UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 184

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HYDRAULIC MODEL STUDIES FOR THE DESIGN OF THE PILOT KNOB WASTEWAY BOULDER CANYON PROJECT ALL-AMERICAN CANAL SYSTEM

By

J. W. Ball

- - -

Denver, Colorado
October 12, 1945

HYD 184

PREFACE

The program of hydraulic model studies to develop a satisfactory design for the Pilot Knob Wasteway on the All-American Canal in California, five miles west of Yuma, Arizona, was performed in the hydraulic laboratory of the Colorado A. and M. College at Fort Collins, Colorado between September 1936 and May 1937. The investigations concerned the flow conditions at the entrance, in the gate section, the chute, the stilling pool and the downstream channel of the wasteway structure. The studies were conducted on a 1 to 36 model of the complete wasteway, including a short section of the All-American Canal, and a 1 to 12 model of a single by-pass sluiceway of the gate section of the wasteway.

The model tests were conducted by D. M. Lancaster, H. W. Brewer and M. R. Spindler. Mr. J. M. Buswell was in immediate charge of the construction and testing of the models and assisted in preparing the data for this report. The work was supervised by J. W. Ball under the general direction of J. E. Warnock. Urgent work in the laboratories prevented an earlier completion of the report.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
October 12, 1945

Laboratory Report No. 184
Hydraulic Laboratory

Compiled by: J. W. Ball
Reviewed by: J. E. Warnock

Subject: Hydraulic model studies for the design of the Pilot Knob Wasteway - All-American Canal System - Boulder Canyon Project.

INTRODUCTION

1. Location and Description.--The Pilot Knob wasteway is located on the All-American Canal in California, approximately five miles west of Yuma, Arizona (figure 1). It consists of an intake section, gate section, chute, and stilling pool. The structure (figures 2 and 3) will waste water into the Colorado River continually to supply the Alamo Canal until the Pilot Knob Power Plant is constructed and will be used afterwards to regulate the water surface in the All-American Canal and waste surplus water when units in the power plant are not operating.

A concrete-lined channel normal to the center line of the All-American Canal, forms the intake of the wasteway. This channel, joined to the side of the canal by transitions, leads to a gate section consisting of four large and two small radial gates, which assist in controlling the water level in the main canal by regulating the flow through the wasteway. It is estimated that the discharge through the gates will vary from 2,000 and 13,155 second-feet, until the power plant is in operation. The flow will pass from the All-American Canal through the entrance channel and the gate structure into a concrete-lined chute under the Southern Pacific Railroad to the stilling pool, thence into the Alamo Canal or the Colorado River, by way of the Rockwood heading. With water flowing through the wasteway, the Rockwood heading will control the minimum depth of tailwater to 16.5 feet for all discharges. With the Colorado River in flood stage, it is possible for the tailwater to reach a depth of 29.5 feet. With no water in the Colorado River, the Alamo Canal, or the wasteway, the estimated minimum depth is 9.5 feet. Normally the total drop from the water in the canal to that in the stilling pool will be 57 feet.

Models of the wasteway on a scale of 1 to 36 and of one by-pass sluiceway to a scale of 1 to 12 were constructed in the Fort Collins laboratory for the purpose of checking the adequacy of the hydraulic features of the wasteway structure.

2. Scope of Tests.--Smooth entrance conditions are essential to the satisfactory operation of a chute or spillway, thus detailed investigations were made concerning the right-angle entrance from the main canal to the wasteway channel.

It is important that the Pilot Knob wasteway have sufficient capacity to discharge the entire flow from the main canal in an emergency. As the capacity of a structure depends on the efficiency of the control section, and the efficiency is lowered by any unnecessary head loss, the investigations concerning this part of the structure involved the streamlining of parts of the gate section.

Features of any structure operating as continuously as it is expected the by-pass sluiceways of the Pilot Knob Wasteway will be operated, should give flow conditions with as little disturbance as possible. Extensive tests were conducted on the 1 to 36 wasteway model and a 1 to 12 model of a single by-pass to study flow conditions in the channel below the gate section and within the sluice conduit. The by-pass capacity was obtained during the investigation.

The material, underlying and adjacent to the full-sized structure being of an easily erodible nature, made it of vital importance to dissipate, as completely as possible, the energy in the high-velocity water entering the pool. Instability of excavation slopes due to shallow water table and seepage, governed the pool depth. The shallow pool thus determined was necessarily of greater width than the channel immediately below the gate section of the wasteway. This greater width introduced the problem of spreading the flow uniformly over the entire width of the pool entrance so as to obtain the proper relation between the upstream and downstream depths for forming the hydraulic jump. After detailed study, the spreading was accomplished by introducing a superelevation or spreader at the junction of the slopes in the channel connecting the gate section with the stilling pool.

The problem on the stilling pool involved the design of features directly responsible for dissipating the energy contained in the influent water and for protecting the stilling pool structure. Length of pool, size of sill, size and effectiveness of the toothed apron at the pool entrance, shape of exit transitions, and extent of downstream riprap were important factors considered.

3. Summary of Results.--Entrance transition designs eliminating excessive turbulence, were evolved from the model tests.

By altering and streamlining the control section slightly, it was possible to increase the capacity sufficiently to handle the flow of the main canal.

Improvement in the action of the by-pass sluiceways was obtained by making the exit angle into the wasteway chute less abrupt and by placing a beam in the roof of each conduit.

A satisfactory means was found for spreading the wasteway flow from the channel width to that of the stilling pool. This was accomplished by superelevating the vertical curve symmetrically about the wasteway centerline between stations 5+50.3 and 6+10.3.

A pool 60 feet long, with a toothed apron 2½ feet high at the entrance and a 5-foot dentated sill at the downstream end, was found best suited to the operating conditions of the wasteway. A shorter pool gave rough surface conditions and a longer one was never utilized completely.

It was found that the paving in the tailrace below the apron was not essential to the satisfactory hydraulic action of the stilling pool.

The model with all the improved features incorporated is shown on figure 4 and plate 1.

THE INVESTIGATION

4. Description of Models.--A metal-lined timber head tank, representing the short length of the All-American Canal adjoining the wasteway, was attached to a 2-foot riser of the underground distribution system of the laboratory (figure 4). The 1:36 model wasteway intake, containing the left entrance transition formed of concrete, was a metal-lined flume attached to the tank representing the portion of the main canal. The flume led to the control section, which was constructed of redwood. The piers were made of the same material and the radial gates were fabricated of heavy galvanized iron. A wooden chute lined with lightweight sheet iron was used for conveying the discharge to the stilling pool. The stilling pool, constructed of wood, was placed in a metal-lined tank which contained sand to represent the tailrace. An adjustable weir at the end of the sand box, hinged at the bottom, was used to regulate the tailwater elevation, which was measured by a float gage attached by a pipe to a piezometric opening in the tailrace.

The model discharge of 1.69 second-feet, which represented the design capacity of the prototype, or 13,155 second-feet, was measured by a 90-degree V-notch weir, from which it was conveyed through the underground distribution system to the short section of the main canal by way of the two-foot riser. The water then flowed into the intake, normal to the center line of the canal, through the gate section, chute, and stilling pool to a channel which returned it to the laboratory circulating system. The elevation of the water surface in the main canal was measured by a point gage fastened to the side of the intake tank.

A metal-lined wooden box attached to the laboratory supply system represented the entrance channel of the wasteway in the 1:12 model of the by-pass sluiceway (figure 7). Piers of redwood were extended into the box to supply the proper entrance conditions to the model. The well structure containing the gate and the downstream conduit of the sluiceway were constructed of redwood. The radial gate was of sheet metal and the conduit downstream from the gate was provided with a covering of transparent plastic sheet to permit viewing the flow within.

5. Preliminary Tests.--The initial test, in which the model was operated throughout the discharge range, indicated that it would be desirable to make changes in the design of several features of the wasteway. These included the transition of the left intake wall, the gate section, the by-pass sluiceways, the chute, and the stilling pool.

6. Study of the Left Entrance Transition.--Flow conditions in the entrance channel were very good when the gates were operating to maintain a constant level in the canal and small quantities were being discharged. However, rough flow existed at the original left entrance transition (design 1, figure 5), when the gates were completely raised and various discharges passed through the wasteway. In view of this action, a satisfactory design for the maximum discharge was considered the criterion and subsequent tests were made accordingly. The disturbance at the transition was caused by the contraction and loss of head resulting from the abrupt change in direction of the flow from the canal to the wasteway (plate 2B). This sharp angle caused the flow to be deflected toward the right wall of the intake, producing a high water surface at the right end of the gate section.

The design of this transition was altered to improve these conditions. The second design (design 2, figure 5) consisting of a warped surface between a straight line at the top and an arc at the base, gave improved flow (plate 2D) but the disturbance at maximum discharge indicated that the transition was still too abrupt. A new design, introducing a more gradual transition consisting of a curved surface between two horizontal circular arcs of equal radii, or a segment of an inclined elliptical cylinder, was tried (design 3, figure 5). Practically all surface disturbances were eliminated with this design. It performed similarly for all discharges and was the most desirable of the shapes so far as hydraulic conditions were concerned (plate 2F). However, it was objectionable because of complex construction. A third design, a combination of this and the previous shape, and of simpler construction, was installed (design 4, figure 5). The turbulence increased but since operation at the maximum discharge was expected to be infrequent, this action was not considered critical and the shape was approved for the final design.

7. Study of the Gate, or Control Section.--The submerged condition which existed for the design discharge on the original control section (plate 3B), was next investigated. Observations indicated that the submergence was due to excessive head loss resulting from the contractions at the ends of the gate structure. The condition was present whether the sluices were open or closed.

Several transitions with openings for the by-pass discharge were placed in the corners immediately upstream from the gates but none worked satisfactorily unless they were extended an appreciable distance upstream. The gate section was free of submergence when temporary extensions to the piers between the main channel and by-pass gates were held in place, thus lengthening the piers seemed the most feasible solution. The two outside piers next to the sluiceways were extended to correspond in length to the center pier, which was to be used as a support for the highway bridge, and all semicircular noses except those on the sloping portion at the upstream end of the short piers were replaced by sharp ones for the purpose of minimizing the pier contractions (recommended design, design 2, figure 6). With this design, the submergence was entirely eliminated, and the water flowed smoothly through the gate openings (plate 3D). This design was later revised to shorten the spans and permit more economical bridge construction. In this case the center pier was shortened, the two adjacent piers were extended 21 feet to support the bridge, and the outside piers were extended a minimum distance to give free flow conditions under the wasteway gates (final design, design 3, figure 6). Although waves reached the top of the gate openings occasionally, the design was considered acceptable and was adopted for the prototype.

