UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDRAULIC MODEL EXPERIMENTS FOR THE DESIGN OF

THE ALCOVA SPILLWAY

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Under Direction of

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RESEARCH ENGINEERS

TECHNICAL MEMORANDUM NO. 513

Denver, Colorado,

Feb. 26, 1936

(PRICE $4.50)

ACKNOWLEDGMENTS

The studies discussed in this memorandum were made by the hydraulic research department of the United States Bureau of Reclamation in its Arapahoe Street laboratory in Denver, Colorado. At the time these tests were made E. W. Lane, Research Engineer, was in charge of the research department. The construction and testing were under the general supervision of W. M. Borland, Associate Engineer, and the author. H. M. Martin and L. R. Brooks, Junior Engineers, handled the construction, and J. M. Buswell and F. L. Panuzio, Junior Engineers, conducted the tests. The report was prepared under the supervision of J. E. Warnock, Research Engineer.

All engineering work of the Bureau of Reclamation is under J. L. Savage, Chief Designing Engineer, and S. O. Harper, Acting Chief Engineer. All activities of the Bureau are under the direction of R. F. Walter, Acting Commissioner.

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A. SUMMARY

Laboratory studies made on a scale model of the proposed spillway for the Alcova Dam showed the original stilling pool to be too wide for best operation, and demonstrated the hydraulic superiority of a narrower stilling pool. The model studies also demonstrated that the gates as originally planned were not large enough to pass the required flow with the pond at the maximum allowable level. The gates and piers were redesigned to correct this condition.

Tests of the stilling pool also resulted in an improved design. The model studies thus brought about a substantial saving in cost, and insured both satisfactory and safe operation.

B. PROJECT

The Alcova Dam of the Casper-Alcova Project on the North Platte River will be just south of the town of Alcova, Wyoming, (fig. 1). It is an earth-fill dam, and the flood flows will be passed by a gate-controlled open spillway situated in the valley wall at the north end of the dam (fig. 2). The spillway is designed to handle a maximum flood flow of 55,000 cubic feet per second. Three stoney gates 25 feet 8 inches wide will admit water to the channel, which drops 150 feet in a length of 700 feet, and increases in width from 95 feet at the gates to 150 feet at the stilling pool. A model of the spillway was built and tested to insure satisfactory operation and to investigate the feasibility of proposed economies.

C. LABORATORY

The Denver hydraulic laboratory of the Bureau of Reclamation is in the basement of the Old Custom House, 16th and Arapahoe Streets, Denver, Colorado, (fig. 3). A 6-inch centrifugal pump having a maximum discharge of three cubic feet per second delivered water to the forebay of the model. The water then flowed over the model, emptied into a sheet-metal return flume and was carried back to a 90-degree V-notch measuring weir. After passing this, it was recirculated by the pump.

During the testing of the model, members of the designing staff had ample opportunity to visit the laboratory and observe the model in operation. This situation was conducive to closer coordination of the construction and hydraulic features of the structure and led to a design superior to that which would have been produced by either organization operating independently. Due to the urgency of obtaining a satisfactory design in a minimum of time, the testing was conducted two shifts per day by crews each consist-

FIG 1

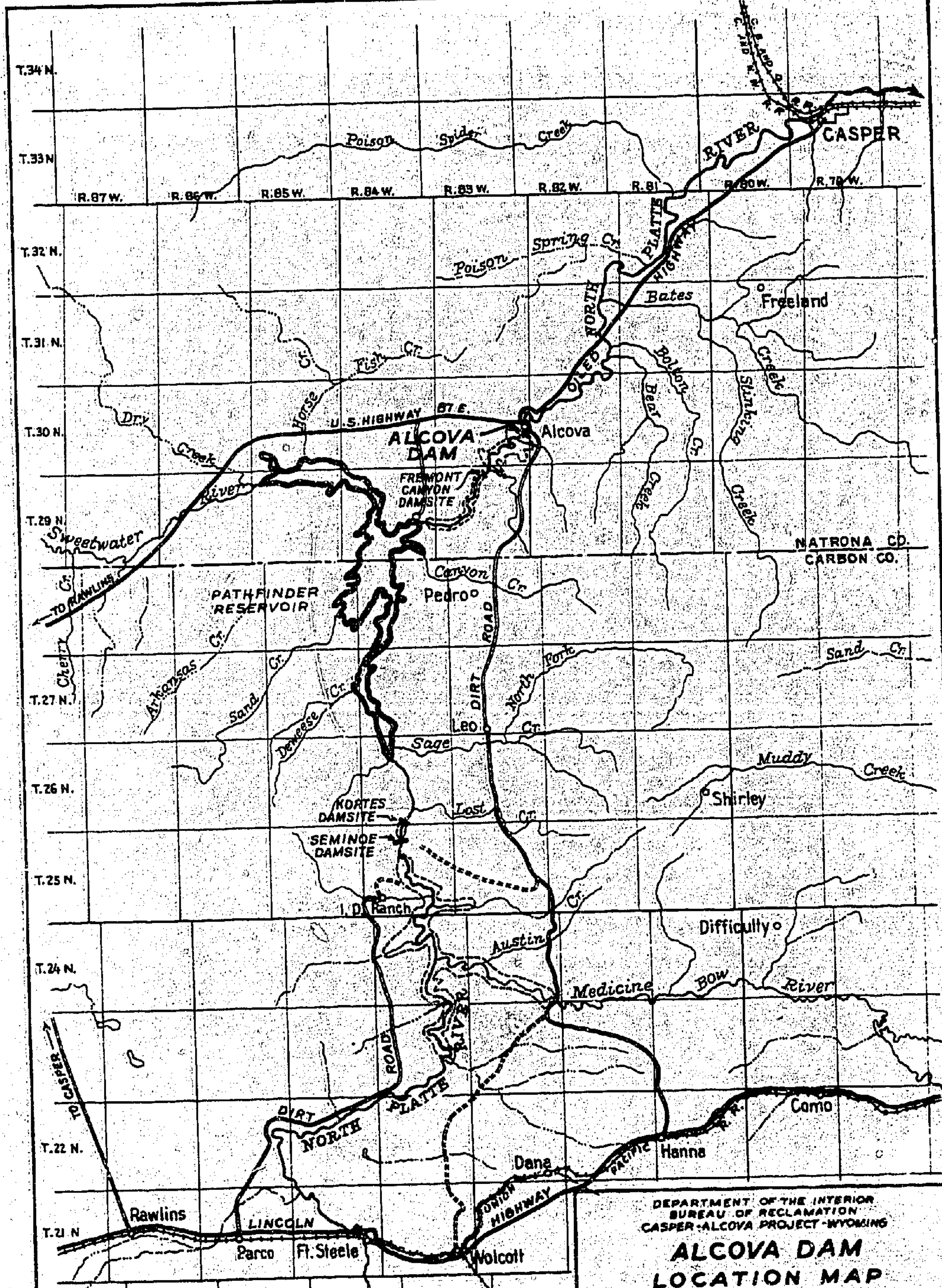
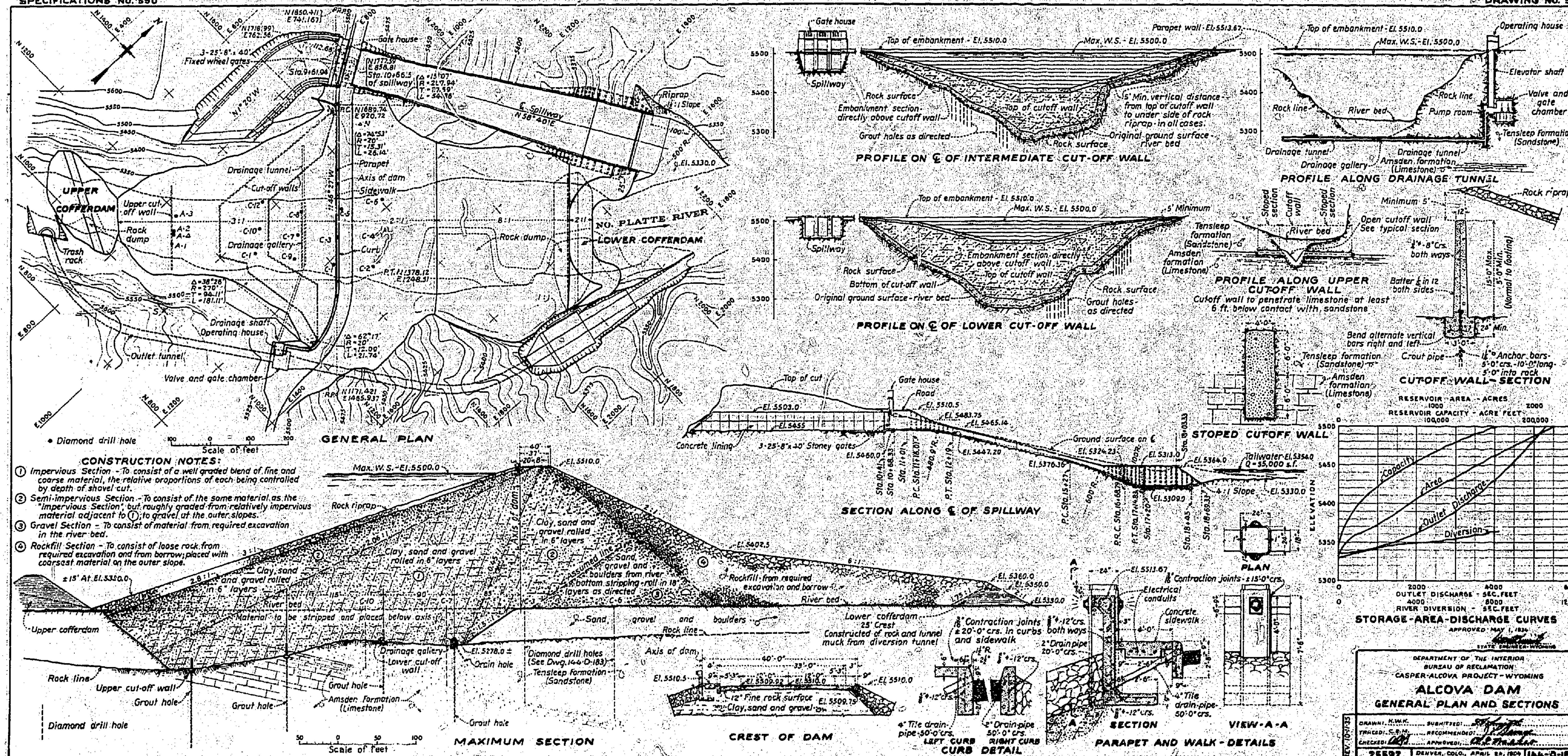

CASPER
Alcova
ALCOVA DAM
FREMONT CANYON DAMSITE
PATHFINDER RESERVOIR
Pedro
Leo
Freeland
Shirley
Difficulty
KORTES DAMSITE
SEMINOE DAMSITE
I.D. Ranch
Rawlins
Parco
Ft. Steele
Wolcott
Dana
Hanna
Como
U.S. HIGHWAY 87 E.
NORTH PLATTE RIVER
DIRT ROAD
LINCOLN
UNION PACIFIC R.R.
HIGHWAY
TO RAWLINS
TO CASPER
Poison Spider Creek
Poison Spring Cr.
Bates
Bolton
Bear Cr.
Stinking Creek
Fish Cr.
Horse Cr.
Dry Creek
Sweetwater River
Canyon Cr.
Sand Cr.
Arkansas Cr.
Cherry Cr.
Deweese Cr.
Sage
North Fork
Lost Cr.
Austin Cr.
Medicine Bow River
Muddy Creek
NATRONA CO.
CARBON CO.
T.34 N.
T.33 N
T.32 N.
T.31 N.
T.30 N.
T.29 N.
T.27 N.
T.26 N.
T.25 N.
T.24 N.
T.22 N.
T.21 N
R.87 W.
R.86 W.
R.85 W.
R.84 W.
R.83 W.
R.82 W.
R.81
R.80 W.
R.79 W.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER-ALCOVA PROJECT-WYOMING
ALCOVA DAM
LOCATION MAP
DRAWN: S.A.K.
TRACED: C.G.G.
CHECKED: J.K.W.
SUBMITTED:
RECOMMENDED:
APPROVED:
24842
DENVER, COLO., SEPT. 27, 1933
144-D-83

