UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDRAULIC MODEL EXPERIMENTS FOR THE DESIGN

of

THE RYE PATCH SPILLWAY

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and

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HYD 3.08

TECHNICAL MEMORANDUM NO. 411

Denver, Colorado

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SUMMARY

Model tests on the Rye Patch Spillway showed that the original design was quite satisfactory from a hydraulic standpoint except that erosion was slightly excessive at the downstream end of the sloped paving. Flow thru the gates was quiet. Flow down the spillway, altho checkered with diamond shaped surface waves produced by the piers, was entirely satisfactory. A good hydraulic jump formed in the pool at all discharges.

It was quite evident that the stilling pool was longer and deeper than necessary. Consequently, model tests were made in an effort to shorten the pool, reduce its depth, and thereby decrease the cost of the structure. It was found from tests, that by the proper arrangement of a stepped apron at the toe of the slope and a rectangular sill at the end of the pool floor, it was possible to shorten the pool and side walls 62 feet. The stilling pool structure as a whole was shortened 67 feet. At the same time, the floor of the pool was raised to elevation 4062 which resulted in a saving of 3 feet of excavation. The rectangular sill combined with a stepped apron which is proposed for the final design, should not cost any more than the dentated sill shown in the original design.

An attempt was made to narrow the spillway section as well as the stilling pool to 70 feet, leaving the width of the gate section 110 feet. With the narrower section, the depth of water in the spillway was increased and flow conditions were somewhat impaired. In the stilling pool, the greater flow per foot of width required a deeper and longer pool to contain the jump at all discharges and corresponding tailwater depths. As the costs of the two structures using the original width and the narrowed width proved to be practically the same, the former which was the better hydraulically, was adopted.

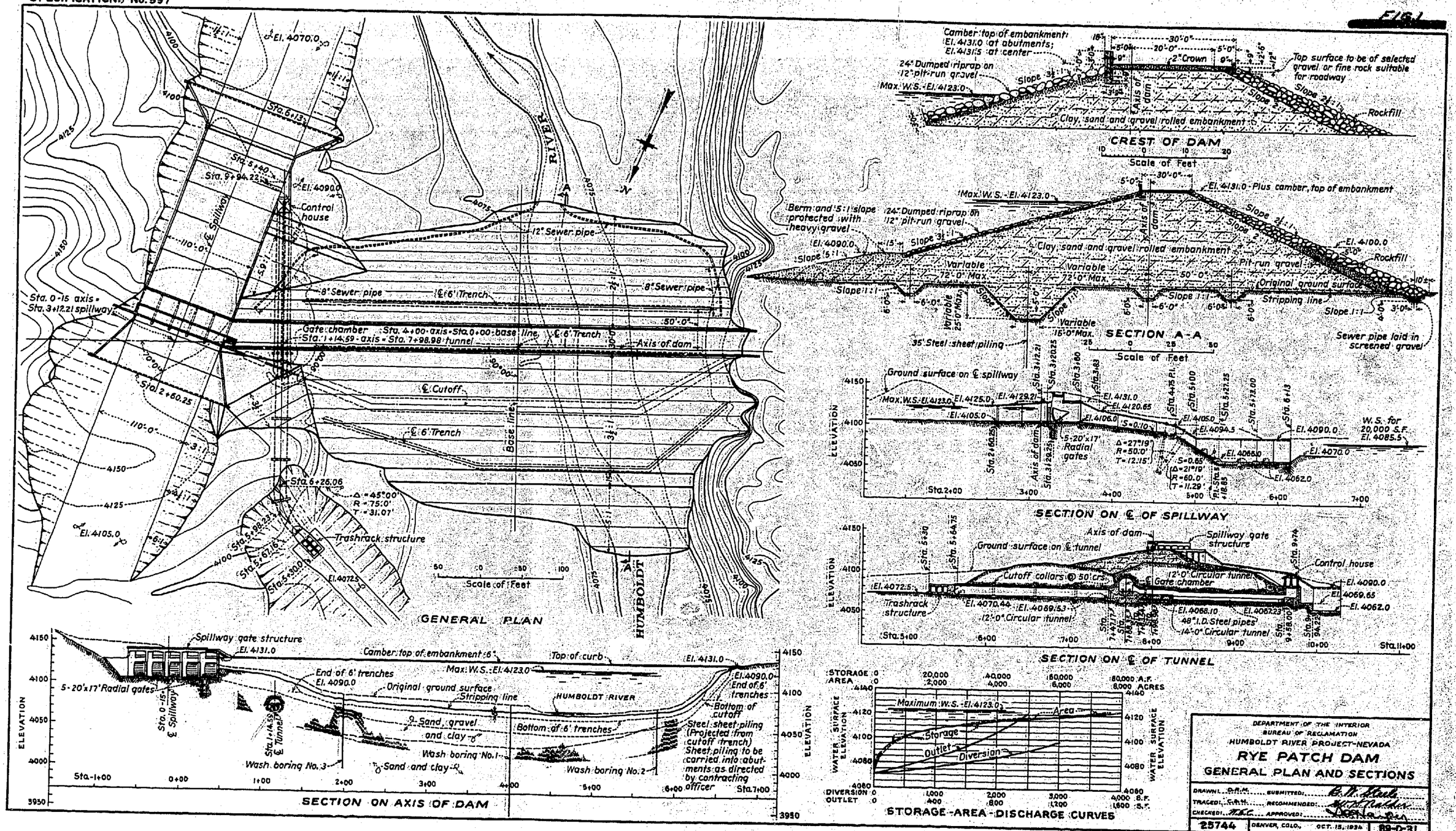
THE PROJECT

Rye Patch Reservoir will supply additional storage capacity to the Humboldt River Irrigation Project of which it will be a part. The dam is to be located on the Humboldt River, two miles north of the town of Rye Patch and about 100 miles northeast of Reno, Nevada. The dam will be of the earth fill type and will provide a reservoir storage capacity of 80,000 acre feet. The drop from maximum reservoir elevation to tailwater will be about 38 feet. A general plan of the dam is shown in figure 1.

The spillway, a plan and section of which is shown in figure 2, will be located at the east end of the dam. It was designed for a maximum discharge of 20,000 c.f.s. with 17 feet of head on the crest. The flow will be controlled by five Tainter gates located in a level

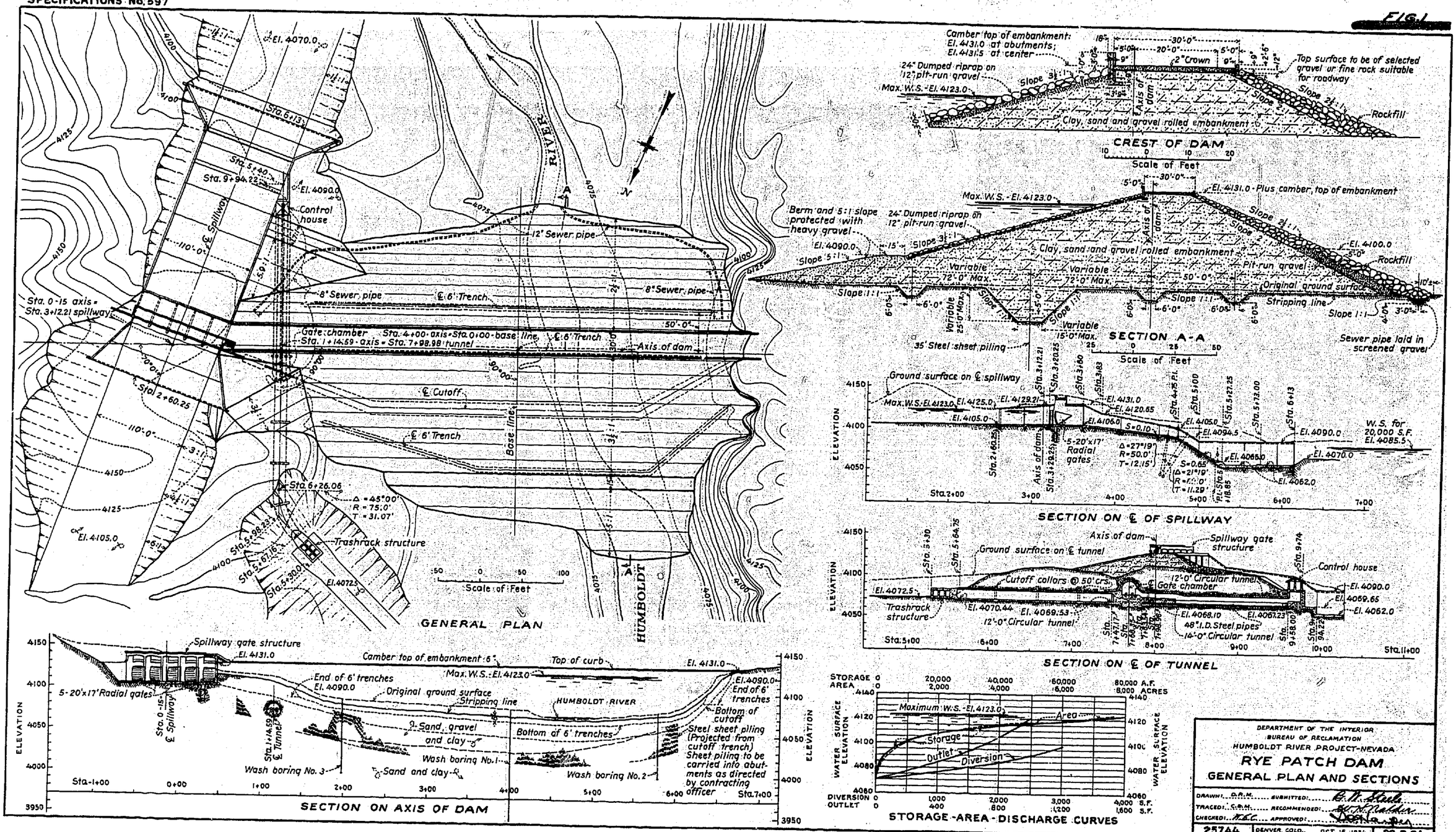
SPECIFICATIONS No. 597

FIG. 1



SPECIFICATIONS No. 597

FIG. 1



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA

RYE PATCH DAM

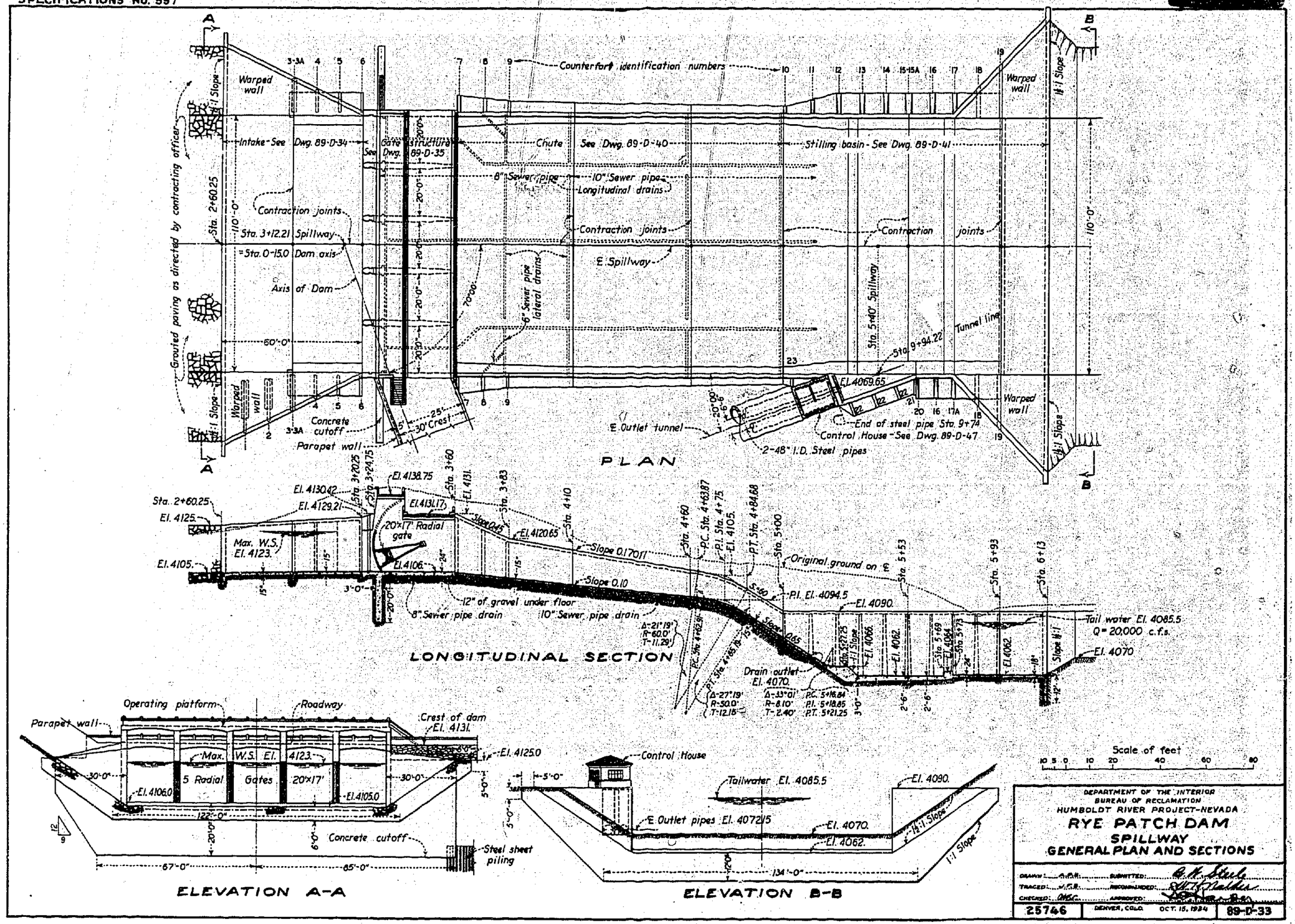
GENERAL PLAN AND SECTIONS

DRAWN: D.R.M. SUBMITTED: B. W. Steele
TRACED: C.B.M. RECOMMENDED: [illegible]
CHECKED: W.E.C. APPROVED: [illegible]

25744 | DENVER, COLO., OCT. 15, 1934 | 89-D-31

SPECIFICATIONS No. 597

FIG. 2



section of the spillway adjacent to the axis of the dam. The spillway is to be of constant width - 110 feet from the gate section to the end of the stilling pool. At the end of the gate section the floor of the spillway will assume a slope of 10:1 for a distance of 104 feet. The slope then changes thru a vertical curve to 0.65 making a drop of 32.5 feet from this point to the floor of the stilling pool. The stilling pool as proposed in the final design will be approximately 42 feet long with a stepped apron at the upstream end and a rectangular sill at the lower end. Downstream from the sill, 40 feet of concrete paving will be placed to insure protection of the river bed at that point, and it will also assist in supporting the warped side walls.

For diversion purposes during low water, two 48-inch steel pipes will be provided to conduct water from the reservoir to the stilling pool. An approximate tail water curve for the river below the dam after its completion is shown in figure 5.

THE LABORATORY

The laboratory is situated 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 12 feet by 6 feet by 4 feet deep, which is partially below the laboratory floor. From here, a 6-inch centrifugal pump with a capacity of 3 c.f.s. raises the measured water up into twin head tanks located above the weir. From the head tanks the water is supplied to the models. After passing thru the models, the water is collected in sheet metal flumes and returned to the weir tank. Thus, the same water is continuously circulated thru the system. Two hook gages are used for observing the head on the V-notch weir, and one head gage is provided for measuring the elevation of the water surface in each of the head tanks.

The experimental work on the Rye Patch model was carried on by a crew of men consisting of one junior engineer and two laborers.

