# HYDRAULIC MODEL STUDY
# OF THE
# NORTH SPILLWAY, ROOSEVELT DAM
# SALT RIVER PROJECT

Prepared for

Salt River Project
Phoenix, Arizona

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## Conclusions

1. The free flow capacity of the north spillway with the present bridge railings and the maximum gate opening fixed at 21 feet (Gates 11 through 19) will be approximately 74,000 cfs at Reservoir El. 244.0 (top of dam parapet) Fig. 4. Assuming a ratio of net length for the two spillways the total flow at Reservoir El. 244.0 would be approximately 153,200 cfs. This flow rate is approximately the same as that obtained from the 1:100 scale model tested by the Bureau of Reclamation in the 1930's.

2. Flow conditions at the spillway piers are severely unbalanced. Water piles up at the left sides of the piers and there are severe contractions at the right sides, Figs. 6 and 7. The nearly right angle direction of flow in the approach channel with respect to the crest of the spillway is the cause of this unbalanced condition.

3. The pile up of water on the left sides of the piers sometimes strikes the structural members of the gates, Fig. 8, particularly at high free-flow discharges.

4. The contraction at the left end of the spillway is more severe than at the spillway piers. The contractions decrease progressively from Gate 11 to Gate 19, Figs. 6 and 7.

5. Vortices will form at the ends of the gates when they are controlling the flow, Fig. 15. The vortex action will be more pronounced at the left ends of the gates than at the right ends. Also, the vortex action will be more severe at large gate openings but will decrease as the gate opening decreases.

6. When the gates are controlling flows at large openings flow conditions at the left end of the spillway will be improved if Gate 11 is fully open. The spillway will discharge 53,500 cfs when Gate 11 is fully open, Gates 12 through 19 are set at a 14-foot opening and the reservoir is at El. 244.0, Curve C, Fig. 11. Assuming the same operation of the gates in the south spillway (Gate 10 fully open and Gates 1-9 open 14 feet) the total discharge will be approximately 110,900 cfs for both spillways.

7. The capacity of the north spillway with all 9 gates at equal but various openings can be determined from the chart of Fig. 10.

8. The capacity of Gates 11 or 19 operating singly can be determined from the chart of Fig. 13. The capacity of any single central gate (12 through 18)can be determined from the chart of Fig. 14.

9. Large vortices form upstream at the ends of an open gate, B, Fig. 15.

10. The discharge of two adjacent central gates (12 through 18) can be determined from the chart of Fig. 16.

11. Large contractions and vortices form at the left end of Gate 13 and at the right end of Gate 14 when the gates are discharging together at any reservoir elevation. (Tops of closed gates are at El. 234)

12. The discharge of two adjacent gates when one is at the end of the spillway (Gates 11 and 12 or 18 and 19) can be determined from the chart of Fig. 17.

13. A large contraction and vortex action takes place at the right end of Gate 12 when Gates 11 and 12 are discharging. Flow conditions at the left end of Gate 11 are less severe because the end is suppressed and there are no concrete blocks at the base of the end pier.

14. The discharge of three adjacent central gates (12 through 18) can be determined from the chart of Fig. 18. The gates tested were No. 13, 14 and 15.

15. Large contractions and vortex action take place at the outer ends of the end gates when any four adjacent central gates are discharging.

16. The spillway discharge for four central gates discharging at various gate openings can be determined from the chart shown in Fig. 19.

17. When the four gate combination of every other central gate is discharging (No's. 12, 14, 16 and 18) each gate has significant end contractions and vortex action. The action is not considered serious.

18. The discharge for the four gate combination of every other gate discharging (Gates 12, 14, 16 and 18) can be obtained from the chart shown in Fig. 20.

19. There will be large contractions and vortex action at the outer ends of the end gates when five adjacent central gates are discharging for any reservoir elevation up to the tops of the closed gates (El. 234.0).

20. The discharges for any five adjacent central gates discharging can be determined from the chart shown in Fig. 21.

21. When every other gate and 5 gates discharge (Gates 11, 13, 15, 17 and 19) there are small vortices at both ends of Gates 13, 15 and 17. No vortices form at the outer ends of Gates 11 and 19. However, flow distrubances occur at these locations when the gate openings are large.

22. The discharges for the 5 gate combination in which every other gate is open (Gates 11, 13, 15, 17 and 19) can be determined from the chart shown in Fig. 22.

23. The concrete blocks at the pier bases introduce losses that result in some reduction in capacity under free-flow conditions and when gates operate at small openings. When gates are operated individually Gates 11 and 19 will pass slightly more water than a central gate because of the absence of concrete anchor blocks at the bases of the end piers, the suppressed flow at the end piers and the greater length.

24. The closed bridge railings, filled with concrete panels to approximately El. 242.5, cause a decrease in the capacity of the spillway at high reservoir elevations and large gate openings, Fig. 9.

25. The bridge across the entrance of the approach channel increases the reservoir elevation upstream from the bridge for a given discharge at gate openings in excess of 12 feet and reservoir elevations above approximately 240, Fig. 9. There is a head loss of approximately one foot due to the bridge when the spillway discharge is approximately 73,000 cfs. Raising of the bridge deck and arches to clear the maximum reservoir elevation will increase the capacity at the above mentioned gate openings and reservoir elevations. Raising the bridge deck and arches was outside the scope of this study, thus the magnitude of the increased capacity was not obtained from the model.

26. The total force on a gate is transmitted radially through the gate radius center. The force is greatest when the gate is closed and the reservoir is at the top of the gate, Figs. 23 and 24. Overflowing a gate will increase the force.

27. The force on a gate when it is closed and the reservoir is at the top of the gate will be approximately 14,030 pounds per linear foot. The maximum force on a gate when the gate is controlling the flow at openings of 1, 4, 8, 12 and 14 feet was determined to be 13,550, 11,610, 11,210, 7,180 and 6,850 pounds per linear foot respectively based on records of pressures measured by piezometers placed in the center of one of the model gates, Figs. 2, 23 and 24.

28. The total maximum load on a 19'-8½" long gate is 276,508 pounds when closed and the reservoir water surface is at the top of the gate (El. 234.0). The total maximum load on a 19'-11¾" long gate is 280,308 pounds when closed and the reservoir water surface is at the top of the gate (El. 234.0).

HYDRAULIC MODEL STUDY OF THE NORTH SPILLWAY
ROOSEVELT DAM, SALT RIVER PROJECT

## INTRODUCTION

### The Project

The Roosevelt Dam, located in the Salt River about 80 miles northeast of Phoenix, Arizona, was constructed by the Bureau of Reclamation during the period 1906-1911. The project is a multipurpose project for storing irrigation water, controlling floods and producing power.

The dam is a 285-foot high arch gravity structure of masonry construction having two spillways excavated into the canyon walls on each side of the main dam. The narrow canyon at the damsite necessitated the excavation of large quantities of solid rock to form the spillway approach channels with sufficient depth for placing the spillway crests at an elevation that would provide control for forecasted flood flows. Both approach channels curve outward into the canyon walls in such a way that the spillway crests are perpendicular to the approach channel entrances, Fig. 1. The crest of the dam is al El. 240.0 and its parapets extend up to El. 244.0.

The spillway crests have undergone changes since their construction. The crests of the spillways were first constructed to El. 219.0. The capacity of this arrangement was expected to be 150,000 cfs. In 1913 the spillway crests were raised 5 feet to El. 224 to increase the storage capacity of the reservoir. In 1920 when large flood flows had to be wasted, steps were taken to again provide more storage capacity.

The maximum storage level was increased to El. 234.0 by cutting the crests to El. 218.25, constructing piers on the crests and installing 15.75-foot high radial gates, Fig. 1. The high piers were strengthened by constructing pin anchorages and concrete anchor blocks at their bases upstream from the radial gates.

Hydraulic model studies were made by the Bureau of Reclamation in the 1930's to assess the existing design and to determine if the capacity could be increased by making minor changes in the structures. The model tests were conducted in the Colorado Agricultural Experiment Station Hydraulic Laboratory then located on the Colorado State University campus on grounds now occupied by the Engineering Building. At that time it was considered that the two spillways should handle flood discharges up to 200,000 cfs. The model used for the investigations was constructed to a scale of 1:100 and contained the dam, both spillways with their approach channels, a portion of the reservoir near the dam and a short section of the downstream river channel. Capacity tests were made for the existing arrangement and for several minor alterations.

The tests showed that the capacity of the existing spillways was approximately 119,000 cfs, far short of the desired 200,000 cfs.

Tests with the piers and gates removed and the crest at El. 218.25 gave a maximum discharge of 172,000 cfs. This arrangement reduced the storage capacity as well as lessened the control of flood waters.

Tests with the anchor block and pin anchorages represented with the crest at El. 218.25 and the reservoir at El. 244.0 indicated a maximum discharge of 152,000 cfs. This arrangement is essentually the same as the 1:25 scale model of the north spillway recently tested in the Hydraulic Laboratory at the Colorado State University Engineering Research Center, which is the subject of this report. The results of the tests on the 1:25 scale model of the north spillway are in close agreement with the tests on the 1:100 scale model made in the 1930's.

Most of the information contained in the Introduction Section of this report was obtained from a draft of a Bureau of Reclamation report that was never published in final form.

### Hydraulic Laboratory, Colorado State University

Hydraulic tests on the 1:25 scale model of the north spillway of Roosevelt Dam, Arizona was conducted in the Hydraulic Laboratory at the Colorado State University Engineering Research Center. The Center is the focal point for research and graduate education. The Center is located on the Foothills Campus near the base of Soldier Canyon Dam, four miles west of Fort Collins, Colorado. The Center's hydraulic laboratory of 50,000 square feet of floor space obtains it water supply from Horsetooth Reservoir which is behind the dam. The supply conduit from the reservoir is 36-inches in diameter to the laboratory and continues as 26-inch pipe for approximately ¼ mile to the CSU Hydro

SPECIFICATIONS No. 663 DRAWING No 2

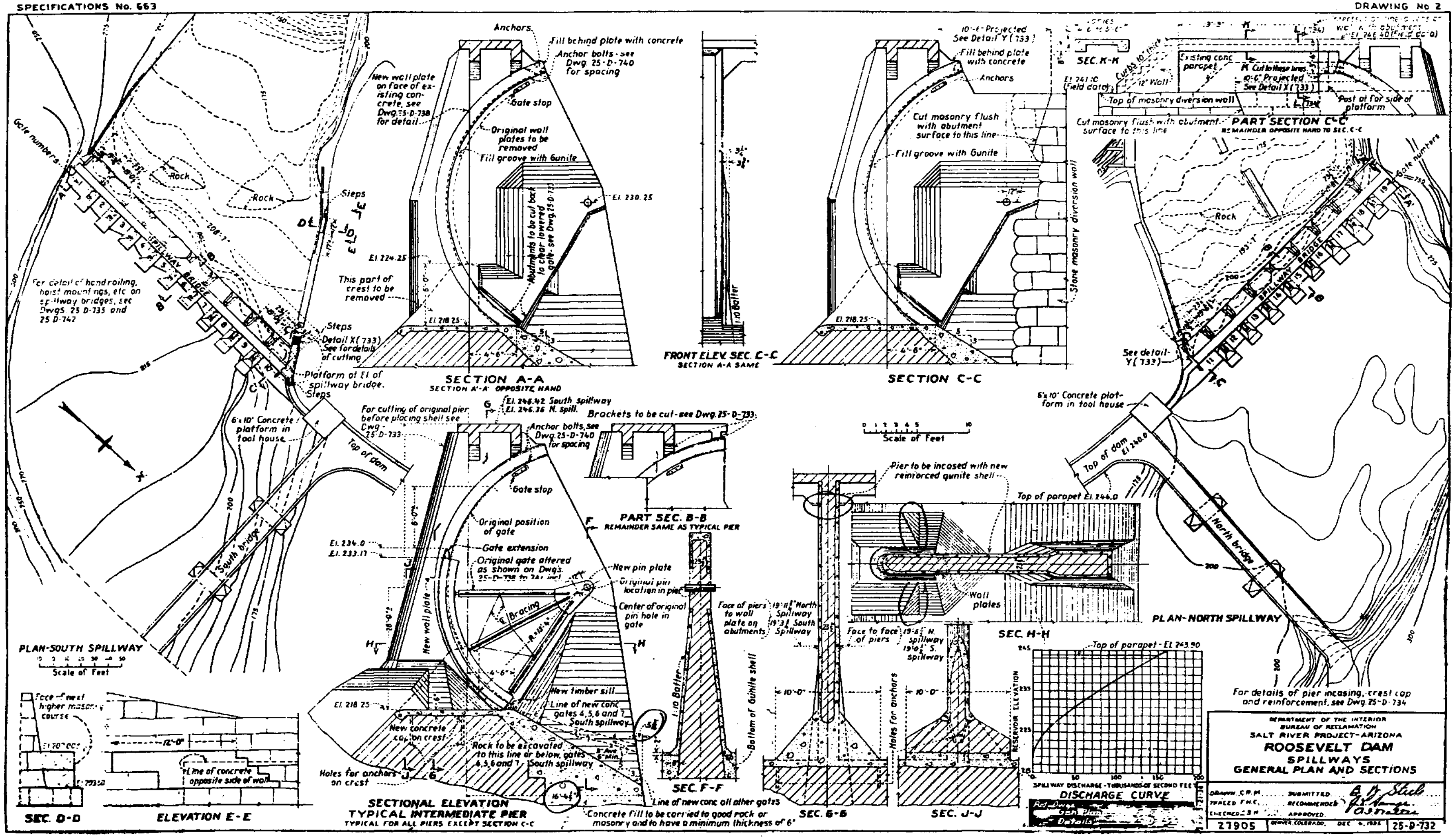



Fig. 1 - Spillways, General Plan and SE Sections (Bureau of Reclamation Drawing No. 25-D-723)

Machinery Laboratory. A 12-inch branch from the conduit is one of the sources of flow into the Hydraulic Laboratory. The laboratory has a system of under-the-floor sumps of one acre foot capacity from where water is pumped and recirculated by several pumps to various parts of the laboratory. A 20-inch vertical pump and an 8-inch vertical pump supplied water to the 1:25 scale model of the Roosevelt Dam Spillway.

There are four principal parts to the Center: the offices for staff and graduate students, the hydraulics laboratory, the fluid dynamics laboratory and the hydro-machinery laboratory. The research activities of the Center are in fluid mechanics, hydraulics, hydrology, ground-water, soil mechanics, hydro-biology, geomorphology and environmental engineering.

The Center includes well equipped machine and woodwork shops. All research facilities of the Center are constructed on site and in the case of the Roosevelt Dam Spillway model study, necessary metal, machine and carpentry work were done by skilled personnel in the shops. The shop personnel are particularly well experienced in the art and skill of model construction.

## PURPOSE OF THE MODEL STUDY

The purposes of the model studies discussed in this report were to calibrate the spillway under various operating conditions, observe flow conditions and determine the forces that the water produces on the radial gates.

## THE MODEL

### Description of Model

The two spillways at Roosevelt Dam are similar except for the number of radial gates that control releases at the spillway crest, Fig. 1. The north spillway has 9 gates that are 15.75 feet high and the south spillway contains 10 similar gates. It was considered that the flow action of the north spillway would be representative of both the north and south spillways, thus only the north structure was represented in the model study. The north spillway was constructed to a scale of 1:25, Fig. 2. The model contained an adequate area of the reservoir to give representative flow action into the approach channel, the approach channel from the reservoir to the spillway crest, the spillway crest at El. 218.25 and the 9 radial control gates. The channel downstream from the crest was not represented. The entire model was contained in a wooden box 13.0 feet wide, 24.5 feet long and 4.0 feet deep set 2.25 feet above the floor of the Laboratory.

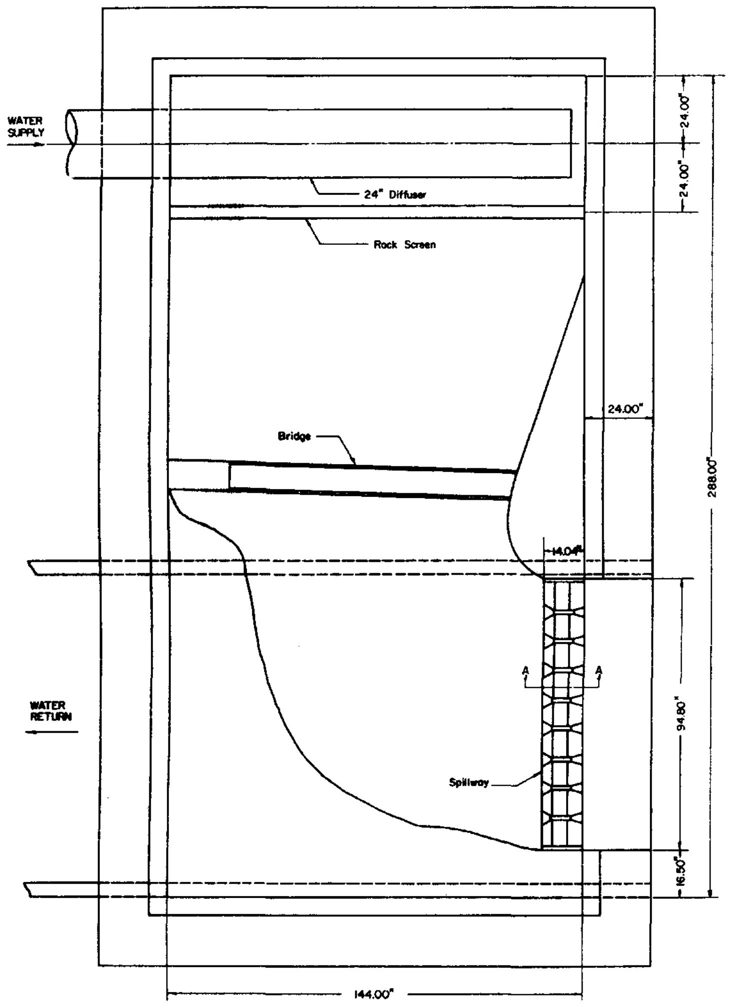
The water for the higher discharges was supplied to the model by a 20-inch pump capable of delivering 23.82 cfs, representing a prototype flow of 74,000 cfs. The supply line from this pump was 18 inches in diameter and contained an 18-inch calibrated orifice meter. An 8-inch pump was used to supply small flows to the model. The 4-inch supply line from this pump contained a 4" x 3.2" volumetrically calibrated orifice meter.

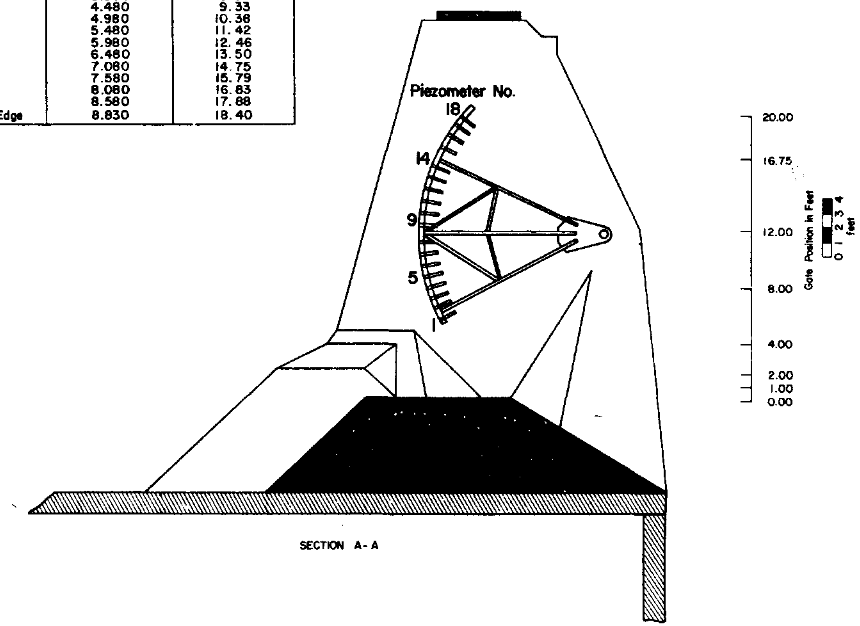
The supply line entered the back upstream corner of the model head box, Fig. 3a. A rock baffle placed across the box 4 feet from the reservoir end of the box quieted the flow from the supply line and directed it toward the approach channel and over the spillway crest. The topography leading to the approach channel and the approach channel were represented by sand shaped to contour and covered with a thin layer of sand-cement motar. The bridge across the entrance to the approach channel was constructed of wood.

The crest, its piers with the concrete blocks at their bases, and the gates were fabricated from clear plastic, Fig. 3a and 3b. All but one of the radial gates and their arms were made of transparent sheet plastic. Set screws were provided in the gate arms to hold the gates at specific openings. Gate settings were made by inserting a given length of brass tubing under the gate and then tightening the arm set screws to hold the gate in place. Lengths of brass tubing representing, 1, 2, 4, 6, 8, 12, 14, 16.75 and 21 feet prototype were used for the tests. Accurate and repetitive openings could be set using this method. Water from the model crest was discharged into a channel under the model and through a floor grating into the under-the-floor laboratory sump for recirculation.

