UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE OVERFLOW SPILLWAY AND THE HALE DITCH IRRIGATION OUTLET--BONNY DAM MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd-331

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

January 31, 1952

LIST OF FIGURES

CONTENTS

CONTENTS--Continued

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Design and Construction Division
Engineering Laboratories Branch
Denver, Colorado
January 31, 1952

Laboratory Report No. Hyd-331
Hydraulic Laboratory Section
Compiled by: E. J. Rusho
Reviewed by: A. J. Peterka
J. N. Bradley

Subject: Hydraulic model studies of the overflow spillway and the Hale Ditch irrigation outlet--Bonny Dam--Missouri River Basin Project

SUMMARY

The model studies of Bonny Dam consisted of three main parts conducted on three hydraulic models: (1) the open-chute spillway, (2) a sluiceway in the overflow section of the spillway, and (3) an irrigation outlet, known as the Hale Ditch outlet, which discharges into a canal, the latter having no connection with the spillway. A 1:60 spillway model, Figure 5, was used to study the performance of the overflow section, the chute, the stilling basin, and the center sluiceway of the spillway. A second model of transparent plastic, on a 1:60 scale, Figure 26, was required for further study of the sluiceway. A third model on a scale of 1:6 was utilized, Figure 31, to study the stilling basin for the Hale Ditch irrigation outlet.

Three arrangements of the overflow section were tested, all of which were satisfactory. The selection of the overflow section was dependent upon economy and the choice of a center sluiceway. The preliminary overflow section, Figure 6, had a U-shaped pier and the crest length was 100 feet. Overflow Section No. 2 was similar to the preliminary except for a smaller cross-sectional area, Figure 9. The recommended Overflow Section No. 3 had two 3-foot piers and a crest length of 115.5 feet with the same shape of cross section as the preliminary.

Three spillway chutes were investigated. The preliminary chute with diverging training walls, Figure 11A, gave unsatisfactory distribution of flow entering the stilling basin, Figure 13A. The training walls of Chute No. 2 were made parallel for a distance of 315 feet downstream from the entrance, Figure 11B, and a crown 1 foot high was installed in the downstream portion to aid in spreading the flow. The performance was improved over the preliminary, Figure 14A. Chute No. 3 had the parallel section of the training walls extended 236 feet more than Chute No. 2, Figure 15. This recommended chute gave satisfactory distribution of flow at all discharges, Figure 14B.

Five tests were made on the spillway stilling basin using two heights of chute blocks and end sills and three arrangements of the wing walls. Since the basin dimensions and apron elevation were satisfactory, there were no changes made in the general basin size or shape, Figure 16. The performance of the basin was adequate for most of the tests. The least erosion occurred with 45-degree wing walls, but these were not used because they would be the most expensive to construct. The recommended basin had 90-degree wing walls, 7.5-foot chute blocks, and an 8-foot end sill, Figure 16E.

Seven tests were made on the center sluiceway. A U-shaped pier 20 feet 3 inches wide was used above the sluiceway in the first three tests, while two piers 3 feet wide were employed in the remaining four tests. A curved roof entrance was used on Sluiceways 1 through 4, but subatmospheric pressures occurred in every case, Figures 21 and 24. The remaining three sluiceways used a sharp-edged entrance, Figures 25 and 29, so the water would spring free of the roof. Pressures were satisfactory when air was supplied. A gate which was half the sluiceway height was used for Sluiceway 6. With the gate in the down position and reservoir elevation 3710, uneven flow occurred. A transparent 1:60 scale model was constructed to determine the cause for this unsatisfactory flow. It was discovered that the roof section downstream from the gate should be raised 1 foot to clear the water surface. This was done for Sluiceway 7, Figure 29, which gave satisfactory performance and acceptable pressures for all conditions of operation.

Three stilling basins for the Hale Ditch outlet were tested with a 1:6 scale model. Converging walls in the upstream end of the basin were used to form a passage for the jet from the hollow-jet valve to the stilling basin. The preliminary stilling basin, Figure 32, was unsatisfactory with flow concentrated at the water surface. Basin No. 2, Figure 34, had a smaller volume than the preliminary and the converging walls were moved 3 feet downstream. The performance was improved, but it was not considered satisfactory. The recommended basin, No. 3, Figure 36, had a slightly larger volume than No. 2, and fillets were added to the floor of the jet passage between the converging walls. Operation was satisfactory for all ranges of discharge.

INTRODUCTION

Bonny Dam, a unit of the Missouri River Basin development, is located on the Republican River in northeastern Colorado 20 miles north of the town of Burlington, Figure 1. The dam is an earth-fill structure, approximately 8,000 feet long, with the crest about 130 feet above stream bed, Figure 2.

The flood control spillway, Figure 3, is a concrete open-chute structure located at the left abutment. The crest at elevation 3710 is uncontrolled and has a net length of 115.5 feet. The chute is 1,000 feet in length and connects to a stilling basin having a width of 215 feet. A 16.5- by 21-foot sluiceway at elevation 3672 passes through the overflow section.

Spillway Chute Studies

Chute No. 1--preliminary. The spillway chute studies were made to develop the lowest cost chute that would provide uniform distribution of flow into the stilling basin. The width of Spillway Chute No. 1 diverged uniformly from 120 feet 3 inches at the overflow section to 215 feet at the stilling basin for a horizontal length of 990 feet, Figure 11A. In this test the preliminary entrance was in place and both the sluiceway and overflow section were operated.

The distribution across the spillway chute varied with the discharge. Appearance of the flow in the chute for discharges of 64,700 and 25,000 second feet is shown in Figures 12A and B. The flow distribution was the most unsatisfactory at a discharge of 40,000 second feet as shown by the appearance of the flow in the stilling basin in Figure 13A. The eddy on the right side of the basin carried sand from the channel and deposited it on the apron. Figure 13B shows the river channel after 1 hour of operation at a discharge of 40,000 second feet with tailwater elevation 3621.1. Stilling basin tests could not be made until the chute was modified to give uniform flow distribution.

Chute No. 2. Spillway Chute No. 2 is shown in Figure 11B. Tests were made on the spillway entrance before conducting the test on Chute No. 2, so the recommended entrance was used in these tests. In addition to the change in training wall alinement, a crown was placed in the lower end of the chute, 1 foot high in the center, and extended 300 feet from Station 25+36 to the PC of the vertical curve, Figure 11B.

The distribution of flow was good for various discharges with good results occurring at 40,000 second feet, which had been the most unsatisfactory condition with Chute No. 1. In the present test the most unsatisfactory distribution occurred at the maximum discharge of 71,400 second feet, Figure 14A, because the crown caused the flow to be concentrated at the sides of the stilling basin. However, the crown was necessary to prevent the center concentration of flow at discharges of around 40,000 second feet.

Chute No. 3--recommended. The training wall alinement was changed for Chute No. 3 by continuing the parallel walls to Station 25+36, Figure 15. The height and location of the crown was unchanged. A 2-foot sea wall was added to the training walls between Stations 22+20 and 23+40 to prevent water from overtopping the walls.

Distribution of flow was satisfactory at all discharges, including the maximum of 71,400 second feet, Figure 14B. The water-surface profile along the training walls and transverse water-surface profiles in the region of the sea walls were obtained and are shown in Figure 15. From these tests the chute was considered satisfactory and tests were next made on the stilling basin.

Stilling Basin Studies

Stilling Basin No. 1--preliminary. The horizontal apron of the preliminary stilling basin was at elevation 3589 and was 102 feet long by 215

feet wide, Figure 16A. These dimensions were unchanged throughout the stilling basin tests. The studies were made on changes in the chute blocks, the end sill, and the wing walls. The preliminary basin had chute blocks 4 feet high and a dentated end sill 8 feet high.

The maximum discharge for this test was 64,700 second feet since this was the maximum with the preliminary entrance in place, as discussed previously. Depth of flow was higher in the center, but the jump was contained in the basin, Figure 17A. Scour was moderate after 1-hour operation at 64,700 second feet and tail-water elevation 3623.0, Figure 17B, but at 40,000 second feet the operation and scour was unsatisfactory, Figures 13A and B. The remaining stilling basin tests were made with the recommended entrance and chute in place, so the maximum discharge was 71,400 second feet.

Stilling Basin No. 2. The chute blocks were increased in height to 7.5 feet to give more turbulence in the basin and an end sill 5 feet high was installed for Basin No. 2, Figure 16B. The operation of the basin for the maximum discharge of 71,400 second feet is shown in Figure 18A. The erosion resulting from operating 1 hour at the maximum discharge and the tail-water elevation at 3623.4 is shown in Figure 18B. The erosion was more severe than in the test with the preliminary basin, but the two tests are not comparable because of the higher discharge of the second test. The greatest depth of scour occurred downstream from each training wall.

Stilling Basin No. 3. Stilling Basin No. 3, Figure 16C, had the 90-degree wing walls replaced with 45-degree wing walls, but other features of the basin were unchanged. Past tests on stilling basin have shown that scour is less at the sides of the basin at the end sill when using 45-degree wing walls. Erosion after 1-hour operation at 71,400 second feet was not severe, Figure 19A. The 45-degree wing walls reduced the scour downstream from each training wall, but the designers decided that the cost of these walls did not justify their installation. A further modification to the wing walls was therefore studied.

Stilling Basin No. 4. Sloping walls which constituted an extension of the training walls were installed instead of the 45-degree wing walls, Figure 16D. The scour after 1-hour operation at 71,400 second feet was unsatisfactory, Figure 19B, since holes occurred in the bed at the ends of the sloping walls.

Stilling Basin No. 5--recommended. The 90-degree wing walls were reinstalled for Basin No. 5, Figure 16E. An 8-foot high end sill was installed while the 7.5-foot high chute blocks were retained. Flow distribution was satisfactory with the major portion of the jump contained in the basin, Figure 20A. Erosion resulting from 1 hour of operation at 71,400 second feet was moderate, Figure 20B. Scour was downstream from the basin so that the cut-off wall at the downstream end of the basin was not endangered. As it was planned to use riprap in the river channel, the basin was considered satisfactory and was thus recommended for construction.

Sluiceway Studies

Sluiceway No. 1--preliminary. Six center sluiceway arrangements were tested with the 1:60 scale spillway model. Later the No. 6 sluiceway of this group and an additional one No. 7 were tested on a separate 1:60 scale model constructed of transparent plastic, as visual observation was desirable.

The preliminary sluiceway, No. 1, Figures 6 and 21A, had the invert entrance at elevation 3672.00 and the width was 14 feet 3 inches. The design discharge for the sluiceway was 10,000 second feet at reservoir elevation 3710.00. Appearance of the flow from the downstream portal, Figures 12A and B, was satisfactory, but a disturbance was caused by the intersection of this flow with the flow from the overflow section. Sluiceway pressures were measured along the roof near the left-side wall and along the floor for various reservoir elevations. Floor pressures were all above atmospheric, but roof pressures were subatmospheric, Figure 21A. The lowest pressure was 18 feet of water below atmospheric at Piezometer No. 2 with reservoir elevation 3736.2.

A discharge-capacity curve was obtained by blocking off the overflow section. The discharge curve, No. 1 of Figure 22, showed a discharge of 10,850 second feet at reservoir elevation 3710.00 or 850 second feet more than desired.

To aid in determining the roof shape that would give satisfactory pressures, the roof section was removed and water-surface profiles were taken throughout the length of the sluiceway. The water-surface profile D of Figure 23 indicated a slope should be used on the roof.

Sluiceway No. 2. The roof of Sluiceway No. 2 was inclined downstream, Figure 21B, to fit the upper water-surface profile, and the roof length was shortened by 42.5 feet. The height of the downstream opening was increased to 20 feet and the U-shaped pier, 20 feet 3 inches wide, was retained.

Operation of the sluiceway was similar to the original design, but pressures on the floor and roof were higher. The pressures at various reservoir elevations are shown plotted in Figure 21B. All pressures were above atmospheric, except at the roof entrance. The lowest pressure was 9 feet of water below atmospheric at Piezometer No. 1 with reservoir elevation 3722.7.

A discharge-capacity curve was obtained, Curve 2, Figure 22. At reservoir elevation 3710.00 the discharge was 8,650 second feet or 1,350 less than the desired 10,000 second feet. The cross-sectional area of Sluiceway No. 2 was greater than Sluiceway No. 1, but the capacity was less, which indicated the low pressures in Sluiceway No. 1 accounted for the greater discharge.

Sluiceway No. 3. The width of Sluiceway No. 3 was increased from 14 feet 3 inches to 16 feet 6 inches and the roof shape was changed, Figure 24A. The U-shaped pier with a width of 20 feet 3 inches was used.

External flow conditions were similar to those of Sluiceways No. 1 and 2. Pressures were obtained and these are shown on Figure 24A. Low pressures occurred at the roof entrance, with the minimum being 21 feet of water below atmospheric at Piezometer No. 1 with reservoir elevation 3711.80.

The discharge capacity, Curve 3, Figure 22, shows a discharge of 9,600 second feet at reservoir elevation 3710 or 400 less than the desired value of 10,000 second feet.

Sluiceway No. 4. Two piers 3 feet wide were next located on the crest as shown in Figure 10 instead of the 20-foot 3-inch U-shaped pier. The overflow section between the 3-foot piers was utilized, resulting in an extension to the roof of the sluiceway, Figure 24B. The 16.5-foot width was retained and the height of the downstream opening was 12.5 feet.

Pressures on the roof were observed and these are plotted in Figure 24B. For reservoir elevations above 3710.00 water from the overflow section caused a back pressure at the portal so that the sluiceway pressures were all above atmospheric. Pressures were below atmospheric for the length of the roof with reservoir elevation 3709.86.

A discharge-capacity curve was obtained, Curve 4, Figure 22. The discharge of 10,150 second feet at reservoir elevation 3710.00 was only 150 second feet more than the required 10,000. Since the curved roof shapes had not proved successful in eliminating subatmospheric pressures, it was decided to use a sharp-edged roof entrance.

Sluiceway No. 5. Sluiceway No. 5, Figure 25A, had a square-edged roof entrance at elevation 3691.5 and an air vent was provided in the roof downstream from the entrance.

Operation was satisfactory with pressures above or very near atmospheric for all reservoir elevations when air was supplied. With the air supply shut off, the pressures decreased and a minimum value of 11 feet of water below atmospheric occurred at Piezometer No. 1, Figure 25A for reservoir elevation 3727.28.

The discharge-capacity curve for this sluiceway is Curve 5 in Figure 22. At reservoir elevation 3710.00 the discharge was 9,600 second feet, indicating that it would be necessary to increase the area at the entrance, Figure 25A, if the desired discharge of 10,000 second feet was to be obtained.

Sluiceway No. 6. The roof entrance of Sluiceway No. 6 was raised to elevation 3697.00 to increase the entrance area for greater discharge. A slide gate with a height of 10 feet 9 inches was installed, Figure 25B. The decision to add the half leaf gate was made after the model studies had progressed to Sluiceway No. 6 which was the reason for not testing the gate previously. The advantage of the gate was closer

flood regulation under certain flood conditions. The gate leaf was about half the sluiceway height to restrict the flow to 5,000 second feet with reservoir elevation 3710.00. Two air vents were provided, one downstream from the entrance and another downstream from the gate with the latter connected to a manifold to supply air for any gate setting.

Pressures were obtained with the air vents open for various reservoir elevations and gate settings and these are shown in Figure 25B. The lowest pressure that occurred was 10 feet of water below atmospheric at Piezometer No. 4 when the bottom of the gate was at elevation 3679.45 and reservoir elevation 3737.58.

With reservoir elevation 3710.00 the required discharge of 10,000 second feet occurred with the gate fully raised and a discharge of 5,000 second feet was obtained with the gate fully lowered. The only unsatisfactory sluiceway flow occurred with this latter condition. The surface of the water leaving the sluiceway was very rough and since the conditions occurring inside the sluiceway could not be observed it was decided to build a plastic model of the sluiceway, including a section of the overflow section.

INVESTIGATION WITH 1:60 TRANSPARENT SLUICEWAY MODEL

The Sluiceway Model

The 1:60 plastic sluiceway model was attached to one side of a 4- by 4-foot sheet-metal-lined wooden head box, Figure 26. Transparent plastic was used for construction of the sluiceway which also included a portion of the overflow section 40 feet wide with plastic training walls. The two piers were made of wood and the gate was built of brass. Piezometers were installed in the sluiceway walls and roof in the region of the gate and also on the upstream and downstream faces of the gate. Air inlets were provided at the upstream roof entrance and downstream from the gate. A 4-inch pipe supplied water to the head box from the laboratory supply system which contained venturi meters for measuring the flow.

Sluiceway Studies

Sluiceway No. 6. Sluiceway No. 6, Figure 25B, the one last tested, was installed in the plastic model. Operation of the sluiceway is shown in Figures 27A and B with reservoir elevation at 3736.80 and 3710.00. The gate was fully open in both cases and no unsatisfactory flow conditions occurred. The water surface in the sluiceway of Figure 27B is flowing free of the roof. At the higher reservoir elevation, Figure 27A, the back pressure caused by the spillway discharge increased the pressure in the sluiceway, causing the sluiceway to fill. Figure 28A shows operation of the sluiceway with the gate in the down position and reservoir elevation 3710.00. The uneven water surface was the same as observed in the spillway model. However, in the plastic model, the cause for the rough water surface could be observed. It was caused by water clinging to the downstream roof section after passing the gate. It broke

free of the roof at a different point on one side than the other, producing a warped water surface with a resulting uneven wave pattern, Figure 28A.

Sluiceway No. 7--recommended. The elevation of the roof of Sluiceway No. 7 immediately downstream from the gate was raised 1 foot to elevation 3695.00, Figure 29, but other dimensions of the sluiceway remained unchanged. Operation of the sluiceway with the gate in the down position and reservoir elevation 3710.00 is shown in Figure 28B. Closed conduit flow ceased after passing over the gate and smooth flow resulted downstream. The improvement is apparent by comparing the two photographs of Figure 28. Pressures were measured on the nine piezometers for various reservoir elevations with the gate lowered to the bottom and raised so that the top of the gate was at the top of the sluiceway. These pressures are shown in the table of Figure 29. All pressures were at or above atmospheric for all operating conditions. Curves were calculated for the total pressure in feet of water on the gate from the pressures observed on the upstream and downstream gate face. These curves are shown in Figure 29 for two gate positions. The highest pressures occurred when the gate was in the down position, but these were lower than would occur from a static head if there were no flow.

Discharge-capacity curves were obtained for three gate settings and these are shown in Figure 30. For reservoir elevation 3710.00, the discharge with gate fully open was 10,000 second feet and with the gate all the way down 5,000 second feet. These were the required discharges for the sluiceway. Results of the tests indicated this design was satisfactory and it was recommended for construction.

INVESTIGATION WITH 1:6 IRRIGATION OUTLET MODEL

The Irrigation Outlet Model

A model of the irrigation outlet for Hale Ditch, Figure 4, was built to a scale of 1:6 so that a 3-inch hollow-jet valve could be used to represent the 24-inch hollow-jet valve of the prototype. The stilling basin was placed in a wooden box lined with sheet metal with a glass panel in the right wall, Figure 31. The channel downstream from the basin was molded in pea gravel and was contained in a metal-lined wooden box. A tailgate at the end of this box was used to regulate the depth of water in the channel which was measured with a staff gage. A piezometer in the 3-inch pipe upstream from the valve was used to measure the pressure head. Water was supplied by a portable 6-inch pump and an orifice meter in the supply line was used to measure the flow.

Irrigation Outlet Studies

Stilling Basin No. 1--preliminary. The preliminary basin, Figure 32, had a 24-inch hollow-jet valve inclined downward at an angle of 15 degrees. The horizontal floor was at elevation 3630.00, giving a basin depth of 4.14 feet for the normal discharge of 10 second feet and

5.62 feet for the maximum discharge of 25 second feet. Two converging walls were located at the upstream end of the basin in accordance with the Boysen Stilling Basin[1] developed in the Hydraulic Laboratory for hollow-jet valves.

Operation of the basin as seen through the glass wall is shown in Figure 33A with the maximum discharge of 25 second feet. The action in the basin was confined to the upstream end, indicating the full volume of the basin was not being used. The model was next operated with the converging walls removed, Figure 33B, to determine their effect upon the basin performance. The stilling action was poor with the flow concentrated at the surface. This demonstrated that the converging walls concentrated the jet and allowed it to penetrate further into the stilling basin.

Stilling Basin No. 2. To decrease the basin volume, since it appeared too large in the preliminary design, the floor was raised 1.5 feet to elevation 3631.50, Figure 34, and the horizontal portion of the floor was shortened from 22 feet to 14 feet 8 inches. The end of the converging walls was placed at the toe of the upstream slope, Figure 34.

Operation of this basin at a discharge of 25 second feet, Figures 35A and B, showed the turbulent action occurred throughout the basin volume except at the downstream end. Surface velocities were high for the flow leaving the basin, indicating high concentration of discharge at the surface. It was believed the depth of the downstream end of the basin was too small, thus increasing the surface velocities.

