Bradley

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

J. N. Bradley

HYDRAULIC MODEL STUDIES OF THE UNITY DAM SPILLWAY

BURNT RIVER PROJECT, OREGON

Hydraulic Laboratory Report No. Hyd.-211

ENGINEERING AND GEOLOGICAL
CONTROL AND RESEARCH DIVISION

J. N. Bradley

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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

Laboratory Report No. 211
Hydraulic Laboratory
Tests by: F. L. Panuzio
H. G. Dewey, Jr.
Written by: R. R. Pomeroy
Reviewed by: J. N. Bradley

Subject: Hydraulic model studies of Unity Dam Spillway--Burnt River Project.

Description of Structure

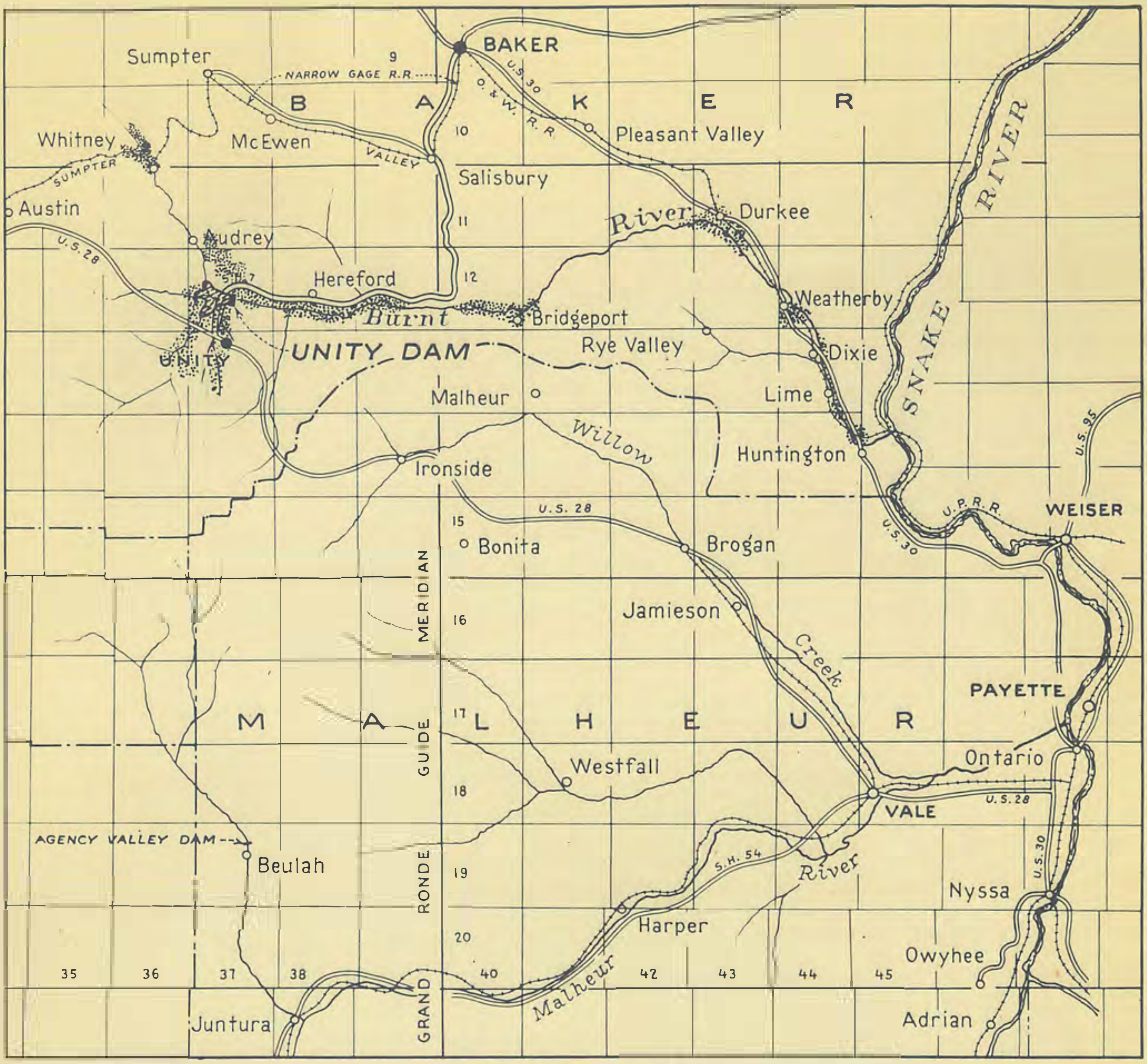
Unity Dam is located between the towns of Unity and Baker, Oregon (Figure 1). The dam is a combination earth and rockfill structure having a total drop of 55 feet from crest to stilling-pool. It intercepts the flow of the Burnt River to form a reservoir with an estimated capacity of 25,120 acre-feet at the maximum water surface elevation of 3820.0. A general plan of the dam is shown on Figure 2 and the spillway is shown in plan and section in Figure 3.

The outlet works and spillway, with designed capacities of 625 and 10,000 second-feet, respectively, are located near the right abutment of the dam. The outlet, consisting of a single 7.5-foot ID circular tunnel, curved in plan, has its exit in the right wall of the spillway stilling-pool. The spillway is controlled by two 24- by 16-foot radial gates, is straight in plan, its centerline making an angle of approximately 84 degrees and 37 minutes with the axis of the dam.

Scope of Tests

Because of uncertainty as to the ability of the spillway to pass the discharges required while maintaining flow conditions not detrimental to the structure itself and surrounding topography, it was decided to conduct a thorough investigation of the original design through the media of model tests.

FIGURE 1

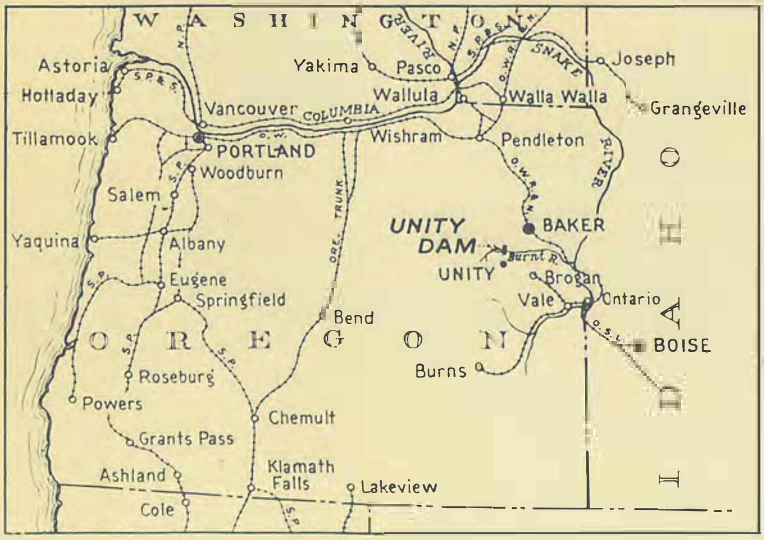


VICINITY MAP

SCALE OF MILES 0 6 12 18

IRRIGATED LANDS TO BENEFIT BY PROJECT.

N.



