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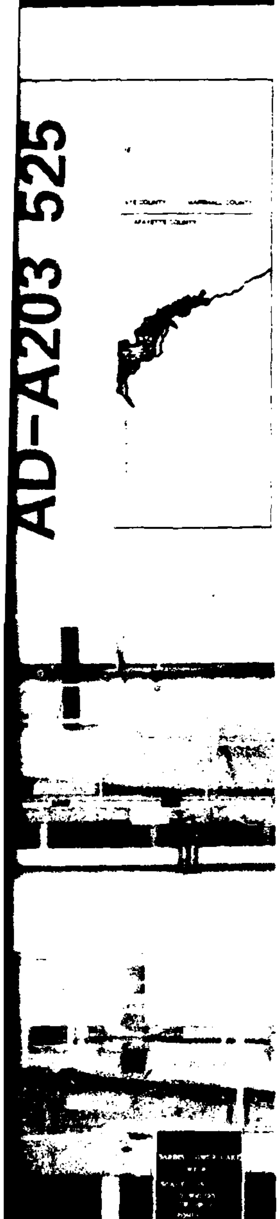

HYDRAULICS
LABORATORY

MISCELLANEOUS PAPER HL-88-11

SARDIS LOWER LAKE ROCK WEIR

Hydraulic Model Investigation

by

Deborah R. Cooper

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

A 1:15-scale hydraulic model simulated a 75-ft-wide center section of the rock weir including 105 ft of the approach and 225 ft of the exit channel. Various gradations of riprap were tested to determine riprap protection requirements on the upstream and downstream slopes, the side slopes, and in the exit channel. Tests indicated that a 36-in.-thick blanket of riprap remained stable through the full range of operation. Observations also indicated that despite the long flat downstream slope (1V on 10H), there was no likelihood of a hydraulic roller forming downstream of the weir.

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PREFACE

The model investigation reported herein was authorized by the US Army Engineer District, Vicksburg (LMK), on 3 September 1987. The studies were conducted in the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES) during the period September to November 1987 under the direction of Messrs. F. A. Herrmann, Jr., Chief, HL, and G. A. Pickering, Chief of the Hydraulic Structures Division. The tests were conducted by Mrs. D. R. Cooper, who also prepared this paper, and Mr. R. Bryant, Jr., both of the Spillways and Channels Branch, under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch.

During the course of the investigation, Messrs. J. Sanders and S. Vowinkel, LMK, visited WES to discuss test results and correlate the results with design studies.

COL Dwayne G. Lee, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
inches	25.4	millimetres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms

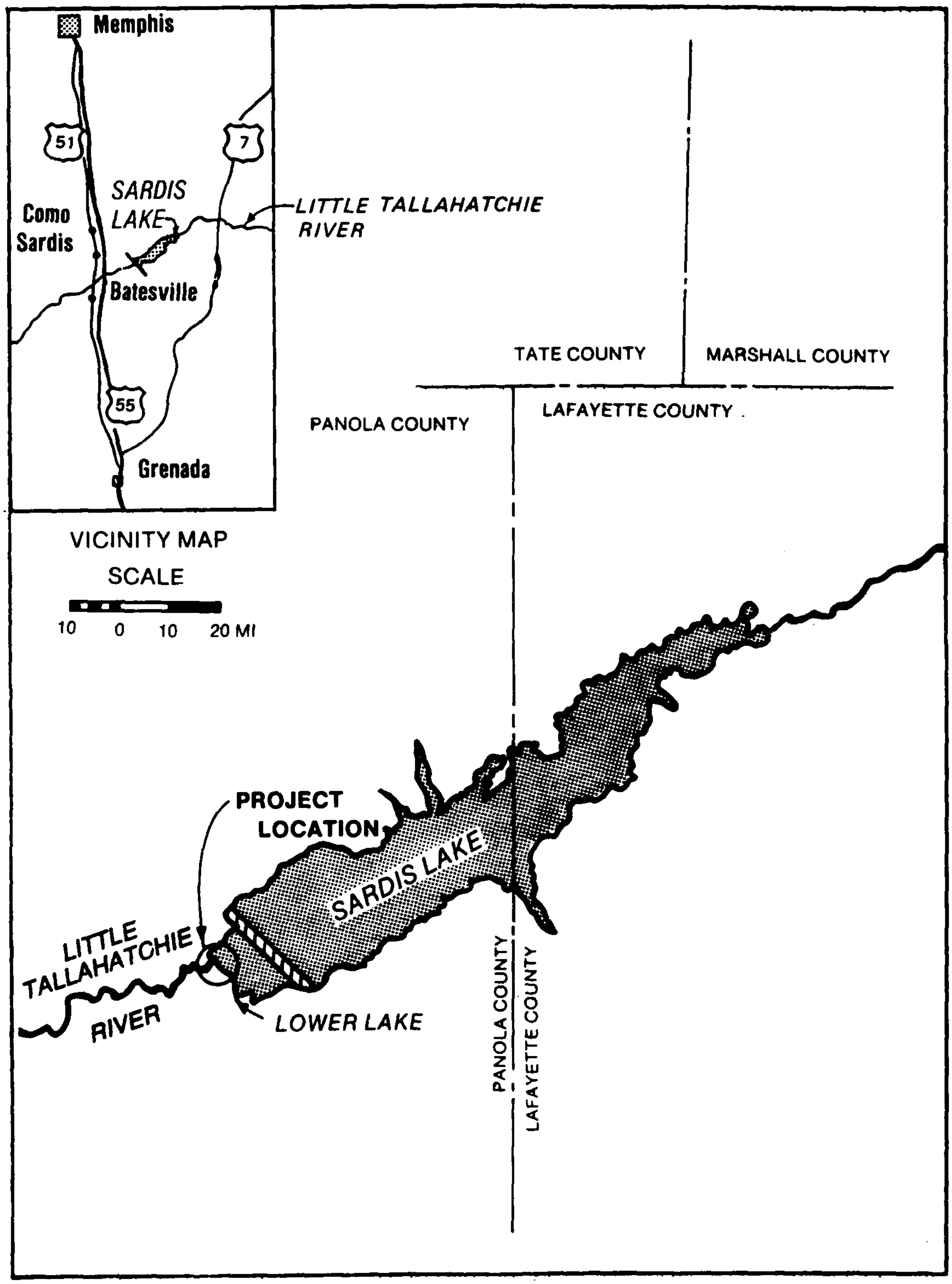

Figure 1. Location map

SARDIS LOWER LAKE ROCK WEIR

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The proposed rock weir will be placed in the Little Tallahatchie River just downstream of its confluence with the Sardis Lower Lake (Figure 1). It will have a clay core, will be capped with graded riprap, and will be constructed in the dry. Water will be permanently impounded behind it with flow continuously over its crest.

2. The weir will be 250 ft long* by 10 ft wide with 1V on 3.5H side slopes. The weir crest elevation will be at el 201**. The approach slope of the weir will be 1V on 4H with an exit slope of 1V on 10H. Riprap will be placed down the upstream slope to el 190, over the weir crest, and for 185 ft downstream of the weir center line. The model limits and the general plan and profile of the portion of the weir investigated in the model study are shown in Plates 1 and 2, respectively.

