UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE CHECK INTAKE STRUCTURE--POTHOLES EAST CANAL COLUMBIA RIVER BASIN PROJECT WASHINGTON

Hydraulic Laboratory Report No. Hyd-411

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
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CONTENTS

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Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and Equipment Section
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Laboratory Report No. Hyd-411
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Submitted by: H. M. Martin

Subject: Hydraulic model studies of the check intake structure--Potholes East Canal--Columbia River Basin Project, Washington

INTRODUCTION

The check intake structure discussed in this report is a replacement for the existing control structure located at Station 1369+30 on the Potholes East Canal approximately 10 miles southeast of Othello, Washington, Figure 1. The intake structure will serve as a check to maintain the water surface elevation in the canal and to control the flow entering Scooteney Reservoir. The structure is designed to pass a maximum discharge of 3,900 second-feet which is controlled by three 20- by 5-foot radial gates, Figure 2. After passing under the gates, the flow enters a short stilling basin, then passes over a sill 2 feet 4 inches high, and flows down a baffled chute on a 2:1 slope. The baffle piers on the 2:1 chute are designed to impede the flow and maintain a near-constant velocity regardless of the length of chute.

The model studies were undertaken to determine the adequacy of the stilling basin and the effectiveness of the baffle piers in slowing the flow on the 2:1 chute.

THE MODEL

A 1:16 scale model was used in the study. The model included a 171-foot length of the Potholes East Canal between Stations 1367+69 and 1369+40, the gate structure and stilling basin, the 2:1 baffled apron, and approximately 80 feet of the outlet channel leading to Scooteney Reservoir. To make the model gates and piers as large as possible and still use an existing canal section which was available in the laboratory, only one-half of the structure was built and tested. Also, to simplify the model construction, slide gates were used to control the flow in the model. Radial gates are used in the prototype. However, since the study was concerned primarily with the stilling basin performance and the effectiveness of the baffled chute, it is believed that the slide gates were sufficiently accurate for this type of study.

For the erosion studies, the channel downstream from the baffled chute was molded in sand having a mean diameter of approximately 1 mm. Water supplied to the model was measured through venturi meters.

THE INVESTIGATION

General

The investigation was concerned primarily with the adequacy of the stilling basin upstream from the sill and the effectiveness of the baffled chute in preventing acceleration of the flow down the chute. The relative efficiency of the various stilling basin designs was judged primarily by the appearance of the flow downstream from the gates and, to some extent, by the distribution of flow at the sill. However, the velocity distribution of the flow leaving the basin was of minor importance since the flow pattern was immediately rearranged by the baffles on the chute. The effectiveness of the baffled chute was determined by the amount of scour in the downstream channel and by the appearance of the flow on the chute. To determine the amount of scour for each design, the outlet channel was molded in sand to elevation 914 feet, and the model was operated for 30 minutes, after which the erosion in the channel bed was measured and made visible with contour lines of white string. The model was operated at all discharges with the normal canal depth of 15.3 feet upstream from the gates.

In the following discussion, the designs of the structure are designated by numerals and letters. The numeral indicates the particular basin design, while the letter refers to the baffle arrangement on the chute. Thus, Design 1A was Basin Design 1, Figure 3, tested with Chute Design A, Figure 4.

Design 1A (preliminary)

The preliminary design of the check intake structure is shown in Figures 2 and 5A. Figure 5B shows the structure discharging 3,900 second-feet. It can be seen that the flow was deflected upward after striking the basin baffle piers, causing relatively high boils and a rough water surface as the water entered the baffled chute. There was very little stilling action between the basin piers and the sill at the top of the chute, and, when the basin piers were removed, the flow swept through the basin and over the sill without forming a hydraulic jump.

Flow down the baffled chute was satisfactory when the basin piers were installed. The upper two rows of baffle piers were submerged in a solid mass of water. Downstream from the second row of piers the solid mass of water began to disintegrate as indicated by the "white" water in Figure 5B.

Erosion patterns for a discharge of 3,900 second-feet at minimum and maximum tail-water elevations of 915 and 925 feet are shown in Figure 5C and D. At minimum tail water, the channel eroded to elevation 904 feet at the base of the chute, Figure 5C. The lowest row of piers on the chute was exposed, indicating the need for a longer chute and another row of baffles at the lower end of the chute. At maximum tail water, Figure 5D, the lowest point in the erosion pattern was 907 feet, located near the right training wall. Since the lowest row of piers was nearly covered with sand, the length of chute and the rows of piers are ample for this operating condition.

Preliminary tests on the structure clearly indicated that the stilling basin of Design 1A was too short. To test the structure under ideal conditions, the basin piers, gates, and curtain wall were removed from the model. Thus, the flow approaching the baffled chute was subcritical, representing an infinitely long stilling basin. Figure 6A shows the baffled chute operating with these ideal approach conditions. The flow entering the chute was smooth, but the flow down the lower reaches of the chute was similar to that of Design 1A. The erosion pattern was approximately 2 feet higher than the preliminary design; elevation 906 feet at the base of the chute.

The above tests were made with the baffle piers in rows spaced at intervals of 9 feet. To determine the effect of placing the piers closer together, the rows of piers were installed at intervals of 6 feet, Figure 4B. There was no apparent change in the appearance of the flow down the chute for the maximum discharge of 3,900 second-feet, Figure 6B. However, the erosion depth at the base of the chute was approximately 2 feet lower, indicating that 9-foot spacing between rows gave less scour than 6-foot spacing. Therefore, in all subsequent tests, the rows were spaced 9 feet apart, and since the lowest row of piers was exposed in all the erosion tests at minimum tail water, another row of piers was added at the base of the 2:1 chute, Figure 4C.

Design 2A

In an attempt to reduce the height of boil and rough water surface at the basin baffle piers, Figure 5B, a row of smaller piers was placed 4 feet upstream from the 3-foot piers, Figure 3B. The smaller piers helped materially in reducing the boil heights. However, the jump swept out at the normal canal depth of 15.3 feet and a discharge of 3,900 second-feet. To prevent the jet from sweeping through the basin, a row of baffle piers 4 feet 6 inches high was placed on the sill, Figure 4C. This change sufficiently increased the depth in the basin to maintain a hydraulic jump; however, the steep water surface between the basin piers and the sill was still evident.

Designs 3C through 7C

From the above tests, it appeared little could be done to improve the stilling basin performance without increasing the basin length. Based on data contained in Hyd-399* for a Type III basin, a basin length of approximately 24 feet is indicated. Since in this modified Type III basin no stilling action takes place until the flow strikes the basin baffle piers, the stilling basin length should be measured between the basin piers and the sill rather than between the gate seat and the sill. Therefore, the structure was lengthened 10 feet in Basins 3 through 7, Figure 3.

The longer structure, Design 3A, was operated with and without the basin piers and with a row of baffle piers placed on the sill. In general, these tests showed that the basin piers were necessary to break up and distribute the high-velocity flow. Although large boils still formed above the basin piers, the height of boil could be reduced by using smaller piers, Figure 7A and B. The baffle piers on the sill increased the conjugate depth, d_2, and vastly improved the basin performance both with and without the basin piers installed. However, the best stilling action took place when piers were installed both in the basin and on the sill.

A series of tests were conducted to determine the optimum height of piers in the stilling basin. Tests on piers 22, 18, 15, and 12 inches high showed that the height of boil became less as the pier height was reduced. With the 12-inch piers installed, the boils formed only when the gates were nearly closed and the discharge was less than approximately 1,500 second-feet. At these low discharges the boils were comparatively small and unobjectionable. For the intermediate pier heights, the boils increased in height and were prevalent over a larger range of discharges. Therefore, 12 inches appeared to be the optimum height for the piers.

Baffle piers with a curved upstream face and from 3 to 8 feet in height were tested in the basin in Designs 5C, 6C, and 7C, Figure 3. These tests showed that, to be effective, the piers should be at least 6 feet in height. With piers less than 6 feet high, boils formed over the piers, causing a rough and uneven water surface in the stilling basin. The best stilling basin operation was obtained with curved-face piers 8 feet in height which gave a comparatively level water surface between the gates and the downstream end of the stilling basin, Figure 7C. However, the differential head across the gates was reduced to the extent

*Progress Report II Research Study on Stilling Basins, Energy Dissipators and Associated Appurtenances.

that it was questionable whether the 5-foot radial gates would pass the design discharge. Therefore, no further investigation of the curved-face piers was made.

