HYDRAULIC LABORATORY

[redacted]

HYD 3.3

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SUMMARY

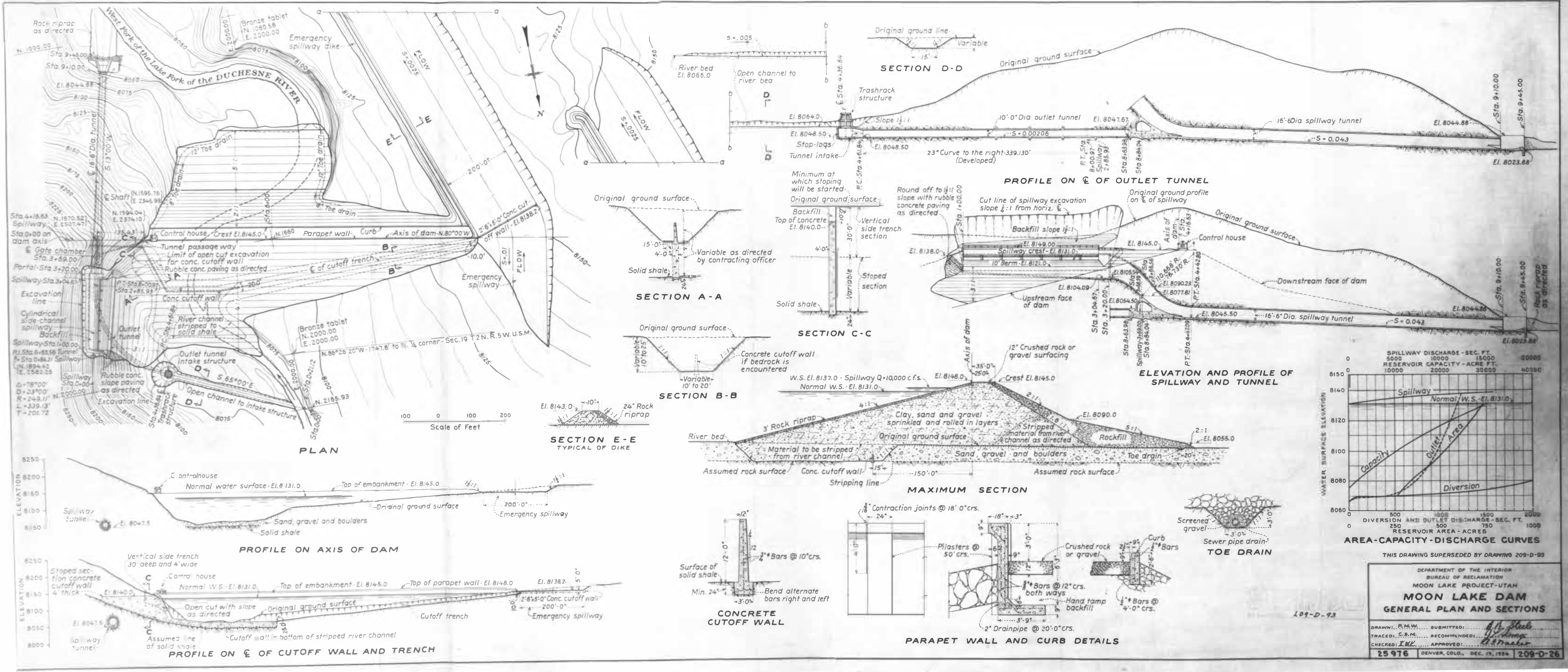
The Moon Lake spillway as in the preliminary design would not carry the maximum discharge of 10,000 c.f.s. without producing an undesirable choking effect in the chute and tunnel. At this discharge, the 15-foot tunnel flowed completely full and the transitional chute flowed partially full, which in turn impeded the flow in the side channel. The diameter of the 15-foot tunnel was increased to 16.5-feet and the lower portion of the chute was enlarged accordingly. This revision gave the spillway ample capacity for the maximum discharge.

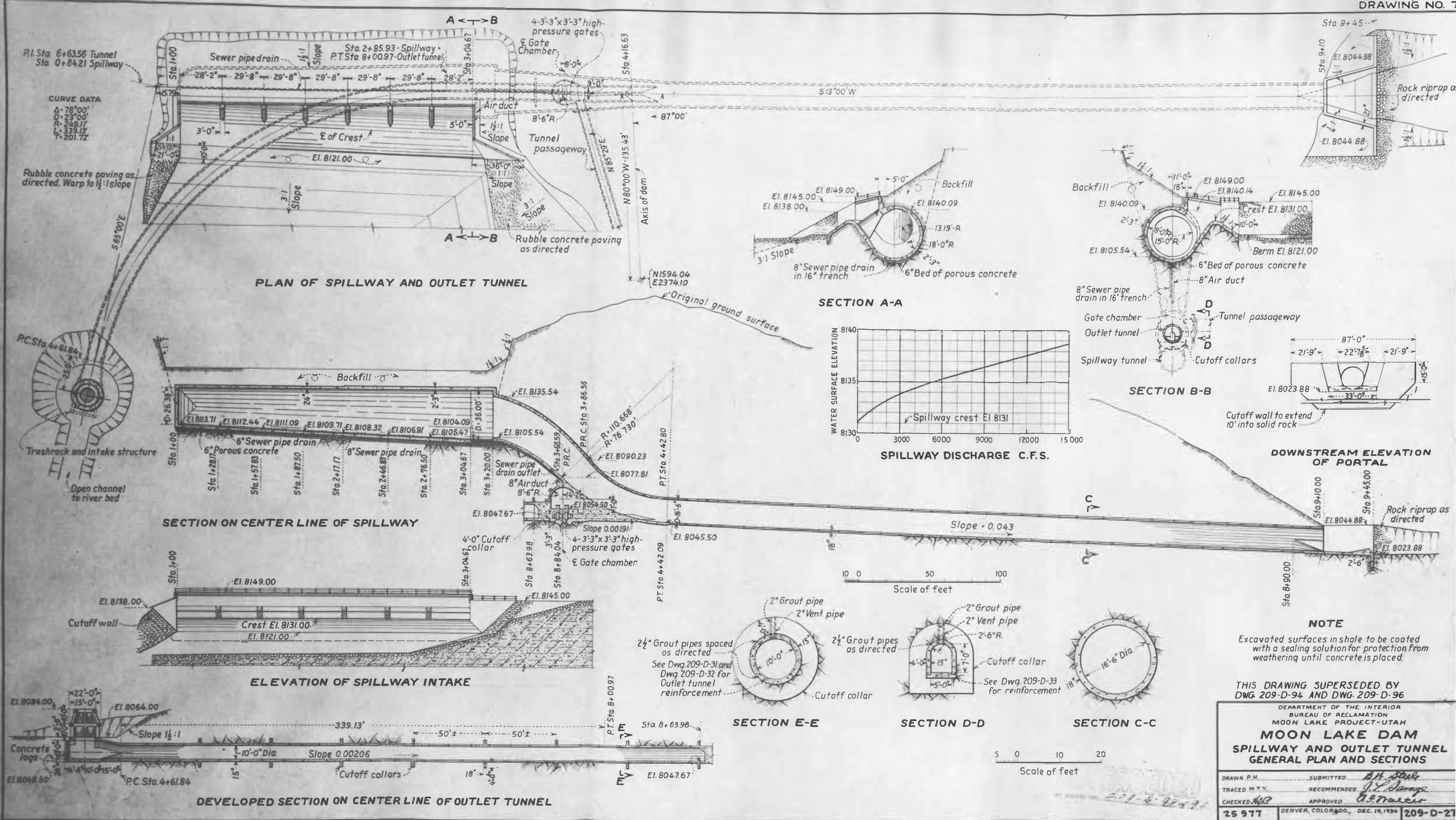
Flow in the chute and tunnel subsequent to this change was rough, unsymmetrical, and noisy. As a result of an extensive series of tests, a design was recommended which had incorporated in it the following features: the shifting of the center line of the chute to coincide with the center line of the side channel; a more gradual transition between the side channel and the portal of the chute; a check 4 feet in height, to be added at the portal of the chute to act as a control and aid in smoothing out the surface of the water before it enters the chute; and a step 4 feet wide on the downstream face of the overflow section to help in preventing the rolling motion of the water in the channel. Each of these revisions or additions improved the flow to some extent, and with the combination, flow conditions were very satisfactory throughout the spillway. Figure 5 shows a comparison of the original and the recommended designs.

THE PROJECT

Moon Lake Dam is to be constructed at the lower end of the present Moon Lake, which is located on the West Fork of the Lake Fork of the Duchesne River in northeastern Utah. The dam site is 32 miles north of the town of Duchesne and about 75 miles east and slightly south of Salt Lake City. The dam will be of the earth fill type having a height of approximately 120 feet above the river, and will increase the storage capacity of the present Moon Lake to 30,000 acre feet. The additional storage will create a supplementary supply of irrigation water for lands already under cultivation, and will open up additional crop acreage in the vicinity which has hitherto been restricted due to the shortage of water.

In connection with the dam, the spillway which will carry off the excess flow during flood seasons is to be located in the east canyon wall somewhat upstream from the axis of the dam. (See figure 1). Due to the abruptness of the canyon walls and the stableness of the rock of which they are formed, a side channel spillway, which proves to be a unique design in this particular case, was proposed. A detailed drawing of the spillway is shown in figure 2. The side channel proper which will be about 200 feet long, will consist of a conical tunnel having a diameter of 30 feet at the upper end and 36 feet at the downstream end, roofed completely by the canyon wall. Thus the canyon wall will be practically undisturbed and the


PLAN
West Fork of the Lake Fork of the DUCHESNE RIVER
Emergency spillway dike
Bronze tablet N. 1080.58 E. 2000.00
Rock riprap as directed
12" Toe drain
8" Toe drain
Toe drain
Control house
Crest El. 8145.0
Parapet wall
Curb
Axis of dam-N.80°00'W
2'6"x5'0" Conc. cut-off wall-El. 8138.2
Emergency spillway
FLOW
Tunnel passage way
Limit of open cut excavation for conc. cutoff wall
Rubble conc. paving as directed
℄ of cutoff trench
Conc. cutoff wall
River channel stripped to solid shale
Outlet tunnel intake structure
Open channel to intake structure
Trashrack structure
Rubble conc. slope paving as directed
Excavation line
Cylindrical side-channel spillway
Backfill
Outlet tunnel
℄ 16'-6" Dia. tunnel
Bronze tablet N. 2000.00 E. 2000.00
N. 88°26'20"W - 1747.6' to ¼ corner - Sec. 19 T.2 N., R.5 W. U.S.M.
Scale of Feet
SECTION A-A
Original ground surface
Variable as directed by contracting officer
Solid shale
SECTION B-B
Concrete cutoff wall if bedrock is encountered
Variable 10' to 20'
SECTION E-E
TYPICAL OF DIKE
El. 8143.0
24" Rock riprap
SECTION D-D
Original ground line
Variable
SECTION C-C
Minimum at which stoping will be started
Original ground surface
Backfill
Top of concrete El. 8140.0
Vertical side trench section
Stoped section
Solid shale
Variable
PROFILE ON ℄ OF OUTLET TUNNEL
River bed El. 8065.0
Open channel to river bed
Trashrack structure
Stop-logs
Tunnel intake
10'-0" Dia. outlet tunnel
S = 0.00206
23° Curve to the right - 339.130' (Developed)
16'-6" Dia. spillway tunnel
S = 0.043
Original ground surface
El. 8023.88
ELEVATION AND PROFILE OF SPILLWAY AND TUNNEL
Cut line of spillway excavation slope ⅛:1 from horiz. ℄
Round off to ½:1 slope with rubble concrete paving as directed
Original ground profile on ℄ of spillway
Backfill slope 1½:1
Spillway crest - El. 8131.0
10' Berm - El. 8121.0
Control house
Upstream face of dam
Downstream face of dam
16'-6" Dia. spillway tunnel
Rock riprap as directed
MAXIMUM SECTION
W.S. El. 8137.0 - Spillway Q = 10,000 c.f.s.
Normal W.S. - El. 8131.0
Axis of dam
12" Crushed rock or gravel surfacing
Crest El. 8145.0
3' Rock riprap
Clay, sand and gravel sprinkled and rolled in layers
Original ground surface
Stripped material from river channel as directed
Rockfill
Material to be stripped from river channel
Sand, gravel and boulders
Toe drain
Assumed rock surface
Conc. cutoff wall
Stripping line
PROFILE ON AXIS OF DAM
Controlhouse
Normal water surface - El. 8131.0
Top of embankment - El. 8145.0
Original ground surface
Emergency spillway
Sand, gravel and boulders
Solid shale
Spillway tunnel
PROFILE ON ℄ OF CUTOFF WALL AND TRENCH
Vertical side trench 30' deep and 4' wide
Stoped section concrete cutoff wall 4' thick
Control house
Normal W.S. - El. 8131.0
Top of embankment - El. 8145.0
Top of parapet wall - El. 8148.0
Open cut with slope as directed
Original ground surface
Cutoff trench
2'6"x5'0" Conc. cutoff wall
Emergency spillway
Assumed line of solid shale
Cutoff wall in bottom of stripped river channel
CONCRETE CUTOFF WALL
Surface of solid shale
½" ϕ Bars @ 10" crs.
Bend alternate bars right and left
PARAPET WALL AND CURB DETAILS
Contraction joints @ 18'0" crs.
Pilasters @ 50' crs.
Crushed rock or gravel
½" ϕ Bars @ 12" crs. both ways
Hand tamp backfill
2" Drainpipe @ 20'-0" crs.
Curb
½" ϕ Bars @ 4'-0" crs.
TOE DRAIN
Screened gravel
Sewer pipe drain
AREA-CAPACITY-DISCHARGE CURVES
SPILLWAY DISCHARGE - SEC. FT.
RESERVOIR CAPACITY - ACRE FT.
WATER SURFACE ELEVATION
Spillway
Normal W.S. - El. 8131.0
Capacity
Outlet
Area
Diversion
DIVERSION AND OUTLET DISCHARGE - SEC. FT.
RESERVOIR AREA - ACRES
THIS DRAWING SUPERSEDED BY DRAWING 209-D-93
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
MOON LAKE DAM
GENERAL PLAN AND SECTIONS
DRAWN: P.M.W. SUBMITTED:
TRACED: C.B.M. RECOMMENDED:
CHECKED: APPROVED:
25976 DENVER, COLO., DEC. 19, 1934 209-D-26


