498

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF WHISKEYTOWN DAM SPILLWAY CENTRAL VALLEY PROJECT, CALIFORNIA

Hydraulics Branch Report No. Hyd-498

DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

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ABSTRACT

Model studies were conducted to develop the hydraulic design of the morning-glory inlet, the tunnel, the flip bucket, and the stream channel. Guide vanes placed on the profile of the inlet straightened the flow through the tunnel and increased the capacity of the inlet. A deflector and air vent provided steady free surface flow, aided in straightening the flow, and limited the flow at maximum reservoir elevation. The ratio of bend radius to tunnel diameter, 5:1, was ample for turning the flow. The walls of the bucket converged, and the left bank of the stream channel flared outward to insure that the jet from the flip bucket will not impinge upon the left bank. A 12-inch corbel along the top inside edge of the flip bucket walls smoothed the appearance of the jet. Excavation of the channel banks eliminated the possibility of the stream clogging with eroded material. Diversion and outlet works flow characteristics in the stream channel were satisfactory.

DESCRIPTORS--spillways/ outlet works/ diversion works/ tunnels/ *spillway crests/ *flip buckets/ control structures/ discharge coefficients/ Froude number/ head losses/ roughness coefficients/ unsteady flow/ vortices/ jets/ *hydraulic models/ cavitation/ pressure measuring equipment/ piezometers/ air demand/ transducers/ tunnel pressures/ guide vanes/ erosion/ streamflow/ tunnel hydraulics/ hydraulic similitude
IDENTIFIERS--morning-glory inlets/ tunnel bends/ tunnel deflectors/ *subatmospheric pressures

CONTENTS

CONTENTS--Continued

CONTENTS--Continued

CONTENTS--Continued

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HYDRAULIC MODEL STUDIES OF WHISKEYTOWN DAM SPILLWAY
Central Valley Project, California

PURPOSE

The studies were conducted to develop the hydraulic design of the morning-glory spillway inlet, the tunnel, the flip bucket, and the stream channel.

CONCLUSIONS

1. The spillway will satisfactorily discharge all flows.

2. Rib vanes placed on the profile of the inlet straightened the flow through the tunnel and increased the capacity of the inlet.

3. A deflector and air vent placed in the vertical bend of the tunnel provided free surface tunnel flow and directed the flow to the invert, thus aiding in straightening the tunnel flow and limiting the flow at maximum reservoir elevation.

4. A vertical bend having a radius of approximately five tunnel diameters between the vertical and horizontal tunnel was found to be ample for turning the flow.

5. The walls of the flip bucket converged in a downstream direction and the left bank of the stream channel flared outward to insure that the jet will not impinge upon the left bank.

6. A 12-inch corbel along the top inside edge of the flip bucket walls smoothed the appearance of the jet for large flows.

7. Excavation of the stream banks provided a straight channel that will not clog with rock eroded by the jet.

8. Hydraulic characteristics in the stream channel are satisfactory for diversion flows and for outlet works flows.

9. Motion pictures of the flow entering the morning-glory inlet, discharging through the tunnel and leaving the flip bucket for the preliminary and recommended designs are on file in the Hydraulics Branch.

ACKNOWLEDGEMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Spillway and Outlet Works Section and the Hydraulics Branch during the period February 1960 to November 1960.

INTRODUCTION

Whiskeytown Dam, a part of the Central Valley Project, is located on Clear Creek about 10 miles west of Redding, California (Figure 1). The dam (Figure 2) is an earthfill structure approximately 2,500 feet long at the crest and approximately 270 feet high above the riverbed.

The ungated spillway located in the left abutment (Figure 3) will discharge 28,650 cfs at maximum reservoir elevation 1220.5 through a tunnel having a morning-glory inlet and a flip bucket at the outlet. The spillway drops the flow 254 feet from the crest of the morning glory to the bucket invert 1,140 feet downstream from the center of the inlet.

The spillway crest has a radius of 44 feet at crest elevation 1210 (Figure 4). It is obstructed only by an air vent pier approximately 5 feet wide. The throat at the base of the morning-glory inlet is 24 feet 6 inches in diameter and joins a tunnel bend which reduces in diameter from 24 feet 6 inches to 21 feet through an arc of 87°29.45'. The bend joins the tunnel which slopes downward 0.04382 to the flip bucket. The arc of the bucket invert has a radius of 48.25 feet and makes an angle of 25° with the horizontal at its downstream end.

The stream channel downstream from the spillway is narrow and twisting with heavily timbered banks. The channel bed is solid rock having vertical and horizontal cracks.

The outlet works located in the left abutment (Figure 6) is designed to discharge about 1,240 cfs at maximum reservoir elevation 1220.5. The flow passes through a 19-foot-diameter tunnel sloping slightly downward to the gate chamber near the center of the dam. At the gate chamber the flow divides into two 45-inch-inside-diameter steel outlet pipes leading to the control house at the outlet portal where it is controlled by two 2-foot 9-inch by 3-foot 9-inch slide gates that discharge into the stream channel.

During construction of the dam the outlet works tunnel will be used for diversion of the streamflow. During this period the gate chamber and the control house will not be completed. Diversion flows will be discharged through the 19-foot-diameter tunnel which transitions to a 19-foot-wide rectangular section and discharges into the stream channel. Diversion discharges for a 10-year flood may reach 13,000 cfs at reservoir elevation 1040.

THE MODEL

A 1:32.78 scale reproduction of the prototype spillway including the diversion structure outlet portal and the outlet works (Figure 7) was constructed and tested in the Bureau of Reclamation Hydraulic Laboratory at Denver, Colorado. A portion of the reservoir surrounding the spillway inlet and a reach of river channel downstream from the stilling basin were also included in the model.

A 467-foot-square area of the reservoir surrounding the spillway inlet was contained in the head box (Figures 7 and 8). The inlet topography was molded in concrete mortar placed on metal lath which had been nailed over wooden templates shaped to the ground surface contours. The surface was given a rough finish to simulate the natural topography of the prototype. The fill surrounding the inlet was represented by a smooth finish.

The spillway crest (Figure 8) was molded in concrete using accurately cut and placed sheet metal templates as guides. Piezometers consisting of 1/16-inch-inside-diameter brass tubes were soldered at right angles to the template profile and filed flush. Twelve rows of piezometers containing 11 piezometers in each row were installed in the crest.

The spillway tunnel extending from the morning-glory inlet to the flip bucket was constructed of transparent plastic and the flip bucket was constructed of sheet metal (Figures 9 and 10). Piezometers were installed throughout the tunnel and flip bucket. The downstream portion of the diversion tunnel which was converted to the outlet works following the diversion tunnel tests (Figure 11) was constructed of sheet metal.

A reach of the stream channel extending approximately 700 feet downstream from the spillway flip bucket was constructed of concrete (Figure 12). During the preliminary tests the streambed below elevation 950 was constructed of 1-1/2-inch gravel (Figure 12A) for erosion tests. Following these tests the gravel bed was cemented with a 3/4-inch layer of concrete (Figure 12B). Tailwater elevation in the stream channel (Figure 13) was controlled by means of a tailgate at the downstream end of the model (Figure 7).

Prior to construction of the head box the spillway flow was piped directly to the near horizontal tunnel as shown in Figures 7 and 12. The depth of flow at the outlet portal of the spillway was computed for several prototype discharges and controlled in the model by means of the slide gate. After the head box containing the morning-glory inlet and tunnel bend was completed, the slide gate and upstream piping were removed, and the horizontal tunnel was attached to the tunnel bend. For both systems the quantity of flow was controlled and measured using a gate valve and a Venturi meter permanently installed in the laboratory supply lines.

Diversion and outlet works flows were supplied by means of a separate pipeline shown in Figures 7 and 11. The computed diversion flow depth at the outlet portal established by means of a slide gate. The quantity of flow was controlled in the same manner as for the spillway. Flow through the two 1.01- by 1.37-inch model slide gates in the outlet works was calibrated using a pressure tap in the floor of the control house (Figure 7). The quantity of flow for the outlet works was then regulated by means of the pressure tap and slide gate in the supply pipeline.

THE INVESTIGATION

The primary purpose of the investigation was to develop the hydraulic design of the inlet structure, the spillway tunnel, the flip bucket, and the shape of the stream channel by studying the characteristics of the flow as it approached, passed through, and discharged from the spillway. Flow conditions in the stream channel as caused by discharges from the diversion structure and from the outlet works were also studied. The investigation of the flip bucket and stream channel was conducted while the reservoir, morning-glory inlet, and tunnel bend were being constructed in the head box. This portion of the study was accomplished by pumping water directly to the horizontal portion of the spillway tunnel (Figure 7). After completion of the head box, flow characteristics through the inlet and tunnel were investigated.

Preliminary Inlet, Vertical Bend, and Tunnel

Design Considerations

The inlet structure (Figure 4) is a morning-glory crest located in the upstream face of the dam near the left bank of the reservoir (Figure 2). The shape of the morning-glory inlet was designed in accordance with Paper No. 2802, American Society of Civil Engineers Transactions. 1/ A deflector and air vent were designed for the morning-glory throat to deflect the flow to the invert of the tunnel to provide ventilation along the crown of the tunnel and to limit the maximum discharge. However, the deflector and vent were not installed in the model during the preliminary studies.

Flow Characteristics

The hydraulic flow characteristics of the spillway inlet and tunnel was initially determined without the use of guide vanes, air vents, or deflectors in the bend. The model was operated at a range of discharges including 32,300 cfs which exceeds the anticipated maximum capacity of 28,780 cfs.

For all flows exceeding about one-fourth of maximum discharge the flow approached the inlet in a curved path except for a small portion of the approach channel near the invert side (Figure 15). Here the curved flow lines met the straight flow lines causing small ridges of water over the crest profile. The curved flow lines were caused by the unsymmetrical approach conditions. Because of the unsymmetrical approach the flow entered the vertical bend unsymmetrically and swayed from side to side as it passed through the vertical bend and sloping tunnel. This swaying characteristic was more noticeable for the smaller discharges (Photographs A and B in Figures 16 and 17).

At approximately 26,850 cfs a mushroom boil formed in the morning-glory inlet. As the flow was increased to the anticipated maximum discharge of 28,780 cfs, the mushroom boil grew larger and a vortex caused by the curved flow lines appeared within the boil (Figure 15B). The vortex was dissipated before passing through the vertical bend (Figure 16C). The crown of the vertical bend apparently received air from the vortex and from entrained air within the mushroom boil. Streaks of entrained air coming through the throat of the morning-glory inlet can be seen in Figure 16C. Flow through the

1/Paper No. 2802, ASCE Transactions, Vol. 121, 1956, p. 311, Morning-glory Shaft Spillways Symposium, "Determination of Pressure-controlled Profiles," by William E. Wagner, M. ASCE.

tunnel was unsteady as indicated by the air pockets that momentarily formed along the crown between sections of tunnel that were completely filled with water (Figure 17C). The size of the vortex and the mushroom boil fluctuated as a result of the unsteady air demand in the tunnel.

At approximately 32,000 cfs no trace of the mushroom boil remained, leaving only the vortex (Figure 15D). For this submerged flow condition the tunnel filled except for the vortex which appeared like a twisted rope extending through the bend to the exit portal of the tunnel (Figures 16D and 17D).

Calibration

The spillway was calibrated for a range of flows up to and exceeding the anticipated maximum discharge of 28,780 cfs at reservoir elevation 1220.5 (Figure 18). At a discharge of 28,500 cfs the reservoir elevation was approximately 0.05 foot above the computed elevation of 1218.71 feet. This slight increase was due to the vortex that appeared within the mushroom (Figure 15B). The presence of the vortex was reflected by the slight upward bend in the discharge curve from about 27,500 cfs to approximately 30,000 cfs (Figure 18B).

At approximately 30,000 cfs the flow changed from free flow to submerged flow as indicated by the discharge curve (Figure 18), and the reservoir rose abruptly from elevation 1219.3 with very little increase in discharge.

Inlet Pressures

Pressures on the profile of the inlet were recorded (Figure 19). For small flows of 14,250 and 7,250 cfs the pressures were above atmospheric near the crest of the spillway and below atmospheric near the throat. These pressures were expected because less-than-design flow does not spring as far from the sharp-crested circular weir near the top of the profile as the design flow but springs farther out in the lower region of the profile. 1/

For a free flow of 28,500 cfs the boil was near crest elevation and pressures were near atmospheric over the top portion of the crest profile (Figure 19). However, for the lower portion of the profile the pressures were well above atmospheric because of the hydrostatic pressure of the mushroom boil and fluctuated considerably as the size of the boil fluctuated. The same was true for 26,850 cfs where the boil fluctuated in the lower portion of the morning-glory inlet. For 25,890 cfs the boil was not present, and pressures were nearly atmospheric for a much greater length of the profile, particularly on the crown side of the morning glory.

When the inlet submerged and acted as an orifice, the pressures along the entire profile were considerably above atmospheric as shown in Figure 19 for 30, 590 cfs. The maximum pressure occurred near the midpoint of the profile.

Vertical Bend and Tunnel Pressures

Pressures along the invert of the vertical bend and tunnel were above atmospheric for all flows (Figure 20). The highest pressure occurred at the midpoint of the vertical bend. Pressures along the crown of the vertical bend were below atmospheric for all flows, particularly at Piezometers 13 and 14 near the upper end of the bend. The lowest pressure of 15. 1 feet below atmospheric occurred at Piezometer 14, indicating the most desirable location for an air vent. For the unsteady flow of 28, 450 cfs the pressures fluctuated considerably, particularly in the horizontal portion of the tunnel.

Preliminary Conclusions

The preliminary tests indicated that guide vanes or piers on the crest profile should be developed to straighten the flow through the vertical bend and tunnel and that a deflector and air vent should be used to deflect the flow to the invert and to provide air for the tunnel. This arrangement would relieve the subatmospheric pressures along the crown of the vertical bend and stabilize the unsteady flow condition through the horizontal tunnel. Calibration of the inlet indicated that a deflector and air vent was needed to limit the maximum discharge at maximum reservoir.

Modifications to the Preliminary Inlet and Vertical Bend

Deflectors and Air Vents

The first modification to the preliminary design was the addition of a deflector and air vent on the crown of the vertical bend beginning at the throat of the morning glory (Figure 4). The deflector extended vertically downward until the desired offset from the crown of the vertical bend was reached. This shape and location was chosen to provide a positive spring point for the free water surface in the bend and to relieve the low pressures observed in the preliminary studies.

A deflector that extended 6 feet 10 inches inward from the crown of the bend with a 3-foot-square air vent immediately below the deflector and a 6-foot-wide vent pier on the crest was installed in the model (Figure 9A). The discharge capacity of the spillway was determined with and without the vent pier and vent. Without the vent and pier the maximum free flow discharge was approximately 29,000 cfs (Figure 18B). With the vent and pier the maximum free flow was reduced to about 25,500 cfs (Figure 18B).

The size of the deflector was reduced to 4 feet. The 3-foot-square air vent and 6-foot-wide pier were retained. With this arrangement the maximum free flow was approximately 28,450 cfs and occurred at reservoir elevation 1218.9 (Figure 18B). For discharges above 28,450 cfs, the inlet submerged and the flow was 28,650 cfs at maximum reservoir elevation 1220.5. This compared favorably with the anticipated maximum value of 28,780 cfs.

The deflector and air vent helped in straightening the flow through the tunnel. However, the smaller flows continued to sway through the vertical bend and tunnel.

Guide Vanes

Preliminary rib-type guide vanes patterned after those used in the Trinity Dam Spillway2/ were not very successful in improving the flow characteristics in the vertical bend and tunnel. The guide vanes consisted of three ribs each 60 feet long and 4 feet high installed in the throat or lower portion of the inlet (Figure 21A). These vanes used in addition to the 4-foot deflector and air vent did not alter the head-discharge curve including the maximum free flow of approximately 28,450 cfs (Figure 18B).

The ribs were replaced with piers located on the crest periphery and extending above maximum reservoir elevation. The piers reduced the size of the vortex within the boil. However, the piers did not straighten the flow in the bend and tunnel at the smaller discharges because the piers were too short to effectively guide these small flows through the morning-glory inlet. Additional piers at various locations on the crest periphery and combinations of guide vanes and piers were also tested without success.

One of the best modifications from the standpoint of eliminating the vortex in the boil and straightening the flow in the bend for smaller discharges was an extension of the piers over the crest down to elevation 1185.93. These were called pier vanes (Figure 21B). Five were used in addition to the deflector and air vent.

2/Bureau of Reclamation Hydraulic Laboratory Report No. Hyd-447, "Hydraulic Model Studies of the Trinity Dam Morning-Glory Spillway, Trinity River Division, Central Valley Project," by W. B. McBirney.

The pier vanes essentially eliminated the vortex within the boil. As a result the maximum free flow was increased from 28,450 to 29,650 cfs and occurred at about reservoir elevation 1219.7 as compared to elevation 1218.8 in previous tests (Figure 18B). Also, all discharges below the maximum free flow occurred at higher reservoir elevations, because the piers reduced the effective crest length.

Since the maximum free flow was increased and the design capacity at maximum reservoir elevation 1220.5 was exceeded by about 1,050 cfs, it was desirable to increase the size of the deflector from 4 feet 0 inch to 4 feet 8 inches to reduce the size of the control section. At the same time the number of pier vanes were increased to six. For this model arrangement the maximum free flow was about 28,700 cfs, and the discharge at maximum reservoir elevation 1220.5 was still about 200 cfs more than the anticipated maximum discharge of 28,780 cfs (Figure 18B).

A disadvantage to the use of piers was that higher reservoir elevations than anticipated were required to route the design flood due to the reduction in crest length by the pier widths. Thus, more reservoir storage will be required during the early flood stages than was anticipated and the design flood routing through the reservoir would need to be changed if this pier arrangement was used.

The possibility that the piers might catch and store floating logs at the crest is another disadvantage to the use of the piers. Therefore, 50- and 75-foot-long logs and a 50-foot-long, 4-foot-diameter tree with dead branches were modeled and placed in the reservoir. The logs usually went over the crest endways and through the tunnel in a satisfactory manner; however, occasionally the 50-foot logs approached the crest sideways and lodged between adjacent piers. The 50-foot tree nearly always hung up on the crest usually on a pier.

Recommended Inlet, Vertical Bend, and Tunnel

Flow Characteristics

The recommended design included the 4-foot 8-inch deflector and air vent with air intake pier in addition to six rib vanes equally spaced around the circular inlet (Figure 4). Each vane was 2 feet 6 inches wide by 7 feet high measured normal to the crest profile. The upstream end of the vanes was at elevation 1209.75, 3 inches below crest elevation, and extended down the crest profile to elevation 1178.40.

The tops of the vanes were placed 3 inches below the crest rather than at crest elevation to reduce the amount of obstruction to the flow at crest elevation. Model logs 50 to 75 feet long and the 50-foot-long tree with branches usually passed over the crest and through the spillway tunnel satisfactorily. When the head over the crest was low the logs sometimes lodged on the crest. Higher heads floated the logs free and allowed them to pass on through the spillway without apparent damage to the structure.

Flow characteristics in the spillway approach were similar to those described for the preliminary study. Compare Figures 22 and 23 with Figure 15. As the flow entered the inlet the crest vanes intercepted and tended to straighten the flow as it fell through the inlet. The vortex in the mushroom boil was almost eliminated (Figures 23B and 23C). Considerable improvement in the flow distribution through the vertical bend and tunnel was achieved (compare Figures 24, 25, and 26 with Figures 16 and 17). The tunnel crown in the vertical bend was much freer from spinning sheets of water in the recommended design than in the preliminary studies.

The whiteness of the water in Figures 24 and 25 was caused by the presence of air entrained in the flow as it fell through the inlet. After the mushroom boil formed as shown in Figure 23B, air was no longer entrained in the flow as shown by the clear water in the vertical bend (Figure 25B). Only a small vortex air passage existed for this flow condition, and maximum use of the air vent was made; closing the air vent caused the tunnel to fill, the reservoir to be drawn down, and air to be entrained in the flow (Figure 25C). Figures 23D and 25D show the magnitude of the vortex when the maximum discharge is exceeded; however, the air vent is still adequate to keep the tunnel from filling.

The bend radius of approximately five times the average tunnel bend diameter proved to be very adequate in smoothly turning the flow through the vertical bend. This ratio was determined based on past experience at other installations (Figure 14). The flow immediately downstream from the bend did not climb the walls of the tunnel as is the case when the ratio of bend radius to the pipe diameter is too small. The flow was also satisfactory in other portions of the tunnel.

Calibration

The head-discharge relationship was affected in three ways by the removal of the pier portion of the vanes: (1) The trash-catching effect which could reduce the discharge was lessened; (2) The discharge for any given reservoir elevation was increased to correspond more nearly to the design flood routing discharge curve (Figure 27); and (3) The maximum capacity of the spillway at maximum reservoir elevation was not exceeded. The maximum free flow was reduced to about 28,450 cfs and the discharge at maximum reservoir elevation 1220.5 was reduced from about 28,950 cfs to approximately 28,650 cfs, slightly under the anticipated maximum of 28,780 cfs. It was important that the maximum discharge be less than rather than over the maximum anticipated value.

Although extreme care was used in fabricating the model deflector and tunnel, it should be noted than an error of 0.01 inch in model diameter results in an error of about 75 cfs in prototype discharge. Thus, discharge accuracies within 100 cfs prototype are not possible in this study.

The discharge coefficient, C, in the equation $Q = CLH^{3/2}$ is plotted in Figure 27. It reaches a maximum of 3.92 just before the flow changes from free flow to submerged flow.

Inlet Pressures

Pressure measurements were made in two of the rib vanes (Figure 28). No subatmospheric pressures lower than 2 feet of water were detected at any of the piezometers.

Pressures were also recorded at some of the piezometers installed on the crest profile (Figure 29). No subatmospheric pressures lower than 1 foot of water were detected. When the boil formed in the inlet, pressures in the vicinity of the boil increased and fluctuated. When the flow changed from free flow to submerged flow, the pressures rose considerably and the fluctuation ceased. This is indicated in Figure 29 by comparing the pressure gradients for 27,000 and 28,600 cfs. Electronic pressure cell measurements of instantaneous dynamic pressure fluctuations along the invert side of the inlet showed very little fluctuations other than those caused by the boil (Figure 29).

Vertical Bend and Tunnel Pressures

Pressures were also measured in the vertical bend and tunnel (Figure 30). All pressures along the crown of the tunnel were atmospheric since the tunnel is fully aerated. However, with the air vent closed the tunnel filled for 28,780 cfs, and pressures on the crown of the tunnel fluctuated considerably to as low as 13 feet of water below atmospheric. This is not an anticipated prototype operating condition. Since the air vent will always be open, this pressure condition was not investigated further.

Pressures were well above atmospheric along the invert of the vertical bend from Piezometer 7 to Piezometer 9 (Figure 30). For the smaller flows the pressures fluctuated considerably at Piezometer 7 located opposite the deflector on the invert of the vertical bend. This was caused by unstable ridges of water flowing over the crest of the inlet and impinging upon this area.

Pressures along the invert of the horizontal tunnel were approximately atmospheric (Figure 30). Pressures were generally lower at the upstream end of the tunnel than at the downstream end.

Instantaneous dynamic pressures measured in the tunnel for a range of flows with the vent open and for the free flow of 28, 450 cfs with the vent closed showed only small pressure fluctuations (Figure 30). The largest fluctuation was about 6 feet of water above and below the average pressure at Piezometer 7 for 7, 125 cfs.

Preliminary Flip Bucket and Stream Channel

Testing Procedures

During the initial tests the water supply to the model was pumped directly to the near-horizontal tunnel bypassing the reservoir and inlet structure. A slide gate (Figures 7 and 12) was installed in the tunnel to control the depth of flow at the exit portal in accordance with the computed values. Later the reservoir, inlet structure, and vertical bend were connected to the horizontal tunnel for testing of the complete structure at which time the hydraulic characteristics of the recommended flip bucket and stream channel were rechecked using the water supply from the model reservoir.

A Manning's roughness coefficient, n = 0. 013, was assumed in computing the expected velocity and depth of flow in the tunnel at Station 14+15 immediately upstream from the flip bucket. For the anticipated maximum discharge of 28, 780 cfs the velocity and depth of flow were computed to be 96. 3 feet per second and 16. 18 feet, respectively. Velocities and flow depths were also computed for smaller discharges to provide a complete range of operating conditions (Figure 31). Velocity heads, percent head loss, and Froude numbers are also shown in Figure 31.

Flow Characteristics

The length, height, and spread of the jet were recorded for a range of discharges and are shown in Figure 32. For all discharges exceeding one-eighth of maximum discharge, the spread of the jet was wider than the excavated channel floor. It was feared that the jet might impinge on the left bank of the channel and endanger the service road (Figure 33).

The flow through the crooked stream channel was very turbulent (Figures 33 and 34). Initial erosion tests were made for the design flow using a streambed consisting of 1-1/2- to 3-inch model stones (Figures 12A and 33B). In a short time the loose material was eroded to the floor of the tailbox (equivalent to a depth of 25 feet prototype) and deposited in the streambed a short distance downstream. This deposit formed a pool which backed the tailwater up to the underside of the jet, submerging the lip of bucket.

The amount of erosion and height of deposit that will occur in the prototype cannot be determined in the model. However, based upon the knowledge that the prototype streambed consists of solid rock having mainly vertical and horizontal cracks, it is believed that erosion will be moderate. Nevertheless, it seemed desirable to straighten the crooked stream channel to reduce the possibility of clogging by eroded material.

