

# STILLING BASIN MODIFICATIONS BULL SHOALS DAM WHITE RIVER, ARKANSAS

Hydraulic Model Investigation



TECHNICAL REPORT NO. 2-488

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## PREFACE

Model studies of modifications for the Bull Shoals Dam stilling basin were authorized by the District Engineer, Little Rock District, Corps of Engineers, on 2 February 1953. Personnel of the Hydraulics Division, Waterways Experiment Station, who participated actively in the studies were: Messrs. F. R. Brown, T. E. Murphy, C. J. Powell, and C. W. Brasfeild.

During the course of the studies, which covered the period from June 1953 to May 1954, Mr. J. H. Douma of the Office, Chief of Engineers; Messrs. H. W. Feldt and R. H. Berryhill of the Southwestern Division; and Messrs. G. R. Schneider, E. B. Madden, and E. B. Pickett of the Little Rock District visited the Waterways Experiment Station to observe the models in operation and to discuss test results.

## CONTENTS

	<u>Page</u>
PREFACE . . . . .	iii
SUMMARY . . . . .	vii
PART I: INTRODUCTION . . . . .	1
Description of the Prototype . . . . .	1
The Problem . . . . .	2
PART II: THE MODELS . . . . .	5
PART III: NARRATIVE OF TESTS . . . . .	7
Stilling Basin Modifications . . . . .	7
Floor Ramp . . . . .	7
Short-radius Vertical-curve Floor Transition . . . . .	9
Dividing Walls . . . . .	9
Long-radius Vertical-curve Floor Transition . . . . .	9
Conduit Roof Extension . . . . .	10
Stilling Basin End Sill (No Baffle Piers) . . . . .	10
Baffle Piers . . . . .	13
PART IV: CONCLUSIONS . . . . .	17
PLATES 1-50	

## SUMMARY

Damage to the Bull Shoals Dam stilling basin was observed immediately downstream from the conduits after about one year of operation. To assist in determining the causes of this damage and devise modifications that would correct the situation, tests were initiated on a 1:12-scale conduit model and a 1:50-scale section model of the spillway. An upward-sloping ramp, replacing the first three steps of the stilling basin, proved most feasible as the basic scheme for permanent repairs to the prototype. Large and rapid pressure fluctuations still occurred at the upstream end of this ramp for conduit discharges but average pressures were positive. High dividing walls between the conduits reduced pressure fluctuations on the stilling basin floor with tailwater elevations as high as 458.0, but were not effective for higher tailwater elevations.

The present 4-ft-high end sill was found inadequate for dissipating energy from conduit flows when the smooth floor ramp was installed. Raising the end sill height to 10 or 12 ft caused retention of deeper tailwater in the basin and resulted in improved stilling action. The higher end sills produced an adequate hydraulic jump under spillway discharge, but were somewhat less effective than the low end sill in preventing erosion in the exit channel. For passage of extremely low flows, some protection below the high end sill is required.

Baffle piers provided improved stilling action for spillway flows, but were of negligible value for conduit discharges. When used in conjunction with a 10- or 12-ft-high end sill, baffle piers of 8-ft height were found to be the most efficient.

The modification selected for construction in the prototype consisted of vertical-faced baffle piers, 8 ft in height, located 50 ft upstream from the original end sill. The end sill was increased in height to 12 ft and a 19.5-ft-long horizontal apron terminated by another 2-ft-high sill was provided downstream for protection of the exit area during periods of low flow.

## STILLING BASIN MODIFICATIONS

### BULL SHOALS DAM, WHITE RIVER, ARKANSAS

#### Hydraulic Model Investigation

#### PART I: INTRODUCTION

#### Description of the Prototype

1. Bull Shoals Dam, located on the White River in the north central part of Arkansas (fig. 1 and plate 1), is a multipurpose structure in that it provides flood control, power development, and recreational facilities for the area. The dam is a straight, concrete-gravity structure, and includes an overflow spillway located in the central portion of the valley with a nonoverflow section on each side. The intake and penstocks for supplying water to the generating units are located in the nonoverflow section to the left of the spillway.

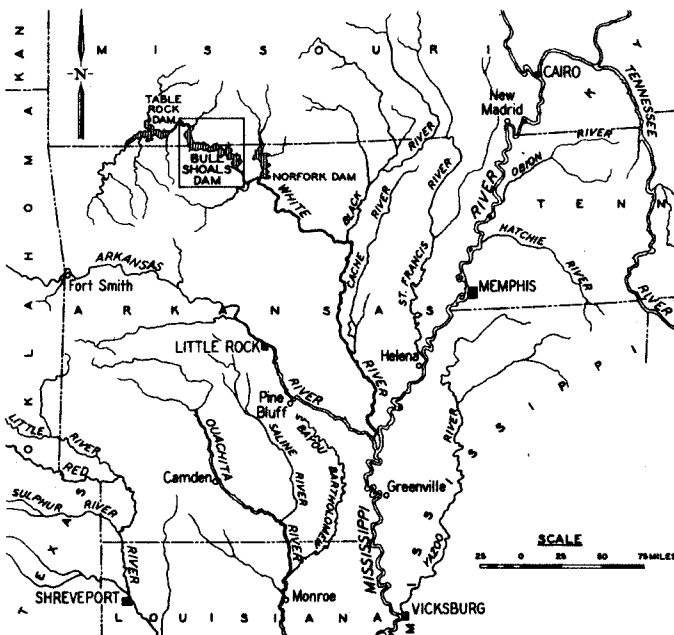


Fig. 1. Location map

2. The spillway, with a crest elevation of 667,\* is surmounted by 17 tainter gates 40 ft wide by 28 ft high for passage of extreme flood flows. Sixteen flood-control sluices, each 4 ft wide by 9 ft high, in the overflow section of the dam pass flood releases when the pool elevation is below the spillway crest (plates 2 and 3). The stilling basin, as constructed initially, consisted of a 200-ft-long apron containing four steps with ellipsoidal

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\* All elevations are in feet above mean sea level.

upstream faces, terminated by a 4-ft-high, stepped end sill. The design of this stilling basin was based on the results of a previous series of model studies conducted at the Waterways Experiment Station.\* In the development of the design, efforts were directed toward securing good hydraulic performance under conduit discharges and acceptable performance for spillway flows. Plate 4 shows details of the stilling basin as initially constructed.

3. Detailed structural and hydraulic data pertinent to the Bull Shoals project are tabulated below:

Structural:

Width of spillway crest (gross)	808.0 ft
Width of spillway crest (net)	680.0 ft
Elevation of spillway crest	667.0
Height of spillway (crest to stilling basin floor)	229.8 ft
Number of crest gates (tainter)	17
Size of gates	40 ft wide by 28 ft high
Elevation of top of gates	695.0
Elevation of stilling basin (lowest point)	437.2
Number of flood-control sluices	16
Size of flood-control sluices	4 ft by 9 ft

Hydraulic:

Spillway design discharge	556,000 cfs
Design pool elevation	703.0
Design head on crest	36.0 ft
Tailwater elevation (design discharge)	514.4
Discharge for one sluice (pool elevation 667.0)	3500 cfs
Tailwater elevation for one sluice (pool elevation 667.0)	452.8

The Problem

4. During the period July 1951 to October 1952, the flood-control sluices were used to regulate downstream flows and to control pool stage increases during the filling of the reservoir. The maximum pool elevation during this period was about 640. In June 1952, an inspection of the

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\* U. S. Army Engineer Waterways Experiment Station, CE, Model Studies of Conduits and Stilling Basin, Bull Shoals Dam, White River, Arkansas, Technical Memorandum No. 2-234 (Vicksburg, Mississippi, June 1947).

stilling basin, by use of probes and underwater viewing devices, disclosed an appreciable amount of damage to the concrete steps as well as an accumulation of assorted debris. Accordingly, it was decided that a cofferdam should be constructed downstream from the end sill so that the stilling basin could be unwatered for a thorough inspection. This inspection revealed that the floor of the basin had been damaged, to varying degrees, immediately downstream from 12 of the 16 flood-control sluices. The most severe damage had occurred just downstream from the top of the first stilling basin step. Erosion of the concrete, in some cases, reached a maximum depth of 3-1/2 ft (fig. 2). The appearance of the damaged concrete



Fig. 2. Typical damage to stilling basin steps

in certain areas indicated that initial damage had been caused by cavitation at or near the tops of the ellipsoidal steps and that, probably thereafter, a combination of cavitation and abrasive action had caused the damage to progress at an ever-increasing rate.

5. Temporary repairs were made below fourteen of the sixteen conduits by covering the first two steps with an upward-sloping concrete ramp. Downstream from one of the two remaining conduits, all four steps were covered by a sloping ramp. The steps below the remaining conduit were left as originally constructed for test purposes. During these repairs pressure cells were embedded in the concrete for determination of pressures.

6. Prototype tests,\* conducted on 28 January 1953, disclosed that pressure fluctuations downstream from the top of the first step, as originally constructed, were in the cavitation range for operations at half-gate opening; at full-gate opening, pressure cells at this position were pulled out of the concrete and no reading was possible. Cells located just downstream from the end of the temporary ramp covering the first two steps recorded pressures that were consistently negative. Pressure fluctuations into the cavitation range also were noted near the beginning of the sloping ramp where positive pressures were expected.

7. Model tests were considered desirable for determining more specifically the causes of damage to the prototype and arriving at the most satisfactory method of making permanent repairs to the stilling basin.

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\* U. S. Army Engineer Waterways Experiment Station, CE, Pressure Cell Tests, Bull Shoals Dam Stilling Basin, Miscellaneous Paper No. 2-77 (Vicksburg, Mississippi, February 1954).

## PART II: THE MODELS

8. A conduit model and a spillway section model were used for the study of stilling basin modifications for Bull Shoals Dam. The conduit model was constructed to a scale of 1:12 and reproduced the downstream end of one active conduit in a three-monolith-wide section of the stilling basin. The spillway section model, constructed to a scale of 1:50, reproduced a 162-ft-wide section of the spillway and stilling basin. While this model was used for the study of spillway discharges only, dummy sluice outlets were placed at the toe of the spillway to insure that true flow patterns would be obtained. For economy purposes an existing model of the crest of Table Rock Dam was used and the Bull Shoals stilling basin elements were installed downstream. Since the Bull Shoals crest shape was not reproduced accurately, it was necessary to conduct tests with computed discharges rather than actual pool elevations.

9. Means were provided on both models for the measurement of discharges and the regulation of tailwater elevations. Steel rails, placed along the sides of the flumes, were graded to specific elevations, and served as supports for measuring devices such as pitot tubes and sounding sticks as well as a convenient means of establishing stations and elevations in the models. Average pressure measurements were made with piezometers while dynamic measurements were made with miniature pressure cells of commercial origin. These cells had diaphragm diameters of 1/2 in. and usable responses up to 800 cycles per sec. They were used in circuit with an amplifier and an oscillograph which produced a permanent record showing pressure fluctuations as inches of scale deflection. A suitable conversion was then made to reduce the measured deflections to feet of water in the prototype.

10. The scales of the Bull Shoals models were such as to cause gravity to be the dominant flow factor. Therefore, Froude's law was used to express the scale relationships existing between model and prototype. These scale relationships were as follows:

<u>Dimension</u>	<u>Scale Relationship</u>		
	<u>General</u>	<u>Conduit Model</u>	<u>Spillway Section Model</u>
Length	$L_r$	1:12	1:50
Area	$A_r = L_r^2$	1:144	1:2500
Velocity	$V_r = L_r^{1/2}$	1:3.464	1:7.071
Time	$T_r = L_r^{1/2}$	1:3.464	1:7.071
Pressure	$P_r = L_r$	1:12	1:50
Discharge	$Q_r = L_r^{5/2}$	1:499	1:17,678

11. The relationships expressed in the preceding paragraph are directly applicable to measurements of velocity, pressure (above the cavitation range), discharge, and water-surface elevation. Results of scour tests, however, should be used only as a basis of comparison of different designs since means for reproducing quantitatively in a model the resistance to scour of a prototype bed material have not yet been developed.

## PART III: NARRATIVE OF TESTS

### Stilling Basin Modifications

12. The stilling basin, as actually constructed in the prototype, was considered as the basic design for the present series of model studies and all revisions were designated as modifications. During the course of the studies 15 modifications were tested under conduit discharges and 8 were checked under spillway flows. The various modifications are designated by letters of the alphabet and are shown in plates 5 and 6. No attempt has been made to present the results in the chronological order in which the tests were conducted; instead the major elements of the basin modifications are discussed as a unit.

13. An important objective of the testing program was the discovery of the cause of damage to the steps in the prototype stilling basin. Since it was suspected that cavitation had caused the initial damage, piezometers were spaced at close intervals throughout the length of the stilling basin. Pressure measurements were made with a conduit discharge of 3725 cfs and a tailwater elevation of 460.0. These tests revealed that very low pressures occurred on the faces of the ellipsoidal steps, the magnitude of the negative pressure being as much as -27 ft of water on the curve of the first step. Plate 7 shows pressure profiles obtained in the 1:12-scale model, in previous tests of a 1:60-scale model, and in pressure cell tests of the prototype. There was excellent agreement between the prototype tests and the 1:12-scale model tests and reasonably good agreement between the small-scale and large-scale model tests. The failure of the 1:60-scale model to reveal the likelihood of cavitation damage was due to the impossibility of installing piezometers in the curved faces of the steps in such a small-scale model.

### Floor Ramp

#### Designs tested

14. Since the prototype damage involved the stilling basin steps and was apparently caused by negative pressures in that area, it was

decided that elimination of the steps should be considered as the first major modification. Consequently, the models were tested with a smooth, upward-sloping ramp covering all four steps of the basin as well as with a ramp covering the first three steps only. As stated in previous reports, the purpose of the reverse slope was to provide continuous pressure on the underside of the jets issuing from the conduits, thus causing the flow to spread laterally as it continued through the stilling basin.

#### Average pressure measurements

15. Under conduit discharge, the full-length ramp produced positive average piezometric pressures throughout the length of the basin floor. With the shortened ramp installed, pressures on the face of the fourth step were above atmospheric for tailwater elevations of 460 and above and dropped only slightly below atmospheric for lower tailwaters. There was little, if any, difference in the stilling action effected by the two ramps. Plates 8 and 9 show velocities and pressures measured in tests of the two ramp lengths. As explained later in paragraph 21, a 10-ft-high end sill was used in these tests to insure sufficient tailwater depth to prevent flow from the conduits from sweeping out of the stilling basin. The negative pressures recorded on the side walls had also been present in the earlier series of model tests. However, no damage to the walls has been observed in the prototype. Spillway discharges produced substantially positive average piezometric pressures on the floor of the basin for both lengths of ramps for all flow conditions. The scour patterns shown in plates 10-13 indicate that there was no difference in the stilling effectiveness of the two ramps for either conduit or spillway discharges.

#### Dynamic pressure measurements

16. To obtain data on pressure fluctuations on the stilling basin floor with the full-length ramp, four miniature pressure cells were installed in modifications B and C (plate 14) and dynamic pressures for conduit discharges were measured. Cell 1-1, located just downstream from the upstream end of the floor ramp, indicated that, when the tailwater interfered with flow at the conduit outlet portal, large and extremely rapid pressure fluctuations occurred. The fluctuations ranged generally from about -20 to about +40 ft of water and the changes usually occurred in 1/3

to 1/75 of a second, prototype time. At the other cell locations, pressures were relatively steady and, in most cases, corresponded roughly to the depth of water on the cell. Results of the pressure cell measurements for modification B are shown in plates 15-17 and a section of a typical oscillogram is shown in plate 18.

#### Short-radius Vertical-curve Floor Transition

17. In an effort to improve conduit flow conditions and reduce impact upon the floor of the basin, an 80-ft-radius, vertical curve was inserted between the original floor and the upward-sloping ramp. This was designated modification G. This revision did not have the desired effect as pressure fluctuations were increased and the average pressures were decreased. Compare plates 15-17 and plates 19-21.

#### Dividing Walls

18. The fact that the fluctuations at cell 1-1 were greatly reduced when the jump was swept out of the basin at tailwater elevation 452.8, as shown by the slopes of the curves and the magnitudes of the positive and negative pressures at the ends of the curves in plates 15 and 16, led to the conclusion that the undesirable pressure conditions were resulting from the backflow of tailwater onto the top of the conduit jet rather than from the direct impact of the jet itself on the basin floor. Consequently, high dividing walls were placed on each side of and parallel to the active conduit and were extended to the ends of the conduit training walls (modification G-1). For low to medium tailwater depths, this revision produced the desired results as can be seen by comparing the slopes of the curves for modifications G and G-1 in plates 19 and 20. Above tailwater elevation 458.0, however, the tailwater began to flow back around the ends of the dividing walls and pressure conditions deteriorated to the level obtained with modification G (plate 21). It was noted that the dividing walls produced improved stilling basin action for conduit discharges.

#### Long-radius Vertical-curve Floor Transition

19. Since the dividing walls of modification G-1 had not been completely satisfactory and would be expensive to install, as well as

impractical for spillway flows, a long-radius, vertical curve was installed in the floor of the basin in place of the 80-ft-radius curve. It was thought that a long, gentle curve might improve flow conditions where the short, abrupt curve had failed. Accordingly, the dividing walls of modification G-1 and the floor ramp between the third and fourth steps were removed (modification I) and a 235-ft-radius transition curve was installed in the basin floor (modification J). The 235-ft-radius transition failed to decrease pressure fluctuations at cell 1-1 to any great extent as can be seen in plates 22-24.

#### Conduit Roof Extension

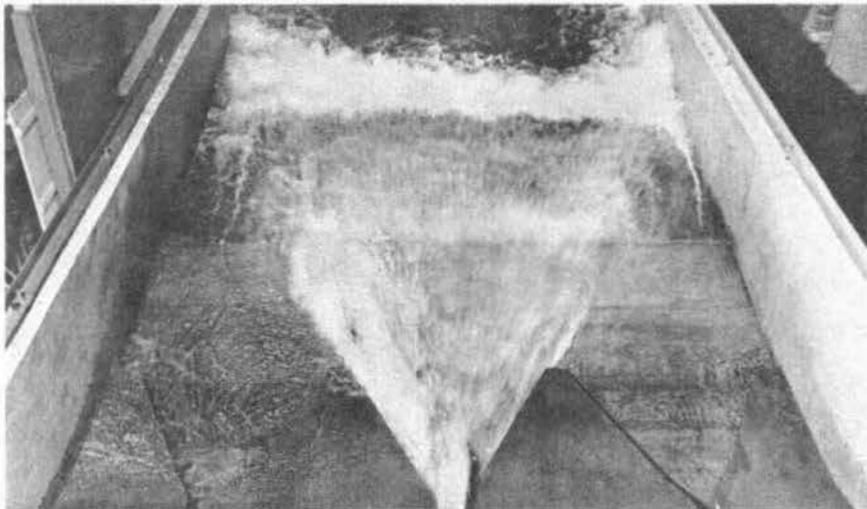
20. In a final effort to improve pressure conditions on the basin floor, the roof of the conduit outlet was extended, parallel to the floor, about 18 ft downstream (modification K). It was thought that this might protect the conduit jet from interference by the inflowing back eddies, especially at high tailwater elevations. Again, the revision failed to accomplish any important improvement as shown by the curves in plates 22-24.

#### Stilling Basin End Sill (No Baffle Piers)

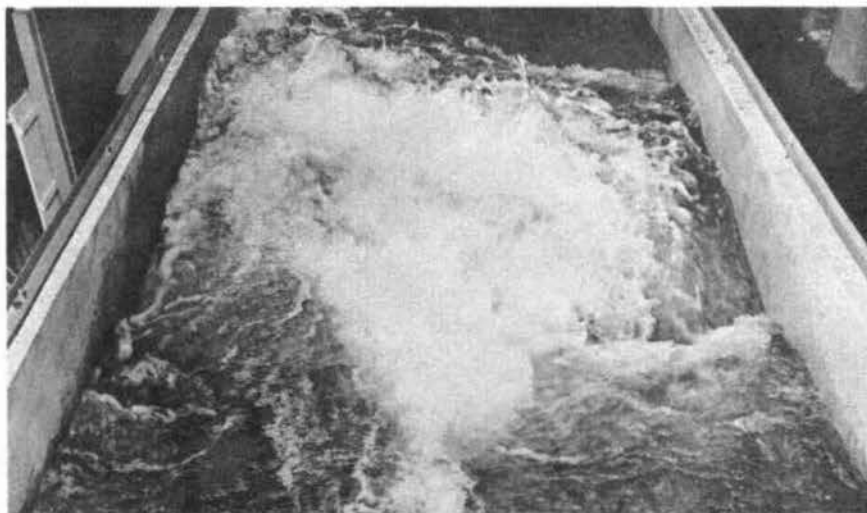
21. During the course of the testing program it became apparent that the 4-ft-high end sill (modification B) did not maintain enough tailwater depth in the stilling basin to provide effective dissipation of energy in conduit flow. At normal tailwater elevation for one conduit discharge (elevation 452.8), the jet swept the tailwater out of the basin and impinged directly upon the end sill, as shown in fig. 3a. Visual observations showed that, as the tailwater elevation was raised, a point was reached at which a partial hydraulic jump was contained in the basin. This critical point was between elevations 458.0 and 460.0 (figs. 3b and 3c). Accordingly, the height of the end sill was raised to 10 ft, or elevation 456.5 (modification D), so that the tailwater retained in the basin would be deep enough at all times to insure adequate stilling action (fig. 4).

22. Although the 10-ft-high end sill proved effective in dissipating

a.  
Tailwater  
elevation  
452.8



b.  
Tailwater  
elevation  
458.0



c.  
Tailwater  
elevation  
460.0

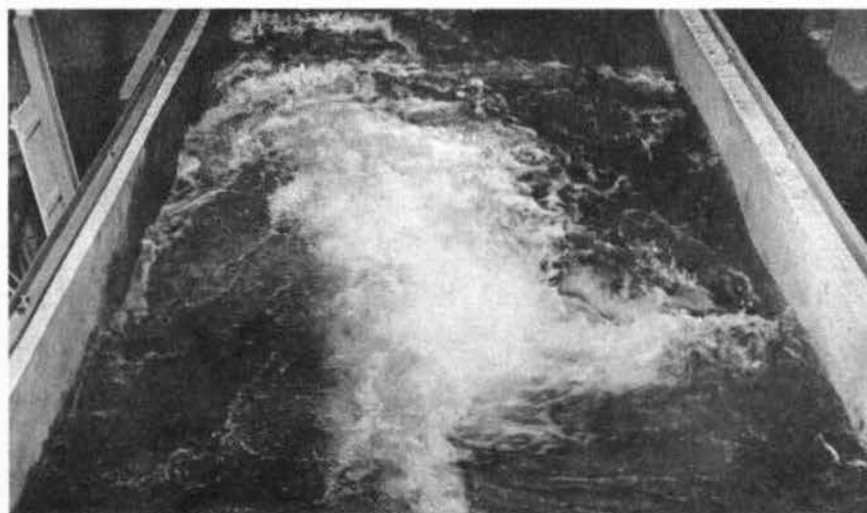
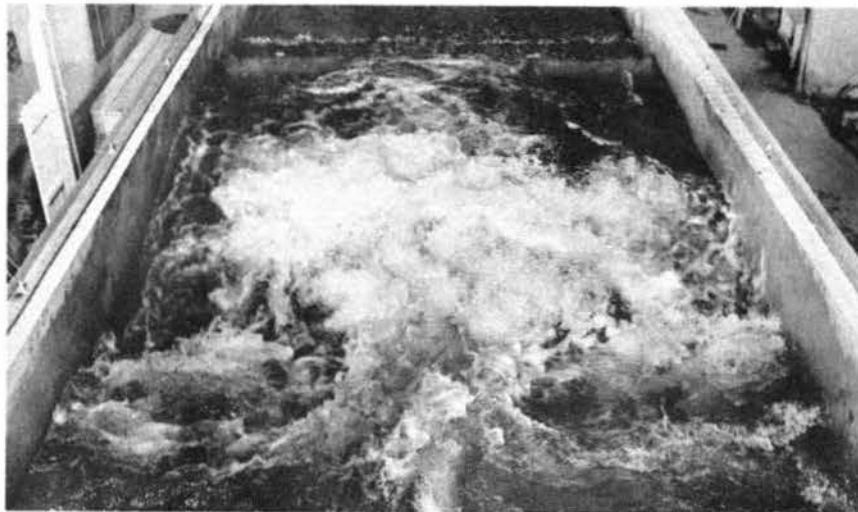


Fig. 3. The high velocity conduit jet (discharge 3500 cfs) impinged directly on 4-ft-high end sill of modification B when tailwater elevation was 452.8, but was contained in stilling basin when tailwater was between 458 and 460



a.  
Tailwater  
elevation  
452.8



b.  
Tailwater  
elevation  
460.0



c.  
Tailwater  
elevation  
464.3

Fig. 4. Ten-foot-high end sill of modification D maintained tailwater depths capable of containing the excess energy of the conduit discharge (3500 cfs) within the stilling basin at all times

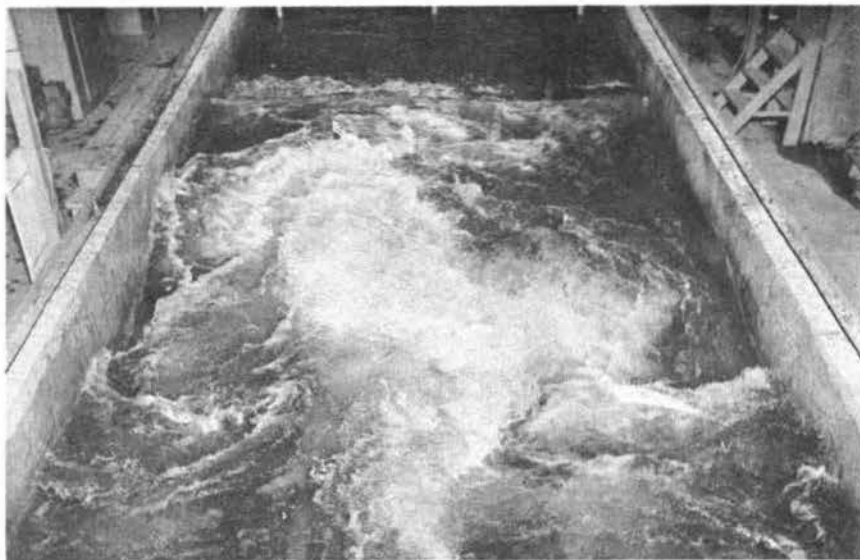
the energy of the conduit flow in the model, it was decided that a 12-ft end sill should also be tested. The higher end sill was considered necessary owing to the fact that the spread of the flow over the end sill is much greater in the prototype than in the 3-monolith-wide model; consequently, a higher end sill will be required in the prototype to produce the same water-surface elevation in the stilling basin as had been produced by the 10-ft end sill in the model. Each of two designs incorporating a 12-ft end sill (modifications I and M) proved to be as effective as, but no more than, the 10-ft end sill. Compare fig. 5 with fig. 4a. Plates 8-10 and plates 25-30 show the results of velocity, pressure, and scour measurements on the basin modifications incorporating the 4-, 10-, and 12-ft-high end sills. For low discharges, the high end sill acts as a secondary weir and some protection to the bed immediately downstream must be provided.

23. Under maximum spillway discharge, four modifications produced a satisfactory hydraulic jump in the basins for normal tailwater elevation (fig. 6). The higher end sills tended to produce deeper scour than the original 4-ft end sill, the variation being from 16 ft for modification B to 26 ft for modification M. Velocity, pressure, and scour measurements for spillway flow are shown in plates 12 and 31-37.

