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UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDRAULIC MODEL STUDY OF THE

ROZA DIVERSION DAM AND APPURTENANT STRUCTURES

By H. G. DEWEY, Jr., ASSISTANT ENGINEER

Under direction of

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and

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TECHNICAL MEMORANDUM NO. 594

Denver, Colorado,

July 11, 1939.

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PREFACE

The hydraulic model study incorporated with the design of the Roza Diversion Dam and appurtenant structures was made in the hydraulic laboratory of the Bureau of Reclamation, Denver, Colorado, under the direction of J. E. Warnock, Research Engineer. The tests were conducted and this report prepared by H. G. Dewey, Jr., Assistant Engineer. All laboratories are under the supervision of Arthur Ruettgers, Senior Engineer, and R. F. Blanks, Engineer. All design work is under the general supervision of J. L. Savage, Chief Designing Engineer. All engineering work is under the direction of R. F. Walter, Chief Engineer; and all activities of the Bureau of Reclamation are under the direction of John C. Page, Commissioner.

The design of the Roza Diversion Dam and appurtenant structures was made under the general supervision of H. R. McBirney, Senior Engineer, and C. P. Vetter, Engineer.

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CHAPTER I - INTRODUCTION AND DESCRIPTION OF MODEL

INTRODUCTION

1. The Prototype.--The Roza Diversion Dam and its appurtenant structures, a headworks, the Yakima Ridge canal, and fish ladders, are situated in the Yakima River between Ellensburg and Yakima, Washington (figures 1 and 2). The diversion dam, which is designed to pass 50,000 second-feet, enables 2,200 second-feet to be diverted through the headworks into the Yakima Ridge canal. To divert this flow, the water surface in the reservoir will be maintained at a constant level by two 14- by 110-foot roller gates at the diversion dam; the dam being shaped to allow submergence of the roller gates enabling removal of ice from the reservoir. The obstruction in the Yakima River caused by the diversion dam requires fish ladders at each abutment to enable salmon to continue upstream to the spawning grounds.

2. Purpose of Model.--Hydraulic model studies were incorporated in the design of these structures to determine: (1) A correct headworks alinement; (2) the performance of the fish ladders; (3) a stilling pool at the toe of the diversion dam; and (4) calibration curves for the dam and the roller gates.

THE MODEL

3. Model Construction.--A 1 to 48 scale model was built and tested in the hydraulic laboratory of the Bureau of Reclamation, Denver, Colorado (figures 3 and 4). The roller gates were made of seamless steel tubing and their traveling mechanism was included as shown in Section A-A, figure 3, enabling duplication of prototype gate settings. The diversion dam was made of light-gage sheet metal to facilitate construction and to eliminate warping. Sufficient river topography was installed upstream and downstream from the diversion dam to provide proper flow conditions. The headworks of the canal, complete with piers, trashracks, and fish screens, was constructed as a unit to facilitate changes in alinement. A small weir was installed under the downstream end of the model box enabling separate measurement of the flow in the canal. The fish ladder and adjacent topography was carefully placed to assure the desired relation between the discharge in the fish ladder and in the river.

Figure 1

SPECIFICATIONS No. 793

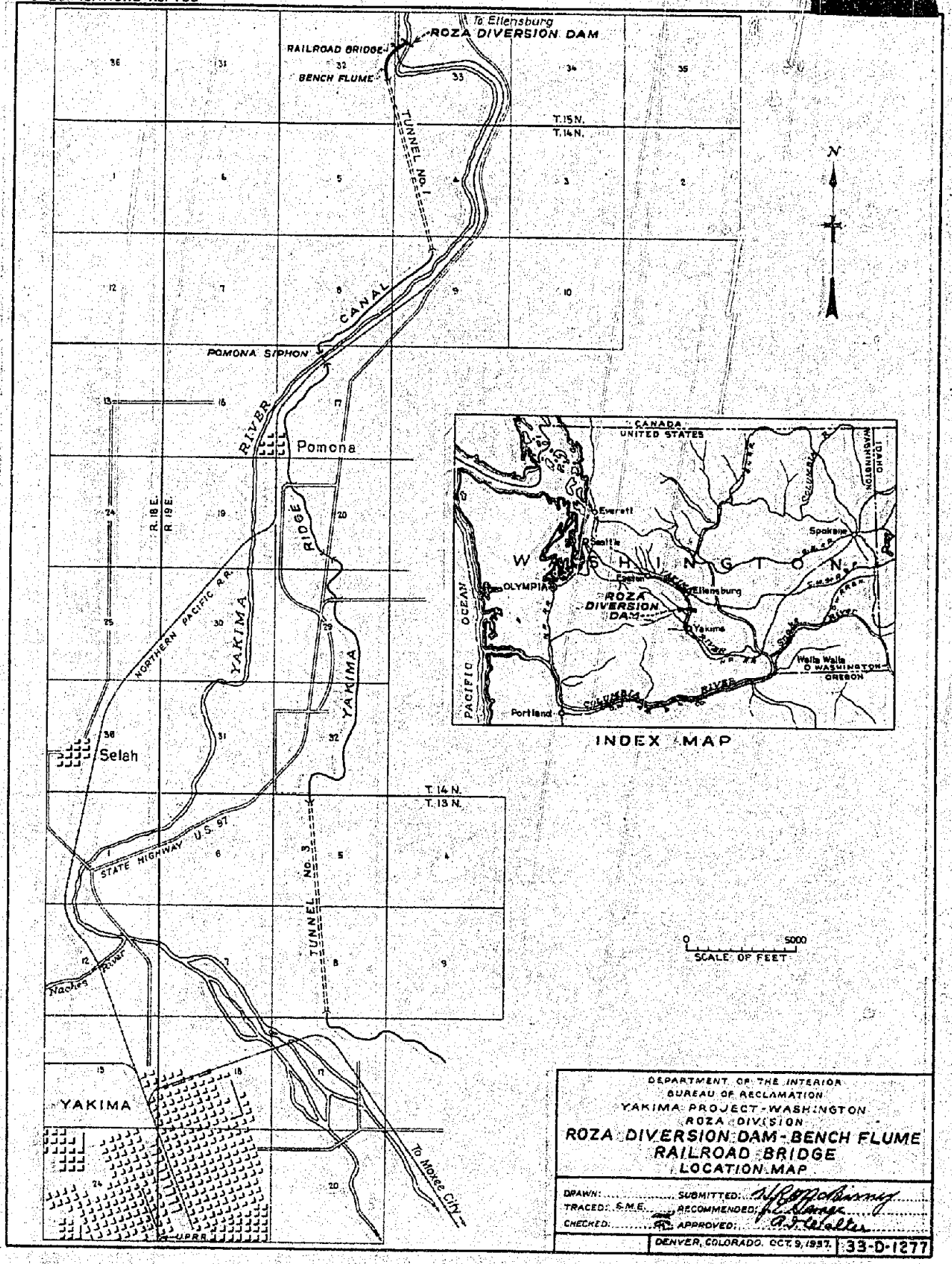


Figure 2

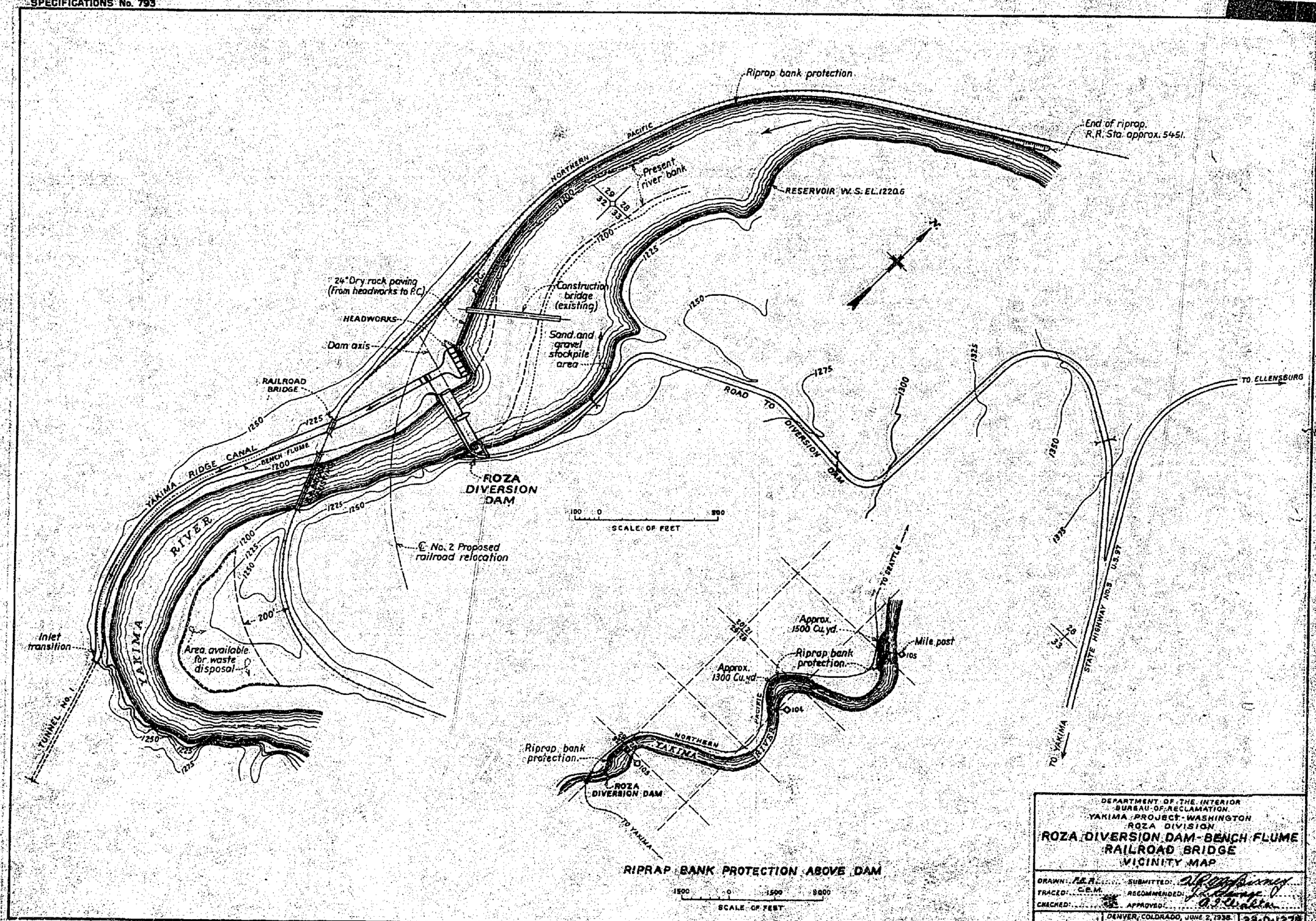
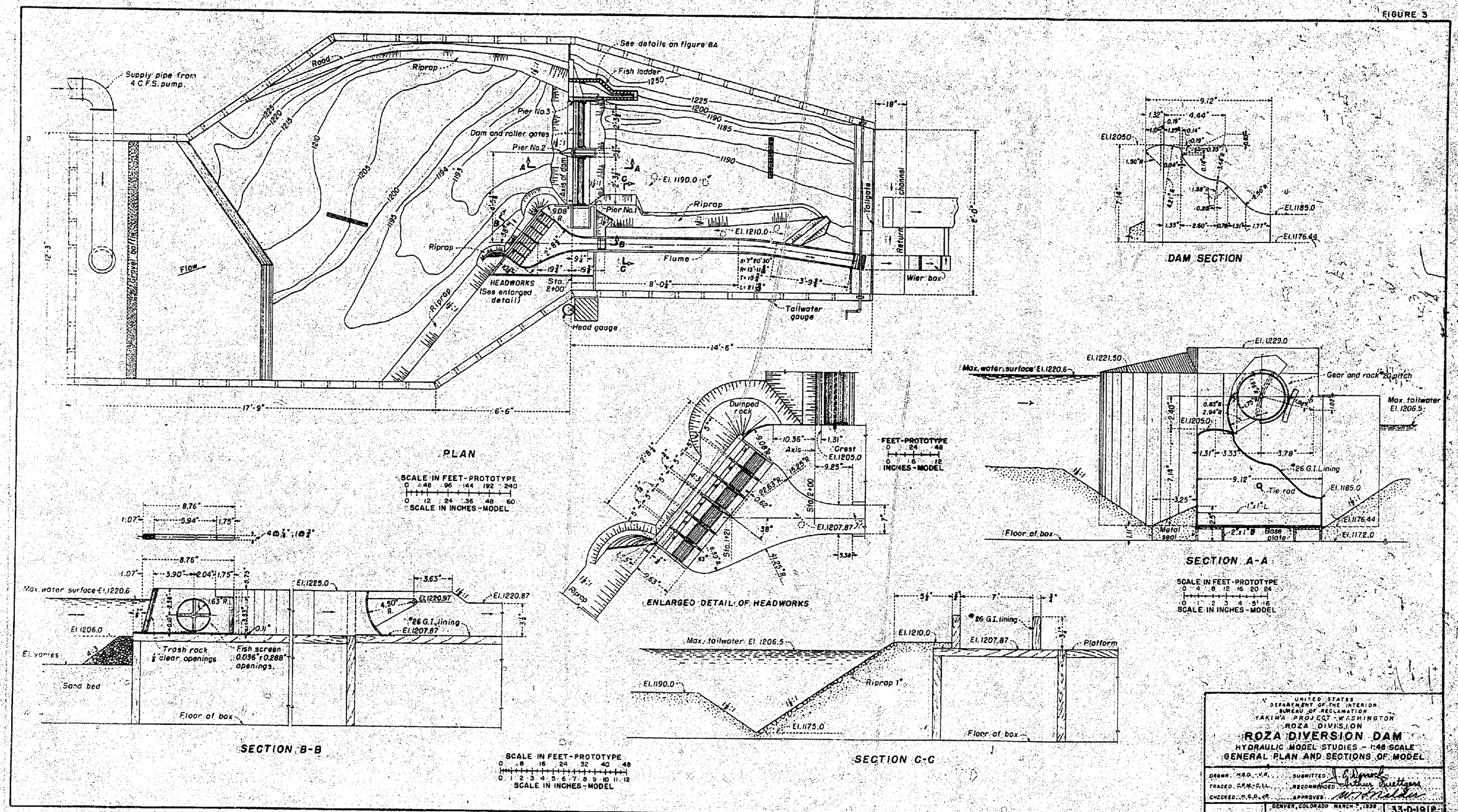
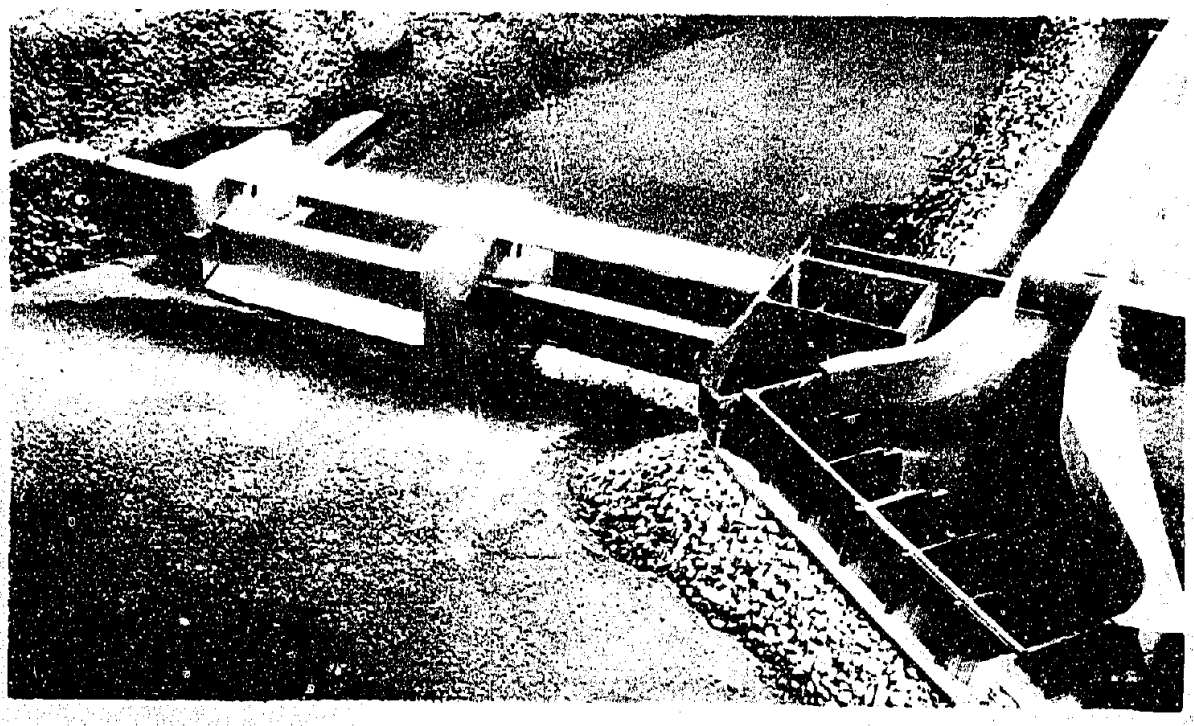

