HYDRAULIC MODEL STUDY
HANSEN SUPPLY CANAL
STILLING BASIN AND PARSHALL FLUME

NORTHERN COLORADO
WATER CONSERVANCY DISTRICT

Civil Engineering Department
Engineering research Center
Colorado State University
Fort Collins, Colorado

November, 1965 CER65JFR51

FINAL REPORT

OF

HYDRAULIC MODEL STUDY

HANSEN SUPPLY CANAL

STILLING BASIN AND PARSHALL FLUME

Prepared for

Northern Colorado Water Conservancy District

Loveland, Colorado

by

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PREFACE

The Engineering Research Center at Colorado State University is located between two lakes, Horsetooth Reservoir of the Colorado-Big Thompson project and College Lake. The laboratories of the Center are strategically located to utilize the high head, 250 feet, available from the reservoir and the storage capacity of the lake. The Center is the focal point for research and graduate education.

There are four principal parts to the Center: the offices for staff and graduate students, the hydraulics laboratory, the fluid dynamics laboratory and the outdoor hydraulics-hydrology laboratory. Included in the research activities of the Center are fluid mechanics, hydraulics, hydrology, groundwater, soil mechanics, hydrobiology, geomorphology and environmental engineering.

The Center includes well-equipped machine and woodwork shops. All research facilities of the Center are constructed on site and for this model study, necessary metal work and carpentry were done by personnel in the shops. The shop personnel are particularly well-experienced in the art and skill of model construction.

Grateful acknowledgment is hereby expressed by the writer to Dr. D. B. Simons, Professor and Associate Dean, College of Engineering, and Mr. S. Karaki, Associate Professor, Department of Civil Engineering for their administrative and technical assistance, to personnel in the shops for their contributions in solving model construction problems, and to others contributing to the model study and preparation of this report. The writer wishes to express his appreciation for the cooperation of the staff of the Northern Colorado Water Conservancy District in providing assistance and helpful suggestions during the model tests.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

This report describes a hydraulic model study of the stilling basin and Parshall flume for the Hansen Supply Canal. The structure was modified to include an underpass wave suppressor. Air vents are provided to relieve air releases and water surface disturbances at the underpass exit. The model construction, tests, conclusions and recommendations are described in this report.

INTRODUCTION

General Description of the Project

The Hansen Supply Canal supplies water from Horsetooth Reservoir to the Cache La Poudre River. The canal has a capacity of 1500 cfs. Approximately one quarter of a mile downstream from the Greeley Waterworks Dam, located at the mouth of Poudre Canyon, the canal bifurcates. From this point, the left[1] branch, known as the Hansen Extension Canal, continues up the south bank of the river, crosses the river in a siphon and discharges into the Poudre Valley Canal. The right branch of the bifurcation enters a stilling basin, passes through a 20-foot Parshall flume and discharges into the river.

Description of the Parshall Flume

Detail plan and profile of the bifurcation, stilling basin, Parshall flume, and appurtenant works are shown in Fig. 1. Radial gates automatically control the water depth in the canal and the discharge into the branches of the bifurcation. The stilling basin consists of a 23-feet long parabolic curved chute approach to the basin, and a hydraulic jump basin 58-feet long. Chute and floor blocks are provided in the basin to assist in the formation and stabilization of the jump.

The chute and basin are 18 feet wide to a point 18-feet 5-inches downstream from the intersection of the chute and the basin floor. At this point the walls flare to 30 feet wide at the entrance to the Parshall flume. The flume has a 20-feet crest length. Downstream from the flume another stilling basin is provided to dissipate the energy before the water discharges into the river.

Scope of Model Study

The purpose of the model study is to investigate hydraulic performance of stilling basin and Parshall flume for the range of discharge from 500 to 1400 cfs. The specific objectives sought in this model study are:

1. Determine through visual observations, photographs, and moving pictures the flow characteristics through the stilling basin and Parshall flume for the discharge range.

2. Determine a means of attenuating the waves generated within the stilling basin before they pass through the Parshall flume.

Model Scale and Criteria

The objective of the model is to develop flows kinematically and dynamically similar to the prototype. Since the hydraulic jump, open channel flow and surface waves are dependent upon gravity predominately, the Froude criterion was chosen to establish the geometric scale.

A model-prototype relationship of 1:10 was determined to be the most feasible from an analysis of scale ratios based upon a model size required for an accurate representation of the flow conditions, available facilities, and economy of cost. Table I contains a list of some of the characteristic model-prototype ratios based upon the selected scale.

TABLE I

MODEL PROTOTYPE SCALE RATIOS

Parameter	Scale Ratio: Function of the length	Scale Ratio: Numerical Ratio	Absolute Magnitude: Prototype	Absolute Magnitude: Model
Length	L_r	1:10	10 ft.	1 ft.
Area	$(L_r)^2$	1:100	100 ft.^{2}	1 ft.^{2}
Velocity	$(L_r)^{1/2}$	1:3.162	10 fps	3.162 fps
Discharge	$(L_r)^{5/2}$	1:316.2	1000 cfs	3.162 cfs

[1] Left and right, as used in this report, refer to the observer's left and right looking downstream