INDEX MAP

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BURNT RIVER PROJECT-OREGON

UNITY DAM
LOCATION MAP

DRAWN P.M.W.	SUBMITTED	B. W. Steele	REV. 11-5-36
TRACED W.H.S.	RECOMMENDED	J. L. Savage	
CHECKED	APPROVED	R. F. Walter	

27774 DENVER, COLO. NOV. 5, 1935 216-D-21

FIGURE 2

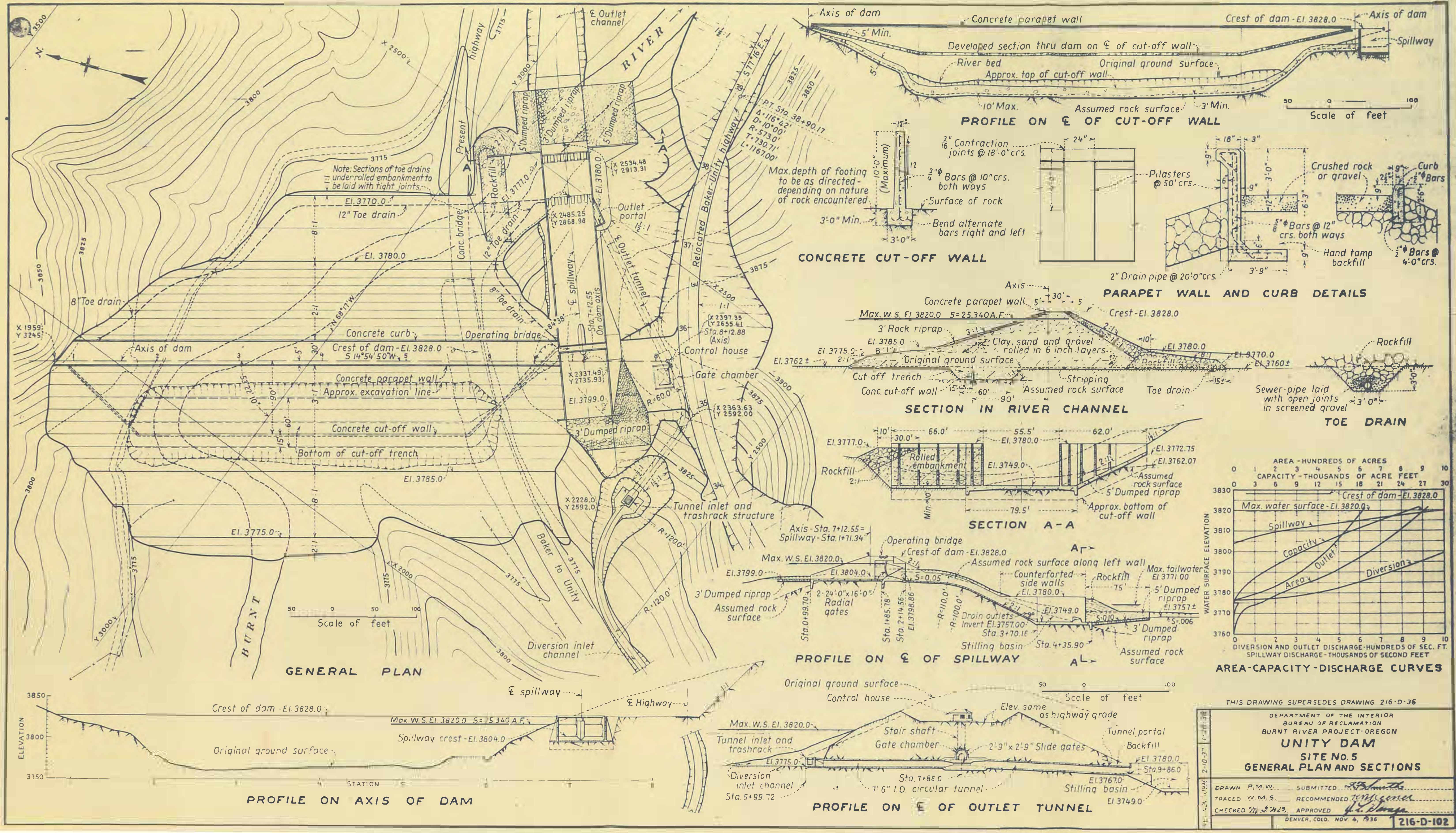
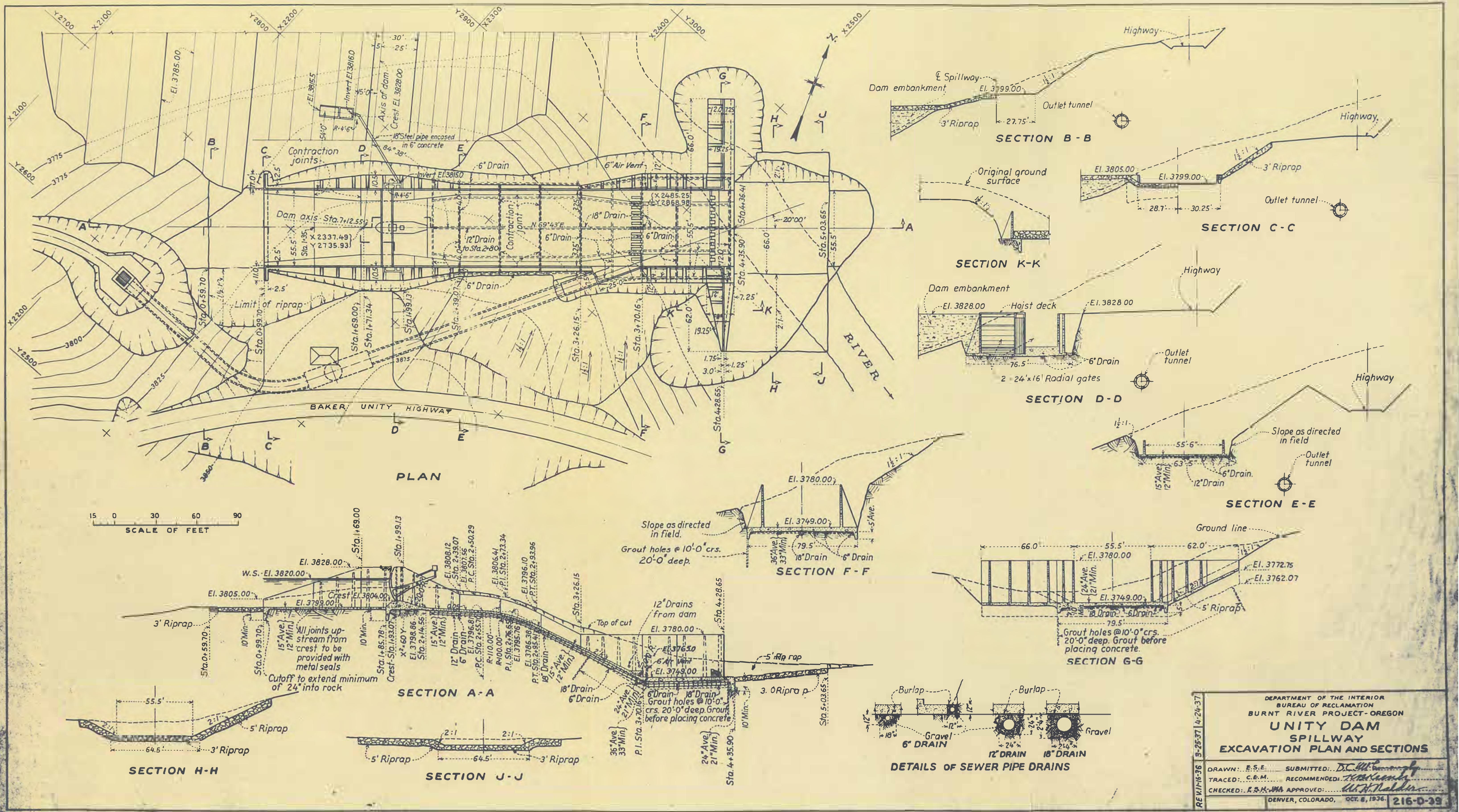

