Division of Research
Hydraulic Laboratory Branch

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF NORTON DAM OUTLET WORKS--MISSOURI RIVER BASIN PROJECT, KANSAS

Hydraulics Branch Report No. Hyd-497

DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

October 21, 1963

CONTENTS

CONTENTS--Continued

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of Chief Engineer
Division of Research
Hydraulics Branch
Denver, Colorado
October 21, 1963

Hydraulics Branch
Report No. Hyd-497
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Subject: Hydraulic model studies of the Norton Dam outlet works--Missouri River Basin Project, Kansas

PURPOSE

The purpose of this model study was to determine the energy dissipating efficiency of the hydraulic jump stilling basin for the slide gate controlled outlet works and to observe the hydraulic operating characteristics of the component features of the structure.

CONCLUSIONS

1. The hydraulic jump stilling basin performed satisfactorily for all discharges tested, Figures 8 through 12, with the control gate either fully or partially opened.

2. Flow conditions in the horizontal conduit and chute were satisfactory for discharges with the gate fully opened. However, with the gate opened less than 50 percent, spreading of the jet was inadequate and the flow concentrated in the center portion of the chute before entering the stilling basin, Figure 13. The configuration of the gate leaf was altered but there was no improvement in the flow pattern. Since this condition had no adverse effect on the operation of the stilling basin, no further attempt was made to improve the flow.

3. Sand erosion tests, Figures 15 through 17, showed a maximum erosion depth of 2.6 feet at the end of the stilling basin after the equivalent of 12 hours prototype operation at a discharge of 385 cubic feet per second with the degraded tailwater condition. An equivalent 12-hour riprap test with Q = 385 cubic feet per second showed no movement of the rock protection, Figure 18.

4. Water manometer and instantaneous dynamic pressures measured throughout the structure were found to be within safe limits of operation, with no severe subatmospheric pressures or excessively large impact pressures observed, Figure 19 and Table 2.

5. Waves along the banks of the downstream channel (Station 9+35) were less than 1 foot in height for all operating discharges, Table 3. Waves along the outside of the stilling basin walls were negligible.

6. Tailwater sweepout tests indicated that the minimum safety margin between the minimum (degraded) tailwater elevation and the tailwater elevation at which the jump first began to leave the basin was approximately 1.9 feet, Table 4. With the tailwater lowered an additional 1.7 feet, 3.6 feet below the tailwater for the degraded channel, the jump left the basin completely. This margin was determined for a maximum discharge of 385 cubic feet per second (reservoir at top of flood-control pool). For a maximum discharge of 316 cubic feet per second (reservoir at top of conservation storage) sweepout was prevented by the sloping apron at the end of the stilling basin.

ACKNOWLEDGMENT

The testing program described in this report was accomplished through cooperation with the Spillways and Outlet Works Section of the Dams Branch, Division of Design.

INTRODUCTION

Norton Dam, a feature of the Missouri River Basin Project, is located on Prairie Dog Creek about 2 miles from Norton, in northwestern Kansas, Figure 1. The dam is approximately 6,400 feet long at the crest and rises about 100 feet above the riverbed.

The principal hydraulic features of the dam are the spillway and the outlet works, Figure 2. The spillway is located in the right abutment of the dam and consists of a 90-foot-wide radial gate controlled overflow crest. The design spillway discharge is 95,000 cubic feet per second at the maximum reservoir elevation, 2341.0.

Model studies of the spillway are reported in Hydraulics Branch Report No. Hyd-493.

The outlet works, Figure 3, consists of a bellmouth entrance leading into a 48-inch-diameter circular conduit, a 2-foot 9-inch-square high-pressure emergency gate, a 38-inch-diameter circular conduit, a 2-foot 9-inch-square high-pressure regulating gate, Figure 4, a 35-foot-long diverging rectangular conduit, a 55-foot-long vertically curved chute, and a 55-foot-long hydraulic jump stilling basin, Figure 5. The last 21 feet of the stilling basin consists of a 4:1 upward sloping apron. The basin includes chute blocks at the upstream end and baffle piers at the start of the upward sloping apron.

The outlet works is designed to pass a maximum discharge of 385 cubic feet per second with the reservoir at the top of the flood control pool, elevation 2331.4.

THE MODEL

The 1:8.25 scale model of the Norton outlet works, Figure 6, included the high-pressure regulating gate, the diverging rectangular conduit between the gate and chute, the diverging vertically curved chute, the hydraulic jump stilling basin, and the downstream river channel to Station 9+60.

The chute was constructed of plywood and tempered masonite and the stilling basin was fabricated with plywood. Piezometers were installed in the floor and one wall of the chute and in one wall of the stilling basin. The downstream channel was initially formed in sand with an average size of 0.8 millimeter; rock with a maximum size of about 2 inches was later added to simulate riprap protection.

Water was supplied through a recirculating distribution system by a centrifugal pump. Discharges were measured by permanent volumetrically calibrated Venturi meters.

The reservoir and outlet works conduit were not included in the model; therefore, the proper velocities of efflux through the gate section were maintained by establishing the computed pressure head immediately upstream from the gate. The pressure head setting was determined according to theoretical upstream head losses.

Tailwater elevations were controlled with an adjustable tailgate according to the tailwater curves shown in Figure 7. Water surface elevations were accurately determined by a hook gage in a stilling well connected to an open tube at Station 9+60.

THE INVESTIGATION

Conditions investigated during the model study are summarized in Table 1, which also includes metric equivalents of discharges and elevations. The maximum discharge of 385 cubic feet per second and the normal discharge of 175 cubic feet per second at 43 percent gate opening occurring with the reservoir at the top of the flood control pool are unlikely operating conditions. The spillway capacity of about 95,000 cubic feet per second is very large in comparison with the outlet works discharge. With the reservoir at the top of the flood control pool the spillway could be utilized in making necessary releases and the outlet works would be shut down. Therefore in judging the basin performance, more weight was given to the maximum discharge of 316 cubic feet per second with the reservoir at the top of the active conservation storage and the corresponding normal discharge of 175 cubic feet per second at 52 percent gate opening. Performance was evaluated for both initial and degraded tailwater conditions, as shown in the table, by general observation of the flow, erosion tests, pressures, wave measurements, and tailwater sweepout tests. Conditions were also observed for a maximum discharge of 260 cubic feet per second, based on maximum losses in the system with Manning's "n" values of 0.012 for steel and 0.013 for concrete. This condition is likely to prevail after some aging of the conduits. The maximum discharges of 385 and 316 cubic feet per second, and the corresponding normal discharge of 175 cubic feet per second, are based on minimum losses with "n" values of 0.008 for both steel and concrete.

Some data were taken and observations made for gate openings of 75, 50, and 25 percent for the conditions of operating heads shown in Table 1, and for both initial and degraded tailwater conditions.

The Preliminary Stilling Basin--(Recommended)

Stilling basin operation.--The stilling basin performed satisfactorily for all discharges tested, including operation at gate openings of 75, 50, and 25 percent. The jump was confined to the basin at all times; turbulence at the downstream end of the basin was relatively slight.

Figure 8 shows the basin operation for the maximum discharge of 385 cubic feet per second which would occur with the reservoir at the top of the flood control pool. For the initial tailwater elevation 2250.7 the basin efficiency was very good, as exhibited by the smooth water surface in the downstream portion of the basin. A large amount of splashing occurred at the toe of the jump but was confined within the basin walls. The traveling surge noted in the photograph was dissipated before entering the river channel. Operation for the degraded tailwater, elevation 2244.3, was not as good as for the higher tailwater, but was still entirely satisfactory. The velocity of the water leaving the basin was higher because of the reduced depth at the end of the sloping apron and some turbulence existed on the surface. Splashing at the toe of the jump was reduced due to the steeper angle of entry of the chute flow into the basin pool.

The basin operation for the maximum discharge of 316 cubic feet per second with the reservoir at the top of the active conservation storage is shown in Figure 9. For the initial tailwater elevation 2250.3 energy dissipation occurred in the upstream portion of the basin and the water surface at the end of the basin was very smooth. Again, some splashing prevailed at the toe of the jump. The hydraulic jump was somewhat rougher for the degraded tailwater elevation 2243.6 but the flow leaving the basin was smooth.

Flow conditions for a maximum discharge of 260 cubic feet per second which would occur with the reservoir at the top of the active conservation pool with maximum losses in the system are shown in Figure 10. It is evident that the basin operation at this flow was very satisfactory for both initial and degraded tailwater conditions.

The normal discharge of 175 cubic feet per second was represented by gate openings of 43 and 52 percent with the reservoir at the top of the flood control pool and the top of the conservation pool, respectively. Figures 11 and 12 show that the basin operation with the initial tailwater elevation 2249.3 was apparently the same for either gate opening. For the degraded tailwater elevation 2241.7 more turbulence occurred in the basin for the 43 percent gate opening because of the higher jet velocity. The water surface at the end of the basin also appeared to be slightly rougher for the 43 percent opening.

Though not shown, the operation at partial gate openings of 75, 50, and 25 percent was satisfactory for the operating heads represented in Table 1, and for both initial and degraded tailwater conditions.

Chute flow conditions.--Flow conditions in the horizontal conduit and on the vertically curved chute were satisfactory for the maximum discharges of 385, 316, and 260 cubic feet per second with the gate fully opened. Flow in the chute was also satisfactory for gate openings greater than 50 percent. Figure 13A is a downstream view of the chute flow for a discharge of 175 cubic feet per second with a 52 percent gate opening. Flow conditions for discharges at larger gate openings were very similar to those observed with a 52 percent gate opening. Figure 13B illustrates an undesirable action on the chute for a discharge of 175 cubic feet per second with the gate 43 percent open, which is also typical for smaller openings. The surface portion of the flow tended to become separated from the main stream and the jet did not spread adequately, causing a concentration of flow in the center of the chute. This concentration caused a dishing effect in the toe of the jump such that the center part of the toe was farther downstream than the sides.

This adverse flow condition was believed to be caused by the improperly shaped model gate used in the study. Although the gate slots were correctly modeled, the prototype gate leaf was inaccurately represented, as shown in Figure 14. The prototype gate leaf was several inches thicker than the leaf represented in the model. It was felt that this discrepancy might have some effect on the chute flow conditions. However, the model gate leaf was revised to duplicate the prototype leaf and there was no noticeable difference between the flow conditions for the original model gate leaf and the revised leaf. Also, discharge coefficients measured at 50 and 25 percent gate openings for the original gate were only slightly lower than corresponding coefficients for the revised gate.

This adverse condition had no apparent influence on the operation of the hydraulic jump. Considering this and the probability that a discharge of 175 cubic feet per second with a 43 percent gate opening will be a very unusual operating condition, it was decided to make no further attempts to correct the flow condition.

Sand erosion and riprap tests.--To further determine the efficiency of the stilling basin, and to provide a rapid determination of possible areas of excessive erosion, the downstream channel was shaped in sand having an average size of approximately 0.8 millimeter.

Three separate tests were conducted. The first consisted of operating the model for 4 hours 10 minutes, a period equivalent to 12 prototype hours, at a discharge of 385 cubic feet per second with degraded tailwater conditions. At the end of this test, erosion about 2.6 feet deep occurred on the right side of the channel, near the downstream end of the stilling basin. The removed material was deposited in the form of a bar farther downstream, Figure 15. The erosion and deposition were apparently due to the increased velocity at the end of the sloping apron.

After reshaping the channel the model was again operated for 12 prototype hours at a discharge of 316 cubic feet per second with degraded tailwater conditions. Erosion approximately 2.0 feet deep occurred at the end of the basin. The eroded material was deposited closer to the basin, as shown in Figure 16.

The channel was again reshaped for the third test. Approximately 1.4 feet of erosion occurred after 12 prototype hours operation with the normal discharge of 175 cubic feet per second, 52 percent gate opening, and degraded tailwater conditions. The resulting pattern is shown in Figure 17.

Rock with maximum size fragments of about 2 inches was added to the sand surface of the channel. This rock represented a size about one-half the size of the largest fragments of the proposed prototype riprap. The model was again operated for a period of time equivalent to 12 prototype hours at a discharge of 385 cubic feet per second and degraded tailwater conditions. At the conclusion of the test no apparent movement of the simulated riprap had occurred. Figure 18 shows the rock bedding as it appeared both before and after the test.

Pressures.--Piezometers were placed along the centerline of the horizontal conduit and vertically curved chute, in the right wall of the conduit and chute near the floor, and in the right wall of the stilling basin, Figure 19. Pressures were first determined using open-tube water manometers connected to each piezometer opening. Instantaneous pressure fluctuations at critical points in the structure were measured with electronic pressure cells and recorded by a direct writing oscillograph.

All pressures in the stilling basin, Figure 19, were above atmospheric. Instantaneous pressures were recorded in the turbulent region of the toe of the hydraulic jump, where previous experience has shown large fluctuations to exist. The lowest pressure occurring in this region was 6.5 feet of water below atmospheric at Piezometer 18 for the normal discharge of 175 cubic feet per second, 52 percent gate opening, and degraded tailwater elevation. Instantaneous pressures were also determined at Piezometers 21, 22, 23, 24, 25, and 26 for 385 and 316 cubic feet per second with the high initial tailwater elevation to determine maximum forces acting on the stilling basin walls. The tables in Figure 19 show the close agreement between the average water manometer pressures and the average instantaneous pressures. Some disagreement between these two values noted in the region of the toe of the hydraulic jump may be explained by the fact that slight discrepancies in the tailwater settings would be reflected in the position of the toe of the jump, which would in turn affect the pressures at a given point in this region.

Pressure profiles, shown in Figure 19, were plotted from the average water manometer pressures at Piezometers 10, 12, 15, 18, 20, 22, and 24.

