UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE SPILLWAY AND OUTLET WORKS FOR CASITAS DAM VENTURA RIVER PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd-404

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

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HYD 404

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Hydraulic Laboratory Branch
Denver, Colorado
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Laboratory Report No. Hyd-404
Written by: W. P. Simmons, Jr.
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Submitted by: H. M. Martin

Subject: Hydraulic model studies of the spillway and outlet works for Casitas Dam--Ventura River Project, California

PURPOSE

Hydraulic model studies were made to insure satisfactory performance of the spillway approach channel, spillway crest, converging and diverging sections of the spillway chute, stilling basin, and outlet works, and to achieve practicable design economies.

CONCLUSIONS

1. A 10,000 cubic yard saving in the rock excavation can be realized for the spillway approach channel by altering the preliminary design to the final design (Figure 7). Even greater savings can be realized while still retaining good approach conditions to the spillway by using the "minimum excavation" design shown on Figures 7 and 9A.

2. An embankment extending into the reservoir at a 45° angle to the spillway center line is required at the right side of the spillway approach to produce acceptable flow conditions (Figure 10). The final

embankment was made large enough to accommodate the outlet works control house and access way (Figures 2 and 10D).

3. The spillway chute can be converged downstream from the crest without causing flow concentrations on the training walls if the crest is curved and the training walls are placed so that if extended they would meet at, or downstream from, the center for the crest curve (Figure 2).

4. The training walls between Stations 3+60 and 4+50 should be raised 2 feet above the preliminary design to provide greater freeboard (Figure 12C). Ample freeboard is provided in the preliminary design for the remainder of the chute.

5. The flow spread evenly in the diverging section at the downstream end of the spillway chute where the 25-foot-wide chute diverged to attain the 46-foot width of the stilling basin (Figures 2 and 12E).

6. The length of the stilling basin must be increased to 105 feet from the initial length of 85 feet to obtain adequate control of the higher discharges and to reduce scour by wave action on the channel banks (Figures 8C and 14B). Also, the basin invert should be lowered 2 feet to elevation 270.0 to assure sufficient tail water depth to allow for river channel degradation.

7. Wing walls at the end of the basin are of no benefit and should not be included in the final design (Figures 13 and 14).

8. There is negligible scour on the river channel bottom, but there is considerable scour on the banks (Figures 13C and 15A, B, and C). Riprap protection must be provided on the banks to maintain the channel section.

9. The releases made through the outlet works pipelines and control valves that enter the upstream right side of the stilling basin will not cause objectionable eddies or disturbances in the stilling basin if directed as shown in Figure 4.

10. Irregular, sluglike flow will enter the stilling basin when small flows pass over the crest. The model showed this critical flow range to be between 200 and 600 cfs. The action is the same as that commonly encountered on long chutes operating with thin sheets of water. Considerable wave action is produced in the stilling basin by the sluglike flow and most of the waves will carry through to the river channel.

ACKNOWLEDGMENT

The design evolved from the model studies represents the cooperative efforts of the Spillways and Outlet Works Section of the Dams Branch and the Hydraulic Laboratory.

INTRODUCTION

Casitas Dam is a part of the Ventura River Project near Los Angeles, California, and is located on Coyote Creek about 2 miles

upstream from the junction with Ventura River (Figure 1). The reservoir will store natural runoff in Coyote Creek and waters diverted from the Ventura River. The stored water will be used downstream for both domestic and irrigation purposes.

The dam is an earthfill structure about 2,000 feet long with a 40-foot-wide crest and a maximum height of 285 feet measured from the creek bed (Figure 2). The spillway and the outlet works are located at the left abutment. The spillway consists of an excavated approach channel, an uncontrolled crest, and a long concrete chute that ends in a jump-type stilling basin. The crest is 50 feet long and is designed to pass discharges up to 7,400 cfs. It is set at elevation 567.00 which corresponds to the normal reservoir water surface. The 105-foot-long by 46-foot-wide stilling basin contains chute blocks at the upstream end and a dentated sill at the downstream end to assist in the energy dissipation (Figure 3). An excavated and riprapped channel conveys the flow from the basin to Coyote Creek.

The outlet works consists of a 51-inch pipeline controlled by a 48-inch hollow-jet valve, and a 14-inch pipeline controlled with a 12-inch butterfly or needle valve (Figure 4). A venturi meter is included in the 14-inch line to measure the rate of flow released. The pipelines enter the upstream right side of the stilling basin and an offset is provided in the training wall to accommodate them. The larger valve is tipped downward on about a 2:1 slope to discharge

parallel to the chute floor and plunge the jet into the pool. The smaller valve is tipped downward about 15°. It is anticipated that nearly all outlet works releases to the river will be made through the 14-inch line. If releases beyond the capacity of the 14-inch line become necessary, the small line will be closed and the 51-inch line opened. Both lines can be operated simultaneously if it should become necessary.

The long spillway chute represented a fairly large percentage of the cost of the project. Special attention was therefore given to reducing the cost as much as practicable. Savings would result if the chute were made narrow. But a 50-foot-long crest was needed to pass the flood flows with the head available, while still maintaining the uncontrolled crest at a high enough elevation to provide ample storage. A workable compromise was reached in which the chute downstream from the 50-foot crest was narrowed to 25 feet and continued at this width through most of its length. To accomplish this convergence without producing undesirable flow concentrations and pileups on the training walls, the Hydraulic Laboratory suggested that the crest be curved so as to direct the flow along essentially radial lines converging toward a common point farther down the spillway (Figure 2). The convergence of the side walls would then be set so that if the walls were extended until they met on the chute center line, this intersection would lie on, or downstream from, the

center used for describing the curve of the spillway crest. These converging walls were connected to the parallel walls of the 25-foot-wide chute with long radius curves. Near the downstream end of the chute the passage diverged to the width of the stilling basin. This divergence was gradual and started at a point on the chute where the slope was moderate. It continued at a constant rate through the second vertical bend where the slope increased, and carried through to the entrance of the 46-foot-wide stilling basin.

The uncertain hydraulic conditions introduced by the convergence and divergence of the spillway chute, and the possibility that important improvements and economies might be made in the spillway approach and in the stilling basin, led to a request for model studies. The model that was constructed and the results that were obtained during this test program are discussed in this report.

THE MODEL

A scale ratio of 1:30 was selected after considering the model size needed to insure good flow conditions, and the space available in the laboratory. This model had a maximum discharge of 1.5 cfs and a length of 62 feet (Figure 5). It was constructed by using an elevated head box that included the approach topography and spillway crest, a separate long chute for the spillway, and a tail box at floor level that included the stilling basin and a portion of the channel to the river. The approach topography in the head box

consisted of the hillside that formed the left abutment of the dam, and the upstream face of the dam (Figure 6A). These were formed by trowelling concrete onto wire lath held to the proper shape by wooden templates. The spillway approach channel was represented as shown in the preliminary design (Figures 6A and 7). The curved spillway crest was made of concrete carefully screeded and trowelled to shape. The training walls, the converging section downstream from the crest, and the remainder of the chute and stilling basin were made of wood in sections convenient for handling. The tail box contained most of the stilling basin so that a study could be made of wing walls at the end of the basin without interference from the box (Figures 6C and 13D). The river channel was formed by placing sand according to topographical contours. In later tests riprap was placed over the sand in the regions near the basin outlet (Figure 15).

Considerable care was taken in constructing the sections of the spillway chute and stilling basin, and in aligning and levelling them as they were assembled on the model. The few slight irregularities that appeared in spite of these precautions were blended out. Then the assembled chute was treated with two coats of a plastic waterproofing material, resanded, and finally painted with an oil base paint to produce a watertight and exceptionally smooth flow passage. These precautions were necessary to keep the friction to as low a value as practicable. But even with these precautions it was

known that the friction would be slightly greater than it should be to represent the prototype conditions. In a short spillway chute this would not be critical, but in a long chute like the one on Casitas the excess friction could slow the flow appreciably. To compensate for this, an extra vertical fall of 0.5 foot was provided by extending the length of the narrow portion of the chute. This extra fall was shown by calculation to be sufficient to produce the proper equivalent velocity at the entrance to the stilling basin. Later tests showed that a velocity equivalent to 96.9 feet per second was obtained in the model. This agreed closely with the 93.0 feet per second calculated for the prototype structure using an "n" value of 0.014. A velocity higher than 93.0 feet per second will occur if the "n" value is less than 0.014.

The originally proposed 54-inch outlet works pipeline and hollow-jet valve were represented by a 2-inch pipe and a 2-inch hollow-jet valve model (Figures 5 and 16). The 14-inch line was represented by a 1/2-inch-diameter flexible hose. On a 1:30 scale the 2-inch model valve was larger than the equivalent 54-inch prototype valve. To compensate for this, the valve was throttled to produce the desired flow when the appropriate head was imposed. The jet action in the pool was much the same as that of a true-sized model and enabled the test program to advance without undue delay or cost. Near the conclusion of the test program the designers reduced the

diameter of the prototype line to 51 inches and the valve to 48 inches. These changes were not made in the model because they would not significantly alter the performance.

Pertinent details, such as the chute blocks and dentated sill in the stilling basin, and riprap in the river channel, were included in the model. Piezometers were placed along the center line of the spillway crest and the second vertical bend so pressures could be measured in these regions (Figures 11A and 12G). A point gage was placed in the head box to measure the reservoir water surface elevation, and in the tail box to measure the tail water elevation. Point gage stations were set up across the chute and along the stilling basin center line to obtain cross sections and profiles of the flow (Figure 12). Water was supplied to the model through the central laboratory supply system which contains calibrated Venturi meters for measuring the rate of flow. A laboratory orifice-venturi meter was used to measure the smaller flows which were below the limit of the 4-inch venturi meter. After passing through the model, the water was returned to the laboratory reservoir for recirculation.

INVESTIGATION

Preliminary Design

The initial operation of the model showed that good approach conditions existed along the left side of the excavated approach channel (Figure 8A). Less satisfactory conditions existed at the right

side because the flow moved along the face of the dam and was unable to smoothly accomplish the turn to the spillway crest (Figure 8A). The flow passed over the crest and into the converging portion of the chute without any large disturbances and with only a slight tendency to rise at the walls (Figure 8B). Continuing down the chute, the flow rapidly accelerated and moved along in a nearly uniform sheet. When the point was reached where the walls of the chute diverged, Station 10+25.00, the flow began to spread and continued to spread through the second vertical bend so that a nearly uniform sheet entered the stilling basin. Adequate performance occurred in the basin for flows up to about 5,000 cfs. At discharges above 5,000 cfs, up to the initially specified maximum of 6,950 cfs, the basin was too short and a poor jump with poor energy dissipation took place (Figure 8C). A large upward boil occurred in the river channel at the basin end and much river bed material circulated in it. With a flow of 6,950 cfs, the jump barely stayed in the basin, and when the tail water was lowered about 1 foot below normal the jump swept from the basin. It was apparent that a longer basin would be required and that the basin invert might have to be lowered.

