Technical Report HL-96-6
August 1996

US Army Corps
of Engineers
Waterways Experiment
Station

Petaluma River, Channel Constriction Project, Sonoma County, California

Hydraulic Model Investigation

by Billy D. Fuller

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Prepared for U.S. Army Engineer District, San Francisco

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3909 Halls Ferry Road
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Final report

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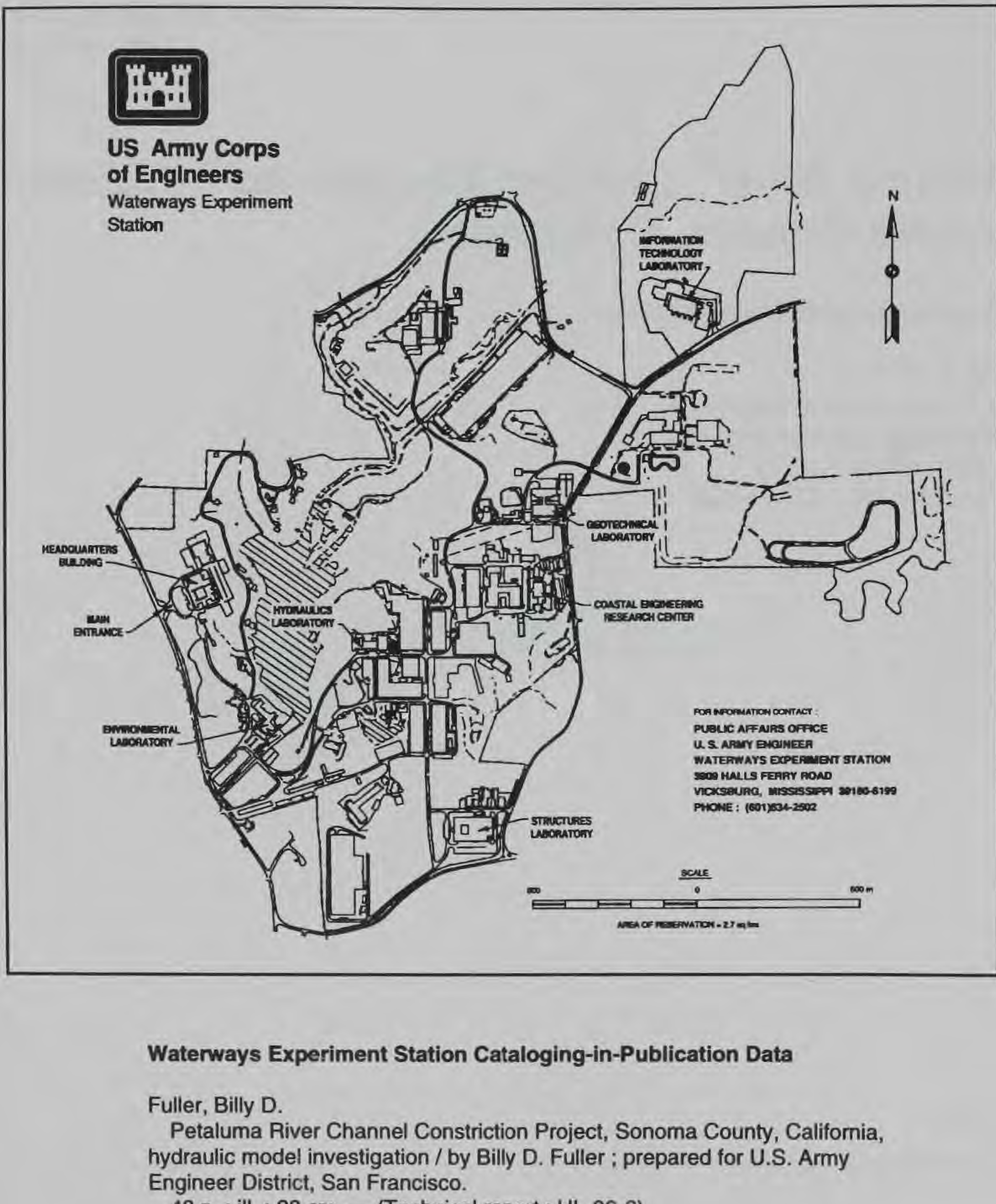

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Contents

Preface

The model investigation reported herein was authorized by the District Commander, U.S. Army Engineer District, San Francisco, 18 April 1995.

The study was conducted by personnel of the Hydraulics Laboratory (HL), U.S. Army Engineer Waterways Experiment Station (WES), during the period April to September 1995. The study was conducted under the direction of Messrs. R. A. Sager, acting Director; R. F. Athow, acting Assistant Director; and J. F. George, acting Chief, Hydraulic Structures Division (HSD). The experiments were conducted by Messrs. D. White, T. Jackson , and B. D. Fuller, Spillways and Channels Branch, HSD, under the supervision of Mr. B. P. Fletcher, Chief of the Spillways and Channels Branch. This report was prepared by Mr. Fuller.

The constriction weir was constructed by Messrs. J. Schultz and J. Jeffreys, Engineering and Construction Services Division (E&CSD), under the supervision of Mr. Ed A. Case, E&CSD. The channel contours were prepared by personnel of the Construction Services Division under the supervision of Mr. Michael B. Sims, E&CSD.

During the course of the investigation, Mr. Carlos Hernandez, Ms. Jerri Kasemsant, and Mr. Bill Firth, U.S. Army Engineer District, San Francisco, visited WES to observe model operation, discuss experiment results, and correlate these results with concurrent design work.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

1 Introduction

Prototype

The proposed structure will be located approximately 64 km (40 miles) north of San Francisco, in the city of Petaluma, CA (Figure 1). Channel improvements are proposed for the stretch of the Petaluma River shown in Figure 2. These improvements will improve the flow conditions of the river in this region. To prevent lowering water-surface elevations and increasing flow velocities in the regions just above the project stretch, a constriction weir was proposed.

The proposed channel constriction is designed to maintain preproject water-surface elevations and flow velocities upstream of the improved channel. The preliminary design for this constriction weir was provided by the U.S. Army Engineer District, San Francisco, and based on the Corps' HEC-2 algorithm.

Purpose of Model Study

The model study was conducted to validate the preliminary design of the constriction weir or modify the weir dimensions as necessary to provide the desired upstream water-surface elevations. Another purpose for this study was to determine if the riprap protection blanket was adequately sized. The proposed blanket (type 1) extended 7.6 m (25 ft) upstream and downstream of the constriction weir and was 0.7 m (27 in.) thick.

2 Model

Description

This 1:10-scale (Figure 3) model was installed in a portion of an existing flume that permitted simulation of the constriction weir and 30 m (100 ft) of upstream and downstream topography from the weir.

The constriction weir (Plate 1) was constructed of plywood to allow easy modification. Modifications of the constriction weir opening and height were made to adjust head loss to achieve the desired upstream water-surface elevations. An isometric view of the approach and exit channels and the constriction weir is shown in Plate 2. Photographs of the model are shown in Figures 4 through 7.

The upstream and downstream riverbeds were molded to the proposed cross section profiles (Plate 3) by using sheet metal templates.

Riprap protection initially proposed consisted of a 0.7-m- (27-in.) thick blanket that extended 7.6 m (25 ft) upstream and downstream from the weir. The riprap protection consisted of crushed limestone with a D_{100} of 0.7 m (27 in.) (Plate 4).

Flow through the model was recirculated using variable velocity pumps, and discharges were measured by use of a calibrated weir. Water-surface elevations were measured with point gauges at the locations coinciding with HEC-2 nodal points. These locations were in the center of the channel, 7.6 m (25 ft) downstream and 15 m (50 ft) upstream of the constriction weir. Velocities were measured with paddle wheel flow meters. Tailwater elevations were maintained by use of an adjustable tailgate.

Scale Relations

The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for the transference of model data to prototype equivalents are as follows:

Characteristics	**Dimensions**[1]	**Scale Relations Model:Prototype**
Length	L_r	1:10
Area	$A_r = L_r^2$	1:100
Velocity	$V_r = L_r^{1/2}$	1:3.1623
Discharge	$Q_r = L_r^{5/2}$	1:316.23
Volume	$V_r = L_r^3$	1:1000
Weight	$W_r = L_r^3$	1:1000
Time	$T_r = L_r^{1/2}$	1:3.1623

[1]Dimensions are in terms of length.

Model measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively to prototype equivalents by means of the scaled relations.

3 Experiments and Results

Riprap Protection Blanket

Hydraulic conditions evaluated in this investigation are provided in Table 1. Initial investigations consisted of evaluating the stability of the proposed riprap protection. The proposed riprap protection blanket (type 1, Plate 5) consisted of riprap D_{100} = 0.7 m (27 in.) extending 7.6 m (25 ft) upstream and 7.6 m (25 ft) downstream of the constriction weir. This protection blanket, when evaluated with the 2-year event, was undermined at the downstream end of the riprap blanket as the model bed material (sand) scoured (Photos 1 through 4).

The downstream end of the riprap blanket was extended to 30 m (100 ft) (type 2 design). A drawing of the type 2 design riprap is shown in Plate 6, and photographs are provided in Figures 8 through 11. The results indicated that the type 2 design riprap plan provided satisfactory protection for the modeled channel for all anticipated flow conditions. It was determined that velocity data should be taken with each flow condition to allow further investigation of possible scouring. The magnitude and direction of current velocities for the type 2 design riprap protection plan with 2-, 10-, 40-, and 100-year events are provided in Plates 7 through 10.

Weir Design

Experiments were then conducted to determine the head loss over the weir for various flow conditions. An experiment consisted of setting the discharge and tailwater elevation, allowing time for the flow to stabilize, and recording the pool elevation. The data from evaluation of the original weir design (type 1) are tabulated in Table 2, which shows a comparison of the measured (model) water-surface elevations with computed values. If the measured water-surface differential equals or minimally exceeds the computed values, the weir design was considered satisfactory. As can be seen in Table 2, the type 1 weir did not provide sufficient head loss for the 10-, 40, and 100-year events.

The length of the upper notch of the weir was reduced from 14.6 (48) to 12.4 m (40.8 ft) to increase the head loss across the weir. This was designated the type 2 design weir, as shown in Plate 11. The water-surface elevations for the 10- and 40-year events are presented in Table 2. These data indicated that the type 2 design weir satisfied the 10-year event but provided only limited improvements for the 40-year event.

To further increase the head loss, the weir was modified by raising the top of the constriction weir from el 13.0 to 14.2.[1] This was designated the type 3 design weir and is shown in Plate 12. The data associated with this design indicated that unsatisfactory results were obtained with the 40-year event (Table 2).

The weir was again modified in an attempt to improve the hydraulic performance of the weir for the full range of flow events. The top of the weir was raised to el 15.0, which is the highest practical elevation in the prototype. Also, by raising the weir to el 15.0, this increased the width of the weir from 12.4 to 13.0 m (40.8 to 42.8 ft) (type 4 design weir, Plate 13). Satisfactory results were obtained for the 2-, 10-, 40-, and 100-year flow events, as shown in Table 2. Although the measured water-surface differential for the 40-year event did not exceed the predicted, the type 4 design weir was accepted, since overbank topography made it impractical to raise the top of the weir above el 15.0. Additional investigation indicated that the type 2 design riprap protection plan was stable for all anticipated flows with the type 4 design constriction weir. The magnitude and direction of current velocities with these designs are shown in Plates 14 through 17.

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[1] Unless stated otherwise, all elevations (el) cited herein are in feet as referred to in the National Geodetic Vertical Datum (NGVD) of 1929. To convert elevations to meters, multiply by 0.3048.

4 Conclusions

Experimental results indicated a riprap protection blanket with a D_{100} of 0.7 m (27 in.), extending 7.6 m (25 ft) upstream and 30 m (100 ft) downstream from the constriction weir and providing adequate erosion protection in the modeled channel. This final design (type 2) is shown in Plate 6. Additional information, velocity magnitudes, and directions were recorded to provide an indication to design engineers as to the erosion potential of the material downstream of the modeled channel.

The final weir design (type 4, Plate 13) provided adequate head loss through the weir. These data are presented in Table 2. Although the measured water-surface differential for the 40-year event did not exceed the predicted, the type 4 design weir was accepted since the top of the weir could not be raised above el 15.0. Further constriction of the notches would raise upstream water-surface elevations and increase velocities downstream for the 2- and 10-year events.