FIG 2

SPECIFICATIONS No. 590

DRAWING No. 5



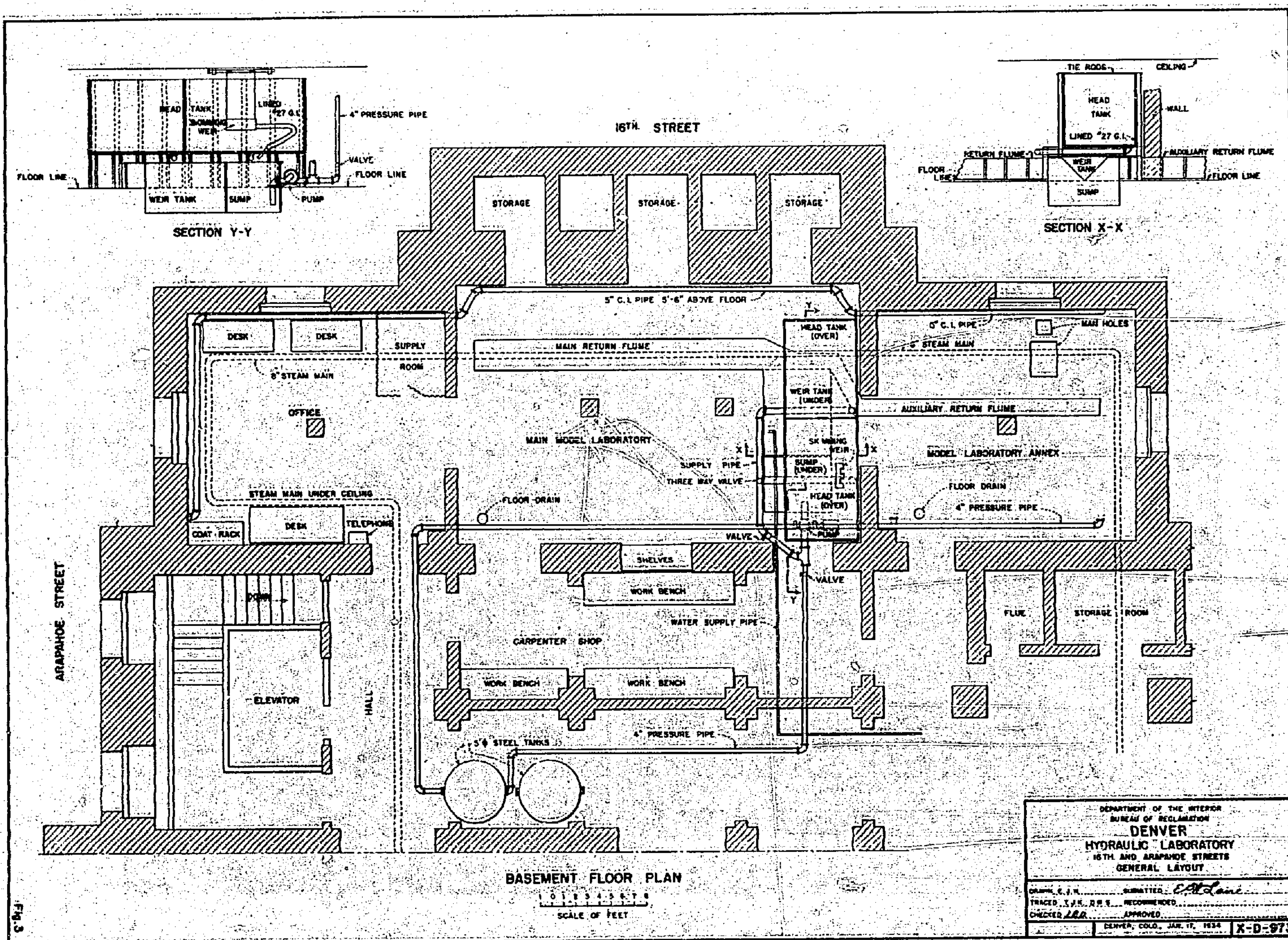

SECTION Y-Y
HEAD TANK
LINED #27 G.I.
SKIMMING WEIR
4" PRESSURE PIPE
VALVE
FLOOR LINE
WEIR TANK
SUMP
PUMP
16TH STREET
STORAGE
SECTION X-X
TIE RODS
CEILING
WALL
RETURN FLUME
AUXILIARY RETURN FLUME
WEIR TANK
SUMP
DESK
SUPPLY ROOM
8" STEAM MAIN
OFFICE
5" C.I. PIPE 5'-6" ABOVE FLOOR
MAIN RETURN FLUME
HEAD TANK (OVER)
WEIR TANK (UNDER)
6" C.I. PIPE
MAN HOLES
AUXILIARY RETURN FLUME
MAIN MODEL LABORATORY
MODEL LABORATORY ANNEX
SUPPLY PIPE
THREE WAY VALVE
SUMP (UNDER)
HEAD TANK (OVER)
PUMP
FLOOR DRAIN
4" PRESSURE PIPE
STEAM MAIN UNDER CEILING
COAT RACK
TELEPHONE
SHELVES
WORK BENCH
VALVE
ARAPAHOE STREET
DOWN
ELEVATOR
HALL
CARPENTER SHOP
WATER SUPPLY PIPE
FLUE
STORAGE ROOM
5' 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.H.
SUBMITTED
TRACED T.J.K. D.R.S.
RECOMMENDED
CHECKED
APPROVED
DENVER, COLO., JAN. 17, 1934
X-D-973

Fig. 3

ing of one Junior Engineer and two laboratory assistants.

D. MODEL

The Alcova spillway model, constructed on a scale ratio of 1 to 72, included the complete spillway from entrance in the reservoir to discharge into the river bed (fig. 4). The model was built of wood and lined with sheet metal. The entire stilling pool, except during the first few tests, was set in a large sand bin, which facilitated changes in the model and enabled a thorough study in the various layouts of the expected scour below the lined stilling pool. To offset the relatively greater roughness of the model, its slope was increased slightly over that of the prototype, in accordance with computations based on Manning's formula and the laws of similitude. Velocities at the entrance to the prototype stilling pool were calculated, as suggested by the design department, by assuming that the velocity head at that point would be 85 percent of the total drop from the reservoir level. Calculations for the model were based on a Kutter's "n" of 0.010. This was found to give actual model velocities too small, and the slope was further increased until proper velocities were obtained. The failure of the calculations to predict velocities accurately was probably due to the very small absolute depths in the model.

E. ORIGINAL DESIGN

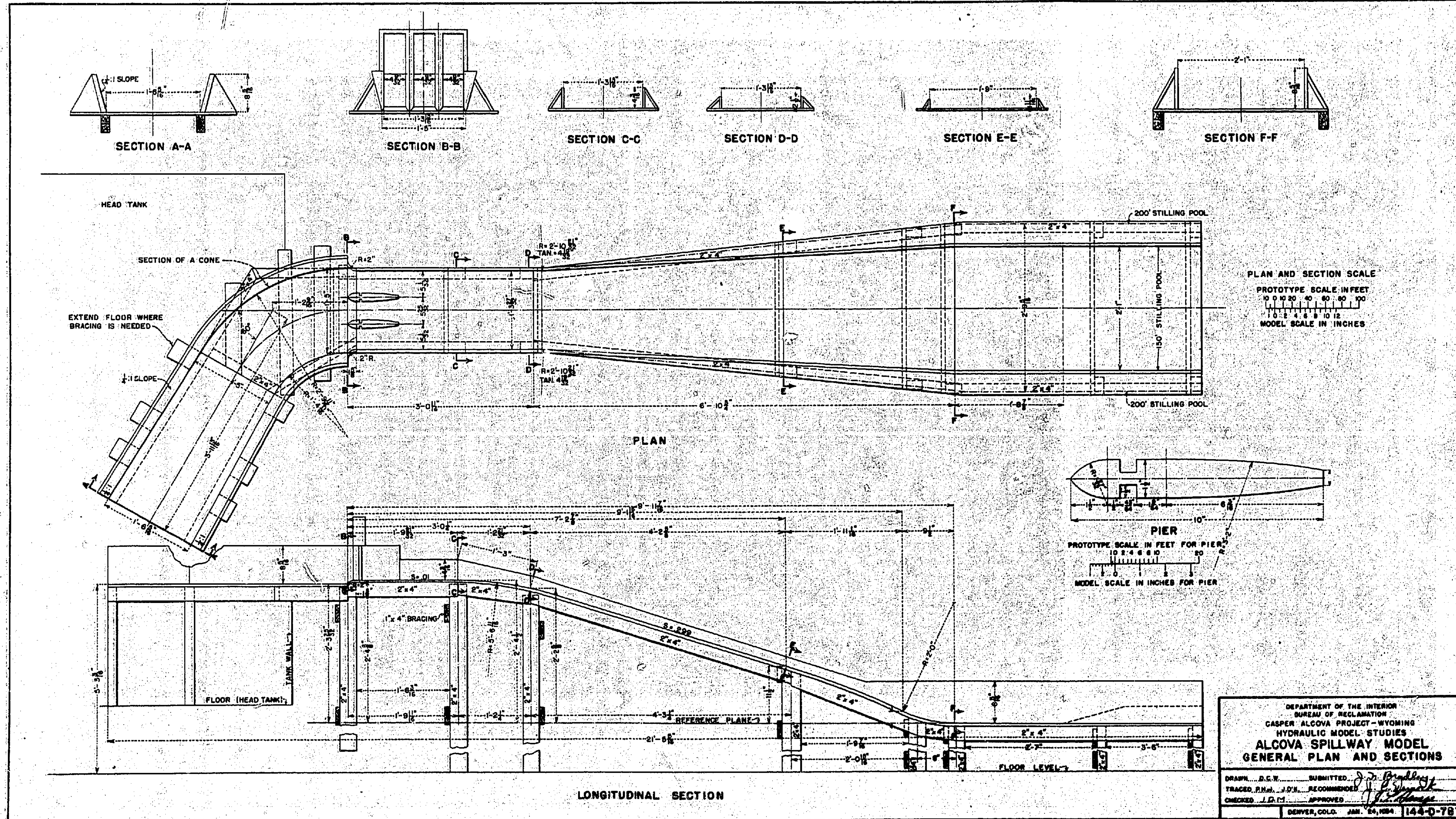
The original design called for three gates 25 feet wide, separated by piers 10 feet thick (fig. 5). This design required a 42-foot head over the gate sill to pass the maximum discharge of 55,000 second-feet, instead of 40 feet as expected (fig. 7, test SP-CAD-1).

The original spillway flared to a pool width of 200 feet. The hydraulic jump forming was very shallow in comparison with the width of the pool, and at small discharges a large whirl formed (plate I). Due to the unsymmetrical approach to the gates, the flow through them and down the spillway was also slightly unsymmetrical, and the whirl in the pool rotated invariably in the same direction.

Tests were made with different conditions downstream of the pool to see what influence they might have (plate II). In test 7 a metal wall simulated the hillside on the left of the tailway, and in test 9 the right wall of the pool was shortened. The former test revealed little, and the latter demonstrated the necessity of thorough lateral confinement of the jump.

The few tests made with a pool 200 feet wide showed conclusively that it should be narrower for best hydraulic performance.

FIGURE 4


SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
HEAD TANK
SECTION OF A CONE
EXTEND FLOOR WHERE BRACING IS NEEDED
200' STILLING POOL
150' STILLING POOL
PLAN
PLAN AND SECTION SCALE
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
PIER
PROTOTYPE SCALE IN FEET FOR PIER
MODEL SCALE IN INCHES FOR PIER
1"x 4" BRACING
TANK WALL
FLOOR (HEAD TANK)
REFERENCE PLANE
FLOOR LEVEL
LONGITUDINAL SECTION
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER ALCOVA PROJECT-WYOMING
HYDRAULIC MODEL STUDIES
ALCOVA SPILLWAY MODEL
GENERAL PLAN AND SECTIONS
DENVER, COLO. JAN. 24, 1934
144-D-787

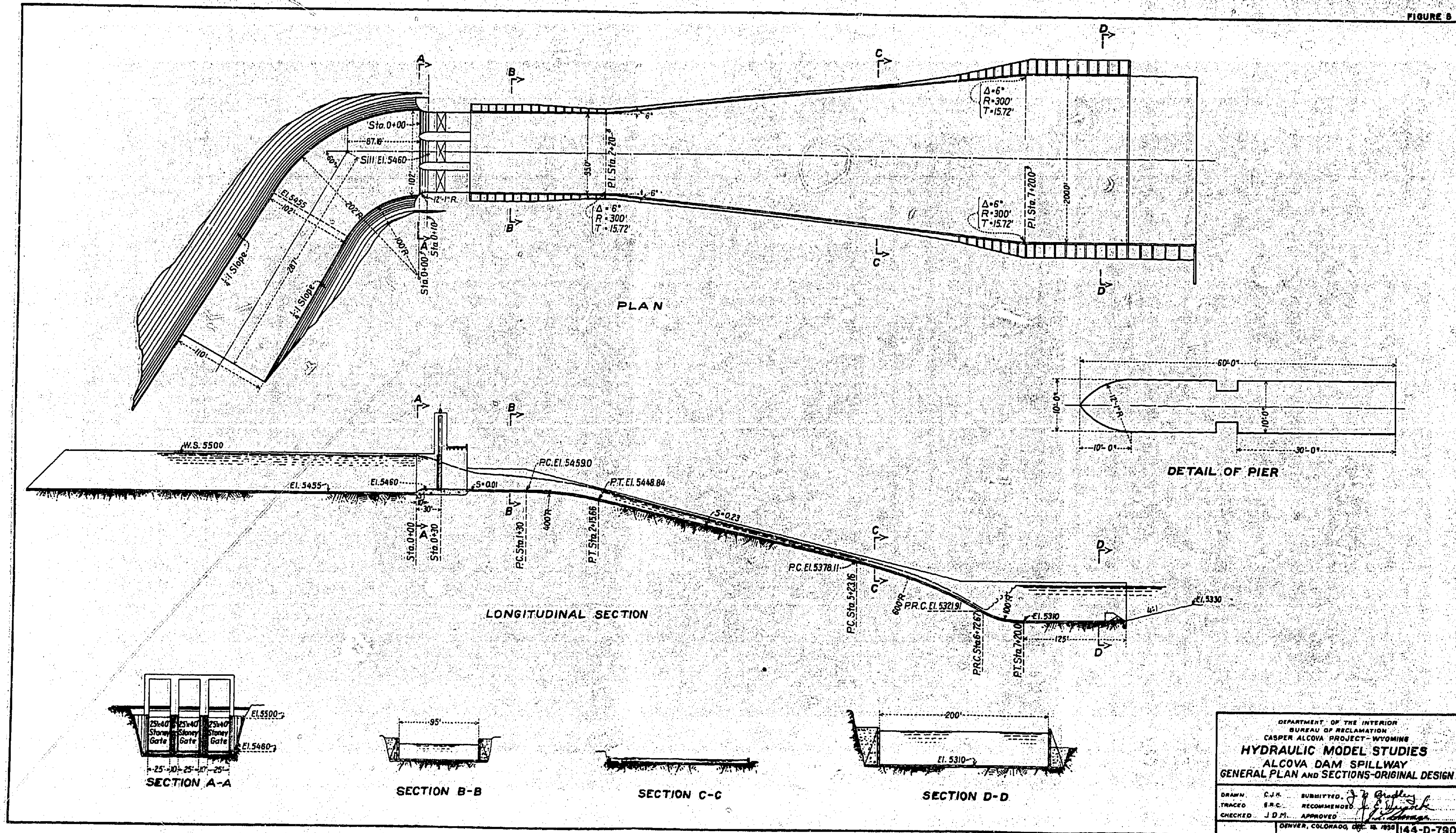
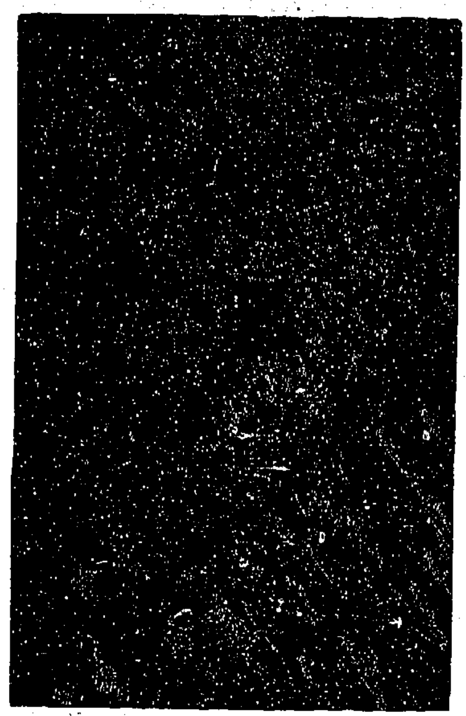