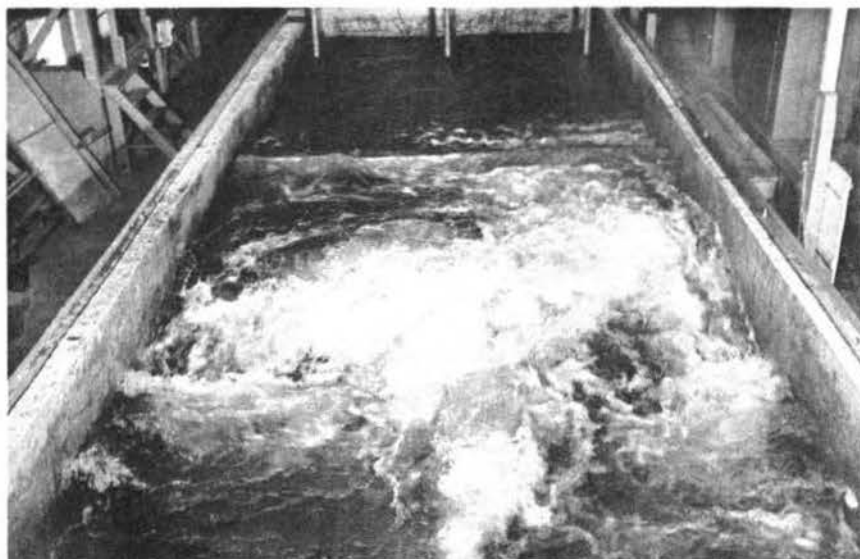
#### Baffle Piers

24. The effect of baffle piers, installed on the floor of the stilling basin, was studied in conjunction with each height of end sill. The first baffle scheme provided for a single row of 8-ft-high baffles, 5-1/2 ft wide, spaced 6-1/2 ft apart, and located about 50 ft upstream from the end sill. A later design incorporated baffles which were 7-1/2 ft wide and were spaced 8-1/2 ft apart; the optimum height for these baffles was to be determined by observation of the effects of baffles of various heights (4, 8, and 12 ft) in the models.

25. For conduit flows, it was found that the installation of baffle piers in conjunction with the 12-ft end sill had little or no effect regardless of the height of baffles used (plates 38-43). When used with the 4-ft end sill, however, the 8-ft baffles reduced the depth of scour from

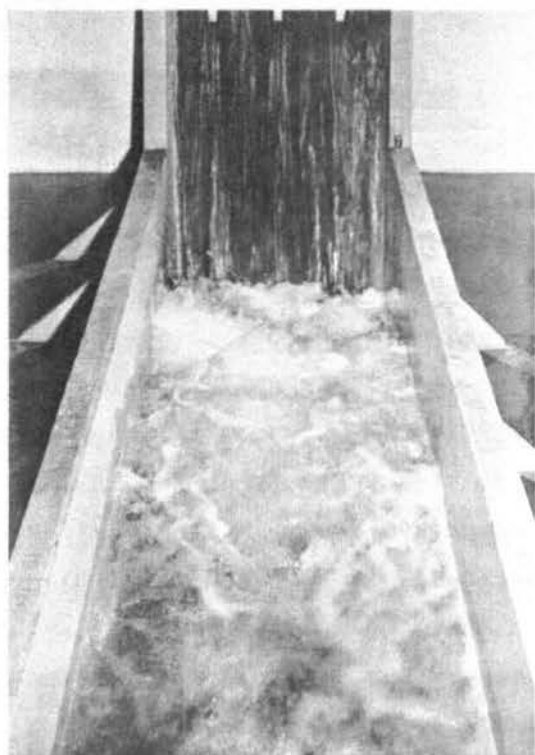


Modification I

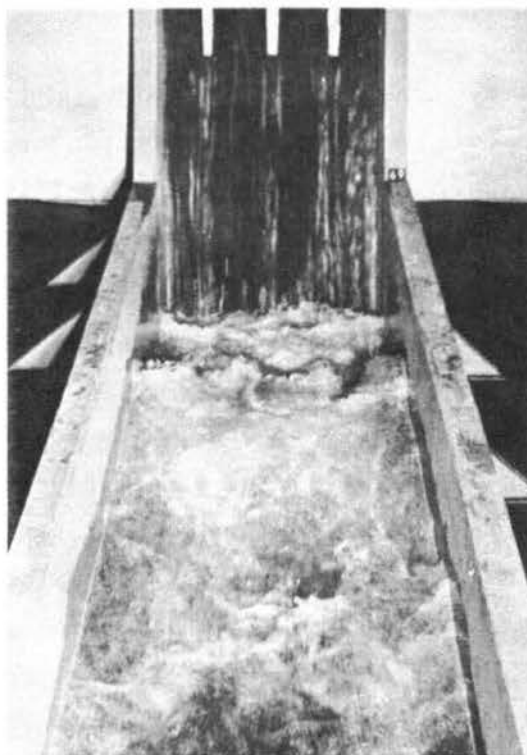


Modification M

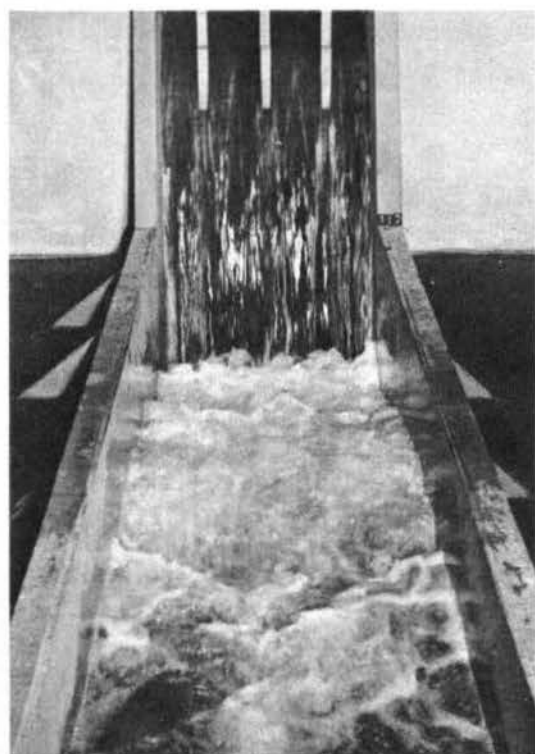
Fig. 5. High velocity jet of conduit discharge (3500 cfs) effectively confined to stilling basin by 12-ft-high end sill of modifications I and M at minimum tailwater elevation of 452.8



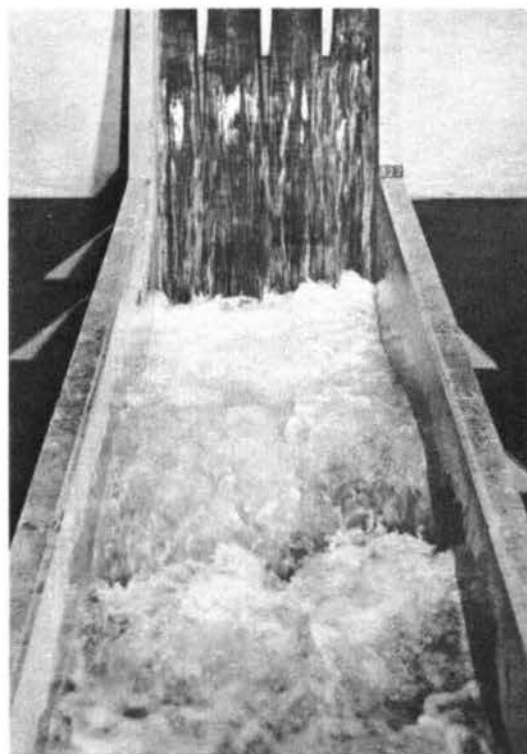
Modification B, 4-ft end sill



Modification D, 10-ft end sill



Modification I, 12-ft end sill



Modification M, 12-ft end sill

Fig. 6. Hydraulic jump formed in stilling basin of modifications B, D, M, and I at spillway design discharge of 556,000 cfs and tailwater el 514.4

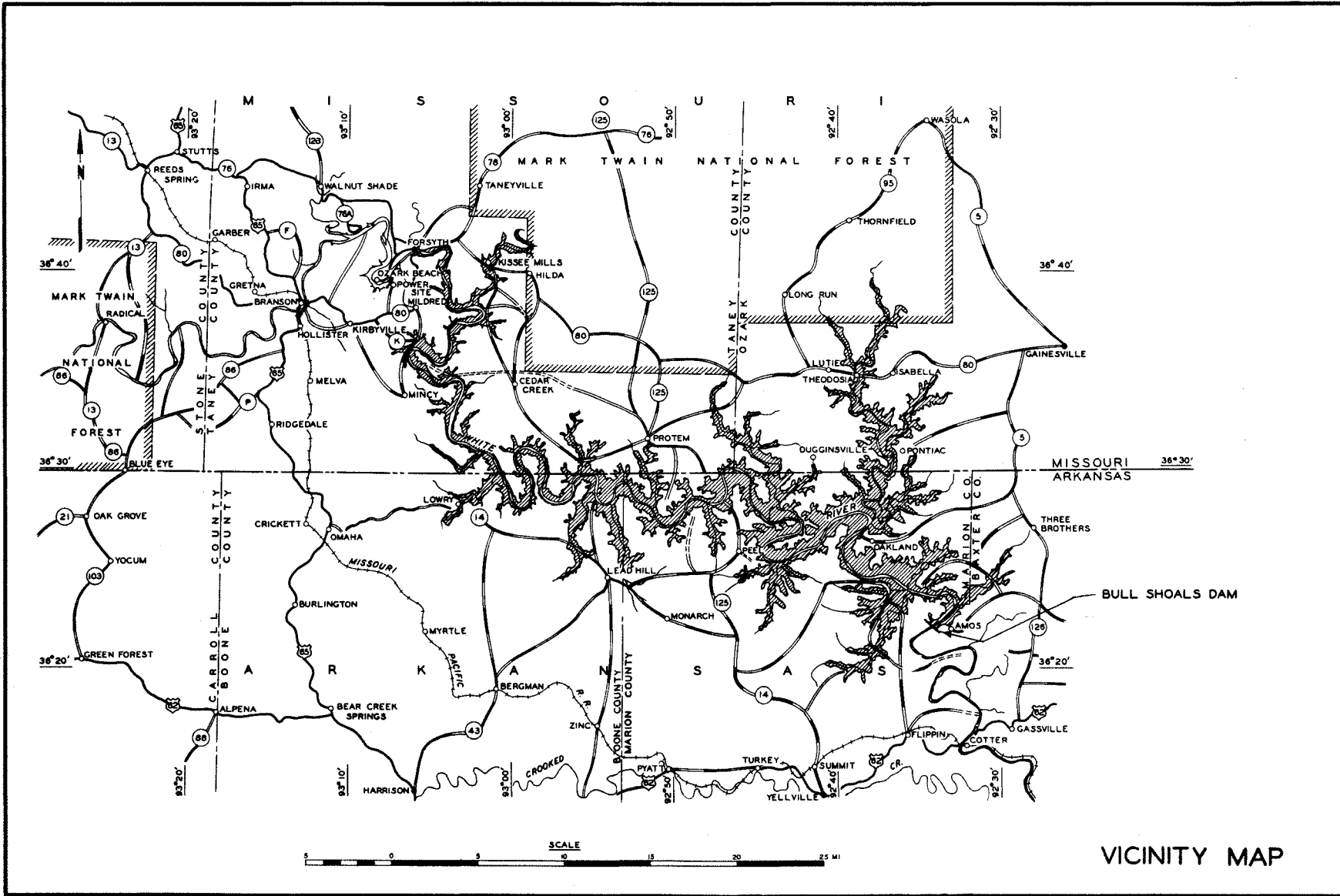
about 16 ft for modification B (no baffles) to about 4 ft for modification A (with baffles); compare plates 28 and 44.

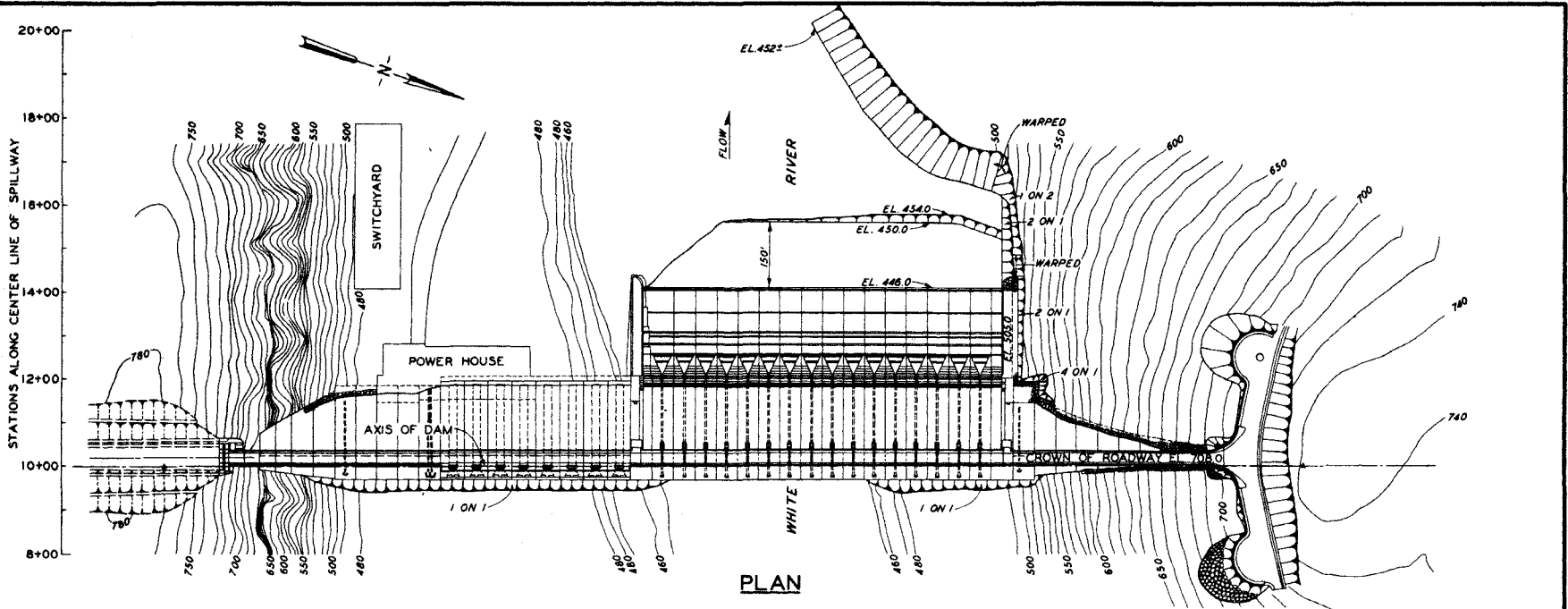
26. In all tests of spillway flows, baffle piers had a beneficial effect. The scour patterns shown in plates 45 and 46 indicate that the original 8-ft-high baffles reduced scour depths to about 50 per cent of those obtained without baffles (plates 12 and 32) for both the 4- and 10-ft-high end sills. Comparison of the scour profiles shown in plates 47, 48, and 49 for modification H, in which baffles 12, 8, and 4 ft high were tried, shows very little difference in effectiveness between the 12- and 8-ft-high baffles. The 4-ft baffles, however, were somewhat less effective than the higher ones, probably because of the 12-ft-high end sill which was a component of modification H. As well as could be determined in the routine course of the testing program, there was no difference in effectiveness of the various baffle spacings under spillway discharges.

## PART IV: CONCLUSIONS

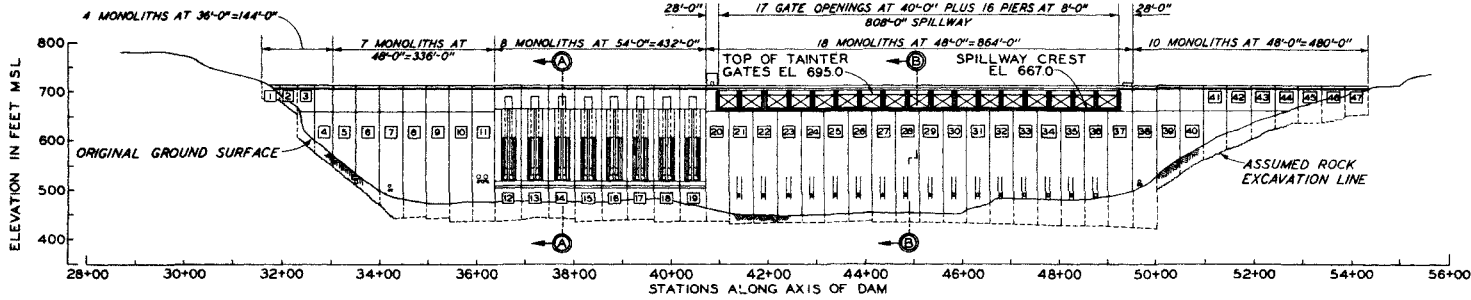
27. The tests demonstrated that the use of a smooth ramp over the upstream three steps of the stilling basin should eliminate the negative pressures that had occurred with conduit flow in the prototype on the first two steps. Dynamic pressure measurements at the upstream end of the ramp indicated that although average pressures were positive, large pressure fluctuations still occurred and it is possible that some damage may result in the prototype. The use of a 10- or 12-ft-high end sill improved stilling action for conduit flow considerably by maintaining a minimum tailwater elevation of about 459 within the basin. One row of baffle piers 8 ft in height will have little or no effect under conduit discharge, but will improve basin action under spillway flow.

28. Use of a high end sill will require a short secondary basin downstream for prevention of scour in that area at low flows. An adaptation of modification H was constructed in the prototype and should operate satisfactorily. The improvements adopted are shown in plate 50.



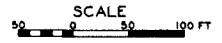
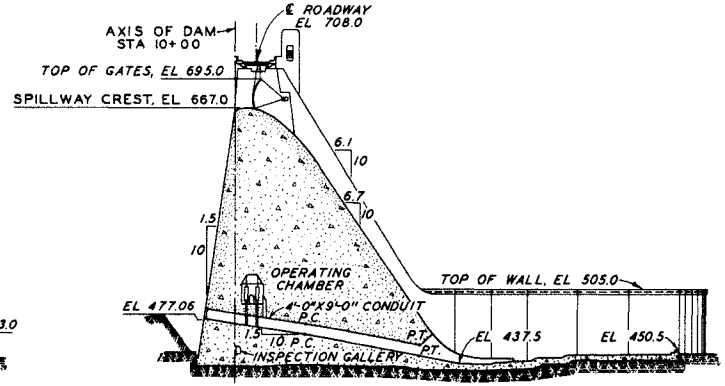
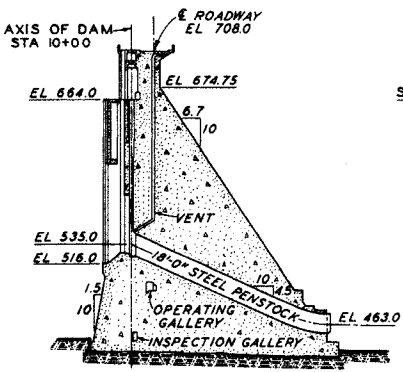
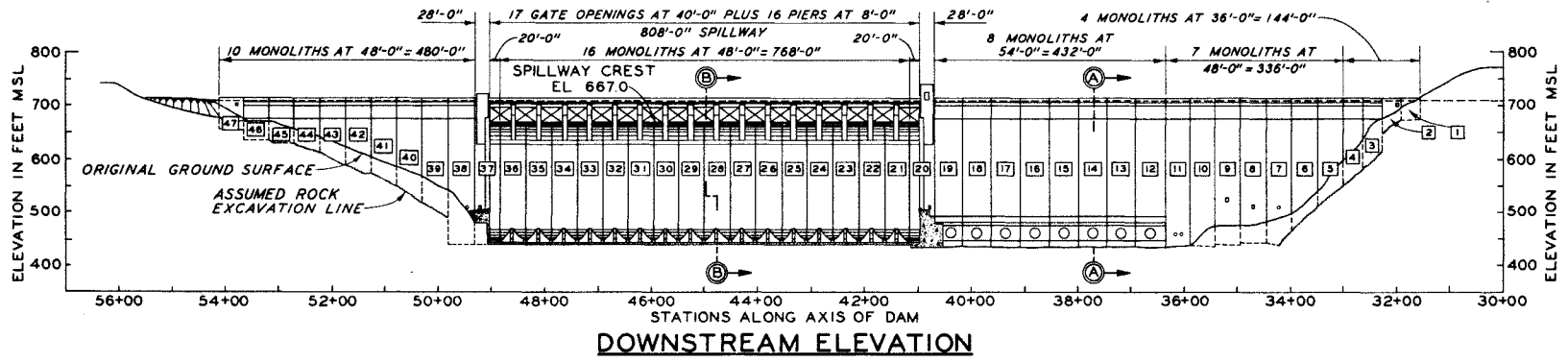


PLAN

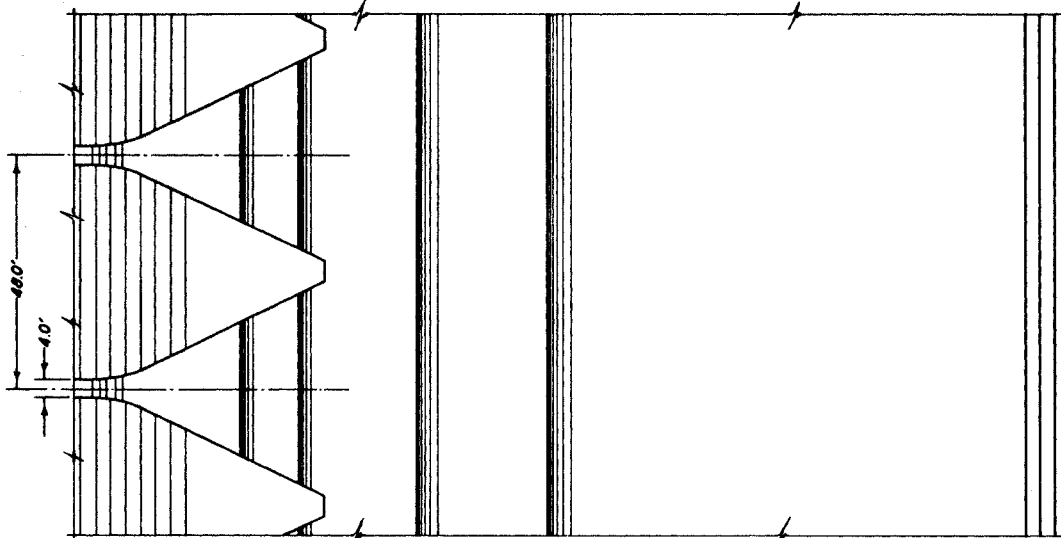


UPSTREAM ELEVATION

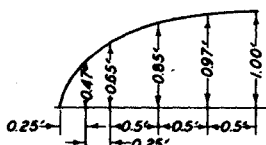
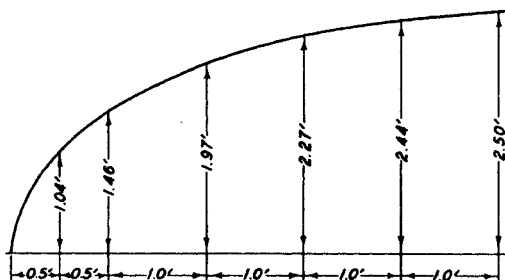
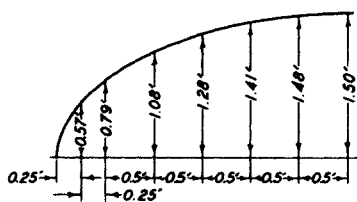
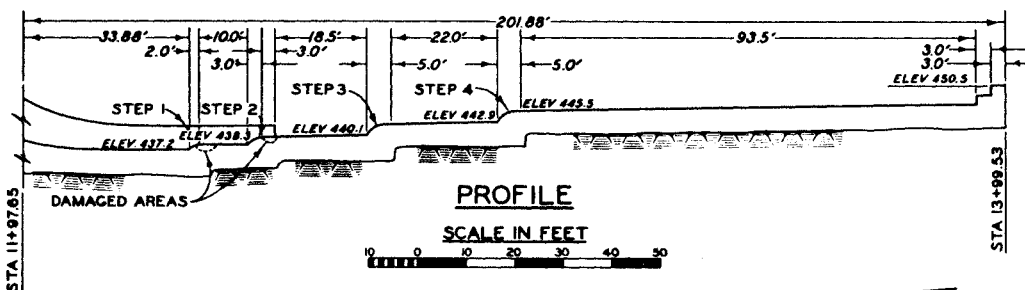
GENERAL PLAN AND ELEVATION



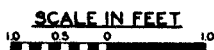
**DOWNSTREAM ELEVATION  
AND SECTIONS**



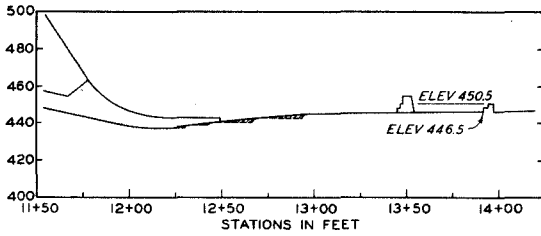
**PLAN**



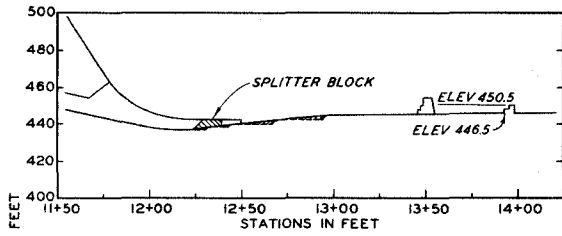
**DETAILS OF STEPS**



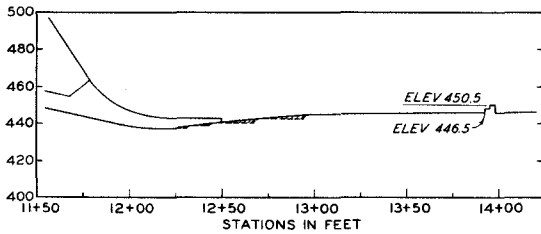
**TYPICAL SLUICE PORTALS AND ORIGINAL STEPS**  
**SLUICE OUTLETS AND STILLING BASIN**