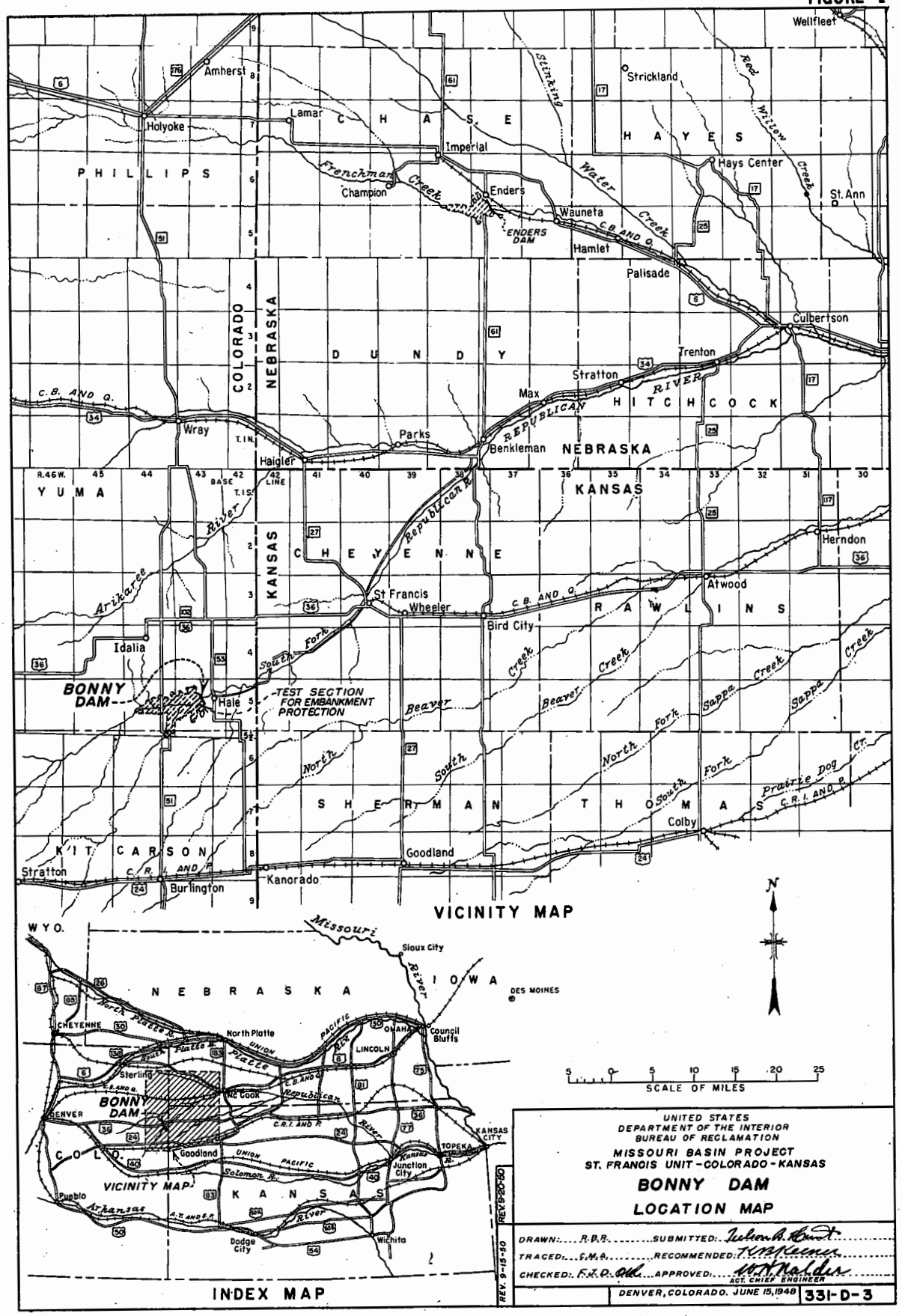
Stilling Basin No. 3--recommended. For Stilling Basin No. 3, Figure 36, the horizontal floor was at elevation 3631.50 and 17 feet in length. The sloping floor downstream had a horizontal length of 11 feet 6 inches as in Stilling Basin No. 1. Converging walls were used as in the two previous basins, but 45-degree fillets were added at the bottom of these walls, Figure 36.

Operation of the stilling basin was satisfactory at all flows up to and including the maximum of 25 second feet. With a discharge of 10 second feet, Figure 37A, the stilling action was satisfactory. At a discharge of 25 second feet, Figure 37B, the turbulent action extended throughout the volume of the basin, indicating that the addition of the fillets to the converging walls increased their effectiveness. Flow leaving the basin was satisfactory with lower surface velocities than occurred in the two previous basins. This stilling basin was considered satisfactory and was recommended for construction.

1/ Hydraulic model studies of the outlet works--Boysen Dam--Missouri River Basin Project. Laboratory Report No. Hyd-283.

Interior - Reclamation - Denver, Colo.

FIGURE 1



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
ST. FRANCIS UNIT - COLORADO - KANSAS

BONNY DAM

LOCATION MAP

DRAWN: R.P.R. SUBMITTED: Julian A. Hunt
TRACED: F.M.A. RECOMMENDED: F.W. Keener
CHECKED: F.J.O. APPROVED: W.H. Nalder ACT. CHIEF ENGINEER

DENVER, COLORADO, JUNE 15, 1948 | 331-D-3

FIGURE 2

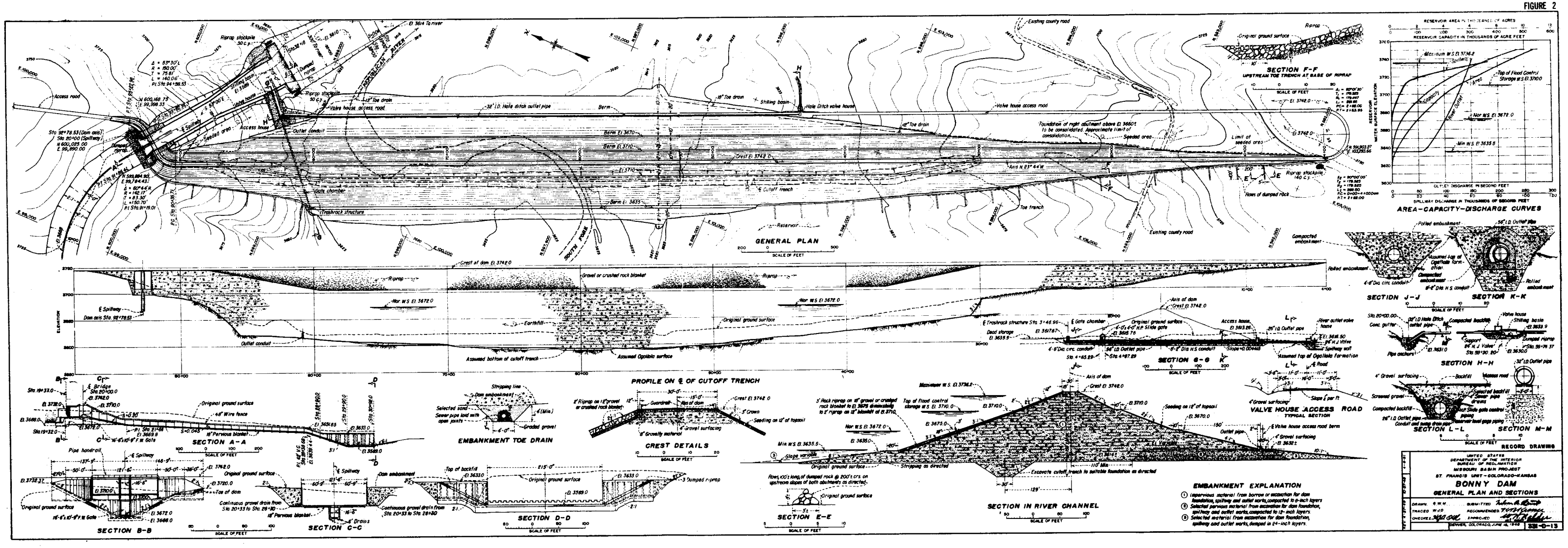

GENERAL PLAN
SCALE OF FEET
SECTION F-F
UPSTREAM TOE TRENCH AT BASE OF RIPRAP
AREA-CAPACITY-DISCHARGE CURVES
RESERVOIR AREA IN THOUSANDS OF ACRES
RESERVOIR CAPACITY IN THOUSANDS OF ACRE FEET
WATER SURFACE ELEVATION
OUTLET DISCHARGE IN SECOND FEET
SPILLWAY DISCHARGE IN THOUSANDS OF SECOND FEET
SECTION J-J
SECTION K-K
SECTION G-G
SECTION H-H
SECTION L-L
SECTION M-M
VALVE HOUSE ACCESS ROAD
TYPICAL SECTION
PROFILE ON ℄ OF CUTOFF TRENCH
SECTION A-A
EMBANKMENT TOE DRAIN
CREST DETAILS
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION IN RIVER CHANNEL
EMBANKMENT EXPLANATION
RECORD DRAWING
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
ST. FRANCIS UNIT - COLORADO-KANSAS
BONNY DAM
GENERAL PLAN AND SECTIONS
DENVER, COLORADO, JUNE 16, 1948
SSI-D-13

FIGURE 3

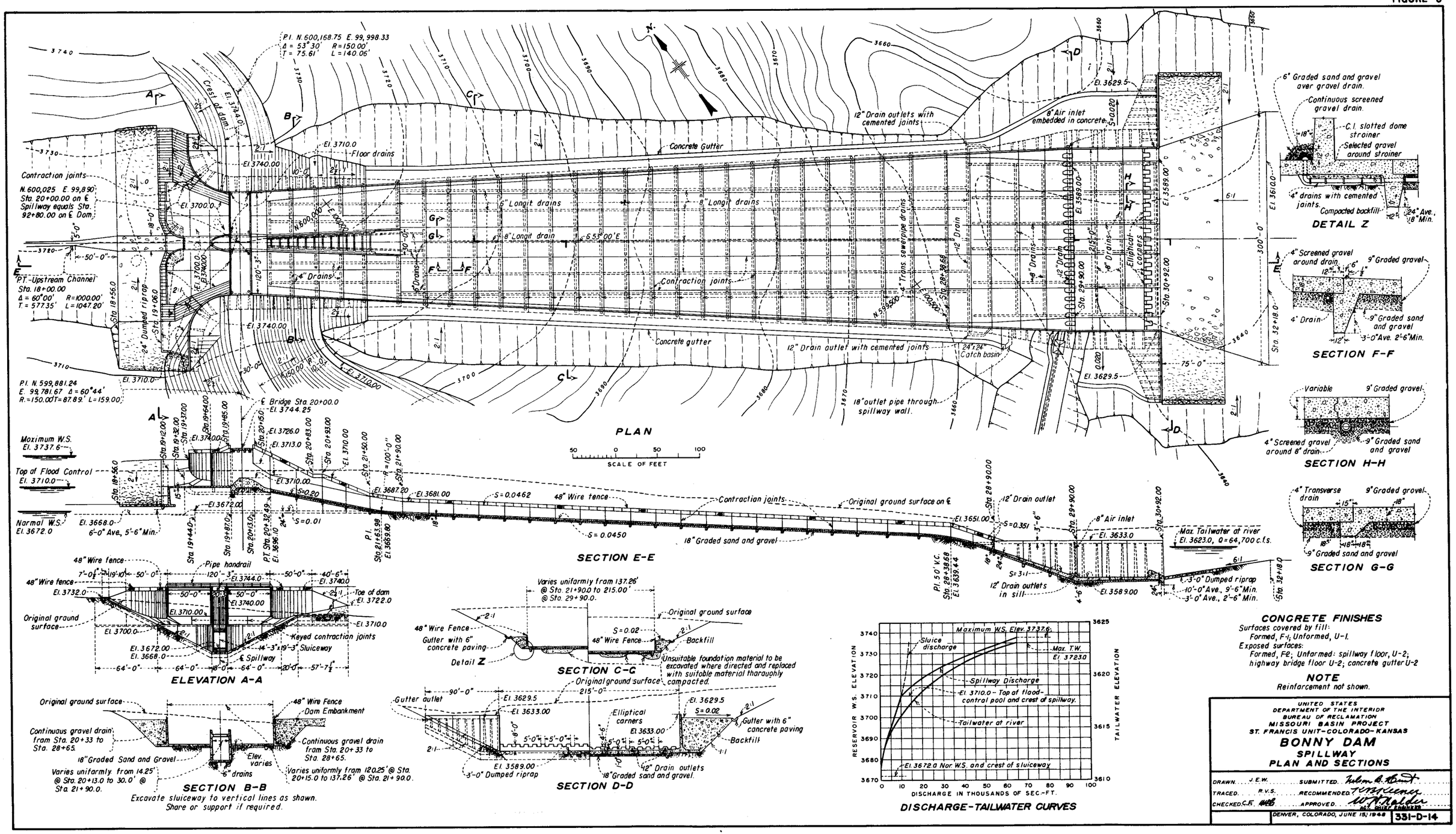
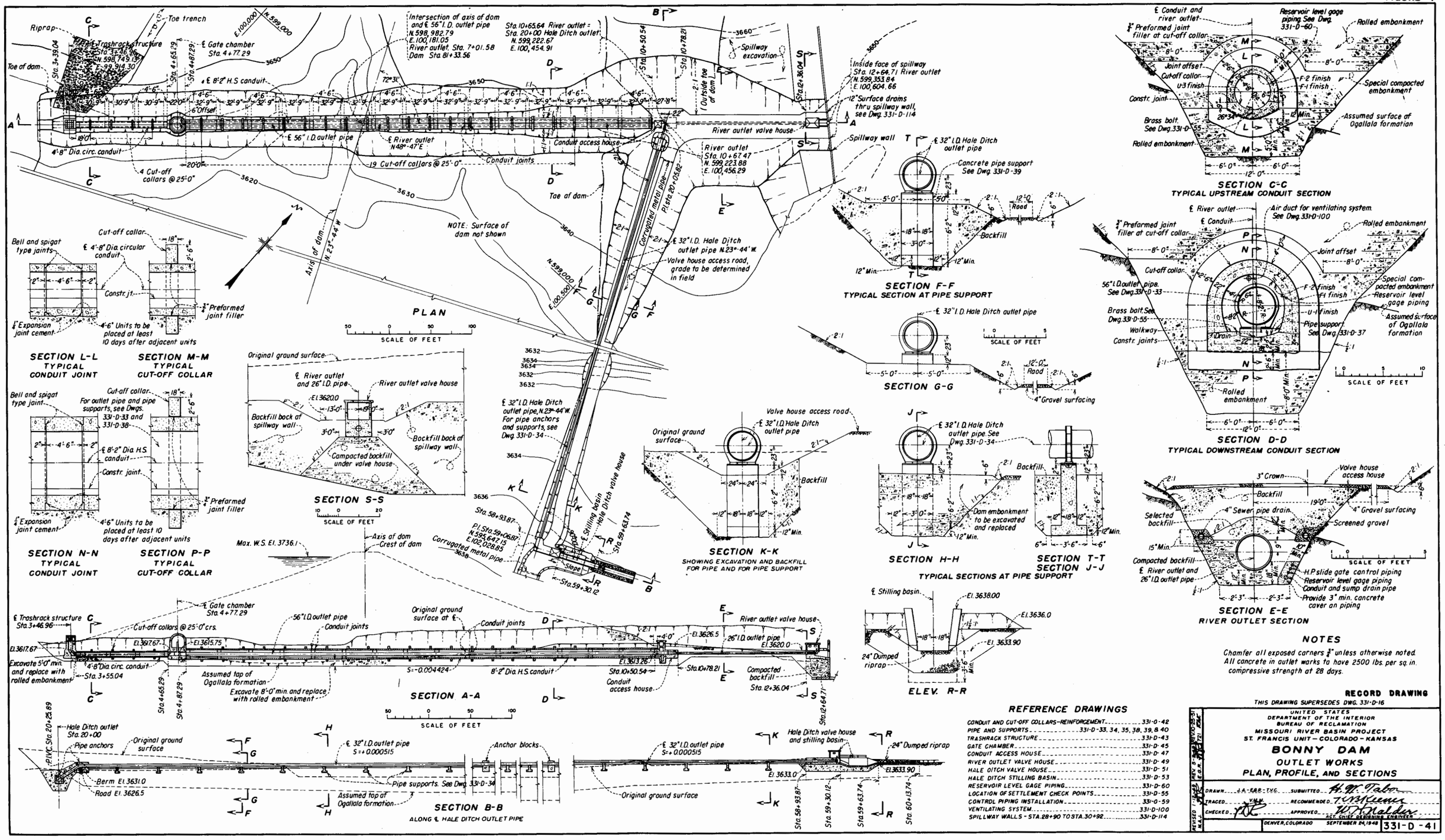

PLAN
SCALE OF FEET
SECTION E-E
ELEVATION A-A
SECTION B-B
SECTION C-C
SECTION D-D
DISCHARGE-TAILWATER CURVES
DETAIL Z
SECTION F-F
SECTION H-H
SECTION G-G
Contraction joints
Concrete Gutter
Concrete gutter
Floor drains
Crest of dam
Upstream Channel
Spillway
Bridge Sta. 20+00.0
Maximum W.S.
Top of Flood Control
Normal W.S.
Pipe handrail
Keyed contraction joints
Sluiceway
Original ground surface
Dam Embankment
Continuous gravel drain from Sta. 20+33 to Sta. 28+65.
Excavate sluiceway to vertical lines as shown. Share or support if required.
Maximum W.S. Elev. 3737.6
Sluice discharge
Max. T.W. El. 3723.0
Spillway Discharge
El. 3710.0 - Top of flood-control pool and crest of spillway.
Tailwater at river
El. 3672.0 Nor. W.S. and crest of sluiceway
RESERVOIR W.S. ELEVATION
TAILWATER ELEVATION
DISCHARGE IN THOUSANDS OF SEC.-FT.
CONCRETE FINISHES
Surfaces covered by fill:
Formed, F-1; Unformed, U-1.
Exposed surfaces:
Formed, F-2; Unformed: spillway floor, U-2; highway bridge floor U-2; concrete gutter U-2
NOTE
Reinforcement not shown.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
ST. FRANCIS UNIT-COLORADO-KANSAS
BONNY DAM
SPILLWAY
PLAN AND SECTIONS
DRAWN J.E.W.
TRACED R.V.S.
CHECKED C.F.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO, JUNE 15, 1948
331-D-14

FIGURE 4


PLAN
SCALE OF FEET
SECTION A-A
SECTION B-B
ALONG ℄ HALE DITCH OUTLET PIPE
SECTION C-C
TYPICAL UPSTREAM CONDUIT SECTION
SECTION D-D
TYPICAL DOWNSTREAM CONDUIT SECTION
SECTION E-E
RIVER OUTLET SECTION
SECTION F-F
TYPICAL SECTION AT PIPE SUPPORT
SECTION G-G
SECTION H-H
SECTION J-J
SECTION K-K
SHOWING EXCAVATION AND BACKFILL FOR PIPE AND FOR PIPE SUPPORT
TYPICAL SECTIONS AT PIPE SUPPORT
SECTION L-L
TYPICAL CONDUIT JOINT
SECTION M-M
TYPICAL CUT-OFF COLLAR
SECTION N-N
TYPICAL CONDUIT JOINT
SECTION P-P
TYPICAL CUT-OFF COLLAR
SECTION S-S
ELEV. R-R
NOTES
Chamfer all exposed corners ¾" unless otherwise noted.
All concrete in outlet works to have 2500 lbs. per sq. in. compressive strength at 28 days.
REFERENCE DRAWINGS
CONDUIT AND CUT-OFF COLLARS-REINFORCEMENT 331-D-42
PIPE AND SUPPORTS 331-D-33, 34, 35, 38, 39, & 40
TRASHRACK STRUCTURE 331-D-43
GATE CHAMBER 331-D-45
CONDUIT ACCESS HOUSE 331-D-47
RIVER OUTLET VALVE HOUSE 331-D-49
HALE DITCH VALVE HOUSE 331-D-51
HALE DITCH STILLING BASIN 331-D-53
RESERVOIR LEVEL GAGE PIPING 331-D-60
LOCATION OF SETTLEMENT CHECK POINTS 331-D-55
CONTROL PIPING INSTALLATION 331-D-59
VENTILATING SYSTEM 331-D-100
SPILLWAY WALLS - STA. 28+90 TO STA. 30+92 331-D-114
RECORD DRAWING
THIS DRAWING SUPERSEDES DWG. 331-D-16
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
ST. FRANCIS UNIT - COLORADO - KANSAS
BONNY DAM
OUTLET WORKS
PLAN, PROFILE, AND SECTIONS
DRAWN J.A.-E.R.B.-T.V.C.
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
ACT. CHIEF DESIGNING ENGINEER
DENVER, COLORADO
SEPTEMBER 24, 1948
331-D-41

The maximum discharge of 71,400 second feet results in a discharge of 332 second feet per lineal foot of stilling basin width. Two 1:60 scale models were used in the studies of the spillway and sluiceway structures.

An outlet works conduit, Figures 2 and 4, is located in the base of the dam near the left bank. The outlet works valve discharges directly into the right side of the stilling basin of the flood control spillway, but this was not installed in the models. A 32-inch conduit branches off from the right side of the main conduit and follows along the downstream base of the dam, Figure 4. The line terminates in a 24-inch hollow-jet valve which discharges into a stilling basin connected to a canal on the right side of the river known as the Hale Ditch. Normal discharge is 10 second feet, but the stilling basin was designed for a maximum discharge of 25 second feet. A model, built to a scale of 1:6, was used to study the irrigation outlet.

INVESTIGATION WITH 1:60 SPILLWAY MODEL

The Spillway Model

The spillway model built to a scale of 1:60 was contained in two metal-lined wooden boxes, Figure 5. An 8- by 10-foot head box 4 feet high contained the topography of the reservoir area for a distance of 350 feet, prototype, upstream from the spillway entrance. The topography was formed by placing metal lath on a wooden framework and covering with concrete mortar. An inclined platform between the head box and tail box supported the spillway chute. The spillway overflow section, chute, and stilling basin were made of concrete screeded to metal templates. The training walls were made of wood covered with sheet metal and the piers and sluiceway were made of sheet metal. An 8- by 16-foot tail box contained the stilling basin as well as 700 feet, prototype, of channel downstream. The riverbed was formed in sand to observe erosion of the material which was one means of determining the effectiveness of the stilling basin.

Piezometers, for pressure measurements, were installed on the floor and roof of the sluiceway and on the overflow section. The reservoir water-surface elevation was measured by means of a point gage in the head box. A staff gage in the channel was used to read the tail-water elevation regulated by a gate on the downstream end of the tail box. A portable pump supplied water to the model through a 6-inch line containing an orifice meter to measure the flow. The maximum model discharge was 2.6 second feet. A rock baffle was located in the head box to smooth out the flow in the reservoir area.

Spillway Overflow Section Studies

Overflow Section No. 1--preliminary. The preliminary entrance structure, Figure 6, had an uncontrolled overflow section with a center sluiceway. A pier 20 feet 3 inches wide divided the overflow section into two 50-foot lengths. Designed maximum discharge was 64,700 second

feet. The model was operated for all ranges of reservoir elevations up to 3736.23 and pressures were measured on the overflow section. The lowest pressure obtained, Figure 7, was 7 feet of water below atmospheric at Piezometer No. 1 with reservoir elevation 3730.94.