Pressures

When an erodible bed was used, Piezometers 1 through 5 on the lip of the bucket (Figure 35) were submerged by the tailwater. Although exact pressures were not recorded, pressures at Piezometers 1 and 2 were slightly subatmospheric and pressures at Piezometers 3, 4, and 5 were near water vapor pressure. Cavitation erosion would probably occur if this condition were allowed to exist in the prototype.

When a stable prototype bed was simulated in the model as in Figures 12B, 33, and 34A, none of the piezometers were submerged by the tailwater, and no severe subatmospheric pressures existed (Figure 35). Pressures at the three piezometers (Nos. 3, 4, and 5) on the downstream side of the bucket lip were slightly subatmospheric. The greatest subatmospheric pressure was about 5 feet of water at Piezometer 4 for the design flow. Pressures recorded along the invert showed the maximum pressure to occur at about 0.6 of the curved distance from the P.C. to the lip of the bucket (Figure 35). This and other pressures in the flip bucket compared favorably with pressures at similar locations in other buckets.[3]

[3] Paper No. 3236, ASCE Transactions, Volume 126, Part I, 1961, page 1270, "Improved Tunnel-Spillway Flip Buckets," by T. J. Rhone and A. J. Peterka.

Flip Bucket and Stream Channel Modifications

To prevent the jet from impinging upon the left bank of the discharge channel and thus endanger the stability of the service road and to prevent clogging of the stream channel, many modifications of the flip bucket and two modifications of the stream channel were tested. The flip bucket was modified by adding deflectors of various degrees to the bucket walls, by adding fillets to the downstream corners of the bucket, by changing the degree of flip, and by changing the flat invert surface of the flip bucket deflector to a circular section. The stream channel downstream from the flip bucket was widened and straightened.

One of the early modifications is shown in Figure 36. The 15° flip angle in the preliminary design was changed to 25° and an 8° deflector extending the full length of the bucket was added to the left wall of the bucket. At the same time the stream channel was made wider by means of an 8° flare in the left bank beginning 100 feet downstream from the bucket, and the bluff on the right bank was removed to eliminate the constriction in the original channel.

The 25° bucket flipped the jet farther downstream particularly at the smaller flows; however, the 25° angle increased the tendency of the jet to spread. The tendency to spread to the left was resisted by the deflector on the left wall of the bucket. A 3° deflector was also installed on the right wall to resist spreading to the right.

The jet from this modified bucket was more ragged along the top and sides of the jet. Therefore, triangular-shaped fillets 4 feet high were installed at the downstream corners of the deflector to trim the sides of the jet and reduce the spread. The fillets accomplished this purpose; however, they caused an unstable fin of water to occur on the underside of the jet that intermittently depressed the jet trajectory. In addition, the two sidewall deflectors and the fillets constricted the flow in the bucket to the extent that the maximum flow nearly filled the portal thus endangering the free passage of air necessary for proper ventilation of the tunnel.

It was decided to radically modify the bucket for the next trial. The bucket was rebuilt in the form of a turned-up tube and was extended 2 feet 6 inches to increase the deflection of the invert to 28°. The performance was improved; however, the jet still spread too much for one-eighth and one-fourth of maximum flow, and a fin of water along the bottom of the jet was more prominent. The fin of water, although more stable, was similar to that observed in the previous bucket.

Recommended Flip Bucket and Stream Channel

Description

The recommended flip bucket (Figures 4 and 10B) includes the turned-up tube type described above but without the additional 3° lift. The curvature of the bucket begins 25 feet upstream from the end of the bucket and terminates at the bucket lip. The bucket deflects the jet 25° from the horizontal at the bucket lip. The sidewalls on each side beginning at the point of curvature of the bucket invert and extending to the downstream end of the bucket converge 3°. A 12-inch-wide overhang or corbel was placed along the top of each wall.

Additional changes were made in the stream channel (Figure 5). The left bank was flared from the end of the bucket on an angle of 4°20' and the bluff farther downstream on the left bank was removed. The promonotory between the outlet works and the spillway channels was shortened approximately 25 percent so that it extended about 100 feet downstream from the bucket.

Flow Characteristics

The jet from the flip bucket was more confined than it had been with the preliminary bucket, particularly for the design flow (Figure 37). The spreading of the jet for flows up to one-fourth maximum discharge was not reduced much by the 3° inward deflection of the sidewalls; however, since the left bank was revised to flare outward, the flow characteristics in the channel were satisfactory for all flows (Figure 38). Dimensions of the jet are shown in Figure 39. The corbel, not shown in Figure 38 but shown in Figure 37, turned the top ragged edges of the design discharge inward to provide a smoother appearing jet.

Erosion characteristics shown in Figures 40 and 41 indicate the location of possible erosion in the prototype but not necessarily the degree. It is believed that erosion in the prototype will be much more moderate than shown here since the prototype channel bed consists mainly of solid rock having vertical and horizontal cracks.

Flow through the stream channel (Figures 42, 43, and 44) was less turbulent than in the preliminary design (Figures 33 and 34). The improvement is greater than shown by the figures since Figures 42, 43, and 44 assume an eroded bed as shown in Figure 10, while an eroded bed was not assumed in Figures 33 and 34. It is believed, therefore, that clogging of the channel is less likely in the recommended design.

Assuming that the channel will erode as much as shown in Figure 40 and that the eroded material will form a bar as shown, the tailwater elevation under the jet was measured and recorded in Figure 45 for various percentages of maximum flow through the spillway. The water surface under the jet rose above the bucket lip only when an eroded hole for 14,250 cfs was stabilized in the channel, and when the spillway flow was less than about 40 percent of the maximum. As the spillway flow was increased, the bar moved farther downstream until the water surface under the jet was below the bucket lip. When the bar was completely gone, only the scour hole remained. Of the three scour holes tested, only the scour hole for 7,125 cfs appeared to cause any appreciable amount of backwater under the jet.

To simulate clogging of the stream channel that might occur downstream from the improved channel, the tailwater was raised until the water surface at the bucket reached the bucket lip. The data plotted in Figure 46 shows that an additional 7 feet of tailwater is needed at a point 780 feet downstream from the bucket for most of the assumed eroded bed conditions to submerge the lip of the bucket. Removing the left bank bluff as recommended lowered the elevation of the water surface under the jet as the flow increased above three-fourths maximum flow. In view of these results, it is not likely that the lip of the bucket will ever be submerged.

Pressures

Submergence of the bucket lip caused no extreme subatmospheric pressure in the recommended flip bucket (Figure 47). Therefore, cavitation erosion is unlikely even if submergence should occur.

For normal operating conditions pressures were near atmospheric or above throughout the bucket structure (Figure 47) and compare favorably with pressures in other structures. 3/ Instantaneous dynamic pressures fluctuated sufficiently to become slightly subatmospheric. No observed pressure was more than 5 feet of water below atmospheric. As in the preliminary bucket the maximum pressure on the invert occurred at approximately 0.6 of the arc length downstream from the P. C. Air vents (Figure 10B) had no apparent effect on the pressures and are not recommended.

The average pressures in the bucket structure were measured when the flow to the model was pumped directly to the horizontal tunnel and again with the flow coming over the spillway inlet. Both are recorded in Figure 50 and show close agreement.

Outlet Works Flows

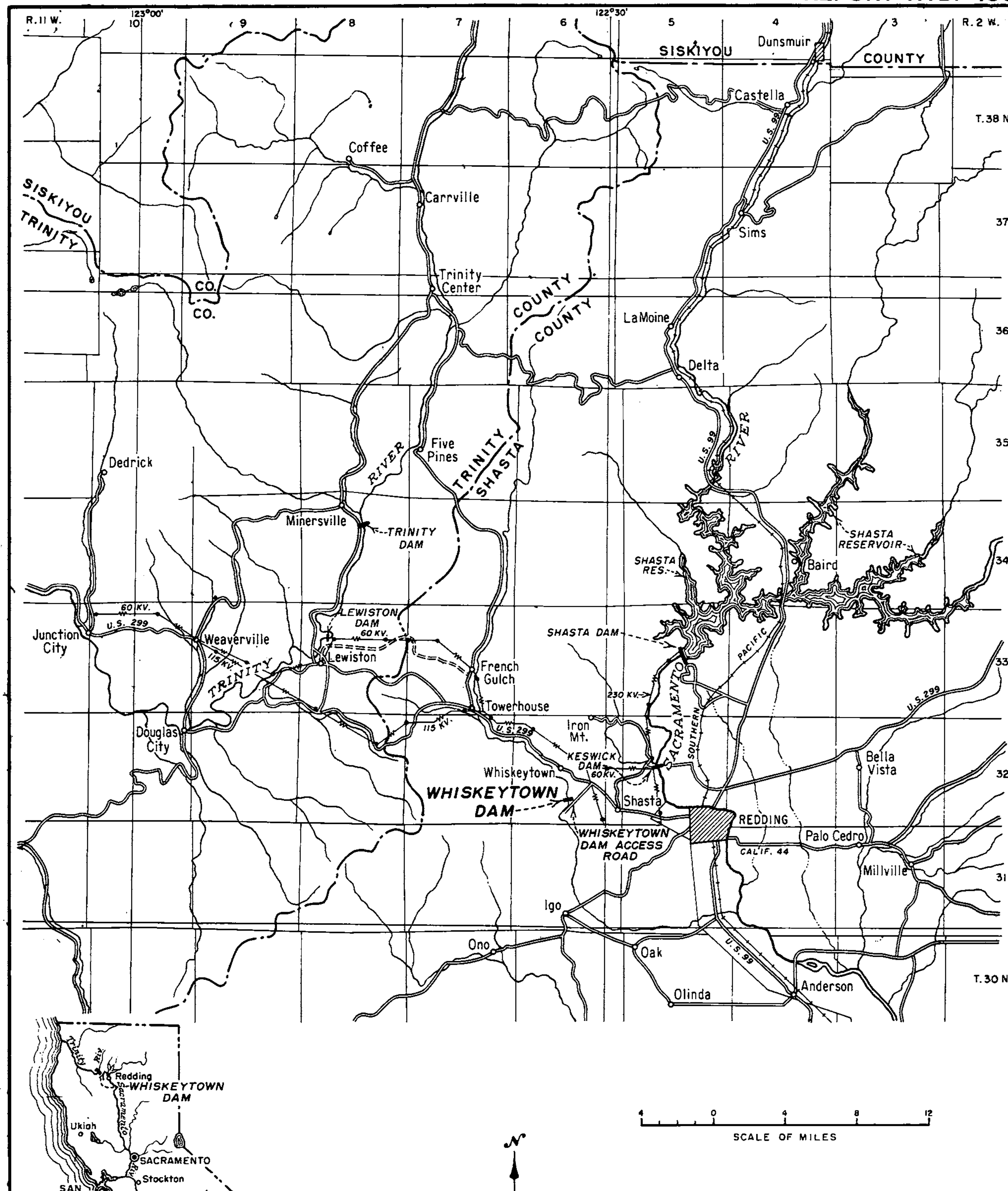
The outlet works (Figure 6) was operated for discharges ranging from 1,215 to 1,240 cfs with the reservoir water surface above the crest and with the slide gates fully open. Flow conditions were satisfactory (Figures 48 and 49). Operation of the outlet works had no significant effect on the water surface elevation beneath the jet when the flip bucket was discharging. The length of jet trajectory is recorded in Figure 50.

Diversion Flows

During construction of the dam the riverflow will be diverted through the partially completed outlet works. The interior of the outlet works gate chamber and the control house (Figure 6) will not be finished until after the diversion phase is completed.

The hydraulic characteristics of diversion flows at the tunnel exit were investigated for a range of discharges and computed velocities (Figures 51 and 52). Flow conditions were satisfactory. Pertinent data concerning the jet and tailwater conditions are recorded in Figure 53.

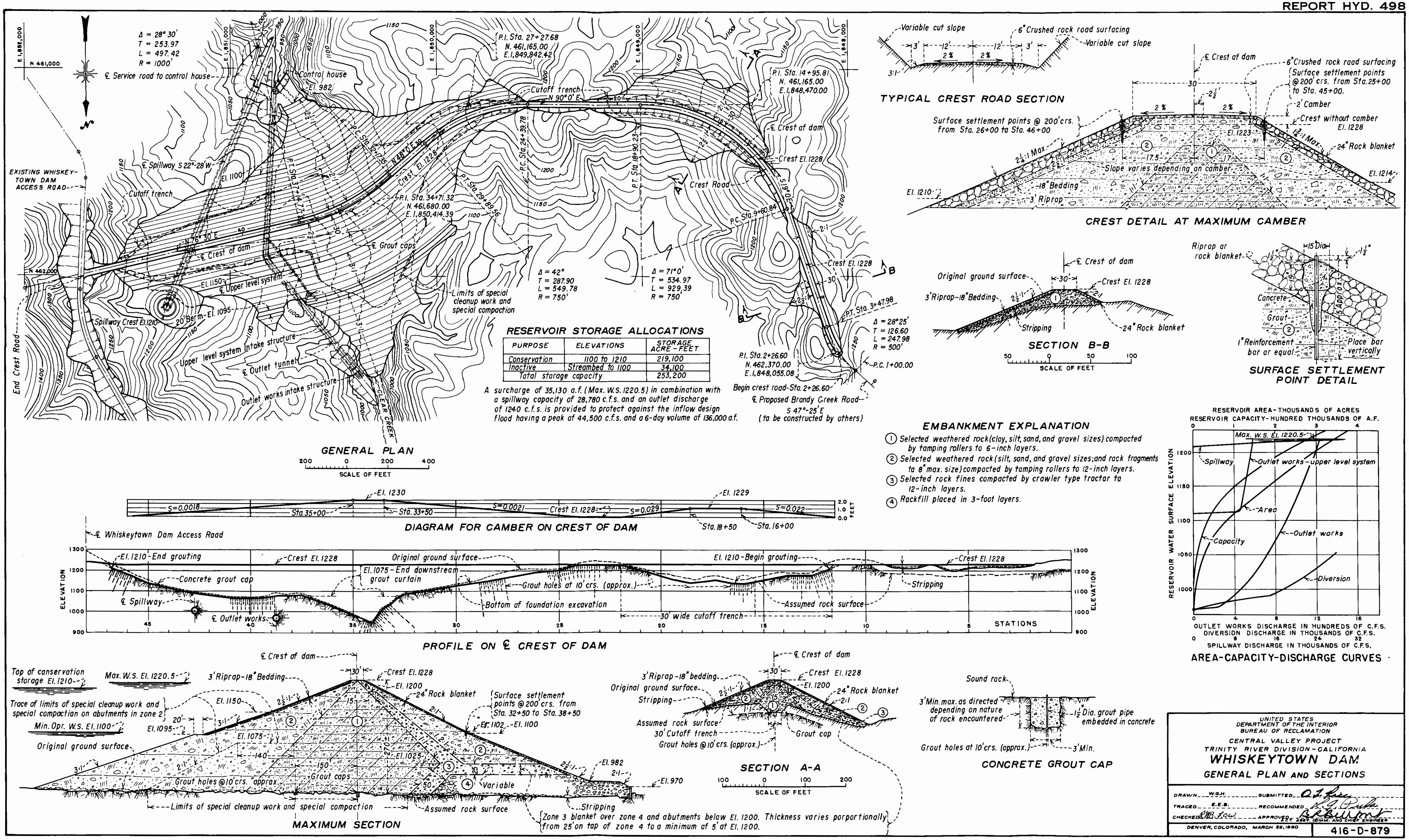
FIGURE 1
REPORT HYD. 498



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION-CALIFORNIA

WHISKEYTOWN DAM
LOCATION MAP

DRAWN B.F.W. SUBMITTED O. L. Rice
TRACED B.F.W. RECOMMENDED S. G. Pulis
CHECKED W.G.H. APPROVED B. R. Blanton ACT. ASST. COMM. AND CHIEF ENGR.
DENVER, COLORADO - DEC. 21, 1959 | 416-D-877



RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATIONS	STORAGE ACRE-FEET
Conservation	1100 to 1210	219,100
Inactive	Streambed to 1100	34,100
Total storage capacity		253,200

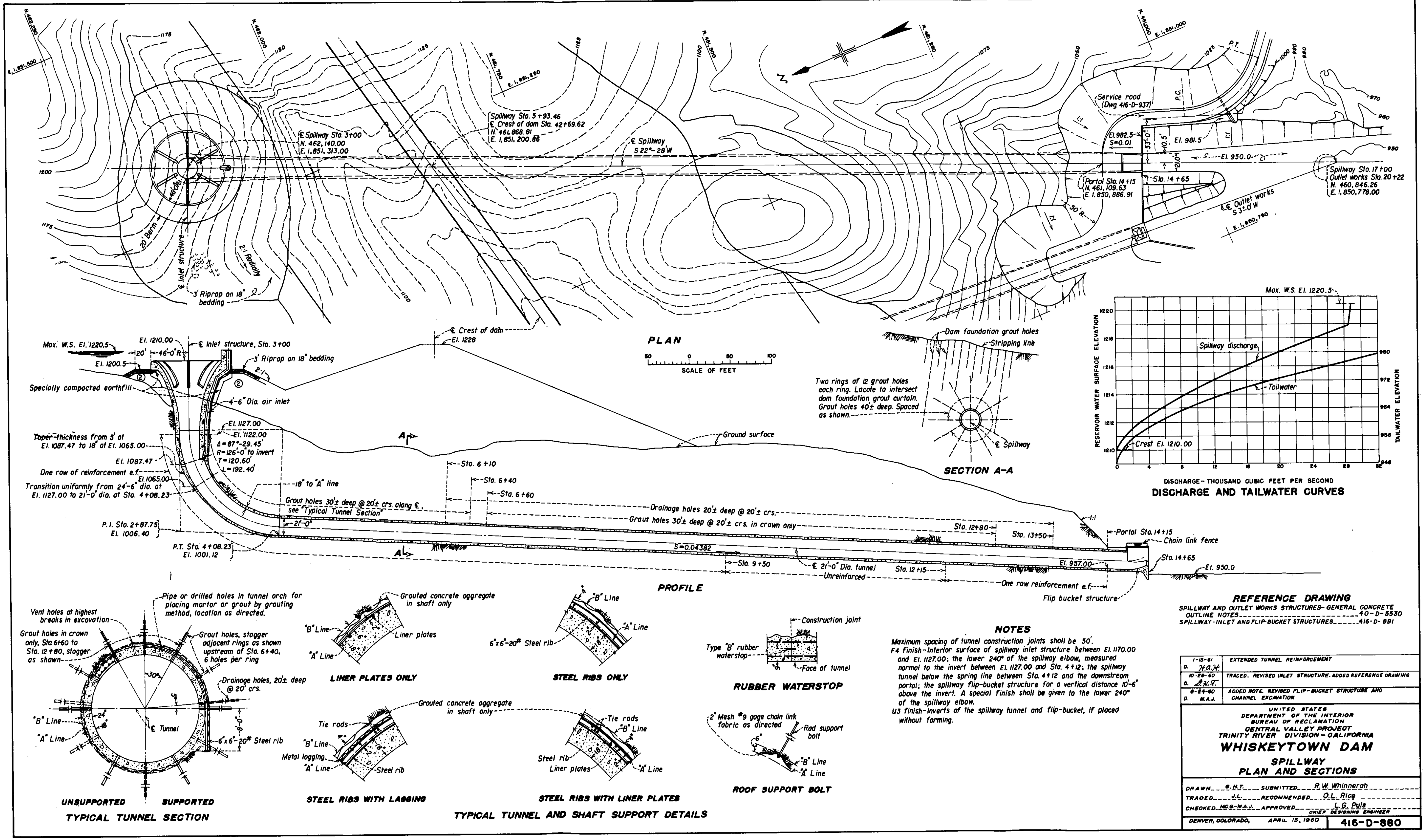
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION-CALIFORNIA

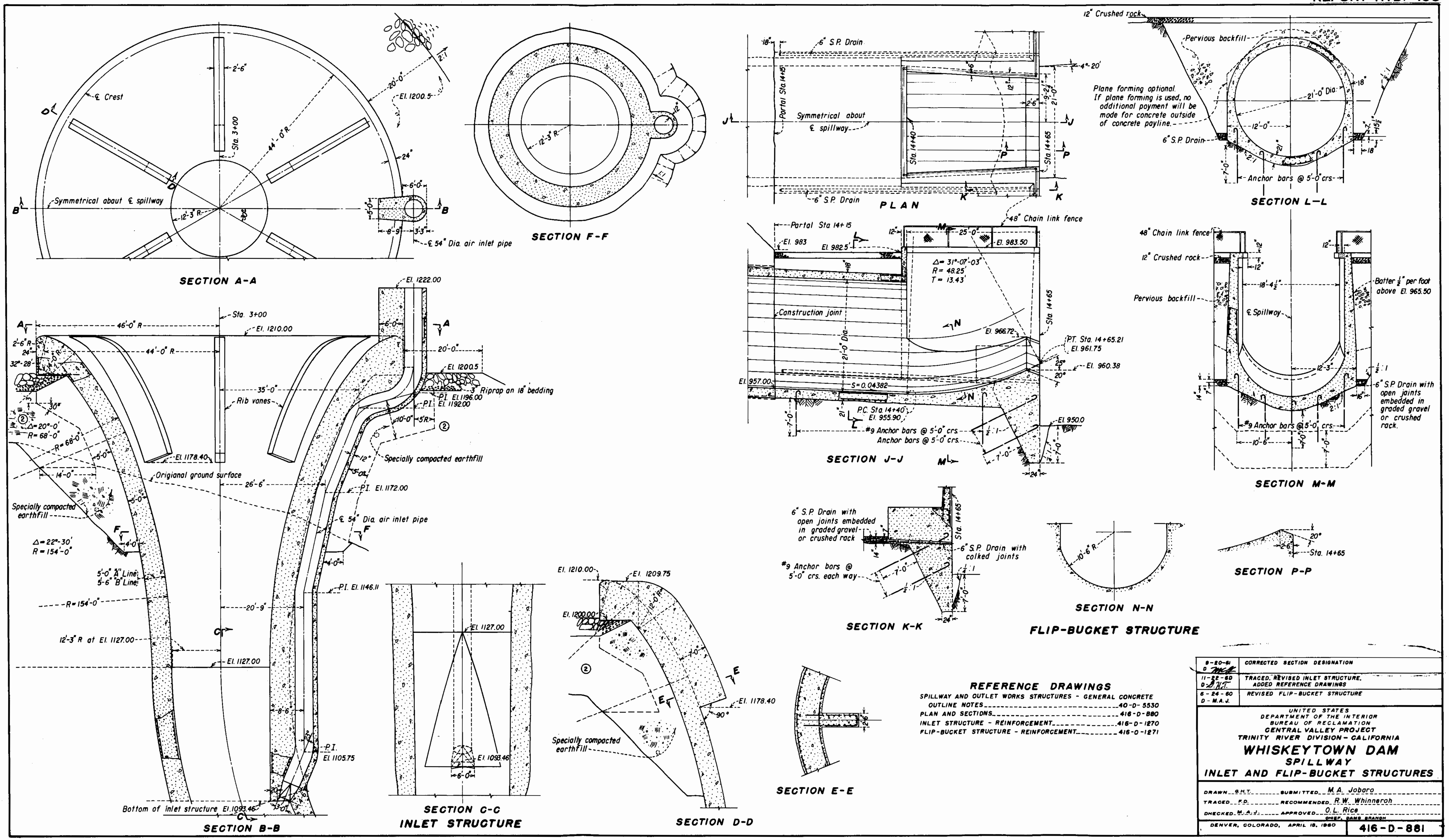
WHISKEYTOWN DAM

GENERAL PLAN AND SECTIONS

DRAWN W.G.H. SUBMITTED
TRACED E.E.B. RECOMMENDED
CHECKED APPROVED
ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO, MARCH 22, 1960

416-D-879


PLAN
SCALE OF FEET
PROFILE
SECTION A-A
DISCHARGE AND TAILWATER CURVES
DISCHARGE-THOUSAND CUBIC FEET PER SECOND
RESERVOIR WATER SURFACE ELEVATION
TAILWATER ELEVATION
Max. W.S. El. 1220.5
Spillway discharge
Tailwater
Crest El. 1210.00
Two rings of 12 grout holes each ring. Locate to intersect dam foundation grout curtain. Grout holes 40± deep. Spaced as shown.
Dam foundation grout holes
Stripping line
Ground surface
Crest of dam
El. 1228
Inlet structure, Sta. 3+00
3' Riprap on 18" bedding
Specially compacted earthfill
4'-6" Dia. air inlet
Drainage holes 20± deep @ 20± crs.
Grout holes 30± deep @ 20± crs. in crown only
Portal Sta. 14+15
Chain link fence
Sta. 14+65
El. 950.0
El. 957.00
Flip bucket structure
One row reinforcement e.f.
Unreinforced
S=0.04382
UNSUPPORTED
SUPPORTED
TYPICAL TUNNEL SECTION
LINER PLATES ONLY
STEEL RIBS ONLY
STEEL RIBS WITH LAGGING
STEEL RIBS WITH LINER PLATES
TYPICAL TUNNEL AND SHAFT SUPPORT DETAILS
RUBBER WATERSTOP
ROOF SUPPORT BOLT
REFERENCE DRAWING
SPILLWAY AND OUTLET WORKS STRUCTURES- GENERAL CONCRETE OUTLINE NOTES ---- 40-D-5530
SPILLWAY-INLET AND FLIP-BUCKET STRUCTURES ---- 416-D-881
NOTES
Maximum spacing of tunnel construction joints shall be 50'.
F4 finish-Interior surface of spillway inlet structure between El. 1170.00 and El. 1127.00; the lower 240° of the spillway elbow, measured normal to the invert between El. 1127.00 and Sta. 4+12; the spillway tunnel below the spring line between Sta. 4+12 and the downstream portal; the spillway flip-bucket structure for a vertical distance 10'-6" above the invert. A special finish shall be given to the lower 240° of the spillway elbow.
U3 finish-Inverts of the spillway tunnel and flip-bucket, if placed without forming.
1-13-61 EXTENDED TUNNEL REINFORCEMENT
10-28-60 TRACED. REVISED INLET STRUCTURE. ADDED REFERENCE DRAWING
6-24-60 ADDED NOTE. REVISED FLIP-BUCKET STRUCTURE AND CHANNEL EXCAVATION
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION-CALIFORNIA
WHISKEYTOWN DAM
SPILLWAY
PLAN AND SECTIONS
DRAWN G.H.T. SUBMITTED R.W. Whinnerah
TRACED J.L. RECOMMENDED O.L. Rice
CHECKED MCG.-M.A.J. APPROVED L.G. Puls CHIEF DESIGNING ENGINEER
DENVER, COLORADO, APRIL 15, 1960
416-D-880