8. Study of the By-pass Sluiceways.--When the two by-pass sluices located on each side of the gate section of the wasteway were operated alone, their jets came together abruptly at the center of the channel below the gate section. A concentration of flow, with considerable splash resulted (plate 4A). This condition, which was attributed to the impact of the jets upon one another as they flowed from the 45-degree outlets, was undesirable and the outlet angle was changed to 30 degrees. Considerable improvement was noted (plate 4B) and this design was accepted, subject to tests on a 1 to 12 model of a single sluice, when it was believed impractical to further decrease the outlet angle. The excessive spray from these outlets at partial gate openings and the pulsating flow, which seemed to occur in the sluice immediately downstream when the gate was raised completely, made it desirable to study the flow conditions in more detail. A model of the right sluice on a scale of 1 to 12 was constructed for this purpose, (figure 7). The construction of a sloping downstream wall in the gate well in the larger model eliminated the pulsating action. The spray at partial gate openings was more noticeable than at full gate (plate 4) and the cause was obvious when the conditions were viewed through the transparent top of the model. The high-velocity water impinged on the 30-degree outside wall of the tunnel and was turned upward to the roof, thence back upstream toward the wasteway channel where it covered the top of the opening as it left the tunnel exit. This thin jet produced spray and closed the conduit exit completely for all except very small flows. These objectionable characteristics were reduced to a minimum by placing a protruding beam in the roof of the conduit (figure 7 and plate 4). Moreover, the beam served to aerate the tunnel at all flows. The sluice was calibrated for various water surface elevations in the canal with the gate raised completely and a head-discharge curve prepared (figure 7). After the final design had been determined, the sluices were installed on the 1 to 36 model where testing was resumed on the

hydraulic features downstream from the control section.

9. Study of the Chute and the Stilling Pool.--The chute leading from the control section to the stilling pool consisted of two sections of sloping channel connected by a vertical curve. The upper part on a slope of 0.006 had a constant width, while the lower part on a 3 to 1 slope had its walls flared symmetrically, increasing the width from 62 to 140 feet (design 1, figure 8). The conditions in the upstream portion of the chute were satisfactory for all gate combinations and it was not necessary to alter this part of the wasteway. The flow through the vertical curve and down the 3 to 1 slope failed to spread sufficiently to follow the diverging walls, thus the water was concentrated in the center of the chute as it entered the stilling pool. The concentration interfered with the formation of the hydraulic jump and gave objectionable turbulence in the stilling pool. The action indicated that better results would be obtained with a narrow and deeper pool but this design was prohibited geologically, thus a means was sought for spreading the jet uniformly across the width of the pool.

Consideration was given to flaring the channel immediately below the gate section, but due to the increase in construction cost this plan was abandoned in favor of a superelevation of the vertical curve. Several shapes of this type of diffuser, with the superelevation symmetrical about the center-line of the wasteway, were investigated (designs 2 to 10, figure 8). Because the size, shape, and position of the superelevation were important factors influencing its efficiency, these characteristics were varied until the most efficient design for the range of discharge was obtained. The diffusers became more effective when placed on the more gradual slope where the velocity of the water was less. This was attributed to the greater spreading action produced by gravity on the more gradual slope. The superelevation was, therefore, placed as far upstream as feasible without reducing the wasteway discharge, preventing draining of the channel, or producing undesirable waves in the channel at low discharges. The spreading was not complete for all discharges in any case, but was more uniform over a wider range on the final than on any of the other designs (design 7, figure 8). The design selected proved very effective in spreading the uneven flow when the gates were operated unsymmetrically (plate 7). With satisfactory entrance conditions for the pool assured, tests concerning the adequacy of the pool were conducted.

10. Study of the Stilling Pool Design.--The pavement downstream from the sill of the original design of the stilling pool was omitted in the model because it was desired to study the effectiveness of various designs in minimizing the erosion of a pool bottom of silt and fine sand. Moreover, it did not seem essential so far as the operation of the pool was concerned to pave such a large area downstream from the apron.

Since under certain conditions of operation it was possible for all the gates in the control section to be opened suddenly, allowing 13,155 second-feet of water to flow into the stilling pool with the tailwater at its minimum elevation, it was imperative that the structure be designed for this contingency. With these conditions the hydraulic jump was completely swept from the original apron (design 1, figure 8). Streaming flow carried beyond the square sill where a standing wave formed and rather severe erosion occurred. It was noted that a substantial increase in tailwater depth was necessary to return the hydraulic jump to the apron when this condition was present, and that a slight increase in tailwater depth would move the jump upstream only if the jump were formed partially, with the streaming flow passing under the surface layer of tailwater. In view of this observation, it was essential for the hydraulic jump to form with its upstream edge in front of the sill, such that streaming flow ceased to carry beyond it into the tailrace at the minimum tailwater elevation. With this condition, the jump would move back rapidly on the apron as the tailwater increased to its normal elevation. It was estimated that normal tailwater on the prototype would be established in about 15 minutes, so the fact that the jump formed near the end of the pool for the minimum elevation was not critical.

The original design apron (design 1, figure 8) was too short when the streams leaving the tops of the high steps of the toothed apron at the upstream end of the pool floor arched over the downstream sill and struck the sand portion of the tailrace. Smaller steps and a longer apron were installed to eliminate this condition (design 2, figure 8). The square sill was replaced by a 2½-foot Rehbock sill. The jump did not sweep off the apron at maximum discharge with a tailwater elevation of 104.0, but the pool seemed to have more than sufficient length and the sill too small. Accordingly, the height of the sill was increased to 5 feet and the pool shortened to its original length (designs 2 and 3, figure 8). The jump still formed on the apron but a high roll appeared over the sill, indicating that the apron needed more length. Before it was lengthened, however, tests were made to determine the essentiality of the upstream steps (toothed apron). They assisted materially in keeping the hydraulic jump on the apron and were indispensable for operating at the low tailwater elevations. The pool length was increased to 60 feet and the appearance was much improved. The steps were as essential as with the shorter apron and were recommended for the prototype. Tests on this arrangement indicated that the pavement downstream from the end of the pool could be replaced by a 50-foot band of riprap and that the warped wing walls could be shortened considerably. Also, that the warped walls were essential in preventing erosion near the downstream corners of the apron. When an acceptable design had been evolved (figure 9) performance tests were made and the model was demonstrated to the design section. The arrangement proved satisfactory for all conditions under which it was expected to operate, including gate combinations (plates 5, 6, and 7). Slight changes in the pool to take care of structural features, which included pavement downstream from the sill and increased warp length, were installed and checked by model tests. The results remained unchanged and the plan was adopted.

CONCLUSIONS

11. Wasteway Structure.--The wasteway design, as evolved from the hydraulic model studies (figure 4) will, under all conditions, adequately and efficiently control flows up to and including the maximum design discharge of 13,155 second-feet.

12. Entrance Transitions.--There will be smooth flow conditions at the wasteway entrance transition for all discharges except those near the maximum. It is anticipated that the wasteway will seldom operate at these discharges, so the rough surface conditions, which did not appear objectionable on the model, should not prove critical.

Smooth flow conditions will always be present at the original design transition on the upstream end of the right wall of the approach section when the operation is the same as that of the model.

13. Gate or Control Section.--A rearrangement and lengthening of the end piers of the gate structure decreased the head loss due to contractions at the ends of this section and eliminated submerged flow through it. Better results were obtained when longer piers were used, but further extension was not considered justified when these piers were not needed for supporting the highway bridge, which crossed upstream from the gate section.

14. By-pass Sluiceways.--The waves and splash resulting from the impingement on each other of the sluiceway jets were materially reduced by changing the angle of the outside exit wall from 45 to 30 degrees and by placing a protruding beam in the roof of each conduit.

15. Chute to Stilling Pool.--The railroad bridge crossing the chute below the gate section should receive little or no splash for any method of wasteway operation.

The flow through the wasteway would not spread to the width of the stilling pool without the superelevation of the floor of the chute at the vertical curve. Superelevating below the curve was ineffective, while above the curve it became too effective, dividing the flow into two streams at low discharges, and forming a standing wave in the channel immediately upstream.

The recommended superelevated spreader, which is symmetrical about the center line at the vertical curve, will spread the wasteway flow very uniformly from a width of 62 feet at the upper end of the chute to 140 feet at the stilling pool entrance for practically all discharges, thereby causing an efficient hydraulic jump to form in the pool. All but very low flows, which will be divided, forming two streams, one along each wall of the wasteway, will be favorably affected by this superelevation. In any case, the conditions for the small discharges are not too objectionable, especially when it is considered that a change to improve the flow for these discharges resulted in undesirable and possibly critical conditions for the maximum discharge. The design evolved from the model studies will give optimum flow conditions throughout the discharge range.