The Recommended Design

From the above investigation, it was concluded that Design 8C, Figures 8A and 9, gave the best stilling basin performance and, for all practical purposes, the least scour in the outlet channel. Design 8C consisted of a stilling basin 31 feet in length and equipped with 12-inch baffle piers immediately downstream from the gates, a row of piers on top of the sill, and chute piers spaced in rows 9 feet apart.

All the previous scour tests indicated that the deepest scour pocket occurred at the downstream end of the right training wall. The excessive scour in this region was undoubtedly due to side eddies which formed at the end of the training wall. To reduce the effect of these eddies, a wing wall, 9 feet in length, was placed normal to the end of the wing wall, Figure 8D. By comparing Figure 8C with Figure 8D, it can be seen that the wing wall was effective in reducing the depth of scour near the right training wall. Therefore, the recommended design should include wing walls to reduce the effects of side eddies at the downstream end of the baffled chute.

Figure 10 shows the operation of the recommended design at discharges of 3,000, 2,000, and 1,000 second-feet. The stilling basin surface is comparatively smooth except for a discharge of 1,000 second-feet when the water is deflected upward at the basin piers, Figure 10D.

Figure 10B shows the scour pattern obtained after a discharge of 3,200 second-feet or a discharge of 50 second-feet per unit width. In general, the average depth of scour is approximately 1 foot less than that obtained with the maximum discharge of 3,900 second-feet (61 second-feet per unit width), Figure 8D. Thus, the amount of scour in the outlet channel can be reduced by designing the structure for a maximum discharge of 50 second-feet per unit width. This lower unit discharge may be accomplished by either increasing the width of the entire structure from 64 to 78 feet and adding another gate, or by maintaining the present gate and gate pier designs and flaring the basin from a width of 64 feet at the gate piers to 78 feet at the sill.

The operation of the former design would be satisfactory and was represented approximately in Figure 10A. The operation of the latter design is represented in Figure 11 by placing a flared training wall downstream from the gate pier. Although the distribution of flow in the flared section was inferior to a basin with parallel walls, it is believed the structure will operate satisfactorily with a flared basin.

A recapitulation of the operation of the various designs is shown in Table 1.

After the completion of the model studies of the check intake structure, a series of tests were conducted to determine the relative merits of constructing the upstream face of the baffle piers vertical or normal to the sloping floor of the baffled chute.

Results of these studies were reported in a memorandum to Chief, Canals Branch, on January 18, 1956. Because the baffle tests are closely related to the check intake studies, the memorandum is included as an appendix to this report.