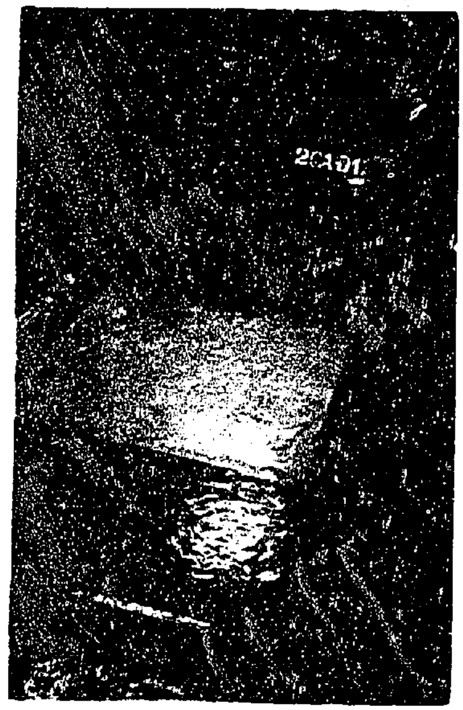
FIGURE 8
PLAN
LONGITUDINAL SECTION
DETAIL OF PIER
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
Sta. 0+00
Sill El. 5460
El. 5455
4:1 Slope
1/2:1 Slope
12'-1" R.
Δ = 6°
R = 300'
T = 15.72'
P.I. Sta. 2+20.3
P.I. Sta. 7+20.0
W.S. 5500
El. 5455
El. 5460
S = 0.01
P.C. El. 5459.0
P.T. El. 5448.84
S = 0.23
P.C. El. 5378.11
P.R.C. El. 5321.91
El. 5310
El. 5330
400' R
600' R
100' R
125'
60'-0"
10'-0"
30'-0"
25'x40' Stoney Gate
El. 5500
El. 5460
95'
200'
El. 5310
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER ALCOVA PROJECT—WYOMING
HYDRAULIC MODEL STUDIES
ALCOVA DAM SPILLWAY
GENERAL PLAN AND SECTIONS—ORIGINAL DESIGN
DRAWN C.J.H.
TRACED S.R.C.
CHECKED J.D.M.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO, DEC. 18, 1936
144-D-790

A. POOL WITH NO FLOW.



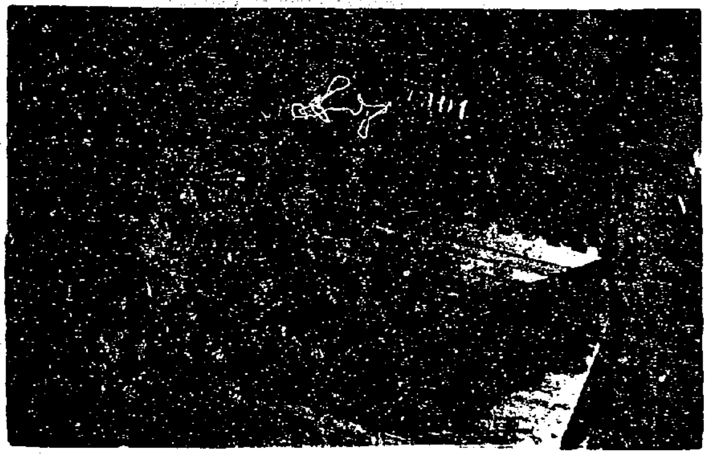
B. DISCHARGE 55,000 SECOND-FEET.

C. DISCHARGE 25,000 SECOND-FEET.

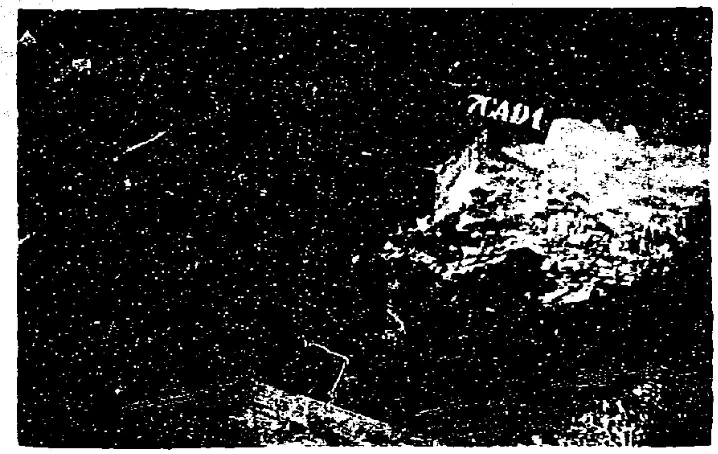


D. DISCHARGE 5,000 SECOND-FEET.

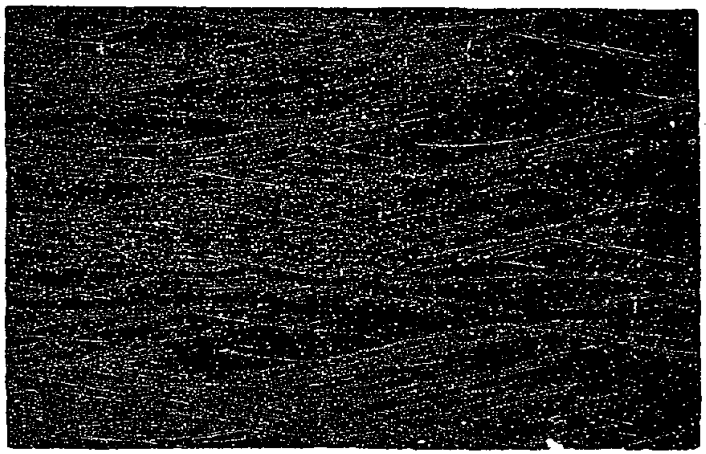
ORIGINAL DESIGN OF STILLING POOL - 200 FEET WIDE.



A. FALSE WALL SIMULATES HILLSIDE.



B. DISCHARGE 55,000 SECOND-FEET.



C. RIGHT WALL OF POOL REMOVED.

D. DISCHARGE 55,000 SECOND-FEET.

VARIATIONS OF ORIGINAL POOL - 200 FEET WIDE.

F. REVISED DESIGN

The structure was then redesigned: the gates were enlarged to a width of 25 feet eight inches, the pier thickness was reduced from 10 feet to 9 feet, and the stilling pool was narrowed to a width of 150 feet (fig. 6). The change in the gates decreased the required head for maximum discharge to 40 feet (fig. 7, test SP-CAD-5); narrowing the pool greatly improved the action of the jump and effectively removed all traces of whirling.

In an effort to make the flow in the spillway symmetrical and also to smooth out the disturbance generated by the piers, temporary alterations were made in the model to form an hydraulic jump just below the piers (plate III). The pier disturbance disappeared but the flow in the spillway remained slightly unsymmetrical. Because of cost considerations, the use of an hydraulic jump immediately below the piers was abandoned. Figure 7, test SP-CAD-3, gives a profile of the jump just below the piers.

G. COMPARATIVE TESTS OF VARIOUS POOL LAYOUTS

After enlarging the gates so that they had sufficient capacity, and limiting the pool width to a value giving reasonably good stilling-pool action, subsequent studies were made in an effort to decrease the length of the pool and reduce the erosion downstream.

Length of Wall on Right Side of Pool

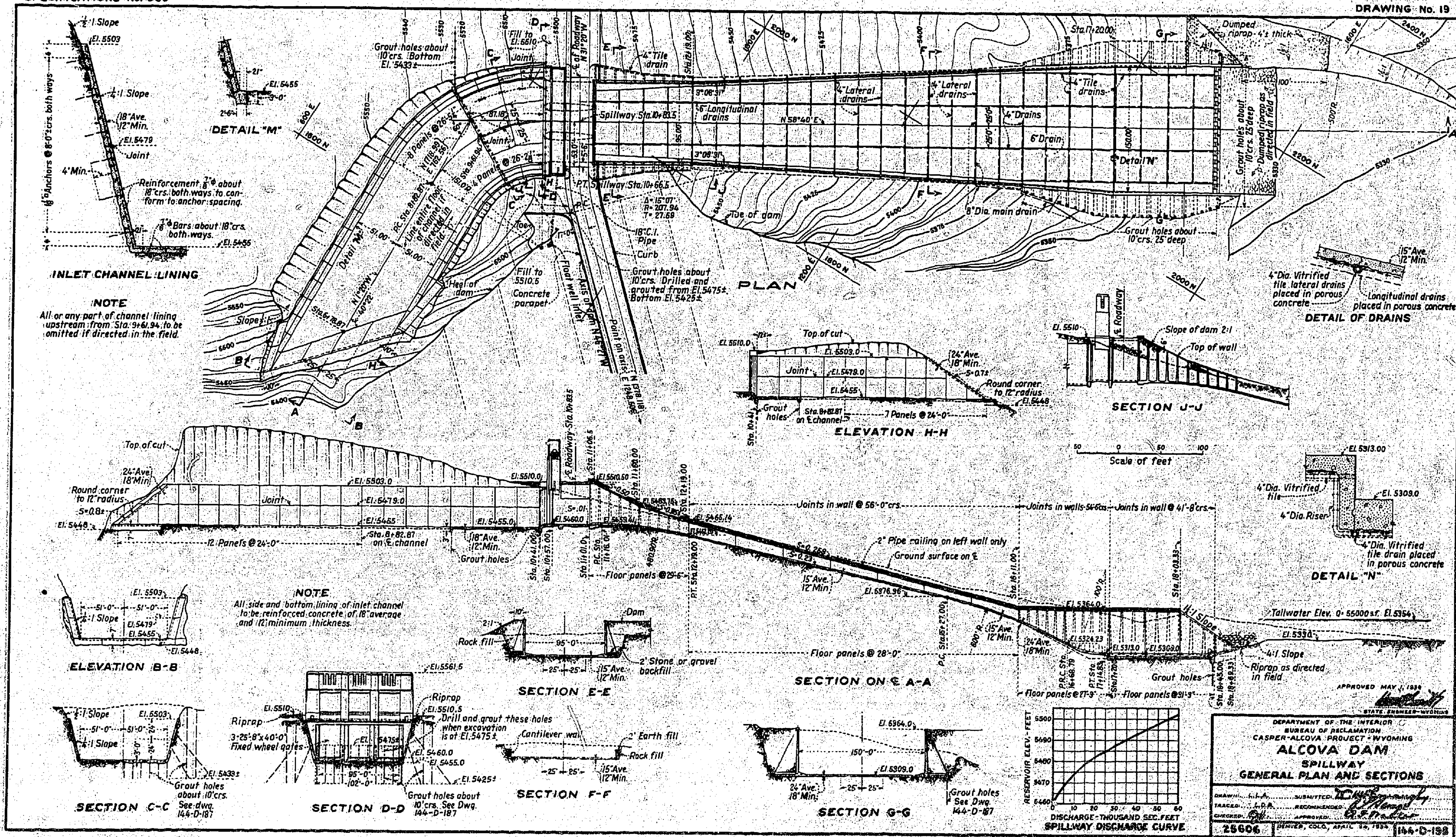
The stilling pool is situated at the downstream toe of the dam, and the right wall of the pool will serve as a retaining wall for the embankment (fig. 2). In order to determine the minimum length of this wall consistent with safety from scouring at the toe of the dam, several lengths of wall were investigated in the model. It was found that a short wall produced very poor hydraulic conditions: water flowed along the toe of the dam and entered the region of the jump from the side, across the sloping end of the stilling-pool wall. Plate II and plate IV show this to be the case. The influx of water from the side interfered with the proper action of the jump, and formed a large whirl or eddy which scoured the river bed near the toe of the dam and at the lower end of the pool wall. The tests indicated that a wall extending to sta. 8+07 at elevation 5367, and with its downstream end sloping off at 1-1/2 to 1 would be satisfactory. A 2 to 1 slope at the lower end of the right wall was also tried, but seemed no better than the steeper slope, and was abandoned because of its greater cost for the same top length.

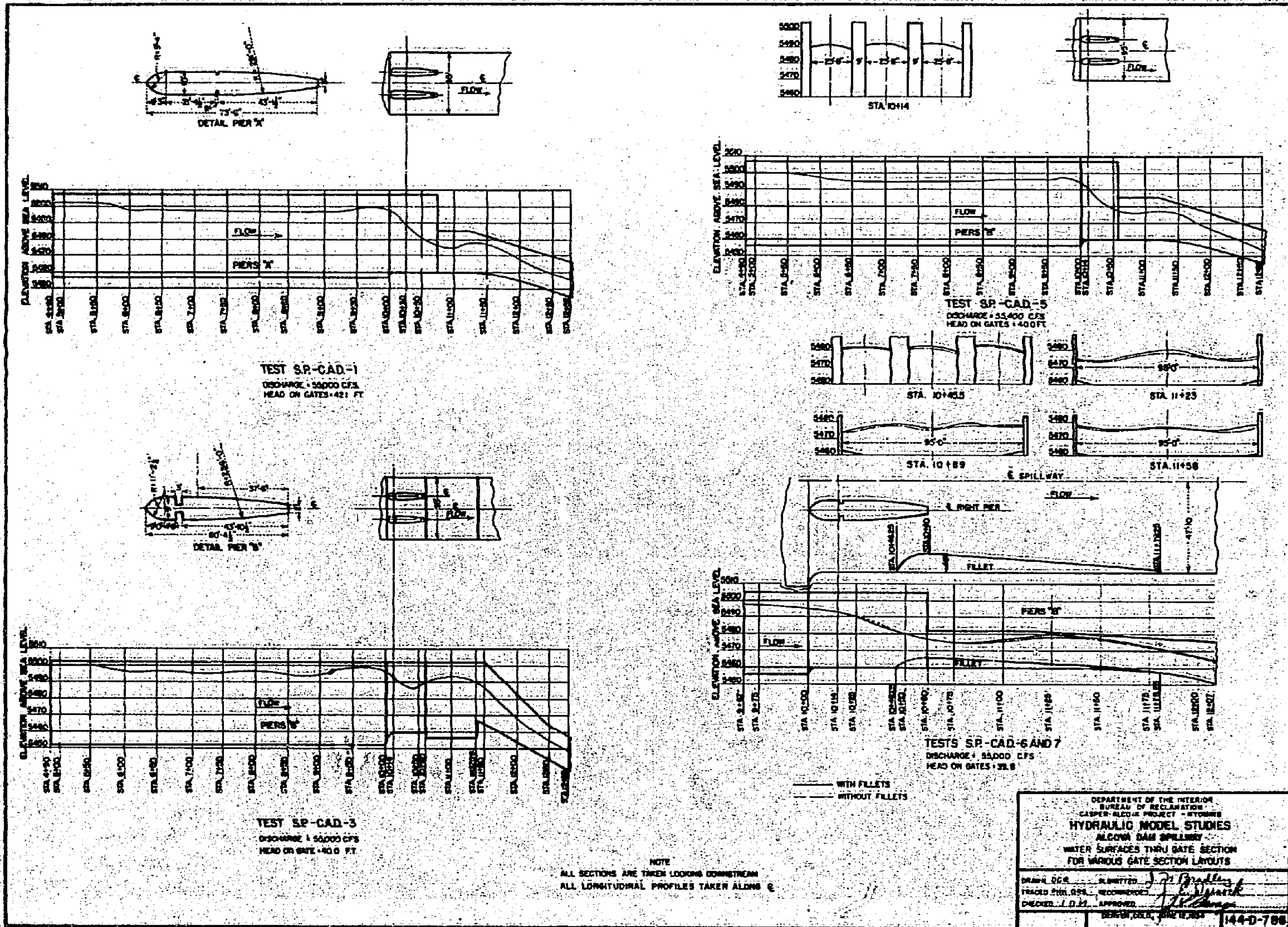
The left wall was vertical and extended far beyond the stilling pool for the majority of the tests. It was understood that the ground in the region would not erode readily, and so little