GENERAL PLAN
Scale of feet
Note: Sections of toe drains under rolled embankment to be laid with tight joints.
Axis of dam
Crest of dam - El. 3828.0
S 14°54'50"W.
Concrete curb
Concrete parapet wall
Approx. excavation line
Concrete cut-off wall
Bottom of cut-off trench
Operating bridge
12" Toe drain
8" Toe drain
Present highway
Relocated Baker-Unity highway
Baker to Unity
Conc. bridge
Outlet portal
Outlet channel
Outlet tunnel
Control house
Gate chamber
3' Dumped riprap
5' Dumped riprap
Rockfill
Tunnel inlet and trashrack structure
Diversion inlet channel
RIVER
BURNT
P.T. Sta. 38+90.17
Max. depth of footing to be as directed - depending on nature of rock encountered
PROFILE ON AXIS OF DAM
Crest of dam - El. 3828.0
Max. W.S. El. 3820.0 S=25,340 A.F.
Spillway crest - El. 3804.0
Original ground surface
℄ spillway
℄ Highway
STATION
ELEVATION
PROFILE ON ℄ OF CUT-OFF WALL
Developed section thru dam on ℄ of cut-off wall
Concrete parapet wall
Crest of dam - El. 3828.0
River bed
Original ground surface
Approx. top of cut-off wall
Assumed rock surface
10' Max.
3' Min.
5' Min.
Spillway
Scale of feet
CONCRETE CUT-OFF WALL
3/16" Contraction joints @ 18'-0" crs.
3/4"φ Bars @ 10" crs. both ways
Surface of rock
Bend alternate bars right and left
3'-0" Min.
PARAPET WALL AND CURB DETAILS
Pilasters @ 50' crs.
Crushed rock or gravel
Curb
5/8"φ Bars @ 12" crs. both ways
Hand tamp backfill
1/2"φ Bars @ 4'-0" crs.
2" Drain pipe @ 20'-0" crs.
SECTION IN RIVER CHANNEL
Max. W.S. El. 3820.0 S=25,340 A.F.
Concrete parapet wall
Crest - El. 3828.0
3' Rock riprap
Clay, sand and gravel rolled in 6 inch layers
Original ground surface
Cut-off trench
Conc. cut-off wall
Stripping
Assumed rock surface
Toe drain
Rockfill
TOE DRAIN
Rockfill
Sewer-pipe laid with open joints in screened gravel
SECTION A-A
Rolled embankment
Rockfill
Assumed rock surface
5' Dumped riprap
Approx. bottom of cut-off wall
PROFILE ON ℄ OF SPILLWAY
Axis - Sta. 7+12.55 = Spillway - Sta. 1+71.34
Operating bridge
Crest of dam - El. 3828.0
Assumed rock surface along left wall
Max. W.S. El. 3820.0
Counterforted side walls
Rockfill
Max. tailwater El. 3771.00
3' Dumped riprap
Assumed rock surface
2-24'-0" x 16'-0" Radial gates
Drain outlets Invert El. 3757.00
Stilling basin
5' Dumped riprap
AREA-CAPACITY-DISCHARGE CURVES
AREA - HUNDREDS OF ACRES
CAPACITY - THOUSANDS OF ACRE FEET
WATER SURFACE ELEVATION
Crest of dam - El. 3828.0
Max. water surface - El. 3820.0
Spillway
Capacity
Outlet
Area
Diversion
DIVERSION AND OUTLET DISCHARGE - HUNDREDS OF SEC. FT.
SPILLWAY DISCHARGE - THOUSANDS OF SECOND FEET
PROFILE ON ℄ OF OUTLET TUNNEL
Original ground surface
Control house
Elev. same as highway grade
Max. W.S. El. 3820.0
Stair shaft
Gate chamber
2'-9" x 2'-9" Slide gates
Tunnel portal
Backfill
Tunnel inlet and trashrack
Diversion inlet channel
7'-6" I.D. circular tunnel
Stilling basin
THIS DRAWING SUPERSEDES DRAWING 216-D-36
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BURNT RIVER PROJECT - OREGON
UNITY DAM
SITE No. 5
GENERAL PLAN AND SECTIONS
DRAWN P.M.W.
TRACED W.M.S.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. NOV. 4, 1936
216-D-102

FIGURE 3


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BURNT RIVER PROJECT - OREGON
UNITY DAM
SPILLWAY
EXCAVATION PLAN AND SECTIONS
DRAWN: E.S.E.
TRACED: C.E.M.
CHECKED: E.S.H.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO, OCT. 8, 1936.
216-D-39
PLAN
SCALE OF FEET
15 0 30 60 90
BAKER UNITY HIGHWAY
RIVER
Contraction joints
Dam axis Sta. 7+12.55
Axis of dam
Crest El. 3828.00
18" Steel pipe encased in 6" concrete
6" Drain
6" Air Vent
18" Drain
12" Drain to Sta. 2+80
Contraction joint
N 69°43' E
Limit of riprap
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION J-J
SECTION K-K
DETAILS OF SEWER PIPE DRAINS
6" DRAIN
12" DRAIN
18" DRAIN
Burlap
Gravel
Highway
Dam embankment
Outlet tunnel
3' Riprap
5' Riprap
Original ground surface
Hoist deck
2 - 24'x16' Radial gates
Slope as directed in field
Ground line
Grout holes @ 10'-0" crs. 20'-0" deep.
Grout holes @ 10'-0" crs. 20'-0" deep. Grout before placing concrete.
All joints upstream from crest to be provided with metal seals
Cutoff to extend minimum of 24" into rock
12" Drains from dam
Top of cut
W.S. - El. 3820.00
El. 3828.00
El. 3805.00
El. 3799.00
El. 3780.00
El. 3749.00

To explore completely the performance characteristics of the structure, the schedule of tests was arranged to give an adequate indication of each of the following:

1. Approach conditions to the gate structure for the original design and for each of six alternate designs tested.
2. Coefficients of discharge for the gate structure for each of the approach designs.
3. Pressures experienced at critical points on the gate structure and stilling-pool for the final design.
4. Flow conditions in the chute and stilling-pool for each design tested.
5. The maximum tailwater range for the original and final designs.
6. Amount of scour below the stilling-pool for the original and nine alternate designs.
7. The effect of outlet discharge on flow conditions in the stilling-pool for the final design.

Summary of Results

1. The approach used in the original design was not completely satisfactory above 80 percent maximum discharge because of turbulence caused by the abrupt transitions used. The use of other designs incorporating slopes and curves to soften these transitions did not improve the performance sufficiently to justify the additional cost. This was particularly true in view of the infrequent intervals during which the structure would be required to carry a discharge greater than 80 percent maximum.

2. It was found that the original approach and gate structure were capable of passing flows approximately 3.5 percent greater than for the maximum designed (Figure 8). The maximum discharges for all of the revised approaches slightly exceeded that of the original design.

3. Pressure studies were made along the centerlines of the channels on each side of the gate structure and at various points in the stilling-pool. The results of these studies are shown in Figure 9.

4. Flow conditions were discovered to be satisfactory in the chute as originally designed. It was found, however, that the normal tailwater in the stilling-pool was approximately 2 feet low for satisfactory functioning of the hydraulic jump in the pool. This resulted in a large secondary wave about 60 feet downstream from the end of the pool walls (Figure 11C) and decreased the allowable tailwater range. After extensive experimentation with regard to the most efficient means for combating this condition, a 3.5-foot step at Station 3+70.16, a 5.5-foot sill at Station 4+25.15 and a series of pool fillets were found to give the best results (Figure 10). These did not entirely eliminate the secondary wave, but made the location of the jump more satisfactory and gave a 3-foot range of tailwater (Figure 12).

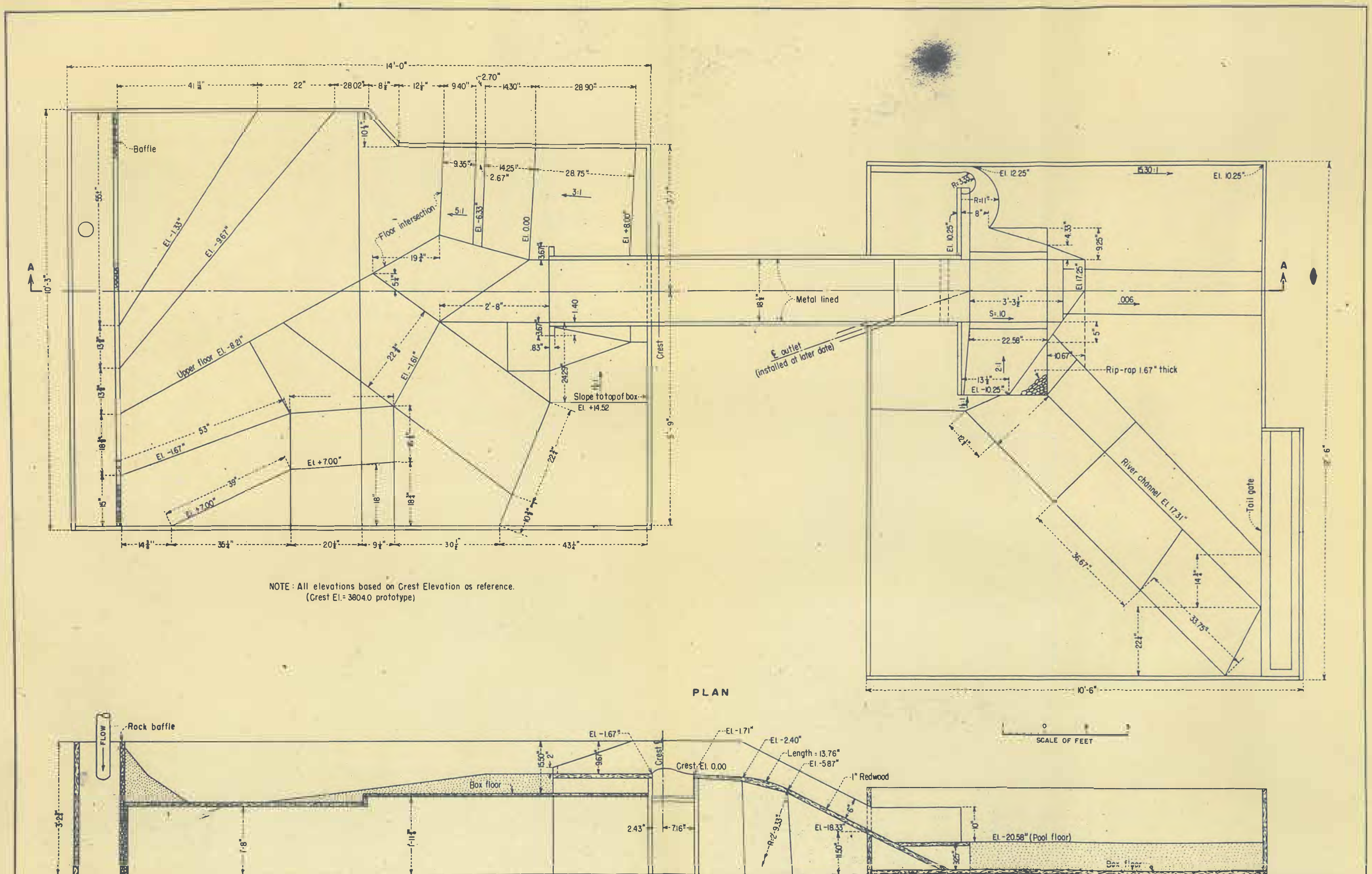
5. The original design allowed a maximum range of the normal tailwater elevation of 2 feet. By the use of the pool design described above, a range of 3 feet was easily obtainable.

