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HYD 27

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Denver, Colorado, September 23, 1937.

MEMORANDUM TO CHIEF DESIGNING ENGINEER.
(F. R. Cline)

Subject: Preliminary report on model studies of New River crossing and wasteway, All-American canal.

INTRODUCTION

1. Synopsis. The water of the All-American Canal will cross New River through a pair of large siphons with inverts about 20 feet below the grade of the adjacent lined canal. A wasteway emptying into the river is also planned. The wasted water, controlled by four radial gates, is to be carried under a roadway through four box culverts. A chute with a 2:1 slope will then drop about 36 feet to the minimum tail-water elevation, and will terminate in a concrete stilling pool.

A model built to a scale of 1:18.6 was used to test the preliminary design of this structure. About 80 feet of straight canal above the wasteway entrance and 50 feet of straight siphon were represented. The intermediate transitions and the wasteway culverts, chute, and pool were also included. The pool was placed in a sand box representing the topography of a portion of the river bed 120 by 170 feet in size.

The model as built from the original design showed excellent conditions around the siphon gate section, through the entrance transitions, and within the straight siphons. Flow in the chute was also good. The culvert design was acceptable but centrifugal force due to a 34-degree, short-radius turn caused unbalanced pressures on the walls and a considerable loss of energy. The details of the wasteway gate section were themselves satisfactory but the entire structure made too great an angle with the canal center line. This arrangement and the exceedingly abrupt approach transition caused a very large draw-down. A satisfactory solution was finally obtained by rotating the entire gate structure through 30 degrees and replacing the original angular intersection with a warp. Rotation was the basic design change, and, in addition to causing more direct flow into the gate section, it allowed a more gradual warp in the approach, shortened the necessary culvert length, and eliminated the curve on the culverts. Thus, simplified design and reduced construction costs as well as improved flow were achieved.

The hydraulic jump in the original pool was rough and currents were violent. Scour at the end of the concrete paving was excessive. To obtain a satisfactory design, the pool floor was lowered two feet, the shape of the left wall was changed, and a dentated step and Rehbock sill were added. Plans of the original and final pool designs are compared in figure 12.

2. Description of project. The All-American canal will deliver about 10,000 second-feet of Colorado River water to the Imperial and Coachella valleys in southeastern California. The new canal will

closely follow the international boundary, although remaining entirely within California. It will make successive deliveries to the main laterals and at New River, two miles west of Calexico, the canal flow will not exceed 3,300 second-feet.

The New River channel is 380 feet wide and roughly 40 feet below the surrounding country. Two inverted siphons, each 13-1/2 feet in diameter, will transport the canal water across the river. Seismic activity requires that the siphons remain exposed, and channel requirements for maximum probable floods make it necessary to place the inverts about 16 feet above the river bed. This fixes the drop into the siphons at 20 feet.

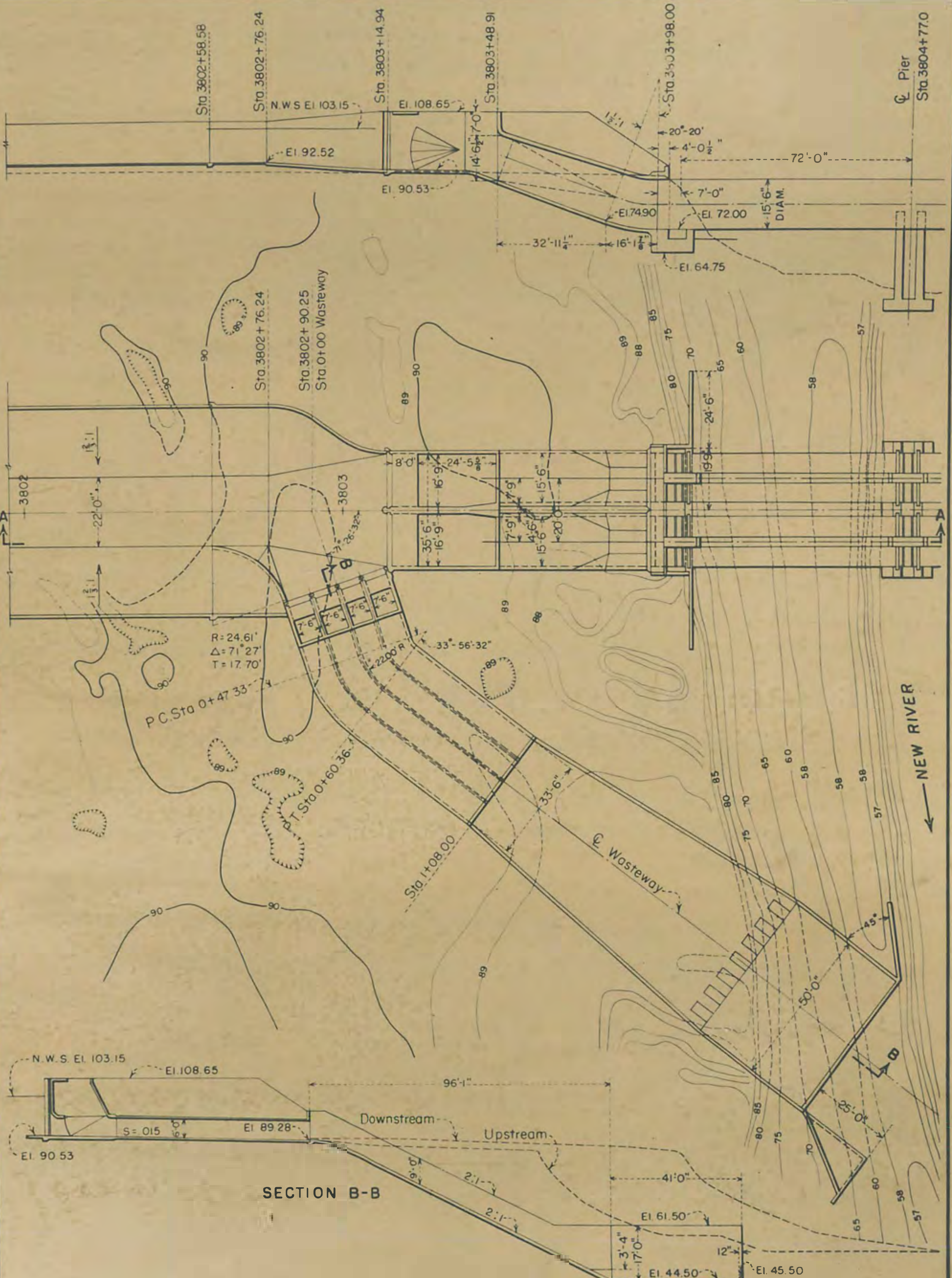
A concrete-lined section will be used immediately upstream from the siphon, as this portion of the canal must be placed on a fill. The transition and drop to the siphon section requires a length of 135 feet. Two radial gates in the transition will control flow into the siphons.

A wasteway will provide for emergency draining of the full canal discharge at this point. Immediately upstream from the siphon entrance transition, a gate structure in the right canal bank will control flow to the four box culverts. In addition to the emergency requirement, one gate and culvert will have frequent use in regulating the flow downstream from the siphon, which should never exceed 2,700 second-feet. The automatic operation of this gate will be float-controlled.

The four box culverts will each be six feet high and eight feet wide and will have a length of 65 feet. They will discharge into a chute dropping 47 feet to the pool floor. The chute will have a 2:1 slope and will increase in width from 33-1/2 to 50 feet. The pool floor will be placed about 11 feet below the present stream bed and will be 37 feet long. The right wall will be parallel to the chute center line, but the left will diverge as shown by figure 13. The plans include a dentated step and a Rehbock sill. Wingwalls on each side will be about 30 feet long. The one on the left will be straight and vertical and that on the right will warp to a 1-1/2:1 slope. Two sheet-piling groins will extend 12 feet downstream with their tops at the elevation of the top of the sill. Riprap will be placed for a distance of 63 feet downstream from the end of the concrete pool floor. Figure 1 shows the structure as originally designed.

3. <u>Necessity for model studies.</u> For several years, the Bureau of Reclamation has used scale models to check designs of unusual or difficult hydraulic structures. When tests indicated that the original design was unsatisfactory, plans were modified as dictated by model studies. The value of this method of design has been demonstrated on numerous occasions.

Designs of several features of this structure were uncertain. The stilling pool and the approach to the wasteway entrance were particularly in doubt. The possible effect of this approach on the flow through the siphon entrance made observations here desirable. The capacity of the wasteway entrance and its influence on the culvert flow, especially with partially opened gates, required investigation. Finally, a test



SECTION B-B

ALL—AMERICAN CANAL

MODEL STUDIES - NEW RIVER CROSSING

ORIGINAL PROTOTYPE DESIGN

F.R.C.

212-D-3065

FIGURE 1

was desired of the effectiveness of the chute in spreading the flow from one culvert only.

The wasteway is an incidental though necessary structure. The importance of flow conditions in it does not warrant an appreciable sacrifice of efficiency in the siphon entrance. Yet good wasteway flow is important, as the upstream gate will be used frequently. The canal velocity will be rather high, requiring that the current come directly into the siphon entrance to avoid undue losses. With the less important wasteway gate structure necessarily placed to the side, the high velocity makes a satisfactory approach design difficult.

As the river bed is a fine sand requiring a particularly efficient stilling pool, it was expected that several tentative designs of the pool as well as of the wasteway approach, would be required before satisfactory results could be obtained. The model was so constructed that these features could readily be changed. Original designs of other features to be investigated were expected to prove satisfactory and special provisions for changing these were not made.

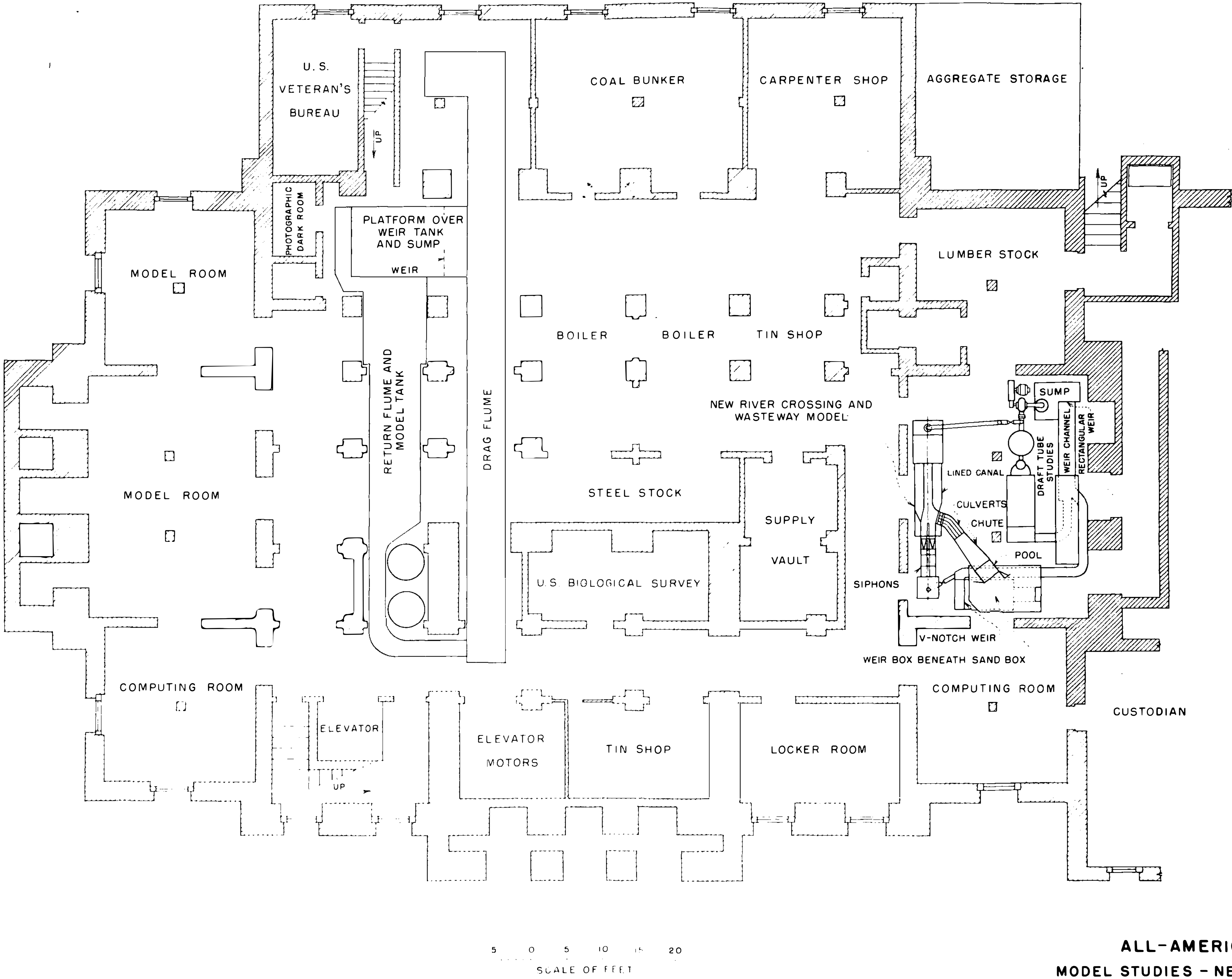
PREPARATION FOR STUDIES

4. Laboratory. The model was built and tests were performed in the U. S. Bureau of Reclamation hydraulic laboratory located in the basement of the Old Customhouse in Denver, Colorado. Figure 2 is a plan of the laboratory, showing the location of the model in the west room.

