960
26	22,240	22,270	22,300	22,330	22,350	22,380	22,410	22,440	22,460	22,490
27	23,810	23,840	23,870	23,900	23,930	23,960	23,990	24,020	24,050	24,080
28	25,380	25,410	25,440	25,470	25,510	25,540	25,570	25,600	25,630	25,660
29	26,950	26,980	27,010	27,050	27,080	27,110	27,150	27,180	27,220	27,250
30	28,530	28,560	28,600	28,630	28,670	28,710	28,740	28,780	28,810	28,850
31	30,100	30,140	30,180	30,220	30,260	30,300	30,330	30,370	30,410	30,450
32	31,680	31,730	31,770	31,810	31,850	31,890	31,930	31,970	32,010	32,050
33	32,950	33,000	33,040	33,080	33,120	33,170	33,210	33,250	33,290	33,330
34	34,220	34,270	34,310	34,360	34,400	34,440	34,490	34,530	34,580	34,620
35	35,490	35,540	35,580	35,630	35,680	35,720	35,770	35,810	35,860	35,910
36	36,840	36,890	36,930	36,980	37,030	37,080	37,130	37,170	37,220	37,270
37	38,180	38,230	38,280	38,330	38,380	38,430	38,480	38,530	38,580	38,630
38	39,530	39,580	39,630	39,690	39,740	39,790	39,840	39,890	39,950	40,000
39	41,330	41,390	41,440	41,490	41,550	41,600	41,660	41,710	41,770	41,820
40	43,130	43,190	43,250	43,300	43,360	43,420	43,480	43,530	43,590	43,650
41	44,930	44,990	45,050	45,110	45,170	45,230	45,290	45,350	45,410	45,470
42	48,100	48,170	48,230	48,300	48,370	48,430	48,500	48,560	48,620	48,690
43	51,280	51,350	51,420	51,490	51,560	51,630	51,700	51,770	51,840	51,910
44	54,450	54,520	54,600	54,670	54,750	54,830	54,900	54,980	55,050	55,130
45	57,330	57,410	57,490	57,570	57,650	57,730	57,810	57,890	57,970	58,050
46	60,200	60,290	60,370	60,460	60,540	60,630	60,710	60,800	60,880	60,970
47	63,080	63,170	63,260	63,350	63,440	63,530	63,620	63,710	63,800	63,890
48	65,250	65,350	65,440	65,540	65,630	65,730	65,820	65,920	66,010	66,110
49	67,430	67,530	67,630	67,730	67,830	67,930	68,020	68,120	68,220	68,320
50	69,610	69,710	69,810	69,920	70,020	70,120	70,230	70,330	70,430	70,530
51	71,890	72,000	72,110	72,220	72,330	72,430	72,540	72,650	72,760	72,870
52	74,180	74,290	74,410	74,520	74,630	74,750	74,860	74,970	75,080	75,200
53	76,470	76,590	76,700	76,820	76,940	77,060	77,180	77,290	77,410	77,530
54	78,730	78,850	78,970	79,100	79,220	79,340	79,460	79,590	79,710	79,830
55	80,980	81,110	81,240	81,370	81,500	81,620	81,750	81,880	82,010	82,130
56	83,240	83,370	83,510	83,640	83,770	83,910	84,040	84,170	84,310	84,440
57	85,610	85,750	85,880	86,020	86,160	86,300	86,440	86,580	86,720	86,860
58	87,970	88,120	88,260	88,410	88,550	88,700	88,840	88,980	89,130	89,270
59	90,330	90,490	90,640	90,790	90,940	91,090	91,240	91,390	91,540	91,690
60	92,410	92,570	92,720	92,880	93,040	93,190	93,350	93,510	93,660	93,820
61	94,490	94,650	94,810	94,970	95,140	95,300	95,460	95,620	95,780	95,940
62	96,560	96,730	96,900	97,070	97,230	97,400	97,570	97,740	97,900	98,070
63	101,900	102,100	102,400	102,600	102,900	103,100	103,400	103,600	103,800	104,100
64	107,200	107,500	107,800	108,200	108,500	108,800	109,100	109,500	109,800	110,100
65	112,500	112,900	113,300	113,700	114,100	114,500	114,900	115,300	115,700	116,100

897.0	897.1	897.2	897.3	897.4	897.5	897.6	897.7	897.8	897.9	898.0	GATE ARRANGE-MENT
											11
											12
											13
											14
											15
											16
											17
											18
											19
13,420	13,440	13,450	13,470	13,480	13,500	13,510	13,530				20
14,920	14,940	14,960	14,970	14,990	15,010	15,030	15,040				21
16,420	16,440	16,460	16,480	16,500	16,520	16,540	16,560				22
17,920	17,950	17,970	17,990	18,010	18,030	18,050	18,070	18,090	18,120	18,140	23
19,460	19,480	19,500	19,530	19,550	19,570	19,600	19,620	19,640	19,660	19,690	24
20,990	21,010	21,040	21,060	21,090	21,110	21,140	21,160	21,190	21,210	21,240	25
22,520	22,550	22,570	22,600	22,630	22,650	22,680	22,710	22,740	22,760	22,790	26
24,110	24,140	24,170	24,190	24,220	24,250	24,280	24,310	24,340	24,370	24,400	27
25,690	25,730	25,760	25,790	25,820	25,850	25,880	25,910	25,950	25,980	26,010	28
27,280	27,320	27,350	27,380	27,420	27,450	27,480	27,520	27,550	27,580	27,620	29
28,880	28,920	28,960	28,990	29,030	29,060	29,100	29,130	29,170	29,200	29,240	30
30,490	30,520	30,560	30,600	30,640	30,680	30,710	30,750	30,790	30,830	30,860	31
32,090	32,130	32,170	32,210	32,250	32,290	32,330	32,370	32,410	32,450	32,490	32
33,380	33,420	33,460	33,500	33,540	33,580	33,630	33,670	33,710	33,750	33,790	33
34,660	34,710	34,750	34,790	34,840	34,880	34,920	34,970	35,010	35,050	35,100	34
35,950	36,000	36,040	36,090	36,130	36,180	36,220	36,270	36,310	36,360	36,400	35
37,320	37,360	37,410	37,460	37,510	37,550	37,600	37,650	37,700	37,740	37,790	36
38,680	38,730	38,780	38,830	38,880	38,930	38,980	39,030	39,080	39,130	39,180	37
40,050	40,100	40,150	40,200	40,250	40,310	40,360	40,410	40,460	40,510	40,560	38
41,880	41,930	41,980	42,040	42,090	42,150	42,200	42,250	42,310	42,360	42,420	39
43,700	43,760	43,820	43,870	43,930	43,990	44,040	44,100	44,160	44,210	44,270	40
45,530	45,590	45,650	45,710	45,770	45,830	45,890	45,950	46,010	46,060	46,120	41
48,750	48,820	48,880	48,950	49,010	49,080	49,140	49,200	49,270	49,330	49,400	42
51,980	52,050	52,120	52,190	52,250	52,320	52,390	52,460	52,530	52,600	52,670	43
55,200	55,270	55,350	55,420	55,500	55,570	55,650	55,720	55,790	55,870	55,940	44
58,130	58,210	58,290	58,360	58,440	58,520	58,600	58,680	58,760	58,840	58,920	45
61,050	61,140	61,220	61,310	61,390	61,470	61,560	61,640	61,730	61,810	61,890	46
63,980	64,070	64,160	64,250	64,340	64,430	64,510	64,600	64,690	64,780	64,870	47
66,200	66,290	66,390	66,480	66,570	66,670	66,760	66,850	66,940	67,040	67,130	48
68,420	68,520	68,610	68,710	68,810	68,910	69,000	69,100	69,200	69,290	69,390	49
70,640	70,740	70,840	70,940	71,050	71,150	71,250	71,350	71,450	71,550	71,650	50
72,970	73,080	73,190	73,290	73,400	73,510	73,610	73,720	73,830	73,930	74,040	51
75,310	75,420	75,530	75,640	75,760	75,870	75,980	76,090	76,200	76,310	76,420	52
77,640	77,760	77,880	77,990	78,110	78,230	78,340	78,460	78,570	78,690	78,800	53
79,950	80,070	80,200	80,320	80,440	80,560	80,680	80,800	80,920	81,040	81,160	54
82,260	82,390	82,510	82,640	82,770	82,890	83,020	83,140	83,270	83,390	83,520	55
84,570	84,700	84,830	84,960	85,100	85,230	85,360	85,490	85,620	85,750	85,880	56
86,990	87,130	87,270	87,400	87,540	87,680	87,810	87,950	88,090	88,220	88,360	57
89,420	89,560	89,700	89,850	89,990	90,130	90,270	90,410	90,560	90,700	90,840	58
91,840	91,990	92,140	92,290	92,430	92,580	92,730	92,880	93,030	93,170	93,320	59
93,970	94,130	94,280	94,440	94,590	94,740	94,900	95,050	95,200	95,360	95,510	60
96,100	96,270	96,430	96,590	96,740	96,900	97,060	97,220	97,380	97,540	97,700	61
98,240	98,400	98,570	98,730	98,900	99,060	99,230	99,390	99,560	99,720	99,890	62
104,300	104,600	104,800	105,100	105,300	105,600	105,800	106,100	106,200	106,300	106,400	63
110,400	110,800	111,100	111,400	111,700	112,100	112,400	112,700	112,900	112,900	112,900	64
116,500	116,900	117,300	117,800	118,200	118,600	119,000	119,400	119,500	119,400	119,400	65

See special instruction for preventing gate overflow on page 3.

TIMS FORD DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	898.0	898.1	898.2	898.3	898.4	898.5	898.6	898.7	898.8	898.9	899.0	899.1	899.2	899.3	899.4	899.5	899.6	899.7	899.8	899.9	900.0	
11																						11
12																						12
13																						13
14																						14
15																						15
16																						16
17																						17
18																						18
19																						19
20																						20
21																						21
22																						22
23	18,140	18,160	18,180	18,200	18,220	18,240	18,260	18,280														23
24	19,690	19,710	19,730	19,760	19,780	19,800	19,830	19,850														24
25	21,240	21,260	21,290	21,310	21,340	21,360	21,390	21,410														25
26	22,790	22,820	22,840	22,870	22,900	22,920	22,950	22,980	23,000	23,030	23,060	23,080	23,110	23,140	23,160	23,190	23,220					26
27	24,400	24,430	24,460	24,490	24,510	24,540	24,570	24,600	24,630	24,660	24,690	24,720	24,740	24,770	24,800	24,830	24,860					27
28	26,010	26,040	26,070	26,100	26,130	26,160	26,190	26,220	26,260	26,290	26,320	26,350	26,380	26,410	26,440	26,470	26,500					28
29	27,620	27,650	27,680	27,720	27,750	27,780	27,820	27,850	27,880	27,910	27,950	27,980	28,010	28,040	28,080	28,110	28,140	28,170	28,210	28,240	28,270	29
30	29,240	29,280	29,310	29,350	29,380	29,420	29,450	29,490	29,520	29,560	29,590	29,630	29,660	29,700	29,730	29,760	29,800	29,830	29,870	29,900	29,940	30
31	30,860	30,900	30,940	30,980	31,010	31,050	31,090	31,120	31,160	31,200	31,240	31,270	31,310	31,350	31,380	31,420	31,460	31,490	31,530	31,570	31,600	31
32	32,490	32,530	32,570	32,600	32,640	32,680	32,720	32,760	32,800	32,840	32,880	32,920	32,960	33,000	33,040	33,070	33,110	33,150	33,190	33,230	33,270	32
33	33,790	33,830	33,870	33,920	33,960	34,000	34,040	34,080	34,120	34,160	34,200	34,240	34,290	34,330	34,370	34,410	34,450	34,490	34,530	34,570	34,610	33
34	35,100	35,140	35,180	35,230	35,270	35,310	35,360	35,400	35,440	35,480	35,530	35,570	35,610	35,660	35,700	35,740	35,780	35,820	35,870	35,910	35,950	34
35	36,400	36,450	36,490	36,540	36,580	36,630	36,670	36,720	36,760	36,810	36,850	36,900	36,940	36,980	37,030	37,070	37,120	37,160	37,210	37,250	37,290	35
36	37,790	37,840	37,880	37,930	37,980	38,020	38,070	38,120	38,160	38,210	38,260	38,300	38,350	38,400	38,440	38,490	38,530	38,580	38,630	38,670	38,720	36
37	39,180	39,220	39,270	39,320	39,370	39,420	39,470	39,520	39,570	39,610	39,660	39,710	39,760	39,810	39,850	39,900	39,950	40,000	40,050	40,090	40,140	37
38	40,560	40,610	40,660	40,710	40,760	40,810	40,870	40,920	40,970	41,020	41,070	41,120	41,170	41,220	41,270	41,320	41,370	41,420	41,470	41,520	41,570	38
39	42,420	42,470	42,520	42,580	42,630	42,680	42,740	42,790	42,840	42,890	42,950	43,000	43,050	43,110	43,160	43,210	43,260	43,320	43,370	43,420	43,470	39
40	44,270	44,330	44,380	44,440	44,490	44,550	44,610	44,660	44,720	44,770	44,830	44,880	44,940	44,990	45,050	45,100	45,160	45,210	45,270	45,320	45,380	40
41	46,120	46,180	46,240	46,300	46,360	46,420	46,470	46,530	46,590	46,650	46,710	46,770	46,820	46,880	46,940	47,000	47,050	47,110	47,170	47,230	47,280	41
42	49,400	49,460	49,520	49,590	49,650	49,710	49,780	49,840	49,900	49,970	50,030	50,090	50,150	50,220	50,280	50,340	50,410	50,470	50,530	50,590	50,650	42
43	52,670	52,740	52,810	52,870	52,940	53,010	53,080	53,150	53,210	53,280	53,350	53,420	53,490	53,550	53,620	53,690	53,760	53,820	53,890	53,960	54,020	43
44	55,940	56,010	56,090	56,160	56,230	56,310	56,380	56,450	56,530	56,600	56,670	56,740	56,820	56,890	56,960	57,030	57,110	57,180	57,250	57,320	57,390	44
45	58,920	59,000	59,070	59,150	59,230	59,310	59,390	59,460	59,540	59,620	59,700	59,770	59,850	59,930	60,010	60,080	60,160	60,240	60,310	60,390	60,470	45
46	61,890	61,980	62,060	62,140	62,230	62,310	62,390	62,470	62,560	62,640	62,720	62,800	62,890	62,970	63,050	63,130	63,210	63,290	63,380	63,460	63,540	46
47	64,870	64,960	65,040	65,130	65,220	65,310	65,400	65,480	65,570	65,660	65,750	65,830	65,920	66,010	66,090	66,180	66,270	66,350	66,440	66,520	66,610	47
48	67,130	67,220	67,310	67,410	67,500	67,590	67,680	67,770	67,870	67,960	68,050	68,140	68,230	68,320	68,410	68,500	68,590	68,680	68,770	68,860	68,950	48
49	69,390	69,490	69,580	69,680	69,780	69,870	69,970	70,070	70,160	70,260	70,350	70,450	70,540	70,640	70,730	70,830	70,920	71,020	71,110	71,210	71,300	49
50	71,650	71,750	71,850	71,960	72,060	72,160	72,260	72,360	72,460	72,560	72,660	72,760	72,850	72,950	73,050	73,150	73,250	73,350	73,450	73,550	73,640	50
51	74,040	74,140	74,250	74,350	74,460	74,560	74,670	74,770	74,880	74,980	75,090	75,190	75,290	75,400	75,500	75,600	75,710	75,810	75,910	76,020	76,120	51
52	76,420	76,530	76,640	76,750	76,860	76,970	77,080	77,190	77,300	77,410	77,520	77,620	77,730	77,840	77,950	78,060	78,170	78,270	78,380	78,490	78,600	52
53	78,800	78,920	79,030	79,150	79,260	79,380	79,490	79,600	79,720	79,830	79,950	80,060	80,170	80,280	80,400	80,510	80,620	80,740	80,850	80,960	81,070	53
54	81,160	81,280	81,400	81,520	81,640	81,760	81,880	82,000	82,120	82,230	82,350	82,470	82,590	82,710	82,820	82,940	83,060	83,180	83,290	83,410	83,530	54
55	83,520	83,640	83,770	83,890	84,020	84,140	84,270	84,390	84,510	84,640	84,760	84,880	85,010	85,130	85,250	85,370	85,490	85,620	85,740	85,860	85,980	55
56	85,880	86,010	86,140	86,270	86,400	86,520	86,650	86,780	86,910	87,040	87,170	87,290	87,420	87,550	87,680	87,800	87,930	88,060	88,180	88,310	88,440	56
57	88,360	88,490	88,630	88,760	88,900	89,030	89,170	89,300	89,440	89,570	89,700	89,840	89,970	90,100	90,240	90,370	90,500	90,630	90,760	90,900	91,030	57
58	90,840	90,980	91,120	91,260	91,400	91,540	91,680	91,820	91,960	92,100	92,240	92,380	92,520	92,660	92,790	92,930	93,070	93,210	93,350	93,480	93,620	58
59	93,320	93,470	93,610	93,760	93,910	94,050	94,200	94,340	94,490	94,630	94,780	94,920	95,070	95,210	95,350	95,500	95,640	95,780	95,930	96,070	96,210	59
60	95,510	95,660	95,810	95,960	96,120	96,270	96,420	96,570	96,720	96,870	97,020	97,170	97,320	97,470	97,620	97,770	97,920	98,070	98,210	98,360	98,510	60
61	97,700	97,850	98,010	98,170	98,330	98,480	98,640	98,800	98,950	99,110	99,260	99,420	99,570	99,730	99,880	100,000	100,200	100,300	100,500	100,700	100,800	61
62	99,890	100,000	100,200	100,400	100,500	100,700	100,900	101,000	101,200	101,300	101,500	101,700	101,800	102,000	102,100	102,300	102,500	102,600	102,800	102,900	103,100	62
63	106,400	106,500	106,500	106,600	106,700	106,800	106,900	107,000	107,100	107,300	107,500	107,600	107,800	108,000	108,200	108,300	108,500	108,700	108,900	109,100	109,200	63
64	112,900	112,900	112,900	112,900	112,900	112,900	112,900	112,900	113,000	113,200	113,400	113,600	113,800	114,000	114,200	114,400	114,600	114,800	115,000	115,200	115,400	64
65	119,400	119,300	119,200	119,200	119,100	119,000	118,900	118,800	118,900	119,100	119,400	119,600	119,800	120,000	120,200	120,400	120,600	120,800	121,100	121,300	121,500	65