SPECIFICATIONS No. 590

FIG 6

DRAWING No. 19




DETAIL PIER "A"
DETAIL PIER "B"
TEST S.P.-CAD.-1
DISCHARGE: 55,000 C.F.S.
HEAD ON GATES: 42± FT.
TEST S.P.-CAD.-3
DISCHARGE: 55,000 CFS
HEAD ON GATE: 40.0 FT.
STA. 10+14
TEST S.P.-CAD.-5
DISCHARGE: 55,400 C.F.S.
HEAD ON GATES: 40 FT.
STA. 10+45.5
STA. 11+23
STA. 10+89
STA. 11+56
℄ SPILLWAY
℄ RIGHT PIER
FILLET
PIERS "B"
PIERS "A"
FLOW
ELEVATION ABOVE SEA LEVEL
TESTS S.P.-CAD.-6 AND 7
DISCHARGE: 55,000 C.F.S.
HEAD ON GATES: 39.8
WITH FILLETS
WITHOUT FILLETS
NOTE
ALL SECTIONS ARE TAKEN LOOKING DOWNSTREAM
ALL LONGITUDINAL PROFILES TAKEN ALONG ℄
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CASPER-ALCOVA PROJECT - WYOMING
HYDRAULIC MODEL STUDIES
ALCOVA DAM SPILLWAY
WATER SURFACES THRU GATE SECTION
FOR VARIOUS GATE SECTION LAYOUTS
DENVER, COLO.
144-D-786

FIGURE 7

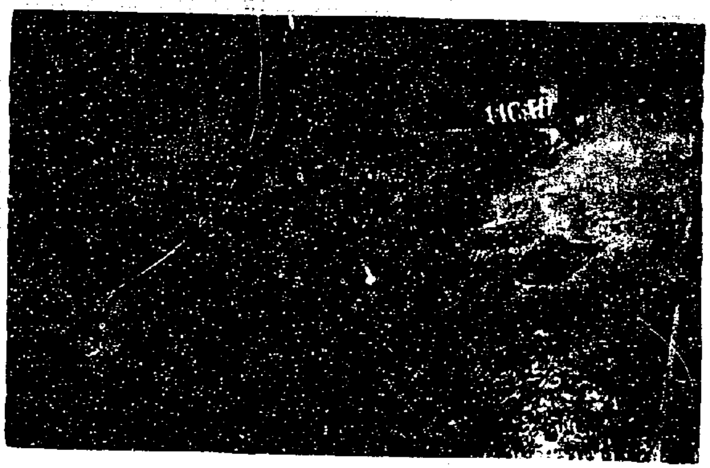
A. ALTERATION TO PRODUCE HYDRAULIC JUMP.

B. DISCHARGE 55,000 SECOND-FEET HYDRAULIC JUMP FORMS BELOW PIERS.

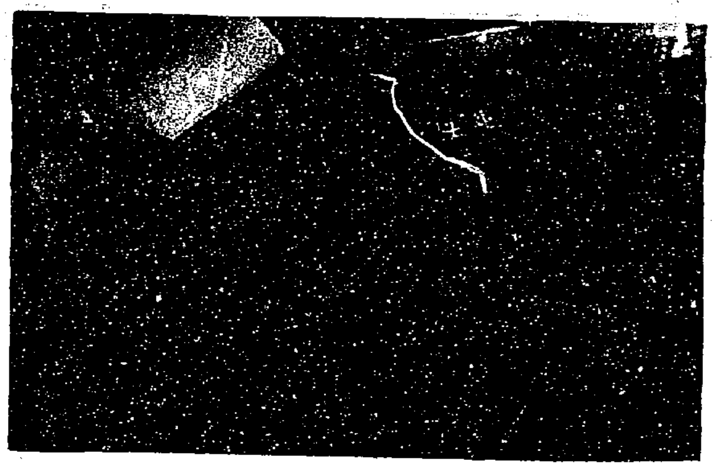
C. REVISED GATE SECTION PIERS 9 FEET THICK.

D. DISCHARGE 55,000 SECOND-FEET.

FLOW THROUGH GATE SECTION.

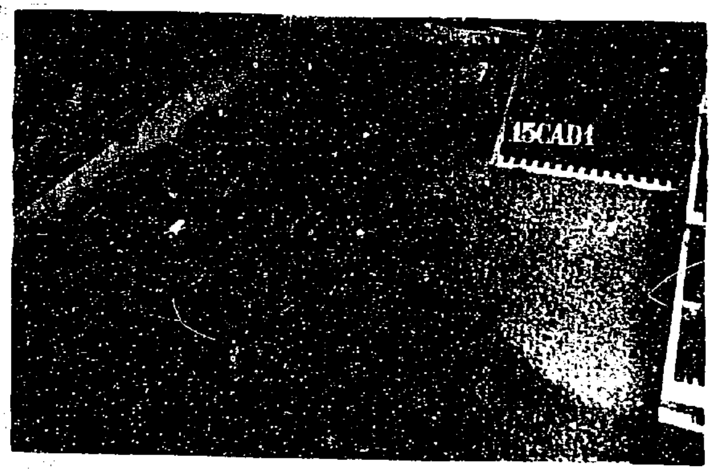


A. DISCHARGE 55.000 SECOND-FEET.



B. BED AFTER ONE HOUR RUN.

C. DISCHARGE 55,000 SECOND-FEET.



D. BED AFTER ONE HOUR RUN.

POOLS WITH LONG AND SHORT WALLS ON RIGHT.

concern was felt for it. The last of the tests were made with a left pool wall which matched the right wall as mentioned above, and then fell back to a 1/4:1 slope downstream of the pool.

Type and Location of Sill

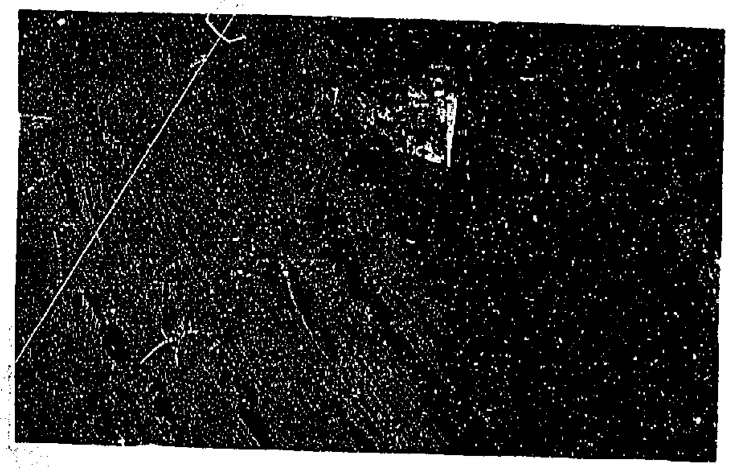
Most of the comparative tests of hydraulic jump action and scour were made with some form of dentated sill; either a straight Rehbock-type sill, or a dentated sill on top of a rectangular sill. Tests showed that a Rehbock sill about 10 feet high was not as effective as a smaller dentated sill 5 feet high, on top of a plain 5-foot rectangular sill. This latter type sill presented more flat area for impact of the water, and permitted less water to pass through the openings. A low dented sill, 5 feet high, placed on the pool floor, gave about the same scour picture as when it was raised from the floor - except that it scoured deeper at all points. Thus, a sill on the floor would demand a deeper cut-off wall at the downstream end of the pool. It was thought to be cheaper to reduce the depth of cut-off wall, and raise the dentated sill by placing it on a rectangular sill. One run was made with extra blocks placed at the end of the dentated sill to see if the erosion which occurred close to the walls could be reduced. The effect was negligible, as may be seen from plate XII.

The sill finally chosen was a dentated sill 5 feet high, placed on a 5-foot high rectangular sill, as shown in figure 10.

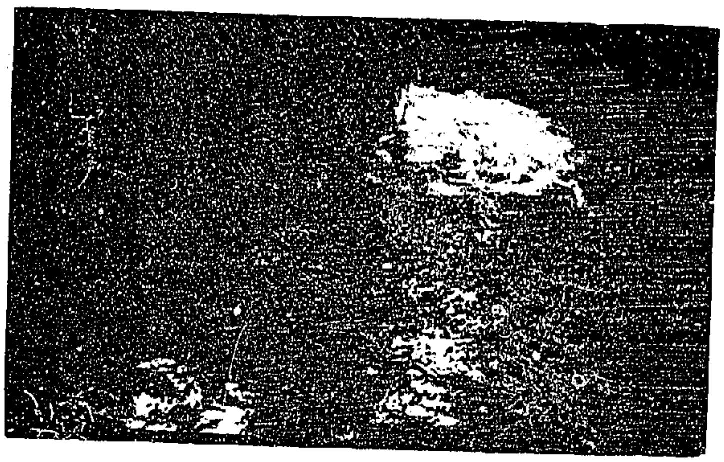
Triangular sills placed either with the vertical face or with the sloping face upstream gave fair results, but not as satisfactory as the dentated sills.

A diffuser sill was tried in two different locations; once at the downstream end of the pool in the same location which was chosen for the dentated sills, and again at the upper end of the pool only very slightly downstream at the foot of the slope. In the first position the action was very similar to that of the dentated sill. Placed close to the slope, the diffuser sill caused very great commotion and a secondary hydraulic jump, together with considerable scour.

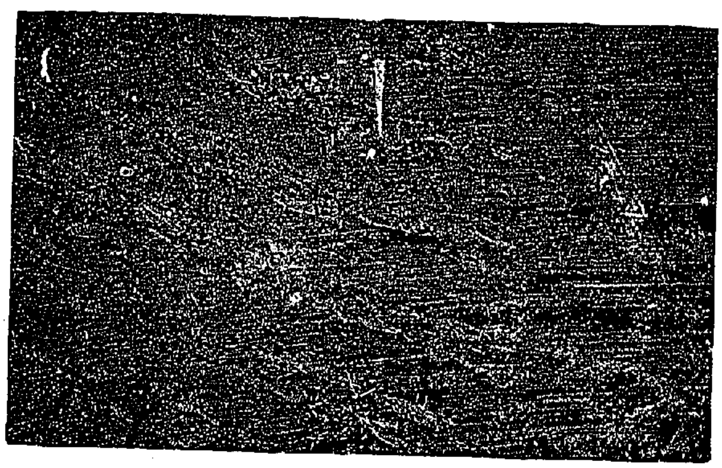
After trying the dentated sill in various positions, it was decided to locate it 113 feet downstream from the beginning of the horizontal pool floor. With the sill at this position, the hydraulic jump formed well, and scour was not at all excessive. Test 46 (plate V and figs. 10 and 11) illustrates the excessive erosion which may be expected with a stilling pool having no sill or apron, and test 40 (plate VI and figs. 8 and 9) shows the results obtained with the same pool plus a dentated sill.



A. BED BEFORE RUN.

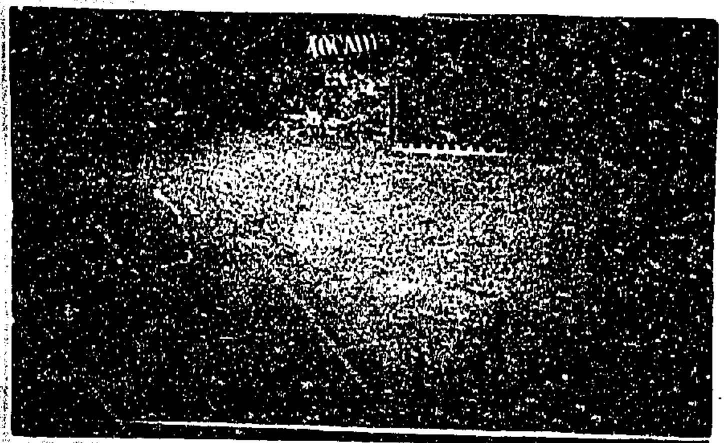


B. DISCHARGE 55,000 SECOND-FEET.

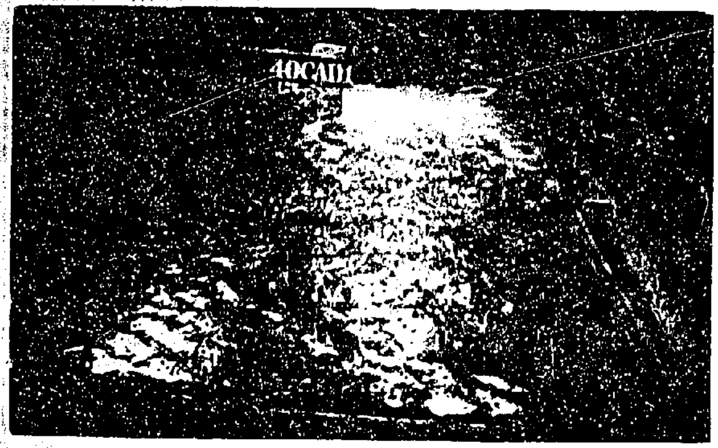


C. BED AFTER ONE HOUR RUN.

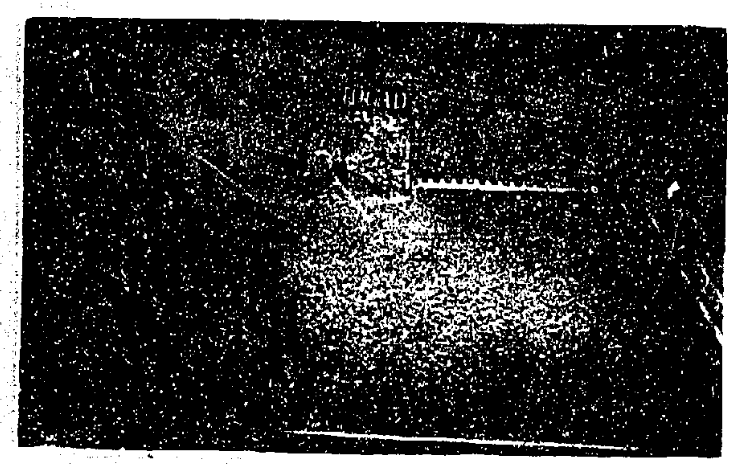
POOL WITH NO SILL.



