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HYDRAULIC MODEL STUDIES OF JOES VALLEY DAM SPILLWAY
EMERY COUNTY PROJECT, UTAH

Hydraulics Branch Report No. Hyd-518

DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
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ABSTRACT

The preliminary design of the morning-glory spillway, which was governed by unusual topographic conditions and economic considerations, exhibited undesirable operating characteristics of vibration and rough flow. Flow improving devices, including tunnel deflectors, anti-vortex piers, and an anti-vortex gravel berm between the entrance and dam embankment were developed with a 1:20 scale model. A long-radius upper bend improved the flow conditions in the inclined shaft and horizontal tunnel. Pressures on the morning-glory crest and in the vertical shaft, inclined shaft, and upper and lower bends were found to be within safe limits of operation. Measurements of rate of airflow through the air vents behind the deflectors indicated about 125 cfs with about half of the total airflow going to each of the upper and lower vents. Headloss between the reservoir and downstream end of the upper bend varied from approximately 24 feet for a discharge of 4,000 cfs to about 12 feet for the maximum discharge of 5,000 cfs. The head versus discharge relationship of the spillway was also determined.

DESCRIPTORS--*spillways/ *model tests/ hydraulics/ hydraulic structures/ *hydraulic models/ *Spillway crests/ appurtenances/ water pressures/ vortices/ piezometers/ pressure measuring equipment/ air demand/ discharge coefficients/ head losses/ tunnel hydraulics/ transition zones/ control structures/ flow/ negative pressures/ velocity/ turbulent flow.

IDENTIFIERS--*morning-glory inlets/ tunnel bends/ tunnel deflectors.

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Subject: Hydraulic model studies of Joes Valley Dam spillway--Emery County Project, Utah.

PURPOSE

The purpose of this study was to investigate the hydraulic-operating characteristics of the morning-glory spillway and to determine any possible improvements in these characteristics.

CONCLUSIONS

1. The preliminary design of the spillway, Figure 11, exhibited undesirable operating characteristics of vibration and rough flow.

2. Deflectors and air vents placed at the bottom of the crest section and in the upper vertical bend established positive control of the flow in the vertical shaft and smoothed the flow in the inclined shaft.

3. Piers placed on the morning-glory crest and a finger berm constructed between the crest and the dam improved the tunnel flow conditions for weir discharges and controlled the vortex which tended to form for submerged discharges, Figures 27 through 30.

4. A gravel berm placed around the morning-glory inlet to increase the stability of the shaft, Figure 18, had no apparent effect on the flow entering the spillway.

5. A long-radius, upper vertical bend improved the flow conditions in the inclined shaft and horizontal tunnel.

6. Pressures on the morning-glory crest and in the vertical shaft, inclined shaft, and upper and lower bends were found to be within safe limits of operation, Tables 5 through 8 and Figure 32.

7. The largest differential head acting on a pier was 1.2 feet of water for the maximum discharge at the maximum reservoir elevation, Table 10. Some scour was evident at the base of Pier 1, Figure 34.

8. The total air demand rate for the spillway was approximately 125 cfs with about half the total airflow going to each of the upper and lower vents, Table 11 and Figure 35.

9. Head loss between the reservoir and the downstream end of the upper bend varied from approximately 24 feet for a discharge of 4,000 cfs to about 12 feet for the maximum discharge of 5,000 cfs, Figure 37. The maximum loss between the deflector at the throat and the downstream end of the upper bend was about 16 feet at a discharge of approximately 4,500 cfs, Figure 37.

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INTRODUCTION

Joes Valley Dam, the principal feature of the Emery County Project in east-central Utah, is located on Seely Creek about 32 miles southwest of Price, Utah, Figure 1. The dam, Figure 2, is an earthfill structure with a height of 195 feet, a crest length of 730 feet, and a fill volume of 1,300,000 cubic yards.

The principal hydraulic features of the dam are a spillway and an outlet works. The outlet works consists of a cut-and-cover conduit with a shaft intake and has a maximum discharge capacity of 465 cfs.

The spillway, Figure 3, the subject of this report, has a morning-glory inlet which leads into a vertical shaft, through a bend, inclined shaft, another bend, and into the horizontal tunnel conduit. Flow from the tunnel discharges onto a vertically curved chute, into a hydraulic jump stilling basin, then into the river channel. The chute, stilling basin, and river channel were not included or tested in the model study.

The morning-glory inlet is 24 feet 1-1/2 inches in diameter at the crestline. The shafts, bends, and horizontal tunnel have a constant diameter of 13 feet. The morning-glory crest was designed according to the results of tests performed on a circular sharp-crested weir as described in the Transactions of the American Society of Civil Engineers, Volume 121, 1959.1/ These data are

1/"Determination of Pressure-Controlled Profiles," by William E. Wagner.

applicable when the flow entering the crest is radial. Flow entering the Joes Valley inlet is radial on the right side of the crest which is open to the main body of the reservoir but tangential on the left side of the crest due to restrictions of the dam embankment and the natural topography.

Economic and structural considerations influenced the hydraulic design of the Joes Valley spillway to a greater than usual extent. Cost studies which led to the final selection of the crest shape indicated that a minimum size spillway would be necessary. Also, the morning-glory type spillway was preferred over the open-chute type because of vulnerability to falling rocks from the high cliffs that exist at the site. The 13-foot-diameter tunnel was selected as a minimum size that would not be plugged by trash. It was also desirable to minimize the size of the morning-glory inlet to reduce the loading on the long vertical shaft. This combination of special conditions resulted in the problem of designing the minimum size crest for a 13-foot-diameter shaft and tunnel and the relationships among the head, crest diameter, and shaft diameter resulted in less than ideal flow conditions.

THE MODEL

The 1:20.29 scale model represented a portion of the reservoir topography surrounding the entrance, the morning-glory inlet, the vertical shaft, upper bend, inclined shaft, lower bend, and approximately 250 feet (about 40 percent of the total length) of the horizontal tunnel. The chute, stilling basin, and downstream channel were not included.

The reservoir topography consisted of wood framing covered with metal lath to which 3/4-inch cement mortar was applied.

The morning-glory crest was formed with concrete and included 32 piezometers in 4 rows, 8 to each row, Figure 4. The vertical and inclined shafts, the bends, and the horizontal tunnel were represented by transparent plastic tubing which allowed viewing flow patterns in these portions of the structure. Piezometers were installed along the invert of the inclined shaft and bends and in 4 vertical rows in the vertical shaft, Figure 5. All piezometers were connected to open-tube water manometers.

Rate of airflow through the vents below the deflectors was measured with 1/2-inch-diameter sharp-edged orifices with pressure taps connected to a sloping oil manometer.

Water was supplied from a subfloor sump and recirculated through the model by a centrifugal pump. Discharges were measured with permanently installed volumetrically calibrated Venturi meters.

Reservoir water surface elevations were estimated with a staff gage and accurately determined by a hook gage in a stilling well located outside the head box.

THE INVESTIGATION

When a morning-glory spillway is designed for near-submerged conditions, as was the case for the preliminary design of Joes Valley spillway, it becomes necessary to either design the crest shape so that the shaft never flows full, place a constriction in the shaft to maintain pressures above atmospheric or provide air vents at the boil to aerate the flow and relieve the subatmospheric pressure in the shaft.

The preliminary design of the Joes Valley spillway included a deflector or constriction at the bottom of the vertical shaft. However, the model indicated that the deflector was not large enough to establish a positive control and maintain above atmospheric pressures in the shaft. The shaft flowed full at or near the maximum discharge and an unexpected siphonic (subatmospheric) head occurred in the shaft. This condition increased the discharge capacity above the desired value and initiated rapid fluctuations in discharge which could produce objectionable vibrations in the prototype structure. Also, undesirable flow conditions were noted in the bends, inclined shaft, and horizontal tunnel. Therefore, the immediate purpose of the model study was to eliminate these undesirable characteristics. Also, pressure distribution on the crest profile was investigated, and devices were developed to improve the downstream flow conditions. The investigation was accomplished through a series of trials which are described in chronological order beginning with the spillway crest alone with no flow-improving appurtenances. General tests such as determination of differential heads acting on the piers, scour around the piers, air demand, and head loss measurements were performed after the recommended design had been established.

Trial 1--Initial Operation--No Appurtenances

Preliminary observations of model spillway operation with no piers or deflectors were made to gain insight into the problems which might be encountered and possible methods of eliminating these problems. The morning-glory crest is shown in Figure 6.

For a discharge of 2,500 cfs, one-half the maximum design discharge, a flow concentration was evident on the downstream side of the crest, Figure 7A.

This concentration, or fin, formed when flows from the right and left sides of the entrance combined. The concentration entered the inlet at a point to the left of the centerline (looking downstream), initiating a swirling condition as the flow entered the upper bend, Figure 7B. This swirling flow caused the inclined shaft to be filled with aerated water and resulted in an asymmetrical pattern as the flow left the lower bend, Figure 7C.

At the maximum discharge of 5,000 cfs similar conditions were observed. The fin of water at the spillway crest had moved to a position nearly 90° to the left of the centerline, as shown in Figure 8A. This new position of the fin and observation of individual curved segments of the flow illustrate the counterclockwise rotation pattern. This rotation resulted in very strong swirling action in the bends and inclined shaft, Figures 8B and 8C.

For the maximum discharge of 5,000 second-feet the reservoir was approximately 1.5 feet below the preliminary design reservoir elevation 6997.4. The spillway was at the critical point of submergence so that the throat was alternately full then partially full. This making and breaking action caused an audible rapid fluttering action and vibrations in the structure. Slight subatmospheric pressures observed in the upper portion of the crest profile were expected because the profile was cut under the optimum shape to provide tangency with the shaft. Subatmospheric pressures as low as 7.3 feet of water occurred in the shaft during the periods of submergence which, through siphonic action, pulled more flow through the shaft until the spillway again became unsubmerged. This cycle was repeated in rapid sequence causing the fluttering and vibration previously described. Tables 1 and 2 and Figure 9 summarize minimum water manometer pressures on the crest profile and in the vertical shaft for one-fourth, one-half, three-fourths, and full maximum discharge. Figure 10 includes the head discharge curve for this first trial.

Table 3 shows the minimum pressures occurring in the preliminary bends and inclined shaft. Subatmospheric pressures at Piezometers 53 and 54 in the inclined shaft were caused by the tunnel filling in the vicinity of Piezometers 54 and 55, which lowered the pressure gradient in the upstream inclined shaft, bend and vertical shaft. Piezometers in these regions indicated highly fluctuating pressures suggesting that the tunnel alternately filled and flowed free.

Trial 2--Preliminary Deflector, Vent, and Crest Pier

A deflector was installed at the bottom of the vertical shaft extending into the upper bend and a single pier was placed on the crest as shown in the preliminary design, Figure 11. Holes were drilled under the deflector to simulate the prototype air vent.

The deflector did not improve the tunnel flow conditions except when the morning glory was completely submerged, a condition which existed only for short periods of time during the maximum discharge. The crest pier improved the entrance flow pattern and reduced the swirling flow in the tunnel. Also, the model indicated that three piers spaced equally on the crest were little more effective than the single pier.

Two undesirable conditions prevailed: Of primary importance was the alternating submergence which occurred for discharges at or near the maximum discharge. Secondly, when the morning glory operated unsubmerged the flow fell unchecked for a distance of approximately 75 feet to the invert of the upper vertical bend. At this point a large amount of air was entrained, and the impact on the invert caused a large fin to form which impinged on the crown of the inclined shaft. The flow then followed the crown through the inclined shaft, Figure 12, and into the lower bend where the tunnel crown again became free. Guide vanes placed on each side of the inclined shaft partially alleviated this condition, but the major portion of the fin passed between the vanes and the undesirable flow continued to exist. It seemed that the problem was partially due to the relatively short radius of the upper bend.

Trial 2 water manometer pressures in the vertical shaft and upper bend for the maximum discharge are shown in Table 4. The table shows somewhat less subatmospheric pressures than those for Trial 1, which suggests that the preliminary deflector gave some improving effect by allowing air to enter the inclined shaft.

Trial 3--12-inch Deflector at Bottom of Crest Profile, Preliminary Crest Pier, and Positions of Upper and Lower Bends Interchanged

To exert more flow control in the vertical shaft, a 12-inch deflector was placed at the bottom of the crest section. In addition, to determine whether a longer radius upper bend would improve flow in the inclined tunnel, the positions of the upper and lower model bends were interchanged.

With the 12-inch deflector installed the reservoir elevation was 6996.2 for the maximum discharge, Figure 10, still well below the limiting elevation of 6998.0. The boil did not drop out of the inlet for the maximum discharge but moved up and down in the entrance, Figure 13. The fluttering and vibration were less severe at a lower discharge of 4,800 cfs. The crest pier reduced the vortex action which formed after submergence. Without the pier the vortex became strong enough to cause the vertical shaft to fill, thus initiating the siphonic action.

The deflector and the interchange of the bends greatly improved flow conditions in the bends and inclined shaft. Bend and inclined shaft flow conditions corresponding to the high and low points of the boil are also shown in Figure 13. Conditions for one-half maximum discharge were also much improved.

Trial 4--Approximately 24-inch Deflector at Bottom of Crest Profile

The 12-inch deflector at the bottom of the crest was replaced by one projecting approximately 24 inches into the conduit. The subatmospheric pressures in the vertical shaft and the making and breaking action which previously occurred at the maximum discharge were eliminated. The morning-glory entrance was completely submerged and a large counterclockwise vortex formed, Figure 14A. A 25-foot-long wall, replacing the crest pier, was very effective in controlling the vortex, Figure 14B. The reservoir elevation stablized at 6997.9 for the maximum discharge. Flow conditions in the bends and inclined shaft were satisfactory for both maximum discharge and one-half maximum discharge.

Although this trial exhibited satisfactory operation, the investigation was continued to ensure the best selection for the recommended design. Figure 15 shows the size and location of deflectors used in the investigation, including those for the preliminary and recommended designs.

Trial 5--Deflector at Bottom of Vertical Shaft

The deflector for this trial differed from the preliminary deflector in Trial 2 in that the Trial 5 deflector projected into the tunnel at the P.C. of the bend while the Trial 2 deflector extended into the upper vertical bend, Figure 15. The first Trial 5 deflector extended horizontally 24 inches into the conduit and showed little improvement in the downstream flow conditions and no effect on the flow in the vertical shaft. Therefore, a 36-inch deflector was installed.

With the 36-inch deflector, flow in the inclined shaft was satisfactory with very little swirling action. Flow conditions in the vertical shaft were not as good for the maximum discharge as those observed in Trial 4. Pressures in the shaft were only slightly subatmospheric but exhibited more fluctuation. The morning-glory entrance became alternately submerged and unsubmerged as shown in Figure 16A and B, and at the maximum discharge the reservoir was about 2 feet below the design elevation, Figure 10.

Flow in the bends and inclined shaft was very good, Figure 16C. However, because of the undesirable head-discharge relationship for this trial it was felt that the deflector should be placed at the bottom of the crest section. Also, it was clearly indicated that a longer radius upper bend should be included, and that a long wall or pier should be installed on the crest.

Trial 6--30-inch Deflector at Bottom of Crest Profile

The size of the 24-inch deflector tested in Trial 4 was increased to 30 inches to determine the head-discharge relation and further refine the choice of deflector size. In addition, the 25-foot-long wall between the crest and the dam was retained for this trial, and the bends remained in the interchanged positions. Flow conditions for one-half maximum discharge were identical to those observed for Trial 5.

The reservoir exceeded the maximum allowable elevation before the maximum discharge was reached. At a discharge of 4,800 cfs the reservoir stood at elevation 6998.2, Figure 10. The wall between the crest and dam effectively controlled the vortex and flow in the bends and inclined shaft was very good, Figure 17. Since the larger deflector resulted in an unacceptable reduction in discharge capacity, it was decided to return to the use of the 24-inch deflector at the bottom of the crest profile.

Trial 7--Bench Fill around Morning-glory Entrance

Figure 18 shows a bench fill placed around the morning-glory for the purpose of increasing the stability of the vertical shaft. There was some thought that this fill might have some undesirable effect on the operation of the spillway. However, no difference in the flow conditions was apparent, and the shallower approach depth had no effect on the discharge capacity. The bench fill therefore, was acceptable for inclusion in the recommended design.

Trial 8--Determination of Optimum Length of Wall for Controlling Vortex

In previous trials a 25-foot-long wall was placed between the crest and the dam embankment to control the vortex which formed during submerged discharges. This trial showed that the wall could be shortened to 20 feet with no loss in effectiveness. Figures 19C and D show entrance conditions for maximum discharge and one-half maximum discharge with the optimum length wall. Shorter walls with lengths of 10 and 15 feet, Figures 19A and B, were found to be too short. The best placement of the wall was determined after installation of the proposed longer radius upper bend.

Trial 9--60-foot-radius Upper Bend and 20-foot-long Pier on Crest

The preliminary 40-foot-radius upper bend was replaced by a bend having a radius of 60 feet. Flow conditions in the bend and inclined shaft were improved over those of Trial 1 but were not as good as had been expected from observations with the upper and lower bends interchanged. The reason for this might be that the new bend had a smaller degree of curvature (35°) than the lower bend placed in the upper position (55°). The new bend provided a steeper slope in the inclined shaft. Turbulence and entrained air which were previously forced to the bottom of the conduit because of the more abrupt change of direction now rose to the surface and caused a very rough water surface in the inclined shaft. Flow conditions are shown in Figure 20.

The poor flow conditions in the bends and inclined shaft were worsened by the pier placed on the crest for this trial. The crest pier consisted of a combination pier and tapered wall, Figure 20A. The length was determined from the tests in Trial 8, and the width was determined according to structural requirements and the necessity for providing an air intake in the top of the pier.

Trial 10--20-foot-long Pier on Crest Normal to Dam and Short Pier 90° Counterclockwise from Normal Pier

In an attempt to improve the poor bend and tunnel flow conditions, a short pier was placed on the crest at a point 90° counter-clockwise from the large pier, Figure 21A. The short pier formed a fin which was meant to counteract the concentration formed by the large pier, thus improving the bend and tunnel flow. However, flow conditions in the bends and inclined shaft, Figure 21B, were worse than those for the previous trial even though the swirling action in the horizontal tunnel was slightly reduced, Figure 21C.

Trial 11--20-foot-long Thin Wall Placed Normal to the Dam 10 Feet from the Crest and Short Pier 90° Counterclockwise from Normal Wall

Previous trials indicated that the large pier was the primary cause of the poor bend and tunnel flow conditions and that additional piers gave little aid in counteracting this effect. Therefore, the large pier was replaced by a thin wall normal to the dam placed 10 feet from the entrance, leaving the crest unobstructed except for the short pier described in Trial 10, Figure 22. Conditions in the bends, inclined shaft, and tunnel were greatly improved. Flow in the inclined shaft was more adequately confined to the invert portion of the conduit and less swirling existed in the horizontal tunnel. Although the end of the wall was approximately 10 feet from the crest, the vortex was effectively controlled during submerged operation, and interference with the entrance flow for unsubmerged discharges was eliminated.

Trial 12--20-foot-long Wall Placed Normal to the Dam 10 Feet from the Crest and Two Piers on Crest 120° Either Side of Wall

Previous trials substantiated the need for a wall placed normal to the dam to control the vortex which formed for submerged discharges. It was also apparent that an additional pier or piers on the crest would improve the unsubmerged flow conditions, provide additional control of the vortex, and provide a means of supplying air to the deflector. For this trial two piers were installed on the crest at points 120° either side of the wall. This placement added symmetry to the appearance of the entrance and improved the flow conditions. For a discharge of 2,500 cfs, Figure 23, conditions in the bends, inclined shaft, and tunnel were greatly improved. The 120° counterclockwise pier, hereafter referred to as Pier 1, established a flow concentration which tended to counteract the natural concentration on the crown side of the crest. Flow through the bends and inclined shaft was relatively smooth and very minor swirling action existed in the downstream tunnel. Discharge capacity was slightly reduced so that the reservoir rose to elevation 6993.8, 0.2 foot above the corresponding elevation for previous trials, Figure 10.