Pressures in the horizontal conduit and chute, Table 2, were measured with the tailwater lowered so that the toe of the hydraulic jump was below Piezometer 15. The high velocity flow in the conduit and chute caused difficulty in obtaining consistent results. Slight changes in the flow surfaces around each piezometer opening produced radically different pressure readings. Special attention was given to smoothing the surfaces around each opening and the resulting water manometer pressures are shown in the table.

Later in the testing program instantaneous pressures were determined and found to be quite different from the water manometer pressures for most of the piezometers. It was felt that warping and cracking of the plywood surface probably accounted for the disagreement. The instantaneous record showed little fluctuation in pressure; therefore, it was decided that the earlier water manometer readings gave an adequate representation of the pressure distribution.

Slightly subatmospheric pressures occurred on the invert of the vertically curved chute for all discharges tested, Table 2. The chute was designed for atmospheric pressure and the pressures are all within 1 foot of water of this value. Slightly subatmospheric pressures were also found in the horizontal conduit immediately downstream from the control gate for the normal discharge of 175 cubic feet per second with either 43 or 52 percent gate opening.

Water surface profiles. --Water surface profiles in the stilling basin are shown in Figure 20. Maximum and minimum fluctuations of the water surface are included for the four test discharges with both initial and degraded tailwater conditions. Comparison of these curves with the corresponding pressure profiles shows excellent agreement.

Transverse profiles were measured at several sections in the horizontal conduit and chute, Figure 21. These profiles clearly show the concentration of flow in the center of the chute caused by inadequate spreading of the gate controlled flow (from approximately Station 8+25 to Station 8+45) for the normal discharge of 175 cubic feet per second at 43 percent gate opening. This condition is also apparent, but much less pronounced for other discharges. The same conclusions may be drawn from Figure 22, which is a plot of the water surface profiles on the centerline of the conduit and chute.

Waves. --Table 3 shows the results of wave measurements in the downstream channel conducted to determine possible erosive effects on the channel slopes and to further evaluate the energy dissipating efficiency of the stilling basin. The waves were measured using a point gage and were found to have a maximum height of only 0.7 foot from trough to crest for discharges of either 385 or 316 cubic feet per second with degraded tailwater conditions. These waves were thought to be too small to have any damaging effects on the channel slopes and added weight to the conclusion that the stilling basin performance was very satisfactory.

Wave heights along the outside of the stilling basin walls were accurately determined with a variable capacitance wire probe. These heights, which would ordinarily be used in connection with pressures inside the basin to determine overturning forces acting on the walls, were found to be negligible.

Tailwater sweepout test. --Tests were conducted to determine the safety margin between the degraded tailwater elevation and the tailwater elevation at which the hydraulic jump begins to sweep from the basin. Results of this test are shown in Table 4. The minimum safety margin against initial sweepout was 1.9 feet and occurred for the 385 cubic feet per second discharge. Initial sweepout is defined as occurring when the chute blocks initially became exposed. Complete sweepout (jump swept from basin) occurred at a margin of approximately 3.6 feet. Sweepout for a discharge of 316 cubic feet per second was impossible because the upward sloping floor at the downstream end of the basin held the jump in the basin. The table also includes results of tests with partial gate openings.

Table 1

OUTLINE OF OPERATING CONDITIONS FOR MODEL STUDY

Condition	Reservoir elevation*	Percent gate opening	Discharge	Tailwater elevation*	
				Initial	Degraded
Reservoir at top of flood control pool, minimum losses in system	710.6 m 2331.4 ft	100	10.9 cms 385 cfs	686.0 m 2250.7 ft	684.1 m 2244.3 ft
		43	5.0 cms 175 cfs	685.6 m 2249.3 ft	683.3 m 2241.7 ft
Reservoir at top of active conservation storage, minimum losses in system**	702.4 m 2304.3 ft	100	9.0 cms 316 cfs	685.9 m 2250.3 ft	683.8 m 2243.6 ft
		52	5.0 cms 175 cfs	685.6 m 2249.3 ft	683.3 m 2241.7 ft
Reservoir at top of active conservation storage, maximum losses in system	702.4 m 2304.3 ft	100	7.4 cms 260 cfs	685.8 m 2249.9 ft	683.6 m 2242.9 ft

*Elevations above mean sea level (M.S.L.).
**In judging suitability of performance, more weight should be given to this condition.

Table 2

WATER MANOMETER PRESSURES IN THE HORIZONTAL CONDUIT AND CHUTE PROTOTYPE FEET OF WATER

Piezometer number	Q = 385 cfs gate 100% open	Q = 316 cfs gate 100% open	Q = 175 cfs gate 52% open	Q = 175 cfs gate 43% open
1	1.9	1.7	0.5	0.2
2	1.6	1.7	-0.2	-1.0
3	0.4	0.6	-0.2	-0.2
4	1.4	1.5	0.3	0.2
5	0.8	0.7	0.4	0.3
6	0.2	0.7	0.1	0.0
7	0.1	0.2	-0.3	-0.4
8	0.0	0.3	-0.5	-0.8
9	-0.4	-0.2	-0.4	-0.4
10	-0.1	0.2	-0.2	-0.2
11	-0.7	-0.7	-0.2	-0.2
12	-0.3	0.1	-0.2	-0.1
13	0.0	0.0	0.0	0.0
14	-0.1	0.2	-0.[illegible]	-0.1
15	-0.6	0.0	-0.7	-0.8

Piezometer locations shown on Figure 19.

Table 3

WAVE HEIGHTS AT STATION 9+35.00 IN PROTOTYPE FEET

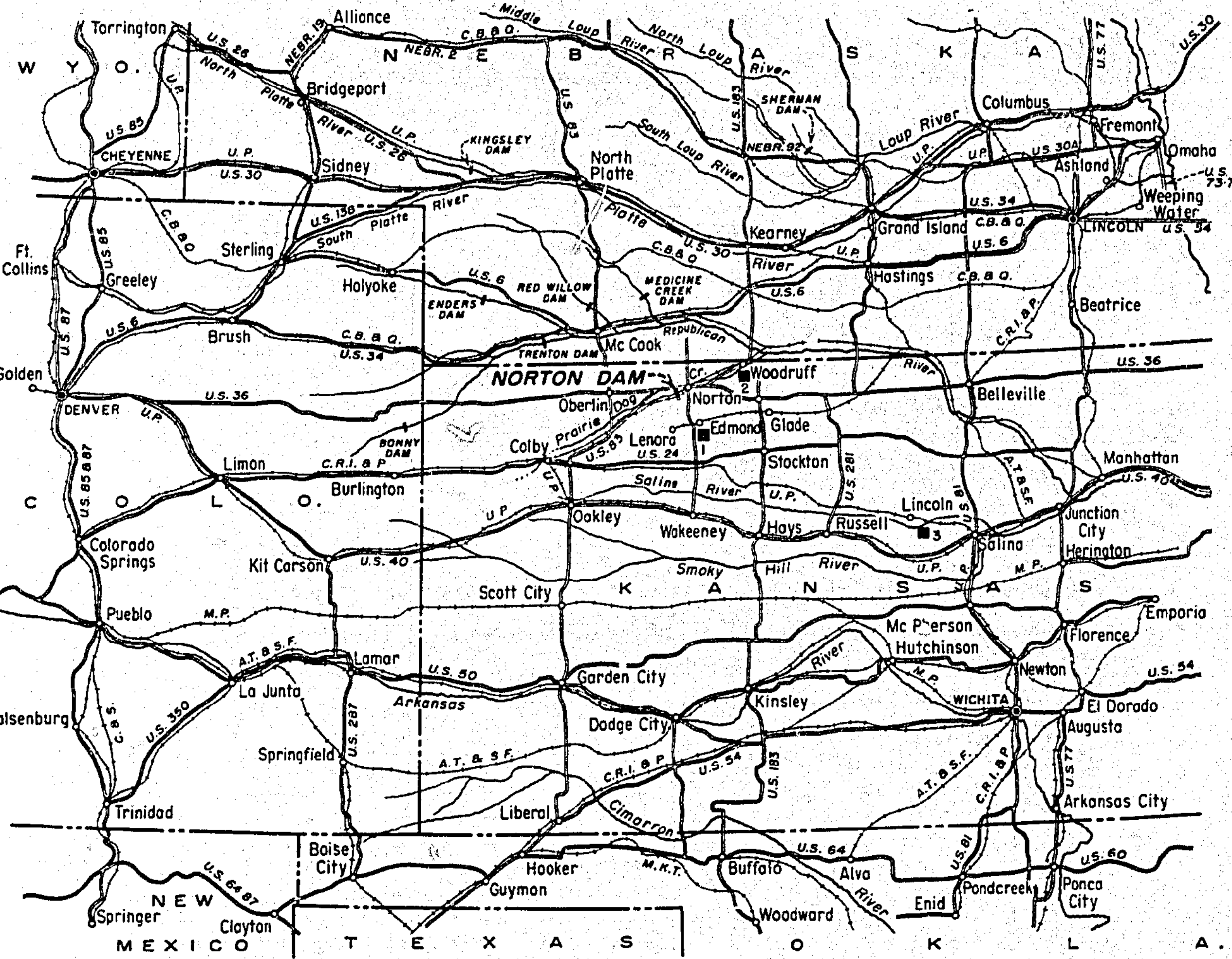
Q cfs	Tailwater elevation	Distance to right of channel ℄	Wave height
385	2250.7	24 ft	0.6
		30 ft	0.5
	2244.3	24 ft	0.7
316	2250.3	24 ft	0.5
		30 ft	0.5
	2243.6	24 ft	0.7
175	2249.3	24 ft	0.5
(Gate 52%		30 ft	0.5
open)	2241.7	20 ft	0.4
		16 ft	0.4

Table 4

TAILWATER SWEEPOUT TESTS

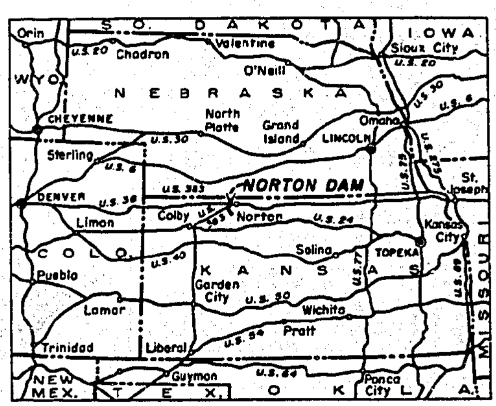
Prototype discharge	Gate opening	Reservoir elevation	Minimum tailwater	Initial sweepout	Complete sweepout
385	100	2331.4	2244.3	2242.4	2240.7
316	100	2304.3	2243.6	No sweepout*	
289	75	2331.4	2243.3	2241.5	None
237	75	2304.3	2242.7	No sweepout	
200	50	2331.4	2242.1	No sweepout*	

*Downstream end of basin controlling.
Initial sweepout--Chute blocks become exposed.
Complete sweepout--Jump leaves basin completely.



