UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES ON NORTON DAM SPILLWAY
MISSOURI RIVER BASIN PROJECT, KANSAS

Hydraulics Branch

Laboratory Report No. Hyd-493

DIVISION OF RESEARCH

OFFICE OF ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

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Hyd 493 NORTON

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Division of Research
Hydraulics Branch
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December 19, 1962

Laboratory Report No. Hyd-493
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Subject: Hydraulic model studies on Norton Dam Spillway--Missouri River Basin Project, Kansas

PURPOSE

The purpose of the model studies was to investigate the hydraulic features of the spillway structure including the size and shape of the spillway piers and approach walls, the placement of the gates, the flow distribution on the chute, and the stilling basin performance.

CONCLUSIONS

1. Flow conditions in the spillway entrance can be improved by modifying the approach wall as shown on Figures 6E and 9B.

2. Flow impingement on the counterweights of the radial gates can be eliminated by raising the gate trunnions, and redesigning the counterweights, as shown in Figure 10. Flow impingement on the face of the center gate can be eliminated by extending and streamlining the noses of the dividing piers, Figure 13.

3. The spillway will discharge the maximum design flow of 95,000 cubic feet per second at reservoir elevation 2340.7, Figure 17.

4. During unsymmetrical spillway operation, the flow overtopped the chute sidewalls at approximately Station 17+75. Overtopping was prevented by increasing the height of the sidewalls between Stations 17+54 and 18+42 and placing a coping strip at the tops of the walls, Figure 22.

5. For symmetrical operation, the flow was well distributed across the chute and confined within the sidewalls, Figure 19.

6. The exit for the spillway chute underdrain should be located at or upstream of Station 19+96 to prevent submergence at low spillway discharges, Figure 23.

7. The stilling basin performed satisfactorily at all discharges, with both symmetrical and unsymmetrical operation, Figure 24. Sweep-out tests indicated that the tailwater could be lowered 6 feet below normal before the toe of the hydraulic jump moved downstream from the chute blocks.

8. Pressure measurements on the chute and basin sidewalls indicated that a maximum sudden pressure fluctuation equivalent to about 61 feet of water should be considered in the structural design of the basin, Table 1.

9. The proposed 2-1/2- to 3-foot riprap protection in the channel was adequate except for a small area along the right bank, Figure 25. Three- to five-foot stones provided adequate protection in all areas.

INTRODUCTION

Norton Dam, a part of the Missouri River Basin Project, is an earth-fill structure located on Prairie Dog Creek about 2 miles southwest of Norton, Kansas, Figure 1. The dam embankment will be approximately 6,400 feet long at the crest and will rise about 100 feet above the river-bed.

The principal hydraulic features are the spillway and the outlet works.

The outlet works, located near the left abutment of the dam, Figure 2, consists of a trashracked bellmouth entrance, approximately 240 feet of 38-inch-diameter circular conduit, a 2-foot 9-inch square high-pressure emergency gate, a 2-foot 9-inch by 2-foot 9-inch high-pressure regulating gate, a 50-foot-long chute, and a 55-foot-long stilling basin equipped with chute blocks and a dentated end sill.

The spillway, Figures 2 and 3, located on the right side of the dam, consist of a 90-foot-wide overfall crest controlled by three 45-foot-radius, counterweighted radial gates separated by two 8-foot-thick concrete piers, a 396-foot-long sloping chute, and a 132-foot-long by 190-foot-wide stilling basin. The stilling basin floor is at elevation 2227.0, 69 feet below the spillway crest. It is equipped with chute blocks and a dentated end sill. The spillway is designed to discharge 95,000 cubic feet per second at the maximum reservoir elevation 2341.0.

The model studies described herein were concerned with the spillway only. Model studies for the outlet works are discussed in Hydraulics Branch Report No. Hyd-497.

THE MODEL

The model, built to a geometrical scale of 1:42, included the crest, gates with counterweights, piers, chute, stilling basin, approximately 500 feet of the downstream channel, and approximately 450 feet of the upstream channel and topography including a 52.68-foot-long concrete approach apron and curved inlet walls, Figures 4 and 5.

Water was supplied to the model through an 8-inch-diameter pipe connected directly to the permanent laboratory water-supply system. The flow was stilled by passing it through a 6-inch-thick rock baffle. Discharges in the model were measured by Venturi meters permanently installed in the laboratory.

The spillway crest and approach apron were constructed of concrete screeded to sheet metal templates. A major portion of the upstream channel and topography was formed in concrete; however, a 100-foot section of the upstream channel between the approach apron and concrete topography was formed in pea gravel to represent the riprapped portion of the channel. Radial gates and inlet walls were fabricated of galvanized sheet metal. The piers, chute, stilling basin, stilling basin chute blocks, and walls were made of wood treated to resist swelling. To facilitate scour testing, the downstream channel was formed in sand having a median diameter of approximately 0.8 millimeter with 90 percent between the Nos. 8 and 200 Tyler Standard screens.

Reservoir elevations were measured by means of a hook gage installed in a stilling well having an inlet located approximately 200 feet upstream from the crest in the center of the approach channel. Tailwater level was controlled by an adjustable tailgate at the downstream end of the model. Tailwater elevations were measured by two staff gages; one gage was located 250 feet downstream from the end of the stilling basin on the left side of the tail box; and the other was located 500 feet downstream from the end of the stilling basin on the right side of the tail box.

Pressure measurements were made on the crest, chute walls, and stilling basin wall by means of piezometers connected to open tube manometers. Piezometers located in critical pressure areas were connected to electronic pressure cells and continuous instantaneous dynamic pressure measurements were obtained and recorded on a direct writing oscillograph.

THE INVESTIGATION

Approach Walls

Approach walls were placed on each side of the entrance to the crest section to direct the flow from the reservoir into the spillway, Figure 5.

Preliminary walls. --The preliminary approach walls curved away from the centerline in a 45° segment of a 50-foot-radius circle and then extended tangentially for an additional 48 feet, Figure 6A. The tops of the walls sloped downward from elevation 2347.0 at Station 15+95.25 and were parallel to and 3.5 feet above the face of the dam.

The appearance of the flow entering the spillway was very good for discharges equal to or less than 50.000 cubic feet per second. There were no eddy currents or excessive drawdown in the flow along the walls and the water passed over the spillway crest very smoothly and evenly. At the maximum discharge of 95,000 cubic feet per second the flow over the tops of the sloping walls interferred with the flow passing along the walls and created turbulence and eddy currents that carried down into the crest section, Figure 7. The resulting uneven water surface impinged on the faces of the gates and also on the gate counterweights.

The spillway capacity at maximum reservoir elevation 2341.0 with the preliminary walls was 95,000 cubic feet per second, reflecting a coefficient of discharge of 3.49.

First revision (Recommended). --The first revision to the approach walls consisted of extending the tops of the walls horizontally at elevation 2343.0 for about 50 feet around the curved section, then sloping them downward on a 2:1 slope until they intersected the ground surface, Figure 6B. In plan the walls were the same as the preliminary except that the wall length upstream from the curve was 2 feet shorter.

The appearance of the flow at the maximum discharge was only slightly improved with this modification, Figure 8A. The turbulence along the right wall was reduced to an almost negligible amount; however, there was still extensive turbulence along the left wall. The impingement on the faces of the two outside gates was improved but heavy impingement still occurred on the face of the center gate and on the counterweights of all three gates.

The coefficient of discharge with the modified approach walls was 3.50, producing a discharge of 95,200 second-feet at the maximum reservoir elevation.

Second revision.--For the second revision the top of the left wall was extended horizontally at elevation 2343.0 for its full length, Figure 6C; in all other respects it was the same as the previous wall. For convenience in the model studies this revision and subsequent revisions were made only to the left wall.

The flow along the wall was improved with this modification, Figure 8B. There was still some turbulence and eddies in the flow but the impingement on the face of the left gate was practically eliminated. However, the flow impingement on the face of the center gate and on the gate counterweights was not improved.

The coefficient of discharge with this arrangement of approach walls was 3.51, giving a discharge of 95,400 cubic feet per second at the maximum reservoir elevation.

Third revision.--A 45° segment of a 50-foot-radius curve was added to the upstream end of the wall for the third revised wall, Figure 6D. This modification did not appreciably improve the flow conditions observed with the previous wall, Figure 9A. However, the coefficient of discharge increased to 3.54 with this arrangement, allowing a discharge of 96,100 cubic feet per second at the maximum reservoir elevation.

Fourth revision.--In the fourth revision the left wall curved away from the spillway entrance in a 50-foot-radius quarter circle with the top of the wall at elevation 2343.0. Upstream from the curve the wall was parallel to the axis of the dam and the top of the wall sloped downward on a 2:1 slope, Figure 6E.

The flow along the fourth modified left wall was comparatively smooth; however, flow still impinged on the faces of the left and center gates and on the left gate counterweight, Figure 9B.

The coefficient of discharge was 3.52, giving a discharge of 95,500 cubic feet per second at the maximum reservoir elevation.

Results of approach wall studies.--The tests indicated that changes in the approach walls would not prevent flow impingement on the counterweights or the faces of the gates. The appearance of the flow did not vary appreciably for any of the walls, although the flow was somewhat smoother with the third and fourth revised walls. The first revision was chosen for the prototype approach walls since this design would be less expensive to construct than either the third or fourth revisions.

Spillway Crest Section

The spillway crest section is that portion of the structure between Stations 15+79.72 and 16+66.00, and includes the ogee crest, piers, and counterweighted radial gates, Figure 3.

Radial gates, preliminary design. --Flow through the crest section was controlled by three 45-foot-radius radial gates. Each gate was 30 feet wide by 36.35 feet high, Figure 10A. These gates were unusual in that the gate arms extended about 41 feet 6 inches downstream from the trunnions and supported a large counterweight.

In the preliminary design the gate arms downstream from the trunnions were of truss girder design and used concrete blocks for the counterweights. The gate trunnions were located at Station 16+38.79 and elevation 2327.50.

The counterweights were designed so that they were about 1 foot above the theoretical water surface for the maximum discharge. However, due to the rough water surface caused by the approach conditions, the flow impinged on the counterweights and on the faces of the gates, Figure 7.

Modifications to the spillway approach walls had not eliminated the impingement so it was decided to raise the gate trunnions and modify the counterweights and counterweight arms. To aid in determining the extent of these changes, water surface profiles and cross sections were obtained so that minimum elevations for the bottom of the gate faces and counterweights could be set, Figure 11.

Radial gates, recommended design. --Based on the data obtained from the water surface profiles, the trunnions were moved upstream to Station 16+38.04 and were raised to elevation 2328.0, Figure 10B. To further elevate the counterweights, the support arms downstream from the trunnions were redesigned by using a box girder having a shallower section and pig iron was used for the counterweight providing the same weight in a smaller volume.

With these modifications the counterweights were about 1 foot above the water surface at maximum discharge, Figure 12A. However, there was still some flow impingement on the bottom of the radial faces of the gates at maximum discharge, Figure 12B.

Spillway piers. --In the preliminary design two 8-foot-wide concrete piers, 89 feet long, separated the three 30-foot bays in the crest section, Figure 13.

The upstream ends of the preliminary piers were streamlined except for a blunt nose that could be used for stoplog guides. It was thought that by extending the piers upstream and further streamlining the noses, the flow impingement on the faces of the gates might be reduced or eliminated.

Accordingly, the piers were extended approximately 4-1/2 feet upstream and the noses were streamlined using short radius circular segments, Figure 13. This alteration lowered and smoothed out the water surface so that the flow did not impinge on the gates, Figure 14. The longer streamlined pier nose was recommended for prototype use.

Floatwell intake.--It was proposed to locate the intake for the floatwell of the automatic gate controls approximately 200 feet upstream from the spillway crest, Figure 3. The water surface profile at the maximum discharge was obtained for a distance of 120 feet upstream from the crest to assure that the proposed intake was beyond the influence of the drop-down curve. The profiles, Figure 15, indicated that the intake location was satisfactory.

Pressures on the spillway crest.--A row of seven piezometers was installed on the centerline of the left spillway bay for obtaining pressure measurements along the crest profile. The measurements indicated that at maximum discharge with the gates fully open, pressures between 12.6 and 27.7 feet of water above atmospheric would occur, Figure 16. With the gate 2 feet open and the reservoir surface at the top of the gate, the pressures varied from atmospheric to 41.6 feet of water above atmospheric. With the gate 4 feet open and the reservoir surface at the top of the gate, the pressures varied from atmospheric to 42.0 feet of water above atmospheric. Thus, no subatmospheric pressures on the crest are expected to occur at normal gate openings or during free flow.

Spillway calibration.--The discharge capacities of the structure for free flow and with the flow controlled by the radial gates were obtained during the studies. Flow measurements were made with the three gates equally opened from 2- to 36-foot openings in 2-foot increments. Three calibration points were obtained at each gate opening with a rising reservoir; two points were obtained with a falling reservoir, except for the two largest gate openings where three points and one point, respectively, were observed. For the free-flow discharge capacity tests, calibration points were obtained at discharges from 5,000 to 95,000 cubic feet per second in approximately 10,000-cubic-feet-per-second increments.

