Interim Report

on

MODEL STUDIES FOR BOCONO DAM

conducted for
Tipton and Kalmbach, Inc.,
Denver, Colorado

through
Colorado State University Research Foundation
Fort Collins, Colorado

October, 1957

CER57ARC28

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SYNOPSIS

Investigations made in the two-dimensional and general model indicate that a primary stilling basin with floor El. 188, length 104m, and height of secondary dam 16m performs satisfactorily. The secondary basin has chute blocks (length 7m x height 7m x width 4m) with 5m clear space in between; its length is 33m with a 2m high sill at its downstream end. A rip-rap apron has to be provided downstream of the secondary basin; the probable maximum size of rip-rap necessary is 1.6m. Detailed specifications for size gradation are given in the text.

Preliminary runs made on the general model have confirmed improvement in flow conditions due to the newly designed undercut crest piers. It appears probable that flow conditions over the crest can also be improved by modifying the corbel and the end piers; these modifications are under study. The re-entrant transition between training walls and river banks causes undesirable eddies and fluctuations which may be avoided by a more favorable transition.

An outline of the future testing program is provided. Drawings showing sections through the models and photographs illustrating the performance of the two-dimensional model are also included.

CONTENTS

I. INTRODUCTION

The investigations described in this report were conducted at the Hydraulics Laboratory of Colorado State University, Fort Collins, for Tipton and Kalmbach, Inc., Denver, Colorado

The present Interim Report gives very briefly the results of studies conducted up to the end of September 1957; the information supplied aims primarily at the finalization of design features. It also presents an outline of investigations being undertaken to finalize design details; hence conclusions presented herein are subject to some modification as the model study progresses.

II. MODEL INVESTIGATIONS

These model studies were conducted for checking the hydraulic performance of the proposed dam and appurtenant structures, and for suggesting improvements based on observation of model performance. The flows tested ranged from 1,000m³/s to 10,000m³/s.

Two separate models have been constructed for these investigations:

A. A two-dimensional section of the stilling basin for determining dimensions for a satisfactory hydraulic energy dissipator structure.

B. A general model of the prototype spillway, dam and appurtenant structures, including river bank topography.

A. Two-dimensional Model

Two sets of runs were conducted in this model. The first set was run with basin floor at El.183, length of basin 100m, height of secondary dam 15m, and various combinations of floor blocks located in the primary basin. This arrangement was then replaced by the stilling basin shown in Dwg. No. 1; it had the following characteristics.

Elevation of basin floor	188.0 m
Length of primary basin	110.0 m
Height of secondary dam	15.0 m
Chute blocks	6.0m(H)x6.0m(L)x4.3 m(w)
Length of secondary basin to sill	35.0 m
+ gravel apron on 6:1 slope	42.5 m

This basin was tested with flows ranging from 1,000m³/s to 10,000m³/s. Photographs were made of its performance, and the water surface profile recorded; these results are presented in Appendix I.

<u>The Primary Stilling Basin</u> as described above performed satisfactorily for all discharges. However, in the range of discharges between

3,700m^3/s and 7,500m^3/s small surges were noticed, which also affected the tailwater in the river. These fluctuations are not considered serious, but will be studied further in the general model. It also appeared possible that the length of the primary basin could be reduced by about 5m; this cut was affected in the later construction of the general model and seems to be satisfactory. Pressure measurements made along the spillway to floor reach of the basin indicated that no negative pressures developed on the floor.

For medium discharges vortices were observed in front of the upstream face of the secondary dam, extending from the vicinity of the bottom to the top of the dam. Since they were in a region of low velocity and energy content, they are not considered serious.

The Secondary Stilling Basin functioned satisfactorily as set up; the chute blocks also appeared to be of appropriate size 6m(H)x6m(L) x4.3m(w) . In case the downstream slope of the secondary dam (1 to 1) is changed, it is important that the horizontal top length of the blocks be kept unchanged. The height may be suitably adjusted. The length of the secondary stilling basin (35m) should not be increased if the downstream slope of the secondary dam is made steeper. Such an increase would have detrimental effects by its influence on the functioning of the end sill.

The Rip-rap Apron worked well for a 6:1 slope when tested with gravel corresponding to a mean rip-rap size of 1.25m. The rip-rap stayed in position for all discharges up to about 11,000m^3/s, when individual grains were eroded from the critical zone. The photographs in Appendix II show clearly the region worst affected. Based on these tests, specifications for the rip-rap apron are recommended as below:

Within a distance of 20m from the end-sill use rip-rap of which

> 50% is larger or equal to 1.6m nominal diameter.
> 50% fits into the interstices of the large rip-rap, but not more than 2% should be smaller than 0.2m nominal diameter.

For the reach 40 to 54 m from the end-sill use rip-rap of which

> 50% is larger or equal to 0.7m nominal diameter.
> 50% fits into the interstices of the larger rip-rap, but not more than 2% should be smaller than 0.2m in nominal diameter.

For the intermediate reach (20m to 40m) between the two given above, gradually vary the rip-rap size within the limits specified for the upstream and downstream reaches.

These specifications should insure against rip-rap erosion and piling against the end-sill. As the gravel tested in the model was rounded, while the rip-rap placed in the field is likely to be rough and irregular, it is believed the rip-rap in the field will perform even more satisfactorily due to interlocking.

B. General Model

This model is a complete 1 to 49.2 (1ft=15meters) representation of the spillway dam, stilling basin, crest gates, river outlets, power house, other appurtenant structures, and downstream topography of the river banks. Its characteristics are shown on Dwg. No. 2.

Preliminary runs have been made on this model and the results are given under:

Middle Piers:- The square-backed piers originally proposed caused an undesirable fin of water to stand up on the spillway face. The recently modified pier design with streamlined downstream face considerably reduces the fin height and flow interference. Photographs showing comparative performance are given in Figs. 1-3, Appendix 3.

These features are desirable as less spray is likely to be created in the vicinity of the nearby power house.

End Piers:- In the end bays of the spillway an undesirable depression of the water surface, with a consequent reduction in discharge, has been noticed around the end piers. It is probable thiseffect can be minimized by extending the upstream face of the end piers parallel to the dam for a length of about 3m. This change is under study.

Corbel:- The flow over the crest is likely to be improved if the present 2m corbel on the upstream face is extended downward to approximately equal the head on the crest. This modification is also being tried on the model.

Gate Operation:- To study the effects of unsymmetrical gate operation, the threegates on the right end of the spillway were opened fully and the remaining gates all shut. This unsymmetrical flow condition induced unsatisfactory stilling action in the primary basin and caused a great swirling eddy with differences in water surface elevation approximating 10m to 15m as shown in Fig. 4, Appendix 3. While such operations are not normally expected this study serves to illustrate the possibilities of faulty operation of spillway gates.

Transition to River Banks:- At the transition between the stilling basin and river banks, objectionable surges and swirls have been observed. Perhaps, these undesirable effects can be reduced by eliminating the re-entrant conditions at the banks immediately downstream of the basin. This aspect needs further study.

The obove observations have been based on preliminary runs made on the general model. A testing program is underway, of which salient features are outlined below.

III. FUTURE TESTING PROGRAM

The principal items remaining on the testing program are outlined below:

1. Calibration of the spillway for different reservoir elevations.

2. Preparation of gate operating schedule for various releases.

3.* Study the interrelationship of river outlets and eyebrows on downstream face of dam.

4. Study the effect of stilling basin operation on pressure variations in draft tubes.

5. Study and record photographically the flow profile past the piers, over the spillway, and through the stilling basin.

6. Ascertaining the appropriate dimensions of spillway crest corbel and upstream section of end piers for improved flow conditions over the crest.

7. Motion pictures will be taken; specifications to be provided by Tipton and Kalmbach, Inc. Also, photographs will be made recording the performance of all important features of the model, and illustrating testing equipment and procedures.

It is anticipated that all testing will be completed by 30 November, 1957.