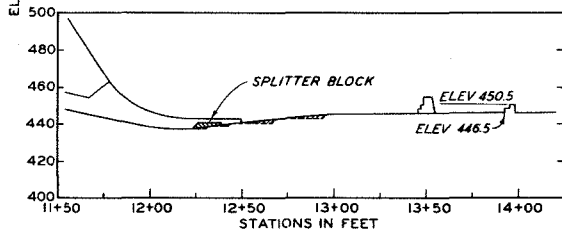
**MODIFICATION A**



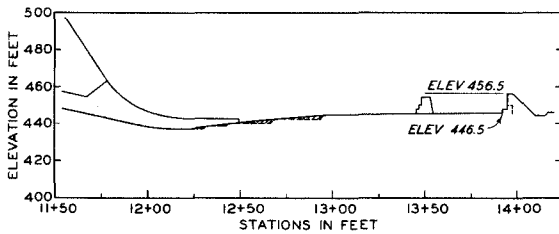
**MODIFICATION F**



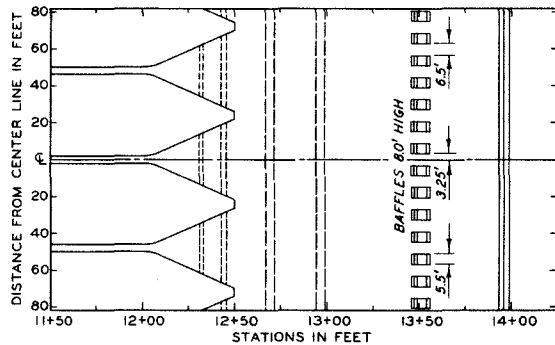
**MODIFICATION B**



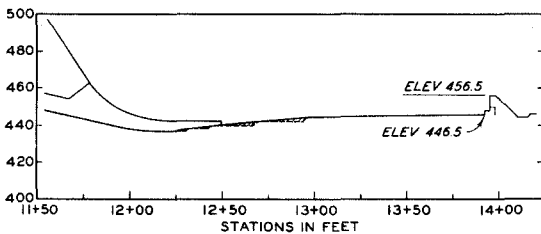
**MODIFICATION F-1**



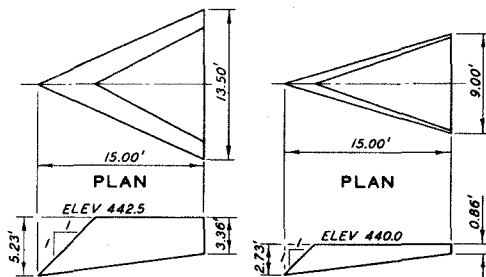
**MODIFICATION C**



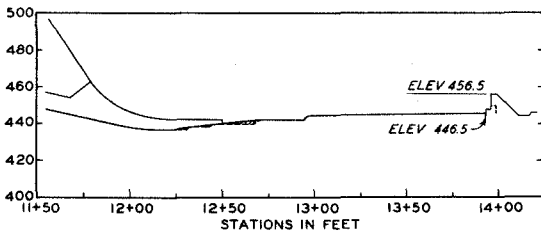
**BAFFLE ARRANGEMENT**  
MODIFICATIONS A, C, F, AND F-1



**MODIFICATION D**

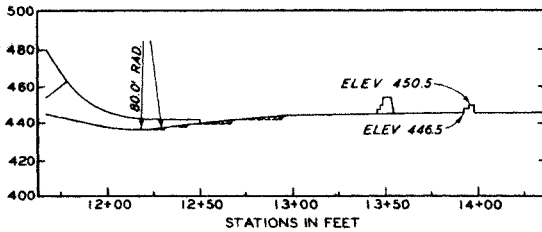


**ELEVATION**      **ELEVATION**  
**MODIFICATION F**   **MODIFICATION F-1**  
**DETAILS OF SPLITTER**

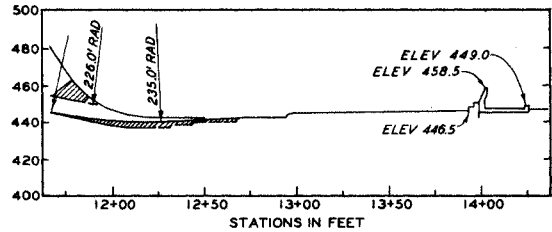


**MODIFICATION E**

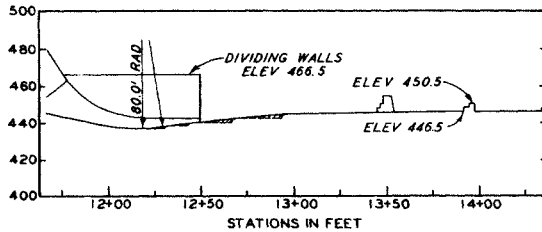
**STILLING BASIN ELEMENTS**  
MODIFICATIONS A TO F-1



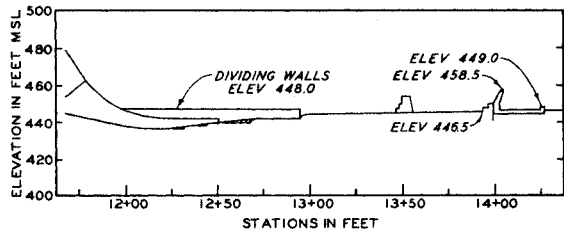
**MODIFICATION G**



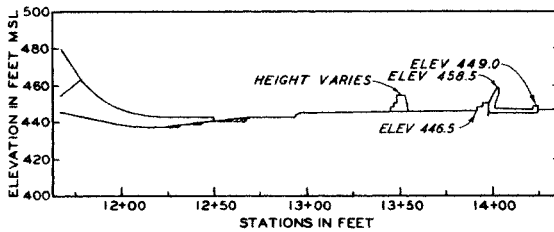
**MODIFICATION K**



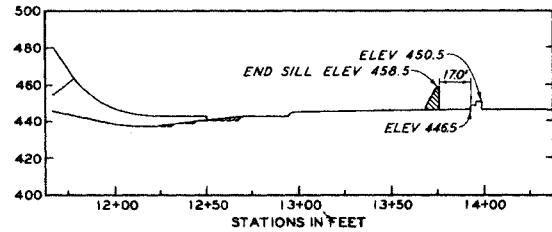
**MODIFICATION G-1**



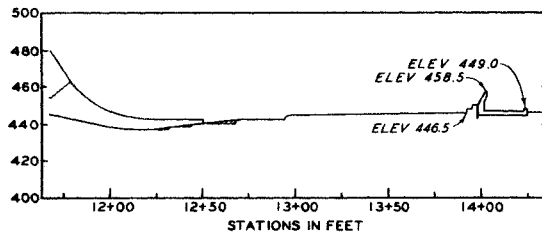
**MODIFICATION L**



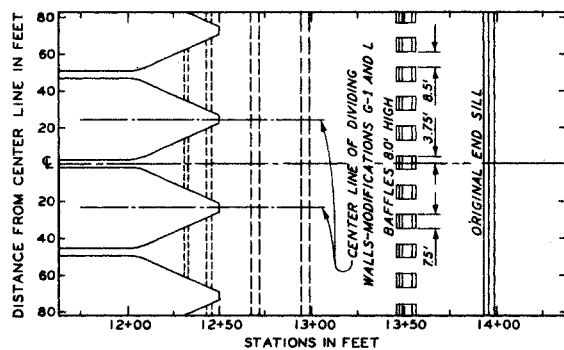
**MODIFICATION H**



**MODIFICATION M**



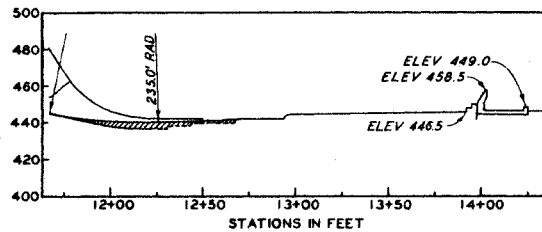
**MODIFICATION I**



**BAFFLE ARRANGEMENT**

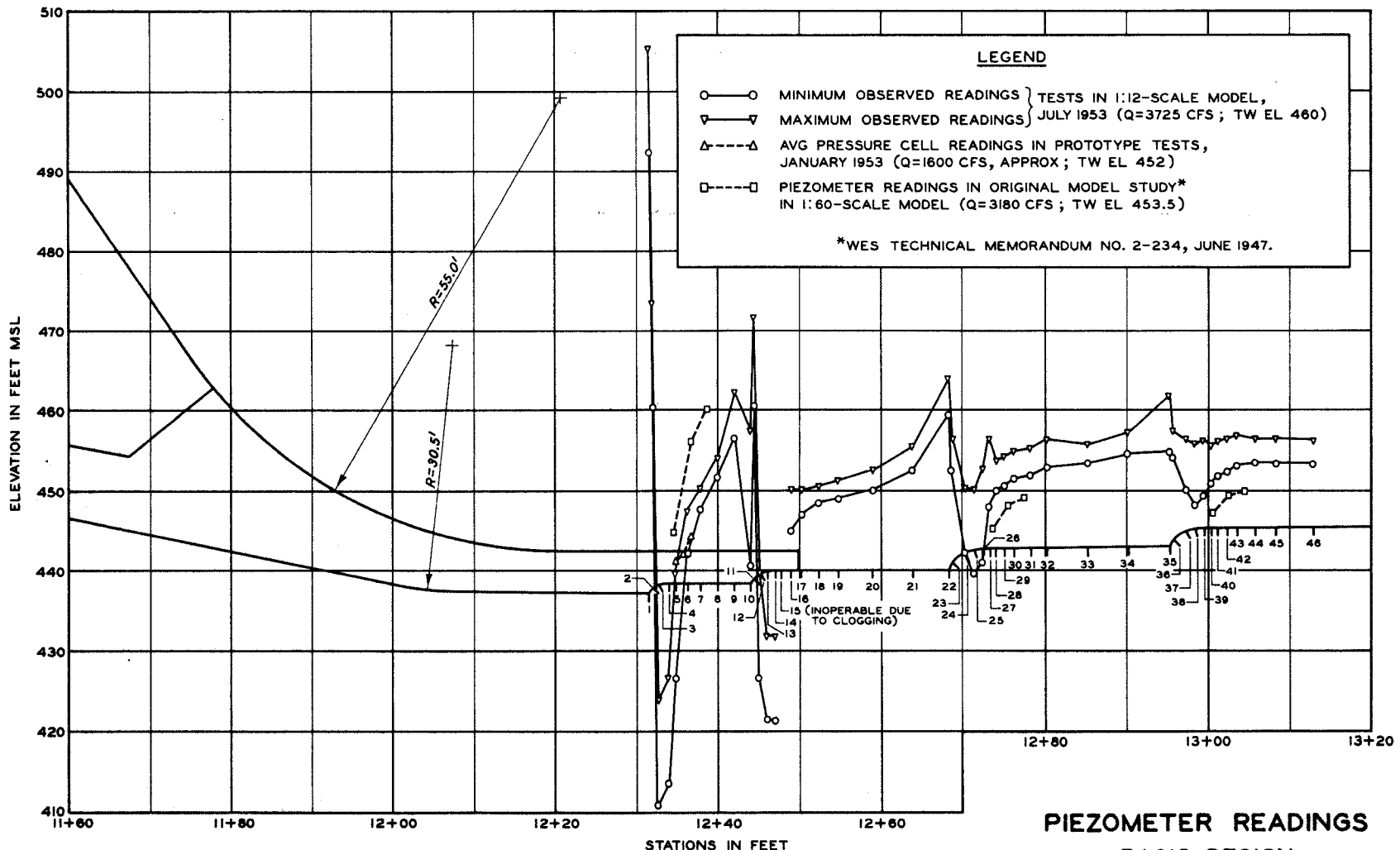
**MODIFICATIONS G, G-1, H, AND L**

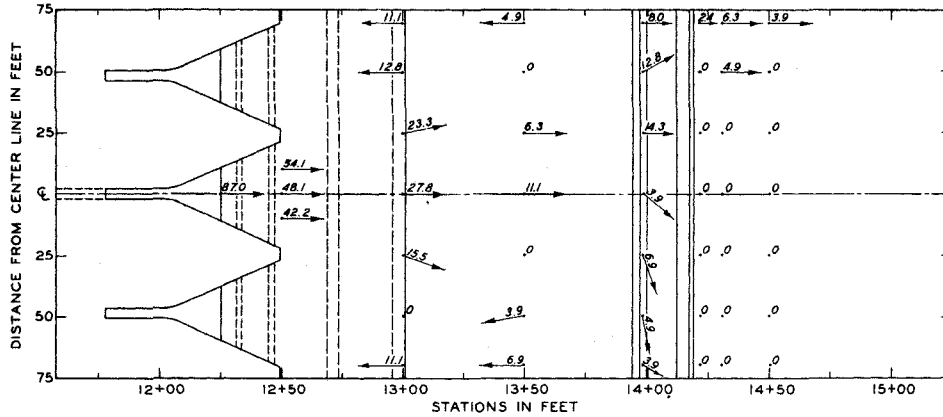
NOTE: BAFFLE HEIGHT VARIES FOR MODIFICATION H.



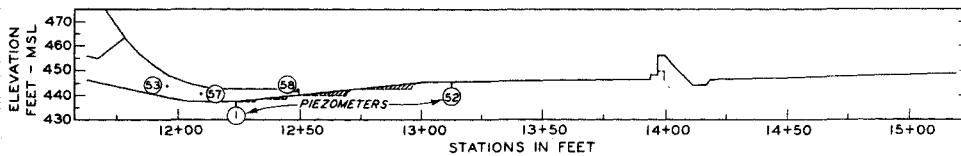
**MODIFICATION J**

**STILLING BASIN ELEMENTS  
MODIFICATIONS G TO M**



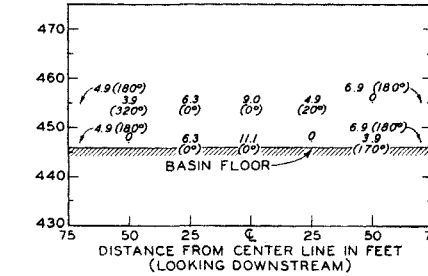


BOTTOM VELOCITIES

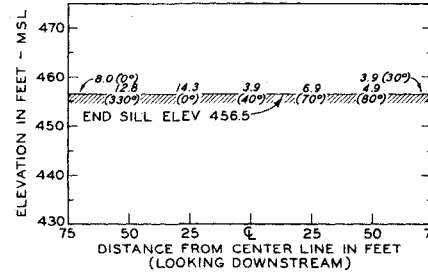


DETAILS OF BASIN

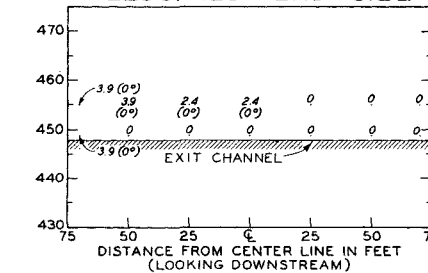
NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 PIEZOMETERS 1 TO 52 ARE ON CENTER LINE OF CONDUIT.  
 PIEZOMETERS 53 TO 57 ARE ON SIDEWALL OF CONDUIT.  
 VELOCITY DIRECTIONS ARE SHOWN IN PARENTHESES AS DEGREES OF AZIMUTH. DOWNSTREAM IS ZERO DEGREES.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.



VELOCITIES - STA 13+50



VELOCITIES - END SILL



VELOCITIES - STA 14+50

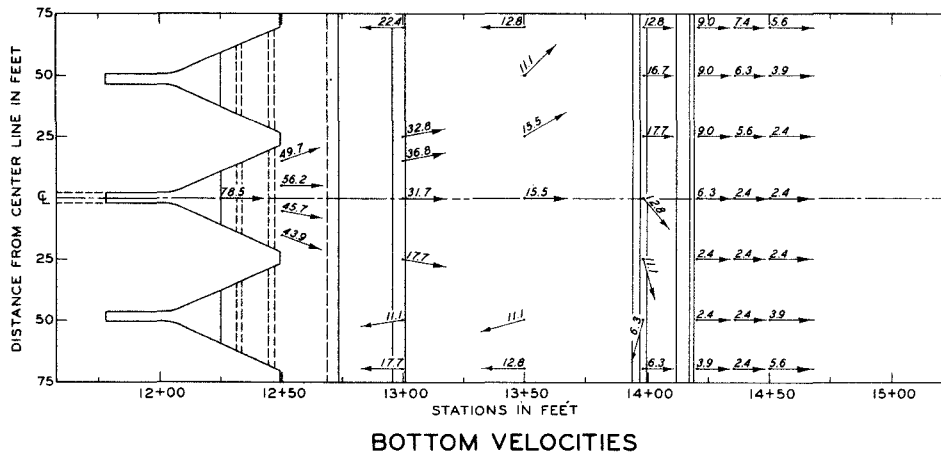
PRESSURE DATA

PIEZ. NO.	STATION	ZERO ELEV.	READING	PRESSURE FT. OF H <sub>2</sub> O
1	12+23.8	437.3	465.5	28.2
2	12+25.3	437.3	471.4	34.2
3	12+26.1	437.3	474.5	37.2
4	12+27.1	437.4	464.5	27.1
5	12+28.9	437.6	460.0	22.4
6	12+30.0	437.8	457.3	19.7
10	12+33.5	438.2	467.0	28.8
11	12+34.2	438.3	453.5	15.2
12	12+35.2	438.4	456.0	17.6
19	12+45.5	439.7	449.0	9.3
20	12+46.5	439.8	456.3	16.7
22	12+48.2	440.0	450.0	10.0
32	12+72.0	442.5	448.5	6.0
33	12+73.0	442.6	454.0	11.4
34	12+73.7	442.7	449.5	6.8
35	12+74.7	442.8	449.0	6.2
45	12+99.0	445.3	452.2	7.2
46	13+00.0	445.4	452.5	7.1
47	13+00.7	445.4	453.0	7.6
48	13+01.7	445.4	454.0	8.6
49	13+02.7	445.4	454.5	9.1
50	13+05.1	445.5	455.0	9.5
51	13+07.5	445.5	455.0	9.5
52	13+12.3	445.5	456.0	10.5
54	12+01.5	441.3	426.9	-14.4
55	12+03.7	440.8	425.6	-13.2

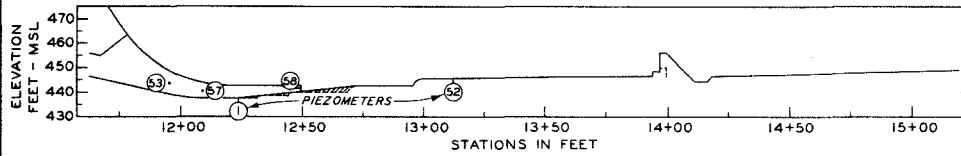
MODEL SCALE 1:12  
**VELOCITIES AND PRESSURES**  
**STILLING BASIN - MODIFICATION D**  
 CONDUIT DISCHARGE 3,500 CFS  
 TAILWATER ELEVATION 460.0

**PRESSURE DATA**

PIEZ NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
19	12+45.5	439.7	446.5	6.8
20	12+46.5	439.8	457.0	17.2
25	12+48.2	440.0	450.5	10.5
32	12+72.0	442.5	446.0	3.5
33	12+73.0	442.6	446.5	3.9
34	12+73.7	442.6	447.0	4.4
35	12+74.7	442.6	448.5	5.9
36	12+75.7	442.6	448.0	5.4
37	12+78.1	442.7	448.5	5.8
38	12+80.5	442.7	448.0	5.3
39	12+85.3	442.8	450.0	7.2
40	12+90.1	442.8	454.5	11.7
41	12+95.0	442.9	461.0	18.1
42	12+95.5	443.9	457.5	13.6
43	12+97.0	444.9	445.0	0.1
44	12+98.0	445.2	450.0	4.8
45	12+99.0	445.3	449.0	3.7
46	13+00.0	445.4	450.0	4.6
47	13+00.7	445.4	451.5	6.1
48	13+01.7	445.4	453.0	7.6
49	13+02.7	445.4	454.0	8.6
50	13+05	445.5	454.5	9.0
51	13+07.5	445.5	455.0	9.5
52	13+12.3	445.5	455.5	10.0

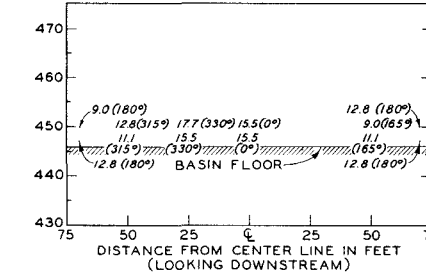


**BOTTOM VELOCITIES**

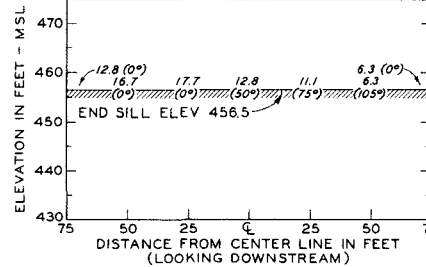


**DETAILS OF BASIN**

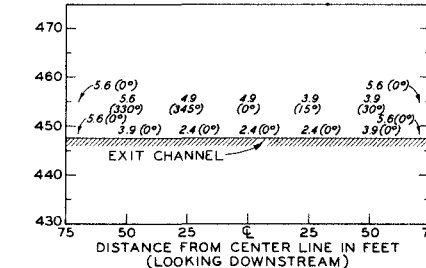
NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 PIEZOMETERS 1 TO 52 ARE ON CENTER LINE OF CONDUIT.  
 PIEZOMETERS 53 TO 57 ARE ON SIDEWALL OF CONDUIT.  
 VELOCITY DIRECTIONS ARE SHOWN IN PAREN- THESE AS DEGREES OF AZIMUTH. DOWNSTREAM IS ZERO DEGREES.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.



**VELOCITIES - STA 13+50**

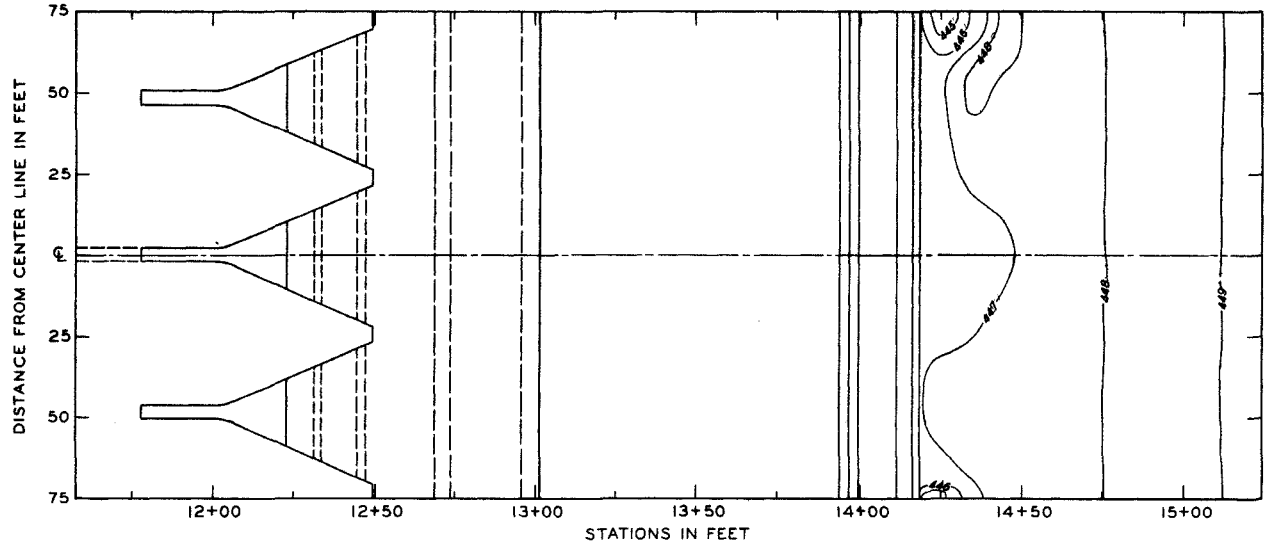


**VELOCITIES - END SILL**

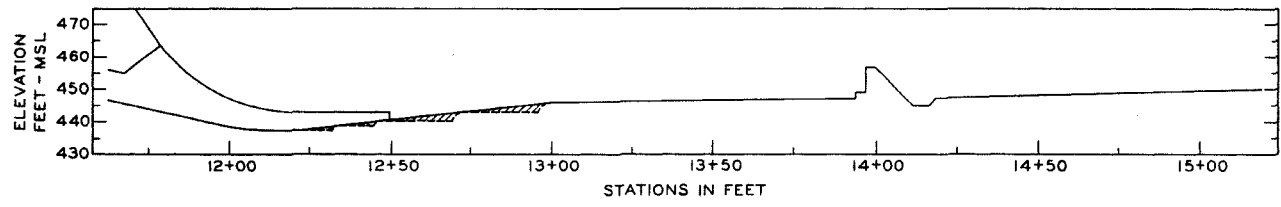


**VELOCITIES - STA 14+50**

MODEL SCALE 1:12  
**VELOCITIES AND PRESSURES**  
**STILLING BASIN - MODIFICATION E**  
 CONDUIT DISCHARGE 3,500 CFS  
 TAILWATER ELEVATION 460.0



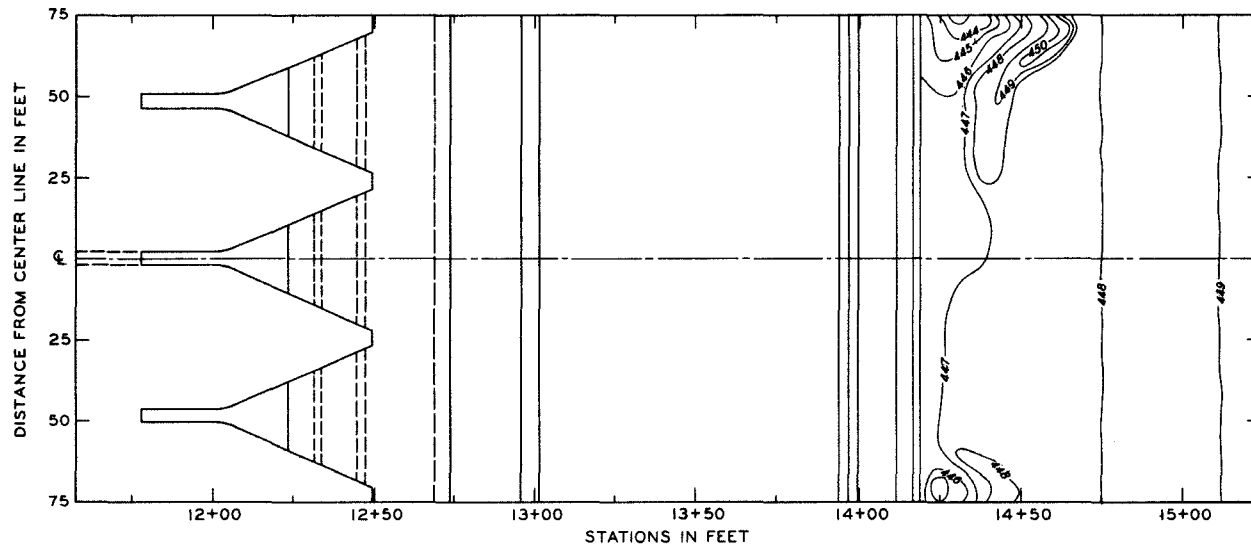
SCOUR PATTERN



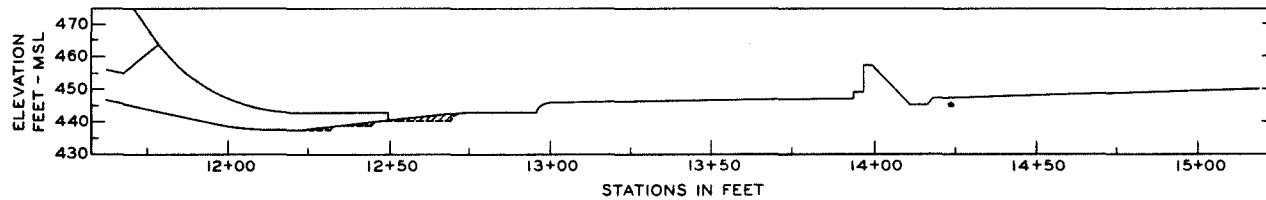
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN - MODIFICATION D  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 4600



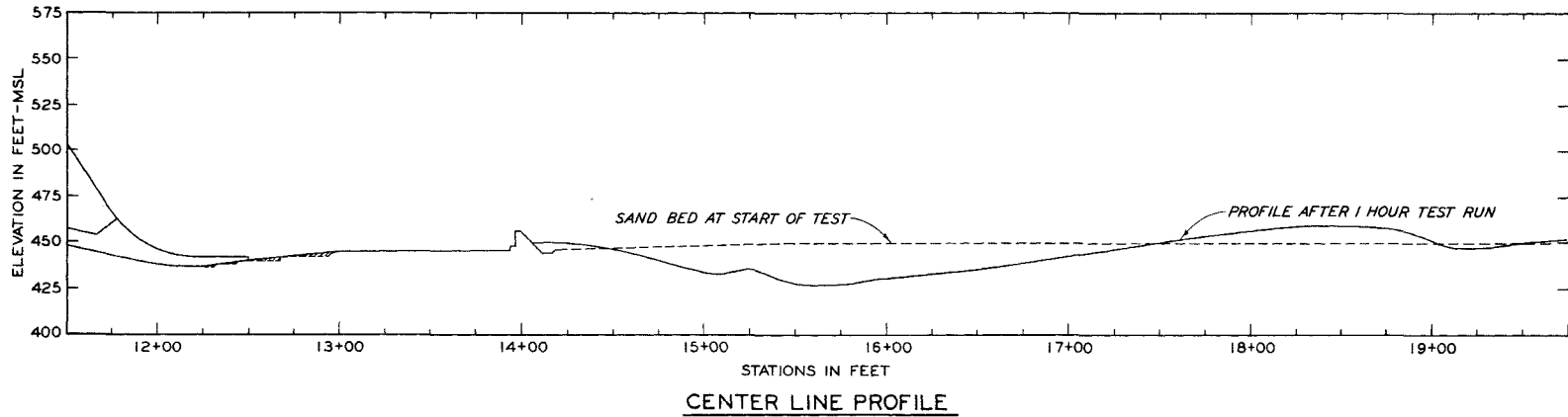
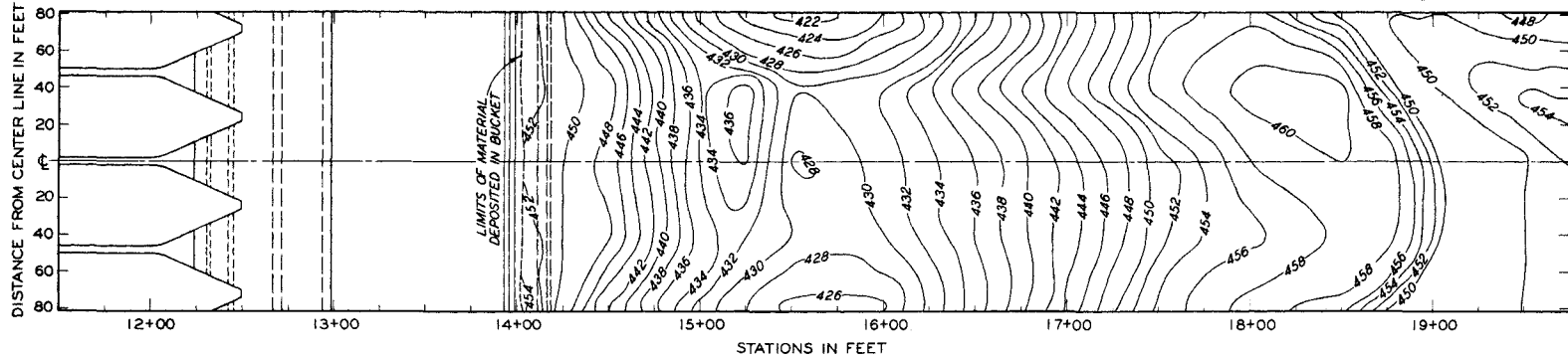
SCOUR PATTERN



CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED  
 FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN  
 PEA GRAVEL.