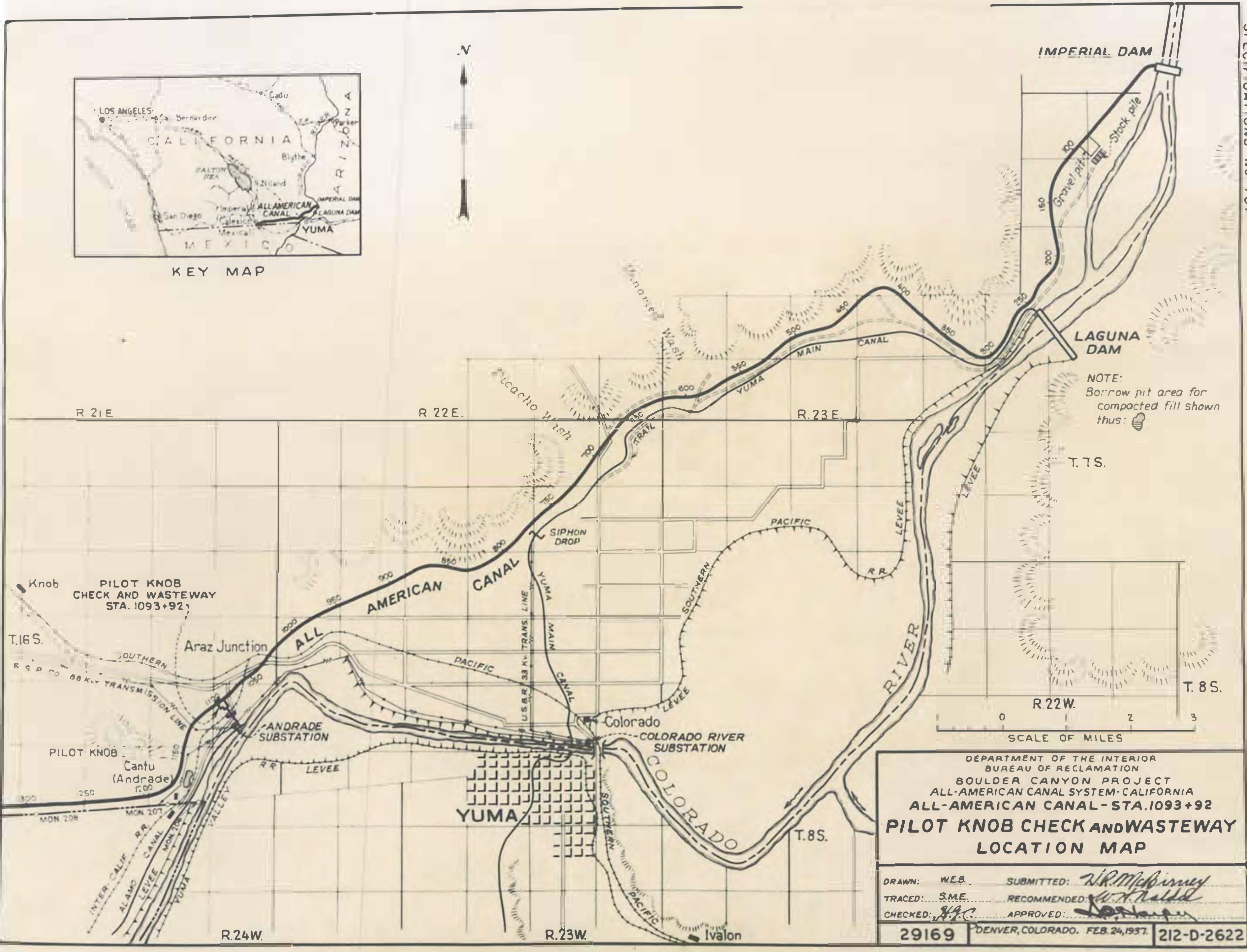
16. Stilling Pool.--The wasteway stilling pool will be very effective in dissipating the energy of the inflowing water when the tailwater becomes normal or above.

The jump should not sweep completely off the apron at the maximum discharge when the tailwater is abnormally low, but should move downstream over the sill. In event the wasteway should be set into operation suddenly at the maximum discharge, the tailwater will reach the normal elevation within a few minutes and the jump will move upstream into the pool, thus this condition cannot be considered serious.

The warped walls at the end of the stilling pool are essential in preventing the formation of return eddies which would scour the banks below the pool. The paved floor downstream from the apron was not essential to the satisfactory performance of the wasteway stilling pool.

The riprap at the end of the warped walls is essential in damping the wave action on the edges of the pool in this vicinity and preventing scour of the channel near the downstream edge of the warp and pavement.

- - -


KEY MAP
LOS ANGELES
San Bernardino
CALIFORNIA
ARIZONA
SALTON SEA
Niland
Blythe
Parker
Cadiz
San Diego
Imperial
Calexico
Mexicali
MEXICO
ALL-AMERICAN CANAL
IMPERIAL DAM
LAGUNA DAM
YUMA
N
IMPERIAL DAM
Stock pile
Gravel pit
LAGUNA DAM
NOTE: Borrow pit area for compacted fill shown thus:
YUMA MAIN CANAL
Picacho Wash
R 21 E.
R 22 E.
R. 23 E.
T. 7 S.
T. 8 S.
T. 16 S.
SIPHON DROP
ALL AMERICAN CANAL
PILOT KNOB CHECK AND WASTEWAY STA. 1093+92
Knob
Araz Junction
SOUTHERN PACIFIC R.R.
S.P. Co. 88 Kv TRANSMISSION LINE
U.S.B.R. 33 Kv TRANS. LINE
ANDRADE SUBSTATION
Colorado
COLORADO RIVER SUBSTATION
LEVEE
PILOT KNOB
Cantu (Andrade)
MON 208
MON 207
MON 206
INTER-CALIF. R.R.
ALAMO CANAL
LEVEE
YUMA VALLEY
YUMA
COLORADO RIVER
R.22W.
0 1 2 3
SCALE OF MILES
R.24W.
R.23W.
Ivalon
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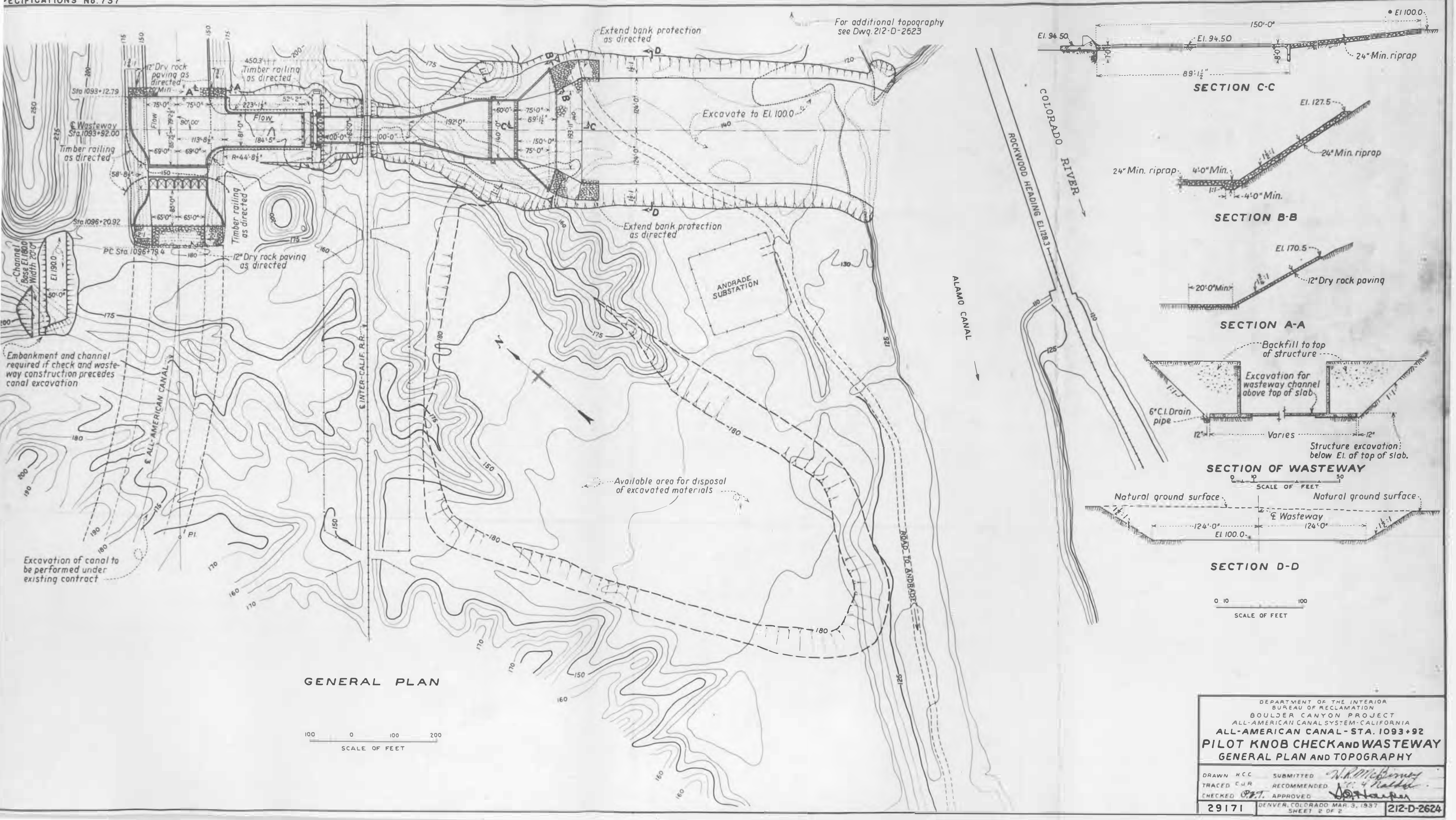
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM-CALIFORNIA
ALL-AMERICAN CANAL - STA. 1093+92
PILOT KNOB CHECK AND WASTEWAY
LOCATION MAP
DRAWN: W.E.B.
TRACED: S.M.E.
CHECKED:
SUBMITTED: W.R. McBirney
RECOMMENDED:
APPROVED:
29169
DENVER, COLORADO. FEB. 24, 1937.
212-D-2622