For the maximum discharge of 5,000 cfs the reservoir rose to elevation 6998.0. Figure 24 shows that the single thin wall and two crest piers were very effective in controlling the vortex. Vortices with opposite directions of rotation trail off the ends of the piers with counteracting effects. Flow in the bends, inclined shaft, and horizontal tunnel was very satisfactory.

Trial 13--Recommended Design--Finger Berm Normal to the Dam and Two Piers on Crest 120° Either Side of Berm

Since the previous trial indicated the desirability of using two crest piers, it remained to determine the proper size of the piers. Because of expected ice conditions in the reservoir, it was necessary that the piers be as small as possible to minimize the effect of ice loading and still be large enough to effectively control the flow. Also, the piers had to be large enough to contain air-inlet piping. Two 30-inch-wide piers approximately 10 feet high above the crest, 9 feet long in a radial direction and extending 3 feet over the crestline into the entrance apparently satisfied these requirements.

An alternative scheme was proposed to control the vortex. The 20-foot-long wall was replaced by a gravel finger berm between the spillway entrance and the dam with the belief that the berm would intercept the rotating flow and, with the aid of the crest piers, effectively control the vortex. The model showed this premise to be correct, and the gravel finger berm was included in the recommended design. An additional deflector was placed below the start of the upper bend to help maintain an open space in the crown of the bends and inclined shaft, Figure 15. Therefore, the recommended design included the 24-inch deflector at the bottom of the crest section as described in Trial 4, an additional deflector at the P.C. of the upper bend, a longer radius upper bend than that used in the preliminary design, a stabilizing fill around the entrance, two crest piers, and a finger berm normal to the dam. The recommended spillway with appurtenant devices is shown in Figure 25. Operating characteristics of the spillway were observed for discharges from 1,000 to 5,000 cfs, in 1,000-cfs increments. The head versus discharge curve for the recommended design is shown in Figure 26 based on the test data in Table 9.

Coefficient of discharge--The discharge coefficients for the recommended spillway were determined from the discharge rating curve and plotted as shown in Figure 27. The coefficients were calculated from the weir equation $Q = C_d L (H)^{3/2}$, where L is the circumference of the crest at elevation 6989.70 and H is the head on the crest (reservoir elevation minus crest elevation). The maximum discharge coefficient of 4.316 corresponded to a head of 4.97 feet at a discharge of approximately 3,400 cfs.

Entrance flow conditions--Figure 28 illustrates the flow conditions at the morning-glory entrance. For a discharge of 1,000 second-feet with the reservoir at elevation 6991.9, 2.2 feet above the spillway crest, flow over the crest was smooth except for the flow concentrations at the piers. Pier 1 had the larger disturbances because of tangential flow in that area of the reservoir. Flow past Pier 2 was in a radial direction and was not strongly influenced by the presence of the pier. For a discharge of 2,000 cfs, reservoir elevation 6993.2 or 3.5 feet above the crest, the same conditions prevailed with the exception that the influence of the piers was increased. The flow concentration past Pier 1 was extended in a clockwise direction toward the centerline on the crown side. For a 3,000 cfs discharge, reservoir elevation 6994.3 or 4.6 feet above the crest, the effect of Pier 1 had extended over more than 25 percent of the crest, and the effect of Pier 2 was also clearly increased. With a discharge of 4,000 second-feet, reservoir elevation 6995.3, 5.6 feet above the crest, the entrance was at the point of submergence with a boil fully formed in the throat. For the maximum discharge of 5,000 cfs the morning-glory was completely submerged with the reservoir at elevation 6998.0, 8.3 feet above the crest. Vortices rotating in opposite directions trailed off the ends of the piers; but due to the controlling effect of the piers and the finger berm, no stable vortex was formed. Very small amounts of air were pulled through the spillway throat.

Flow conditions in the vertical bends and inclined shaft--Flow conditions in the upper and lower vertical bends and in the inclined shaft are shown in Figure 29. For a discharge of 1,000 cfs some swirling action prevailed in the inclined shaft. At this low discharge, the upper deflector had little effect and the flow passing through the throat tended to move away from the invert and climb the sides of the tunnel. The swirling was straightened as the flow passed through the lower bend. For the 2,000-cfs discharge the flow through the upper bend and inclined shaft was apparently smoother; however, a dishing effect was initiated in the lower bend with the depth lower in the center than at the sides of the conduit. As the discharge increased to 3,000 cfs, the flow became more stable due to the increased effects of the upper deflector and the crest piers. The flow was confined to the tunnel invert and a relatively smooth flow surface existed through the bends and inclined shaft. For a discharge of 4,000 cfs with a boil formed in the spillway throat, flow conditions were very good. The flow surface was slightly roughened by air entrained in the boil, but no swirling existed. With the morning-glory spillway completely submerged at the maximum discharge of 5,000 cfs flow through the bends and inclined shaft was excellent.

Flow conditions in the horizontal tunnel--For a discharge of 1,000 cfs some swirling action was present, Figure 30, but gave no cause for concern because of the small depth and discharge. For the 2,000-cfs discharge somewhat undesirable conditions prevailed because of the dishing effect in the lower bend. A fin was formed immediately downstream from the lower bend where the flow which had previously climbed the sides of the conduit moved back toward the center. The dishing effect was repeated downstream where the fin struck the bottom of the conduit. This condition was substantially reduced at the end of the model tunnel. Since the model represented only about 40 percent of the prototype tunnel, it was felt that the flow leaving the prototype outlet portal would be comparatively smooth and have no adverse effect on the operation of the stilling basin. As the discharge increased to 3, 000 cfs conditions in the tunnel improved, and the flow surface became relatively smooth. For the 4, 000-cfs discharge some swirling action was noted; however, this action was negligible at the end of the model tunnel. The tunnel flow was very smooth for the maximum discharge of 5, 000 cfs with only a slight tendency to climb the conduit walls.

Flow patterns in the reservoir--Flow patterns in the model reservoir, Figure 31, were obtained by taking time lapse photographs of the movement of confetti on the water surface. The regions of radial flow on the left side and of tangential flow on the right side of the entrance are clearly illustrated as well as the effect of the finger berm between the entrance and the dam. Figure 31E also shows the opposite directions of rotation of the vortices trailing off the ends of the piers.

Pressure measurements--Table 5 lists average water manometer pressures on the spillway crest recorded for discharge increments of 1, 000 cfs. Pressures became more subatmospheric as the discharge increased up to the maximum discharge of 5, 000 cfs when the spillway was completely submerged and all pressures became near, or above, atmospheric. The minimum pressure observed was 4. 0 feet of water below atmospheric at Piezometer 40 for a discharge of 4, 000 cfs. The pressures were very steady with practically no fluctuation. Average water manometer pressures in the vertical shaft, Table 6, were higher than the crest pressures. The minimum pressure was 0. 5 foot of water below atmospheric occurring at various discharges for several piezometers. The shaft pressures also showed very little fluctuation in contrast with observations made for the preliminary design. Figure 32 shows profiles of pressures on the crest and in the vertical shaft.

Average water manometer pressures measured in the vertical bends and inclined shaft are listed in Table 7. Fluctuations in pressure were greater than observed on the crest and in the vertical shaft because of the tendency for the flow to swing along the tunnel invert. The largest fluctuation (from maximum to minimum) of 5. 3 feet of water occurred at Piezometer 50 for a discharge of 1, 000 cfs. The magnitude of the fluctuations decreased as the discharge increased. The impact effect of the flow falling through the vertical shaft is shown at Piezometer 50. As the flow moves into the inclined shaft the pressure is reduced to near hydrostatic at Piezometer 51 and increases again at Piezometer 52 as the flow enters the lower bend.

To further investigate the magnitude and fluctuations of the pressures, several piezometers were selected for determination of instantaneous dynamic pressures utilizing electronic pressure cells. These instantaneous pressures are summarized in Table 8. The piezometers used to record these data were chosen by inspection of the water manometer data to determine the piezometers which showed the largest pressure fluctuations or the most severe subatmospheric pressures. Table 8 shows that the lowest instantaneous pressure was 4.5 feet of water below atmospheric at Piezometer 28 near the top of the morning-glory crest for a discharge of 4,000 cfs. Comparison of the average instantaneous pressures in Table 8 with the corresponding average water manometer pressures in Tables 5, 6, and 7 shows close agreement.

Differential head on piers--Observation of the flow around Pier 1 showed a higher water surface on the right side of the pier (looking toward the center of the morning-glory) than on the left side, Figure 33. The water surface on both sides of the pier was measured to estimate the magnitude of overturning forces acting on the pier. The magnitude of the differential increased with an increase in discharge resulting in an unbalanced head of 1.2 feet at the maximum discharge of 5,000 cfs, Table 10, which was not considered excessive. Because of essentially radial flow past Pier 2, no difference in water surface was apparent.

Scour around piers--The tangential flow which caused a differential head on Pier 1 also resulted in turbulent eddies and accompanying scour on the left side of the pier base.

Individual pieces of the small gravel used to form the stabilizing fill around the morning-glory were picked up and swept over the crest. The area around the piers was formed in sand to estimate the extent of scour to be expected in the prototype. Figure 34 shows the resulting pattern around Pier 1 after operation at a discharge of 3,000 cfs for 1 hour (equivalent to approximately 4 and 1/2 prototype hours). It should be noted that most of the erosion occurred during the first 10 minutes of operation, and that the magnitude of the discharge had no apparent effect on the extent of erosion. This test suggested that large riprap should be carefully placed around Pier 1 to insure against small riprap being drawn into the spillway tunnel. No scour occurred around Pier 2.

Air demand--Rate of airflow into each of the vents located beneath the upper and lower deflectors was checked to determine the adequacy of the area of the air-inlet piping and to provide data for future designs. The air-inlet piping is shown in Figure 25. A limiting air velocity of about 300 fps has been set, based on past experience, to avoid undesirable noise. Rate of air inflow was measured by 1/2-inch-diameter sharp-edged orifices placed over each of the vents. No attempt was made to represent the air piping in the model. The differential head of air through the orifice was determined with a sloping manometer filled with oil of known specific gravity. The quantity of air flowing through the orifice was computed from the equation:

$$Q = CA \sqrt{2gH}$$

where:

C = coefficient of discharge = 0.601
A = area of orifice
H = differential head in feet of air

The differential head was corrected for temperature and barometric pressure. Test results which were converted to prototype by Froudian relationships are given in Table 11. Figure 35 shows lower vent airflow, upper vent airflow, and total airflow versus the spillway discharge. Rate of airflow through each of the vents was approximately equal, as shown in Figure 35. The total air demand increased to about 102 cfs at a spillway discharge of 1,900 cfs, then decreased to 98 cubic feet of air per second at 2,500 cfs. Apparently more air was pulled through the entrance by the flow passing through the spillway throat in this range of discharges, reducing the necessary flow of air through the vents. Above 2,500 cfs spillway discharge the flow became smoother, pulling in less air through the entrance and the airflow through the vents increased to a maximum of 126 cfs at a spillway discharge of 4,600 cfs. The airflow then decreased as the vortex action increased allowing more air to pass through the entrance. According to these model data the maximum velocity would occur in the 18-inch pipe leading from the lower vent with a value of about 36 feet per second. The maximum air velocity through each of the 15-inch pipes in the tops of the piers would be about 17 feet per second. These velocities are well within the recommended limit.

The model showed that neither the pressures in the free space along the crown side of the vertical shaft nor the flow conditions changed when the air vents were alternately opened and closed. This indicates that because of the relatively short length of horizontal tunnel in the model, air was able to move upstream along the tunnel crown from the outlet portal when the vents were blocked. Since the model represented only about 40 percent of the prototype tunnel length it cannot be said whether the prototype will function in the same way.

Head losses--Loss in head through the spillway entrance, vertical shaft, and upper bend was determined for use in future designs of morning-glory spillways. The depth of flow was measured at the downstream end of the upper bend, Figure 36, from which the velocity, velocity head, and corresponding elevation of the energy gradeline were computed. An accurate determination of losses could not be made because of extreme difficulty in measuring the depth of flow, especially for discharges below 4,000 cfs. Above 4,000 cfs the flow became relatively smooth and more dependable depth measurements could be made. It should be noted, however, that the losses determined from the model are only estimates because of the inaccuracies in depth measurement, bulking effects of entrained air and nonuniform velocity distribution.

Since the conduit was flowing full at the upper deflector it was possible to compute the velocity and velocity head and, with the measured pressure head, the elevation of the energy gradeline could be determined at the spillway throat. The losses between the reservoir and upper deflector and between the upper deflector and the downstream end of the upper bend could then be compared as in Figure 37. The loss between the reservoir and upper deflector decreased steadily as the discharge increased, clearly indicating the decreasing turbulent mixing as the inlet filled. However, an increase in loss between the deflector and the downstream end of the upper bend occurred between discharges of 4,200 and 4,400 cfs. This increase was apparently due to turbulent energy dissipation in the vertical shaft and upper bend. Above 4,400 cfs the turbulence decreased, the flow became relatively smooth, and the losses again decreased to a minimum value at the maximum discharge of 5,000 cfs.

METRIC EQUIVALENTS

Table 12 lists the metric equivalents of important quantities referred to in this report.

Table 1

MINIMUM PRESSURES* ON SPILLWAY CREST WITH NO DEFLECTORS OR VENTS--PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=3,750 cfs	Q=2,500 cfs	Q=1,250 cfs
1	-0.4	1.4	1.4	-1.6
2	-2.6	-1.6	-0.8	0.4
3	-2.8	-2.0	-1.0	0.0
4	-3.2	-2.4	-1.2	0.0
5	-3.7	-2.8	-1.8	-0.6
6	-2.6	-1.6	-0.8	-0.4
7	-2.2	-0.8	-0.2	-0.2
8	-5.1	-0.6	0.0	0.0
13	-3.0	-1.0	0.4	1.4
14	-4.5	-2.6	-1.0	0.4
15	-4.5	-2.8	-1.2	0.2
16	-4.9	-3.2	-1.6	-0.2
17	-4.9	-3.2	-1.8	-0.6
18	-3.4	-2.0	-1.0	-0.4
19	-3.0	-1.0	-0.6	-0.2
20	-4.1	0.0	0.6	0.6
25	-3.7	-1.0	0.6	1.6
26	-5.5	-2.8	-1.0	0.4
27	-5.3	-3.0	-1.2	0.0
28	-5.5	-3.4	-1.6	-0.2
29	-5.1	-3.4	-1.8	-1.2
30	-3.0	-2.2	-1.0	-0.2
31	-3.2	-1.4	-1.0	-0.4
32	-7.1	-1.8	-1.6	-1.2
37	-2.8	-1.6	-0.2	1.2
38	-4.9	-3.2	-1.4	0.2
39	-4.7	-3.0	-1.4	0.0
40	-5.1	-3.4	-1.8	-0.4
41	-5.1	-3.7	-2.0	-0.6
42	-3.4	-2.2	-1.2	-0.4
43	-2.8	-1.2	-0.6	-0.2
44	-6.7	-2.0	-1.6	-1.0

Piezometer locations shown on Figure 4.

*Measured with open tube water manometers.

Table 2

MINIMUM PRESSURES* IN SHAFT WITH NO DEFLECTORS OR VENTS--PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=3,750 cfs	Q=2,500 cfs	Q=1,250 cfs
9	-5.3	-0.4	-0.2	-0.2
10	-4.3	-0.6	0.0	0.0
11	-4.7	0.0	0.0	0.2
12	-4.7	-0.6	-0.4	0.0
21	-5.9	-0.6	-0.2	-0.2
22	-4.5	-0.2	-0.2	-0.2
23	-5.1	-0.4	-0.2	0.0
24	-5.3	-1.2	-0.6	-0.6
33	-4.5	0.4	0.2	0.0
34	-5.1	0.4	0.2	0.2
35	-5.5	-0.2	-0.4	-0.2
36	-5.5	-0.2	0.0	-0.2
45	-3.0	0.8	1.0	0.6
46	-4.9	-0.2	0.0	0.0
47	-7.3	-0.8	-0.6	-0.6
48	-7.1	-0.8	-0.8	-0.6

Piezometer locations shown on Figure 5.

*Measured with open tube water manometers.

Table 3

MINIMUM PRESSURES* IN PRELIMINARY BENDS AND TUNNEL WITH NO DEFLECTORS OR VENTS--PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=3,750 cfs	Q=2,500 cfs	Q=1,250 cfs
49	3.0	4.3	3.2	2.2
50	15.6	10.3	7.9	2.4
51	22.5	21.7	17.7	14.6
52	3.2	6.3	4.7	2.6
53	-18.7	-16.6	-14.0	-9.3
54	-6.1	-3.4	-3.7	-2.4
55	1.8	2.2	0.2	-0.6

Piezometer locations shown on Figure 5.

*Measured with open tube water manometers.

Table 4

WATER MANOMETER PRESSURES IN SHAFT AND UPPER BEND WITH PRELIMINARY DEFLECTOR AND AIR VENT--PROTOTYPE FEET OF WATER

Q=5,000 cfs

Piezometer number	Maximum pressure	Maximum pressure	Maximum pressure
9	-2.8	-4.1	-3.5
10	-2.0	-3.0	-2.5
11	-2.0	-3.7	-2.9
12	-2.8	-4.3	-3.6
21	-3.4	-5.3	-4.4
22	-2.6	-5.3	-4.0
23	-2.2	-4.5	-3.4
24	-3.2	-4.9	-4.1
33	-2.0	-2.8	-2.4
34	-1.8	-3.2	-2.5
35	-2.6	-3.9	-3.3
36	-2.4	-3.4	-2.9
45	-0.6	-2.8	-1.7
46	-2.4	-3.9	-3.2
47	-3.2	-4.9	-4.1
48	-3.2	-4.5	-3.9
49	8.7	3.0	5.9
50	20.7	16.2	18.5
51	26.2	22.1	24.2

Piezometer locations shown on Figure 5.

Table 5

AVERAGE WATER MANOMETER PRESSURES ON SPILLWAY CREST FOR THE RECOMMENDED DESIGN-- PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=4,000 cfs	Q=3,000 cfs	Q=2,000 cfs	Q=1,000 cfs
1	6.7	0.4	0.9	1.3	1.6
2	6.6	-1.9	-1.2	-0.3	0.4
3	4.4	-2.2	-1.4	-0.6	0.2
4	4.0	-2.6	-2.0	-1.0	0.0
5	3.2	-2.2	-2.2	-1.4	-0.6
6	3.3	0.1	-0.8	-0.8	-0.4
7	4.0	2.1	1.0	0.0	-0.2
8	Covered by deflector				
13	2.0	-2.7	-1.0	0.3	1.2
14	3.4	-1.4	-0.4	0.1	0.6
15	4.0	-1.0	-0.2	0.1	0.4
16	4.1	-0.9	-0.2	0.0	0.4
17	4.2	-0.4	-0.4	-0.2	0.0
18	3.2	-0.1	-0.2	-0.2	0.0
19	2.8	-0.2	0.0	0.0	0.0
20	2.4	0.4	0.5	0.6	0.4
25	3.4	-1.0	0.4	1.0	1.6
26	1.7	-3.7	-2.0	-0.6	0.4
27	1.9	-3.7	-2.2	-0.8	0.0
28	2.2	-3.9	-2.4	-1.0	0.0
29	0.4	-2.9	-2.4	-1.4	-0.4
30	2.8	-0.2	-1.0	-0.6	-0.2
31	2.0	-0.3	-0.6	-0.6	-0.6
32	-0.2	0.0	0.0	-0.1	-0.8
37	3.9	-0.9	0.1	0.9	1.4
38	2.2	-3.7	-2.2	-0.8	0.2
39	2.5	-3.7	-2.2	-1.0	0.0
40	2.6	-4.0	-2.6	-1.2	-0.2
41	2.4	-3.2	-2.8	-1.6	-0.6
42	3.0	-0.6	-1.4	-1.0	-0.4
43	3.9	1.5	0.3	-0.2	-0.2
44	Covered by deflector				

Piezometer locations shown on Figure 4.

