rvice

Blanko

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE OUTLET WORKS-- MEDICINE CREEK DAM-- FRENCHMAN-CAMBRIDGE DIVISION-- MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd. 273

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

January 16, 1951

CONTENTS

APPENDIX

CONTENTS--Continued

APPENDIX

FOREWARD

Hydraulic model studies of the outlet works for Medicine Creek Dam, Frenchman-Cambridge Division, Missouri River Basin Project, were conducted in the Hydraulic Laboratory of the Bureau of Reclamation at Denver, Colorado, during the period of March 1947 to June 1948.

The final plans, evolved from this study, were developed through the cooperation of the staffs of the Spillway and Outlets Section No. 2, the Mechanical Section, and the Hydraulic Laboratory.

During the course of the model studies, Messrs. H. W. Tabor and E. L. Redding of Spillway and Outlets Section No. 2 frequently visited the laboratory to observe the model operation and to discuss test results. Messrs. W. G. Weber and John W. Adolpson of the Mechanical Section observed the tests on the downstream gate frame.

These studies were conducted by Messrs. T. J. Rhone, G. L. Beichley, and W. B. McBirney. The writer was in charge of the investigations under the supervision of Messrs. A. J. Peterka and J. N. Bradley.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Research and Geology Division
Denver, Colorado
January 16, 1951

Laboratory Report No. Hyd-273
Hydraulic Laboratory
Compiled by: W. E. Wagner
Reviewed by: A. J. Peterka

Subject: Hydraulic model studies of the outlet works--Medicine Creek Dam--Frenchman-Cambridge Division--Missouri River Basin Project

SUMMARY

The hydraulic model studies discussed in this report were made to test and develop a satisfactory stilling basin for the Medicine Creek Dam outlet works, to develop an economical and workable transition between the stilling basin and the downstream channel, and to check the performance of a modified type of slide gate used to regulate the flow. The results and recommendations contained herein are based on studies conducted on a 1:12 scale model of the outlet works, Figure 4.

As a result of the model studies, several changes were made in the preliminary arrangement of the stilling basin and transition in addition to a redesign of the downstream gate frame.

The roof of the downstream gate frame, Figure 6, was raised to provide ventilation of the issuing jet and to permit the jet to flow free of the roof, Figure 7. Also, the parallel sidewalls of the gate frame in the preliminary design were flared outward to take advantage of the natural tendency for the flow to spread laterally. Uniform distribution of the flow across the width of the basin was obtained by adjusting the angle of divergence. Changes in the gate leaf design resulting from model studies of the Cedar Bluff outlet works, which has a similar gate and which was being investigated concurrently with these studies, were also tested in the model.

Six different stilling basins were tested, Figures 12 and 13. The recommended design differed from the preliminary basin in that the downstream portion of the basin was widened from 10 feet 8 inches to 13 feet, a steeper parabolic trajectory curve was installed, and diverging training walls were used to uniformly spread the flow from the gate frame to the stilling basin. Figure 22 is a detailed drawing embodying the recommended changes evolved from these studies.

Four arrangements of the transition from the stilling basin to the downstream channel were studied. The tests resulted in the elimination of the warped training walls which were replaced with vertical walls sloping from 14.4 feet at the basin to 1 foot in height at the channel. These changes resulted in considerable economy in construction costs with no sacrifice in the operating characteristics of the transition. Figure 18 shows the various transitions tested, while Figure 19 shows a discharge of 300 second-feet through the transitions, and Figure 20 indicates the amount of the resulting scour.

The feasibility of installing baffle piers and/or siderails in the stilling basin was investigated and results of these studies are discussed on page 11.

The performance of the recommended basin was satisfactory at all flows. Figures 23 to 25, inclusive, show the operation of the recommended design at discharges of 434, 300, and 150 second-feet.

Water-surface profiles and pressures along the invert curve leading to the basin were obtained and are shown in Figures 30 to 34

INTRODUCTION

Medicine Creek Reservoir is a part of the Frenchman-Cambridge Division of the Missouri River Basin Project and, in conjunction with the Enders Reservoir, will be used for storage of irrigation water and flood control. Medicine Creek Dam is located approximately 10 miles north of Cambridge, Nebraska, Figure 1, on Medicine Creek which discharges into the Republican River. The dam is a compacted earth structure approximately 4,000 feet in length, rising 102 feet above the streambed.

The spillway, which is uncontrolled and has a crest length of 229 feet and a maximum discharge capacity of 98,000 cubic feet per second, is located at the left abutment of the dam. Approximately 1,600 feet to the right of the spillway is located the outlet works through which water is released for irrigation purposes. The design flow through the outlet works is 300 second-feet although the stilling basin has been designed for a maximum discharge of 462 second-feet at the maximum reservoir elevation of 2394.8 feet.

The outlet works consist of a 44-inch diameter outlet pipe, 306 feet in length and installed in an 8-foot diameter horseshoe tunnel, which was used for diversion purposes during construction; the stilling basin; transition; and a channel joining the stilling basin to the original streambed. Flow through the outlet works is controlled by a 3-foot 3-inch by 3-foot 3-inch high-pressure slide gate, located at the downstream end of the outlet pipe, Figures 2 and 3.

The hydraulic model tests discussed in this report were necessary to study the distribution of flow downstream from the slide gate, the stilling basin performance, and the flow distribution as the water enters the downstream channel.

THE 1:12 SCALE MODEL

Construction of Model

The model of the outlet works was built to a geometrical scale of 1:12 and consisted of a headbox used to represent the reservoir, a short section of 3.67-inch diameter pipe leading from the headbox to the control house, a 3-1/4- by 3-1/4-inch slide gate, the stilling basin, and a section of the channel below the basin, Figure 4. The outlet pipe upstream from the control house was not modeled since the outlet pipe flows under pressure and no hydraulic problems are anticipated in that portion of the structure. The outlet pipe was represented by a 3-foot length of pipe, 3.67 inches in diameter, which was equipped with a bell-mouth entrance and flow straightener at the inlet end. Water was supplied to the headbox from one of the portable laboratory pumps and was metered through a combination venturi and orifice meter. Flow into the stilling basin was controlled by a small handwheel incorporated in the 3-1/4- by 3-1/4-inch slide gate, which was built to scale to represent the 3-foot 3-inch by 3-foot 3-inch prototype gate. Tail-water elevations in the stilling basin and channel, which were set according to the tail-water curve, Figure 35, were controlled by a tail gate located at the downstream end of the model.

The headbox, stilling basin, and downstream channel were constructed of wood and lined with galvanized sheet metal. The invert curve and transition were made of neat concrete formed to metal templates. The trapezoidal channel below the basin was formed of concrete over metal lath and placed 3 inches below grade. During the erosion and wave studies the channel was filled to grade by placing compacted sand over the concrete. The mean diameter of the sand used in the erosion tests was 0.9 millimeter with approximately 27 percent passing a No. 30 sieve and 10 percent retained by a No. 8 sieve.

Operation of Model

Since the outlet conduit from the trashrack structure to the gate chamber was not reproduced in the model, the conduit head losses upstream from the slide gate were calculated to determine the head required in the model reservoir.

Two methods of calculating the head losses were used: The Manning formula where

$$V = \frac{1.486}{n} r^{\frac{2}{3}} S^{\frac{1}{2}}$$

and the Darcy formula where the loss of head due to friction,

$$h_f = f\frac{1}{d}\frac{v^2}{2g}$$

Throughout the range of reservoir elevations, the Darcy formula gave approximately 10 percent more discharge for a given head than the Manning formula. At normal reservoir elevation and with the gate wide open, the Manning formula gave a discharge of 392 second-feet while the Darcy formula gave a discharge of 434 second-feet for the same operating conditions.

To assure that the stuides covered each possible condition, the model was operated at normal reservoir elevation using the maximum discharges obtained from each friction loss formula. The entire range of prototype flows below maximum were also studied at normal reservoir elevation by partially closing the slide gate. At reservoir elevations above normal, water will spill over the uncontrolled spillway and, normally, the outlet works will not be used to release water under these conditions.

Figure 5 shows the head-discharge relationships for gate openings from 10 to 100 percent for the outlet works. These curves were computed by the Spillway and Outlets Section No. 2 after the model studies were completed.

THE INVESTIGATION

Slide Gate Studies

Sidewalls of downstream gate frame. The 3-foot 3-inch by 3-foot 3-inch high-pressure gate, Figures 6 and 7A, which had been used on Bureau projects since 1935, was installed in the model for the preliminary stilling basin studies discussed on page 6. However, as the stilling basin tests progressed, it became apparent that, in addition to changes in the stilling basin, alterations of the downstream gate frame were necessary to obtain satisfactory lateral flow distribution before the jet reached the stilling pool.

The stilling basin studies indicated that diverging training walls were desirable to permit the jet to spread from the 3-foot 3-inch width at the gate to the 13-foot width of the stilling basin. (Basin No. 4, page 8). With the diverging training walls, the distribution of flow immediately below the gate was satisfactory at all heads when the gate was wide open. However, at partial gate openings, the edges of the jet failed to follow the training walls for a short distance below the end of the downstream gate frame. This was due to the restraining effect of parallel walls of the downstream gate frame which prevented the natural tendency of the jet to spread at the gate leaf.

The parallel sidewalls of the downstream gate frame were removed and the diverging training walls extended to the gate leaf, Figures 7B and 12D. With the sidewalls of the gate frame thus flared, the jet was permitted to spread laterally immediately after leaving the gate leaf. At partial gate openings, the distribution of flow at the gate leaf was noticeably improved with the jet spreading laterally to the diverging training walls. At full-gate opening the appearance of the flow was essentially the same as before.

To determine the maximum amount of flare permissible, the training walls were changed to different angles of divergence and the flow along the walls observed. It was found that for angles of divergence above $8^{\circ}30'$, the edges of the jet failed to follow the training walls. Therefore, the maximum angle of flare should not exceed $8^{\circ}30'$.

Roof of downstream gate frame. When the gate was in the fully open position and discharging 200 second-feet or above, the jet adhered to the roof of the downstream gate frame. Although no piezometers were installed for verification, it was believed that, in the prototype, pressures below atmospheric would be developed along the roof of the gate frame, especially in the vicinity of the gate leaf, and that some means of venting was necessary to relieve this conditions.

Several measures were tested to provide aeration of the gate frame roof. An air vent, 5 inches in diameter (prototype), was placed in the center of the gate frame roof immediately downstream from the gate leaf, Figure 7C. This vent supplied only enough air to free the jet in the vicinity of and downstream from the air vent. The air failed to spread laterally across the roof below the gate leaf.

Since adequate aeration was not provided by the single air vent, the roof was raised 5 inches to permit air to enter from the end of the gate frame, Figure 7D. This arrangement provided adequate aeration and the top of the jet was fully aerated back to the gate leaf.

Due to the difficulty of designing a gate with the 5-inch rise in the gate frame roof, the downstream gate frame was modified by replacing the 5-inch rise with a sloping roof from the gate leaf, Figure 7E. The appearance of the jet was essentially the same as before, and the jet did not adhere to the sloping roof. On the basis of these tests, it was recommended that the downstream gate frame be modified to conform to the design shown in Figures 7B and E. Figure 8 is a detailed drawing of the downstream gate frame developed by the Mechanical Section which embodies the recommendations made by the laboratory.

Gate leaf and gate slots. At partial gate openings and normal reservoir elevation, especially in the discharge range of 100 to 150 second-feet, a flow disturbance, similar to a diamond pattern, was

observed immediately downstream from the gate leaf along the jet surface, Figure 9A. The disturbance appeared to be due to a discontinuity of flow at the gate slots. Although the disturbance itself was not objectionable, the flow pattern indicated that further studies should be made to determine its cause and to investigate the possibility of low pressures in the downstream gate frame.

Since model studies were about to be initiated on Cedar Bluff outlet works for which a similar type of slide gate was proposed, it was decided to thoroughly investigate the gate leaf and slots using a model gate built specifically for gate testing.* These studies resulted in a redesign of the bottom of the gate leaf and the addition of fillets upstream from the gate slots.

Effect of gate modifications on stilling basin performance. The gate modifications recommended for the Cedar Bluff outlet works gate were also tested in the Medicine Creek Model after the stilling basin studies had been completed. Tests using the modified gate were made to ascertain whether the gate changes had affected the stilling basin performance. Although the flow leaving the gate was improved by eliminating the disturbance previously described, flow into the stilling basin was not adversely affected. Therefore, no further stilling basin modifications were considered necessary, and the gate improvements evolved from the Cedar Bluff studies were also incorporated in the Medicine Creek gate design.

Operation of gate. Figures 9B and C shows a comparison of the flow issuing from the downstream gate frame with the slide gate fully open and with the gate approximately 97 percent open. In each case the discharge was approximately 434 second-feet at normal reservoir elevation. A close study of the two photographs reveals that the flow was more evenly distributed when the gate was 97 percent open. There was a lack of spreading when the gate was 100 percent open, and the flow failed to follow the diverging training walls. However, if the jet was pinched by slightly closing the gate, the surface of the jet flattened and the flow distributed evenly between the training walls.

Therefore, it is recommended that, except in emergencies, the maximum gate opening shall not exceed 95 percent.

Stilling basin Studies

Preliminary basin. Initially, the model was constructed according to the preliminary basin design, Figure 2, using the original slide gate. The model is shown in Figure 10. For discharges of 392

---

*Hydraulic Laboratory Report No. 245, "Hydraulic Model Studies of Cedar Bluff Outlet Works"

and 434 second-feet at normal reservoir elevation, the flow distribution in the stilling basin was only fair with most of the flow confined to the upper two-thirds of the stilling pool depth. Because of the relatively high tail water, the flow tended to race over the top of the pool surface rather than plunge downward to the pool bottom. The flow was also concentrated along the centerline of the basin and large surges were prevalent throughout its length, Figure 11A. However, when the slide gate was partially closed to discharge 300 and then 150 second-feet at the same reservoir elevation, the jet failed to penetrate the stilling pool and skipped along the surface of the pool, Figure 11B.

These adverse conditions were improved somewhat by placing two training walls, which diverged to the full basin width at the end of the invert curve, immediately downstream from the outlet, Figure 14. The diverging training walls helped to confine the flow before it entered the stilling pool, but the jet still failed to penetrate the full pool depth.

Basin No. 2. To improve the distribution of flow before it entered the pool, a horizontal floor, 15 feet long, was placed between the end of the outlet and the origin of the invert curve, Figure 12B. Diverging training walls were also placed downstream from the gate frame. When the gate was fully open, the horizontal floor helped to spread the jet, especially for the maximum discharge, but the lateral distribution of the jet for a discharge of 150 second-feet through a partially open gate was still unsatisfactory.

At partial gate openings the edges of the jet failed to follow the training walls for a short distance below the end of the gate frame. This was apparently due to the restraining effect of the parallel walls of the downstream gate frame. To remove this restraining effect, the sidewalls of the downstream gate frame were flared, and the jet was permitted to spread laterally immediately after leaving the gate frame. With the sidewalls flared, the distribution of flow immediately below the gate was noticeably improved for partial gate openings. At full gate opening, the appearance of the flow was essentially the same as observed before the gate frame sidewalls were flared.

Basin No. 3. Although the previous tests showed that the distribution of flow as the jet entered the pool was still inadequate the appearance of the stilling action also indicated the 10-foot 8-inch width of the basin was insufficient. It was decided to make a series of tests using wider basins to determine whether the basin performance could be improved.

For Basin No. 3, the stilling basin was widened and diverging training walls were placed between the gate frame and the basin, Figure 12C. Tests were made using basin widths of 24, 16, and 13 feet. The width of basin was varied by placing training walls within the tailbox to give any desired width. The 24-foot basin was entirely too wide, and a jump did not form for discharges of either 434 or 150 second-feet.

The width of basin was then reduced to 16 feet. The stilling pool operation was improved but an unstable jump still formed for all discharges and the full 16-foot width of basin was not utilized by the stilling action.

The basin width was then further reduced to 13 feet. At the maximum discharge, the full basin width was utilized and the stilling action was satisfactory. However, for a discharge of 150 second-feet and partial gate opening, the jet had a tendency to flow over the tail-water surface and to occupy only the top portion of pool resulting in surges accompanied by considerable splashing.

At this point in the investigation, the basin appeared to be sufficiently wide and it was believed adequate stilling action could be obtained with this basin by improving the flow pattern of the jet before it entered the stilling pool.

Basin No. 4. Major changes in the upper end of the stilling basin, from the gate leaf to the end of the trajectory curve, were made for Basin No. 4. The downstream gate frame was made divergent laterally from 3 feet 3 inches at the gate leaf to 4 feet 1 inch at a point 3 feet downstream from the gate leaf. Training walls joined the gate frame and followed the same angle of divergence ($7^{\circ}55'$) until they intersected the parallel walls of the 13-foot-wide basin. In addition, a horizontal floor, 9 feet long, was placed downstream from the gate frame and a steeper invert trajectory curve was used. Basin No. 4 is shown in Figure 12D.

Tests were run with discharges of 150 and 434 second-feet at normal reservoir elevation, Figure 14. The stilling pool operation was vastly improved. The horizontal floor together with the diverging gate frame and training walls improved the distribution of flow below the gate with the result that the flow entering the stilling basin was comparatively uniform. The steeper invert curve permitted the jet to penetrate more deeply into the pool and a fairly stable jump formed in the basin. The surges and splash were reduced as compared to the previous tests but some were still prevalent.

Basin No. 5. Basin No. 5 differed from Basin No. 4 in that the horizontal floor was removed and the origin of the invert curve was moved to the end of the gate frame, Figure 13A. This change was made to determine whether the horizontal floor was required for the steeper trajectory curve. Piezometers were installed in the invert curve to ascertain whether subatmospheric pressures were caused by the steeper trajectory.

Tests were run through the full range of discharges and the stilling pool operation was satisfactory. However, from visual observations, it appeared that the jet did not spread as uniformly as in the

previous tests when the 9-foot long horizontal floor was used. Figure 15 shows the model discharging 150 and 434 second-feet.

Pressures along the invert were recorded for discharges of 150 and 434 second feet at normal reservoir elevation. Piezometers No. 1 and 2, located 3 and 6 feet, respectively, downstream from the origin showed pressures of 6 inches of water (prototype) below atmospheric at a discharge of 150 second-feet. The remaining piezometers showed pressures above atmospheric. All the pressures were above atmospheric for a discharge of 434 second-feet, Figure 16.

Basin No. 6. Since the tests on the previous basin showed no seriously low pressures along the invert curve, a still steeper parabolic curve, $-X^2 = -143.28y$, was installed. To offset the effect of the steeper curve, a horizontal floor, 6 feet long, Figure 13B, was placed between the gate frame and the origin of the curve to help spread the jet before it passed over the trajectory curve into the stilling basin. The steeper parabolic curve permitted the flow to enter the jump at a steeper angle and shortened the transition section into the basin.

The model was operated at flows of 150 and 434 second-feet. In this range of discharges the jet spread satisfactorily and a stable, uniform jump formed in the stilling basin due to the steeper entry, Figure 17. The waves in the channel below the structure were not objectionable, Figure 19A, and erosion in the channel downstream from the concrete floor of the transition was 1.3 feet at the lowest point, Figure 20A. Pressures observed along the invert curve, Figure 34, were approximately atmospheric or above. The horizontal floor upstream from the curve probably helped to prevent the pressures from being somewhat lower.

It is recommended that the horizontal floor, trajectory curve, and basin dimensions tested in Basin No. 6 be used for construction in the field. However, further tests on the transition from the rectangular stilling basin to the trapezoidal channel were made to determine the most economical design for that section of the structure.

Transition Studies

The channel below the stilling basin is 6.4 feet higher than the basin floor and the bottom of the channel leading from the basin to the river is 12 feet wider than the stilling basin, Figures 2 and 18. Therefore, a transition is needed to convey the flow from the stilling basin to the outlet channel.

The transition of the preliminary design consisted of an upward slope from the basin floor to the bottom of the channel and warped

wing walls which varied from the vertical at the end of the basin to a slope of 1-1/2:1 at the channel, Figure 18A. A warped training wall is not simple to construct in the field because of the complicated form work and since the stilling basin studies, using the preliminary transition, showed no particular advantages in operation, it became apparent that a less costly transition might be substituted without sacrificing any of the operational efficiency in the stilling pool or transition.

Several variations of the preliminary design were tested. Among these were vertical wing walls in place of the warped walls, vertical walls with sloping top, and longer and milder sloping bottom in the transition. These different designs are shown in Figure 18.

From visual observations of the flow, there appeared to be no appreciable difference in the operation using the various transitions, Figure 19. In each case the flow followed the diverging walls and was uniformly distributed throughout the width of the transition. One noticeable objection to the vertical wall transition was the formation of areas at the end of each wing wall where no flow occurred, Figure 19B. These areas were partially eliminated by sloping the tops of the wing walls to a point 1 foot above the channel bottom, Figure 19C. The training walls of Transition No. 4 were the same as those in the recommended transition, but the sloping floor was extended 20 feet upstream into the basin, Figure 18. This change had the effect of shortening the effective length of the stilling basin. The longer sloping bottom used in Transition No. 4, Figure 19D, gave satisfactory flow through the transition but the stilling pool operation appeared less adequate. It was felt that the additional length of stilling basin afforded by the recommended transition was needed for the higher discharges and during diversion.

Scour tests in the channel below the transition were run for each of the above designs and are shown on Figure 20. Each design was tested by operating the model for a period of time equivalent to 2.3 hours prototype at a discharge of 300 second-feet.

The erosion tests showed approximately the same scour for each of the transition designs. In each case the scour was negligible, amounting to between 1 and 2 feet below the concrete floor at the downstream end of the transition. The deepest scour occurred approximately 10 feet downstream from the transition and near the right side of the channel, Figure 18. Since the transition with sloping vertical walls, Figure 18C, was the most economical of those tested and gave satisfactory flow with little erosion, this design is recommended for construction in the field.

The Recommended Design

The recommended design for the complete structure, evolved from the gate, stilling basin, and transition studies, is shown on Figures 21 and 22. Figures 23 to 25, inclusive, show the operation of the recommended basin for discharges of 150, 300, and 434 second-feet at normal reservoir elevations.

Studies were also made to determine the feasisibity of placing baffle piers or side rails in the stilling basin, Figures 26 to 28, inclusive. Results of these tests are shown on Figures 29 to 32, inclusive, in which wave heights and average water-surface profiles are compared for different conditions. A study of Figure 29 reveals that by installing baffle piers on the basin floor, the wave heights were reduced from an average of approximately 0.6 foot to 0.33 foot and the use of rails only reduced the wave heights approximately 0.1 foot in the range of discharges tested. The height of waves were measured in the channel at a point 10 feet downstream from the transition and 3 feet from the left edge of the water surface. The recorded wave height was the difference in elevation between the maximum crest and minimum trough of the waves measured during a time interval in the model of about 1 minute.

