Rhone

379

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES ON THE BIFURCATION STRUCTURE AT STATION 283+11.98--POUDRE SUPPLY CANAL COLORADO-BIG THOMPSON PROJECT

Hydraulic Laboratory Report No. Hyd-379

ENGINEERING LABORATORIES

OFFICE OF THE ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

June 7, 1954

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES ON THE BIFURCATION STRUCTURE AT STATION 283+11.98--POUDRE SUPPLY CANAL COLORADO-BIG THOMPSON PROJECT

Hydraulic Laboratory Report No. Hyd-379

ENGINEERING LABORATORIES

OFFICE OF THE ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

June 7, 1954

CONTENTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of the Assistant Commissioner
and Chief Engineer
Engineering Laboratories
Denver, Colorado
June 7, 1954

Laboratory Report No. Hyd-379
Hydraulic Laboratory
Compiled by: T. J. Rhone
Checked and
reviewed by: A. J. Peterka

Subject: Hydraulic model studies on the bifurcation structure at Station 283+11.98--Poudre Supply Canal--Colorado-Big Thompson Project

SUMMARY

The Poudre Supply Canal, which connects Horsetooth Dam Reservoir and the Cache La Poudre River, contains a bifurcation structure just upstream from the junction of the canal and the river. Just downstream from the bifurcation structure is the only water-measuring station on the canal; and since the canal replenishes water borrowed from the Cache La Poudre River, it is necessary that an accurate measurement of the flow be made at this point. As is the custom for small canal structures, the canal was constructed without benefit of a model study. The fact that the canal had been designed for velocities about twice as great as normally used made it difficult to predict flow conditions.

When the prototype canal was operated for the first time, it was apparent that flow conditions in and downstream from the bifurcation structure were not satisfactory. The flow around the abrupt turn produced a tilted water surface at the radial gate and poor distribution of flow entering the stilling basin. The uneven water surface and an inefficient hydraulic jump in the stilling basin caused surges and waves 10 to 18 inches in height that carried down into the measuring flume making it impossible to obtain a reliable water surface elevation for an accurate discharge determination, Figure 1.

Initial operation of the model showed a very similar flow pattern including the tilted water surface around the turn, the rough hydraulic jump, and 10- to 18-inch waves in the measuring flume, Figure 5.

Several methods were tried to obtain satisfactory flow conditions in the measuring flume. Unsuccessful methods included several attempts to even the tilted water surface at the curve, all of which caused the upstream water level to rise and overtop the canal banks.

Equally unsuccessful were attempts to improve the energy dissipation by the use of baffle blocks on the sloped floor upstream from the measuring flume and to dampen the waves by log rafts.

The method ultimately used for the recommended design made use of two curtain walls placed across the channel in the transition section a short distance downstream from the bifurcation structure, Figure 9. The curtain walls were very effective in producing a smooth water surface at all discharges. In the model the waves were 4 to 7 inches high compared to the original 10 to 18 inches.

Prototype wave measurements made after the recommended changes had been installed showed very close agreement to similar model measurements, Figure 11.

INTRODUCTION

The Poudre Supply Canal runs between the Horsetooth Reservoir and the Cache La Poudre River and is used to restore any water that is diverted upstream for irrigation purposes. At Station 283+11.98 the Poudre Supply Canal branches into two sections, the Windsor section and the continuation of the Poudre Supply Canal, Figure 2. The Poudre Supply Canal section carries the greater portion of the discharge and also makes the more abrupt turn of the two sections. The flow in the Poudre Supply Canal section discharges into the Poudre River a short distance downstream from the bifurcation structure. Prior to entering the Poudre River, the flow goes through a Parshall-type measuring flume so that an accurate record of the discharge can be maintained.

Prototype operation had revealed that the flow in the measuring flume was too turbulent for current meter ratings and the waves too high for accurate water surface determination by either staff gage readings or water level recorder charts. The rough water surface was the reflection of an uneven approach condition caused by the abrupt turn at the bifurcation structure upstream and an inefficient hydraulic jump. The flow around this turn had an extreme drawdown that was not leveled before it entered the stilling basin upstream from the measuring flume. The drawdown at the bifurcation turn and the rough water surface in the measuring flume are shown in Figure 1.

The water surface fluctuation was as great as 18 inches in the measuring flume, and in order to obtain an accurate discharge record this fluctuation had to be reduced to about 4 inches.

THE MODEL

The model of the bifurcation structure was constructed to a scale of 1:18 and included a 100-foot section of the canal upstream from the bifurcation structure and approximately 100 feet of both the Windsor section and the Poudre Supply Canal section, Figure 3. The canals and measuring flume were constructed from plywood and the radial control gates at the bifurcation structure were made from sheet metal. Water was supplied to the model through a 6-inch pipe connected to a portable laboratory pump. The discharge was measured with an orifice Venturi meter.

Three criteria were used in judging the effectiveness of any modification made to improve the flow conditions. The measurements and the equipment used to obtain them are as follows:

1. Velocity determination in measuring flume. Obtained as a measure of the evenness of the flow distribution. A Bentzel tube was used to obtain the velocity measurements.

2. Water surface elevation. The water surface elevation in the canal was obtained by a point gage and in the measuring flume by means of an open tube manometer connected to a piezometer opening located, to scale, in the standard location recommended for a Parshall-type measuring flume.

3. Water surface fluctuation. The water surface fluctuation was measured at the staff gage in the measuring flume by an electronic wave-measuring device. The electronic device is a varying capacitance-type instrument consisting of a 32-gage enamel coated copper wire stretched between the two arms of a "U" support. This wire, placed vertically in the water so that the waves cover a center portion of its length at all times, acts as a capacitance. The copper wire and the water form the two capacitance plates, and the enamel coating the dielectric. This capacitance is connected as a part of the active leg of a balanced 5,000 cycles per second alternating current bridge. Any change of water level on the wire throws the bridge off balance. This off balance is linear with the wave height, within limits, and can be recorded as a continuous trace on an oscillograph. A profile of the wave motion can thus be studied and its time constant, frequency, and amplitude analyzed.