FIGURE 1



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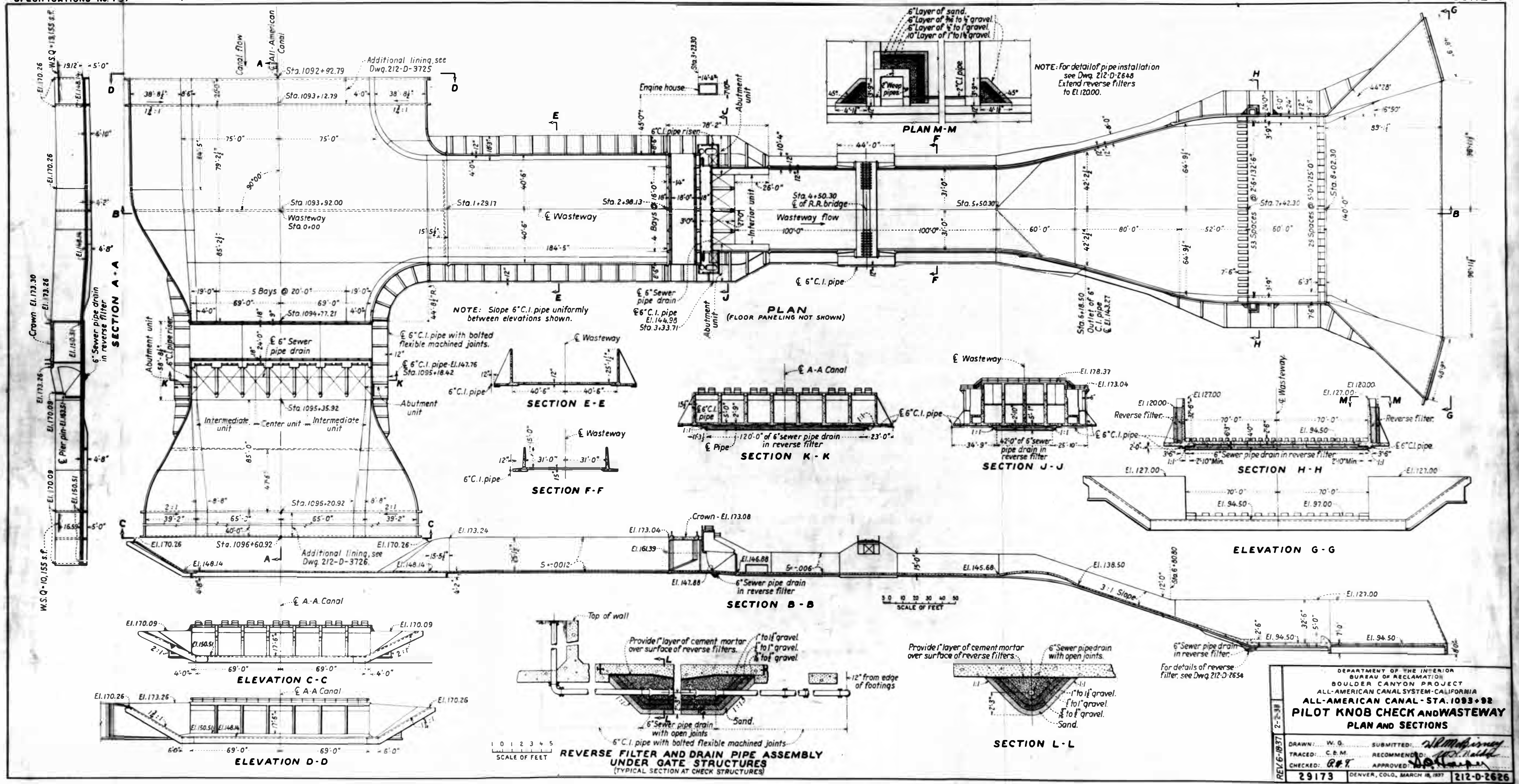
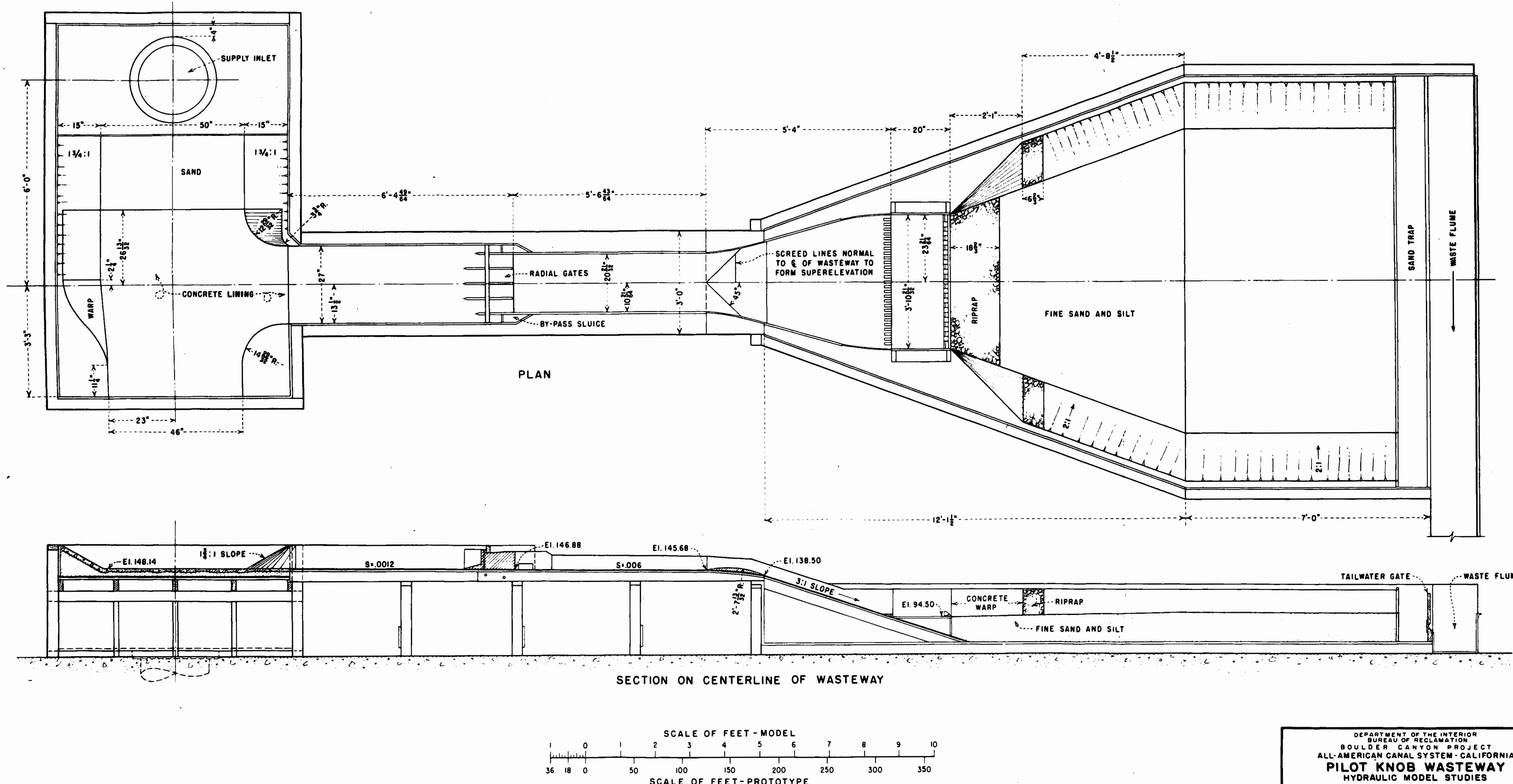
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM - CALIFORNIA
ALL-AMERICAN CANAL - STA. 1093+92
PILOT KNOB CHECK AND WASTEWAY
GENERAL PLAN AND TOPOGRAPHY
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
29171
DENVER, COLORADO MAR. 3, 1937
SHEET 2 OF 2
212-D-2624
GENERAL PLAN
SCALE OF FEET
SECTION C-C
SECTION B-B
SECTION A-A
SECTION OF WASTEWAY
SECTION D-D
For additional topography see Dwg. 212-D-2623
Extend bank protection as directed
Excavate to El. 100.0
12" Dry rock paving as directed
Timber railing as directed
Sta 1093+12.79
℄ Wasteway Sta. 1093+92.00
Sta 1096+20.92
PC Sta 1096+79.4
Flow
Channel Base El. 180.0 Width 20.0'
Embankment and channel required if check and wasteway construction precedes canal excavation
Excavation of canal to be performed under existing contract
℄ ALL-AMERICAN CANAL
℄ INTER-CALIF. R.R.
ANDRADE SUBSTATION
Available area for disposal of excavated materials
ROAD TO ANDRADE
ALAMO CANAL
ROCKWOOD HEADING El. 128.3
COLORADO RIVER
El. 94.50
El. 100.0
24" Min. riprap
El. 127.5
4'-0" Min.
El. 170.5
20'-0" Min.
12" Dry rock paving
Backfill to top of structure
Excavation for wasteway channel above top of slab
6" C.I. Drain pipe
Varies
Structure excavation below El. of top of slab.
Natural ground surface
℄ Wasteway
124'-0"
El. 100.0


PLAN
(FLOOR PANELING NOT SHOWN)
PLAN M-M
SECTION A-A
SECTION E-E
SECTION F-F
SECTION K-K
SECTION J-J
SECTION H-H
ELEVATION G-G
SECTION B-B
ELEVATION C-C
ELEVATION D-D
REVERSE FILTER AND DRAIN PIPE ASSEMBLY UNDER GATE STRUCTURES
(TYPICAL SECTION AT CHECK STRUCTURES)
SECTION L-L
NOTE: For detail of pipe installation see Dwg. 212-D-2648. Extend reverse filters to El. 120.00.
NOTE: Slope 6" C.I. pipe uniformly between elevations shown.
Wasteway flow
Canal flow
Engine house
Abutment unit
Interior unit
Intermediate unit
Center unit
Sta. 1093+92.00
Wasteway Sta. 0+00
Sta. 4+50.30 ℄ of R.R. bridge
Provide 1" layer of cement mortar over surface of reverse filters.
6" Sewer pipe drain in reverse filter
6" C.I. pipe with bolted flexible machined joints
SCALE OF FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM-CALIFORNIA
ALL-AMERICAN CANAL - STA. 1093+92
PILOT KNOB CHECK AND WASTEWAY
PLAN AND SECTIONS
DRAWN: W. G.
TRACED: C. B. M.
CHECKED: R.H.T.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLO., MARCH 18, 1937
29173
212-D-2626



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BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM - CALIFORNIA