Riprap bank protection
End of riprap. R.R. Sta. approx. 5451.
NORTHERN PACIFIC
Present river bank
RESERVOIR W.S. EL. 1220.6
24" Dry rock paving (From headworks to P.C.)
HEADWORKS
Dam axis
Construction bridge (existing)
Sand and gravel stockpile area
RAILROAD BRIDGE
YAKIMA RIDGE CANAL
BENCH FLUME
ROZA DIVERSION DAM
℄ No. 2 Proposed railroad relocation
ROAD TO DIVERSION DAM
TO ELLENSBURG
STATE HIGHWAY No. 3 U.S. 97
TO YAKIMA
TO SEATTLE
YAKIMA RIVER
Inlet transition
TUNNEL No. 1
Area available for waste disposal
Approx. 1500 Cu. yd.
Mile post
Riprap bank protection
Approx. 1300 Cu. yd.
Riprap bank protection
ROZA DIVERSION DAM
TO YAKIMA
SCALE OF FEET
RIPRAP BANK PROTECTION ABOVE DAM
SCALE OF FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT-WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM-BENCH FLUME
RAILROAD BRIDGE
VICINITY MAP
DRAWN: F.E.R.
TRACED: C.E.M.
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO, JUNE 2, 1938
33-D-1278

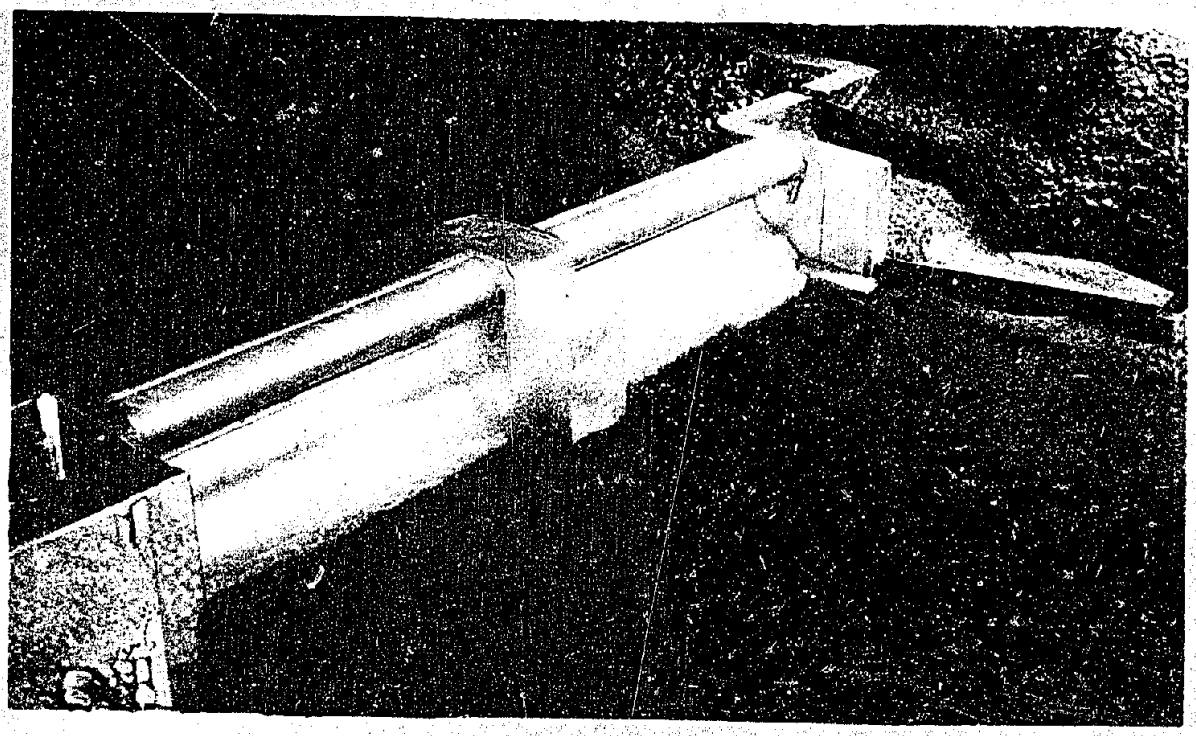
FIGURE 3



PLAN
SCALE IN FEET-PROTOTYPE
SCALE IN INCHES-MODEL
Supply pipe from 4 C.F.S. pump
Road
Riprap
See details on figure 8A
Fish ladder
Pier No.3
Dam and roller gates
Pier No.2
Pier No.1
Axis of dam
El. 1190.0
El. 1210.0
Flume
Tailgate
Return channel
Wier box
Tailwater gauge
Head gauge
HEADWORKS (See enlarged detail)
Sta. 2+00
Gravel baffle
Flow
17'-9"
6'-6"
14'-6"
8'-0½"
3'-9⅜"
12'-3"
DAM SECTION
El. 1205.0
El. 1185.0
El. 1176.44
ENLARGED DETAIL OF HEADWORKS
Dumped rock
Axis
Crest El. 1205.0
El. 1207.87
FEET-PROTOTYPE
INCHES-MODEL
SECTION A-A
Max. water surface El. 1220.6
El. 1221.50
El. 1229.0
Gear and rack 20 pitch
Max. tailwater El. 1206.5
El. 1205.0
#26 G.I. Lining
Tie rod
El. 1185.0
El. 1176.44
El. 1172.0
Metal seal
Base plate
Floor of box
SECTION B-B
Max. water surface El. 1220.6
El. 1206.0
El. varies
Sand bed
Trash rack ⅛" clear openings
Fish screen 0.036" x 0.288" openings
El. 1225.0
El. 1220.97
El. 1220.87
#26 G.I. lining
El. 1207.87
Floor of box
SECTION C-C
Max. tailwater El. 1206.5
El. 1190.0
El. 1175.0
Riprap 1"
El. 1210.0
El. 1207.87
#26 G.I. lining
Platform
Floor of box
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
HYDRAULIC MODEL STUDIES - 1:48 SCALE
GENERAL PLAN AND SECTIONS OF MODEL
DRAWN: H.G.D. - V.R.
TRACED: C.F.M. - C.L.L.
CHECKED: H.G.D. - J.R.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO MARCH 7, 1939
33-D-1918



A. LOOKING DOWNSTREAM.



A. LOOKING UPSTREAM.

ORIGINAL DESIGN.

CHAPTER II - TESTS ON HEADWORKS

ORIGINAL DESIGN

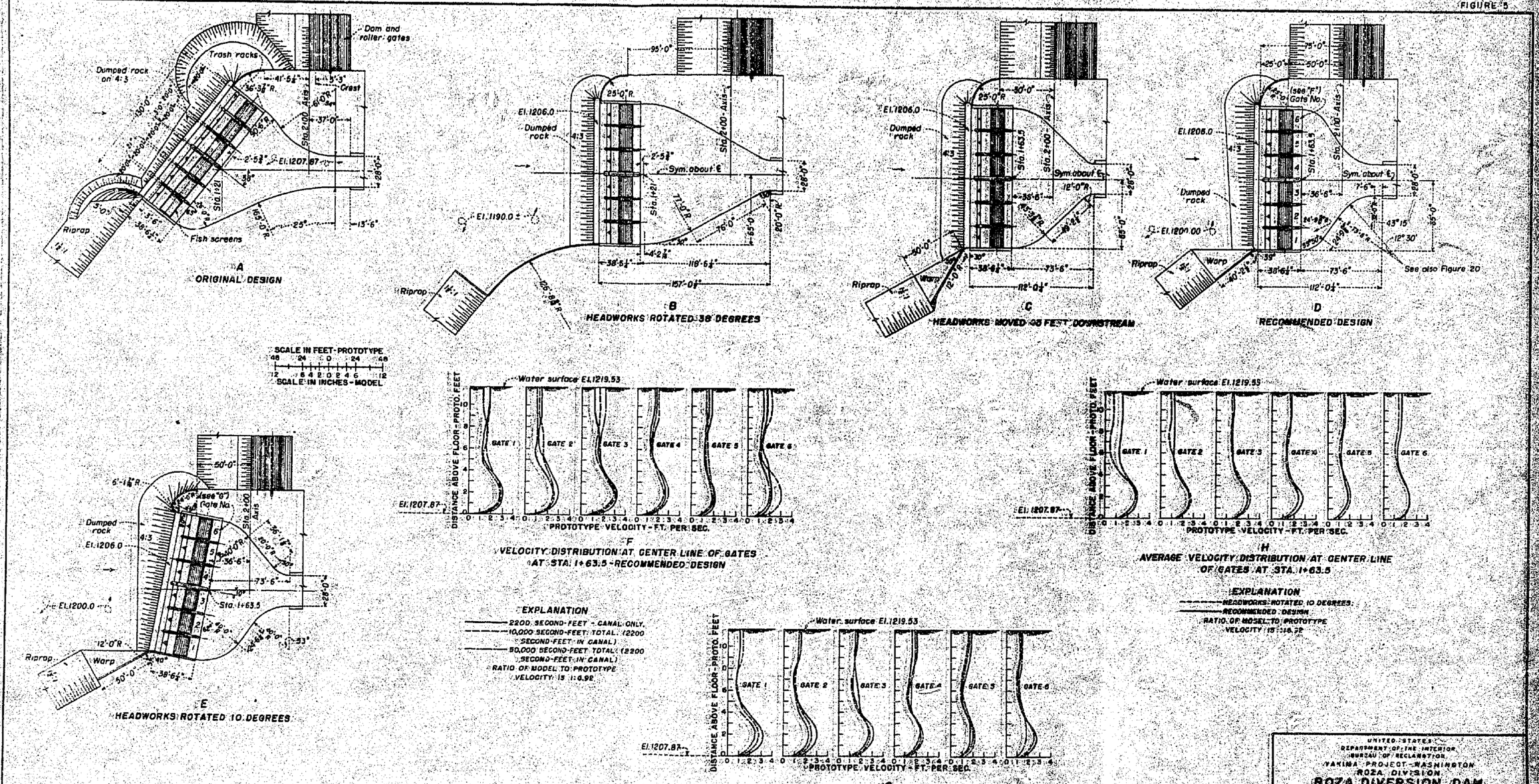
4. Description of Headworks.--The headworks to the Yakima Ridge canal consists of six openings or panels formed by piers which support a trashrack and fish screen between each opening (section B-B, figure 3; and figure 5A). The width of openings are determined so that the velocity of the flow through them will not be greater than about two feet per second for the maximum discharge of 2,200 second-feet diverted into the headworks. This is necessary to prevent fish, especially fingerlings, from being trapped against the fish screens due to excessive velocities. The fish screens are required to prevent salmon and other fish from entering the canal. The screens will be rotated slowly in the prototype to prevent debris from collecting on them, and a gantry will be provided to remove the fish screens from the headworks for cleaning (section E-E, figure 17). As the flow passes from the reservoir through the openings and into a transition, it is controlled by a radial gate placed downstream from the canal entrance (section B-B, figure 3).

5. Flow in Original Design.--The original alinement of the headworks was rotated 38 degrees clockwise from a line normal to the axis of the dam (figures 3 and 5A). This alinement reduced the length of the vertical training wall extending from the headworks to the right abutment of the dam, but it caused unsymmetrical flow through the headworks. Observations on the model revealed that when 2,200 second-feet was diverted into the headworks, most of the flow entered the two openings at the left side, causing an eddy in the transition to the canal. This eddy directed the flow upstream along the right side of the transition, causing the flow at that point to proceed through the openings and back into the river.