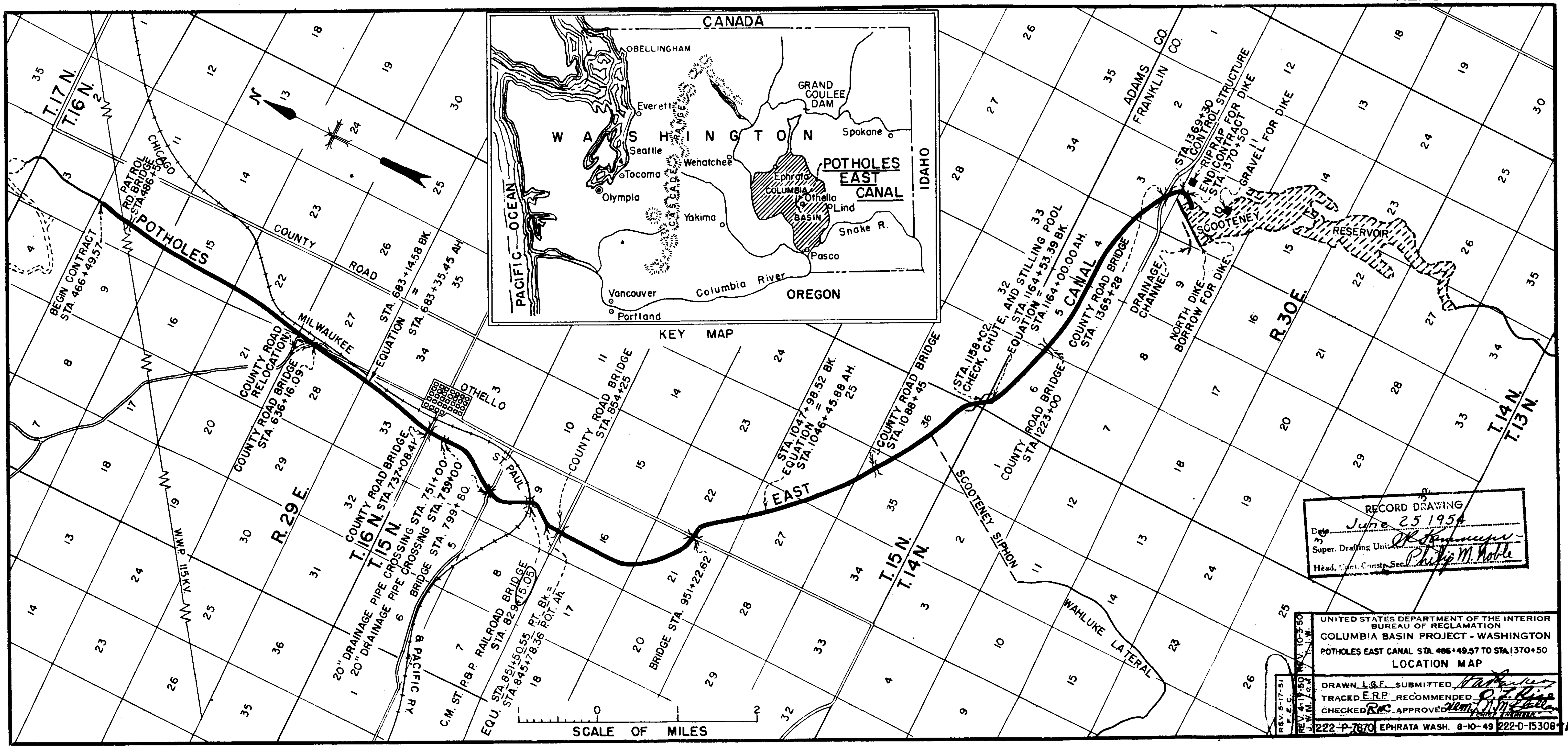
Table 1

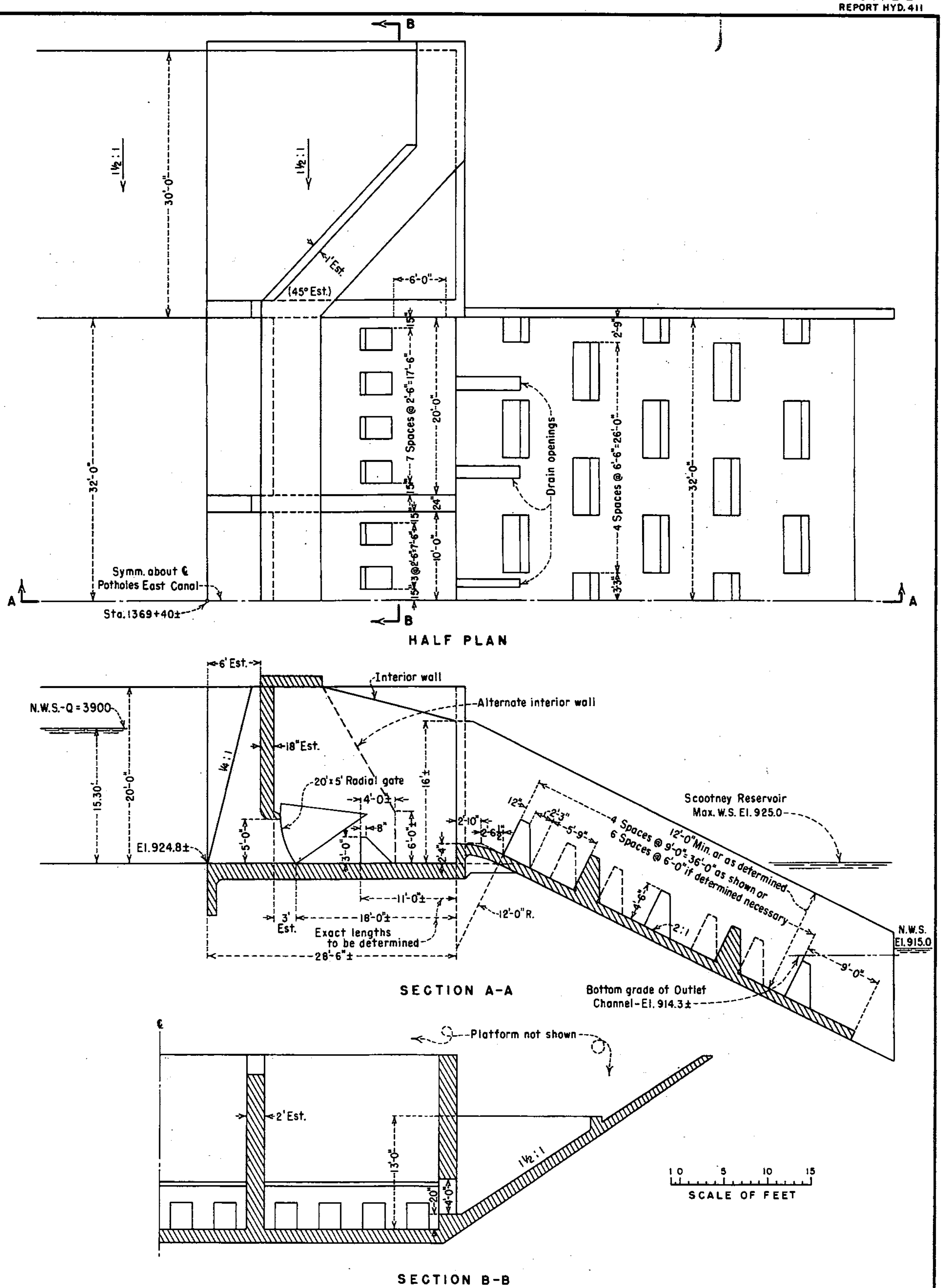
RECAPITULATION OF INVESTIGATION

Design* Stilling Basin	Design* Baffled chute	Discharge (cfs)	Tailwater (ft)	Maximum depth of scour	Remarks
1 (pre)	A (pre)	3,900	915	904	Large boils above basin piers
1 (pre)		3,900	925	907	Similar operation, but less scour
**1	A	3,900	915	904+	Basin piers removed. Jump sweeps out
**1	B	3,900	915	904-	More material moved in outlet channel
2	C	3,900	915	904+	Jump remains in basin
3	A	3,900	915	-	Boils above basin piers. Rough basin
3	C	3,900	915	-	Better basin performance. Boils prevalent
3	C	3,900	915	-	Basin piers removed. High-velocity flow strikes step
4	C	3,900	915	-	22-inch basin piers. Boils prevalent
4	C	3,900	915	-	18-inch basin piers. Boils reduced in height
4	C	3,900	915	904+	12-inch basin piers. Boils form for Q = 1,500 cfs
4	C	3,900	915	-	15-inch basin piers. Boils form for Q = 2,500 cfs
5	C	3,900	915	-	Operation similar to Design 3C
6	C	3,900	915	904+	Excellent operation, but reduced Q
7	C	3,900	915	-	Fair operation. Boils prevalent
8	C	3,900	915	906-	Good operation
8	C	3,200	915	907	Excellent operation
8	C	2,000	915	-	Excellent operation
8	C	1,000	915	-	Boils form above basin piers

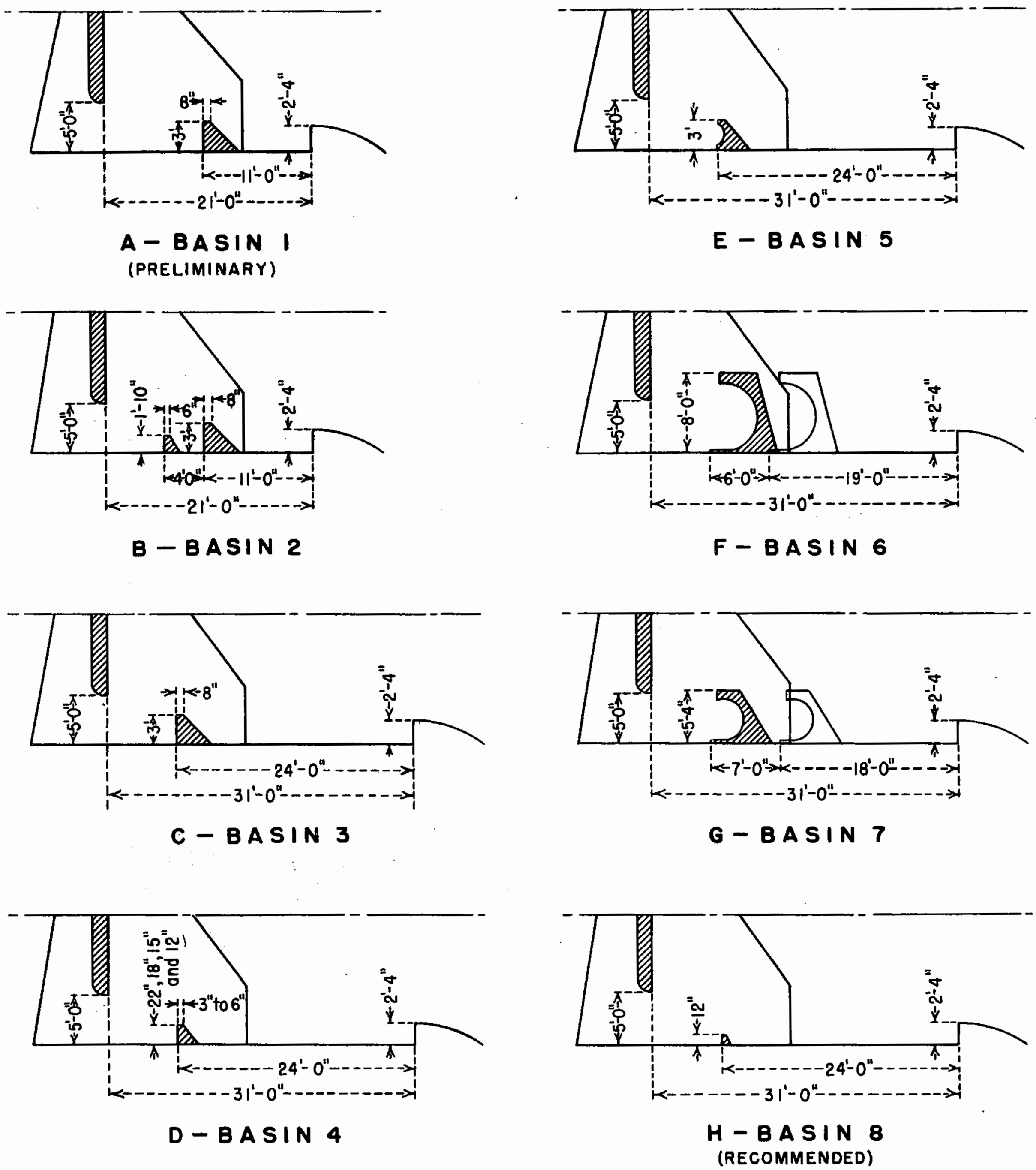
*See Figures 3 and 4 for details of basin and chute designs.
**Basin piers and gates removed.

