HYD 41

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC LABORATORY REPORT NO. 41

Model studies of the structures at stations 581+00, 677+00, 738+85, and the slope canal headworks on the Sun River Project, Montana.

by

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Denver, Colorado

November 7, 1938

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 41
Hydraulic Laboratory
Compiled by: J. E. Warnock

Reviewed by:

Subject: Model studies of the structures at stations 581+00, 677+00, 738+85, and the slope canal headworks on the Sun River Project, Montana.

1. Difficulty has been encountered for some time with the operation of the above structures in the field. The design section, therefore, requested models constructed of some typical installations in an effort to remedy the undesirable conditions of flow. In response, the hydraulic laboratory constructed and tested four models, all on a scale of 1 to 15, between the dates of October 1, 1937, and March 1, 1938. The following is a report on this work.

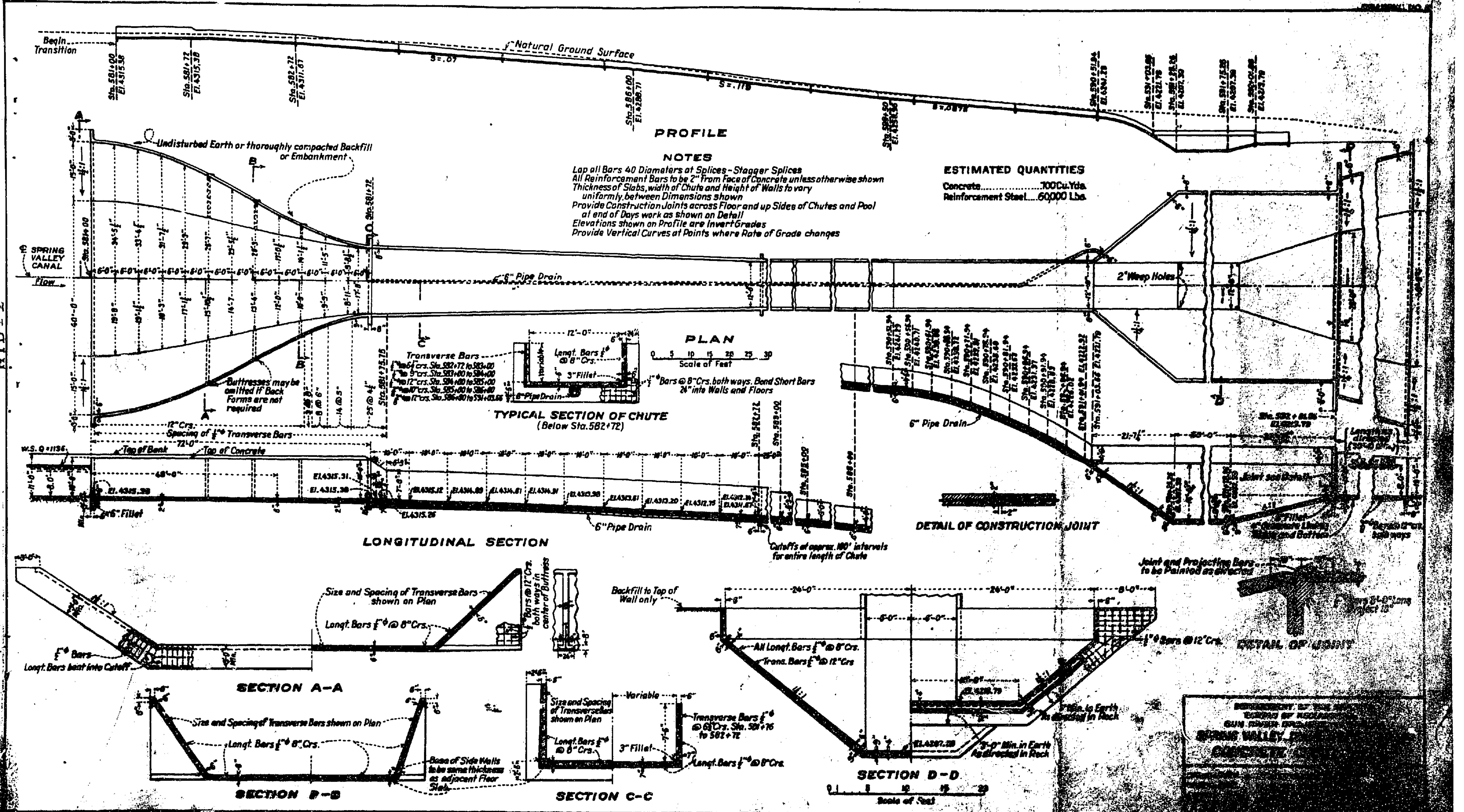
2. Since the length of the chute drops at stations 581+00 and 677+00 were excessive, complete models could not be made but the stilling pools were assimilated by inserting an adjustable rectangular orifice which discharged into a short section of the chute. The proper velocity at the entrance to the pool was obtained by manipulation of the orifice to obtain the correct cross-sectional area at this point based on the original design computations.

Since the stilling pool of the drop at station 581+00 (figure 1) failed in the field, a replacement was necessary which offered an opportunity to try a new design. The three remaining structures are still in fair condition structurally, hence minor changes were proposed to improve the undesirable flow conditions inherent in these. The flow conditions in each structure were studied at a discharge of 1,136 second-feet; however, the final result is based on a discharge increased to 1,300 second-feet, with the exception of the headworks which was tested at a maximum discharge of 1,600 second-feet.

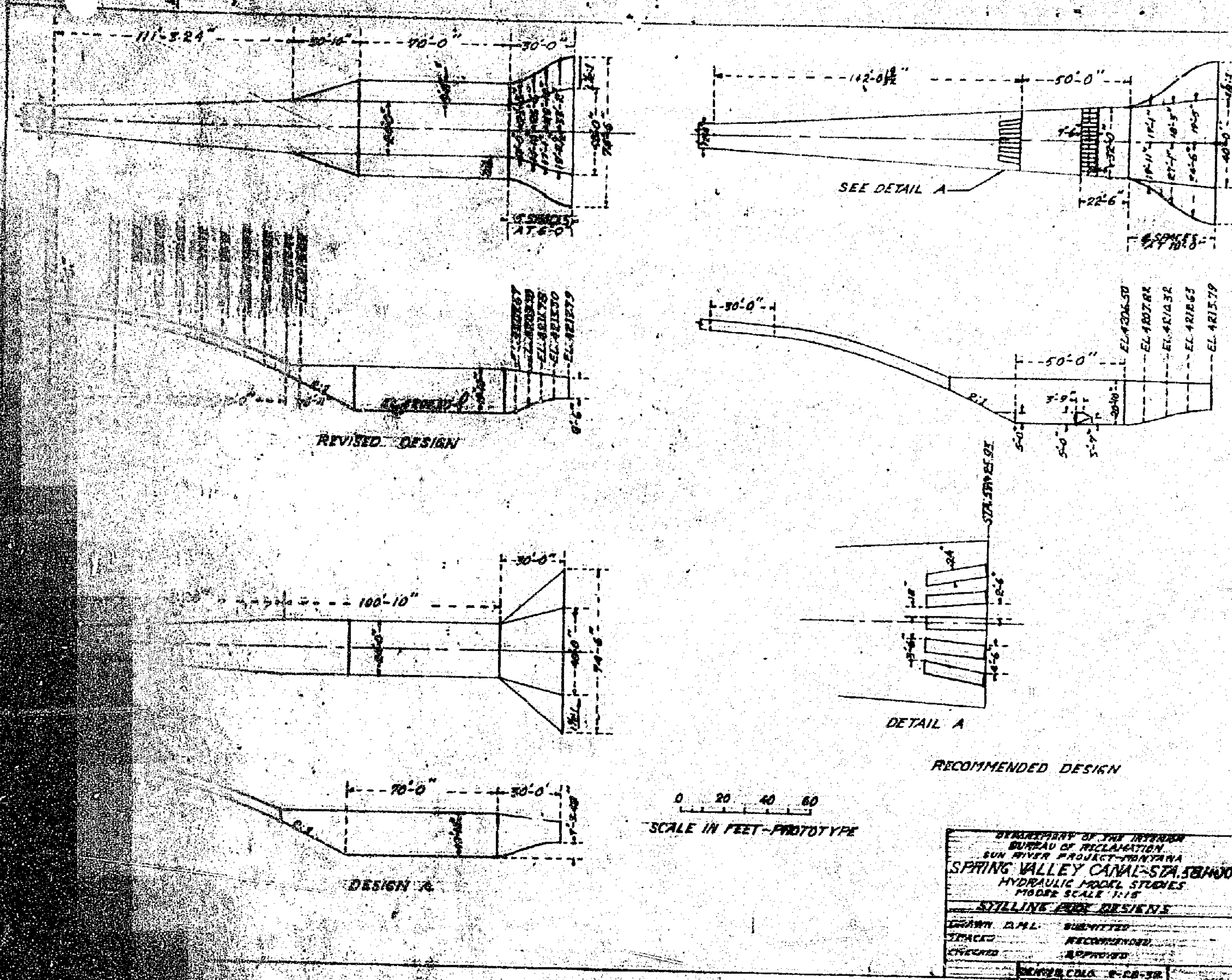
Chute Drop at Station 581+00

3. The first model (figure 2, revised design) consisted essentially of a rectangular chute and a trapezoidal stilling pool

FIGURE 1



Begin Transition
Natural Ground Surface
PROFILE
NOTES
Lap all Bars 40 Diameters at Splices - Stagger Splices
All Reinforcement Bars to be 2" From Face of Concrete unless otherwise shown
Thickness of Slabs, width of Chute and Height of Walls to vary uniformly between Dimensions shown
Provide Construction Joints across Floor and up Sides of Chutes and Pool at end of Days work as shown on Detail
Elevations shown on Profile are Invert Grades
Provide Vertical Curves at Points where Rate of Grade changes
ESTIMATED QUANTITIES
Concrete..........700 Cu.Yds.
Reinforcement Steel.....60,000 Lbs.
Undisturbed Earth or thoroughly compacted Backfill or Embankment
℄ SPRING VALLEY CANAL
Flow
6" Pipe Drain
2" Weep Holes
PLAN
Scale of Feet
Buttresses may be omitted if Back Forms are not required
Spacing of Transverse Bars
TYPICAL SECTION OF CHUTE
(Below Sta. 582+72)
Transverse Bars
Longt. Bars @ 8" Crs.
3" Fillet
6" Pipe Drain
Bars @ 8" Crs. both ways. Bend Short Bars 24" into Walls and Floors
Top of Bank
Top of Concrete
LONGITUDINAL SECTION
6" Pipe Drain
Cutoffs at approx. 100' intervals for entire length of Chute
DETAIL OF CONSTRUCTION JOINT
Joint see Detail
Joint and Projecting Bars to be Painted as directed
DETAIL OF JOINT
SECTION A-A
Size and Spacing of Transverse Bars shown on Plan
Longt. Bars @ 8" Crs.
Longt. Bars bent into Cutoff
SECTION B-B
Base of Side Walls to be same thickness as adjacent Floor Slab
SECTION C-C
Size and Spacing of Transverse Bars shown on Plan
Variable
3" Fillet
Backfill to Top of Wall only
All Longt. Bars @ 8" Crs.
Trans. Bars @ 12" Crs.
SECTION D-D
Scale of Feet



SEE DETAIL A
RECOMMENDED DESIGN
DETAIL A
REVISED DESIGN
DESIGN A
0 20 40 60
SCALE IN FEET-PROTOTYPE
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SUN RIVER PROJECT-MONTANA
SPRING VALLEY CANAL-STA. 5811+00
HYDRAULIC MODEL STUDIES
MODEL SCALE 1:15
STILLING POOL DESIGNS
DRAWN D.M.L.
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. 8-28-38
EL.4206.50
EL.4207.82
EL.4210.32
EL.4212.63
EL.4215.79

FIGURE 2

with side slopes of 1/2 to 1. A transition served as an easement from this to the canal section.

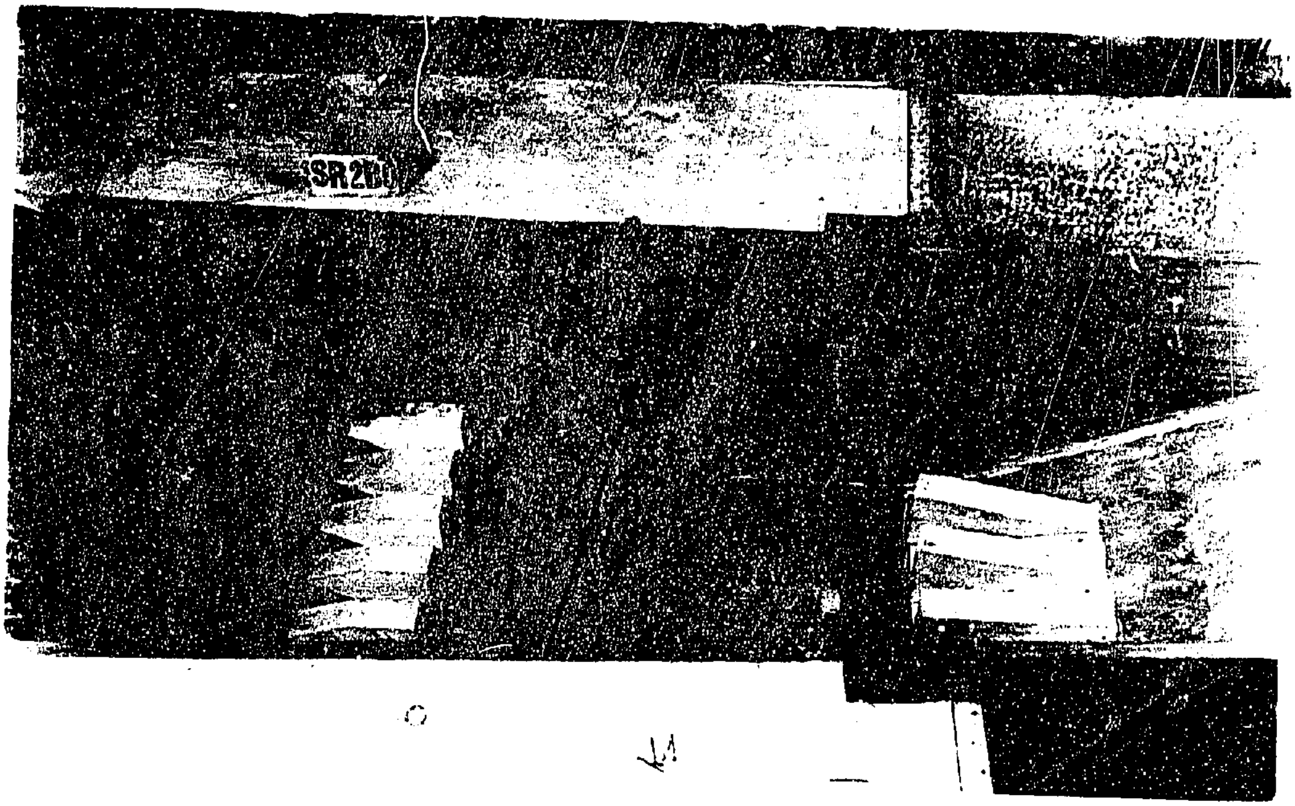
At the lower discharge of 1,136 second-feet the water surface was very rough, causing severe waves and surges in the unlined canal section. Various sills were tried on the slope and on the horizontal apron with little improvement.