Figure 1. Vicinity map

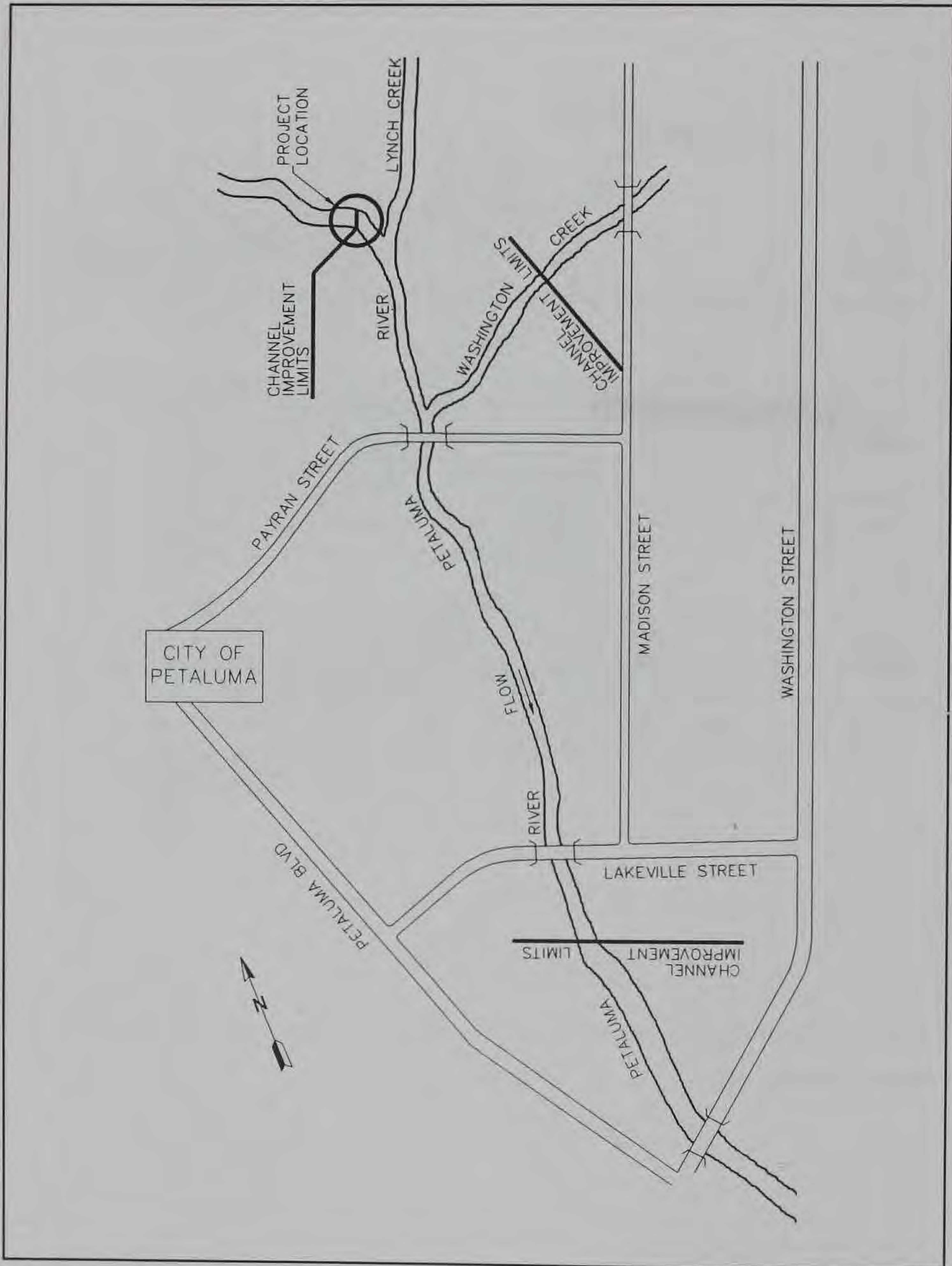


Figure 2. Location map

Figure 3. The 1:10-scale model, downstream view

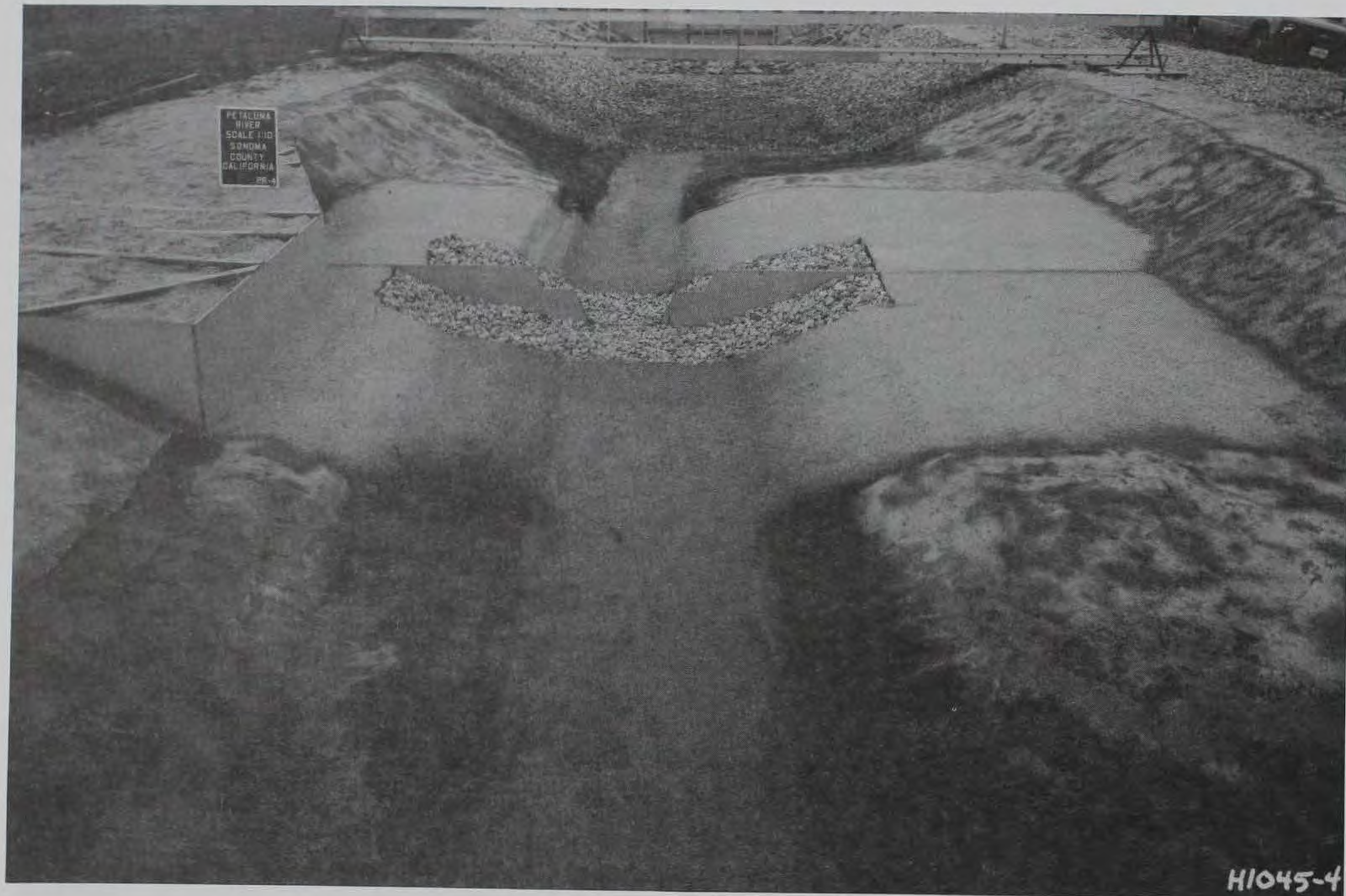


Figure 4. Upstream view of weir

Figure 5. Side view of weir

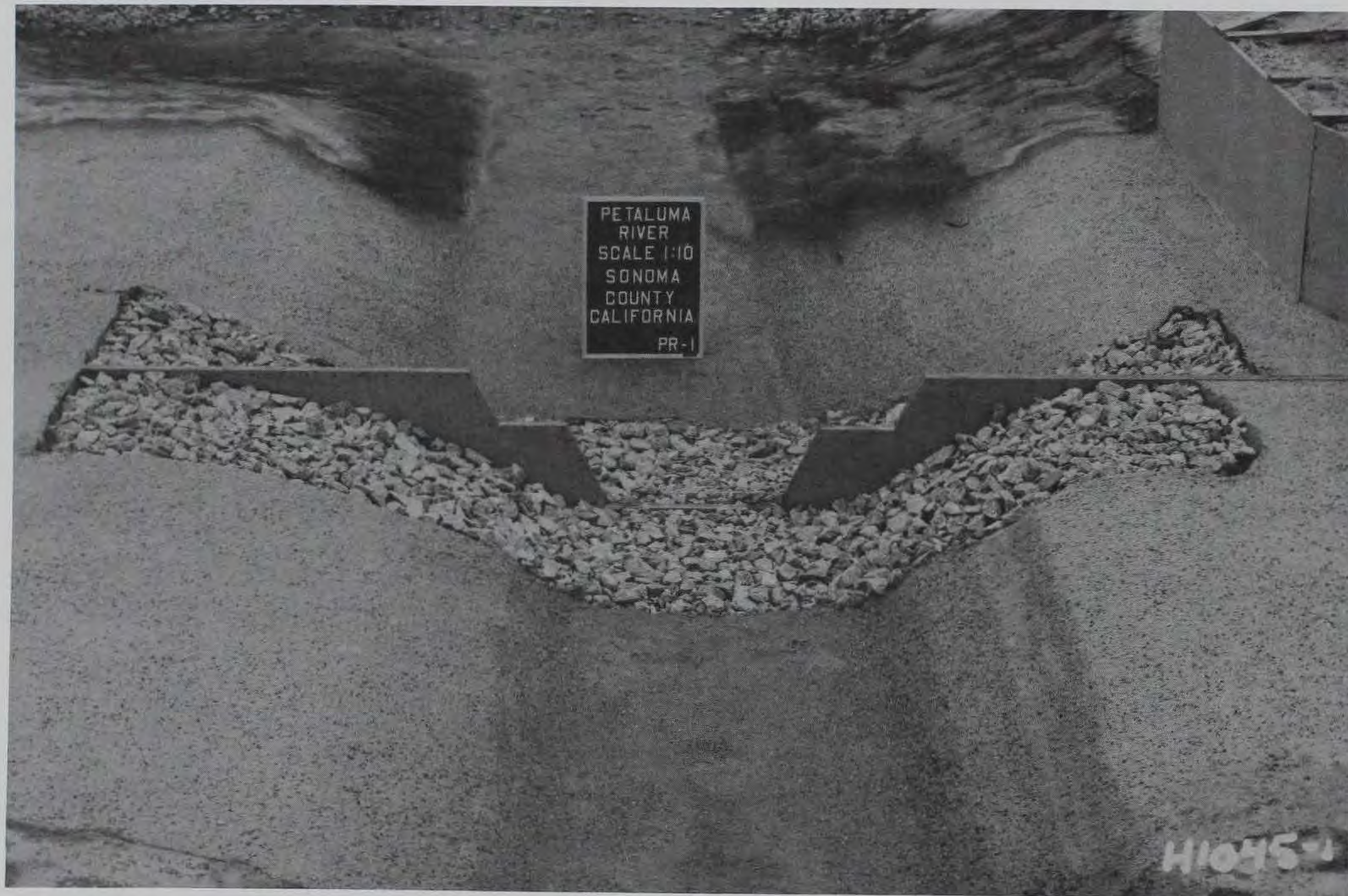


Figure 6. Downstream view of weir

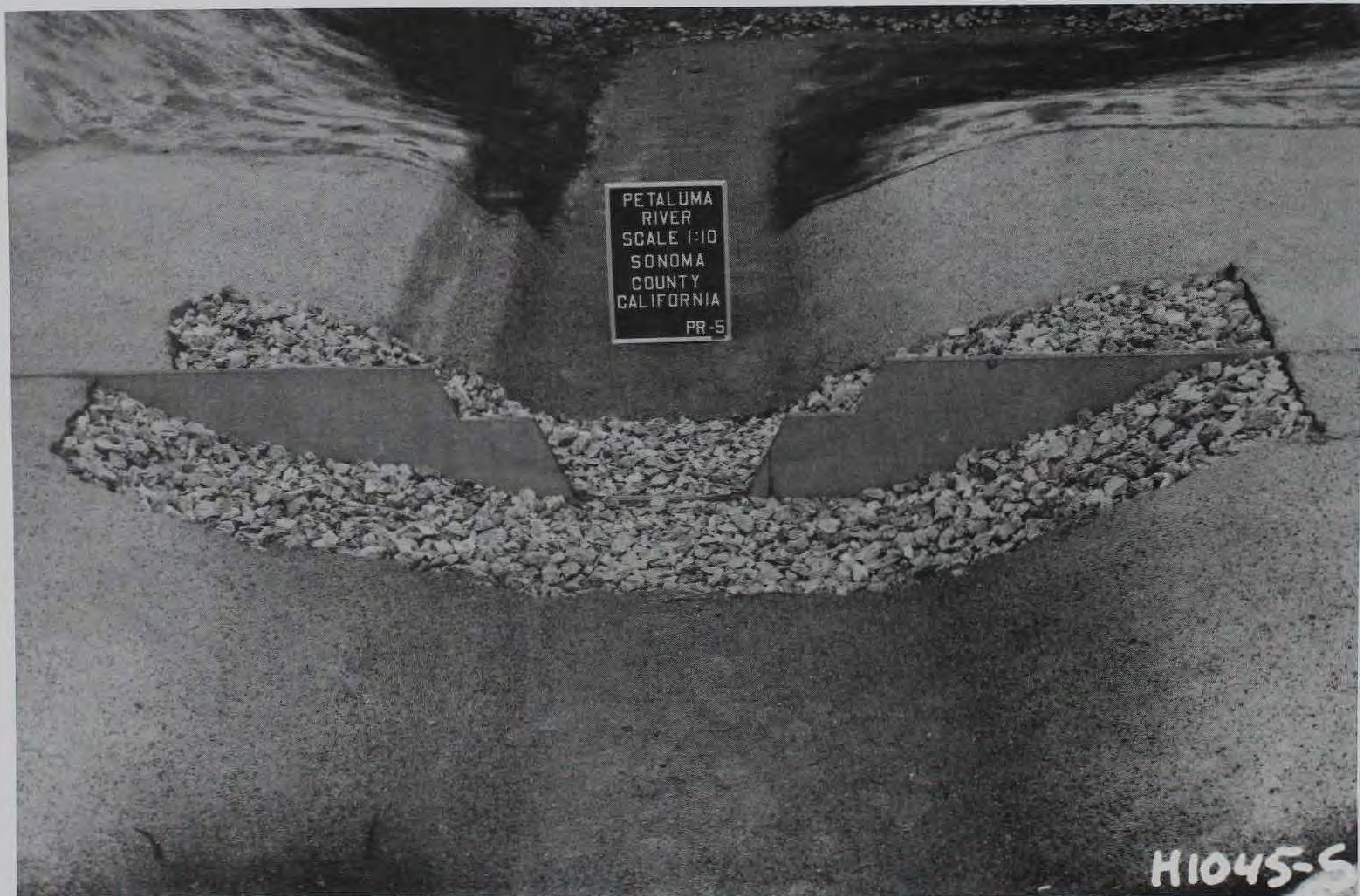


Figure 7. View of weir, upstream

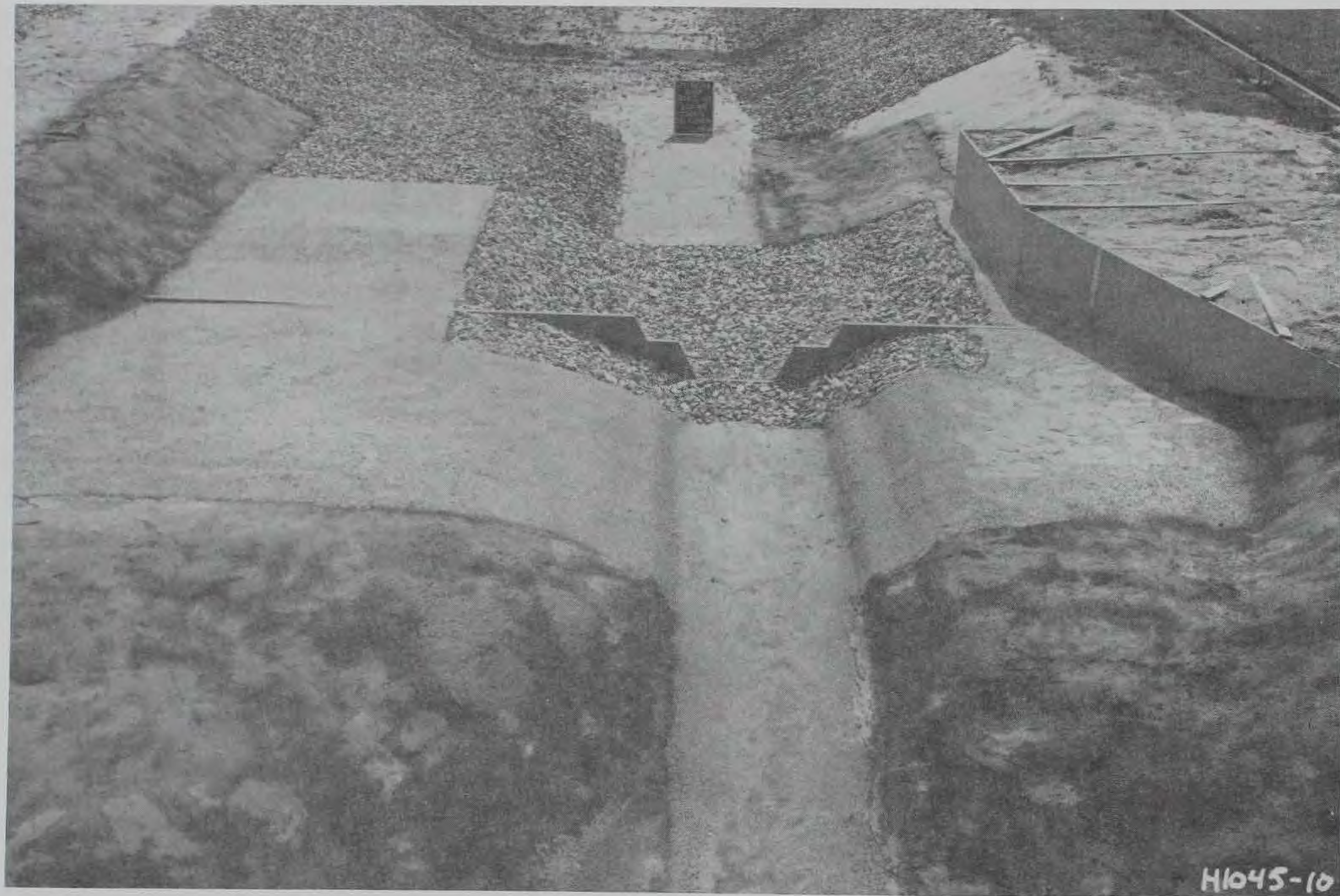


Figure 8. Type 2 riprap design, downstream general view

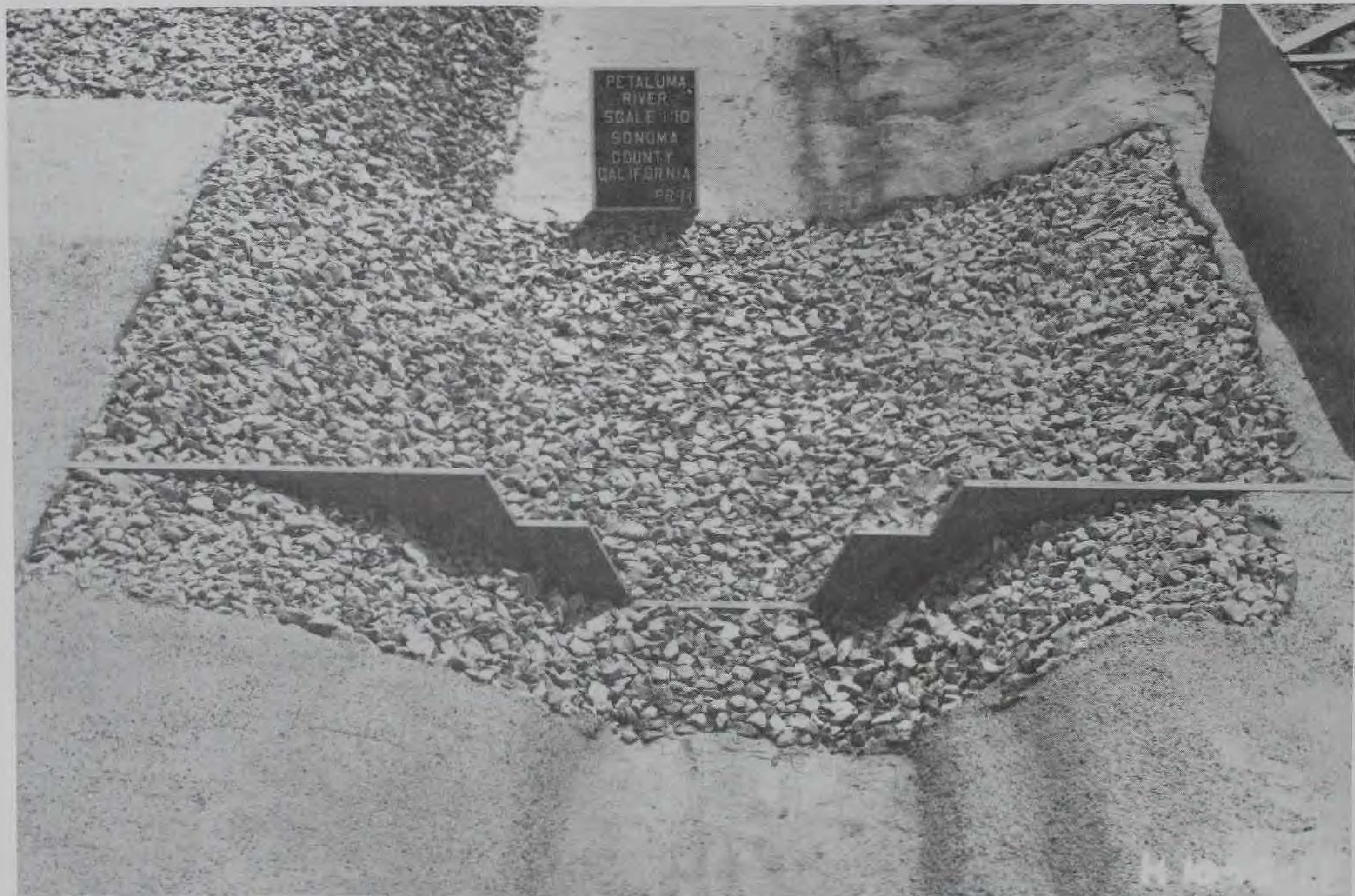


Figure 9. Type 2 riprap design, downstream view

Figure 10. Type 2 riprap design, side view

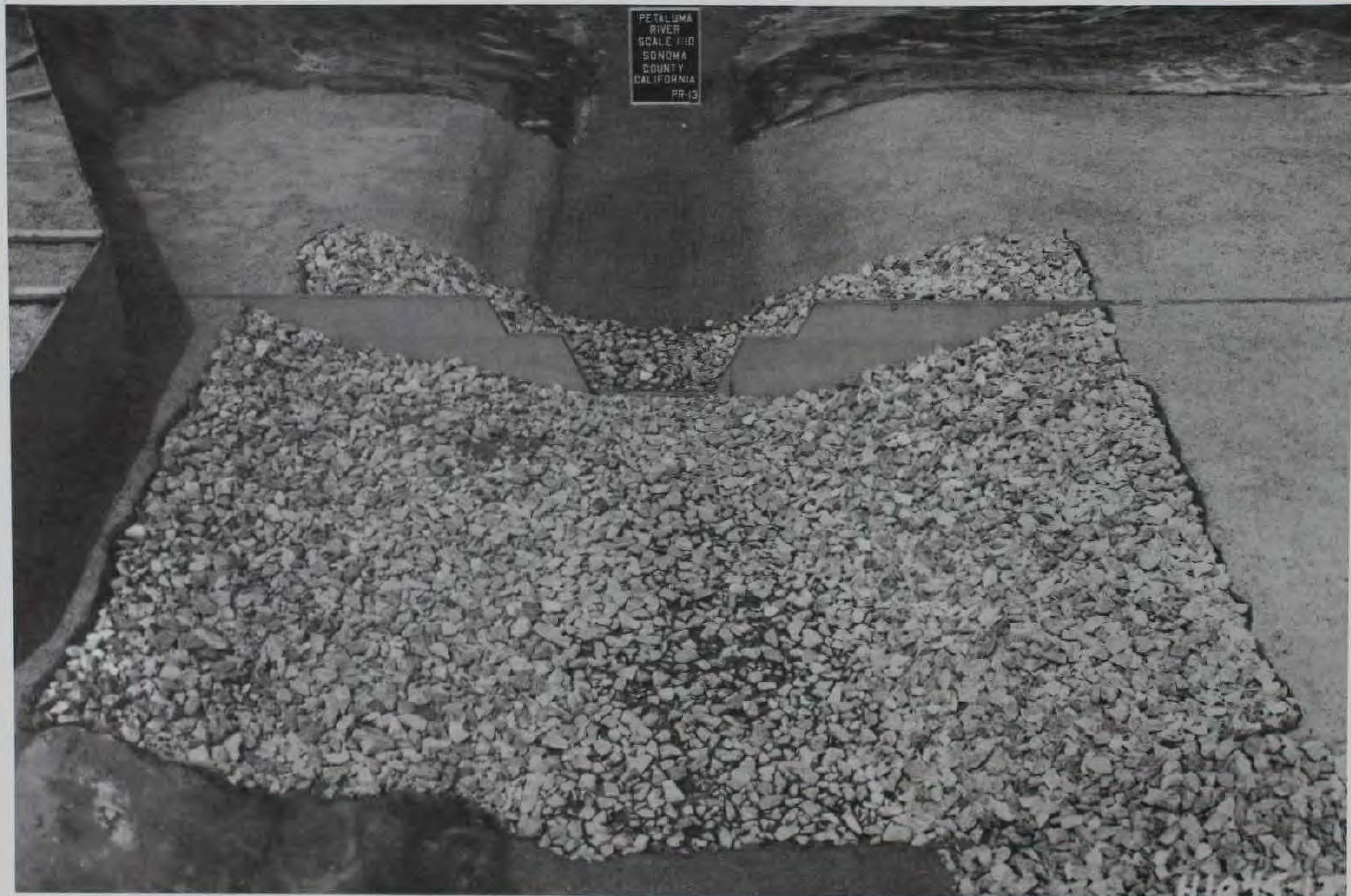


Figure 11. Type 2 riprap design, upstream view

Table 1
Hydraulic Conditions