Head-discharge curves for gate-controlled and free-flow and discharge coefficients for free flow were computed and plotted Figure 17. These curves indicate that the maximum discharge of 95,000 cubic feet per second will occur at reservoir elevation 2340.7 which is slightly below the design value of 2341.0.

Spillway Chute

The spillway chute is 106 feet wide at its upstream end, Station 16+66.0, and diverges to a width of 190 feet at the entrance to the stilling basin, Station 20+62.0. The floor of the chute has a downward slope of 0.01 between Stations 16+66.0 and 19+13.76, a vertical curve between Stations 19+13.76 and 19+93.76, and a 2:1 slope between Stations 19+96.76 and 20+62.0, Figure 3.

Symmetrical operation. --With the reservoir at maximum elevation and the gates approximately 20 feet open, large fins of water formed just downstream from each pier, Figure 18A. These fins were caused by the confluence of the flows from adjacent bays. Since the fins were well out near the center of the chute, they were considered unobjectionable and no corrective measures were taken to eliminate them. Smaller fins also formed at other discharges and gate openings, Figure 18B.

The water spread evenly across the chute for all flows; the flow was well confined within the sidewalls; and the overall operation was completely satisfactory. Maximum and minimum water surface profiles along each wall of the chute for maximum discharge are shown in Figure 19.

With the center gate closed and the two outside gates full open, the flow was equally distributed across the chute as it entered the stilling basin. The flow from the two bays smoothly merged about 100 feet downstream from the crest with only a very small wave forming at the confluence.

When only the center gate was in operation the flow distribution across the chute was adequate; there was a slight flow concentration in the center of the chute as it entered the stilling basin but this caused no adverse conditions.

Unsymmetrical operation. --When either of the outside gates was opened approximately 10 percent with the center gate fully open, a fin of water formed at the downstream end of the piers, crossed to the sidewall, and overtopped the wall at about Station 17+75, Figure 20. The water surface profile for this condition is shown on Figure 21. Overtopping was prevented by increasing the wall height and by adding an 18-inch-wide coping strip on the top of the inside face of the wall, Figures 20 and 22. When either of the outside gates was closed with the center gate fully open, this action did not occur.

Operation with one outside or two adjacent gates full open was also satisfactory. The flow did not overtop the chute sidewalls, however, there was a moderate flow concentration in the basin on the same side as the operating gates.

Gallery drain. --The spillway chute underdrains empty into a central gallery beneath the chute. Drainage water leaves this gallery througl a 24-inch-diameter concrete pipe and empties onto the spillway chute Initially the drain exit was located at Station 20+16.00, Figure 23. A low flows of approximately 2,000 to 5,000 cubic feet per second, the hydraulic jump submerged this drain exit. Water surface profiles taken for discharges of 2,000, 5,000, 7,500, and 10,000 cubic feet per second, Figure 23, indicated that if the drain exit were relocated at about Station 19+96 it would not be covered by the hydraulic jump. It was recommended that the drain be located at or upstream of this station to prevent excessive back pressure on the drain.

Stilling Basin

The spillway stilling basin is a rectangular, hydraulic jump basin 132 fe long by 190 feet wide, Figure 3. The floor of the basin is at elevation 2227.0 and the tops of the sidewalls are at elevation 2281.0. Chute blocks are placed at the upstream end of the basin.

Performance. --The flow in the stilling basin was observed at several discharges from 2,000 cubic feet per second up to and including 95,000 cubic feet per second, and the operation was excellent for all flows. The appearance of the flow for discharges of 25,000, 45,000, and 95,000 cubic feet per second is shown on Figure 24. For all discharges, the hydraulic jump was well distributed across the basin anc was contained adequately within the sidewalls. At the maximum discharge there was an occasional splash over the wall at the extreme downstream end of the basin. Since the end of the basin extends out into the tailwater pool, these splashes cause no damage to the channel banks and no corrective measures were taken.

Water surface profiles along the sidewalls were obtained for the maximum discharge, Figure 19. The sidewalls were not overtopped at any time except by the occasional splashes.

With one or two gates operating, the flow was evenly distributed acros the chute by the time it entered the upstream end of the stilling basin and the basin performance was satisfactory for any unsymmetrical operation.

Sweepout tests. --To determine the minimum tailwater for proper operation of the hydraulic jump, the model was operated at the maximum discharge of 95,000 cubic feet per second and the tailwater gradually lowered below the normal tailwater of elevation 2276.5. At tailwater elevation 2272.5, the upstream ends of the chute blocks were uncovered intermittently during surges of the hydraulic jump. At tailwater elevation 2270.8, the toe of the jump moved downstream near the end of the sloping chute and the chute blocks occasionally were completely uncovered. The jump moved out into the basin floor when the tailwater was lowered to elevation 2270.0. Based on these tests, the hydraulic jump for maximum discharge will not sweep from the basin until the tailwater depth is at least 6 feet below the normal tailwater.

A structural design analysis of the stilling basin had indicated that additional thickness in the floor slab at the base of the walls would be necessary. It was proposed to accomplish this by adding a triangular fillet along each wall for the full length of the stilling basin, Figure 3. The fillets were 3 feet thick at the walls and tapered to the floor 15 feet out from the wall.

The fillets were represented in the model stilling basin by wooden wedges. The model was operated at various discharges and no noticeable difference in the basin performance could be detected.

Pressure investigations.--Fifteen piezometers were installed in the left wall and floor of the stilling basin, Figure 19, to measure the dynamic and static pressure loads in the stilling basin.

Average pressure measurements were obtained for the maximum discharge with single-leg water manometers connected to the piezometers; in addition, instantaneous dynamic pressure measurements were recorded by means of pressure cells and recording oscillograph. The pressure values obtained by both methods are shown in Table 1.

The pressures obtained by the water manometers indicated that no subatmospheric pressures nor excessively high impact pressures were present. The instantaneous dynamic pressure tests showed that intermittent pressures as low as 12.6 feet of water below atmospheric at Piezometer No. 4 and as high as 62.2 feet of water above atmospheric at Piezometer No. 11 should be considered in the structural design of the basin. In addition, the tests revealed that instantaneous pressure fluctuations as great as 61 feet of water (at Piezometer No. 4) also should be considered. The average of the maximum and minimum dynamic pressures compared very favorably with the pressures observed on the water manometers.

Erosion studies.--To determine the effectiveness of the stilling basin against erosion in a movable bed, the downstream channel initially was formed in sand, Figure 25A. After 1-hour model operation at maximum discharge, the scour at the end of the basin was very moderate consisting mainly of a small area about 2 feet deep near the right wall. However, some erosion occurred along the right bank about 50 feet downstream from the end of the basin, Figure 25A. This was caused by a eddying action in the flow as it returned upstream along the right bank.

Riprap, 2-1/2 to 3 feet in diameter, represented in the model by 3/8- to 3/4-inch stones, was then placed in the channel just downstream of the stilling basin as shown by Figure 25B. At the end of 1 hour's operation at maximum discharge, no movement of the riprap at the end of the stilling basin was noted, but a slight movement occurred along the right bank, Figure 25B.

Larger riprap, 3-1/2 to 5 feet in diameter, represented in the model by 1- to 1-1/2-inch stones, was placed on the right bank and the model operated at maximum discharge for 1 hour. These larger stones prevented any movement of the riprap. It was felt, however, that the riprap movement along the right bank was insufficient to necessitate the larger riprap; therefore, the smaller riprap was specified for the prototype.

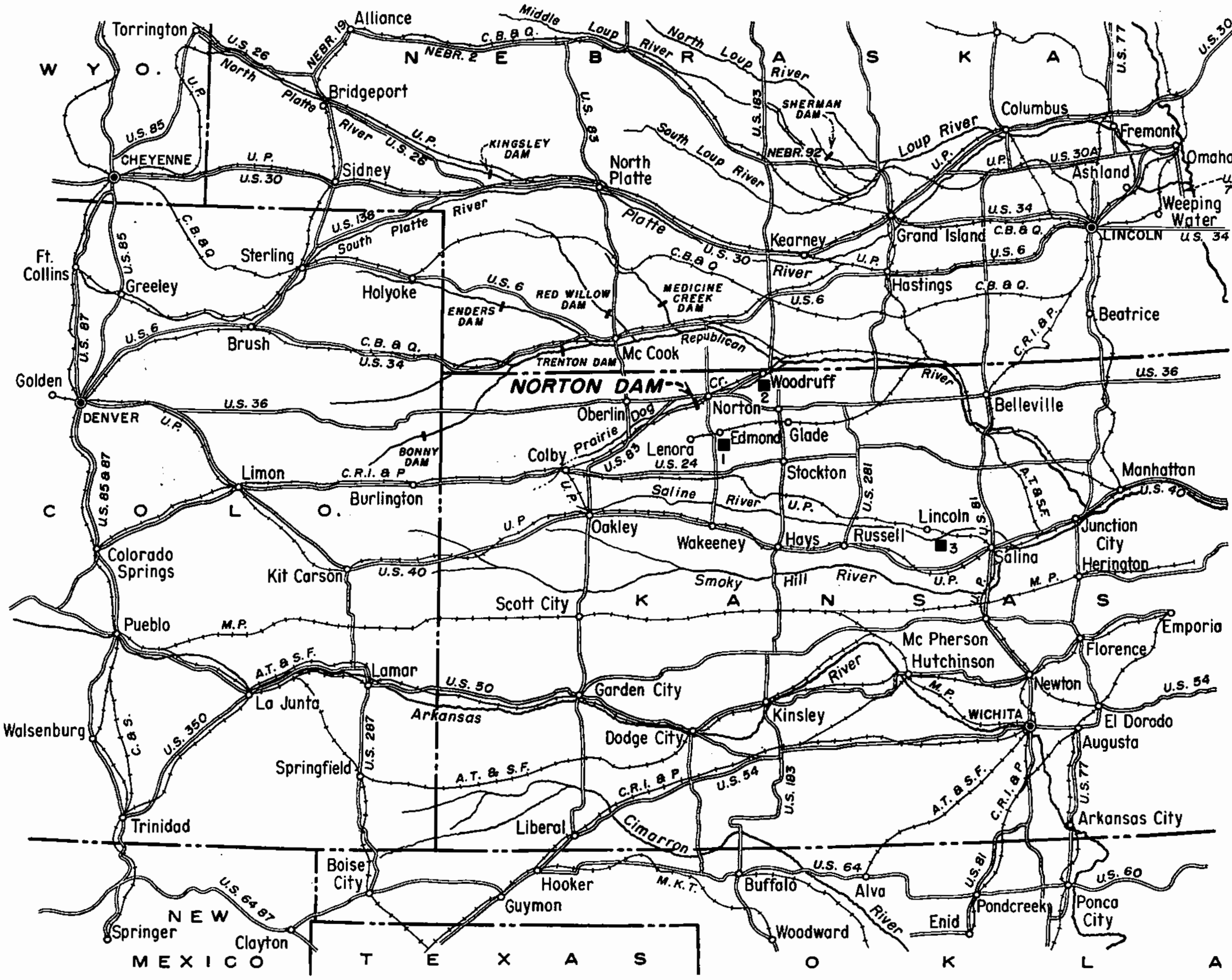
Table 1

PRESSURES IN CHUTE AND STILLING BASIN SIDEWALLS

Piez. No.	Station	Elevation	Dynamic pressures			Water manometer pressures
			Min.	Max.	Avg.	
1	20+18	2249.0	0	11.8	5.9	5.5
2	20+18	2253.3	10.1	19.3	14.7	12.6
3	20+62	2230.8	26.9	55.4	41.1	30.2
4	20+62	2240.8	-12.6	48.3	17.9	19.3
5	21+06	2230.6	10.5	35.7	23.1	24.4
6	21+06	2240.6	-1.1	38.9	18.9	19.7
7	21+06	2250.6	-2.1	21.0	9.5	10.9
8	21+50	2230.7	28.6	48.7	38.6	38.2
9	21+50	2240.7	10.9	41.2	26.0	28.1
10	21+50	2250.7	8.4	26.0	17.3	17.2
11	21+65	2230.6	30.2	62.2	46.2	47.5
12	21+65	2245.0	18.5	37.0	27.7	23.1
13	21+65	2260.0	2.1	15.1	8.6	10.1
14	21+80	2245.0	16.8	31.9	24.4	20.6
15	21+80	2260.0	5.0	16.8	10.9	10.1

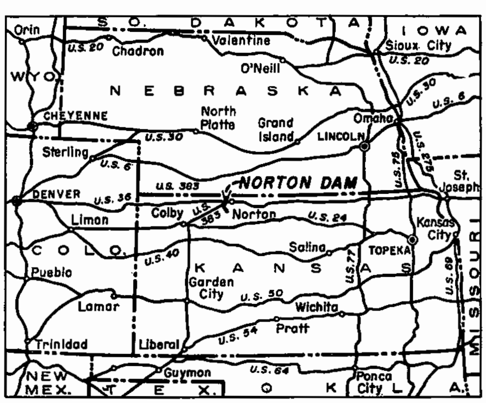
Notes:

1. See Figure 19 for piezometer locations.
2. All pressures are in feet of water relative to atmospheric.
3. Pressures taken for discharge of 95,000 cubic feet per second with tailwater elevation 2276.5.
4. Waves and surges caused water surface outside of wall to vary between elevations 2275.0 and 2278.0 at Station 21+85.0 during these tests.