SECTION A-A
SECTION F-F
PLAN
SECTION L-L
SECTION J-J
SECTION M-M
SECTION B-B
SECTION C-C
INLET STRUCTURE
SECTION D-D
SECTION E-E
SECTION K-K
SECTION N-N
SECTION P-P
FLIP-BUCKET STRUCTURE
Symmetrical about ℄ spillway
℄ Crest
Sta. 3+00
44'-0" R.
12'-3" R.
℄ 54" Dia. air inlet pipe
El. 1200.5
El. 1222.00
El. 1210.00
46'-0" R
35'-0"
Rib vanes
El. 1178.40
3" Riprap on 18" bedding
Specially compacted earthfill
Origianal ground surface
P.I. El. 1172.00
P.I. El. 1146.11
El. 1127.00
12'-3" R at El. 1127.00
Bottom of inlet structure El. 1093.46
El. 1093.46
Δ=22°-30'
R=154'-0"
Δ=20°-0'
R=68'-0"
5'-0" "A" Line
5'-6" "B" Line
6" S.P. Drain
Portal Sta. 14+15
Symmetrical about ℄ spillway
Sta. 14+40
Sta. 14+65
48" Chain link fence
El. 983
El. 982.5'
El. 983.50
Δ= 31°-07'-03"
R= 48.25'
T= 13.43'
Construction joint
21'-0" Dia.
El. 957.00
S=0.04382
P.C. Sta. 14+40
El. 955.90
P.T. Sta. 14+65.21
El. 961.75
El. 960.38
El. 966.72
El. 950.0
#9 Anchor bars @ 5'-0" crs.
Anchor bars @ 5'-0" crs.
12" Crushed rock
Pervious backfill
Plane forming optional.
If plane forming is used, no additional payment will be made for concrete outside of concrete payline.
6" S.P. Drain
21'-0" Dia.
Anchor bars @ 5'-0" crs.
Batter ½" per foot above El. 965.50
℄ Spillway
6" S.P. Drain with open joints embedded in graded gravel or crushed rock.
#9 Anchor bars @ 5'-0" crs.
6" S.P. Drain with open joints embedded in graded gravel or crushed rock
6" S.P. Drain with colked joints
#9 Anchor bars @ 5'-0" crs. each way
10'-6" R
Sta. 14+65
El. 1210.00
El. 1209.75
El. 1200.00
El. 1178.40
Specially compacted earthfill
REFERENCE DRAWINGS
SPILLWAY AND OUTLET WORKS STRUCTURES - GENERAL CONCRETE OUTLINE NOTES 40-D-5530
PLAN AND SECTIONS 416-D-880
INLET STRUCTURE - REINFORCEMENT 416-D-1270
FLIP-BUCKET STRUCTURE - REINFORCEMENT 416-D-1271
9-20-61 CORRECTED SECTION DESIGNATION
11-22-60 TRACED, REVISED INLET STRUCTURE, ADDED REFERENCE DRAWINGS
6-24-60 D-M.A.J. REVISED FLIP-BUCKET STRUCTURE
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION - CALIFORNIA
WHISKEYTOWN DAM
SPILLWAY
INLET AND FLIP-BUCKET STRUCTURES
DRAWN G.H.T. SUBMITTED M.A. Jabara
TRACED F.D. RECOMMENDED R.W. Whinnerah
CHECKED M.A.J. APPROVED O.L. Rice
CHIEF, DAMS BRANCH
DENVER, COLORADO, APRIL 18, 1960
416-D-881

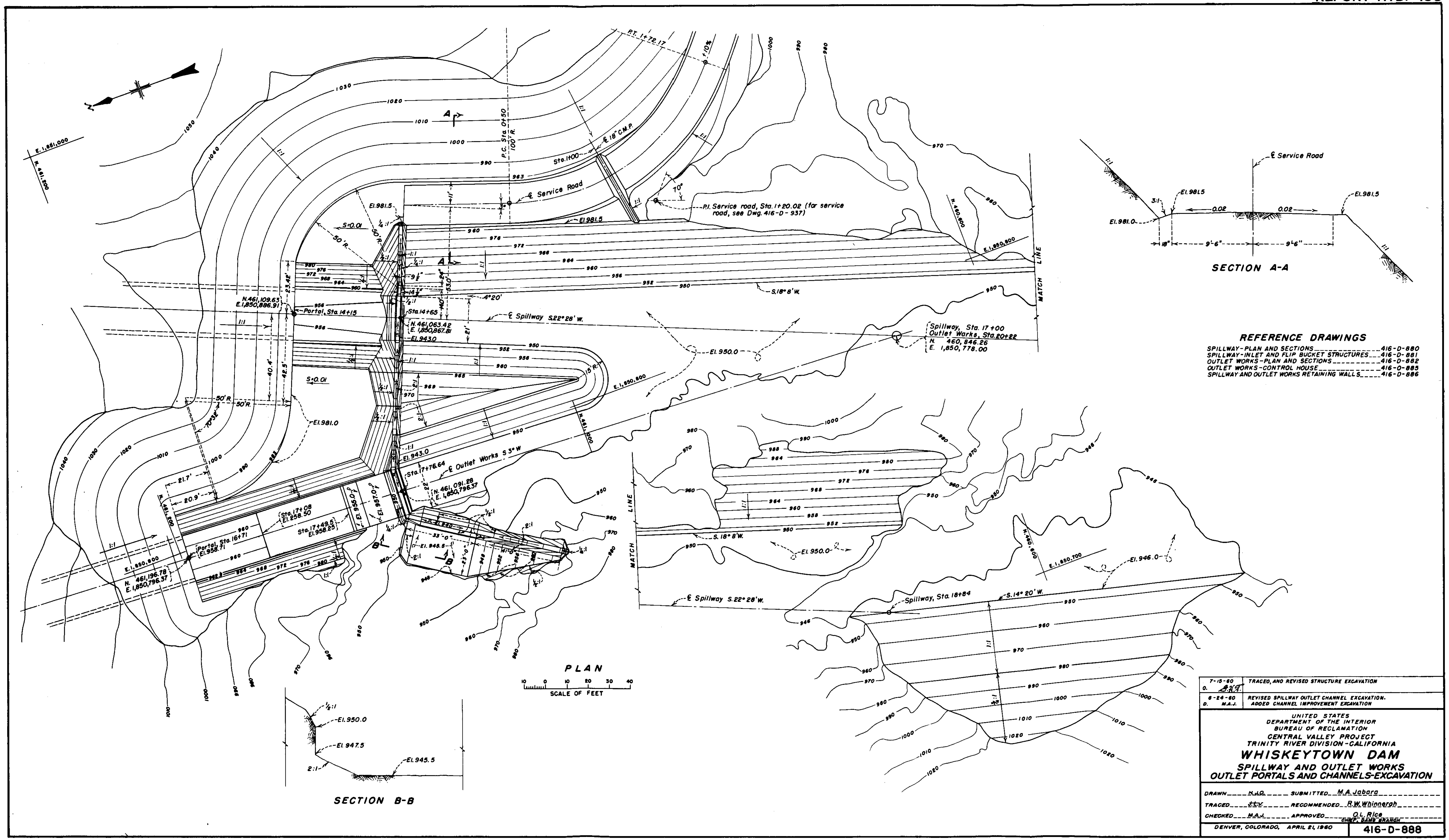
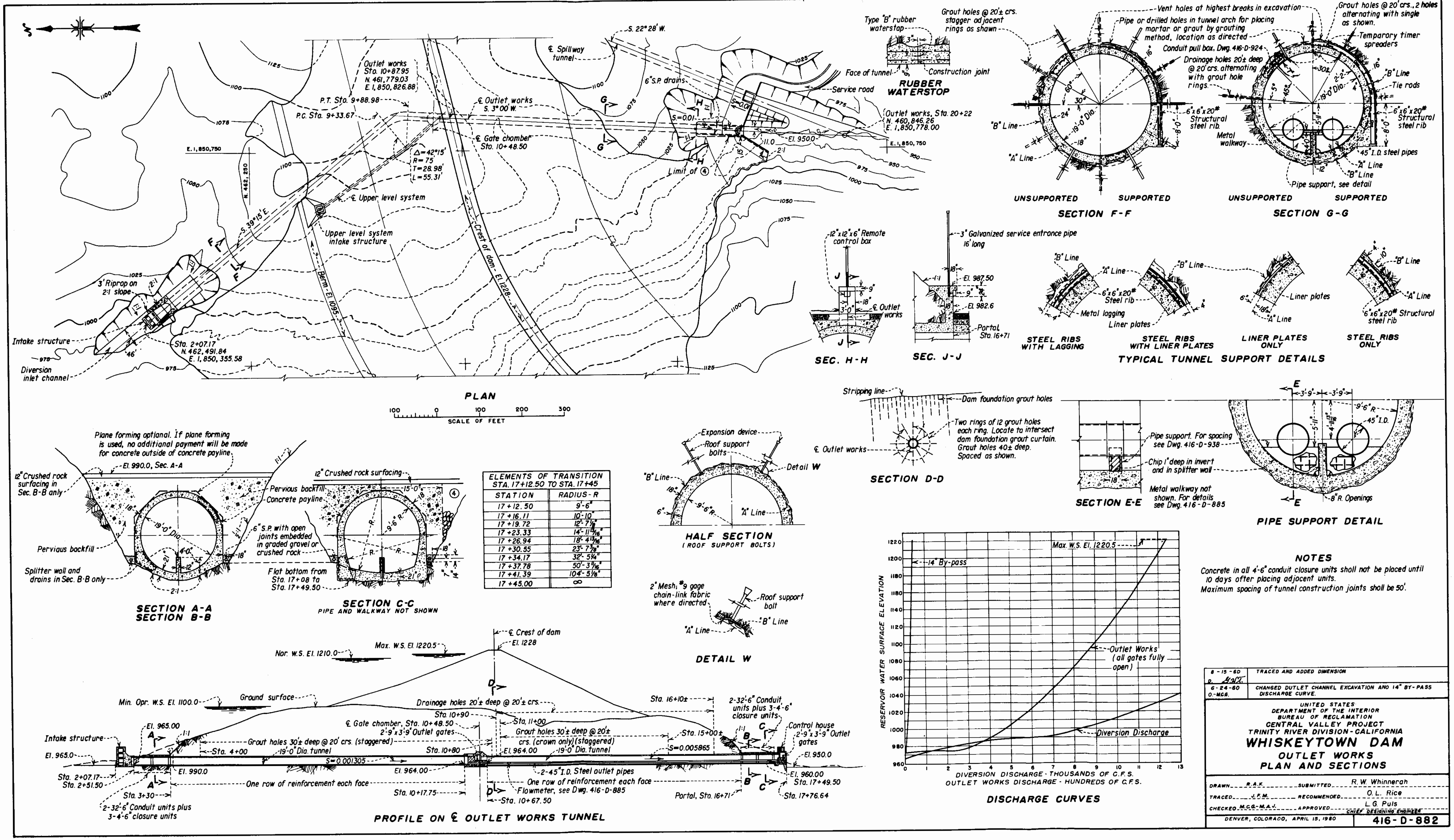
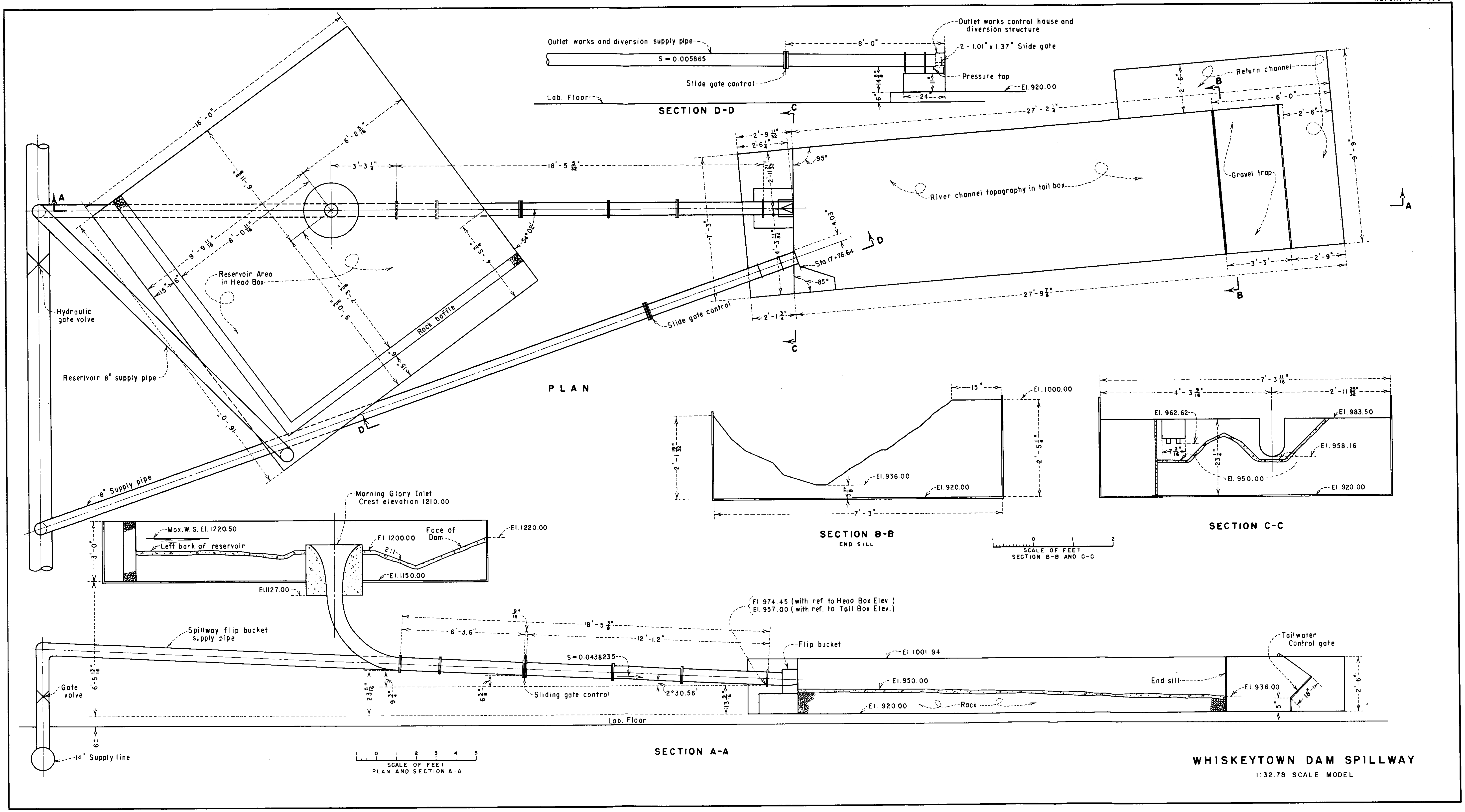

SECTION A-A
E£ Service Road
El. 981.5
El. 981.0
REFERENCE DRAWINGS
SPILLWAY-PLAN AND SECTIONS_____416-D-880
SPILLWAY-INLET AND FLIP BUCKET STRUCTURES___416-D-881
OUTLET WORKS-PLAN AND SECTIONS_____416-D-882
OUTLET WORKS-CONTROL HOUSE_____416-O-885
SPILLWAY AND OUTLET WORKS RETAINING WALLS_____416-D-886
PLAN
SCALE OF FEET
SECTION B-B
El. 950.0
El. 947.5
El. 945.5
7-15-60 TRACED, AND REVISED STRUCTURE EXCAVATION
6-24-60 REVISED SPILLWAY OUTLET CHANNEL EXCAVATION. ADDED CHANNEL IMPROVEMENT EXCAVATION
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
TRINITY RIVER DIVISION-CALIFORNIA
WHISKEYTOWN DAM
SPILLWAY AND OUTLET WORKS
OUTLET PORTALS AND CHANNELS-EXCAVATION
DRAWN H.J.O. SUBMITTED M.A. Jabara
TRACED J.L.V. RECOMMENDED R.W. Whinnerah
CHECKED M.A.J. APPROVED O.L. Rice CHIEF, DAMS BRANCH
DENVER, COLORADO, APRIL 21, 1960
416-D-888

FIGURE 6
REPORT HYD. 498



ELEMENTS OF TRANSITION STA. 17+12.50 TO STA. 17+45	
STATION	RADIUS - R
17 + 12.50	9'-6"
17 + 16.11	10'-10"
17 + 19.72	12'-7 1/8"
17 + 23.33	14'-11 [illegible]/16"
17 + 26.94	18'-4 13/16"
17 + 30.55	23'-7 3/8"
17 + 34.17	32'-5 1/4"
17 + 37.78	50'-3 11/16"
17 + 41.39	104'-5 1/8"
17 + 45.00	∞



WHISKEYTOWN DAM SPILLWAY

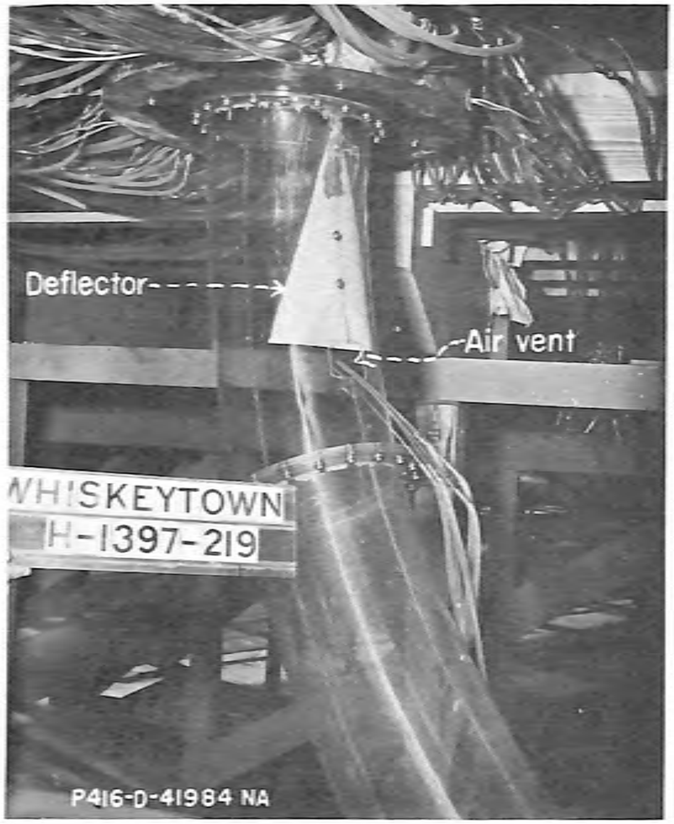
1:32.78 SCALE MODEL

A. Reservoir topography.

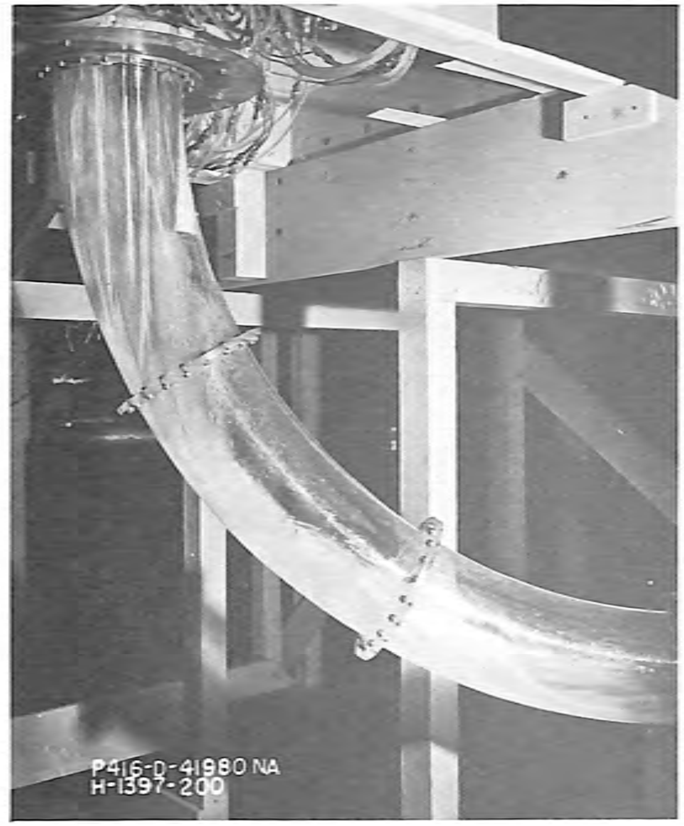
B. Inlet construction.

WHISKEYTOWN DAM SPILLWAY
RESERVOIR AND INLET CONSTRUCTION

1:32. 78 Scale Model



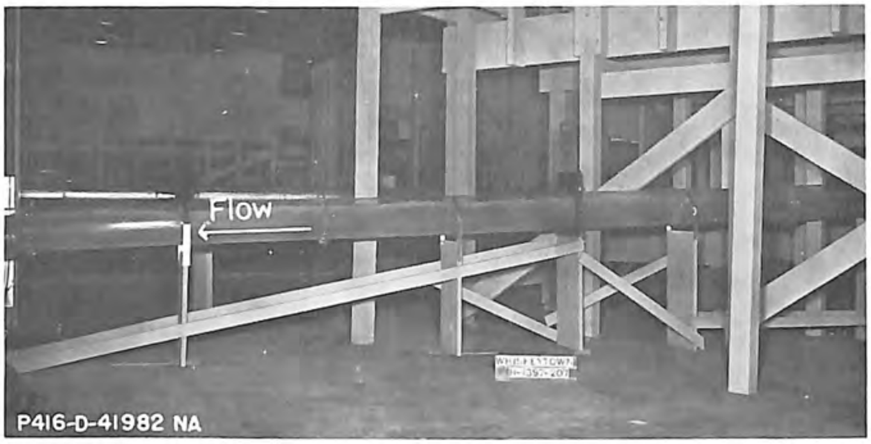
A. Deflector and air vent. Piezometer tubes through air vent extend to the crest piers.



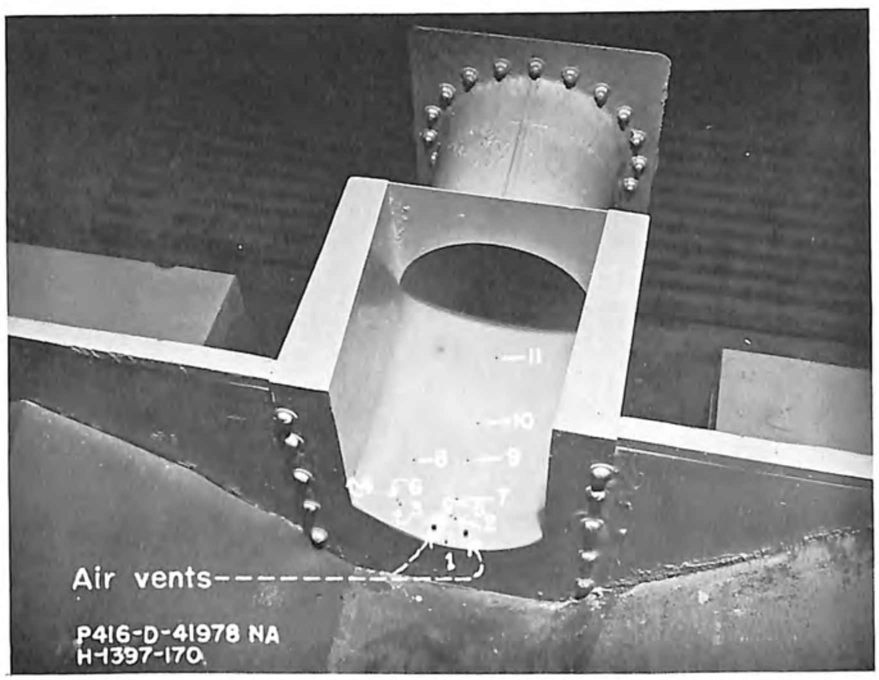
B. Flow in transparent plastic tunnel bend.