A pressure tap in the floor of the reservoir area of the model box served as a means of recording the

| Piezometer Locations | | |
|---|---|---|
| Piezometer No. | Model Cumulative distance along gate, inches | Prototype Cumulative distance along gate, feet |
| Bottom edge | 0 | 0 |
| 1 | 0.100 | 0.21 |
| 2 | 0.600 | 1.25 |
| 3 | 1.100 | 2.29 |
| 4 | 1.600 | 3.33 |
| 5 | 2.100 | 4.38 |
| 6 | 2.600 | 5.42 |
| 7 | 3.100 | 6.46 |
| 8 | 3.500 | 7.29 |
| 9 | 3.980 | 8.29 |
| 10 | 4.480 | 9.33 |
| 11 | 4.980 | 10.38 |
| 12 | 5.480 | 11.42 |
| 13 | 5.980 | 12.46 |
| 14 | 6.480 | 13.50 |
| 15 | 7.080 | 14.75 |
| 16 | 7.580 | 15.79 |
| 17 | 8.080 | 16.83 |
| 18 | 8.580 | 17.88 |
| Top Edge | 8.830 | 18.40 |



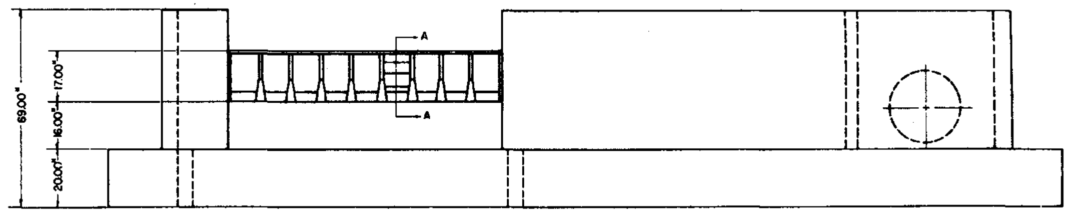
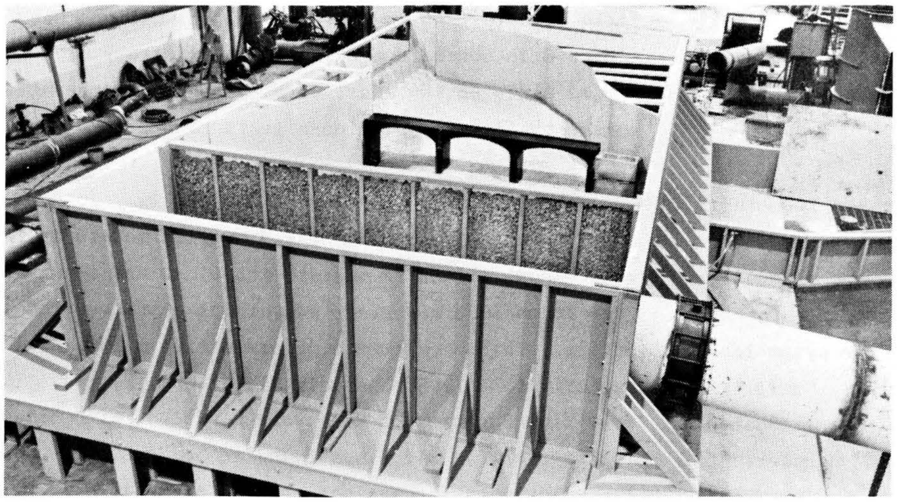
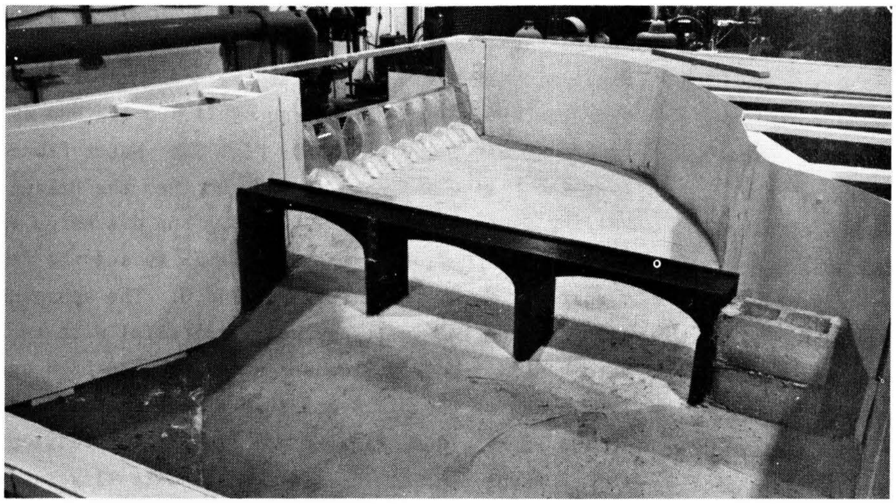



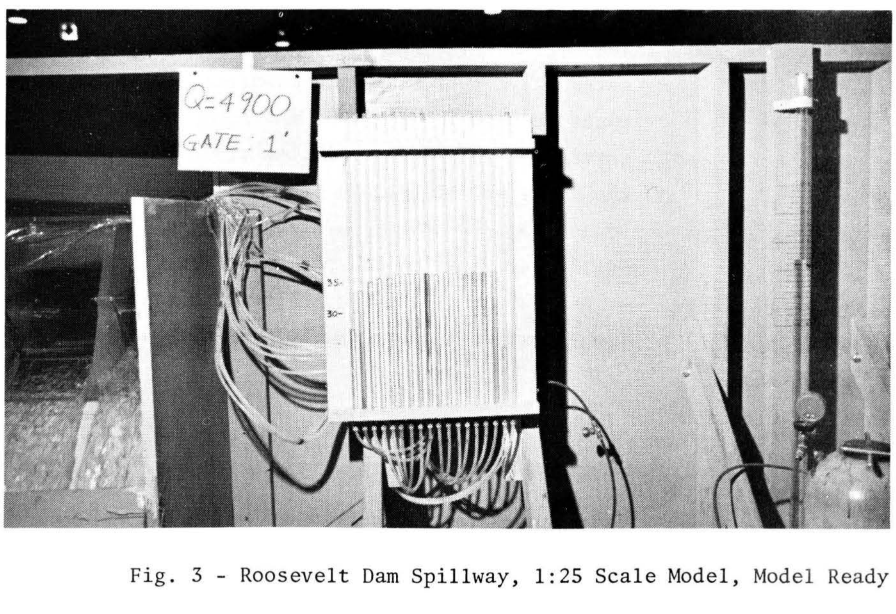

Fig. 2 - Model Arrangement



a. Completed Model



b. Model Approach Channel Bridge and Crest




c. Manometer Board, and Tubing for Gate Piezometers

Fig. 3 - Roosevelt Dam Spillway, 1:25 Scale Model, Model Ready for Testing

reservoir elevation. A 3/4" tygon tube from the pressure tap to a glass tube attached to a board graduated to represent prototype elevations, permitted recording the reservoir water level for the various test conditions.

One of the model gates, including its structural members, was constructed of brass sheet and angles. Eighteen pressure taps or piezometers were placed in the face of the gate at its centerline to record the pressures on the gate for determining the water loads for various operating conditions, Fig. 2. Small tygon tubing extending from the piezometers to a graduated manometer board served for measuring the pressures on the gates. Pressure distribution data were used to determine the forces exerted on the gates.

Test Procedure

The model gates were set at a desired elevation and combination, the pump was started and all air bled from the orifice meter leads and the supply piping system. Water was then supplied to the model slowly until the desired reservoir elevation was reached. Once the steady state flow conditions were attained, data related to discharge (differential head on orifice meter), reservoir elevation, pressures on face of gate, gate settings and combinations were recorded. Also, flow conditions in the approach channel, at the bridge and at the crest and gates were observed and recorded. At the end of a test the gate combination and elevation were reset to a predetermined condition and further test runs conducted or the water supply to the model shut off. A differential manometer and open end manometers were used to measure the differential heads on the orifice meters. Flow conditions in the model were recorded photographically.

## TEST RESULTS

Flow Conditions and Capacity of North Spillway (Gates 11 through 19)

Free Flow. The Roosevelt Dam Spillway model, Figs. 2 and 3, was built according to Bureau of Reclamation Drawings F-2-102 and 25-D-732, Fig. 1, which showed the bridge railings to be open pipe railings with concrete bases. The bases on both sides of the model bridge were built to represent a prototype elevation of 240.0. The initial tests on the model were made with this bridge arrangement until the railings were altered to agree with field surveys and photographs of the field structure which showed that the railings were closed with concrete panels to approximately El. 242.5. The railings on the model were raised to represent this elevation and pertinent tests conducted.

The free-flow capacity of the spillway was obtained, using previously calibrated orifice meters in the water supply lines to measure the flows and a manometer gage to measure reservoir elevations upstream from the bridge. This permitted a determination of the spillway capacity for given reservoir elevations, Fig. 4. The free-flow capacity at Reservoir El. 244.0 with bridge railings at El. 242.5 was found to be 74,000 cfs. The free-flow capacity was not changed significantly when the bridge rails were raised to represent the prototype.

The water surface at the upstream side of the bridge was near the elevation of the arches of the bridge when the free-flow discharge was 40,700 cfs, Fig. 5a. With the railings at El. 240.0 water flowed over the bridge at a discharge of 74,400 cfs and a reservoir elevation of 243.8, Fig. 5b. Water flowed over the bridge as shown in Fig. 5c when the bridge railings were raised to El. 242.5. The discharge was 66,250 cfs, the gates were open 16.75 ft and the reservoir was at approximately El. 246.0. The approach direction to the spillway, nearly parallel with the gate controlled crest, causes water to pile high on the left sides of the piers and severe contractions to form on the right sides, Figs. 6 and 7. The contraction at the abutment pier at the left end of Gate 11 was particularly severe, Figs. 6a and 7a. The surface of the spillway crest adjacent to the pier was visable at times. The direction of flow changes almost 90 degrees in passing from the approach channel through Gate No. 11. The contractions and pile up on the piers decreased for gates at greater distances along the crest and to the right of Gate 11, Figs. 6b and 7. At times the flow contracted and impacted on the structural frame work at the right end of Gate No. 13 which was fabricated from brass, Fig. 8. The flow also impacted on the trunnion pin at the right end of the gates for discharges greater than about 49,200 cfs. Flow conditions were quite rough upstream and to the left of Gate 11, Fig. 6.

Gate Controlled Flow, Bridge Railing El. 240.0. Observations and calibrations were made with the gates

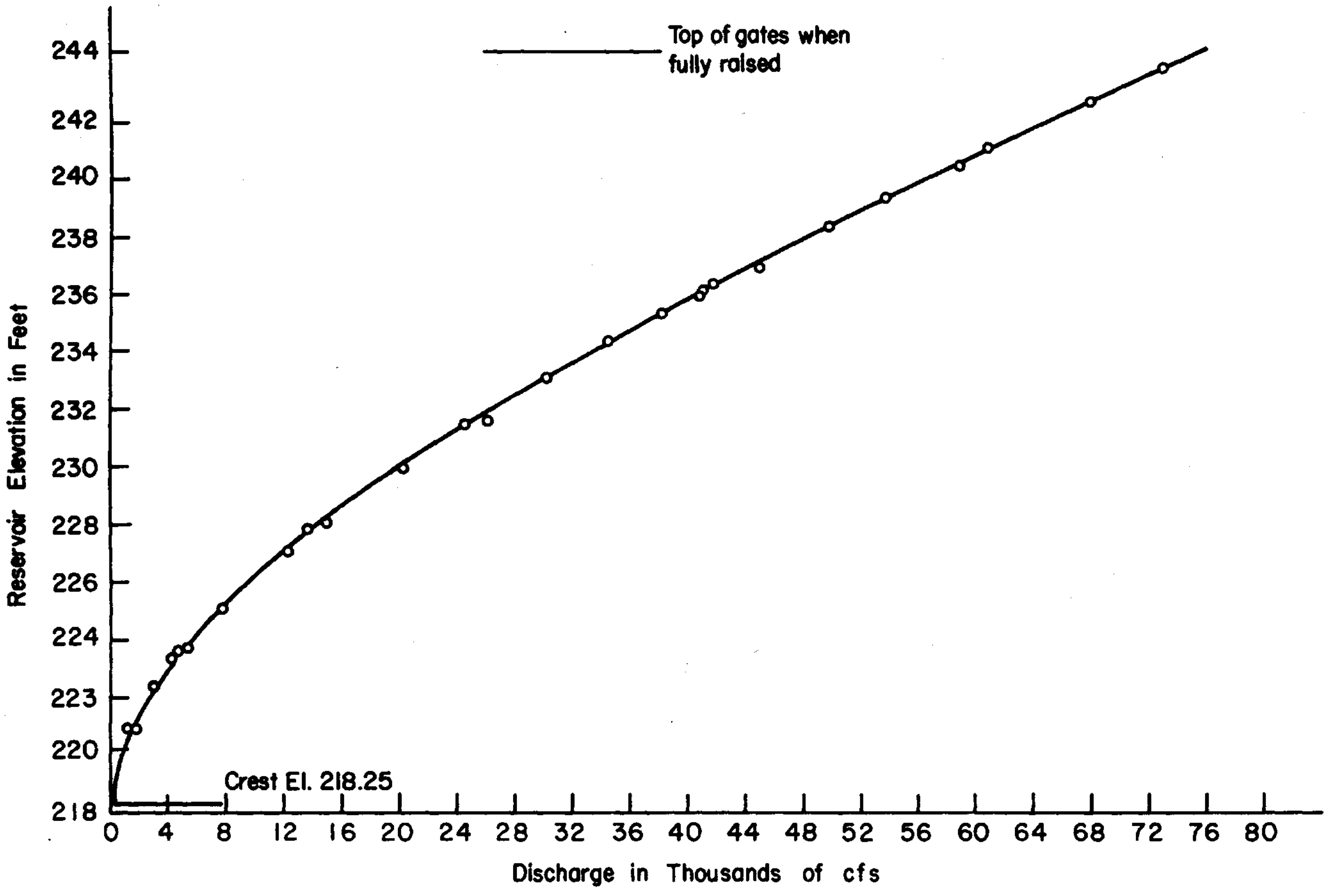
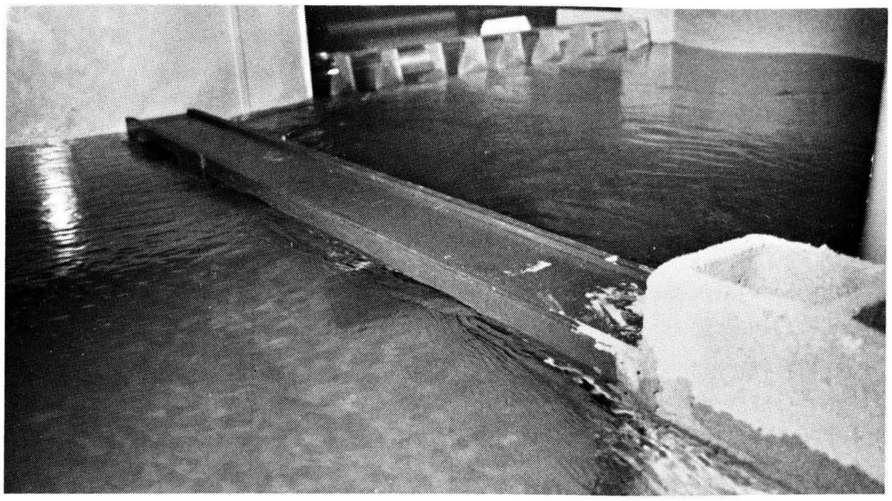
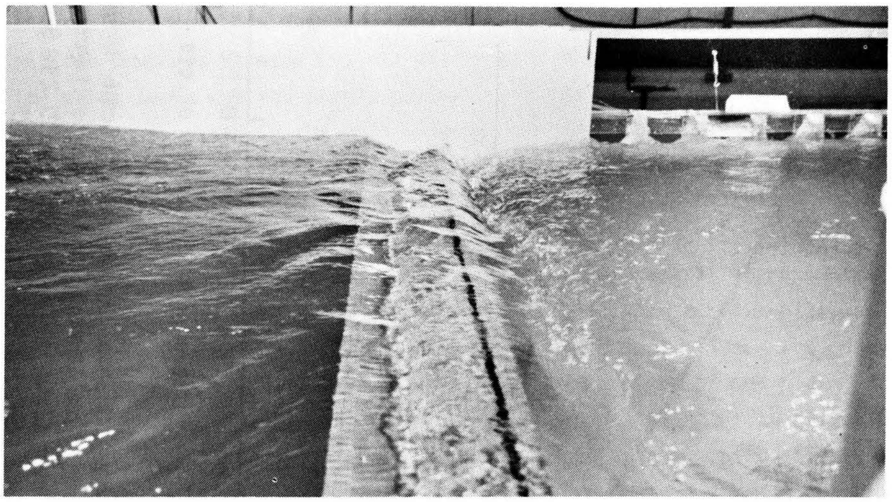


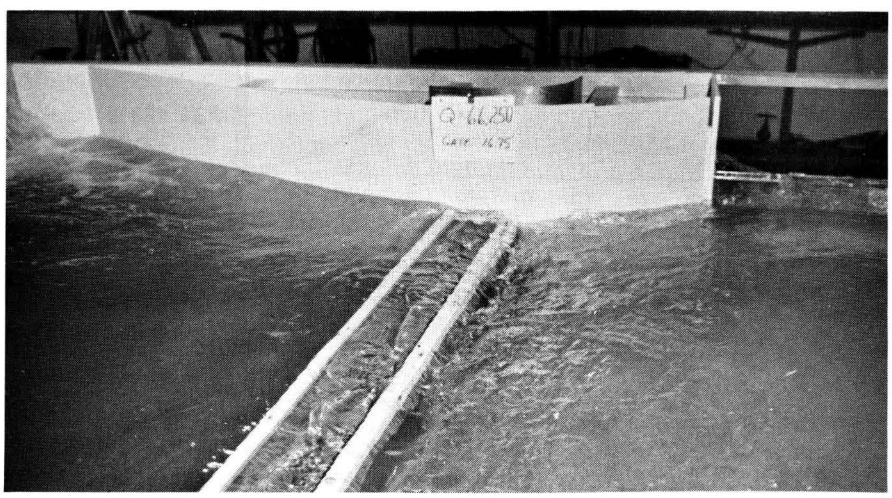

FIGURE 4. Roosevelt Dam Spillway, 1:25 Scale Model
Free Flow Capacity Curve, (Gates 11 through 19)
Note: Crown of bridge arch at El. 238.6
Bridge Railings at El. 242.5



a. Flow Conditions at Bridge Free-Flow Discharge of 40,700 cfs

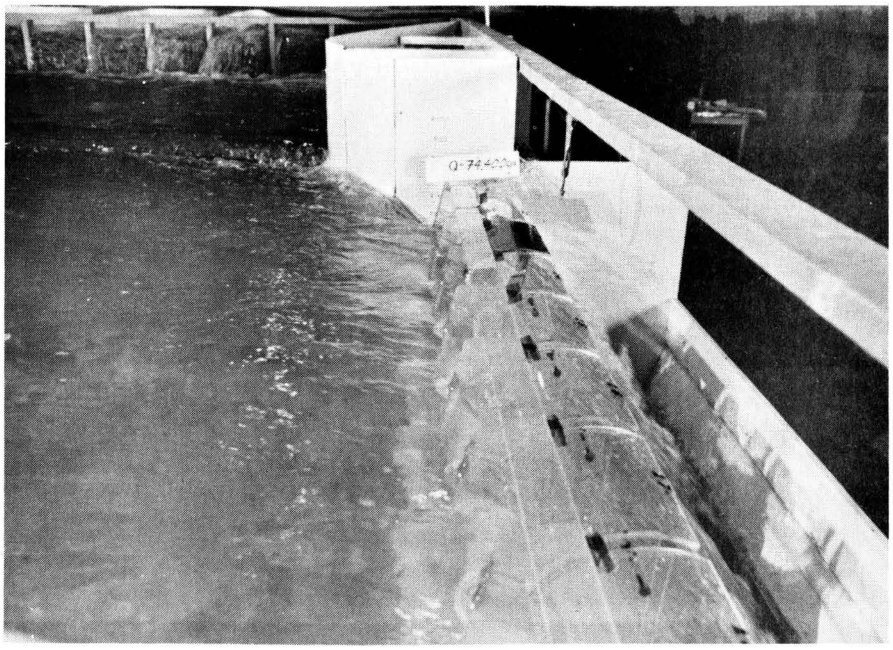


b. Water Flowing over Bridge, Top of Railings El. 240 Discharge 74,400 cfs Reservoir El. 243.8