■ ROCK DEPOSITS

1. Vicinity of Edmond, Kansas.
2. Vicinity of Woodruff, Kansas.
3. Vicinity of Lincoln, Kansas.



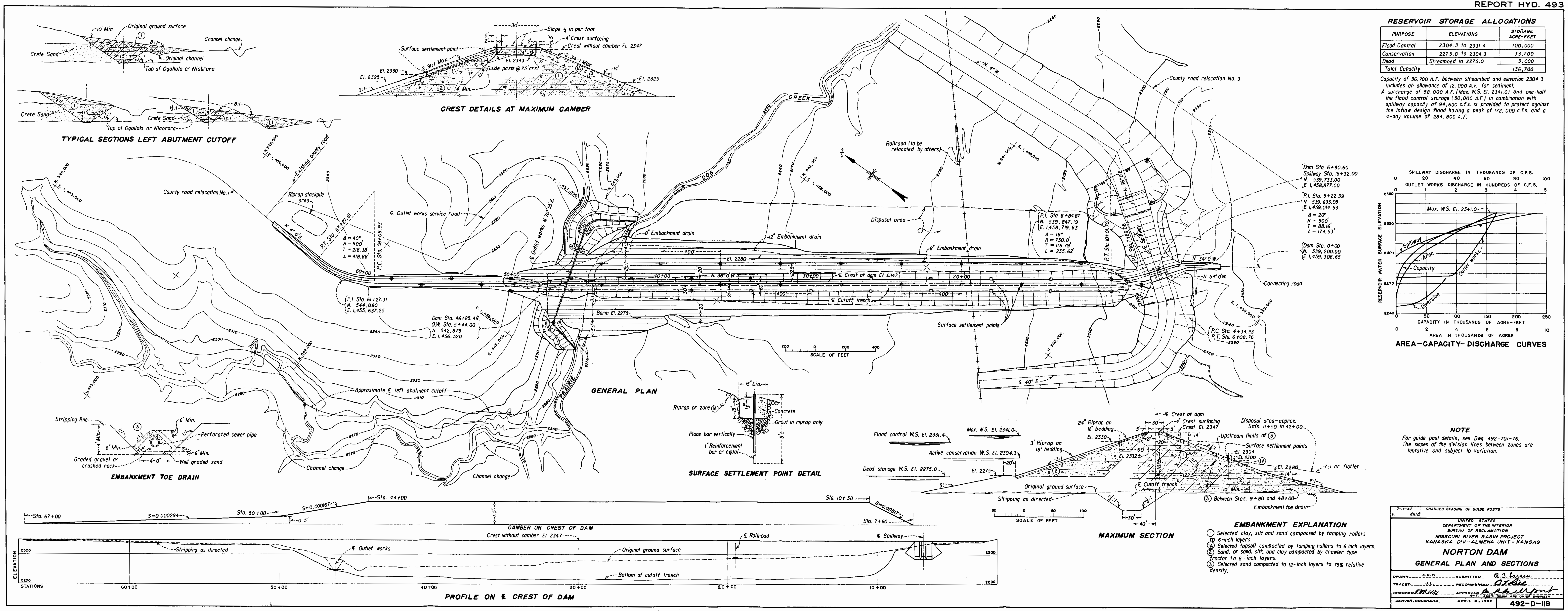
KEY MAP

SCALE OF MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
KANASKA DIVISION–ALMENA UNIT–KANSAS

NORTON DAM
LOCATION MAP

DRAWN W.W.S. SUBMITTED R. J. Larsen
TRACED W.W.S. RECOMMENDED O. F. Rise
CHECKED CWB/WL APPROVED [signature]
ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO, APRIL 6, 1962 | 492-D-115



RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATIONS	STORAGE ACRE-FEET
Flood Control	2304.3 to 2331.4	100,000
Conservation	2275.0 to 2304.3	33,700
Dead	Streambed to 2275.0	3,000
Total Capacity		136,700

Capacity of 36,700 A.F. between streambed and elevation 2304.3 includes an allowance of 12,000 A.F. for sediment.
A surcharge of 58,000 A.F. (Max. W.S. El. 2341.0) and one-half the flood control storage (50,000 A.F.) in combination with spillway capacity of 94,600 c.f.s. is provided to protect against the inflow design flood having a peak of 172,000 c.f.s. and a 4-day volume of 284,800 A.F.

FIGURE 3
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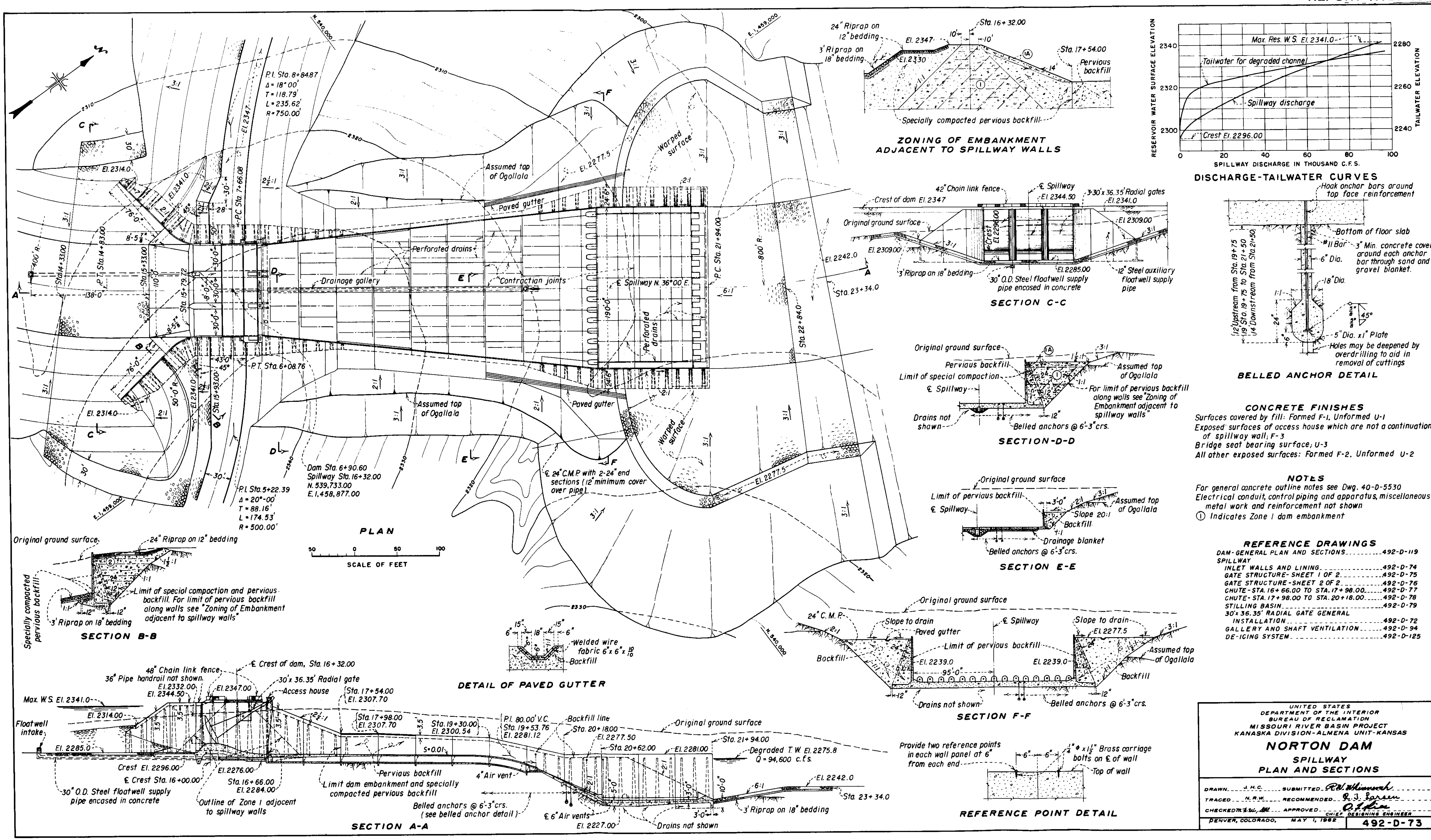
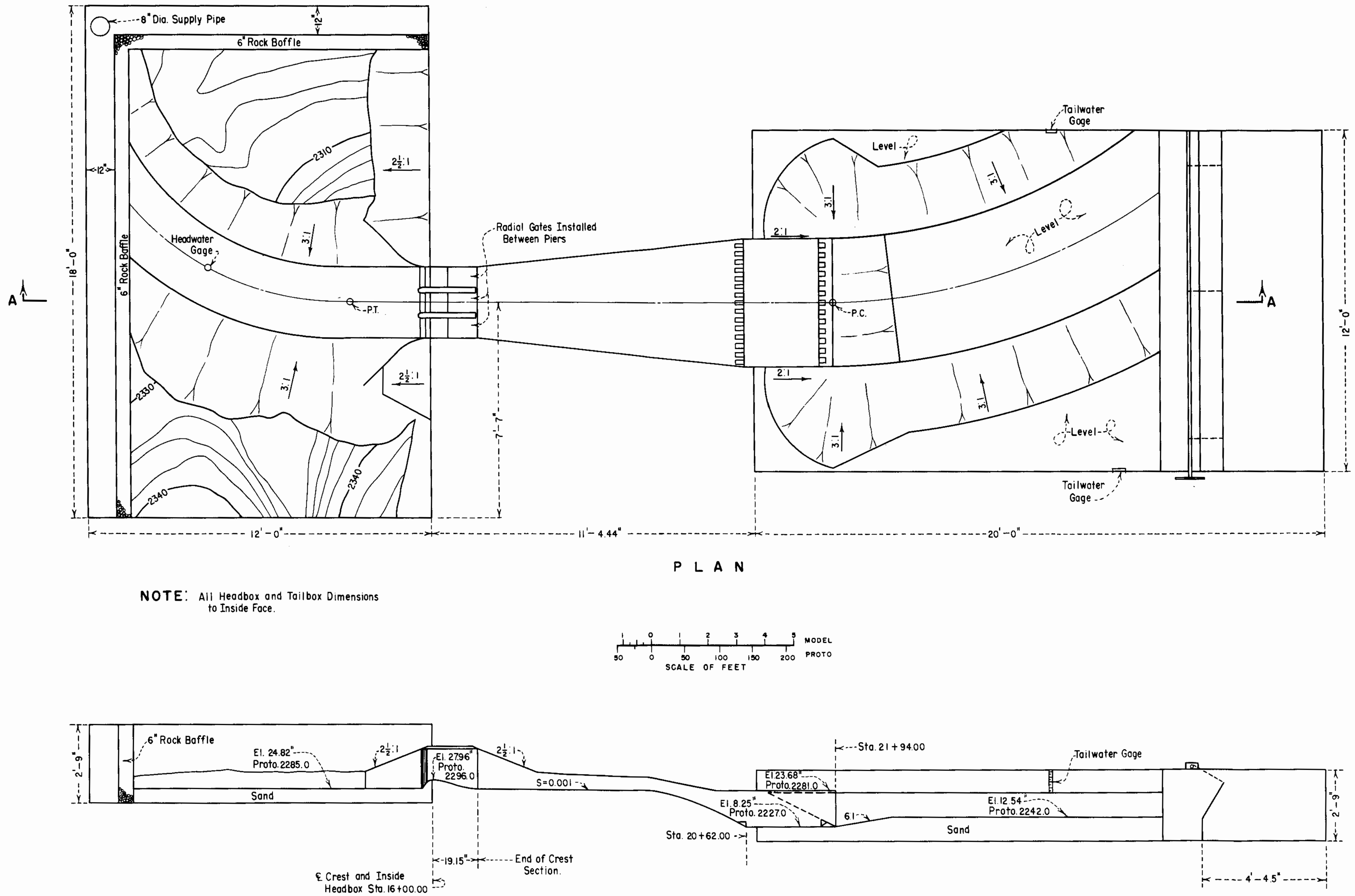
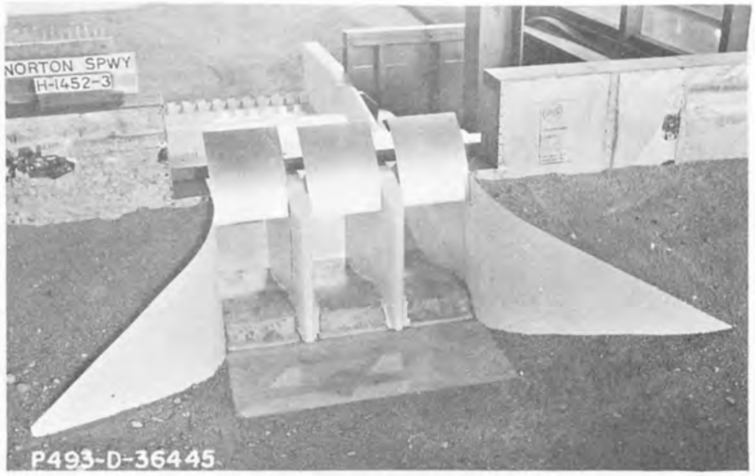