See special instruction for preventing gate overflow on page 3.

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PART 2

SLUICE DISCHARGE TABLE

MAY 2008

INSTRUCTIONS FOR USE OF TABLE

1. Table Update

These tables are identical to the tables dated March 2004 and supersede the tables dated January 1971. The revised discharges were generated using the computer code SPILLQ and are only slightly different from those in the 1971 tables.

2. Purpose of Table

These tables provide a means of setting up or determining the discharge through the 2-foot-by-2-foot sluice gate located in the powerhouse. They give the discharge in cubic feet per second through the sluice for various headwater elevations and gate opening positions.

The energy equation with empirical hydraulic friction and head loss coefficients was used to compute the tabulated discharges through the 36-inch sluice pipe and 2-foot-by-2-foot sluice gate. Discharge measurements in the Elk River below the dam in September 1971 verified that the calculated discharges are reasonable.

The 36-inch emergency gate valve in the intake tower should be left wide open at all times.

3. Arrangement of Table

The discharge table gives discharges in cubic feet per second for each 2 feet of headwater elevation between 850 feet and 900 feet at 25 percent, 50 percent, 75 percent, and 100 percent gate openings. Only the gate opening positions shown in the table should be used. Headwater elevations are shown at the top of each column. Gate opening positions are listed in the left column.

Discharges are recorded to the nearest 5 cubic feet per second for discharges less than 100 cubic feet per second and to the nearest 10 cubic feet per second for discharges greater than 100 cubic feet per second. Because the accuracy of the calculations does not warrant greater refinement, there should be no interpolation between values given in these tables.

4. Gate Opening Indicator

The gate opening indicator consists of a pointer and dial graduated for each 5 percent of gate opening. The pointer was set at zero gate opening position with the sluice gate seated against the metal sill on the floor of the sluice.

5. Use of Table

Discharges should be taken from the tables for the tabulated values nearest to those observed. For example, if the headwater elevation is 866.7 feet and the valve is set to 75 percent open, the discharge of 170 cubic feet per second is found in the row headed 865.

When the actual headwater elevation is exactly halfway between tabular values, the larger value should be used in determining the discharge.

TIMS FORD DAM

SLUICE DISCHARGE

IN CUBIC FEET PER SECOND

Sluice Opening percent	HEADWATER ELEVATION													
	850	852	854	856	858	860	862	864	866	868	870	872	874	876
25	55	55	55	55	55	60	60	60	60	60	60	60	60	60
50	100	100	110	110	110	110	110	110	110	110	110	120	120	120
75	140	150	150	150	150	150	150	160	160	160	160	160	160	160
100	210	210	210	220	220	220	220	220	230	230	230	230	230	230

Sluice Opening percent	HEADWATER ELEVATION													
	878	880	882	884	886	888	890	892	894	896	898	900		
25	65	65	65	65	65	65	65	65	65	65	70	70		
50	120	120	120	120	120	120	120	130	130	130	130	130		
75	170	170	170	170	170	170	170	180	180	180	180	180		
100	240	240	240	240	240	240	250	250	250	250	250	250		

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Attachment 7

L58 090529 80Q

Bellefonte Nuclear Units 3&4

Hydrology Project

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

Tennessee Valley Authority

Revision 0 - May 29, 2009

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

Issue

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

Background

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

Basis for the All Gates/Outlets Open

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

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

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

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

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

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

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

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

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

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

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

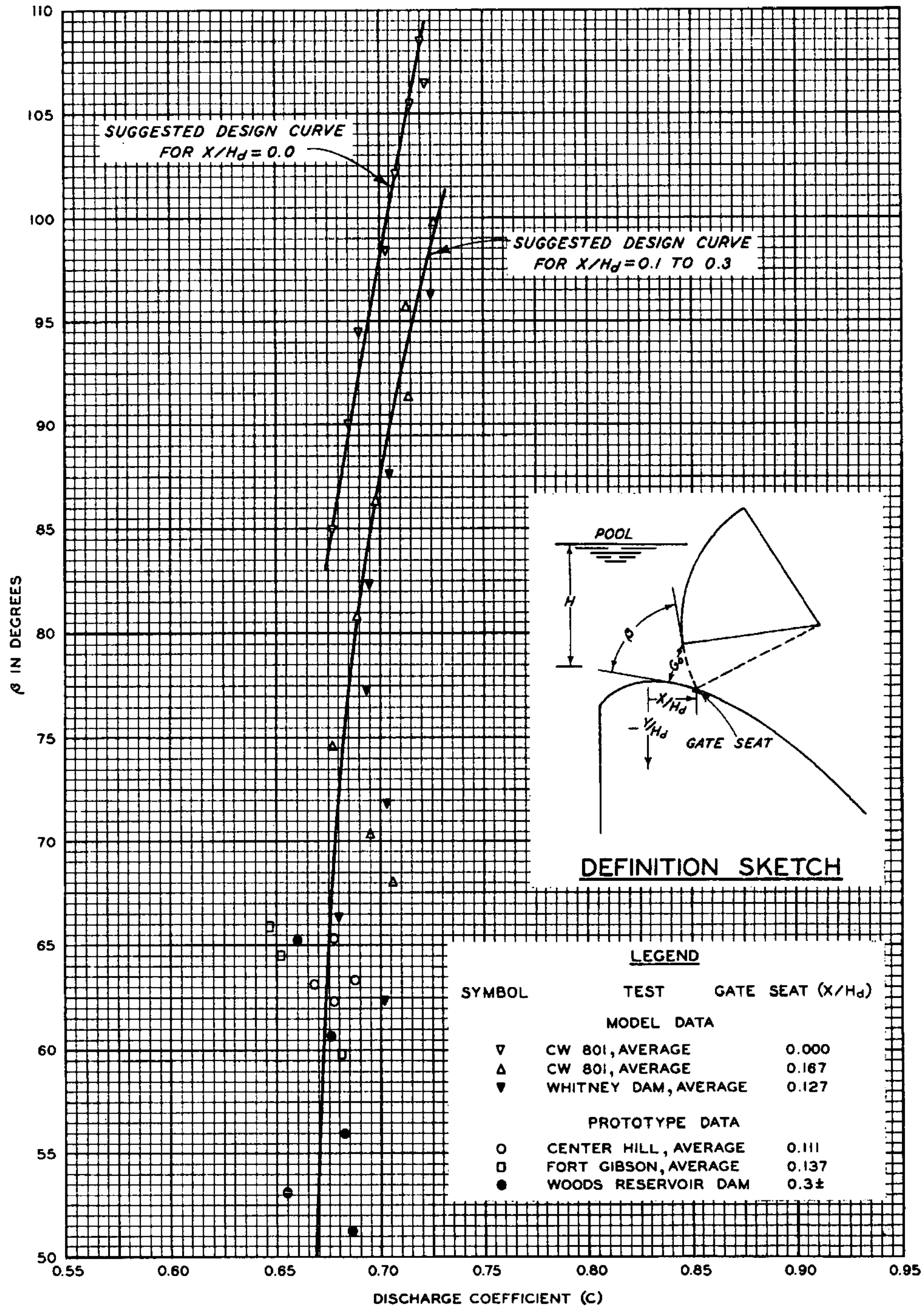
Conclusion

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

Prepared: Greg Lowe (signature) **Date:** 5/28/09

Concurrence: Charles L. Bach (signature) **Date:** 5/28/09

Approved: K. R. Spates (signature) **Date:** 5/29/09



FORMULA

$$Q = CG_oB\sqrt{2gH}$$

WHERE:

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

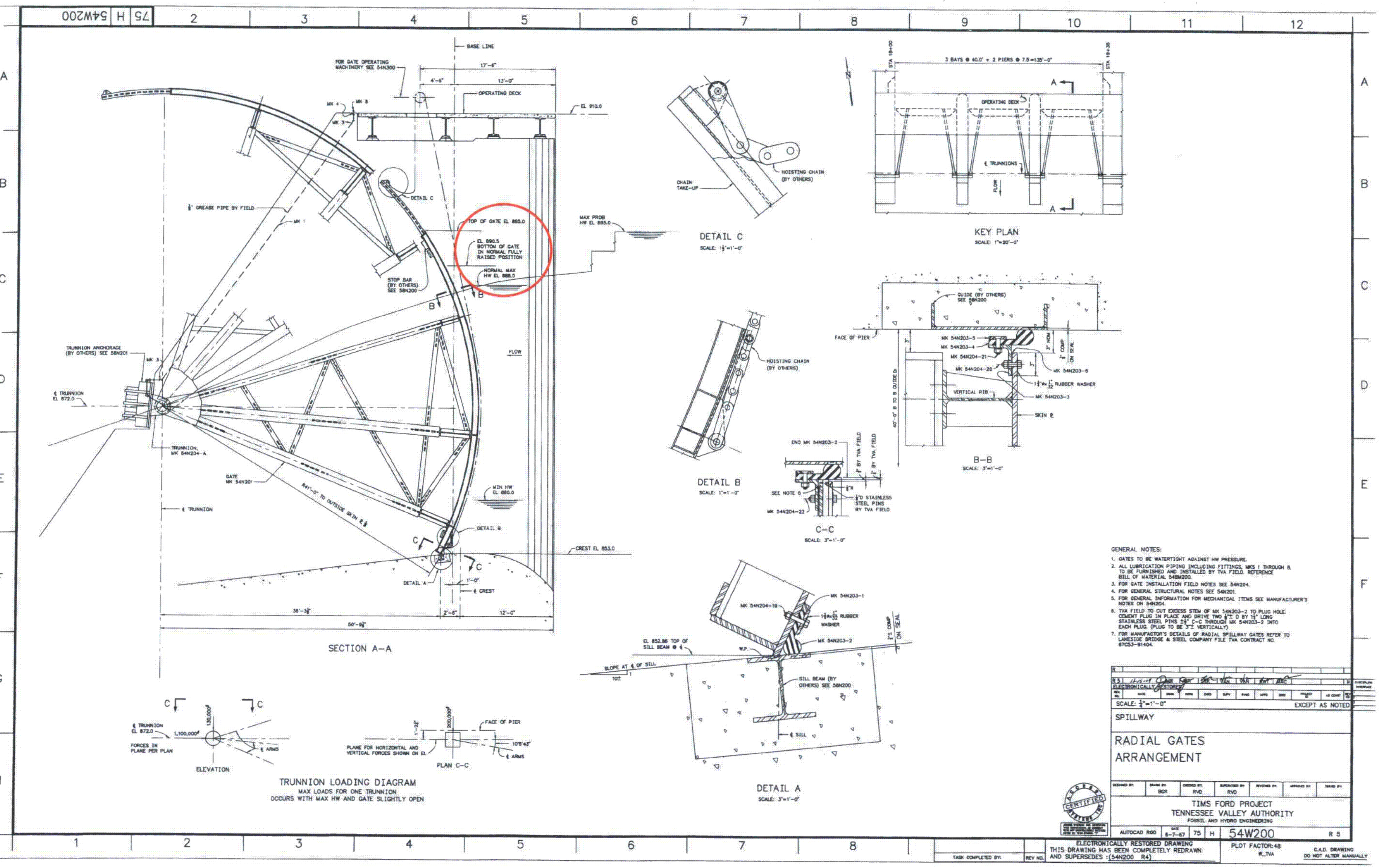
TAINTER GATES ON SPILLWAY CRESTS

DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 311-1

WES 3-56

Attachment A2



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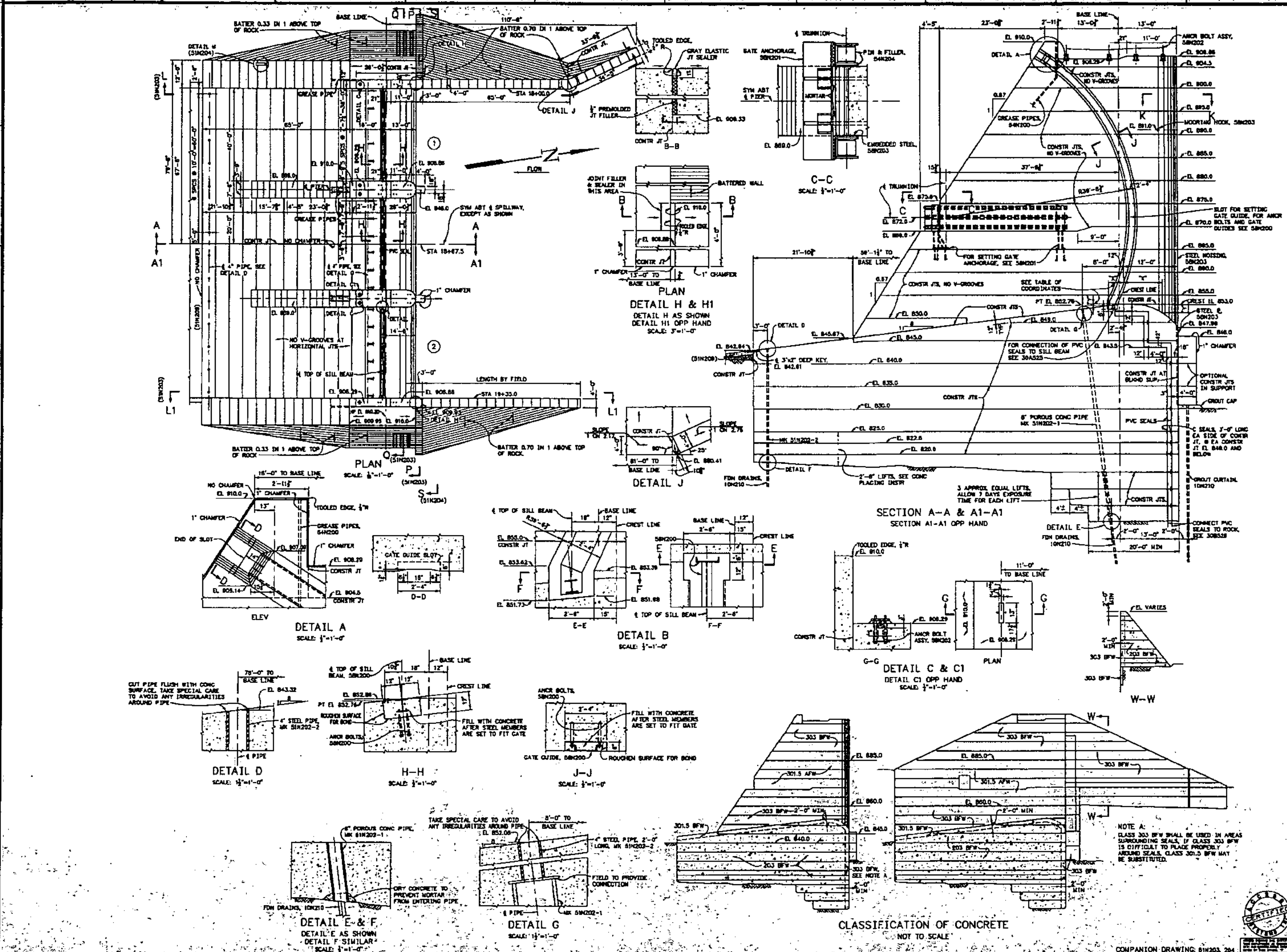
Attachment A3



COORDINATES OF WEIR PROFILE					
UPSTR OF CREST LINE			DNSTR OF CREST LINE		
Y = X²/343			Y = X^1.85/31.25		
X	Y	ELEV	X	Y	ELEV
*0.0'	0.0'	853.000	*0.0'	0.0'	853.000
2.0	0.023	852.977	#1.503	0.054	852.946
4.0	0.187	852.813	2.0	0.091	852.909
6.0	0.630	852.370	•2.60	0.136	852.864
8.0	1.493	851.507	♦3.391	0.235	852.765
10.0	2.915	850.085			
+12.0	5.038	847.962			

* CREST LINE
\+ UPSTREAM FACE
\# UPSTREAM EDGE OF SILL BEAM SLOT
• ℄ SILL BEAM
♦ PT

NOTE:
FOR NOTES AND REFERENCE DRAWING SEE 51N203.

CONCRETE PLACING INSTRUCTIONS:
THE TOP OF EACH MASS LIFT SHALL BE LEFT EXPOSED ACCORDING TO THE TABLE BELOW. MINIMUM EXPOSURE TIME FOR LIFTS NOT OTHERWISE NOTED SHALL BE 3 DAYS. MINIMUM EXPOSURE TIME FOR LIFTS IN PIERS AND END WALLS ABOVE WEIR MASS SHALL BE 3 DAYS.

		PLACING TEMPERATURES—DEGREES F											
		80–75		75–70		70–65		65–60		60–55		BELOW 55	
	LIFT	HT	EXP	HT	EXP	HT	EXP	HT	EXP	HT	EXP	HT	EXP
WEIR MASS	1	CONCRETE SHALL NOT BE PLACED WHEN PLACING TEMPERATURE EXCEEDS 70°				*5±	7	*5±	6	*5±	6	*5±	3
	2					2½	5	2½	4	5	5	5	3
	3					2½	4	2½	3	5	3		
	4					5	7	5	5				
	5					5	3	5	3				
UPSTREAM RETAINING WALLS	1	2½	7	2½	6	2½	6	2½	4	2½	3	2½	3
	2	2½	5	2½	4	2½	4	5	5	5	3	5	3
	3	5	7	5	6	5	4	5	3				
	4	5	3	5	3	5	3						

* FIRST LIFT ON SLOPING FDN BEDDING PLANE MAY VARY IN HEIGHT FROM 2 FEET TO 4 FEET MAXIMUM.

MAXIMUM HEIGHT OF LIFT IN FEET
MINIMUM EXPOSURE TIME IN DAYS

PLACING TEMPERATURE OF CONCRETE AND AMBIENT TEMPERATURE ASSUMED DURING EXPOSURE OF LIFT ARE ASSUMED TO BE THE SAME AS THE AVERAGE DAILY TEMPERATURE. IF THERE IS 10° F OR MORE DIFFERENCE BETWEEN PLACING TEMPERATURE AND AVERAGE DAILY AIR TEMPERATURES, CONTACT DIVISION OF ENGINEERING DESIGN FOR INSTRUCTIONS. IN CASE THE TOP OF A LIFT IS LEFT EXPOSED FOR 14 DAYS OR MORE, THE LIFT FOLLOWING SHALL BE CONSIDERED AS THE FIRST LIFT AND THE ABOVE PROCEDURE FOLLOWED.

R 3 ELECTRONICALLY RESTORED

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

SPILLWAY

CONCRETE
BLOCKS 1 & 2
OUTLINE – SHEET 1

RBR, ELT. | ELT. | ATO, RBR. | RBR, NCB.

TIMS FORD PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R00 | 6-15-99 | 75 | C | 51W202 | R 3

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES : (51N202 R2)

PLOT FACTOR:96
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

CDQ000020080022

HYDRAULIC DESIGN CRITERIA

SHEETS 111-1 to 111-2/1

OVERFLOW SPILLWAY CREST

1. Previous Crest Shapes. Some early crest shapes were based on a simple parabola designed to fit the trajectory of the falling nappe. Bazin's experiments of the 19th century were the basis of many early designs. The Bureau of Reclamation conducted extensive experiments on the shape of the nappe over a sharp-crested weir (reference 2). Numerous crests have been designed using the coordinates of the lower surface of the nappe for the shape of the crest, without resort to an equation. The Huntington District has used an equation involving the 1.82 power of X and the Nashville District has used the 1.88 power of X .

2. Standard Shape, Downstream Quadrant. A comparison of the Bureau of Reclamation data with those of other experimenters was made by the Office, Chief of Engineers. On the basis of this study, Circular Letter No. 3281 was issued on 2 September 1944, suggesting the use of the 1.85 power of X . This equation is given in Hydraulic Design Charts 111-1 and 111-2 and was adopted to define the downstream quadrant shape.

3. Point of Tangency. The slope function graph of the tangents X and Y to the downstream quadrant is shown in Chart 111-1 to facilitate the location of the point of tangency α . Although it is realized that the tangent point will often be determined analytically for the final design, this graph should be of value in the preliminary layouts in connection with stability analyses and cost estimates. The downstream tangent points can be computed from

$$\frac{X}{H_d} = 1.096 \left(\frac{1}{\alpha}\right)^{1.176} \qquad (1)$$

and

$$\frac{Y}{H_d} = 0.592 \left(\frac{1}{\alpha}\right)^{2.176} \qquad (2)$$

where H_d is the design head.

4. Standard Shape, Upstream Quadrant. The upstream quadrant shape of circular arcs originally defined in Chart 111-1, dated 4-1-52 (revised 8-60), resulted in a surface discontinuity at the vertical spillway face. A third, short-radius arc ($R = 0.04H_d$) incorporated in this design has been model tested (reference 1) and found to result in

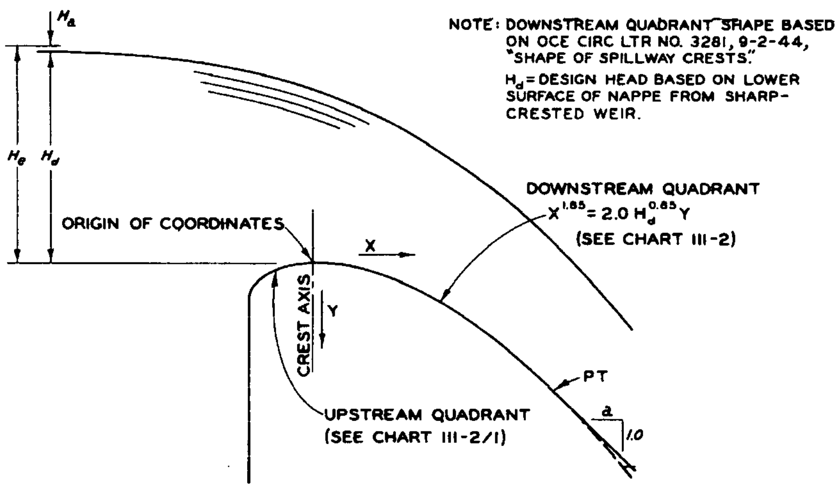
improved pressure conditions and discharge coefficients for heads exceeding the design head. Chart 111-2/1 (revised 9-70) presents this upstream crest quadrant design. A table of coordinates in terms of X/H_d and Y/H_d is included as Chart 111-2 for design convenience.

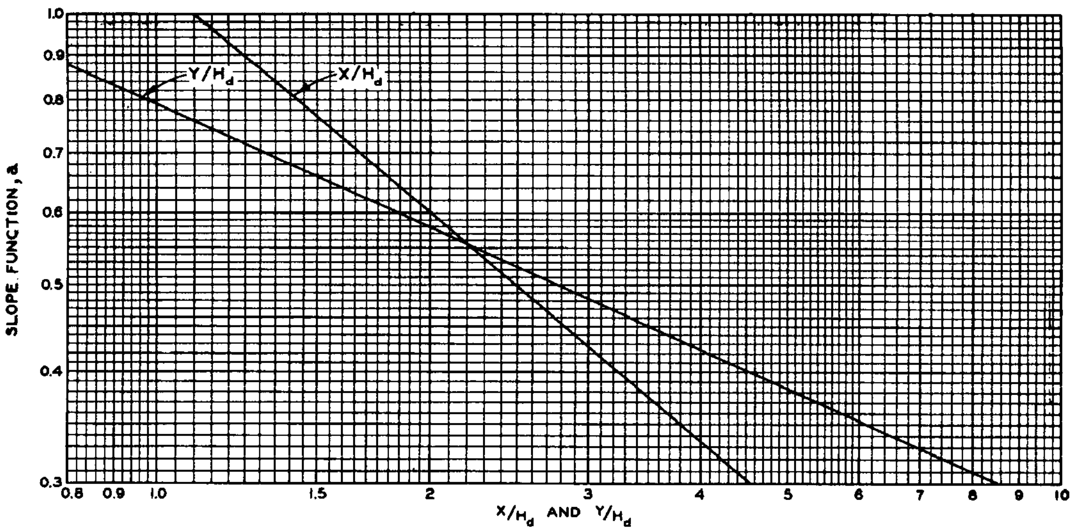
5. Recent model studies have verified the elliptical upstream quadrant design also presented in reference 1. This method, depicted in Hydraulic Design Charts 111-20 through 111-25/1, should be used for future spillway design. The Standard Shape Criteria will be retained for reference purposes.

6. References.

(1) U. S. Army Engineer Waterways Experiment Station, CE, Investigations of Various Shapes of the Upstream Quadrant of the Crest of a High Spillway; Hydraulic Laboratory Investigation, by E. S. Melsheimer and T. E. Murphy. Research Report H-70-1, Vicksburg, Miss., January 1970.

(2) U. S. Bureau of Reclamation, U. S. Department of the Interior, Boulder Canyon Project, Hydraulic Investigations; Studies of Crests for Overfall Dams. Part VI, Bulletin 3, Denver, Colo., 1948.





NOTE: COORDINATES OF TANGENT POINT FOR PRELIMINARY LAYOUTS AND ESTIMATES.

OVERFLOW SPILLWAY CREST
TANGENT ORDINATES

HYDRAULIC DESIGN CHART III-1

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI
REV 8-60
WES 4-1-52

X	$X^{1.85}$	X	$X^{1.85}$	H_d	$2H_d^{0.85}$	H_d	$2H_d^{0.85}$	H_d	$2H_d^{0.85}$
0.10	0.0141	6	27.515	1	2.000	26	31.896	51	56.554
.15	.0299	7	36.596	2	3.605	27	32.937	52	57.495
.20	.0509	8	46.851	3	5.088	28	33.971	53	58.434
.25	.0769	9	58.257	4	6.498	29	35.000	54	59.370
.30	.1078	10	70.795	5	7.855	30	36.024	55	60.303
.35	.1434	12	99.194	6	9.172	31	37.041	56	61.234
.40	.1836	14	131.928	7	10.460	32	38.054	57	62.162
.45	.2283	16	168.897	8	11.713	33	39.063	58	63.088
.50	.2774	18	210.017	9	12.946	34	40.066	59	64.011
.60	.3887	20	255.215	10	14.159	35	41.067	60	64.932
.70	.5169	25	385.646	11	15.354	36	42.062	61	65.851
.80	.6618	30	540.349	12	16.532	37	43.053	62	66.767
.90	.8229	35	718.664	13	17.696	38	44.040	63	67.681
1.00	1.000	40	920.049	14	18.847	39	45.023	64	68.594
1.20	1.401	45	1144.045	15	19.985	40	46.002	65	69.503
1.40	1.864	50	1390.255	16	21.112	41	46.978	66	70.411
1.60	2.386	55	1658.330	17	22.229	42	47.950	67	71.317
1.80	2.967	60	1947.959	18	23.335	43	48.919	68	72.221
2.00	3.605	65	2258.863	19	24.433	44	49.884	69	73.123
2.50	5.447	70	2590.785	20	25.521	45	50.846	70	74.022
3.00	7.633	75	2943.496	21	26.602	46	51.807	71	74.920
3.50	10.151	80	3316.779	22	27.674	47	52.761	72	75.816
4.00	12.996	90	4124.285	23	28.741	48	53.714	73	76.710
4.50	16.160	100	5011.872	24	29.799	49	54.663	74	77.603
5.00	19.638			25	30.852	50	55.610	75	78.493

OVERFLOW SPILLWAY CREST EQUATIONS

$$X^{1.85} = 2H_d^{0.85}Y, \quad Y = \frac{X^{1.85}}{2H_d^{0.85}}; \text{ WHERE } H_d = \text{DESIGN HEAD}$$

NOTE: SEE CHART 111-2/1 FOR UPSTREAM QUADRANT COORDINATES.