THE INVESTIGATION

All of the investigations included in this report were performed to improve the flow in the Poudre Supply Canal section of the bifurcation structure. No tests were made on the Windsor section after preliminary model investigations had shown that it operated satisfactorily.

Three methods appeared as possible means of correcting the existing poor flow conditions. They were (1) to correct the extreme drawdown around the turn of the bifurcation structure and thereby provide a level water surface before the flow enters the stilling basin; (2) to improve the efficiency of the energy dissipation in the check section by means of baffle blocks, end sills, or other appurtenances. This would provide a smooth water surface before the flow entered the measuring weir; (3) to reduce the water surface fluctuation in the measuring flume by the use of rafts, baffle blocks, or curtain walls located in the transition.

Drawdown Elimination

Several methods of eliminating the water surface drawdown at the gate were tried. These included placing straightening vanes of various heights in the canal upstream from the turn to guide the flow around the turn and placing baffle blocks of several sizes at the turn to reduce the velocity sufficiently to produce a level water surface. In all tests the corrective value was slight and all caused the water surface elevation to rise and to overtop the canal banks upstream.

The drawdown could have been decreased by replacing the turn with a curve of longer radius, but this would have necessitated extensive revisions to the prototype structure; no investigations of this type were made.

Alteration of Stilling Basin

The stilling basin or check section just downstream from the turn consisted of a drop and a stilling basin with chute blocks and baffles, Figure 2. The flow entering the check section was not evenly distributed, Figure 4, and combined with the turbulence in the stilling basin caused the very rough water surface in the measuring flume. Figure 1 shows the water surface in the prototype structure, and Figure 5 shows comparable pictures of the action in the model.

Several methods of increasing the amount of energy dissipation were investigated. The first investigation was made to determine the effectiveness of different size chute blocks and baffles; although several combinations were tried, none showed sufficient promise to warrant extensive investigation.

The next tests were made to improve the stilling action by increasing the water depth in the check section. This could be accomplished by either lowering the floor of the check section or by raising the floor of the downstream measuring flume. The latter method was investigated in the model by adding 9- and 12-inch thicknesses to the floor, Figure 6. In both of these tests the irregular flow and rough water surface were slightly improved but the added height caused the water surface to overtop the structure at a discharge of 1,250 cfs. Since none of the tests had shown promise in improving the flow at the stilling basin, no further tests were made at this section.

The accurate measurement of the flow was required by the State Engineer. His representative, Mr. Ralph W. Parshall, a frequent observer during the model tests, suggested that a system of "dragons teeth" placed on the drop might serve the purpose of both straightening the flow and improving the energy dissipation in the check section. In keeping with this suggestion an energy dissipator was made from thirty-nine 8 by 8 angles, 8 feet long, placed in six rows on the curve of the drop, Figure 7. The model was operated at 1,000 and 1,500 cfs, and the flow appearance upstream and downstream from the dissipator checked for uniformity. Figure 8 shows the downstream flow appearance in the check section at the two discharges. The dissipator provided a very even flow distribution and reduced the water surface fluctuation in the measuring flume from a 10- to a 4-inch average. The flow downstream from the check section was excellent in all respects; however, the flow upstream was not satisfactory. The dissipator caused so much flow resistance that the upstream water surface overtopped the canal banks at all discharges greater than 1,000 cfs. Since the cost of increasing the height of the canal lining would be very high, the designers decided not to adopt the dissipator as a corrective measure.

Wave Dampeners

The most effective method of reducing the water surface fluctuation in the measuring flume was to incorporate some method of dampening the waves in the transition section located between the drop and the measuring flume. Three methods were investigated in the model, they were (1) small blocks or baffles on the sloped floor of the transition, (2) a timber raft in the transition, and (3) one or more curtain walls or skimming weirs in the transition.

1. Baffles or blocks. Although several different sizes and arrangements of blocks were tried, none seemed to give promise of more than a very slight improvement of the flow.

2. Timber raft. Two types of rafts were investigated in the model; one simulated a flat, or two-dimensional timber raft. The other was a three-dimensional system of timbers fastened together in such a manner that the natural period of oscillation of the system was as far different as practical from the period of the

waves in the transition. Thus, the natural inability of the raft to oscillate at the wave period had the effect of dampening the magnitude of the total water surface fluctuation.

The first type of raft was not satisfactory since it had a tendency to accentuate the wave action instead of dampening it. A raft of the second type was developed that was effective in producing a comparatively smooth water surface for the maximum discharge; however, for smaller discharges with other wave periods it was not effective. Several designs of the second type were tried but in all cases if the raft was effective at one discharge it was not effective at others.

3. Curtain walls, recommended. Although the laboratory hesitates to recommend and the designers are reluctant to accept curtain walls and skimming weirs for use in canals because of their makeshift appearance and the fact that they are trash collectors, they will usually produce a quiet water surface when all else fails. Because nothing else that was economically feasible produced the desired results, it was decided to develop a curtain wall arrangement to quiet the water surface in the measuring flume.

For the initial tests the curtain wall was placed across the transition section about 8 feet downstream from the end of the check section, Station 284+05.5. The lower edge was placed 4 feet above the transition floor; this dimension was determined by the water surface elevation for a discharge of 600 cfs. Field and laboratory tests showed that at this discharge the surface waves first appeared. When the lower edge of the curtain wall was placed about 4 inches below this water surface, the waves became negligible. This curtain wall was effective for all flows up to about 1,100 cfs when the water surface again became too rough. In order to extend the range of the smooth water, a second curtain wall was placed about 24 feet downstream from the first. This curtain wall was set with its lower edge about 4 inches below the water surface for a discharge of 1,100 cfs. The combination of the two curtain walls, Figure 9, kept the water surface fluctuation at a minimum for all discharges. Figure 10 shows the model and the appearance of the flow at a discharge of 1,250 cfs. When compared with Figure 5, the improvement in the appearance of the water surface is very apparent. Figure 11 shows a comparison of the water surface fluctuations before and after the curtain walls were added. Curves A and B are the fluctuations obtained from the model before and after the curtain walls were installed; Curve C shows the water surface fluctuation measured in the prototype structure after the curtain walls were added. All measurements were made at the standard staff gage location. The model indicated that before the curtain walls were added the average fluctuation was about 10 inches with a maximum of about 17 inches; after the walls were installed the average fluctuation was about 4 inches and the maximum only 7 inches.

