UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

\- - -

HYDRAULIC LABORATORY REPORT NO. 151

\- - -

MODEL STUDIES OF THE ALVA B. ADAMS TUNNEL INLET CONTROL STRUCTURE COLORADO-BIG THOMPSON PROJECT, COLORADO

By

FRED LOCHER and C. V. ADKINS

\- - -

Denver, Colorado,
Sept. 21, 1944

HYD 151

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
September 21, 1944

Laboratory Report No. 151
Hydraulic Laboratory
Compiled by: Fred Locher
C. V. Adkins
Reviewed by: J. E. Warnock

Subject: Model studies of the Alva B. Adams tunnel inlet control structure - Colorado-Big Thompson project, Colorado.

1. General. The plans for constructing the Alva B. Adams tunnel, the Shadow Mountain Dam, the Granby Dam, and the Green Mountain Dam were the outgrowth of extensive study and research with respect to reclaiming large arable areas in northeastern Colorado and along the Colorado River Valley in western Colorado. There is an insufficient supply of water east of the Continental Divide to irrigate properly all of the land under cultivation in northern Colorado, especially in dry years. In addition, there are several hundred thousand acres of tillable land lying idle in northern Colorado because of insufficient irrigation water. Surveys on the Western Slope and hydrographs from various points along the Colorado River showed that except in extremely dry years there was more than enough water flowing down the Colorado River to supply the Shoshone power plant and to irrigate properly all land that ever could be brought under a Colorado River irrigation system.

Green Mountain Dam was built to provide reserve storage for replacing any shortage in the Colorado River flow caused by diversion to the Eastern Slope. It will also supply power to the Middle Park area and the Granby Reservoir pumping plant.

Granby Reservoir will be created by placing a dam on the Colorado River about 6 miles northeast of Granby. This reservoir will store water diverted from Willow, Strawberry, and Meadow Creeks, as well as Colorado River water. This reservoir will provide the supply to be diverted to the Eastern Slope. An electrically driven pumping plant on the north shore of Granby Reservoir will pump this water up to a canal flowing into Shadow Mountain Lake. This lake will be formed by a dam about half a mile below the junction of the North Fork and the Grand Lake outlet. The water flowing into Shadow Mountain Lake will flow by gravity into Grand Lake, thus maintaining approximately the same water level in both lakes.

The Alva V. Adams tunnel will serve as a conduit for passing the diverted water to the Eastern Slope where it will be used for power development and irrigation. Part of the power developed on the Eastern Slope by this water will be transmitted across the Continental Divide to drive the pumping plant at Granby Reservoir.

The maximum variation in water surface in Grand and Shadow Mountain Lakes has been fixed between elevations 8367.00 and 8365.00. The crest of the outlet control structure was fixed by act of Congress at elevation 8365.00, thus allowing a head of 2 feet to pass the maximum discharge. It is planned that off-peak power will be used for pumping from Granby Reservoir into Shadow Mountain Lake. This will make it necessary to store water in both Shadow Mountain Lake and Grand Lake to produce a constant flow through the tunnel when the pumps are not operating. With the crest of the control structure at elevation 8365.00, a required flow of 550 second-feet, and a water surface at elevation 8364.70 at the tunnel portal, it was necessary that the outlet control structure be designed with the minimum hydraulic losses possible to obtain this flow. If a minimum head of 1 foot is required to force 550 second-feet over the crest, the storage in the two lakes having their water surface at elevation 8367.00 will provide a continuous flow of 550 second-feet for approximately 41 hours without operating the pumps. This storage will provide for stopping the pumps when other demands for power are at their peak, for power failure, or for other unforeseen circumstances.

2. Scope of model tests. Since it was necessary to utilize as much of the available storage as possible to provide for emergencies,

it was desirable to have the hydraulic losses through the structure as low as reasonably possible. The model tests were instigated to determine a design for the control structure which would cause a minimum loss of head at a reasonable cost and at the same time comply with the requirements of the law authorizing the project.

3. The proposed original design. The proposed original design (figure 1) consisted of 20 covered bays opening into a double side-channel spillway having a gate-controlled outlet which was connected to the tunnel portal by a double transition. In the tests with a 1:10 model of this design, the water surface at the gate pin was set at the theoretical elevation of 8365.83 for the discharge of 550 second-feet. From this it was found that the corresponding lake water surface necessary to produce this flow was elevation 8366.34, or 0.34 of a foot higher than was anticipated in the design. When the elevation of the water surface at the gate pin was raised to 8365.88, it caused a corresponding change in the lake surface elevation, indicating that the section controlling the flow was downstream from the crest. By lowering the water surface in the gate section until critical flow occurred at the crest, it was not possible to draw the water surface in the lake below elevation 8366.04 and obtain a flow of 550 second-feet. This was a condition unobtainable in the prototype, but it showed definitely that the anticipated lake surface of 8366.00 would not cause a flow of 550 second-feet with this design.