5. Equipment and arrangement. These tests were run with equipment used for the Grand Coulee turbine studies. Special hours were arranged to avoid neglecting either problem. Available space would accommodate only a "left handed" model, or one in which the wasteway led to the left instead of to the right as in the prototype.

A 20-horsepower motor and an 8-inch, 4-second-foot centrifugal pump supplied water from the sump to the model, a general plan of which is shown by figure 3. The head tank was 3 feet, 10 inches wide, 6 feet long, and 4 feet, 10 inches deep. Entrance bells and a gravel baffle straigntened the flow before delivering it to a sheet-metal channel. Straight for almost four feet, this represented correctly the cross section of the lined canal upstream from the structure.

A box 5 feet, 10-1/2 inches long, with a maximum width of 3 feet, 8-1/2 inches, was attached to the end of the standard canal section. The floor was two inches below the canal bottom. The shape was such that the various wasteway and siphon approach designs could readily be represented by false wooden and concrete floors and walls. A pier and two sheet-metal siphon gates were also installed. Two openings were left in the box walls, one in the downstream end and one in the left side. Here the siphon entrance and the culvert gate sections were connected.



ALL-AMERICAN CANAL

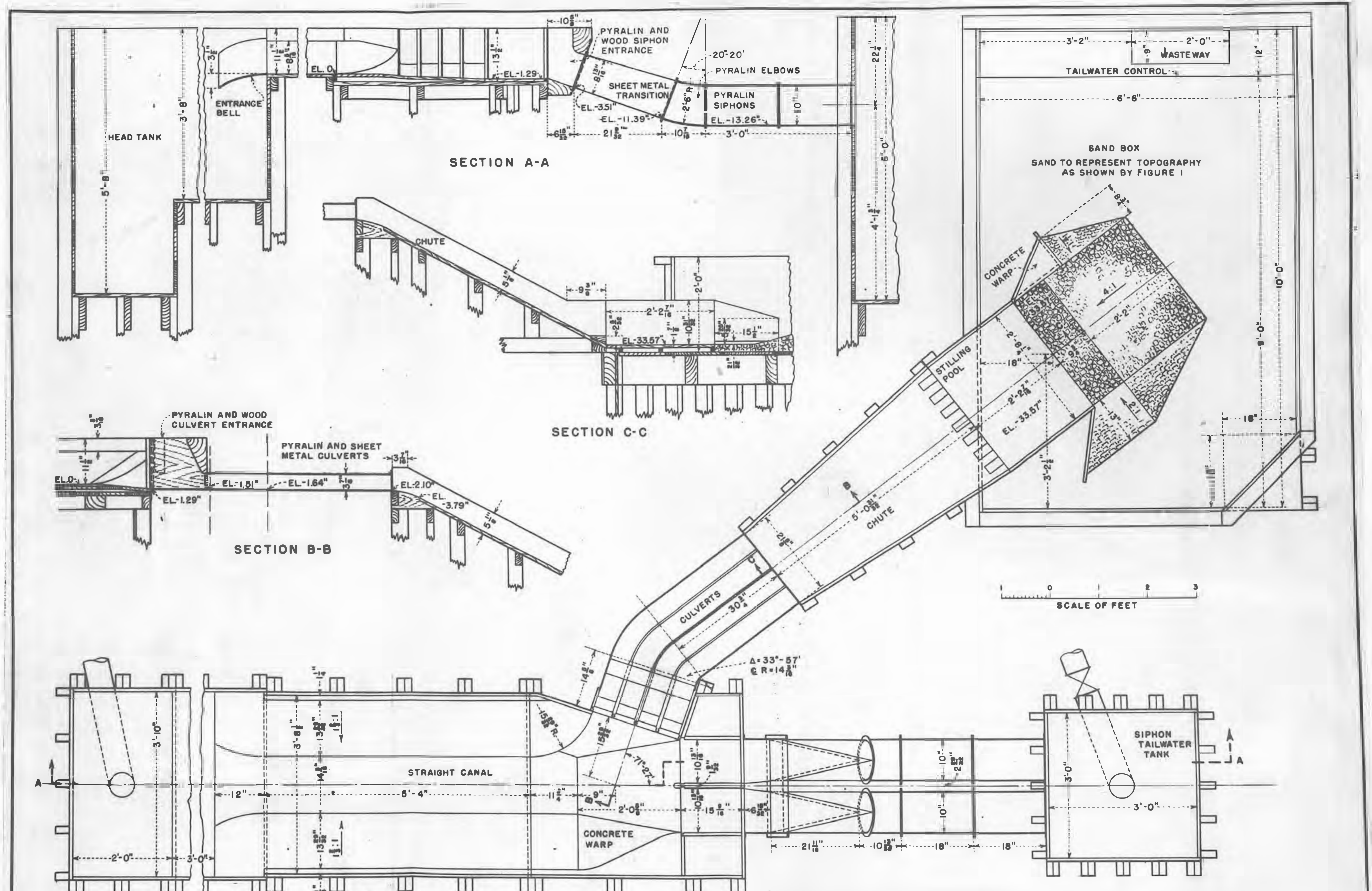
MODEL STUDIES - NEW RIVER CROSSING

DENVER HYDRAULIC LABORATORY - 16TH AND ARAPAHOE STREETS

PLAN OF LABORATORY SHOWING MODEL LOCATION
ORIGINAL DESIGN INSTALLED

212-D-3066

FIGURE 2



For details of siphon entrances and siphons, see figure 4.
For details of various siphon and wasteway approaches, see figure 6.
For details of culverts and chute, see figure 8.
For details of original and final pools, see figure 12.
Elevations are in inches below canal floor.

ALL-AMERICAN CANAL

MODEL STUDIES - NEW RIVER CROSSING

GENERAL PLAN OF ORIGINAL MODEL

F.R.C. 212-D-3067

FIGURE 3

An assembly of several model units formed the transition to the siphon. The closed conduit entrance was a short section with wooden top and bottom and pyralin sides, bolted to cover the opening in the downstream end of the division box. Construction as shown by figure 4 was very simple. The pyralin sides permitted visual inspection of the flow. Two sheet-metal transitions were bolted to the downstream end of the wood and pyralin section and transformed the conduits from rectangular to 10-inch circular cross sections in a length of 20-5/8 inches. The rectangular ends were 10 inches wide and 8-13/16 inches high. The straight inverts were on 37 percent grades. Molded pyralin elbows ten inches long then formed the grade changes to the horizontal siphons, which were represented by 10-inch pyralin pipes, three feet long. These, in turn, discharged into a tailwater box.

Figure 8 shows the wasteway culvert and gate details. The gate section was bolted to the left wall of the division box. As in the siphon entrance, plane side walls were of pyralin and curved top surfaces and piers were cut out of wood. A pyralin bottom and sheet-metal radial gates were used.

The culvert unit was fastened to the gate section. Outside walls were of pyralin and divisions consisted of hollow sheet-metal shapes. The top and bottom were planes, or slight warps where the culverts were on a curve, and were readily formed of pyralin. They were screwed to the interior walls and cemented to the sides. The unit was 21-15/16 inches wide and 3-7/8 inches high. The original gate structure and culverts were 4-1/2 feet long and included a 34-degree turn.

The culverts discharged into a sheet-metal chute which dropped 2 feet, 7-1/2 inches in a horizontal length of 5 feet, 1 inch. The grade was straight except for a short vertical curve at the upstream end. The width increased from 21-5/8 to 32-1/4 inches. The downstream width was carried into the pool, which was 2 feet, 2-7/16 inches long. Wood was used for the side walls and the right wing wall. The left wing wall was a concrete warp.

The stilling pool was located in a box 10 feet long, 6-1/2 feet wide, and two feet deep. The topography was formed of a fine sand and gravel to scale represented the riprap. A hinged gate was provided to control the tailwater elevation. The forebay of a large weir received the flow from the sand box.

The sheet-metal weir box was 8-1/4 feet long, 4-1/4 feet wide, and four feet deep. Two gravel baffles were placed 13-1/2 inches apart. The 90-degree V-notch weir was set four feet from the downstream baffle and two feet above the floor. An open channel led directly to the forebay of the master weir, which discharged the total model flow directly into the pump sump. This master weir had a 2-foot crest installed in a box 2 feet wide and 4-1/2 feet deep. Two sets of vertical board baffles were located 6-1/2 feet upstream.

The siphons emptied into a box three feet square and six feet deep. A six-inch pipe line ran from the bottom to the sheet-iron channel which

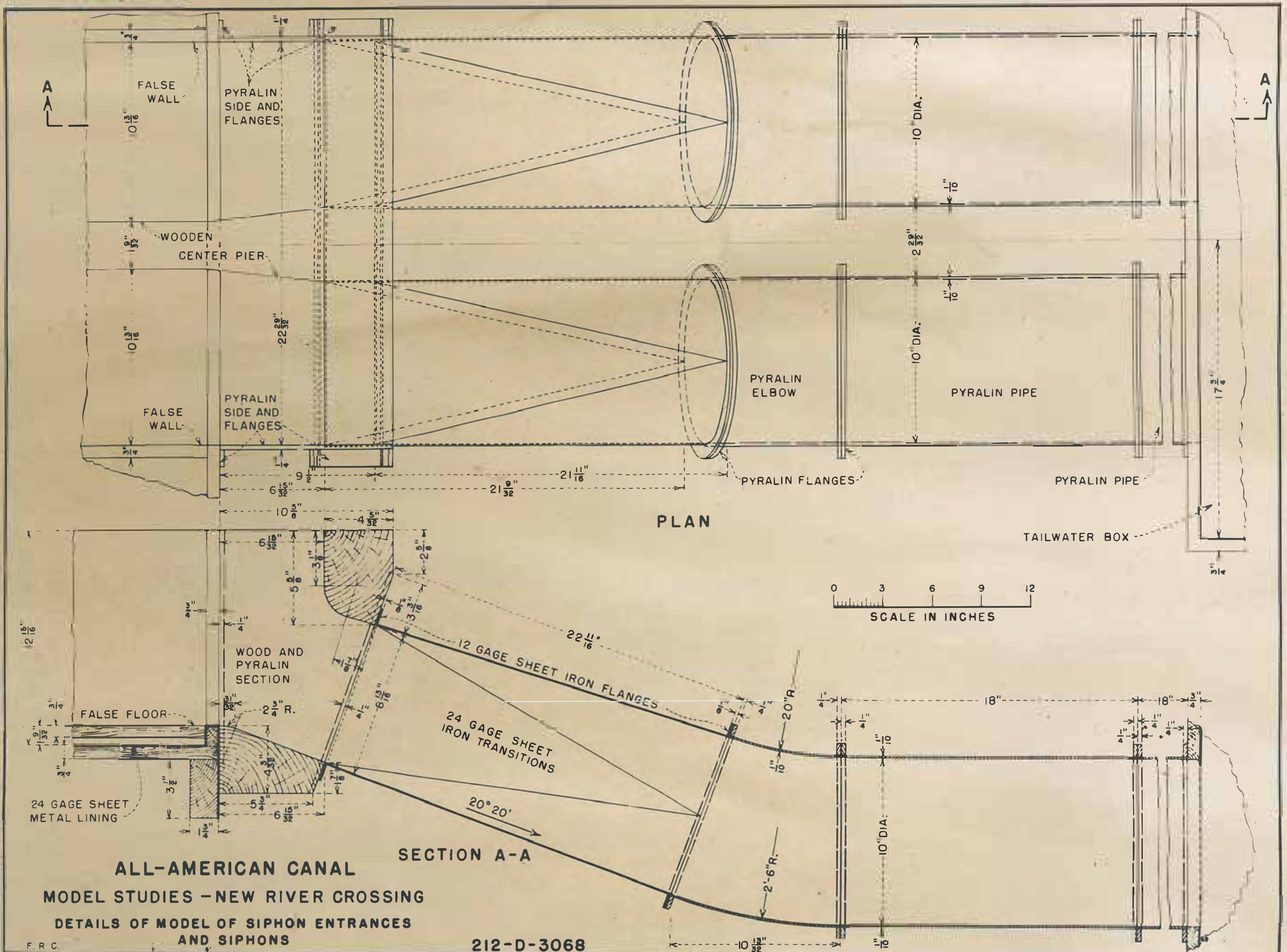

FALSE WALL
PYRALIN SIDE AND FLANGES
WOODEN CENTER PIER
PYRALIN ELBOW
PYRALIN PIPE
PYRALIN FLANGES
TAILWATER BOX
10" DIA.
PLAN
SCALE IN INCHES
0 3 6 9 12
WOOD AND PYRALIN SECTION
FALSE FLOOR
24 GAGE SHEET METAL LINING
12 GAGE SHEET IRON FLANGES
24 GAGE SHEET IRON TRANSITIONS
20° 20'
20" R.
2'-6" R.
SECTION A-A
ALL-AMERICAN CANAL
MODEL STUDIES - NEW RIVER CROSSING
DETAILS OF MODEL OF SIPHON ENTRANCES AND SIPHONS
212-D-3068
F. R. C.