6. The model was run for a total elapsed time of 4.5 hours at various tailwater elevations with a 3.0-foot dentated step, a 5.5-foot sill, and stilling-pool fillets in place. The scour was found to be of small consequence, and could be principally attributed to the secondary wave mentioned above (Figures 12 and 14). Removal of the dentated step resulted in severe scour downstream (Figure 16).

7. The outlet flow was found to be so small as to be of little influence on flow conditions in the stilling-pool (Figure 13).

Description of Model

The model of Unity Dam Spillway was constructed to a scale of 1:36 and consisted of a headbox, the entrance and channel of the spillway, and a tailbox (Figure 4). The outlet was added at a later date. The



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BURNT RIVER PROJECT - OREGON

UNITY DAM
MODEL DRAWING
1:36 HYDRAULIC MODEL STUDIES

DRAWN A.S.R. SUBMITTED
TRACED A.R.U.-M.A.F. RECOMMENDED
CHECKED APPROVED
DENVER, COLORADO — MAY 1, 1948

headbox was made of wood with light sheet-metal lining and enclosed a rock baffle for flow distribution, a portion of the topography upstream from the gate structure, and a portion of the gate structure proper. The spillway entrance and channel were constructed of sheet metal and wood. The tailbox was constructed in the same manner as the headbox and included a hinged, wooden canvas-lined gate for regulating the tailwater elevation.

Water columns attached to piezometer openings in the head and tailboxes were utilized to measure the reservoir and tailwater elevations. The topography of the approach area represented in the model was formed of a mixture of concrete, small rocks, and sand. That of the stilling-pool area was formed of sand only so that erosion could be easily studied.

Approach Studies

The original prototype design provided for a right angle transition between the upstream face of the dam and the vertical left wall of the gate structure (Figure 2). This vertical wall extended back to Station 0+99.70, 93.37 feet upstream from the crest axis, its height decreasing at such a rate as to remain flush with the face of the dam. During the initial test run of the model, before the radial gates were installed, it was obvious that considerable turbulence was inherent in the approach channel when the maximum water surface elevation of 3820.0 was reached. This disturbance was caused by the intersection of flow across the face of the dam with that parallel to the axis of the spillway. The condition was concentrated almost exclusively along the left transition wall, that portion occurring along the right approach wall being of minor magnitude (Figure 5).

It was decided to install the gates and to determine at what discharge, with constant pond elevation of 3820.0, this turbulence became appreciable. If the critical discharge proved to approach the maximum designed capacity of 10,000 second-feet, it might be advisable to retain the original approach. Tests showed that such turbulence

A. Entrance to spillway.

B. Flow of 10,000 second-feet.

C. Flow of 10,000 second-feet. Turbulence at left approach wall.

APPROACH CHANNEL STUDIES, ORIGINAL DESIGN

A. Revised Approach No. 1.

B. Revised Approach No. 2.

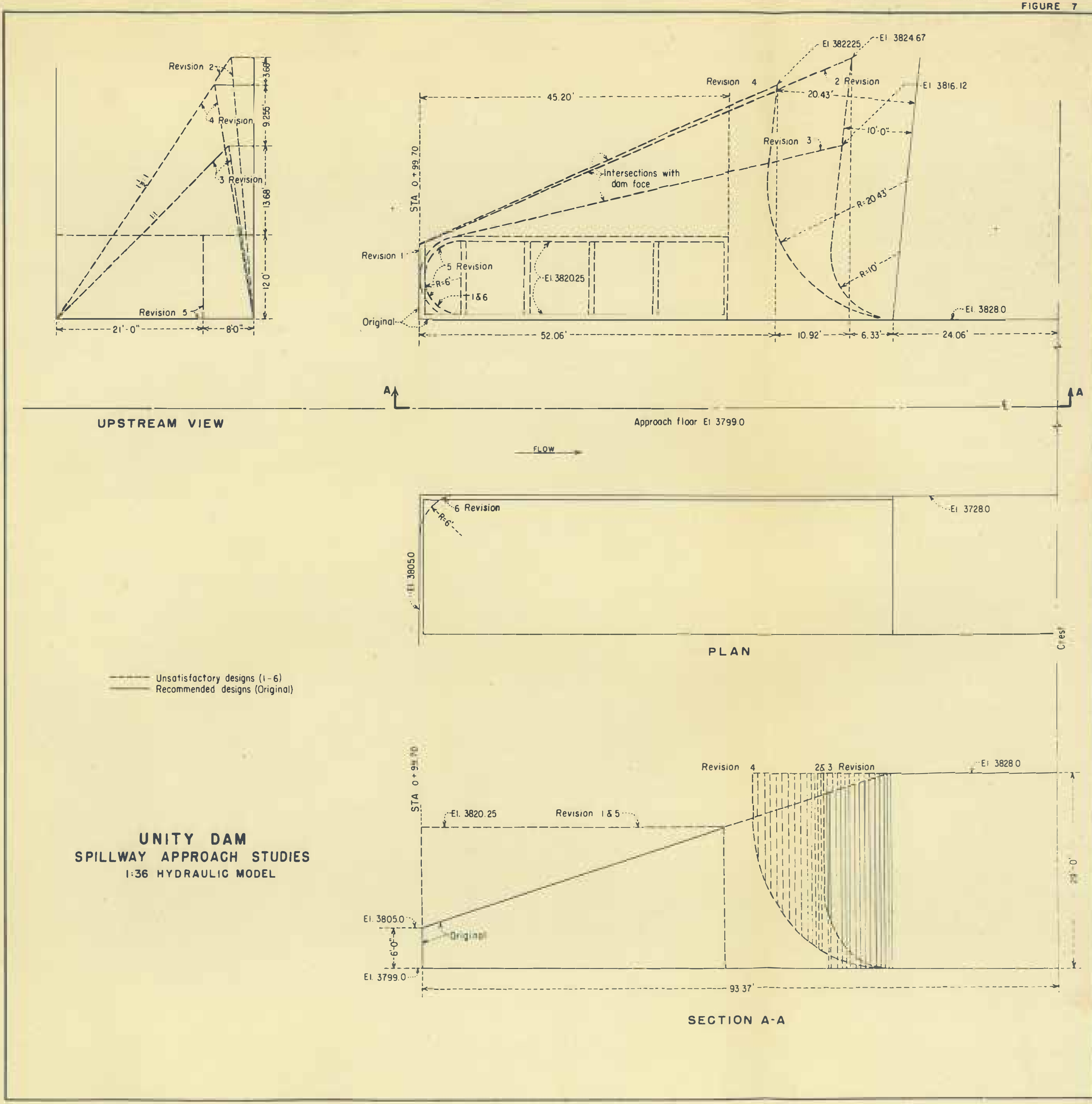
C. Revised Approach No. 3.

