UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDRAULIC MODEL STUDIES FOR THE DESIGN

OF

THE TAYLOR PARK DAM SPILLWAY

----

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and

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HYD 3.8

TECHNICAL MEMORANDUM NO. 474

Denver, Colorado

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(PRICE $1.80)

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The Project

The proposed Taylor Park Dam will be located on the Taylor River about 35 miles south and somewhat west of Leadville, Colorado. It will be of the earth fill type having a height of approximately 174 feet above the river bed and the reservoir created by the dam will have a capacity of about 106,000 acre feet. This will provide some storage of irrigation water for the Uncompahgre Project and should correct for shortages of flow in the Gunnison River which have in the past occurred in the later part of the irrigation season.

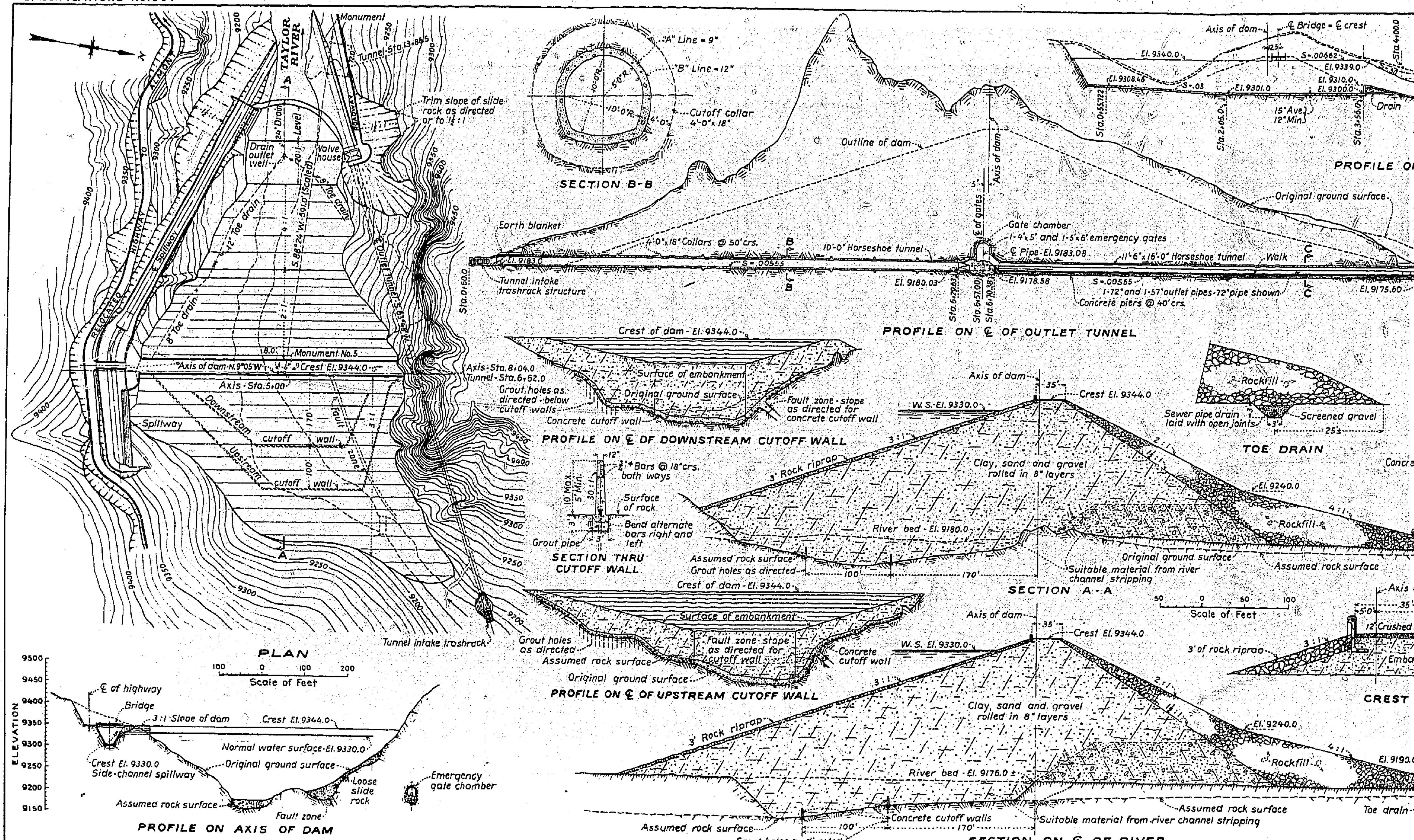
The spillway in conjunction with the dam will be of the side channel type with an open trapezoidal chute leading from the channel to the river below the dam. It will be located on the south side of the dam as shown in figure 1 and due to the nature of the topography, the spillway will have a horizontal curve beginning at the downstream end of the crest. A detailed drawing of the spillway is shown in figure 2. The overflow section will constitute a free crest approximately 180 feet long over which the maximum designed discharge of 10,000 c.f.s. should flow with a head of approximately 6 feet. As shown in figure 2, a check 8 feet high located near the downstream end of the crest will act as a control to maintain low velocities in the side channel and aid in smoothing out the surface of the water before it enters the trapezoidal chute. The upper 166 feet of the chute will be on a slope of 0.020, the next 280 feet on a slope of 0.25, the next 190 feet on a slope of 0.34, then a vertical curve will change this slope to horizontal for the remainder of the distance to the river. As the river bed is a stable rock formation, no artificial provision will be made to dissipate the energy of the water entering the river. The total drop from maximum water surface level to tailwater will be approximately 149 feet.

A tunnel in the right canyon wall will be utilized to conduct water from the reservoir to the river below the dam for irrigation demands when the spillway is not in operation.

The Laboratory

The Taylor Park Spillway was tested in the laboratory located in the basement of the Old Custom House in Denver. 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 by 12 by 4 feet deep, which



TAYLOR RIVER
Monument
Tunnel-Sta.13+86.5
Trim slope of slide rock as directed or to 1½:1
RELOCATED HIGHWAY
Spillway
Drain outlet well
24" Drain
Level
Valve house
20:1
S.88°24'W.-591.0'(Scaled)
12" Toe drain
8" Toe drain
Toe drain
€ Outlet Tunnel
Monument No.5
Axis of dam-N.9°05'W.
Crest El. 9344.0
Axis-Sta.5+00
Axis-Sta.8+04.0
Tunnel-Sta.6+62.0
Downstream cutoff wall
Upstream cutoff wall
Fault zone
Spillway
Tunnel intake trashrack
PLAN
Scale of Feet
SECTION B-B
"A" Line = 9"
"B" Line = 12"
Cutoff collar 4'-0"x18"
Outline of dam
Earth blanket
4'-0"x18" Collars @ 50' crs.
10'-0" Horseshoe tunnel
Gate chamber
1-4'x5' and 1-5'x6' emergency gates
€ Pipe-El. 9183.08
11'-6"x16'-0" Horseshoe tunnel
Walk
Tunnel intake trashrack structure
El. 9180.03
El. 9178.58
S=.00555
1-72" and 1-57" outlet pipes-72" pipe shown
Concrete piers @ 40' crs.
Original ground surface
PROFILE ON € OF OUTLET TUNNEL
Axis of dam
€ Bridge = € crest
El. 9340.0
El. 9339.0
El. 9310.0
El. 9301.0
El. 9300.0
15" Ave. 12" Min.
Drain
PROFILE ON
Crest of dam-El. 9344.0
Surface of embankment
Original ground surface
Grout holes as directed below cutoff walls
Concrete cutoff wall
Fault zone-slope as directed for concrete cutoff wall
PROFILE ON € OF DOWNSTREAM CUTOFF WALL
¾" Bars @ 18" crs. both ways
Surface of rock
Bend alternate bars right and left
Grout pipe
SECTION THRU CUTOFF WALL
Axis of dam
Crest El. 9344.0
W.S.-El. 9330.0
3' Rock riprap
Clay, sand and gravel rolled in 8" layers
River bed - El. 9180.0
El. 9240.0
Rockfill
Assumed rock surface
Grout holes as directed
Original ground surface
Suitable material from river channel stripping
SECTION A-A
Rockfill
Sewer pipe drain laid with open joints
Screened gravel
TOE DRAIN
Scale of Feet
Crest of dam-El. 9344.0
Surface of embankment
Grout holes as directed
Assumed rock surface
Original ground surface
Fault zone-slope as directed for cutoff wall
Concrete cutoff wall
PROFILE ON € OF UPSTREAM CUTOFF WALL
Axis of dam
Crest El. 9344.0
W.S. El. 9330.0
3' Rock riprap
Clay, sand and gravel rolled in 8" layers
River bed - El. 9176.0±
El. 9240.0
Rockfill
El. 9193.0
Assumed rock surface
Concrete cutoff walls
Suitable material from river channel stripping
Grout holes as directed
Toe drain
SECTION ON € OF RIVER
3' of rock riprap
12" Crushed
Embar
CREST
ELEVATION
€ of highway
Bridge
3:1 Slope of dam
Crest El. 9344.0
Normal water surface-El. 9330.0
Crest El. 9330.0 Side-channel spillway
Original ground surface
Loose slide rock
Emergency gate chamber
Assumed rock surface
Fault zone
PROFILE ON AXIS OF DAM