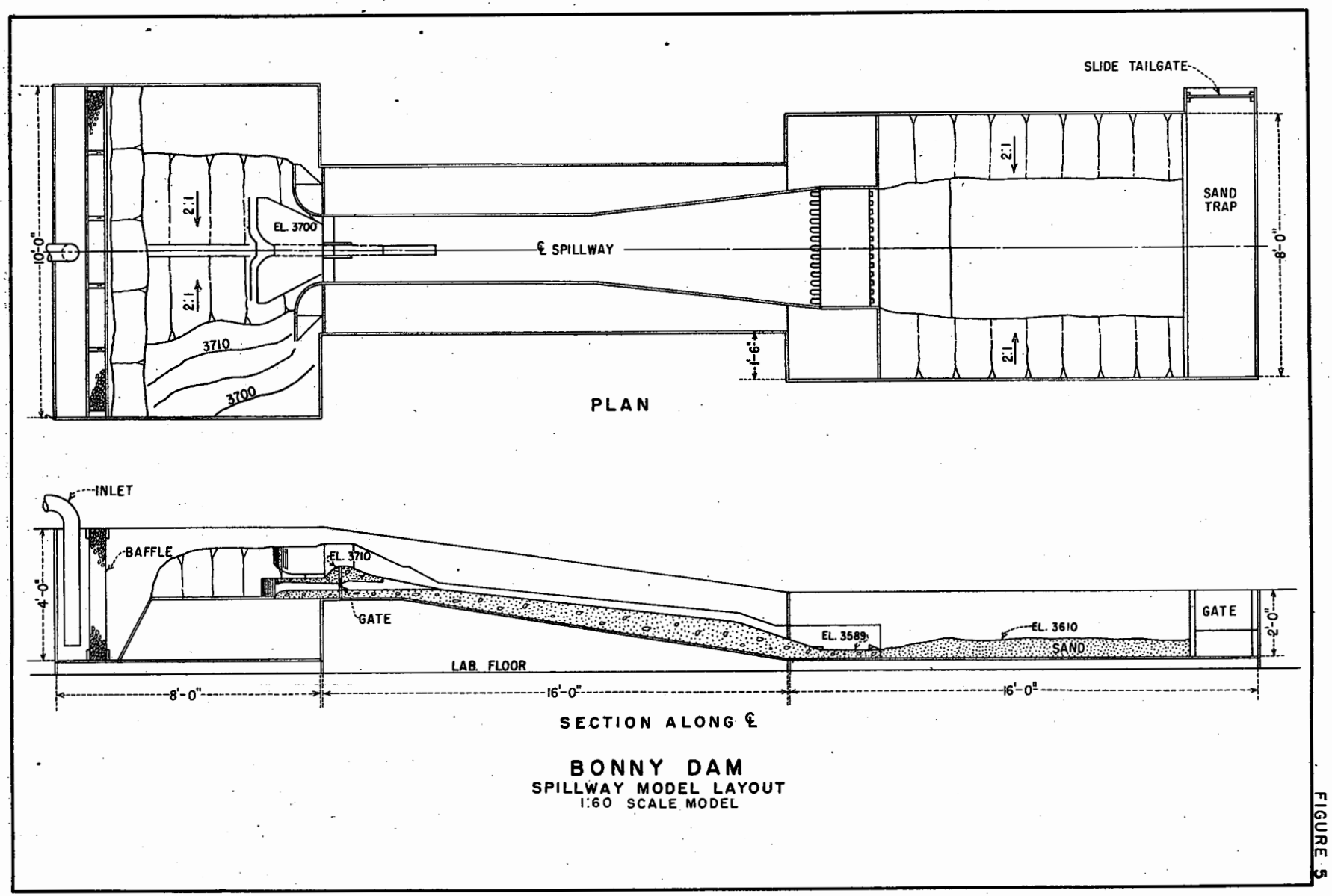
The sluiceway was blocked off and a discharge-capacity curve was obtained for the overflow section, No. 1, Figure 8. A coefficient of discharge curve is also shown with a maximum value of 3.61. These tests indicated the overflow section was satisfactory, but the designers asked for additional tests on an overflow shape having a smaller cross section, as better economy might result.

Overflow Section No. 2. The overflow section shown in Figure 9 was next installed in the model without changing other features of the entrance. This resulted in lowering of the floor near Station 20+34 by about 7 feet, which increased the height of the training walls by the same amount. Pressures were obtained over the overflow face for various reservoir elevations and these are shown in Figure 9. Subatmospheric pressures occurred on several of the piezometer locations for a large range of reservoir elevations. The minimum pressure was 13 feet of water below atmospheric at Piezometer No. 2. However, these pressures were considered satisfactory.

A discharge-capacity curve was again obtained for the overflow section by blocking off the center sluiceway. The net crest length remained at 100 feet. At corresponding reservoir elevations, greater discharge occurred than with Overflow Section No. 1, as shown by both the discharge-capacity curve and the coefficient of discharge curve, crest No. 2, Figure 8. An economic study by the designers showed Overflow Section No. 1 could be built at the least cost, so Overflow Section No. 2 was discarded.

Overflow Section No. 3--recommended. The shape of Overflow Section No. 3, Figure 10, was the same as No. 1, but the crest length was 115.5 feet due to changes in features of the entrance such as two 3-foot piers instead of one 20-foot 3-inch pier. The increase in length of crest made it necessary for the designers to make a new flood-routing calculation. This computation takes into account the reservoir storage in computing the spillway discharge due to a given flood flowing into the reservoir. The maximum discharge computed for Overflow Section No. 3 was 71,400 second feet instead of 64,700 given for the preliminary entrance. This higher discharge was used in all remaining tests with Overflow Section No. 3 installed.

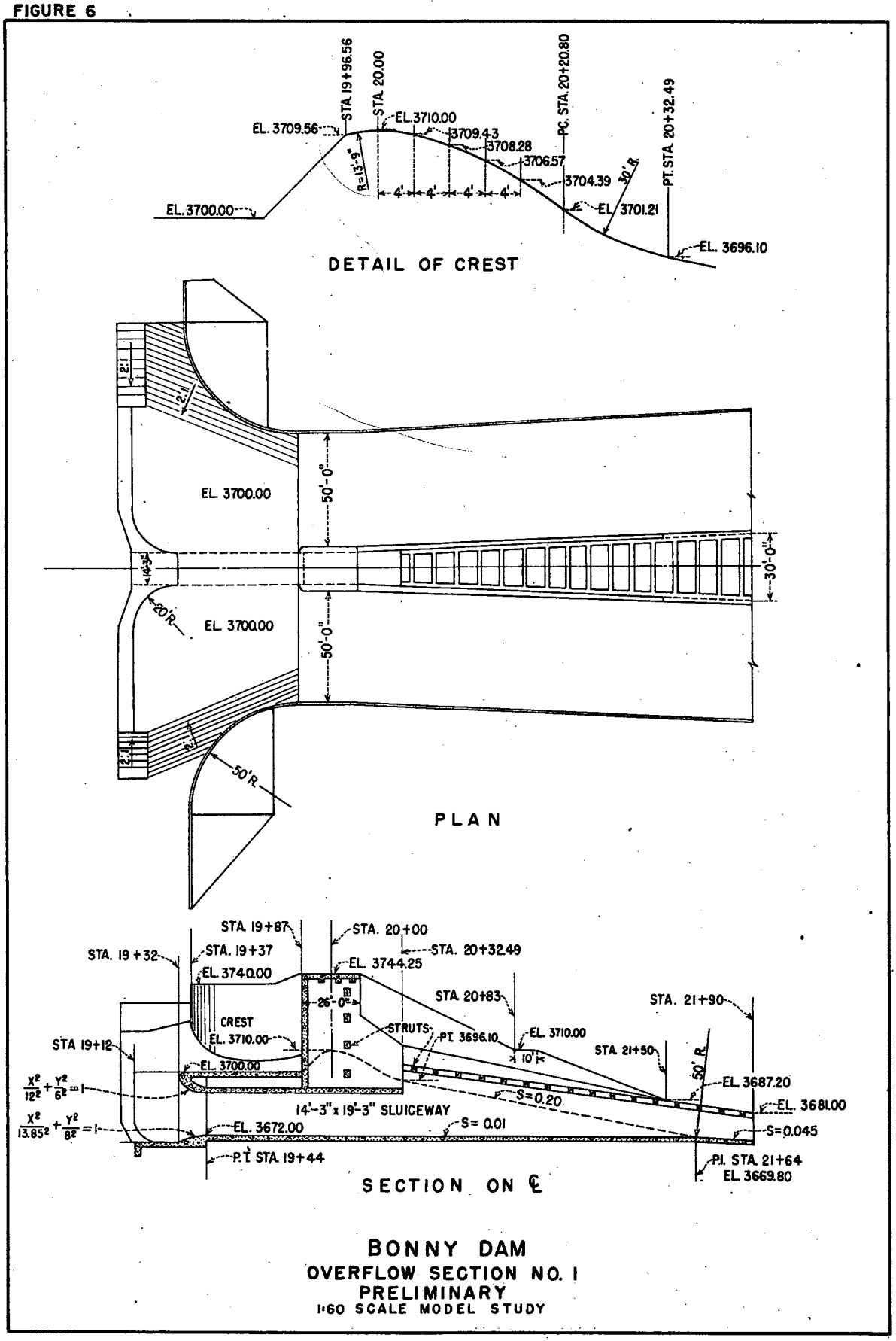
Pressure tests were not made, but a discharge-capacity curve was obtained with the sluiceway blocked. The curve is shown, No. 3, Figure 8, together with the curve for the coefficient of discharge. This overflow section was considered satisfactory and was recommended for construction in the field.



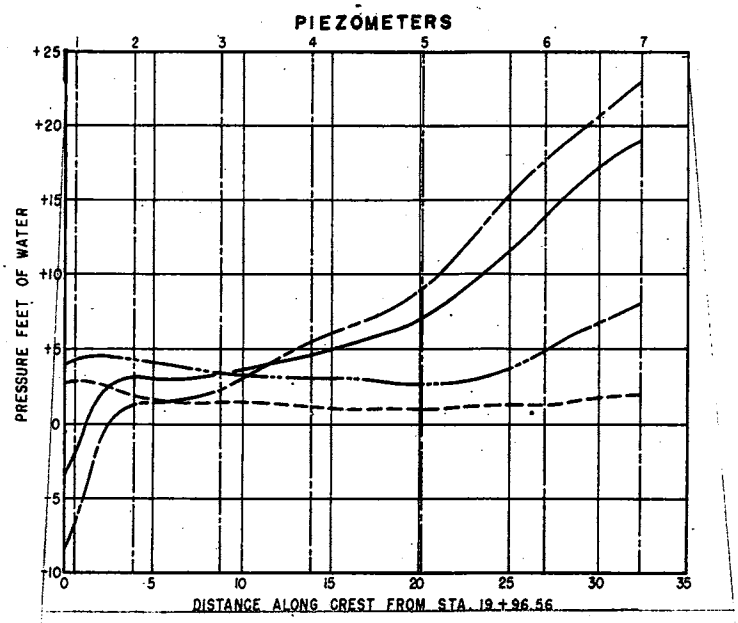
BONNY DAM
SPILLWAY MODEL LAYOUT
1:60 SCALE MODEL