OVERFLOW SPILLWAY CREST

DOWNSTREAM QUADRANT

TABLE OF FUNCTIONS

HYDRAULIC DESIGN CHART 111-2

REV 8-60

WES 4-52

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

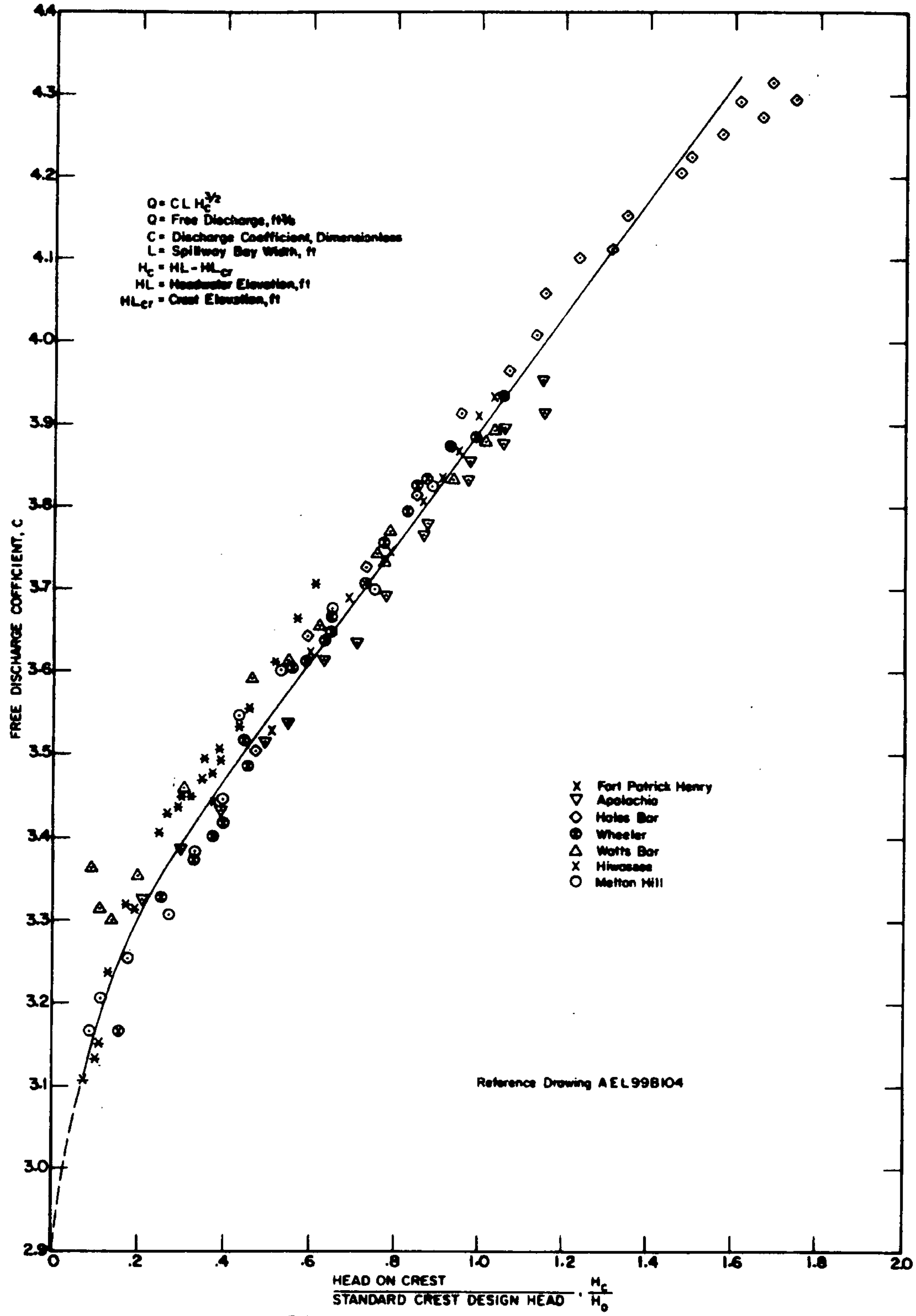


FIGURE A1: FREE DISCHARGE COEFFICIENTS

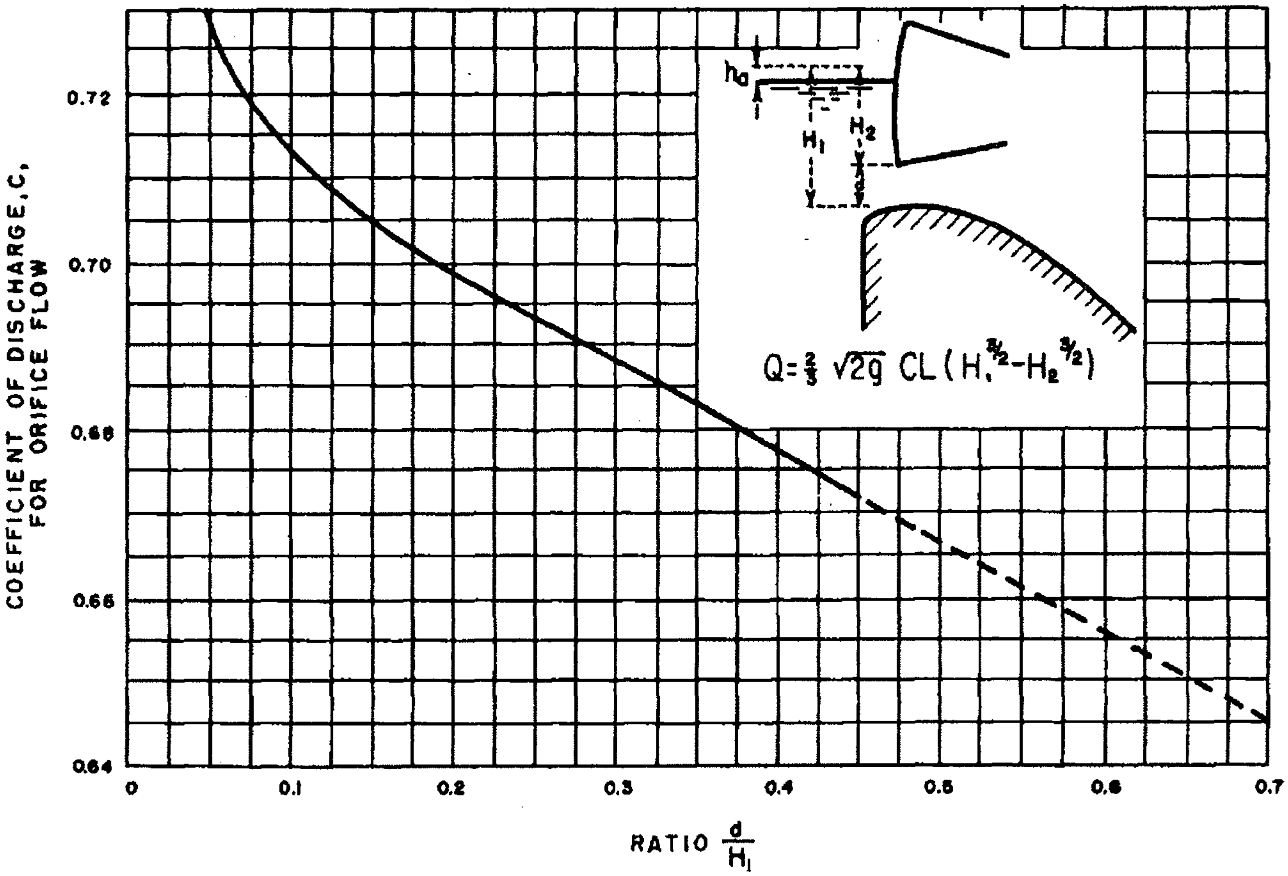


Figure 9-21. Coefficient of discharge for flow under a gate (orifice flow).–288-D-3045

procedures as for river outlets discussed in chapter X.

9-16. *Side Channel Control Structures.*–The side channel control structure consists of an ogee crest to control releases from the reservoir, and a channel immediately downstream of and parallel to the crest to carry the water to the discharge channel.

(a) *Layout.*–The ogee crest is designed by the methods in section 9-10 if the crest is uncontrolled or section 9-13 if it is controlled.

The cross-sectional shape of the side channel trough will be influenced by the overflow crest on the one side and by the bank conditions on the opposite side. Because of turbulences and vibrations inherent in side channel flow, a side channel design is ordinarily not considered except where a competent foundation such as rock exists. The channel sides will, therefore, usually be a concrete lining placed on a slope and anchored directly to the rock. A trapezoidal cross section is the one most often employed for the side channel trough. The width of such a channel in relation to the depth should be considered. If the width to depth ratio is large, the depth of flow in the channel will be shallow, similar to that depicted by the cross section *abfg* on figure 9-23. It is evident that for this condition a poor diffusion of the incoming flow with the channel flow will result. A cross section with a minimum width-depth ratio will provide the best hydraulic performance, indicating that a cross section approaching that depicted as *adj* on the figure would be the ideal choice both from the standpoint of hydraulics and economy. Minimum bottom widths are required, however, to avoid construction difficulties due to confined working space. Furthermore, the stability of the structure and the hillside which might be jeopardized by an extremely deep cut in the abutment must also

TVA 489 (REV-9 47)

CDQ000020080022

SHEET ____ OF ____

Attachment A7

COMPUTED BJC DATE 2-2-71

CHECKED ____ DATE ____

This data summary was taken from data book labled - "Tims Ford 1:100 Spillway Model"

TVA 489 (REV-9 47)

SHEET ____ OF ____

Tims Ford

COMPUTED ____ DATE ____

CHECKED JWE DATE 1-25-71

Gate Opening	HW El	Q
X · Trainees Work		
12	885.9	41,730
16	877.62	42090
16	892.4	59590
16	884.12	50 480
24	893.22	79 820
24	887.72	71 070
24	896.9	85 870
32	898.42	107 700
32	900.7	112 160
32	895.4	102660
32	902.02	114 880
24	898.3	87726
8	876.7	23040
8	894.62	32 450
5	881.72	16,600
5	897.32	21,110
20	894.02	70,200
20	891.72	68040
20	889.72	64,850
20	898.82	76 560
20	882.82	54,730
28	893.13	89,360
28	894.92	91 480
28	900.62	101 400
28	890.72	84,480
12	900.22	50,900
12	893.92	46,090
12	880.72	36 290
8	888.72	29 870
8	883.22	26,870
5	889.32	19,550
5	883.42	17,240
10	887.42	35,100
10	883.92	32590

TVA 489 (REV-9 47)

SHEET ______ OF ______

COMPUTED ______ DATE ______

CHECKED JWB DATE 1-25-71

Gate Opening	HW EL	Q
10	898.12	40,700
10	893.22	38000
Free	899.02	124,900
Free	898.42	122,300
Free	900.72	131,800
Free	901.12	134 000
Free	902.32	138,700
Free	894.5	107,100
Free	897.3	118,700
Free	894.72	107,300
Free	896.9	116,060
Free	896.4	114,400
~~Free~~ 10'	893.9	41,220

Average Gate Openings
ft above Crest

Tims Ford

(Field Measurements Summary)

COMPUTED BJC DATE 1-13-71
CHECKED JWB DATE 1-18-71

	Gate IND	Gate 1	Gate 2	Gate 3	AVG.	INDICATOR	EL. MID-POINT	
0.5	99.50	0.358	0.370	0.365	0.364	0.5	853.100	
1	99.00	0.915	0.930	0.933	0.926	1	853.425	
2	98.00	2.045	2.062	2.065	2.057	2	854.029	
3	97.00	3.185	3.205	3.202	3.197	3	854.599	
4	96.00	4.342	4.365	4.355	4.354	4	855.177	
5	95.00	5.520	5.540	5.520	5.527	5		
6	94.00	6.708	6.722	6.710	6.713	6	856.357	
7	93.00	7.910	7.925	7.910	7.915	7		
8	92.00	9.120	9.135	9.115	9.123	8		
9	91.00	10.338	10.350	10.342	10.343	9	858.172	
10	90.00	11.560	11.578	11.558	11.565	10		
12	88.00	14.030	14.040	14.020	14.030	12	860.015	
14	86.00	16.485	16.542	16.510	16.512	14	861.256	
16	84.00	19.025	19.040	19.000	19.022	16		
18	82.00	21.515	21.525	21.495	21.511	18		
20	80.00	23.608	24.010	23.970	23.863	20		
22	78.00	26.475	26.485	26.438	26.466	22	866.233	
24	76.00	28.905	28.900	28.870	28.891	24	867.445	
26	74.00	31.310	31.305	31.265	31.293	26		
28	72.00	33.702	33.710	33.660	33.691	28		
30	70.00	36.085	36.085	36.030	36.067	30	871.033	↑ setting 30 in Spillway Tables
	68.70	37.640	*	*		31.3		
(1)	69.11	37.145	37.150	37.090	37.128	30.89		
(2)	68.73	*	37.606	37.550	37.577	31.27		V_{avg} = 36.067 ft

(1) Limit switch setting (see following sheets); V_{avg} = 37.128 ft

(2) Overtravel switch setting (see following sheets), V_{avg} = 37.577 ft

SHEET ______ OF ______

GATE OPENING MEASUREMENTS

C GATE NO. 1 DATE 1-5-70

Tims Ford

COMPUTED KWK DATE ______

CHECKED BJC DATE 1-13-71

(1)

	GATE IND. READ	LINK NO.		LEFT SIDE TAPE READ FT.	LEFT SIDE CORR TAPE READ FT.	LEFT SIDE ZERO TAPE READ FT.	LEFT SIDE GATE OPEN FT.		RIGHT SIDE TAPE READ FT.	RIGHT SIDE CORR TAPE READ FT.	RIGHT SIDE ZERO TAPE READ FT.	RIGHT SIDE GATE OPEN FT.	
					+0.13	-0.10				+0.13	-0.10		
	99.50			0.320			0.350		0.335			0.365	0.358
	99.00			0.880			0.910		0.890			0.920	0.915
	98.00			2.010			2.040		2.020			2.050	2.045
	97.00			3.155			3.185		3.155			3.185	3.185
	96.00			4.310			4.340		4.315			4.345	4.342
	95.00			5.490			5.520		5.490			5.520	5.520
	94.00			6.675			6.705		6.680			6.710	6.708
	93.00			7.880			7.910		7.880			7.910	7.910
	92.00			9.090			9.120		9.090			9.120	9.120
	91.00			10.310			10.340		10.305			10.335	10.338
	90.00			11.530			11.560		11.530			11.560	11.560
	88.00			14.000			14.030		14.000			14.030	14.030
	86.00			16.455			16.485		16.455			16.485	16.485
	84.00			19.000			19.030		18.990			19.020	19.025
	82.00			21.490			21.520		21.480			21.510	21.515
	80.00			23.580			23.610		23.575			23.605	23.608
	78.00			26.450			26.480		26.440			26.470	26.475
	76.00			28.880			28.910		28.870			28.900	28.905
	74.00			31.280			31.310		31.280			31.310	31.310
	72.00			33.677			33.707 (700)		33.675			33.705	33.702
	70.00			36.050			36.080		36.060			36.090	36.085
(2)	68.70			37.610			37.640		37.615			37.640	37.640
(1)	69.11			37.110			37.140		37.120			37.150	37.145

