University of Washington
Department of Civil and Environmental Engineering

THE MOSSYROCK DAM HYDRAULIC MODEL INVESTIGATION

Howard S. Strausser

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THE MOSSYROCK DAM

Hydraulic Model Investigation of

Revised Plunge Pool

Conducted for:

City of Tacoma

Department of Public Utilities

Light Division

By:

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PREFACE

This hydraulic model investigation was undertaken at the request of Harza Engineering Company by the authors during the period 16 December 1965 and 31 January 1966. The City of Tacoma, Department of Public Utilities was the client.

The study was conducted on the already existing Mossyrock Dam model at the Charles W. Harris Hydraulics Laboratory, University of Washington. Model alterations and data collection was done by the authors. A motion picture record of the model performance was prepared by the Audio-Visual Services and is to be considered a part of this report. Appreciation is extended to Professor Eugene P. Richey for his timely advice and suggestions.

Frequent consultations were held with Mr. Earl J. Beck, Project Manager and Mr. Otto Lunn, Resident Engineer of Harza Engineering Company.

LIST OF FIGURES

LIST OF PLATES

SUMMARY

The main point of concern in this phase of the study was the determination of velocity magnitudes on the boundaries of the plunge pool with the most recent topographical features incorporated in the model. The 100,000 cfs was emphasized in this study since it was deemed to be an optimum flood flow of a reasonable rate of occurrence. The reservoir was maintained at elevation 770 which required partial gate control at all flows.

INTRODUCTION

For a complete description of the Mossyrock Model and the test facilities, reference should be made to the original report: THE MOSSYROCK DAM, HYDRAULIC MODEL INVESTIGATION, Technical Report No. 17, Charles W. Harris Hydraulics Laboratory, University of Washington, December 1964. Since the spillway, fitted with 4 warped buckets, was not photographed and shown in the original report, Plate 1 showing this configuration has been included in this report for the record.

As excavation of the damsite progressed, it became apparent that the existing rock foundation differed to a certain degree in its contours from that anticipated. First, the dam axis had to be shifted about 50 feet upstream to take advantage of a better quality rock at the abutments. Second, the curvature of the downstream face of the dam was revised and thus required an additional bulge to be constructed on the existing model. Third, the original model study indicated that it would be advisable to re-position the spillway with respect to the dam itself thereby placing the spillway jet in a more symmetrical orientation with respect to the plunge pool topography. Fourth, the actual plunge pool rock topography differed to some extent with that which was expected on the basis of core borings. Finally, the complete removal of the upstream migrant fish facilities required a change of model configuration in that area and removed the performance of such facilities from further consideration.

The over-all changes became so extensive that a complete reconstruction of the plunge pool boundaries and the powerhouse were deemed necessary. Since the original model had to be used and it appeared to be a prohibitive operation to move the spillway 10 feet toward the arch centerline, it was decided to establish the existing spillway centerline as a reference. The new powerhouse location and the plunge pool topography were therefore oriented with respect to the spillway centerline. Field surveys were maintained as excavation progressed and this information was forwarded to the authors at frequent intervals so that the latest and most complete topographical data could be incorporated in the model. The initial tests were done with the floor of the pool at elevation 275; however, subsequent excavation indicated that a floor at elevation 250 would be advisable. The test results reported herewith are based upon the floor at this latter position. The powerhouse had to be relocated almost 10 feet closer to the jet and the rock island also had to be re-positioned in the pool. Plates 2 and 3 are intended to show the final configuration of the contours and powerhouse location. The thin layer of small gravel shown on the floor in Plate 3 was used to determine erosion tendencies.

INSTRUMENTATION

The velocities were measured in the original model by means of a pressure (Statham) cell and recorded on a Brush recorder. Only the maximum velocities were reported. In this investigation, since time was very limited, it was decided to measure only average velocities by means of the standard Prandtl tube, thus eliminating the time required to reduce the data to usable form. The scale of the Prandtl tube was graduated to read the average model velocity directly in feet per second. As the model was operated according to the Froude criterion,

$$\frac{V_p}{V_m} = \left(\frac{l_p}{l_m}\right)^{1/2}$$

$$\text{or,} \qquad V_p = \sqrt{60} \; V_m$$

An examination of data from the original model was made and it was found that the average velocities measured in the present instance agreed almost exactly with those average velocities obtained from the Statham recordings. As a consequence, it would be safe to conclude that transient <u>maximum</u> velocities will occur which are about 50% greater than the averages reported herewith. It should be emphasized that only those velocities in very close proximity to the boundaries were measured; no measurements were made at any great distance from the boundaries.

In order to check the impact of the jet on the floor of the plunge pool, a total of 35 piezometers were arranged in a symmetrical pattern on said floor and their deflections were compared to the piezometric head indicated by the static pressure. Since the influence of the jet directly on the floor was quite small, the results are not reported here.

Velocity checks were made in those areas deemed to be critical such as the tailrace of the powerhouse and the sides of the powerhouse.

In order to obtain an indication of possible scour on the floor of the pool, about 2 inches of a fine gravel and sand mixture were spread on the bottom after all velocity measurements were completed. The movement (or lack of it) of this material was observed by means of an underwater viewing tube which proved to be a most convincing piece of equipment since it permitted our first opportunity to visually examine the behavior of the jet after discharging into the pool. The bubbles of air entrained by the jet as well as dye injected at various points also were used to indicate velocity magnitudes and directions.

RESULTS AND CONCLUSIONS

As mentioned, velocity data was collected for flows of 25,000; 50,000 and 100,000 cfs. in the prototype. It should be noted that these are true spillway flows since none of the turbines were in operation; therefore, these are flows in excess of turbine discharge. For all of these flows, the gates were regulated so as to maintain a reservoir level at 770. Discharge was passed through all four spillway bays (Plates 4, 6, 8) and, in addition, since flows up to 25,000 cfs. are likely to be passed through only one bay and flows to 50,000 cfs. through two bays, Plates 5 and 7 were made showing these respective conditions just for the record. Velocity measurements, however, were restricted to flows through all four bays since this placed the spillway jet in closest proximity to the side boundaries.

The boundary velocities are tabulated for the three flows as follows: Table I, 25,000 cfs.; Table II, 50,000 cfs.; Table III, 100,000 cfs. Those special velocity observations which are of interest are shown as footnotes to each table. Examination of results from the preceding model investigation indicate that these average velocities will be exceeded by 50% for short periods. Reliable readings of velocities less than 8 fps. were not possible with the Prandtl tube and are therefore indicated by the note "less than 8 fps." rather than by absolute values.

To assist the reader in orienting the locations where velocities were measured, Figure 1 has been prepared showing these points located with respect to the spillway centerline and the dam axis; salient features of the powerhouse and topography are also shown for clarity. Figures 2 and 3 show some of the key velocities encountered at a flow of 100,000 cfs. in a plan view and longitudinal cross-section respectively.

The surface conditions of the plunge pool were altered to some extent. The height and appearance of the surface boil is not noticeably changed; however, the re-alignment of the spillway has drastically reduced the large circulatory flow previously noted and at the same time has reduced the ride-up of wave action on the left bank. On the right bank, conditions do not appear to be appreciably different so far as the powerhouse is concerned. Plates 9 and 10 show the conditions on left and right banks in turn at a flow of 100,000 cfs. They also indicate a relatively quiescent flow between jet and dam structure.