With this design, where critical flow did not occur at the crest, the two bays directly in front of the gate section discharged approximately seven times as much water as the two end bays. In addition, there was considerable turbulence and loss of head in the side channel due to the extended piers downstream from the crest. By removing this part of the piers (figure 4A), the loss in head was reduced 0.05 of a foot. Due to the uneven distribution of flow along the crest and the projecting piers, it was considered advisable to change to a more suitable design whereby the head losses which so seriously reduced the available storage would be minimized.

4. Improved design B. This design was a fan-shaped arrangement (figures 2, 3, and 4C) having 20 bays at 11-foot 11-inch centers at the crest, spaced on a segment of a circle such that the central angle was 121° 04' 18". The intake to the bays was below the water surface, and the entire structure was covered to permit satisfactory operation during the winter months. The floor of the structure downstream from the crest was designed to eliminate deceleration of the flow between the crest and the tunnel portal. Actually, acceleration of the water was continuous, except through the gate section, until it reached the tunnel velocity at the portal. This involved changing the former gate section and both transitions leading to the tunnel portal.

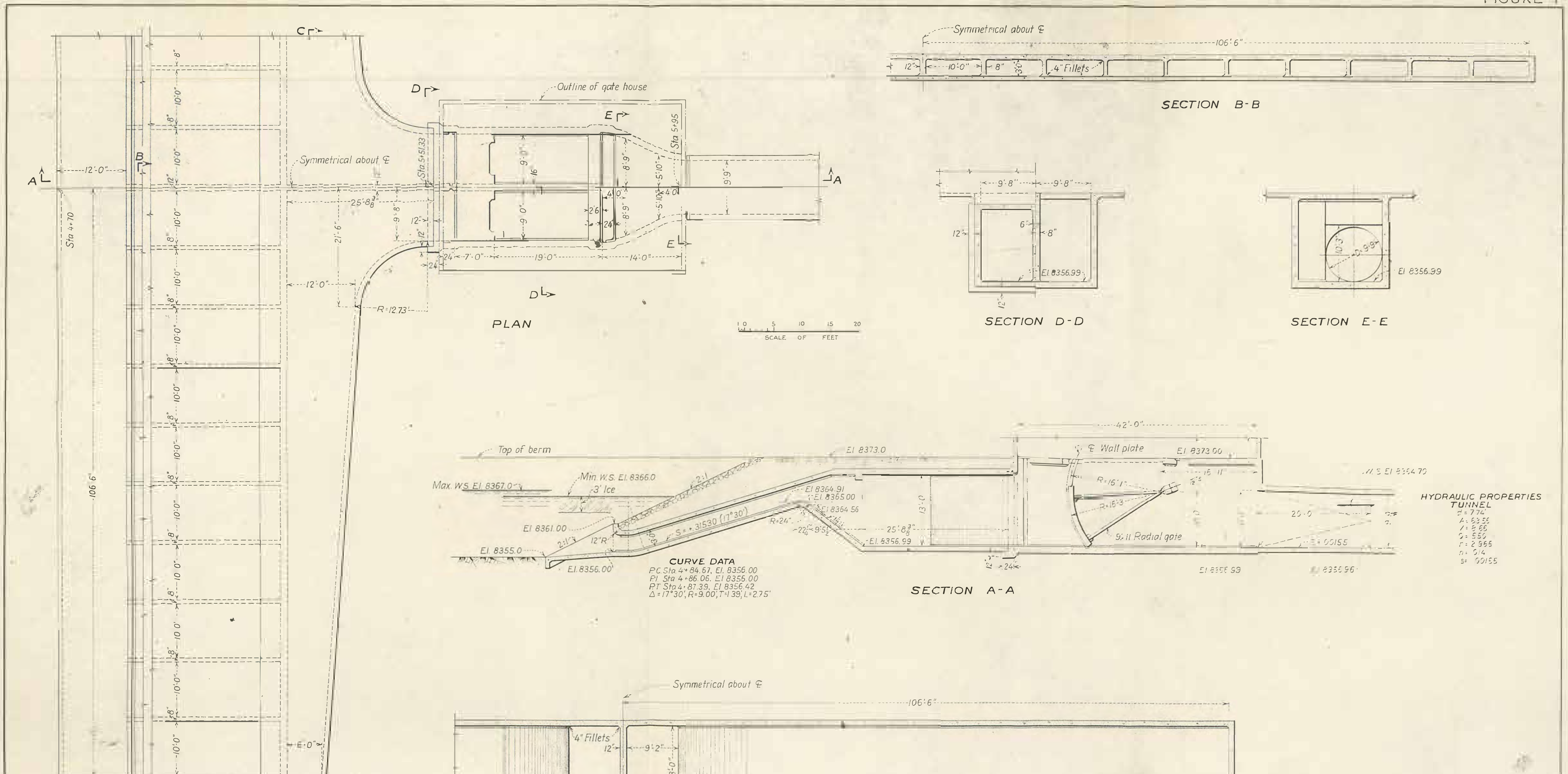
Tests with this arrangement with a 1:24 model indicated a decided improvement over the former design. Equal amounts of water passed through each of the bays, and there were no indications of undesirable flow. With the water surface at the tunnel portal set at elevation 8364.70, the corresponding lake water surface required to produce a flow of 550 second-feet was elevation 8366.15. This indicates that the total loss in the structure due to friction, turbulence, or otherwise, was 0.29 of a foot or 55 percent of loss in the former design. This saving in head also represents an additional 9.8 hours of storage at maximum discharge.