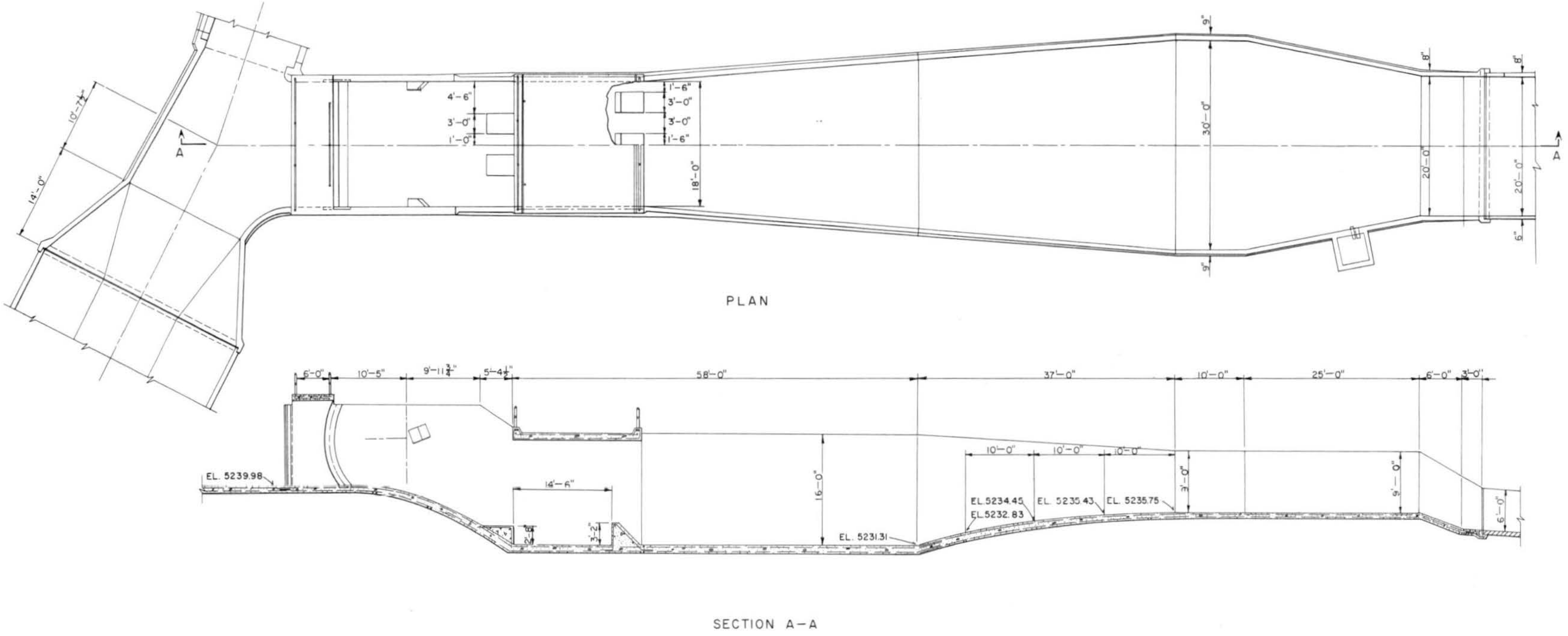

FIG. 1 DETAIL OF STRUCTURE

Model Construction

Dimensions of the model facilities and the arrangement are given in Fig. 2. A photograph of the completed model is shown in Fig. 3. Water for the model was supplied through the 36-inch pipeline from Horsetooth Reservoir. The discharge was controlled by a Rockwell Hypresphere valve. A calibrated Venturi meter in the supply line was used to measure the discharge. Plywood was the main construction material for the model. The transition between the lined canal and the bifurcation was formed in concrete.

Model Tests and Results

The model study was concerned with the prevention or attenuation of surface waves in the Parshall flume. The waves are generated by the hydraulic jump formed in the stilling basin. The short reach between the stilling basin and the Parshall flume is not of a sufficient length for the waves to be attenuated by friction and gravity. Many methods to reduce or eliminate these waves were attempted. The more significant tests are discussed hereinafter.

Dentated End Sill

A dentated end sill 3-feet 2-inches high with 6 dentations was installed at the downstream end of the stilling basin. A sketch of the dentated end sill is shown in Fig. 4. The sill was then moved upstream at 5-feet intervals. No noticeable change in the wave height or frequency was observed with the sill installed at any position.

Baffle Blocks

Five additional baffle blocks of the same size as the existing blocks were installed on the basin floor. The relative location of the additional blocks is shown in Fig. 5. Figure 6 shows the water surface at the Parshall flume for the original conditions and for the conditions with five additional baffle blocks. Some reduction in the wave magnitude could be observed with the added blocks installed. The reduction was not sufficient to constitute a solution to the problem. The extra baffle blocks were removed.

Baffle Block B

The three original baffle blocks were replaced with a modified baffle block (hereafter referred to as block B). Block B was 4-1/2 feet in height with fillets at the top and bottom of the upstream face. The dimensions of block B are given in Fig. 7.

The increased cross section of block B caused the hydraulic jump to move slightly upstream. Block B did not appear to have any significant effect on the reduction of the waves generated by the hydraulic jump. The water surface at the Parshall flume with block B installed is shown in Fig. 8 . Waves are 1.3 to 1.5 feet in height at the staff gage.

Underpass Wave Suppressors

An underpass wave suppressor was designed and installed in the model. The design based upon data developed by the Bureau of Reclamation[2] indicated a suppressor 21 feet in length (hereafter referred to as suppressor A). Suppressor A was placed at several locations within the flume to determine the location at which the suppressor was most effective. Placement of the suppressor too near the upstream end of the stilling basin allowed the high velocity jet to pass through the suppressor and generate waves 0.3 to 0.5 feet in height at a discharge of 700 cfs.

Placement of the suppressor too near the Parshall flume crest was not satisfactory. If the suppressor was submerged sufficiently to be effective for a large range of discharges, the increased head on the suppressor created higher velocity flows through the Parshall flume. Reducing the submergence and thus reducing the head on the suppressor required that the discharge be 850 cfs or greater before the suppressor became effective.

The location at which the suppressor is most effective is shown in Fig. 9. The roof of the underpass is 7 feet above the stilling basin floor. Also shown in Fig. 9 are the suppressor modifications which were tested. The modifications are designated as suppressors C, D, and E.

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[2] Peterka, A. J., Hydraulic Design of Stilling Basins and Energy Dissipators. Engineering Monograph No. 25, U. S. Bureau of Reclamation, revised July 1963, pp 48-56.

