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HYDRAULIC MODEL INVESTIGATION

TECHNICAL REPORT NO. 188-1

Blue River Channel Improvement Project at Kansas City, Missouri

SPONSORED BY
U. S. ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT

CONDUCTED BY
DIVISION HYDRAULIC LABORATORY
U. S. ARMY CORPS OF ENGINEERS
NORTH PACIFIC DIVISION
BONNEVILLE, OREGON

AUGUST 1984

US Army Corps of Engineers
Seattle District

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER
Technical Report No. 188-1

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*
BLUE RIVER CHANNEL IMPROVEMENT PROJECT AT
KANSAS CITY, MISSOURI,
Hydraulic Model Investigation

5. TYPE OF REPORT & PERIOD COVERED
Final Report

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Army Engineer Division, North Pacific
Division Hydraulic Laboratory
Bonneville, Oregon 97008

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Engineer District, Kansas City
700 Federal Building
601 East 12th Street, Kansas City, Missouri 64106

12. REPORT DATE
August 1984

13. NUMBER OF PAGES
116

14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*

15. SECURITY CLASS. *(of this report)*
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Hydraulic Model
Blue River, Missouri
Channel Improvement
Riprap
Bridge loss

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A 1:40-scale model was used to verify design of the Blue River Channel Improvement Project through a highly developed area of Kansas City, Missouri. Eleven bridges located within the project reach complicated hydraulic conditions within the channel. The report describes various bridge and pier modifications tested to improve these flow conditions.

Tests made to evaluate the proposed channel riprap design are also described.

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PREFACE

Model studies of the Blue River channel improvement project were authorized by the Office of Chief of Engineers, on 24 October 1979 at the request of the U.S. Army Engineer District, Kansas City. Model studies were conducted at the Division Hydraulic Laboratory, U.S. Army Engineer Division, North Pacific, during the period July 1980 to February 1982.

The studies were conducted by Mr. A. G. Nissila who was assisted by Mr. R. R. Stocker under the direct supervision of Mr. R. L. Johnson. The Director of the Laboratory was Mr. P. M. Smith. This report was prepared by Mr. M. M. Kubo, Hydraulics Section, U.S. Army Engineer District, Seattle.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.0283168	cubic metres per second
pounds (mass)	0.4535924	kilograms

BLUE RIVER CHANNEL IMPROVEMENT PROJECT AT KANSAS CITY, MISSOURI

Hydraulic Model Investigations

PART I: INTRODUCTION

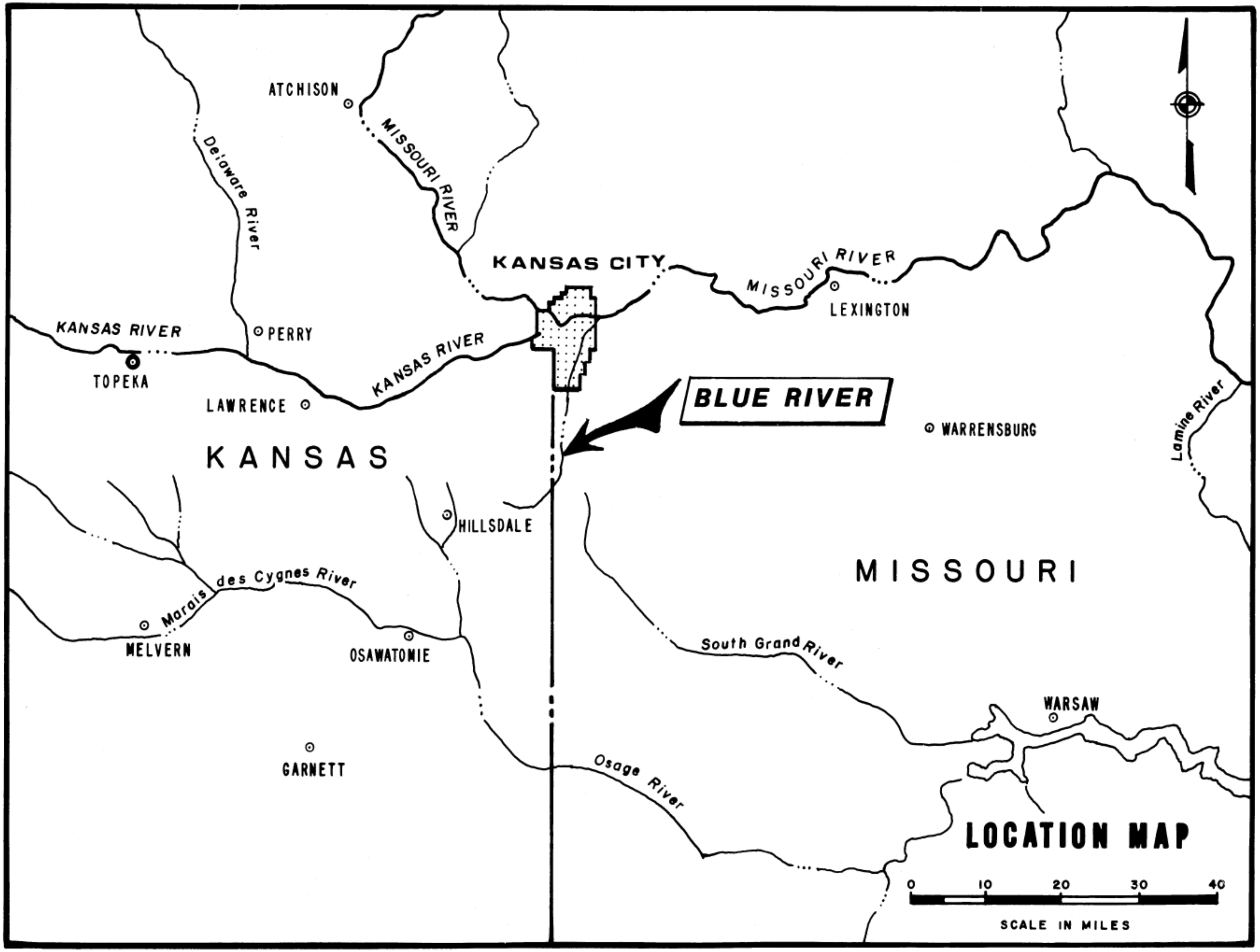
The Project

1. The Blue River--frequently referred to as the Big Blue River for clarification from its neighboring Little Blue River—is a right-bank tributary of the Missouri River (figure 1). The project consists of improving the existing channel from its confluence with the Missouri River upstream for approximately 12 river miles (plate 1).