Purpose of the Model Study

3. Although the design of the Sardis Lower Lake Weir was based on sound hydraulic design practice, model analysis of its performance was desired to evaluate the performance of the long flat downstream slope. This section model investigation was concerned particularly with flow conditions in the approach and exit, and embankment and channel protective stone requirements.

Presentation of Data

4. In the presentation of the test results, no attempt was made to

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* A table of factors for converting non-SI units of measurement to SI (metric) units of measurement is presented on page 3.

** All elevations (el) and stages cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

introduce the data in the chronological order in which the tests were conducted. Instead, as each element of the structure is considered, all tests conducted thereon are described in detail. All model data are presented in terms of prototype equivalents.

PART II: THE MODEL

Description

5. The section model of the Sardis Lower Lake Weir (Figure 2) was constructed to a linear scale ratio of 1:15 and reproduced a 75-ft-wide center section of the proposed 225-ft-long rock weir and topography in an area extending 105 ft upstream and 380 ft downstream from the center line of the weir (Plate 1). The weir was molded of sand with a sheet metal cut-off wall through the center line of the crest and capped with riprap as shown in Plate 2. The weir was located in a 5-ft-wide plexiglas flume. This permitted better visual observation and evaluation of the hydraulic performance of the weir.

Appurtenances

6. Water used in the operation of the model was supplied by pumps and the discharges were measured by orifice plates. Discharges in the model were based on unit discharges over the weir in the prototype. Water-surface elevations were obtained with point gages. Velocities were measured using a pitot tube set midway between the crest elevation (el 201 NGVD) and the upper pool elevation for the various discharges. Current patterns were determined by means of dye injected into the water and confetti sprinkled on the water surface.

Interpretation of Model Results

7. The accepted equations of hydraulic similitude, based upon the Froudian criterion were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. The general relations expressed in terms of the model scale or length ratio, L_r, are presented in the following tabulation:

Figure 2. 1:15 scale model

Dimension	Ratio	Scale Relations
Length	L_r	1:15
Area	$A_r = L_r^2$	1:225
Weight	$W_r = L_r^3$	1:3375
Velocity	$V_r = L_r^{1/2}$	1:3.8730
Discharge	$Q_r = L_r^{5/2}$	1:871.425
Time	$T_r = L_r^{1/2}$	1:3.8730

8. Quantitative measurements of discharge, water-surface elevation, and velocity in the model were converted to prototype dimensions by means of the above scale relations.

Test Procedure

9. Tests were conducted in the model to observe flow conditions downstream of the rock weir and protective riprap requirements for discharges of 50 to 7,500 cfs in combination with various tailwater elevations. In observing the flow conditions, several constant discharges were introduced into the model, the tailwater was varied, and the upper pool elevation was measured for each condition. Tests were conducted to measure the upper pool elevation for discharges up to 7,500 cfs. The water-surface elevations were measured using point gages located 143 ft upstream and 370 ft downstream of the weir crest center line.

10. Velocities were measured over the crest center line with a pitot tube halfway between the crest elevation and the upper pool elevation for discharges of 800, 1,500, 3,000, 4,500, 6,500 and 7,500 cfs, using the channel tailwater rating curve data provided by the Vicksburg District (Table 1).

11. Riprap stability tests were run using these same channel tailwater rating curve data as provided by the Vicksburg District (Table 1). The discharge was introduced into the model and the tailwater was set. The model was operated for 12 continuous hours at this condition and the model was inspected for any damage to the riprap.

PART III: TEST RESULTS

The Weir

12. The details of the rock weir are shown in Plate 2. The weir crest was 15 ft above the channel floor with a 1V-on-4H upstream face, a flat 10-ft-wide crest and a 1V-on-10H downstream face.

13. Tests were conducted to observe the hydraulic performance of the rock weir for discharges of 50 to 7,500 cfs in combination with various tailwaters ranging from about 1 ft below the minimum tailwater elevation and 1 ft above the normal expected tailwater, as provided by the Vicksburg District (Plate 3). Logs 3-ft-long and having an average simulated weight of 20 lbs, a plastic boat simulating a 14-ft-long boat with a total weight of 772 lbs and a flat-bottomed boat simulating a 12-ft-long boat with a total weight of 276 lbs were alternately introduced 95 ft upstream of the crest center line and their mode of passage over the weir was recorded. For discharges up to and including 2,500 cfs, the water flowed over the cut-off wall and down through the riprap so that the riprap remained exposed as shown in Photos 1- 4. Each object became lodged against the exposed riprap after passing over the cut-off wall (see Photo 5). For discharges over 2,500 cfs, through the full range of tailwaters, each object flowed on downstream of the crest. The presence or absence of a roller downstream of the crest was initially determined by observing submerged flow patterns and the objects' behavior once they had passed over the crest of the rock weir. For discharges up to and including 3,000 cfs, an eddy formed along the right side of the model where the weir toe intersected the natural slope of the bed (about 95 ft downstream of the weir center line). A dye stream introduced downstream of the rock weir indicated that, while there was some return flow, no roller was present. Because there were no tendencies of excessive hesitation downstream of the weir and/or flipping of the test objects, it was concluded that no roller will form downstream of the rock weir crest with a 1V on 10H downstream slope through the full range of operation.

14. The discharge characteristics were determined by introducing various constant discharges (based on unit discharge) into the model and observing the corresponding upper pool elevation for various tailwater elevations.

Sufficient time was allowed for stabilization of the upper pool elevation. Basic calibration data are shown in Plate 4.

15. Velocities over the weir crest center line for the channel tailwater rating curve data (Table 1) are tabulated in Table 2.

Riprap Requirements

16. Details of the riprap protection in the approach area and the downstream channel are shown on Plate 2. For all tests, the approach area, weir crest and 135 ft downstream of the crest center line were covered with protective stone simulating prototype stone with an average weight of 130 lbs. For an additional 50 ft, the exit channel was covered with stone with an average weight of 25 lbs. Riprap gradation curves for all riprap used in tests are plotted in Plates 5 and 6, respectively. The riprap remained stable during all discharges using the channel tailwater rating curve data in Table 1.

17. The model was revised to include the left 1V on 3.5H side slope, a 50-ft-wide section of the 250-ft-wide rock weir and topography in an area extending 138 ft upstream and 215 ft downstream from the center line of the weir (Plate 7). For all tests, the side slopes were covered with protective stone simulating prototype stone with an average weight of 130 lbs. The protection for the rock weir remained the same (Plate 8). The riprap remained stable during all discharges using the channel tailwater rating curve data in Table 1.

PART IV: DISCUSSION

18. The Sardis Lower Lake Weir will essentially be submerged during all phases of operation. Because of this and the long flat downstream slope, there was some concern that a potentially dangerous roller would develop on the downstream face of the weir. Tests with dye streams injected into the flow and several objects introduced over the weir indicated that although a small eddy was present at discharges of 50 to 3,000 cfs, there was no roller present through the full range of operation.

19. Protective stone with an average weight of 130 lbs placed on the upstream face and along the weir for 135 ft downstream of the crest center line, immediately followed by a 50-ft length of protective stone in the exit channel with an average weight of 25 lbs, remained stable through the full range of operation.

20. Protective stone with an average weight of 130 lbs placed on the 1V on 3.5H side slopes remained stable through the full range of operation.

21. It is recommended that a 36-in.-thick blanket of protective stone with an average weight of 130 lbs be placed on the 1V on 3.5H side slopes, 1V on 4H approach slope, over the crest and 135 ft downstream of the crest center line immediately followed by a 50-ft-length of protective stone in the exit channel with an average weight of 25 lbs.