WHISKEYTOWN DAM SPILLWAY
VERTICAL BEND CONSTRUCTION

1:32.78 Scale Model



A. Horizontal tunnel.



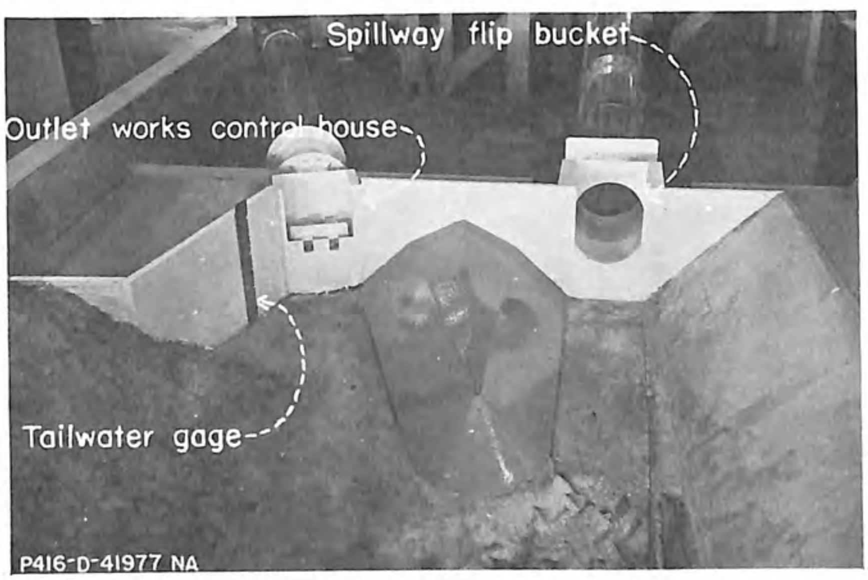
B. Recommended flip bucket showing piezometer locations. (Air vents not recommended.)

WHISKEYTOWN DAM SPILLWAY
TUNNEL AND FLIP BUCKET CONSTRUCTION

1:32.78 Scale Model

Figure 11
Report Hyd-498

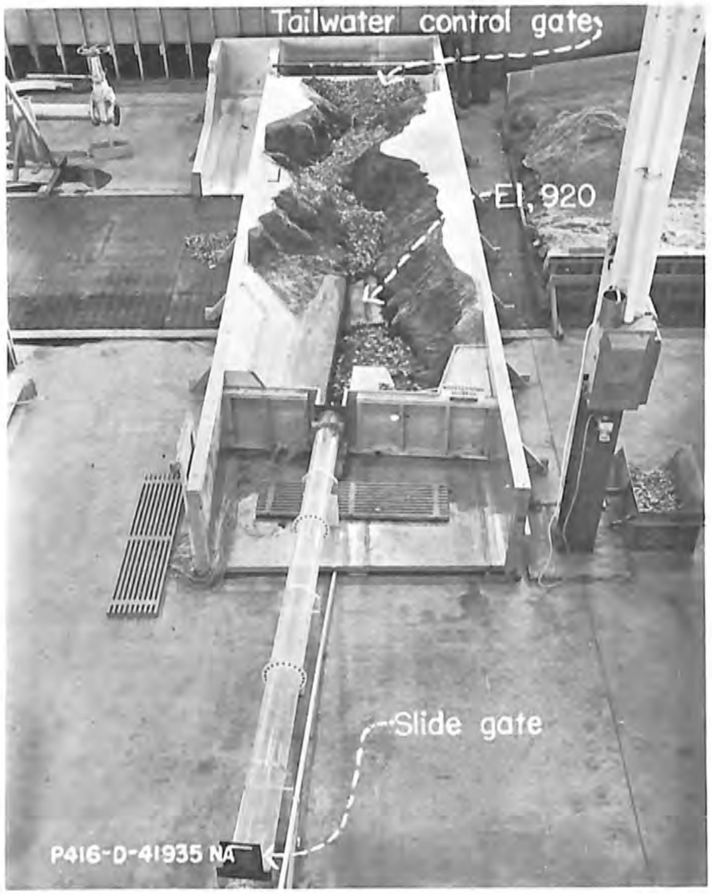
A. Diversion tunnel outlet portal and spillway flip bucket.

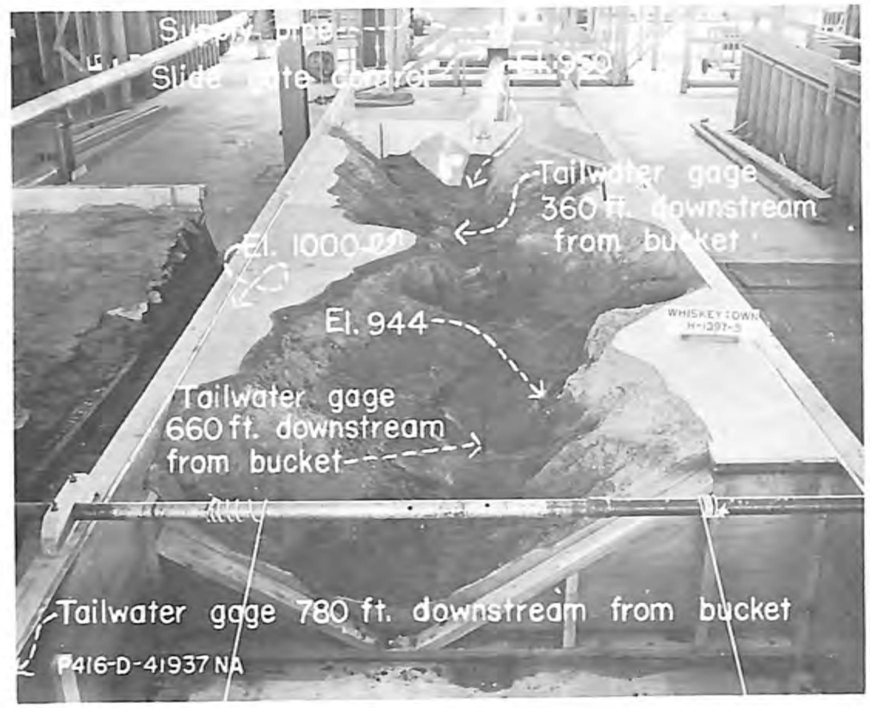


B. Outlet works structure and spillway flip bucket.

WHISKEYTOWN DAM SPILLWAY
OUTLET WORKS AND DIVERSION PORTAL AND SPILLWAY FLIP BUCKET

1:32.78 Scale Model

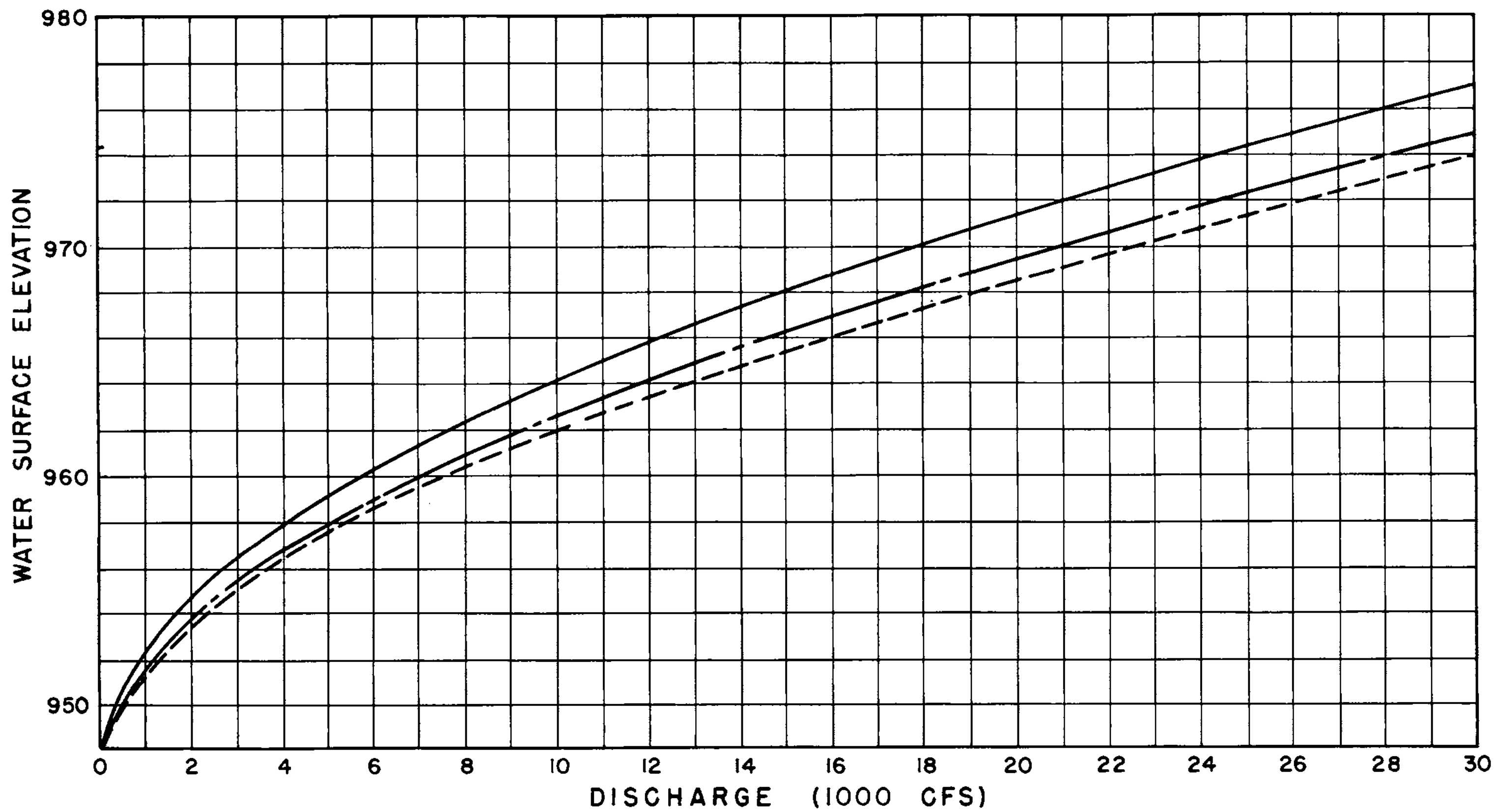




B. Stable streambed.

A. Spillway tunnel and
erodible streambed.

WHISKEYTOWN DAM SPILLWAY
SPILLWAY TUNNEL AND STREAM CHANNEL CONSTRUCTION



360 feet downstream from bucket
660 feet downstream from bucket
780 feet downstream from bucket

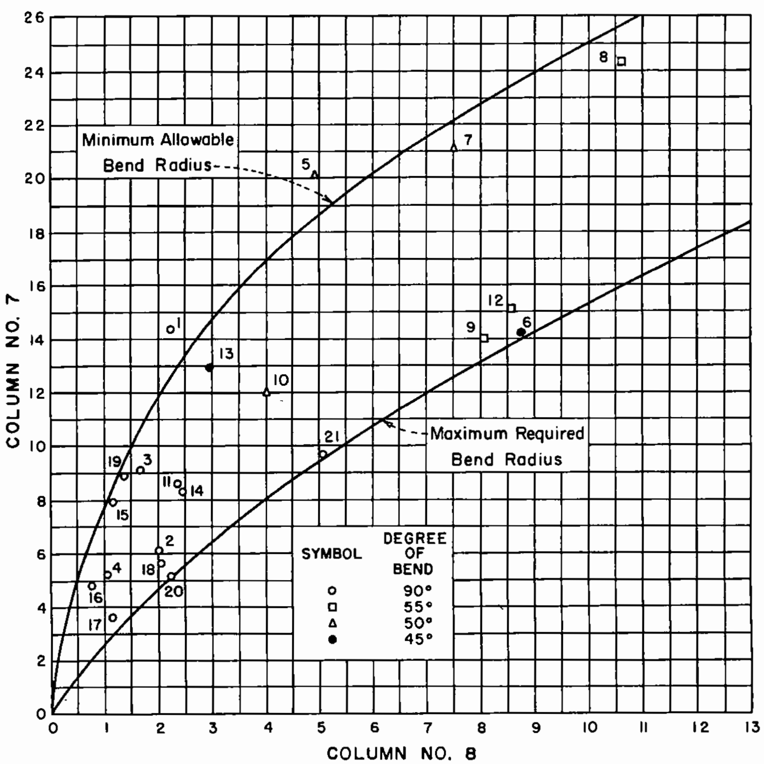
NOTE: Tailwater elevation in the model was controlled by the tailwater control gate 780 feet downstream from bucket.

WHISKEYTOWN DAM SPILLWAY

TAILWATER CURVES

FIGURE 13
REPORT HYD. 498

627



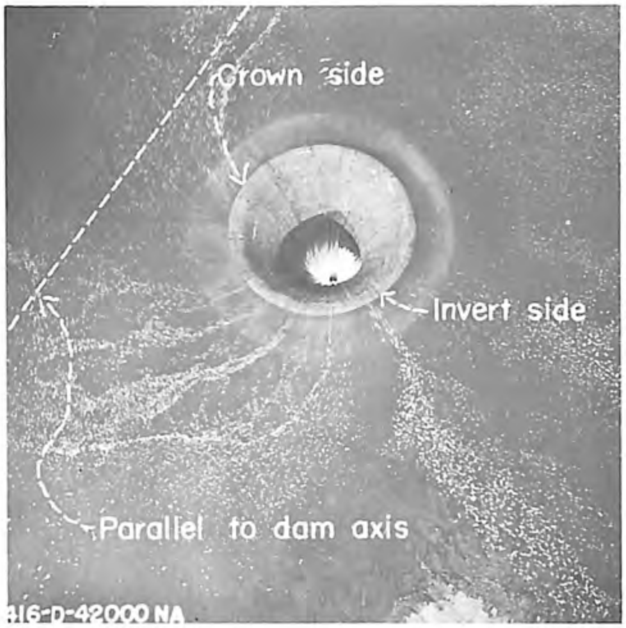
*	DAMS	COLUMNS							
		1	2	3	4	5	6	7	8
1	Owyhee	40000	22.5'	Circular	323'	90°	50'	14.36	2.22
2	Gibson	50000	29.5'	Circular	179'	90°	59'	6.07	2.00
3	Heart Butte	5600	11' to 14'	Circular	113'	90°	21'	9.06	1.68
4	Shade Hill	5400	12.5' to 13.5'	Circular	67'	90°	14'	5.16	1.07
5	Hungry Horse	49400	24.5'	Circular	492'	50°	120'	20.06	4.90
6	Wu Sheh	66000	27'	Circular	383'	45°	236'	14.19	8.75
7	Trinity	23800	20'	Circular	422'	50°	150'	21.11	7.50
8	Flaming Gorge	28800	18'	Circular	437'	55°	191'	24.27	10.61
9	Glen Canyon	138000	41'	Circular	574'	55°	330'	13.99	8.04
10	Hoover		50'	Circular	601'	50°	200'	12.02	4.00
11	Lady Bower		15'	Circular	129'	90°	35'	8.57	2.33
12	Yellowtail	92000	32'	Circular	485'	55°	274'	15.14	8.56
13	Fontana	158000	34'	Circular	440'	45°	100'	12.94	2.94
14	Davis Bridge		22.5'	Circular	188'	90°	55'	8.34	2.44
15	Taf Fechon		13'	Circular	103'	90°	15'	7.92	1.15
16	Pontian Ketchie		13'	Circular	62'	90°	10'	4.78	0.77
17	Silent Valley		16'	Circular	57'	90°	18'	3.56	1.12
18	Monuherikia Falls		17'	Circular	96'	90°	35'	5.65	2.06
19	Burnhope		12'	Circular	106'	90°	16'	8.85	1.33
20	Kingsley		28.5'	Circular	148'	90°	64'	5.19	2.25
21	Whiskeytown	28650	24.5' to 21.0'	Circular	219'	90°	113.8' to 115.5'	9.64	5.06

*Number designates location on graph.

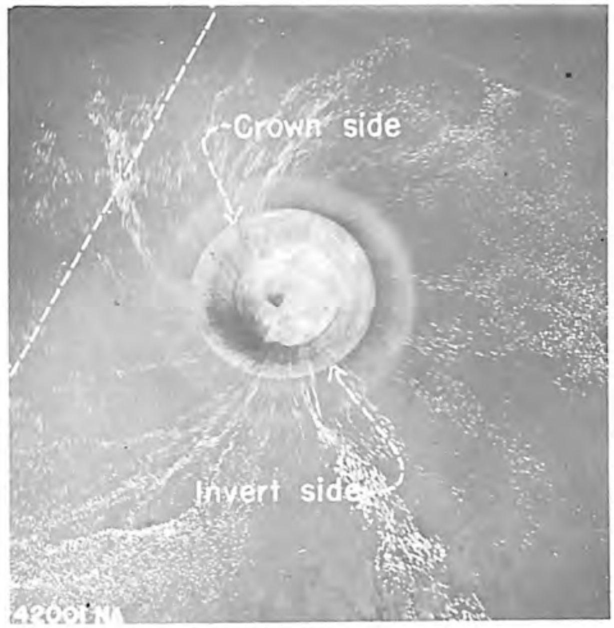
Column 1 – Discharge in c.f.s.
Column 2 – Bend tunnel diameter in feet
Column 3 – Tunnel shape through bend.
Column 4 – Reservoir elevation minus tunnel invert elevation at P.T. of Bend.
Column 5 – Degree of bend curvature.
Column 6 – Radius of bend on center line of tunnel.
Column 7 – Ratio of column 4 to column 2.
Column 8 – Ratio of column 6 to column 2.

WHISKEYTOWN DAM SPILLWAY

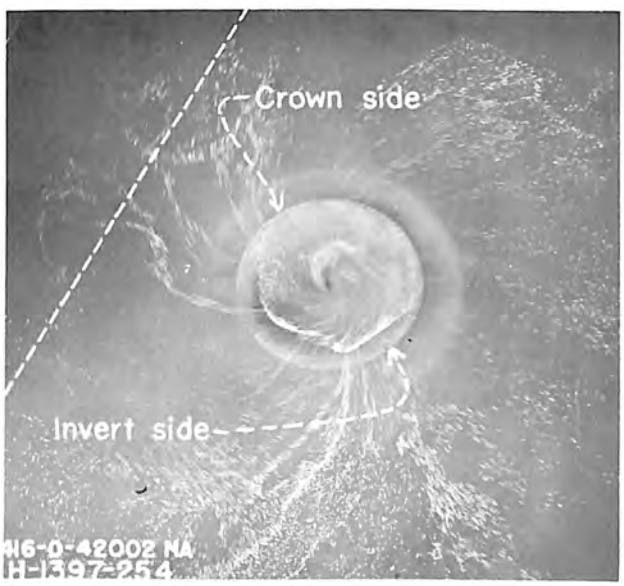
BEND RADIUS RELATIONSHIPS FOR OTHER SPILLWAYS



A. 14,250 cfs,
Res. El. 1215.7.



B. 28,780 cfs,
Res. El. 1218.9.



C. 30,300 cfs,
Res. El. 1225.5.

D. 32,300 cfs,
Res. El. 1231.2.

Note: See inlet topography in Figure 8. No guide vanes, deflector, or air vent.

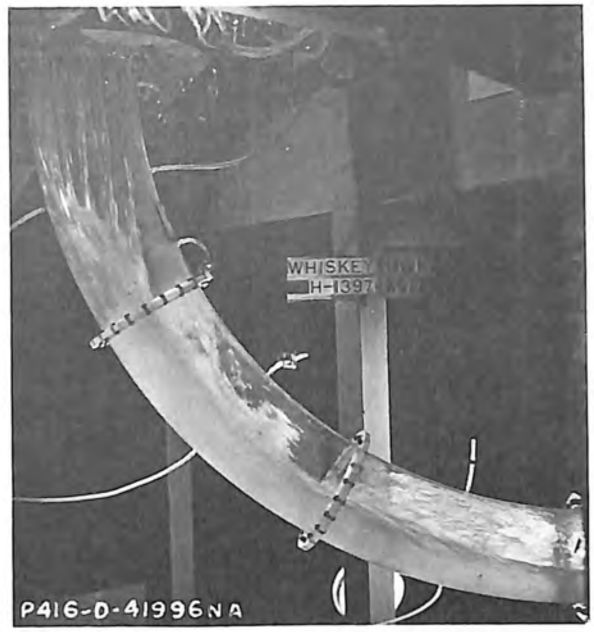
A and B are free flows.
C and D are submerged flows.

WHISKEYTOWN DAM SPILLWAY
FLOW IN PRELIMINARY MORNING-GLORY INLET

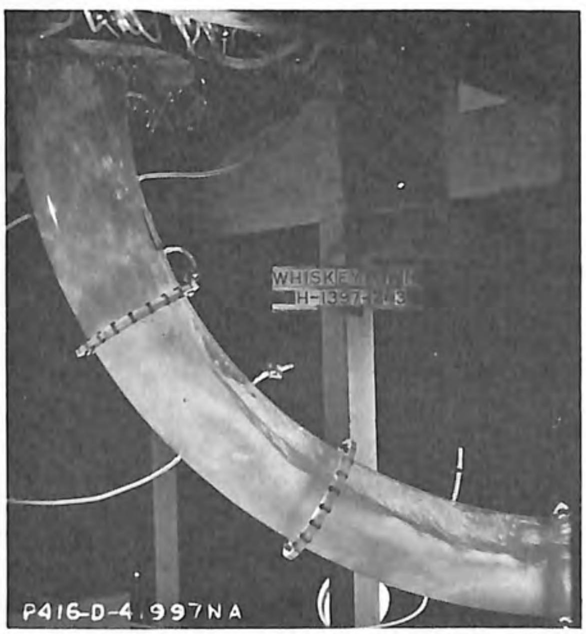
1:32.78 Scale Model

Figure 16
Report Hyd-498

A. 3,560 cfs



B. 14,250 cfs



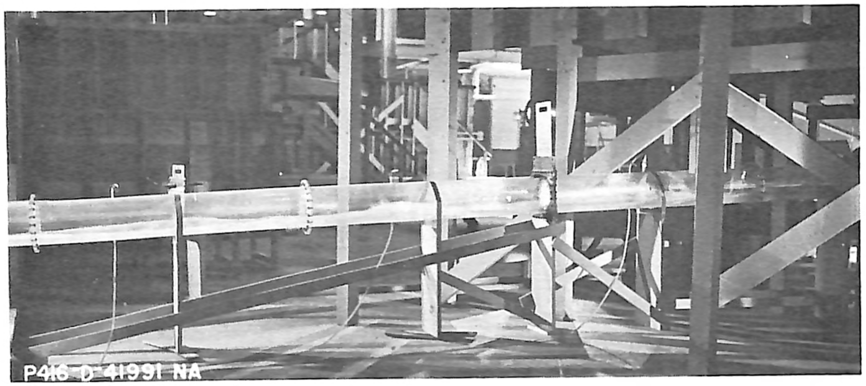
C. 28,780 cfs

D. 32,300 cfs

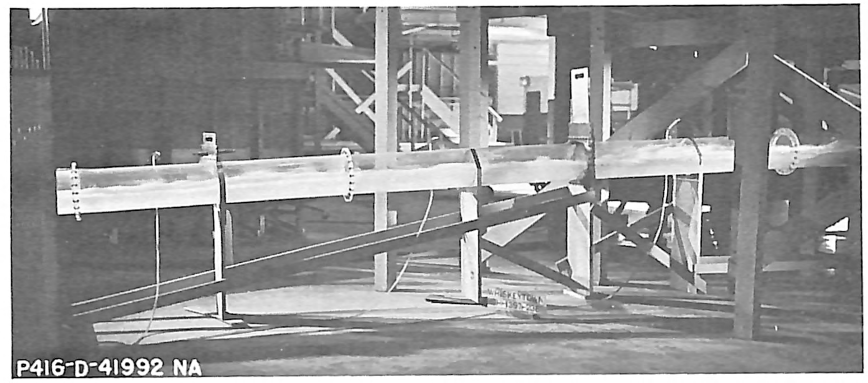
Note: No rib vanes, deflector or air vent.

