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MODEL STUDIES OF THE KORTES DAM SPILLWAY AND THE RIVER CHANNEL DOWNSTREAM KORTES DAM

MISSOURI BASIN PROJECT-KENDRICK UNIT WYOMING

Hydraulic Laboratory Report No. 206

ENGINEERING AND GEOLOGICAL
CONTROL AND RESEARCH DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

AUGUST 2, 1946

UNITED STATES
DEPARTMENT OF THE INTERIOR
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Branch of Design and Construction
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and Research Division
Denver, Colorado
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Laboratory Report No. 206
Hydraulic Laboratory
Compiled by: C. V. Adkins
Reviewed by: **J. N. Bradley**

Subject: Model studies of the Kortes Dam Spillway and the river channel downstream--Kendrick Unit, Wyoming--Missouri Basin Project.

INTRODUCTION

Problem. The design of the Kortes Dam Spillway included an uncontrolled, circular, overflow crest, spilling into a 30-foot diameter tunnel, Figure 1. The two were to be connected by a transition, consisting of part open channel and part closed conduit. The best shape for this transition was not known. The laboratory was assigned the problem of developing a workable design for a transition to connect the overflow section with the tunnel.

Summary. Initial model tests showed that the design of the circular overflow section spilling into the circular tunnel was basically sound, and could be made to work by making refinements in the transition section. A transition was designed and installed in the model and found to work satisfactorily for all design flows. Vertical sections of the transition were elliptical in shape as shown on Figure 2. This design of the transition was accepted as final. The following pertinent data were obtained from subsequent tests and observations made on the model:

1. The maximum capacity of the tunnel was slightly over sixty thousand second-feet. Choking began for a discharge of approximately sixty-three thousand three hundred second-feet.

2. The water-surface elevations along the walls and centerlines of the open part of the transition were obtained for flows of 50,000 and 60,000 second-feet, Figure 3. These were submitted to the design department as an aid in designing the walls.

3. End contractions on the crest were eliminated by the addition of curved wing walls, Figure 4. It was recommended that these walls, or similar ones, be constructed on the prototype.

4. Velocity traverses were made at three sections in the vertical elbow to determine the nature of the flow as it passed from the transition into the circular tunnel. The patterns show the velocity distribution to be quite uniform, Figure 5.

5. The flow in the tunnel rode high along the outside of the horizontal bend. Some of it spiralled across the top of the tunnel, as may be seen from the transverse profiles on Figure 6.

6. The jet from the tunnel flattened as it entered the river, and plunged across the channel. At higher flows, water climbed the left canyon wall and rode high for some distance downstream, Figures 7 and 8. The laboratory recommended that if feasible, the tunnel alinement be changed to direct the jet down the river channel rather than across it. This recommendation was substantiated by previous tests made on the Seminoe Spillway. The tests on the latter showed that flows approaching 50,000 second-feet would wash out the road across the river and remove considerable overburden from the canyon wall.

7. The alternate plan for the tunnel alinement shown on Figure 1 was installed on the model and tested. The plan did not work satisfactorily at higher flows because of the narrowness of the channel and the shallowness of the tailwater. The plan of the original tunnel alinement was accepted for the final design because:

a. The cost of the proposed change was prohibitive.

b. The hydraulic features of the proposed change were not exceptionally favorable.

c. Flow conditions in the river channel were acceptable for flows up to 20,000 second-feet passing through the original design. Moreover, flows greater than 20,000 second-feet are expected to be infrequent.

8. It was recommended that the left canyon wall be stripped of all overburden from elevation 5934 to at least elevation 6060 between Stations 7+25 and 12+25. Otherwise, a flood would deposit the material in the river channel downstream and make future dredging operations necessary.

The prototype. Kortes Dam is located on the North Platte River in Wyoming, approximately two miles downstream from Seminoe Dam, and 30 miles northeast of Rawlins, Wyoming, Figure 9. The dam is of the concrete-gravity type with a crest length of 440 feet at a distance of 200 feet above the riverbed. There will be an uncontrolled, curved spillway at the right abutment of the dam, discharging into a 30-foot diameter concrete-lined tunnel, about five hundred and ten feet in length. The length of the crest axis will be 117.81 feet. The spillway was designed for a maximum flood of 50,000 second-feet, as was the spillway at Seminoe Dam. The storage capacity will be 5,000 acre-feet at the maximum reservoir elevation of 6165.7.

The Kortes powerplant, to be located at the toe of the dam, will be served by three 108-inch penstocks. The plant will accommodate three units, each consisting of a 12,000-kw vertical shaft generator driven by an 18,500-horsepower turbine.

INVESTIGATION OF THE SPILLWAY TRANSITION

The 1:60 model. A model of the entire Kortes Spillway, and part of the downstream river channel, was constructed in the laboratory. The crest was placed in one side of a 6- by 6-foot box such that the inside face of the box corresponded to the upstream face of the dam, and the bottom of the box corresponded to the riverbed elevation upstream from the dam. The water supply entered the box behind a rock baffle. The main part of the box served as the reservoir behind the dam and spillway. The overflow section and transition were constructed by setting galvanized iron templates in place, and screeding in the true surfaces with a mixture of sand, cement, and plaster of Paris. The topography upstream from the crest, and downstream from the tunnel exit, was formed by cutting wooden contours to correspond to 10-foot intervals, prototype, and setting them

in such position as to allow an inch covering of metal lath and concrete in the model. The tunnel, from the downstream end of the transition, was made from plexiglass and lumarith so that flow conditions might be observed in the horizontal and vertical bends.

Several point gages were used, one in the head box to record reservoir elevations, one at the downstream end of the river channel to observe the tailwater, one in the river channel immediately downstream from the powerhouse tailrace to determine the drawdown caused by operation of the spillway, and one at the uncovered section of the spillway transition for obtaining water-surface profiles. A Pitot tube with a special attachment for adjustment in a vertical plane was installed above the vertical elbow for obtaining velocity traverses in that region.

The original design of the spillway transition. The original overflow spillway shape was designed to fit the parabola, $X^2 = -46y$, along any radial line. The radius of the crest will be 75 feet, with an axis length of 117.81 feet. The overflow section will be connected to a 30-foot diameter tunnel by means of a transition, but the best shape of the transition was not known. The design, as received by the laboratory, showed the bottom of the transition to be a flat slope tangent to the crest at Station 1+27.41 on the centerline only. Either side of the centerline, the slope dropped vertically below the edge of the crest a distance which varied with the distance from the centerline. The side walls were curved as shown in plan on Figure 2. The laboratory was assigned the problem of developing a workable transition design.

Preliminary tests on the spillway transition. The model was constructed according to the original design and operated through the entire range of discharges. The water passing over the ends of the overflow section tended to fold under the water passing over the center. The flow had a tendency to concentrate in the center of the chute. Conditions appeared to be favorable and it was believed that a satisfactory transition could be developed. The bottom of the transition section was tentatively rounded with molding clay. Operation indicated the shape to be an improvement over the flat bottom and that a transition with elliptical vertical sections would be satisfactory.

The revised design of the spillway transition. The lower half of a transition involving elliptical vertical sections was installed on the model. The vertical sections are shown on Figure 2. Line "A" was used as a reference line with the ellipses all coming tangent to the side walls on this line. The model was operated through the entire range of discharges, and the transition found to be satisfactory. Due to unsymmetrical approach conditions, the flow over the crest was deeper on the right end than on the left, a condition which was more pronounced at higher flows. Consequently, at the higher flows, a fin forming in the center was forced toward the left side, part of it impinging on the wall at the lower end of the transition. The impingement caused a fin to spiral across the top of the tunnel in the vertical elbow. No damage of any consequence is expected in the prototype from this action.

Various types of dividing walls and blocks were placed along the center of the transition to prevent the formation of the fin in the center. Flow conditions were not improved with these devices, therefore, the plan was abandoned. The side walls were next shifted inward toward the centerline to reduce the width of the transition. Such a procedure would save rock excavation and concrete work on the prototype. The results were not satisfactory, for large fins splashed over the left side wall and flow conditions in general were rougher throughout the transition. Therefore, the original location of the side walls was considered satisfactory, and it was recommended that they be constructed accordingly on the prototype.

The top of the transition was installed so that the capacity of the structure could be determined. For the maximum flow of 50,000 second-feet, the model indicated a clearance of about ten feet, prototype, between the high fin and the crown of the tunnel portal, Figure 10A. The fin, which moved back and forth in a lateral direction across the water surface, reached its maximum height near the tunnel portal. Water impinged on the right headwall of the tunnel for a flow of 60,000 second-feet, Figure 10B. The tunnel choked for a flow of approximately sixty-three thousand three hundred second-feet.

In general, the water surface had a slick, glassy appearance until it was well inside the tunnel. It is possible that the higher velocities

on the prototype will cause entrainment of air and a rough water surface. In that event, the actual capacity of the prototype will be less than indicated by the model.

The water surface elevations along the walls and in the center of the spillway were obtained for flows of 50,000 and 60,000 second-feet, Figure 3. These were submitted to the design department as an aid in designing the walls. Transverse profiles were plotted at several sections of the open transition, to show the nature of the flow, Figure 11. They show the depth to be greater over the right end. The transition was considered satisfactory in every respect and was recommended for the final design.

INVESTIGATION OF THE OVERFLOW SECTION

The spillway approach. The original design of the approach to the spillway, with the exception of the curved wing-walls, is shown in plan on Figure 4. The corners at the ends of the overflow section produced undesirable end contractions. The head over the crest, for a flow of 50,000 second-feet, was 24 feet instead of the computed 23 feet. It was believed that wing-walls could be installed to reduce the end contractions and subsequently increase the crest coefficients.

Curved wing walls having a radius of 30 feet, prototype, were installed as shown on Figure 4. The end contractions were eliminated, and the head over the overflow section was reduced from 24 to 23.6 feet for a flow of 50,000 second-feet. There was a slight concentration of flow along the right wing-wall that was more pronounced at the higher discharges, Figure 10.

The curved walls were recommended from a hydraulic standpoint. The left wall however, as installed on the model, would project from the upstream face of the dam, Figure 4. This would be objectionable from a structural as well as an aesthetic viewpoint. In the final prototype design, the entire spillway structure was moved downstream sufficiently to permit the right end of the dam to be curved and used as the left wing-wall of the spillway, Figure 1. To make connections between the face of the dam and the curved side wall of the spillway transition, the 30-foot radius was increased to 41.43 feet. The same radius was used for the right

wing-wall. The longer radii were not tested on the model, but their effect upon entrance conditions will be helpful rather than detrimental.

Coefficients of discharge. Approach conditions can also affect the coefficients of discharge. As was shown in the preceding section, the wing-walls increased these coefficients. Two runs were made with the wing-walls in place, but without topography in the approach channel. The resulting coefficients were higher than those obtained with the topography in place. For this reason, a coefficient curve was obtained with the approach topography cut to elevation 6110, and another with the topography at elevation 6130, as originally designed. They are shown on Figure 12 along with the head-discharge curve for approach elevation 6130.0. Further excavation of the approach topography increased the coefficients, but not sufficiently to justify the expense involved on the prototype. It was recommended that the approach channel be excavated to elevation 6130.

Various flows passing into the spillway are shown in Figures 10, 13, and 14B. It may be seen in Figure 10 that the depth is greater over the right end of the spillway. The splash above the portal in Figure 10B is caused from the flow impinging on the right headwall. All three figures show how the flow concentrates in the center before entering the tunnel. The approach channel, as recommended, is shown in Figure 14A.

INVESTIGATION OF FLOW IN THE TUNNEL

Flow conditions in the vertical elbow. As previously described, the flow passing over the overflow section concentrated in the center of the transition above the vertical elbow. To study the flow as it passed through the elbow, the velocity distribution was obtained at Sections A-A, B-B, and C-C for a discharge of 50,000 second-feet, Figure 5. Velocities were determined with a Pitot tube mounted on a tilting baseplate. With this arrangement the tube could be tilted and the nose set parallel to the flow at any point in the elbow. Three holes were cut in the top of the elbow at each of the sections, one on the centerline, and one at each of the quarter points, to permit insertion of the Pitot tube. The velocity contours, shown on Figure 5, were plotted from the data obtained in this manner. The slightly unsymmetrical pattern probably results from the difference in depths as the flow passes over the crest.

Flow conditions in the tunnel. The bend in the tunnel caused the high velocity flow to climb the outside wall at all discharges. Part of the water spiralled across the top of the tunnel and returned to the main jet farther downstream, Figures 15, 16, 17, and 18. There was considerable spray and entrainment of air at higher flows. This occasionally caused the tunnel to appear to flow full at the exit for a flow of 50,000 second-feet, when this was not actually the case. Several transverse profiles were taken to show the nature of the flow for a discharge of 50,000 second-feet, and are shown on Figure 6. The condition in the tunnel was not considered of a serious nature, since the jet emerging from the tunnel spread quite evenly over the bottom of the river channel, Figure 7.