Table 1

Channel Tailwater Rating Curve Data*

Discharge, Q cfs	Tailwater el ft, NGVD	Duration of Flow, hr
50	192.5	12
200	193.3	12
800	195.7	12
1,500	197.5	12
3,000	201.8	12
4,500	202.9	12
6,500	205.0	12
7,500	205.8	12

* Data represent the expected tailwater elevation which will occur if proposed channel improvements are made in the Little Tallahatchie River.

Table 2

Velocity Measurements

Q cfs	TW EL ft, NGVD	Avg V Across Weir C_L fps	V_{MAX} Across Weir C_L fps	V_{MIN} Across Weir C_L fps
800	195.7	5.3	6.9	4.4
1,500	197.5	6.5	7.8	5.6
3,000	201.8	7.6	8.8	6.6
4,500	202.9	8.4	8.9	7.8
6,500	205.0	8.4	9.1	7.6
7,500	205.8	8.4	8.5	8.1

NOTE: Velocities measured halfway between crest elevation (el 201) and upper pool elevation.

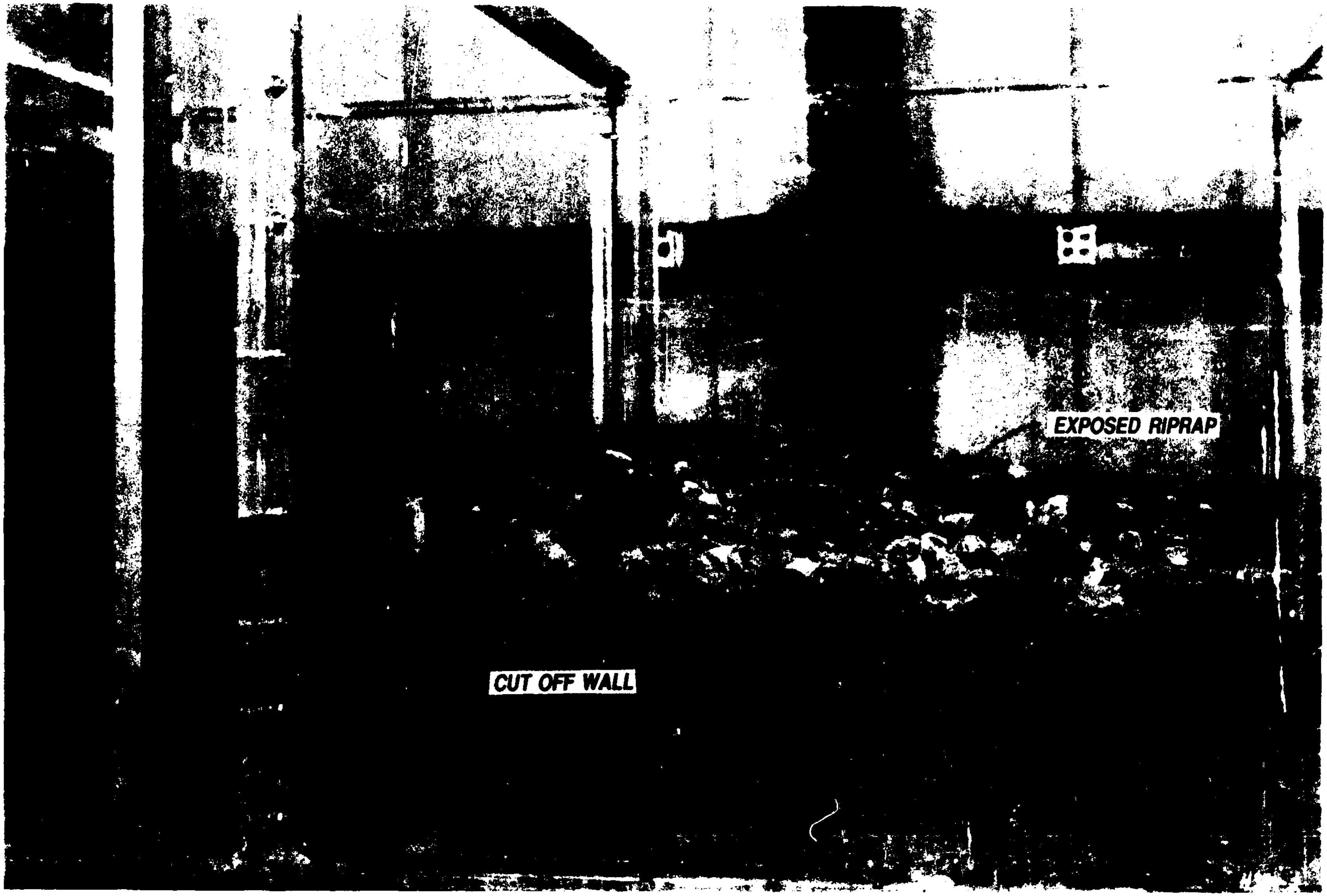


Photo 1. Q = 50 cfs; TW EL 195.0 ft NGVD