2. A major portion of the project is in a highly congested industrial area with numerous street, highway, and railroad bridges. Space permitting, the improved channel would consist of an earth-cut section with riprap as required. In more-confined areas the channel would be a rock shell section with steeper side slopes and narrower top width. A concrete-lined channel would be provided in the vicinity of the Armco rolling mill where rights-of-way are not available for an earth-cut or rock shell section.

3. The channel improvements were designed for a discharge of 35,000 cfs with a coincident 10-year-frequency flood on the Missouri River. The design discharge represents approximately a 30-year-frequency flood. The water surface profile used for design of the project was based on a step-method energy balance computation which considered the Manning friction factor value "n" to range from 0.012 in the concrete-lined section to 0.06-0.10 at timberlines or congested overbank areas.

Figure 1


ATCHISON
MISSOURI RIVER
Delaware River
KANSAS CITY
MISSOURI RIVER
LEXINGTON
KANSAS RIVER
PERRY
KANSAS RIVER
TOPEKA
LAWRENCE
BLUE RIVER
WARRENSBURG
Lamine River
KANSAS
HILLSDALE
MISSOURI
Marais des Cygnes River
MELVERN
OSAWATOMIE
South Grand River
WARSAW
GARNETT
Osage River
LOCATION MAP
0
10
20
30
40
SCALE IN MILES

Need for Model Studies

4. The design for channel improvement of the Blue River was in accordance with sound engineering procedures; however, the need for a model study was considered essential due to significant energy dissipation problems expected at some bridge locations with the possible occurrence of a hydraulic jump under certain conditions. Final design configurations of the bridges affected were to be dictated by results of the model study. The model study was considered essential to insure the integrity of the channel design while attempting to minimize the real estate requirements by the city of Kansas City.

PART II: THE MODEL

Description

5. Constructed to a scale ratio of 1:40, the model included the 3,443-foot-long concrete-lined channel section adjacent to the Armco rolling mill, 4,322 feet of rock shell channel, 609 feet of grouted riprap channel followed by 2,397 feet of rock shell and earth-cut channel, and the overbank flow area in the Armco rail yard adjacent to the concrete channel. The reach modeled contained 11 bridges and the Independence Avenue overpass in the rail yard. The area was bounded by high ground and buildings of the steel mill that acted as principal flow boundaries. The main study area was at bridges B-5 and B-6, which were located at the downstream end of the concrete channel. The bridges had large skewed piers in the channel and were located in the middle of a curve that extended into the riprapped channel downstream. Details of the model as originally studied are shown on photographs 1 through 11 and plates 2 and 3.

6. The model was supported by wood or steel stringers between pipe and timber bents that could be adjusted vertically as required. The channel and overbank topography were constructed of concrete grout. All bridges were constructed of plastic and fine-finished painted wood. The section simulating the concrete-lined channel was slope corrected for a discharge of 35,000 cfs and finished with epoxy paint to compensate for the excessive roughness of the model. The rock shell channel was roughened with concrete stipple and small rock, and brushy overbank areas were roughened with cubes of rubberized hair (photograph 9). All buildings were made of styrofoam blocks that were cut to shape.

7. The model was calibrated by varying the roughness of each reach so the water surface slope with the design discharge condition (35,000 cfs with tailwater coincident to 10-year flood on the Missouri River) reproduced the water surface computed for that reach (plate 4). The slope correction incorporated into the concrete channel reaches was slightly greater than required and these reaches were roughened with small gravel (photograph 12) to reproduce the computed water surface. Model operation prior to testing indicated that the left bank transition from earth cut to rock shell upstream of bridge B-10 and the right bank alinement upstream of bridge B-6 caused flow separation (photograph 13). The abrupt bank sections were redesigned and incorporated into the model as shown on plates 2 and 3 and considered part of the original design for testing.

Scale Relationship

8. The required similitude of the models to the prototype was obtained with the following scale relationship based on the Froude model law:

Dimensions	Ratio	Scale Relationship
Length	$L_r = L_r$	1:40
Area	$A_r = L_r2$	1:1600
Velocity	$V_r = L_r^{1/2}$	1:6.325
Time	$T_r = L_r^{1/2}$	1:6.325
Discharge	$Q_r = L_r^{5/2}$	1:10,119
Roughness	$N_r = L_r^{1/6}$	1:1.849

PART III: TESTS AND RESULTS

Original Design

General Flow Conditions

9. Tests were accomplished to observe general flow conditions in the model with river discharges of 10,000, 20,000, 35,000 (design discharge), 42,000 (50-year discharge) and 52,800 cfs (100-year discharge) with the design tailwater condition (elevation 736) which represents the 10-year frequency Missouri River water surface elevation at the mouth of the Blue River. The 35,000-, 42,000-, and 52,800-cfs dicharges were also observed with a lower than design tailwater condition to determine the affect of tailwater conditions on the design features of the Blue River project. For this latter evaluation, the tailwater used in the model was the minimum that physically occurred in the model with unrestricted outflow for the Blue River discharges tested. The conditions depicted in the model for the low tailwater condition are considered conservative because the tailwater simulated was actually lower than that which would occur in the prototype with backwater from the Missouri River.

