

University of Minnesota  
St. Anthony Falls Hydraulic Laboratory

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WISSOTA HYDRO PLANT  
AUTOMATIC SPILLWAY GATE STUDIES  
PHASE II

by

Warren Q. Dahlin, Joseph M. Wetzel

Heinz G. Stefan, and Bashar Sinokrot

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## I. INTRODUCTION

Northern States Power Company (NSP) is examining various alternatives to modify the automatic spillway gates at the Wissota Hydro Plant on the Chippewa River at Chippewa Falls, Wisconsin. The gates are called "stauwerke" gates. The main purpose of the study is to assure that the automatic spillway gates operate properly during a probable-maximum-flood (PMF) as required by the Federal Energy Regulatory Commission (FERC) and the Department of Natural Resources (DNR). The position of the gates must be controllable so that they can be fully lowered or raised with Lake Wissota at its normal elevation of 898.0 ft. The gates must go down for the design flood which currently is the PMF. The spillway has 13 automatic gates, each 64 feet, wide in the configuration shown in Fig. 1. NSP conducted field tests on Gate 1 at the south end of the spillway on April 15, 1988, in which the gate was pulled down to 7.2 ft. It was not possible to test the prototype gates from 7.2 ft down to the fully lowered position of 10.8 ft. During the tests, pulldown forces, piezometric pressures, and water surface profiles were measured. The results of the field tests down to 7.2 ft were correlated with a physical hydraulic model at the St. Anthony Falls Hydraulic Laboratory. These studies are summarized in a previous project report\* by the Laboratory. As reported in these studies, good correlation was observed between the field tests and the model tests. The model studies were expanded to include gate positions down to 10.8 ft (the full-down position of the gate), and the results were extrapolated to the prototype. It was concluded from the calculated gate hinge moments that the gates would probably not remain in the full-down position at the higher discharges without additional force being applied.

Flow over a convex curved shape can result in an increase in velocity and reduced pressure at the boundary. This reduced pressure can be noted considerably upstream from the point of tangency, as the flow senses the presence of the curvature. Furthermore, flow separation can occur from the surface, and the location at which the separation occurs is not stable. This was noted in the earlier studies as "flashing" between ventilated and non-ventilated flow across the width of the gate. The instability created changes in the pressures and thus changes in the forces on the gate. In fact, the gate had to be tied down to prevent oscillations. To eliminate the instability, it is desirable from hydrodynamic considerations to fix the point of separation by introducing a sharp edge, or by removing the curved surface.

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\*Dahlin, Warren Q., Wetzel, Joseph M., and Stefan, Heinz G., "Wissota Hydro Plant Automatic Spillway Gate Studies, Phase I," Project Report No. 275, August, 1988.

Consideration was given to gate revisions which could reduce the large magnitude of the negative pressures occurring on and near the curved lip section of the gate. If this could be achieved, the gate hinge moment would be increased and the gates would have a greater tendency to remain in the lower positions. It was suggested that further studies were needed to evaluate the performance of the gate revisions. Although the original 1-1/2 gate model was still operational at the Laboratory, gate changes on this model would take considerable time and consequently be more costly than other alternatives. Therefore, it was decided to build a section model in the laboratory 20-inch glass sided channel where revisions to the gate could be made in a shorter time, thus effecting a savings in both time and costs. The section model would also be more convenient to operate resulting in less testing time required.

A 1:14 scale model, the same scale as the 1-1/2 gate model, was fabricated and installed in the 20-inch channel. The gate width represented about 12 ft in the prototype. The model was operated with the gate at similar settings as in the prototype tests and in the 1-1/2 gate model tests. Visual observations, piezometric pressures, and water surface profiles were observed.

In both the prototype and the model, gravity is the predominant motion-producing force. For this type of system the greatest degree of dynamic similarity is obtained when the model-prototype relationships are established by the Froude law. The following expressions were used to convert dimensions and hydraulic quantities from model to prototype or vice versa. The letter L is the length in ft, Q the discharge in cfs, V the velocity in fps, P the pressure head in ft, T the time, f the frequency. The subscripts m and p refer to model and prototype, respectively, and the subscript r denotes the ratio of model to prototype.

Quantity	Ratio	Scale Relation
Length, L	$L_r = L_m/L_p$	1:14
Discharge, Q	$Q_r = L_r^{5/2}$	1:733
Velocity, V	$V_r = L_r^{1/2}$	1:3.74
Pressure, P	$P_r = L_r$	1:14
Time, T	$T_r = L_r^{1/2}$	1:3.74
Frequency, f	$f_r = 1/L_r^{1/2}$	0.267

For example if the velocity in the model is 1.0 fps, the corresponding velocity in the prototype will be 3.74 fps.

## II. CONCLUSIONS

1. The negative pressures occurring on the curved lip section of the original gate can be eliminated by revisions of the shape in that area.

2. Gate R1, which is a flat plate extended to elevation 898 ft in the closed position, experienced only positive pressures but would require extensive gate modifications.

3. Gate R2, in which an angle was attached to the curved section of the gate with the tip at elevation 898 ft, produced all positive pressures but could be damaged by debris and ice.

4. Gate R3, in which a wedge was attached to the curved section of the gate with the tip at elevation 898 ft, had all positive pressures on the wedge and the gate upstream of the wedge. Gate R3 appears to be a satisfactory design and is recommended for the Wisconsin automatic gates.

5. The R3 gates in the full-down position will pass a total discharge of 230,000 cfs for a headwater elevation of 906 ft. This is the same discharge as previously found for the curved lip gates in the Phase I studies.

6. At a headwater elevation of 898 ft, the gate hinge moments for the R3 gate are essentially the same as the calculated resistive moment of the 289 kip counterweight system for all gate positions. The curved lip gate hinge moments are about the same until the gate is lowered to about 3 ft, after which the hinge moments due to the water load are reduced and the gate must be held down.

The R3 gate will go down and remain down for higher headwater elevations unless additional force is applied to the counterweight system. Gate control can be exercised by this method.

### III. DESCRIPTION OF MODEL

A 1:14 undistorted model scale was selected for the section model. The same scale had been used for the 1-1/2 gate model. The section model was conveniently installed in the Laboratory's 20-inch wide glass sided channel which is 30-ft long by 36-inches high. The channel includes an existing 12-inch diameter supply line for higher flows with a 3-inch diameter by-pass for lower flows, a calibrated weir for metering the inflow, and a tailwater control weir. The water supply was obtained by gravity from the Laboratory supply channel which is connected to the Mississippi River. The model gate including clearances and seals was 10.25 inches wide which at the 1:14 scale represents 11.96 ft in the prototype. The section modelled is shown as the center of gate 1 in Fig. 1, but could be the center of any of the other gates if the approach and tailrace elevations were similar. The floor of the channel was set at elevation 870 ft. The gate and spillway structure was placed next to the glass on the right side of the channel as shown in Figures 2 and 3 so that the flow patterns could be conveniently observed and photographed, and the water surface profiles measured. A plywood wall was installed between the spillway and gate and the left side of the channel proper (Fig. 2). A sheet metal curved section at the upstream end of the wall served as a transition for the inflow into the model section. A row of 16 pressure taps was drilled along the centerline of the gate as shown in Fig. 4. The model taps are at approximately the same locations as the taps in both the 1-1/2 gate model and the prototype gate. The pressure taps were connected by plastic tubing to a manometer board outside the channel where the piezometric pressures were observed and the values recorded. The tubing passed through the spillway structure beneath the gate, through the wall, and over the channel side to the manometer board. No attempt was made to model the weight or weight distribution of the gate, or to measure gate forces. During the tests the gate was supported from below and fixed so it could not move. A gate arm opening was cut in the structure beneath the gate to provide for ventilation of air under the gate as would occur in the prototype. A grid spaced at 5-ft prototype intervals was placed on the front glass, as shown in Fig. 3, to provide a means for recording the water surface profiles. Figure 5 shows the tailwater rating curve used to set the tailwater elevations in the model; these data were provided by the sponsor.

## IV. MODEL OBSERVATIONS

### A. ORIGINAL CURVED LIP GATE

Observations were made on the original curved lip gate section shown in Fig. 4 to compare with the results from the previous 1-1/2 gate model. The elevation of the gate crest was varied from 896 to 890 ft in two ft increments with headwater elevations of 898 and 906 for each gate position. The piezometric pressures and water surface profiles were recorded, and the results are presented in Figures 6 through 13. With the gate in the fully down position, observations were made with headwater elevations of 898 to 906 ft, in two ft increments. The results are shown in Figs. 14 and 15. Tabulated values of piezometric pressures, water surface elevations, and computations of gate hinge moments are presented in Appendix A.

The plotting scale has been distorted in each of these figures so that the shape of the gate and structure is not realistic. The flow conditions (FC) have been identified with symbols on each figure, and these symbols refer to the specific values tabulated below the plot.

The measured piezometric heads show the decrease in pressure near and on the curved lip, even for the low discharges. As the discharge increases, either by an increase in the headwater or by lowering of the gate, the magnitude of the pressure reduces and becomes negative. With the gate 8 ft down and a headwater elevation of 906 ft, it is shown in Fig. 12 that the minimum pressure is about 23 ft below atmospheric. Such a low pressure on the full scale gate could result in local cavitation. However, as will be discussed later, the gate cannot be maintained in this position without an additional restraining force being applied. Comparing results from similar headwaters and discharges, the section model shows good agreement with the 1-1/2 gate model. For example, with the gate down 6 ft and headwater elevation at 898 ft, the piezometric pressure is about 888.5 ft (slightly negative) at a distance of 12 ft from the hinge in both the section model (Fig. 10) and the 1-1/2 gate model. Water surface profiles are also similar. With the gate in the fully down position at 10.8 ft, the piezometric pressures vary somewhat in comparing results from the two models. The water surface profiles show no significant differences.

### B. TYPE R1

With the original curved lip gate, negative pressures were observed on the curved section of the gate in both the 1-1/2 gate model and the section model. As discussed previously, because of these negative pressures the gate would not stay fully down (10.8 ft) for the higher flows. As the curved

section of the gate has considerable effect on the pressure distribution, reducing or eliminating the curved section of the gate was discussed with Northern States Power Company.

The first revision to the gate geometry was a simple flat plate extended to elevation 898 ft, eliminating the curved section completely as shown in Fig. 16. The R1 gate in the down position is shown in Fig. 3. The R1 gate was tested with the gate fastened down in the lowest position of 10.8 ft as shown in the photos of Figures 17 through 22. Figure 17 shows the model with the headwater elevation at 900 ft,  $Q/\text{gate}$  of 10,439 cfs,  $Q$  total of 135,700 cfs, and the corresponding tailwater elevation of 882.4 ft. The jet separates from the end of the gate resulting in a ventilated area just downstream of the gate as shown. The jet impinges on the tailrace about 10 ft downstream of the end of the spillway.

In the region of jet impingement, the jet divides into two components. One of these components is directed downstream, and the other is directed upstream. The upstream jet runs up the face of the spillway and creates a roller. This roller can be quite intense, and may be sufficient to move rocks or other material that may be present at the toe of the spillway. It should be noted that the tests with the original curved lip gate showed about the same roller at the same flow conditions. This is probably due to the fact that the jet separates from the curved lip gate, and the jet trajectory is similar for both the curved and flat gates. For the same flow conditions, the piezometric pressures are all positive, as shown in the photo in Fig. 18. The horizontal dark line indicates the elevation of the flat gate, and the dyed water in the tubes shows the piezometric pressures above that elevation. The piezometric pressures are also shown plotted in Fig. 23 and the water surface profile in Figure 24. Also shown in these figures are the results of observations at headwater elevations of 902, 904, and 906 ft. Piezometric pressures are positive at all headwater elevations as shown. Figure 19 shows the model in operation at a headwater of 902 ft and Fig. 20 at 904 ft. The gate is still fully ventilated at a headwater of 902 ft and partially ventilated at a headwater of 904 ft. With the headwater elevation raised to 906 ft, the gate is naturally unventilated as shown in Fig. 21. The gate was ventilated by injecting air up through the gate arm opening resulting in the flow pattern shown in Fig. 22. Forced ventilation did not affect the discharge, headwater elevation, tailwater elevation, or piezometric pressures significantly. The water surface is essentially unaffected from the horizontal distance of -25 ft to about 10 ft and is slightly higher from about 20 ft to 35 ft. The ventilated condition for a headwater of 906 ft is plotted in Figures 23 and 24. The data are tabulated in Appendix A.

### C. TYPE R2

Observations on Type R1 showed that the pressure distribution on the gate was all positive and would tend to keep the gate down. If a flat plate was to replace existing Wissota gates, the cost for such a replacement would be excessive. With that in mind, it was decided to explore other possibilities which would achieve similar results and not require extensive revisions.

Figure 25 shows one such geometry. The existing gate was left intact, and an angle was attached to the gate as shown. The top of the angle is at elevation 898 ft and in line with the face of the gate. In effect, this is similar to the Type R1, as the top of the angle is the separation point for the water jet, but the remainder of the gate downstream of the angle is left intact. Observations were made with the gate down 2 ft with headwaters of 898 and 906 ft and with the gate down 10.8 ft with headwaters varying from 898 to 906 ft. The results are presented in Figs. 26 through 29. When compared to R1, the water surface profiles (Figures 27 and 29) show no significant differences. The piezometric pressures presented in Figures 26 and 28 are all positive upstream of the angle. With the gate full down (Fig. 28), the pressures rise slightly just upstream of the angle, which is at a distance of 11.5 ft from the hinge. This is a local effect of the angle geometry. Just downstream of the angle, the pressures are slightly negative, caused by the separation of the jet, but this is insignificant. Basically the R2 geometry has a similar effect on the hydraulic characteristics of the flow over the gate as Type R1.

#### D. TYPE R3

Although the Type R2 gate provided the desired results, there was some concern that the angle could be damaged by debris and ice. To alleviate this condition, the wedge shaped geometry shown in Figs. 30 and 31 was added to the gate. This is in effect the flat plate geometry of Gate R1 fabricated on the original curved gate. The original tip extension is left on the gate, so that when the gate is in the fully raised position, it is possible to walk across the gate if necessary. The extension also reduces the chance of water falling into the gate arm openings at the higher gate positions. Although the performance was expected to be the same as the R1 gate, the tests were repeated to ensure that no adverse effects or jet reattachment would occur.

Observations were made on Gate R3 with the gate down 2, 4, 6, 8, and 10.8 ft, and for various headwaters up to 906 ft. Figure 32 shows a photo of the model in operation with the gate down 2 ft and a headwater elevation of 898 ft. The flow jet passes over the wedge at the crest and remains attached to the gate downstream of the wedge. The resulting piezometric pressures are shown in the photo of the manometer board in Fig. 33 and are all positive. Figures 34 and 35 show the flow patterns with the gate down 2 ft and headwater elevations of 902 and 906 ft, respectively. For these headwater conditions, the flow jet separates at the tip of the wedge and does not reattach to the gate downstream of the wedge. The gate remains ventilated. Figure 36 shows a plot of the piezometric pressures with the gate down 2 ft for various headwaters from 898 to 906 ft. The pressures are all positive upstream of the wedge and on the wedge, with slightly negative pressures occurring just downstream of the wedge in one instance. A plot of the water surface profiles for the same flow conditions is presented in Fig. 37. The data are tabulated in Appendix A, along with the computations of the gate loads.

Figures 38 through 41 show the test results with the gate down 4 ft. In these tests, observations were also made with the headwater at 896 ft and the results plotted separately in Figures 39 and 41. Again, all pressures on the wedge and upstream of the wedge are positive with slightly negative pressures on the gate downstream of the wedge, as shown in Figures 38 and 39.

Figures 42 through 46 show photos of the model in operation with the gate down 6 ft and for various headwaters from 896 to 906 ft. For the lower headwaters the flow jet separates at the tip of the wedge and does not reattach to the gate downstream of the wedge, as shown in the photos of Figures 42, 43, and 45. With the headwater at 906 ft, the gate was unventilated. Ventilation was caused to occur by placing a small tube on the sides of the gate as shown in Fig. 46. This would in effect be simulating the effect of the piers in the prototype structure. Figure 44 shows a photo of the manometer board with a headwater elevation of 898 ft; the resulting pressures are all positive. With the gate down 6 ft, piezometric pressures and water surface profiles were recorded for headwater elevations from 894 up to 906 ft with the results presented in Figures 47 through 50. The pressures are all positive on the wedge, and the gate upstream of the wedge, and atmospheric or near zero pressure on the gate downstream of the wedge as shown in Figures 47 and 48.

With the gate down 8 ft, observations were made for headwater elevations from 892 up to 906 ft. The results are presented in Figures 51 through 54. The piezometric pressures are all positive, and the water surface profiles show nothing unusual.

With the gate down 10.8 ft, observations were made at headwater elevations from 898 to 906 ft. Figure 55 shows a photo of the flow pattern with the headwater at 898 ft. The gate is fully ventilated. Figure 56 shows a photo of the piezometric pressures on the manometer board. Figure 57 shows the flow pattern with a headwater of 902 ft and Fig. 58 a headwater of 906 ft. With a headwater of 902 ft, the gate is partially ventilated. At a headwater of 906 ft, the gate was unventilated until a small pipe was placed on the far side near the downstream end of the gate, as shown in Fig. 58. The piezometric pressures are presented in Fig. 59; pressures are positive on the wedge and the gate upstream of the wedge and slightly negative on the gate downstream of the wedge. The water surface profiles are presented in Fig. 60 and show nothing unusual. The supporting data are tabulated in Appendix A.



## V. DISCUSSION OF TEST RESULTS

### A. HEAD-DISCHARGE CURVES

#### 1. All Gate Configurations - Full Down Position

A comparison of the head-discharge relationship for all the gate types tested is shown in Fig. 61. The comparison is made for the gate in the fully lowered position. Note that there are two sets of data for the gate with the curved lip. Data identified as Curve I refer to the data collected in the 1-1/2 gate model of Phase I. The Curve II data were taken in the present series of Phase II tests with the section model. The total discharge refers to the discharge for 13 gates. There is very little difference noted in the head-discharge relationships for all gate types.

#### 2. Curved Lip and R3 Gates

The most extensive tests were conducted with the recommended R3 gate configuration. Headwater elevations from 894 to 906 ft were used with gate positions varying in 2 ft increments from the 2 ft down to the fully down position. These data are shown in Fig. 62. Also plotted are the results for the curved lip gate at headwaters of El. 898 and 906 ft for various gate positions.

### B. GATE HINGE MOMENTS

A summary of the gate hinge moments for the curved lip gate at two headwater elevations and gate R3 for seven headwater elevations is shown in Fig. 63. These gate hinge moments have been calculated from the measured pressure distributions. The method used was similar to that used in the Phase I studies and the field tests. The experimental data and calculated values are tabulated in Appendix A.

Also included in Fig. 63 is the calculated resistive gate moment which is due to the counterweight system. The moment equation was derived by others and was also plotted in the Phase I report for a total counterweight of 289 kips. This equation is given in Appendix B for reference purposes. The counterweight of 289 kips is the dry weight. If the gallery is flooded at high tailwaters, the submerged weight would be less.

The abscissa in Fig. 63 is the gate crest elevation. This can also be considered as the "gate down" position by referencing the fully closed position to El. 898. Thus, El. 892 corresponds to the gate down 6 ft.

First, consider the original curved lip gate. At a headwater elevation of 898 ft, the hinge moment is essentially the same as the resistive moment until the gate lowers to about 3 ft. As the gate is lowered further, the gate moment is less than the resistive moment, and therefore the gate will not remain at that position unless an additional external force is applied to hold it down.

With the headwater elevation at 906 ft, a similar situation exists, except that the gate would go down much faster in the first 3 feet. This is an unrealistic scenario, as it is highly unlikely that such a high headwater would exist with the gates near the fully raised position.

Second, for the revised gate geometry R3, the shape of the gate moment curves due to the water pressure distribution is somewhat different. Curves for a number of headwater elevations are shown in Fig. 63. For a headwater elevation of 898 ft, the gate moment due to water pressure is essentially balanced by the counterweight system for all gate positions. The difference in the curves for the straight gate and the curved lip gate is associated with the lack of negative pressures on the straight gate. At headwaters greater than El. 898, the gate hinge moments for the R3 gate exceed the resistive moments and the gate should remain down.

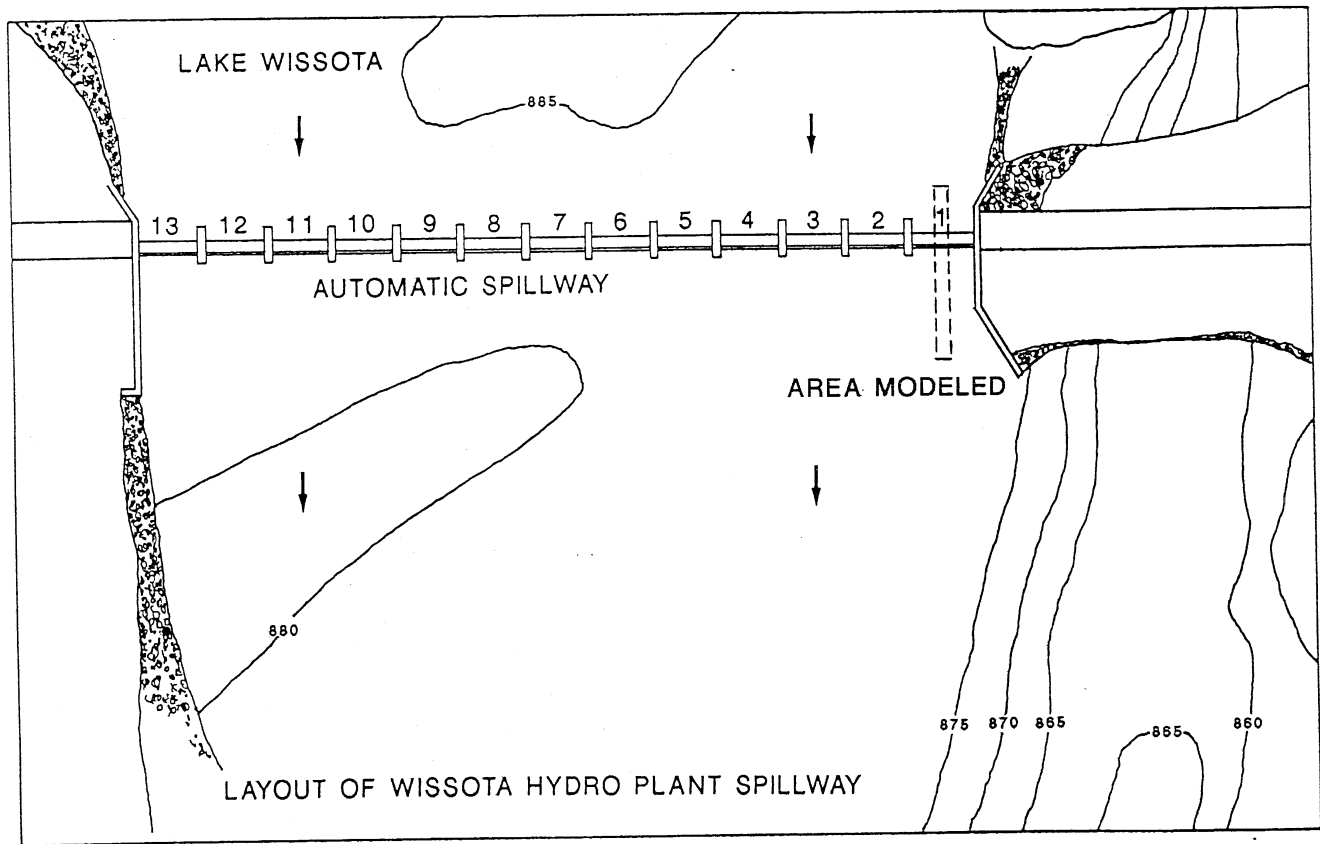


Fig. 1. Layout of Wissota Hydro Plant spillway.

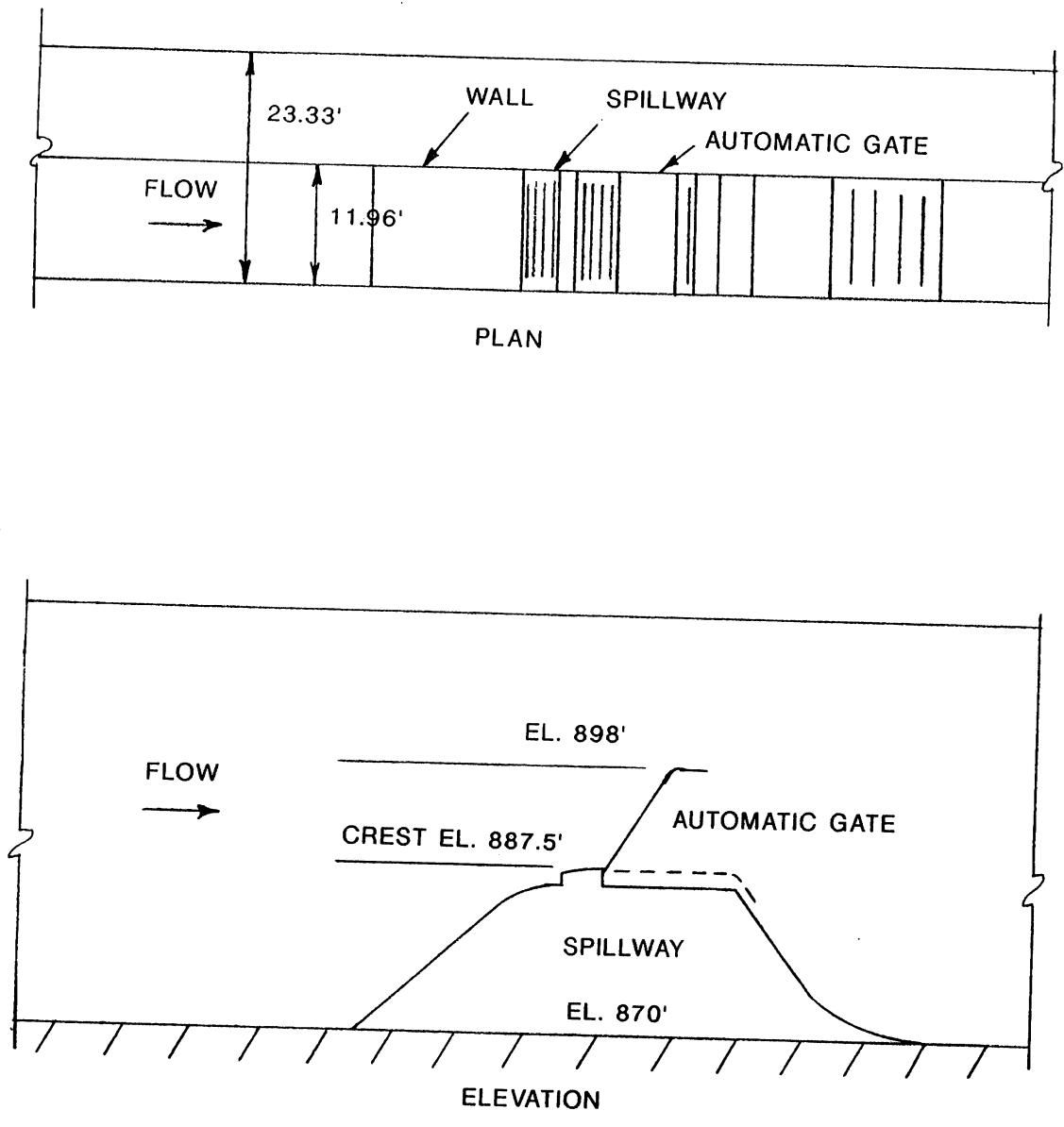


Fig. 2. Model layout.

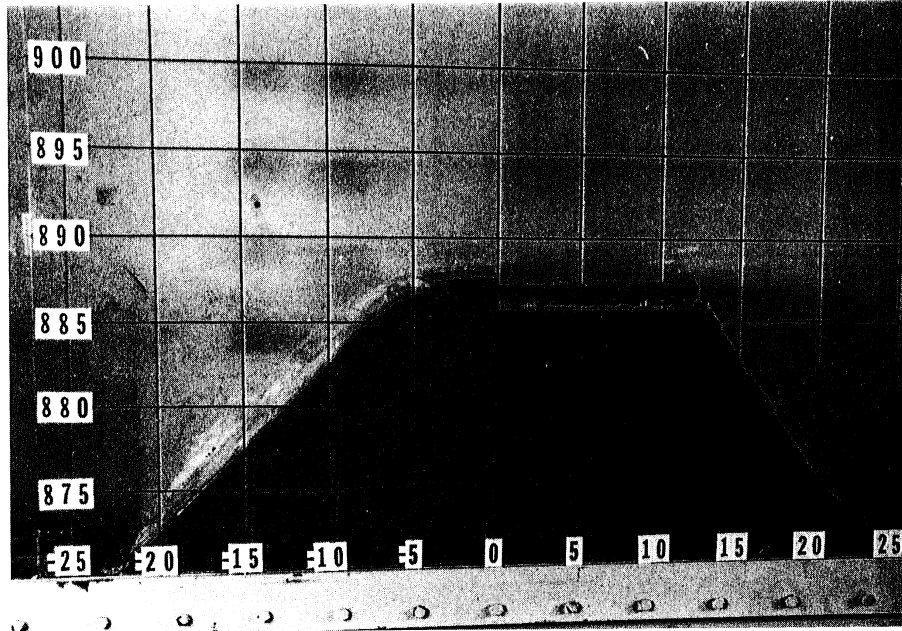
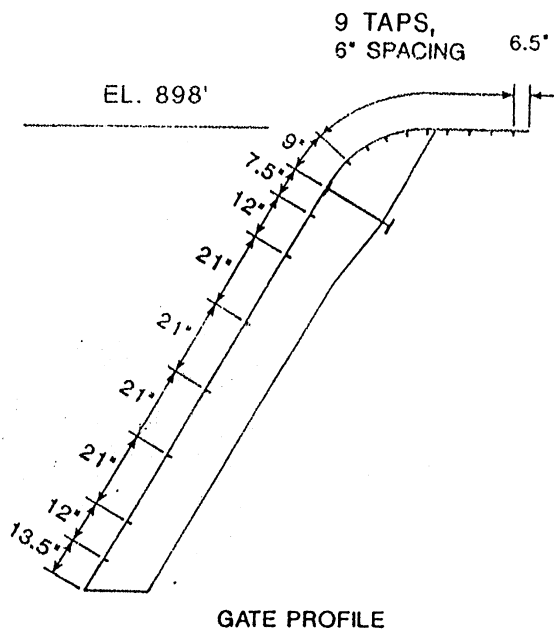


Fig. 3. Gate R1, photo of the model in the 20-inch channel.



ORIGINAL GATE  
 PRESSURE TAP LOCATIONS  
 WISSOTA GATE STUDY

Fig. 4. The original gate with pressure tap locations.

