UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF TRINITY DAM OUTLET WORKS

Hydraulic Laboratory Report No. Hyd-439

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

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Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and
Equipment Section
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Laboratory Report No. Hyd-439
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Subject: Hydraulic model studies of Trinity Dam outlet works

SUMMARY

Hydraulic model studies of Trinity Dam outlet works were conducted on a 1:28 scale model to develop the hydraulic design of the outlet works stilling basin.

Observations made on the flow in the model showed the general concept of the preliminary structure to be satisfactory, but that the hydraulic performance of the basin could be improved by reducing the basin length. It was also shown that improvement could be realized by increasing the upward slope of the outlet channel from 5:1 to 2:1. Water surface profiles were obtained from the model for use in the structural design of the basin walls.

ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Spillway and Outlet Works Section and the Hydraulic Laboratory during the period from October 1956 to January 1957. Wai-Han Cheng from Formosa assisted in performing the laboratory tests.

INTRODUCTION

Trinity Dam is a part of the California Central Valley Project. It is located on the Trinity River about 25 miles northwest of Redding, California, Figure 1. The dam, Figure 2, is an earthfill structure approximately 2,450 feet long at the crest, approximately 505 feet high from the foundation, and approximately 2,600 feet wide at the base and 40 feet wide at the crest. It is a multipurpose structure having a spillway, outlet works, and powerhouse.

The spillway is an uncontrolled morning-glory concrete crest structure with a concrete-lined, 20-foot-diameter inclined shaft and tunnel having an open concrete chute with a flip bucket at the end. The spillway crest is at elevation 2370, 17 feet below maximum reservoir elevation. The spillway is located in the left abutment and discharges into the river channel downstream from the powerhouse and outlet works. At maximum reservoir elevation 2387, it is designed to discharge 24,000 second-feet.

An auxiliary outlet works for releasing water during early stages of construction is located in the left abutment, Figure 2, and discharges into the spillway tunnel. It is designed to discharge 2,500 second-feet at normal reservoir elevation 2370.

A powerplant at the left abutment near the downstream toe of the dam discharges into the river channel. It is supplied through two penstocks that branch from the main conduit which terminates in the outlet works.

The outlet works is located in the left abutment about 150 feet downstream from the powerhouse and discharges into the river at almost a right angle to the channel center line approximately 450 feet upstream from the point at which the spillway discharges into the channel. It is designed for 7,670 second-feet at the maximum reservoir elevation.

The outlet works, Figures 3 and 4, consists of a concrete intake structure, a concrete-lined, 28-foot-diameter tunnel with fixed-wheel gate, a 28-foot-diameter concrete conduit, a concrete control house with two 84-inch ring follower gates and two 84-inch hollow-jet valves, a concrete stilling basin, and an outlet channel. The outlet works stilling basin and downstream channel are the features studied in this hydraulic investigation. The exact tail water elevation for any one operating condition will depend upon whether or not Lewiston Dam downstream is built and the reservoir elevation at which it will operate, Figure 3.

THE MODEL

The outlet works model, Figure 6, was a 1:28 scale reproduction of the prototype. It included the 84-inch hollow-jet valves and approach pipes, the stilling basin, the outlet channel, and a portion of the river channel.

Two 3-inch hollow-jet valves carefully machined of brass represented the 84-inch prototype valves. The model valves could be opened and closed over the full range of prototype valve openings.

A plywood stilling basin constructed within a test flume represented the prototype basin. One wall of the test flume was glass and was used as one wall of the basin so that the flow could be observed throughout the depth of the basin. The outlet channel and river topography were molded in sand to provide a movable bed for studying erosion characteristics of the flow from the basin. This downstream area represented a prototype area 196 feet long and 224 feet wide.

Water was supplied to the model through a manifold where it was divided between two 3-inch pipes with flexible hose connections leading to the hollow-jet valves. The 6-inch venturi meter located at the southwest corner of the laboratory was used to measure the discharge. The desired piezometric head on the model valves was obtained by opening or closing the hollow-jet valves to give the proper reading on a gage attached to the pipe section just upstream from the valves. Water surface elevations in the river channel were regulated with a tailgate and measured with a staff gage located as shown in Figure 6.

THE INVESTIGATION

The primary purpose of the investigation was to develop the hydraulic design of the outlet works stilling basin. No other basin of this type had been tested in the Bureau's laboratory at such high heads; therefore, it was necessary to check the basin dimensions by model studies. To accomplish this, it was necessary to study the flow characteristics within the basin and the downstream river channel for a wide range of operating conditions. This type of basin was first developed for Boysen Dam outlet works and later adapted for use at Falcon and Yellowtail Dams. These studies are discussed in Hydraulic Laboratory Reports No. Hyd-283, 276, and 414, respectively.

Preliminary Basin

The preliminary basin dimensions, Figure 7, were determined by extrapolating data obtained from the previous hollow-jet outlet works basin studies of this type. The preliminary 135-foot-long basin was designed for 7,000 second-feet discharging equally through both valves, Figure 2, with the reservoir water surface at the spillway crest. The total head at the valves was computed to be 260 feet. For an emergency operating condition, 4,200 second-feet discharged through one valve with the reservoir at or near maximum water surface elevation, the total head at the valve was 380 feet.

The possible tail water elevation range is shown by Curves 1, 2, 3, and 4 on Figure 3. The river channel in the area just downstream from the powerhouse tailrace and outlet works stilling basin will be excavated and dredged to elevation 1890 or rock, whichever is higher as shown in Figure 5. This excavation will influence the tail water elevation at the stilling basin as shown by tail water Curves 1 and 4 in Figure 3. After Lewiston Dam is built, the reservoir elevation at Lewiston Dam will influence the tail water as shown by Curves 2 and 3 in Figure 3. These two tail water curves were used in the model tests.

Conditions in the preliminary basin for the design flow of 7,000 second-feet with the tail water at elevation 1902 are shown in Figure 8(A) and (B). Very good stilling action was indicated by the smoothness of the water surfaces in the basin and downstream. Wave heights at the tail water gage in the river channel seldom exceeded 1/2-foot prototype from the minimum trough elevation to the maximum crest elevation, Figure 9. A description of the hydraulic action within the basin, Figure 8(A), is as follows: The circular hollow-jet flow from the valve is transformed by the converging walls to a vertical jet which is as high and as wide as the rectangular opening at the downstream end of the walls. As the jet leaves the converging walls it penetrates the tail water pool, striking the basin floor. Part of the jet spreads laterally and climbs the basin walls while the other part continues along the floor. Eventually, the flow that rises along the walls falls inward and becomes a part of the pool. The flow that continues along the floor loses momentum and eventually rises. Part of this flow that rises turns upstream, as in the case of a hydraulic jump, and part continues in a downstream and upward direction.

If the tail water is too deep, the upward motion of the flow is dampened by submergence. Bottom currents continue along the floor, preventing the formation of energy-reducing eddies, and some of the effectiveness of the stilling action is lost. If the tail water is too shallow, splashing occurs in the upstream portion of the basin because the upward motion of the flow is not sufficiently submerged. If the tail water is so low that no submergence occurs, the flow passes through the basin uninterrupted. This is called sweep out, and very little energy is lost within the basin. To provide the best overall performance, the tail water must be neither too deep nor too shallow. The elevation of the preliminary basin floor appeared to be about right for tail water elevations shown by Curves 2 and 3, Figure 3. To verify this observation, wave heights were measured in the river channel for a range of tail water and recorded in Figure 9.

Emergency operation with one valve discharging 4,200 second-feet, Figure 8(C), is the most severe operating condition. For this condition, the jet was not submerged at the upstream end of the basin, and a rather high boil occurred at the downstream end. The tendency to sweep out was greater than with both valves discharging because the discharge per unit foot of basin width is more and the tail water elevation is 2 feet less. Waves in the river channel were higher than when both valves were discharging but seldom exceeded 1 foot, Figure 9.

The erosion pattern shown in Figure 10 for both valves discharging 7,000 second-feet indicated good energy dissipation in the basin. However, sand was deposited in the outlet channel and about 24 feet upstream into the basin. Undercurrents could be seen carrying sand upstream from the discharge channel into the basin and swirling it around on the basin floor. The concrete floor of the prototype might be damaged by such action. It was concluded that a shorter basin would allow the bottom currents to pass over the end sill in a positive manner, thereby preventing upstream currents from moving bed material into the basin.

Basin without converging walls. To verify the need for the converging walls, the basin was tested without them. The basin then produced unstable flow, Figures 11(A) and 12(A). Surges which occurred in the basin sometimes extended into the river channel, causing waves 5 feet high.

The basin, discharging 2,100 second-feet from each valve with and without converging walls, is shown in Figure 13. Without the walls, the jets from the valves do not penetrate to the full depth of the stilling basin pool. Surges in the upstream portion of the basin travel through the basin and into the river channel. With the converging walls, the jet penetrates to the floor of the pool and dissipates its energy throughout the basin. The water surface from the basin is smooth. These tests proved the necessity of the converging walls.

Converging wall gap width. The converging walls were re-installed, but with a gap of 7 feet between the downstream ends of the two walls. The performance was better than with no walls but not nearly so good as for the preliminary design gap width of 4 feet 8-1/2 inches, Figures 11 and 12. Decreasing the width still further to 3 feet 6 inches did not improve the performance or reduce wave heights in the river channel.

End sill moved upstream 24 feet. A shorter basin, 111 feet long, was approximated in the model by placing the end sill 24 feet farther upstream, Figure 14. The purpose was to prevent bed material, including sand and gravel, from being drawn into the basin by the subsurface upstream current discussed in the erosion test for the preliminary design.

This shorter basin performed satisfactorily when discharging 7,000 second-feet, Figure 14(A). The water surface was smooth at the end of the basin, and waves in the river channel, although higher than in the preliminary design, did not exceed 1 foot. Very little erosion occurred in the outlet channel as shown in Figure 14(B). The shorter basin floor was very effective in keeping bed material out of the basin even for small discharges. For all flows, there was a downstream current passing over the end sill which prevented bed material from being drawn into the basin.

With 4,200 second-feet discharging through one valve, Figure 14(C), the basin was not so effective. Waves were 3 feet high in the river channel. In addition, the action in the basin was closer to sweep-out conditions than with the preliminary basin. However, it was concluded that a true model representation of a basin 111 feet long should be tested.

Basin Length, 111 Feet; Center Wall Length, 90 Feet

The model was altered to determine the true effect of reducing the basin length to 111 feet. The performance of this basin, Figure 15(A) and (B), was about the same as the preliminary basin with the end sill moved upstream. Waves were still about 3 feet high in the river channel, and the action in the basin was closer to the sweep-out condition than before. With 4,200 second-feet through one valve, the jump swept out of the basin at tail water elevation 1900.

Basin Length, 111 Feet; Center Wall Length, 36 Feet

The length of the center training wall was reduced from 90 to 36 feet to help keep the jump in the shortened basin. The performance of this basin is shown in Figure 15(C) and (D). Waves in the river channel at the staff gage were about twice as high as with the longer center wall. This was true for 7,000 second-feet discharging from two valves as well as for 4,200 second-feet discharging from one valve. For 7,000 second-feet, the waves were 2-1/2 feet high; and for 4,200 second-feet, they were 5 feet high. The basin, therefore, was not satisfactory; however, the jump did stay in the basin better than when the longer center wall was used.

Basin Length, 123 Feet; Center Wall Length, 66 Feet

The basin and the center wall were lengthened 12 feet and 30 feet, respectively, to improve the performance. This provided a basin floor and center wall that were 12 and 24 feet shorter than the preliminary design, respectively. To accomplish this modification in the model, the basin was extended 12 feet (prototype) into the tail box, Figure 16.

The performance of this basin, Figure 17(A) and (B), appeared to be satisfactory for 7,000 second-feet from both valves but not for 4,200 second-feet from one valve. For 4,200 second-feet, with the tail water at elevation 1900, the flow was on the verge of sweeping out of the basin.

Basin Length, 123 Feet; No Center Wall

The center wall was removed completely. For 7,000 second-feet with two valves operating, Figure 17(C), the jump remained within the basin, but the flow was very unstable. Sometimes the flow was surging in one side of the basin, while in the other side the flow was receding. This unstable and unsymmetrical operating condition caused waves 4.5 feet high at the staff gage in the river channel. Also, erosion occurred along the end sill and in the outlet channel, more so than for any previous basin arrangement tested. The basin was, therefore, relatively ineffective in dissipating energy.

For 4,200 second-feet from one valve, there was no danger of sweep out, even at a very low tail water; but the flow in the upstream portion of the basin splashed 10 to 20 feet above the tops of the basin walls, elevation 1917, Figure 17(D). Waves in the river channel were 4-1/2 feet high.

Recommended Basin

A center wall was re-installed to stabilize the flow. The basin length of 123 feet was retained. The center wall was 36 feet long or 54 feet shorter than the preliminary design. The basin was 12 feet shorter than the preliminary design. This basin is shown in Figures 18 through 27.

At this stage in the investigation, design computations showed that for 2-valve operation the total head at the valves could be 284 feet; in which case, the discharge for 2 valves operating 100 percent open would be 7,200 second-feet. For one-valve operation, the total head at the valve could be 326 feet which would discharge 3,900 second-feet with the valve fully open. Later, these capacities were increased again to 7,670 second-feet for 2-valve operation with 315 feet of head at the valves and to 4,260 second-feet for 1-valve operation with 392 feet of head at the valve.

For 7,200 second-feet, Figure 19A, the recommended basin appeared to perform satisfactorily. For 7,670 second-feet, Figure 19(B), some splashing occurred in the upstream portion of the basin; however, waves at the staff gage in the river channel, Figure 19(C), seldom exceeded 1.75 feet in height. For one-valve emergency operation at 4,260 second-feet, Figures 20(A) and (B), the flow surged in the basin; however, the maximum wave height at the river channel gage seldom exceeded 2.75 feet. For 3,900 second-feet, Figure 20(C), the performance was better.

Sweep-out test data for a range of discharges, Figure 21, show that the lowest expected tail water curve provides a safety factor of approximately 5 feet or more of tail water depth for either 1- or 2-valve operation at design capacities, and more safety factor for lesser discharges. The basin performed quite well while the tail water was being lowered to the sweep-out condition.

Raising the tail water above the design elevations produced a rough water surface in the river channel. For example, if the tail water is at elevation 1913, which could be possible while the spillway is discharging, the outlet works discharging 7,670 second-feet produces a high boil and a rough water surface in the river channel, Figure 22. The performance, however, was considered to be acceptable for this emergency operating condition.