Average water-surface profiles were measured along the centerline of the structure. The effect on the water-surface profiles of using rails or baffle piers is shown on Figures 30, 31, and 32 for discharges of 150, 300, and 434 second-feet, respectively. It will be noted that the rails had little effect on the water-surface profile. However, when the baffle piers were installed and at the higher discharges of 300 and 434 second-feet, the hydraulic jump formed farther upstream on the trajectory curve tending to shorten the required length of stilling basin.

Since the stilling basin performed satisfactorily without the use of baffle piers or rails and since the slight improvement in the stilling basin performance resulting from their use was not warranted by the added expense of installing them, the recommended basin does not include either baffle piers or rails.

Pressures were obtained along the invert curve for discharges of 150, 300, and 434 second-feet at normal reservoir elevation with normal tail water. The lowest pressures recorded under these normal operating conditions were 0.1 foot (prototype) below atmospheric at Piezometer No. 7 for discharges of 150 and 300 second-feet, Figure 34.

Piezometers No. 1, 2, and 3 were placed in the corner formed by the floor and right sidewall of the downstream gate frame to determine whether adverse pressures were present along the floor of the gate frame. The pressures measured at these points were all above atmospheric and are shown on Table 1. Figure 33 shows the location of the 16 piezometers.

The shape of the invert curve, especially at the downstream end, was also checked for adverse pressures at heads well above the normal reservoir elevation. Pressures were obtained for gate openings of 25, 50, 75, and 100 percent and for total heads up to 95 feet measured in the conduit at a point 1 diameter upstream from the gate. In each case, the channel downstream from the stilling basin was removed so that the jet swept through the basin permitting the downstream end of the curve to be studied without the influence of tail water in the stilling basin. Results of these tests are tabulated in Table 1.

The lowest pressure recorded under these abnormal conditions was 1-1/2 feet (prototype) below atmospheric at Piezometer No. 7 for a discharge of 724 second-feet and a total head at the gate of 74 feet. This head at the gate represents a reservoir elevation well above the maximum pool of 2394.8 feet. Therefore, the trajectory curve is apparently safe against cavitation for all possible operating conditions.

Interior - Reclamation - Denver, Colo.

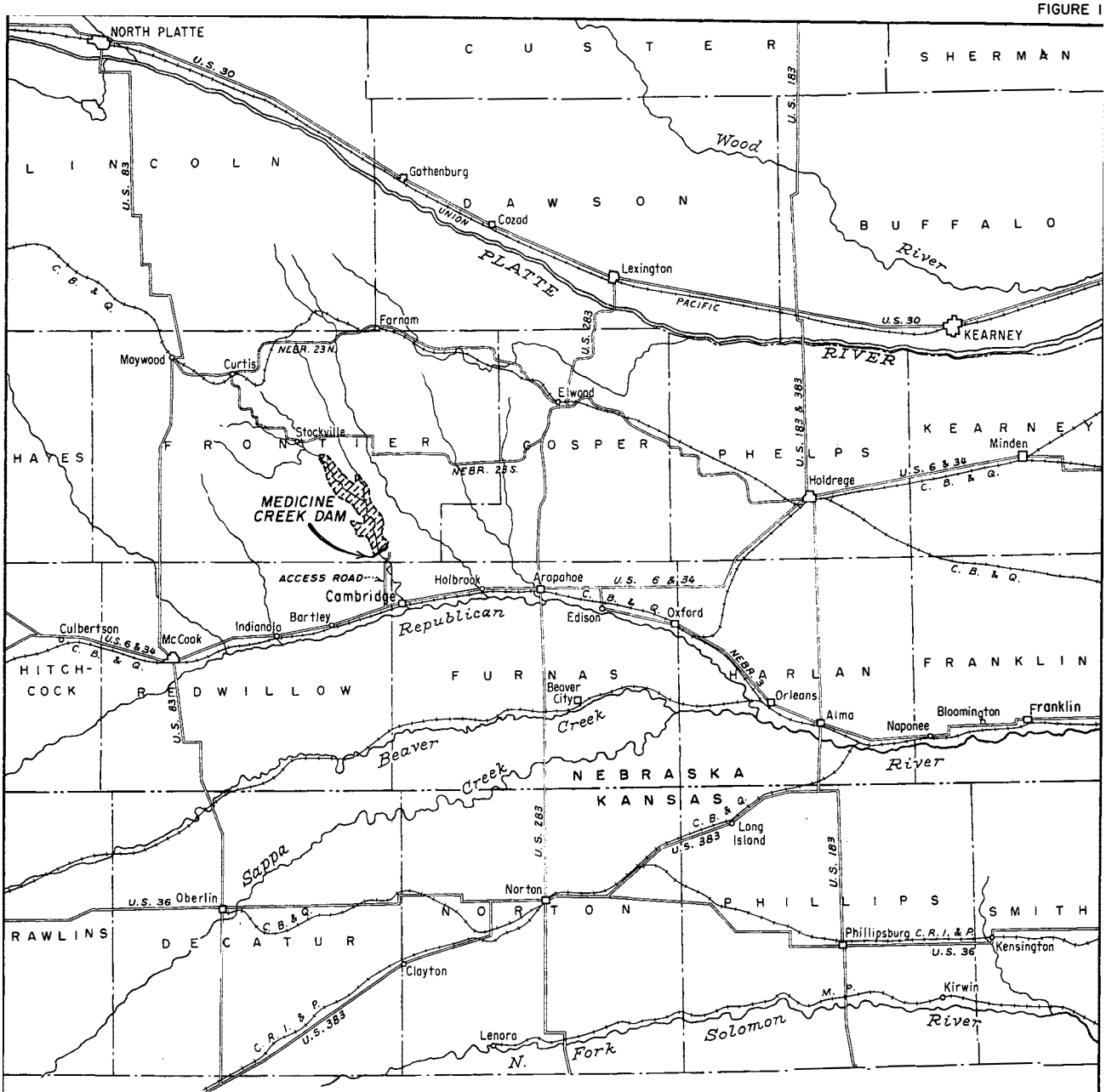
Table 1

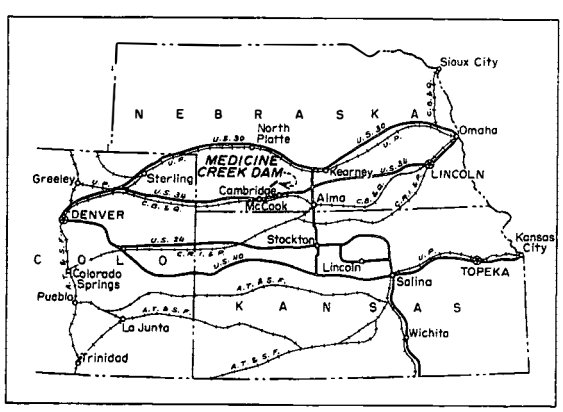
PRESSURES ALONG INVERT CURVE
For Various Gate Openings

Total head one diameter upstream from gate	Pressures in feet of water prototype							
	51	56	54	46	95	93	86	74
Gate opening in percent	25	50	75	100	25	50	75	100
Discharge in second-feet	126.2	212.0	363.0	568.7	168.6	278.2	457.9	723.8
Pressure head at gate in feet prototype	49	50	36	1	91	82.5	56.5	1
Piezometer No.								
1	14.8+	14.8+	14.1	0.0	14.8+	14.8+	14.8+	-0.3
2	2.3	7.3	9.3	0.0	5.9	11.7	14.8+	-0.2
3	3.2	4.9	5.3	0.3	9.1	10.4	9.8	0.3
4	0.4	0.4	0.8	1.4	0.4	0.3	0.5	1.1
5	0.2	0.2	0.4	1.0	0.1	0.0	1.0	0.4
6	0.4	0.3	0.3	0.6	0.4	0.2	0.3	-0.1
7	-1.0	-0.5	-0.5	-0.2	-0.6	-0.9	-0.8	-1.5
8	0.0	0.0	0.0	0.4	0.1	-0.3	-0.2	-0.5
9	0.6	0.8	0.7	0.9	1.0	1.0	1.2	0.5
10	0.2	0.4	0.2	-0.1	0.7	0.6	0.3	-0.3
11	0.5	0.7	0.7	0.3	1.0	1.0	1.0	0.4
12	-0.1	-0.1	-0.2	-0.1	0.1	-0.1	-0.3	-0.6
13	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.1	-0.3
14	0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
15	*0.9	0.5	0.5	0.6	0.3	0.3	0.6	0.3
16	*1.6	0.1	1.3	0.2	0.0	0.0	0.0	0.0

*Pressures influenced by tail water.

FIGURE 1





KEY MAP

10 0 10 20

SCALE OF MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MISSOURI BASIN PROJECT

FRENCHMAN-CAMBRIDGE UNIT – NEBRASKA

MEDICINE CREEK DAM

LOCATION MAP

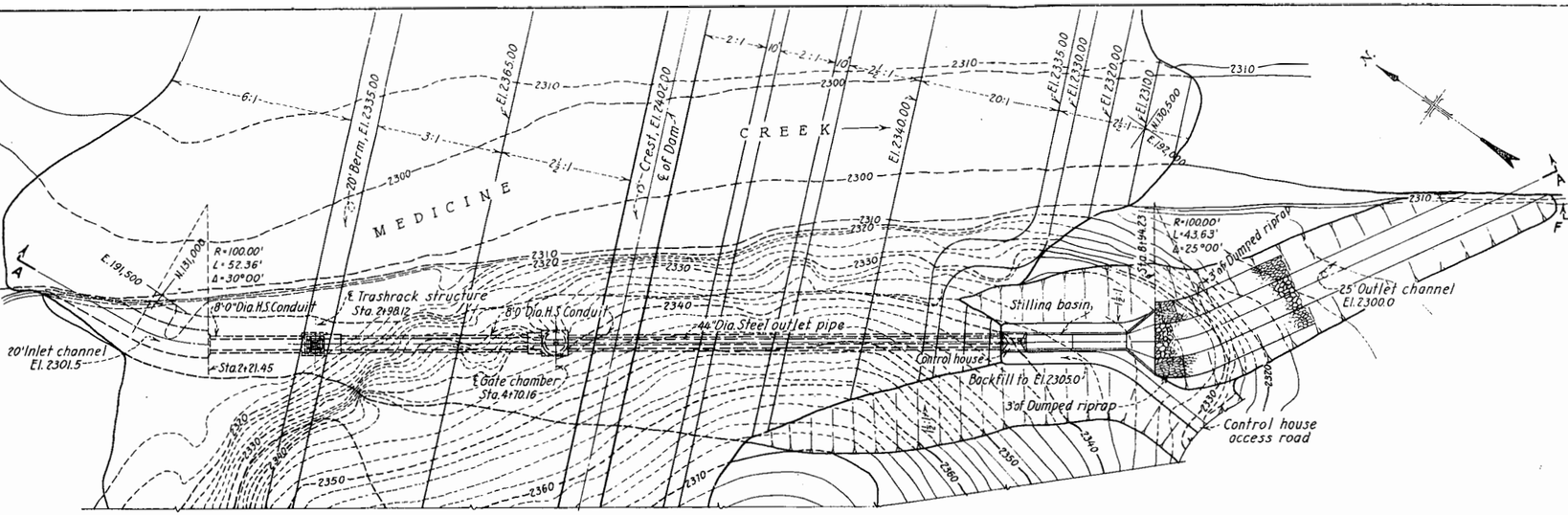
DRAWN: E.C.P. SUBMITTED: Julian B. Blunt

TRACED: B.F.W. RECOMMENDED: T. W. Blaney

CHECKED: W.H.C. Lowe APPROVED: Joseph Lawson
CHIEF ENGINEER

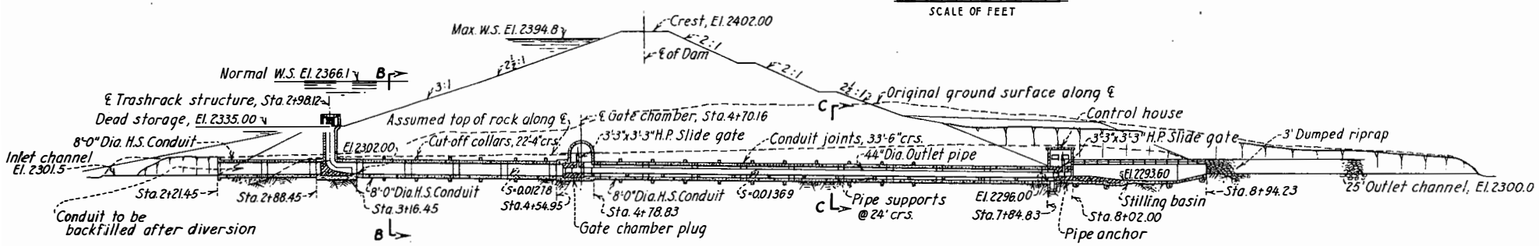
DENVER, COLORADO, SEPT. 16, 1947 | 328-D-265

FIGURE 2

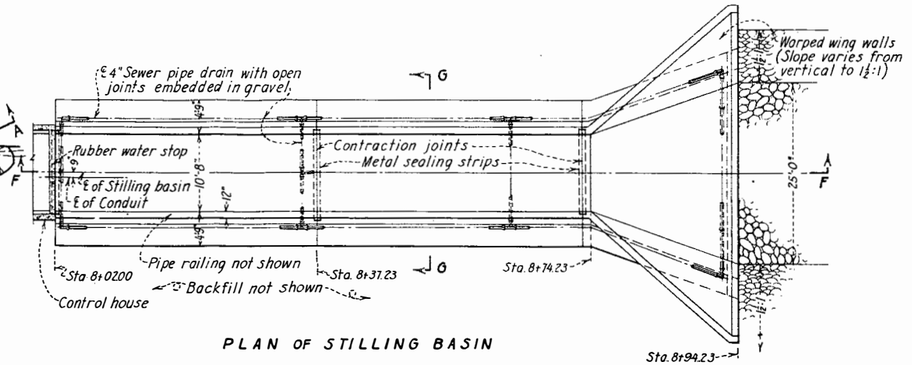


PLAN

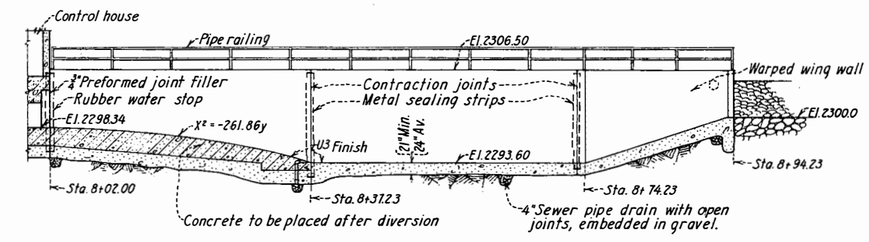
1 00 50 100
SCALE OF FEET



SECTION A-A ALONG ℄ OF OUTLET WORKS

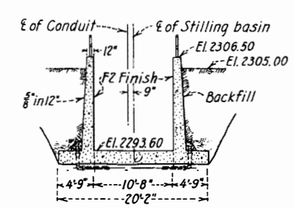


PLAN OF STILLING BASIN



SECTIONAL ELEVATION F-F OF STILLING BASIN

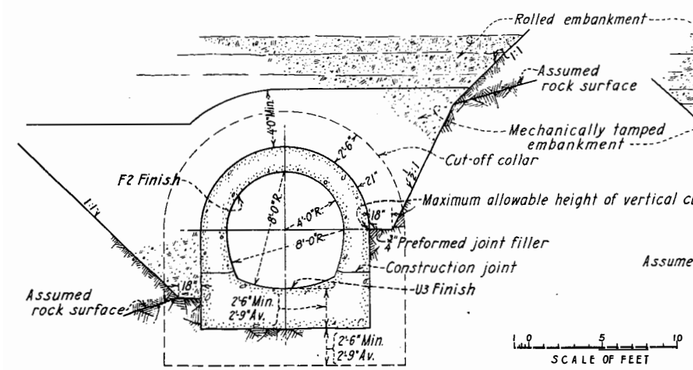
5 0 5 10 15 20
SCALE OF FEET



SECTION G-G
STILLING BASIN

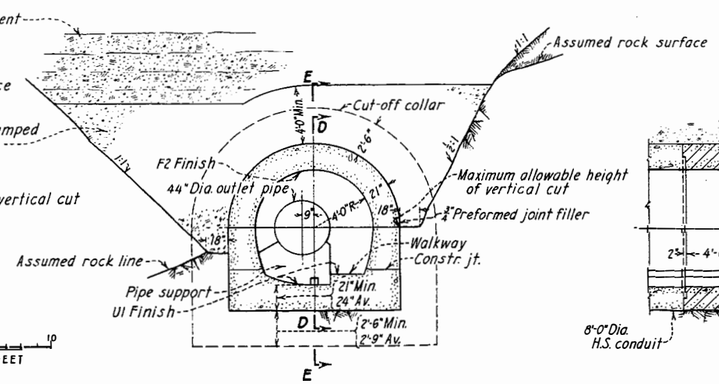
NOTES

The following items are not shown: reinforcement, electrical conduit and apparatus, control piping and apparatus, ventilating system, sump pump, miscellaneous piping and drains and resevoir level gage.

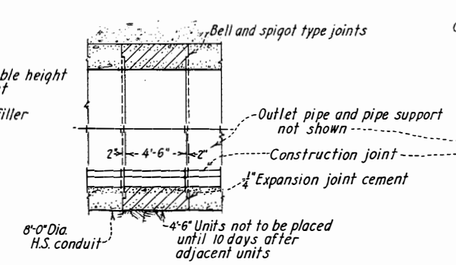


SCALE OF FEET

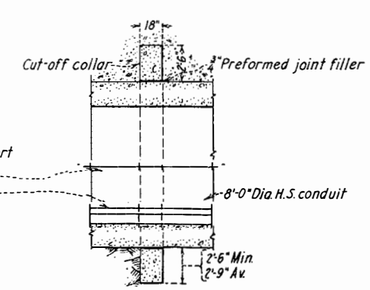
SECTION B-B
CONDUIT ABOVE GATECHAMBER



SECTION C-C
CONDUIT BELOW GATECHAMBER



SECTION D-D
TYPICAL CONDUIT JOINT



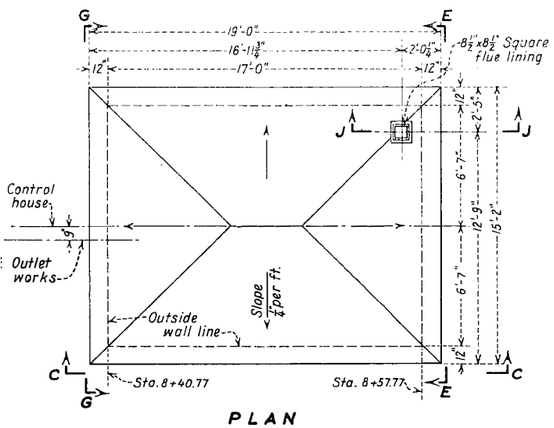
SECTION E-E
TYPICAL CUT-OFF COLLAR

328-D-425

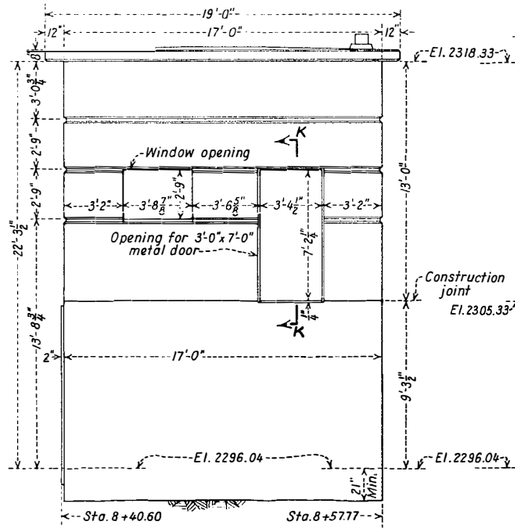
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
FRENCHMAN-CAMBRIDGE UNIT—NEBRASKA

MEDICINE CREEK DAM
OUTLET WORKS
PLAN AND SECTIONS

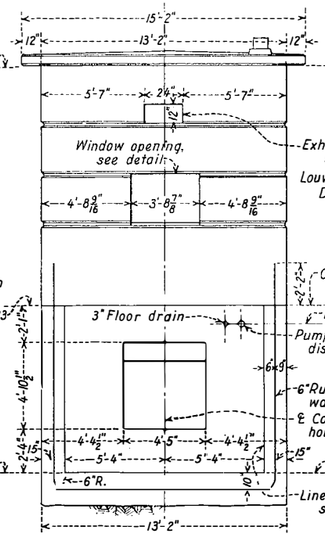
DRAWN E.O.R. SUBMITTED
TRACED L.C.R. RECOMMENDED
CHECKED APPROVED CHIEF ENGINEER
DENVER, COLORADO. SEPT. 16 1947 328-D-276