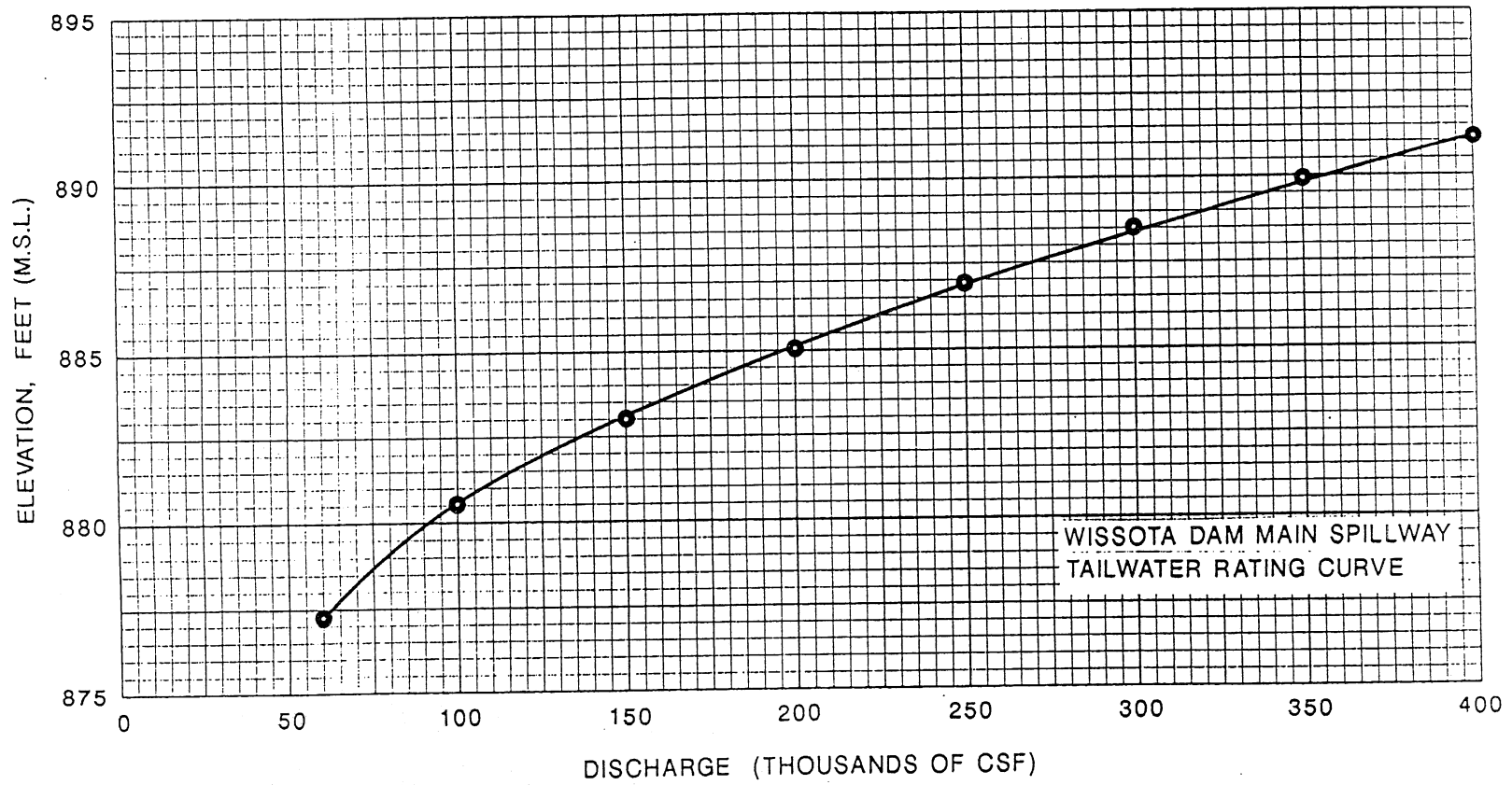


Fig. 5 Wissota Dam main spillway, tailwater rating curve.

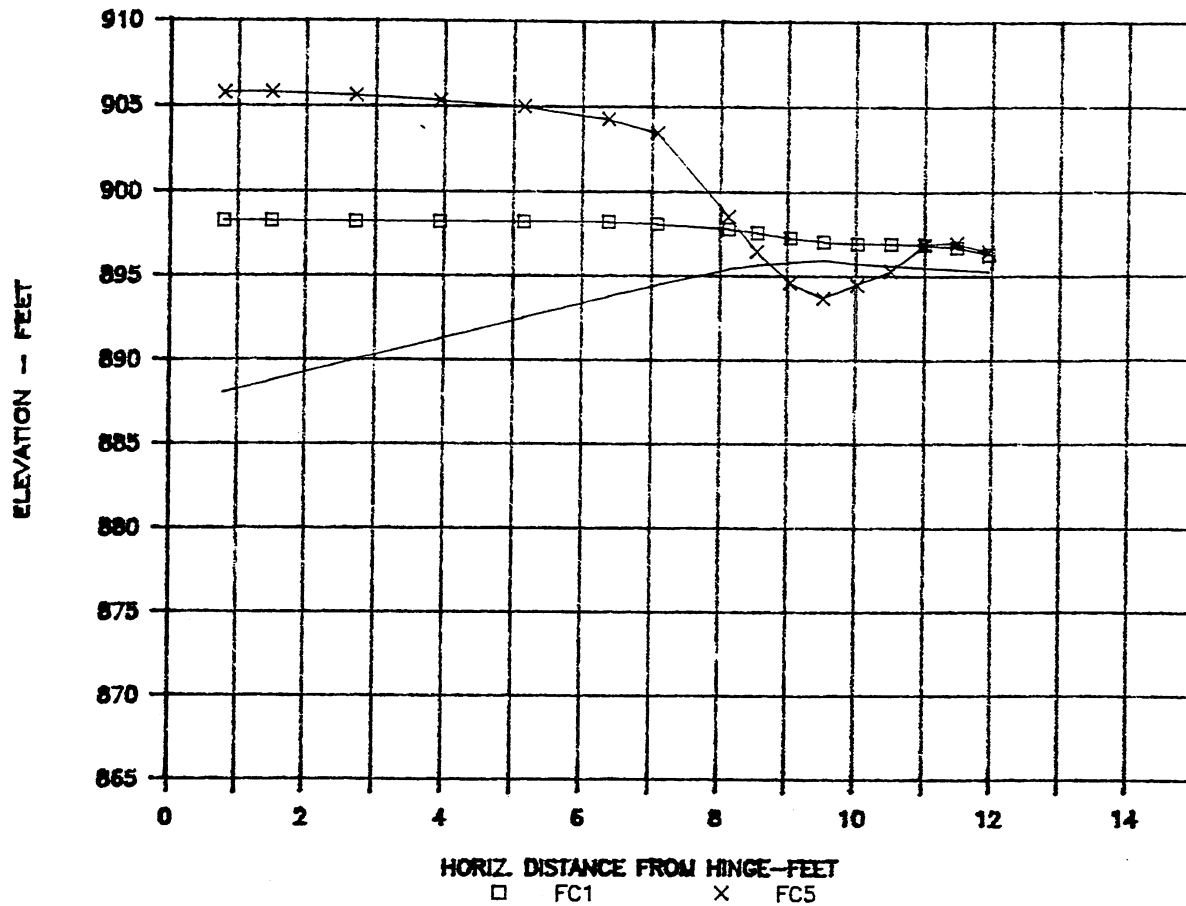


Fig. 6. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 2 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898         906
T.W. Elev.-ft      870.0       881.3
Q/gate -cfs        773         8830
Q(total -cfs      10052        114790
*****

```



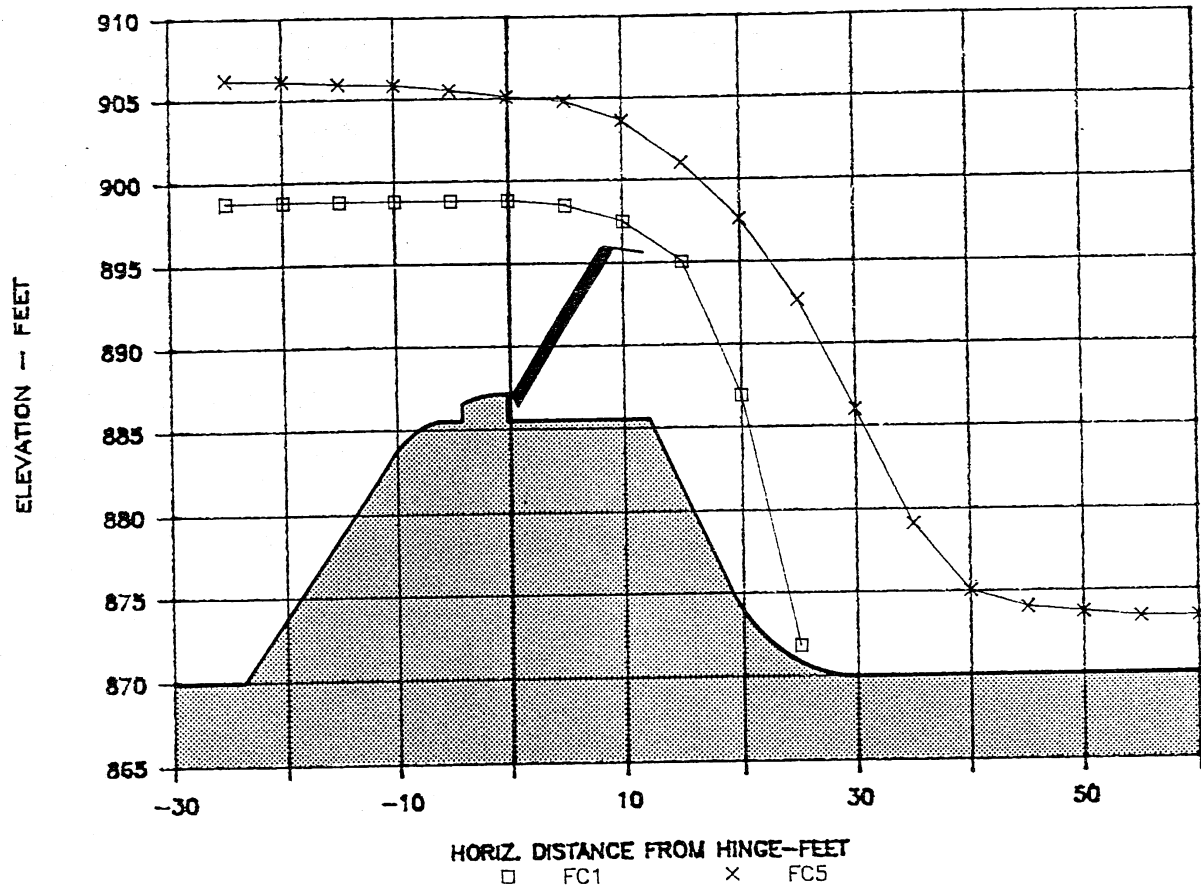


Fig. 7. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 2 ft

Flow Cond. F.C.	1	5
H.W. Elev.-ft	898	906
T.W. Elev.-ft	870.0	881.3
Q/gate -cfs	773	8830
Q(total) -cfs	10052	114790

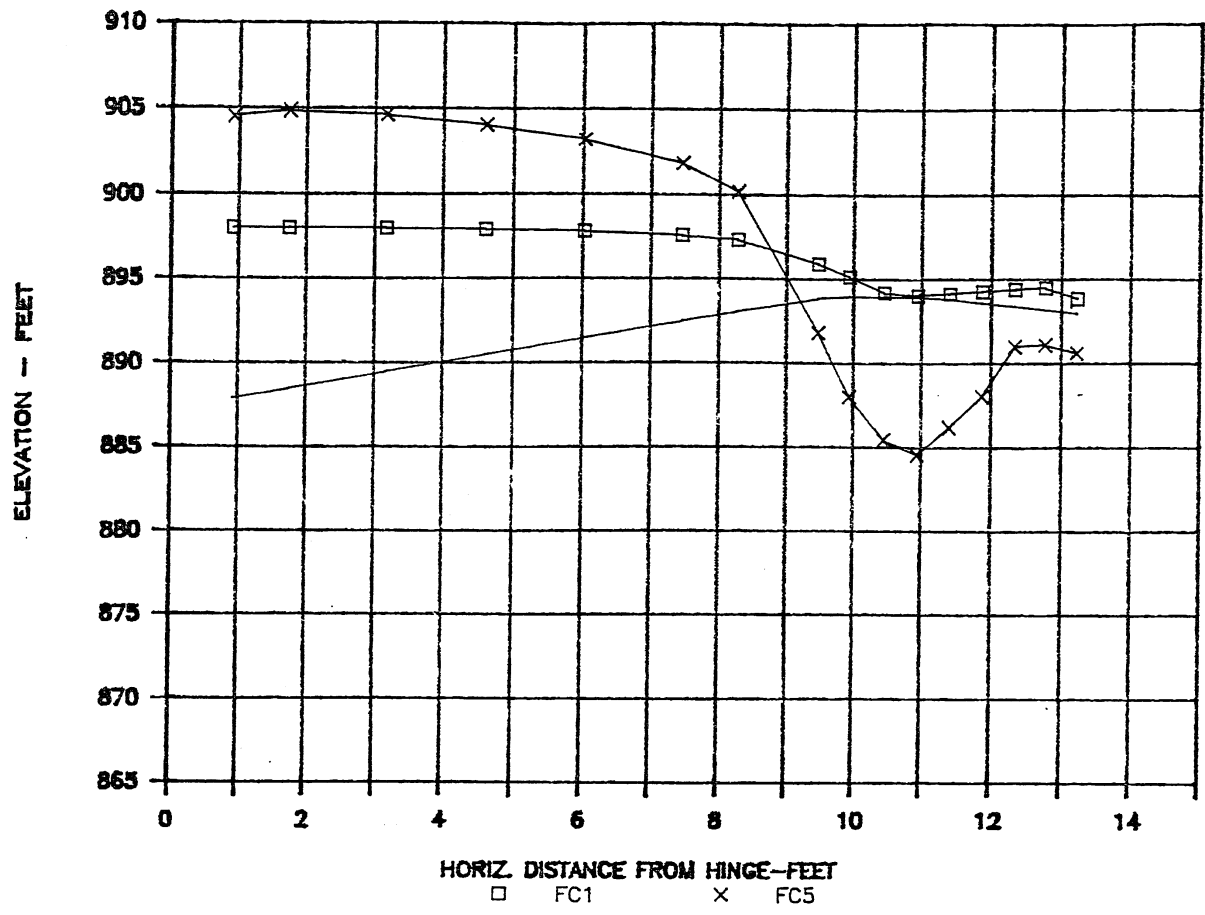
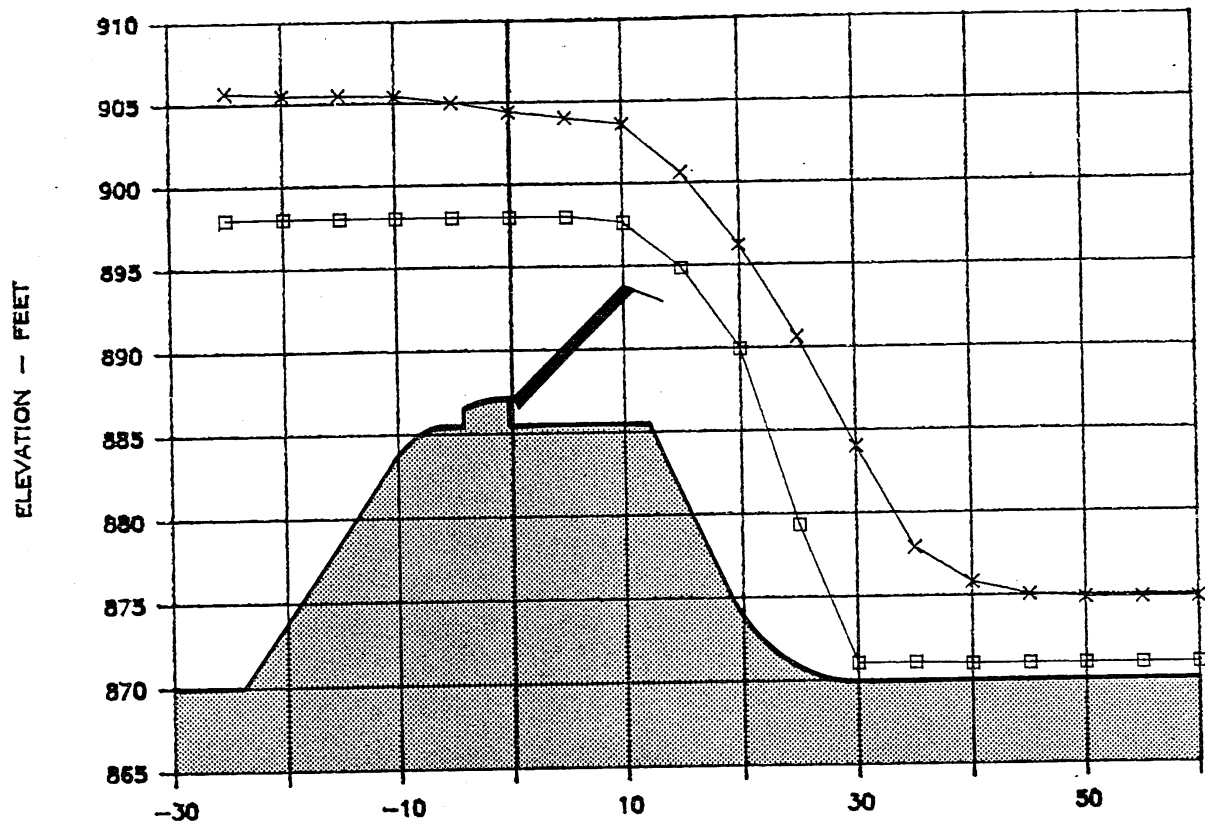


Fig. 8. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 4 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898         906
T.W. Elev.-ft      872.5       882.9
Q/gate -cfs        2082        11302
Q(total) cfs       27066       146930
*****

```

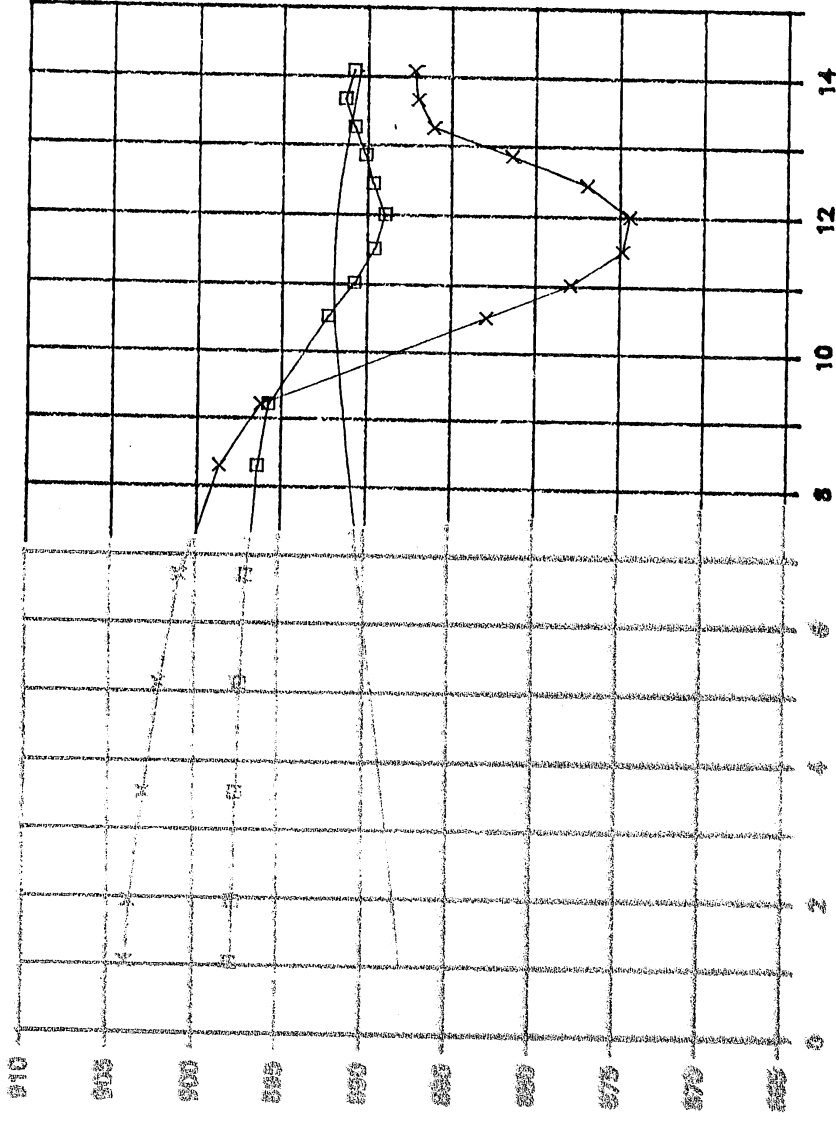


HORIZ. DISTANCE FROM HINGE—FEET  
 □ FC1      × FC5  
 Fig. 9. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 4 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft       898    906
T.W. Elev.-ft       872.5  882.9
Q/gate -cfs         2082   11302
Q(total) -cfs       27066  146930
*****

```



WATER PRESSURE HINGE - FEET  
 □ FC1  
 × FC5

FIG. 10. MESSUR AN GATE TESTS  
 HYDROMETRIC PRESSURE HEAD  
 1/14 Section Model  
 Gate Down 6 ft

Flow Cond. P.C.	1
Flow Elev. ft	906
Flow Elev. ft	884.6
Gate - CFS	14324
Gate - CFS	186210

ELEVATION - FEET



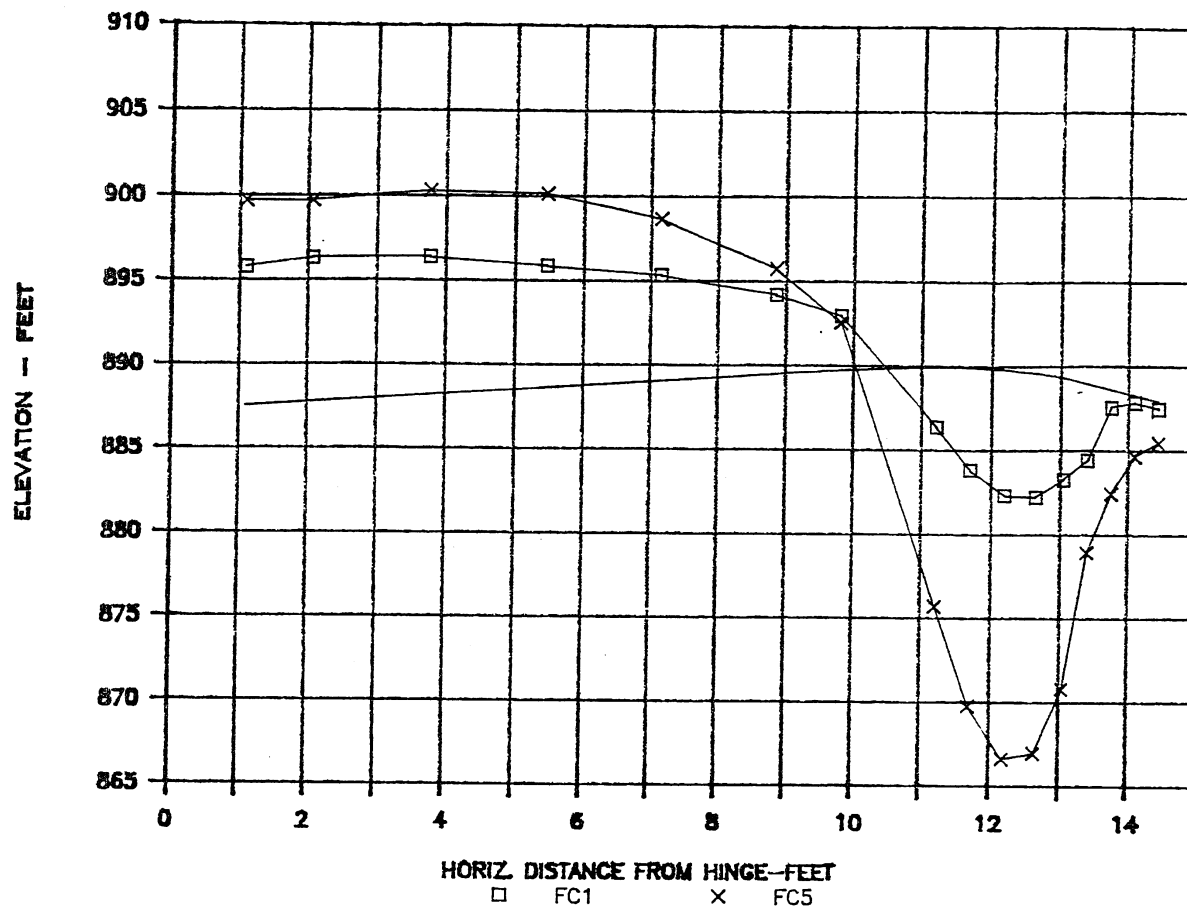


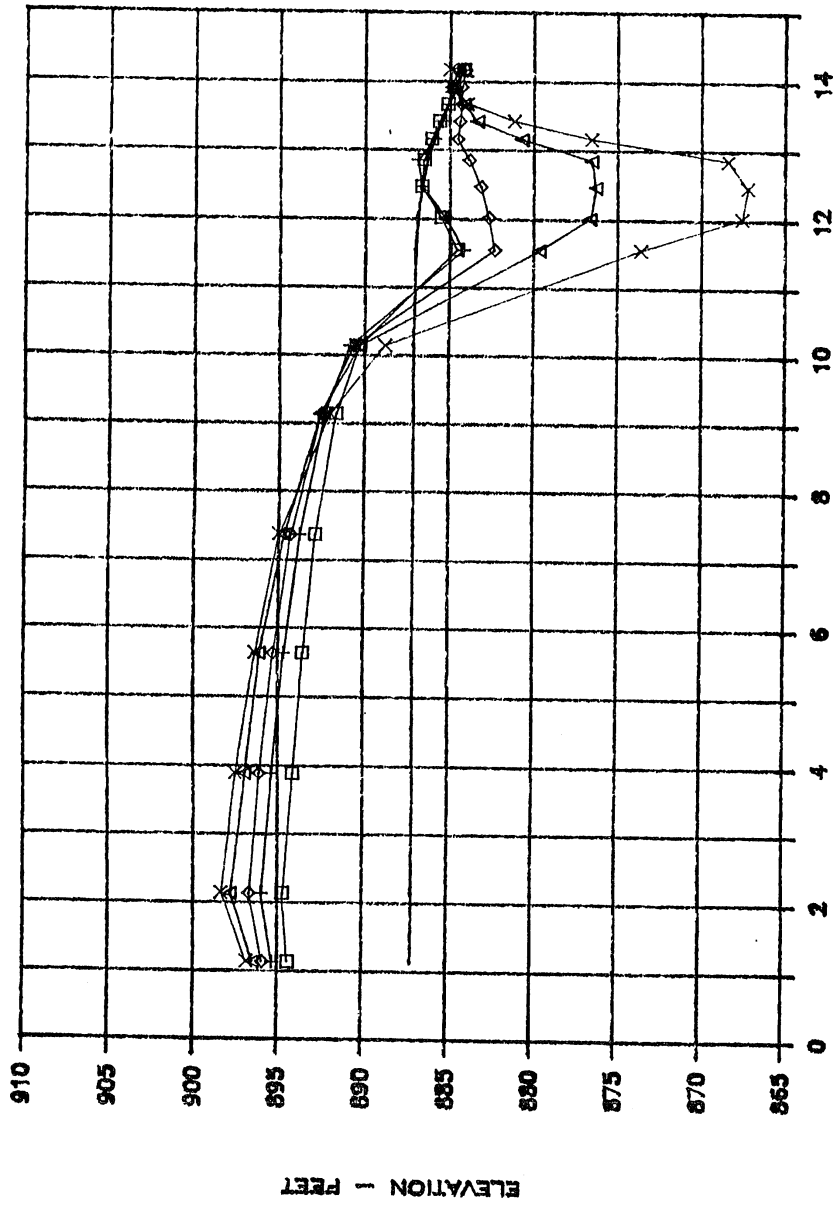
Fig. 12. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 8 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898        906
T.W. Elev.-ft      878.7      885.5
Q/gate -cfs        5655      16208
Q(total) cfs       73515     210700
*****

```





□ FC1    + FC2    ◇ FC3    △ FC4    × FC5  
**HORIZ. DISTANCE FROM HINGE--FEET**

Fig. 14. MISSOURI DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 10.8 ft

```

#####
Flow Cond. F.C. 1 2 3 4 5
H.W. Elev.-ft 898 900 902 904 906
T.W. Elev.-ft 883.2 884.8
Q/gate -cfs 7122 9551 11809 14755 17680
Q(total -cfs 92586 124160 153520 191820 229840
#####
  
```



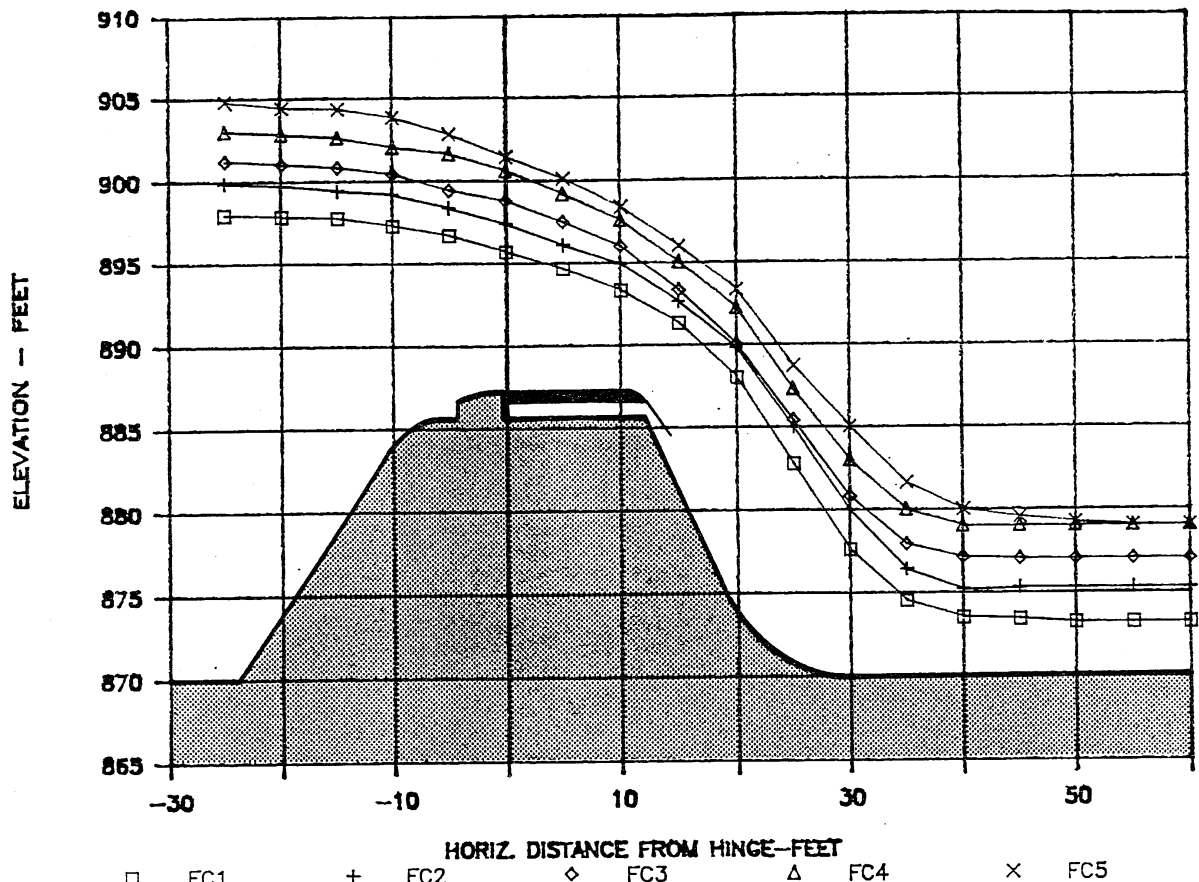
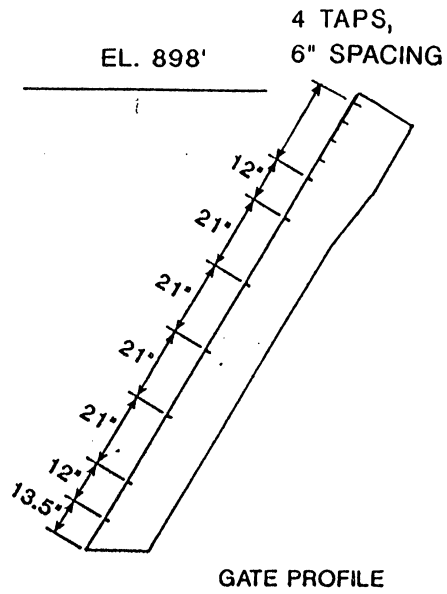


Fig. 15. MISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 10.8 ft

Flow Cond. F.C.	1	2	3	4	5
H.W. Elev.-ft	898	900	902	904	906
T.W. Elev.-ft			883.2	884.8	
Q/gate -cfs	7122	9551	11809	14755	17680
Q(total) -cfs	92586	124160	153520	191820	229840



GATE R1  
PRESSURE TAP LOCATIONS  
WISSOTA GATE STUDY

Fig. 16. Gate R1, pressure tap locations.