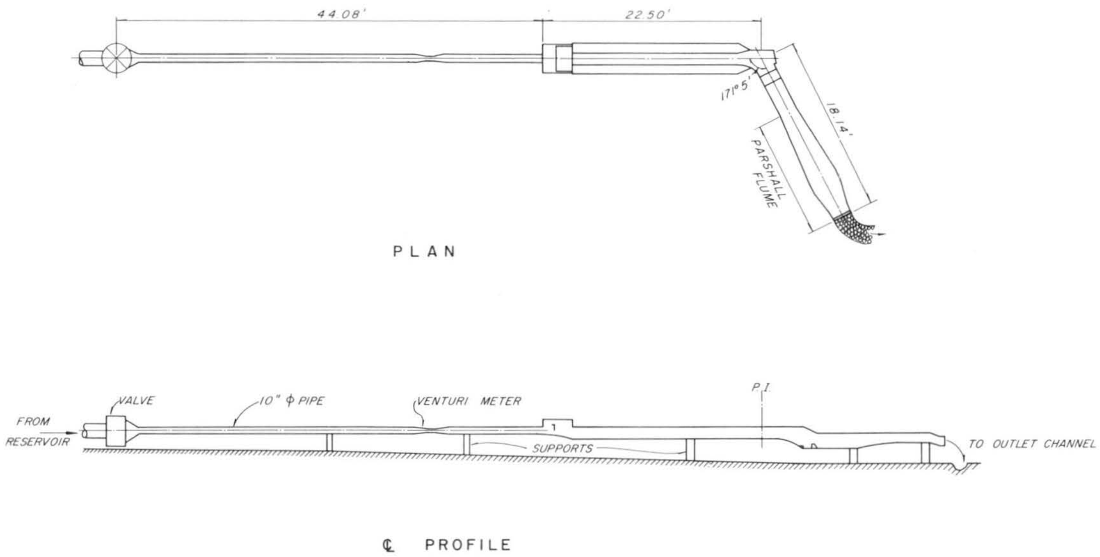

Figure 2. Schematic drawing of model.

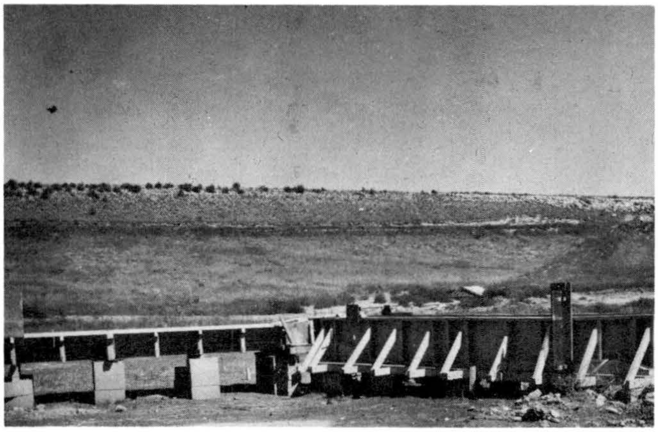

Figure 3. Photograph of the completed model.