(1) Normal limit switch set

2) Overtravel " " at 68.73

0.26 Normal Lower 4" slack chain

0.33 Overtravel 6" " "

SHEET ______ OF ______

GATE OPENING MEASUREMENTS — Tims Ford

B GATE NO. 2 DATE 1-6-72

COMPUTED KW J.C. JC DATE ______

(2) CHECKED BJC DATE 1-15-71

	GATE IND. READ	LINK NO.		LEFT SIDE TAPE READ FT.	CORR TAPE READ FT.	ZERO TAPE READ FT.	GATE OPEN FT.		RIGHT SIDE TAPE READ FT.	CORR TAPE READ FT.	ZERO TAPE READ FT.	GATE OPEN FT.	AVE
					+0.13	-0.10				+0.13	-0.10		
	99.50			0.350			0.380		0.330			0.360	0.370
	99.00			0.910			0.940		0.890			0.920	0.930
	98.00			2.040			2.070		2.025			2.055	2.062
	97.00			3.180			3.210		3.170			3.200	3.205
	96.00			4.340			4.370		4.330			4.360	4.365
	95.00			5.510			5.540		5.510			5.540	5.540
	94.00			6.690			6.720		6.695			6.725	6.722
	93.00			7.890			7.920		7.900			7.930	7.925
	92.00			9.100			9.130		9.110			9.140	9.135
	91.00			10.310			10.340		10.330			10.360	10.350
	90.00			11.540			11.570		11.555			11.585	11.578
	88.00			14.000			14.030		14.020			14.050	14.040
	86.00			16.500			16.530		16.525			16.555	16.542
	84.00			19.000			19.030		19.020			19.050	19.025 (40)
	82.00			21.480			21.510		21.510			21.540	21.525
	80.00			23.960			23.990		24.000			24.030	24.010
	78.00			26.440			26.470		26.470			26.500	26.485
	76.00			28.850			28.880		28.890			28.920	28.895 (902)
	74.00			31.260			31.290		31.290			31.320	31.305
	72.00			33.660			33.690		33.700			33.730	33.710
	70.00			36.040			36.070		(R) 36.070			36.100	36.085
(1)	69.11			37.110			37.140		37.130			37.160	37.150
(2)	68.73			37.560			37.590		37.590			37.620	37.605

(1) Normal limit switch set

(2) Over travel " "

Wind blowing tape

SHEET ____ OF ____

GATE OPENING MEASUREMENTS Tims Ford

A GATE NO. 3 DATE 1-7-70

Kenneth Kirkpatric

Joe Clift

COMPUTED KWK DATE ____

CHECKED BJC DATE 1-13-71

					LEFT SIDE					RIGHT SIDE			
	GATE				CORR	ZERO				CORR	ZERO		
	IND.	LINK		TAPE	TAPE	TAPE	GATE		TAPE	TAPE	TAPE	GATE	
	READ	NO.		READ	READ	READ	OPEN		READ	READ	READ	OPEN	
				FT.	FT.	FT.	FT.		FT.	FT.	FT.	FT.	Ave
					+0.13	-0.10				+0.13	-0.10		
✓ 0.50	99.50	0.5		0.340			0.370		0.330			0.360	0.365
✓ 1.00	99.00			0.910			0.940		0.895			0.925	0.933
✓ 2.00	98.00			2.040			2.070		2.030			2.060	2.065
✓ 3.00	97.00			3.175			3.205		3.170			3.200	3.202
✓ 4.00	96.00			4.330			4.360		4.320			4.350	4.355
✓ 5.00	95.00			5.490			5.520		5.490			5.520	5.520
✓ 6.00	94.00			6.680			6.710		6.680			6.710	6.710
✓ 7.00	93.00			7.880			7.910		7.880			7.910	7.910
✓ 8.00	92.00			9.080			9.110		9.090			9.120	9.115
✓ 9.00	91.00			10.310			10.340		10.315			10.345	10.342
✓ 10.00	90.00			11.530			11.560		11.525			11.555	11.558
✓ 12.00	88.00			13.980			14.010		14.000			14.030	14.020
✓ 14.00	86.00			16.470			16.500		16.490			16.520	16.510
✓ 16.00	84.00			18.960			18.990		18.980			19.010	19.000
✓ 18.00	82.00			21.450			21.480		21.480			21.510	21.495
✓ 20.00	80.00			23.930			23.960		23.950			23.980	23.970
✓ 22.00	78.00			26.400			26.430		26.415			26.445	26.438
✓ 24.00	76.00			28.830			28.860		28.850			28.880	28.870
26.00	74.00			31.220			31.250		31.250			31.280	31.265
28.00	72.00			33.610			33.640		33.650			33.680	33.660
30.00	70.00			35.990			36.020		36.010			36.040	36.030
(1)	69.11			37.050			37.080		37.070			37.100	37.090
(2)	68.73			37.510			37.540		37.530			37.560	37.550
	(1)	Normal limit switch set											
	(2)	Overtravel " "											

Attachment A9

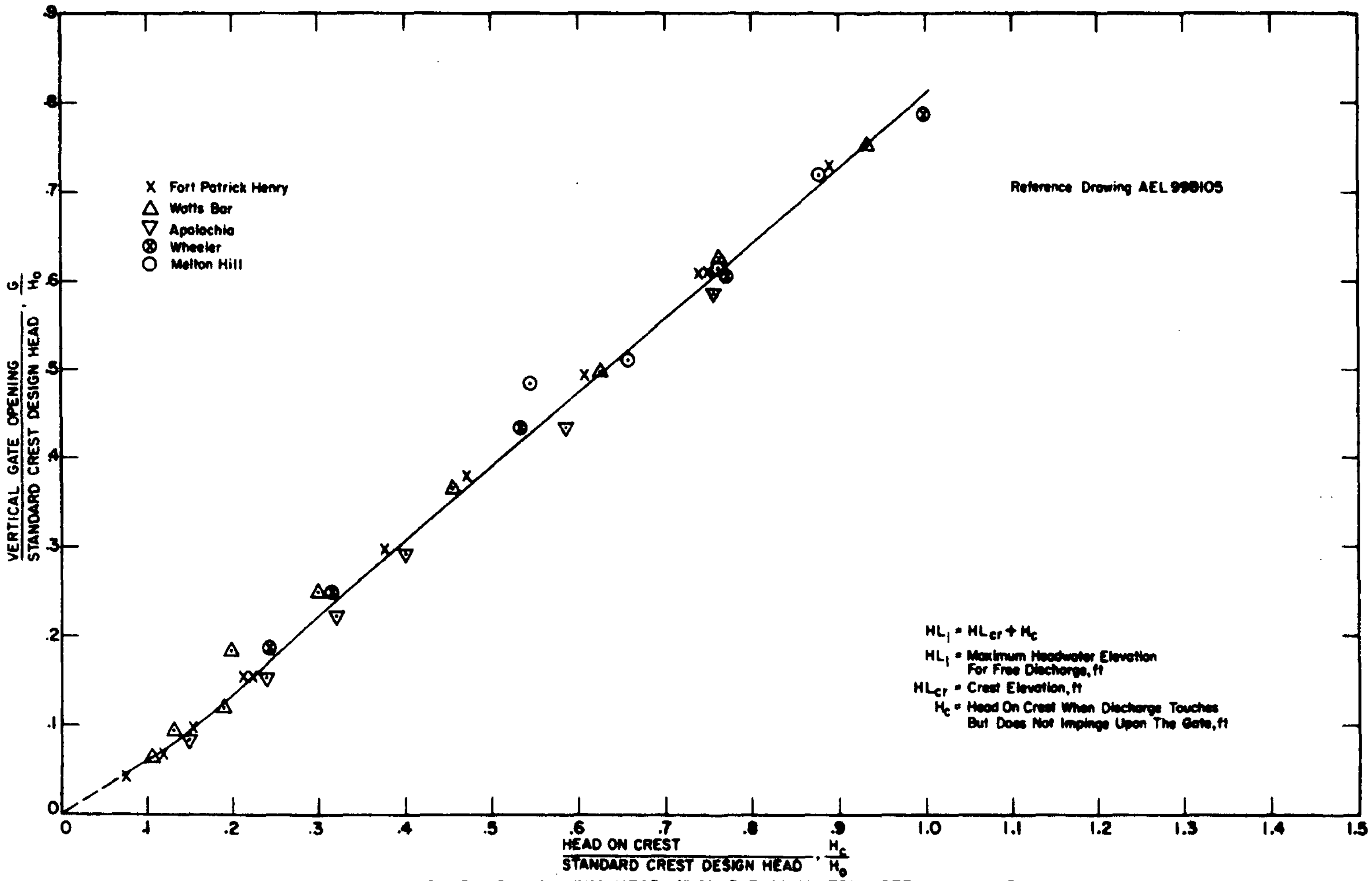


FIGURE A2: MAXIMUM HEADWATER ELEVATION FOR FREE DISCHARGE

CDQ000020080022

TVA Tims Ford Model Data and C_f/H_c Relationship

October 2009

BWSC | Barge Waggoner Sumner & Cannon, Inc.

Since the Tims Ford Dam configuration is not standard, the most reasonable data source for use in defining the spillway free discharge C_f/H_c relationship is the historic TVA model data, if available. Model data was collected for Tims Ford Dam but was not formally documented by TVA following the original model study. This informal model data and the resulting C_f/H_c relationship has been maintained in River Operations files. Dr. Gerald Schohl, a former TVA expert in dam model studies, reviewed the informal files and provided the appropriate information to BWSC in the attached Excel spreadsheet (Attachment 1).

Under the "Free Discharge" tab of the spreadsheet, the historic model data is tabulated and shown graphically. Since the model data is clustered in the 37 to 50 feet range, development of the C_f/H_c characteristic curve required additional data to construct a technically defendable relationship over the H_c=0 to 50 foot range. As noted in the spreadsheet, the theoretical C_f coefficient for a broad-crested weir is 3.087 (see Attachment 2). Using the model data and the USACE anchoring coefficient for H_c=0, the historic polynomial for the C_f/H_c relationship was developed.

It is noted that the C_f at H_c=0 in the historic polynomial is 3.0665 (as opposed to the 3.087 USACE coefficient). The historic polynomial results from a "best fit" of the model data and the anchoring USACE coefficient. Based on a review of the model data provided and the USACE data, the historic polynomial provided is considered technically acceptable and representative of the true flow coefficient value over the H_c range from 0 to 50 feet.

Attachments:

Attachment 1 – Tims Ford Model.xls (spreadsheet provided by TVA River Operations)

Attachment 2 – USACE Hydraulic Design Criteria Sheet 111-3

HYDRAULIC DESIGN CRITERIA

SHEET 111-3

SPILLWAY CREST

DISCHARGE COEFFICIENT

HIGH OVERFLOW DAMS

1. General. Discharge over an uncontrolled spillway crest is computed using the equation

$$Q = CLH_e^{3/2}$$

where

Q = total discharge, cfs

C = discharge coefficient (Hydraulic Design Chart 111-3)

L = effective crest length, ft (Hydraulic Design Sheet 111-3/1)

H_e = energy head on crest, ft

2. Design Criteria. Early studies of the discharge coefficient C used the relation of C to the ratio H_e/H_d. These studies indicated that C ranged from 3.90 to 4.10 at design head and decreased to 3.10 at zero head. An approximation of the upper value can be derived by transferring the sharp-crested weir coefficient to a rounded weir crest that fits the lower nappe. The head on the rounded crest is known to be 0.888 times the head on the sharp crest. Using a discharge coefficient of 3.33 for a sharp-crested weir and assuming the velocity of the approach flow to be negligible, the coefficient for design head is derived as 3.93. The lower limit of $C = 3.10$ closely approximates the theoretical broad-crested weir coefficient of 3.087. The theory, which is based on critical depth in rectangular channels, is given by King.[1] Friction can be expected to reduce the coefficient at low heads. New, smooth concrete crests should have a high coefficient at low heads compared to crests that have been roughened by weathering or other causes.

3. Test Data. The curve in Chart 111-3 is based primarily on data obtained from model tests conducted under Corps of Engineers Engineering Studies Item 801, General Spillway Investigation, at the U. S. Army Engineer Waterways Experiment Station (WES). Only those tests in which a deep approach channel and negligible velocity of approach existed were used in developing the curve. The plotted points from ES 801 are the basis for the curve above the H_e/H_d ratio of 0.4. Prototype test results are plotted for the low head range, and that portion of the curve is based on

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

Paper No. 2677 Vol. 119, 1954

RATING CURVES FOR FLOW OVER DRUM GATES

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

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

Synopsis

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

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

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

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

Introduction

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

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

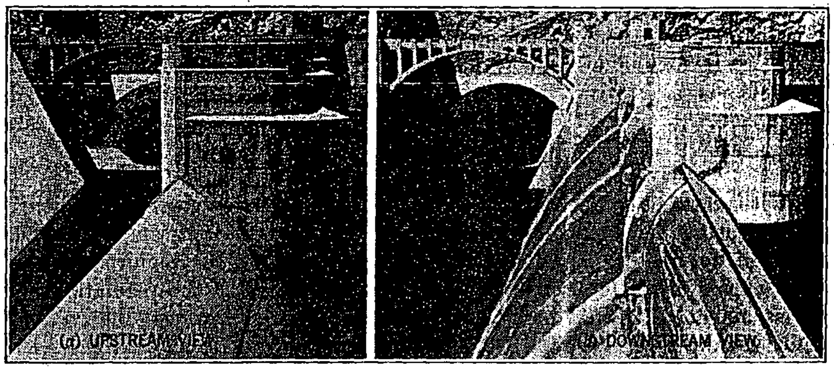


FIG. 1.—DRUM GATE, 100 FT BY 16 FT, AT HOOVER DAM (ARIZONA-NEVADA)

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

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

[2] "Discha[illegible]oefficients for Irregular Overfall Spillway Sections," by J. N. Bradley, *Engineering Monograph N*[illegible]*Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo., March, 1952.

sec-ft, is questionable. Measurement of the flow over the drum gates, which is now possible, would have afforded a continuous record and one that would be as accurate for floods as for normal flows.

Characteristics of the Drum Gate

As a measuring device, the drum gate resembles a sharp-crested weir with a curved upstream face over the greater part of its travel. With an adequate positioning indicator, the drum gate can serve as a very satisfactory metering device.