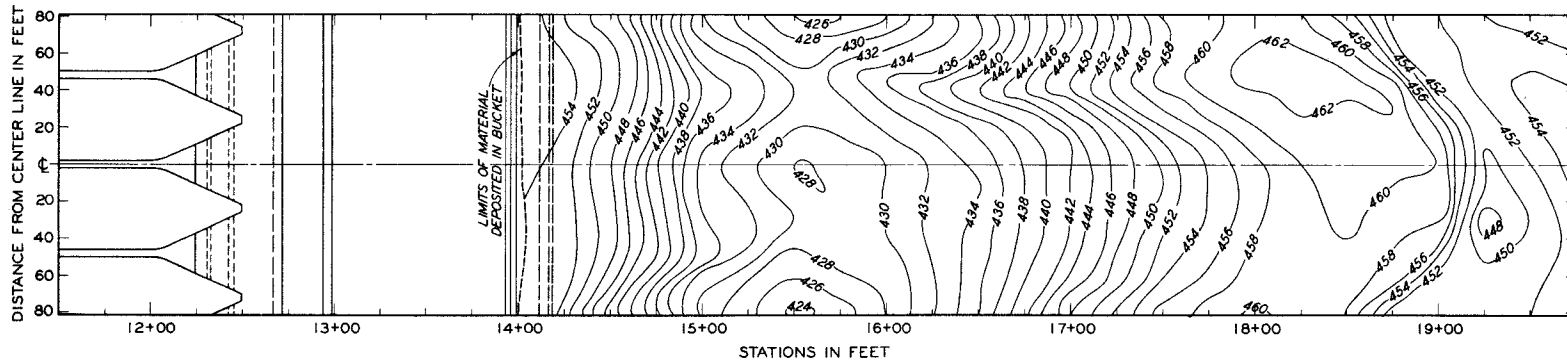
MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN - MODIFICATION E**  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 4600



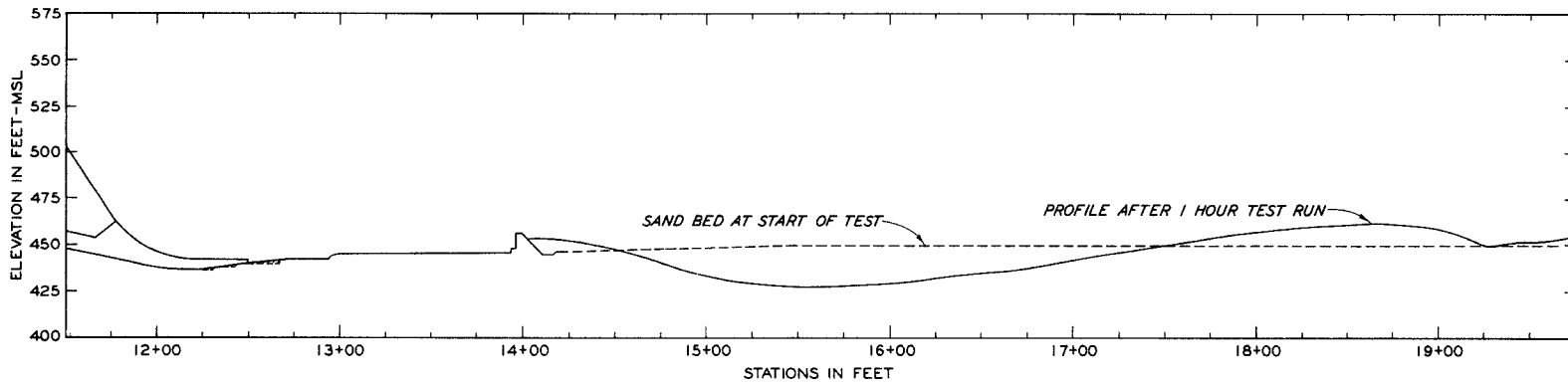
NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN - MODIFICATION D**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



SCOUR PATTERN



CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STATION 10+00  
EXIT CHANNEL WAS MOLDED IN SAND.

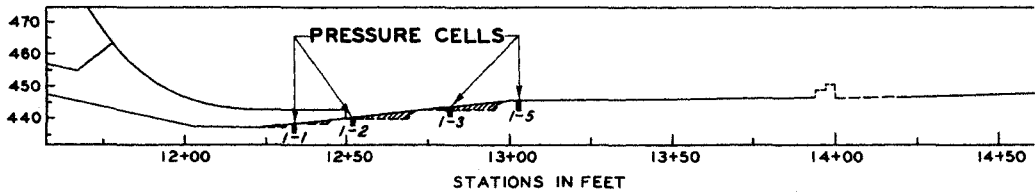
MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**

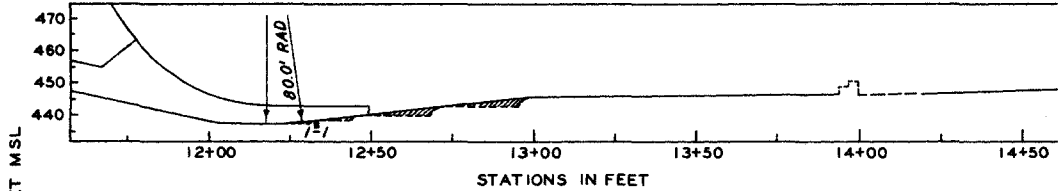
**STILLING BASIN - MODIFICATION E**

SPILLWAY DISCHARGE 556.000 CFS

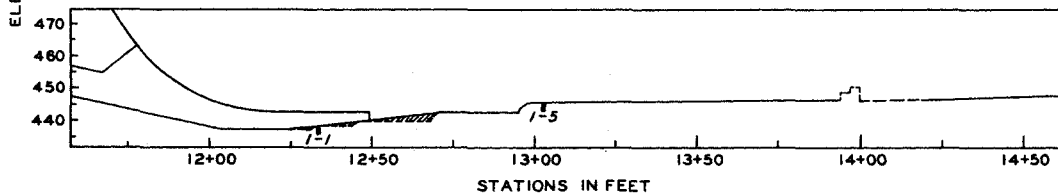
TAILWATER ELEVATION 514.4



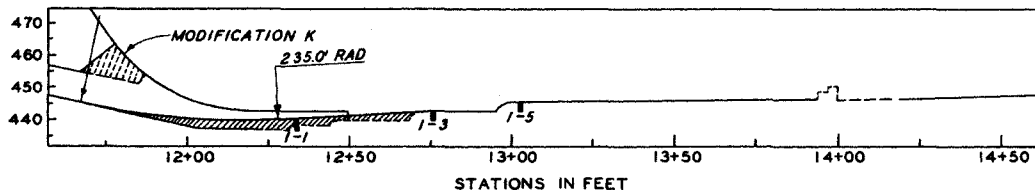
**MODIFICATIONS B AND C**



**MODIFICATIONS G AND G-1**



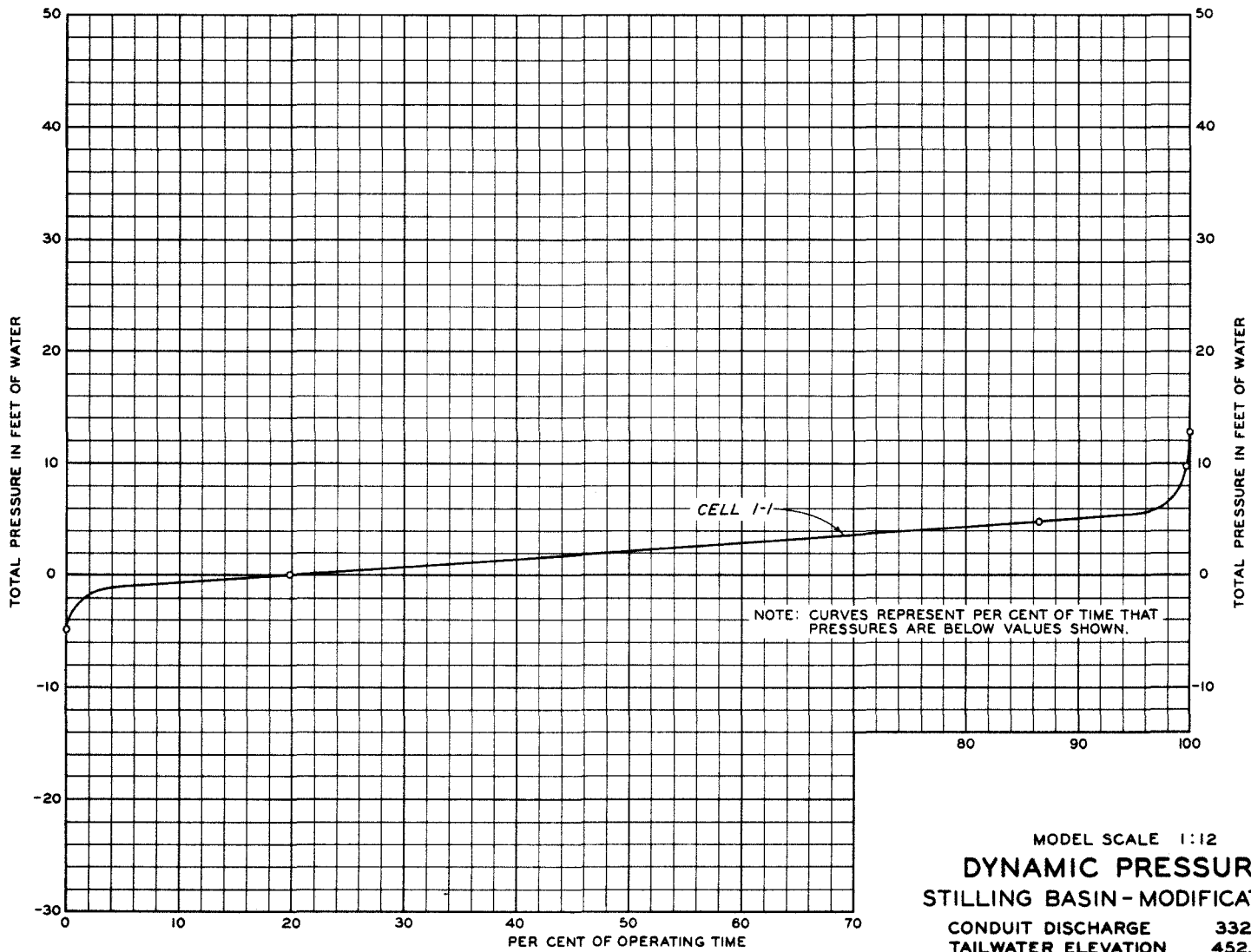
**MODIFICATION I**



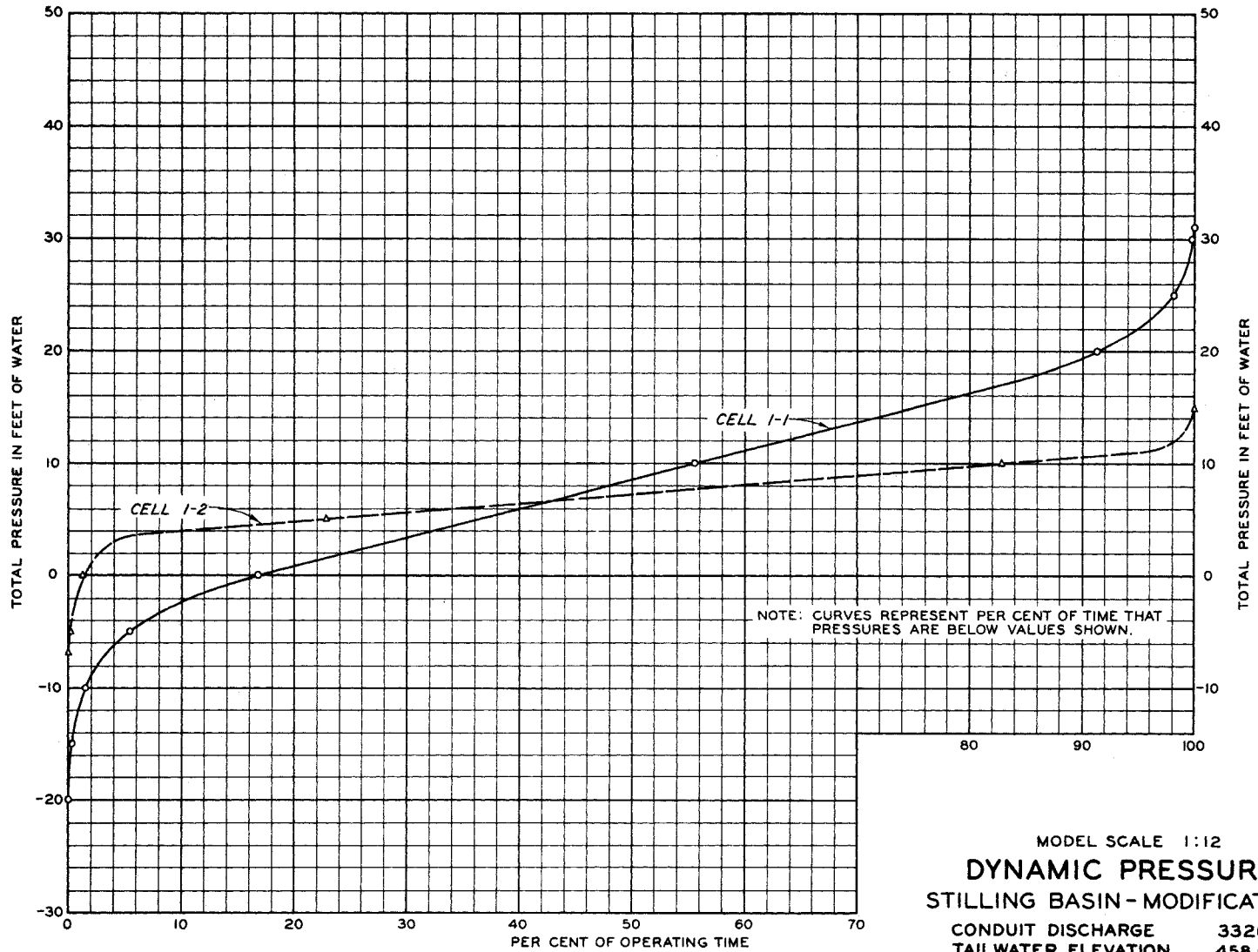
**MODIFICATIONS J AND K**

NOTE: BAFFLE PIER AND END SILL  
ARRANGEMENTS NOT SHOWN.

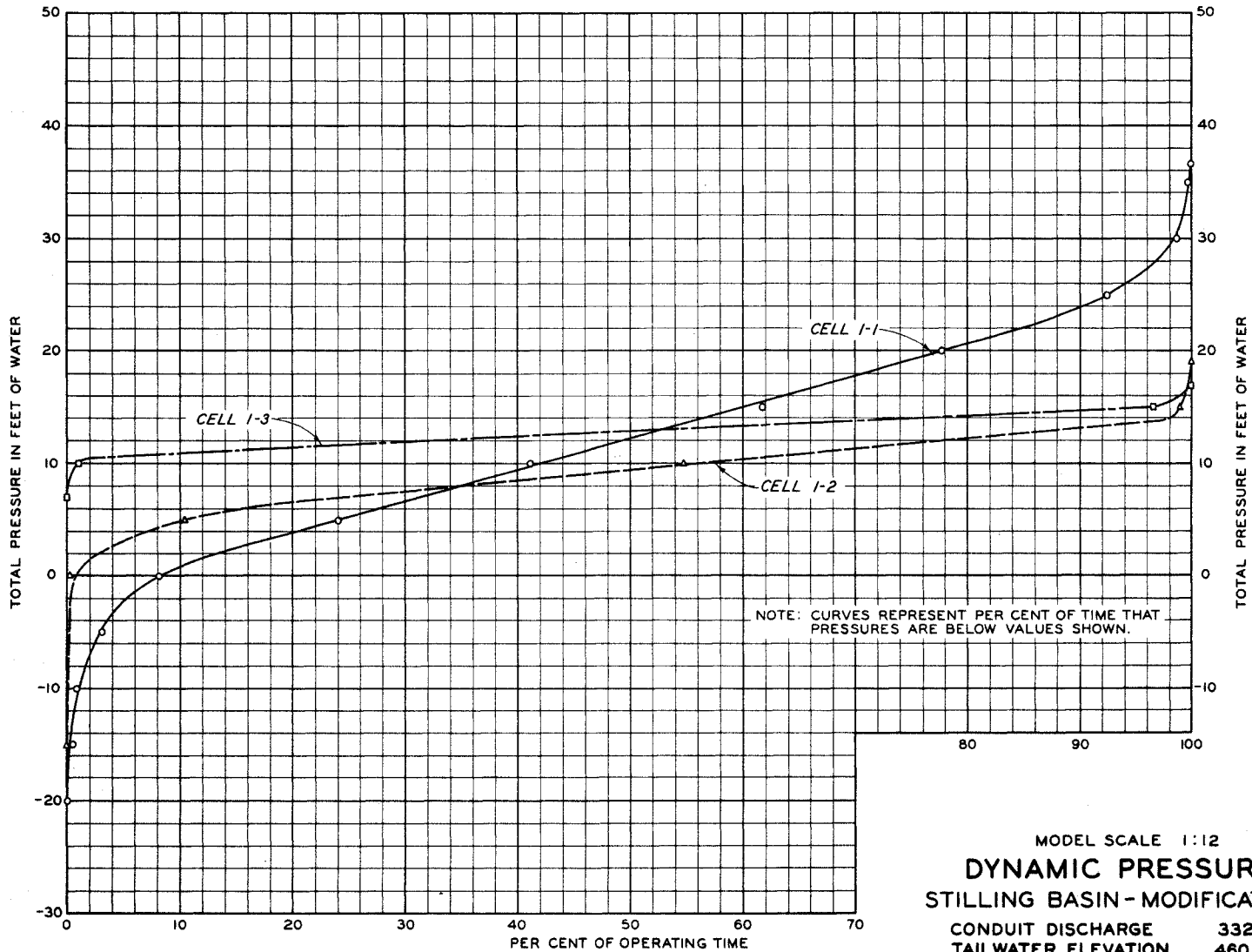
**PRESSURE CELL LOCATIONS**



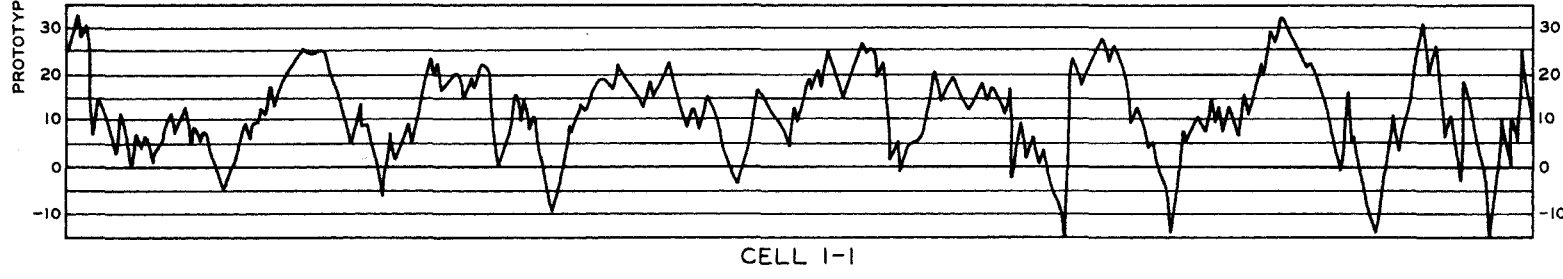
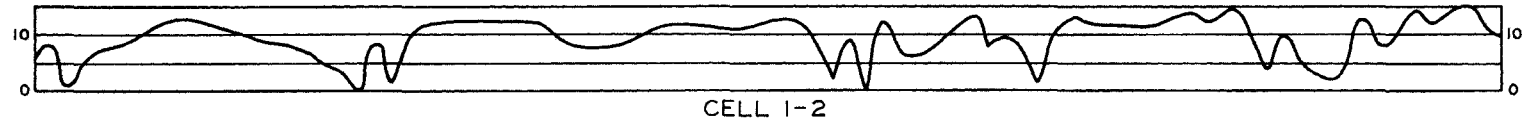
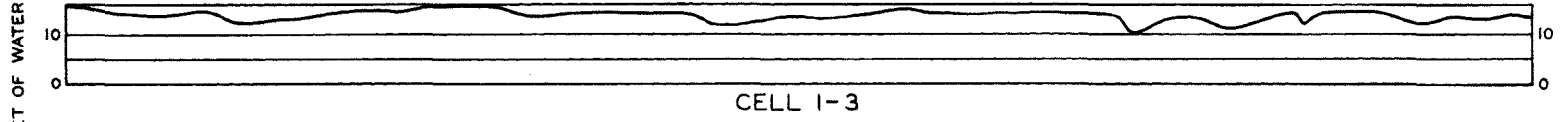
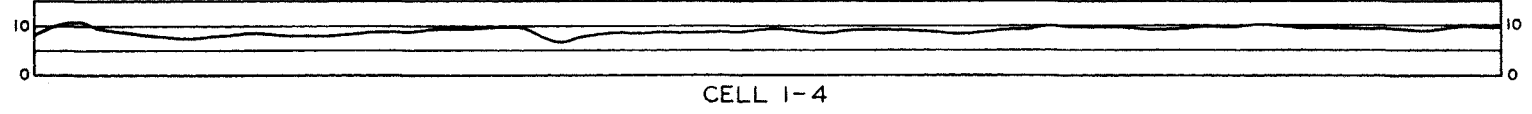
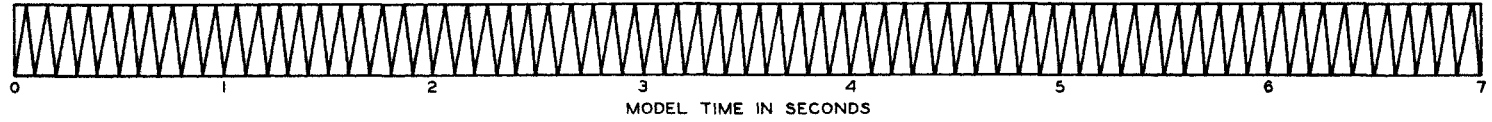
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
STILLING BASIN - MODIFICATION B  
CONDUIT DISCHARGE 3320 CFS  
TAILWATER ELEVATION 452.8



MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
**STILLING BASIN - MODIFICATION B**  
 CONDUIT DISCHARGE 3320 CFS  
 TAILWATER ELEVATION 458.0