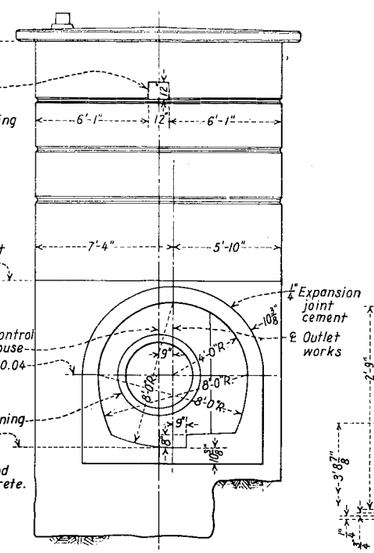
PLAN



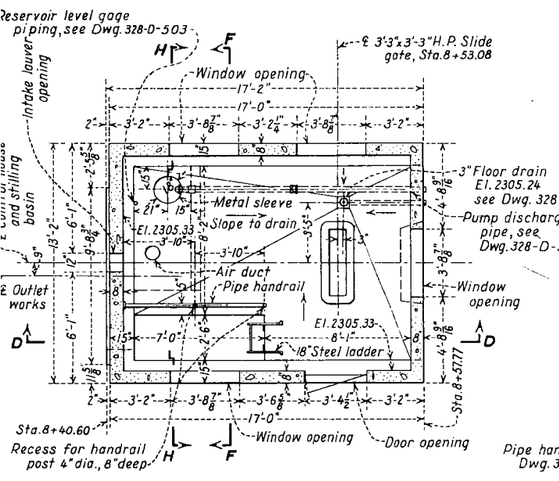
ELEVATION C-C



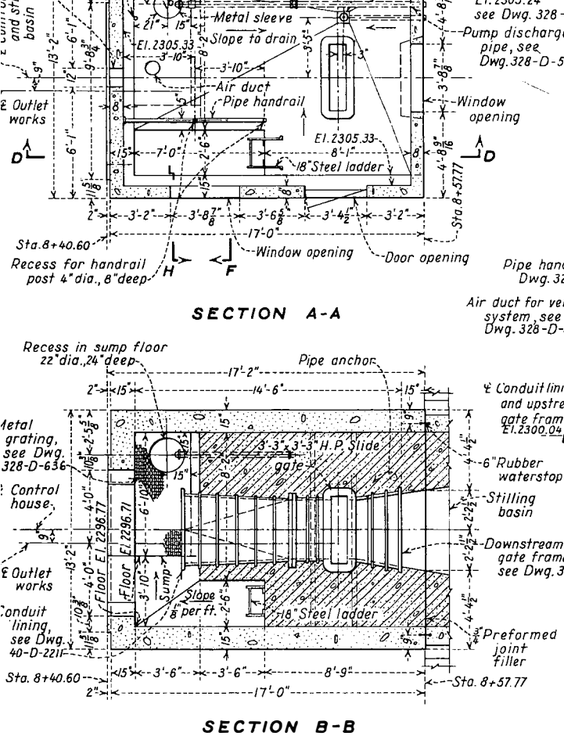
ELEVATION E-E



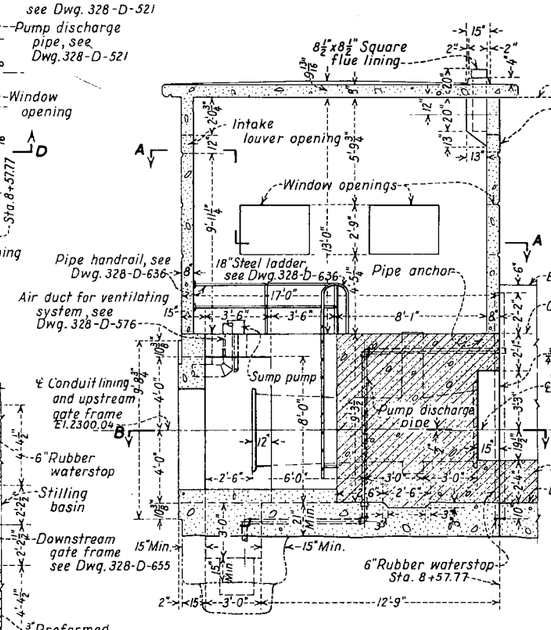
ELEVATION G-G



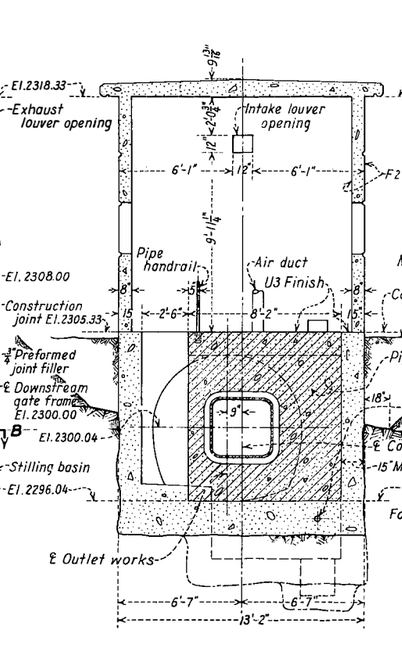
SECTION A-A



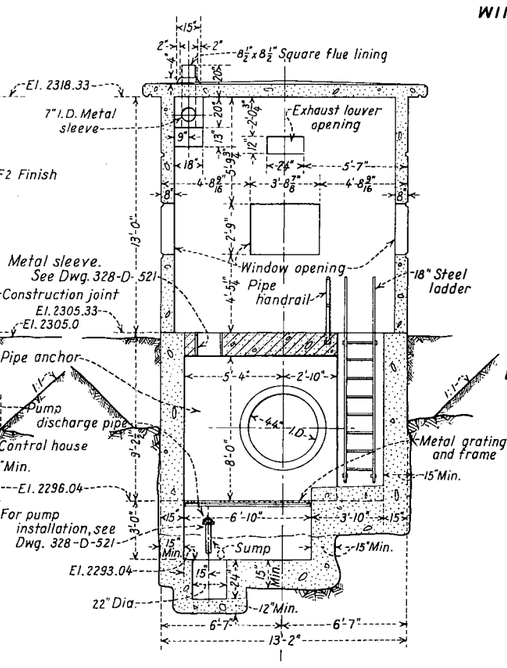
SECTION B-B



SECTION D-D

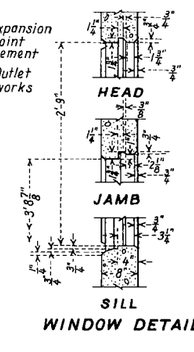


SECTION F-F

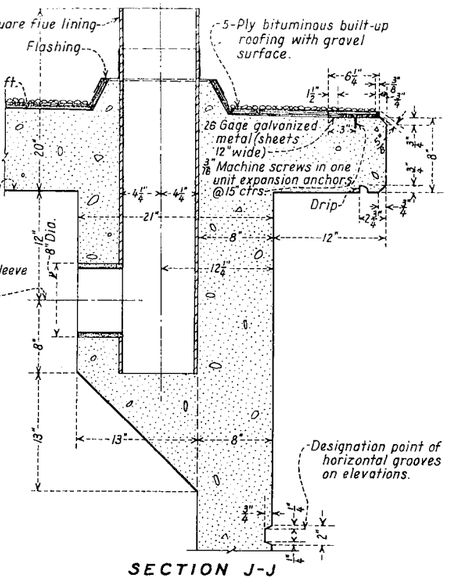


SECTION H-H

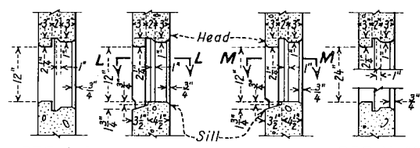
SCALE OF FEET



WINDOW DETAIL

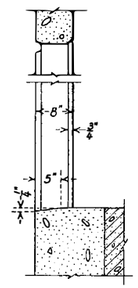


SECTION J-J



SEC. L-L INTAKE LOUVER OPENING DETAIL

SEC. M-M EXHAUST LOUVER OPENING DETAIL



SEC. K-K DOOR OPENING DETAIL

NOTES

Pipe anchor and structure above El. 2305.33 to be constructed after diversion.
Chamfer all exposed corners 3/4" unless otherwise noted.

REFERENCE DRAWINGS

PLAN, PROFILE AND SECTIONS OF CONDUIT	328-D-582
CONTROL HOUSE SUBSTRUCTURE - REINFORCEMENT	328-D-434
CONTROL HOUSE SUPERSTRUCTURE AND PIPE ANCHOR REINFORCEMENT	328-D-435
STILLING BASIN	328-D-436
3'-3"x3'-3" H.P. SLIDE GATE ASSEMBLY	40-D-2212
CONDUIT LINING	40-D-2211
RESERVOIR LEVEL GAGE PIPING	328-D-503
VENTILATING SYSTEM	328-D-576
SPECIAL PARTS 3'-3"x3'-3" H.P. SLIDE GATE	328-D-654, 655, 656, 657
METAL WORK	328-D-636
CONTROL HOUSE PIPING	328-D-521

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
FRENCHMAN-CAMBRIDGE UNIT-NEBRASKA

MEDICINE CREEK DAM

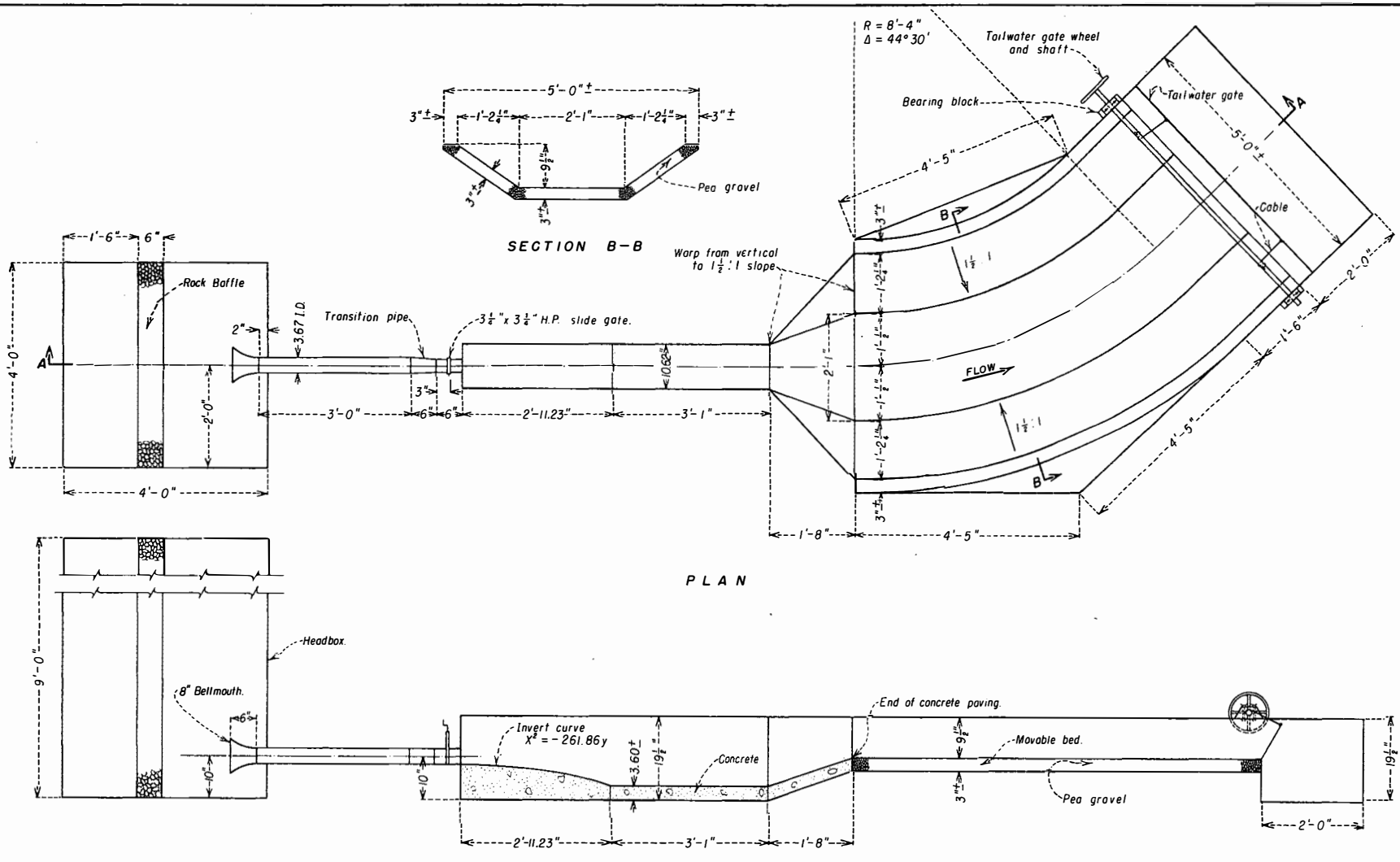
OUTLET WORKS CONTROL HOUSE

DRAWN E.G.B. SUBMITTED
TRACED H.O.B. RECOMMENDED
CHECKED E.K.R. APPROVED ASST. CHIEF ENGINEER

DENVER, COLORADO · FEB. 20, 1948

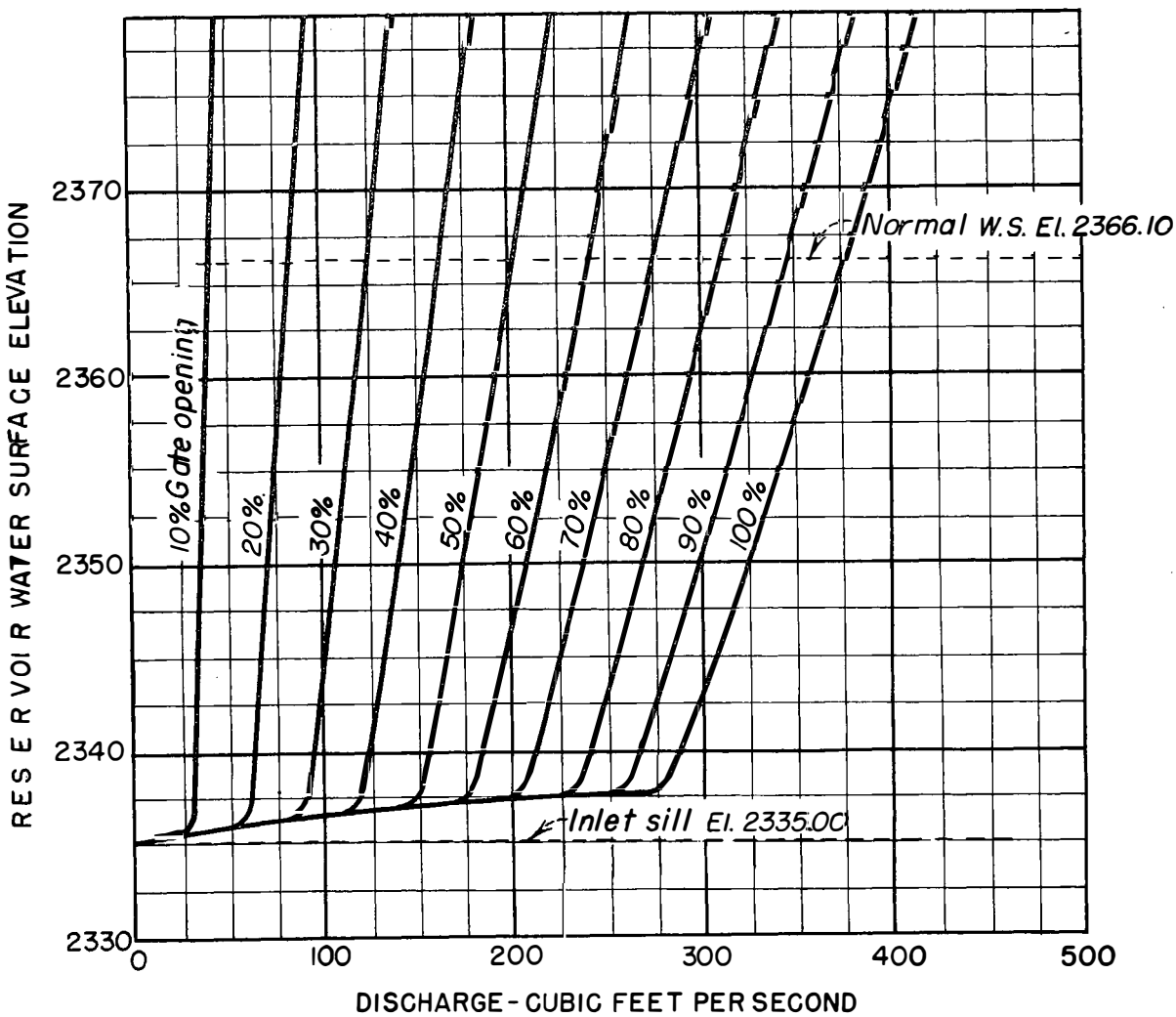
328-D-433

REVISED 5-27-48 FIELD REV. 8-11-50 E.G.B.



MEDICINE CREEK DAM
OUTLET WORKS
1 : 12 SCALE MODEL

FIGURE 4



NOTE

Any variation in discharge from these curves as determined by measurements of flow downstream from the outlet works should be reported to the Chief Engineer.

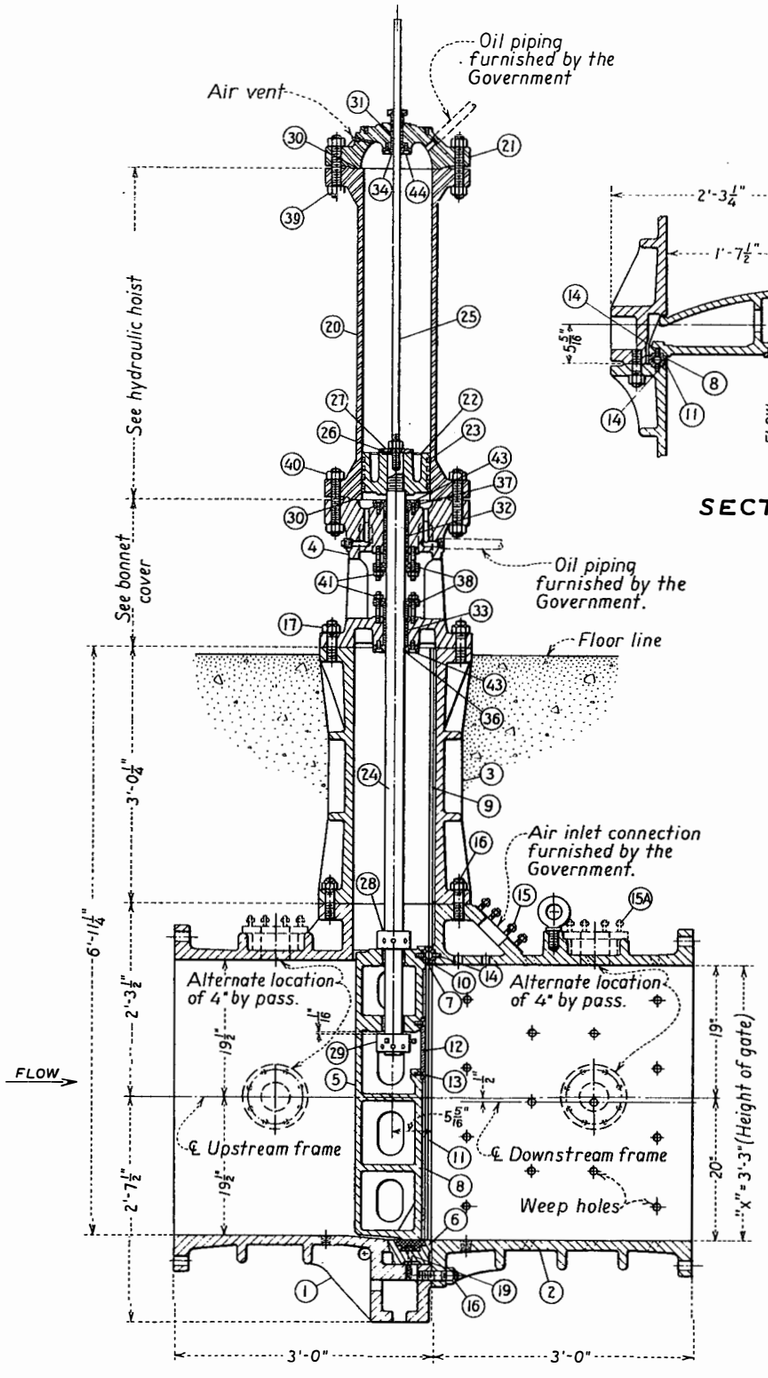
Regulating gate - 3'-3" X 3'-3" High pressure slide gate.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
FRENCHMAN-CAMBRIDGE DIV. NEBR.

MEDICINE CREEK DAM
OUTLET WORKS
DISCHARGE CURVES

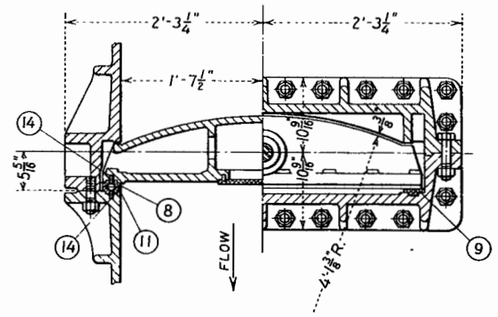
DRAWN C. E. H. SUBMITTED K. W. Tabor
TRACED P. W. S. RECOMMENDED Wilson B. Hunt
CHECKED H.E.M. APPROVED W. H. Walder
CHIEF DESGN. ENGR.

DENVER, COLORADO, JULY 20, 1950 | 328-D-1006

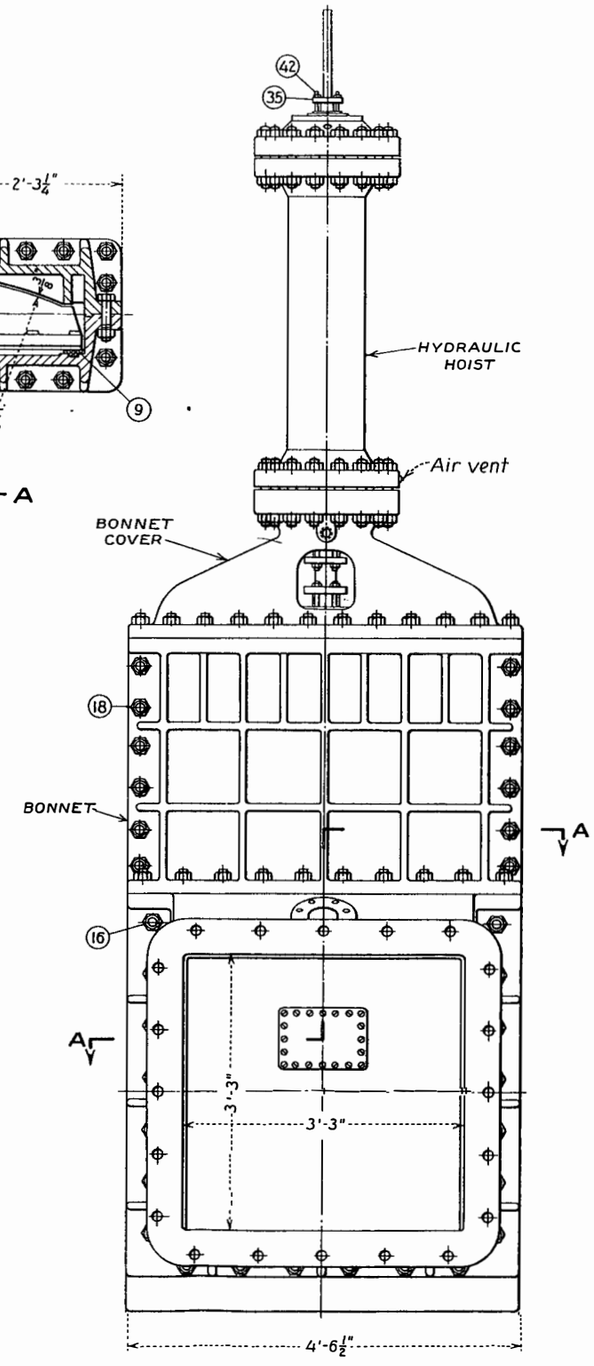


UPSTREAM FRAME DOWNSTREAM FRAME

Weep holes not required unless specified



SECTION A-A



LIST OF DRAWINGS

GATE

ASSEMBLY WITH HYDRAULIC HOIST 40-D 2212
UPSTREAM FRAME 40-D-2109
DOWNSTREAM FRAME 40-D-2110
LEAF AND SEATS 40-D-2111
BONNET, BOLTS AND LIST OF PARTS 40-D-2112
BONNET COVER ..... *

HOIST

CYLINDER, PISTON, STEM ..... *
PACKING, GLANDS, STUDS, SCREWS, LIST OF PARTS ..... *

CONDUIT

CONDUIT LINING ..... *
CONDUIT LINING TRANSITION ..... *

* See List of Drawings in Specifications for Number.

DESIGN DATA

Cast iron gate leaf-Class 25-maximum designed head 90 ft.
Cast iron gate leaf-Class 40-maximum designed head 140 ft.
Cast steel gate leaf-maximum designed head 250 ft.
Working pressure in cylinder 750 #/□". Designed pressure 1000 #/□".
Bronze gate seat-coefficient of friction = 0.6 (starting)
Concrete surrounding conduit and bonnet castings designed to carry all the load.