PLAN OF SPILLWAY AND OUTLET TUNNEL
P.I. Sta. 6+63.56 Tunnel
Sta. 0+84.21 Spillway
CURVE DATA
Δ=78°00'
D=23°00'
R=249.11'
L=339.13'
T=201.72'
Sewer pipe drain
Sta. 2+85.93 - Spillway
P.T. Sta. 8+00.97 - Outlet tunnel
4-3'-3"x3'-3" high-pressure gates
℄ Gate Chamber
Air duct
℄ of Crest
El. 8121.00
Tunnel passageway
Rubble concrete paving as directed. Warp to 1½:1 slope
Rubble concrete paving as directed
Axis of dam
N80°00'W-135.43'
N85°29'E
S13°00'W
S65°00'E
N1594.04
E2374.10
Original ground surface
P.C. Sta. 4+61.84
Trashrack and intake structure
Open channel to river bed
Rock riprap as directed
El. 8044.88
SECTION A-A
El. 8149.00
El. 8145.00
El. 8138.00
El. 8140.09
13.19'-R.
18'-0"R.
3:1 Slope
8" Sewer pipe drain in 16" trench
6" Bed of porous concrete
Backfill
SECTION B-B
El. 8140.14
Crest El. 8131.00
Berm El. 8121.00
El. 8105.54
8" Air duct
Gate chamber
Outlet tunnel
Spillway tunnel
Tunnel passageway
Cutoff collars
SPILLWAY DISCHARGE C.F.S.
WATER SURFACE ELEVATION
Spillway crest El. 8131
DOWNSTREAM ELEVATION OF PORTAL
El. 8023.88
Cutoff wall to extend 10' into solid rock
SECTION ON CENTER LINE OF SPILLWAY
6" Sewer pipe drain
6" Porous concrete
8" Sewer pipe drain
El. 8135.54
El. 8090.23
El. 8077.81
El. 8054.50
El. 8047.67
El. 8045.50
Slope 0.00191
Slope = 0.043
4'-0" Cutoff collar
4-3'-3"x3'-3" high-pressure gates
℄ Gate chamber
Sewer pipe drain outlet
8" Air duct
Scale of feet
ELEVATION OF SPILLWAY INTAKE
El. 8149.00
El. 8138.00
El. 8145.00
Cutoff wall
Crest El. 8131.00
El. 8121.00
DEVELOPED SECTION ON CENTER LINE OF OUTLET TUNNEL
El. 8084.00
El. 8064.00
El. 8048.50
Concrete logs
Slope 1½:1
10'-0" Dia.
Slope 0.00206
Cutoff collars
P.C. Sta. 4+61.84
Sta. 8+63.98
El. 8047.67
SECTION E-E
2" Grout pipe
2" Vent pipe
2½" Grout pipes spaced as directed
See Dwg. 209-D-31 and Dwg. 209-D-32 for Outlet tunnel reinforcement
Cutoff collar
SECTION D-D
2½" Grout pipes as directed
Cutoff collar
See Dwg. 209-D-33 for reinforcement
SECTION C-C
16'-6" Dia.
NOTE
Excavated surfaces in shale to be coated with a sealing solution for protection from weathering until concrete is placed.
THIS DRAWING SUPERSEDED BY DWG. 209-D-94 AND DWG. 209-D-96
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
MOON LAKE DAM
SPILLWAY AND OUTLET TUNNEL
GENERAL PLAN AND SECTIONS
DRAWN P.H.
TRACED M.T.Y.
SUBMITTED
RECOMMENDED
APPROVED
25977
DENVER, COLORADO, DEC. 19, 1934
209-D-27

side channel will be protected from rock slips. The spillway will have a free overflow crest which will be in the open and visible from the reservoir. Water passing over the crest will enter the conical channel through a long horizontal slot-like opening in the canyon wall. Six concrete piers equally spaced and resting on the crest will serve as supports to strengthen the arch of the conical channel section. The piers serve only this one purpose as no gates or devices for controlling the spillway flow are provided. With 168.67 feet of free crest, it will be possible to obtain the maximum discharge of 10,000 c.f.s. through the spillway with a head of approximately 6 feet on the crest.

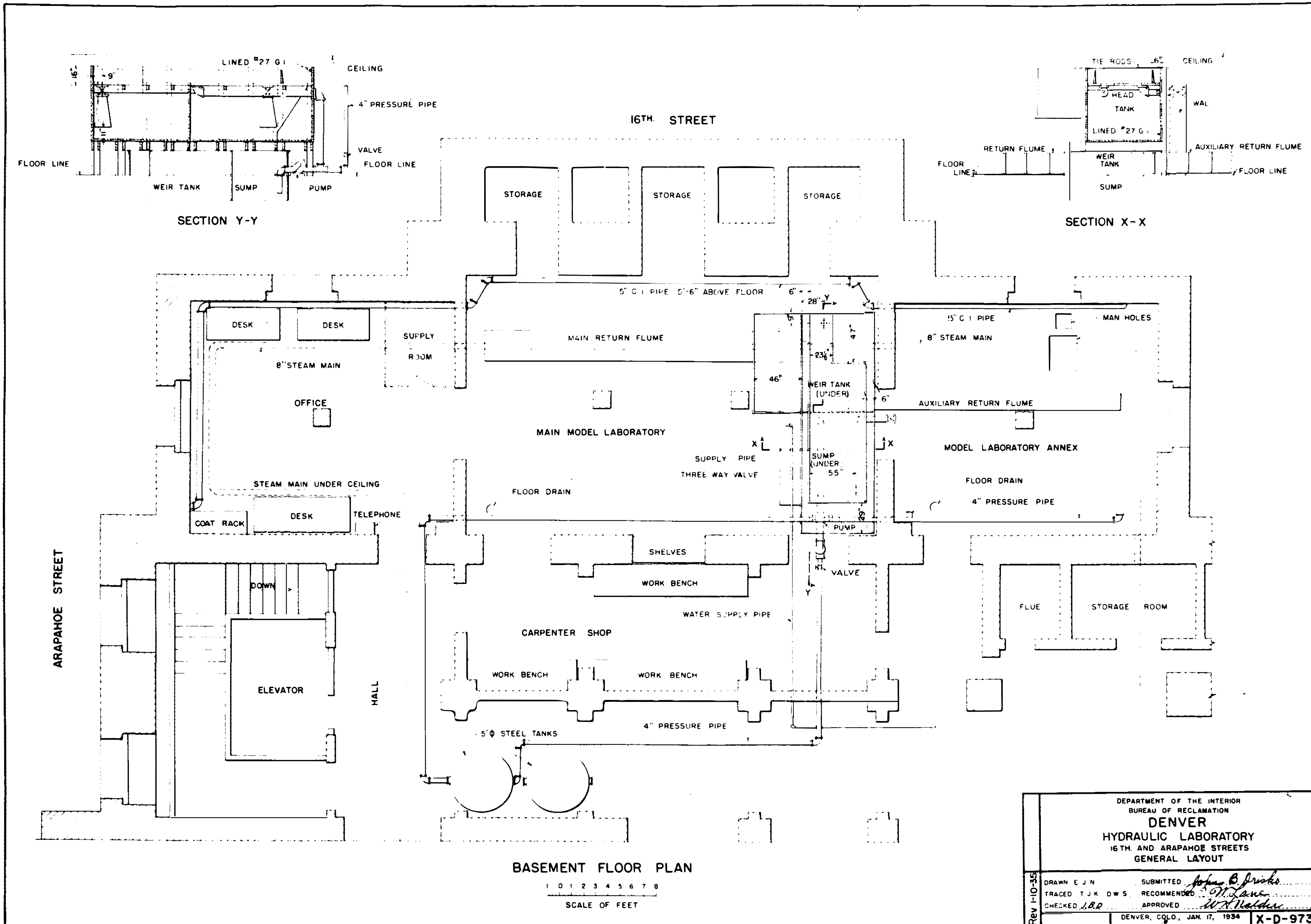
Beginning at the lower end of the conical channel, a transitional chute, circular in section but gradually decreasing in diameter, will conduct the water from the spillway through a drop of 60 feet in a distance of 122 feet, to a 16.5-foot constant diameter tunnel. The 16.5-foot tunnel, which will have a slope of 0.043, will convey the water to the outlet portal from which it will discharge directly into the river below the dam. The original diversion tunnel will be utilized to conduct water for irrigation purposes, when the spillway is not in operation, from the reservoir to the 16.5-foot spillway tunnel, which in turn will deliver it to the river below the dam. (See figure 2). The control works will be located just above the junction of the two tunnels.

THE LABORATORY

The laboratory in which the model of the Moon Lake spillway was constructed and tested is located in the basement of the Old Custom House in Denver, where it is easily accessible to the designing staff of the Bureau of Reclamation. A plan of the laboratory is shown in figure 3.

Water for supplying the models is measured over a 90° V-notch weir located in the end of a weir tank 6 feet by 12 feet by 4 feet deep, which is partially below the laboratory floor. From here, a 6-inch centrifugal pump having a capacity of 3 c.f.s. raises the measured water up into a constant level tank, located as high as the ceiling of the laboratory will permit. A stationary skimming weir makes it possible to maintain a constant head of water in this tank. The water flows from the constant level tank through two 8-inch calibrated gate valves, then through large expanding cones into two head tanks located directly below the constant level tank. Water is then supplied to the models directly from these head tanks.

With this arrangement, two models can be operated simultaneously. After passing through the models, the water is collected in sheet metal flumes and returned to the weir tank. Thus, the same water is continuously circulated through the system. Two hook gages are used to observe the head on the V-notch weir and one hook gage is provided for measuring the elevation of the water surface in each of the head tanks.



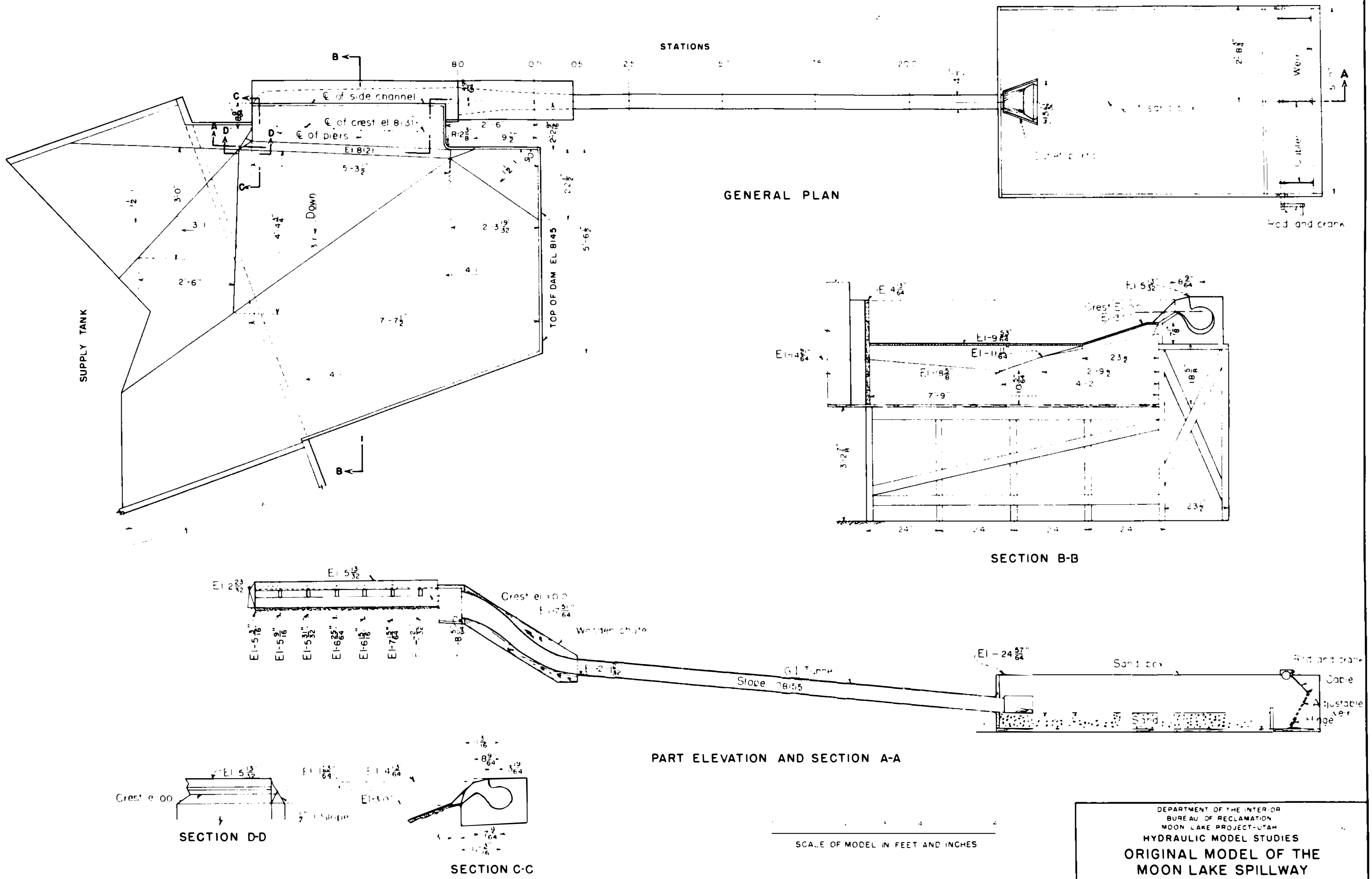
16TH. STREET
ARAPAHOE STREET
SECTION Y-Y
LINED #27 G I
CEILING
4" PRESSURE PIPE
VALVE
FLOOR LINE
FLOOR LINE
WEIR TANK
SUMP
PUMP
SECTION X-X
TIE RODS
CEILING
HEAD TANK
LINED #27 G I
WAL
RETURN FLUME
AUXILIARY RETURN FLUME
FLOOR LINE
FLOOR LINE
WEIR TANK
SUMP
STORAGE
STORAGE
STORAGE
5" C I PIPE 5'-6" ABOVE FLOOR
DESK
DESK
SUPPLY ROOM
8" STEAM MAIN
OFFICE
STEAM MAIN UNDER CEILING
COAT RACK
DESK
TELEPHONE
MAIN RETURN FLUME
MAIN MODEL LABORATORY
FLOOR DRAIN
SUPPLY PIPE
THREE WAY VALVE
46"
47"
28"
WEIR TANK (UNDER)
SUMP (UNDER)
55"
29"
PUMP
VALVE
5" C I PIPE
MAN HOLES
8" STEAM MAIN
AUXILIARY RETURN FLUME
MODEL LABORATORY ANNEX
FLOOR DRAIN
4" PRESSURE PIPE
SHELVES
WORK BENCH
WATER SUPPLY PIPE
CARPENTER SHOP
WORK BENCH
WORK BENCH
4" PRESSURE PIPE
5' Φ STEEL TANKS
FLUE
STORAGE ROOM
DOWN
ELEVATOR
HALL
BASEMENT FLOOR PLAN
SCALE OF FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER
HYDRAULIC LABORATORY
16 TH. AND ARAPAHOE STREETS
GENERAL LAYOUT
DRAWN E J N
TRACED T J K D W S
CHECKED J.B.D.
SUBMITTED John B. Drisko
RECOMMENDED M Lane
APPROVED W H Nalder
DENVER, COLO., JAN. 17, 1934
X-D-973
Rev 1-10-35

FIGURE 3

THE ORIGINAL MODEL

A model of the Moon Lake spillway was constructed in the laboratory on a scale of 1 to 40. A drawing of the model as originally built is shown in figure 4. The spillway proper, which includes the conical side channel and the overflow section, was made of No. 24 gage sheet metal, shaped and soldered to eight heavy sheet metal ribs which were in turn mounted on a frame made up of light structural steel angles. By using this method of construction, the resulting model was very accurate and rigid. It was thus possible to set this piece on a platform and level the crest by means of a leveling screw located at each corner of the steel frame. The six piers were made of redwood and were dowelled to the crest. Pressure from above was provided to hold them in place. The approach to the spillway represented the prototype topography to scale, and consisted of a wooden framework covered with sheet metal.