The gravel bottom was continuously observed through the viewing tube as the flow was gradually increased. Not until the spill approached 70,000 cfs. was any movement noticed, and the initial movement appeared to be of a transient and local nature. After discharging 100,000 cfs. for a time interval roughly comparable to 4 to 6 hours on the prototype, the plunge pool was de-watered and erosion effects were examined. As may be seen in Plate 11, there will be a tendency for erosion at the toe of the slope. Unfortunately, no definitive answer can be given as to just exactly what size of material will be moved in the prototype under similar conditions. On the basis of the underwater observations, however, it would be safe to conclude that the region in the vicinity of the dam structure itself would be the last to be affected by any flow. No bed movement was to be seen at the base of the dam even at flows in excess of 100,000 cfs. and velocities in excess of 6 fps. would not be encountered at this discharge. The slope at the downstream end of the pool can be expected to take the brunt of the jet erosion, as shown by Figure 4. Here, the velocities become quite large and considerable erosion can be anticipated certainly at flows much above 50,000 cfs. At the higher discharges, a separation effect is noted at the top of the slope on the downstream end. As a result, a bar is formed in this area which may be seen in Plates 11 and 12. A gradual rounding or gradation is recommended at this location to reduce the separation and thereby reduce or eliminate this bar formation. If this bar is not permitted to form, the flow from the pool to the river will not be as constricted.

A flow reversal was noted against the right bank which attained average velocities of about 12 fps. at a 100,000 cfs. discharge. This flow caused some erosion of the gravel bank and carried some of this eroded material down into the plunge pool and a small amount into the No. 1 draft tube; whether this deposition will occur when the turbines are in operation is questionable.

It is concluded that: (1) The structure itself is proof against the hydraulic effects up to the anticipated maximum flows. (2) The amount and extent of the paved area will depend largely upon the quality of the boundary material. (3) The downstream bottom slope will be eroded to some stable equilibrium configuration and the rate and degree of such erosion will depend, at least in part, upon the amount and size of loose material permitted to accumulate in the downstream portion of the plunge pool. (4) Overburden and loose material might well be removed from both left and right banks immediately downstream from the plunge pool. (5) No adverse effects were noted on the powerhouse which would not normally be expected.

TABLE 1

Average Boundary Velocities

Q = 25,000 cfs

Q = 25,000 cfs. Upstream end of jet at 140' on T.W. Surface

T.W. @ 437' Downstream end of jet at 285' on T.W. Surface

Dist. from Dam Axis	Left					℄	Right				
	125'	100'	75'	50'	25'	Spill.	25'	50'	75'	100'	125'
50'											
100'											
150'						Less than 8 fps.					
200'											
250'											
300'	-	12	-	10	-	10	-	<8	-	8	
350'	-	14	-	12	-	8	-	<8	-	<8	
470'	-	-	-	10	-	10	-	10	-	-	

No velocities greater than 8 fps were detected on side or bottom boundaries.

<u>T A B L E   2</u>

Average Boundary Velocities

Q = 50,000 cfs

Q = 50,000 cfs. Upstream end of jet at 125' on T.W. Surface

T.W. @ 448' Downstream end of jet at 260' on T.W. Surface

Dist. from	Left					℄	Right				
Dam Axis	125'	100'	75'	50'	25'	Spill.	25'	50'	75'	100'	125'
50'											
100'											
150'					Less than 8 fps						
200'											
250'											
300'	-	-	-	<8	-	< 8	-	8	-	-	-
350'	-	-	-	10	-	22	-	18	-	10	-
470'	-	-	-	16	-	22	-	16	-	-	-

Special observations: 10 fps in front of draft tubes - C.W. circulation. <8 fps along D.S. face of Powerhouse. Max. velocity of 18 fps noted along left bank at juncture of floor, slope and bank. Max. velocity of 8 fps noted at juncture of Powerhouse foundation and downstream end of rock island.

TABLE 3

Average Boundary Velocities

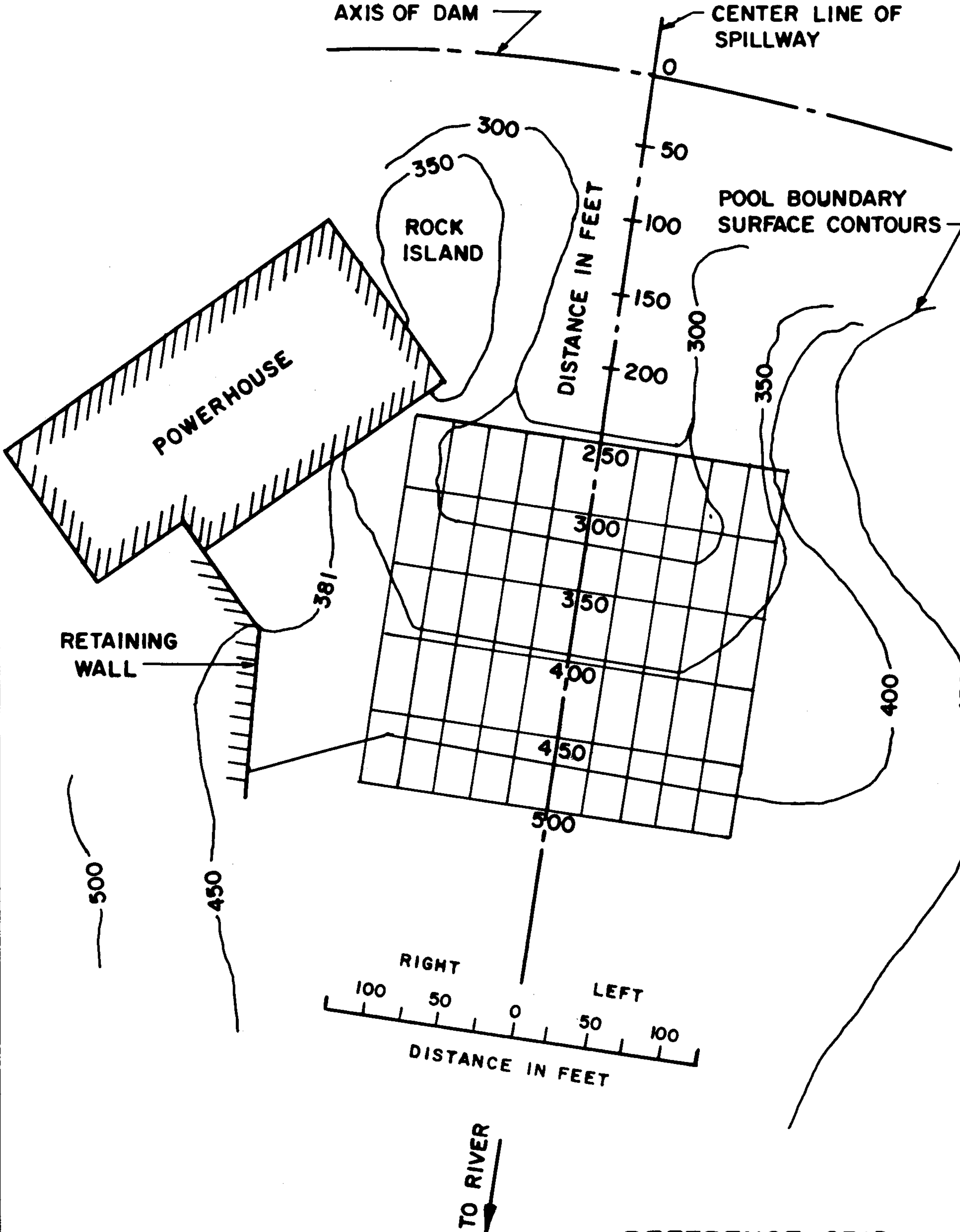
Q = 100,000 cfs

Q = 100,000 cfs. Upstream end of jet at 100' on T.W. Surface

T.W. @ 467' Downstream end of jet at 235' on T.W. Surface

Dist. from Dam Axis	Left 125'	Left 100'	Left 75'	Left 50'	Left 25'	CL Spill.	Right 25'	Right 50'	Right 75'	Right 100'	Right 125'
50'											
100'						Less than 8 fps.					
150'											
200'											
250'	-	-	-			15 fps toward dam			-	-	-
300'	-	-	24	26	26	20	18	12	12	-	-
350'	-	28	24	28	32	44	36	28	22	-	-
470'	24	28	34	40	40	36	28	24	16	12	-

Special observations: 12 fps velocities noted along front and sides of powerhouse. C.W. circulation in front of draft tubes. Max. velocity of 25 fps noted along left bank opposite jet at mid-depth of pool. Max. velocity on right boundary, 12 fps, on slope in front of powerhouse.