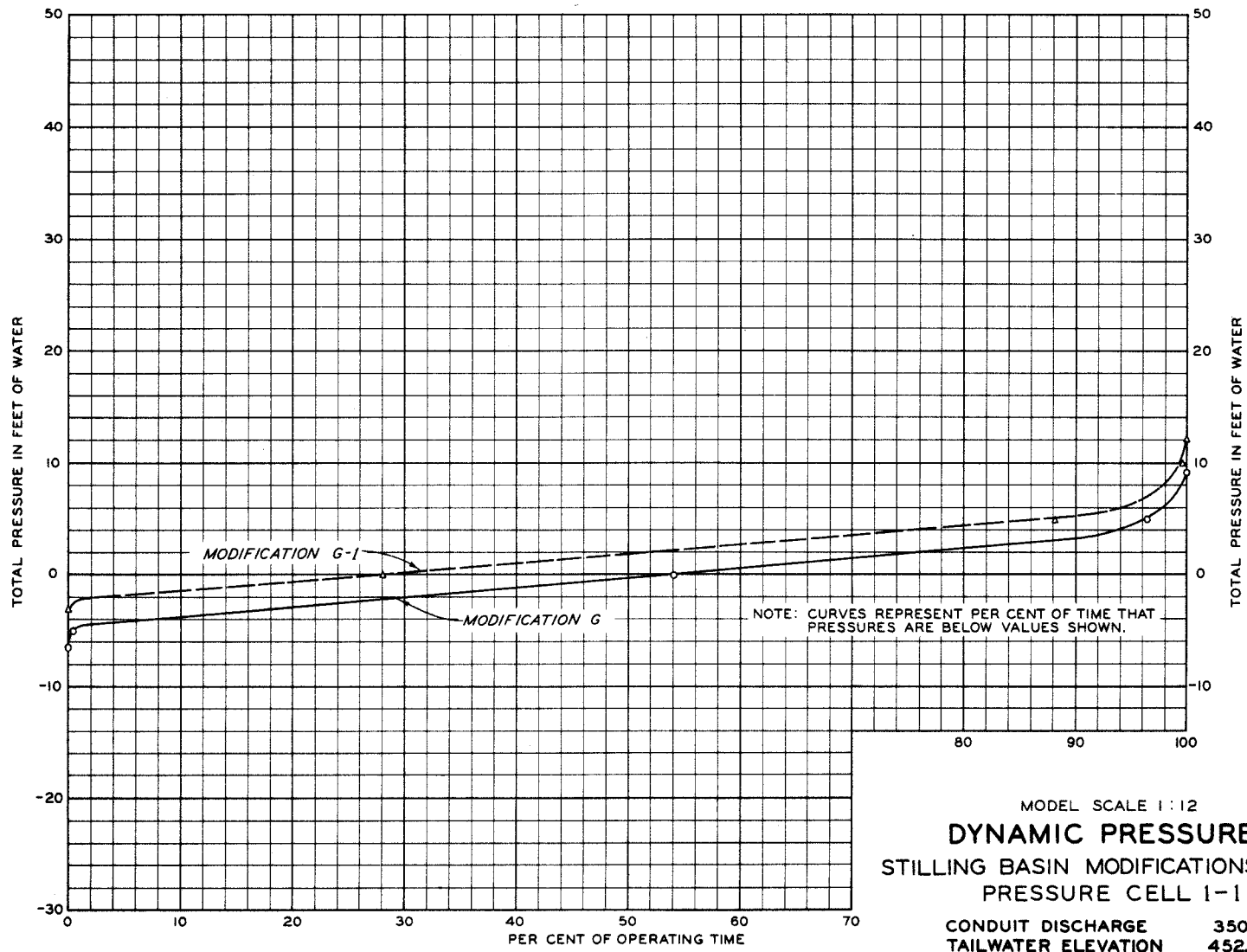


MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN - MODIFICATION B  
 CONDUIT DISCHARGE 3320 CFS  
 TAILWATER ELEVATION 460.0

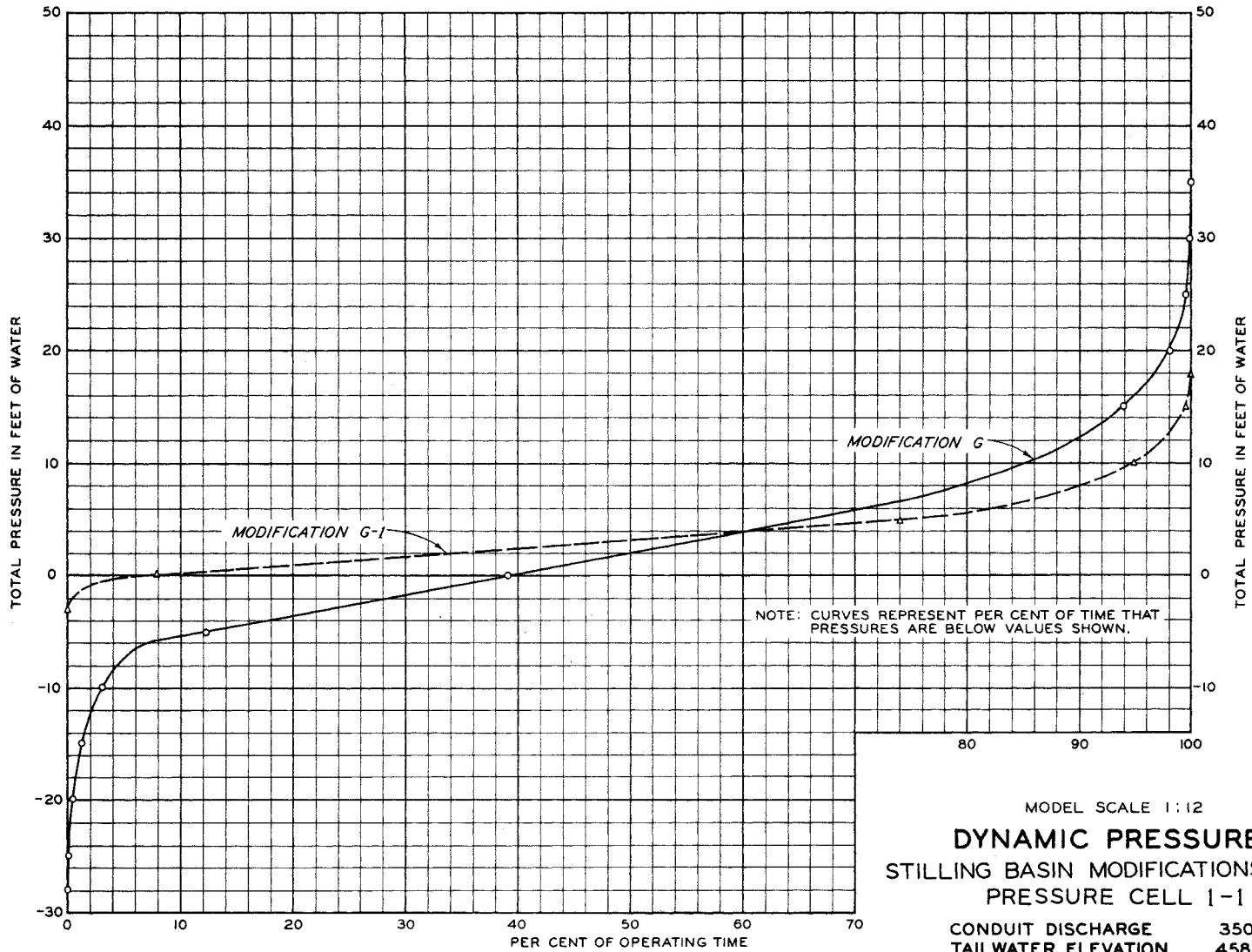


NOTE: MODIFICATION B.  
TAILWATER EL 460.0.

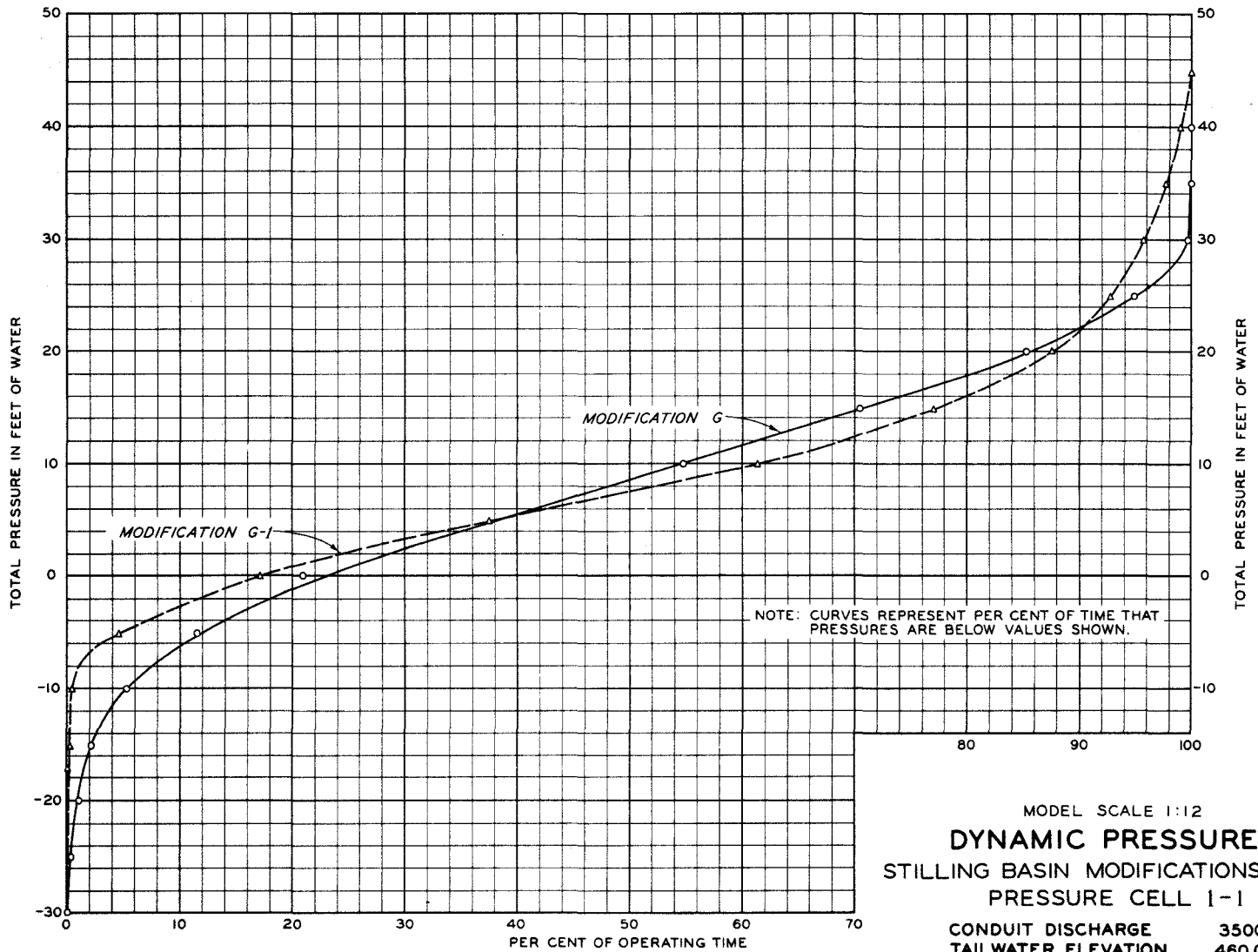
TYPICAL OSCILLOGRAM



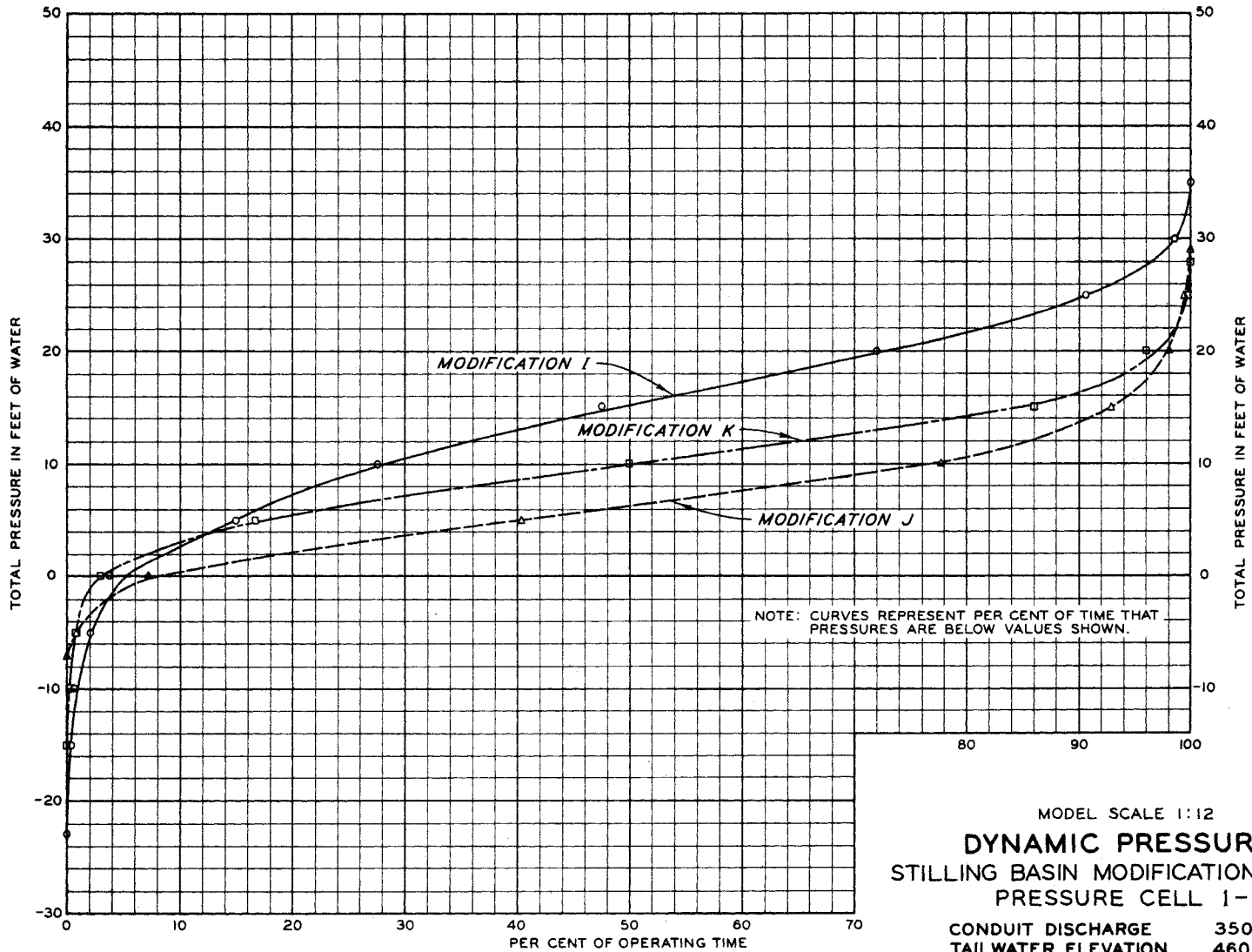
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS G, G-1  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8



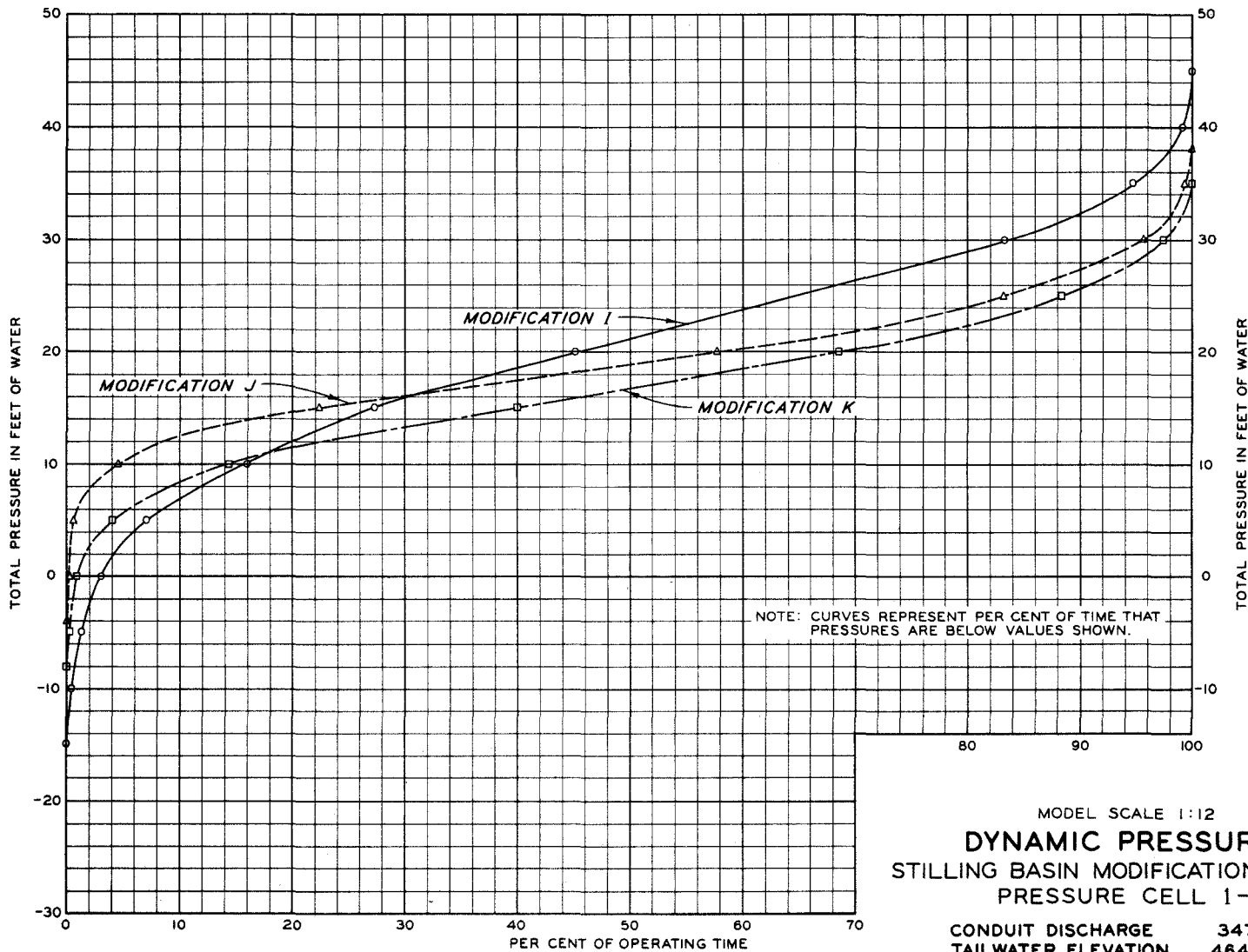
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS G, G-1  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 458.0



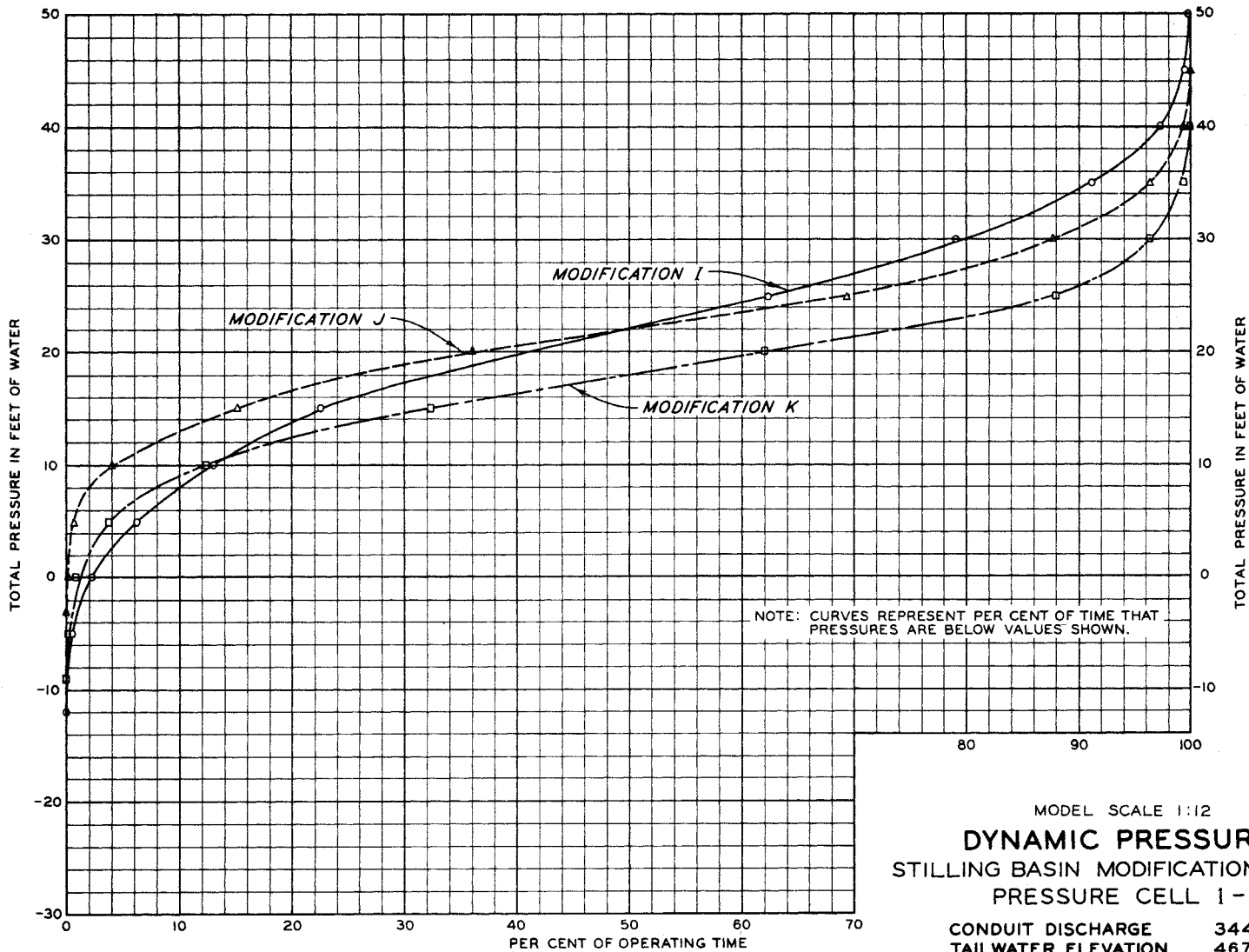
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS G, G-1  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 460.0



MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS I, J, K  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 460.0



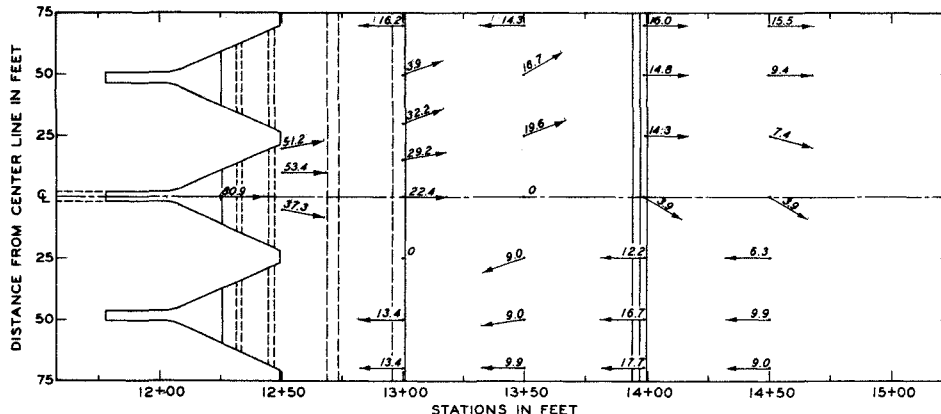
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS I, J, K  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3470 CFS  
 TAILWATER ELEVATION 464.3



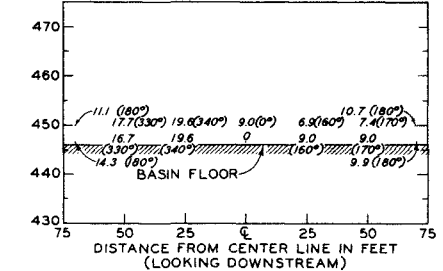
MODEL SCALE 1:12  
**DYNAMIC PRESSURES**  
 STILLING BASIN MODIFICATIONS I, J, K  
 PRESSURE CELL 1-1  
 CONDUIT DISCHARGE 3440 CFS  
 TAILWATER ELEVATION 467.3

**PRESSURE DATA**

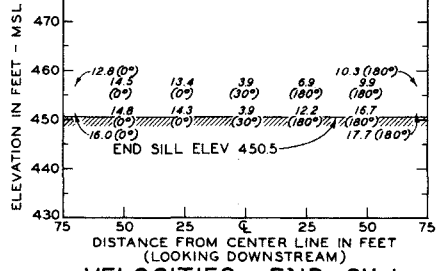
PIEZ NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
1	12+23.8	437.3	464.5	27.2
2	12+25.3	437.3	470.5	33.2
3	12+26.1	437.3	474.0	36.7
4	12+27.1	437.4	464.5	27.1
5	12+28.5	437.6	460.5	22.9
6	12+30.0	437.6	459.0	20.2
10	12+33.5	438.2	465.0	26.6
11	12+34.2	438.3	453.5	15.2
12	12+35.2	438.4	455.0	16.6
19	12+45.5	438.7	449.0	9.3
20	12+46.5	438.6	455.0	15.2
22	12+48.2	440.0	450.5	10.5
32	12+72.0	442.5	453.5	11.0
33	12+73.0	442.6	456.0	13.4
34	12+73.7	442.7	454.0	11.3
35	12+74.7	442.8	454.0	11.2
45	12+99.0	445.3	455.0	9.7
46	13+00.0	445.4	455.0	9.6
47	13+00.7	445.4	455.5	10.1
48	13+01.7	445.4	455.5	10.1
49	13+02.7	445.4	456.0	10.6
50	13+05.1	445.5	456.0	10.5
51	13+07.5	445.5	456.5	11.0
52	13+12.3	445.5	456.5	11.0
54	12+01.5	441.3	425.6	-15.7
55	12+03.7	440.8	424.3	-16.5



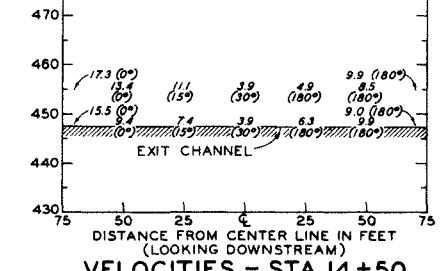
**BOTTOM VELOCITIES**



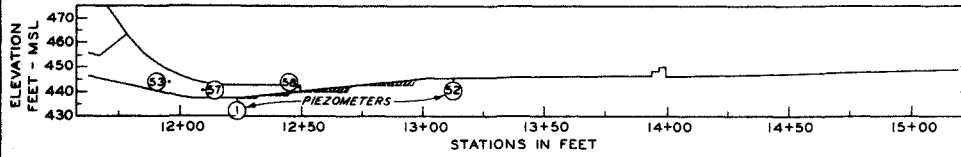
**VELOCITIES - STA 13+50**



**VELOCITIES - END SILL**



**VELOCITIES - STA 14+50**

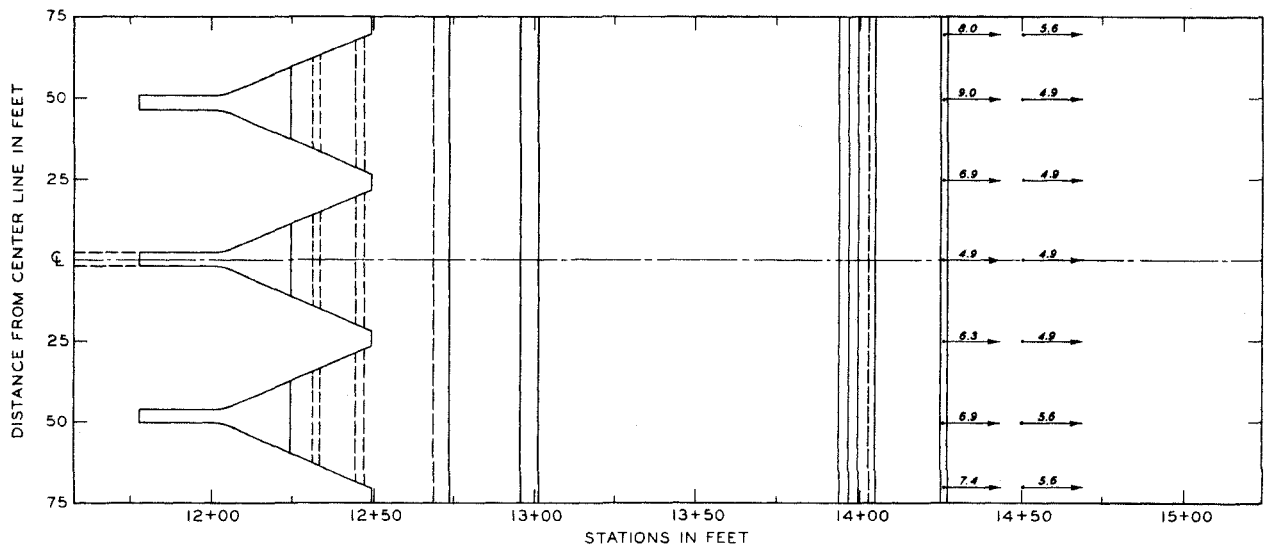


**DETAILS OF BASIN**

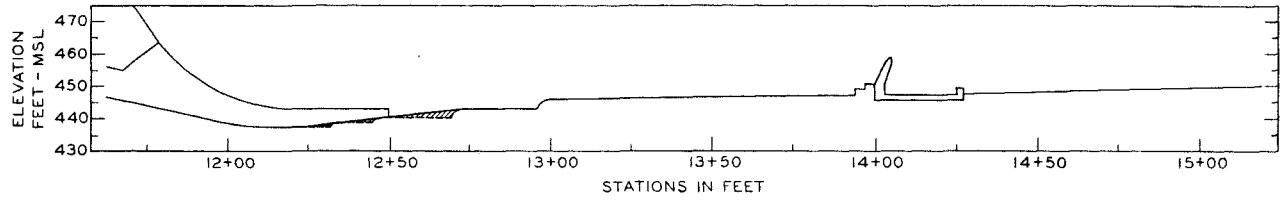
NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 PIEZOMETERS 1 TO 52 ARE ON CENTER LINE OF CONDUIT.  
 PIEZOMETERS 53 TO 57 ARE ON SIDEWALL OF CONDUIT.  
 VELOCITY DIRECTIONS ARE SHOWN IN PARENTHESES AS DEGREES OF AZIMUTH. DOWNSTREAM IS ZERO DEGREES.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