The transitional chute leading from the lower end of the conical side channel to the 15-foot constant diameter tunnel was carved in a laminated block of wood. Pieces of 2- by 12-inch California white pine were marked and sawed such that the greater part of the material to be removed was sawed out before the boards were assembled. The pieces were then glued and screwed together so that the block was in two halves. The remainder of the material to be removed was dug out with gouges and chisels to the final shape. The two halves were then bolted together as a unit. A portion of the top of the chute was made removable for observation purposes. The two 39-inch



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT–UTAH
HYDRAULIC MODEL STUDIES

ORIGINAL MODEL OF THE MOON LAKE SPILLWAY

DRAWN E.C.P. F.L.P. SUBMITTED
TRACED H.M. C.R.S. RECOMMENDED
CHECKED J.N.B. APPROVED

DENVER, COLO. JAN. 29, 1935 | 209-D-63

FIGURE 4

A. SIDE CHANNEL - DISCHARGE 10,000 C.F.S.

B. LOWER END OF CHUTE - DISCHARGE 10,000 C.F.S.

C. UPPER END OF CHUTE.
DISCHARGE 10,000 C. F. S.

ORIGINAL DESIGN.

square conduits which will connect the original diversion tunnel with the spillway tunnel were built into the lower end of the chute block. Before installation, the block was thoroughly oiled and varnished to prevent swelling and warping. A large heavy sheet metal collar was soldered onto the downstream end of the conical side channel. Both collars had various sets of holes drilled in them so that it would be possible to shift the position of the chute to the left, right, up or down with respect to the center line of the side channel.

The 15-foot circular tunnel which connects the chute with the outlet portal was rolled out of sheet metal. The outlet portals used in the following tests were also made of the same material. A watertight sand box which had an adjustable weir at the downstream end was constructed around the outlet portal. The weir made is possible to set the tailwater at any desired elevation, and the sand in the box gave some indication as to the points where erosion could be expected in the prototype. A piezometer connected to the box registered the tailwater elevation directly.

Five piezometers were located in the throat of the wooden chute for the purpose of investigating the pressures in that zone. These were connected by rubber hoses to a reading board where the pressures were observed. Water surface readings were also taken by means of a point gage for various sections in the side channel, chute, and tunnel. The head on the crest was observed from a hook gage which was connected to the head tank.

THE ORIGINAL DESIGN

The model as originally designed indicated that a few changes should be made. A sketch of the original design is shown in figure 5 and photographs of the same are shown in plate 1. At the maximum discharge of 0.988 c.f.s. which corresponds to 10,000 c.f.s. in the prototype, the side channel was flowing nearly full at the downstream end and the crest was submerged at the upper end. The rolling motion, ever present in side channel spillways, was repeatedly broken up on the right side of the channel by the six piers, but it persisted on the left side and the water entered the chute with a pronounced whirl. The greater portion of the chute was flowing full at maximum discharge, and the 15-foot tunnel was flowing completely full. Photograph C (plate I) shows the water surface in the upper part of the chute, and photograph A shows the side channel in operation for the maximum discharge of 10,000 c.f.s. From all evidence, the 15-foot tunnel was too small and it backed the water up in the chute. This in turn raised the water surface in the side channel sufficiently to submerge the crest at the upper three pier spaces.

In order to prove definitely that the 15-foot tunnel was too small, a run was made with the tunnel disconnected from the chute. As the water flowed out of the chute, it was caught in a temporary sheet metal flume and returned to the system. With the tunnel removed, the choking effect was partially relieved in the chute; but it can be seen from photograph B (plate I) that the chute still flowed full at the lower end.

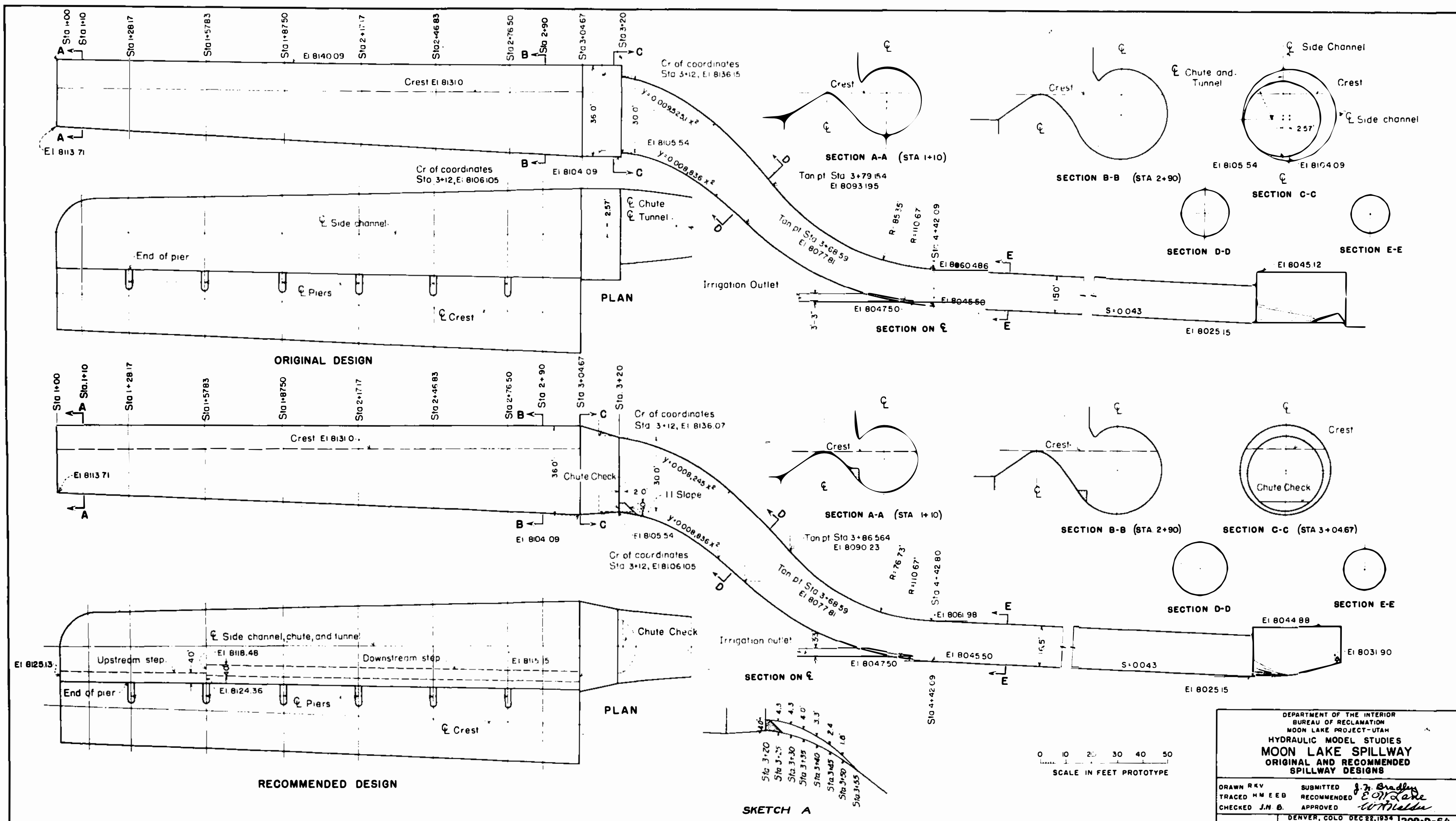

ORIGINAL DESIGN
PLAN
Crest El 8131.0
El 8140.09
El 8113.71
El 8104.09
El 8105.54
Cr of coordinates Sta 3+12, El 8136.15
Cr of coordinates Sta 3+12, El 8106.105
℄ Side channel
℄ Chute
℄ Tunnel
End of pier
℄ Piers
℄ Crest
Irrigation Outlet
SECTION ON ℄
SECTION A-A (STA 1+10)
SECTION B-B (STA 2+90)
SECTION C-C
SECTION D-D
SECTION E-E
℄ Side Channel
℄ Chute and Tunnel
Crest
S=0.043
El 8025.15
El 8045.12
El 8045.50
El 8047.50
RECOMMENDED DESIGN
PLAN
Crest El 8131.0
Cr of coordinates Sta 3+12, El 8136.07
Cr of coordinates Sta 3+12, El 8106.105
Chute Check
1:1 Slope
℄ Side channel, chute, and tunnel
Upstream step
Downstream step
El 8125.13
El 8118.48
El 8124.36
El 8115.15
End of pier
℄ Piers
℄ Crest
Irrigation outlet
SECTION ON ℄
SECTION A-A (STA 1+10)
SECTION B-B (STA 2+90)
SECTION C-C (STA 3+04.67)
SECTION D-D
SECTION E-E
El 8061.98
El 8044.88
El 8031.90
El 8045.50
El 8047.50
El 8025.15
S=0.043
SKETCH A
SCALE IN FEET PROTOTYPE
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
ORIGINAL AND RECOMMENDED SPILLWAY DESIGNS
DRAWN R.K.V. SUBMITTED J.N. Bradley
TRACED H.M. E.E.B. RECOMMENDED E.W. Lane
CHECKED J.N.B. APPROVED
DENVER, COLO. DEC. 22, 1934
209-D-64

FIGURE 5

REVISIONS

Revision A - Larger Tunnel and Chute

The design department suggested that the 15-foot tunnel be increased to a diameter of 16.5 feet and the lower portion of the chute be enlarged accordingly. These changes were made with the result that both chute and tunnel flowed partially full at maximum discharge, which was the object desired. With the first difficulty solved, another became quite conspicuous. The rolling motion of the water in the side channel continued downstream causing the flow to be very rough and unsymmetrical in the chute and tunnel.

Revision B - Alignment of Chute

In an effort to iron out the rolling flow, the center line of the chute was shifted to various positions with respect to the center line of the channel. It was found that flow conditions, although short of satisfactory, were best when the center line of the chute coincided with the center line of the channel. Shifting the chute up or down made no appreciable difference, consequently the elevations of this portion of the spillway remained unchanged.

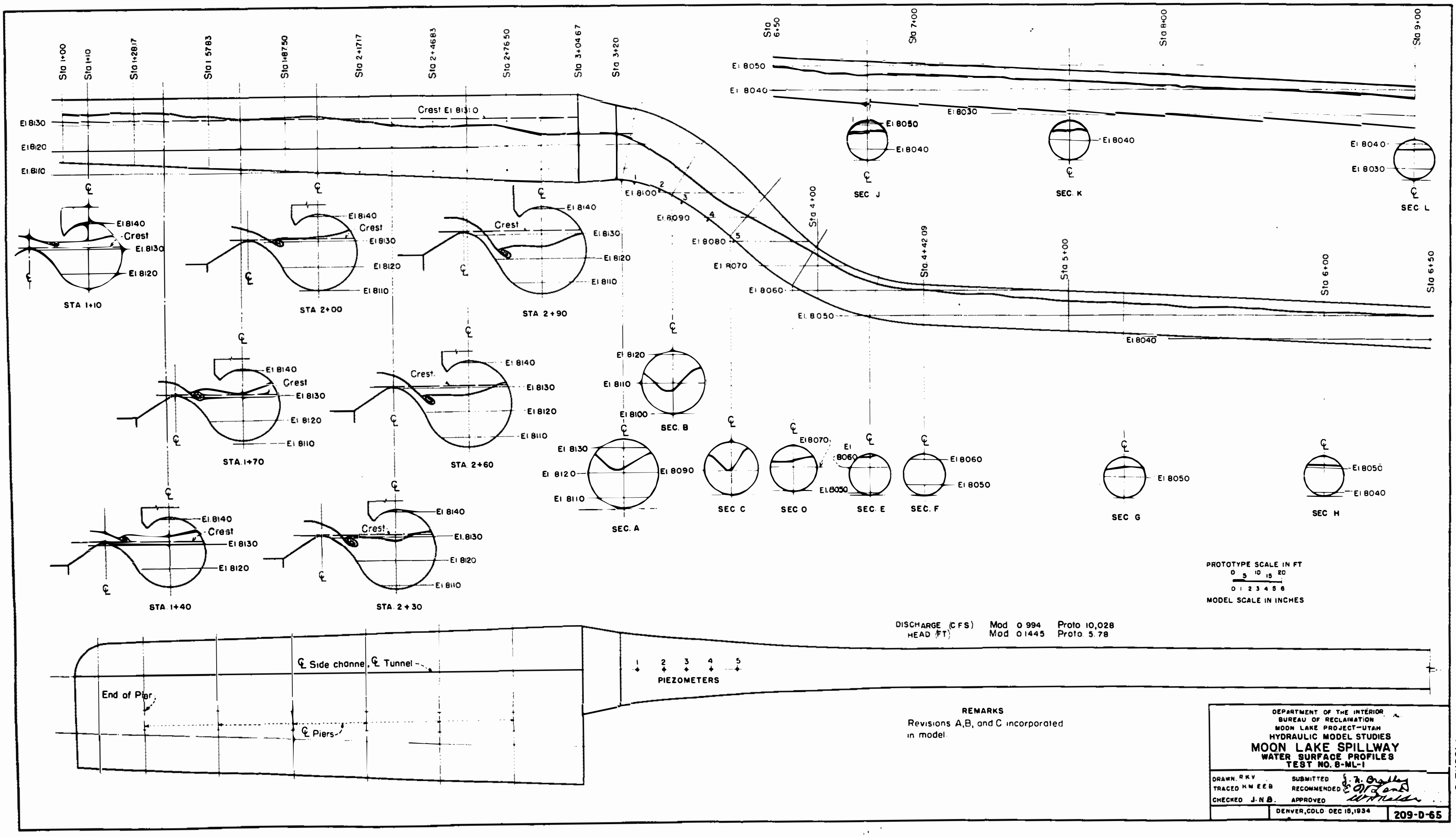
Revision C - Entrance to Chute

A smooth conical transition 15.33 feet long, extending from station 3+04.67 to station 3+20 (See sketch of recommended design in figure 5) was installed between the 36-foot diameter side channel and the 30-foot diameter chute portal. Also, the small protruding vane at station 3+04.67, which was originally used in conjunction with the offset, was removed. A slight improvement in flow conditions was noticeable due to these changes. Test 8-1 shown in figure 6 shows the water surface at various sections taken along the channel, chute, and tunnel, and a profile of the water surface on the center line for a discharge of 10,000 c.f.s. In test 8-1, the above three revisions A, B, and C, were incorporated in the model. There was still considerable room for improvement in flow conditions. Note the irregularity of the water surface in sections A, B, C, and D shown in figure 6. Photograph A (plate II) is a view looking upstream at the conical side channel through the upper portion of the chute. Photograph B shows the spillway in operation for a discharge of 10,000 c.f.s.