4. The model was then changed to conform to figure 2, design A, which differed from the previous design in that the pool walls were vertical. The resulting flow conditions were improved. Additional improvement was accomplished by diverging the pool walls in a downstream direction. With this set-up, it was then possible to shorten the length of the pool by 20 feet.

Due to the lack of sufficient tail-water data it was decided to install a sill in the pool as a factor of safety. Numerous combinations of toothed aprons and sills were tried until satisfactory flow conditions were obtained (figures 3 to 6, inclusive). It was necessary to raise the downstream elevation of the transition one foot to prevent the water from going over the top at the maximum discharge of 1,300 second-feet. The recommended design for this chute drop is shown on figure 2.

Chute Drop at Station 677+00

5. This model was made to conform to the existing field structure (figure 7, original design). Since the jet sprang free of the chute at the lower vertical curve for the original design discharge of 1,136 second-feet, the first problem was to redesign this curve (figures 8 and 9). The new design was based on a discharge of 1,300 second-feet (figure 7-A). Typical flow conditions invariably obtained in trapezodial stilling pools were observed. The narrow jet of water issuing from the chute does not spread; hence, the jump is effective only in the center of the pool. Since the tail-water elevation is greater than that of the water surface at the front of the jump, a flow in an upstream direction persists on both sides of the pool. This water again contacts the jet at the entrance to the pool, goes through the jump, and again returns



NO FLOW

DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4221.2

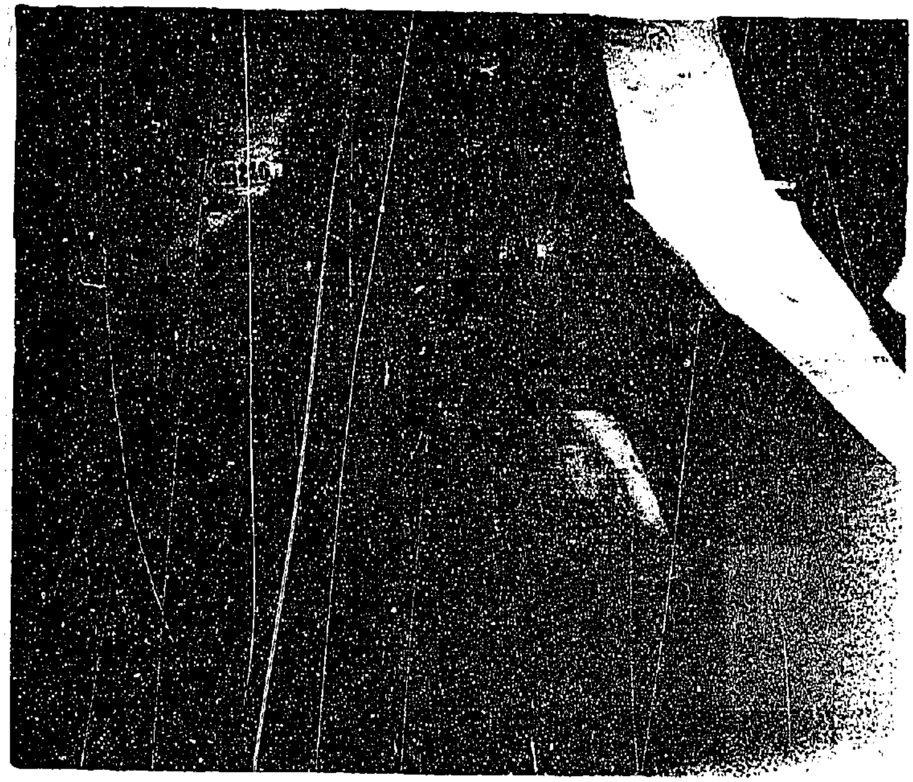
RECOMMENDED DESIGN, STILLING POOL

DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4221.74

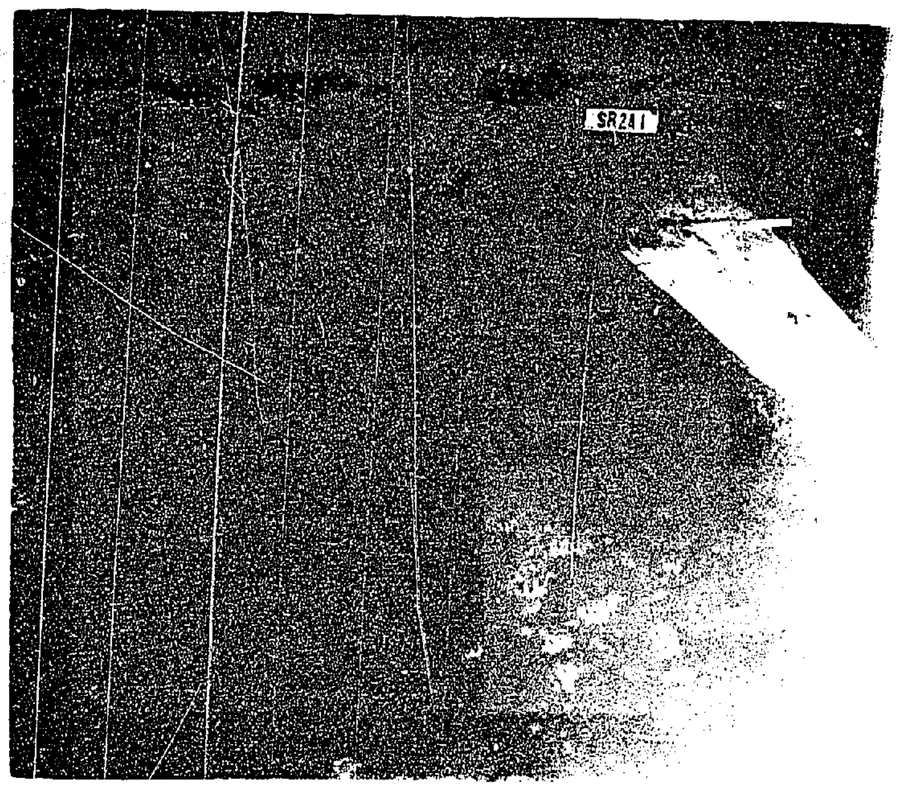
DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4222.64

RECOMMENDED DESIGN STILLING POOL

FIGURE 5



NO FLOW



DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4221.29

FIGURE 6

DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4221.74

DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4222.64

RECOMMENDED DESIGN STILLING POOL

FIGURE 7.

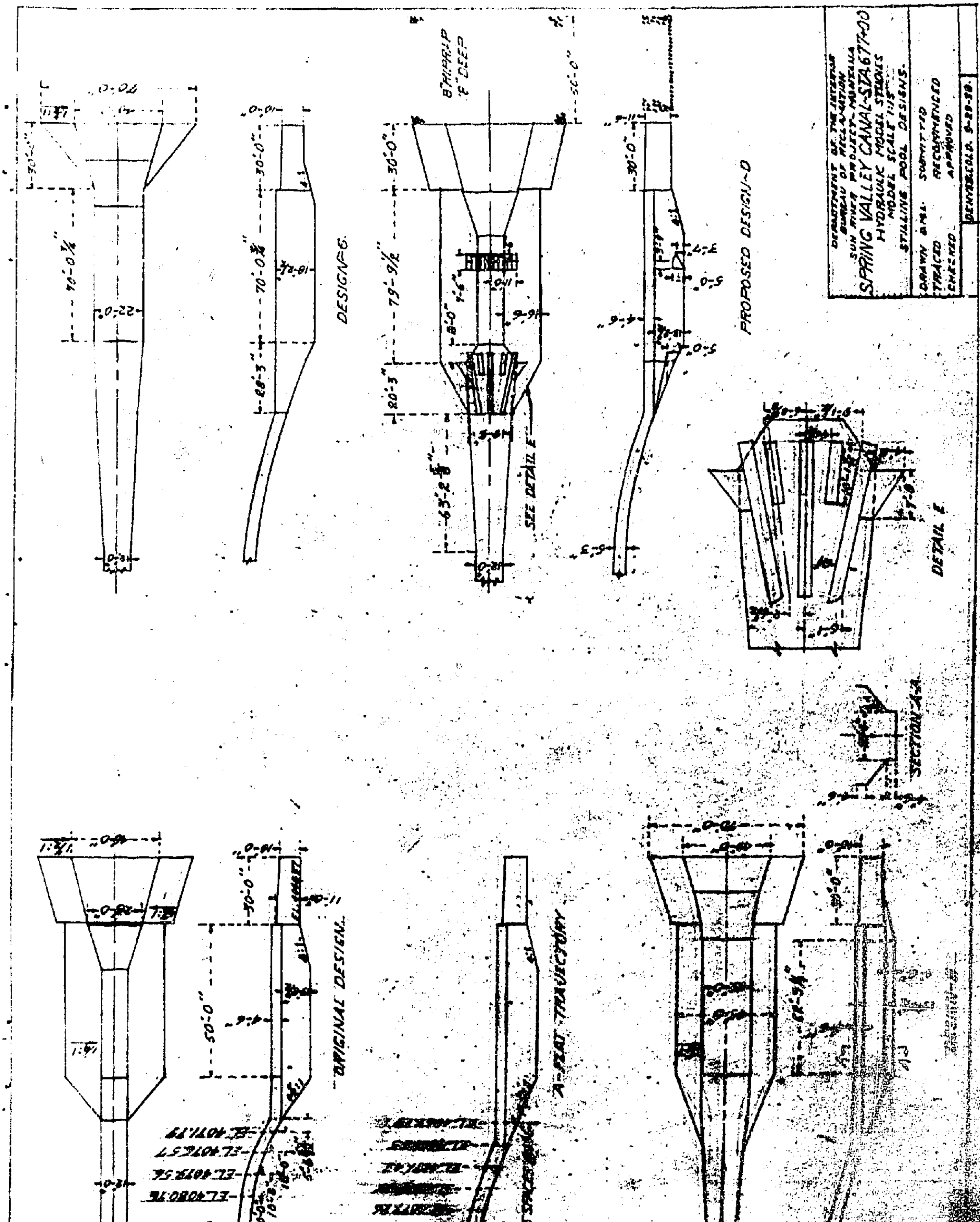
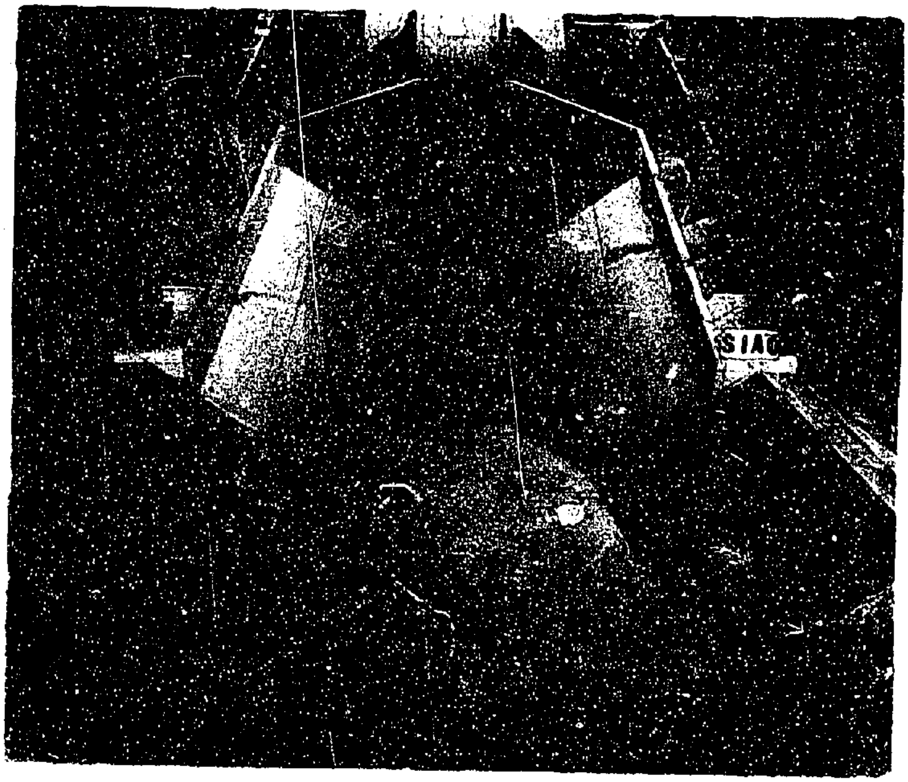

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SUN RIVER PROJECT-MONTANA
SPRING VALLEY CANAL-STA677+00
HYDRAULIC MODEL STUDIES
MODEL SCALE 1:15
STILLING POOL DESIGNS
DESIGN-G
PROPOSED DESIGN-D
SEE DETAIL E
DETAIL E
SECTION-A-A
ORIGINAL DESIGN
A-FLAT TRAJECTORY
8" RIPRAP 2' DEEP
30'-0"
70'-0 3/4"
79'-9 1/2"
50'-0"