5. The final design. Investigations to determine the most economical crest length for the improved design revealed that by reducing the number of bays from 20 to 18 caused the lake surface to rise from elevation 8366.15 to elevation 8366.18. By reducing the number of bays to 16 the water surface in the lake raised to elevation 8366.22, or 0.07 of a foot above the 20-bay arrangement. In the model the reduction in the number of bays was accomplished by filling the bays as shown in figure 4B. No changes were made in the floor to compensate for the difference in flow through the remaining bays. However, this correction was made in the prototype. The loss in storage that resulted from reducing the

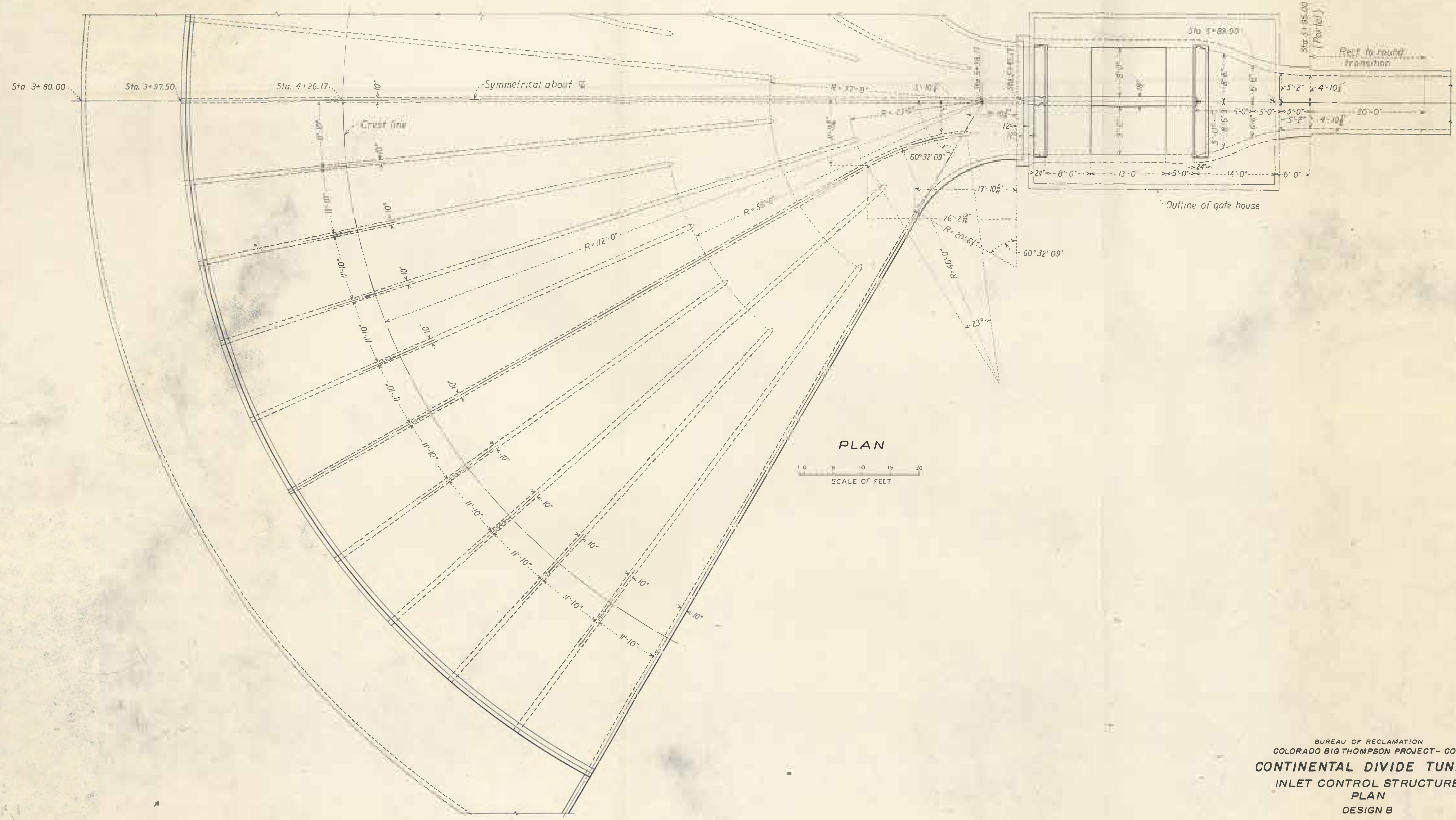
number of bays to 16 amounted to approximately 3 hours of flow at 550 second-feet. It was decided that the decreased cost obtained by removing the four outside bays justified the additional loss in storage. The model was not tested with the fish screen in place, and the losses due to the screen will be in addition to those measured in the model.