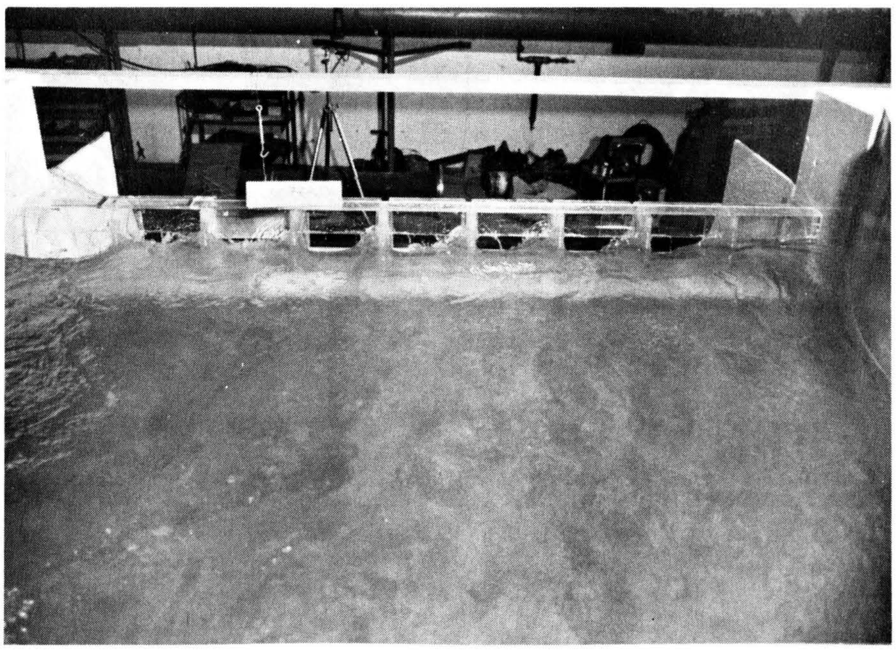



c. Water Flowing over Bridge, Top of Railings El. 242.5 Discharge 66,250 cfs Reservoir El. 246.0 Gates Open 16.75 ft

Fig. 5 - Roosevelt Dam Spillway, 1:25 Scale Model, Flow Conditions at Bridge

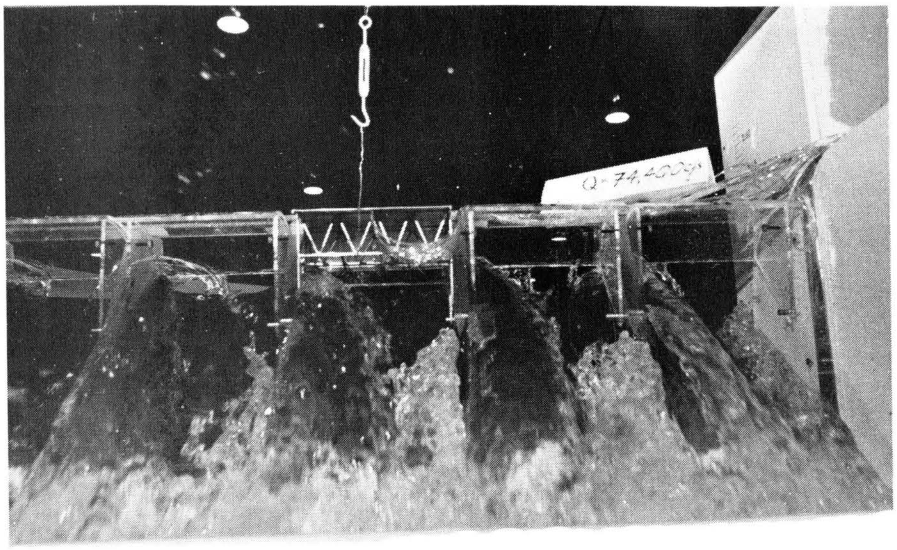


a. Severe Contraction at Left End of Gate 11

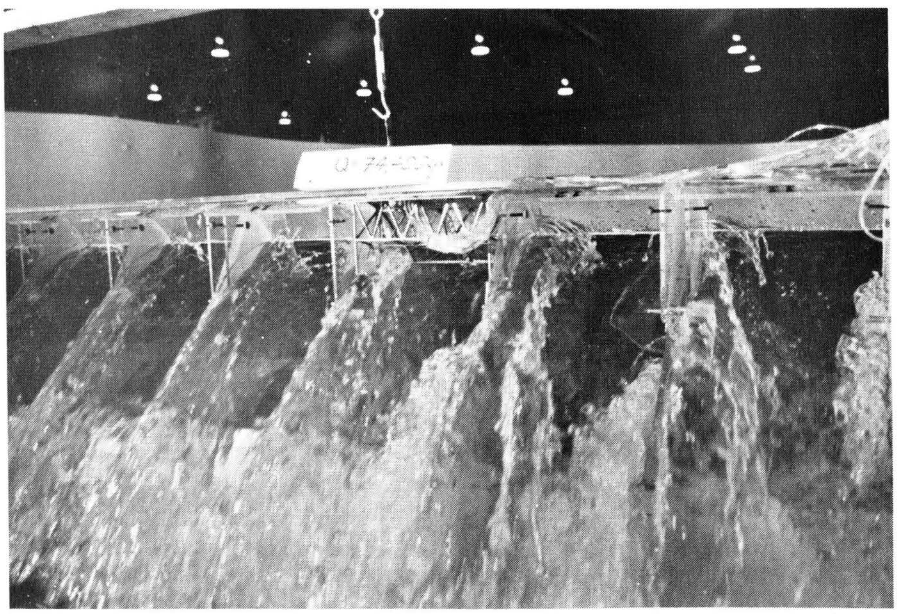


b. Flow Condition at Crest, Piers and Gates

Fig. 6 - Roosevelt Dam Spillway, 1:25 Scale Model, Flow Conditions at Spillway Gates and Piers, Discharge of 74,400 cfs, Reservoir El. 243.8

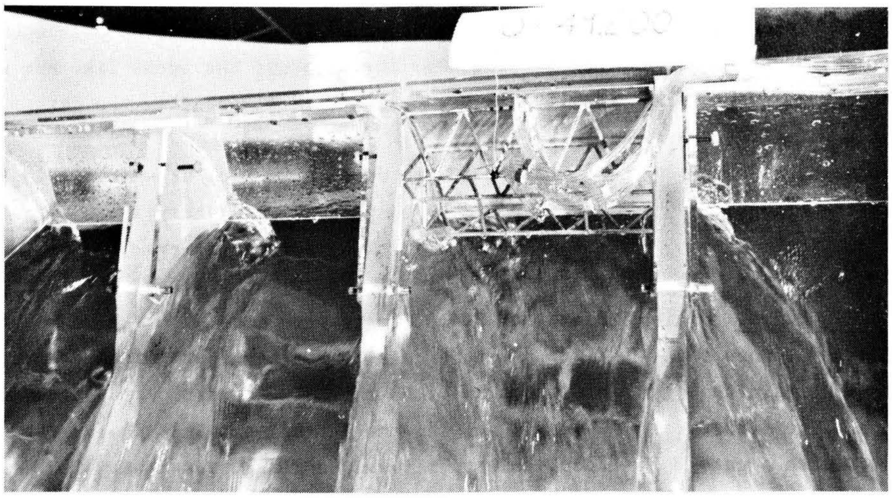


a. Flow Contractions and Pile-up at Piers. Flow Contacts Gate Structural Member

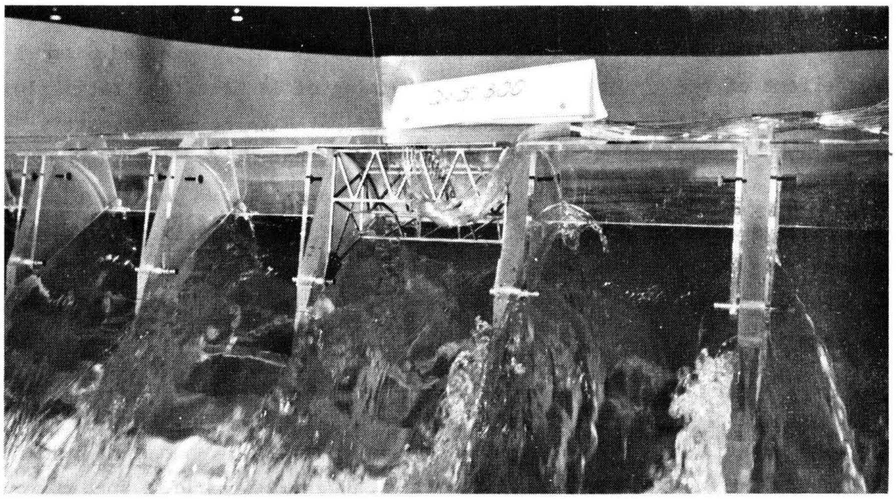


b. Flow Pipe-up on Left Sides of Piers

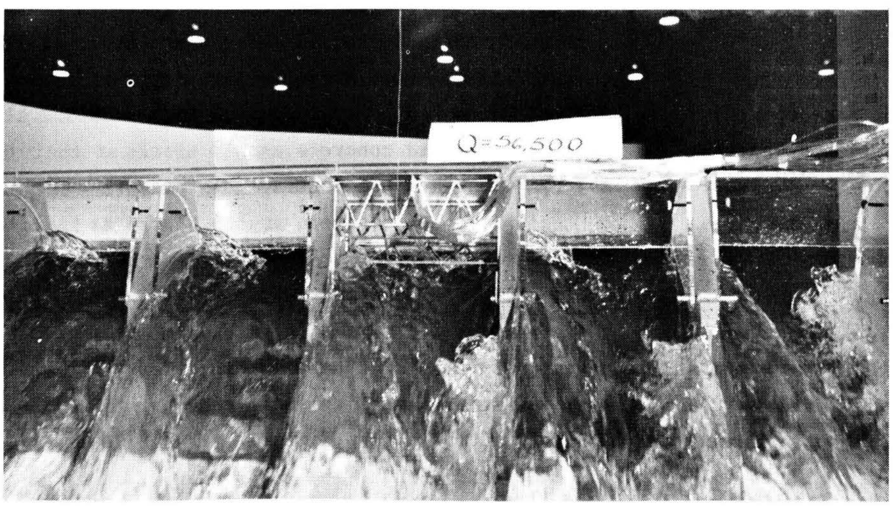
Fig. 7 - Roosevelt Dam Spillway, 1:25 Scale Model, Flow Conditions at Crest and Piers. Free-Flow Discharge of 74,400 cfs, Reservoir El. 243.8.



a. Flow Conditions at Gate Frame and Trunnion Pins Discharge 49,200 cfs Reservoir El. 238.0



b. Flow Condition at Gate Frame and Trunnion Pins Discharge 51,300 cfs Reservoir El. 238.5




c. Flow Conditions at Gate Frame and Trunnion Pins Discharge 56,500 cfs Reservoir El. 239.8

Fig. 8 - Roosevelt Dam Spillway, 1:25 Scale Model, Flow Conditions at Gate Frames and Trunnion Pins, Gates Open 16.75 feet, Various Discharges

set at openings of 1-foot, 4 feet, 8 feet, 16.75 feet and 21 feet. A discharge chart was made which was later replotted when the bridge railings were changed to represent El. 242.5. When the bridge railings were changed tests were made to ascertain their effect on the discharge capacity at large gate openings since only these openings were affected by the bridge obstruction, Fig. 9.

Gate Controlled Flow, Bridge Railing El. 242.5. Calibration tests and observations were made at gate openings of 12, 14, 16.75 and 21 feet to ascertain the effects of the raised bridge railings. The effect was not significant at Reservoir El. 240.0 with a gate opening of 12 feet and a discharge of approximately 40,000 cfs, Fig. 9. The effect of the higher bridge railings with a 14-foot gate opening was more noticeable. The decrease in discharge began at approximately Reservoir El. 239.0 and a discharge of 44,500 cfs. The higher bridge railings caused a decrease of about 3.7 percent at a Reservoir El. 244.0. The effect of the raised bridge railing with the gates open 16.75 feet was greater than at the two smaller openings. There was no change up to Reservoir El. 238.0. The decrease in discharge due to the higher bridge railings was very pronounced at higher reservoir elevations, Fig. 9. The decrease in capacity at Reservoir El. 244.0 was 4.5 percent, the flow being decreased from 66,500 to 63,400 cfs.

The effect of the raised railing with a gate opening of 21 feet was not significant, Fig. 9. The decrease in discharge began at approximately Reservoir El. 241.0. At a Reservoir El. of 244.0 the decrease was approximately 1.3 percent. Gate openings below 12 feet were not affected by the raising of the bridge railings.

The calibrations for free flow, gate openings of 1, 4, and 8 feet with the low bridge railings and the calibrations with 12, 14, 16.75 and 21 feet with the higher railings were used to prepare the discharge chart shown in Fig. 10. The chart was developed by first plotting discharge versus reservoir elevation for each tested gate opening then plotting gate opening versus discharge for selected reservoir elevations. The values of discharge at the selected reservoir elevations plotted for gate opening increments of one foot were used to produce the discharge chart shown in Fig. 10. The locus of the top of the gates (highest point of gate) was determined for various gate openings and plotted on the figure. The parts of the gate opening versus discharge curves above the locus line are not applicable because water will overflow the gates.

Since it was desired to know at what opening the gates should be to pass approximately 105,000 cfs through the 19 gates of both spillways (Gates 1 through 10 and Gates 11 through 19) with the reservoir at Elevation 244.0, tests were made with the gates open 14 feet. In this case it has been determined from previous observations that flow conditions upstream from Gates 11 and 12 were better when Gate 11 was raised completely to allow free flow through it while Gates 12 through 19 were controlling the flow at openings of 14 feet. The total discharges through Gates 11 through 19 for these settings and reservoir elevations of 240.0, 242.0 and 244.0 were 46,500, 50,200 and 53,500 cfs respectively, Fig. 11. Assuming that Gate 10 of the left spillway would be fully open and Gates 1 through 9 at an opening of 14 feet, the total flow for both spillways is estimated to be approximately 96,400, 104,000 and 110,900 cfs for the three reservoir elevations. The ratio of spillway net lengths, obtained from Fig. 1, was used to arrive at these discharges.

Flow Conditions and Capacity, Various Gate Combinations and Openings

Free-Flow Capacity of Gates Operating Individually. The capacity of individual gates under free-flow conditions was determined by the calibration of selected gates. The end gates (Gates 11 and 19) and two central gates (Gates 13 and 15) were used in these tests. The end gates differed from the central gates in that the outer ends were suppressed and the end piers did not contain the concrete anchor blocks at their bases. All central gates had contractions at both ends and all central piers had concrete anchor blocks at their bases. All central gates had contractions at both ends and all central piers had concrete anchor blocks at their bases. The concrete anchor blocks of the central piers extended into the flow passages where they introduced losses that produced a decrease in gate capacity. The calibrations showed that the discharges for the end gates (Gate 11 and 19) were the same and that the discharges for the central gates (Gates 12 through 18) were equal, but less than for the end gates, Fig. 12. Gates 11 and 19 were longer than the other gates, Fig. 1.

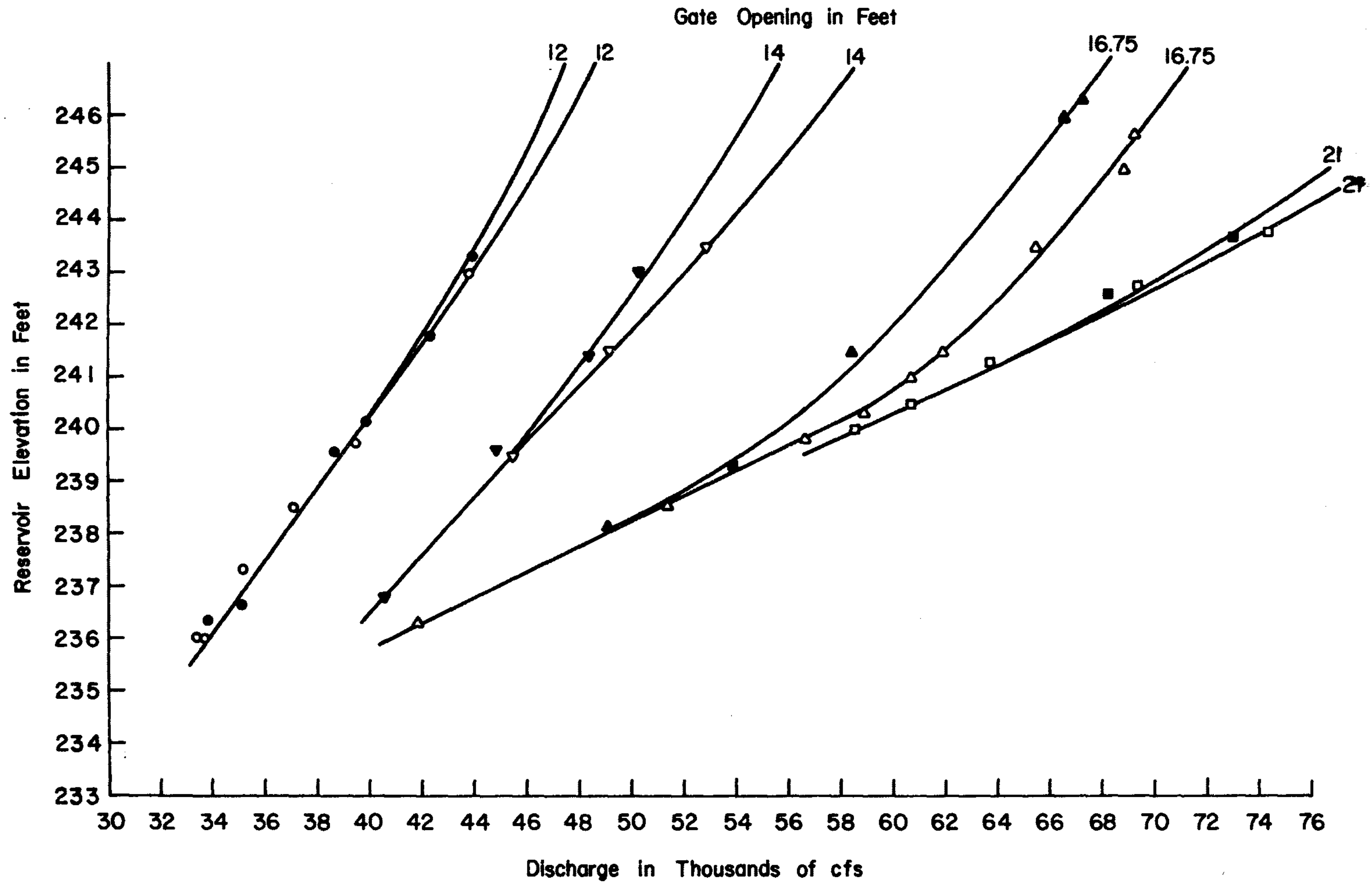



FIGURE 9. Roosevelt Dam Spillway, 1:25 Scale Model, Effect of Bridge Railing Height on Discharge, North Structure (Gates 11 through 19)
NOTE: Open Symbol is for Low Bridge Railings
Darkened Symbol is for Raised Bridge Railings (El. 242.5)