Table 6

AVERAGE WATER MANOMETER PRESSURES IN SHAFT FOR THE RECOMMENDED DESIGN--PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=4,000 cfs	Q=3,000 cfs	Q=2,000 cfs	Q=1,000 cfs
9	-0.2	-0.2	-0.2	-0.2	0.0
10	-0.2	-0.2	-0.2	-0.2	0.0
11	-0.2	-0.2	-0.2	-0.2	0.0
12	-0.3	-0.3	-0.2	-0.2	0.0
21	0.4	-0.1	-0.4	-0.3	0.0
22	0.4	0.2	0.0	-0.2	0.0
23	0.6	0.6	0.1	0.7	0.0
24	1.0	0.6	-0.5	-0.5	0.0
33	1.5	0.3	0.0	-0.3	0.1
34	1.3	1.5	0.5	1.1	0.4
35	0.1	0.8	1.1	0.5	-0.2
36	1.7	1.1	1.0	0.6	0.0
45	0.2	0.2	0.0	0.4	0.0
46	-0.2	-0.2	-0.2	-0.2	0.0
47	-0.5	-0.3	-0.2	-0.2	-0.2
48	-0.3	-0.2	-0.2	-0.2	-0.2

Piezometer locations shown on Figure 5.

Table 7

AVERAGE WATER MANOMETER PRESSURES IN BENDS AND TUNNEL FOR THE RECOMMENDED DESIGN--PROTOTYPE FEET OF WATER

Piezometer number	Q=5,000 cfs	Q=4,000 cfs	Q=3,000 cfs	Q=2,000 cfs	Q=1,000 cfs
49	15.5	14.8	9.5	8.1	2.0
50	18.9	16.7	14.2	10.0	15.3
51	3.4	2.7	2.3	1.1	0.8
52	28.2	24.4	19.5	14.7	8.6
53	24.0	19.6	14.8	9.4	3.1
54	25.1	21.6	17.9	13.6	8.0
55	7.6	6.4	4.9	3.3	2.3
56	6.0	5.4	4.5	3.0	2.4

Piezometer locations shown on Figure 5.

Table 8

INSTANTANEOUS DYNAMIC PRESSURES
FOR THE RECOMMENDED DESIGN--
PROTOTYPE FEET OF WATER

Run number	Piezometer number	Instantaneous pressures		
		Maximum	Minimum	Average
1 (Q=2,000 cfs)	49	16.0	3.0	7.9
	50	19.9	-1.2	10.1
	51	5.5	-3.4	0.6
	52	25.8	7.1	14.8
	53	15.2	5.1	10.8
	54	19.3	10.1	14.2
2 (Q=4,000 cfs)	25	-0.4	-1.2	-0.8
	26	-3.4	-4.1	-3.9
	27	-2.0	-3.2	-2.4
	28	-3.7	-4.5	-4.1
	29	-2.2	-4.1	-3.0
	30	-0.2	-1.0	-0.6
3 (Q=4,000 cfs)	31	1.2	-1.8	-0.4
	32	2.8	-2.2	-0.2
	33	6.1	-2.0	0.0
	34	12.4	-3.9	1.2
	35	5.1	-1.0	1.0
	36	6.1	-2.8	1.2
4 (Q=5,000 cfs)	12	-0.3	-0.3	-0.3
	48	-0.2	-0.2	-0.2

Piezometer locations shown on Figures 4 and 5.

Table 9

SUPPORTING DATA FOR
RECOMMENDED DISCHARGE CURVE

Q (cfs)	Reservoir elevation (ft)
425	6991.00
591	6991.34
816	6991.67
1,048	6992.01
1,238	6992.30
1,563	6992.72
1,995	6993.23
2,495	6993.78
2,994	6994.29
3,385	6994.67
3,756	6995.04
4,044	6995.32
4,329	6995.60
4,531	6995.85
4,715	6996.17
4,885	6996.78
5,010	6998.02

Table 10

DIFFERENTIAL HEAD ACTING
ON PIER NO. 1

Q (cfs)	Differential head (Prototype feet of water)
1,000	0.2
2,000	0.2
3,000	0.6
4,000	1.0
5,000	1.2

Table 11

AIR DEMAND FOR RECOMMENDED DESIGN
IN PROTOTYPE CFS

Spillway discharge cfs	Reservoir elevation	Rate of airflow Top vent	Rate of airflow Bottom vent
601	6991.3	33.7	23.9
994	6991.9	42.1	37.3
1,570	6992.7	50.4	48.9
1,995	6993.2	51.5	50.4
2,505	6993.8	50.4	47.8
3,000	6994.3	52.8	52.8
4,006	6995.3	61.6	60.6
5,017	6998.0	62.7	61.6

Table 12

METRIC EQUIVALENTS OF IMPORTANT QUANTITIES REFERRED TO IN THIS REPORT

Feature	English units	Metric units
Height of dam	195 feet	59.4 meters
Length of dam at crest	730 feet	222.5 meters
Fill volume	1,300,000 yd^3	994,000 m^3
Diameter of morning-glory at crest	24 feet 1 and 1/2 inches	7.35 meters
Diameter of tunnel	13 feet	3.96 meters
Maximum spillway discharge	5,000 cfs	141.6 cms
Head on crest at maximum discharge for recommended design	8.3 feet	2.53 meters
Maximum total air demand	102 cfs	2.89 cms
Size of recommended deflector at bottom of crest profile	24 inches	60.96 cm
Height of crest piers above crest	10.3 feet	3.14 meters
Length of crest piers	12 feet	3.66 meters
Width of crest piers	30 inches	76.2 cm

FIGURE 1
REPORT HYD-518

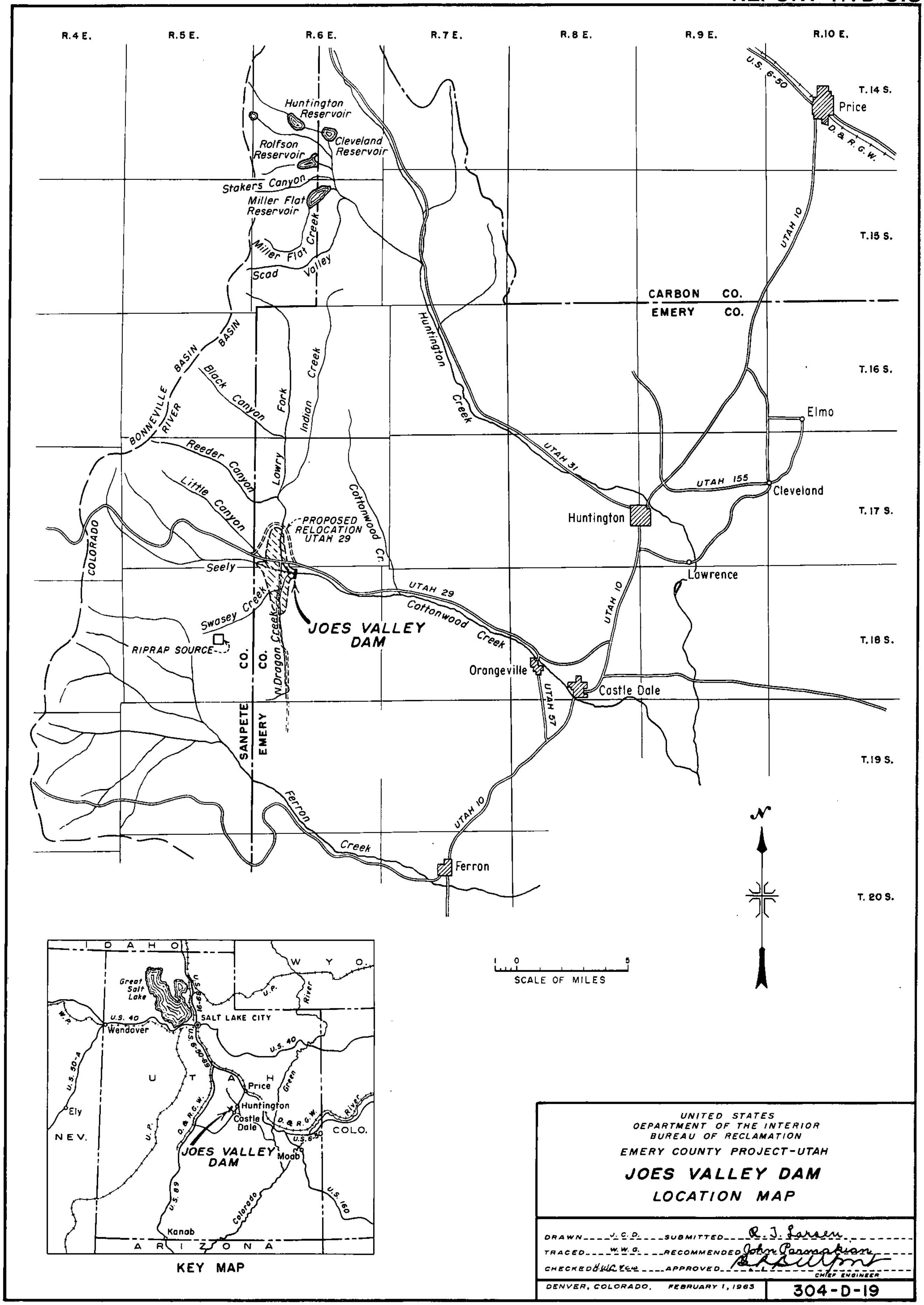
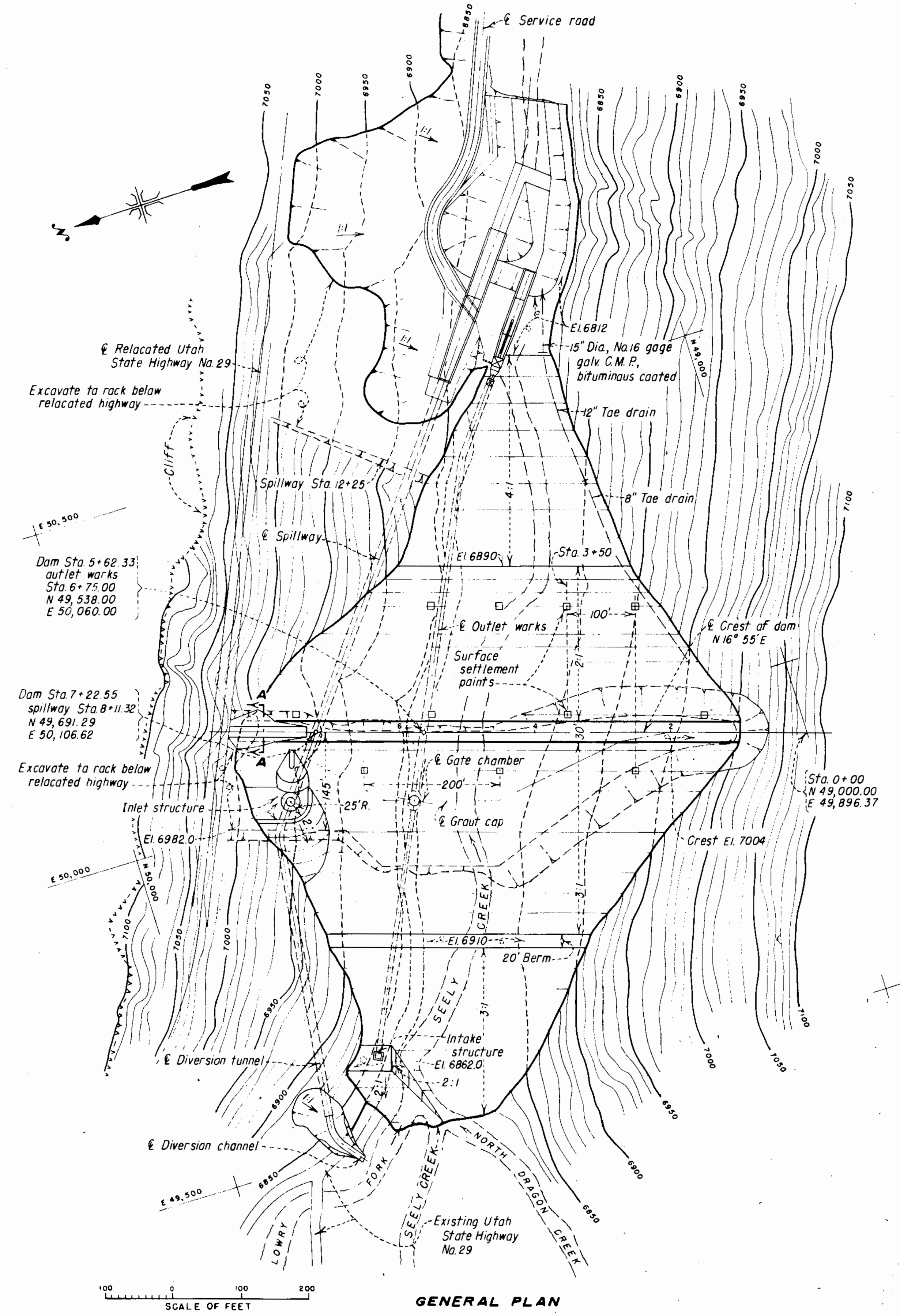
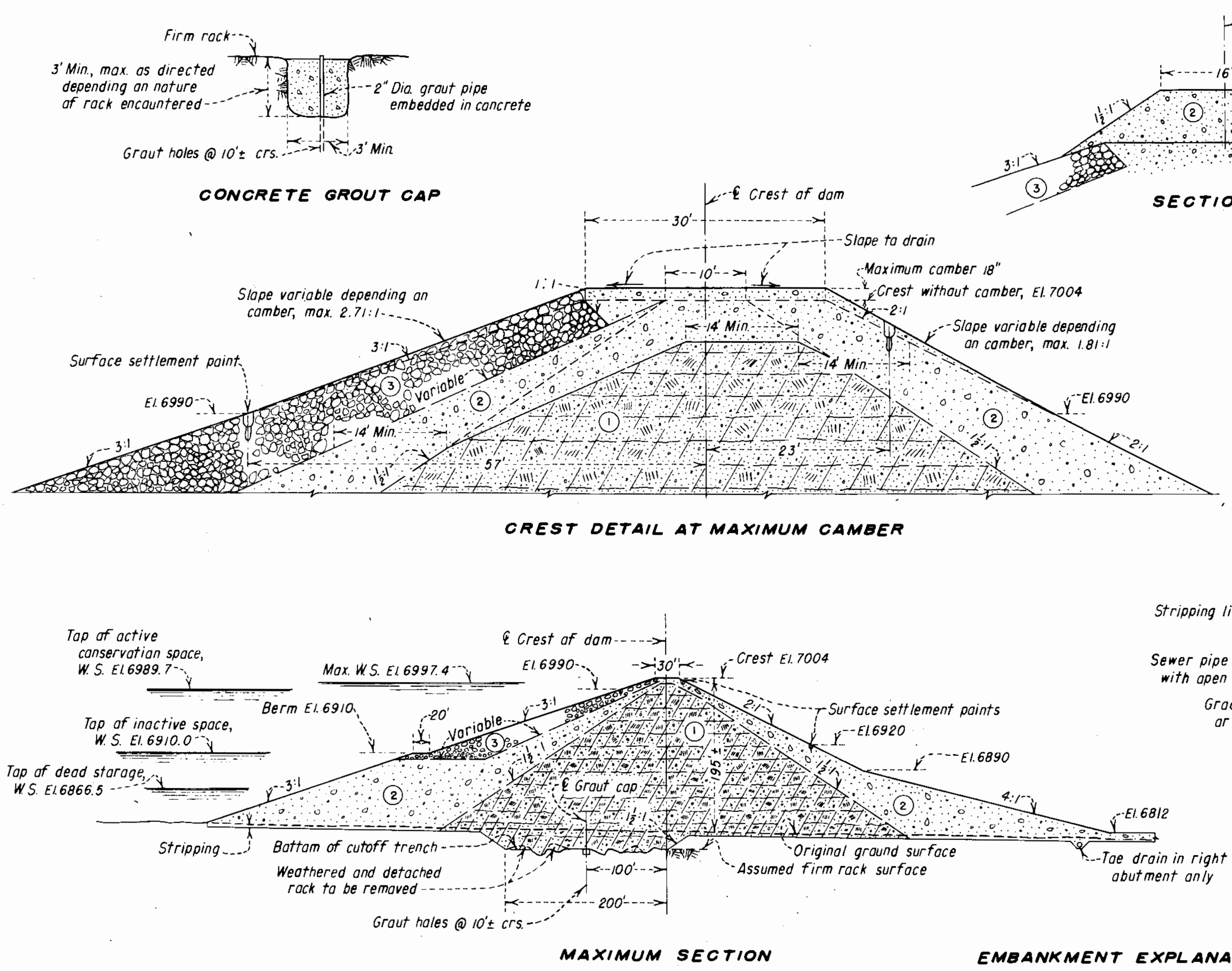
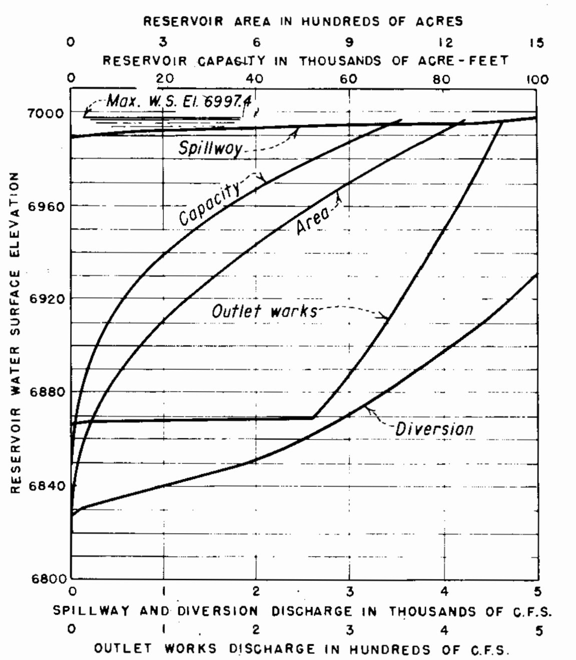


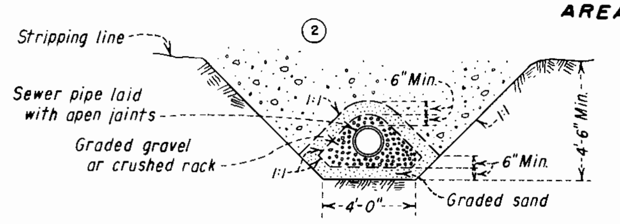
FIGURE 2
REPORT HYD-518



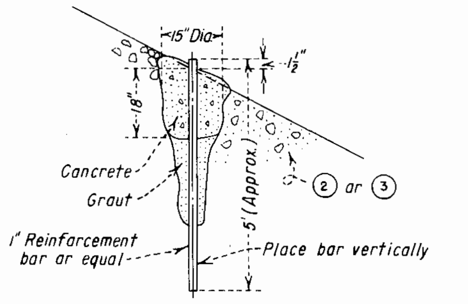




AREA-CAPACITY-DISCHARGE CURVES



EMBANKMENT TOE DRAIN DETAIL



SURFACE SETTLEMENT POINT DETAIL

EMBANKMENT EXPLANATION

(1) Clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers
(2) Sand, gravel, and cobbles compacted to 12-inch layers to 75% relative density
(3) Cobbles and boulders placed in 3-foot layers

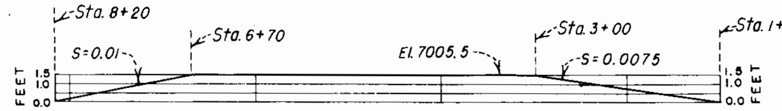
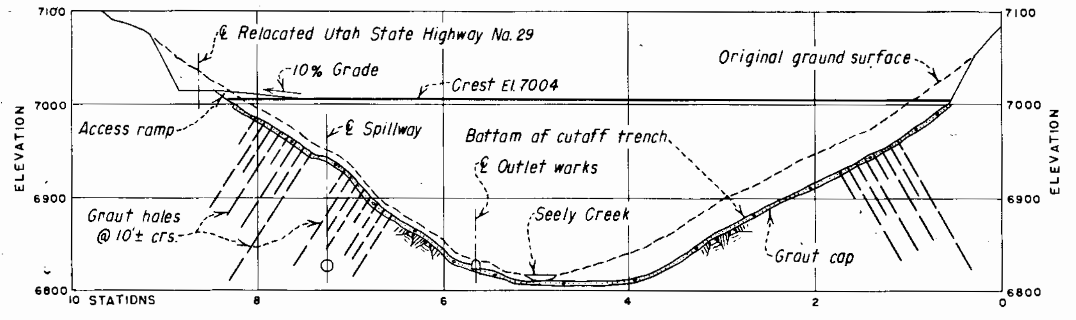


DIAGRAM FOR CAMBER ON CREST OF DAM



PROFILE ON ℄ CREST OF DAM

RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATIONS	STORAGE ACRE-FEET
Active conservation	6910.0 to 6989.7	54,600
Inactive	6866.5 to 6910.0	6,990
Dead	Streambed to 6866.5	870
Total reservoir capacity		62,460*

*Includes an allowance of 8500 a.f. for sediment inflow in 100 years of which 3500 a.f. are deposited in the active conservation space
A surcharge of 9400 a.f. (Max. W.S. El. 6997.4) in combination with a spillway discharge of 5000 c.f.s. is provided to protect against the inflow design flood which has a peak of 14,300 c.f.s. and a 15-day volume of 55,400 a.f.