TESTS LEADING TO RECOMMENDED DESIGN OF HEADWORKS

6. Alinement and Position Changed.--To eliminate the unfavorable flow conditions of the original design, the headworks was rotated 38 degrees counterclockwise until its center line became normal with the axis of the dam (figure 5B). With this alinement, the flow entered each opening more uniformly and the eddy in the transition was eliminated, enabling all the flow to

FIGURE 5



UNITED STATES
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YAKIMA PROJECT - WASHINGTON
ROZA DIVISION

ROZA DIVERSION DAM

HYDRAULIC MODEL STUDIES - 1:48 SCALE
ALINEMENT OF HEADWORKS STUDIED IN MODEL

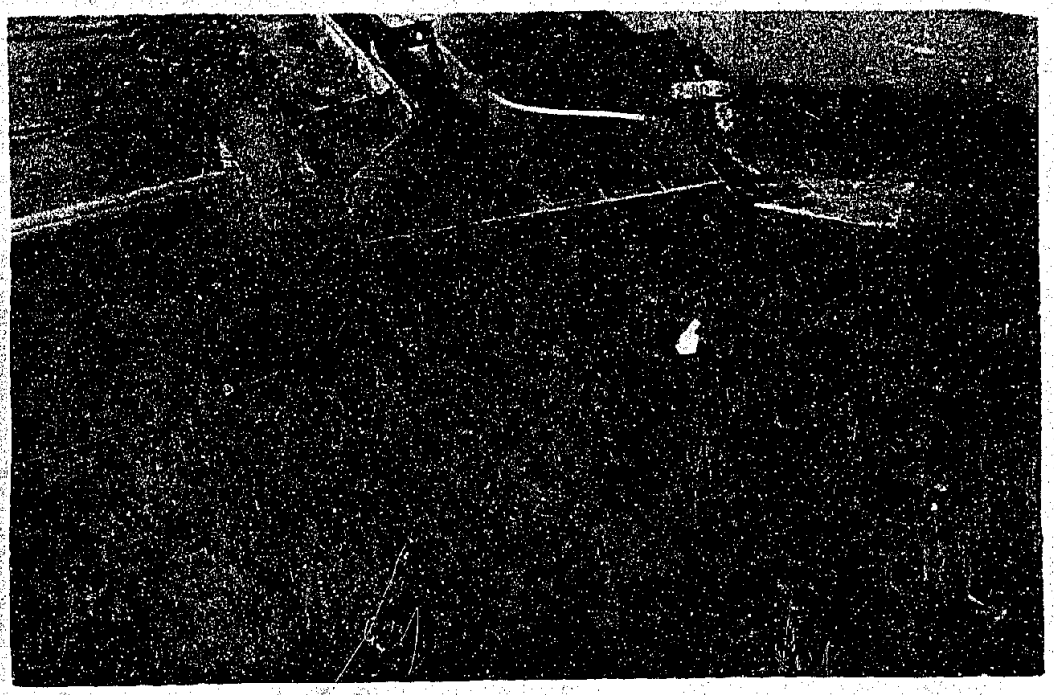
DRAWN [illegible] SUBMITTED [illegible]
TRACED [illegible] RECOMMENDED [illegible]
CHECKED [illegible] APPROVED [illegible]
DENVER, COLORADO, MARCH 13, 1950

proceed downstream through the transition and into the canal.

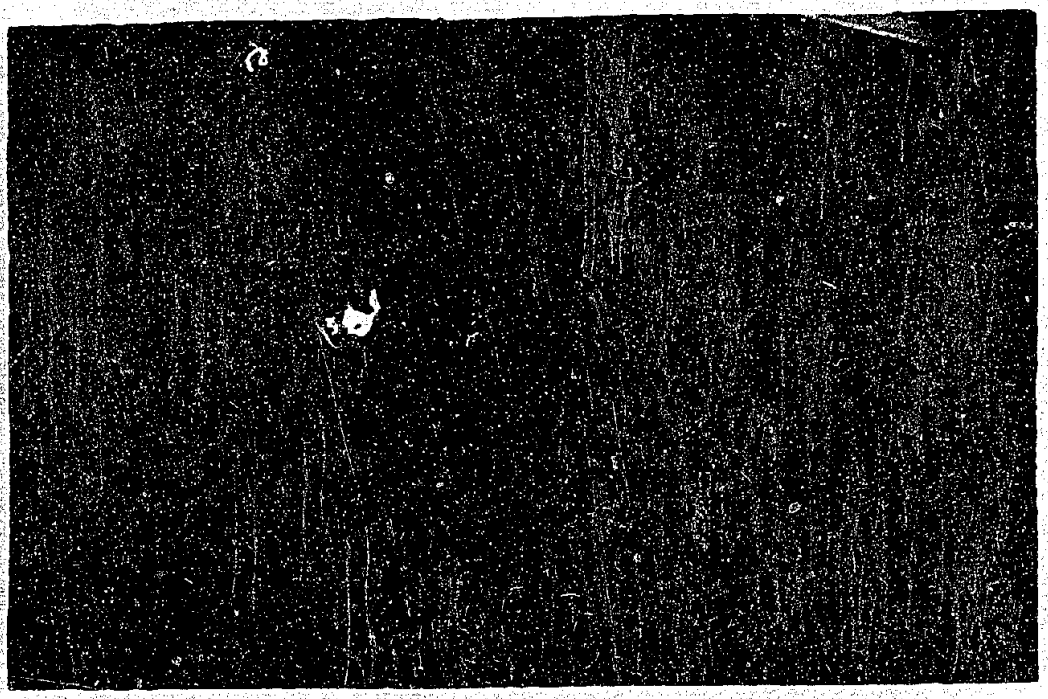
Although the flow conditions were improved, it was necessary to move the headworks 45 feet downstream to reduce the length of the vertical training wall extending from the headworks to the right abutment of the dam (figure 5C). This did not effect the uniform flow distribution, but the reduction in length of the transition caused small waves or ripples on the water surface at the entrance to the canal. A transition was designed, therefore, to give uniform acceleration and reduction in depth in the transition. The waves or ripples were eliminated, but the side walls of this transition (not shown) projected too far in front of each slide opening. As a result, the velocity of the flow through each side opening was apparently deflected upwards at the transition walls, causing eddies or vortices to develop. A slight change in the shape of the transition eliminated the undesirable eddies or vortices, and this shape was adopted in the recommended design.

7. Recommended Design of Headworks.--The alinement of the recommended design (figures 5D and 6B) allowed a uniform flow distribution through each opening of the headworks. Its position, however, did not permit any reduction in the length of the vertical training wall extending from the headworks to the right abutment of the dam. If the headworks had been moved downstream to shorten this wall, the transition to the canal would have been too abrupt. The position of the warp and the $1\frac{1}{2}$ to 1 side slope (figures 5D and 17) eliminated a large eddy which formed in other designs, during higher discharges, upstream from the headworks along the $1\frac{1}{2}$ to 1 riprapped slope. Although this eddy did not scour, it prevented the formation of a more uniform velocity distribution in the approach of the headworks. By introducing dye into the flow, a study was made of the streamlines occurring along the side slope and the warp. This permitted the position of the warp and the side slope to be readily determined, which would give a better velocity distribution at the approach.

To check the flow distribution through the headworks of the recommended design, velocity measurements were taken at the center line of each opening (trashracks and fish screen in place) at station 1+63.5 (figure 5D). These measurements were taken with 2,200 second-feet flowing through the headworks into the canal: first, with no flow over the diversion dam, and then with a total combined flow (canal plus diversion dam) of 10,000 and 50,000 second-feet. The flow distribution (figure 5F) is seen to be quite uniform through each opening but also somewhat better in the first two openings than for the alinement shown on



A. HEADWORKS ROTATED TEN DEGREES.



B. RECOMMENDED DESIGN.

HEADWORKS.

figures 5E and 6A in which the headworks has been rotated 10 degrees. The velocity data for this design are shown on figure 5G. The average velocity of each design for the three discharges is shown on figure 5H.

It was hoped that if the headworks was rotated 10 degrees clockwise that a saving could be made by reducing the length of the vertical training wall extending from the headworks to the right abutment of the dam. This was not realized, however, because a rotation of 10 degrees affected the velocity distribution and it did not permit any reduction of length of training wall, since some curvature of the wall was necessary at the left end of the headworks. Any additional change in alinement in this direction would approach the unfavorable conditions existing with the original alinement.

8. Turbulence in Flow at Right Abutment.--At maximum or near maximum discharge, considerable turbulence and boiling occurred with each headworks alinement near the right abutment of the dam, a few feet upstream from the right roller gate. This condition was not considered serious enough to require elimination. Its cause was never fully determined, but it may have been due in part to the drawdown occurring in the flow as it passed around the curved part of the vertical wall at the left end of the headworks. During large discharges, the velocity of approach to the roller gates is considerable, and any drawdown occurring under this condition may have created this turbulence. At low discharges, the turbulence is nearly eliminated, but a vortex forms in its place. It may be necessary to remove any debris at the water surface which becomes trapped near this vortex.

CHAPTER III - TESTS ON FISH LADDER

FUNCTION OF FISH LADDER

9. Design Features.--The presence of salmon in the Yakima River during spawning season requires fish ladders to be installed at the diversion dam to enable the fish to pass that obstruction. There are at least five features to be included in the design of any fish ladder: (1) Salmon must be able to pass through a fish ladder with a minimum of effort and injury; (2) the entrance to the fish ladder should be placed in the immediate vicinity of the obstruction to be passed; (3) some means should be provided at the entrance to the fish ladder to attract the salmon from the main flow of the river; (4) the flow within the fish ladder should have a relatively low velocity and be free from excessive turbulence; and (5) the exit of a fish ladder should not be placed near a gate structure.

Salmon do not feed during migration to their spawning grounds but live from the stored energy in their bodies. This requires an easy passage to be provided at any obstruction. If injury occurs, a protective film on the body of the salmon may be broken, permitting fungi to attack the fish, which may prove fatal. During the migration from the ocean, the Pacific salmon proceed only upstream and will not reverse their direction. This makes it essential to have the fish ladder entrance adjacent to the main obstruction in the river, enabling the salmon to proceed immediately upstream into the ladder. In addition, the salmon must be quickly attracted to the entrance by turbulence created by the flow from the fish ladder as the flow spills into the river. As the salmon proceed up the fish ladder, some turbulence must be created by allowing the flow to spill over weirs installed in the ladder. If this turbulence is excessive, the salmon may jump out of the ladder, and if the velocity of the water in the fish ladder is excessive, it may require the expending of too much energy by the salmon. Should an exit of a fish ladder be placed too near a gate structure, the fish leaving the ladder may be caught in the swiftly moving water discharging into the gate and be swept downstream.

FISH LADDERS IN MODEL

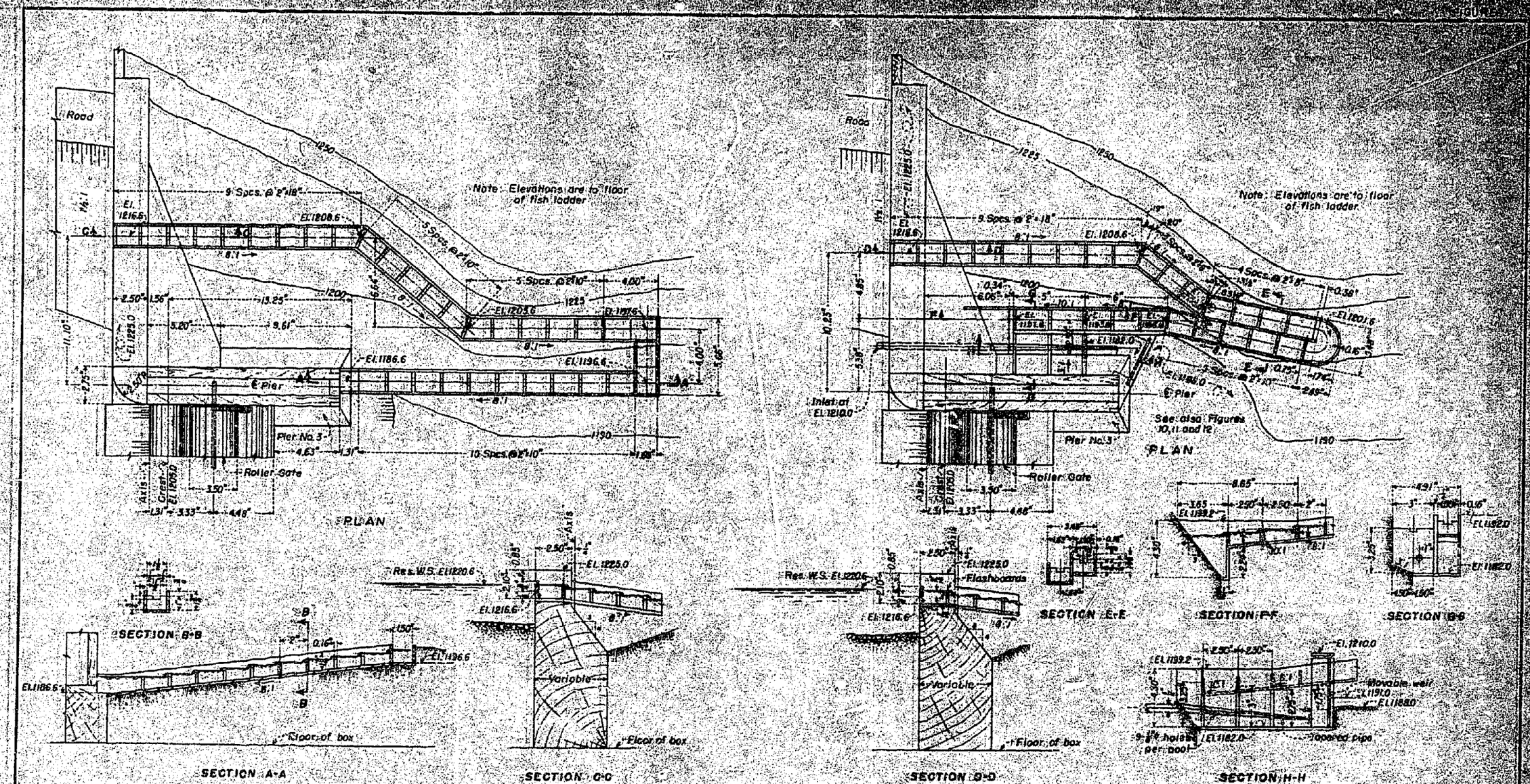
10. Original Design.--The original fish ladder design (figures 7A and 8A) was inadequate because it did not include

all the foregoing features. Although the position of the exit and the velocity of flow in the ladder was satisfactory, it would be necessary for salmon to reverse their direction to enter the lower leg sloping into the river (section A-A, figure 7A). During the flow over the diversion dam, this leg filled with gravel, which was also undesirable. No definite entrance or attraction was provided, and as the flow in the fish ladder entered the right-angled bend at the top of the lower leg, the flow spilled out of the ladder. This condition probably would have resulted in fish leaping completely out of the ladder.

11. Recommended Design.--After a new design had been made to include all desirable features and had been installed in the model, representatives from the Bureau of Fisheries, Seattle, Washington, observed its performance and agreed on the recommended design shown on figures 7B, 8B, and 8C. In this design, additional water (80 second-feet) was admitted into the lower pools by installing a pipe from the reservoir to the fish ladder (figures 7B, section H-H; and figure 9). This additional discharge, together with the flow of the fish ladder (6 second-feet), caused increased turbulence in the river as the flow spilled over an adjustable weir at the fish ladder entrance (figure 8B; section H-H, figure 10; and figure 11). The addition of this weir permits regulation of the flow spilling into the river with respect to tailwater changes.

When the diversion dam was operating, an undesirable eddy formed in the river at the entrance to the fish ladder. The velocity in the eddy was considered excessive and its upstream component was not conducive to salmon finding the entrance. A small training wall placed a few feet downstream from the entrance (figures 8B and 8C) reduced the size and the velocity of the eddy, but it was decided to locate the training wall in the field upon completion of the prototype structure.