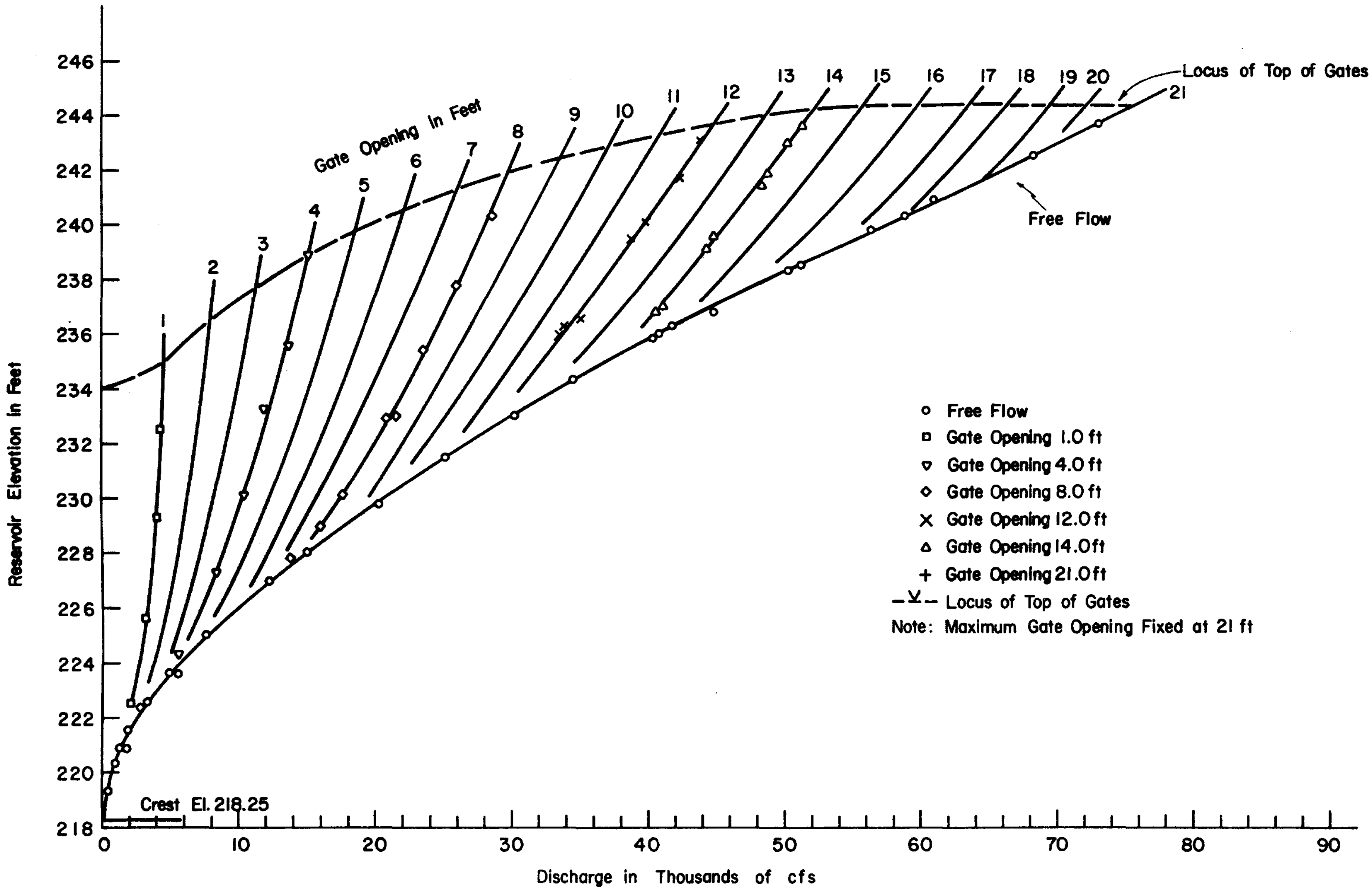



FIGURE 10. Roosevelt Dam Spillway, 1:25 Scale Model, Capacity Curves
Free Flow and Various Gate Openings (Gates 11 through 19)
Note: Crown of bridge arch at El. 238.6
High bridge railings - Prototype El. 242.5

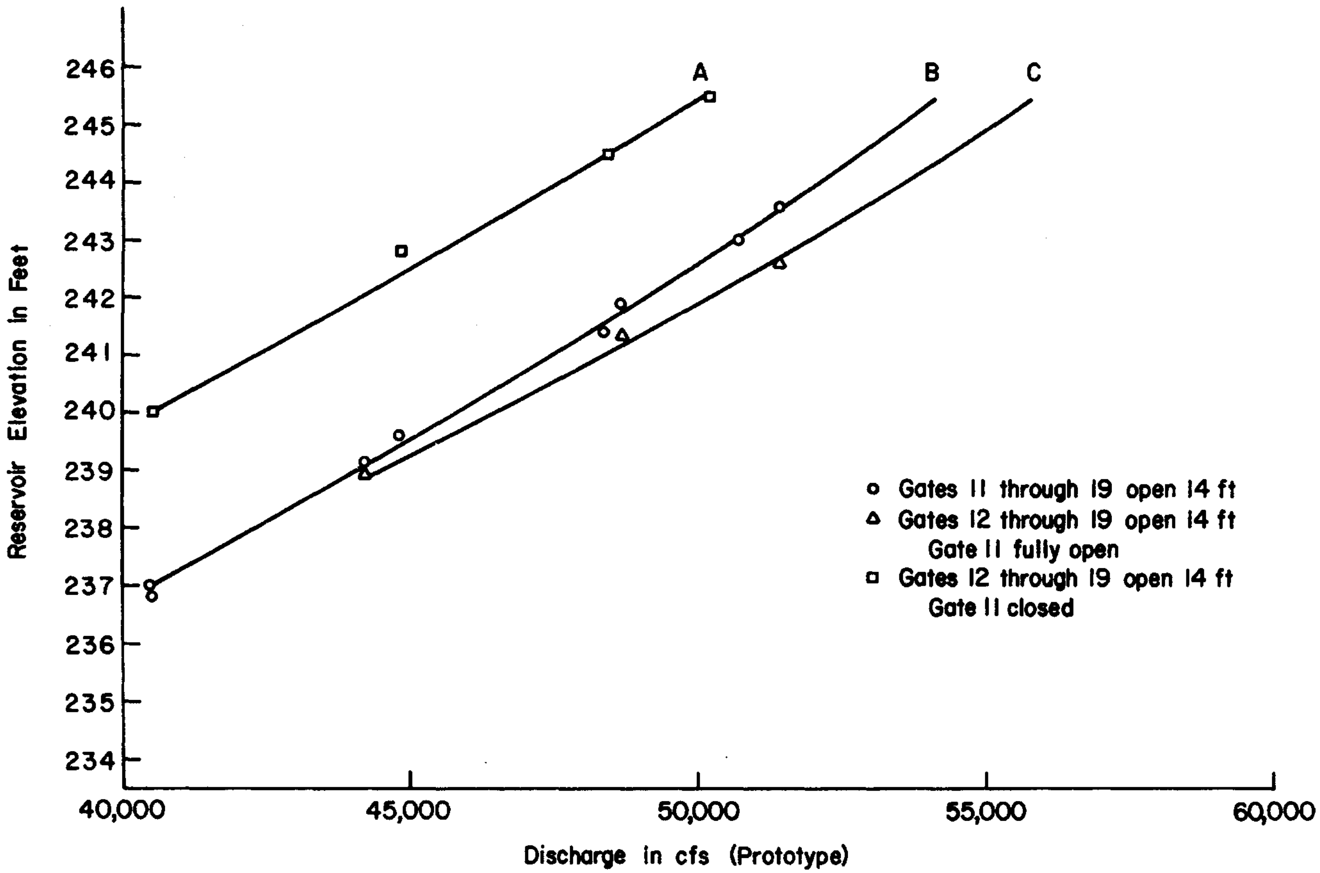



FIGURE 11. Roosevelt Dam Spillway, 1:25 Scale Model
Effect of Gate 11 being fully open or closed,
Gates 12 through 19 open 14 feet
Note: Data is for raised bridge railings

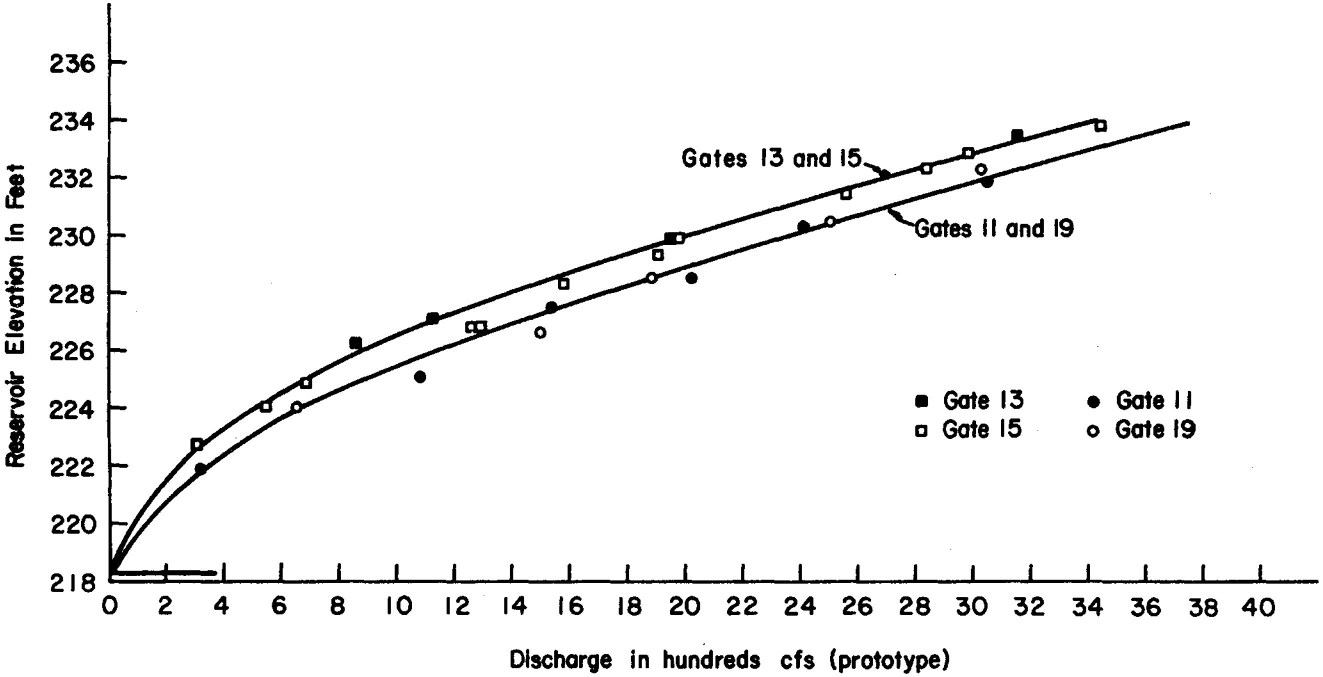



FIGURE 12. Roosevelt Dam Spillway, 1:25 Scale Model, Discharge for Single Gates Free Flow. Note: Gates 11 and 19 have less contraction on one end than Gates 12 through 18.

Single Gate Operation, Various Openings. Gates 11 and 13 were calibrated individually at various openings to determine if the discharge would be the same or different. The end gates of the spillway were the same length while Gates 12 through 18 were the same length but slightly shorter than the end gates (19'-11¾" and 19'-8½"). The calibration curves are shown in Figs. 13 and 14. The discharge for any given reservoir elevation and gate opening was greater for Gate 11 than for Gate 13. Two factors contribute to this difference. Gate 11 is longer than Gate 13 and the end pier does not contain concrete anchor blocks at its base to interfere with the flow. Also, the left end of Gate 11 is suppressed. Gate 13 is shorter than Gate 11 and the piers at both ends of the gate have concrete anchor blocks at their bases that interfere with the flow. Also, large vortices and contractions form at both ends of the gate. Typical small and large vortices are shown at locations A and B, Fig. 15. The calibration curves for Gate 11 apply to Gate 19 and the calibration curves for Gate 13 apply to Gates 12 through 18.

The total discharge computed from the single-gate calibrations is greater than that obtained when all gates were calibrated together. This difference is attributed to the greater head losses at the bridge and in the approach channel when the flow quantity is much greater and all gates are discharging.

Two-Gate Operation, Various Openings. There were no objectionable flow conditions upstream from the gates when Gates 13 and 14 were discharging. However, very large contractions and strong vortices formed at the outer ends of the two gates, location B, Fig. 15. The action was at the left end of Gate 13 and the right end of Gate 14 when these two gates were discharging. Also at small gate openings there were very turbulent flow actions at the ends of the gates caused by the concrete anchor blocks at the bases of the piers. The calibration chart from which the discharge from any two adjacent central gates (Gates 12 through 18) can be determined is shown in Fig. 16. When an end gate and an adjacent gate are discharging the contractions and vortex action at the outer end of the end gate are less severe than for the outer ends of both gates, when two adjacent central gates (Gates 12 through 18) are discharging. The partially suppressed condition and the absence of concrete anchor blocks at the base of the end pier contributes to these less severe conditions. The outer end of the gate adjacent to the end gate has a very severe contraction and vortex action. Tails of the vortices pass down and under the gate when the gate opening is 8 feet, B, Fig. 15. The action was significantly milder at a 2-foot gate opening. The discharge for two adjacent gates with one of them an end gate (Gates 11 and 12 or 18 and 19) can be determined from the chart of Fig. 17.

Three-Gate Operation, Various Openings. The flow conditions at the outer ends of the outer gates with three adjacent central gates operating are similar to those for two-gate operation of the central gates (12 through 18). Severe vortex action occurred in these locations for the 6 and 8-foot gate openings. The action was less severe at the 2 and 4-foot openings. Discharges for the four gate openings and various reservoir elevations were obtained by testing Gates 13, 14 and 15. The results are shown by the chart shown in Fig. 18. The chart applies to any three adjacent central gates (Gates 12 through 18).

Four-Gate Operation, Various Openings. The flow conditions at the outer ends of the outer gates with four adjacent central gates operating at 2, 4, 6, and 8-foot openings are similar to those for the outer ends of the outer gates when three adjacent central gates (Gates 12 through 18) are operating. Severe contractions and vortices form at these locations for the larger openings. The vortex action is mild for the 2-foot opening. The discharge chart for this 4-gate combination is shown in Fig. 19. An additional 4-gate combination with every other gate discharging (Gates 12, 14, 16 and 18) were observed and calibrated. The discharge chart for this 4-gate combination is shown in Fig. 20.

Five-Gate Operation, Various Openings. Gates 13, 14, 15, 16 and 17 were operated at openings of 2, 4, 6 and 8 feet. The calibration chart for this combination is shown in Fig. 21. Tests were made also with every other gate discharging (Gates 11, 13, 15, 17 and 19). The calibration chart for this gate combination is shown in Fig. 22. The charts of Figs. 21 and 22 can be used to determine discharges for the respective gate combinations.

The vortex action at the outer ends of Gates 13 and 17 were less severe than for the two-, three-, and four-gate combinations but as before the larger vortices occurred at the 8-foot gate opening and their size decreased as the opening decreased.

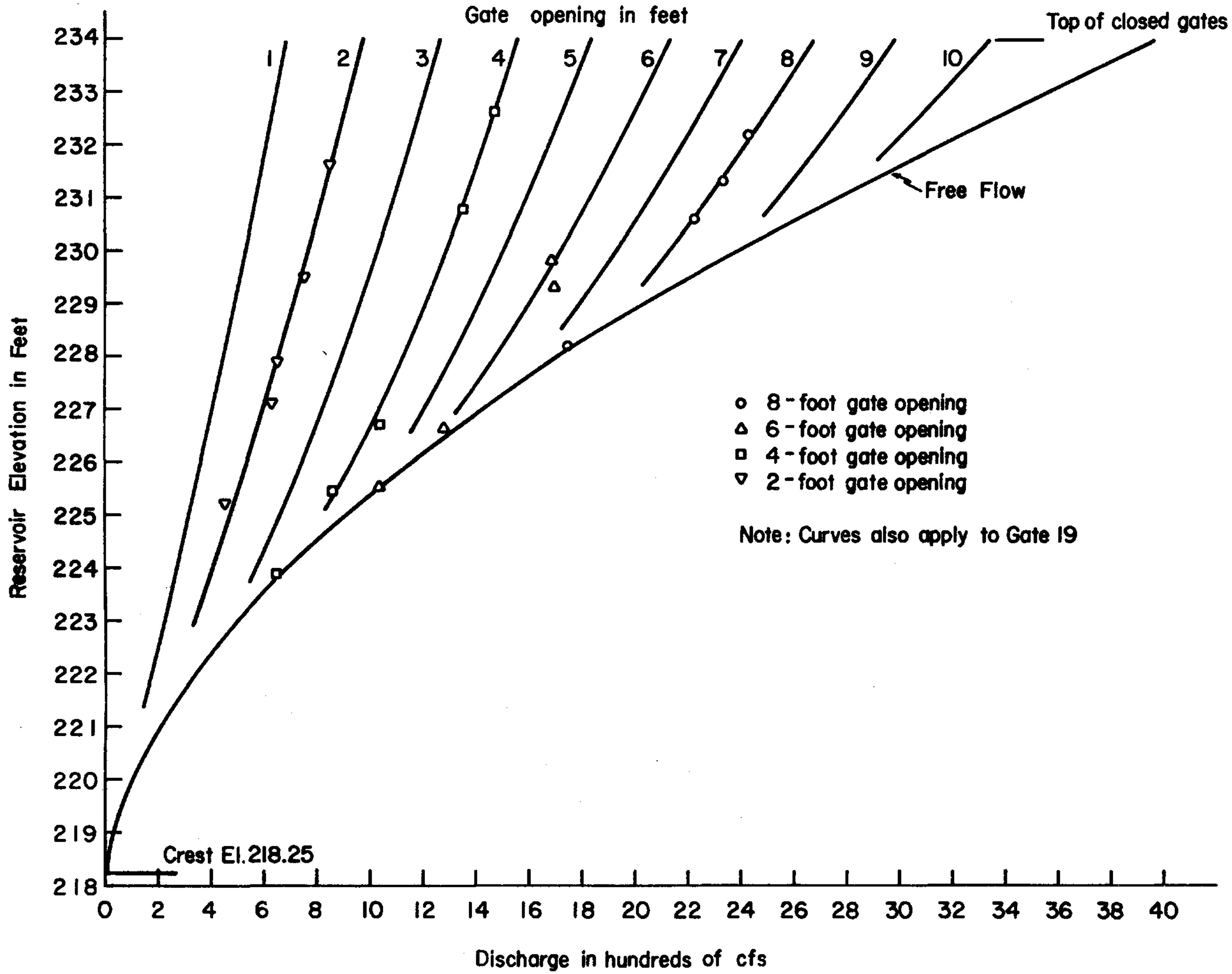



FIGURE 13. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gate 11, Various Gate Openings

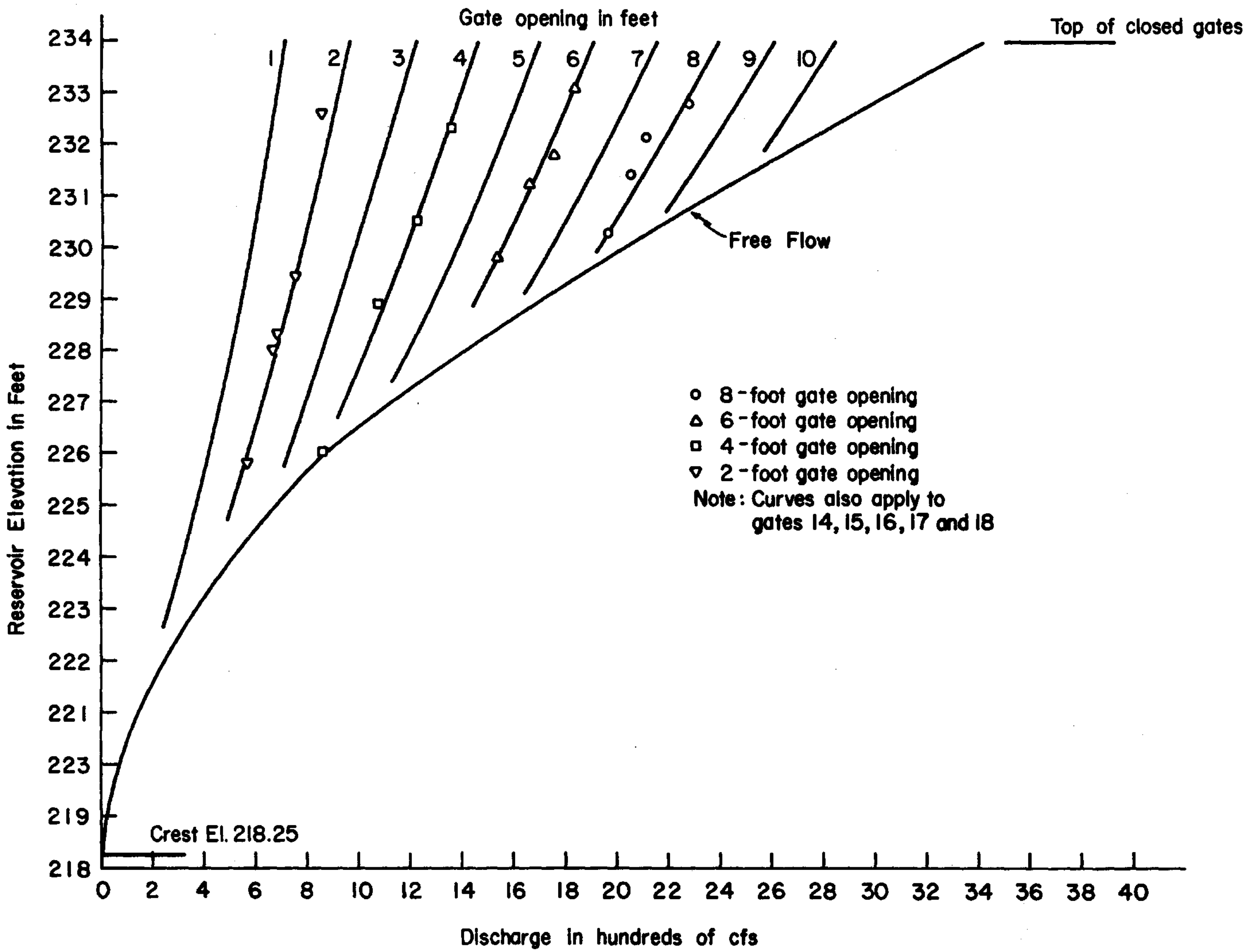



FIGURE 14. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gate 13, Various Gate Openings