FIG. 1

DRAWING No. 23

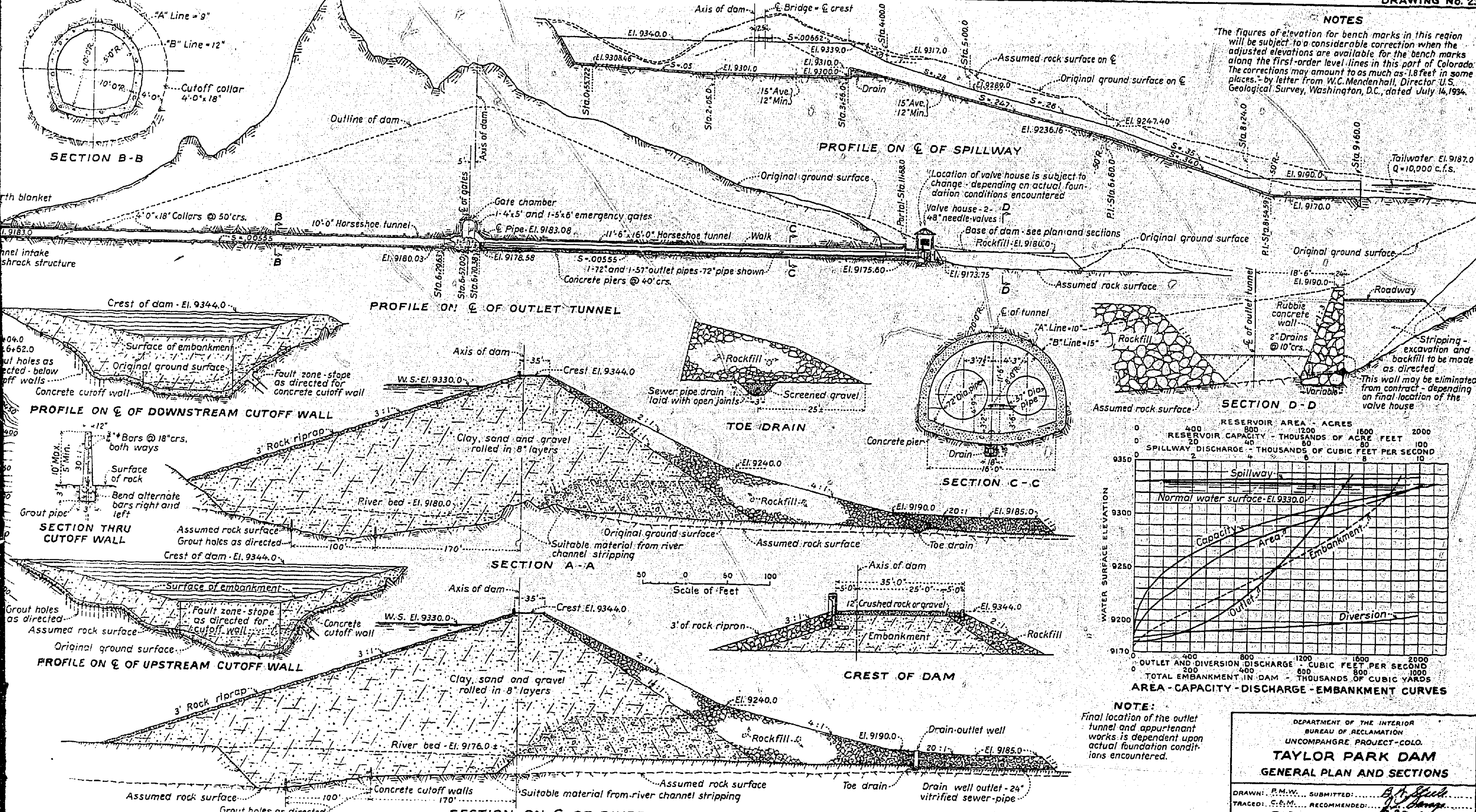
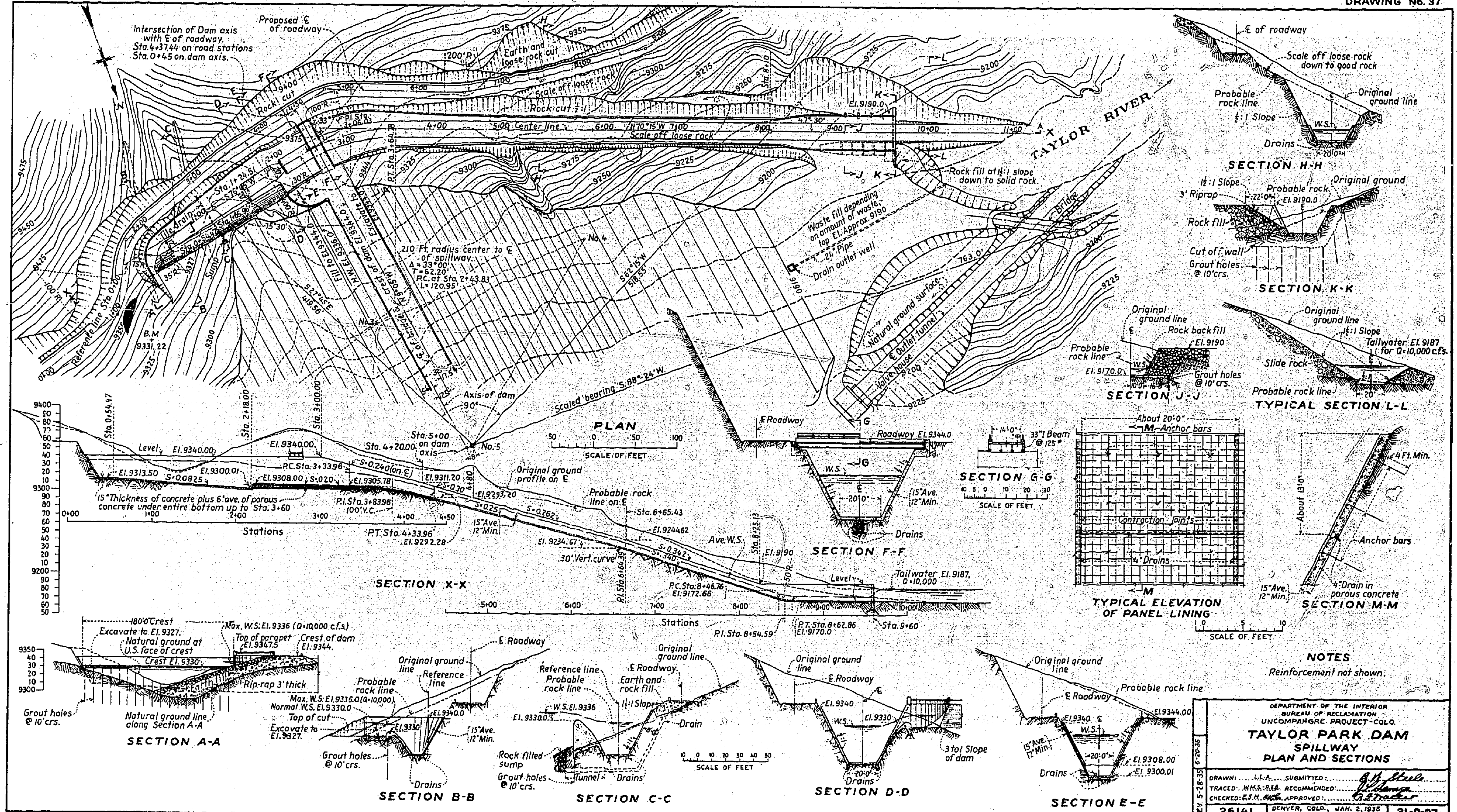


FIG. 2

DRAWING No. 37



is partially below the laboratory floor. From here, a 6-inch centrifugal pump having a capacity of 3 c.f.s. raises the 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 calibrated gate valves, then through large expanding cones into two head reservoirs located directly below the constant level tank.

It was necessary to construct a temporary forebay tank to supply the Taylor Park model. Water was conducted from one of the head reservoirs to this forebay by means of a siphon. After leaving the model, a sheet metal flume returned the water to the weir tank where it was measured and then recirculated through the system. Two hook gages were used to observe the head on the measuring weir and a point gage operating in a stilling well connected to the model forebay was employed for measuring the head on the Taylor Park model crest.