SHOP NOTE

With screws 14 and bronze seats 7, 8, 9, 10 and 11 in place, lock screws with 4 center punch scores in head. After this assembly, make final machining on sliding faces of bronze seats which must be in a true plane.

FIELD NOTE

When assembling for installation, the finished faces of all flanged joints are to be smoothly coated with a thin mixture of white lead and graphite and bolted together while this coating is plastic. The shanks and threads of all bolts and studs are to be similarly treated.

THIS DRAWING SUPERSEDES DRAWING 40-D-2108

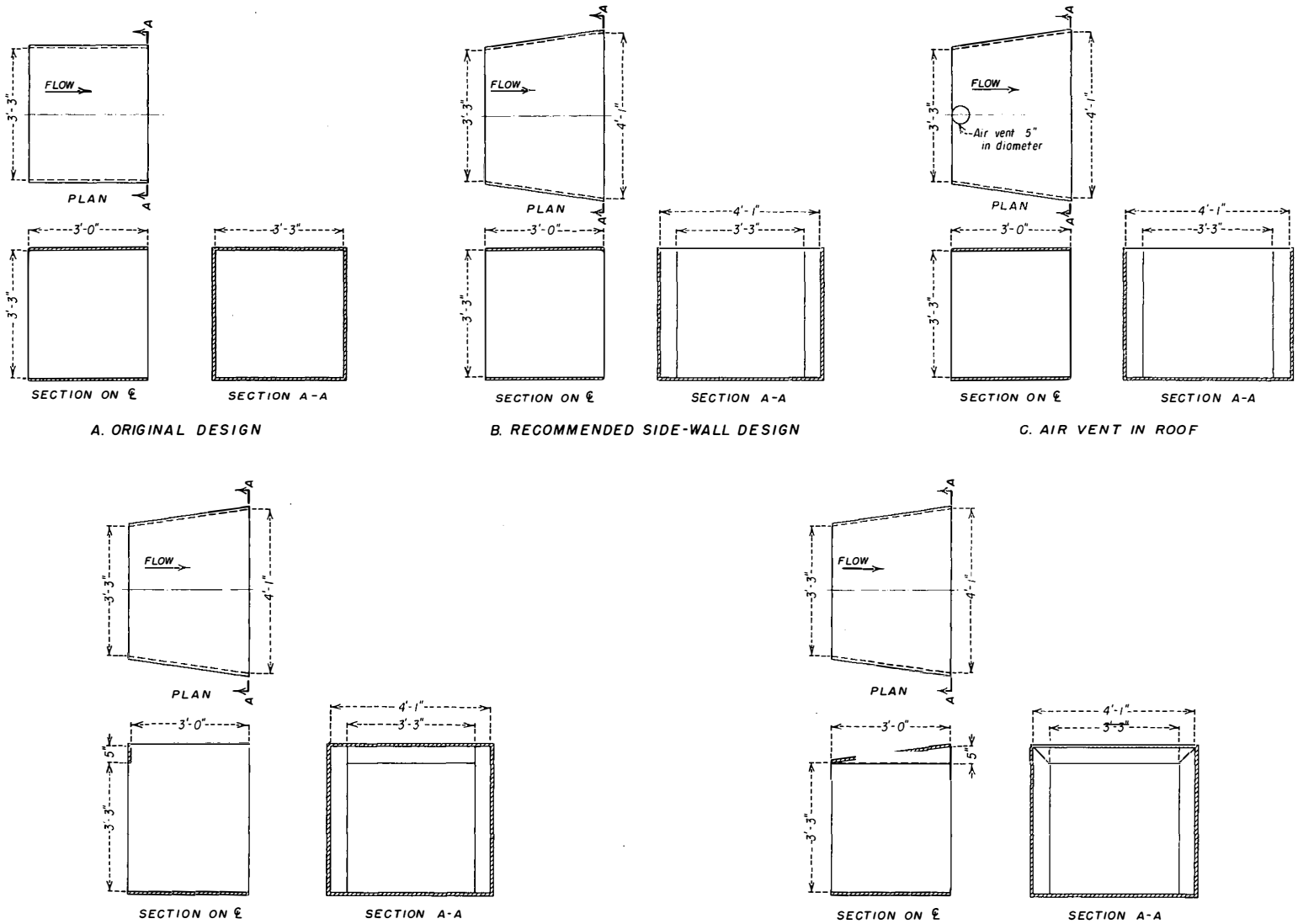
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE

3'-3" x 3'-3" HIGH PRESSURE GATE
ASSEMBLY WITH HYDRAULIC HOIST

REV. 12-21-40

DRAWN: J.M.L. SUBMITTED: G. H. Dyer
TRACED: J.D.-C.C.H. RECOMMENDED: J. L. Savage
CHECKED: E.G. R.D.H. APPROVED: A. F. Walter

28070 | DENVER, COLO. OCT 8, 1935 SHEET 1 OF 6 | 40-D-2212

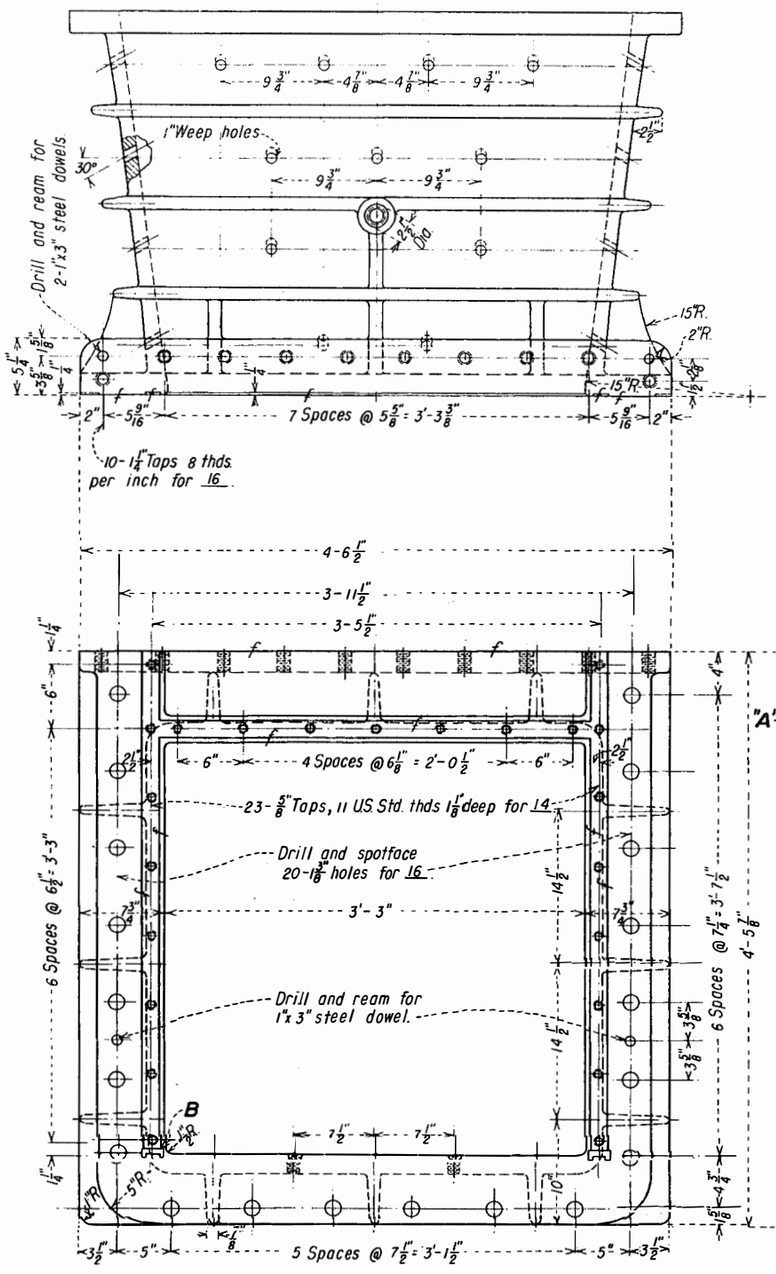


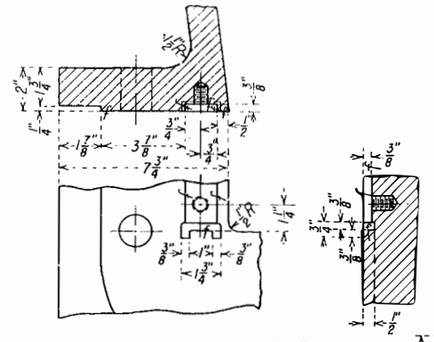
MEDICINE CREEK DAM OUTLET WORKS

MODIFICATIONS OF DOWNSTREAM GATE FRAME

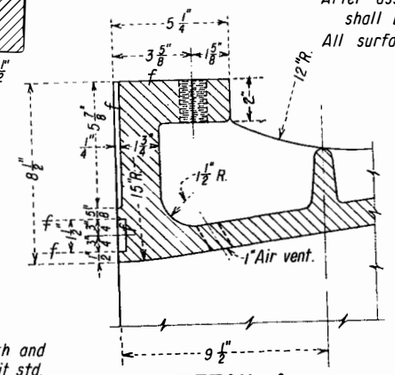
1 : 12 SCALE MODEL

FIGURE 7





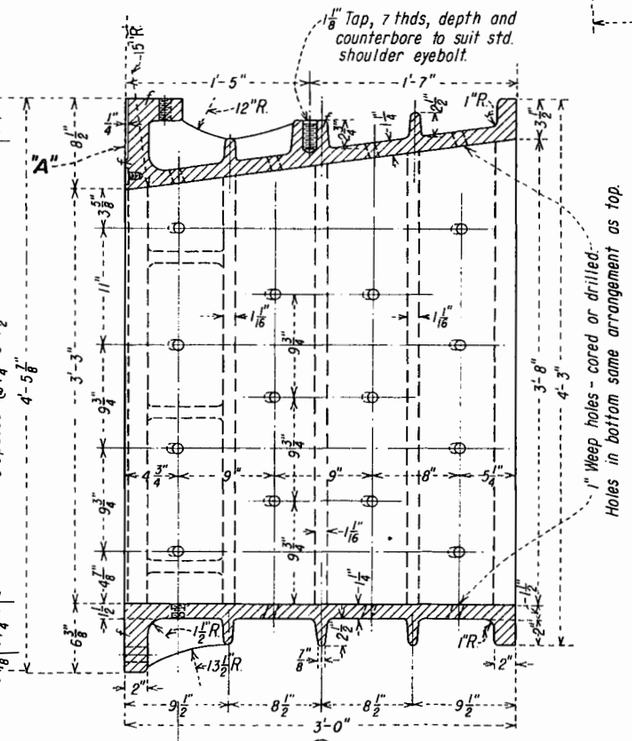
DETAIL "B"



DETAIL A

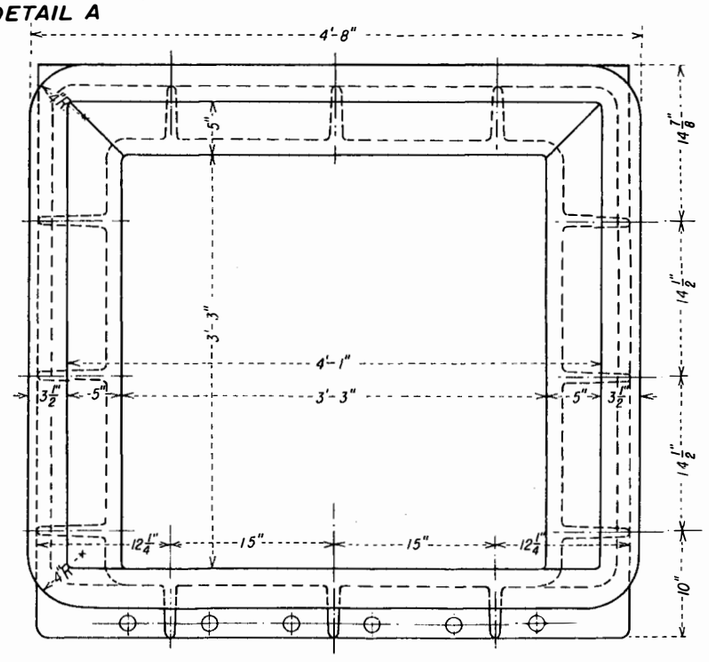
NOTES

For eyebolt requirements, see specifications.
Horizontal finished surface for bonnet connection to be finished with upstream and downstream frames bolted together, with dowels in place.
After assembly of bronze seats, cap screws which hold seats in place, shall be locked tight by center punch marks in heads of screws.
All surfaces marked "f" to be Average finish.



(2A)

DOWNSTREAM FRAME
CLASS 25
CAST IRON - ONE REQUIRED.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
FRENCHMAN CAMBRIDGE UNIT - NEBRASKA

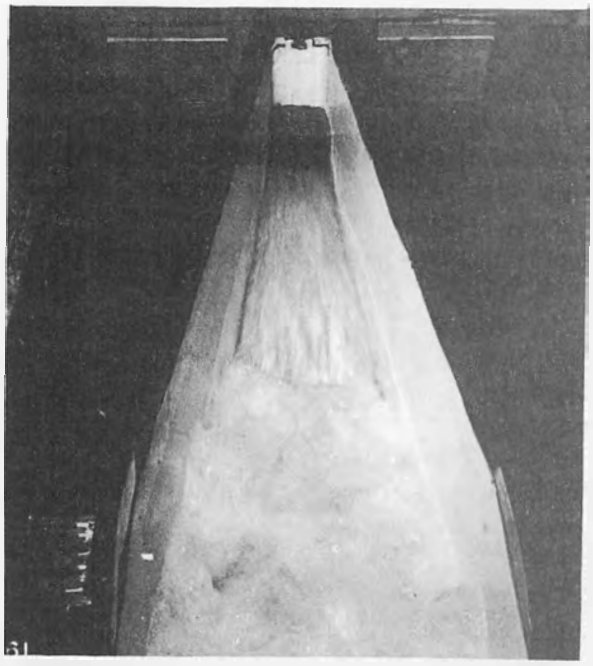
MEDICINE CREEK DAM
OUTLET WORKS
3'-3" x 3'-3" HIGH PRESSURE GATE
DOWNSTREAM FRAME

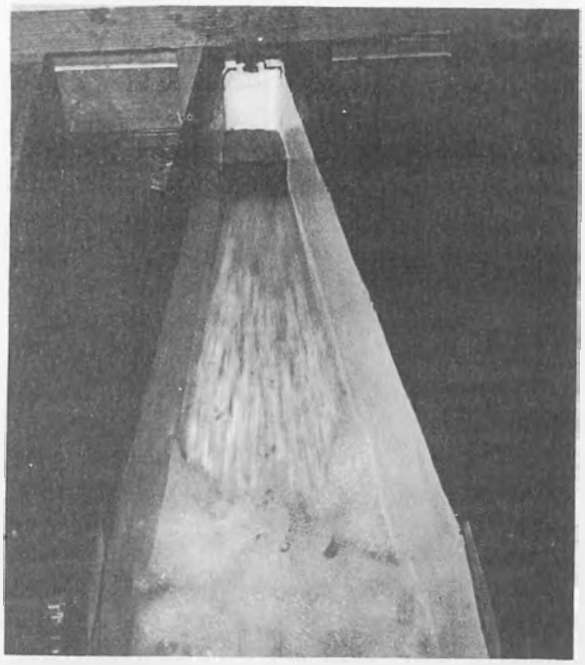
DRAWN W.N.C. SUBMITTED H.E. Shed
TRACED D.A.N. RECOMMENDED A. H. Richardson
CHECKED A.N.M. APPROVED D. N. McClellan CHIEF ENGINEER

DENVER, COLORADO, AUG. 18, 1948 SHEET 3 OF 6 | 328-D-655

Figure 9

A. Discharge = 150 second-feet. Note flow disturbance downstream from gate leaf.





Discharge = 434 second-feet

B. Slide gate fully open

C. Gate closed slightly to pinch jet.

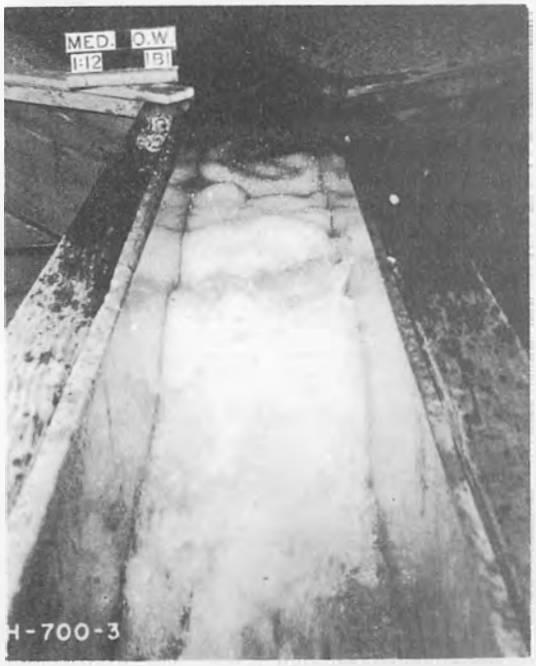
MEDICINE CREEK OUTLET WORKS
Flow Through Downstream Gate Frame
1:12 Scale Model