A. BED BEFORE RUN.



B. DISCHARGE 55,000 SECOND-FEET.



C. BED AFTER ONE HOUR RUN.

POOL WITH DENTATED SILL.

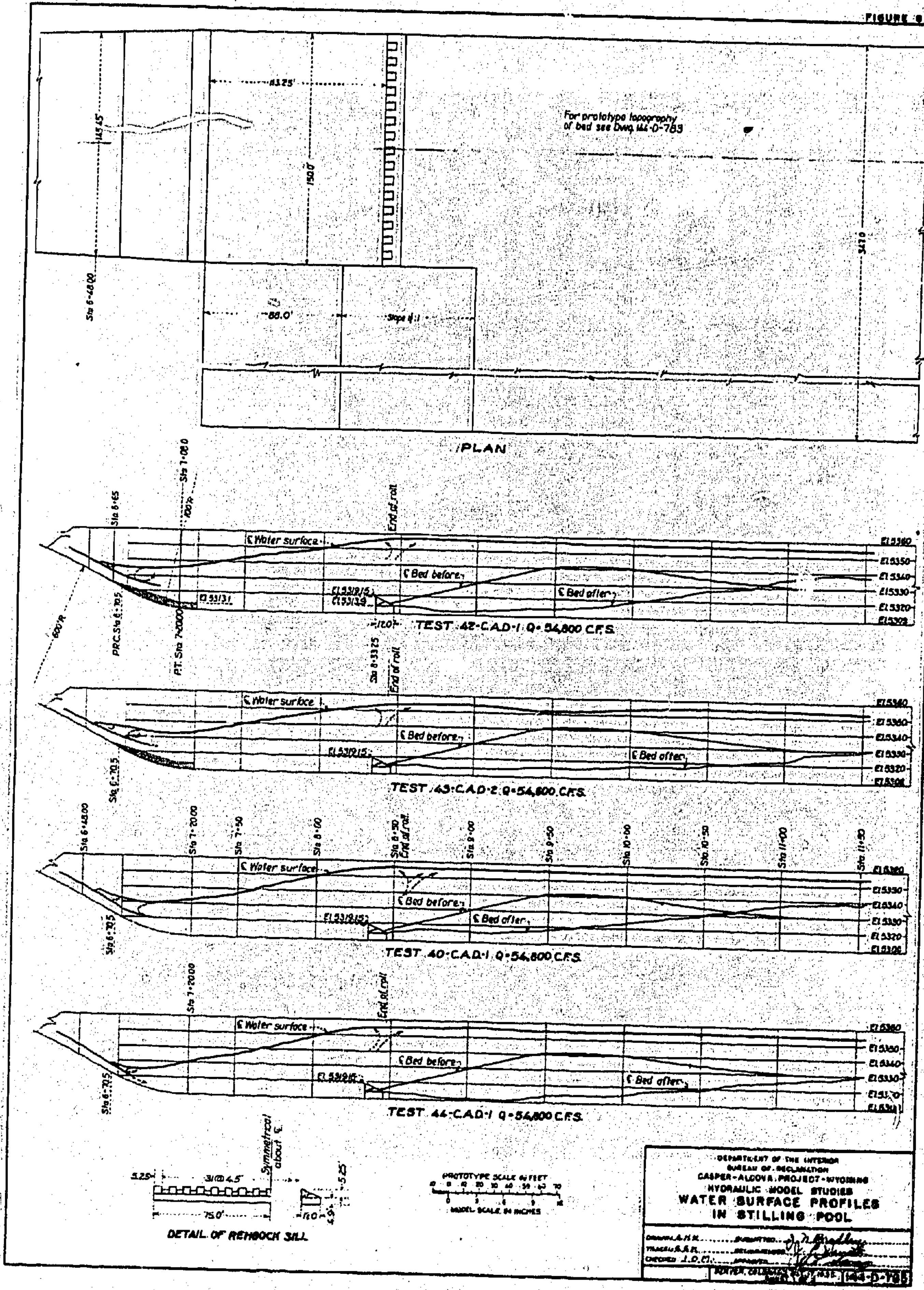
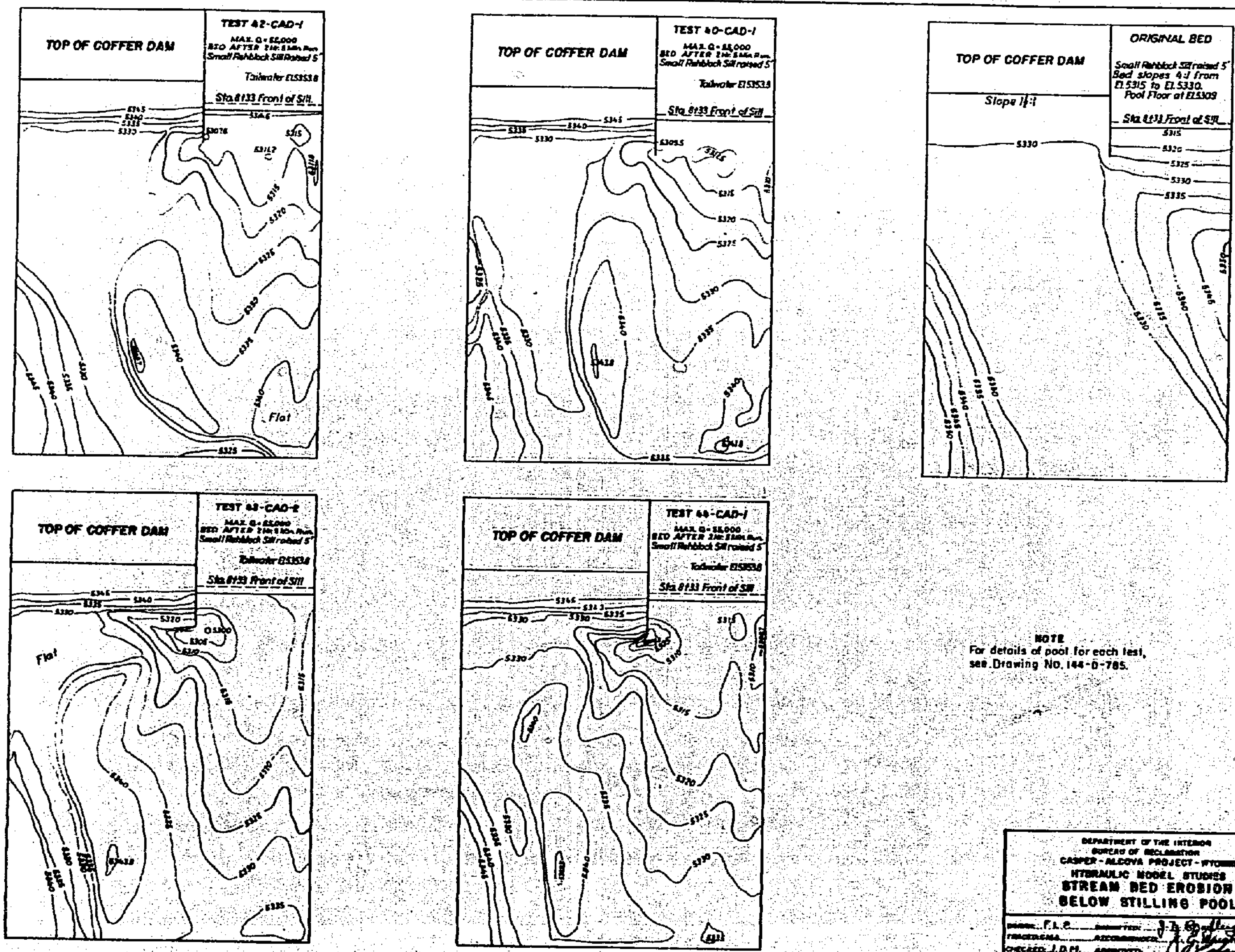


FIGURE 8
For prototype topography of bed see Dwg. 144-D-783
PLAN
C Water surface
C Bed before
C Bed after
End of roll
TEST 42-C.A.D.-1 Q=54,800 C.F.S.
TEST 43-C.A.D.-2 Q=54,800 C.F.S.
TEST 40-C.A.D.-1 Q=54,800 C.F.S.
TEST 44-C.A.D.-1 Q=54,800 C.F.S.
DETAIL OF REHBOCK SILL
Symmetrical about C
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER-ALCOVA PROJECT-WYOMING
HYDRAULIC MODEL STUDIES
WATER SURFACE PROFILES
IN STILLING POOL
144-D-785



NOTE
For details of pool for each test, see Drawing No. 144-D-785.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER - ALCOVA PROJECT - WYOMING
HYDRAULIC MODEL STUDIES
STREAM BED EROSION BELOW STILLING POOL

DRAWN: F.L.P. SUBMITTED: J.E. Bradley
TRACED: RECOMMENDED:
CHECKED: J.D.H. APPROVED:
DENVER, COLORADO
144-D-783

FIGURE 9

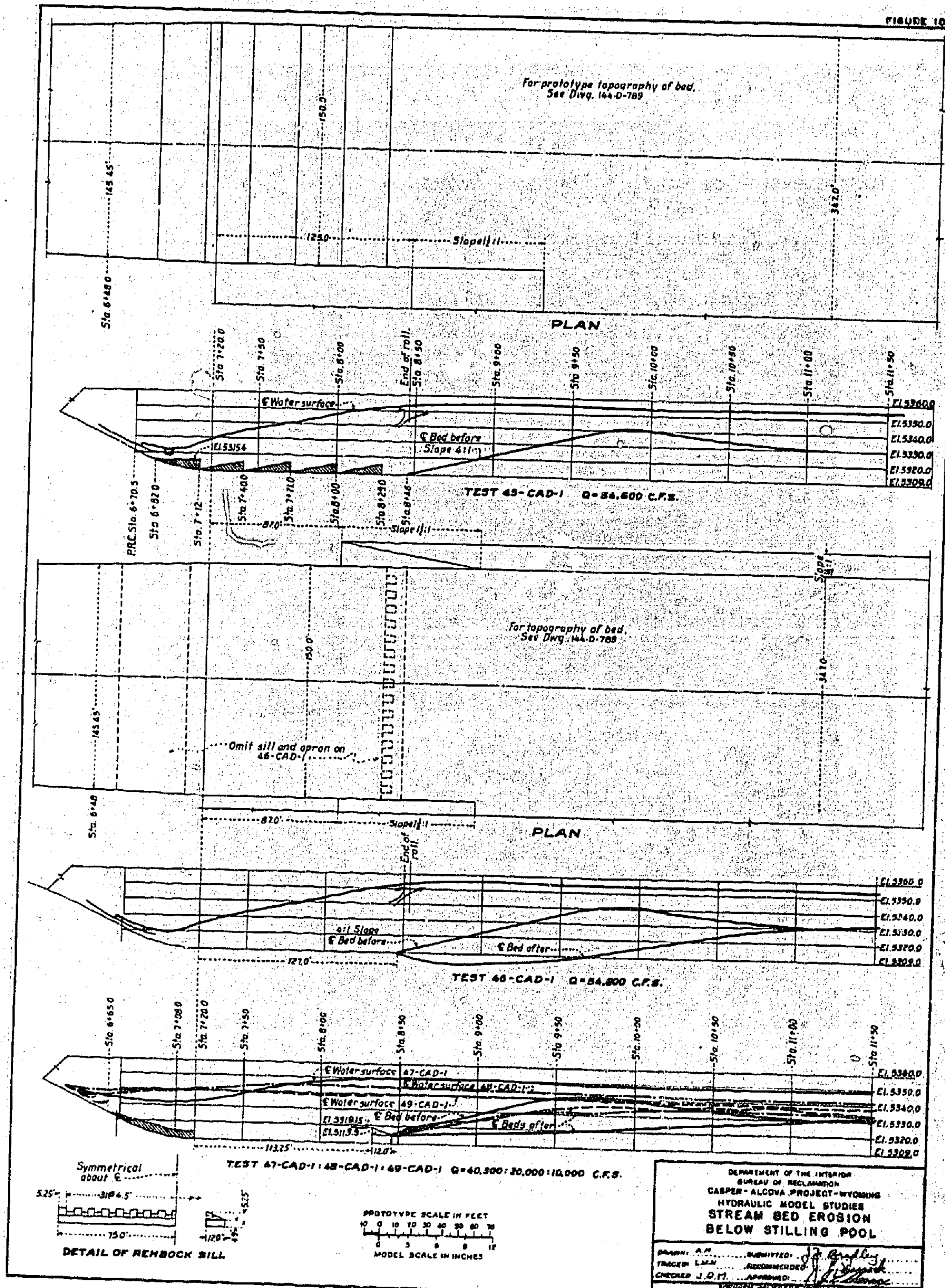
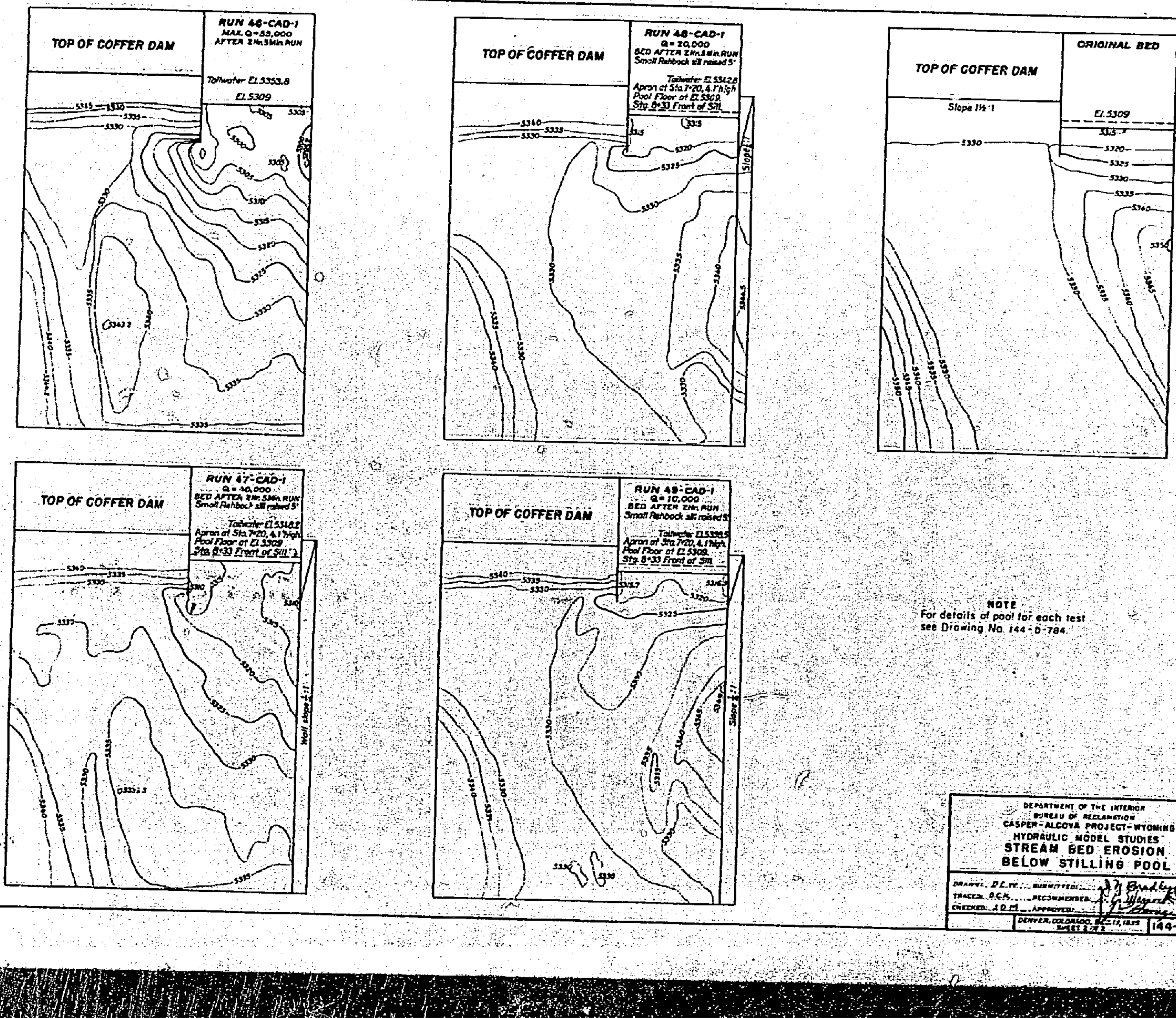