THE MODEL

A model of the spillway was constructed in the laboratory on a scale of 1 to 50. It included the approach to the gates, the gate section, spillway section, stilling pool, and a sand box below the pool which represented the bed of the river. (See figure 4). The model was constructed of wood and lined with sheet metal to insure water-tightness. The transition walls above the gates and below

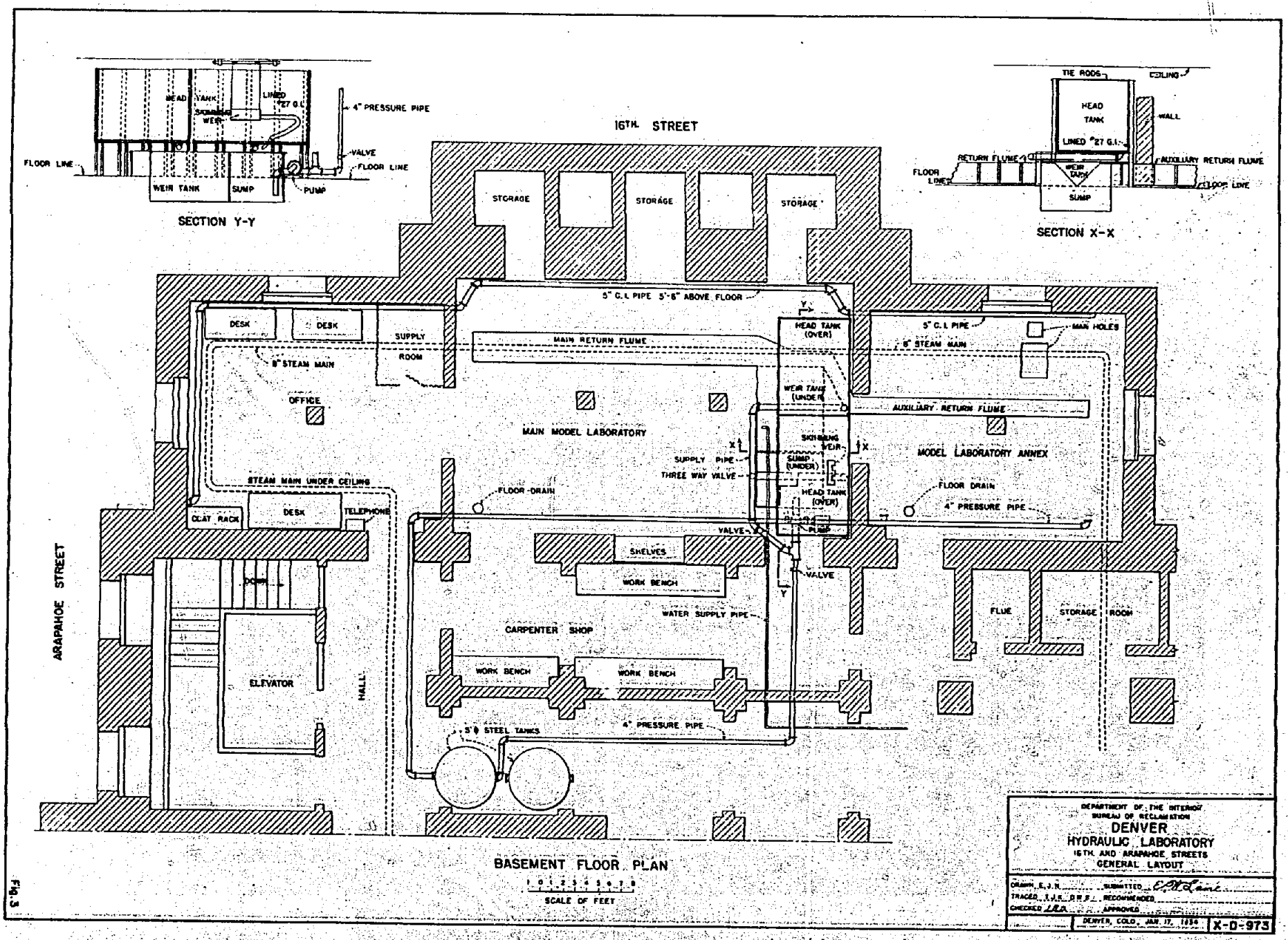
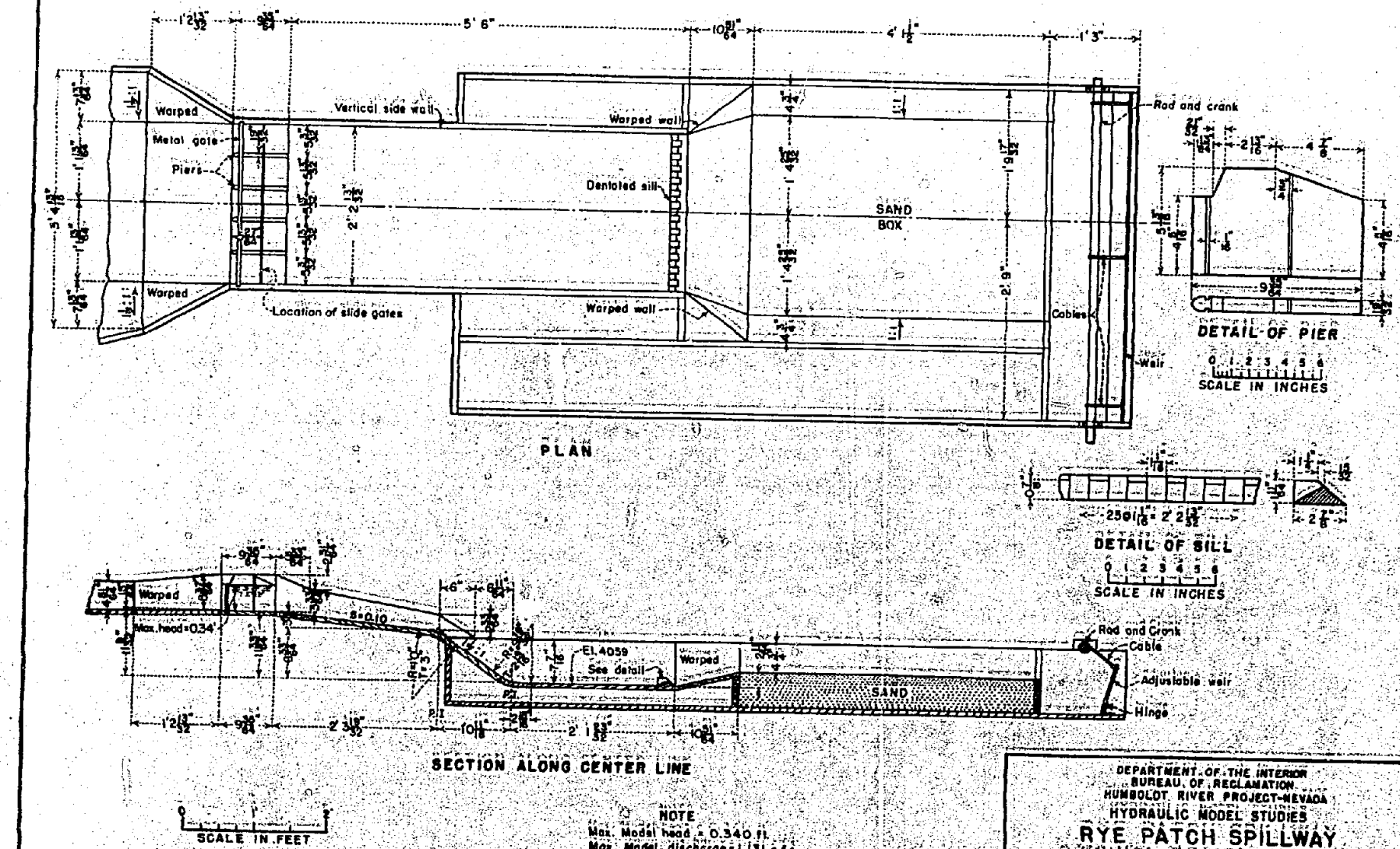

SECTION Y-Y
HEAD TANK
LINED #27 G.I.
SKIMMING WEIR
4" PRESSURE PIPE
VALVE
FLOOR LINE
WEIR TANK
SUMP
PUMP
16TH. STREET
STORAGE
STORAGE
STORAGE
SECTION X-X
TIE RODS
CEILING
HEAD TANK
LINED #27 G.I.
WALL
RETURN FLUME
AUXILIARY RETURN FLUME
WEIR TANK
SUMP
5" C.I. PIPE 5'-6" ABOVE FLOOR
DESK
DESK
SUPPLY ROOM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

Fig. 3



NOTE
Max. Model head = 0.340 ft.
Max. Model discharge = 1.131 c.f.s.
Model scale = 1:50.

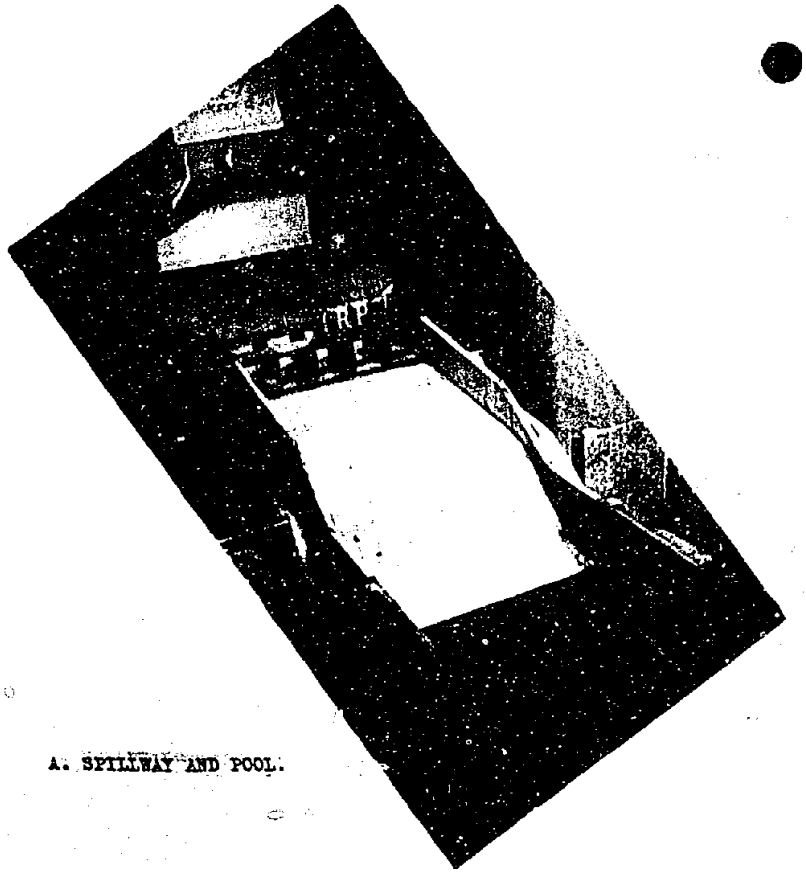
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY
ORIGINAL DESIGN - MODEL

DRAWN H.W.R. SUBMITTED J. N. Bradley
TRACED O.S.Y. J.O.K. RECOMMENDED E. W. Lane
CHECKED J.N.B. APPROVED [illegible]

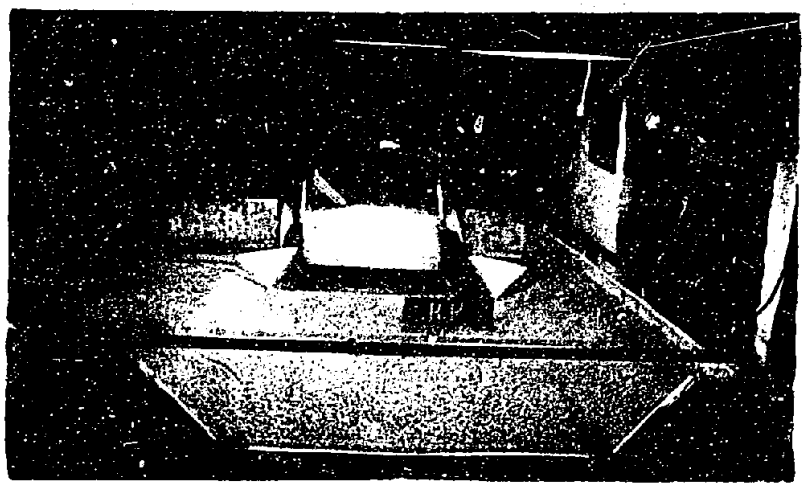
DENVER, COLO. SEPT. 6, 1934 89-D-53

FIG. 4

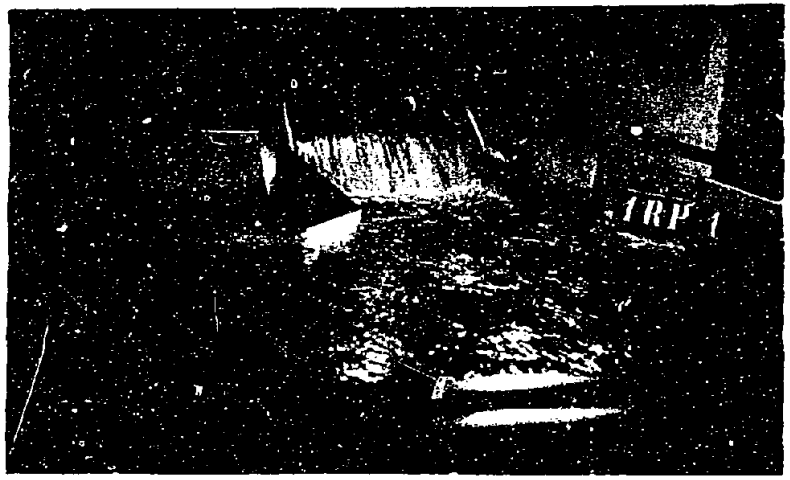


A. SPILLWAY AND POOL.

C. FLOW THROUGH HEAD GATES.
LOOKING DOWNSTREAM.



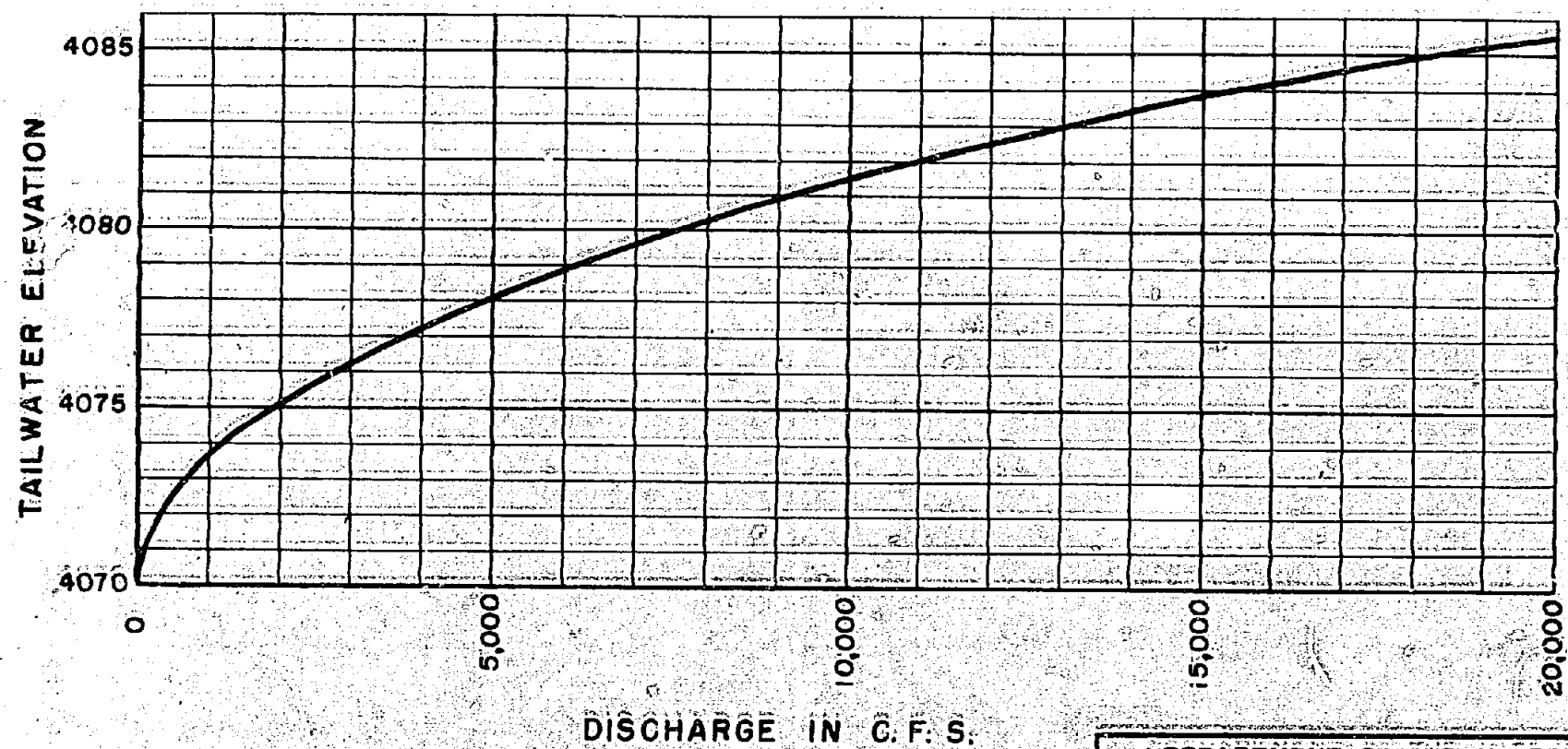
B. SAND BED BEFORE RUN.



D. MAXIMUM DISCHARGE 20,000 C.F.S.

ORIGINAL DESIGN.

PLATE I



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT—NEVADA
HYDRAULIC MODEL STUDIES
RYE PATCH SPILLWAY
TAILWATER CURVE

DRAWN H.W.B. SUBMITTED J. N. Bradley
TRACED D.S.Y.-J.O.K. RECOMMENDED E. P. Lane
CHECKED T.N.B. APPROVED J. L. Savage

DENVER, COLO. OCT. 24, 1934 | 89-D 54

FIG. 5

the stilling pool were made of plaster of paris, and the piers were built of redwood. All surfaces other than metal were either saturated with oil or coated with varnish. For gates, pieces of heavy sheet metal were made to slide in the gate slots shown on figure 4. Radial gates were not installed on the model. The head on the crest was measured by a hook gage connected to the head tank. The maximum discharge for the model was 1.131 c.f.s. which corresponds to 20,000 c.f.s. on the prototype.