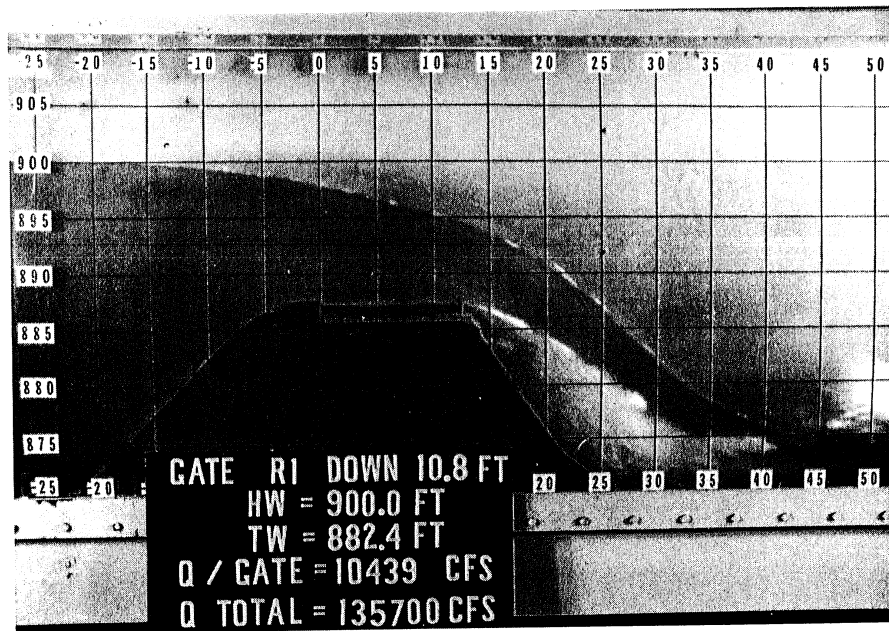


Fig. 17. Photo showing Gate R1 down 10.8 ft, H.W. Elev. = 900.0 ft, T.W. Elev. = 882.4 ft,  $Q/\text{gate} = 10,439$  cfs,  $Q$  total = 135,700 cfs.

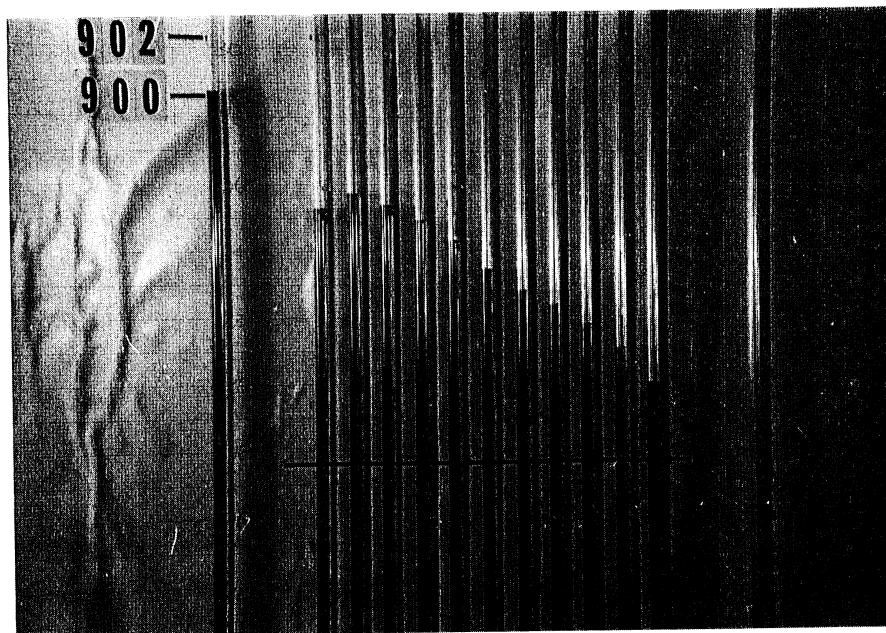


Fig. 18. Photo showing the manometer board with Gate R1 down 10.8 ft, H.W. elev. = 900.0 ft, T.W. elev. = 882.4 ft,  $Q/\text{gate} = 10,439$  cfs,  $Q$  total = 135,700 cfs.

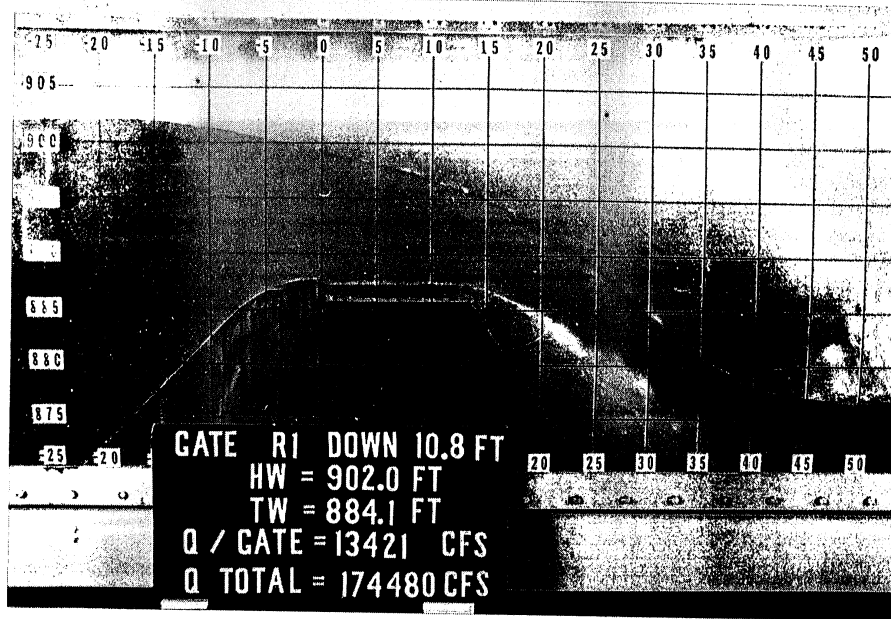


Fig. 19. Photo showing Gate R1 down 10.8 ft, H.W. elev. = 902.0 ft, T. W. elev. = 884.1 ft, Q/gate = 13,421 cfs, Q total = 174,480 cfs.

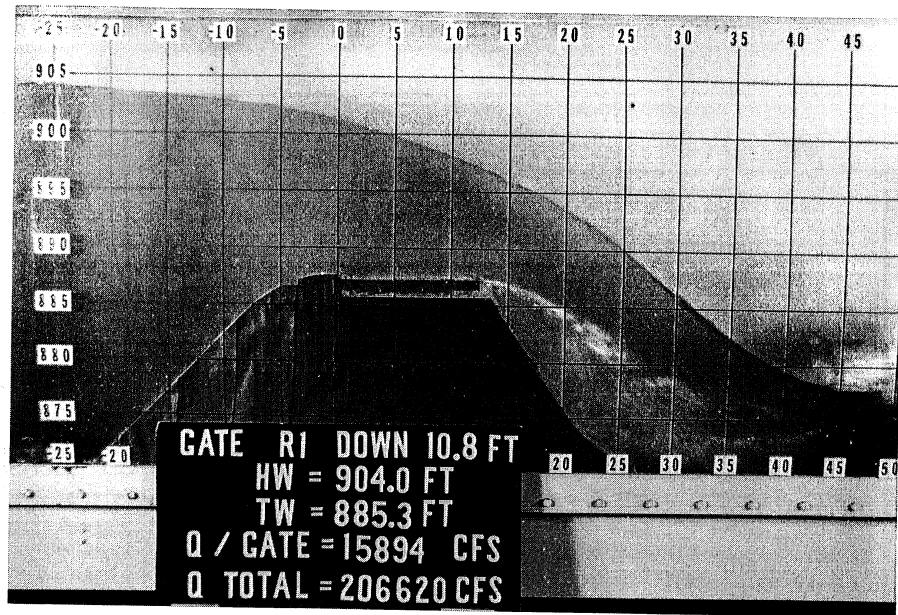


Fig. 20. Photo showing Gate R1 down 10.8 ft, H.W. elev. = 904 ft, T. W. elev. = 885.3 ft, Q/gate = 15,894 cfs, Q total = 206,620 cfs.

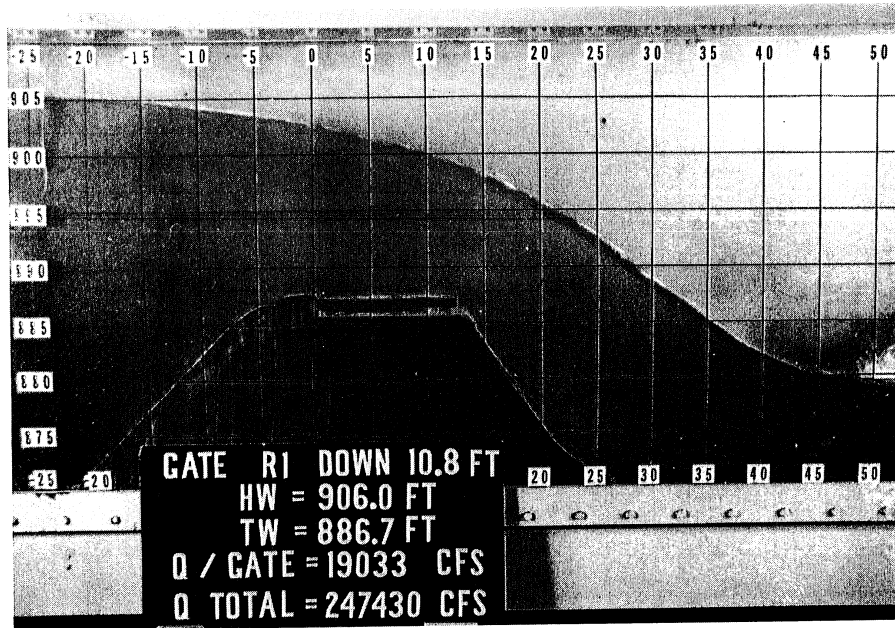


Fig. 21. Photo showing Gate R1 down 10.8 ft, H.W. elev. = 906.0 ft, T. W. elev. = 886.7 ft,  $Q/gate = 19,033$  cfs,  $Q$  total = 247,430 cfs.

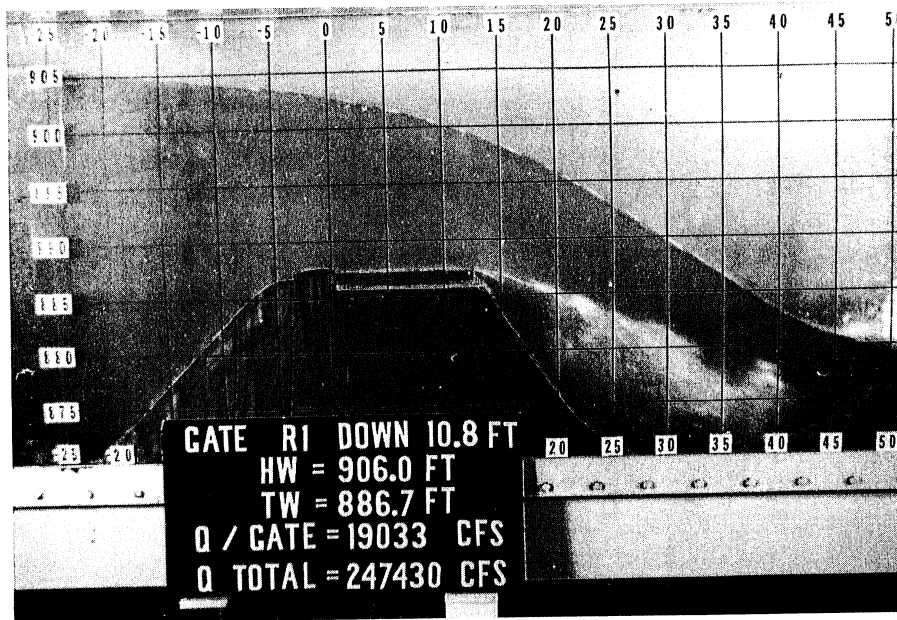


Fig. 22. Photo showing Gate R1 down 10.8 ft, H.W. elev. = 906.0 ft, T. W. elev. = 886.7 ft,  $Q/gate = 19,033$  cfs,  $Q$  total = 247,430 cfs.

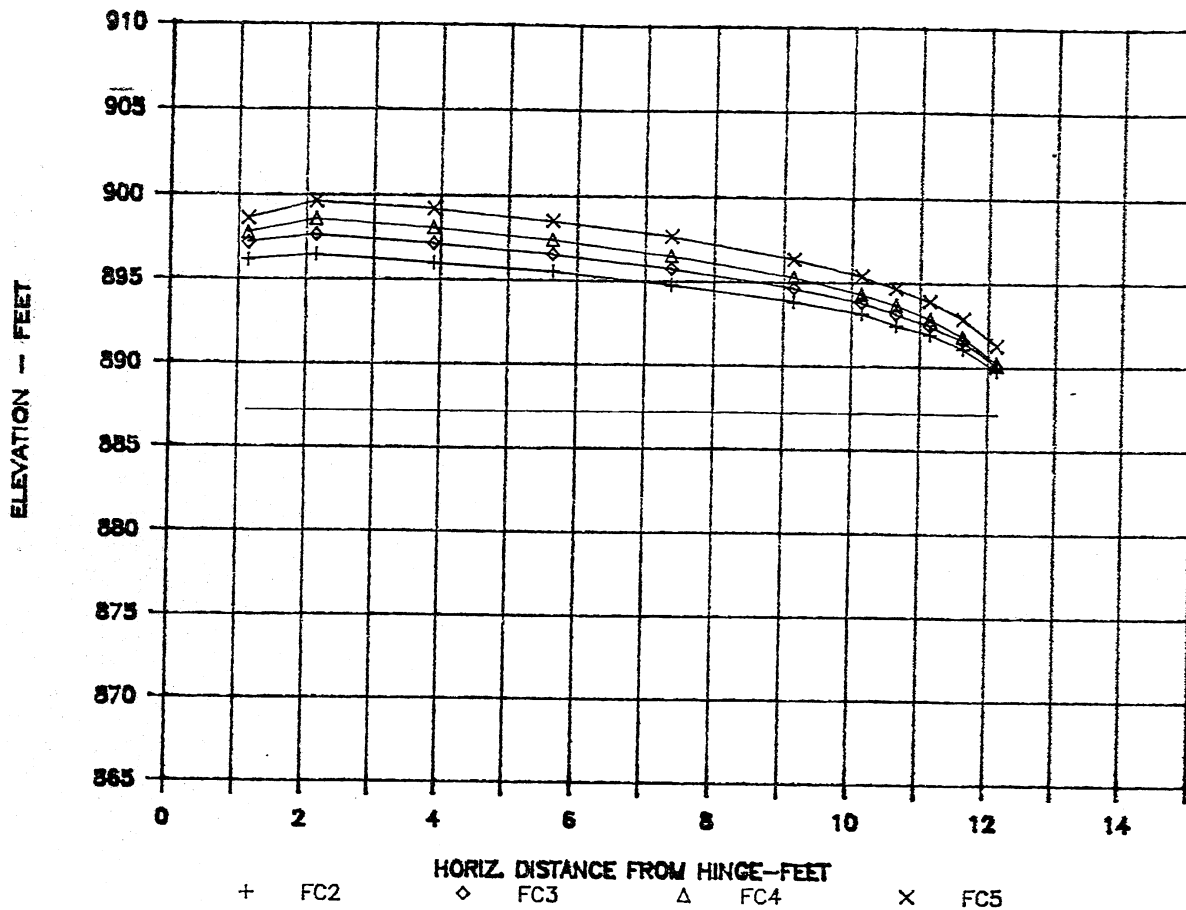


Fig. 23. WISGOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R1 Down 10.8 ft

```

*****
Flow Cond. F.C.      2      3      4      5
H.W. Elev.-ft      900     902     904     906
T.W. Elev.-ft      882.4   884.1   885.3   886.7
Q/gate -cfs        10439   13421   15894   19033
Q(total -cfs       135700  174480  206620  247430
*****
  
```

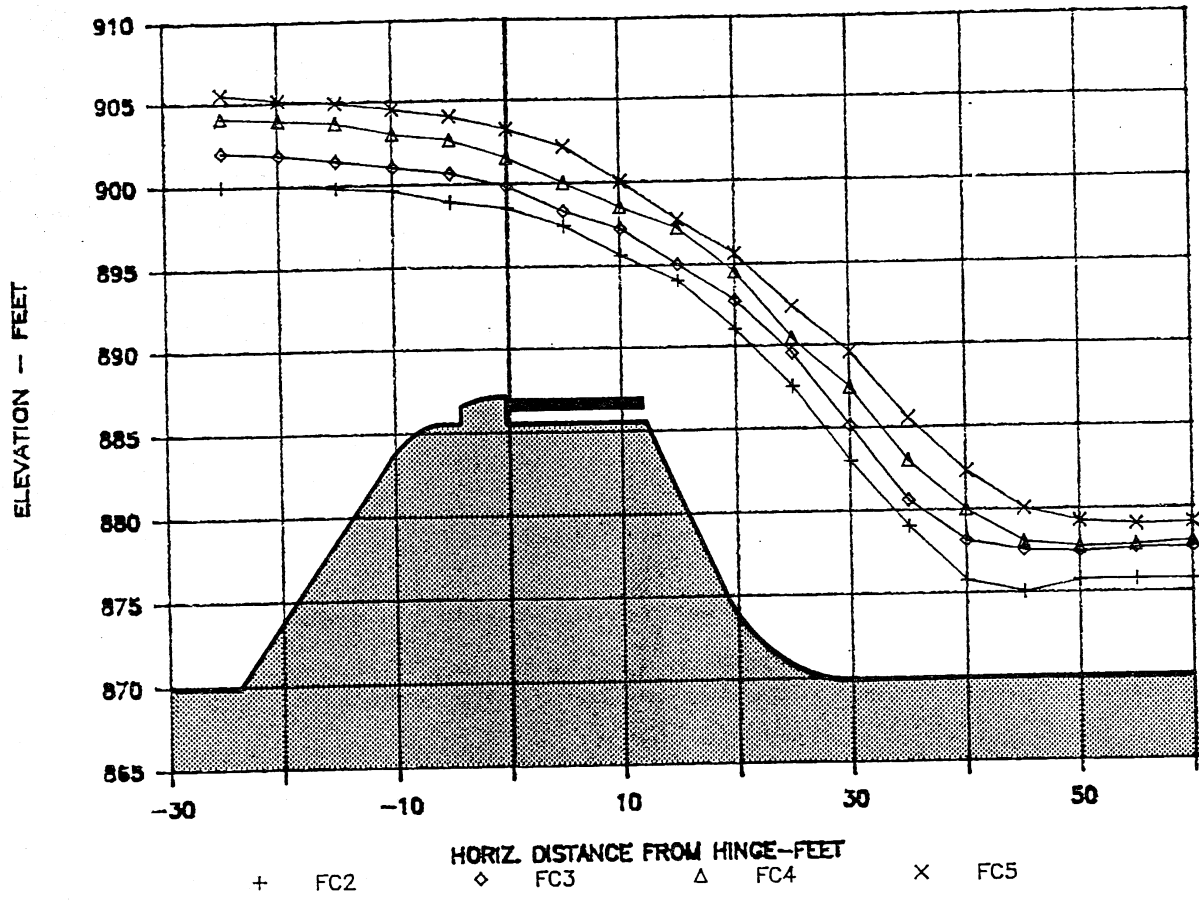
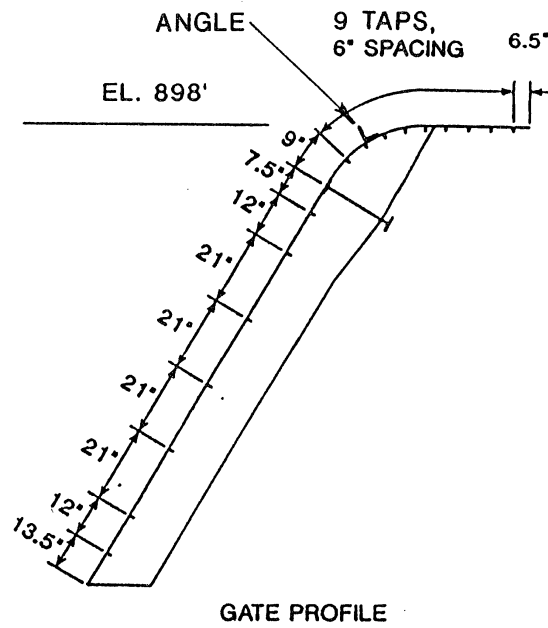


Fig. 24. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R1 Down 10.8 ft

Flow Cond. F.C.	2	3	4	5
H.W. Elev.-ft	900	902	904	906
T.W. Elev.-ft	882.4	884.1	885.3	886.7
Q/gate -cfs	10439	13421	15894	19033
Q(total) -cfs	135700	174480	206620	247430



GATE R2  
 PRESSURE TAP LOCATIONS  
 WISSOTA GATE STUDY

Fig. 25. Gate R2, pressure tap locations.



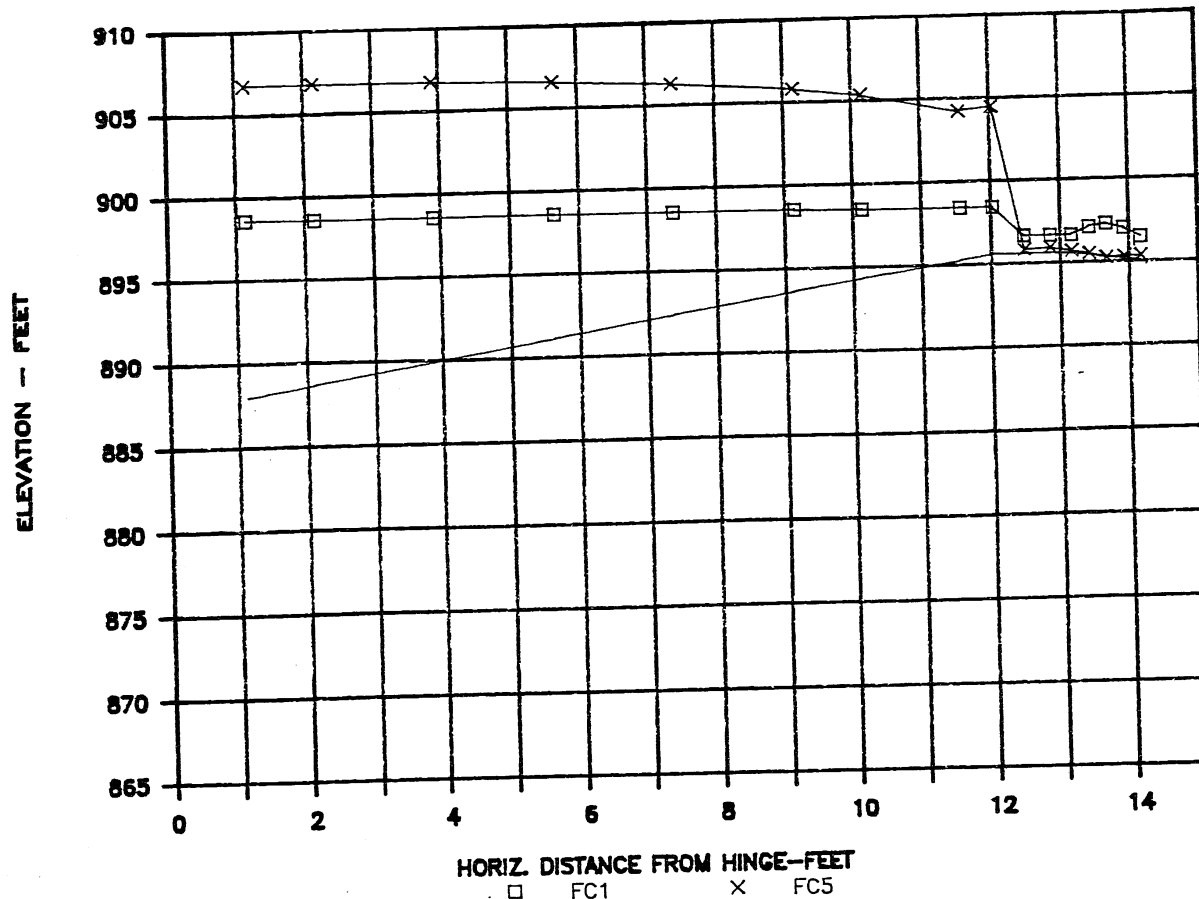


Fig. 26. MISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R2 Down 2 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898          906
T.W. Elev.-ft      870.0        881.3
Q/gate -cfs        773          8830
B(total -cfs       10052        114790
*****
  
```

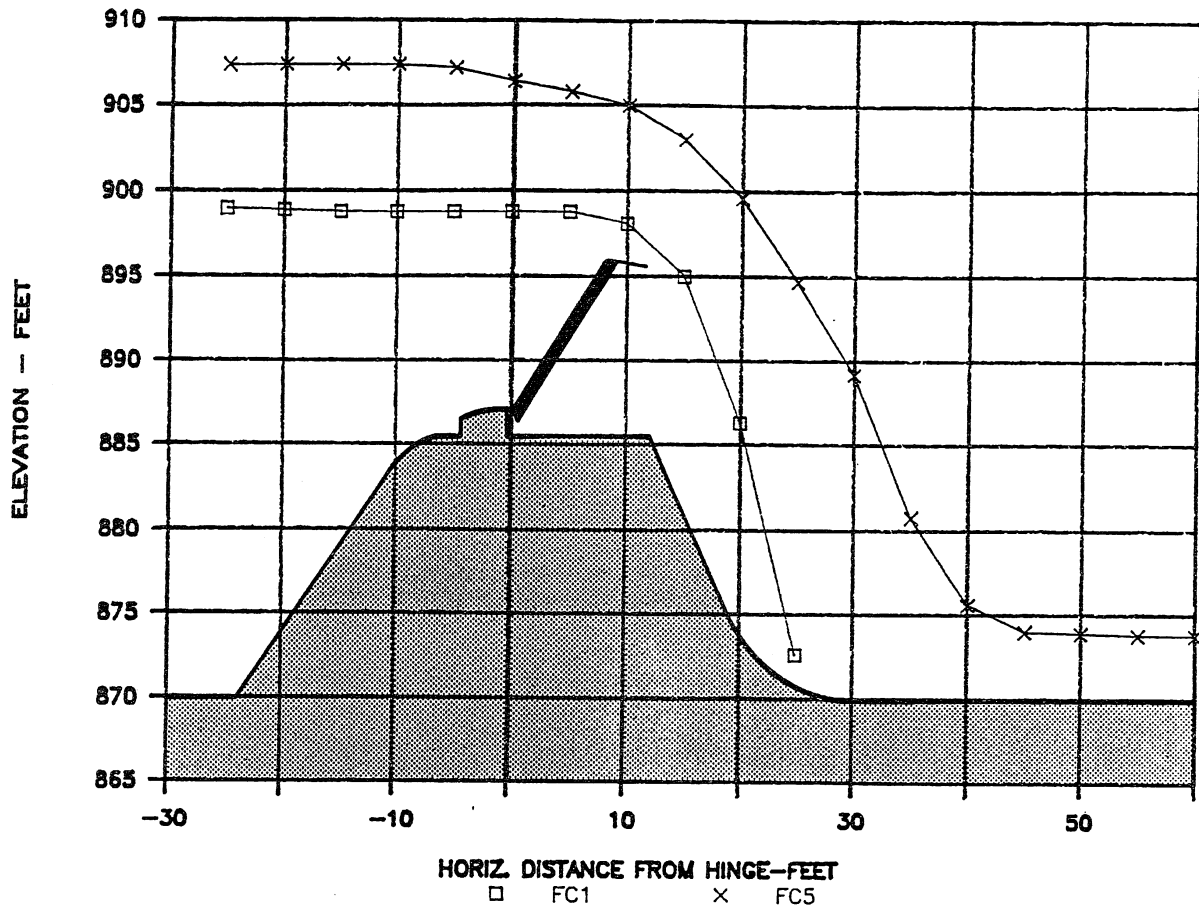


Fig. 27. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R2 Down 2 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft      898    906
T.W. Elev.-ft      870.0  881.3
Q/gate -cfs        773    8830
Q(total) -cfs      10052  114790
*****

```

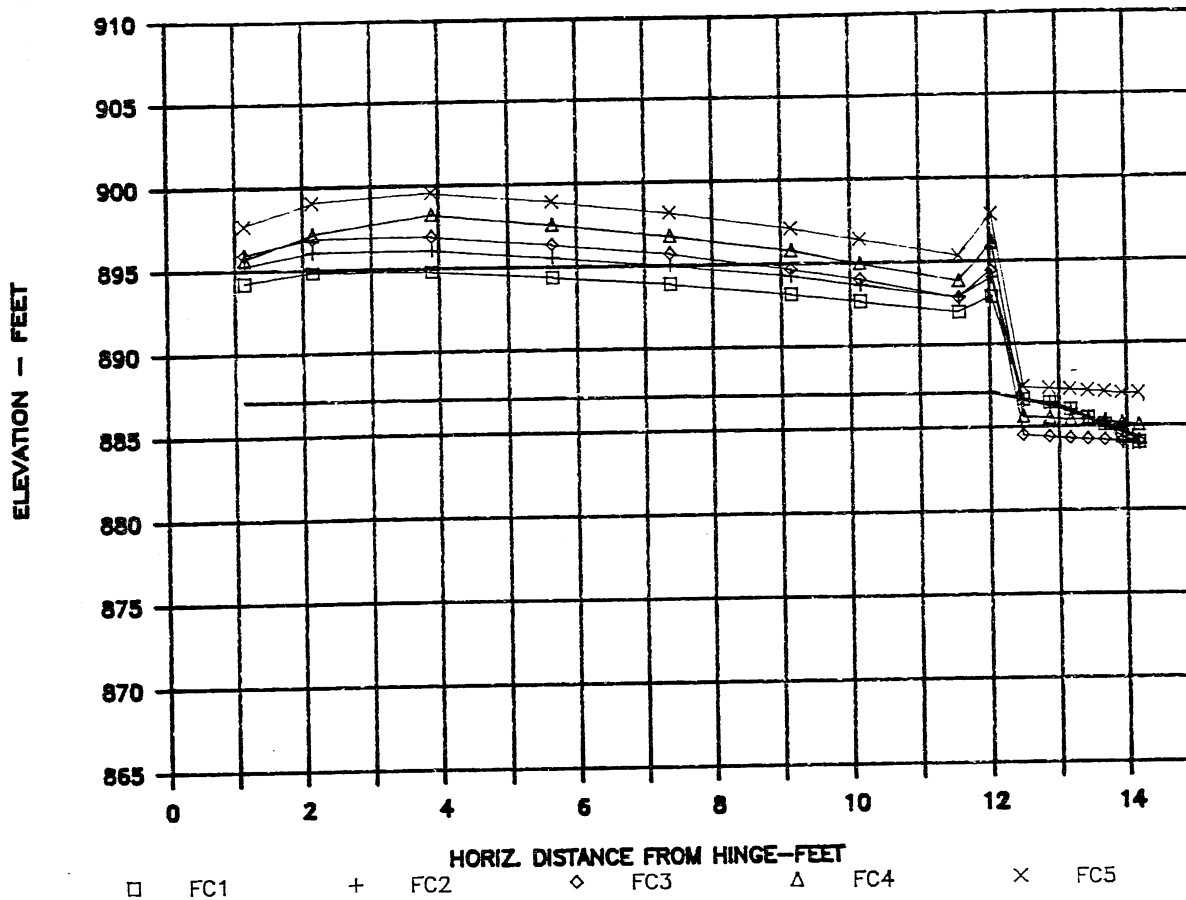


Fig. 28. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R2 Down 10.8 ft

Flow Cond.	F.C.	1	2	3	4	5
H.W. Elev.-ft		898	900	902	904	906
T.W. Elev.-ft		880.1	881.8	883.2	884.8	886.1
Q/gate -cfs		7122	9551	11809	14755	17650
Q(total -cfs		92586	124160	153520	191820	229840