Figure 4

in turn led to the master weir. A gate valve in this line controlled the siphon tailwater.

Six-inch diameter stilling wells were connected to each weir forebay by 3/4-inch pipes. Heads were measured by vernier hook gages. A pipe entrance on each side of the rectangular weir box was set normal to the wall surface, four feet upstream and two feet above the floor. The entrance for the V-notch weir stilling well was a 3/4-inch perforated horizontal pipe placed three feet upstream and two inches above the floor.

A piezometer on the canal-floor center line at the end of the standard section was used for observations of water surface elevation. Piezometer rings 2-1/2 feet downstream from the beginning of the standard siphon section indicated the siphon heads. Several openings distributed over the sand-box floor were connected to a glass tube for observing the river bed tailwater elevation.

Several simple changes were made as testing progressed. The warp in the wasteway entrance approach required a larger division box. Wasteway gate section rotation demanded other changes of the division box. Curve elimination necessitated culvert reconstruction. Fortunately, the new length equalled the original length of straight culvert. The curved portion was removed and the remainder flanged and bolted together. This also required chute and pool relocation but no change in individual unit construction. River tailwater elevations lower than those originally indicated were demanded, requiring removal of the tail gate. A number of bricks in the wasteway controlled the tailwater elevation.

6. <u>Technique.</u> Materials used required values of Kutter's "N" for prototype and model of 0.014 and 0.010 respectively. Neglecting such minor effects as that due to the viscosity of the fluid, the relative roughnesses of prototype and model surfaces fix the scale at which strict geometrical and hydraulic similitude may be achieved simultaneously. Lack of space and pump capacity prohibited use of the desired scale of $\left(\frac{N_m}{N_p}\right)^6$ or 1/7.52 and necessitated sacrifice of geometrical similitude to obtain the required pool velocity.

Prototype hydraulic computations were made through each culvert and down the chute to determine the velocity entering the pool. Model flow was determined for one culvert only, as prototype calculations had shown practically no differences between the several culverts. Computations showed hydraulic similitude warranted no culvert corrections, but required an increased velocity into the pool. This was achieved by a steeper chute rather than by a greater length. The model pool floor was lowered 0.217 foot.

The curved culverts complicated frictional correction computations. Customary treatment of curve losses by using an arbitrarily increased Kutter's "N" was unsatisfactory. Separate evaluations of curve and wall friction loss was desired. The only available data were a paper by Sanjiva Puttu Raju*, describing a series of tests performed by him in Germany. These data, although not comprehensive, were used in the ab-

*"Versuche über den Strömungswiderstand gekrümmter offener Kanäle" in Mitteilungen des Hydraulischen Instituts der Technischen Hochschule München," Heft. 6, 1933.

sence of better information. Curve losses thus calculated were exceptionally large due to short radii. They were added to wall friction losses in the hydraulic computations. Actual tests later indicated that computed losses were fairly close.

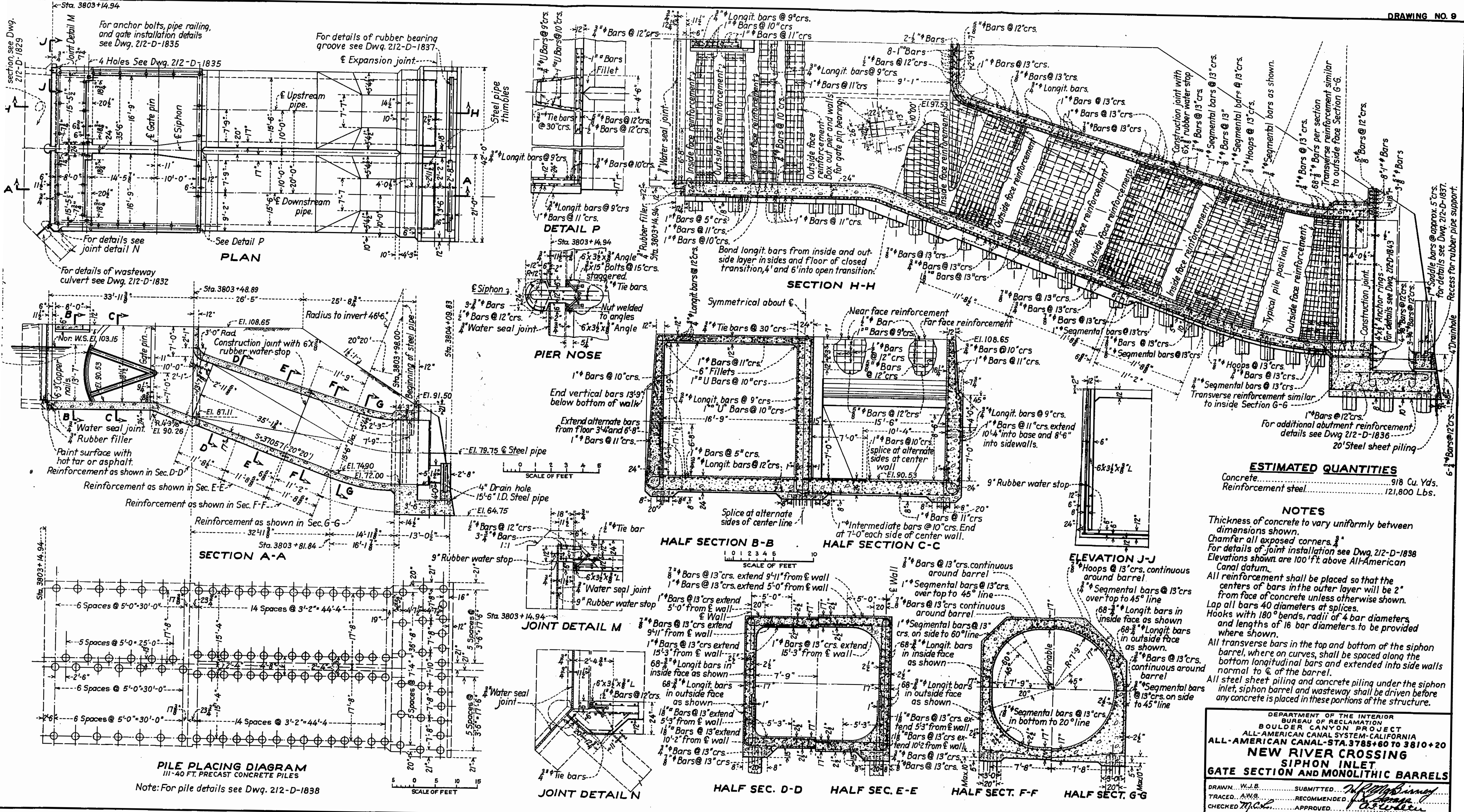
Relative merits of pool designs were judged on flow appearance as well as amount and location of scour. The sand bed was arranged before each ten-minute run. Comparisons between the various designs were made, using sand. Only the final test required scale riprap. Maximum discharge and minimum tailwater were set for each run. Still and moving pictures of the jump were taken as well as pictures of the scoured sand bed after completion of each test. Topographic sketches of the scoured sand bed were also made. Flow appearances alone evaluated merits of designs of other features. Photographs were taken showing the flow under various conditions in other portions of the model.

PROCEDURE

7. Siphon entrance transitions and siphons. The original model showed highly satisfactory siphon flow, necessitating no siphon or entrance design changes. Subsequent wasteway changes neither improved nor impaired siphon conditions. Division section flow was invariably good with closed wasteway gates. With partially opened gates, later designs improved flow to the wasteway without affecting the flow to the siphons.

The pier and the warp opposite the wasteway entrance were highly satisfactory. Gate section flow was smooth. Conditions in the entrance to the closed conduit as seen through the pyralin walls appeared to be excellent. Transitions to the circular section were made of sheet metal, but good conditions where the flow could again be seen indicated proper design. Currents in the pyralin elbows were satisfactory. Siphon velocity distribution was excellent. Figure 5 shows the final prototype details of the siphon entrance.

8. Approach to wasteway gate section. The original design gave unsatisfactory results. Unnecessary turns complicated the entire wasteway plan. Desirable approach conditions demanded their elimination. This was eventually done. The deflection to the wasteway entrance center line was decreased 30 degrees, eliminating the curve in the culvert. This change improved hydraulic conditions in both approach and culverts. Concrete and earthwork costs were also slightly decreased. Several variations of this general plan were tested before accepting a final solution.



ESTIMATED QUANTITIES

Concrete.......................................918 Cu. Yds.
Reinforcement steel.......................121,800 Lbs.

NOTES

Thickness of concrete to vary uniformly between dimensions shown.
Chamfer all exposed corners $\frac{3}{4}$"
For details of joint installation see Dwg. 212-D-1838
Elevations shown are 100 ft. above All-American Canal datum.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 40 diameters at splices.
Hooks with 180° bends, radii of 4 bar diameters and lengths of 16 bar diameters to be provided where shown.
All transverse bars in the top and bottom of the siphon barrel, where on curves, shall be spaced along the bottom longitudinal bars and extended into side walls normal to ℄ of the barrel.
All steel sheet piling and concrete piling under the siphon inlet, siphon barrel and wasteway shall be driven before any concrete is placed in these portions of the structure.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM-CALIFORNIA
ALL-AMERICAN CANAL-STA. 3785+60 TO 3810+20

NEW RIVER CROSSING
SIPHON INLET
GATE SECTION AND MONOLITHIC BARRELS

DRAWN W.J.B. SUBMITTED
TRACED A.W.G. RECOMMENDED
CHECKED M.C.L. APPROVED

28964 | DENVER, COLORADO, NOV. 24, 1936 | 212-D-1831

Figure 6a shows the original design. The vertical cylindrical surface had excessive curvature, preventing flow from following the wall. The water surface along the curve gradually dropped due to centrifugal force, being only slightly above the floor in front of the upstream gate. Water flowing along the bank shot across the vortex and struck the steep edge of the eddy, forcing it farther from the first culvert inlet. Plate IA and B show this condition.

A warp from the sloping side to the vertical culvert wall replaced the cylindrical entrance curve. The gate section was unchanged. Results remained poor, although the free jet was eliminated. The vortex due to the excessive turn was not improved, as shown by plate I, C, and D. These tests gave convincing evidence that the high canal velocity prohibited so sharp a turn.

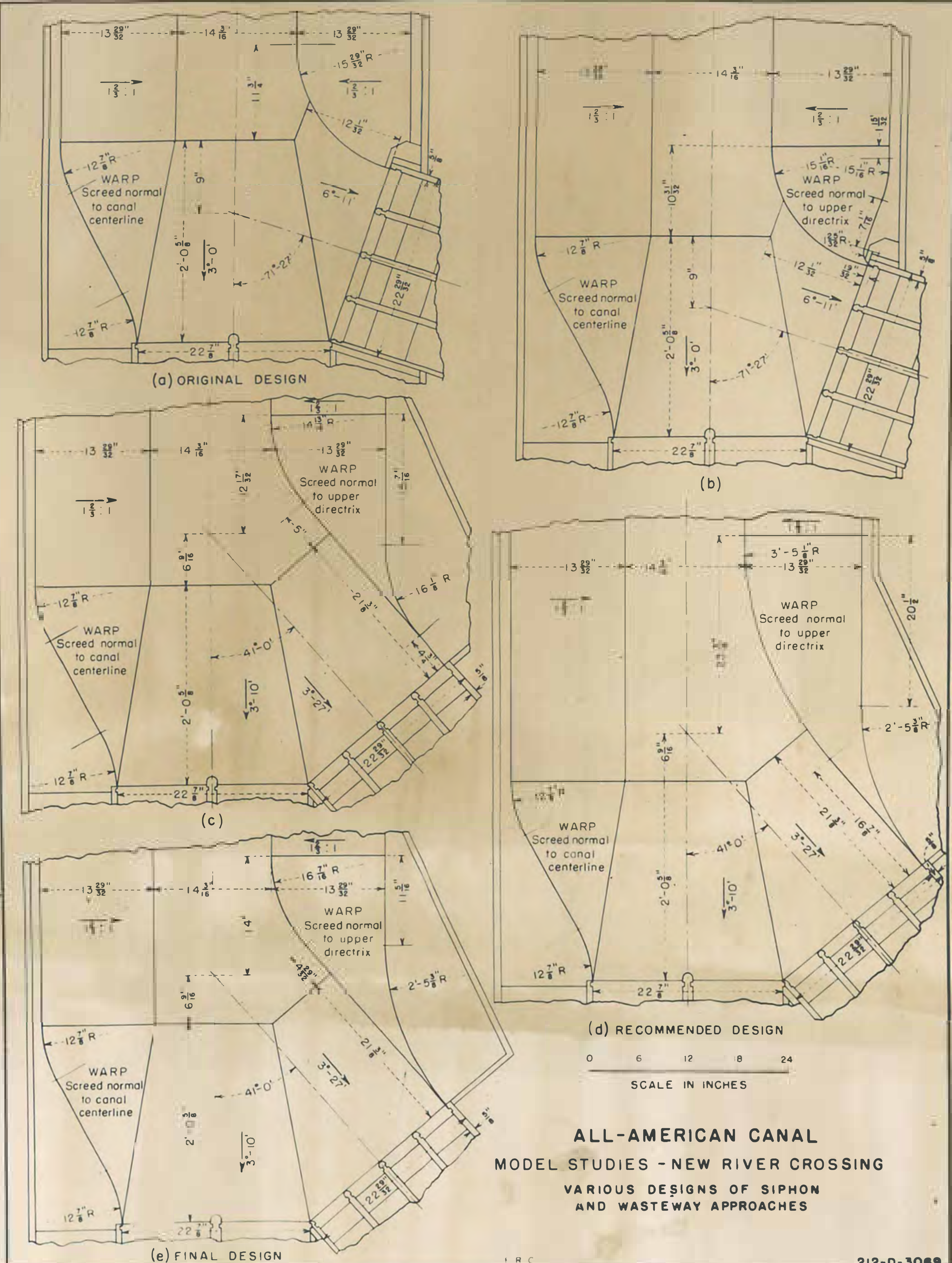
A 30-degree gate section rotation allowed more direct flow into the culverts, and was expected to remedy this condition. Figure 6C shows this change, including a new warp. Greatly improved conditions resulted. Centrifugal force caused no appreciable surface drop near the gate. Each culvert, including the difficult and important upstream one, now took approximately equal flow. A very undesirable eddy existed near the center of the warp, especially when the canal water surface dropped below normal. This indicated incomplete development of warp efficiency, however, rather than poor basic design. Plate II A and B show the approach flow.