In order to study erosion of the river bed below the stilling pool, a sand box was provided at that location. The downstream end of the box was provided with a hinged weir by which the tailwater depth for the model could be easily adjusted and accurately controlled. The tailwater depth was observed from a piezometer which was connected to the sand box.

In order to obtain corresponding velocities in model and prototype, the slope of the model was increased slightly over that shown in the prototype (Fig. 2.).

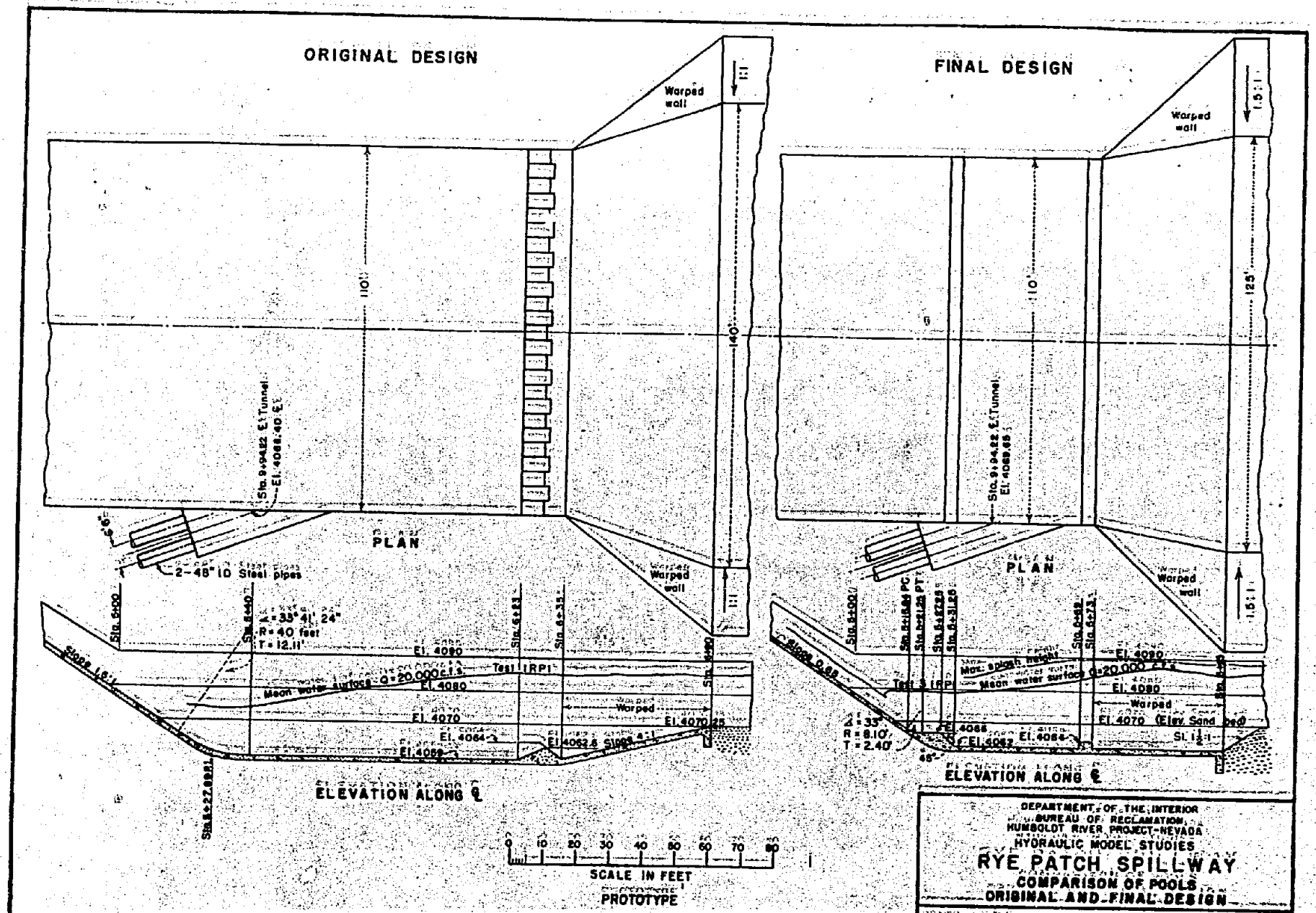
The two 48-inch tunnels which constitute the outlet works were not installed in the model until the last few tests.

THE ORIGINAL DESIGN

As originally designed, (Fig. 6) the Ryo Patch Spillway had a horizontal pool 95 feet long, the elevation of which was 4059. A Rehbock dentated sill was placed at the downstream end of the pool to assist in the formation of a jump and to help prevent erosion below the sill. (See Sill A, Fig. 9). The 4:1 slope downstream from the sill was paved with concrete in the initial design and was similarly made in the original model. A drawing of the original model is shown in figure 4 and photographs in plate I.

Test 1, figure 8, shows a profile of the sand surface below the paving in the original model, before and after a fifteen minute run, and shows also the water surface in the pool for a maximum discharge of 20,000 c.f.s. After seeing this model in operation it was evident that the stilling pool could be shortened considerably, and that the sloped paving downstream from the pool was undesirable.

The remainder of the spillway was very satisfactory. Approach conditions above the gates were good and the flow down the spillway proper, altho topped with numerous surface waves produced by the piers, was very satisfactory. (See photograph C, plate I and photograph D, plate III.) The height of the largest surface wave measured above the average water surface did not exceed 1.5 feet in the prototype.



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY
COMPARISON OF POOLS
ORIGINAL AND FINAL DESIGN

DRAWN H.W.B. SUBMITTED J. H. Bradley
TRACED D.S.Y. J.O.R. RECOMMENDED
CHECKED J.H.D. APPROVED

DENVER, COLO. SEPT. 24, 1934. 89-D-55

FIG. 6

The only portion of the spillway then in which research studies were justifiable was in the stilling pool. Some thirty tests using various layouts were made on this portion of the model and some of these are discussed in the following pages.

"Length of pool" as used thruout this report is the length of the horizontal pool floor measured from the intersection of the floor and bucket to the downstream edge of the sill. In cases where stopped aprons are used, the "length of pool" is measured from the joint at which the stopped apron intersects the floor of the pool to the downstream edge of the sill. Riprap or concrete which is located downstream from the sill is referred to as paving and not as part of the pool.

STILLING POOL TESTS

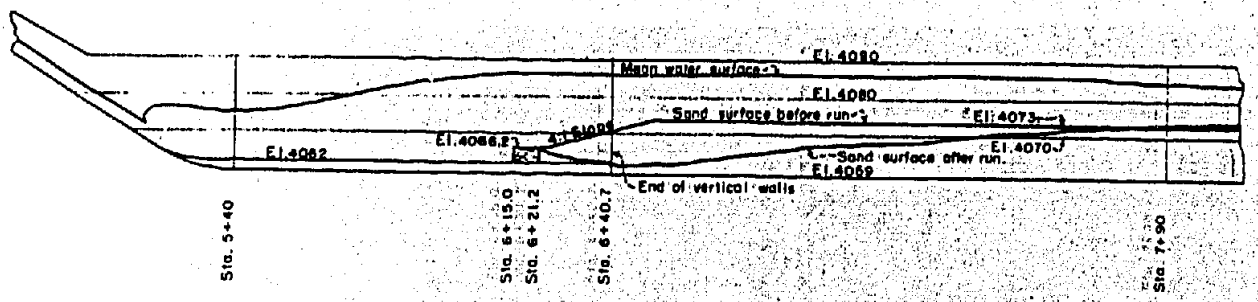
Rectangular Sills.

For test 3, a profile of which is shown in figure 7, the floor of the stilling pool was raised three feet to elevation 4062.0 and the length of the pool was shortened to 86 feet. The side walls extended 19.5 feet downstream from the end of the pool. A plain rectangular sill (sill B, figure 9) was placed at the end of the pool. Concrete paving was carried out 19.5 feet below the sill at the same elevation as the stilling pool floor. From figure 7, it can be seen that no objectionable effects were produced; a good hydraulic jump formed in the pool and erosion below the paving was an improvement compared with test 1 (figure 8). (Photographs of test 3 are shown in A and B, Plate II.) Notice in photograph B, how the downward roller continually piled the sand against the downstream side of the sill. Gravel placed in the pool upstream from the sill was instantly washed out. All comparative tests were made at the maximum discharge of 20,000 sec. ft.

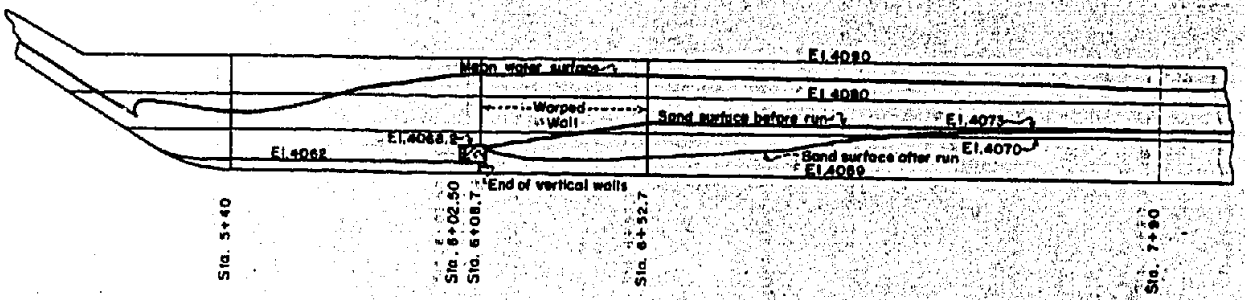
Test 12, shown in figure 7, was an attempt to shorten the pool still more. In this case, sill B was again used at the end of a stilling pool 73 feet long at elevation 4062. The side walls were also shortened so that they met the transitions slightly upstream from the lower edge of the sill. There was no paving below the sill. A good jump continued to form, and erosion below the sill was no worse than in the two previous tests. (See A, B, and C, plate III.)

Test 18 (figure 7) was made with sill B placed on the end of a stilling pool floor 61 feet long. Conditions in the pool (Photograph D, plate III) were about the same as in previous tests except for the formation of a slight boil over the sill. Erosion below the sill was becoming more pronounced due to the length of the pool being shortened.

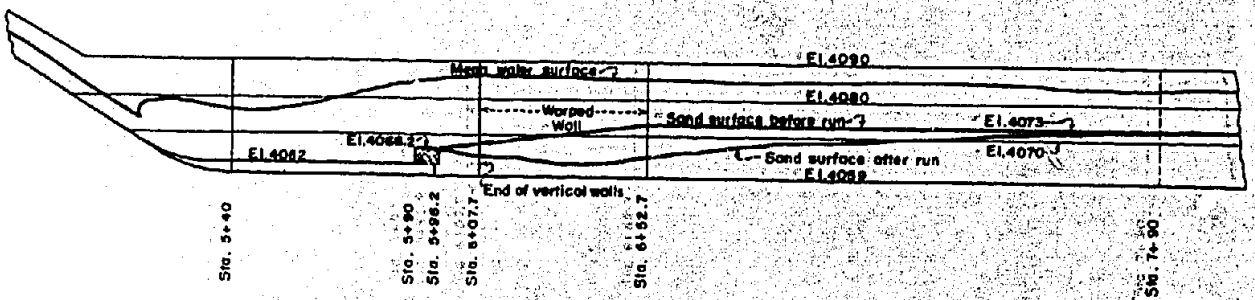
FIG. 7



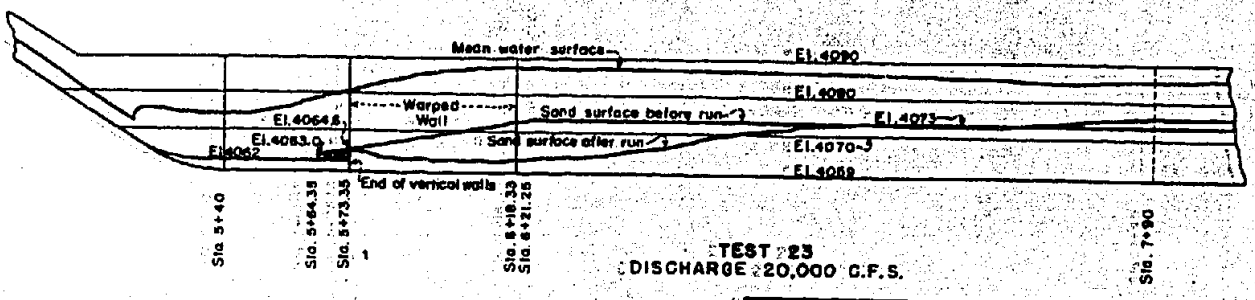
TEST 3
DISCHARGE 20,000 C.F.S.



TEST 12
DISCHARGE 20,100 C.F.S.



TEST 18
DISCHARGE 20,000 C.F.S.



TEST 23
DISCHARGE 20,000 C.F.S.

0 10 20 30 40 50
SCALE IN FEET
PROTOTYPE

RECTANGULAR SILLS

DEPARTMENT OF THE INTERIOR
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HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY

PROFILES OF WATER SURFACES AND SAND SURFACES FOR TESTS 3, 12, 18, AND 23.

DRAWN H.W.S. SUBMITTED J. L. Bradley
TRACED D.P.Y. J.O.X. RECOMMENDED
CHECKED J.N.B. APPROVED

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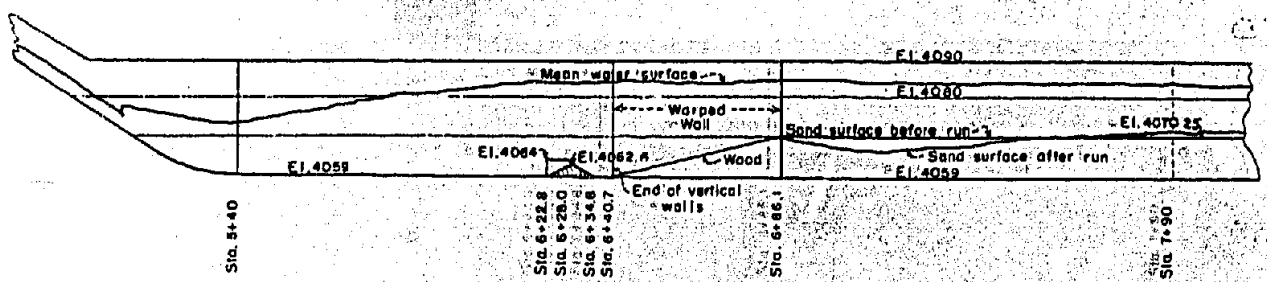
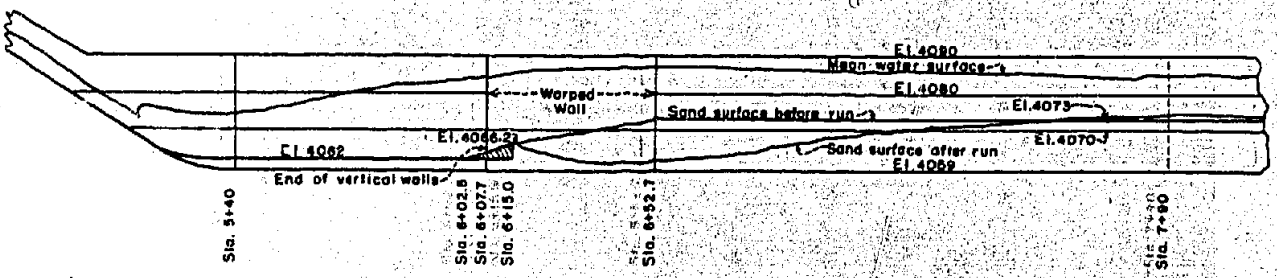
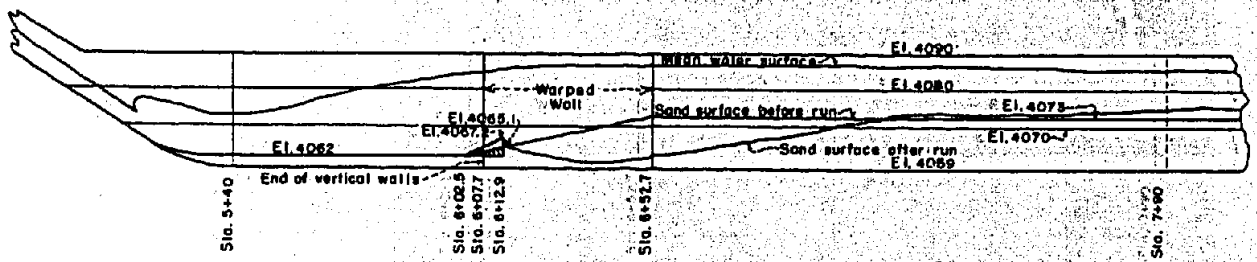
FIG. 8



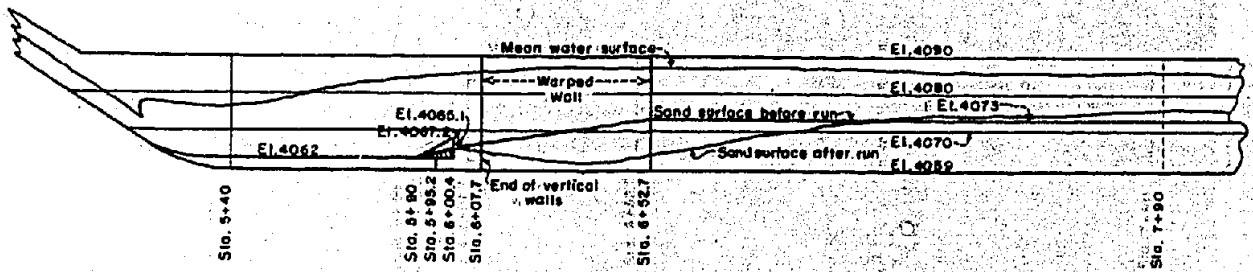
TEST 1
DISCHARGE 20,000 C.F.S.
ORIGINAL DESIGN



TEST 13
DISCHARGE 20,000 C.F.S.