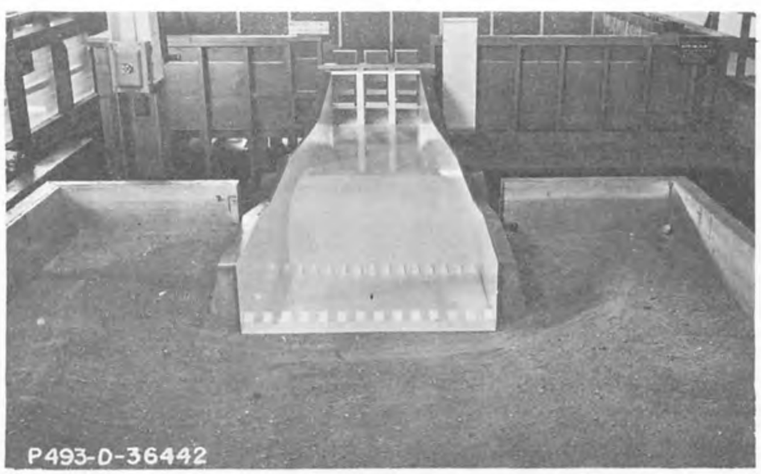
NORTON DAM SPILLWAY

1:42 SCALE MODEL

MODEL ARRANGEMENT



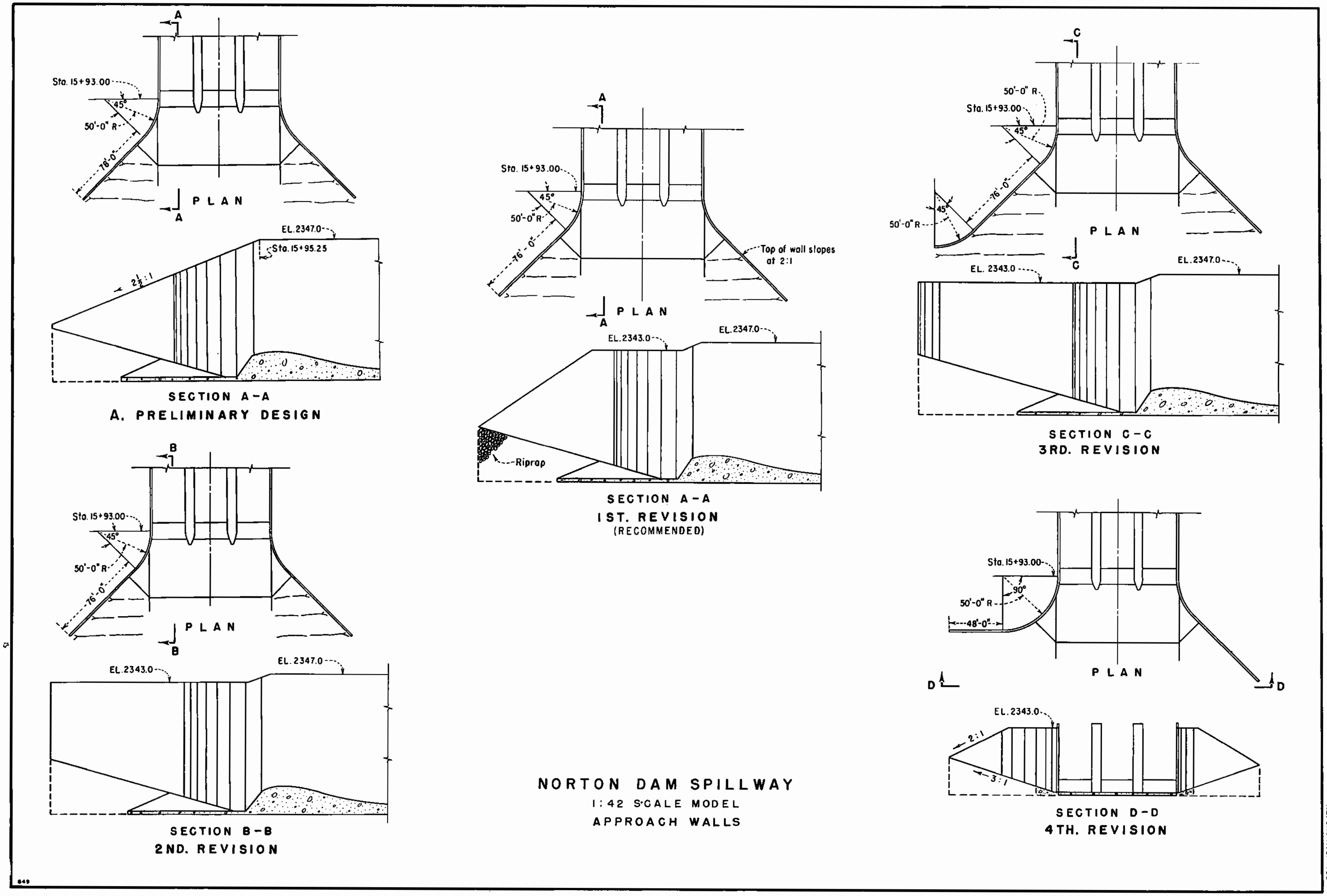
Preliminary spillway approach.



Spillway chute and stilling basin.

NORTON DAM SPILLWAY
1:42 Scale Model

The model



NORTON DAM SPILLWAY
1:42 SCALE MODEL
APPROACH WALLS

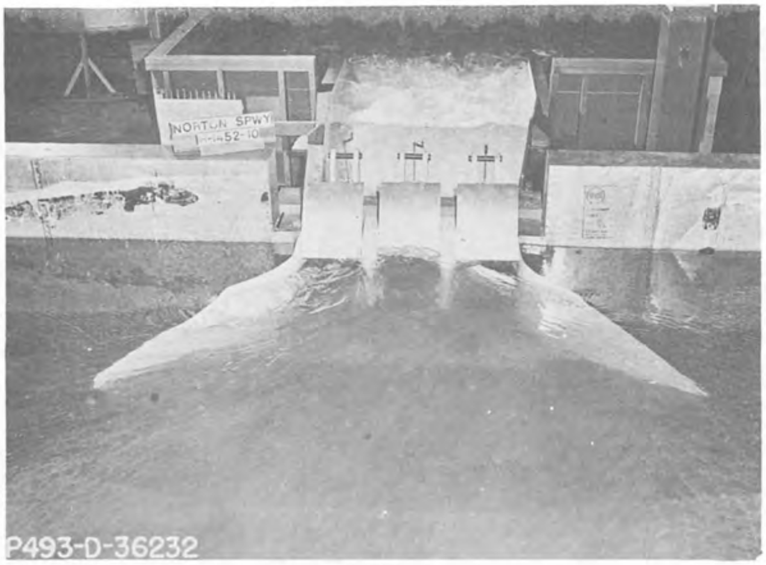
FIGURE 6
REPORT HYD. 493

Flow at spillway approach.

Flow impinging on counterweights.

NORTON DAM SPILLWAY
1:42 Scale Model

Preliminary Approach and Gate Section
Discharge = 95,000 cfs



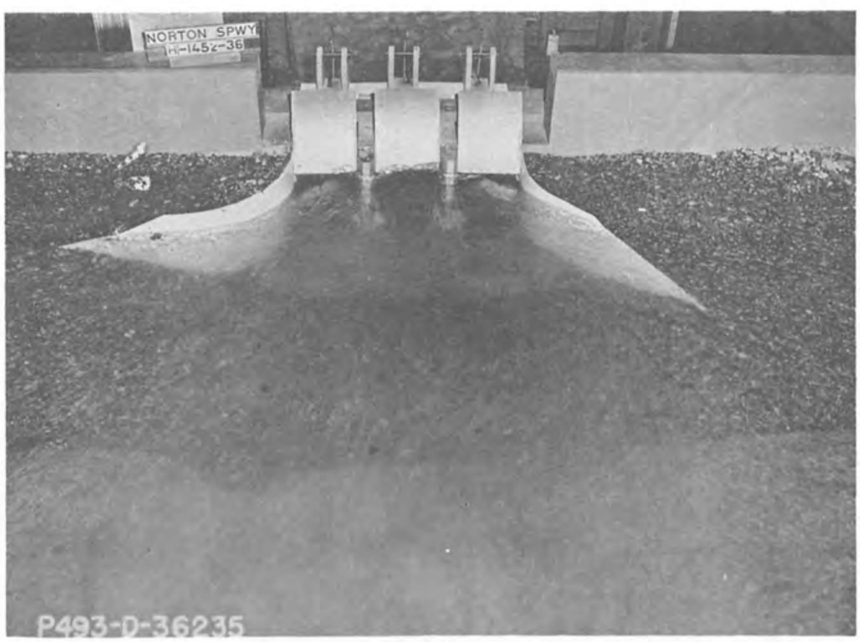
A. First revision to approach walls (Recommended).

B. Second revision to approach walls.

NORTON DAM SPILLWAY
1:42 Scale Model

Flow at Revised Approach Walls
Discharge = 95,000 cfs

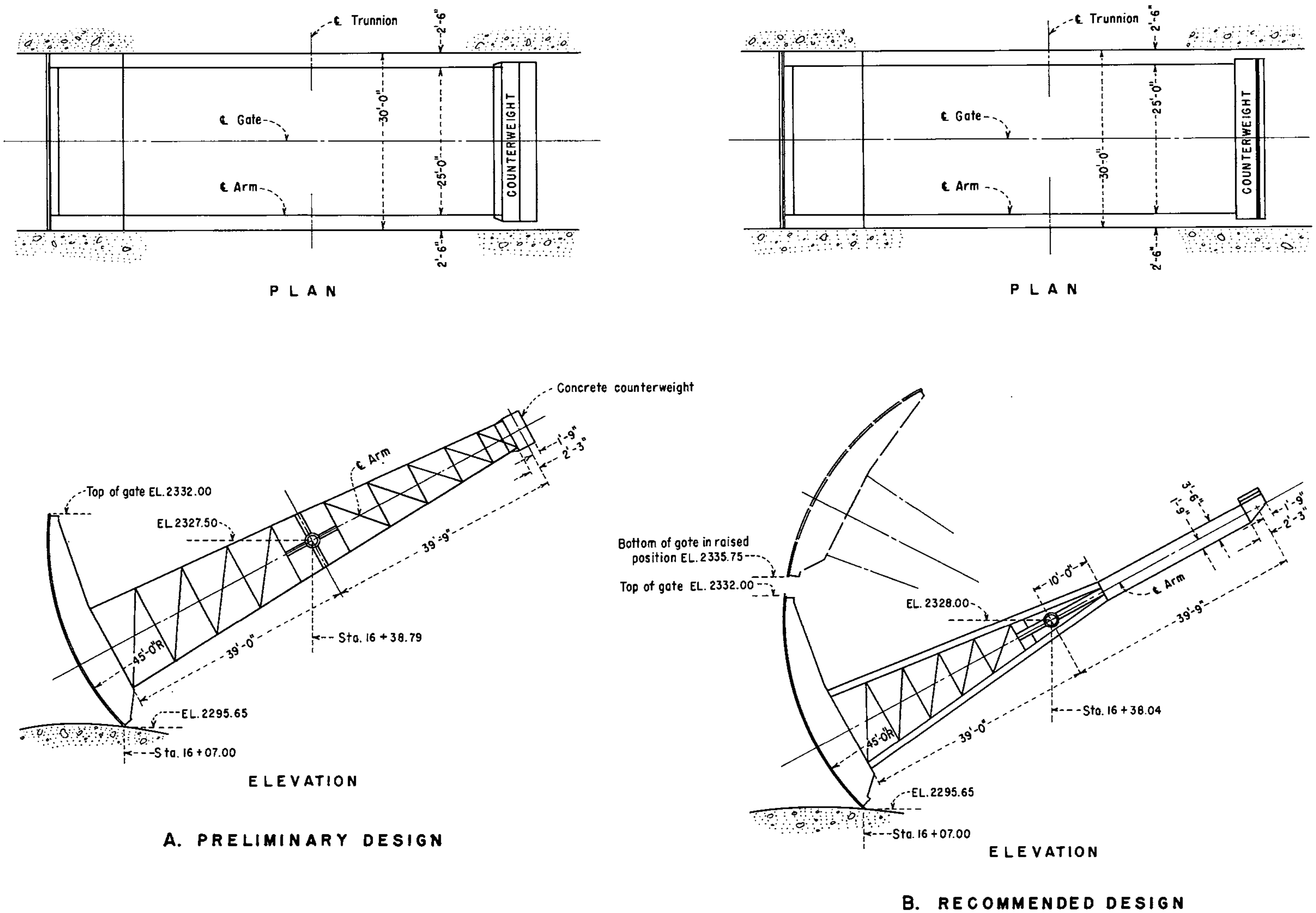
A. Third revision to left wall.