A longer warp with gentler curvature improved conditions. Surface drop in front of the gates became practically nonexistent. Plate II C shows the smooth approach flow. The surface eddy along the warp disappeared under normal conditions, but a drop in the canal surface due to the opening of all wasteway gates caused it to reappear. This was the most satisfactory design tested.

Increased construction costs prohibited a longer warp than absolutely necessary. The design shown by figure 6e was therefore installed. The warp was nine inches shorter. The upper directrix remained unchanged but the radius of the curve in the lower directrix was shortened over two feet. Plate V A shows the siphon and wasteway approaches and entrances. Results were inferior to those previously obtained. Approach flow was much rougher. The eddy along the warp was present with normal canal water surface, and became quite pronounced when all gates were opened (plate III). Regardless of the superiority of the previous design, this was accepted because the shorter warp was expected to be somewhat cheaper. Figure 7 shows the final prototype details.

9. Wasteway culvert entrance and gate section. The first tests demonstrated that the original design was satisfactory. It was evident that poor approach conditions alone caused existing entrance disturbances. Capacity requirements were exceeded. When lateral disturbances were eliminated and smooth approach flow was developed, as discussed above, excellent culvert conditions prevailed.

It was feared that water at high velocities shooting from under partially opened gates would form a jump immediately downstream. Ve-



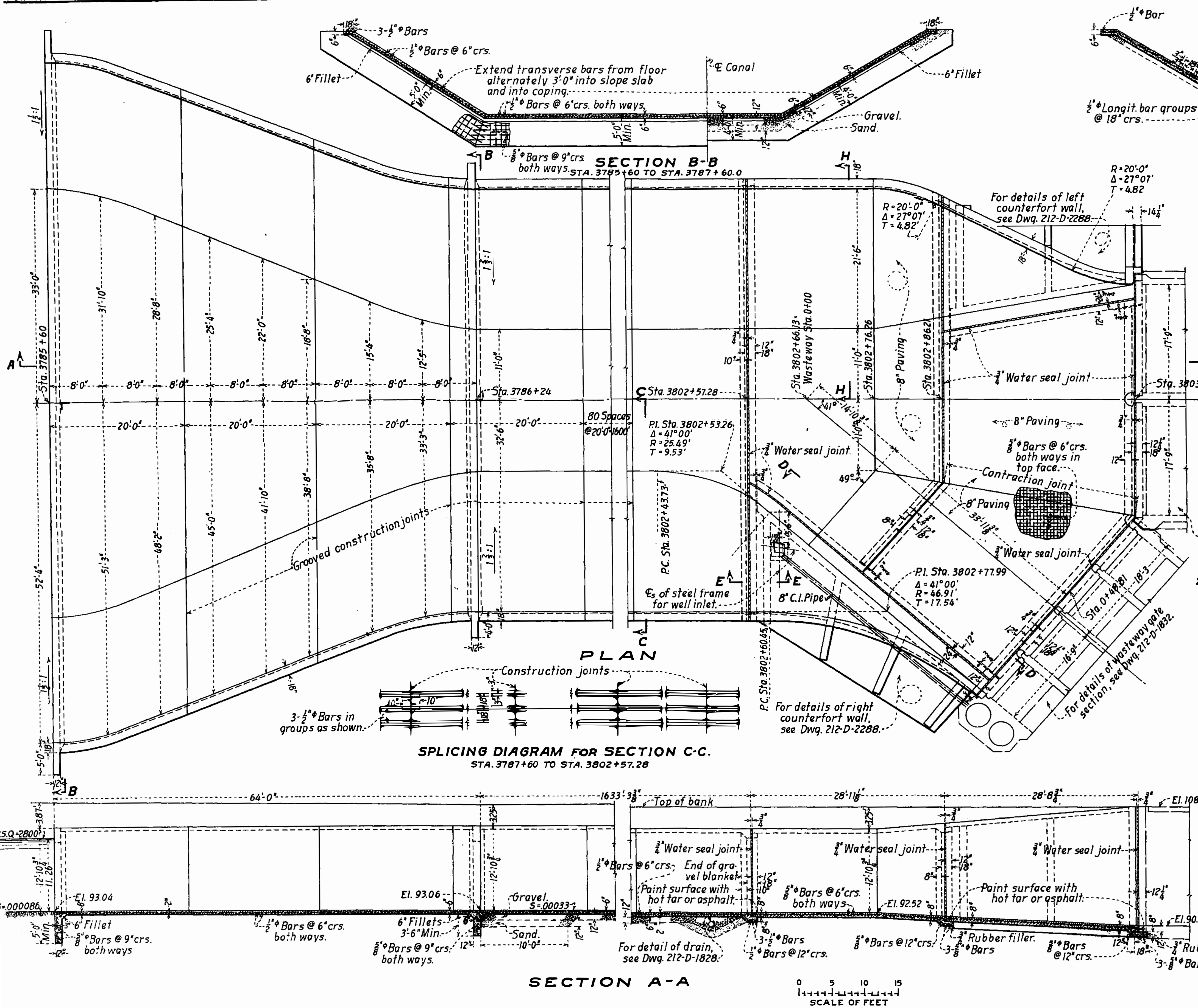
ALL-AMERICAN CANAL

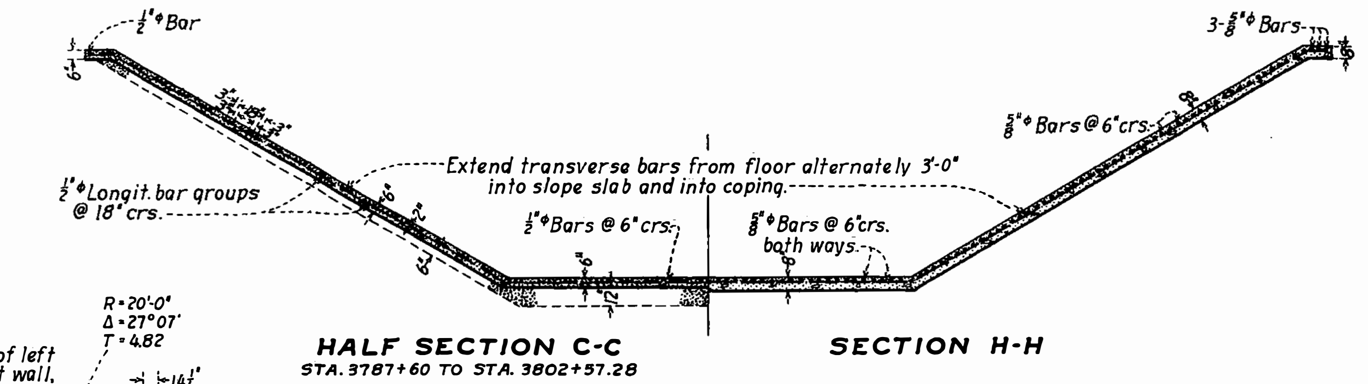
MODEL STUDIES - NEW RIVER CROSSING

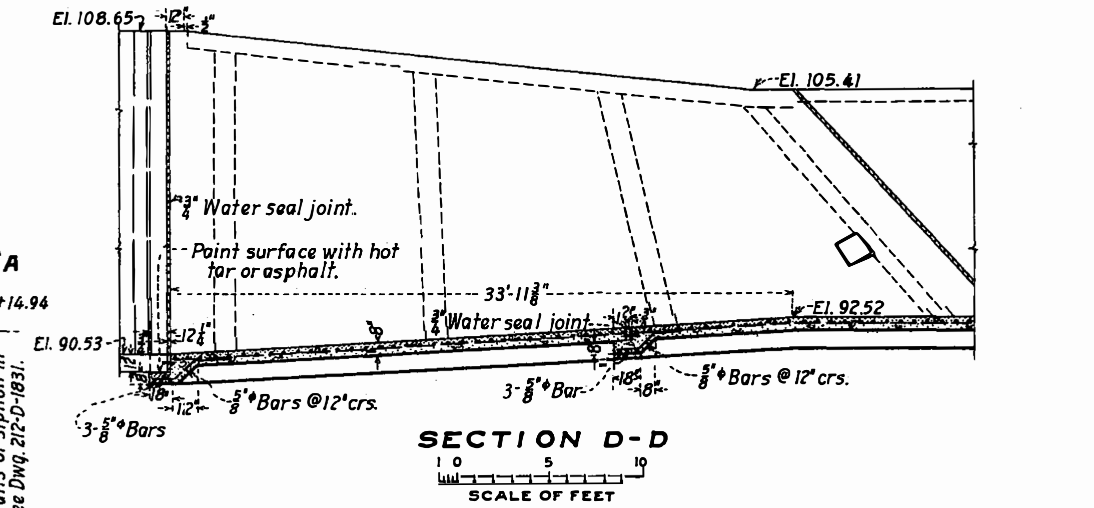
VARIOUS DESIGNS OF SIPHON AND WASTEWAY APPROACHES

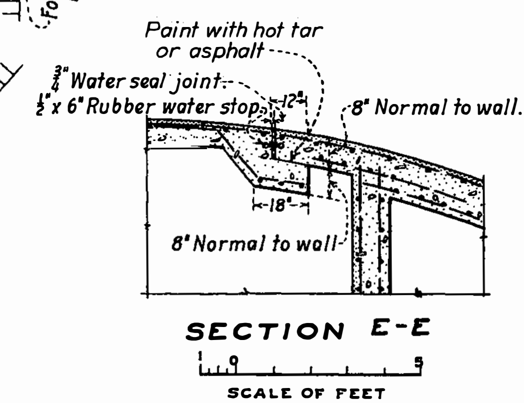
212-D-3069

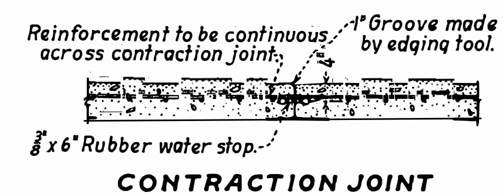
FIGURE 6











ESTIMATED QUANTITIES

Concrete (Canal lining)	2410 Cu. Yds.
Concrete (Siphon inlet transitions)	212 Cu. Yds.
Reinforcement Steel	332,550 Lbs.

NOTES

Footings and slabs shall be placed on undisturbed earth or thoroughly compacted embankment.
Thickness of concrete to vary uniformly between dimensions shown.
Chamfer all exposed corners ¾".
For details of joints, see Dwg. 212-D-1838.
Elevations shown are 100' above All-American Canal Datum.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 40 diameters at splices.
Hooks with 180° bends, radii of 4 bar diameters and lengths of 16 bar diameters to be provided where shown.