Revision D - Check at Chute Entrance

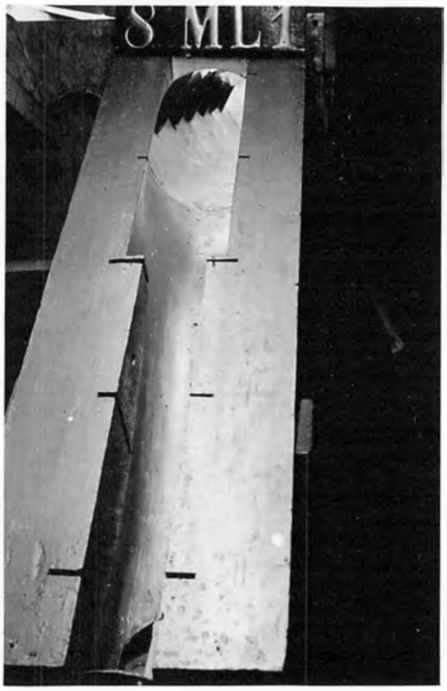
Another attempt was made to smooth out the flow by inserting checks of various heights at station 3+20. It was thought that a check of the proper height would act as a control and tend to smooth out the surface before the water entered the chute. Best results were obtained while using a check 4 feet high and this will be referred to as revision D. When the check was much lower than 4 feet, it lost the greater part of its effectiveness in smoothing out the flow, and when it was higher than this amount, it increased the submergence at the upper end of the crest. For a more detailed description of these checks see the log of tests in the appendix.

Test 7-1 (figure 7) shows the plot of a run at maximum discharge with a flat topped check 4 feet high installed at station 3+20. Photograph C (plate II) shows a picture of the check, and photograph



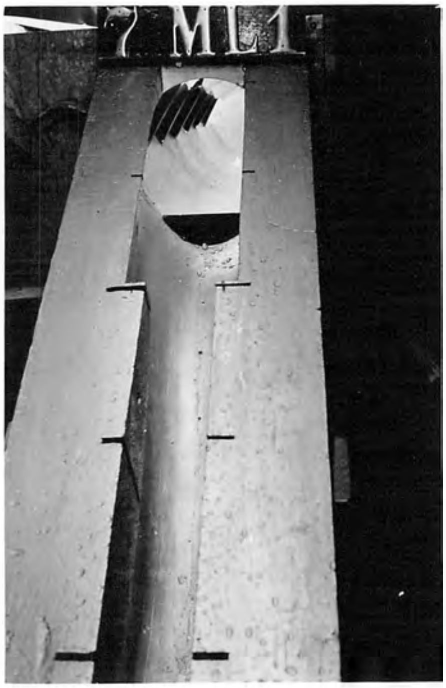
Crest El 8131.0
STA 1+10
STA 2+00
STA 2+90
STA 1+70
STA 2+60
STA 1+40
STA 2+30
SEC. A
SEC. B
SEC. C
SEC. D
SEC. E
SEC. F
SEC. G
SEC. H
SEC. J
SEC. K
SEC. L
PROTOTYPE SCALE IN FT
MODEL SCALE IN INCHES
DISCHARGE (CFS) Mod 0.994 Proto 10,028
HEAD (FT) Mod 0.1445 Proto 5.78
℄ Side channel, ℄ Tunnel
End of Pier
℄ Piers
PIEZOMETERS
REMARKS
Revisions A,B, and C incorporated in model
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT—UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
WATER SURFACE PROFILES
TEST NO. 8-ML-1
DRAWN R.K.V.
TRACED K.M. E.E.B.
CHECKED J.N.B.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. DEC 18, 1934
209-D-65

FIGURE 6

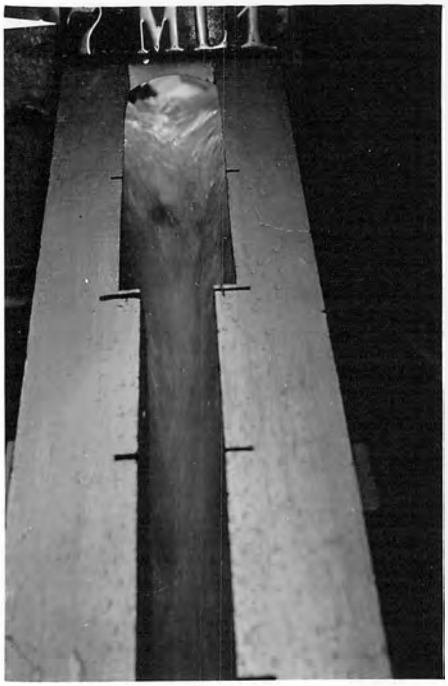


A. REVISIONS A, B, AND C.

B. REVISIONS A, B, AND C.
DISCHARGE 10,000 C.F.S.

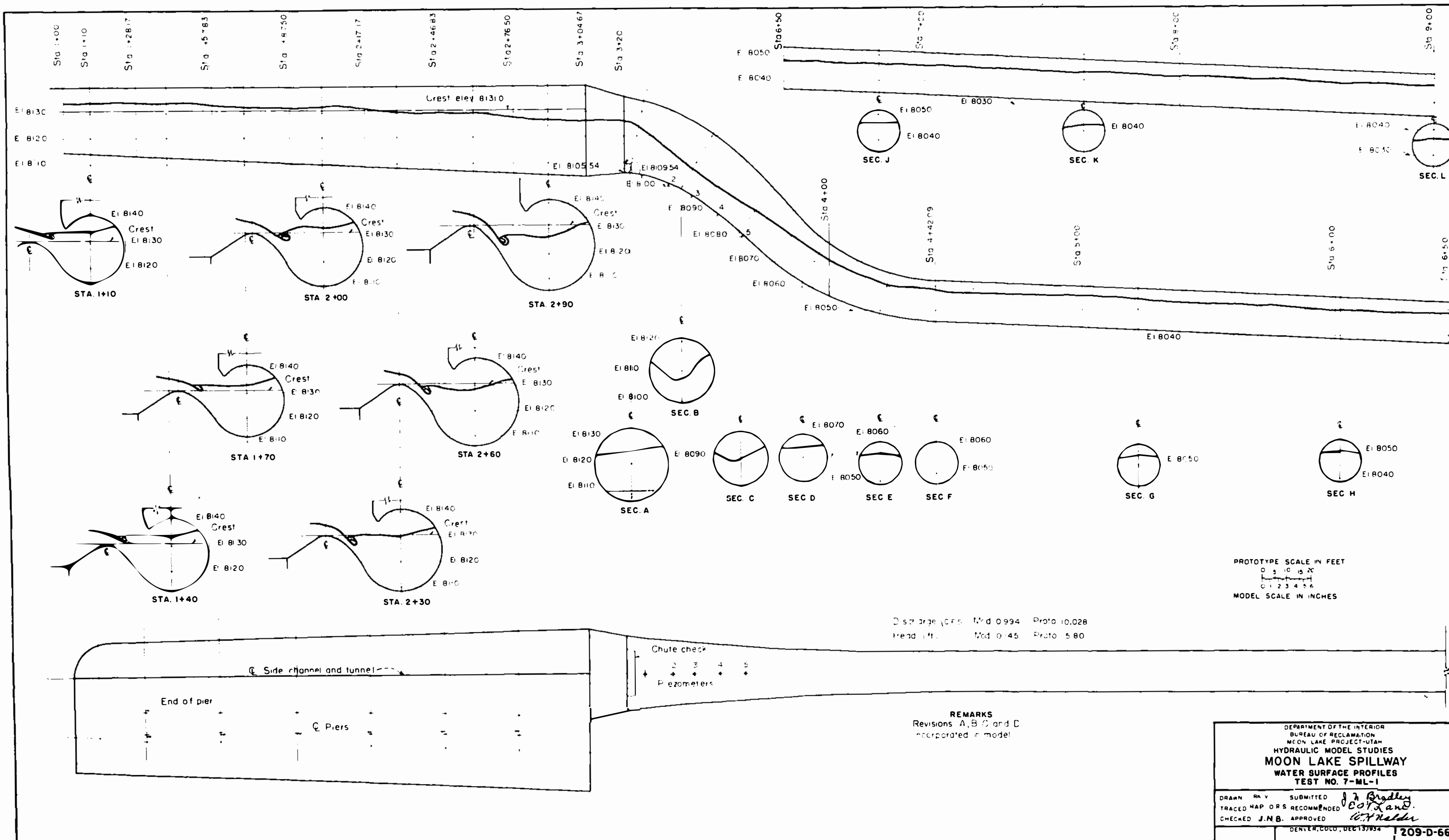


C. REVISIONS A, B, C, AND D.



D. REVISIONS A, B, C, AND D.
DISCHARGE 10,000 C.F.S.

REVISED DESIGNS.
LOOKING UPSTREAM THROUGH CHUTE.



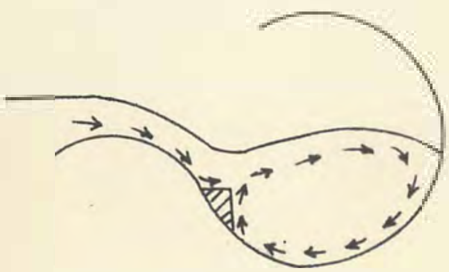
Crest elev 8131.0
El 8105.54
El 8109.54
Chute check
Piezometers
C Side channel and tunnel
End of pier
C Piers
STA. 1+10
STA. 2+00
STA. 2+90
STA. 1+70
STA. 2+60
STA. 1+40
STA. 2+30
SEC. A
SEC. B
SEC. C
SEC. D
SEC. E
SEC. F
SEC. G
SEC. H
SEC. J
SEC. K
SEC. L
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
REMARKS
Revisions A, B, C and D incorporated in model
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
WATER SURFACE PROFILES
TEST NO. 7-ML-1
DRAWN
TRACED
CHECKED J.N.B.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO., DEC. 13, 1934
209-D-66

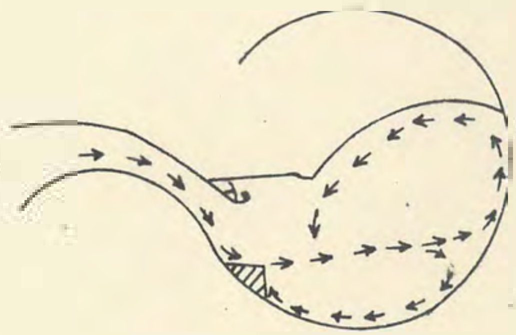
FIGURE 7

D shows the spillway discharging at a 10,000 c.f.s. with the check installed. The model as for test 7-1 involved a combination of all revisions so far made, namely A, B, C, and D. Flow conditions in the chute showed a slight but noticeable improvement over those encountered in previous tests.