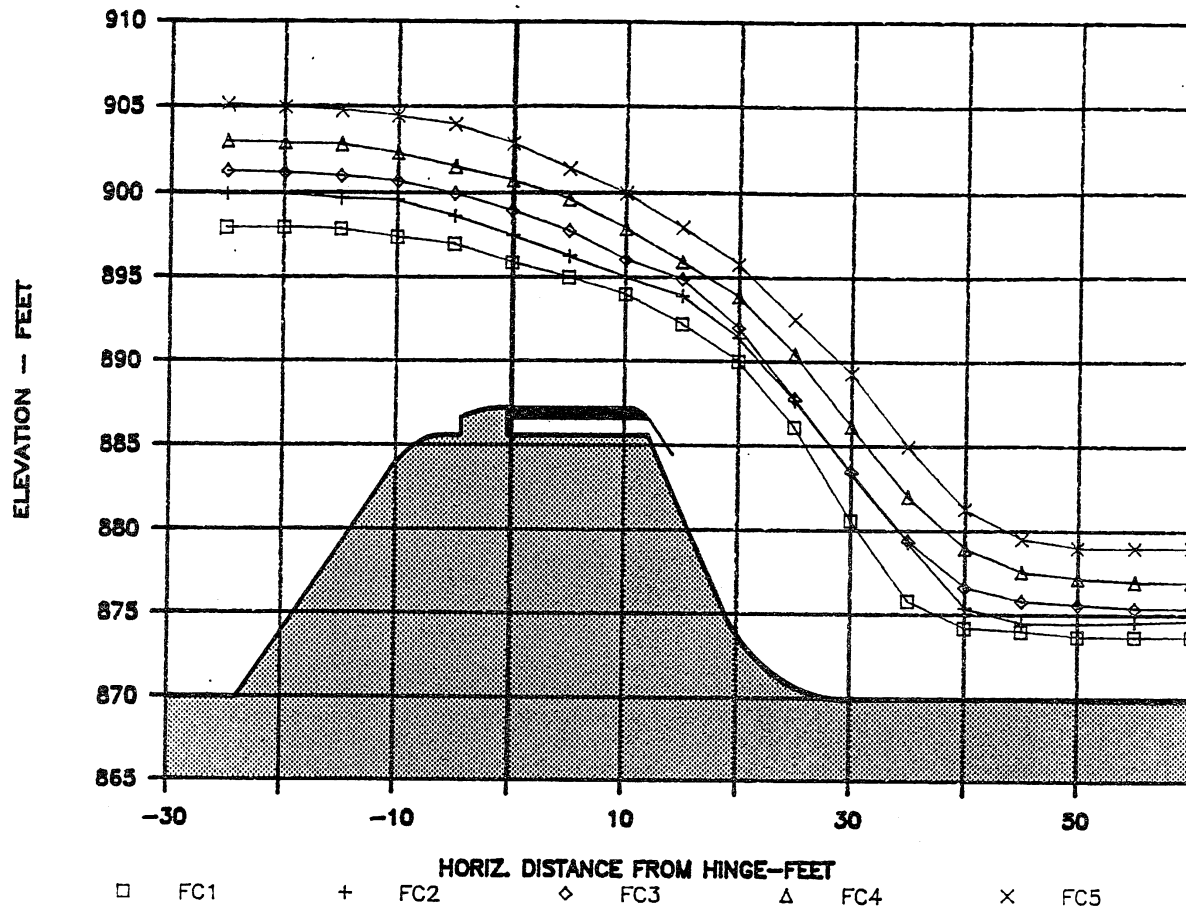


Fig..29. MISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R2 Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898    900    902    904    906
T.W. Elev.-ft      880.1  881.8  883.2  884.8  886.1
Q/gate -cfs        7122   9551  11809  14755  17680
Q(total) -cfs      92586  124160 153520 191820 229940
*****
  
```

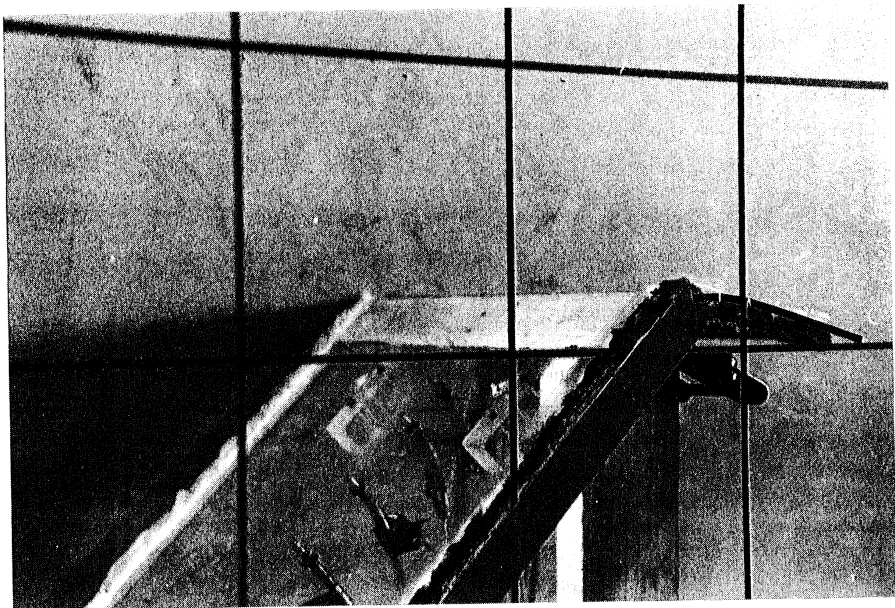
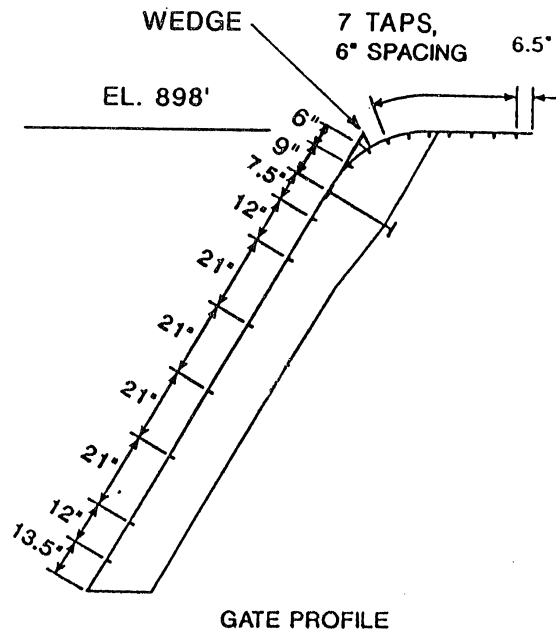


Fig. 30. Photo showing Gate R3.



GATE R3  
 PRESSURE TAP LOCATIONS  
 WISSOTA GATE STUDY

Fig. 31. Gate R3, pressure tap locations.

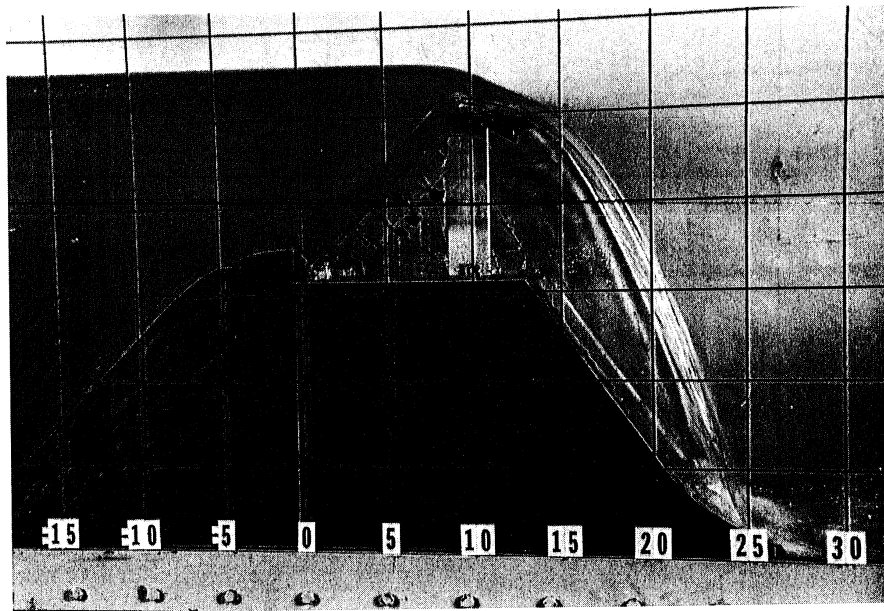


Fig. 32. Photo showing Gate R3 down 2 ft, H.W. elev. = 898 ft, T.W. elev. = 870 ft,  $Q/\text{gate} = 392$  cfs,  $Q$  total = 5102 cfs.

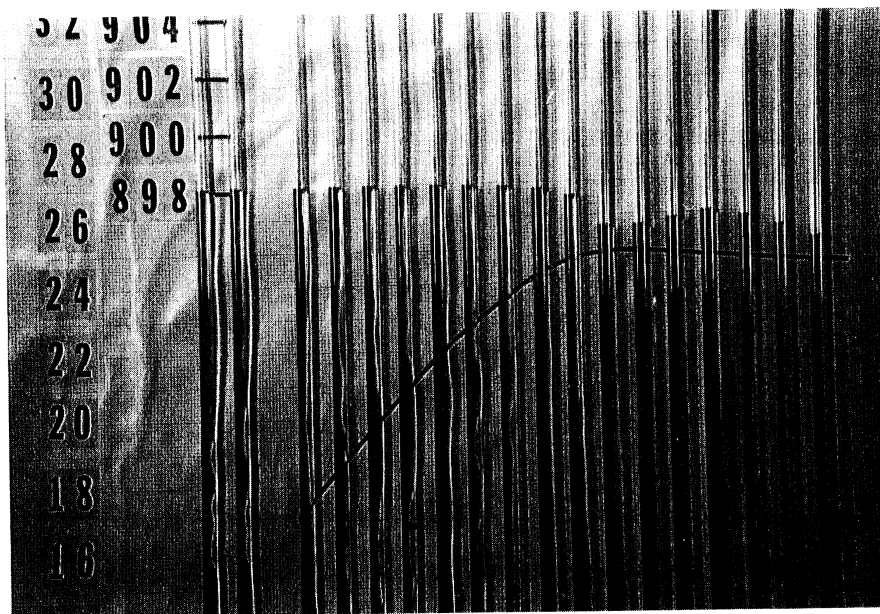


Fig. 33. Photo showing the manometer board with Gate R3 down 2 ft, H.W. elev. = 898 ft, T.W. elev. = 870 ft,  $Q/\text{gate} = 392$  cfs,  $Q$  total = 5102 cfs.

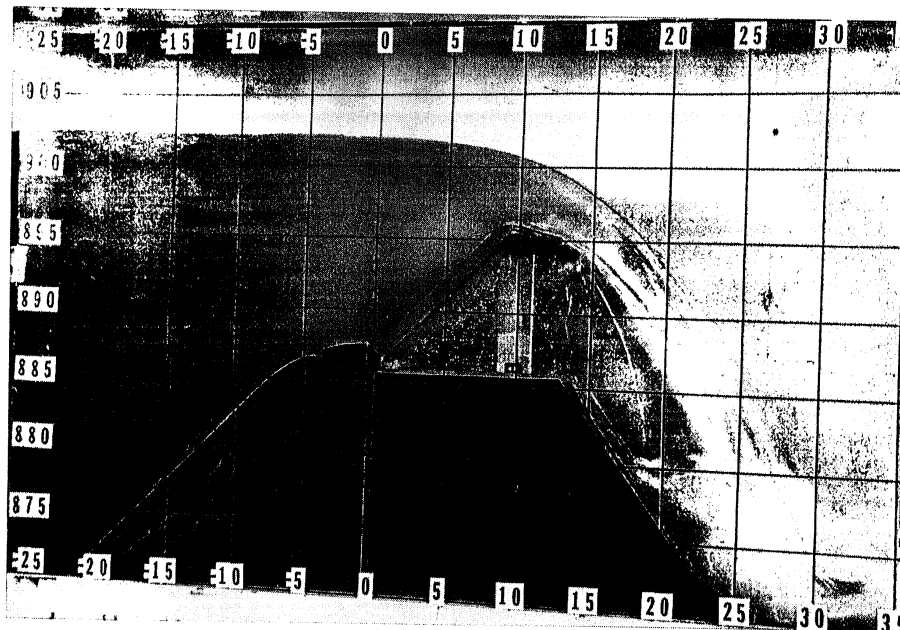


Fig. 34. Photo showing Gate R3 down 2 ft, H.W. elev = 902 ft, T.W. Elev = 875.8 ft,  $Q/\text{gate} = 3728$  cfs,  $Q$  total = 48,466 cfs.

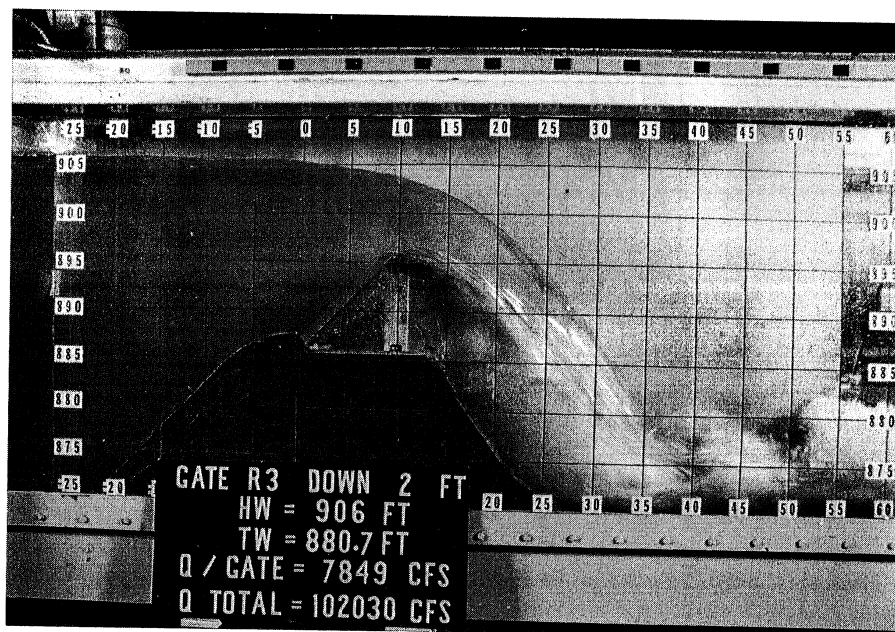
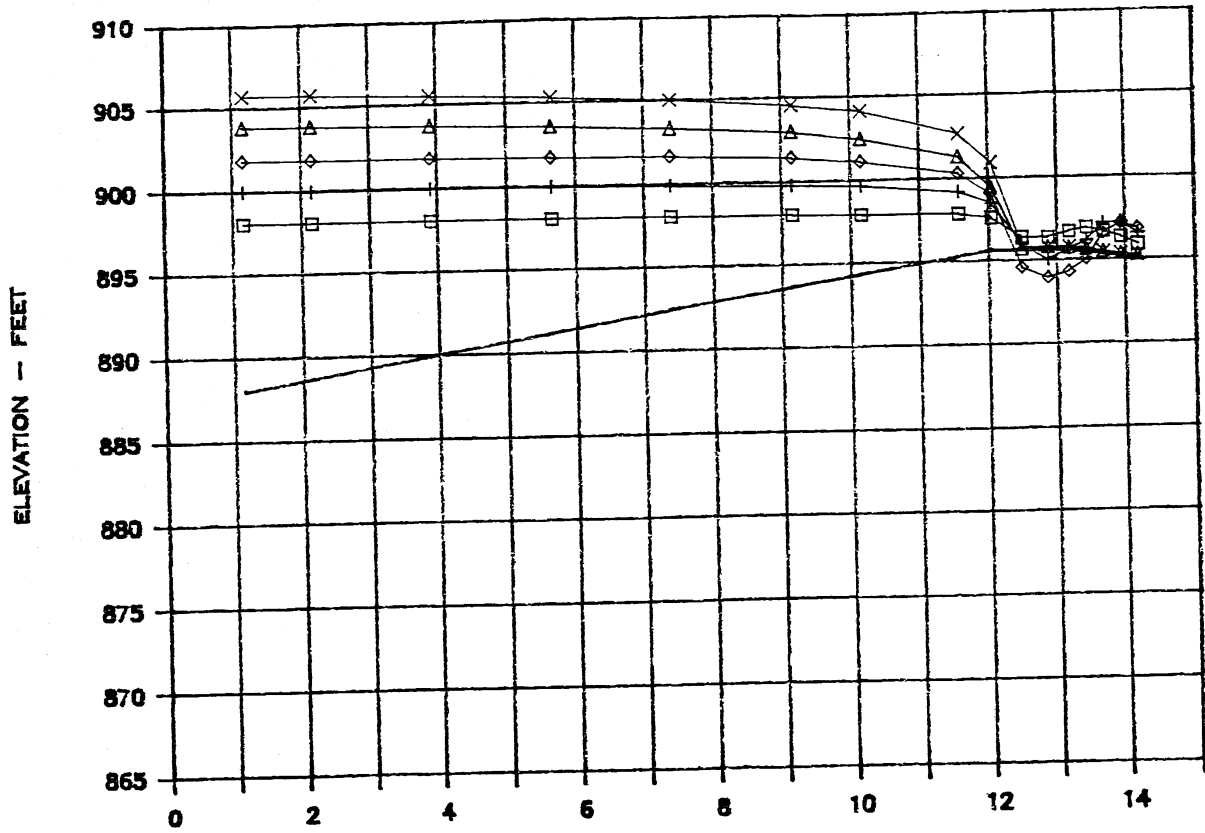


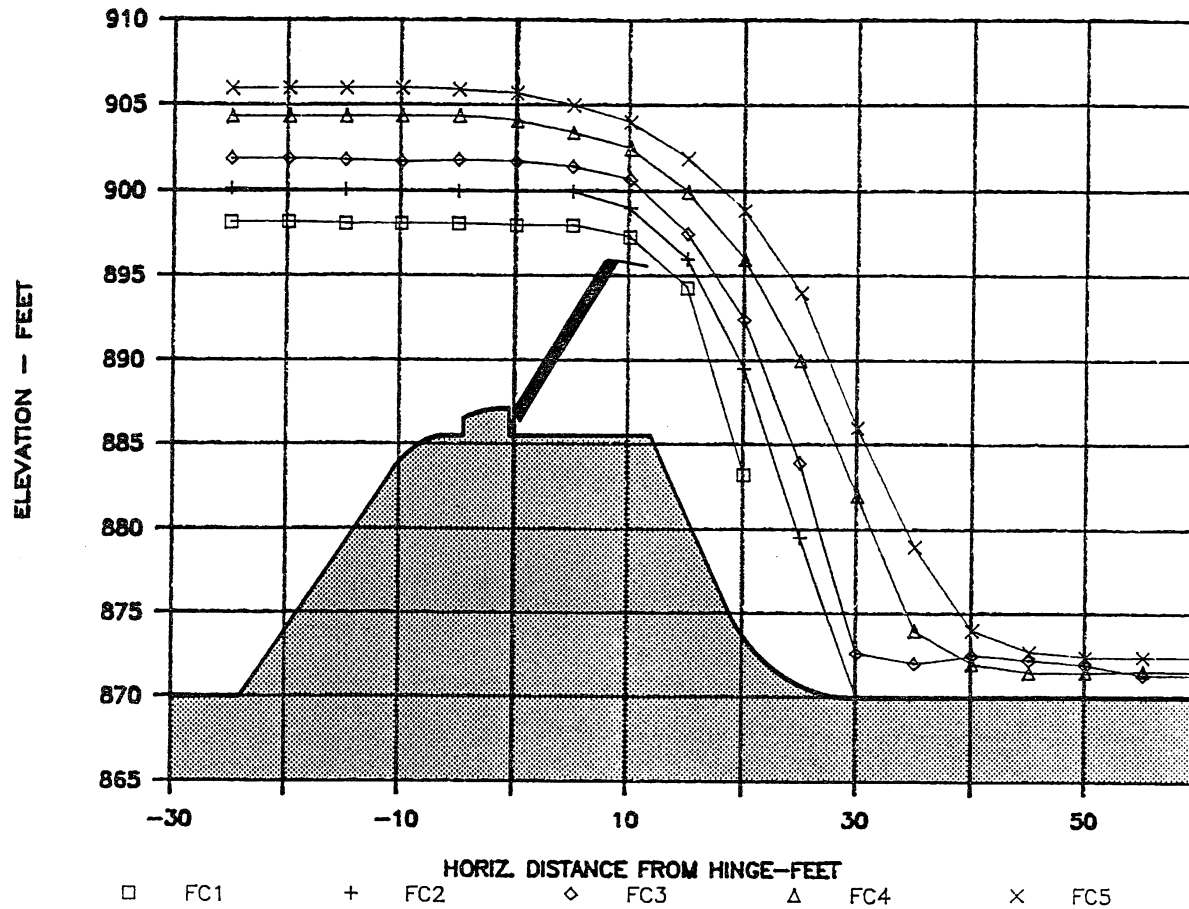
Fig. 35. Photo showing Gate R3 down 2 ft, H.W. elev = 906 ft, T.W. Elev = 880.7 ft,  $Q/\text{gate} = 7849$  cfs,  $Q$  total = 102,030 cfs.





□ FC1      + FC2      ◇ FC3      △ FC4      × FC5  
 Fig. 36. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 2 ft

Flow Cond. F.C.	1	2	3	4	5
H.W. Elev.-ft	898	900	902	904	906
T.W. Elev.-ft	870	872.5	875.8	878.8	880.7
Q/gate -cfs	392	1962	3728	5887	7849
Q(total -cfs)	5102	25508	48466	76525	102033



□ FC1      + FC2      ◇ FC3      △ FC4      × FC5  
 Fig. 37.    WISSOTA DAM GATE TESTS  
              WATER SURFACE PROFILES  
              1:14 Section Model  
              Gate R3 Down 2 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft       898     900     902     904     906
T.W. Elev.-ft       870     872.5   875.8   878.8   880.7
Q/gate -cfs         392     1962    3728    5887    7849
Q(total) -cfs       5102    25508   48466   76525   102033
*****
  
```

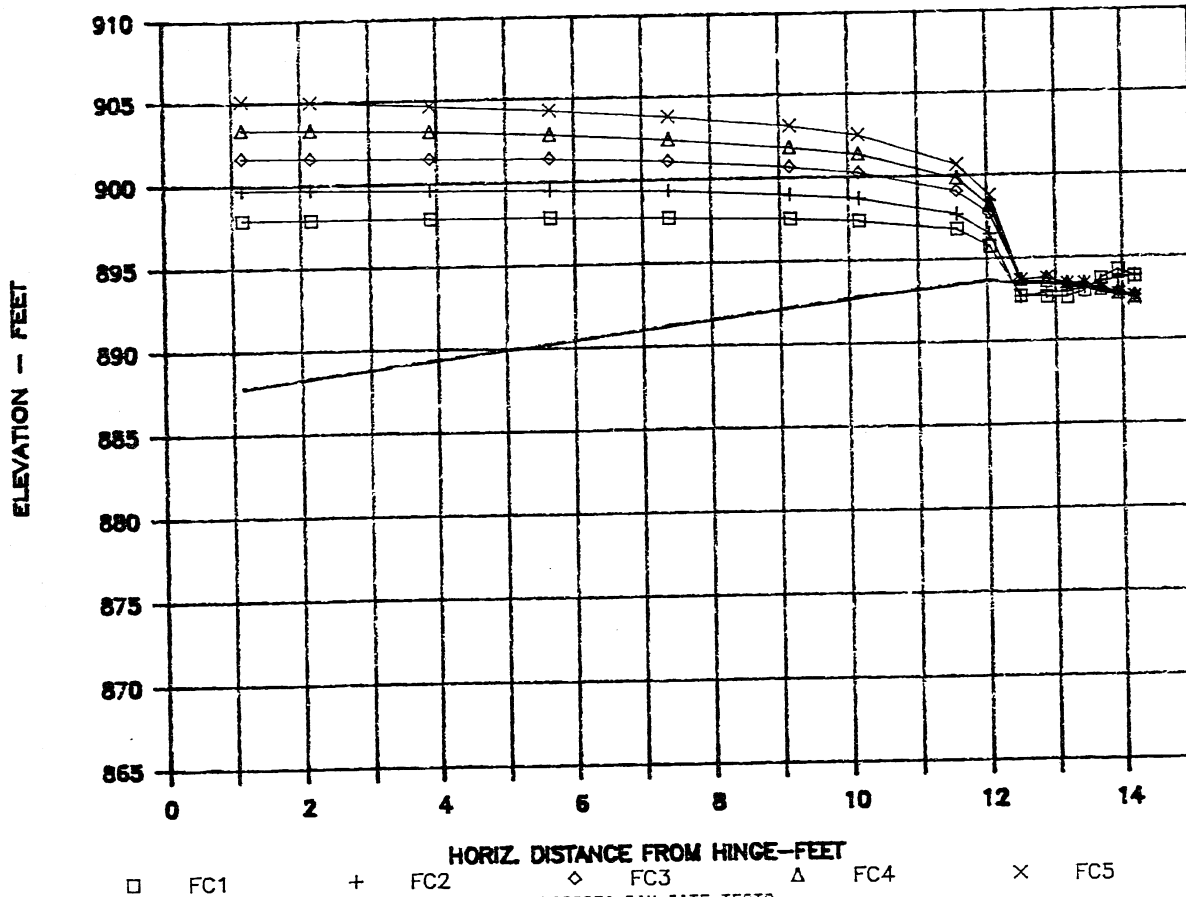


Fig. 38. WIGGOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 4 ft

	1	2	3	4	5	6
Flow Cond. F.C.	1	2	3	4	5	6
H.W. Elev.-ft	898	900	902	904	906	896
T.W. Elev.-ft	870.0	875.5		880.8	882.0	
Q/gate -cfs	2040	3650	5769	7731	9772	620
Q(total) -cfs	26529	47446	74995	100500	127030	8061

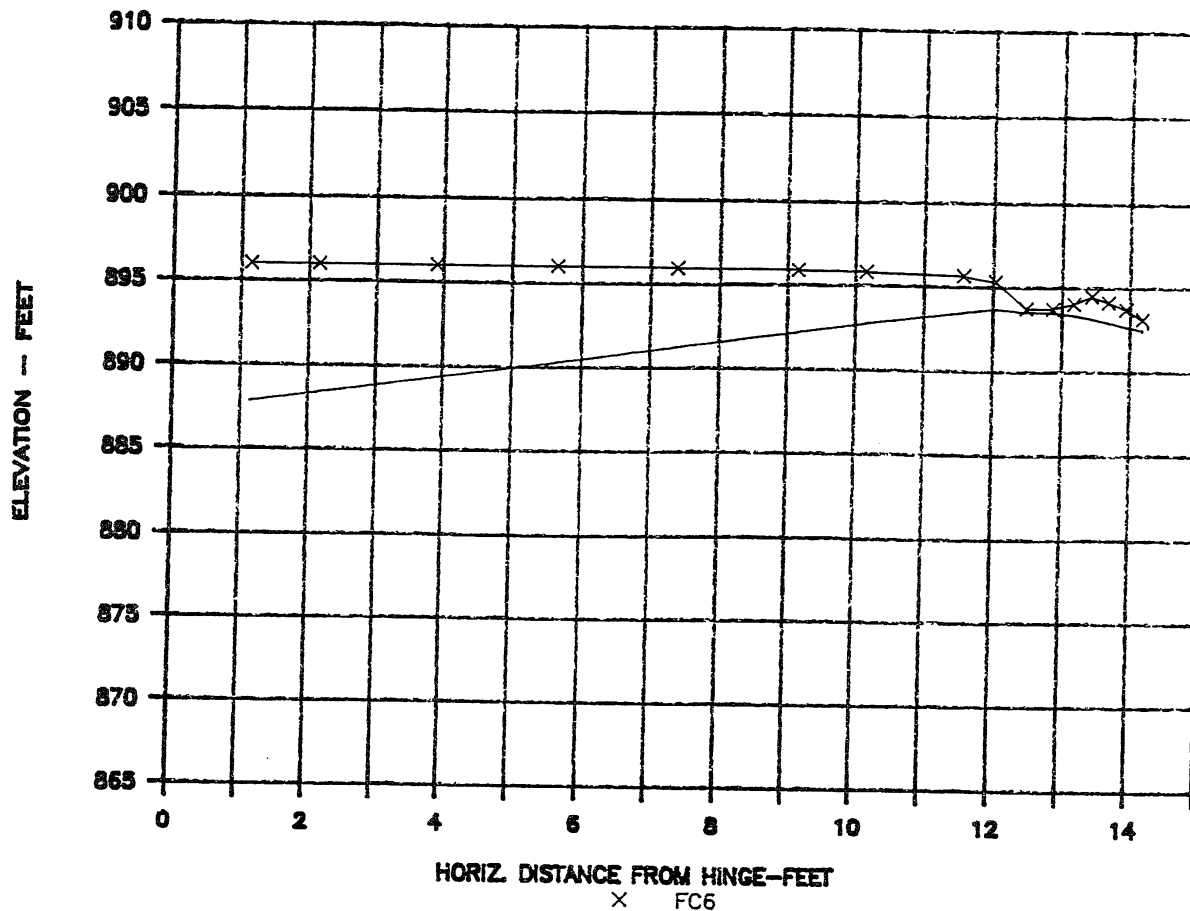
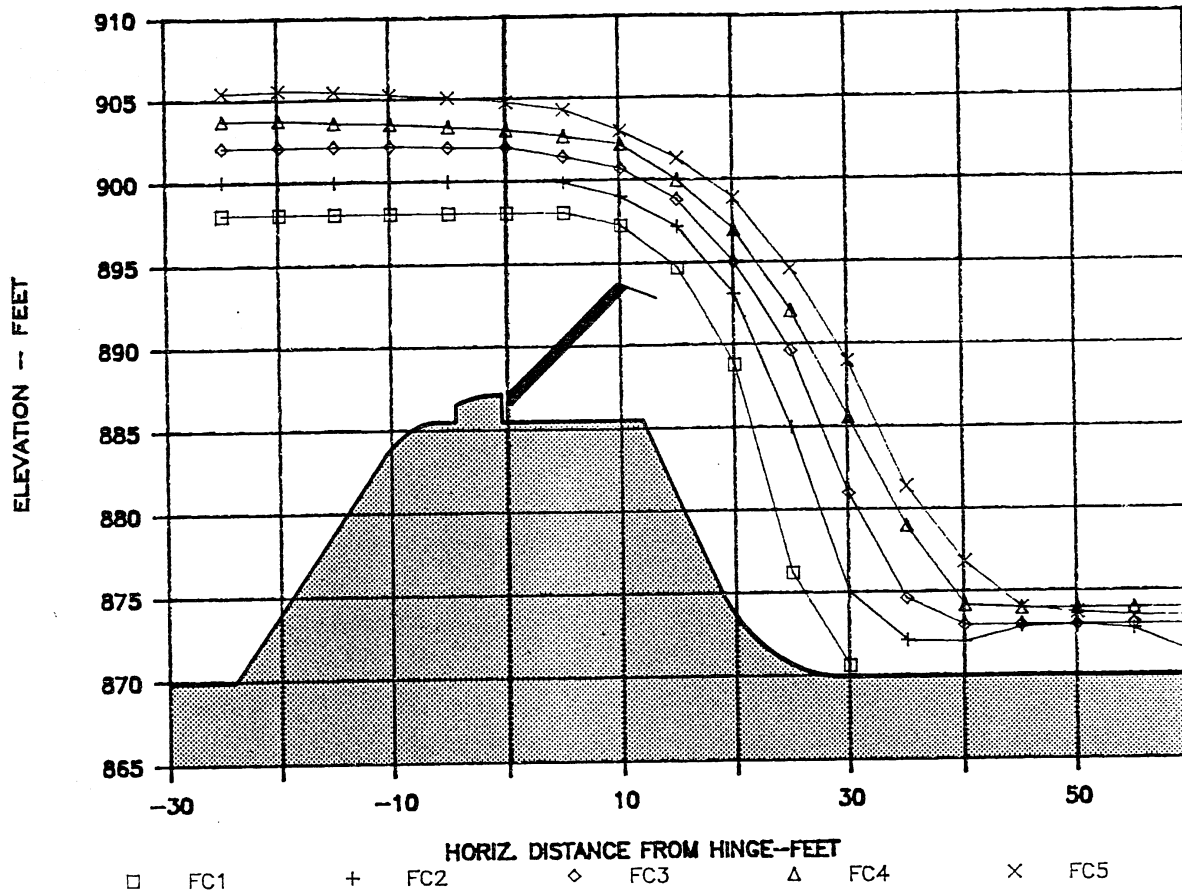