Excavation in Spillway Approach Channel

The excavation for the spillway approach channel, as shown in the preliminary design, is extensive (Figures 6 and 7). Tests showed that this excavation could be reduced without detrimental effect

on the flow by modifying the channel. The tests were made by partly filling in, in a step by step process, the model approach. This filling was continued until the reservoir elevation began to increase for the maximum rate of flow (Figures 7 and 9A). Even at this point of minimum recommended excavation there were no harmful flow conditions along the left approach wall. The approach shape adopted approximated the above "minimum" approach, but was more easily laid out and provided a slightly more liberal water passage (Figures 7 and 9B). At moderate and high spillway flows an eddy forms along the upstream portion of the left excavated slope, and there may be a tendency for floating debris to accumulate. At small flows the eddy does not form. This final approach shape permits a saving of about 10,000 cubic yards of rock excavation over the preliminary design.

Embankment at Right-hand Spillway Approach

An embankment that extends into the reservoir to the right of the spillway is necessary to control the turbulence that occurs at the right side of the spillway approach (Figure 10). The best angle for the embankment depended to a large extent upon the shape of the excavated left approach slope. If this approach was made abrupt by reducing the excavation, the required outward angle of the right abutment, relative to the spillway center line, increased. A 45° angle was needed for the final channel and good results were obtained with an embankment 50 feet long (Figure 10B). Results obtained with

an embankment 30 feet long were not as good but nevertheless satisfactory (Figure 10C). The final embankment is a compromise that includes the placement found to be satisfactory in the model, and the size needed to provide space for the outlet works control house and access way (Figure 2). Acceptable performance was obtained and this design will be used on the prototype structure (Figure 10D).

Spillway Crest

The curved spillway crest directed the flow along converging lines so that there was little tendency for water to climb the converging training walls. The pressures measured by piezometers in the crest were above atmospheric at all rates of flow and were considered satisfactory (Figures 11A and B). A calibration curve showing the relation of reservoir elevation to discharge is presented in Figure 11C.

Spillway Chute

The water surface in the converging portion of the spillway chute just downstream from the crest was somewhat uneven, but this unevenness smoothed out rapidly as the flow accelerated downstream (Figures 12C, D, and E). It seemed desirable to increase the height of the training walls between Stations 3+60 and 4+50 by 2 feet to obtain greater freeboard. As the flow continued down the chute, the velocity increased rapidly and the depth of the stream decreased so that there will be ample freeboard to take care of prototype air

insufflation. The stream spread uniformly in the diverging section of the chute and the pressures measured along the center line of the second vertical bend were positive (Figures 12E, G, and H). At a flow representing 6,950 second-feet the velocity near the stilling basin entrance, Station 13+04, was equivalent to 96.9 feet per second. This agrees well with the 93.0-foot per second velocity computed for the structure using an "n" value of 0.014. The profile of the hydraulic jump, measured along the basin center line, is shown in Figure 12F.

Stilling Basin

In the preliminary design, wing walls were provided at the outlet of the stilling basin. These walls were not included in the model during most of the test program because the initial tests indicated that they were not necessary. The tests did show, however, that the 85-foot-long basin of the preliminary design was too short to adequately control the higher discharges. The jump barely stayed in the basin and there was a violent upward boil just downstream from the basin that circulated large quantities of riverbed material (Figure 8C). Scour tests showed that there was no tendency for digging in the channel bottom, but that considerable scour occurred along the channel side slopes (Figure 13A). With the basin lengthened to represent 115 feet good control was obtained at the high discharges and very little riverbed material circulated in the flow at the basin

outlet (Figure 14A). The scour was similar to, but less severe than, that formed by the short basin (Figure 13B). A 105-foot-long basin performed nearly as well as the 115-foot one, and only a moderate amount of riverbed material circulated in the flow at the basin outlet (Figure 14B). The scour was similar to that of the 85- and 115-foot basins and of intermediate intensity (Figure 13C). It should be noted that some riverbed material was retained in each of the basins at the end of their respective scour tests (Figures 13A, B, and C). With the 105-foot-long basin the tail water could be lowered about 3-1/2 feet before the jump was swept from the basin. This was not considered an adequate safety factor and it was increased to 5-1/2 feet by lowering the basin floor 2 feet to elevation 270.0. The model basin was not altered to represent this condition, but the tail water was raised the equivalent amount to demonstrate that satisfactory flow conditions would prevail.

When wing walls at right angles to the basin center line were added at the end of the 105-foot basin, the flow conditions inside of, and directly downstream from the basin were similar to those that occurred without the walls (Figure 14C). There were, in addition, waves that travelled outward along the walls to attack the channel side slopes. The scour for about 1 hour's operation at 6,950 second-feet is shown in Figure 13D. The walls did not improve the performance of the basin and they are not recommended.

Additional scour tests were made with the 105-foot-long stilling basin without wing walls and with riprap protection in the channel near the stilling basin (Figure 15A). Two sizes of riprap material were used in the model, 3/8- to 3/4-inch angular gravel, and 1/8- to 3/8-inch angular pea gravel. The sand bed was excavated and the riprap placed in a 2-inch layer to bring the surface to grade. A flow of 6,950 second-feet was imposed for 1 hour and 40 minutes. The scour that resulted in the heavier material was probably less than will occur in the prototype, and the scour that occurred in the lighter material was proably greater (Figures 15B and C). In general, even with the 1/8- to 3/8-inch gravel there was little movement of the riprap material and considerable movement in the sand downstream from the riprap. The light riprap was punctured at the top of the left bank and the underlying sand was brought down upon the lower slope (Figure 15C). It is important that the channel protection be carried sufficiently high to be above any possible waves, and that it be carried far enough downstream to prevent excessive channel widening. It is recommended that the riprap be extended upward to elevation 310 on the side slopes, and downstream to Station 16+00. On the basis of the above scour test results, and on the recommendation for channel protection, it was concluded that the 105-foot basin without wing walls and with chute blocks and a dentated sill is satisfactory.

Outlet Works

The 54-inch hollow-jet valve (changed to 48-inch in final design), when placed as shown in the preliminary design (Figure 4), did not cause undue turbulence in the stilling basin or show a tendency to build up an eddy that would carry riverbed material into the basin (Figures 16A and B). Similarly, when flows passed down the spillway no disturbance was created by the training wall offset which accommodated the outlet valves (Figures 16C, D, and E). The performance was considered satisfactory. It may be expected that the valves will receive considerable splashing whenever the spillway operates.

The 1/2-inch flexible hose used to represent the 14-inch line showed that for best results the service valve should be directed to discharge parallel to the offset section in the training wall that provides room for the outlet valve, and should be turned downward about 15° (Figure 4). It is permissible, however, to turn this valve somewhat further to the left to clear the large valve (Figure 4). Care should be taken to avoid an angle greater than about 30° with the basin center line.

Irregular Flow in Spillway Chute at Low Discharges

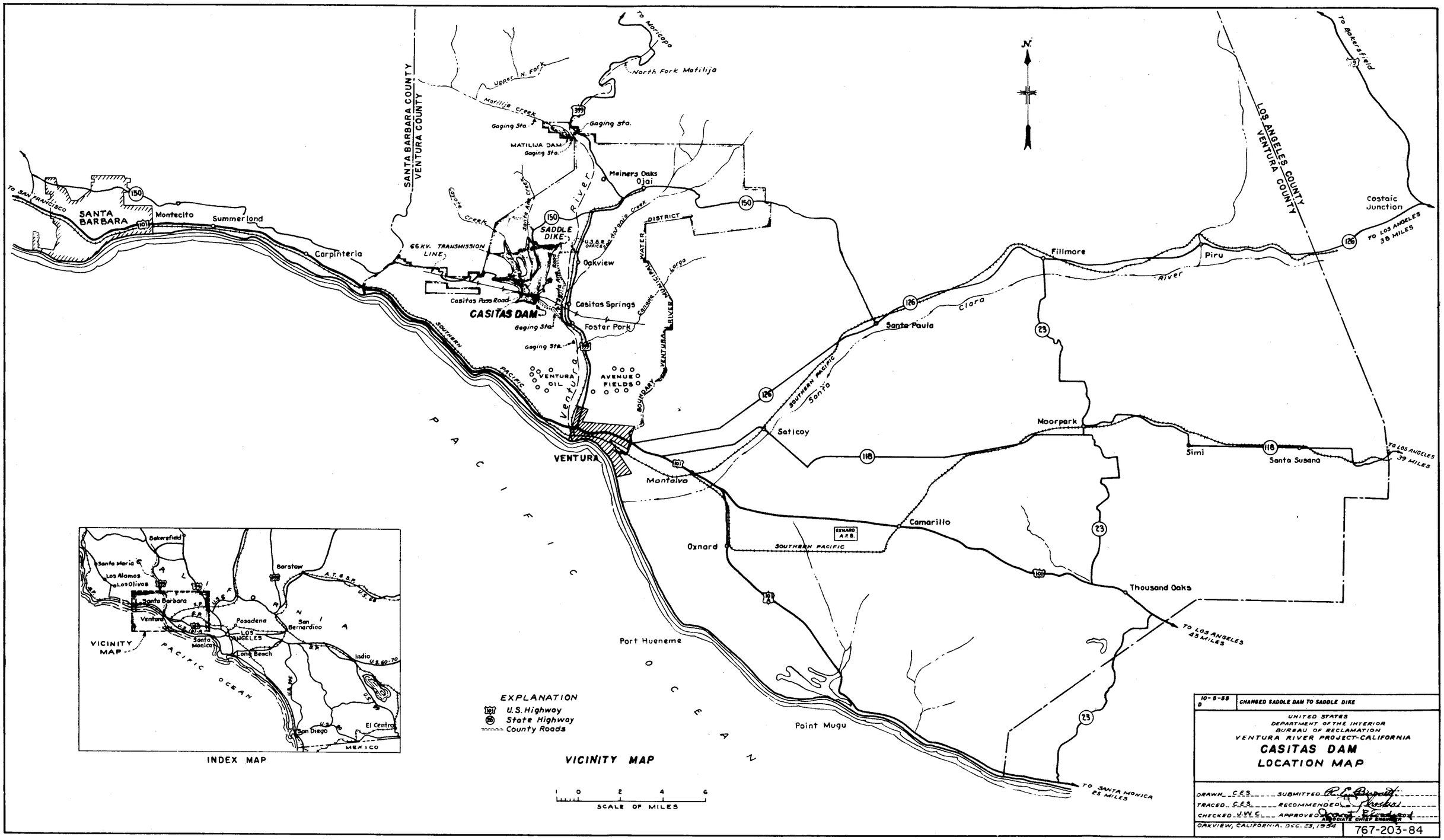
As in many long chutes operating with small flows and depths, uniform rates of flow introduced at the top become nonuniform as the flow approaches the bottom due to a transformation of the initial sheet into waves or "slugs." Very briefly this transformation is as follows:

At the top of the chute small surface irregularities appear and take on the form of wavelets (Figure 17A). As the flow moves down the inclined chute the larger of these wavelets overtake and absorb the smaller ones so that the waves become fewer, but larger and stronger (Figure 17B). This action continues through the remainder of the chute and by the time a given segment of flow reaches the stilling basin the waves are powerful and capable of creating considerable disturbance in the basin (Figure 17C). In the Casitas structure spray may overtop the walls and waves will splash up on the outlet valves and carry through the basin into the river channel. The model indicated that flows between 200 and 600 second-feet would produce this action in a severe enough form to justify attention. At flows lower than 200 second-feet there was insufficient water to cause trouble, and at flows greater than 600 second-feet the flow depth became great enough so the action diminished or ceased completely. A flow equivalent to 300 cfs produced the roughest model action and waves 5 feet in equivalent height were created. In the prototype structure the critical flow range may be different from that indicated by the model because the model action is modified at small discharges when surface tension becomes a predominating factor.