One important feature was added during the study of the fish ladder problem. In the event salmon should proceed upstream along the right bank of the river, it was considered probable that fish would be attracted by the flow from the right section of the diversion dam. Unless a fish ladder was installed in this area, the salmon would probably attempt to jump the diversion dam instead of proceeding across the river to the fish ladder on the opposite bank. Consequently, it was considered advisable to install an additional fish ladder at the right abutment of the diversion dam (figure 12). A tunnel will be provided through the dam to connect this fish ladder with the lower pools of the one installed at the left abutment (figures 11 and 12). It was considered unnecessary to install the added fish ladder and connecting tunnel in the model.



A
ORIGINAL DESIGN

B
RECOMMENDED DESIGN

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
ROZA DIVERSION
ROZA DIVERSION DAM
HYDRAULIC MODEL STUDIES - 1:25 SCALE
FISH LADDER DESIGNS IN MODEL

FIGURE 7

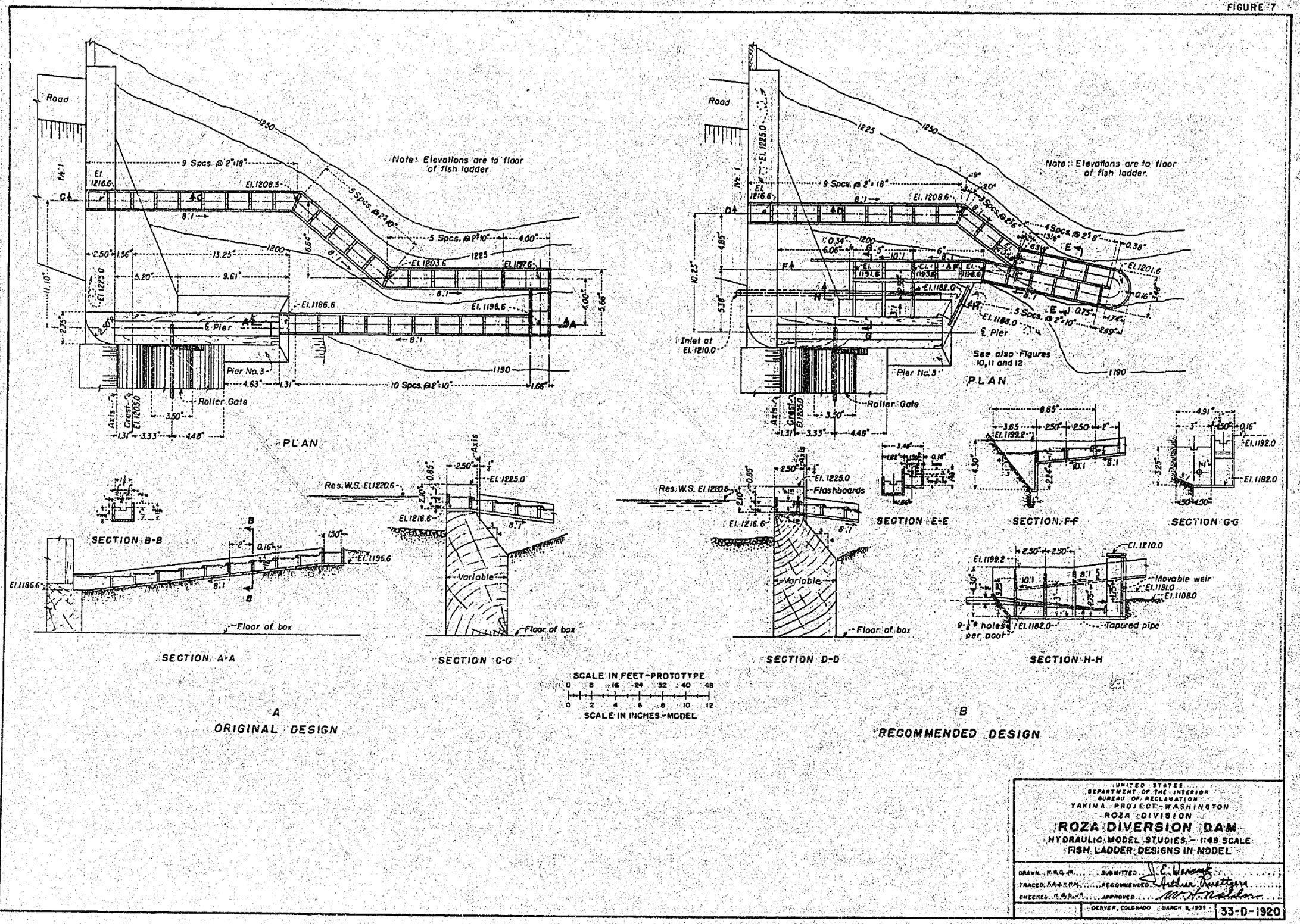
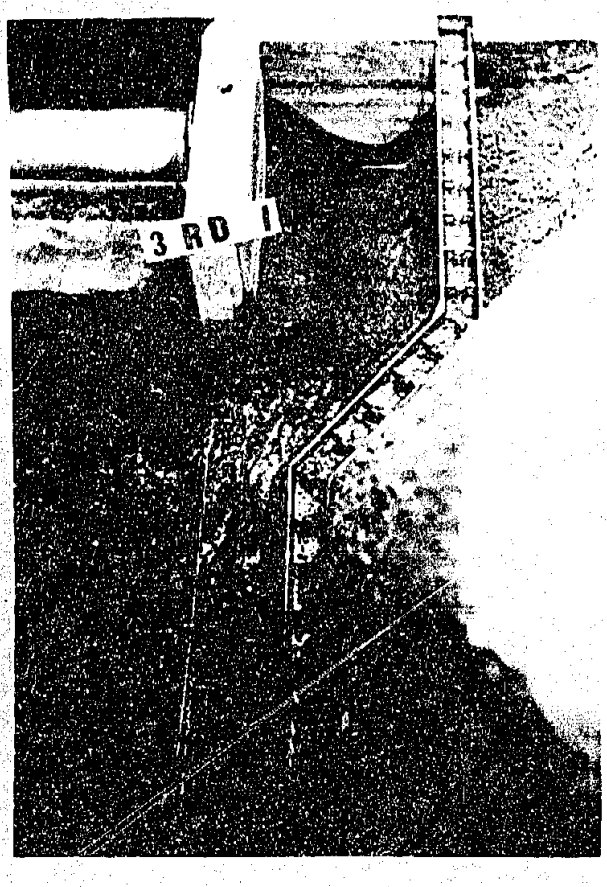
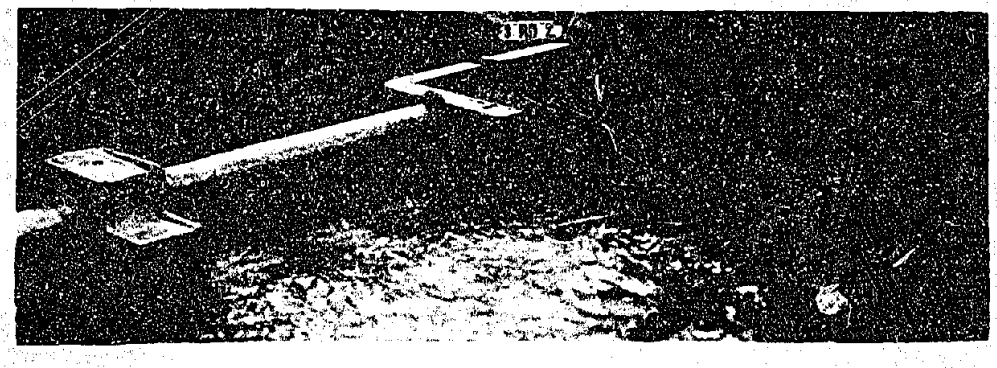

Road
Note: Elevations are to floor of fish ladder
9 Spcs @ 2'-18"
5 Spcs. @ 2'-10"
10 Spcs. @ 2'-10"
Pier No. 3
Roller Gate
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
Inlet at El. 1210.0
See also Figures 10, 11 and 12
Flashboards
Variable
Floor of box
Movable weir
Tapered pipe
SCALE IN FEET-PROTOTYPE
SCALE IN INCHES-MODEL
A
ORIGINAL DESIGN
B
RECOMMENDED DESIGN
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT-WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
HYDRAULIC MODEL STUDIES, - 1:48 SCALE
FISH LADDER DESIGNS IN MODEL
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO MARCH 8, 1933
33-D-1920

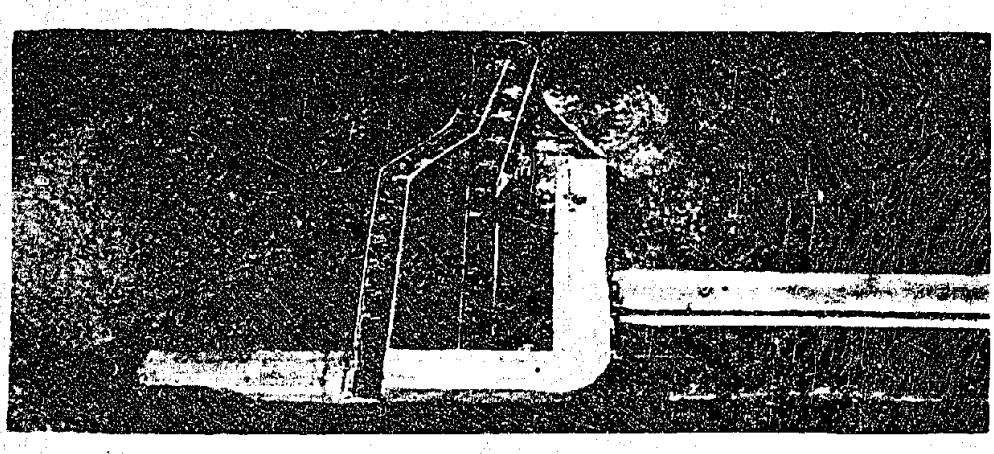
FIGURE 8



A. ORIGINAL DESIGN.



B. RECOMMENDED DESIGN.



C. RECOMMENDED DESIGN.

FISH LADDER.

Figure 9

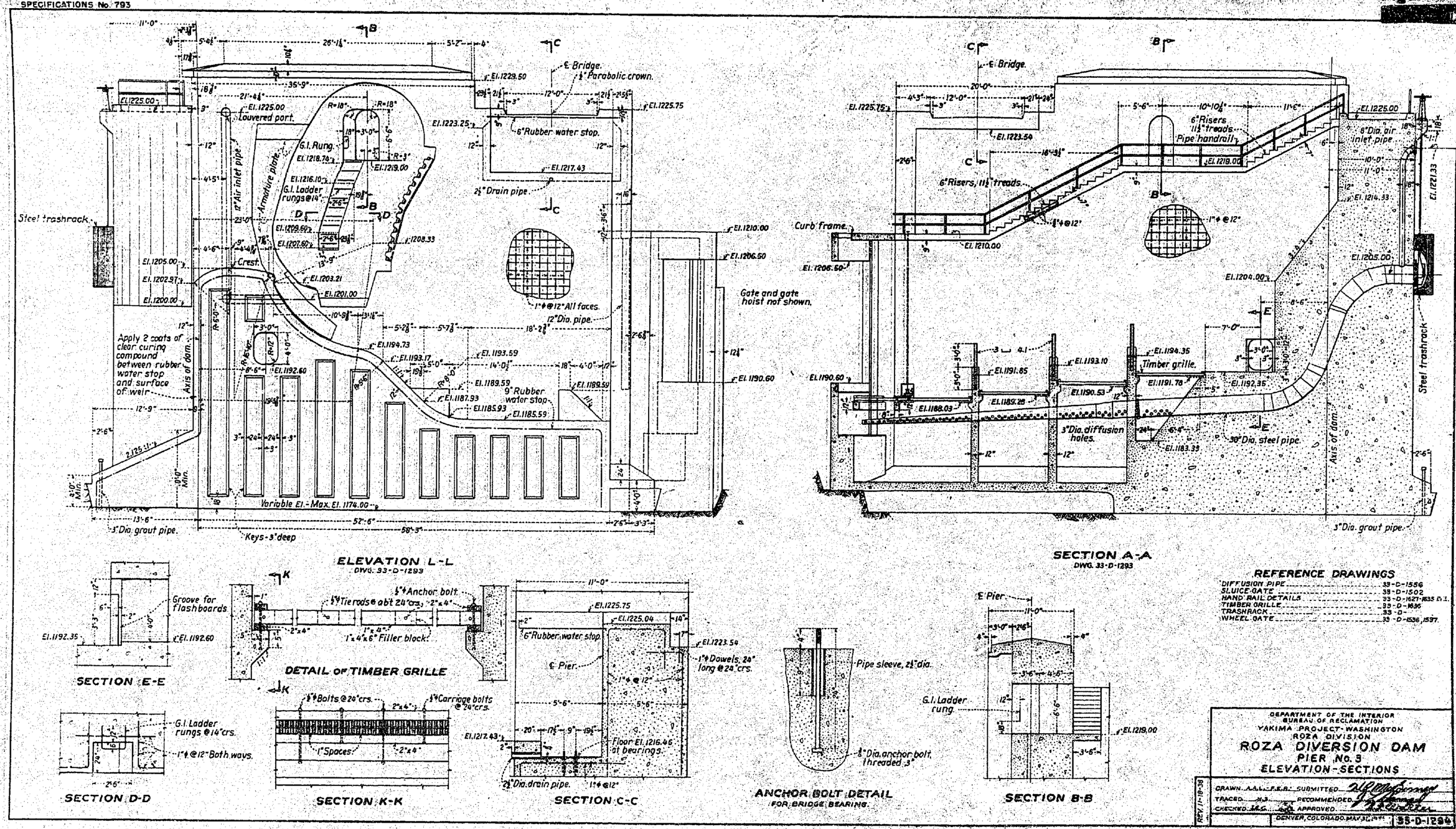

ELEVATION L-L
DWG. 33-D-1293
SECTION A-A
DWG. 33-D-1293
SECTION E-E
DETAIL OF TIMBER GRILLE
SECTION D-D
SECTION K-K
SECTION C-C
ANCHOR BOLT DETAIL
FOR BRIDGE BEARING
SECTION B-B
Steel trashrack
Louvered port.
12" Air inlet pipe
Armature plate
G.I. Rung
G.I. Ladder rungs @ 14"
Crest
Apply 2 coats of clear curing compound between rubber water stop and surface of weir
Axis of dam
Variable El.-Max. El. 1174.00
3" Dia. grout pipe.
Keys-3" deep
6" Rubber water stop.
2½" Drain pipe
9" Rubber water stop
12" Dia. pipe.
1"φ @ 12" All faces.
Gate and gate hoist not shown.
Curb frame.
6" Risers 11½" treads
Pipe handrail
8" Dia. air inlet pipe
Timber grille.
3" Dia. diffusion holes.
30" Dia. steel pipe
Groove for flashboards
½"φ Anchor bolt
½"φ Tie rods @ abt 24" crs.
1"x4"x6" Filler block.
½"φ Bolts @ 24" crs.
½"φ Carriage bolts @ 24" crs.
1" Spaces
G.I. Ladder rungs @ 14" crs.
1"φ @ 12" Both ways.
1"φ Dowels, 24" long @ 24" crs.
Floor El. 1216.46 at bearings.
2½" Dia. drain pipe.
Pipe sleeve, 2½" dia.
⅝" Dia. anchor bolt, threaded 3"
G.I. Ladder rung.
REFERENCE DRAWINGS
DIFFUSION PIPE 33-D-1556
SLUICE GATE 33-D-1502
HAND RAIL DETAILS 33-D-1627-1635 & 1
TIMBER GRILLE 33-D-1636
TRASHRACK 33-D-
WHEEL GATE 33-D-1536, 1537
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT-WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
PIER No. 3
ELEVATION-SECTIONS
DENVER, COLORADO, MAY 31, 1939
33-D-1294