ALWAYS THINK SAFETY

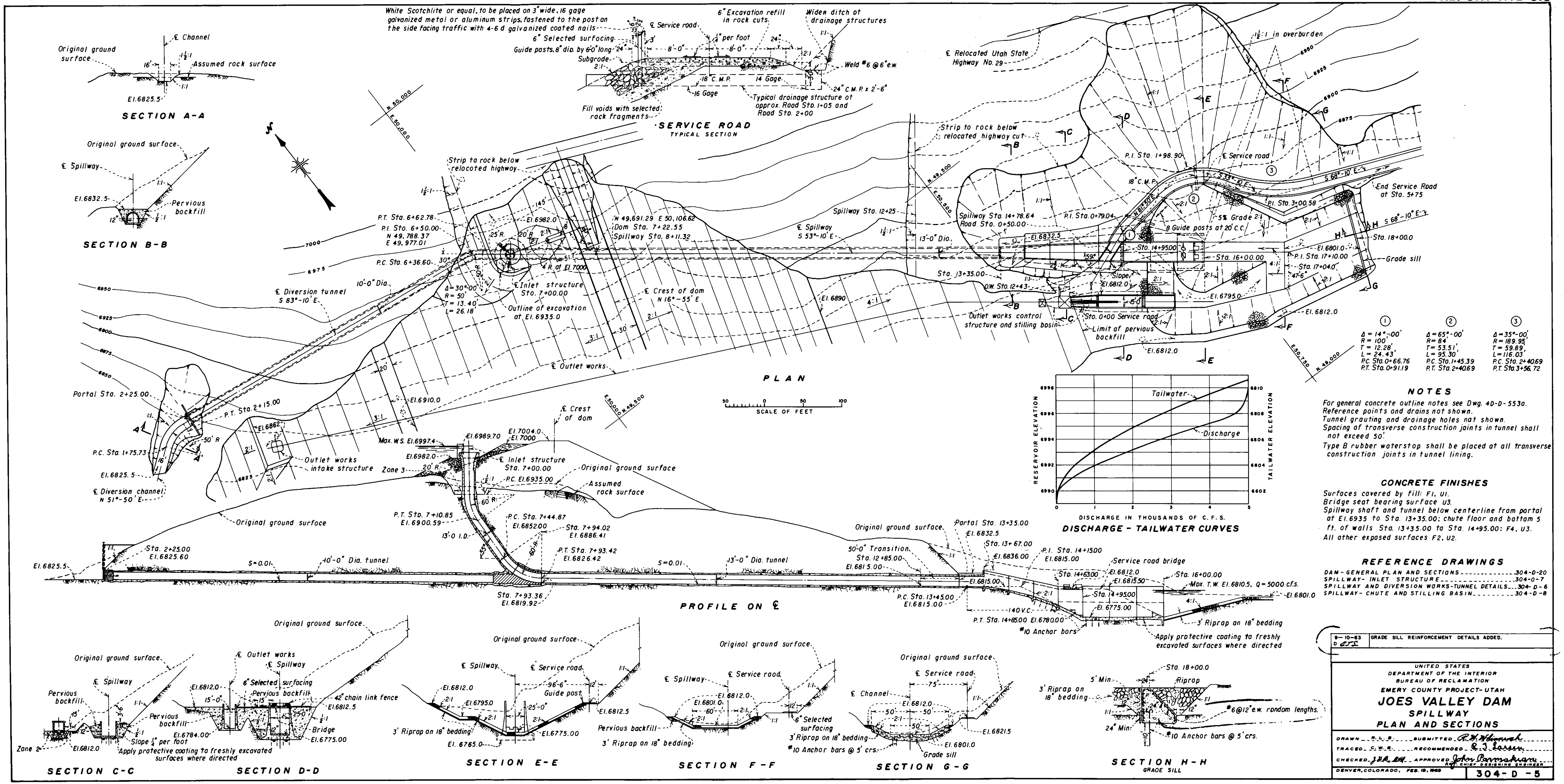
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EMERY COUNTY PROJECT - UTAH

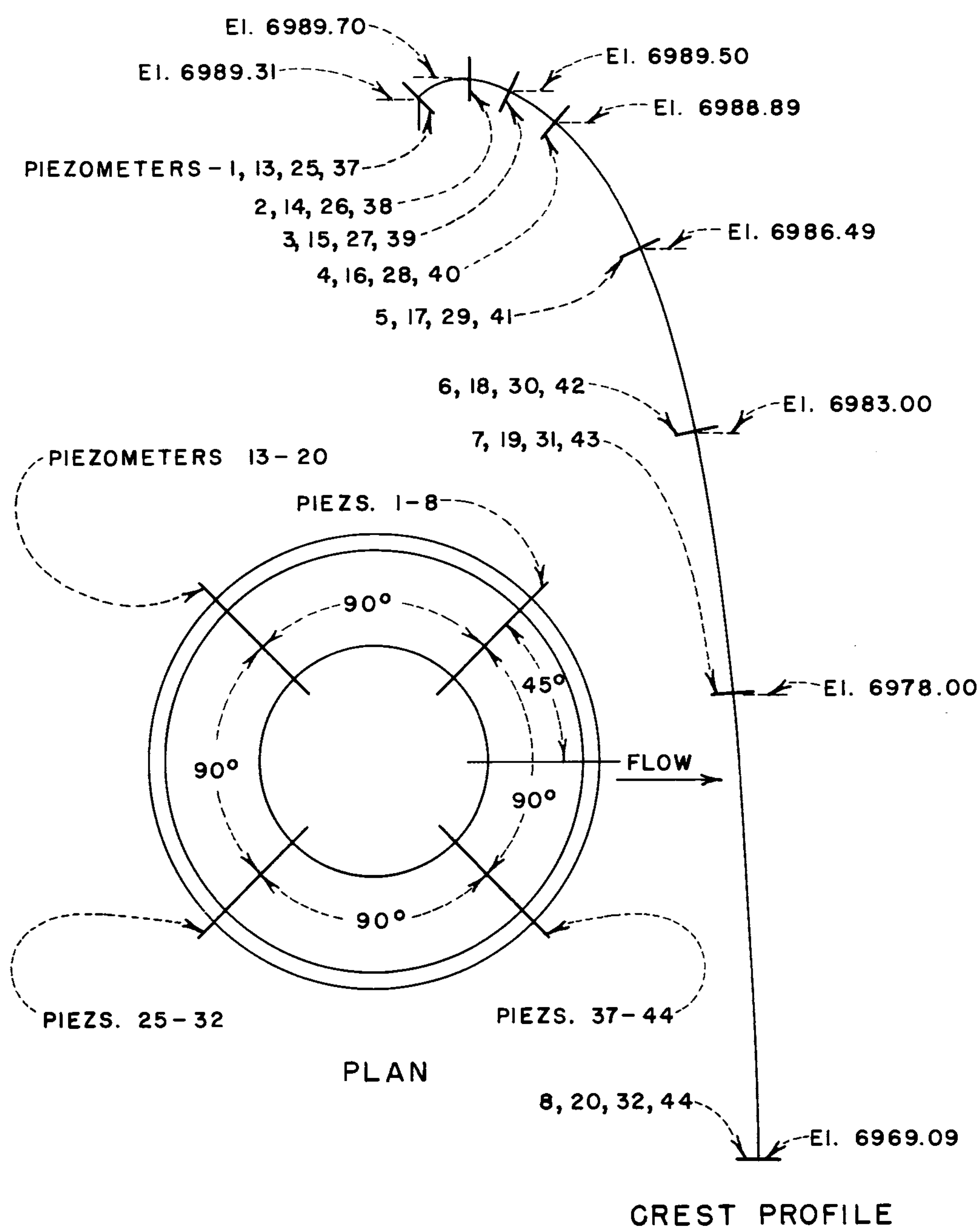
JOES VALLEY DAM

GENERAL PLAN AND SECTIONS

DRAWN A.Z. SUBMITTED R. J. Larsen
TRACED W.A.P. RECOMMENDED John Parmakian
CHECKED [illegible] APPROVED [illegible] CHIEF ENGINEER
DENVER, COLORADO, FEBRUARY 1, 1963
304-D-20

FIGURE 3
REPORT HYD-518

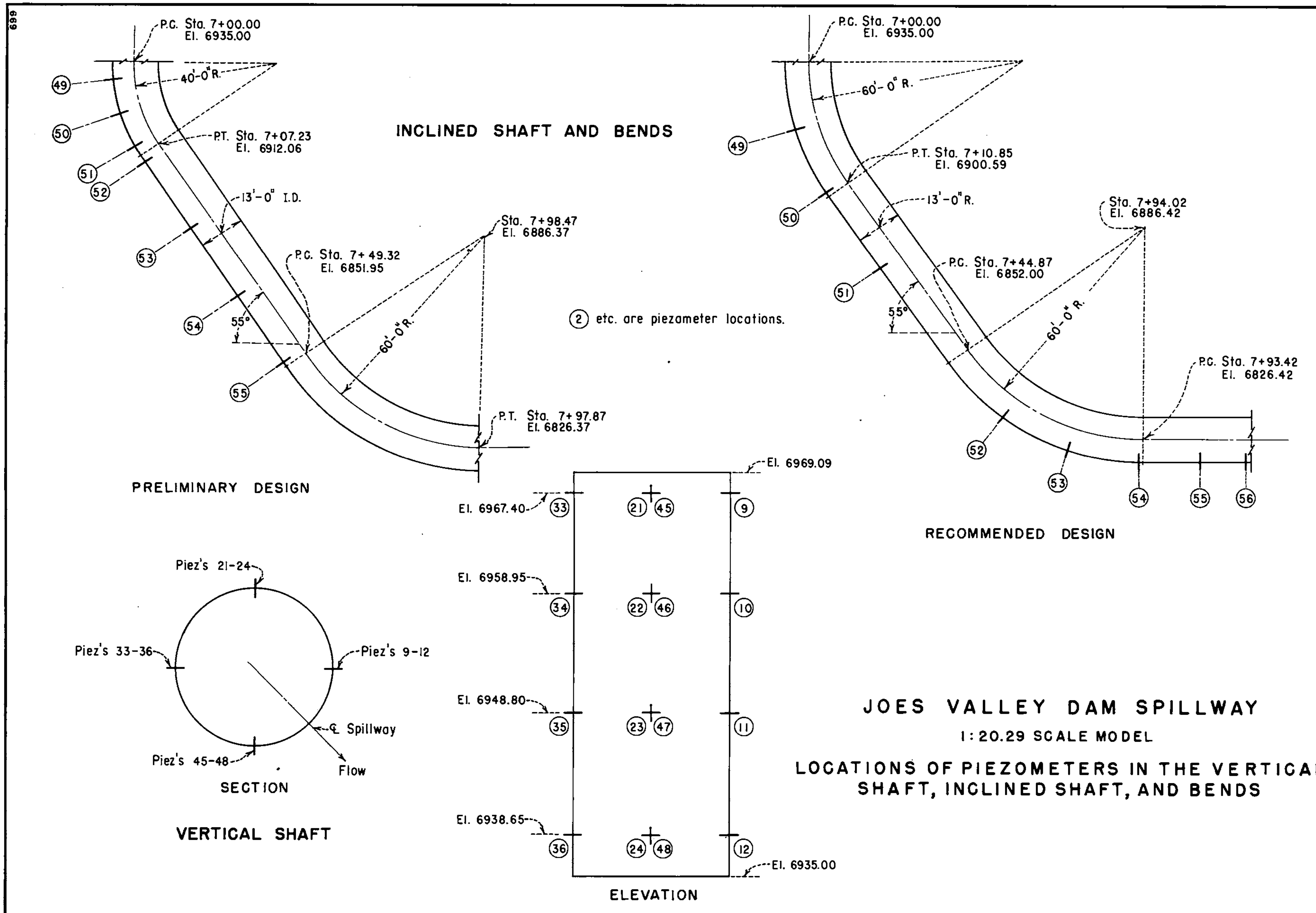




JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

SPILLWAY CREST PROFILE
PIEZOMETER LOCATIONS



JOES VALLEY DAM SPILLWAY

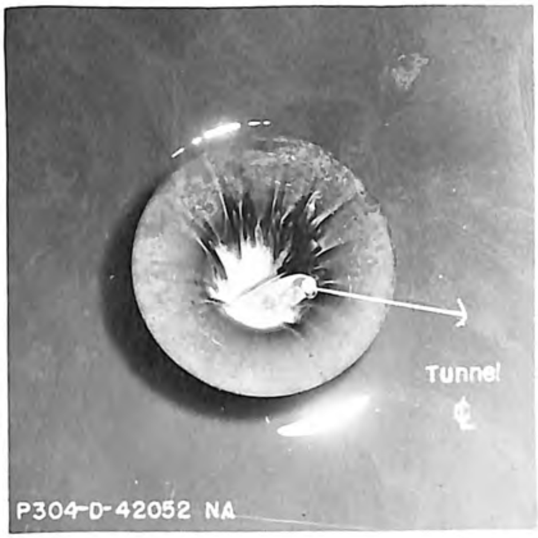
1:20.29 SCALE MODEL

LOCATIONS OF PIEZOMETERS IN THE VERTICAL SHAFT, INCLINED SHAFT, AND BENDS

FIGURE 5
REPORT HYD-518

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Trial 1. Morning-glory Entrance



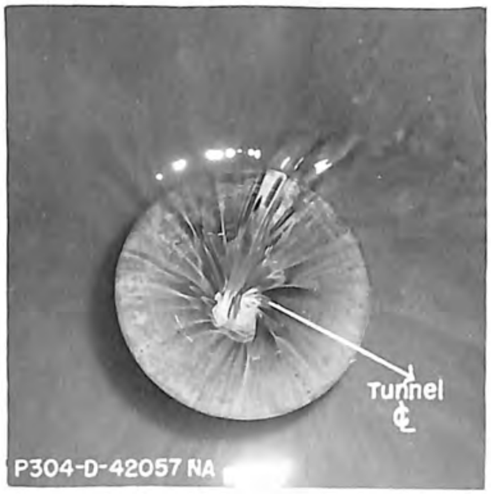
A. Entrance Flow Conditions

B. Flow in the Upper Bend

C. Flow in the Lower Bend

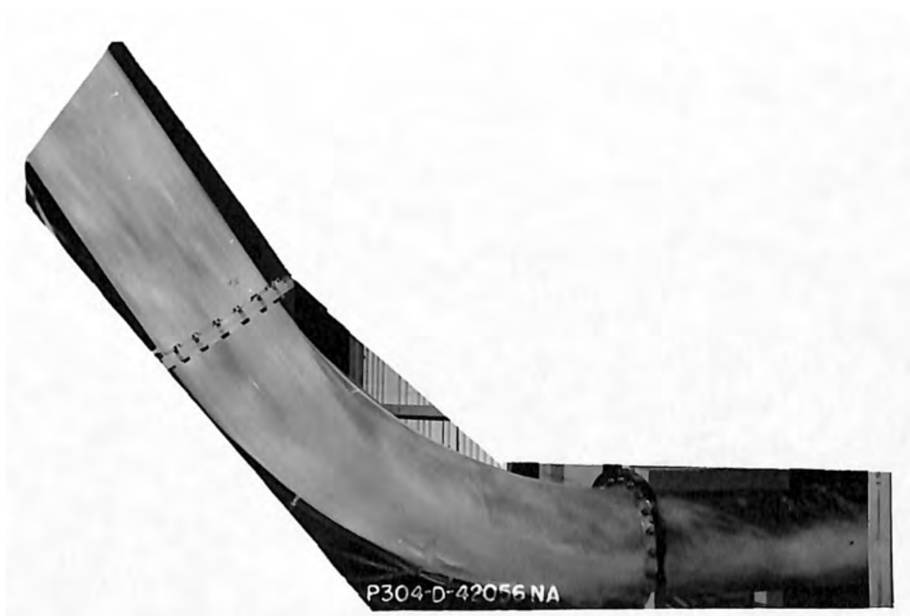
JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Spillway Flow Conditions for Trial 1
Q = 2,500 cfs, Reservoir Elevation 6993.6
No Appurtenances



A. Entrance Conditions

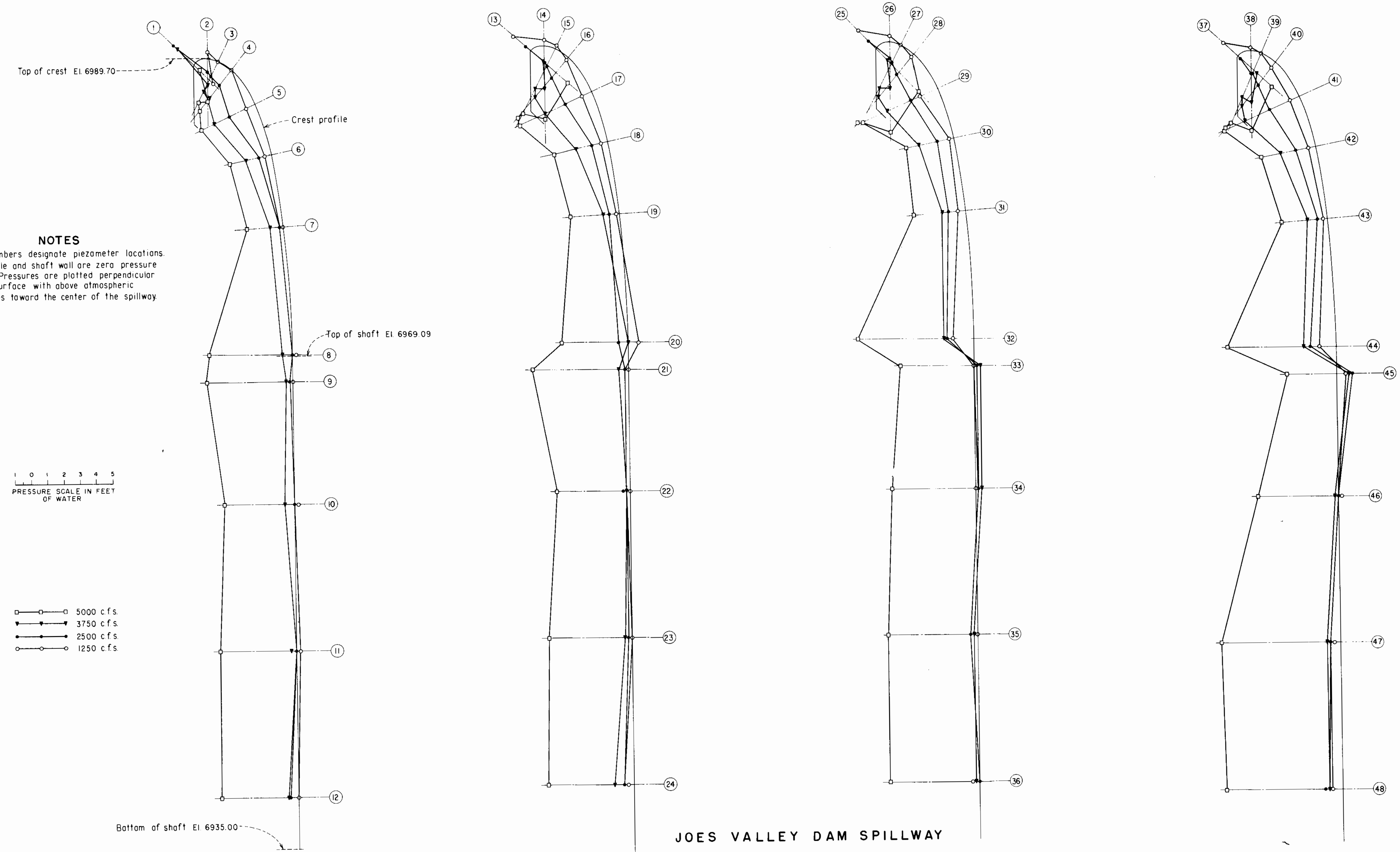
B. Flow in the Upper Bend



C. Flow in the Lower Bend

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Spillway Flow Conditions for Trial 1
Q = 5,000 cfs, Reservoir Elevation 6995.7