The Model

The model of the Taylor Park Spillway was constructed in the laboratory on a scale of 1:50. A drawing of the model as originally designed is shown in figure 5 and photographs of the original model are shown in plate I. In order to have the model fit in the limited amount of space available, it was necessary to make it an exact opposite of the prototype (see figure 5). The forebay, the approach to the overflow crest, the side channel (exclusive of the overflow crest) and the chute were all constructed of wood and lined with sheet metal. The spillway crest was constructed by bending a piece of no. 20 gage sheet metal around several heavy sheet metal ribs, cut to the proper shape and soldering it to them. The ribs in turn were mounted rigidly on small structural steel angles. The assembled crest section was then set in the correct location, leveled up, bolted in place, and the rest of the model soldered to it.

A watertight box with a sliding weir in the downstream end was constructed around the lower end of the chute for the purpose of regulating the tailwater depth at this point.

The Original Design

As originally designed (see figure 4) the model worked quite well except for the action in the chute. Flow over the crest and in the side channel was very satisfactory. Photographs A and B (plate I) show views of the original side channel and photograph C

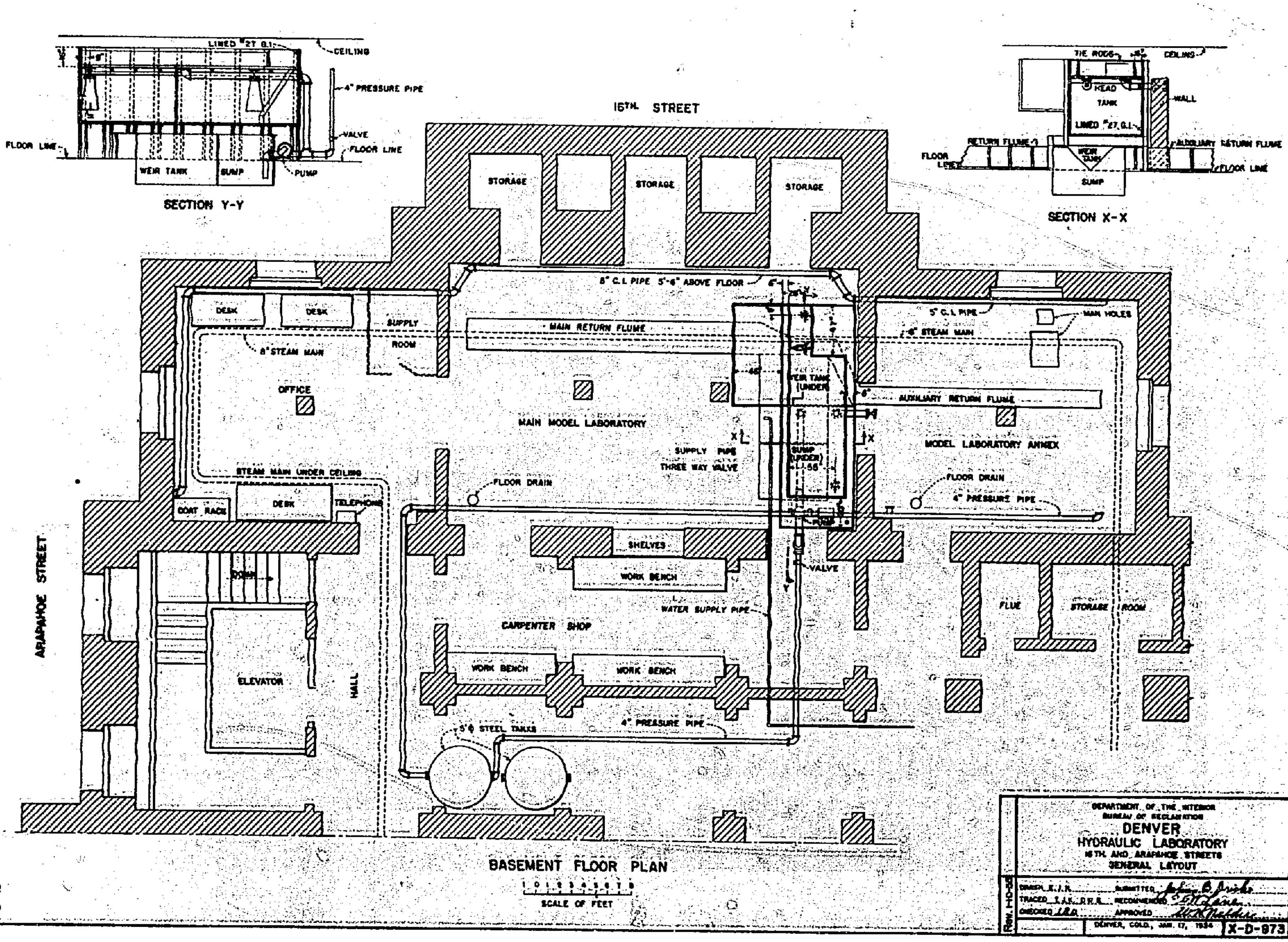
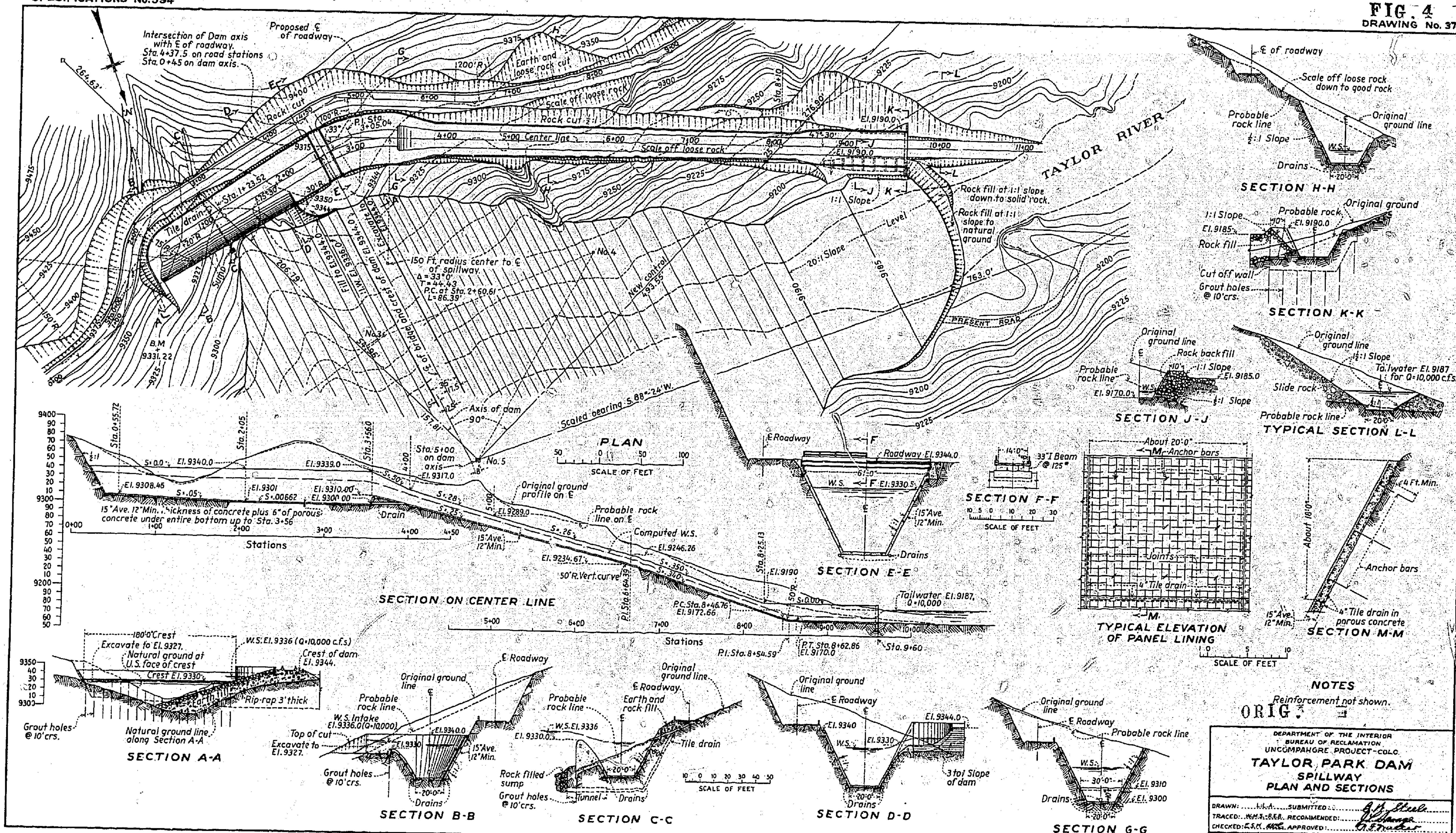
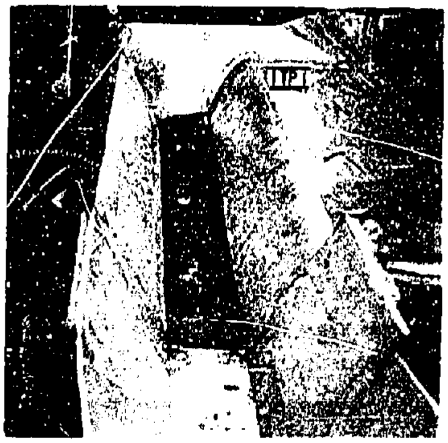