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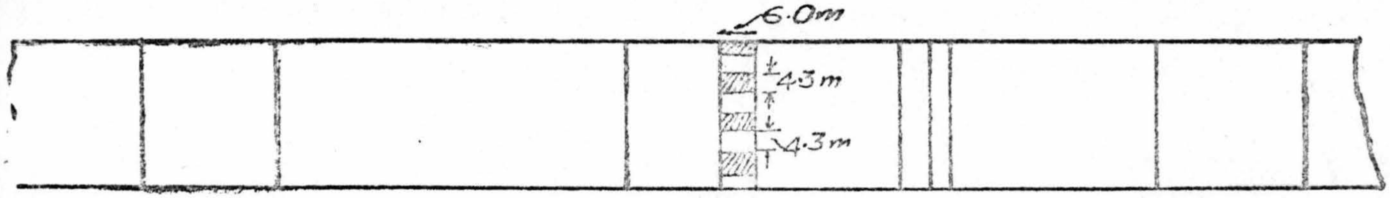
* Items marked with asterisk may necessitate construction of larger scale models for accurate pressure and flow investigations.

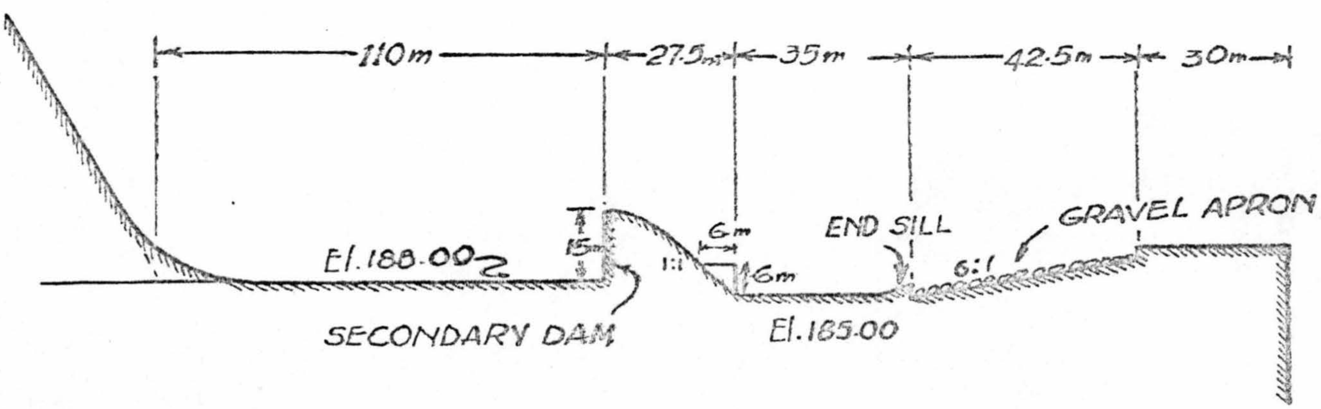
IV. CONCLUDING REMARKS

The tests on the two-dimensional model have been concluded. The primary purpose of these tests was to determine dimensions of the stilling basins. It is believed that the proximity of the glass walls in such models of narrow width (2ft) magnifies disturbances in the flow, and this factor should be kept in mind while interpreting the drawings and photographs of water surface profile. Furthermore, more air is invariably entrained in the prototype than in the model.

The general model gives a more realistic reproduction of actual overall performance. Results of these tests will be communicated as the tests progress. Tests completed to date indicate the basic structure is hydraulically sound.



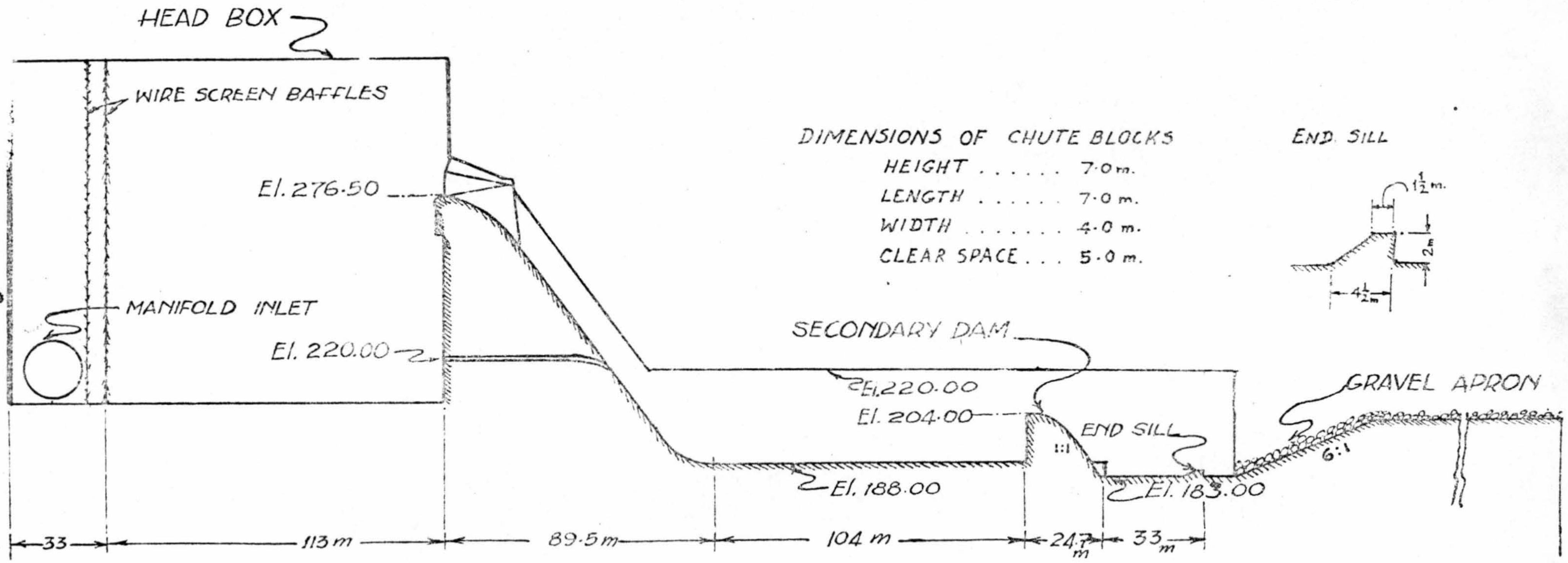
PLAN



SECTION

Scale: 1 inch = 48.0 metres.

BOCONO DAM MODEL STUDIES	
Proj. 752	CSU HYD LAB
for R.J. TIPTON, ASSOCIATED ENGRS. INC	
TWO DIMENSIONAL MODEL	
Drawn by PKM	Appvd.