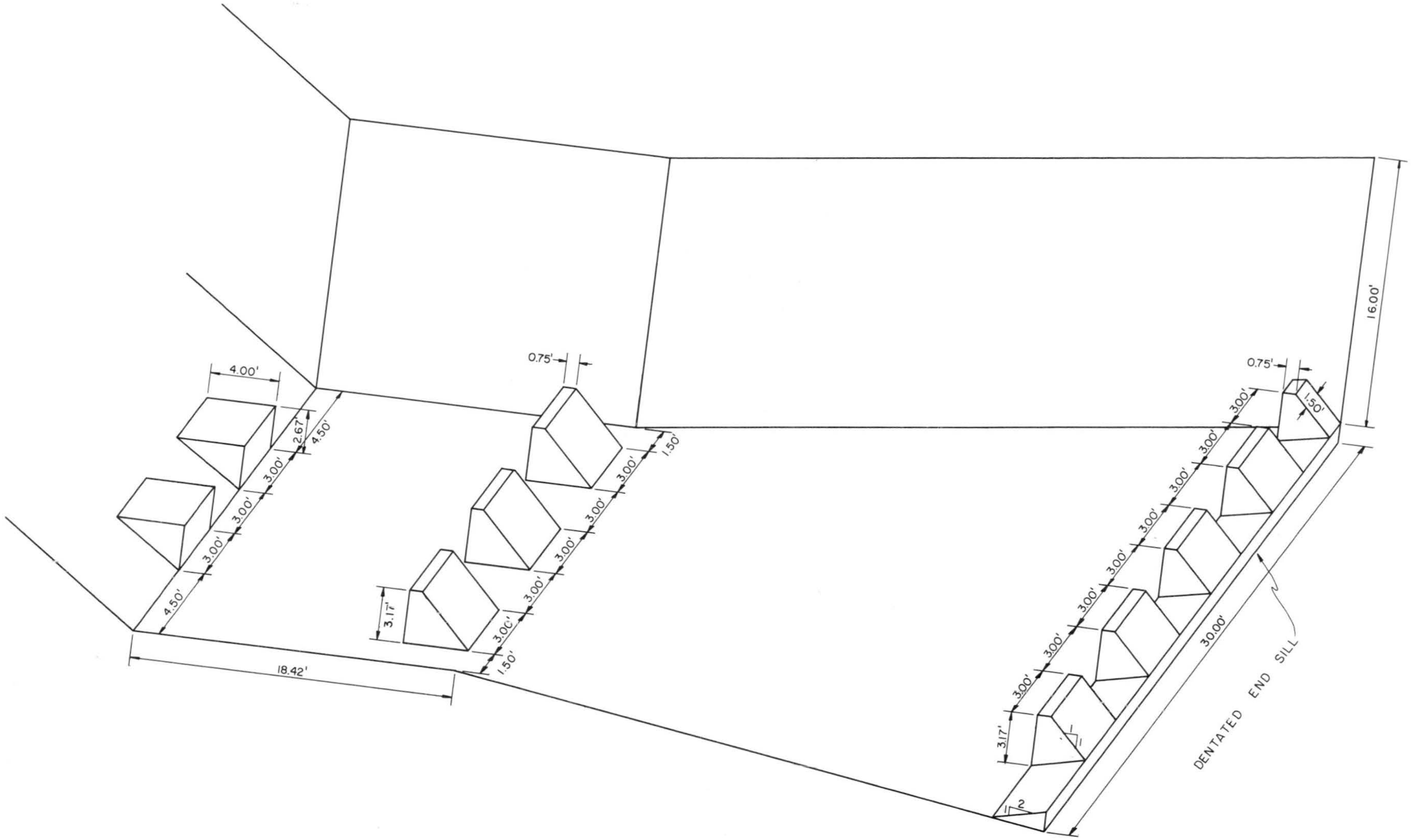

FIG. 4 DENTATED END SILL

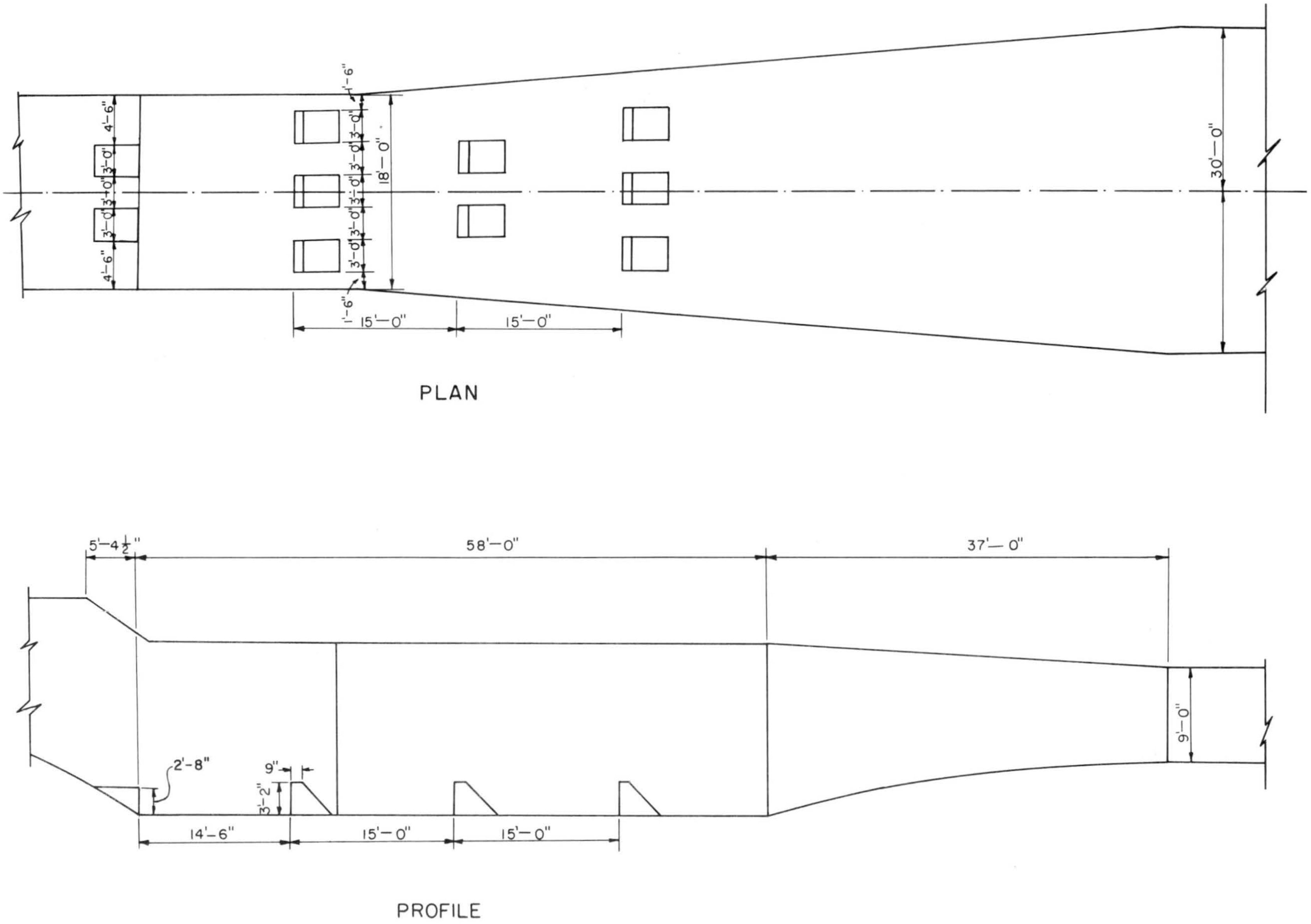

FIG. 5 BAFFLE BLOCK LOCATIONS

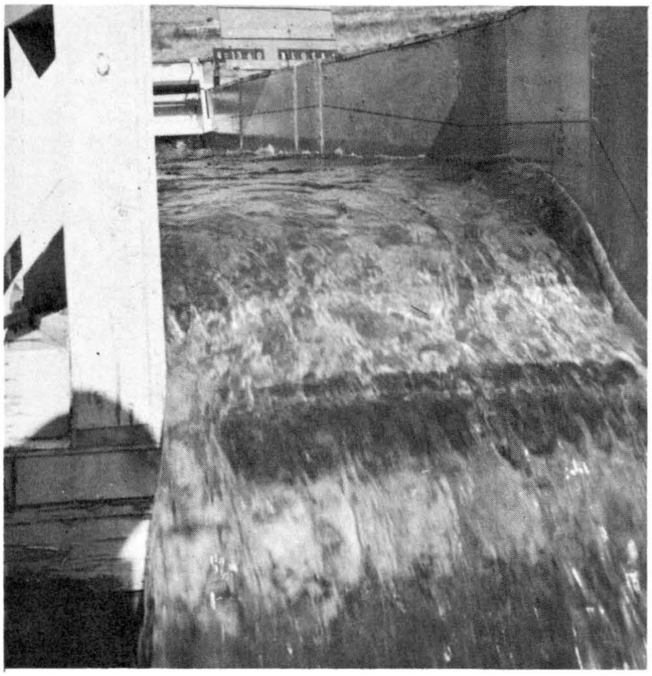

Figure 6(a) Water surface in Parshall flume - no modifications.