Typical Small and Large Vortices
at Ends of Gates

Fig. 15 - Roosevelt Dam Spillway, 1:25 Scale Model,
Vortex Action at Ends of Gates

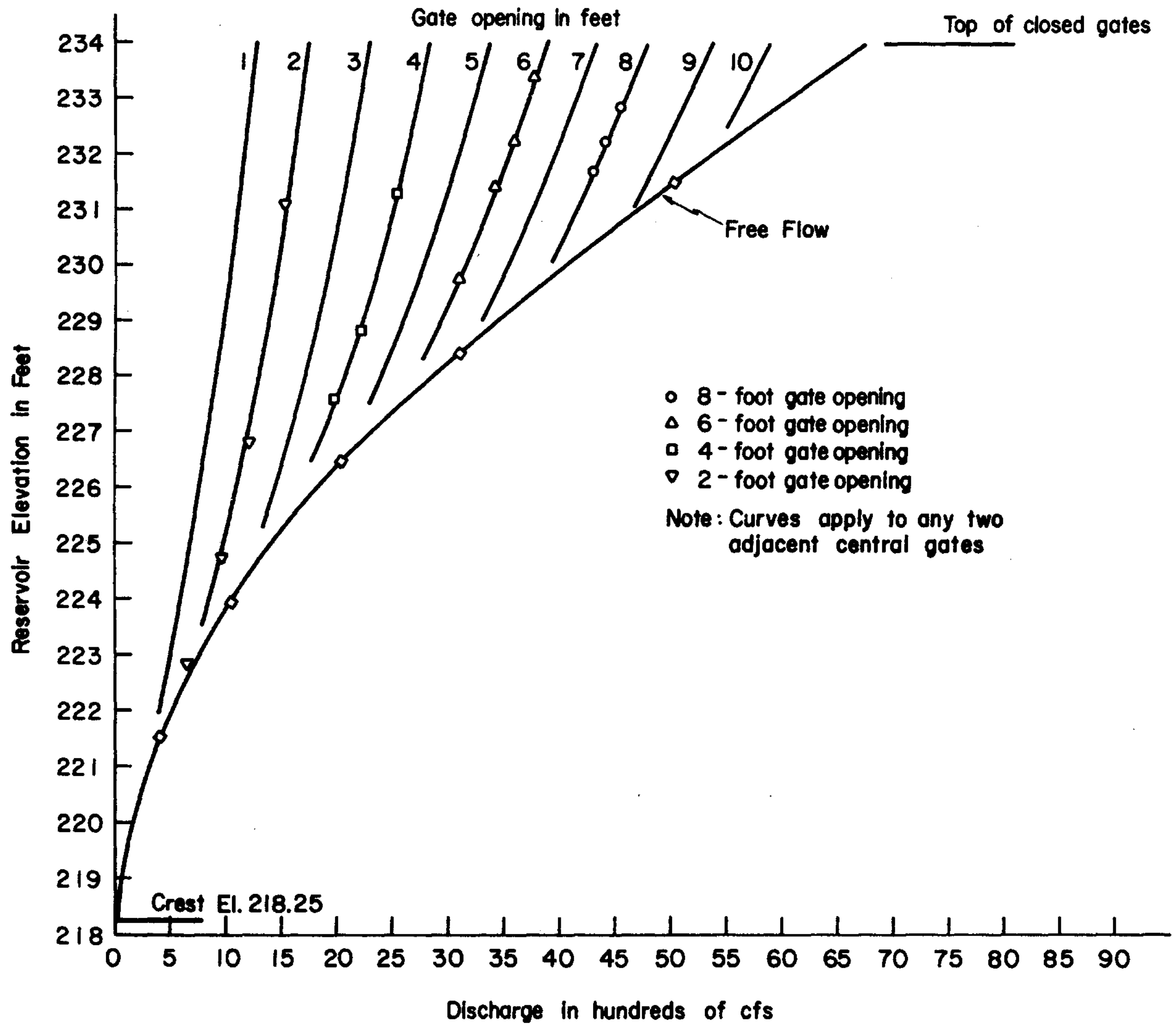



FIGURE 16. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 13 and 14
Various Gate Openings

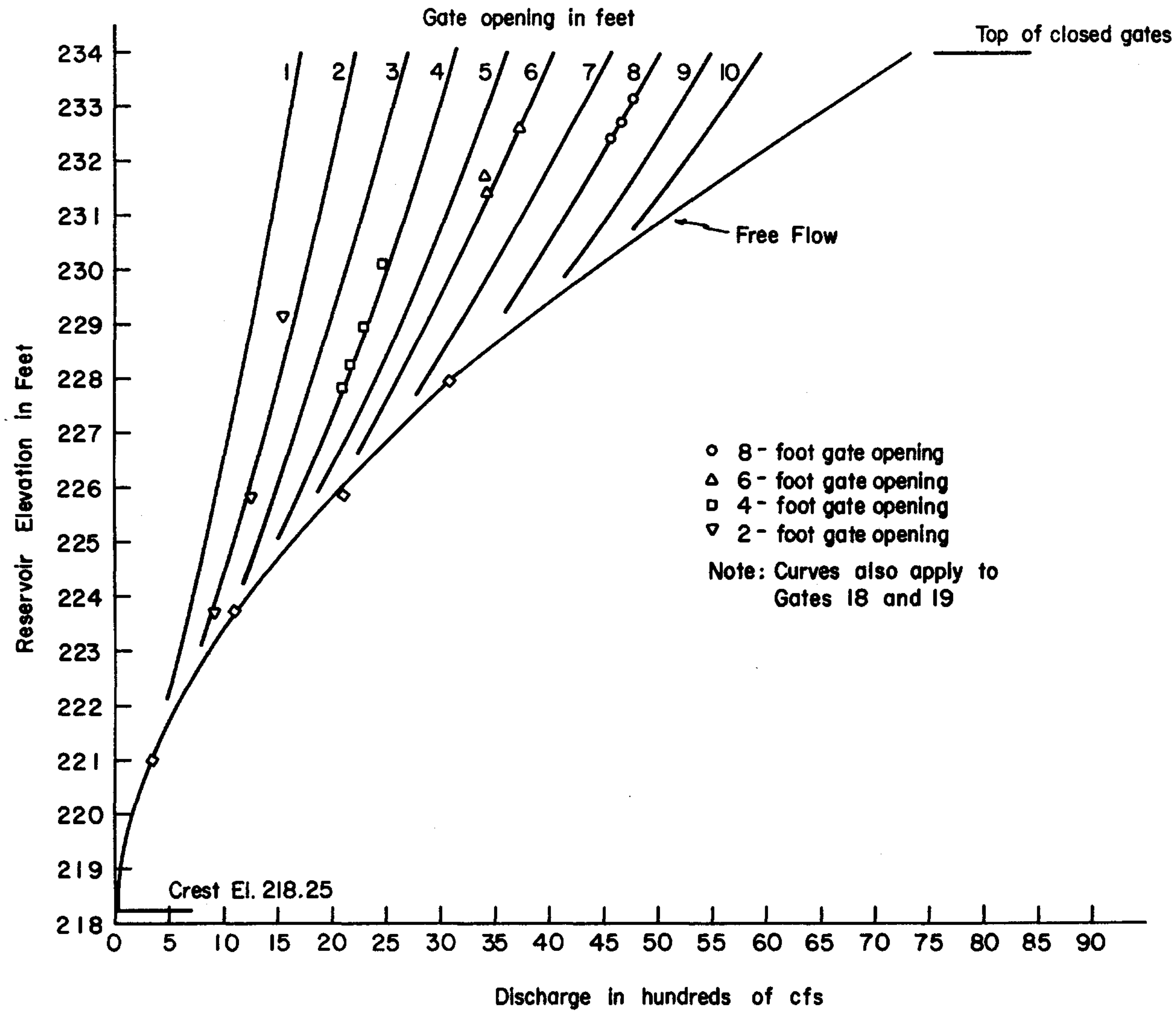



FIGURE 17. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 11 and 12
Various Gate Openings

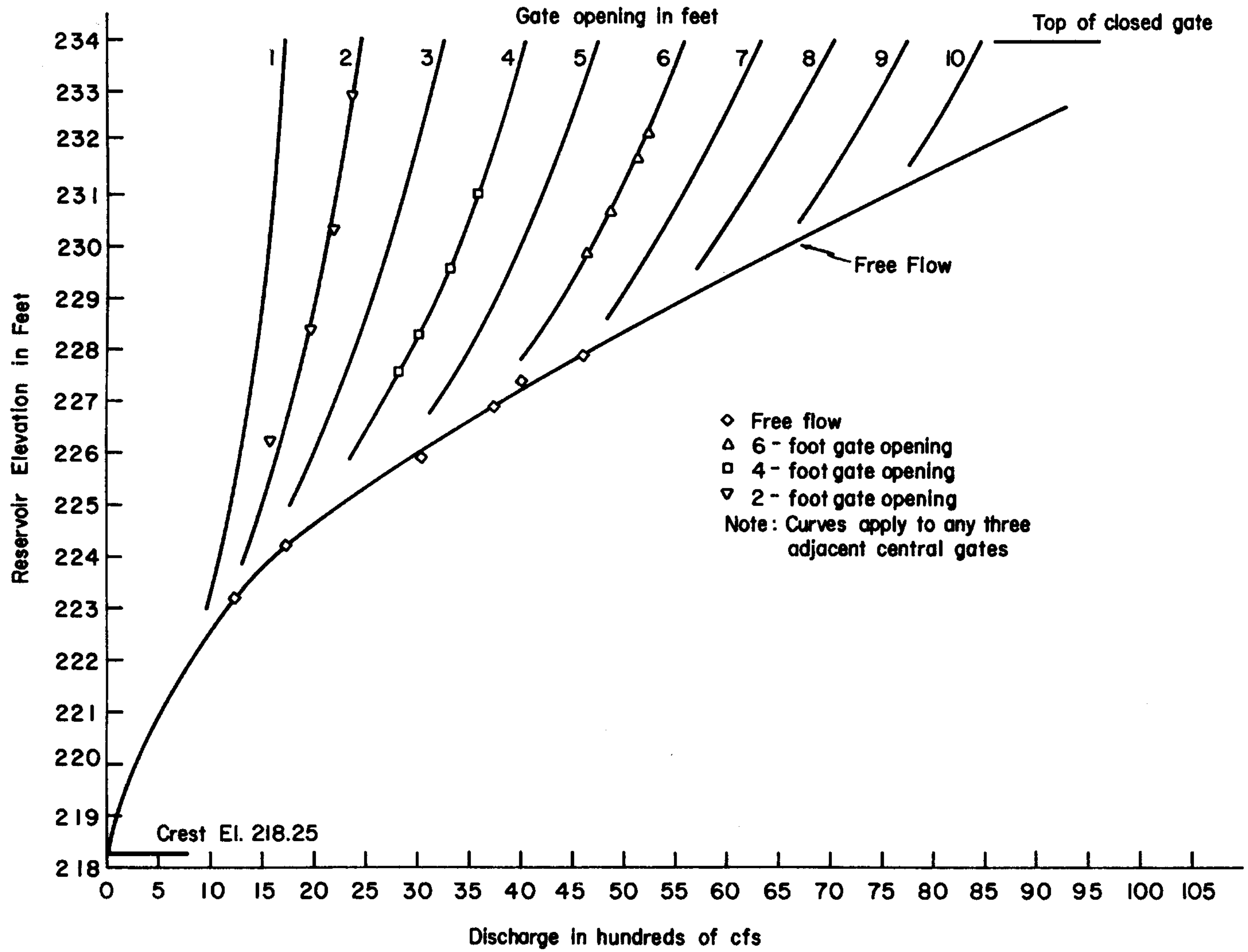



FIGURE 18. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 13, 14 and 15
Various Gate Openings

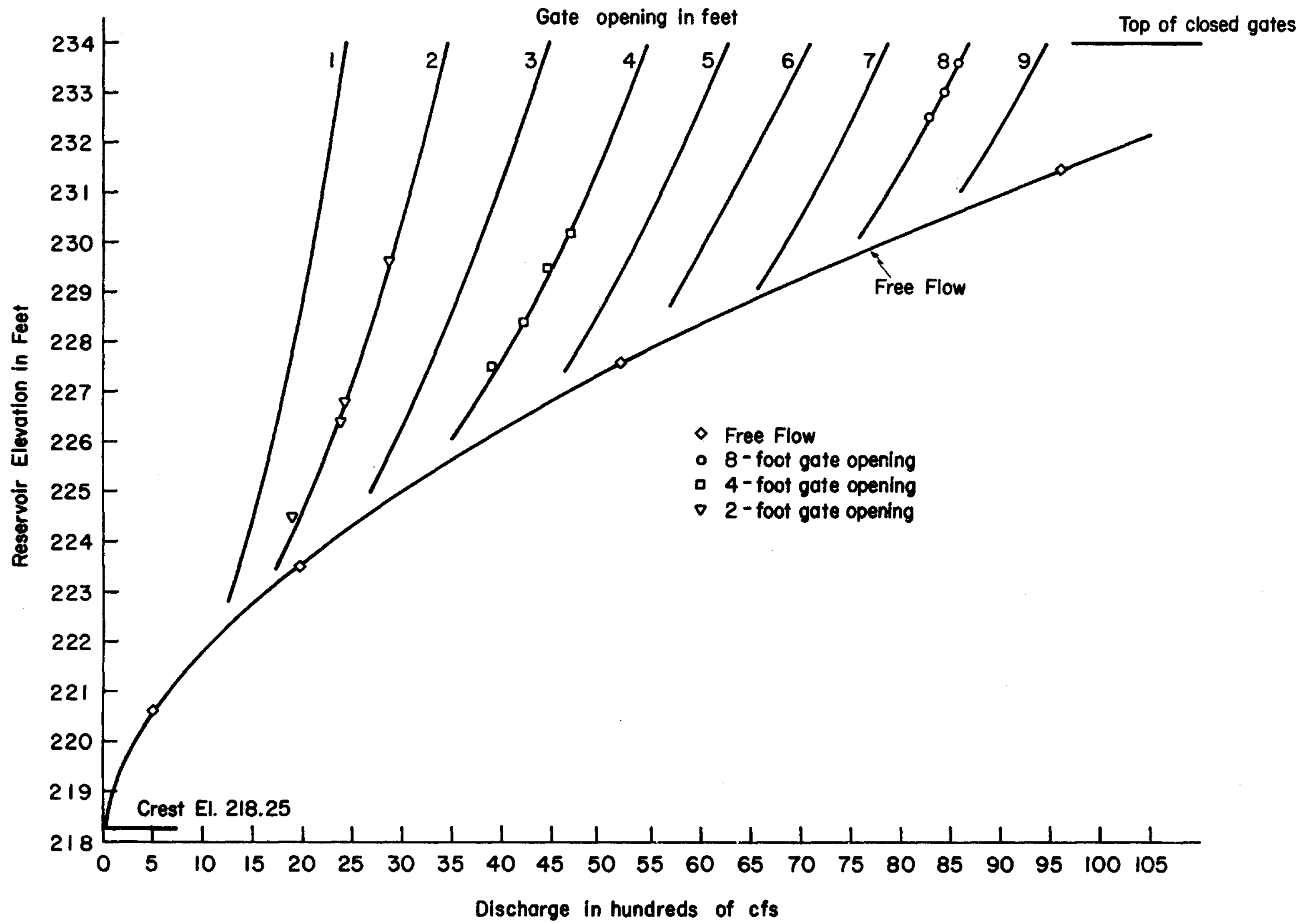



FIGURE 19. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 13, 14, 15 and 16
Various Gate Openings

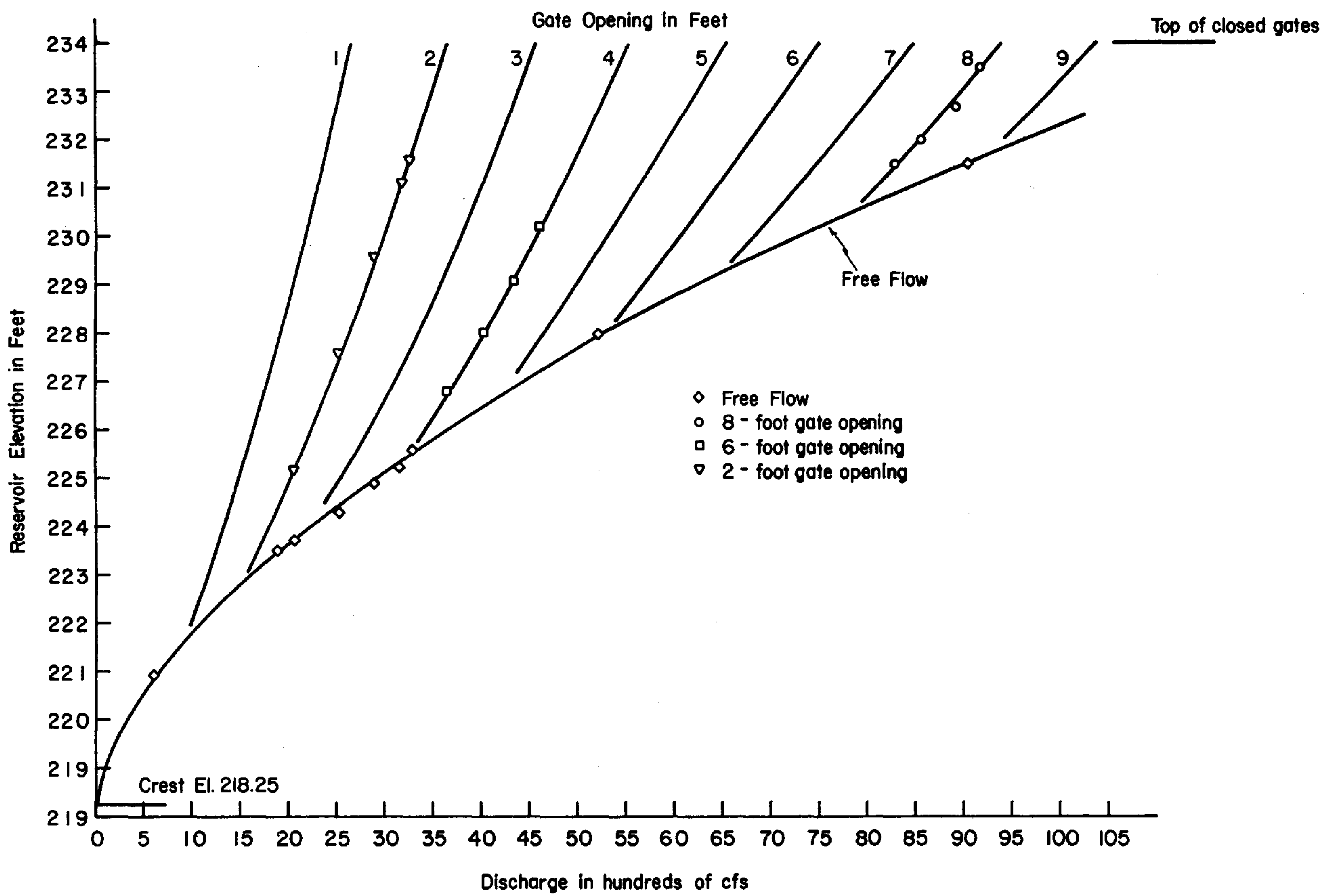



FIGURE 20. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of gates 12, 14, 16 and 18
Various Gate Openings