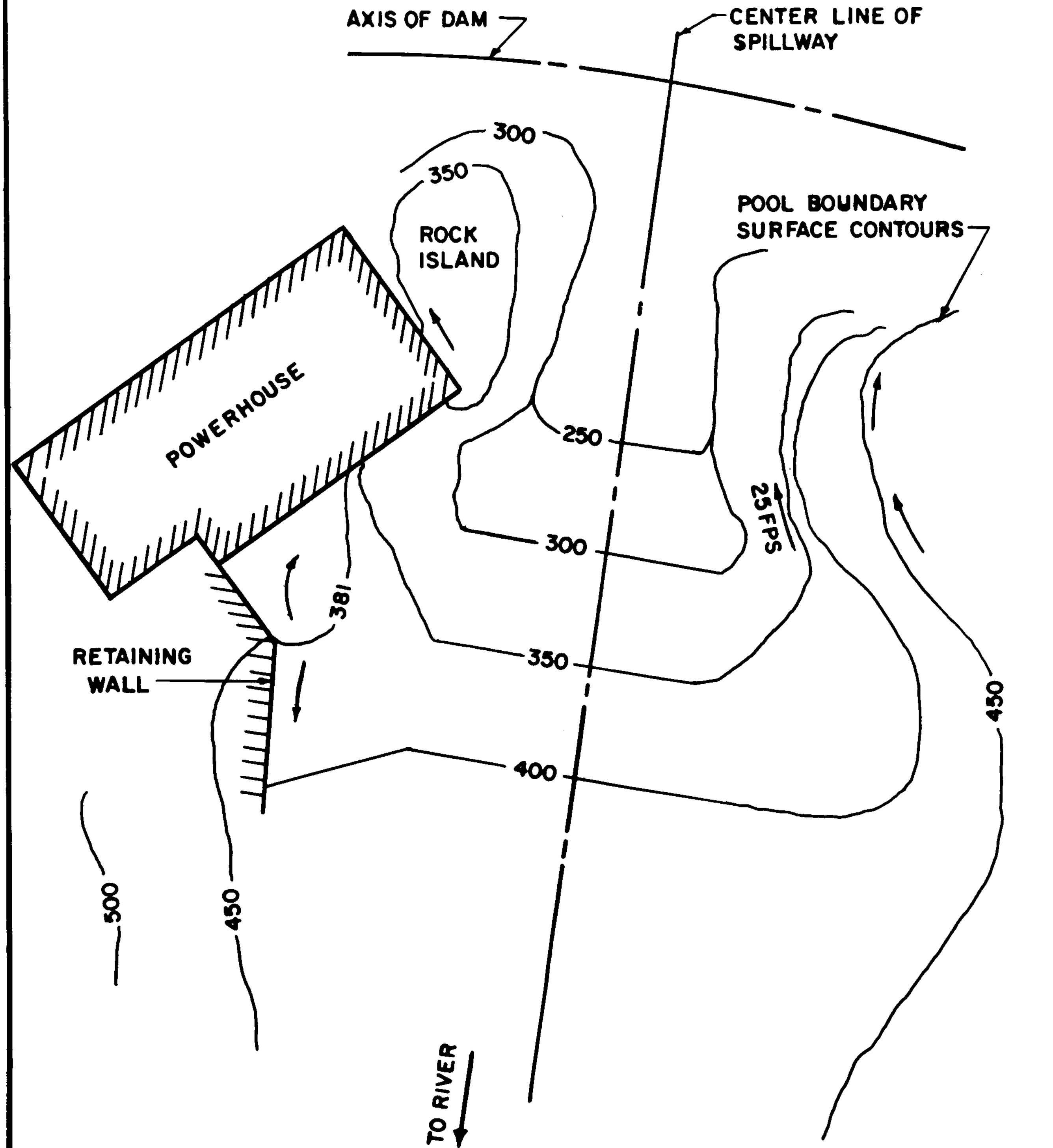


REFERENCE GRID

NOTE:
WORK THIS DWG. WITH TABLES 1,2 & 3

SCALE: 1" = 100 FEET

FIGURE 1



NOTE:
⟵ VELOCITY LESS THAN 12 FPS UNLESS NOTED

SURFACE AND POOL BOUNDARY VELOCITIES
Q = 100,000 CFS
T.W. = 467
RESERVOIR 770

SCALE: 1" = 100 FEET

FIGURE 2

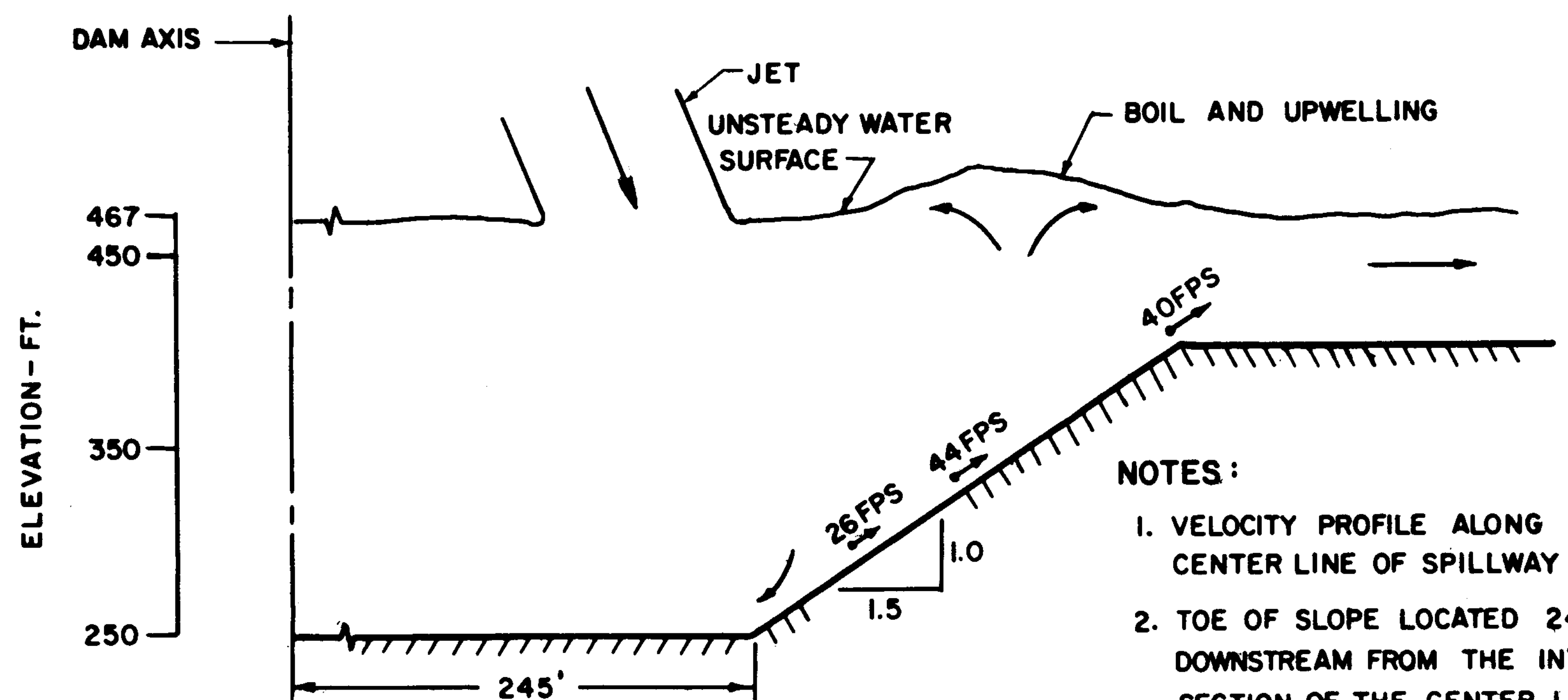
SPILLWAY JET PROFILE

MAXIMUM AVERAGE VELOCITIES

Q = 100,000 CFS

FOUR WARPED BUCKETS

RESERVOIR 770

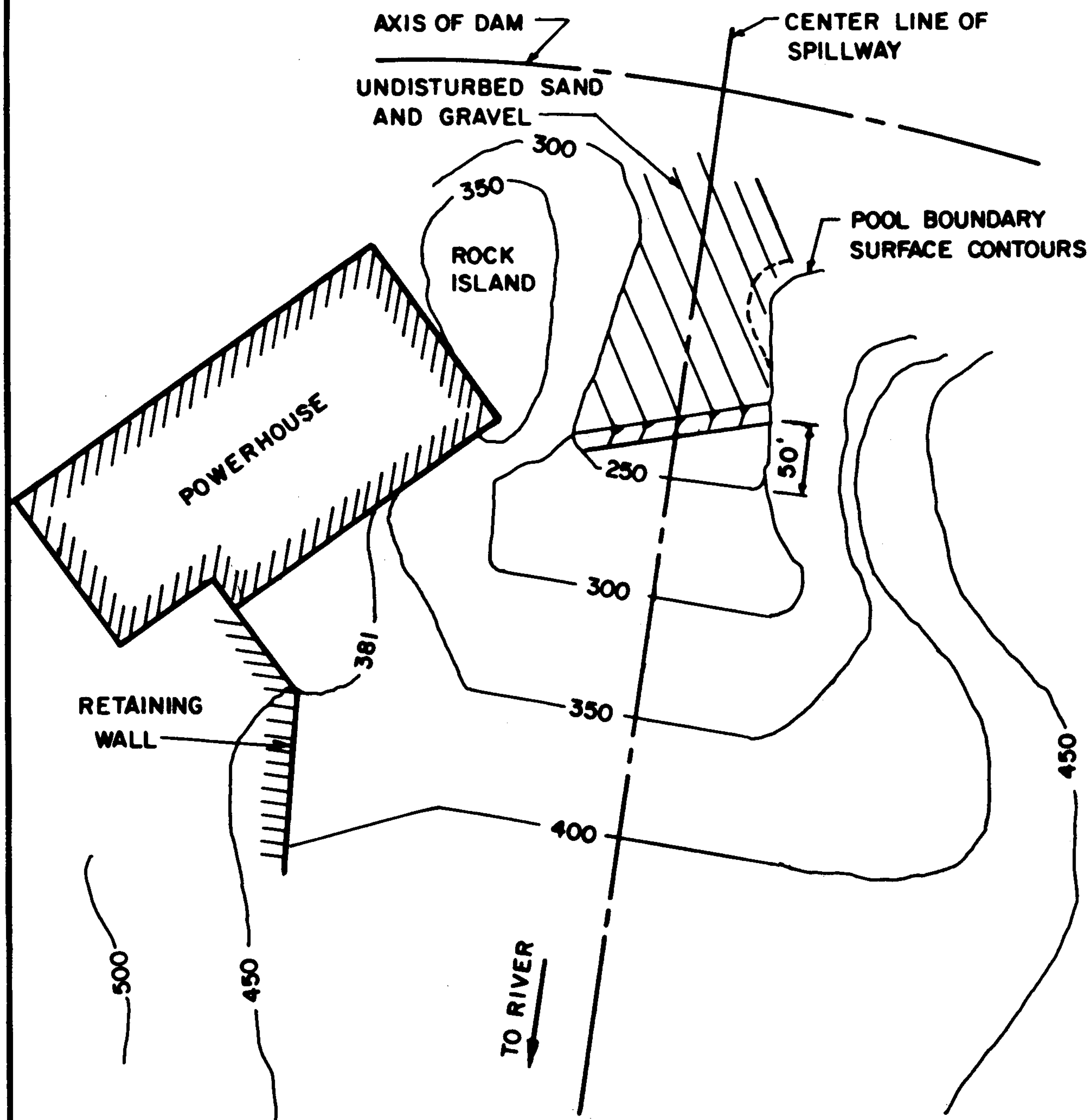


NOTES:

1. VELOCITY PROFILE ALONG CENTER LINE OF SPILLWAY
2. TOE OF SLOPE LOCATED 245 FT. DOWNSTREAM FROM THE INTERSECTION OF THE CENTER LINE OF THE SPILLWAY AND AXIS OF DAM
3. WORK THIS DRAWING WITH TABLE 3

SCALE: 1" = 100 FEET

FIGURE 3



NOTES:

1. INITIAL CONDITION:
   PLUNGE POOL LINED TO ELEV. 250,
   SAND AND GRAVEL TO ELEV. 260.
2. TOE OF SLOPE LOCATED 245 FT. DOWNSTREAM FROM THE INTERSECTION OF AXIS OF DAM AND CENTER LINE OF SPILLWAY.