FIGURE 10
For prototype topography of bed, See Dwg. 144-D-789
PLAN
TEST 45-CAD-1 Q=54,600 C.F.S.
For topography of bed, See Dwg. 144-D-789
Omit sill and apron on 46-CAD-1
PLAN
TEST 46-CAD-1 Q=54,600 C.F.S.
TEST 47-CAD-1 : 48-CAD-1 : 49-CAD-1 Q=40,300 : 30,000 : 10,000 C.F.S.
Symmetrical about ℄
DETAIL OF REHBOCK SILL
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER - ALCOVA PROJECT - WYOMING
HYDRAULIC MODEL STUDIES
STREAM BED EROSION
BELOW STILLING POOL
144-D-784



NOTE
For details of pool for each test see Drawing No. 144-D-784.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER-ALCOVA PROJECT-WYOMING
HYDRAULIC MODEL STUDIES
STREAM BED EROSION BELOW STILLING POOL

DRAWN: D.L.M. SUBMITTED:
TRACED: O.C.H. RECOMMENDED:
CHECKED: J.D.M. APPROVED:
DENVER, COLORADO, DEC. 12, 1935 SHEET 2 OF 2 144-D-789

FIGURE 11

Stepped Apron

Runs were made both with and without stepped aprons, or "step-offs" at the beginning of the pool. Various heights of stepped apron were investigated. It was noticed that a high apron produced a less foamy jump than a low apron. A low apron, on the other hand, seemed to induce a better looking jump than a smooth pool (no apron). There was little difference in the scour produced, either with or without an apron. A low apron, 4 feet high, was incorporated in the final design.

Tests 41 and 42 (plate VIII) compare the results obtained with high and low aprons, and tests 40 and 42 (figs. 8 and 9) show similar pools with and without an apron.

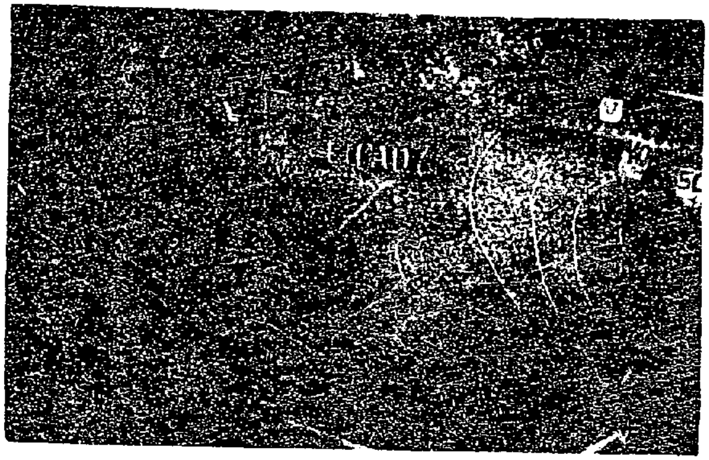
Effect of Sand Size on Scour in the Model

Scour tests in the model were made with coarse sand at first. The question arose whether or not the use of finer sand in the model would show a different scour pattern, and so the coarse sand was replaced with building sand. Further tests showed that, although the absolute scour was not exactly the same, with the fine material, the pattern was very similar. Inasmuch as it is not safe, as yet, to predict the amount of scour to be expected in a prototype from model tests but only the general location or pattern of scour, either the coarse or the fine sand gave a proper indication. Psychologically, perhaps, the fine sand is to be preferred, for it makes the absolute scour slightly greater, and accentuates the need for proper precaution.

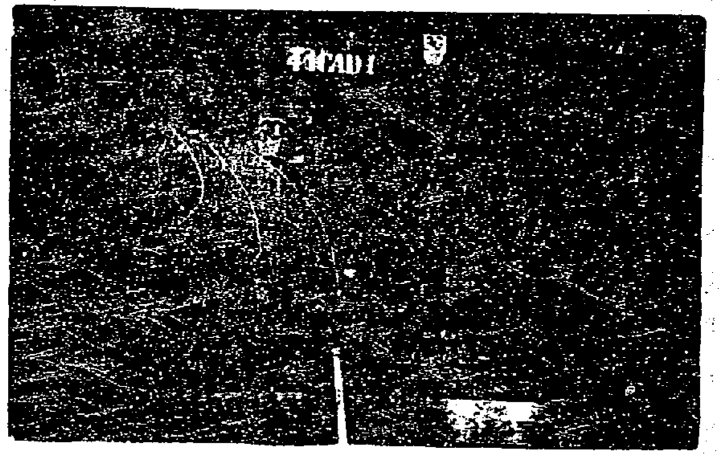
Test 43 (plate VIII and figs. 8 and 9) shows the scour obtained with fine sand in contrast to that given by coarse sand shown in test 42 (plate VII and figs. 8 and 9).

Saw-tooth Pool Floor

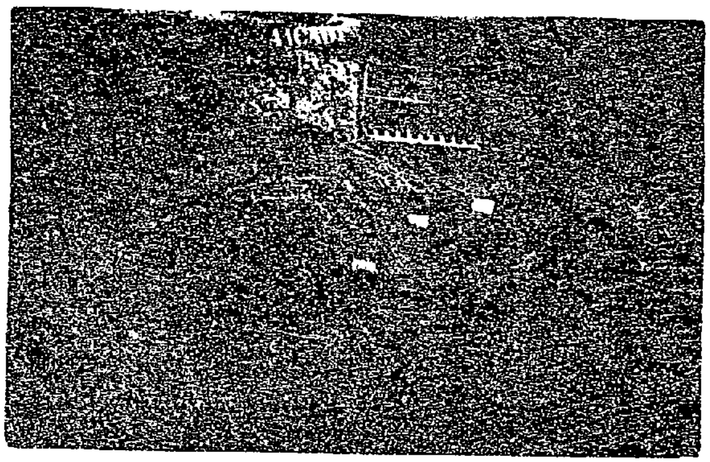
One test was made with a pool having a floor similar to a saw-tooth roof, with the sloping faces upstream and the steep vertical drops on the downstream side. It was suggested that the roller which would form in each of the pockets would contribute to the energy dissipation and would greatly reduce the bottom velocity which produces the harmful scouring. The resultant scour was about the same as that given by the conventional pool, and the jump action looked much poorer. Plate IX and test 45 (fig. 10) illustrate this pool and its behavior.



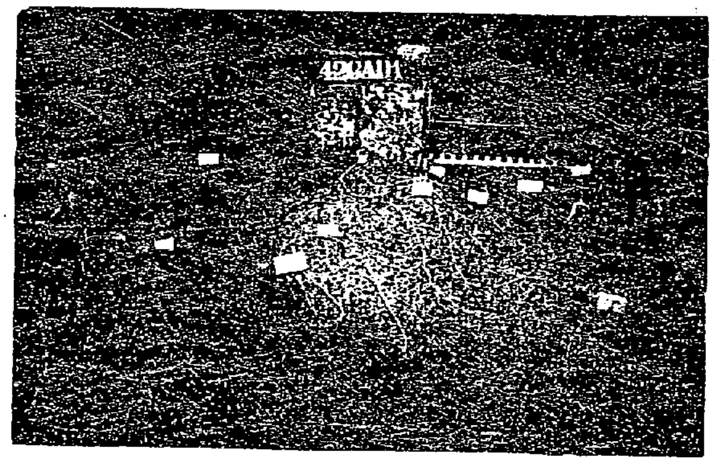
A. BED BEFORE RUN, LOOKING UPSTREAM.



B. BED BEFORE RUN, LOOKING DOWNSTREAM.



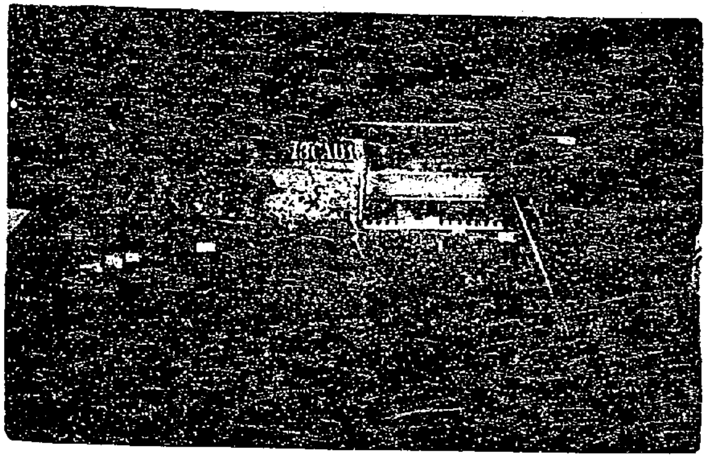
C. BED AFTER RUN, STEPPED APRON
7.9 FEET HIGH.



D. BED AFTER RUN, STEPPED APRON
4.3 FEET HIGH.

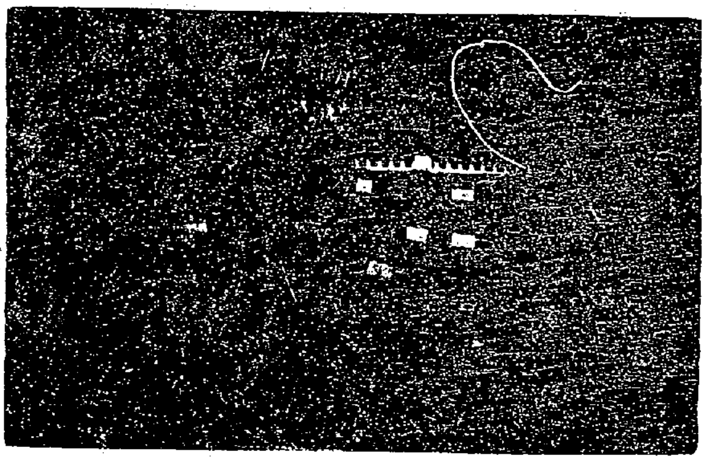
POOL WITH SILL AND STEPPED APRON.

PLATE VIII

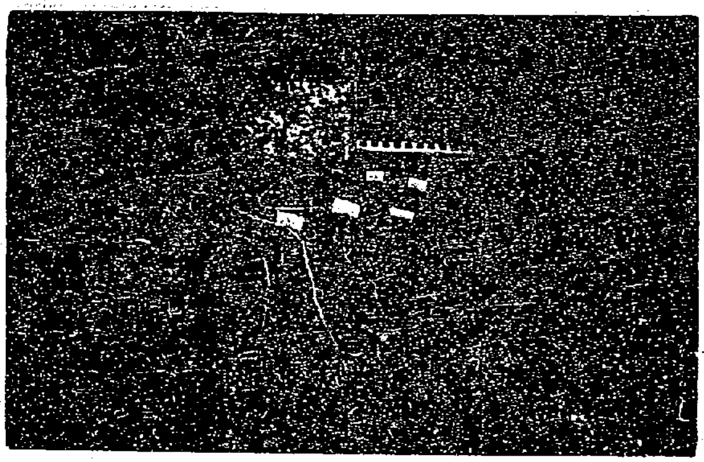


A. BED BEFORE RUN

B. DISCHARGE 55,000 SECOND-FEET.



C. BED AFTER ONE HOUR RUN.



D. BED AFTER ONE HOUR RUN, SAND HAD HAD COARSE GRAINS SIEVED OUT.

SCOUR WITH SAND IN TAILWAY (COMPARE PLATE VII, C).

A. BED BEFORE RUN.

B. DISCHARGE 55,000 SECOND-FEET.

C. BED AFTER ONE HOUR RUN.

POOL WITH SAW-TOOTH FLOOR.

Pressure Measurements on Step and Pool Floor

Piezometers were installed on the vertical face of the stepped apron, and along the pool floor, as shown in figure 12, and observation made of the pressure, with four different discharges. The results are also shown in figure 12. The plots indicate mean pressures. There was considerable fluctuation in the piezometer tubes 6, 7, 8, and 9; some fluctuation in tubes 5, 10, 11, 12, and 13; and little fluctuation in the downstream tubes 1, 2, 3, and 4. Because of the small size of the model, the large amount of air in the water of the jump, and the complication of rapidly fluctuating pressures, too much significance should not be attached to the numerical value of the pressures obtained in these runs.

H. FINAL DESIGN

The final design of stilling pool as evolved from the model tests was substantially that shown in figure 6. It included a stepped apron 4.3 feet high, a Rehbock-type dentated sill 5 feet high placed upon a rectangular sill 5 feet high and at a distance of 113 feet downstream from the step of the apron. The top of the pool wall on the right was at elevation 5367, and extended downstream to sta. 8+07, and then dropped off at 1-1/2:1 to meet the riprap downstream of the sill. The pool wall on the left matched that on the right, and dropped back to a 1/4:1 side-slope excavated in the hillside.

Tests 42, 43, 47, 48, and 49 (plates VII, VIII, X, XI, and XII), and figures 8, 9, 10, and 11 show the design and hydraulic action of the final design of pool.