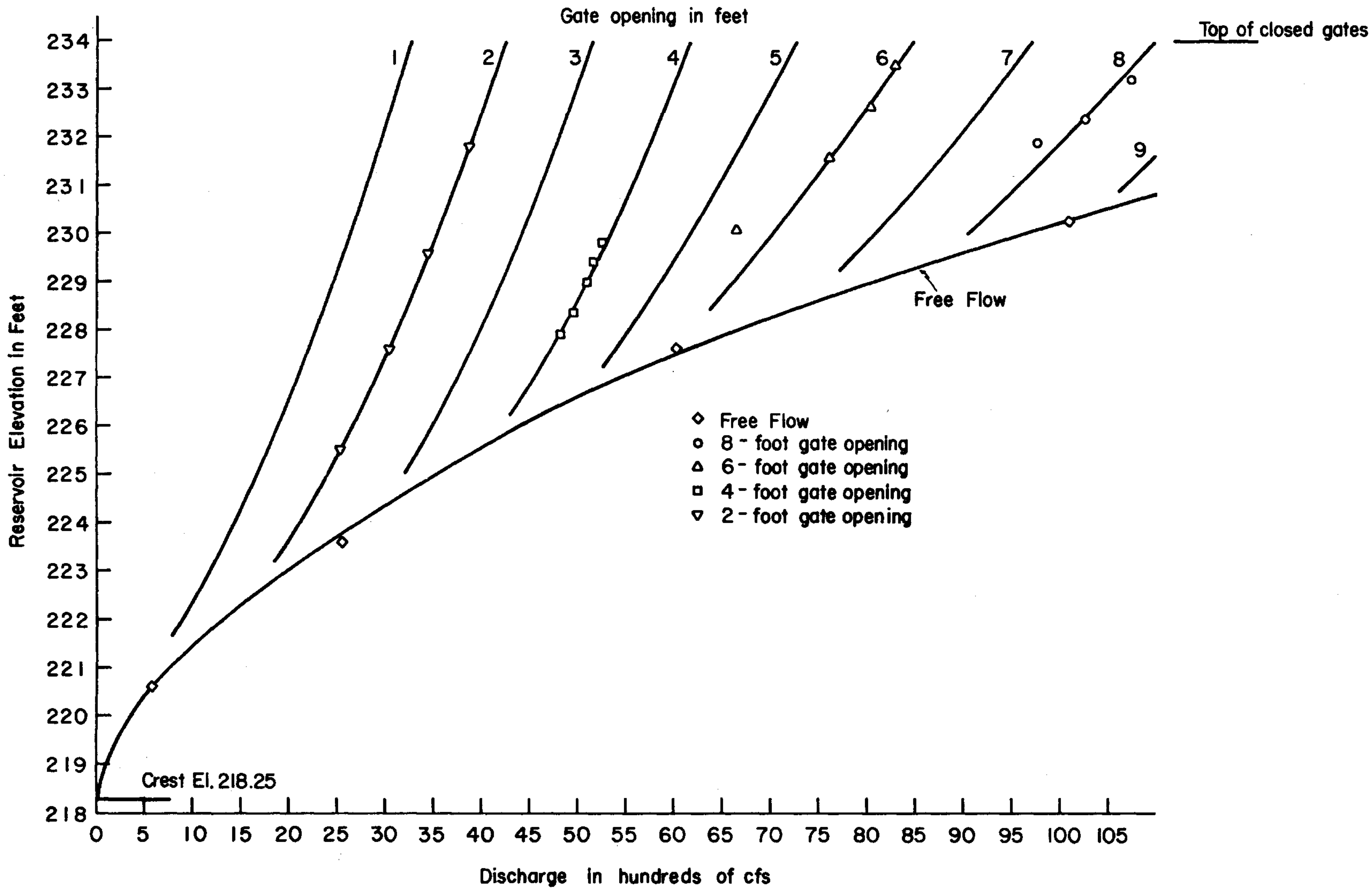



FIGURE 21. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 13, 14, 15, 16 and 17
Various Gate Openings

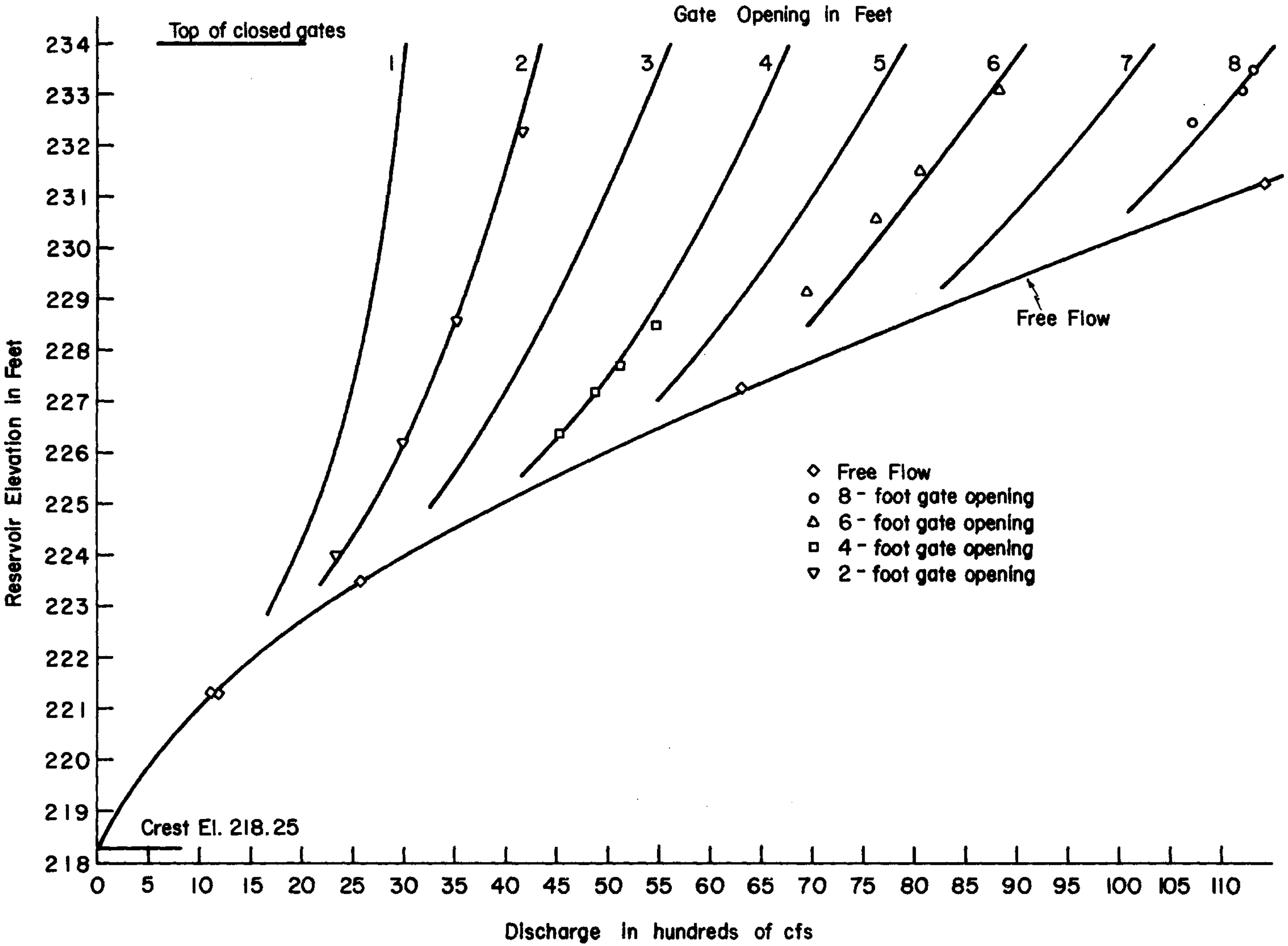



FIGURE 22. Roosevelt Dam Spillway, 1:25 Scale Model
Capacity of Gates 11, 13, 15, 17 and 19
Various Gate Openings

Water Load on Gates

Two methods of determining the forces acting on the gate trunnion pins were considered when the test program was planned for the 1:25 scale model. One method was to construct one of the model gates in such a way that load cells could be attached to the gate and its trunnions. The second method was to obtain the pressure distribution on the face of one gate by installing piezometers in the gate as shown in Fig. 2. This second method was used because of the simplicity of the instrumentation and the ease of installing piezometers.

Pressures on Face of Gate. Eighteen pressure taps (piezometers) were installed on the centerline of one gate, Fig. 2. Tygon tubing of small diameter, attached to the pressure taps, were connected to glass tubing mounted on a board graduated in units representing prototype elevations, Fig. 3c. The pressure at a tap was determined by subtracting the piezometer elevation from the water surface reading on the board for various gate openings and reservoir elevations. Data were obtained for three or four reservoir elevations for gate openings of 1, 4, 8, 12 and 14 feet. In most of the tests the water surface was somewhat below the tops of the gates, making it necessary to extrapolate the data to determine the maximum water load which would occur when the water surface was at the top of the gates. This was done by plotting the piezometer pressure versus reservoir water level tested. The pressures, in feet of water, for each piezometer, gate opening and reservoir water level are tabulated in Table 1. The pressures in the table were plotted as acting radially on the face of the gate to represent the pressure distribution on the gate. It was assumed that the pressure distribution was the same throughout the gate length.

Loads on Gates. The water load per foot of gate length was obtained by multiplying the area of the pressure distribution diagram by the density of water.

The area of each pressure distribution diagram was measured by a planimeter which was set to record square inches. The areas in square inches were multiplied by $(2.54)^2$ to change them to square centimeters. The areas in square centimeters were then changed to square feet prototype by multiplying by a conversion factor of 4 or the square feet represented by one square centimeter of the plots in Figs. 23 and 24. The areas in square feet were then multiplied by the density of water 62.4 (pounds per cubic foot) to obtain the water load in pounds per linear foot of the gates. The areas in square centimeters and the water load for each gate opening when the reservoir was at the top of the gates are given in Figs. 23 and 24. Because the water surface was below the top of the gates in many of the tests it was necessary to extrapolate the pressure data for various of the gate openings to arrive at the pressures and forces that will exist with the water at the tops of the gates.

The water load is a maximum when the gate is closed and the reservoir water surface is at the top of the gate. A triangular horizontal load of 15.75 feet in height (gate sill to top of gate when closed) was used to develop the pressure distribution diagram shown in Fig. 23. The area and water load was then obtained in the same manner as for the various gate openings. The load was determined to be 14,000 pounds per linear foot. The total load for a 19'-11¾" long gate would be 280,308 pounds (140 tons) or 70 tons per gate trunnion pin. The load for a closed 19'-8½" long gate would be 276,500 pounds.

The water loads for 1, 4, 8, 12 and 14-foot gate openings with the water surface at the top of the gates were determined to be 12,200, 11,600, 8,300, 6,600 and 6,400 pounds per foot, respectively. Any time the water surface in the reservoir is below the tops of the gates the loads will be less accordingly.

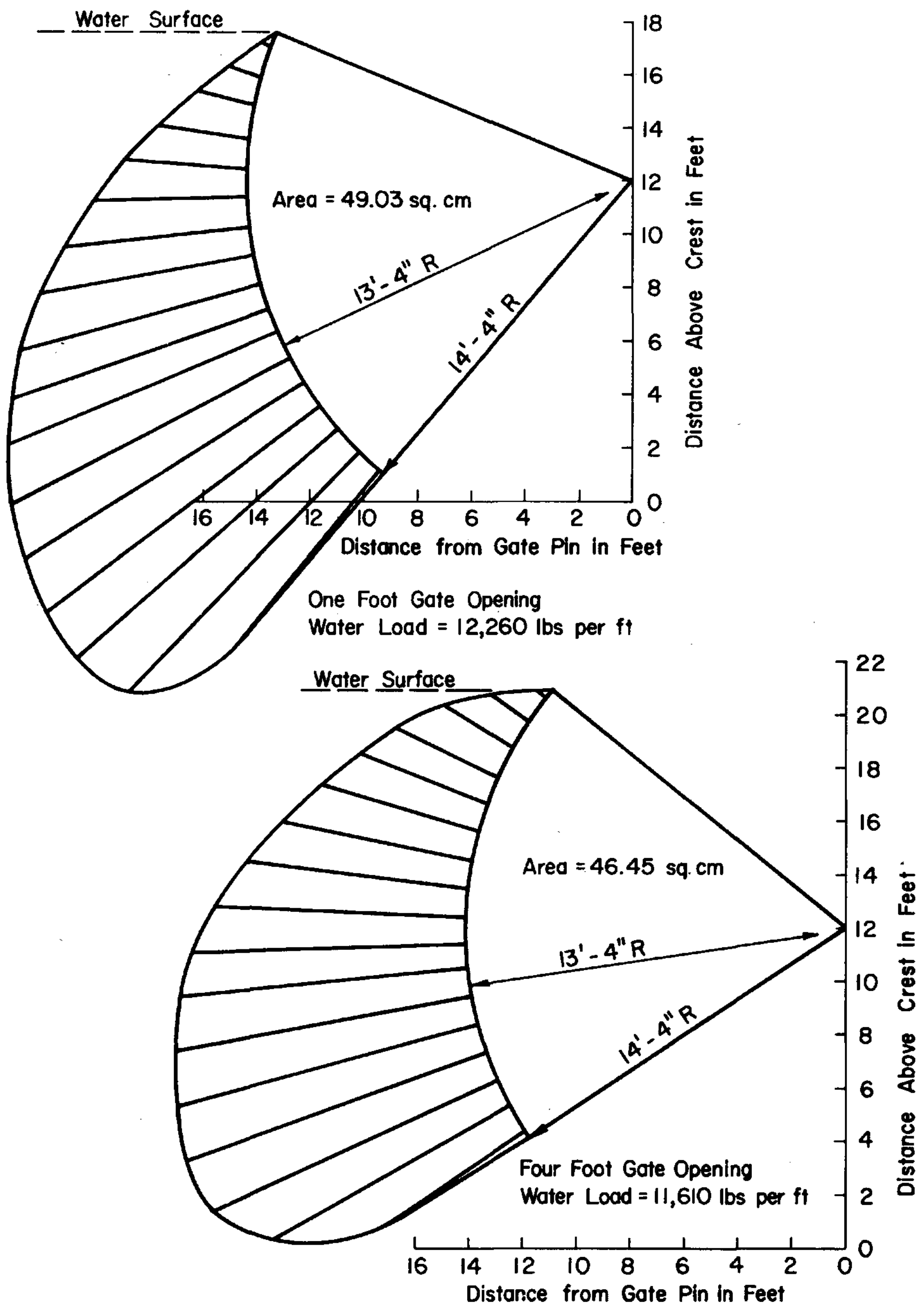
TABLE I

Pressure on Radial Gates
(Based on Piezometer Readings)

| Test No. | TEST 6 | | | | TEST 3 | | | | TEST 4 | | | | | TEST 5 | | | | | TEST 15 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run No. | 3 | 4 | 6 | X | 2 | 3 | 4 | 5 | 3 | 4 | 5 | 6 | X | 3 | 4 | 5 | 6 | X | 4 | 5 | 7 | 9 | X |
| Gate Opening Ft. | 1.0 | 1.0 | 1.0 | 1.0 | 4.0 | 4.0 | 4.0 | 4.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 |
| Reservoir El. | 221.5 | 225.6 | 232.5 | 231.5* | 227.3 | 233.3 | 235.6 | 238.9* | 232.9 | 235.4 | 237.8 | 240.3 | 243.0* | 236.0 | 238.4 | 239.7 | 243.0 | 244.0* | 236.8 | 239.6 | 241.4 | 243.0 | 245.0* |
| Piezometer No. | Pressure in Feet of Water Prototype | | | | Pressure in Feet of Water Prototype | | | | Pressure in Feet of Water Prototype | | | | | Pressure in Feet of Water Prototype | | | | | Pressure in Feet of Water Prototype | | | | |
| 1 | 1.2 | 2.7 | 5.9 | 7.7 | 1.4 | 2.8 | 3.6 | 4.6 | 5.2 | 5.1 | 3.6 | 4.2 | 4.2 | 2.5 | 2.8 | 3.4 | 4.5 | 4.7 | 3.0 | 3.8 | 4.1 | 4.6 | 5.0 |
| 2 | 1.6 | 4.8 | 10.3 | 12.1 | 2.6 | 6.1 | 7.7 | 9.9 | 4.4 | 5.4 | 6.9 | 8.4 | 9.1 | 3.5 | 5.0 | 6.2 | 8.2 | 8.6 | 3.2 | 5.9 | 6.5 | 7.8 | 8.8 |
| 3 | 1.2 | 4.6 | 10.8 | 12.7 | 2.6 | 6.8 | 8.7 | 11.3 | 4.1 | 5.6 | 7.4 | 9.3 | 10.1 | 3.2 | 4.7 | 6.3 | 8.5 | 9.0 | 2.3 | 4.8 | 6.2 | 8.0 | 9.2 |
| 4 | 0 | 4.3 | 10.5 | 12.4 | 2.2 | 6.9 | 8.9 | 11.7 | 3.5 | 5.5 | 7.3 | 9.3 | 10.4 | 2.2 | 4.3 | 5.8 | 8.3 | 8.7 | 1.3 | 3.7 | 5.4 | 7.4 | 8.2 |
| 5 | 0 | 3.0 | 9.5 | 11.7 | 0.8 | 6.0 | 8.0 | 10.8 | 2.0 | 4.2 | 6.1 | 8.2 | 9.8 | 0 | 2.5 | 2.5 | 5.2 | 8.2 | 0 | 1.8 | 4.1 | 7.2 | 7.5 |
| 6 | 0 | 3.0 | 9.5 | 11.3 | 0.4 | 6.0 | 8.1 | 10.0 | 1.9 | 3.9 | 5.9 | 8.2 | 9.1 | 0 | 2.5 | 4.2 | 6.9 | 7.4 | 0 | 1.8 | 3.4 | 5.6 | 7.2 |
| 7 | 0 | 2.2 | 8.7 | 10.6 | 0 | 5.5 | 7.3 | 10.4 | 1.0 | 2.9 | 5.2 | 7.4 | 8.3 | 0 | 1.6 | 3.3 | 6.0 | 6.4 | 0 | 1.1 | 2.6 | 4.7 | 6.6 |
| 8 | 0 | 1.3 | 7.8 | 9.8 | 0 | 4.7 | 6.5 | 9.7 | 0.3 | 1.9 | 4.4 | 6.7 | 7.6 | 0 | 0.6 | 2.5 | 5.2 | 5.7 | 0 | 0 | 1.7 | 3.9 | 6.0 |
| 9 | 0 | 0.4 | 7.0 | 8.8 | 0 | 3.7 | 5.6 | 8.8 | 0 | 0.9 | 3.4 | 5.7 | 6.9 | 0 | 0 | 1.6 | 4.4 | 4.5 | 0 | 0 | 0.9 | 2.9 | 5.0 |
| 10 | 0 | 0 | 4.8 | 7.8 | 0 | 1.6 | 4.3 | 6.7 | 0 | 0 | 0.9 | 3.7 | 5.8 | 0 | 0 | - | 2.0 | 3.5 | 0 | 0 | 0 | 1.7 | 4.0 |
| 11 | 0 | 0 | 5.0 | 6.8 | 0 | 1.7 | 3.9 | 7.0 | 0 | 0 | 1.6 | 3.9 | 4.9 | 0 | 0 | 0 | 2.9 | 2.9 | 0 | 0 | 0 | 1.7 | 3.3 |
| 12 | 0 | 0 | 3.8 | 5.6 | 0 | 0.4 | 2.8 | 5.9 | 0 | 0 | 0.6 | 2.7 | 3.7 | 0 | 0 | 0 | 1.7 | 2.3 | 0 | 0 | 0 | 0.8 | 2.3 |
| 13 | 0 | 0 | 2.3 | 4.3 | 0 | 0 | 1.0 | 4.1 | 0 | 0 | 0 | 1.3 | 2.7 | 0 | 0 | 0 | 0.4 | 1.4 | 0 | 0 | 0 | 0 | 1.6 |
| 14 | 0 | 0 | 1.9 | 3.5 | 0 | 0 | 1.0 | 4.1 | 0 | 0 | 0 | 1.5 | 2.0 | 0 | 0 | 0 | 0.9 | 1.0 | 0 | 0 | 0 | 0 | 1.1 |
| 15 | 0 | 0 | 0.6 | 2.0 | 0 | 0 | 1.7 | 3.1 | 0 | 0 | 0 | 0.6 | 1.3 | 0 | 0 | 0 | 0.3 | 0.8 | 0 | 0 | 0 | 0 | 0.7 |
| 16 | 0 | 0 | 0 | 1.0 | 0 | 0 | 0 | 2.0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0.3 |
| 17 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0.1 |
| Top of Gate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