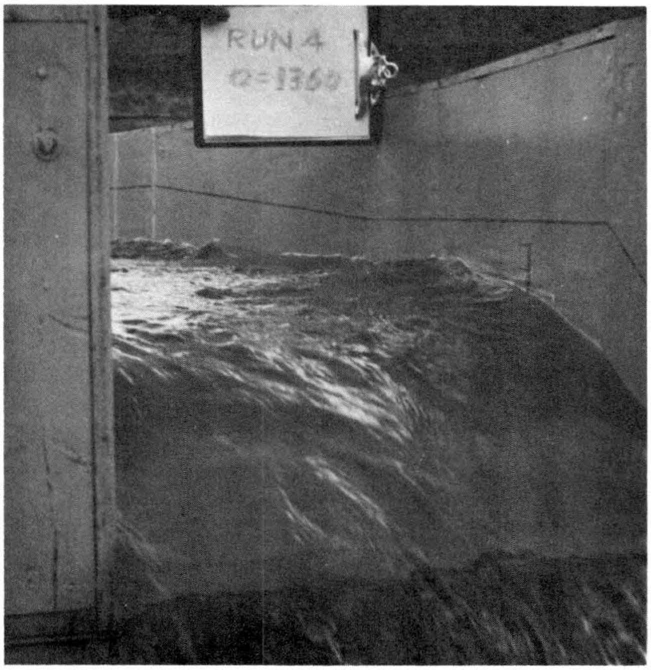

Figure 6(b) Water surface in Parshall flume with five additional baffle blocks installed on basin floor.

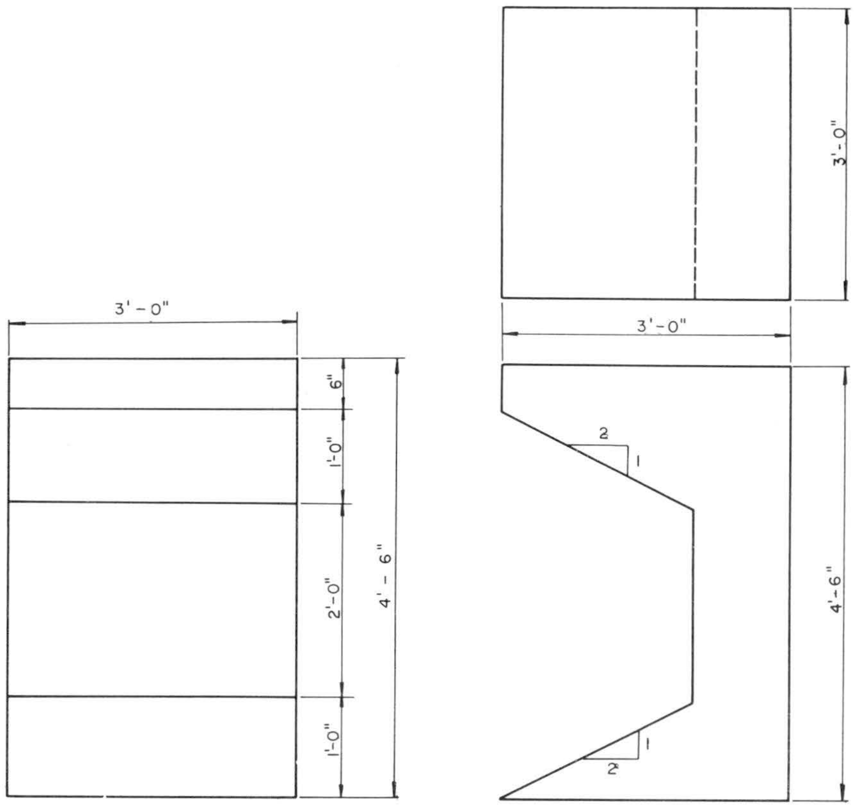

Figure 7. Baffle block B.

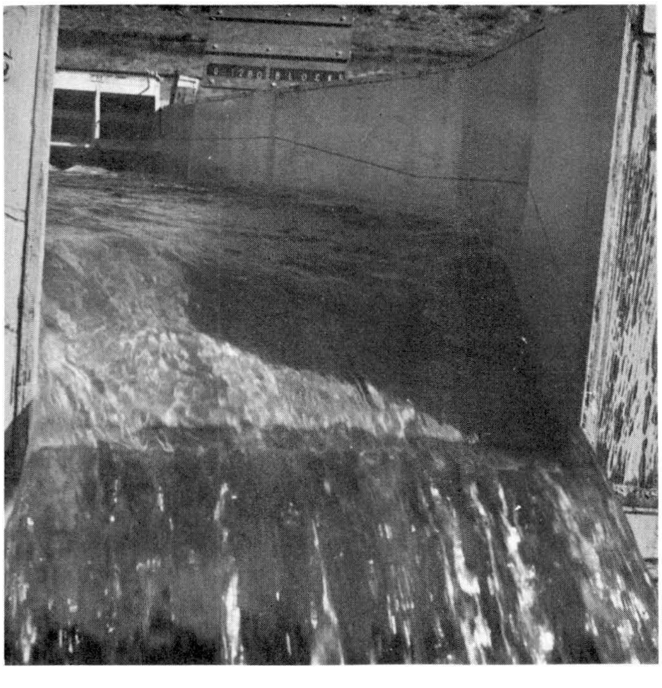

Figure 8. Water surface at the Parshall flume with block B installed. Q = 1280.