BED MOVEMENTS ON PLUNGE POOL FLOOR
Q = 100,000 CFS
RESERVOIR 770

SCALE: 1" = 100 FEET

FIGURE 4

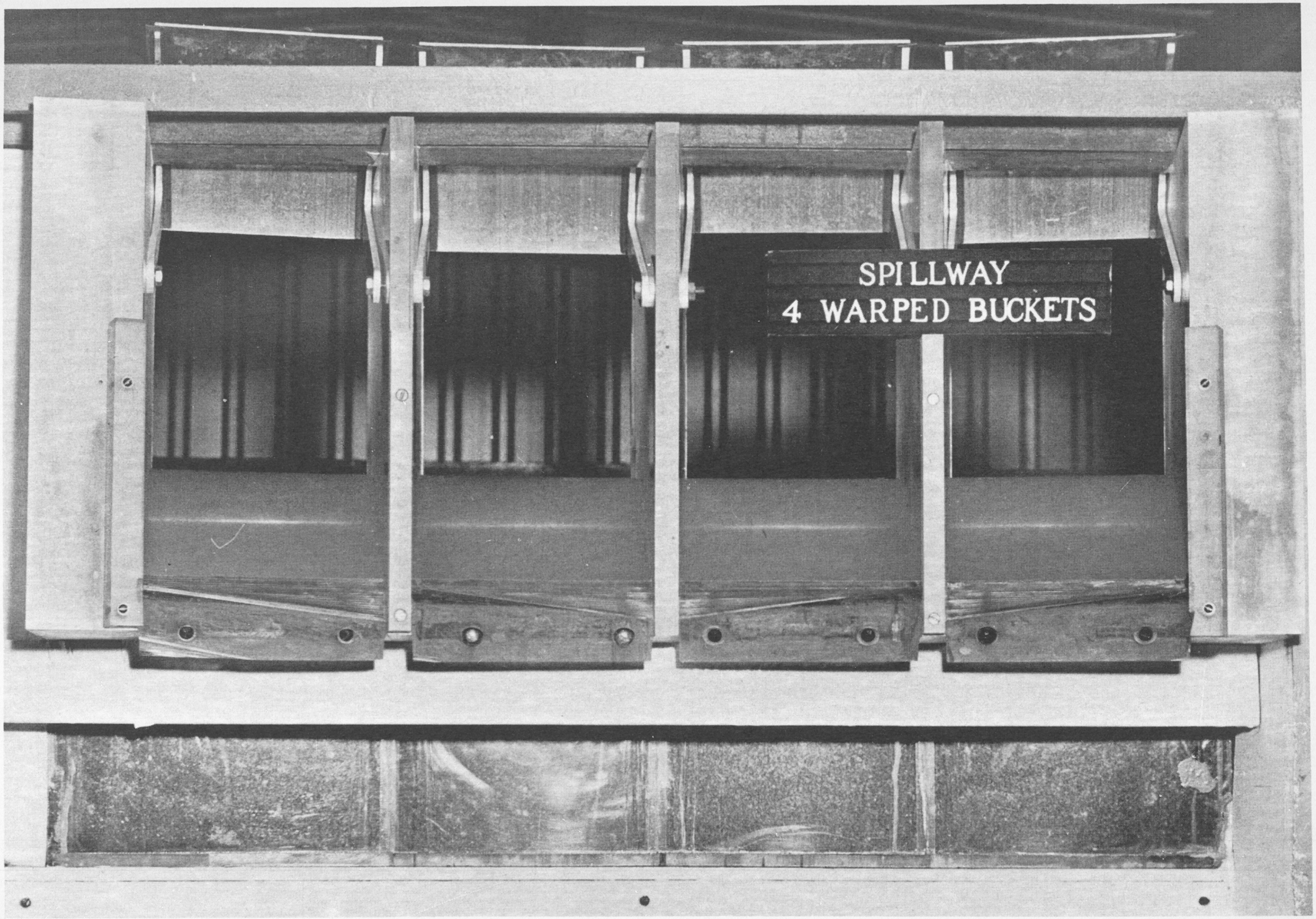


PLATE 1


SPILLWAY
4 WARPED BUCKETS
MOSSYROCK
DAM MODEL
FINAL PLUNGE
POOL GEOMETRY
JAN 25 1966

PLATE 2

PLATE 3

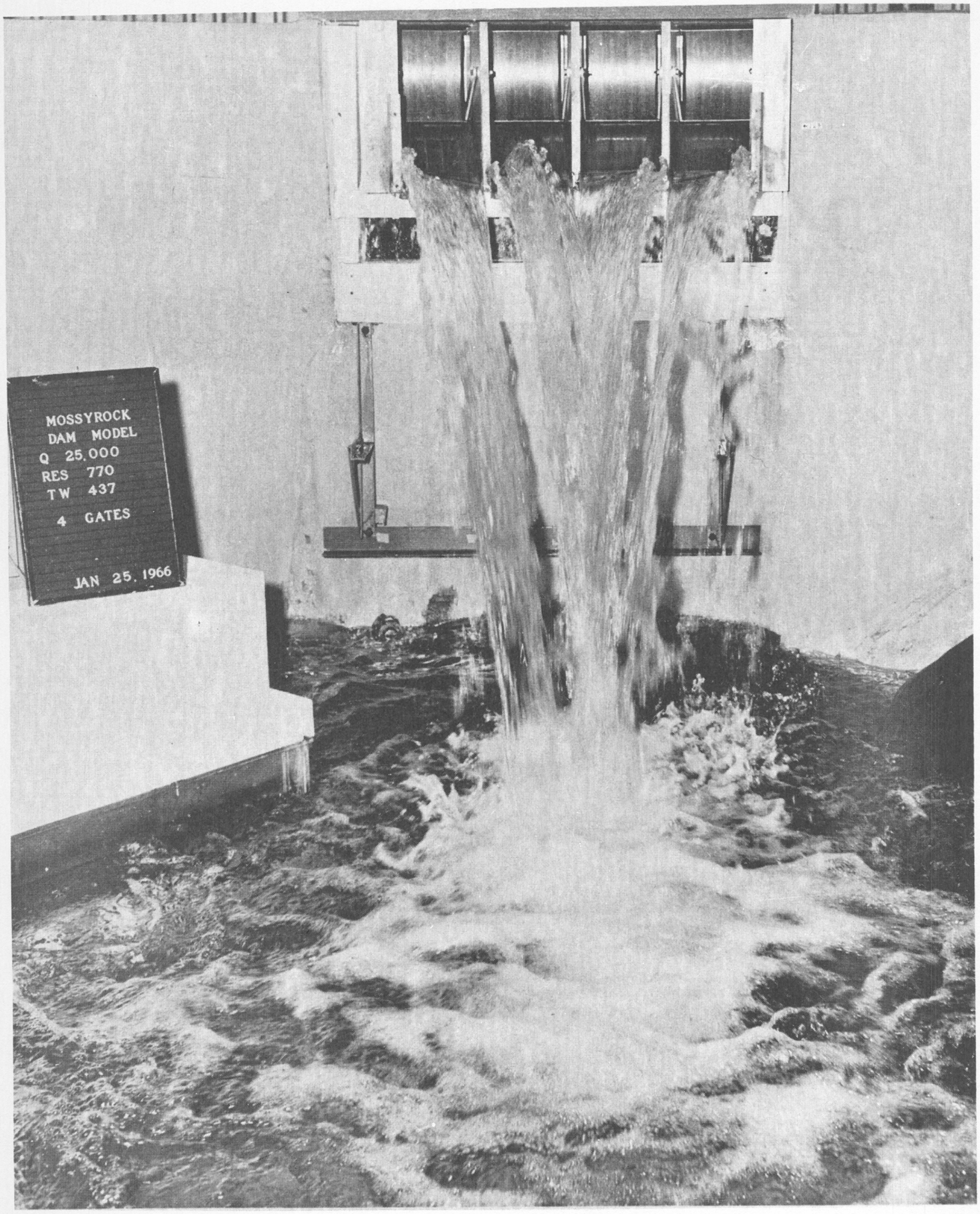
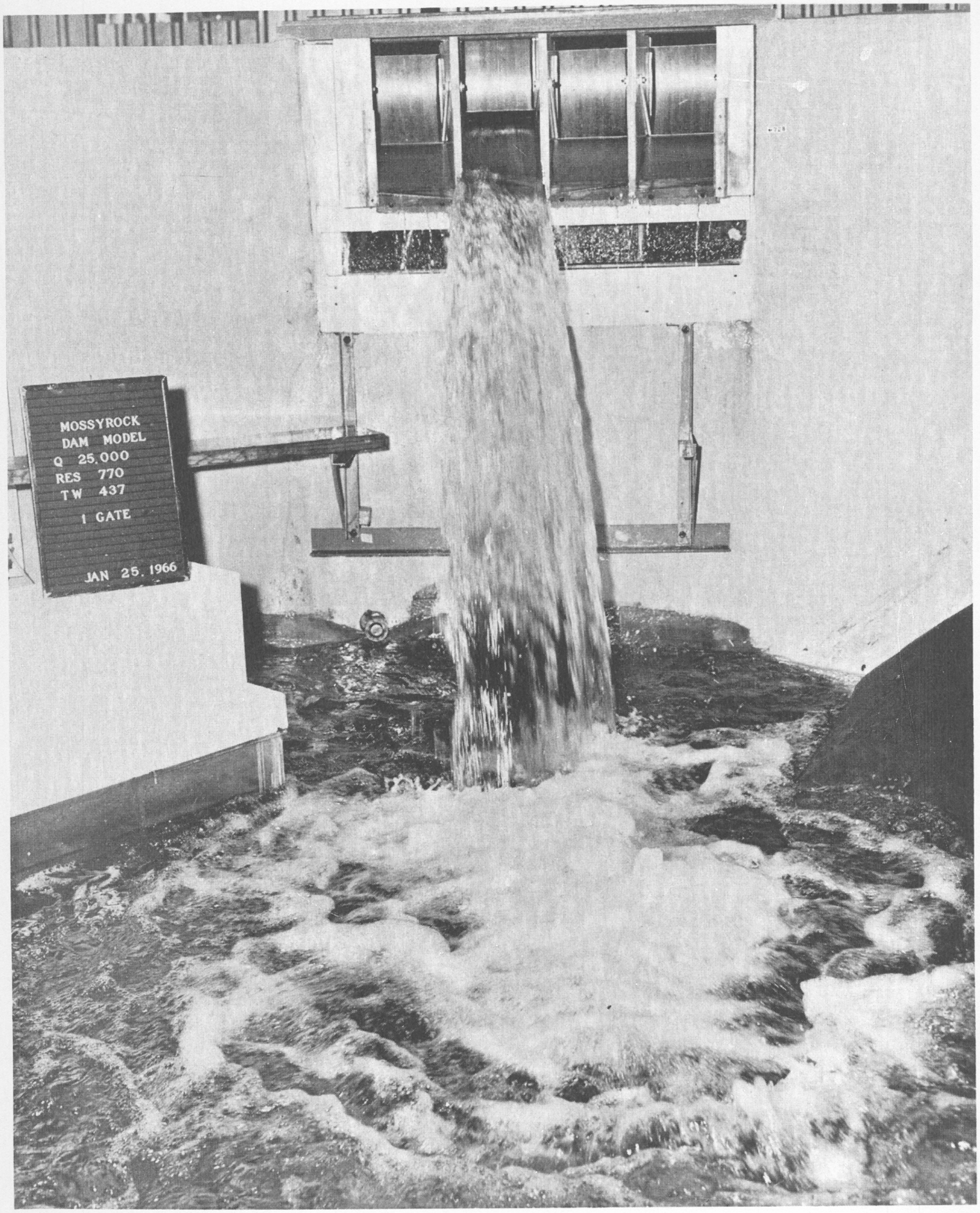