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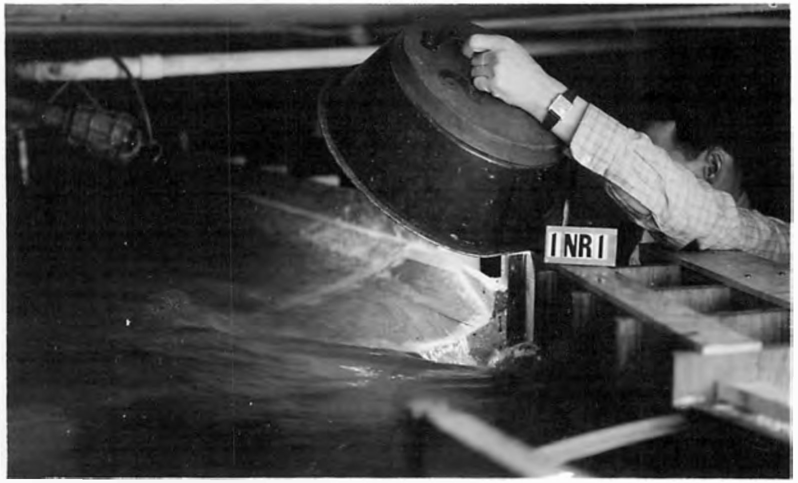
ALL-AMERICAN CANAL SYSTEM-CALIFORNIA
ALL-AMERICAN CANAL-STA. 3785+60 TO 3810+20
NEW RIVER CROSSING
CONCRETE LINED INLET CANAL
CANAL AND SIPHON INLET TRANSITIONS

DRAWN: W.E.B. SUBMITTED:
TRACED: L.M.N. RECOMMENDED:
CHECKED: M.C.L. APPROVED:
28961 DENVER, COLORADO FEB. 4, 1937. 212-D-1829

Figure 7.



(A) ORIGINAL DESIGN - FROM DOWNSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

(B) ORIGINAL DESIGN - FROM UPSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

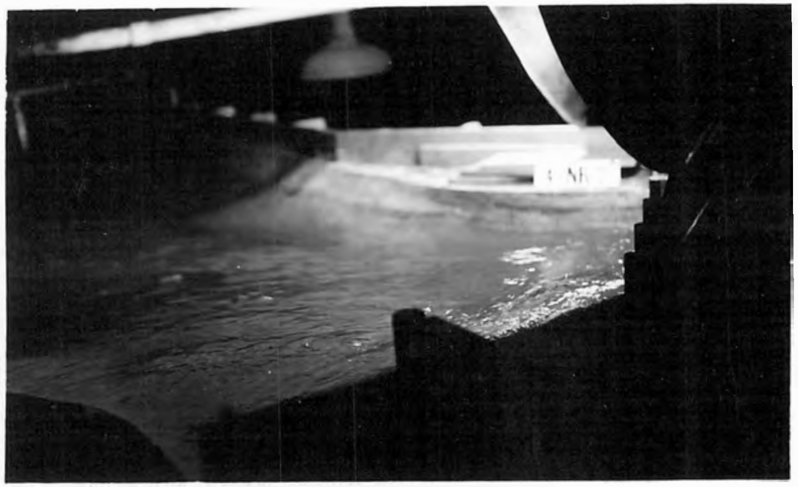
(C) ORIGINAL ENTRANCE WITH WARP - FROM DOWNSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

(D) ORIGINAL ENTRANCE WITH WARP - FROM UPSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

PLATE I

(A) REVISED ENTRANCE WITH SHORT WARP - FROM DOWNSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

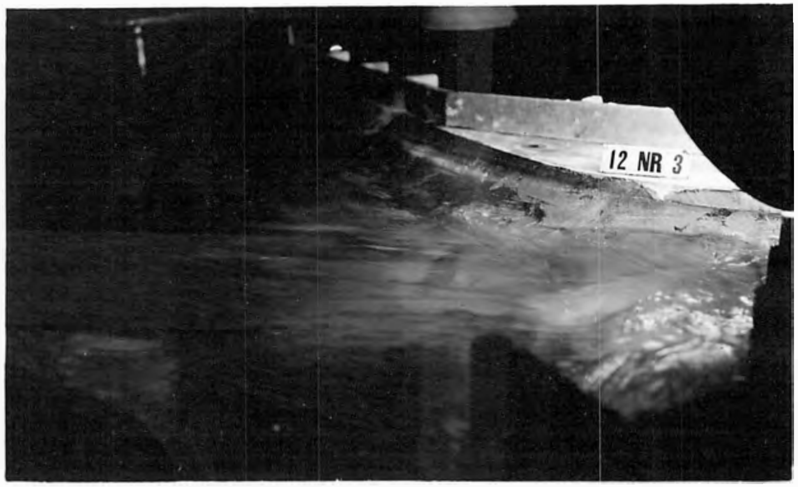
(B) REVISED ENTRANCE WITH SHORT WARP - FROM UPSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY



(C) REVISED ENTRANCE WITH LONG WARP - FROM DOWNSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

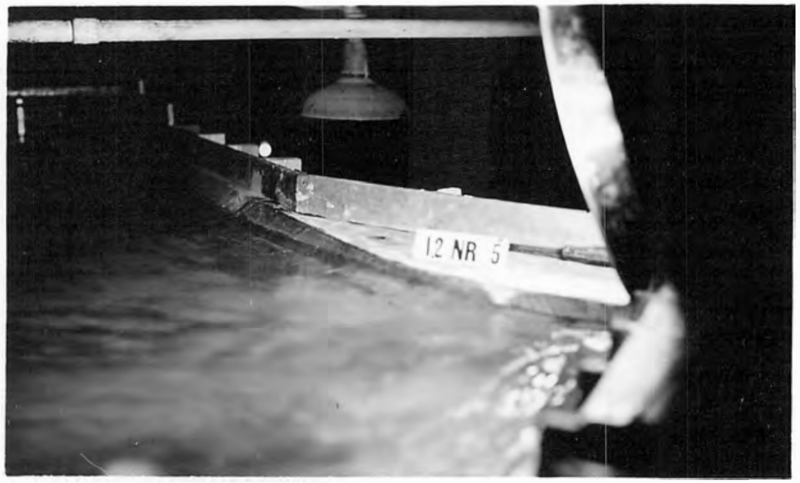
(D) REVISED ENTRANCE WITH LONG WARP - FROM UPSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

PLATE II



(A) FINAL DESIGN – FROM DOWNSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY

(B) FINAL DESIGN – FROM UPSTREAM
MAXIMUM DISCHARGE INTO WASTEWAY



(C) FINAL DESIGN – NORMAL CANAL WATER SURFACE
MAXIMUM DISCHARGE INTO SIPHON AND UPSTREAM CULVERT ONLY

(D) FINAL DESIGN – NORMAL CANAL WATER SURFACE
MAXIMUM DISCHARGE INTO SIPHON AND UPSTREAM CULVERT ONLY

PLATE III

locities maintained by the culvert slope were sufficient to prevent any evidence of this in the model, however. Figure 9 shows the final prototype details.

10. Culverts. Detailed tests were not required. The various conditions were observed through the pyralin top. All proved satisfactory, some superior to the others, however. Depths approximated those computed for frictional corrections. Culverts were in no danger of flowing full.

Centrifugal force caused flow against culvert tops. The extreme case was maximum discharge around the sharpest curve, when two-thirds the width of the top was wetted. This was not particularly objectionable, but would cause additional stresses in tops and outside walls. Poor approach conditions also caused surface disturbances.

Culvert straightening eliminated the necessity of designing walls to resist centrifugal force. With this revision, no water hit the culvert tops. The improved approach reduced surface eddies. Model tests indicated that culvert design was hydraulically satisfactory even with the original plan, but that curve elimination improved results.

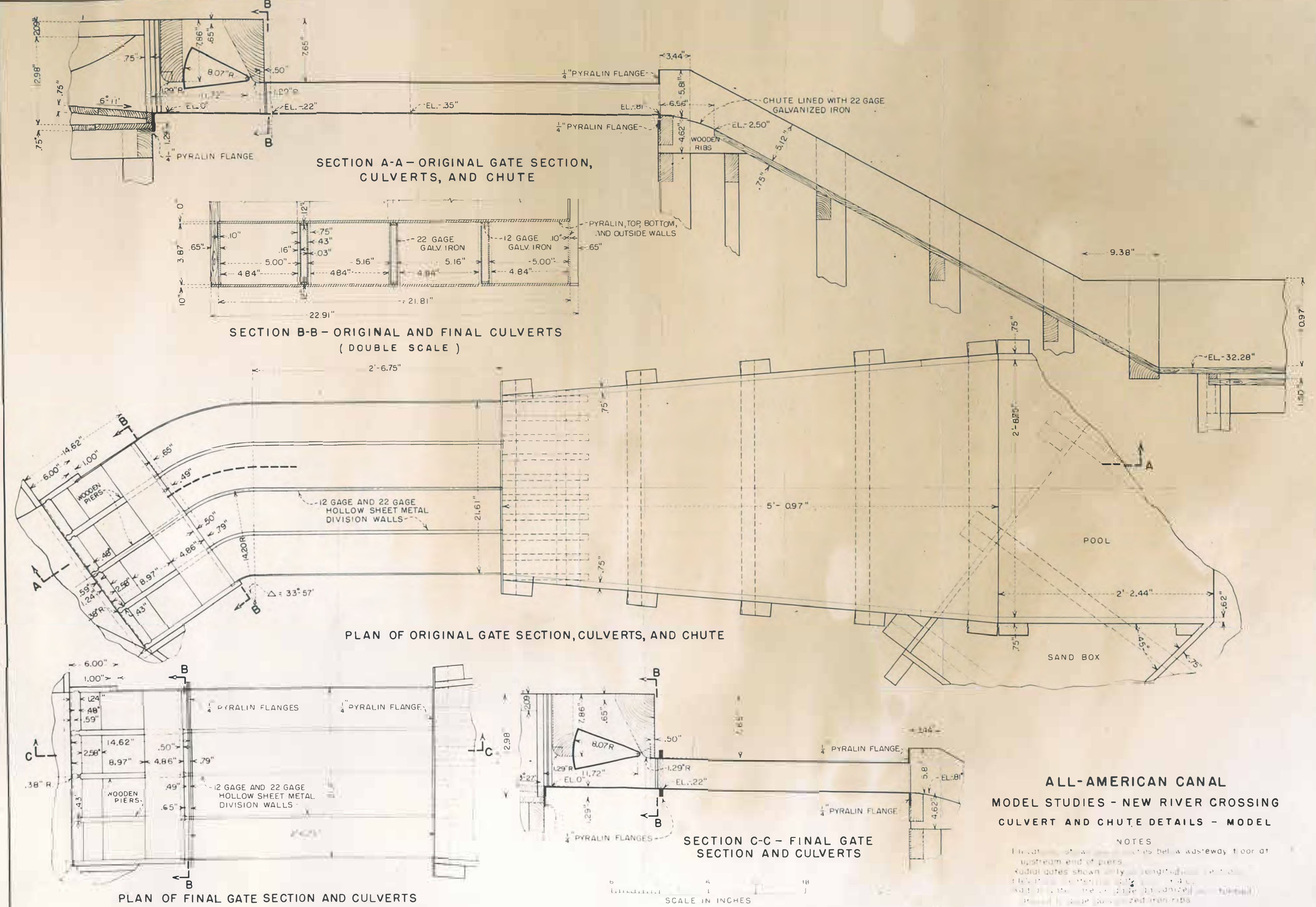
11. Chute. The original design gave excellent results. The vertical curve appeared to fit the trajectory of the jet. With flow through all culverts, the conservative rate of widening provided constant depths in any cross section. Culvert walls caused only minor fins.

Operating singly at full capacity, the upstream culvert provided satisfactory chute flow. At the pool entrance, the flow was fairly well distributed over nearly the full width (plate IV A and B).

12. Stilling pool. The recommended design differed appreciably from that originally proposed, as had been expected. Several types of changes constituted the design evolution; the floor was depressed, a shorter pool proved sufficient, and wing and pool walls on the upstream side were changed. Several sills and dentated steps were tested before obtaining satisfactory results. Two low groins extending into the riprap formed an important design addition.

Although the sand box occupied all available space, a larger box would have been desirable. A violent eddy persisted, filling the entire area, and was largely responsible for erosion beyond the paving. This eddy is expected in the prototype but the smallness of the box undoubtedlymagnified it in the model. This effect possibly caused a tendency toward overdesign.

That the original design placed the pool floor too high was immediately apparent. An ideal jump would require much more tailwater but groundwater presence limited the prototype floor lowering to two feet. The model was changed to correspond with this minimum elevation for all subsequent tests.