MODEL-PROTOTYPE CONFORMITY

On April 8, 1953, the Poudre Supply Canal was operated so that the performance characteristics of the canal structures could be tested by the designers and laboratory engineers. The results of the tests have been reported in a Hydraulic Laboratory Field Trip Report No. 1382.

One of the structures that was checked was the measuring flume at the bifurcation structure. The recommended curtain walls had been placed in the transition section upstream from the measuring flume, and prototype tests were made to determine the water surface fluctuations and the velocity distribution in the measuring flume. Two similar measurements were made in the model so that the degree of model-prototype conformity could be determined.

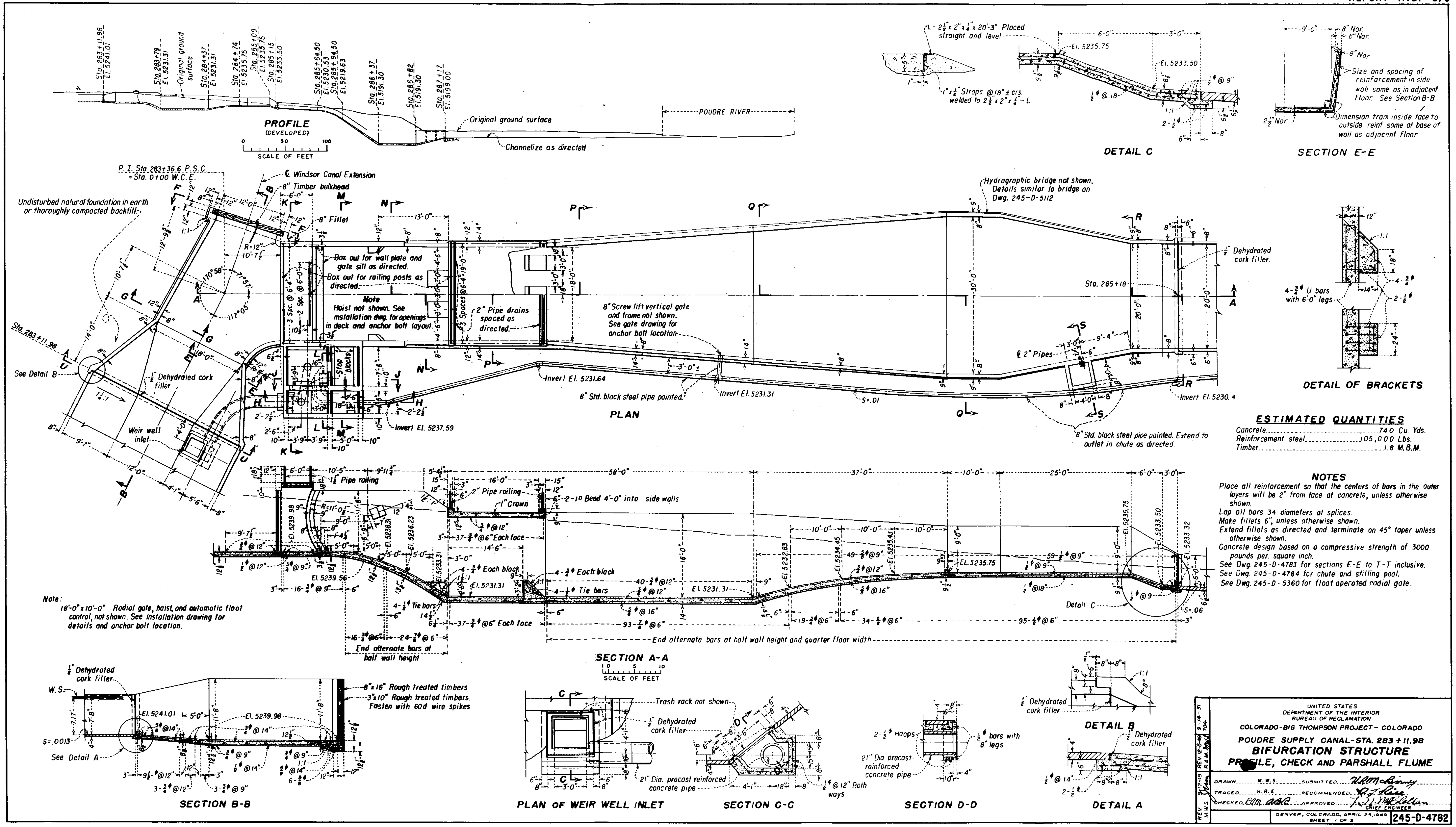
Motion pictures showing the water surface fluctuation at the staff gage in the prototype measuring flume were compared with similar model measurements made with an electronic wave recorder. The frequency and magnitude of the fluctuations in the model and prototype are compared in Figure 11, Curves E and C. The model prototype conformity is very close. In both cases the waves seem to have a period of about 3 seconds and a magnitude of approximately 0.3 foot. The water surface shows more fluctuation between peaks in the model than in the prototype, but this is probably caused by the electronic recorder being more sensitive to the changes than motion pictures taken at 16 and 32 frames per second.

The prototype discharge was determined by current meter traverse in the measuring flume, and this value was used as a check on the discharge indicated on the flume recorder. A similar velocity traverse was made in the model to compare the velocity distribution. The two traverses are plotted on Figure 12, again the similarity between the model and prototype is very close.