TEST 14
DISCHARGE 20,100 C.F.S.



TEST 17
DISCHARGE 20,100 C.F.S.

0 10 20 30 40 50
SCALE IN FEET
PROTOTYPE

TRIANGULAR SILLS

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY

PROFILES OF WATER SURFACES AND SAND SURFACES FOR TESTS 1, 13, 14, AND 17.

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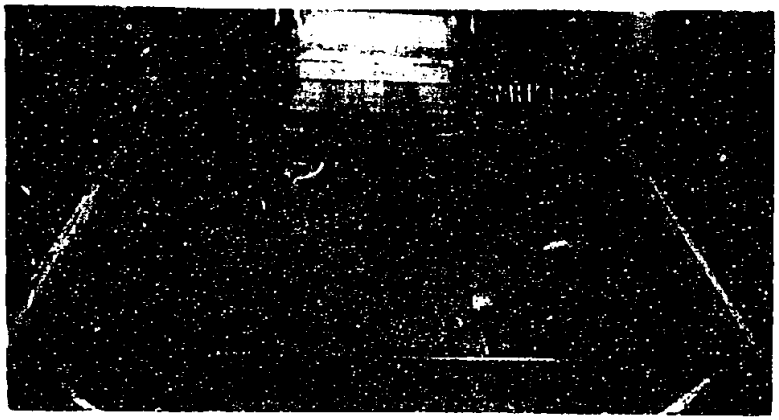
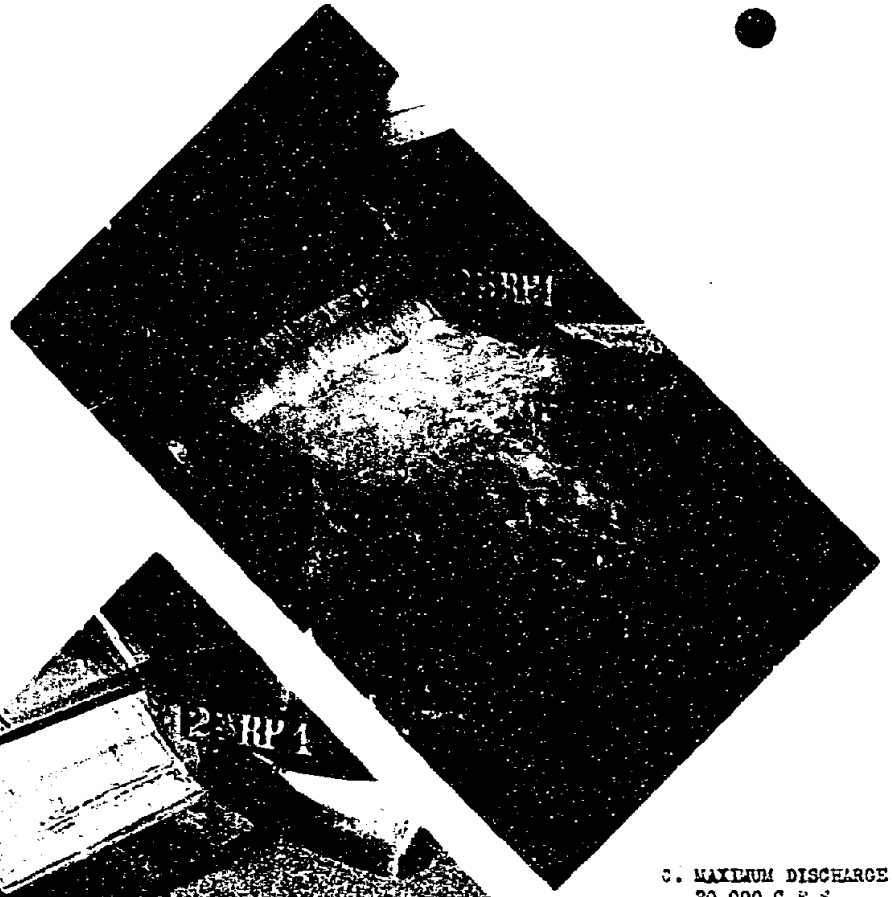
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO. AUG. 20, 1954 | 84-D-57

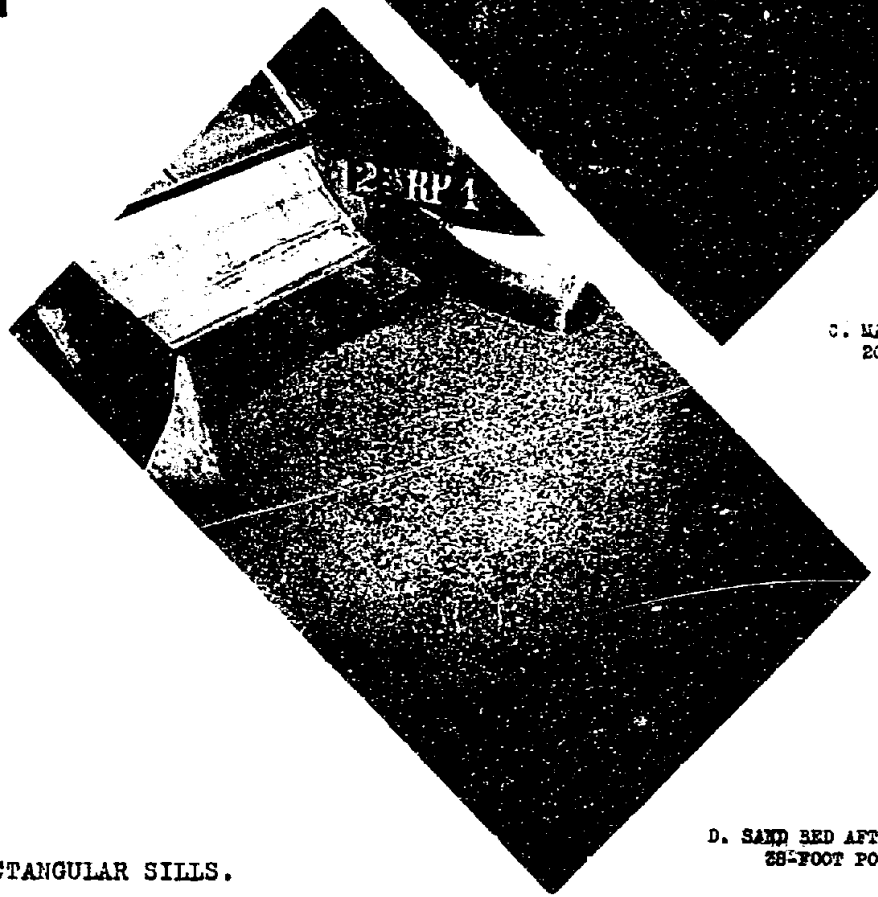
A. SAND BED BEFORE RUN.



B. SAND BED AFTER RUN.
86-FOOT POOL.



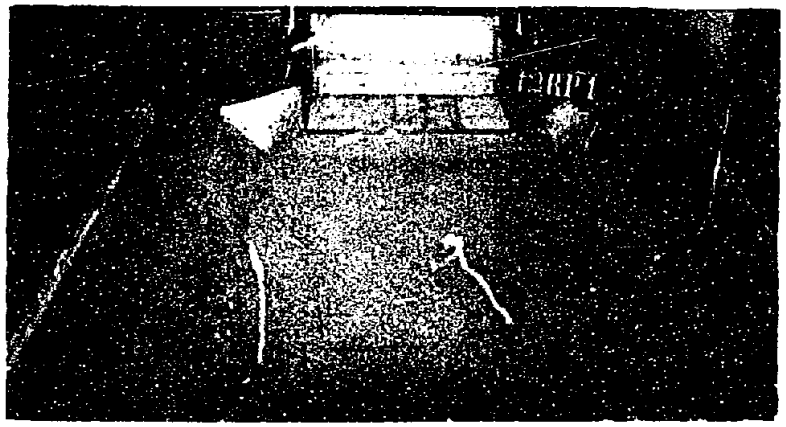
C. MAXIMUM DISCHARGE
20,000 C.F.S.



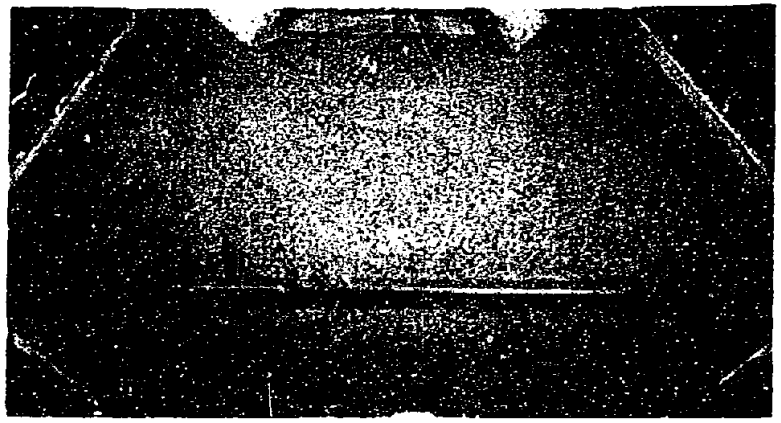
D. SAND BED AFTER RUN.
28-FOOT POOL.

RECTANGULAR SILLS.

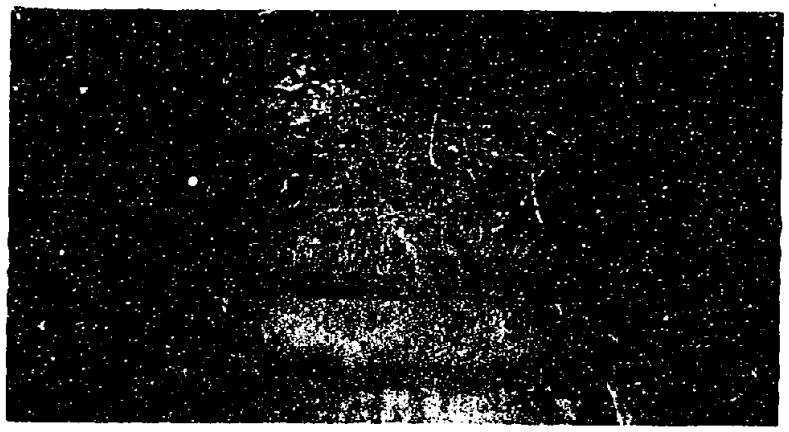
PLATE II



A. SAND BED BEFORE RUN.



C. SAND BED AFTER RUN.
73-FOOT POOL

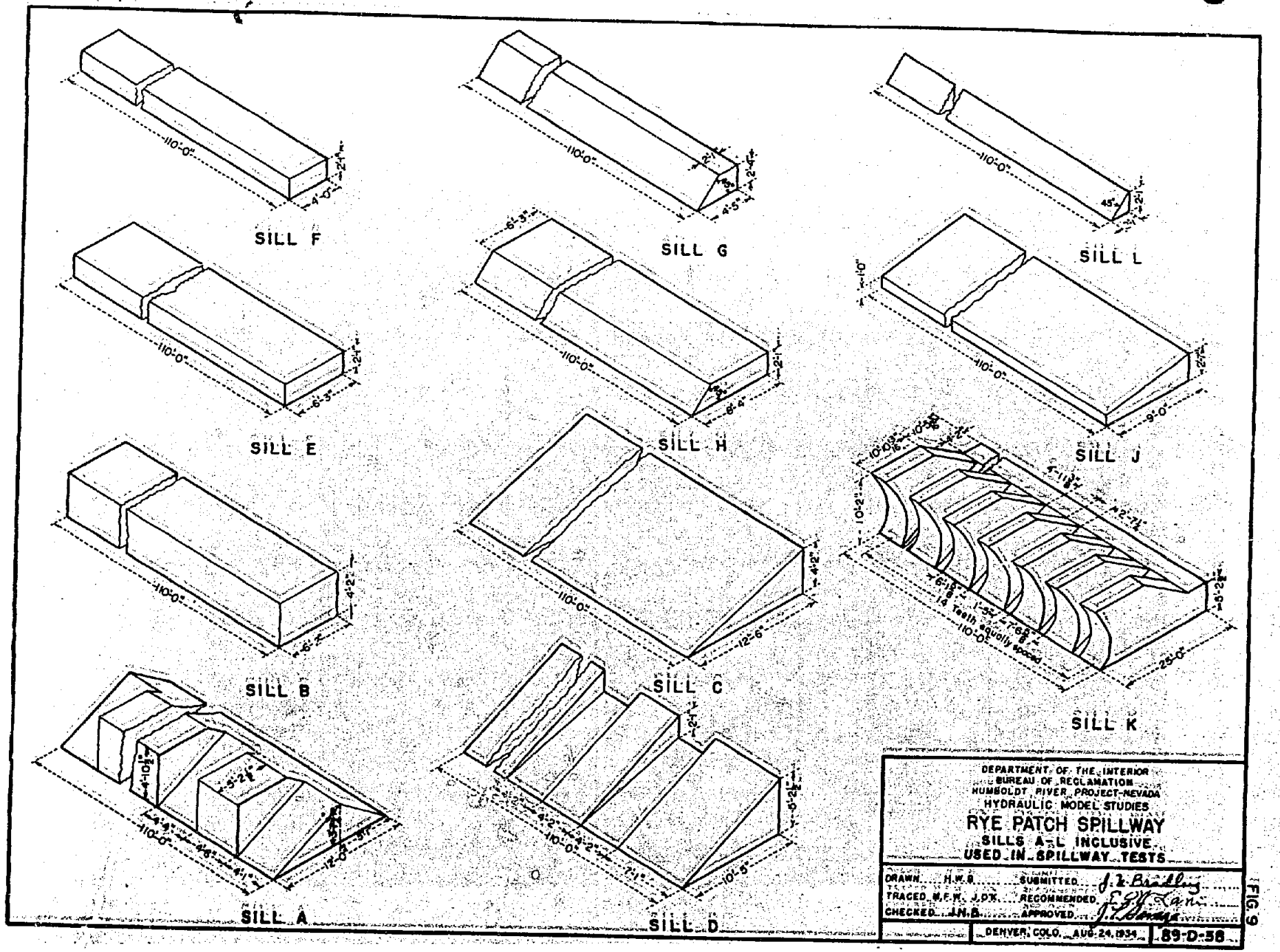


B. DISCHARGE 20,000 C.F.S.

D. DISCHARGE 20,000 C.F.S.
61-FOOT POOL.

RECTANGULAR SILLS.