MODEL SCALE 1:12

**VELOCITIES AND PRESSURES**  
**STILLING BASIN - MODIFICATION B**  
 CONDUIT DISCHARGE 3,500 CFS  
 TAILWATER ELEVATION 460.0



BOTTOM VELOCITIES

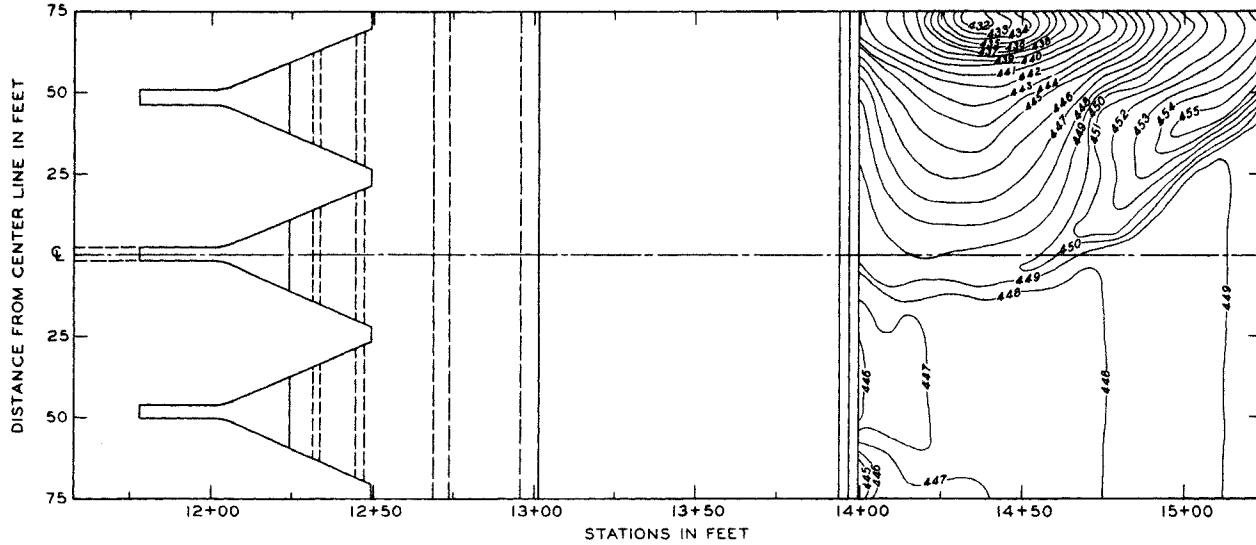


DETAILS OF BASIN

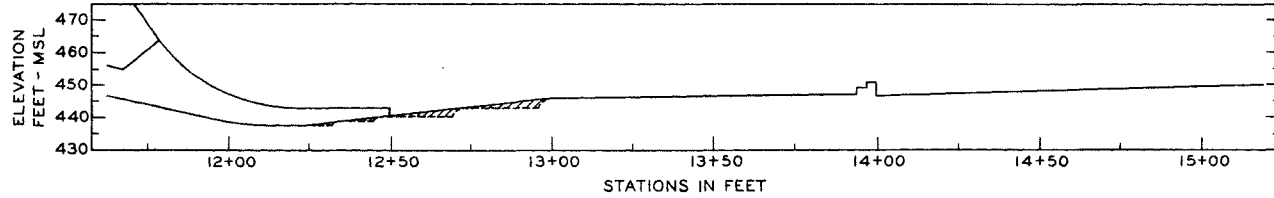
NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

MODEL SCALE 1:12  
**BOTTOM VELOCITIES**  
 STILLING BASIN - MODIFICATION I  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8





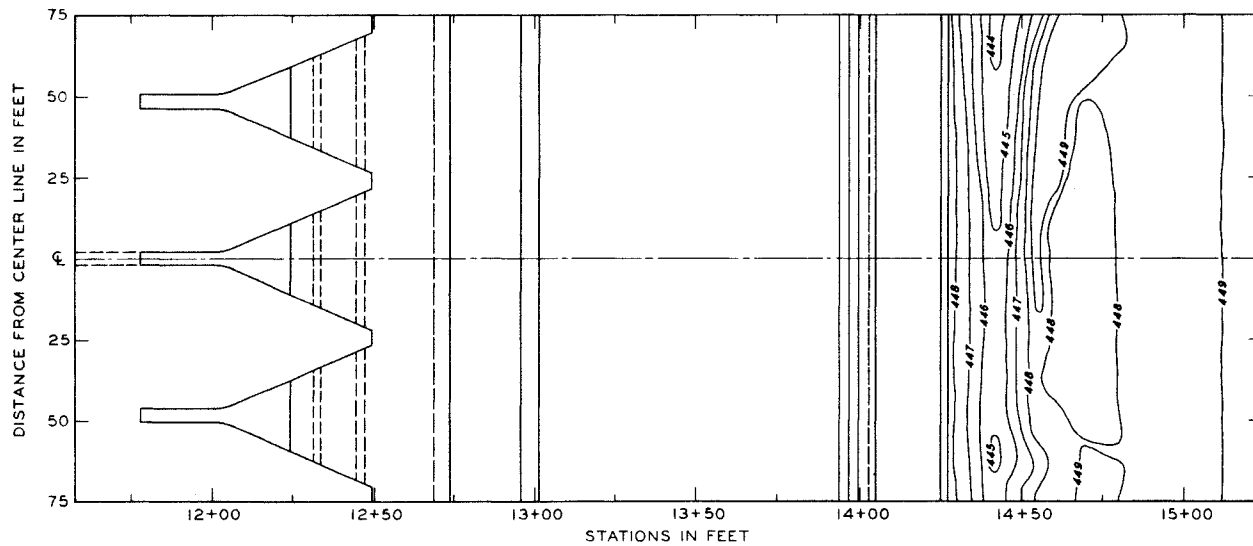
SCOUR PATTERN



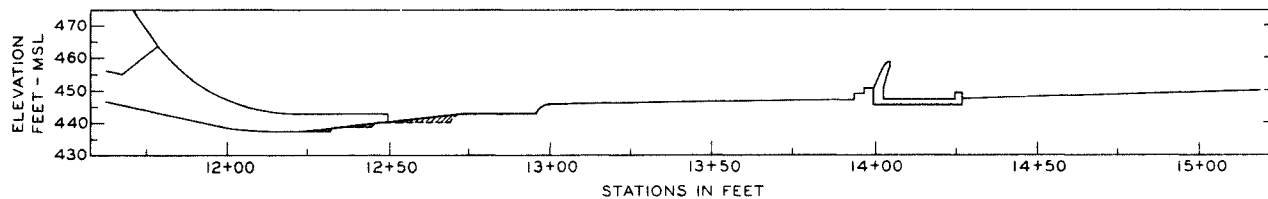
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN-MODIFICATION B**  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 460.0



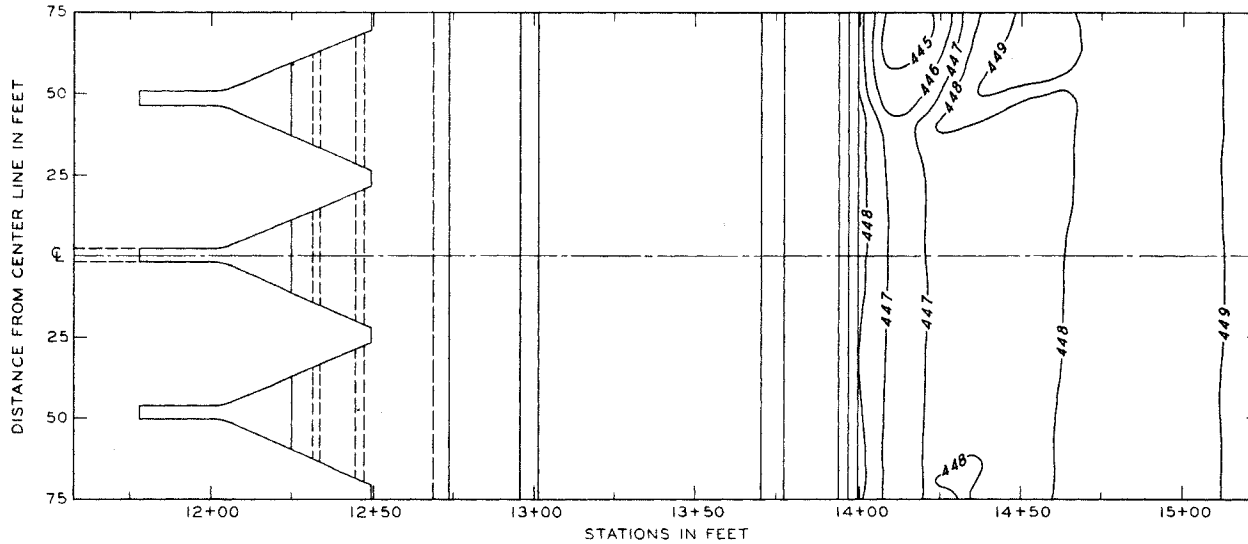
SCOUR PATTERN



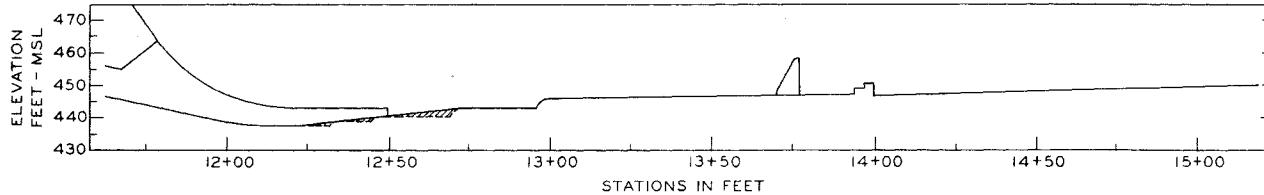
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED  
 FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN  
 PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN-MODIFICATION I**  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8



SCOUR PATTERN



CENTER LINE PROFILE

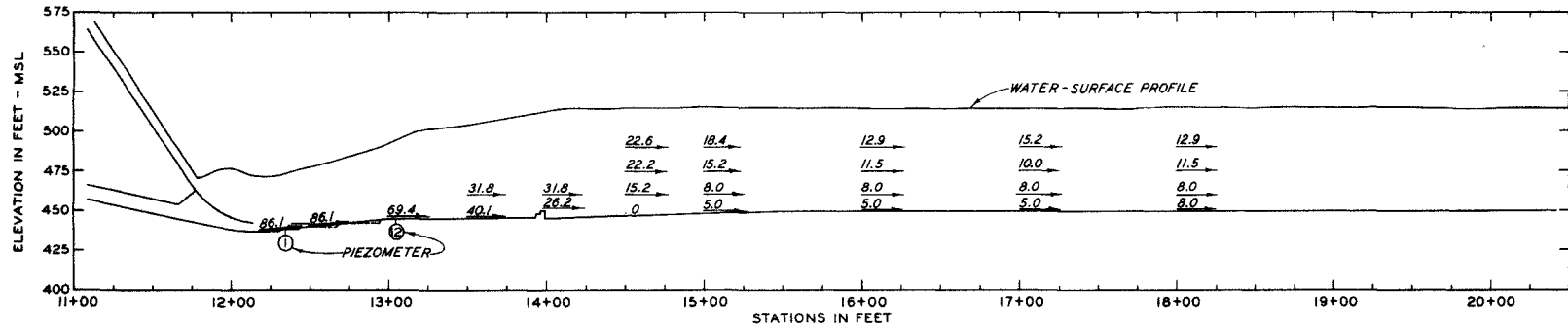
NOTE: AXIS OF DAM IS STA 10+00.

CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.

EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN-MODIFICATION M**  
**CONDUIT DISCHARGE 3500 CFS**  
**TAILWATER ELEVATION 452.8**



CENTER LINE VELOCITIES

**PRESSURE DATA**

PIEZ NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
1	12+34.5	438.3	515.0	76.7
2	12+36.5	438.6	506.0	67.4
4	12+47.5	439.9	505.0	65.1
7	12+74.0	442.7	481.0	38.3
8	12+76.0	442.9	476.0	33.1
9	12+78.0	443.1	484.0	40.9
10	13+01.0	445.4	480.0	34.6
11	13+03.0	445.4	484.0	38.6
12	13+05.0	445.5	486.0	40.5
13	12+49.5	442.0	492.0	50.0

NOTE: AXIS OF DAM IS STA 10+00.

VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

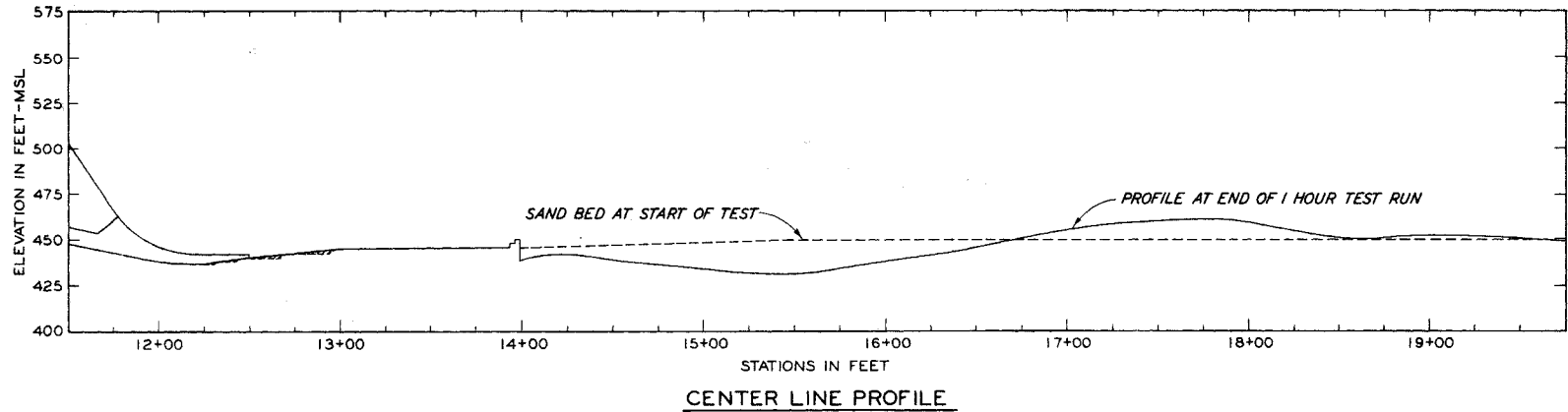
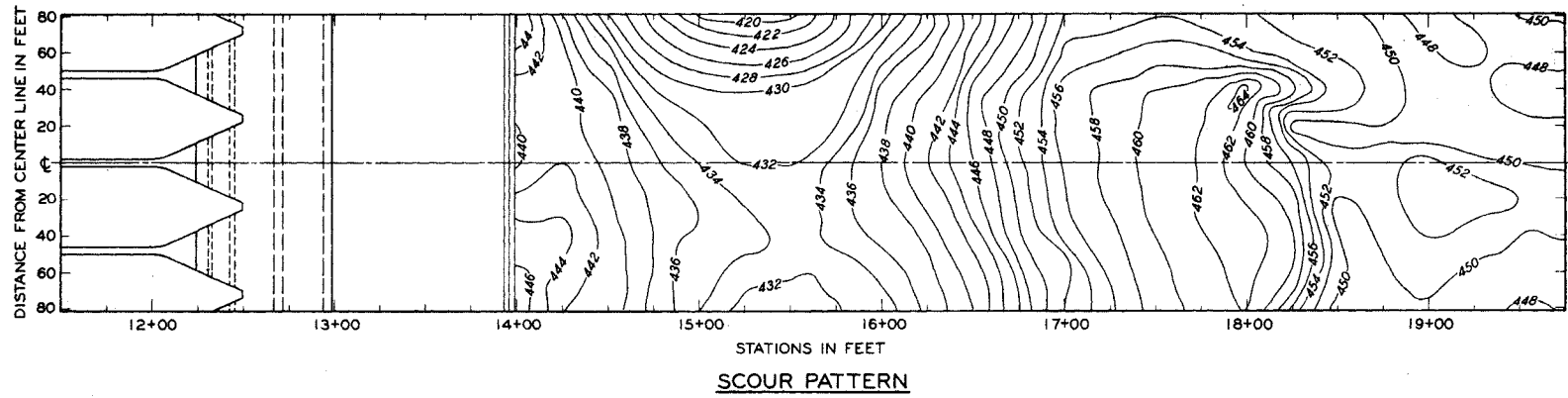
EXIT CHANNEL WAS MOLDED IN CEMENT MORTAR.

PIEZOMETERS NOS. 1 THROUGH 12 ARE ON CENTER LINE OF CONDUIT.

PIEZOMETER NO. 13 IS ON NOSE OF CONDUIT TRAINING WALL.

MODEL SCALE 1:50

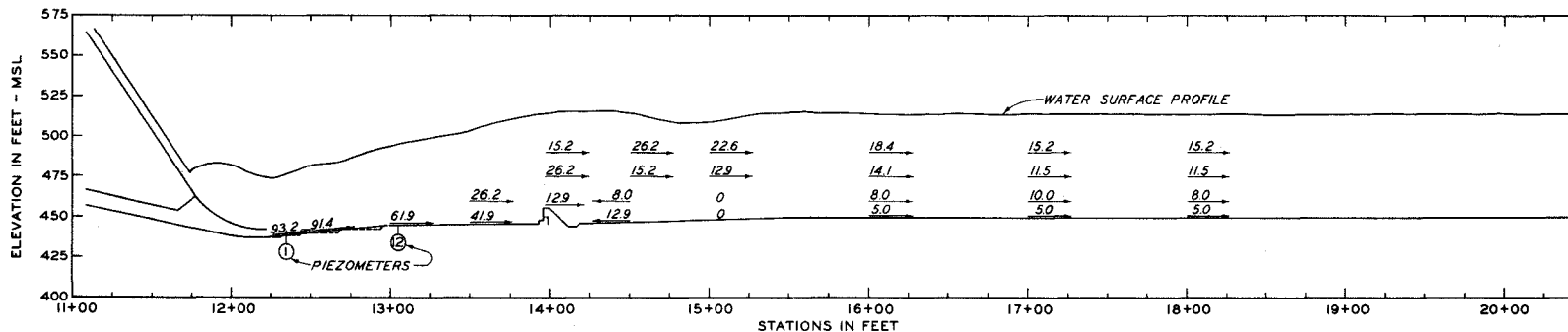
**FLOW CHARACTERISTICS**  
**STILLING BASIN - MODIFICATION B**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN - MODIFICATION B**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



CENTER LINE VELOCITIES

**PRESSURE DATA**

PIEZ. NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
1	12+34.5	438.3	520.0	81.7
2	12+36.5	438.6	507.0	68.4
4	12+47.5	439.9	505.0	65.1
7	12+74.0	442.7	482.0	39.3
8	12+76.0	442.9	480.0	37.1
9	12+76.0	443.1	486.0	42.9
10	13+01.0	445.4	480.0	34.6
11	13+03.0	445.4	484.0	38.6
12	13+05.0	445.5	486.0	40.5
13	12+49.5	442.0	494.0	52.0

NOTE: AXIS OF DAM IS STA 10+00.

VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

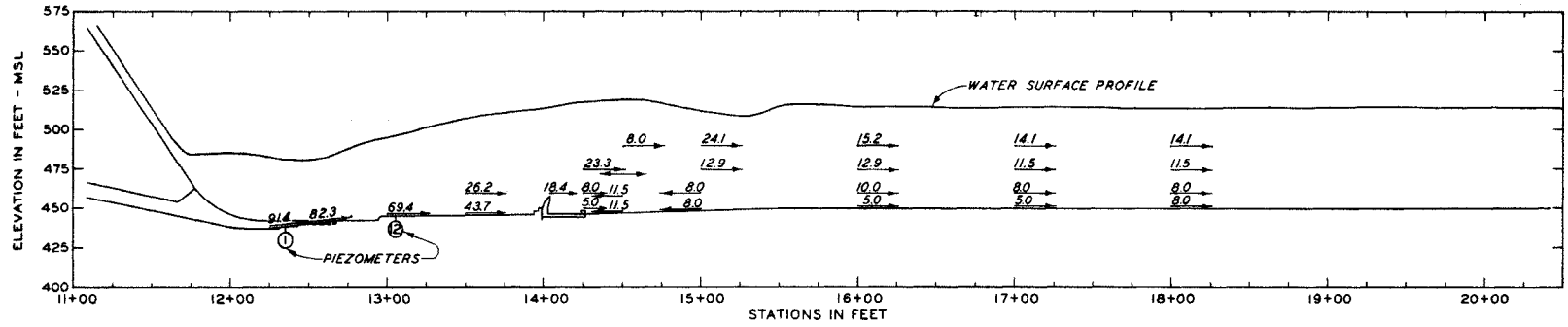
EXIT CHANNEL WAS MOLDED IN CEMENT MORTAR.

PIEZOMETERS NOS. 1 THROUGH 12 ARE ON CENTER LINE OF CONDUIT.

PIEZOMETER NO. 13 IS ON NOSE OF CONDUIT TRAINING WALL.

MODEL SCALE 1:50

**FLOW CHARACTERISTICS**  
**STILLING BASIN - MODIFICATION D**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



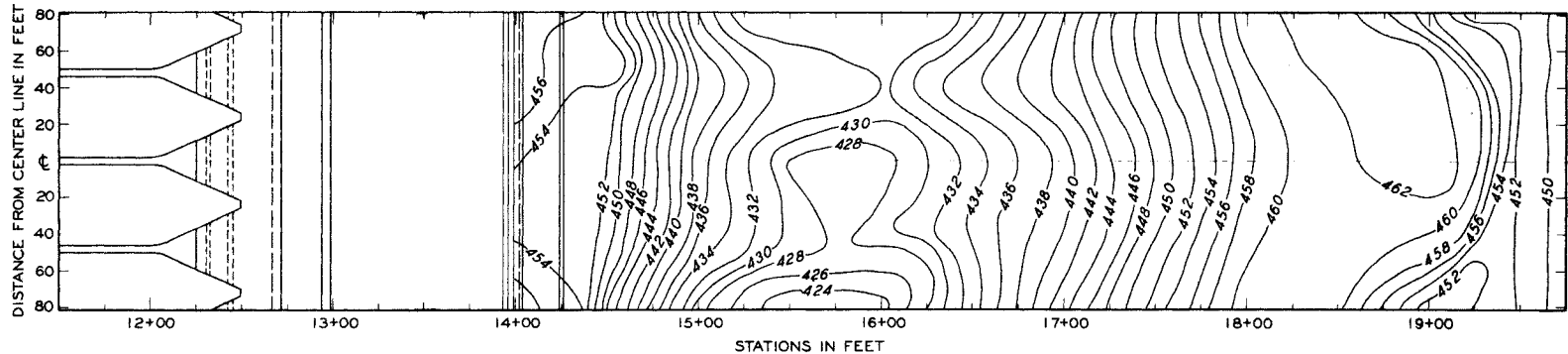
CENTER LINE VELOCITIES

PRESSURE DATA

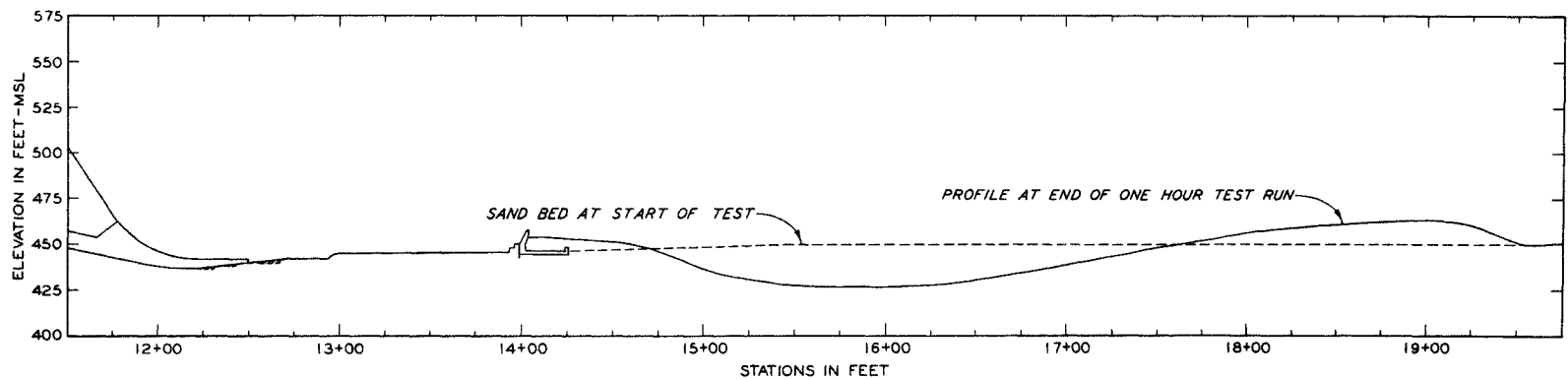
PIEZ NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
1	12+34.5	438.3	521.0	82.7
2	12+36.5	438.6	511.0	72.4
4	12+47.5	439.9	501.0	61.1
7	12+74.0	442.6	465.0	22.4
8	12+76.0	442.6	460.0	37.4
9	12+78.0	442.7	484.0	41.3
10	13+01.0	445.4	475.0	29.6
11	13+03.0	445.4	483.0	37.6
12	13+05.0	445.5	487.0	41.5
13	12+49.5	442.0	495.0	53.0

NOTE: AXIS OF DAM IS STA 10+00.  
 VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.  
 EXIT CHANNEL WAS MOLDED IN CEMENT MORTAR.  
 PIEZOMETERS NOS. 1 THROUGH 12 ARE ON CENTER LINE OF CONDUIT.  
 PIEZOMETER NO. 13 IS ON NOSE OF CONDUIT TRAINING WALL.