The final design as it will appear in the field is shown on figures 5 and 6. The control structure has been moved upstream 183.5 feet to the lake shore. The additional loss due to the covered conduit connection between the inlet control structure and the gate house has been compensated for by lowering the tunnel grade line.

- - -



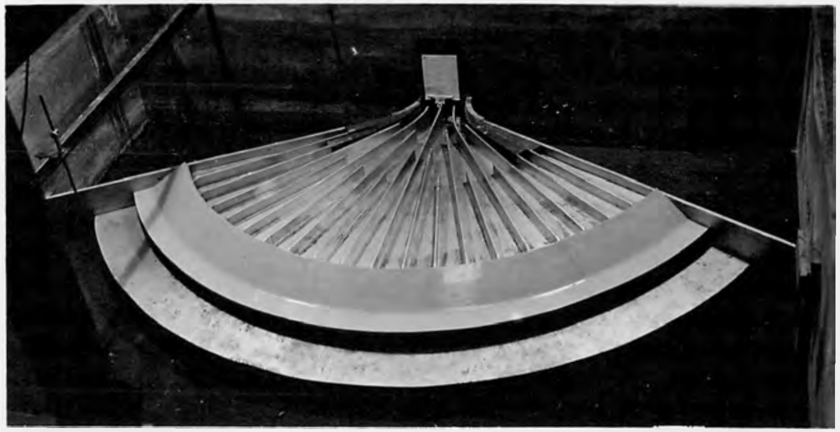
BUREAU OF RECLAMATION
COLORADO BIG THOMPSON PROJECT - COLO.
CONTINENTAL DIVIDE TUNNEL
INLET CONTROL STRUCTURE
DESIGN A



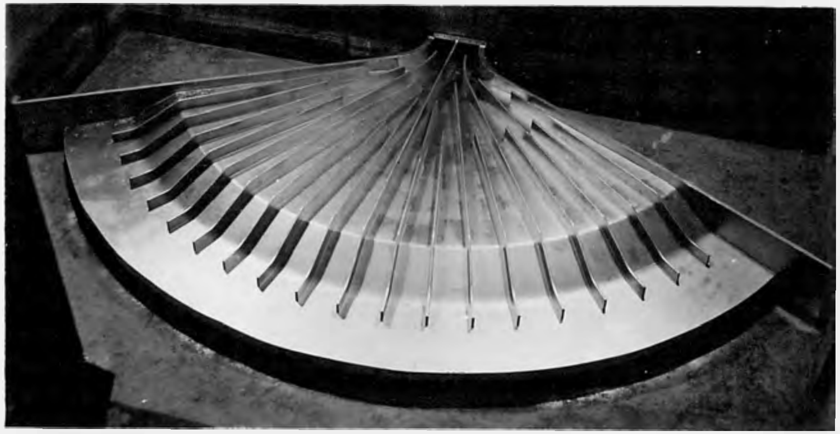
BUREAU OF RECLAMATION
COLORADO BIG THOMPSON PROJECT- COLO.