10. Water surface profiles with the design tailwater are shown on plate 5. Flow conditions with discharges up to 35,000 cfs (design discharge) were acceptable with the flow generally confined within channel. Although minor flooding occurred over low bank areas in the vicinity of, and downstream from, the grouted riprap section, such flooding in this area was considered acceptable. Small, but acceptable, eddies occurred at numerous locations. Flooding limits, channel velocities and flow conditions with 35,000 cfs flow are shown on plates 6 and 7 and photographs 14 through 16. The floodwall (top elevation 744) protecting the rolling mill along the left bank of the channel between

bridges B-6 and B-7 was not overtopped. Flow in the curves near the upstream end of the floodwall near bridges B-7 and B-7A was superelevated 1.4 and 0.8 feet, respectively. Localized areas of supercritical flow occurred around the main in-channel piers of bridges B-5 and B-6. Overbank flow initially began with a discharge of about 37,000 cfs and occurred along the left bank of the channel between stations 470+00 and 490+00 (bridge B-10). Extensive overbank flooding through the rail yard on the right bank of the channel between stations 490+00 and 528+00 (bridge B-7) occurred with a discharge of approximately 40,000 cfs. Flow conditions with a discharge of 42,000 cfs (50-year flood) are shown on plates 8 and 9 and photographs 17 through 19. The entire length of the floodwall at the rolling mill was overtopped. With a discharge of 52,800 cfs (100-year flood), the entire area modeled was flooded. As shown on plates 10 and 11, water overtopped the right bank near station 487+00 (just upstream from bridge B-10) with velocities of 7 to 8 fps, flowed overland through the rail yard with velocities up to 11 fps, and reentered the main channel at numerous locations between stations 500+00 and 545+00. Photographs 20 through 22 show flow conditions along the channel reach.

11. Channel flow was subcritical with all discharges tested in the model. The maximum capacity of the low-flow channel of the concrete section of the project was determined to be 315 cfs at which time water was at full depth near the upstream end of the low-flow channel.

12. Water surface profiles in the channel with the minimum possible model tailwater are shown on plate 12. With Blue River discharges of 35,000, 42,000, and 52,800 cfs, the minimum model tailwater was 7.7, 6.8, and 6.1 feet lower than the design tailwater condition, respectively. Flow conditions with the various

discharges tested are shown on plates 13 though 18. With the design discharge--35,000 cfs--flow was confined to the channel and bottom velocities in the earth-cut section between stations 555+00 and 577+00 ranged from about 8 to 19 fps. This was approximately a 40-percent increase over velocities which occurred through that reach with the design tailwater condition. Overbank flow conditions through the rail yard with discharges of 42,000 and 52,800 cfs were similar to those which existed with the design tailwater except that water depths with the low tailwater condition were about 0.5 foot less.

Bridges

13. Flow conditions around the numerous bridges existing in the project area were of primary interest in the model study. Tests were accomplished with discharges of 35,000, 42,000, 52,800, and 71,000 cfs to evaluate effects of bridge piers and pier modifications, debris accumulations at bridge openings, and bridge failures. The 71,000-cfs discharge was approximately the maximum that could be contained in the model and is considered representative of the standard project flood for that portion of the river valley represented by the model.

14. With the design discharge and tailwater, flow impinged on bridges B-4, B-6, B-7, B-7A, and B-10. Flow conditions at bridges B-4, B-5, B-6, and B-10 are shown on photographs 23 and 24. Plates 19 through 25 show water surface cross sections both up and downstream from bridges B-4, B-5, B-6, B-7, B-7A, B-8, and B-10 for various discharges with the design tailwater condition. Bridge head loss from the upstream side of B-6 to the downstream side of B-5 with the design discharge and tailwater was 2 feet and increased to 4.4 feet with the minimum tailwater condition.

15. Flow conditions at bridges B-5 and B-6 with their existing piers are shown in photographs 25 and 26 and on plates 26 through 29 for the design discharge with design and minimum tailwaters. The center pier (pier 2) of bridge B-6 was large, blunt nosed, and skewed to the flow near the center of the channel and the large, skewed right pier of bridge B-5 was in its wake. The maximum water surface differential side to side on the B-5 bridge piers was 9 feet with design tailwater and 11 feet with minimum tailwater.

16. Due to the flow impingement and a potential for debris buildup on the bridges, tests were accomplished to determine the effect of failures of bridge B-4 and B-10 upon channel flow conditions. Tests were accomplished with the bridges either on their side (photograph 27) or in an upright position (photograph 28) within the channel. Flow conditions in the immediate vicinity of the bridges with the design discharge and tailwater are shown in photographs 29 and 30. Water surface profiles with the bridges either on their sides or upright in the channel are shown on plates 30 and 31, respectively.

Riprap Protection

17. The model was used to verify the riprap design between stations 552+64 and 564+70 (100 feet downstream from bridge B-4). The model riprap, which had a specific gravity of 2.64 and was graded to simulate the prototype design gradation, was placed on the 1V to 3H side slopes with a thickness of 24 inches. The unprotected channel bottom was modeled as a moveable bed of pea gravel. The criteria used to evaluate riprap performance was that it must withstand a discharge of at least 52,800 cfs (100-year flood) with the minimum tailwater condition simulated in the model. The following three riprap sizes were tested: 18-inch

(D_{50}=11.5 inch), 21-inch (D_{50}=12.6 inch), and 24-inch (D_{50}=15.9 inch). With all three sizes tested, riprap failure occurred near the left abutment of bridge B-4 (photograph 31). The discharges at which the failure occurred were 54,000, 70,000, and 71,000 cfs for the respective 18-, 21- and 24-inch riprap sizes.

18. The original design was for grouted riprap in the channel between stations 546+55 and 552+64. However, loosely placed 18-inch riprap was simulated in the model between stations 549+64 and 552+64 and successfully withstood discharges up to 71,000 cfs with minimum tailwater.

Modifications Tested

Channel

19. Widening of the channel downstream from station 572+00 (bridge B-3) was evaluated as a method of reducing water surface elevations at bridges B-5 and B-6. The widened channel was simulated in the model by reducing tailwater at station 550+00. Tests were accomplished with the tailwater reduced to computed elevations of 740.0 and 745.0 feet (1.3 feet below the design tailwater) for discharges of 35,000 and 52,800 cfs, respectively. This simulated channel widening resulted in a 0.6-foot reduction in water surface elevation just upstream from bridge B-6 (plate 32).

20. The original channel design at bridge B-3 included relocation of an existing Armco mill roadway passing beneath the right span of the bridge (photograph 11). As shown on plates 33 and 34, the relocation had no appreciable affect on flow conditions and was therefore not included in the final design.