MODEL SCALE 1:50  
**FLOW CHARACTERISTICS**  
**STILLING BASIN - MODIFICATION I**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



SCOUR PATTERN

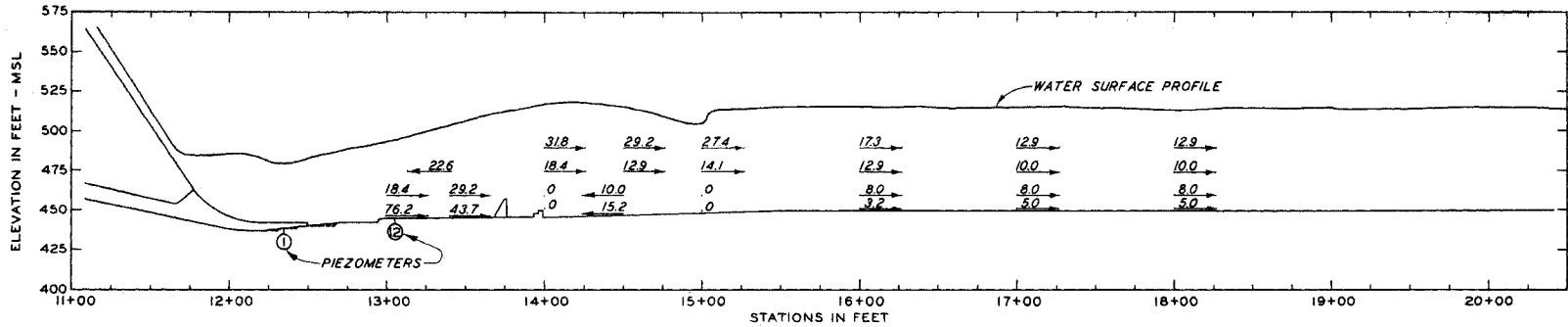


CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN-MODIFICATION I**  
**SPILLWAY DISCHARGE 556,000 CFS**  
**TAILWATER ELEVATION 514.4**



CENTER LINE VELOCITIES

**PRESSURE DATA**

PIEZ NO.	STATION	ZERO ELEV	READING	PRESSURE FT OF H <sub>2</sub> O
1	12+34.5	438.3	521.0	82.7
2	12+38.5	438.6	511.0	72.4
4	12+47.5	439.9	500.0	60.1
7	12+74.0	442.6	465.0	22.4
8	12+76.0	442.6	480.0	37.4
9	12+78.0	442.7	484.0	41.3
10	13+01.0	445.4	473.0	27.6
11	13+03.0	445.4	481.0	35.6
12	13+05.0	445.5	486.0	40.5
13	12+49.5	442.0	495.0	53.0

NOTE: AXIS OF DAM IS STA 10+00.

VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

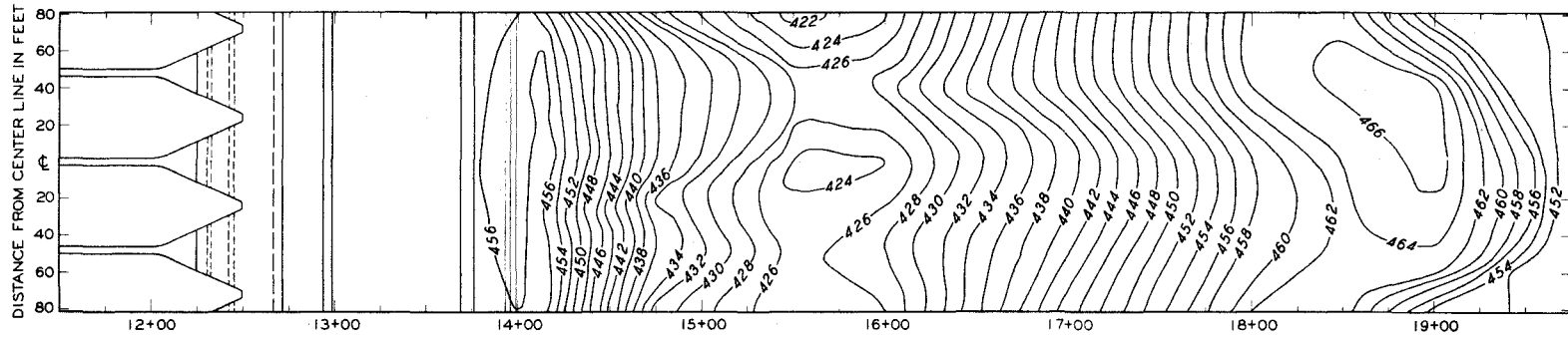
EXIT CHANNEL WAS MOLDED IN CEMENT MORTAR.

PIEZOMETERS NOS. 1 THROUGH 12 ARE ON CENTER LINE OF CONDUIT.

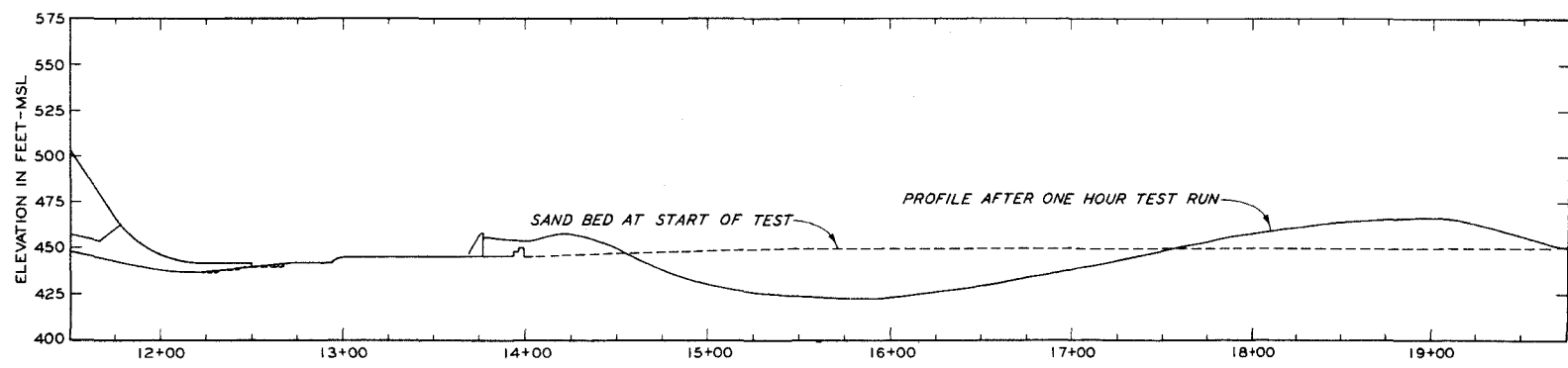
PIEZOMETER NO. 13 IS ON NOSE OF CONDUIT TRAINING WALL.

MODEL SCALE 1:50

**FLOW CHARACTERISTICS**  
**STILLING BASIN - MODIFICATION M**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



STATIONS IN FEET  
SCOUR PATTERN

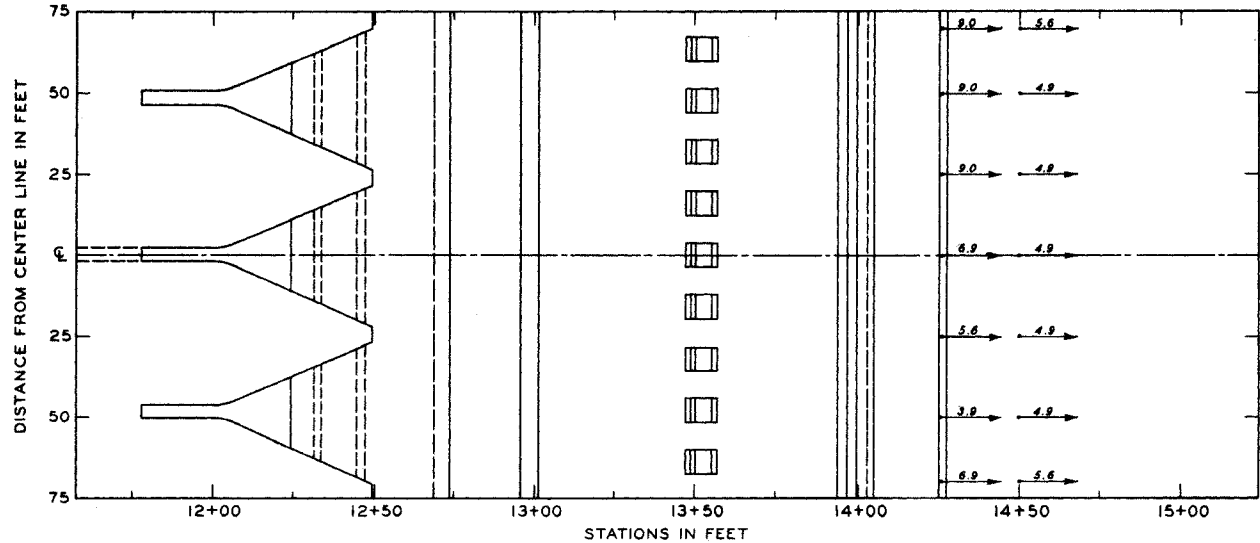


STATIONS IN FEET  
CENTER LINE PROFILE

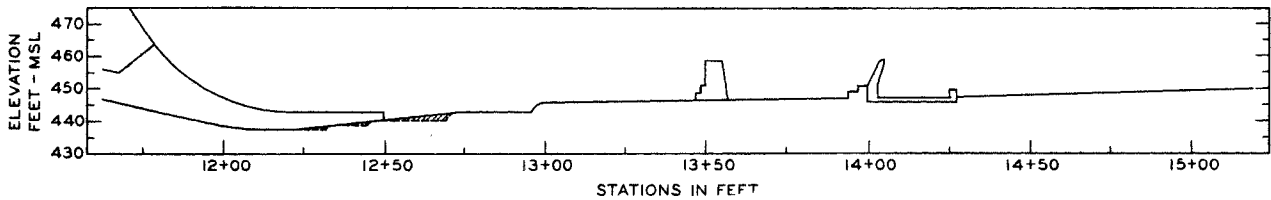
NOTE: AXIS OF DAM IS STATION 10+00.  
 EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN-MODIFICATION M  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



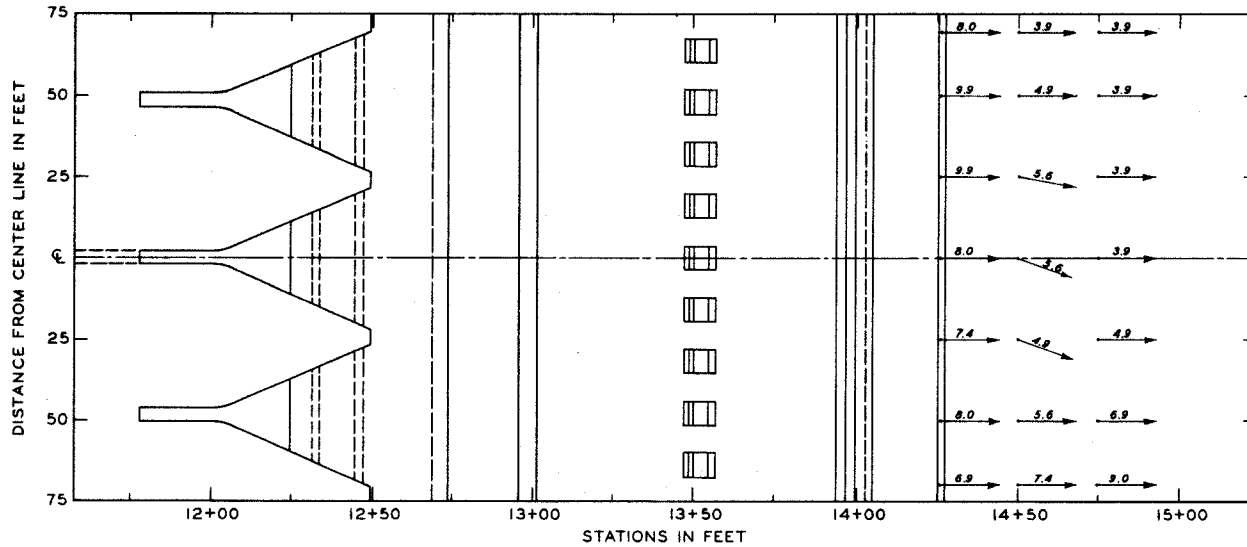
**BOTTOM VELOCITIES**



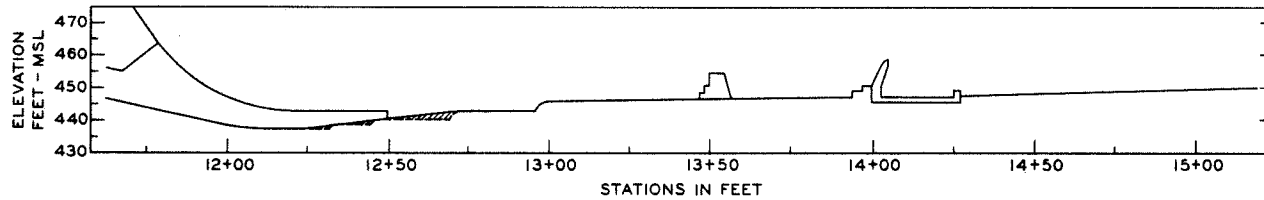
**DETAILS OF BASIN**

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

MODEL SCALE 1:12  
**BOTTOM VELOCITIES**  
 STILLING BASIN-MODIFICATION H  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 12-FT BAFFLES INSTALLED



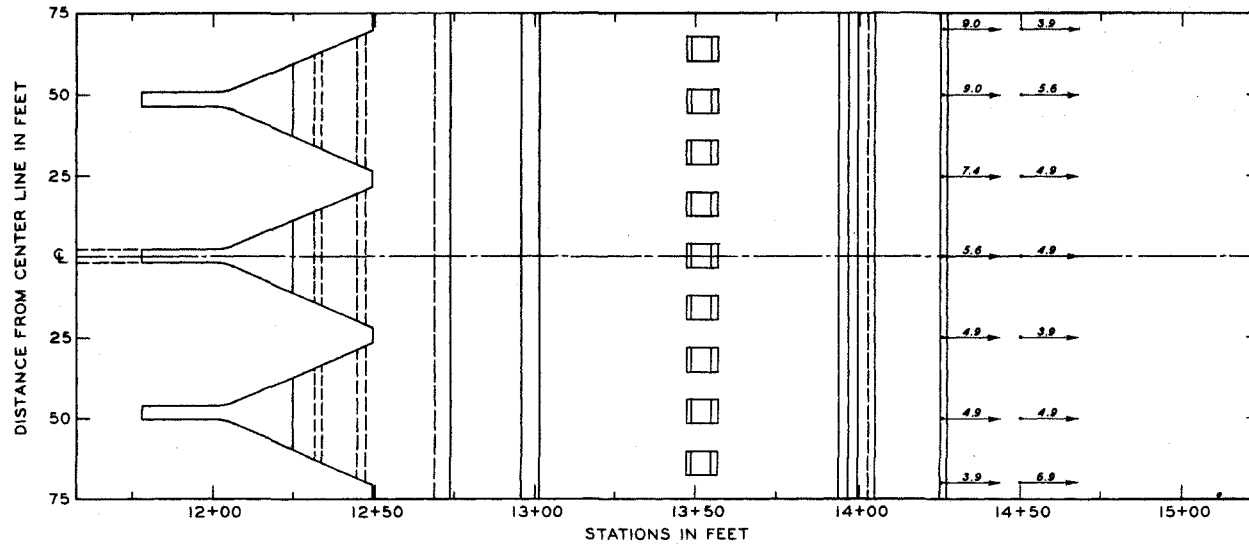
**BOTTOM VELOCITIES**



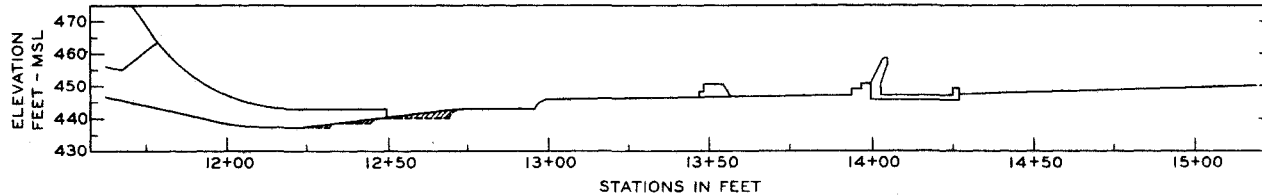
**DETAILS OF BASIN**

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

MODEL SCALE 1:12  
**BOTTOM VELOCITIES**  
**STILLING BASIN-MODIFICATION H**  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 8-FT BAFFLES INSTALLED



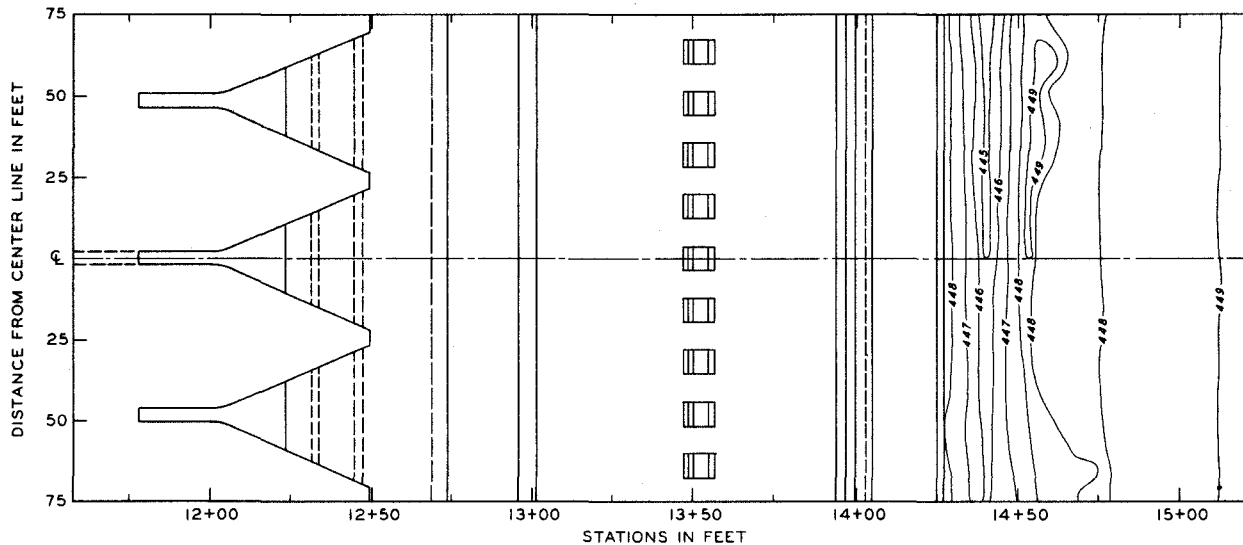
**BOTTOM VELOCITIES**



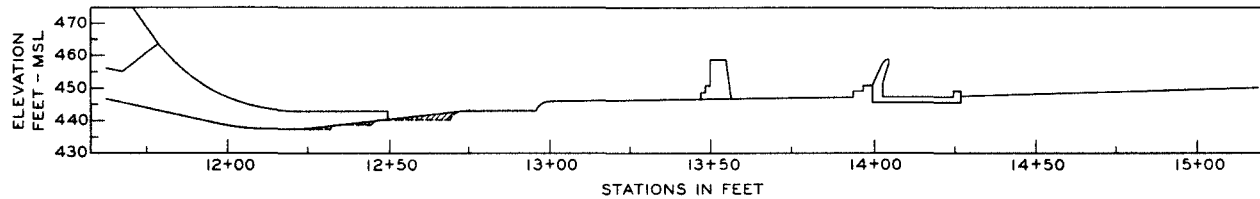
**DETAILS OF BASIN**

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 ALL VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

MODEL SCALE 1:12  
**BOTTOM VELOCITIES**  
 STILLING BASIN-MODIFICATION H  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 4-FT BAFFLES INSTALLED



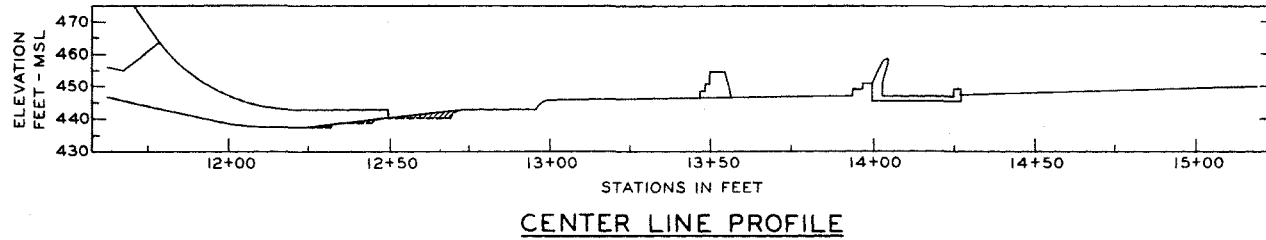
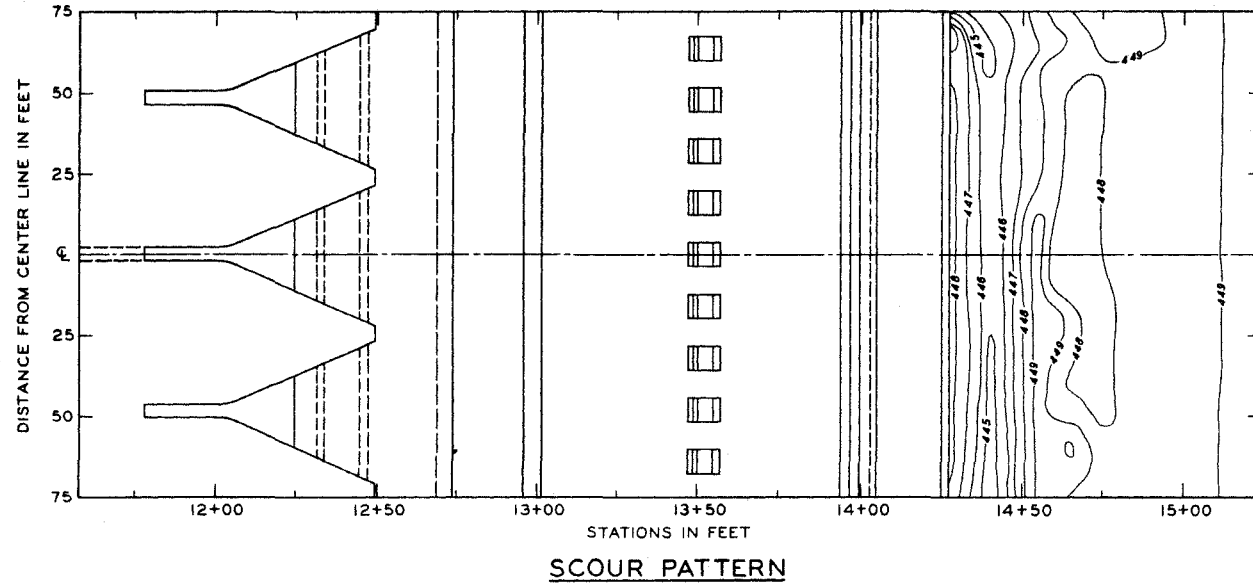
SCOUR PATTERN



CENTER LINE PROFILE

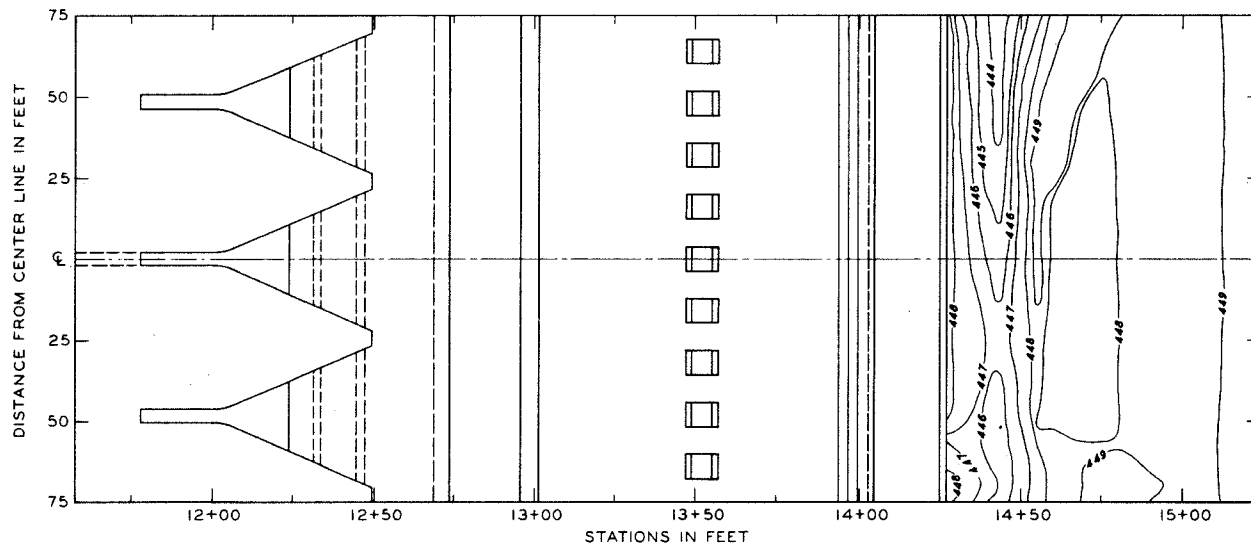
NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED  
 FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN  
 PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN-MODIFICATION H  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 12-FT BAFFLES INSTALLED

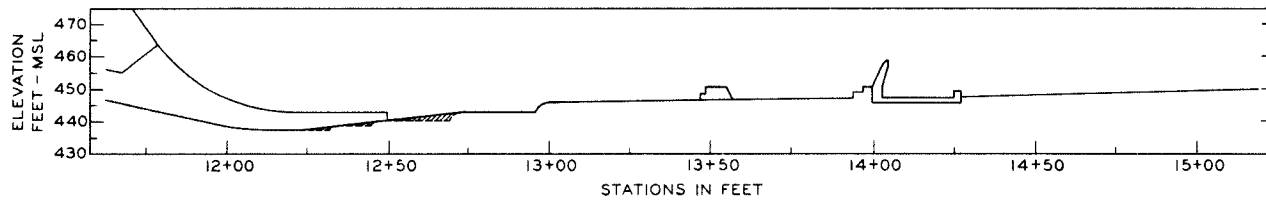


NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN-MODIFICATION H  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 8 - FT BAFFLES INSTALLED