■ ROCK DEPOSITS

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



KEY MAP

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

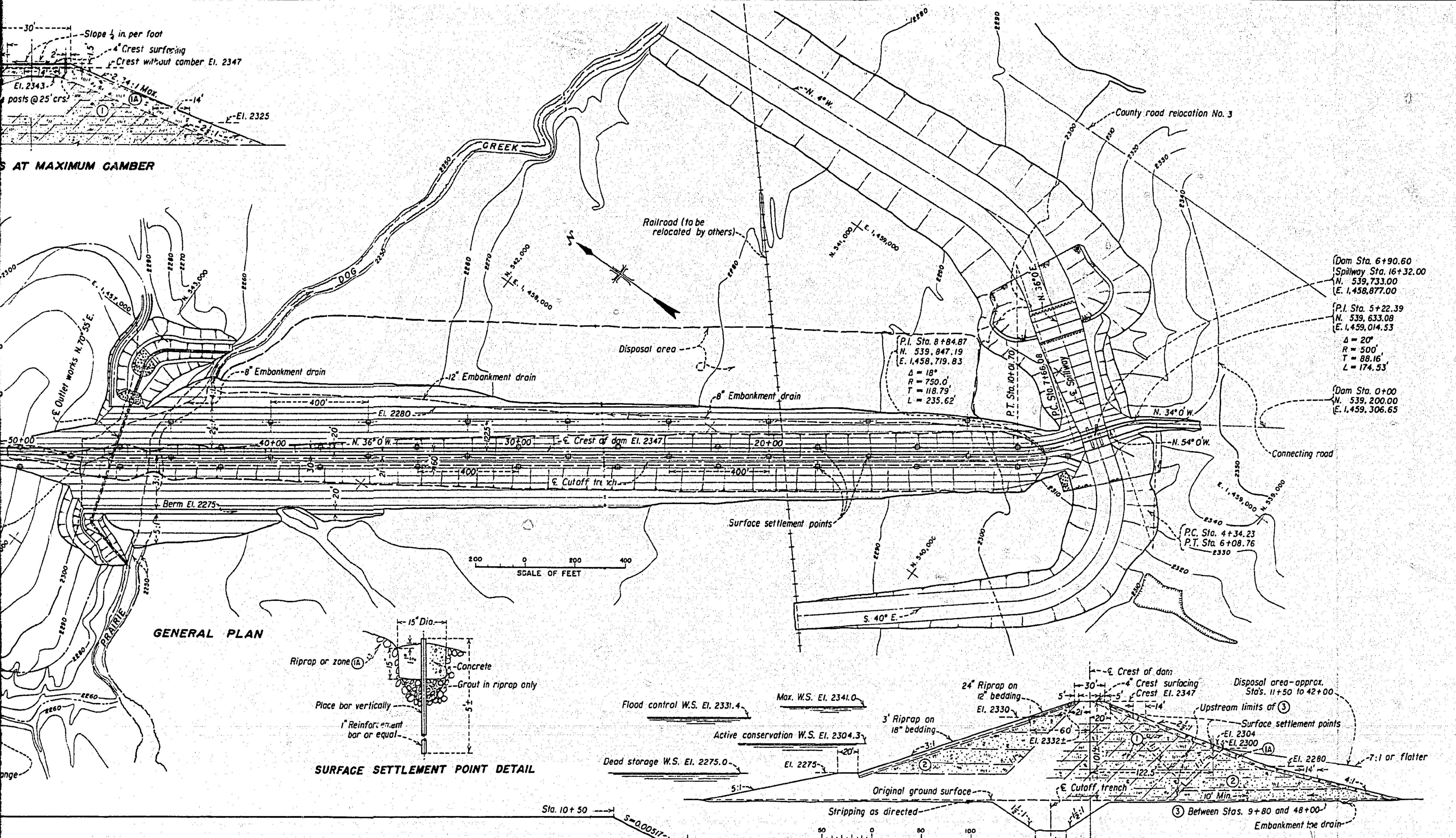
NORTON DAM
LOCATION MAP

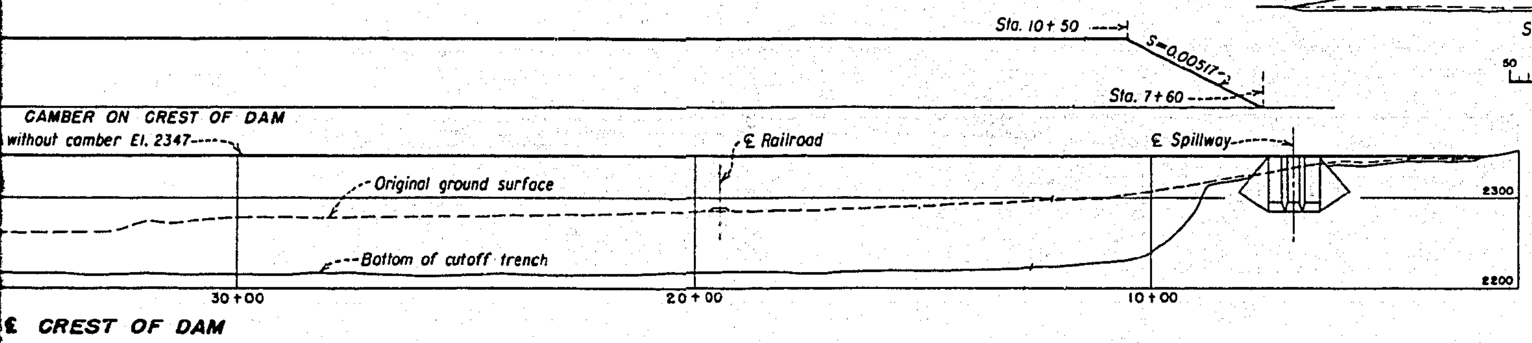
DRAWN W.W.G. SUBMITTED R. J. Larsen
TRACED W.W.G. RECOMMENDED J. F. Rice
CHECKED [signature] APPROVED [signature]
ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO, APRIL 6, 1962 | 492-D-115

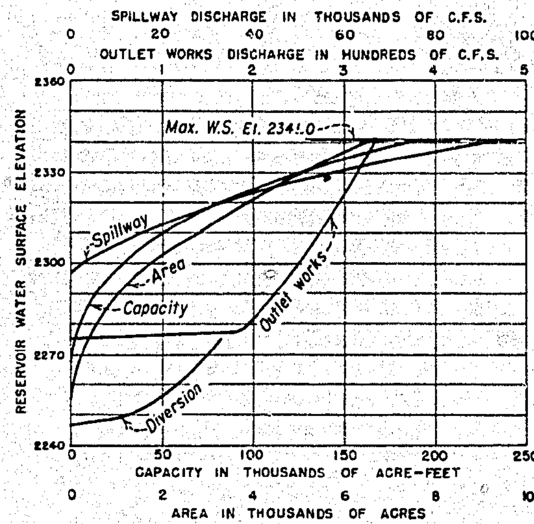
RESERVOIR STORAGE ALLOCATIONS

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 1[illegible] c.f.s. and a 4-day volume of 284,800 A.F.







AREA-CAPACITY-DISCHARGE CURVES

NOTE

For guide post details, see Dwg. 492-701-76.
The slopes of the division lines between zones are tentative and subject to variation.

EMBANKMENT EXPLANATION

① Selected clay, silt and sand compacted by tamping rollers to 6-inch layers.
(1A) Selected topsoil compacted by tamping rollers to 6-inch layers.
② Sand, or sand, silt, and clay compacted by crawler type tractor to 6-inch layers.
③ Selected sand compacted to 12-inch layers to 75% relative density.

7-11-62 D. AWB	CHANGED SPACING OF GUIDE POSTS

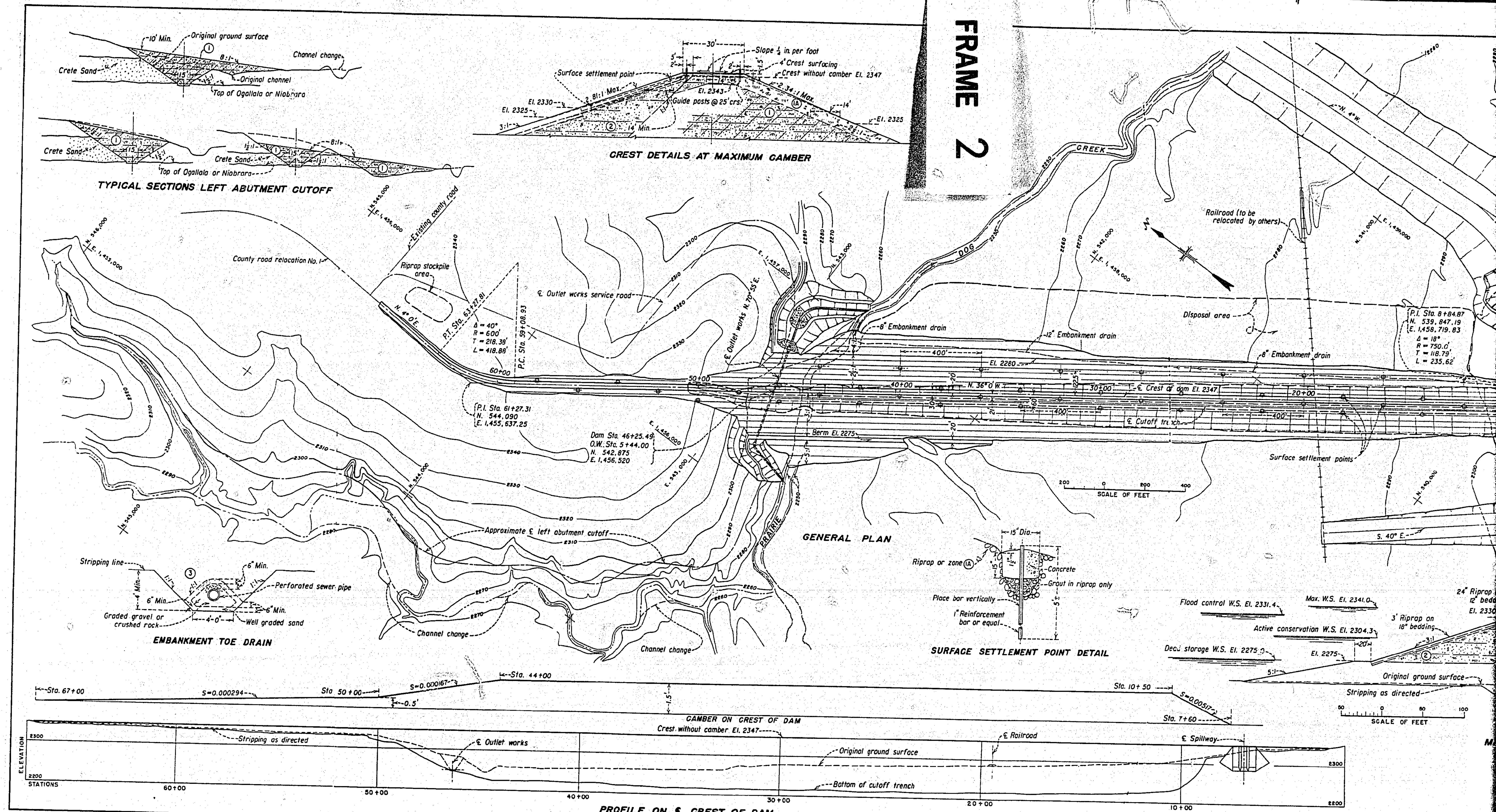
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
KANASKA DIV.-ALMENA UNIT-KANSAS

NORTON DAM

GENERAL PLAN AND SECTIONS

DRAWN E.C.P. SUBMITTED [signature]
TRACED J.L. RECOMMENDED [signature]
CHECKED [signature] APPROVED [signature] ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO. APRIL 9, 1962 492-D-119

FRAME 2



TYPICAL SECTIONS LEFT ABUTMENT CUTOFF
Original ground surface
Channel change
Crete Sand
Original channel
Top of Ogallala or Niobrara
CREST DETAILS AT MAXIMUM CAMBER
Slope 1/4 in. per foot
4' Crest surfacing
Crest without camber El. 2347
Surface settlement point
Guide posts @ 25' crs.
El. 2343
El. 2330
El. 2325
GENERAL PLAN
Existing county road
County road relocation No. 1
Riprap stockpile area
℄ Outlet works service road
P.T. Sta. 63+27.81
P.C. Sta. 59+08.93
Δ = 40°
R = 600'
T = 218.39'
L = 418.88'
P.I. Sta. 61+27.31
N. 544,090
E. 1,455,637.25
Dam Sta. 46+25.49
O.W. Sta. 5+44.00
N. 542,875
E. 1,456,520
℄ Outlet works N. 70°55' E.
8" Embankment drain
12" Embankment drain
El. 2280
N. 36°0' W.
℄ Crest of dam El. 2347
℄ Cutoff trench
Berm El. 2275
Surface settlement points
Disposal area
Railroad (to be relocated by others)
P.I. Sta. 8+84.87
N. 539,847.19
E. 1,458,719.83
Δ = 18°
R = 750.0'
T = 118.79'
L = 235.62'
DOG CREEK
PRAIRIE
Approximate ℄ left abutment cutoff
Channel change
SCALE OF FEET
S. 40° E.
EMBANKMENT TOE DRAIN
Stripping line
Perforated sewer pipe
Graded gravel or crushed rock
Well graded sand
SURFACE SETTLEMENT POINT DETAIL
15" Dia.
Riprap or zone (1A)
Concrete
Grout in riprap only
Place bar vertically
1" Reinforcement bar or equal
Flood control W.S. El. 2331.4
Max. W.S. El. 2341.0
Active conservation W.S. El. 2304.3
Dead storage W.S. El. 2275.0
24" Riprap
3' Riprap on 18" bedding
El. 2275
Original ground surface
Stripping as directed
CAMBER ON CREST OF DAM
Sta. 67+00
S=0.000294
Sta. 50+00
S=0.000167
Sta. 44+00
Sta. 10+50
S=0.00517
Sta. 7+60
PROFILE ON ℄ CREST OF DAM
Crest without camber El. 2347
Stripping as directed
℄ Outlet works
℄ Railroad
℄ Spillway
Original ground surface
Bottom of cutoff trench
ELEVATION
STATIONS