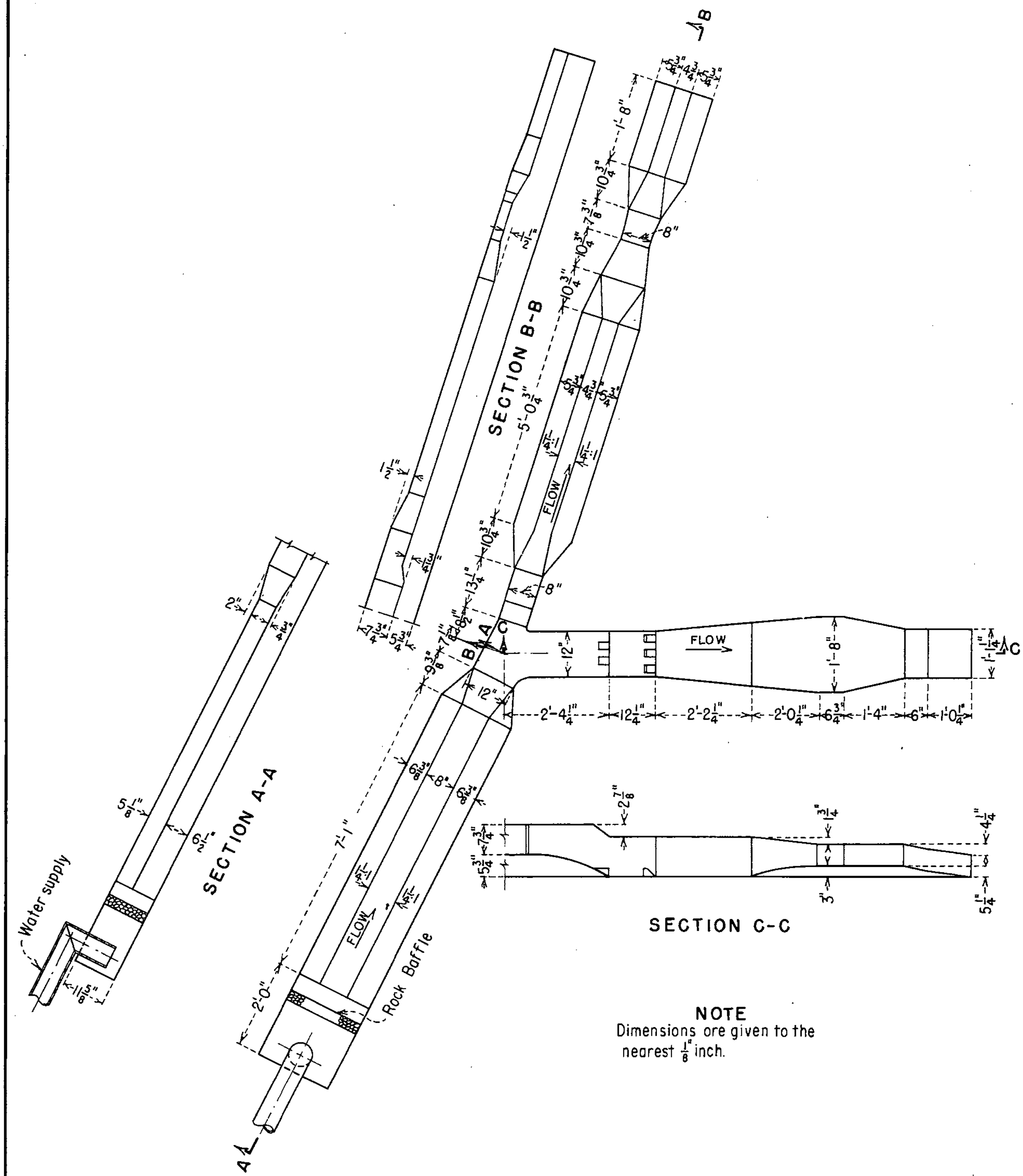
A. Looking downstream in Measuring Flume. The water surface fluctuation averages about 10 inches with a maximum of 18 inches.

B. Water Surface Drawdown at radial gate.

Poudre Supply Canal
Bifurcation Structure at Sta. 283+11.98
Prototype Operation at 1275 cfs