Figure 10

SPECIFICATIONS No. 793

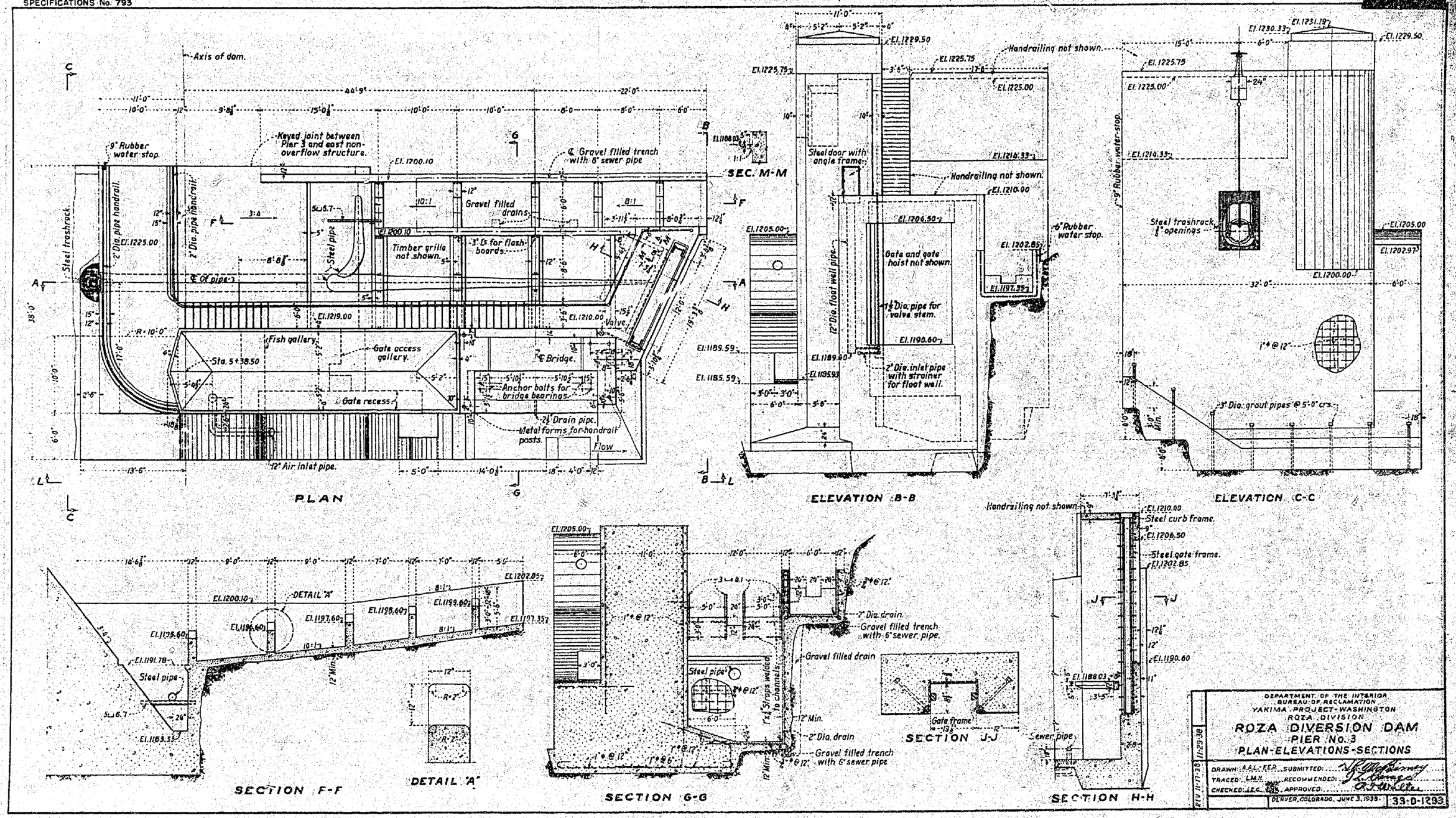
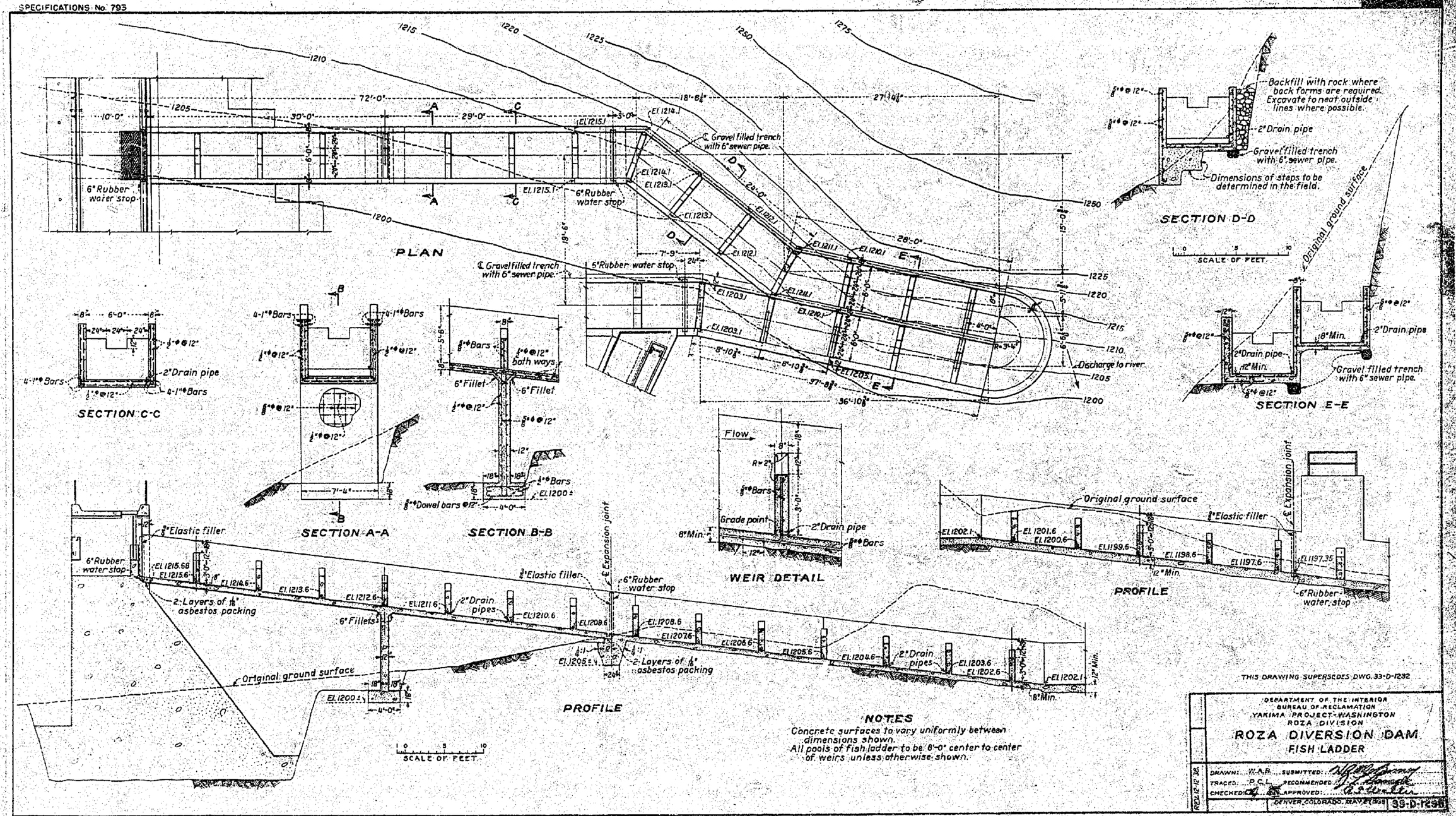
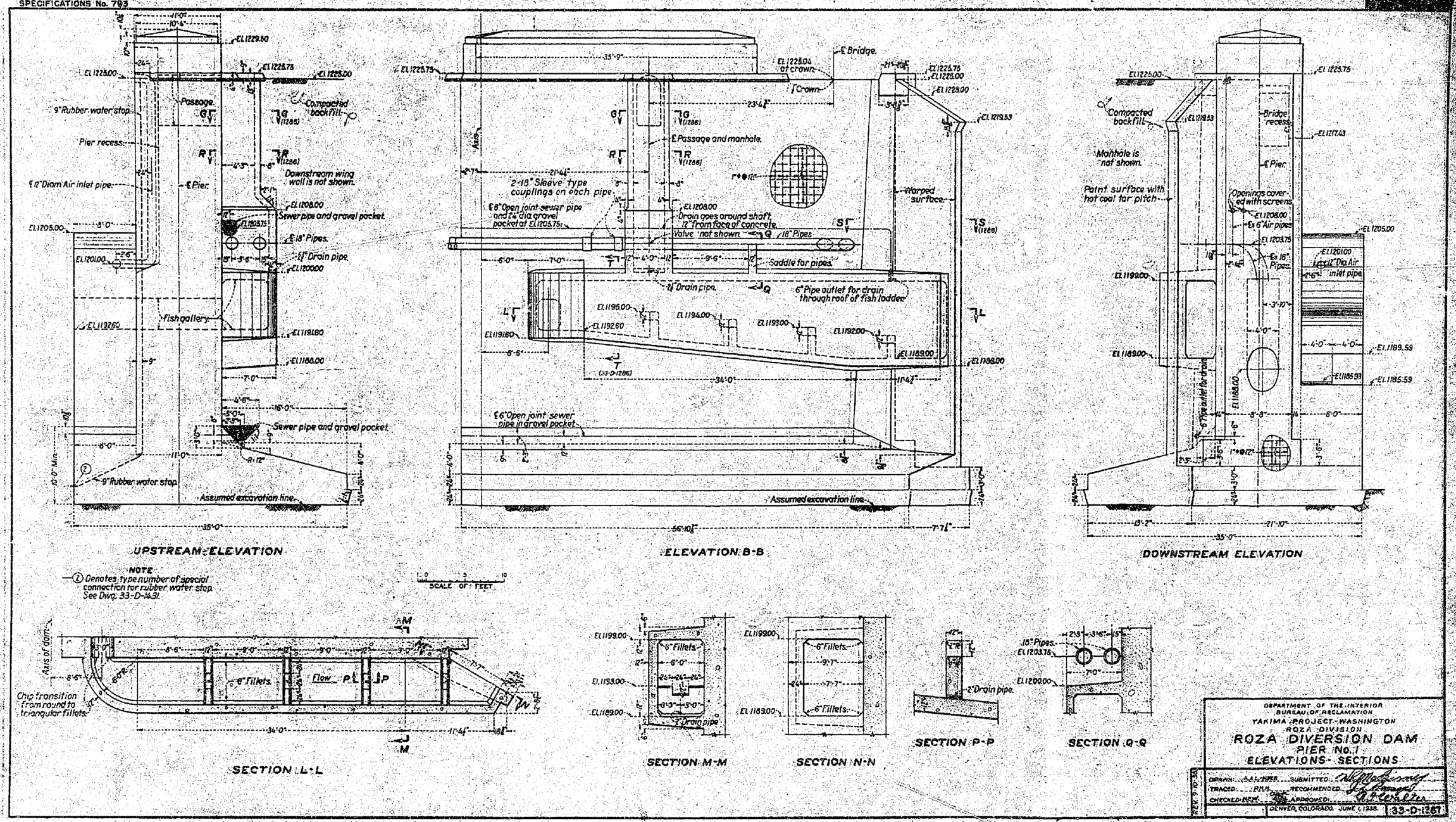


Figure 16



NOTES

Concrete surfaces to vary uniformly between dimensions shown.
All pools of fish ladder to be 8'-0" center to center of weirs unless otherwise shown.


SPECIFICATIONS No. 793
UPSTREAM ELEVATION
ELEVATION B-B
DOWNSTREAM ELEVATION
NOTE
② Denotes type number of special connection for rubber water stop. See Dwg. 33-D-1431.
SCALE OF FEET
SECTION L-L
SECTION M-M
SECTION N-N
SECTION P-P
SECTION Q-Q
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT-WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
PIER No. 1
ELEVATIONS - SECTIONS
DENVER, COLORADO. JUNE 1, 1938.
33-D-1287

CHAPTER IV - TESTS ON STILLING POOL

SCOUR PREVENTION AT TOE OF DAM

12. Original Design.--The original design of the diversion dam did not include a stilling pool for preventing scour at the toe, principally because it was believed that the basaltic rock of the foundation would resist scouring. Experience shows, however, that even the best bedrock may eventually scour, and as a matter of safety, a stilling pool should be included in a design of this type. A tendency for scour to occur in the model was noted during a discharge representing 50,000 second-feet, the maximum discharge. In a short time the gravel in the river bed was completely removed to the bottom of the model box (elevation 1172.0) for a prototype distance of about 50 feet downstream.

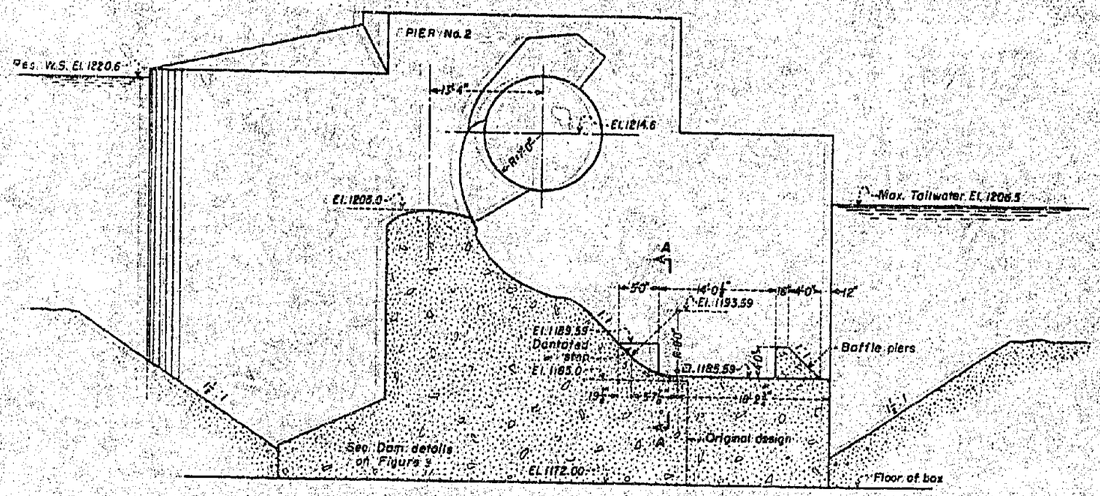
13. Dentated Bucket.--Two designs were developed in the model to reduce scouring at the toe of the dam: A dentated bucket and a dentated apron (figure 13). The dentated bucket was developed after tests had been made with various radii and positions of a bucket. It was especially difficult to obtain a bucket which would operate efficiently. At maximum discharge, the thickness of jet flowing over the dam was considerable, and to prevent excessive cost the bucket had to be placed as close as possible to the toe of the dam. As a direct result, it was difficult to deflect the thick jet upwards in a bucket of small radius. Because of this difficulty, the flow oscillated between a diving jet, which scoured severely, and a roller, which prevented excessive scour. The bucket shown on figures 13B and 14A finally eliminated the oscillation in the flow, but the boiling above the bucket was excessive. Dentates were cut into the bucket to reduce this boil, but this did not prove effective (figures 14B and C).