WHISKEYTOWN DAM SPILLWAY
FLOW IN BEND WITH PRELIMINARY INLET

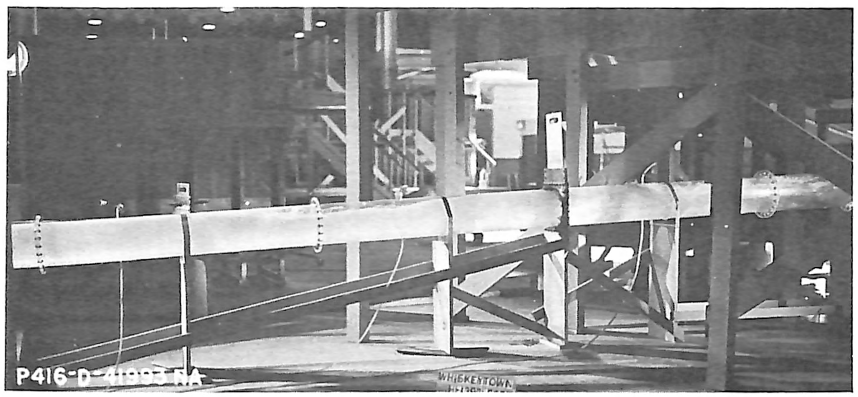
1:32.78 Scale Model



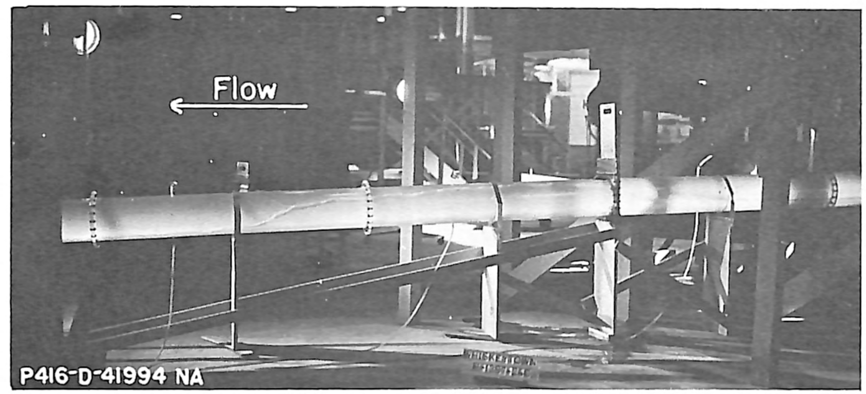
A. 3, 560 cfs



B. 14, 250 cfs



C. 28, 780 cfs

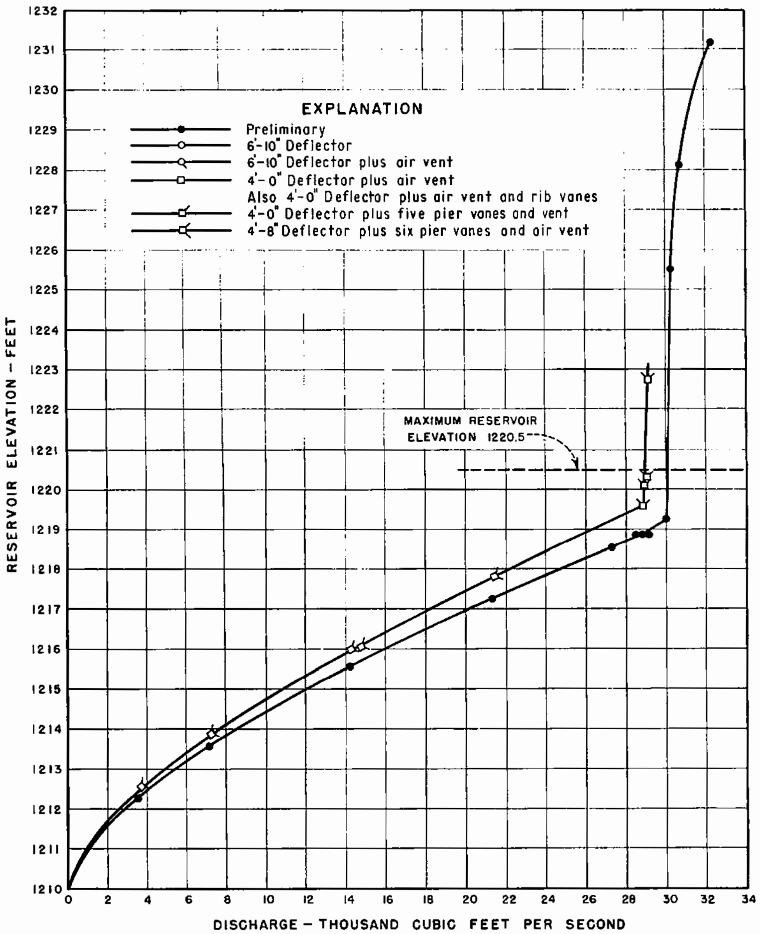


D. 32, 300 cfs

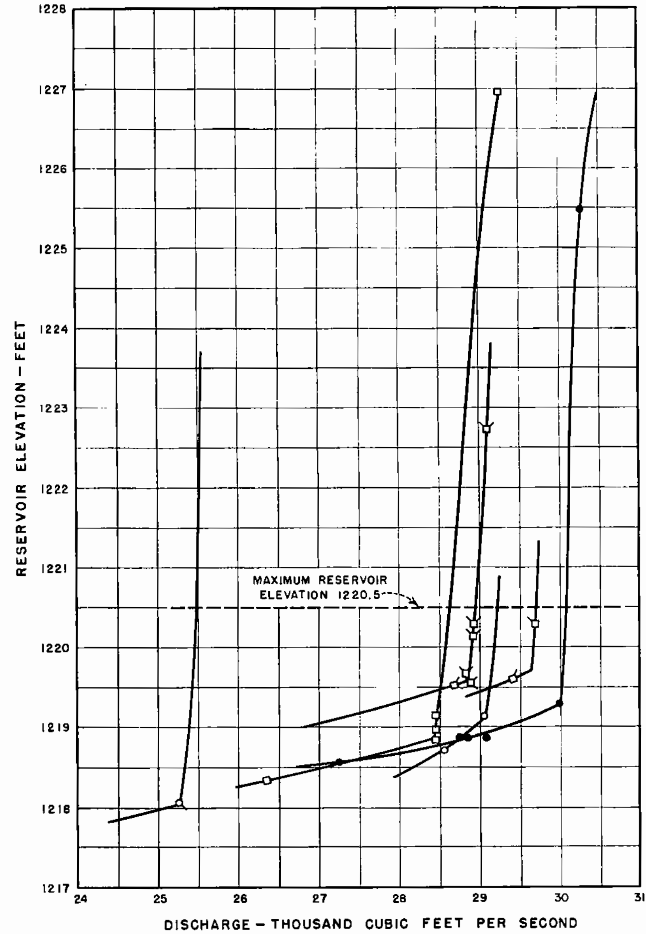
Note: No rib vanes, deflector or air vent.

WHISKEYTOWN DAM SPILLWAY
FLOW IN TUNNEL WITH PRELIMINARY INLET

1:32. 78 Scale Model



A.



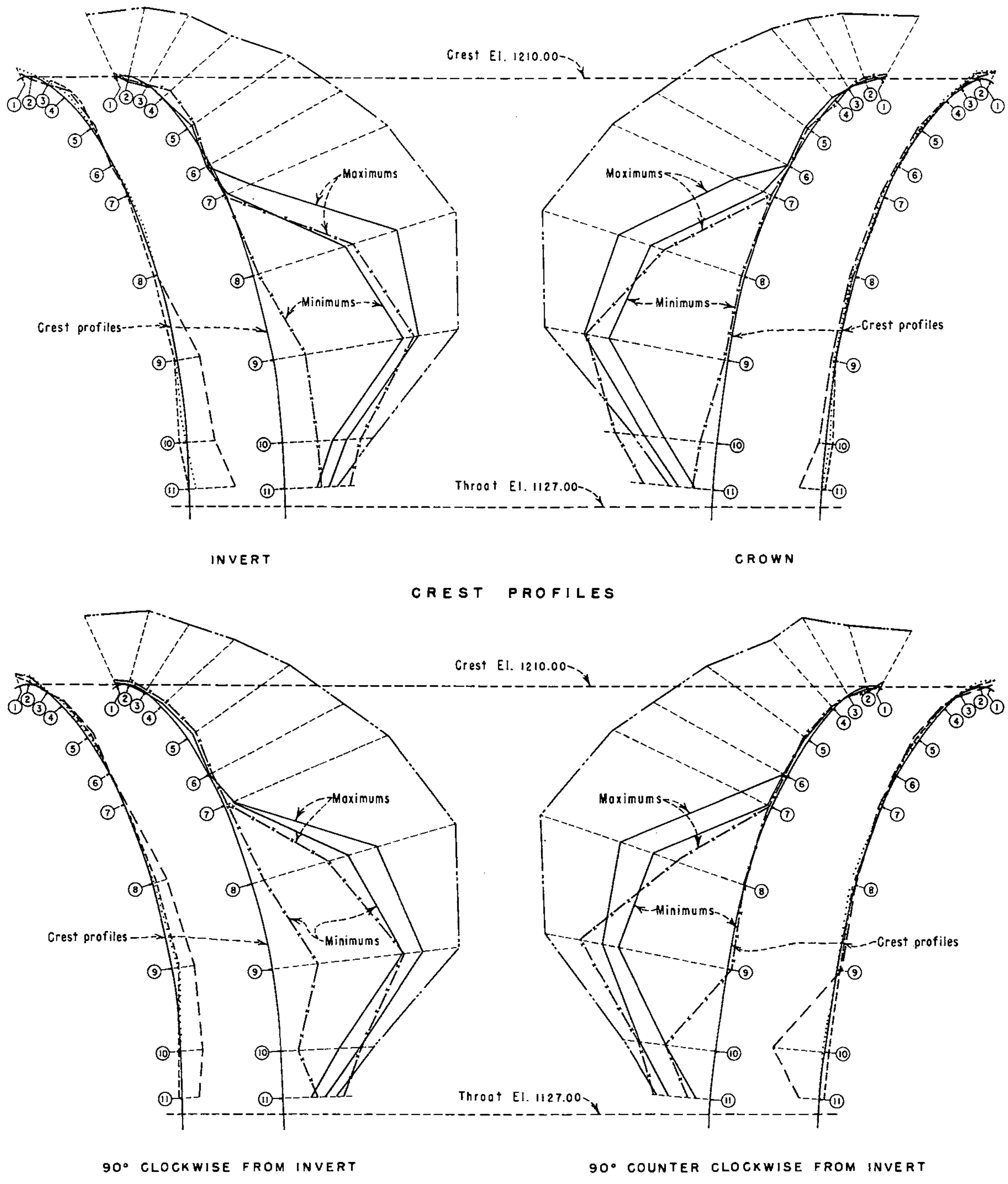
B. (ENLARGEMENT OF "A")

WHISKEYTOWN DAM SPILLWAY

DISCHARGE CAPACITY CURVES FOR PRELIMINARY DESIGNS

1:32.78 SCALE MODEL

FIGURE 18
REPORT HYD. 498



NOTES

- Discharge = 7250 C.F.S.
- Discharge = 14250 C.F.S.
- Discharge = 25890 C.F.S.
- Discharge = 26850 C.F.S. *
- Discharge = 28450 C.F.S.
- Discharge = 30590 C.F.S.

Circled numbers designate piezometer locations.
Crest profile is the zero pressure datum.
Pressures above atmospheric are plotted toward the center of the morning-glory.
*Boil elevation fluctuated in lower portion of morning glory.

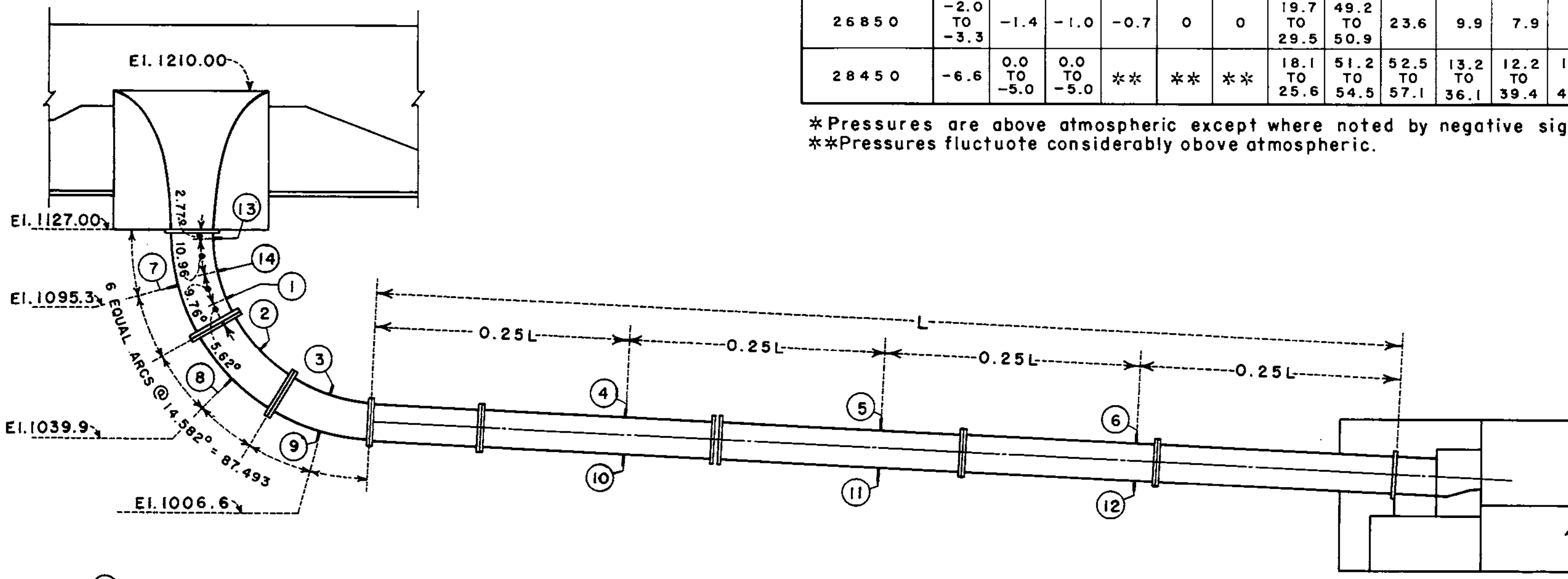
WHISKEYTOWN DAM SPILLWAY

PRESSURES IN PRELIMINARY INLET

1:32.78 SCALE MODEL

DISCHARGE C.F.S.	* PIEZOMETRIC PRESSURES IN PROTOTYPE FEET OF WATER													
	P I E Z O M E T E R S													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
7125	0	0	0	0	0	0	0.7	17.1	16.4	-0.4	0.4	2.0	-1.7 TO -6.6	-2.0
14250	0	0	0	0	0	0	17.4	27.3	—	1.7	2.0	4.3	-3.3 TO -7.6	-3.3 TO -6.6
21375	0.4	0	0	0	0	0	20.7	40.7	15.1	8.2	6.6	6.6	-3.7 TO -7.6	-2.7
25890	-1.0	-0.7	-1.0	0	0	0	28.2	50.5	21.4	6.3	5.6	8.6	-2.3 TO -6.6	-8.2
26850	-2.0 TO -3.3	-1.4	-1.0	-0.7	0	0	19.7 TO 29.5	49.2 TO 50.9	23.6	9.9	7.9	7.3	-8.6	-10.9
28450	-6.6	0.0 TO -5.0	0.0 TO -5.0	**	**	**	18.1 TO 25.6	51.2 TO 54.5	52.5 TO 57.1	13.2 TO 36.1	12.2 TO 39.4	12.2 TO 42.7	-11.2	-15.1

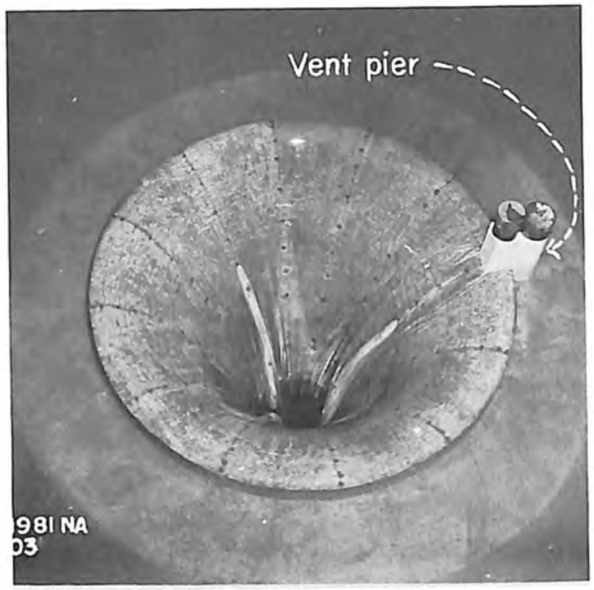
*Pressures are above atmospheric except where noted by negative sign
**Pressures fluctuote considerably obove atmospheric.



(No.) Designates piezometer location
L Denotes the model tunnel length (604.72 feet)

WHISKEYTOWN DAM SPILLWAY
PRESSURES IN TUNNEL WITH PRELIMINARY INLET
1:32.78 SCALE MODEL

FIGURE 20
REPORT HYD. 498



A. Three rib vanes and vent pier (3, 125 cfs).

B. Five pier vanes including one with vent intake (28, 780 cfs).

WHISKEYTOWN DAM SPILLWAY
MORNING-GLORY INLET MODIFICATIONS

1:32. 78 Scale Model

Figure 22
Report Hyd-498

A. Six rib vanes, air vent pier and 4'-8" deflector in bend.

B. 3,560 cfs, Res. El. 1212.4.

C. 7,125 cfs, Res. El. 1213.8.

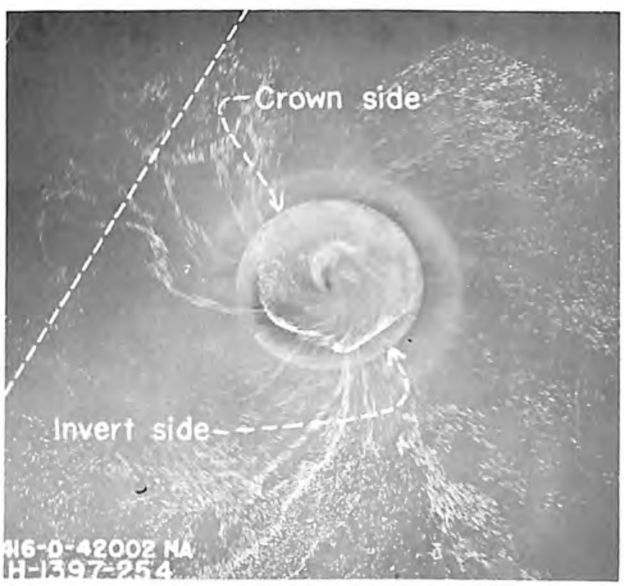
D. 14,250 cfs, Res. El. 1215.8.

WHISKEYTOWN DAM SPILLWAY
FLOW IN RECOMMENDED MORNING-GLORY INLET

1:32.78 Scale Model

A. Boil forms in throat
27,000 cfs,
Res. El. 1218.7.

B. 28,450 cfs,
Res. El. 1218.9
(Maximum free flow).



C. 28,750 cfs,
Res. El. 1226±
(Submerged flow).

D. 29,320 cfs,
Res. El. 1230±

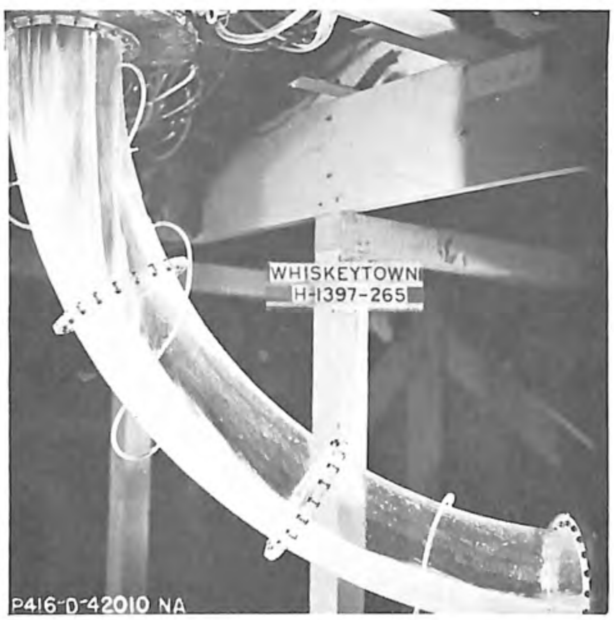
WHISKEYTOWN DAM SPILLWAY
FLOW IN RECOMMENDED MORNING-GLORY INLET

1:32.78 Scale Model

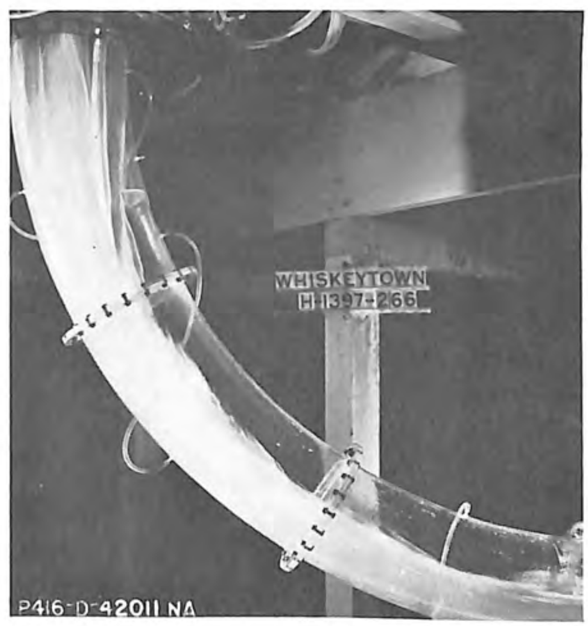
Figure 24
Report Hyd-498

A. Deflector and air vent.

B. 3,560 cfs



C. 7,125 cfs

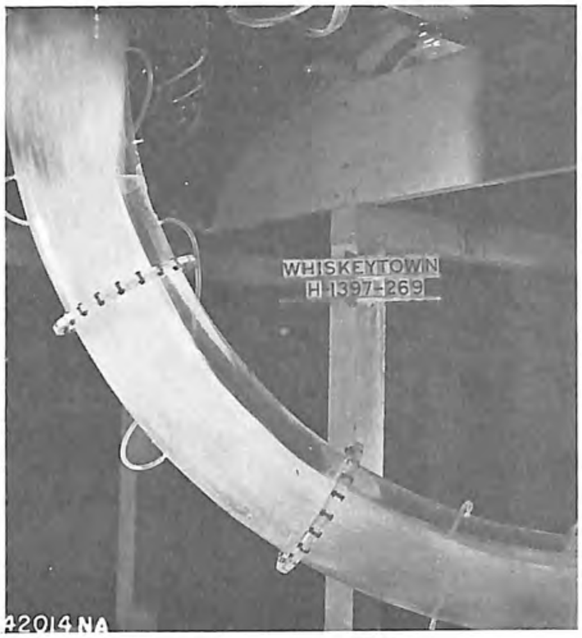


D. 14,250 cfs

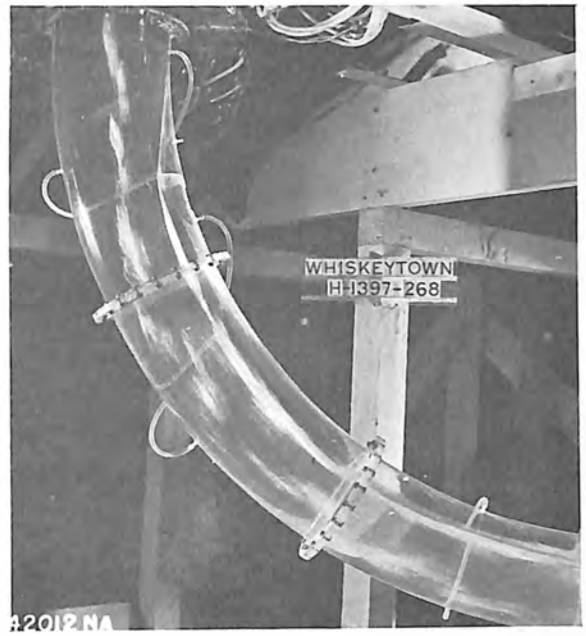
Note: White water indicates air is drawn through inlet.

WHISKEYTOWN DAM SPILLWAY
FLOW IN BEND WITH RECOMMENDED INLET

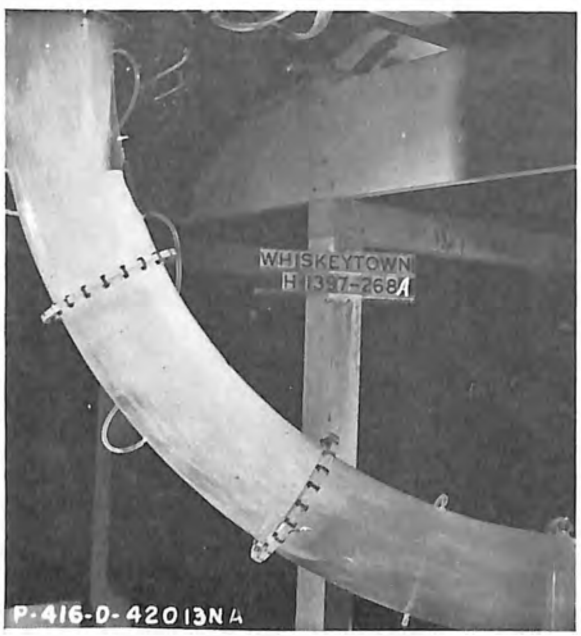
1:32.78 Scale Model



A. 27,000 cfs



B. 28,450 cfs (Note small vortex from inlet.)



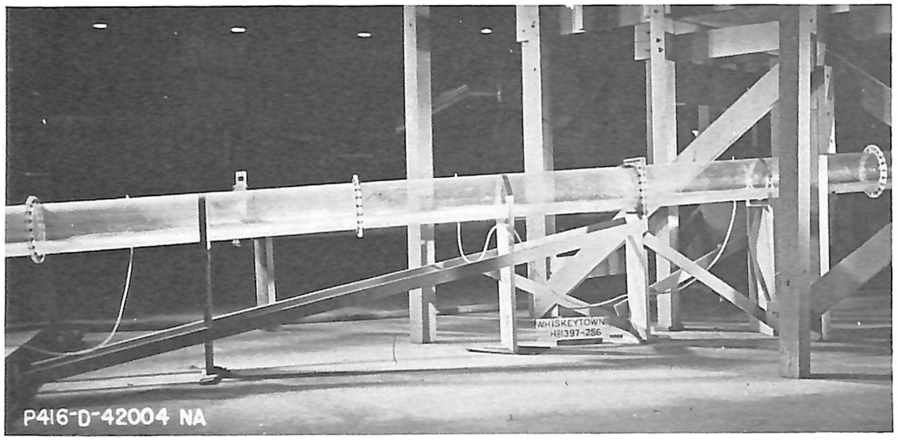
C. 28,450 cfs (Air vent closed.)

D. 29,320 cfs (Note vortex from inlet.)

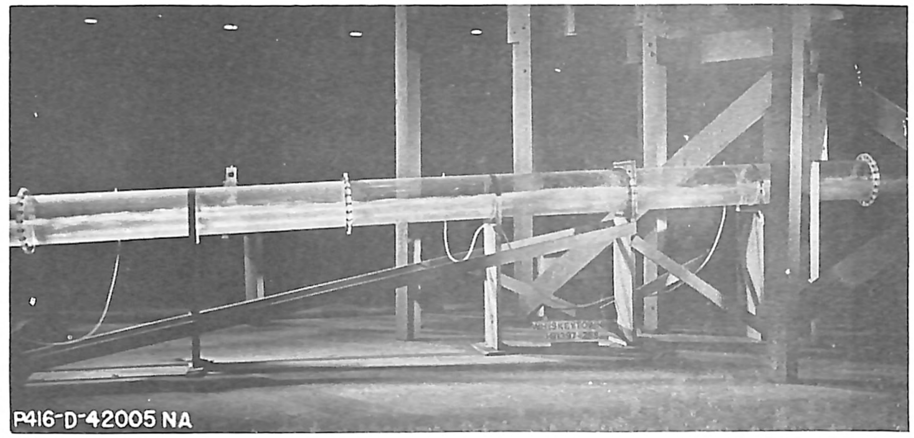
Note: Clear water indicates air is drawn through air vent and vortex.
White water indicates air is drawn through inlet.