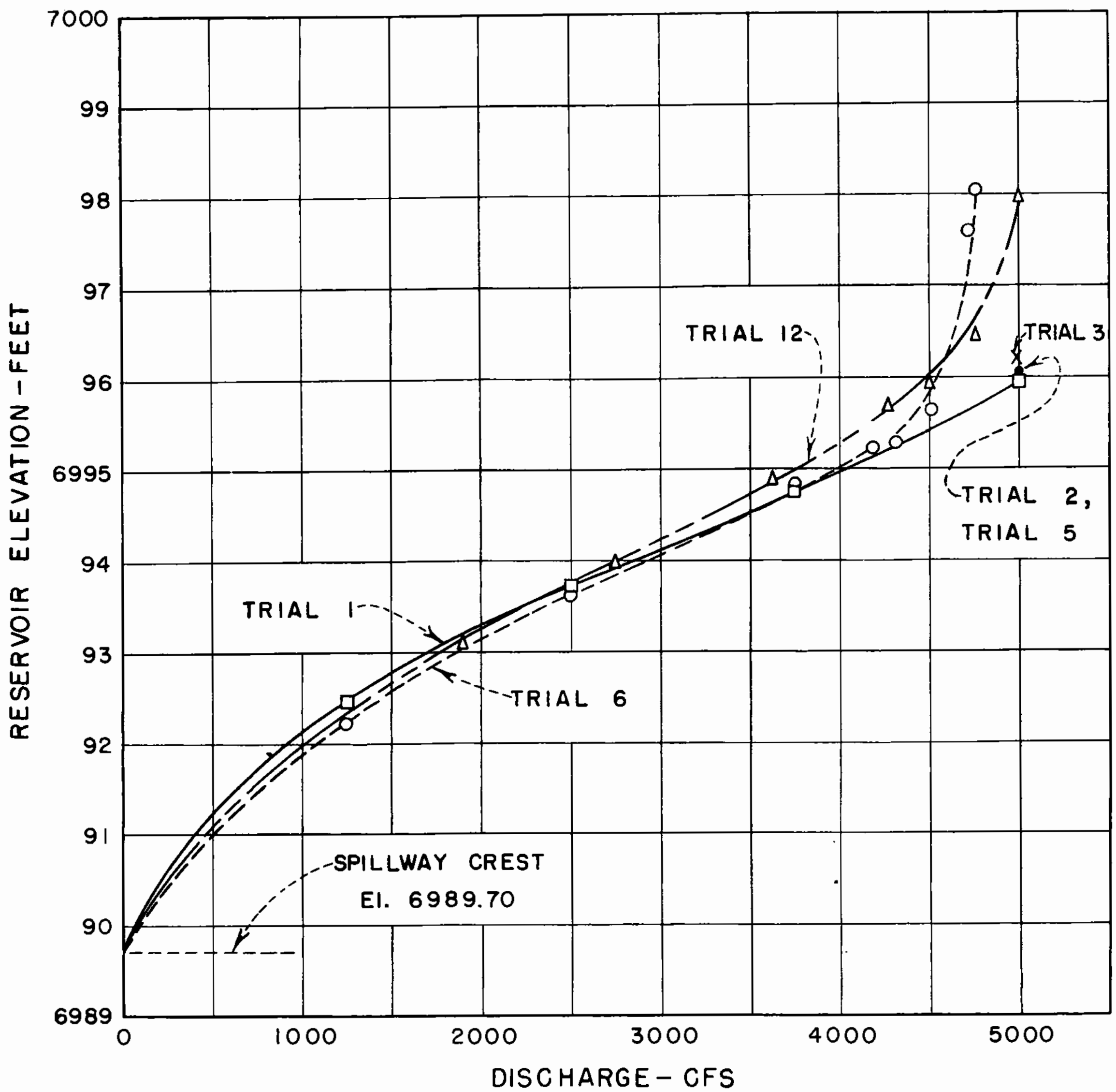
NOTES

Circled numbers designate piezometer locations. Crest profile and shaft wall are zero pressure datums. Pressures are plotted perpendicular to the surface with above atmospheric pressures toward the center of the spillway.

JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

CREST AND SHAFT PRESSURE PROFILES FOR TRIAL 1

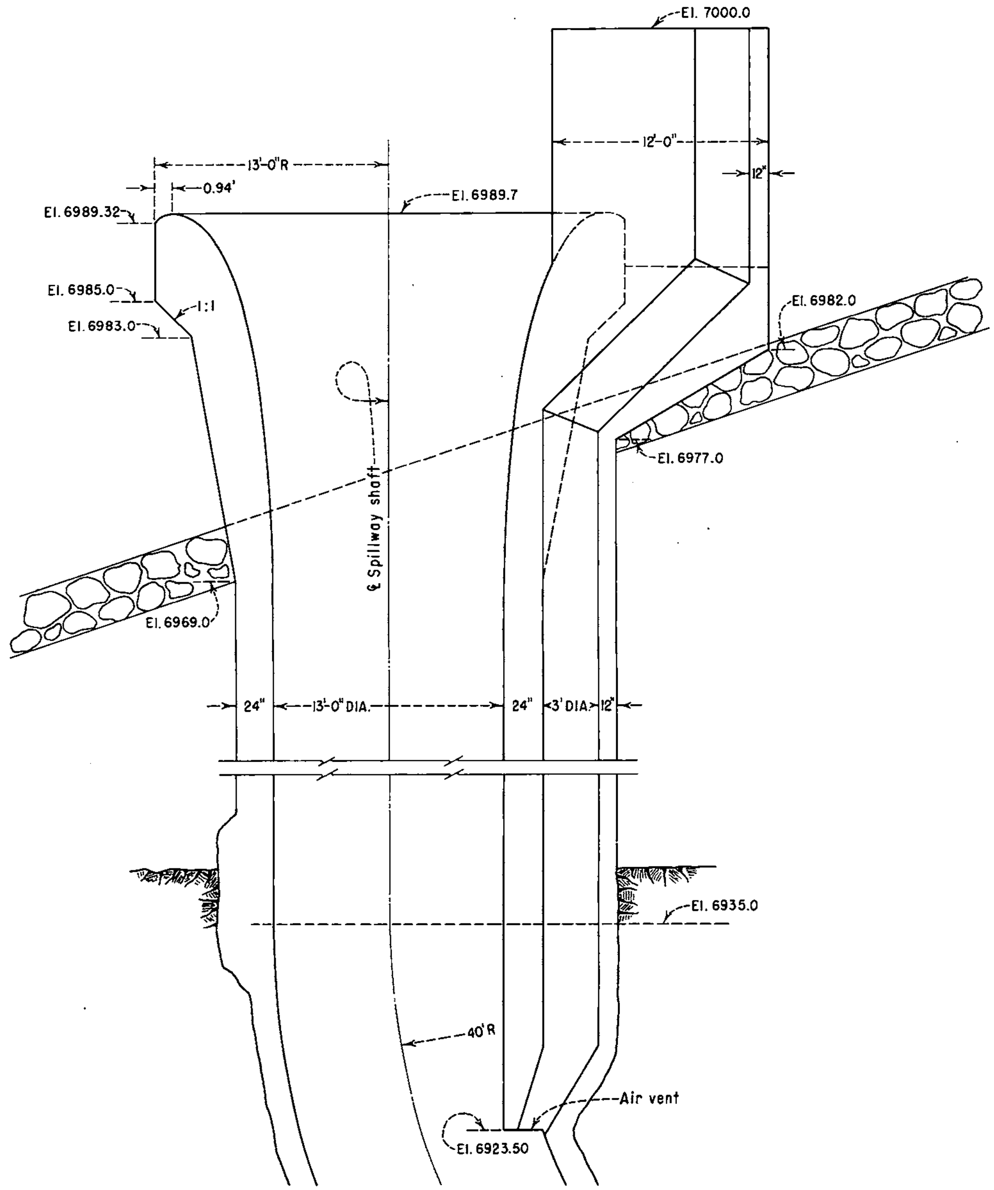


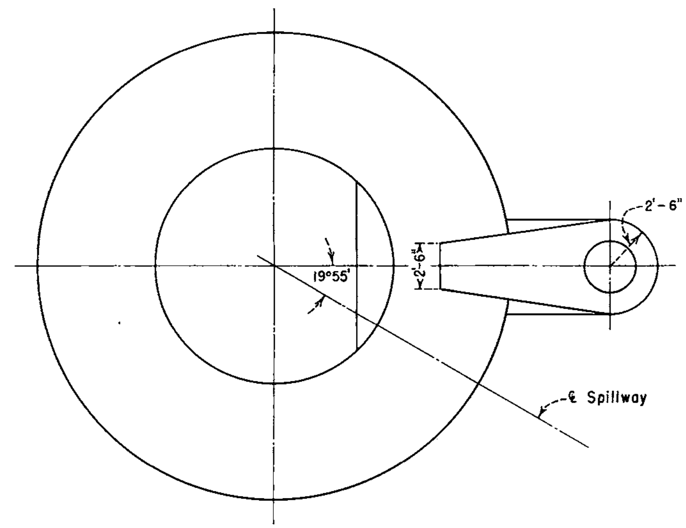
JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

HEAD VS. DISCHARGE CURVES FOR
TRIALS 1,2,3,5,6 & 12

FIGURE 11
REPORT HYD-518





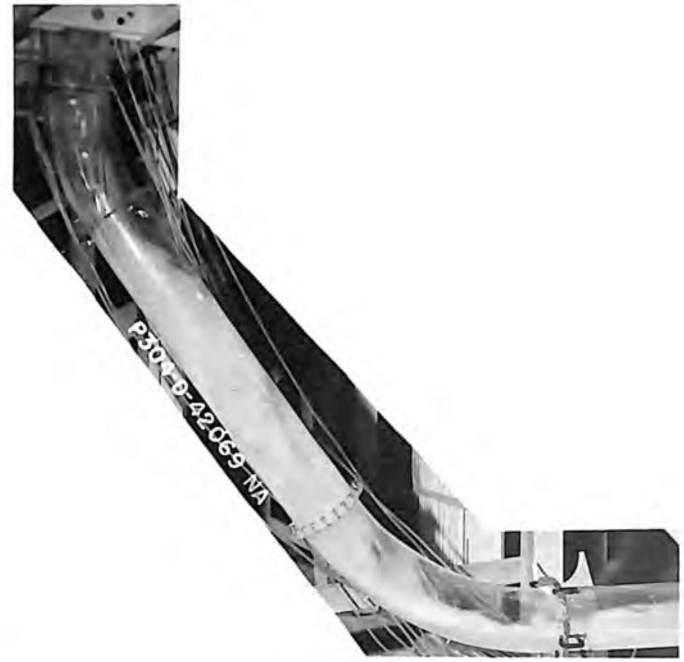
PLAN

JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

PRELIMINARY DESIGN

A. Q = 5,000 cfs, Reservoir El. 6995.7

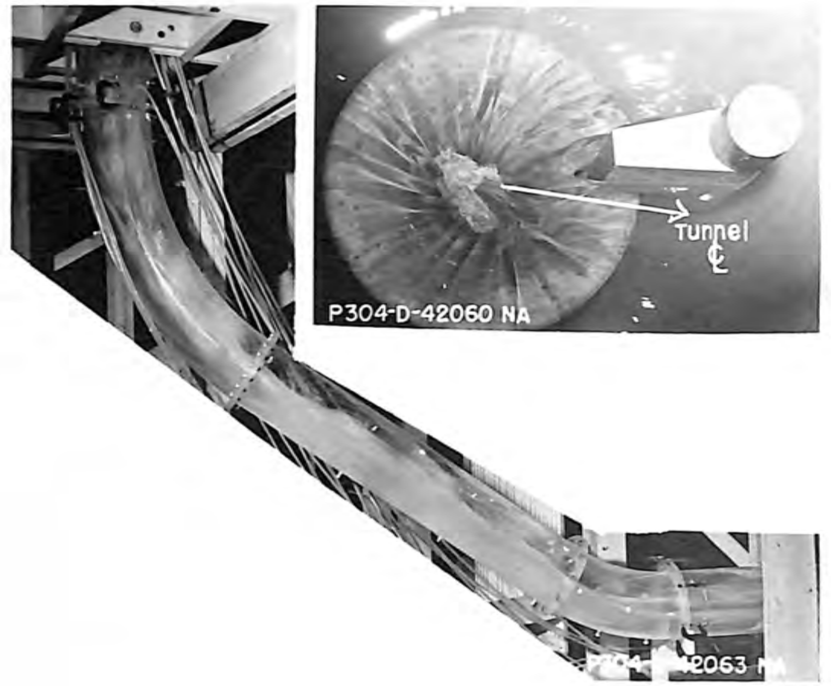


B. Q = 2,500 cfs, Reservoir El. 6993.6

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions in the Bends and Inclined
Shaft for Trial 2 - Preliminary Deflector
and Single Pier on Crest

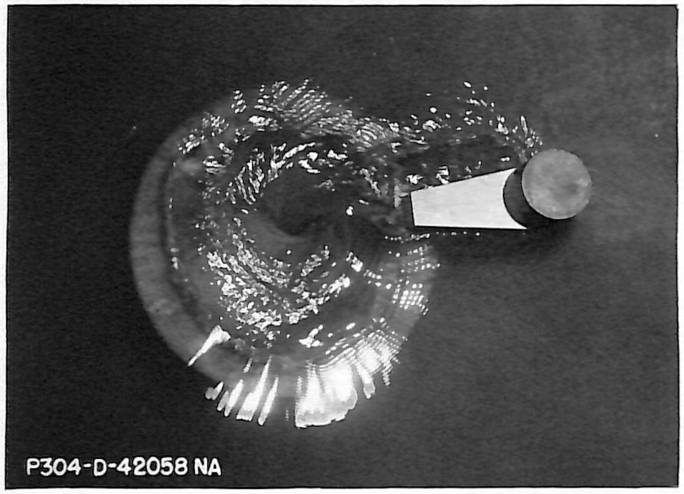
A. Smooth Condition Corresponding to High Point of Boil



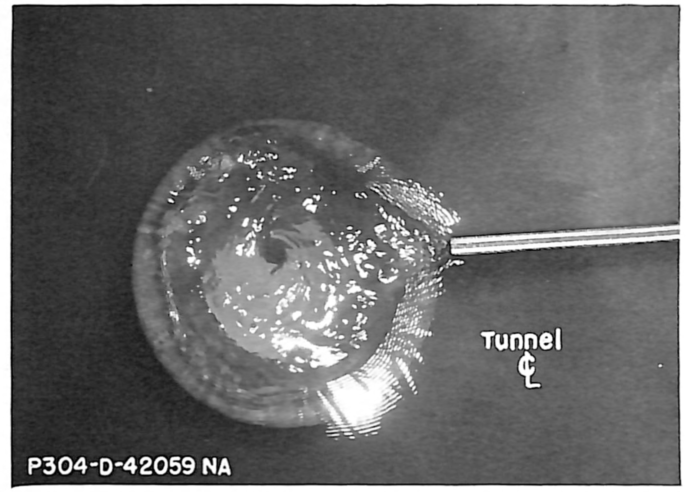
B. Rough Condition Corresponding to Low Point of Boil

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions in the Bends and Inclined Shaft
for Trial 3 - 12 Inch Deflector at Bottom of Crest Section
and Preliminary Pier on Crest-Bends Interchanged
Q = 5,000 cfs, Reservoir Elevation 6996.2



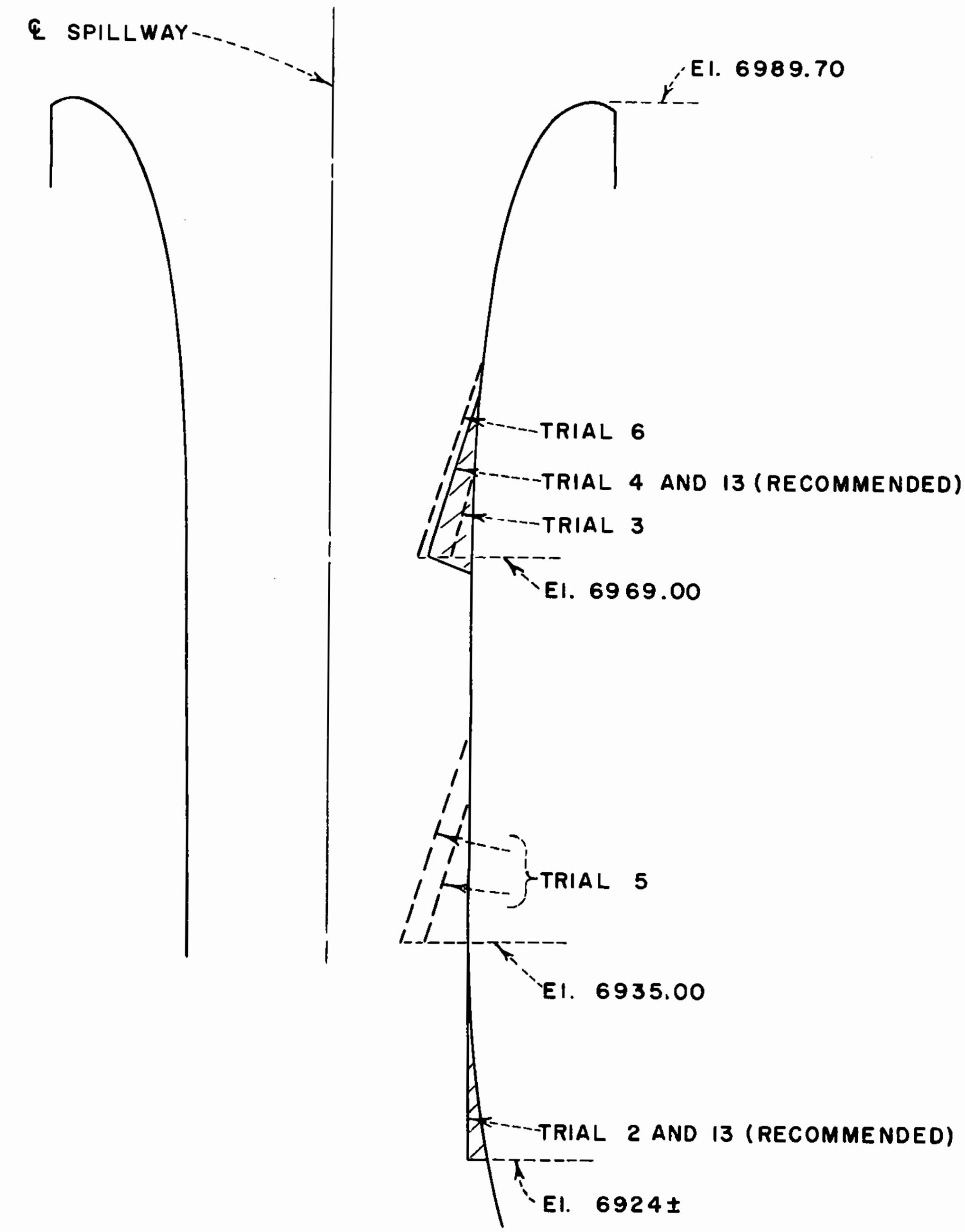
A. Q = 5,000 cfs, Reservoir El. 6997.8 and Rising Rapidly