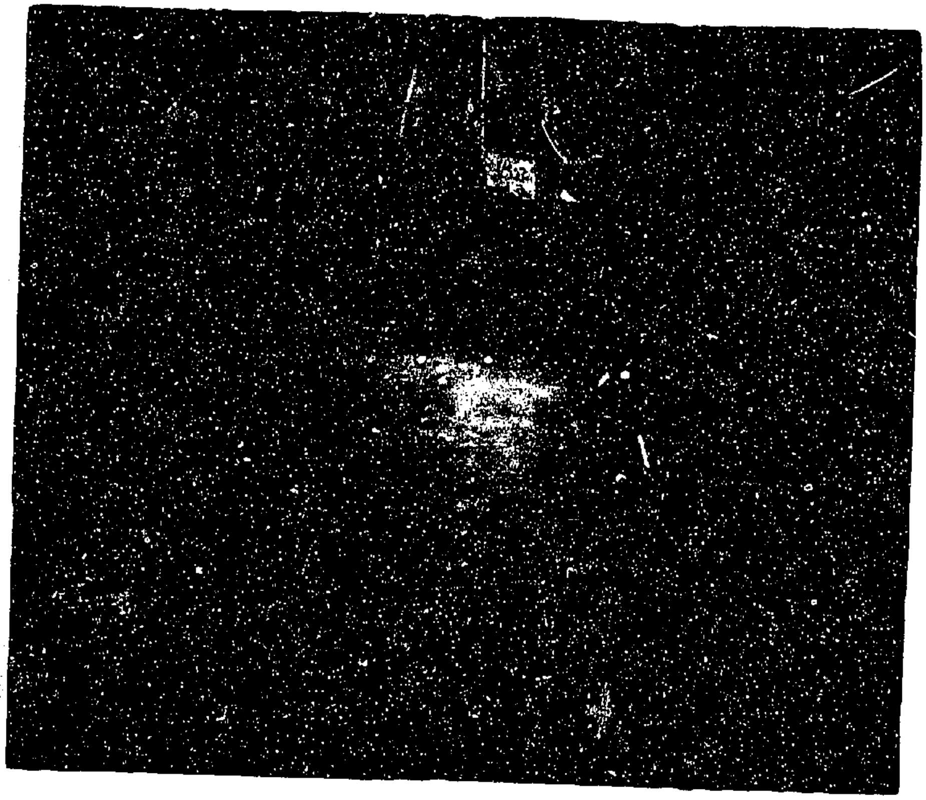
FIGURE 8



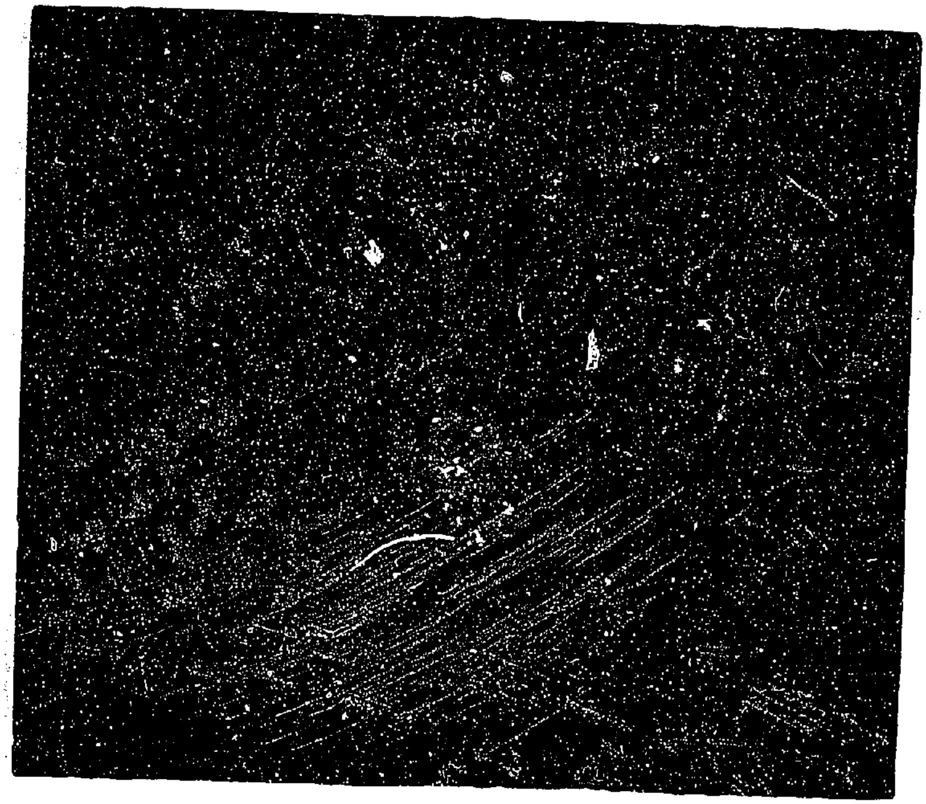
NO FLOW

DISCHARGE 980 SECOND-FEET - TAILWATER ELEVATION 4067.86

ORIGINAL DESIGN



DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4067.86



DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4068.47

ORIGINAL DESIGN

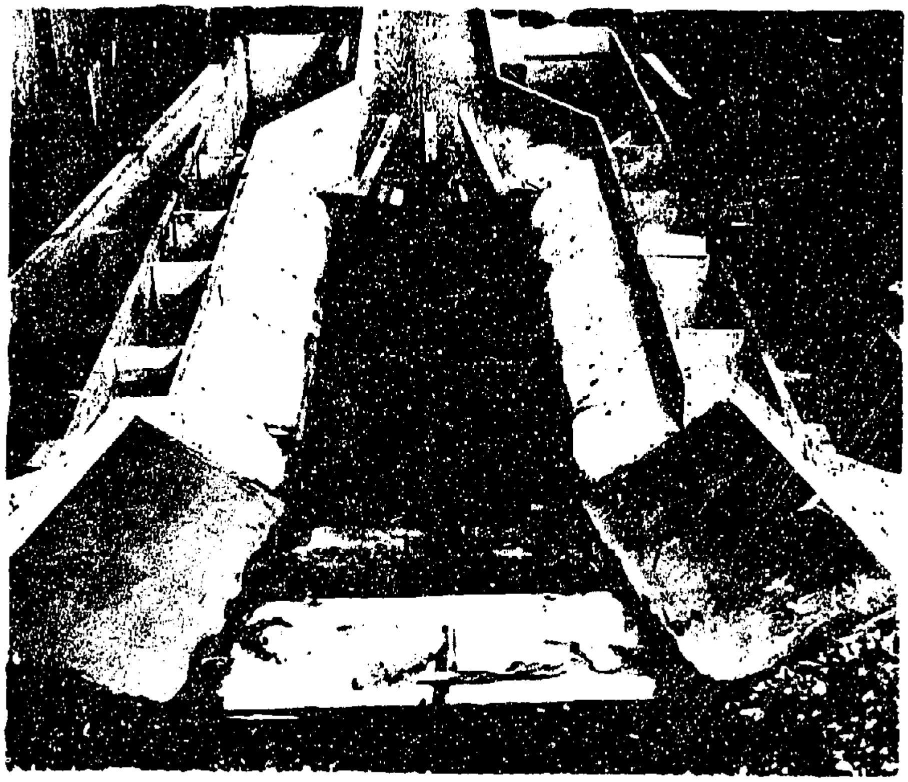
by way of the sides of the pool. As a result, the water in the pool assumes a constant whirling motion in both directions. With low tail water, the water in the pool occasionally whirled in one direction; by changing the direction of the jet with a board the whirl could be reversed. The return flow on the sides of this type of pool produces an unstable condition which causes a splashing on the sloping sides resulting in transverse waves which would endanger the side slopes of an earth canal. The sloping pool walls give rise to a beach effect and the surface disturbances thus created are translated to all points of the pool with the result that the water surface is continually in a choppy state.

Previous studies indicated that the proper shape of this pool should be rectangular. For economic reasons the pool was constructed as shown on figure 7, design B. This gave no improvement. However, when the vertical walls were extended the full height of the pool (figure 7, design C) better flow conditions were obtained. Due to the narrowness of the section a toothed apron and sill were necessary to obtain satisfactory flow conditions. This design was recommended by the laboratory but the design department felt that the cost of such a structure would be excessive.

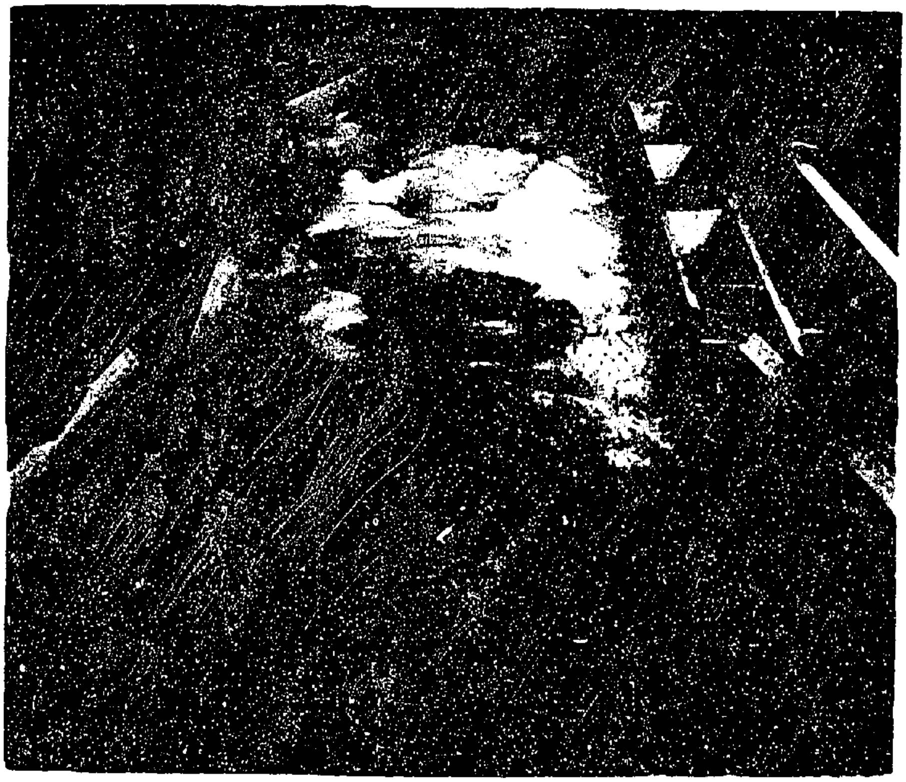
The original design pool was again constructed and various types of teeth and sills were tried to spread the jet as it entered the pool. It was necessary to raise the elevation of the transition walls to prevent the splash from going over the top. The proposed design is shown on figures 7, 10, and 11. Water surface profiles of the pool are shown on figure 12.

Drop at Station 738+85

6. The model of the drop at station 738+85 conformed to the field structure as shown on figure 13. This drop was of such proportions that it was impossible to obtain a real hydraulic jump as shown on figures 14 and 15. Instead, merely a surface disturbance was evident. An examination of the curve, shown below, will be enlightening. The energy content per foot of width is low and the depths, d_1, (depth upstream from jump) and d_2 (depth downstream from

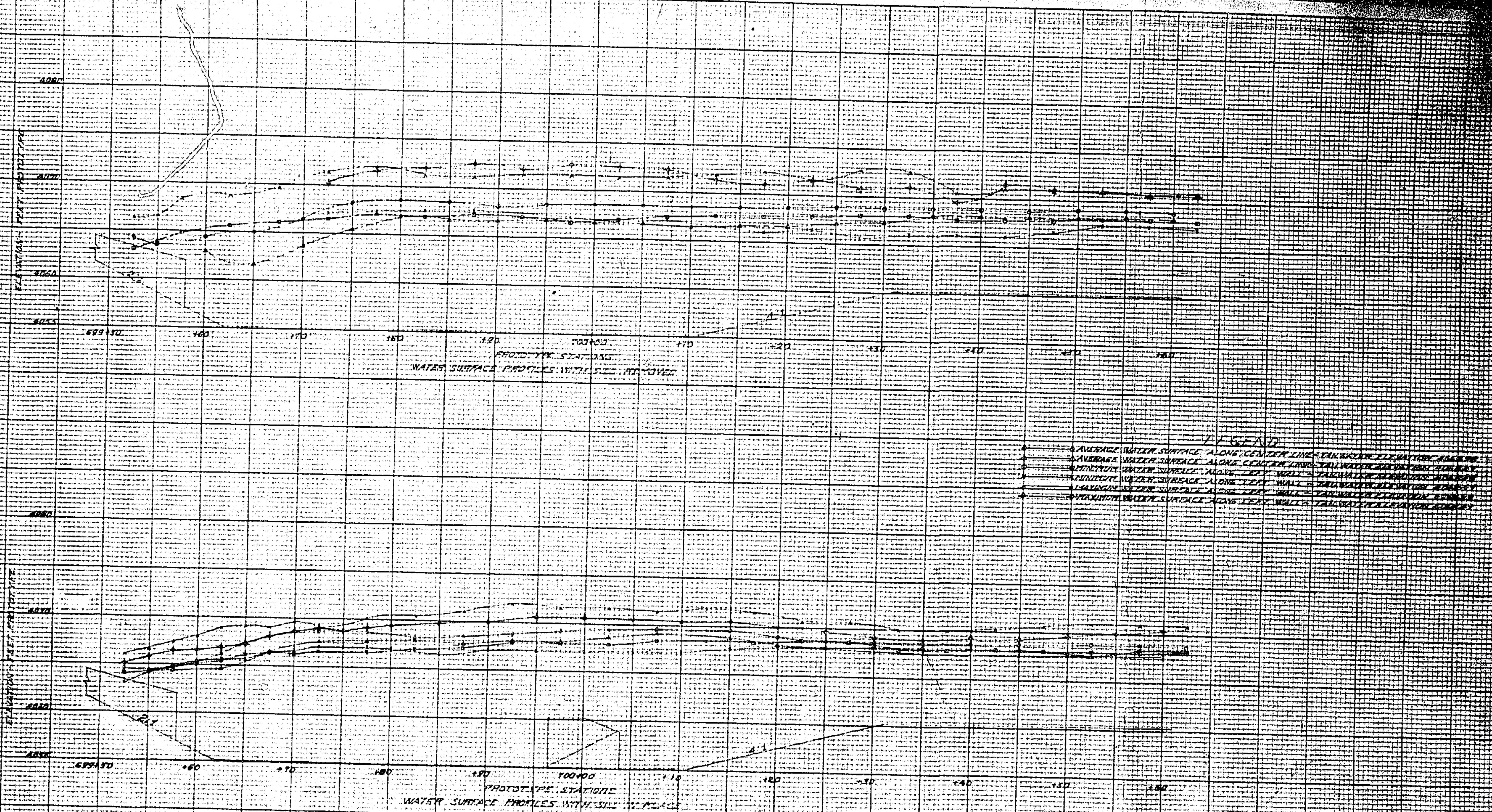


NO FLOW



DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4067.86

PROPOSED DESIGN



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SUN RIVER PROJECT - MONTANA
SPRING VALLEY CANAL - STA. 677+00
HYDRAULIC MODEL STUDIES
MODEL SCALE 1:16
WATER SURFACE PROFILES