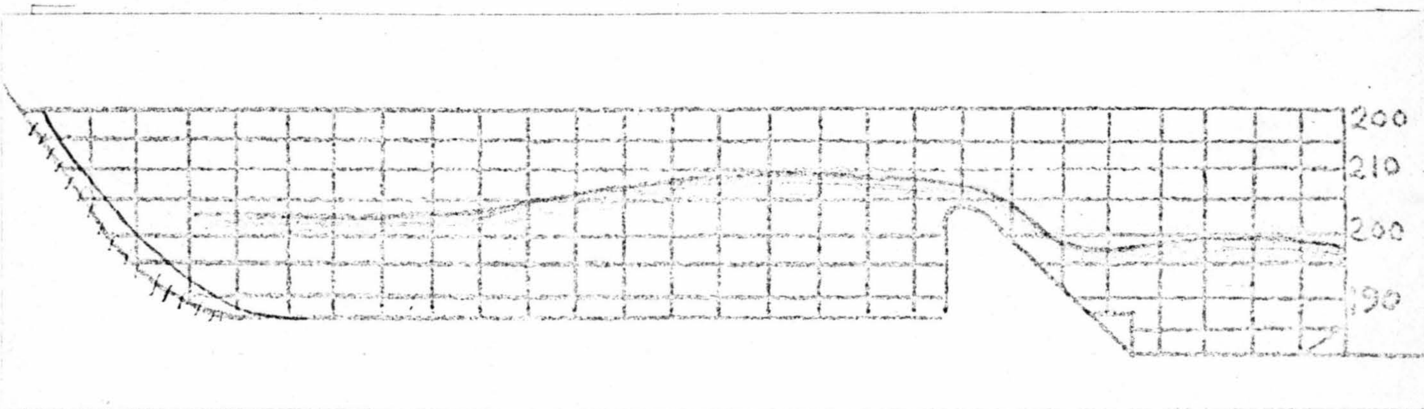


SCALE: 1 inch = 50.0 metres

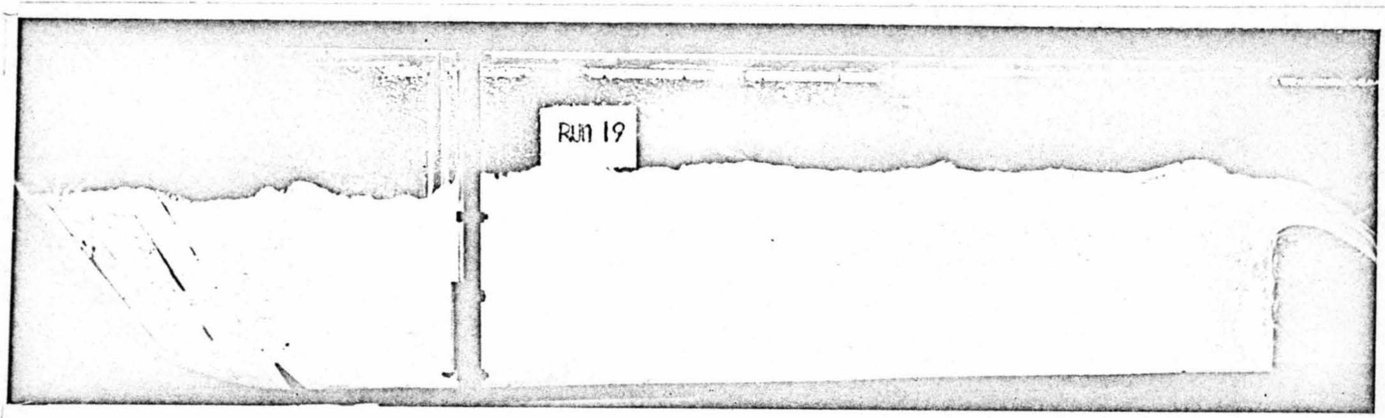
BOCONO DAM MODEL STUDIES	
Proj. 752	C.S.U. HYD. LAB
for R.J. TIPTON, ASSOCIATED ENGRS. INC	
SECTION THRU GEN. MODEL	
Drawn by. PKM	Appvd.
Date. Oct. 3, 1957	No. 2.