21. The original design was modified between stations 546+55 and 552+64 during the model studies by extending the concrete section from station 546+55 to station 546+85, by shortening the transition between the concrete section and the riprap section from 609 feet to 125 feet, by reducing the height of the left bank slope to only the elevation of the existing sewer pipe, and by replacing the grouted riprap with loosely placed riprap (plate 35 and photograph 32). The 24-inch-thick riprap blanket (21-inch rock on the upstream 100 feet and 18-inch rock on the remainder) was placed over a 24-inch bed of pea gravel to simulate a filter to evaluate the potential for riprap failure resulting from leaching of the filter. Previous tests of 18-inch riprap in the transition section indicated that the riprap would withstand discharges up to 71,000 cfs (paragraph 18). With a discharge of 42,000 cfs

and design tailwater, the maximum bottom velocity measured in the modified channel was 13 fps and occurred near the upstream end of the riprapped section (plate 36). The maximum velocity was less than 19 fps with a discharge of 52,800 cfs and minimum tailwater. Failure of the riprap did not occur until velocities reached 19 and 20 fps for the 18- and 21-inch rock, respectively. The model indicated that 18-inch rock was satisfactory throughout the entire riprapped reach of the modified channel.

Bridges

22. Due to the relatively large head loss (2 to 4.4 feet depending on tailwater) which occurred between bridges B-5 and B-6 with design discharge, primary attention was devoted to improving flow conditions through this reach of the channel. Various pier nose shapes and guide vanes were tested on the existing piers of the two bridges. Although the pier nose modifications created some localized flow improvement, none created major improvement across both bridges. With the original-design channel geometry, removal of the bridge piers from the flow decreased the head loss between bridges B-5 and B-6 to 0.5 and 1.9 feet at design discharge with design and minimum tailwater, respectively. With the center pier of bridge B-6 modified to include two circular columns, the head loss across bridges B-5 and B-6 with design conditions was only reduced 0.3 foot from that which occurred with the existing pier. The modification resulted in reducing the water level differential from side to side of the bridge piers from 9 to 6 feet at bridge B-5 and from 5 to 2 feet at bridge B-6, as compared to the original-design pier shape.

23. Following the channel modification discussed in paragraph 21, further studies were accomplished to evaluate flow improvement modifications at bridges B-4, B-5, and B-6. Water surface profiles in the modified channel from downstream of bridge B-4 to

upstream of bridge B-6 were determined with the existing bridges (plate 37) and with various combinations of bridge modifications including (1) improvement (photograph 33) and removal of piers at bridges B-5 and B-6, (2) addition of end spans at bridge B-4 (photograph 34), and (3) addition of streamlined cowls on the upstream bottom girder of the bridges. Plates 38 through 44 and photographs 35 through 43 show water surface profiles and flow conditions with the various improvements tested in the model. As shown in table 1, the largest decrease in water level upstream of bridge B-6 (2.2 feet at design discharge) resulted when the piers of bridges B-5 and B-6 were removed from the flow. Modification of the B-5 and B-6 bridge piers was also relatively successful in decreasing water levels upstream of bridge B-6. Neither addition of end spans to bridge B-4 nor streamlining the upstream bottom girder of the three bridges with 3.5 feet radius quarter-round sections were effective. Cross sectional velocity distribution through bridges B-5 and B-6 with the design discharge (design and minimum tailwater) with bridge piers removed from the flow and with the bridge B-6 pier improved is shown on plates 46 through 48. The water surface profiles along both sides of bridges B-5 and B-6 bridge piers with the B-6 pier improvement are shown on plates 49 and 50 for the design discharge condition with design and minimum tailwater, respectively. Plate 51 illustrates the bridge B-4 cross-sectional water surface profile with end spans added to the bridge.

PART IV: SUMMARY

24. A 1:40-scale model was used to verify design of the proposed Blue River channel improvement project. The model simulated a length of approximately 10,770 feet of channel and 11 bridges with piers and abutments.

25. Initial tests revealed that large head losses occurred through the channel reach between bridges B-5 and B-6. Various bridge pier modifications were tested to improve this condition—the most successful being removal of the bridge piers from the flow.

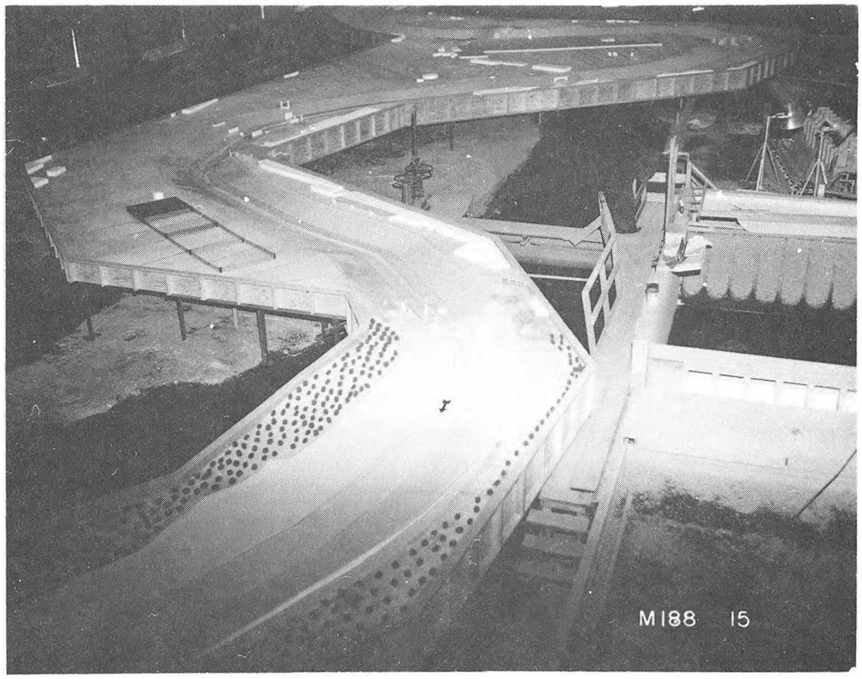
26. Moveable-bed modeling was used to evaluate the ability of the design riprap to withstand design flow conditions. The model showed that the riprap size proposed was satisfactory and indicated areas where grouted riprap could be replaced with loosely placed riprap.