* Reservoir Water Surface at Top of Gate

X Values were Extrapolated using Data for other Runs



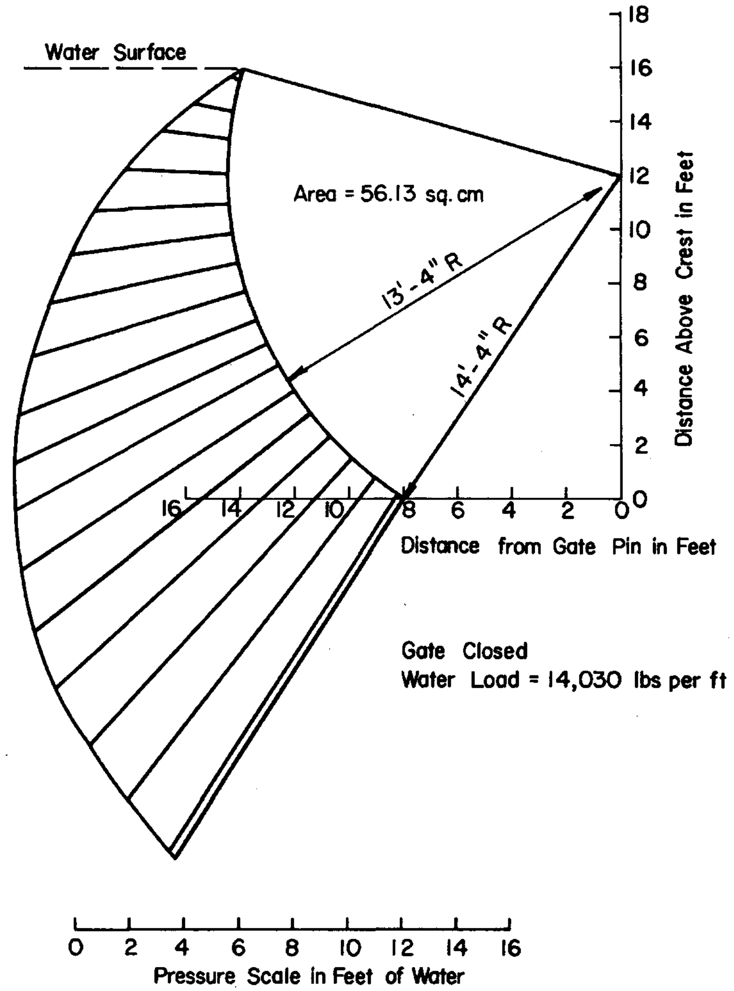
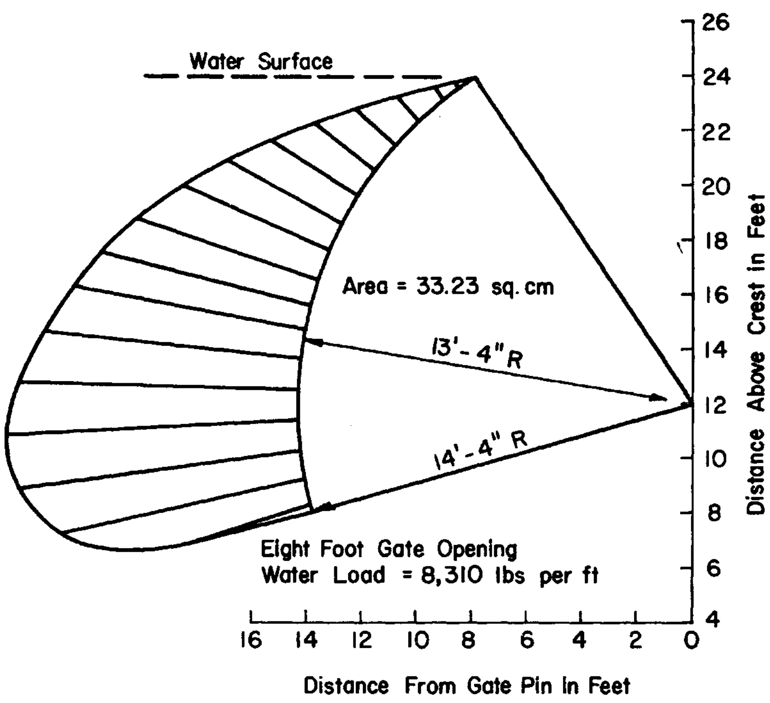
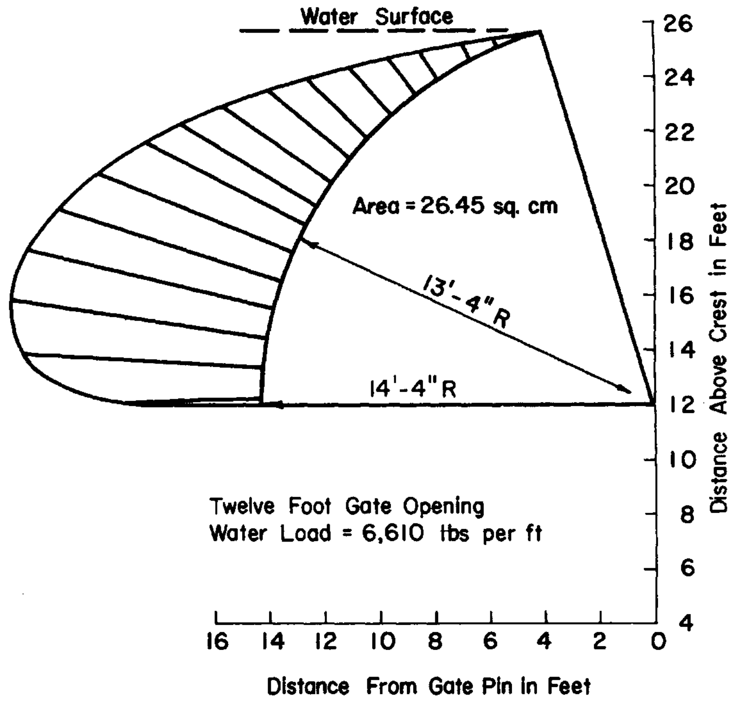
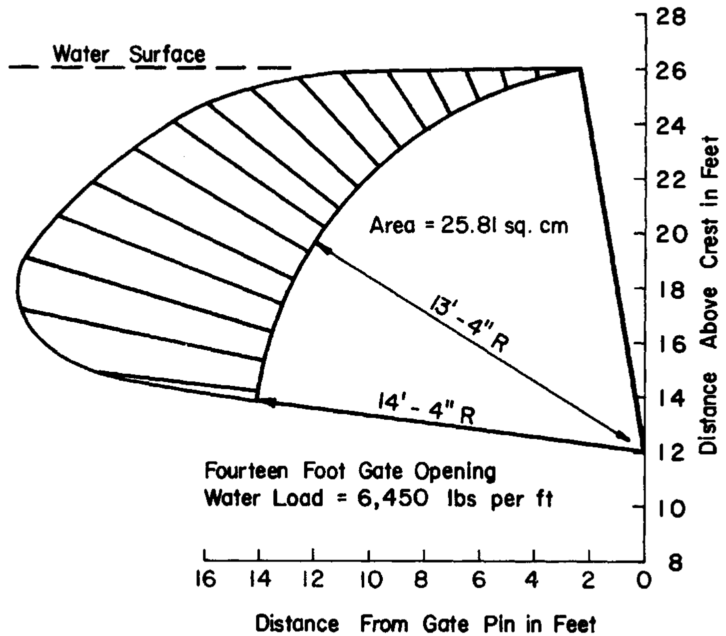




FIGURE 23. Roosevelt Dam Spillway, 1:25 Scale Model
North Structure (11 through 19)
Pressure Distribution on Radial Gates
Gates Closed and Open 1 and 4 Feet
Force on Gates per Foot of Length

Note: Spillway Crest El. 218.25



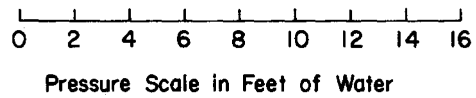




FIGURE 24. Roosevelt Dam Spillway, 1:25 Scale Model
North Structure (Gates 11 through 19)
Pressure Distribution on Radial Gates
Gates Open 8, 12 and 14 Feet
Force on Gates per Foot of Length

Note: Spillway Crest El. 218.25

APPENDIX

Raw Data

Hydraulic Model Study
of the
North Spillway, Roosevelt Dam
Salt River Project
Arizona

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
Capacity of Gates 11 through 19

| Orifice | Run No. | Δh ft | Qmodel cfs | Qproto cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 1. All Gates Open 16.75 ft Bridge Deck El. 240.0 | | | | | | |
| 4" | 1 | 5.758 | 0.910 | 2,843.8 | 222.3 | Free Flow |
| | 2 | 7.260 | 1.028 | 3,212.8 | 222.5 | |
| | 3 | 2.449 | 0.596 | 1,862.5 | 220.8 | |
| | 4 | 1.196 | 0.417 | 1,304.6 | 220.8 | |
| 18" | 5 | 2.254 | 13.024 | 40,699.3 | 236.0 | |
| | 6 | 3.495 | 16.409 | 51,280.3 | 238.5 | |
| | 7 | 4.204 | 18.087 | 56,521.4 | 239.8 | |
| | 8 | 4.532 | 18.812 | 58,803.4 | 240.3 | W.S. El. 238.0 d.s. from West Bridge Pier |
| | 9 | 4.796 | 19.387 | 60,584.0 | 241.0 | |
| | 10 | 4.995 | 19.807 | 61,896.9 | 241.5 | Gates 14-19 controlling flow. W.S. El. 240.0 d.s. from Bridge Pier |
| | 11 | 5.561 | 20.959 | 65,496.9 | 243.5 | Gates 11-19 controlling flow. W.S. El. 242.0 d.s. from Bridge Pier. Vortex at left ends of Gates 11-19. Vortex (Type "4"). Water splashes over top of gates. |
| | 12 | 5.944 | 21.707 | 67,836.1 | 245.0 | W.S. El. 243.75 d.s. Bridge Pier, Gates 11-19 controlling flow. Splash over tops of all gates. Vortex (Type"4") at left ends of all gates. Water runs across top of bridge (El. 240.0) |
| | 13 | 6.174 | 22.146 | 69,206.6 | 245.6 | (Same conditions as for Run 12) W.S. El. 244.5 d.s. Bridge Pier |
| | 14 | 2.377 | 13.393 | 41,854.7 | 236.3 | |
| 4" | 15 | 1.690 | 1.690 | 5,436.1 | 224.0 | |
| | 16 | 1.296 | 1.525 | 4,765.9 | 223.5 | |
| Test 2. All Gates Open 16.75 ft Bridge Deck El. 240.0 | | | | | | |
| 18" | 1 | 0.230 | 3.913 | 12,227.8 | 227.0 | Free Flow |
| | 2 | 0.340 | 4.808 | 15,024.0 | 228.0 | |
| | 3 | 0.595 | 6.456 | 20,175.8 | 229.8 | |
| | 4 | 0.905 | 8.053 | 25,164.6 | 231.5 | |
| | 5 | 1.280 | 9.666 | 30,207.5 | 233.0 | |
| | 6 | 1.650 | 11.050 | 34,531.3 | 234.3 | W.S. El. 235.0 d.s. Bridge Pier |
| | 7 | 2.220 | 12.919 | 40,374.7 | 235.8 | |
| | 8 | 2.708 | 14.372 | 44,912.0 | 236.8 | W.S. El. 236.0 d.s. Bridge Pier |
| | 9 | 3.370 | 16.100 | 50,305.7 | 238.3 | |
| | 10 | 3.993 | 17.602 | 55,004.9 | 239.5 | Flow tops bridge, W.S. El. 238.0 d.s. Bridge Pier |
| | 11 | 4.760 | 19.310 | 60,344.0 | 242.6 | Results questionable |
| | 12 | 5.460 | 20.758 | 64,867.5 | 245.0 | Results questionable |
| | 13 | 3.228 | 15.736 | 49,173.5 | 238.0 | Initial contact of Trunnions and Gate Structural Members |
| | 14 | 2.590 | 14.013 | 43,790.6 | 236.8 | Flow touching bottom of gate superstructure Not trunnion pins |
| | 15 | 0.095 | 2.456 | 7,674.2 | 225.0 | |
| Test 3. All Gates Open 4 ft Bridge Deck El. 240.0 | | | | | | |
| 18" | 1 | 0.050 | 1.751 | 5,471.8 | 224.3 | Water just touching lip of Gate 19 (free-flow) |
| | 2 | 0.110 | 2.653 | 8,290.6 | 227.3 | |
| | 3 | 0.218 | 3.804 | 11,887.5 | 233.3 | |
| | 4 | 0.290 | 4.421 | 13,815.6 | 235.6 | |
| | 5 | 0.343 | 4.830 | 15,093.7 | 238.9 | Water just touching top of bridge deck |
| | 6 | 0.170 | 3.337 | 10,428.1 | 230.1 | W.S. at top of all gates, no spill |
| Test 4. All Gates Open 8 ft Bridge Deck El. 240.0 | | | | | | |
| 18" | 1 | 0.284 | 4.370 | 13,664.9 | 227.8 | Flow in contact with lip of Gate 19 only |
| | 2 | 0.385 | 5.130 | 16,040.8 | 229.0 | Flow just above lips of all gates |
| | 3 | 0.629 | 6.648 | 20,775.3 | 232.9 | |
| | 4 | 0.791 | 7.501 | 23,441.4 | 235.4 | Water touches crown of arch of bridge (outside arch) |
| | 5 | 0.954 | 8.230 | 25,873.5 | 237.8 | Vortices (Type"4" and "5") at ends of gates. |
| | 6 | 1.145 | 9.115 | 23,484.7 | 240.4 | Water just flowing over bridge, vortices at ends of gates. |
| | 7 | .679 | 6.922 | 21,629.6 | 233.5 | |
| | 8 | .465 | 5.670 | 17,718.4 | 230.1 | |

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
Capacity of Gates 11 through 19

| Orifice | Run No. | Δh ft | $Q_{model}$ cfs | $Q_{proto}$ cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 5. All Gates Open 12 ft — Bridge Deck El. 240.0 | | | | | | |
| 18" | 1 | 0.868 | 7.878 | 24,617.2 | 231.5 | Water just touching lip of gate 19 (Free-flow) |
| | 2 | 1.260 | 9.587 | 29,957.9 | 233.3 | Water just above gate lips except Nos. 11 and 12 |
| | 3 | 1.575 | 10.783 | 33,695.3 | 236.0 | Water just above crown of outside bridge arch Just under center arch |
| | 4 | 1.890 | 11.870 | 37,092.5 | 238.4 | Water above bridge arches but not flowing over bridge |
| | 5 | 2.128 | 12.635 | 39,484.3 | 239.7 | Water just overflowing bridge deck. Vortices form at ends of gates |
| | 6 | 2.588 | 14.001 | 43,772.7 | 243.0 | Vortices form at ends of gates w.s. near top of gate 19 |
| | 7 | 1.708 | 11.253 | 35,165.6 | 237.3 | |
| Test 6. All Gates Open 1 ft — Bridge Deck El. 240.0 | | | | | | |
| 4" | 1 | 0.105 | 0.125 | 390.6 | 219.3 | Water below gates (free-flow) |
| | 2 | 0.700 | 0.320 | 1,000.2 | 220.3 | Water just touches lip of Gate 19 |
| | 3 | 2.500 | 0.601 | 1,880.6 | 221.5 | |
| | 4 | 6.700 | 0.981 | 3,066.5 | 225.6 | |
| | 5 | 11.490 | 1.298 | 3,995.7 | 229.3 | |
| | 6 | 12.810 | 1.352 | 4,225.3 | 232.5 | |
| | 7 | - | 0.623 | 1,962.1 | 222.5 | |
| Test 7. All Gates Open 21 ft — Bridge Deck El. 240.0 | | | | | | |
| 18" | 1 | 4.483 | 18.709 | 58,467.6 | 240.0 | |
| 18" & 4" | 2 | - | 23.818 | 74,430.8 | 243.8 | |
| 18" | 3 | 6.274 | 28.334 | 69,275.0 | 242.8 | |
| | 4 | 5.271 | 20.376 | 63,674.6 | 241.3 | |
| | 5 | 4.810 | 19.417 | 60,677.1 | 240.5 | |
| Test 8. All Gates Open 21 ft — Bridge railings raised to represent prototype El. 242.5 | | | | | | |
| 18" | 1 | 1.975 | 12.148 | 37,962.3 | 235.3 | |
| | 2 | 3.307 | 15.938 | 49,805.3 | 238.4 | |
| | 4 | - | 21.313 | 68,167.7 | 242.6 | |
| | 5 | - | 23.366 | 73,020.5 | 243.7 | |
| | 6 | 3.821 | 17.200 | 53,752.1 | 239.3 | |
| Test 9. Gate 19 Open, Other Closed — Bridge Deck at El. 240.0 | | | | | | |
| 4" | 1 | 1.580 | 0.479 | 1,497.8 | 226.6 | Free Flow |
| | 2 | 2.460 | 0.597 | 1,865.6 | 228.5 | Free Flow |
| | 3 | 4.440 | 0.800 | 2,500.4 | 230.5 | Free Flow |
| | 4 | 6.520 | 0.968 | 3,025.4 | 232.3 | Free Flow |
| | 5 | 0.290 | 0.207 | 646.0 | 224.0 | Free Flow |
| Test 10. Gate 11 Open, Other Closed — Bridge Deck El. 240.0 | | | | | | |
| 4" | 1 | 0.820 | 0.346 | 1,081.8 | 225.0 | Free Flow |
| | 2 | 2.880 | 0.646 | 2,017.3 | 228.5 | Free Flow |
| | 3 | 6.620 | 0.975 | 3,043.3 | 231.8 | Free Flow |
| | 4 | 4.100 | 0.769 | 2,403.6 | 230.3 | Free Flow |
| | 5 | 1.650 | 0.490 | 1,531.3 | 227.5 | Free Flow |
| | 6 | 0.070 | 0.120 | 319.2 | 221.8 | Free Flow |
| Test 11. Gate 13 Open, Other Closed — Bridge Railings Raised El. 242.5 | | | | | | |
| 4" | 1 | 2.730 | 0.628 | 1,964.5 | 229.8 | Free Flow |
| | 2 | 7.090 | 1.009 | 3,153.8 | 233.5 | Free Flow |
| | 3 | 0.870 | 0.356 | 1,114.0 | 227.1 | Free Flow |
| | 4 | 0.500 | 0.271 | 846.4 | 226.2 | Free Flow |

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale

| Orifice | Run No. | Δh ft | $Q_{model}$ cfs | $Q_{proto}$ cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 12. Gate 15 Open, Others Closed Bridge Deck El. 240.0 | | | | | | |
| 4" | 1 | 0.330 | 0.220 | 688.8 | 224.8 | Free Flow |
| | 2 | 1.120 | 0.404 | 1,262.8 | 226.8 | Free Flow |
| | 3 | 2.570 | 0.610 | 1,906.5 | 229.3 | Free Flow |
| | 4 | 4.650 | 0.819 | 2,550.4 | 231.5 | Free Flow |
| | 5 | 6.360 | 0.956 | 2,988.3 | 232.8 | Free Flow |
| | 6 | 1.740 | 0.503 | 1,571.9 | 228.3 | Free Flow |
| | 7 | 0.210 | 0.126 | 550.5 | 224.0 | Free Flow |
| Test 13. Gate 15 Open, Others Closed Bridge Railings Raised El. 242.5 | | | | | | |
| 4" | 1 | 0.070 | 1.101 | 3,442.2 | 233.8 | Free Flow |
| | 2 | 5.472 | 0.908 | 3,839.0 | 232.3 | Free Flow |
| | 3 | 1.141 | 0.417 | 1,305.0 | 226.9 | Free Flow |
| | 4 | 0.065 | 0.098 | 307.7 | 222.7 | Free Flow |
| | 5 | 2.750 | 0.631 | 1,971.6 | 229.9 | Free Flow |
| Test 14. All Gates Open 12 ft Bridge Railings Raised El. 242.5 | | | | | | |
| 18" | 1 | 1.548 | 10.686 | 33,393.5 | 236.0 | |
| | 2 | 1.548 | 10.686 | 33,393.5 | 238.8 | (Gate 11 Closed) |
| | 3 | 2.050 | 12.389 | 38,715.1 | 239.5 | |
| | 4 | 1.586 | 10.824 | 33,826.5 | 236.3 | |
| Test 15. All Gates Open 14 ft Bridge Railings Raised El. 242.5 Gate 11 Closed Part Time | | | | | | |
| 18" | 1 | 1.545 | 10.673 | 33,355.6 | 234.1 | |
| | 2 | 1.545 | 10.673 | 33,355.6 | 235.7 | (Gate 11 Closed) |
| | 3 | 2.235 | 12.966 | 40,518.2 | 236.8 | |
| | 4 | 2.234 | 12.966 | 40,518.2 | 240.0 | (Gate 11 Closed) |
| | 5 | 2.701 | 14.328 | 44,775.4 | 239.6 | |
| | 6 | 2.701 | 14.328 | 44,775.4 | 242.8 | (Gate 11 Closed) |
| | 7 | 3.125 | 15.470 | 48,344.4 | 241.4 | |
| | 8 | 3.125 | 15.470 | 48,344.4 | 244.5 | (Gate 11 Closed) |
| | 9 | 3.353 | 16.056 | 50,174.4 | 243.0 | |
| | 10 | 3.353 | 16.056 | 50,174.4 | 245.5 | (Gate 11 Closed) |
| Test 16. All Gates Open 16.75 ft Bridge Railings Raised El. 242.5 | | | | | | |
| 18" | 1 | 2.365 | 13.358 | 41,743.3 | 236.3 | |
| | 2 | 3.210 | 15.690 | 49,033.0 | 237.1 | |
| | 3 | 4.460 | 18.659 | 58,379.4 | 241.5 | Water at top of bridge |
| | 4 | 5.560 | 20.957 | 65,490.7 | 246.0 | Water above bridge |
| | 5 | 5.682 | 21.199 | 66,247.0 | 246.3 | Water over bridge |
| Test 17. All Gates Open 14 ft Bridge Railings Raised El. 242.5 Gate 11 full open part time | | | | | | |
| 18" | 1 | 1.677 | 11.147 | 34,833.4 | 234.5 | |
| | 1a | 1.677 | 11.147 | 34,833.4 | 234.5 | (Gate 11 fully open) |
| | 2 | 2.280 | 13.103 | 40,946.0 | 237.0 | |
| | 2a | 2.280 | 13.103 | 40,946.0 | 237.0 | (Gate 11 fully open) |
| | 3 | 2.640 | 14.155 | 44,234.0 | 239.1 | |
| | 3a | 2.640 | 14.155 | 44,234.0 | 238.9 | (Gate 11 fully open) |
| | 4 | 3.166 | 15.577 | 48,679.6 | 241.9 | |
| | 4a | 3.166 | 15.577 | 48,679.6 | 241.3 | (Gate 11 fully open) |
| | 5 | 3.511 | 16.450 | 51,405.8 | 243.6 | |
| | 5a | 3.511 | 16.450 | 51,405.8 | 242.6 | (Gate 11 fully open) |
| Test 18. All Gates Open 12 ft Bridge Railings Raised El. 242.5 | | | | | | |
| 18" | 1 | 1.697 | 11.215 | 35,047.0 | 236.6 | |
| | 2 | 21.67 | 12.757 | 39,864.0 | 240.1 | |
| | 3 | 2.426 | 13.538 | 42,307.0 | 241.8 | |
| | 4 | 2.600 | 14.042 | 43,881.0 | 243.3 | Water near top of gates |