Fig. 39. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 4 ft

Flow Cond. F.C.	1	2	3	4	5	6
H.W. Elev.-ft	898	900	902	904	906	896
T.W. Elev.-ft	870.0	875.5		880.8	882.0	
Q/gate -cfs	2040	3650	5769	7731	9772	620
Q(total) -cfs	26529	47446	74995	100500	127030	8061



HORIZ. DISTANCE FROM HINGE--FEET

□ FC1      + FC2      ◇ FC3      △ FC4      × FC5

Fig. 40. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 4 ft

Flow Cond. F.C.	1	2	3	4	5	6
H.W. Elev.-ft	898	900	902	904	906	896
T.W. Elev.-ft	870.0	875.5		880.8	882.0	
Q/gate -cfs	2040	3650	5769	7731	9772	620
Q(total) -cfs	26529	47446	74995	100500	127030	8061

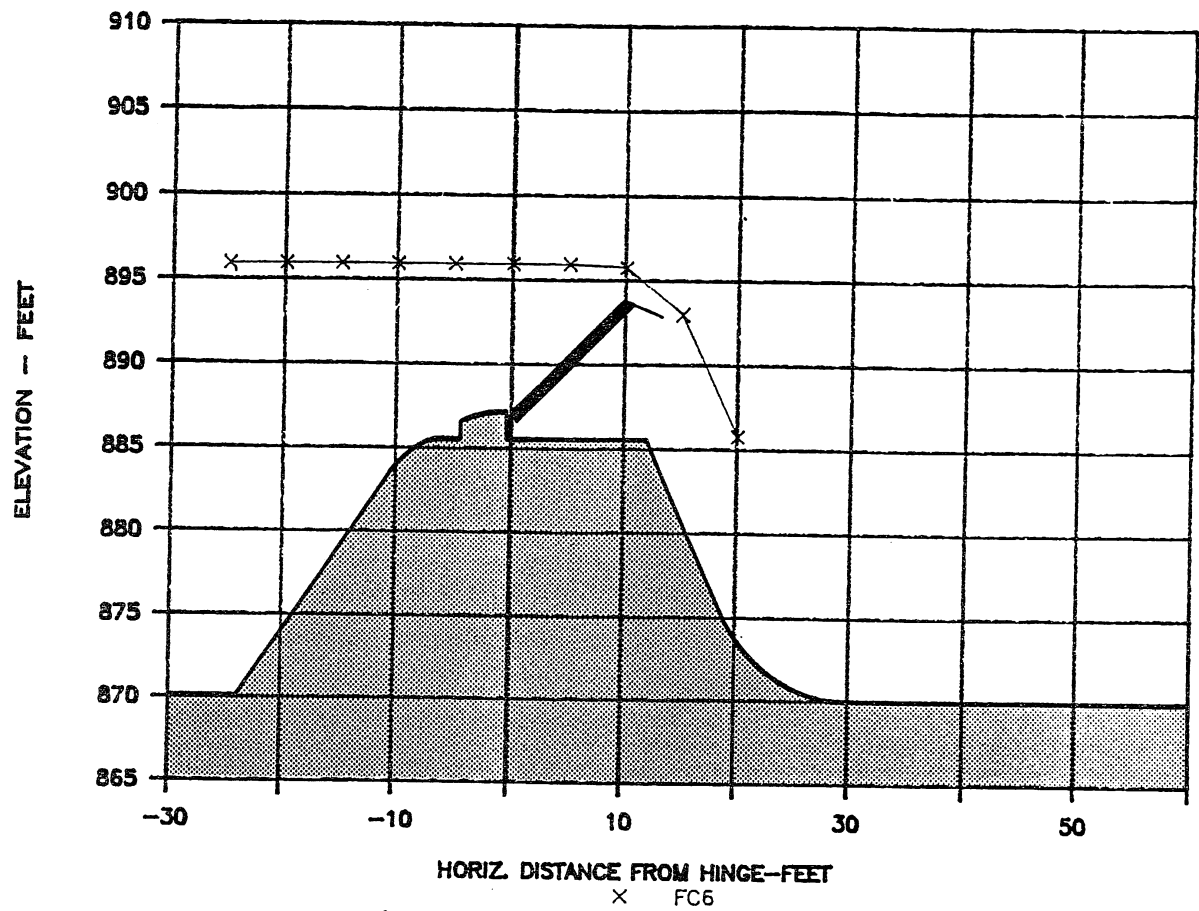


Fig. 41. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 4 ft

	1	2	3	4	5	6
Flow Cond. F.C.	1	2	3	4	5	6
H.W. Elev.-ft	898	900	902	904	906	896
T.W. Elev.-ft	870.0	875.5		880.8	882.0	
Q/gate -cfs	2040	3650	5769	7731	9772	620
Q(total) -cfs	26529	47446	74995	100500	127030	8061

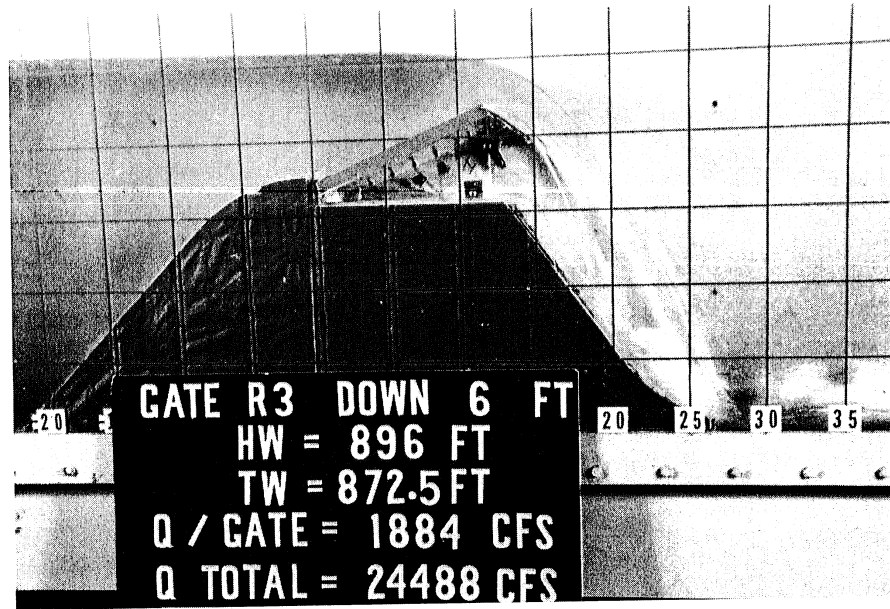


Fig. 42. Photo showing Gate R3 down 6 ft, H.W. elev. = 896 ft., T.W. elev = 872.5 ft,  $Q/gate = 1884$  cfs,  $Q$  total = 24,488 cfs.

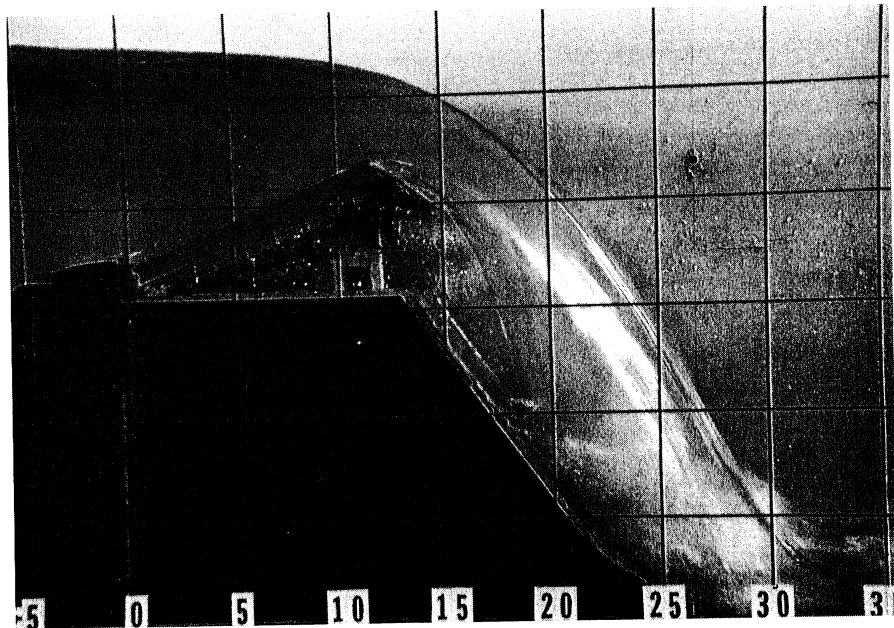


Fig. 43. Photo showing Gate R3 down 6 ft, H.W. elev. = 898 ft., T.W. elev = 875 ft,  $Q/gate = 3453$  cfs,  $Q$  total = 44,895 cfs.

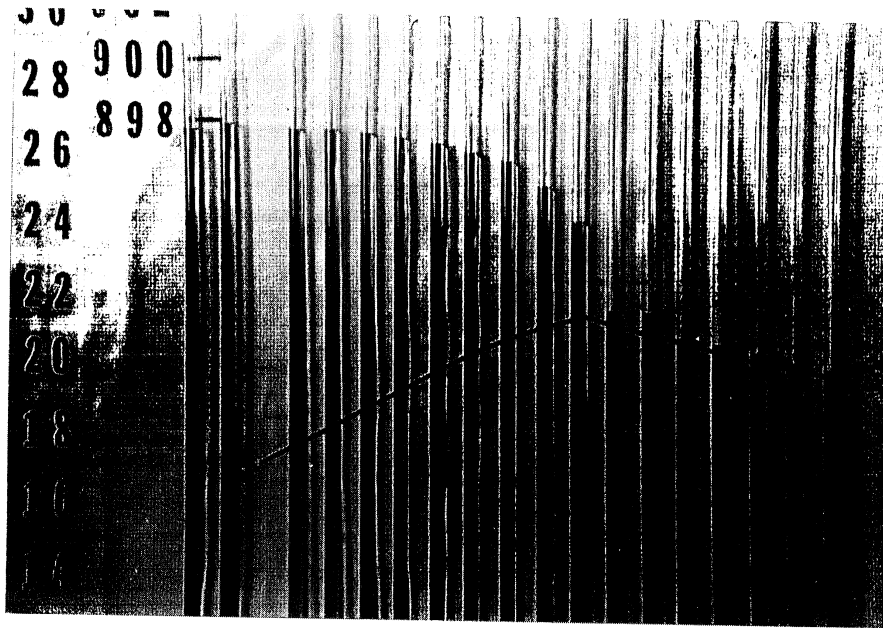


Fig. 44. Photo showing the manometer board with gate R3 down 6 ft, H. W. elev = 898 ft, T.W. elev. = 875 ft.  $Q/\text{gate} = 3453$  cfs,  $Q$  total = 44,895 cfs.

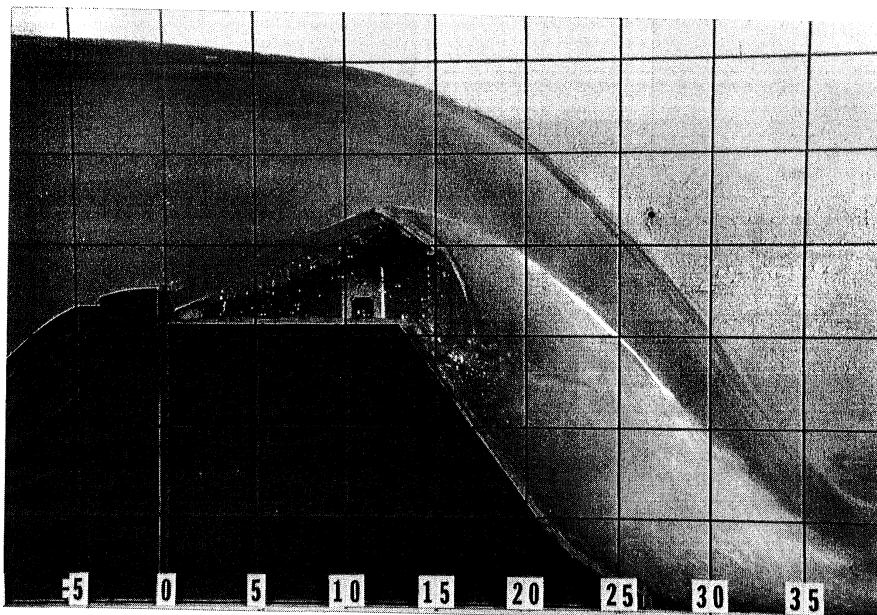


Fig. 45. Photo showing Gate R3 down 6 ft, H.W. elev = 902 ft, T.W. elev = 880.7 ft,  $Q/\text{gate} = 7,888$  cfs,  $Q$  total = 102,540 cfs.



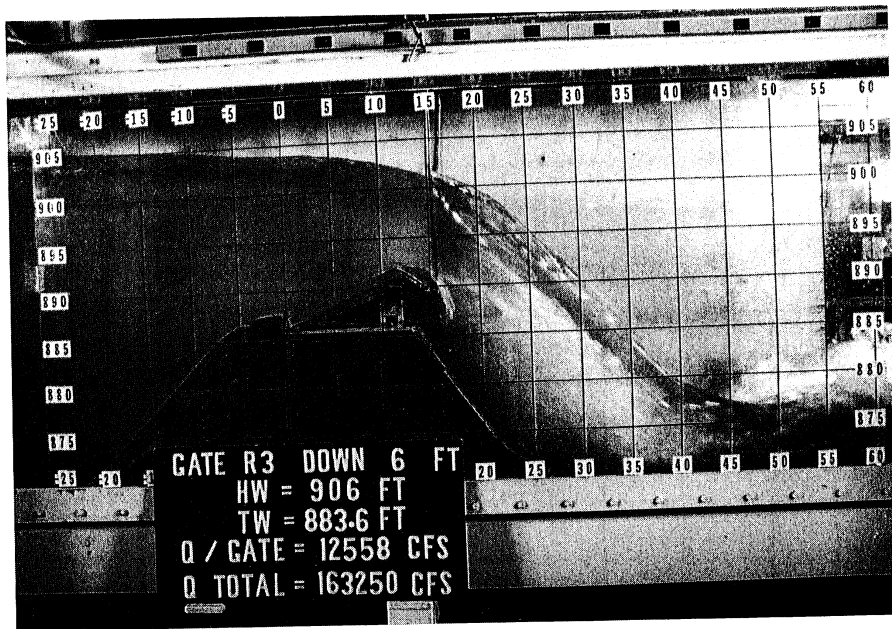


Fig. 46. Photo showing Gate R3 down 6 ft, H.W. elev = 906 ft, T.W. elev = 883.6 ft, Q/gate = 12,558 cfs, Q total = 163,250 cfs.

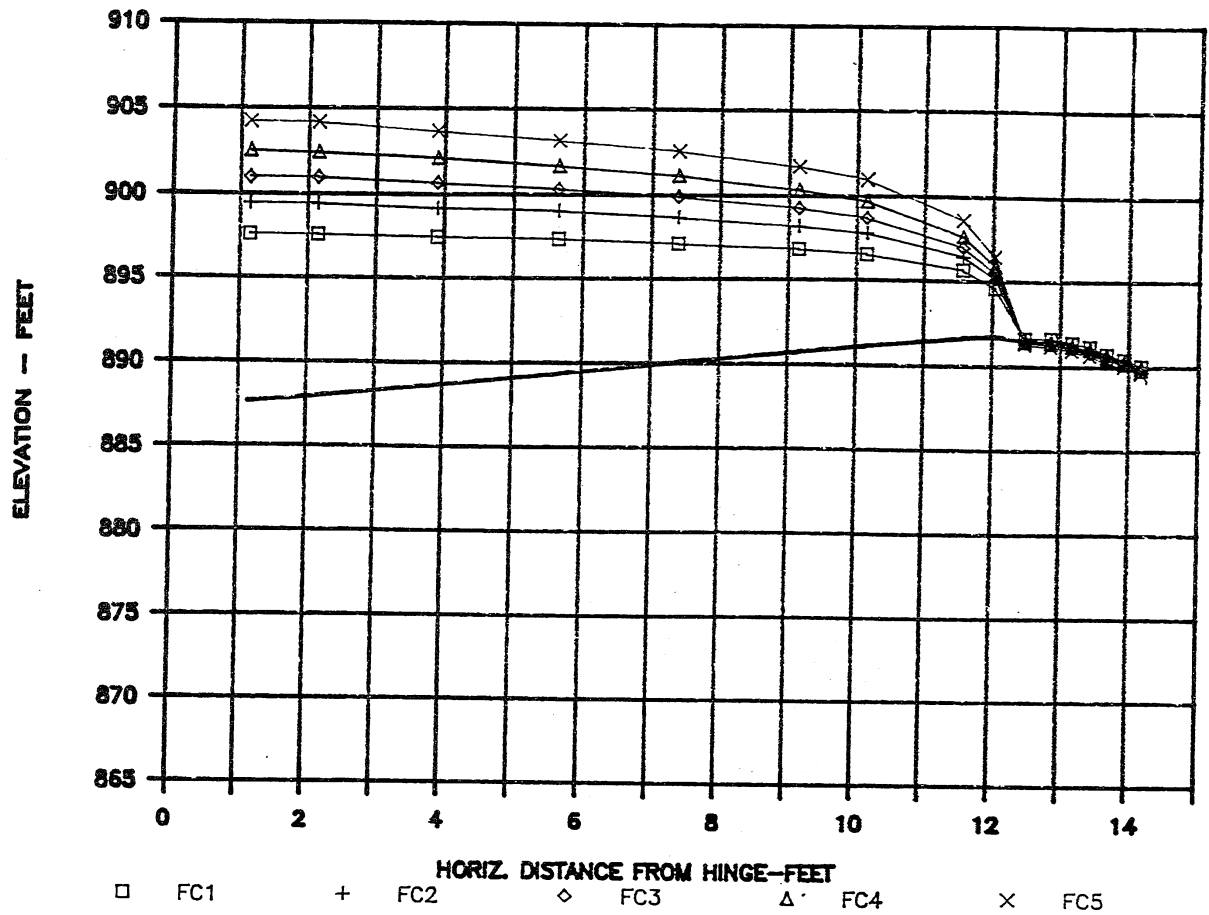


Fig. 47. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 6 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5      6      7
H.W. Elev.-ft      898     900     902     904     906     896     894
T.W. Elev.-ft      875.0  878.8  880.7  882.2  883.6  872.5
Q/gate -cfs        3453   5769   7888   10125  12558  1884    620
Q(total) -cfs      44895  74995  102540 131620 163250 24488   8061
*****
  
```

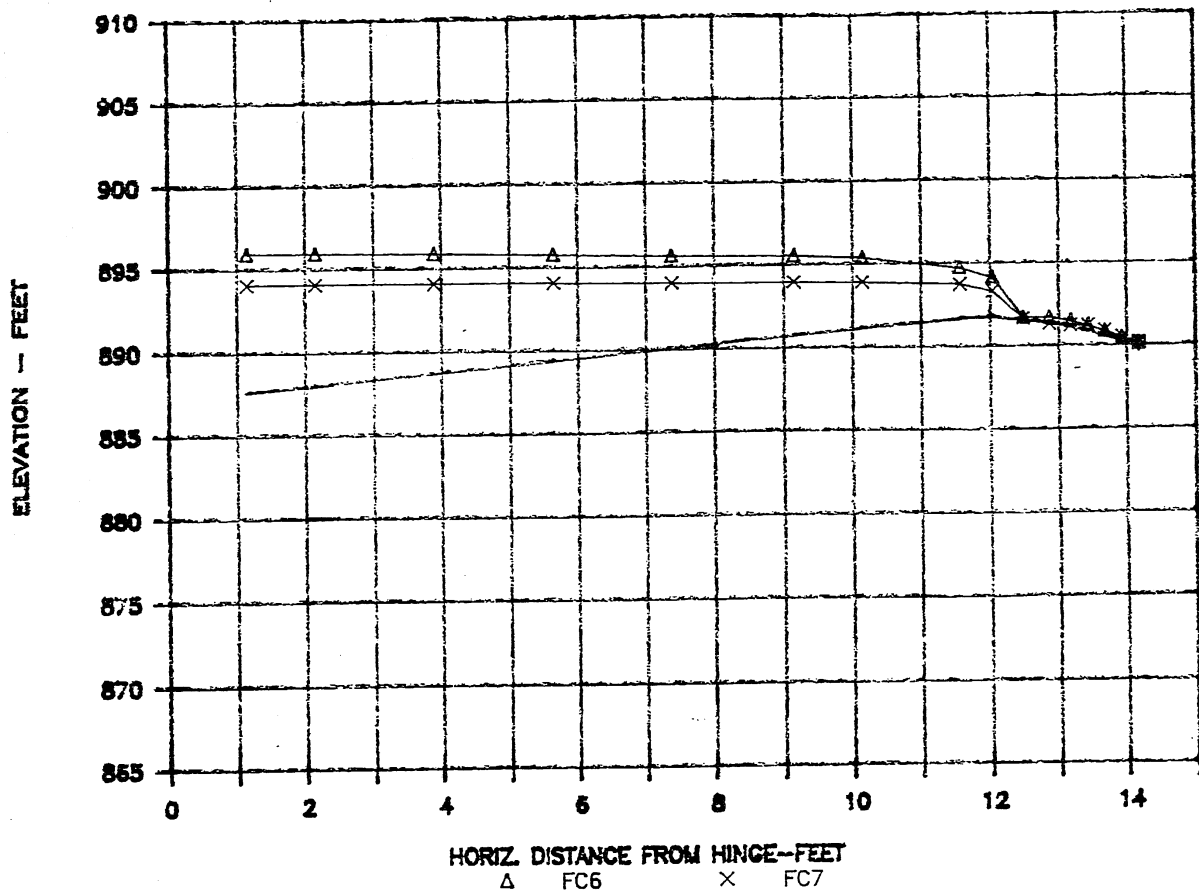


Fig. 48. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 6 ft

Flow Cond. F.C.	1	2	3	4	5	6	7
H.W. Elev.-ft	898	900	902	904	906	896	894
T.W. Elev.-ft	875.0	878.8	880.7	882.2	883.6	872.5	
Q/gate -cfs	3453	5769	7888	10125	12558	1884	620
Q(total) -cfs	44895	74995	102540	131620	163250	24488	8061

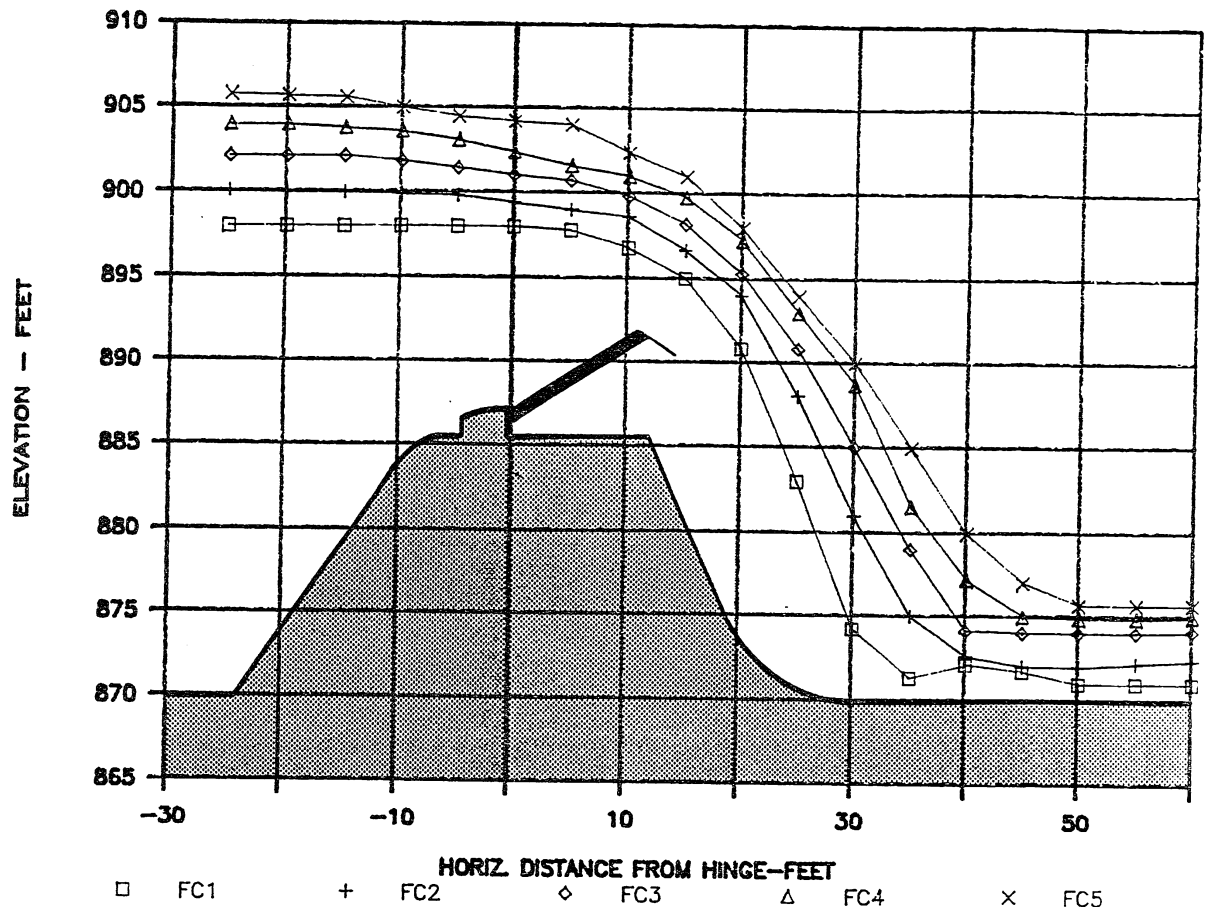


Fig. 49. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 6 ft

Flow Cond. F.C.	1	2	3	4	5	6	7
H.W. Elev.-ft	898	900	902	904	906	896	894
T.W. Elev.-ft	875.0	878.8	880.7	882.2	883.6	872.5	
Q/gate -cfs	3453	5769	7888	10125	12558	1884	620
Q(total) -cfs	44895	74995	102540	131620	163250	24488	8061

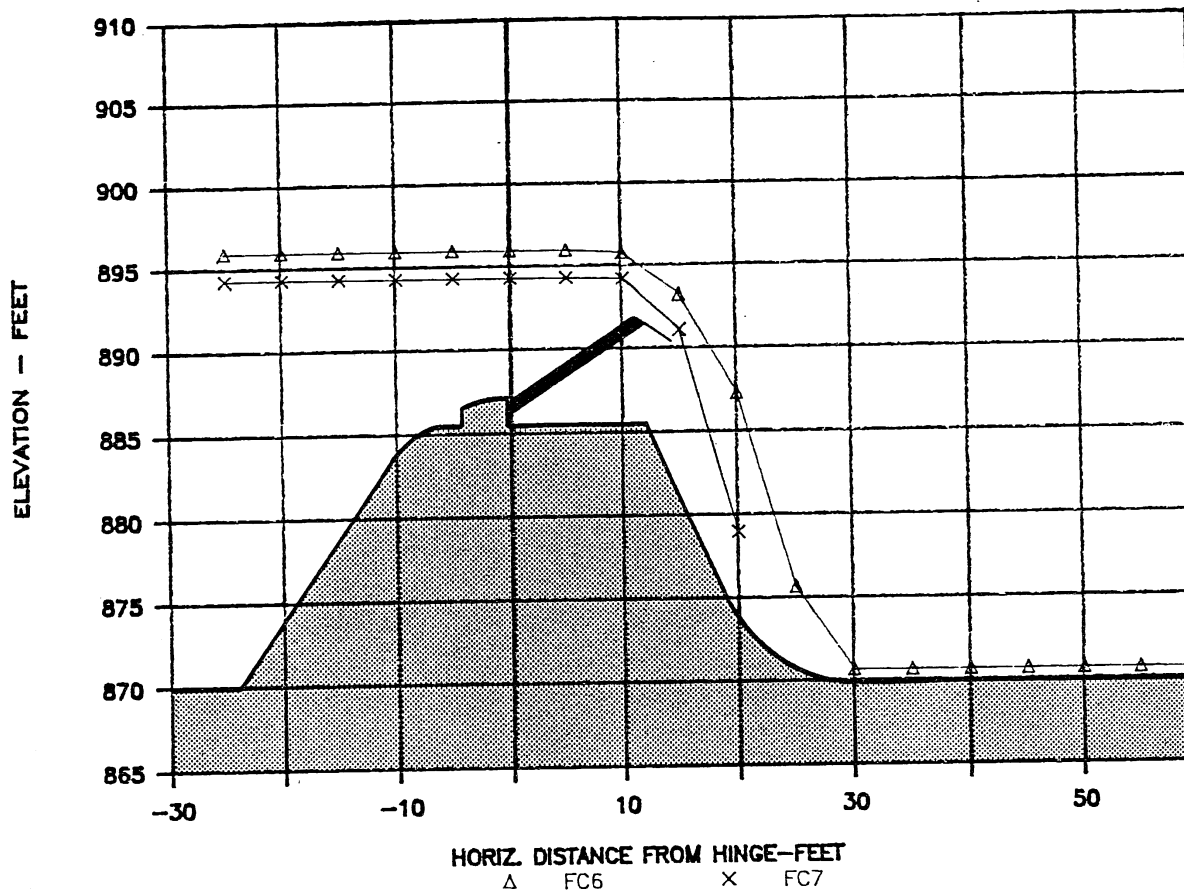
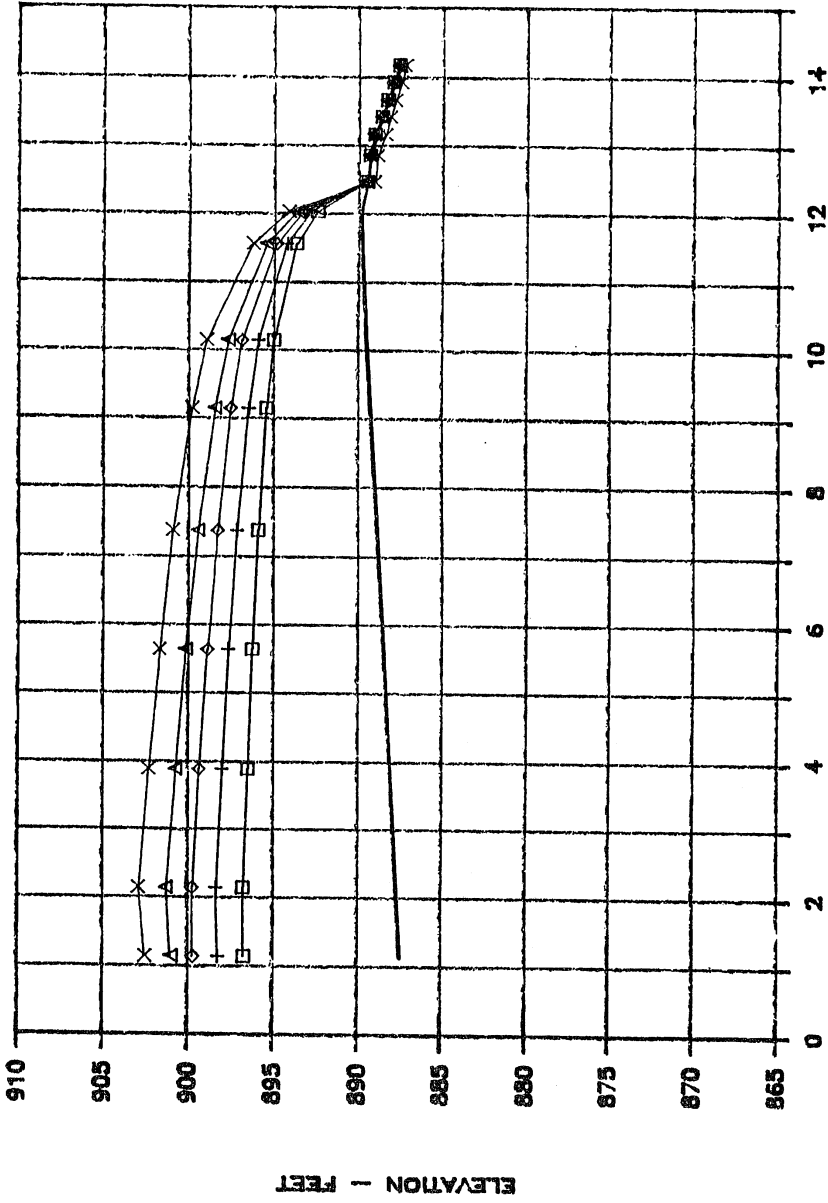


Fig. 50. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 6 ft

Flow Cond. F.C.	1	2	3	4	5	6	7
H.W. Elev.-ft	898	900	902	904	906	896	894
T.W. Elev.-ft	875.0	878.8	880.7	882.2	883.6	872.5	
Q/gate -cfs	3453	5769	7888	10125	12558	1884	620
Q(total) -cfs	44895	74995	102540	131620	163250	24488	8061



□ FC1 + FC2 ◇ FC3 △ FC4 × FC5

Fig. 51. MISSOURI DAM GATE TESTS  
 PRESSURE PIPE PRESSURE HEAD  
 114 Section Model  
 Gate 53 Down 8 ft

Flow Cond.	F.C.	1	2	3	4	5	6	7	8
H.W. Elev.-ft		898	900	902	904	906	896	894	892
T.W. Elev.-ft		878.3	880.4	882.0	883.5	884.8	875.5	872.6	870.0
Q/gate -cfs		5375	7535	9693	12283	14913	3591	1370	691
Q(total) -cfs		69893	97952	126010	159680	193860	46680	25510	8979

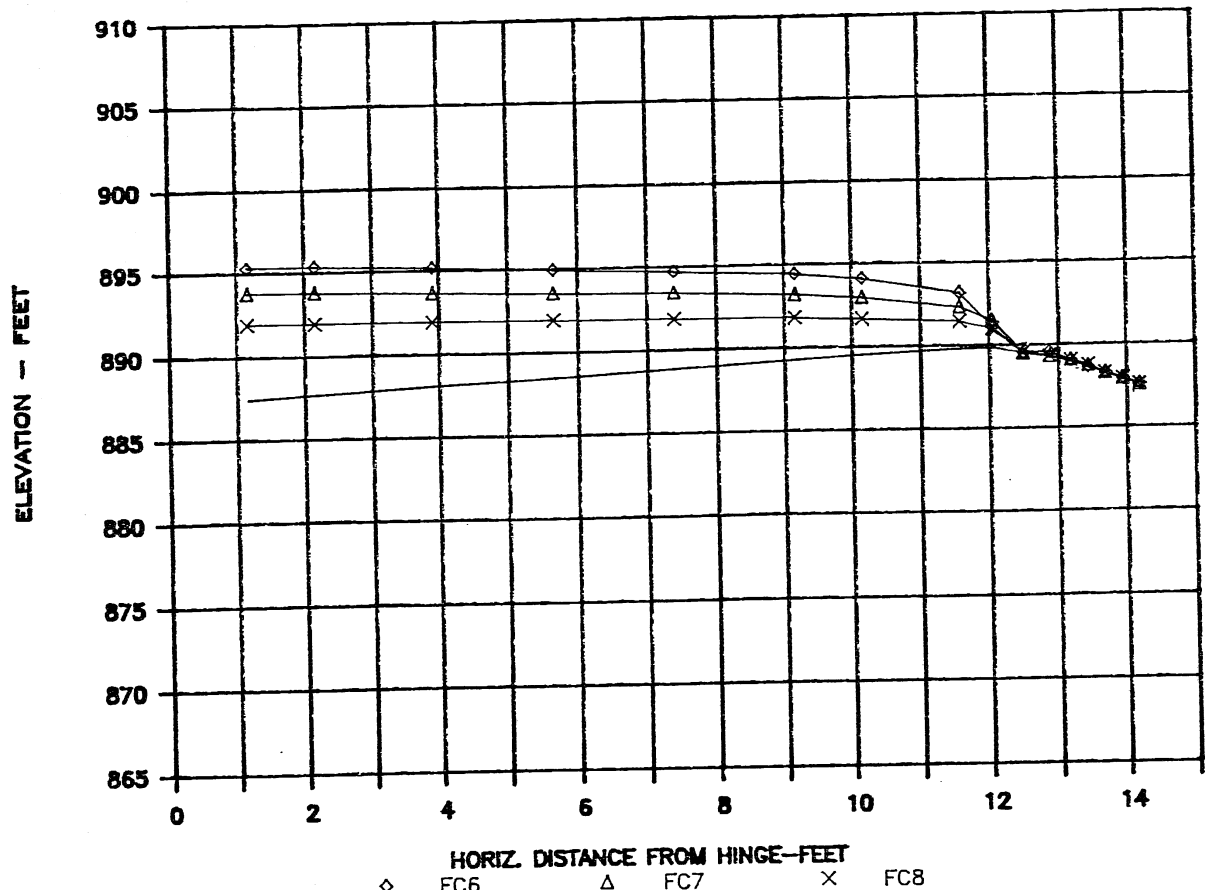
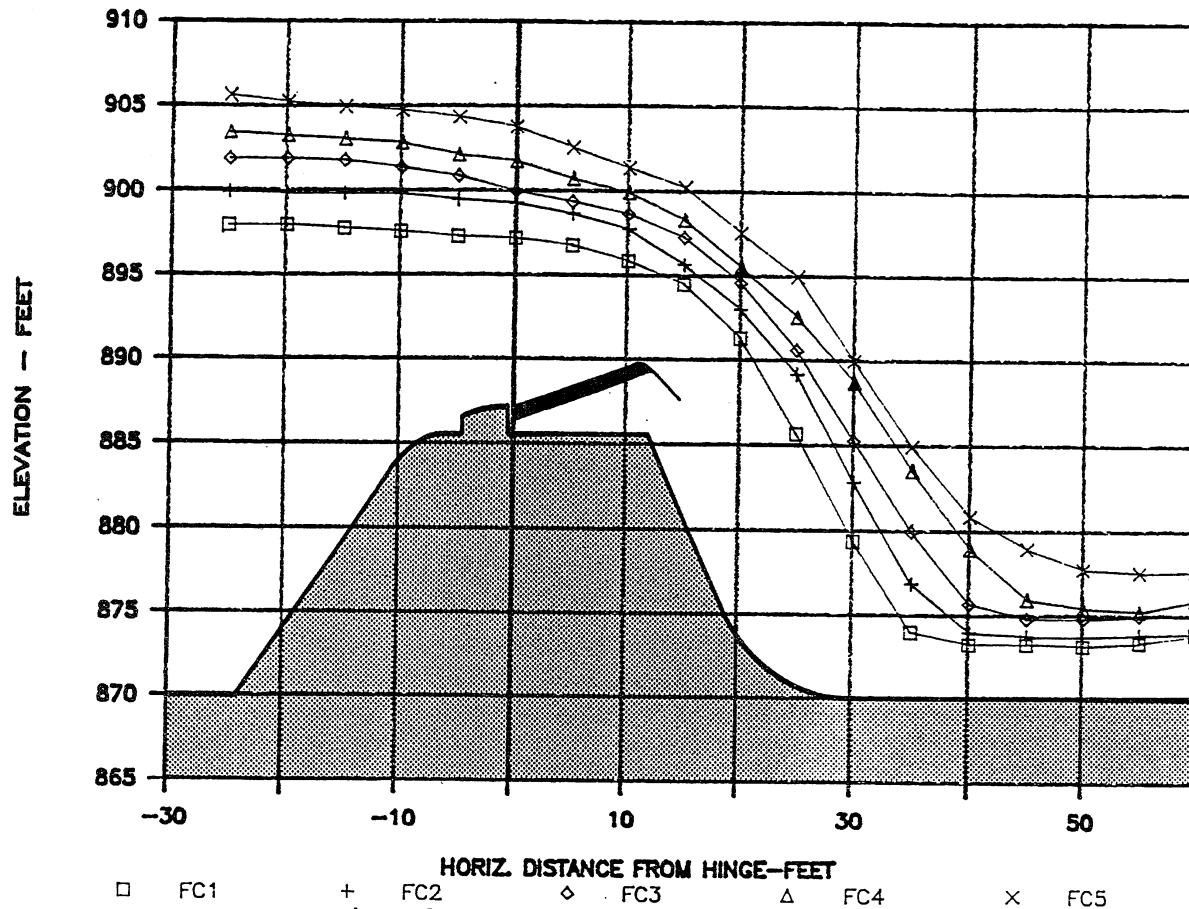


Fig. 52. MISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 8 ft

Flow Cond. F.C.	1	2	3	4	5	6	7	8
H.W. Elev.-ft	898	900	902	904	906	896	894	892
T.W. Elev.-ft	878.3	880.4	882.0	883.5	884.8	875.5	872.6	870.0
Q/gate -cfs	5376	7535	9693	12283	14913	3591	1970	691
Q(total) -cfs	69893	97952	126010	159680	193860	46680	25610	8979



□ FC1      + FC2      ◇ FC3      △ FC4      × FC5  
 Fig. 53.      WISSOTA DAM GATE TESTS  
                  WATER SURFACE PROFILES  
                  1:14 Section Model  
                  Gate R3 Down 8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5      6      7      8
H.W. Elev.-ft      898     900     902     904     906     896     894     892
T.W. Elev.-ft      878.3  880.4  882.0  883.5  884.8  875.5  872.6  870.0
Q/gate -cfs        5376   7535   9693  12283  14913  3591   1970    691
Q(total) -cfs      69893  97952 126010 159680 193860 46680  25610   8979
*****
  