INVESTIGATION OF FLOW IN THE RIVER CHANNEL

Drawdown at the powerhouse tailrace. The tailrace was designed with sufficient depth to prevent the turbines being unwatered by operation of the spillway. As a matter of general interest, the tailwater elevations were obtained for various discharges in the river channel immediately downstream from the powerhouse, with a flow of 3,300 second-feet passing through the turbines. They are shown plotted on Figure 19 along with the normal tailwater elevations. The drawdown curve indicates that for flows above 8,000 second-feet through the spillway, power generation will remain nearly constant.

Flow conditions in the river channel. The right channel wall, immediately downstream from the tunnel exit, prevented the jet from spreading its normal amount. This is evident from the standing fins along the right wall shown in Figures 7 and 20B. The wall was then cut back so that the bottom of the slope fell along the broken line as shown on Figure 1. This allowed the jet to spread, thus reducing the concentration of flow plunging across the river channel. It was recommended that the right wall be cut back in this manner on the prototype.

The tunnel, as originally designed, approached the river channel at a very abrupt angle, thus directing the flow across the channel. For flows of 20,000 second-feet and less, the jet was turned down the channel without excessive impingement on the opposite canyon wall, Figures 20 and 21B. At flows higher than 20,000 second-feet, water rode high along the opposite wall for quite a distance before returning to the river, Figures 7 and 8. The normal tailwater elevation for a discharge of

50,000 second-feet is 5970, whereas the flow occasionally reached elevation 5995 on the canyon wall. The combined action of weathering and impact of floods could erode enough material from the canyon wall to form a bar in the river and make future dredging operations necessary. If not removed, the bar would raise the tailwater and reduce the effective head on the turbines.

The spillway tunnel at the Seminoe Dam enters the river at approximately the same angle as at Kortes Dam. It was shown by model tests that floods of the order of 50,000 second-feet passing through the Seminoe spillway would wash out a road on the opposite canyon wall, and would strip all overburden from the immediate area downstream from the tunnel.

From a hydraulic viewpoint, it was suggested that the downstream end of the Kortes spillway tunnel be relocated to direct the spillway flow directly down the river channel. This would shorten the horizontal bend in the tunnel and reduce the tendency of the flow to spiral across the top of the tunnel.

Alternate tunnel alinement. The tunnel alinement was changed, reducing the angle of the horizontal curve from 23.5° to 9.75°, Figure 1. The tunnel was extended 600 feet downstream from the new P.I. Operation of the model showed the jet to be only partially diffused as it entered the tailwater. The canyon was too narrow, and the tailwater insufficient to dissipate the energy of the higher flows. Because of lack of laboratory space, the length of river channel on the model was not sufficient to permit proper evaluation of tailwater conditions with this arrangement of the tunnel. Flow conditions around the horizontal bend were slightly improved.

The last 60 feet of the tunnel was then replaced with open channel in the alternate design. A parabolic deflector was built in the bottom of this section to lift the jet onto the surface of the tailwater. The deflector and the proposed relocation of the tunnel are shown on Figure 1. Operation of the model indicated the change to be satisfactory for flows up to approximately thirty thousand second-feet, Figures 22b and 23. At higher flows, the tailwater was not deep enough nor the canyon sufficiently wide to dissipate the energy completely. The jet penetrated the tailwater

and gouged the riverbed. Part of the jet was deflected upward but the greater portion flowed along the channel bottom. The result was a high-velocity jet flowing down the river channel, Figure 24. If the riverbed contained sufficient loose material, the jet at the higher flows will scour a hole in the channel bottom, creating a natural stilling pool. The bar downstream, however, would need to be removed from the river channel to prevent excessive tailwater at the powerhouse.

Details from the design department showed that if the tunnel were relocated as above, the last 100 feet would be open channel instead of the 60 feet as constructed on the model. The model was not changed, since the results would have been altered very little. Moreover, the study showed the proposed change to be prohibitive from an economic viewpoint.

The original tunnel alinement was accepted as the final design and recommended for construction because:

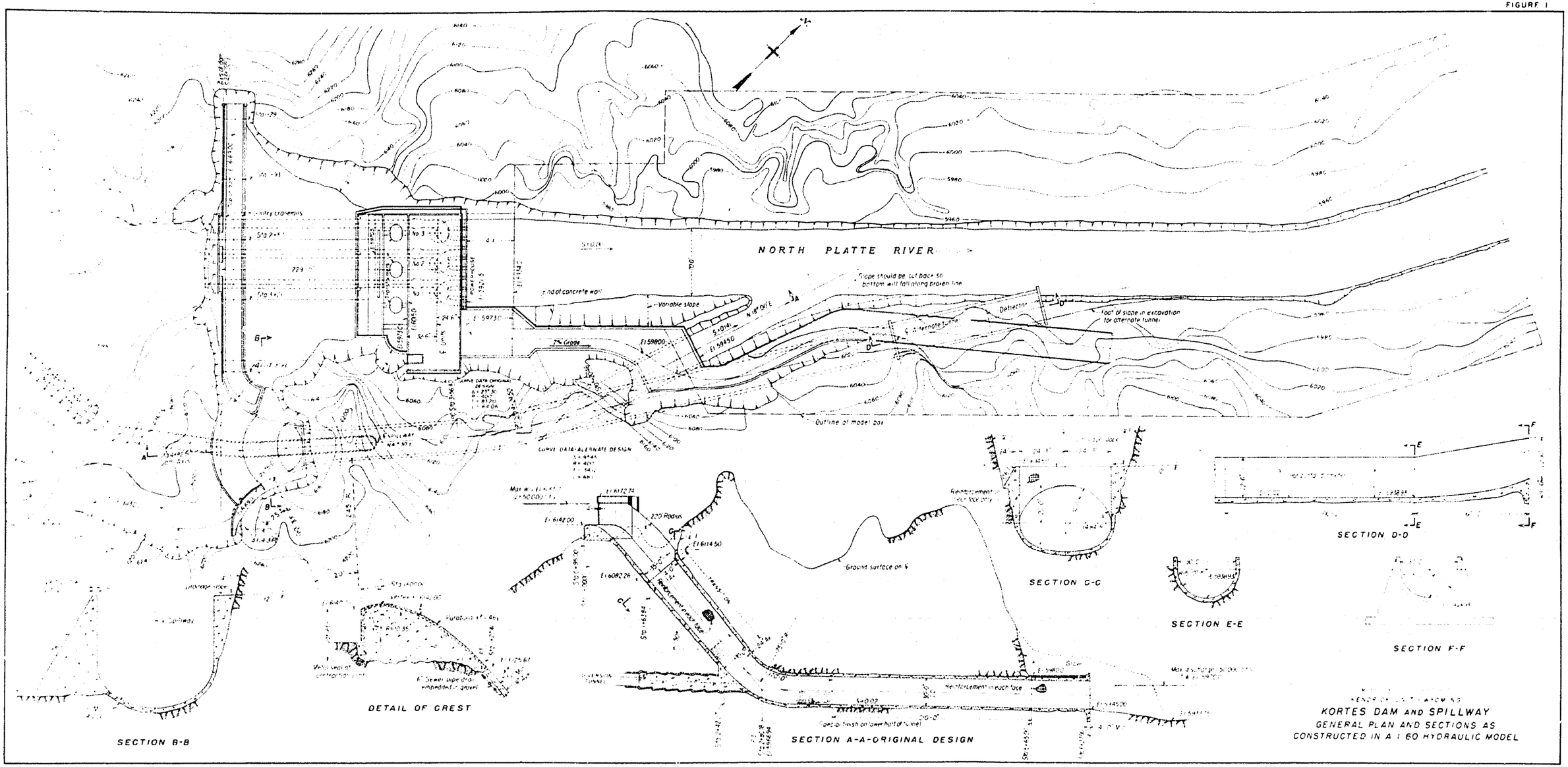
1. The cost of the proposed change was prohibitive.

2. The hydraulic characteristics of the proposed change were not entirely satisfactory at the higher flows.

3. Flow conditions in the river channel were acceptable for discharges up to 20,000 second-feet passing through the original design. Moreover, flows greater than 20,000 second-feet are expected to be infrequent.

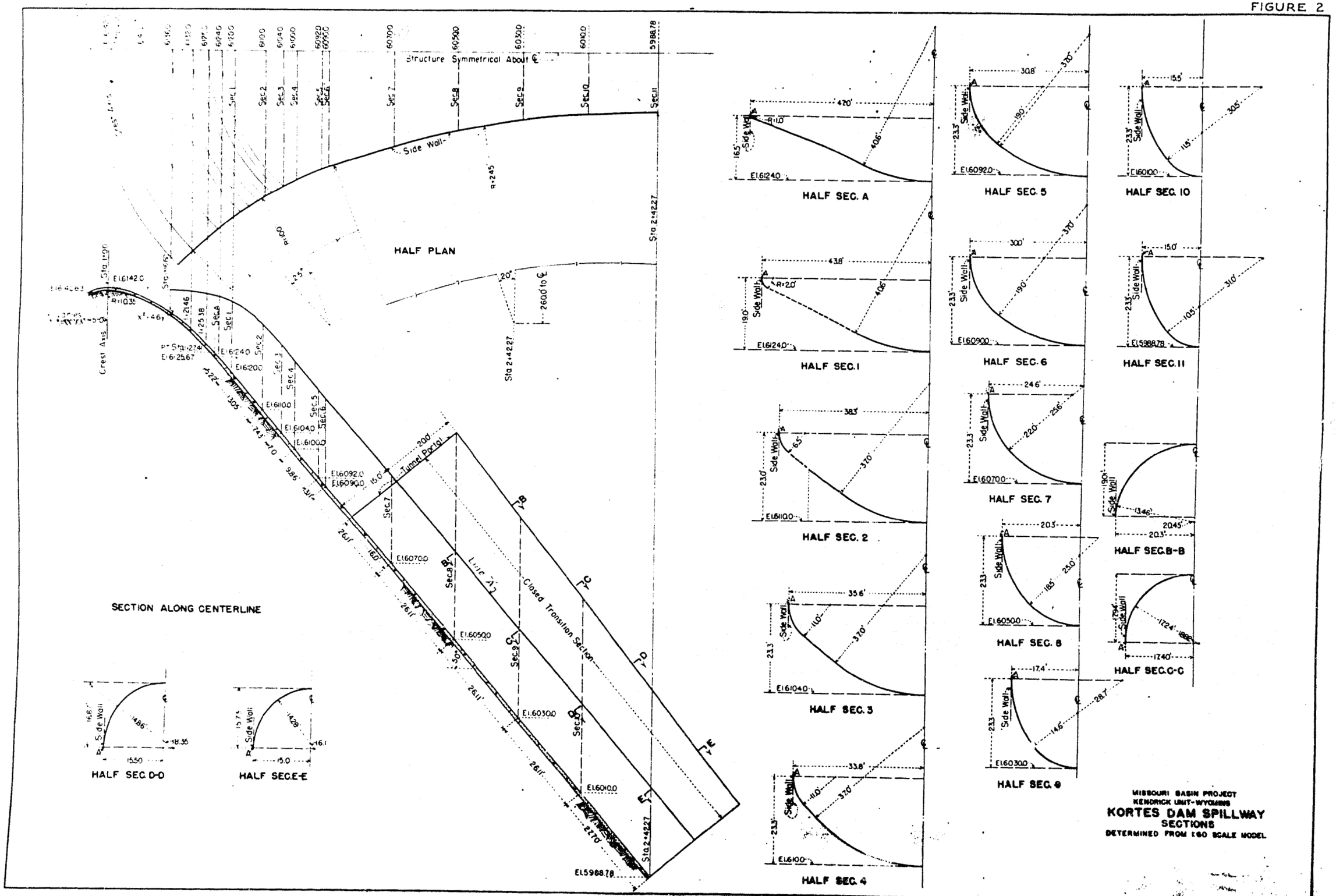
The general plan and sections of the spillway as recommended for construction are shown on Figure 1. The vertical sections of the recommended transition design are shown on Figure 2.