Revision E - Step Sill Below Overflow Crest

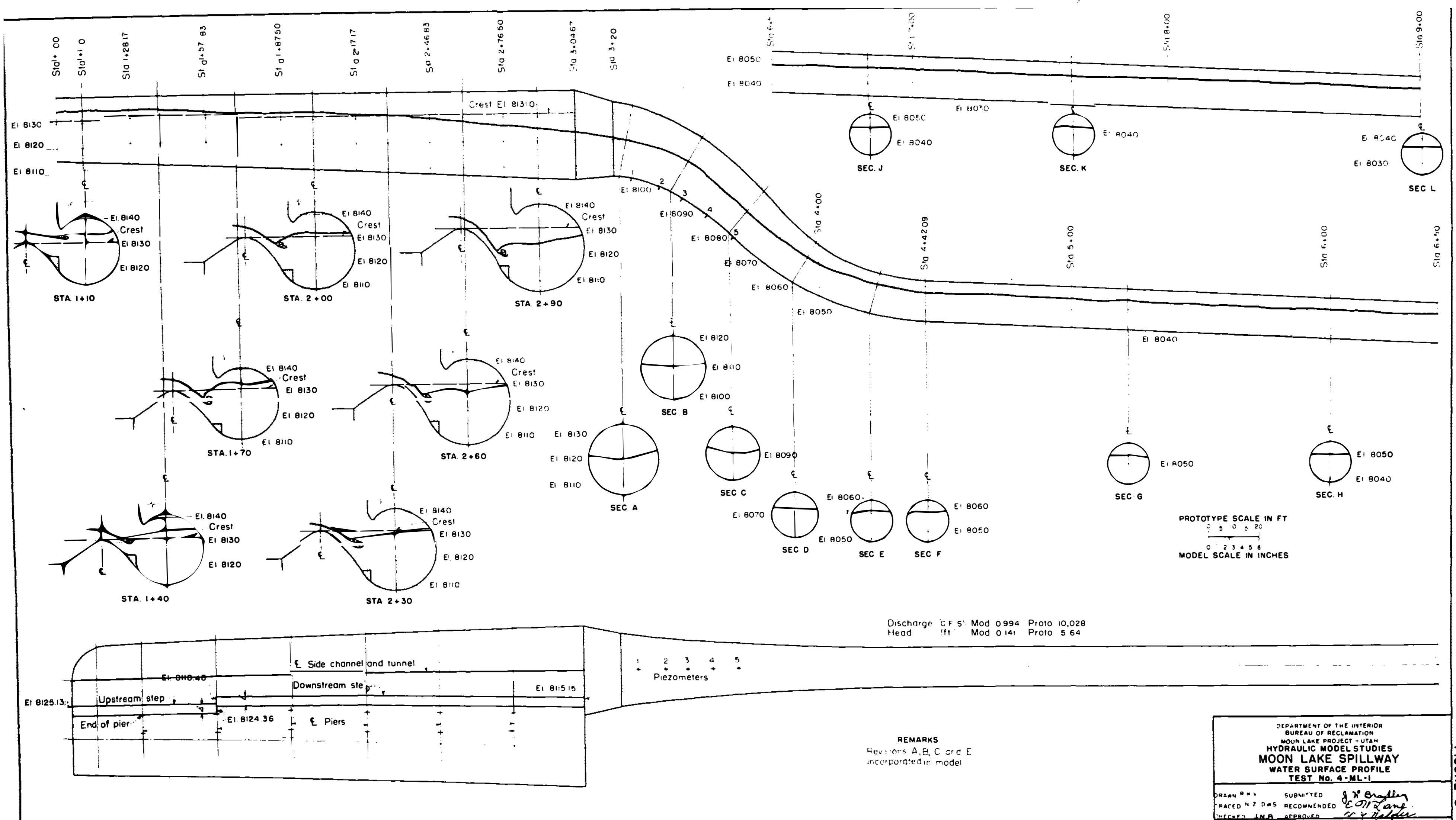
Although the revisions made thus far improved flow conditions to some extent, they failed to produce the desired results. This being the case, an attempt was made to deflect the water as it fell over the crest and prevent the familiar rolling flow from forming in the side channel. To do this, various small steps were constructed on the downstream face of the overflow section in many positions. In some cases, the step was in one piece extending the full length of the crest, while in others, it was made in two pieces with the upstream piece set higher on the overflow section than the downstream piece. Results obtained using these steps were very encouraging as the intensity of the rolling motion was greatly reduced. Likewise, flow conditions in the chute were much improved. The best results were obtained with the step in two pieces. The upstream piece was placed directly against the downstream edge of the piers from station 1+00 to station 1+57.83. The downstream piece was set about 6 feet down the overflow face from the downstream edge of the piers, from station 1+57.83 to station 3+04.67. The actual locations of these steps are shown in the sketch of the recommended design on figure 5. The upstream step reversed the customary roller in the upper portion of the side channel as shown below in sketch I. The downstream step split the jet so that a roller was formed in both directions as shown below in sketch II. In this case, the counter clockwise roller predominated.


Sketch I


Sketch II

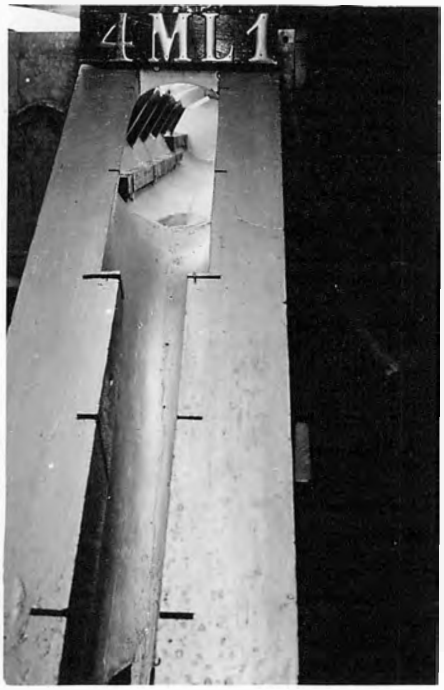
This combination of rollers evidently counteracted one another to some extent as very good flow conditions were produced in the side channel, chute, and tunnel. For a more detailed account of the various step sills tried and their locations, see the appendix of this report.

Test 4-1 (figure 8) shows a profile on the center line and some sections for a run at maximum discharge using steps 4 feet wide installed as shown in figure 5. Photograph A (plate III) is a view of the layout, and photograph B shows the spillway operating at 10,000 c.f.s. The model during these tests had incorporated in it revisions A, B, C, and E (D being omitted).

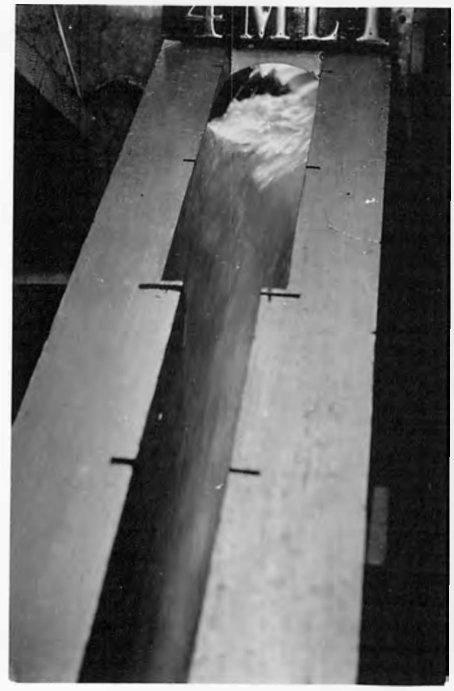


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT - UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
WATER SURFACE PROFILE
TEST No. 4-ML-1
Discharge (C.F.S.) Mod 0.994 Proto 10,028
Head (ft) Mod 0.141 Proto 5.64
REMARKS
Revisions A, B, C and E incorporated in model
PROTOTYPE SCALE IN FT
MODEL SCALE IN INCHES
Side channel and tunnel
Downstream step
Upstream step
End of pier
Piers
Piezometers
Crest El 8131.0
STA. 1+10
STA. 1+40
STA. 1+70
STA. 2+00
STA 2+30
STA. 2+60
STA. 2+90
SEC. A
SEC. B
SEC. C
SEC. D
SEC. E
SEC. F
SEC. G
SEC. H
SEC. J
SEC. K
SEC. L

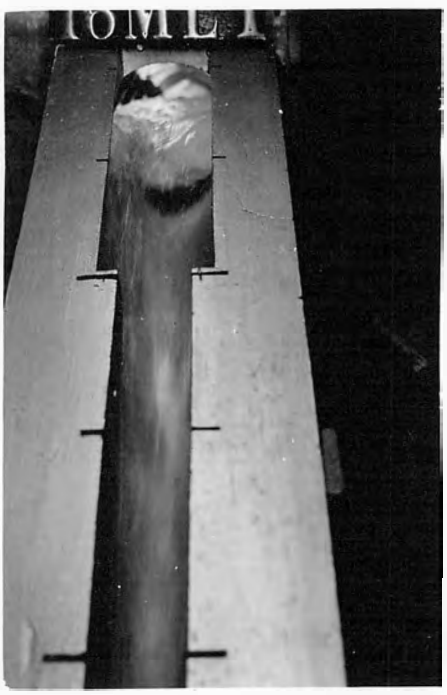
FIGURE 8



A. REVISIONS A, B, C, AND E.



B. REVISIONS A, B, C, AND E.
DISCHARGE 10,000 C.F.S.



C. RECOMMENDED DESIGN.
DISCHARGE 10,000 C.F.S.

D. RECOMMENDED DESIGN.
DISCHARGE 6,000 C.F.S.

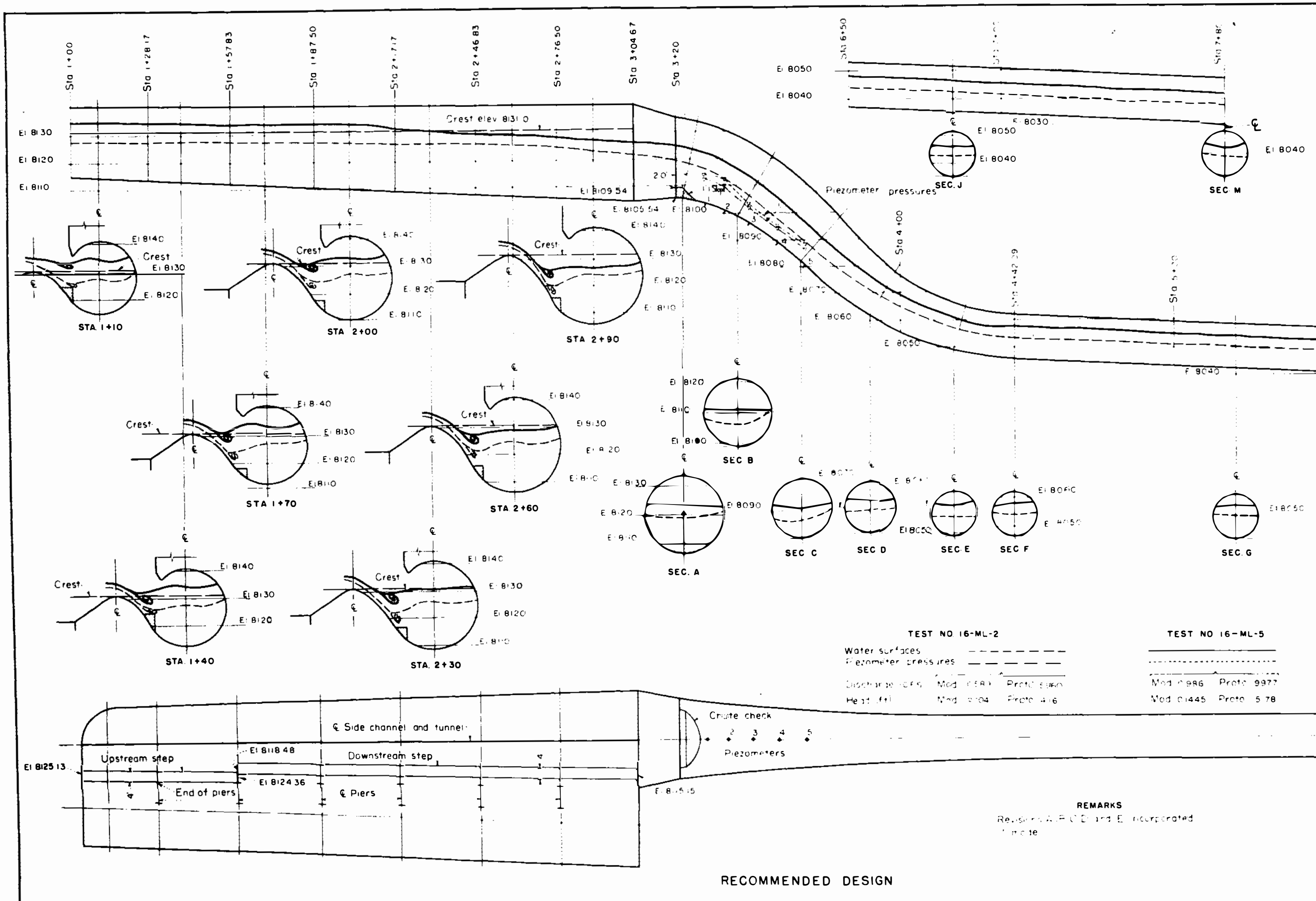
REVISED DESIGNS.
LOOKING UPSTREAM THROUGH CHUTE.

THE RECOMMENDED SPILLWAY DESIGN

The layout recommended to the design department as the best from a hydraulic standpoint, had incorporated in it all revisions thus far made, namely A to E inclusive. It was found that flow conditions were further improved when both the step on the crest and the check at the chute portal were installed in the model. The step broke up the rolling motion in the channel, and the check acted as a control helping to level off the surface of the water before it entered the chute. As the proposed revisions offered no especially difficult problems from a structural standpoint, the design department accepted the layout recommended by the hydraulic research department.

Tests 16-5 and 16-2 (figure 9) show the center line profiles and some sections taken along the channel, chute, and tunnel for runs of 10,000 c.f.s. and 6,000 c.f.s. respectively for the model as finally revised. Tests 16-1 and 16-3 (figure 10) are plotted for runs of 8,000 c.f.s. and 4,000 c.f.s. Photographs C and D (plate III) show the model of the recommended spillway discharging at 10,000 and 6,000 c.f.s. respectively.

With some of the previous layouts, flow conditions for a discharge of 6,000 c.f.s. were in some cases inferior to those at maximum discharge. For the recommended design, however, it can be seen from the plots and pictures that flow conditions were very satisfactory at all discharges. A sketch of the spillway as recommended is shown in figure 5. A drawing of the original design is also shown