PILOT KNOB WASTEWAY

HYDRAULIC MODEL STUDIES

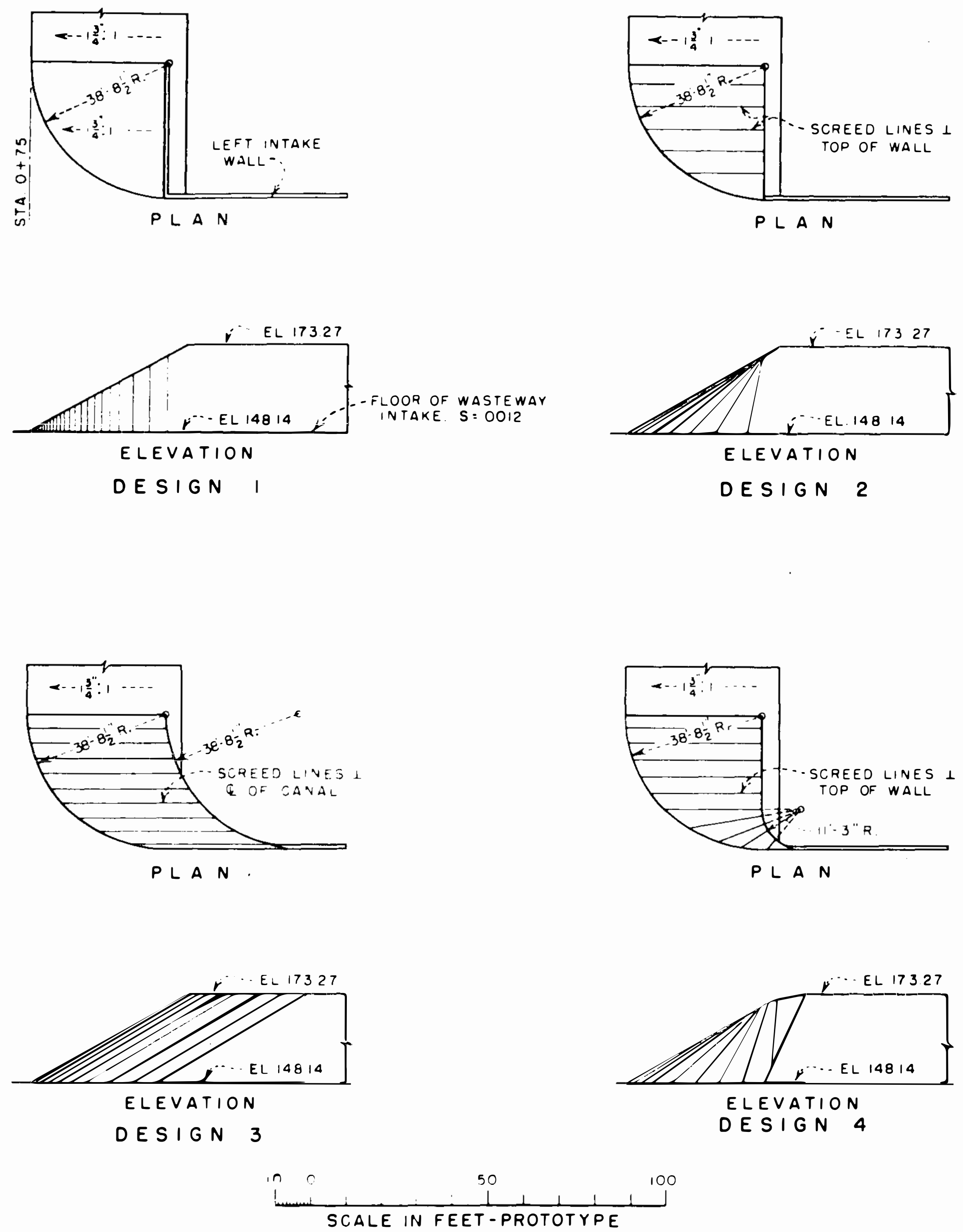
MODEL SCALE 1:36

GENERAL MODEL LAYOUT - RECOMMENDED DESIGN

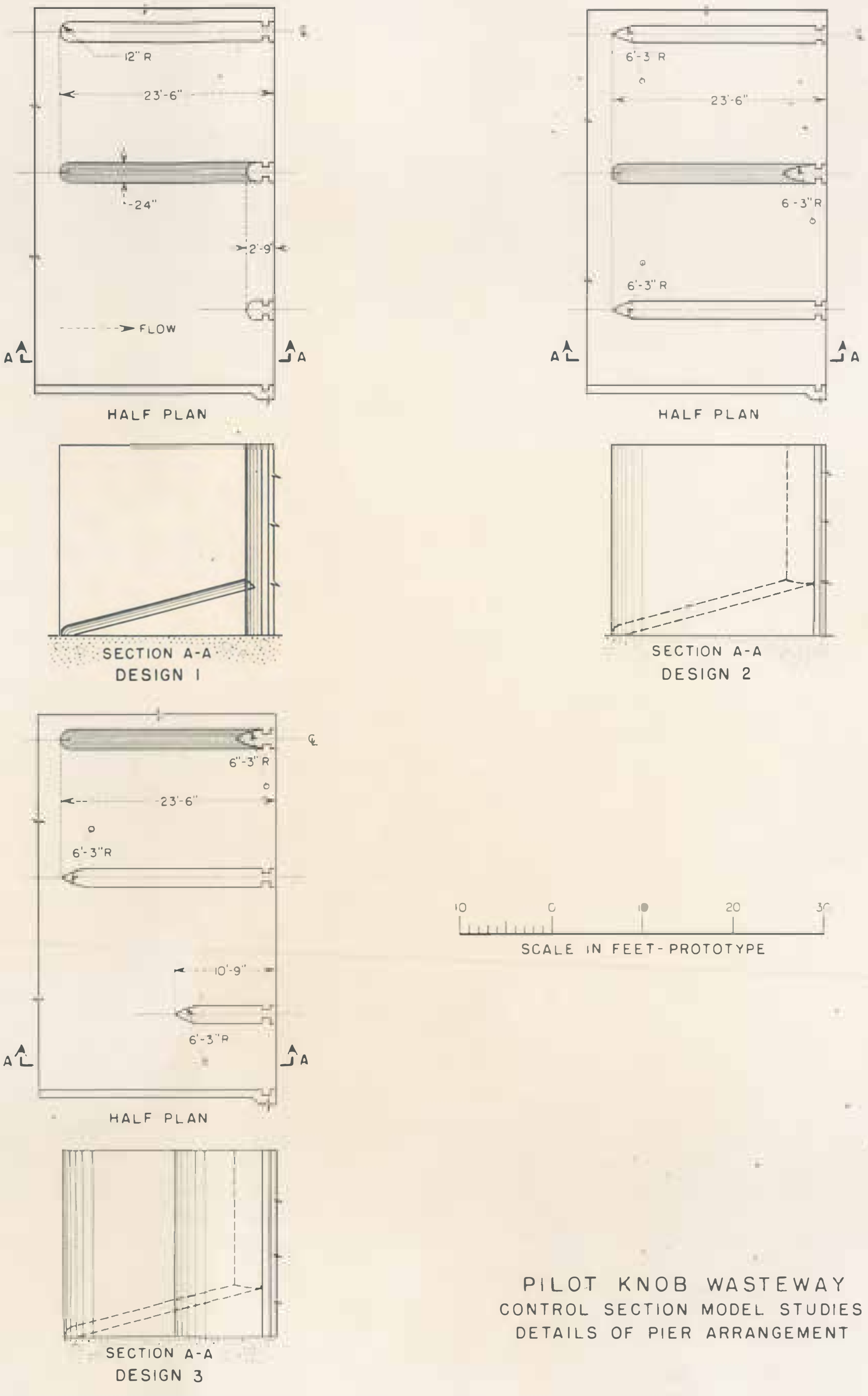
DRAWN J.M.B. SUBMITTED
TRACED R.W.B.-R.L.A. RECOMMENDED
CHECKED APPROVED

DENVER, COLORADO - DECEMBER 23, 1938

FIGURE 5

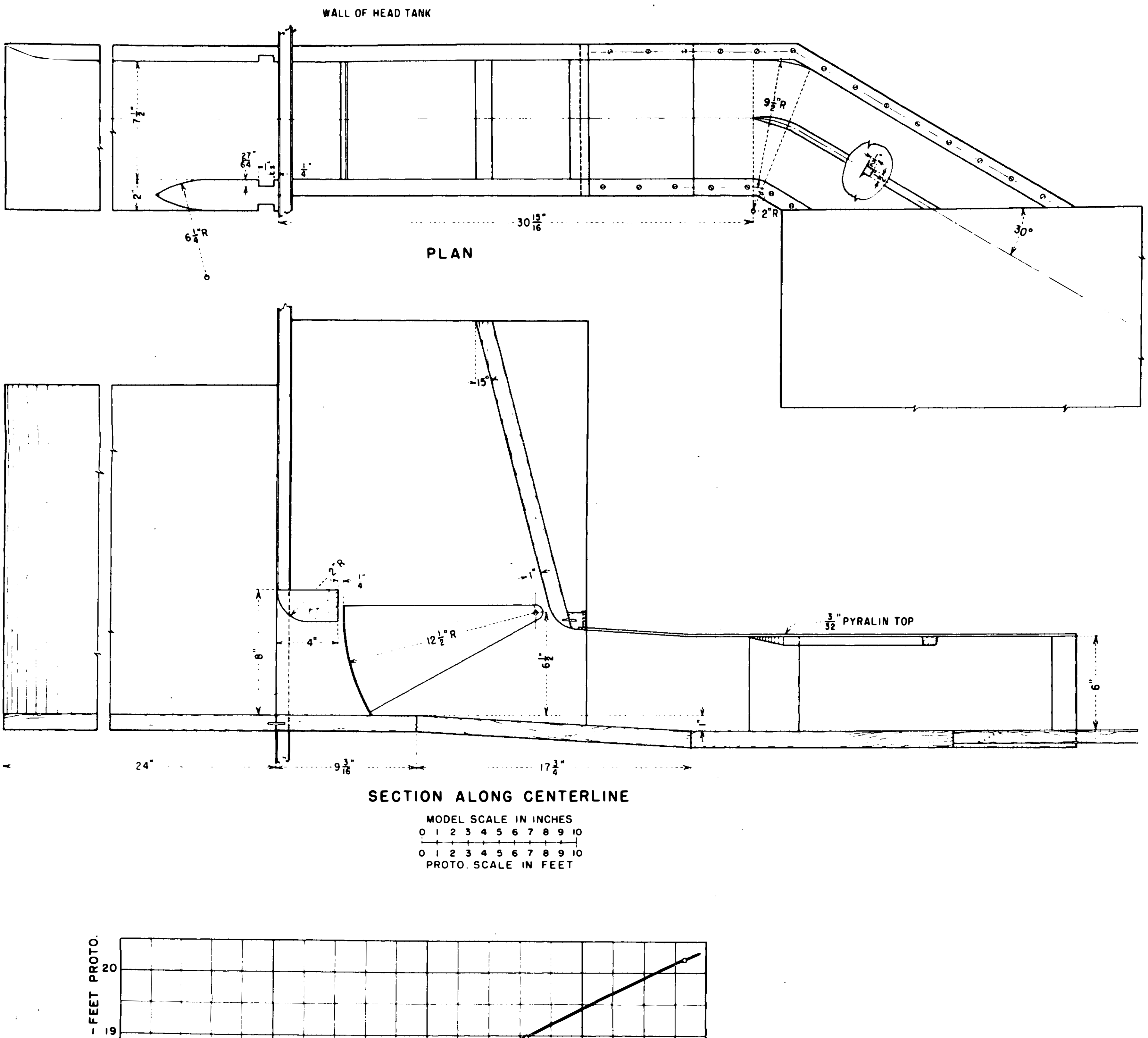


PILOT KNOB WASTEWAY
ENTRANCE TRANSITION MODEL STUDIES
DETAILS OF TRANSITION SHAPES



PILOT KNOB WASTEWAY
CONTROL SECTION MODEL STUDIES