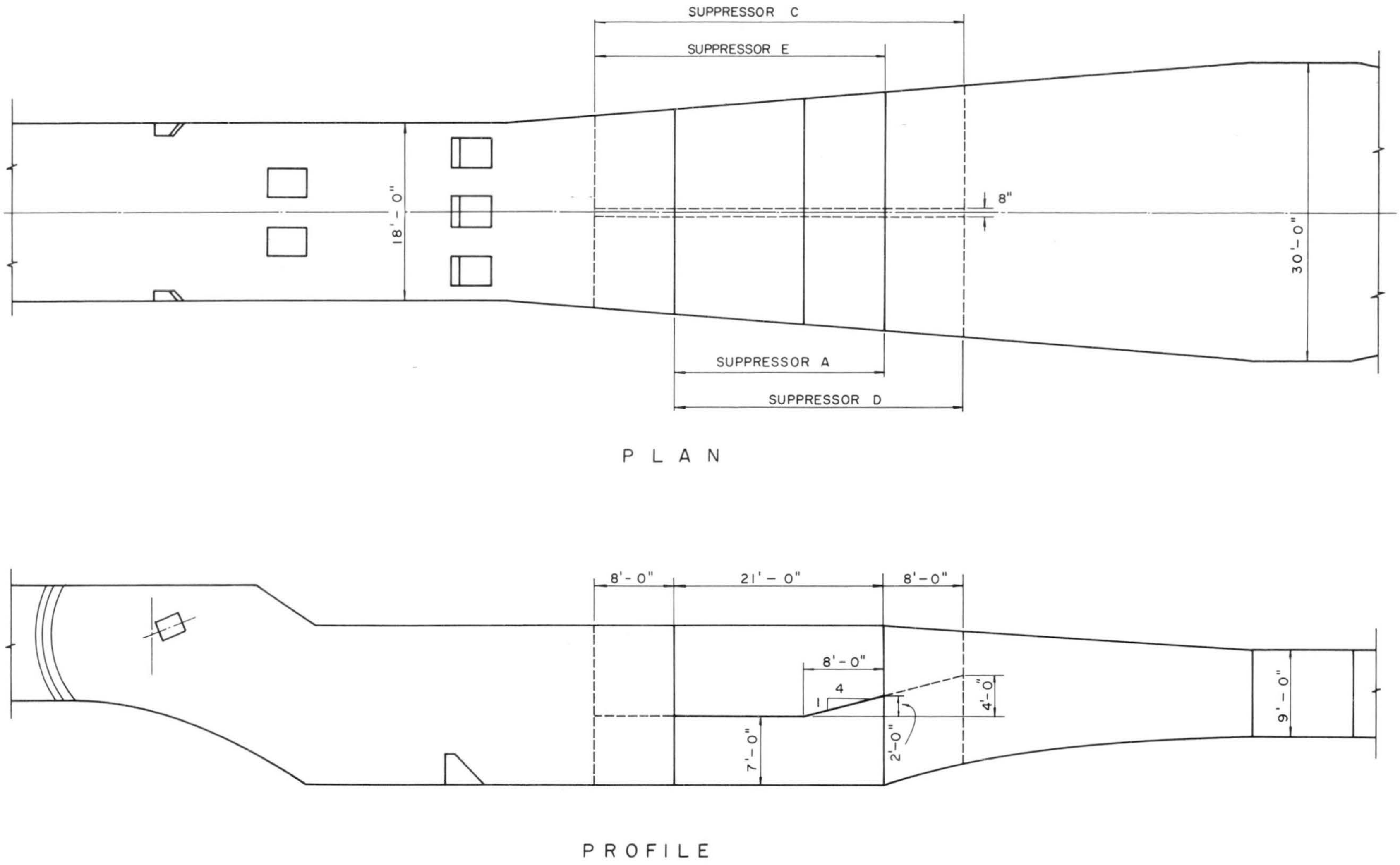

FIG. 9 SUPPRESSOR LOCATIONS AND MODIFICATIONS

Suppressors, A, C, D and E are equally effective in reducing wave heights for discharges up to about 750 cfs. Figure 10 shows the percent of wave height reductions found at different discharges for each suppressor. Figure 10 indicates that the suppressors A, C, D and E are satisfactory in reducing waves over the specified discharge range. The magnitude of the waves without suppression and with suppressors A, C, D and E installed are given in Table II. Figures 11 and 12 show the water surface at the Parshall flume for discharges of 710 cfs and 1120 cfs respectively, without and with suppressor A installed.

Additional tests were made with baffle block B replacing the original baffle blocks and suppressor A installed. No measurable difference in wave heights from those given in Table II for suppressor A were observed during these tests.

TABLE II

Wave Heights at Parshall Flume in Feet-Prototype

Discharge in cfs	710	1120	1360
Wave height before suppression	0.75	1.0	1.5
Wave height with suppressor A	0.06	0.11	0.25
Wave height with suppressor C	0.06	0.08	0.15
Wave height with suppressor D	0.06	0.10	0.20
Wave height with suppressor E	0.06	0.10	0.18