DRAWN: D.M.L.	SUBMITTED:
TRACED:	RECOMMENDED:
CHECKED:	APPROVED:
	DENVER, COLORADO

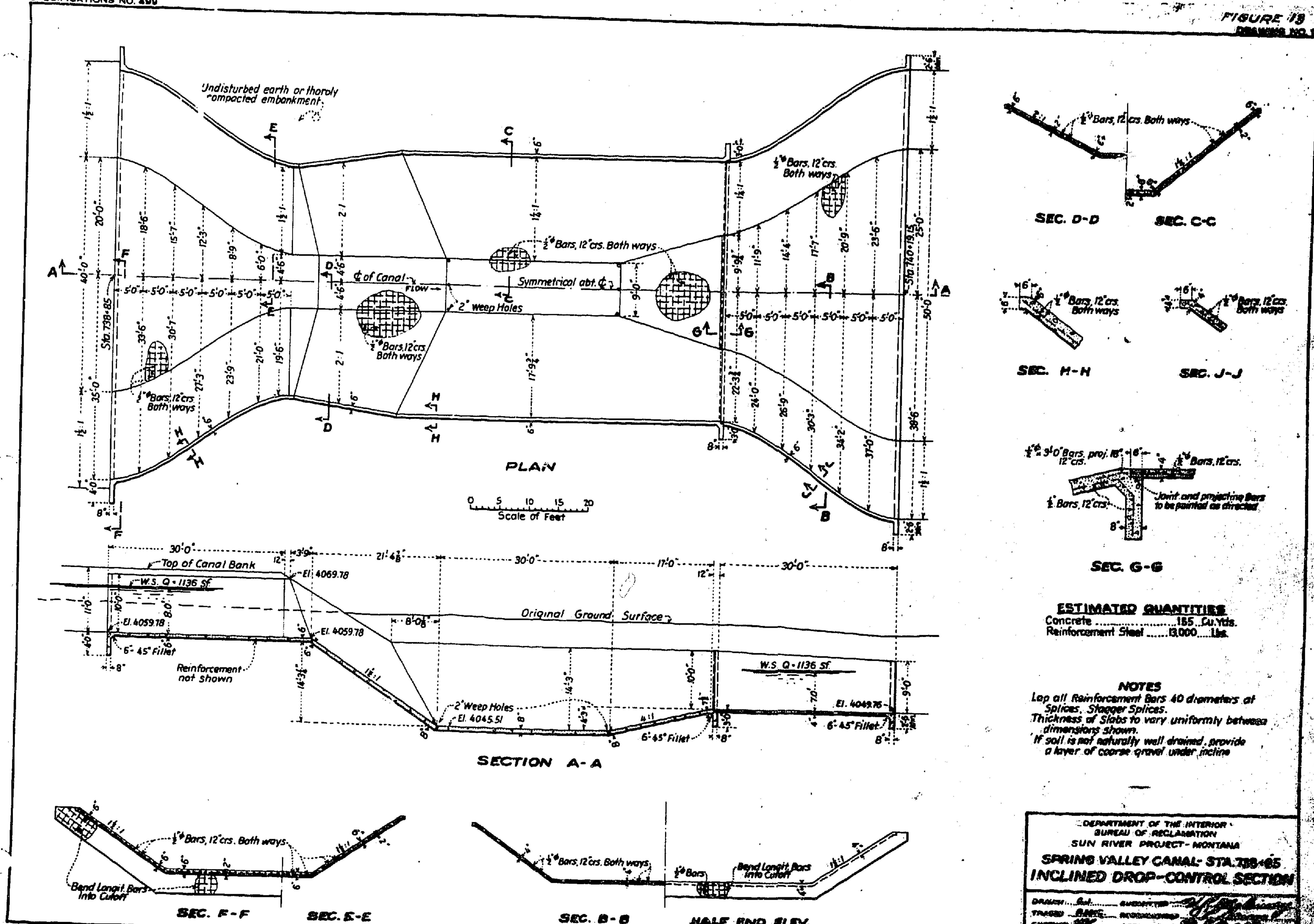
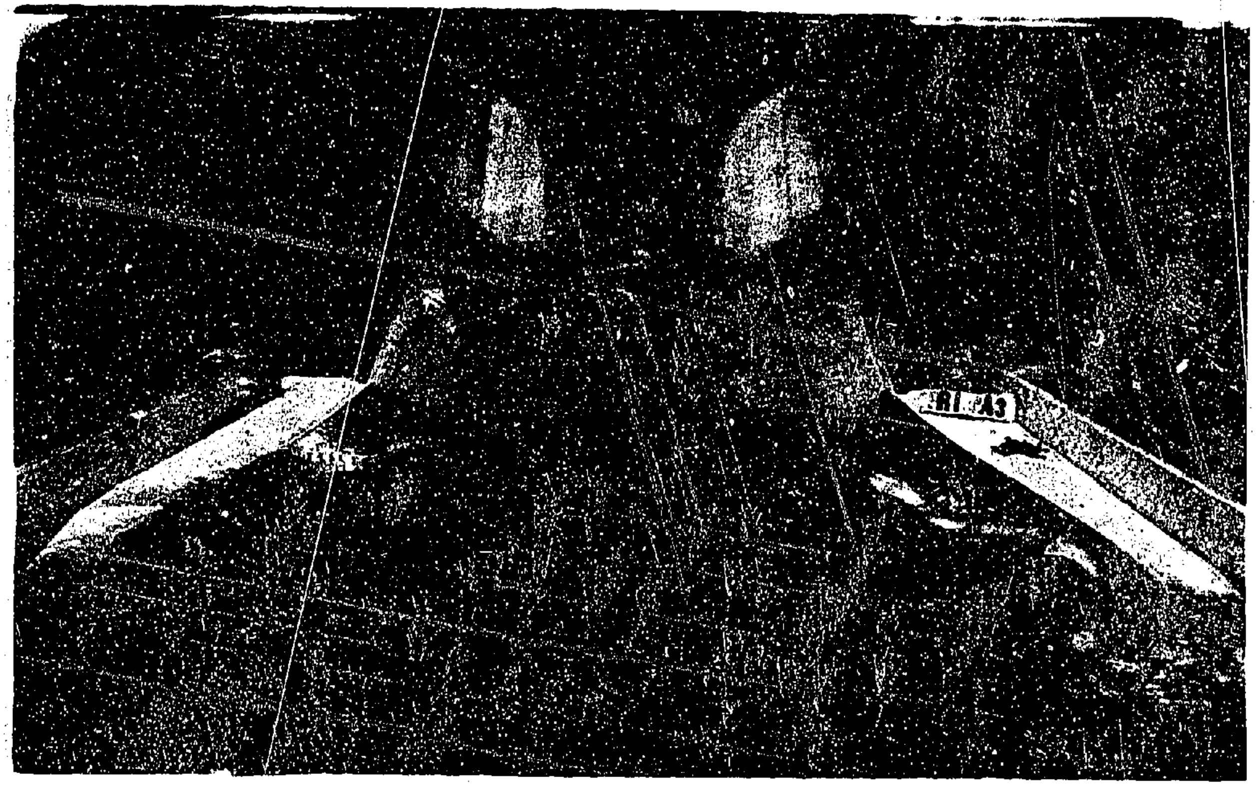


FIGURE 13
DRAWING NO 10
Undisturbed earth or thoroly compacted embankment
$\frac{1}{2}$"φ Bars, 12" crs. Both ways
¢ of Canal
FLOW
Symmetrical abt. ¢
2" Weep Holes
Sta. 739+85
Sta. 740+19.13
PLAN
Scale of Feet
SEC. D-D
SEC. C-C
SEC. H-H
SEC. J-J
$\frac{1}{2}$"φ x 3'-0" Bars, proj. 18", 12" crs.
Joint and projecting Bars to be painted as directed
SEC. G-G
Top of Canal Bank
W.S. Q = 1136 Sf
El. 4069.78
El. 4059.78
6"-45° Fillet
Reinforcement not shown
Original Ground Surface
2" Weep Holes
El. 4045.51
El. 4049.76
SECTION A-A
Bend Longit. Bars into Cutoff
SEC. F-F
SEC. E-E
SEC. B-B
HALF END ELEV.
ESTIMATED QUANTITIES
Concrete ....165 Cu.Yds.
Reinforcement Steel ......13,000 Lbs.
NOTES
Lap all Reinforcement Bars 40 diameters at Splices. Stagger Splices.
Thickness of Slabs to vary uniformly between dimensions shown.
If soil is not naturally well drained, provide a layer of coarse gravel under incline
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SUN RIVER PROJECT - MONTANA
SPRING VALLEY CANAL - STA. 738+65
INCLINED DROP-CONTROL SECTION
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

NO FLOW

DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4057.06

ORIGINAL DESIGN



[illegible]

DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4057.36

ORIGINAL DESIGN

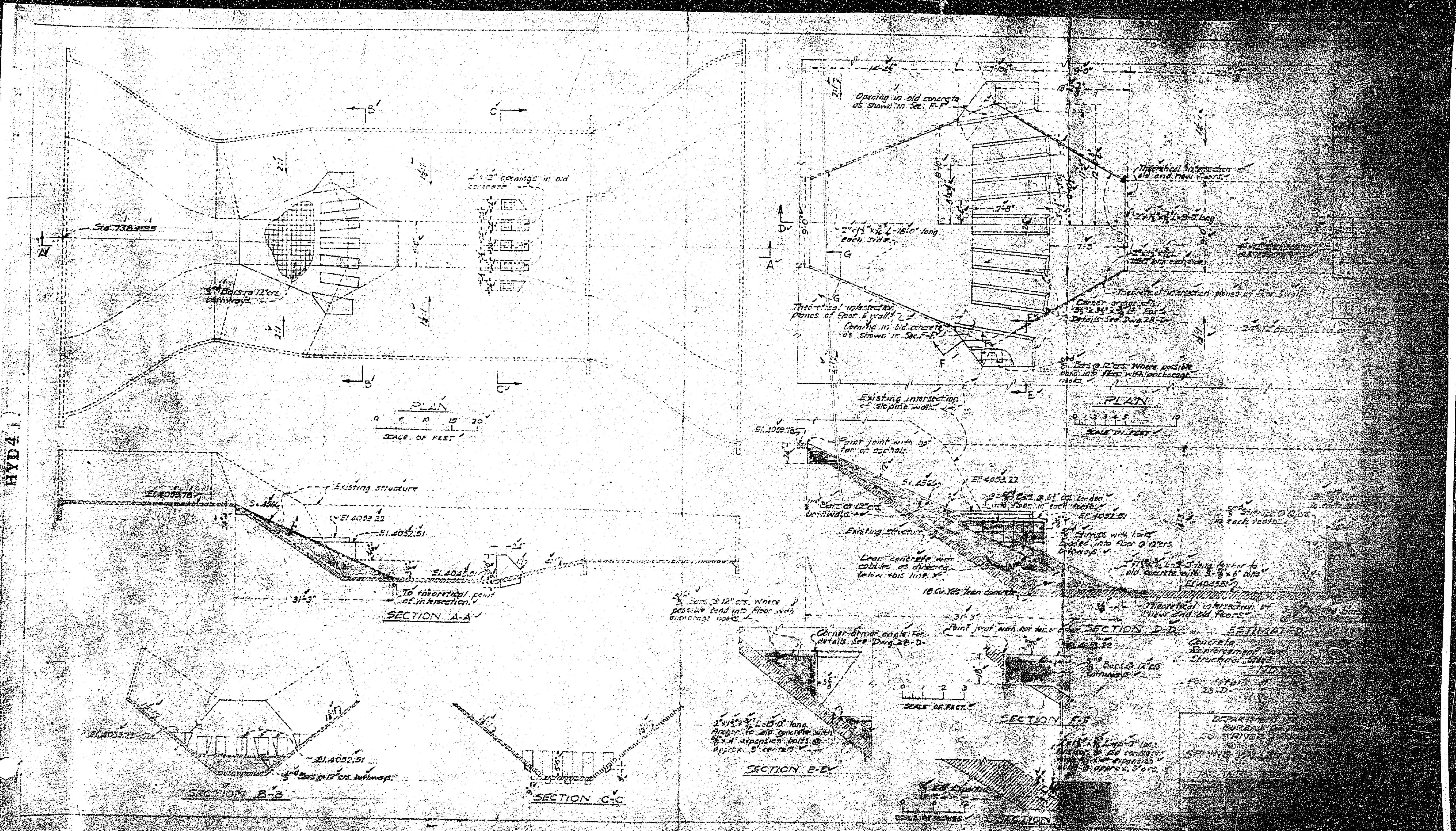
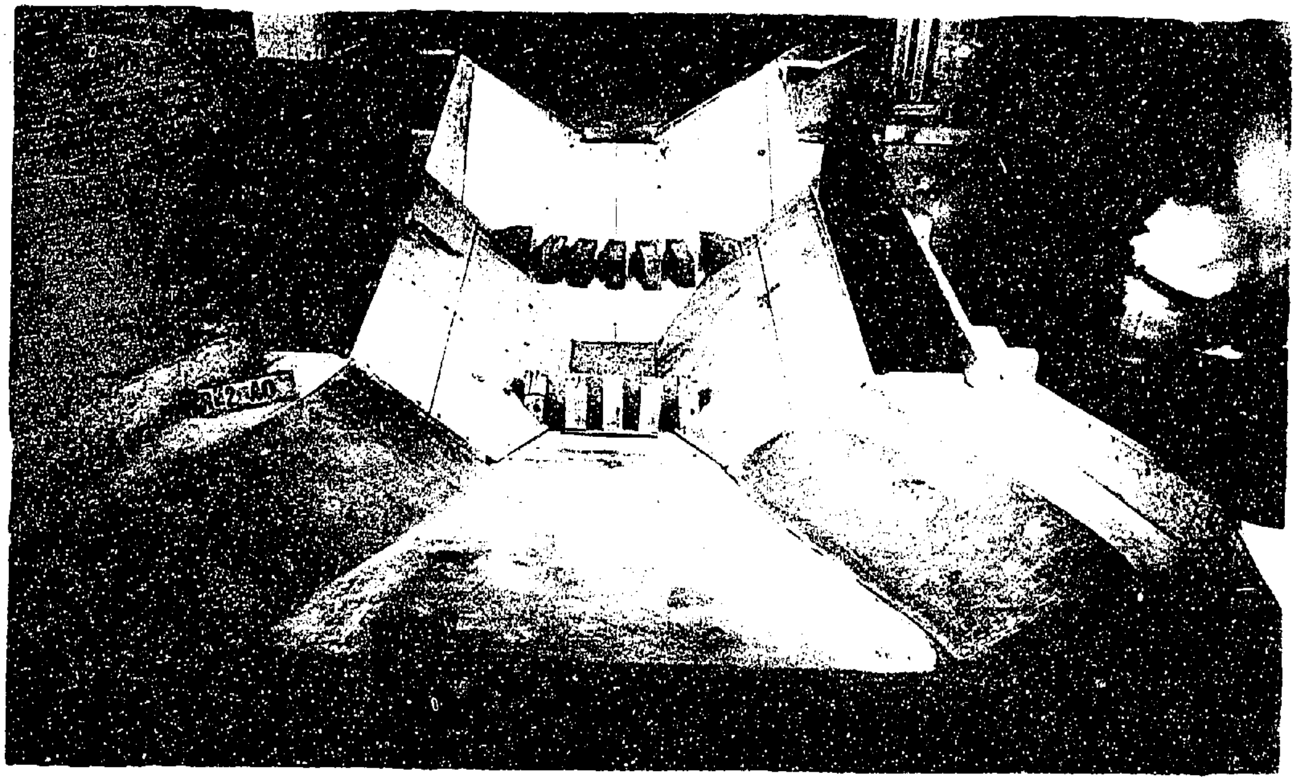
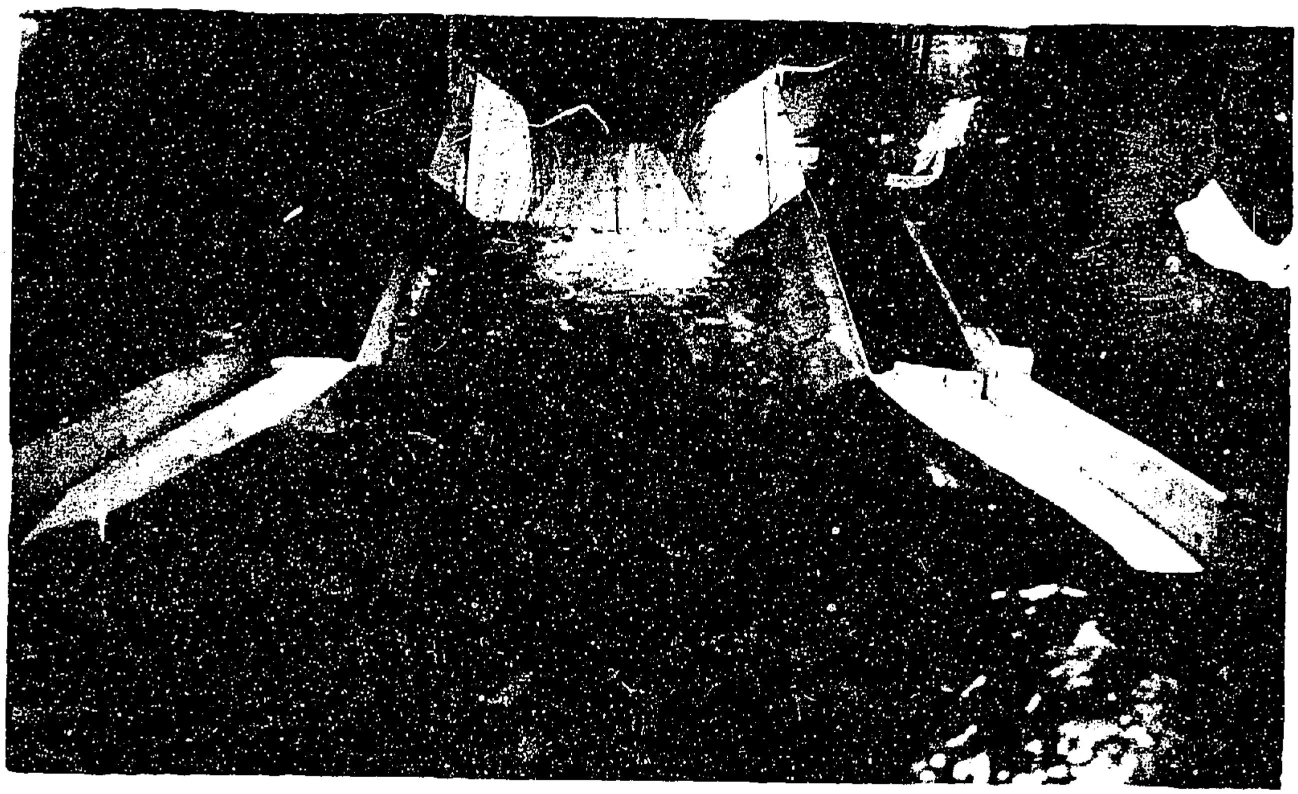