FIGURE 1
REPORT HYD.411





POTHOLES EAST CANAL
CHECK INTAKE STRUCTURE AT STATION 1369+40±
PRELIMINARY DESIGN

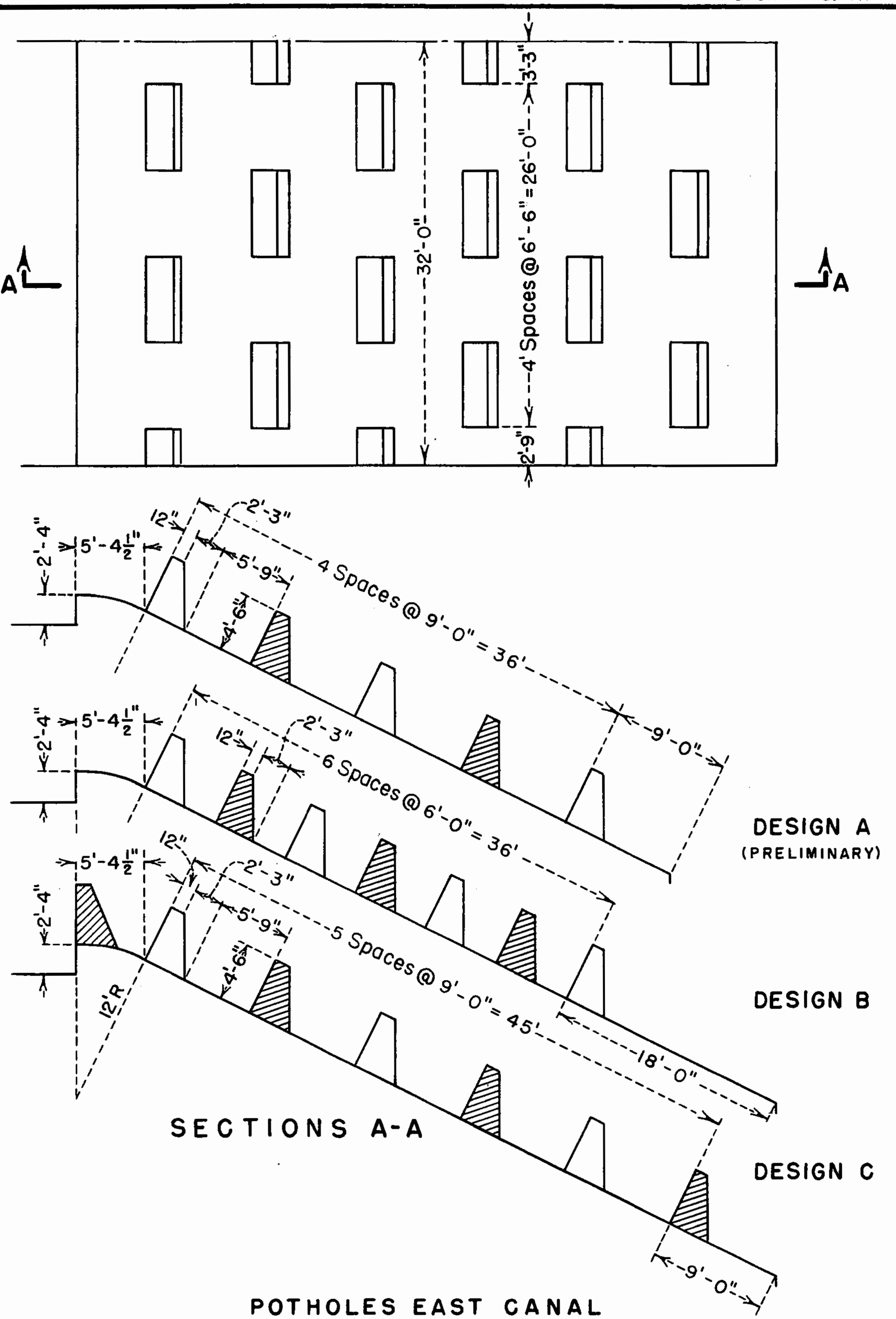


POTHOLES EAST CANAL

CHECK INTAKE STRUCTURE AT STATION 1369+40±

STILLING BASIN DESIGNS

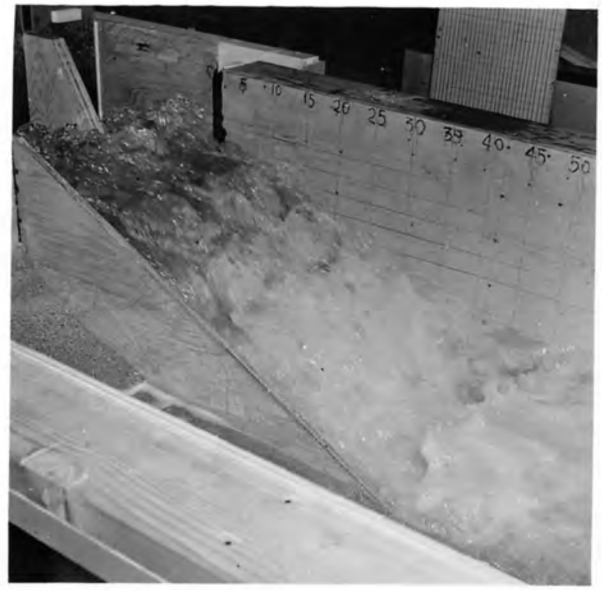
1:16 SCALE MODEL



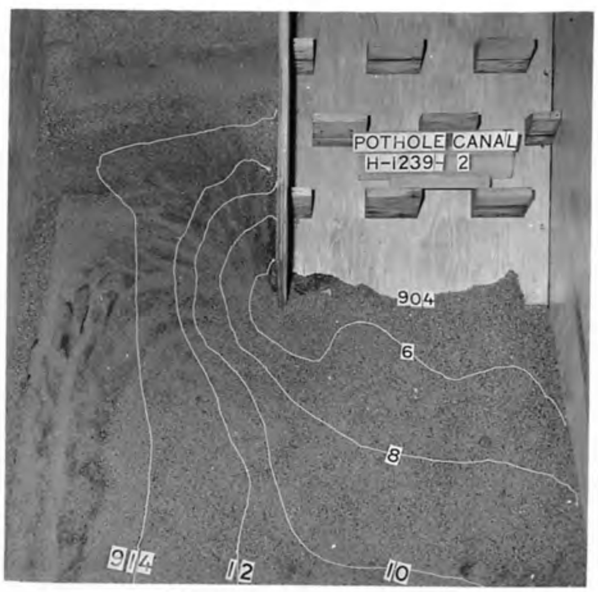
POTHOLES EAST CANAL
CHECK INTAKE STRUCTURE AT STATION 1369+40±
BAFFLED CHUTE DESIGN
1:16 SCALE MODEL