B. Fourth revision to left wall.

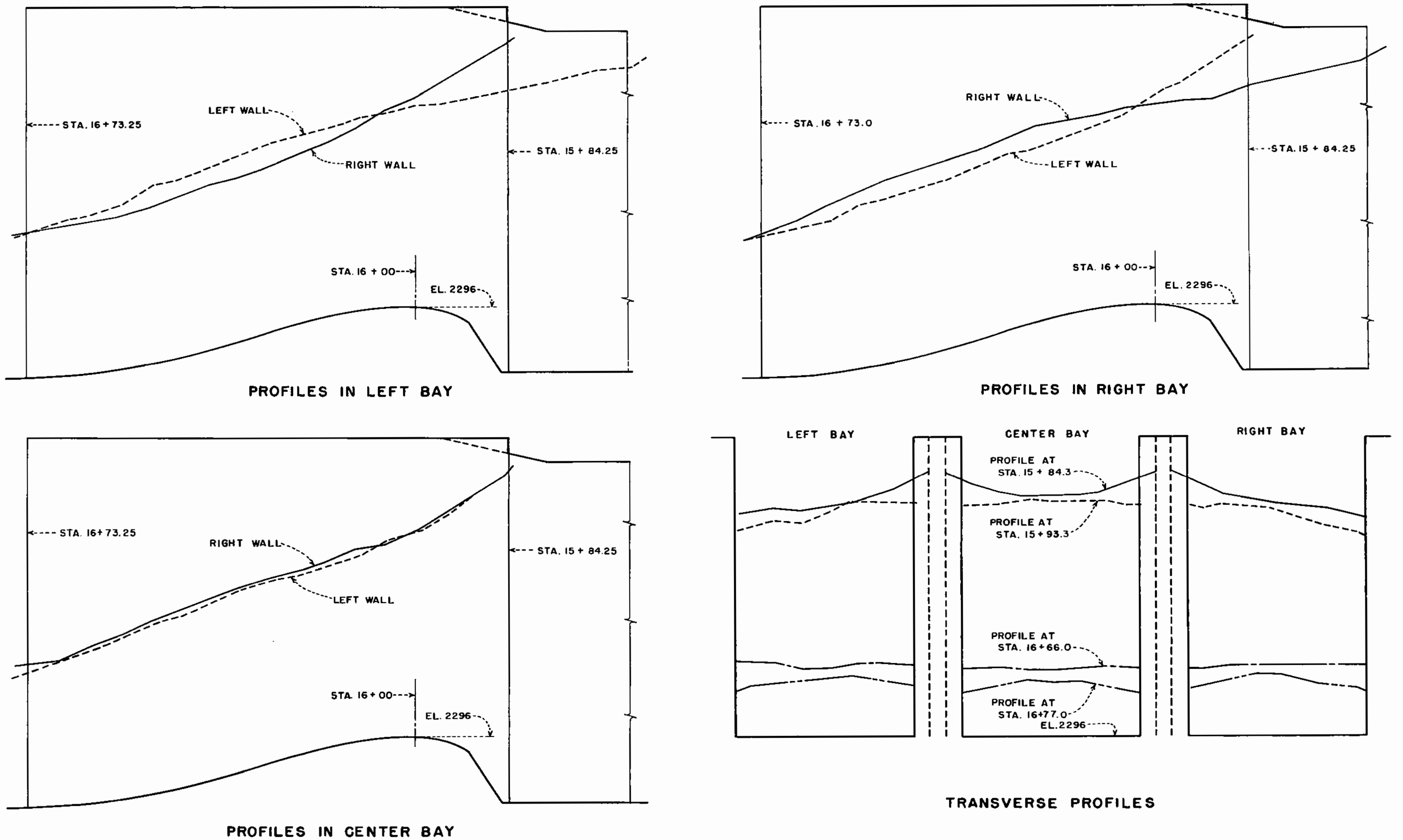
NORTON DAM SPILLWAY
1:42 Scale Model

Flow at Revised Approach Walls
Discharge = 95,000 cfs



NORTON DAM SPILLWAY
1:42 SCALE MODEL
RADIAL GATES

FIGURE 10
REPORT HYD. 493



0 10 20 30
SCALE OF FEET

NORTON DAM SPILLWAY

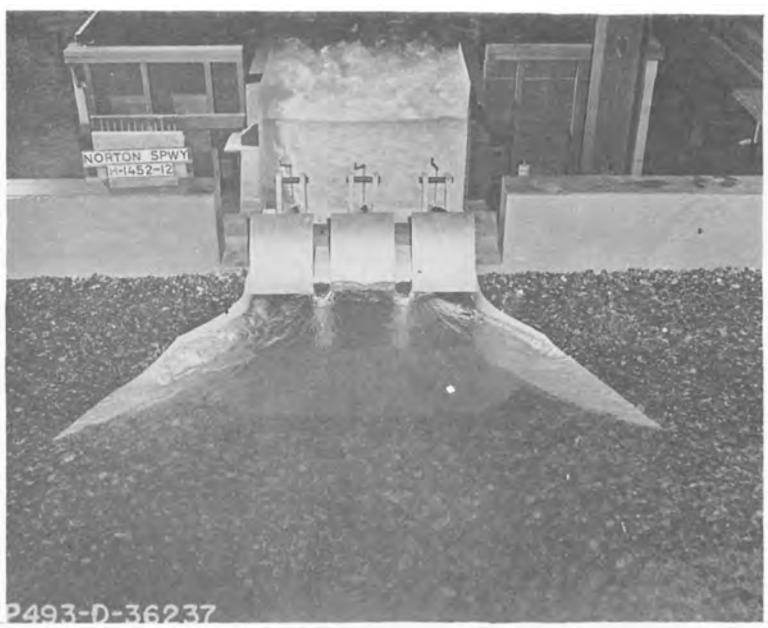
1:42 SCALE MODEL

WATER SURFACE PROFILES IN CREST SECTION
WITH RECOMMENDED APPROACH WALLS AND PRELIMINARY PIERS

DISCHARGE = 95,000 cfs.
FOR ALL PROFILES

FIGURE 11
REPORT HYD. 493

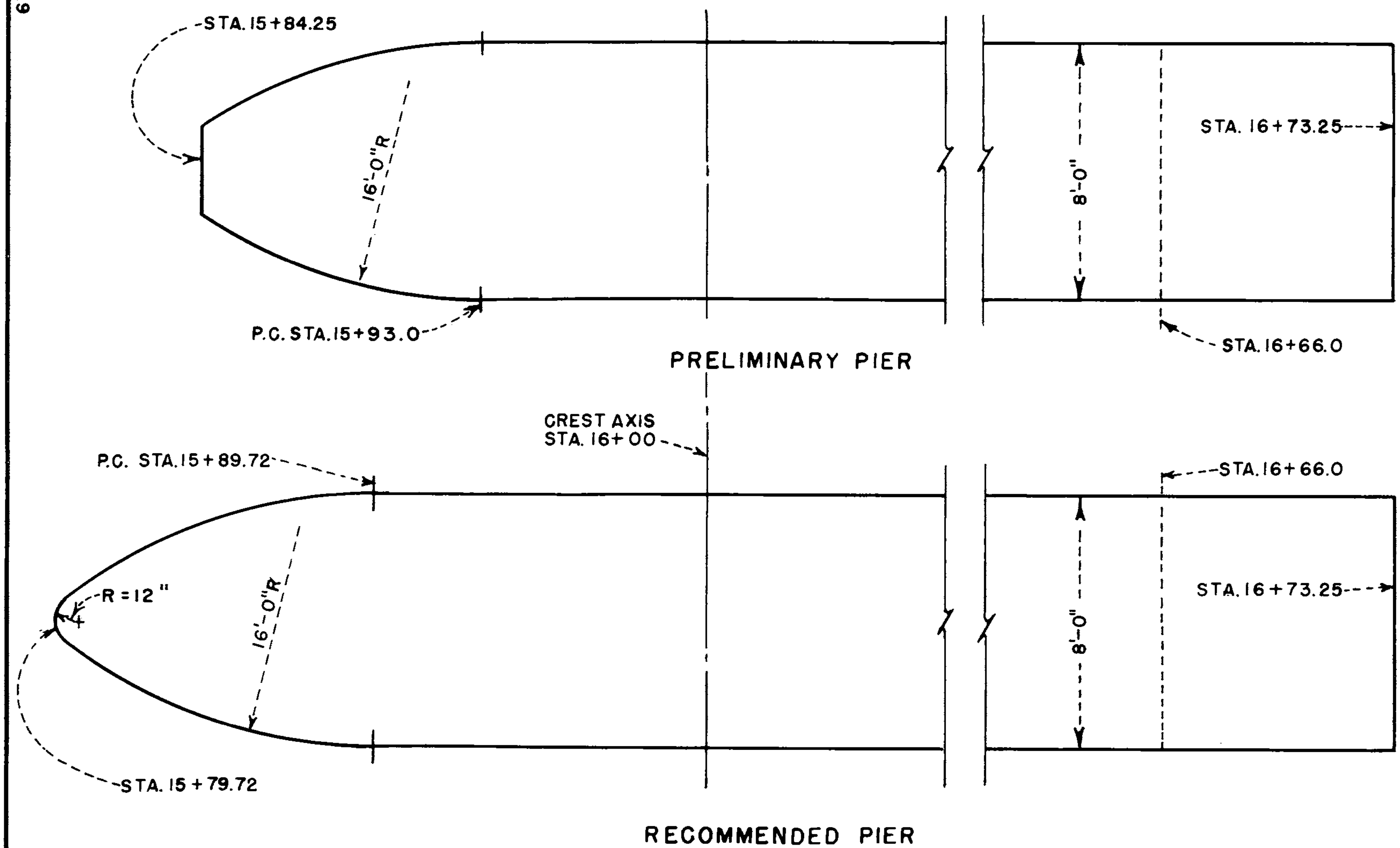
A. Flow at recommended counterweights



B. Flow at spillway approach.
Preliminary piers, recommended.
Trunnion location.

NORTON DAM SPILLWAY
1:42 Scale Model

Flow Conditions in Spillway
Approach and Crest Section
Discharge = 95,000 cfs



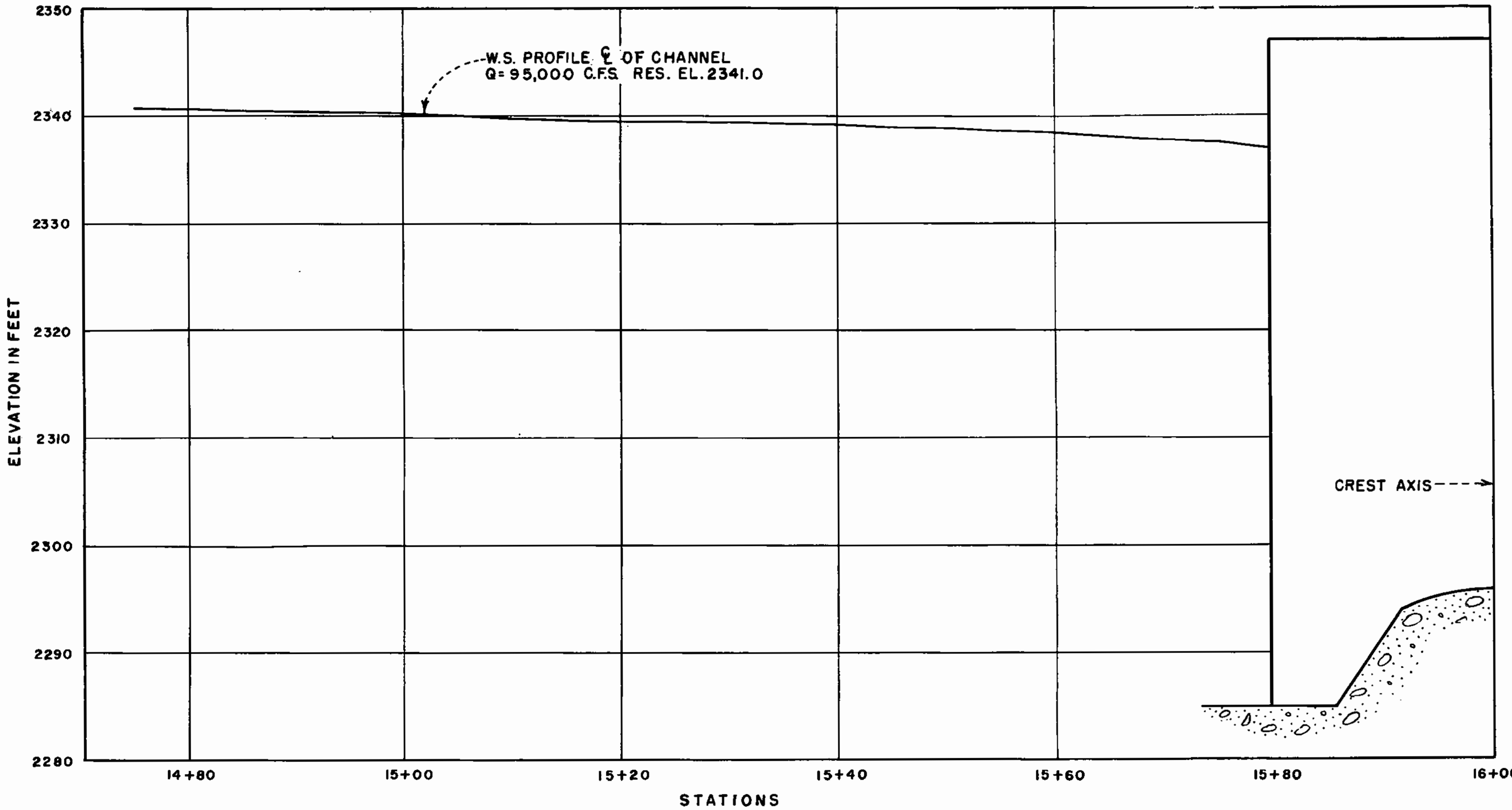
NORTON DAM SPILLWAY
1:42 SCALE MODEL
SPILLWAY PIERS