TABLE 1

DECREASE IN WATER LEVEL UPSTREAM FROM BRIDGE B-6 RESULTING FROM VARIOUS BRIDGE MODIFICATIONS

Modification	Decrease from existing, feet		
	Discharge, cfs		
	35,000	42,000	52,800
B-4, added end spans	0.2	0.4	0.2
B-4 end spans; B-5 and B-6 pier modification	1.0	0.9	1.0
B-5 pier modification	0.6	0.8	0.4
B-6 pier modification	0.8	0.6	0.2
B-5 and B-6 pier modification	0.9	0.9	0.5
B-5 and B-6 pier removed from flow	2.2	2.8	3.6
B-4, B-5, B-6 cowled girder	0.1	0.2	——
B-4, B-5, B-6 cowled girder; B-5 and B-6 pier modification	0.8	1.0	0.7

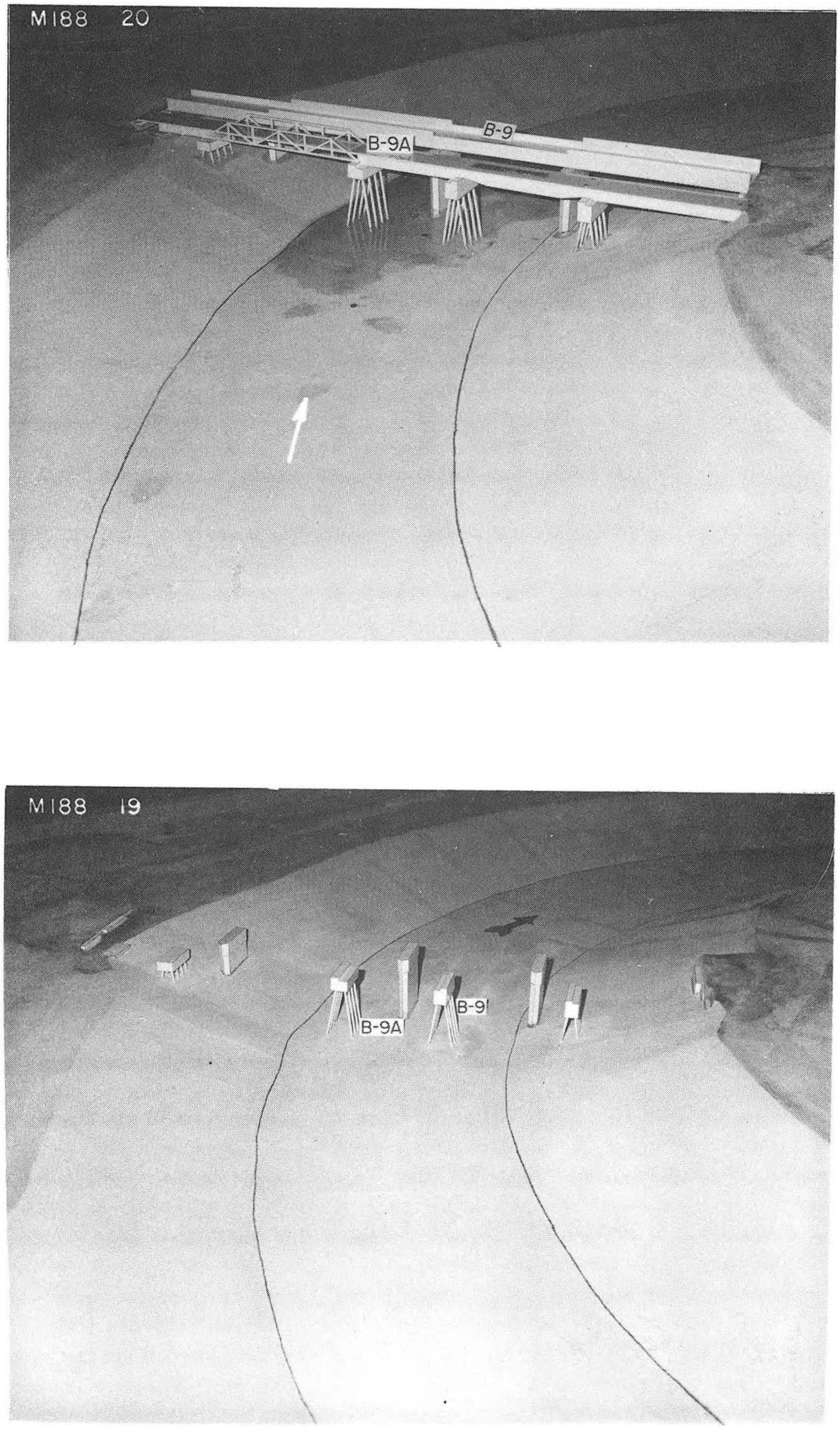
Looking downstream



Looking upstream

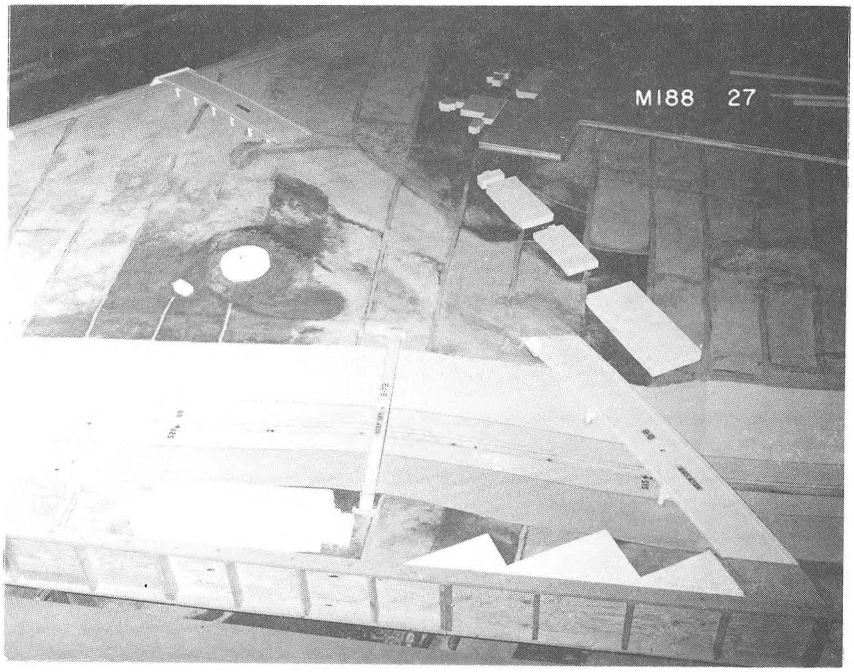
Photograph 1. Blue River Channel model (before final roughness adjustment for verification, bridge superstructure removed to show piers)