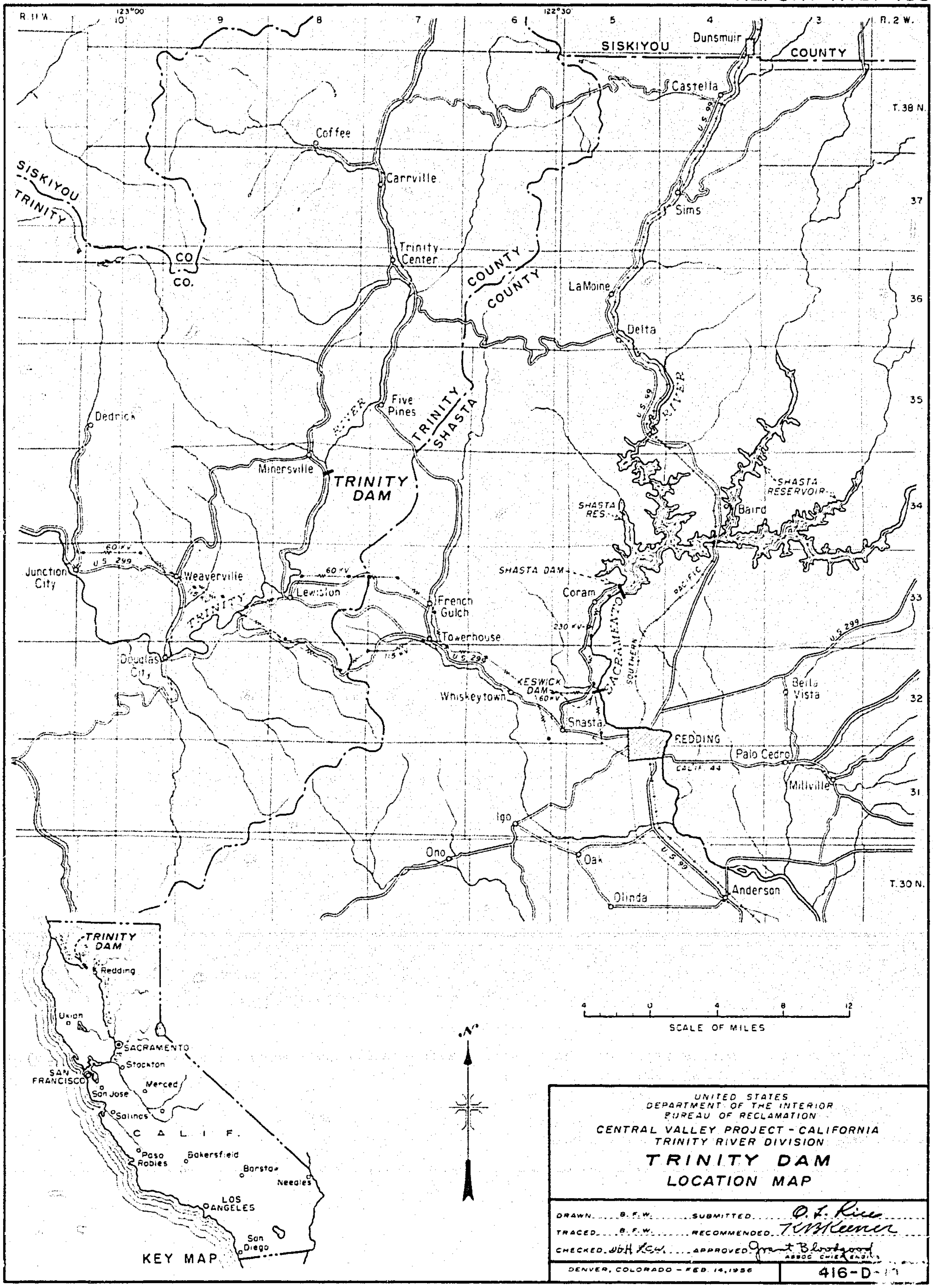
One valve discharging 4,260 second-feet with tail water elevation 1913, Figure 23, is very improbable, and it is not recommended for the prototype. Waves in the river channel at the staff gage were 5 feet high.

In the preliminary design, the outlet channel bottom had a 5:1 upward slope from elevation 1870 at the basin end sill to elevation 1890 in the downstream channel. The erosion test for this design, Figure 10, indicated that bed material was deposited in the channel until the slope of the channel bed downstream of the sill became approximately 2:1. Therefore, for the recommended design a 2:1 excavation slope was molded in the model bed, Figure 16. An erosion test with the recommended basin design for 7,670 second-feet with tail water at elevation 1902, Figure 24(A), showed that the 2:1 slope of the channel bed was not eroded and that very little erosion occurred along the end sill. The 2:1 slope was therefore recommended for the prototype. The slight erosion of the channel banks was caused by side eddy currents and sloughing of the wet sand. This type of erosion is not considered serious since the prototype banks will be protected by riprap. With the tail water lowered to elevation 1899, the erosion in the discharge channel for 7,670 second-feet was a little more severe, Figure 24(B). The performance, however, was satisfactory. For one valve discharging 3,900 second-feet with the tail water at elevation 1898, the lowest expected elevation, no erosion occurred along the end sill. In fact, bed material was deposited within the basin, Figure 24(C). This deposition is not desirable since movement of material within the basin may abrade the concrete. However, one-valve operation is for emergencies only, so the action is not considered critical.

Water surface profiles, Figures 25 through 27, recorded for a range of operating conditions, were obtained to aid in the structural design of the basin walls. Wave heights at the staff gage in the river channel are shown with each profile.

The recommended design was altered slightly for prototype use. The center wall length of 36 feet was increased to 40 feet to match a construction joint, and the gap width between the converging walls was increased from 4 feet 8-1/2 inches to 4 feet 10-1/2 inches. These variations will not materially affect the basin performance indicated by the model tests.

FIGURE 1
REPORT HYD. 439



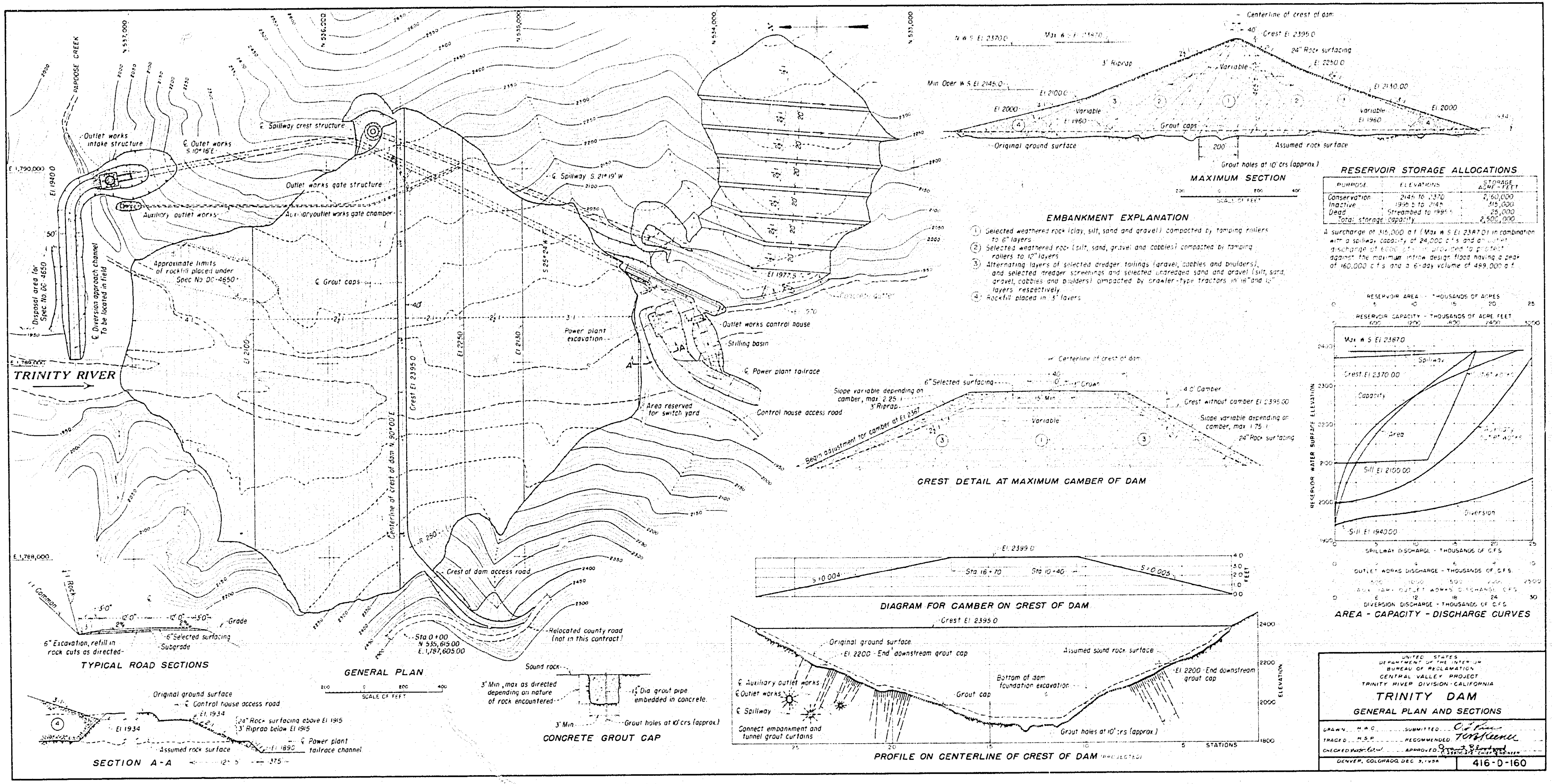

TRINITY RIVER
PAPOOSE CREEK
Outlet works intake structure
℄ Outlet works S 10°16' E
℄ Spillway crest structure
Outlet works gate structure
Auxiliary outlet works
Auxiliary outlet works gate chamber
℄ Spillway S 21°19' W
Approximate limits of rockfill placed under Spec No DC-4650
℄ Grout caps
Disposal area for Spec No DC-4650
℄ Diversion approach channel To be located in field
Power plant excavation
Outlet works control house
Stilling basin
℄ Power plant tailrace
Area reserved for switch yard
Control house access road
Centerline of crest of dam N 90°00' E
Crest El 2395.0
Crest of dam access road
Relocated county road (not in this contract)
Sta 0+00
N 535,615.00
E 1,787,605.00
GENERAL PLAN
TYPICAL ROAD SECTIONS
6" Excavation, refill in rock cuts as directed
Subgrade
6" Selected surfacing
Grade
SECTION A-A
Original ground surface
℄ Control house access road
24" Rock surfacing above El 1915
3' Riprap below El 1915
Assumed rock surface
℄ Power plant tailrace channel
CONCRETE GROUT CAP
Sound rock
3' Min, max as directed depending on nature of rock encountered
1½" Dia grout pipe embedded in concrete
Grout holes at 10' crs (approx)
MAXIMUM SECTION
Centerline of crest of dam
Crest El 2395.0
24" Rock surfacing
3' Riprap
Min Oper W S El 2145.0
Original ground surface
Assumed rock surface
Grout caps
Grout holes at 10' crs (approx)
EMBANKMENT EXPLANATION
(1) Selected weathered rock (clay, silt, sand and gravel) compacted by tamping rollers to 6" layers
(2) Selected weathered rock (silt, sand, gravel and cobbles) compacted by tamping rollers to 12" layers
(3) Alternating layers of selected dredger tailings (gravel, cobbles and boulders), and selected dredger screenings and selected undredged sand and gravel (silt, sand, gravel, cobbles and boulders) compacted by crawler-type tractors in 18" and 12" layers respectively
(4) Rockfill placed in 3' layers
RESERVOIR STORAGE ALLOCATIONS
PURPOSE | ELEVATIONS | STORAGE ACRE-FEET
Conservation | 2145 to 2370 | 2,160,000
Inactive | 1995.5 to 2145 | 315,000
Dead | Streambed to 1995.5 | 25,000
Total storage capacity | | 2,500,000
A surcharge of 315,000 a f (Max W S El 2387.0) in combination with a spillway capacity of 24,000 c f s and an outlet discharge of 6000 c f s is provided to protect against the maximum inflow design flood having a peak of 160,000 c f s and a 6-day volume of 499,000 a f.
CREST DETAIL AT MAXIMUM CAMBER OF DAM
Begin adjustment for camber at El 2367
4.0' Camber
Crest without camber El 2395.00
24" Rock surfacing
DIAGRAM FOR CAMBER ON CREST OF DAM
El 2399.0
Sta 16+70
Sta 10+40
PROFILE ON CENTERLINE OF CREST OF DAM
Crest El 2395.0
Original ground surface
Assumed sound rock surface
Bottom of dam foundation excavation
Grout cap
Grout holes at 10' crs (approx)
℄ Auxiliary outlet works
℄ Outlet works
℄ Spillway
Connect embankment and tunnel grout curtains
STATIONS
AREA - CAPACITY - DISCHARGE CURVES
RESERVOIR AREA - THOUSANDS OF ACRES
RESERVOIR CAPACITY - THOUSANDS OF ACRE FEET
RESERVOIR WATER SURFACE ELEVATION
Max W S El 2387.0
Crest El 2370.00
Sill El 2100.00
Sill El 1940.00
Capacity
Area
Spillway
Diversion
SPILLWAY DISCHARGE - THOUSANDS OF C.F.S.
OUTLET WORKS DISCHARGE - THOUSANDS OF C.F.S.
DIVERSION DISCHARGE - THOUSANDS OF C.F.S.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION - CALIFORNIA
TRINITY DAM
GENERAL PLAN AND SECTIONS
DRAWN H.A.C. SUBMITTED
TRACED H.S.P. RECOMMENDED
CHECKED APPROVED ASSOCIATE CHIEF ENGINEER
DENVER, COLORADO, DEC. 3, 1958
416-D-160