DETAILS OF PIER ARRANGEMENT

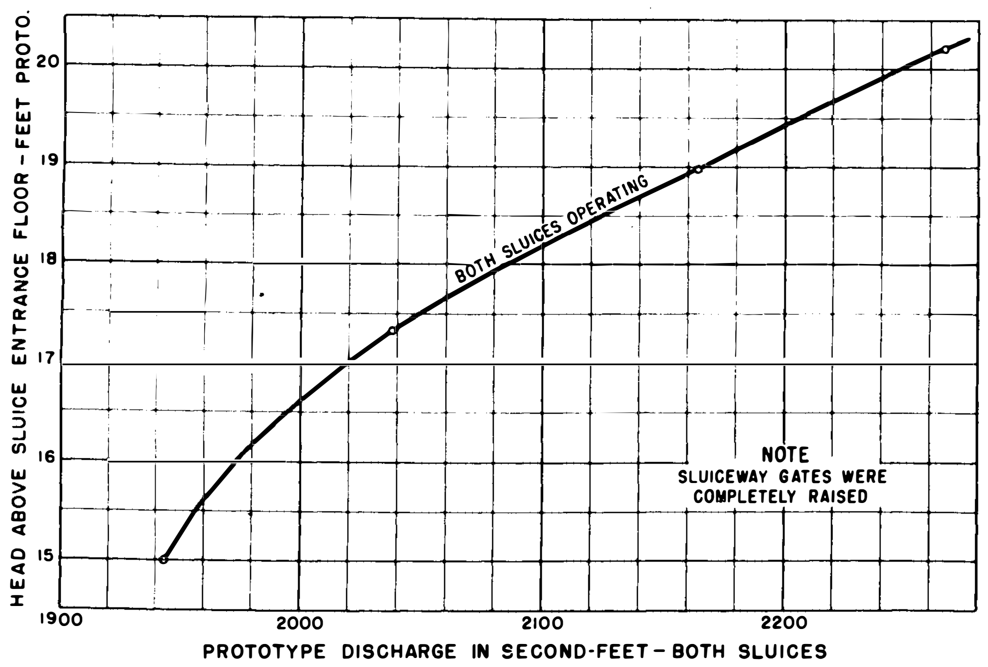
FIGURE 7



PLAN

SECTION ALONG CENTERLINE

MODEL SCALE IN INCHES
0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8 9 10
PROTO. SCALE IN FEET



PILOT KNOB WASTEWAY
DISCHARGE CURVE - BYPASS SLUICES

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
ALL AMERICAN CANAL SYSTEM - CALIFORNIA

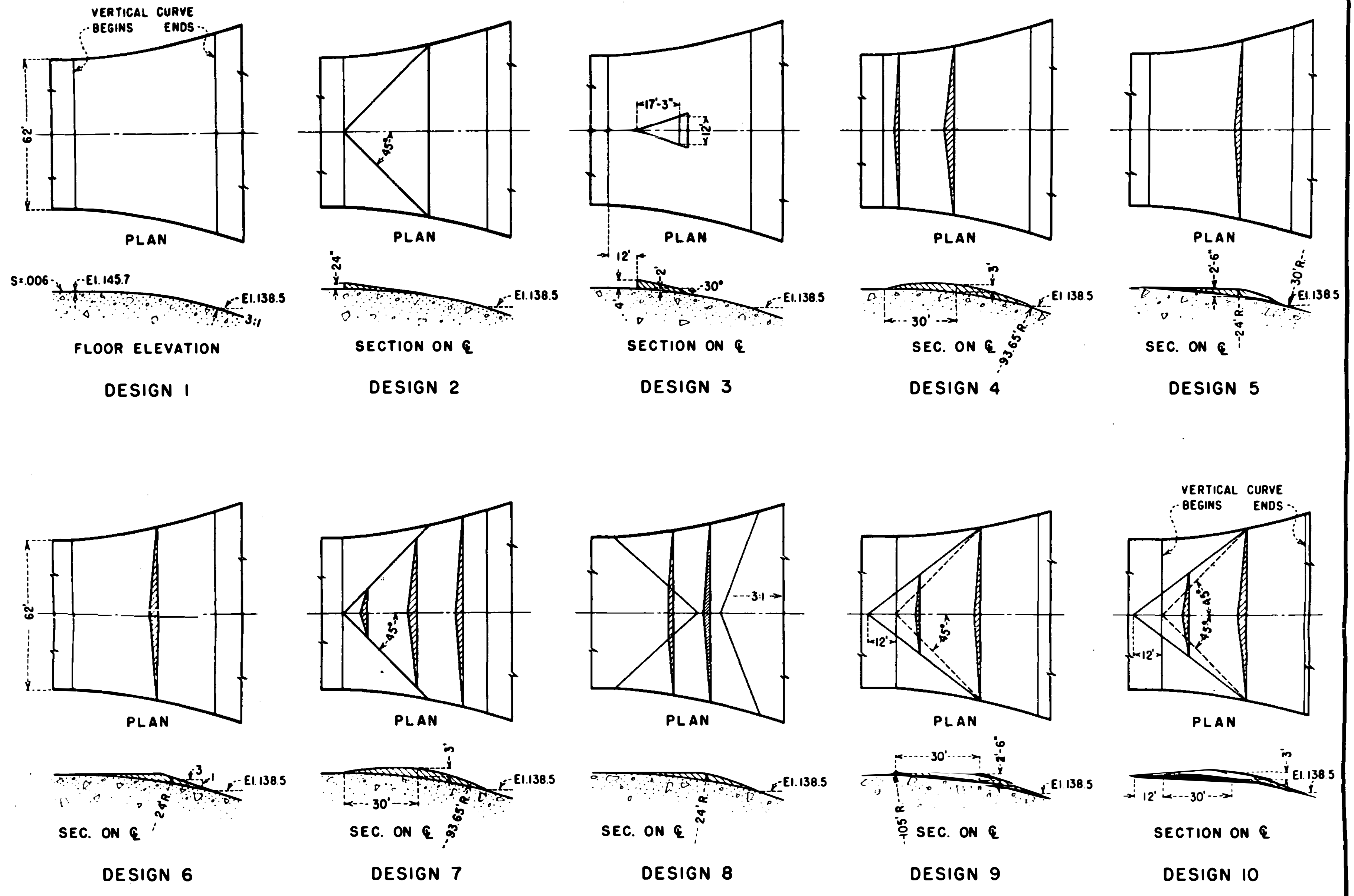
PILOT KNOB WASTEWAY
HYDRAULIC MODEL STUDIES
BY-PASS SLUICE — SCALE 1:12
MODEL LAYOUT AND DISCHARGE CURVE