CONTINENTAL DIVIDE TUNNEL
INLET CONTROL STRUCTURE
PLAN
DESIGN B

A. Proposed design with piers in side channel spillway removed.
(Left half of structure)



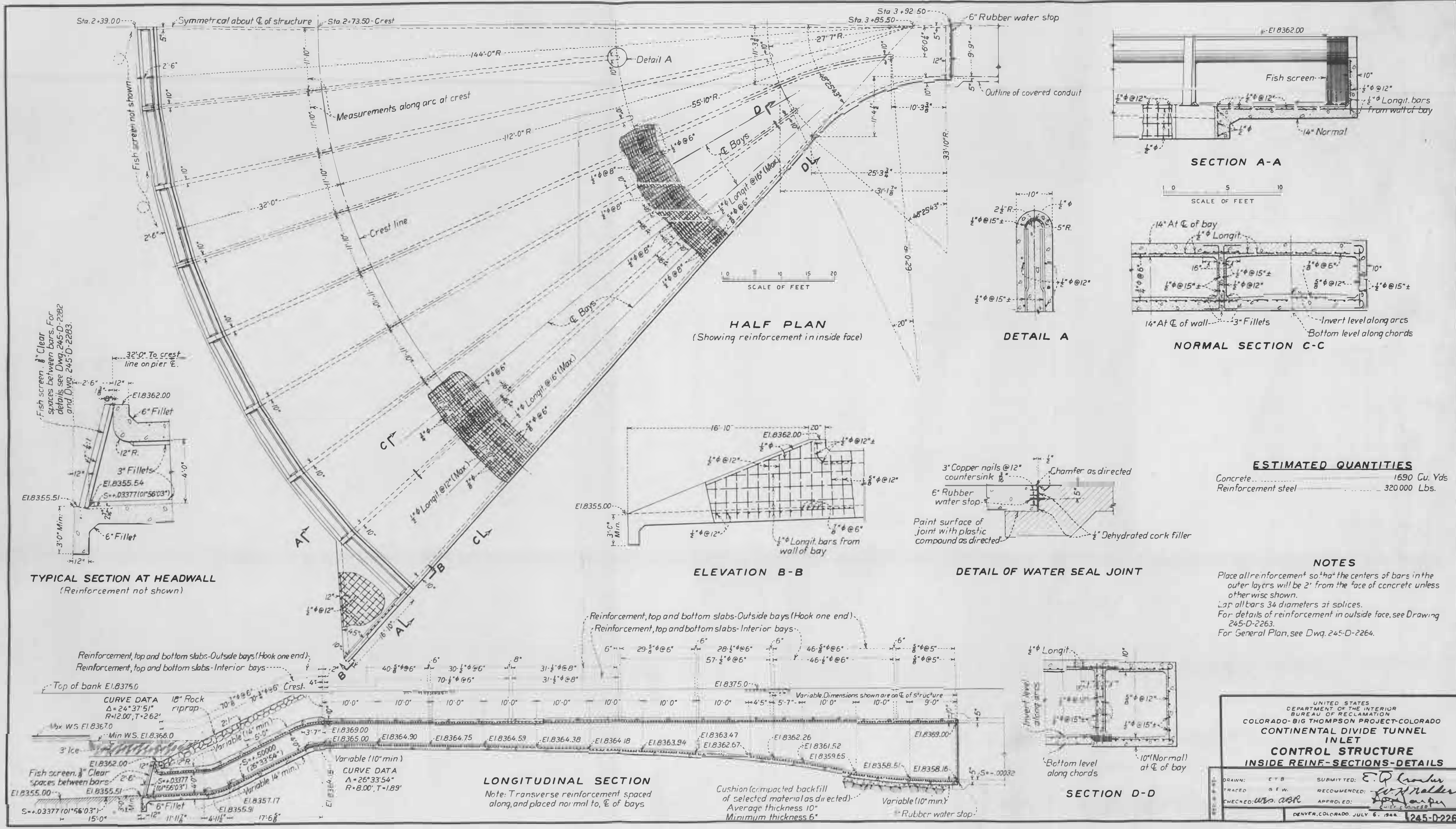
B. Improved design with four bays closed and the bays partially covered.