HYD 41
PLAN
SCALE OF FEET
Sta. 138+93.5
2'x12" openings in old concrete
5/8" Bars @ 12" crs. both ways
SECTION A-A
Existing structure
To theoretical point of intersection
31'-3"
El. 4052.51
El. 4053.22
SECTION B-B
SECTION C-C
SECTION B-B
SECTION D-D
SECTION F-F
SCALE IN FEET
Opening in old concrete as shown in Sec. F-F
Theoretical intersection of old and new floors
Theoretical intersection planes of floor & wall
Existing intersection of sloping walls
Paint joint with tar or asphalt
Existing structure
Lean concrete with cobbles, as directed, below this line
18 Cu. Yds. lean concrete
Corner armor angle. For details See Dwg. 28-D-
ESTIMATED
Concrete
Reinforcement Bars
Structural Steel
DEPARTMENT
BUREAU
RIVER

FIGURE 17



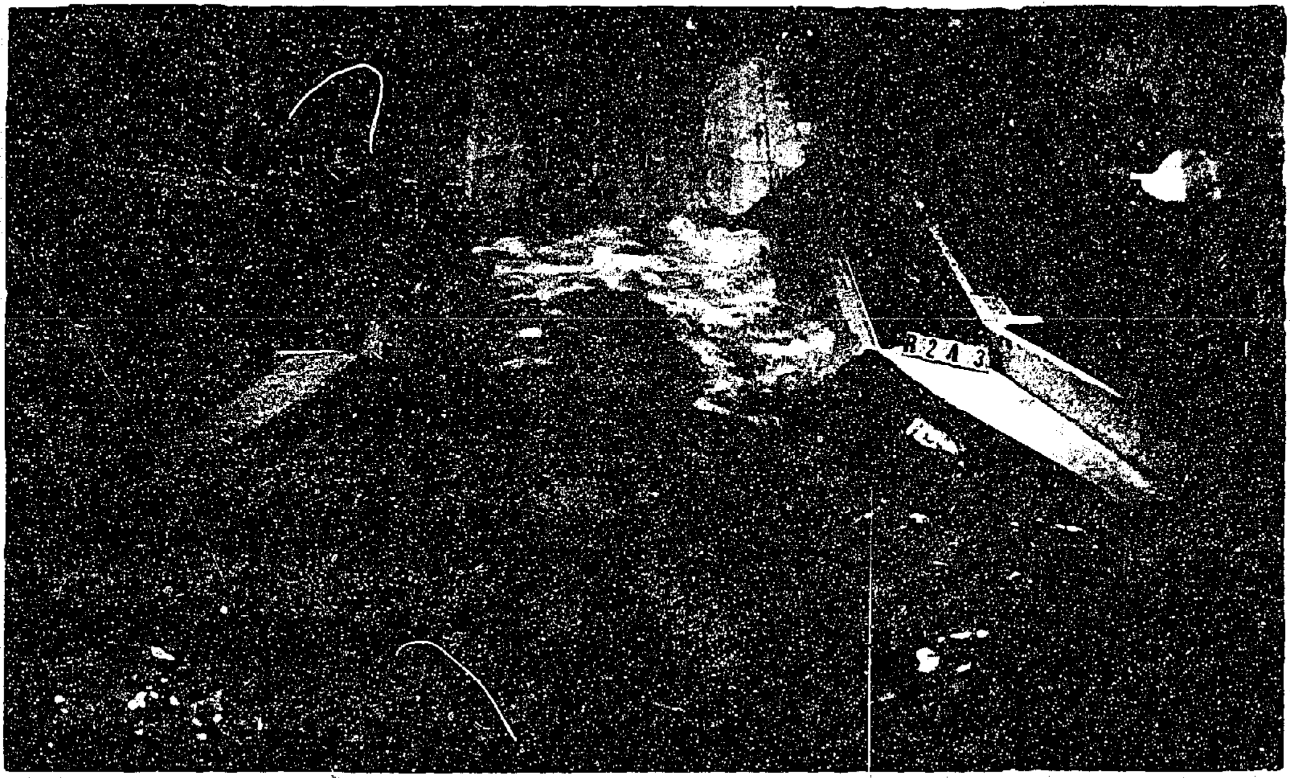
NO FLOW



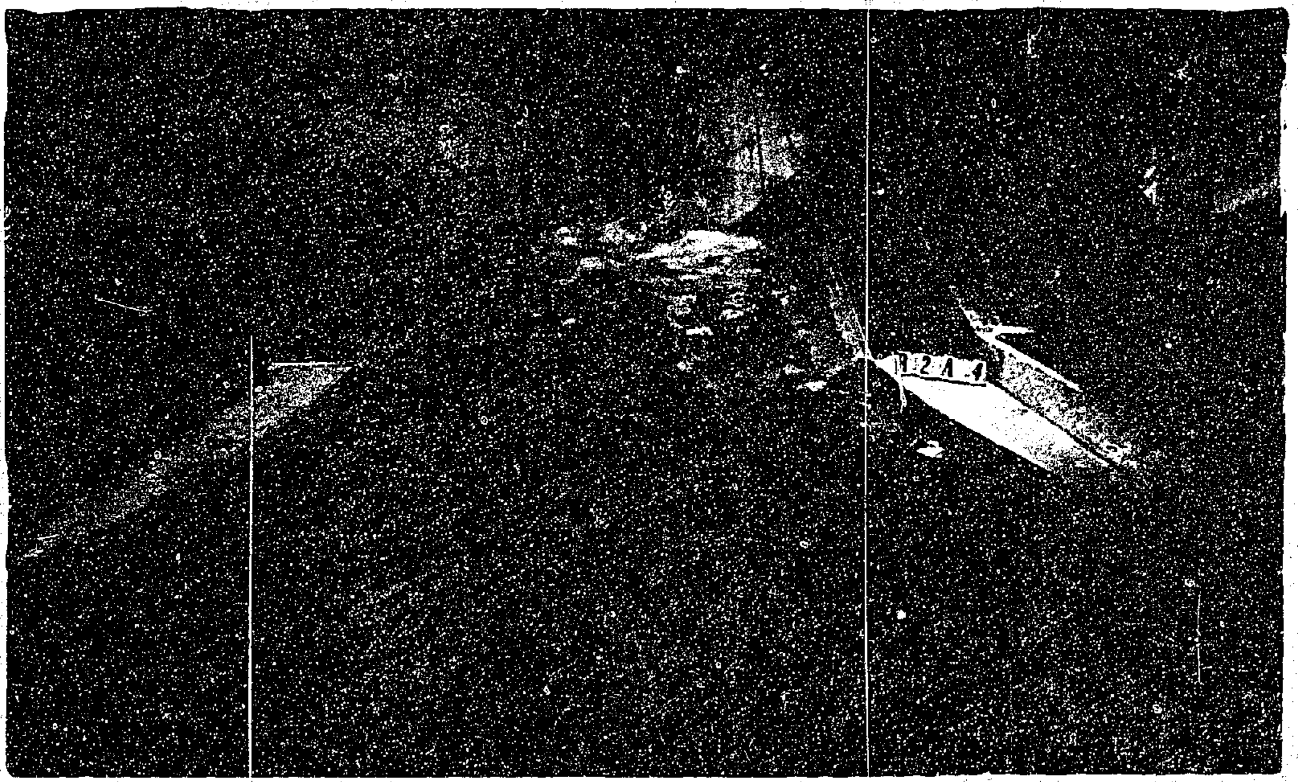
DISCHARGE 1136 SECOND-FEET - TAILWATER ELEVATION 4057.06

PROPOSED DESIGN

FIGURE 18



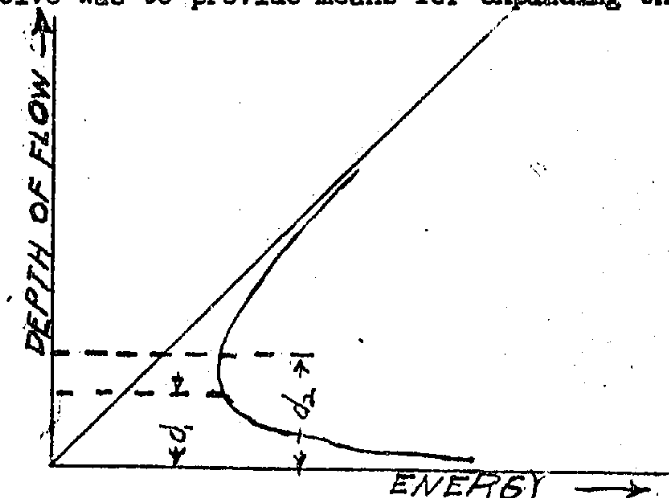
DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4057.06



DISCHARGE 1300 SECOND-FEET - TAILWATER ELEVATION 4057.36

PROPOSED DESIGN

jump) differ by only a small amount which brings this structure near the left side of the curve where the jump approaches a standing wave. As it was impossible to obtain a useful hydraulic jump, an alternative was to provide means for expanding the jet



Energy Curve

and distributing the velocity as uniformly as possible across the pool. Extensive tests resulted in the proposed design which is shown in figure 16. Flow conditions are shown on figures 17 and 18.

Slope Canal Headworks

7. The model of the headworks conformed to the field structure (figure 19) the essential parts being a transition into a tunnel which contained the three gates and another transition from the tunnel to the canal section. Severe erosion occurred in the unlined canal as a result of the jet shooting through without spreading to form a hydraulic jump (figures 20 and 21). The jet followed one side of the transition, causing a large whirlpool. The direction of the whirl could be reversed by deflecting the jet to the opposite side. For economic reasons, a revision of the present structure was desirable.