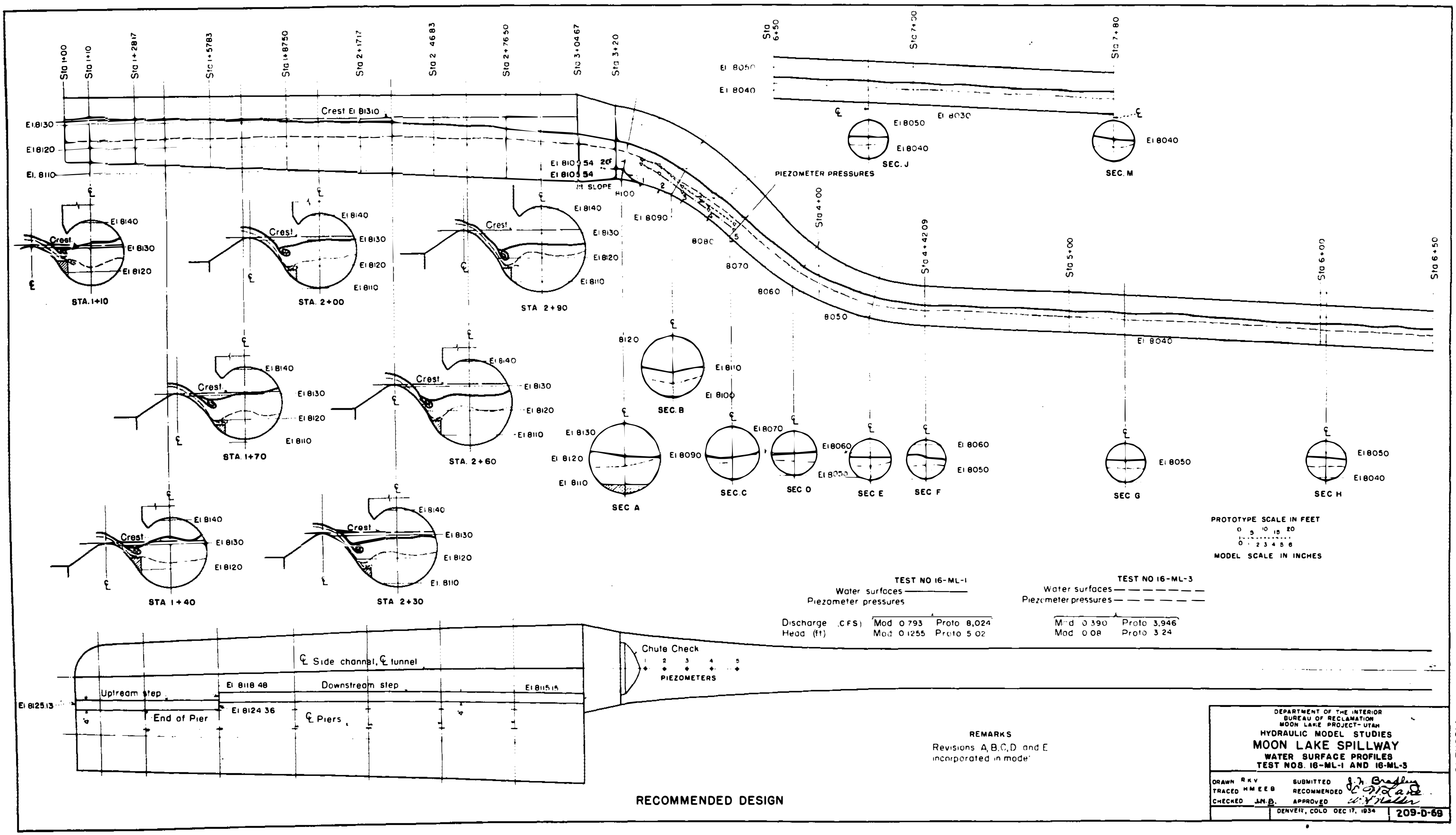


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
HYDRAULIC MODEL STUDIES

MOON LAKE SPILLWAY
WATER SURFACE PROFILES
TESTS NOS. 16-ML-2 AND 16-ML-5

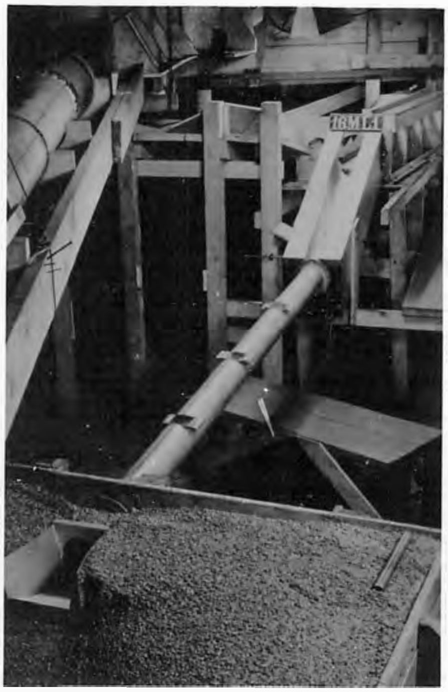
DRAWN R.K.V. SUBMITTED J. N. Bradley
TRACED H.M.ORS. RECOMMENDED E.W. Lane
CHECKED J.N.B. APPROVED W.F. Nelder
DENVER, COLO., DEC. 19, 1934 209-D-68

FIGURE 9

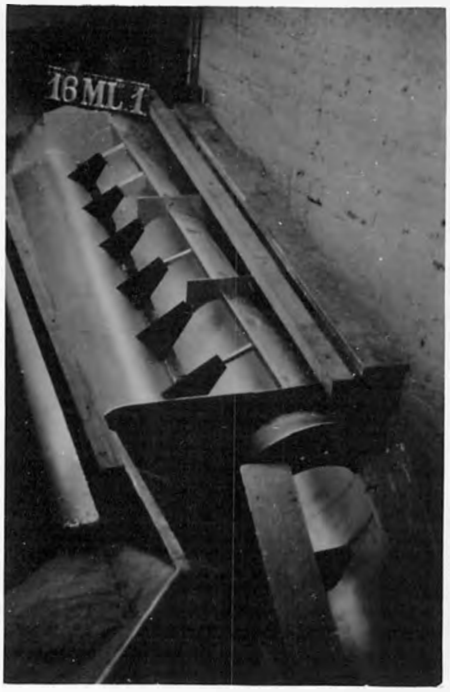


Crest El 8131.0
Sta 1+00
Sta 1+10
Sta 1+28.17
Sta 1+57.83
Sta 1+87.50
Sta 2+17.17
Sta 2+46.83
Sta 2+76.50
Sta 3+04.67
Sta 3+20
Sta 4+00
Sta 4+42.09
Sta 5+00
Sta 6+00
Sta 6+50
Sta 7+00
Sta 7+80
PIEZOMETER PRESSURES
STA. 1+10
STA. 2+00
STA 2+90
STA. 1+70
STA. 2+60
STA 1+40
STA 2+30
SEC A
SEC. B
SEC. C
SEC D
SEC E
SEC F
SEC G
SEC H
SEC. J
SEC. M
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
TEST NO 16-ML-1
Water surfaces
Piezometer pressures
TEST NO 16-ML-3
Water surfaces
Piezometer pressures
Discharge (CFS) Mod 0.793 Proto 8,024
Head (ft) Mod 0.1255 Proto 5.02
Mod 0.390 Proto 3,946
Mod 0.08 Proto 3.24
Side channel, tunnel
Upstream step
Downstream step
End of Pier
Piers
Chute Check
PIEZOMETERS
REMARKS
Revisions A, B, C, D and E incorporated in model
RECOMMENDED DESIGN
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT - UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
WATER SURFACE PROFILES
TEST NOS. 16-ML-1 AND 16-ML-3
DRAWN R.K.V. SUBMITTED
TRACED H.M.E.E.B. RECOMMENDED
CHECKED J.N.B. APPROVED
DENVER, COLO. DEC. 17, 1934
209-D-69

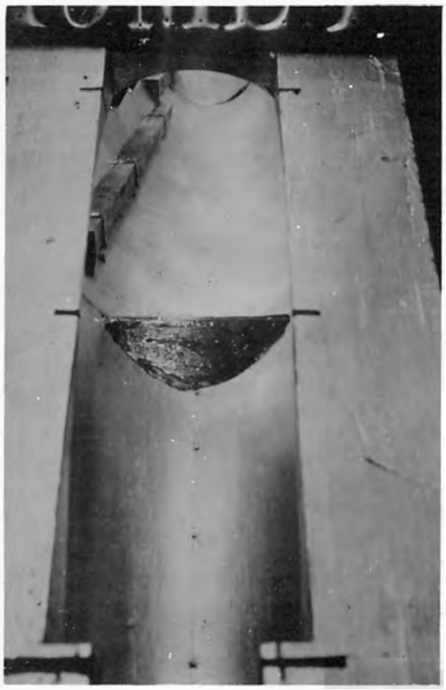
FIGURE 10



A. GENERAL VIEW OF MODEL.



B. VIEW OF SIDE CHANNEL AND OVERFLOW SECTION.



C. VIEW LOOKING UPSTREAM THROUGH PORTAL OF CHUTE.

D. SPILLWAY - DISCHARGE 10,000 C.F.S.

RECOMMENDED DESIGN.
REVISIONS A, B, C, D, AND E.

on the same page for the purpose of comparison. Other photographs of the model representing the recommended design are shown on plate IV.

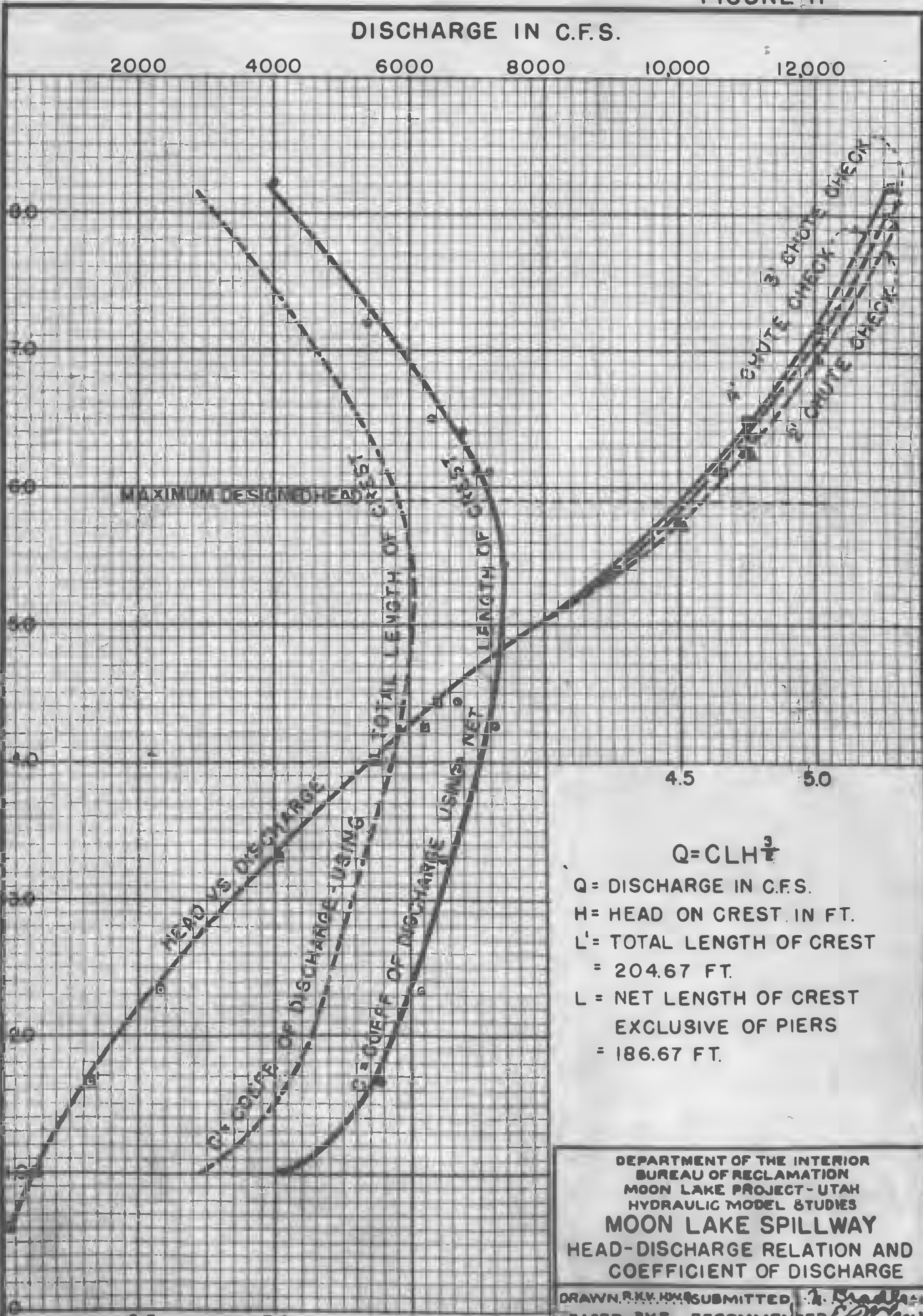
The pressures recorded by the five piezometers which were located in the invert of the chute are shown plotted on figures 9 and 10 for the four runs made on the recommended design. In no case was a pressure recorded which was below atmospheric.

A false floor made of sheet metal was installed in the upper portion of the chute commencing at the top of the 4-foot check and extending downstream 35 feet to a point where it joined the invert of the chute as shown in sketch A, figure 5. With this in place, the upper portion of the chute was transformed into a horseshoe section with the invert horizontal (perpendicular to the center line of the spillway). Inasmuch as there were no pressures recorded below atmospheric without the false floor, it is practically certain that this would also be true with the false floor installed. As it would have meant a considerable amount of work to get pressures on the false floor and as time was limited, they were not obtained. However, there seems to be no objectionable reason against raising the chute invert in the prototype, if desired. Observations showed the water surface in the chute to be as smooth with this false floor as without it, at all discharges.

It was found that water flowing from the original diversion tunnel to the 16.5-foot spillway tunnel produced a negligible effect on flow conditions in the latter.

THE COEFFICIENT OF DISCHARGE AND THE HEAD DISCHARGE RELATION

As it is difficult to estimate the coefficient of discharge for an overflow section such as that of the Moon Lake spillway, where part of the crest is submerged at maximum discharge, a series of runs were made on the model to determine the coefficient experimentally for various heads. Using the formula $Q = CLH^{3/2}$, the coefficients were computed using two crest lengths namely, the full length of crest or 204.67 feet, and the net length of crest (exclusive of the pier widths) or 186.67 feet. These coefficients are plotted as two separate curves on figure 11. Due to the piers being located on the downstream side of the overflow section rather than on top of the crest as is usually the case, doubt was expressed as to what extent the piers would affect the flow over the crest - hence the two curves. The piers did affect the discharge, but not as much as would have been the case had they been located on top of the crest. Also plotted on figure 11, indicated by a heavy full line, is a curve showing the relation head bears to discharge in the recommended design. Submergence commences when the head on the crest reaches about 5 feet, as both the head-discharge and coefficient curves indicate. Above 5 feet, the value of the coefficient falls off and likewise the rate at which the discharge is increasing, decreases. For the maximum designed discharge of 10,000 c.f.s., the head on the crest is 5.90 feet and the coefficient of discharge computed using the net crest length is 3.80.



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT - UTAH
HYDRAULIC MODEL STUDIES

MOON LAKE SPILLWAY

HEAD-DISCHARGE RELATION AND COEFFICIENT OF DISCHARGE

DRAWN R.K.V. H.V.B.	SUBMITTED
TRACED R.V.P.	RECOMMENDED
CHECKED J.N.B	APPROVED

DENVER, COLO., 12-26-34 209-D-70

The maximum capacity of the spillway is about 13,000 c.f.s. but this would require a head of about 8.2 feet on the crest. At this discharge, submerged flow existed at the upper four pier spaces, the chute was flowing partially full, and the 16.5-foot tunnel was flowing practically full. Note how the coefficient of discharge drops from 3.80 for a discharge of 10,000 c.f.s. to 3.00 for a discharge of 13,000 c.f.s. (figure 11).