FIGURE 3
REPORT HYD-497

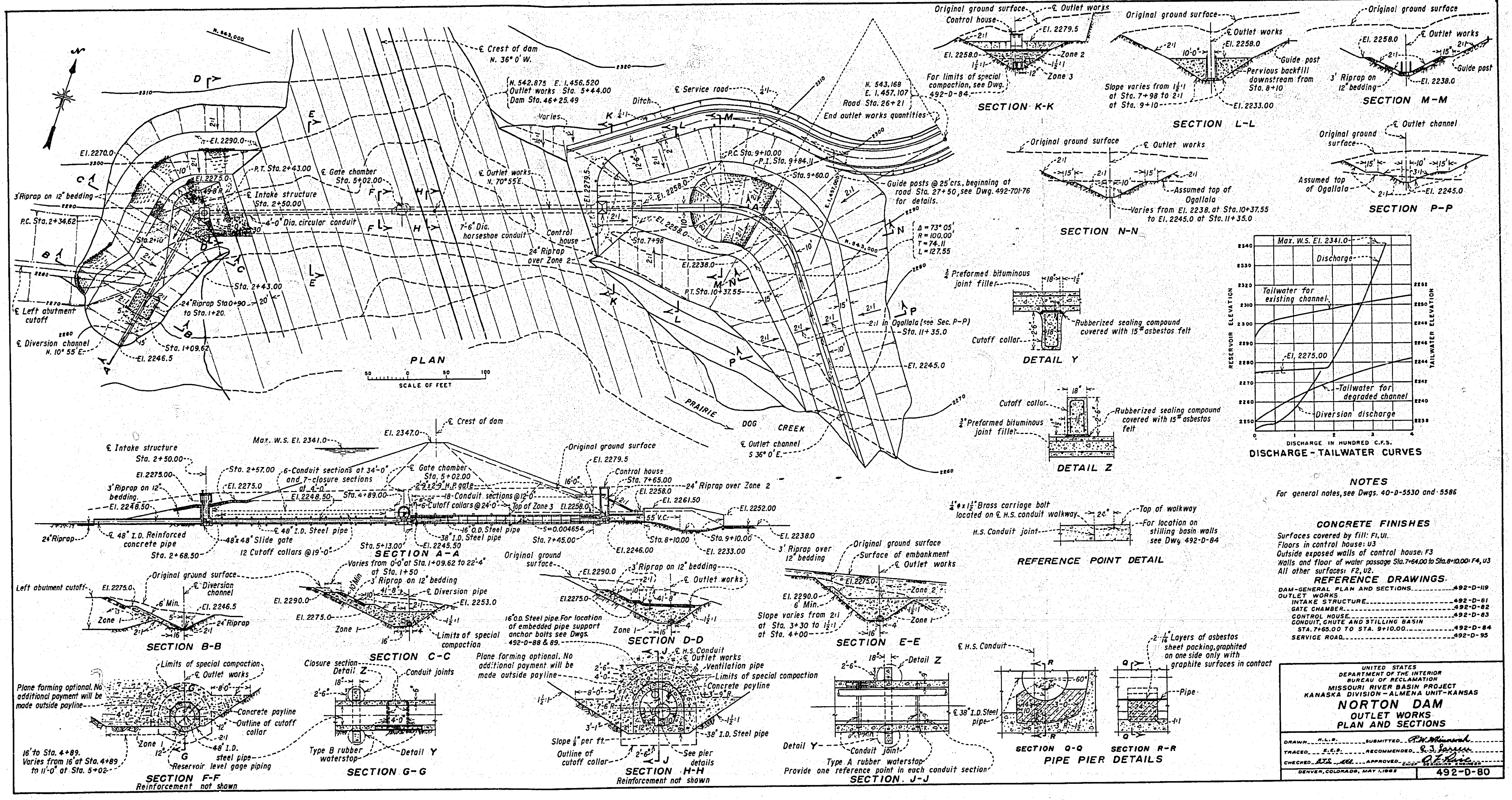
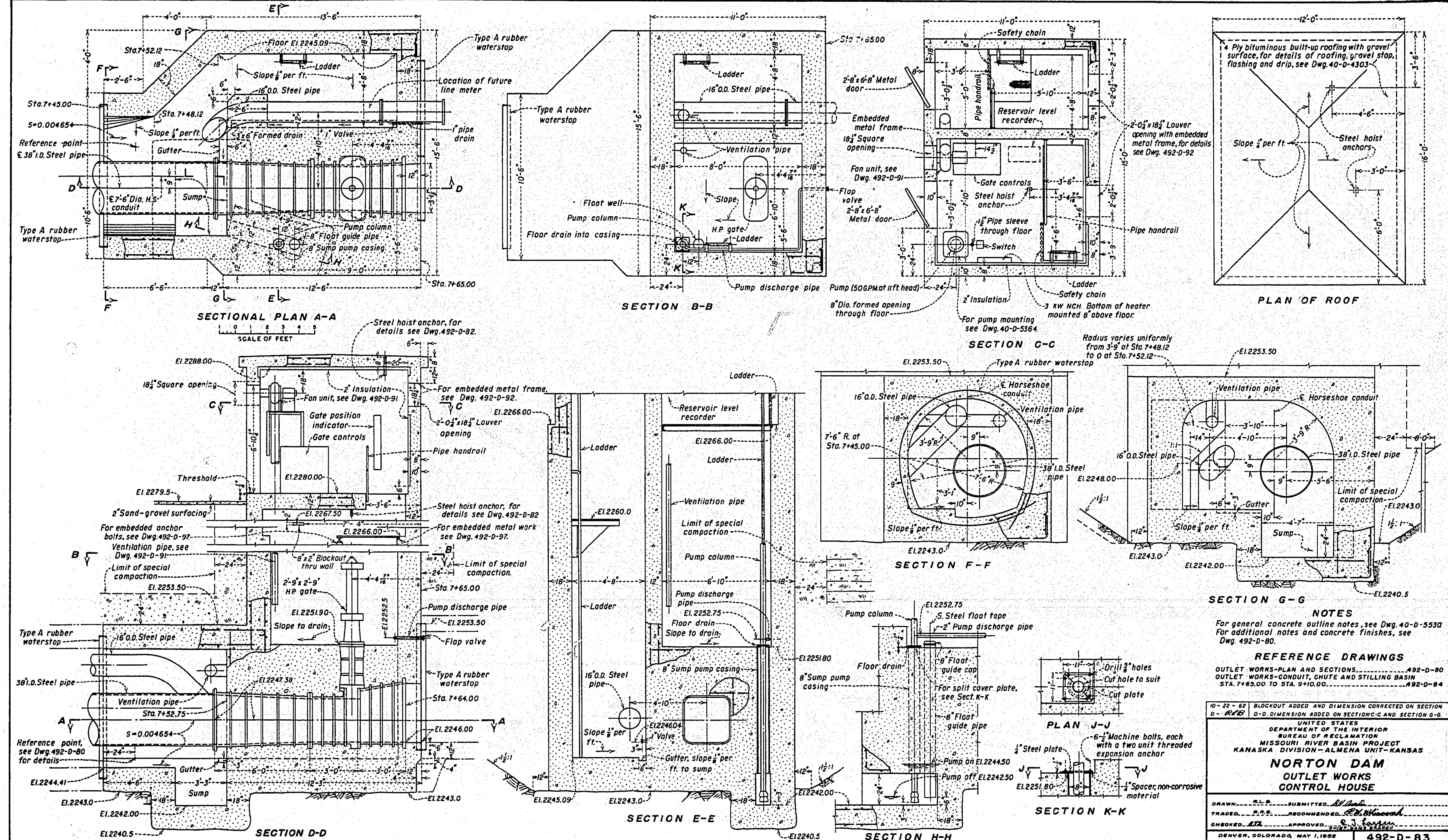
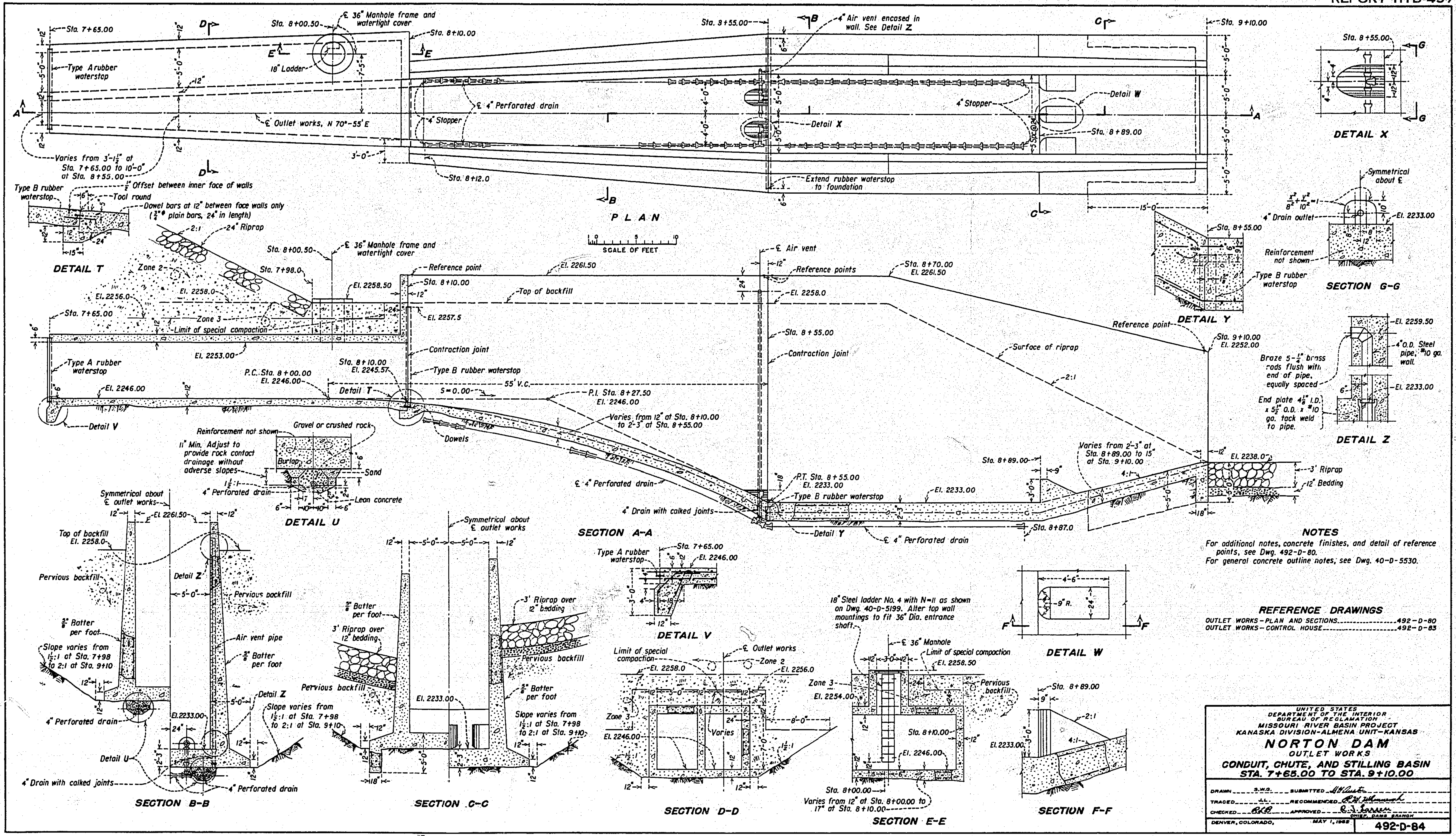


FIGURE 4
REPORT HYD-497




PLAN
SECTION A-A
DETAIL T
DETAIL U
DETAIL V
DETAIL W
DETAIL X
DETAIL Y
DETAIL Z
SECTION G-G
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SCALE OF FEET
NOTES
For additional notes, concrete finishes, and detail of reference points, see Dwg. 492-D-80.
For general concrete outline notes, see Dwg. 40-D-5530.
REFERENCE DRAWINGS
OUTLET WORKS-PLAN AND SECTIONS.....492-D-80
OUTLET WORKS-CONTROL HOUSE.....492-D-83
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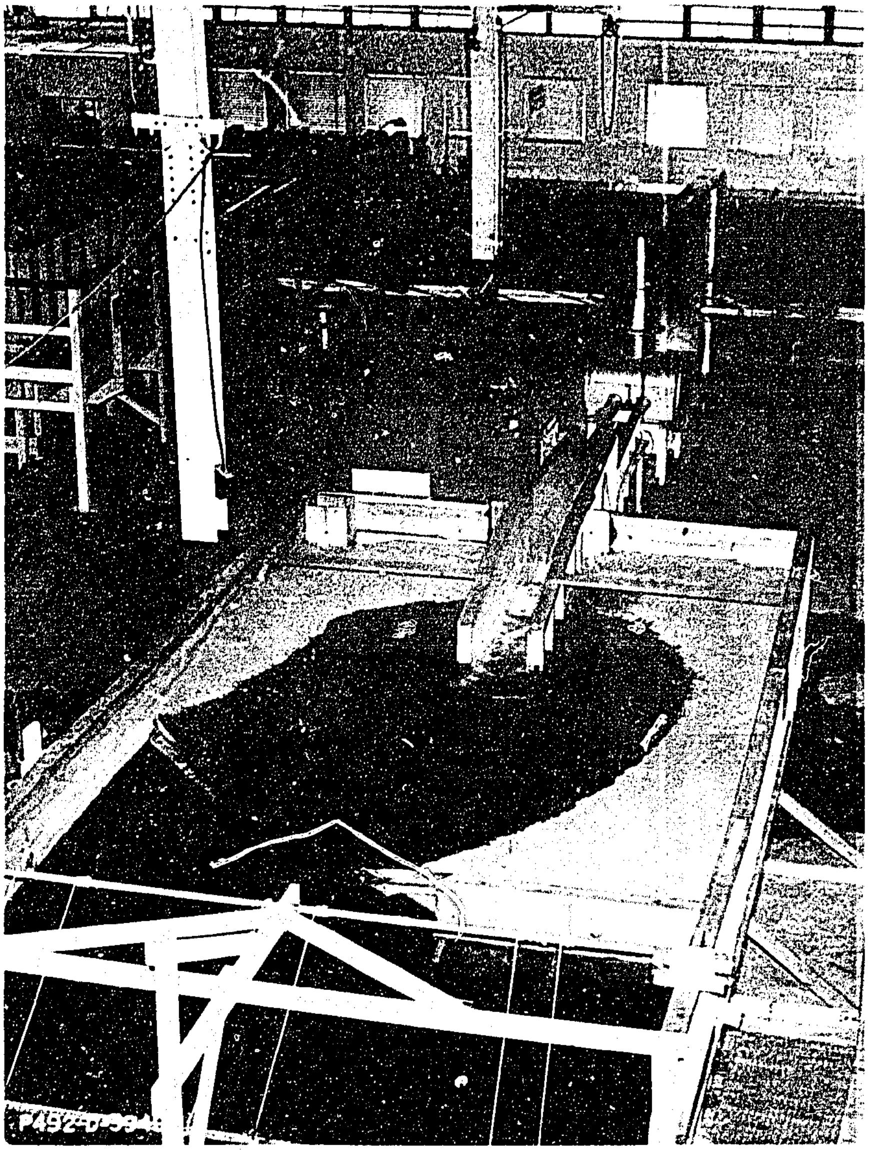
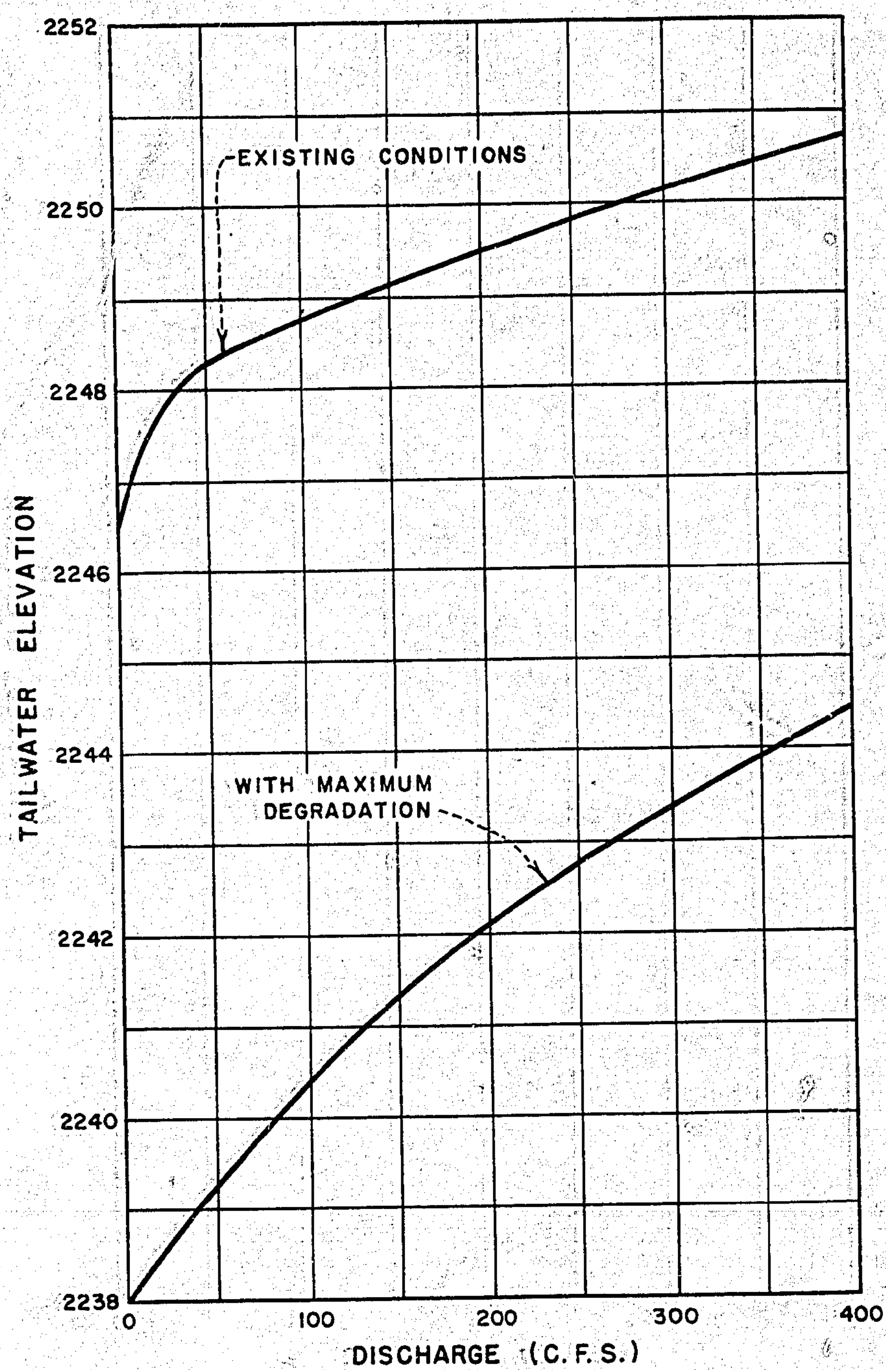
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
KANASKA DIVISION-ALMENA UNIT-KANSAS
NORTON DAM
OUTLET WORKS
CONDUIT, CHUTE, AND STILLING BASIN
STA. 7+65.00 TO STA. 9+10.00
DENVER, COLORADO, MAY 1, 1962
492-D-84