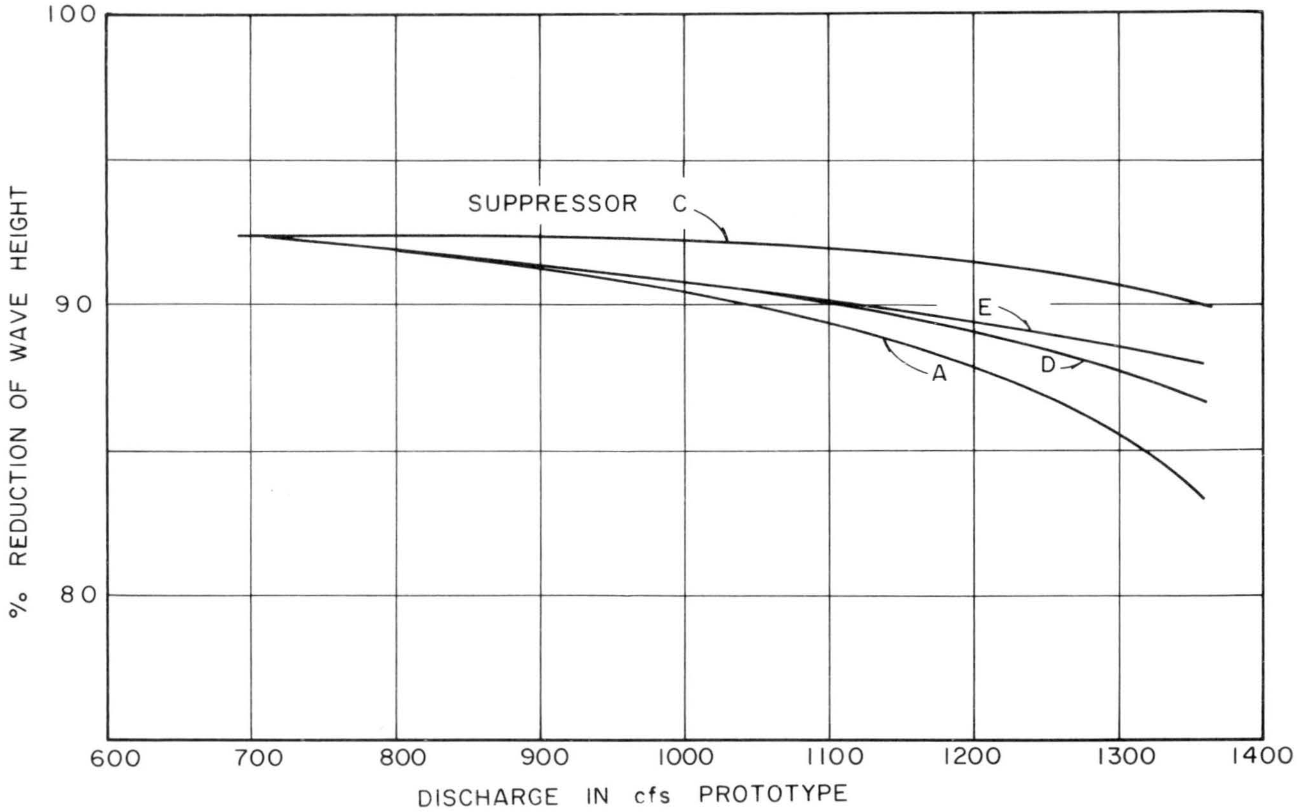

FIG. 10 WAVE REDUCTION AT PARSHALL FLUME

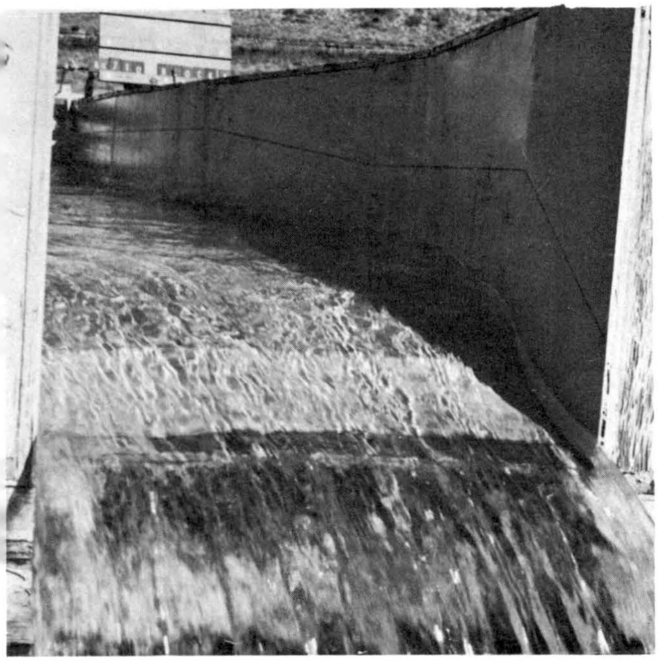

Figure 11(a) Water surface in Parshall flume - Q = 710 cfs.

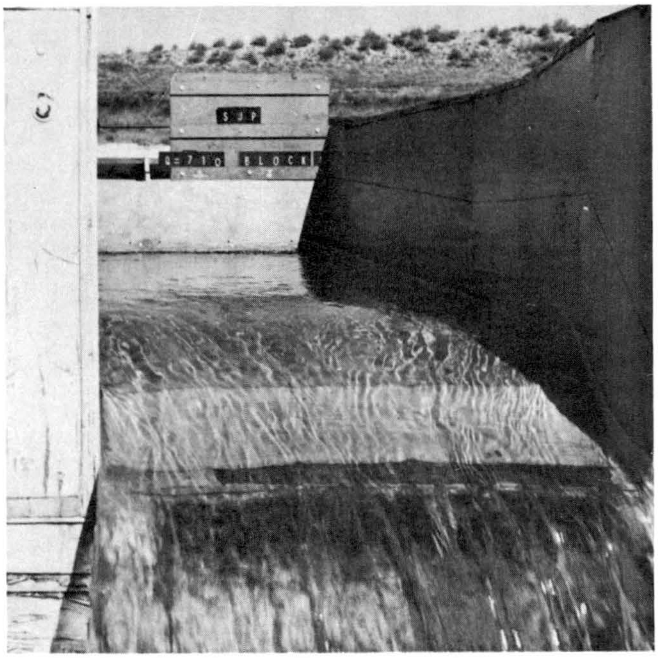

Figure 11(b) Water surface in Parshall flume with suppressor A installed - Q = 710 cfs.

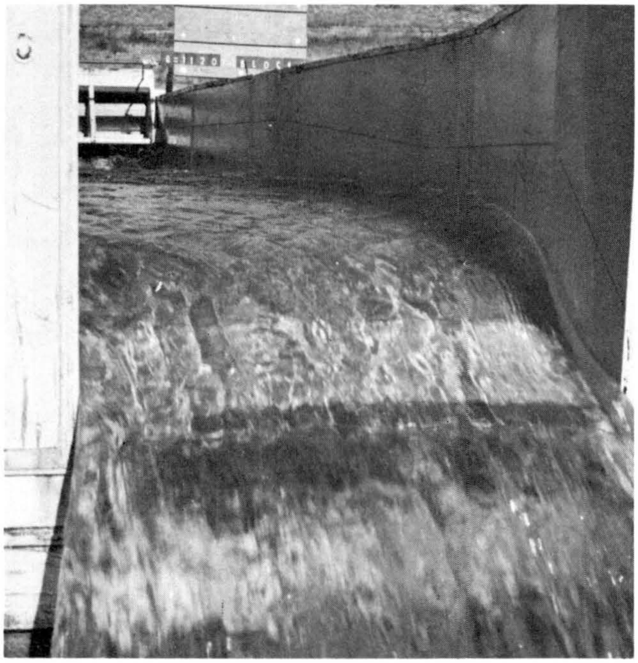

Figure 12(a) Water surface in Parshall flume - Q = 1120 cfs.