FIGURE 1



KORTES DAM AND SPILLWAY
GENERAL PLAN AND SECTIONS AS
CONSTRUCTED IN A 1:60 HYDRAULIC MODEL

FIGURE 2


Structure Symmetrical About ℄
HALF PLAN
Side Wall
Sta 2+42.27
Crest Axis
Tunnel Portal
Line "A"
Closed Transition Section
SECTION ALONG CENTERLINE
HALF SEC. D-D
HALF SEC. E-E
HALF SEC. A
HALF SEC. 1
HALF SEC. 2
HALF SEC. 3
HALF SEC. 4
HALF SEC. 5
HALF SEC. 6
HALF SEC. 7
HALF SEC. 8
HALF SEC. 9
HALF SEC. 10
HALF SEC. 11
HALF SEC. B-B
HALF SEC. C-C
MISSOURI BASIN PROJECT
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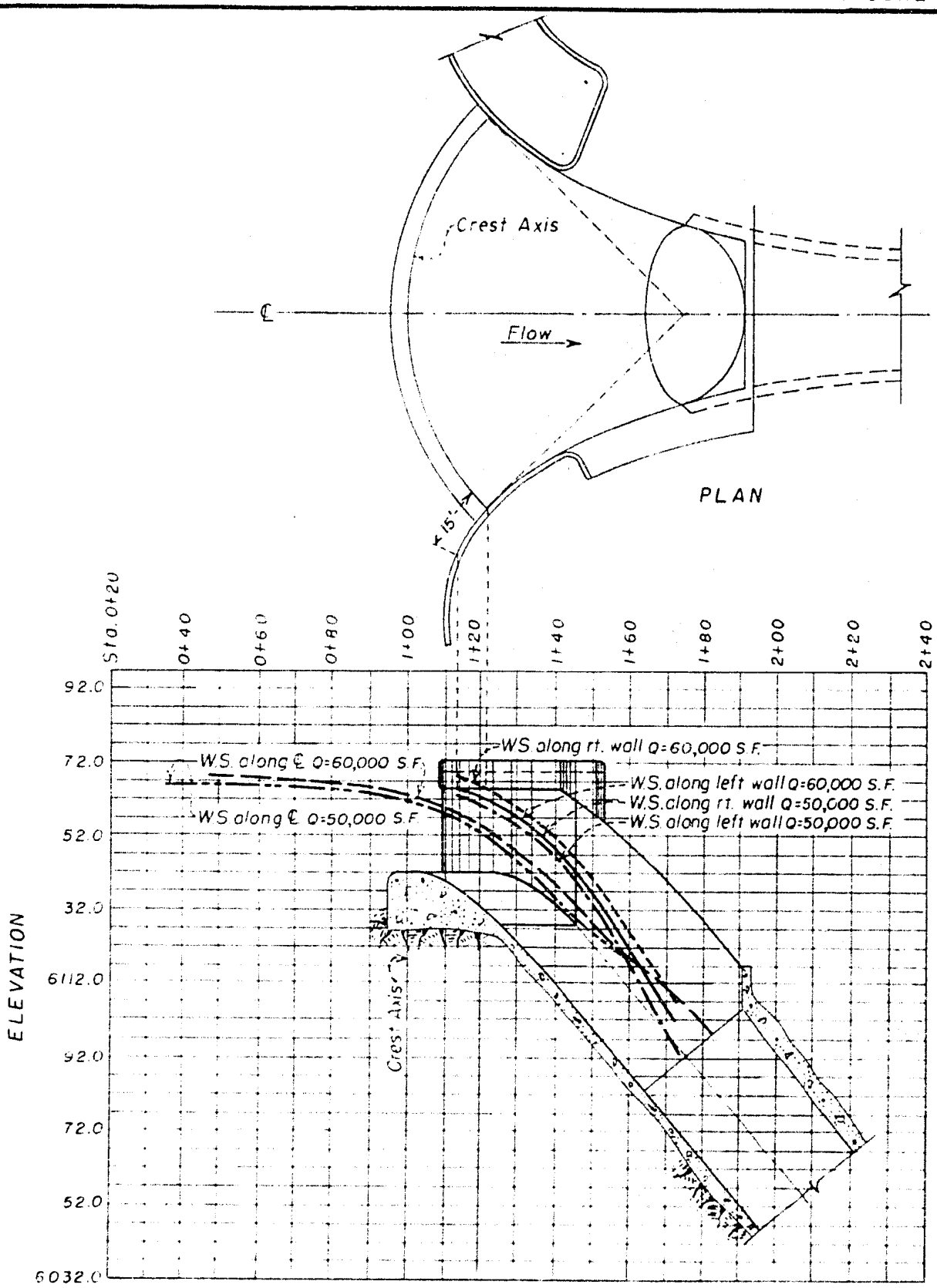
KORTES DAM SPILLWAY
SECTIONS
DETERMINED FROM 1:60 SCALE MODEL

FIGURE 3



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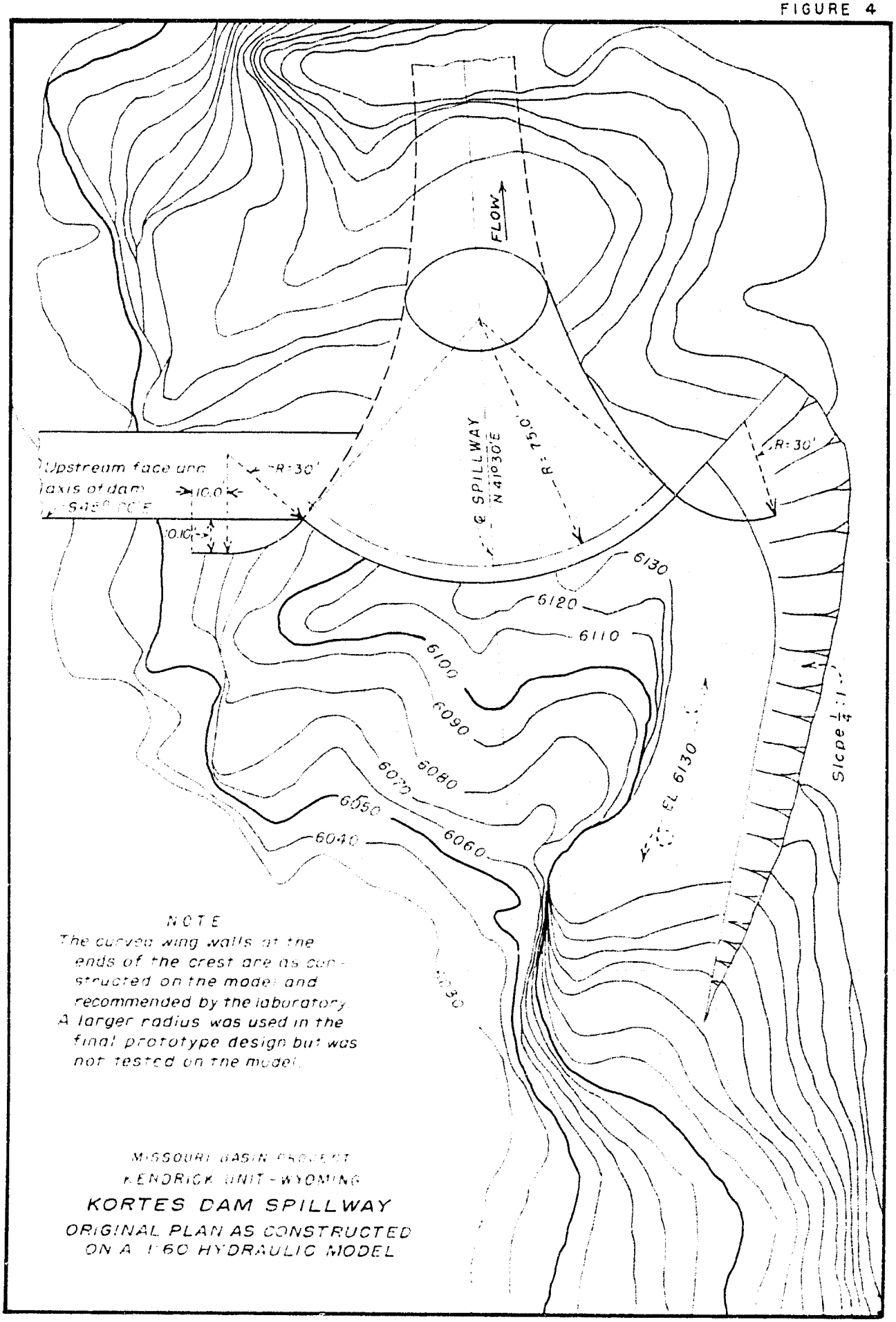
KORTES DAM SPILLWAY

LONGITUDINAL PROFILES OF WATER SURFACES OVER THE SPILLWAY DETERMINED ON A1:60 HYDRAULIC MODEL

FIGURE 4



NOTE

The curved wing walls at the ends of the crest are as constructed on the model and recommended by the laboratory. A larger radius was used in the final prototype design but was not tested on the model.

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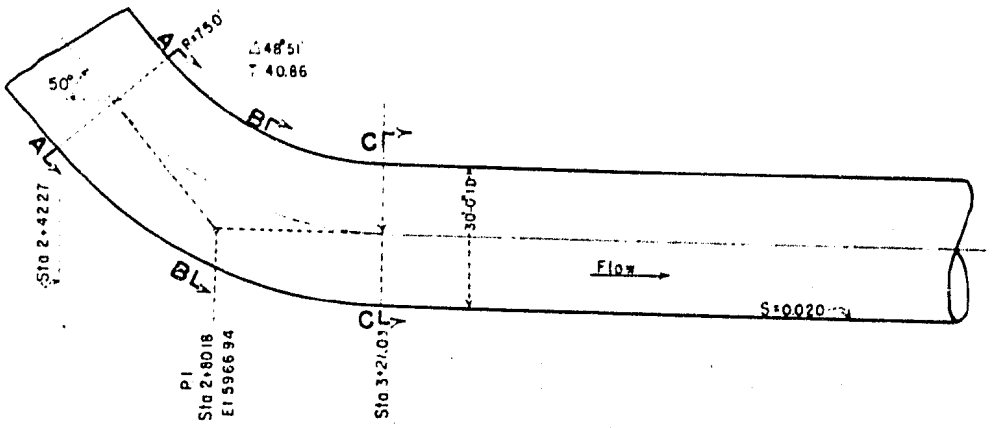
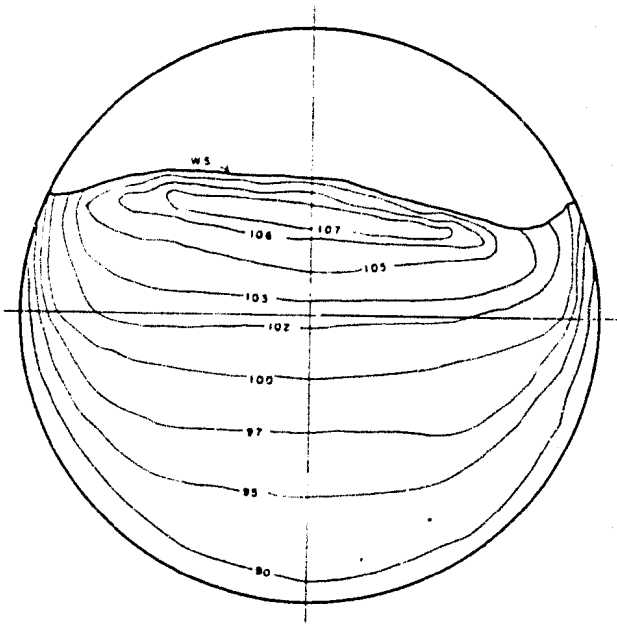
KORTES DAM SPILLWAY

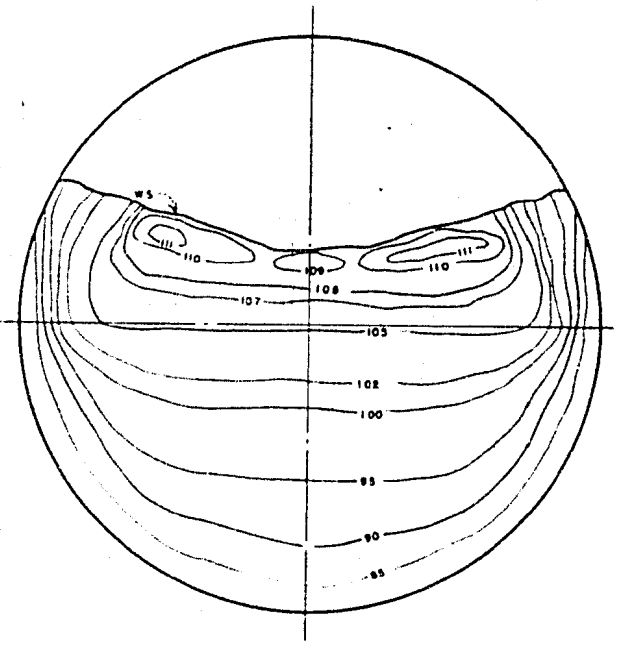
ORIGINAL PLAN AS CONSTRUCTED ON A 1:60 HYDRAULIC MODEL