SECTION Y-Y
LINED #27 G.I.
CEILING
4" PRESSURE PIPE
VALVE
FLOOR LINE
FLOOR LINE
WEIR TANK
SUMP
PUMP
16TH. STREET
SECTION X-X
TIE RODS
CEILING
HEAD TANK
LINED #27 G.I.
WALL
RETURN FLUME
AUXILIARY RETURN FLUME
FLOOR LINE
FLOOR LINE
WEIR TANK
SUMP
STORAGE
STORAGE
STORAGE
8" C.I. PIPE 5'-6" ABOVE FLOOR
5" C.I. PIPE
MAN HOLES
6" STEAM MAIN
DESK
DESK
SUPPLY ROOM
MAIN RETURN FLUME
8" STEAM MAIN
OFFICE
WEIR TANK (UNDER)
AUXILIARY RETURN FLUME
MAIN MODEL LABORATORY
SUPPLY PIPE
THREE WAY VALVE
SUMP (UNDER)
MODEL LABORATORY ANNEX
STEAM MAIN UNDER CEILING
FLOOR DRAIN
FLOOR DRAIN
4" PRESSURE PIPE
COAT RACK
DESK
TELEPHONE
PUMP
SHELVES
WORK BENCH
VALVE
DOWN
WATER SUPPLY PIPE
FLUE
STORAGE ROOM
ARAPAHOE STREET
CARPENTER SHOP
ELEVATOR
HALL
WORK BENCH
WORK BENCH
5'Φ STEEL TANKS
4" PRESSURE PIPE
BASEMENT FLOOR PLAN
SCALE OF FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER
HYDRAULIC LABORATORY
16TH. AND ARAPAHOE STREETS
GENERAL LAYOUT
DENVER, COLO., JAN. 17, 1934
X-D-973