FIGURE 13
REPORT HYD. 493

Figure 14
Report Hyd-493

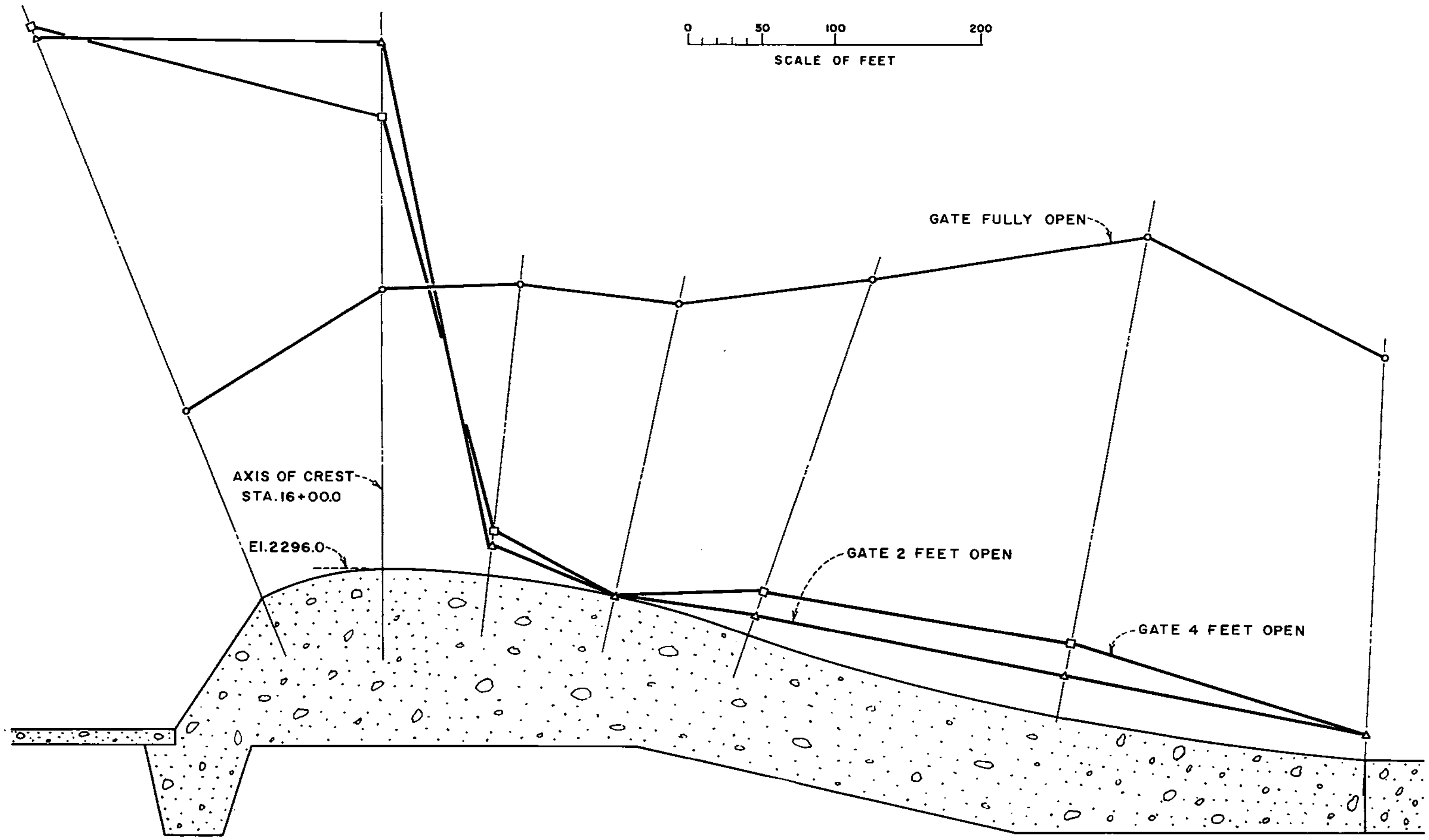
NORTON DAM SPILLWAY
1:42 Scale Model

Flow at Spillway Approach
Recommended Piers and Walls



NORTON DAM SPILLWAY
1:42 SCALE MODEL
WATER SURFACE PROFILE UPSTREAM FROM CREST

FIGURE 15
REPORT HYD. 493



NORTON DAM SPILLWAY

1:42 SCALE MODEL

PRESSURES ON SPILLWAY CREST

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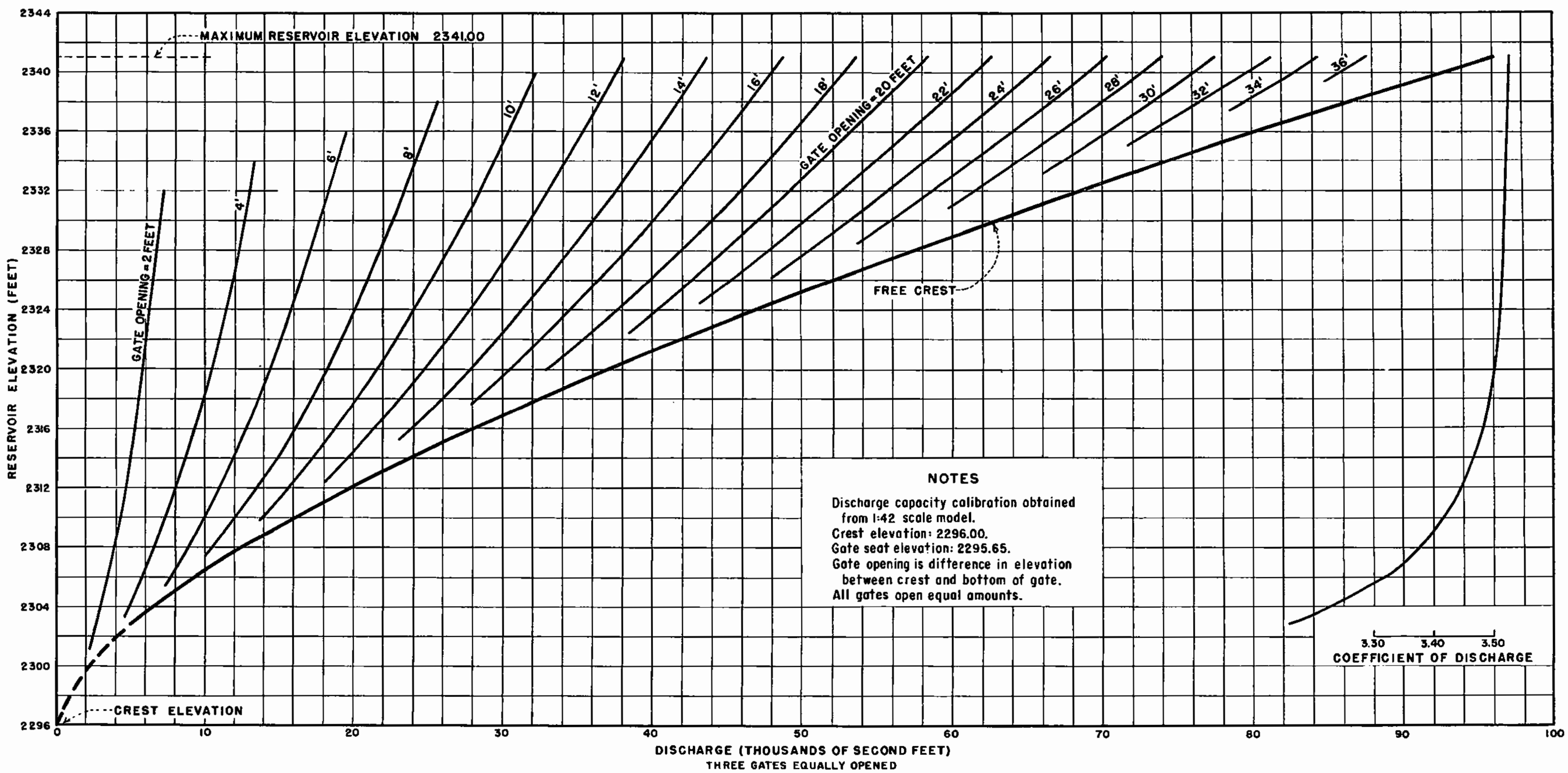
FIGURE 16
REPORT HYD. 493



NORTON DAM SPILLWAY
1:42 SCALE MODEL
DISCHARGE CAPACITY

FIGURE 17
REPORT HYD. 493

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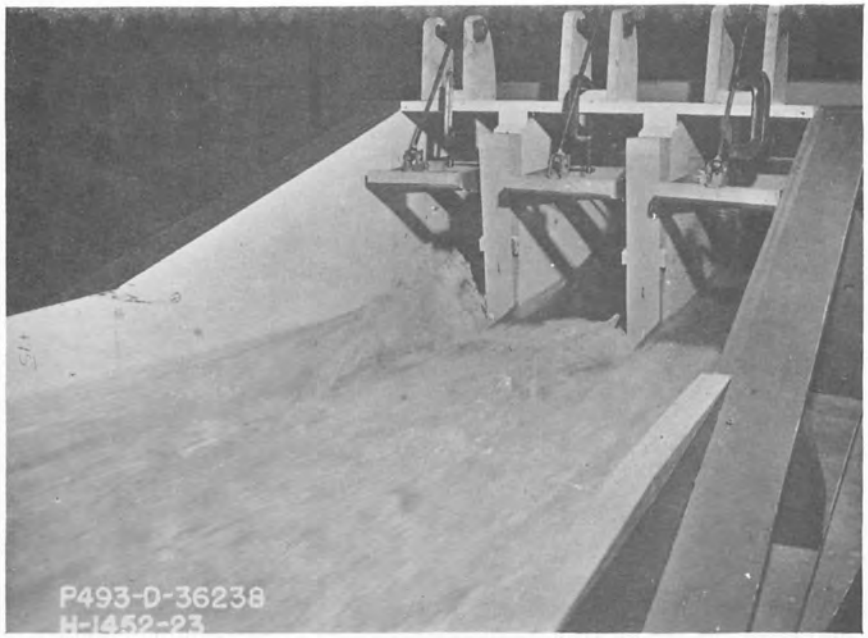
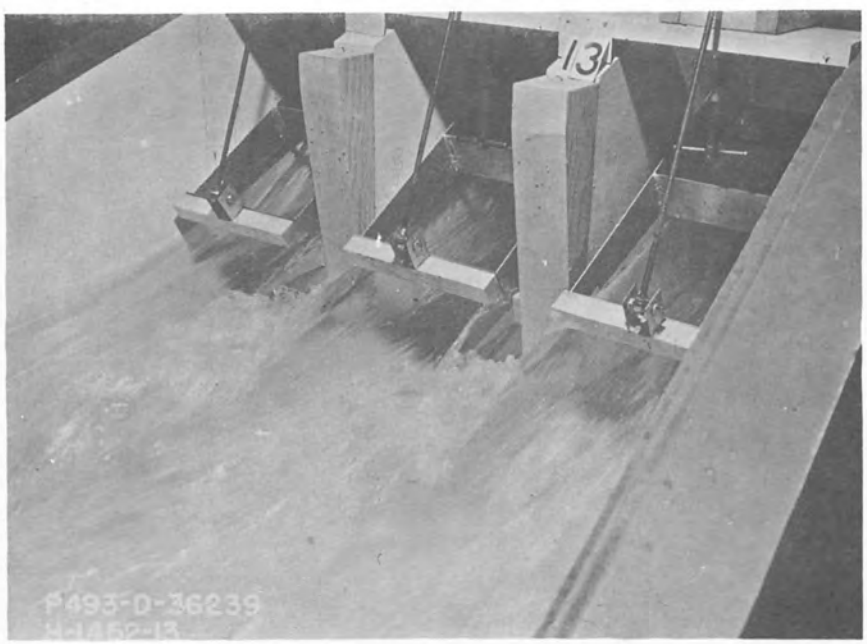