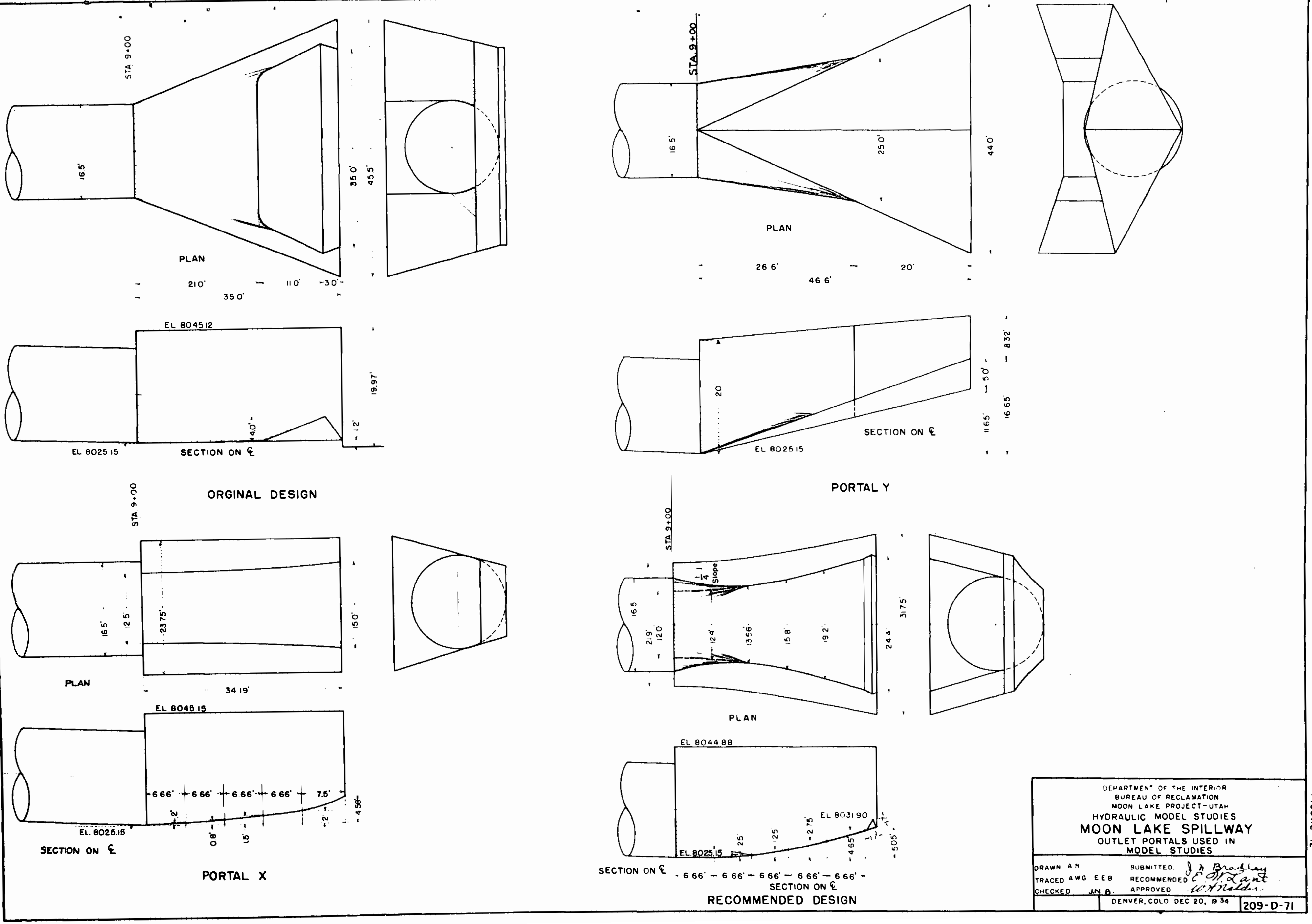
Successive calibration runs were made on the model of the recommended design with checks 2, 3, and 4 feet in height placed at the chute portal in order to determine how the height of the check affects the water surface in the side channel, and in turn, the discharge over the crest. The results of these tests are plotted with broken lines on the head-discharge curve in figure 11. Up to a head of 5 feet on the crest, the checks did not affect the discharge. For a head above 5 feet, the checks decreased the discharge over the crest directly as the height of the check increased. For the designed head of 5.90 feet, the check 4 feet in height decreased the discharge about 500 c.f.s. as compared with the corresponding discharge for the spillway with all checks removed. As the head required for a discharge of 10,000 c.f.s. was still less than 6 feet and flow conditions were much the best in the chute and tunnel when the 4-foot check was installed, it was adopted in the recommended design.

THE OUTLET PORTAL

Original Design

Inasmuch as erosion of the river bed below the tunnel outlet can have no serious consequences, no attempt was made to design the outlet to cause the formation of a hydraulic jump. Instead, it was designed to shoot the jet upward and outward so as to clear the outlet and strike the river some 150 feet downstream. As the outlet portal will be constructed on a sand and gravel deposit, the problem in this particular case is to reduce back wash, produced by the jet striking the river, to a minimum.

It was found that the outlet as originally designed (See original design, figure 12) would be endangered by undercutting. A large fin was present at each side of the fan-shaped jet which upon striking the river created a whirlpool on each side of the portal structure. The high velocity currents undercut the portal and also washed away most of the sand that was piled against the side walls when the tailwater elevation was normal or greater than normal. Photographs A and B (plate V) show two views of the jet issuing from the original portal. Notice the heavy fin on each side of the fan and the resulting whirlpools on each side of the structure. Photograph C (plate V) is a picture of the sand box after a 15-minute run at maximum discharge and normal tailwater. If it had not been for the board and the bricks shown in the photographs, practically all of the sand which is behind them would have been eroded. Unfortunately there were no pictures taken to verify the fact, but in previous tests made without the board and bricks, the



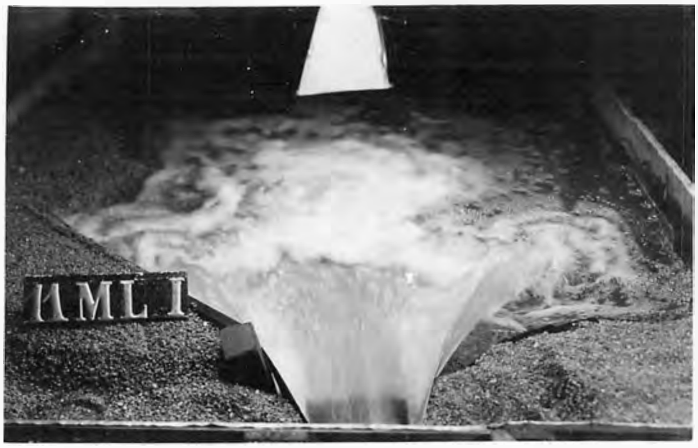
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT–UTAH
HYDRAULIC MODEL STUDIES

MOON LAKE SPILLWAY

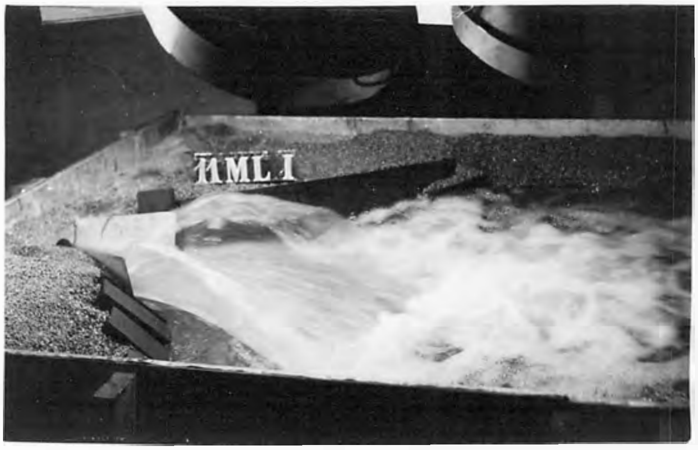
OUTLET PORTALS USED IN MODEL STUDIES

DRAWN A.N.	SUBMITTED J. E. Bradley
TRACED AWG EEB	RECOMMENDED E. W. Lane
CHECKED J.N.B.	APPROVED W. H. Nalder
	DENVER, COLO. DEC. 20, 1934 — 209-D-71

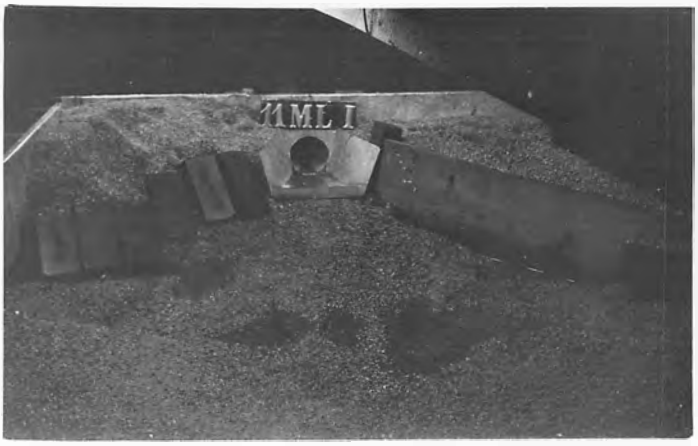
FIGURE 12



A. PLAN VIEW OF JET.



B. VIEW SHOWING TRAJECTORY OF JET.



C. SAND BED AFTER 15 MINUTE RUN.

ORIGINAL DESIGN OF OUTLET PORTAL.
DISCHARGE 10,000 C.F.S.

portal was left standing with practically nothing to support it.

Model tests were made on the portal structure in an effort to eliminate the fins on the sides of the fan-shaped jet and to shoot the jet as far down the river as possible. It should be mentioned, that due to the limited amount of space in the laboratory, it was necessary to cut 120 feet off of the 16.5-foot tunnel in order to make the tests on the outlet portals. It was desired not to build the spillway model on a scale smaller than 1:40 so shortening the tunnel was the next best thing to do.

Portal X

As a first attempt to improve conditions about the outlet portal, the structure was revised as shown for portal X in figure 12. The side walls were drawn in parallel, the sill was omitted, and the floor was changed to slope upward in a downstream direction. The resulting jet was more concentrated and did shoot farther out into the river than the one in the original design. Its concentrated shape, however, caused considerable disturbance in the form of waves and surges which gradually washed away a good part of the material around the portal. Erosion was less pronounced than in the former case, but was still sufficient to make it necessary to classify this structure as questionable. Photograph A (plate VI) shows this portal in operation, and photograph B shows the sand box after a run of 15 minutes duration.

A. VIEW SHOWING TRAJECTORY OF JET.
DISCHARGE 10,000 C.F.S.

C. VIEW OF JET.
DISCHARGE 10,000 C.F.S.

B. SAND BED AFTER 15 MINUTE RUN.

OUTLET PORTAL X.

D. SAND BED AFTER 15 MINUTE RUN.

OUTLET PORTAL Y.

Portal Y

A third but entirely different type of portal which was tried on the model is shown as portal Y, in figure 12. The floor on the center line, beginning at station 9+00, sloped upward in a downstream direction with a slope of 0.375. From the center line, the floor sloped downward on either side until it met the side walls. The lines of intersection on the floor with the side walls had slopes of 0.25. A cross section taken perpendicular to the center line would show the floor to be of triangular shape. The purpose in sloping the floor away from the center line was to spread the jet laterally giving an exceptionally wide fan of equal thickness. In addition, the upward slope in the downstream direction should throw the jet a considerable distance out into the river.

The results obtained from the model of this portal did not come entirely up to expectations. The jet had a wide spread of uniform thickness but it did not carry as far down the river as was desired. It was impossible to increase the slope of the floor in the direction of the center line as it was already necessary that the tunnel be three-fourths full before water could begin to run over the downstream end of the portal floor. Photograph C (plate VI) shows this portal in operation, and photograph D is a view of the sand box after a 15-minute run.

In an attempt to increase the horizontal trajectory of the jet, a small triangular sill was constructed at the end of the portal floor. As a result, the water instead of jumping straight off the end of the floor veered to either side, making the jet thin at the center and thick at the sides. This was exactly the condition experienced in the original design.

The Recommended Portal Design

After a series of tests on floors of different slopes and side walls flaring at various angles, a portal was constructed which embodied a combination of the original design and portal X.

The flaring side walls resembled the original design and the parabolic slope on the floor was similar to that in portal X. In addition, a small triangular sill was constructed on the end of the floor to give the jet increased elevation. A sketch of this portal which is designated at the "Recommended Design" is shown in figure 12. Photographs of the portal discharging at 10,000 c.f.s. are shown in B (plate VII) and A (plate VIII). Photographs A and C (plate VII) show the river bed before and after a 15-minute run made at maximum discharge and normal tailwater. The tags shown in C represent elevations from 8013 to 8105. Photographs B and C (plate VIII) show the recommended portal discharging at 6,000 and 2,000 c.f.s. respectively.

It can be observed from the photographs that this portal worked very well. The jet did not spread as evenly as in the initial design of portal Y, but it did carry to a point farther down the river. Very little back wash was noticeable at any discharge and erosion was a minimum. Notice in the pictures showing the portal in operation, that with normal tailwater, the river bed under the

A. SAND BED BEFORE RUN.

B. DISCARGE 10,000 C.F.S.

C. SAND BED AFTER 15 MINUTE RUN.

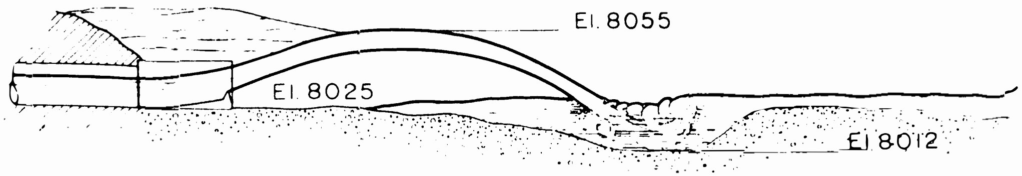
RECOMMENDED OUTLET PORTAL DESIGN.