DRAWN J. M. B.	SUBMITTED
TRACED E. W. P. - C. I. L.	RECOMMENDED
CHECKED	APPROVED

DENVER, COLORADO - DEC. 27, 1938

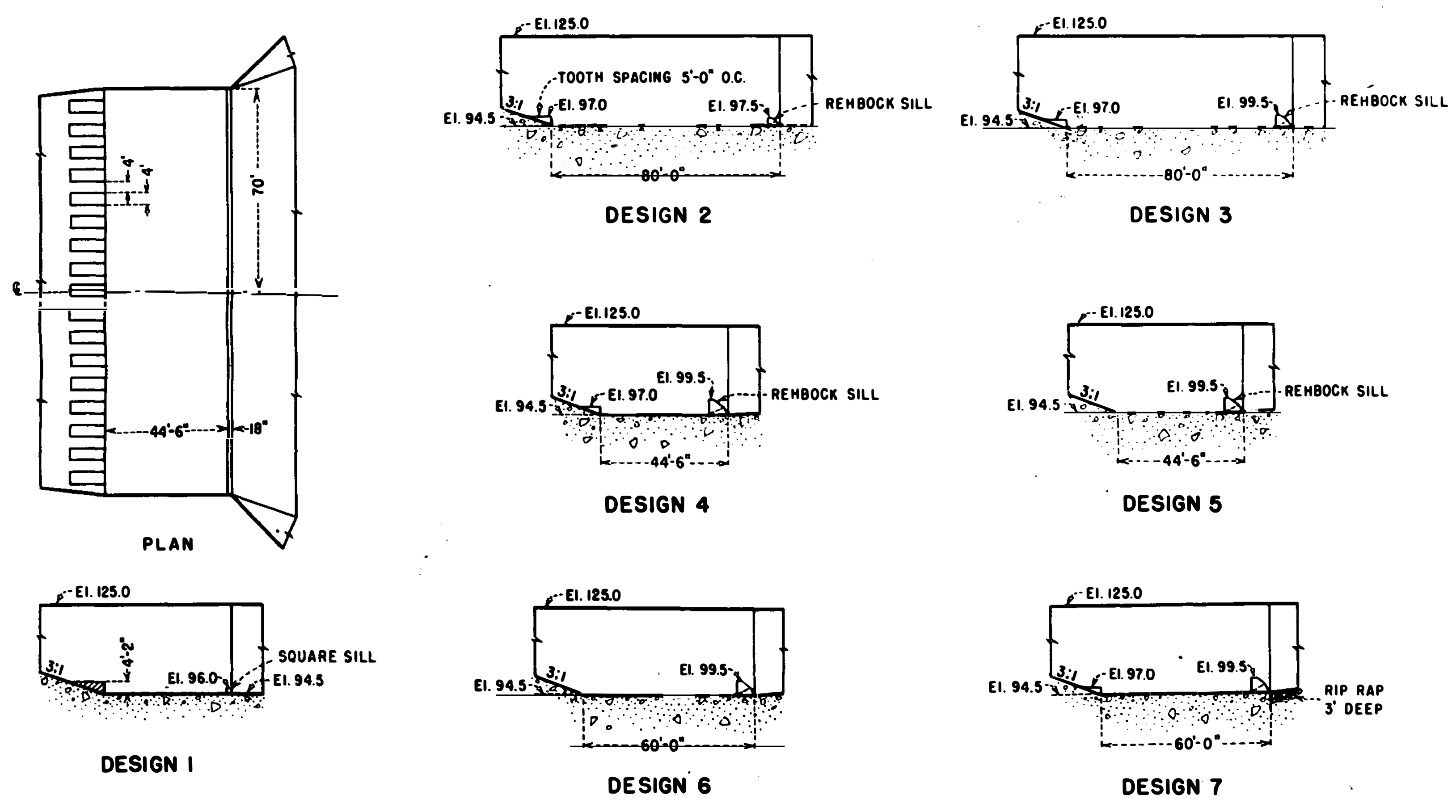
FIGURE 7

FIGURE 8



DIFFUSER FOR SPREADING FLOW AT VERTICAL CURVE

10 0 50 100
SCALE IN FEET-PROTOTYPE

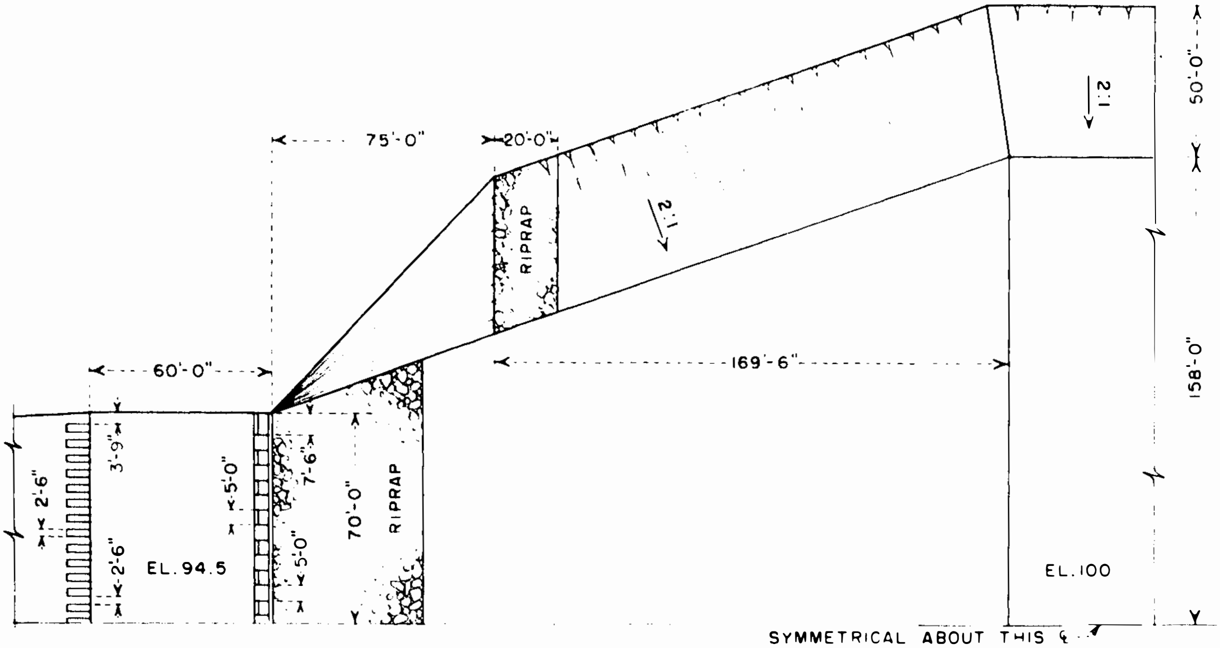


STILLING POOL

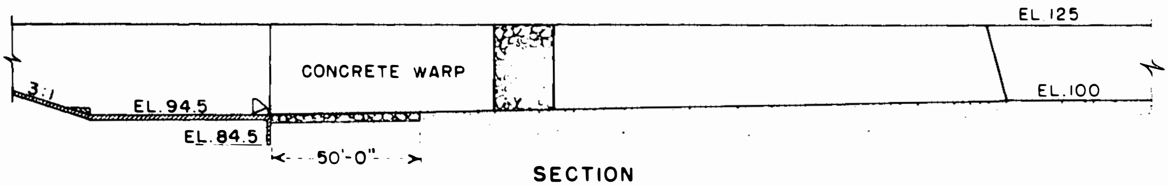
PILOT KNOB WASTEWAY

CHUTE AND STILLING POOL MODEL STUDIES
DETAILS OF POOL AND DIFFUSER DESIGNS

FIGURE 8



HALF PLAN

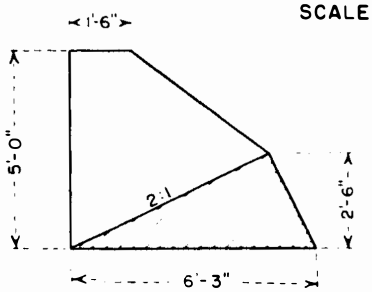


SECTION

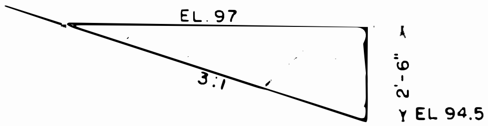
RECOMMENDED STILLING POOL

10 0 50 100

SCALE IN FEET - PROTOTYPE



DETAILS OF SILL



DETAILS OF TOOTHED APRON

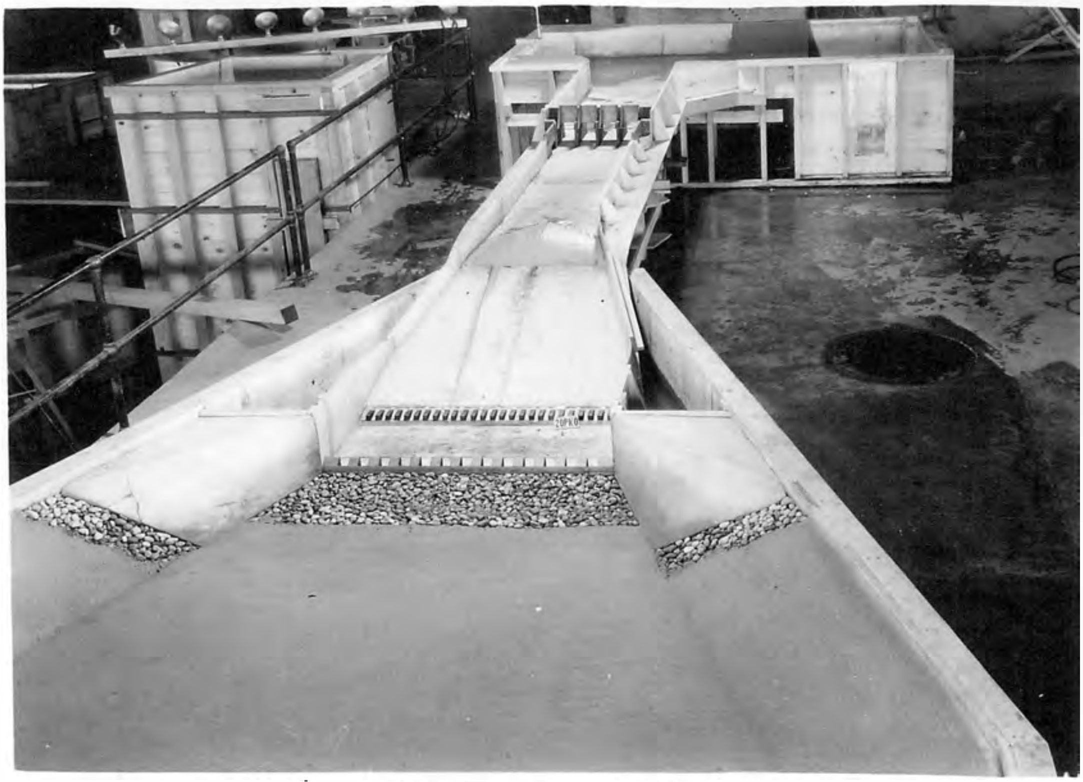
1 0 1 2 3 4 5

SCALE IN FEET - PROTOTYPE

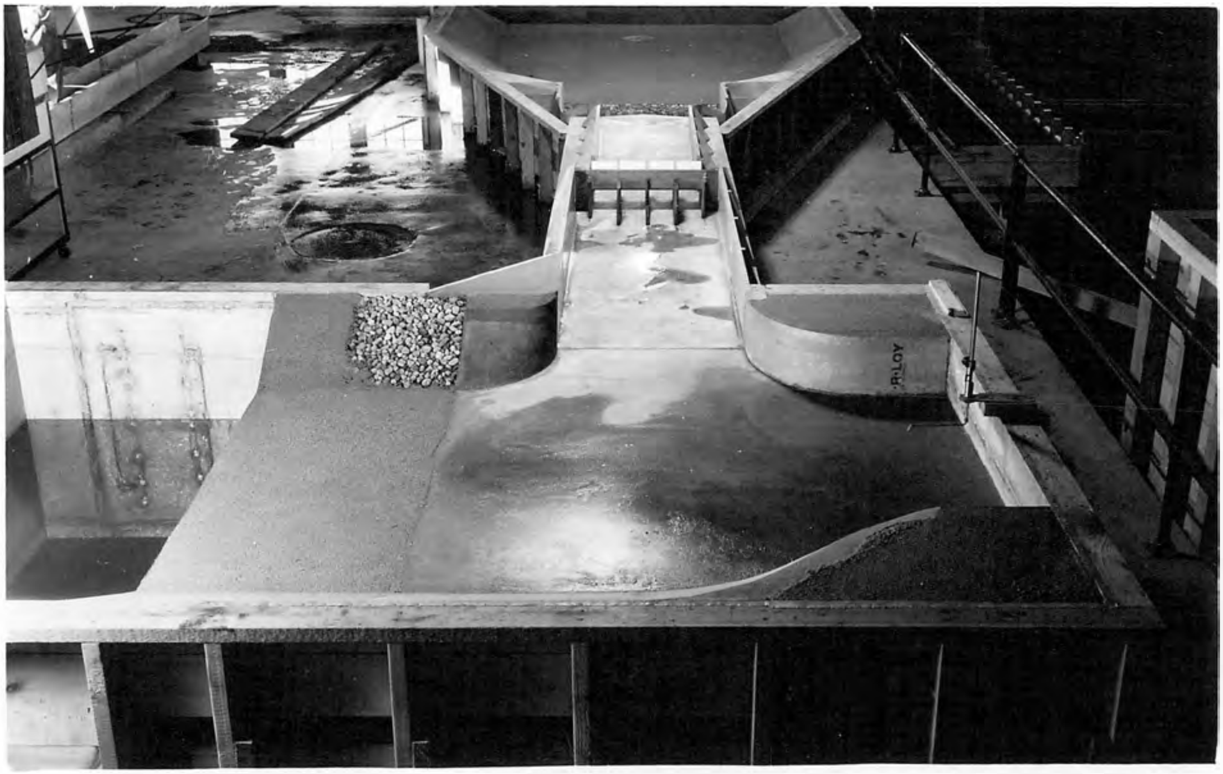
PILOT KNOB WASTEWAY

STILLING POOL MODEL STUDIES
DETAILS OF RECOMMENDED POOL

J M B.



CHANNEL AND STILLING POOL.



ENTRANCE AND CONTROL SECTION.

RECOMMENDED WASTEWAY DESIGN - NO FLOW.

SET-UP. ORIGINAL DESIGN. DISCHARGE 13,155 SECOND-FEET.

SET-UP. ALTERNATE DESIGN NO. 1. DISCHARGE 13,155 SECOND-FEET.

SET-UP. ALTERNATE DESIGN NO. 2. DISCHARGE 13,155 SECOND-FEET

SET-UP. FINAL DESIGN. DISCHARGE 13,155 SECOND-FEET.

FLOW CONDITIONS AT LEFT ENTRANCE - VARIOUS TRANSITION DESIGNS.

SET-UP.

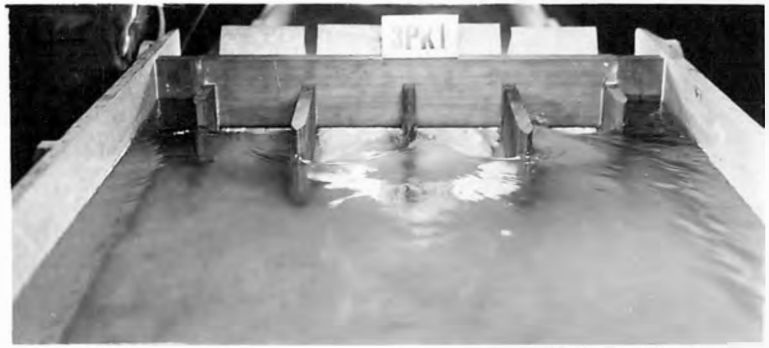
ORIGINAL PIER DESIGN.

DISCHARGE 13,155 SECOND-FEET.

SET-UP.

RECOMMENDED PIER DESIGN.

DISCHARGE 13,155 SECOND-FEET