PLATE III



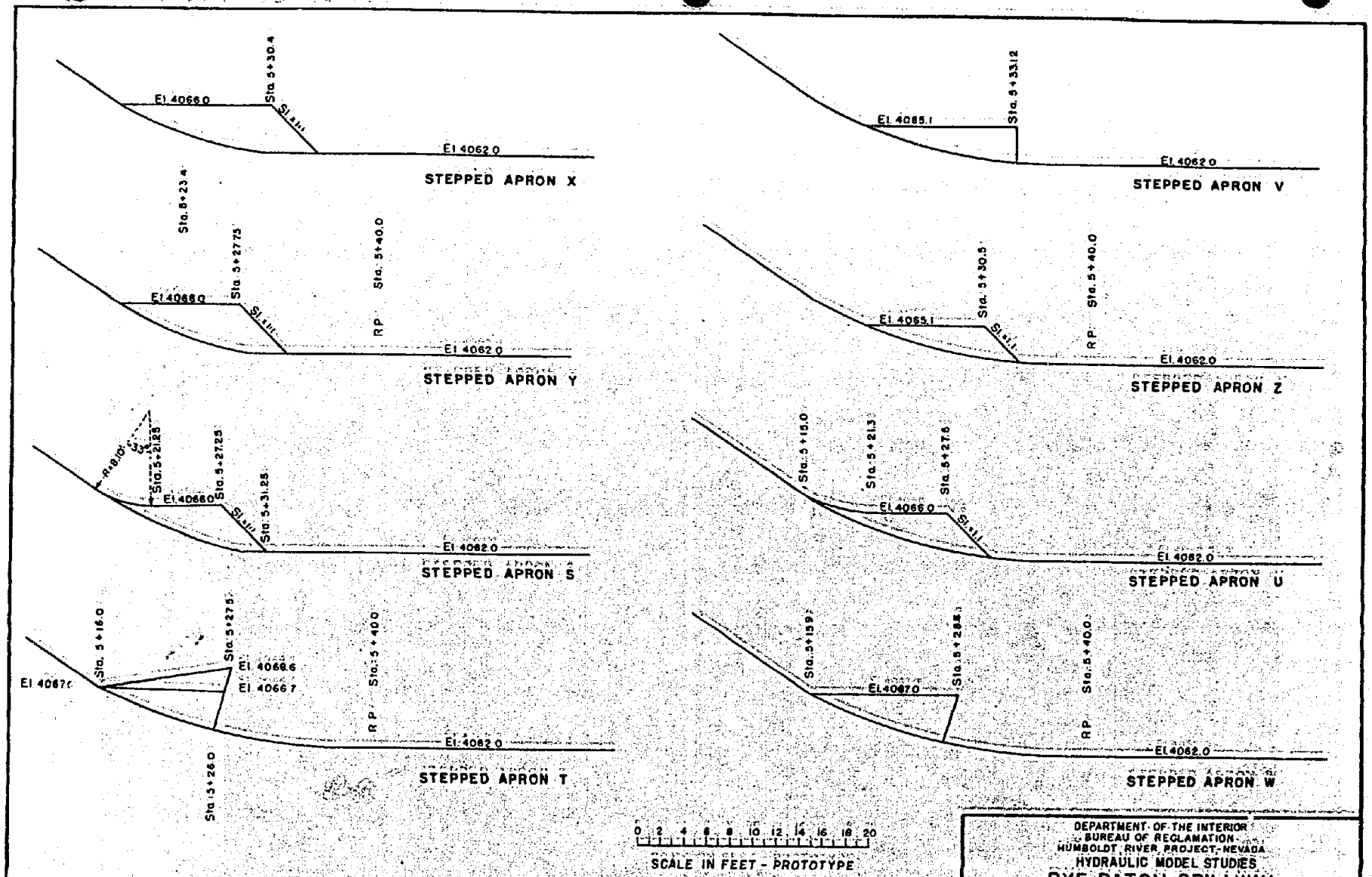
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY
SILLS A-L INCLUSIVE
USED IN SPILLWAY TESTS

DRAWN H.W.B. SUBMITTED J. L. Bradley
TRACED W.F.W. J.D.K. RECOMMENDED E. W. Lane
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO. AUG. 24, 1934 89-D-58

FIG. 9



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT, NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY

STEPPED APRONS S-Z INCLUSIVE
USED IN SPILLWAY TESTS

DRAWN H.W.B. SUBMITTED J. B. Bradley
TRACED R.A.P. O.R.S. RECOMMENDED E. J. Lane
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO., SEPT. 13, 1934 | 89-D-59

FIG. 10

In test 23 (figure 7) the pool floor and the vertical side walls were shortened to 38 feet. In this case however, sill J (figure 9) was placed at the end of the pool floor. As a result of this revision, a pronounced boil occurred over the sill at each side of the pool, although it was not as noticeable in the center. Consequently, erosion near the sides of the pool was much worse than at the center. (See photographs C and D, plate II.) Another very objectionable feature of this layout was that the jump could be made to sweep out of the pool while holding the tailwater at normal depth.

Triangular Sills.

In order to investigate the merits of the triangular sill, various sills of this type were constructed and tested on stilling pool floors of different lengths, the procedure followed being similar to that used in testing the rectangular sills. Test 13, the profile of which is shown in figure 8, shows the results produced by a plain triangular sill (sill C, figure 9) placed on the end of a stilling pool floor 80 feet long. The water surface was higher and the erosion deeper than for a rectangular sill on a floor of approximately the same length. Note how the sand was piled against the downstream face of the sill, and how the erosion was greater farther downstream than in previous tests.

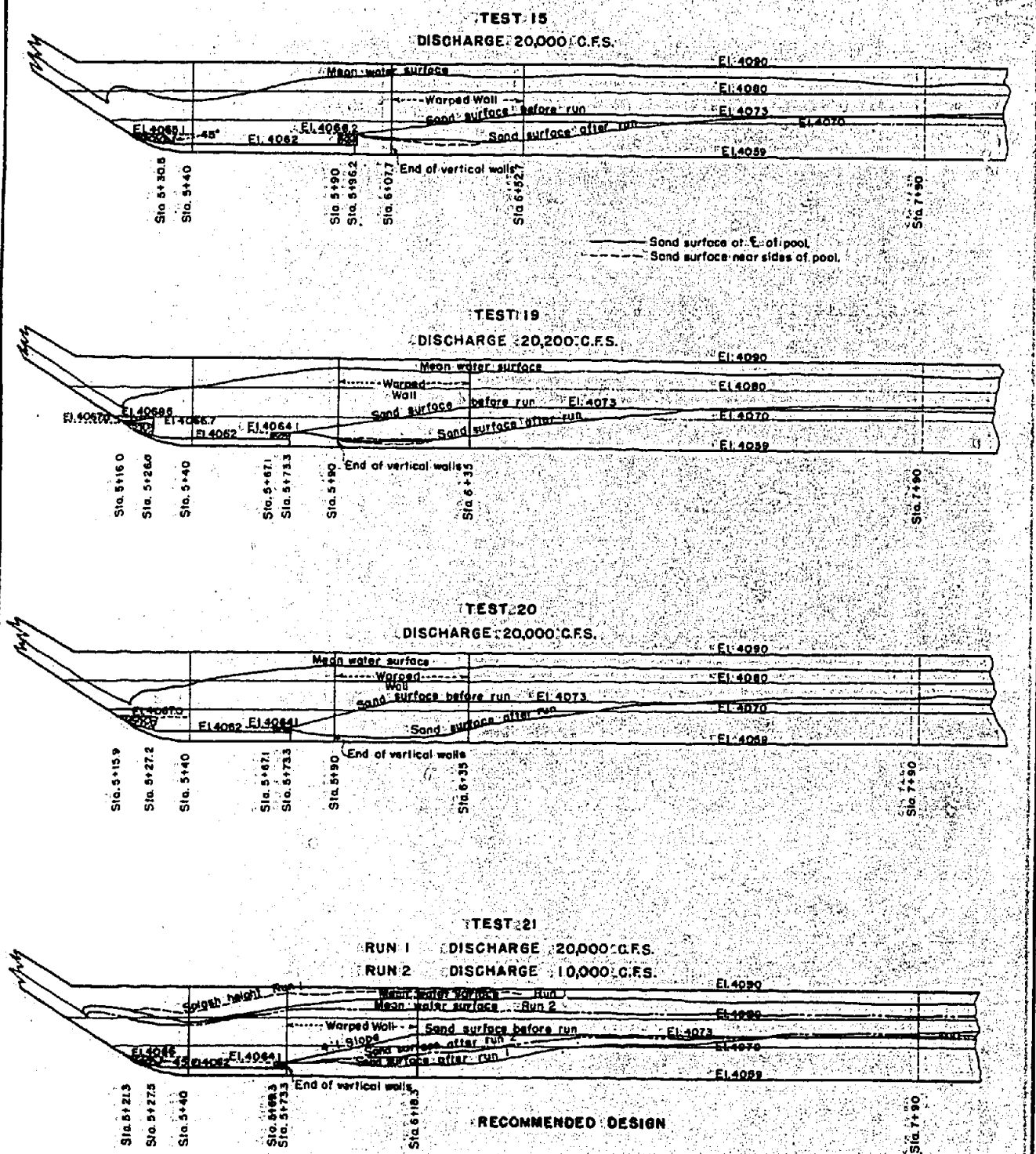
In test 14 (figure 8), a compound sill having teeth (sill D, figure 9) was used on a pool floor 77 feet long. In test 17 (figure 8), the same sill was used on an apron 65 feet long. Pool action and scour in both cases were very similar to that encountered in test 13. The triangular sills showed no noticeable improvement over the rectangular ones. The rectangular sills however, had some advantages over the triangular ones.

Rectangular Sill with Stepped Apron.

As the triangular sills were not very satisfactory, it was thought feasible to return to the rectangular sill, and in addition, try a small stepped apron at the lower end of the spillway slope. This idea was carried out in test 15, shown in figure 11. Sill B (figure 9) was placed at the end of a stilling pool 61 feet long, and in addition a stepped apron (sketch Z, figure 10) was installed on the lower portion of the spillway slope at elevation 4065.1. The results were encouraging as can be seen from the profile and from the photographs on plate IV. A good jump was formed in a short pool, and the erosion was not in any way harmful. Improvements from this combination were expected and the following tests were made accordingly.

Test 19 (figure 11), was made with sill E (figure 9) on the end of a pool floor 47 feet long. In addition, sill D (figure 9) was used as a stepped apron as shown in sketch T, (figure 10). Results

FIG. 11



RECOMMENDED DESIGN

0 10 20 30 40 50
SCALE IN FEET
PROTOTYPE

STEPPED APRON AND SILL

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT - NEVADA
HYDRAULIC MODEL STUDIES

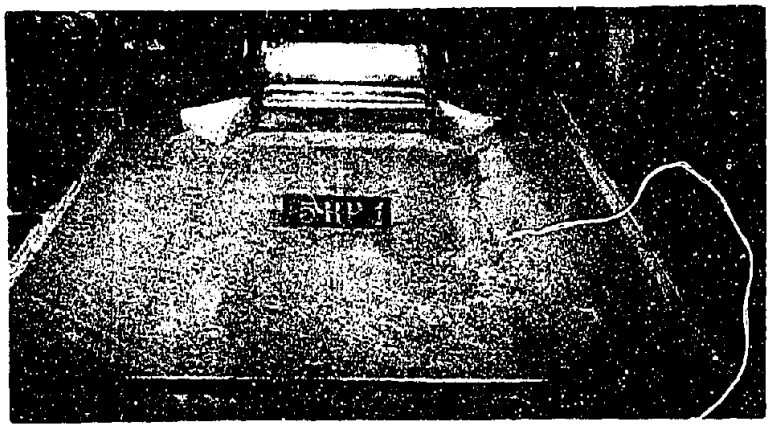
RYE PATCH SPILLWAY

PROFILES OF WATER SURFACES AND SAND SURFACES FOR TESTS 15, 19, 20 AND 21

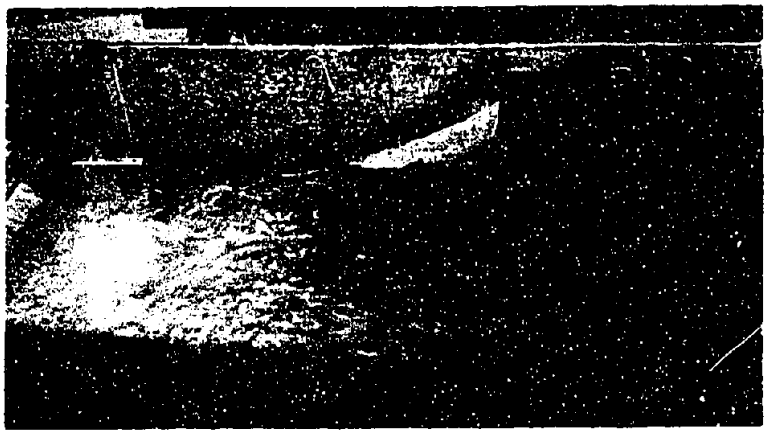
DRAWN H.W.B. SUBMITTED J. N. Bradley
TRACED M.C.G. CRS. RECOMMENDED E. O. Wolane
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO., AUG. 20, 1934

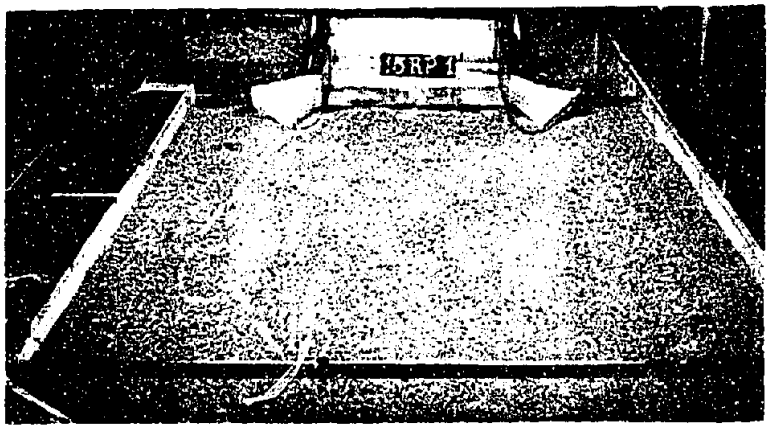
89-D-60



A. SAND BED BEFORE RUN.



B. MAXIMUM DISCHARGE 20,000 C.F.S.

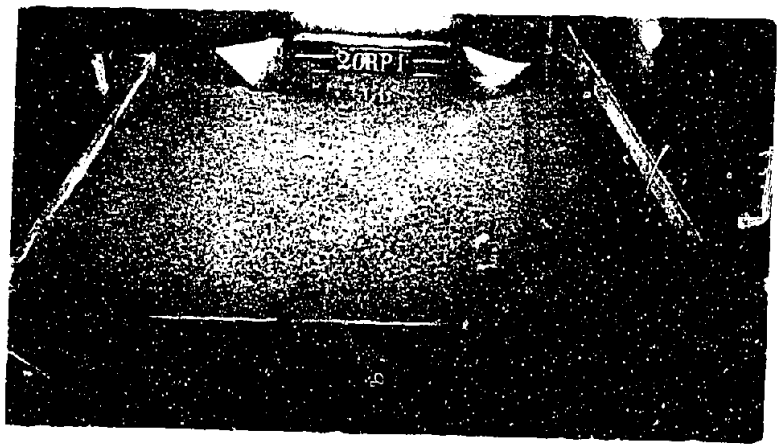


C. SAND BED AFTER RUN. 61-FOOT POOL.
STEPPED APRON AT ELEVATION 4065.0.

RECTANGULAR SILL AND STEPPED APRON.

A. SAND BED BEFORE RUN.

B. DISCHARGE 20,000 C.F.S.



C. SAND BED AFTER RUN. 36-FOOT POOL.
STEPPED APRON AT ELEVATION 4066.7.

RECTANGULAR SILL AND STEPPED APRON.

from this test showed no improvement over test 15.

Test 20 (figure 11) was made with sill E (figure 9) located on the end of a pool floor 46 feet long. Stepped apron W (figure 10) was installed on the spillway slope at elevation 4067.0. Results in this case showed no improvement over test 15. Photographs are shown in plate V.

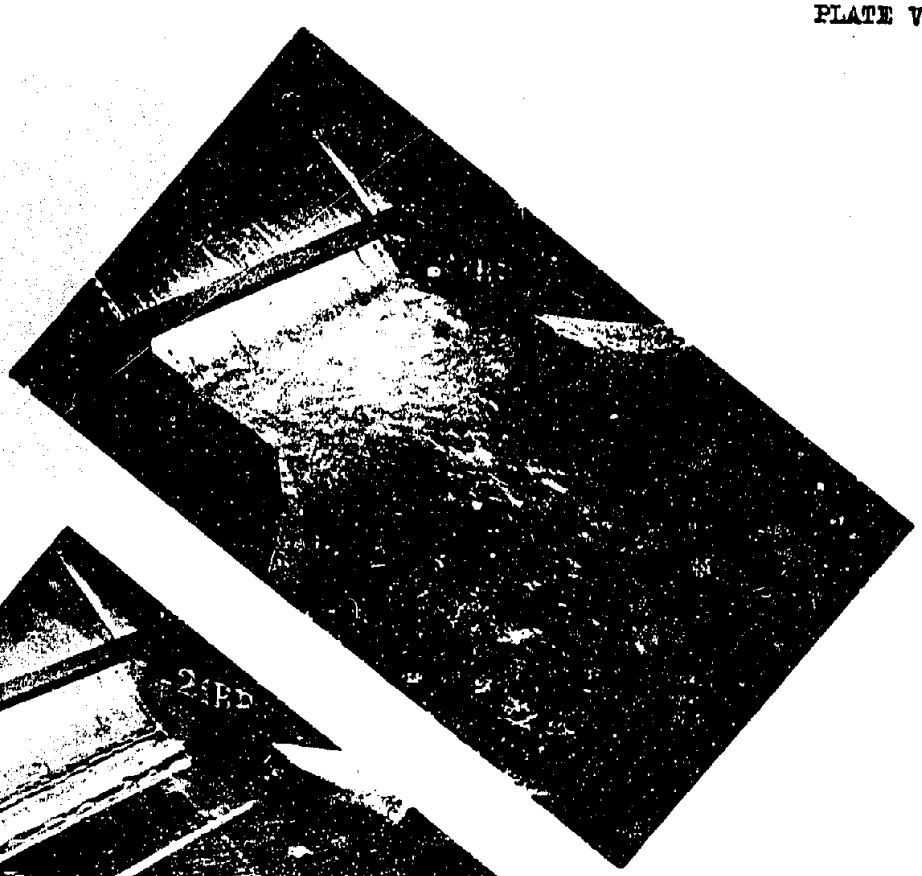
The Recommended Design.