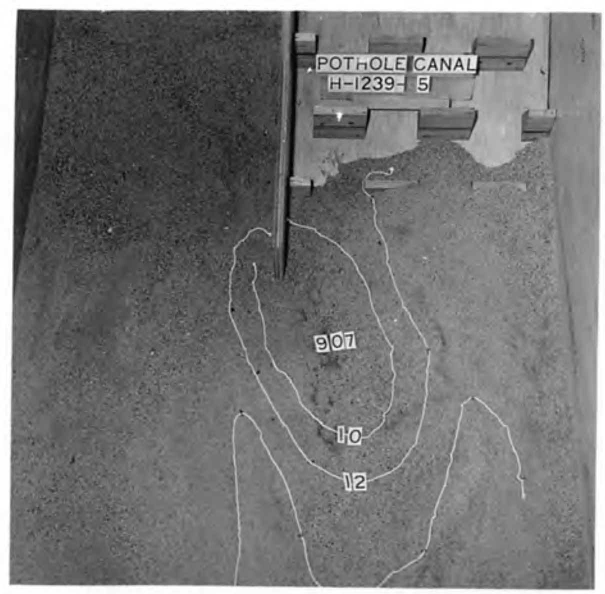
548

A. The 1:16 scale model



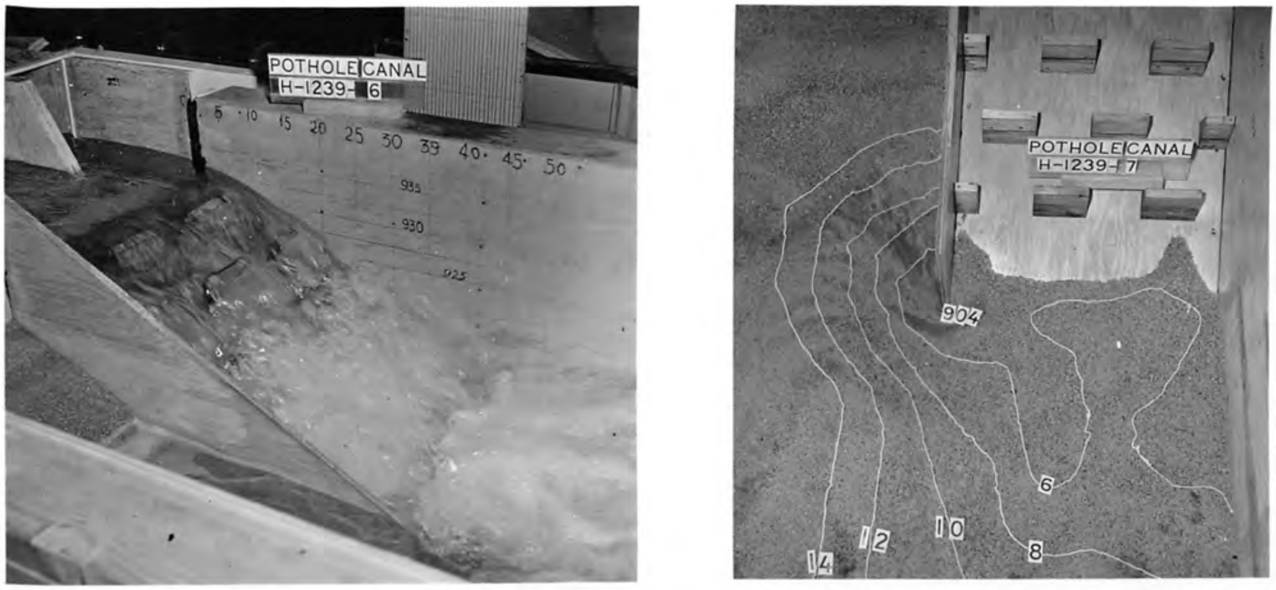
B. Discharge = 3,900 cfs



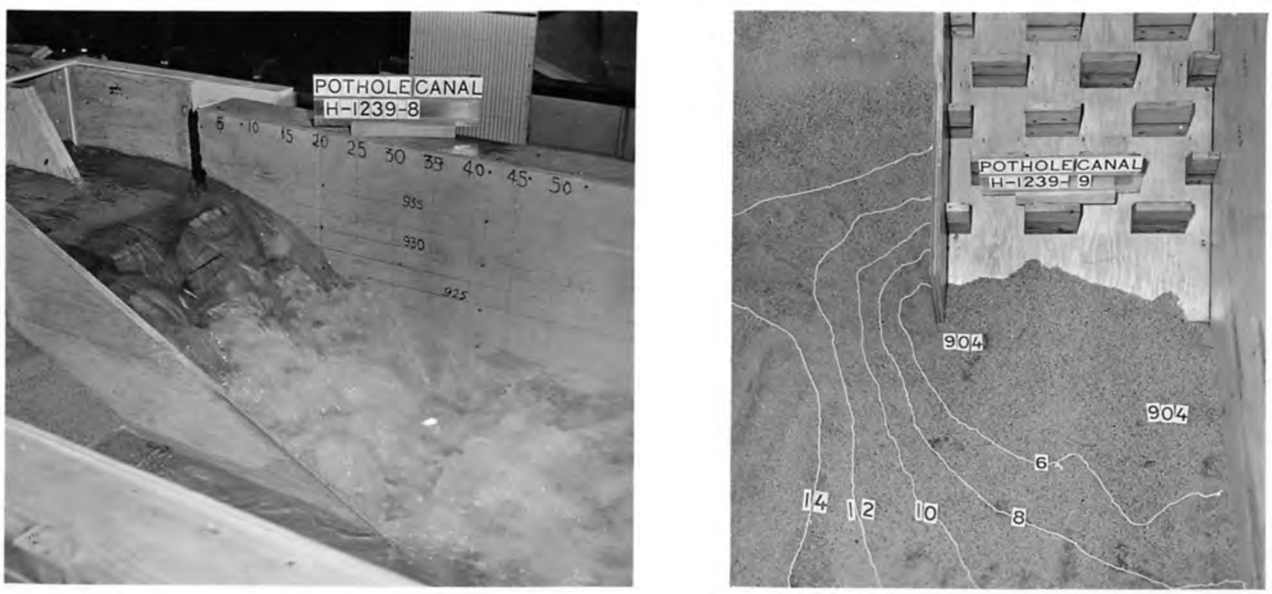


C. Minimum Tailwater = 915 feet D. Maximum Tailwater = 925 feet
Erosion after discharge of 3,900 cfs for 30 minutes

POTHOLES EAST CANAL
Check Intake Structure
Preliminary Design
1:16 Scale Model



A. Design 1A. Rows of piers on chute spaced 9' 0" apart.

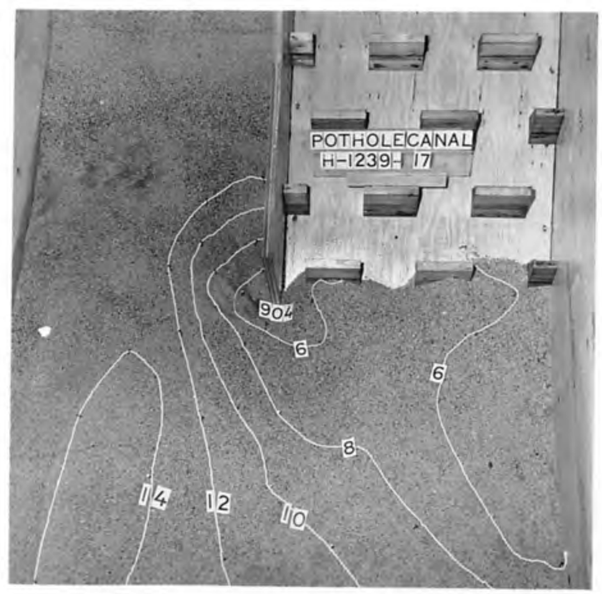


B. Design 1B. Rows of piers on chute spaced 6' 0" apart.

POTHOLES EAST CANAL
Check Intake Structure
With Gates, Curtain Wall, and Basin Piers Removed
Q = 3,900 cfs
1:16 Scale Model

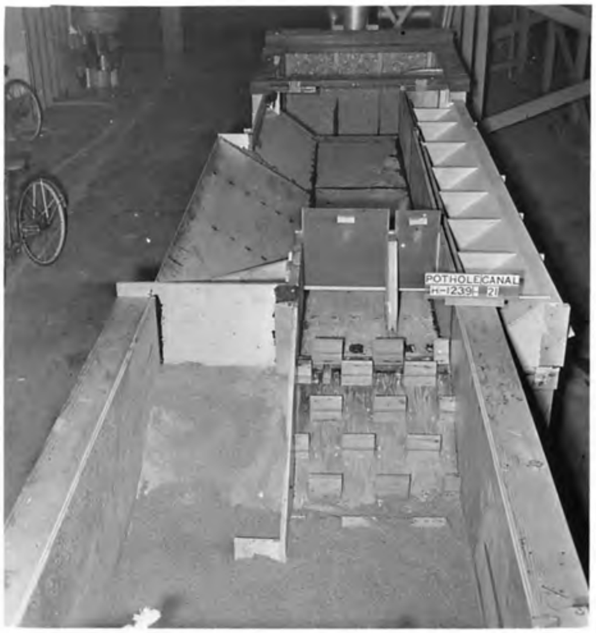
A. Design 3C. Note boils above basin piers