SET-UP.

FINAL PIER DESIGN.

DISCHARGE 13,155 SECOND-FEET.

FLOW CONDITIONS THROUGH CONTROL SECTION - VARIOUS PIER DESIGNS.

PLATE 3

45° SLUICE EXIT

30° SLUICE EXIT

WITHOUT DEFLECTOR

WITHOUT DEFLECTOR

WITH DEFLECTOR

DISCHARGE 1,080 SECOND-FEET

WITHOUT DEFLECTOR

WITH DEFLECTOR

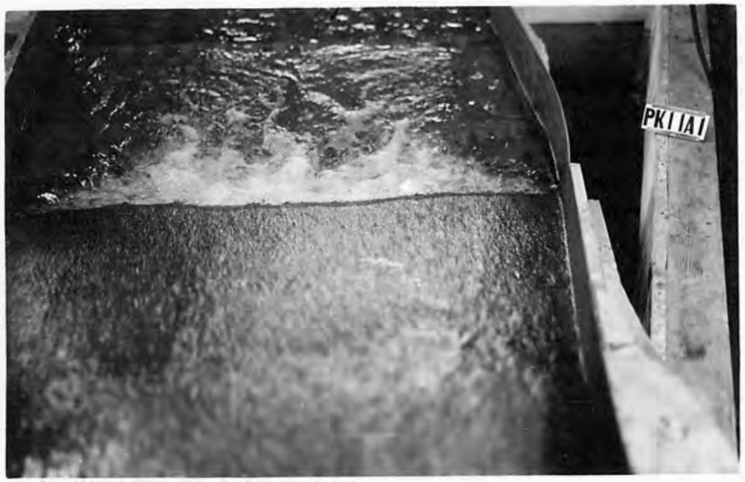
DISCHARGE 685 SECOND-FEET

WITHOUT DEFLECTOR

WITH DEFLECTOR

DISCHARGE 280 SECOND-FEET

FLOW THROUGH BY-PASS SLUICES WITH AND WITHOUT DEFLECTOR IN ROOF OF SLUICE CONDUIT. 19-FOOT HEAD ON SLUICE.



DISCHARGE 2,500 SECOND-FEET

DISCHARGE 5,000 SECOND-FEET.

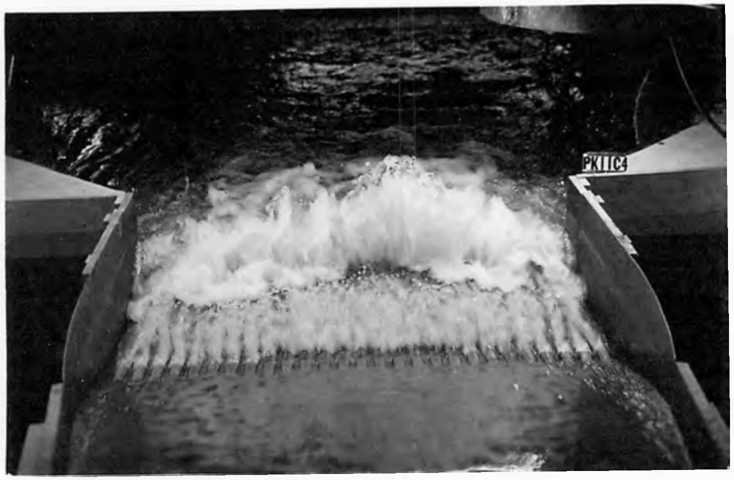
NORMAL TAILWATER ELEVATION 111.0

DISCHARGE 10,000 SECOND-FEET.

DISCHARGE 13,155 SECOND-FEET.

NORMAL TAILWATER ELEVATION 111.0

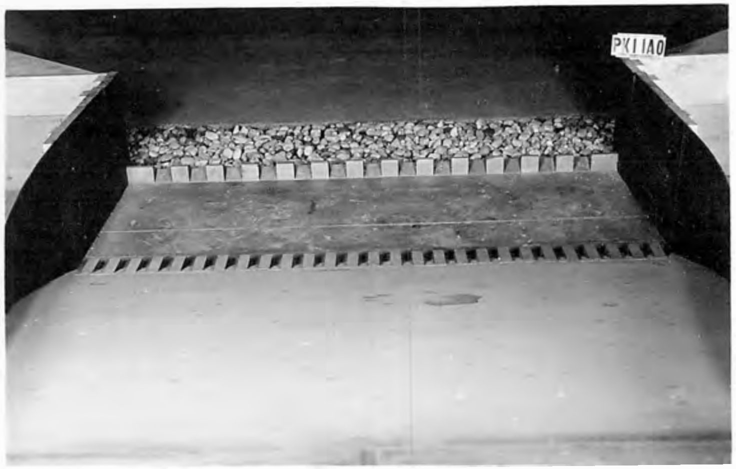
STILLING POOL ACTION - VARIOUS DISCHARGES WITH NORMAL TAILWATER.
RECOMMENDED POOL DESIGN.



MINIMUM TAILWATER (EL. 104.0)

MAXIMUM TAILWATER (EL. 124.0)

DISCHARGE 13,155 SECOND-FEET.



BEFORE TEST

ACCUMULATIVE SCOUR FOR TEST.

NO FLOW

STILLING POOL CONDITIONS - VARIOUS TAILWATER ELEVATIONS.
RECOMMENDED POOL DESIGN.

GATE 4 ONLY OPEN

GATE 3 ONLY OPEN

DISCHARGE 3,250 SECOND-FEET

GATES 1 AND 2 OPEN

GATES 1 AND 3 OPEN

DISCHARGE 6,500 SECOND-FEET

GATES 2 AND 3 OPEN

GATES 1 AND 4 OPEN

DISCHARGE 6,500 SECOND-FEET.

GATES 1, 2 AND 3 OPEN

GATES 1, 2 AND 4 OPEN

DISCHARGE 9,750 SECOND-FEET.

STILLING POOL ACTION FOR VARIOUS GATE COMBINATIONS