When the drum gate simulates a sharp-crested weir—that is, when a line drawn tangent to the downstream lip of the gate makes a positive angle with the horizontal, as in Fig. 2(*a*), four principal factors are involved. These factors are H, the total head above the high point of the gate; θ, the angle made by a line drawn tangent to the downstream lip of the gate and the horizontal; r, the radius of the gate or an equivalent radius, should the curvature of the

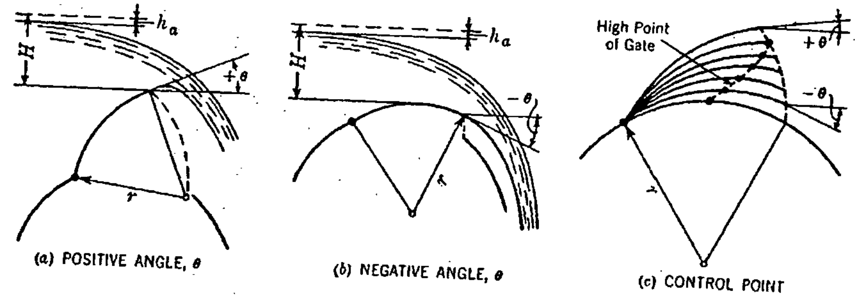


FIG. 2.—DRUM-GATE POSITIONS

gate involve a parabola; and C_q, the coefficient of discharge in $Q = C_q L H^{3/2}$, 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

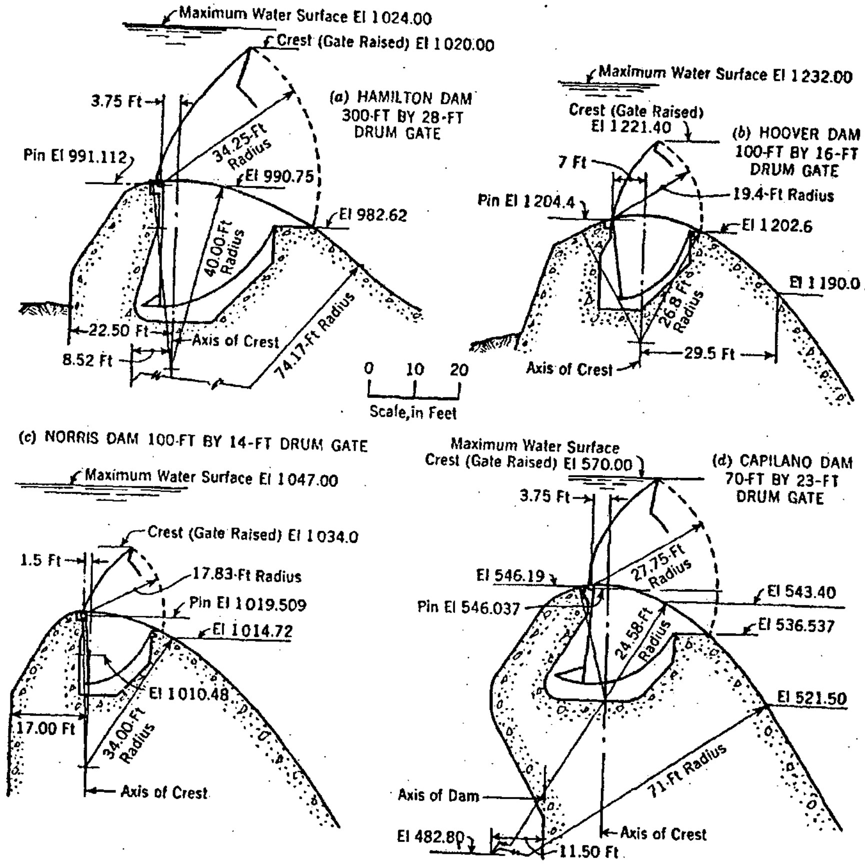


Fig. 3.—Examples of Drum-Gate Cross Sections

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	3.610
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	3.800		
574	3.550	1040	3.845	5	3.980		
572	3.500	1035	3.815				
570	3.400	1030	3.745				
Gate Elevation 572.0		Gate Elevation 1030.0					
580	3.725	1055	3.890				
578	3.720	1050	3.890				
576	3.680	1045	3.885				
574	3.620	1040	3.880				
		1035	3.875				
Gate Elevation 573.0		Gate Elevation 1032.0					
580	3.760	1055	3.870				
578	3.760	1050	3.875				
576	3.765	1045	3.880				
575	3.780	1040	3.895				
574	3.900	1035	3.920				
Gate Elevation 575.0		Gate Elevation 1034.0					
580	3.780	1055	3.815				
578	3.790	1050	3.835				
577	3.840	1045	3.855				
576	3.950	1040	3.885				
		1036	3.945				

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

TABLE 2.[a]—(*Continued*)

Hoover Dam (Arizona-Nevada) Shape 4-M3		Hoover Dam (Arizona-Nevada) Shape 8-M5		Hoover Dam (Arizona-Nevada) Shape 7-C4	
Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4	
26	3.670	28	3.735	26	3.665
22	3.605	25	3.705	22	3.615
18	3.540	20	3.650	18	3.540
14	3.472	15	3.565	14	3.450
10	3.405	10	3.460	10	3.360
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	3.050
14	3.615	16	3.492	15	3.580
11	3.585	12	3.428	11	3.508
8	3.555	8	3.330	7	3.415
Gate Elevation 1213.4		Gate Elevation 1213.4		Gate Elevation 1213.0	
20	3.880	20	3.765	19	3.800
17	3.875	16	3.765	16	3.845
14	3.876	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.

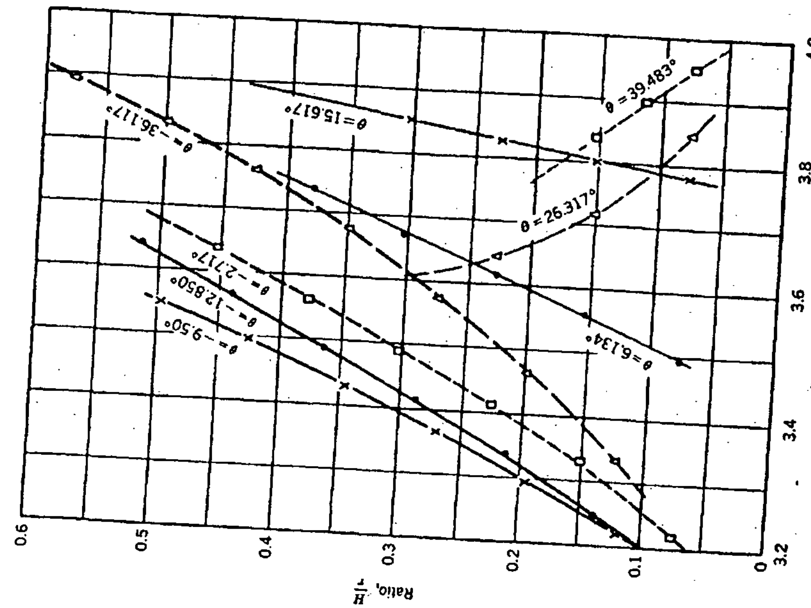


Fig. 5.—Dimensionless Plotting of Data from Model of Shasta Dam Drum Gate

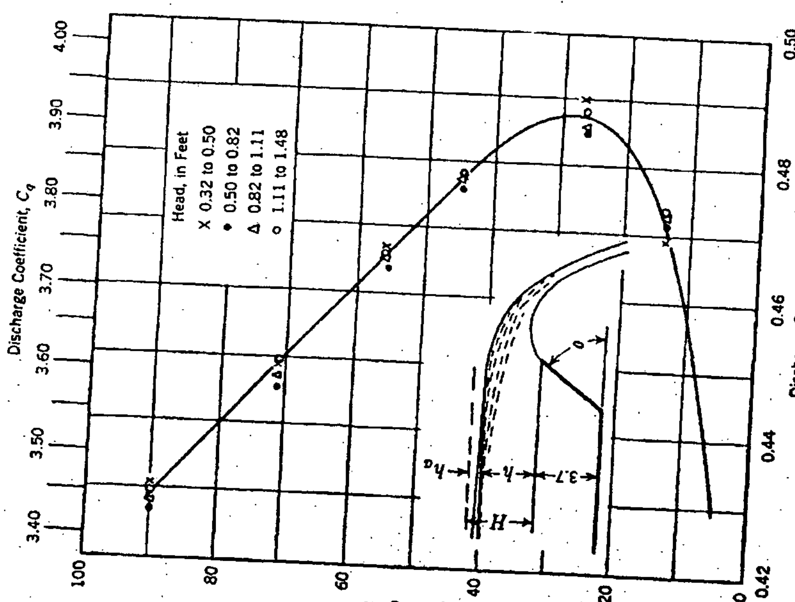


Fig. 4.—Results of Bazin's Experiments on Sloping Weirs

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

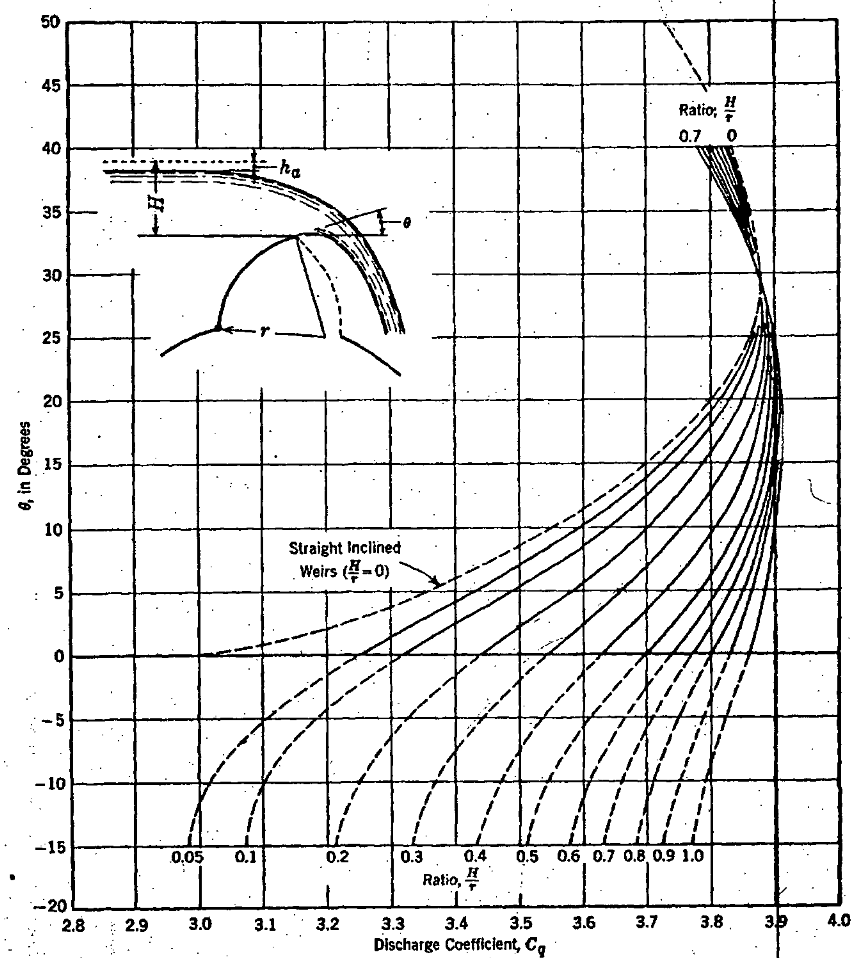


FIG. 6.—GENERAL CURVES FOR THE DETERMINATION OF DISCHARGE COEFFICIENTS

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_e and C_e are the designed head and the coefficient for the designed head, respectively. This chart was reproduced from a previous publication[2] and represents a curve well supported by tests of some fifty overfall spillway crests having wide variation in shape and operating conditions.

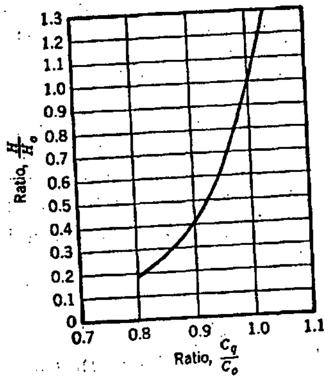


FIG. 7.—COEFFICIENTS OF DISCHARGE FOR OTHER THAN THE DESIGNED HEAD

APPLICATION OF RESULTS

From the plan and section of the Black Canyon Diversion Dam (Idaho), shown in Figs. 8 and 9, assume that it becomes necessary to compute and construct a rating curve for one drum gate for each 0.5 ft of gate elevation. The scale on the gate position indicator is calibrated to show the elevation of the high point of the gate, and the gate has a constant radius of 21.0 ft. The gate is 64 ft long. The coefficient of discharge for the free crest is $C_o = 3.48$ for the designed head (H_o) of 14.5 ft.

With the coefficient of discharge known for free flow at the designed head, the entire free-flow coefficient curve can be established by consulting Fig. 7. The free-flow coefficient curve for Black Canyon Dam spillway (for which $H_o = 14.5$ ft 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.

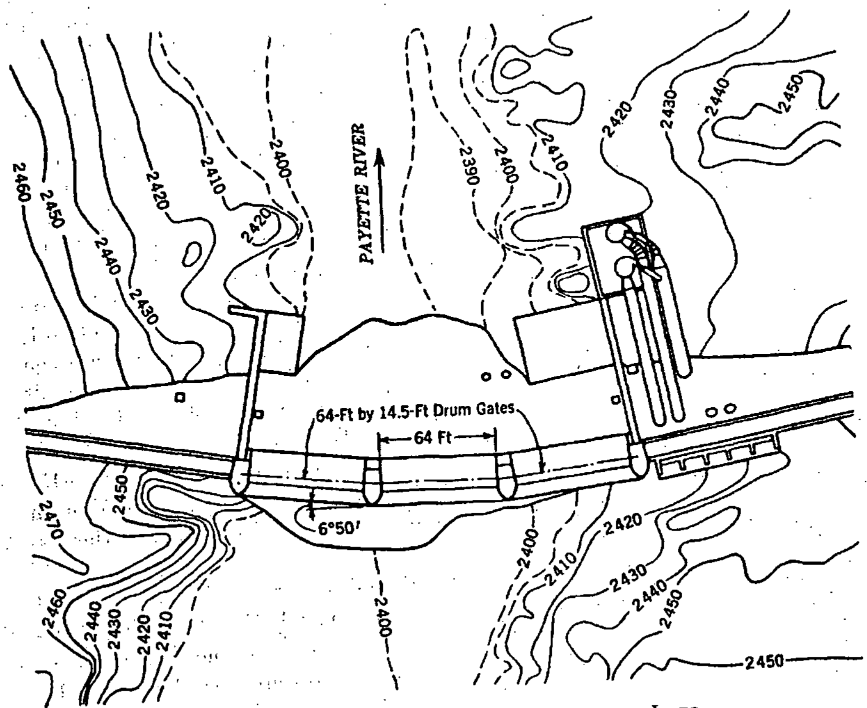


FIG. 8.—PLAN OF BLACK CANYON DIVERSION DAM IN IDAHO

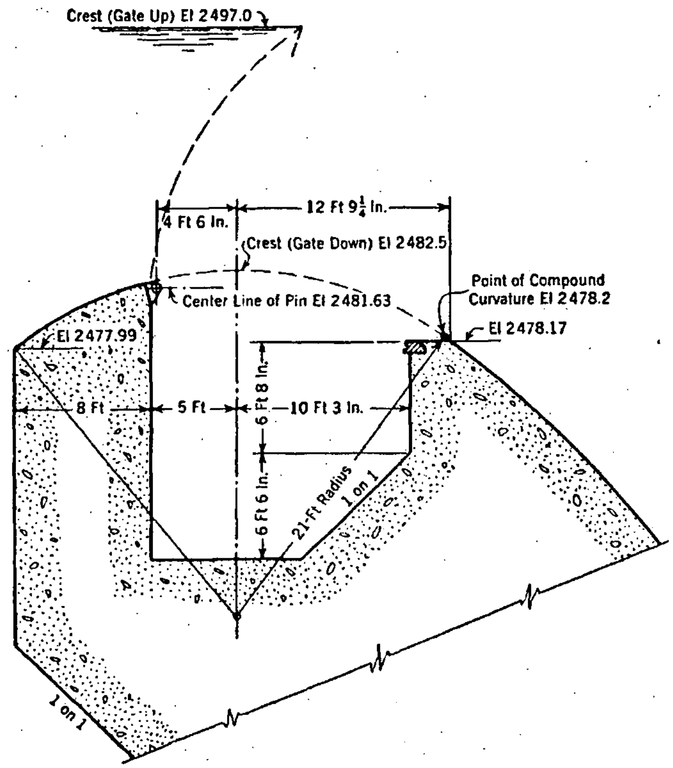


FIG. 9.—SPILLWAY CREST DETAIL, BLACK CANYON DAM IN IDAHO

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	1,614
3	2485.5	0.207	0.815	2.835	943
2	2484.5	0.138	0.760	2.042	478

[a] $H_o = 14.5$ ft. [b] $C_o = 3.48$. [c] The discharge for one gate: $Q = C_q L H^{3/2}$, in which $L = 64.0$ ft.