B. Design 3C with basin piers removed



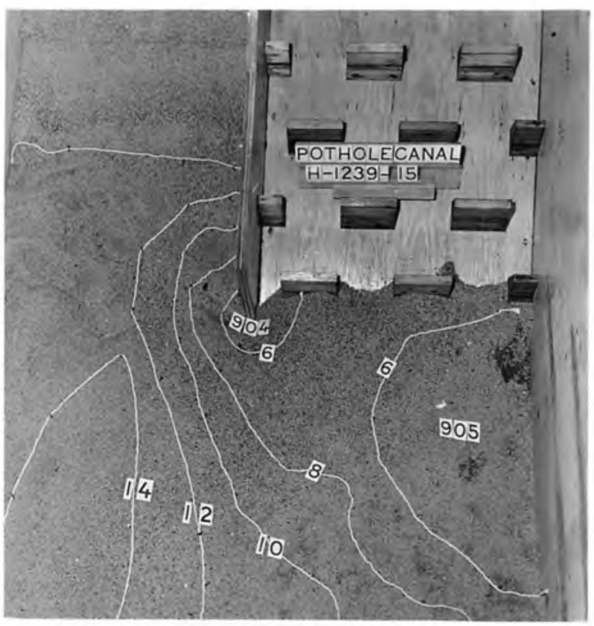
C. Design 6C. Capacity of gates considerably reduced

POTHOLES EAST CANAL
Check Intake Structure
Operation of Designs 3C and 6C
Discharge 3, 900 cfs
1:16 Scale Model



A. Design 8C (Recommended)

B. Discharge 3,900 cfs

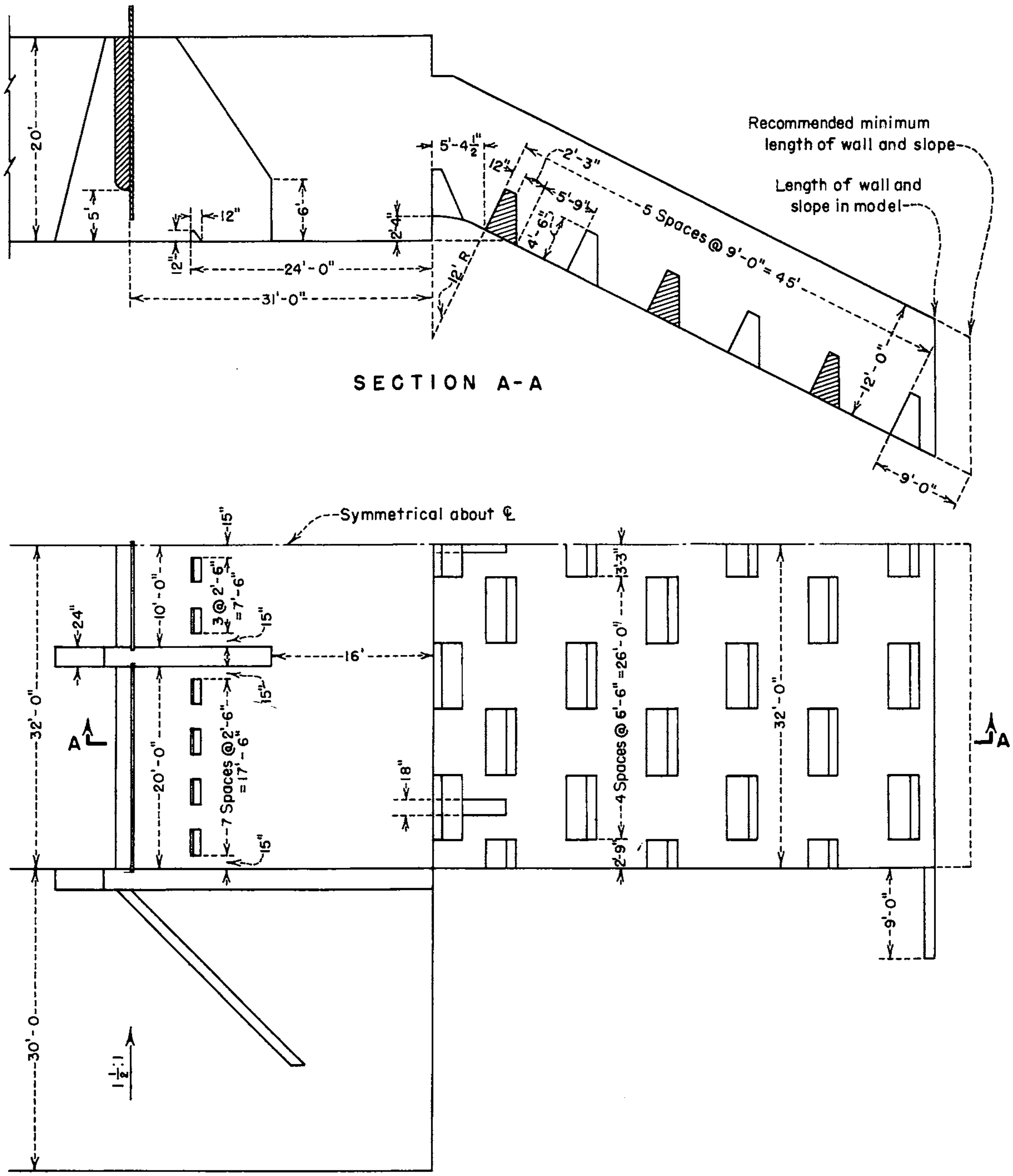


C. No wing wall at end of training wall

D. With wing wall 9 feet long, installed

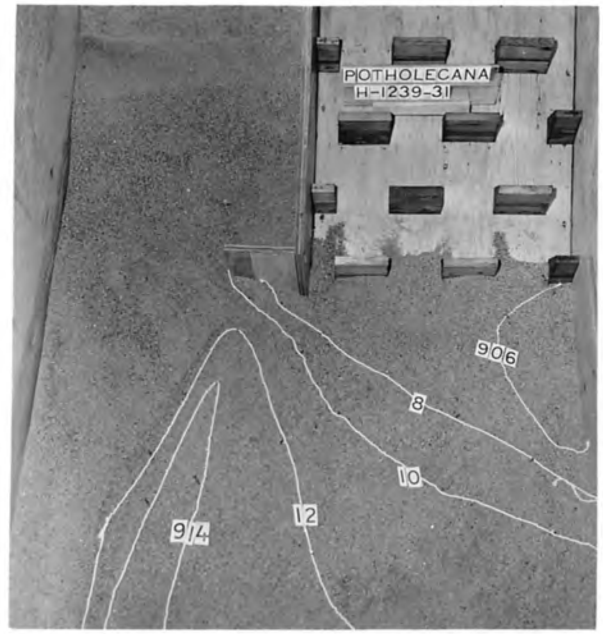
Scour after discharging 3,900 cfs - Minimum tailwater Elev. 915.0

POTHOLES EAST CANAL
Check Intake Structure
Operation of Recommended Design
1:16 Scale Model



POTHOLES EAST CANAL
CHECK INTAKE STRUCTURE AT STATION 1369+40±
COLUMBIA BASIN PROJECT
1:16 SCALE MODEL

A. Discharge 3,000 cfs
Canal depth = 15.3 feet



B. Scour after 3,200 cfs

C. Discharge 2,000 cfs
Canal depth = 15.3 feet

D. Discharge 1,000 cfs. Canal depth = 15.3 feet. Note boil at basin piers.

POTHOLES EAST CANAL
Check Intake Structure
Operation of Recommended Design
1:16 Scale Model

Basin width flared from 64 feet at downstream end of gate piers to 78 feet at sill. Discharge 50 cfs per unit width.

POTHOLES EAST CANAL
Check Intake Structure
Operation of Flared Basin
1:16 Scale Model

APPENDIX

Memorandum

Denver, Colorado

Chief, Canals Branch

January 18, 1956

Chief, Hydraulic Laboratory Branch

Results of tests to determine the merits of constructing baffle piers with the upstream face vertical and normal to the sloping floor of a baffled chute

At the request of Messrs. Terrell and Curtis, a series of tests were conducted in the Hydraulic Laboratory to determine the relative hydraulic merits of constructing piers on baffled chute with the upstream pier face (1) vertical and (2) normal to the slope.

The tests were conducted in the 1:16 model of the check intake structure of Potholes East Canal. The model represented a 200-foot length of approach channel, chute on a 2:1 slope, and an outlet channel filled with sand for erosion studies. A vertical step 2 feet 4 inches high was placed at the upstream end of the 2:1 slope. For the purpose of these tests piers 3 feet high and spaced 4 feet 6 inches apart were placed on the 2:1 chute. Details of the piers are shown in Figure 1. The model was operated at a discharge equivalent to 35 second-feet per foot of channel width. The control gates were removed from the structure to provide ideal entrance conditions to the sloping apron.