FIGURE 5

FIGURE 6



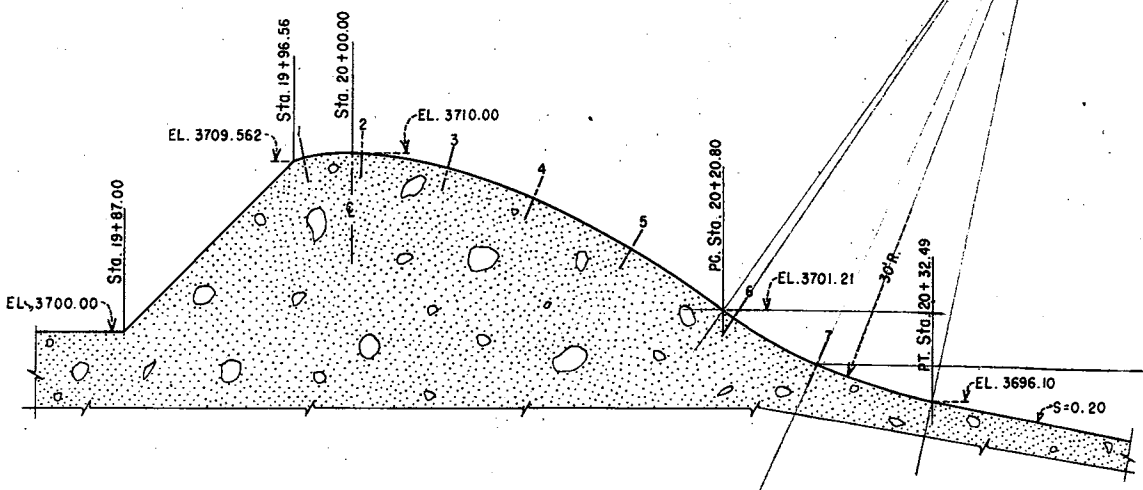
BONNY DAM
OVERFLOW SECTION NO. 1
PRELIMINARY
1:60 SCALE MODEL STUDY



PRESSURES ON CREST

LEGEND

PRESSURE LINE	RESERVOIR ELEV.
———	3736.23
— — —	3730.94
—·—·—	3719.96
- - - -	3713.48



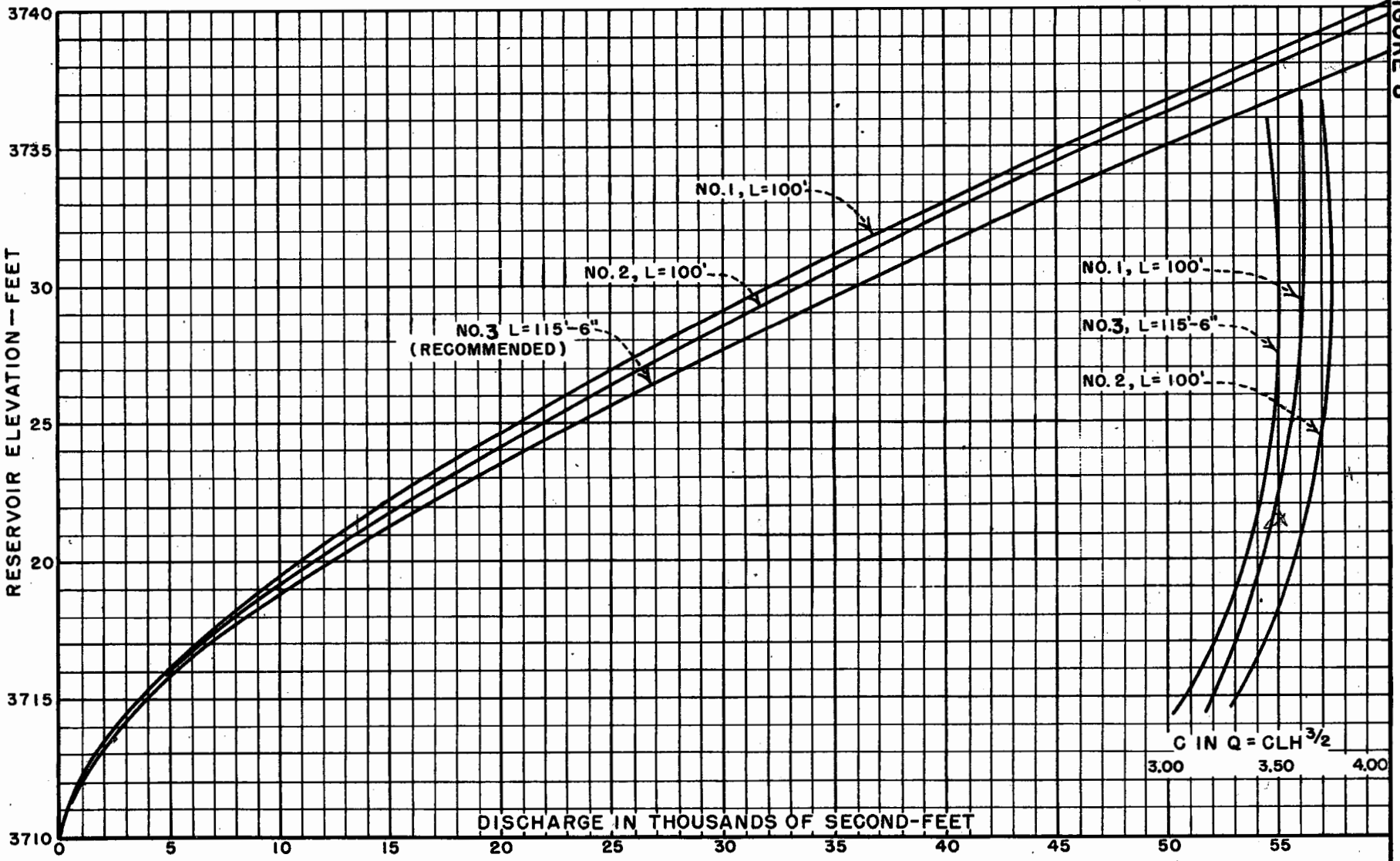
OVERFLOW SECTION

BONNY DAM

OVERFLOW SECTION NO. 1 — RECOMMENDED

1:60 SCALE MODEL STUDY

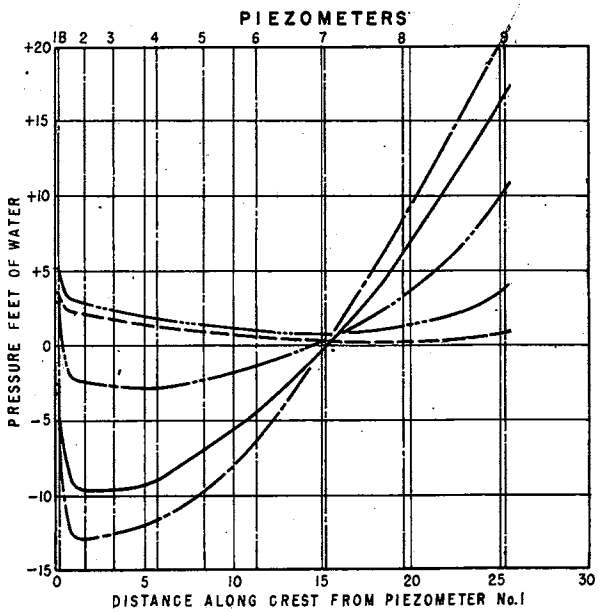
FIGURE 8



BONNY DAM

SPILLWAY DISCHARGE CAPACITY CURVES

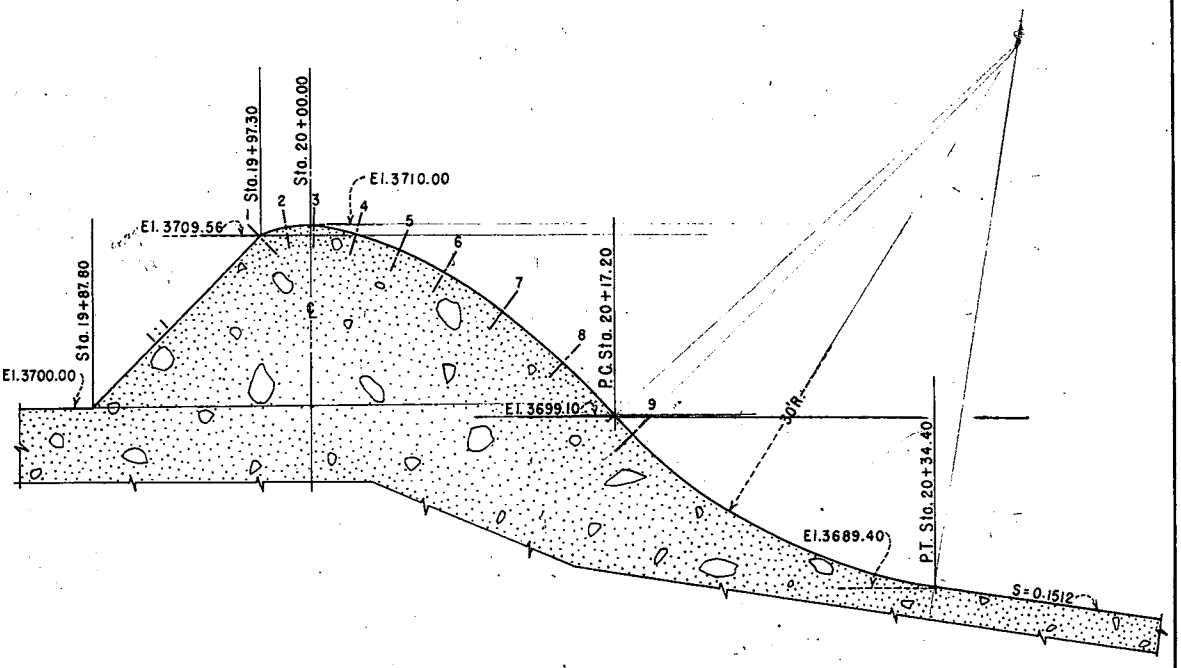
1:60 MODEL



LEGEND

PRESSURE LINE	RESERVOIR ELEV.
	3738.86
	3734.48
	3727.34
	3718.76
	3713.60

PRESSURES ON CREST



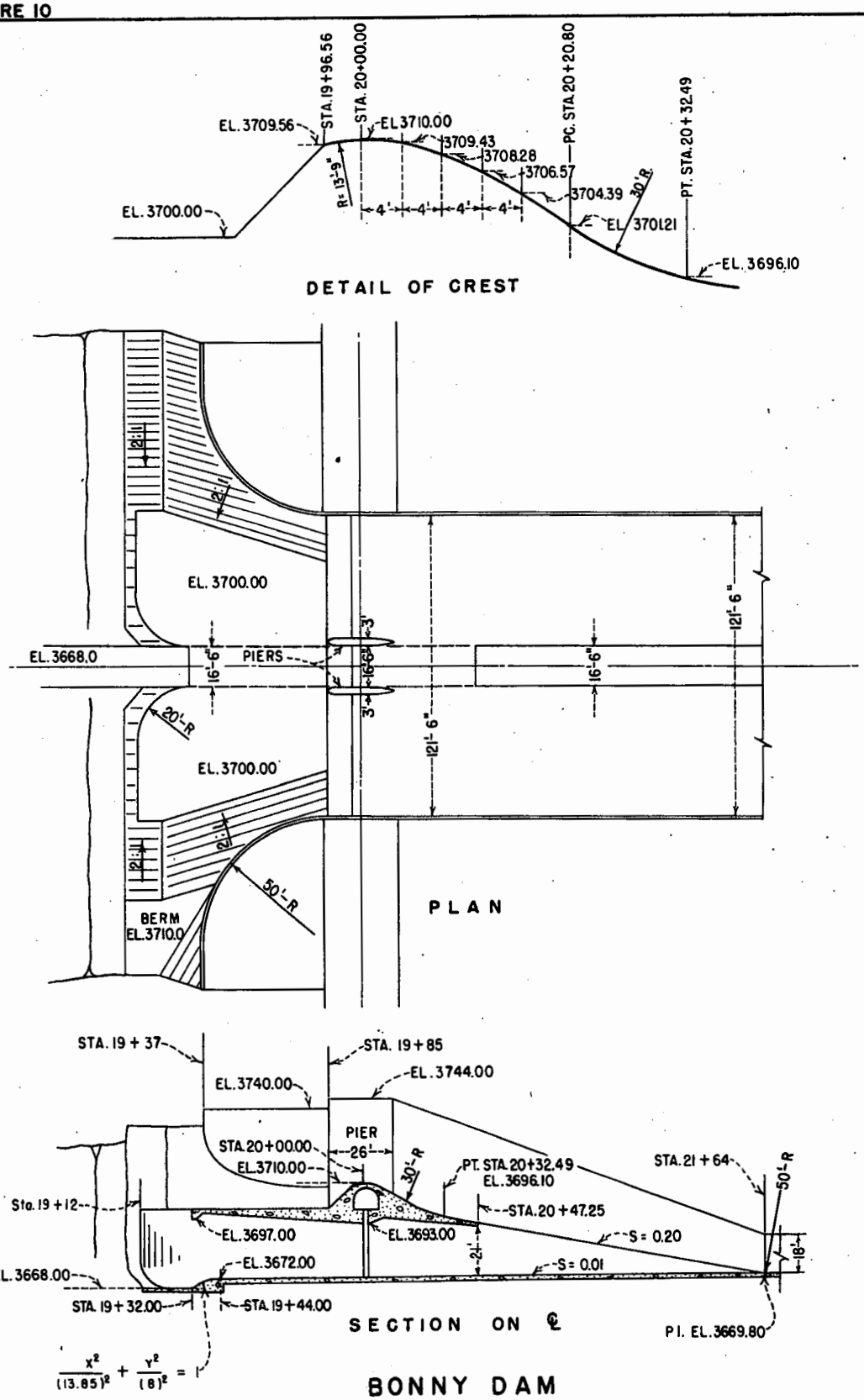
OVERFLOW SECTION

BONNY DAM

OVERFLOW SECTION NO. 2

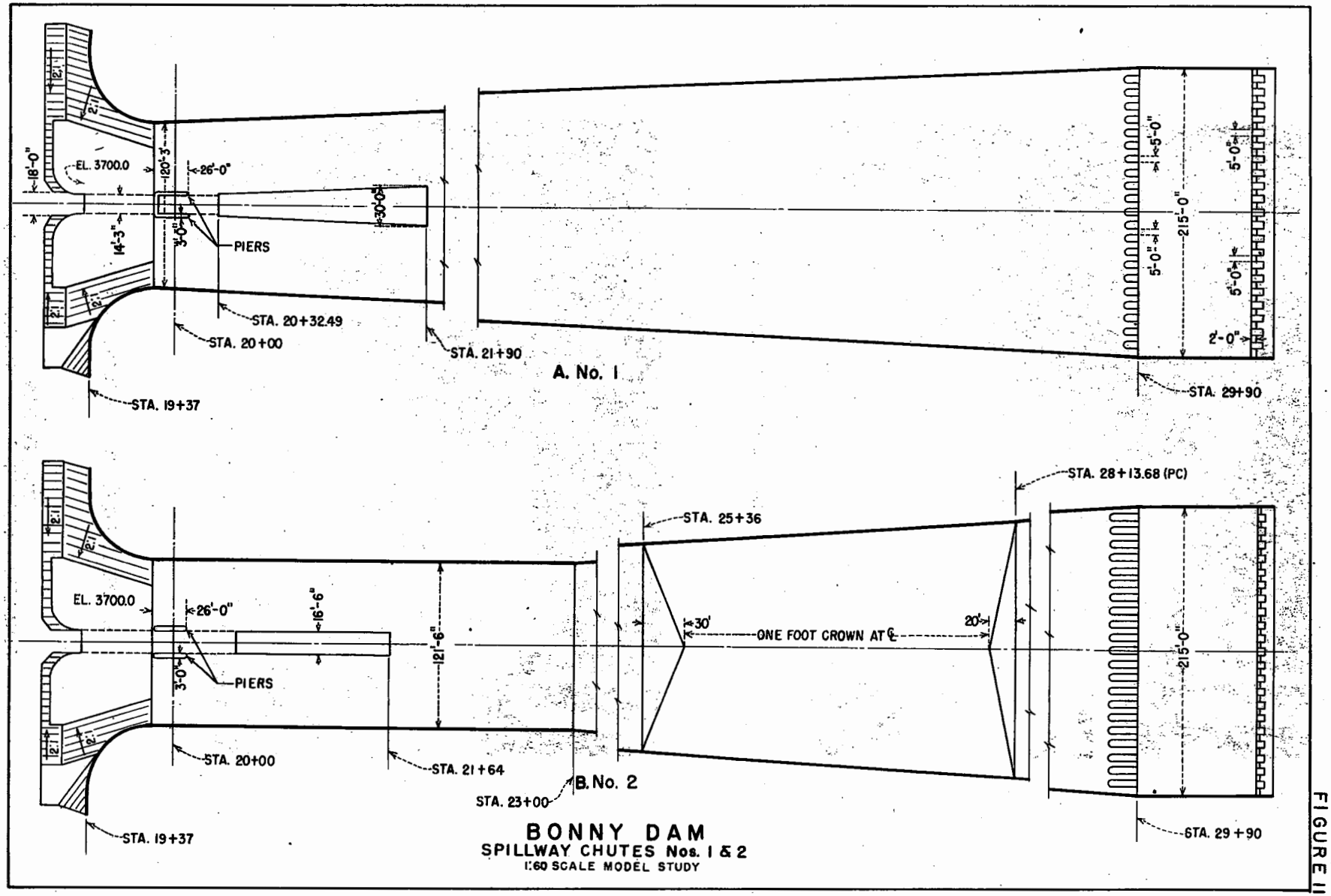
1:60 SCALE MODEL STUDY

FIGURE 10



BONNY DAM

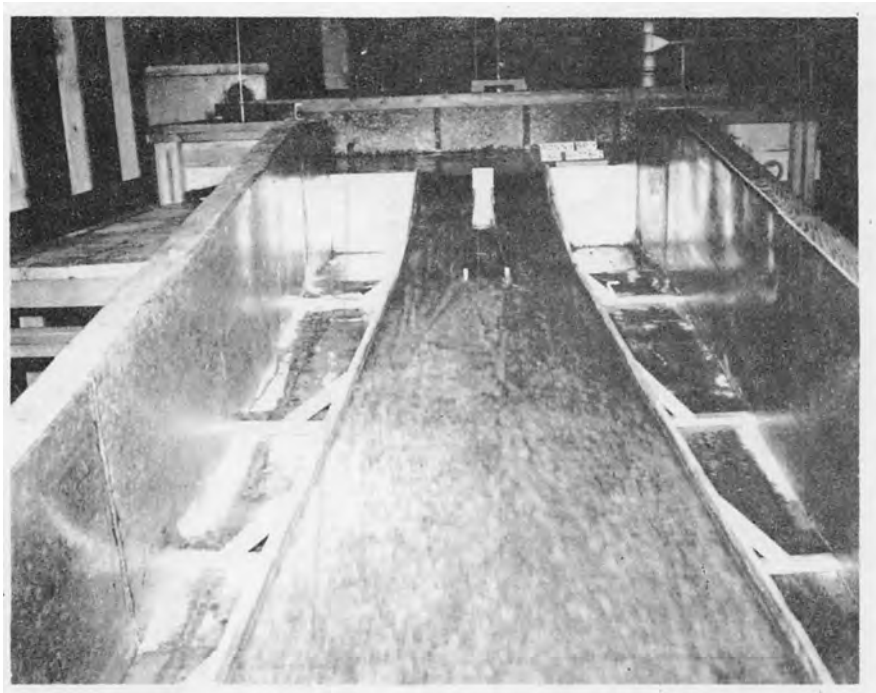
OVERFLOW SECTION NO. 3
RECOMMENDED
1:60 SCALE MODEL STUDY



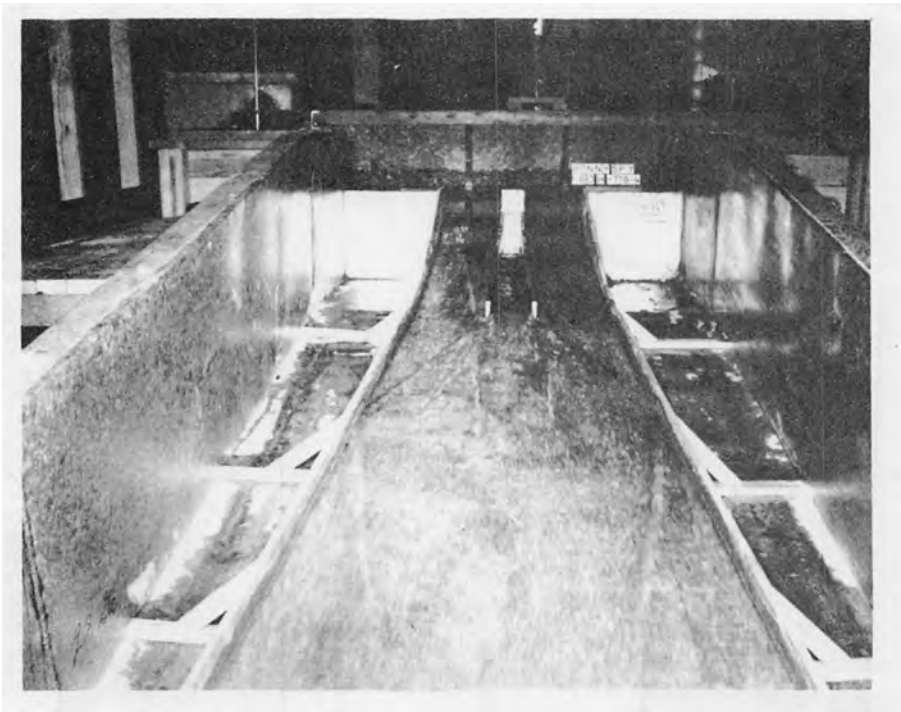
BONNY DAM
SPILLWAY CHUTES Nos. 1 & 2
1:60 SCALE MODEL STUDY

FIGURE II

FIGURE 12

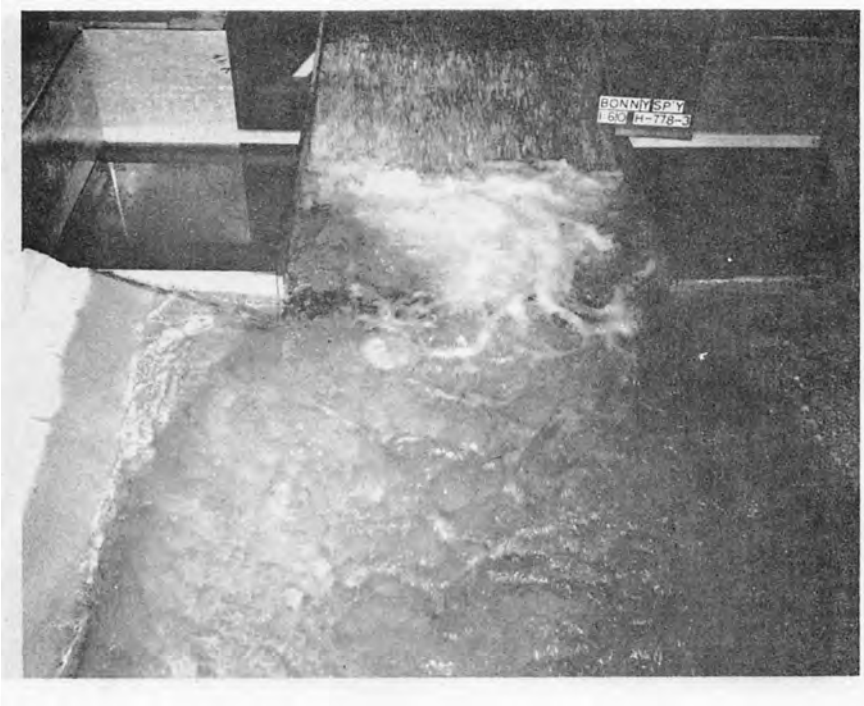


A. DISCHARGE 64, 700 SECOND-FEET

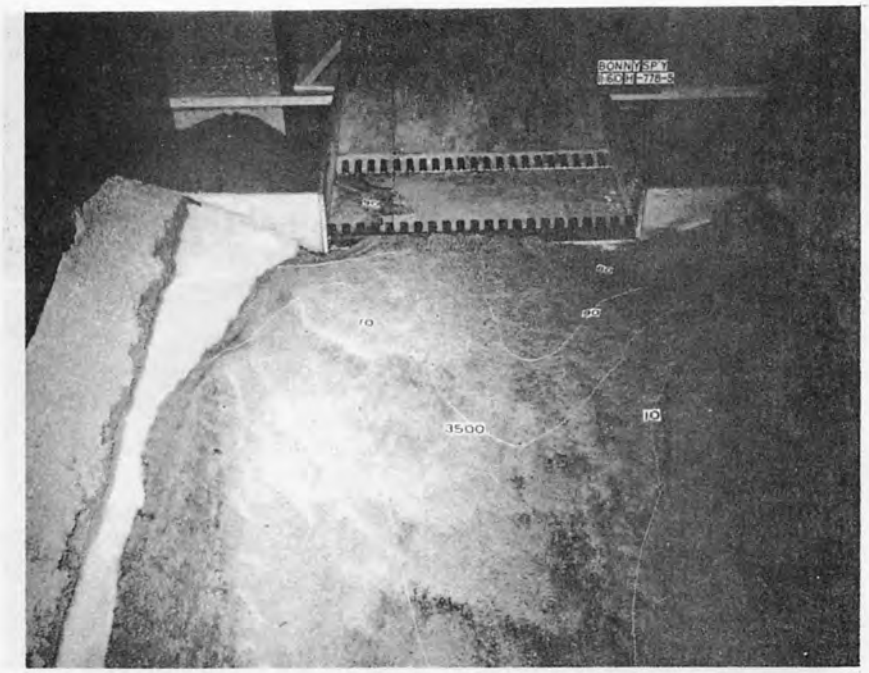


B. DISCHARGE 25, 000 SECOND-FEET

BONNY DAM
SPILLWAY CHUTE NO. 1 - PRELIMINARY
1:60 SCALE MODEL STUDY



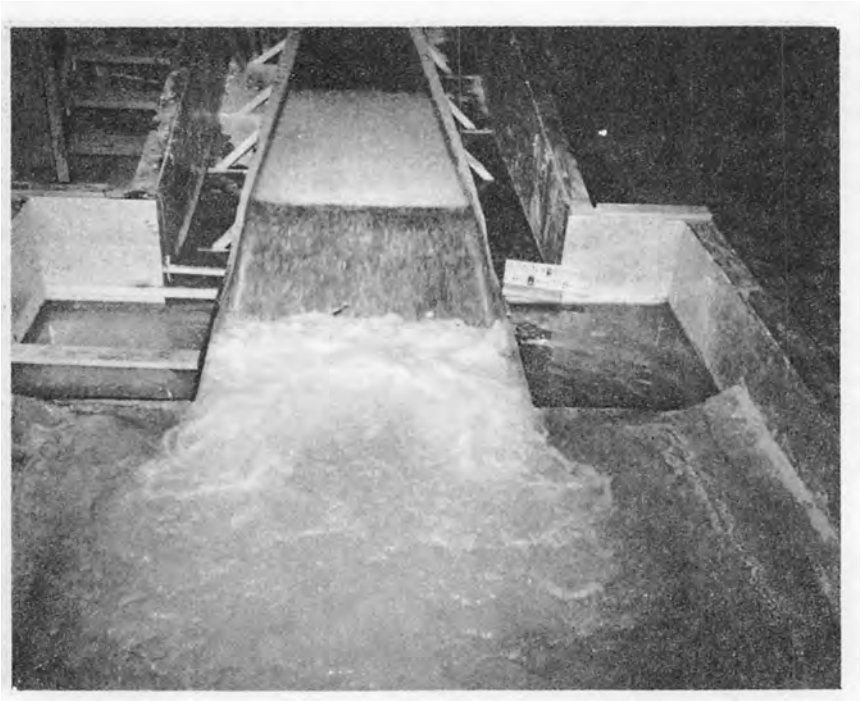
A. DISCHARGE 40,000 SECOND-FEET



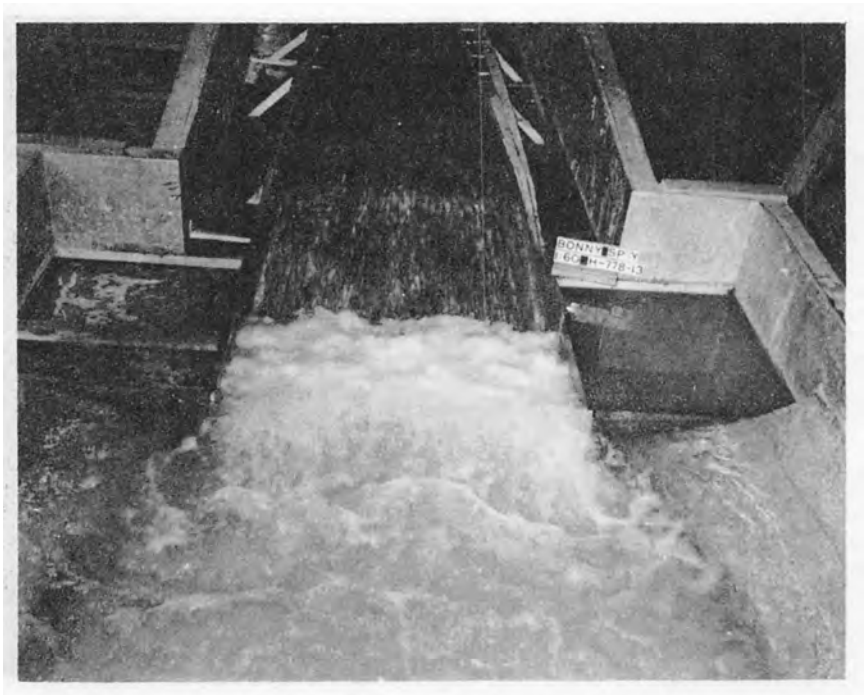
B. SCOUR AFTER ONE HOUR AT 40,000 SEC.-FT.
TAILWATER ELEVATION 3621.1