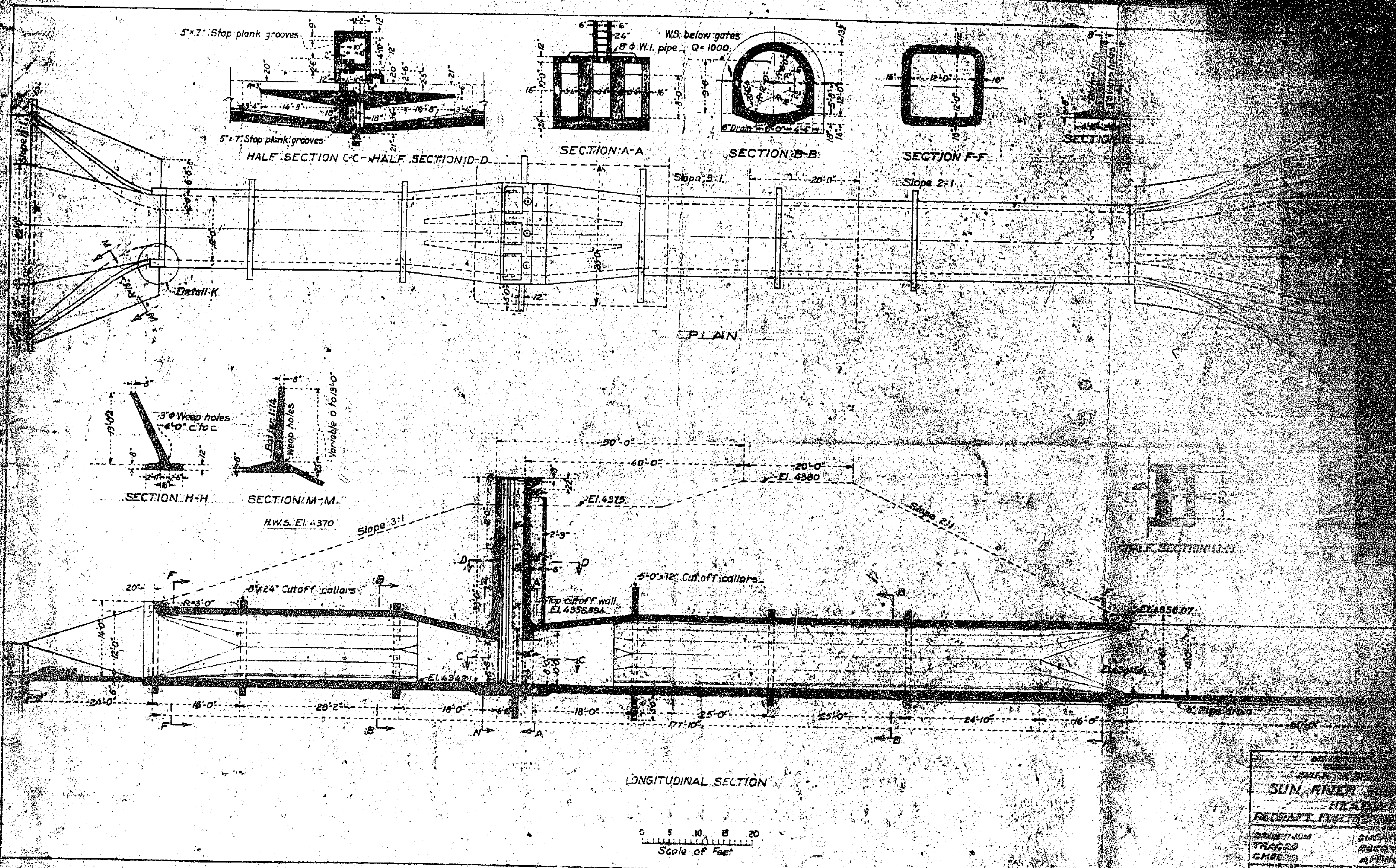
8. Various shaped humps were tried at different locations on the pool floor as shown on figure 22. It was possible to obtain satisfactory flow conditions with the tunnel air vents closed; however, under this condition the hydraulic jump formed inside the tunnel and produced a severe vibration. Hence, it was necessary to abandon this set-up.

The next trial consisted of placing a pier in the pool to spread the jet. Several piers were tried as shown on figure 22 but no improvement in flow conditions was obtained.

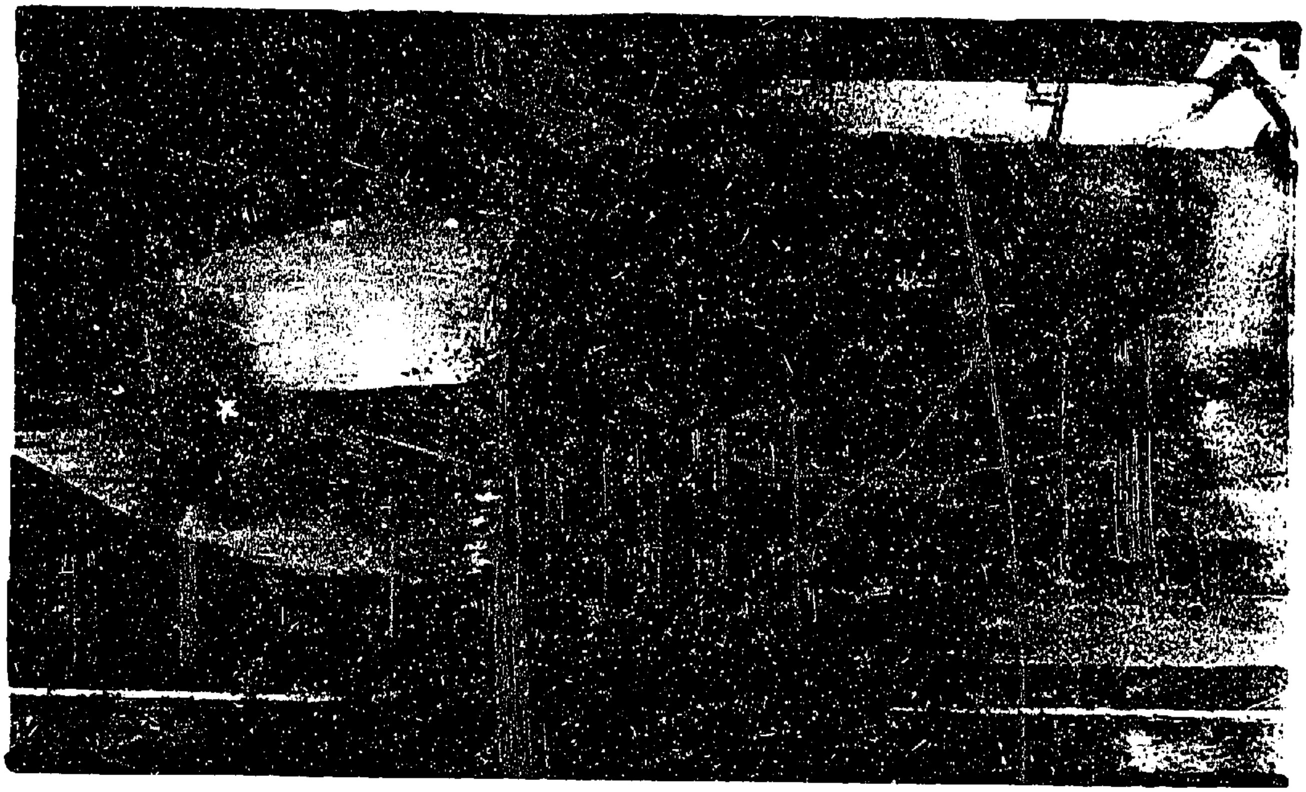
A stop-log weir in conjunction with the sill (figure 23) gave a satisfactory solution. At low discharges the flow passes through the eight-foot opening in the weir (figure 24). It is necessary to have this opening when the reservoir elevation is low. At the higher discharges some energy is dissipated by impact of the jet falling over the weir. The remaining velocity is distributed uniformly over the width of the apron (figure 25). The proposed design is shown on figure 26. Calibration curves are shown on figure 27.

\- - -

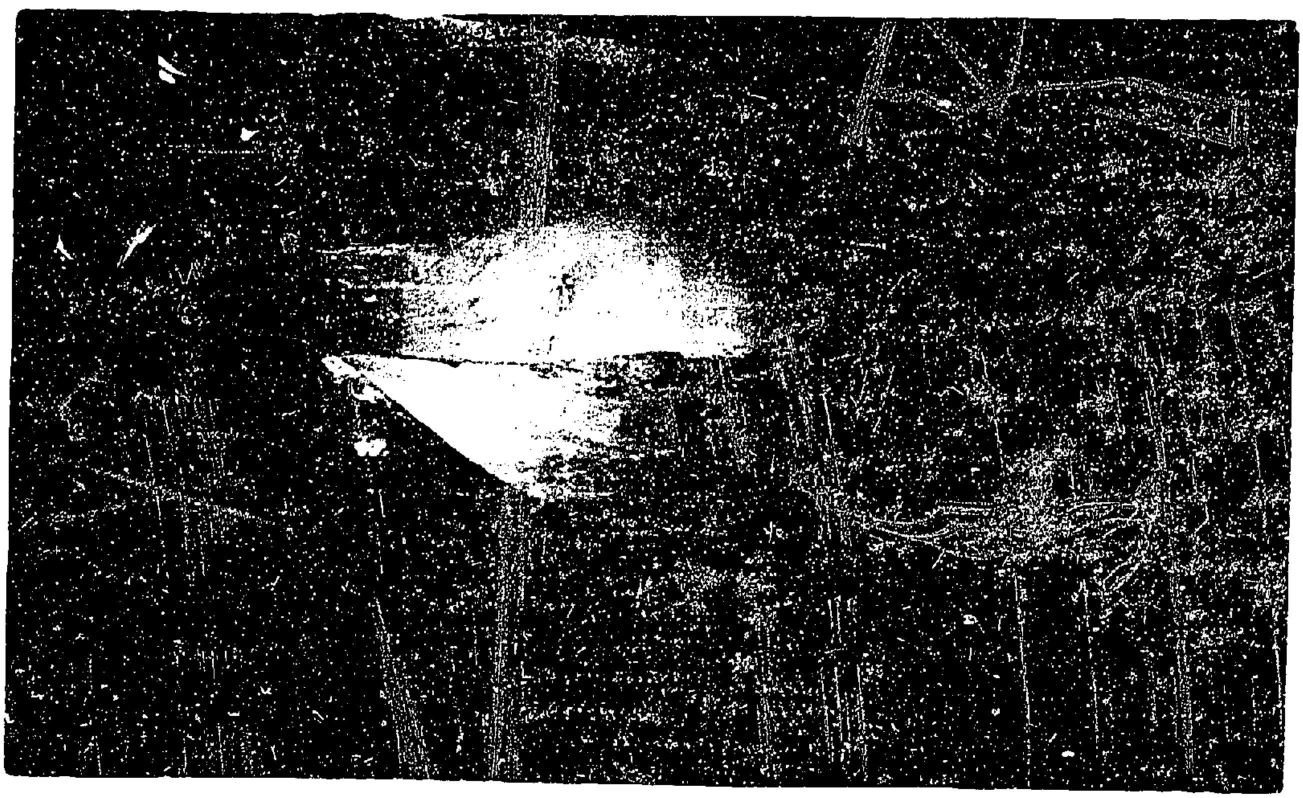
J. E. Warnock.



5"x7" Stop plank grooves
5"x7" Stop plank grooves
HALF SECTION C-C - HALF SECTION D-D
W.S. below gates
8" ϕ W.I. pipe
Q = 1000
SECTION A-A
SECTION B-B
SECTION F-F
Slope 3:1
Slope 2:1
Detail K
PLAN
3" ϕ Weep holes 4'-0" C. to C.
Weep holes
Variable 0 to 13'-0"
SECTION H-H
SECTION M-M
H.W.S. El. 4370
El. 4375
El. 4380
Slope 3:1
Slope 2:1
8"x24" Cutoff collars
5'-0"x12" Cutoff collars
Top cutoff wall El. 4355.694
El. 4356.07
El. 4342
HALF SECTION N-N
6" Pipe drain
LONGITUDINAL SECTION
Scale of Feet
SUN RIVER
REDRAFT
TRACED
CHECKED