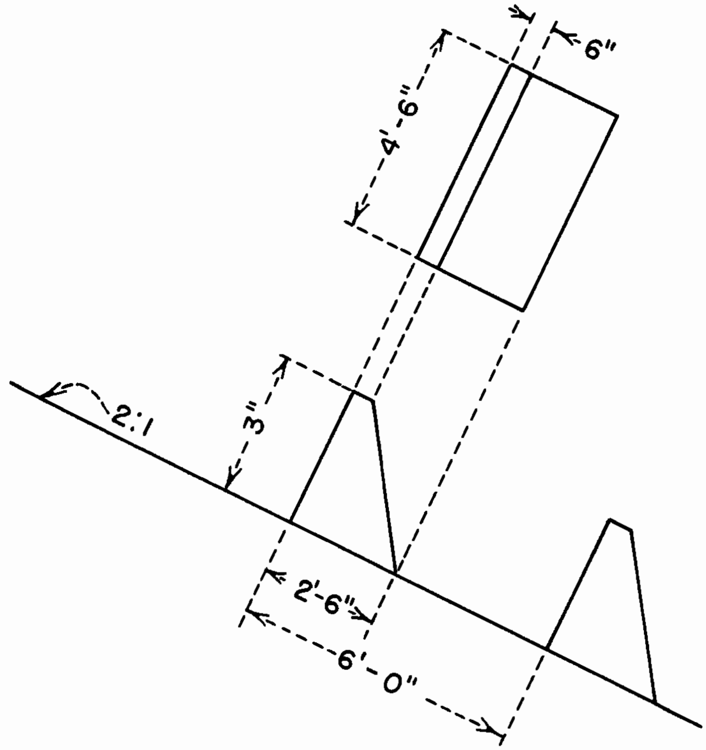
Two criteria were used to determine the effectiveness of each set of baffle piers: (1) Height of splash. One side wall was painted with water-soluble paint which appeared darker when wetted by the splash from the piers. (2) Amount of erosion. Scour patterns in the outlet channel were obtained for each set of piers after the model had operated for one-half hour.

Figure 2 shows the results using the two sets of baffle piers. The photographs on the right side of Figure 2 indicate the test set-up and the results with the upstream face of the baffles placed normal to the 2:1 slope while the photographs on the left were obtained with the pier face vertical, Figure 1. By noting the height of the water marks along the painted wall in Figure 2C, it can be seen that the splash extended to approximately elevation 740 feet with the pier faces placed normal to the slope. When the vertical-faced piers were installed, the splash extended to elevation 735 feet. Thus, the height of splash was about 5 feet lower with the vertical-faced piers. No attempt was made to determine the quantity of water which would pass over the top of a training wall of normal height. However, it can be assumed that the amount of water passing over a given training wall would be proportional to the height of splash.

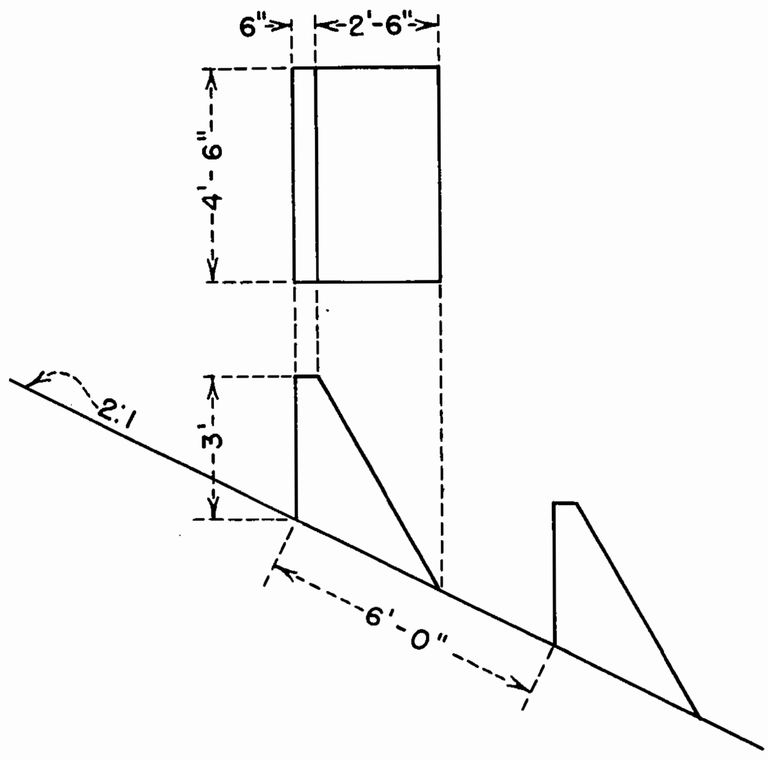
Figure 2D shows the scour pattern obtained with the two pier shapes. With the normal-faced piers installed the eroded bed was slightly higher in the vicinity of the right training wall than when vertical-faced piers were used, as indicated by the position of the 909-foot contour. However, for practical purposes, there is no difference in the two scour patterns. It should be noted that the scour pocket (elevation 906) along the left training wall was a result of the wall of symmetry and would not occur if the entire width of structure had been constructed.

The above tests indicate no conclusive superiority of one shape of block over the other as far as depth of scour is concerned. Although the depth of scour using the normal-faced piers was slightly less in the vicinity of the right training wall, the difference in the two scour patterns was too small to be conclusive. However, similar tests were made during the studies on the check intake structure, Potholes East Canal, using baffle piers 4 feet 6 inches high and a unit discharge of 61 second-feet. Results of these tests are shown in Figure 3. Although the outlet channel scoured to elevation 904 feet with each set of piers, more material was moved when the vertical-faced piers were installed. With the normal-faced piers, the low area in the resulting scour pattern was confined to a small pocket near the end of the right training wall as indicated by the 906-foot contour. The low area in the vicinity of the right wall was considerably larger when the vertical-faced piers were installed. This same tendency, although to a smaller extent, is indicated in the scour patterns of Figure 2 for the 3-foot piers.

From these tests, it is concluded that a baffled chute with the upstream face of the piers placed normal to the chute slope will give slightly less scour in the outlet channel than chute equipped with vertical-faced piers. Therefore, the normal-faced piers are recommended for locations where the scour must be kept to a minimum and splash over the training walls will create no unusual problems. However, in those locations where splash will cause washing and drainage problems, the vertical-faced piers are recommended to keep the amount of splash to a minimum.