BONNY DAM
STILLING BASIN NO. 1 - PRELIMINARY
1:60 SCALE MODEL STUDY

FIGURE 14



A. SPILLWAY CHUTE NO. 2



B. SPILLWAY CHUTE NO. 3 - RECOMMENDED

BONNY DAM
SPILLWAY CHUTES NOS. 2 AND 3
DISCHARGE 71,400 SECOND-FEET
1:60 SCALE MODEL STUDY

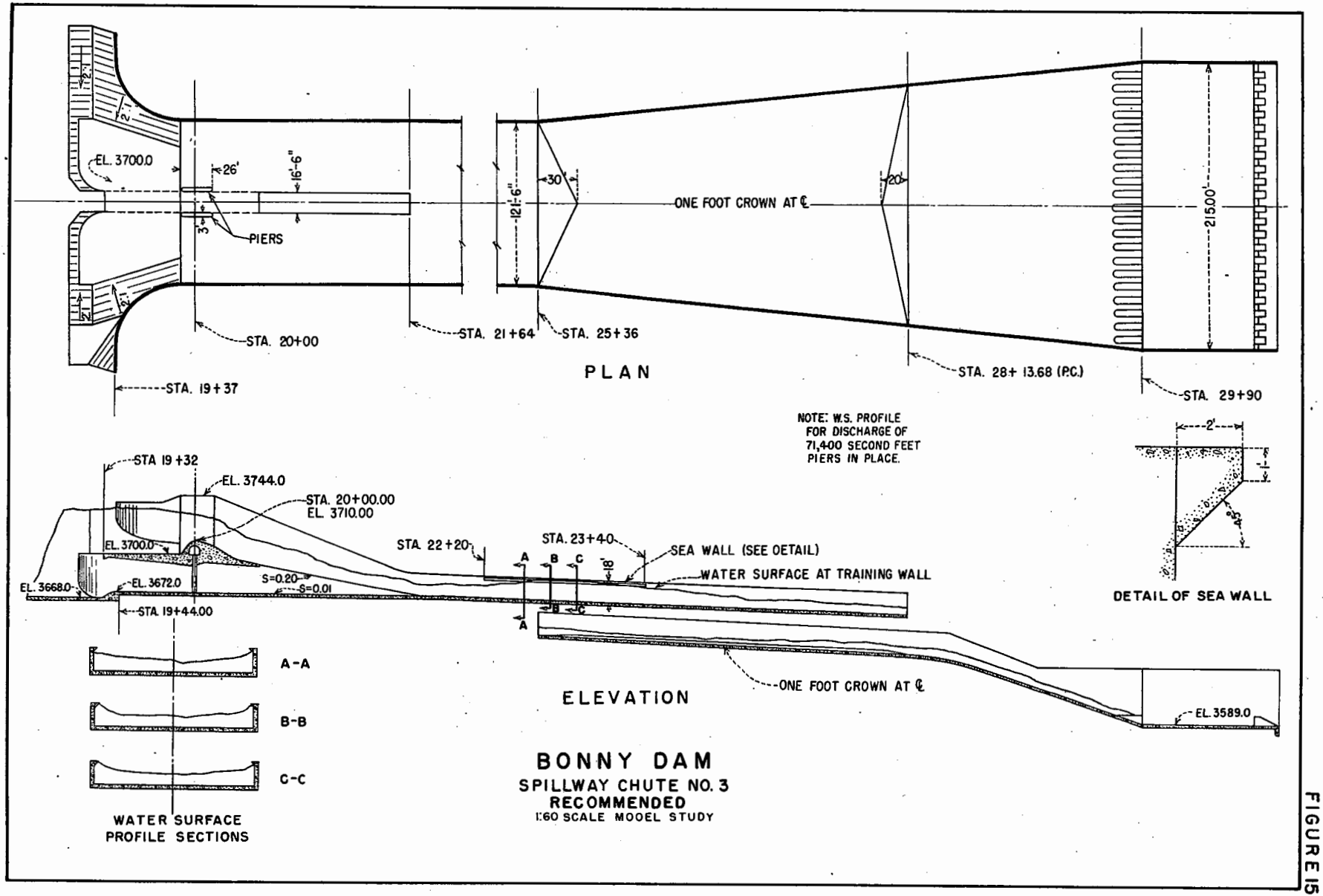
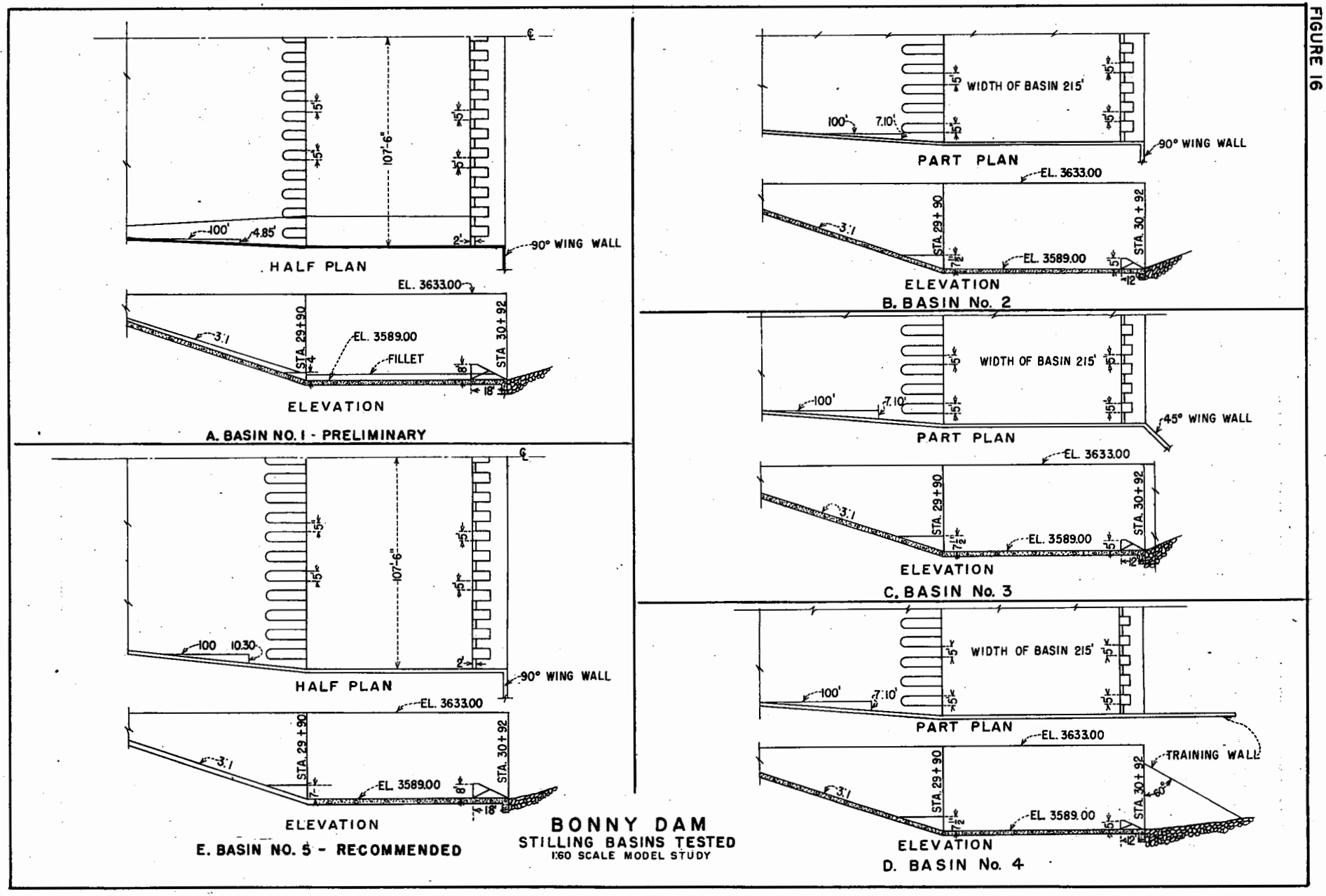
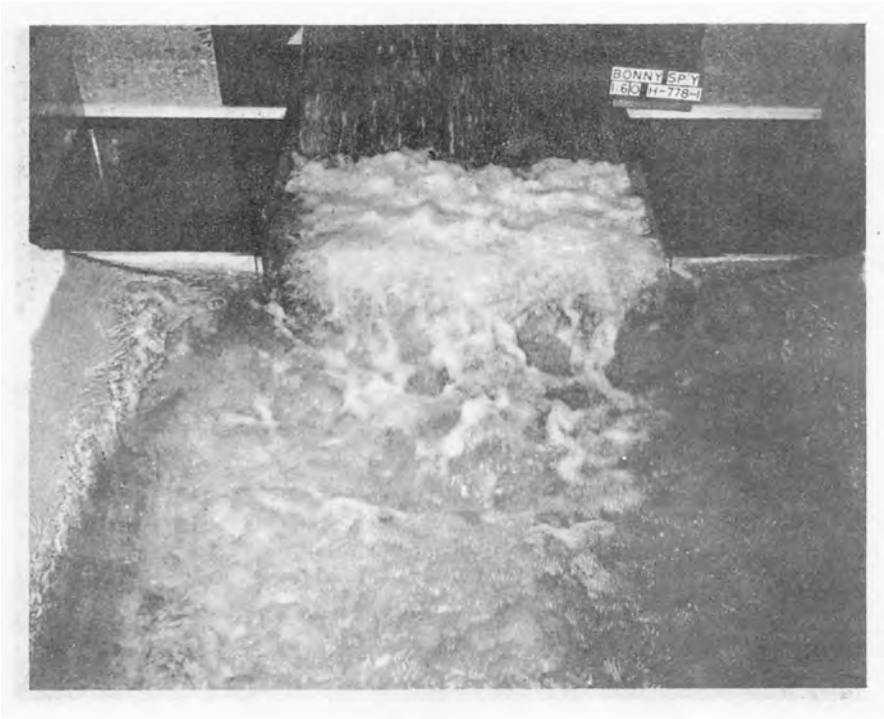

EL. 3700.0
26'
16'-6"
3'
PIERS
121'-6"
30'
ONE FOOT CROWN AT ℄
20'
215.00'
STA. 20+00
STA. 21+64
STA. 25+36
STA. 19+37
PLAN
STA. 28+ 13.68 (P.C.)
STA. 29+90
NOTE: W.S. PROFILE
FOR DISCHARGE OF
71,400 SECOND FEET
PIERS IN PLACE.
2'
1'
45°
DETAIL OF SEA WALL
STA 19+32
EL. 3744.0
STA. 20+00.00
EL. 3710.00
EL. 3700.0
EL. 3668.0
EL. 3672.0
S=0.20
S=0.01
STA. 19+44.00
STA. 22+20
STA. 23+40
A
B
C
18'
SEA WALL (SEE DETAIL)
WATER SURFACE AT TRAINING WALL
ONE FOOT CROWN AT ℄
EL. 3589.0
ELEVATION
A-A
B-B
C-C
WATER SURFACE
PROFILE SECTIONS
BONNY DAM
SPILLWAY CHUTE NO. 3
RECOMMENDED
1:60 SCALE MODEL STUDY

FIGURE 15

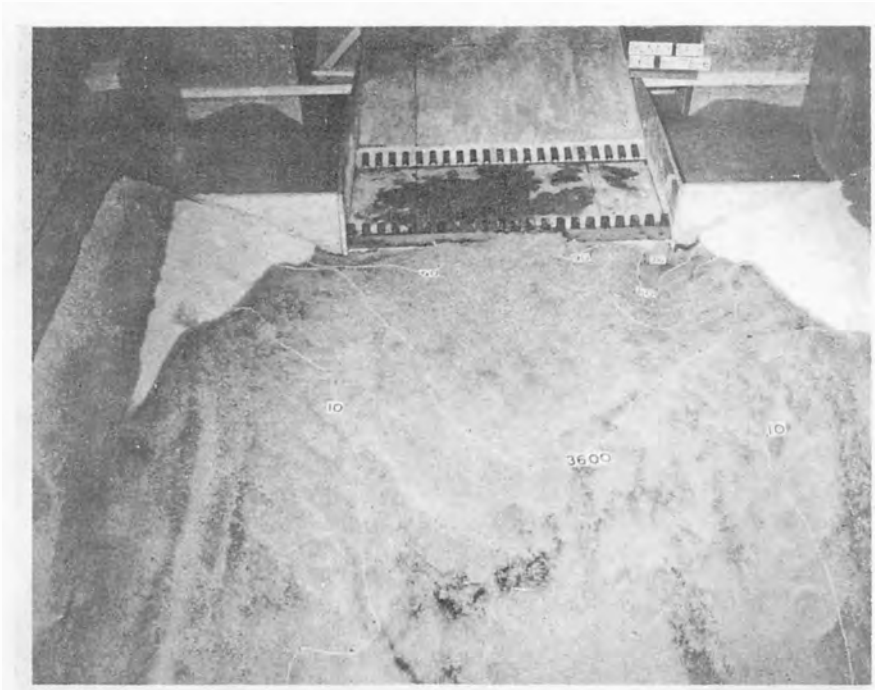
FIGURE 16



BONNY DAM
STILLING BASINS TESTED
1:60 SCALE MODEL STUDY



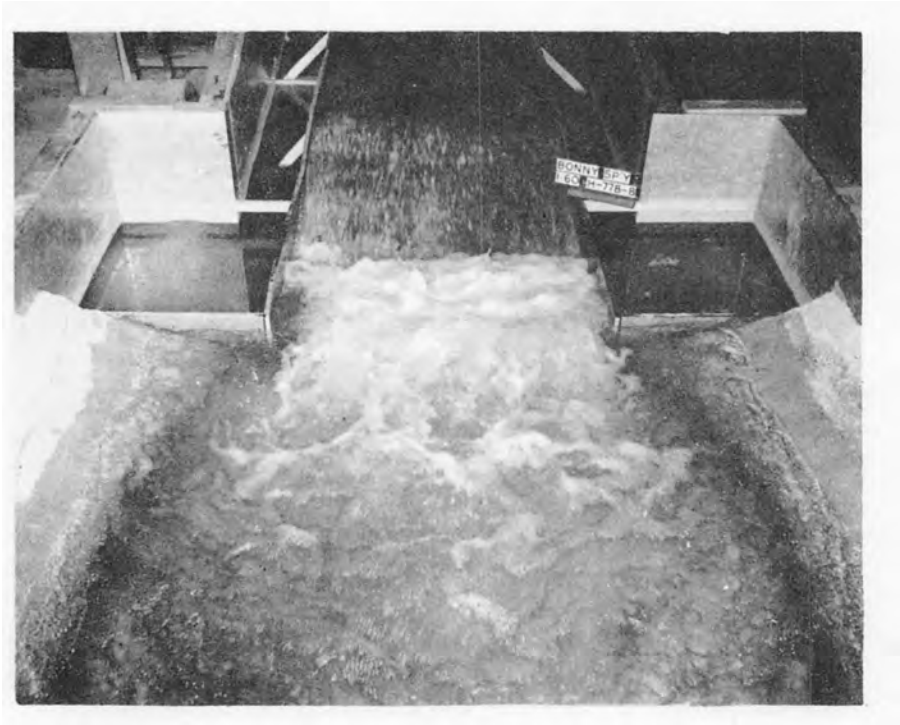
A. DISCHARGE 64,700 SECOND-FEET



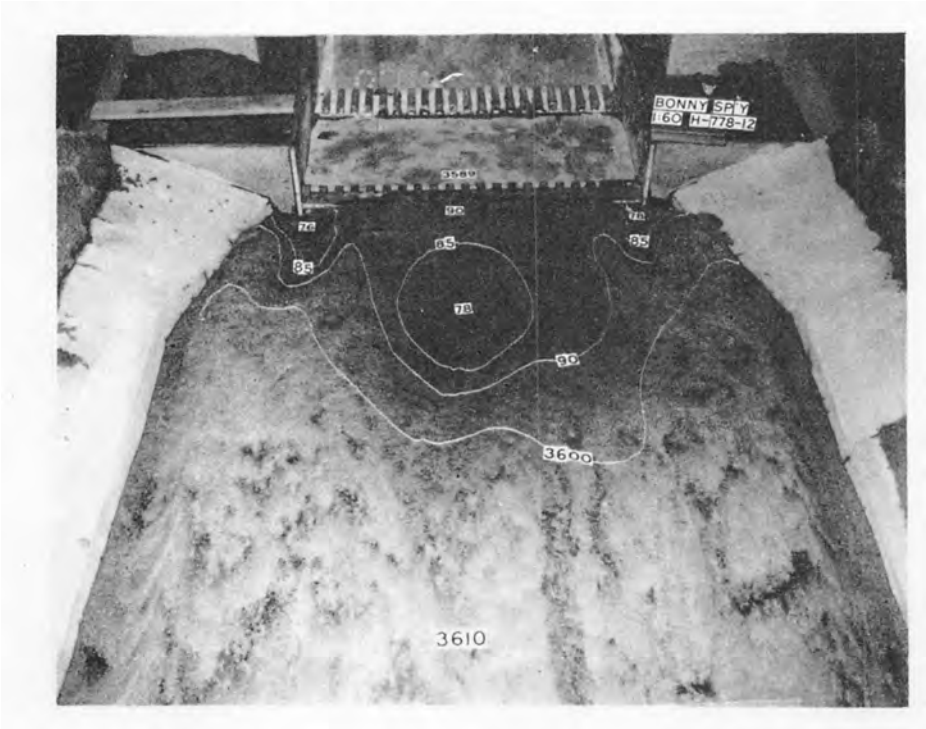
B. SCOUR AFTER ONE HOUR AT 64,700 SEC.-FT.
T. W. ELEVATION 3623.0

BONNY DAM
STILLING BASIN NO. 1 - PRELIMINARY
1:60 SCALE MODEL STUDY

FIGURE 18



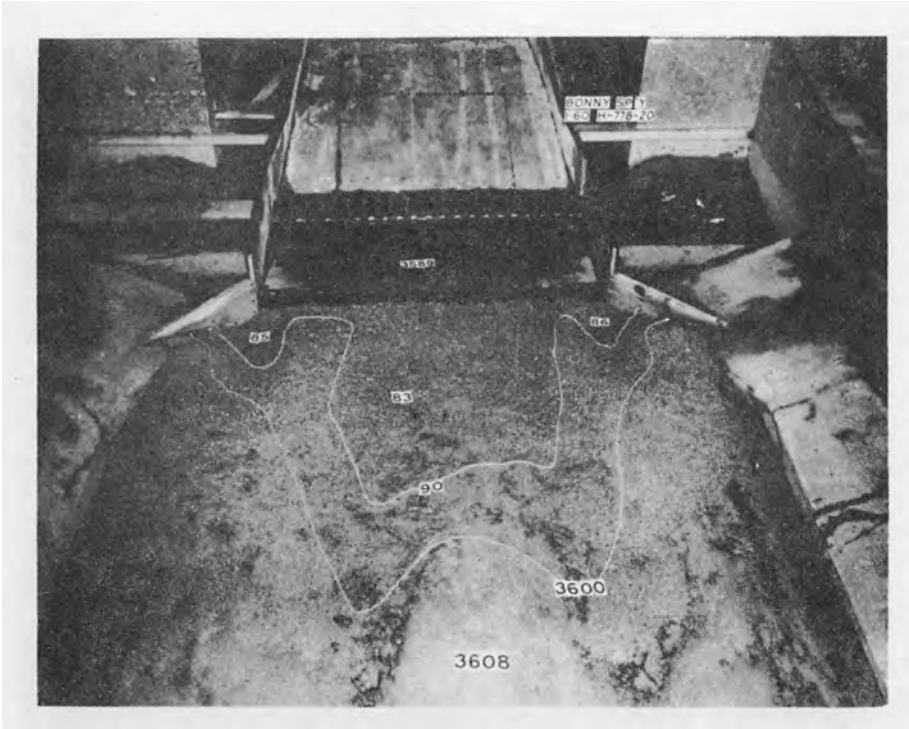
A. DISCHARGE 71,400 SECOND-FEET



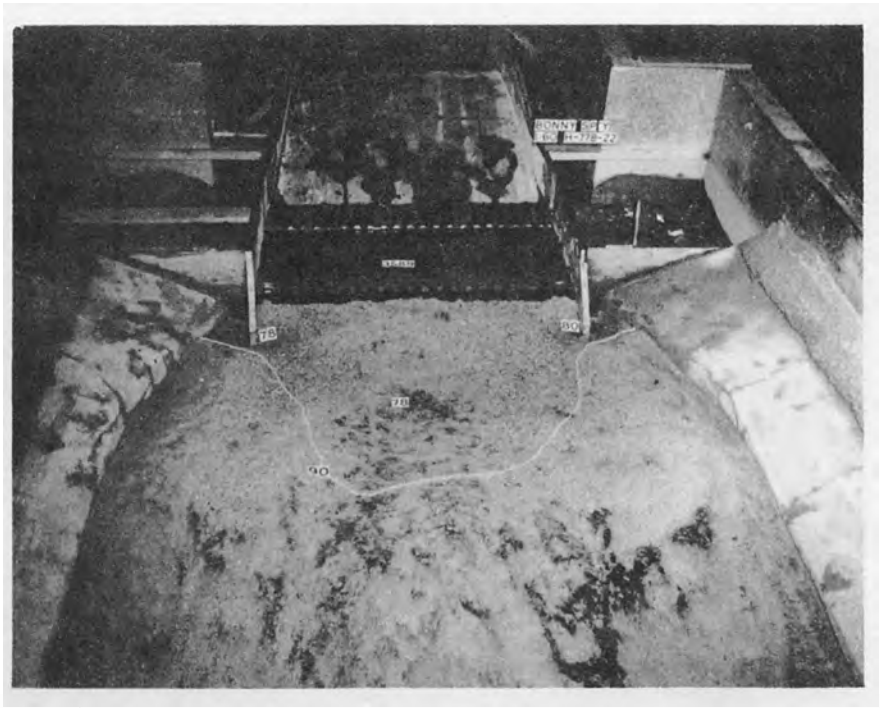
B. SCOUR AFTER ONE HOUR AT 71,400 SEC.-FT.
T. W. ELEVATION 3623.4

BONNY DAM
STILLING BASIN NO. 2
1:60 SCALE MODEL STUDY

FIGURE 19



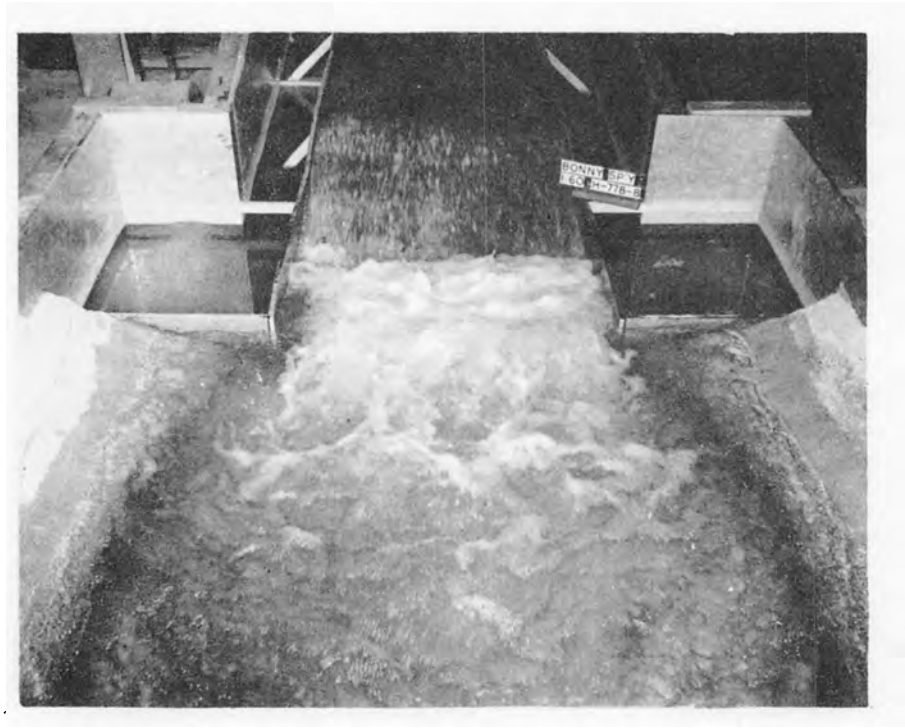
A. STILLING BASIN NO. 3



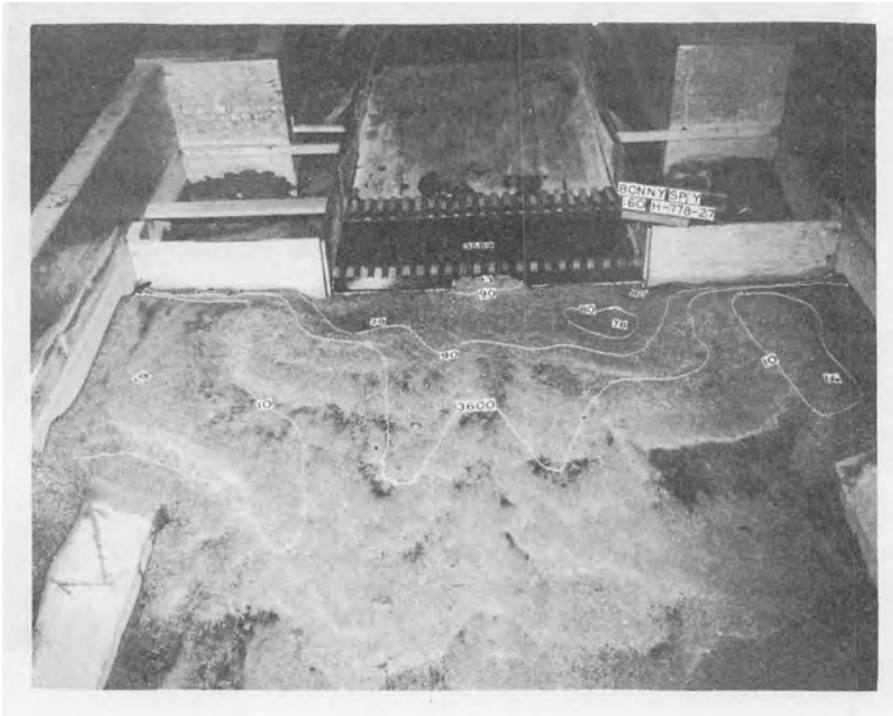
B. STILLING BASIN NO. 4

BONNY DAM
SCOUR AFTER ONE HOUR AT 71,400 SEC.-FT.
T. W. ELEVATION 3623.4
STILLING BASINS NOS. 3 AND 4
1:60 SCALE MODEL STUDY