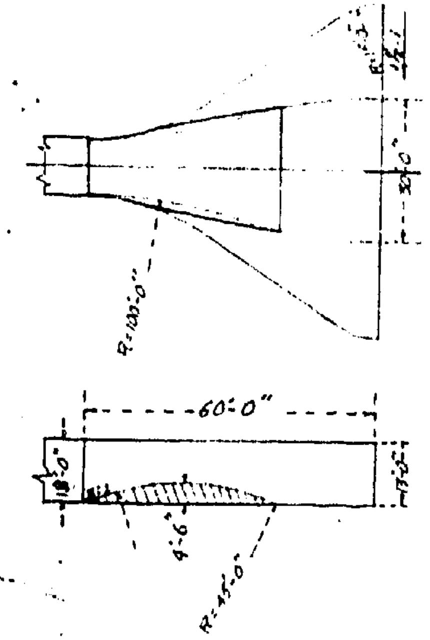


NO FLOW

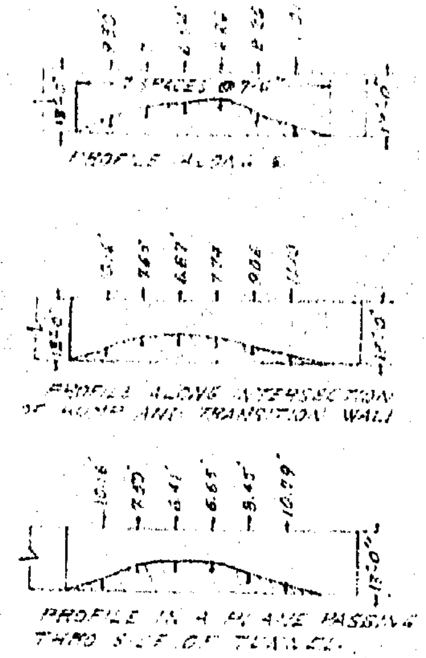


DISCHARGE 400 SECOND-FEET - TAILWATER ELEVATION 4345.0

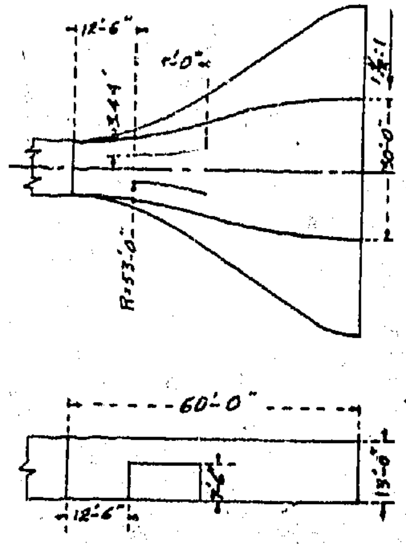
ORIGINAL DESIGN



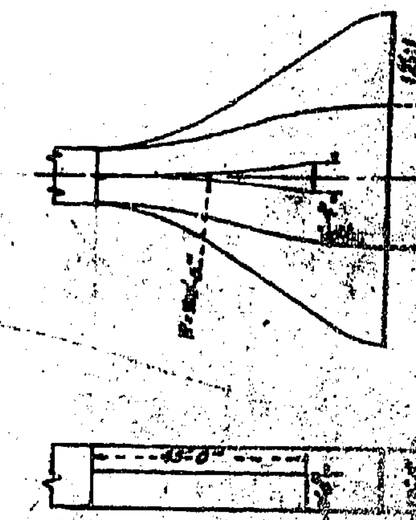
DESIGN A



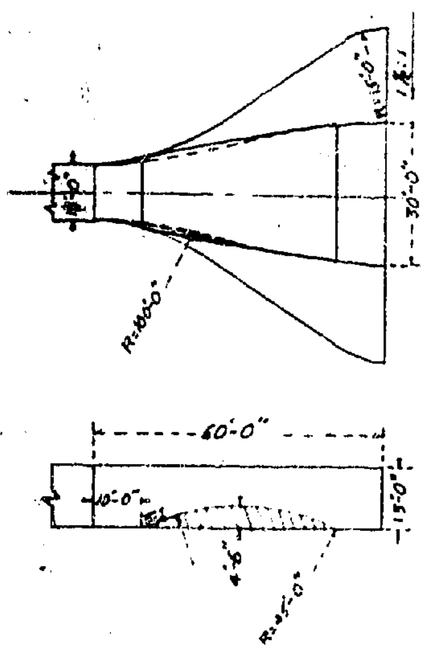
DESIGN C



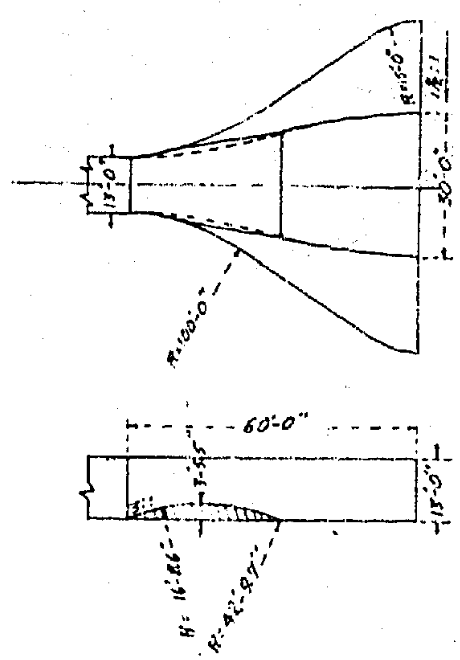
DESIGN E



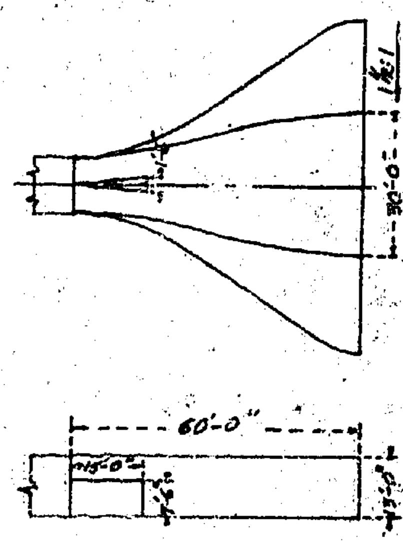
DESIGN G



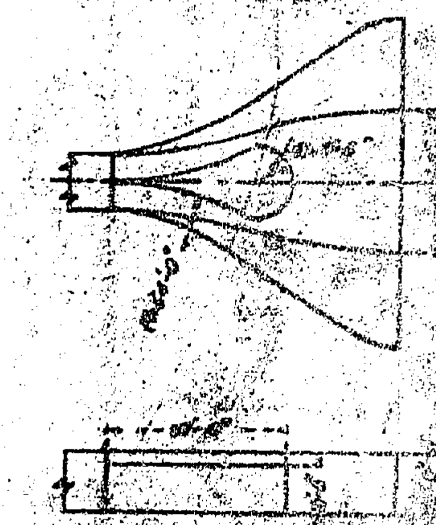
DESIGN B



DESIGN D



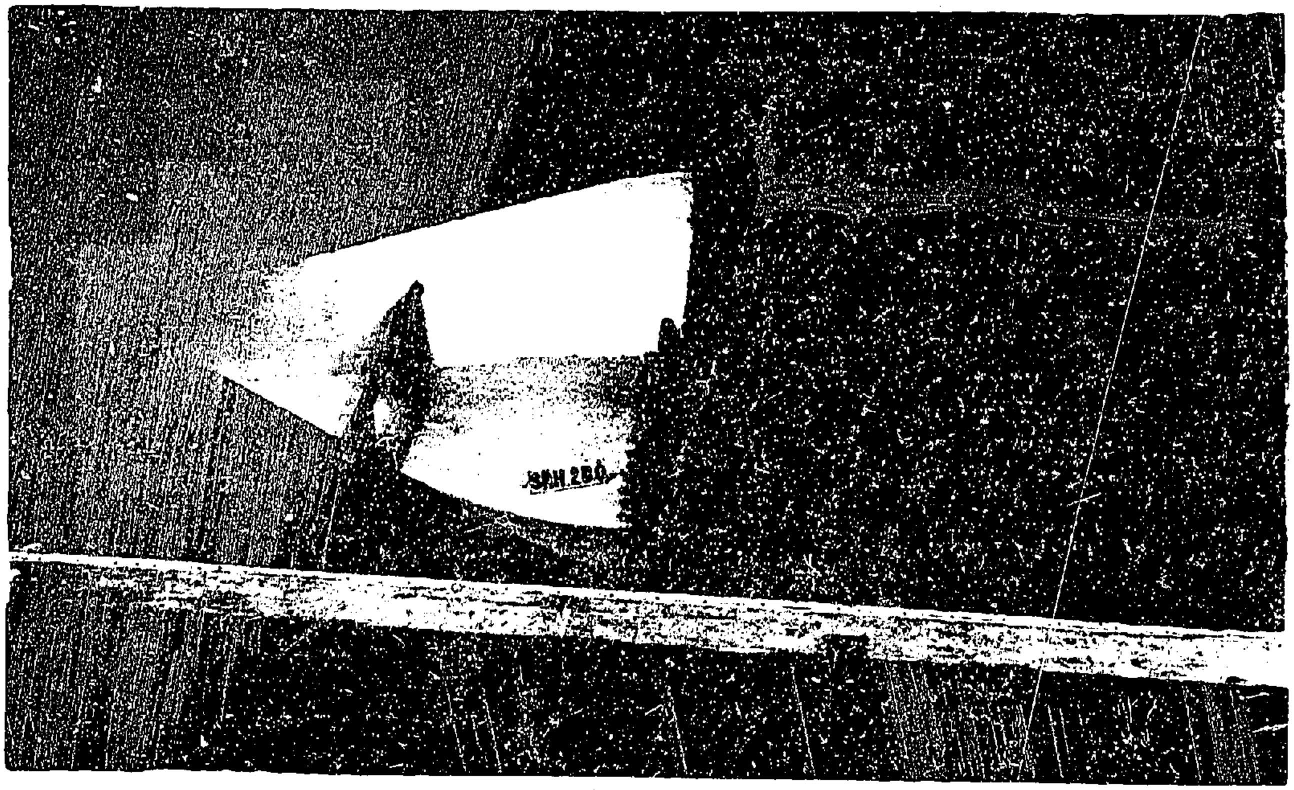
DESIGN F



DESIGN H

SUN RIVER S

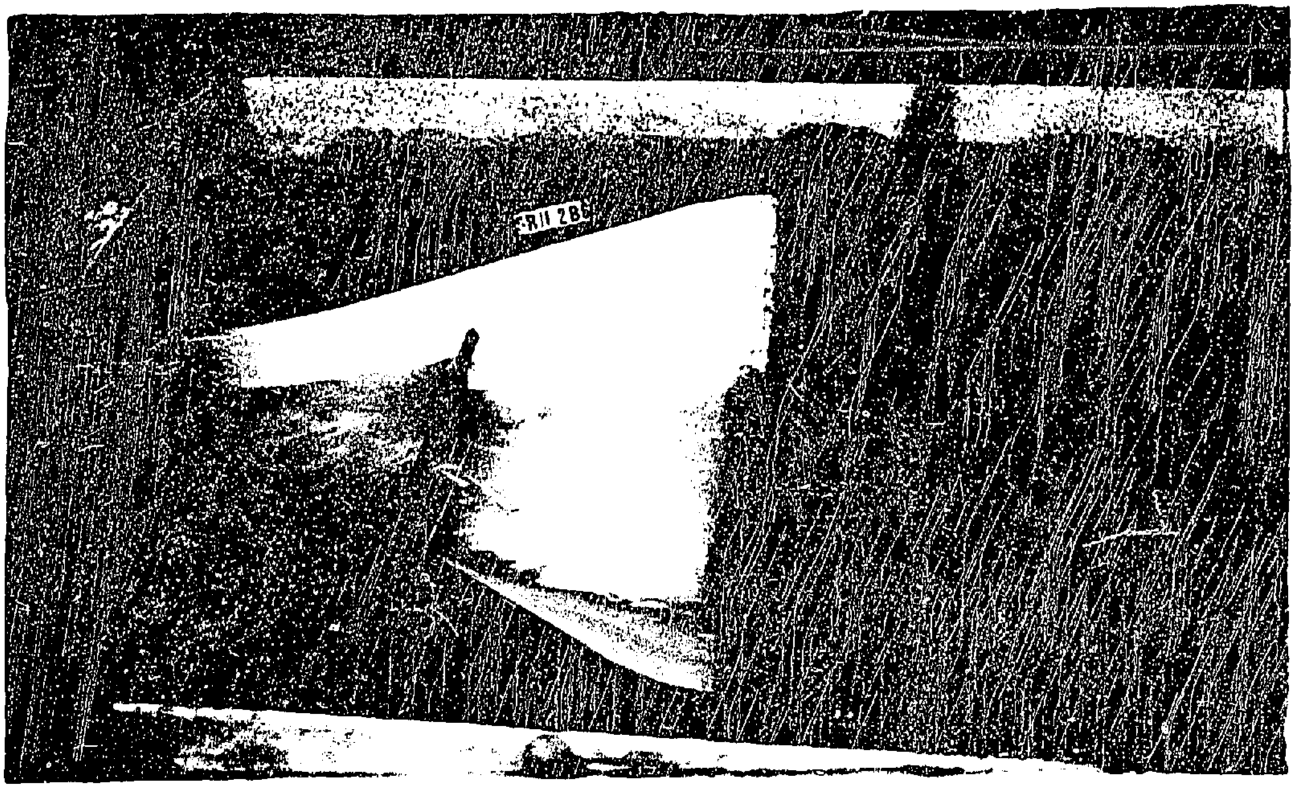
DRAWN
TRACED
CHECKED



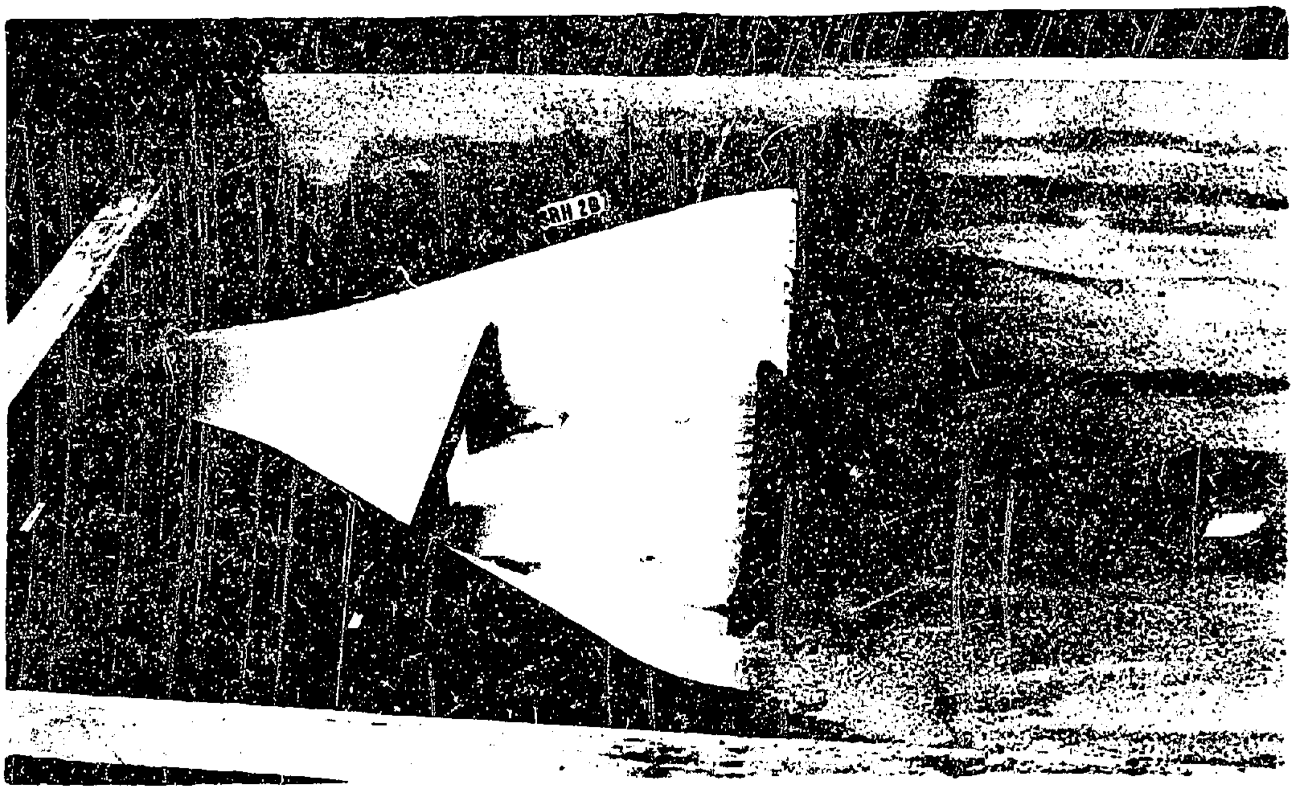
NO FLOW

DISCHARGE 400 SECOND-FEET - TAILWATER ELEVATION 4365.0. WEIR GATE CLOSED

PROPOSED DESIGN



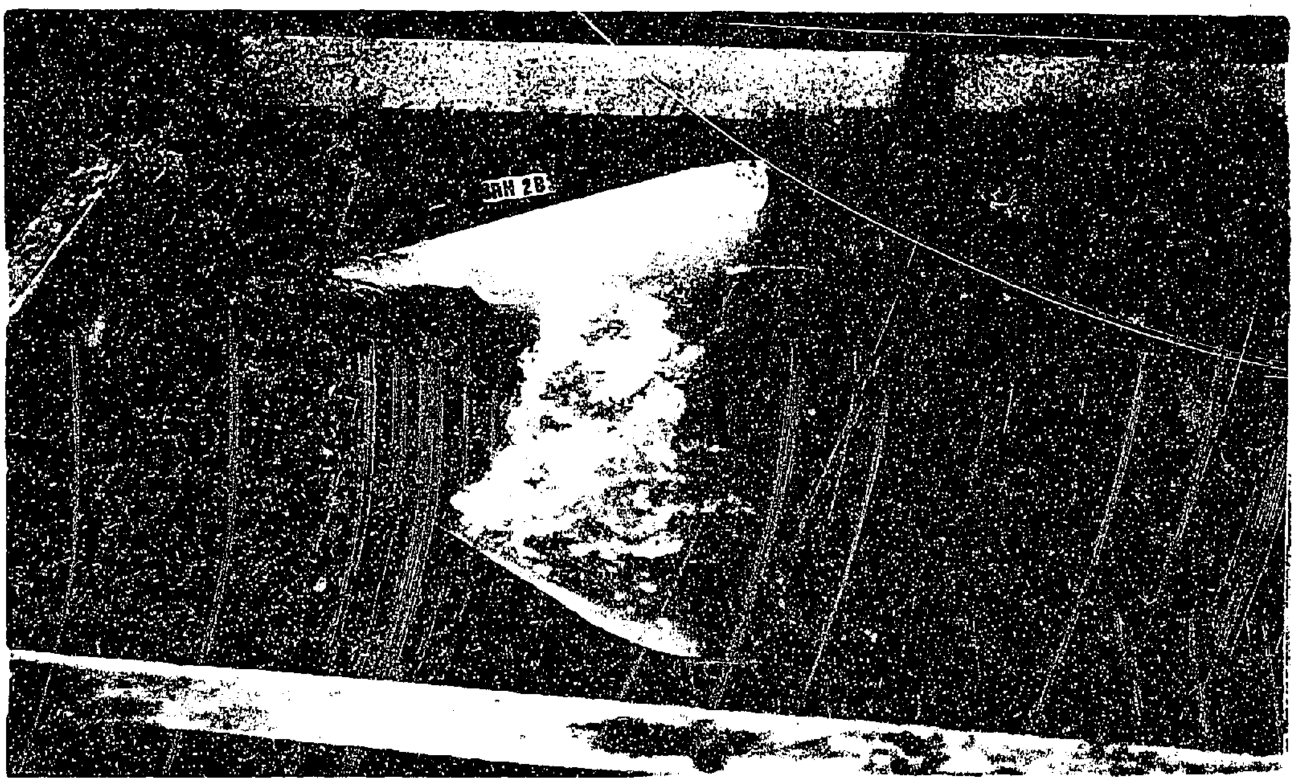