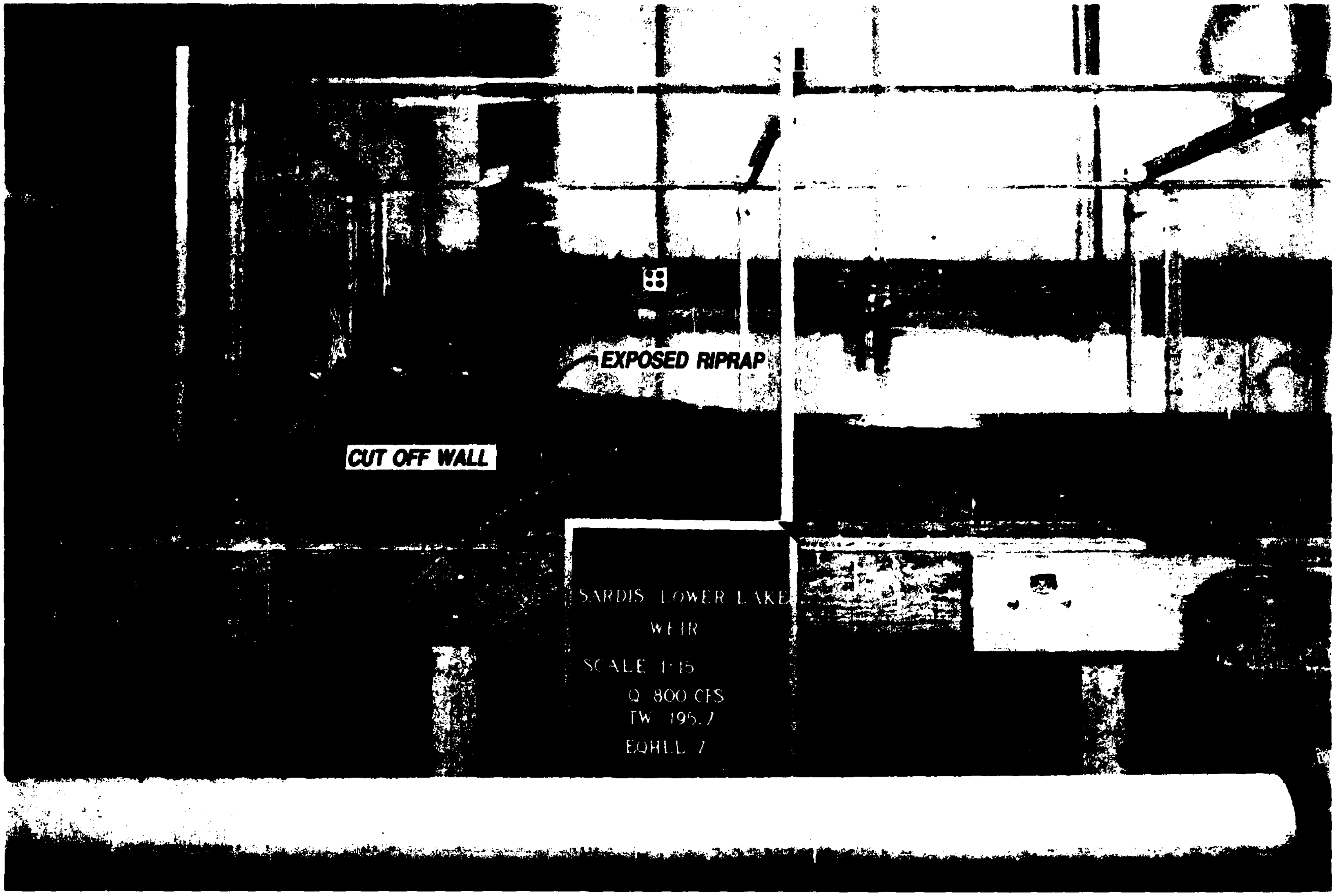


Photo 2. Q = 800 cfs; TW EL 195.7 ft NGVD

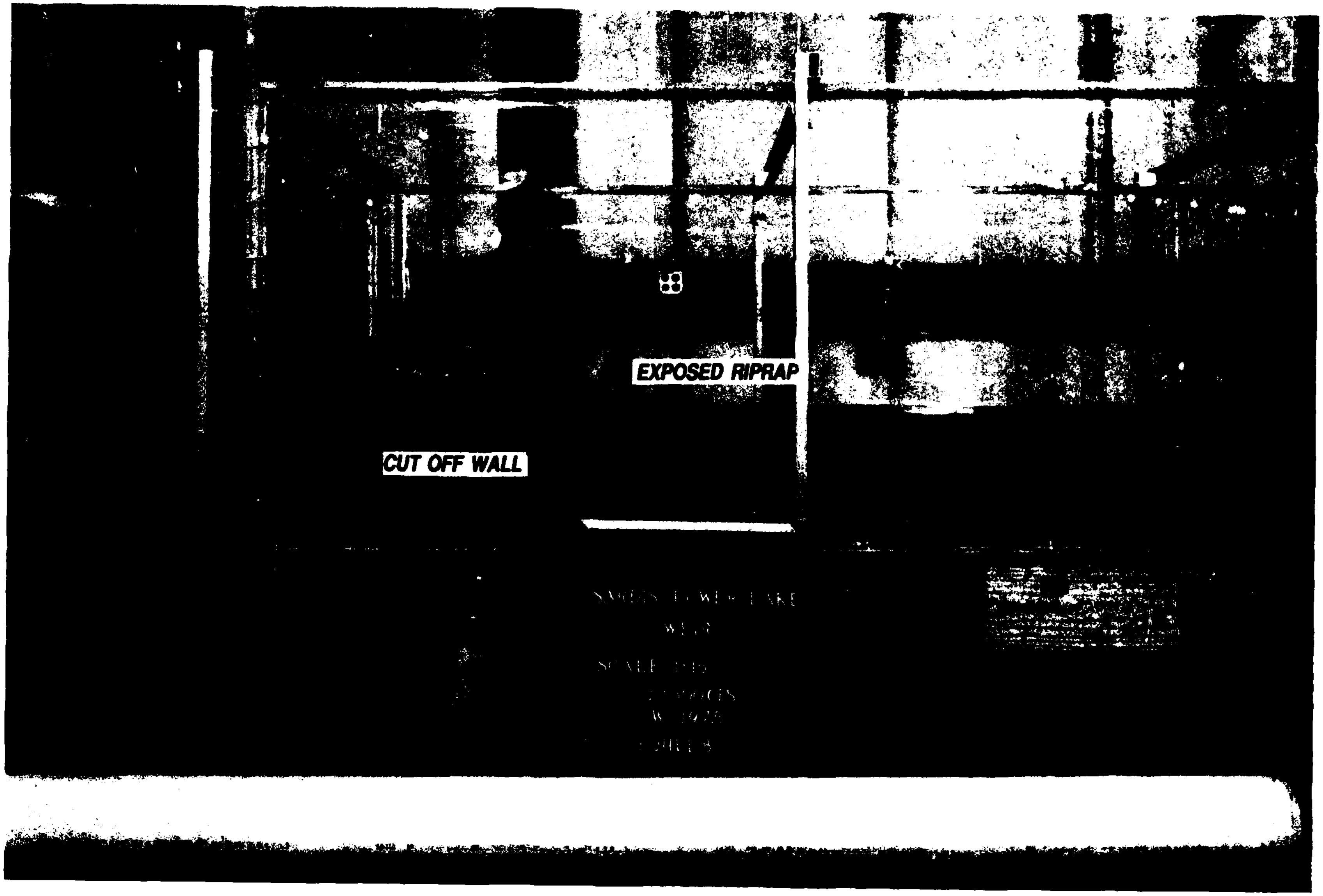


Photo 3. Q = 1500 cfs; TW EL 197.5 ft NGVD

Photo 4. Q = 2500 cfs; TW EL 199.5 ft NGVD

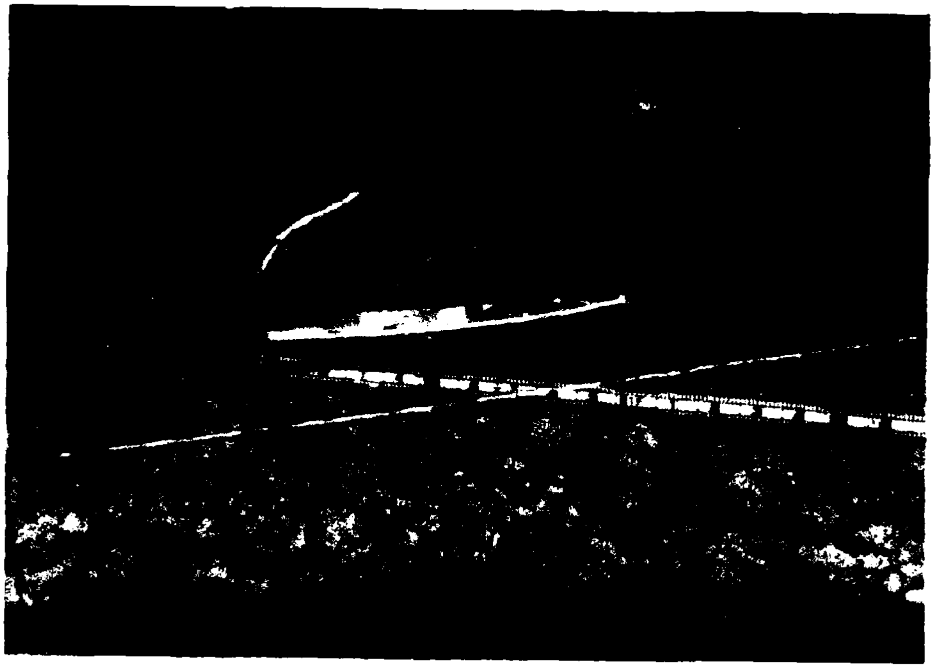


Photo 5. 14-ft-long boat lodged on exposed riprap

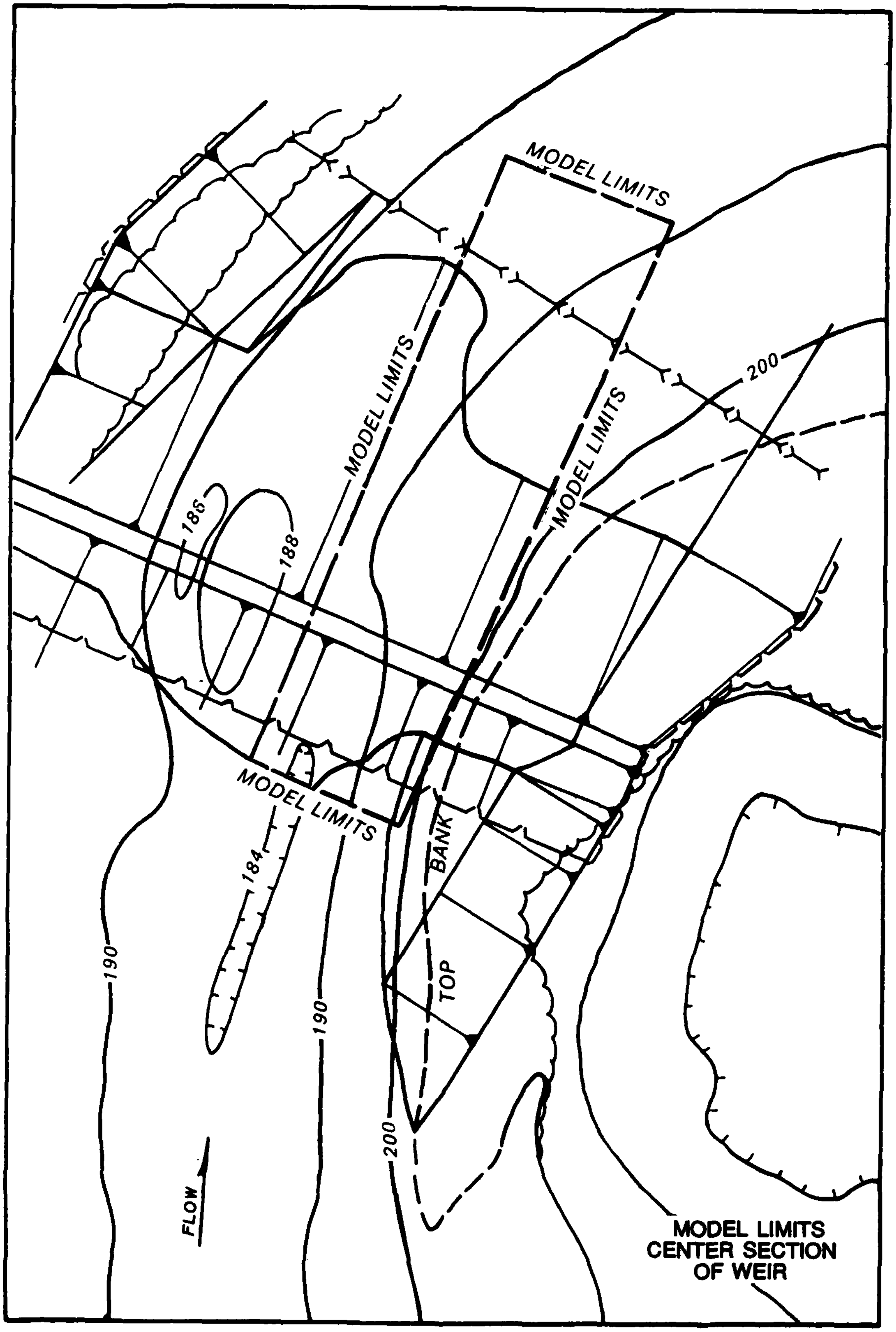
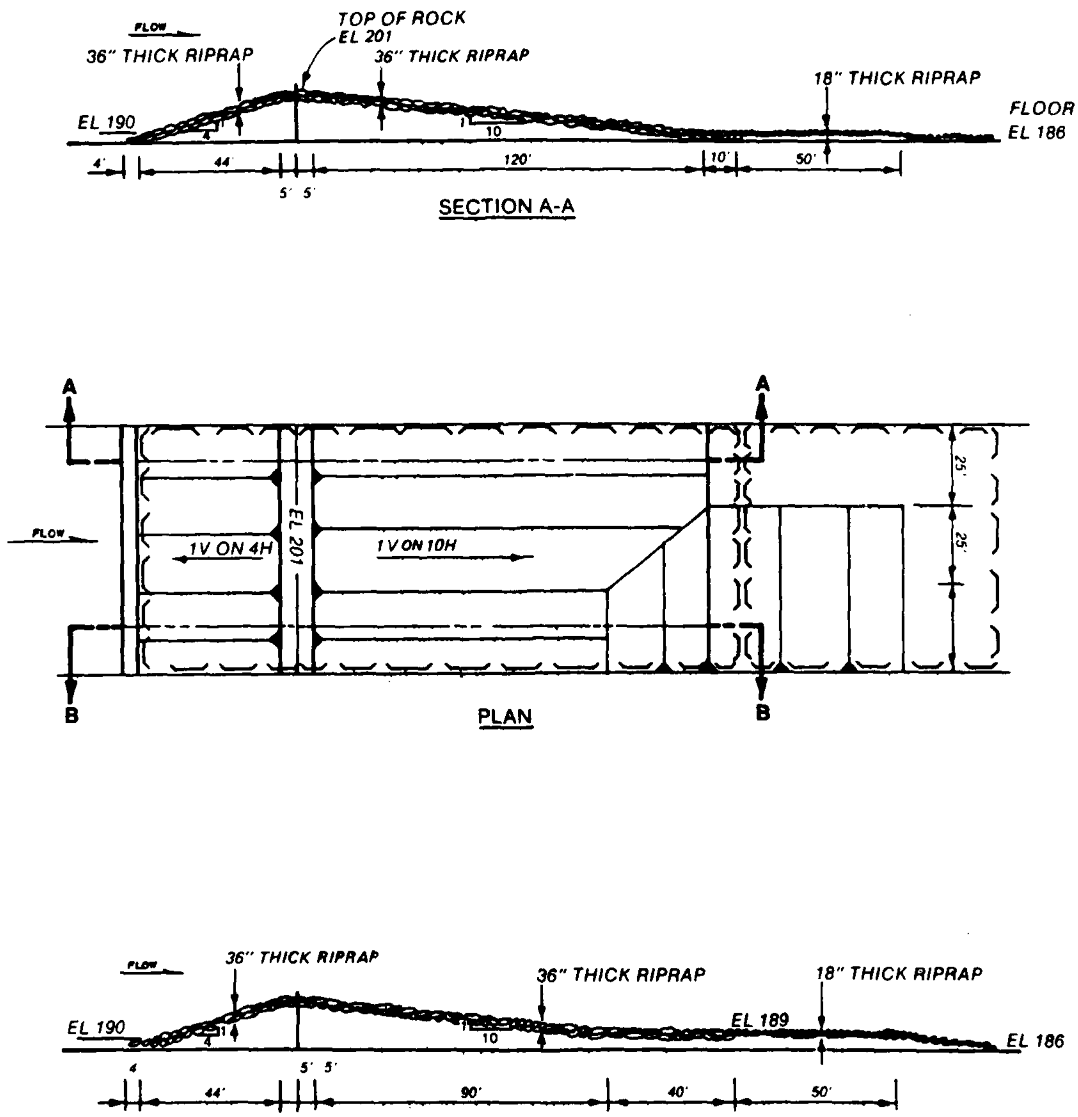
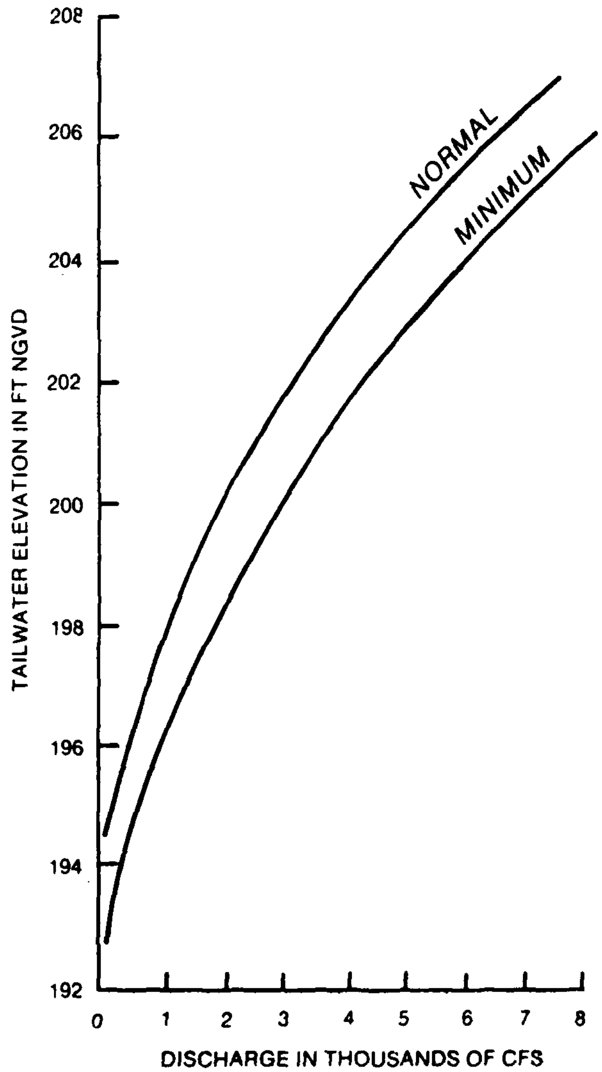