Tests were made using screens, hardware cloth, riffles, and lumps of modeling clay on the chute to see if artificial roughness would reduce or eliminate the formation of these slugs. The tests were not very successful and at present there seems to be no

practicable way to prevent the action except to provide narrower and deeper chutes. This was not desirable on the Casitas chute and consideration should be given to providing light riprap protection on the channel slopes for a considerable distance downstream of the heavy protection. Small spillway discharges are not unlikely on the Casitas structure and may occur for appreciable periods due to the uncontrolled crest.

FIGURE 1
Report Hyd. 404



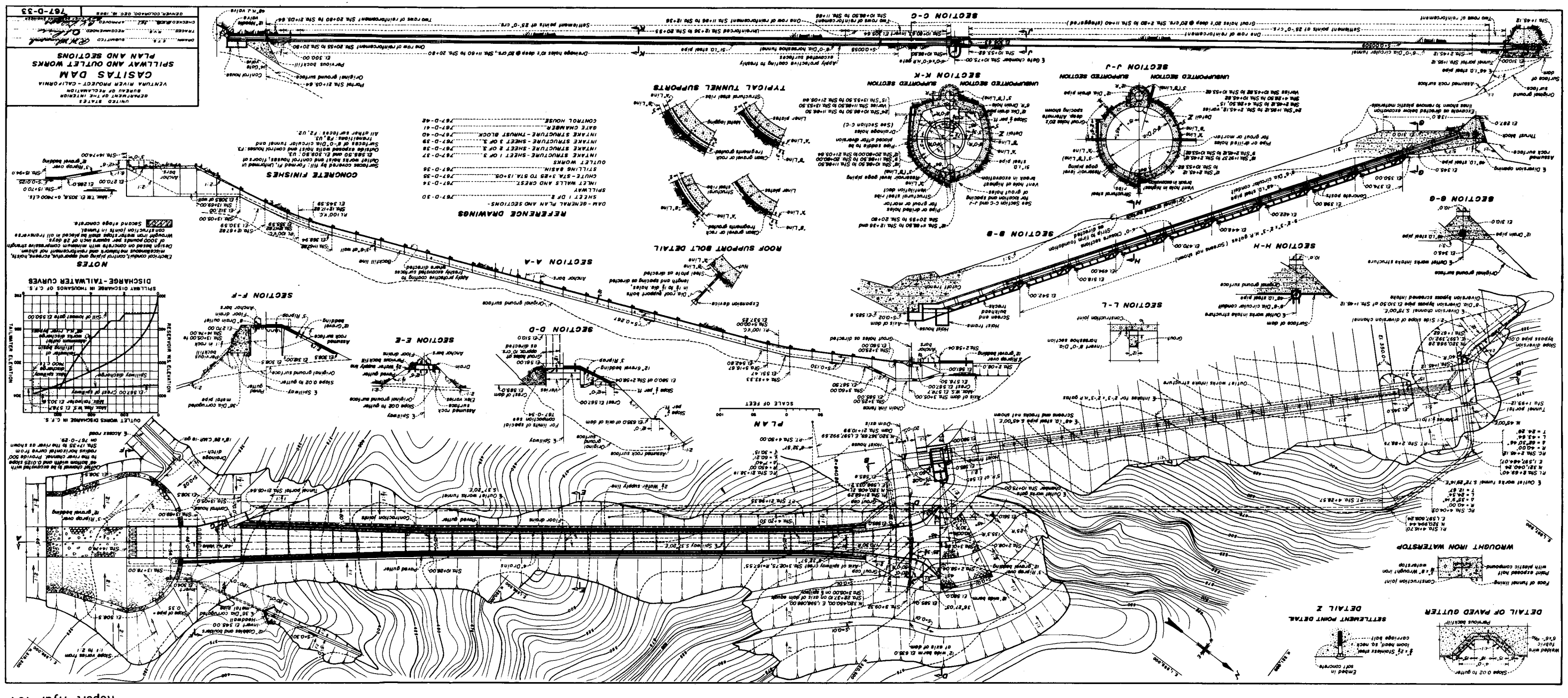
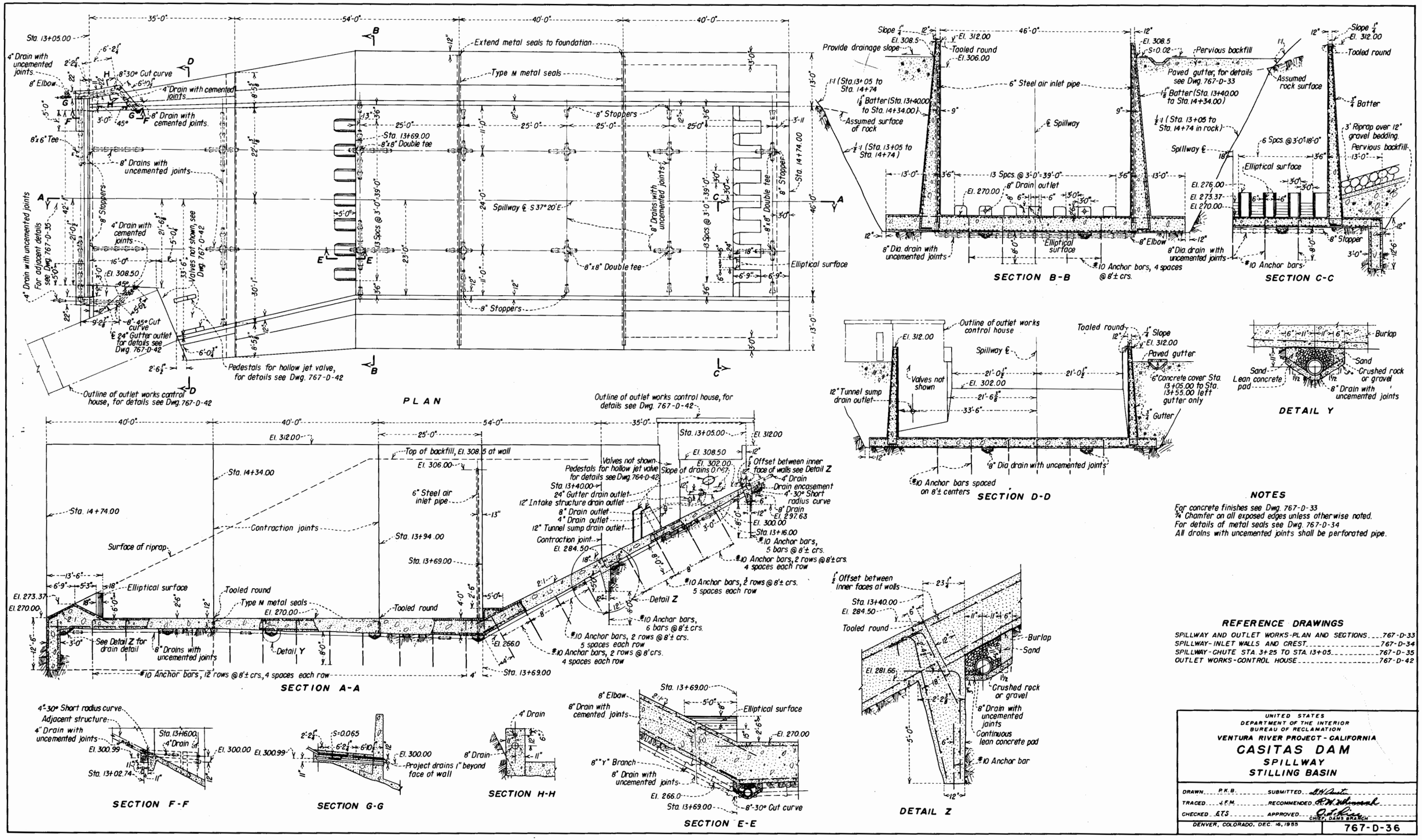


FIGURE 2
Report Hyd. 404

FIGURE 3
Report Hyd. 404



NOTES

For concrete finishes see Dwg. 767-D-33
¾" Chamfer on all exposed edges unless otherwise noted.
For details of metal seals see Dwg. 767-D-34
All drains with uncemented joints shall be perforated pipe.

REFERENCE DRAWINGS

SPILLWAY AND OUTLET WORKS-PLAN AND SECTIONS	767-D-33
SPILLWAY-INLET WALLS AND CREST	767-D-34
SPILLWAY-CHUTE STA. 3+25 TO STA. 13+05	767-D-35
OUTLET WORKS-CONTROL HOUSE	767-D-42

UNITED STATES
DEPARTMENT OF THE INTERIOR
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VENTURA RIVER PROJECT - CALIFORNIA