PLATE 4



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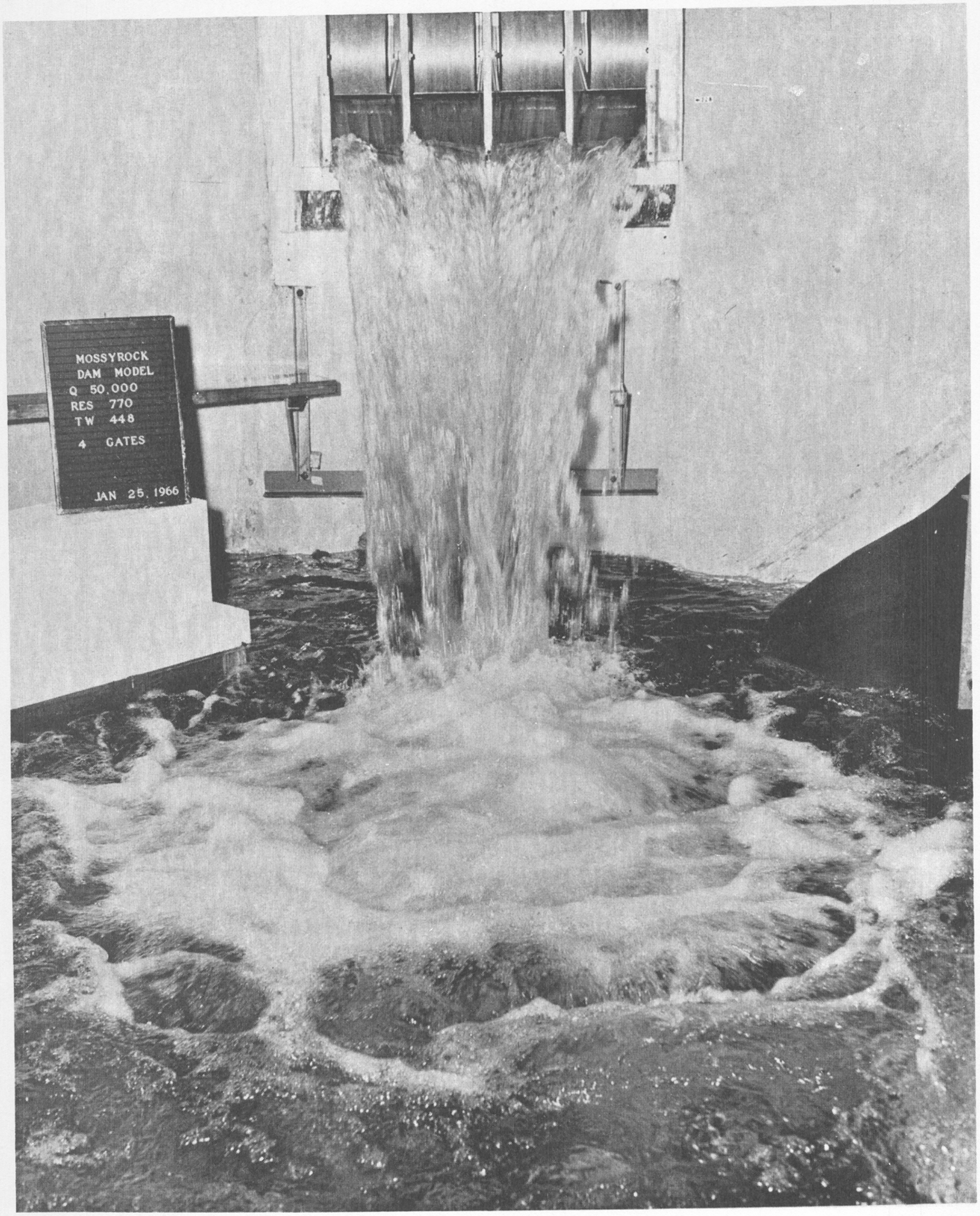

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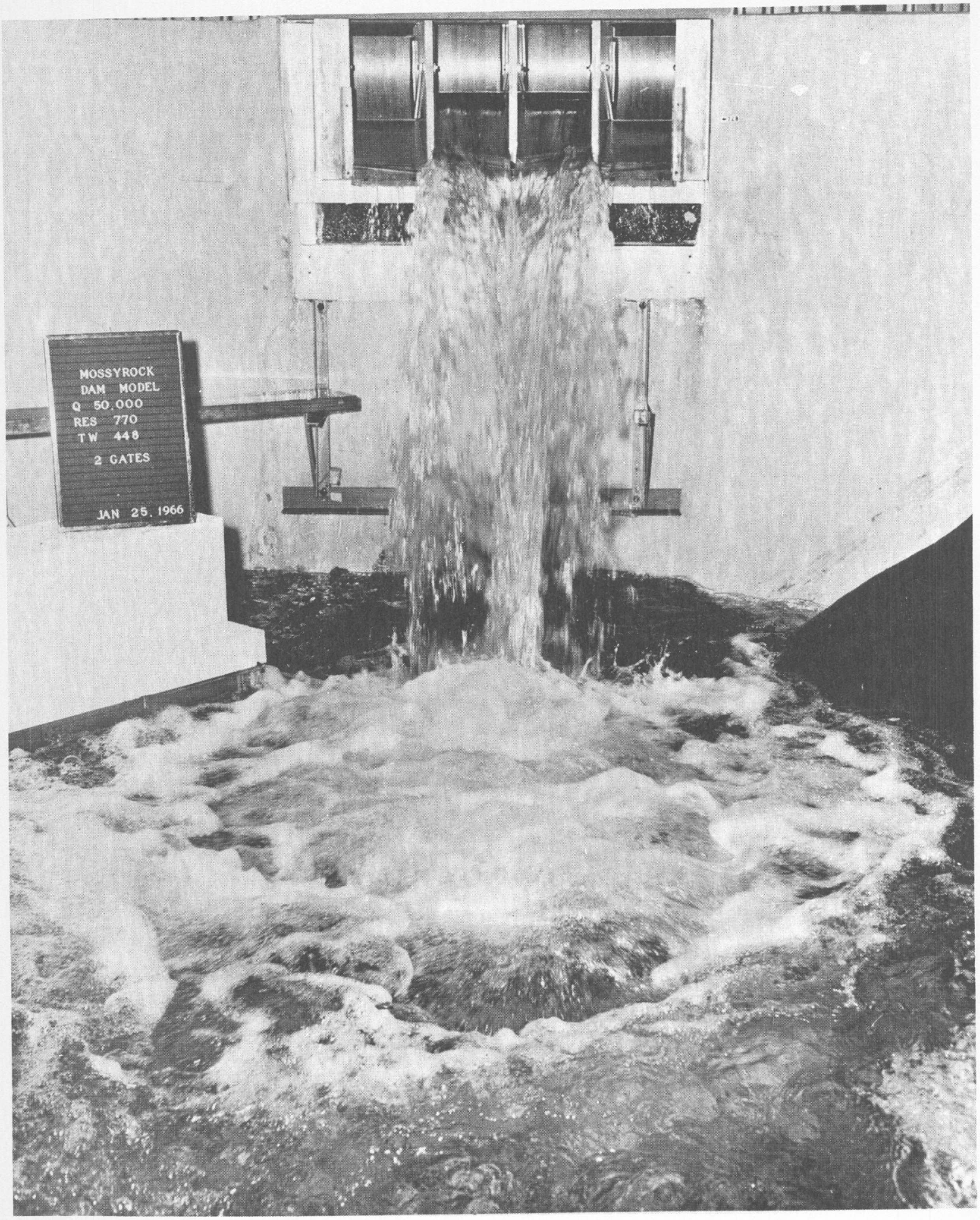