Event, Years	Discharge cfs	Discharge m^3/sec	Headwater El, ft	Tailwater El, ft
2	1,150	32.6	6.88	5.99
10	3,740	105.9	13.71	11.39
40	7,070	200.2	17.66	15.25
100	8,860	250.9	18.37	17.39

Table 2
Weir Designs, Types 1, 2, 3, and 4

Event, Years	Discharge		Measured			Computed		
	cfs	m^3/sec	Tailwater El, ft	Headwater El, ft	Difference, ft	Tailwater El, ft	Headwater El, ft	Difference, ft
Original (Type 1)								
2	1,150	32.6	5.82	6.97	1.15	5.99	6.88	0.89
10	3,740	105.9	11.42	13.12	1.70	11.39	13.71	2.32
40	7,070	200.2	15.33	16.31	0.98	15.25	17.66	2.41
100	8,860	250.9	17.40	18.16	0.76	17.39	18.37	0.98
Type 2								
2	1,150	32.6	Not Tested			5.99	6.88	0.89
10	3,740	105.9	11.42	13.77	2.35	11.39	13.71	2.32
40	7,070	200.2	15.32	16.47	1.15	15.25	17.66	2.41
100	8,860	250.9	Not Tested			17.39	18.37	0.98
Type 3								
2	1,150	32.6	Not Tested			5.99	6.88	0.89
10	3,740	105.9	Note Tested			11.39	13.71	2.23
40	7,070	200.2	15.32	17.02	1.70	15.25	17.66	2.41
100	8,860	250.9	Not Tested			17.39	18.37	0.98
Type 4								
2	1,150	32.6	5.82	7.07	1.25	5.99	6.88	0.89
10	3,740	105.9	11.42	13.77	2.35	11.39	13.71	2.32
40	7,070	200.2	15.32	17.42	2.10	15.25	17.66	2.41
100	8,860	250.9	17.40	18.67	1.25	17.39	18.37	0.98

Photo 1. Riprap failure, downstream general view; discharge 350.5 m^3/sec (1,150 cfs); headwater el 2.10 m (6.88 ft); tailwater el 1.83 m (5.99 ft)

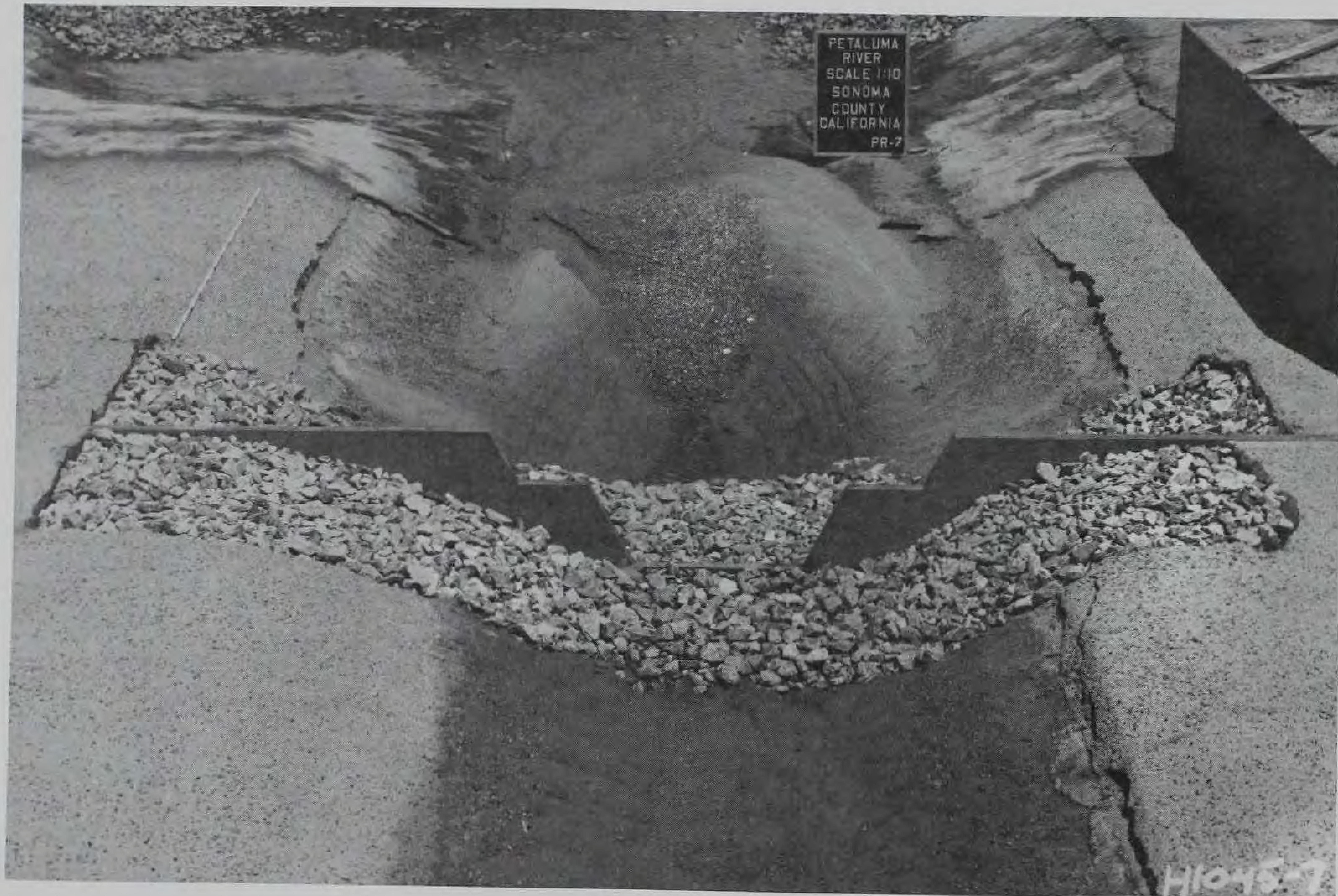


Photo 2. Riprap failure, downstream view; same flow conditions as shown in Photo 1

Photo 3. Riprap failure, upstream general view; same flow conditions as shown in Photo 1