RECORD DRAWING

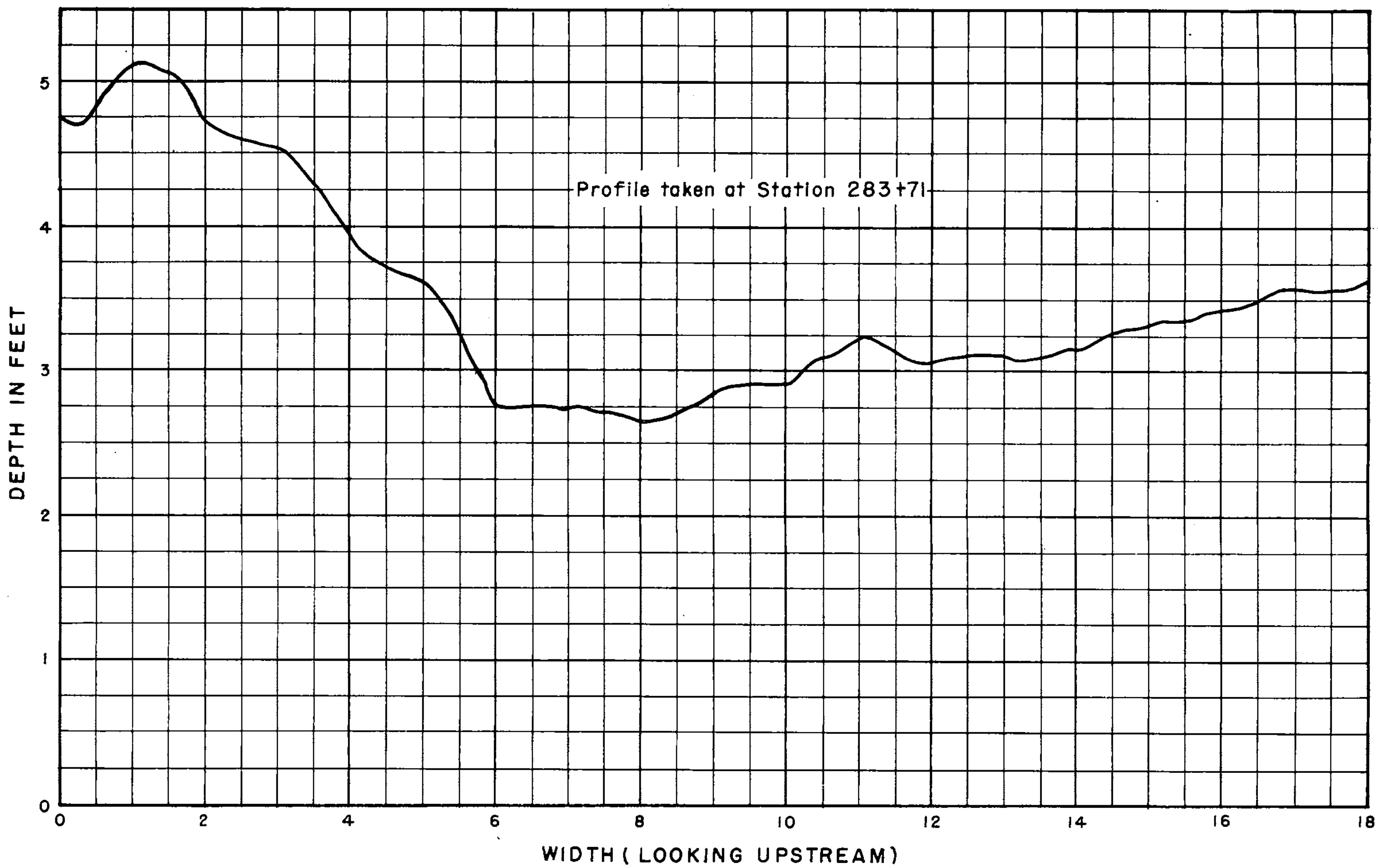


POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

BIFURCATION STRUCTURE

MODEL LAYOUT



POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

WATER SURFACE PROFILE UPSTREAM FROM CHECK STATION

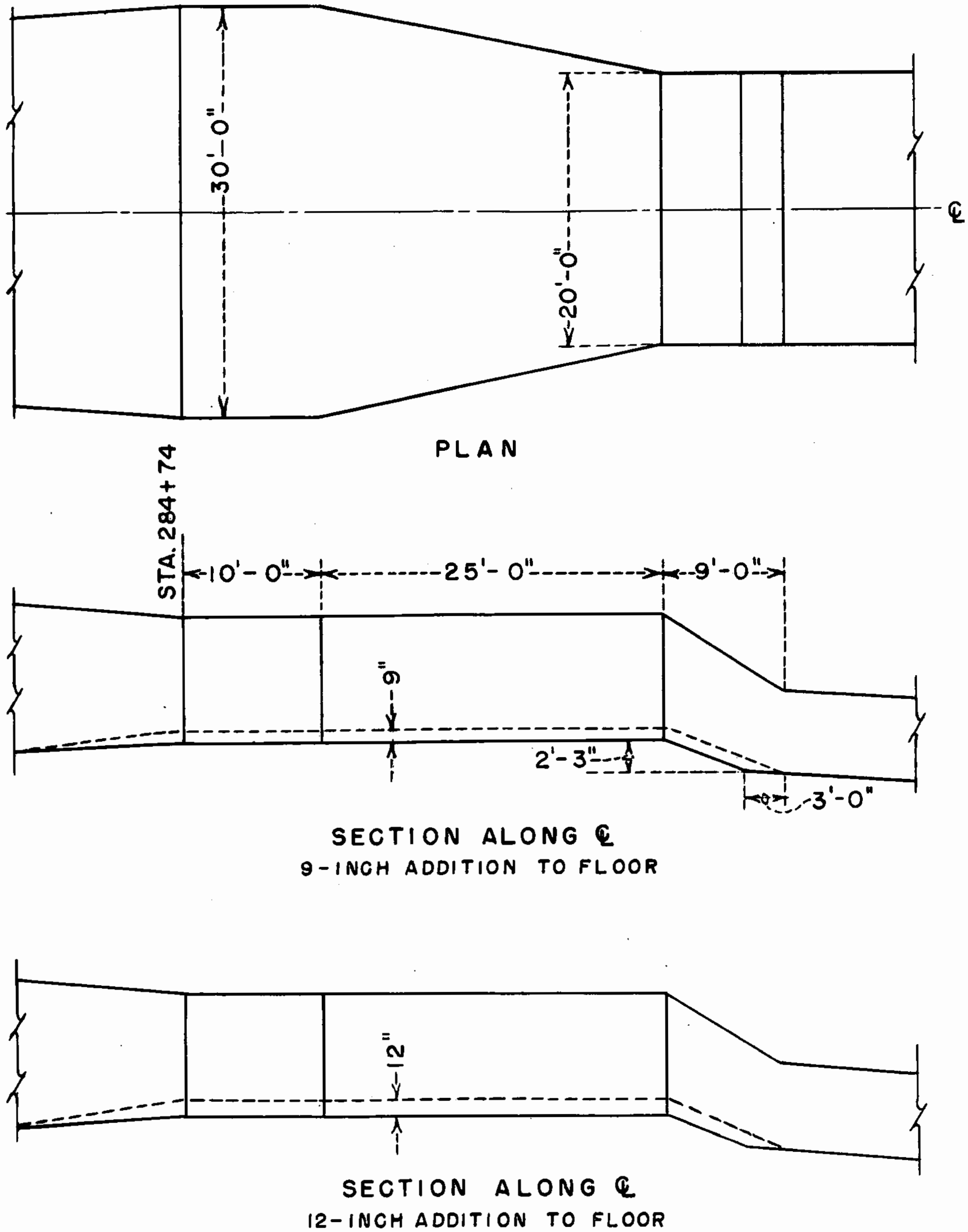
FIGURE 4