CASITAS DAM
SPILLWAY
STILLING BASIN

DRAWN P.K.B. SUBMITTED
TRACED J.F.M. RECOMMENDED
CHECKED E.T.S. APPROVED CHIEF, DAMS BRANCH

DENVER, COLORADO, DEC. 16, 1955 — 767-D-36

FIGURE 4
Report Hyd. 404

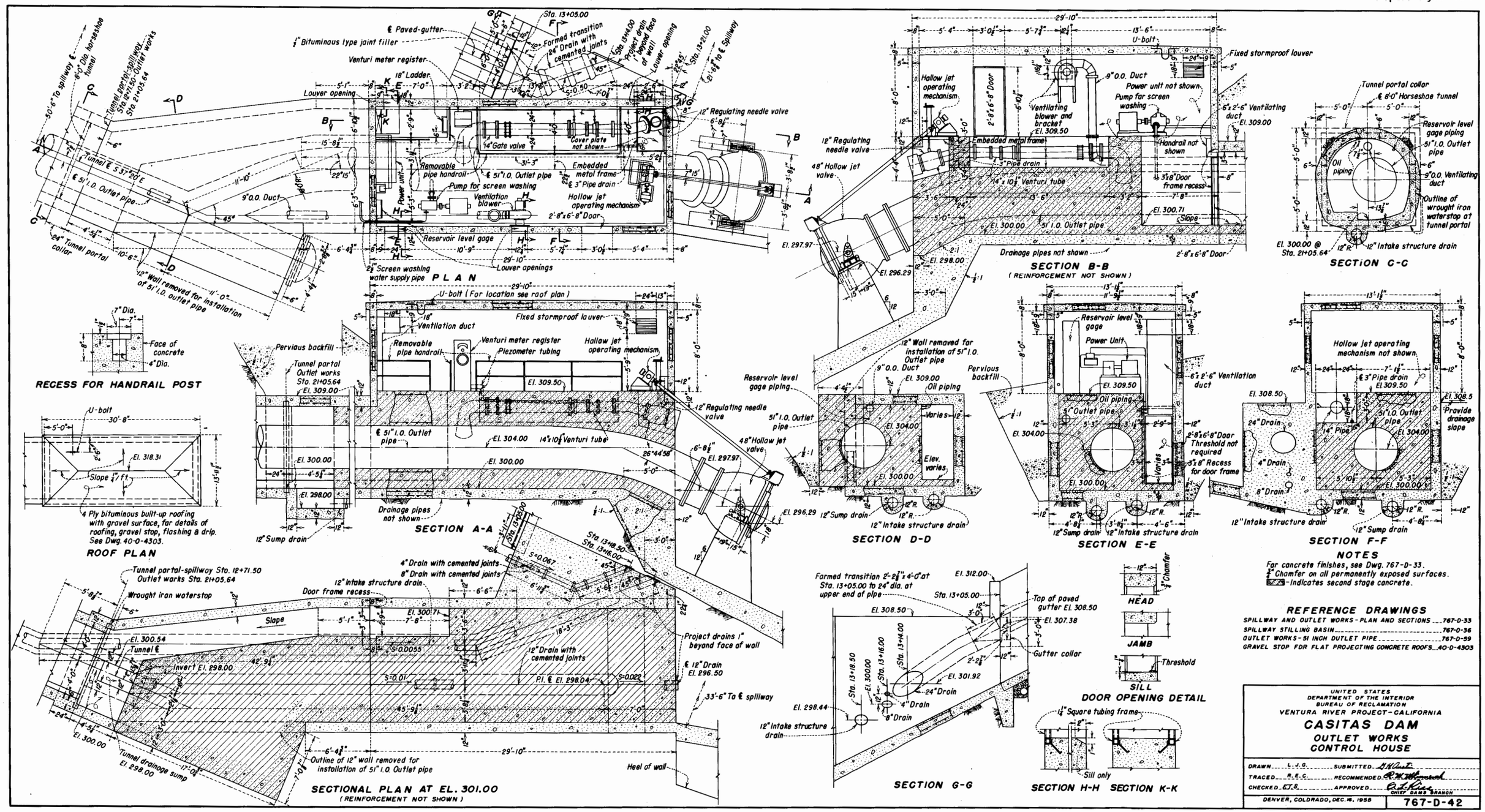
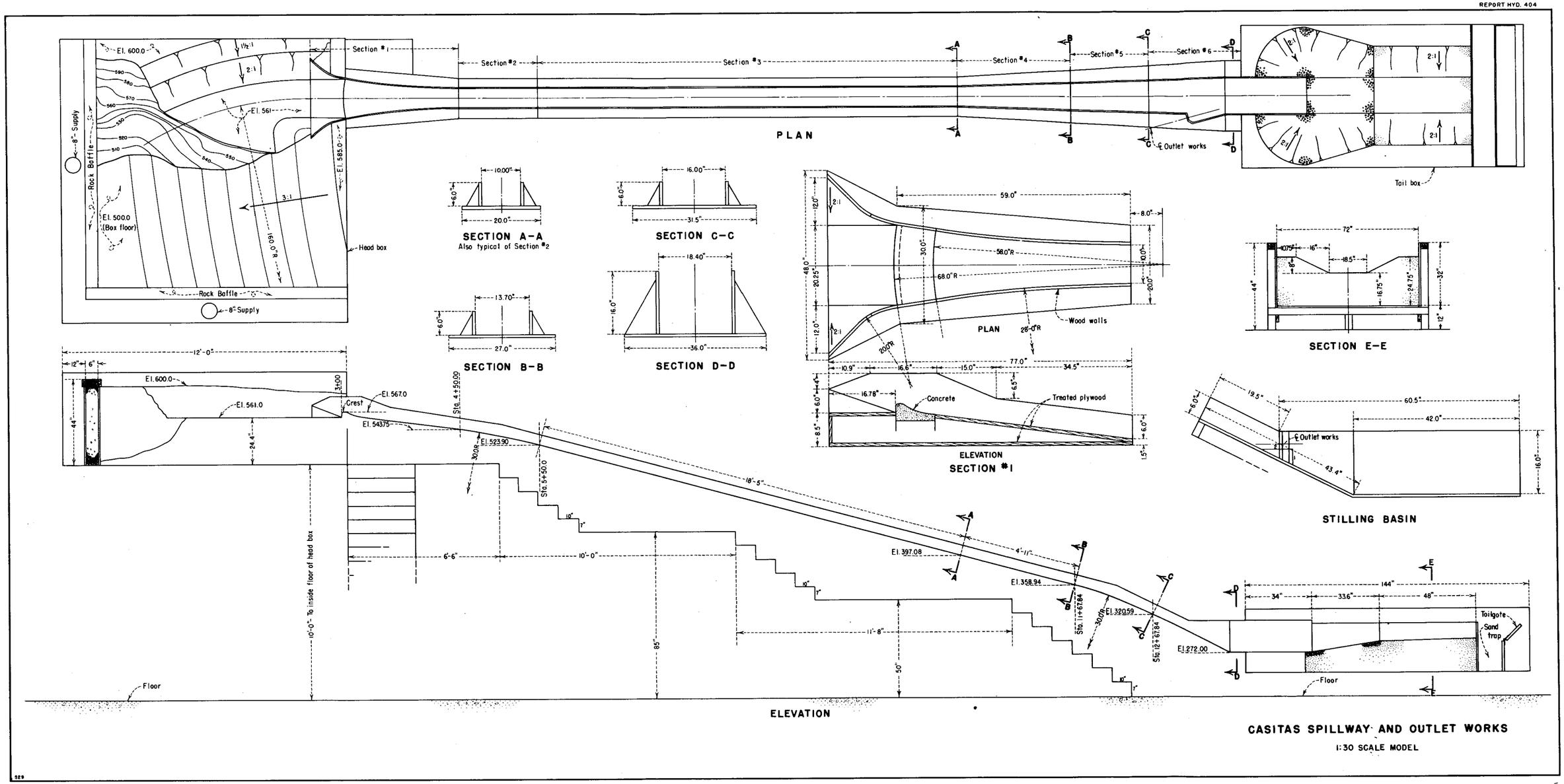