DISCHARGE 400 SECOND-FEET - TAILWATER ELEVATION 4345.0 WEIR GATE OPEN



CANAL AFTER DISCHARGE OF 1800 SECOND-FEET.

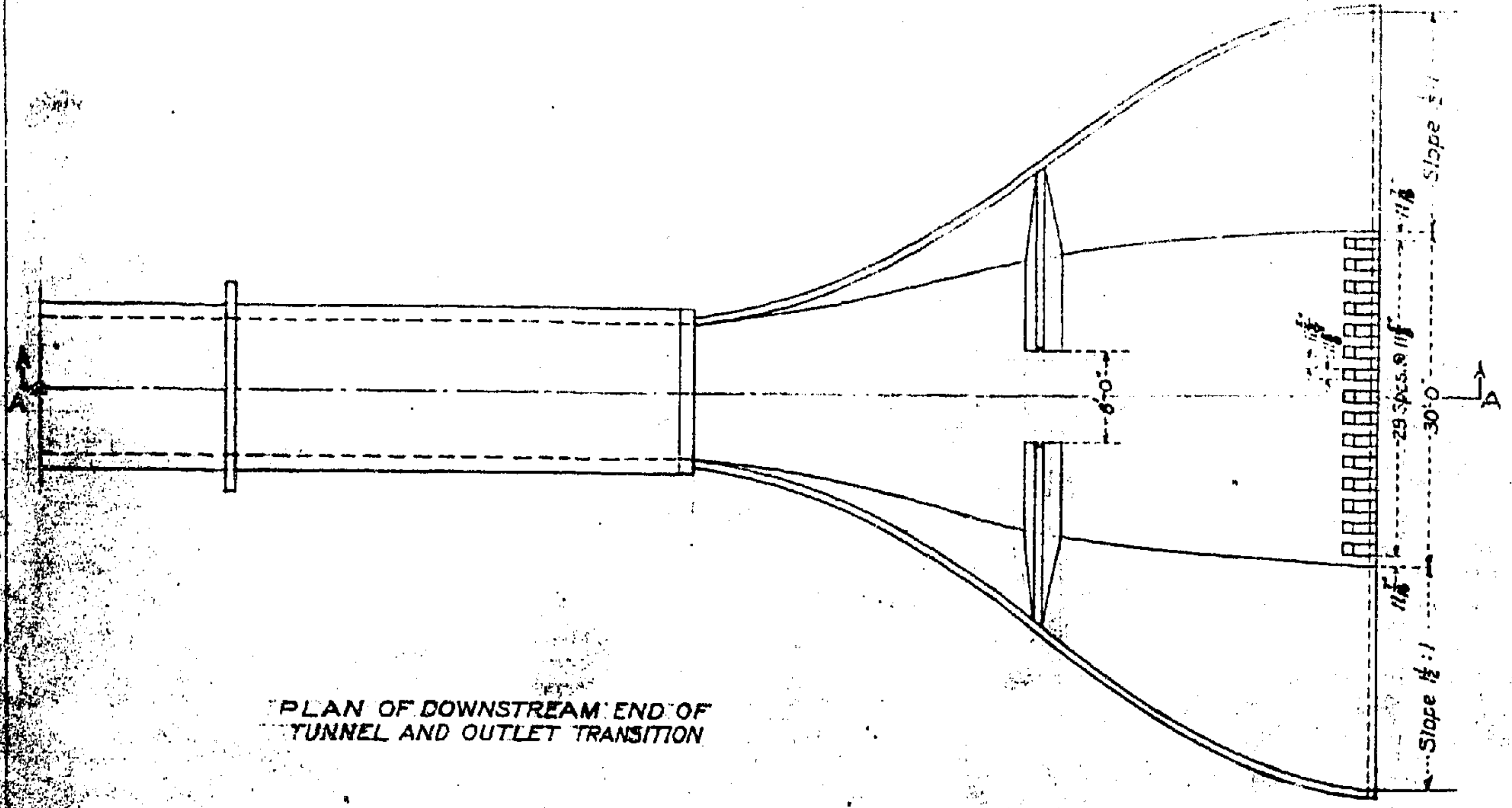
PROPOSED DESIGN

DISCHARGE 800 SECOND-FEET - TAILWATER ELEVATION 4347.0. WEIR GATE CLOSED

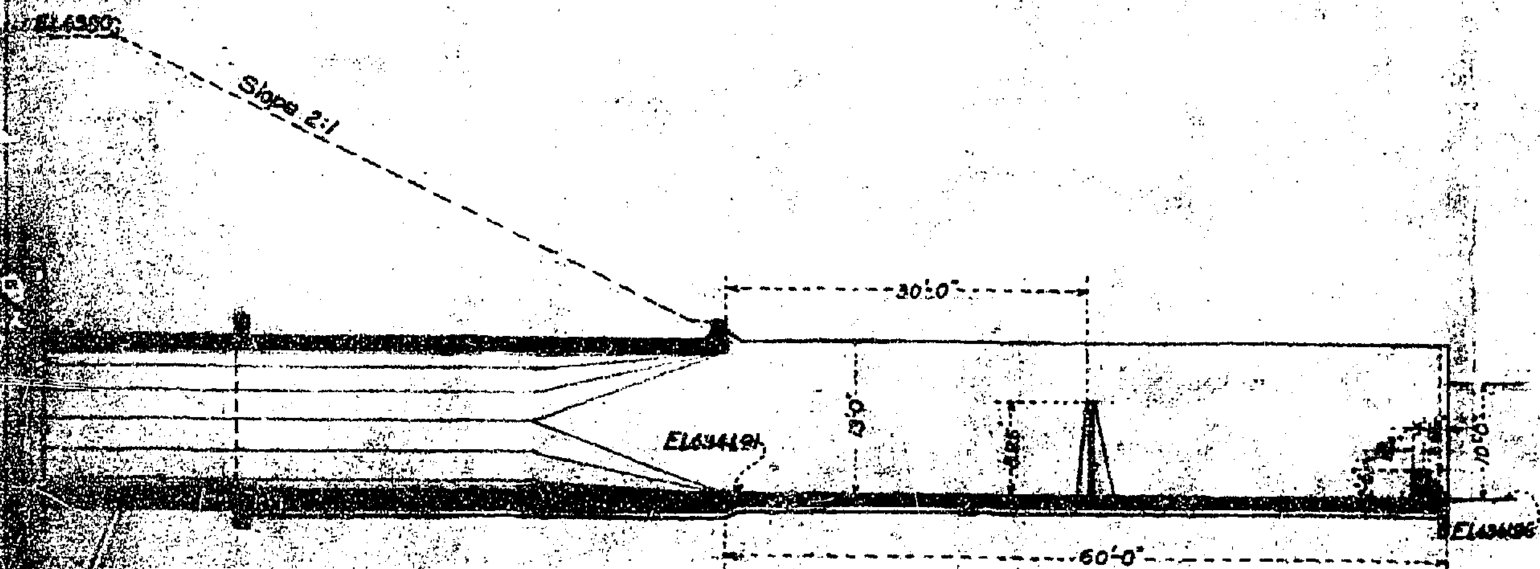


DISCHARGE 1600 SECOND-FEET - TAILWATER ELEVATION 4354.0. WEIR GATE CLOSED.

PROPOSED DESIGN

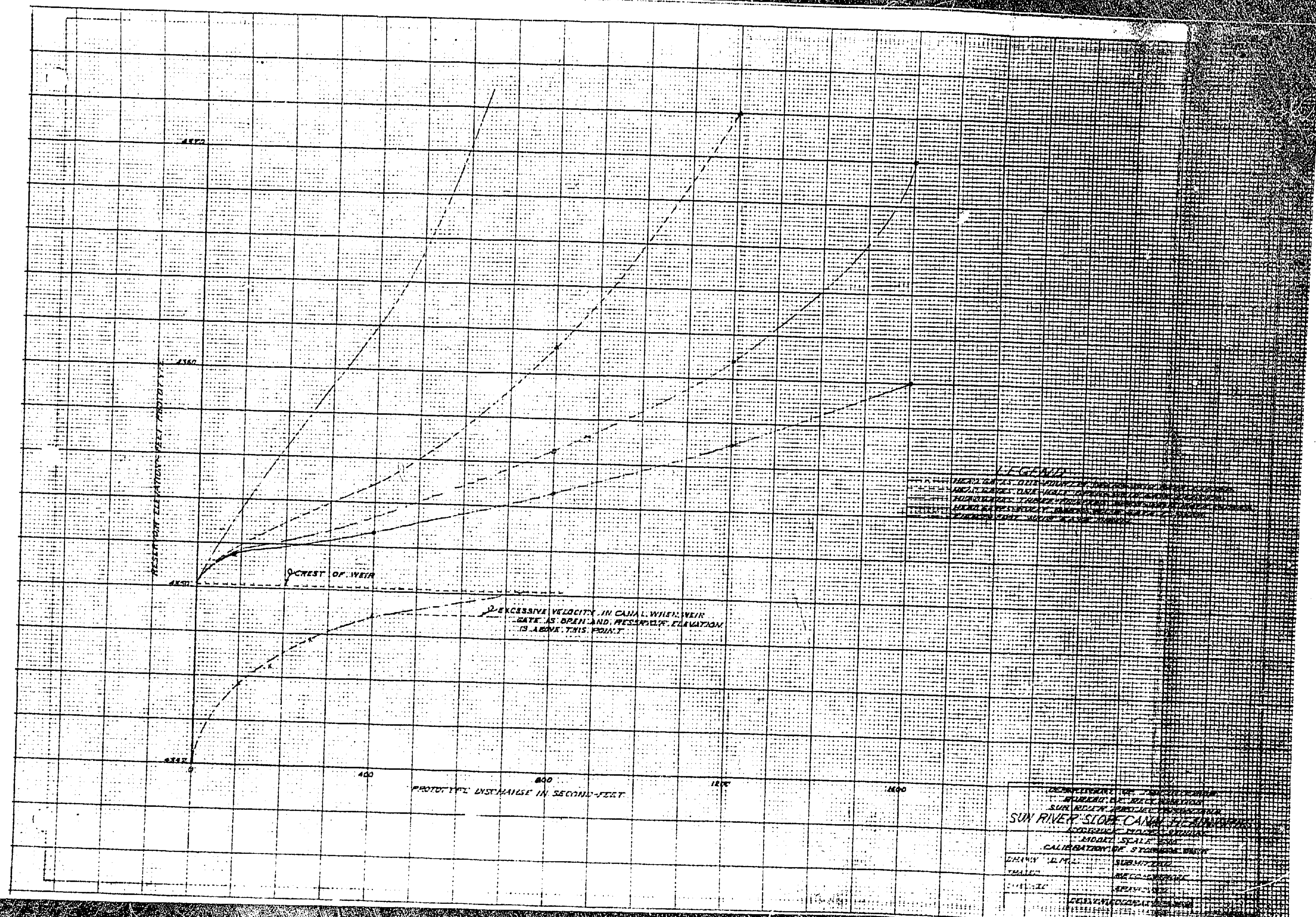


PLAN OF DOWNSTREAM END OF TUNNEL AND OUTLET TRANSITION



SECTION A-A

0 5 10 15 20
Scale of Feet



4350
4360
0
400
800
1200
1600
PROTOTYPE DISCHARGE IN SECOND-FEET
CREST OF WEIR
EXCESSIVE VELOCITY IN CANAL WHEN WEIR
GATE AS OPEN AND RESERVOIR ELEVATION
IS ABOVE THIS POINT
LEGEND
SUN RIVER SLOPE CANAL
MODEL SCALE
CALIBRATION OF
DRAWN
SUBMITTED