D. Revised Approach No. 4.

E. Revised Approach No. 5.

F. Revised Approach No. 6.

SPILLWAY APPROACH STUDIES, REVISED DESIGNS



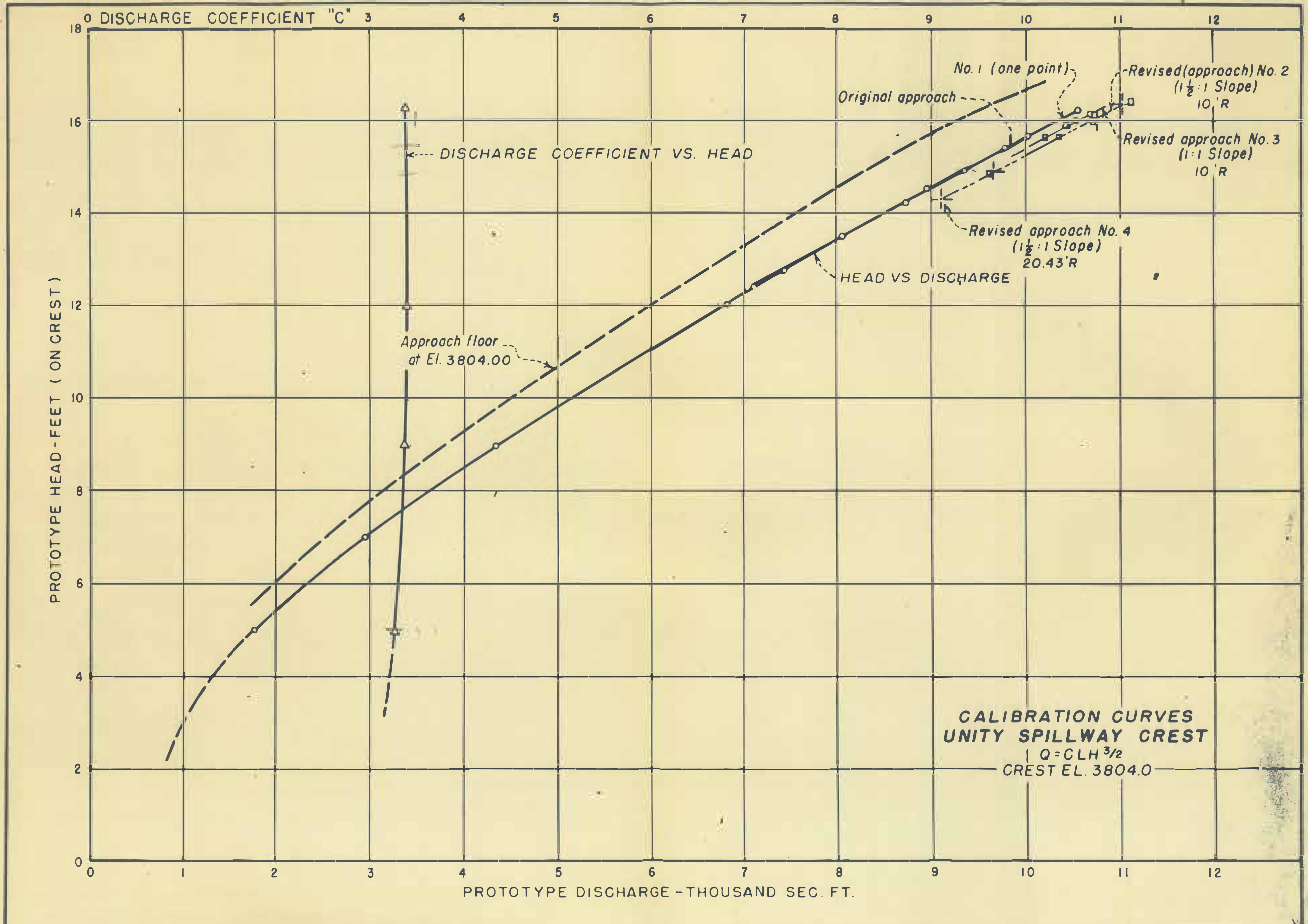
UNITY DAM
SPILLWAY APPROACH STUDIES
1:36 HYDRAULIC MODEL

began to form at 8,250 second-feet with symmetrical gate operation, increasing rapidly in magnitude as the flow was increased to 10,000 second-feet. The critical discharge was therefore shown to be slightly more than 80 percent maximum.

Since the occasions when it would be necessary to pass the maximum flow through the structure would probably be rare, it seemed reasonable to recommend the retention of the original approach design. However, it was requested that an attempt be made to improve the approach conditions at high discharges. Several designs were tested. The first revision (Figures 6A and 7) consisted of extending the gate structure sidewalls back to Station 0+99.70 with a constant height greater than the maximum water surface elevation. The corners at Station 0+99.70 were rounded to a 6-foot radius to promote smoother flow at that point. The performance (Figure 6A) of this entrance was an improvement over the original, but was not entirely satisfactory.

Revised Approaches 2, 3, and 4 (Figure 7) were attempts to make the transition from the upstream dam face to the approach channel less abrupt by substituting various intermediate slopes. In each case, the turbulent area still existed, although reduced in size. Figures 6B, C, and D show the flow in these approaches.

Revised Approaches 5 and 6 (Figure 7) were modifications of 1, with the curves at the upstream ends of the two walls extended to become semicircular in plan. The performance, Figures 6E and F, was somewhat improved over the former designs. Tests were also made on the original approach with one gate open. When the right gate was open, a maximum flow of approximately 5,400 second-feet could be passed with a reservoir elevation of 3820.0. No appreciable turbulence in the approach channel was apparent. Measurement of the maximum flow with only the left gate open was not made, but it was observed to be of about the same magnitude as that for the right gate. No unusual disturbances were noted in this case either.



CALIBRATION CURVES
UNITY SPILLWAY CREST
$Q = CLH^{3/2}$
CREST EL. 3804.0

Upon balancing the cost of the various revisions against the performance obtained, it was decided to retain the original approach, because of its low cost and adequate performance up to 80 percent maximum discharge.

Spillway Calibration

Extensive tests were run on each approach except Nos. 5 and 6 to obtain data for plotting head discharge and coefficient curves, Figure 8. Examination of the curves for the original approach show a maximum flow of approximately 10,350 second-feet for a head of 16 feet, or 3.5 percent more than required. Revised Approaches 1, 2, 3, and 4 gave slightly greater discharges than the original design at equivalent heads, but the advantages of these designs were not considered sufficient to warrant the additional expense.

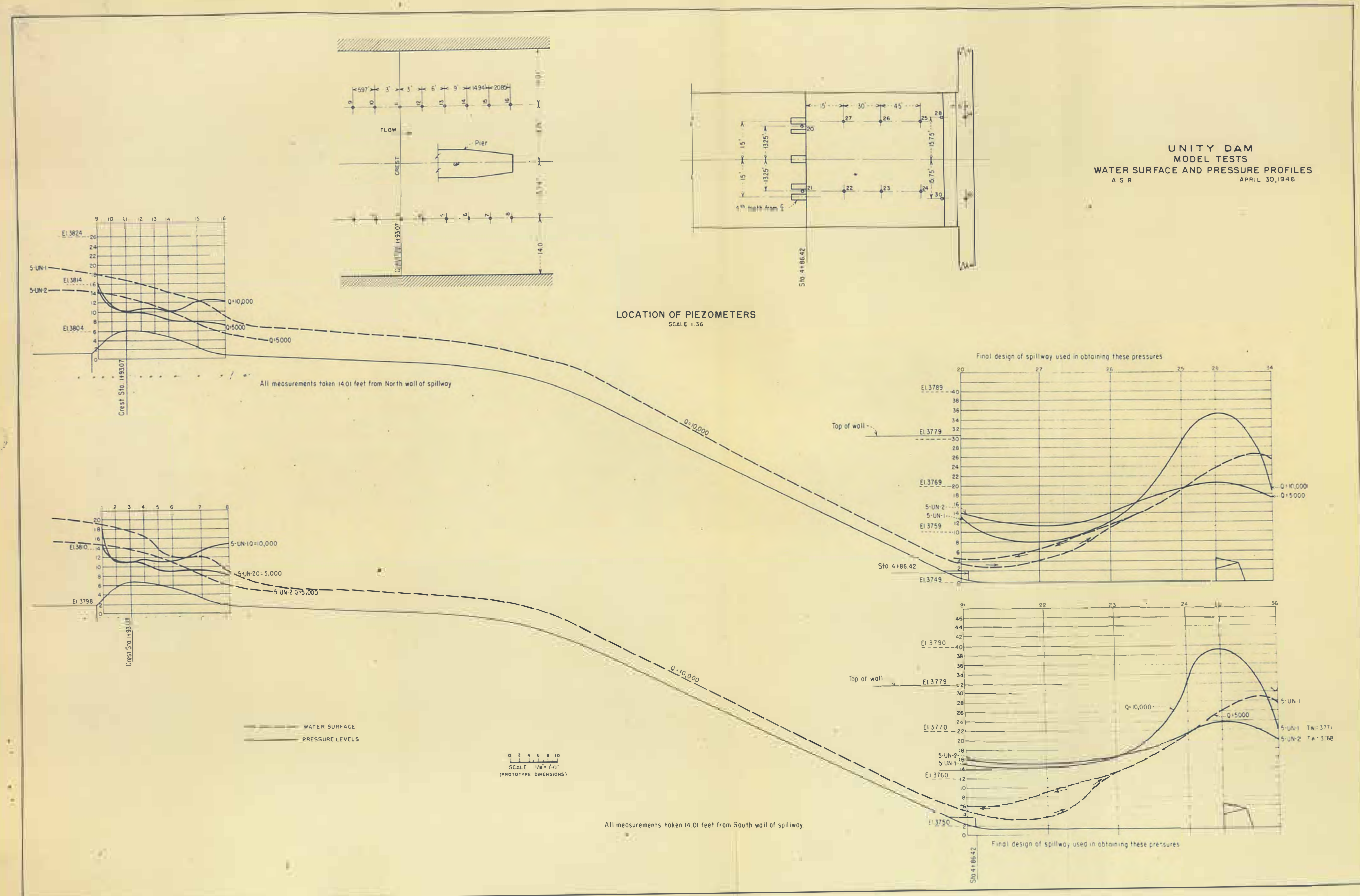
The original approach channel was again tested with the approach floor raised to elevation 3804.0 (the same as that of the crest). The maximum discharge for this setup was about 92 percent of that required (Figure 8), consequently this arrangement was abandoned. The original approach channel was therefore recommended as the final design.