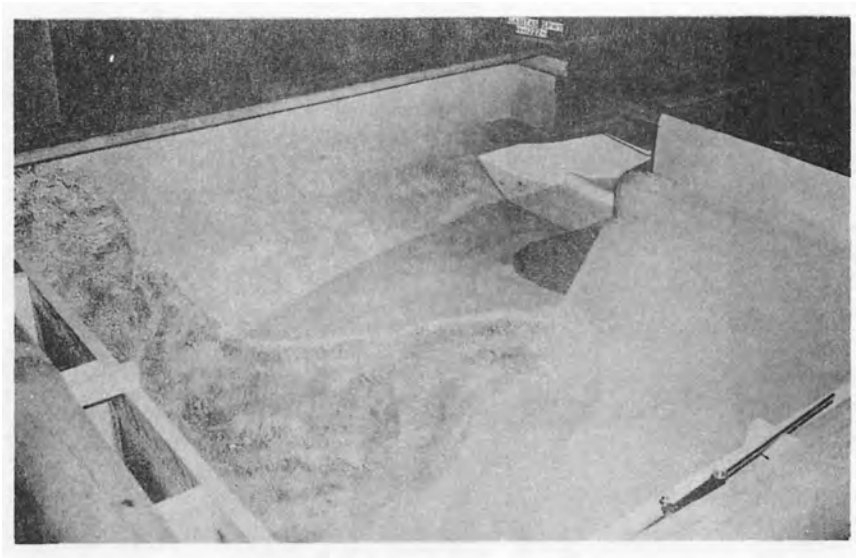
FIGURE 5
REPORT HYD. 404



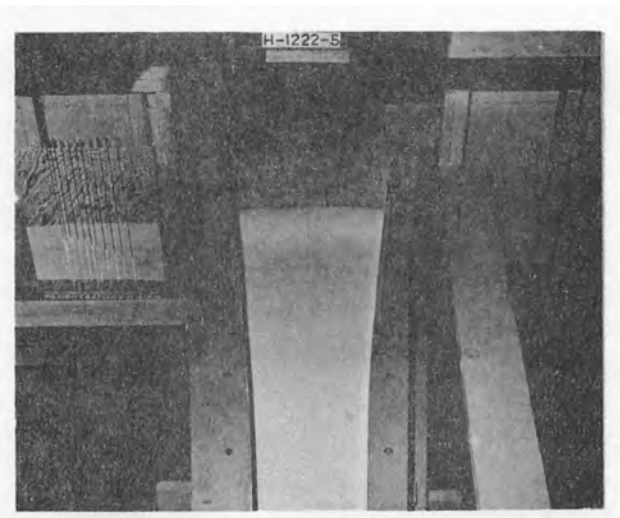
CASITAS SPILLWAY AND OUTLET WORKS

1:30 SCALE MODEL

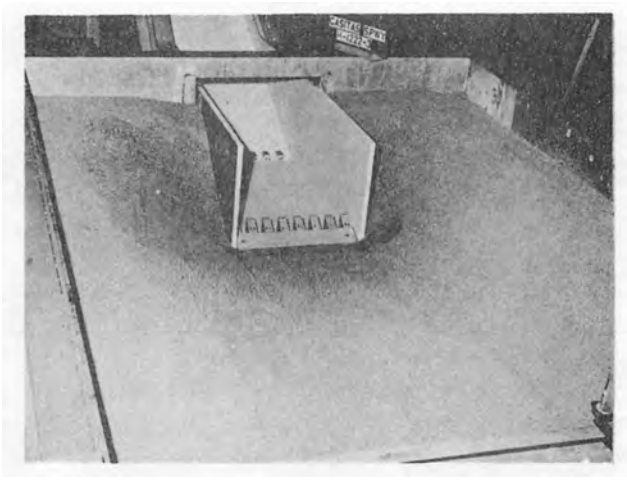
FIGURE 6
Report Hyd. 404



A. Head box with approach channel and upstream face of dam.



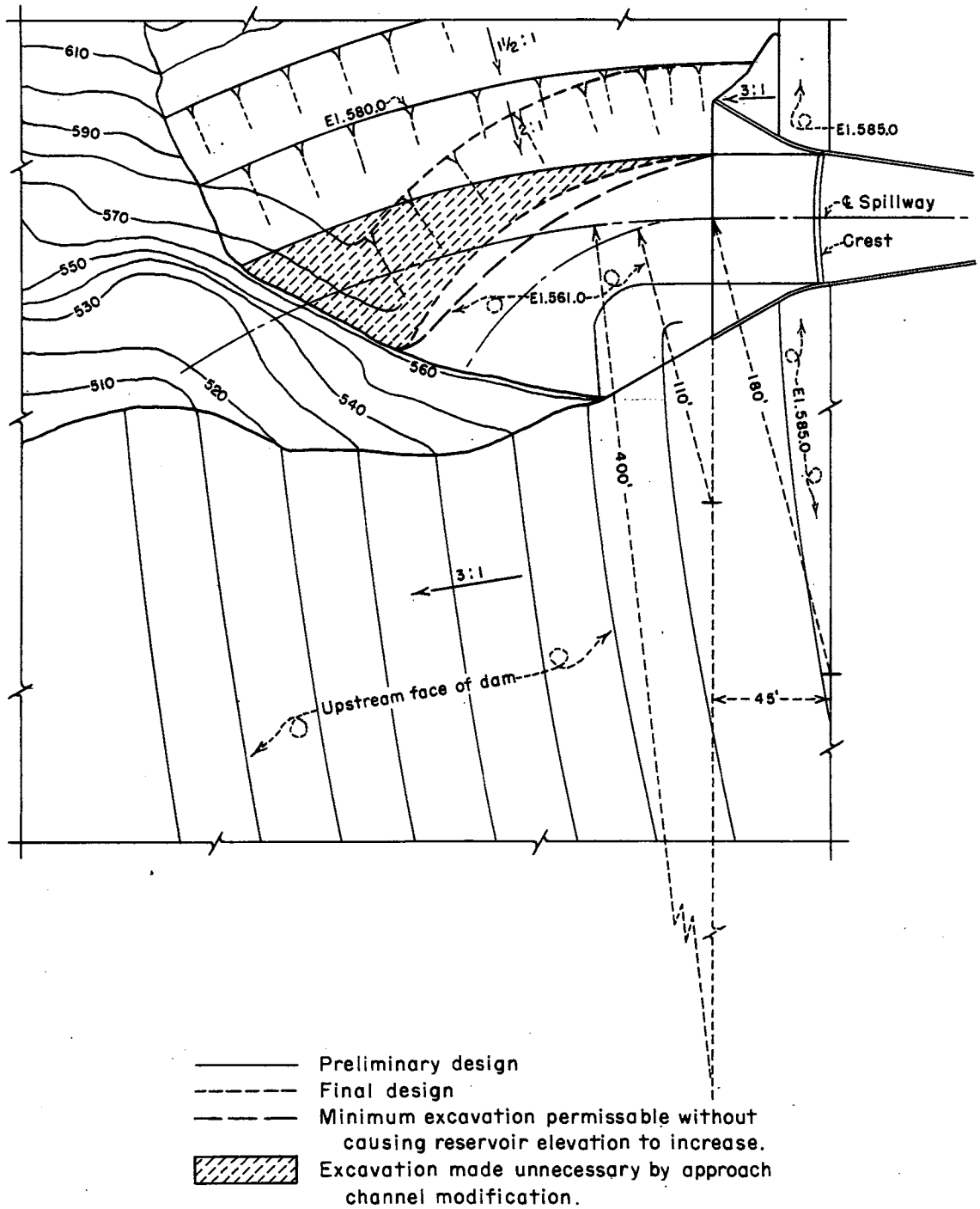
B. Curved crest and converging chute.



C. Tail box with 85 foot long stilling basin, and channel to river.

CASITAS SPILLWAY AND OUTLET WORKS
Preliminary Design - No flow

1:30 scale model



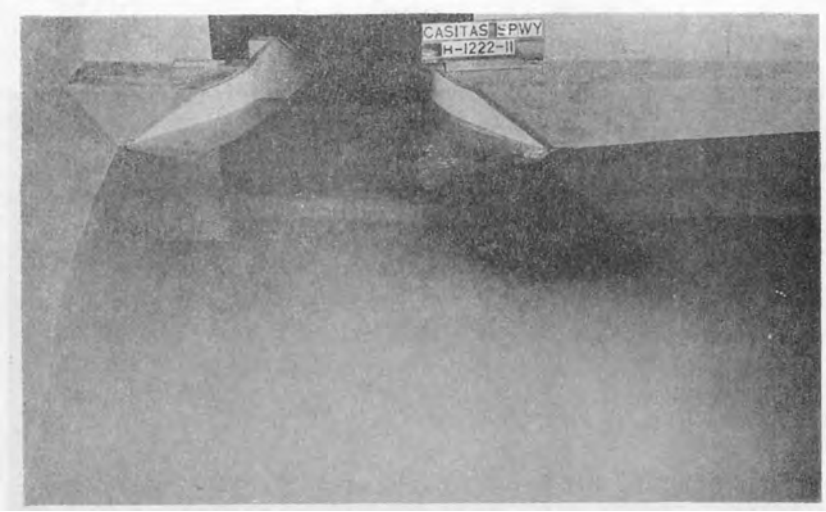
Preliminary design
Final design
Minimum excavation permissable without causing reservoir elevation to increase.
Excavation made unnecessary by approach channel modification.

CASITAS SPILLWAY AND OUTLET WORKS

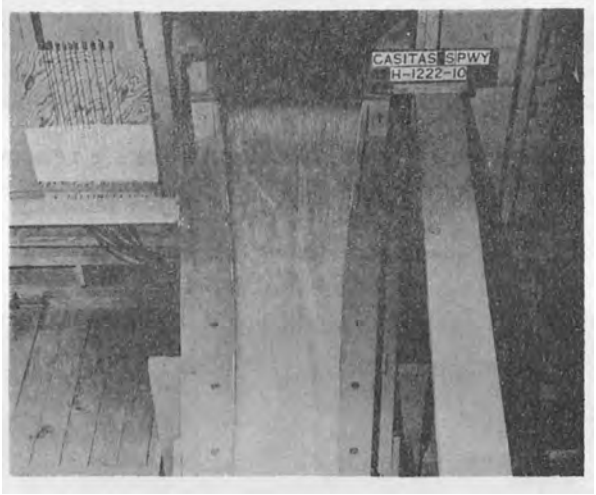
APPROACH CHANNEL MODIFICATIONS

DATA FROM 1:30 SCALE MODEL

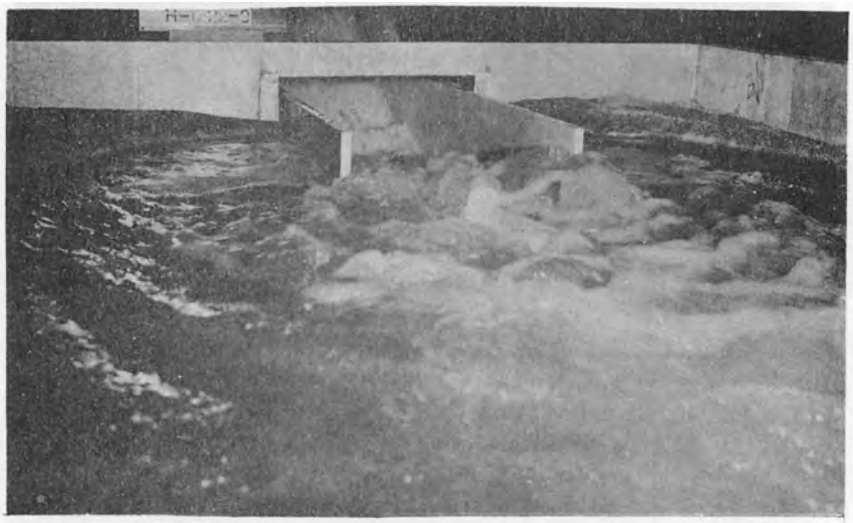
FIGURE 8
Report Hyd. 404



A. Approach conditions are good at left of channel, poor at right side at face of dam.



B. Flow converged after passing over crest, and did not pile up on training walls.



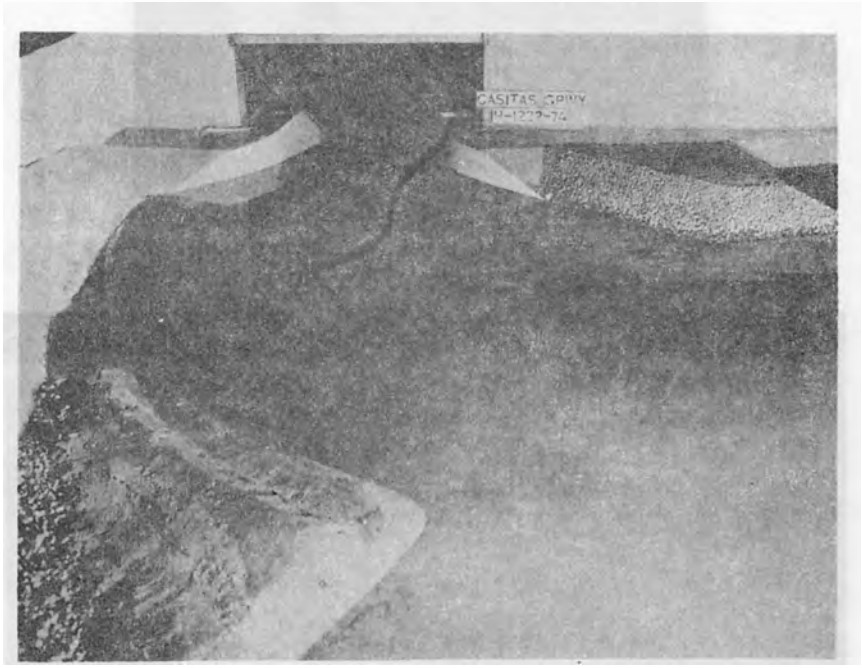
C. Stilling basin was too short for high discharges, poor jump occurred with large boil at basin end.

CASITAS SPILLWAY AND OUTLET WORKS
Preliminary Design - Flow conditions with 6,950 cfs.

1:30 scale model

FIGURE 9
Report Hyd. 404

A. Minimum excavation without causing reservoir elevation increase. Q = 6, 950 cfs.

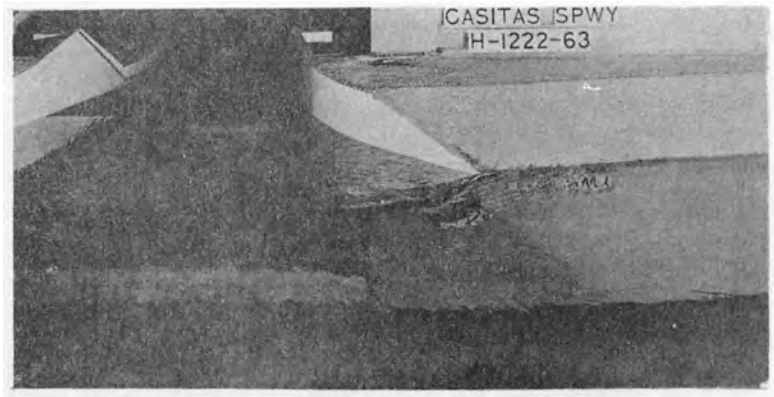


B. Final excavation, and right hand embankment. Q = 7, 400 cfs.

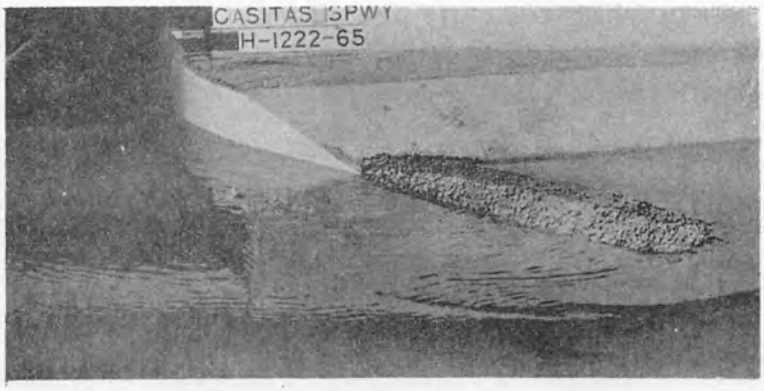
CASITAS SPILLWAY AND OUTLET WORKS
Flow with reduced excavation in spillway approach channel.