C. Improved design without cover over the bays.

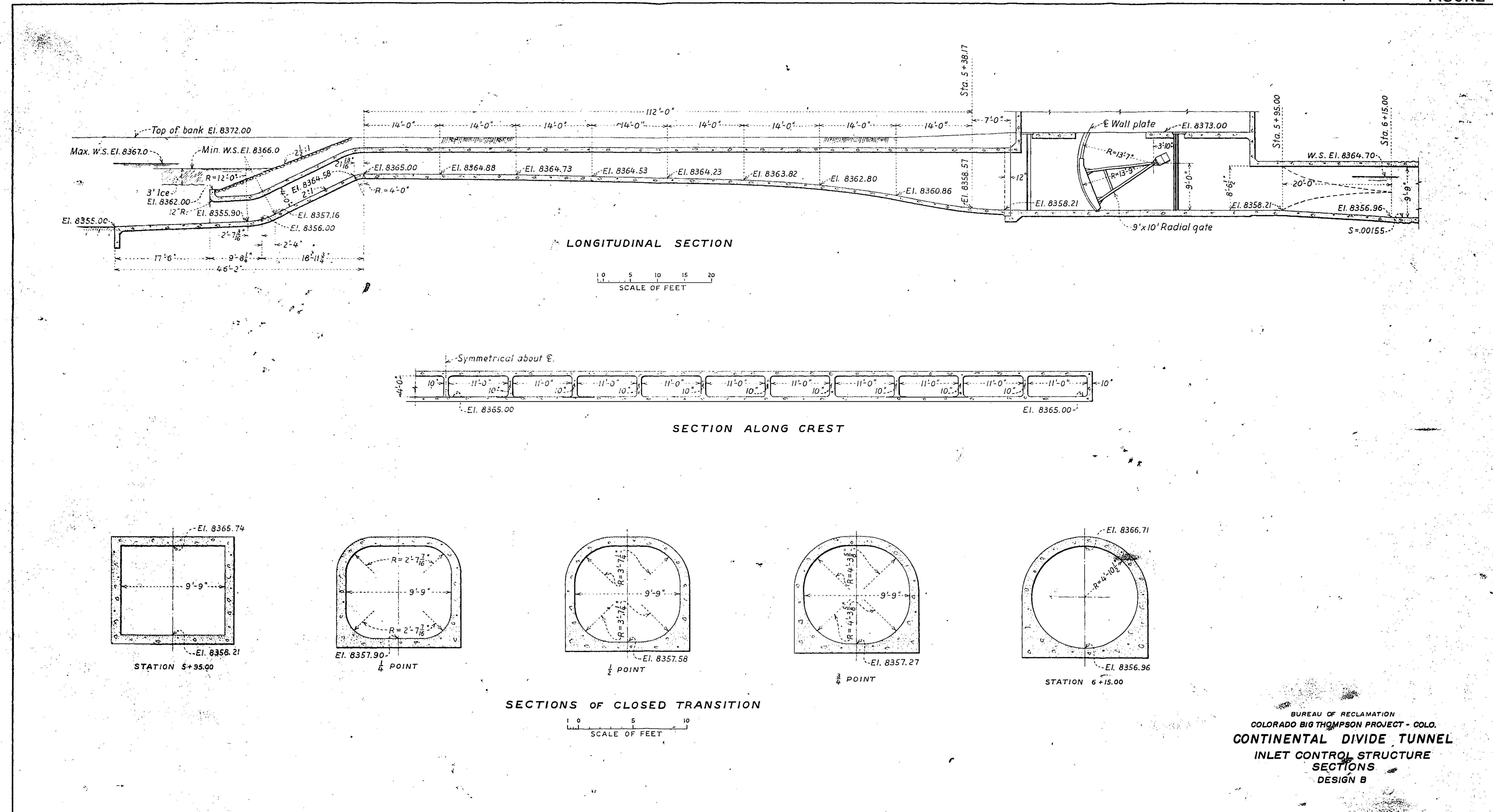
DESIGNS FOR INTAKE CONTROL STRUCTURE

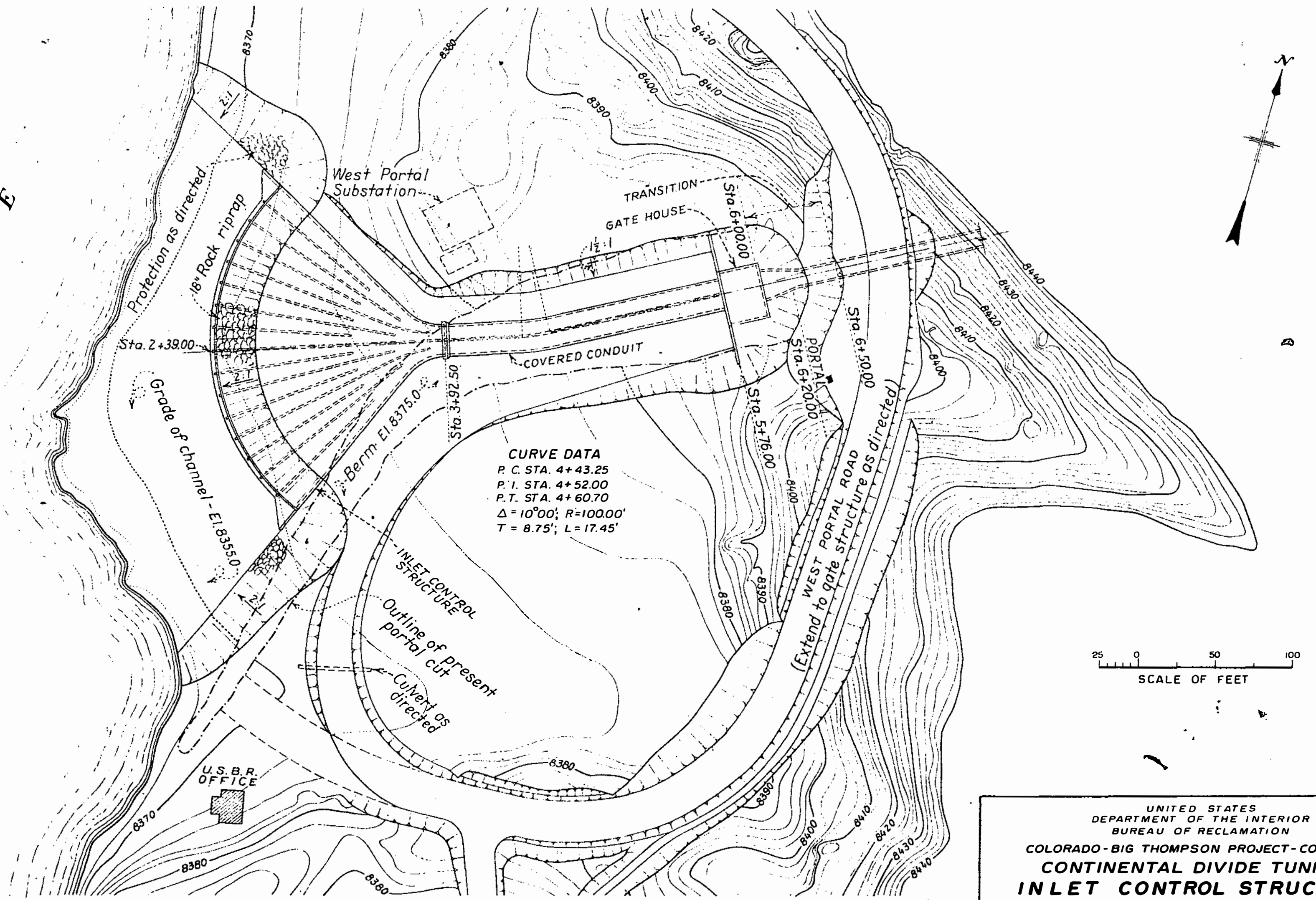
FIGURE 5



HALF PLAN
(Showing reinforcement in inside face)
Sta. 2+39.00
Symmetrical about ℄ of structure
Sta. 2+73.50-Crest
Sta. 3+92.50
Sta. 3+85.50
6" Rubber water stop
Outline of covered conduit
Detail A
Measurements along arc at crest
Crest line
Fish screen not shown
℄ Bays
144'-0"R
112'-0"R
55'-10"R
27'-7"R
32'-0"
33'-10"R
SCALE OF FEET
SECTION A-A
El. 8362.00
Fish screen
½"ϕ Longit. bars from wall of bay
14" Normal
DETAIL A
NORMAL SECTION C-C
14" At ℄ of bay
½"ϕ Longit.
14" At ℄ of wall
3" Fillets
Invert level along arcs
Bottom level along chords
TYPICAL SECTION AT HEADWALL
(Reinforcement not shown)
Fish screen. ⅜" Clear spaces between bars. For details see Dwg. 245-D-2282 and Dwg. 245-D-2283.
32'-0" To crest line on pier ℄.
El. 8362.00
6" Fillet
12" R.
3" Fillets
El. 8355.54
El. 8355.51
S=+.03377 (01°56'03")
ELEVATION B-B
El. 8362.00
El. 8355.00
½"ϕ Longit. bars from wall of bay
DETAIL OF WATER SEAL JOINT
3" Copper nails @12" countersink 1/16"
Chamfer as directed
6" Rubber water stop
Paint surface of joint with plastic compound as directed
½" Dehydrated cork filler
ESTIMATED QUANTITIES
Concrete .... 1690 Cu. Yds
Reinforcement steel .... 320 000 Lbs.
NOTES