RECOMMENDED DESIGN

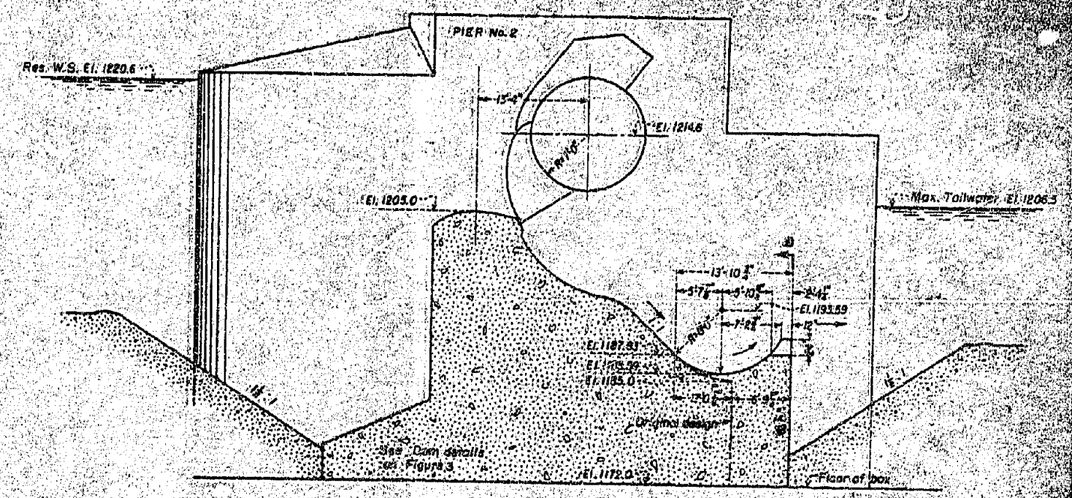
14. Dentated Apron.--The dentated bucket was abandoned in favor of a dentated apron (figures 13A and 15A), which was adopted as the recommended design. Although this design was more costly, the improvement in the flow conditions warranted the added expense. By comparing the flow conditions of the recommended design (figures 15 and 16) with the flow conditions of the dentated bucket (figure 14), the boiling of the latter design is apparent.

The apron of the recommended design was placed at the elevation necessary for the formation of a hydraulic jump, and after correct dentates had been determined, a discharge representing 50,000 second-feet was run in the model for two hours, the river bed consisting of 1/4-inch gravel. The resulting scour is shown on figure 15A. An additional scour test was made using fine sand; but the scour was still slight at the end of a two-hour run at maximum discharge.

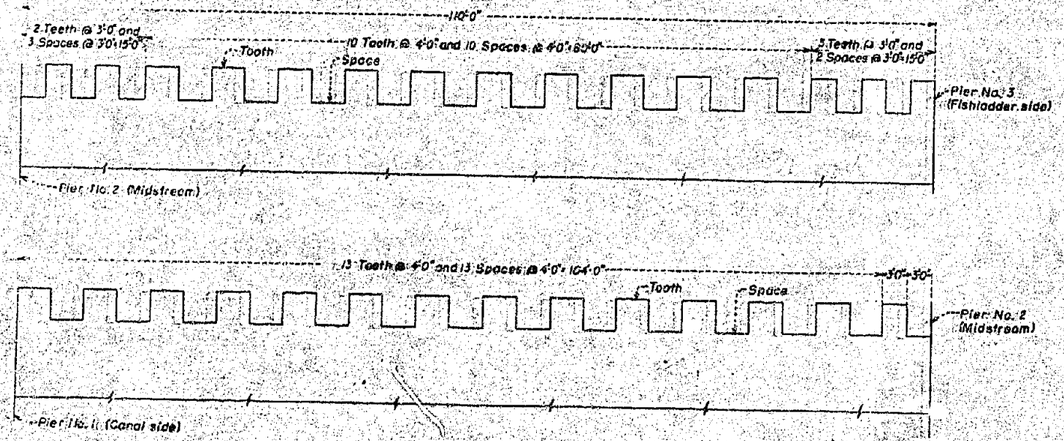
In the event that a flood of 25,000 second-feet could be passed by only one roller gate, this condition was studied in the model. It was noted that the jet at the apron was deflected above the tailwater instead of taking the form of a hydraulic jump. Observations disclosed that a ground roller moved material upstream to the toe of the dam eliminating any danger of scour at that point. The river bed of the model was scoured, however, immediately below the point at which the deflected jet plunged into the tailwater; but this scouring is far enough downstream from the dam to be of little concern.



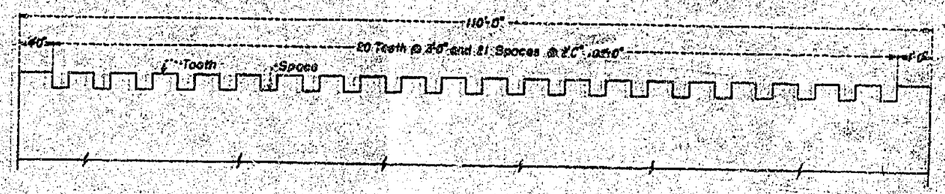
A
RECOMMENDED DESIGN



B
DENTATED BUCKET DESIGN



SECTION A-A
ARRANGEMENT OF DENTATED STEPS
(BAFFLE PIERS ARE PLACED OPPOSITE SPACES)



SECTION B-B
ARRANGEMENT OF TEETH
(SYMMETRICAL ABOUT CENTER LINE OF PIER No. 2)

SCALE IN FEET-PROTOTYPE
0 4 8 12 16 20 24
0 1 2 3 4 5 6
SCALE IN INCHES-MODEL

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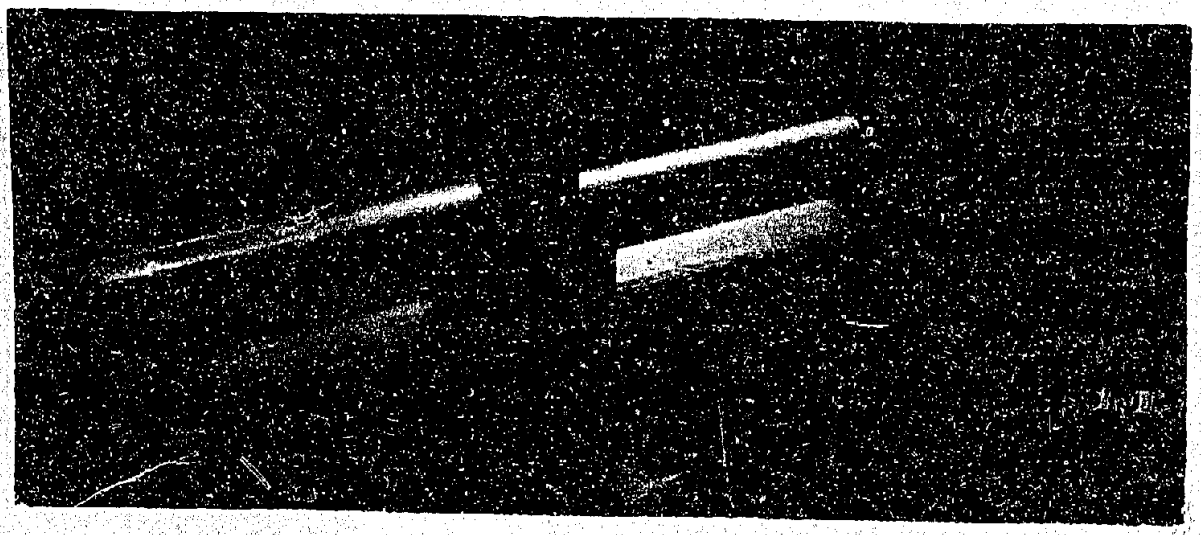
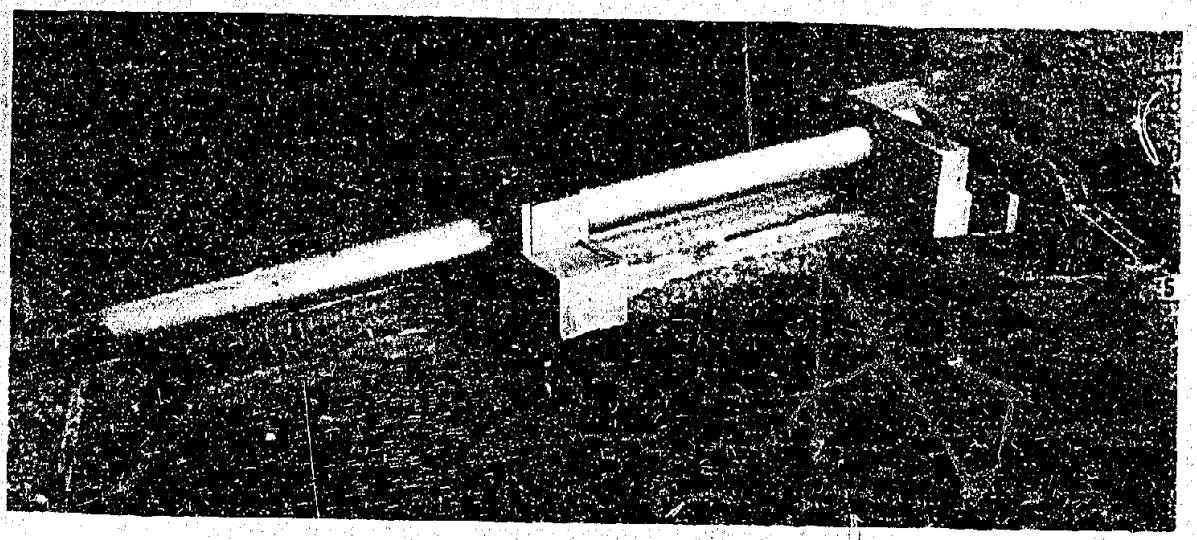
YAKIMA PROJECT - WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
HYDRAULIC MODEL STUDIES - 1:48 SCALE
SCOUR PREVENTION STUDIES IN MODEL

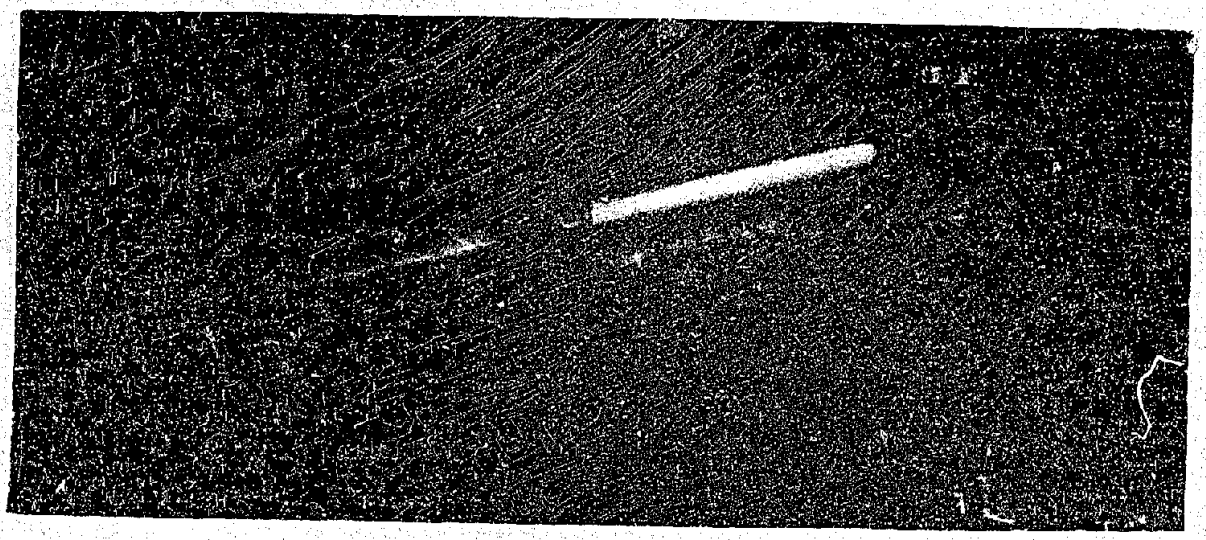
DRAWN: N.G.P.K. SUBMITTED: [illegible]
TRACED: E.H.R.-P.A. RECOMMENDED: [illegible]
CHECKED: R.S.P. APPROVED: [illegible]
DENVER, COLORADO MARCH 8, 1954
33-D-1951