The Model

MEDICINE CREEK OUTLET WORKS
Preliminary basin
1:12 Scale Model

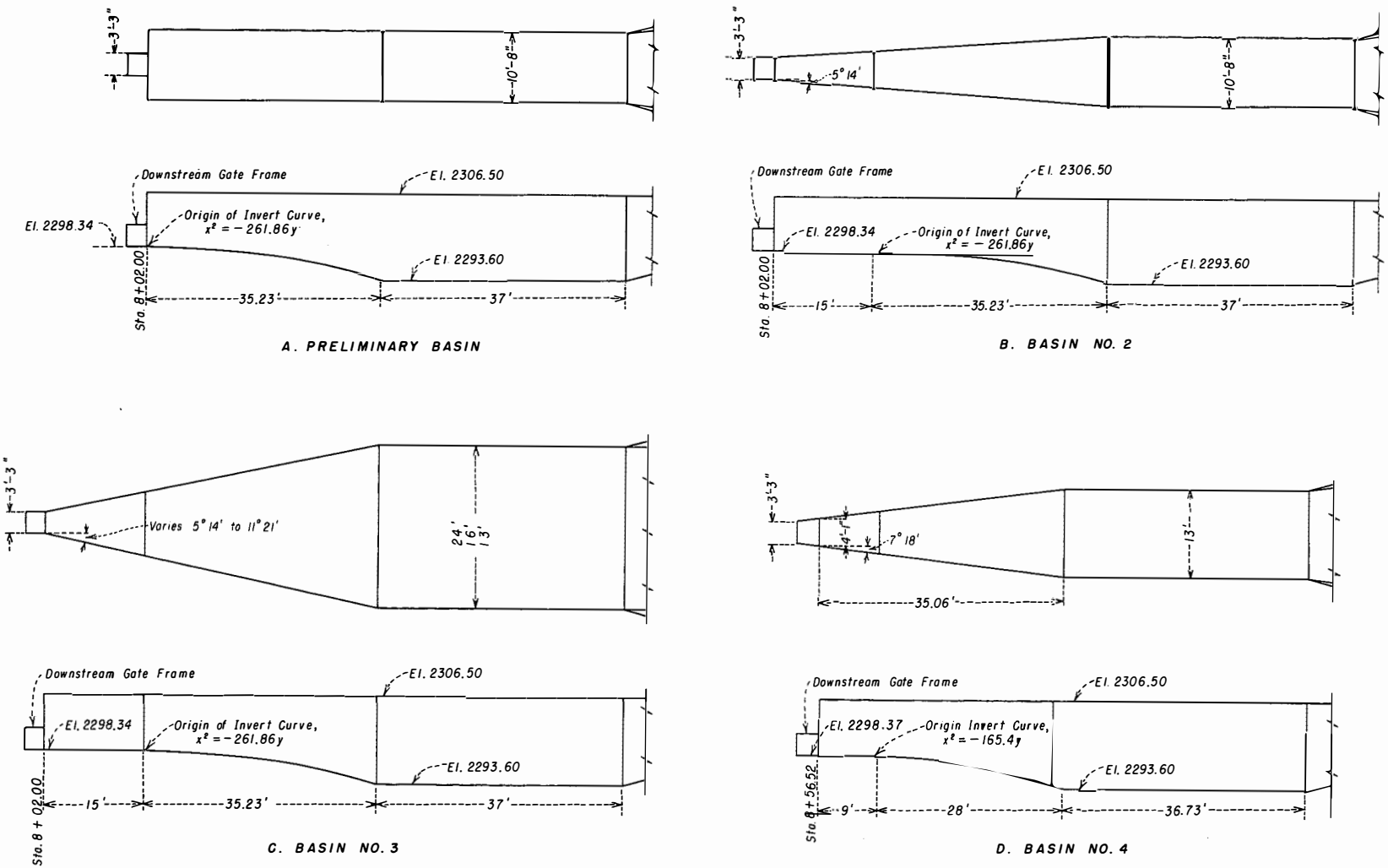
Figure 11

A. Discharge = 434 second-feet



B. Discharge = 150 second-feet

MEDICINE CREEK OUTLET WORKS
Preliminary basin
1:12 Scale Model

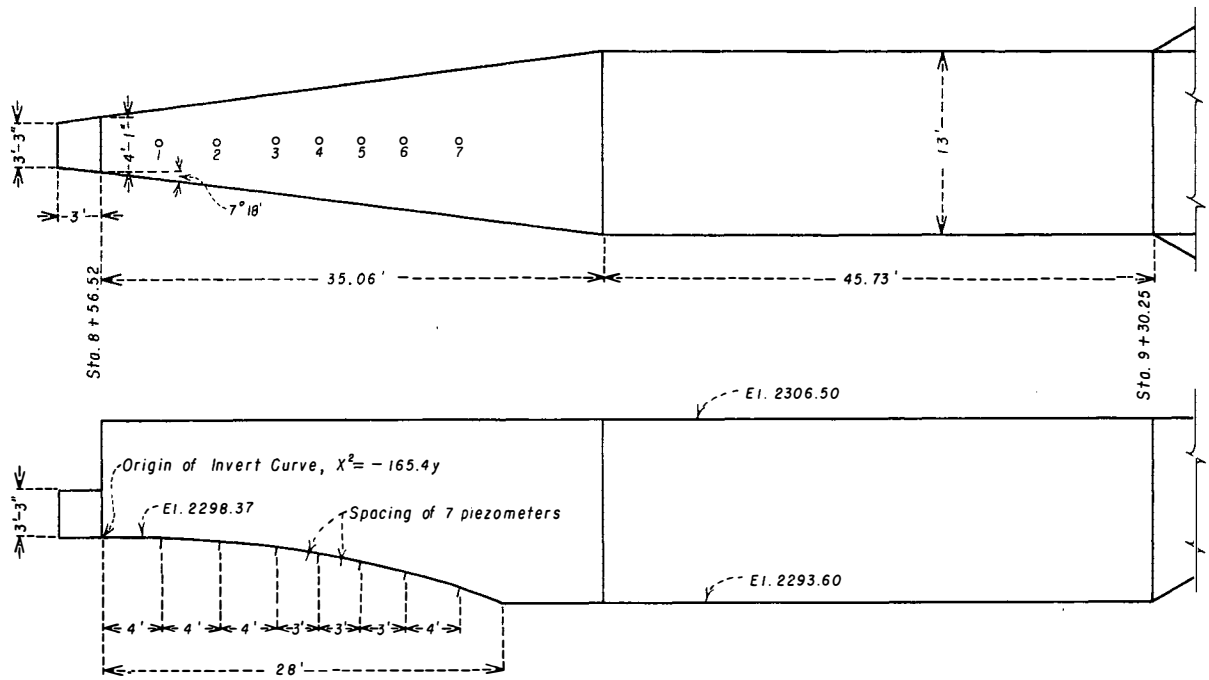


MEDICINE CREEK DAM — OUTLET WORKS

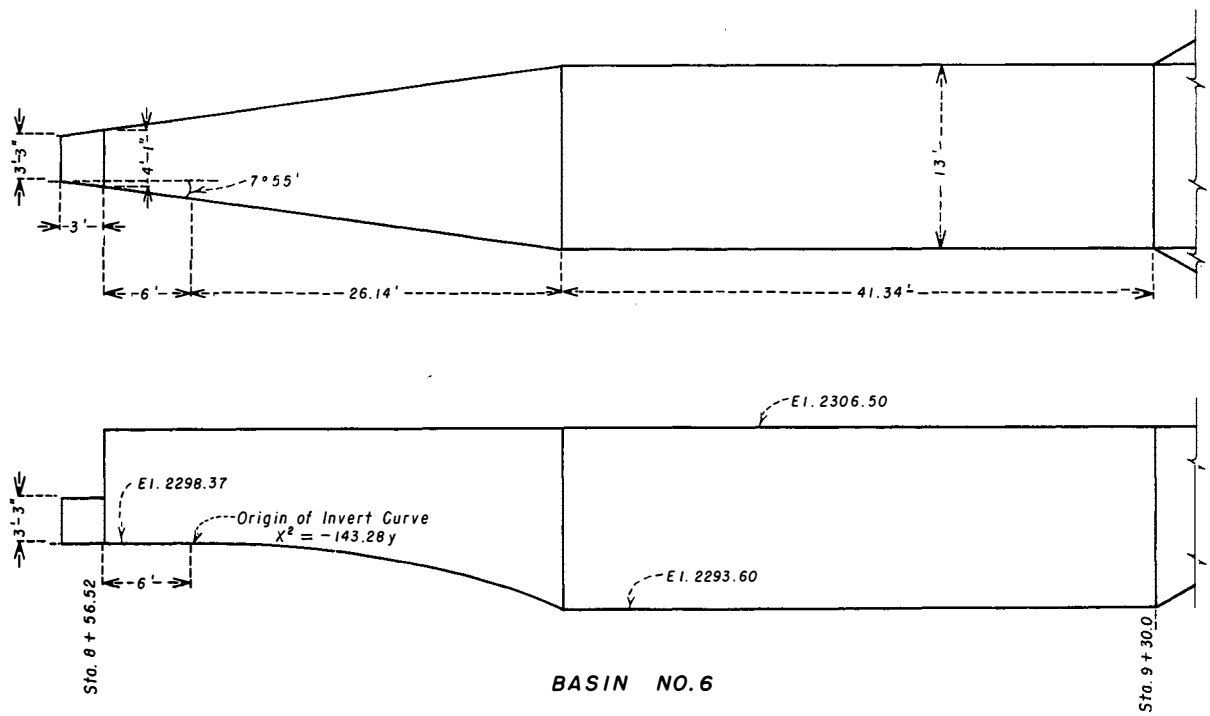
STILLING-BASIN DESIGNS

1:12 SCALE MODEL

FIGURE 12



BASIN NO. 5



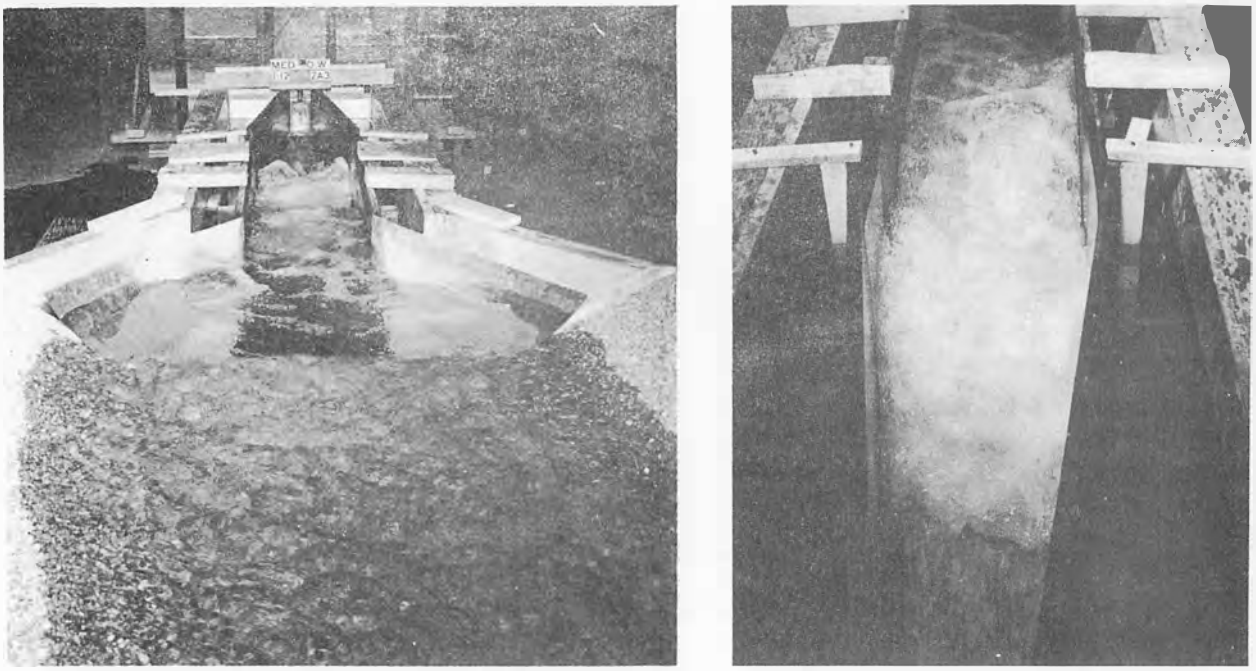
BASIN NO. 6

MEDICINE CREEK DAM — OUTLET WORKS

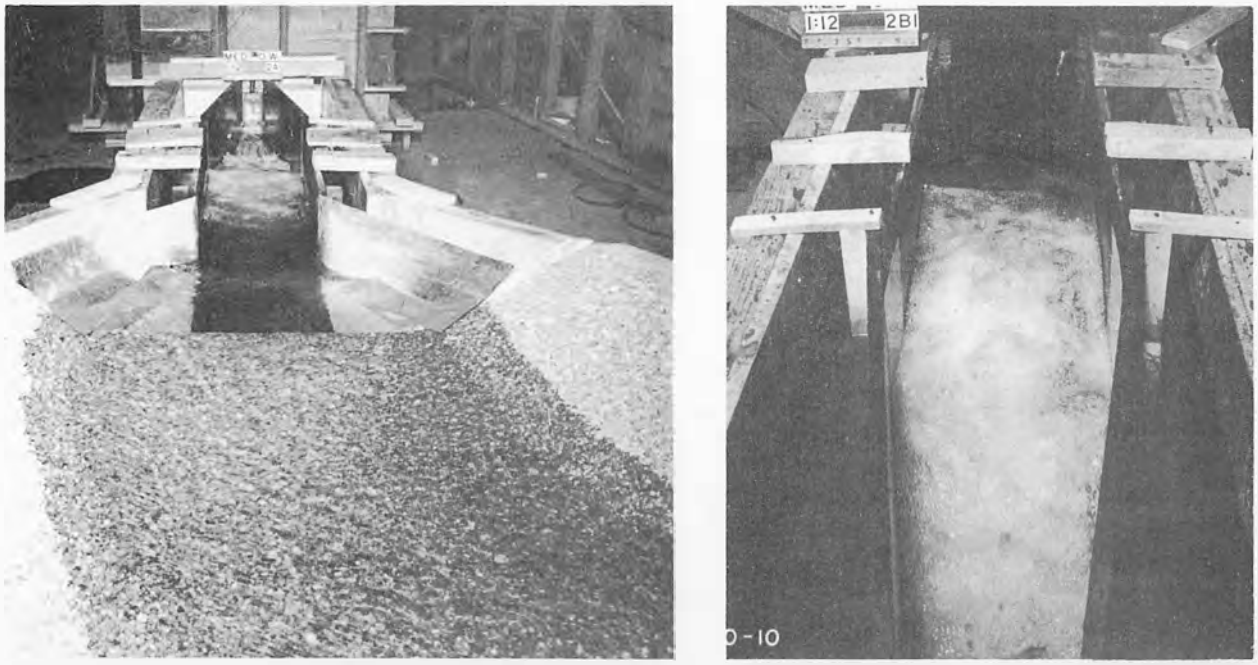
STILLING-BASIN DESIGNS

1:12 SCALE MODEL

Figure 14

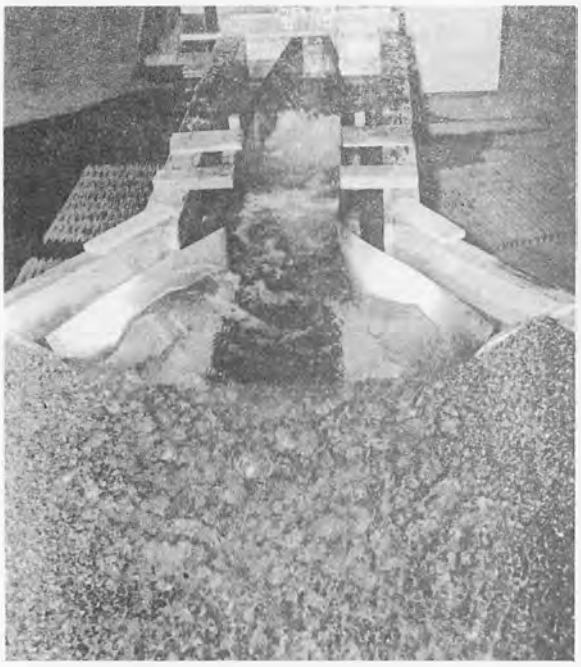


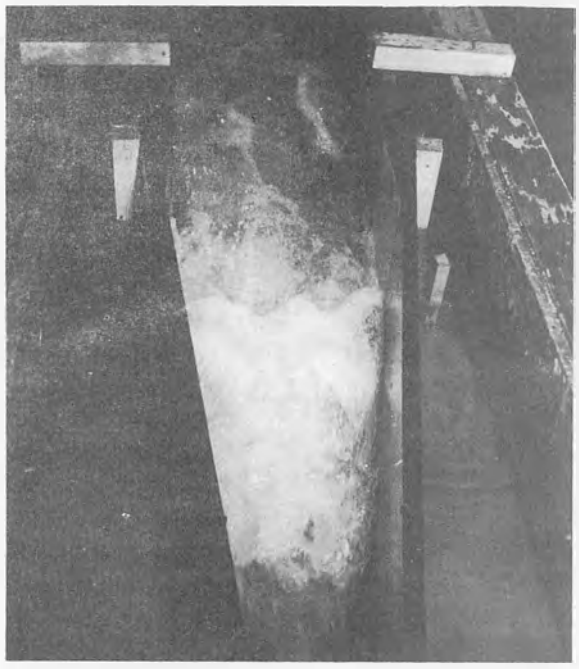
A. Discharge = 434 second-feet



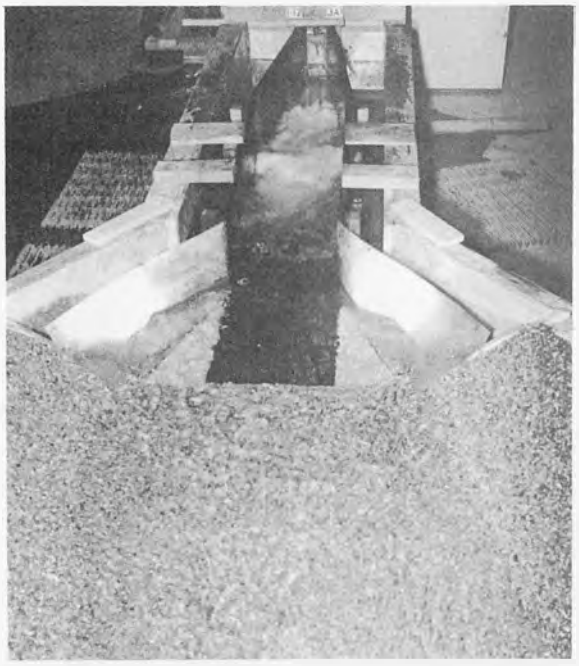
B. Discharge = 150 second-feet

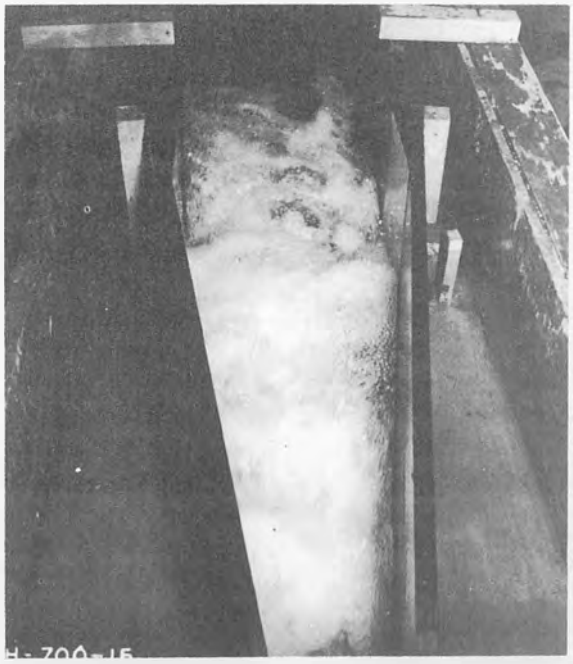
MEDICINE CREEK OUTLET WORKS
Basin No. 4
1:12 Scale Model