Test 21 (figure 11), a slight revision of test 20, proved to be the ideal layout as it gave the best results obtained with a short pool. A 42 foot pool was used with sill F (figure 9) placed at the downstream end, and stepped apron U (figure 10) dropped to elevation 4066.0. Evidently the improved conditions in this case must have been due to the proper elevation of the stepped apron. Photographs of test 21 are shown on plate VI. It can be seen that erosion was slightly more marked near the ends of the sill than in the center after the maximum discharge of 20,000 c.f.s. However, erosion results were comparable to those obtained using the longer stilling pools. A slight boil was present above the sill but a good jump formed at all discharges. It was impossible to sweep the jump out of the pool even with discharges above maximum. The layout as in test 21 was recommended to the designing department as the best for a short stilling pool.

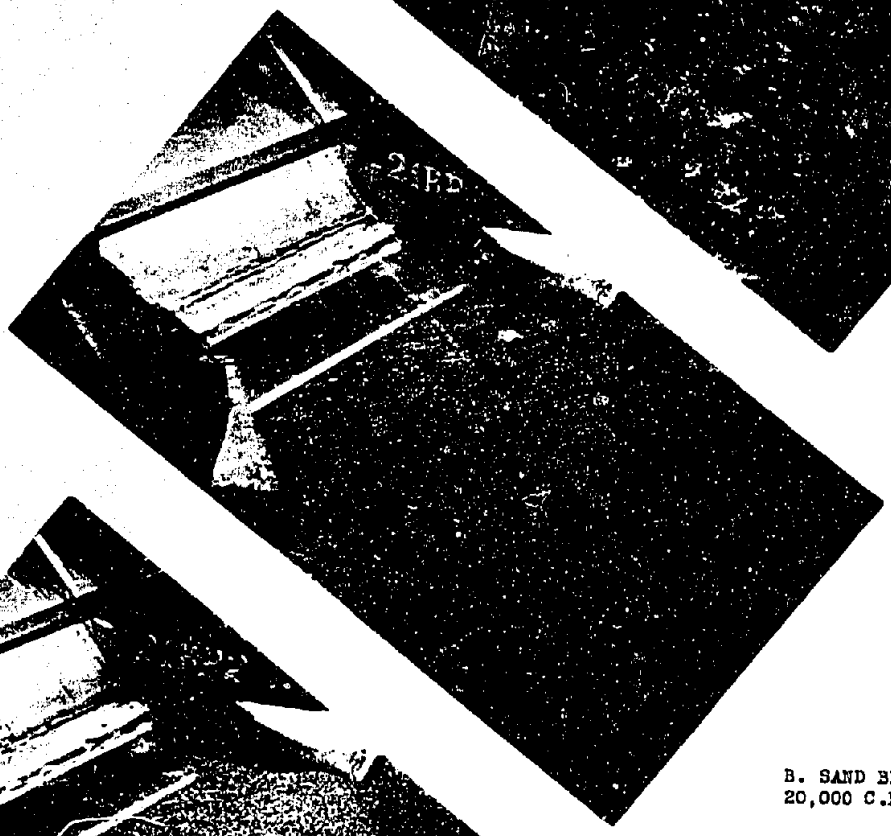
Paving Downstream from Sill.

The designing department accepted with one exception the design recommended by the research department. Instead of leaving the river in its natural state, 40 feet of concrete paving on a slope of about 6:1 was proposed for the river bed below the sill. The model was revised to simulate this design and test 27 (figure 12) shows the profile for a discharge of 20,000 sec. ft. It should be noted that 20 feet of riprap were added below the paving at elevation 4070.0. The riprap was added subsequent to a test made without it. In both cases, erosion was very bad. The excessive erosion was partially due to the fact that the paving which sloped upward in a downstream direction decreased the cross sectional area, thus increasing the velocity of the water after it had left the jump. In this scheme, full advantage was not gained from the jump.

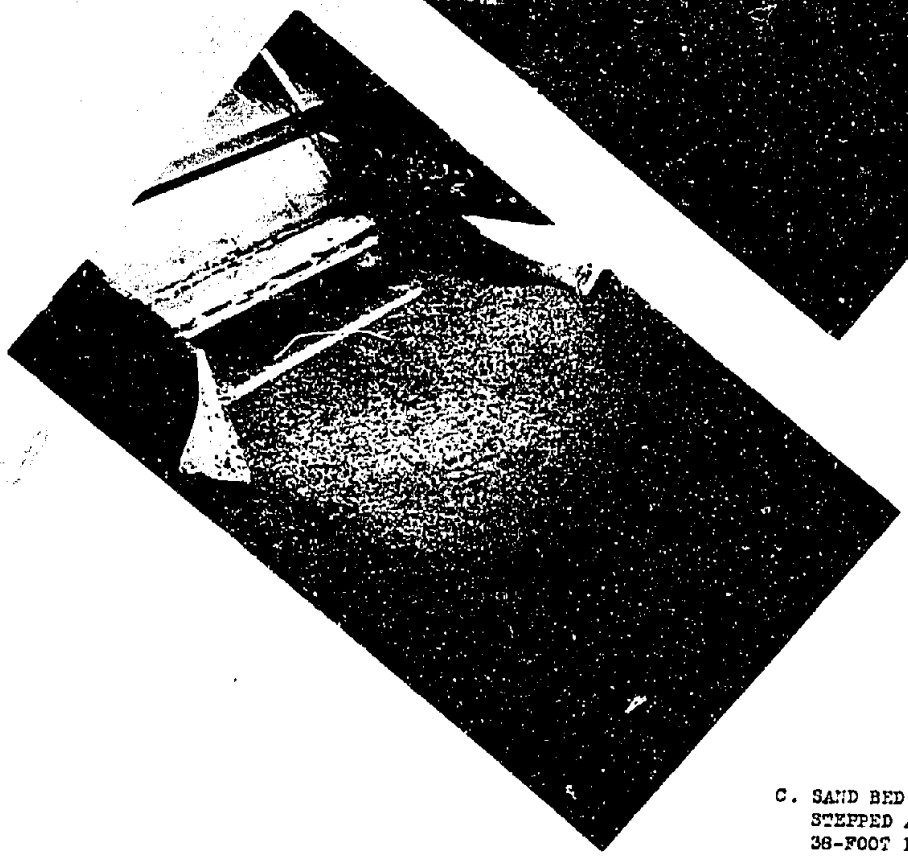
Test 29 (figure 12) shows a profile of the same layout as above except that the concrete paving located below the sill was dropped to a horizontal position, level with the top of the sill. At maximum discharge, erosion downstream from the paving was again sufficient to be considered dangerous. In the last two tests discussed, the sand was cut away from the end of the paving in a different manner than in previous tests, in which the tendency was for it to be continually



A. DISCHARGE 20,000 C.F.S.



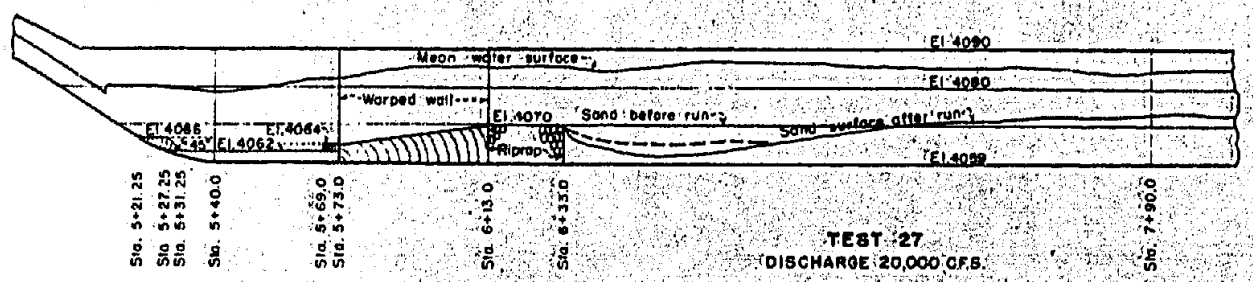
B. SAND BED AFTER A 20,000 C.F.S. RUN.



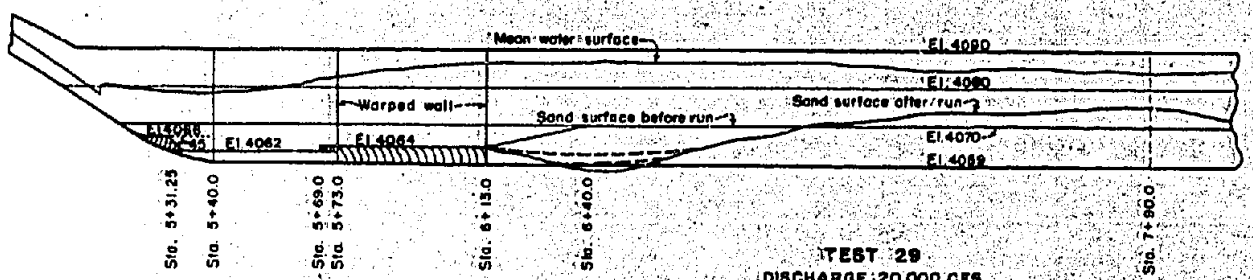
C. SAND BED AFTER A 10,000 C.F.S. RUN. STEPPED APRON AT ELEVATION 4066.0. 38-FOOT POOL.

RECOMMENDED DESIGN.

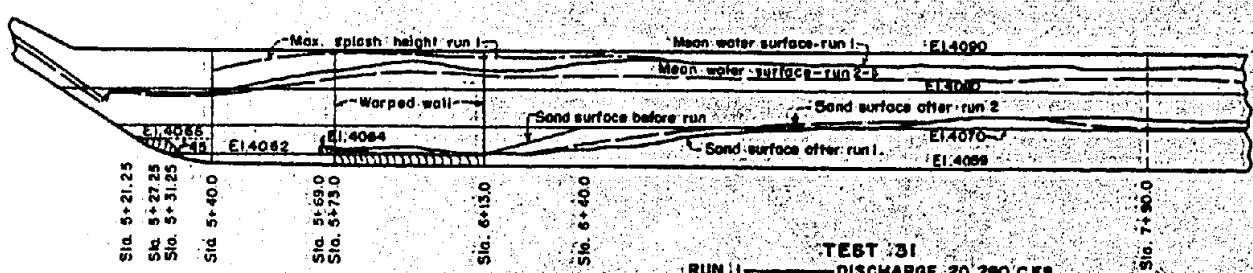
FIG. 12



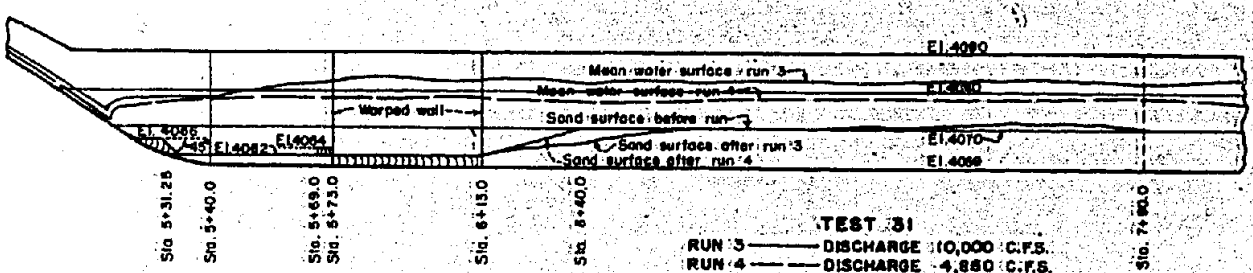
TEST 27
DISCHARGE 20,000 C.F.S.
——— Sand surface at ℄ of pool.
- - - - Sand surface near sides of pool.



TEST 29
DISCHARGE 20,000 C.F.S.



TEST 31
RUN 1 ——— DISCHARGE 20,280 C.F.S.
RUN 2 — — — DISCHARGE 15,080 C.F.S.
FINAL DESIGN



TEST 31
RUN 3 ——— DISCHARGE 10,000 C.F.S.
RUN 4 — — — DISCHARGE 4,880 C.F.S.
FINAL DESIGN

0 10 20 30 40 50
SCALE IN FEET
PROTOTYPE

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY

PROFILES OF WATER SURFACES AND SAND SURFACES FOR TESTS 27, 29, AND 31

DRAWN H.W.B. SUBMITTED J. H. Bradley
TRACED H.N., J.O.K. RECOMMENDED E. W. Lane
CHECKED APPROVED D. L. Savage

DENVER, COLO. NOV. 16, 1934 | 89-D-61

built up directly below the sill. Probably an explanation for this difference is that in the last two mentioned tests the paving was high enough to interfere with the formation of the submerged roller downstream from the sill.

The Final Design.

In order to give this submerged roller a chance to perform, the paving downstream from the sill was dropped to the same elevation as the floor of the pool. The excellent conditions resulting were practically a duplicate of those previously obtained in test 21. Erosion of the sand below the paving was very satisfactory. One revision made on the final design which does not appear previous to this, is the manner in which the warped walls intersect the paving. Instead of the intersections being parallel to the center line of the pool, they flare out from a width of 110 feet at the sill to 125 feet at the downstream end of the walls. (See figure 6.) Test 31, runs 1 to 4 inclusive, (figure 12) show the profiles of the sand erosion below the paving and the water surfaces in the pool for discharges of 20,000, 15,000, 10,000, and 5,000 c.f.s. respectively. Photographs of the model portraying the final design before, during, and after a run at maximum discharge are shown on plate VII. Photographs of the final design taken for runs of 15,000 and 10,000 c.f.s. are shown on plate VIII and those for a discharge of 5,000 c.f.s. are on plate IX.

Velocity Distribution below Pool.

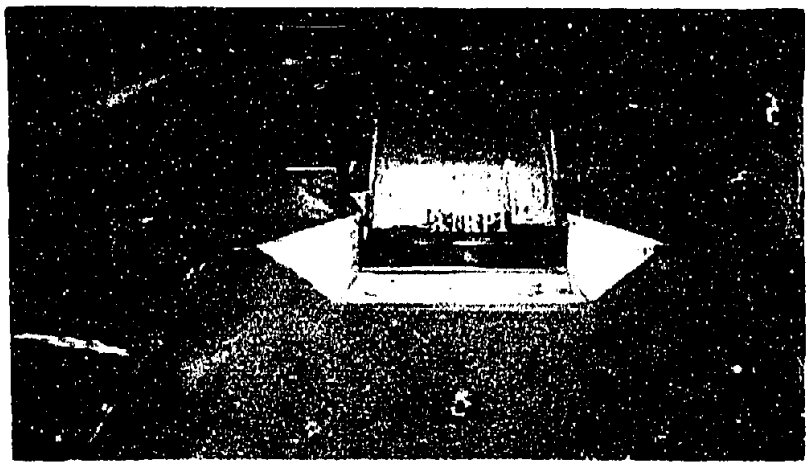
In order to get some idea as to the velocity distribution below the jump, pitot tube readings were taken at station 6+13 on the final design. (See figure 6.) The readings were converted into prototype velocities and are shown plotted on figure 13. It can be seen that a very symmetrical and satisfactory velocity distribution was present below the pool. Notice the negative velocities near the pool floor for which the submerged roller was responsible.

The Outlet Tunnels.

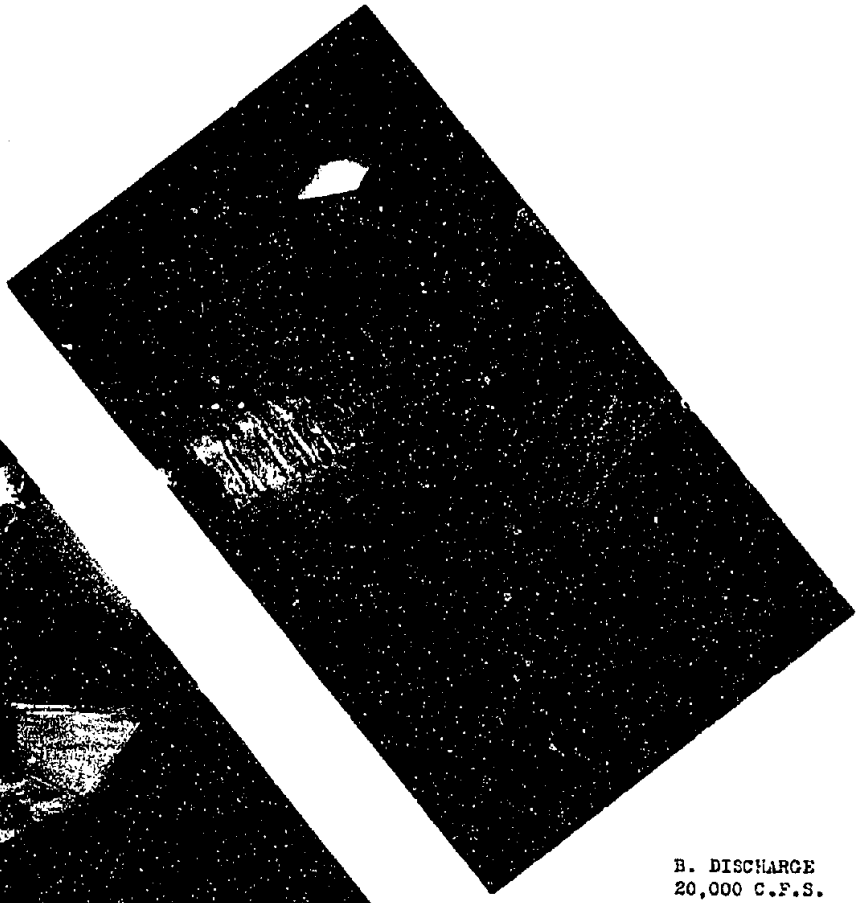
It was found that the two 48-inch outlet tunnels which will discharge into the stilling pool produced a negligible effect on the model. Photograph C, (plate IX) shows the two tunnels discharging at their maximum capacity of 500 c.f.s. each.