FIGURE 3
REPORT HYD. 439

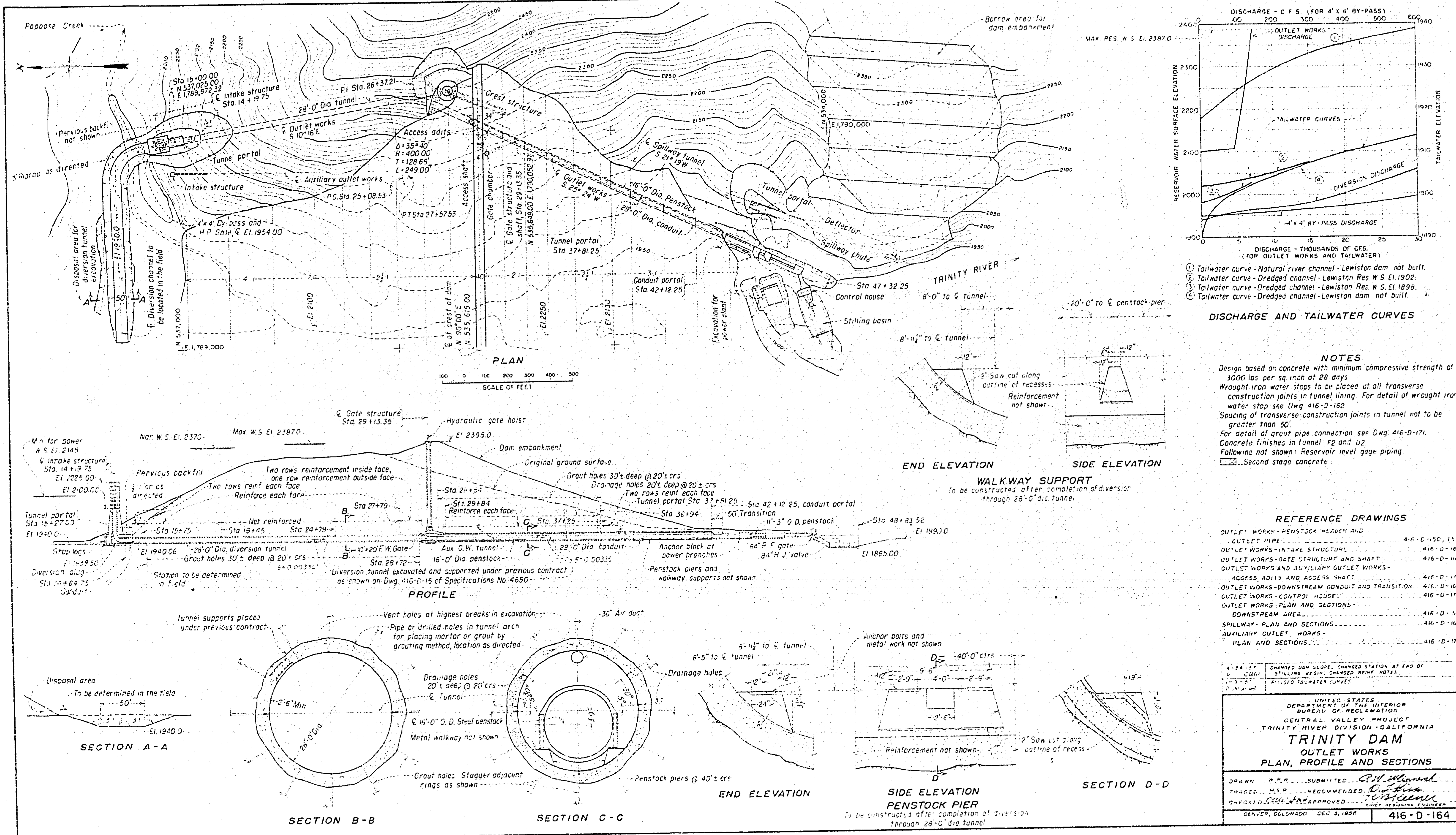


FIGURE 4
REPORT HYD. 439

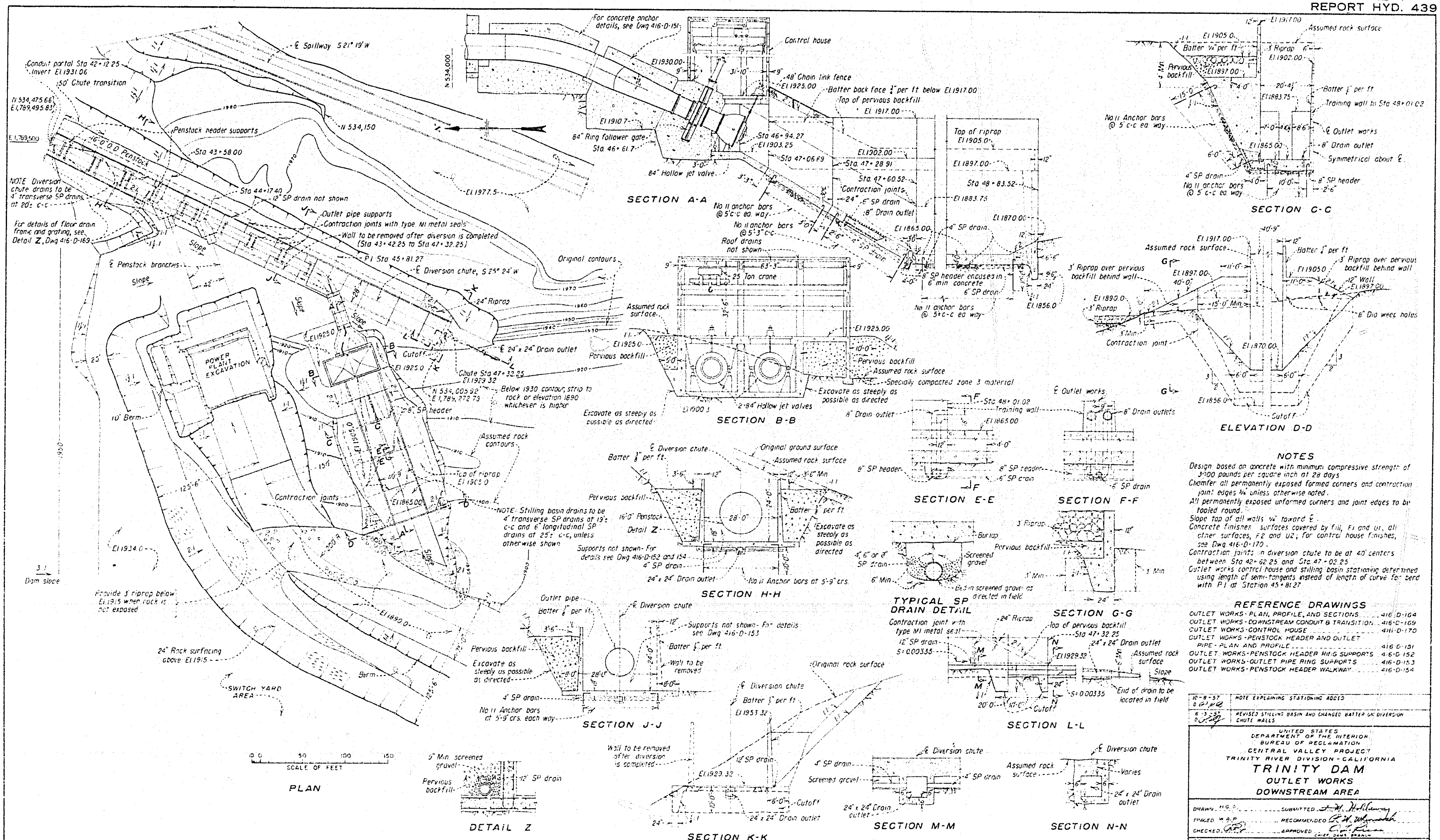
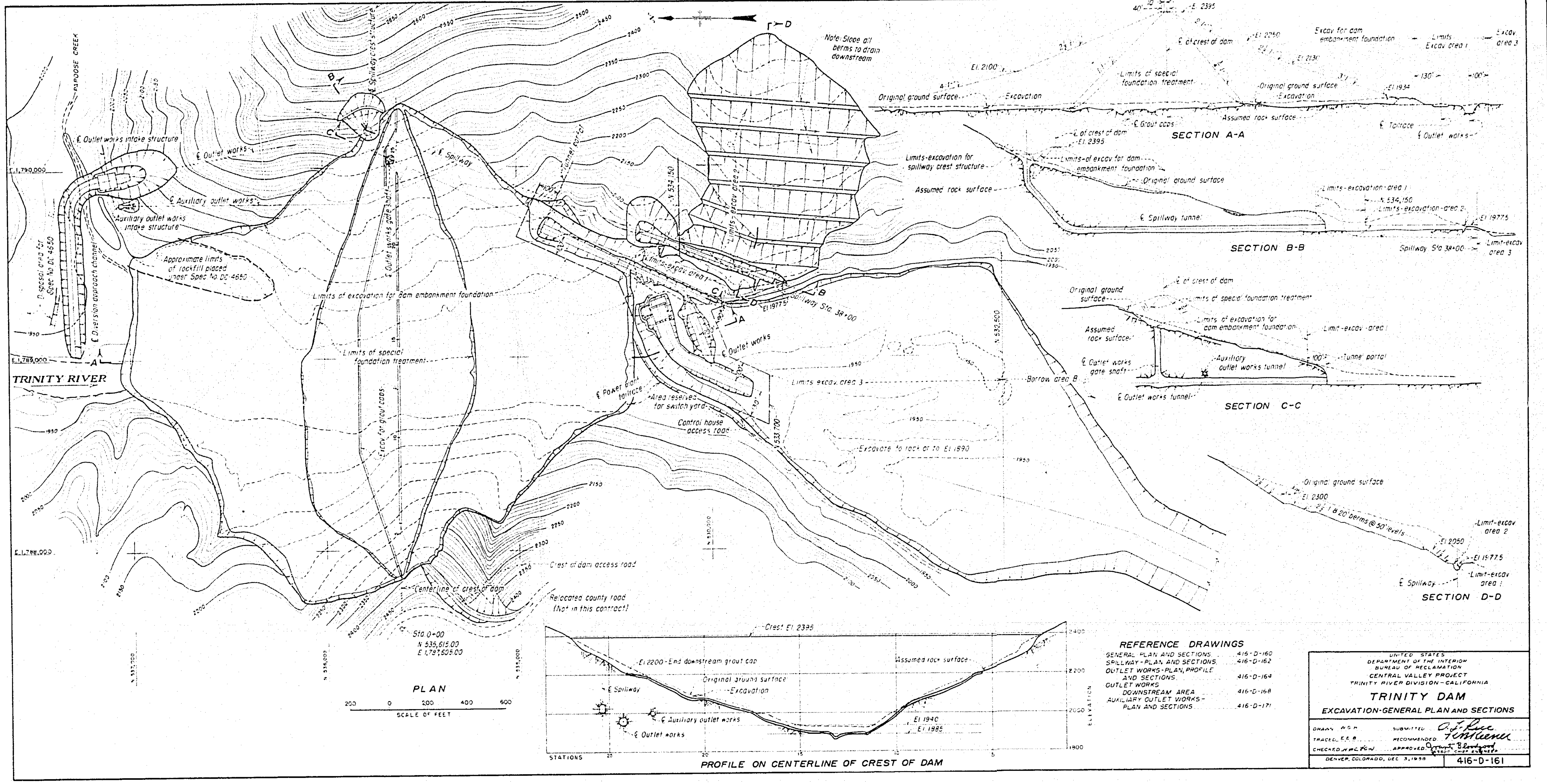
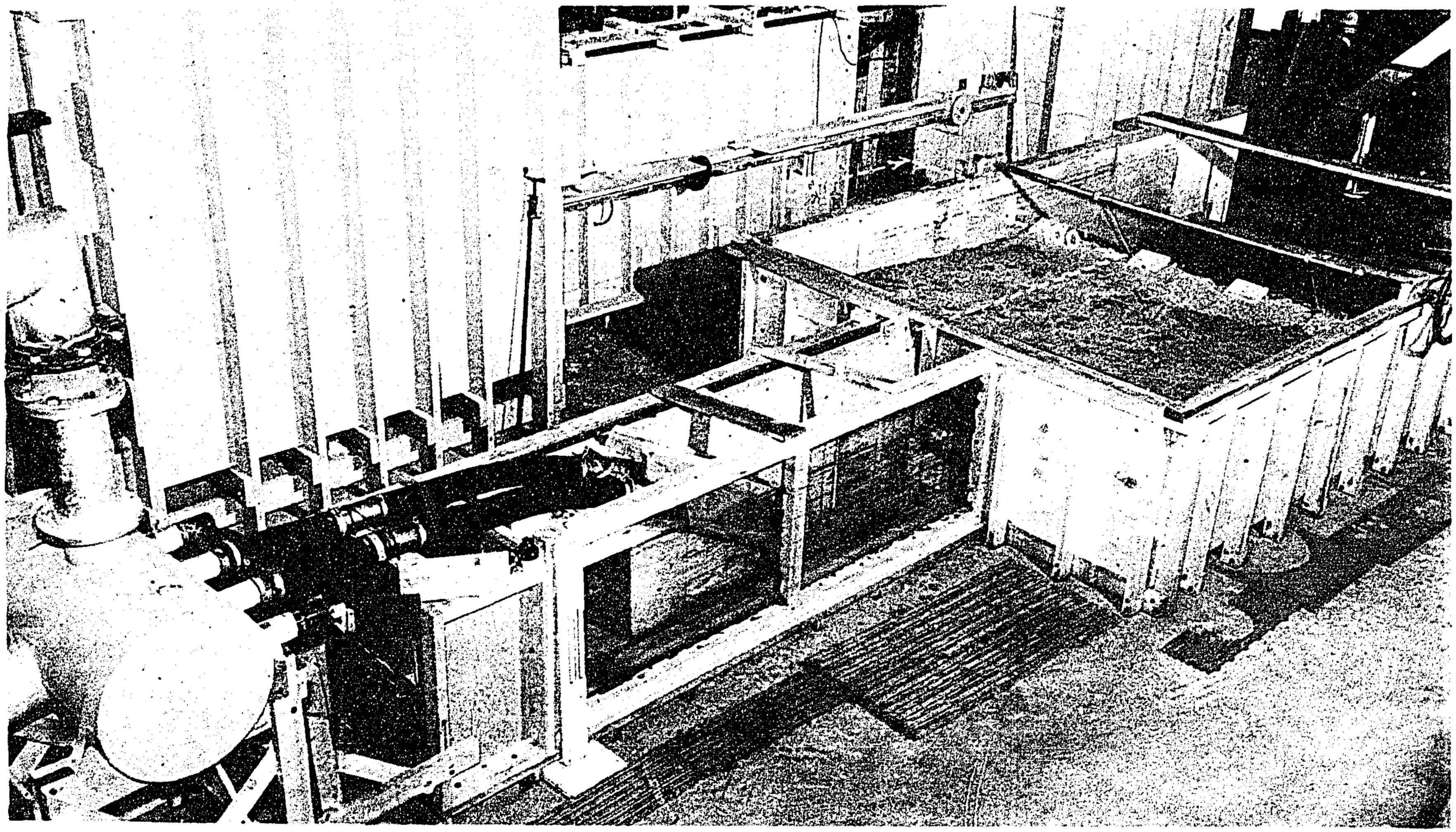