Pressure Studies on Crest

Piezometers were installed on the crest as shown in Figure 9. Pressures and water surface profiles were taken for discharges of 10,000 and 5,000 second-feet. The pressure distribution was satisfactory, and no points of negative pressure could be found.

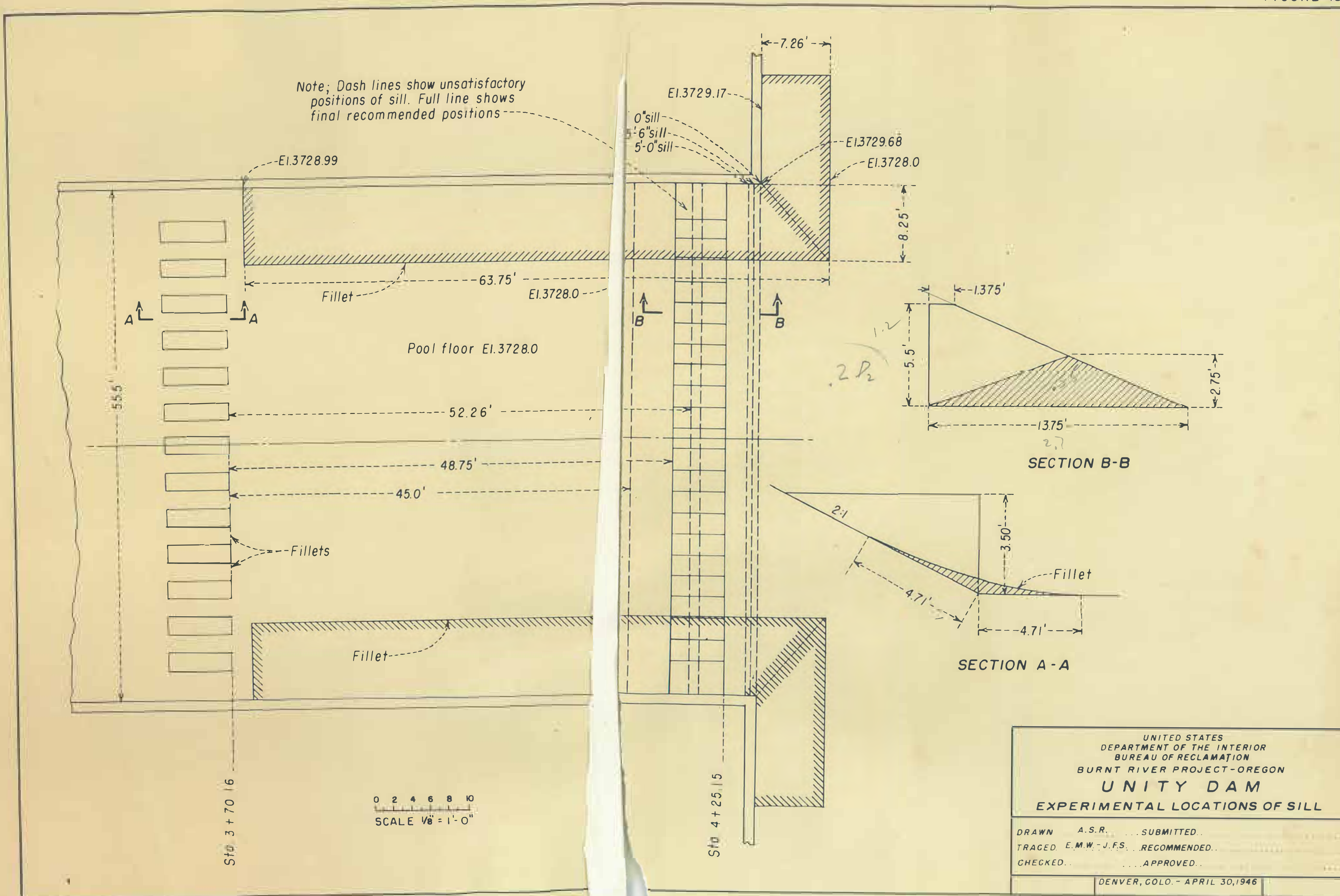
Stilling-pool Studies

The original stilling-pool design provided for the placing of a 2.5-foot dentated step at Station 3+70.16 and a 5.0-foot combination Rehbock sill at Station 4+28.66, 58.5 feet downstream from the dentated step (Figures 10 and 11A). This arrangement was incorporated in the model and a discharge corresponding to the maximum prototype of 10,000 second-feet allowed to flow down the spillway. The tailwater was



UNITY DAM
MODEL TESTS
WATER SURFACE AND PRESSURE PROFILES
A.S.R. APRIL 30, 1946

FIGURE 10



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BURNT RIVER PROJECT-OREGON

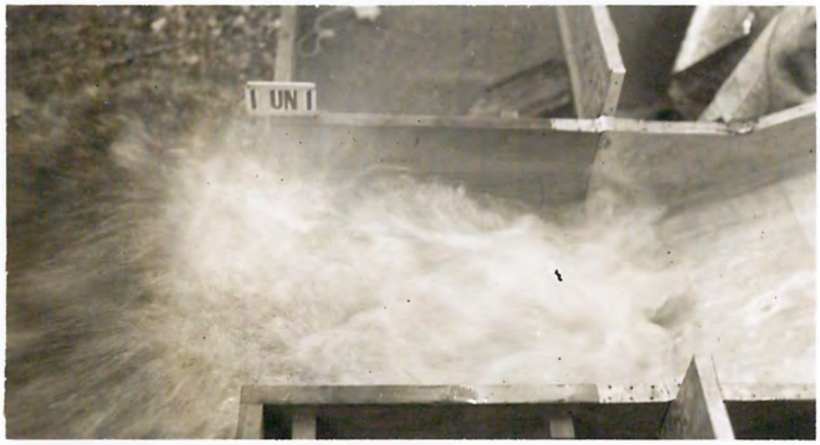
UNITY DAM

EXPERIMENTAL LOCATIONS OF SILL

DRAWN A.S.R. SUBMITTED
TRACED E.M.W.-J.F.S. RECOMMENDED
CHECKED APPROVED

DENVER, COLO. - APRIL 30, 1946

A. Stilling pool and topography downstream.



B. Position of hydraulic jump for maximum discharge of 10,000 second-feet. Tailwater El. 3771.0.

C. Position of secondary wave. Maximum discharge of 10,000 second-feet. Tailwater El. 3771.0.

STILLING POOL STUDIES, ORIGINAL DESIGN

held at elevation 3771 (normal tailwater elevation, Figure 2). A noticeable secondary wave existed approximately 60 feet downstream from the lower end of the training-walls, and the hydraulic jump occurred too far downstream on the apron, indicating a deficiency of tailwater, Figures 11B and C. By raising the tailwater surface 2 feet, this wave disappeared, indicating that the pool floor should be lowered that amount. However, because of the cost of such excavation, it was decided to seek another solution.

The height of the dentated step was first changed to 3.0 feet and then to 3.5 feet in an effort to remedy the objectionable features. No difference in the relative effectiveness of any one of the three sizes could be noticed, except that the largest step seemed to be the more preferable for the low discharge conditions. Previous experience had indicated that it was best to have the effective height of the teeth in the dentated step equal to the thickness of the jet. Since the jet was approximately 3.0 feet thick, it was decided to use the 3.50-foot step (effective height about 3.0 feet because of the 0.57 foot thick fillet later installed between the teeth, Figure 10).