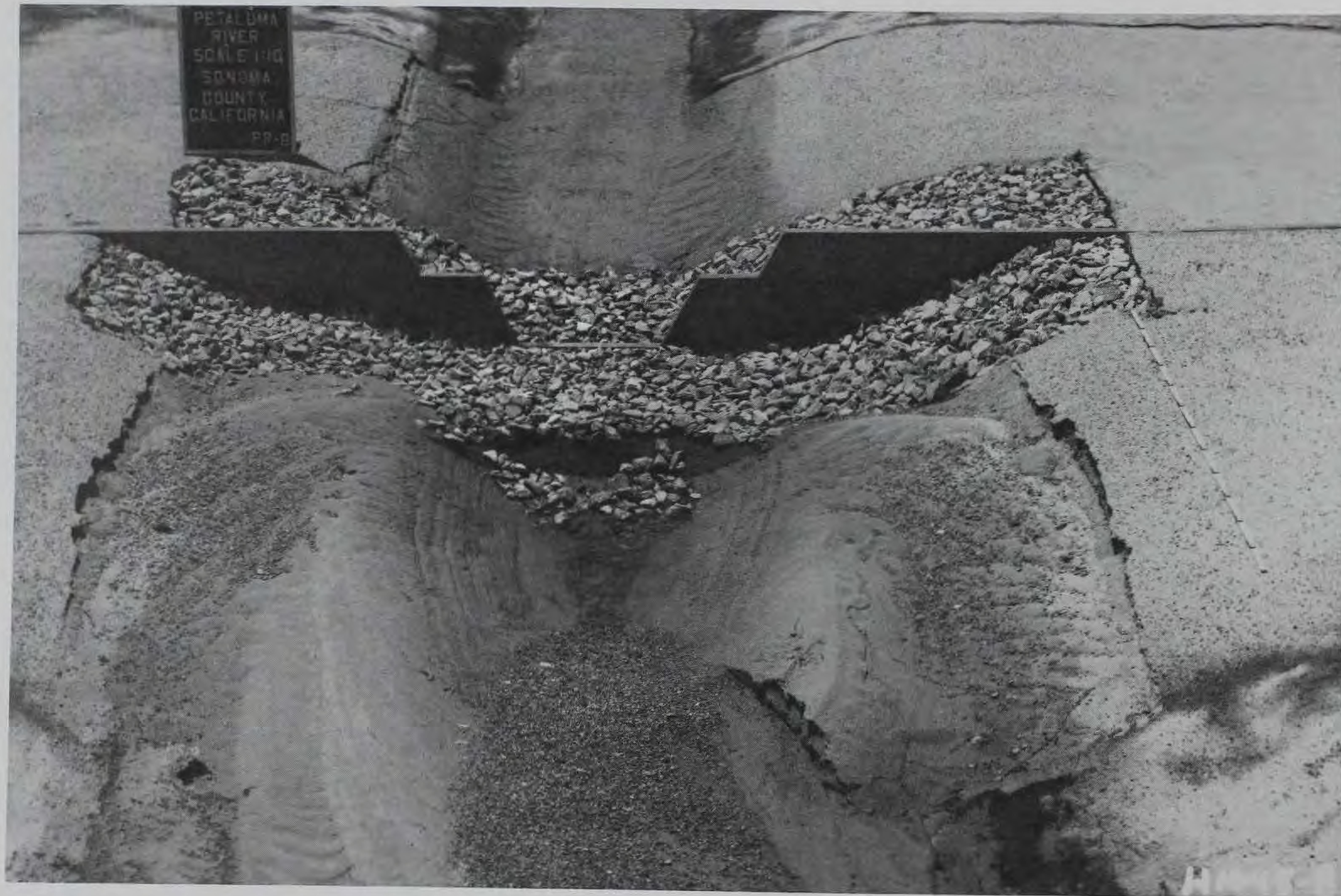
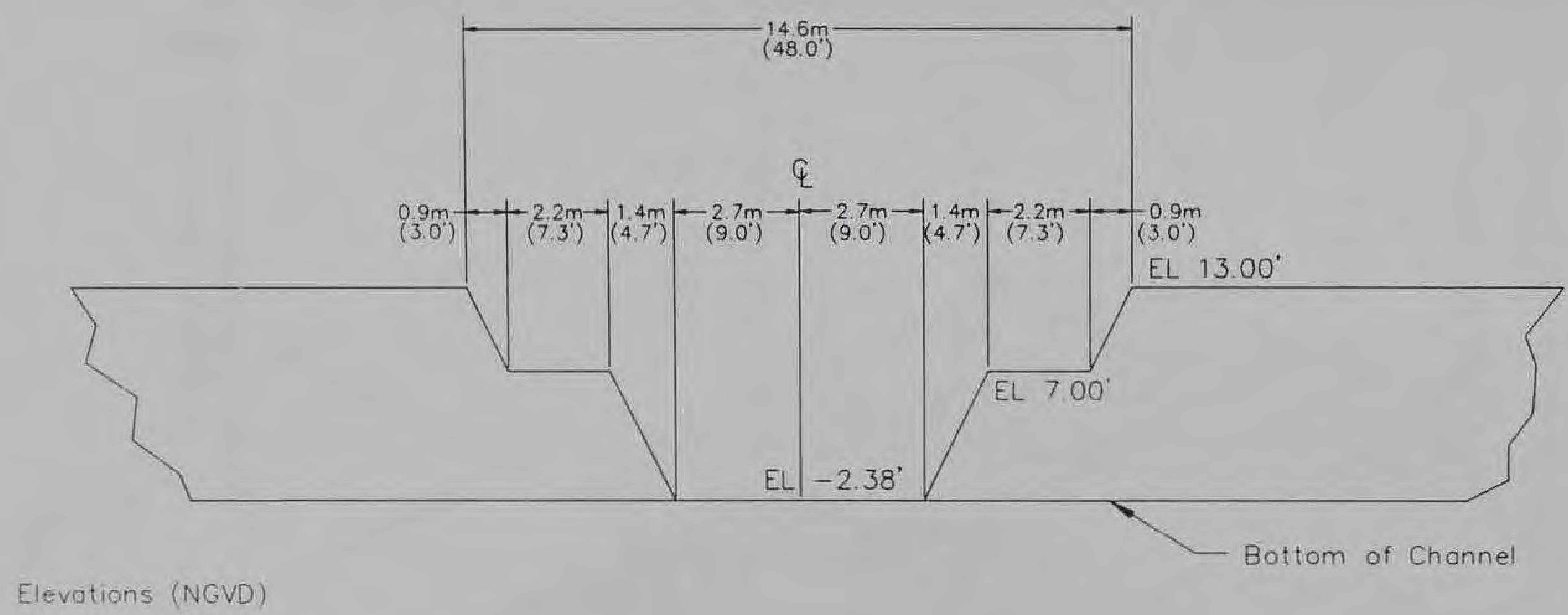
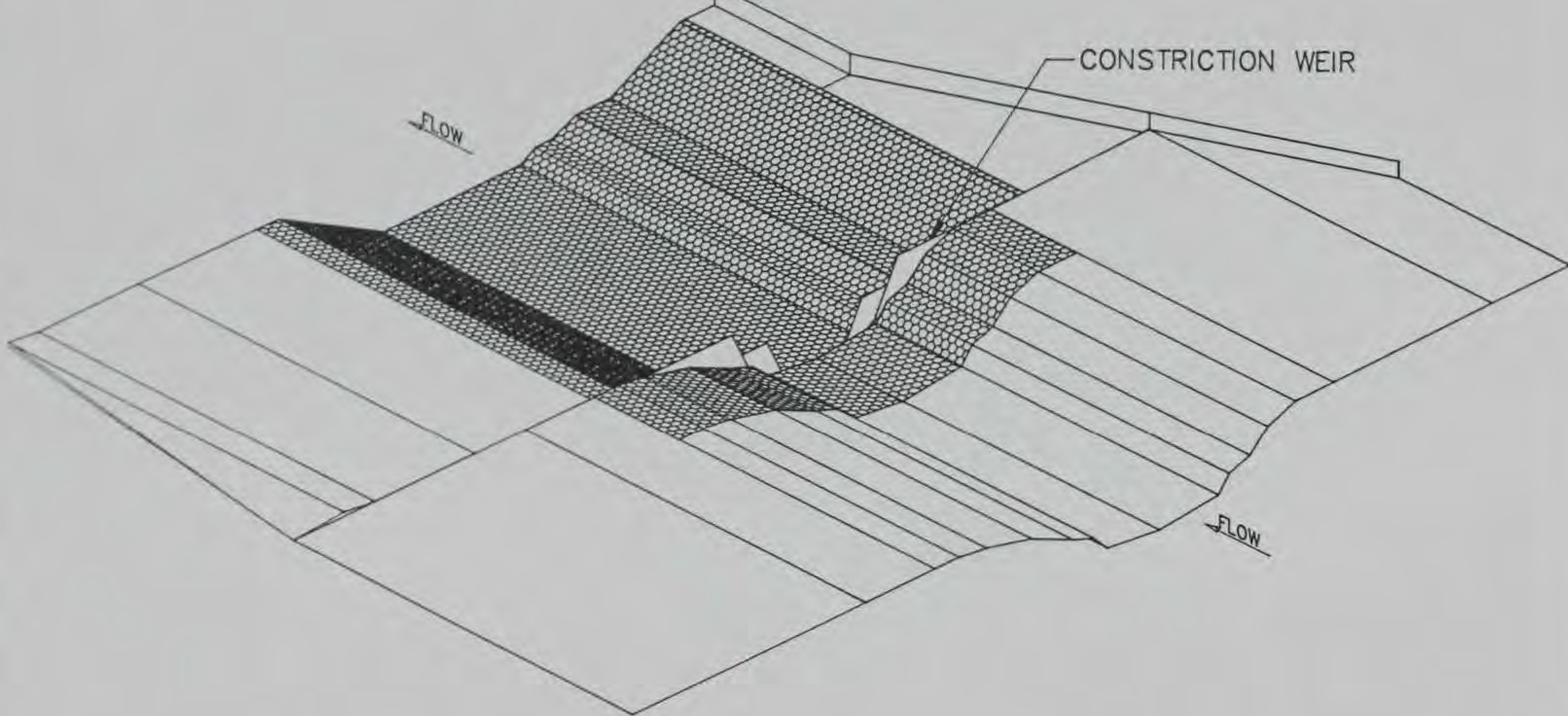


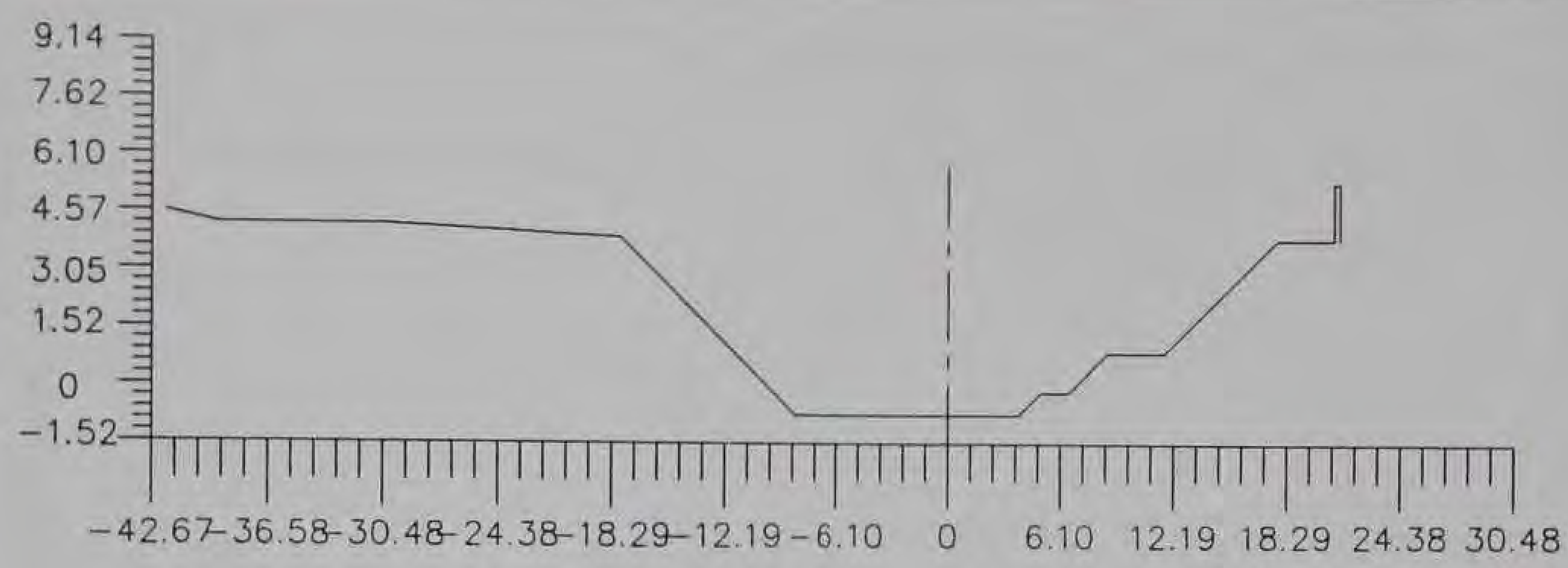
Photo 4. Riprap failure, upstream view; same flow conditions as shown in Photo 1