1:30 scale model

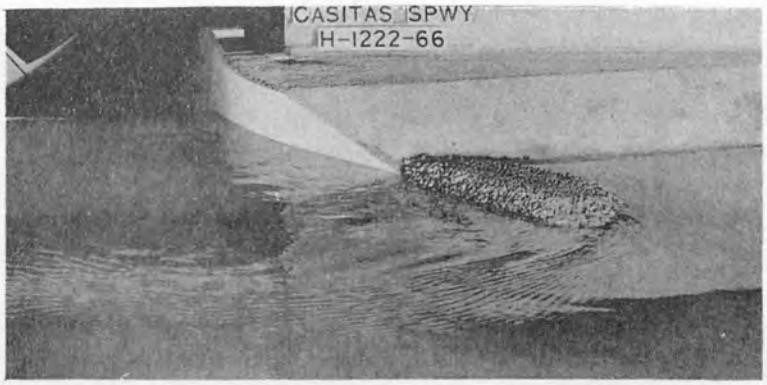
FIGURE 10
Report Hyd. 404



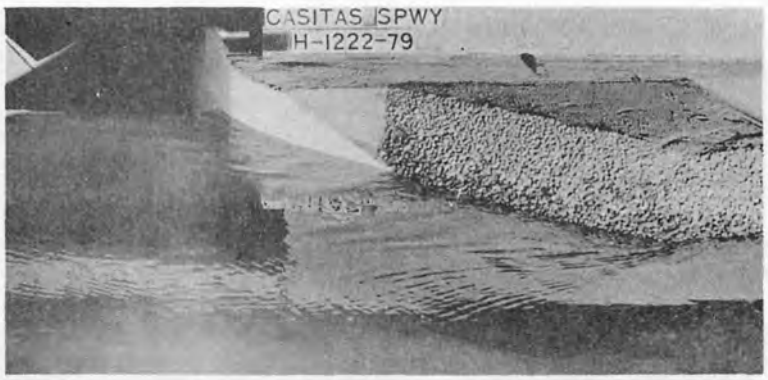
A. Preliminary design Q = 6, 950 cfs.



B. 50 foot long embankment at 45° angle to spillway centerline. Q = 6, 950 cfs.



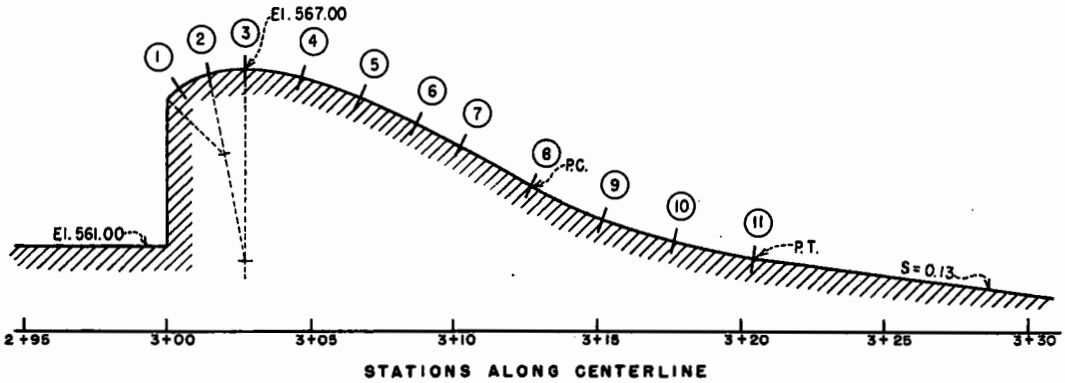
C. 30 foot long embankment at 45° angle to spillway centerline. Q = 6, 950 cfs.



D. Final embankment Q = 7, 400 cfs.

CASITAS SPILLWAY AND OUTLET WORKS
Flow conditions at right side of spillway approach

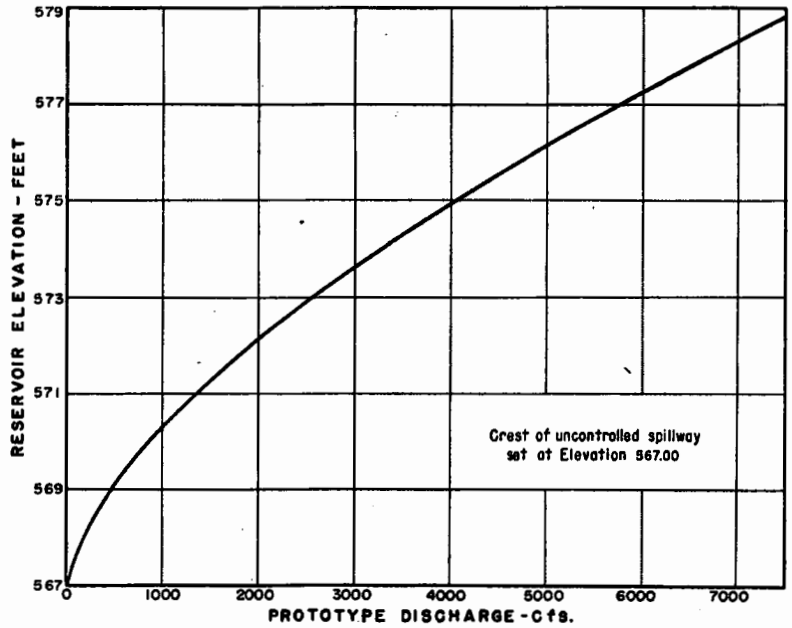
1:30 scale model



A. POSITION OF PIEZOMETERS ALONG CENTERLINE OF SPILLWAY CREST

Q	PIEZOMETERS										
	1	2	3	4	5	6	7	8	9	10	11
3000	3.60	2.76	2.16	1.71	1.29	1.71	2.55	4.50	4.83	4.71	4.11
6950	3.54	2.34	1.50	1.74	2.10	3.63	5.64	8.88	9.69	9.90	9.09

B. PIEZOMETER PRESSURES IN FEET OF WATER, PROTOTYPE, ABOVE PIEZOMETER STATION

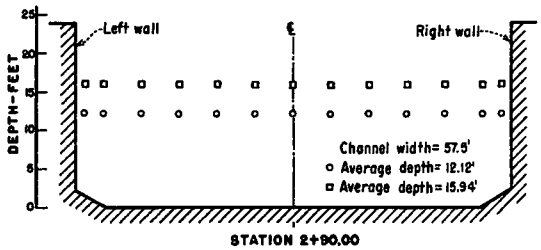


C. RATE OF FLOW-vs-RESERVOIR ELEVATION FOR UNCONTROLLED CREST

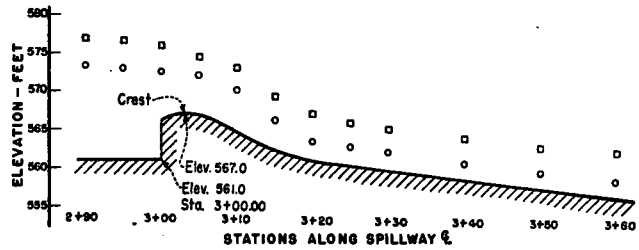
CASITAS SPILLWAY AND OUTLET WORKS
SPILLWAY CREST PRESSURES, AND DISCHARGE

DATA FROM 1:30 SCALE MODEL

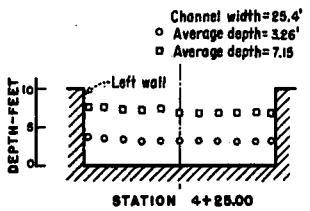
829



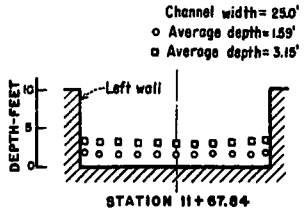
A. WATER SURFACE IN APPROACH TO SPILLWAY CREST



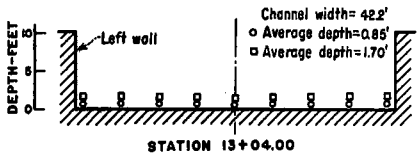
B. WATER SURFACE ALONG SPILLWAY CREST CENTERLINE



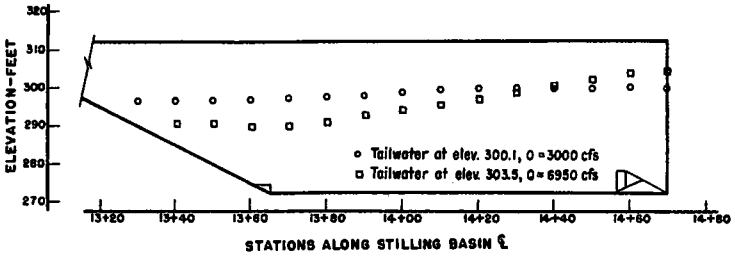
C. WATER SURFACE IN CHUTE NEAR FIRST VERTICAL BEND



D. WATER SURFACE IN CHUTE AT SECOND VERTICAL BEND

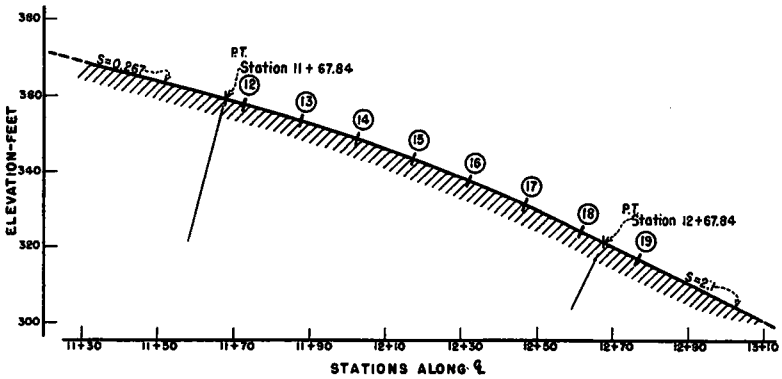


E. WATER SURFACE IN CHUTE AT STILLING BASIN ENTRANCE



F. WATER SURFACE ALONG STILLING BASIN CENTERLINE
105 FOOT BASIN WITH INVERT AT EL. 272.00
PROTOTYPE BASIN WILL BE LOWERED TO EL. 270.00

o – 3000 cfs
□ – 6950 cfs



G. LOCATION OF PIEZOMETERS ON SECOND VERTICAL BEND

Q	PIEZOMETERS							
	12	13	14	15	16	17	18	19
3000	3.36	3.00	3.39	2.64	0.84	2.70	2.49	3.63
6950	4.80	4.05	5.25	3.69	1.41	3.84	3.90	6.03