REPORT HYD. 379

A. Looking from measuring flume toward bifurcation structure.

B. Appearance in stilling basin at 1250 cfs.

C. Appearance of flow in stilling basin and measuring flume at 1250 cfs.

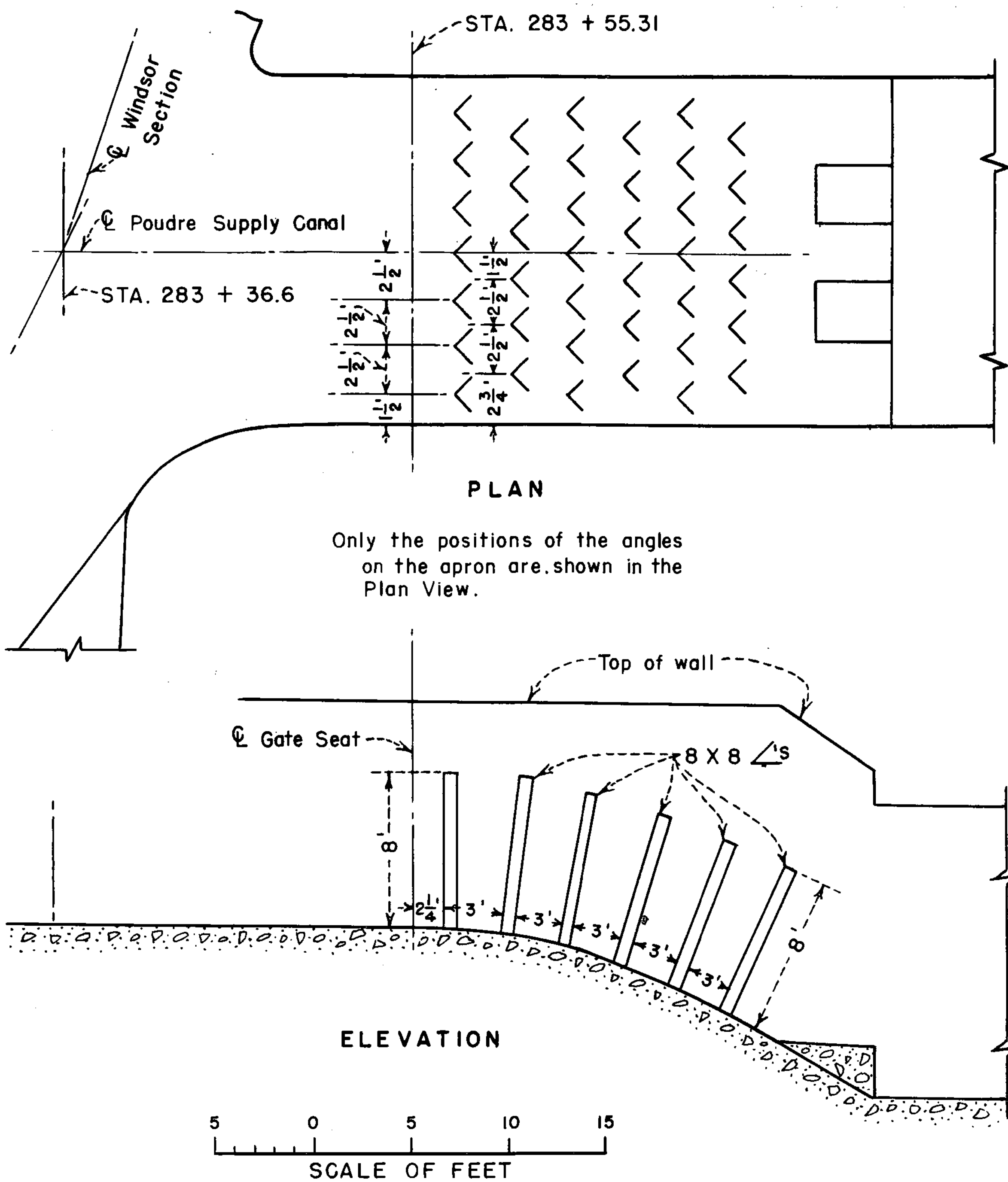
Poudre Supply Canal
Bifurcation Structure Model Studies
Preliminary Design



POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

ADDITIONS TO FLOOR OF PARSHALL FLUME



POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

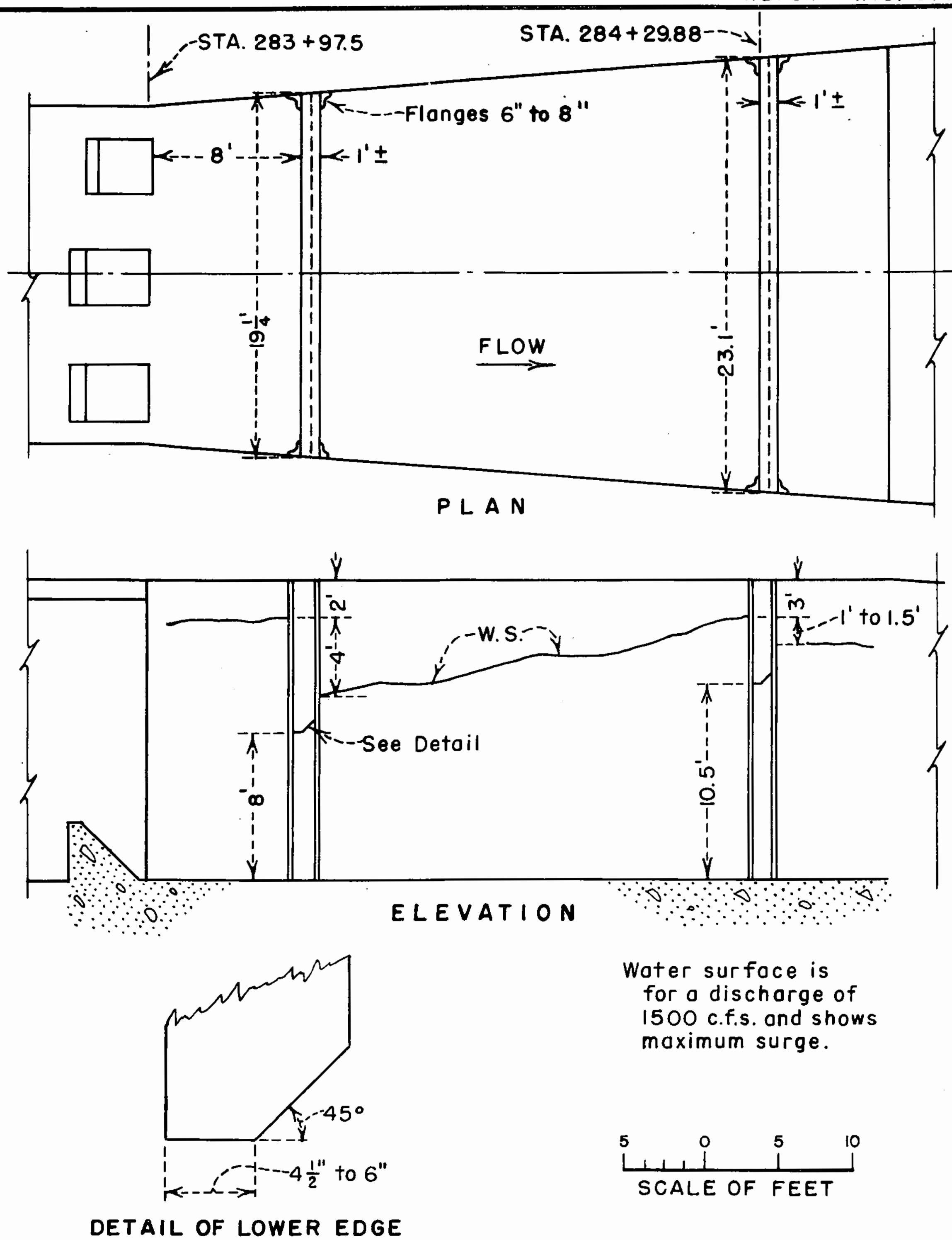
ENERGY DISSIPATOR

Discharge 1000 cfs

Discharge 1500 cfs

Poudre Supply Canal
Bifurcation Structure Model Studies
Energy Dissipator Upstream from Stilling Basin

Figure 8



POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

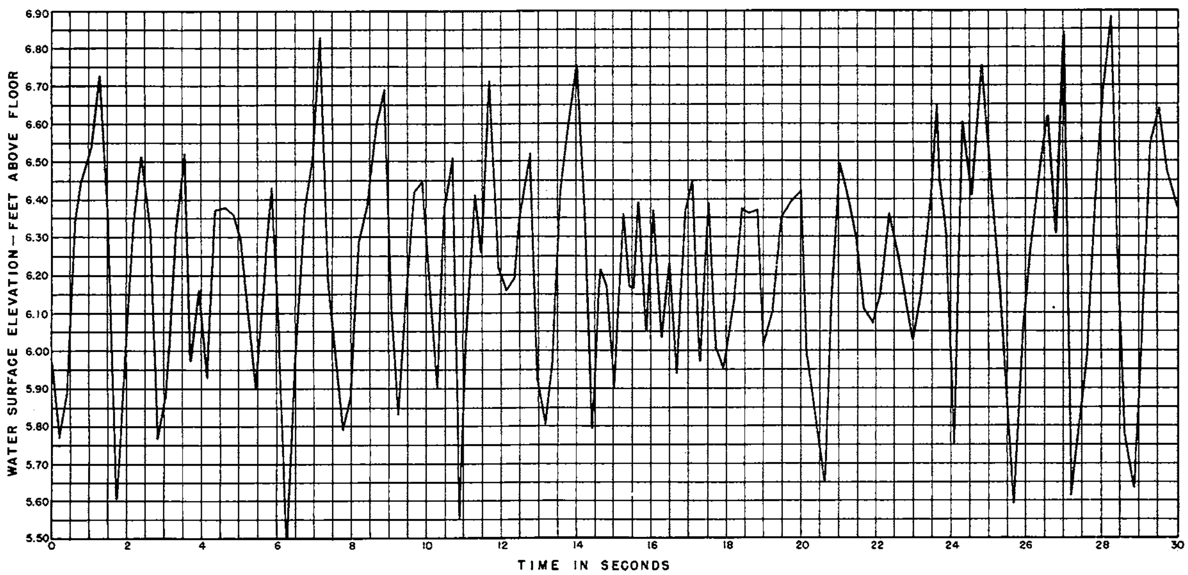
CURTAIN WALLS

A. Curtain walls looking up-
stream.

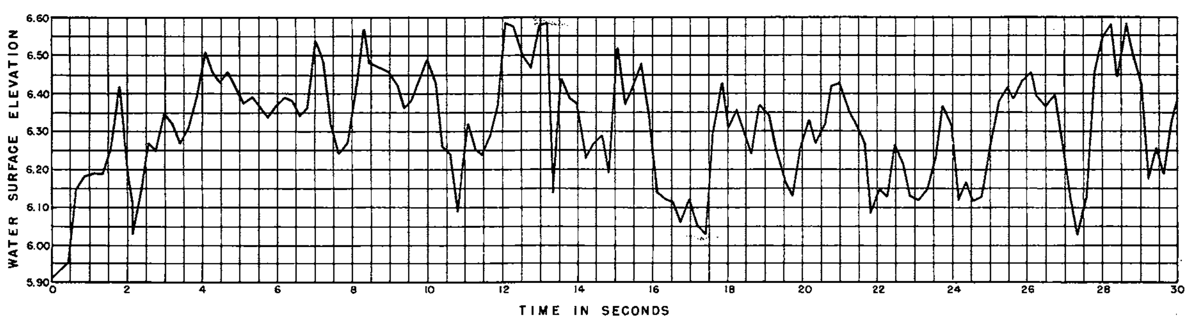
B. Stilling basin performance
at 1250 cfs.