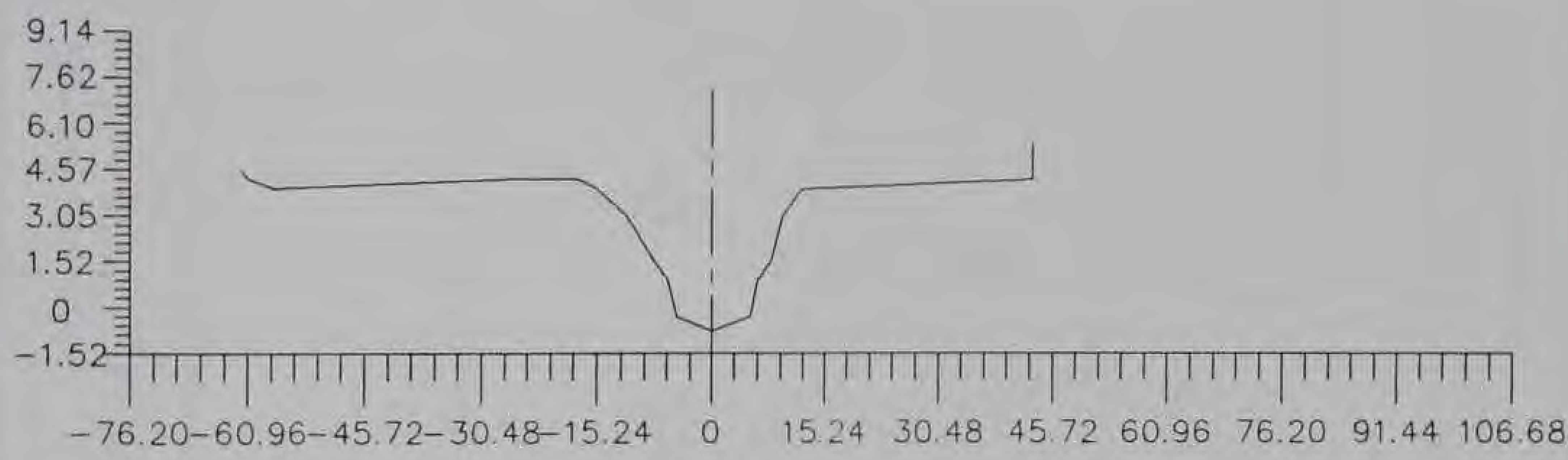
TYPE 1 WEIR DESIGN



MODEL OF PETALUMA CONSTRICTION WEIR



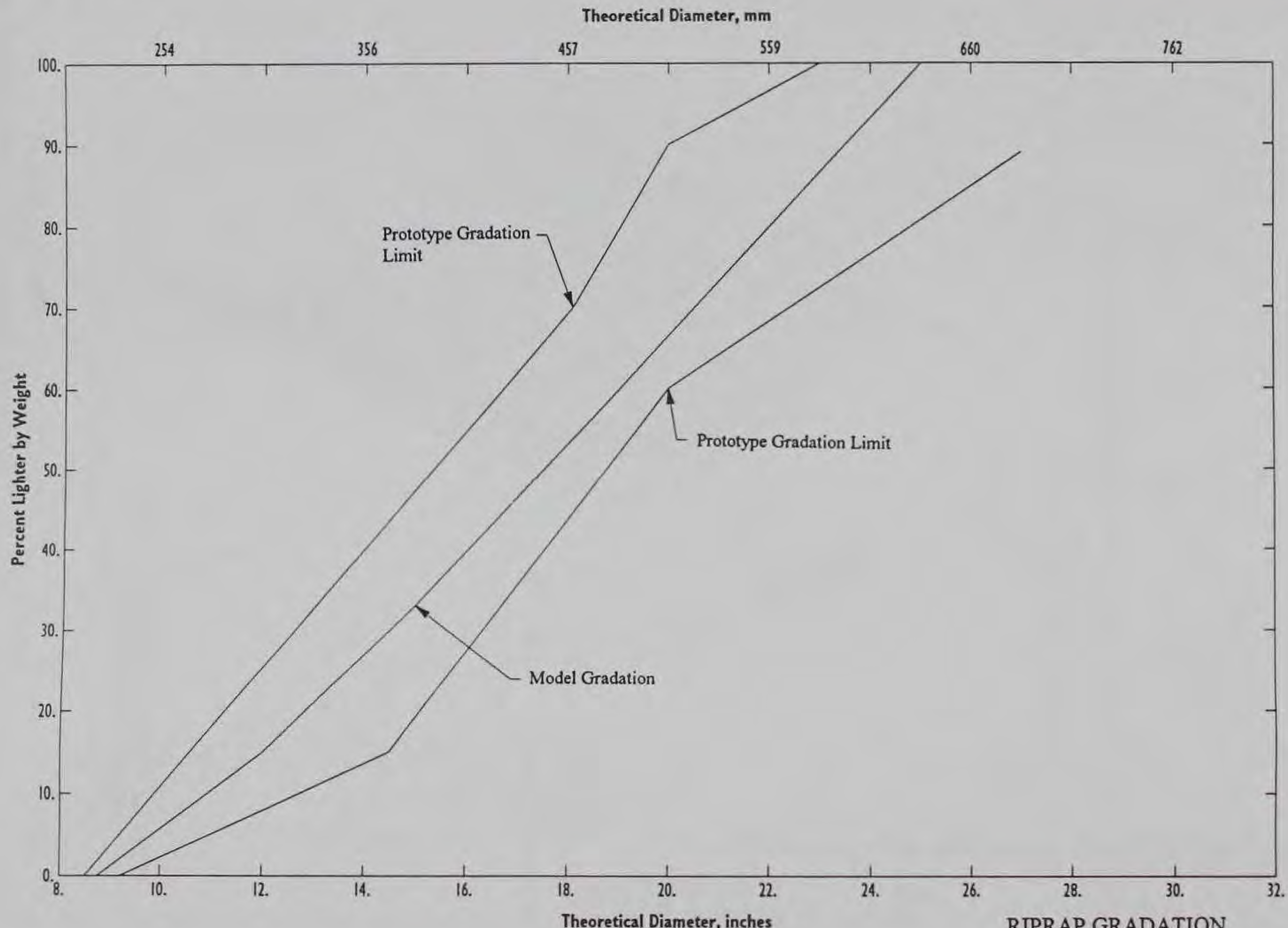
SECTION A-A



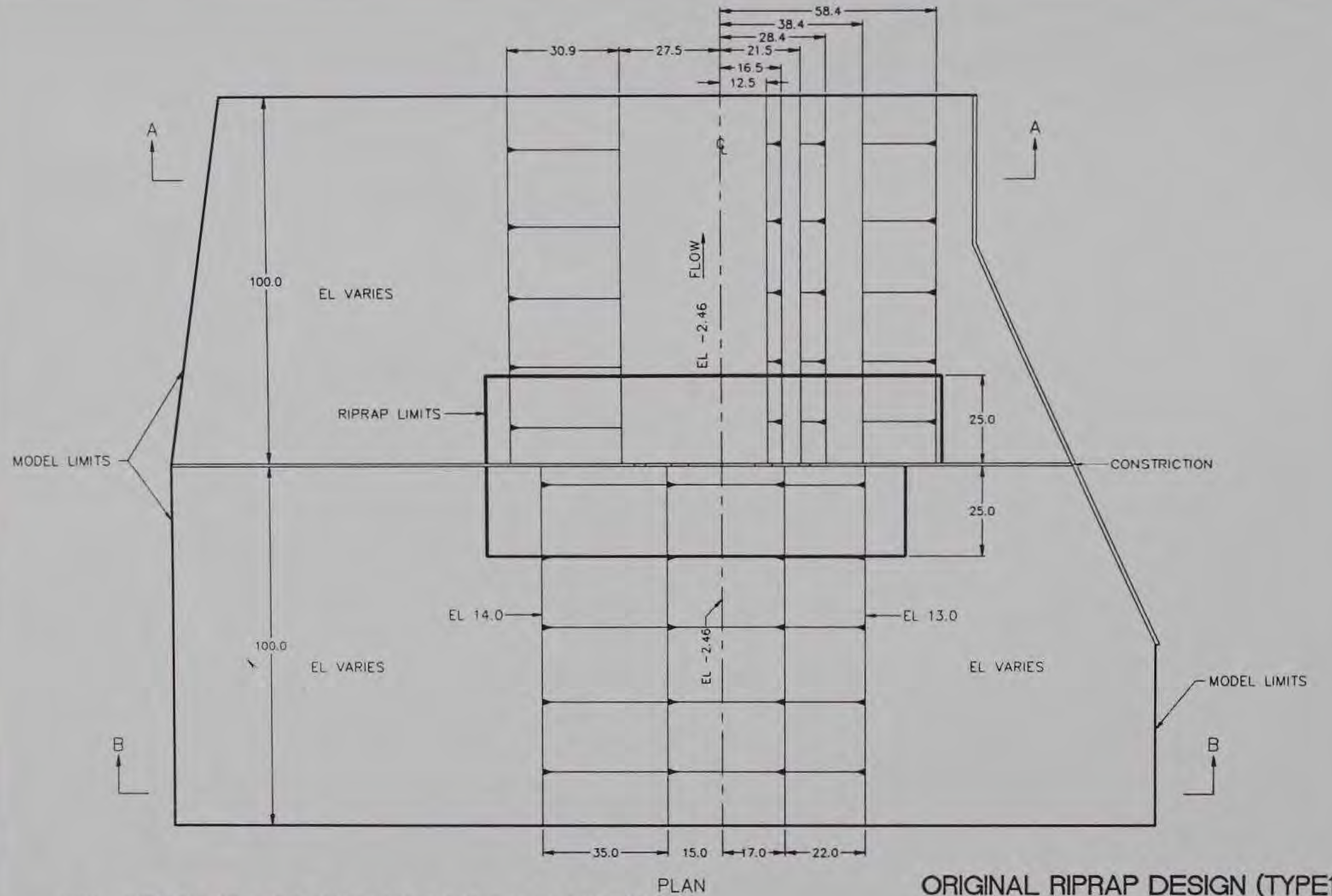
SECTION B-B

Note: Sections are from Plates 5 and 6.
Dimensions are in meters.

PETALUMA
SECTIONS UPSTREAM AND DOWNSTREAM
OF CONSTRICTION WEIR



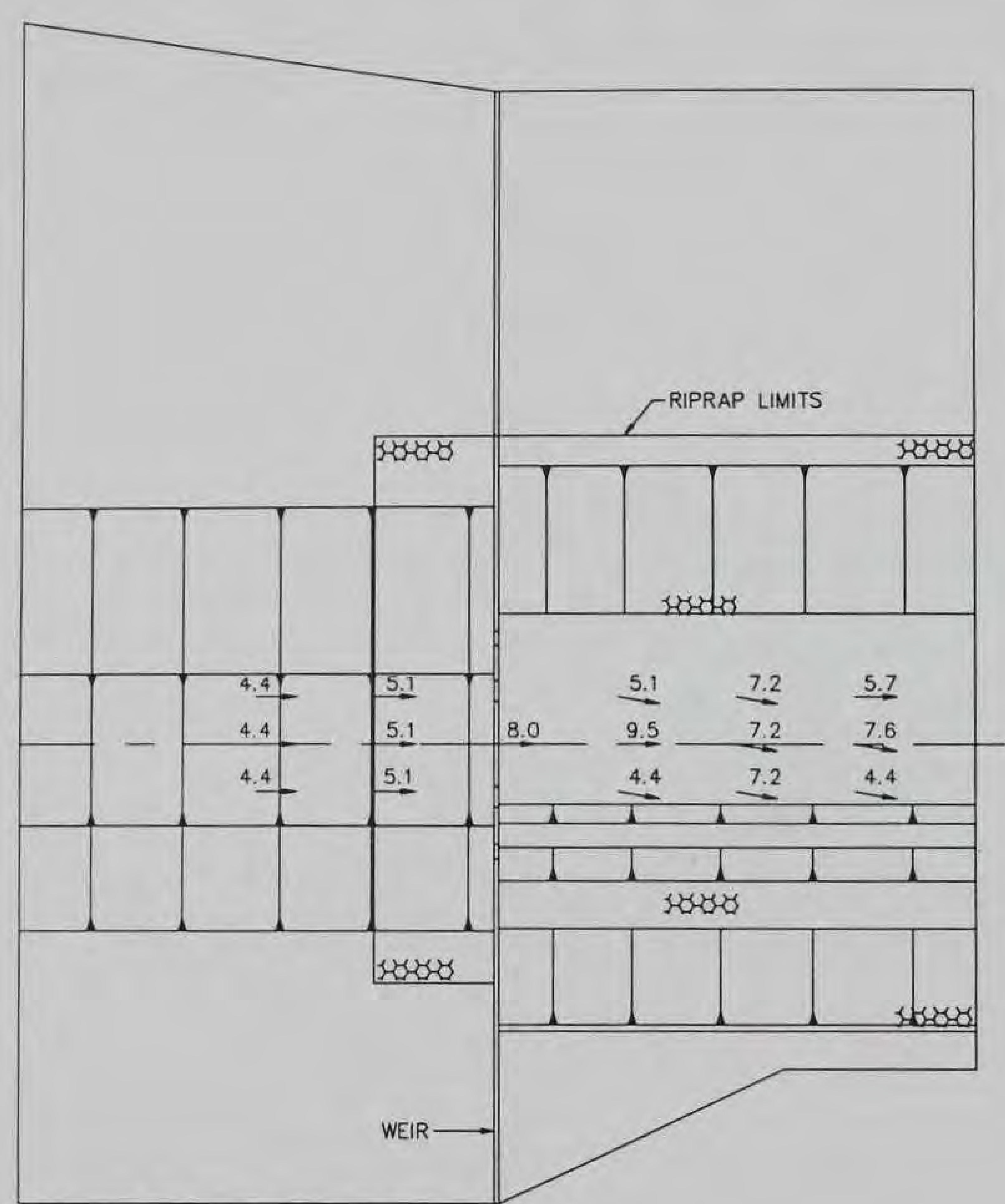
RIPRAP GRADATION



NOTE: DIMENSIONS ARE IN FEET. TO CONVERT TO METERS, MULTIPLY BY 0.3048.