APPENDIX I

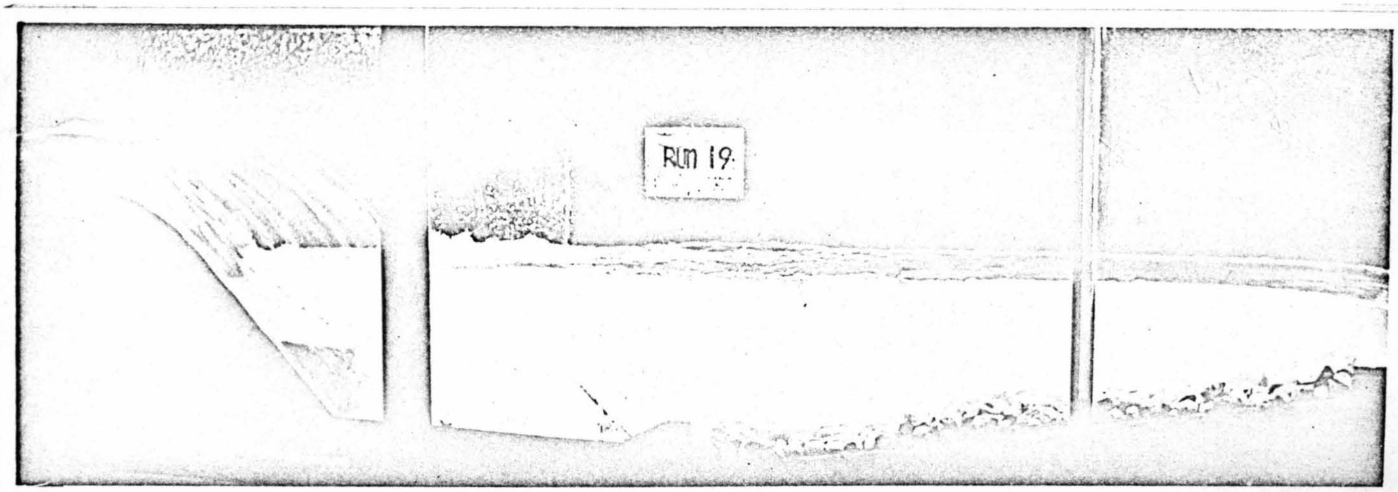
Discharge: $Q = 3,200\ m^3/s$



Water Surface Profile

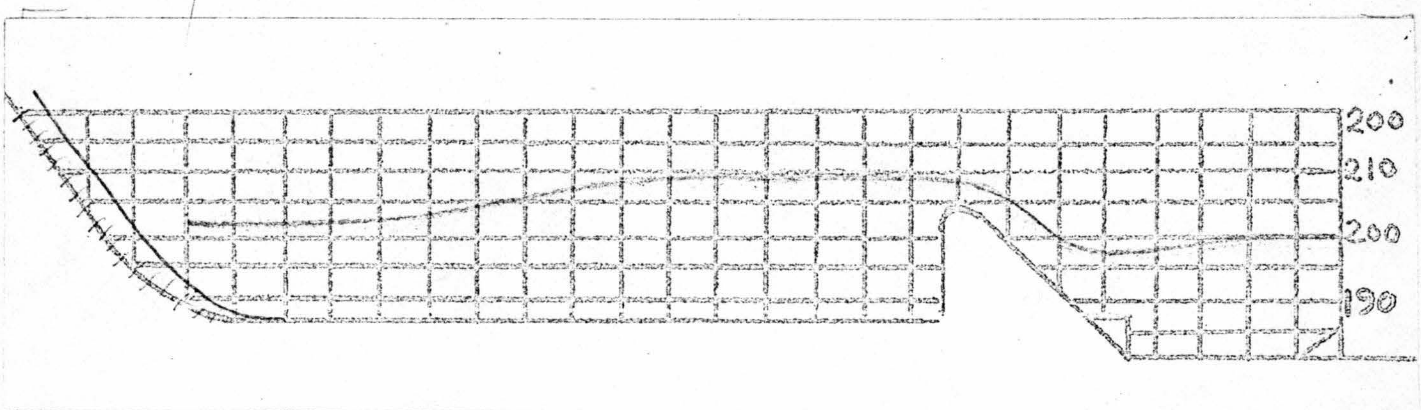


Primary Basin

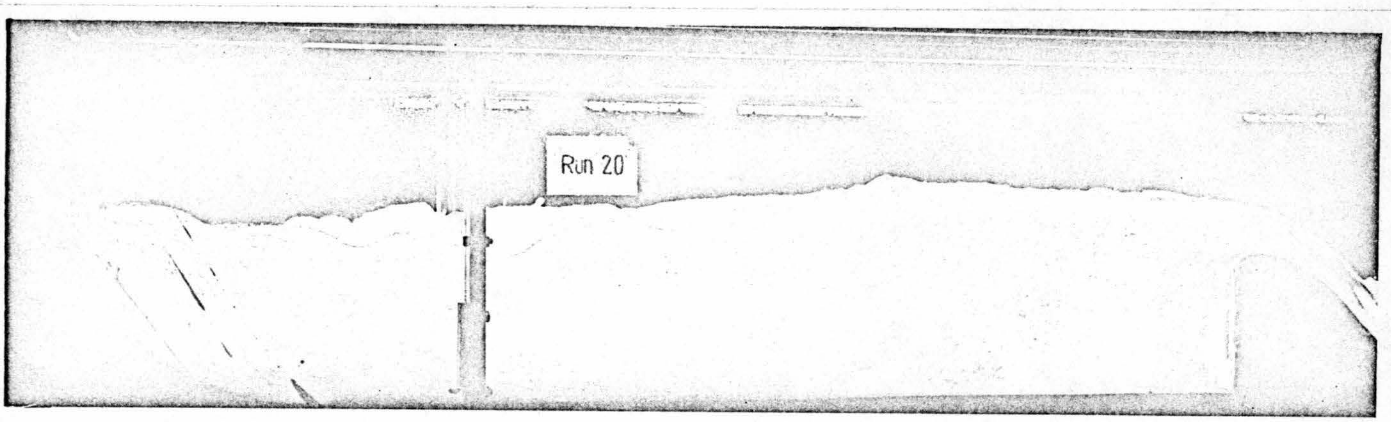


Secondary Basin

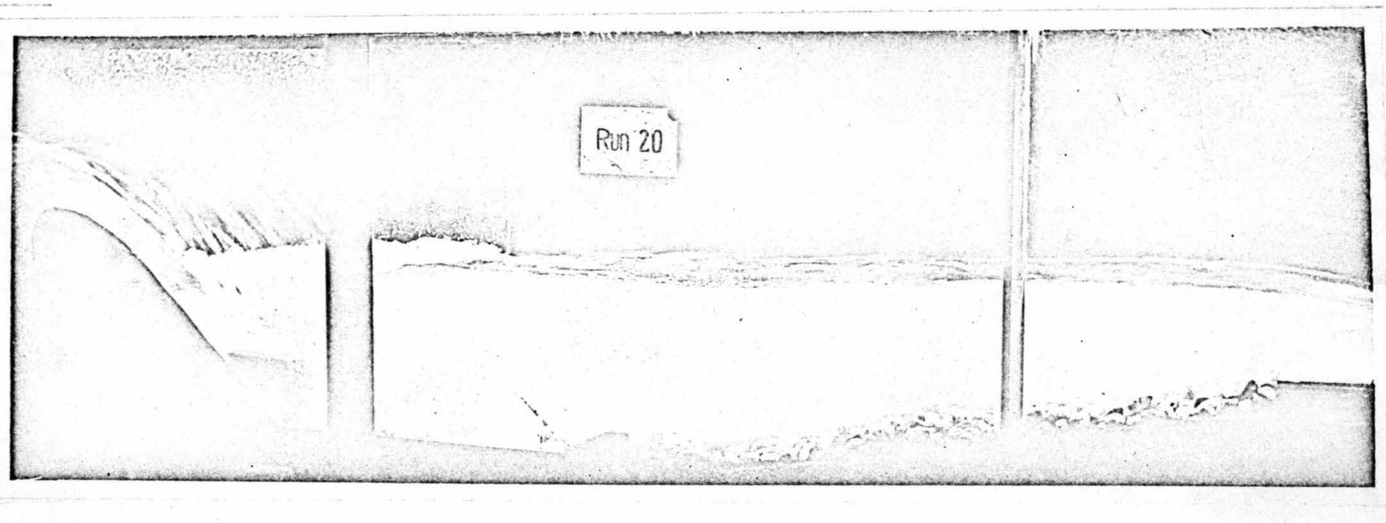
Discharge: $Q = 4,100\ m^3/s$



Water Surface Profile

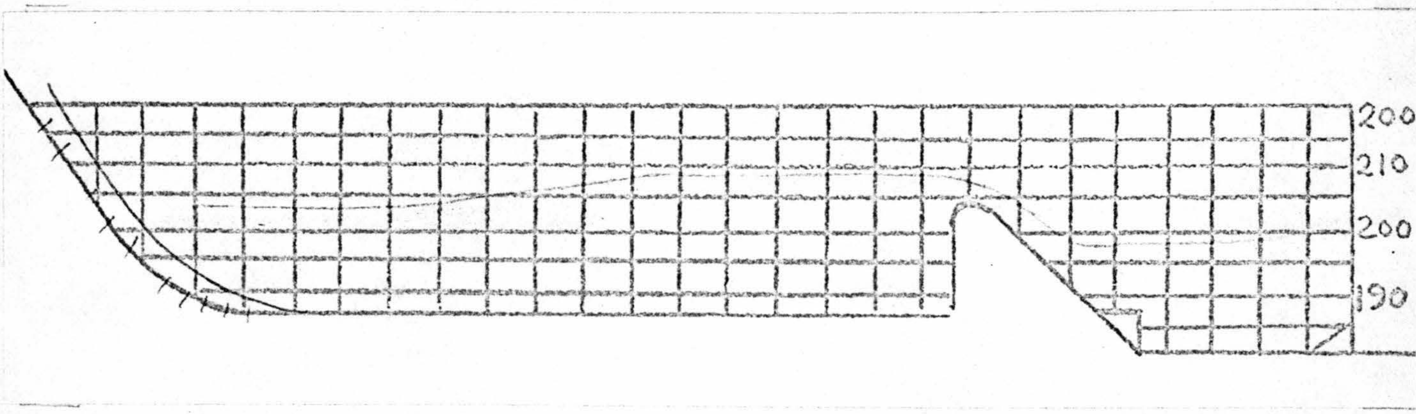