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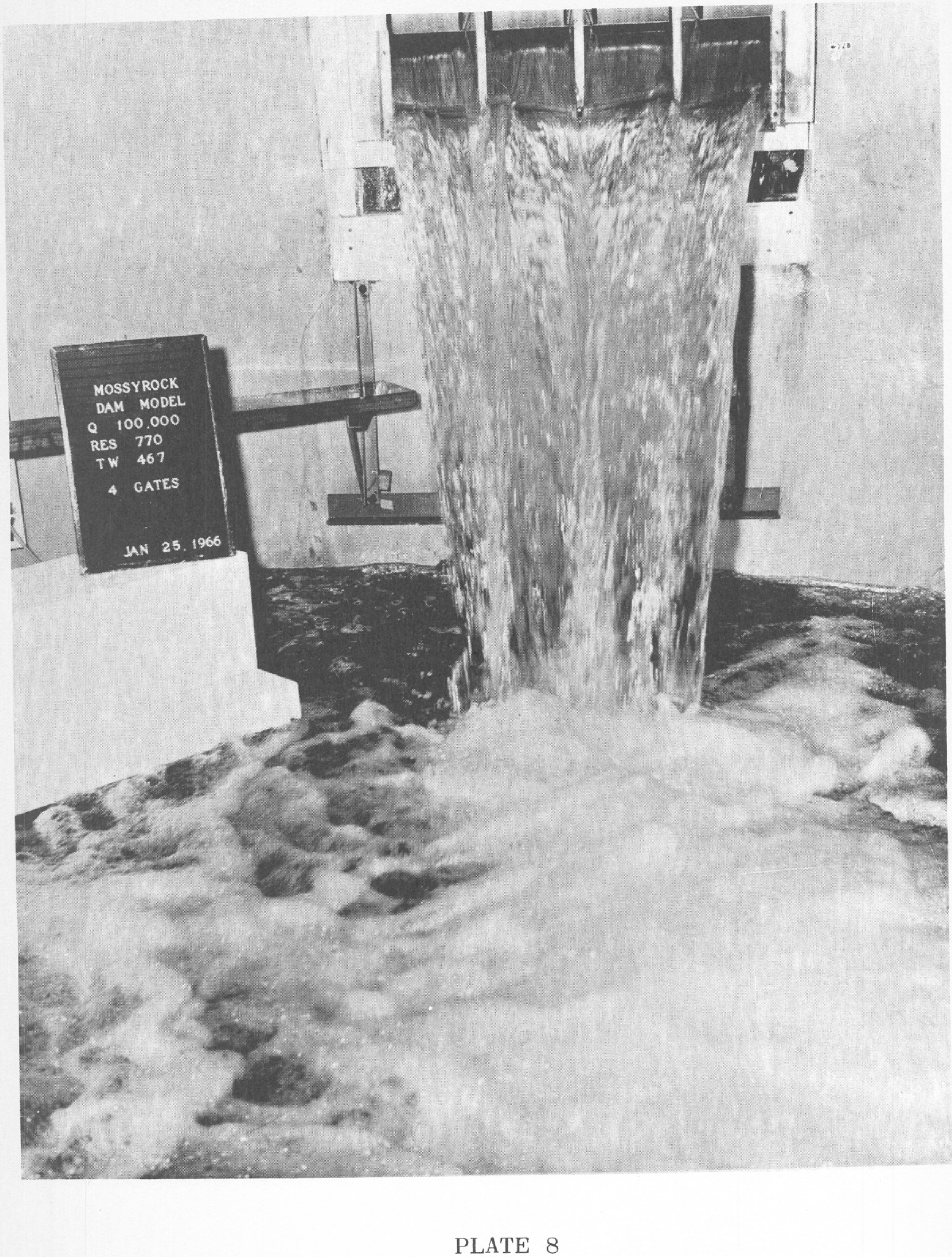
MOSSYROCK
DAM MODEL
Q 100,000
RES 770
TW 467
4 GATES
JAN 25, 1966

PLATE 8

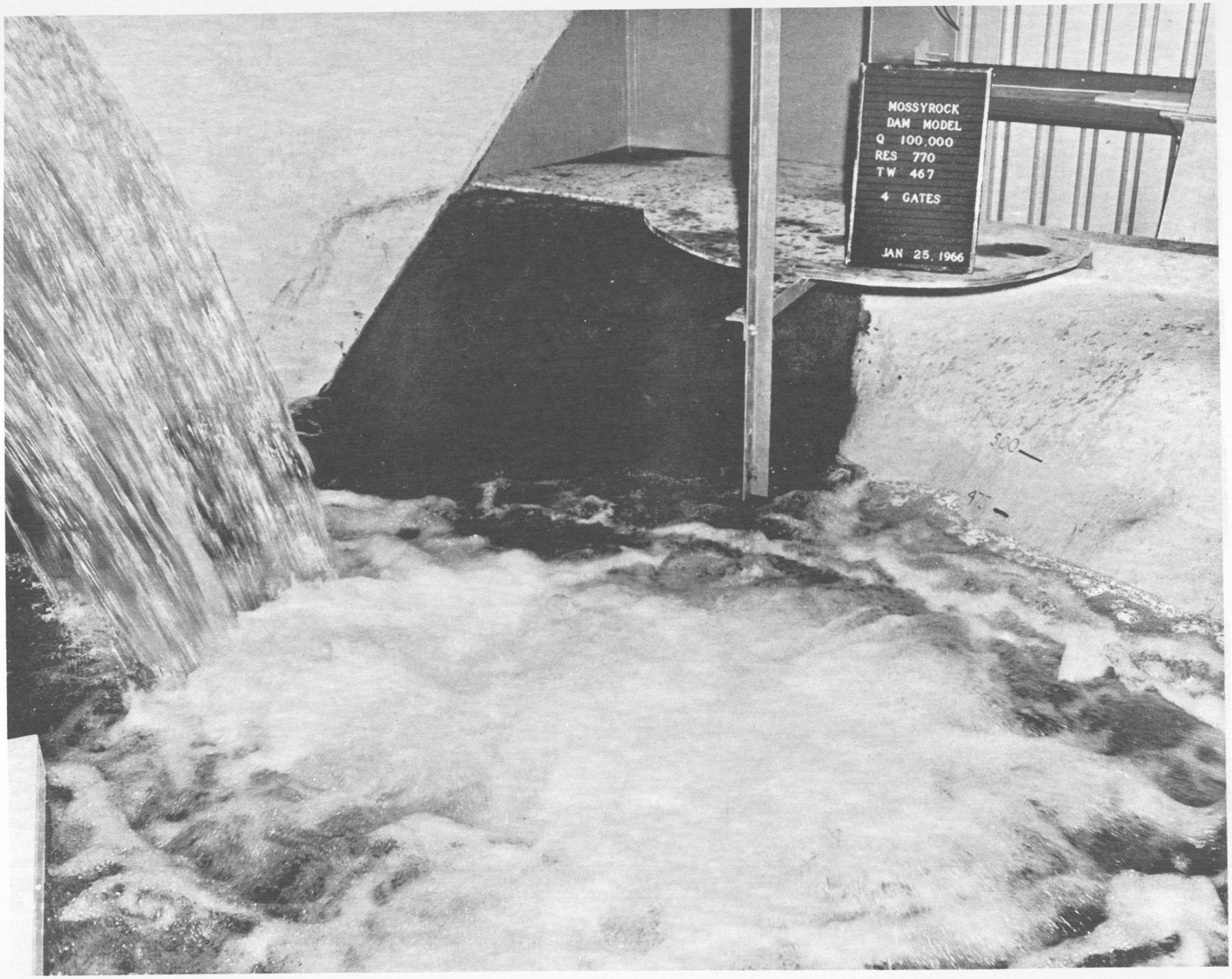
MOSSYROCK
DAM MODEL
Q 100,000
RES 770
TW 467
4 GATES
JAN 25, 1966
300
477