WHISKEYTOWN DAM SPILLWAY
FLOW IN BEND WITH RECOMMENDED INLET

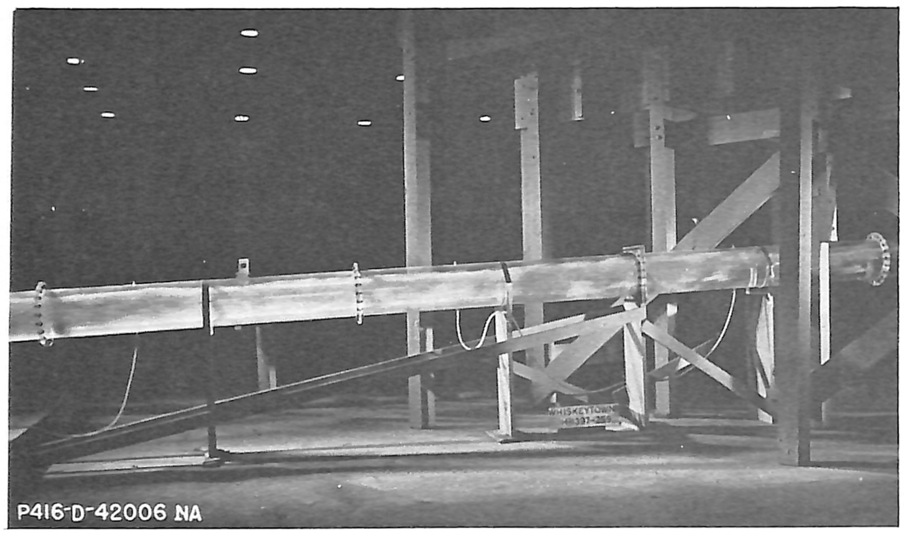
1:32.78 Scale Model



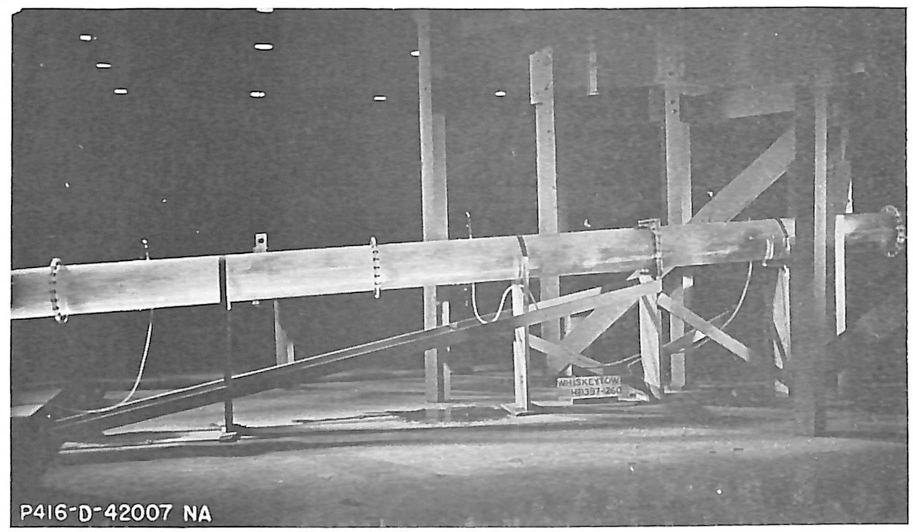
A. 3,560 cfs



B. 14,250 cfs



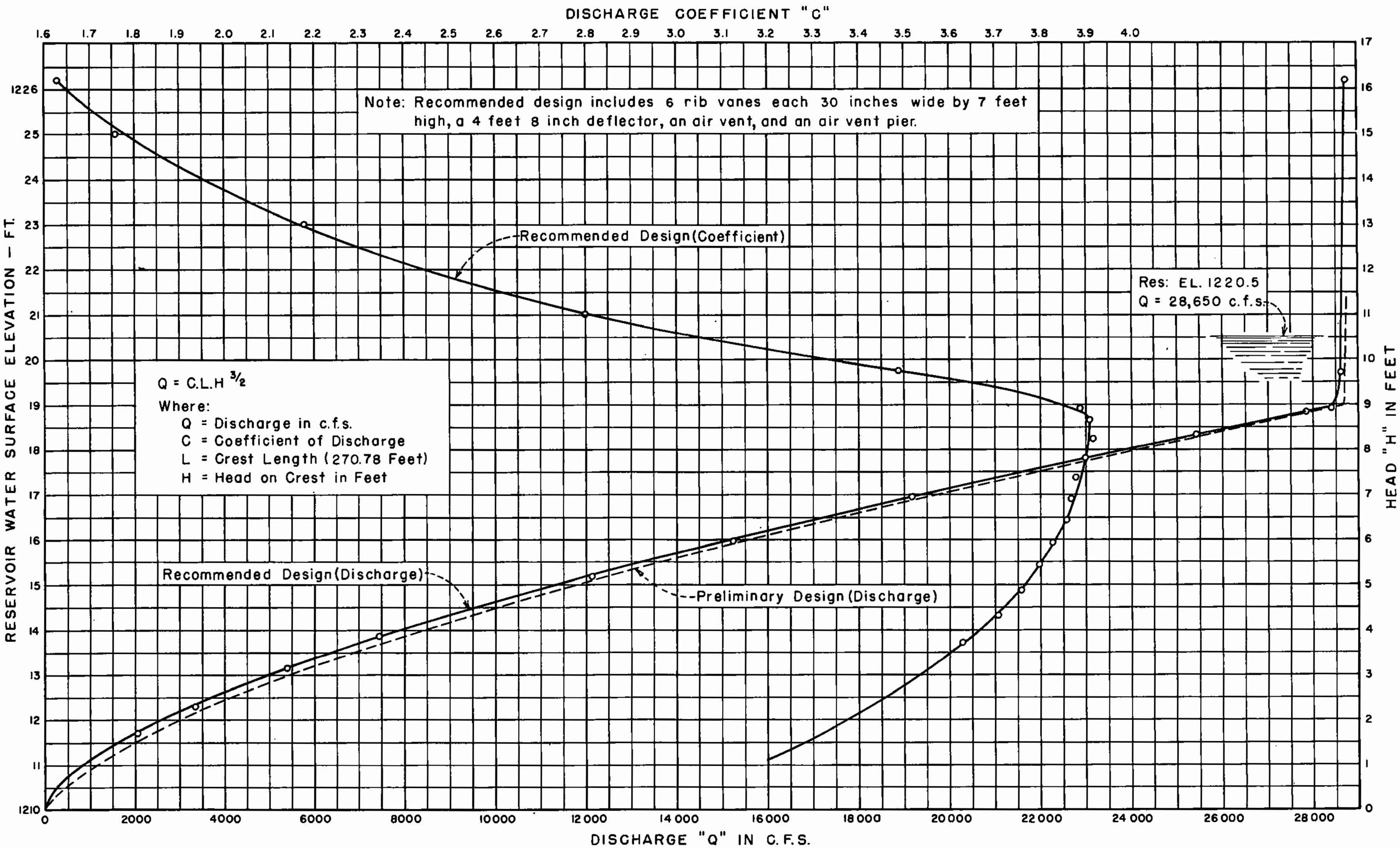
C. 28,450 cfs



D. 28,450 cfs; air vent closed, note positive pressure forcing flow out crown piezometers.

WHISKEYTOWN DAM SPILLWAY
FLOW IN TUNNEL WITH RECOMMENDED INLET

1:32.78 Scale Model

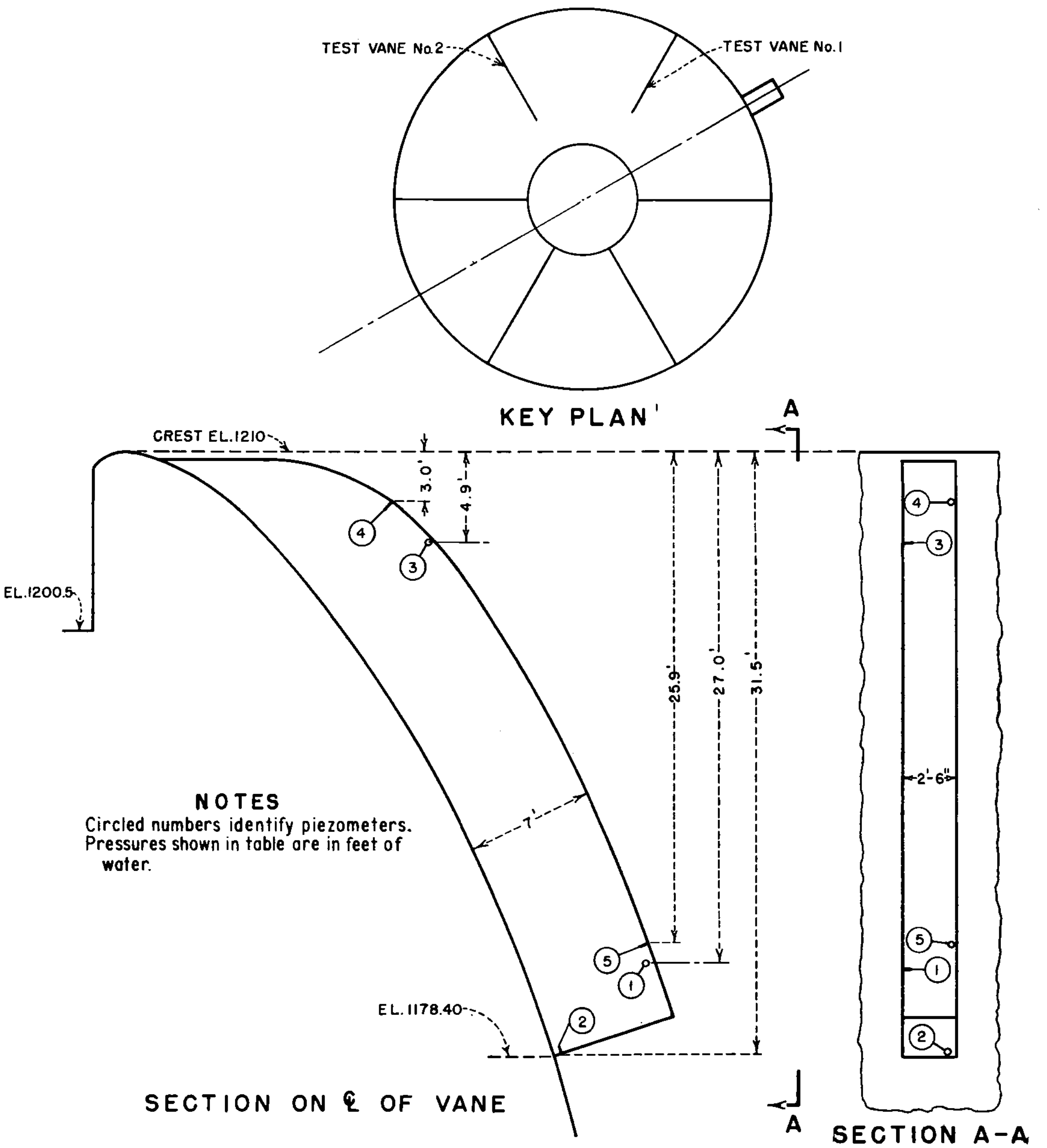


WHISKEYTOWN DAM SPILLWAY

DISCHARGE CAPACITY AND COEFFICIENT CURVES

1:32.78 SCALE MODEL

FIGURE 27
REPORT HYD. 498



NOTES
Circled numbers identify piezometers.
Pressures shown in table are in feet of water.

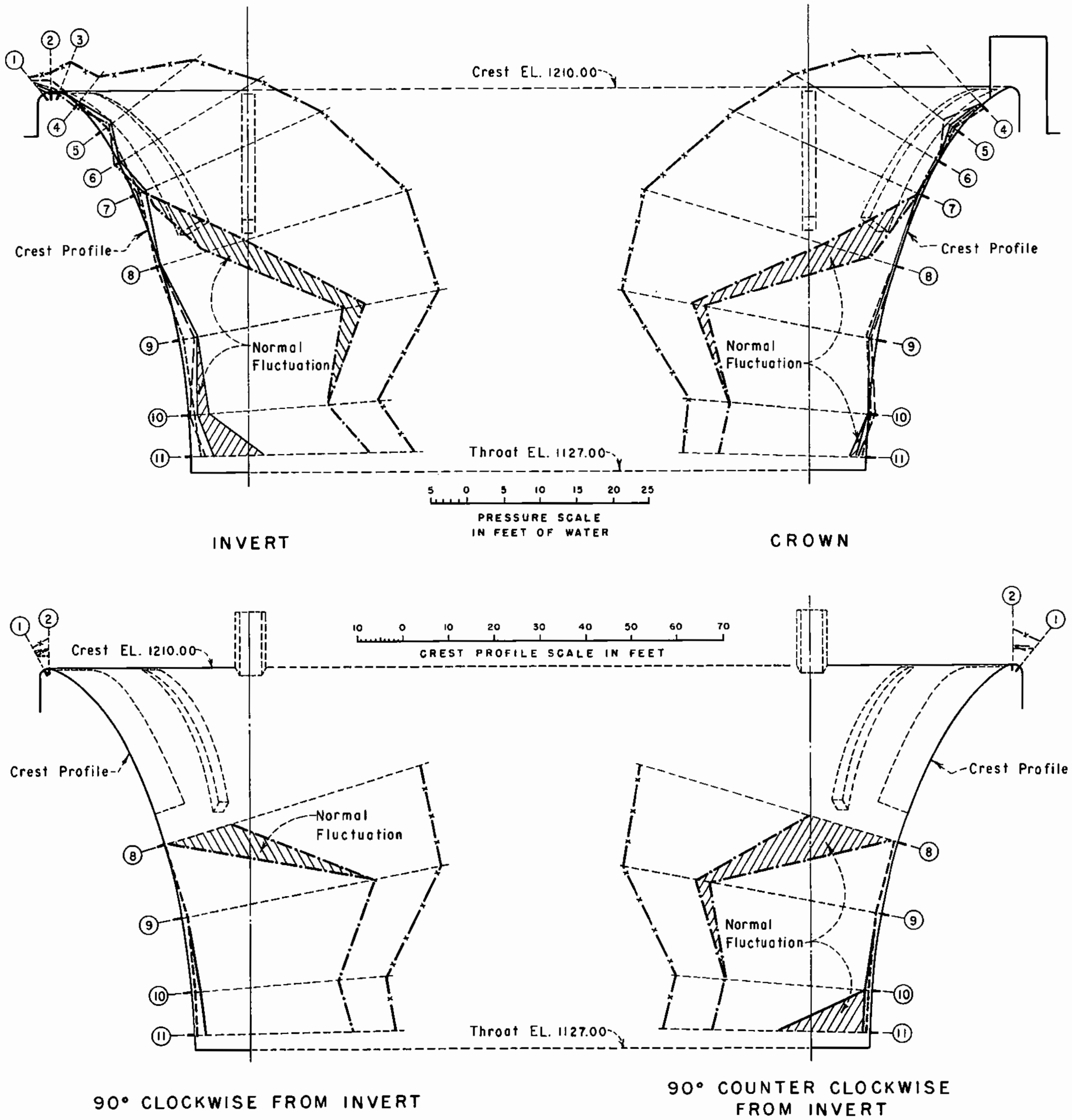
TEST VANE	DISCHARGE (C.F.S.)	PRESSURE AT PIEZOMETERS					REMARKS
		1	2	3	4	5	
1	25 890	+1.4	+0.4	−0.7	−1.7	0	No boil
	27 000	+1.0	+0.7	−0.7	−1.7	0	Boil at base of crest vane *
	28 750	+33.8	+34.5	+16.1	+12.5	+32.2	Reservoir elevation 1225.5± *
2	25 890	+0.4	0	−2.0	−0.4	+0.4	No boil
	27 000	+5.6	+11.8	+1.0	−0.7	+2.3	Boil at base of crest vane.*
	28 750	+32.8	+34.8	+15.8	14.5	+32.8	Reservoir elevation 1225.5 ±*

* See Figure 23

WHISKEYTOWN DAM SPILLWAY

RIB VANE PRESSURES — RECOMMENDED DESIGN

1:32.78 SCALE MODEL



DISCHARGE C.F.S.	INSTANTANEOUS DYNAMIC PRESSURE FLUCTUATION ABOVE AND BELOW AVERAGE									
	PIEZOMETERS ON INVERT SIDE OF INLET									
	2		4		6		8		10	
	NORMAL	MAXIMUM	NORMAL	MAXIMUM	NORMAL	MAXIMUM	NORMAL	MAXIMUM	NORMAL	MAXIMUM
7125	0.1	0.2	0.1	0.2	0.1	0.2	0	0	0.5	1.0
21375	0.4	0.9	0.4	0.7	0.5	0.7			1.2	2.6
27000	0.4	0.5	0.3	0.4	0.3	0.4			2.3	5.6
28600	0.3	0.6	0.3	0.5	0.6	1.0	1.6	4.1	2.3	8.2

All pressures are in prototype feet of water.

EXPLANATION
FOR PRESSURE GRADIENTS

- 7125 C.F.S.
- 21375 C.F.S.
- 25890 C.F.S.
- 27000 C.F.S.
- 28600 C.F.S.

NOTES

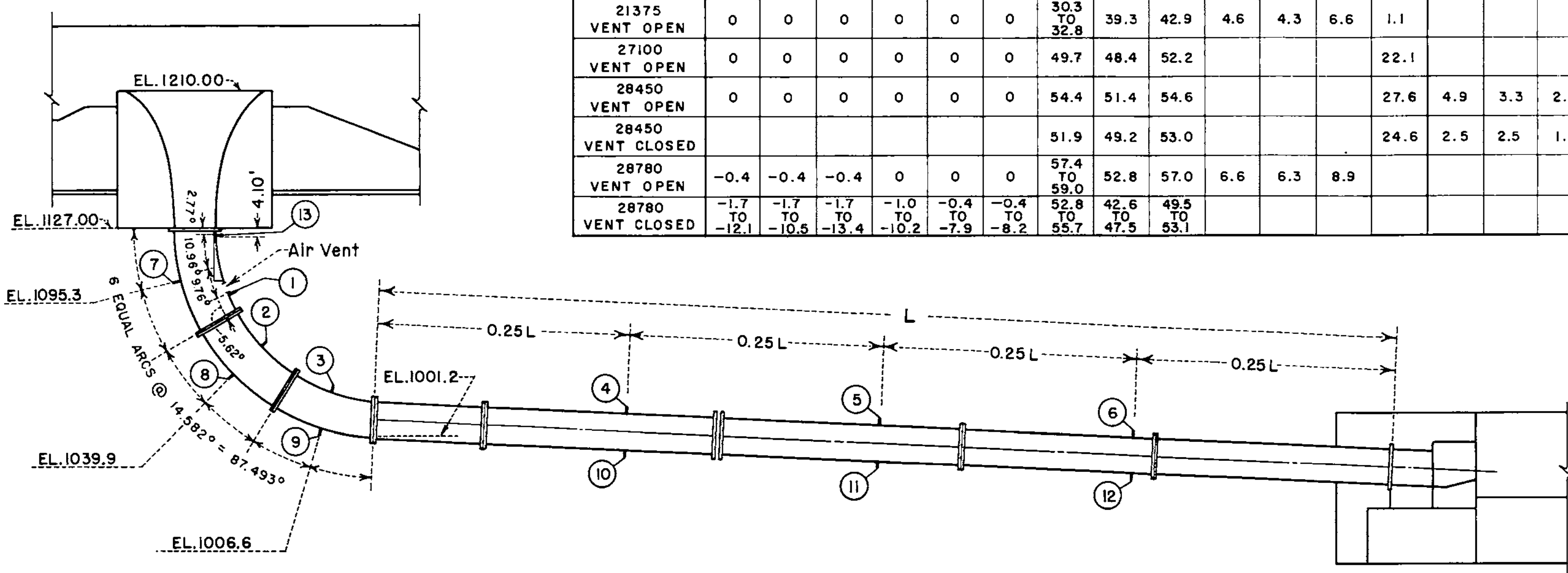
Crest profile is zero pressure datum.
Pressures above atmospheric are plotted toward the center of the morning-glory.
Circled numbers designate piezometer locations.

WHISKEYTOWN DAM SPILLWAY

PRESSURES IN RECOMMENDED INLET

1:32.78 SCALE MODEL

DISCHARGE C.F.S.	PIEZOMETRIC PRESSURES IN PROTOTYPE FEET OF WATER													NORMAL DYNAMIC PRESSURE FLUCTUATION ABOVE OR BELOW AVERAGE				
	PIEZOMETERS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	7	8	9	10	13
3560 VENT OPEN	0	0	0	0	0	0	3.0 TO 4.1	11.2	7.9				0	4.9	1.6	1.3	2.5	0
7125 VENT OPEN	0	0	0	0	0	0	5.4 TO 17.8	14.2	17.5	−1.3	−0.7	1.0	0	5.9	3.3	1.3	2.5	0
14250 VENT OPEN	0	0	0	0	0	0	27.9 TO 33.6	27.6	30.3	1.4	1.7	4.0	0.5					
21375 VENT OPEN	0	0	0	0	0	0	30.3 TO 32.8	39.3	42.9	4.6	4.3	6.6	1.1					
27100 VENT OPEN	0	0	0	0	0	0	49.7	48.4	52.2				22.1					
28450 VENT OPEN	0	0	0	0	0	0	54.4	51.4	54.6				27.6	4.9	3.3	2.0	3.3	4.6
28450 VENT CLOSED							51.9	49.2	53.0				24.6	2.5	2.5	1.3	3.3	2.6
28780 VENT OPEN	−0.4	−0.4	−0.4	0	0	0	57.4 TO 59.0	52.8	57.0	6.6	6.3	8.9						
28780 VENT CLOSED	−1.7 TO −12.1	−1.7 TO −10.5	−1.7 TO −13.4	−1.0 TO −10.2	−0.4 TO −7.9	−0.4 TO −8.2	52.8 TO 55.7	42.6 TO 47.5	49.5 TO 53.1									

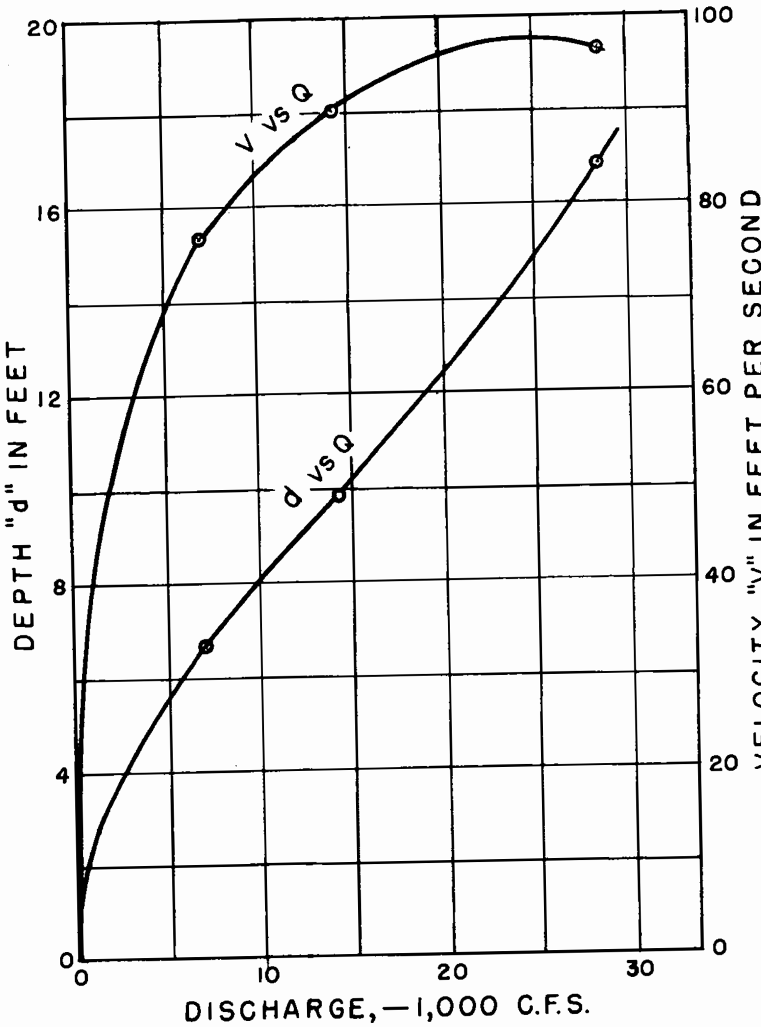


(No.) Designates piezometer location
"L" is the model length of tunnel (604.72 feet)