The Rehbock sill was then moved upstream to a point corresponding to Station 4+21.40 on the prototype. This moved the position of the jump upstream, but caused a marked amount of wash over the training-walls at the higher discharges. The secondary wave moved upstream 15 feet from its original position, but was appreciably increased in size. This solution was therefore considered to be undesirable.

A 3.50-foot sill was next placed at Station 4+28.21. This caused the secondary wave and the wash over the training-walls to disappear, but decreased the tailwater range sufficiently to render it unsatisfactory. A series of fillets was then installed in the pool (Figure 10). The sill was left at Station 4+28.66 but increased to 4.0 feet in height. This proved to be a very poor design as it caused the jump to move beyond the limits of the training-walls, and reduced the tailwater range.

Substituting a 6.0-foot sill for the one above increased the tailwater range and forced the jump upstream, but the secondary wave increased. The size of this sill exceeded practical limits.

It seemed advisable, therefore, to move the sill upstream. A 5.0-foot sill and a 5.5-foot sill were tried at Station 4+25.15, with the larger sill proving the more satisfactory. This design gave the following performance (Figure 12):

1. Discharge = 5,000 second-feet, tailwater varied between limits of 3765.8 and 3767.8--conditions very satisfactory.
2. Discharge = 8,500 second-feet, tailwater varied between limits of 3768.1 and 3770.1--conditions very satisfactory.
3. Discharge = 10,000 second-feet (design maximum), tailwater varied between limits of elevations 3768.0 and 3771.0--conditions satisfactory. The position of the front of the jump was approximately 20 feet upstream from the end of the training-wall. There was no wash over the walls. The secondary wave still existed at normal tailwater, but was reduced in size.
4. Discharge = 14,000 second-feet, tailwater held at elevation 3774.0--the hydraulic jump remained in the pool.

It was therefore recommended that the final prototype pool design include a 3.5-foot dentated step at Station 3+70.16 and a 5.5-foot dentated sill at Station 4+25.15, with the fillets as shown in Figure 10.

Pressure Studies for Stilling-pool

Piezometers were installed in the stilling-pool as shown in Figure 9. The pressure distribution obtained from these piezometers is plotted on the same figure as a matter of record.

Outlet Studies

The outlet works were installed after completion of the spillway studies. This is shown to the right of the spillway on Figure 13A. Because of the relatively low-maximum discharge of the outlet (625 second-feet)

FIGURE 12

A. Position of hydraulic jump.
Tailwater El. 3771.0.

B. Position of hydraulic jump.
Tailwater El. 3769.0.

C. Position of hydraulic jump.
Tailwater El. 3768.0.

STILLING POOL STUDIES
MAXIMUM DISCHARGE OF 10,000 SECOND-FEET
RECOMMENDED DESIGN

A. Downstream portal of outlet.

B. Maximum flow through outlet;
625 second-feet.

C. Maximum flow through outlet
and spillway.

OUTLET WORKS, RECOMMENDED DESIGN

in comparison to that of the spillway, no trouble was anticipated. A series of tests was made with only the outlet discharging and also with the outlet discharging in conjunction with various spillway flows. No detrimental conditions were observed, and the design was considered to be satisfactory. Figure 13B shows maximum discharge through the outlet, and Figure 13C shows maximum discharge both through the outlet and over the spillway.

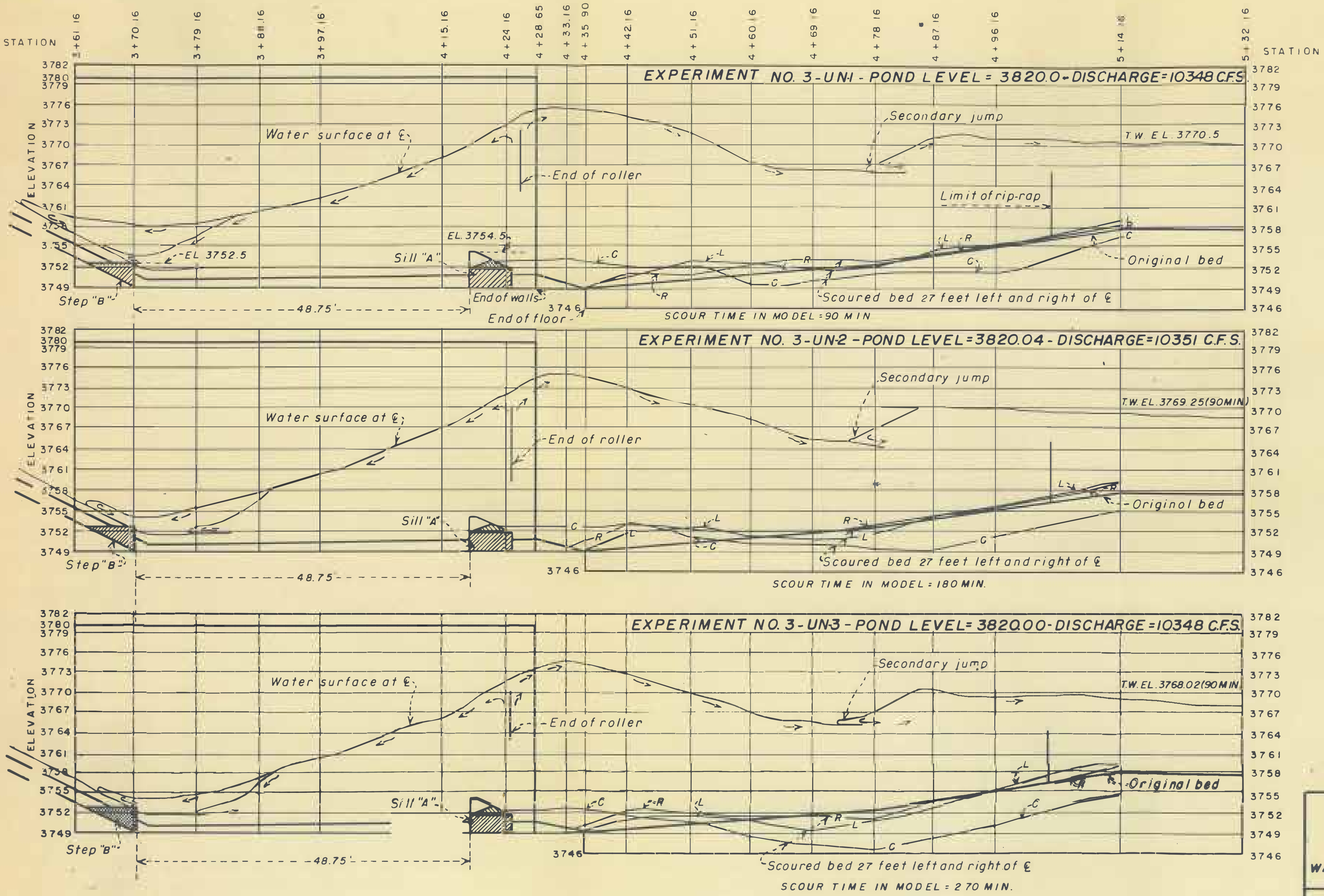
Scour Studies

The final recommended pool design included a 3.5-foot dentated step (effective height approximately 3.0 feet because of the fillet used, Figure 10). In making the scour tests, it was decided to use a 3.0-foot dentated step to assure material displacement which in all probability would be more pronounced than that occurring on the prototype. Figure 15A shows the bed previous to the scour tests. In the first test the model was run at the maximum discharge of 10,000 second-feet for 90 minutes while the tailwater elevation was maintained at 3771.0. Very little scour was noted at the end of this time (Figures 14 and 15B). There was very little displacement of the material on both sideslopes, but a small amount of the riprap directly under the secondary wave was moved. Most of the material moved from its original location was deposited immediately downstream from the sill.

The model was next run at maximum discharge for an additional 90 minutes at a tailwater elevation of 3769.0. The topography below the stilling-pool was not reset, thus giving an indication of what the scour would be at the end of 180 minutes. The low tailwater caused a turbulent condition which moved material from the nose of the fill embankment and from the side topography at elevations 3774 and 3775. No movement was noticed on the right slope. The pocket formed in the riprap on the 0.10 slope was slightly larger, and more sand was deposited immediately downstream from the sill, Figures 14 and 15C.