Photograph 2. Bridge B-10 and adjacent channel
Electric furnace building in background (upper right)
(Before final roughness adjustment for verification)



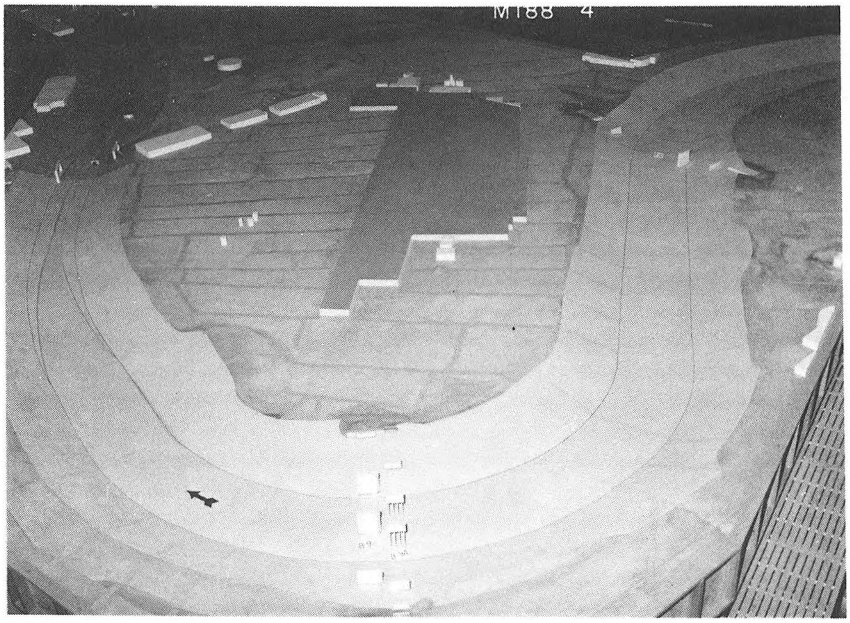
Photograph 3. Bridges B-9 and B-9A and adjacent channel (before final roughness adjustment for verification)

Independence Avenue overpass and railyard
Looking downstream

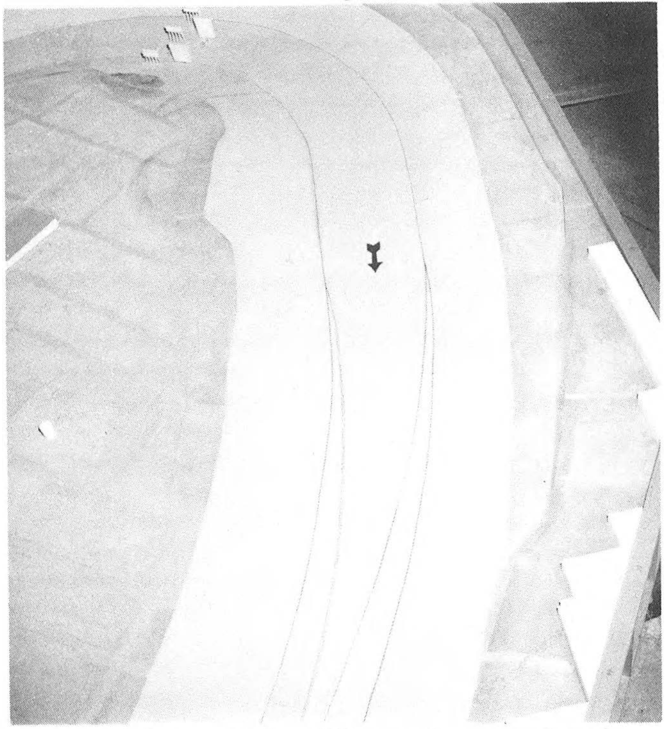


Bridges B-7B and B-8 (Independence Avenue)
and adjacent channel and overbank,
Independence Avenue overpass in background

Photograph 4. Station 512+00 to 522+00 (before final roughness adjustment for verification)

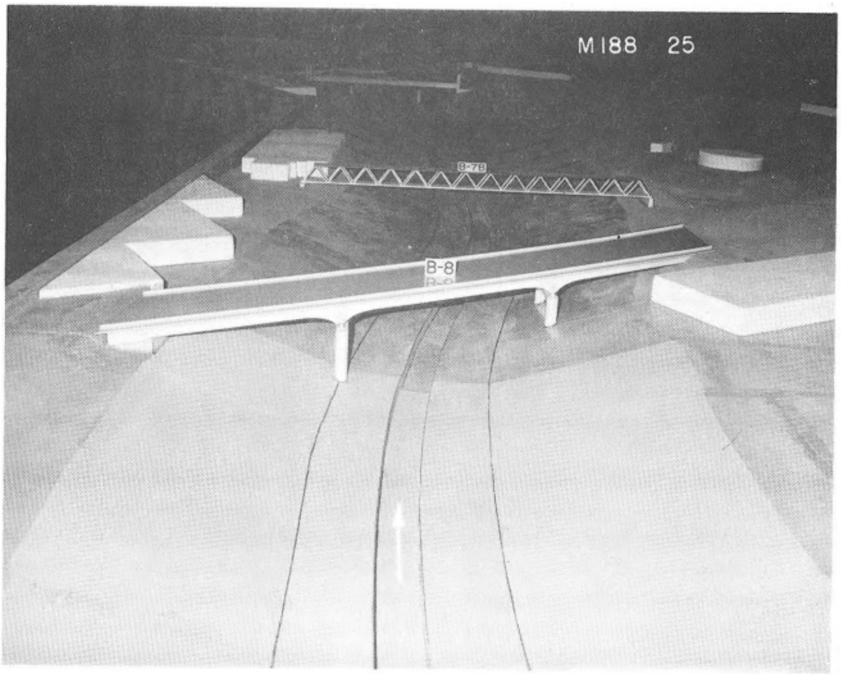


Transition in left center, bridges B-9 and B-9A and rock shell channel in foreground, electric furnace building in center