```



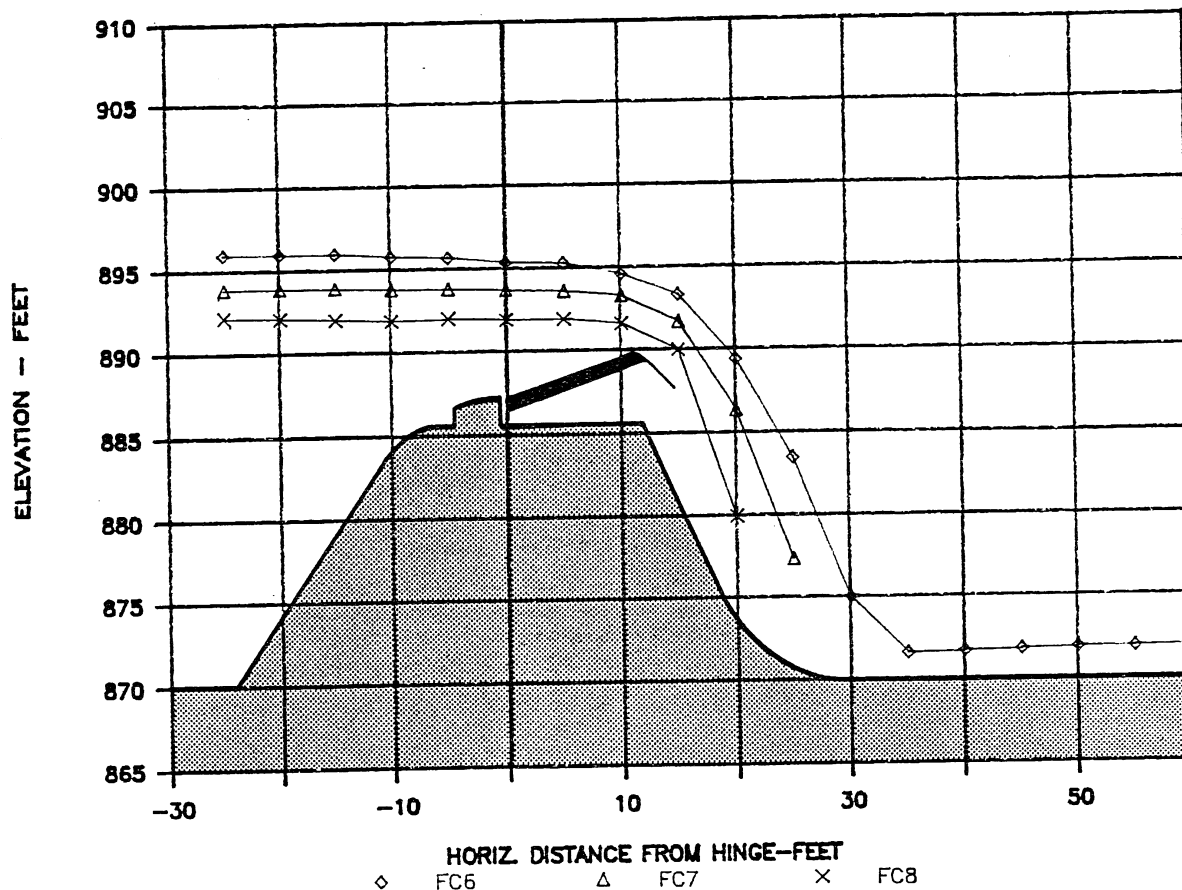


Fig. 54. WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 8 ft

Flow Cond. F.C.	1	2	3	4	5	6	7	8
H.W. Elev.-ft	898	900	902	904	906	896	894	892
T.W. Elev.-ft	878.3	880.4	882.0	883.5	884.8	875.5	872.6	870.0
Q/gate -cfs	5376	7535	9693	12283	14913	3591	1970	691
Q(total) -cfs	69893	97952	126010	159680	193860	46680	25610	8979

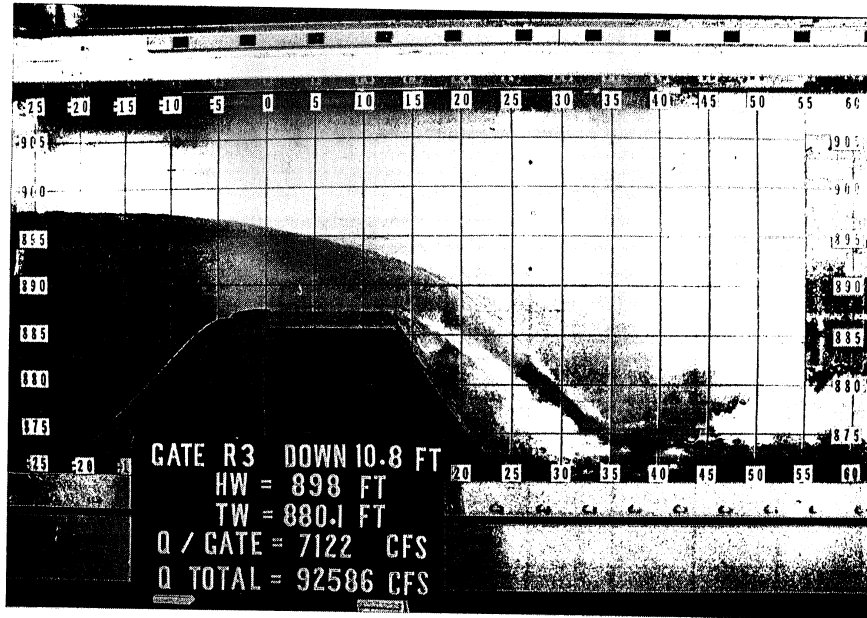


Fig. 55. Photo showing Gate R3 down 10.8 ft, H.W. elev = 898 ft, T.W. elev = 880.1 ft, Q/gate = 7122 cfs, Q total 92,586 cfs.

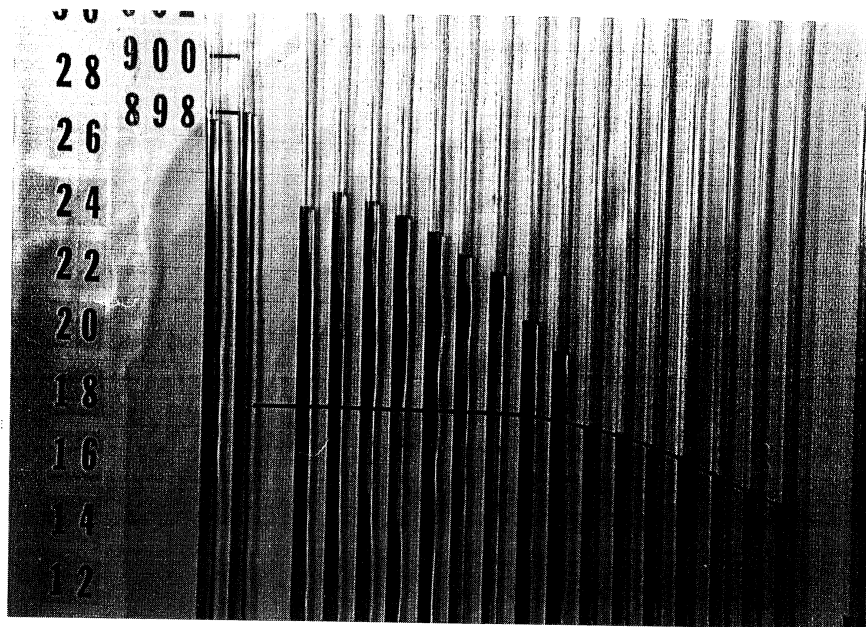


Fig. 56. Photo showing manometer board with gate R3 down 10.8 ft, H.W. elev = 898 ft, T.W. = 880.1 ft, Q/gate = 7122 cfs, Q total = 92,586 cfs.

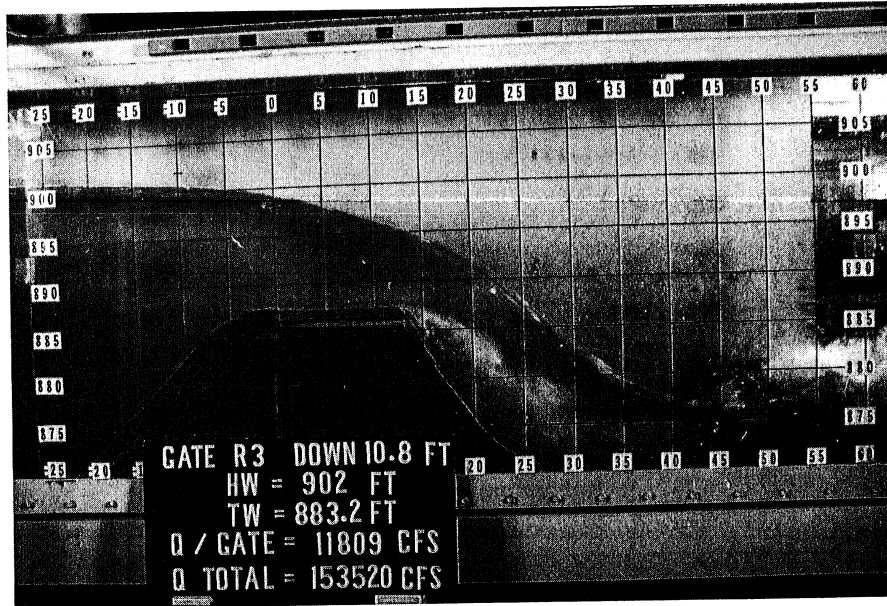


Fig. 57. Photo showing Gate R3 down 10.8 ft, H.W. elev. = 902 ft, T.W. elev. = 883.2 ft,  $Q/\text{gate} = 11,809$  cfs,  $Q$  total = 153,520 cfs.

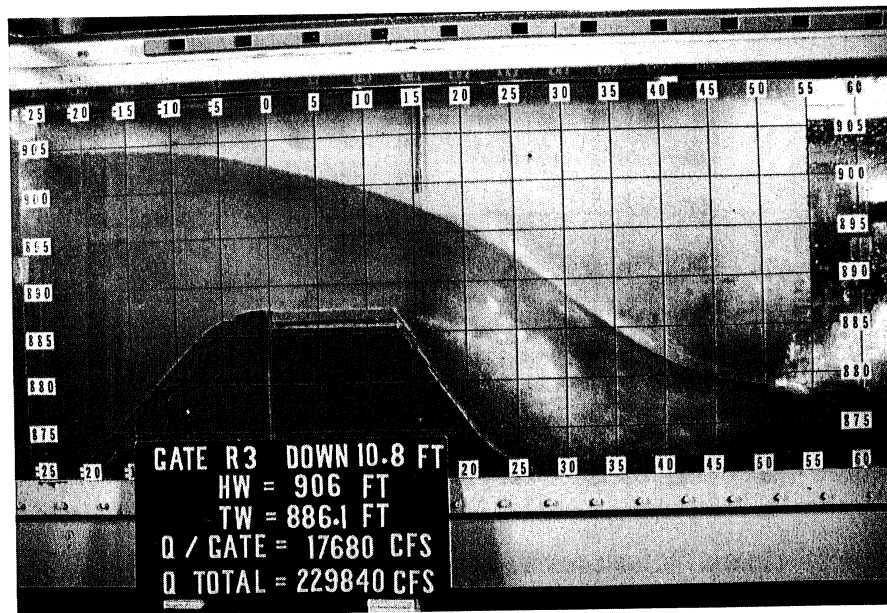


Fig. 58. Photo showing Gate R3 down 10.8 ft, H.W. elev. = 906 ft, T.W. elev. = 886.1 ft,  $Q/\text{gate} = 17,680$  cfs,  $Q$  total = 229,840 cfs.

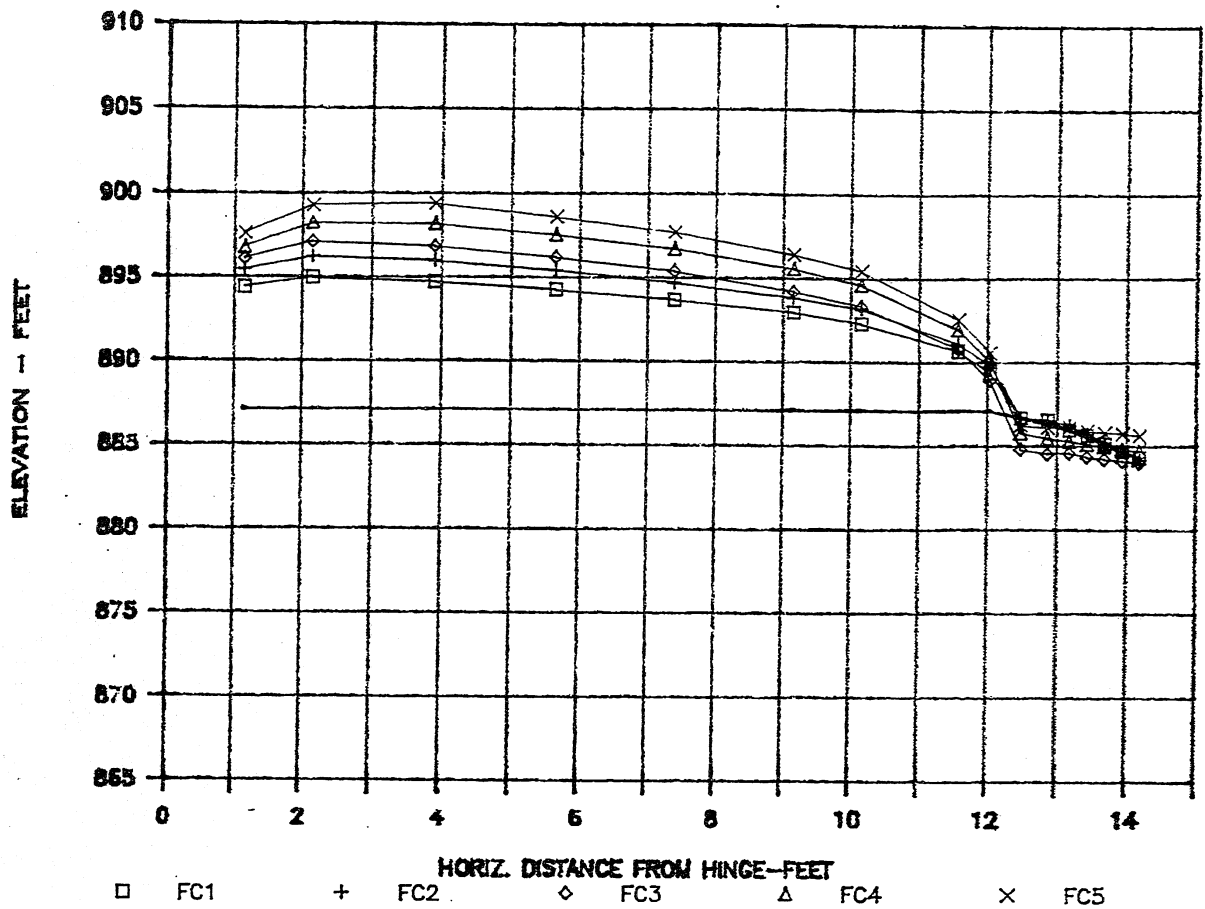
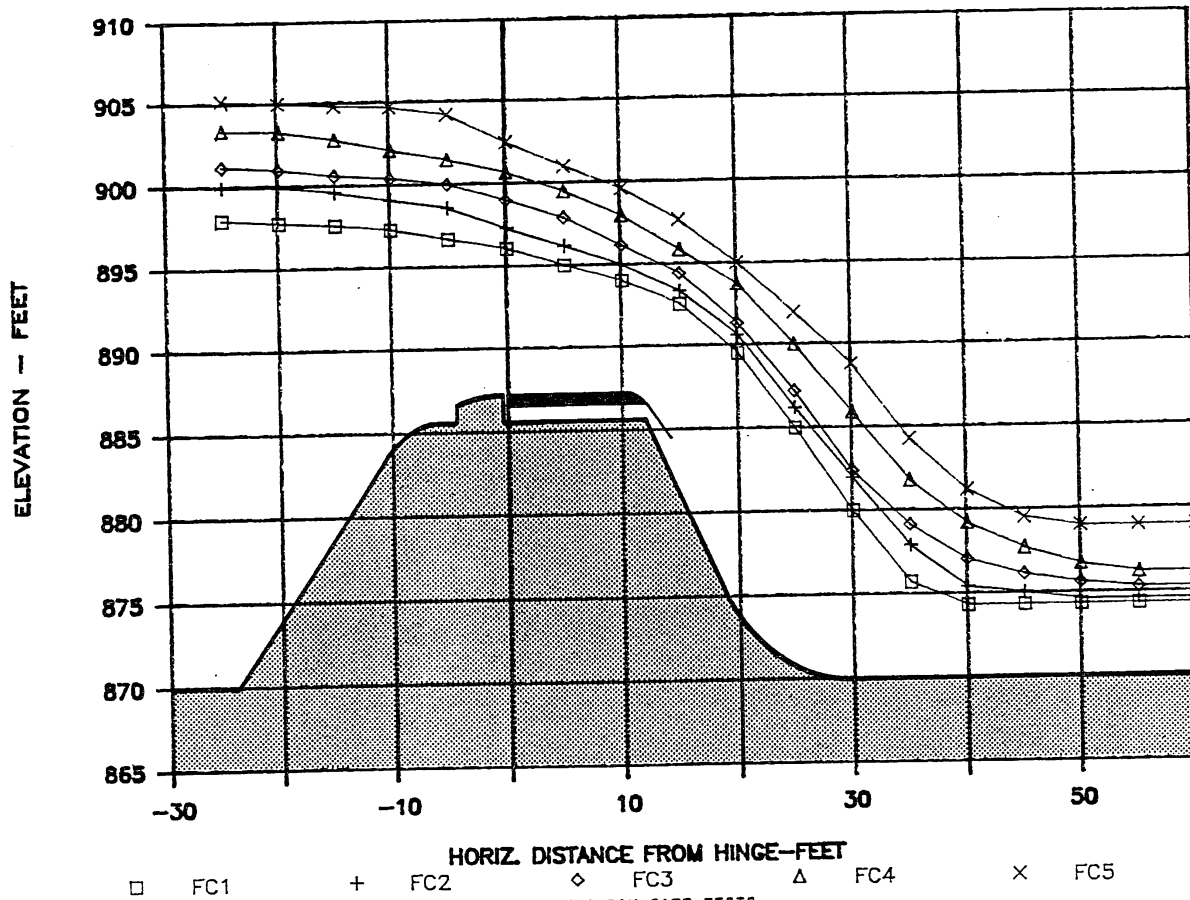


Fig. 59. WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 10.8 ft

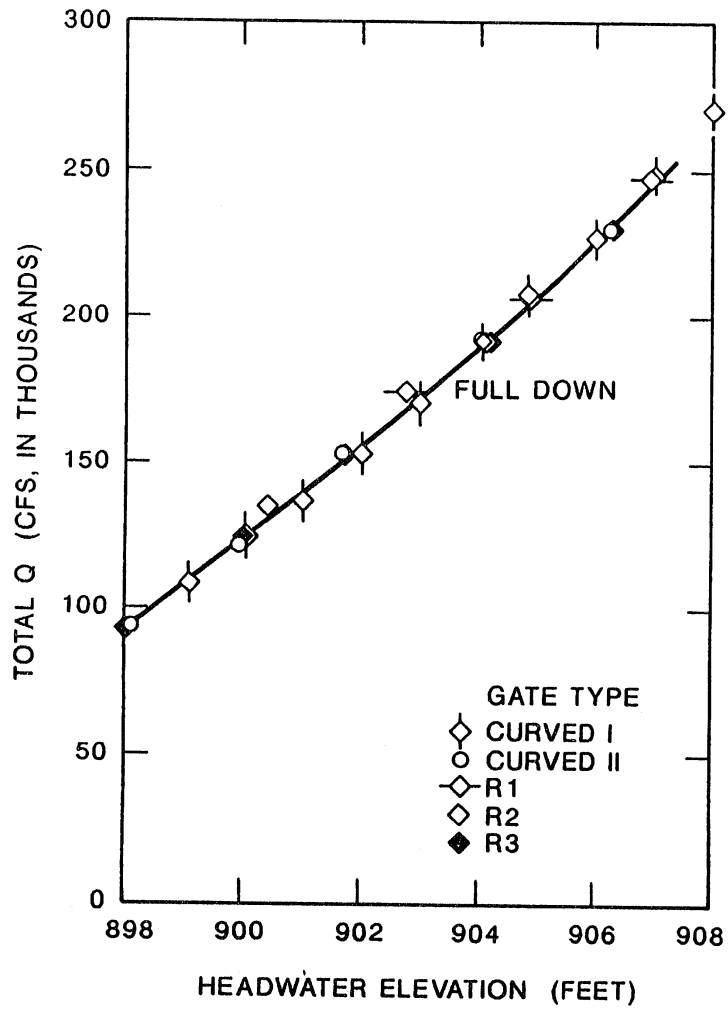
```

*****
Flow Cond. F.C.    1      2      3      4      5
H.W. Elev.-ft     898    900    902    904    906
T.W. Elev.-ft     880.1  881.8  883.2  884.7  886.1
Q/gate -cfs       7122   9551  11809  14705  17680
Q(total -cfs      92586  124160 153520 191170 229840
*****
  
```



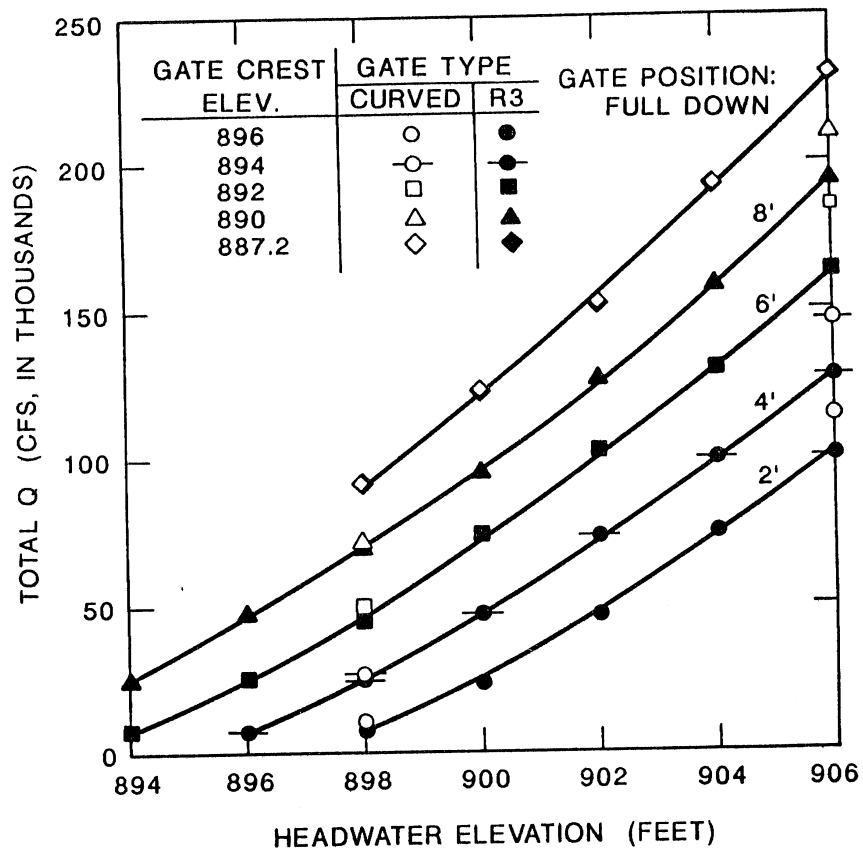
□ FC1      + FC2      ◇ FC3      △ FC4      × FC5  
 Fig. 60. MISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 10.8 ft

Flow Cond. F.C.	1	2	3	4	5
H.W. Elev.-ft	898	900	902	904	906
T.W. Elev.-ft	880.1	881.8	883.2	884.7	886.1
Q/gate -cfs	7122	9551	11809	14705	17560
Q(total) -cfs	92586	124160	153520	191170	229840



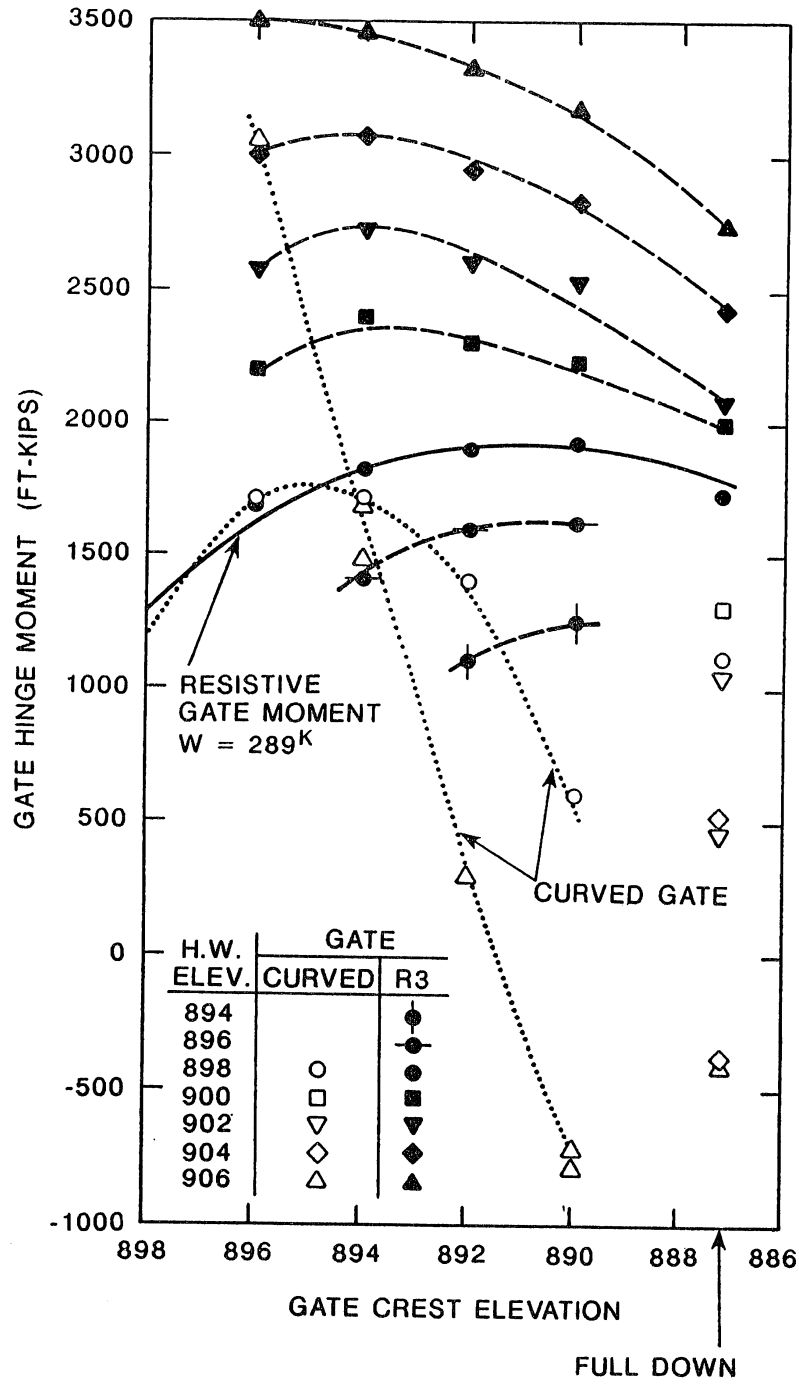
COMPARISON OF HEAD  
DISCHARGE CURVES  
ALL GATES FULL DOWN

Fig. 61. Comparison of head-discharge curves - all gates, full down.