FIGURE 5

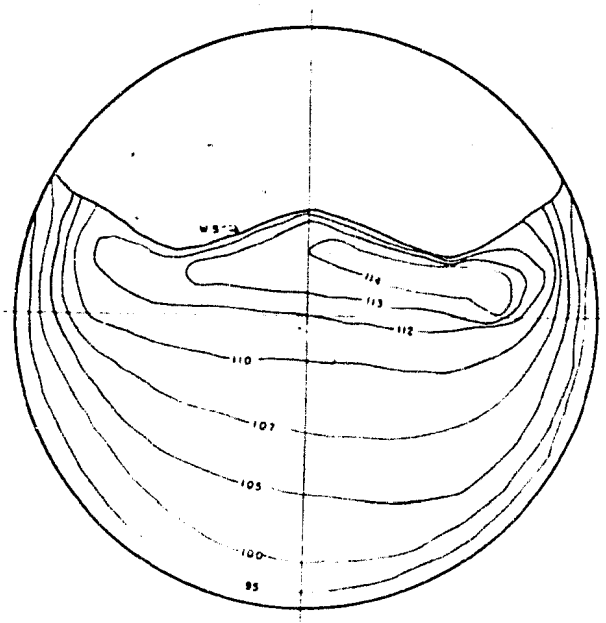




SECTION A-A



SECTION B-B



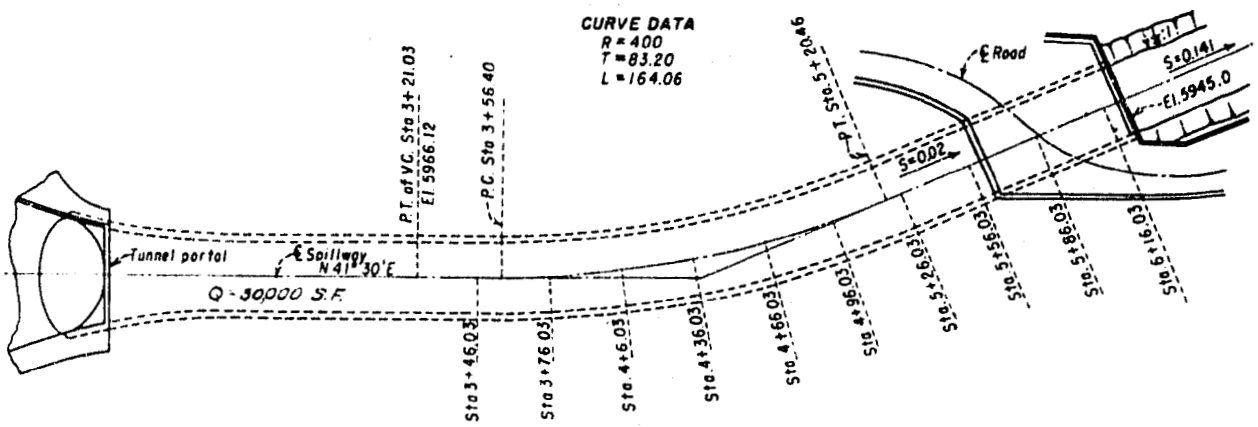
SECTION C-C

NOTE
All velocity measurements taken for a discharge of 50,000 c.f.s.

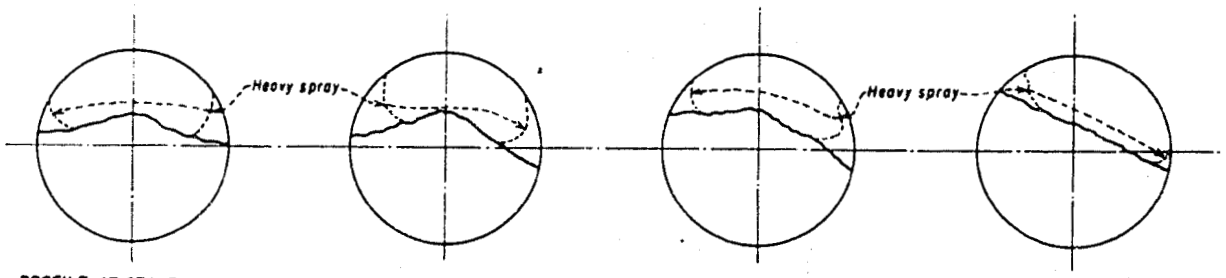
MISSOURI BASIN PROJECT
KENDRICK UNIT-WYOMING

KORTES DAM SPILLWAY
VELOCITY DISTRIBUTION AS DETERMINED FROM A 1:60 SCALE HYDRAULIC MODEL

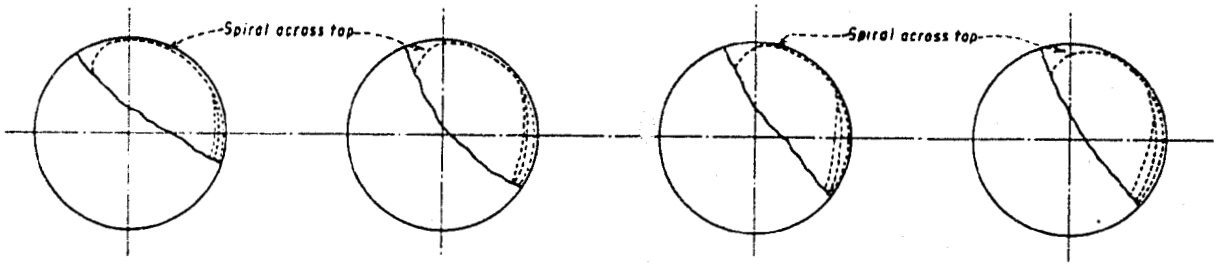
FIGURE 6



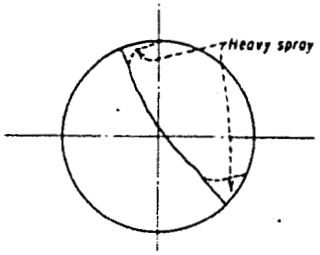
PLAN OF SPILLWAY TUNNEL



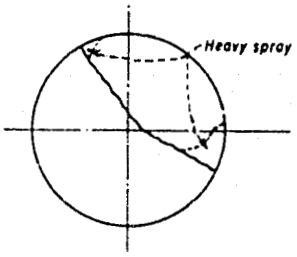
PROFILE AT STA. 3+46.03 PROFILE AT STA. 3+76.03 PROFILE AT STA. 4+6.03 PROFILE AT STA. 4+36.03



PROFILE AT STA. 4+66.03 PROFILE AT STA. 4+96.03 PROFILE AT STA. 5+26.03 PROFILE AT STA. 5+56.03



PROFILE AT STA. 5+86.03



PROFILE AT STA. 6+16.03

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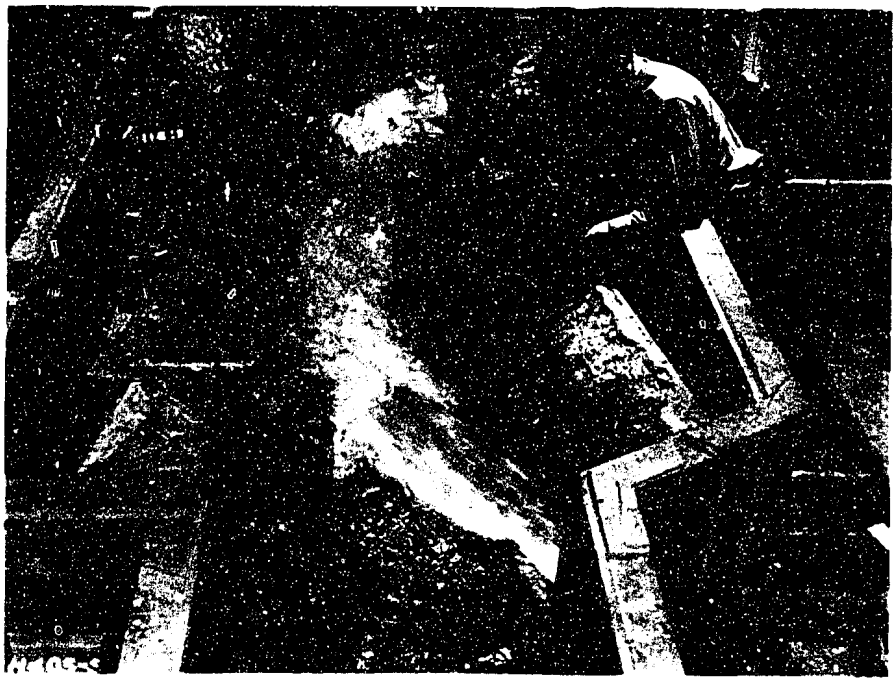
KORTES DAM SPILLWAY