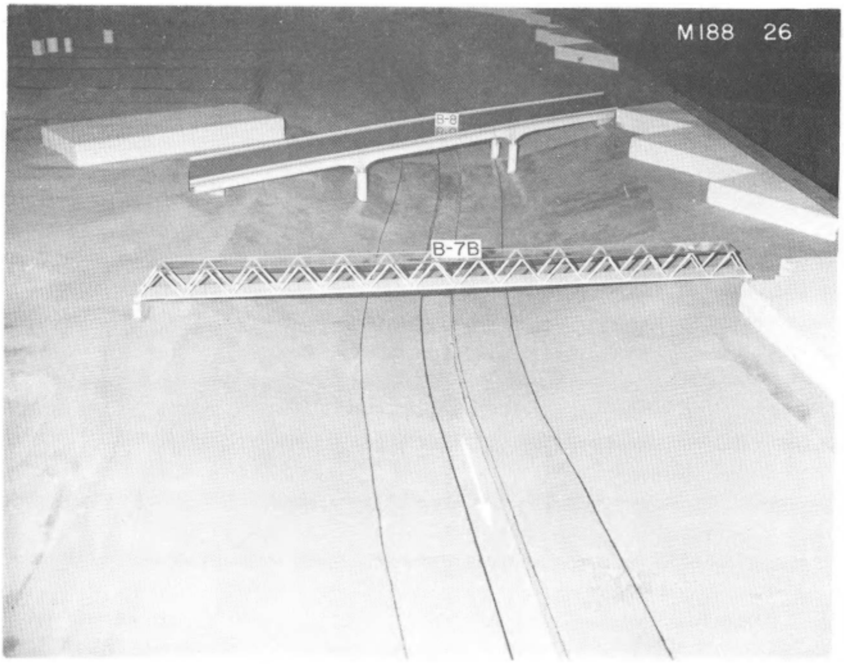


Transition and adjacent overbank

Photograph 5. Transition from rock shell to concrete channel (before final roughness adjustment for verification)