B. Q = 5,000 cfs, Reservoir El. 6997.9

JOES VALLEY DAM SPILLWAY

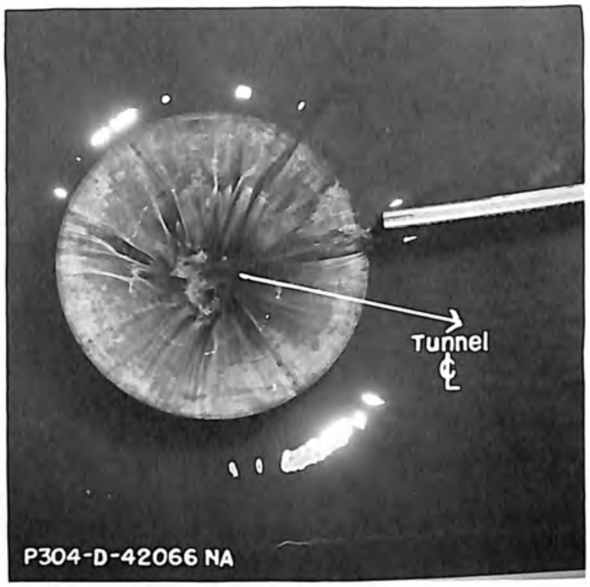
1:20.29 Scale Model
Comparison of Entrance Conditions with
Preliminary Crest Pier and with 25-foot
Wall Normal to Dam - Trial 4



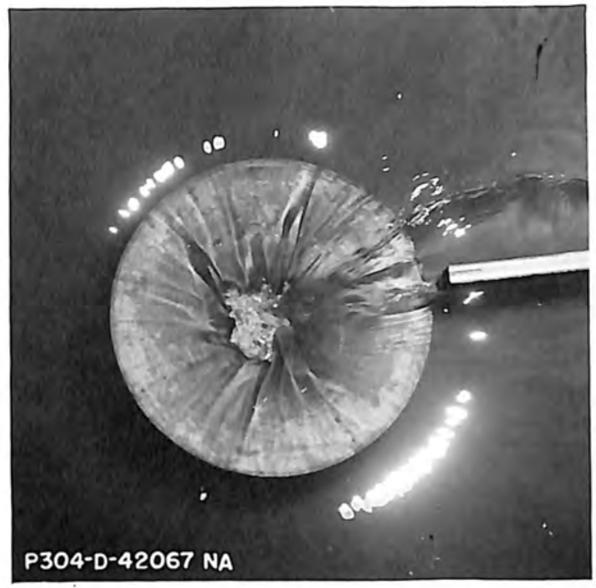
JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

TRIAL DEFLECTOR LOCATIONS



A. Unsubmerged Condition

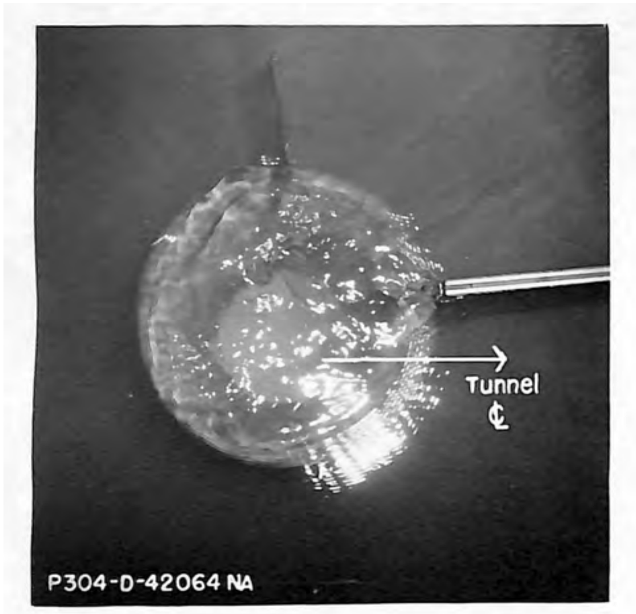


B. Submerged Condition

C. Flow in Bends and Inclined Shaft

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 5
Q = 5,000 cfs, Reservoir Elevation 6995.9
36-inch Deflector at Bottom of
Vertical Shaft



A. Entrance Conditions

B. Flow in Bends and Inclined Shaft

JOES VALLEY DAM SPILLWAY

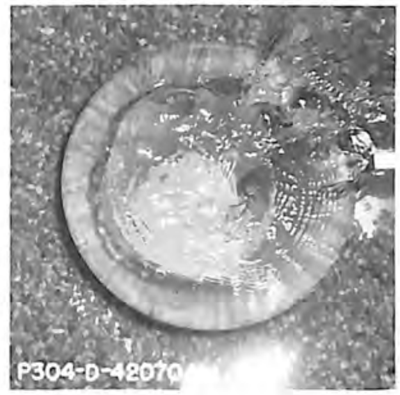
1:20.29 Scale Model
Flow Conditions for Trial 6
Q = 4,800 cfs, Reservoir Elevation 6998.2
30-inch Deflector at Bottom of Crest Profile

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Trial 7 - Stabilizing Bench Fill
Around Morning-glory Entrance

Figure 18
Report Hyd-518

A. 10-foot Wall
Q = 5, 000 cfs



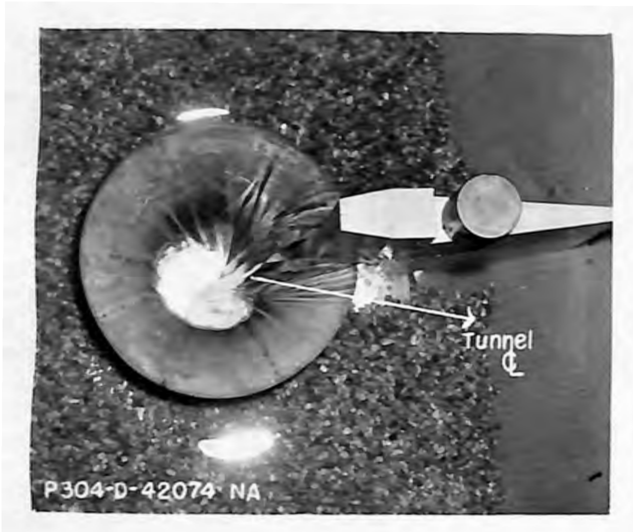
B. 15-foot Wall
Q = 5, 000 cfs

C. 20-foot Wall
Q = 5, 000 cfs

D. 20-foot Wall
Q = 2, 500 cfs

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Trial 8 - Determination of Optimum Wall
Length for Vortex Control



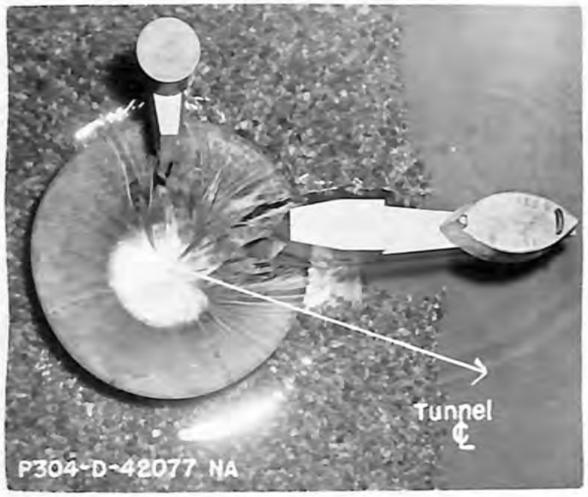
A. Entrance Conditions

B. Flow in the Bends and Inclined Shaft

C. Flow in the Horizontal Tunnel

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 9
Q = 2,500 cfs, Reservoir Elevation 6993.6
60-foot-radius Upper Bend and 20-foot-long Pier on Crest



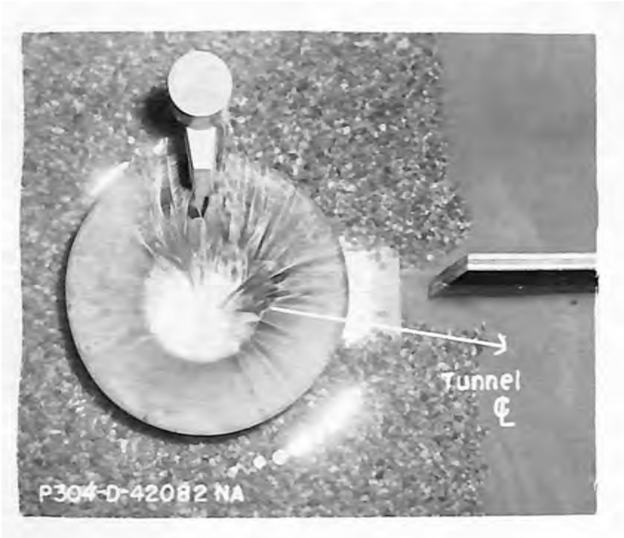
A. Entrance Conditions

B. Flow in the Bends and Inclined Shaft

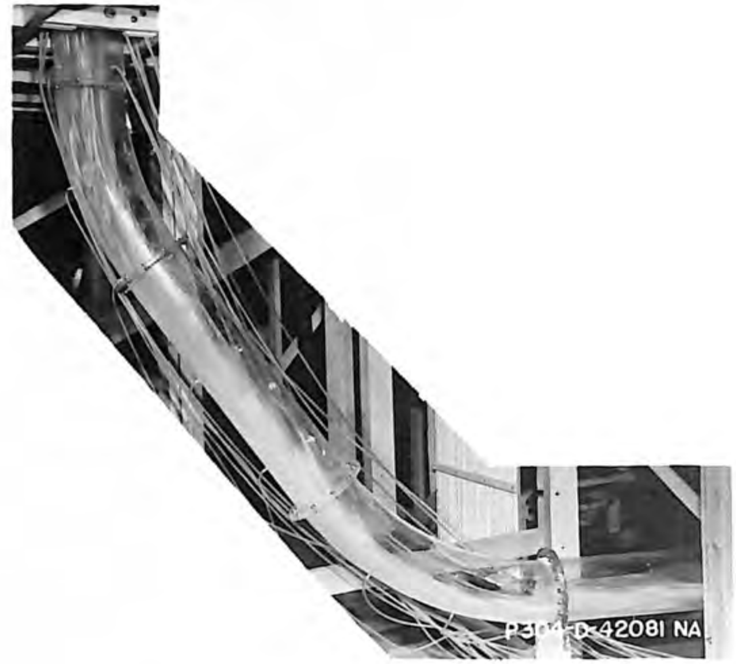
C. Flow in the Horizontal Tunnel

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 10
Q = 2,500 cfs, Reservoir Elevation 6993.6
20-foot-long Pier on Crest Normal to
Dam and Short Pier 90° Counter-
clockwise from Normal Pier



A. Entrance Conditions



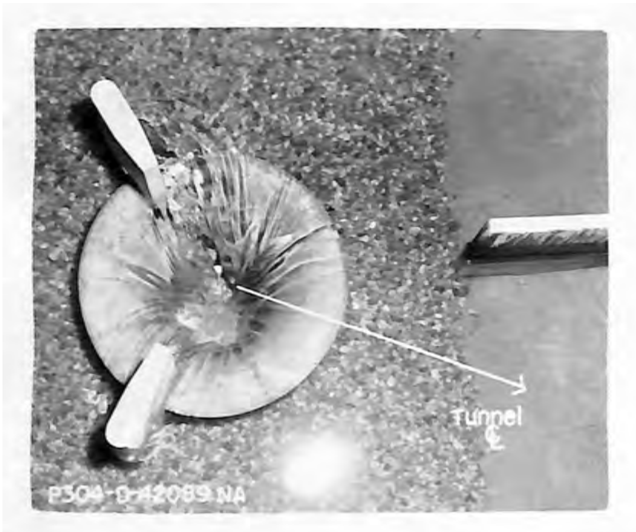
B. Flow in the Bends and Inclined Shaft

C. Flow in the Horizontal Tunnel

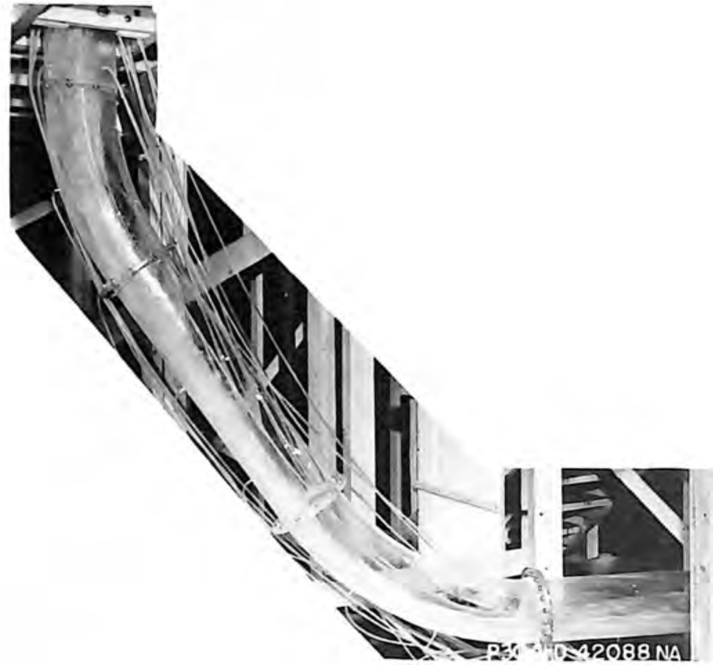
JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 11
Q = 2,500 cfs, Reservoir Elevation 6993.6
20-foot-long Thin Wall Placed Normal to the Dam 10 Feet from the Crest and Short Pier 90° Counterclockwise from Normal Wall

Figure 22
Report Hyd-518



A. Entrance Conditions



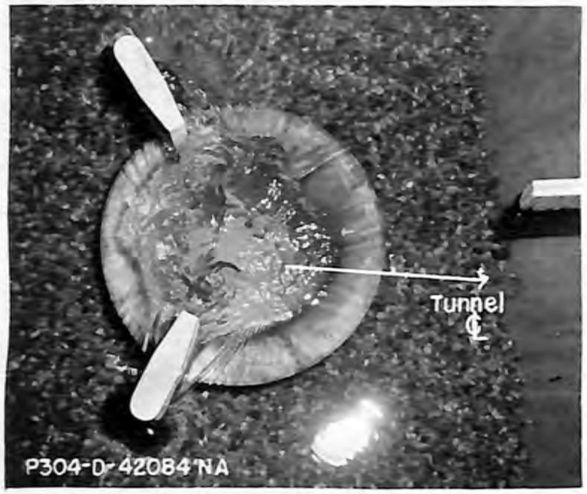
B. Flow in the Bends and Inclined Shaft

C. Flow in the Horizontal Tunnel

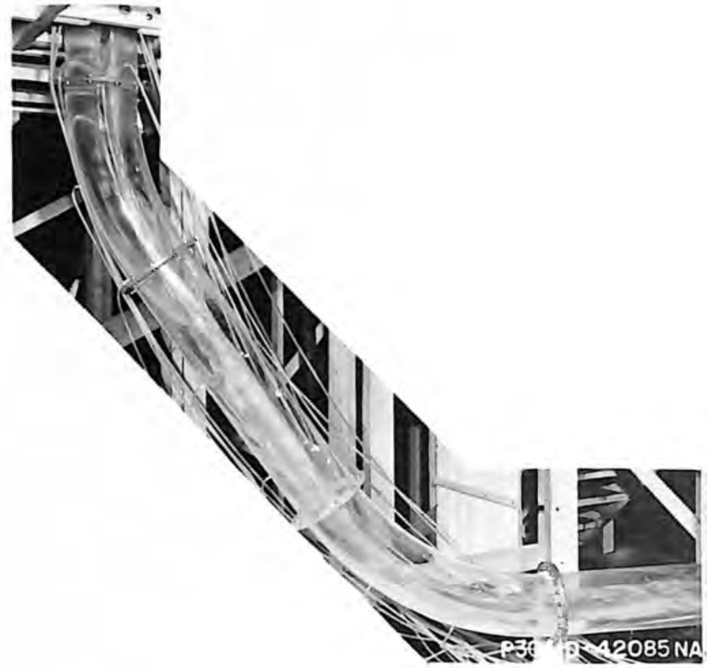
JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 12
Q = 2,500 cfs, Reservoir Elevation 6993.8
20-foot-long Wall Placed Normal to
the Dam 10 Feet from the Crest and
Two Piers on Crest 120° Either
Side of Wall

Figure 23
Report Hyd-518



A. Entrance Conditions



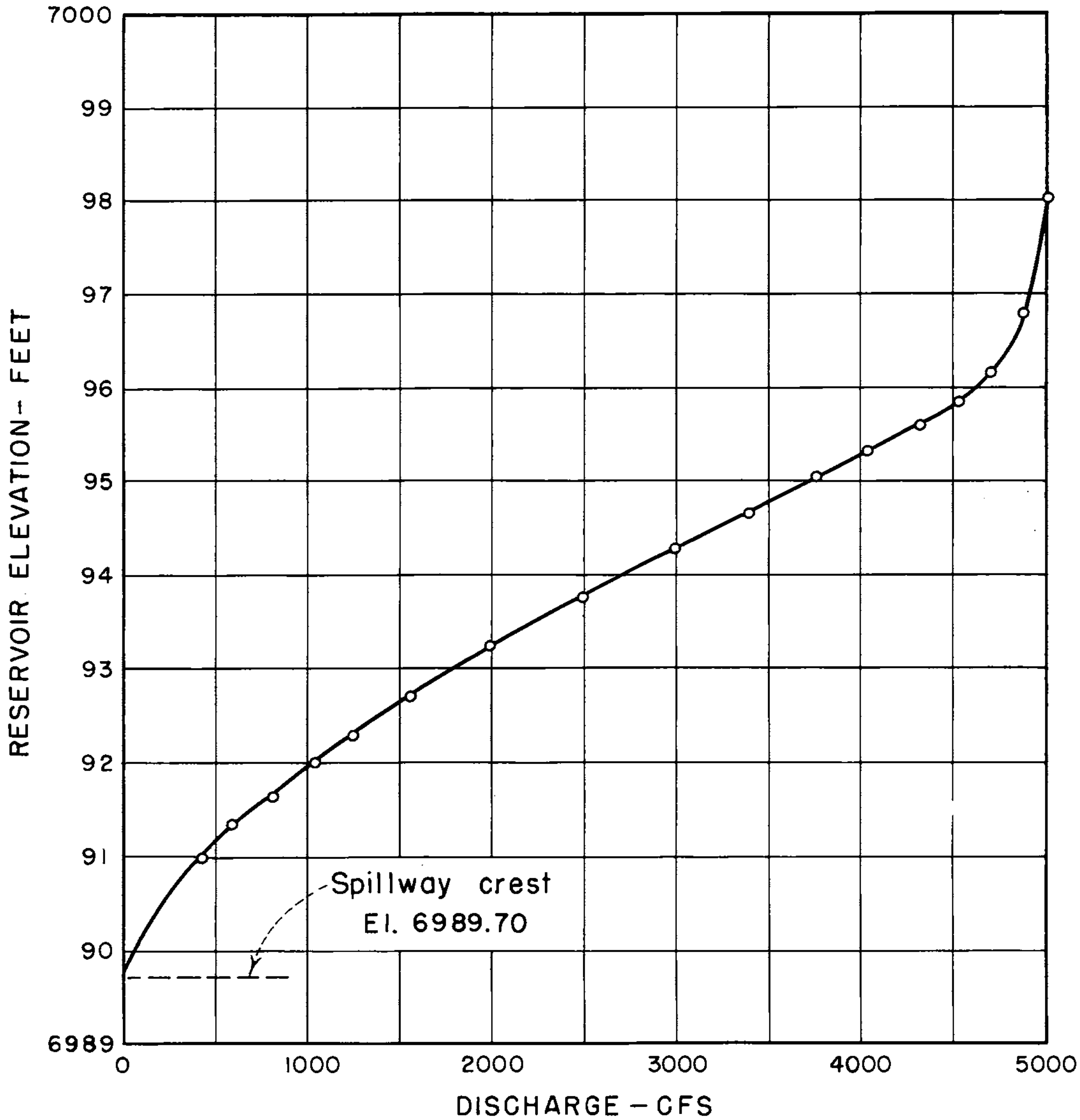
B. Flow in the Bends and Inclined Shaft

C. Flow in the Horizontal Tunnel

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow Conditions for Trial 12
Q = 5,000 cfs, Reservoir Elevation 6998.0