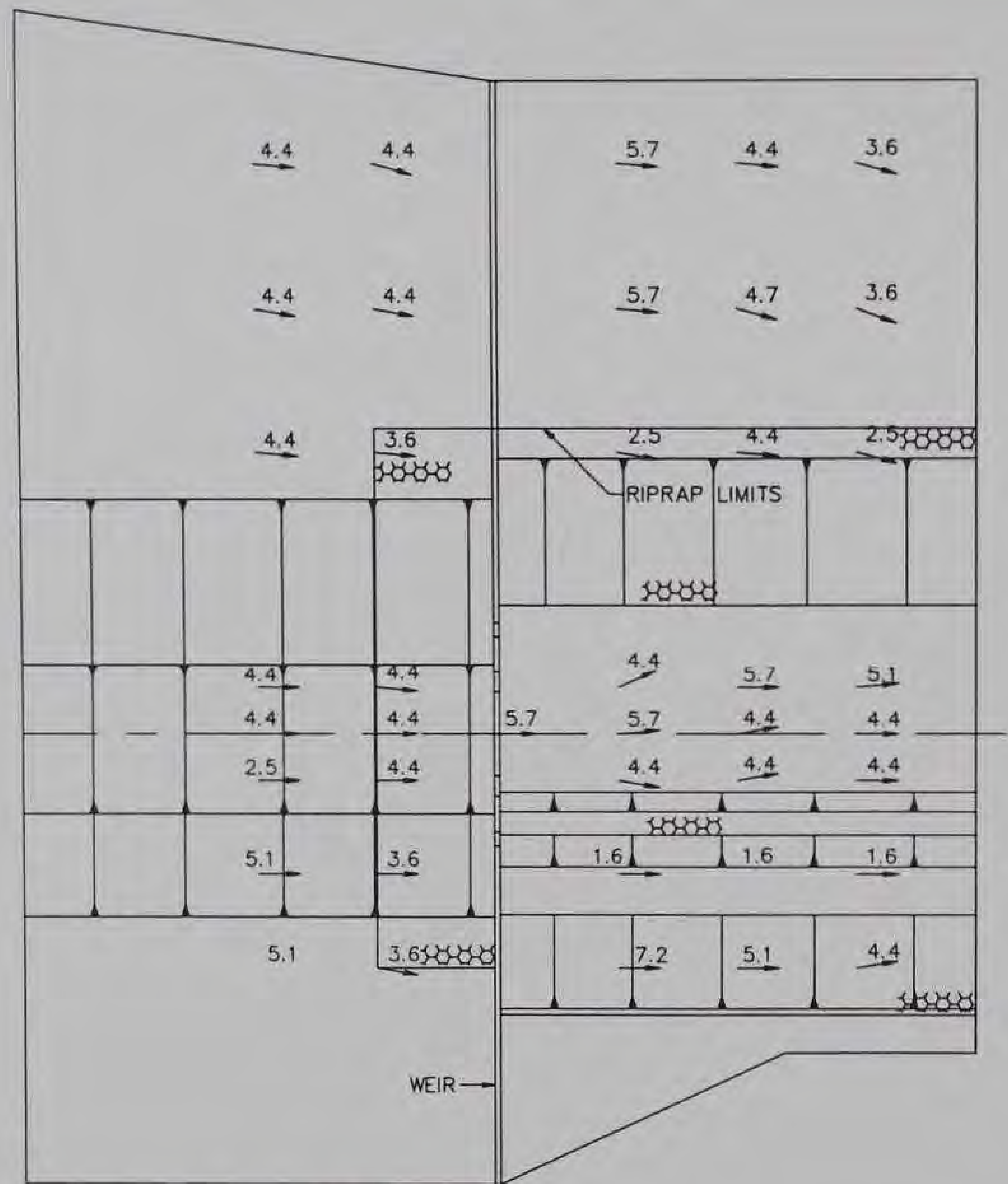
ORIGINAL RIPRAP DESIGN (TYPE1)

Plate 8



NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

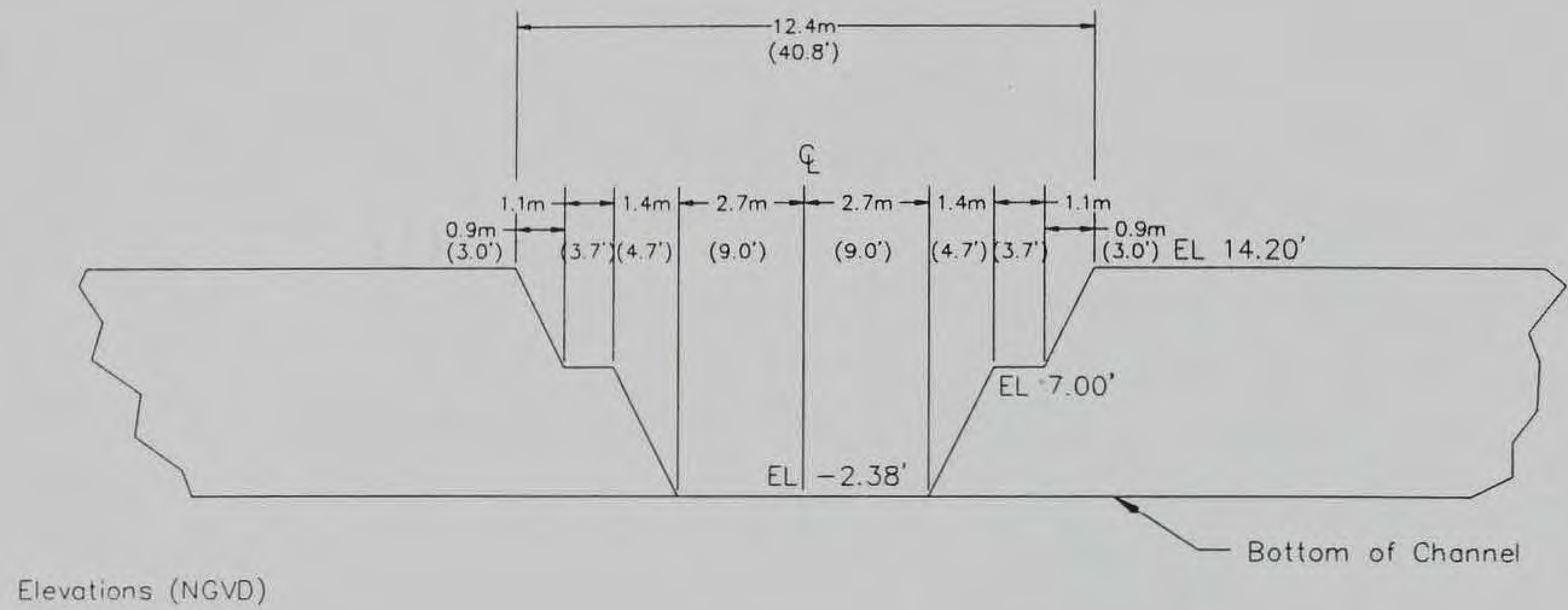
TYPE 1 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
10 YEAR EVENT



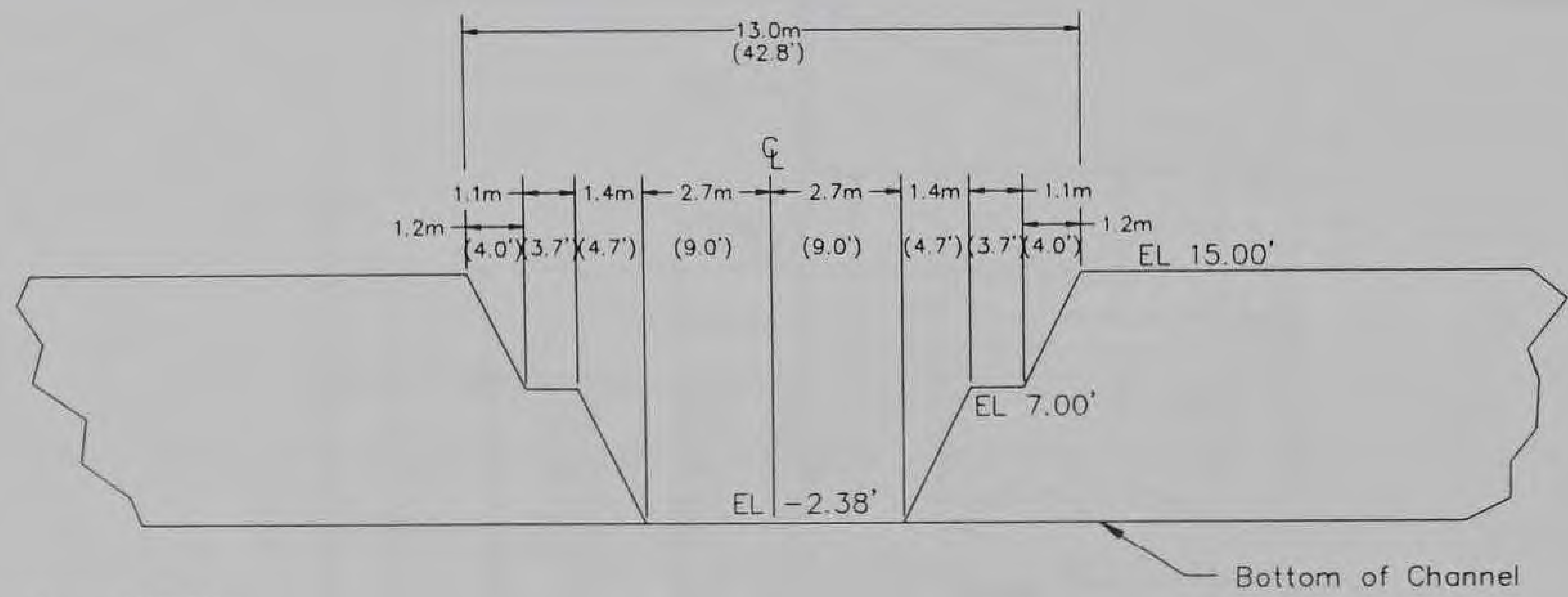
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 1 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
40 YEAR EVENT