NORTON DAM OUTLET WORKS
1:8.25 Scale Model

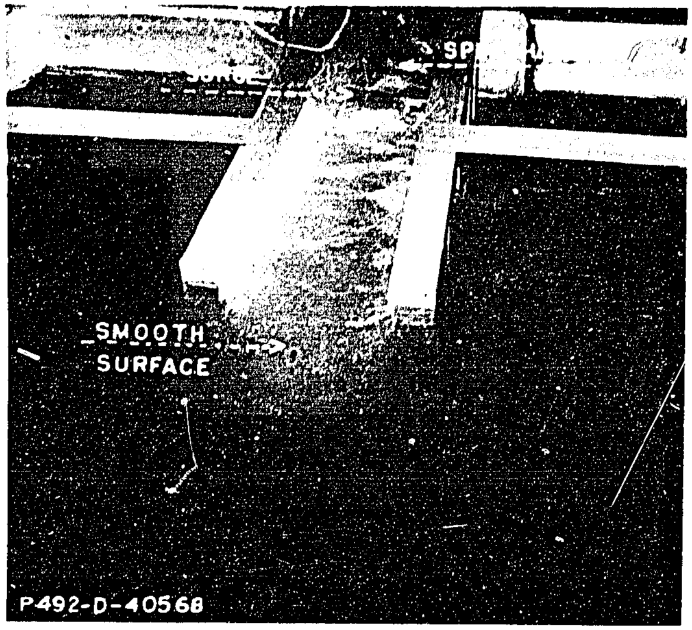
Completed Model



NORTON DAM OUTLET WORKS

1:8.25 SCALE MODEL

TAILWATER CURVES

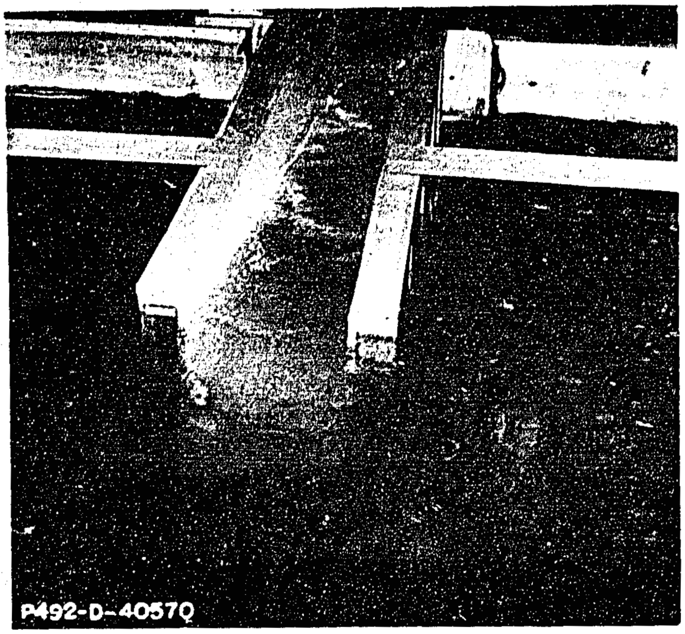


A. Tailwater elevation 2250.7

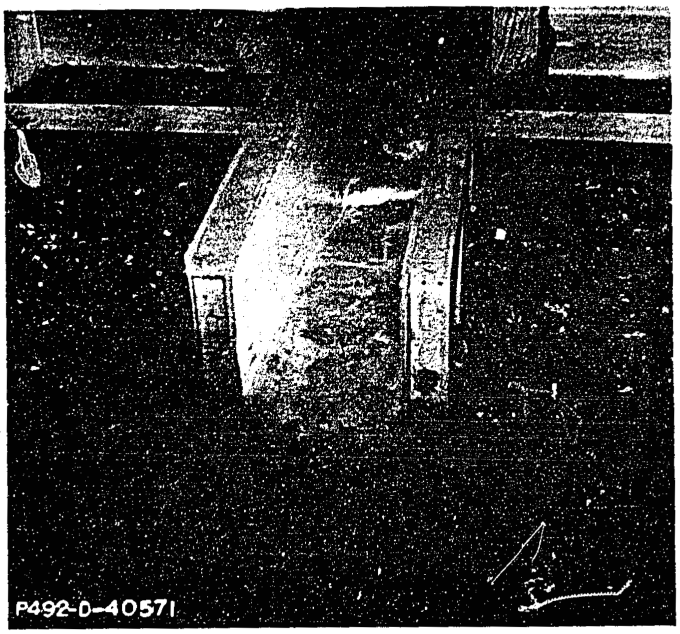
B. Tailwater elevation 2244.3

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Stilling basin operation for Q = 385 cubic feet per second, minimum losses in system, 100 percent gate opening, reservoir at top of flood control pool.



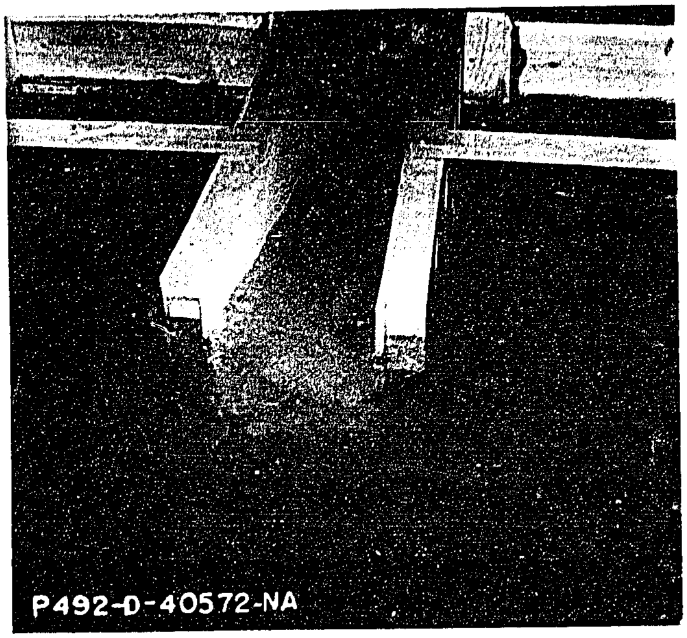
A. Tailwater elevation 2250.3



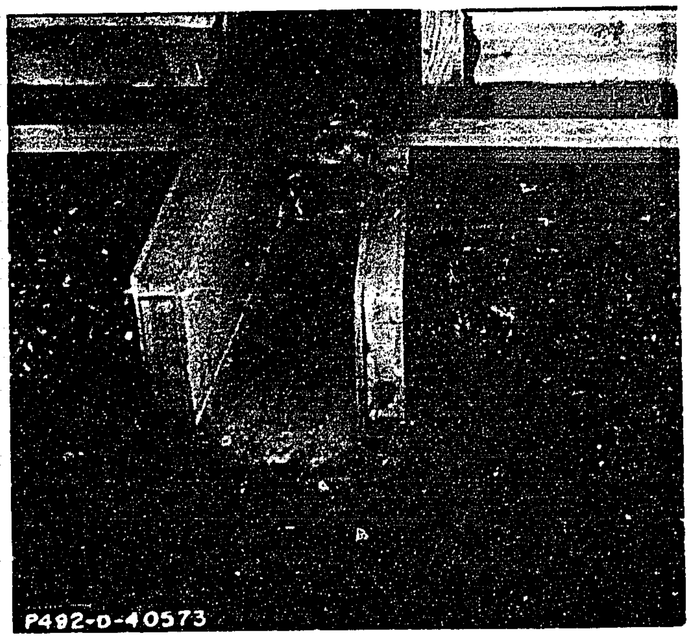
B. Tailwater elevation 2243.6

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Stilling basin operation for Q = 316 cubic feet per second, minimum losses in system, 100 percent gate opening, reservoir at top of active conservation storage.



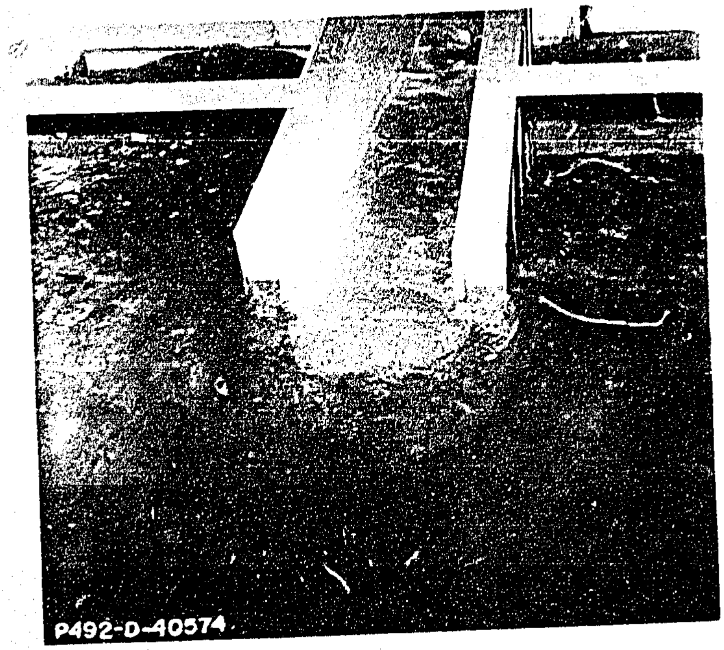
A. Tailwater elevation 2249.9



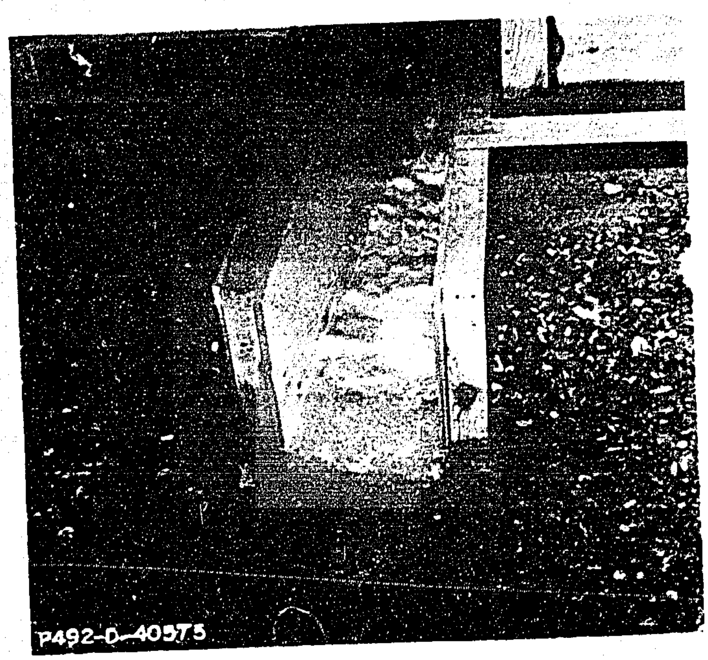
B. Tailwater elevation 2242.9

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Stilling basin operation for Q = 260 cubic feet per second, maximum losses in system, 100 percent gate opening, reservoir at top of active conservation storage.