SECTION A-A – ORIGINAL GATE SECTION, CULVERTS, AND CHUTE

SECTION B-B – ORIGINAL AND FINAL CULVERTS (DOUBLE SCALE)

PLAN OF ORIGINAL GATE SECTION, CULVERTS, AND CHUTE

PLAN OF FINAL GATE SECTION AND CULVERTS

SECTION C-C – FINAL GATE SECTION AND CULVERTS

ALL-AMERICAN CANAL

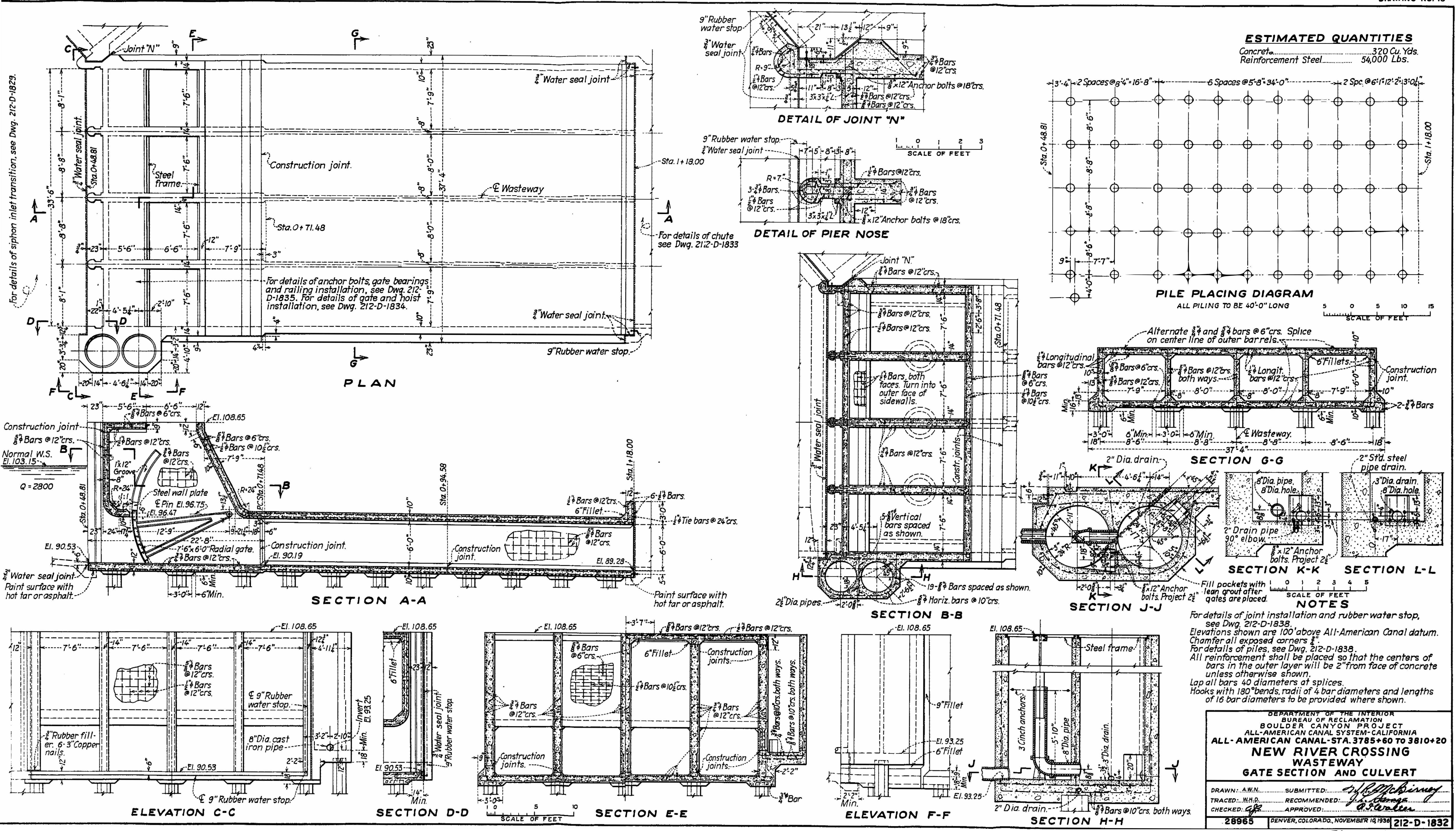
MODEL STUDIES – NEW RIVER CROSSING

CULVERT AND CHUTE DETAILS – MODEL

NOTES

[illegible] below wasteway floor at upstream end of piers.
Radial gates shown [illegible]
[illegible]
[illegible]
[illegible] iron ribs.

212-D-3070


ESTIMATED QUANTITIES
Concrete 320 Cu. Yds.
Reinforcement Steel 54,000 Lbs.
PLAN
DETAIL OF JOINT "N"
DETAIL OF PIER NOSE
PILE PLACING DIAGRAM
ALL PILING TO BE 40'-0" LONG
SECTION A-A
SECTION B-B
SECTION G-G
SECTION J-J
SECTION K-K
SECTION L-L
ELEVATION C-C
SECTION D-D
SECTION E-E
ELEVATION F-F
SECTION H-H
For details of siphon inlet transition, see Dwg. 212-D-1829.
For details of chute see Dwg. 212-D-1833
For details of anchor bolts, gate bearings and railing installation, see Dwg. 212-D-1835. For details of gate and hoist installation, see Dwg. 212-D-1834.
7'-6"x6'-0" Radial gate.
NOTES
For details of joint installation and rubber water stop, see Dwg. 212-D-1838.
Elevations shown are 100' above All-American Canal datum.
Chamfer all exposed corners 3/4".
For details of piles, see Dwg. 212-D-1838.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 40 diameters at splices.
Hooks with 180° bends, radii of 4 bar diameters and lengths of 16 bar diameters to be provided where shown.
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BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM-CALIFORNIA
ALL-AMERICAN CANAL-STA. 3785+60 TO 3810+20
NEW RIVER CROSSING
WASTEWAY
GATE SECTION AND CULVERT
DRAWN: A.W.N.
TRACED: W.H.D.
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
28965
DENVER, COLORADO, NOVEMBER 10, 1936
212-D-1832

Figure 9.

(A) **FINAL DESIGN** — LEFT CULVERT ONLY OPERATING AT FULL CAPACITY

(B) **FINAL DESIGN**
LEFT CULVERT ONLY OPERATING AT FULL CAPACITY

(C) **POOL SHAPE "C"** — MAXIMUM DISCHARGE
TAILWATER ELEVATION 56.0 FEET

PLATE IV

A secondary sill and baffle piers were severally installed and tested. No improvements were noted. The main sill was then tried in various locations. Paving beyond it appeared unnecessary. These tests indicated that a pool as short as 37.2 feet would give results comparable with those from the original 41.1-foot length. The shorter pool was adopted.

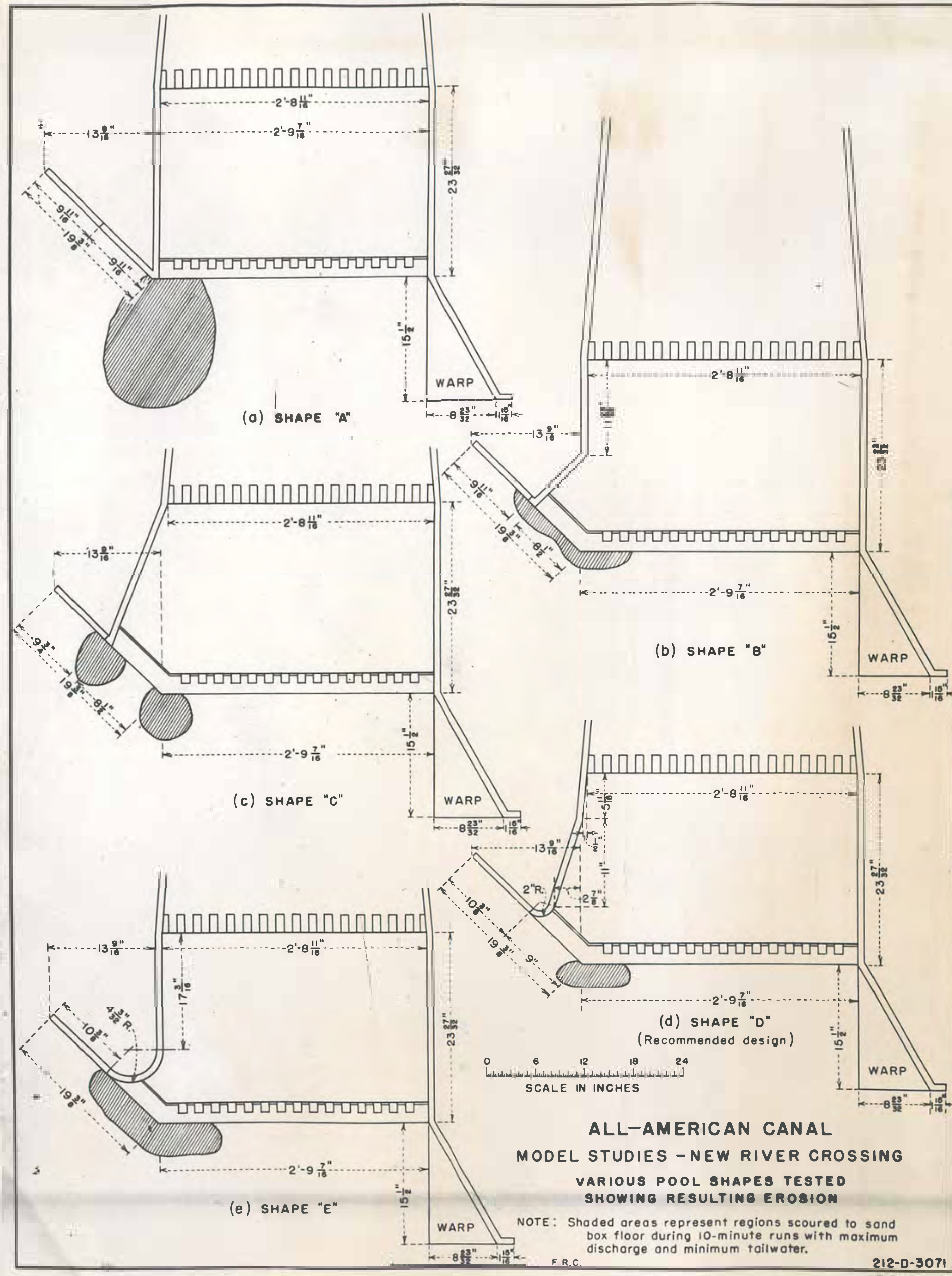
The rectangular pool was now tested at the lower elevation, using sand topography and no riprap. Surface conditions appeared excellent in the pool but the large eddy in the river bed caused considerable erosion. A large area near the end of the right side wall was scoured to the box floor which would have been at elevation 41.6' in the prototype. In an effort to force the eddy farther out into the river, effective changes in the right side wall were made. Figure 10 shows the various shapes tested. Ten-minute runs with maximum discharge and minimum tailwater scoured the shaded areas to the floor. Plate IV C shows surface conditions while testing "Plan C." Little difference in jump appearance was detected between the several designs. "Plan D", selected on the basis of minimum scour, was used for step and sill tests and eventually for the final design.

Actually the various dentated steps produced results differing very slightly, although the original teeth seemed too coarse. After testing several sizes, teeth 1.75 feet high, 1.55 feet wide, and spaced on 3.1-foot centers were selected. The tooth shape was then changed in an effort to move the jump upstream. The tops were given a 6:1 slope. This was not successful. Tests were next made without the use of a step, causing the jump to move downstream. Further step changes were not expected to result in material improvements and were discontinued.

Various shapes and sizes of sill teeth were tested but not recorded. Most of them produced about equally satisfactory results. A standard Rehbock design with tooth and space widths of 1.55 feet was finally adopted. This sill was then tested at different heights by placing various rectangular strips beneath it. Height proved a much more important factor than shape. The section shown in figure 12b produced best results.

Erosion was most severe near the angle point in the end of the pool floor (figure 10d). Changes were tried in the portion of the sill affecting this region. Teeth were removed for some tests, spaces were filled for others, the sill was entirely removed from the diagonal portion of the pool end for one run, but most changes had little effect. Best conditions resulted from the dentated sill along the square end combined with a solid sill along the diagonal part.

Further erosion control was attempted by installing groins extending into the sand. As many as three groins were used. Positions, lengths, and top elevations were varied. Surface appearances were not affected. Some combinations reduced scour remarkably and others increased it. Figure 11 shows results of the various tests.