C. Smooth flow in measuring flume at 1250 cfs.

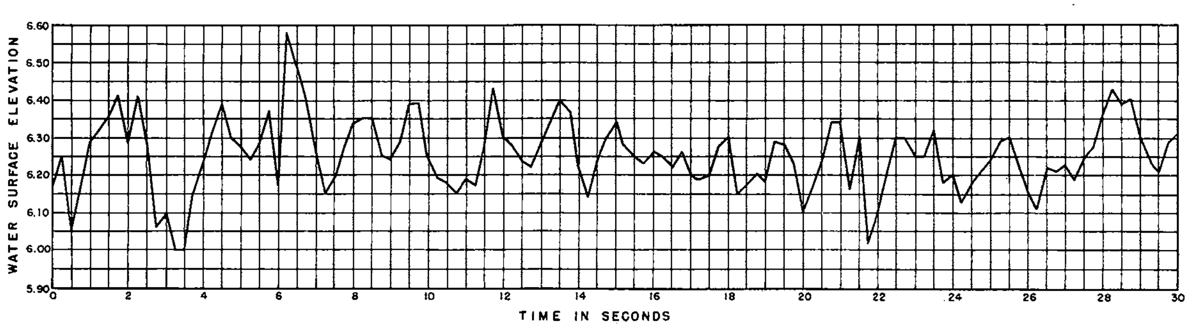
Poudre Supply Canal
Bifurcation Structure Model Studies
Recommended Curtain Walls



A. WATER SURFACE FLUCTUATION BEFORE MODIFICATION
OBTAINED FROM 1:18 SCALE MODEL



B. WATER SURFACE FLUCTUATION AFTER RECOMMENDED MODIFICATION
OBTAINED FROM 1:18 SCALE MODEL



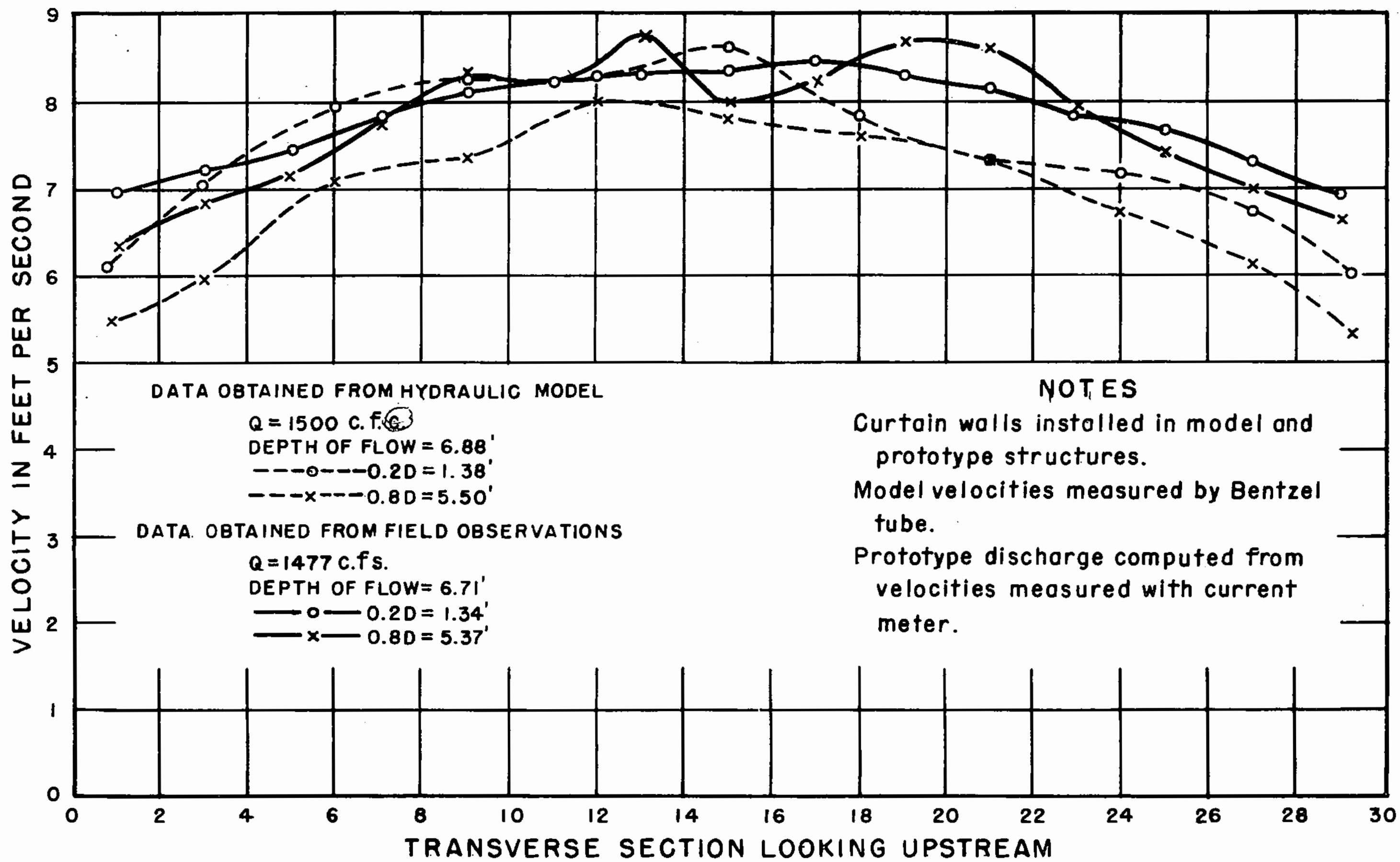
C. WATER SURFACE FLUCTUATION AFTER MODIFICATION
OBTAINED FROM PROTOTYPE OBSERVATIONS

POUDRE SUPPLY CANAL

1:18 SCALE MODEL STUDIES

WATER SURFACE FLUCTUATION IN MEASURING FLUME

FIGURE 12
REPORT HYD. 379



POUDRE SUPPLY CANAL

MODEL AND PROTOTYPE VELOCITIES AT STATION 285 + 12

RECOMMENDED MODIFICATIONS