FIGURE 5
REPORT HYD. 439



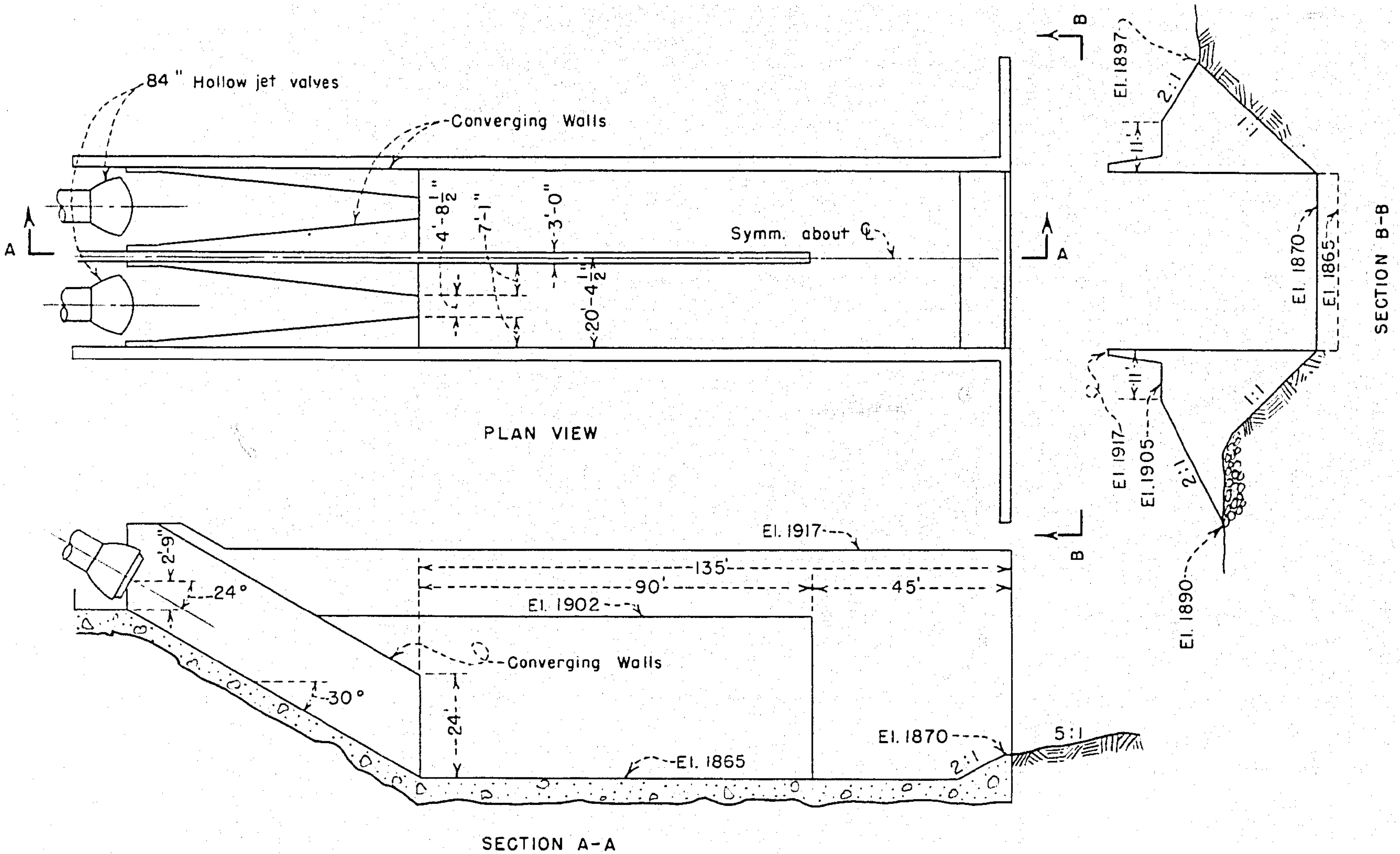


TRINITY DAM OUTLET WORKS

1:28 Scale Model

Figure 6
Report HYD 439

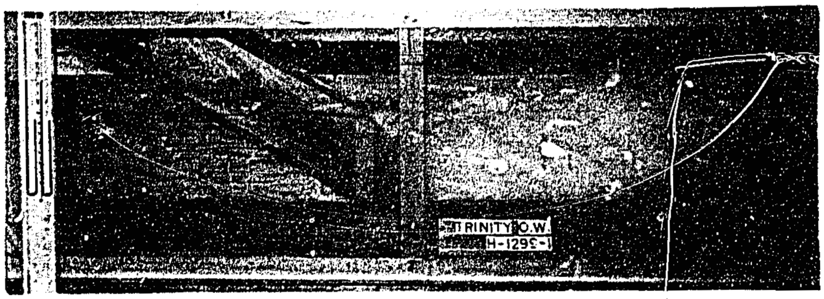
570



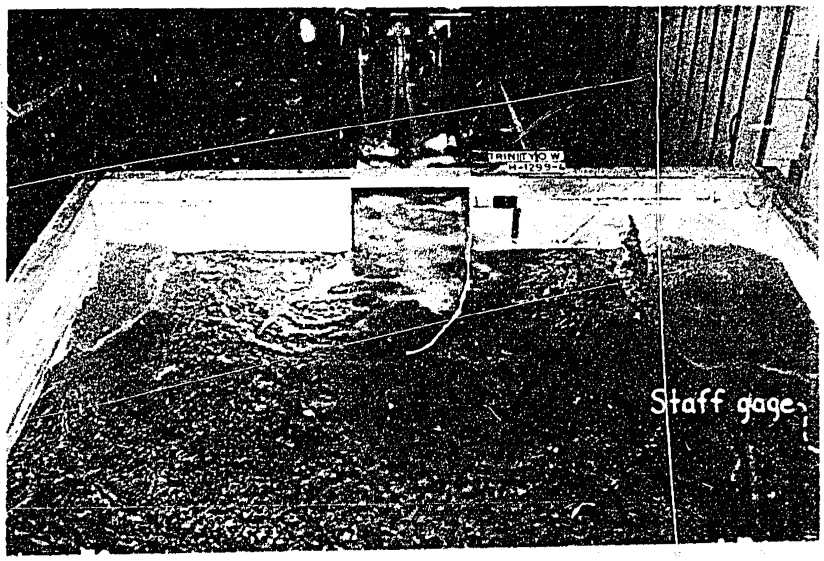
TRINITY DAM OUTLET WORKS

PRELIMINARY BASIN DIMENSIONS

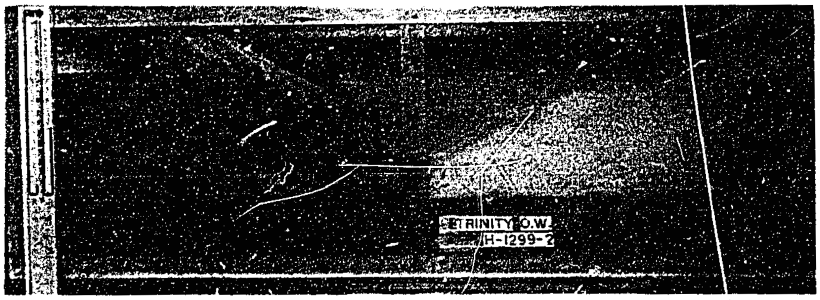
FIGURE 7
REPORT HYD. 439



A. 7,000 cfs, Two valves, Head at valves 260 ft., Tail-water elevation 1902.



B. Same as A above.
Waves in river channel at staff gage 0.5' high.



C. 4,200 cfs, One valve, Head at valve 380 ft., Tail-water elevation 1900.

TRINITY DAM OUTLET WORKS

Flow Conditions--Preliminary Basin
1:28 Scale Model

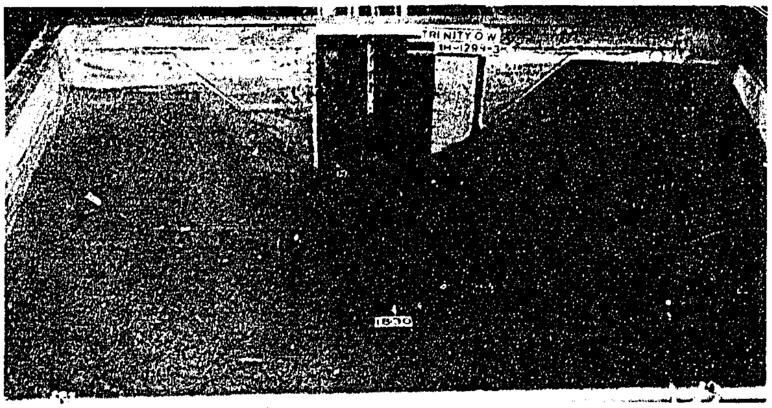
NUMBER OF VALVES	DISCHARGE C.F.S.	HEAD AT VALVE FT.	TAILWATER ELEVATION	WAVE HEIGHTS * FT.
TWO	7,000	260	1902	1/2
TWO	7,000	260	1904	1
TWO	7,000	260	1908	3
TWO	7,000	380	1902	1/2
TWO	7,000	380	1904	1 1/4
ONE	4,200	380	1902	1
ONE	4,200	380	1904	1 1/2

* Wave height were measured as the difference between the maximum wave crest elevation and the minimum wave trough elevation at the model staff gage in the river channel, FIGURE 6.

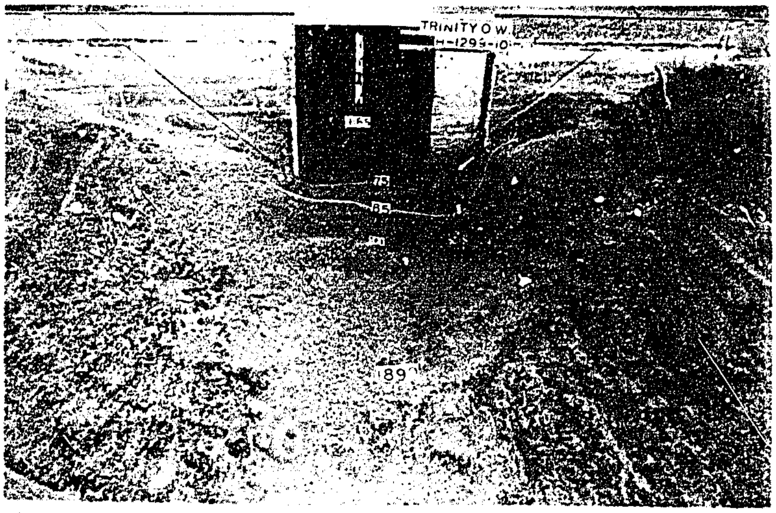
TRINITY DAM OUTLET WORKS

TAILWATER WAVE HEIGHTS — — PRELIMINARY BASIN

1:28 SCALE MODEL



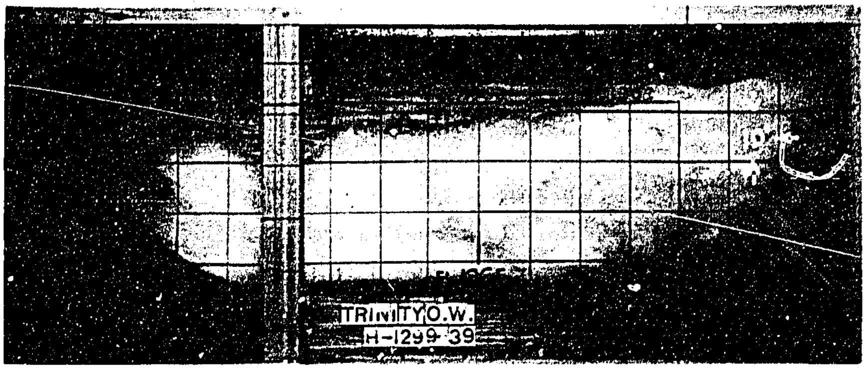
A. Discharge channel shape prior to Erosion Test.



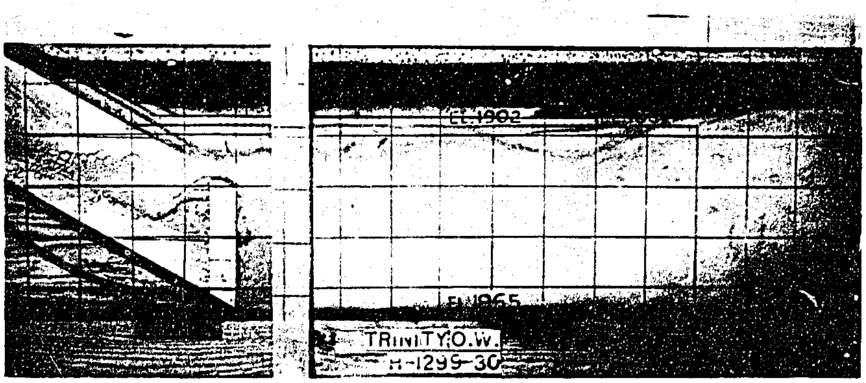
B. Erosion pattern after 30 minute model test run. Discharge 7,000 cfs - Two valves - Head 260' - T. W. El. 1902.