HEAD DISCHARGE CURVES  
R3 AND CURVED LIP GATES  
VARIOUS POSITIONS

Fig. 62. Head discharge curves - R3 and curved lip gates, various positions.



GATE HINGE MOMENTS  
R3 AND CURVED LIP GATES

Fig. 63. Gate hinge moments - R3 and curved lip gates.



APPENDIX A

```

*****
tube      Elevation -feet      dist tube      elev. of
number    F.C. 1  F.C. 5          to hinge -ft  tube-ft
*****
1          896.29  896.47          11.95         895.31
2          896.70  896.99          11.47         895.43
3          896.88  896.88          10.99         895.55
4          896.93  895.30          10.50         895.67
5          896.93  894.48          10.01         895.79
6          897.05  893.67           9.52         896.00
7          897.28  894.60           9.03         895.77
8          897.58  896.47           8.54         895.63
9          897.81  898.57           8.11         895.39
10         898.10  903.47           7.07         894.43
11         898.22  904.28           6.37         893.71
12         898.22  904.98           5.14         892.45
13         898.22  905.33           3.93         891.20
14         898.22  905.63           2.71         889.95
15         898.28  905.80           1.49         888.70
16         898.28  905.74           0.79         887.98
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 2 ft

```

*****
Flow Cond.  F.C.      1          5
H.W. Elev.-ft      898          906
T.W. Elev.-ft      870.0        881.3
Q/gate -cfs        773          8830
Q(total -cfs      10052        114790
*****

```

```

*****
Distance          Elevation -feet
                   F.C. 1  F.C. 5
*****
-25                898.8  906.2
-20                898.8  906.1
-15                898.8  905.9
-10                898.8  905.8
-5                 898.8  905.5
0                  898.8  905.1
5                  898.5  904.8
10                 897.5  903.6
15                 895.0  901.0
                   893.8  894.5
20                 886.9  897.6
                   885.0  890.5
25                 871.8  892.6
                   885.0
30                 886.0
                   879.4
35                 879.1
                   873.0
40                 875.0
45                 874.0
50                 873.7
55                 873.4
60                 873.4
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 2 ft

```

*****
Flow Cond. F.C.    1      5
H.W. Elev.-ft     898    906
T.W. Elev.-ft     870.0  881.3
Q/gate -cfs       773    8830
Q(total) -cfs     10052  114790
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1   F.C. 5      Area of Arm to
tube number      Surface Surface
*****
   1          0.47   0.55          0.8   9.583
   2          0.36   0.44          0.5   9.083
   3          0.35   0.35          0.5   8.583
   4          0.32  -0.09          0.5   8.083
   5          0.30  -0.34          0.5   8.405
   6          0.32  -0.70          0.5   9.661
   7          0.50  -0.39          0.5  10.579
   8          0.68   0.29          0.5  11.126
   9          1.60   2.10          0.94 11.282
  10          2.76   6.79          1.19 10.125
  11          3.54   8.31          1.38  9.125
  12          4.64  10.09          1.75  7.375
  13          4.31   8.68          1.75  5.625
  14          3.50   6.63          1.75  3.875
  15          1.75   3.13          1.38  2.125
  16          1.18   2.03          1.63  1.125
*****
Total
Gate
Moment
ft-kips          26.57708 47.88972

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate Down 2 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898          906
T.W. Elev.-ft      870.0        881.3
Q/gate -cfs        773          8830
Q(total) -cfs      10052        114790
*****

```

tube number	Elevation -feet		dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 5		
1	893.84	890.63	13.23	893.00
2	894.48	891.10	12.77	893.21
3	894.37	890.98	12.33	893.42
4	894.25	888.07	11.87	893.63
5	894.13	886.20	11.40	893.84
6	894.02	884.57	10.93	893.96
7	894.19	885.44	10.44	893.99
8	895.13	888.01	9.93	893.94
9	895.88	891.80	9.47	893.79
10	897.34	900.20	8.27	893.02
11	897.58	901.83	7.45	892.44
12	897.81	903.23	6.02	891.43
13	897.93	904.05	4.60	890.42
14	897.98	904.63	3.17	889.41
15	897.98	904.87	1.74	888.40
16	897.98	904.52	0.92	887.82

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 4 ft

Flow Cond.	F.C.	1	5
H.W. Elev.-ft		898	906
T.W. Elev.-ft		872.5	882.9
Q/gate -cfs		2082	11302
Q(total) cfs		27066	146930

```

*****
Elevation -feet
Distance      F.C. 1  F.C. 5
*****
-25           898.0  905.7
-20           898.0  905.5
-15           898.0  905.5
-10           898.0  905.4
-5            898.0  905.0
0             898.0  904.4
5             898.0  904.0
10            897.6  903.6
15            894.8  900.6
              892.3  892.0
20            889.9  896.2
              886.2  888.1
25            879.3  890.6
              876.7  881.1
30            871.0  884.0
              876.0
35            871.0  877.9
              871.0
40            870.9  875.8
45            870.9  875.0
50            870.9  874.8
55            870.9  874.8
60            870.9  874.8
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 4 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft       898     906
T.W. Elev.-ft       872.5   882.9
Q/gate -cfs         2082    11302
Q(total) -cfs       27066   146930
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1  F.C. 5      Area of Arm to
tube number      Surface Surface
*****
      1      0.40  -1.13      0.8  9.583
      2      0.36  -0.60      0.5  9.083
      3      0.25  -0.65      0.5  8.583
      4      0.16  -1.40      0.5  8.083
      5      0.08  -2.00      0.5  8.405
      6      0.02  -2.83      0.5  9.661
      7      0.07  -2.82      0.5 10.579
      8      0.41  -2.06      0.5 11.126
      9      1.39  -1.32      0.94 11.282
     10      3.25   5.40      1.19 10.125
     11      4.03   7.38      1.38  9.125
     12      5.14   9.51      1.75  7.375
     13      4.61   8.37      1.75  5.625
     14      3.63   6.44      1.75  3.875
     15      1.75   3.01      1.38  2.125
     16      1.16   1.91      1.63  1.125
*****
Total
Gate
Moment
ft-kips      26.70582 27.20480

```

WISCONSIN DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate Down 4 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft      898      906
T.W. Elev.-ft      872.5    882.9
Q/gate -cfs      2082    11302
Q(total) -cfs    27066    146930
*****

```

```

*****
tube      Elevation -feet      dist tube      elev. of
number    F.C. 1  F.C. 5          to hinge -ft  tube-ft
*****
1         890.81  887.25          14.08         890.47
2         891.33  887.02          13.67         890.76
3         890.75  886.08          13.26         891.05
4         890.11  881.42          12.85         891.34
5         889.64  876.93          12.44         891.63
6         888.94  874.42          12.00         891.83
7         889.58  874.83          11.51         891.96
8         890.75  877.92          11.01         892.00
9         892.27  882.93          10.52         891.93
10        895.77  896.23           9.20         891.40
11        896.41  898.68           8.29         890.98
12        896.93  900.90           6.70         890.25
13        897.23  902.07           5.12         889.52
14        897.46  902.94           3.53         888.79
15        897.63  903.76           1.94         888.06
16        897.75  903.93           1.03         887.64
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 6 ft

```

*****
Flow Cond.  F.C.      1          5
H.W. Elev.-ft      898          906
T.W. Elev.-ft      876.1        884.6
Q/gate -cfs        3855        14324
Q(total) cfs       50115       186210
*****

```



```

*****
Distance      Elevation -feet
              F.C. 1  F.C. 5
*****
-25           898.0  905.8
-20           898.0  905.2
-15           898.0  905.0
-10           898.0  904.5
-5            898.0  904.0
0             898.0  903.5
5             897.4  902.5
10            896.4  901.3
15            894.0  899.0
              890.0
20            888.5  895.8
              884.6
25            880.6  890.0
              876.0
30            872.2  883.0
35            871.7  878.7
40            871.7  876.8
45            871.7  876.0
50            871.8  875.4
55            871.9  875.4
60            872.0  875.4
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 6 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft       898     906
T.W. Elev.-ft       876.1   884.6
Q/gate -cfs         3855    14324
Q(total) -cfs       50115   186210
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1   F.C. 5   Area of Arm to
tube number      Surface Surface
*****
      1         0.16   -1.54         0.8   9.583
      2         0.16   -1.06         0.5   9.083
      3        -0.08   -1.33         0.5   8.583
      4        -0.31   -2.50         0.5   8.083
      5        -0.52   -3.86         0.5   8.405
      6        -0.87   -5.25         0.5   9.661
      7        -0.78   -5.66         0.5  10.579
      8        -0.43   -4.89         0.5  11.126
      9         0.22   -5.95         0.94 11.282
     10         3.28    3.63         1.19 10.125
     11         4.27    6.05         1.38  9.125
     12         5.38    8.58         1.75  7.375
     13         4.73    7.71         1.75  5.625
     14         3.67    5.99         1.75  3.875
     15         1.75    2.87         1.38  2.125
     16         1.16    1.86         1.63  1.125
*****
Total
Gate
Moment
ft-kips      21.78613 4.659205

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate Down 6 ft

```

*****
Flow Cond. F.C.      1          5
H.W. Elev.-ft      898          906
T.W. Elev.-ft     876.1        884.6
Q/gate -cfs        3855        14324
Q(total) -cfs     50115        186210
*****

```

tube number	Elevation -feet		dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 5		
1	887.48	885.50	14.44	887.92
2	887.83	884.68	14.09	888.28
3	887.54	882.47	13.74	888.63
4	884.45	878.97	13.39	888.99
5	883.28	870.80	13.03	889.35
6	882.23	866.95	12.63	889.63
7	882.35	866.60	12.18	889.84
8	883.87	869.75	11.69	889.97
9	886.38	875.70	11.20	889.99
10	892.97	892.56	9.81	889.70
11	894.19	895.77	8.84	889.45
12	895.36	898.68	7.14	889.01
13	895.88	900.14	5.45	888.58
14	896.41	900.32	3.76	888.14
15	896.29	899.68	2.06	887.70
16	895.77	899.68	1.09	887.45

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 8 ft

Flow Cond.	F.C.	1	5
H.W. Elev.-ft		898	906
T.W. Elev.-ft		878.7	885.5
Q/gate -cfs		5655	16208
Q(total) cfs		73515	210700

```

*****
Elevation -feet
Distance      F.C. 1  F.C. 5
*****
-25           898.1  905.6
-20           898.1  905.0
-15           898.0  904.9
-10           898.0  904.4
-5            897.7  904.0
0             897.0  903.2
5             896.3  901.9
10            895.2  900.3
15            892.8  898.0
              887.7  892.7
20            887.0  894.4
              881.0  882.2
25            878.6  890.0
              873.7  875.8
30            873.6  884.0
              870.0  870.0
35            872.8  879.4

40            872.8  878.0
45            872.8  877.9
50            872.8  877.7
55            872.8  877.7
60            872.7  877.7
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 8 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft       898     906
T.W. Elev.-ft       878.7   885.5
Q/gate -cfs         5655   16208
Q(total) -cfs       73515  210700
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1  F.C. 5      Area of Arm to
tube number      Surface Surface
*****
   1      -0.21  -1.16      0.8  9.583
   2      -0.13  -1.02      0.5  9.083
   3      -0.29  -1.65      0.5  8.583
   4      -1.14  -2.53      0.5  8.083
   5      -1.59  -4.86      0.5  8.405
   6      -2.23  -6.84      0.5  9.661
   7      -2.47  -7.67      0.5 10.579
   8      -2.12  -7.02      0.5 11.126
   9      -2.39  -9.46      0.94 11.282
  10       2.46   2.15      1.19 10.125
  11       3.73   4.96      1.38  9.125
  12       5.11   7.79      1.75  7.375
  13       4.49   7.10      1.75  5.625
  14       3.50   5.15      1.75  3.875
  15       1.57   2.19      1.38  2.125
  16       0.95   1.40      1.63  1.125
*****
Total
Gate
Moment
ft-kips      9.227769 -11.4548

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate Down 8 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft      898      906
T.W. Elev.-ft      878.7    885.5
Q/gate -cfs      5655    16208
Q(total) -cfs      73515    210700
*****

```

```

*****
tube          Elevation -feet          dist tube          elev. of
number       F.C. 1 F.C. 2 F.C. 3 F.C. 4 F.C. 5 to hinge -ft tube-ft
*****
  1          884.22 884.22 884.10 884.57 885.03 14.17          884.29
  2          884.80 884.80 884.33 884.92 884.92 13.92          884.72
  3          885.15 885.15 884.33 884.22 883.98 13.67          885.15
  4          885.62 885.50 884.45 883.40 881.18 13.42          885.59
  5          886.08 885.97 884.57 880.72 876.52 13.16          886.02
  6          886.55 886.90 883.87 876.52 868.35 12.85          886.39
  7          886.67 886.67 883.17 876.28 867.18 12.46          886.71
  8          885.50 885.27 882.70 876.63 867.53 12.02          886.96
  9          884.57 884.22 882.35 879.67 873.60 11.55          887.10
 10          890.28 890.87 890.63 890.28 888.77 10.13          887.17
 11          891.68 892.38 892.56 892.62 892.03  9.13          887.17
 12          892.85 893.78 894.31 894.72 894.95  7.37          887.17
 13          893.55 894.72 895.30 896.12 896.35  5.63          887.17
 14          894.13 895.42 896.12 896.99 897.52  3.88          887.17
 15          894.72 896.00 896.70 897.81 898.33  2.13          887.17
 16          894.37 895.30 895.88 896.47 896.82  1.13          887.17
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898      900      902      904      906
T.W. Elev.-ft                883.2    884.8
Q/gate -cfs        7122    9551    11809    14755    17680
Q(total -cfs      92586    124160    153520    191820    229840
*****

```

```

*****
                                Elevation-feet
Distance      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5
*****
-25           898.0  899.9  901.2  903.0  904.8
-20           897.9  899.7  901.0  902.8  904.4
-15           897.8  899.4  900.8  902.6  904.3
-10           897.3  899.2  900.4  902.0  903.8
-5            896.7  898.4  899.4  901.6  902.8
0             895.7  897.4  898.8  900.6  901.4
5             894.6  896.1  897.5  899.2  900.1
10            893.3  894.9  896.0  897.6  898.4
15            891.3  892.6  893.3  895.0  896.0
              885.8  886.7  887.0  886.2  886.0
20            888.0  889.8  890.0  892.2  893.3
              882.5  883.1  883.3  883.0  883.3
25            882.8  885.0  885.4  887.3  888.7
              878.2  878.9  878.8  879.4  880.0
30            877.6  880.0  880.8  883.0  885.0
              872.7  874.7  875.0  876.3  877.0
35            874.5  876.4  877.9  880.0  881.6
              870.6  871.6  873.0  872.7
40            873.5  875.2  877.1  879.0  880.0
45            873.4  875.3  877.0  879.0  879.5
50            873.2  875.3  877.0  879.0  879.2
55            873.2  875.3  877.0  879.0  879.0
60            873.2  875.3  877.0  879.0  879.0
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898      900      902      904      906
T.W. Elev.-ft                883.2  884.8
Q/gate -cfs        7122    9551    11809    14755    17680
Q(total) -cfs     92586   124160  153520  191820  229840
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
F.C. 1 F.C. 2 F.C. 3 F.C. 4 F.C. 5 Area of Arm to
tube number Surface Surface
*****
1 -0.04 -0.04 -0.09 0.13 0.36 0.8 9.583
2 0.02 0.02 -0.11 0.06 0.06 0.5 9.083
3 0.00 0.00 -0.22 -0.25 -0.31 0.5 8.583
4 0.01 -0.02 -0.29 -0.55 -1.11 0.5 8.083
5 0.02 -0.01 -0.38 -1.39 -2.49 0.5 8.405
6 0.05 0.15 -0.76 -2.98 -5.44 0.5 9.661
7 -0.01 -0.01 -1.17 -3.44 -6.45 0.5 10.579
8 -0.51 -0.59 -1.48 -3.58 -6.74 0.5 11.126
9 -1.68 -1.91 -3.14 -4.92 -8.93 0.94 11.282
10 2.34 2.78 2.60 2.34 1.20 1.19 10.125
11 3.55 4.10 4.23 4.28 3.82 1.38 9.125
12 4.57 5.33 5.75 6.08 6.27 1.75 7.375
13 3.92 4.64 4.99 5.50 5.64 1.75 5.625
14 2.95 3.49 3.79 4.16 4.38 1.75 3.875
15 1.38 1.62 1.74 1.95 2.04 1.38 2.125
16 0.82 0.93 1.00 1.06 1.10 1.63 1.125
*****
Total
Gate
Moment
ft-kips 17.39304 20.46748 16.46725 8.434109 -6.61345

```

WISSOTA DAM GATE TESTS  
COMPUTATION OF GATE LOAD  
1:14 Section Model  
Gate Down 10.8 ft

```

*****
Flow Cond. F.C. 1 2 3 4 5
H.W. Elev.-ft 898 900 902 904 906
T.W. Elev.-ft 883.2 884.8
Q/gate -cfs 7122 9551 11809 14755 17680
Q(total) -cfs 92586 124160 153520 191820 229840
*****

```



```

*****
tube      Elevation -feet      dist tube      elev. of
number    F.C. 2  F.C. 3  F.C. 4  F.C. 5  to hinge -ft  tube-ft
*****
1          889.76  890.05  890.23  891.28  12.12         887.17
2          891.10  891.57  891.80  892.85  11.62         887.17
3          891.92  892.44  892.85  893.90  11.13         887.17
4          892.44  893.14  893.67  894.66  10.63         887.17
5          893.14  893.78  894.31  895.36  10.13         887.17
6          893.84  894.66  895.30  896.35   9.13         887.17
7          894.78  895.77  896.53  897.63   7.37         887.17
8          895.53  896.58  897.40  898.51   5.63         887.17
9          896.00  897.17  898.10  899.21   3.88         887.17
10         896.47  897.63  898.57  899.62   2.13         887.17
11         896.12  897.17  897.75  898.57   1.13         887.17
*****

```

WISSOTA DAM GATE TESTS  
PIEZOMETRIC PRESSURE HEAD  
1:14 Section Model  
Gate R1 Down 10.8 ft

```

*****
Flow Cond. F.C.      2      3      4      5
H.W. Elev.-ft      900     902     904     906
T.W. Elev.-ft      882.4   884.1   885.3   886.7
Q/gate -cfs      10439   13421   15894   19033
Q(total -cfs     135700  174480  206620  247430
*****

```

```

*****
Elevation-feet
Distance      F.C. 2  F.C. 3  F.C. 4  F.C. 5
*****
-25           900.0  902.0  904.1  905.5
-20           900.0  901.8  903.9  905.1
-15           899.8  901.4  903.7  904.9
-10           899.6  901.0  903.0  904.5
-5            898.9  900.6  902.6  904.0
0             898.5  899.8  901.5  903.2
5             897.4  898.3  900.0  902.1
10            895.6  897.2  898.5  900.0
15            894.0  895.0  897.2  897.7
              887.0  887.0  886.5  886.9
20            891.0  892.7  894.5  895.6
              883.2  885.0  884.5  885.0
25            887.5  889.5  890.4  892.3
              880.7  882.4  881.3  883.0
30            883.0  885.1  887.4  889.5
              875.8  878.0  877.6  880.0
35            879.0  880.6  883.0  885.5
              871.7  875.0  875.0  875.0
40            875.7  878.1  880.0  882.3
45            875.0  877.5  878.0  880.0
50            875.7  877.4  877.7  879.2
55            875.7  877.6  877.8  879.0
60            875.7  877.6  878.0  879.1
*****

```

WISSOTA DAM GATE TESTS  
WATER SURFACE PROFILES  
1:14 Section Model  
Gate R1 Down 10.8 ft

```

*****
Flow Cond. F.C.      2      3      4      5
H.W. Elev.-ft       900     902     904     906
T.W. Elev.-ft       882.4   884.1   885.3   886.7
Q/gate -cfs         10439   13421   15894   19033
Q(total) -cfs       135700  174480  206620  247430
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 2  F.C. 3  F.C. 4  F.C. 5      Area of Arm to
tube number      Surface Surface
*****
   1   1.24   1.38   1.47   1.97       0.635  12.122
   2   1.42   1.59   1.68   2.06       0.5    11.620
   3   1.65   1.83   1.97   2.34       0.5    11.130
   4   1.75   1.98   2.15   2.48       0.5    10.628
   5   2.83   3.13   3.38   3.88       0.75   10.125
   6   5.22   5.86   6.37   7.19      1.375   9.125
   7   6.12   6.92   7.53   8.43      1.75   7.375
   8   5.14   5.78   6.28   6.96      1.75   5.625
   9   3.74   4.23   4.63   5.09      1.75   3.875
  10   1.70   1.91   2.08   2.27      1.375   2.125
  11   1.02   1.14   1.21   1.30      1.625   1.125
*****
Total
Gate
Moment
ft-kips  31.83136 35.76828 38.74797 43.97303

```

WISSOTA DAM GATE TESTS  
COMPUTATION OF GATE LOAD  
1:14 Section Model  
Gate R1 Down 10.8 ft

```

*****
Flow Cond. F.C.      2      3      4      5
H.W. Elev.-ft      900     902     904     906
T.W. Elev.-ft      882.4   884.1   885.3   886.7
Q/gate -cfs        10439   13421   15894   19033
Q(total) -cfs      135700  174480  206620  247430
*****

```

```

*****
tube      Elevation -feet      dist tube      elev. of
number    F.C. 1  F.C. 5      to hinge -ft  tube-ft
*****
  1      896.53  895.42      14.17      895.13
  2      897.05  895.36      13.92      895.26
  3      897.34  895.30      13.67      895.39
  4      897.17  895.59      13.42      895.53
  5      896.70  895.77      13.16      895.65
  6      896.70  896.00      12.85      895.69
  7      896.70  895.88      12.46      895.64
  8      898.45  904.52      12.02      895.64
  9      898.45  904.28      11.55      895.29
 10      898.51  905.39      10.13      894.32
 11      898.57  905.86      9.13      893.61
 12      898.57  906.33      7.37      892.38
 13      898.63  906.62      5.63      891.14
 14      898.63  906.79      3.88      889.91
 15      898.63  906.85      2.13      888.67
 16      898.63  906.79      1.13      887.96
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R2 Down 2 ft

```

*****
Flow Cond.  F.C.      1      5
H.W. Elev.-ft      898      906
T.W. Elev.-ft      870.0      881.3
Q/gate -cfs      773      8830
Q(total -cfs      10052      114790
*****

```

```

*****
          Elevation -feet
Distance   F.C. 1   F.C. 5
*****
-25         899.0   907.4
-20         898.9   907.4
-15         898.8   907.4
-10         898.8   907.4
-5          898.8   907.2
0           898.8   906.4
5           898.8   905.8
10          898.1   905.0
15          895.0   903.0
           894.8   896.0
20          886.3   899.6
           885.5   892.8
25          872.6   894.7
           871.6   887.8
30                                     889.2
                                     880.0
35                                     880.8
                                     870.0
40                                     875.6
45                                     874.0
50                                     873.9
55                                     873.8
60                                     873.8
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R2 Down 2 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft       898     906
T.W. Elev.-ft       870.0   881.3
Q/gate -cfs         773     8830
Q(total) -cfs       10052   114790
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1  F.C. 5      Area of Arm to
tube number      Surface Surface
*****
      1      0.67   0.14      0.8   9.583
      2      0.51   0.03      0.5   9.083
      3      0.52  -0.02      0.5   8.583
      4      0.41   0.02      0.5   8.083
      5      0.28   0.03      0.5   8.405
      6      0.30   0.09      0.5   9.661
      7      0.17   0.04      0.25  10.579
      8      1.60   5.05      0.76  11.992
      9      2.11   6.00      0.93  11.502
     10      3.15   8.32      1.19  10.125
     11      3.89   9.62      1.38   9.125
     12      4.98  11.23      1.75   7.375
     13      4.60   9.51      1.75   5.625
     14      3.69   7.14      1.75   3.875
     15      1.82   3.33      1.38   2.125
     16      1.22   2.15      1.63   1.125
*****
Total
Gate
Moment
ft-kips      29.92565 62.68251

```

WISSOTA DAM GATE TESTS  
COMPUTATION OF GATE LOAD  
1:14 Section Model  
Gate R2 Down 2 ft

```

*****
Flow Cond. F.C.      1      5
H.W. Elev.-ft      898      906
T.W. Elev.-ft      870.0    881.3
Q/gate -cfs        773      8830
Q(total) -cfs      10052    114790
*****

```

tube number	Elevation -feet					dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5		
1	884.04	883.98	884.10	885.15	887.02	14.17	884.29
2	884.39	884.04	884.10	885.27	887.02	13.92	884.72
3	885.15	885.15	884.22	885.38	887.13	13.67	885.15
4	885.56	885.56	884.28	885.50	887.19	13.42	885.59
5	886.08	886.08	884.33	885.50	887.31	13.16	886.02
6	886.49	886.55	884.45	885.62	887.37	12.85	886.40
7	886.73	886.67	884.57	885.73	887.48	12.46	886.71
8	892.91	894.08	894.48	896.23	897.87	12.02	887.17
9	892.03	892.91	892.85	893.90	895.42	11.55	887.17
10	892.73	893.73	894.02	895.07	896.47	10.13	887.17
11	893.20	894.31	894.72	895.88	897.17	9.13	887.17
12	893.90	895.07	895.77	896.88	898.22	7.37	887.17
13	894.37	895.65	896.41	897.63	898.98	5.63	887.17
14	894.83	896.18	896.99	898.33	899.62	3.88	887.17
15	894.89	896.12	896.93	897.23	899.09	2.13	887.17
16	894.25	895.30	896.00	895.77	897.75	1.13	887.17

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R2 Down 10.8 ft

Flow Cond.	F.C.	1	2	3	4	5
H.W. Elev.-ft		898	900	902	904	906
T.W. Elev.-ft		880.1	881.8	883.2	884.8	886.1
Q/gate -cfs		7122	9551	11809	14755	17680
Q(total -cfs		92586	124160	153520	191820	229840

```

*****
Elevation-feet
Distance      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5
*****
-25           898.0  900.0  901.3  903.1  905.2
-20           898.0  900.0  901.2  903.0  905.0
-15           897.9  899.7  901.0  902.9  904.8
-10           897.4  899.6  900.7  902.4  904.5
-5            897.0  898.7  900.0  901.6  904.0
0             895.9  897.5  899.0  900.8  902.9
5             895.0  896.3  897.8  899.7  901.4
10            894.0  895.0  896.1  898.0  900.0
12.8          887.2  887.2  887.2  887.2  887.2
15            892.2  893.9  894.9  896.0  898.0
              886.6  886.7  887.0  886.3
20            890.0  891.4  892.0  893.9  895.8
              884.6  885.0  884.2  884.4
25            886.1  887.7  887.8  890.5  892.5
              880.8  880.7  880.0  880.7
30            880.6  883.4  883.5  886.2  889.3
              875.0  876.0  875.8  877.0
35            875.8  879.3  879.4  882.1  885.0
              870.0  871.5  870.0  872.6
40            874.2  875.4  876.6  879.0  881.3
45            874.0  874.5  875.8  877.6  879.5
50            873.7  874.5  875.6  877.2  879.0
55            873.7  874.6  875.4  877.0  879.0
60            873.7  874.7  875.4  877.0  879.0
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R2 Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5'
H.W. Elev.-ft       898      900      902      904      906
T.W. Elev.-ft       880.1  881.8  883.2  884.8  886.1
Q/gate -cfs         7122   9551  11809  14755  17680
Q(total) -cfs       92586  124160 153520 191820 229840
*****