Place all reinforcement so that the centers of bars in the outer layers will be 2" from the face of concrete unless otherwise shown.
Lap all bars 34 diameters at splices.
For details of reinforcement in outside face, see Drawing 245-D-2263.
For General Plan, see Dwg. 245-D-2264.
LONGITUDINAL SECTION
Note: Transverse reinforcement spaced along, and placed normal to, ℄ of bays
Reinforcement, top and bottom slabs-Outside bays (Hook one end)
Reinforcement, top and bottom slabs-Interior bays
Top of bank El. 8375.0
CURVE DATA
Δ=24°37'51"
R=12.00', T=2.62'
18" Rock riprap
Max. W.S. El. 8367.0
Min. W.S. El. 8366.0
3' Ice
Fish screen. ⅜" Clear spaces between bars
El. 8362.00
El. 8355.00
El. 8355.51
S=+.03377 (01°56'03")
Variable (14" min.)
S=+.50000 (26°33'54")
CURVE DATA
Λ=26°33'54"
R=8.00', T=1.89'
Variable (10" min.)
Variable. Dimensions shown are on ℄ of structure
El. 8369.00
El. 8365.00
El. 8364.90
El. 8364.75
El. 8364.59
El. 8364.38
El. 8364.18
El. 8363.94
El. 8363.47
El. 8362.67
El. 8362.26
El. 8361.52
El. 8359.65
El. 8358.51
El. 8358.16
El. 8369.00
El. 8357.17
El. 8355.91
S=-.00032
Cushion (compacted backfill of selected material as directed) Average thickness 10" Minimum thickness 6"
Rubber water stop
SECTION D-D
½"ϕ Longit.
Invert level along arcs
Bottom level along chords
10" (Normal) at ℄ of bay
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT-COLORADO
CONTINENTAL DIVIDE TUNNEL