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
(Gates 11 through 19)

| Orifice | Run No. | Δh ft | $Q_{model}$ cfs | $Q_{proto}$ cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 19. Gate 11 open 2 ft | | | | | | |
| 4" | 1 | 0.140 | 0.144 | 450.0 | 225.2 | |
| | 2 | 0.500 | 0.271 | 846.5 | 233.5 | Top of closed gates |
| | 3 | 0.295 | 0.209 | 651.5 | 227.9 | |
| | 4 | 0.400 | 0.243 | 757.8 | 229.5 | |
| | 5 | 0.505 | 0.272 | 850.6 | 231.6 | |
| | 6c | 0.280 | 0.213 | 634.9 | 227.1 | |
| Test 20. Gate 11 open 4 ft | | | | | | |
| 4" | 1 | 0.300 | 0.210 | 657.0 | 223.8 | |
| | 2 | 1.280 | 0.432 | 1,349.2 | 230.7 | |
| | 3 | 1.525 | 0.471 | 1,471.7 | 232.6 | |
| | 4 | 0.510 | 0.274 | 854.8 | 225.4 | |
| | 5c | 0.745 | 0.330 | 1,031.6 | 226.7 | |
| Test 21. Gate 11 open 6 ft | | | | | | |
| 4" | 1 | 0.750 | 0.330 | 1,035.0 | 225.4 | |
| | 2 | 1.160 | 0.411 | 1,285.0 | 226.6 | |
| | 3 | 1.990 | 0.537 | 1,679.4 | 239.8 | |
| | 4 | 3.215 | 0.682 | 2,130.5 | 234.1 | |
| | 5c | 2.025 | 0.542 | 1,694.0 | 229.3 | |
| Test 22. Gate 11 open 8 ft | | | | | | |
| 4" | 1 | 2.140 | 0.557 | 1,741.0 | 228.2 | |
| | 2 | 3.510 | 0.712 | 2,227.0 | 230.6 | |
| | 3 | 4.180 | 0.777 | 2,428.1 | 232.2 | |
| | 4 | 5.010 | 0.849 | 2,654.8 | 233.8 | Top of closed gates |
| | 5c | 3.785 | 0.739 | 2,310.1 | 231.3 | |
| Test 23. Gate 13 open 2 ft | | | | | | |
| 4" | 1 | 0.225 | 0.182 | 569.6 | 225.8 | |
| | 2 | 0.300 | 0.210 | 657.0 | 228.0 | |
| | 3 | 0.395 | 0.241 | 753.0 | 229.4 | |
| | 4 | 0.500 | 0.270 | 846.5 | 231.6 | |
| | 5c | 0.320 | 0.217 | 678.4 | 228.3 | |
| Test 24. Gate 13 open 4 ft | | | | | | |
| 4" | 1 | 0.800 | 0.342 | 1,068.7 | 228.9 | |
| | 2 | 1.275 | 0.431 | 1,346.6 | 232.3 | |
| | 3 | 1.425 | 0.455 | 1,423.0 | 234.1 | Top of closed gates |
| | 4 | 0.520 | 0.276 | 863.0 | 226.0 | |
| Test 25. Gate 13 open 6 ft | | | | | | |
| 4" | 1 | 1.660 | 0.491 | 1,535.0 | 229.8 | |
| | 2 | 2.380 | 0.587 | 1,835.2 | 233.1 | |
| | 3 | 2.180 | 0.562 | 1,757.0 | 231.8 | |
| | 4 | 1.940 | 0.530 | 1,658.3 | 231.2 | |
| Test 26. Gate 13 open 8 ft | | | | | | |
| 4" | 1 | 2.730 | 0.629 | 1,964.5 | 230.2 | |
| | 2 | 3.660 | 0.727 | 2,272.0 | 232.8 | |
| | 3 | 2.980 | 0.657 | 2,051.7 | 231.4 | |
| | 4 | 3.160 | 0.676 | 2,112.3 | 232.2 | |
| Test 27. Gates 13 and 14 open 2 ft | | | | | | |
| 4" | 1 | 0.310 | 0.214 | 668.0 | 222.8 | |
| | 2 | 0.660 | 0.311 | 971.4 | 224.2 | |
| | 3 | 1.610 | 0.484 | 1,511.8 | 231.1 | |
| | 4 | 1.020 | 0.386 | 1,205.5 | 226.8 | |

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
(Gates 11 through 19)

| Orifice | Run No. | Δh ft | $Q_{model}$ cfs | $Q_{proto}$ cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| **Test 28. Gates 13 and 14 open 4 feet** | | | | | | |
| 4" | 1 | 2.680 | 0.623 | 1,946.6 | 227.6 | |
| | 2 | 3.210 | 0.681 | 2,128.8 | 228.8 | |
| | 3 | 5.500 | 0.890 | 2,780.6 | 233.9 | W.S. top of gates |
| | 4 | 4.480 | 0.804 | 2,511.6 | 231.3 | |
| **Test 29. Gates 13 and 14 open 6 feet** | | | | | | |
| 4" | 1 | 7.83* | 1.085 | 3,391.0 | 231.4 | |
| | 2 | 8.58* | 1.135 | 3,548.4 | 232.2 | |
| | 3 | 9.64* | 1.203 | 3,759.5 | 233.4 | |
| | 4 | 6.41* | 0.983 | 3,072.3 | 229.7 | |
| **Test 30. Gates 13 and 14 open 8 ft** | | | | | | |
| 4" | 1 | 14.92* | 1.494 | 4,669.0 | 233.5 | W.S. top of gates |
| | 2 | 13.93* | 1.444 | 4,513.7 | 232.8 | |
| | 3 | 13.23* | 1.407 | 4,398.3 | 232.2 | |
| | 4 | 12.56* | 1.371 | 4,286.5 | 231.7 | |
| **Test 31. Gates 11 and 12 open 2 ft** | | | | | | |
| 4" | 1 | 0.610 | 0.299 | 934.2 | 223.7 | |
| | 2 | 1.100 | 0.401 | 1,251.5 | 225.8 | |
| | 3 | 1.710 | 0.498 | 1,557.7 | 229.1 | |
| | 4 | 2.180 | 0.562 | 1,757.0 | 233.2 | |
| **Test 32. Gates 11 and 12 open 4 ft** | | | | | | |
| 4" | 1 | 3.100 | 0.669 | 2,092.3 | 227.8 | |
| | 2 | 3.710 | 0.732 | 2,287.3 | 228.9 | |
| | 3 | 4.345 | 0.792 | 2,473.7 | 230.1 | |
| | 4 | 3.385 | 0.699 | 2,185.6 | 228.2 | |
| **Test 33. Gates 11 and 12 open 6 ft** | | | | | | |
| 4" | 1 | 10.433* | 1.251 | 3,910.0 | 233.7 | W.S. top of gates |
| | 2 | 7.992* | 1.096 | 3,425.6 | 231.7 | |
| | 3 | 6.378* | 0.980 | 3,063.0 | 230.7 | |
| | 4 | 9.448* | 1.193 | 3,730.0 | 232.6 | |
| | 5 | 7.913* | 1.090 | 3,409.0 | 231.4 | |
| **Test 34. Gates 11 and 12 open 8 ft** | | | | | | |
| 4" | 1 | 14.291* | 1.462 | 4,570.2 | 232.4 | |
| | 2 | 14.882* | 1.492 | 4,663.0 | 232.7 | |
| | 3 | 15.590* | 1.527 | 4,772.0 | 233.1 | |
| | 4 | 16.378* | 1.565 | 4,890.0 | 233.5 | W.S. top of gates |
| **Test 35. Gates 13, 14 and 15 open 2 ft** | | | | | | |
| 4" | 1 | 1.935 | 0.530 | 1,656.2 | 226.2 | |
| | 2 | 3.360 | 0.697 | 2,177.6 | 230.3 | |
| | 3 | 4.000 | 0.760 | 2,374.3 | 232.9 | |
| | 4 | 2.790 | 0.635 | 1,986.0 | 228.4 | |
| **Test 36. Gates 13, 14 and 15 open 4 ft** | | | | | | |
| 4" | 1 | 1.070* | 0.899 | 2,800.3 | 227.6 | |
| | 2 | 7.480* | 1.061 | 3,315.0 | 229.6 | |
| | 3 | 8.700* | 1.143 | 3,573.0 | 231.0 | |
| | 4 | 6.142* | 0.962 | 3,006.0 | 228.3 | |

* Δh = inches of Hg

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
(Gates through 19)

| Orifice | Run No. | Δh ft | Qmodel cfs | Qproto cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| **Test 37. Gates 13, 14 and 15 open 6 ft** | | | | | | |
| 4" | 1 | 1.070 | 0.395 | 1,234.5 | 223.2 | Free Flow |
| | 2 | 2.120 | 0.554 | 1,733.0 | 224.2 | Free Flow |
| | 3 | 14.567* | 1.476 | 4,614.0 | 229.9 | |
| | 4 | 16.142* | 1.553 | 4,855.0 | 230.7 | |
| | 5 | 17.913* | 1.636 | 5,112.0 | 231.7 | |
| | 6 | 18.528* | 1.666 | 5,206.0 | 232.2 | |
| **Test 39. Gates 13, 14** | | | | | | |
| 4" | 1 | 6.417* | 0.983 | 3,072.4 | 225.9 | Free Flow |
| | 2 | 9.567* | 1.198 | 3,745.3 | 226.9 | Free Flow |
| | 3 | 14.567* | 1.476 | 4,613.8 | 227.9 | Free Flow |
| | 4 | 10.945* | 1.281 | 4,003.8 | 227.4 | Free Flow |
| **Test 40. Gates 13, 14, 15 and 16 open 2 ft** | | | | | | |
| 4" | 1 | 2.362* | 0.599 | 1,871.4 | 224.5 | |
| | 2 | 3.819* | 0.760 | 2,375.0 | 226.4 | |
| | 3 | 5.512* | 0.912 | 2,849.0 | 229.6 | |
| | 4 | 4.016 | 0.779 | 2,435.0 | 226.8 | |
| **Test 41. Gates 13, 14, 15 and 16 open 4 ft** | | | | | | |
| 4" | 1 | 10.315* | 1.244 | 3,888.0 | 227.5 | |
| | 2 | 12.086* | 1.346 | 4,206.0 | 228.4 | |
| | 3 | 13.504* | 1.422 | 4,443.6 | 229.5 | |
| | 4 | 15.000* | 1.498 | 4,681.3 | 230.2 | |
| **Test 43. Gates 13, 14, 15 and 16 open 8 ft** | | | | | | |
| 18" | 1 | 0.113 | 2.695 | 8,422.0 | 233.0 | |
| | 2 | 0.118 | 2.247 | 8,583.6 | 233.6 | |
| | 3 | 0.122 | 2.798 | 8,742.6 | 234.2 | |
| | 4 | 0.109 | 2.646 | 8,270.0 | 232.5 | |
| **Test 44. Gates 13, 14, 15, 16 and 17 open 2 ft** | | | | | | |
| 4" | 1 | 4.370* | 0.813 | 2.539.2 | 225.5 | Vortex action at outer ends of Gates 13 and 17 |
| | 2 | 6.299* | 0.974 | 3,044.1 | 227.6 | |
| | 3 | 8.110* | 1.104 | 3,450.6 | 229.6 | |
| | 4 | 10.236* | 1.239 | 3,873.0 | 231.8 | |
| **Test 45. Gates 13, 14, 15, 16 and 17 open 4 ft** | | | | | | |
| 4" | 1 | 15.905* | 1.542 | 4,819.3 | 227.8 | Very strong vortices at outer ends of gates 13 and 17 |
| | 2 | 16.771* | 1.631 | 4,948.0 | 228.3 | |
| | 3 | 17.795* | 1.631 | 5,095.4 | 229.0 | |
| | 4 | 18.425* | 1.659 | 5,184.0 | 229.4 | |
| | 5 | 18.779* | 1.675 | 5,233.3 | 229.8 | |

* Δh = inches Hg

DATA SHEET

Roosevelt Dam Spillway Model Study
1:25 Scale
(Gates 11 through 19)

| Orifice | Run No. | Δh ft | Qmodel cfs | Qproto cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 46. Gates 13, 14, 15, 16 and 17 open 6 ft | | | | | | |
| 18" | 1 | 1.093 | 2.432 | 7,600.0 | 231.6 | Vortex action slightly stronger than for 4 ft opening |
| | 2 | 0.103 | 2.567 | 8,022.0 | 232.6 | |
| | 3 | 0.110 | 2.653 | 8,290.4 | 233.5 | |
| | 4 | 0.072 | 2.122 | 6,631.4 | 230.1 | |
| Test 47. Gates 13, 14, 15, 16 and 17 open 8 ft | | | | | | |
| 18" | 1 | 0.165 | 3.280 | 10,250.0 | 252.4 | |
| | 2 | 0.180 | 3.439 | 10,746.4 | 233.2 | |
| | 3 | 0.188 | 3.522 | 11,006.0 | 233.8 | |
| | 4 | 0.150 | 3.124 | 9,762.1 | 231.9 | |
| Test 48. Gates 12, 14, 16 and 18 open 2 ft | | | | | | |
| 4" | 1 | 6.772* | 1.010 | 3,155.4 | 231.1 | |
| | 2 | 2.874* | 1.041 | 3,254.0 | 231.6 | |
| | 3 | 2.874* | 0.660 | 2,062.7 | 225.2 | |
| | 4 | 5.669* | 0.925 | 2,889.2 | 229.6 | |
| | 5 | 4.291* | 0.805 | 2,516.5 | 227.6 | |
| Test 49. Gates 12, 14, 16 and 18 open 4 ft | | | | | | |
| 4" | 1 | 9.094* | 1.169 | 3,652.3 | 226.8 | |
| | 2 | 10.984* | 1.284 | 4,011.0 | 228.0 | |
| | 3 | 12.795* | 1.384 | 4,326.4 | 229.0 | |
| | 4 | 14,488* | 1.472 | 4,601.4 | 230.2 | |
| Test 51. Gates 12, 14, 16 and 18 open 8 ft | | | | | | |
| 18" | 1 | 0.110 | 2.653 | 8,290.4 | 231.5 | Vortices at ends of all open gates. |
| | 2 | 0.117 | 2.736 | 8,551.5 | 232.0 | at outer ends of gates 12 and 18 |
| | 3 | 0.127 | 2.858 | 8,930.1 | 232.7 | |
| | 4 | 0.133 | 2.936 | 9,174.8 | 233.6 | |
| Test 52. Gates 11, 13, 15, 17 and 19 open 2 ft | | | | | | |
| 18" | 1 | 3.700* | 0.748 | 2,338.3 | 224.0 | No vortex action at outer ends of Gates 11 and 19 |
| | 2 | 6.063* | 0.956 | 2,987.0 | 226.2 | Vortices occur at both ends of other open gates |
| | 3 | 8.425* | 1.125 | 3,516.5 | 228.6 | |
| | 4 | 11.929* | 1.337 | 4,178.5 | 232.3 | |
| Test 53. Gates 11, 13, 15, 17 and 19 open 4 ft | | | | | | |
| 4" | 1 | 13.937* | 1.444 | 4,513.7 | 225.4 | |
| | 2 | 16.181* | 1.555 | 4,860.6 | 227.2 | |
| | 3 | 17.913* | 1.636 | 5,112.2 | 227.7 | |
| | 4 | 20.590* | 1.753 | 5,478.0 | 228.5 | |
| Test 54. Gates 11, 13, 15, 17 and 19 open 6 ft | | | | | | |
| 18" | 1 | 0.078 | 2.218 | 6,932.6 | 229.2 | |
| | 2 | 0.093 | 2.433 | 7,603.0 | 230.6 | |
| | 3 | 0.103 | 2.567 | 8,022.0 | 231.5 | |
| | 4 | 0.123 | 2.818 | 8,805.5 | 233.1 | |
| | 5 | 0.130 | 2.897 | 9,053.2 | 233.7 | |

* Δh = inches Hg

DATA SHEET

Roosevelt Dam Spillway Model Studies
1:25 Scale
(Gates 11 through 19)

| Orifice | Run No. | Δh ft | $Q_{model}$ cfs | $Q_{proto}$ cfs | Res. El. | Remarks |
|---|---|---|---|---|---|---|
| Test 55. Gates 11, 13, 15, 17 and 19 open 8 ft | | | | | | |
| 18" | 1 | 1.178 | 3.422 | 10,694.0 | 232.5 | Large vortex at left end of gale 11 |
| | 2 | 0.195 | 3.587 | 12,209.3 | 233.1 | Smaller vortices at other open gates |
| | 3 | 0.199 | 3.623 | 11,322.3 | 233.5 | |
| | 4 | 0.207 | 3.699 | 11,558.0 | 233.9 | |
| Test 56. Gates 11, 13, 15, 17 and 19 open | | | | | | |
| | 1 | 0.065 | 2.100 | 6,283.5 | 227.3 | Free Flow |
| | 2 | 0.214 | 3.765 | 11,765.0 | 231.5 | Free Flow |
| | 3 | 0.847* | 0.360 | 1,125.0 | 221.3 | Free Flow |
| | 4 | 1.010 | 0.384 | 1,200.0 | 221.3 | Free Flow |
| | 5 | 4.700 | 0.823 | 2,572.0 | 223.5 | |
| Test 57. Gates 13, 14, 15, 16 and 17 | | | | | | |
| | 1 | 0.235 | 0.186 | 582.0 | 220.6 | Free Flow |
| | 2 | 4.600 | 0.814 | 2,545.0 | 223.6 | Free Flow |
| | 3 | 0.060 | 1.928 | 6,024.0 | 227.6 | Free Flow |
| | 4 | 0.160 | 3.232 | 10,100.0 | 230.3 | Free Flow |
| | 5 | 0.217 | 3.792 | 11,850.0 | 231.5 | |
| Test 58. Gates 13, 14, 15 and 16 open | | | | | | |
| 4" | 1 | 0.170 | 0.159 | 495.7 | 220.6 | Free Flow |
| | 2 | 2.735 | 0.629 | 1,966.3 | 223.5 | Free Flow |
| 18" | 3 | 0.045 | 1.657 | 5,177.0 | 227.6 | Free Flow |
| | 4 | 0.145 | 3.069 | 9,589.3 | 231.5 | Free Flow |
| Test 59. Gates 12, 14, 16 and 18 open | | | | | | |
| 4" | 1 | 0.260 | 0.196 | 612.0 | 220.9 | Free Flow |
| | 2 | 2.565 | 0.610 | 1,904.7 | 223.5 | Free Flow |
| 18" | 3 | 0.050 | 1.751 | 5,472.3 | 228.6 | Free Flow |
| | 4 | 0.130 | 2.897 | 9,053.2 | 231.5 | Free Flow |
| | 5 | | | | | Free Flow |
| Test 60. Gates 11 and 12 open | | | | | | |
| 4" | 1 | 3.140 | 0.674 | 2,106.0 | 225.8 | Free Flow |
| | 2 | 6.770 | 0.986 | 3,083.0 | 227.0 | Free Flow |
| | 3 | 0.880 | 0.359 | 1,121.0 | 223.7 | Free Flow |
| | 4 | 0.080 | 0.109 | 341.0 | 221.0 | Free Flow |
| Test 61. Gates 13 and 14 open | | | | | | |
| 4" | 1 | 0.110 | 0.128 | 400.0 | 221.5 | Free Flow |
| | 2 | 0.083 | 0.348 | 1,089.0 | 223.9 | Free Flow |
| | 3 | 6.830 | 0.991 | 3,096.0 | 228.4 | Free Flow |
| | 4 | 2.970 | 0.658 | 2,055.0 | 226.4 | Free Flow |
| | 5 | 17.323* | 1.609 | 5,028.0 | 231.5 | Free Flow |

* Δh = inches Hg