WHISKEYTOWN DAM SPILLWAY

PRESSURES IN TUNNEL WITH RECOMMENDED INLET

1:32.78 SCALE MODEL



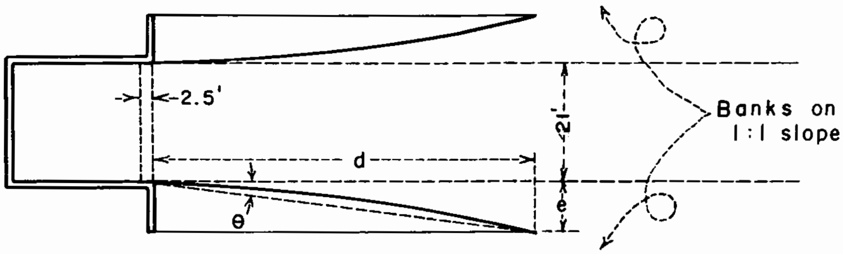
*F = $\frac{V}{\sqrt{gd}}$

DISCHARGE IN C.F.S.	TOTAL HEAD IN FT.	d IN FT.	V IN FT.	VELOCITY HEAD IN FT.	% OF HEAD LOSS	FROUDE No. F*
7125	256.7	6.6	76.1	89.9	62.4	5.2
14 250	258.8	9.8	90.0	125.8	47.6	5.0
21375	260.4	13.1	97.0	146.1	38.9	4.4
28780	263.5	17.1	96.0	143.1	39.2	3.9

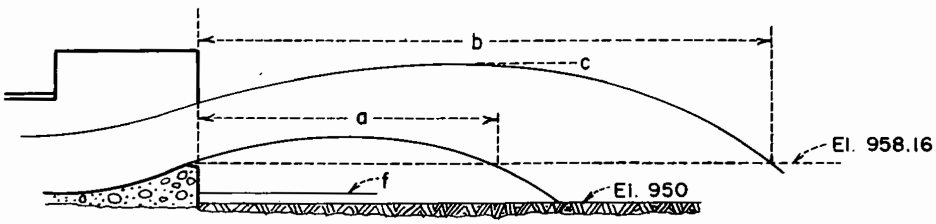
WHISKEYTOWN DAM SPILLWAY

FLOW DEPTH AND VELOCITY AT DOWNSTREAM PORTAL

1:32.78 SCALE MODEL



PLAN



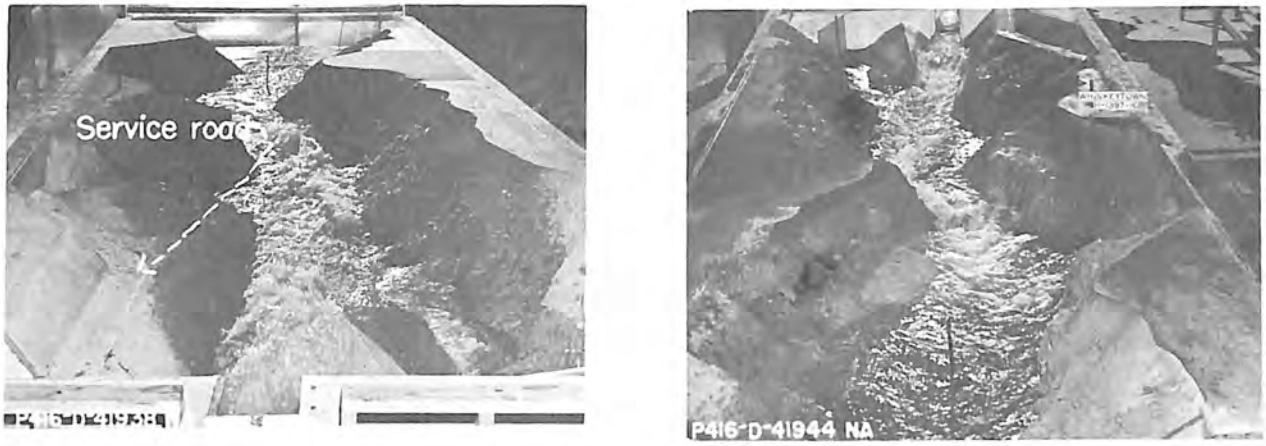
PROFILE

JET DIMENSIONS IN FEET							
DISCHARGE	a	b	c	d	e	f	θ
1/4 MAX.	49.2	98.3	966.4	49.2	8.2	DRY	9°-28'
1/2 MAX.	49.2	131.1	969.1	65.6	8.2	DRY	7°-08'
3/4 MAX.	32.8	147.6	970.5	54.6	6.8	951	7°-08'
FULL MAX.	27.3	153.0	973.9	57.4	6.8	954	6°-48'

EXPLANATION

a. Minimum length of jet projection.
b. Maximum length of jet projection.
c. Elevation at top of jet.
d. Distance at which jet strikes wall.
e. Side deflection where jet strikes wall.
f. Tailwater elevation.

WHISKEYTOWN DAM SPILLWAY
PRELIMINARY FLIP BUCKET JET DIMENSIONS
1:32.78 SCALE MODEL



A. 7,125 cfs--Tailwater Elevation 959.9

B. 14,250 cfs--Tailwater Elevation 965.4

C. 21,375 cfs--Tailwater Elevation 970.0

Tailwater elevations controlled at tailgate (see Figure 12).

WHISKEYTOWN DAM SPILLWAY
FLOW IN PRELIMINARY STABLE STREAM CHANNEL

1:32.78 Scale Model

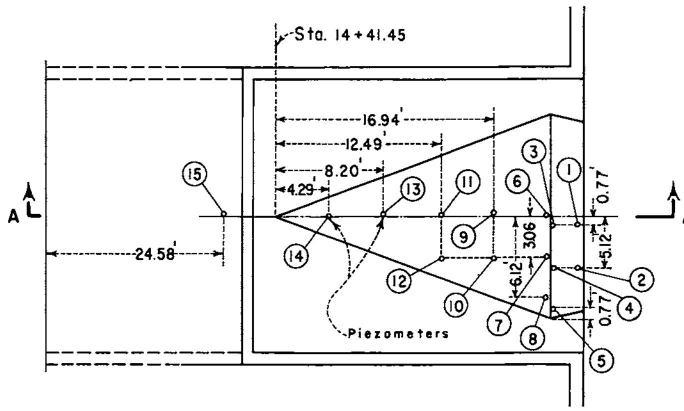
Figure 34
Report Hyd-498

A. 28, 780 cfs in stable stream channel. Tailwater elevation 974. 4 at tailgate (780 feet downstream from flip bucket).

B. Erosion in erodible streambed after 28, 780 cfs discharged approximately 30 minutes model time with tailwater elevation 974. 4.

WHISKEYTOWN DAM SPILLWAY
FLOW OF 28, 780 CFS IN PRELIMINARY STREAM CHANNEL

1:32. 78 Scale Model

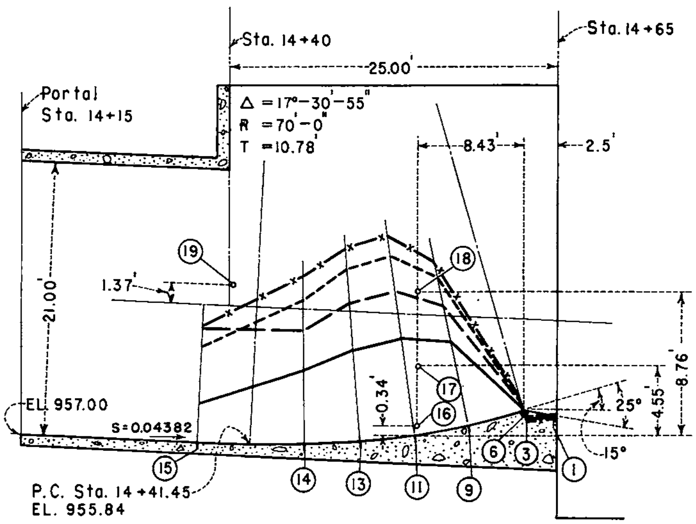


PLAN

EXPLANATION FOR PRESSURE GRADIENTS

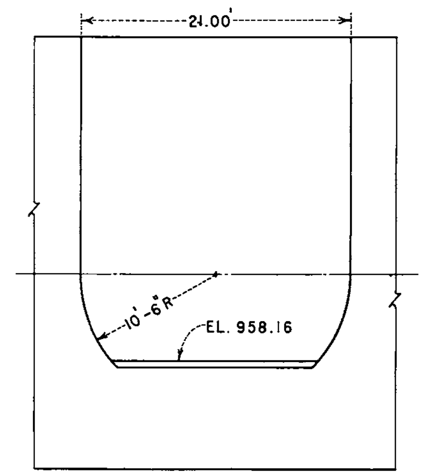
- (solid line) $\frac{1}{4}$ Max. Discharge
- (long dashes) $\frac{1}{2}$ Max. Discharge
- (short dashes) $\frac{3}{4}$ Max. Discharge
- —x—x— Full Max. Discharge

Circled numbers designate piezometer locations.
Invert profile on ℄ of bucket is zero pressure datum for pressure gradients.



SECTION A-A

PRESSURE GRADIENTS ON ℄ OF BUCKET



END VIEW

DISCHARGE C.F.S.	PRESSURES																		
	PIEZOMETERS																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
$\frac{1}{4}$ MAX.	0.00	0.00	−2.20	−1.83	−1.83	+2.05	+1.10	+2.93	+27.1	+30.4	+31.5	+34.4	+29.7	+23.8	+13.2	+29.7	0.0	0.0	+0.73
$\frac{1}{2}$ MAX.	0.00	0.00	−2.64	−3.77	−1.83	+4.39	+3.88	−0.73	+39.2	+43.9	+46.1	+49.5	+44.3	+36.3	+37.0	+42.1	+10.6	+0.62	+0.73
$\frac{3}{4}$ MAX.	0.00	0.00	−2.38	−4.76	−2.38	+5.86	+4.03	+0.37	+48.4	+50.9	+57.5	+57.5	+54.9	+45.8	+30.4	+51.3	+19.8	+10.6	−1.83
28780*	0.00	0.00	−2.75	−4.76	−2.13	+8.24	+5.13	+1.10	+53.5	+52.0	+64.5	+64.1	+61.5	+53.5	+37.4	+57.1	+27.1	+19.1	−0.55

*Maximum flow

NOTES

All pressures are in prototype feet of water.
Atmospheric pressure is zero pressure.
Tailwater was controlled 660 feet down stream from bucket.
The stream channel was not erodible, therefore, the tailwater did not back up under the jet to submerge any of the piezometers.

WHISKEYTOWN DAM SPILLWAY

PRESSURES IN PRELIMINARY FLIP BUCKET

1:32.78 SCALE MODEL

827

A. 25-degree flip bucket with an 8-degree left wall deflector plus a left bank cut and a right bank cut.

B. 7,125 cfs

C. 28,780 cfs - Normal tailwater plus 10 feet.

D. 28,780 cfs - Normal tailwater.

WHISKEYTOWN DAM SPILLWAY
FLOW IN MODIFIED FLIP BUCKET AND STREAM CHANNEL

1:32.78 Scale Model

Figure 37
Report Hyd-498

A. 28,450 cfs

B. 28,450 cfs

Note: Flow is turned inward by the 1-foot corbel along top of bucket sidewalls.

WHISKEYTOWN DAM SPILLWAY
FLOW IN RECOMMENDED FLIP BUCKET

1:32.78 Scale Model

Spillway - 1,000 cfs

Spillway - 3,560 cfs

Spillway - 7,125 cfs

Spillway - 14,250 cfs

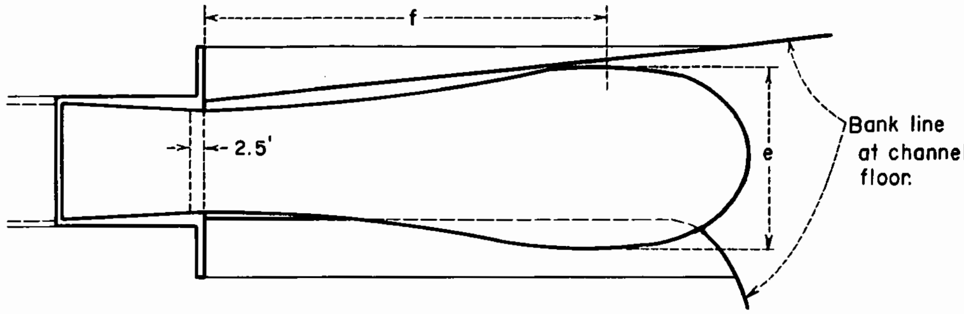
Spillway - 21,375 cfs

Spillway - 28,780 cfs

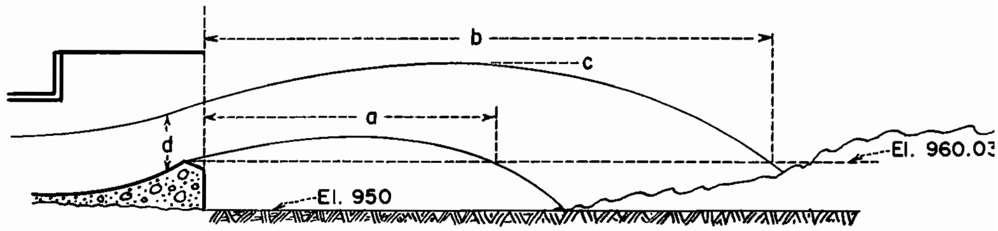
Note: Outlet works flows ranged from 1,210 cfs to 1,240 cfs

WHISKEYTOWN DAM SPILLWAY
FLOW FROM THE RECOMMENDED FLIP BUCKET AND OUTLET WORKS

1:32.78 Scale Model



PLAN



PROFILE

JET DIMENSIONS IN FEET							
DISCHARGE	*VELOCITY	a	b	c	d	e	f
1/8 MAX.	67.20	117.5	142.0	990.7	4.30	41.0	109.2
1/4 MAX.	75.30	142.0	164.0	995.5	6.63	35.5	158.5
1/2 MAX.	90.00	161.0	191.2	1001.0	9.78	24.6	191.2
3/4 MAX.	94.40	164.0	232.0	1005.4	13.20	24.6	232.0
FULL MAX.	96.30	139.2	232.0	1011.9	16.90	27.3	232.0

*Velocity in feet per second

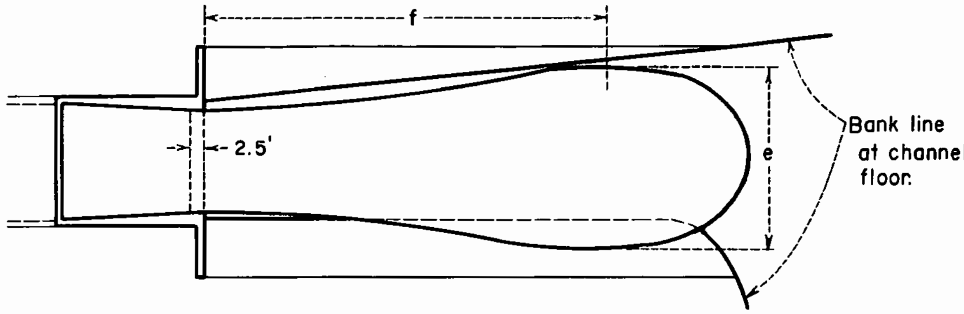
EXPLANATION

a. Minimum length of jet projection.
b. Maximum length of jet projection.
c. Elevation at top of jet.
d. Depth of jet in portal.
e. Maximum width of jet projection.
f. Distance from bucket to maximum width of jet.

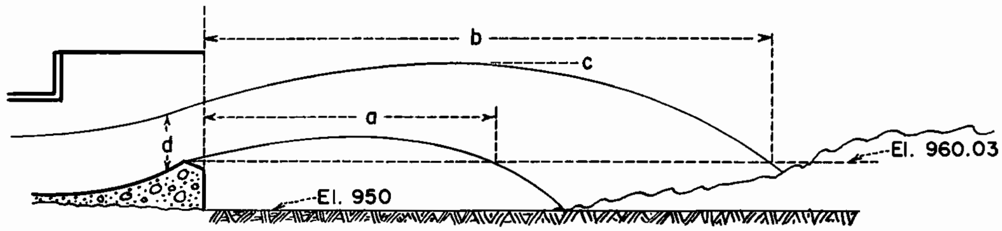
WHISKEYTOWN DAM SPILLWAY

RECOMMENDED FLIP BUCKET JET DIMENSIONS

1:32.78 SCALE MODEL



PLAN



PROFILE

JET DIMENSIONS IN FEET							
DISCHARGE	*VELOCITY	a	b	c	d	e	f
1/8 MAX.	67.20	117.5	142.0	990.7	4.30	41.0	109.2
1/4 MAX.	75.30	142.0	164.0	995.5	6.63	35.5	158.5
1/2 MAX.	90.00	161.0	191.2	1001.0	9.78	24.6	191.2
3/4 MAX.	94.40	164.0	232.0	1005.4	13.20	24.6	232.0
FULL MAX.	96.30	139.2	232.0	1011.9	16.90	27.3	232.0

*Velocity in feet per second

EXPLANATION

a. Minimum length of jet projection.
b. Maximum length of jet projection.
c. Elevation at top of jet.
d. Depth of jet in portal.
e. Maximum width of jet projection.
f. Distance from bucket to maximum width of jet.

WHISKEYTOWN DAM SPILLWAY
RECOMMENDED FLIP BUCKET JET DIMENSIONS
1:32.78 SCALE MODEL

Figure 40
Report Hyd-498

A. 3, 560 cfs

B. 7, 125 cfs

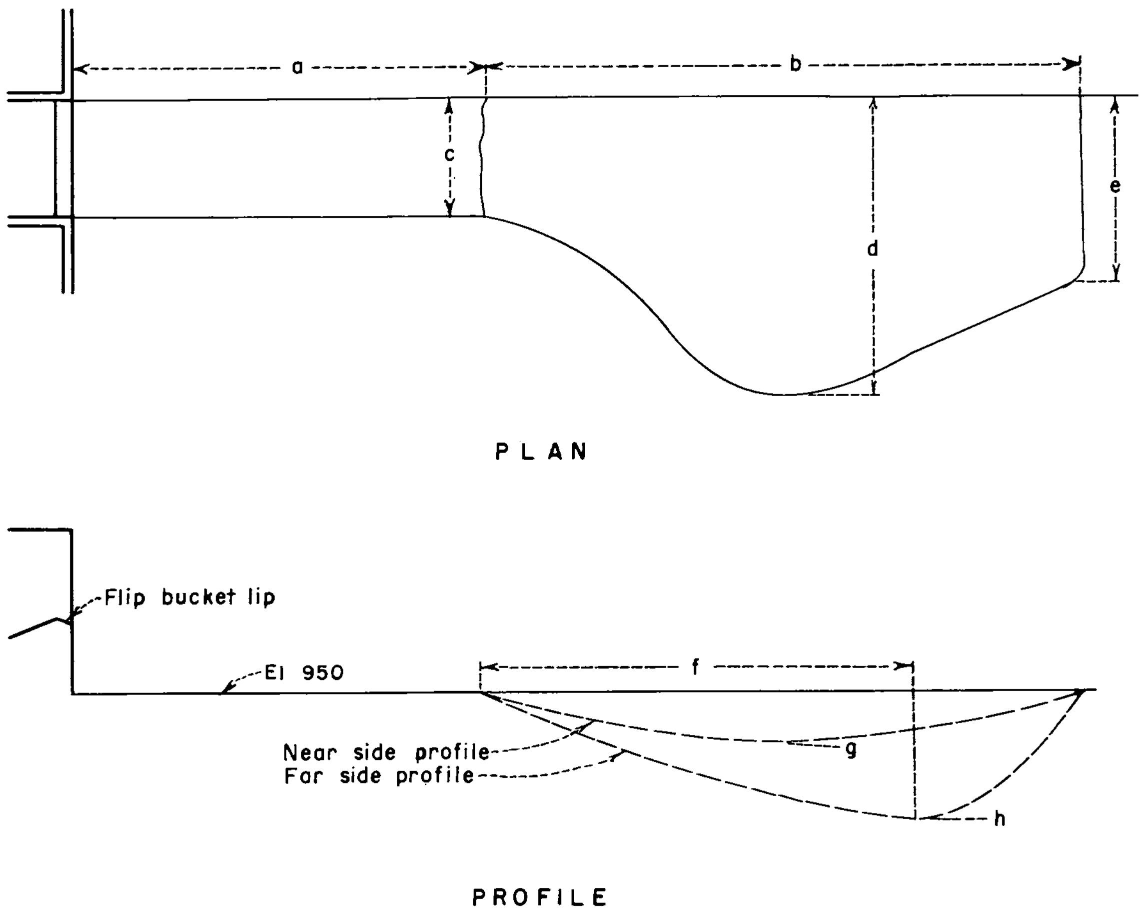
Note: The gravel bed in the stream, shown in D, was eroded for 20 minutes (model time) and then stabilized with mortar. The hole was again filled with aggregate and eroded an additional 20 minutes at the same discharge to form the bar. In A, the left bank bluff was not removed but test results were not affected. A wooden ledge along left side of depression was fixed in the model but would be subject to erosion in the prototype.

C. 14, 250 cfs

D. Streambed before each test. 1-1/2" gravel.

WHISKEYTOWN DAM SPILLWAY
EROSION TESTS IN RECOMMENDED STREAM CHANNEL

1:32. 78 Scale Model



HOLE DIMENSIONS IN FEET									
DISCHARGE IN C.F.S.	a	b	c	d	e	f	g	h	*VOLUME OF HOLE
3560	84	92	21	33	23	72	945	936	501
7125	84	154	21	59	40	124	944	933	1611
14 250	84	217	21	59	41	168	943.5	925	2576

* Volume in cubic yards

EXPLANATION

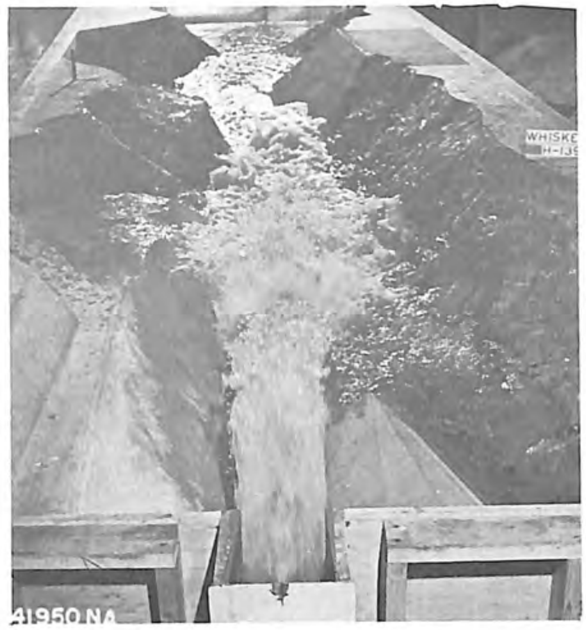
a. Distance from flip bucket to hole.
b. Length of hole.
c. Upstream width of hole.
d. Maximum width of hole.
e. Downstream width of hole
f. Distance from beginning of hole to maximum depth.
g. Elevation of hole depth on near side.
h. Elevation of hole depth on far side.

WHISKEYTOWN DAM SPILLWAY

EROSION HOLE DIMENSIONS

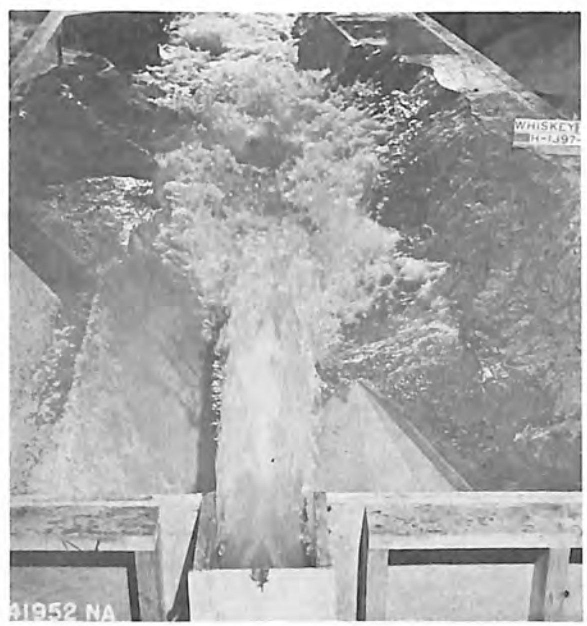
1:32.78 SCALE MODEL

A. 3,560 cfs - Tailwater elevation 956.2



B. 7,125 cfs - Tailwater elevation 959.9

C. 14,250 cfs - Tailwater elevation 965.4



D. 28,780 cfs - Tailwater elevation 974.4

Note: Streambed contains the eroded hole and bar shown in Figure 40A.

WHISKEYTOWN DAM SPILLWAY
FLOW IN THE STREAM CHANNEL

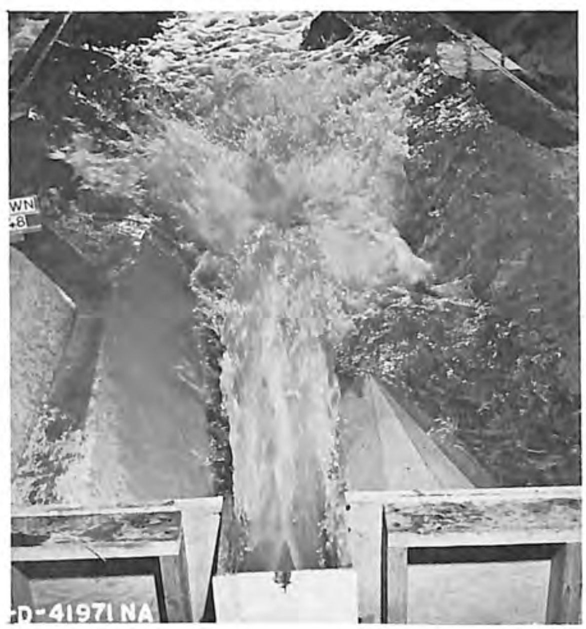
1:32.78 Scale Model

Figure 43
Report Hyd-498

elevation 956. 2

elevation 959. 9

C. 14, 250 cfs - Tailwater
elevation 965. 4



D. 28, 780 cfs - Tailwater
elevation 974. 4

Note: Streambed contains the eroded hole and bar shown in Figure 40B.