MODEL LIMITS
MODEL LIMITS
MODEL LIMITS
MODEL LIMITS
200
186
188
184
190
190
200
BANK
TOP
FLOW
MODEL LIMITS
CENTER SECTION
OF WEIR

PLATE 1

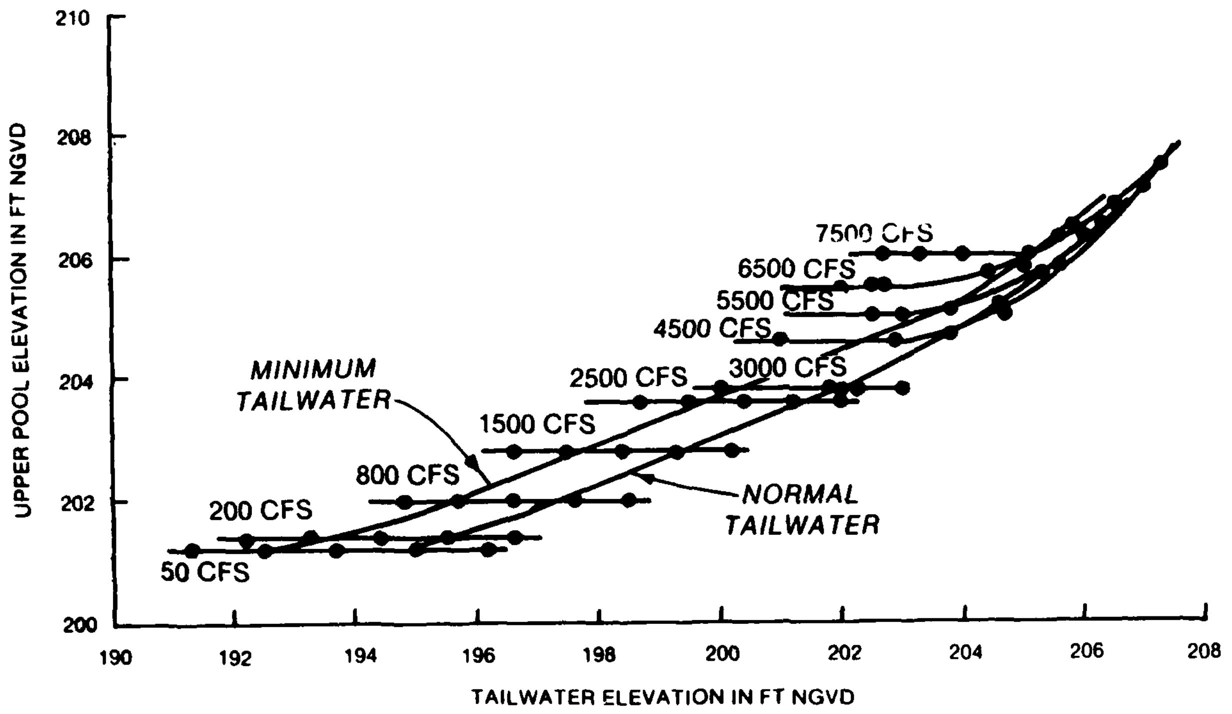


PROFILE SECTIONS

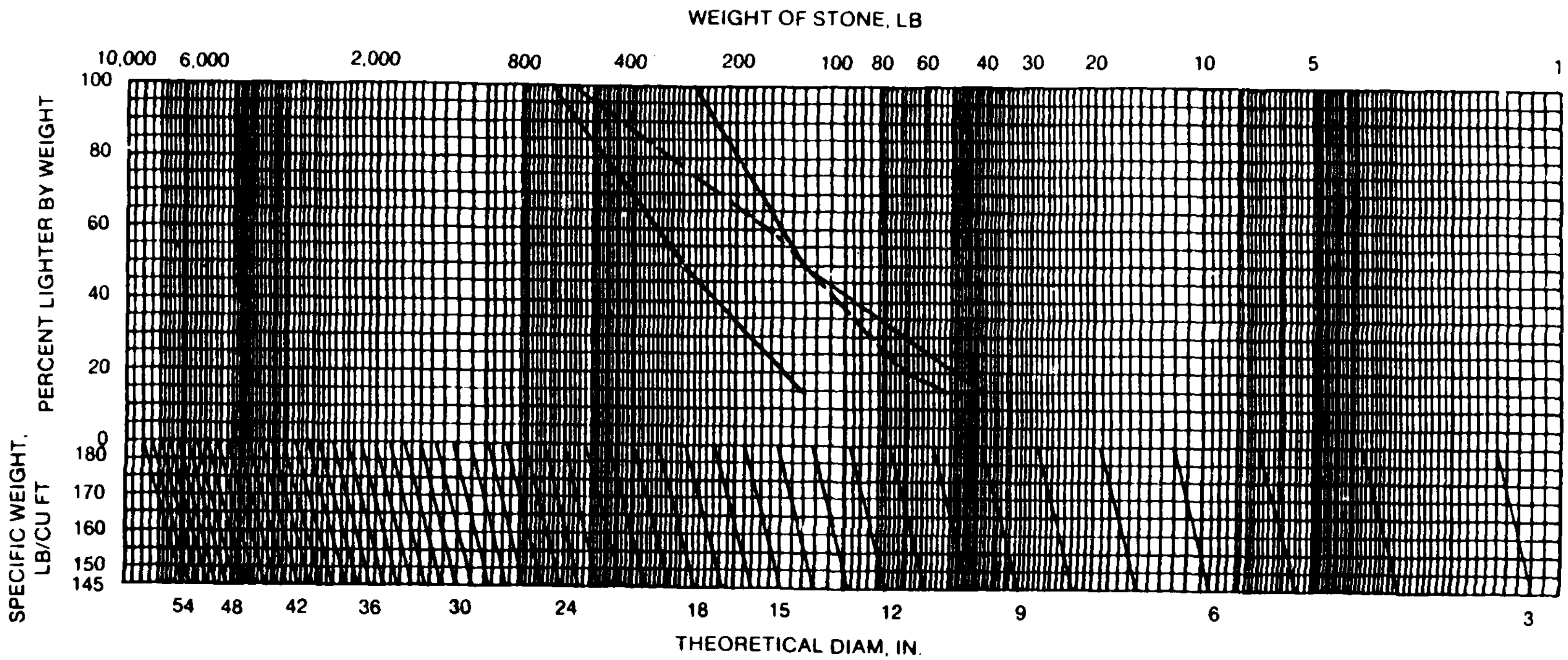
SARDIS LOWER LAKE WEIR
SECTION MODEL
1:15 SCALE
36" THICK RIPRAP



TAILWATER CURVES



CALIBRATION DATA



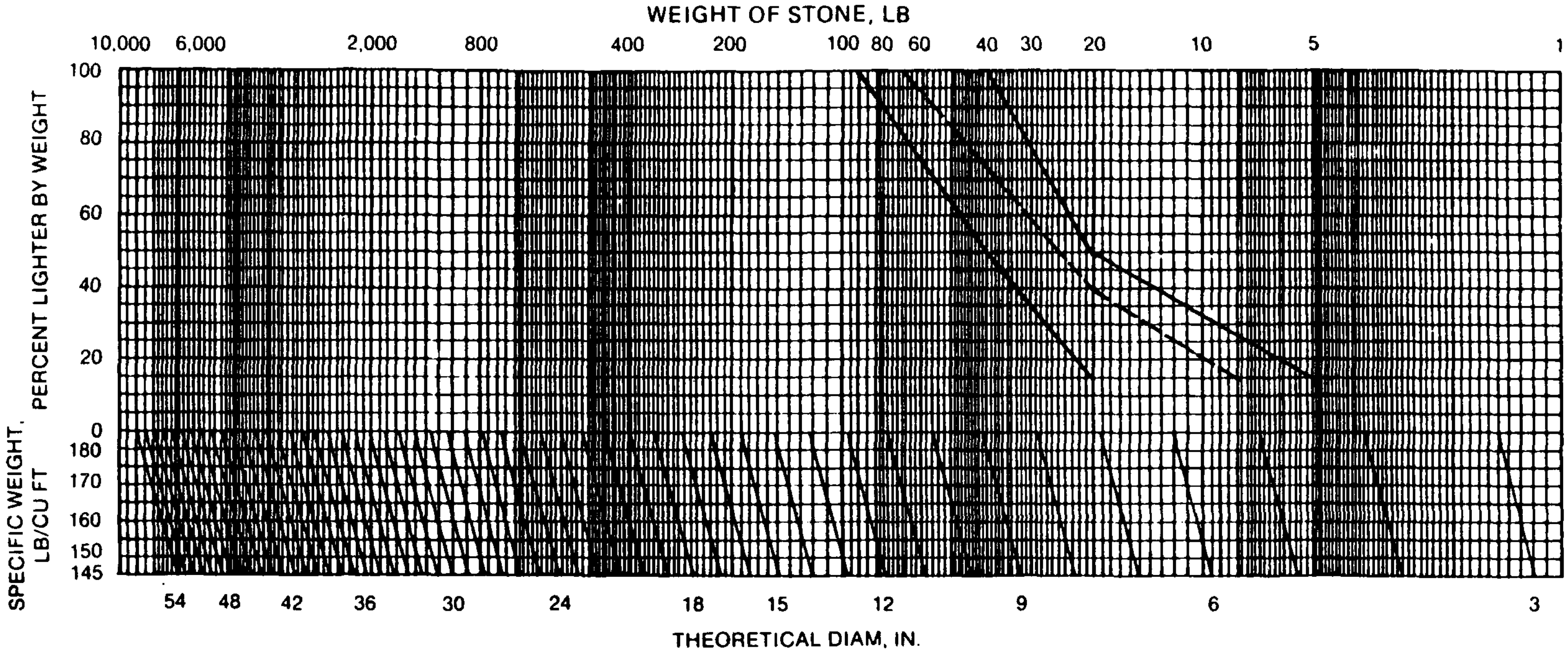
SPECIFIC WEIGHT OF STONE 155 LB/CU FT