THE HEAD DISCHARGE RELATION

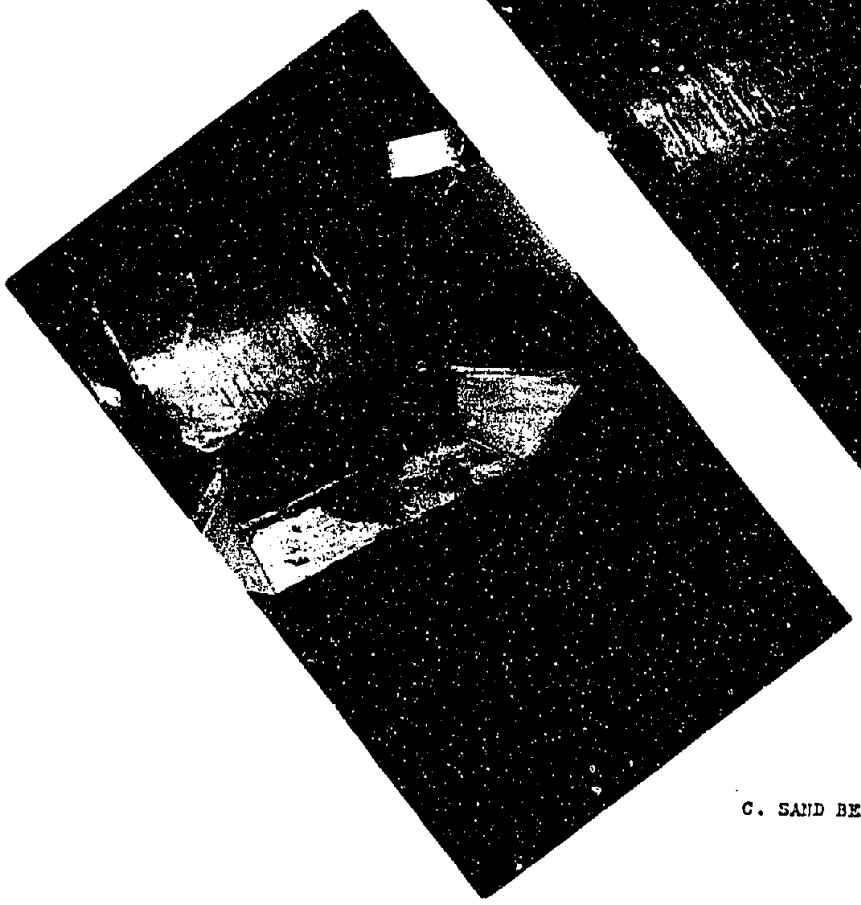
The discharge formula which was obtained for the crest of the Rye Patch Spillway where L is the width of gate section exclusive of piers, is



A. SAND BED BEFORE RUN.

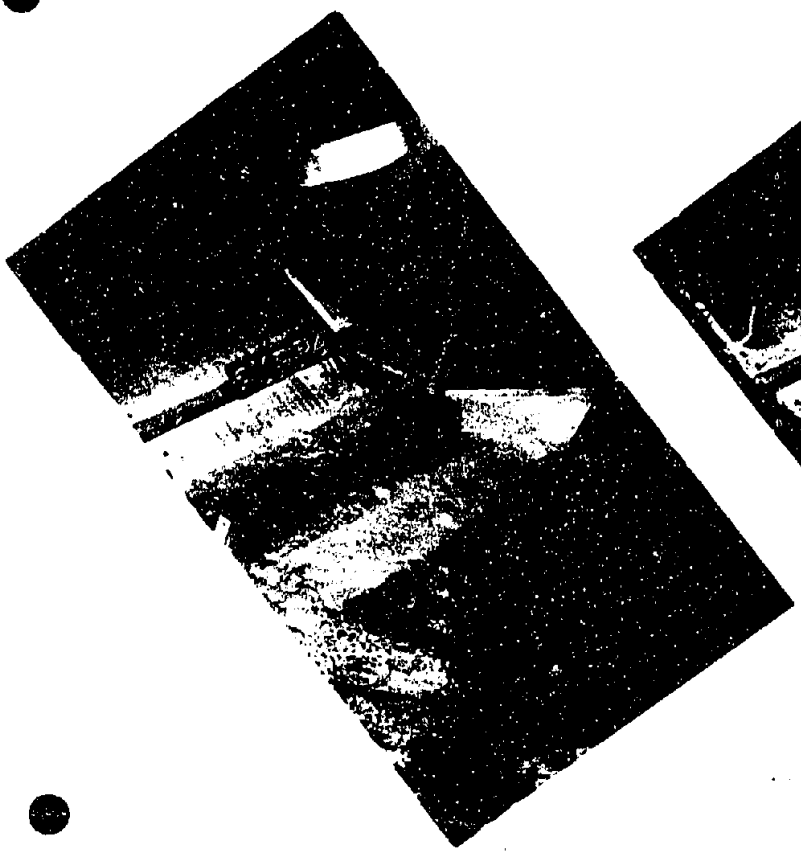


B. DISCHARGE
20,000 C.F.S.

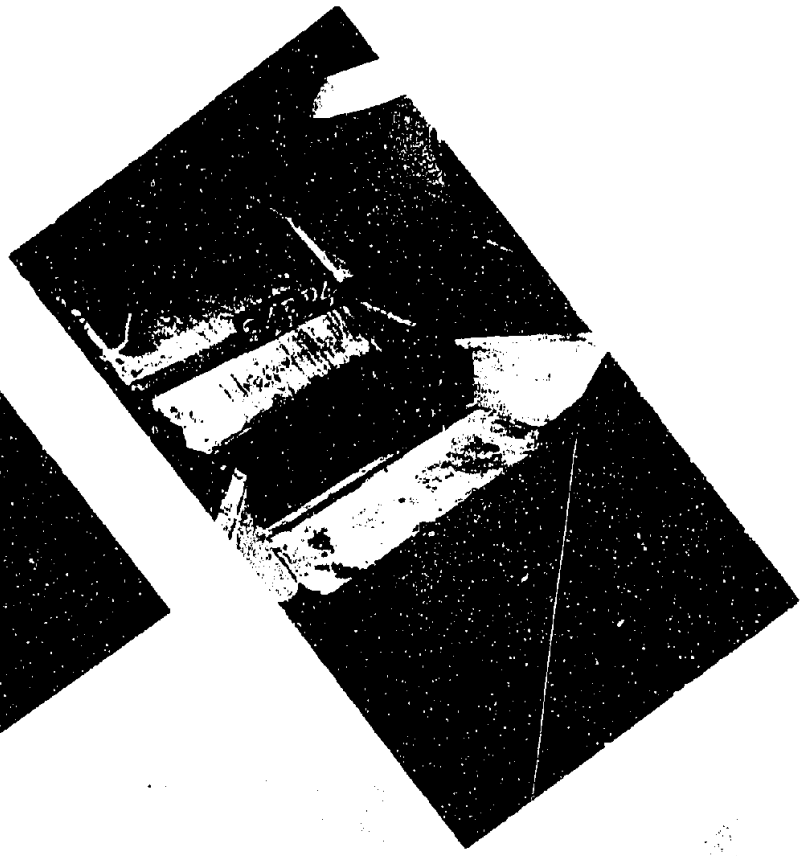


C. SAND BED AFTER RUN.

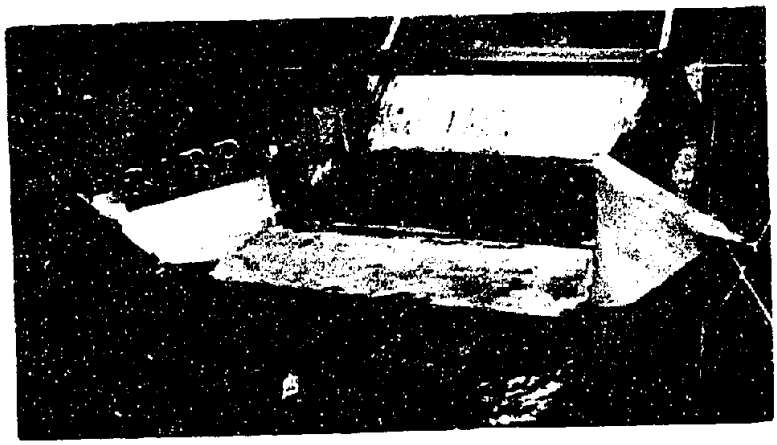
FINAL DESIGN.



A. DISCHARGE 5,000 C.F.S.

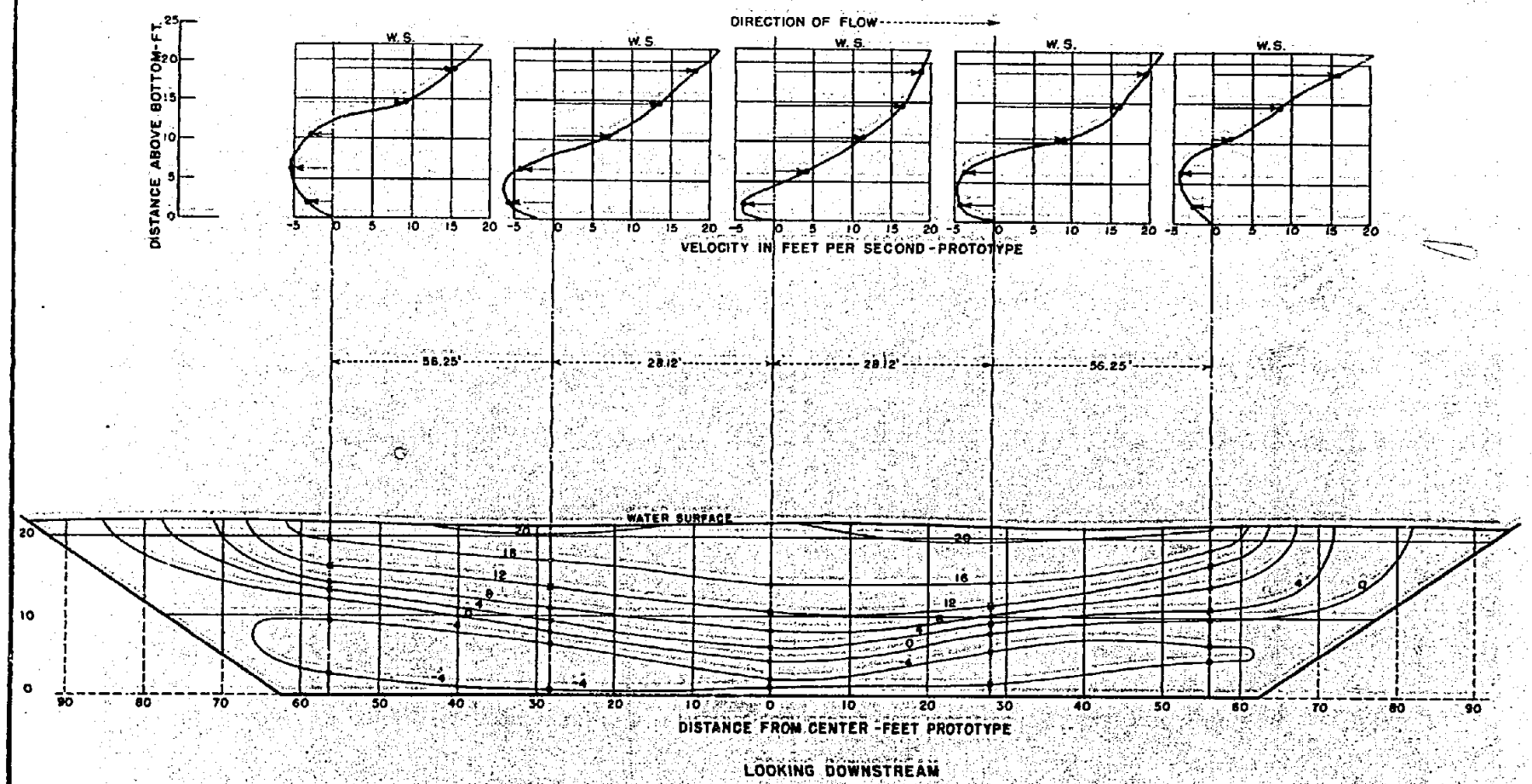


B. SAND BED AFTER RUN.
DISCHARGE 5,000 C.F.S.



C. MAXIMUM DISCHARGE THROUGH OUTLET TUNNELS.

FINAL DESIGN.



LOOKING DOWNSTREAM

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

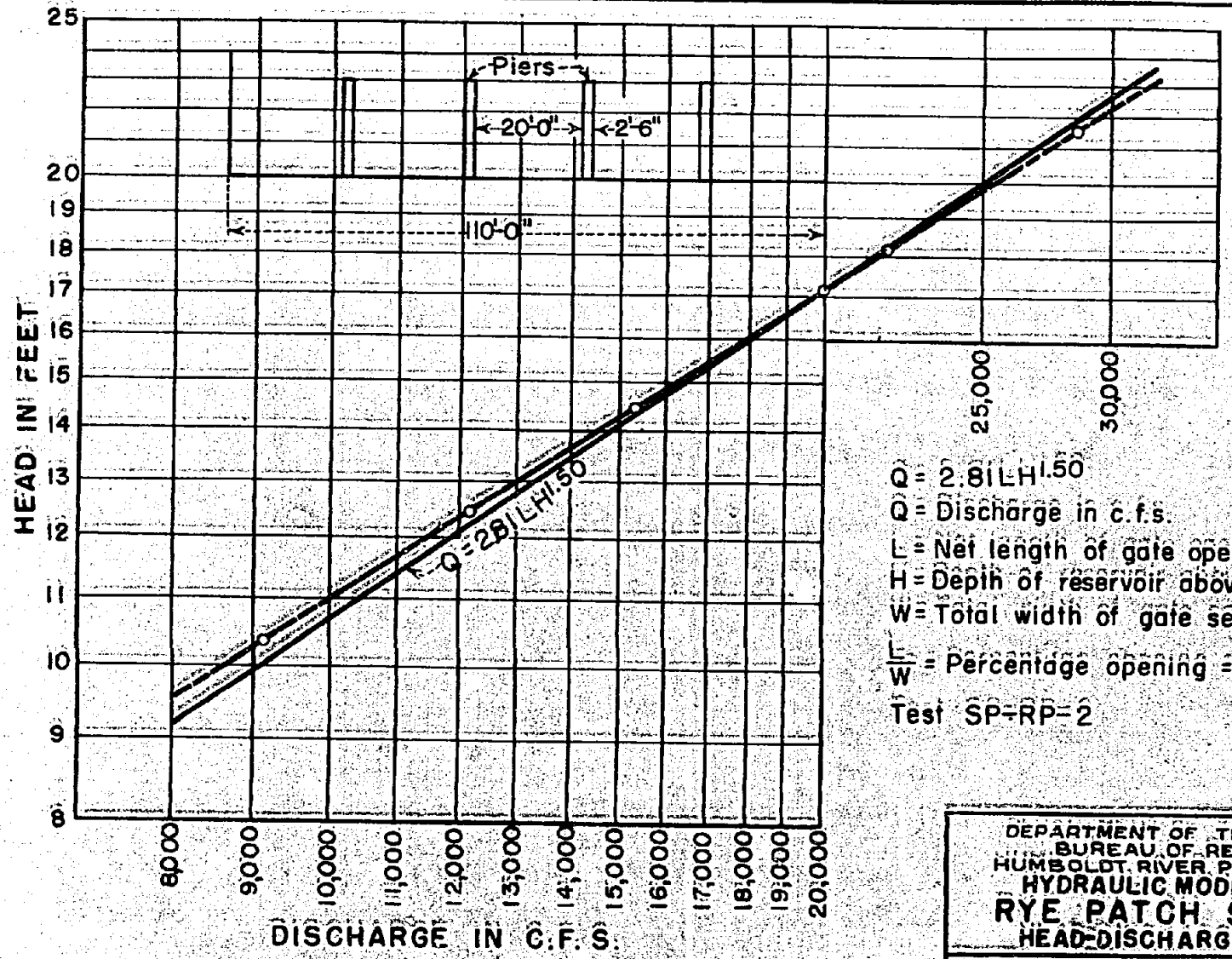
RYE PATCH SPILLWAY

VELOCITY DISTRIBUTION AT END OF WARPS

DRAWN H.W.B. SUBMITTED J. N. Bradley
TRACED R.A.P. O.R.S. RECOMMENDED E. B. W. Lane
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO., SEPT 27, 1934 | 89-D-62

FIG. 13



$Q = 2.81 L H^{1.50}$

Q = Discharge in c.f.s.