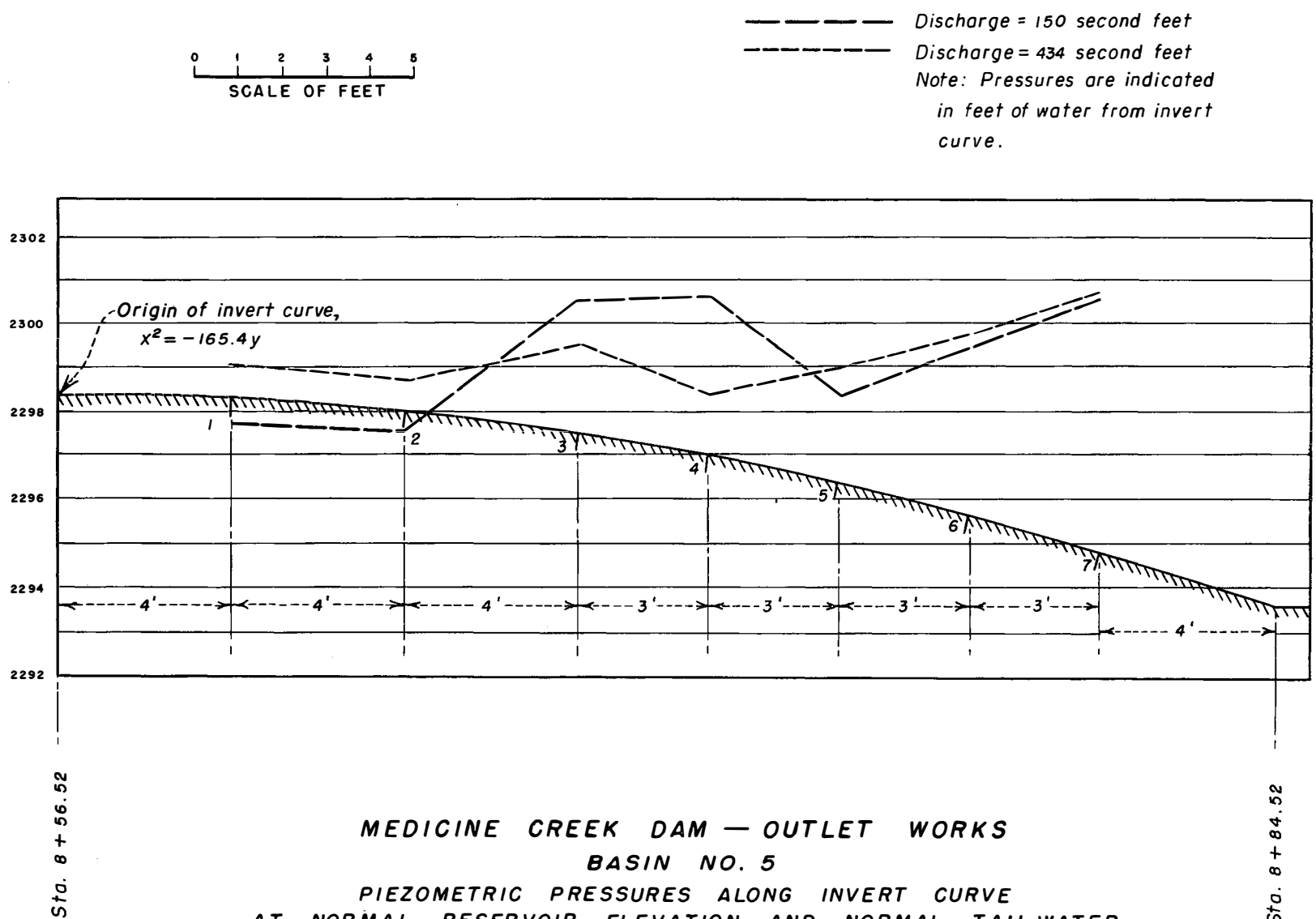
A. Discharge = 434 second-feet





B. Discharge = 150 second-feet

MEDICINE CREEK OUTLET WORKS
Basin No. 5
1:12 Scale Model



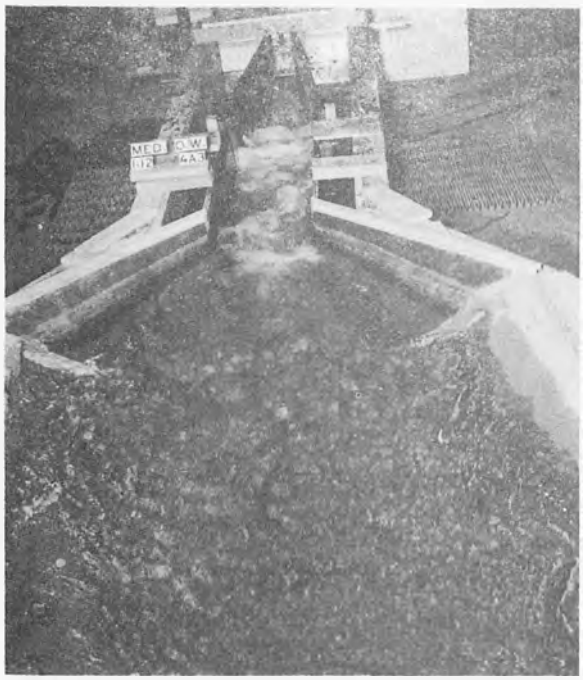
MEDICINE CREEK DAM — OUTLET WORKS

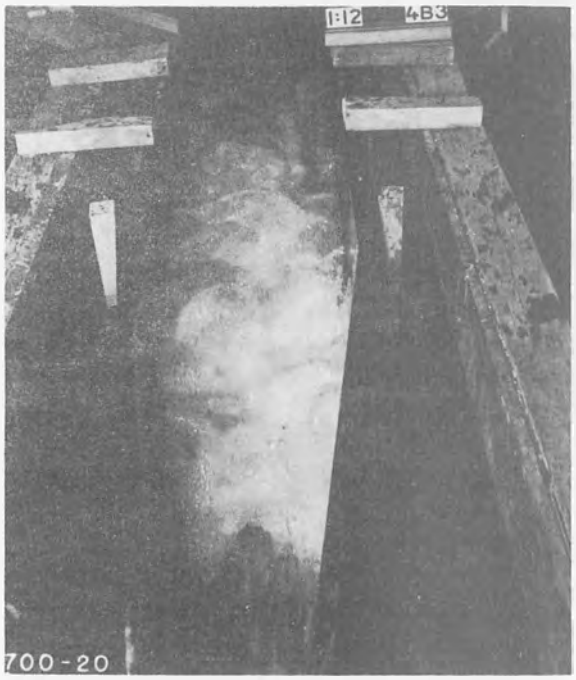
BASIN NO. 5

PIEZOMETRIC PRESSURES ALONG INVERT CURVE
AT NORMAL RESERVOIR ELEVATION AND NORMAL TAILWATER

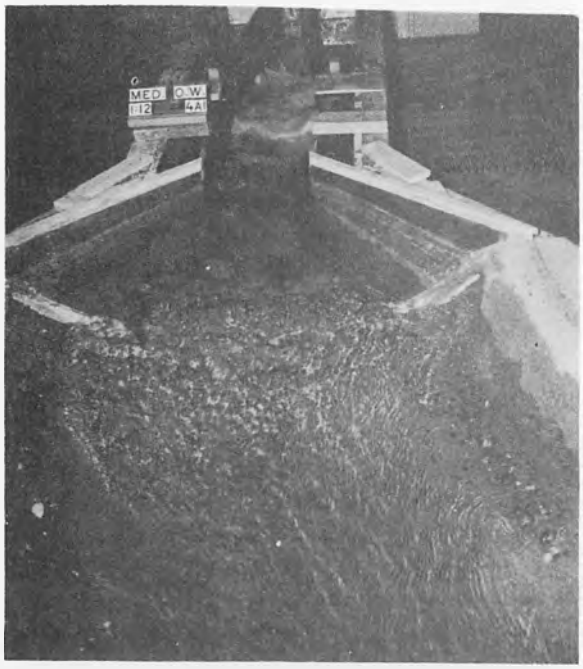
1 : 12 SCALE MODEL

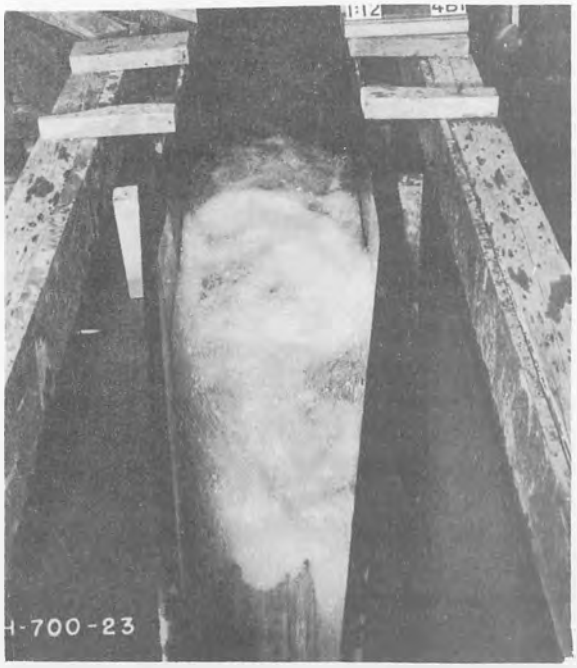
FIGURE 16





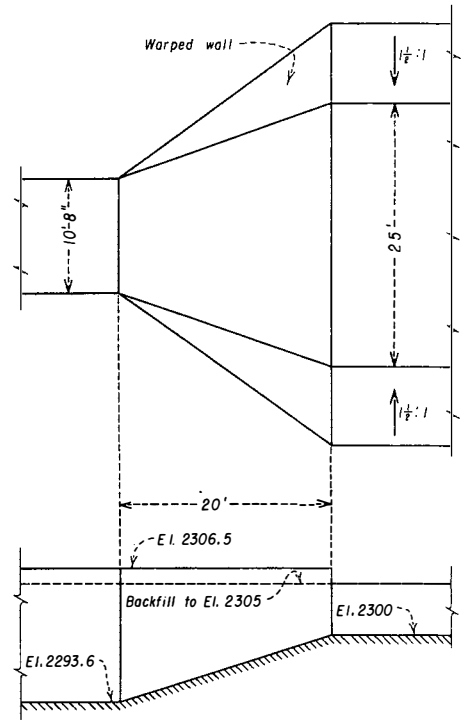
A. Discharge = 434 second-feet



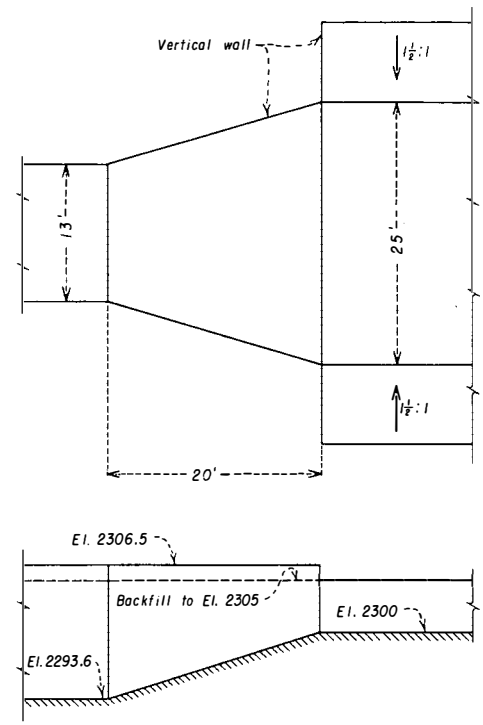


B. Discharge = 150 second-feet

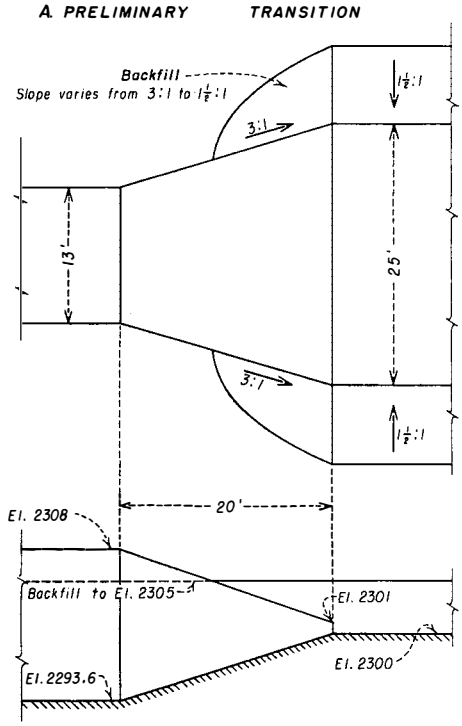
MEDICINE CREEK OUTLET WORKS
Basin No. 6
1:12 Scale Model



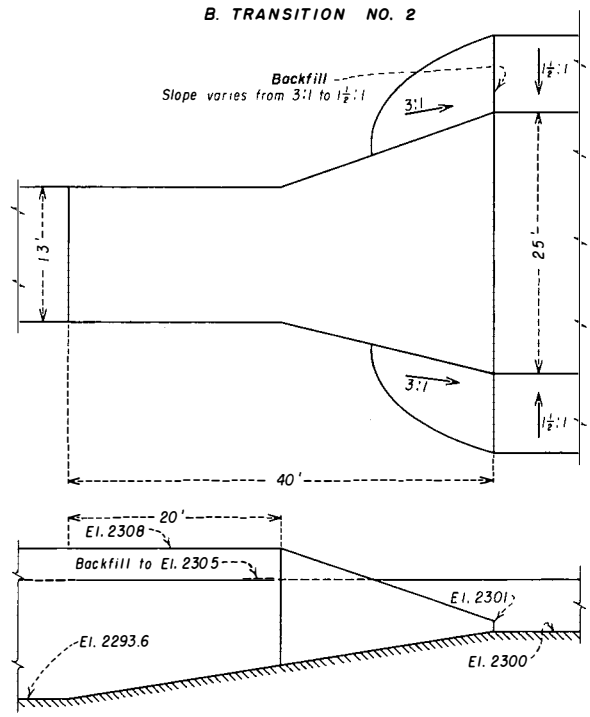
A. PRELIMINARY TRANSITION



B. TRANSITION NO. 2

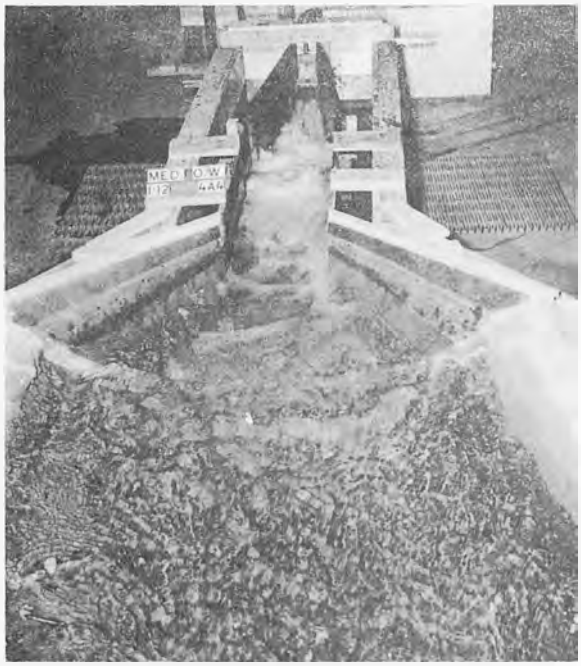


C. TRANSITION NO. 3
(RECOMMENDED)



D. TRANSITION NO. 4

MEDICINE CREEK DAM — OUTLET WORKS
TRANSITION DESIGNS
1:12 SCALE MODEL



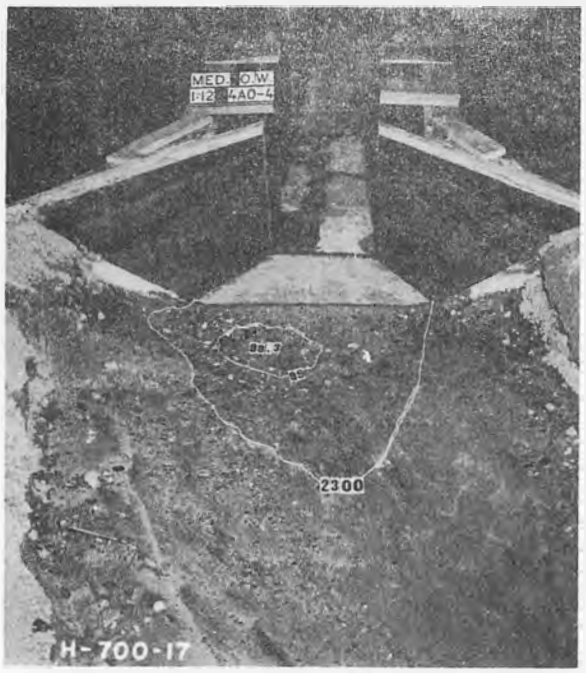
A. Preliminary Transition

B. Transition No. 2

C. Recommended Transition

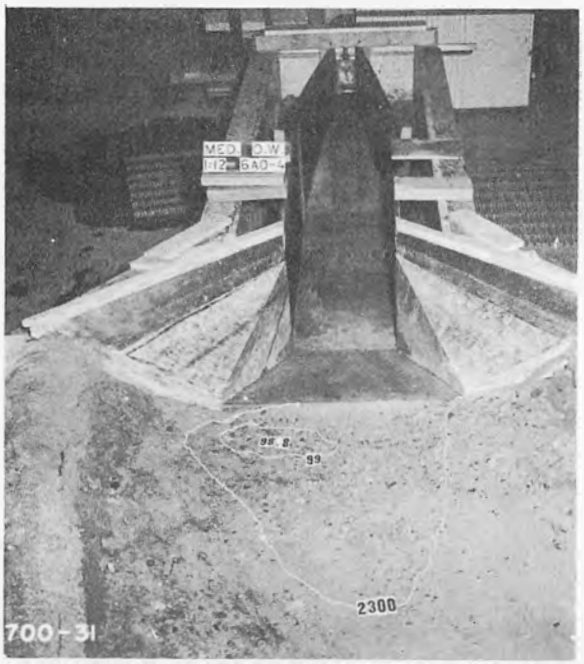
D. Transition No. 4

MEDICINE CREEK OUTLET WORKS
Discharge of 300 second-feet through various transitions
1:12 Scale Model

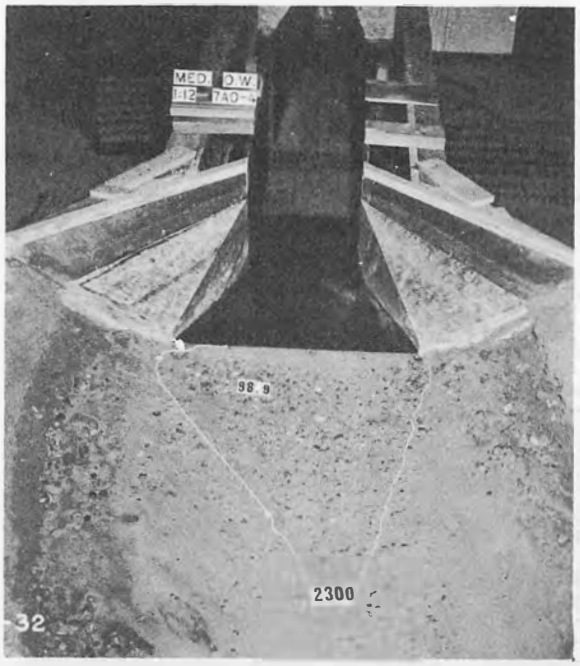


A. Preliminary Transition

B. Transition No. 2

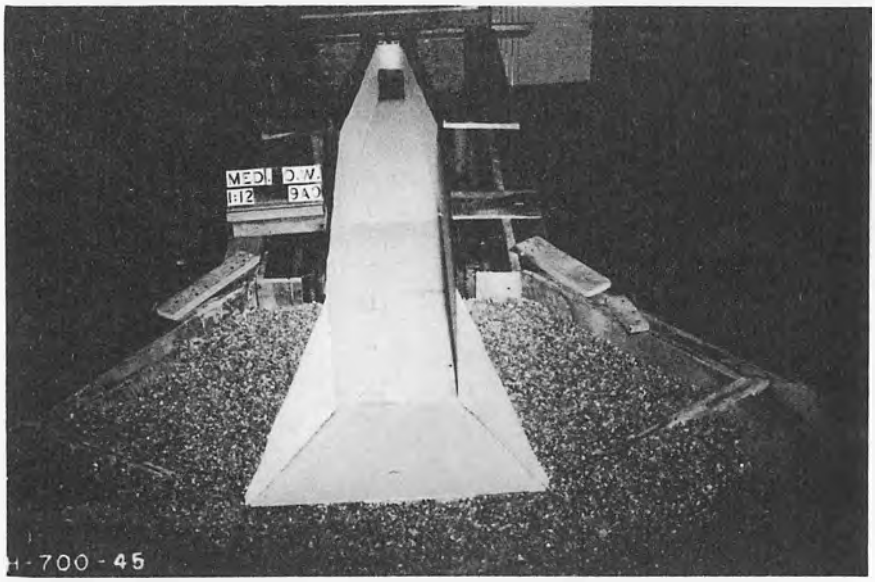


C. Recommended Transition



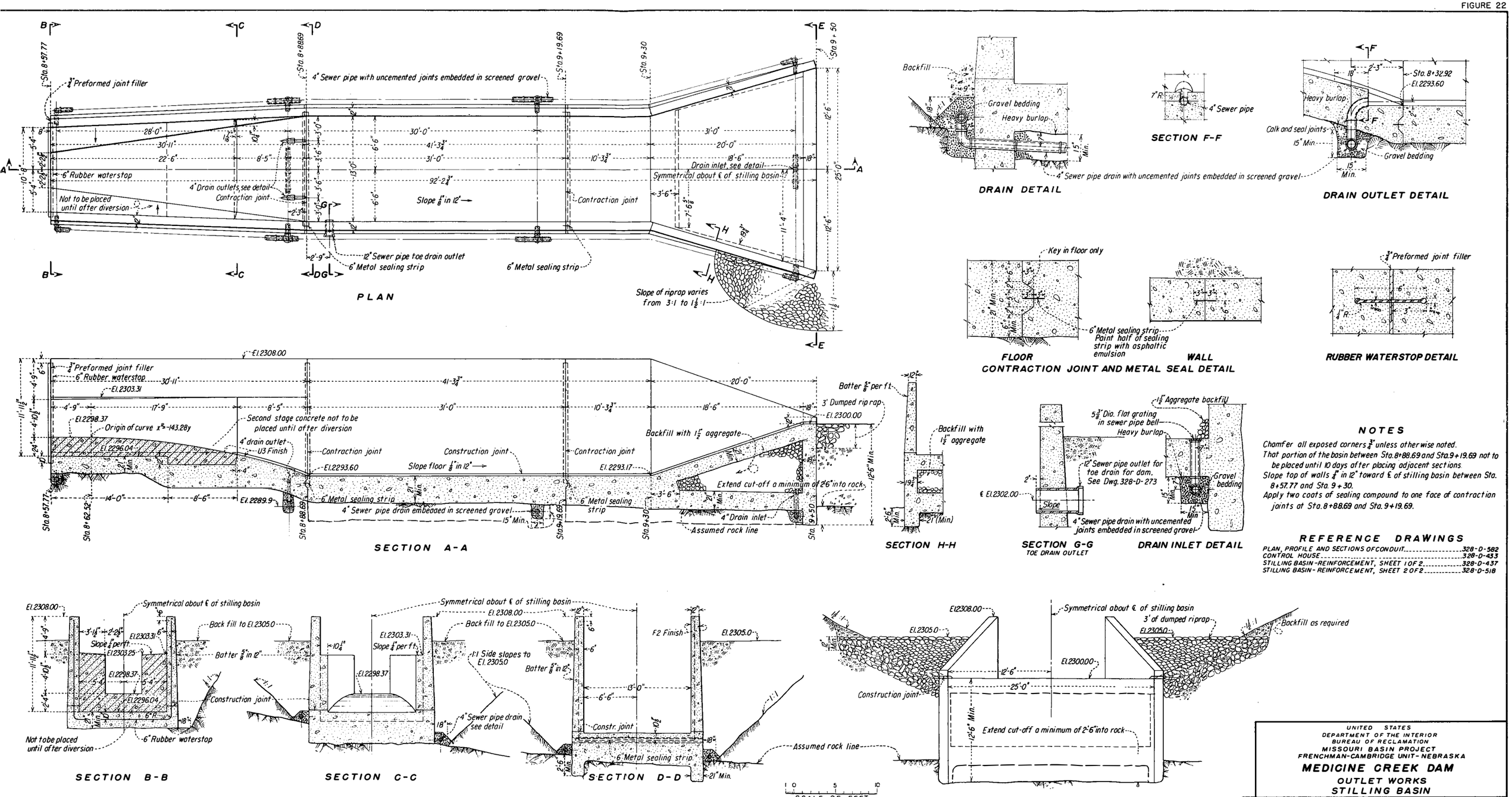
D. Transition No. 4

MEDICINE CREEK OUTLET WORKS
Scour after 3.2 hours (prototype) operation
1:12 Scale Model



The Model

MEDICINE CREEK OUTLET WORKS
Recommended Basin
1:12 Scale Model



NOTES

Chamfer all exposed corners 3/4" unless otherwise noted.
That portion of the basin between Sta. 8+88.69 and Sta. 9+19.69 not to be placed until 10 days after placing adjacent sections.
Slope top of walls 1/8" in 12" toward ℄ of stilling basin between Sta. 8+57.77 and Sta. 9+30.
Apply two coats of sealing compound to one face of contraction joints at Sta. 8+88.69 and Sta. 9+19.69.

REFERENCE DRAWINGS

PLAN, PROFILE AND SECTIONS OF CONDUIT	328-D-582
CONTROL HOUSE	328-D-433
STILLING BASIN-REINFORCEMENT, SHEET 1 OF 2	328-D-437
STILLING BASIN-REINFORCEMENT, SHEET 2 OF 2	328-D-518

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
FRENCHMAN-CAMBRIDGE UNIT-NEBRASKA

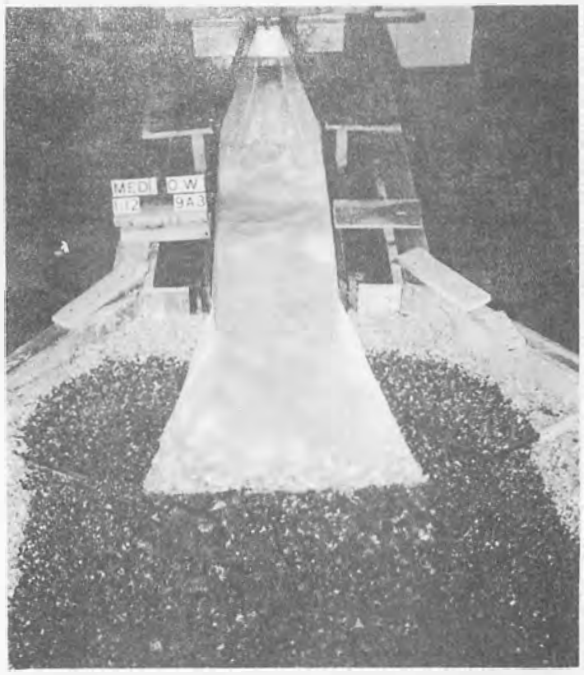
MEDICINE CREEK DAM

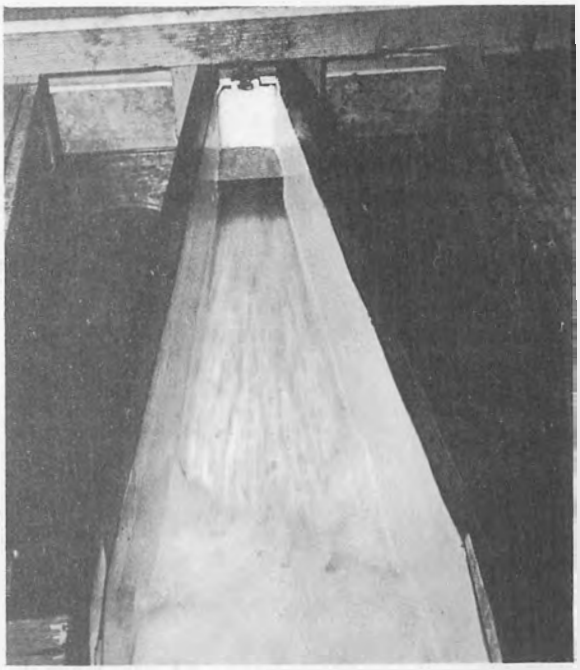
OUTLET WORKS
STILLING BASIN

DRAWN E.G.R. SUBMITTED H.W. Talbot
TRACED W.L.W.P. RECOMMENDED T.W. Keenan
CHECKED E.G.R. APPROVED W.H. Nalder, ASST. CHIEF ENGINEER

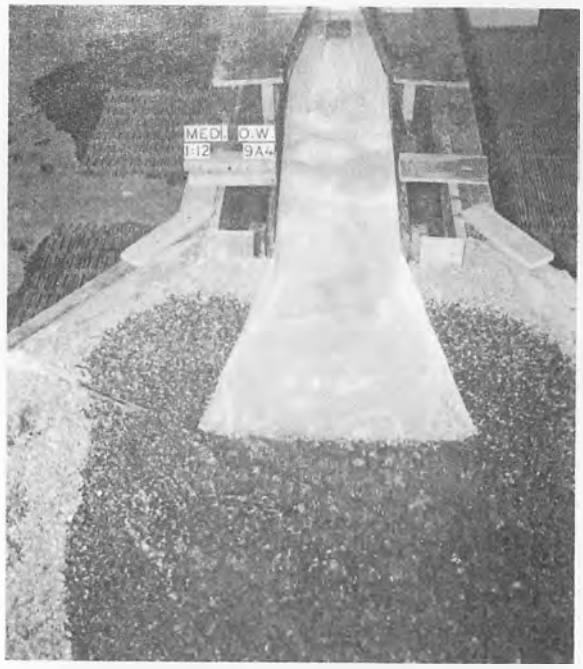
DENVER, COLORADO. FEB. 20, 1948 328-D-436