INLET
CONTROL STRUCTURE
INSIDE REINF.-SECTIONS-DETAILS
DRAWN: E.T.B.
TRACED: G.F.W.
CHECKED: W.R.S. A.B.R.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO. JULY 6, 1944
245-D-2262

FIGURE 3


LONGITUDINAL SECTION
Top of bank El. 8372.00
Max. W.S. El. 8367.0
Min. W.S. El. 8366.0
3' Ice
El. 8362.00
El. 8355.00
El. 8355.90
El. 8357.16
El. 8356.00
El. 8364.58
El. 8365.00
El. 8364.88
El. 8364.73
El. 8364.53
El. 8364.23
El. 8363.82
El. 8362.80
El. 8360.86
El. 8358.21
El. 8373.00
El. 8356.96
W.S. El. 8364.70
S=.00155
R=4'-0"
R=12'-0"
112'-0"
14'-0"
7'-0"
17'-6"
46'-2"
Sta. 5+38.17
Sta. 5+95.00
Sta. 6+15.00
℄ Wall plate
9'x10' Radial gate
SCALE OF FEET
Symmetrical about ℄
11'-0"
El. 8365.00
SECTION ALONG CREST
El. 8365.74
9'-9"
El. 8358.21
STATION 5+95.00
R=2'-7 7/16"
El. 8357.90
1/4 POINT
El. 8357.58
1/2 POINT
El. 8357.27
3/4 POINT
El. 8366.71
R=4'-10 1/2"
El. 8356.96
STATION 6+15.00
SECTIONS OF CLOSED TRANSITION
SCALE OF FEET
BUREAU OF RECLAMATION
COLORADO BIG THOMPSON PROJECT - COLO.
CONTINENTAL DIVIDE TUNNEL
INLET CONTROL STRUCTURE
SECTIONS
DESIGN B



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO-BIG THOMPSON PROJECT-COLORADO

CONTINENTAL DIVIDE TUNNEL

INLET CONTROL STRUCTURE

GENERAL PLAN

REV. 9-30-44

DRAWN: E.T.B. SUBMITTED:
TRACED: M.R. RECOMMENDED:
CHECKED: APPROVED: CHIEF ENGINEER

DENVER, COLORADO JULY 3, 1944

245-D-2264

FIGURE 6