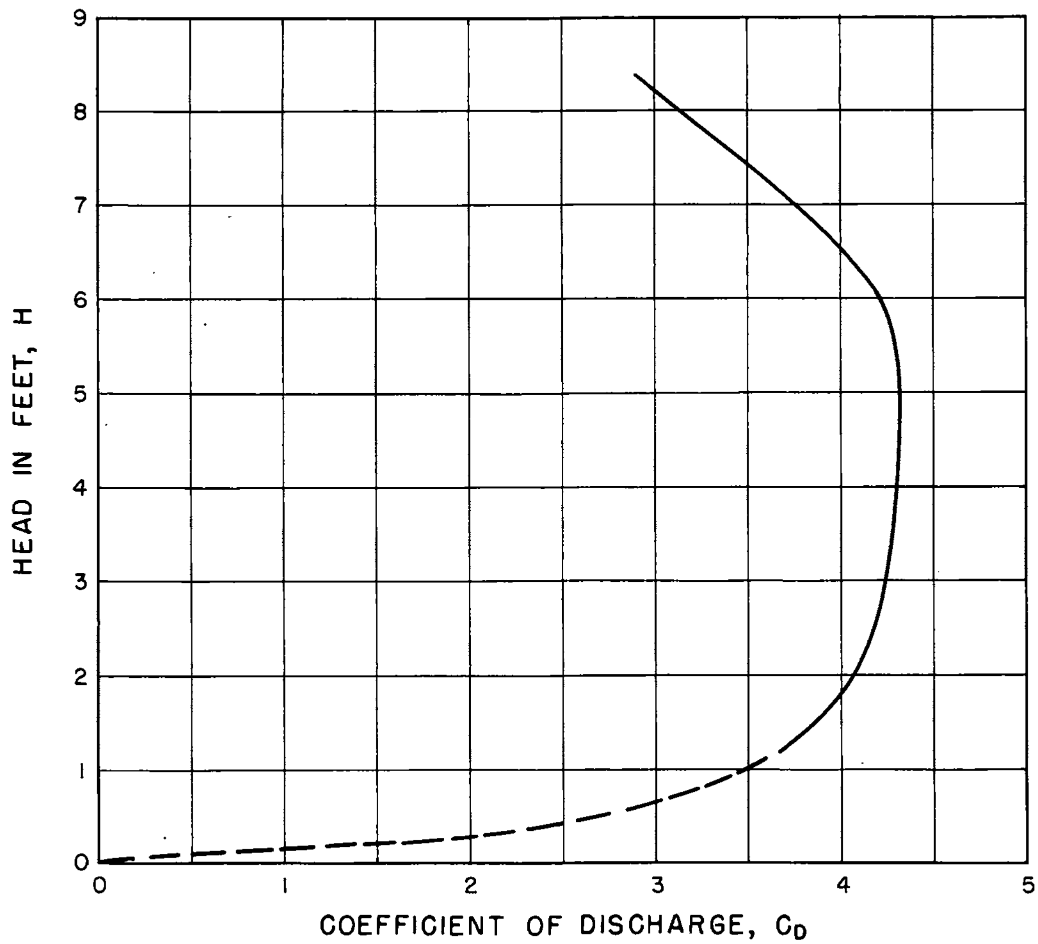
Figure 24
Report Hyd-518



JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

HEAD VS. DISCHARGE CURVE FOR RECOMMENDED DESIGN



$C_D = Q/LH^{3/2}$

L = circumference of crest at El. 6989.70 (corrected for pier width)

H = head on crest

JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

COEFFICIENT OF DISCHARGE CURVE
RECOMMENDED DESIGN

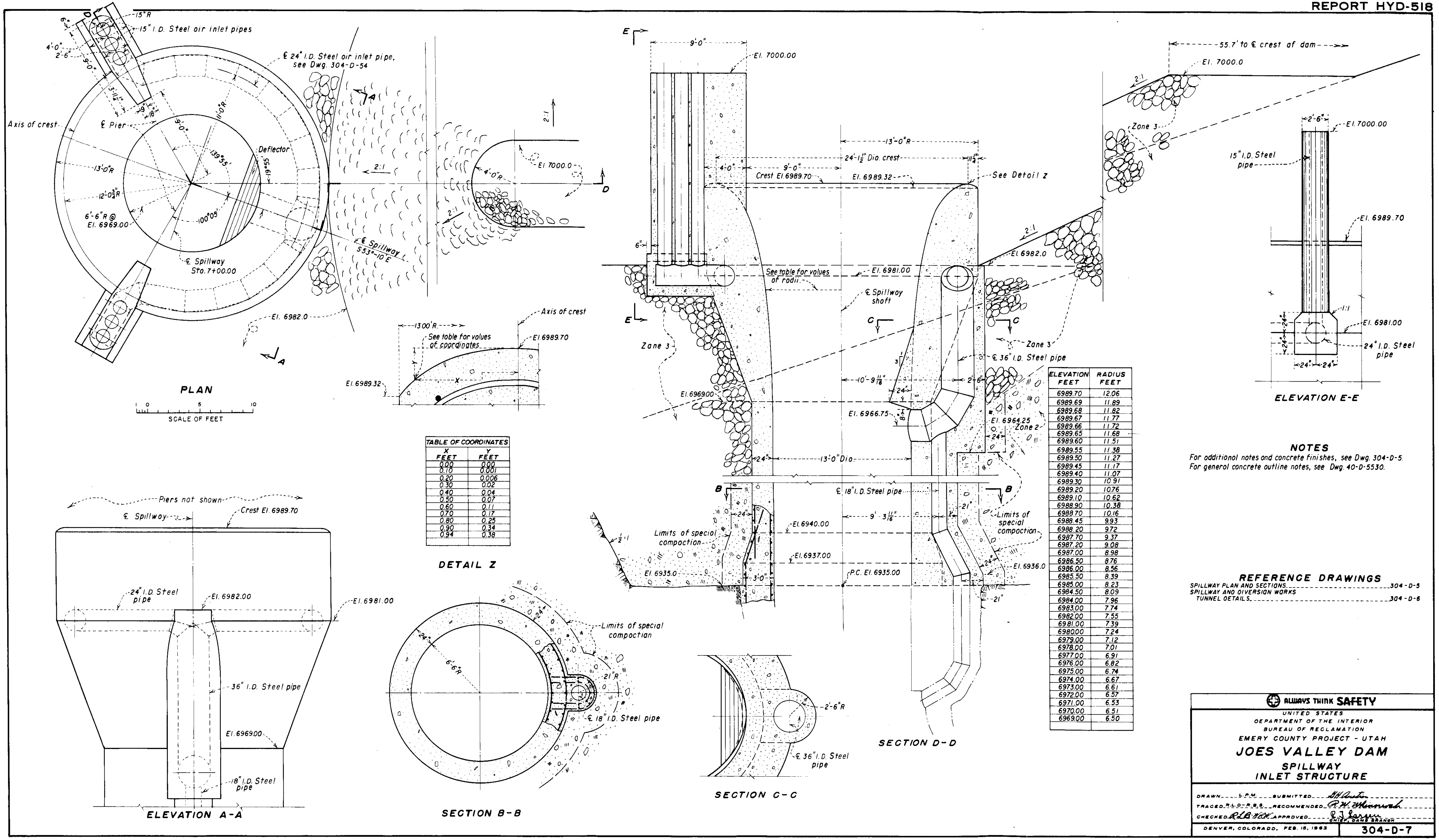


TABLE OF COORDINATES	
X FEET	Y FEET
0.00	0.00
0.10	0.001
0.20	0.006
0.30	0.02
0.40	0.04
0.50	0.07
0.60	0.11
0.70	0.17
0.80	0.25
0.90	0.34
0.94	0.38

ELEVATION FEET	RADIUS FEET
6989.70	12.06
6989.69	11.89
6989.68	11.82
6989.67	11.77
6989.66	11.72
6989.65	11.68
6989.60	11.51
6989.55	11.38
6989.50	11.27
6989.45	11.17
6989.40	11.07
6989.30	10.91
6989.20	10.76
6989.10	10.62
6988.90	10.38
6988.70	10.16
6988.45	9.93
6988.20	9.72
6987.70	9.37
6987.20	9.08
6987.00	8.98
6986.50	8.76
6986.00	8.56
6985.50	8.39
6985.00	8.23
6984.50	8.09
6984.00	7.96
6983.00	7.74
6982.00	7.55
6981.00	7.39
6980.00	7.24
6979.00	7.12
6978.00	7.01
6977.00	6.91
6976.00	6.82
6975.00	6.74
6974.00	6.67
6973.00	6.61
6972.00	6.57
6971.00	6.53
6970.00	6.51
6969.00	6.50

NOTES

For additional notes and concrete finishes, see Dwg. 304-D-5.
For general concrete outline notes, see Dwg. 40-D-5530.

REFERENCE DRAWINGS

SPILLWAY PLAN AND SECTIONS 304-D-5
SPILLWAY AND DIVERSION WORKS TUNNEL DETAILS 304-D-6

ALWAYS THINK SAFETY

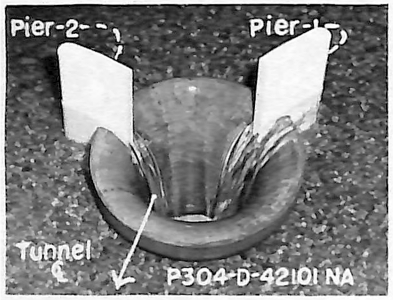
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EMERY COUNTY PROJECT - UTAH

JOES VALLEY DAM

SPILLWAY INLET STRUCTURE

DRAWN: L.P.M. SUBMITTED: G.H. Austin
TRACED: R.L.D.-R.B.S. RECOMMENDED: R.W. Whinnerah
CHECKED: R.L.B. W.C.K. APPROVED: L.J. Larsen, CHIEF, DAMS BRANCH

DENVER, COLORADO, FEB. 15, 1963 | 304-D-7



A. Q = 1,000 cfs
Reservoir El. 6991.9

B. Q = 2,000 cfs
Reservoir El. 6993.2

Q = 3,000 cfs
Reservoir El. 6994.3

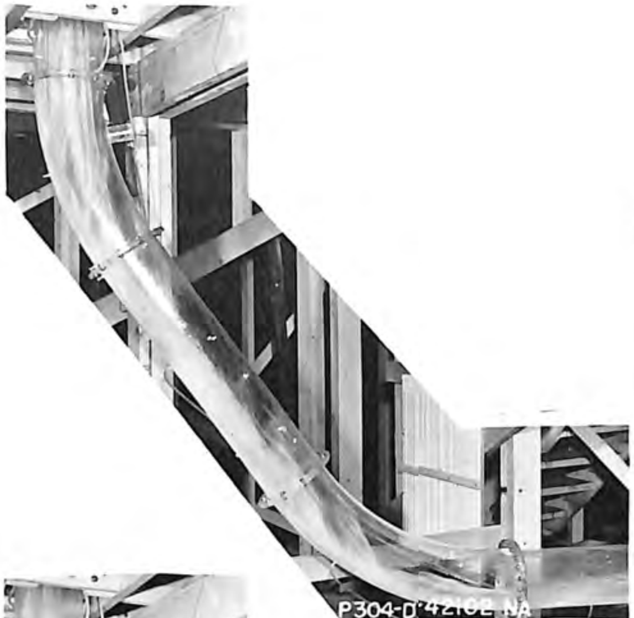
D. Q = 4,000 cfs
Reservoir El. 6995.3

Q = 5,000 cfs
Reservoir El. 6998.0

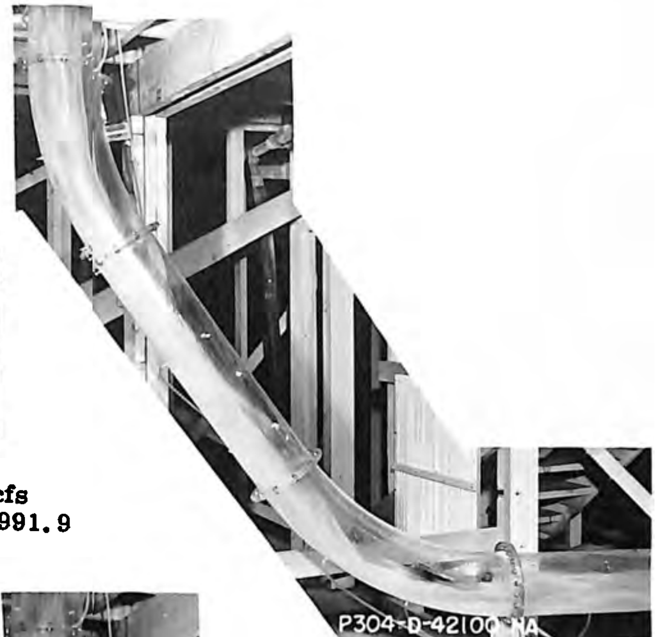
JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Morning-glory Entrance
Conditions for Trial 13
Recommended Design

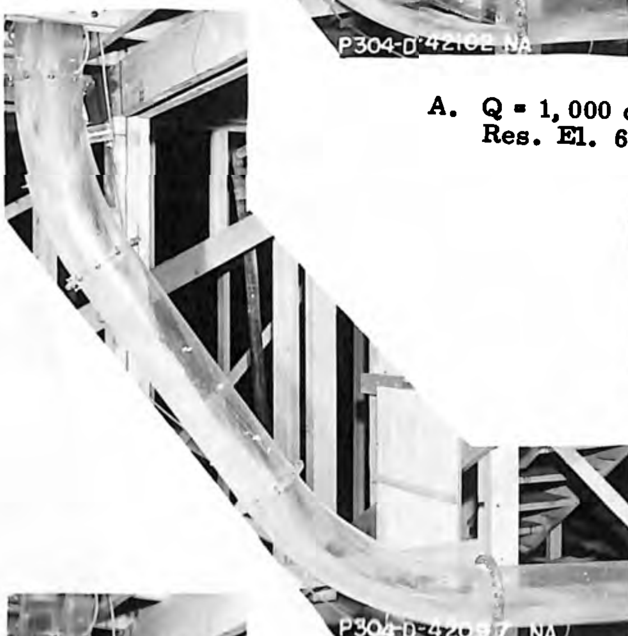
Figure 28
Report Hyd-518



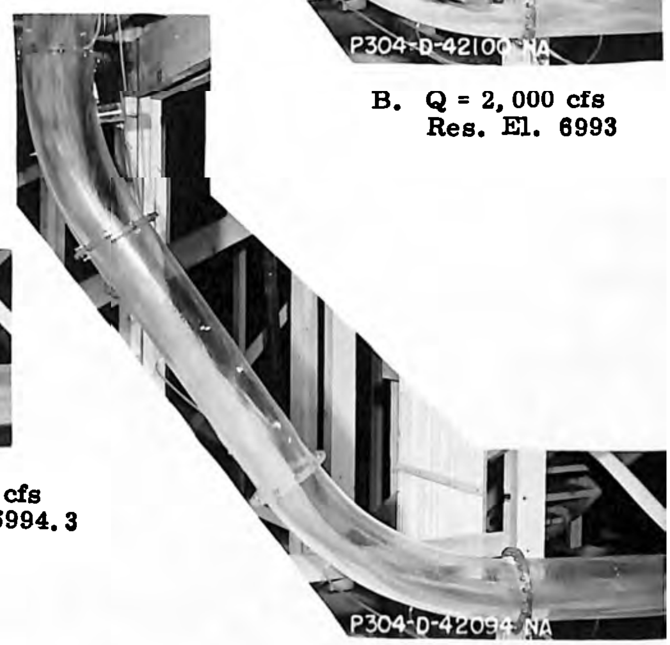
A. Q = 1,000 cfs
Res. El. 6991.9



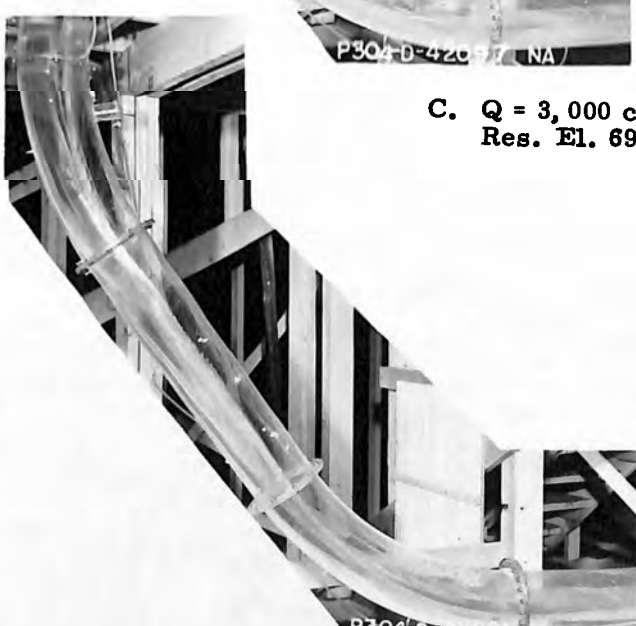
B. Q = 2,000 cfs
Res. El. 6993



C. Q = 3,000 cfs
Res. El. 6994.3



D. Q = 4,000 cfs
Res. El. 6995.3



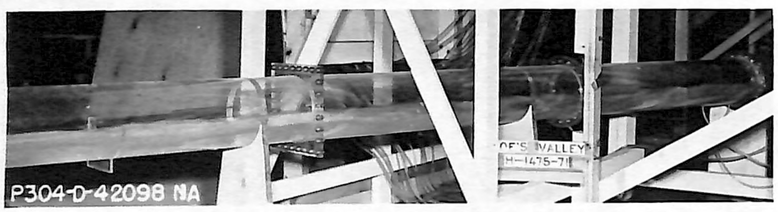
E. Q = 5,000 cfs
Res. El. 6998.0

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow in the Bends and
Inclined Shaft for Trial 13
Recommended Design

A. Q = 1,000 cfs, Reservoir Elevation 6991.9

B. Q = 2,000 cfs, Reservoir Elevation 6993.2



C. Q = 3,000 cfs, Reservoir Elevation 6994.3

D. Q = 4,000 cfs, Reservoir Elevation 6995.3

E. Q = 5,000 cfs, Reservoir Elevation 6998.0

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Flow in the Horizontal Tunnel for
mmended Design

Figure 30
Report Hyd-518

A. Q = 1,000 cfs
Reservoir Elevation 6991.9

B. Q = 2,000 cfs
Reservoir Elevation 6993.2

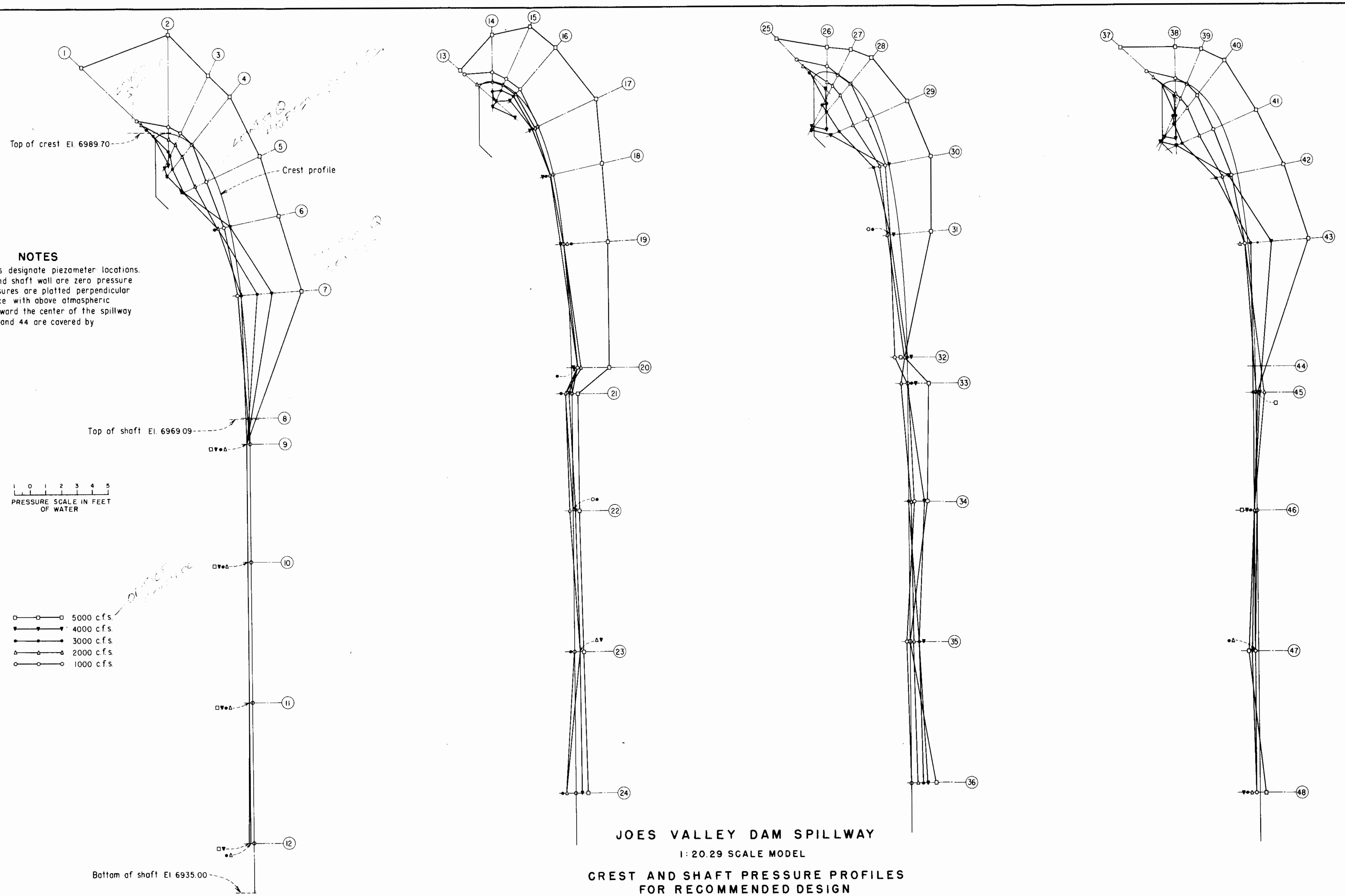
C. Q = 3,000 cfs
Reservoir Elevation 6994.3