```



```

*****
Incremental Moments About Hinge Pin (ft-kips)
F.C. 1 F.C. 2 F.C. 3 F.C. 4 F.C. 5 Area of Arm to
tube number Surface Surface
*****
1 -0.12 -0.15 -0.09 0.41 1.30 0.8 9.583
2 -0.09 -0.19 -0.18 0.15 0.65 0.5 9.083
3 0.00 0.00 -0.25 0.06 0.53 0.5 8.583
4 -0.01 -0.01 -0.33 -0.02 0.40 0.5 8.083
5 0.02 0.02 -0.44 -0.14 0.34 0.5 8.405
6 0.03 0.05 -0.59 -0.24 0.29 0.5 9.661
7 0.00 -0.01 -0.35 -0.16 0.13 0.25 10.579
8 3.26 3.93 4.16 5.15 6.08 0.76 11.992
9 3.25 3.83 3.79 4.49 5.50 0.93 11.502
10 4.18 4.93 5.15 5.94 6.99 1.19 10.125
11 4.74 5.61 5.93 6.85 7.86 1.38 9.125
12 5.42 6.36 6.92 7.82 8.90 1.75 7.375
13 4.42 5.21 5.67 6.43 7.25 1.75 5.625
14 3.24 3.81 4.16 4.72 5.27 1.75 3.875
15 1.41 1.64 1.79 1.84 2.18 1.38 2.125
16 0.81 0.93 1.01 0.98 1.21 1.63 1.125
*****
Total
Gate
Moment
ft-kips 30.56387 35.94865 36.34704 44.29317 54.88627

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R2 Down 10.8 ft

```

*****
Flow Cond. F.C. 1 2 3 4 5
H.W. Elev.-ft 898 900 902 904 906
T.W. Elev.-ft 880.1 881.8 883.2 884.8 886.1
Q/gate -cfs 7122 9551 11809 14755 17680
Q(total) -cfs 92586 124160 153520 191820 229840
*****

```

tube number	Elevation -feet					dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5		
1	895.88	896.58	896.82	895.24	895.24	14.17	895.13
2	896.35	897.23	897.17	895.30	895.30	13.92	895.26
3	896.70	897.17	896.58	895.48	895.48	13.67	895.39
4	896.93	896.12	895.01	895.65	895.71	13.42	895.53
5	896.70	895.65	894.25	895.71	895.77	13.16	895.65
6	896.35	895.01	893.90	895.77	895.77	12.85	895.69
7	896.41	896.00	894.54	895.65	895.77	12.46	895.64
8	897.58	898.51	899.03	899.44	900.90	12.02	895.64
9	897.87	899.21	900.32	901.31	902.65	11.55	895.29
10	897.93	899.68	901.13	902.48	904.11	10.13	894.32
11	897.98	899.79	901.43	902.94	904.52	9.13	893.61
12	898.04	899.91	901.66	903.29	904.98	7.37	892.38
13	898.04	899.97	901.72	903.53	905.28	5.63	891.14
14	898.04	899.97	901.78	903.70	905.51	3.88	889.91
15	898.04	899.97	901.83	903.82	905.68	2.13	888.67
16	898.04	900.03	901.83	903.82	905.68	1.13	887.96

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 2 ft

Flow Cond.	F.C.	1	2	3	4	5
H.W. Elev.-ft		898	900	902	904	906
T.W. Elev.-ft		870	872.5	875.8	878.8	880.7
Q/gate -cfs		392	1962	3728	5887	7849
Q(total -cfs		5102	25508	48466	76525	102033

Distance	Elevation-feet				
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5
-25	898.2	900.2	901.9	904.4	906.0
-20	898.2	900.1	901.9	904.4	906.0
-15	898.1	900.1	901.8	904.4	906.0
-10	898.1	900.0	901.7	904.4	906.0
-5	898.1	900.0	901.8	904.4	905.9
0	898.0	900.0	901.7	904.1	905.7
5	898.0	900.0	901.4	903.4	905.0
10	897.3	899.0	900.7	902.5	904.0
					896.7
15	894.3	896.0	897.5	900.0	901.9
	892.8	893.9	894.0	894.7	895.5
20	883.2	889.5	892.4	896.0	898.9
	878.0	887.0	888.5	889.0	891.9
25		879.5	883.9	890.0	894.0
		876.0	878.9	884.0	886.2
30		870.0	872.6	882.0	886.0
				876.5	879.0
35			872.0	874.0	879.0
				870.0	873.0
40			872.5	872.0	874.0
45			872.2	871.5	872.7
50			871.9	871.5	872.4
55			871.3	871.6	872.4
60			871.3	871.5	872.4

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 2 ft

Flow Cond. F.C.	1	2	3	4	5'
H.W. Elev.-ft	898	900	902	904	906
T.W. Elev.-ft	870	872.5	875.8	878.8	880.7
Q/gate -cfs	392	1962	3728	5887	7849
Q(total) -cfs	5102	25508	48466	76525	102033

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  Area of Arm to
tube number      Surface Surface
*****
      1  0.36  0.70  0.81  0.05  0.05      0.8  9.583
      2  0.31  0.56  0.54  0.01  0.01      0.5  9.083
      3  0.35  0.48  0.32  0.02  0.02      0.5  8.583
      4  0.35  0.15 -0.13  0.03  0.04      0.5  8.083
      5  0.28  0.00 -0.37  0.02  0.03      0.5  8.405
      6  0.20 -0.21 -0.54  0.02  0.02      0.5  9.661
      7  0.13  0.06 -0.18  0.00  0.02      0.25 10.579
      8  1.10  1.63  1.93  2.16  2.99      0.76 11.992
      9  1.72  2.62  3.36  4.02  4.91      0.93 11.502
     10  2.71  4.03  5.12  6.13  7.36      1.19 10.125
     11  3.44  4.86  6.14  7.33  8.57      1.38  9.125
     12  4.56  6.06  7.47  8.79 10.15      1.75  7.375
     13  4.24  5.42  6.50  7.61  8.68      1.75  5.625
     14  3.44  4.26  5.02  5.84  6.60      1.75  3.875
     15  1.71  2.07  2.41  2.77  3.11      1.38  2.125
     16  1.15  1.38  1.59  1.81  2.03      1.63  1.125
*****
Total
Gate
Moment
ft-kips 26.05063 34.04784 39.98156 46.61736 54.61482

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R3 Down 2 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898      900      902      904      906
T.W. Elev.-ft      870      872.5    875.8    878.8    880.7
Q/gate -cfs        392      1962     3728     5887     7849
Q(total) -cfs      5102     25508    48466    76525    102033
*****

```

tube number	Elevation -feet						dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5	F.C. 6		
1	893.84	893.90	892.62	892.50	892.56	893.14	14.17	892.50
2	894.25	893.73	892.85	892.73	892.73	893.73	13.92	892.72
3	893.73	893.55	893.08	892.97	893.08	894.13	13.67	892.95
4	892.91	893.08	893.32	893.43	893.43	894.48	13.42	893.18
5	892.56	892.91	893.43	893.43	893.43	894.02	13.16	893.40
6	892.62	892.85	893.78	893.55	893.78	893.73	12.85	893.53
7	892.68	892.62	893.67	893.67	893.67	893.73	12.46	893.58
8	895.77	896.53	897.75	898.22	898.80	895.30	12.02	893.72
9	896.82	897.75	899.09	899.85	900.67	895.65	11.55	893.45
10	897.40	898.74	900.26	901.37	902.53	895.83	10.13	892.70
11	897.58	899.03	900.67	901.83	903.12	895.88	9.13	892.15
12	897.75	899.38	901.13	902.42	903.82	895.94	7.37	891.20
13	897.87	899.50	901.37	902.83	904.28	896.00	5.63	890.24
14	897.93	899.62	901.48	903.12	904.63	896.00	3.88	889.29
15	897.93	899.73	901.60	903.29	904.98	896.00	2.13	888.33
16	897.93	899.73	901.66	903.35	905.10	896.00	1.13	887.78

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 4 ft

Flow Cond.	F.C.	1	2	3	4	5	6
H.W. Elev.-ft		898	900	902	904	906	896
T.W. Elev.-ft		870.0	875.5		880.8	882.0	
Q/gate -cfs		2040	3650	5769	7731	9772	620
Q(total) -cfs		26529	47446	74995	100500	127030	8061

```

*****
                                Elevation-feet
Distance      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  F.C. 6
*****
-25            898.1  900.1  902.1  903.8  905.5  896.0
-20            898.1  900.0  902.1  903.8  905.6  896.0
-15            898.1  900.0  902.1  903.6  905.5  896.0
-10            898.1  900.0  902.1  903.5  905.3  896.0
-5             898.1  900.0  902.0  903.3  905.1  896.0
 0             898.1  900.0  902.0  903.1  904.8  896.0
 5             898.1  899.9  901.4  902.7  904.3  896.0
10             897.3  899.0  900.7  902.2  903.0  895.8
15             894.7  897.2  898.8  900.0  901.3  893.0
              892.3  893.0  893.6  893.5  892.6  892.0
20             888.8  893.0  895.0  897.0  898.9  885.8
              885.7  889.0  890.0  891.0  891.9  884.7
25             876.2  885.0  889.6  892.0  894.6
              875.0  882.0  884.0  885.0  887.3
30             870.6  875.0  881.0  885.6  889.0
              871.6  875.0  879.0  880.9
35             872.1  874.6  879.0  881.4
              871.0  874.9
40             872.0  873.0  874.2  876.8
45             872.9  873.0  874.0  874.0
50             873.0  873.0  874.0  873.7
55             872.7  873.0  874.0  873.5
60             871.3  873.0  874.0  873.5
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 4 ft

```

*****
Flow Cond. F.C.    1      2      3      4      5      6
H.W. Elev.-ft     898     900     902     904     906     896
T.W. Elev.-ft     870.0  875.5         880.8  882.0
Q/gate -cfs       2040   3650   5769   7731   9772   620
Q(total) -cfs    26529  47446  74995  100500 127030 8061
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
F.C. 1 F.C. 2 F.C. 3 F.C. 4 F.C. 5 F.C. 6 Area of Arm to
tube number Surface Surface
*****
1 0.64 0.67 0.06 0.00 0.03 0.31 0.8 9.583
2 0.43 0.28 0.04 0.00 0.00 0.28 0.5 9.083
3 0.21 0.16 0.04 0.00 0.04 0.32 0.5 8.583
4 -0.07 -0.02 0.03 0.06 0.06 0.33 0.5 8.083
5 -0.22 -0.13 0.01 0.01 0.01 0.16 0.5 8.405
6 -0.28 -0.20 0.08 0.01 0.08 0.06 0.5 9.661
7 -0.15 -0.16 0.01 0.01 0.01 0.02 0.25 10.579
8 1.16 1.60 2.29 2.56 2.89 0.90 0.76 11.992
9 2.25 2.87 3.77 4.27 4.82 1.47 0.93 11.502
10 3.53 4.54 5.68 6.52 7.39 2.35 1.19 10.125
11 4.26 5.41 6.69 7.61 8.62 2.93 1.38 9.125
12 5.28 6.59 8.00 9.03 10.16 3.82 1.75 7.375
13 4.68 5.69 6.83 7.73 8.63 3.54 1.75 5.625
14 3.65 4.37 5.16 5.85 6.49 2.84 1.75 3.875
15 1.76 2.09 2.43 2.74 3.05 1.40 1.38 2.125
16 1.16 1.37 1.59 1.78 1.98 0.94 1.63 1.125
*****
Total
Gate
Moment
ft-kips 28.30694 35.11705 42.70494 48.18910 54.25584 21.67205

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R3 Down 4 ft

```

*****
Flow Cond. F.C. 1 2 3 4 5 6
H.W. Elev.-ft 898 900 902 904 906 896
T.W. Elev.-ft 870.0 875.5 880.8 882.0
Q/gate -cfs 2040 3650 5769 7731 9772 620
Q(total) -cfs 26529 47446 74995 100500 127030 8061
*****

```

```

*****
tube          Elevation -feet
number        F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  F.C. 6  F.C. 7  dist tube  elev. of
              to hinge -ft  tube-ft
*****
  1          890.11  889.99  889.93  889.93  889.70  890.11  890.11  14.17      889.98
  2          890.46  890.40  890.28  890.28  890.05  890.46  890.46  13.92      890.28
  3          890.75  890.63  890.63  890.63  890.34  890.81  890.87  13.67      890.59
  4          891.22  890.98  890.87  891.10  890.69  891.16  891.16  13.42      890.90
  5          891.45  891.33  891.16  891.28  890.98  891.45  891.16  13.16      891.19
  6          891.68  891.57  891.45  891.45  891.22  891.68  891.28  12.85      891.42
  7          891.68  891.57  891.51  891.51  891.33  891.68  891.63  12.46      891.56
  8          894.66  895.24  895.53  896.00  896.53  894.08  893.26  12.02      891.80
  9          895.71  896.53  897.05  897.75  898.68  894.72  893.67  11.55      891.61
 10          896.58  897.87  898.74  899.79  901.02  895.36  893.84  10.13      891.08
 11          896.88  898.28  899.33  900.43  901.78  895.53  893.90   9.13      890.69
 12          897.17  898.74  899.97  901.25  902.65  895.65  893.96   7.37      890.02
 13          897.40  899.09  900.38  901.78  903.23  895.77  894.02   5.63      889.34
 14          897.52  899.27  900.73  902.24  903.76  895.88  894.02   3.88      888.67
 15          897.63  899.50  901.02  902.53  904.23  895.94  894.02   2.13      887.99
 16          897.63  899.50  901.02  902.65  904.28  895.94  894.02   1.13      887.60
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 6 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5      6      7
H.W. Elev.-ft      898      900      902      904      906      896      894
T.W. Elev.-ft      875.0    878.8    880.7    882.2    883.6    872.5
Q/gate -cfs        3453    5769    7888    10125    12558    1884    620
Q(total) -cfs      44895    74995    102540   131620   163250   24488    8061
*****

```



Distance	Elevation-feet						
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5	F.C. 6	F.C. 7
-25	898.0	900.1	902.1	904.0	905.8	896.0	894.3
-20	898.0	900.0	902.1	904.0	905.7	896.0	894.3
-15	898.0	900.0	902.1	903.8	905.6	896.0	894.3
-10	898.0	899.9	901.8	903.6	905.0	896.0	894.3
-5	898.0	899.8	901.4	903.1	904.5	896.0	894.3
0	898.0	899.4	901.0	902.4	904.2	896.0	894.3
5	897.8	899.0	900.7	901.6	904.0	896.0	894.3
10	896.8	898.6	899.8	901.0	902.4	895.8	894.2
15	895.0	896.7	898.2	899.8	901.0	893.2	891.1
	891.4	891.9	891.8	891.8	891.4	890.9	890.0
20	890.8	894.0	895.3	897.3	898.0	887.3	879.0
	887.3	888.8	889.5	889.2	890.0	885.0	877.0
25	883.0	888.0	890.8	893.0	894.0	875.7	
	880.0	882.4	885.0	885.0	886.8	874.0	
30	874.2	881.0	885.0	888.7	890.0	870.7	
	871.0	876.0	879.5	880.0	882.3		
35	871.3	875.0	879.0	881.6	885.0	870.7	
			871.5	875.0	876.7		
40	872.1	872.6	874.1	877.2	880.0	870.7	
45	871.7	872.0	874.0	875.0	877.0	870.7	
50	871.0	872.0	874.0	874.9	875.7	870.7	
55	871.0	872.2	874.0	874.9	875.7	870.7	
60	871.0	872.4	874.1	875.0	875.7	870.7	

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 6 ft

Flow Cond. F.C.	1	2	3	4	5	6	7
H.W. Elev.-ft	898	900	902	904	906	896	894
T.W. Elev.-ft	875.0	878.8	880.7	882.2	883.6	872.5	
Q/gate -cfs	3453	5769	7888	10125	12558	1884	620
Q(total) -cfs	44895	74995	102540	131620	163250	24488	8061

```

*****
Incremental Moments About Hinge Pin (ft-kips)
      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  F.C. 6  F.C. 7
tube number
*****
      1   0.06   0.01  -0.02  -0.02  -0.13   0.06   0.06
      2   0.05   0.03   0.00   0.00  -0.07   0.05   0.05
      3   0.04   0.01   0.01   0.01  -0.07   0.06   0.07
      4   0.08   0.02  -0.01   0.05  -0.05   0.07   0.07
      5   0.07   0.04  -0.01   0.02  -0.05   0.07  -0.01
      6   0.08   0.04   0.01   0.01  -0.06   0.08  -0.04
      7   0.02   0.00  -0.01  -0.01  -0.04   0.02   0.01
      8   1.63   1.96   2.12   2.39   2.69   1.29   0.83
      9   2.74   3.28   3.63   4.10   4.72   2.07   1.37
     10   4.14   5.10   5.76   6.55   7.47   3.22   2.08
     11   4.86   5.96   6.79   7.66   8.71   3.81   2.52
     12   5.76   7.02   8.01   9.04  10.17   4.53   3.17
     13   4.95   5.99   6.78   7.64   8.53   3.95   2.87
     14   3.74   4.48   5.10   5.74   6.38   3.05   2.26
     15   1.76   2.11   2.38   2.66   2.97   1.46   1.10
     16   1.15   1.36   1.54   1.72   1.91   0.95   0.73
*****
Total
Gate
Moment
ft-kips 31.12389 37.42147 42.08263 47.56472 53.08850 24.73689 17.15457

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R3 Down 6 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5      6      7
H.W. Elev.-ft      898      900      902      904      906      896      894
T.W. Elev.-ft      875.0    878.8    880.7    882.2    883.6    872.5
Q/gate -cfs        3453    5769    7888    10125    12558    1884     620
Q(total) -cfs      44895    74995    102540   131620   163250   24488    8061
*****

```

tube num	Elevation -feet								dist tube to hinge -ft	elev. of tube-ft
	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5	F.C. 6	F.C. 7	F.C. 8		
1	887.60	887.60	887.60	887.60	887.25	887.60	887.60	887.60	14.17	887.57
2	887.95	887.95	887.95	887.95	887.48	887.95	887.95	887.95	13.92	887.93
3	888.30	888.30	888.30	888.30	887.83	888.30	888.30	888.30	13.67	888.30
4	888.65	888.65	888.65	888.65	888.13	888.65	888.77	888.77	13.42	888.67
5	889.06	889.06	889.06	889.06	888.42	889.06	889.12	889.06	13.16	889.02
6	889.35	889.35	889.35	889.35	888.88	889.58	889.35	889.35	12.85	889.33
7	889.47	889.53	889.53	889.53	889.06	889.53	889.53	889.53	12.46	889.54
8	892.44	892.85	893.26	893.61	894.13	891.10	891.51	890.98	12.02	889.88
9	893.67	894.25	894.83	895.42	896.23	893.14	892.33	891.45	11.55	889.77
10	894.95	895.88	896.82	897.63	898.92	894.08	892.97	891.68	10.13	889.46
11	895.42	896.47	897.52	898.45	899.79	894.43	893.20	891.80	9.13	889.24
12	895.88	897.17	898.28	899.44	900.90	894.72	893.43	891.86	7.37	888.84
13	896.23	897.63	898.86	900.14	901.66	894.95	893.55	891.92	5.63	888.44
14	896.47	897.98	899.33	900.73	902.30	895.18	893.67	891.92	3.88	888.05
15	896.76	898.33	899.73	901.25	902.88	895.36	893.78	891.92	2.13	887.65
16	896.70	898.22	899.68	900.96	902.48	895.30	893.78	891.92	1.13	887.42

WISCONSIN DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 8 ft

Flow Cond.	F.C.	1	2	3	4	5	6	7	8
H.W. Elev.-ft		898	900	902	904	906	896	894	892
T.W. Elev.-ft		878.3	880.4	882.0	883.5	884.8	875.5	872.6	870.0
Q/gate -cfs		5376	7535	9693	12283	14913	3591	1970	691
Q(total) -cfs		69893	97952	126010	159680	193860	46680	25610	8979

```

*****
                                Elevation-feet
Distance      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  F.C. 6  F.C. 7  F.C. 8
*****
-25            898.0   900.0   901.9   903.5   905.7   896.0   893.9   892.2
-20            898.0   899.9   901.9   903.3   905.3   896.0   893.9   892.1
-15            897.8   899.9   901.8   903.1   905.0   896.0   893.9   892.0
-10            897.6   899.9   901.4   902.9   904.8   895.8   893.8   891.9
-5             897.3   899.5   900.9   902.2   904.4   895.7   893.8   892.0
0              897.2   899.3   900.0   901.8   903.8   895.4   893.7   891.9
5              896.8   898.7   899.4   900.8   902.6   895.3   893.6   891.9
10             895.9   897.8   898.7   900.0   901.4   894.6   893.3   891.6
15             894.5   895.7   897.3   898.4   900.3   893.3   891.7   890.0
20             889.6   889.8   889.8   889.8   889.6   889.5   889.0   888.2
25             891.3   893.0   894.6   905.6   897.6   889.4   886.4   880.0
              886.0   887.7   887.3   887.7   887.3   885.5   884.0   879.0
30             885.7   889.2   890.6   892.6   895.0   883.5   877.4
              881.0   882.9   883.3   884.4   884.8   879.1   875.0
35             879.4   882.9   885.3   888.8   890.0   875.0
              875.4   877.2   879.4   880.6   880.0   871.7
40             874.0   876.9   880.0   883.6   885.0   871.6
              872.5   873.6   875.6   877.0
45             873.3   874.0   875.7   879.0   880.9   871.7
50             873.3   873.8   874.8   876.0   879.0   871.8
55             873.2   873.8   874.8   875.5   877.8   871.9
60             873.4   873.9   875.0   875.3   877.6   871.9
              873.9   874.0   875.0   876.0   877.7   872.0
*****

```

WISSOTA DAM GATE TESTS  
 WATER SURFACE PROFILES  
 1:14 Section Model  
 Gate R3 Down 8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5      6      7      8
H.W. Elev.-ft       898     900     902     904     906     896     894     892
T.W. Elev.-ft       878.3   880.4   882.0   883.5   884.8   875.5   872.6   870.0
Q/gate -cfs         5376    7535    9693   12283   14913   3591    1970    691
Q(total) -cfs       69893   97952  126010  159680  193860  46680   25610   8979
*****

```

Incremental Moments About Hinge Pin (ft-kips)										
tube number	F.C. 1	F.C. 2	F.C. 3	F.C. 4	F.C. 5	F.C. 6	F.C. 7	F.C. 8	Area of Surface	Arm to Surface
1	0.01	0.01	0.01	0.01	-0.15	0.01	0.01	0.01	0.8	9.583
2	0.01	0.01	0.01	0.01	-0.13	0.01	0.01	0.01	0.5	9.083
3	0.00	0.00	0.00	0.00	-0.12	0.00	0.00	0.00	0.5	8.583
4	-0.01	-0.01	-0.01	-0.01	-0.14	-0.01	0.02	0.02	0.5	8.083
5	0.01	0.01	0.01	0.01	-0.16	0.01	0.03	0.01	0.5	8.405
6	0.01	0.01	0.01	0.01	-0.13	0.08	0.01	0.01	0.5	9.661
7	-0.01	-0.00	-0.00	-0.00	-0.08	-0.00	-0.00	-0.00	0.25	10.579
8	1.46	1.69	1.92	2.12	2.42	0.69	0.93	0.63	0.76	11.992
9	2.60	2.99	3.38	3.77	4.31	2.25	1.71	1.12	0.93	11.502
10	4.13	4.83	5.53	6.15	7.11	3.47	2.64	1.67	1.19	10.125
11	4.85	5.68	6.50	7.24	8.29	4.07	3.11	2.01	1.38	9.125
12	5.67	6.71	7.60	8.54	9.71	4.73	3.70	2.43	1.75	7.375
13	4.79	5.65	6.40	7.19	8.12	4.00	3.14	2.14	1.75	5.625
14	3.56	4.20	4.77	5.36	6.03	3.02	2.38	1.64	1.75	3.875
15	1.67	1.95	2.21	2.49	2.79	1.41	1.12	0.78	1.38	2.125
16	1.06	1.24	1.40	1.55	1.72	0.90	0.73	0.51	1.63	1.125
Total Gate Moment	29.80732	34.96233	39.74653	44.42699	49.59175	24.64947	19.51809	12.98784		

WISCONSIN DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R3 Down 8 ft

Flow Cond. F.C.	1	2	3	4	5	6	7	8
H.W. Elev.-ft	898	900	902	904	906	896	894	892
T.W. Elev.-ft	878.3	880.4	882.0	883.5	884.8	875.5	872.6	870.0
Q/gate -cfs	5376	7535	9693	12283	14913	3591	1970	691
Q(total) -cfs	69893	97952	126010	159680	193860	46680	25610	8979

```

*****
tube      Elevation -feet      dist tube      elev. of
number    F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  to hinge -ft  tube-ft
*****
  1      884.33  884.22  883.98  884.68  885.62  14.17      884.29
  2      884.68  884.80  884.10  884.80  885.73  13.92      884.72
  3      885.15  885.27  884.22  884.98  885.79  13.67      885.15
  4      885.62  885.73  884.33  885.09  885.85  13.42      885.59
  5      885.97  886.20  884.57  885.27  886.08  13.16      886.02
  6      886.55  886.55  884.51  885.44  886.08  12.85      886.40
  7      886.67  886.73  884.80  885.79  886.20  12.46      886.71
  8      889.35  889.82  888.88  889.99  890.52  12.02      887.17
  9      890.63  891.10  890.75  891.92  892.50  11.55      887.17
 10      892.27  893.20  893.32  894.60  895.42  10.13      887.17
 11      892.97  893.84  894.19  895.53  896.41   9.13      887.17
 12      893.67  894.72  895.36  896.70  897.69   7.37      887.17
 13      894.25  895.42  896.18  897.52  898.57   5.63      887.17
 14      894.72  896.00  896.82  898.16  899.38   3.88      887.17
 15      894.95  896.23  897.11  898.22  899.27   2.13      887.17
 16      894.37  895.42  896.06  896.76  897.58   1.13      887.17
*****

```

WISSOTA DAM GATE TESTS  
 PIEZOMETRIC PRESSURE HEAD  
 1:14 Section Model  
 Gate R3 Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898      900      902      904      906
T.W. Elev.-ft      880.1  881.8  883.2  884.7  886.1
Q/gate -cfs        7122  9551  11809  14705  17680
Q(total -cfs      92586 124160 153520 191170 229840
*****

```

```

*****
Elevation-feet
Distance      F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5
*****
-25           898.0  900.0  901.2  903.4  905.2
-20           897.8  900.0  901.0  903.3  905.0
-15           897.6  899.6  900.6  902.8  904.8
-10           897.3  899.1  900.4  902.1  904.7
-5            896.7  898.6  900.0  901.5  904.2
0             896.1  897.3  899.0  900.7  902.5
5             895.0  896.2  897.9  899.5  901.0
10            894.0  895.0  896.2  898.0  899.6
12.8          887.2  887.2  887.2  887.2  887.2
15            892.5  893.3  894.4  895.9  897.7
              887.0  886.7  886.6  886.8  886.6
20            889.5  890.6  891.3  893.7  895.0
              884.0  884.5  884.0  884.0  884.3
25            885.0  886.2  887.2  890.0  891.9
              880.0  880.0  880.0  880.0  880.8
30            880.0  882.0  882.4  885.9  888.8
              875.0  875.0  875.0  875.0  876.0
35            875.7  877.9  879.1  881.8  884.3
              870.0  870.0  870.8  871.0
40            874.3  875.4  877.0  879.2  881.2
45            874.3  875.0  876.1  877.7  879.5
50            874.3  874.6  875.6  876.7  879.0
55            874.3  874.6  875.3  876.2  879.0
60            874.3  874.6  875.3  876.2  879.0
*****

```

WISSOTA DAM GATE TESTS  
WATER SURFACE PROFILES  
1:14 Section Model  
Gate R3 Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5'
H.W. Elev.-ft       898      900      902      904      906
T.W. Elev.-ft       880.1  881.8  883.2  884.7  886.1
Q/gate -cfs         7122   9551  11809  14705  17680
Q(total) -cfs       92586  124160 153520 191170 229840
*****

```

```

*****
Incremental Moments About Hinge Pin (ft-kips)
tube number  F.C. 1  F.C. 2  F.C. 3  F.C. 4  F.C. 5  Area of Arm to
Surface Surface
*****
1  0.02  -0.04  -0.15  0.19  0.63  0.8  9.583
2  -0.01  0.02  -0.18  0.02  0.29  0.5  9.083
3  0.00  0.03  -0.25  -0.05  0.17  0.5  8.583
4  0.01  0.04  -0.32  -0.13  0.07  0.5  8.083
5  -0.01  0.05  -0.38  -0.20  0.02  0.5  8.405
6  0.05  0.05  -0.57  -0.29  -0.10  0.5  9.661
7  -0.01  0.00  -0.32  -0.15  -0.08  0.25  10.579
8  1.24  1.51  0.97  1.60  1.90  0.76  11.992
9  2.31  2.62  2.39  3.17  3.56  0.93  11.502
10 3.83  4.53  4.62  5.59  6.20  1.19  10.125
11 4.55  5.24  5.52  6.57  7.26  1.38  9.125
12 5.23  6.08  6.59  7.67  8.47  1.75  7.375
13 4.35  5.07  5.53  6.36  7.00  1.75  5.625
14 3.19  3.74  4.08  4.65  5.17  1.75  3.875
15 1.42  1.66  1.82  2.02  2.21  1.38  2.125
16 0.82  0.94  1.02  1.10  1.19  1.63  1.125
*****
Total
Gate
Moment
ft-kips 27.00087 31.53603 30.39038 38.12991 43.96284

```

WISSOTA DAM GATE TESTS  
 COMPUTATION OF GATE LOAD  
 1:14 Section Model  
 Gate R3 Down 10.8 ft

```

*****
Flow Cond. F.C.      1      2      3      4      5
H.W. Elev.-ft      898      900      902      904      906
T.W. Elev.-ft      880.1    881.8    883.2    884.7    886.1
Q/gate -cfs        7122     9551    11809    14705    17680
Q(total) -cfs      92586    124160  153520  191170  229840
*****

```



APPENDIX B

## APPENDIX B

The resistive gate moment has been analyzed by Ayres Associates\* and the equations and pertinent dimensions were given in their report. These equations were used in the computation of the resistive gate moment shown in Fig. 63, and are presented below for reference purposes. The additional force(chain pull) was taken to be zero, and the total counterweight per gate was 289 kips. The equation for the gate moment (GM) in foot-kips due to the counterweight system is

$$GM = \frac{A}{B} [289C + 0.8F] + 0.8 E - 32D - 5.35A$$

The lever arms, A through F, are a function of the gate position and have been determined graphically by Ayres Associates for the curved lip gate. The measured values are tabulated below. Values for the straight gates are the same for the same gate position. However, the elevation of the gate crest of the straight gate is slightly higher at a given position. Since this difference has been calculated to be less than 0.4 ft, for purposes of the comparisons here the difference has been neglected. The gate position is nominally the distance from the normal pool El. 898 to the gate crest.

---

\*Northern States Power Company, Wisconsin Hydro Plant Automatic Spillway Gate Pulldown Test, May 10, 1988 (report prepared by Ayres Assoc., Eau Claire, Wisconsin).

Gate Position ft	Lever Arms ft						GM ft-kips
	A	B	C	D	E	F	
0.0	7.79	5.00	3.12	4.08	6.25	4.10	1243
0.5	8.32	5.38	3.52	4.55	5.75	3.50	1392
0.1	8.54	5.61	3.78	5.00	5.25	3.10	1465
2.0	9.07	5.85	4.13	5.55	4.33	2.10	1630
3.0	9.44	5.97	4.35	6.05	3.50	1.30	1748
3.6	9.60	6.02	4.43	6.30	3.00	0.80	1792
4.0	9.70	6.02	4.47	6.45	2.60	0.40	1826
5.0	9.85	5.89	4.47	6.75	2.00	-0.30	1893
6.0	9.98	5.70	4.33	7.05	1.25	-1.00	1912
7.0	10.04	5.44	4.15	7.20	1.50	-1.80	1928
8.0	10.04	5.12	3.92	7.40	0.00	-2.30	1927
9.0	10.04	4.60	3.50	7.50	-0.50	-2.95	1908
10.0	10.00	3.96	2.96	7.52	-0.83	-3.60	1858
11.0	10.00	3.15	2.30	7.55	-0.96	-4.20	1804