Fig.3

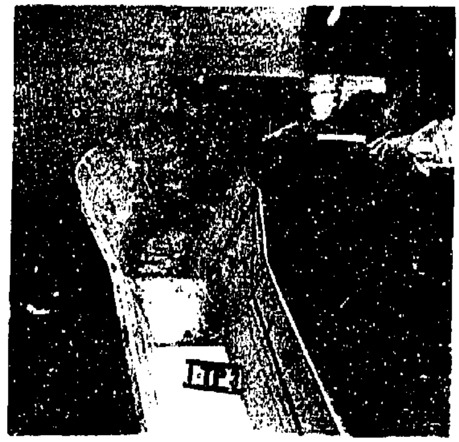
SPECIFICATIONS No. 594

FIG. 4
DRAWING No. 37

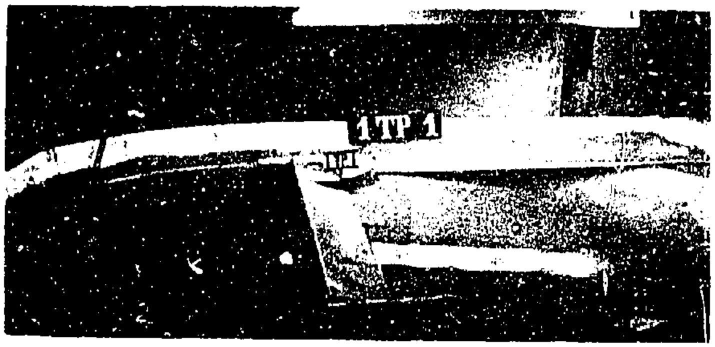




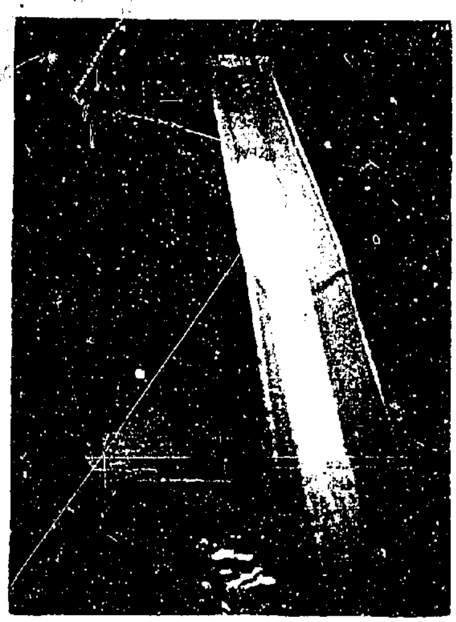
A. SIDE CHANNEL



B. CHECK AND CURVE IN CHANNEL

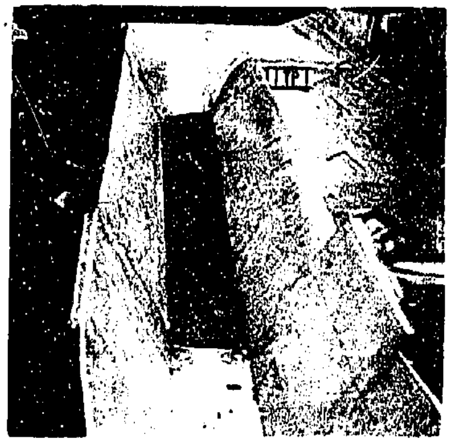


C. SIDE CHANNEL WITH MAXIMUM DISCHARGE

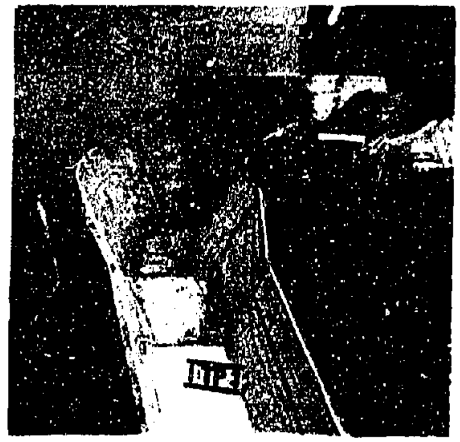


D. CHUTE WITH MAXIMUM DISCHARGE

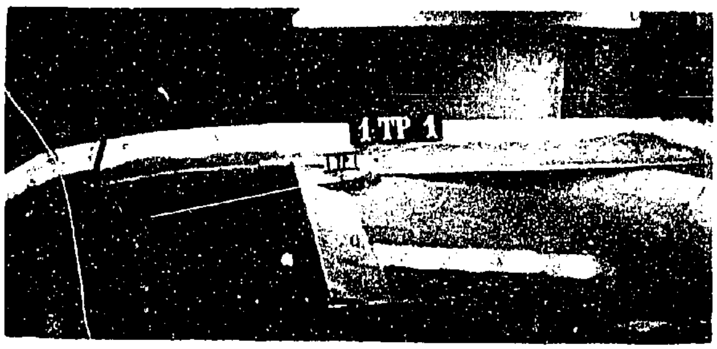
ORIGINAL DESIGN



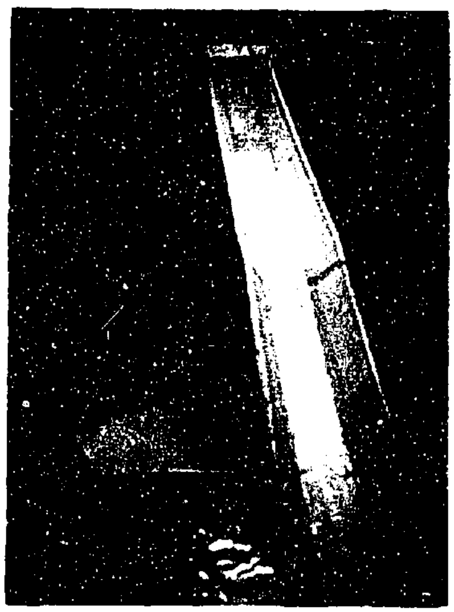
A. SIDE CHANNEL



B. CHECK AND CURVE IN CHANNEL

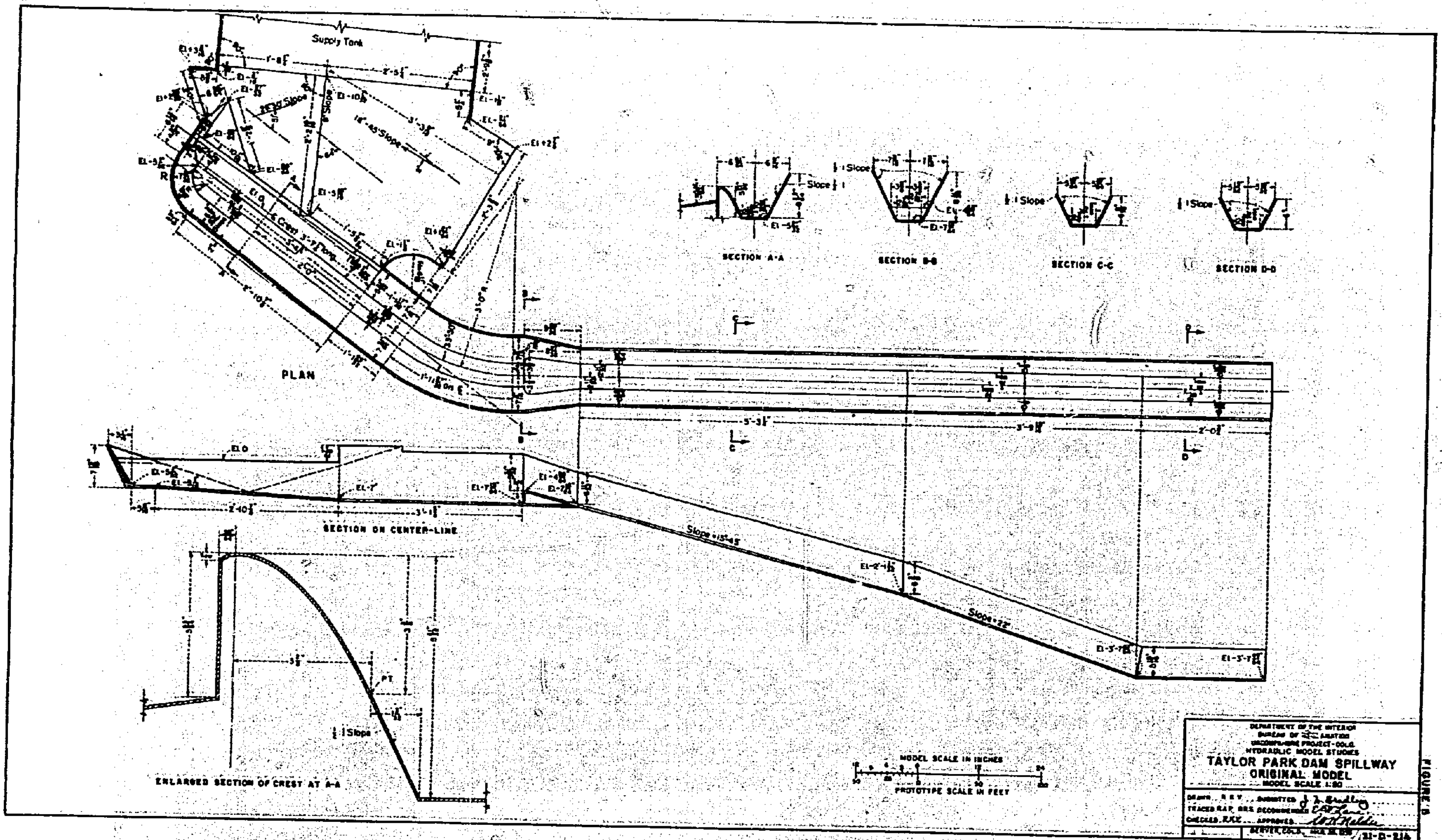


C. SIDE CHANNEL WITH MAXIMUM DISCHARGE



D. CHUTE WITH MAXIMUM DISCHARGE

ORIGINAL DESIGN



Supply Tank
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION ON CENTER-LINE
ENLARGED SECTION OF CREST AT A-A
Slope=15°45'
Slope=22°
MODEL SCALE IN INCHES
PROTOTYPE SCALE IN FEET
DEPARTMENT OF THE INTERIOR
UNCOMPAHGRE PROJECT-COLO.
HYDRAULIC MODEL STUDIES
TAYLOR PARK DAM SPILLWAY
ORIGINAL MODEL
MODEL SCALE 1:30
31-D-214

FIGURE 8

shows it in operation. In flowing around the bend in the channel downstream from the crest, the water had a tendency to climb the outer wall. At the downstream end of the curve, a check 10 feet high acted as a control and just downstream from the check the cross-section of the channel was reduced by means of a fairly abrupt transition (see figure 4). The combination of these factors caused a somewhat irregular water surface in the chute as can be dimly seen in photograph D (plate I). The water surface was traversed with large criss-cross waves beginning at the contraction just below the check. Upon striking the sides of the chute these waves produced a series of stationary waves with crests perpendicular to the direction of flow. This condition was not of a serious nature but it was thought that a revision might result in an improvement and further experimentation was carried on to this end.

Revisions on the Original Design

Control Moved Upstream

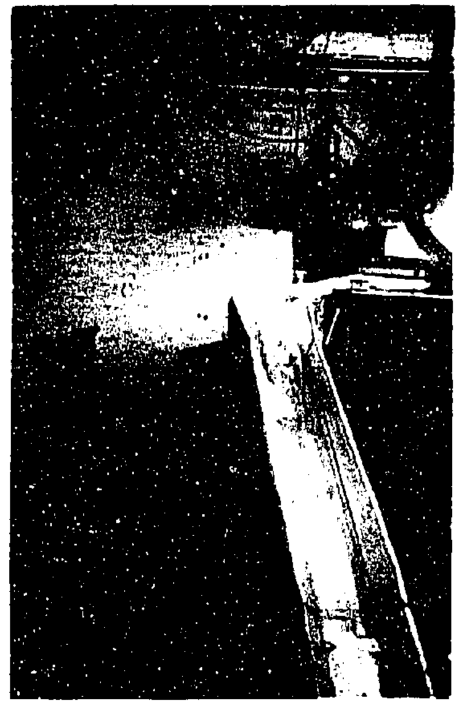
In the original design, the water flowing around the bend downstream from the overflow crest was flowing at subcritical velocities for which any disturbance moves upstream and is swallowed by the flow. The question arose as to whether the water could be made to flow around the bend at supercritical velocities for which any disturbance is swept along by the flow and is carried downstream. A few rough experiments showed the latter idea to be feasible and after a few preliminary tests, which indicated the maximum elevation of a check at station 2 + 60, which would not flood the side channel at maximum discharge, the model was rebuilt to study the problem in more detail.

With the control moved upstream, most of the waves in the chute were eliminated and the action in the steep portion was much improved. The water rode higher than before on the outside wall of the curve as a result of the increased velocities in this region.

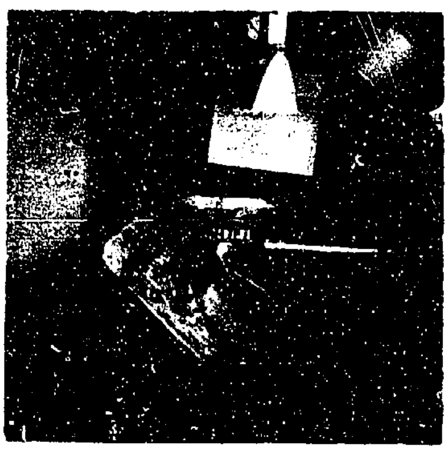
Easement Curve Installed.

In an effort to eliminate the superelevation of the water surface in the curved channel which in turn was expected to further improve the flow in the chute, the constant radius curve shown in figure 4 was replaced by a spiral as shown in figure 2 and photograph A (plate II). With this change, a more gradual transition was incorporated in this portion of the spillway, with the result that the chute now had a uniform cross-section throughout its length. This combination of revisions reduced the superelevation of the water surface in the curved channel and practically eliminated the waves which formerly persisted at intervals down the chute. Flow

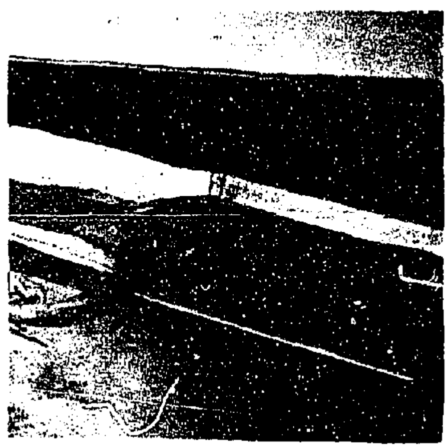
A. REVISED CURVE IN CHANNEL



B. REVISED CHANNEL WITH
DISCHARGE 10,000 SECOND-FEET



C. SIDE CHANNEL IN OPERATION
DISCHARGE 10,000 SECOND-FEET



D. FLOW ABOVE CHECK WITH
DISCHARGE 10,000 SECOND-FEET

REVISED CURVE IN CHANNEL

throughout the spillway was now very satisfactory. The photographs on plate II were taken of the revised model. Photograph A shows the spillway as revised, photographs C and D show the upper portion of the spillway in operation at the maximum discharge, and photograph B shows the flow down the chute for the same discharge. Notice in B the absence of the waves in the chute.