FIGURE 20



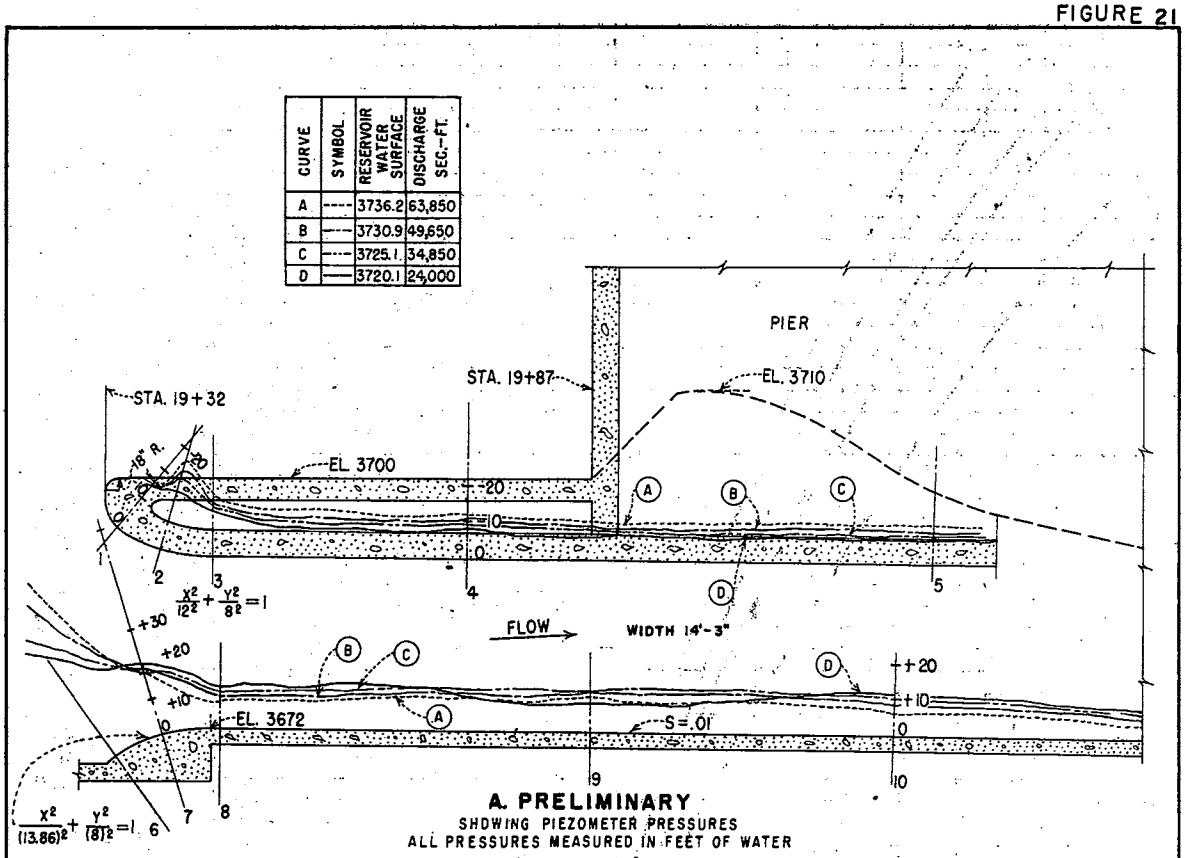
A. DISCHARGE 71,400 SECOND-FEET



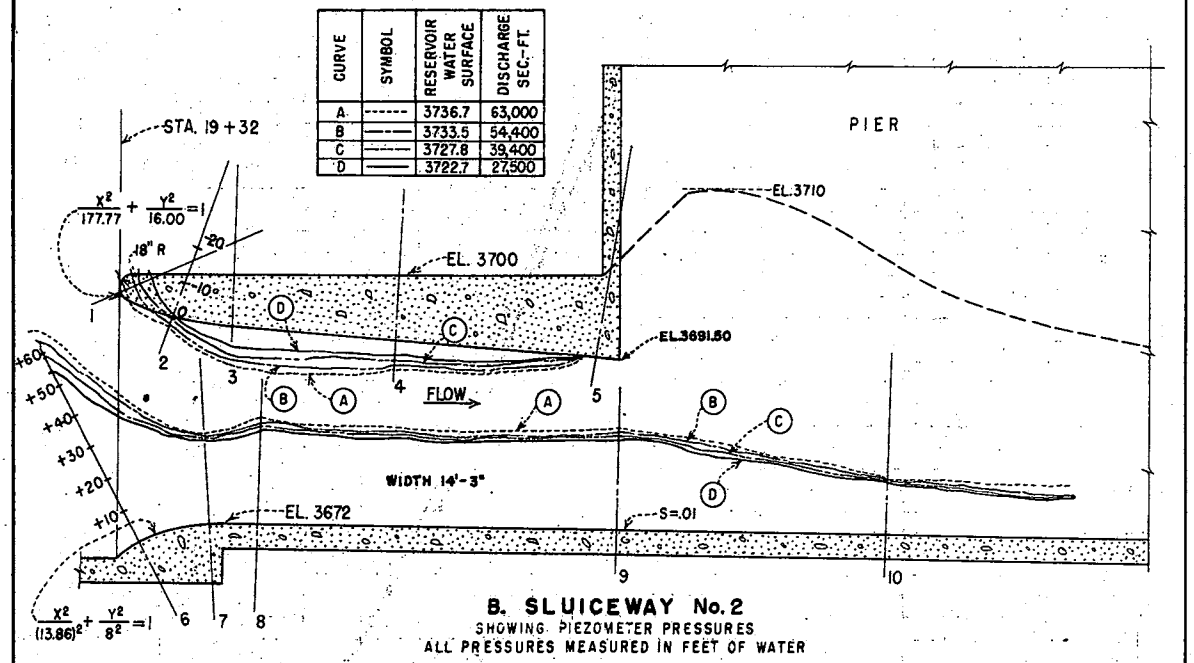
B. SCOUR AFTER ONE HOUR AT 71,400 SEC.-FT.
T. W. ELEVATION 3623.4

BONNY DAM
STILLING BASIN NO. 5 - RECOMMENDED
1:60 SCALE MODEL STUDY

FIGURE 21



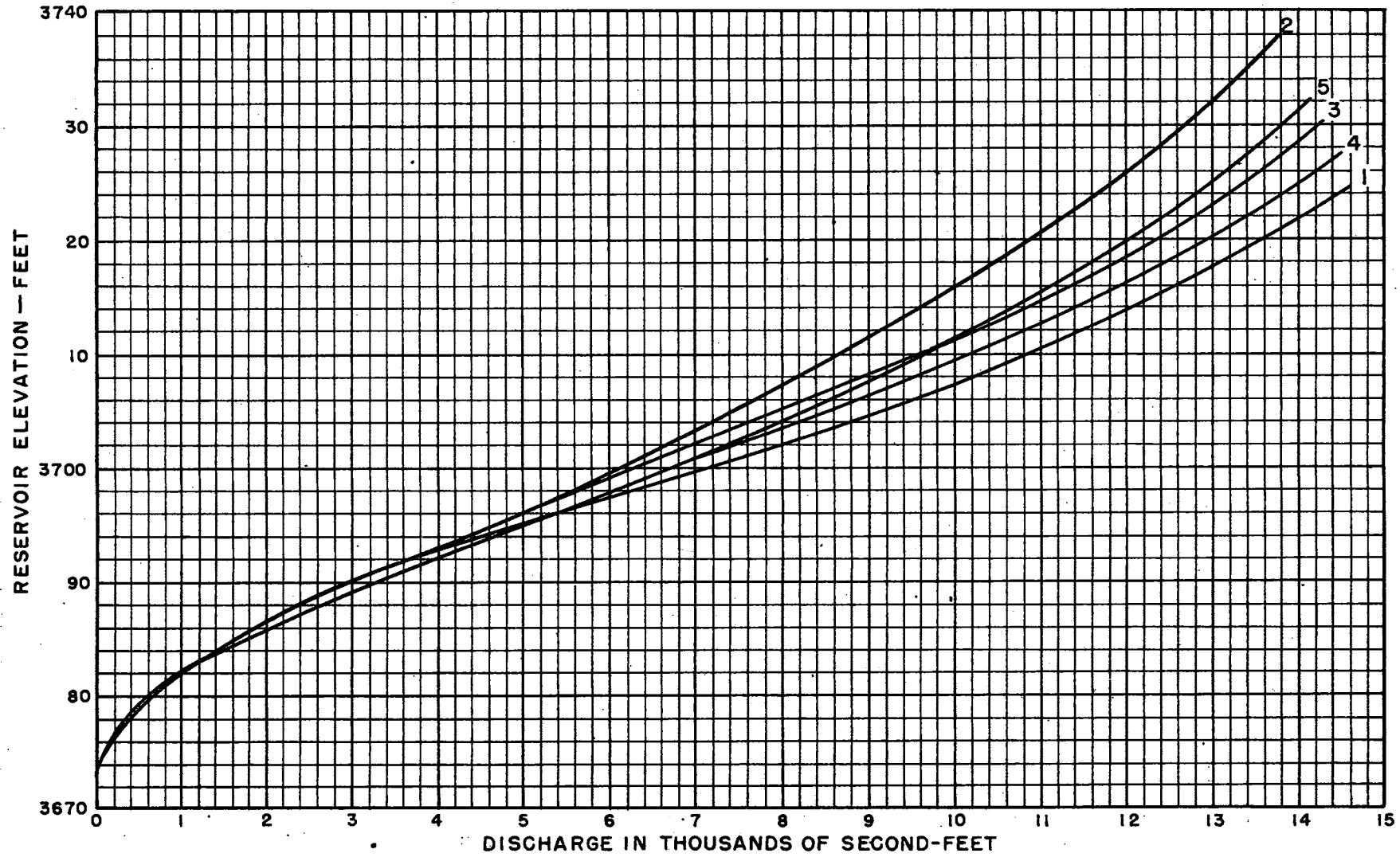
A. PRELIMINARY
SHOWING PIEZOMETER PRESSURES
ALL PRESSURES MEASURED IN FEET OF WATER



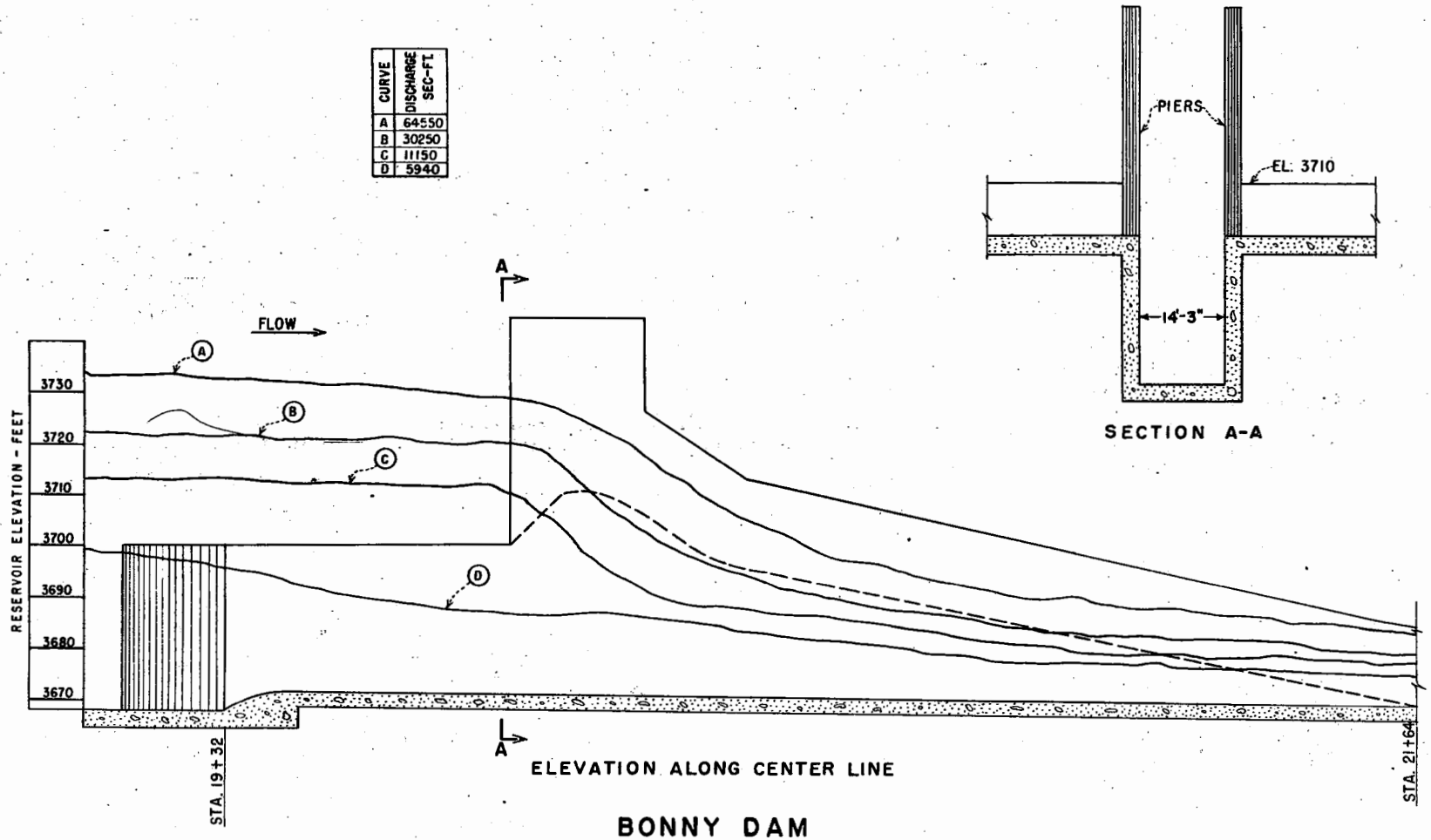
B. SLUICEWAY No. 2
SHOWING PIEZOMETER PRESSURES
ALL PRESSURES MEASURED IN FEET OF WATER

BONNY DAM
SLUICEWAYS 1 & 2 & PRESSURES
1:60 SCALE MODEL

FIGURE 22



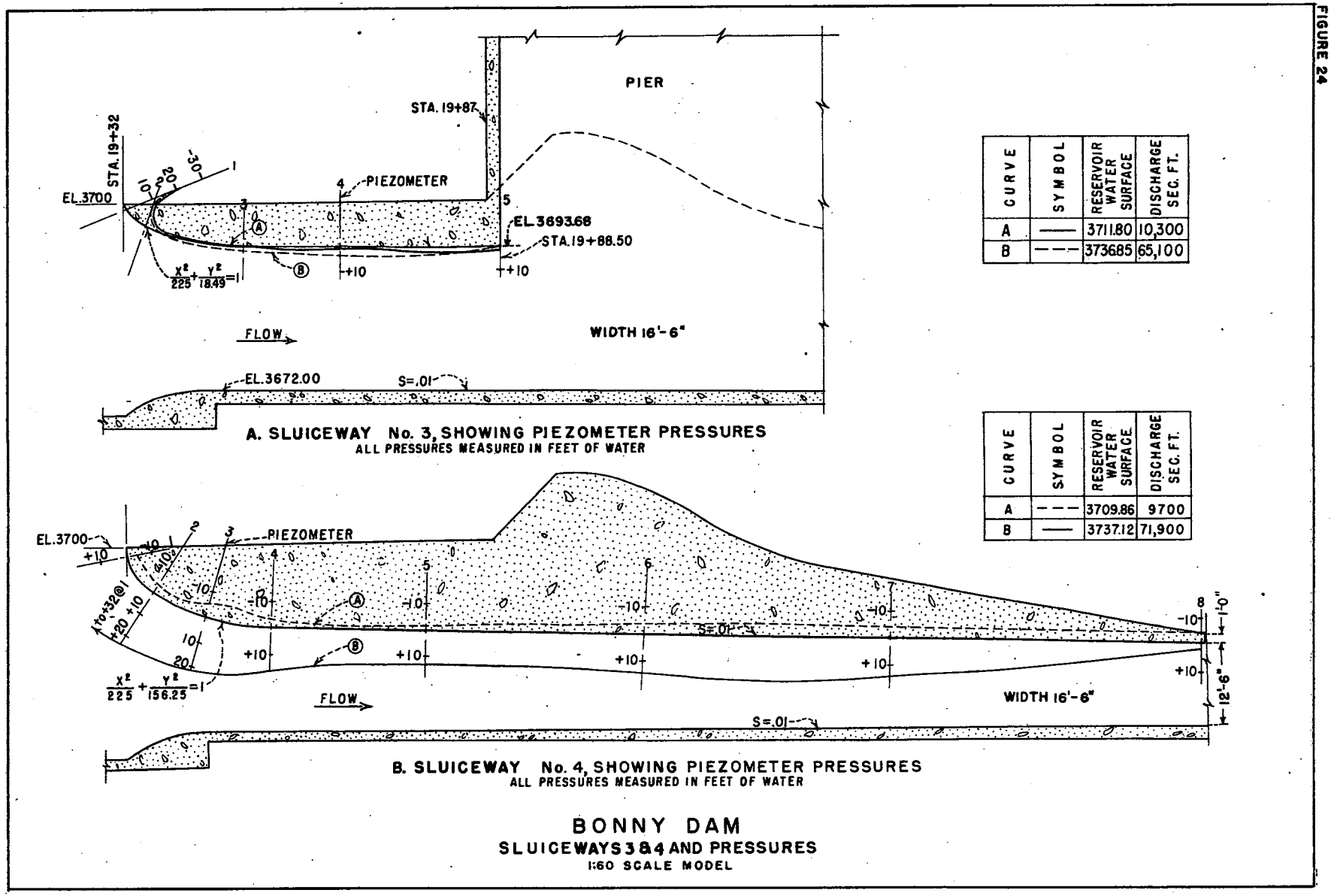
BONNY DAM
SLUICEWAY DISCHARGE CAPACITY CURVES
SLUICEWAYS 1-5, 1:60 MODEL



BONNY DAM
SLUICEWAY NO. 1 - PRELIMINARY
WATER SURFACE PROFILES WITH TOP REMOVED
1:60 SCALE MODEL

FIGURE 23

FIGURE 24



CURVE	SYMBOL	RESERVOIR WATER SURFACE	DISCHARGE SEC. FT.
A	——	3711.80	10,300
B	— — —	3736.85	65,100

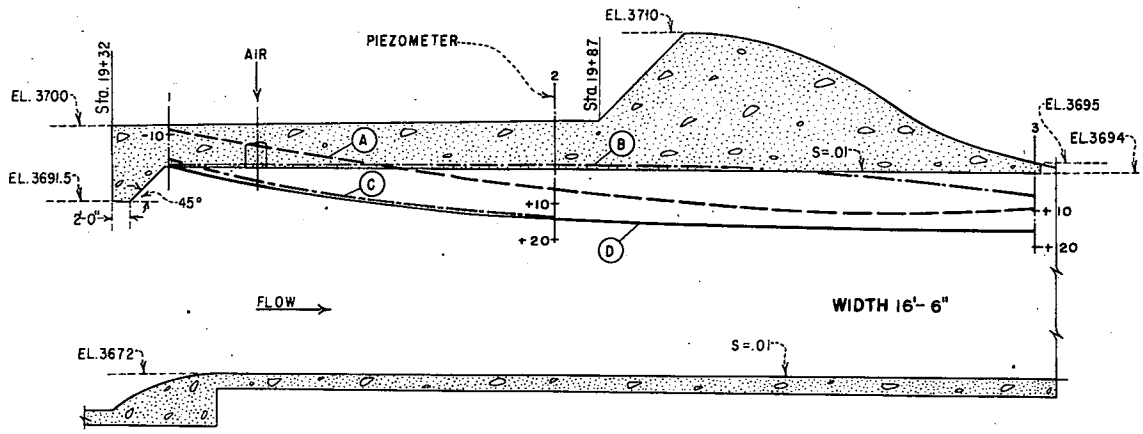
CURVE	SYMBOL	RESERVOIR WATER SURFACE	DISCHARGE SEC. FT.
A	— — —	3709.86	9700
B	——	3737.12	71,900