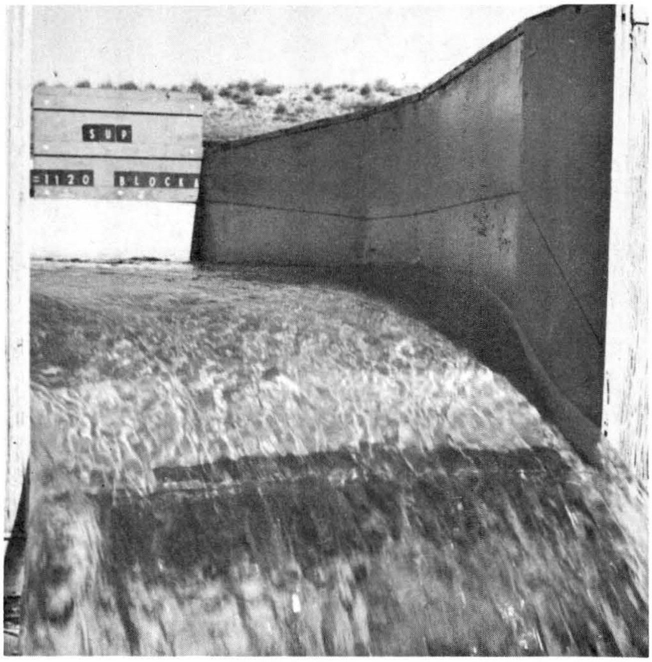

Figure 12(b) Water surface in Parshall flume with suppressor A installed - Q = 1120 cfs.

CONCLUSIONS AND RECOMMENDATIONS

Operation of the stilling basin and Parshall flume without any modifications results in waves up to 1-1/2 feet in height passing over the crest of the flume. Additional baffle blocks or larger baffle blocks do not significantly reduce the wave amplitude.

Flow conditions through the Parshall flume were made satisfactory by the addition of an underpass wave suppressor. Four suppressors were tested; each performed satisfactorily. Wave heights were reduced 83.3% to 90% at a discharge of 1360 cfs. A wave reduction of 83.3% at 1360 cfs was considered satisfactory.

Suppressor A produced the 83.3% reduction in wave height. It is recommended and will effect some economy in the cost of materials and construction over the other suppressors. Observation of the prototype in operation shows considerable air entrainment for discharges above 500 cfs. To provide some relief for air release and resulting surface turbulence at the underpass exit, air vents should be provided in the roof of the underpass suppressor. The air vents should be approximately 4-inches in diameter. The location and orientation of the recommended suppressor and air vents are shown in Fig. 13.

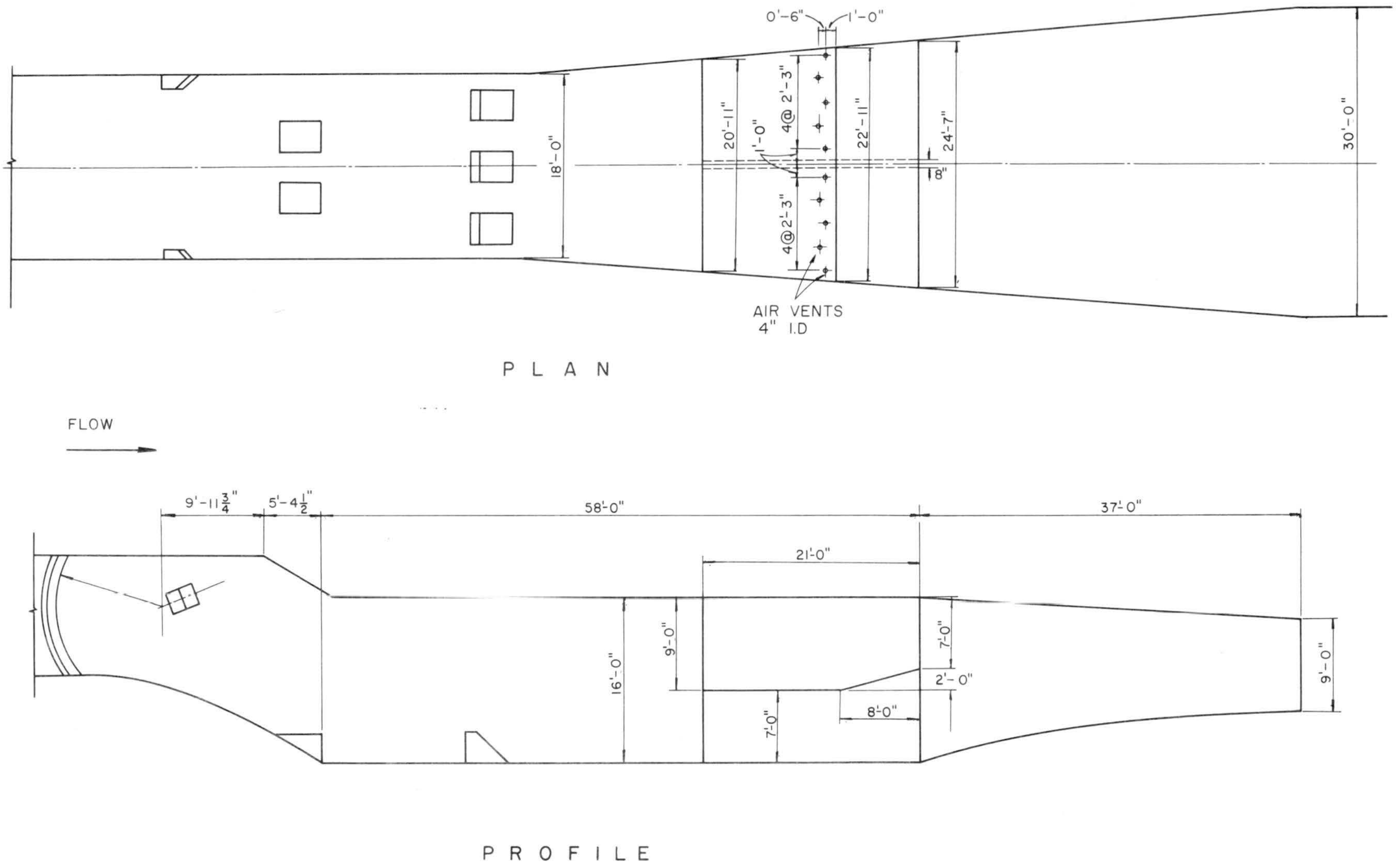

FIG. 13 RECOMMENDED UNDERPASS WAVE SUPPRESSOR