Floor of Side Channel Raised.

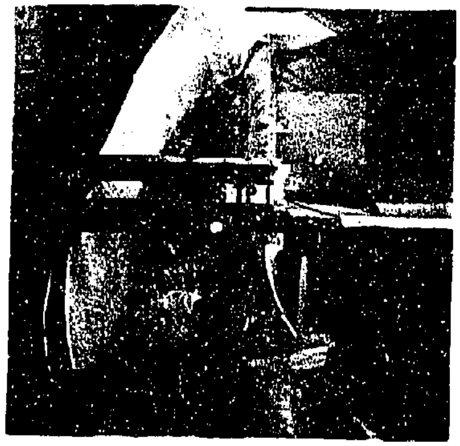
The side channel excavation will consist entirely of rock and if its cross-section can be reduced a saving will be effected in the cost of construction. For this reason tests were made with the floor at the upper end of the channel raised various amounts, the downstream end remaining in its original position. Flow over the crest was not in any way retarded by raising the channel floor in this manner, but for the higher positions of the floor, considerable splashing and boiling was present at the upstream end of the channel and this proved to be the factor which dictated the limiting position of the floor. As finally designed, the channel floor will be made level at elevation 9313.50 down to station 0 + 54.47 and the remainder will be on a slope of 0.0825 as shown in figure 2.

Width of Side Channel Reduced.

As the splashing and boiling at the upstream end of the channel limited the amount that the channel floor could be raised, the side channel was further reduced in area by reducing its width as shown in photographs A, B, C, and D on plate III. The channel was made as narrow as possible without raising the head on the crest for maximum discharge. Photographs D and E (plate III) show the completely revised spillway operating at the maximum discharge of 10,000 c.f.s. Notice in D that the side channel is flowing practically full. This proves to be a slight advantage from a hydraulic viewpoint as well as from a structural standpoint as the water surface in the side channel was not as rough and the boil and splash at the upstream end not as pronounced as in the original design. A drawing of the completely revised spillway is shown in figure 2.

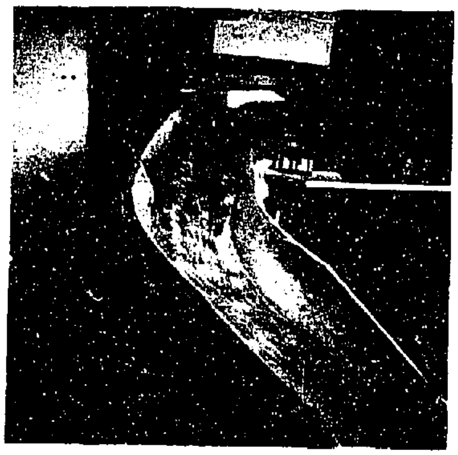
In addition to improving the hydraulic action in the Taylor Park spillway (made possible by these model studies) by moving the control upstream, changing the curvature of the channel downstream from the control check, and reducing the cross-sectional area of the side channel itself, a material saving of approximately $5,000 was made in the construction cost.

A. SIDE CHANNEL IN OPERATION
DISCHARGE 2,100 SECOND-FEET

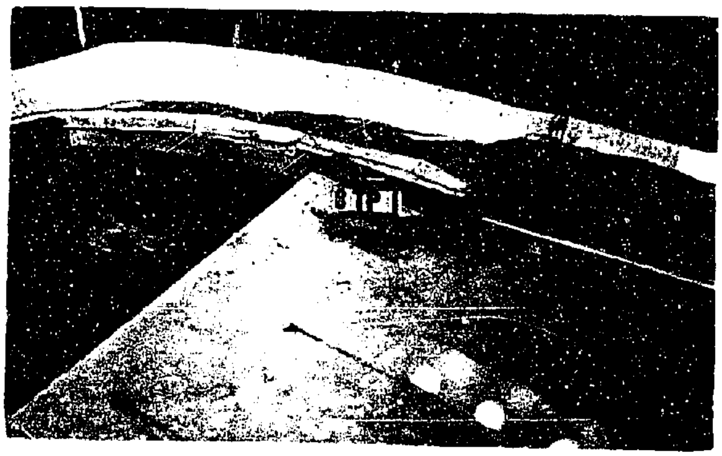


B. DISCHARGE 2,100 SECOND-FEET

C. DISCHARGE 6,100 SECOND-FEET



D. DISCHARGE 10,000 SECOND-FEET



E. FLOW ABOVE CHECK WITH
DISCHARGE 10,000 SECOND-FEET

RECOMMENDED DESIGN

Water Surface Profiles

Water surface profiles were taken along the recommended spillway for three discharges and these are shown plotted on figure 6. The depths of flow are shown at various stations along the spillway. In the curved portion of the chute, the average as well as the maximum water surface is plotted, the maximum always occurring on the side opposite the crest. The profile for test 8-1 was taken while the spillway was operating at the maximum discharge of 10,000 c.f.s. and tests 7-1 and 6-1 were obtained for partial discharges. For test 6-1 the maximum and average water surfaces in the curved chute were so nearly alike that they plotted as a single line. The profiles well illustrate the effectiveness of the control check at station 2+18.0 and also show the flow down the chute to be regular and absent from anything but very small surface waves for the three discharges. Photographs taken during these runs are shown on plate III.

Conditions at Lower end of Chute

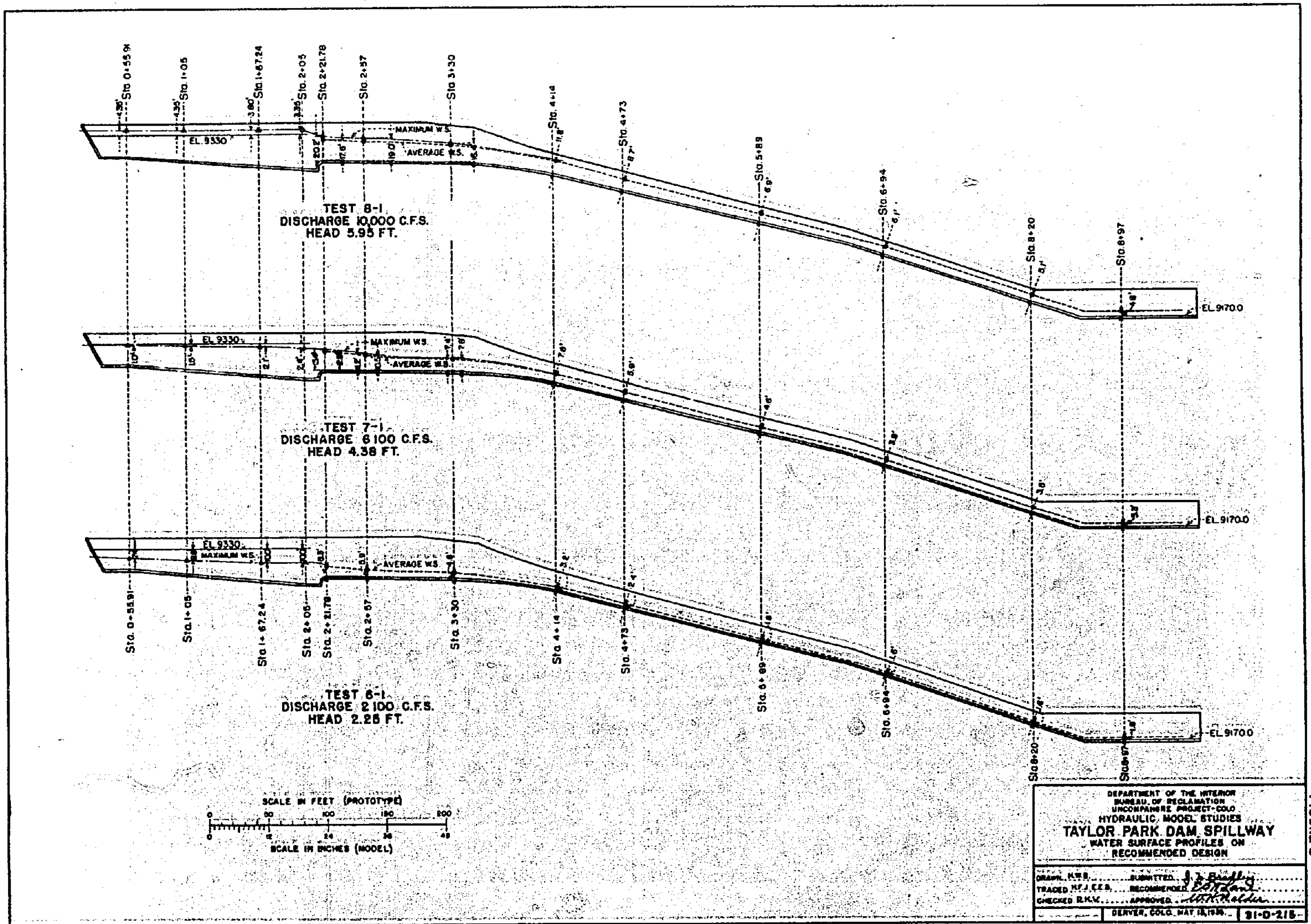
As the rock river bed is quite stable downstream from the lower end of the chute, little attention was paid to this portion of the structure. Photograph A (plate IV) shows the water from the chute entering the river for the maximum discharge and corresponding tailwater depth. Photograph B on the same plate is another view of the same thing taken farther downstream.