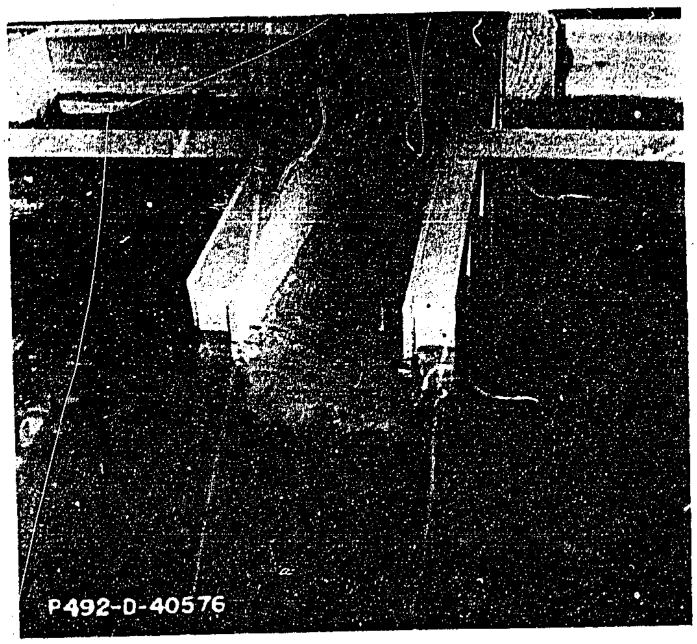
A. Tailwater elevation 2249.3



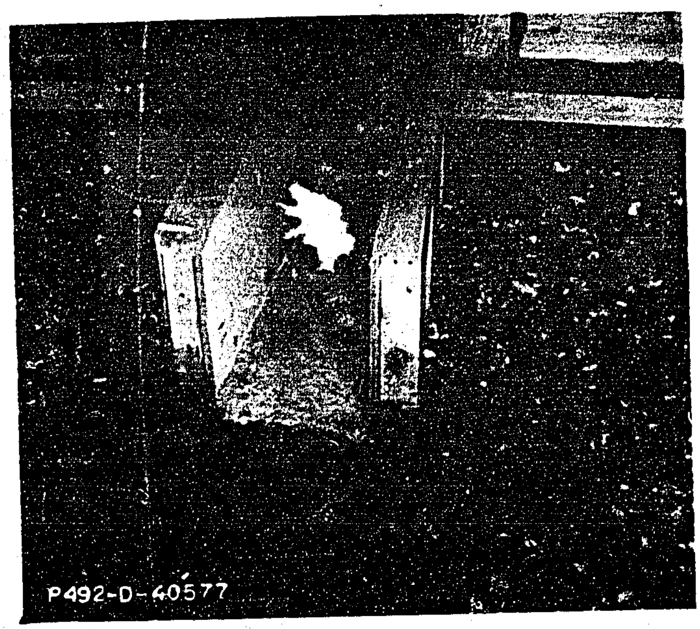
B. Tailwater elevation 2241.7

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Stilling basin operation for Q = 175 cubic feet per second, minimum losses in system, 43 percent gate opening, reservoir at top of flood control pool.



A. Tailwater elevation 2249.3



B. Tailwater elevation 2241.7

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

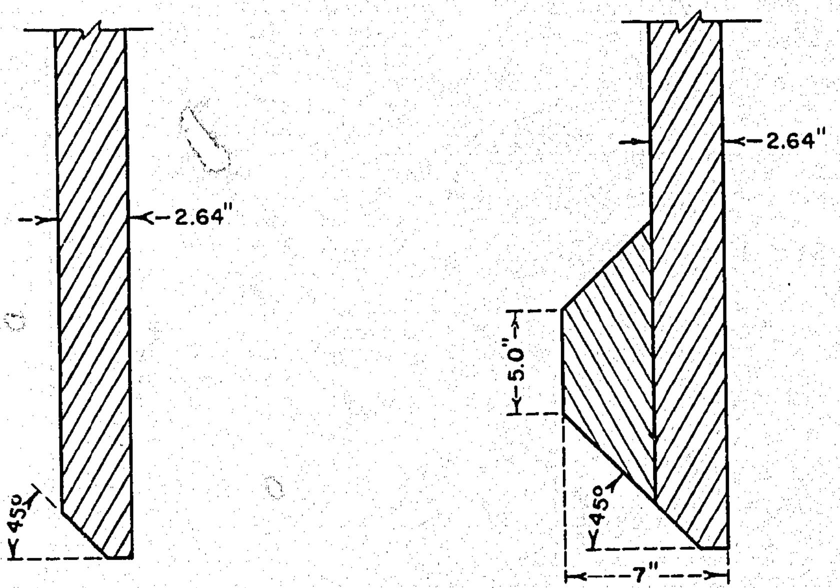
Stilling basin operation for Q = 175 cubic feet per second, minimum losses in system, 52 percent gate opening, reservoir at top of active conservation storage.

A. 52 percent gate opening. Reservoir at top of active conservation storage

B. 43 percent gate opening. Reservoir at top of flood control pool

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Flow conditions on the chute for Q = 175 cubic feet per second.



MODEL GATE LEAF

REVISED GATE LEAF
(To represent prototype leaf)

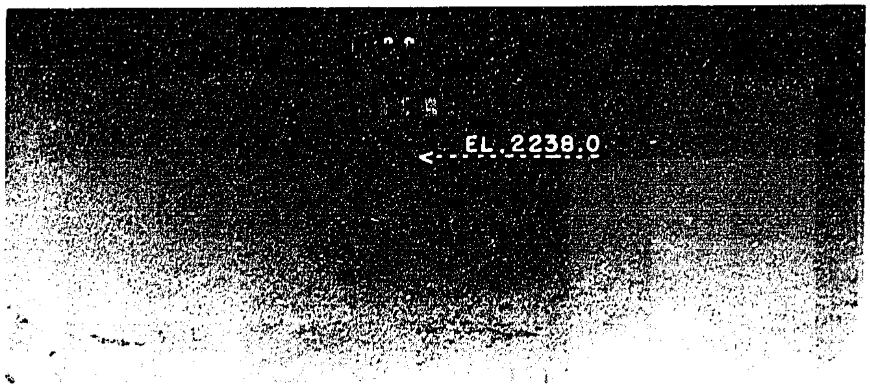
PERCENT GATE OPENING	MODEL LEAF DISCHARGE COEFFICIENT	REVISED MODEL LEAF DISCHARGE COEFFICIENT
50	.365	.373
25	.175	.178

$$C = \frac{Q}{A\sqrt{2gH}}$$

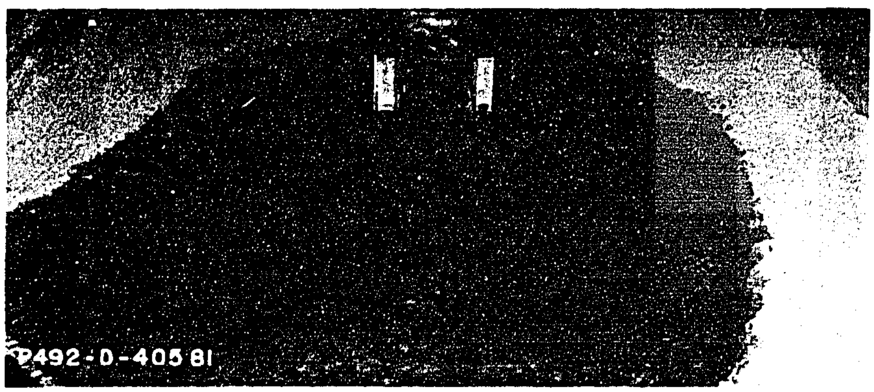
C = coefficient of discharge
A = area of 100 percent gate opening
H = total head (pressure head + velocity head) immediately upstream from gate.

NORTON DAM OUTLET WORKS
1:8.25 SCALE MODEL
DISCHARGE COEFFICIENTS FOR MODEL GATE LEAF AND REVISED MODEL GATE LEAF

663



A. Sand bed before erosion test.

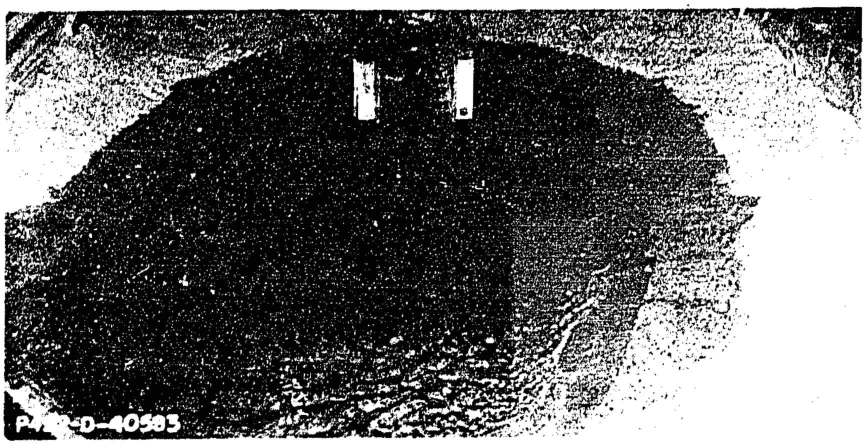


B. Q = 385 cubic feet per second, tailwater elevation 2244.3

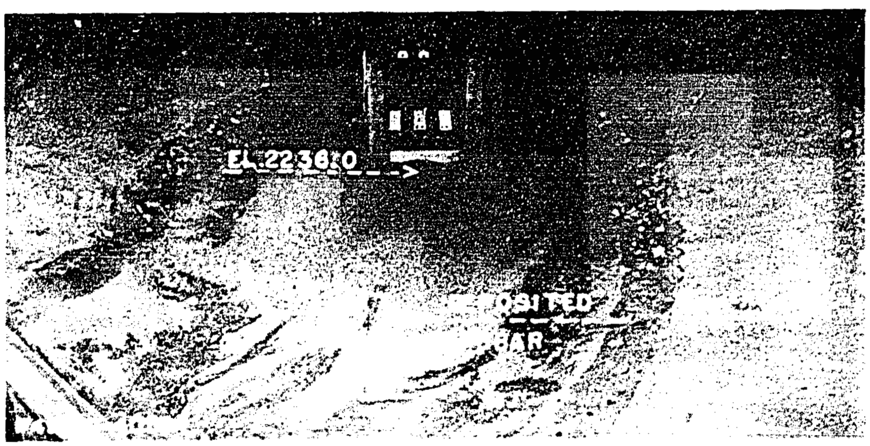
C. Sand bed after 12 equivalent prototype hours at discharge in B.

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Erosion test for maximum discharge with minimum losses in system, reservoir at top of flood control pool.



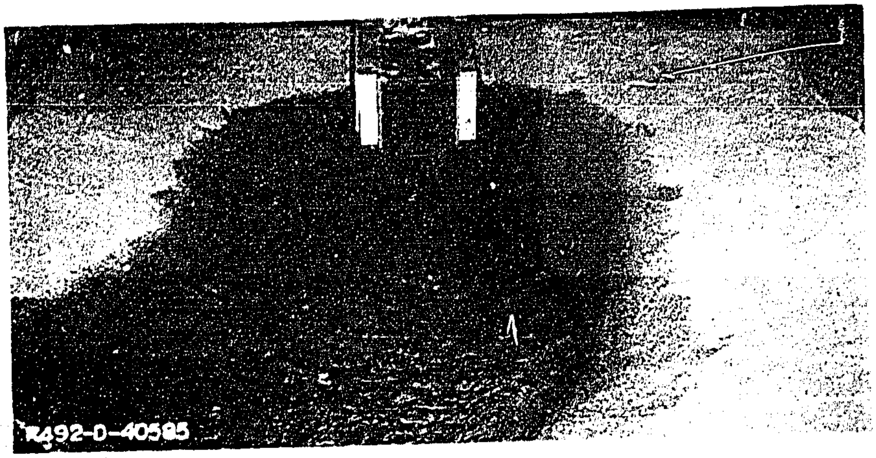
A. Q = 315 cubic feet per second, tailwater elevation 2243.6



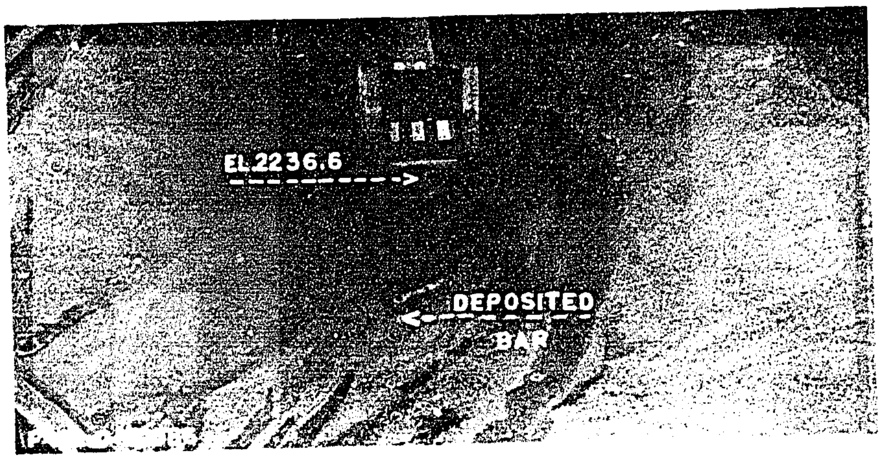
B. Sand bed after 12 equivalent prototype hours at discharge in A.