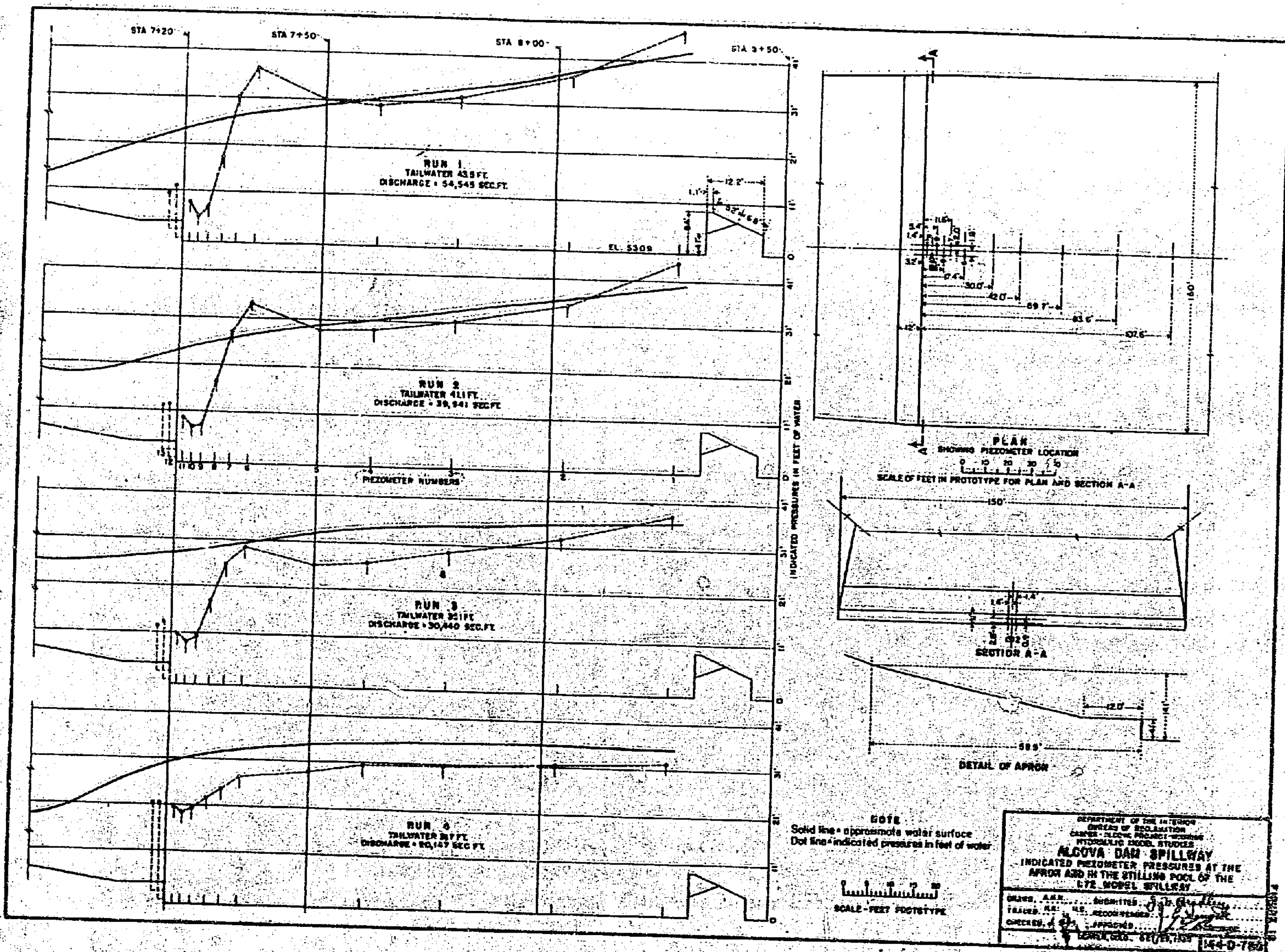
I. NARROW POOL

After extensive studies had been made on the pool with a width of 150 feet, a narrower pool of only 95 feet in width was tried. This required a much deeper pool for the same tailwater elevation and was not economical.

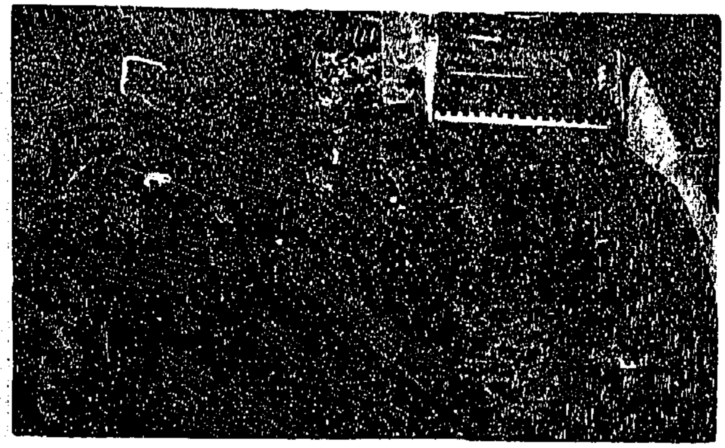
J. FLOW THROUGH THE GATES

A series of tests was made to determine the coefficient in the formula $Q = CLH^{3/2}$ for the discharge through the gates, where Q is the discharge in cubic feet per second, C is a coefficient, L is the total net length of gate opening, and H is the height of the energy line $(d + \frac{V^2}{2g})$ above the gate sill, measured in the channel just upstream from the gates. Measurements on the Alcova gave a result, $Q = 2.85LH^{3/2}$ (fig. 13).

FIGURE 19



STA 7+20
STA 7+50
STA 8+00
STA 8+50
RUN 1
TAILWATER 43.9 FT.
DISCHARGE = 54,545 SEC.FT.
EL. 5309
RUN 2
TAILWATER 41.1 FT.
DISCHARGE = 39,941 SEC.FT.
PIEZOMETER NUMBERS
RUN 3
TAILWATER 35.1 FT.
DISCHARGE = 30,440 SEC.FT.
RUN 4
TAILWATER 29 FT.
DISCHARGE = 20,147 SEC.FT.
INDICATED PRESSURES IN FEET OF WATER
PLAN
SHOWING PIEZOMETER LOCATION
SCALE OF FEET IN PROTOTYPE FOR PLAN AND SECTION A-A
SECTION A-A
DETAIL OF APRON
NOTE
Solid line = approximate water surface
Dot line = indicated pressures in feet of water
SCALE - FEET PROTOTYPE
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ALCOVA DAM SPILLWAY
INDICATED PIEZOMETER PRESSURES AT THE APRON AND IN THE STILLING POOL OF THE 1:72 MODEL SPILLWAY
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

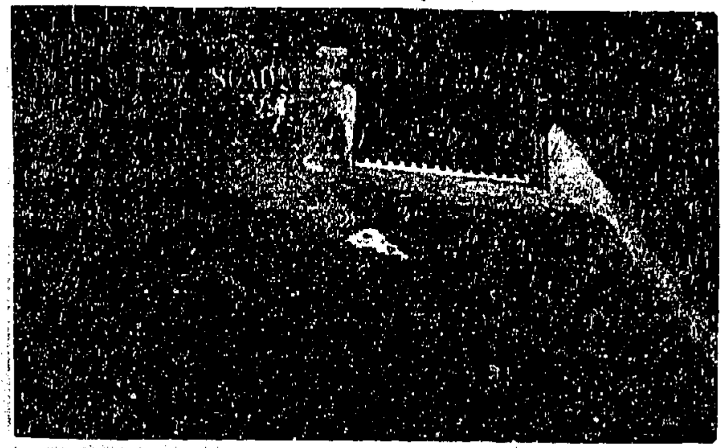


A. BED BEFORE RUN.

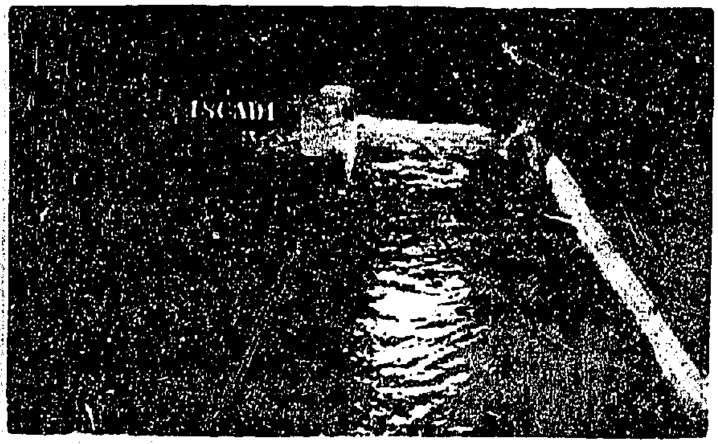
B. DISCHARGE 40,000 SECOND-FEET.

C. BED AFTER ONE HOUR RUN.

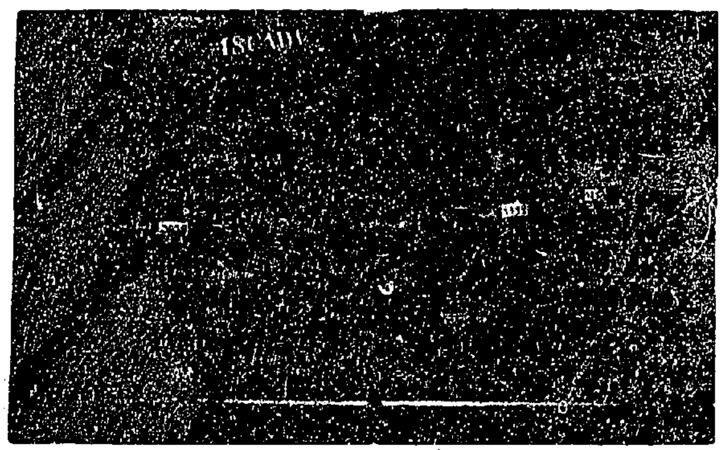
FINAL DESIGN.



A. BED BEFORE RUN.

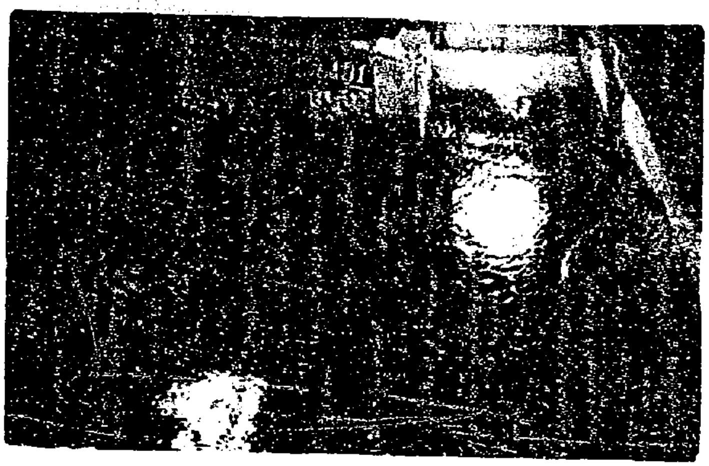


B. DISCHARGE 20,000 SECOND-FEET.

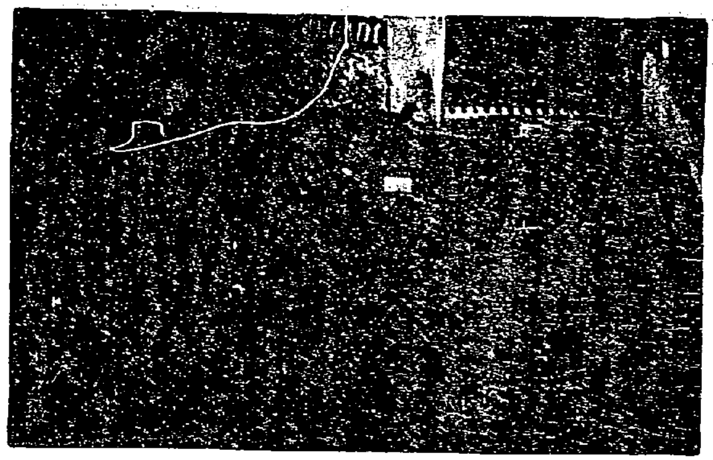


C. BED AFTER RUN.

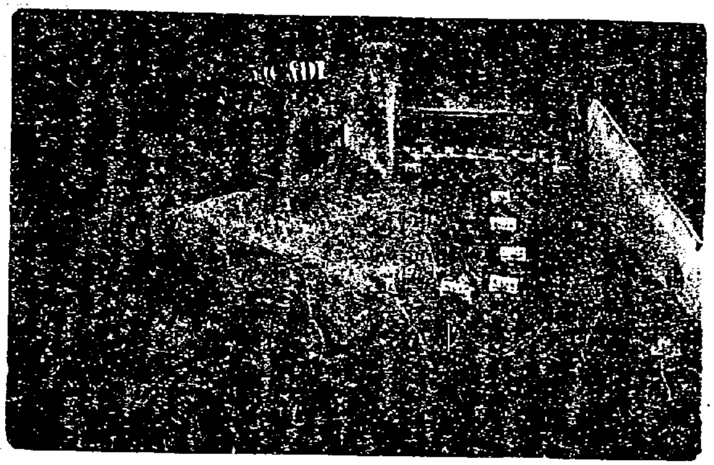
FINAL DESIGN.



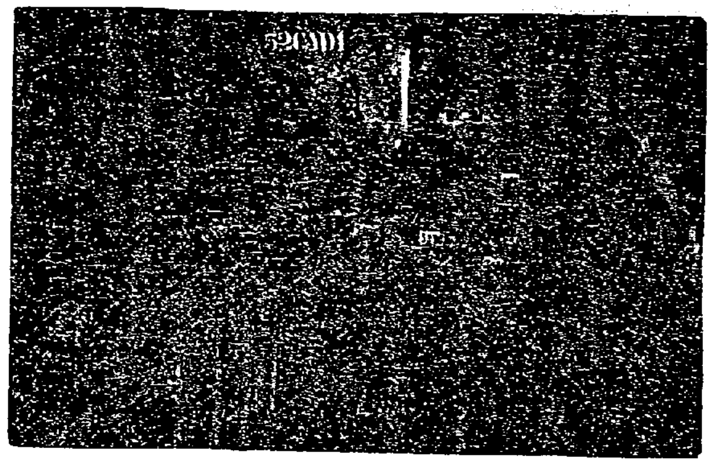
A. DISCHARGE 10,000 SECOND-FEET.



B. BED AFTER ONE HOUR RUN.

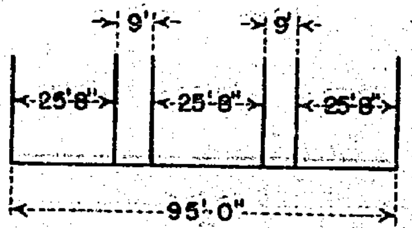


C. BED AFTER ONE HOUR RUN AT 55,000 SECOND-FEET; SILL WITH END BLOCKS.



D. BED AFTER ONE HOUR RUN AT 55,000 SECOND-FEET; SILL WITHOUT END BLOCKS.

FINAL DESIGN - EFFECT OF END BLOCKS ON SILL.