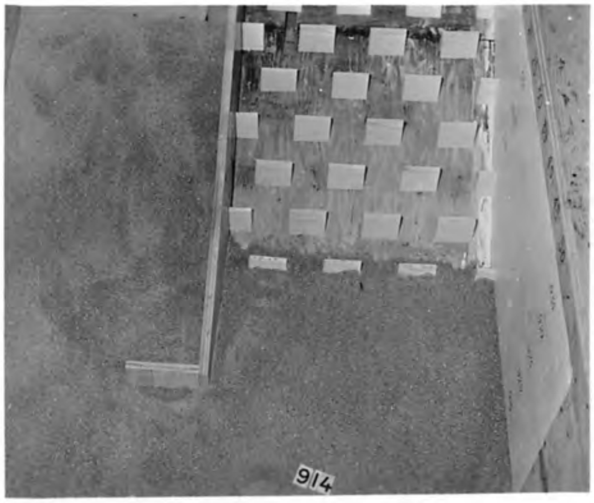


A PIER WITH FACE NORMAL TO SLOPE

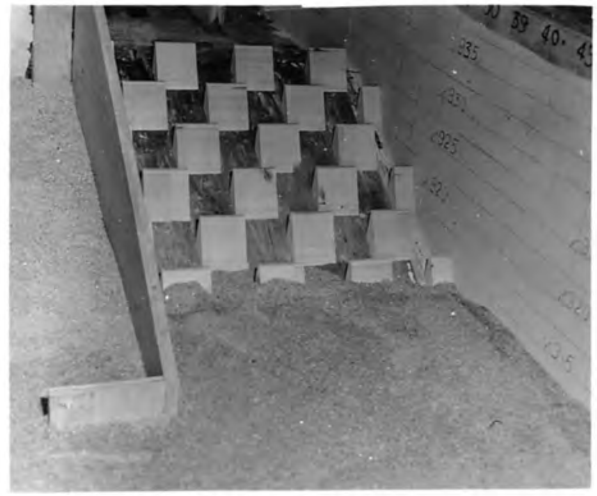


B. PIER WITH VERTICAL FACE

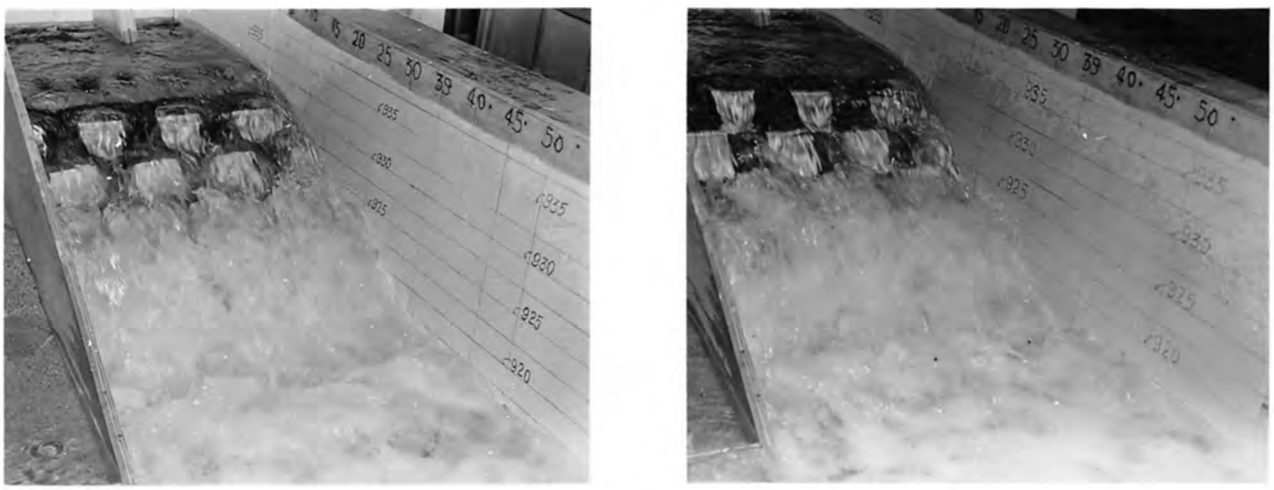
BAFFLED CHUTE STUDIES



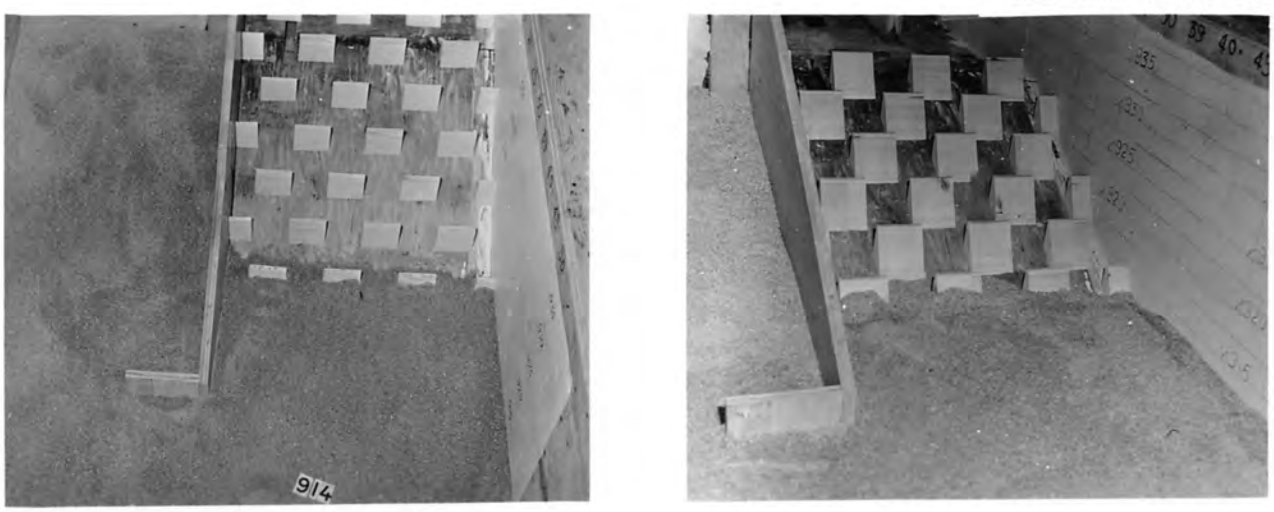
A. Upstream pier faces normal to slope.



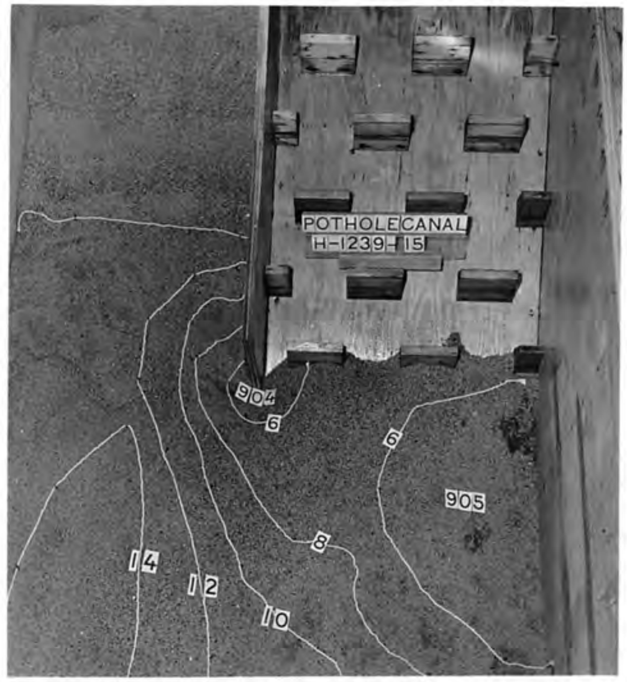
B. Upstream pier faces vertical.



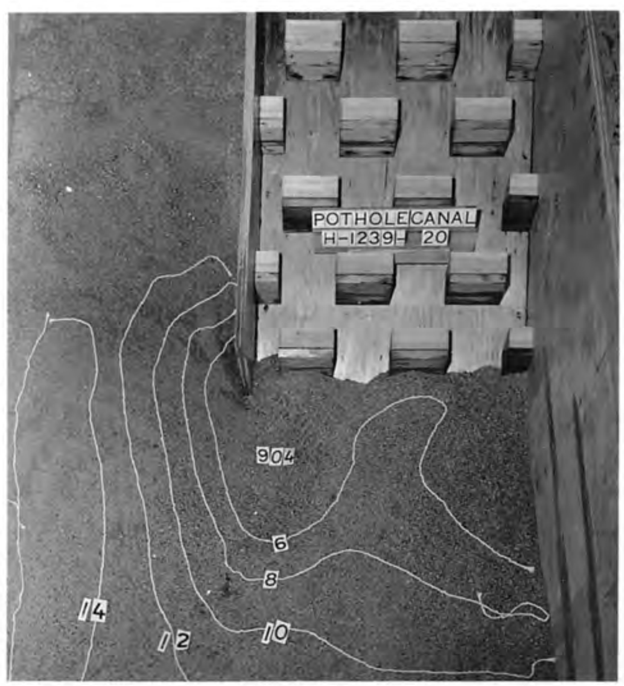
C. Discharge 35 cfs per foot of channel width.



D. Erosion after 1/2 hour of operation



A. Upstream pier faces normal to slope.



B. Upstream pier faces vertical.

BAFFLED CHUTE STUDIES
Check Intake Structure - Potholes East Canal
Discharge 61 cfs Per Foot of Channel Width