The third test consisted of running the model with the same discharge and a tailwater elevation of 3768.0 for an additional 90 minutes. The topography was again left in the position it had assumed in the previous test. It was found following the test that more scour action at the

FIGURE 14



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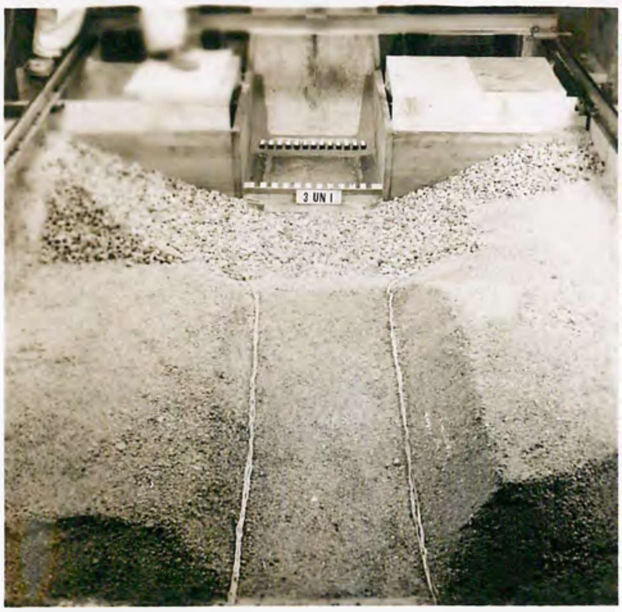
BURNT RIVER PROJECT-OREGON

UNITY DAM-SPILLWAY

HYDRAULIC MODEL STUDIES
WATER SURFACE AND SCOUR PROFILES
WITH DENTATED STEP

DRAWN H. G. D. JR.
TRACED C. R. W.
DENVER, COLO.



A. Topography below stilling pool.

B. Scour caused by flow of 10,000 second-feet (Tailwater El. 3771.0) for 90 minutes-model time.

C. Scour caused by flow of 10,000 second-feet (Tailwater El. 3771.0 for 90 minutes, 3769.0 for 90 minutes) for 180 minutes-model time.

D. Scour caused by flow of 10,000 second-feet (Tailwater El. 3771.0 for 90 minutes; 3769.0 for 90 minutes, 3768.0 for 90 minutes) for 270 minutes-model time.

SCOUR STUDIES
WITH 3.0-FOOT DENTATED STEP AND 5.5-FOOT DENTATED SILL
RECOMMENDED DESIGN

nose of the left fill embankment and surrounding topography had occurred, resulting in the formation of a steep bank on that side. The enlargement of the pocket in the riprap, and the deposition of material downstream from the sill had also continued (Figure 15D).

The scour conditions indicated by the performance of the model in the above tests were not sufficient to cause concern, leading to the conclusion that the pool design chosen would perform satisfactorily. It was suggested that the worth of the dentated step could be demonstrated more conclusively by repeating the above series of tests without it. This procedure was followed, the results showing conclusively that the dentated step was necessary to reduce the velocity of flow entering the pool and to aid in counteracting the effects of a normal tailwater insufficient for proper operation of the hydraulic jump. In all cases, the jump occurred too far downstream, with consequent severe scour, when the dentated step was removed. The results of comparable scour tests for the dentated step removed are shown on Figure 16.

Recommendations

In view of the model results obtained, the following recommendations are made:

1. That the original approach be retained because the turbulence inherent in this design does not appear except at high discharges and because of the additional cost involved in the alternate designs.
2. That the original gate structure and channel be retained.
3. That a 3.5-foot dentated step, a 5.5-foot combination Rehbock sill, and a series of fillets, as shown in Figure 10, be installed in the stilling-pool to reduce scour and increase the tailwater range.

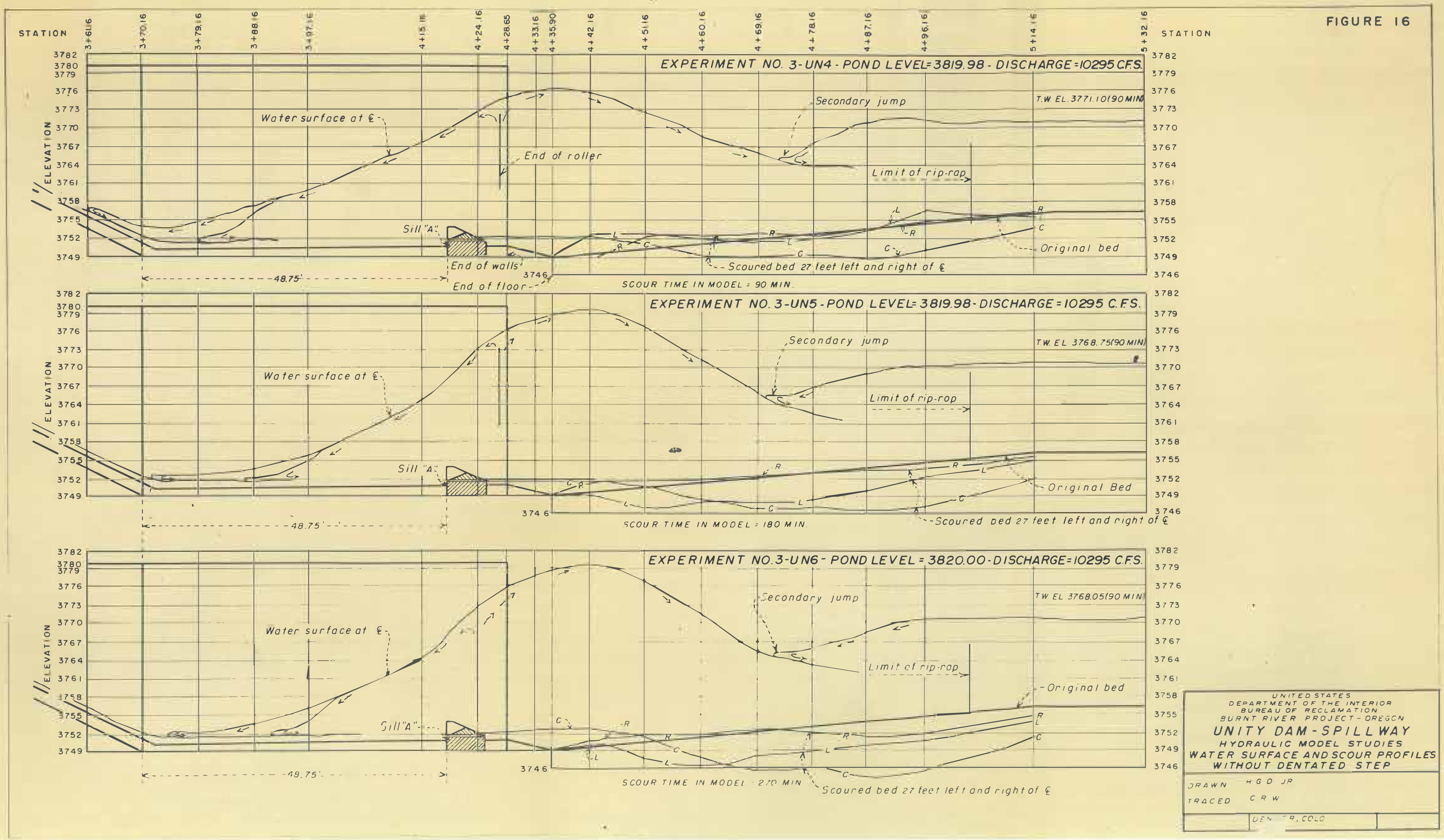


FIGURE 16
STATION
EXPERIMENT NO. 3-UN4 - POND LEVEL= 3819.98 - DISCHARGE = 10295 C.F.S.
Water surface at ℄
End of roller
Secondary jump
T.W. EL. 3771.10 (90 MIN)
Limit of rip-rap
Sill "A"
End of walls
End of floor
Original bed
Scoured bed 27 feet left and right of ℄
SCOUR TIME IN MODEL = 90 MIN.
EXPERIMENT NO. 3-UN5 - POND LEVEL= 3819.98 - DISCHARGE = 10295 C.F.S.
T.W. EL 3768.75 (90 MIN)
Original Bed
SCOUR TIME IN MODEL = 180 MIN.
EXPERIMENT NO. 3-UN6 - POND LEVEL = 3820.00 - DISCHARGE = 10295 C.F.S.
T.W. EL 3768.05 (90 MIN)
SCOUR TIME IN MODEL = 270 MIN
48.75'
ELEVATION
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BURNT RIVER PROJECT - OREGON
UNITY DAM - SPILLWAY
HYDRAULIC MODEL STUDIES
WATER SURFACE AND SCOUR PROFILES
WITHOUT DENTATED STEP
DRAWN H G D JR
TRACED C R W
DENVER, COLO

Reviewer's Note

The model study on the Unity Dam Spillway was performed in 1936. This report was prepared in 1946 from the original notes and data. Naturally, methods of testing and design conceptions have changed in the intervening ten years, thus, the logic followed in the test program described in this report differs somewhat from that which would be followed today.