Primary Basin

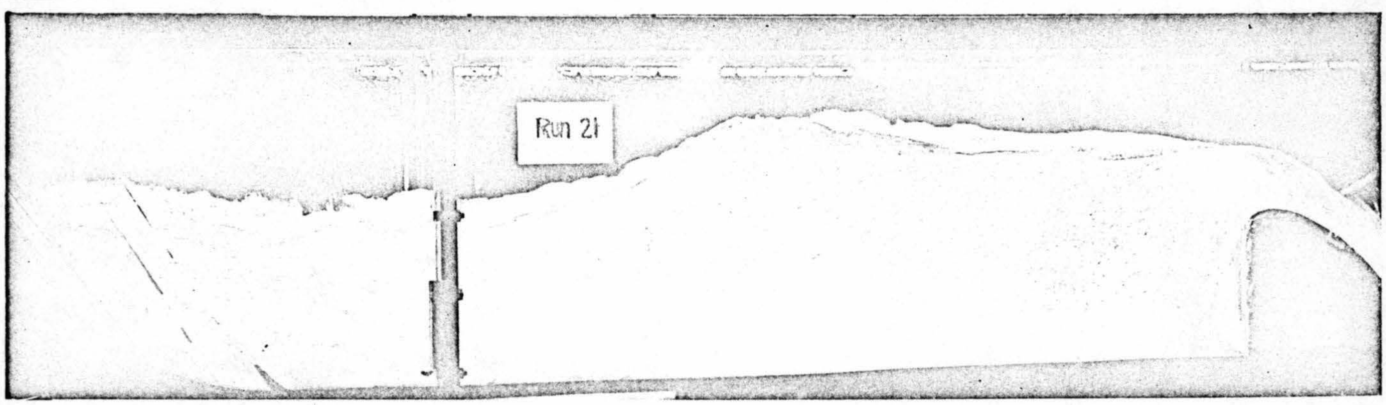


Secondary Basin

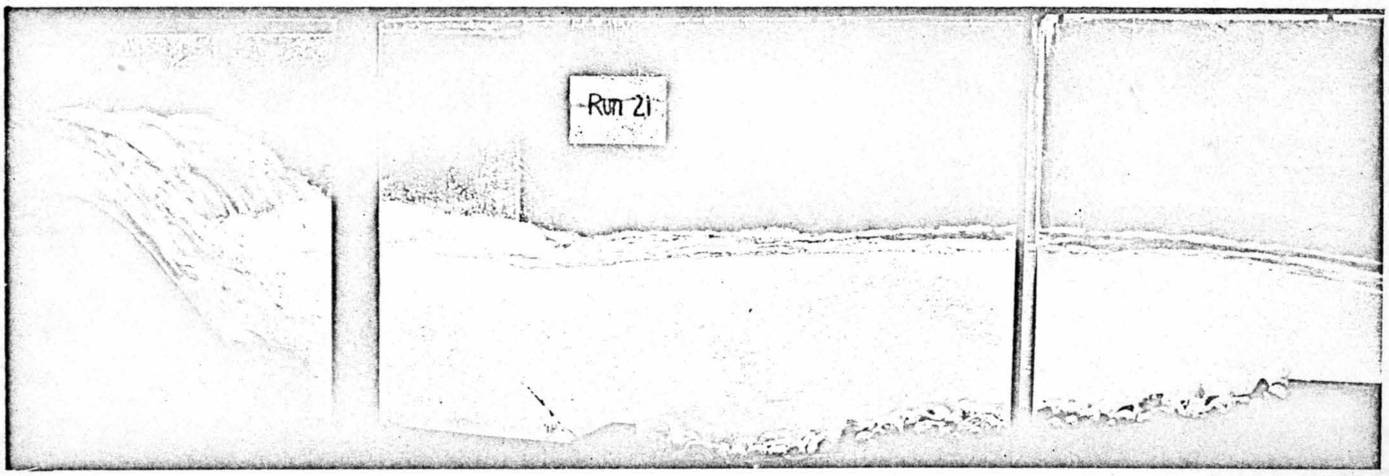
Discharge: $Q = 5{,}000\ m^3/s$



Water Surface Profile

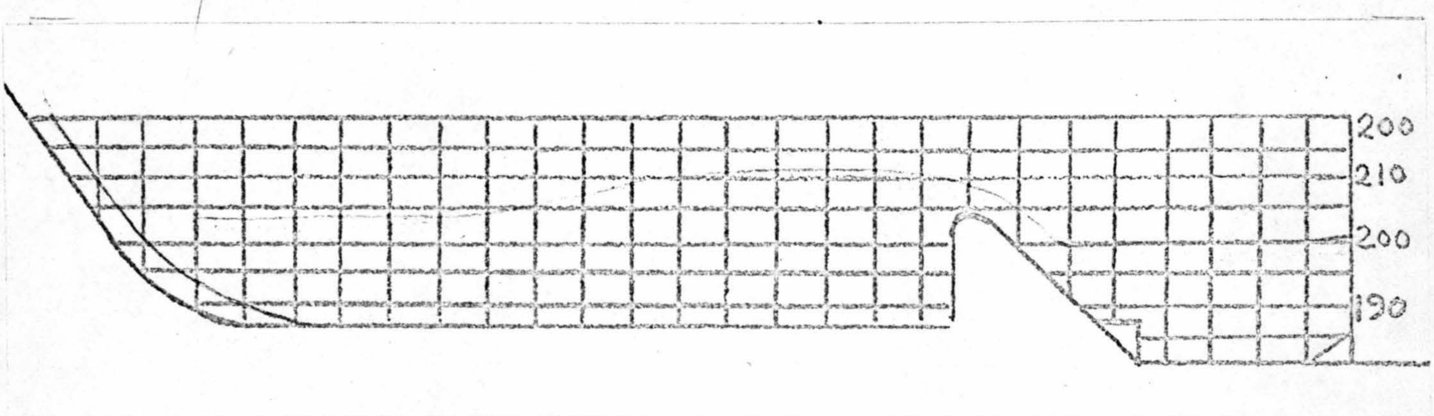


Primary Basin

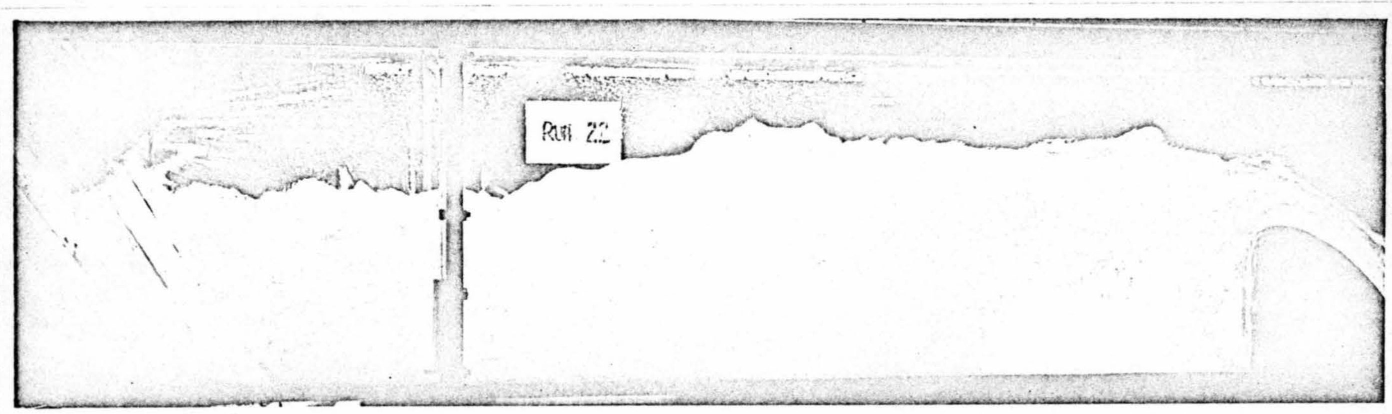


Secondary Basin

Discharge: Q= 6,100 m³/s



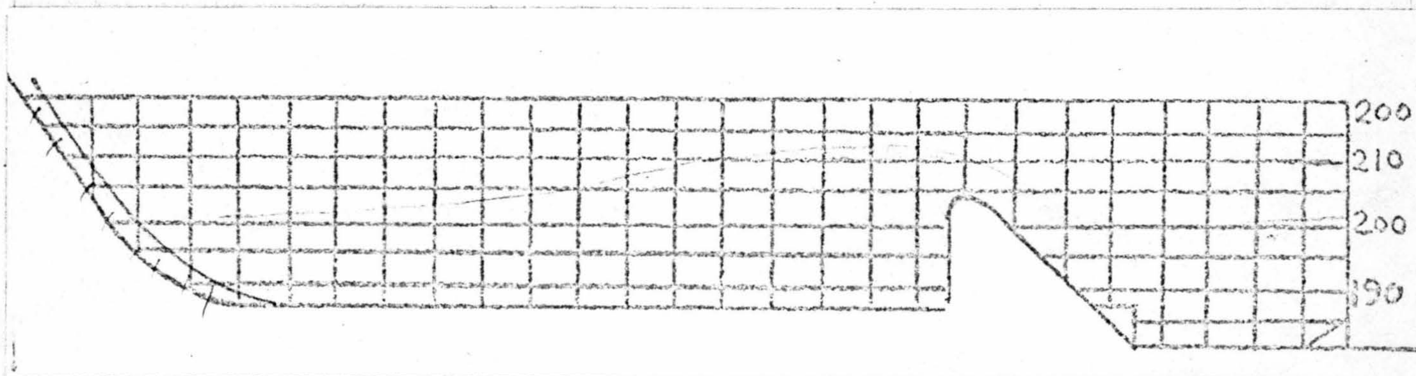