A. DISCHARGE 10,000 C.F.S.

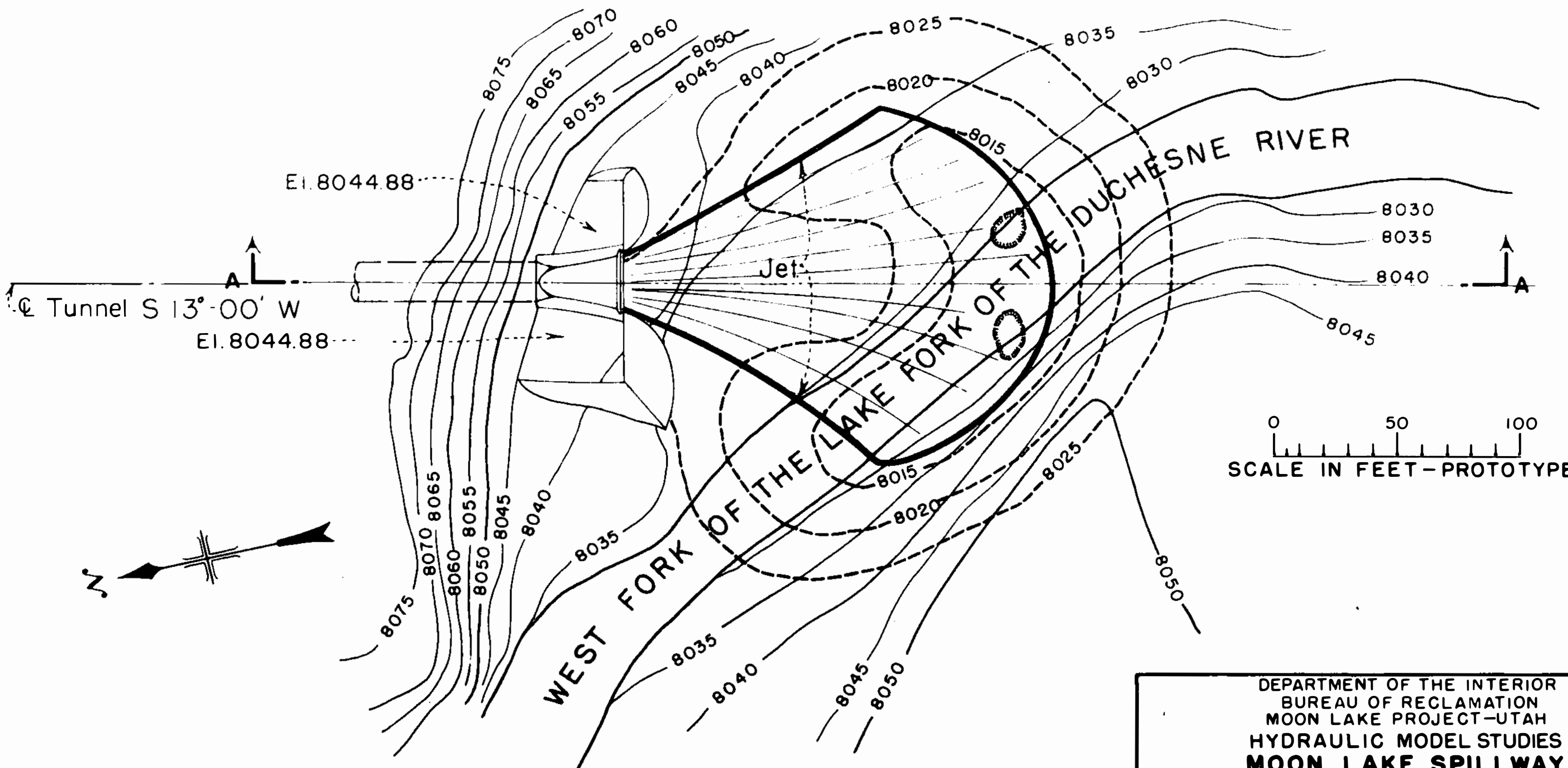
B. DISCHARGE 6,000 C.F.S.

C. DISCHARGE 2,000 C.F.S.

RECOMMENDED OUTLET PORTAL DESIGN



SECTION A-A (AFTER 15 MINUTE RUN)



EXPLANATION

Full contours show present topography at portal site.
Dashed contours show topography of model sand-box after 15 minute run.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MOON LAKE PROJECT-UTAH
HYDRAULIC MODEL STUDIES
MOON LAKE SPILLWAY
TRAJECTORY OF JET AT OUTLET PORTAL
RECOMMENDED DESIGN

DRAWN R.K.V. SUBMITTED J. N. Bradley
TRACED D.S.Y. O.R.S. RECOMMENDED E. W. Lane
CHECKED J.N.B. APPROVED W. H. Nalder

DENVER, COLO., DEC. 27, 1934 | **209-D-72**

FIGURE 13

jet was unwatered for all discharges. This was due almost entirely to the absence of back wash.

Figure 13 shows a plan and section (drawn to scale) of the jet discharging at 10,000 c.f.s. with normal tailwater. The full lines represent the present topography at the portal site. The dotted lines indicate the topography of the sand in the model sand box after a 15-minute run at maximum discharge.

It should be mentioned, that erosion shown by the model is not in any way indicative of the amount of erosion that will occur in the prototype. It indicates only where it will probably occur. Sand box tests are of greater value as a means of comparison. In other words, it can be definitely stated that the layout in one test is better than that in another as erosion indicated by the model was less in the first than in the second.

A complete summary of all model tests made on the Moon Lake spillway is recorded in the appendix of this report.

ACKNOWLEDGMENTS

The construction and testing of the Moon Lake spillway model was under the supervision of J.B. Drisko who is in charge of the hydraulic section of the laboratory. He was assisted by Junior Engineers H.M. Martin and L.R. Brooks who were in charge of construction, and J.M. Buswell and F.L. Fanuzio who directed the test crew. The illustrations used in this report and the necessary office computations were worked up by Junior Engineers R.K. Vierck, A.H. Neal H.W. Brewer and E.C. Parks.

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APPENDIX

MOON LAKE SPILLWAY - MOON LAKE PROJECT

LOG OF TESTS

Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Width in ft.	Step On Overflow Section: Step	Elevation in ft.: Upstream End	Elevation in ft.: Downstream End	Outlet Portal	Note: The break between the upstream and downstream steps occurs at Sta. 1+57.83. Unless otherwise stated, all checks are 2 ft. wide and have vertical upstream and downstream faces. Remarks
1-1	10,042	Original	2.57-L	Original	None	--	None	---	---	None	Choking effect at tunnel entrance.
2-1	10,000	See Remarks	2.57-L	Original	None	--	None	---	---	None	Flattened upper portion of chute curve with Plasticene; had no effect.
2-2	10,000	Original	2.57-R	Original	None	--	None	---	---	None	Conditions as bad as for 1-1.
2-3	10,000	Original	0.00 (Rev. B)	Original	None	--	None	---	---	None	Best chute position in relation to spillway.
2-4	10,000	Original	Rev. B	Original	None	4	See	remarks		None	Tried steps on ogee below piers. Square step discarded. Triangular step very effective in eliminating whirl of water in side channel, and stopping spiral flow down chute.
2-5	10,000	Original	Rev. B	Original	3, 4 & 6	4	One-piece	8122.75	8115.86	None	Check helped to level the flow thru chute.
2-6 & 2-7	10,000	Original	Rev. B	See Remarks (Rev. C)	3	4	"	8122.75	8115.86	None	Rev. C - Installed smooth transition from 36' dia. side channel to 30' dia. chute, and removed protruding vane from across sec. at Sta. 3+04.67. Improved flow down chute.

APPENDIX (Continued)

						Step On Overflow Section					
								Elevation in ft.			
Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Width in ft.	Step	Upstream End	Downstream End	Outlet Portal	Remarks
2-8	10,000	Original	Rev. B	Rev. C	3	4	One-piece	8122.75	8115.86	None	Includes Rev. B, C, 3' check, and 4' step. Best arrangement. Flow conditions fair.
3-1	10,000	See Remarks (Rev. A)	"	"	3	4	Up-str'm Down-str'm	8125.13 8119.19	8124.36 8115.86	None	Rev. A - Changed chute profile curve and tunnel dia. (from 15' to 16.5'). Flow in side channel, down chute, and thru tunnel quiet and smooth.
3-2	10,000	Rev. A	"	"	3	4	Up-str'm Down-str'm (Rev.E)	8125.13 8118.48 (Rev.E)	8124.36 8115.15 (Rev.E)	None	Various positions and different lengths of steps tried. Best arrangement (Rev. E) - Upstream step at base of 2 upstream piers, downstream step 6' down ogee from base of 5 downstream piers.
4-1	10,028	"	"	"	3	4	Rev.E	Rev.E	Rev.E	None	Same arrangement as 3-2. Flow conditions good.
5-1	10,028	"	"	"	4	4	"	"	"	None	Same as 4-1 except check 4' high and 3' wide used. Flow improved.

APPENDIX (Continued)

						Step On Overflow Section					
								Elevation in ft.			
Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Width in ft.	Step	Upstream End	Downstream End	Outlet Portal	Remarks
6-1	9,998	Rev. A	Rev. B	Rev. C	6	4	Rev. E	Rev. E	Rev. E	None	Same as 5-1 except check 6' high and 3' wide used. Increased head over crest and splash at chute bottom.
6-2	See Remarks	"	"	"	6	3	Up-str'm Down-str'm	8125.13 8118.48	8124.36 8115.15	None	Same as 6-1 except steps 3' wide used. Coefficient of discharge runs.
7-1	10,028	"	"	"	4	-	None	--	--	None	Same as 5-1 except no steps on ogee. Flow very unsatisfactory down chute.
8-1	10,028	"	"	"	3	-	None	--	--	None	Same as 4-1 except no steps on ogee. Flow very bad down chute.
9-1	10,028	"	"	"	3	3	Up-str'm Down-str'm	8125.13 8118.48	8124.36 8115.15	None	Same as 4-1 except steps 3' wide used. Flow quite satisfactory.
9-2	6,061	"	"	"	3	3	"	"	"	None	Flow rough and splashy down chute.
9-3	1,943	"	"	"	3	3	"	"	"	None	Flow very good.
9-4	See Remarks	"	"	"	3	3	"	"	"	None	Coefficient of discharge runs.

APPENDIX (Continued)

Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Width in ft.	Step On Overflow Section: Step	Step On Overflow Section: Elevation in ft.: Upstream End	Step On Overflow Section: Elevation in ft.: Downstream End	Outlet Portal	Remarks
10-1	6,041	Rev. A	Rev. B	Rev. C	4	3	Up-str'm Down-str'm	8125.13 8118.48	8124.36 8115.15	None	Same as 9-2 except check 4' high and 3' wide used. Flow greatly improved, but still rough.
11-1	10,000	"	"	"	4	3	"	"	"	Orig.	Cut 120' off lower end of tunnel, and installed original outlet portal. Scour of river-bed bad.
11-2	10,000	"	"	"	4	3	"	"	"	See Remarks	Same as 11-1 except outlet changed to one very similar to recommended portal. Jet improved and scour reduced.
11-3	6,000	"	"	"	4	3	"	"	"	"	See remarks for 11-2.
11-4	2,000	"	"	"	4	3	"	"	"	"	See remarks for 11-2.
11-5	10,000	"	"	"	4	3	"	"	"	Portal X	Changed portal. Scour bad. Removed curved wall at Sta. 1+00; had no effect.
12-1	10,038	"	"	"	4	3	"	"	"	Recommended	Outlet portal very similar to that of 11-2.
12-2	See Remarks	"	"	"	4	3	"	"	"	"	Coefficient of discharge runs.

APPENDIX (Continued)

Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Step On Overflow Section				Outlet Portal	Remarks
						Width in ft.	Step	Elevation in ft.			
								Upstream End	Downstream End		
13-1	9,977	Rev. A	Rev. B	Rev. C	4	3	Up-str'm Down-str'm	8125.00 8118.48	8124.36 8115.15	Recommended	10' of the crest removed from upstream end. (Upstream end of upstream step is at Sta. 1+10). Flow did not change.
13-2	See Remarks	"	"	"	4	3	"	"	"	"	Coefficient of discharge runs.
14-1	10,084	"	"	"	See Rem'ks (Rev. D)	3	Up-str'm Down-str'm	8125.13 8118.48	8124.36 8115.15	"	Rev. D - Check 4' high and 2' wide on top, with vertical upstream face, and 1:1 slope on downstream face. Flow good.
14-2	See Remarks	"	"	"	Rev. D	3	"	"	"	"	Coefficient of discharge runs.
15-1	5,960	"	"	"	"	3	One-piece	8126.48	8114.08	"	Not as good as previous runs at same discharge.
16-1	8,024	"	"	"	"	4	Rev. E	Rev. E	Rev. E	"	Flow good.
16-2	5,960	"	"	"	"	4	"	"	"	"	Flow rough and noisy down chute.
16-3	3,946	"	"	"	"	4	"	"	"	"	Flow fair.
16-4	2,125	"	"	"	"	4	"	"	"	"	Flow good.

APPENDIX (Continued)

Test No.	Discharge in c.f.s	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Step On Overflow Section Width in ft.	Step	Elevation in ft. Upstream End	Downstream End	Outlet Portal	Remarks
16-5	9,977	Rev. A	Rev. B	Rev. C	Rev. D	4	Rev. E	Rev. E	Rev. E	Recommended	Flow good
16-6	See Remarks	"	"	"	"	4	"	"	"	"	Coefficient of discharge runs.
17-1	9,977	"	"	"	"	4	One-piece	8119.80	8115.15	"	Flow good.
17-2	6,071	"	"	"	"	4	"	"	"	"	Flow rough and noisy.
17-3	8,191	"	"	"	"	4	"	"	"	"	Flow good.
17-4	1,923	"	"	"	"	4	"	"	"	"	Flow good.
17-5	3,936	"	"	"	"	4	"	"	"	"	Flow good.
18-1	11,000	"	"	"	"	4	Rev. E	Rev. E	Rev. E	"	Windows put over tunnel holes.
	12,000	"	"	"	"	4	"	"	"	"	Upper half of chute put on. Flow
	13,000	"	"	"	"	4	"	"	"	"	good; becomes rougher and more noisy as discharge increases. 13,000 is max. discharge with no choking.
19-1	See Remarks	"	"	"	3	4	"	"	"	"	Coefficient of discharge runs.

Test No.	Discharge in c.f.s.	Chute and Tunnel	Chute Offset in ft.	Transition to Chute	Height of Check in ft.	Step On Overflow Section		Elevation in ft.		Outlet Portal	Remarks
						Width in ft.	Step	Upstream End	Downstream End		
20-1	See Remarks	Rev. A	Rev. B	Rev. C	2	4	Rev. E	Rev. E	Rev. E	Recommended	Coefficient of discharge runs.
H-1	10,000	"	"	"	Rev. D	4	"	"	"	Portal Y	Scour of river-bed slightly excessive.
21-1	10,000	"	"	"	"	4	"	"	"	Recommended	Finished model of recommended portal installed. Jet improved and scour reduced.
22-1	10,000	"	"	"	"	4	"	"	"	"	Visual runs with false floor installed in upper portion of chute. Flow very good at all discharges.