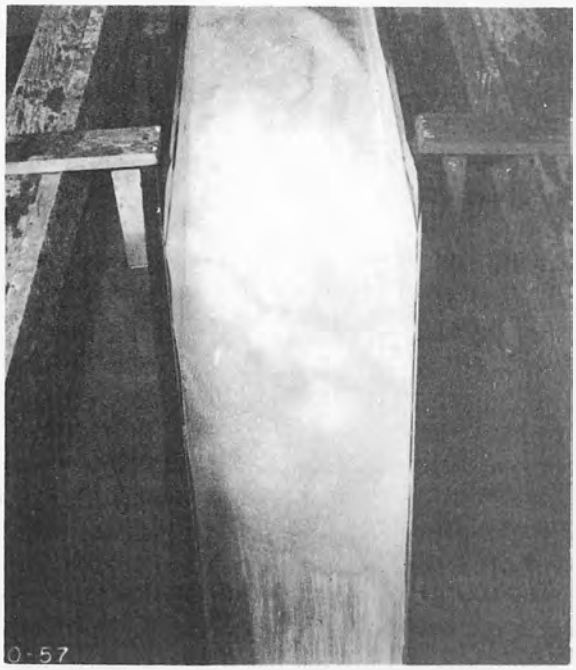
FIELD REVISED 8-1-50

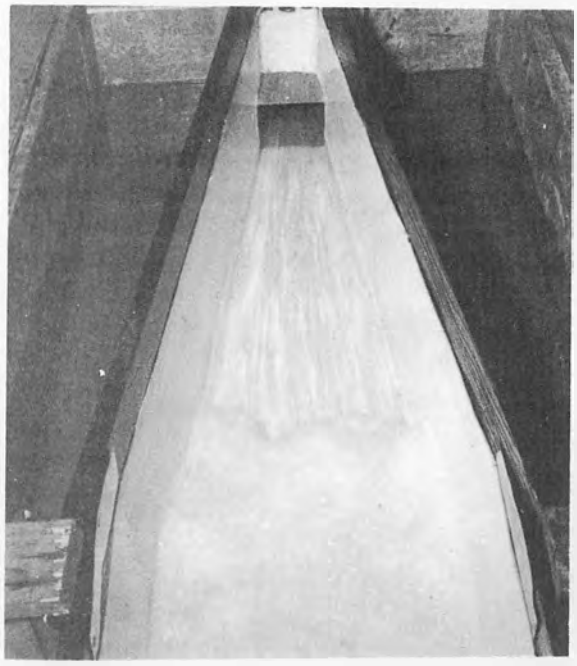




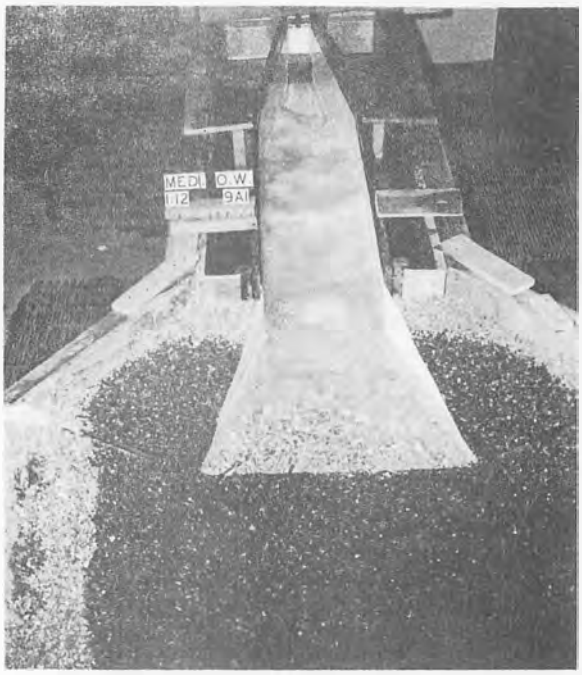
MEDICINE CREEK OUTLET WORKS
Recommended Basin
Discharge = 434 second-feet
Normal Reservoir Elevation - 2366.1 feet
1:12 Scale Model

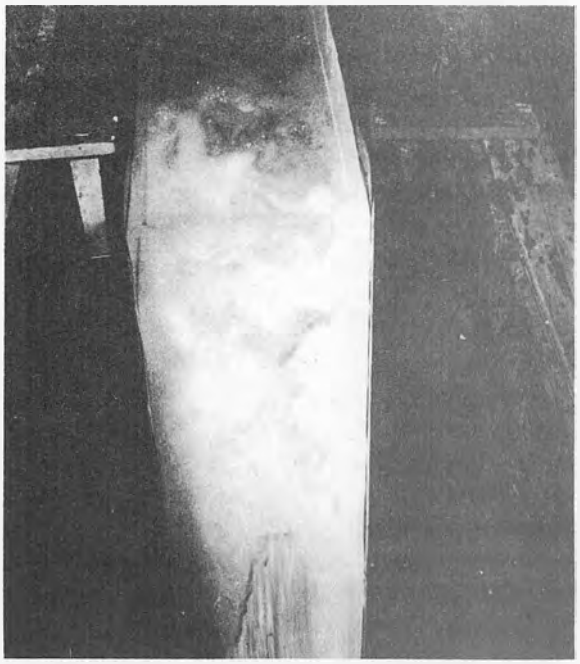


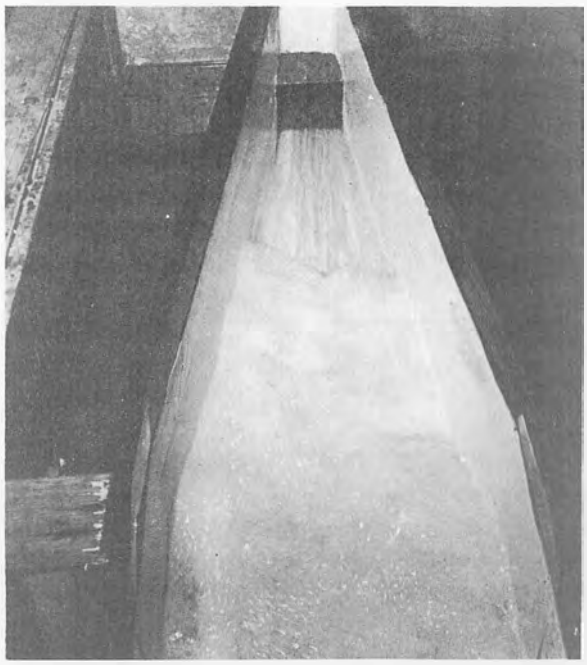




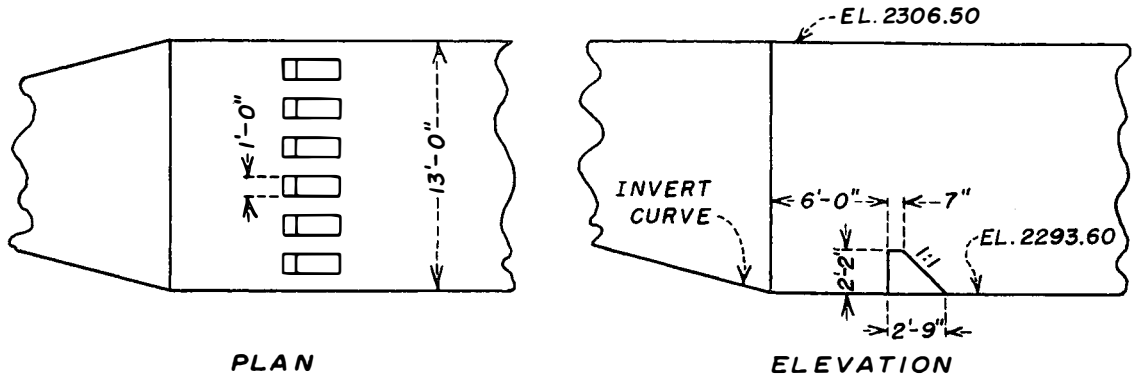
MEDICINE CREEK OUTLET WORKS
Recommended Basin
Discharge = 300 second-feet
Normal Reservoir Elevation - 2366.1 feet
1:12 Scale Model



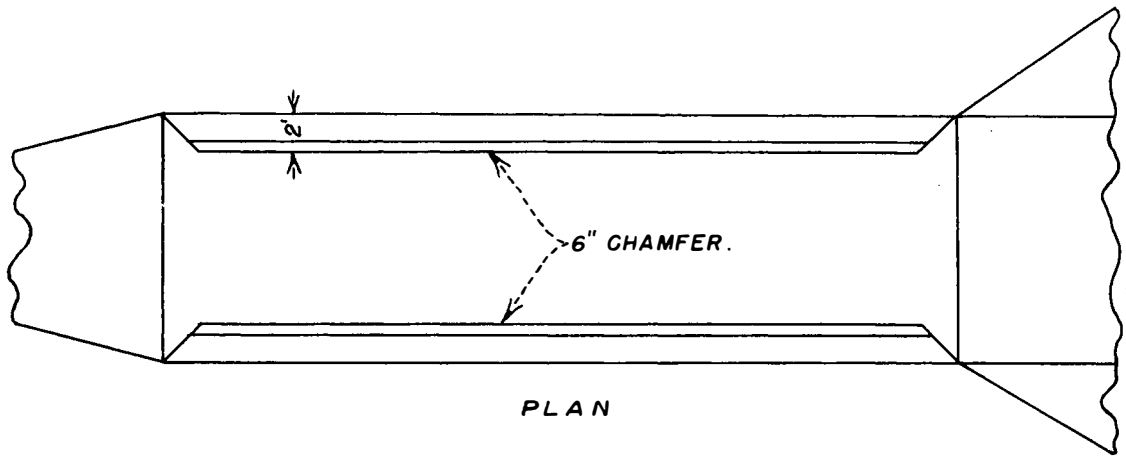


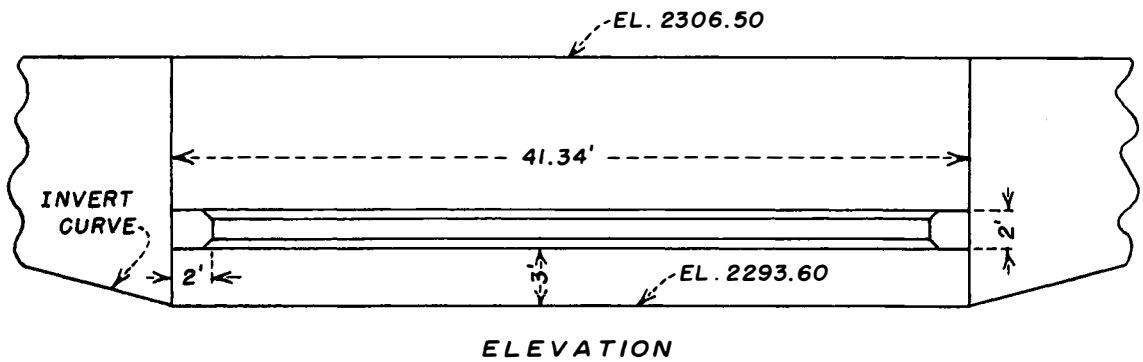


MEDICINE CREEK OUTLET WORKS
Recommended Basin
Discharge = 150 second-feet
Normal Reservoir Elevation - 2366.1 feet
1:12 Scale Model



BAFFLE PIER DETAILS





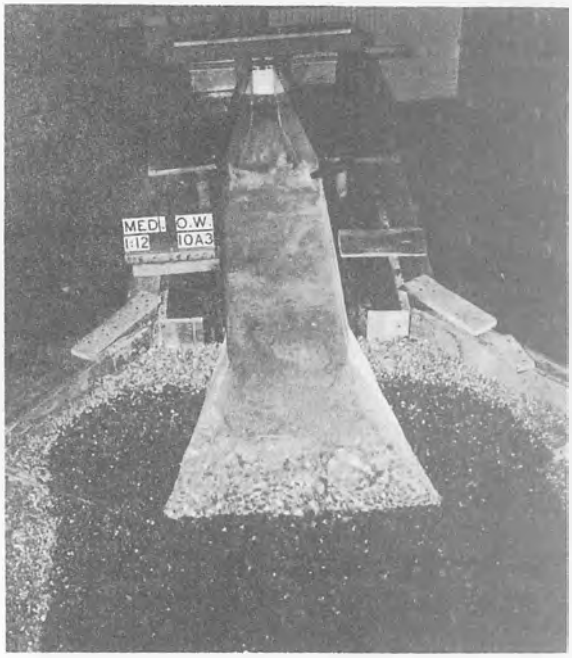
SIDE RAIL DETAILS

MEDICINE CREEK DAM — OUTLET WORKS

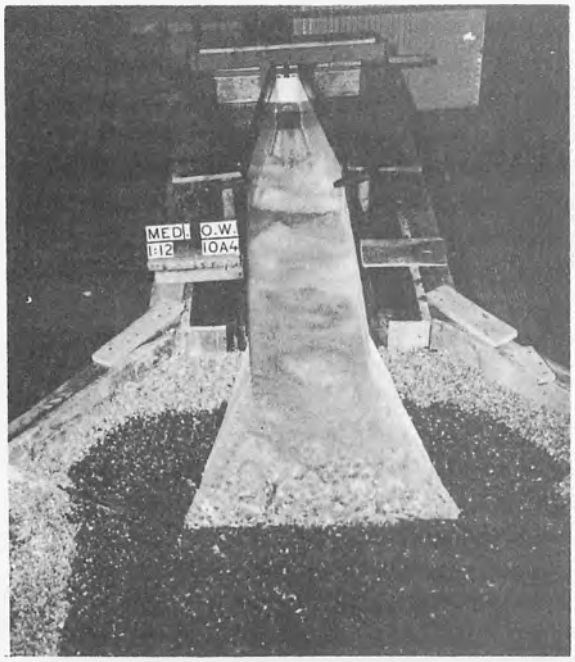
DETAILS OF BAFFLE PIERS AND SIDE RAILS

1:12 SCALE MODEL

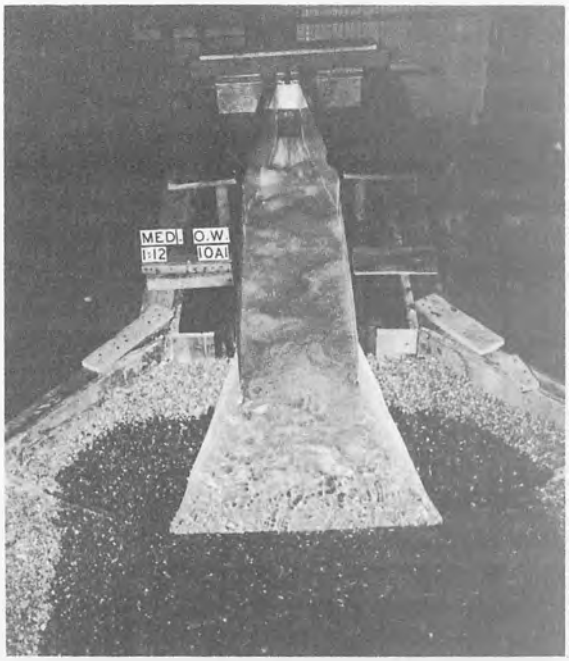
A. The Model



B. Discharge = 434 second-feet



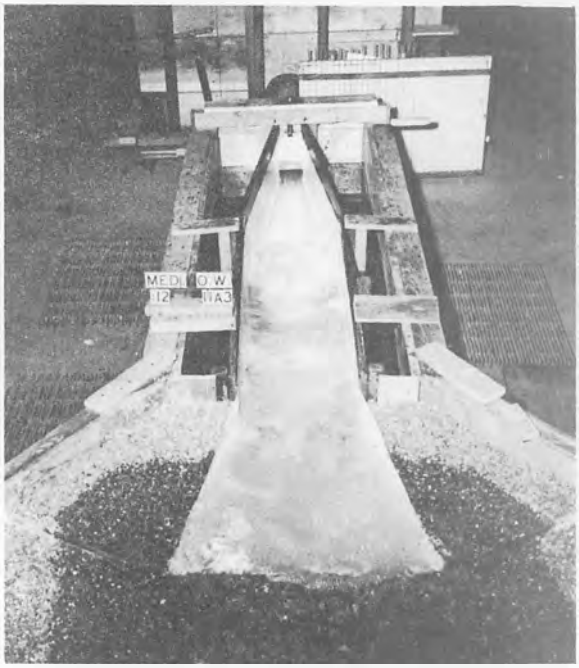
C. Discharge = 300 second-feet



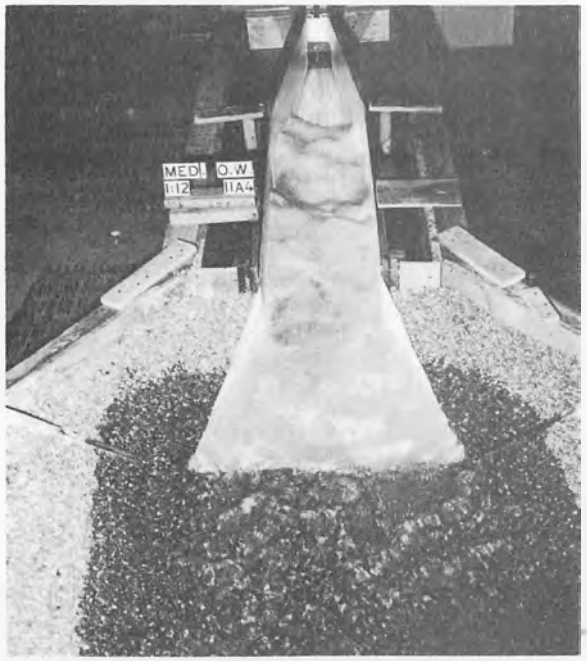
D. Discharge = 150 second-feet

MEDICINE CREEK OUTLET WORKS
Baffle Piers installed in Basin No. 6
1:12 Scale Model