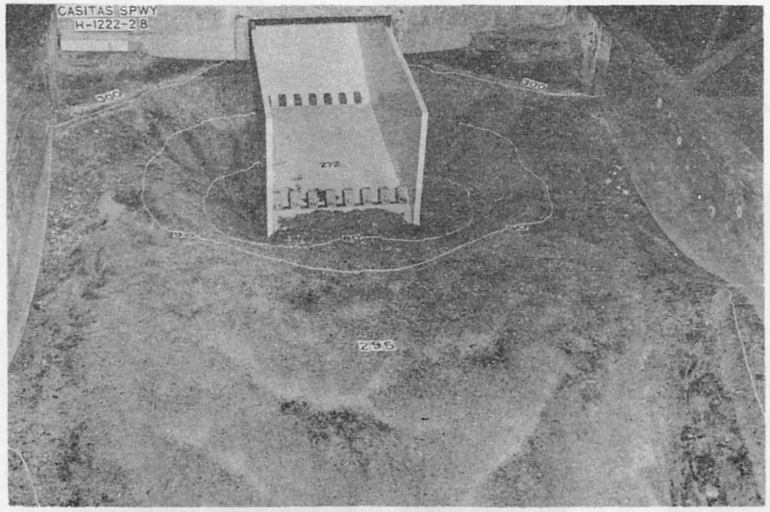
H. PIEZOMETER PRESSURES IN FEET OF WATER ABOVE THE PIEZOMETER STATION

CASITAS SPILLWAY AND OUTLET WORKS

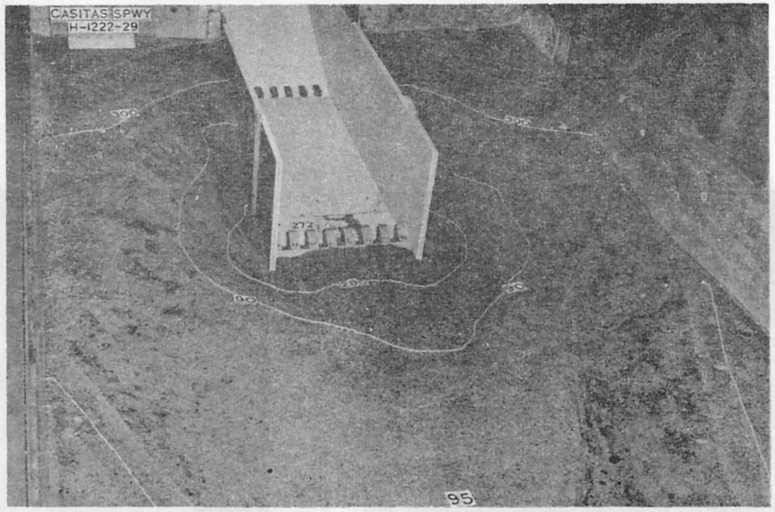
WATER SURFACE CROSS-SECTIONS AND PROFILES ON SPILLWAY CHUTE AND BASIN, AND PRESSURES ON SECOND VERTICAL BEND

DATA FROM 1:30 SCALE MODEL

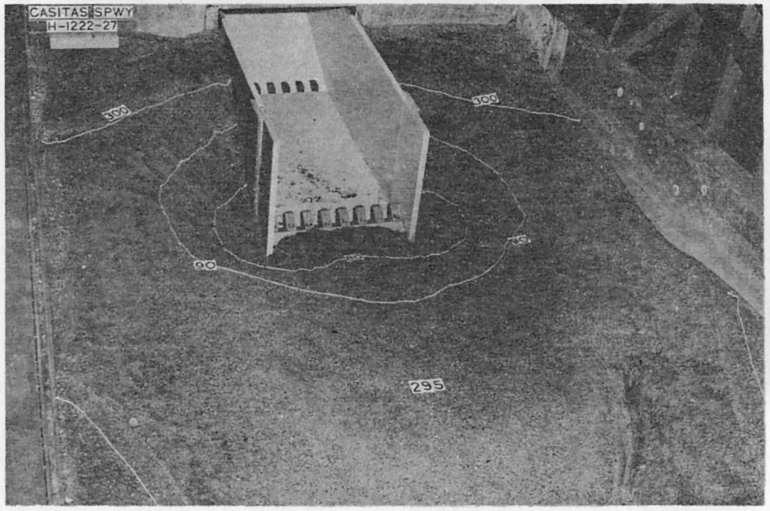
529



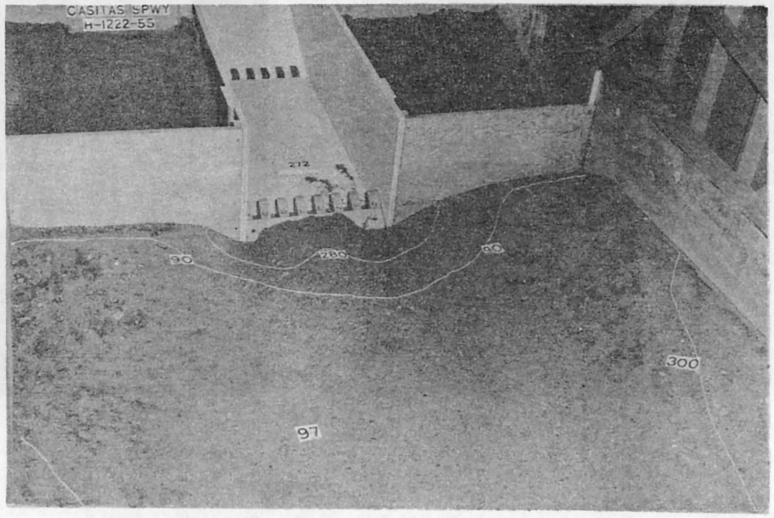
A. 85 foot long basis (preliminary design).



B. 115 foot long basin.



C. 105 foot long basin (recommended design).



D. 105 foot long basin with wing walls.

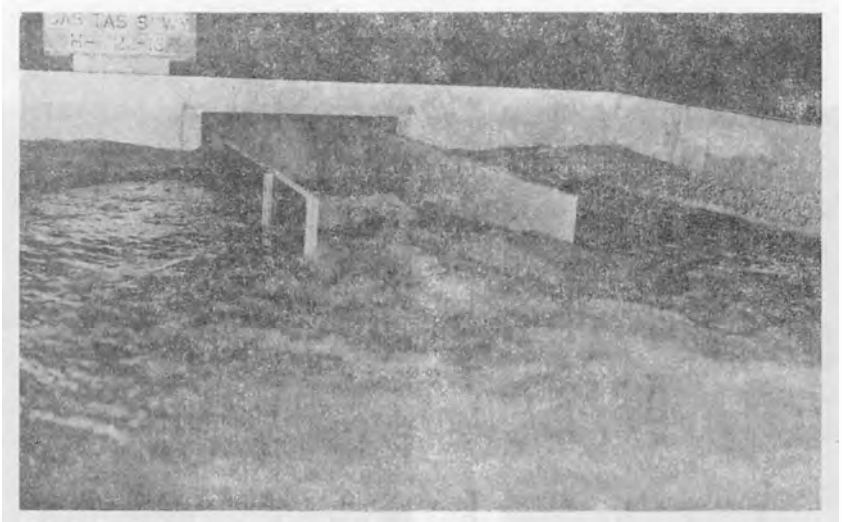
Figure 5C gives bed shape before each test.

CASITAS SPILLWAY AND OUTLET WORKS
Scour in sand river bed after 1 hour of operation at 6,950 cfs.

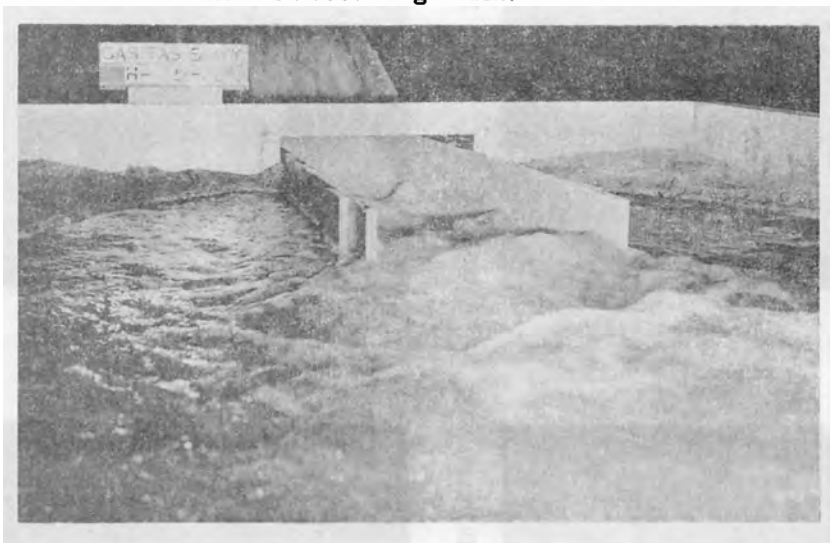
1:30 scale model

FIGURE 13
Report Hyd. 404

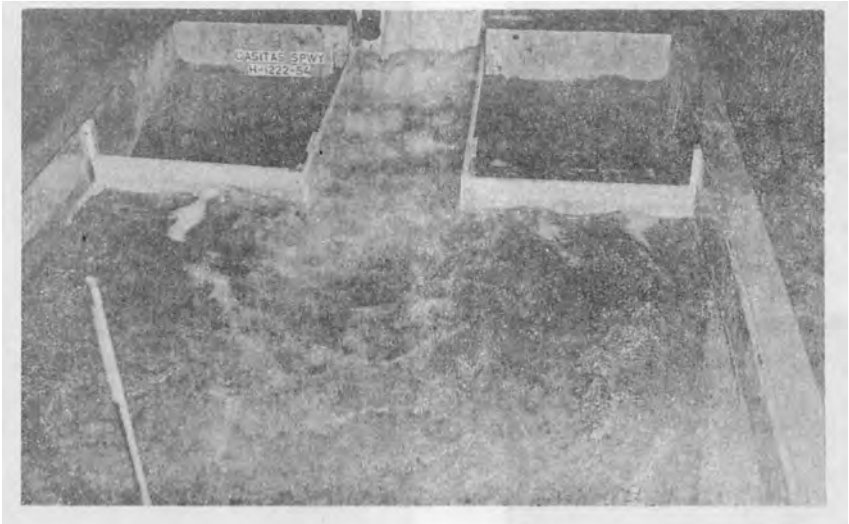
FIGURE 14
Report Hyd. 404



A. 115 foot long basin.



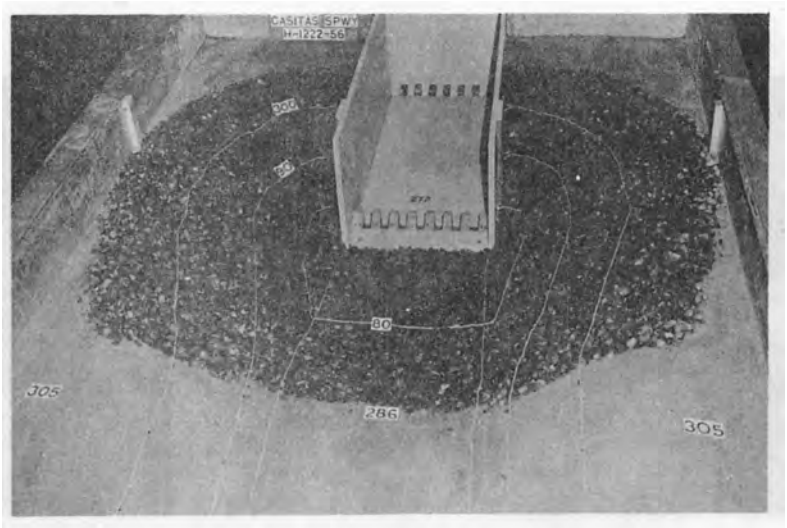
B. 105 foot long basin (recommended design).