BONNY DAM

SLUICEWAYS 3 & 4 AND PRESSURES

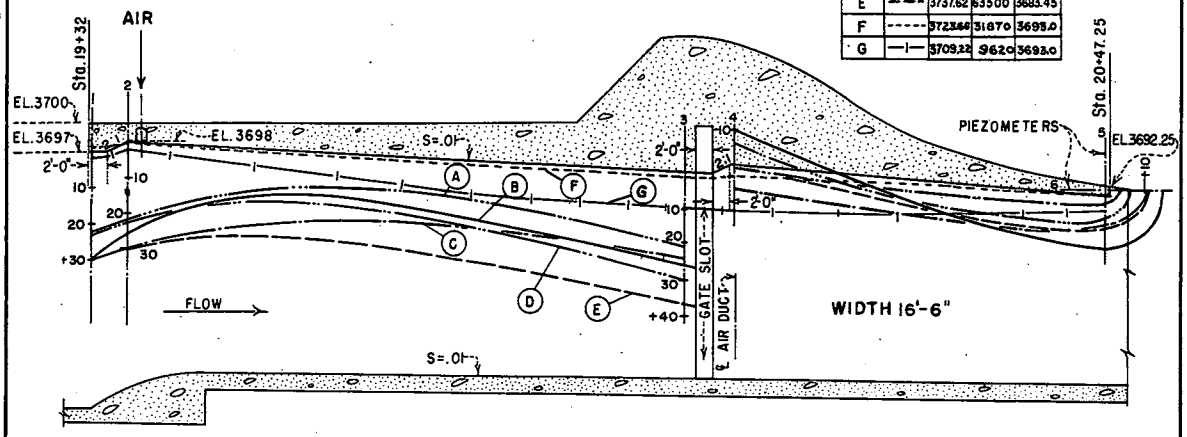
1:60 SCALE MODEL

CURVE	SYMBOL	RESERVOIR WATER SURFACE	DISCHARGE SEC. FT.	AIR SUPPLIED
A		3727.28	43300	NO
B		3727.28	43300	YES
C		3735.56	71400	NO
D		3735.56	71400	YES



A. SLUICEWAY No. 5, SHOWING PIEZOMETRIC PRESSURES
ALL PRESSURES MEASURED IN FEET OF WATER

CURVE	SYMBOL	RESERVOIR WATER SURFACE	DISCHARGE SEC. FT.	ELEVATION BOTTOM OF GATE
A		3729.24	42400	3679.45
B		3737.58	63500	3679.45
C		3737.40	63500	3671.45
D		3729.30	42400	3683.45
E		3737.62	63500	3683.45
F		3723.66	31870	3693.0
G		3709.22	9620	3693.0



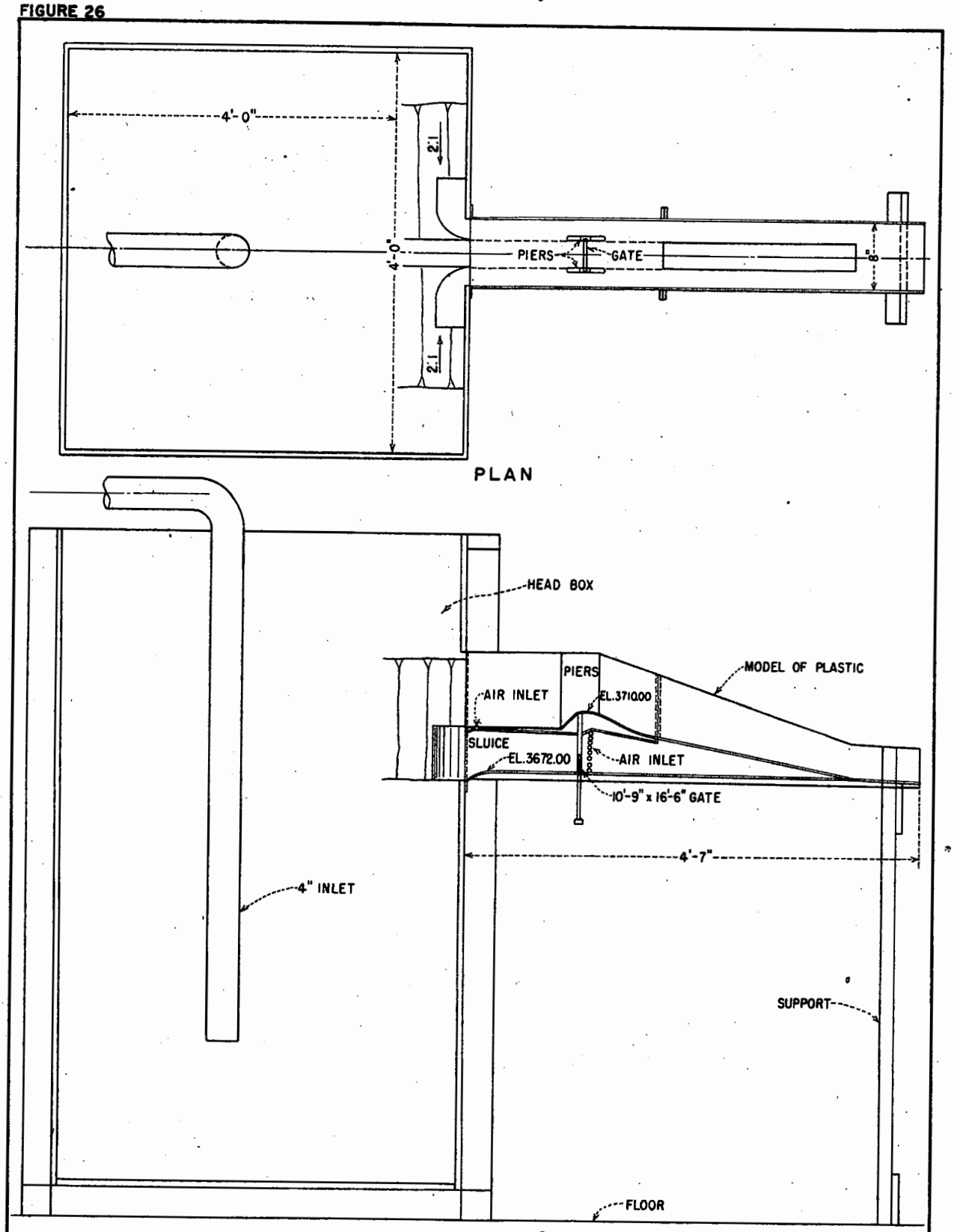
B. SLUICEWAY No. 6, SHOWING PIEZOMETRIC PRESSURES
ALL PRESSURES MEASURED IN FEET OF WATER

NOTE: A control gate (16'-6" x 10'-9") was added to the structure for this design.

BONNY DAM
SLUICEWAYS 5 & 6 AND PRESSURES
1:60 SCALE MODEL

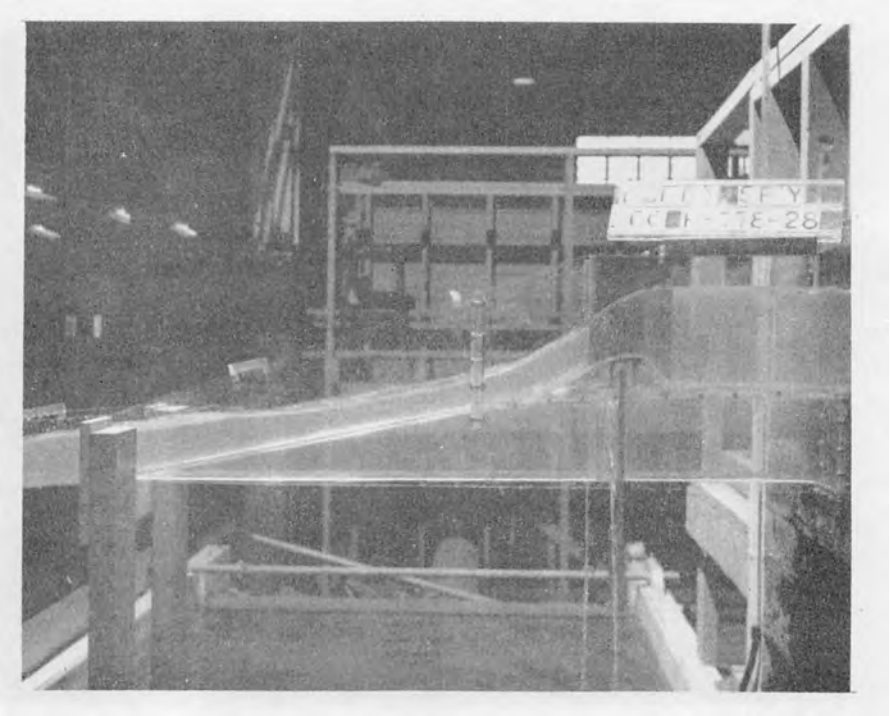
A.S.R. 6-2-49

FIGURE 26

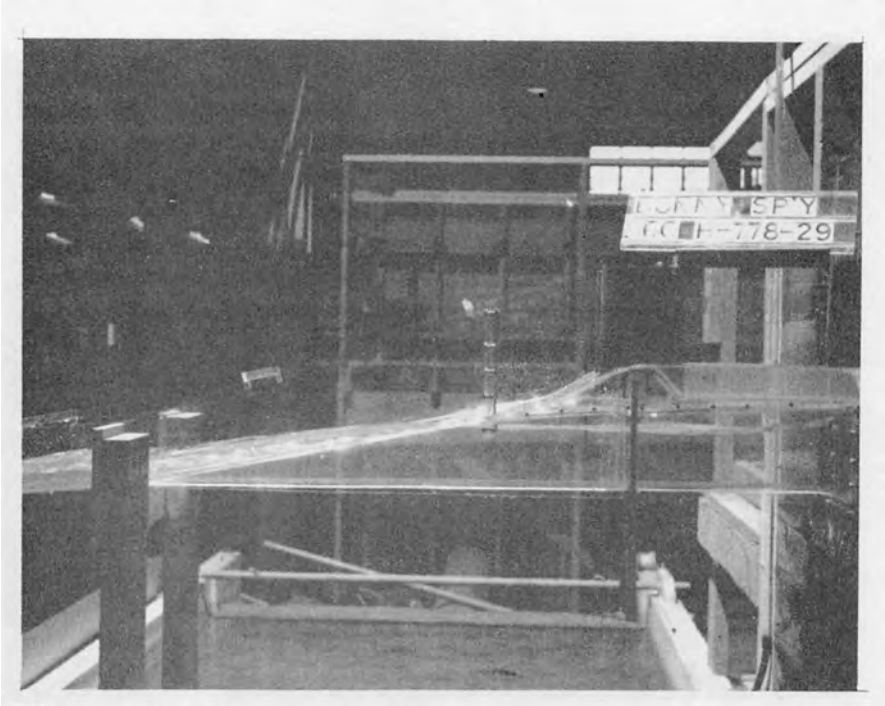


BONNY DAM
SPILLWAY SLUICE
1:60 MODEL LAYOUT

FIGURE 27



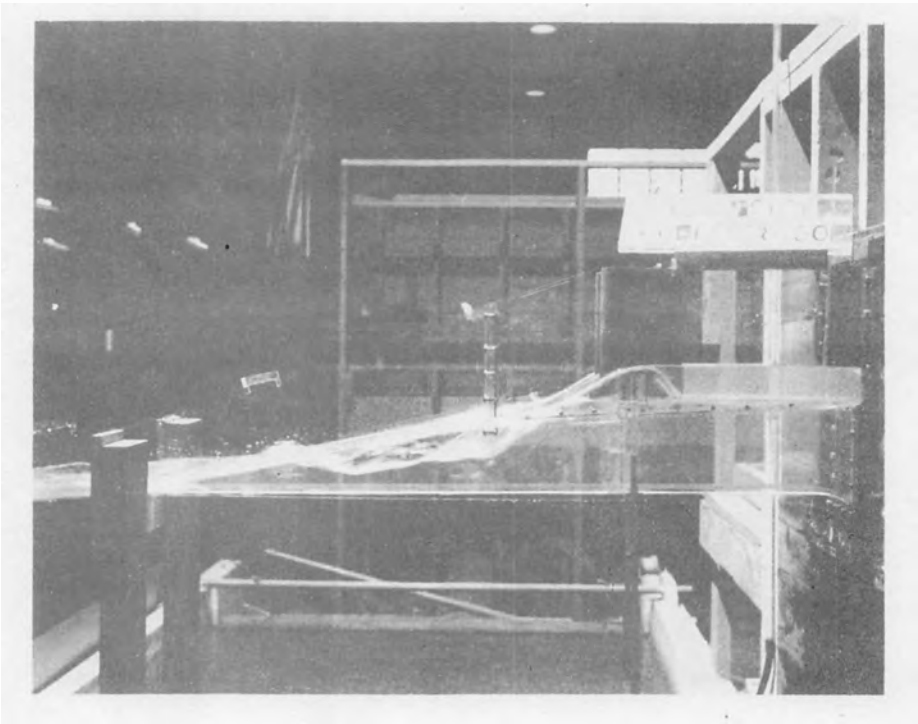
A. MAXIMUM RES. EL. 3736.80- GATE OPEN



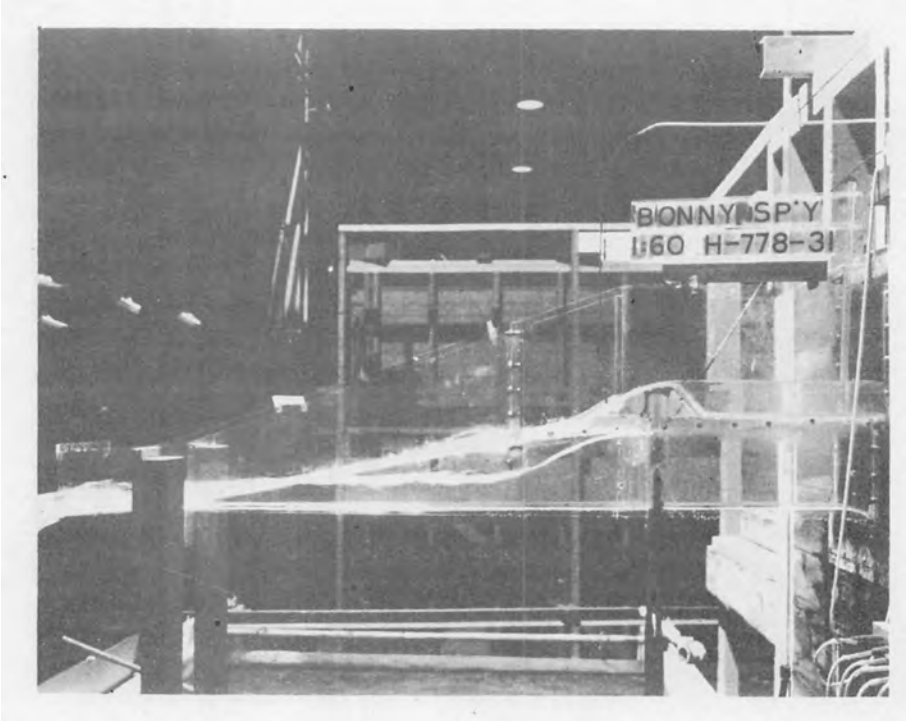
B. DISCHARGE 10,000 SEC.-FT.-GATE OPEN

BONNY DAM
SLUICEWAY NO. 6
1:60 PLASTIC MODEL STUDY

FIGURE 28

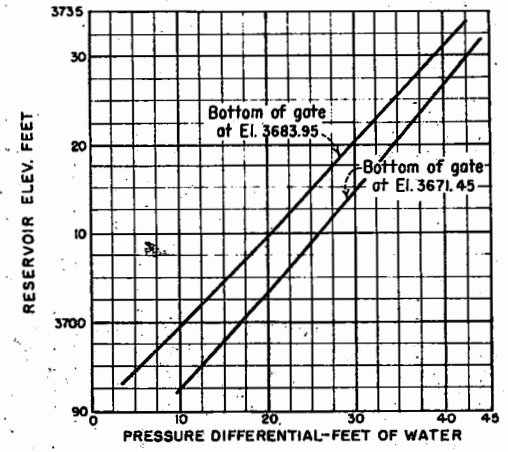


A. SLUICEWAY NO. 6
DISCHARGE 5,000 SEC.-FT. - GATE DOWN



B. SLUICEWAY NO. 7 - RECOMMENDED
DISCHARGE 5,000 SEC.-FT. - GATE DOWN

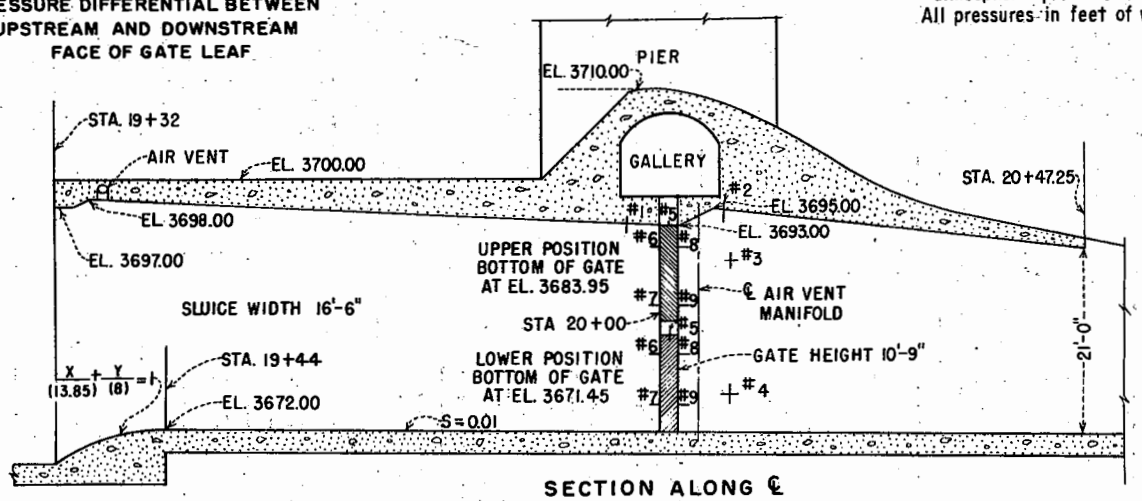
BONNY DAM
COMPARISON OF SLUICEWAYS NOS. 6 AND 7
1:60 PLASTIC MODEL STUDY



PRESSURE DIFFERENTIAL BETWEEN UPSTREAM AND DOWNSTREAM FACE OF GATE LEAF

GATE POSITION	RESERVOIR WATER SURFACE	PRESSURE ON PIEZOMETER								
		1	2	3	4	5	6	7	8	9
UPPER	3734.7	+36			+7		+41	+44		
UPPER	3724.9	+27.5			+6		+31	+35		
UPPER	3705.7	+8.5			+4.5		+13	+18		
UPPER	3694.0	0			+3.5		+2	+7.5		
LOWER	3734.5	+21	+35	+6	+9	+5	+53	+60	+9	+14
LOWER	3728.5	+17	0	+2	+7	+2	+47	+54	+5	+11
LOWER	3713.6	+9	0	+1	+6	+2	+33	+39	+5	+10
LOWER	3705.8	+5	0	+1	+5.5	+2	+26	+32	+5	+10
LOWER	3698.3	+1	0	0	+5	+2	+19	+24.5	+4	+9
LOWER	3693.1	0	0	0	+4.5	+1	+14	+20	+3	+8

NOTE: Piezometers 2,3,5,8, & 9 were at atmospheric pressure for upper gate position. All pressures in feet of water.