TRINITY DAM OUTLET WORKS

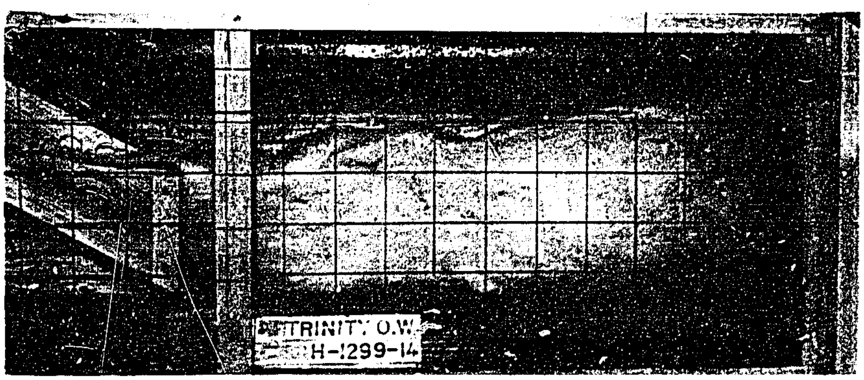
Erosion Test--Preliminary Basin
1:28 Scale Model



A. No Converging Walls. Waves 5' high in river channel at gage.



B. Converging Wall gap 7'-0". Waves 3' high in river channel at gage.

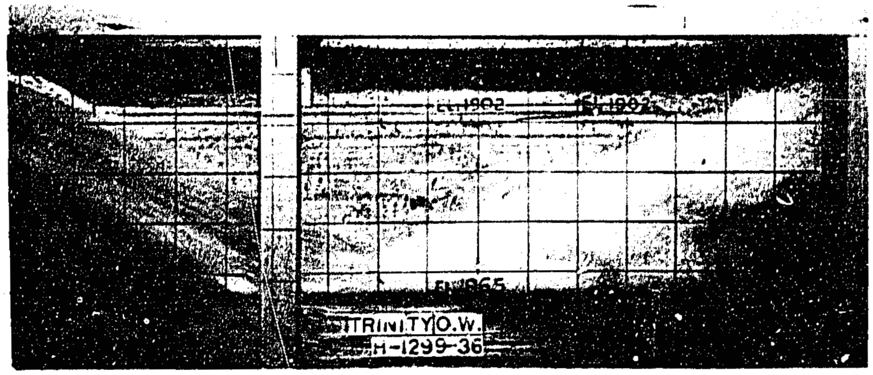


C. Converging Wall gap 4'-8½". Waves 6" high in river channel at gage.

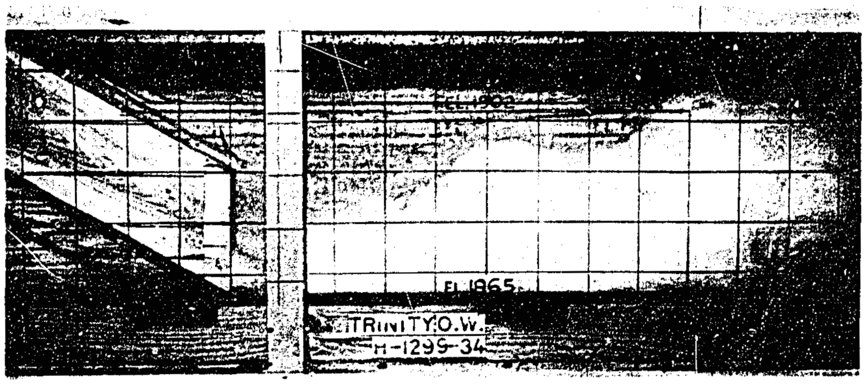
Discharge 7,000 cfs - Head at valves 260' -
Tail-water elevation 1902

TRINITY DAM OUTLET WORKS

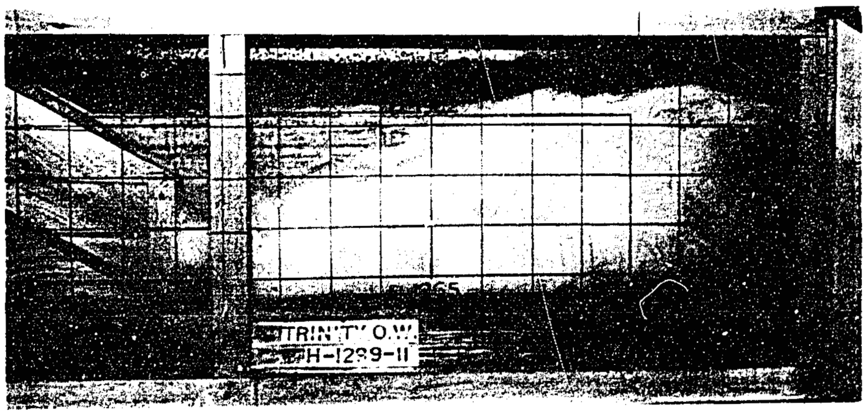
Converging Wall Tests--Two-Valve Operation
1:28 Scale Model



A. No Converging Walls. Waves 5' high in river channel at gage.



B. Converging Wall gap 7'-0". Waves 4' high in river channel at gage.

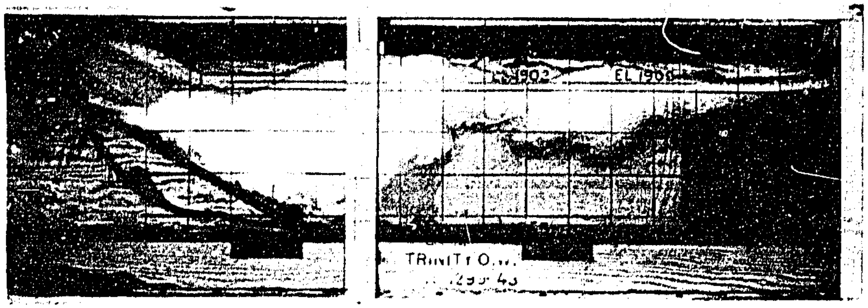


C. Converging Wall gap 4'-8½". Waves one foot high in river channel at gage.

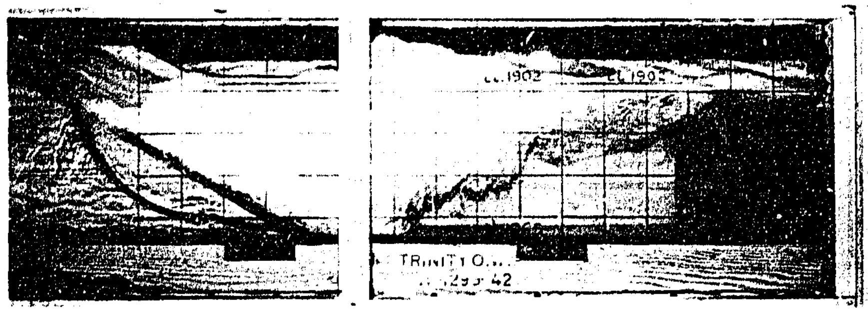
Discharge 4, 200 cfs - Head at valve 380' -
Tail-water elevation 1900

TRINITY DAM OUTLET WORKS

Converging Wall Tests--One Valve Operation
1:28 Scale Model

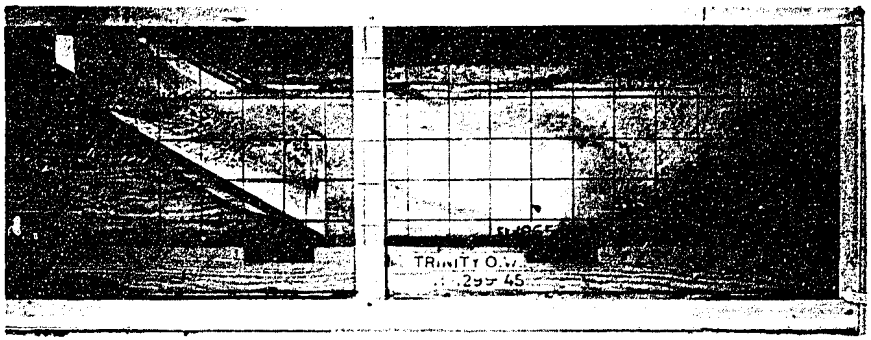


A. Head at valves 260' - T. W. El. 1902.
Waves in river channel 2' high at gage.

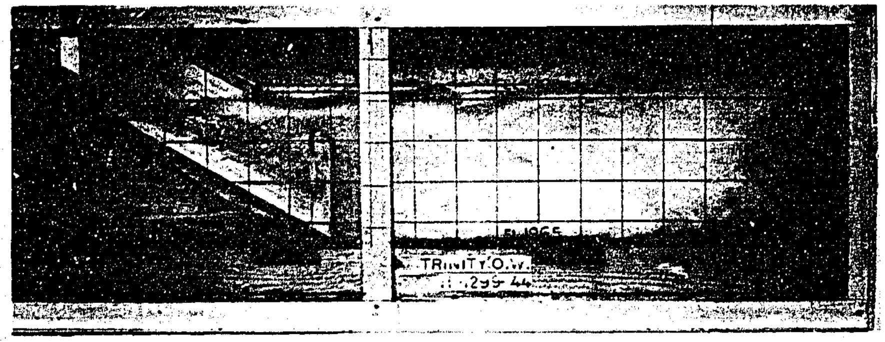


B. Head at valves 380' - T. W. El. 1902.
Waves in river channel 2.5' high at gage.

No Converging Walls



C. Head at valves 260' - T. W. El. 1902.
Waves in river channel one foot high at gage.



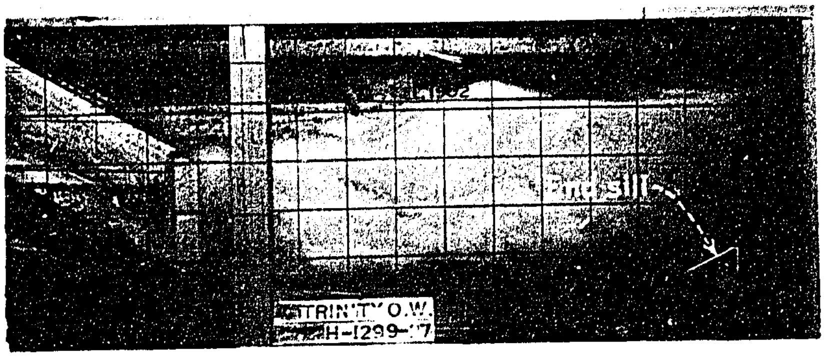
D. Head at valves 380' - T. W. El. 1902.
Waves in river channel one foot high at gage.

Converging Walls with 4'-8½" gap

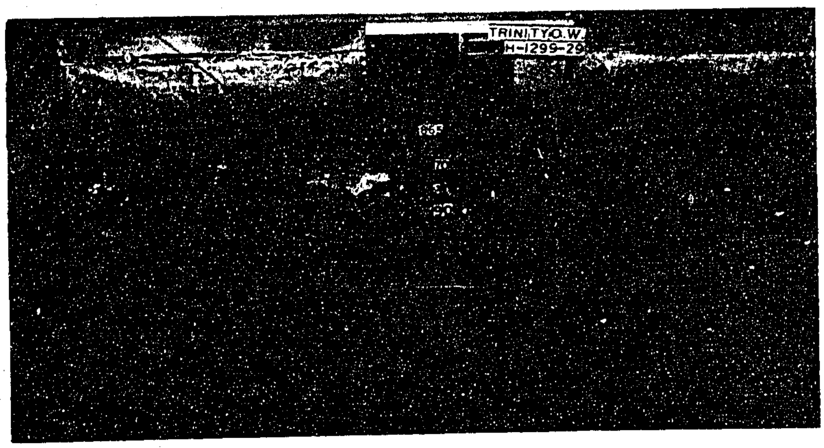
TRINITY DAM OUTLET WORKS

Flow Conditions With and Without Converging Walls--
2100 Second Feet Per Valve
1:28 Scale Model

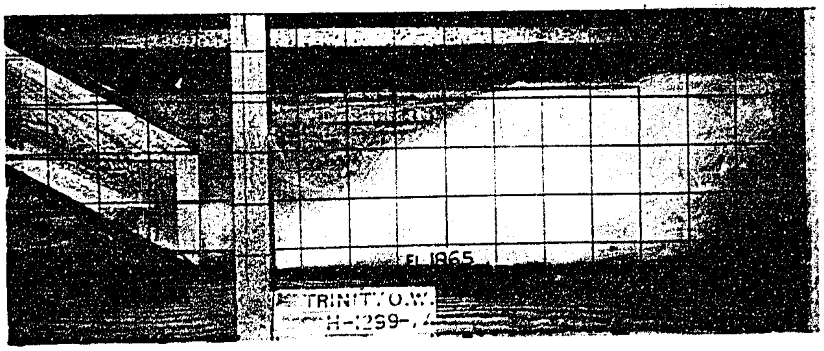
Figure 13
Report HYD 439



A. 7,000 cfs, Two valves, Head at valves 260 ft., T.W. elev. 1902. Waves one foot high at gage in river channel.



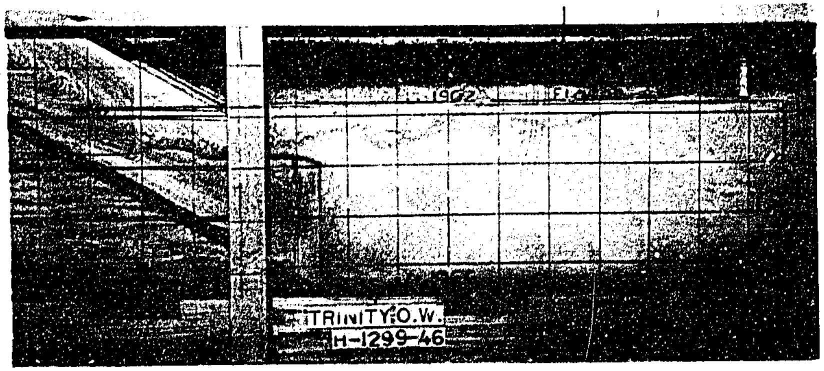
B. Erosion Pattern after 30 min. model test run at operating conditions in A.



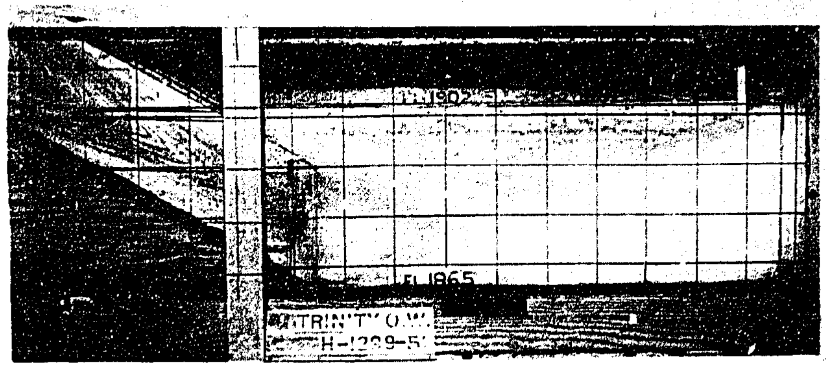
C. 4,200 cfs, One valve, Head 380 ft. at valve, T.W. elev. 1902. Waves 3' high at gage in river channel.