WHISKEYTOWN DAM SPILLWAY
FLOW IN THE STREAM CHANNEL

1:32. 78 Scale Model

A. 3,560 cfs - Tailwater elevation 956.2

B. 7,125 cfs - Tailwater elevation 959.9

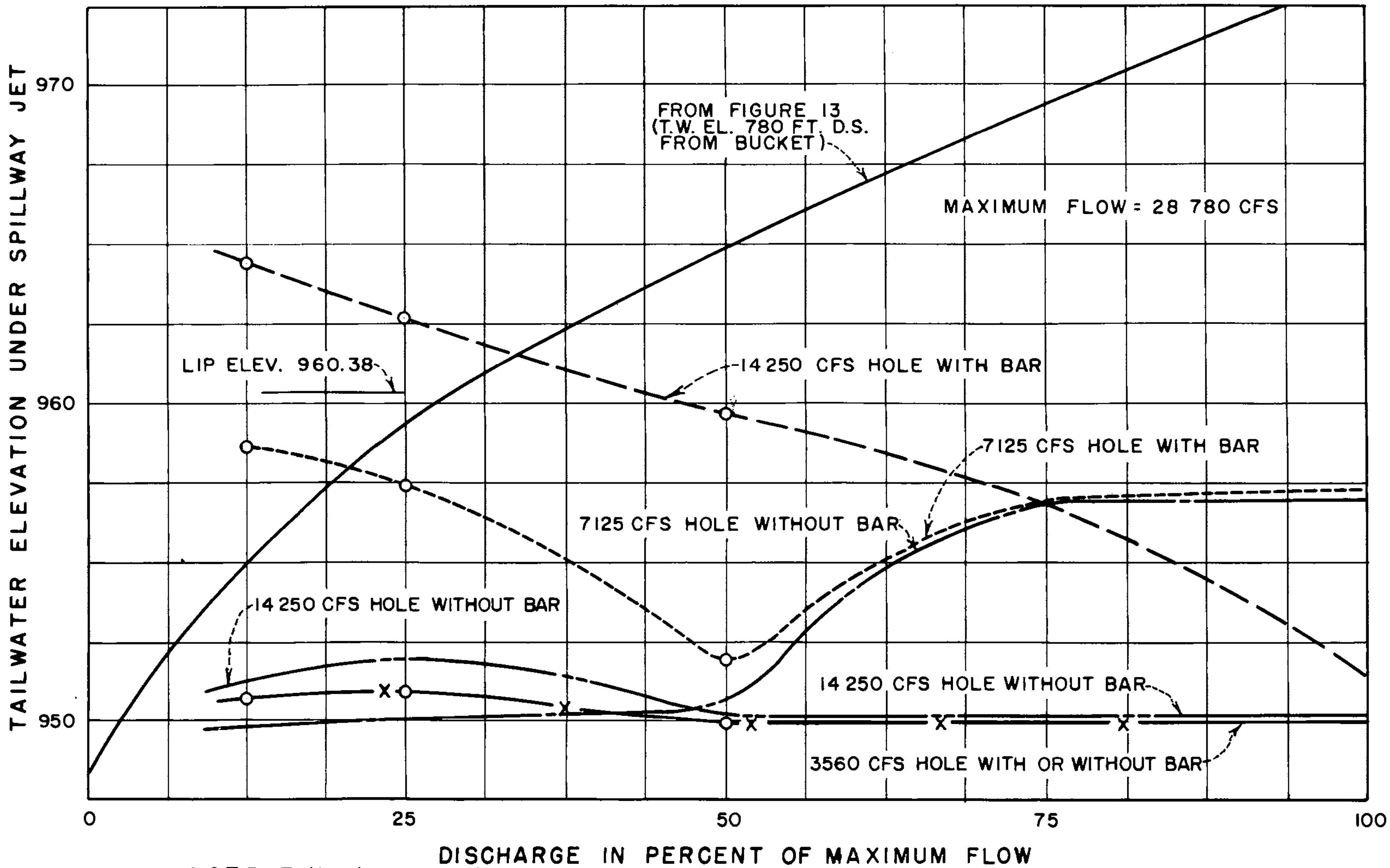
C. 14,250 cfs - Tailwater elevation 965.4

D. 28,780 cfs - Tailwater elevation 974.4

Note: Streambed contains the eroded hole and bar shown in Figure 40C.

WHISKEYTOWN DAM SPILLWAY
FLOW IN THE STREAM CHANNEL

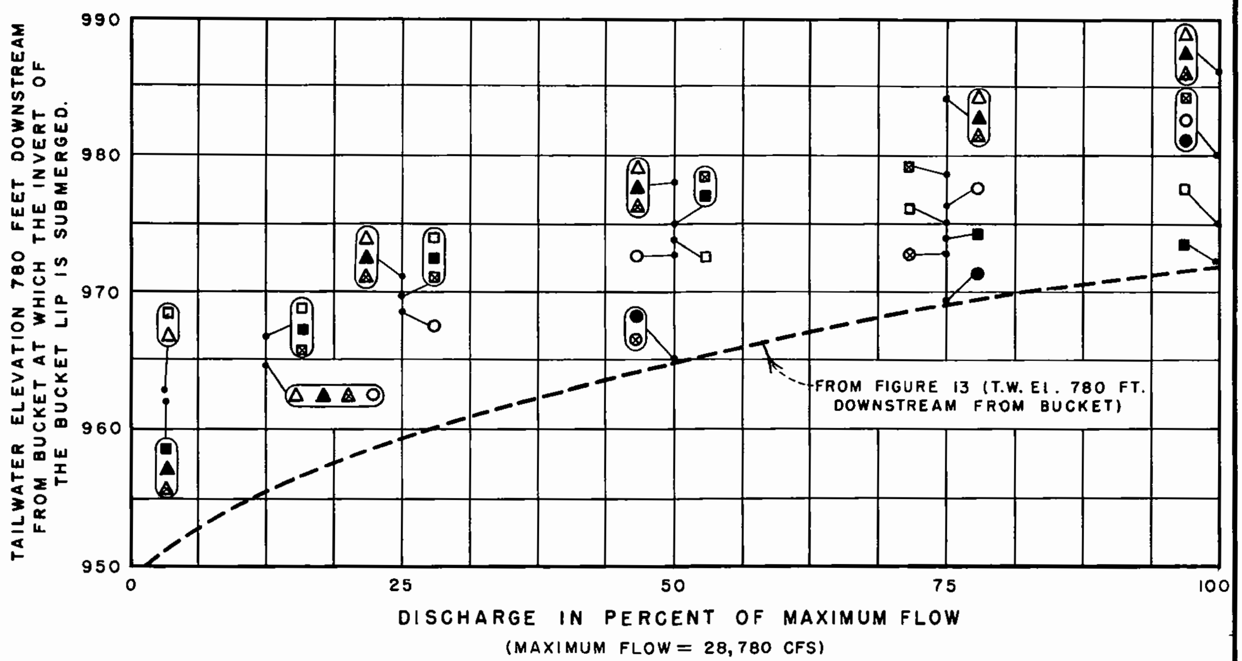
1:32.78 Scale Model



NOTE: Tailwater elevation in outlet works channel was about one foot higher than under jet circled points (o) designate test conditions shown in Figures 42 through 44.

WHISKEYTOWN DAM SPILLWAY
WATER SURFACE ELEVATION UNDER JET
1: 32.78 SCALE MODEL

FIGURE 45
REPORT HYD. 498



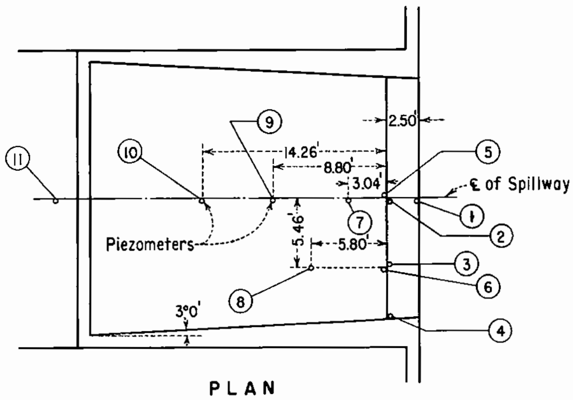
STREAM CHANNEL EROSION CONDITIONS

○ — With right bank bluff removed and 14250 C.F.S. erosion hole with no bar.
□ — With right bank bluff removed and 7125 C.F.S. erosion hole with no bar.
△ — With right bank bluff removed and 3560 C.F.S. erosion hole with no bar.
● — With right bank bluff removed and 14250 C.F.S. erosion hole with bar.
■ — With right bank bluff removed and 7125 C.F.S. erosion hole with bar.
▲ — With right bank bluff removed and 3560 C.F.S. erosion hole with bar.
⊗ — With bluff on both banks removed and 14250 C.F.S. erosion hole with bar.
⊠ — With bluff on both banks removed and 7125 C.F.S. erosion hole with bar.
◬ — With bluff on both banks removed and 3560 C.F.S. erosion hole with bar.

WHISKEYTOWN DAM SPILLWAY

SUBMERGENCE OF THE BUCKET LIP

1:32.78 SCALE MODEL

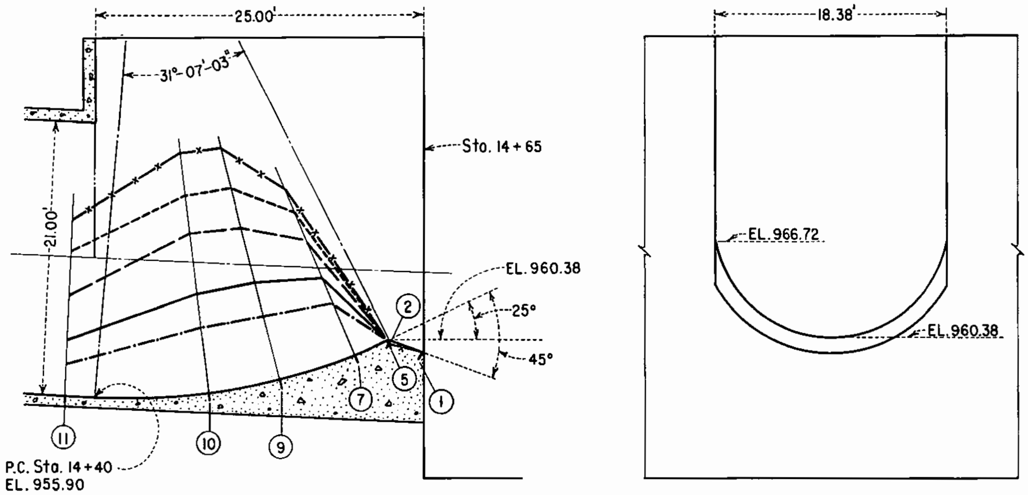


PLAN

EXPLANATION FOR PRESSURE GRADIENTS

- —·—·—· 3,560 cfs.
- ———— 7,125 cfs.
- — — — 14,250 cfs.
- - - - - - 21,375 cfs.
- —x—x—x— 28,780 cfs.

Circled numbers designate piezometer locations.
Invert profile on ℄ of bucket is zero pressure datum for pressure gradients.



SECTION ON ℄

END VIEW

PRESSURE GRADIENTS ON ℄ OF BUCKET

PIEZOMETER NO.	3560 C.F.S.				7125 C.F.S.				14250 C.F.S.				21375 C.F.S.			28450 C.F.S.			
	AVERAGE PRESSURE				AVERAGE PRESSURE				AVERAGE PRESSURE				AVERAGE PRESSURE			AVERAGE PRESSURE			
	$*^{1}$	**	***	****	$*^{2}$	**	***	****	$*^{3}$	**	***	****	$*^{4}$	**	***	$*^{5}$	**	***	****
1	3.0	0.0	0.0		1.6	0.0	0.0		4.9	0.0	0.0		3.0	0.0	0.0	4.9	0.0	0.0	
2	2.0	-1.7	-0.9	0.3	1.0	-1.4	-0.9	1.0	5.9	-1.4	-0.9	1.3	3.0	-1.0	-0.9	5.9	-1.4	-0.9	0.6
3	-0.4	-1.0	-1.1	0.6	-1.0	-0.7	-1.1	1.0	3.9	-1.4	-1.1	1.6	1.6	-1.4	-1.1	3.6	-1.4	-1.1	1.3
4	3.9	4.0		2.0	7.5	7.6		4.3	11.8	9.6		8.2	9.8	10.2		15.7	12.5	15.1	8.2
5	3.3	-1.7	-1.1	1.6	3.6	0.0	0.3	2.3	9.2	2.3	2.8	2.3	9.8	4.6	5.0	13.8	6.6	6.9	3.3
6	6.6	-2.7	-0.3	1.3	-1.3	-2.7	1.1	2.0	4.9	-1.7	4.1	2.3	5.9	1.0	6.3	7.9	2.3	2.3	3.6
7		17.8	17.0			26.3	27.9			39.1	43.5			48.9	53.6	58.0	57.1	60.1	
8		10.2	10.2			22.0	21.9			39.4	40.2			49.2	51.9		58.7	60.4	
9		20.4	15.9			31.2	29.5			49.6	49.8			62.3	63.4		75.4	72.4	
10		20.4	20.8	7.9		31.2	35.0	10.5		50.2	55.2	11.5		62.3	69.2		76.1	77.9	10.5
11		9.9	6.9			17.1	14.5			31.5	29.5		43.9	45.3	43.2		55.4	54.7	

EXPLANATION

$*^{1}$ Tailwater El. 963.5 under jet
$*^{2}$ Tailwater El. 962.5 under jet
$*^{3}$ Tailwater El. 967.0 under jet
$*^{4}$ Tailwater El. 965.0 under jet
$*^{5}$ Tailwater El. 967.0 under jet
** Tailwater below El. 960.38 under jet. Slide Gate Control used to regulate velocity at P.C. Sta. 14+40.
*** Tailwater below El. 960.38 under jet. Morning glory inlet used to establish velocity at P.C. Sta. 14+40.
**** Standard deviation of instantaneous dynamic pressure fluctuation above or below average.

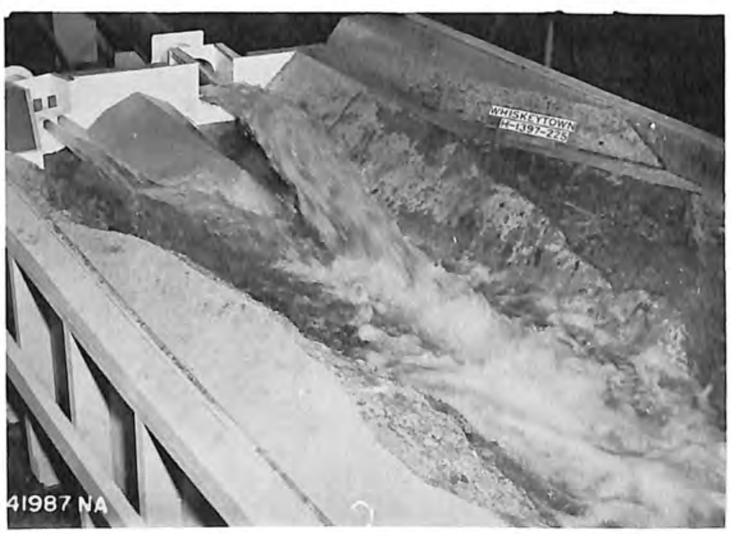
NOTES

All pressures are in prototype feet of water.
Atmospheric pressure is zero pressure.
The stream channel was not erodible, therefore, the tailwater under the jet was below El. 960.38 for normal tailwater regulation. The tailwater was regulated 780 feet downstream from bucket.

WHISKEYTOWN DAM SPILLWAY
PRESSURES IN RECOMMENDED FLIP BUCKET
1:32.78 SCALE MODEL

A. Scour hole in riverbed was eroded in loose aggregate and stabilized with mortar. Spillway flow was 7,125 cfs.

B. Spillway - 3,560 cfs
Outlet works - 1,215 cfs



C. Spillway - 7,125 cfs
Outlet works - 1,220 cfs

WHISKEYTOWN DAM SPILLWAY
FLOW FROM RECOMMENDED FLIP BUCKET AND OUTLET WORKS

1:32.78 Scale Model

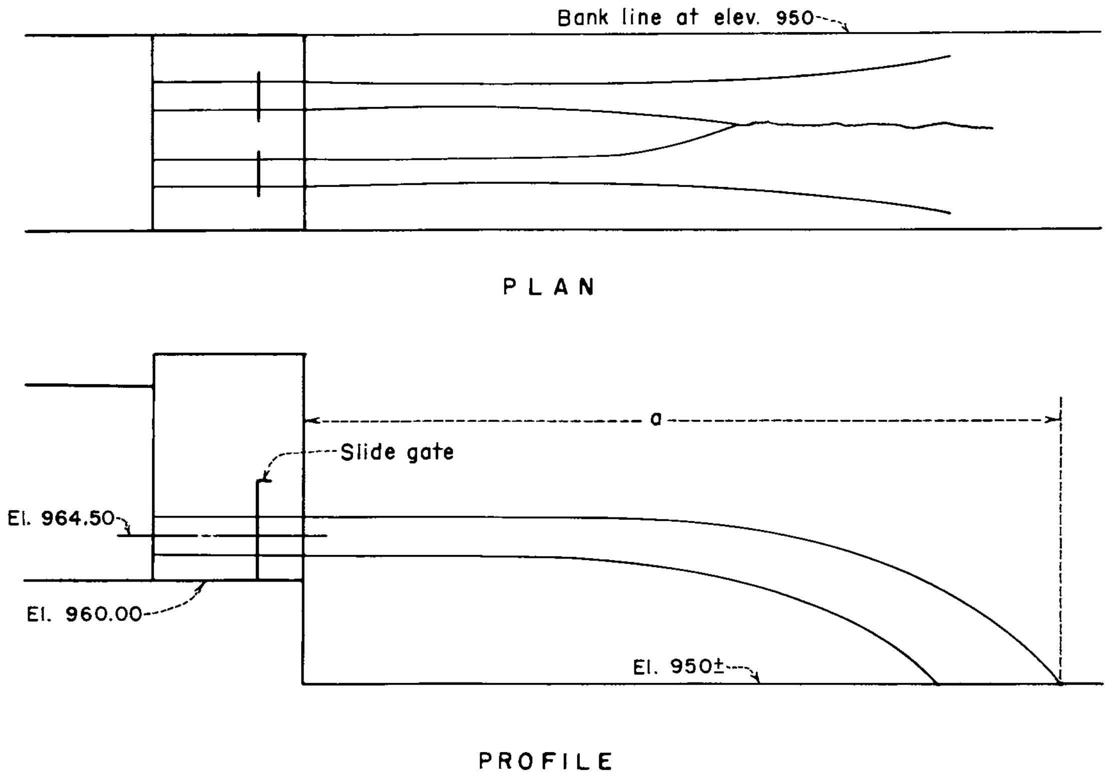
A. Spillway - 14,250 cfs
Outlet works - 1,225 cfs

B. Spillway - 21,375 cfs
Outlet works - 1,230 cfs

C. Spillway - 28,780 cfs
Outlet works - 1,240 cfs

WHISKEYTOWN DAM SPILLWAY
FLOW FROM RECOMMENDED FLIP BUCKET AND OUTLET WORKS

1:32.78 Scale Model



DISCHARGE C.F.S.	VELOCITY F.P.S.	a
1215	58.8	62.8
1220	59.1	62.8
1225	59.4	62.8
1230	59.6	62.8
1240	60.0	62.8

EXPLANATION

a. Maximum length of jet projection in feet

WHISKEYTOWN DAM

OUTLET WORKS JET DIMENSIONS

1:32.78 SCALE MODEL

A. 575 cfs

B. 3,110 cfs

C. 5,590 cfs

D. 10,000 cfs

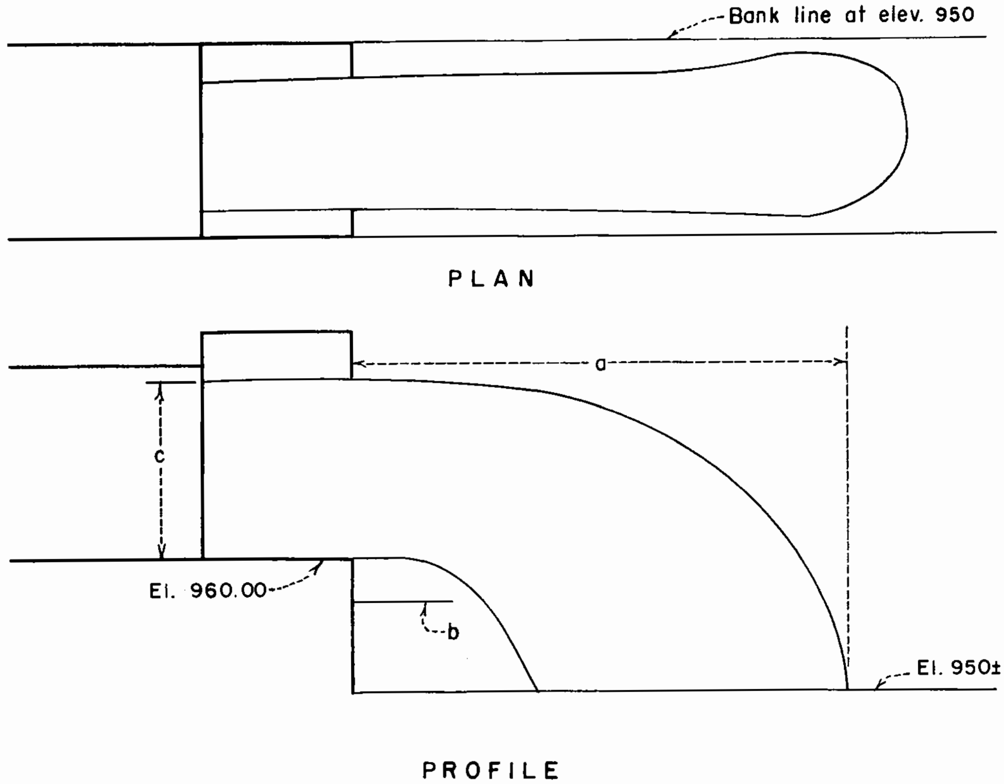
WHISKEYTOWN DAM
DIVERSION FLOWS

1:32.78 Scale Model

Figure 52
Report Hyd-498

WHISKEYTOWN DAM
DIVERSION FLOW - 13,400 CFS

1:32.78 Scale Model



Q	FLOW DIMENSIONS				
	v	a	b	c	d
575	10.4	16.4	951.5	1.94	951.5
1105	12.5	20.5	953.0	3.14	953.0
1430	13.6	21.9	954.0	3.74	954.0
3110	17.5	30.0	956.5	6.44	956.5
4195	19.8	35.5	957.5	7.89	957.5
5590	20.1	35.5	959.0	11.36	959.0
* 8000	28.2	35.5	962.5	FULL	962.5
*10 000	35.3	43.7	965.0	FULL	965.0
*12 000	42.3	51.9	965.5	FULL	965.5
*13 400	47.3	54.6	966.5	FULL	966.5

*Water overtops bank between diversion structure and spillway bucket (See figures 51 and 52).

EXPLANATION

Q = Diversion discharge in cfs.
v = Average portal velocity in feet per second.
a. Maximum length of jet projection in feet.
b. Tailwater elevation at flip bucket.
c. Average depth of flow @ portal in feet.
d. Tailwater elevation 360 feet downstream from flip bucket.

WHISKEYTOWN DAM

DIVERSION FLOW DIMENSIONS

1:32.78 SCALE MODEL

GPO 839-363

ABSTRACT

Model studies were conducted to develop the hydraulic design of the morning-glory inlet, the tunnel, the flip bucket, and the stream channel. Guide vanes placed on the profile of the inlet straightened the flow through the tunnel and increased the capacity of the inlet. A deflector and air vent provided steady free surface flow, aided in straightening the flow, and limited the flow at maximum reservoir elevation. The ratio of bend radius to tunnel diameter, 5:1, was ample for turning the flow. The walls of the bucket converged, and the left bank of the stream channel flared outward to insure that the jet from the flip bucket will not impinge upon the left bank. A 12-inch corbel along the top inside edge of the flip bucket walls smoothed the appearance of the jet. Excavation of the channel banks eliminated the possibility of the stream clogging with eroded material. Diversion and outlet works flow characteristics in the stream channel were satisfactory.

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HYD-498
Beichley, G. L.
HYDRAULIC MODEL STUDIES OF WHISKEYTOWN DAM SPILLWAY, CENTRAL VALLEY PROJECT, CALIFORNIA
Laboratory Report, Bureau of Reclamation, 17p, 53 fig, 3 ref, 1963

DESCRIPTORS--spillways/ outlet works/ diversion works/ tunnels/ *spillway crests/ *flip buckets/ control structures/ discharge coefficients/ Froude number/ head losses/ roughness coefficients/ unsteady flow/ vortices/ jets/ *hydraulic models/ cavitation/ pressure measuring equipment/ piezometers/ air demand/ transducers/ tunnel pressures/ guide vanes/ erosion/ streamflow/ tunnel hydraulics/ hydraulic similitude
IDENTIFIERS--morning-glory inlets/ tunnel bends/ tunnel deflectors/ *subatmospheric pressures

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