D. Q = 4,000 cfs
Reservoir Elevation 6995.3

E. Q = 5,000 cfs
Reservoir Elevation 6998.0

JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Reservoir Flow Patterns for Trial 13
Recommended Design



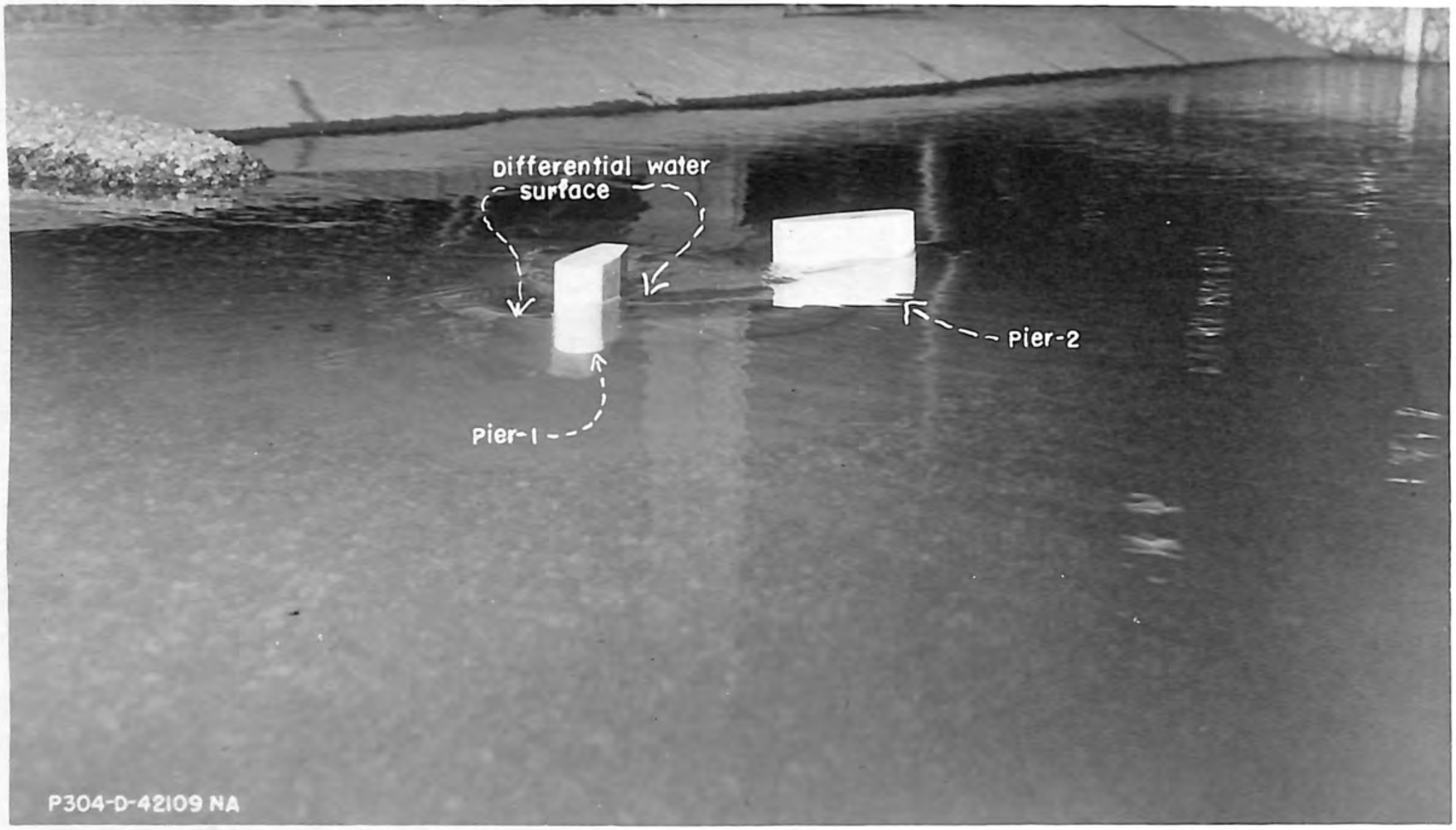
NOTES

Circled numbers designate piezometer locations.
Crest profile and shaft wall are zero pressure datums. Pressures are plotted perpendicular to the surface with above atmospheric pressures toward the center of the spillway.
Piezometers 8 and 44 are covered by deflector.

JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

CREST AND SHAFT PRESSURE PROFILES FOR RECOMMENDED DESIGN

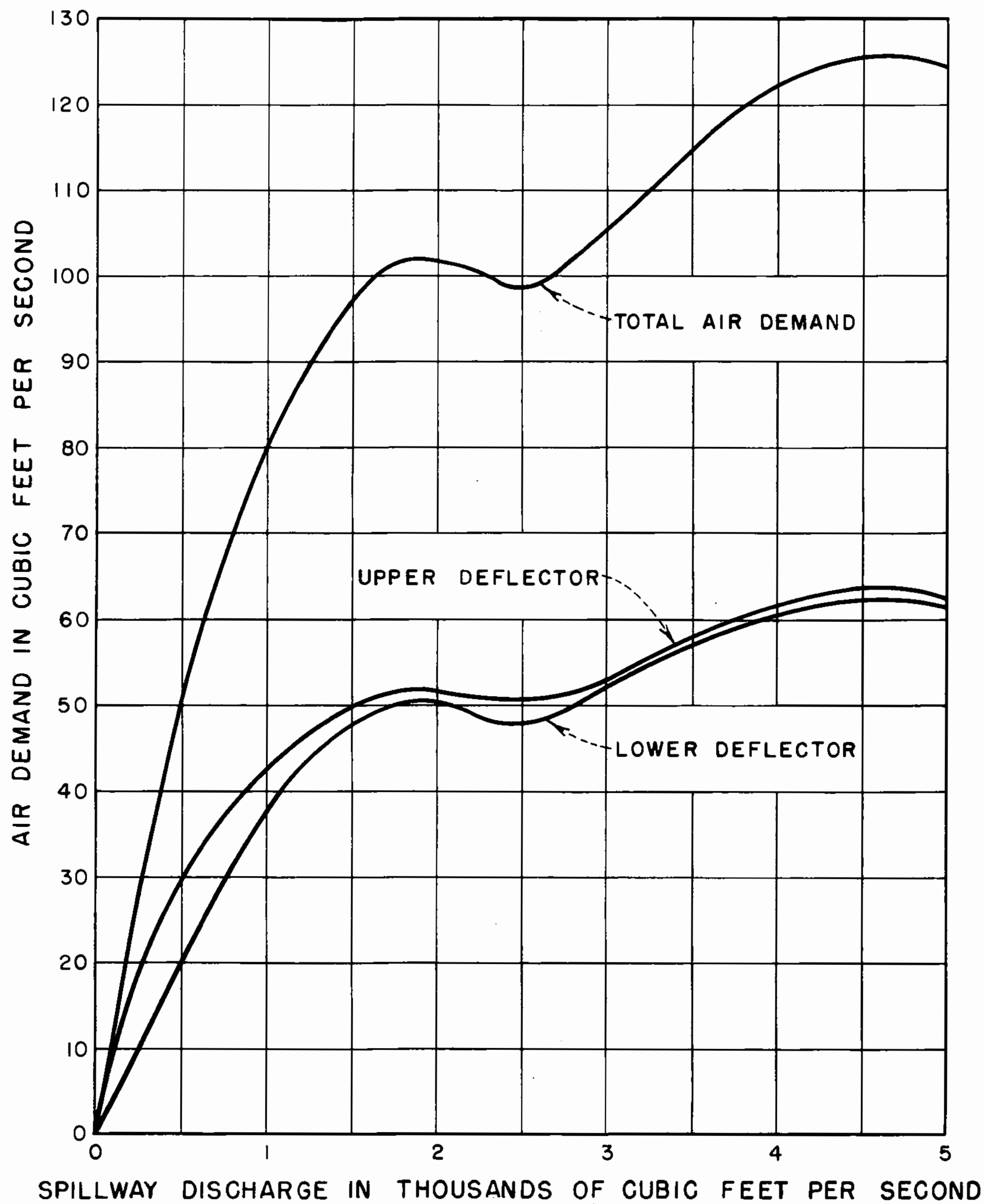


JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Differential Water Surfaces at Pier 1 for
Maximum Discharge of 5,000 cfs

JOES VALLEY DAM SPILLWAY

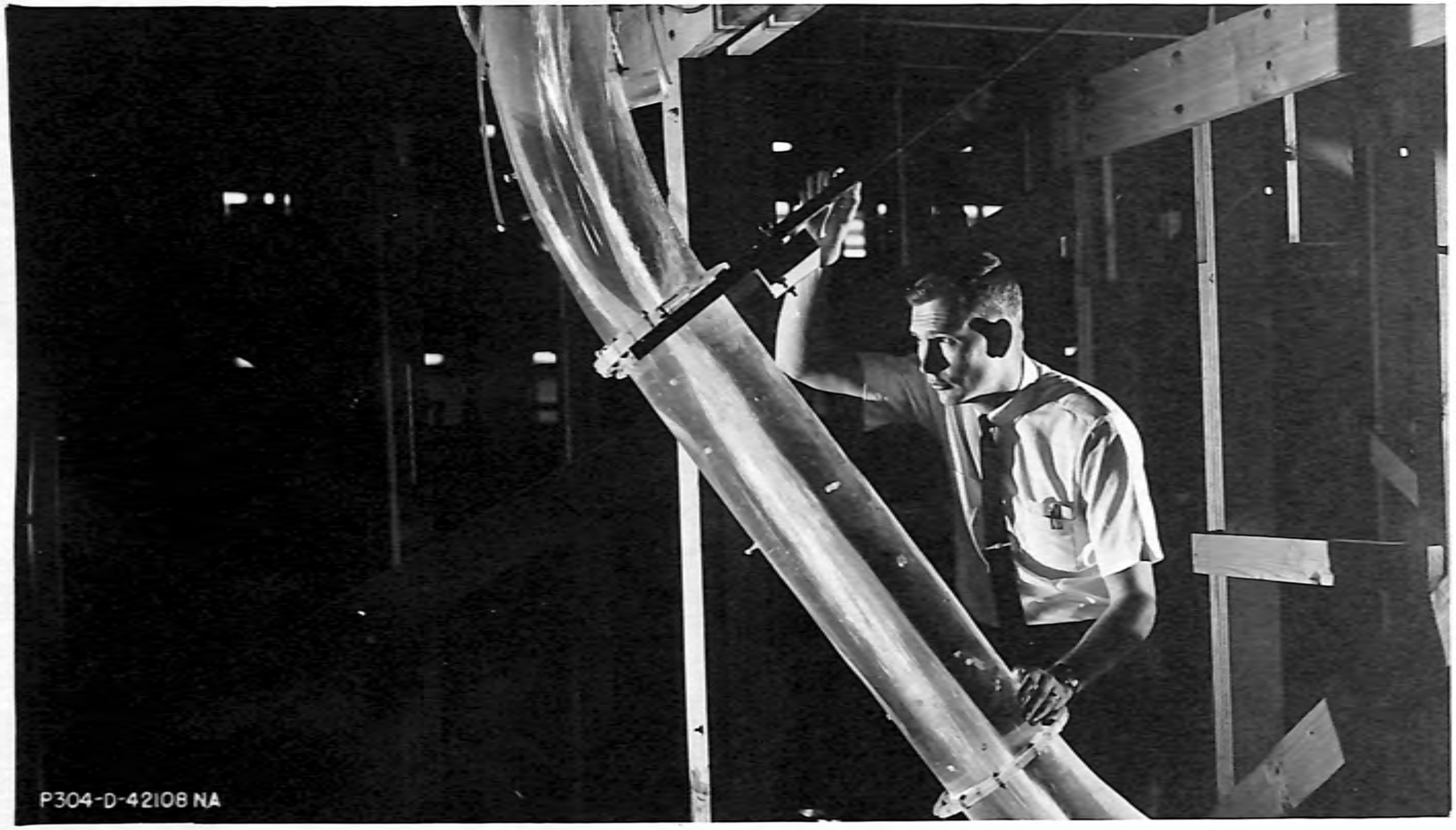
1:20.29 Scale Model
Scour Around Pier 1 After 1 Hour Model
Operation at Q = 3,000 cfs



JOES VALLEY DAM SPILLWAY

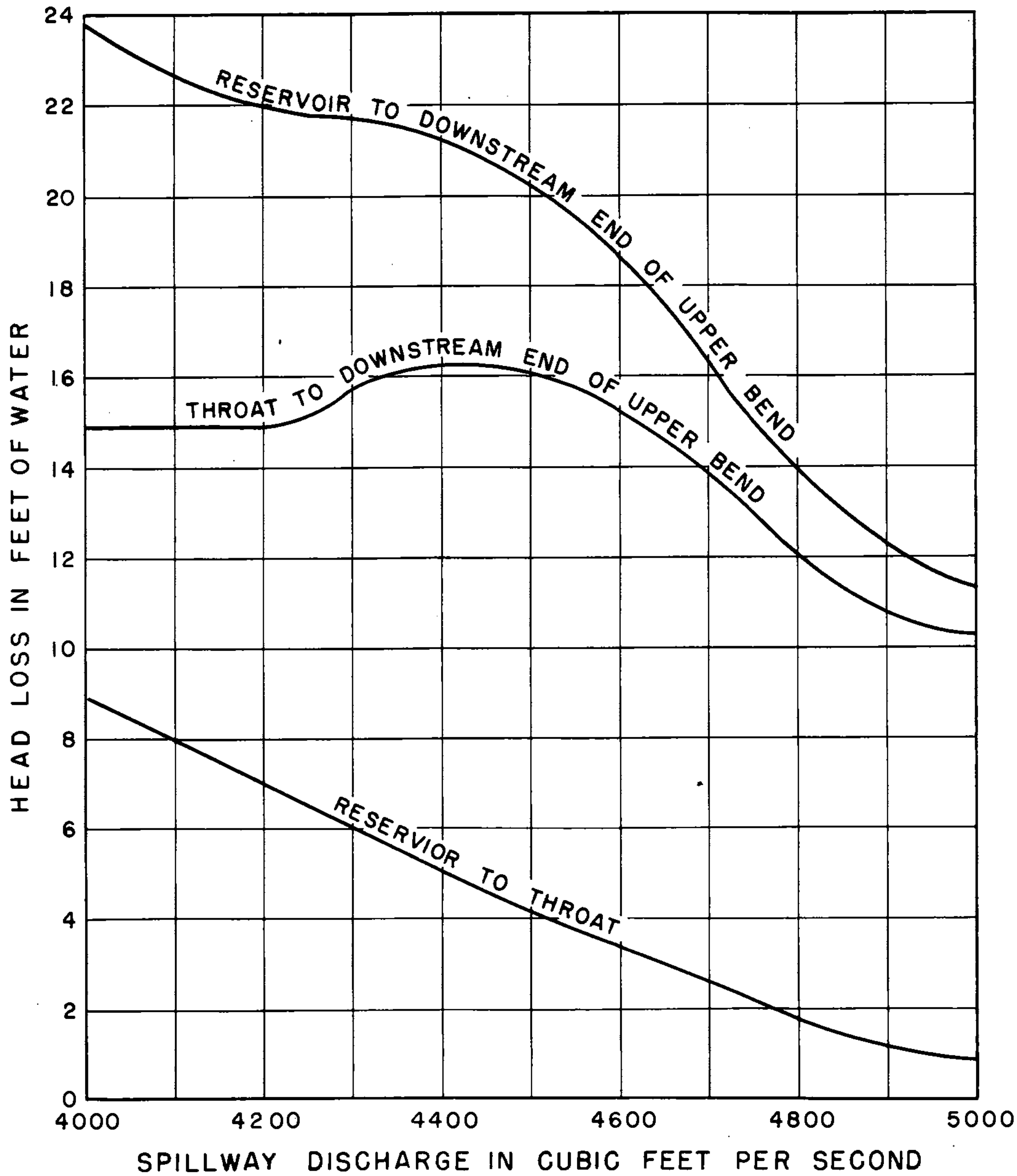
1:20.29 SCALE MODEL

AIR DEMAND CURVES FOR
RECOMMENDED DESIGN



JOES VALLEY DAM SPILLWAY

1:20.29 Scale Model
Depth Measurement for Computation of
Head Losses



JOES VALLEY DAM SPILLWAY

1:20.29 SCALE MODEL

HEAD LOSSES FOR SUBMERGED DISCHARGES-4000 TO 5000 CFS

GPO 839-802

ABSTRACT

The preliminary design of the morning-glory spillway, which was governed by unusual topographic conditions and economic considerations, exhibited undesirable operating characteristics of vibration and rough flow. Flow improving devices, including tunnel deflectors, anti-vortex piers, and an anti-vortex gravel berm between the entrance and dam embankment were developed with a 1:20 scale model. A long-radius upper bend improved the flow conditions in the inclined shaft and horizontal tunnel. Pressures on the morning-glory crest and in the vertical shaft, inclined shaft, and upper and lower bends were found to be within safe limits of operation. Measurements of rate of airflow through the air vents behind the deflectors indicated about 125 cfs with about half of the total airflow going to each of the upper and lower vents. Headloss between the reservoir and downstream end of the upper bend varied from approximately 24 feet for a discharge of 4,000 cfs to about 12 feet for the maximum discharge of 5,000 cfs. The head versus discharge relationship of the spillway was also determined.

ABSTRACT

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HYD-518
King, D. L.
HYDRAULIC MODEL STUDIES OF JOES VALLEY DAM SPILLWAY, EMERY COUNTY PROJECT, UTAH
Office of Chief Engineer, Denver, 16 p., 12 tables, 37 fig., 1964

DESCRIPTORS--*spillways/ *model tests/ hydraulics/ hydraulic structures/ *hydraulic models/ *Spillway crests/ appurtenances/ water pressures/ vortices/ piezometers/ pressure measuring equipment/ air demand/ discharge coefficients/ head losses/ tunnel hydraulics/ transition zones/ control structures/ flow/ negative pressures/ velocity/ turbulent flow.

IDENTIFIERS--*morning-glory inlets/ tunnel bends/ tunnel deflectors.

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IDENTIFIERS--*morning-glory inlets/ tunnel bends/ tunnel deflectors.