Should the jet issuing from the chute prove to loosen the rock in the river bed and threaten any damage to the structure, a small bucket can be constructed at the end of the chute which will lift and spread the jet as shown in photograph C (plate IV). A sketch of a bucket which satisfactorily spread the jet and shot it a safe distance downstream is shown on figure 7. This inexpensive bucket will eliminate scour directly downstream from the end of the chute and the spreading of the jet over a greater area will decrease the amount of energy to be dissipated per unit of area*.

*For additional information on the spreading of jets of this type see Technical Memorandum No. 437 on "Hydraulic Model Studies for the Design of the Moon Lake Spillway." By J. N. Bradley and J. B. Drisko.

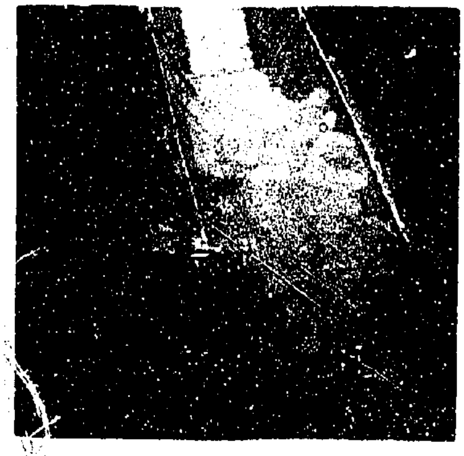
The Head Discharge Relation and the Coefficient of Discharge.

A series of runs were made for the purpose of calibrating the spillway crest. The full line on figure 8 indicates the head

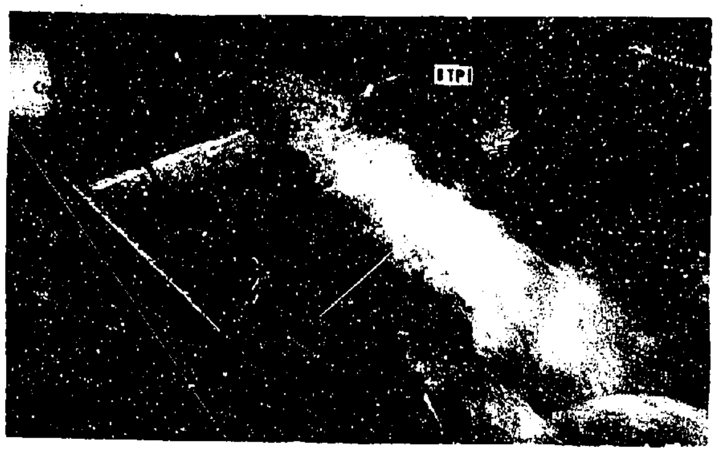


TEST 8-1
DISCHARGE 10,000 C.F.S.
HEAD 5.95 FT.
TEST 7-1
DISCHARGE 6100 C.F.S.
HEAD 4.38 FT.
TEST 6-1
DISCHARGE 2100 C.F.S.
HEAD 2.25 FT.
MAXIMUM W.S.
AVERAGE W.S.
EL. 9330
EL. 9170.0
Sta. 0+55.91
Sta. 1+05
Sta. 1+67.24
Sta. 2+05
Sta. 2+21.78
Sta. 2+57
Sta. 3+30
Sta. 4+14
Sta. 4+73
Sta. 5+89
Sta. 6+94
Sta. 8+20
Sta. 8+97
SCALE IN FEET (PROTOTYPE)
SCALE IN INCHES (MODEL)
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNCOMPAHGRE PROJECT-COLO.
HYDRAULIC MODEL STUDIES
TAYLOR PARK DAM SPILLWAY
WATER SURFACE PROFILES ON
RECOMMENDED DESIGN
DRAWN H.W.S.
TRACED H.F.J. E.E.S.
CHECKED R.K.V.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. MAY 13, 1936
31-D-215