TRANSVERSE WATER SURFACE PROFILES

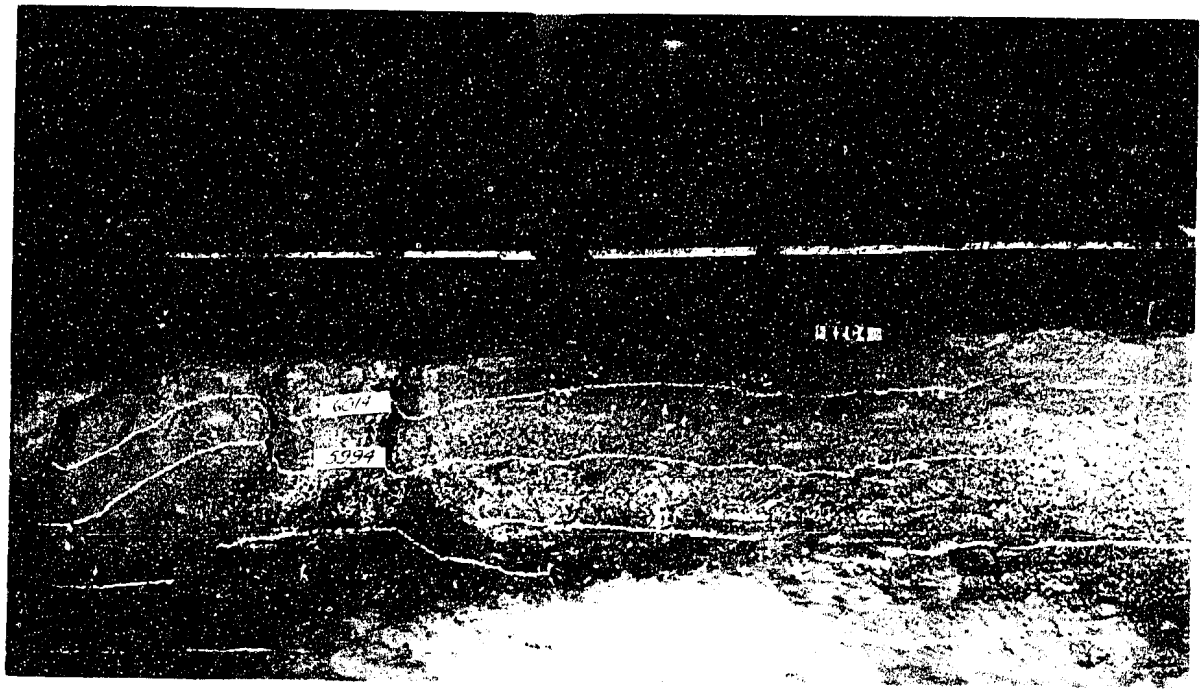
DETERMINED ON A 1:60 HYDRAULIC MODEL

A. Looking downstream. Spillway discharging 30,000 second-feet



B. Looking downstream. Spillway discharging 50,000 second-feet

KOPTES DAM SPILLWAY
Flow in River Channel of 1:60 Model

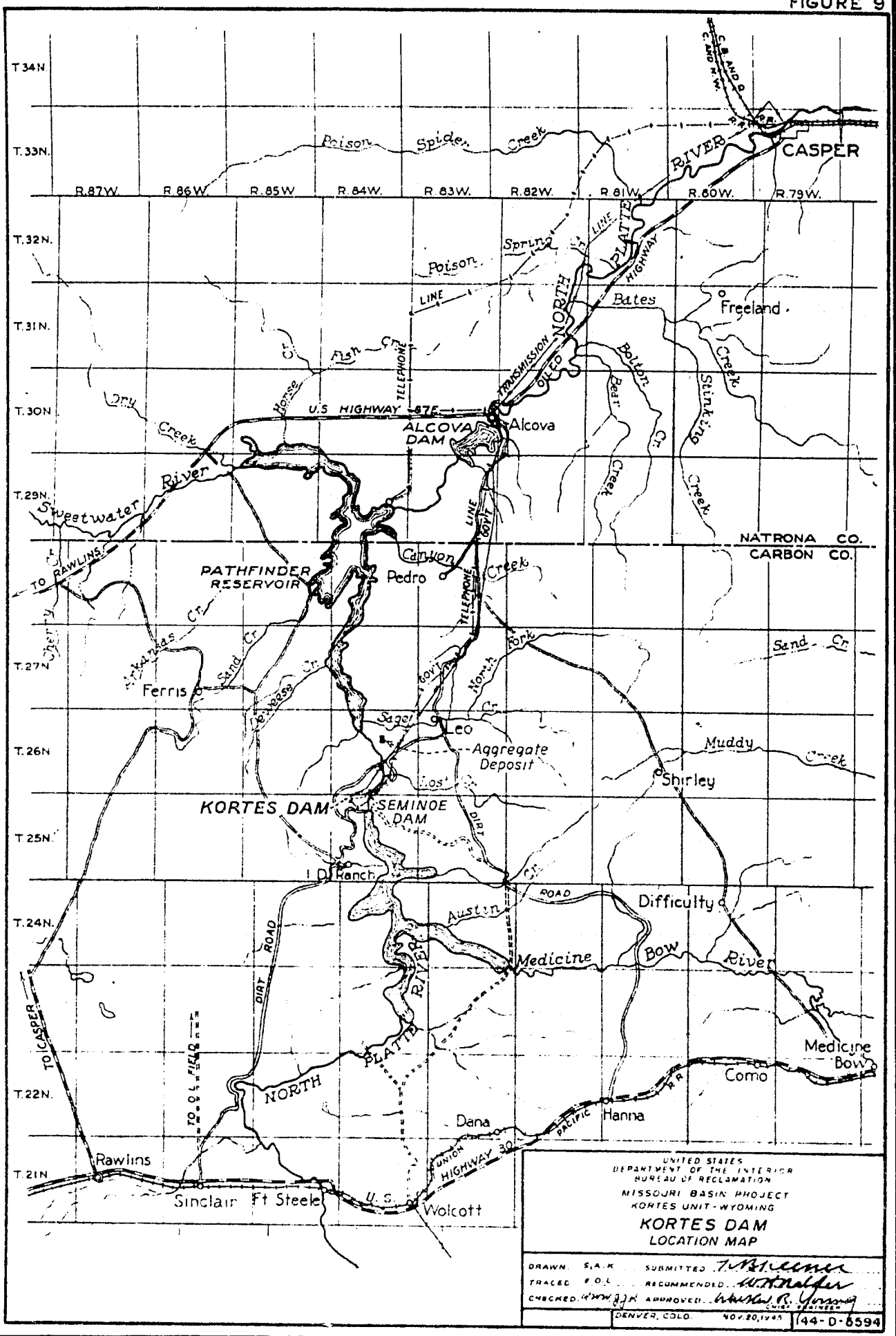


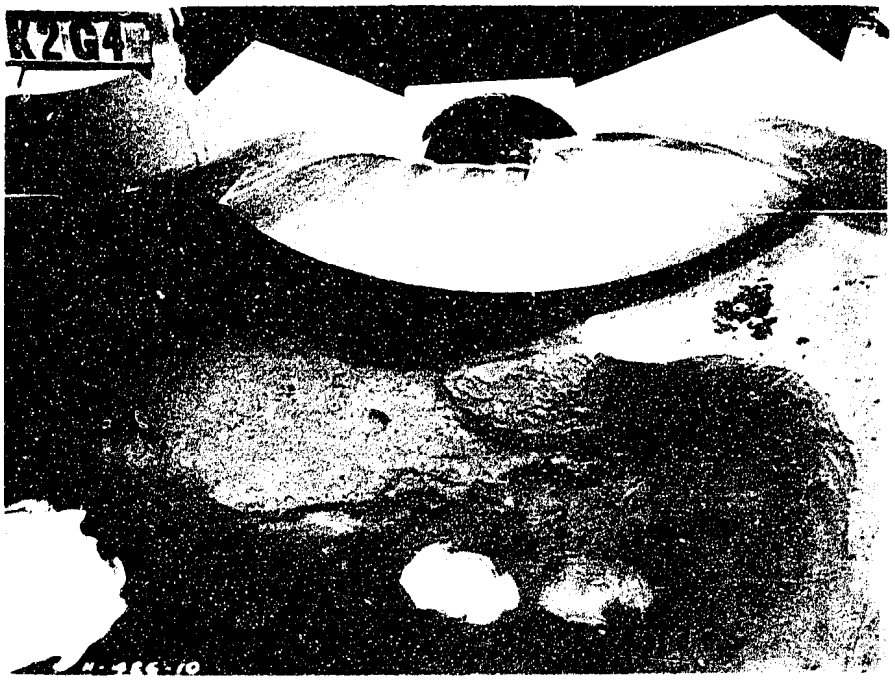
A. Looking toward left canyon wall. Discharge = 30,000 second-feet

B. Looking toward left canyon wall. Discharge = 50,000 second-feet.

KORTES DAM SPILLWAY
Flow on Left Canyon Wall of 1:60 Model

FIGURE 9


T.34N.
T.33N.
T.32N.
T.31N.
T.30N.
T.29N.
T.27N.
T.26N.
T.25N.
T.24N.
T.22N.
T.21N.
R.87W.
R.86W.
R.85W.
R.84W.
R.83W.
R.82W.
R.81W.
R.80W.
R.79W.
CASPER
Poison Spider Creek
NORTH PLATTE RIVER
Poison Spring Creek
LINE
Bates
Freeland
Bolton Creek
Bear Cr.
Great Cr.
Stinking Creek
TRANSMISSION LINE
OLD HIGHWAY
TELEPHONE
U.S. HIGHWAY 87E
ALCOVA DAM
Alcova
Dry Creek
Horse Cr.
Fish Cr.
Sweetwater River
TO RAWLINS
NATRONA CO.
CARBON CO.
PATHFINDER RESERVOIR
Pedro
Canyon Creek
GOV'T LINE
Cherry Cr.
Arkansas Cr.
Sand Cr.
Ferris
Pennsylvania Cr.
Sand Cr.
North Fork
Sage Cr.
Leo
Aggregate Deposit
Muddy Creek
Shirley
Lost
KORTES DAM
SEMINOE DAM
DIRT ROAD
DJ Ranch
Austin
Difficulty
Medicine Bow River
Medicine Bow
Como
Hanna
Dana
PACIFIC
UNION
HIGHWAY 30
TO CASPER
TO O.L. FIELD
Rawlins
Sinclair
Ft Steele
U.S.
Wolcott
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI BASIN PROJECT
KORTES UNIT - WYOMING
KORTES DAM
LOCATION MAP
DRAWN S.A.K.
TRACED F.O.L.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
CHIEF ENGINEER
DENVER, COLO. NOV. 20, 1945
44-D-6594

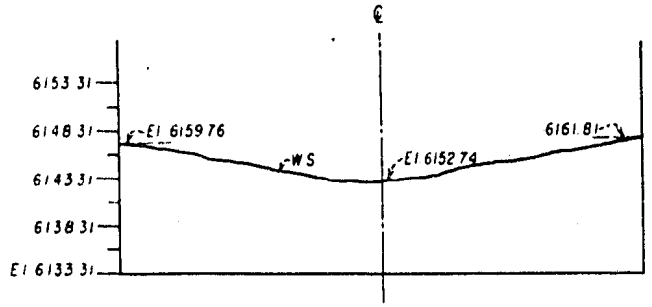


A. Looking into spillway tunnel - Discharge = 50,000 second-feet - Showing greater depth over right side.

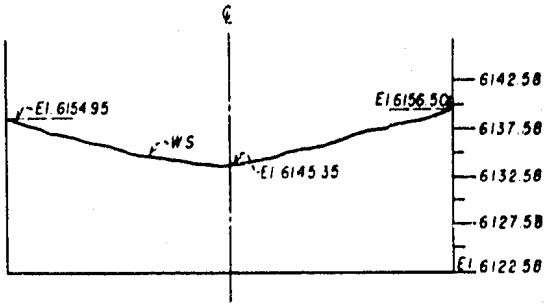
B. Looking into spillway tunnel - Discharge = 60,000 second-feet - Showing splash above right headwall.

KORTES DAM SPILLWAY
Flow Over Spillway Crest of 1:60 Model

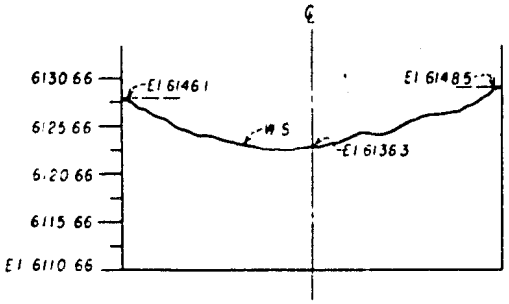
FIGURE 11



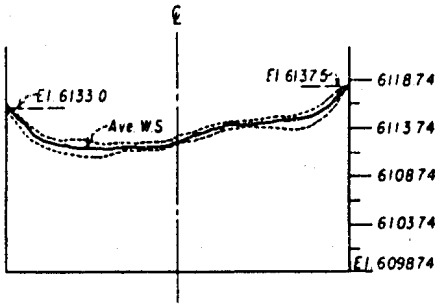
TRANSVERSE PROFILE AT STA. 1+20.00



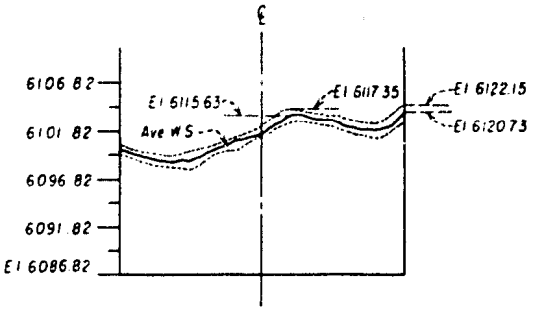
TRANSVERSE PROFILE AT STA. 1+30.00



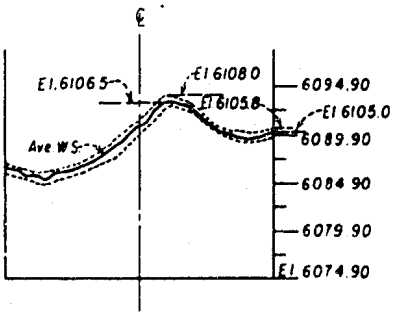
TRANSVERSE PROFILE AT STA. 1+40.00



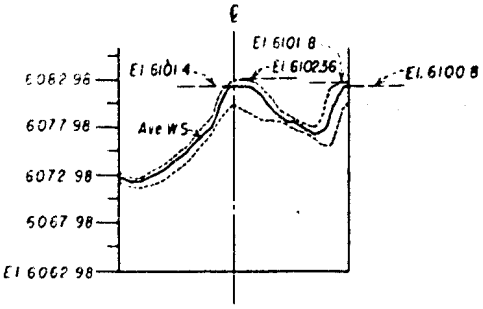
TRANSVERSE PROFILE AT STA. 1+50.00



TRANSVERSE PROFILE AT STA. 1+60.00



TRANSVERSE PROFILE AT STA. 1+70.00



TRANSVERSE PROFILE AT STA 1+80.00

NOTES

Down in the region where the last four profiles were taken, and below, the water surface elevations varied because of ropes playing back and forth on the surface. The dotted lines represent maximum and minimum points recorded on the model. They do not represent a profile of the water surface at some given instant, but mean that at some time during the observation the water surface at any point in the profile reached the elevations indicated by the dotted lines. Discharge was 50,000 c.f.s. View looking downstream