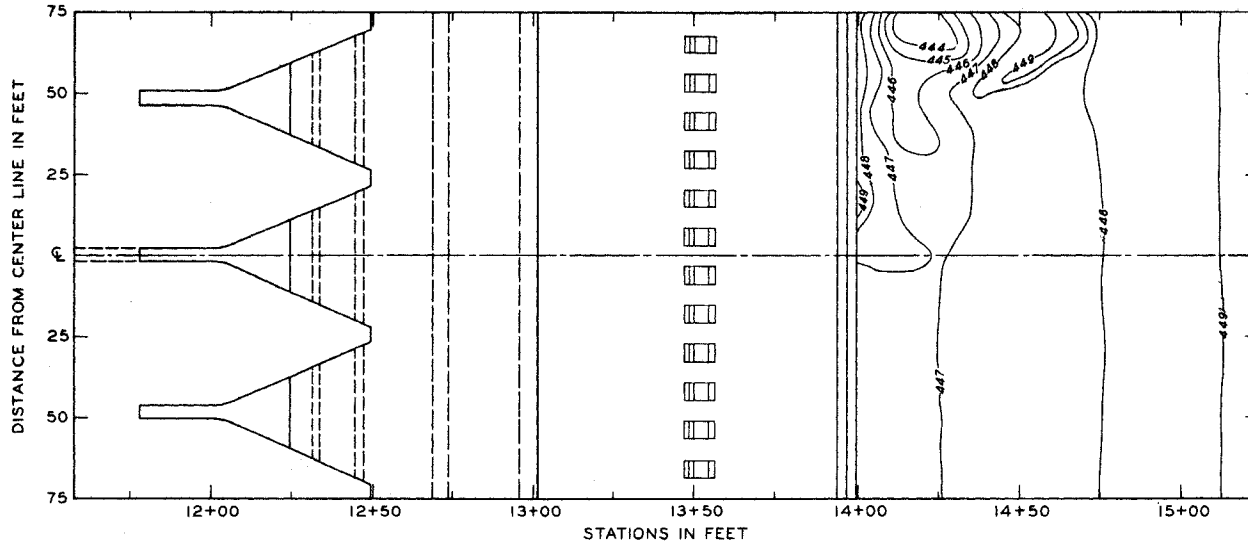
SCOUR PATTERN



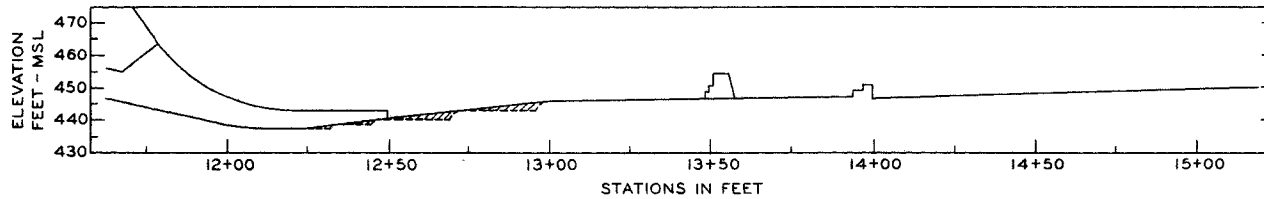
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN-MODIFICATION H  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 452.8  
 4-FT BAFFLES INSTALLED



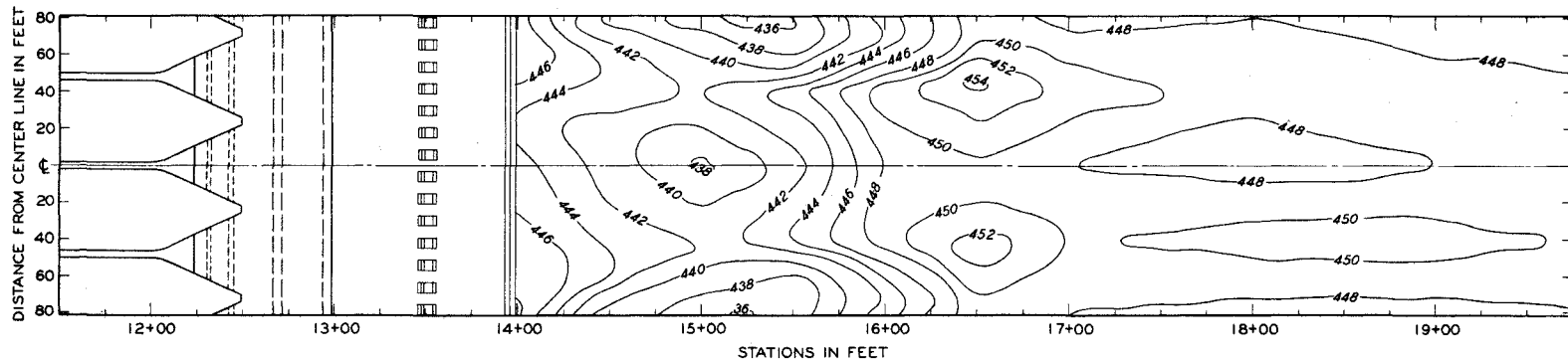
SCOUR PATTERN



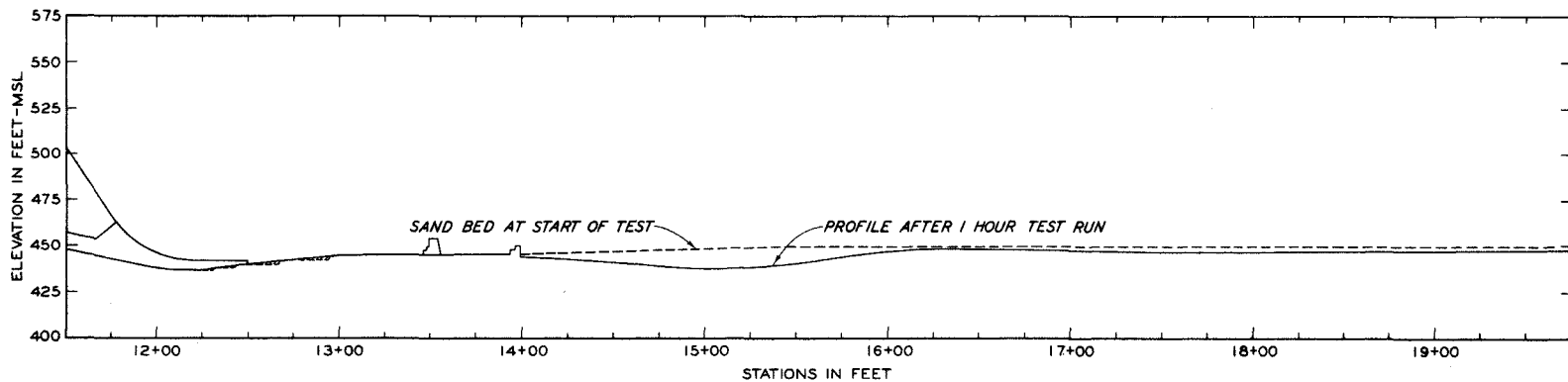
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STA 10+00.  
 CENTER CONDUIT WAS OPERATED FULLY OPEN FOR ALL TESTS.  
 EXIT CHANNEL WAS MOLDED IN PEA GRAVEL.

MODEL SCALE 1:12  
**SCOUR PATTERN AND PROFILE**  
 STILLING BASIN-MODIFICATION A  
 CONDUIT DISCHARGE 3500 CFS  
 TAILWATER ELEVATION 460.0



SCOUR PATTERN

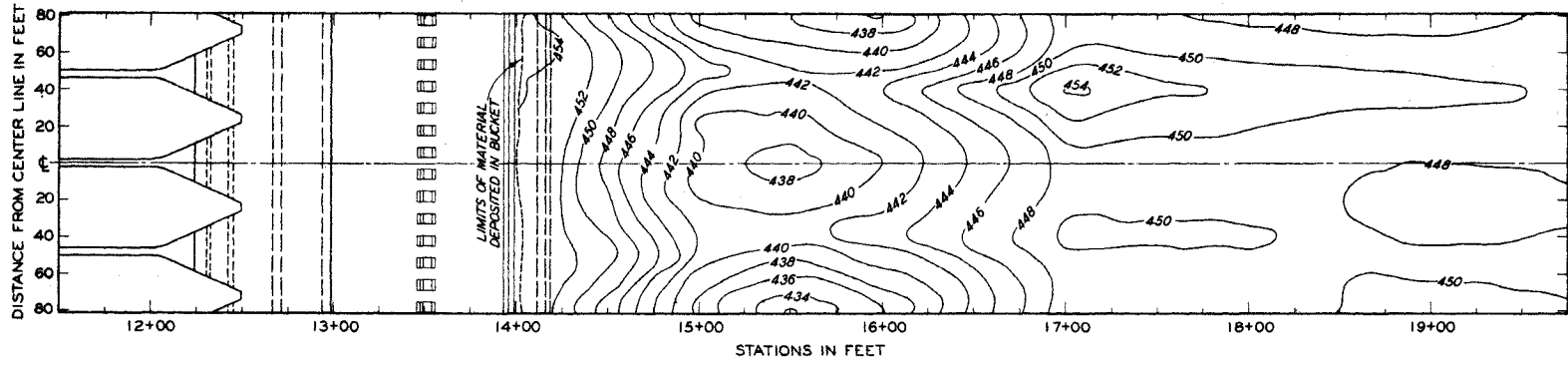


CENTER LINE PROFILE

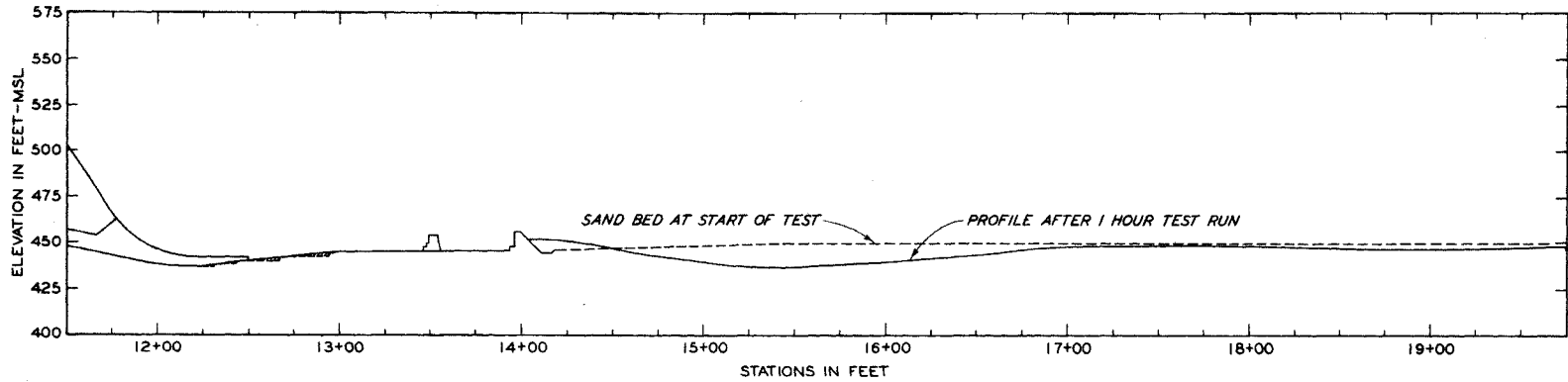
NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN - MODIFICATION A**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



SCOUR PATTERN

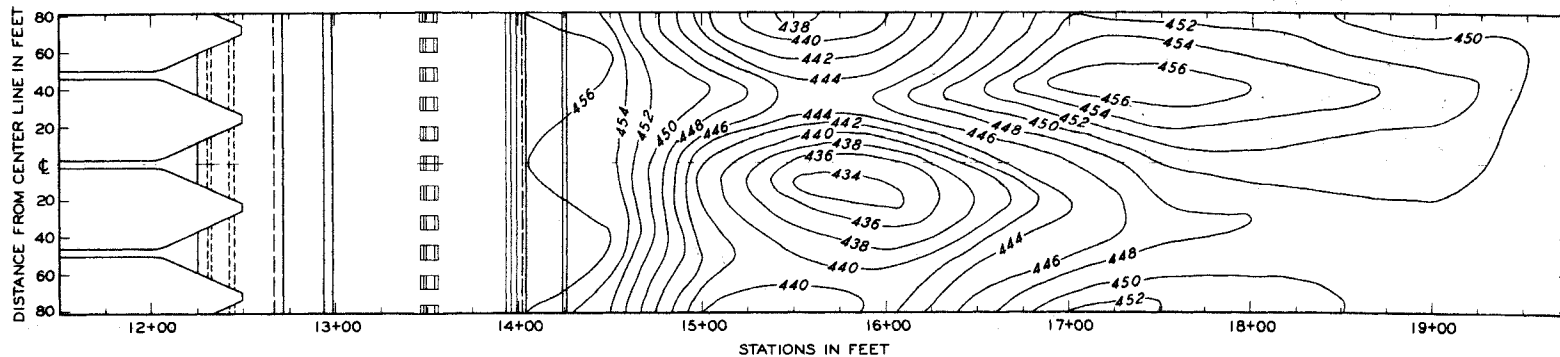


CENTER LINE PROFILE

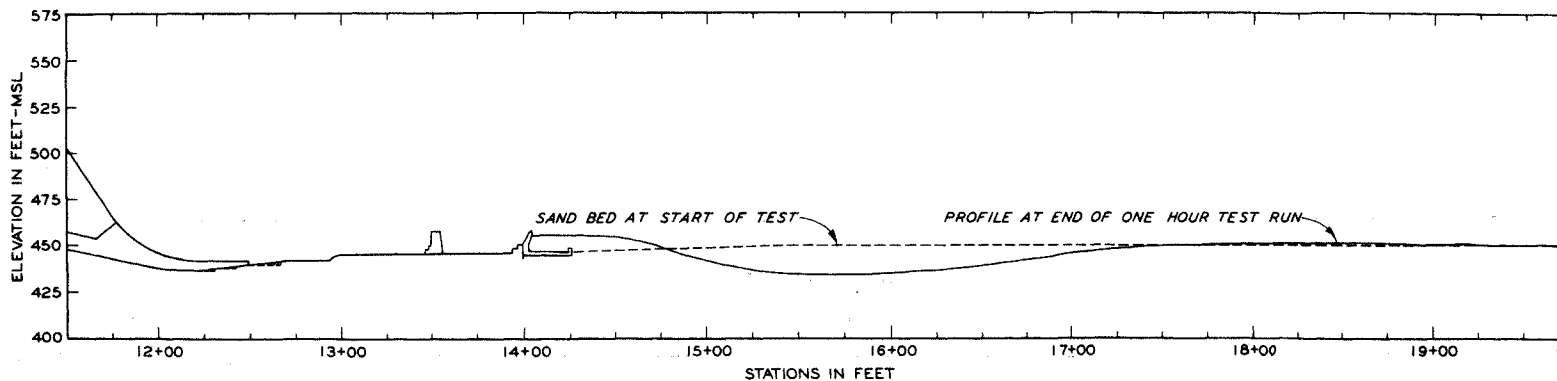
NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**  
**STILLING BASIN - MODIFICATION C**  
 SPILLWAY DISCHARGE 556,000 CFS  
 TAILWATER ELEVATION 514.4



SCOUR PATTERN



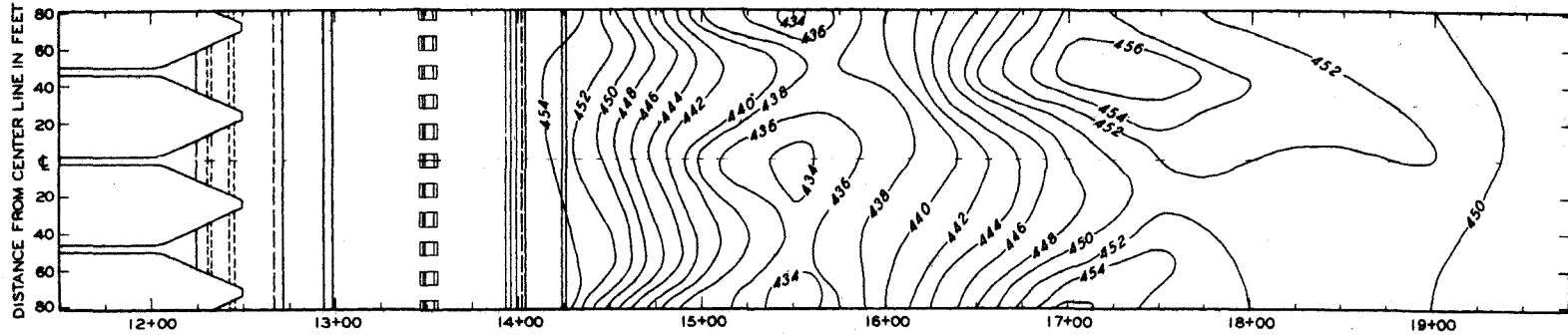
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

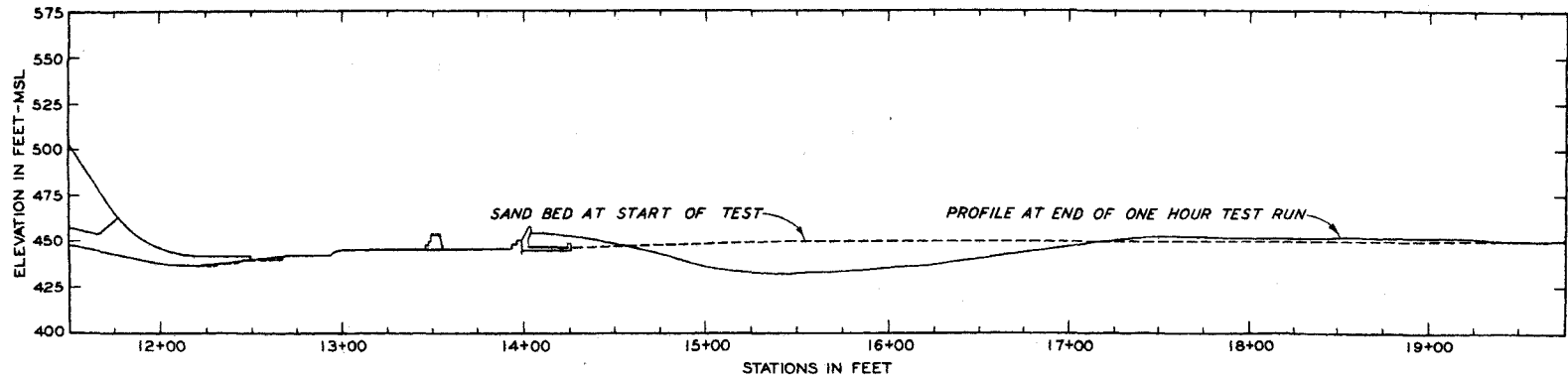
MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**

STILLING BASIN-MODIFICATION H  
12-FT BAFFLES INSTALLED  
SPILLWAY DISCHARGE 556,000 CFS  
TAILWATER ELEVATION 514.4



STATIONS IN FEET  
SCOUR PATTERN



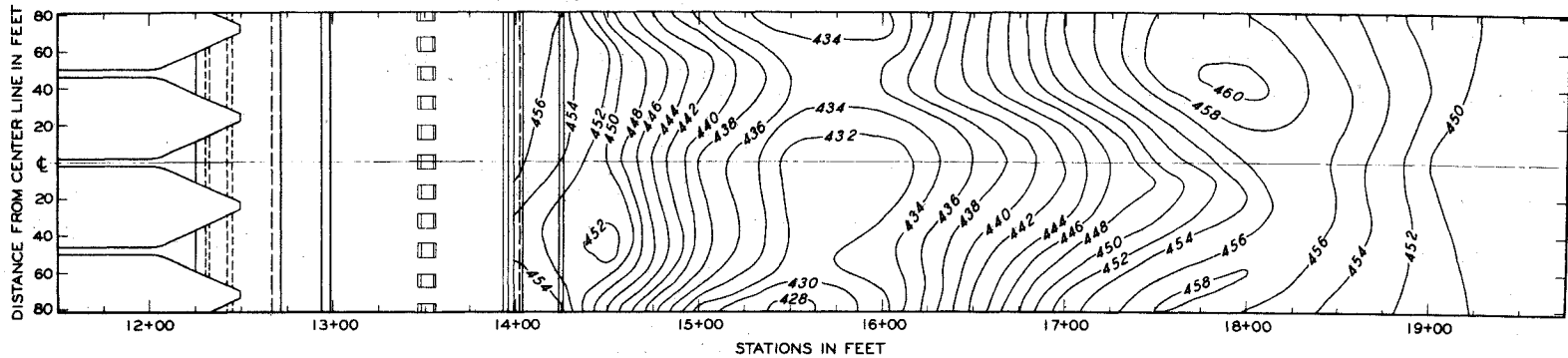
STATIONS IN FEET  
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

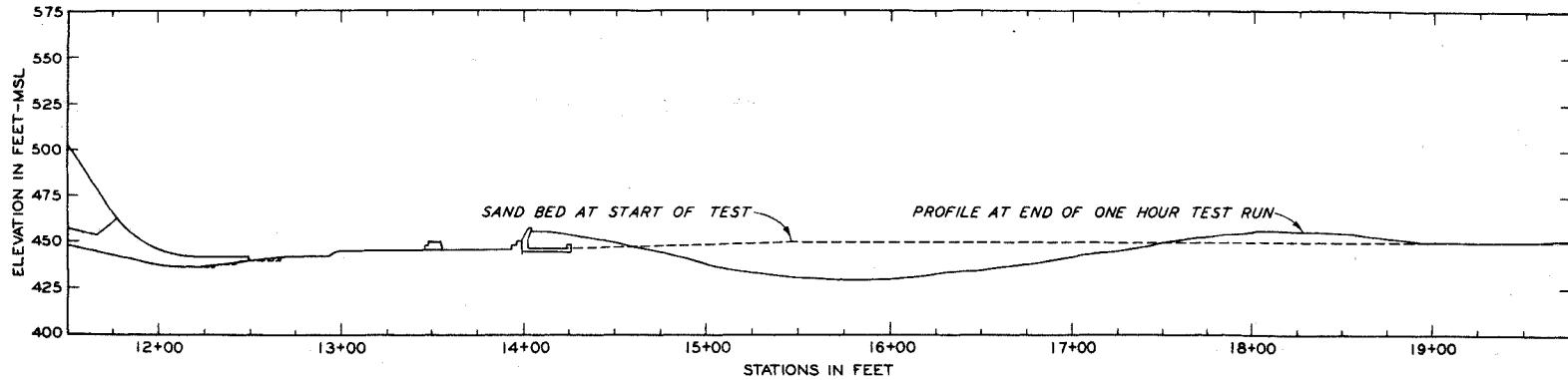
MODEL SCALE 1:50

**SCOUR PATTERN AND PROFILE**

STILLING BASIN-MODIFICATION H  
8-FT BAFFLES INSTALLED  
SPILLWAY DISCHARGE 556,000 CFS  
TAILWATER ELEVATION 514.4



SCOUR PATTERN



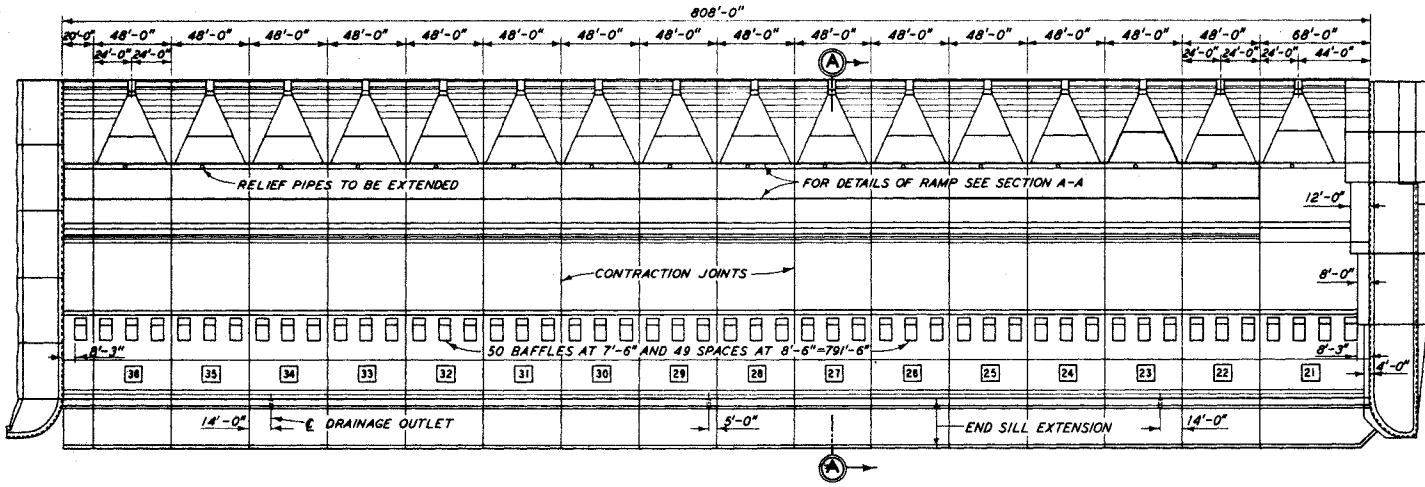
CENTER LINE PROFILE

NOTE: AXIS OF DAM IS STATION 10+00.  
EXIT CHANNEL WAS MOLDED IN SAND.

MODEL SCALE 1:50

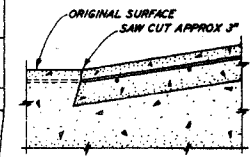
### SCOUR PATTERN AND PROFILE

STILLING BASIN-MODIFICATION H  
4 -FT Baffles INSTALLED  
SPILLWAY DISCHARGE 556,000 CFS  
TAILWATER ELEVATION 514.4



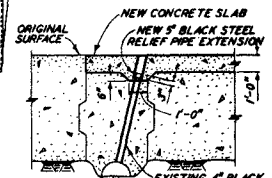
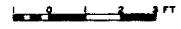
**PLAN**

**SCALE**



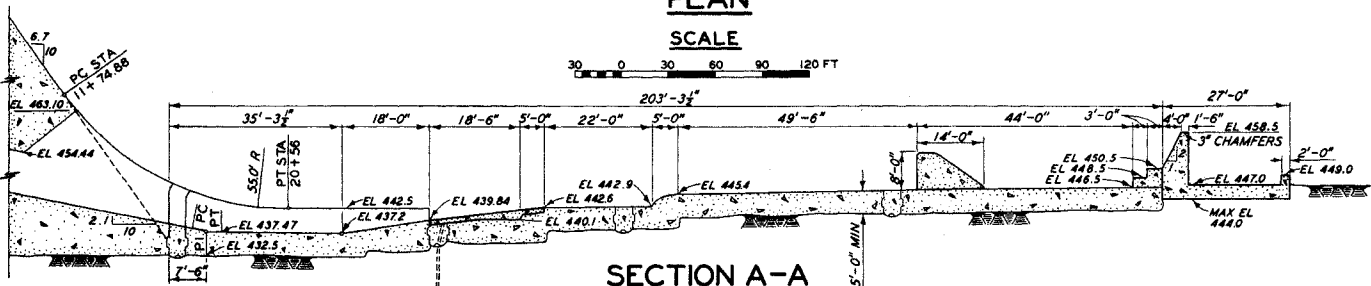
**DETAIL A**

**SCALE**



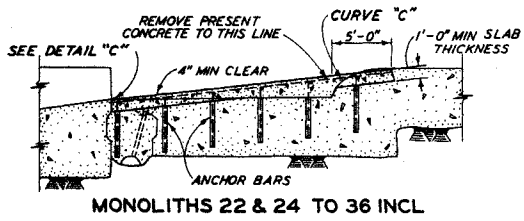
**DETAIL "C"**

**SCALE**

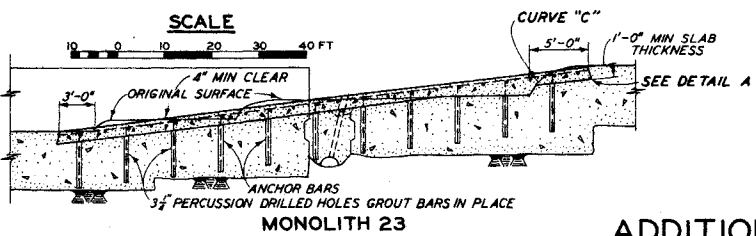


**SECTION A-A**

**SCALE**



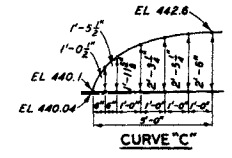
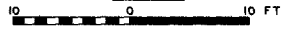
**MONOLITHS 22 & 24 TO 36 INCL**



**MONOLITH 23**

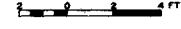
**LONGITUDINAL SECTIONS**

**SCALE**



**CURVE "C"**

**SCALE**



ADDITIONS TO STILLING BASIN  
PLAN, SECTIONS, AND DETAILS