C. 105 foot long basin with wingwalls.

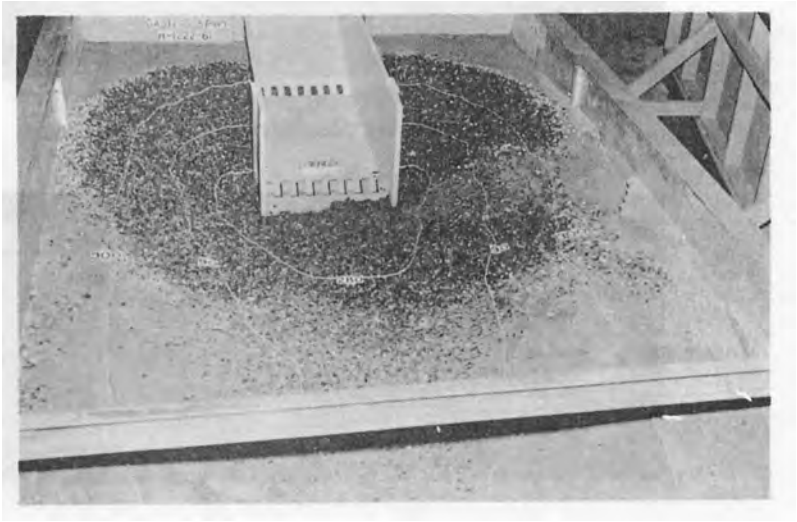
CASITAS SPILLWAY AND OUTLET WORKS
Performance with basins 115 and 105 feet long
without wingwalls, and 105 feet long with wingwalls. Q = 6,950

1:30 scale model



A. 3/8 to 3/4-inch gravel riprap before tests.

B. 3/8 to 3/4-inch gravel after 1 hour and 40 minutes operation at 6, 950 cfs.

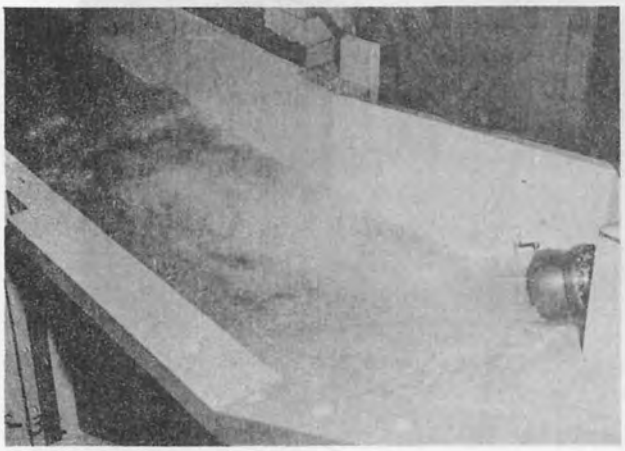


C. 1/8 to 3/8-inch gravel after 1 hour and 40 minutes operation at 6, 950 cfs.

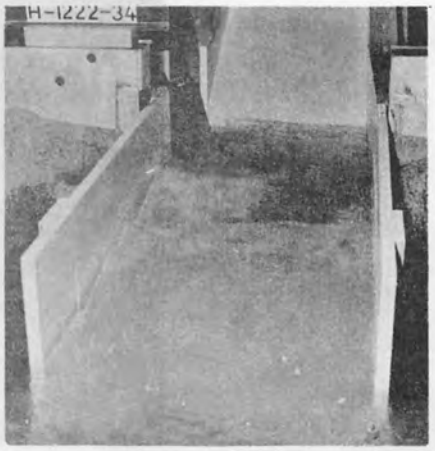
CASITAS SPILLWAY AND OUTLET WORKS
Scour produced in riprapped river channel with 105 foot long recommended stilling basin.

1:30 scale model

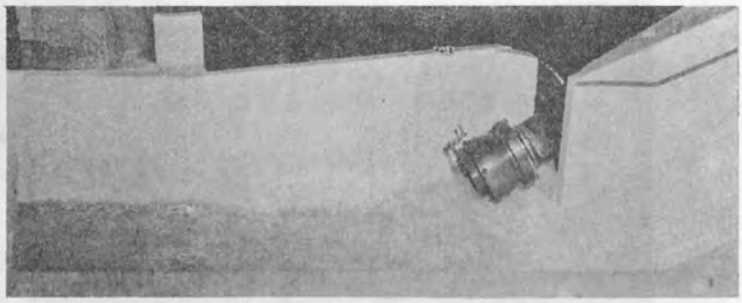
FIGURE 16
Report Hyd. 404



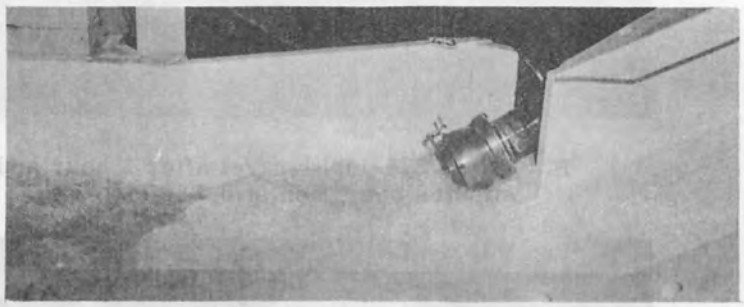
A. Valve discharging 740 cfs.



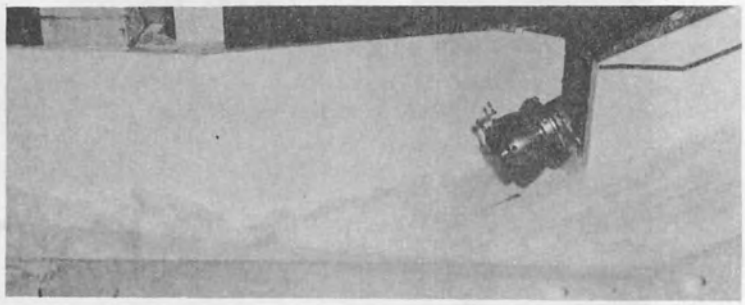
B. Valve discharging 740 cfs.



C. Spillway discharging 400 cfs.



D. Spillway discharging 3, 000 cfs.

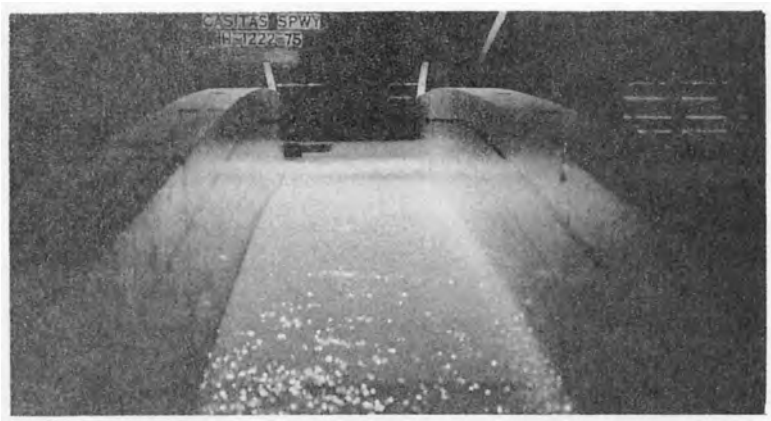


E. Spillway discharging 6, 950 cfs.

CASITAS SPILLWAY AND OUTLET WORKS
Flow conditions with outlet valve discharging into stilling basin, and at valve with spillway discharging.

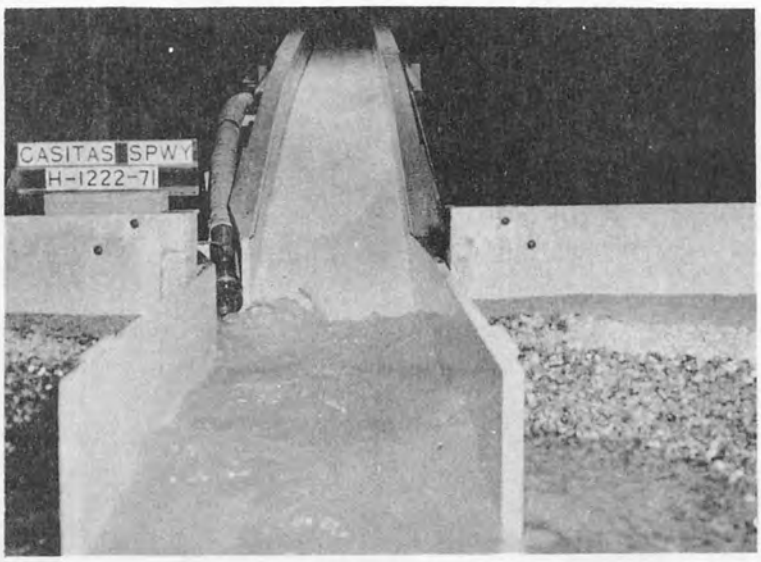
1:30 scale model

FIGURE 17
Report Hyd. 404



A. Smooth flow at crest becomes disturbed, and small waves form.

B. Waves become larger as big ones overtake, and absorb small ones.



C. Waves are large and strong when they reach stilling basin, and create rough flow in pool.

CASITAS SPILLWAY AND OUTLET WORKS
Progressive stages of "Slug" flow in spillway chute at low discharges. Q = 300 cfs.

1:30 scale model

Interior - Reclamation - Denver, Colo.