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

Erosion test for maximum discharge with minimum losses in system, reservoir at top of active conservation storage.



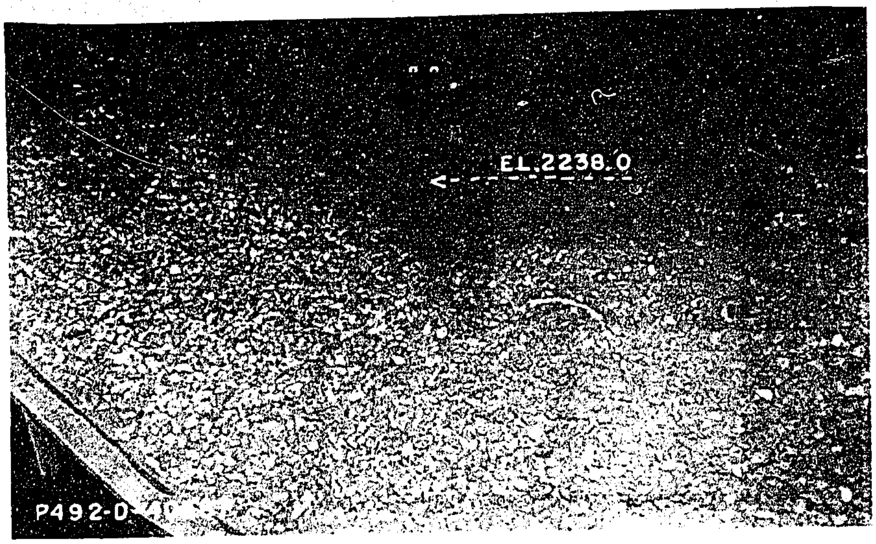
A. Q = 175 cubic feet per second, 52 percent gate opening, tailwater elevation 2241.7



B. Sand bed after 12 equivalent prototype hours at discharge in A.

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

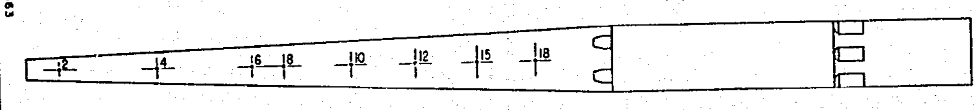
Erosion test for normal discharge with minimum losses in system, reservoir at top of active conservation storage.



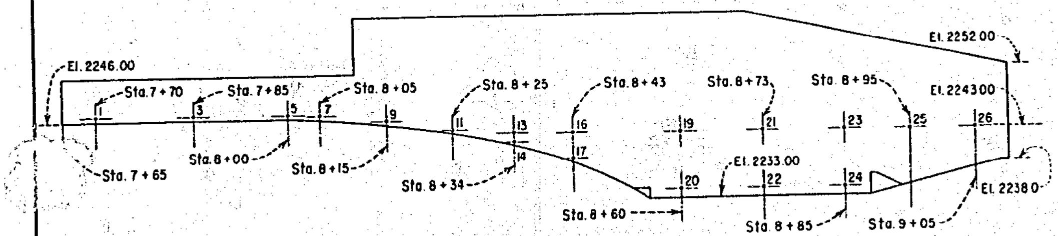
Condition of riprap before and after 12 hours (equivalent prototype time) operation with Q = 385 cubic feet per second, tailwater elevation 2244.3

NORTON DAM OUTLET WORKS
1:8.25 Scale Model

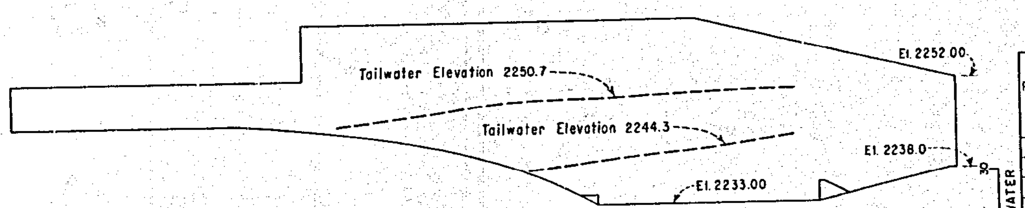
Riprap Test



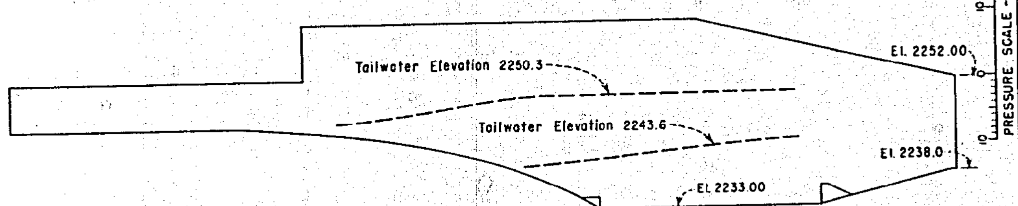
PIEZOMETER LOCATIONS
PLAN



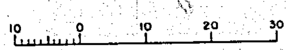
PIEZOMETER LOCATIONS
ELEVATION
PIEZOMETERS ARE LOCATED IN RIGHT TRAINING WALL OF STILLING BASIN



PRESSURE PROFILES
Q = 385 C.F.S.



PRESSURE PROFILES
Q = 316 C.F.S.



PRESSURES - PROTOTYPE FEET OF WATER
Q = 385 C.F.S. GATE 100% OPEN

PIEZOMETER NUMBER	TAILWATER ELEVATION 2250.7						TAILWATER ELEVATION 2244.3					
	WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
9	0.2	-0.4	-0.1	—	—	—	—	—	—	—	—	—
10	-1.8	-2.1	-2.0	—	—	—	—	—	—	-0.5	-1.7	-1.5
11	3.1	2.3	2.7	—	—	—	—	—	—	—	—	—
12	2.9	2.1	2.5	—	—	—	—	—	—	0.7	-0.2	0.2
13	5.1	4.4	4.8	—	—	—	—	—	—	—	—	—
14	6.8	6.0	6.4	—	—	—	—	—	—	4.0	-3.4	-0.1
15	6.8	6.4	6.6	—	—	—	—	—	—	1.0	0.2	0.6
16	6.2	5.1	5.7	—	—	—	0.0	0.0	0.0	—	—	—
17	10.9	10.1	10.5	—	—	—	0.0	-0.7	-0.4	15.2	-3.8	2.0
18	10.9	10.1	10.5	—	—	—	1.2	0.7	1.0	15.8	-4.3	1.7
19	7.8	6.2	7.0	—	—	—	0.0	0.0	0.0	—	—	—
20	15.9	14.9	15.4	—	—	—	6.7	5.5	6.1	—	—	—
21	7.9	7.0	7.5	8.7	7.4	8.1	0.2	0.0	0.1	—	—	—
22	16.4	15.7	16.1	17.8	16.0	17.3	8.0	7.1	7.6	—	—	—
23	8.0	7.5	7.8	8.7	7.6	8.3	1.3	0.3	0.8	—	—	—
24	17.0	16.5	16.8	17.2	16.3	16.7	10.1	9.1	9.6	—	—	—
25	7.9	7.6	7.8	9.0	7.8	8.4	2.0	1.4	1.7	—	—	—
26	7.8	7.7	7.8	8.6	7.8	8.2	1.7	1.4	1.6	—	—	—

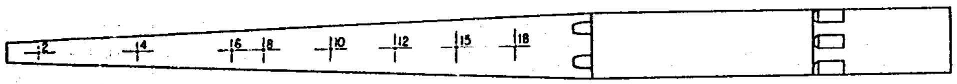
Q = 316 C.F.S. GATE 100% OPEN

PIEZOMETER NUMBER	TAILWATER ELEVATION 2250.3						TAILWATER ELEVATION 2243.6					
	WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
9	0.9	0.1	0.5	—	—	—	—	—	—	—	—	—
10	0.1	-0.6	-0.3	—	—	—	—	—	—	-0.5	-1.3	-0.9
11	4.0	3.0	3.5	—	—	—	—	—	—	—	—	—
12	4.1	3.4	3.8	—	—	—	—	—	—	0.6	-0.2	0.2
13	6.0	4.9	5.5	—	—	—	—	—	—	—	—	—
14	7.9	7.1	7.5	—	—	—	—	—	—	3.2	-3.4	0.1
15	7.8	7.2	7.5	—	—	—	—	—	—	0.6	0.6	0.6
16	7.1	5.9	6.5	—	—	—	0.0	0.0	0.0	—	—	—
17	12.0	11.1	11.6	—	—	—	1.4	0.8	1.1	14.4	-3.8	2.0
18	12.4	11.6	12.0	—	—	—	2.8	2.4	2.6	14.9	-4.3	1.7
19	7.8	6.9	7.4	—	—	—	0.0	0.0	0.0	—	—	—
20	16.6	15.7	16.2	—	—	—	7.4	6.4	6.9	—	—	—
21	7.8	7.4	7.6	8.3	7.1	7.6	0.5	0.1	0.3	—	—	—
22	16.5	16.2	16.4	17.0	16.0	16.5	8.7	7.9	8.3	—	—	—
23	7.8	7.4	7.6	8.1	7.3	7.6	1.2	0.5	0.9	—	—	—
24	16.7	16.3	16.5	16.6	15.9	16.3	9.7	9.0	9.4	—	—	—
25	7.3	7.1	7.2	8.2	7.3	7.8	1.2	0.7	1.0	—	—	—
26	7.7	7.5	7.6	8.2	7.3	7.8	0.9	0.7	0.8	—	—	—

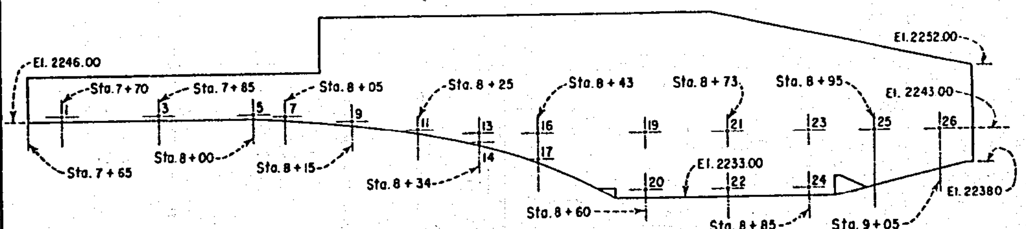
Pressure measured above piezometer opening.
Blank spaces indicate no data were taken.