ALL-AMERICAN CANAL

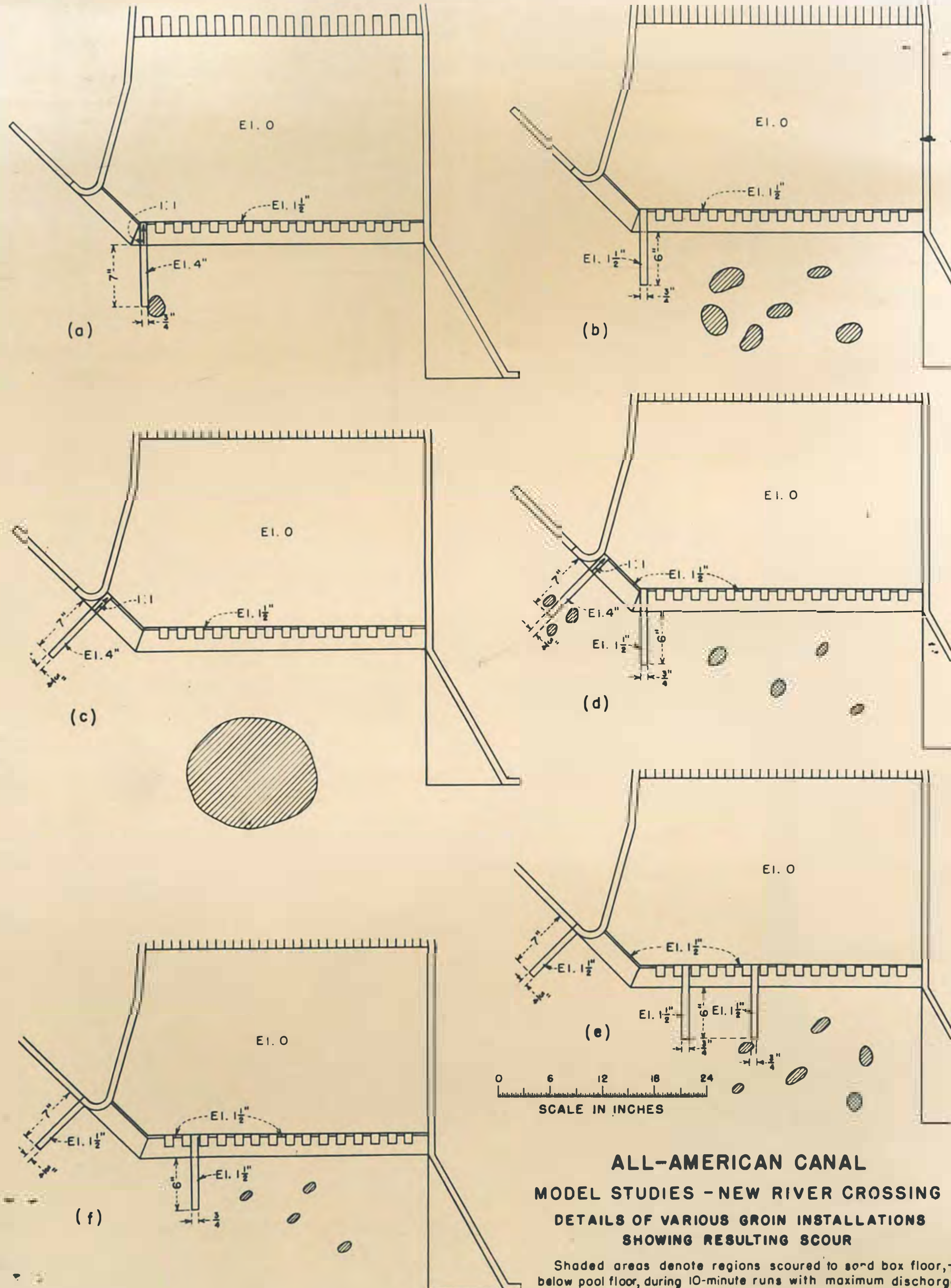
MODEL STUDIES – NEW RIVER CROSSING

VARIOUS POOL SHAPES TESTED SHOWING RESULTING EROSION

NOTE: Shaded areas represent regions scoured to sand box floor during 10-minute runs with maximum discharge and minimum tailwater.

F.R.C.

212-D-3071



ALL-AMERICAN CANAL

MODEL STUDIES - NEW RIVER CROSSING

DETAILS OF VARIOUS GROIN INSTALLATIONS SHOWING RESULTING SCOUR

Shaded areas denote regions scoured to sand box floor, $\frac{3}{16}$" below pool floor, during 10-minute runs with maximum discharge and minimum tailwater.

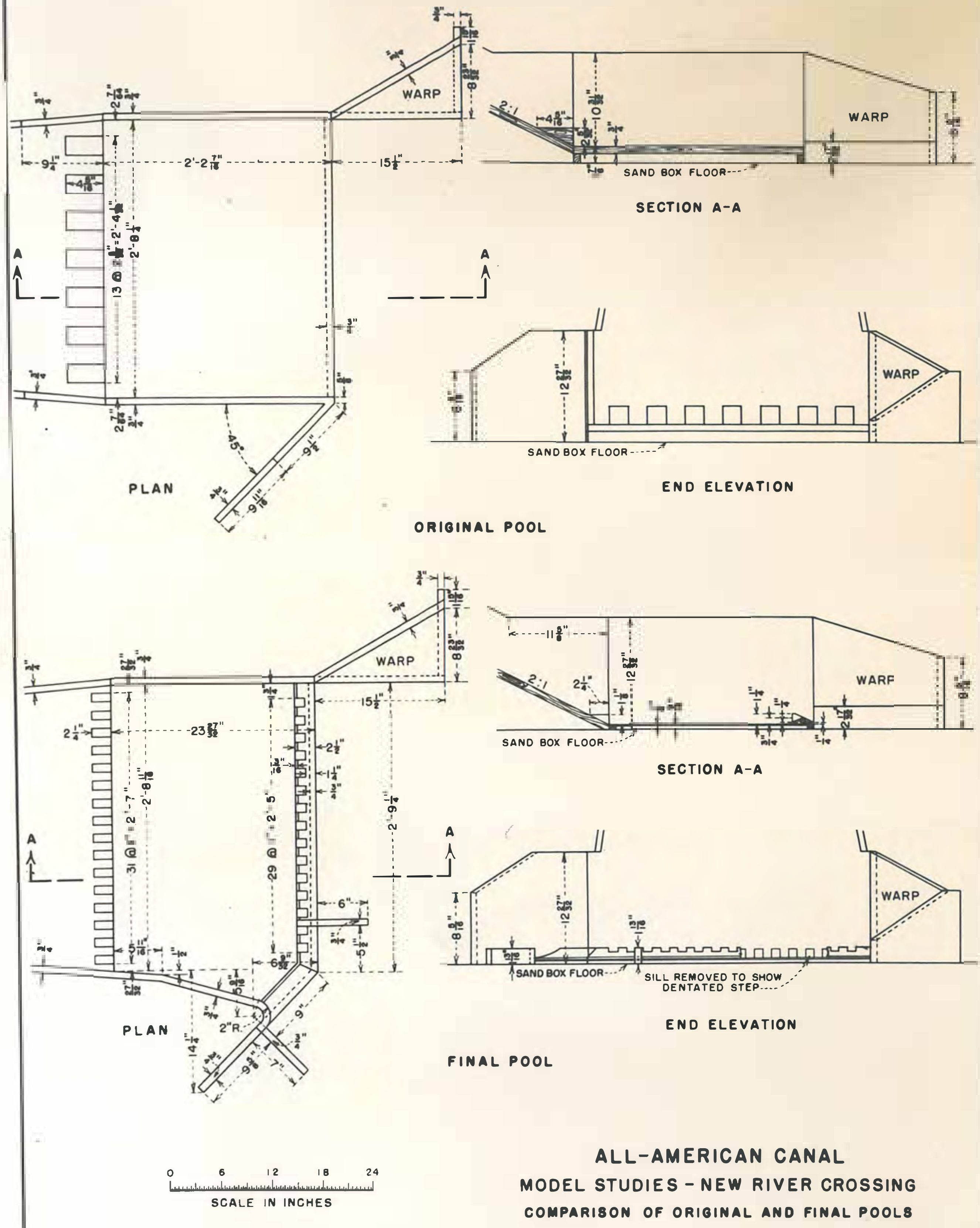
Elevations shown are in inches above pool floor.

Tests made with "Shape D" and final sill design only are shown.

F. R. C.

212-D-3072

FIGURE 11



ALL-AMERICAN CANAL

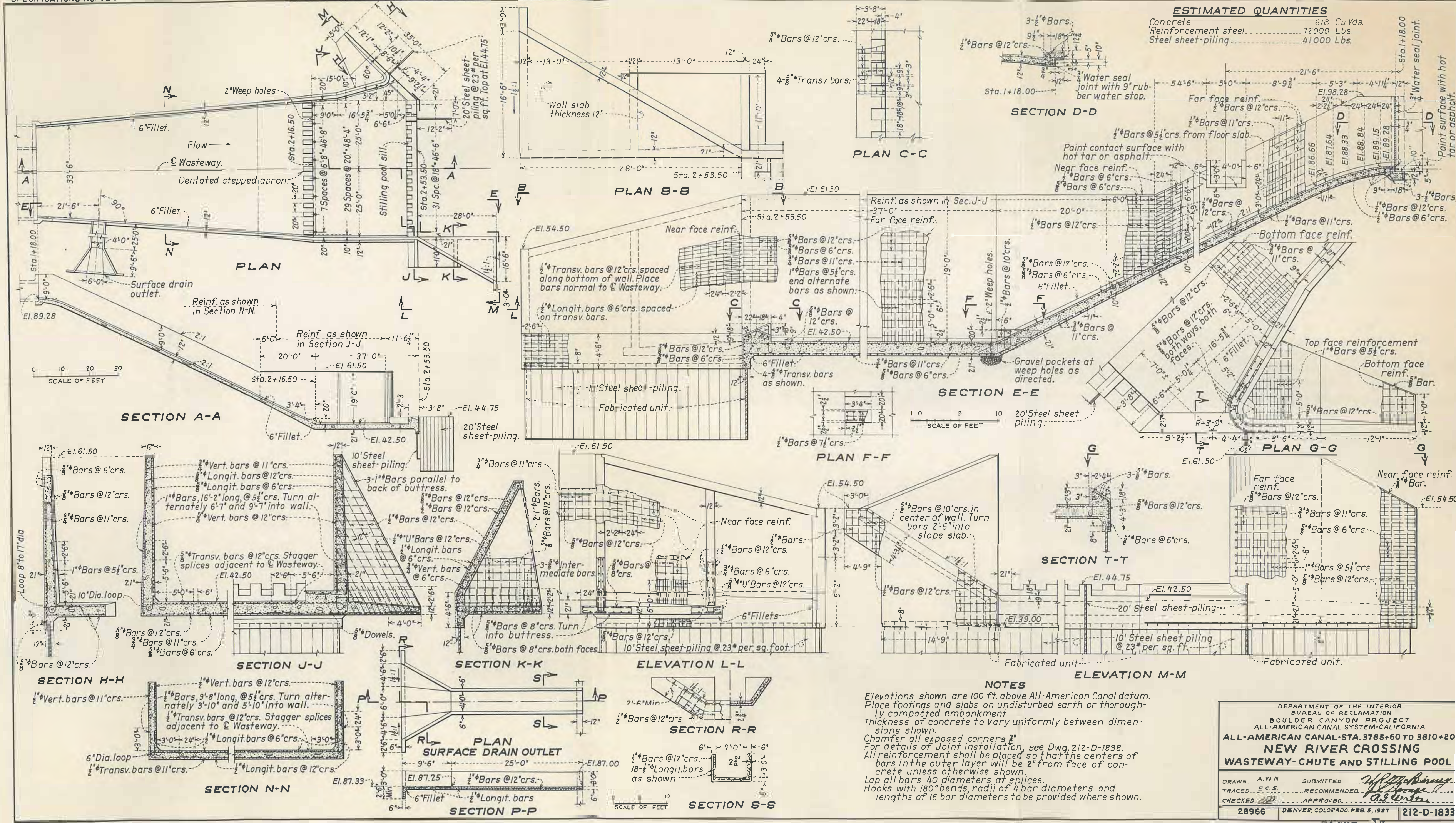
MODEL STUDIES - NEW RIVER CROSSING

COMPARISON OF ORIGINAL AND FINAL POOLS

F.R.C.

212-D-3073

FIGURE 12



ESTIMATED QUANTITIES

Concrete	618 Cu.Yds.
Reinforcement steel	72000 Lbs.
Steel sheet-piling	41000 Lbs.

NOTES

Elevations shown are 100 ft. above All-American Canal datum.
Place footings and slabs on undisturbed earth or thoroughly compacted embankment.
Thickness of concrete to vary uniformly between dimensions shown.
Chamfer all exposed corners $\frac{3}{4}$"
For details of Joint installation, see Dwg. 212-D-1838.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 40 diameters at splices.
Hooks with 180° bends, radii of 4 bar diameters and lengths of 16 bar diameters to be provided where shown.

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ALL-AMERICAN CANAL-STA. 3785+60 TO 3810+20
NEW RIVER CROSSING
WASTEWAY-CHUTE AND STILLING POOL

DRAWN A.W.N. SUBMITTED
TRACED E.C.S. RECOMMENDED
CHECKED APPROVED

28966 | DENVER, COLORADO, FEB. 5, 1937 | 212-D-1833

Figure 13.

Figure 12b shows the final pool design, a composite of the best features developed by previous tests. It was installed with sand topography and riprap to scale. Results were satisfactory but not perfect. Plate VI shows the pool action under several conditions. Riprap proved stable as evidenced by plate V, showing the gravel before and after lengthy tests under the most adverse discharge and tailwater conditions. It was decided that further improvements would probably not be worth the time necessary to develop them. Prototype design shown by figure 13 closely followed this final model, which is compared with the original design in figure 12.

SUMMARY

13. Results. These experiments were another example of model study value in hydraulic design. Tests demonstrated the excellence of the original plans of several features. The cost of investigating these was slight. On the other hand, some poor conditions were discovered and corrected. The pool gave poor results. Its construction as originally designed would have been a mistake. Flow approaching the wasteway entrance was also poor. Moving the entrance and thus providing more direct approach partly remedied this condition. This also accomplished culvert curve elimination. A further step was the use of an approach warp, although the one finally selected was not the best one tested. In correcting approach flow, the model work probably paid for itself many times over. Figure 14 shows the final prototype general plan.