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

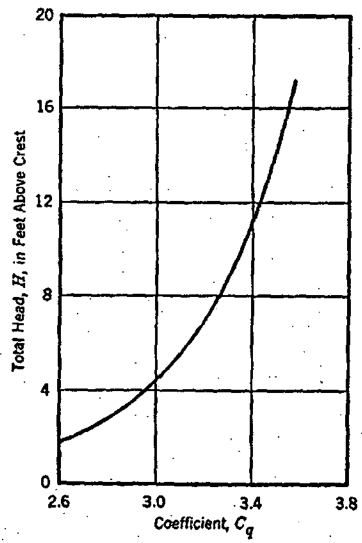


FIG. 10.—HEAD-COEFFICIENT CURVE, BLACK CANYON DAM, IN IDAHO

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

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

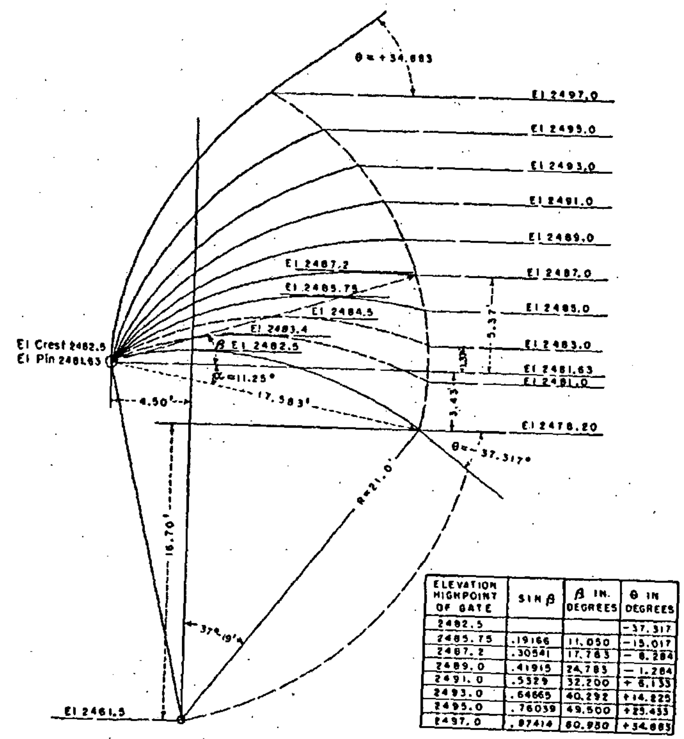
As the angle θ is given negative values, the procedure for determining the discharge remains the same for angles between 0 and −15°, except that the head on the gate is measured above the high point rather than above the lip. Discharge computations for negative angles of the gate down to −15.017° are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

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

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

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

for various constant values of the discharge as shown in Fig. 13. Fortunately, the result is a straight-line variation for any constant value of discharge. The lines in Fig. 13 are not quite parallel and there is no assurance that they will be straight for every drum gate. Nevertheless, this will not detract appreciably from the accuracy obtained. Interpolated information from Fig. 13 is then utilized to construct the additional curves in Fig. 12. If all curves are considered, Fig. 12 shows the completed rating for the Black Canyon Dam spillway for 0.5-ft gate intervals. For intermediate values, straight-line interpolation is permissible.



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

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

CONCLUSIONS

This paper has demonstrated how an existing control structure, such as the Black Canyon Dam spillway, can also serve as a rating station. The accuracy of rating curves obtained by the method is estimated to approach that of an average current-meter traverse of the river providing that (1) the gate position indicators are made as large as possible and are accurately calibrated, (2) the reservoir gage can be read to within 0.05 ft, (3) nearly atmospheric pressure exists under the sheet of water after it springs from the gate, and (4) all gates are set at approximately the same elevation.

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

Set (1)	Reservoir elevation, in ft (2)	H, in ft[a] (3)	Ratio, $\frac{H}{r}$ (4)	Coefficients, C_q (5)	$H^{3/2}$, in ft (6)	Q, in cu ft per sec[b] (7)
Gate Elevation 2497.0; $\theta = +34.88°$						
A	2498.0	1	0.048	3.86	1	247
	2499.0	2	0.095	3.86	2.828	699
	2500.0	3	0.143	3.86	5.196	1.283
Gate Elevation 2495.0; $\theta = +23.43°$						
B	2496.0	1	0.048	3.85	1	246
	2497.0	2	0.095	3.86	2.828	698
	2498.0	3	0.143	3.87	5.196	1,284
	2499.0	4	0.190	3.87	8.00	1,979
	2500.0	5	0.238	3.88	11.18	2,770
Gate Elevation 2493.0; $\theta = +14.22°$						
C	2494.0	1	0.048	3.69	1	236
	2495.0	2	0.095	3.73	2.828	675
	2496.0	3	0.143	3.75	5.196	1,247
	2498.0	5	0.238	3.80	11.18	2,719
	2500.0	7	0.333	3.84	18.52	4,552
Gate Elevation 2491.0; $\theta = +6.13°$						
D	2492.0	1	0.048	3.47	1	222
	2493.0	2	0.095	3.51	2.828	635
	2494.0	3	0.143	3.57	5.196	1,187
	2496.0	5	0.235	3.63	11.18	2,597
	2498.0	7	0.333	3.70	18.52	4,386
	2500.0	9	0.429	3.77	27.00	6,515
Gate Elevation 2489.0; $\theta = -1.28°$						
E	2490.0	1	0.048	3.21	1	205
	2491.0	2	0.095	3.28	2.828	594
	2492.0	3	0.143	3.34	5.196	1,111
	2494.0	5	0.238	3.45	11.18	2,469
	2496.0	7	0.333	3.545	18.52	4,202
	2498.0	9	0.429	3.63	27.00	6.273
	2500.0	11	0.524	3.695	36.48	8.627
Gate Elevation 2487.2; $\theta = -8.28°$						
F	2488.0	0.8	0.038	3.02	0.716	138
	2489.0	1.8	0.086	3.10	2.415	470
	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: $Q = C_q L H^{3/2}$.

In connection with provision (3), the blunt piers on the Black Canyon Dam spillway, Figs. 8 and 9, provide effective aeration under the overfalling sheet of water for all but very small heads with gate completely raised. In the case of provision (4), uniform operation of the gates is also most desirable from the standpoint of stilling basin operation for minimum erosion downstream.

Discharge measurements on the prototype are desirable whenever possible as a check on the accuracy of the foregoing method. Sufficient observations should be taken, however, to establish the fact that the prototype information is consistent and reliable.

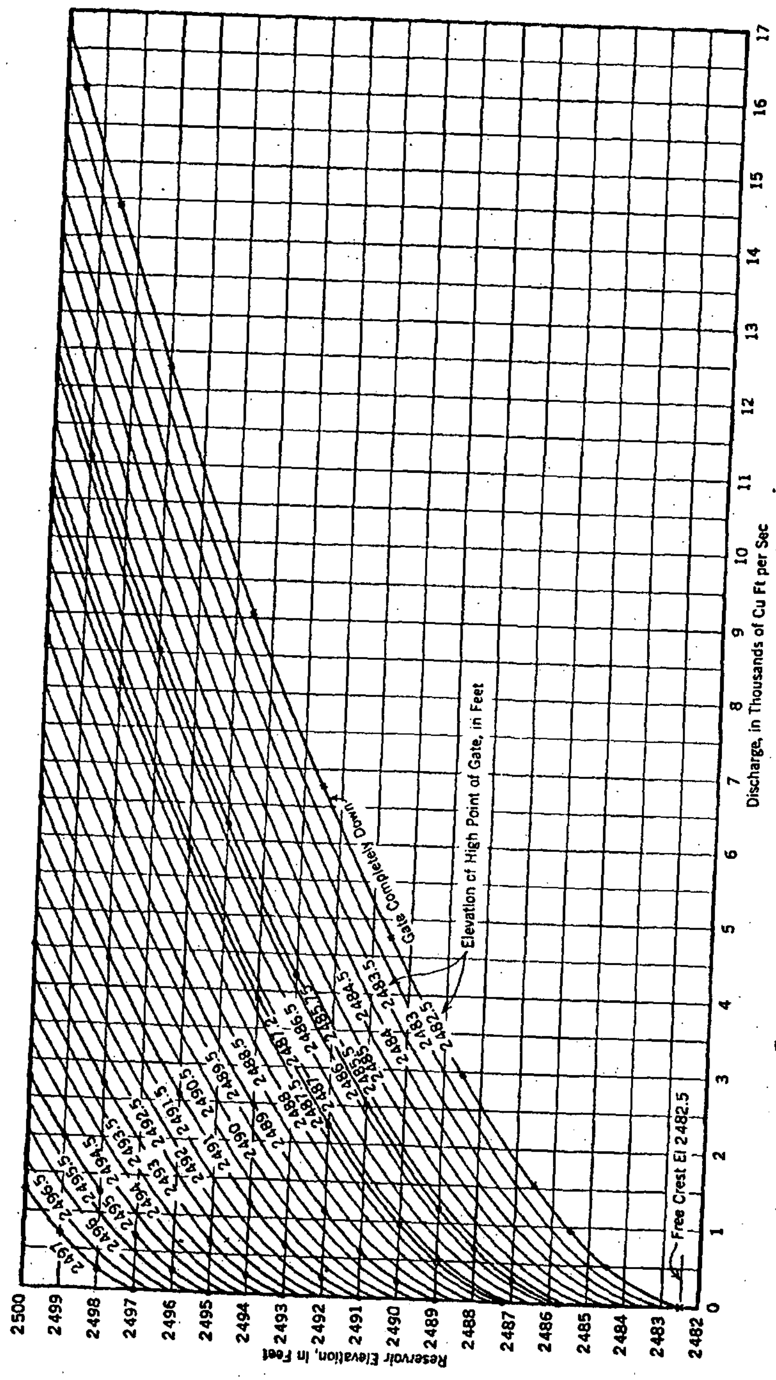


FIG. 12.—RATING CURVES FOR BLACK CANYON DAM DRUM-GATE SPILLWAY IN IDAHO

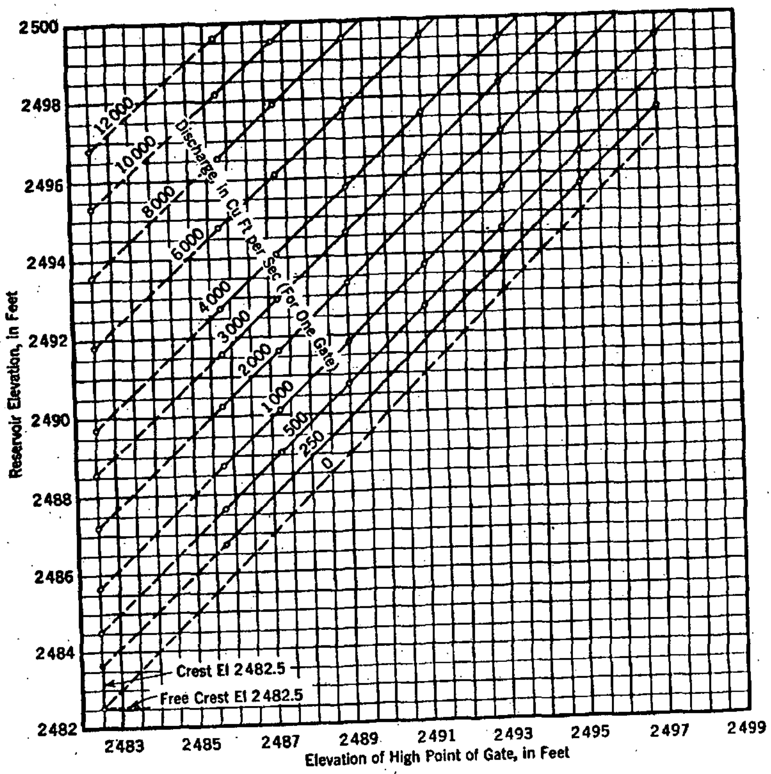


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

ACKNOWLEDGMENTS

The writer wishes to thank C. E. Blee, M. ASCE, chief engineer of the Tennessee Valley Authority for the use of the data on the Norris Dam Spillway; Hal Birkeland, M. ASCE, of the International Engineering Corporation, for obtaining permission to include the Bhakra and Capilano Dam spillways in the paper; and the chief engineer of the Panama Canal for use of the data on the Madden Dam spillway. The writer is also grateful to the Bureau of Reclamation for the use of the remainder of the experimental information. He also wishes to thank his engineering associates, H. M. Martin, M. ASCE, D. J. Hebert, and A. J. Peterka, A. M. ASCE, for their most helpful comments and suggestions.

DISCUSSION

GUIDO WYSS[6].—The information presented by Mr. Bradley is of utmost value for determining the quantities of discharge over drum gates under various heads for any gate position. This information will permit operators in the field to adjust the gate position from corresponding chart values in such a manner as to obtain the desired flow. The use of drum gates as an actual metering device for spillway quantity discharges is unique and the results obtained are more practicable and reliable than those obtained by stream gaging, especially when this gaging is conducted during periods of high floods.

It would have been interesting if the author had presented an investigation of the flow, profiles of the upper and lower nappe surfaces, as well as the actual water pressures on the upstream plate of the drum gate by use of charts. This would afford an opportunity to obtain the true loading conditions on the gate during the cycle of operation from fully-raised gate to fully-lowered gate. This information would be important in the determination of the buoyancy and loading criteria of the gate structure.

SAM SHULITS,[7] M. ASCE.—An outstanding contribution to the design and operation of drum gates has been presented in this report of the author's work at the USBR. The paper and its complement[2] fill a great need.