$Q = 2.85\ L\ H^{1.5}$

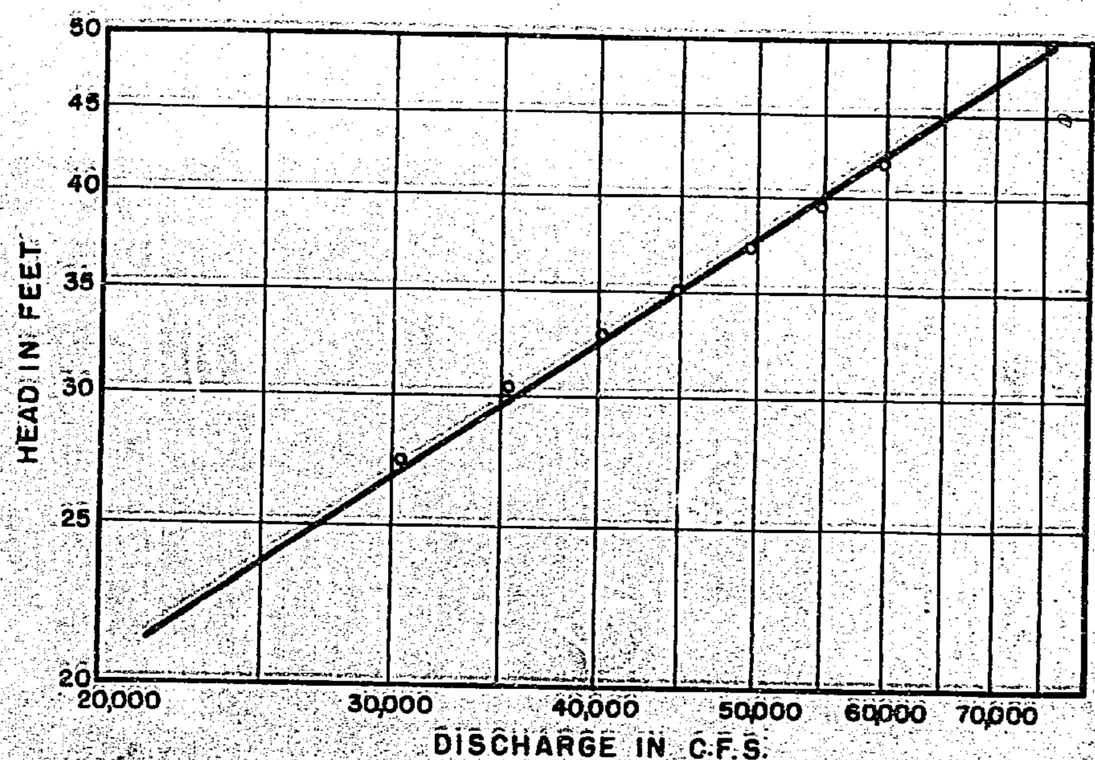
Q = Discharge in c.f.s.

L = Net length of openings = 77 feet

H = Depth of reservoir above gate sill.

W = Total width at pier section = 95'-0"

$\frac{L}{W}$ = Percentage opening = 0.810



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CASPER ALCOVA PROJECT — WYOMING
HYDRAULIC MODEL STUDIES

CASPER ALCOVA SPILLWAY

HEAD-DISCHARGE RELATION THROUGH GATES

DRAWN ... V.L.S. ... SUBMITTED ...
TRACED D.S.Y.-J.P.H. RECOMMENDED ...
CHECKED ... J.D.M. APPROVED ...

DENVER, COLO. OCT 18, 1934 | 144-D-791

FIGURE 13

Bracing of Gate Section

Tests were made on a modified design of the gate structure, in which bracing, stiffening, counterforting for the side walls was located inside the channel rather than outside. This expedient would save a great deal of excavation and expense. The tests showed that the inside bracing, as proposed, did not affect the flow through the gates or raise the pond level at any discharge.

A P P E N D I X

LOG OF TESTS - CASPER-ALCOVA SPILLWAY

Test & Run No.	Discharge Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
Tests 1 to 13 were made with a stilling pool 200 feet wide						
1-CAD-1	54,800	none	10.5' Rehbock at Sta. 8+21-1/4		Original design	Pool looks good.
1-CAD-2	54,800	"	"		" "	Lower tailwater than 1-CAD-1.
2-CAD-1	4,750		"		" "	Pool looks good; flow smooth; whirl in left half of pool.
3-CAD-1	54,800	"	None		Bare pool, no sill	Not as good as with sill.
4-CAD-1	24,800	"	"		Original design	Whirl in pool, on both sides.
5-CAD-1	55,000	"	10.5' Rehbock at Sta. 8+40	Extends to Sta. 9+30, vertical end	Tailway widened to simulate prototype river bed	Eddy at downstream end of right-hand wall of stilling pool. Flow otherwise satisfactory.
6-CAD-1	55,000	"	"	"	Curved metal wall downstream from pool, on left to simulate the hillside	Flow similar to test 5.
7-CAD-1	55,000	"	"	"	Same as 6-CAD-1; except curve of metal wall was altered	Flow better than test 6.
8-CAD-1	55,000	"	"	Extends to Sta. 8+65	Similar to 5-CAD-1 except for shortening of right wall	Flow similar to test 5.
9-CAD-1	55,000	"	"	Stops at 7+20; Low wall 10.5' high from 7+20 to 8+65	Right wall entirely removed except for low rim 10.5' high	Large eddy forms in river bed, and water flows into pool from right. Very bad.

1 Stationing given is upstream edge of sill

Test & Run No.	Discharge Sec.ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
10-CAD-1	55,000	None	10.5' Rehbock at Sta. 8+40	Extends to 7+80 full height; 10.5' high to 8+65	Right wall added	Better than test 9, but right wall still too short.
11-CAD-1	55,000	"	"	"	Curved left wall added as in test 6	Similar to test 10.
12-CAD-1	55,000	"	"	Extends to 8+28 full height; 10.5' high to 8+65	Right wall lengthened curved left wall retained	Flow better than test 10; no water flowing into side of stilling pool.
13-CAD-1	55,000	"	"	"	Curved left wall removed	Flow good; small eddy at end of right wall.
Tests 14 to 54 and 56 to 62 were made with a stilling pool 150' wide						
14-CAD-1	55,000	None	5.25' Rehbock at Sta. 8+35.5	Extends to 8+47.5		
15-CAD-1	55,000	"	"	Extends to 8+47.5 but downstream end cut off at 2:1	Sand placed below pool to represent natural topography and river-bed	Erosion around end of right wall.
16-CAD-1	55,000	"	"	Extends to 7+80 at El. 5377, drops 2:1 to 9+18	Sand removed, below pool, to El. 5330	No scour below sill or at end of right wall; a sand bank formed downstream, to El. 5344.
17-CAD-1	55,000	"	10.1' Rehbock at Sta. 8+22	"	"	Similar to above, less erosion.
18-CAD-1	55,000	8.25' high	None	"	"	Bad scour at end of pool and around right wall.

1 Stationing given is upstream edge of sill.

Test & Run No.	Discharge Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
19-CAD-1	55,250	6.75' high	5.25' Rehbock at Sta. 8+35	Extends to 7+80 at El. 5377, drops 2:1 to 9+18	Sand removed, below pool, to el. 5330	No scour below sill or around right wall; sand bank formed downstream.
20-CAD-1	55,250	5.25' high	"	"	"	Same as test 19.
21-CAD-1	55,000	None	Triangular sill 5.25' high, flat face upstream, at Sta. 8+35	"		Not quite as good a layout as test 16.
22-CAD-1	55,000	"	10.5' triangular sill, flat face upstream, at Sta. 8+32	"		Very similar to test 17.
23-CAD-1	55,000	"	10.5' high, 15.5' wide triangular sill at 8+32, sloping face upstream.	"		Not as good as test 22.
24-CAD-1	55,000	"	5.25' Rehbock on a 4.9' plain sill at Sta. 8+24	"		Practically no erosion.
25-CAD-1	55,000	"	None	"		Excessive erosion, right wall undermined.
26-CAD-1	55,000	"	5.25' Rehbock on an 8' plain sill at Sta. 8+35.5	"		Similar to test 24, water surface in pool rougher.

1 Stationing given is upstream edge of sill.

Test & Run No.	Discharge Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
27-CAD-1	55,000	None	5.25' Rehbock on a 4.9' plain sill at Sta. 8+35.5	Extends to 7+80 at El. 5377, drops 2:1 at 9+18	Curved wall put in topography below pool, on left side, up to existing ground surface	Very little erosion.
28-CAD-1	55,000	"	"	Extends to 7+80 at El. 5379, thence $1\frac{1}{2}$:1 to 8+85	"	Similar to test 27.
29-CAD-1	55,000	"	Same as test 28	Same as test 28	No excavation in tailway of pool, natural hill covered to prevent erosion	About the same as previous runs.
30-CAD-1	55,000	"	"	"	All natural topography formed in sand	Same.
31-CAD-1	55,200	"	Same sill, at Sta. 8+23	"		Similar to test 30.
32-CAD-1	55,300	"	Same sill, at Sta. 8+11	"		Slightly more erosion.
33-CAD-1	55,000	"	Same sill, at Sta. 8+45	Extends to 7+86 at El. 5379, thence $1\frac{1}{2}$:1 to 8+91	New <u>LOWER TAILWATER</u> for this and all subsequent runs	Very little erosion.
34-CAD-1	55,000	"	Same sill, at Sta. 8+31	"		Little erosion.
35-CAD-1	55,200	"	Same sill, at Sta. 8+13	Extends to 7+74 at El. 5379, thence $1\frac{1}{2}$:1 to 8+79		About the same.

1 Stationing given is upstream edge of sill.

Test & Run No.	Discharge Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
36-CAD-1	55,000	7.5' high	Same sill, at Sta. 8+13	Extends to 7+92 at El. 5364.5, thence $1\frac{1}{2}$:1 to 8+75	Both walls cut down to lower elevation (5364.5)	Erosion about the same, water splashes over stilling pool walls.
37-CAD-1	55,000	"	Same sill, at Sta. 8+33	Extends to 8+08 at El. 5365, thence $1\frac{1}{2}$:1 to 8+93		Long (3 hr.) run produced slight holes near walls. Velocities in pool measured.
37-CAD-2	55,000	None	"	"		Check velocities taken
38-CAD-1	55,000	None	As before	Same	Pool has been dropped to give higher velocities.	Velocity measurements made made in pool.
39-CAD-0	55,000	"	"	"	Stilling pool raised slightly.	Velocity measured in pool.
39-CAD-1	55,000	"	"	"		Check run on 39-CAD-0
39-CAD-2	55,000	"	"	"		Check run on 39-CAD-0.
40-CAD-1	54,800	"	"	"	Same as test 37-CAD-2	Erosion slight.
41-CAD-1	54,800	7.9' high	"	"		About the same.
42-CAD-1	54,800	4.1' high	"	"		Erosion less, water quieter than test 41.
43-CAD-1	54,800	"	"	"	Finer sand used, having some coarse particles	Erosion slightly greater, but in same places as before.

1 Stationing given is upstream edge of sill

Test & Run No.	Discharge Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
43-CAD-1	55,000	4.1' high	As before	Same	Finer sand has had coarse particles screened out	Same.
44-CAD-1	55,000	None	"	"		Same.
45-CAD-1	55,000	Floor of pool made up of saw-tooth-like steps, 30' long and 6' high Right wall extended to Sta. 8+45 at El. 5369, thence $1\frac{1}{2}$:1 to Sta. 9+30				Erosion similar to test 43-CAD-2.
46-CAD-1	55,000	None	None	Extends to 8+07 at El. 5369, thence $1\frac{1}{2}$:1 to 8+93	Both pool walls alike; below pool, left wall falls back to [illegible]:1	Scour very bad.
47-CAD-1	40,270	4.1' high	5.25' Rehbock on a 4.9' plain sill at Sta. 8+33	"	Same as 43-CAD-2	Very little erosion.
48-CAD-1	20,020	"	2.25' Rehbock on a 4.9' plain sill at 8+33	Extends to 8+07 at El. 5369, thence $1\frac{1}{2}$:1 to 8+93	Same as 43-CAD-2	Almost no erosion.
49-CAD-1	10,060	"	"	"	"	Negligible erosion. Unequal gate openings caused whirl in pool.
50-CAD-1	55,000	Set-up similar to test 45, but saw-teeth sloped upward				Jump did not stay in pool.
51-CAD-1	55,000	4.1' high	9.5' Rehbock at Sta. 8+23 plus end blocks	"		Slight holes eroded near walls.

[1] Stationing given is upstream edge of sill.

Test & Run No.	Discharge Sec. ft.	Description of Set-up			Remarks
		Stepped Apron	Sill[1]	Right Pool Wall	
52-CAD-1	55,000	4.1' high	Same without end blocks	Extends to 8+07 at El. 5369, thence $1\frac{1}{2}$:1 to 8+93	About the same.
53-CAD-1	55,000	"	4.7' Rehbock on a 4.7' plain sill fine teeth at Sta. 8+33	"	Slight holes near walls.
54-CAD-1	55,000	"	Same, e xcept teeth are wider	"	Similar to test 53, slightly less erosion.
55-CAD-1	34,700		This test made with a pool only 95' wide, erosion excessive, and very high tailwater required.		
55-CAD-2	55,000		Similar to test 55, but worse.		
56-CAD-1	55,000	4.1' high	4.7' Rehbock on a 4.7' plain sill, wide teeth, at Sta. 8+33	Same as test 54	Pressure measurements in stilling pool.
57-CAD-1 to 7	55,000 to 30,280				Measurements of head on gates and discharge.
58-CAD-1 to 4	54,545 to 20,150	Same as test 54 - CAD - 1			Pressure measurements in stilling pool.
59-CAD-1 to 6	60,000 to 12,400				Measurements of head on gates and discharge.

[1] Stationing given is upstream edge of sill.

Test & Run No.	Discharge, Sec. ft.	Stepped Apron	Sill[1]	Right Pool Wall	Description of Set-up	Remarks
60-CAD-1 to 5	55,400 to 10,000					Measurements of profiles down chute.
61-CAD-1	55,000	4.1' high	Diffuser sill 10' high at Sta. 8+36			Similar to results obtained with dentated sill.
62-CAD-1	55,000	"	Diffuser sill 10' high placed immediately below apron			Excessive boil in stilling pool and bad erosion below pool.
SP-CAD-1 to 7						Measurements of flow through gates and profiles, for various set-ups.

1 Stationing given is upstream edge of sill.