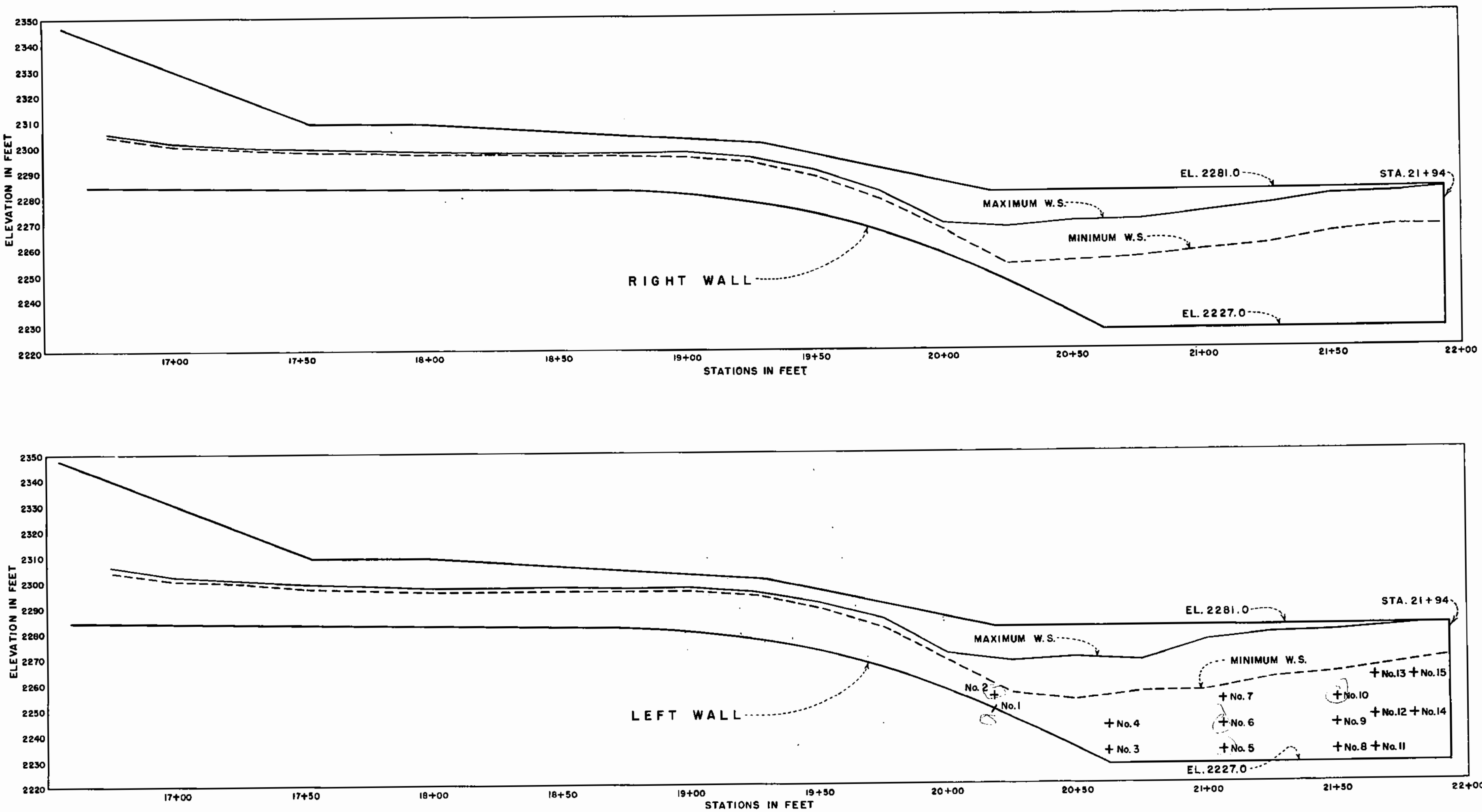
A. Gates open 20 ft--Reservoir Elev. 2341.0.



B. Gates full-open--Reservoir Elev. 2341.0.

NORTON DAM SPILLWAY
1:42 Scale Model

Flow Downstream from
Recommended Spillway Piers



NOTES

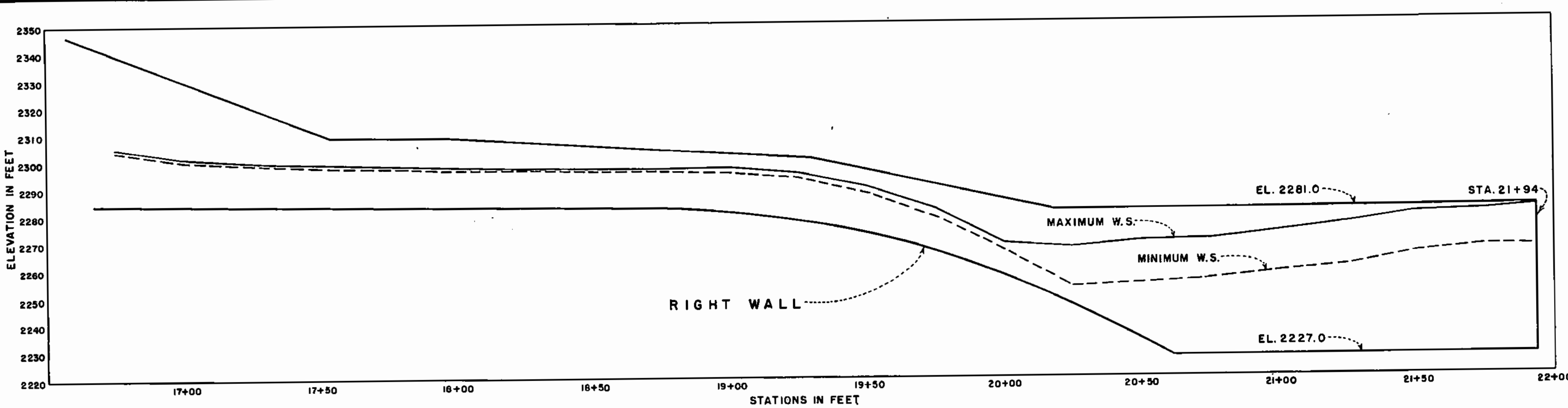
1. Profiles taken for discharge = 95,000 cfs. tailwater Elevation 2276.5
2. Numbers identify piezometer locations in left wall.
3. Piezometer No. 1 is in chute floor about 5 feet from left wall.

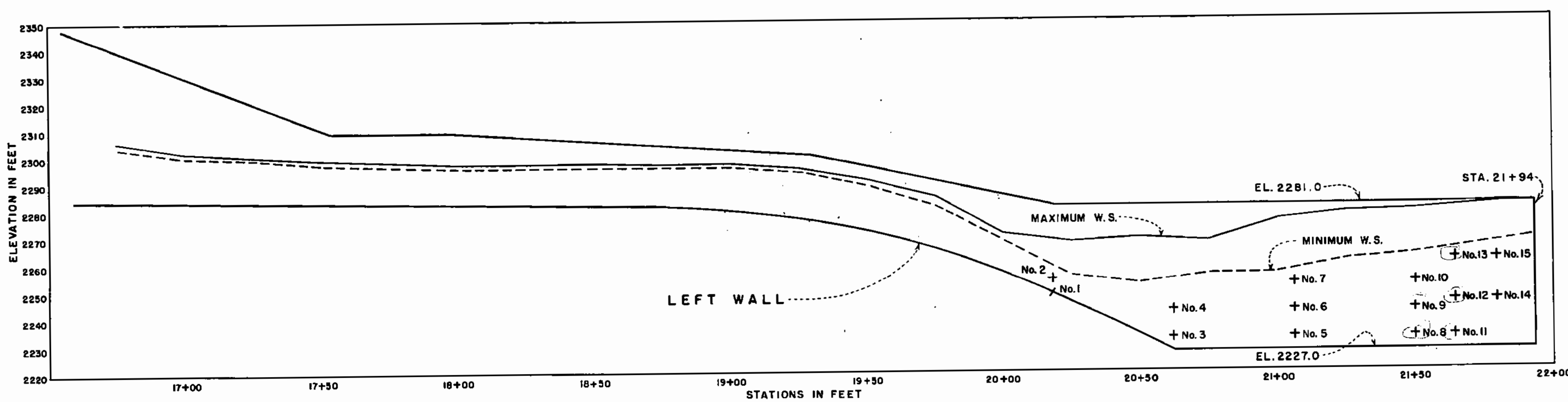
NORTON DAM SPILLWAY

1:42 SCALE MODEL

WATER SURFACE PROFILES IN CHUTE AND STILLING BASIN

FIGURE 19
REPORT HYD. 493





NOTES

1. Profiles taken for discharge = 95,000 cfs. tailwater Elevation 2276.5
2. Numbers identify piezometer locations in left wall.
3. Piezometer No. 1 is in chute floor about 5 feet from left wall.

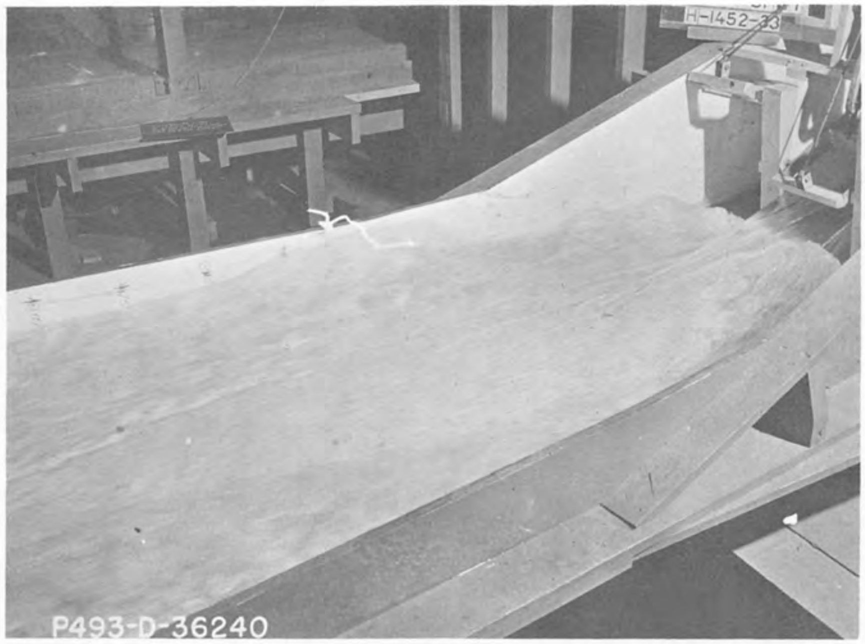
NORTON DAM SPILLWAY

1:42 SCALE MODEL

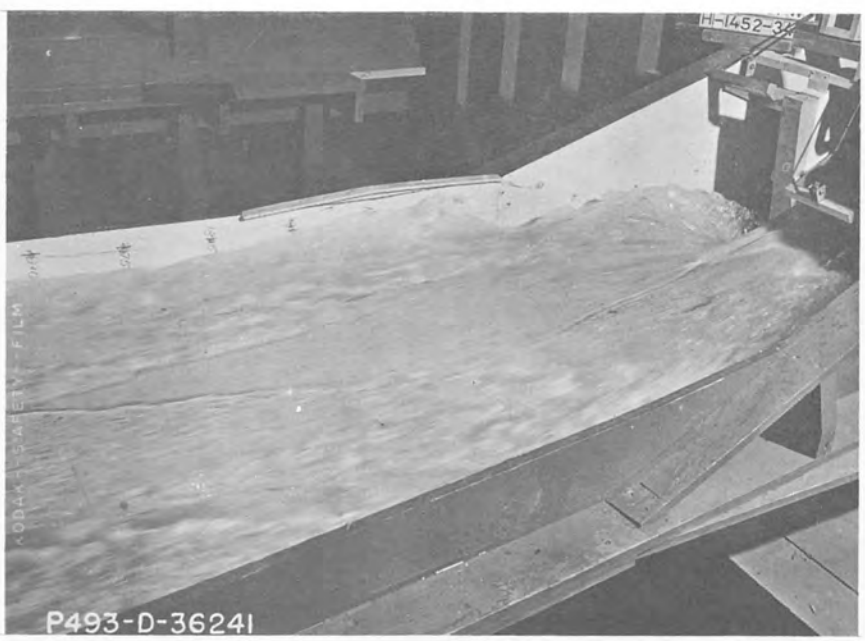
WATER SURFACE PROFILES IN CHUTE AND STILLING BASIN