PLATE 9

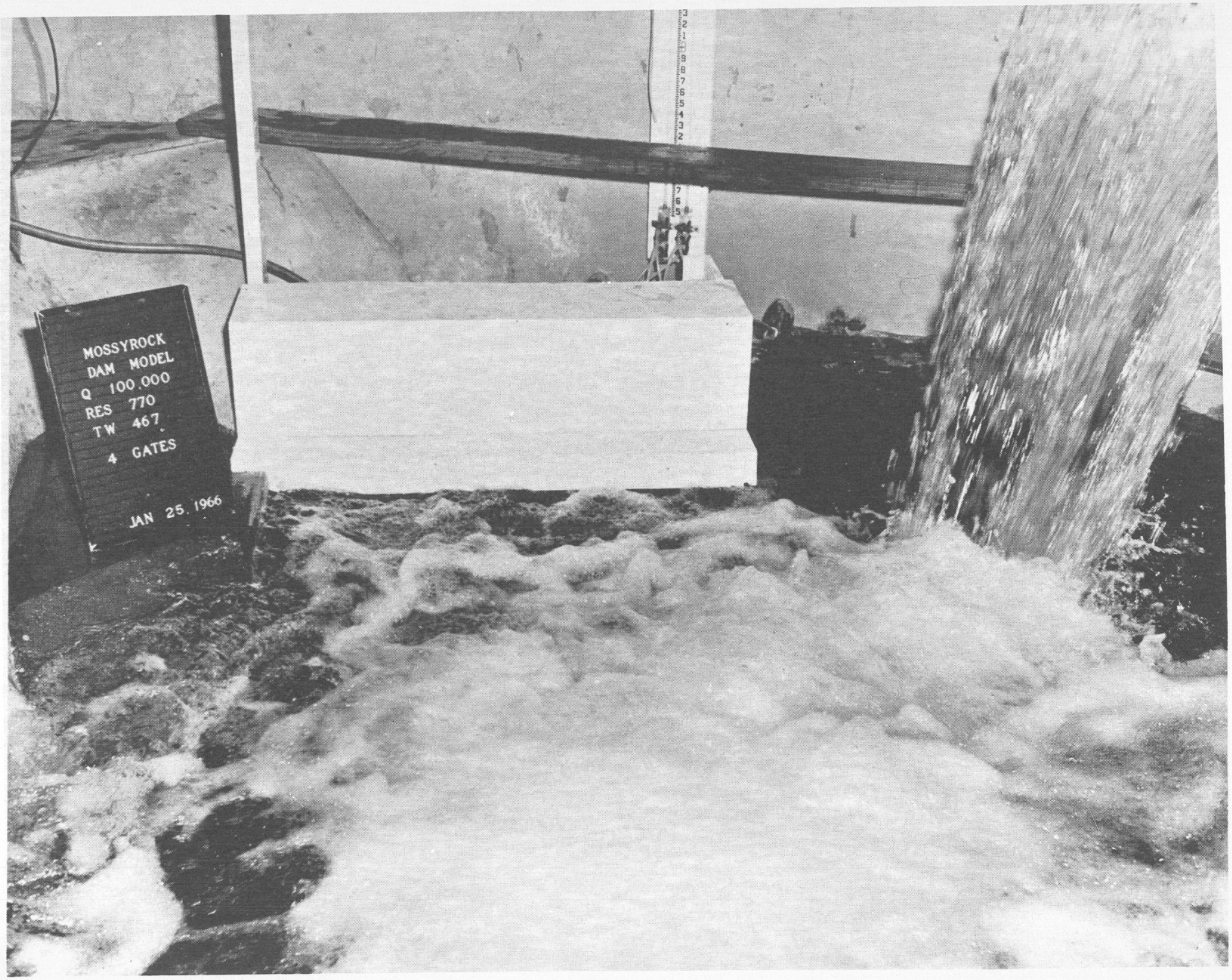
MOSSYROCK
DAM MODEL
Q 100,000
RES 770
TW 467
4 GATES
JAN 25, 1966

PLATE 10

PLATE 11

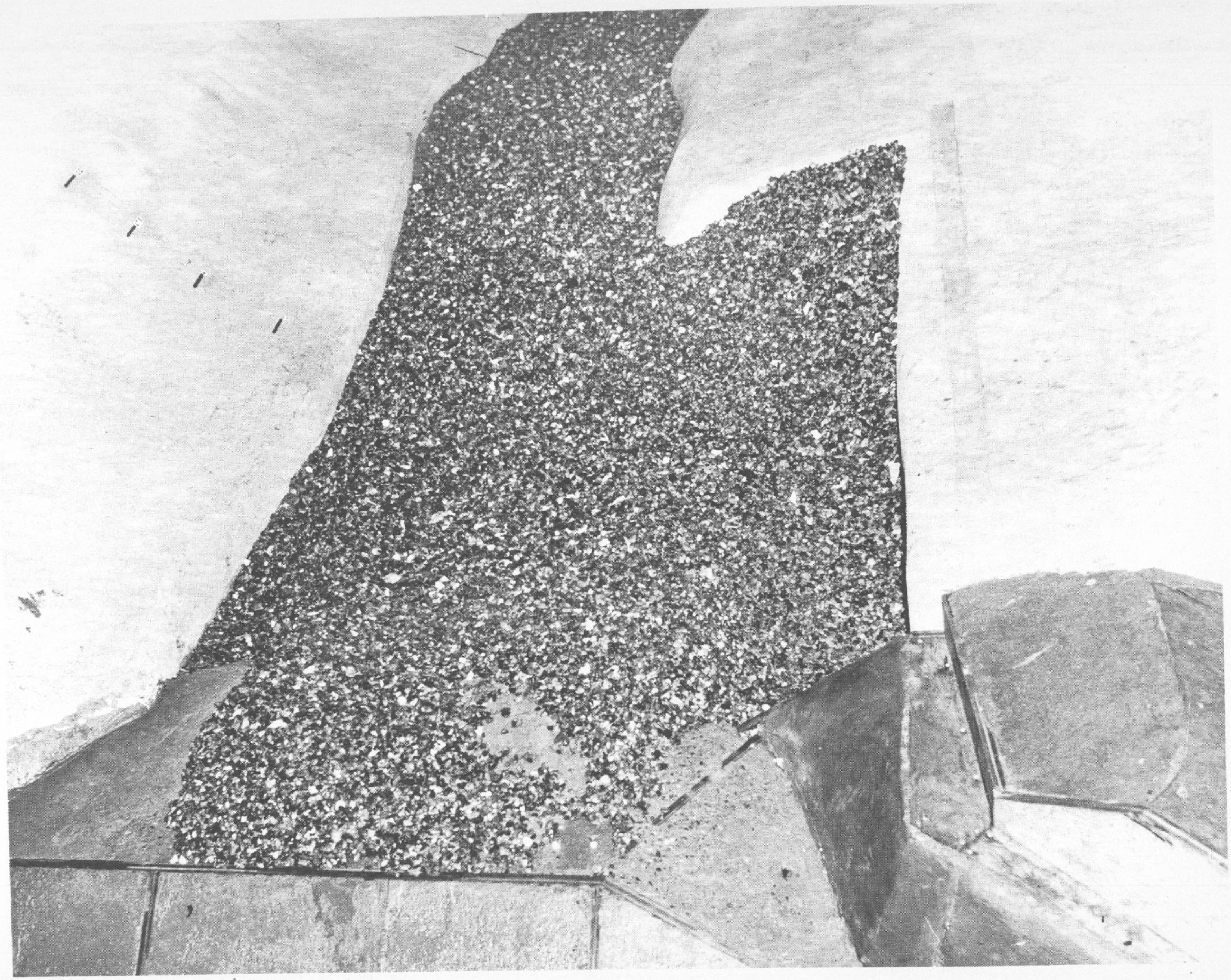

PLATE 12