NORTON DAM OUTLET WORKS
1:8.25 SCALE MODEL
PIEZOMETER LOCATIONS, STILLING BASIN PRESSURES, AND PRESSURE PROFILES

SHEET 1 OF 2

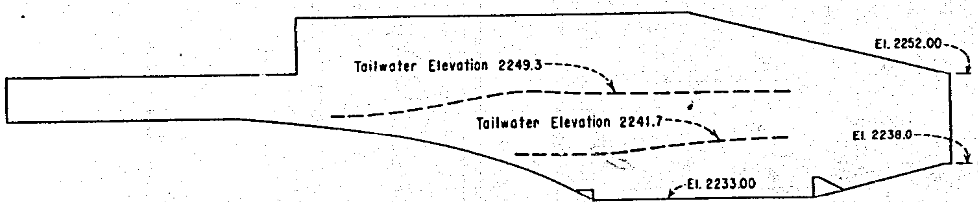


PIEZOMETER LOCATIONS PLAN

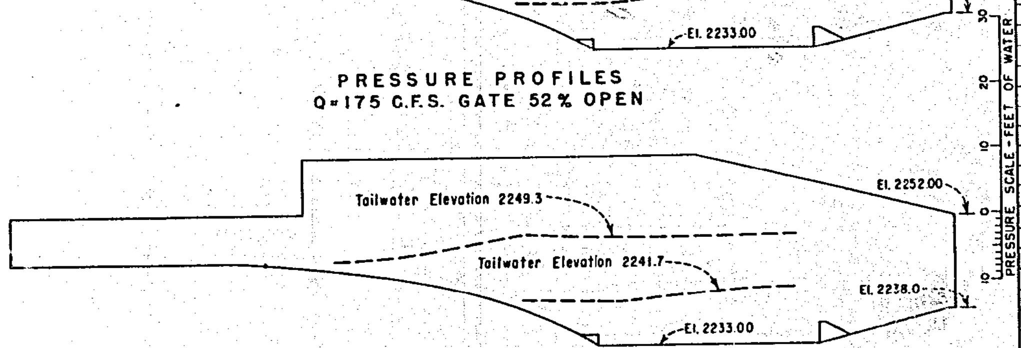


PIEZOMETER LOCATIONS ELEVATION

PIEZOMETERS ARE LOCATED IN RIGHT TRAINING WALL OF STILLING BASIN



PRESSURE PROFILES
Q=175 C.F.S. GATE 52% OPEN



PRESSURE PROFILES
Q=175 C.F.S. GATE 43% OPEN

10 0 10 20 30
SCALE OF FEET

PRESSURES—PROTOTYPE FEET OF WATER
Q=175 C.F.S. GATE 52% OPEN

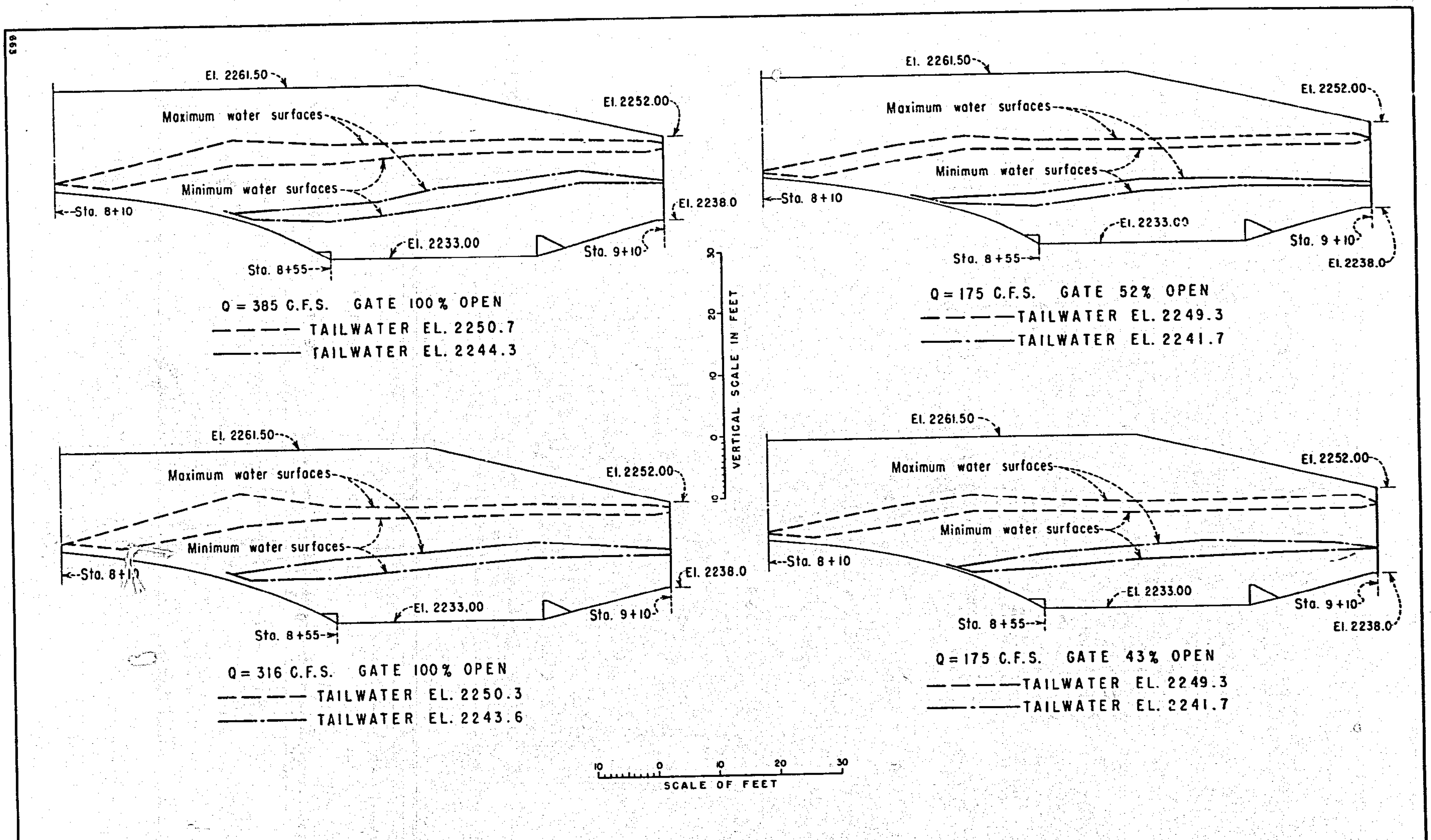
PIEZOMETER NUMBER	TAILWATER ELEVATION 2249.3 — WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			TAILWATER ELEVATION 2241.7 — WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
9	0.5	0.0	0.3				—	—	—	—	—	—
10	-1.4	-1.9	-1.7				—	—	—	-1.3	-2.1	-1.7
11	3.1	2.4	2.8				—	—	—	—	—	—
12	3.3	2.6	3.0				—	—	—	0.7	-0.2	0.2
13	5.1	4.3	4.7				—	—	—	—	—	—
14	7.3	6.3	6.8				—	—	—	2.4	-2.6	-0.1
15	15.4	14.9	15.1				—	—	—	0.2	0.2	0.2
16	6.4	5.9	6.2				—	—	—	—	—	—
17	11.4	11.0	11.2	NO INSTANTANEOUS PRESSURES TAKEN			1.5	1.1	1.3	11.9	-3.8	2.0
18	11.7	11.2	11.5				1.6	1.3	1.5	13.3	-6.5	1.7
19	6.4	6.0	6.2				—	—	—	—	—	—
20	15.2	14.8	15.0				6.4	5.3	5.9	—	—	—
21	6.4	6.1	6.3				—	—	—	—	—	—
22	15.2	14.9	15.1				7.6	6.8	7.2	—	—	—
23	6.5	6.3	6.4				—	—	—	—	—	—
24	15.3	15.1	15.2				8.1	7.6	7.9	—	—	—
25	6.6	6.3	6.5				—	—	—	—	—	—
26	6.5	6.4	6.5				—	—	—	—	—	—

Q=175 C.F.S. GATE 43% OPEN

PIEZOMETER NUMBER	TAILWATER ELEVATION 2249.3 — WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			TAILWATER ELEVATION 2241.7 — WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
9	0.4	0.0	0.2				—	—	—			
10	-2.2	-2.7	-2.5				—	—	—			
11	3.1	2.3	2.7				—	—	—			
12	3.1	2.5	2.8				—	—	—			
13	5.0	4.2	4.6				—	—	—			
14	6.7	5.9	6.3				—	—	—			
15	6.7	6.0	6.4				—	—	—			
16	6.5	4.9	5.7				—	—	—			
17	11.5	10.8	11.2	NO INSTANTANEOUS PRESSURES TAKEN			1.2	0.7	1.0	NO INSTANTANEOUS PRESSURES TAKEN		
18	11.6	10.9	11.3				-0.6	-0.7	-0.7			
19	6.5	5.9	6.2				—	—	—			
20	15.1	14.8	15.0				6.0	4.6	5.3			
21	6.5	6.2	6.4				—	—	—			
22	15.2	14.9	15.1				7.1	6.4	6.8			
23	6.6	6.2	6.4				—	—	—			
24	15.3	15.1	15.2				7.8	7.2	7.5			
25	6.6	6.3	6.5				—	—	—			
26	6.5	6.4	6.5				—	—	—			

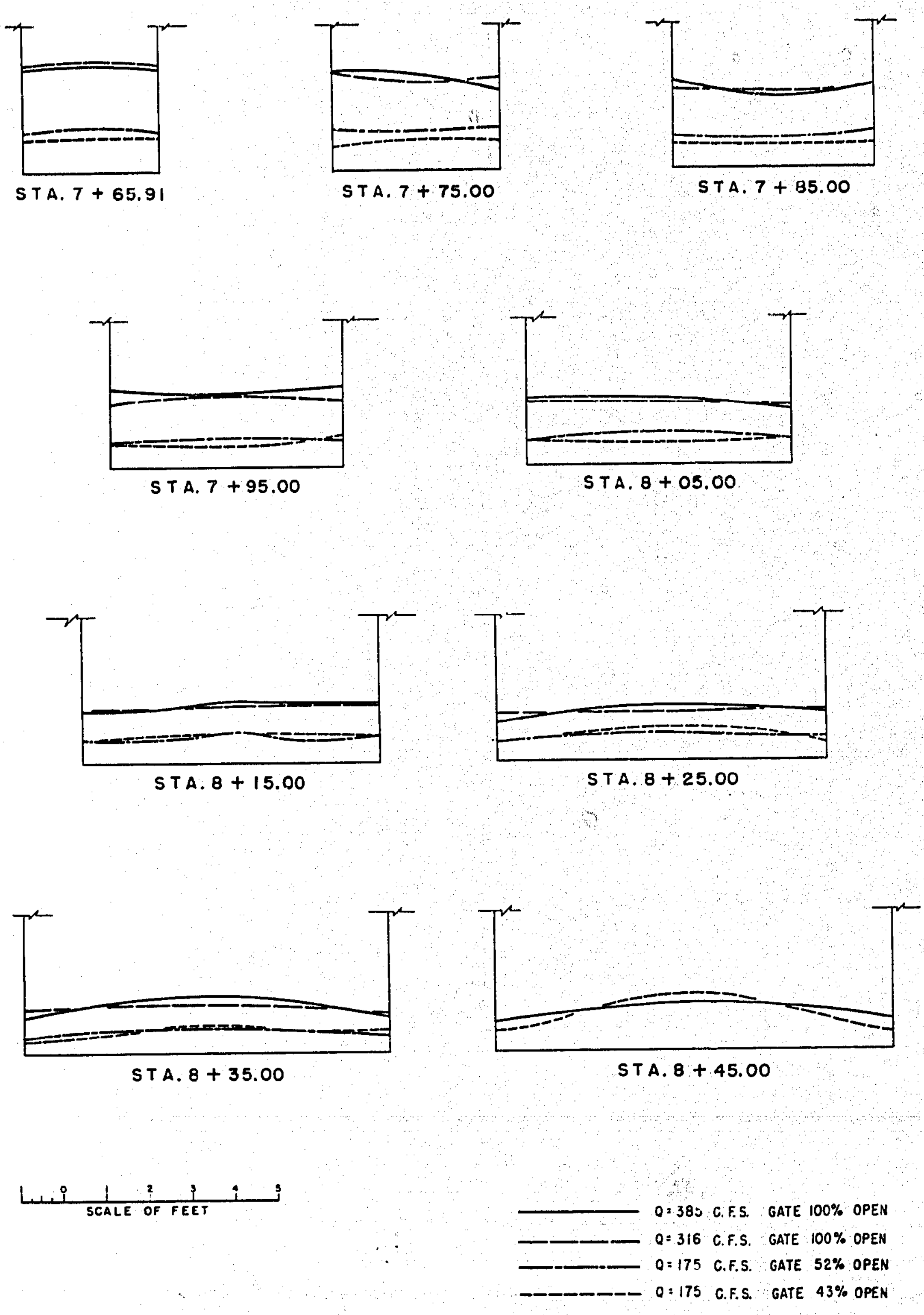
Pressure measured above piezometer opening.
Blank spaces indicate no data were taken.

NORTON DAM OUTLET WORKS
1:8.25 SCALE MODEL
PIEZOMETER LOCATIONS, STILLING BASIN PRESSURES, AND PRESSURE PROFILES



NORTON DAM OUTLET WORKS
1:8.25 SCALE MODEL
STILLING BASIN WATER SURFACE PROFILES

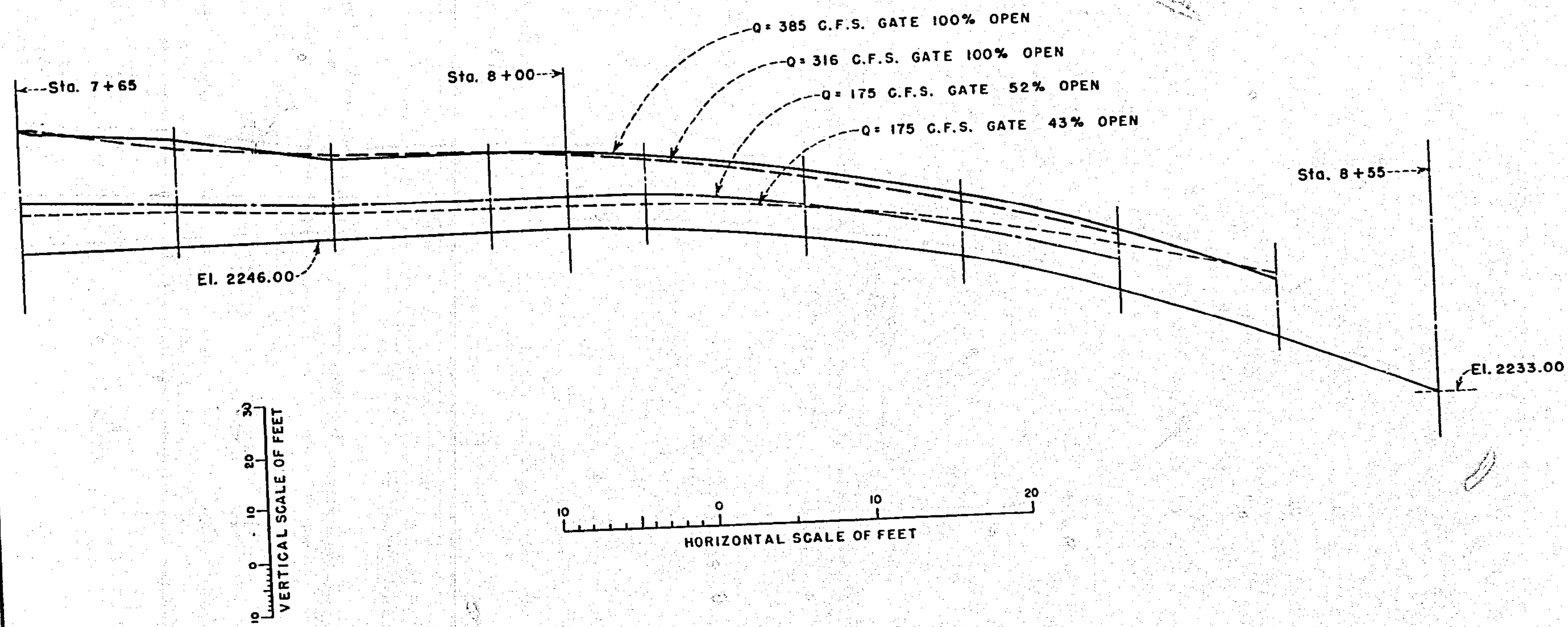
FIGURE 21
REPORT HYD. 497



NORTON DAM OUTLET WORKS

1:8.25 SCALE MODEL

CHUTE TRANSVERSE WATER SURFACE PROFILES



NORTON DAM OUTLET WORKS

1:8.25 SCALE MODEL

CHUTE ℄ WATER SURFACE PROFILES

GPO 837-332