A. DENTATED BUCKET.

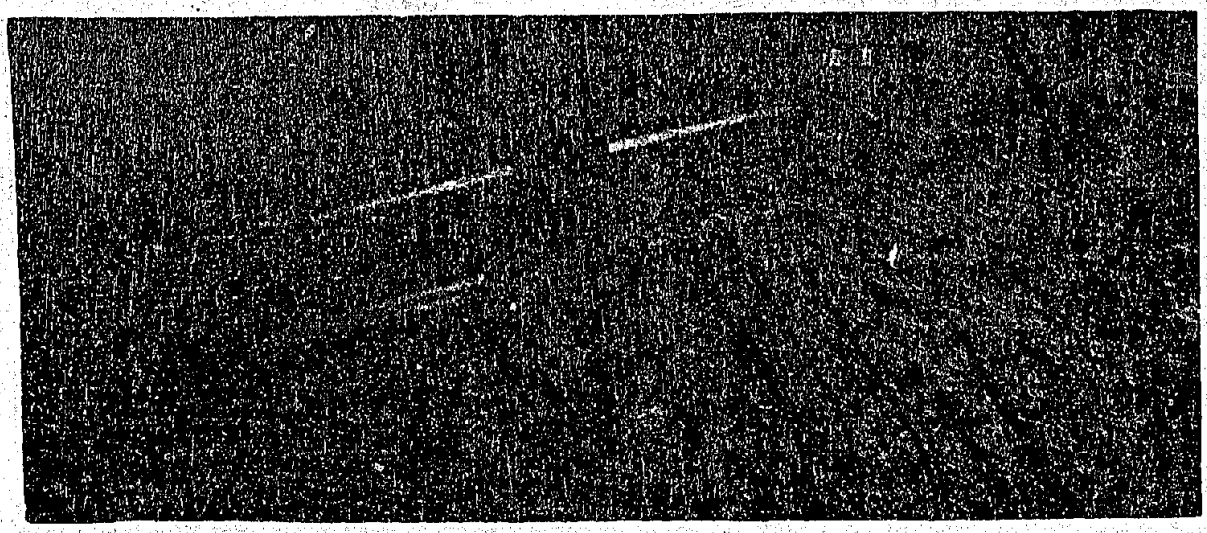


B. DISCHARGE 10,000 SECOND-FEET
POND ELEVATION 1220.6
TAILWATER ELEVATION 1197.3

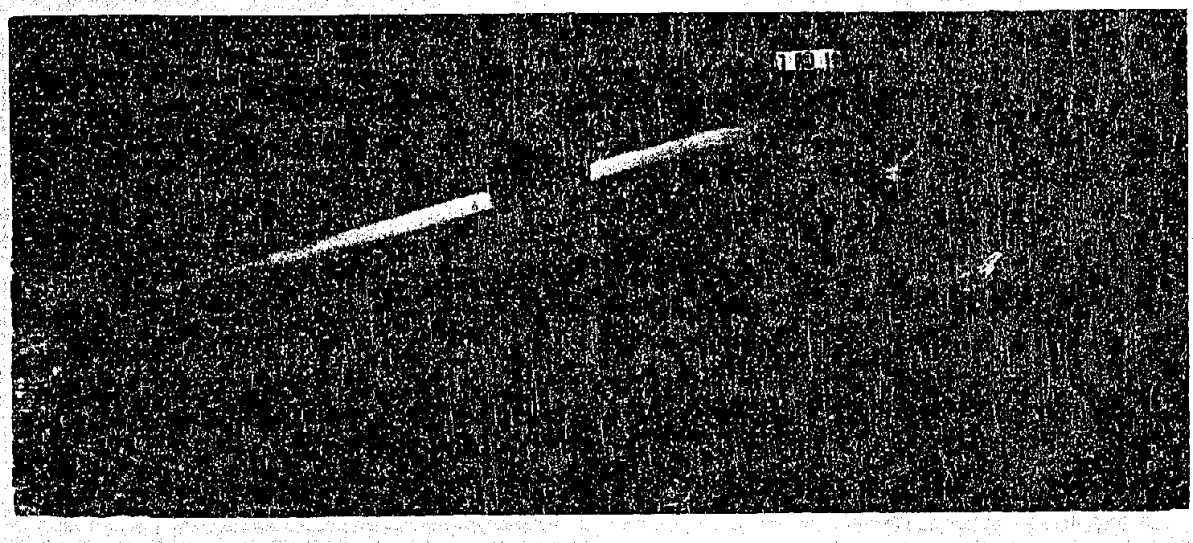


C. DISCHARGE 50.000 SECOND-FEET
POND ELEVATION 1220.6
TAILWATER ELEVATION 1206.5

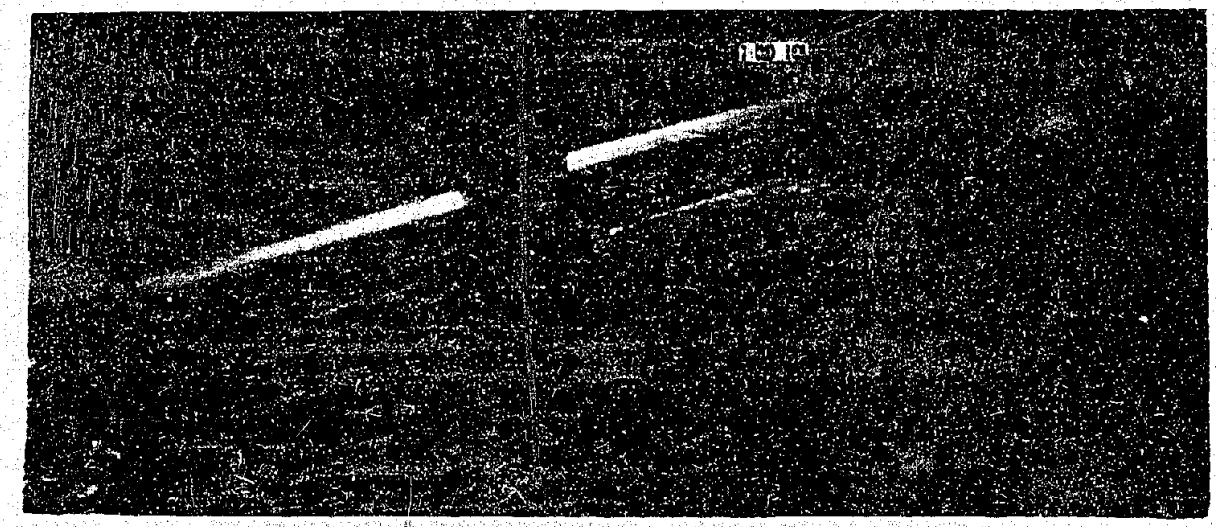
DENTATED BUCKET DESIGN.



A. DENTATED APRON



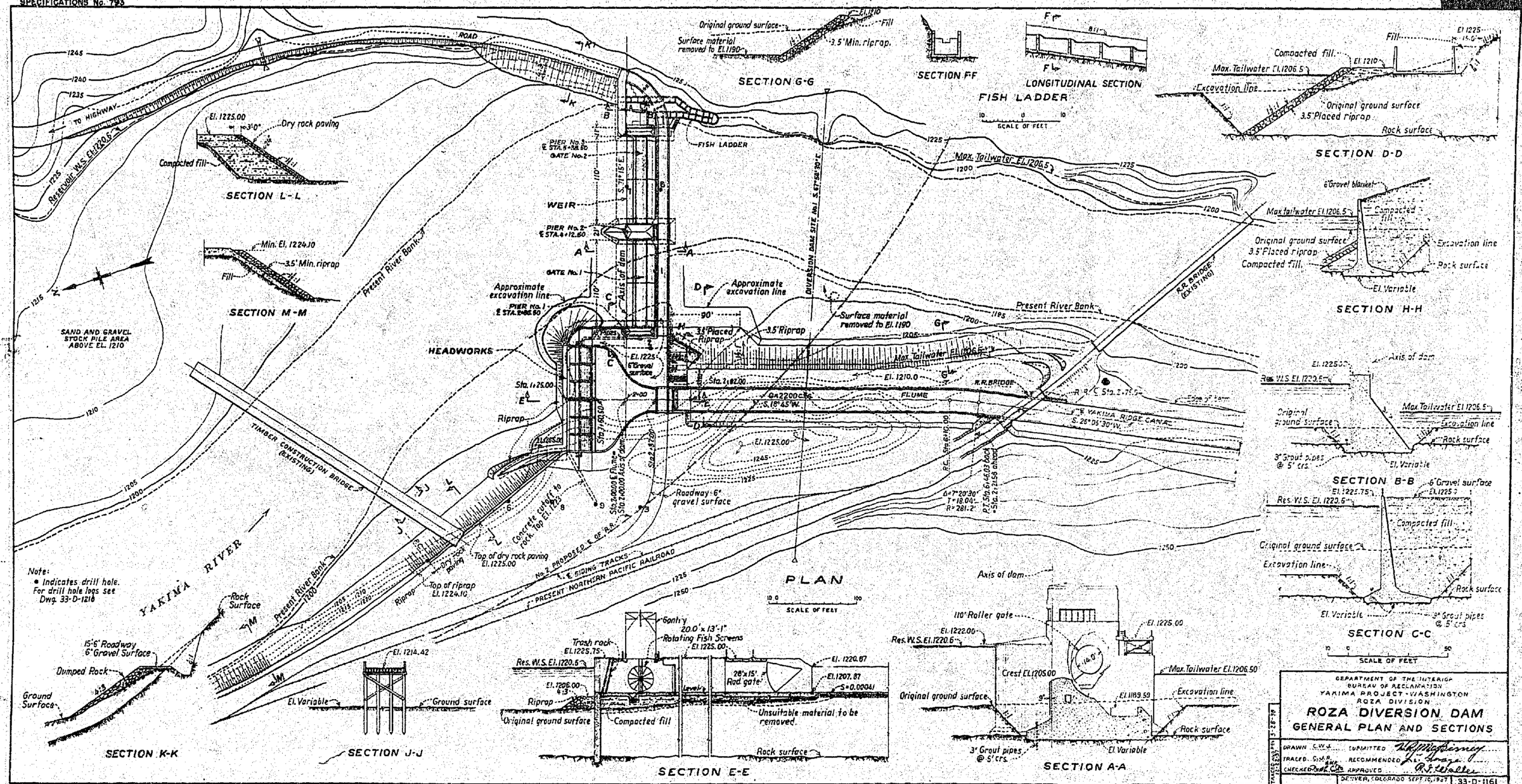
B. DISCHARGE 10,000 SECOND-FEET
POND ELEVATION 1220.6
TAILWATER ELEVATION 1197.3



C. DISCHARGE 10,000 SECOND-FEET LEFT GATE
POND ELEVATION 1220.6
TAILWATER ELEVATION 1197.3

RECOMMENDED DESIGN.

Figure 17


SPECIFICATIONS No. 793
PLAN
SCALE OF FEET
SECTION G-G
SECTION F-F
LONGITUDINAL SECTION
FISH LADDER
SECTION D-D
SECTION L-L
SECTION M-M
SECTION H-H
SECTION B-B
SECTION C-C
SECTION K-K
SECTION J-J
SECTION E-E
SECTION A-A
WEIR
HEADWORKS
FLUME
R.R. BRIDGE
R.R. BRIDGE (EXISTING)
TIMBER CONSTRUCTION BRIDGE (EXISTING)
YAKIMA RIVER
Present River Bank
Reservoir W.S. El. 1220.6
TO HIGHWAY
ROAD
SAND AND GRAVEL STOCK PILE AREA ABOVE EL. 1210
Note:
• Indicates drill hole.
For drill hole logs see Dwg. 33-D-1218
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
GENERAL PLAN AND SECTIONS
DRAWN C.W.J.
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO SEPT 10, 1937
33-D-1161

CHAPTER V - CALIBRATION TESTS

CALIBRATION OF DIVERSION DAM AND ROLLER GATES

15. Experimental and Theoretical Curves.--The calibration study was divided into three parts: (1) Free discharge at the diversion dam; (2) discharge under the roller gates; and (3) discharge over the left roller gate. Figure 18 shows rating curves for free discharge at the dam, including curves of discharge versus head and coefficient of discharge versus head, for both crests operating simultaneously and separately. The velocity of approach has not been icnluded in the relation $Q = CLH^{3/2}$.

Figure 19 shows curves for discharge and coefficient of discharge versus gate opening for flow under each roller gate--a separate calibration for each gate; other basic data are also shown. During this calibration, the reservoir (model) was maintained at elevation 1220.6.

Figure 20 shows experimental and theoretical rating curves for flow over the left roller gate. The experimental coefficients of discharge were obtained from the relation:

$$Q = C\, d^{3/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where Q = discharge per foot.
C = coefficient of discharge.
d = head on gate (figure 20).

The theoretical coefficients of discharge were obtained from the relations:

$$\log_e \left(\frac{r_1 + d - h'}{r_1}\right) = \frac{2h'}{r_1 + d - 3h'} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

and

$$C = (r_1 + d - h') \cdot \sqrt{\frac{2gh'}{d^3}} \cdot \log_e \left(\frac{r_1 + d - h'}{r_1}\right) \quad \ldots \quad (3)$$

where r_1 = radius of roller gate (7'-0") (figure 20).

h' = total available head at point on water surface above gate through the vertical (figure 20).

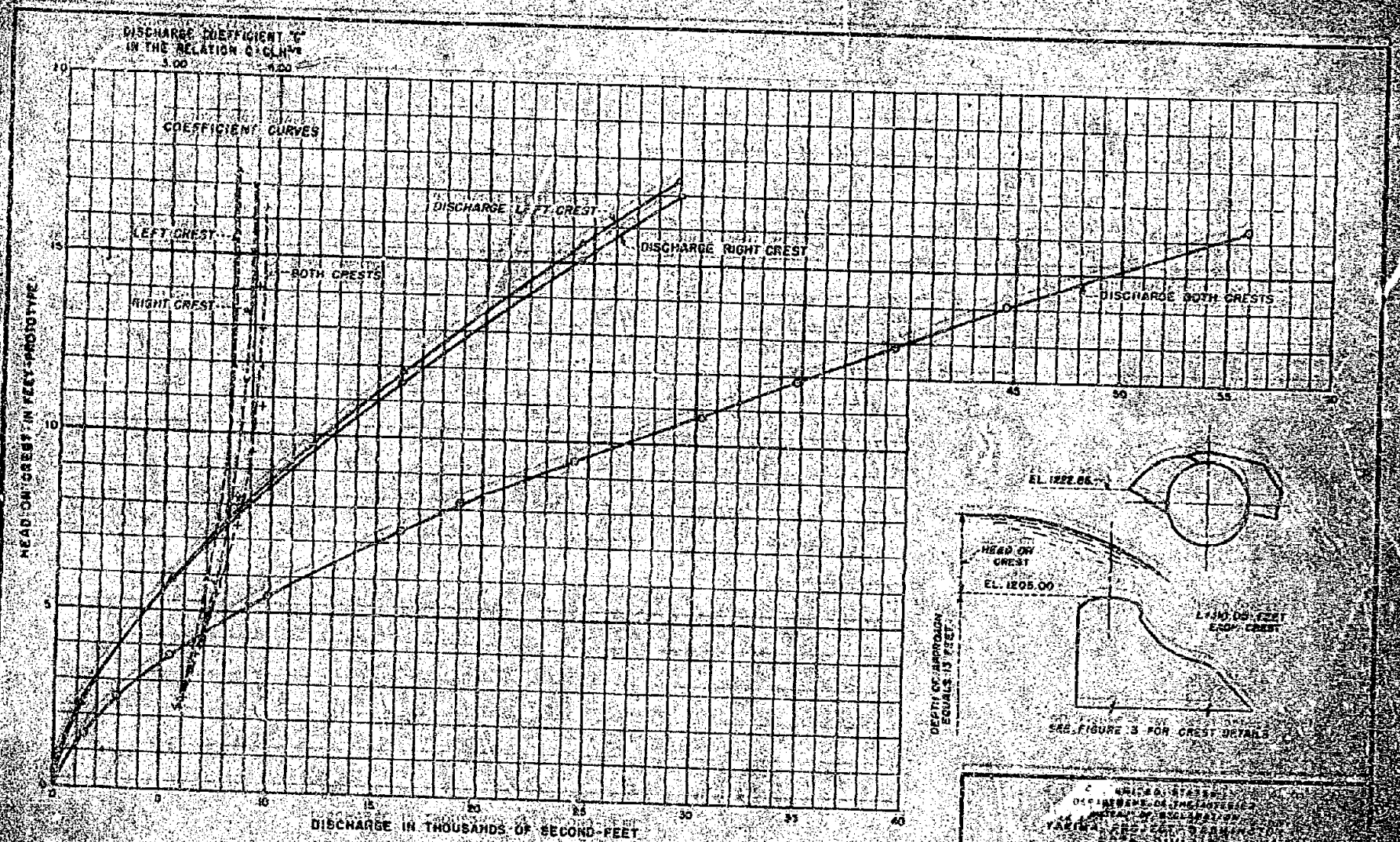
d = head on gate (figure 20).