Since 1928, when the Freeman Scholarships were established, there has been a tremendous development of hydraulic model research in the laboratories of the United States. Although these laboratories are unexcelled in size and quality, many hydraulic engineers have pondered the procession of models (spillways, stilling pools, and river reaches) in the period from 1928 to 1953 with few, if any, summaries or proposals for design to reduce the dependence on models. In Mr. Bradley's work there is strong evidence that the laboratories will produce correlations and syntheses—not more models.

When it is realized that many of the most famous and productive laboratories in the United States did not exist prior to 1928, the lack of correlation and synthesis for general use is understandable. The hope is that other works of similar quality will be added to engineering literature.

BOB BUEHLER,[8] A. M. ASCE.—An interesting and clever use of data has resulted in a method by which records of gate settings at dams can be made a substitute for missing stream-flow records and can be used to augment existing records. The construction of a dam and reservoir often floods an established stream gage. Unless the gage is replaced below the dam or upstream from the reservoir, subsequent stream flow usually is not accurately known. Sometimes a series of dams (each causing the water to back up to the dam above) prevents continuing established gages at the strategic points where they had been

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located. The less accurate—and more costly—slope stations are not completely satisfactory alternatives to the single-line rating stations.

If the spillway of a dam can be rated with an accuracy comparable to the accuracy obtainable with a gage (as demonstrated by Mr. Bradley for certain spillway types), and if allowance is made for flow through other water outlets such as turbines, locks, and sluices, the structure is then superior in some respects to the gage. For example, the rating of the dam should be permanent, whereas the rating of a gage usually requires frequent checking.

Mr. Bradley's method for rating drum gates not only allows records for ordinary stream flow to be supplemented, but also probably gives a more accurate determination of extreme flood rates than do most gages. He has made an important contribution to the planning and design of drum-gated structures.

The author has presented a method for rating a spillway at all heads provided the coefficient for one appreciable head is known. He also states that a coefficient for the designed head can be estimated for most spillways by a method previously published.[3] 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 $C_s = 3.48$. [c] C_s would be 3.466 for this discharge.

and H_D represents the design head in feet. The design head is that head which produces a standard lower nappe that agrees closely with the spillway profile.

[9] "Flow over Rounded Crests," by R. N. Brudenell, *Engineering News-Record*, July 18, 1935, p. 95.

Eq. 1 was intended to be used with heads greater than $H_D/4$, although the equation has been found to agree closely with model data for somewhat lower heads. Without knowing any coefficients, Eq. 1 gives discharges that agree closely with those obtained by Mr. Bradley for Black Canyon Dam. In the case of Black Canyon Dam, Mr. Bradley used one known coefficient and the curve of Fig. 7. Free-flow discharges computed by the two methods are shown in Cols. 2 and 3, Table 5. The procedure by which Eq. 1 was applied will be described subsequently.

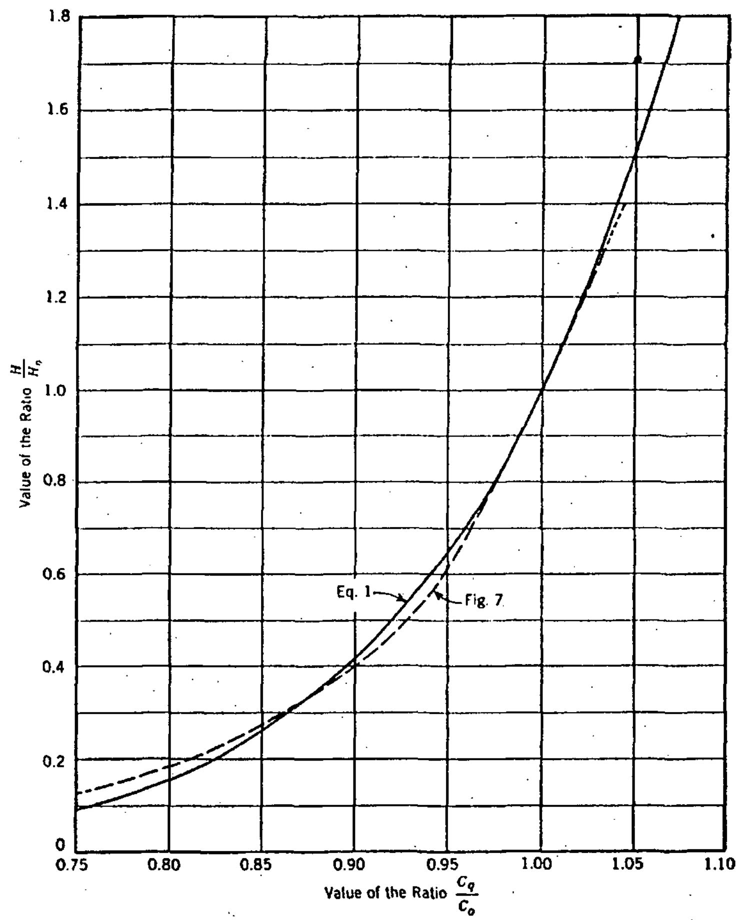

FIG. 14.—COMPARISON OF VALUES OBTAINED FROM FIG. 7 AND EQ. 1

It is assumed that in choosing Black Canyon Dam for his example, the author knew that his method would yield discharges close to known values. The good agreement for all except the low heads shows that, in this example, Eq. 1 (using only the shape of the spillway) also produces suitable results.

This good agreement suggests, too, that there must be a close relationship between the curve in Fig. 7 and a similar curve that can be derived from Eq. 1. To examine the relationship, theoretical discharge coefficients were computed by using

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

and Eq. 1, from which

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

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

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

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

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

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

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

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

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

TABLE 6.—COMPARISON OF FREE-FLOW SPILLWAY COEFFICIENTS

Total head, in feet	Coefficient obtained from model test	USING EQ. 1		USING FIG. 7		USING FIG. 14	
		C_q	Difference, in percent	C_q	Difference, in percent	C_q	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GRAND COULEE DAM (WASHINGTON)							
35	3.920			3.914	− 0.15	3.902	−0.46
30	3.842			3.831	− 0.29	3.827	−0.39
25	3.745			3.745[a]	0	3.745[a]	0
20	3.635			3.655	+ 0.55	3.651	+0.44
15	3.510			3.550	+ 1.14	3.524	+0.40
10	3.352			3.370	+ 0.54	3.356	+0.12
5	3.220			3.138	− 2.54	3.168	−1.62
BHAKRA DAM (INDIA)							
28	3.680			3.736	+ 1.52	3.732	+1.41
23	3.645			3.645[a]	0	3.645[a]	0
18	3.550			3.547	− 0.08	3.543	−0.20
13	3.420			3.434	+ 0.41	3.404	−0.47
8	3.275			3.215	− 1.83	3.208	−2.04
3	3.120			2.748	−11.92	2.854	−8.53
SHASTA DAM (CALIFORNIA)							
38	3.895			3.910	+ 0.39	3.899	+0.10
33	3.835			3.839	+ 0.10	3.831	−0.10
28	3.760			3.760[a]	0	3.760[a]	0
23	3.675			3.677	+ 0.05	3.674	−0.03
18	3.575			3.591	+ 0.45	3.568	−0.20
13	3.465			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	3.716	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.635	+1.54	3.580[a]	0	3.580[a]	0
20	3.500	3.539	+1.11	3.494	− 0.17	3.490	−0.29
15	3.400	3.420	+0.59	3.394	− 0.18	3.369	−0.91
10	3.290	3.258	−0.97	3.222	− 2.07	3.208	−2.50
5	3.160	2.997	−5.16	3.000	− 5.06	3.029	−4.14
FRIANT DAM (CALIFORNIA)							
20	3.650			3.717	+ 1.84	3.706	+1.53
17	3.625			3.639	+ 0.39	3.632	+0.19
14	3.550			3.550[a]	0	3.550[a]	0
11	3.460			3.458	− 0.06	3.452	−0.23
8	3.340			3.348	+ 0.24	3.319	−0.63
5	3.175			3.142	− 1.04	3.131	−1.38
2	2.965			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—(*Continued*)

Total head, in feet (1)	Coefficient obtained from model test (2)	Using Eq. 1: C_e (3)	Using Eq. 1: Difference, in percent (4)	Using Fig. 7: C_e (5)	Using Fig. 7: Difference, in percent (6)	Using Fig. 14: C_e (7)	Using Fig. 14: Difference, in percent (8)
NORRIS DAM (TENNESSEE) H_D = 35 FT							
35	3.915	3.969	+1.38	3.934	+ 0.49	3.923	+0.20
30	3.845	3.897	+1.35	3.852	+ 0.18	3.848	+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	3.006	−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.

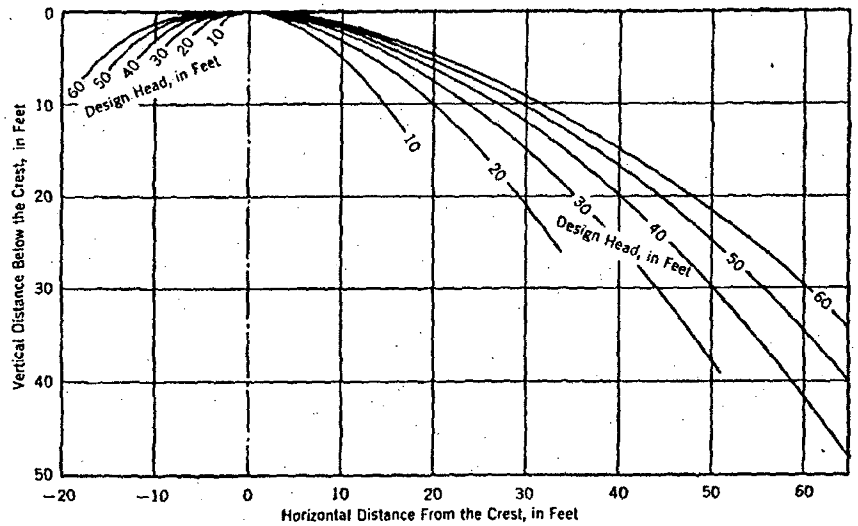

FIG. 15.—STANDARD SPILLWAY SHAPES

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

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

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

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

TABLE 7.—COORDINATES OF A STANDARD SPILLWAY CREST

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

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

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

So far as is known, the application of standard nappe shapes (for which discharge coefficients are known) to actual spillways on a basis of reasonable best fit was first suggested by W. M. Borlund.[11] Mr. Borlund used a curve of observed C_e-value plotted against H/H_e. In 1942, C. E. Kindsvater, M. ASCE, suggested a similar procedure in which the curve of C_e versus H/H_e was derived from Eq. 1. Mr. Kindsvater's work (not published) should give results comparable to those obtained herein.

The material presented is regarded as an excellent check on that part of Mr. Bradley's work which relates to free discharge over an ogee spillway.

F. B. CAMPBELL,[12] M. ASCE, AND A. A. MCCOOL,[13] J. M. ASCE.—The experimental data on discharge coefficients for flow over drum gates are a welcome addition to the published information on flow over spillways, or the observation and recording of the flow of streams. A paper by Robert E. Horton has been a guide for the estimation of flows over spillways since its publication.[14] The basic information for the discharge over curved crests which fit the under side of a nappe from a sharp-crested weir can be deduced from investigations made by Bazin,[15,16] although the published record of these experiments has not been generally available to engineers in the United States. The investigations conducted by the USBR (proposed by E. W. Lane, M. ASCE) embraced and extended the scope of Bazin's work which is often used as the basis for overflow spillway shapes.[3] Although good estimates for discharge over free-overflow crests can be accomplished rather simply, the problem becomes complicated when flow through partly opened crest gates is involved.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

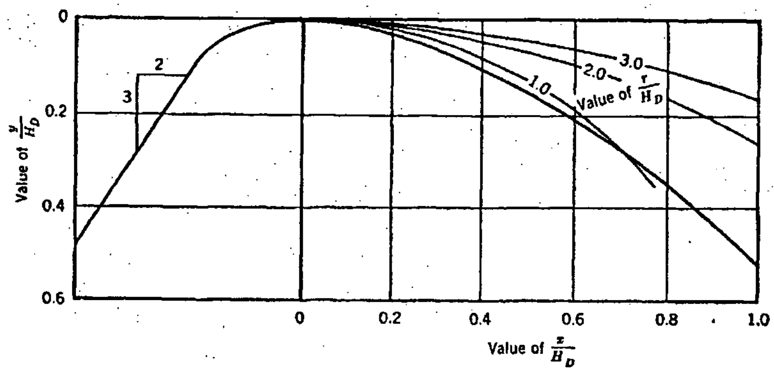

FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

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

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

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

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

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

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

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

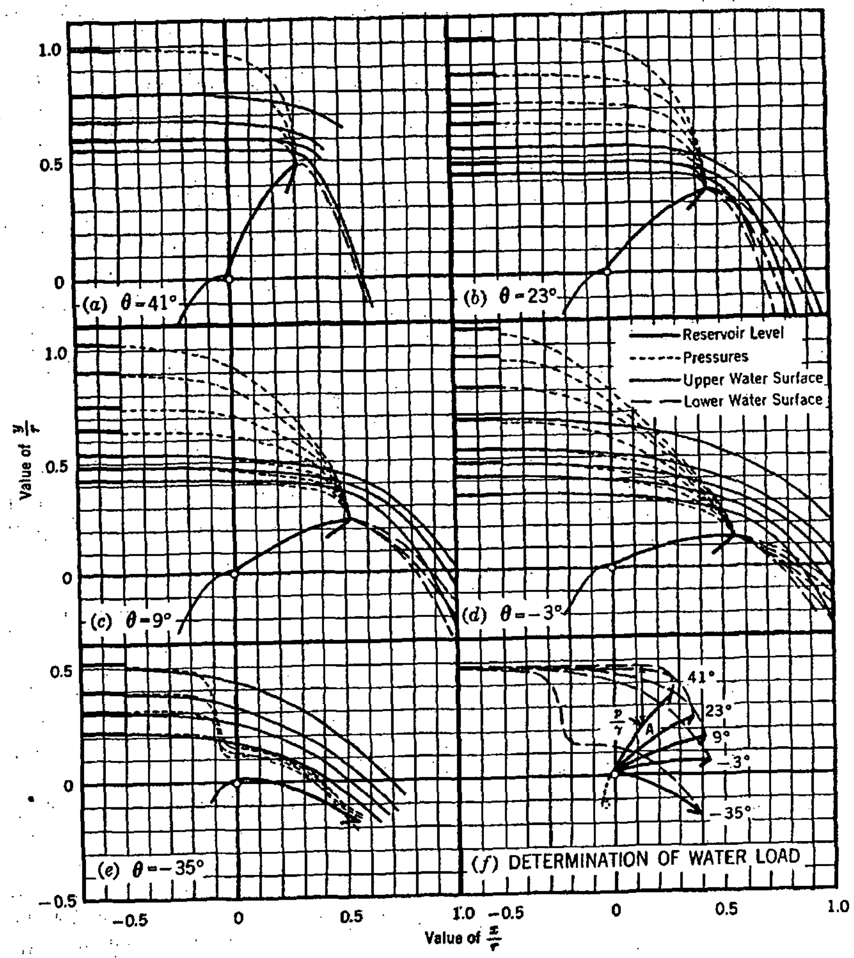

FIG. 17.—PRESSURES AND WATER-SURFACE PROFILES

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.