TRINITY DAM OUTLET WORKS

Flow Conditions and Erosion With End Sill Moved Upstream 24 Feet
1:28 Scale Model

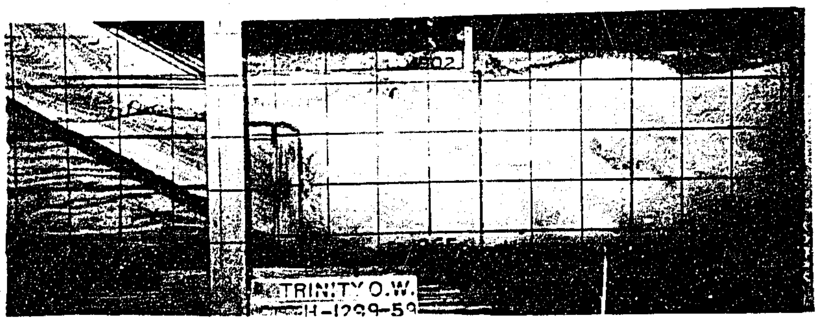


A. 7,000 cfs, Two valves, Head at valves 260', T. W. elev. 1902. Waves in river channel at gage one foot high.

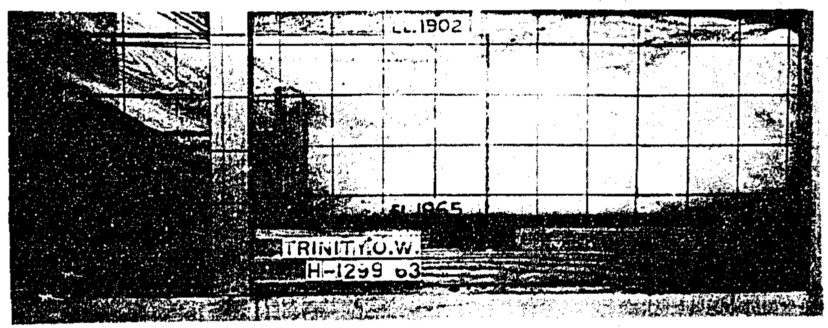


B. 4,200 cfs, One valve, Head at valve 380', T. W. El. 1900. Waves in river channel at gage 2.5' high.

Center Wall 90 Feet Long



C. 7,000 cfs, Two valves, Head at valves 260', T. W. El. 1902. Waves in river channel at gage 2' high.



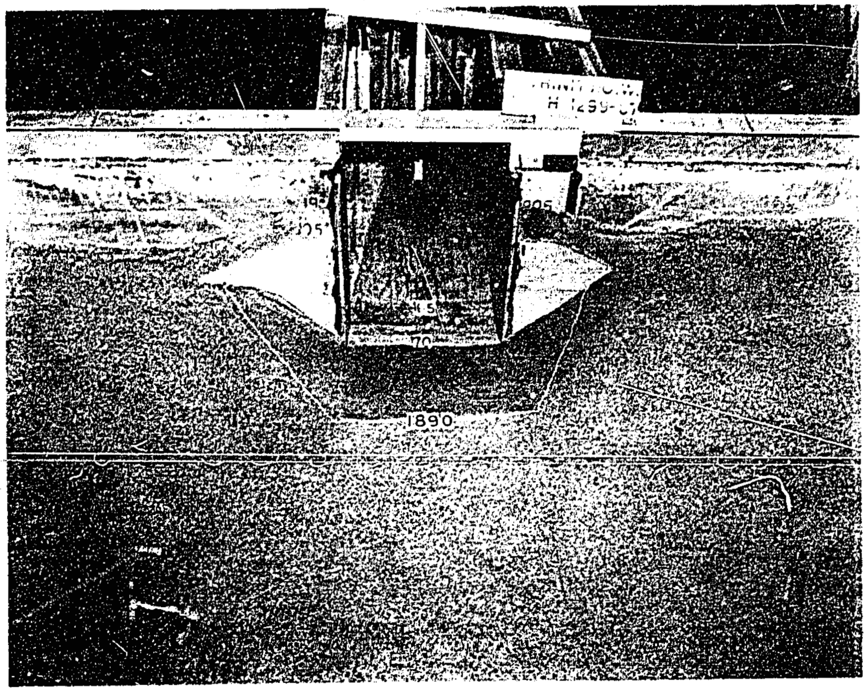
D. 4,200 cfs, One valve, Head at valve 380', T. W. El. 1900. Waves in river channel at gage 5' high.

Center Wall 36 Feet Long

TRINITY DAM OUTLET WORKS

Flow Conditions With Basin 111 Feet Long
1:28 Scale Model

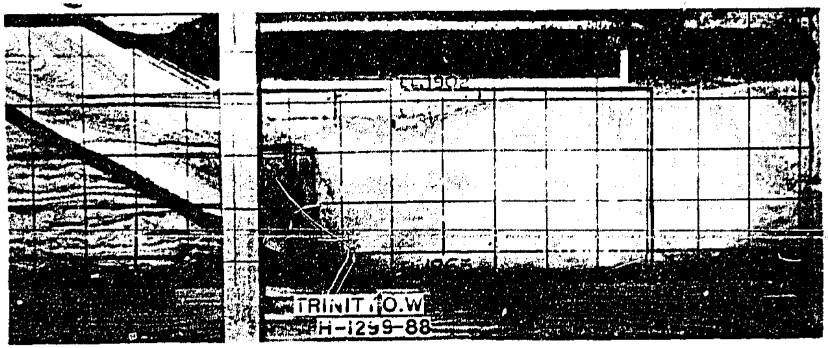
Figure 15
Report HYD 439



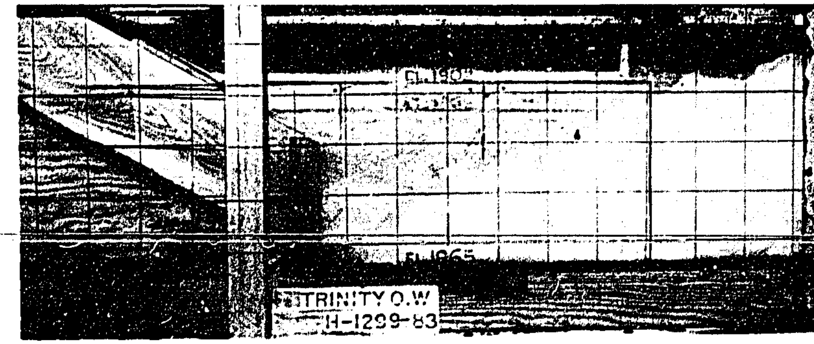
Basin extends 12' (prototype) into Tail box. Discharge channel slopes 2:1 from El. 1870 to El. 1890.

TRINITY DAM OUTLET WORKS

Basin 123 Feet Long
1:28 Scale Model

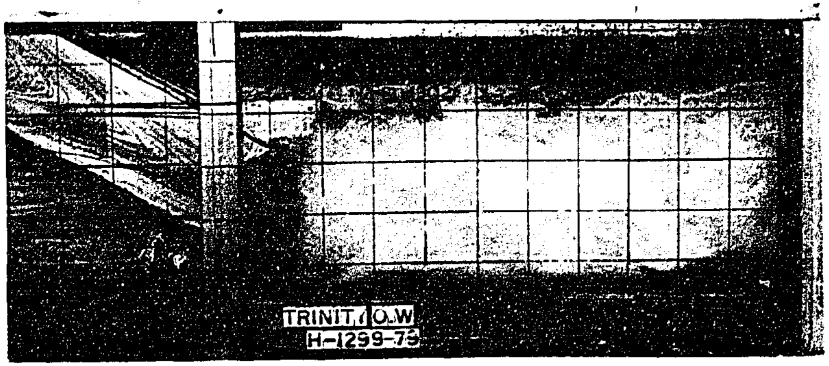


A. 7,000 cfs, Two valves, Head at valves 260', T.W. El. 1902. Waves 1.5' high in river channel at gage.

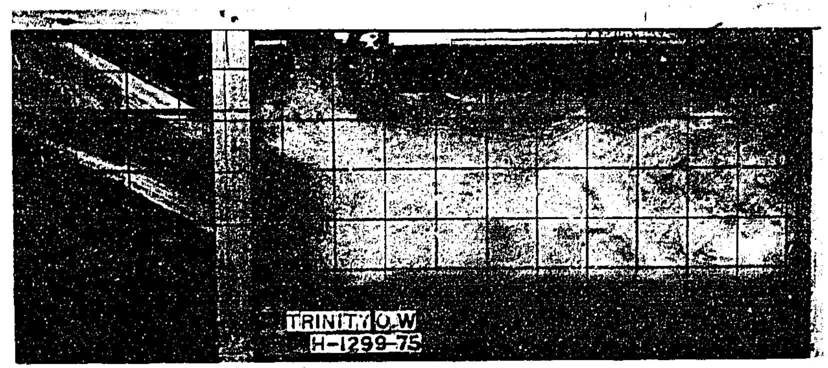


B. 4,200 cfs, One valve, Head at valve 380', T.W. El. 1900. Waves 3.5' high in river channel at gage.

Center Wall 66 Feet Long



C. 7,000 cfs, Two valves, Head at valves 260', T.W. El. 1902. Waves 4.5' high in river channel at gage.



D. 4,200 cfs, One valve, Head at valve 380', T.W. El. 1902. Waves 4.5' high in river channel at gage.

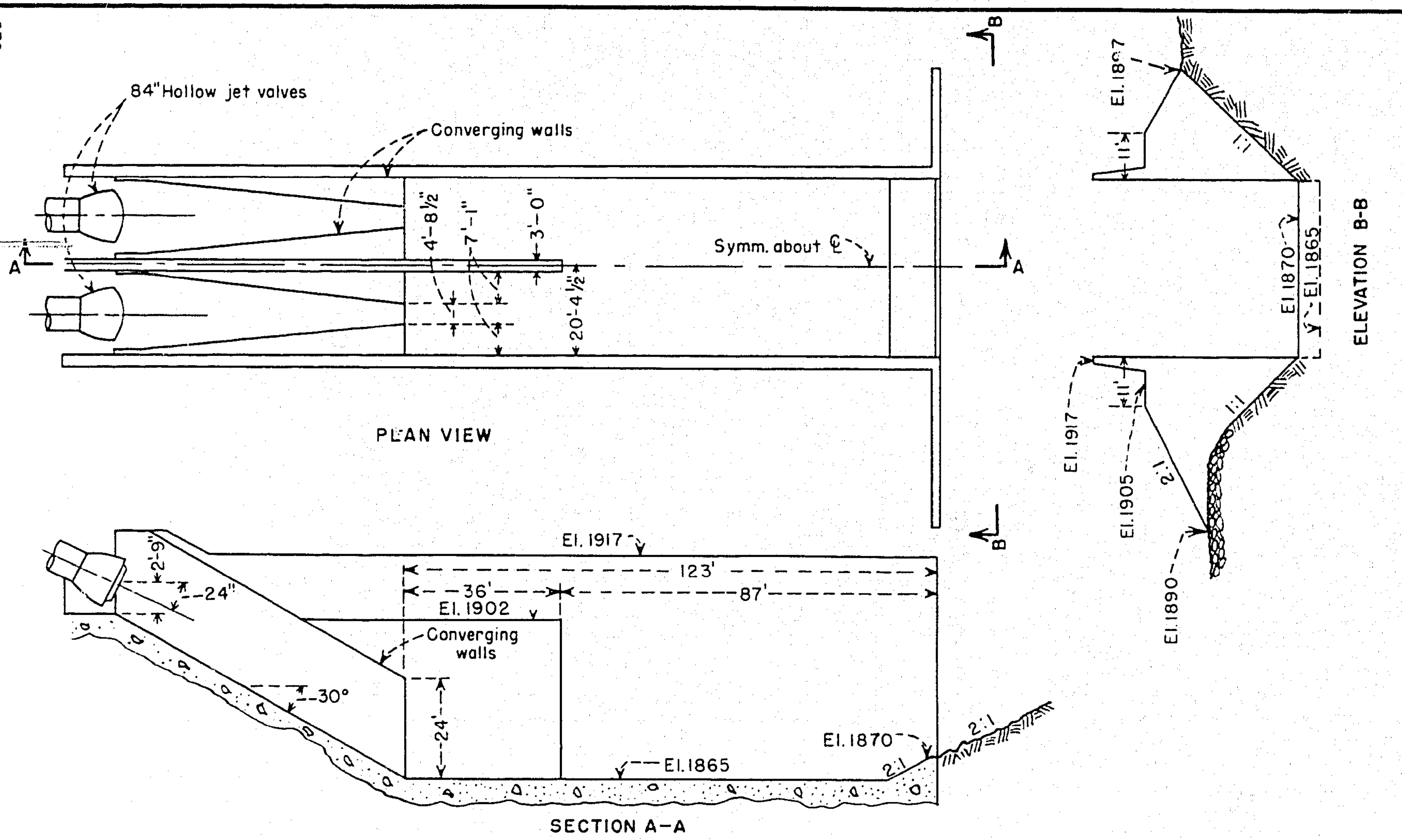
No Center Wall

TRINITY DAM OUTLET WORKS

Flow Conditions With Basin 123 Feet Long
1:28 Scale Model

Figure 17
Report HYD 439

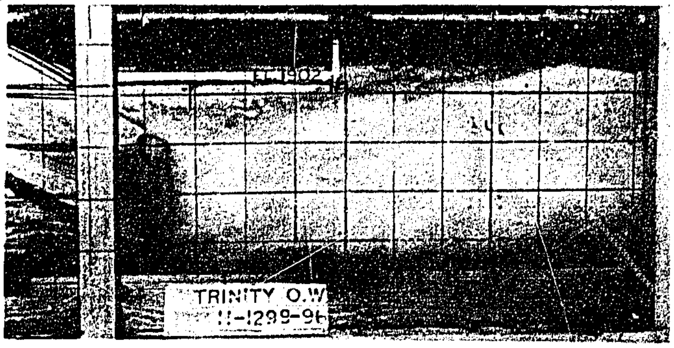
570



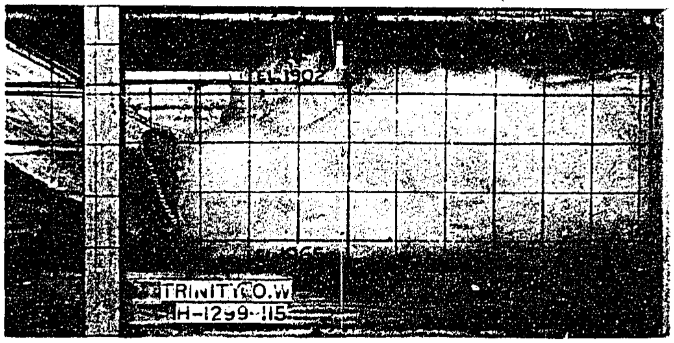
TRINITY DAM OUTLET WORKS

RECOMMENDED BASIN DIMENSIONS

FIGURE 18
REPORT HYD 439



A. 7,200 cfs
Head at valves 284'
T.W. El. 1902

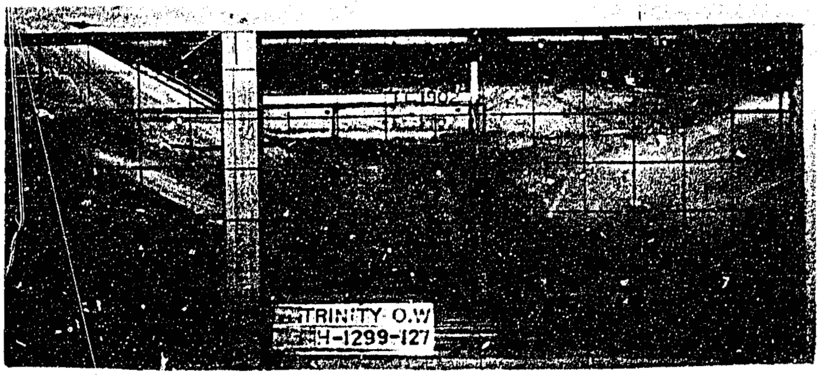


B. 7,670 cfs
Head at valves 315'
T.W. El. 1903

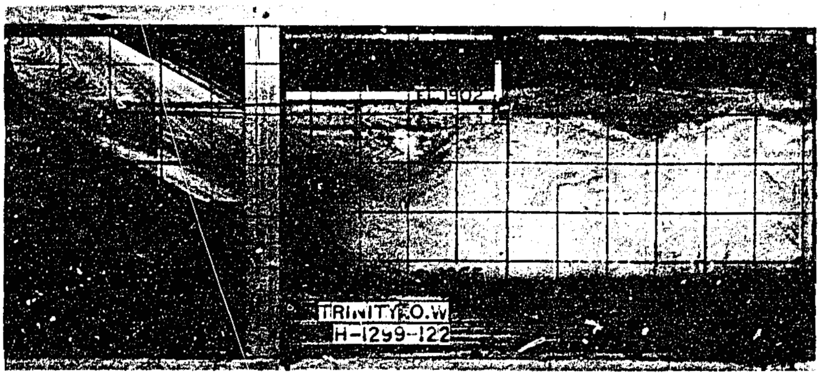
C. 7,670 cfs
Head at valves 315'
T.W. El. 1902
Waves 1.75' high in river channel at gage.