Plate 12

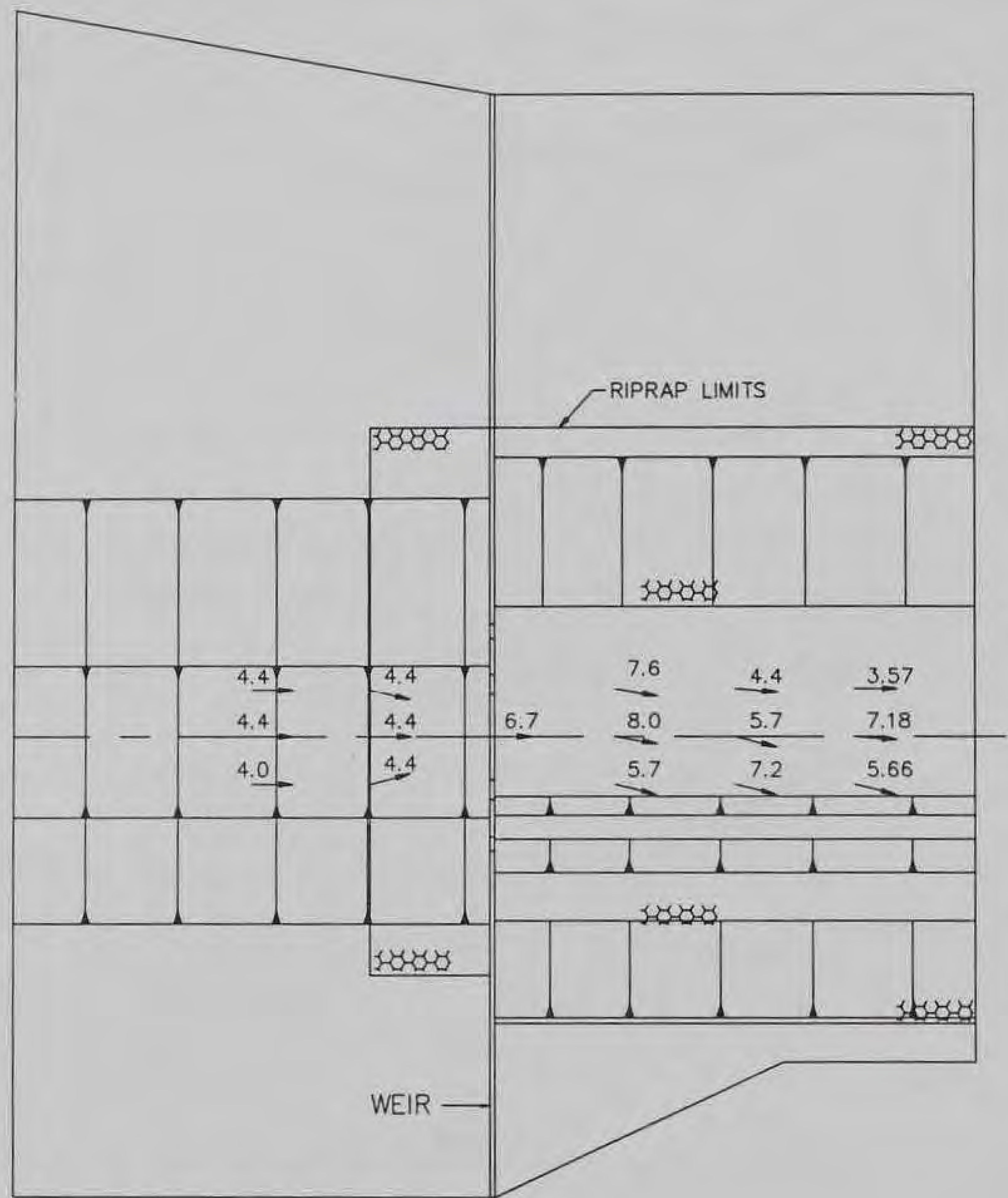


TYPE 3 WEIR DESIGN



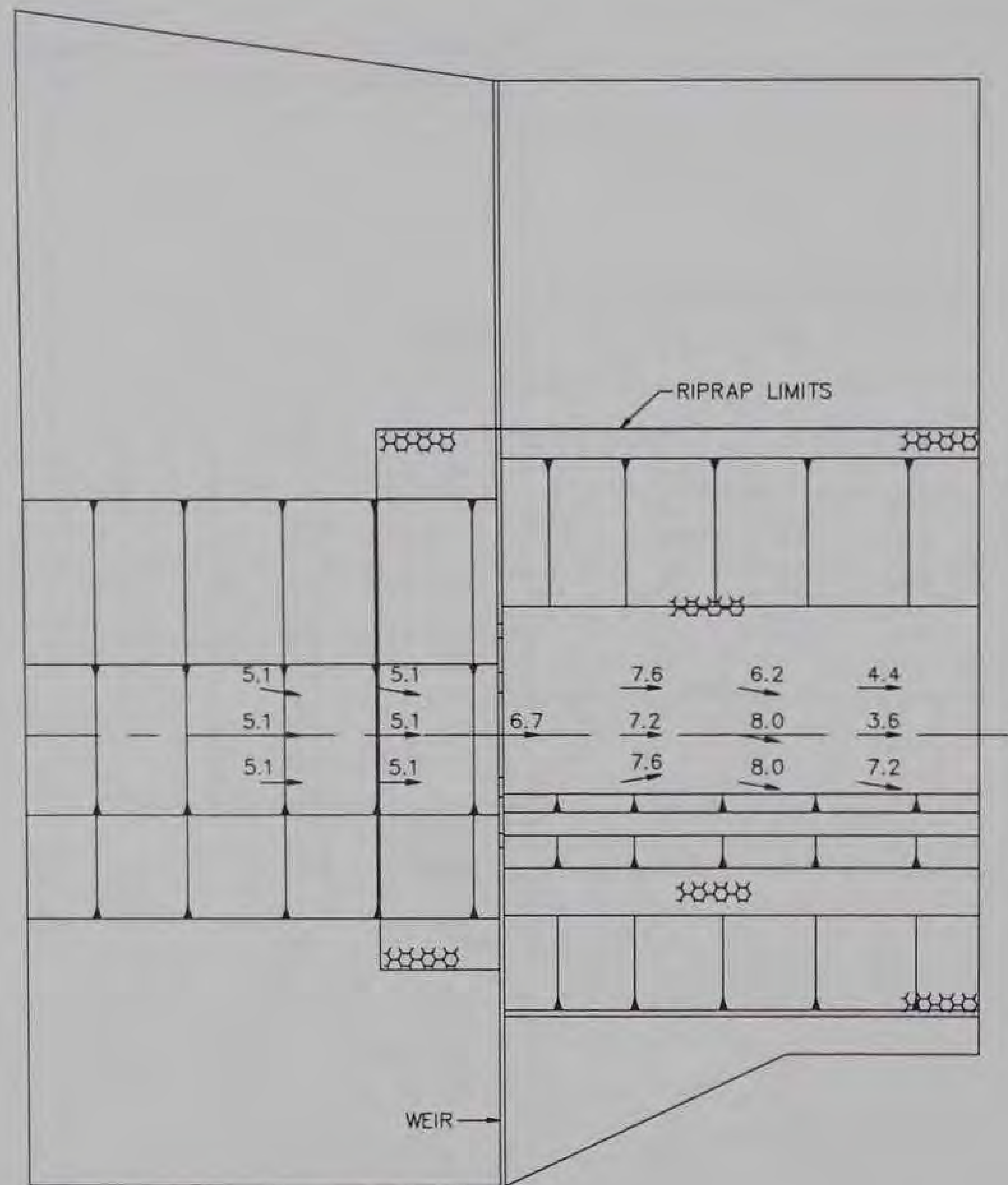
Elevations (NGVD)

TYPE 4 WEIR DESIGN



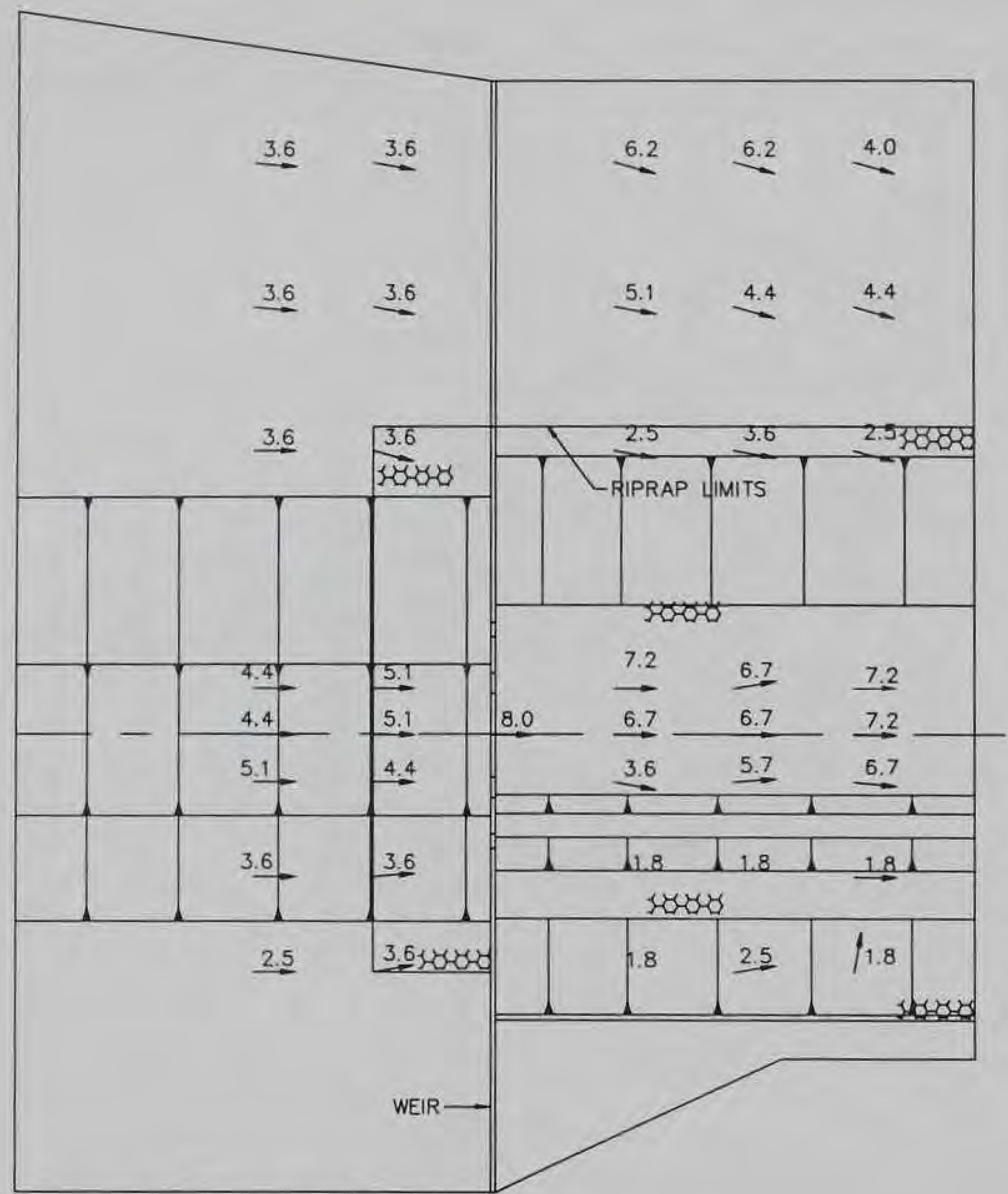
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 4 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
2 YEAR EVENT



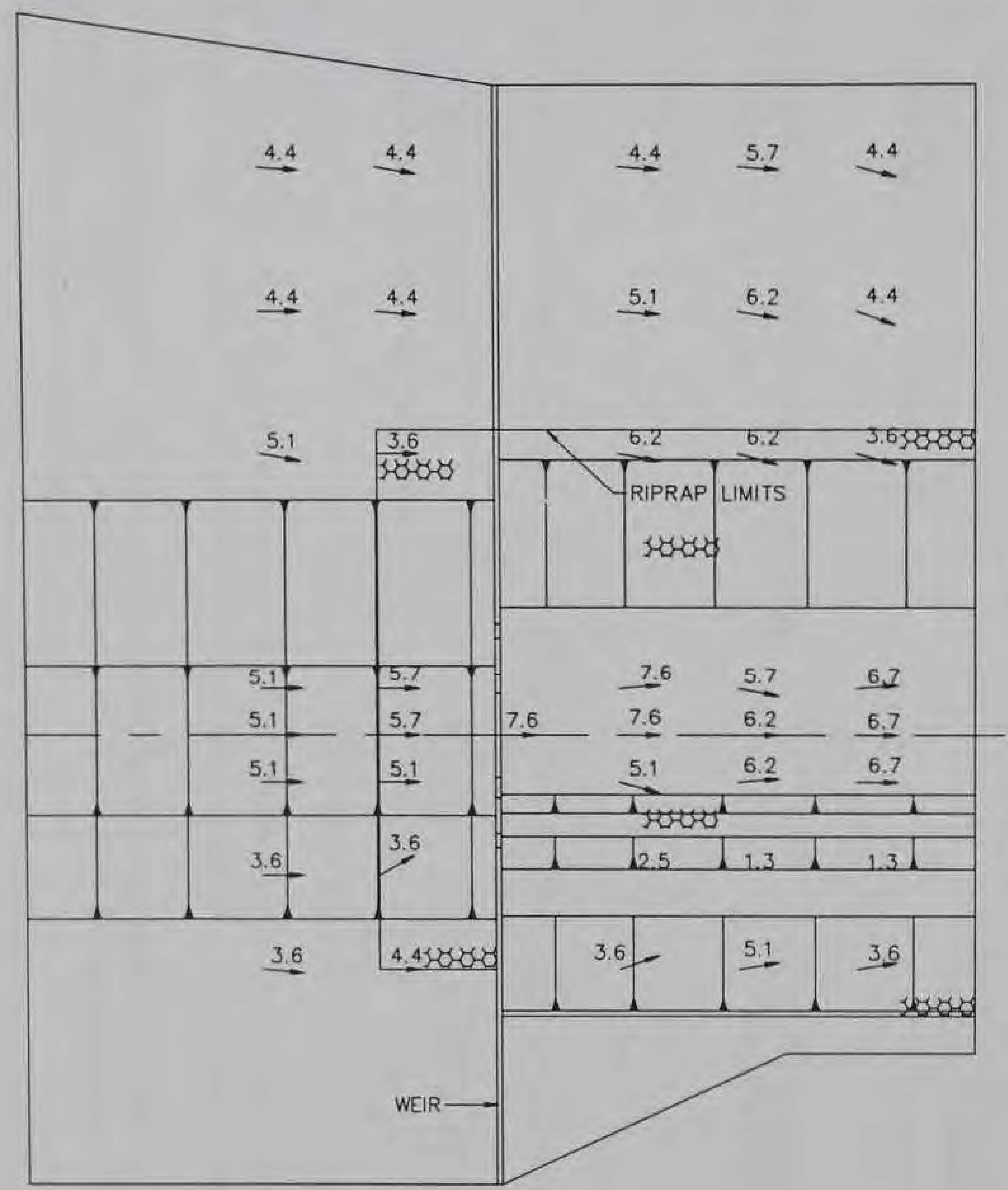
NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 4 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
10 YEAR EVENT



NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 4 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
40 YEAR EVENT



NOTE: VELOCITIES ARE IN PROTOTYPE FT PER SEC, MEASURED 1 FT ABOVE THE BOTTOM. TO CONVERT TO M/SEC. MULTIPLY BY 0.3048

TYPE 4 WEIR DESIGN
TYPE 2 RIPRAP DESIGN
100 YEAR EVENT

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13. ABSTRACT *(Maximum 200 words)*

The model study was conducted to validate the preliminary design of the constriction weir, to modify the weir dimensions as necessary to provide the desired upstream water-surface elevations, and to determine if the riprap protection blanket was adequately sized.

The 1:10-scale model indicated the need for extending the riprap blanket downstream from the weir to ensure protection of the streambed inside the reach of the modeled area. It was also necessary to modify the constriction weir to achieve the desired upstream water-surface elevations and erosion protection.

For the flow conditions tested, the riprap blanket and constriction weir design presented will provide erosion protection.

14. SUBJECT TERMS

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Constriction weir	Riprap

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