C = coefficient of discharge.

By assuming values of d in equation (2), r_1 being constant, a trial and error solution will determine corresponding values of h'. Using these values of d and h', the theoretical coefficients of discharge C are obtained from equation (3). The derivation of equations (2) and (3) may be found in technical memorandum No. 562, "Design of Roller Gates," by C. P. Vetter.

A comparison of the experimental and theoretical discharge coefficients shows the latter to be about eight percent greater. Sufficient experimental data were taken to permit its substitution into equation (3), the relation for theoretical coefficients of discharge. When this is done, the coefficients obtained are nearly equal to the theoretical coefficients obtained by assuming various values of d and h in equations (2) and (3). Compare coefficient versus head (d) curves on figure 20 of "Theoretical" and "Experimental Based on Theoretical." Similarly, if the experimental coefficients obtained from equation (3) are used to determine the discharge from equation (1), the resulting head versus discharge curve, "Experimental Based on Theoretical C" (figure 20), agrees nearly with the "Theoretical" discharge curve obtained from equation (1), but using values of C computed from equations (2) and (3). The experimental discharge versus head curve is also about eight percent less than the theoretical curve (figure 20), since the experimental coefficients are about eight percent less than the theoretical.

A closer agreement between purely experimental coefficients of discharge and those obtained from theoretical considerations is not expected, since the experimental coefficients are based on the usual weir relation $Q = CLH^{3/2}$. The theoretical values of the discharge coefficient, on the other hand, are based on principles and assumptions of hydrodynamics as expressed in equations (2) and (3). It is interesting to note, however, that when experimental data are substituted in equation (3) instead of equation (1), the theoretical and experimental coefficients more nearly agree. This evidently confirms the theoretical assumptions. Closer agreement is particularly difficult to obtain here, because of the small scale model and the small model discharges. The eight-percent variations may be accounted for in the errors of discharge and other experimental measurements. This is evident, since the experimental data substituted in equation (3) are independent of any discharge measurements; but the experimental values of C obtained from equation (3) agree closely with the theoretical values as has been shown.



ROSA DIVERSION DAM
HYDRAULIC MODEL STUDIES
CALIBRATION CURVES FOR FREE DISCHARGE

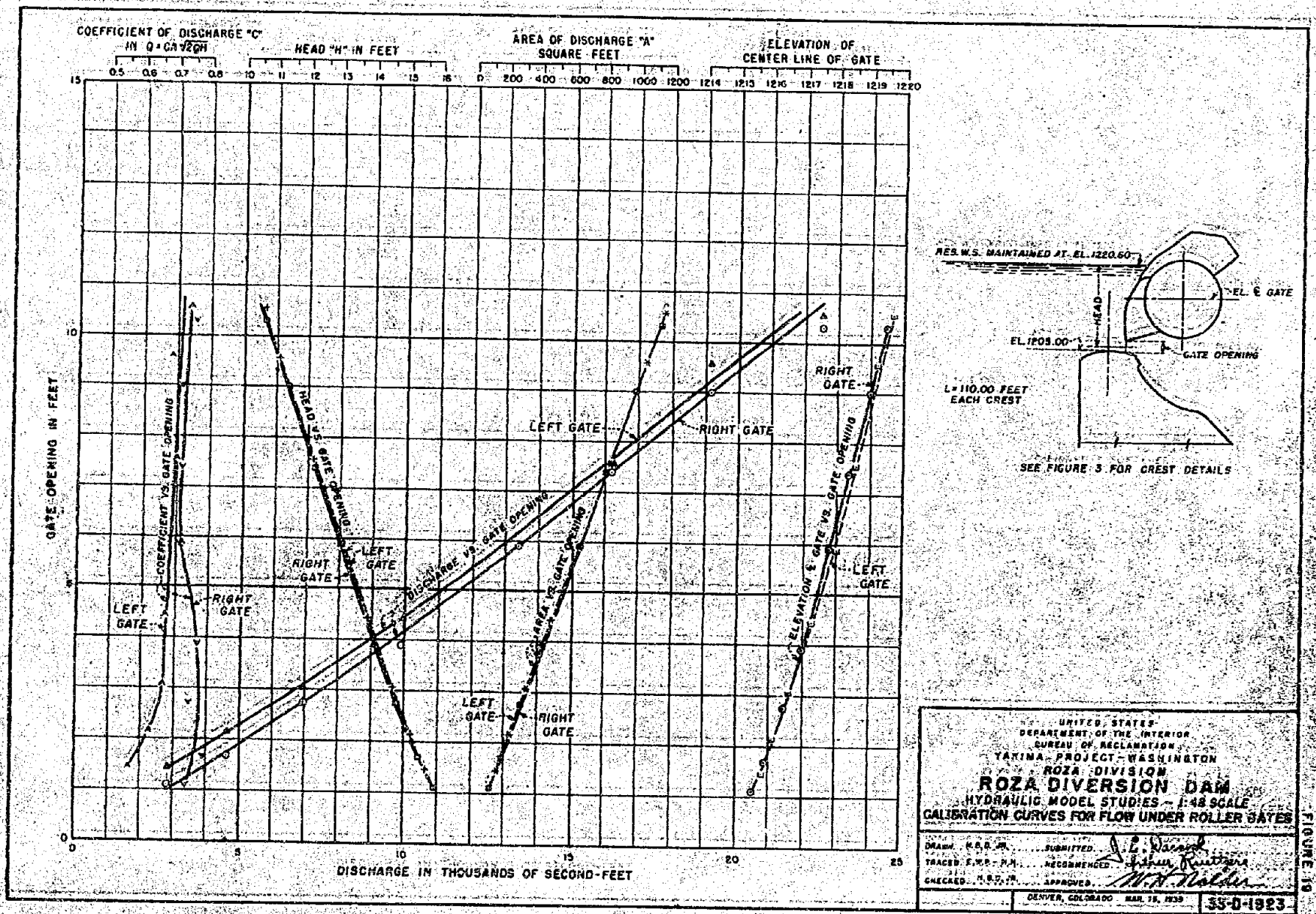
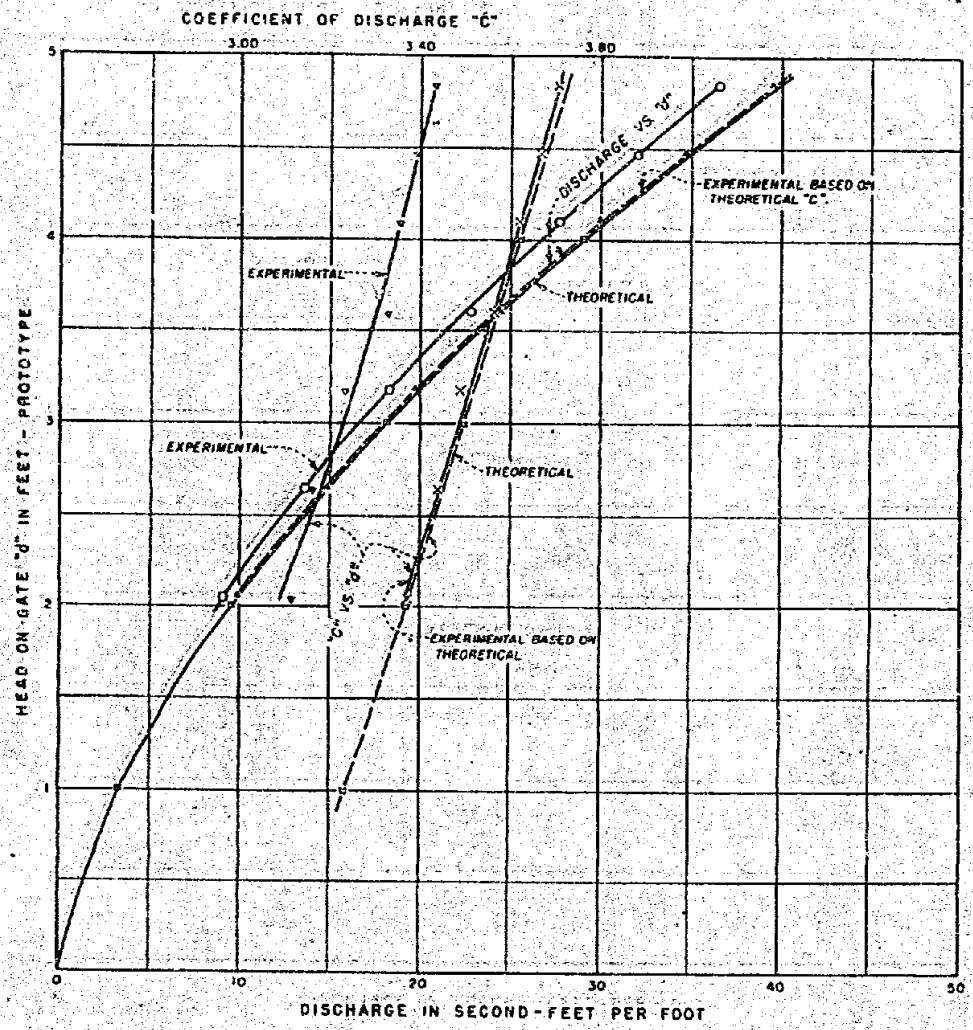
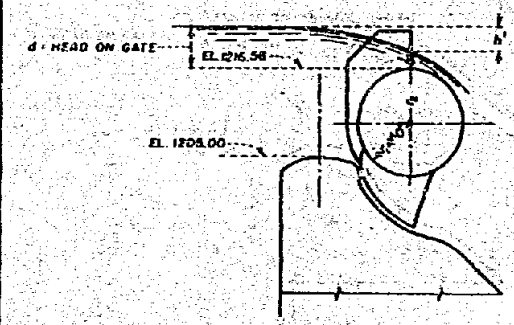

COEFFICIENT OF DISCHARGE "C" IN Q = CA√2GH
0.5 0.6 0.7 0.8
HEAD "H" IN FEET
10 11 12 13 14 15 16
AREA OF DISCHARGE "A" SQUARE FEET
0 200 400 600 800 1000 1200
ELEVATION OF CENTER LINE OF GATE
1214 1215 1216 1217 1218 1219 1220
GATE OPENING IN FEET
0 5 10 15
DISCHARGE IN THOUSANDS OF SECOND-FEET
0 5 10 15 20 25
COEFFICIENT VS. GATE OPENING
HEAD VS. GATE OPENING
DISCHARGE VS. GATE OPENING
AREA VS. GATE OPENING
ELEVATION ℄ GATE VS. GATE OPENING
LEFT GATE
RIGHT GATE
RES. W.S. MAINTAINED AT EL. 1220.60
EL. ℄ GATE
HEAD
EL. 1205.00
GATE OPENING
L = 110.00 FEET EACH CREST
SEE FIGURE 3 FOR CREST DETAILS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
ROZA DIVISION
ROZA DIVERSION DAM
HYDRAULIC MODEL STUDIES - 1:48 SCALE
CALIBRATION CURVES FOR FLOW UNDER ROLLER GATES
DRAWN H.B.D. JR.
TRACED E.W.P. - H.H.
CHECKED H.B.D. JR.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO MAR. 15, 1939
33-D-1923

FIGURE 19





UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
ROZA DIVISION

ROZA DIVERSION DAM

HYDRAULIC MODEL STUDIES - 1:48 SCALE

CALIBRATION CURVES FOR FLOW OVER LEFT ROLLER GATE

DRAWN. H.S.D., JR. SUBMITTED. J. E. Dennis
TRACED. F.G.-F.R. RECOMMENDED. Arthur Peterson
CHECKED. H.S.D., JR. APPROVED. W. H. Nalder

DENVER, COLORADO - MAR. 13, 1939 | 33-D-1924

FIGURE 20

CHAPTER VI - CONCLUSIONS

SUMMARY OF RESULTS

16. Headworks.--From the model studies it was possible to obtain a satisfactory alinement which produced a uniform flow distribution through the headworks (figures 5D, 5F, and 6B). No definite rule can be stated regarding the alinement of a headworks at a diversion dam. In this particular study, however, uniform flow distribution through the headworks was best obtained when the line of openings was not parallel to the direction of flow in the river. This assumes some velocity across the face of the headworks due to flow passing over the diversion dam. If there is no velocity across the face of the headworks, then the headworks alinement is not very important as far as uniform flow distribution is concerned.

17. Fish Ladder.--A satisfactory fish ladder design was evolved in the model (figure 7B; 8B and 8C; and figures 9 to 12, inclusive). This study also revealed the necessity of placing an additional fish ladder at the right abutment of the diversion dam (figure 12). It is important to provide fish ladders at obstructions in a river which salmon follow from the ocean to their spawning grounds. Fish ladder designs should include all the features listed on page 14. Where headworks structures are present, or other outlets are provided in the river, fish screens should be placed to prevent salmon from entering these structures, as they migrate to the ocean.

18. Stilling Pool.--A dentated apron was developed adopting a hydraulic jump to eliminate excessive scouring at all discharges (figures 13A, 15, and 16). Good design practice includes stilling pools for prevention of scour at the toe of an overfall dam. Even if the bedrock of the foundation is durable and can probably resist scouring, it is advisable to take necessary precautions and provide some means of protecting a channel from scour at the toe of an overfall dam or spillway. Figure 17 shows general plan and sections of complete recommended design.

19. Calibration.--Neglecting the velocity of approach, the experimental coefficient of discharge for free discharge over the diversion dam varies on the average from 3.20 for a head of 2.25 feet, to 3.80 for a head of 17.0 feet (figure 18). The coefficients are slightly different for separate and simultaneous crest operation.

The coefficients of discharge for flow under the roller gates varies on the average from 0.68 for a gate opening of 1.5 feet, to 0.72 for a gate opening of 10.5 feet. In computing these coefficients from the orifice relation, $Q = CA\sqrt{2gH}$, H was measured from the reservoir water surface (maintained constant at elevation 1220.6) to the geometrical center of the gate opening (figure 19).

In determining coefficients of discharge for flow over roller gates, it is evident from this study that the theoretical relations, equations (2) and (3), page 29, are justified. The experimental data indicate that the coefficient of discharge varies from 3.12 for a head on the gate of 2.00 feet, to 3.43 for a head of 4.85 feet. The theoretical coefficients are about eight percent greater (figure 20).

- - -