Water Surface Profile



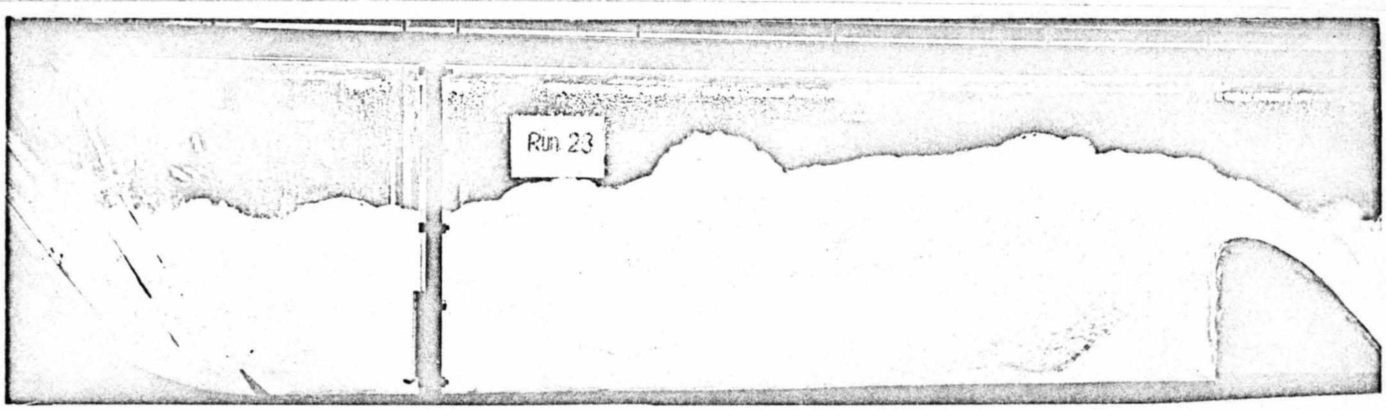
Primary Basin

Secondary Basin

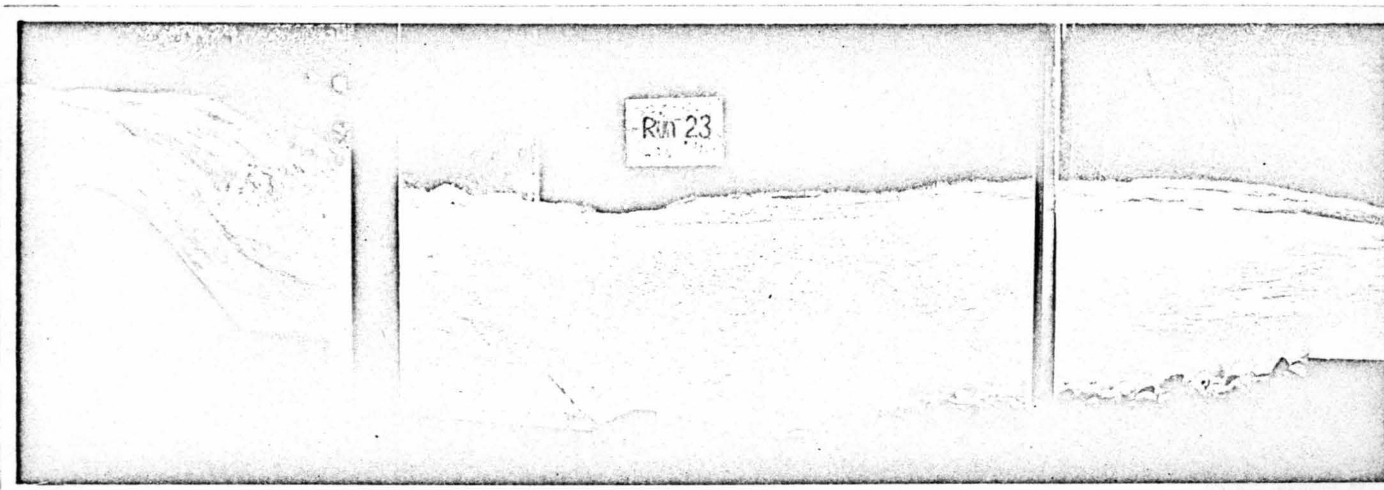
Discharge: $Q = 7,500\ m^3/s$



Water Surface Profile

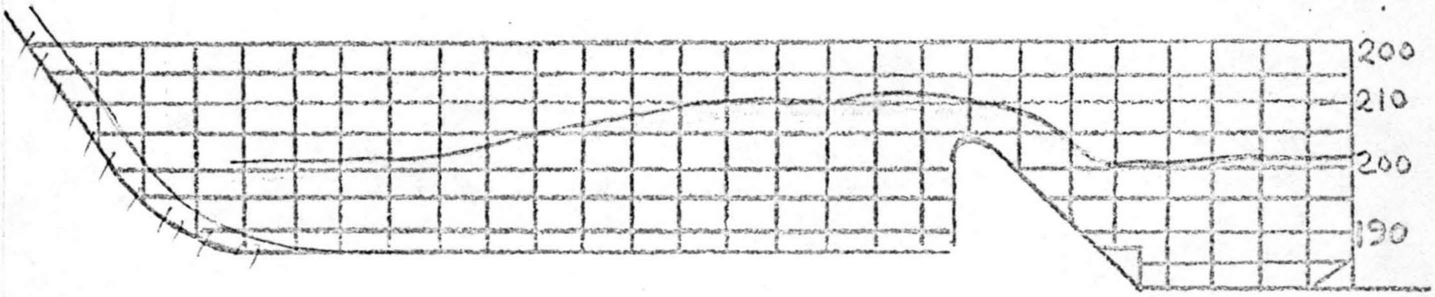


Primary Basin

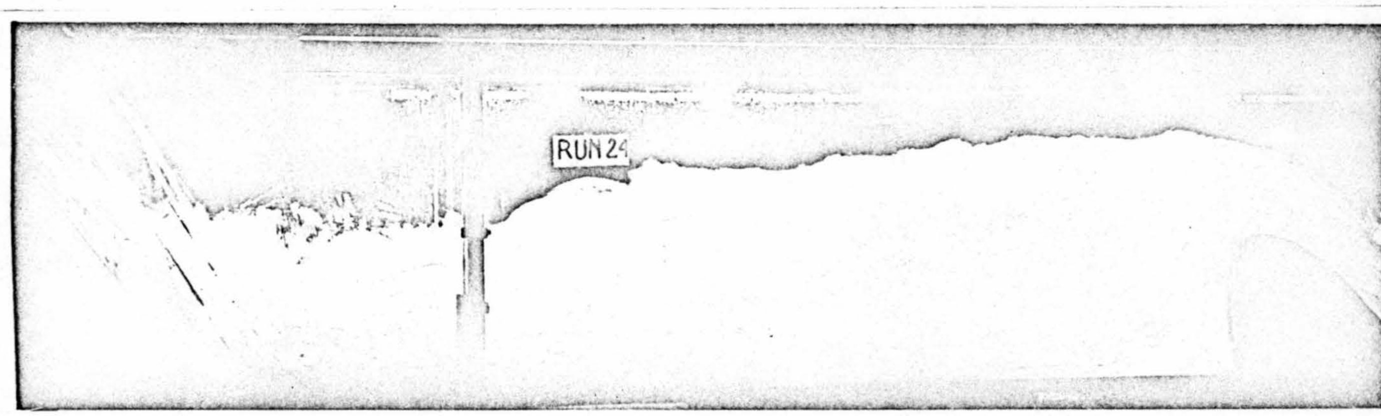


Secondary Basin

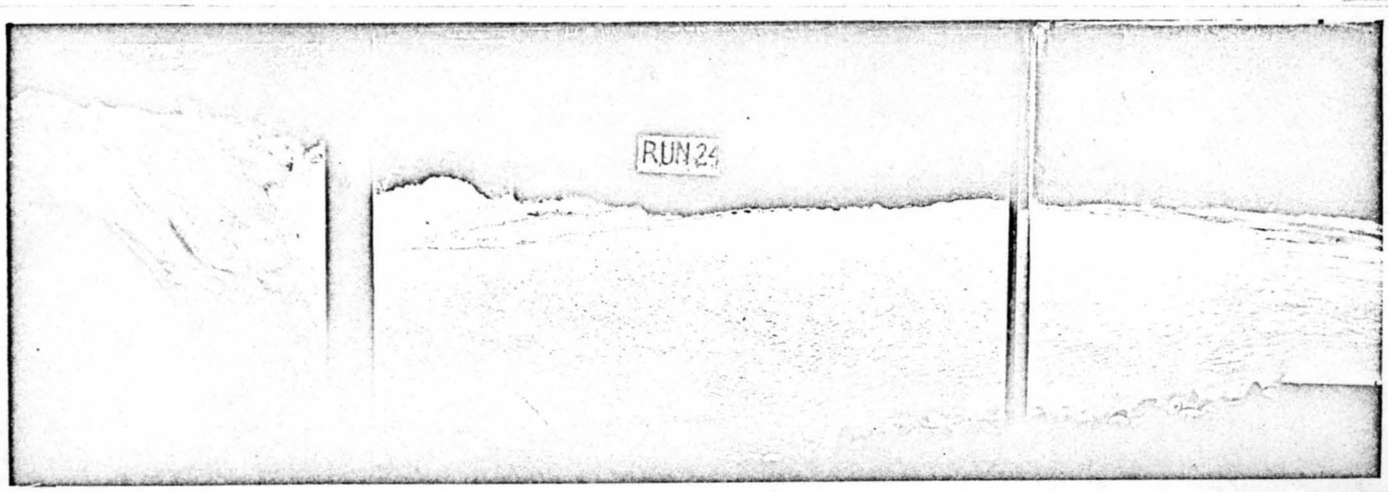