TRINITY DAM OUTLET WORKS

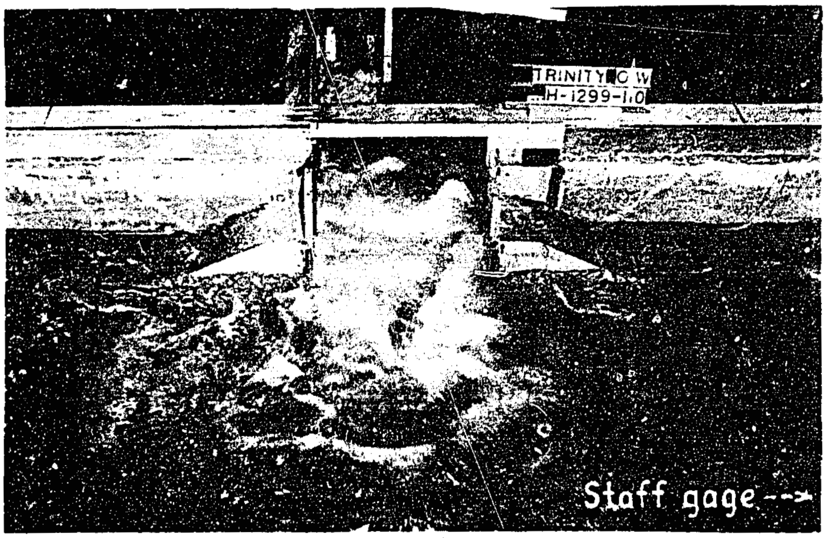
Flow Conditions in Recommended Basin--Two Valve Operation
1:28 Scale Model



A. Left valve discharging 4,260 cfs, Head at valve 392', T.W. El. 1899.



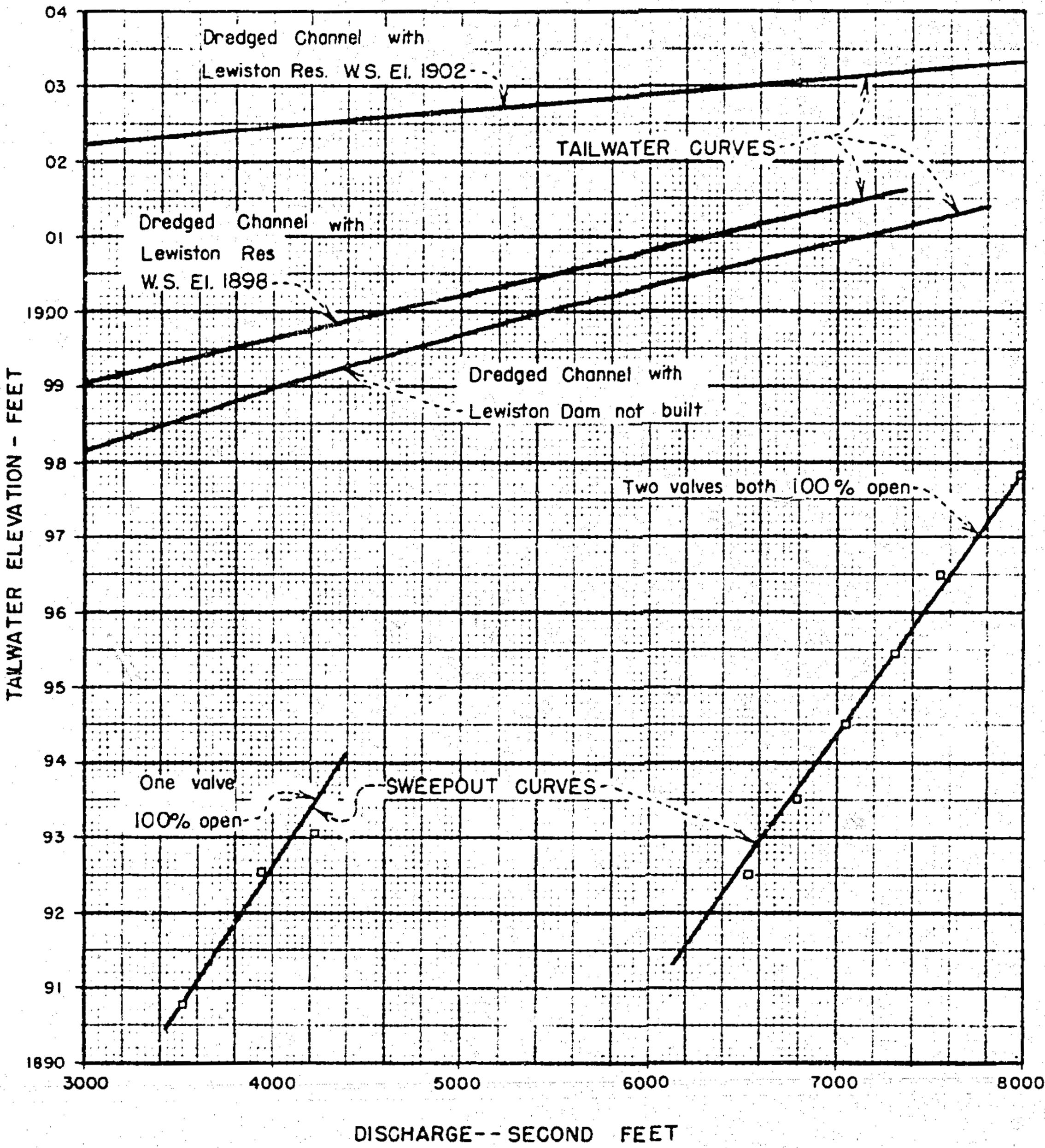
B. Same as A except right valve discharging. Waves 2.75' high in river channel at gage.



C. Right valve discharging 3,900 cfs, Head at valve 326', T.W. El. 1898. Waves 2.5' high in river channel at gage.

TRINITY DAM OUTLET WORKS

Flow Conditions in Recommended Basin--
One Valve Operation
1:28 Scale Model

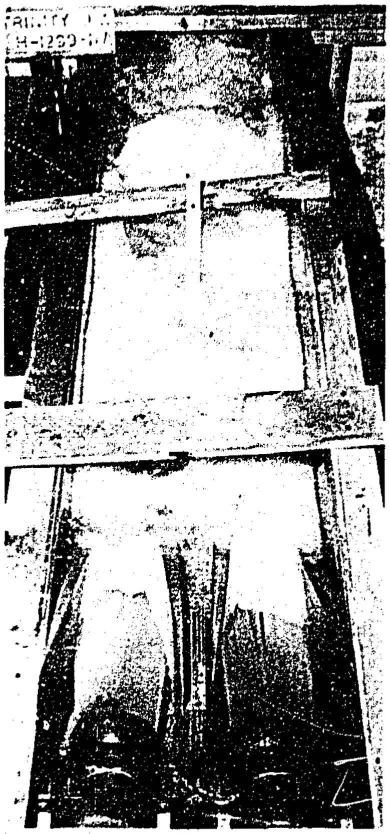


Sweepout Tailwater is defined here as that elevation where momentarily no water rolls back on to the flow from one valve. The flow from one valve always sweeps out before the flow from the other.

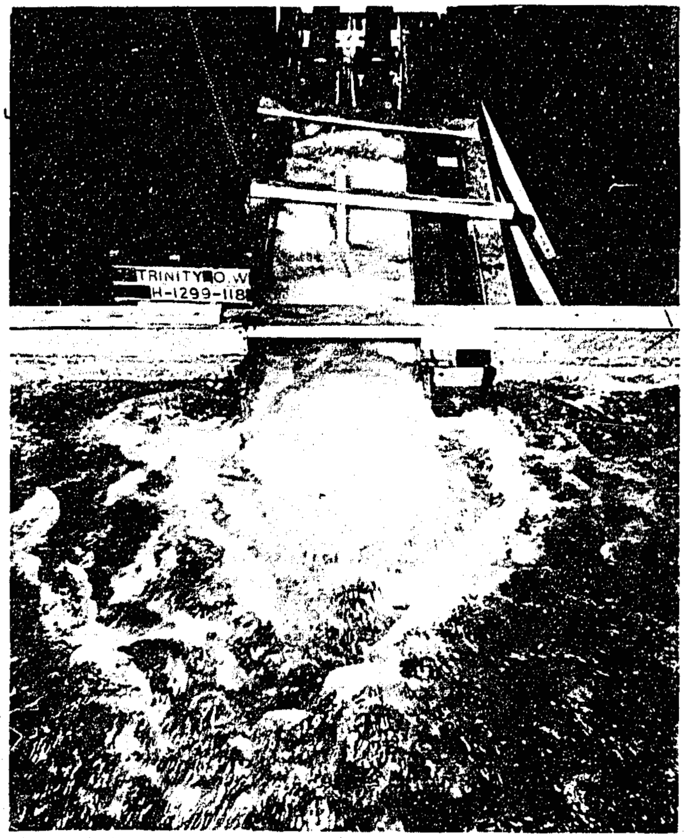
TRINITY DAM OUTLET WORKS

JUMP SWEEPOUT CURVES --RECOMMENDED BASIN

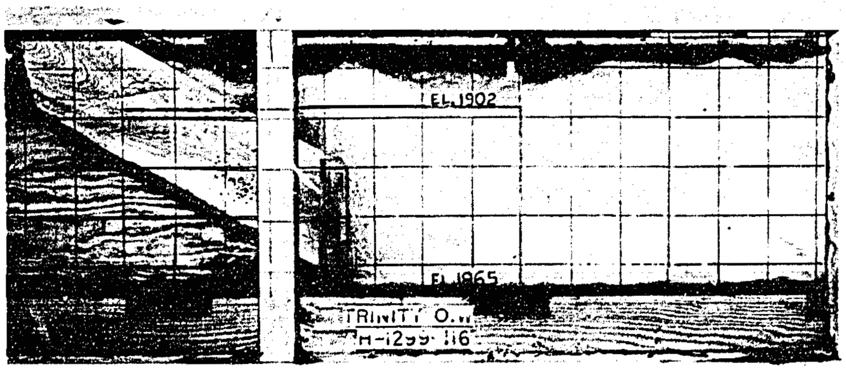
1:28 SCALE MODEL



A. View from upstream



B. View from downstream

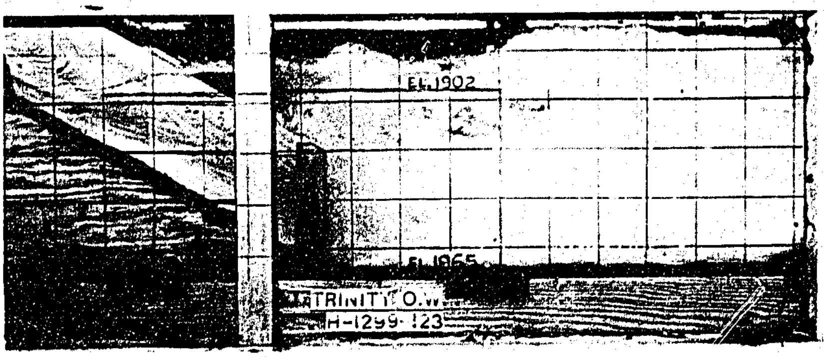


C. Side View

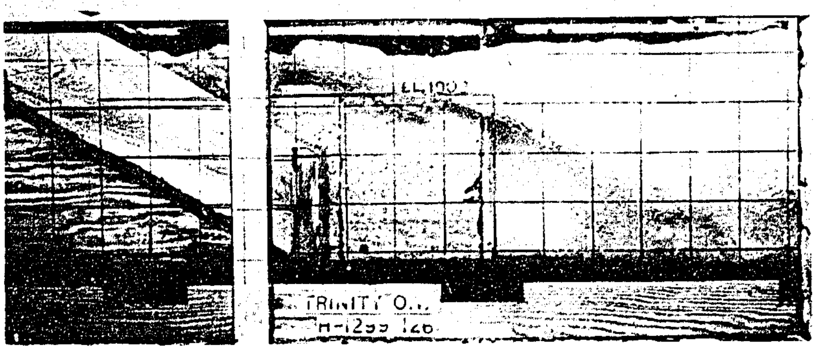
7,670 cfs--Head at valves 315'

TRINITY DAM OUTLET WORKS

Two-Valve Operation For Tail-Water Elevation 1913--Recommended Basin
1:28 Scale Model



A. Right valve discharging 4, 260 second feet. Head 392' at valve. Waves 5' high in river channel at gage.

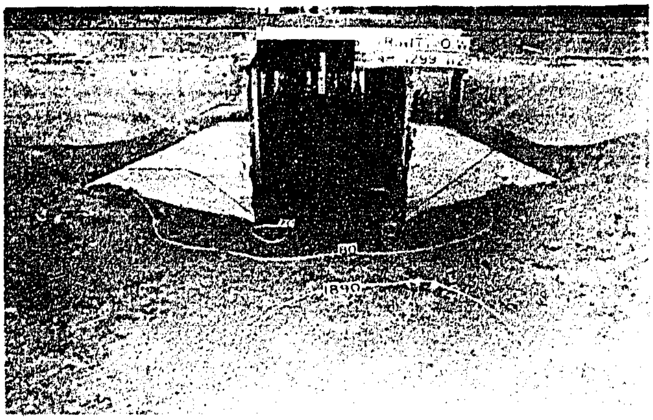


B. Same as A except left valve discharging.

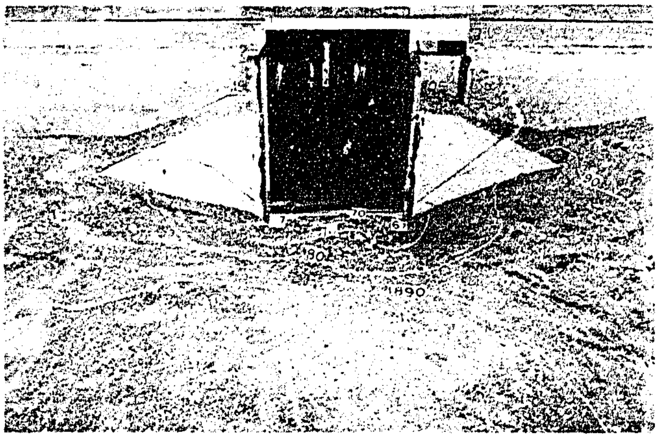
NOTE:
Not a recommended operating condition.