LEGEND

—— PROTYPE GRADATION

---- MODEL GRADATION

RIPRAP GRADATION CURVES
36" THICK RIPRAP



SPECIFIC WEIGHT OF STONE 155 LB/CU FT

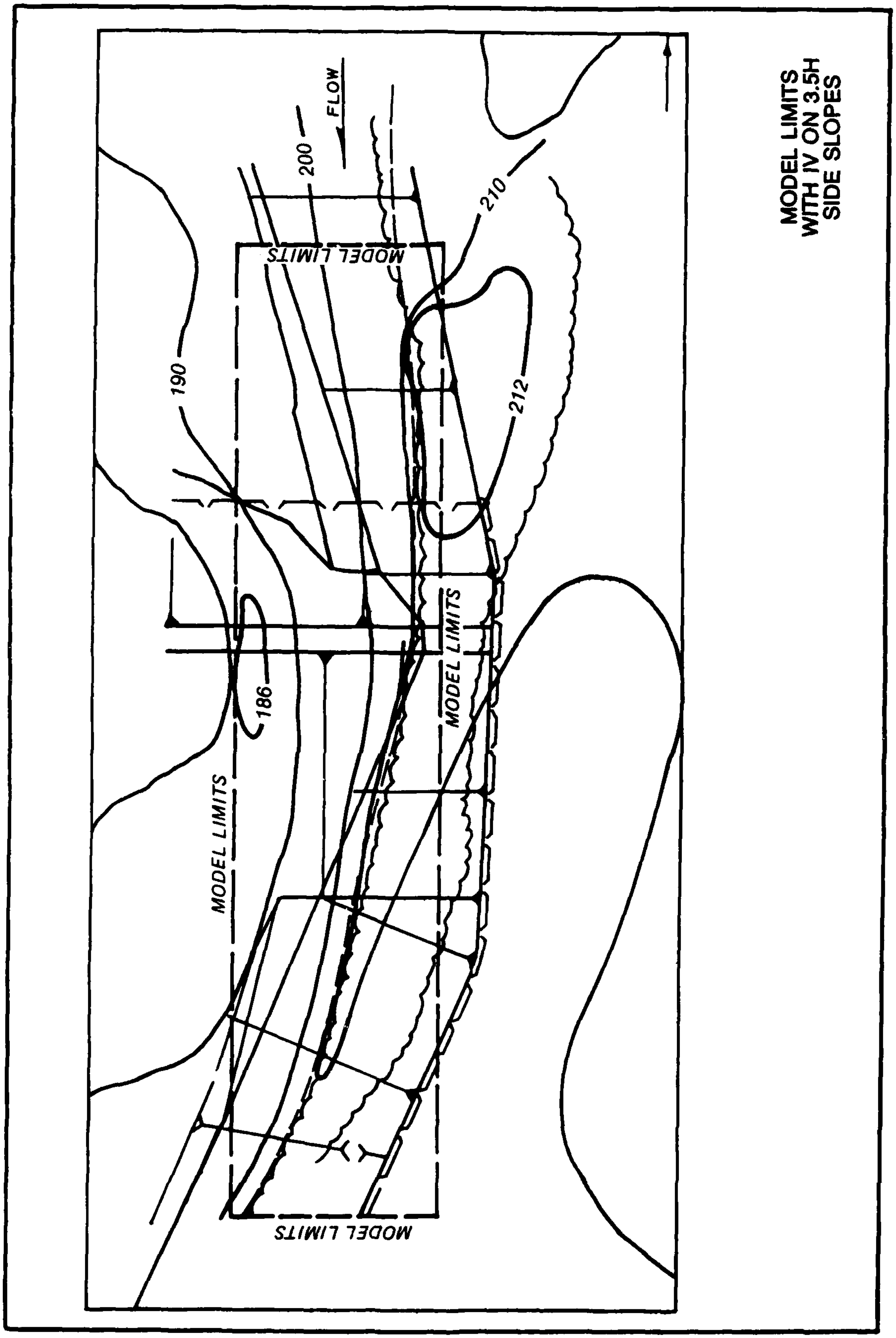
LEGEND

—— PROTYPE GRADATION

---- MODEL GRADATION

RIPRAP GRADATION CURVES

18" THICK RIPRAP


MODEL LIMITS
WITH IV ON 3.5H
SIDE SLOPES
FLOW
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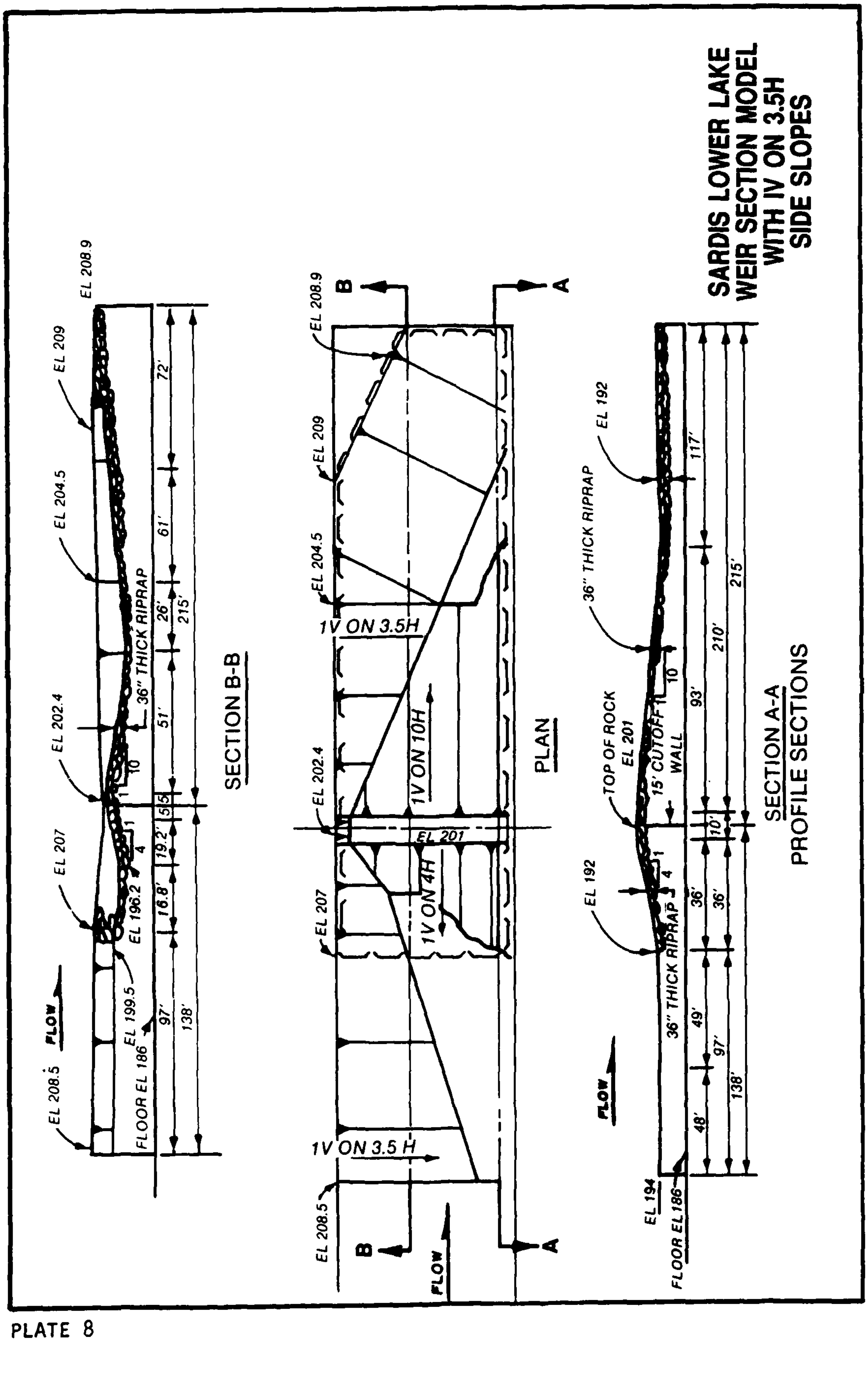
210
212
190
186
MODEL LIMITS
MODEL LIMITS
MODEL LIMITS
MODEL LIMITS


SARDIS LOWER LAKE WEIR SECTION MODEL WITH IV ON 3.5H SIDE SLOPES
SECTION B-B
PLAN
SECTION A-A
PROFILE SECTIONS
FLOW
EL 208.5
EL 207
EL 202.4
EL 204.5
EL 209
EL 208.9
EL 199.5
EL 196.2
EL 186
FLOOR EL 186
36" THICK RIPRAP
15' CUTOFF WALL
TOP OF ROCK EL 201
EL 201
EL 192
EL 194
1V ON 3.5H
1V ON 10H
1V ON 4H
B
A
72'
61'
26'
51'
215'
138'
97'
16.8'
19.2'
117'
210'
93'
10'
36'
49'
48'