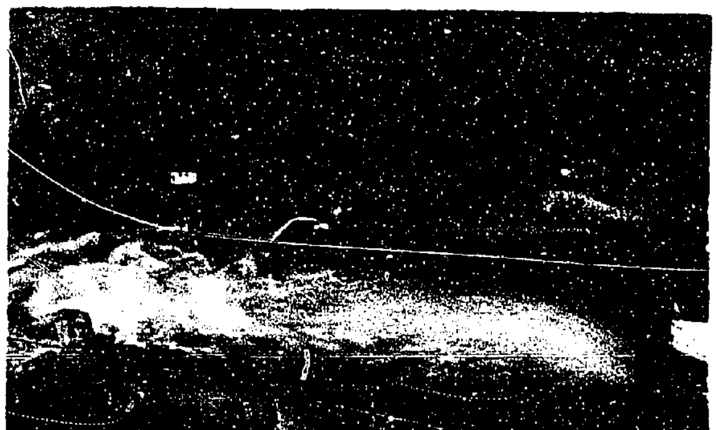
FIGURE 6



A. FLOW AT LOWER END OF CHUTE
WITH NORMAL TAILWATER AND
DISCHARGE 10,000 SECOND-FEET

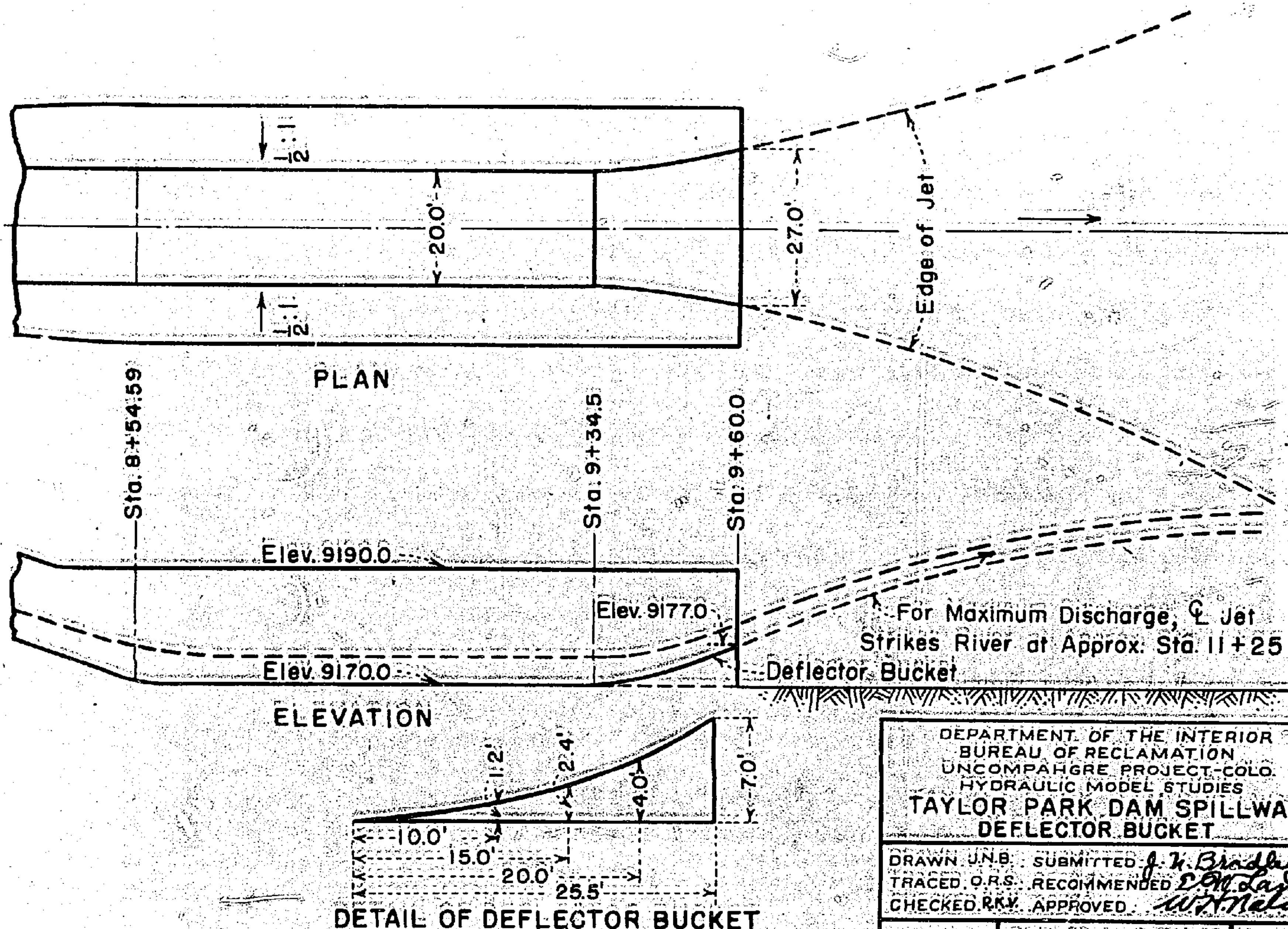


B. FLOW CONDITIONS IN RIVER
WITH NORMAL TAILWATER AND
DISCHARGE 10,000 SECOND-FEET



C. JET SPREAD BY RAISING FLOOR
AT END OF CHUTE

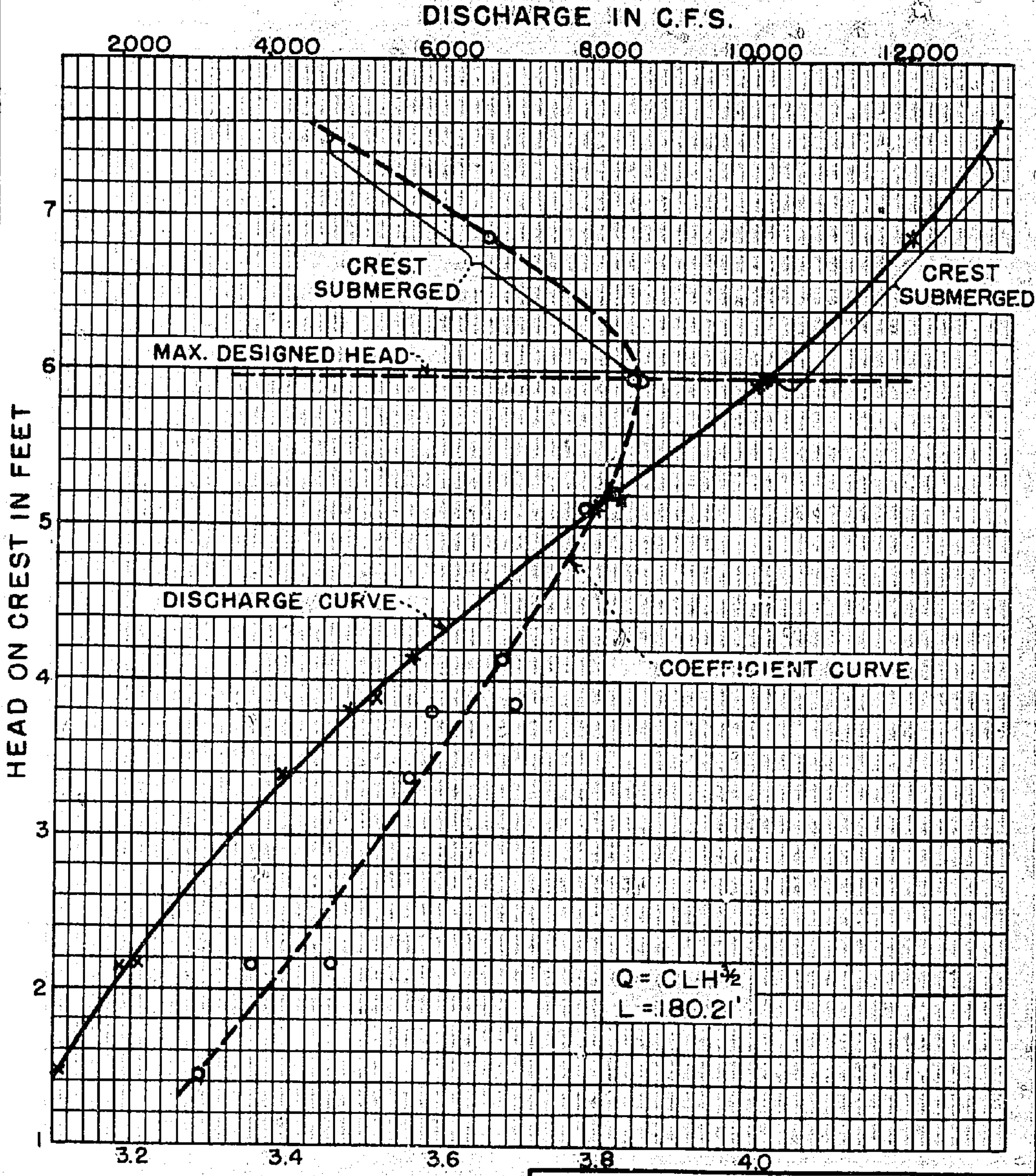
FIGURE 7



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNCOMPAHGRE PROJECT-COLO.
HYDRAULIC MODEL STUDIES
TAYLOR PARK DAM SPILLWAY
DEFLECTOR BUCKET

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

DENVER, COLO. 7-18-35 31-D-216



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNCOMPAHGRE PROJECT - COLO.
HYDRAULIC MODEL STUDIES
TAYLOR PARK DAM SPILLWAY
RELATION OF HEAD ON CREST TO DISCHARGE AND COEFFICIENT OF DISCHARGE

DRAWN AHN-RKV	SUBMITTED J. N. Bradley
TRACED D.R.S.	RECOMMENDED E. W. Lane
CHECKED R.K.V.	APPROVED W. H. Nalder

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discharge relation obtained from these runs. This line shows that a head of 5.95 feet on the crest is required for the maximum designed discharge of 10,000 sec. ft.

The broken line on figure 8 is the coefficient of discharge curve which was obtained by substituting the above results into the formula $Q = CLH^{3/2}$, using L = 180.21 feet which was the length of crest arrived at when the actual length of the model crest was multiplied by the model scale of 50. In spite of the shallow approach to the overflow crest, this curve shows a coefficient of discharge of 3.84 for the maximum designed head. Both curves fall off rapidly after the maximum designed head is reached as submergence of the crest commences at this point.

Acknowledgements

The work in the hydraulic laboratories is under the general direction of E. W. Lane. The construction and testing of the Taylor Park model was supervised by J. B. Drisko. He was assisted in the laboratory by Junior Engineers H. M. Martin, L. R. Brooks, and H. W. Brewer. The office work was performed by R. K. Vierck and A. H. Noal.

APPENDIX

TAYLOR PARK DAM SPILLWAY
LOG OF TESTS

Test no.	Discharge C.F.S.	Setup	Remarks
1 - 1	10,000	Original Design = Control below curve.	Crest coefficient run
2	10,000	" " " " "	"
3	10,000	" " " " "	"
2 - 1	1,047	" " " " "	"
2	2,024	" " " " "	"
3	5,020	" " " " "	"
4	8,170	" " " " "	"
5	12,000	" " " " "	"
6	16,320	" " " " "	"
3 - 1	10,000	Original design with control removed and adjustable control installed above curve	Runs to determine the best height of control at upper end of curve.
2	10,000	"	"
3	10,000	"	"
4	10,000	"	"
5	10,000	"	"
6	10,000	"	"

APPENDIX (Cont.)
TAYLOR PARK DAM SPILLWAY
LOG OF TESTS

Test no.	Discharge C.F.S.	Setup	Remarks
3 - 7	10,000	Original design with control removed and adjustable control installed above curve	Runs to determine the best height of control at upper end of curve.
4 - 1	10,000	Original design except for new easement curve, new control and upper end of spillway floor raised	Run to see if spillway channel can be narrowed without raising pond elevation.
5 - 1	10,040	Same as 4-1 except that upper end of spillway channel is narrower - Control above new curve	Crest coefficient run profile measurements
6 - 1	2,100	"	"
7 - 1	6,100	"	"
8 - 1	10,040	"	"
2	10,000	Same as 5-1 except chute is shorter and steeper	Run to determine scour at exit
3	10,000	Same as 8-2 except for sill on pool floor	"
9 - 1	10,000	Same as 8-3	"
10 - 1	1,902	Same as 8-2 which is Original pond topography, original crest, narrower and shallower spillway channel, new control above curve, new easement curve instead of arc of circle to carry high velocity water to chute, shorter and steeper chute with the same drop, and original pool and exit topography.	Crest coefficient run.
2	3,969		"
3	5,533		"
4	7,849		"

APPENDIX (Cont.)

TAYLOR PARK DAM SPILLWAY
LOG OF TESTS

Test no.	Discharge C.F.S.	Setup	Remarks
5	10,041	Same as 8-2 which is Original pond topography; original crest, narrower and shallower spillway channel, new control above curve, new easement curve instead of arc of circle to carry high velocity water to chute, shorter and steeper chute with the same drop, and original pool and exit topography.	Crest coefficient run.
6	11,844		"
7	13,603		"
8	4,791		"