SECTION ALONG ℄

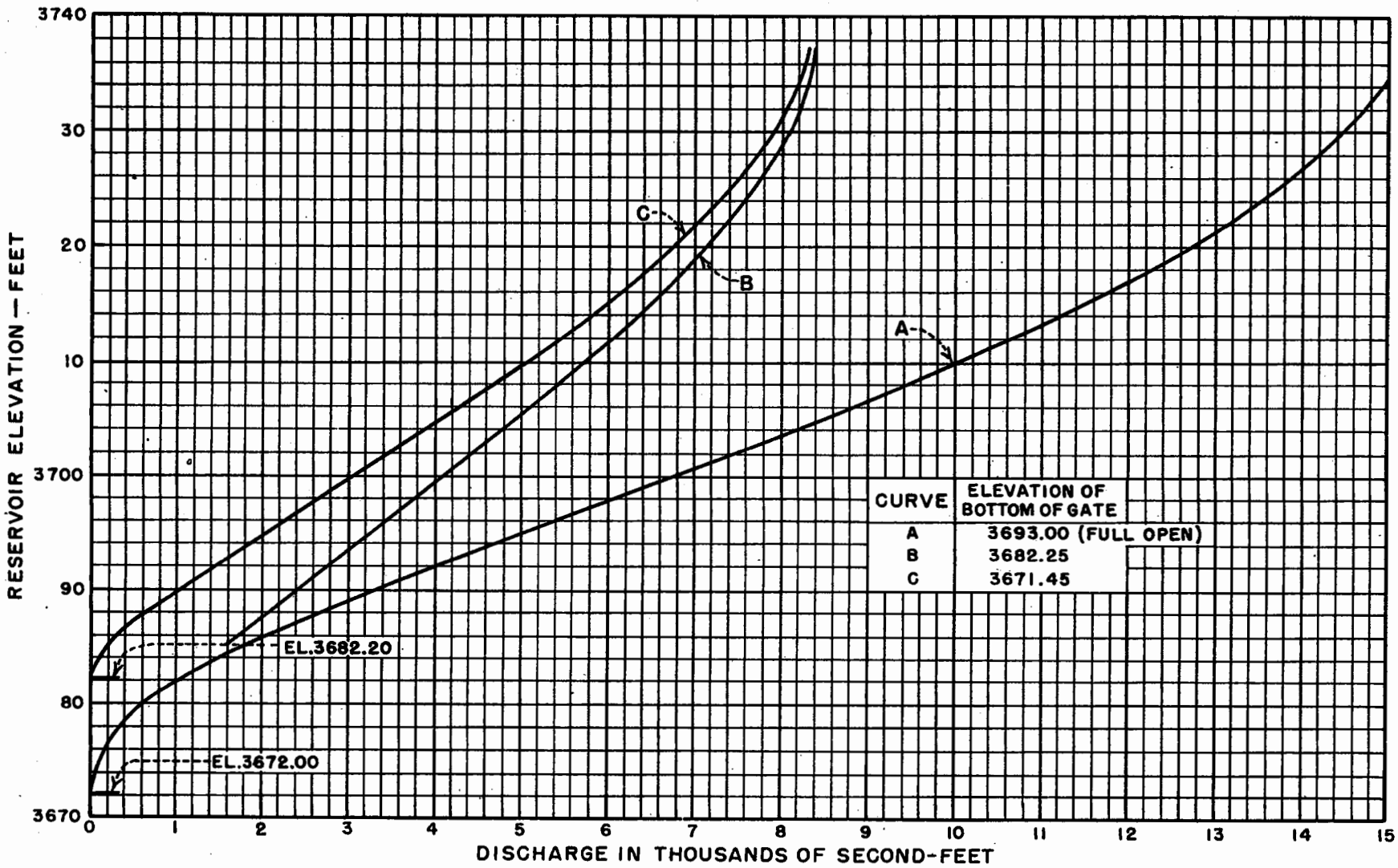
BONNY DAM

RECOMMENDED SLUICEWAY NO. 7 AND PRESSURES

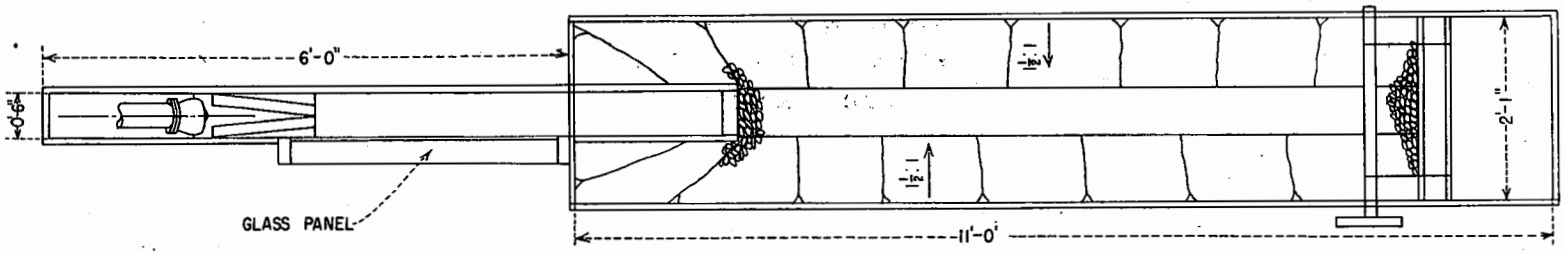
1:60 SCALE MODEL

FIGURE 29

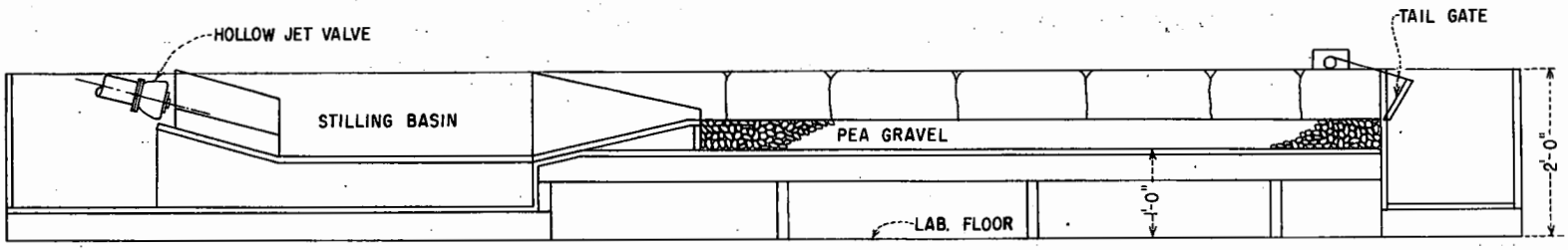
FIGURE 30



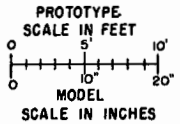
BONNY DAM
SLUICEWAY DISCHARGE CAPACITY CURVES
NO. 7 - RECOMMENDED - 1:60 MODEL



PLAN



SECTION ALONG CENTER LINE



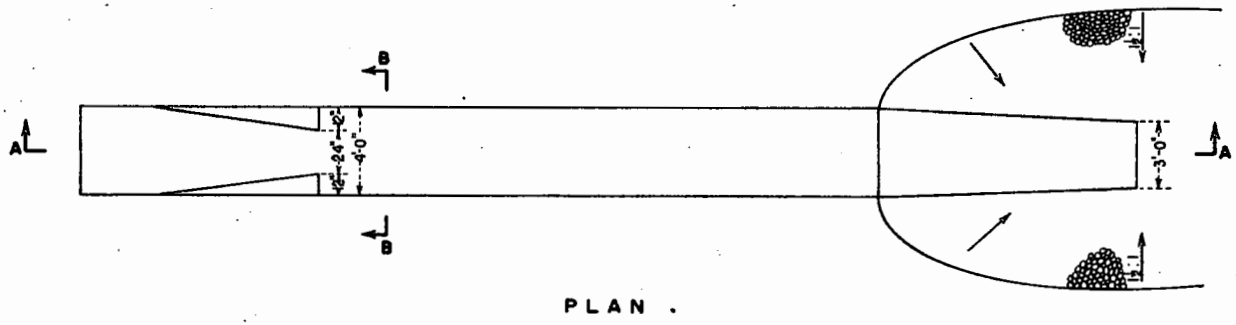
BONNY DAM

HALE DITCH STILLING BASIN

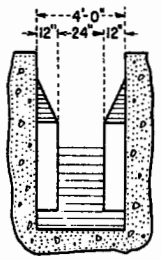
1:6 SCALE MODEL LAYOUT

FIGURE 31

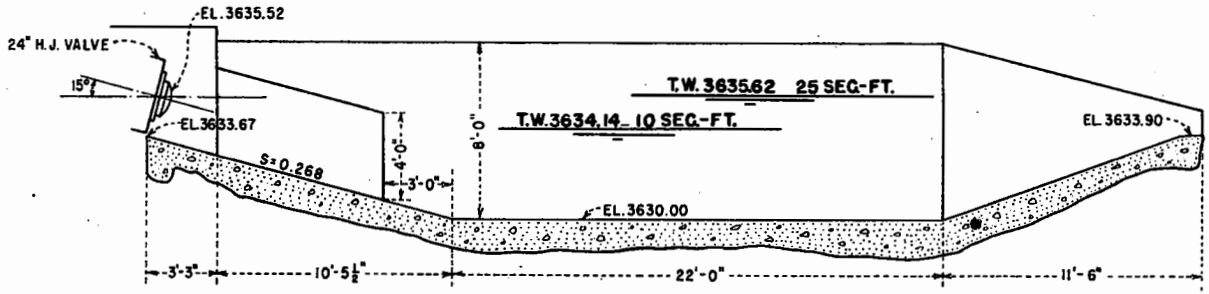
FIGURE 32



PLAN



SECTION B-B

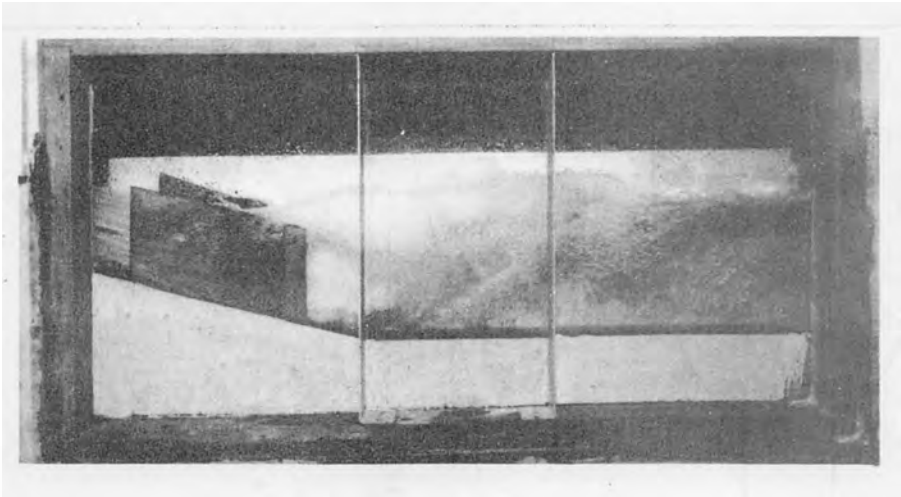


SECTION A-A

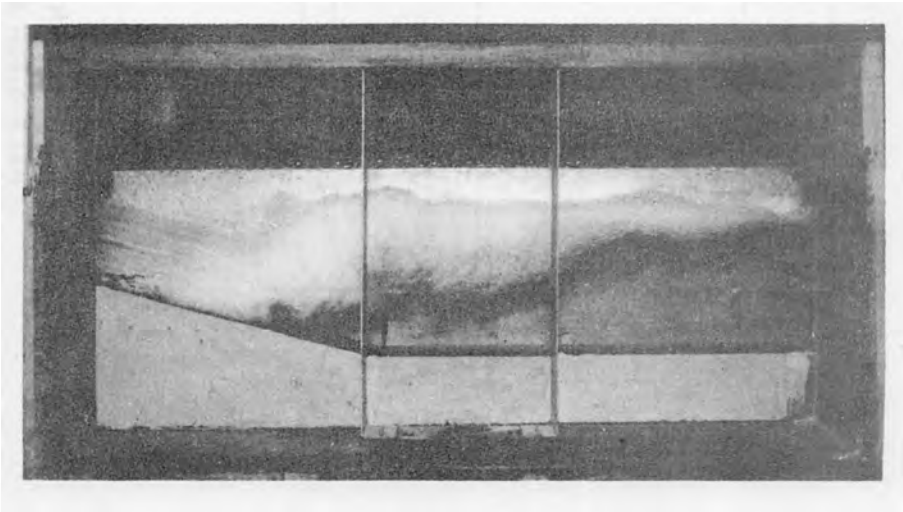
BONNY DAM

HALE DITCH STILLING BASIN

BASIN NO. 1 - PRELIMINARY



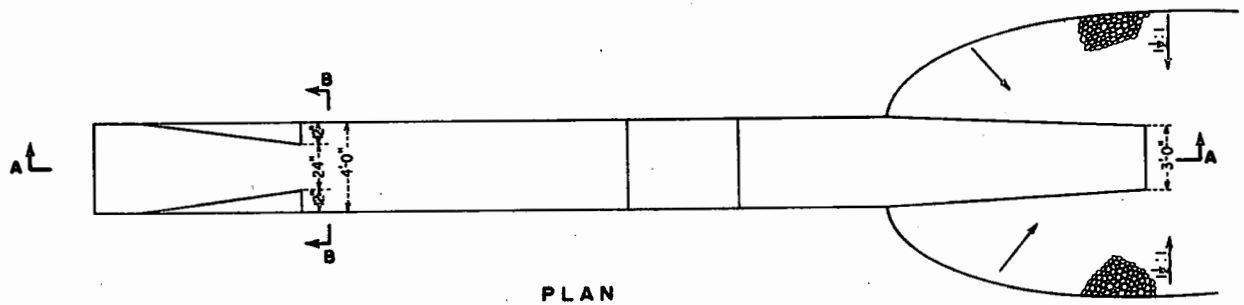
A. SIDE VIEW - DISCHARGE 25 SEC.-FT.



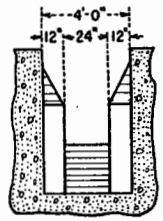
B. SIDE VIEW - DISCHARGE 25 SEC.-FT.
CONVERGING WALLS REMOVED

BONNY DAM
HALE DITCH IRRIGATION OUTLET
STILLING BASIN NO. 1
1:6 SCALE MODEL STUDY

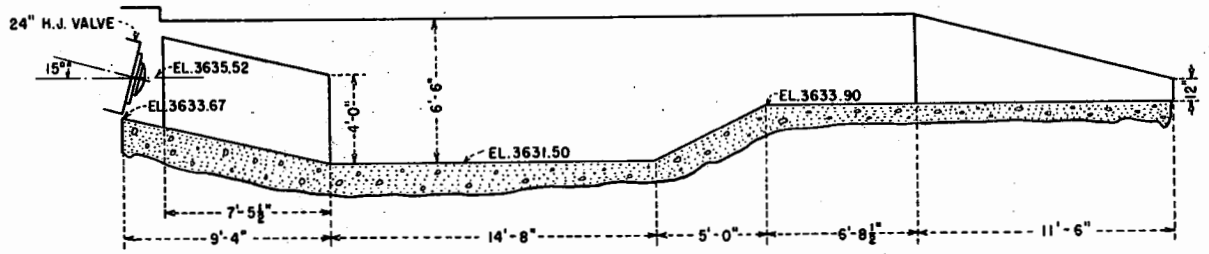
FIGURE 34



PLAN



SECTION B-B



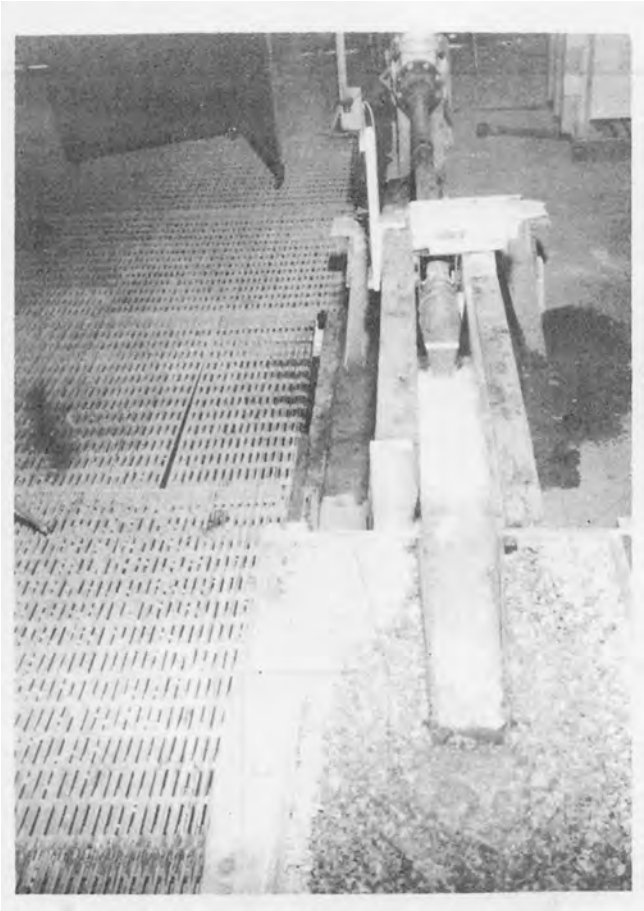
SECTION A-A

BONNY DAM

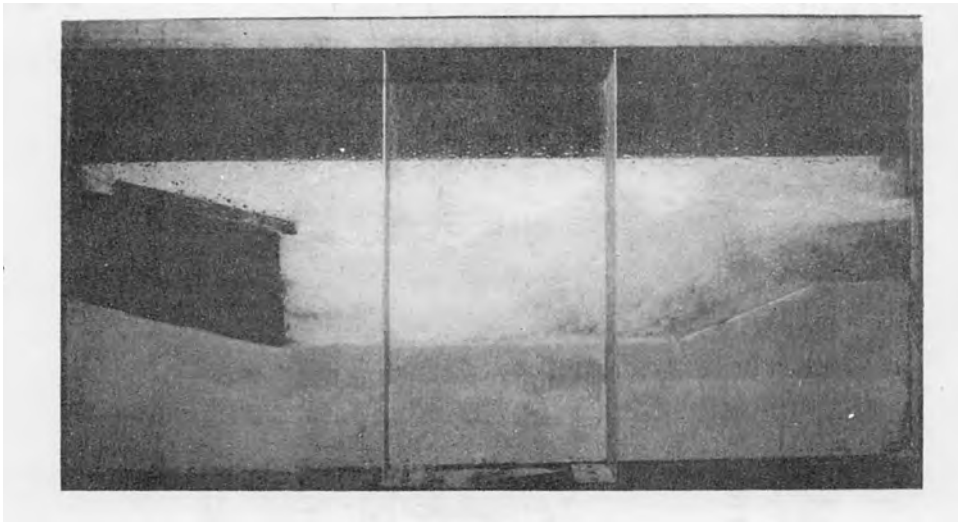
HALE DITCH STILLING BASIN

BASIN NO. 2

FIGURE 35



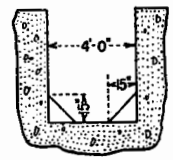
A. VIEW LOOKING UPSTREAM
DISCHARGE 25 SEC.-FT.



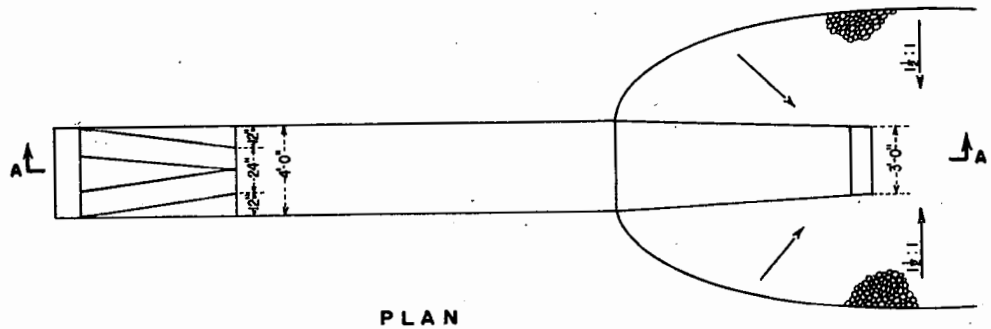
B. SIDE VIEW - DISCHARGE 25 SEC.-FT.

BONNY DAM
HALE DITCH IRRIGATION OUTLET
STILLING BASIN NO. 2
1:6 SCALE MODEL STUDY

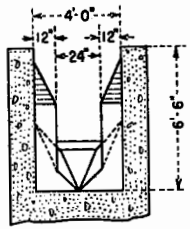
FIGURE 38



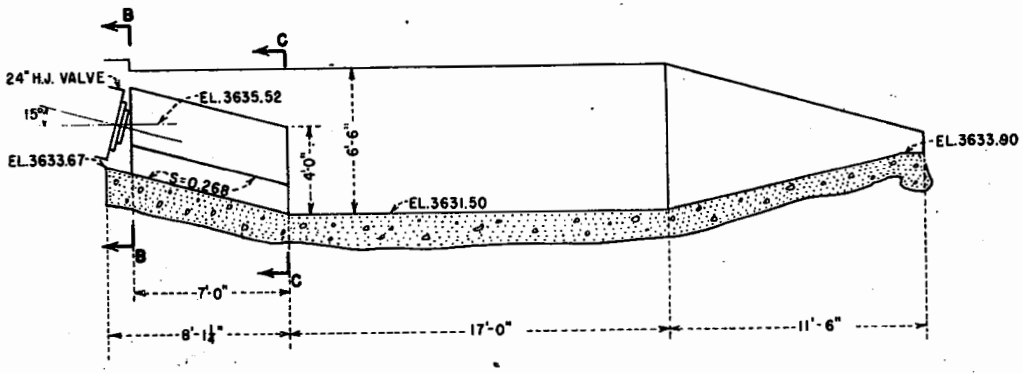
SECTION B-B



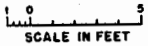
PLAN



SECTION C-C



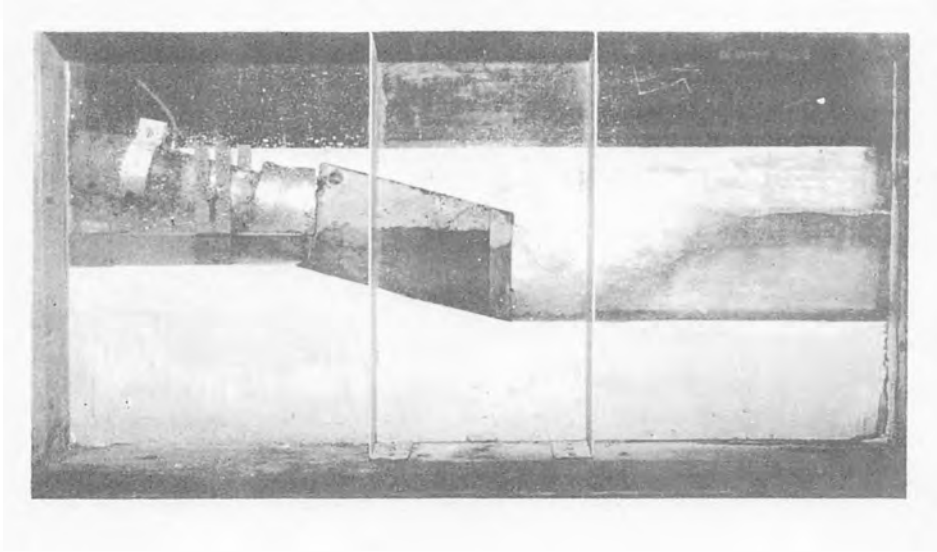
SECTION A-A



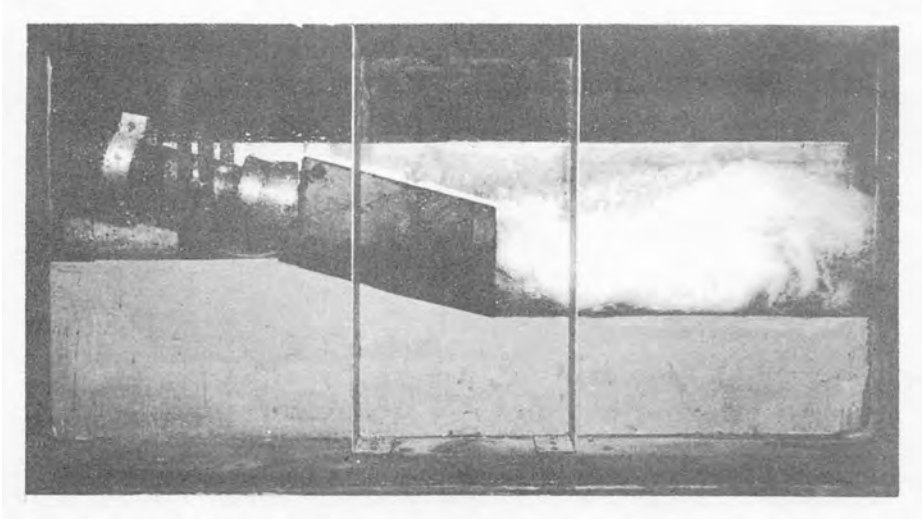
BONNY DAM

HALE DITCH STILLING BASIN

BASIN NO. 3 - RECOMMENDED



A. SIDE VIEW - DISCHARGE 10 SEC.-FT.



B. SIDE VIEW - DISCHARGE 25 SEC.-FT.

BONNY DAM
HALE DITCH IRRIGATION OUTLET
STILLING BASIN NO. 3 - RECOMMENDED
1: 6 SCALE MODEL STUDY