L = Net length of gate openings = 100'

H = Depth of reservoir above gate sill

W = Total width of gate section = 110'

$\frac{L}{W}$ = Percentage opening = .909

Test SP-RP-2

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HUMBOLDT RIVER PROJECT-NEVADA
HYDRAULIC MODEL STUDIES

RYE PATCH SPILLWAY

HEAD-DISCHARGE RELATION

DRAWN H.W.B. SUBMITTED J. L. Bradley
TRACED D.S.Y. J.O.K. RECOMMENDED F. O. Lane
CHECKED J.N.B. APPROVED J. L. Savage

DENVER, COLO. OCT. 24, 1934 | 89-D-63

FIG. 14

(1) $Q = 2.97LH^{1.55}$ for the model and
(2) $Q = 2.45LH^{1.55}$ for the prototype.

A curve of reservoir elevation plotted against discharge for the prototype from which the coefficient and exponent in formula (2) was taken is shown in figure 14. This curve is indicated by the dotted line drawn thru the points. As is evident from the above two formulae, the coefficients vary for model and prototype when the exponent is other than 1.50. This is because the coefficient C is dimensionless only when the exponent of H is 1.50.

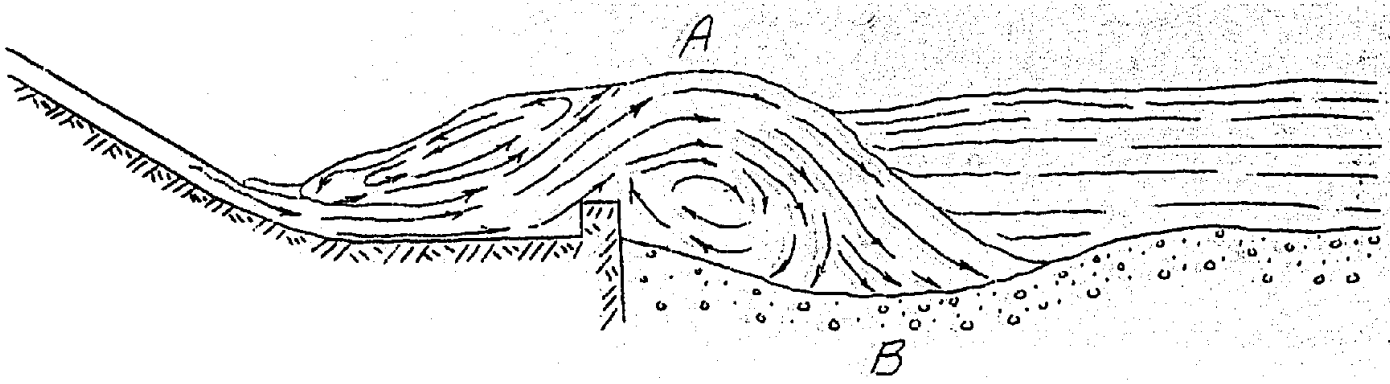
In order to have a single equation which will apply to both model and prototype, a line was drawn thru the point of maximum head and discharge with a slope of 1.50. (See figure 14.) This line, altho somewhat inaccurate for the lower discharges, gives the equation $Q = 2.81LH^{1.50}$ and is applicable to both model and prototype in this form.

GATE COMBINATIONS

Numerous gate combinations were tried with the various gates open, closed, and partially open, in order to witness the effects produced on the flow down the spillway and on the action in the stilling pool. In no case was there any outstanding undesirable action produced even when the flow was unsymmetrical down the spillway. The various gate combinations produced a negligible effect on pool action.

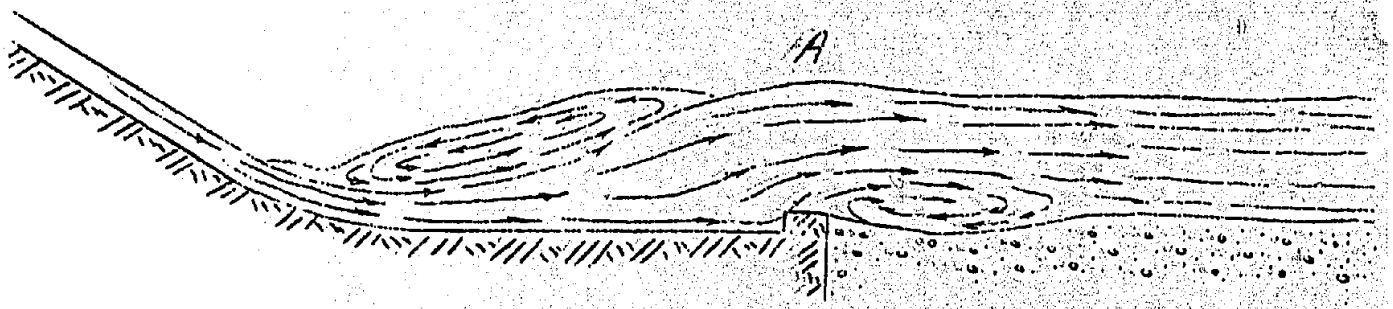
SECONDARY REMARKS ON STILLING POOL ACTION

Relation of Sill to Length of Pool.



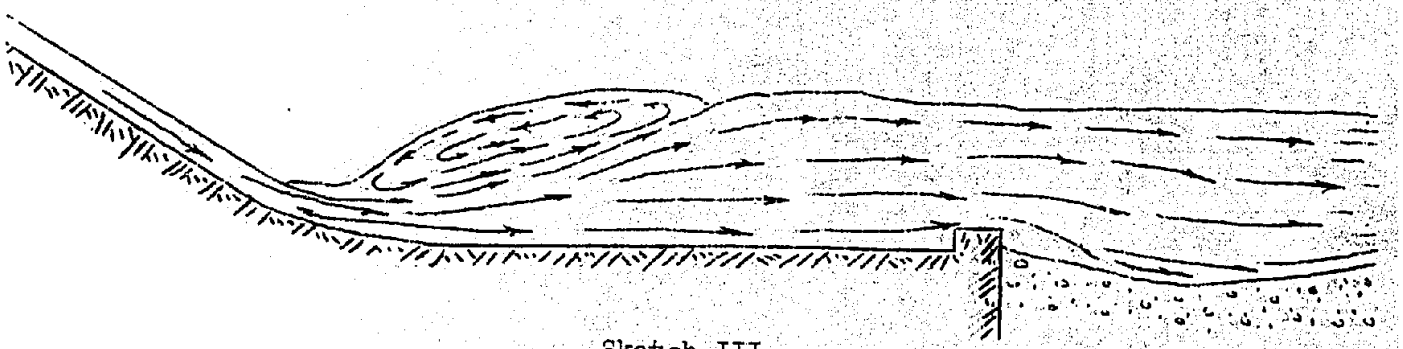
Sketch I

Sketch I illustrates the action that takes place when a high sill is placed on a short apron. The entering jet of water, still not greatly expanded and traveling at a high velocity, strikes the sill with considerable impact and hurdles over it producing a high boil on the water surface at A and heavy erosion at B.



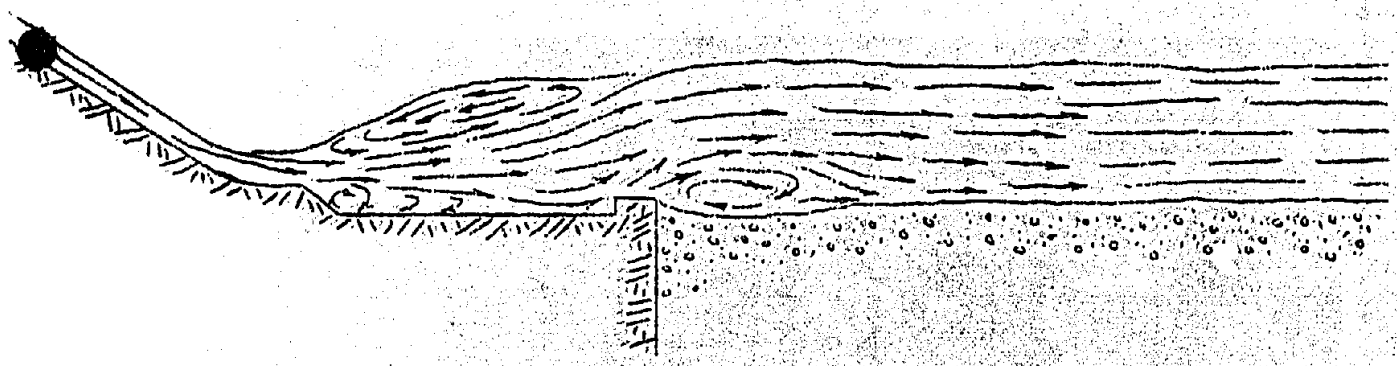
Sketch II

A slightly lower sill and a longer pool produce an action more like that shown in sketch II. The jet has had a chance to expand slightly before reaching the sill; consequently, less water traveling at a reduced velocity impinges on the sill than in case I. In the second case, the water in rising to flow over the sill produces a lifting action on the water above. As a result, the faster traveling water flows near the surface as at A, (sketch II) and a submerged protecting roller is formed below the sill at B. This is the type of action much desired in stilling pools, and pools which are of this nature are usually non-destructive in character.



Sketch III

If the same sill as in case II is used and the pool is again lengthened as shown in sketch III, the lifting action of the sill is much less and the flow passes over it with little or no disturbance causing considerable erosion downstream. The higher velocities in this case are still near the bottom.



Sketch IV

If a stepped apron is introduced at the beginning of the pool as in sketch IV, the jet which leaves it can expand both up and down. In this way, the cross sectional area of the jet is increased and the velocity decreased so that the sill can be placed on a very short apron and still have present the proper amount of lifting action to produce good pool conditions. This is thought to be the action that takes place in the Rye Patch stilling pool.

Sloping the Stepped Apron.

It was found in various tests that sloping the stepped apron up or down sometimes improved conditions at the higher or lower discharges but seldom worked satisfactorily for all discharges. The horizontal step gave the most dependable results. All stepped aprons however, were sensitive in the action they produced when the stilling pool was too short or the apron too high.

Varying the Width of Sill.

From a series of tests made on sills H, G, and L, (figure 9) it was found that varying the width of a sill when placed on the downstream end of an apron produced no noticeable difference in the pool conditions or in the erosion below the sill. This would indicate that a sill can be made as narrow as structural conditions will allow.

A summary of all model tests made on the Rye Patch Spillway is recorded in the appendix.

Acknowledgment is made for the cooperation of the following junior engineers: H. M. Martin and L. R. Brocks in charge of construction, J. M. Buswell and F. L. Panuzio in charge of testing, and H. W. Brewer for his work in preparing the test data for this report.

RYE PATCH SPILLWAY
HUMBOLDT RIVER PROJECT
LOG OF TESTS

(All discharges at 20,000 c.f.s. unless otherwise stated)

EST NO.	REVISION	LENGTH OF POOL	ELEV. OF POOL	SILL	STEPPED APRON	POOL	TAILRACE	SCOUR	REMARKS
RP 1	Original	94.8	4059.0	A	None	Quiet	Quiet	Little	Satisfactory in general.
RP 1A	"	94.8	4059.0	A	"	"	"	"	Satisfactory 4:1 Slope is in sand.
1 RP 2	"	12.5	4059.0	A	"	"	"	"	Showed pool could be shortened. Front of jump nearly vertical.
1 RP 3	"	41.7	4059.0	A	"	"	"	"	Not as good as 1 RP 2.
1 RP 4	"	13.0	4059.0	C	"	Fair	Fast	Bad	Jump sweeps out of pool at slight drop in tailwater.
1 RP 5	"	41.7	4059.0	C	"	"	"	"	Slightly better than 1 RP 4.
RP 6	"	94.6	4059.0	C	"	Quiet	Quiet	Little	Comparable with 1 RP 1.
P RP 1	"	94.8	4059.0	A	"	"	"	"	Series of runs to determine coefficient of discharge.
RP 1-9	"	Various	4059.0	Various	"	---	---	---	Series of runs to find pool that swept out at lowest tailwater.
RP 10	---	"	4063.2	"	"	---	---	---	Results showed floor raised too much.
RP 1	A	85.7	4062.0	B	"	Good	Quiet	Little	Showed pool floor could be raised three foot.
RP 1	A	73.2	4062.0	B	"	"	"	"	About the same as 3 RP 1. Indicates that original pool can be shortened.
RP 1	A	60.7	4062.0	B	"	Slightly Rough	"	"	Tailrace is slightly faster. Otherwise the same as 3 RP 1.
RP 1	A	79.5	4062.0	C	"	Good	Fast	Pronounced	Pool same as 3 RP 1 but erosion is more noticeable.
RP 1	A	67.0	4062.0	C	"	"	"	"	Same as 6 RP 1.
RP 1	A	64.9	4062.0	D	"	"	"	"	Same as 6 RP 1.
RP 1	A	77.4	4062.0	D	"	"	"	"	Same as 6 RP 1.

RYE PATCH SPILLWAY
HUMBOLDT RIVER PROJECT
LOG OF TESTS

(All discharges at 20,000 c.f.s. unless otherwise stated)

TEST NO.	REVISION	LENGTH OF POOL	ELEV. OF POOL	SILL	STEPPED APRON	POOL	TAILRACE	SCOUR	REMARKS
10 RP 1	A	75.6	4062.0	B	V	Quiet	Fast	Little	Some improvement over last few runs.
11 RP 1	A	81.9	4062.0	C	V	"	Good	Pronounced	Fairly good looking jump.
12 RP 1	B	73.2	4062.0	B	None	Good	"	Little	Very good looking pool, jump and tailrace.
13 RP 1	E	79.5	4062.0	C	"	"	"	Pronounced	Same as 12 RP 1 except erosion slightly worse.
14 RP 1	B	77.4	4062.0	D	"	"	"	"	Slightly better than 13 RP 1.
15 RP 1	C	62.7	4062.0	B	Z	Slightly Rough	Quiet	Very little	Slightly rougher than the longer pool.
16 RP 1	C	66.9	4062.0	D	Z	Quiet	"	Little	Scour deeper than 15 RP 1.
17 RP 1	C	64.9	4062.0	D	None	Slightly Rough	Good	"	Scour comparable to 16 RP 1.
18 RP 1	C	60.7	4062.0	B	"	Quiet	Fast	"	Slight boil forms over sill.
19 RP 1	D	47.3	4062.0	E	T	Slightly Rough	Quiet	"	Comparable to 15 RP 1.
20 RP 1	D	46.1	4062.0	E	W	"	"	"	Comparable to 15 RP 1.
21 RP 1	D	41.8	4062.0	F	U	Very Quiet	"	Very little	Recommended for final design.
21 RP 2	D	41.8	4062.0	F	U	Very Quiet	"	" "	Very good pool and slight erosion. Discharge equal 10,000 c.f.s.
22 RP 1	E	25.0	4062.0	K	None	Rough	High & Fast	Severe	Sill not adaptable to this type of spillway.
23 RP 1	E	37.8	4062.0	J	"	Slightly Rough	Fair	Little	Boil formed over the sill.
24 RP 1	E	39.0	4062.0	L	X	Quiet	Fast	Bad	Erosion is deep near the sides.

RYE PATCH SPILLWAY
HUMBOLDT RIVER PROJECT
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TEST NO.	REVISION	LENGTH OF POOL	ELEV. OF POOL	SILL	STEPPED APRON	POOL	TAILRACE	SCOUR	REMARKS
25 RP 1	E	45.8	4062.0	G	Y	Quiet	Fast	Bad	Comparable to 24 RP 1.
26 RP 1	E	49.9	4062.0	H	Y	"	"	"	Comparable to 24 RP 1.
27 RP 1	F	41.8	4062.0	F	S	"	"	Excessive	Paving on a 1:1 slope placed downstream from sill.
28 RP 1	F	41.8	4062.0	F	S	Slightly Rough	Fairly Fast	Bad	Paving interferes with the formation of the submerged roller.
29 RP 1	F	41.8	4062.0	F	S	"	"	Dangerous	40 feet of paving downstream from sill at elevation 4064.0.
30 RP 1	F	41.8	4062.0	F	S	"	"	Very Little	40 feet of paving downstream from sill at elevation 4062.0.
31 RP 1	F	41.8	4062.0	F	S	"	"	"	Final design. Discharge 20,000 c.f.s.
31 RP 2	F	41.8	4062.0	F	S	"	Quiet	Very Slight	Final design. Discharge 15,000 c.f.s.
31 RP 3	F	41.8	4062.0	F	S	Quiet	"	"	Final design. Discharge 10,000 c.f.s.
31 RP 4	F	41.8	4062.0	F	S	"	"	Negligible	Final design. Discharge 5,000 c.f.s.