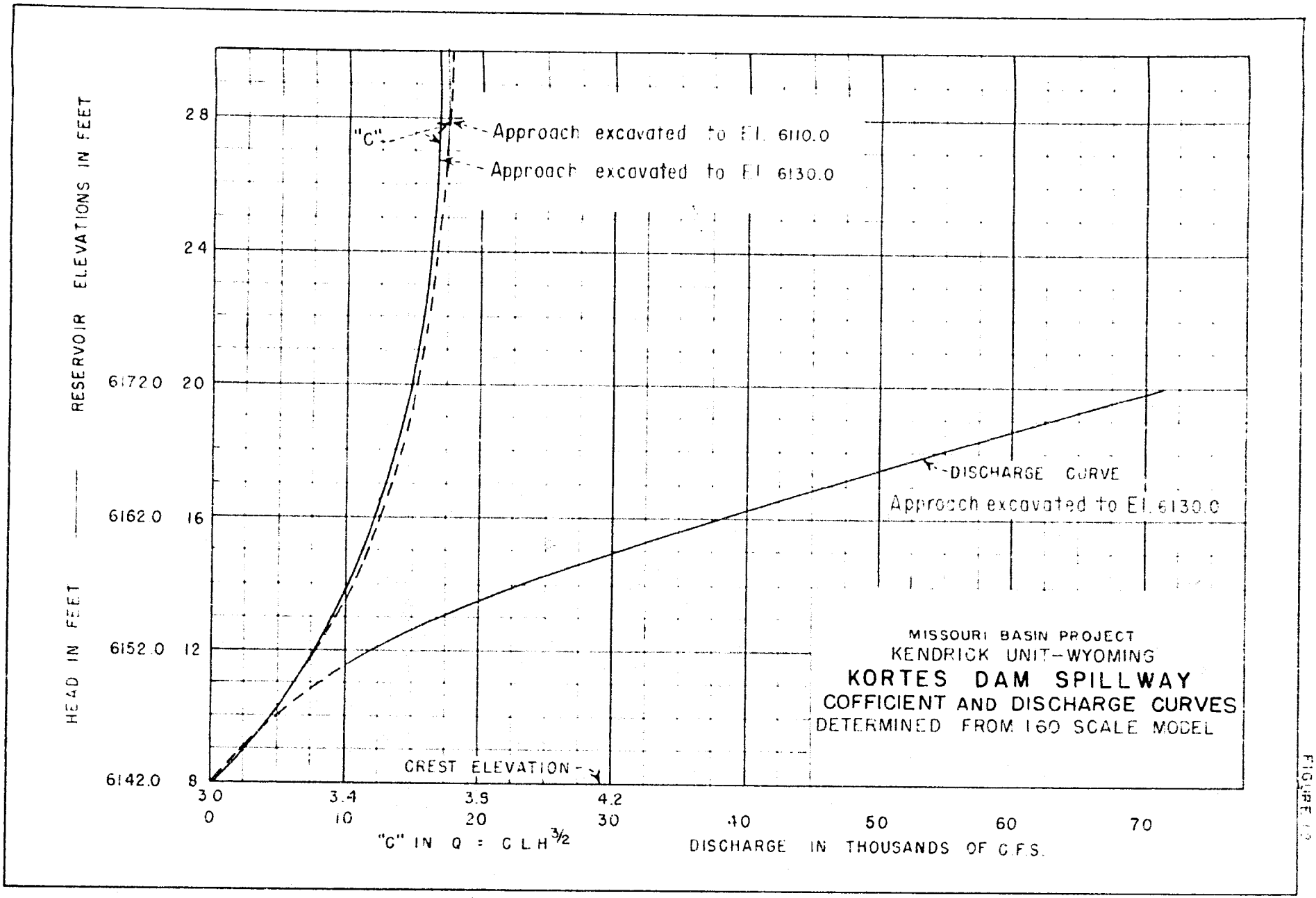
MISSOURI BASIN PROJECT

KENDRICK UNIT – WYOMING

KORTES DAM AND SPILLWAY

TRANSVERSE PROFILES ALONG UNCOVERED PART OF SPILLWAY TRANSITION

DETERMINED FROM A 1:60 HYDRAULIC MODEL


HEAD IN FEET
RESERVOIR ELEVATIONS IN FEET
28
24
20
16
12
8
6172.0
6162.0
6152.0
6142.0
"C"
Approach excavated to El. 6110.0
Approach excavated to El 6130.0
DISCHARGE CURVE
Approach excavated to El. 6130.0
CREST ELEVATION
3.0
3.4
3.9
4.2
0
10
20
30
40
50
60
70
"C" IN Q = C L H^3/2
DISCHARGE IN THOUSANDS OF C.F.S.
MISSOURI BASIN PROJECT
KENDRICK UNIT-WYOMING
KORTES DAM SPILLWAY
COFFICIENT AND DISCHARGE CURVES
DETERMINED FROM 160 SCALE MODEL

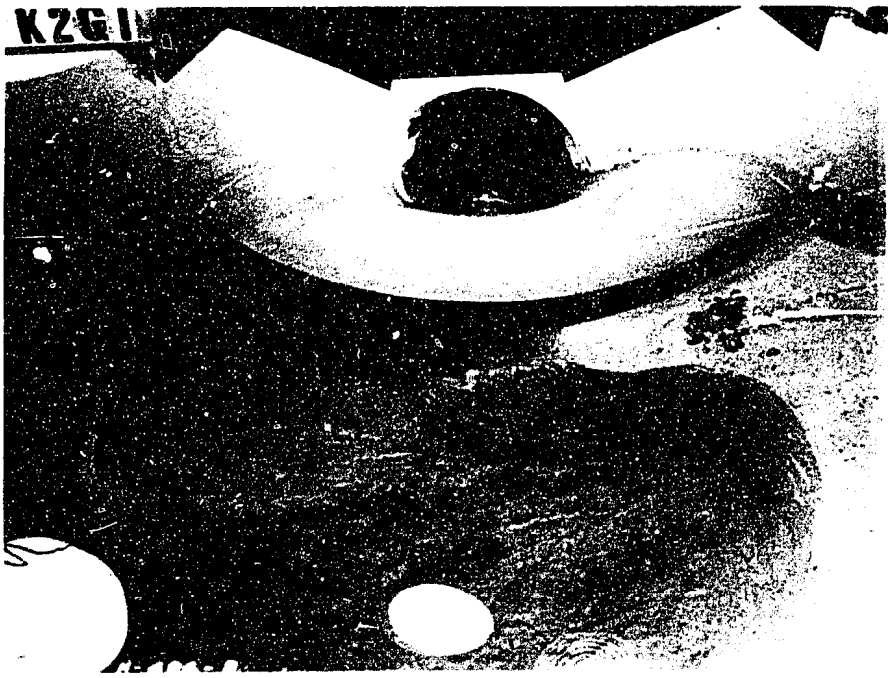
FIGURE

A. Looking into spillway tunnel. Discharge = 20,000 second-feet.

B. Looking into spillway tunnel. Discharge = 30,000 second-feet.

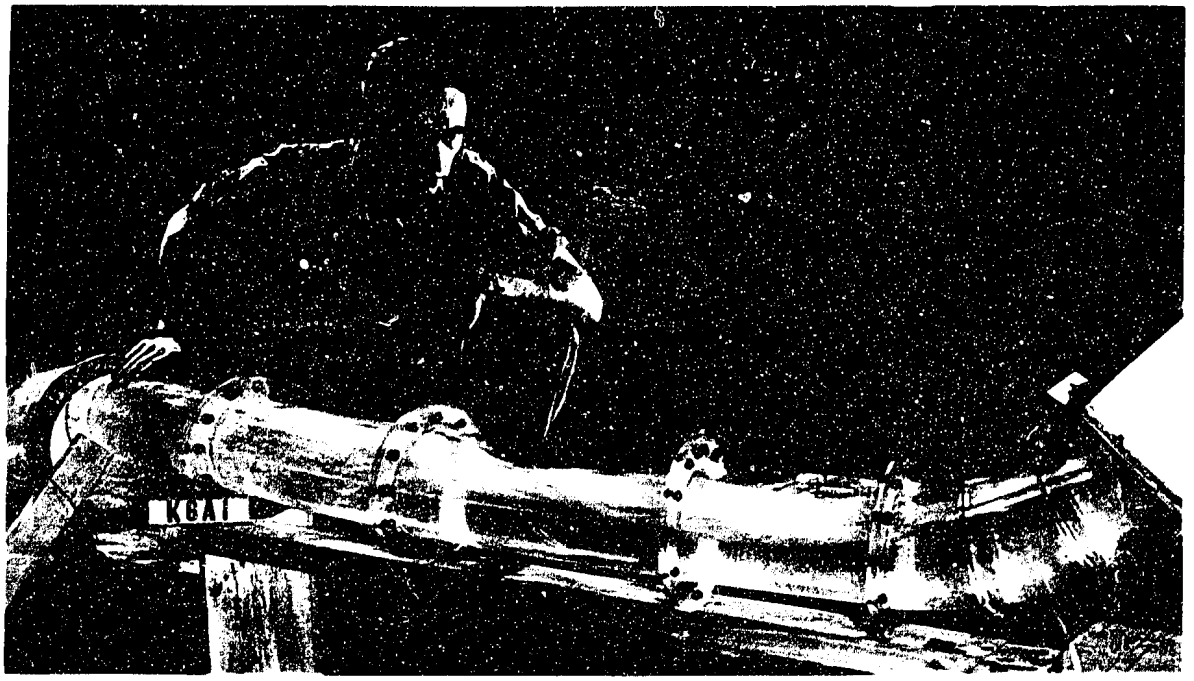
KORTES DAM SPILLWAY
Flow Over Spillway Crest of 1:60 Model