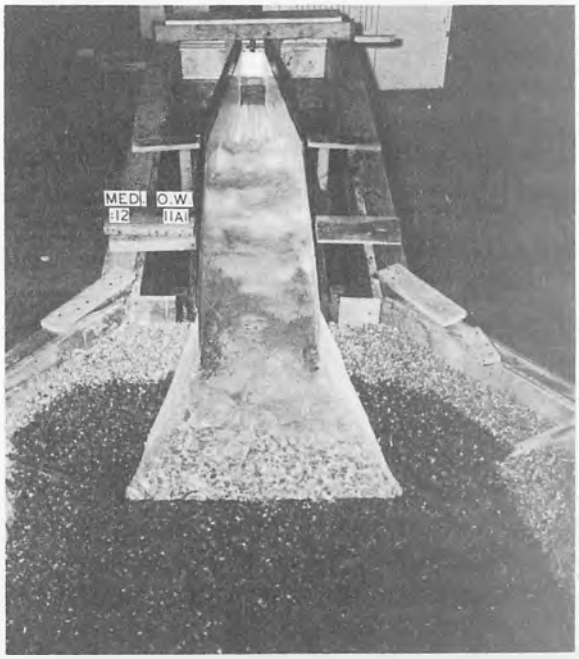
A. The Model



B. Discharge = 434 second-feet

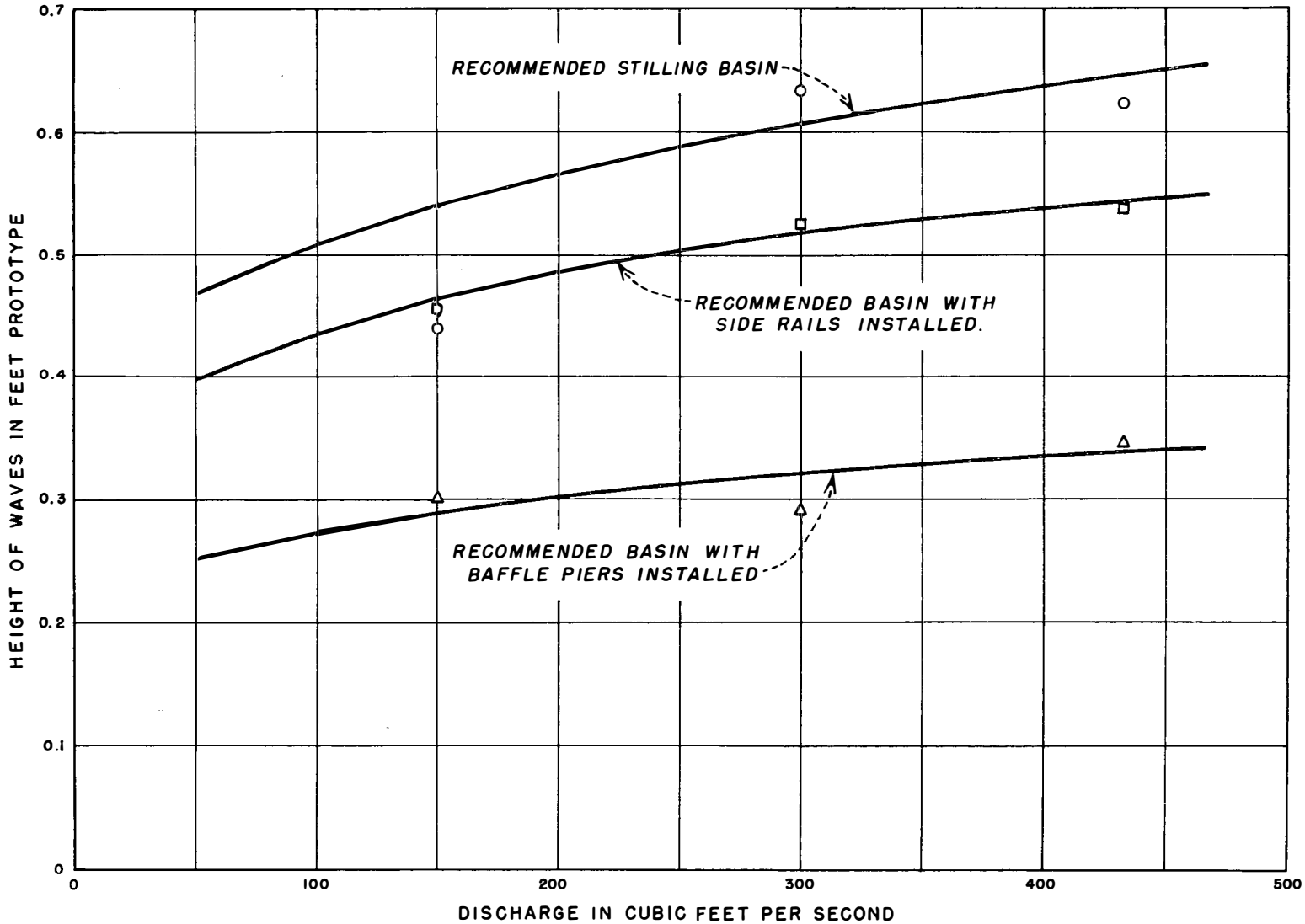


C. Discharge = 300 second-feet



D. Discharge = 150 second-feet

MEDICINE CREEK OUTLET WORKS
Side Rails installed in Basin No. 6
1:12 Scale Model

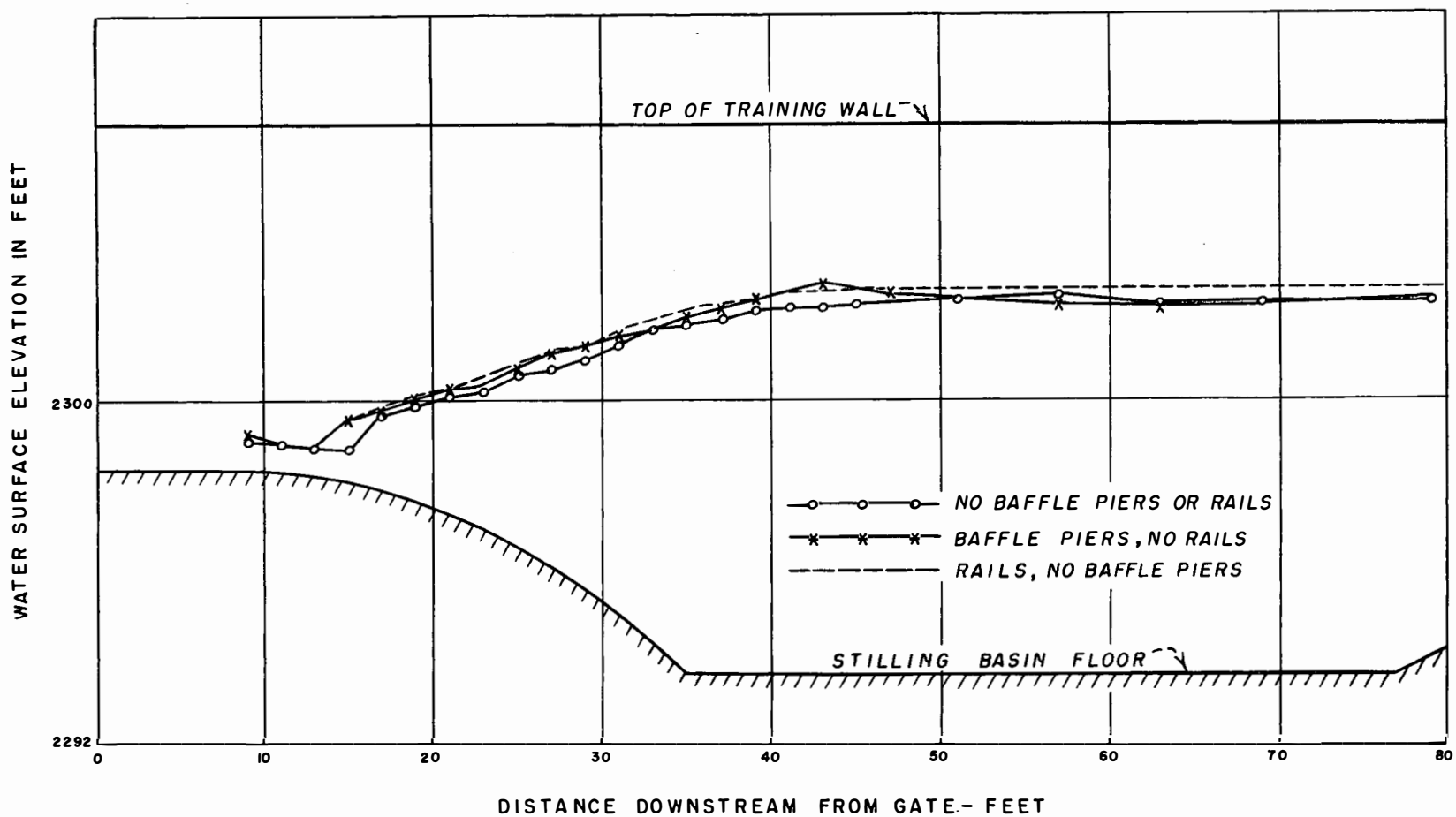


MEDICINE CREEK DAM — OUTLET WORKS

COMPARISON OF WAVE HEIGHTS

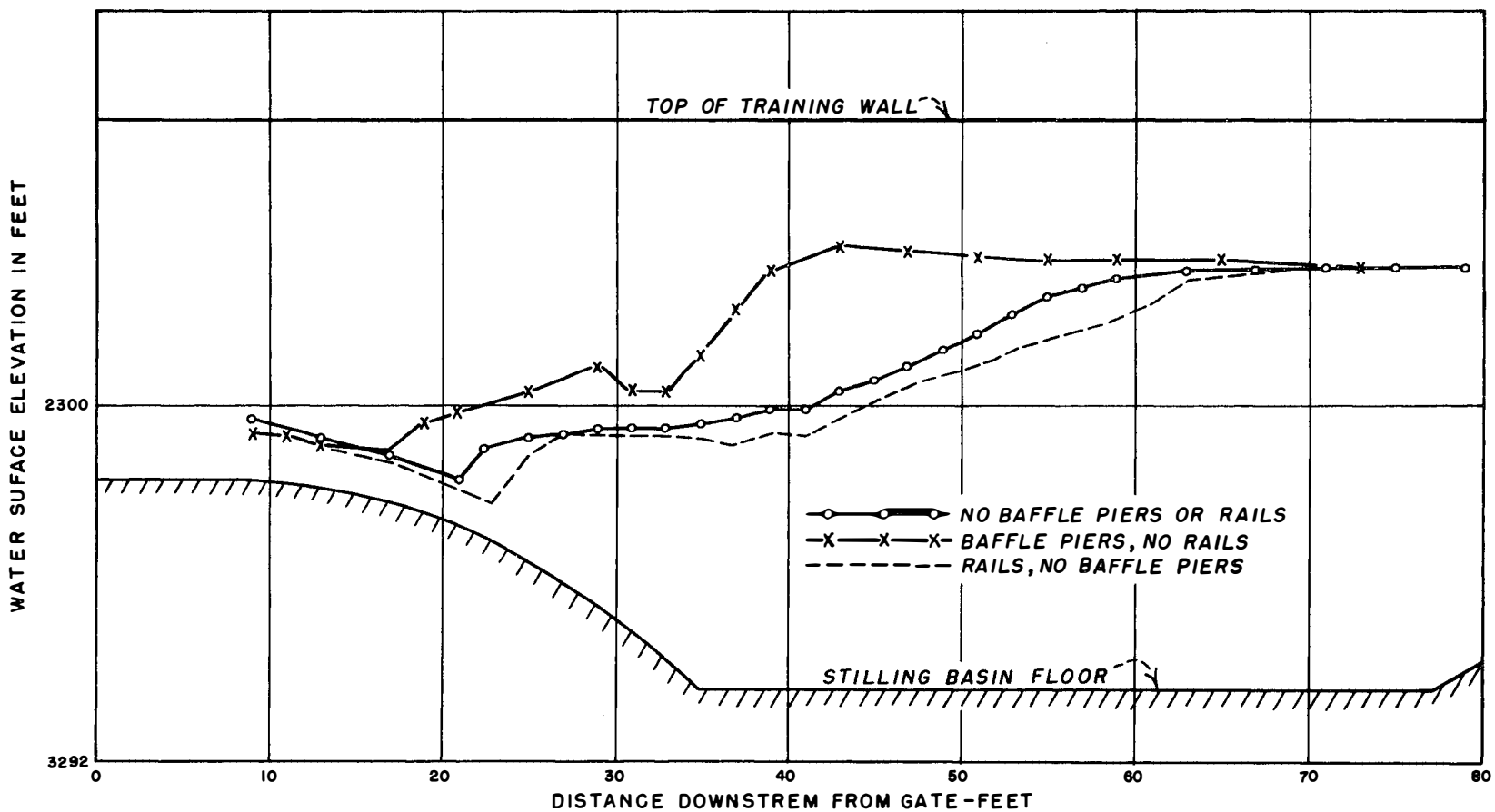
1:12 SCALE MODEL

FIGURE 29



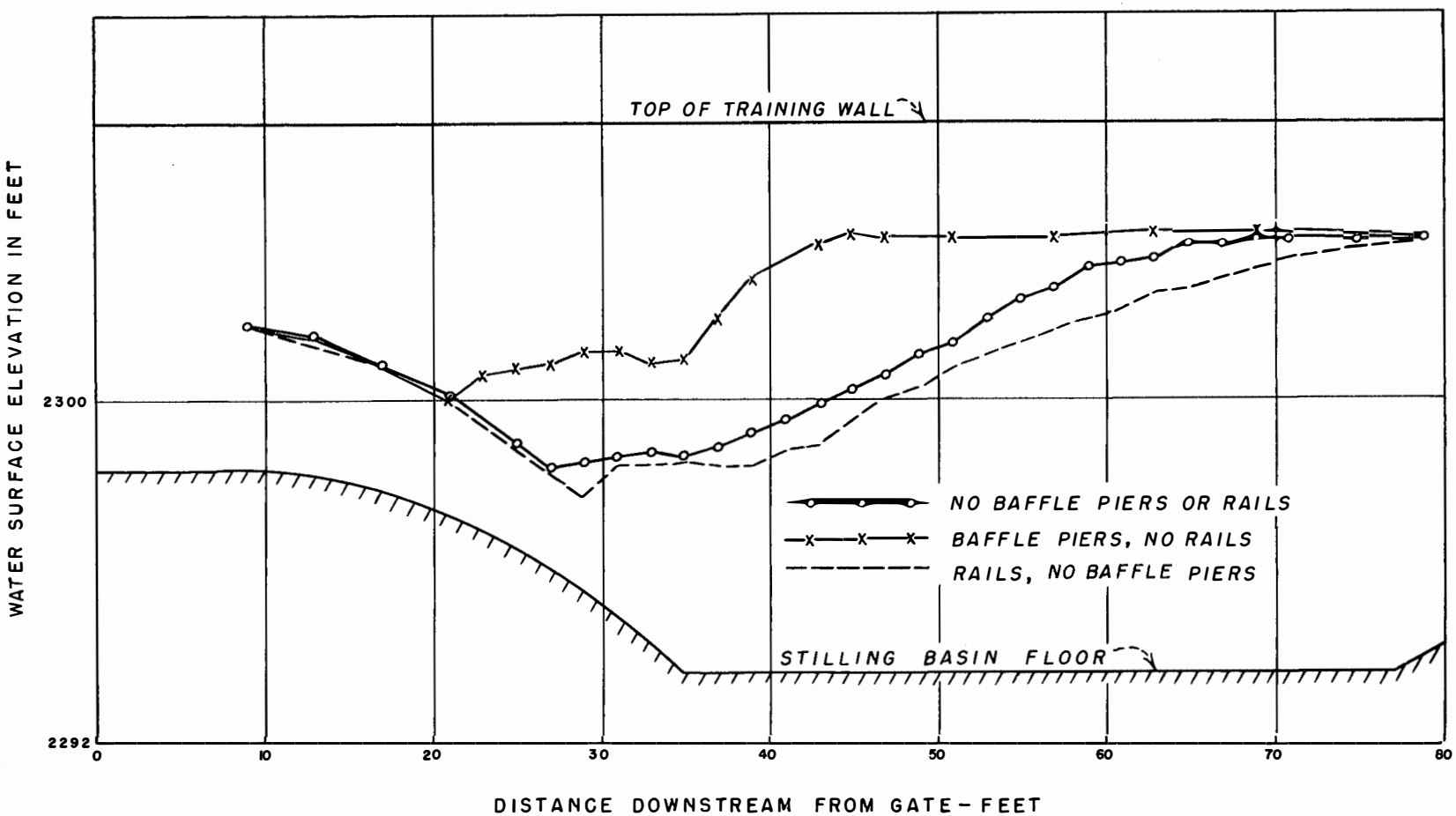
MEDICINE CREEK DAM — OUTLET WORKS
RECOMMENDED BASIN
WATER SURFACE PROFILES
Q = 150 cfs
1 : 12 SCALE MODEL

FIGURE 30



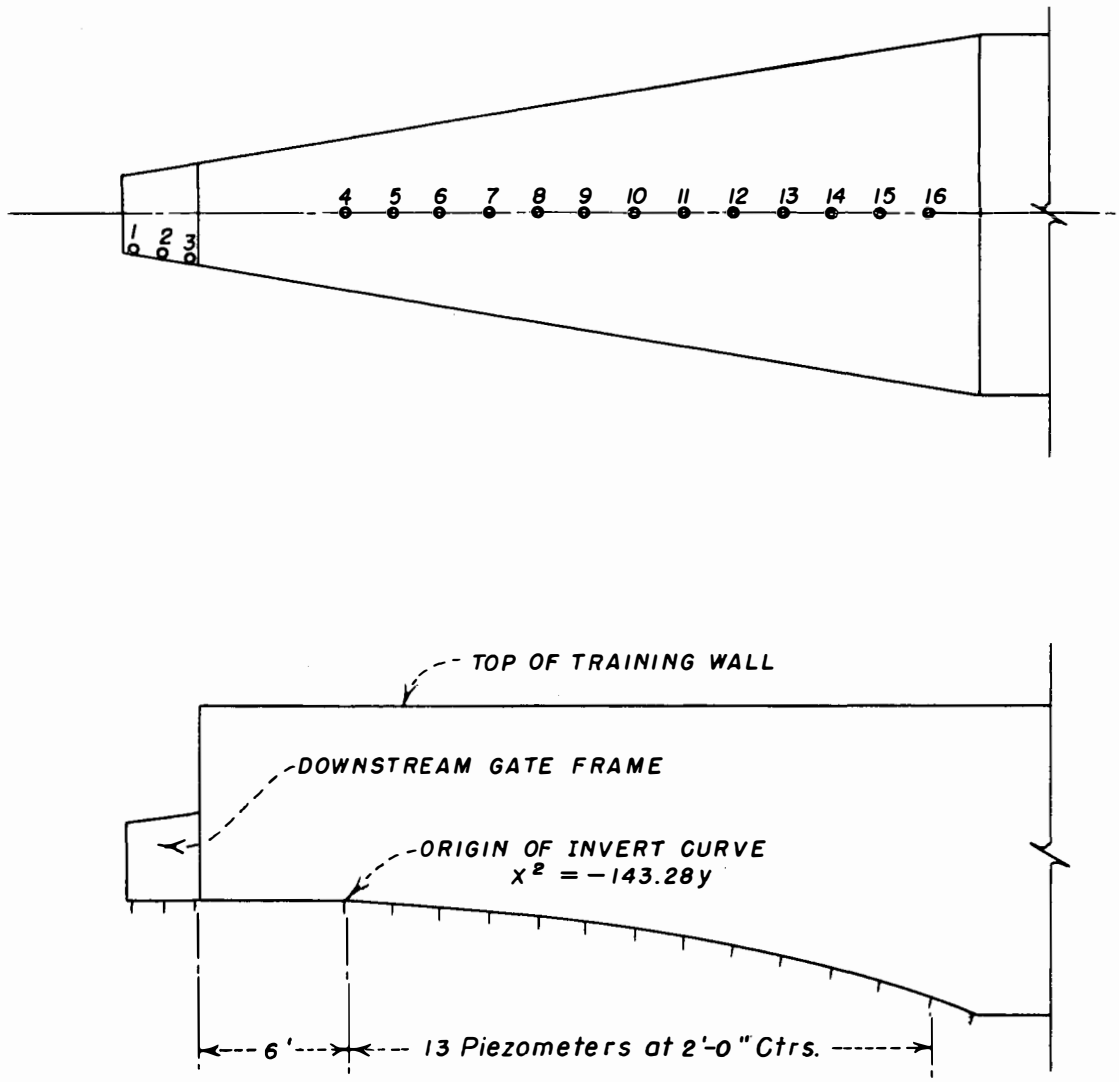
MEDICINE CREEK DAM — OUTLET WORKS
RECOMMENDED BASIN
WATER SURFACE PROFILES
Q = 300 cfs
1 : 12 SCALE MODEL

FIGURE 31



MEDICINE CREEK DAM — OUTLET WORKS
RECOMMENDED BASIN
WATER SURFACE PROFILES
Q = 434 cfs
1 : 12 SCALE MODEL

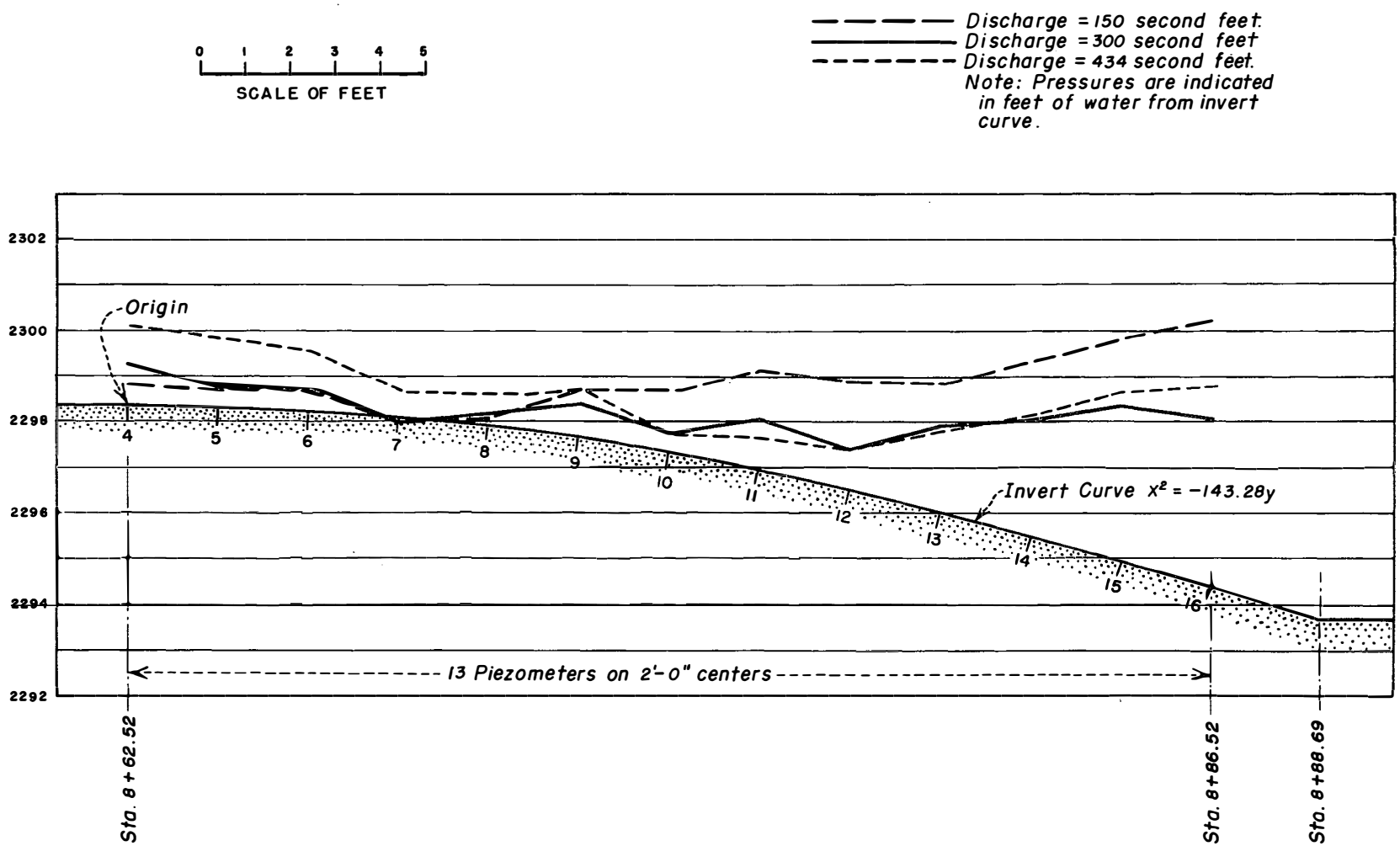
FIGURE 32



MEDICINE CREEK DAM — OUTLET WORKS

LOCATION OF PIEZOMETERS

1:12 SCALE MODEL



MEDICINE CREEK DAM — OUTLET WORKS

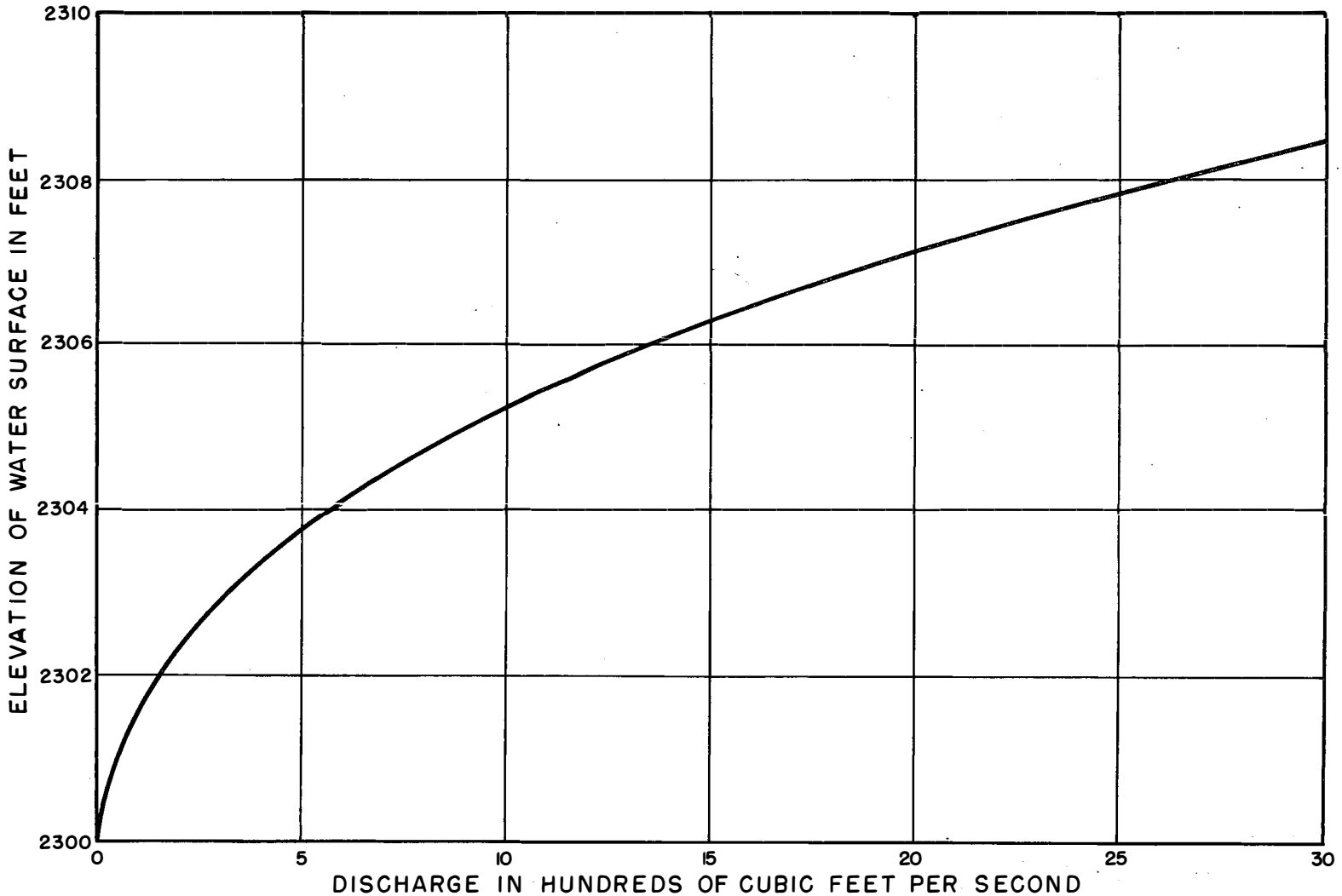
BASIN NO. 6 — RECOMMENDED BASIN

PIEZOMETRIC PRESSURES ALONG INVERT CURVE

AT NORMAL RESERVOIR ELEVATION AND NORMAL TAILWATER

1 : 12 SCALE MODEL

FIGURE 34



MEDICINE CREEK DAM
NATURAL CHANNEL TAILWATER CURVE

FIGURE 35