Discharge: Q = 9,000 m^3/s



Water Surface Profile

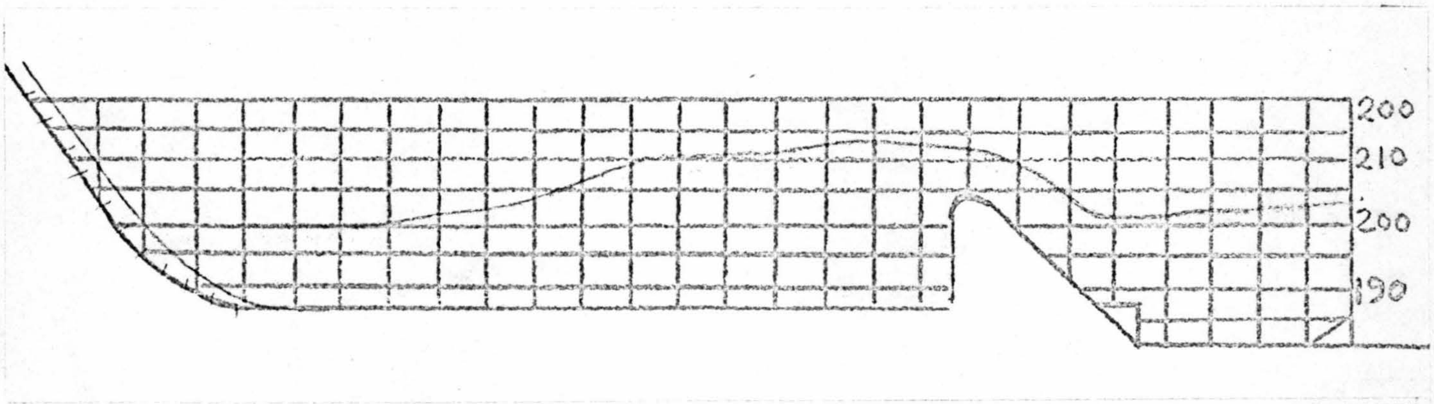


Primary Basin

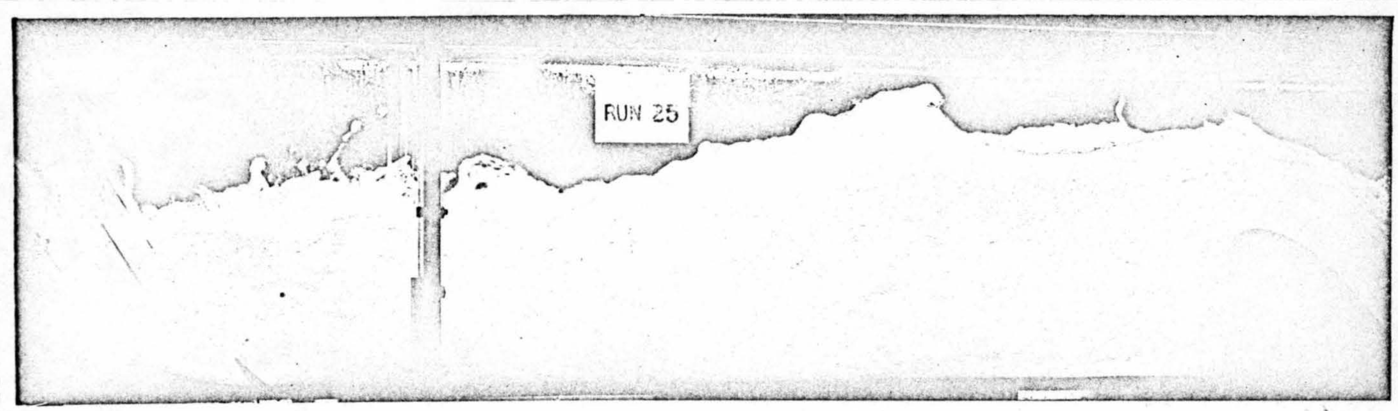


Secondary Basin

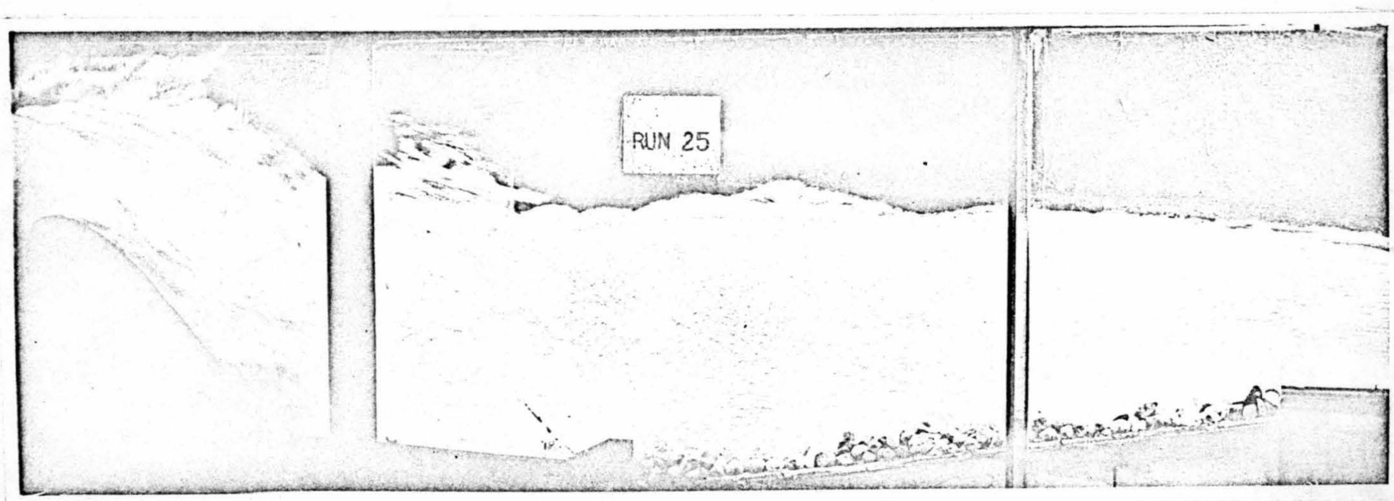
Discharges: Q = 10,000 m^3/s



Water Surface Profile



Primary Basin



Secondary Basin

APPENDIX II

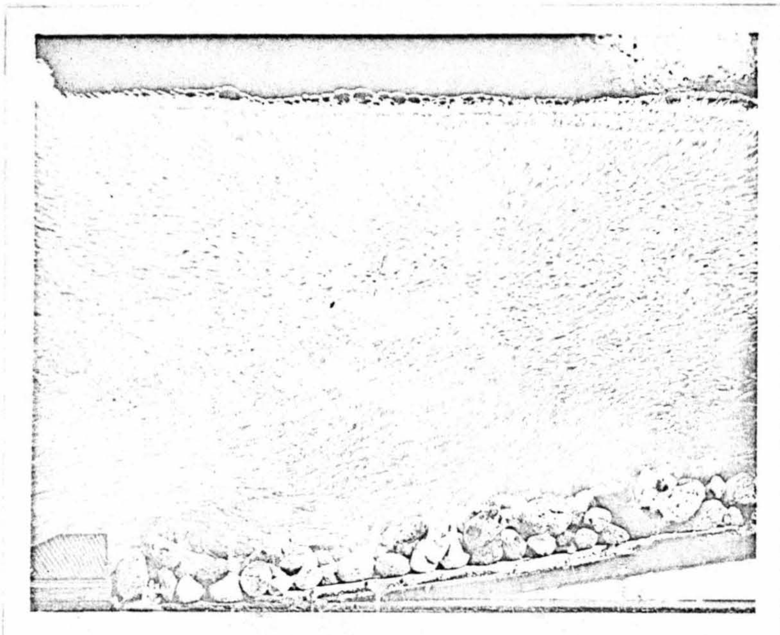


Fig. 1