7 8 11
4 9 12
3 10 13
2 5 14
1 6 15

FIGURE 19
REPORT HYD. 493



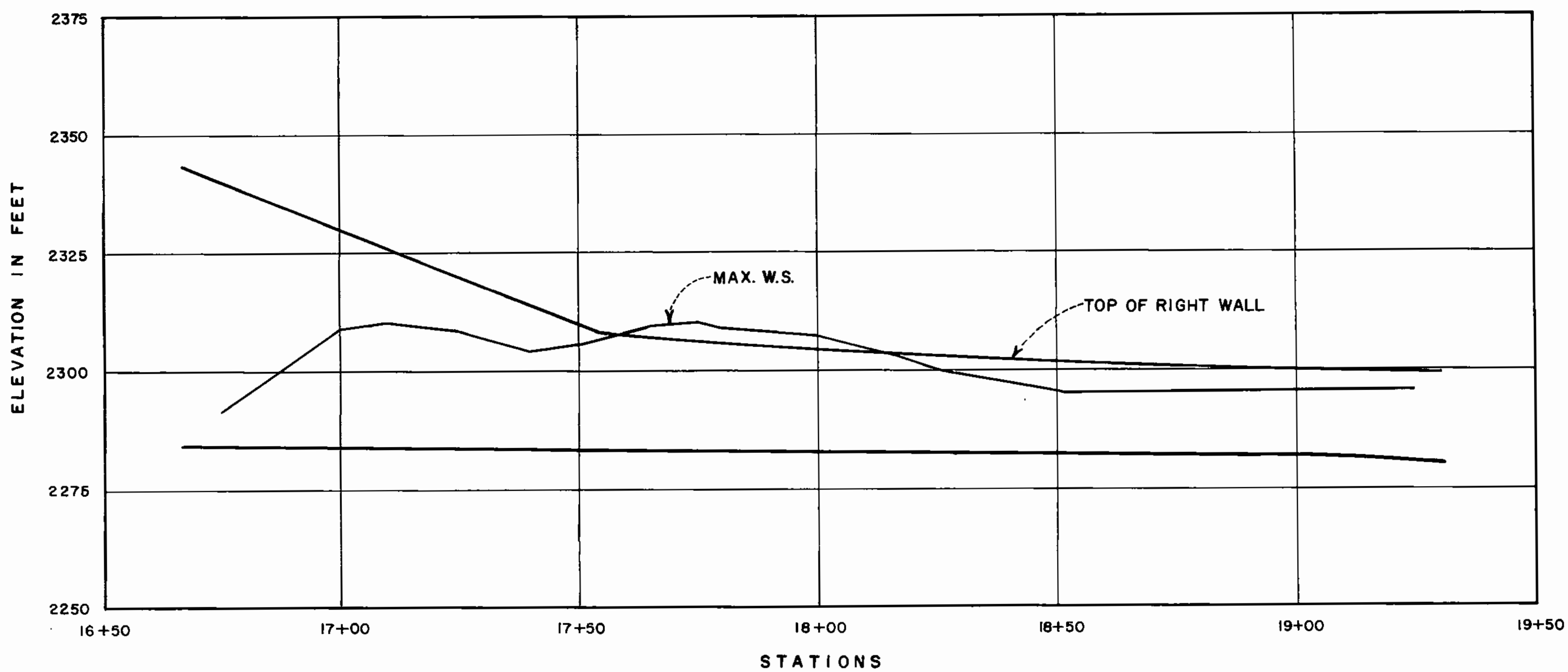
Without coping strip on sidewall.



With coping strip on sidewall.

NORTON DAM SPILLWAY
1:42 Scale Model

Flow on Chute with Unsymmetrical
Gate Operation



NORTON DAM SPILLWAY

1:42 SCALE MODEL

WATER SURFACE PROFILE FOR UNSYMMETRICAL GATE OPENING

(LEFT AND CENTER GATES FULL OPEN - RIGHT GATE APPROX. 10% OPEN)

FIGURE 21
REPORT HYD. 493

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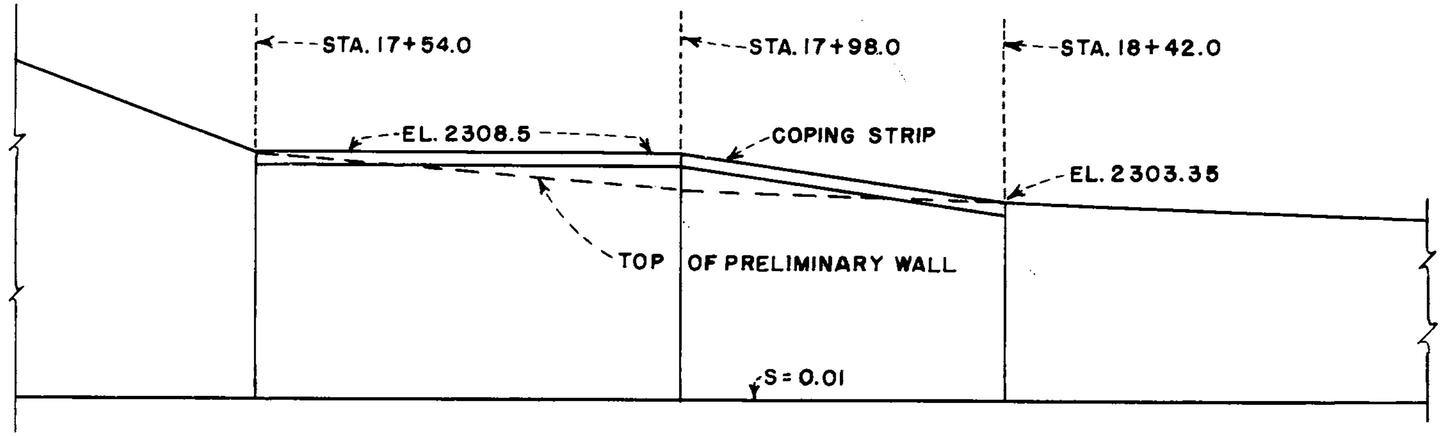
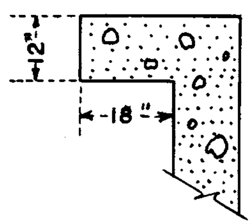


ELEVATION

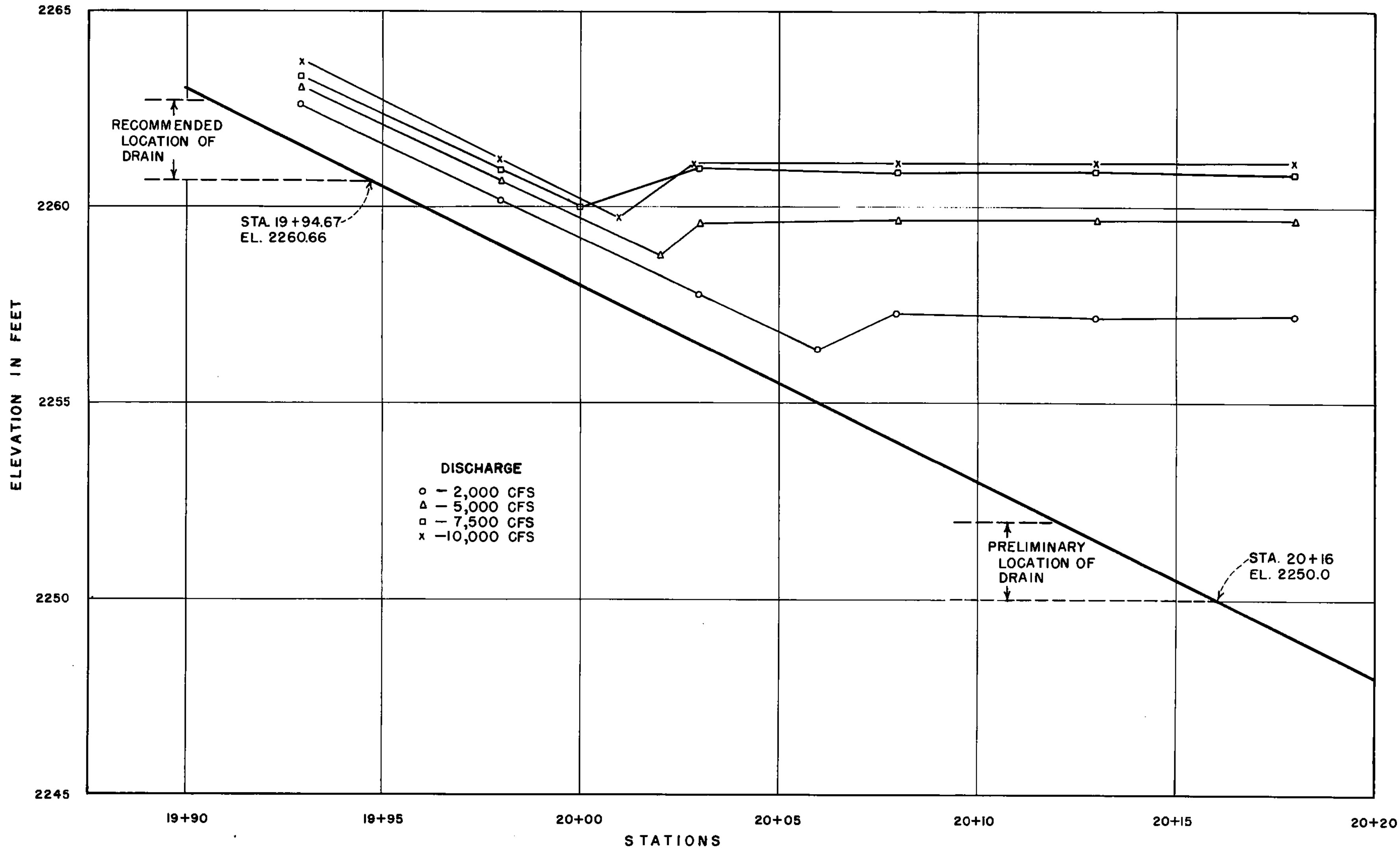


DETAIL OF COPING STRIP

NORTON DAM SPILLWAY

1:42 SCALE MODEL

RECOMMENDED COPING STRIP ON CHUTE SIDEWALLS



NORTON DAM SPILLWAY

1:42 SCALE MODEL

WATER SURFACE PROFILES ON ℄ OF CHUTE BETWEEN STATIONS 19+93 AND 20+18

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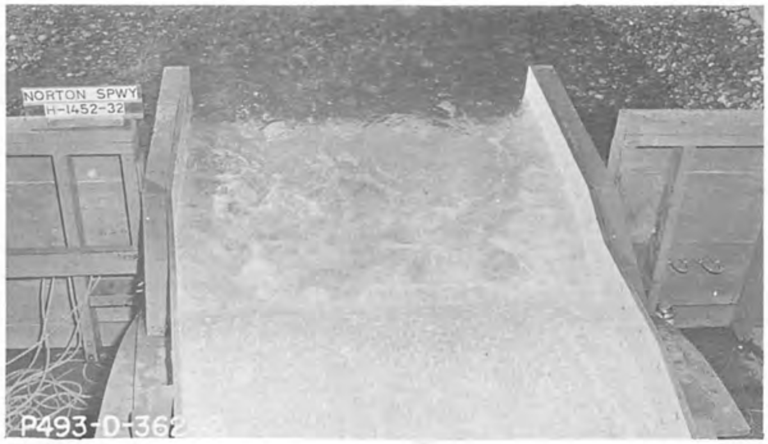
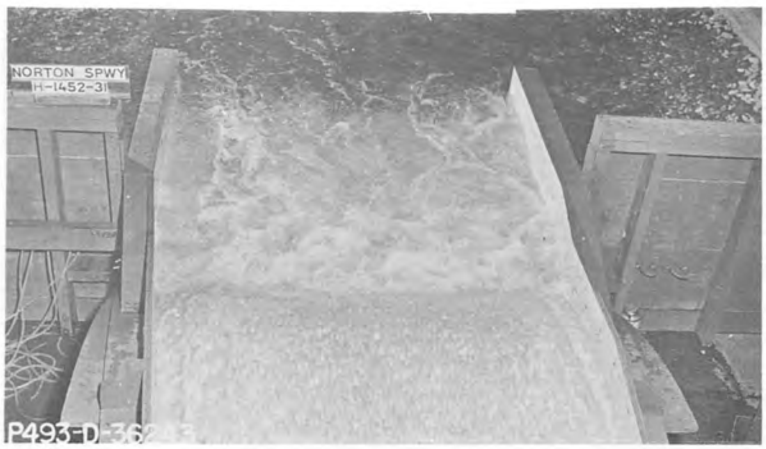
FIGURE 23
REPORT HYD. 493



Discharge = 25,000 cfs. T.W. El. = 2264.8.



Discharge = 45,000 cfs. T.W. El. = 2269.5.

Discharge = 95,000 cfs. T.W. El. = 2276.5.

NORTON DAM SPILLWAY
1:42 Scale Model

Flow Distribution in
Recommended Stilling Basin

Channel prior to erosion tests

A. Channel formed in sand.

B. Channel protected with 2-1/2- to 3-foot riprap.

NORTON DAM SPILLWAY
1:42 Scale Model

Erosion after 1-hour Operation at 95,000 cfs.

GPO 830666