A. Looking into spillway tunnel - Showing excavation as recommended.

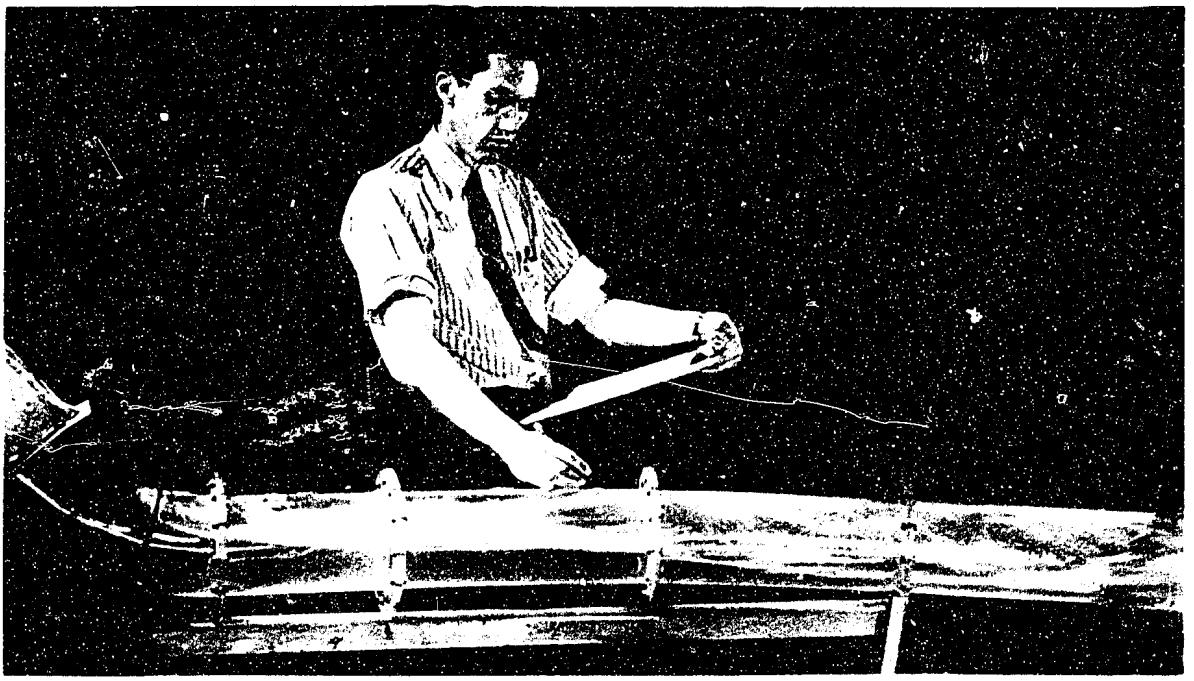


B. Looking into spillway tunnel. Discharge = 10,000 second-feet Flow concentration in center of tunnel.

KORTES DAM SPILLWAY
Spillway Crest and Tunnel Portal

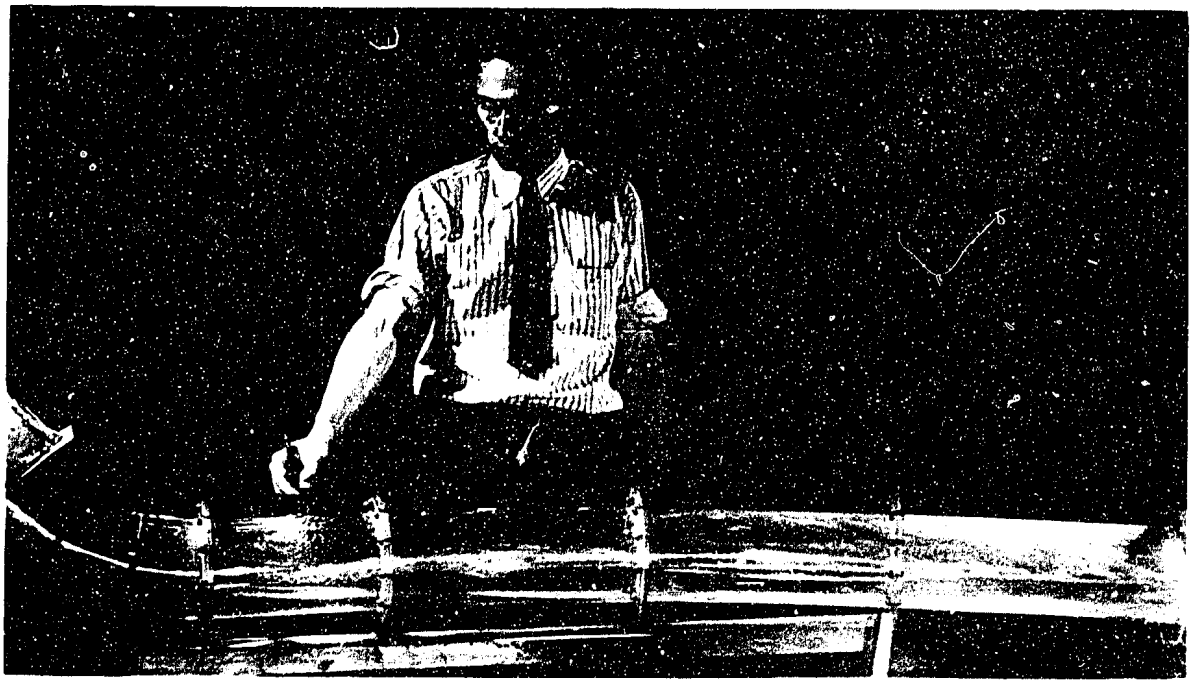


A. Looking at outside of horizontal bend. Discharge = 50,000 second-feet

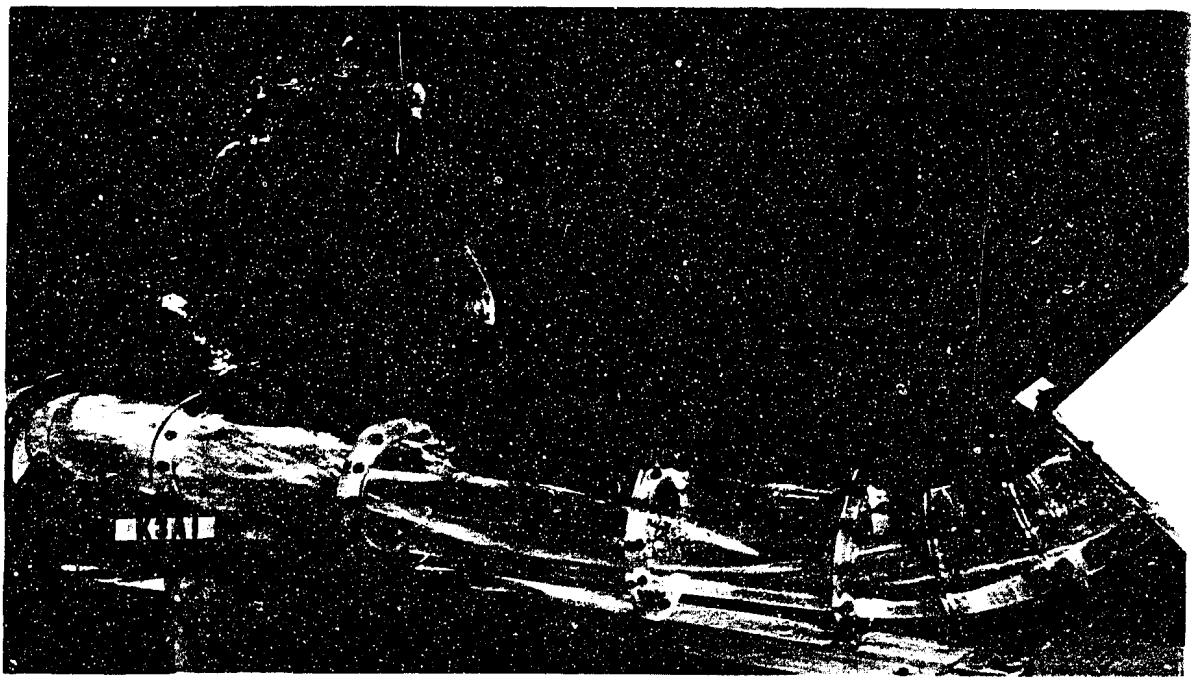


B. Looking at inside of horizontal bend. Discharge = 50,000 second-feet.

KORTES DAM SPILLWAY
Flow in Tunnel of 1:60 Model



A. Looking at inside of horizontal bend of tunnel. Discharge = 20,000 second-feet. Note flow across top of tunnel.

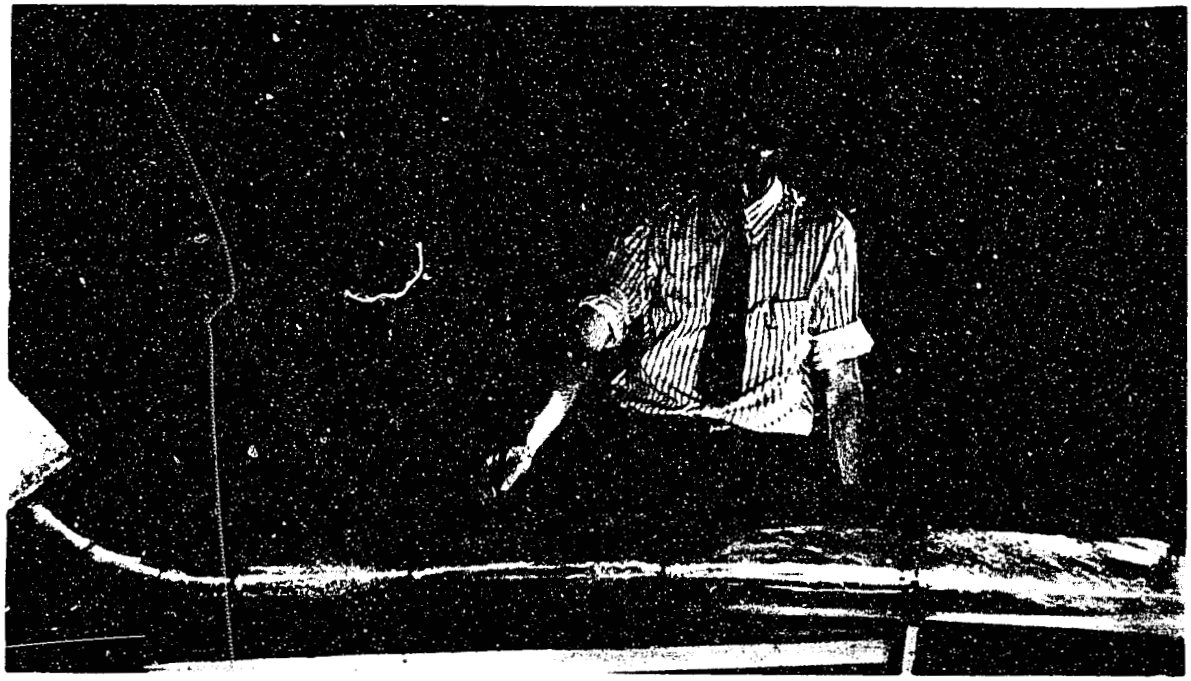


B. Looking at outside of horizontal bend of tunnel. Discharge = 20,000 second-feet.

KORTES DAM SPILLWAY
Flow in Tunnel of 1:60 Model

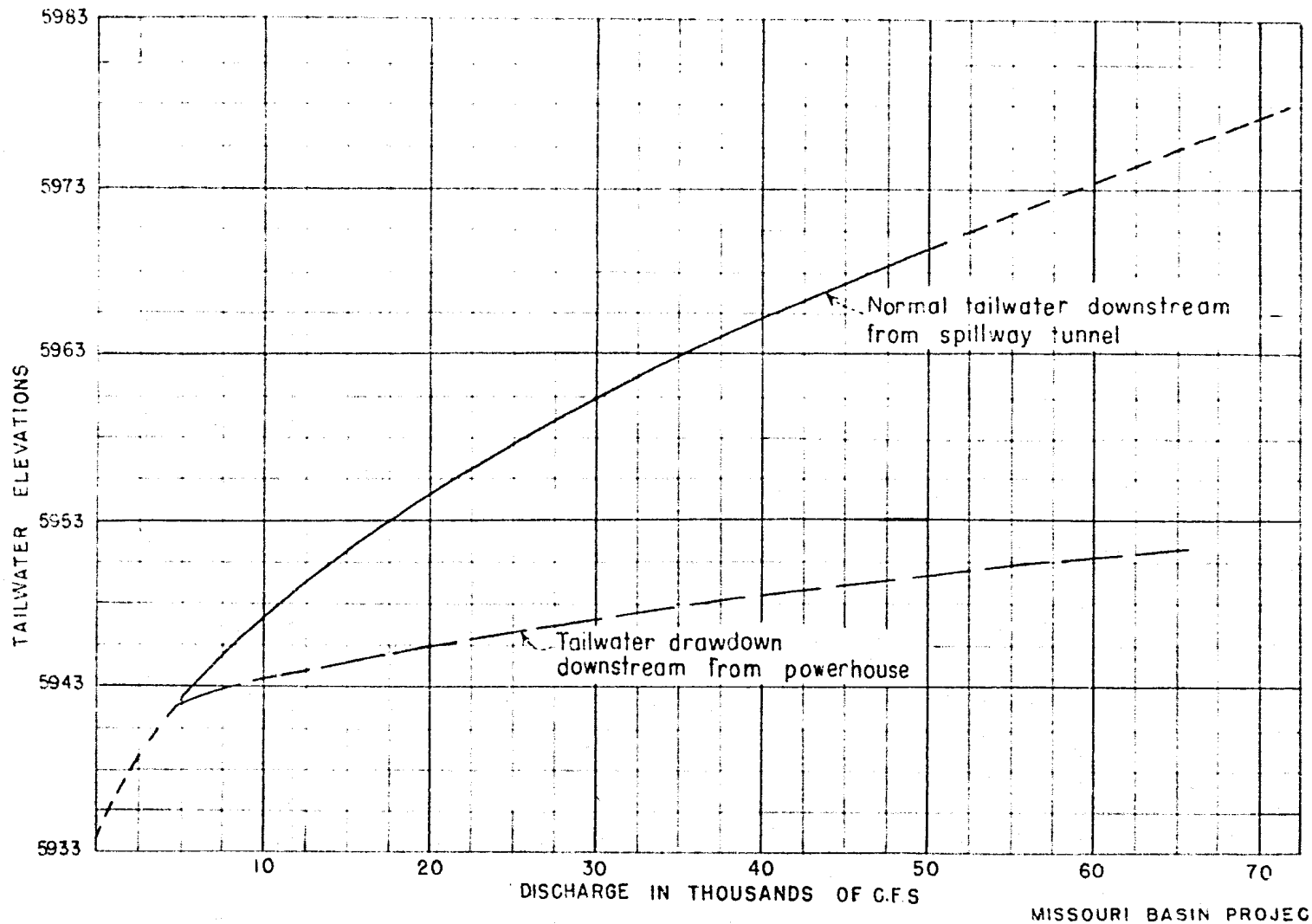
FIGURE 18

A. Looking at outside of horizontal bend in tunnel. Discharge = 10,000 second-feet.



B. Looking at inside of horizontal bend in tunnel. Discharge = 10,000 second-feet.

KORTES DAM SPILLWAY
Flow in Tunnel of 1:60 Model



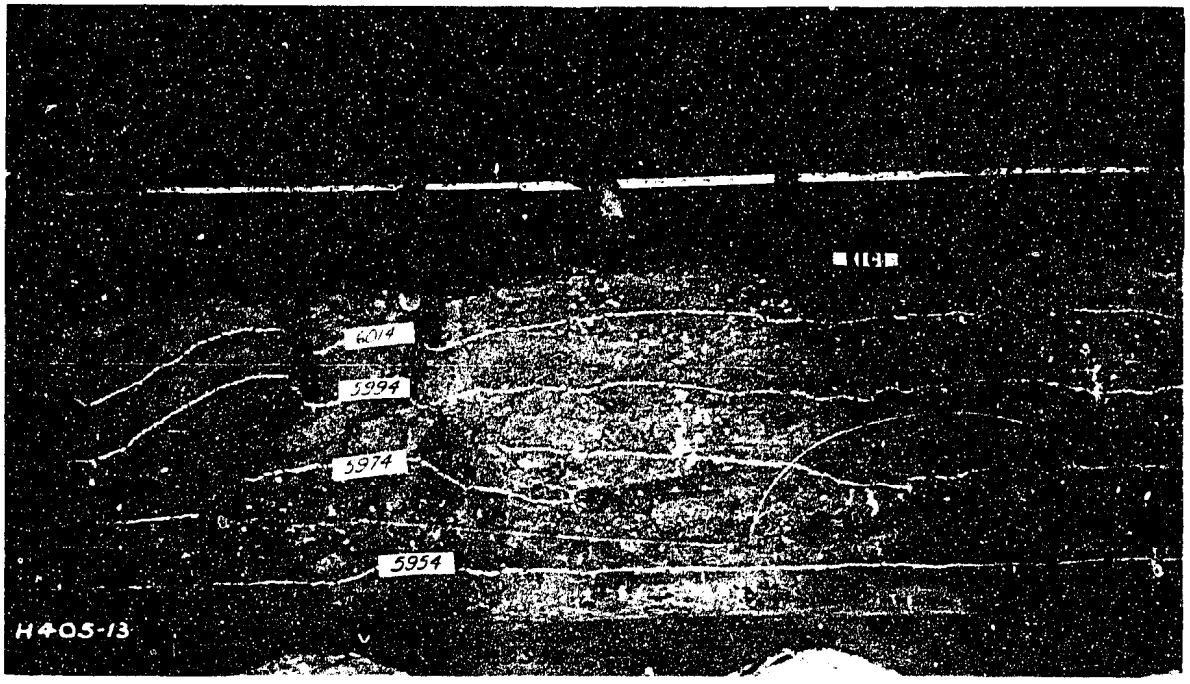
MISSOURI BASIN PROJECT
KENDRICK UNIT-WYOMING
KORTES DAM SPILLWAY
TAILWATER ELEVATIONS