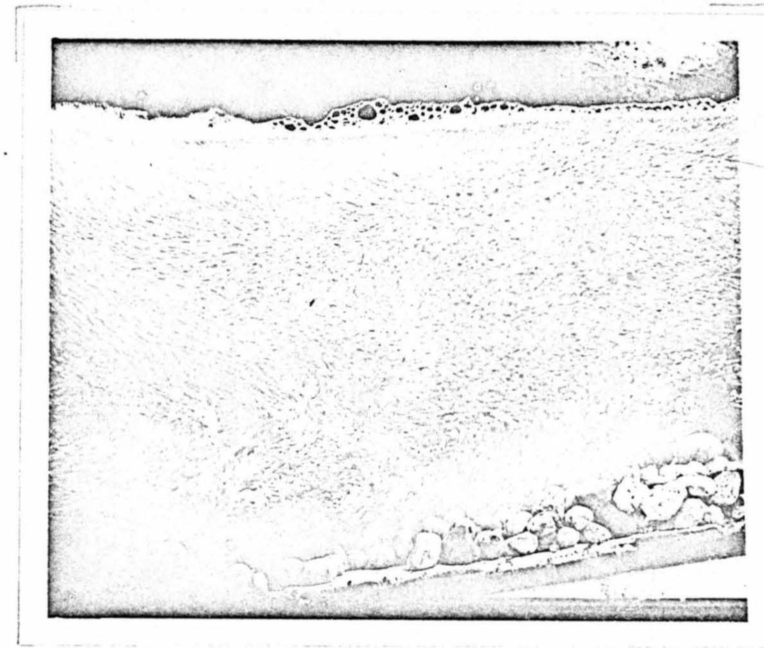


Fig. 2

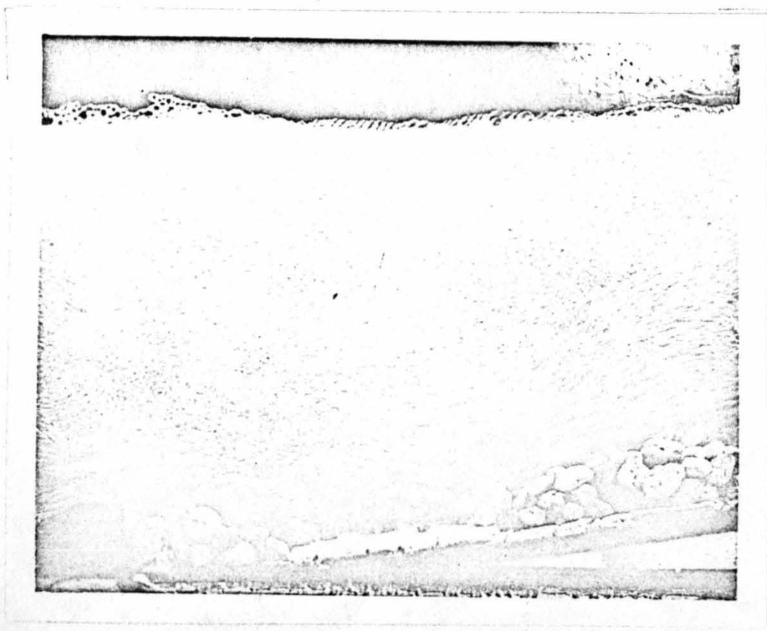


Fig. 3

LIKELY LOCATION OF MAXIMUM EROSION

$Q > 10,000\ m^3/s$

APPENDIX III

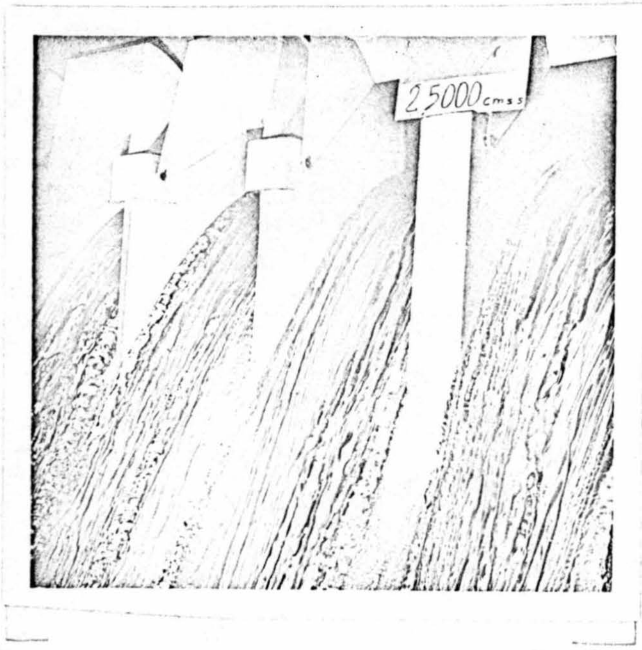


Fig. 1

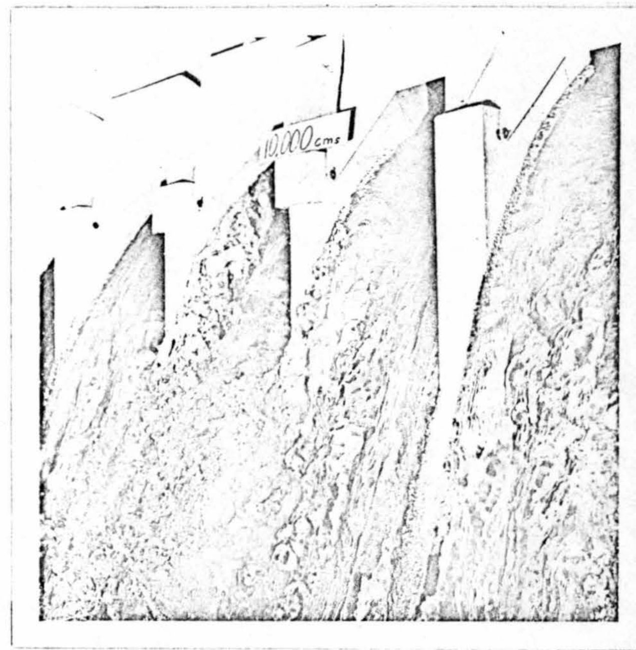


Fig. 2

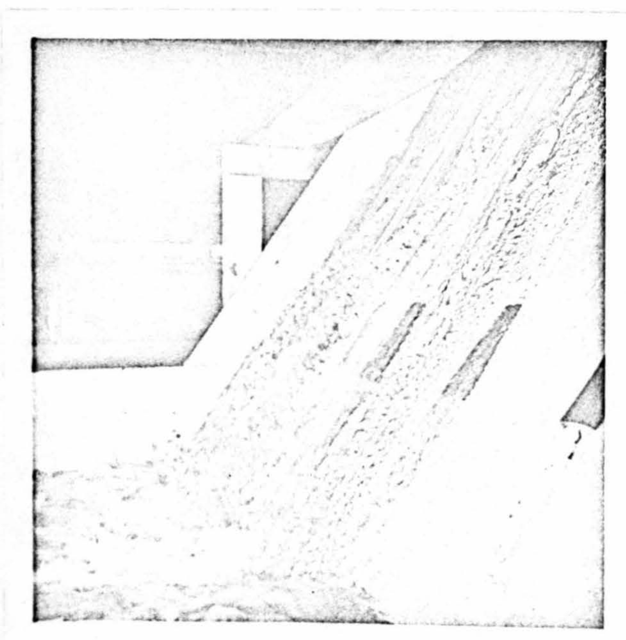


Fig. 3

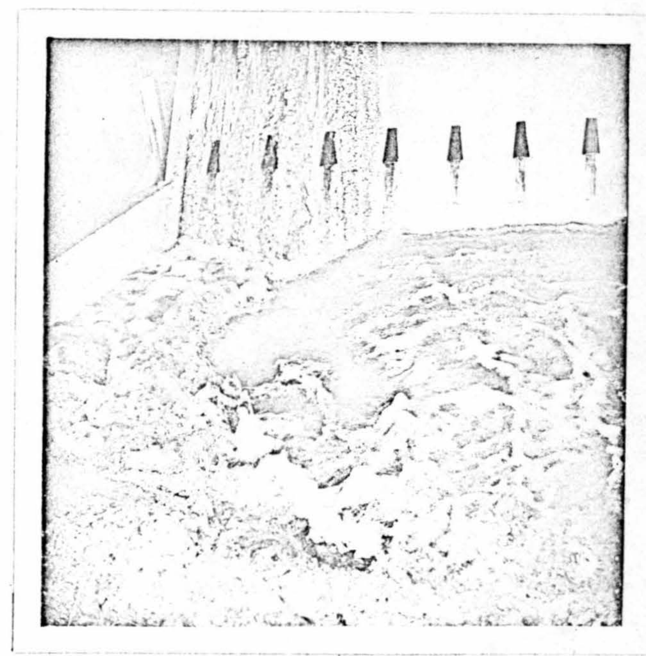


Fig. 4