14. Conclusions. These studies indicated the difficulty of stilling-pool design by use of a theoretical or empirical method. Minor factors often control pool action and designs should be checked by model studies whenever efficient operation is desired.

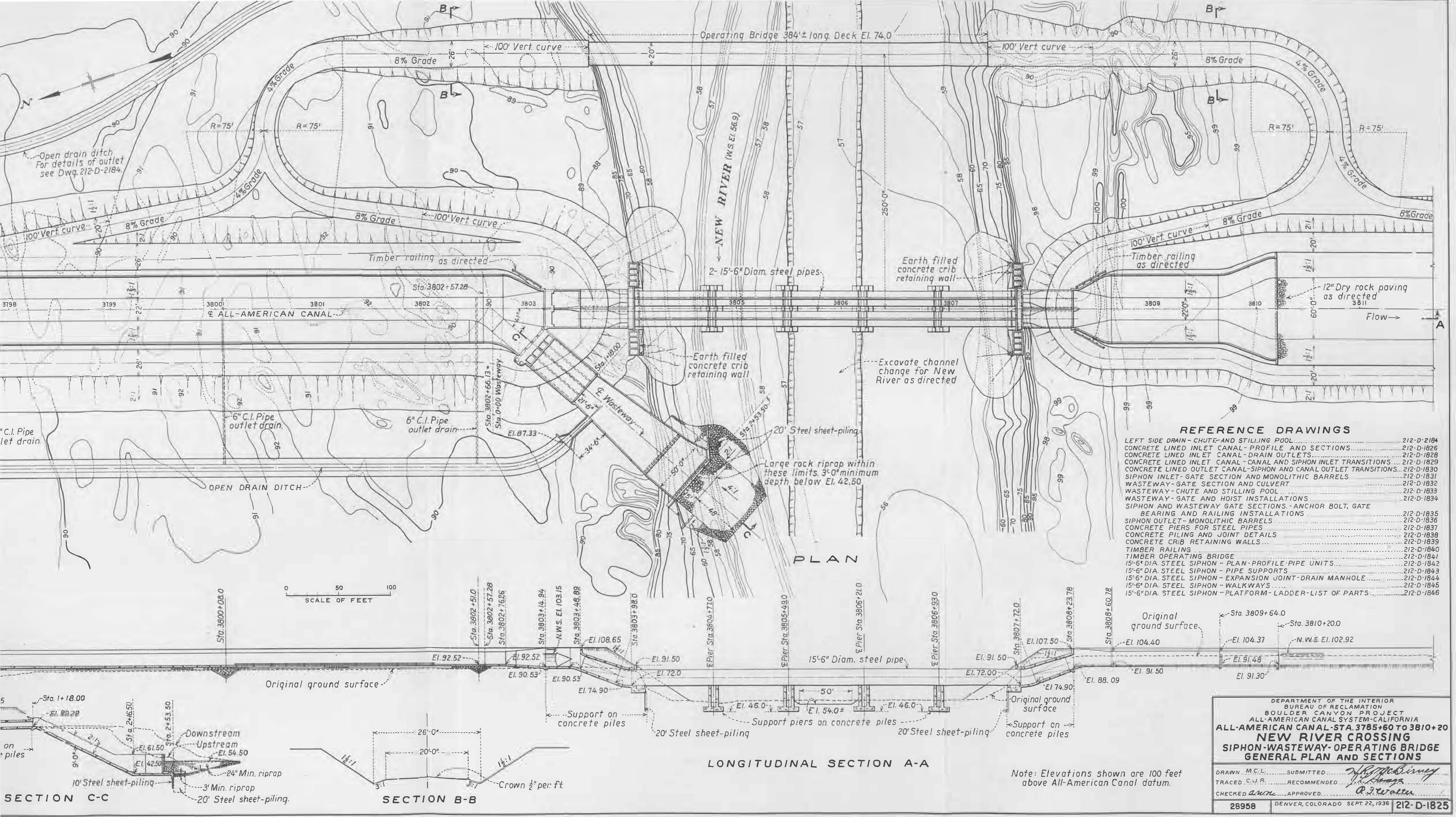
Tests of groins showed that they can be advantageously used in stilling-pool construction as well as for beach-erosion control.

Sill tests indicated that tooth size and shape are not of primary importance. Apparently the sill height above the floor has much more effect on operation.

Runs without a dentated step showed the importance of vertical jet dispersion in keeping the jump upstream. Larger teeth caused excessive vertical spread, however. Some water hit the upstream face of the roller, moving it downstream. Sloping teeth showed no beneficial results, although they promise to have definite value in some cases.

Wasteway approach studies indicated that high velocity flow in open channels cannot efficiently make sharp turns. Excessive losses must result. Good flow distribution immediately downstream cannot be achieved. The superiority of warps over angular intersections were also indicated.

- - -



Operating Bridge 384'± long. Deck El. 74.0
100' Vert curve
8% Grade
4% Grade
R=75'
Open drain ditch
For details of outlet
see Dwg. 212-D-2184.
NEW RIVER (W.S. El. 56.9)
Timber railing as directed
2-15'-6" Diam. steel pipes
Earth filled
concrete crib
retaining wall
Sta. 3802+57.28
℄ ALL-AMERICAN CANAL
12" Dry rock paving
as directed
Flow
℄ Wasteway
Sta. 3802+66.13 = Sta. 0+00 Wasteway
6" C.I. Pipe
outlet drain
El. 87.33
OPEN DRAIN DITCH
20' Steel sheet-piling
Large rock riprap within
these limits. 3'-0" minimum
depth below El. 42.50
Excavate channel
change for New
River as directed
PLAN
SCALE OF FEET
REFERENCE DRAWINGS
LEFT SIDE DRAIN - CHUTE AND STILLING POOL ... 212-D-2184
CONCRETE LINED INLET CANAL - PROFILE AND SECTIONS ... 212-D-1826
CONCRETE LINED INLET CANAL - DRAIN OUTLETS ... 212-D-1828
CONCRETE LINED INLET CANAL - CANAL AND SIPHON INLET TRANSITIONS ... 212-D-1829
CONCRETE LINED OUTLET CANAL - SIPHON AND CANAL OUTLET TRANSITIONS ... 212-D-1830
SIPHON INLET - GATE SECTION AND MONOLITHIC BARRELS ... 212-D-1831
WASTEWAY - GATE SECTION AND CULVERT ... 212-D-1832
WASTEWAY - CHUTE AND STILLING POOL ... 212-D-1833
WASTEWAY - GATE AND HOIST INSTALLATIONS ... 212-D-1834
SIPHON AND WASTEWAY GATE SECTIONS - ANCHOR BOLT, GATE BEARING AND RAILING INSTALLATIONS ... 212-D-1835
SIPHON OUTLET - MONOLITHIC BARRELS ... 212-D-1836
CONCRETE PIERS FOR STEEL PIPES ... 212-D-1837
CONCRETE PILING AND JOINT DETAILS ... 212-D-1838
CONCRETE CRIB RETAINING WALLS ... 212-D-1839
TIMBER RAILING ... 212-D-1840
TIMBER OPERATING BRIDGE ... 212-D-1841
15'-6" DIA. STEEL SIPHON - PLAN-PROFILE-PIPE UNITS ... 212-D-1842
15'-6" DIA. STEEL SIPHON - PIPE SUPPORTS ... 212-D-1843
15'-6" DIA. STEEL SIPHON - EXPANSION JOINT-DRAIN MANHOLE ... 212-D-1844
15'-6" DIA. STEEL SIPHON - WALKWAYS ... 212-D-1845
15'-6" DIA. STEEL SIPHON - PLATFORM-LADDER-LIST OF PARTS ... 212-D-1846
Original ground surface
15'-6" Diam. steel pipe
Support on concrete piles
20' Steel sheet-piling
Support piers on concrete piles
LONGITUDINAL SECTION A-A
Downstream
Upstream
24" Min. riprap
3' Min. riprap
10' Steel sheet-piling
20' Steel sheet-piling.
SECTION C-C
Crown ½" per ft.
SECTION B-B
Note: Elevations shown are 100 feet
above All-American Canal datum.
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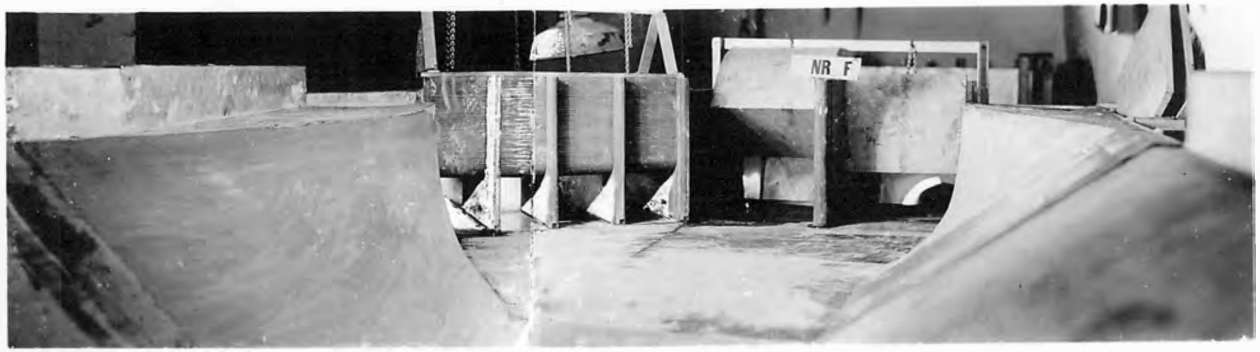
NEW RIVER CROSSING
SIPHON-WASTEWAY-OPERATING BRIDGE
GENERAL PLAN AND SECTIONS
DRAWN M.C.L. SUBMITTED
TRACED C.J.R. RECOMMENDED
CHECKED APPROVED
28958
DENVER, COLORADO SEPT. 22, 1936
212-D-1825

Figure 14.



(A) FINAL DESIGN - WARPS AND ENTRANCES

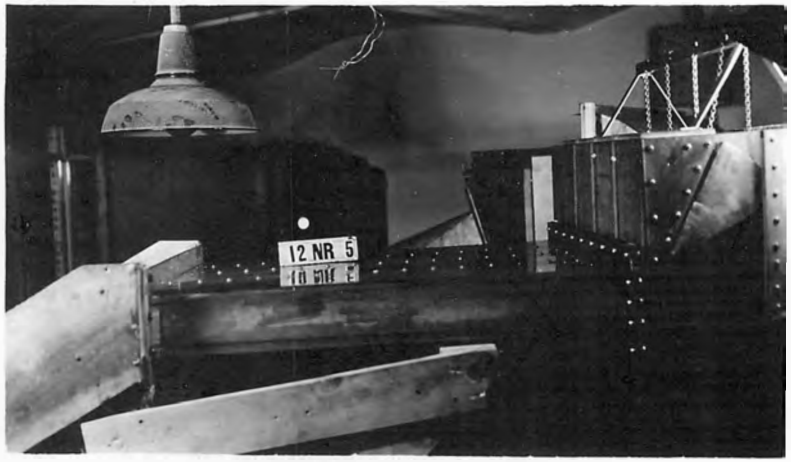
(B) POOL AND RIPRAP BEFORE FINAL TESTS

(C) POOL AND RIPRAP AFTER FINAL TESTS

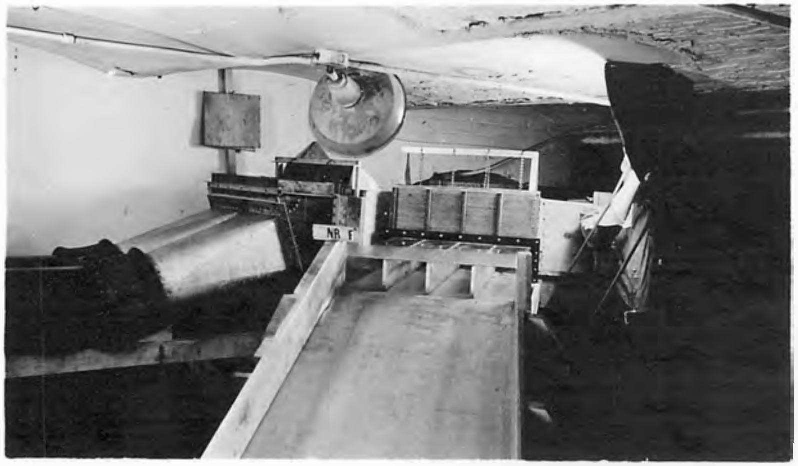
PLATE V

(A) FINAL POOL DESIGN — MAXIMUM DISCHARGE
TAILWATER ELEVATION 57.0 FEET

(B) FINAL POOL DESIGN — MAXIMUM DISCHARGE
TAILWATER ELEVATION 53.0 FEET



(C) CULVERTS AND WASTEWAY GATES



(D) SIPHONS, CULVERTS, AND CHUTE

PLATE VI