TRINITY DAM OUTLET WORKS

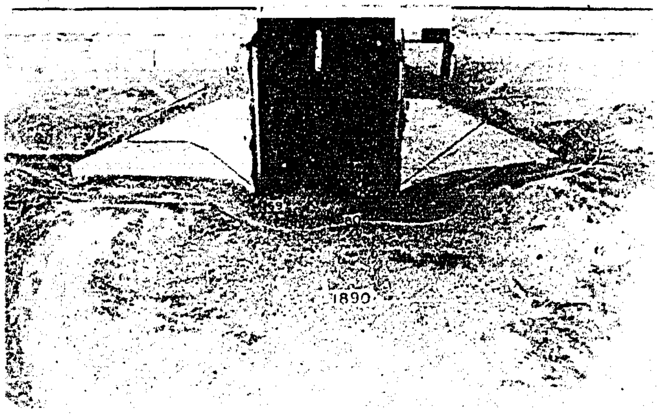
One-Valve Operation for Tail-Water Elevation 1913--
Recommended Basin
1:28 Scale Model



A. Two valves discharging 7,670 cfs. Head at valves 315'. T.W. El. 1902. Erosion pattern after one hour model test run.



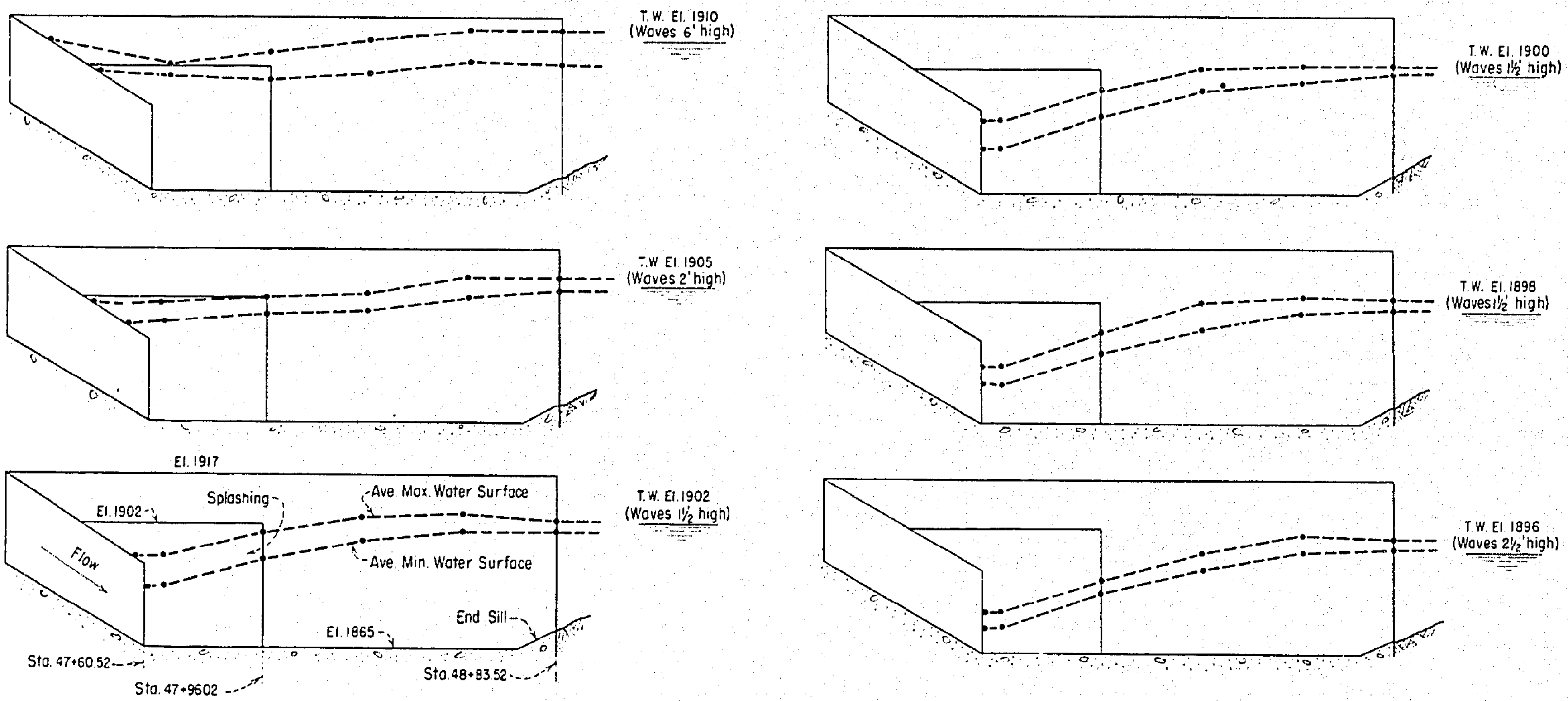
B. Two valves discharging 7,670 cfs. Head at valves 315'. T W. El. 1899. Erosion pattern after one hour model test run.



C. Right valve discharging 3,900 cfs. Head at valve 326'. T.W. El. 1898. Erosion pattern after one hour model test run.

TRINITY DAM OUTLET WORKS

Erosion Tests--Recommended Basin
1:28 Scale Model



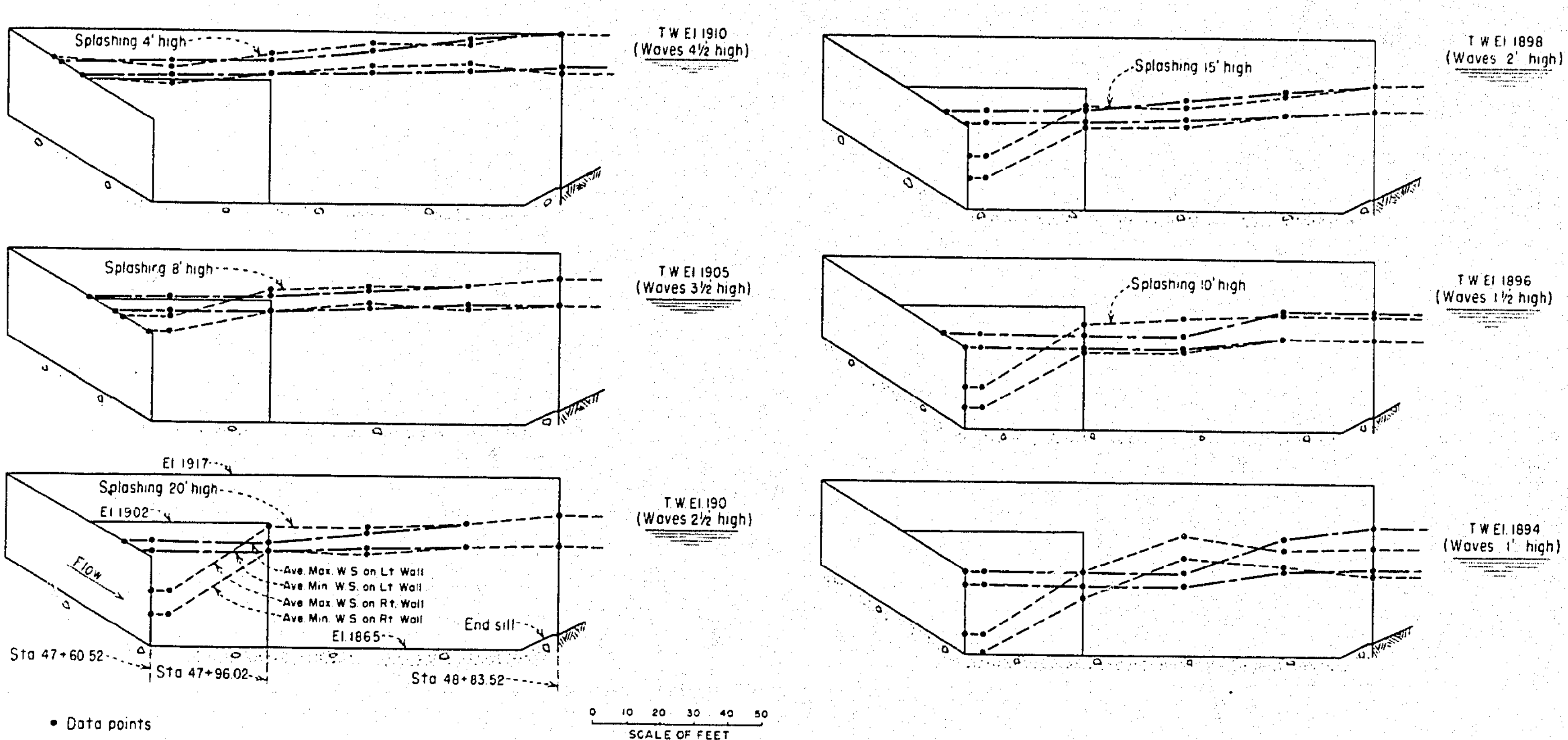
• Data points

Two valves, discharging 7,200 cfs. Head at valves 284 feet

0 10 20 30 40 50
SCALE IN FEET

TRINITY DAM OUTLET WORKS
WATER SURFACE PROFILES IN RECOMMENDED BASIN
TWO VALVE OPERATION
1:28 SCALE MODEL

FIGURE 25
REPORT HYD 439

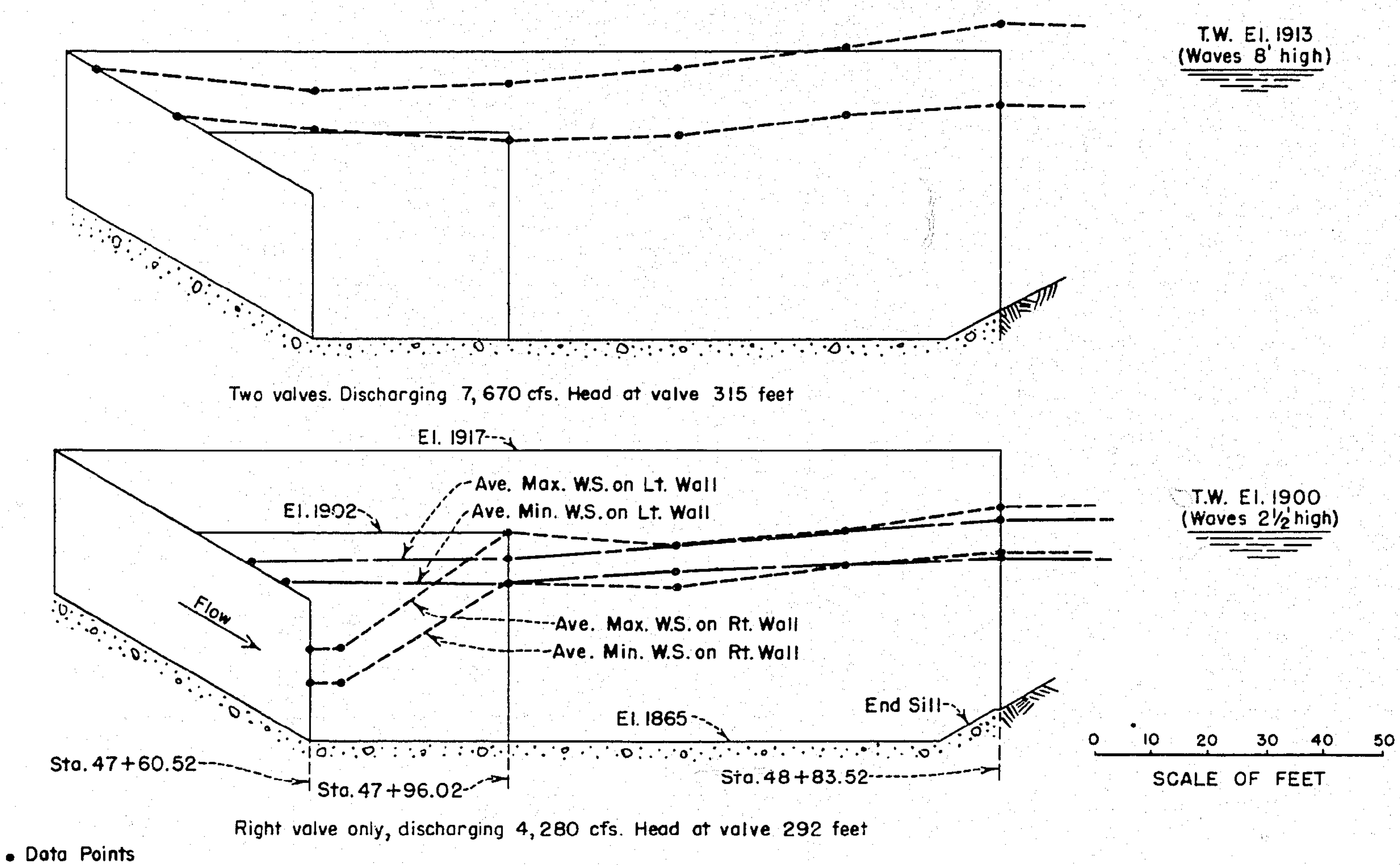


Right valve only, discharging 3,900 cfs. Head at valves 326 feet

TRINITY DAM OUTLET WORKS

WATER SURFACE PROFILES IN RECOMMENDED BASIN
ONE VALVE OPERATION
1:28 SCALE MODEL

FIGURE 26
REPORT HYD 439



TRINITY DAM OUTLET WORK

WATER SURFACE PROFILS IN RECOMMENDED BASIN

1:28 SCALE MODEL

FIGURE 27
REPORT HYD. 439

GPO 852105