FIGURE 19

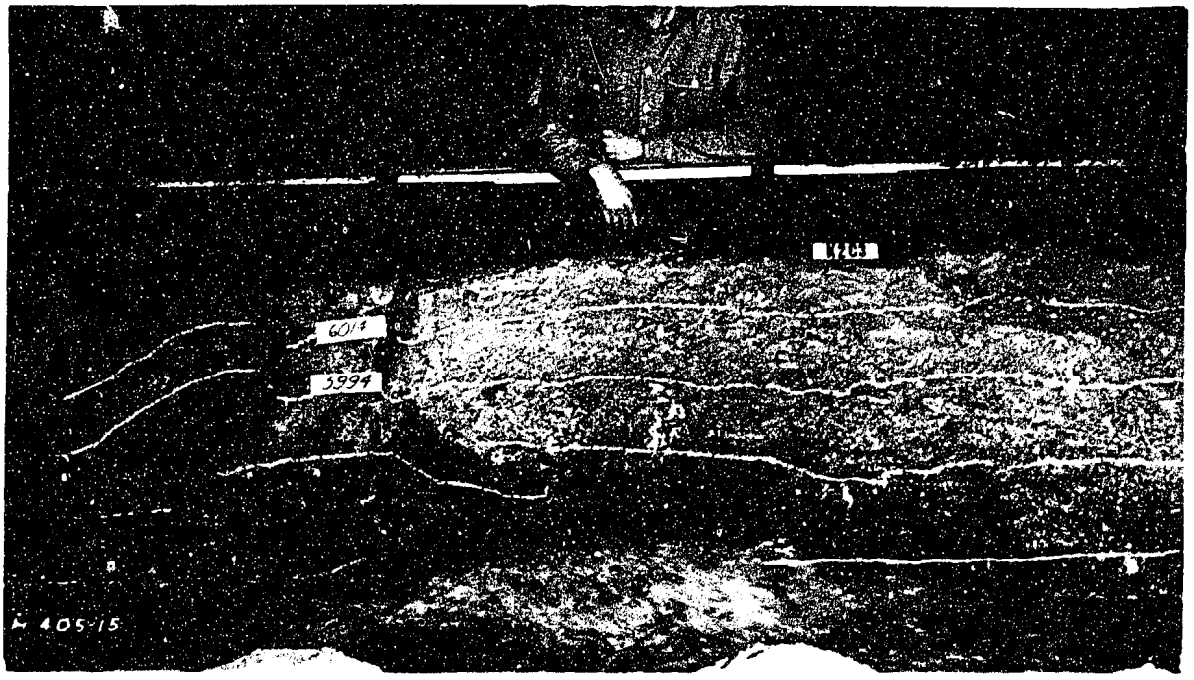
A. Looking downstream - Spillway discharging 10,000 second feet.

B. Looking downstream - Spillway discharging 20,000 second-feet. Showing fin along wall immediately downstream from tunnel portal.

KORTES DAM SPILLWAY
Flow in River Channel of 1:60 Model



A. Looking toward left canyon wall. Model dry.



B. Looking at left canyon wall. Discharge = 20,000 second-feet.

KORTES DAM SPILLWAY
Flow on Left Canyon Wall of 1:60 Model

A. Looking upstream into exit of tunnel.

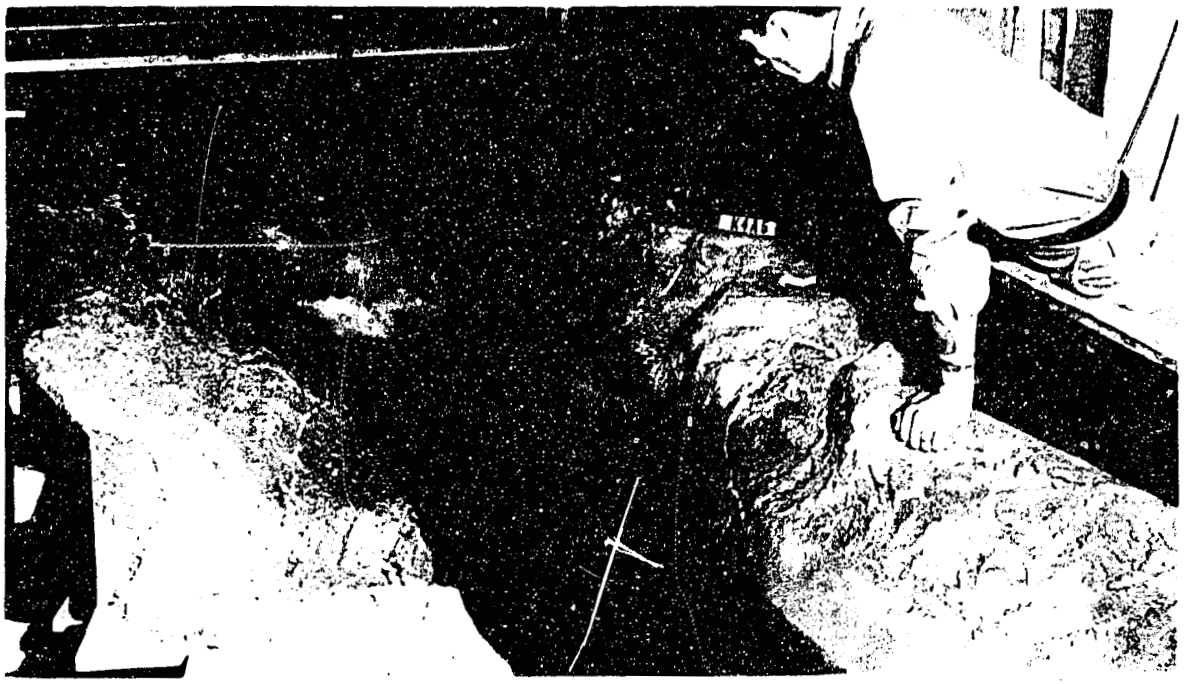
B. Looking downstream. Discharge = 10,000 second-feet.

KORTES DAM SPILLWAY
Alternate Tunnel Alinement

A. Looking downstream. Discharge = 20,000 second-feet.

B. Looking downstream. Discharge = 30,000 second feet.

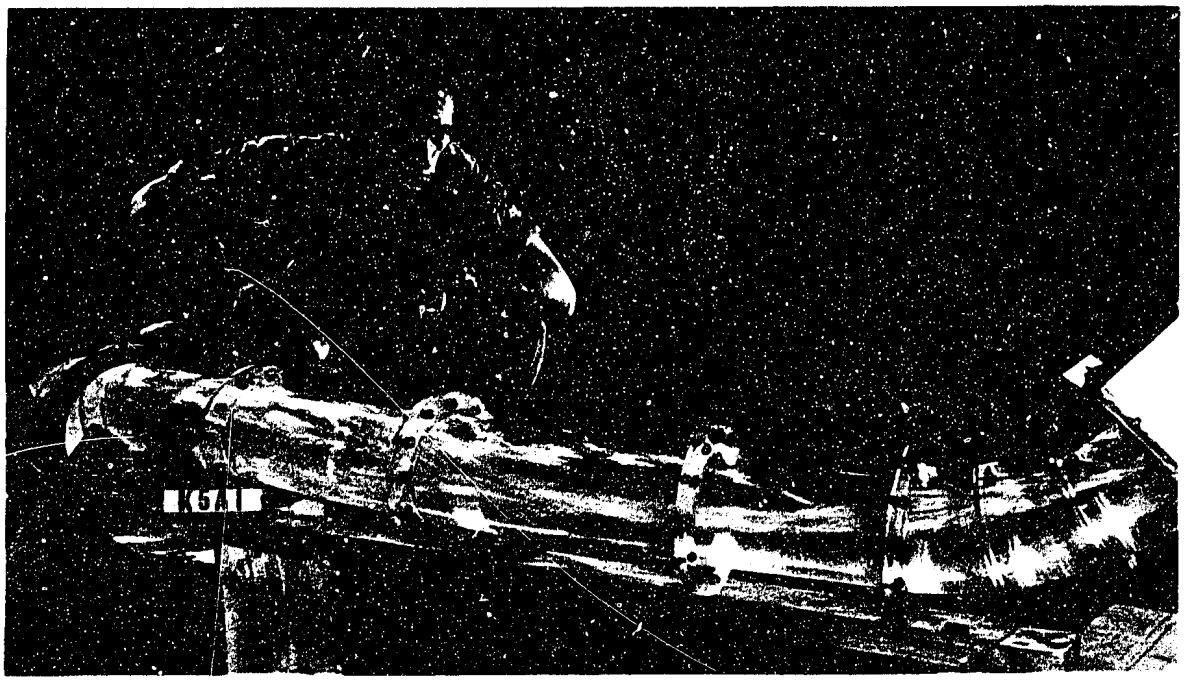
KORTES DAM SPILLWAY
Flow From Alternate Tunnel of 1:60 Model



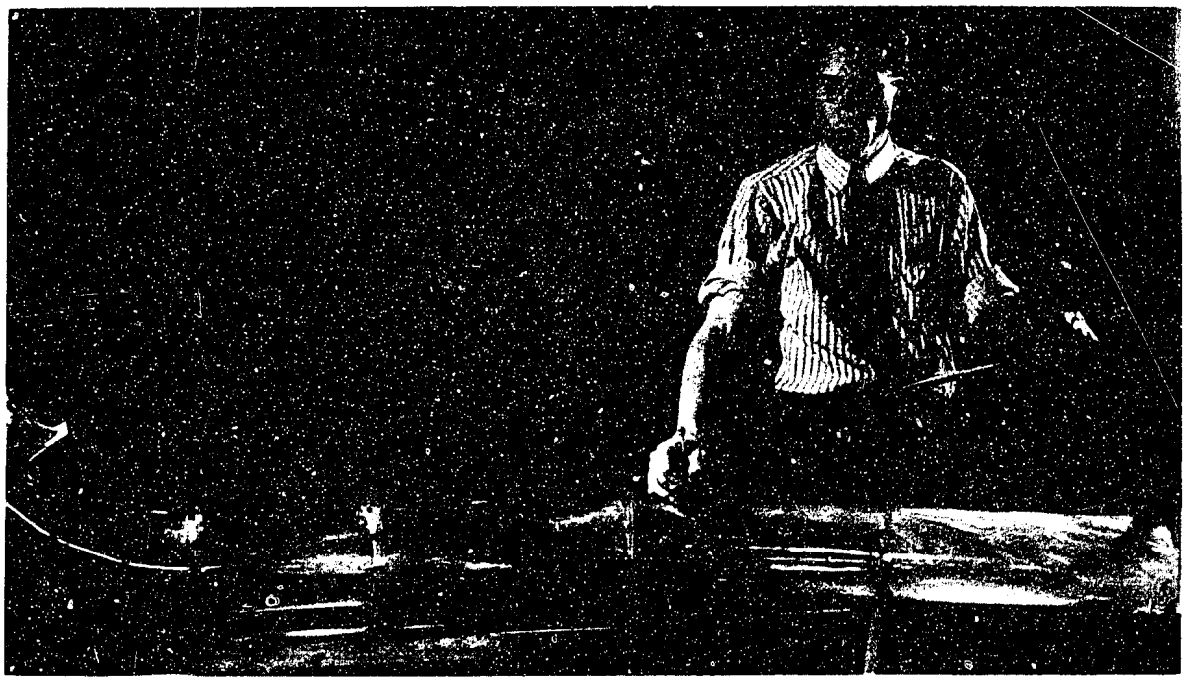
A. Looking downstream. Discharge = 50,000 second-feet. Jet penetrates to the river bed.

B. Looking downstream. Discharge = 60,000 second-feet.

KORTES DAM SPILLWAY
Flow From Alternate Tunnel of 1:60 Model



A. Looking at outside of horizontal bend of tunnel. Discharge = 40,000 second-feet.



B. Looking at inside of horizontal bend of tunnel. Discharge = 40,000 second-feet.

KORTES DAM SPILLWAY
Flow in Tunnel of 1:60 Model