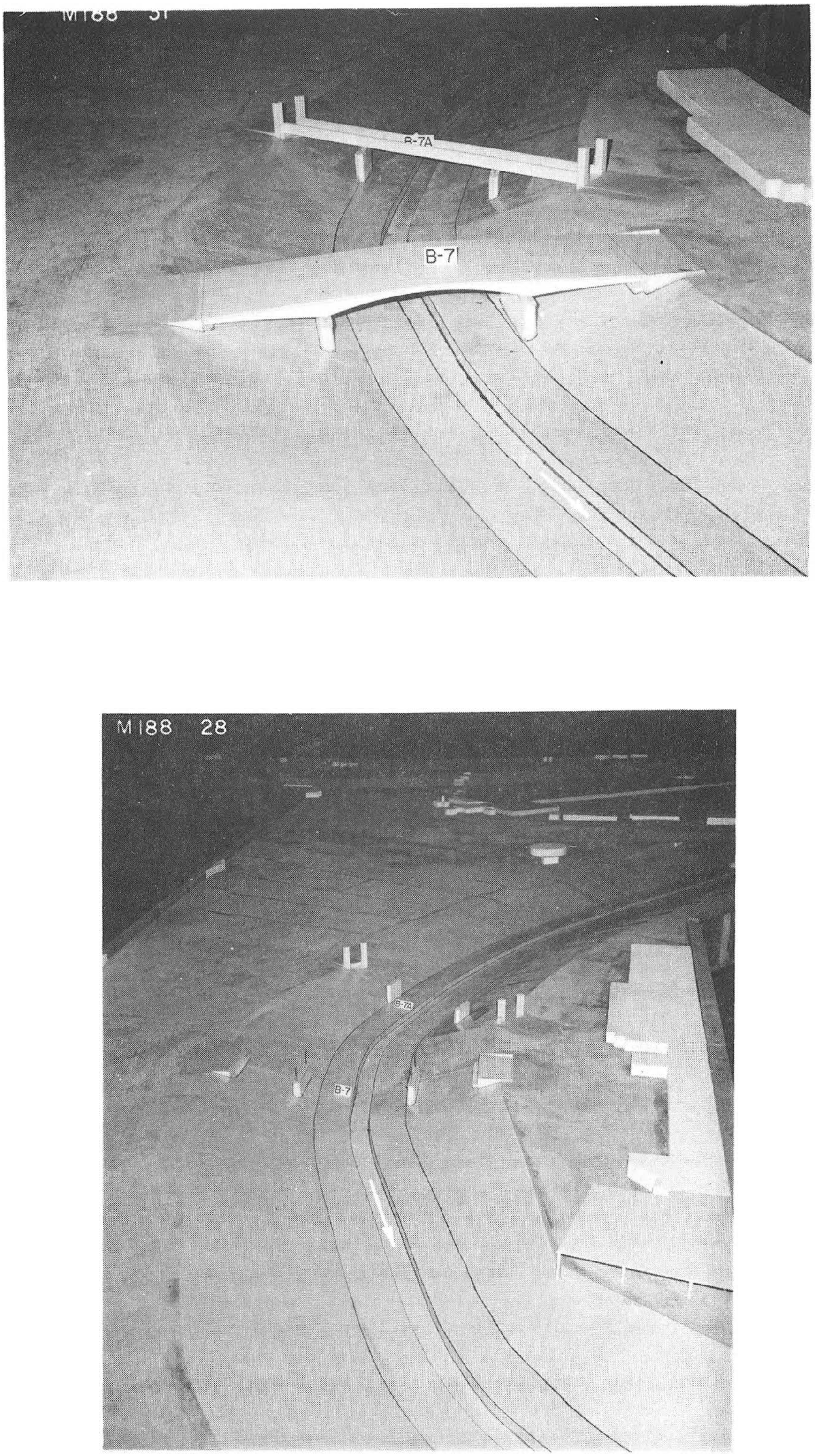


Looking downstream

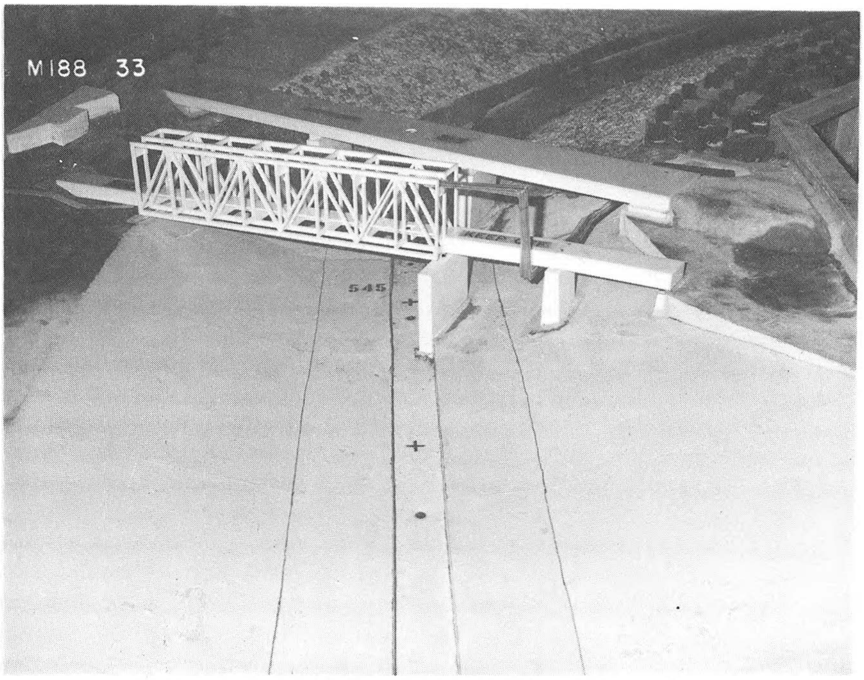


Looking upstream

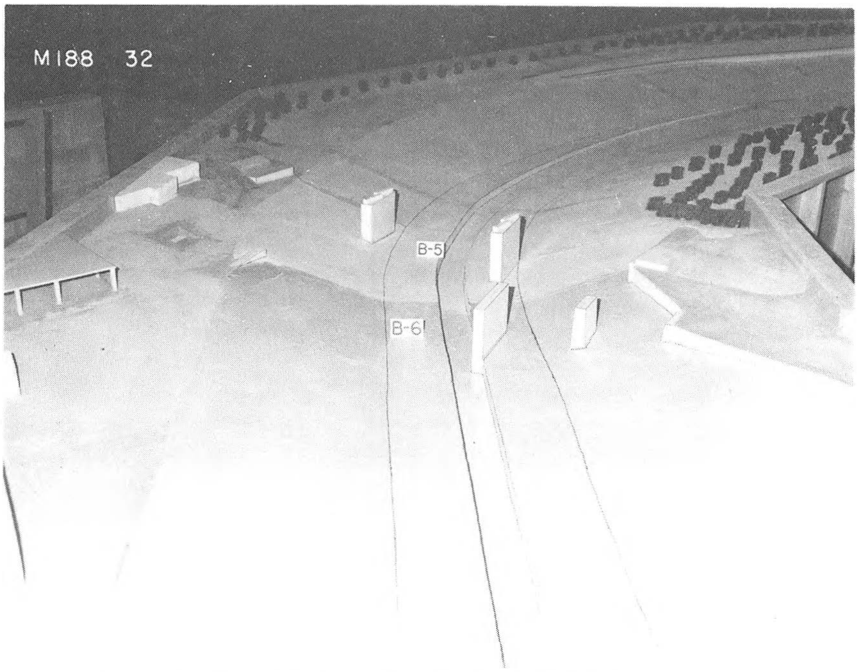
Photograph 6. Bridges B-7B and B-8 and adjacent channel



Photograph 7. Bridges B-7 and B-7A and adjacent channel, rolling mill building and flood wall on left bank (right side of photographs) (before final roughness adjustment for verification)

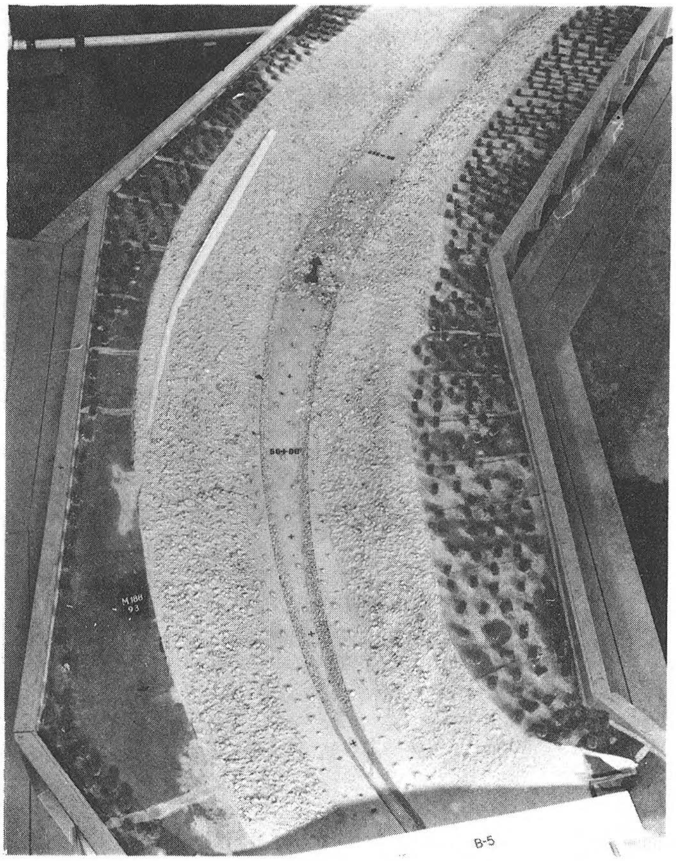


After verification of channel

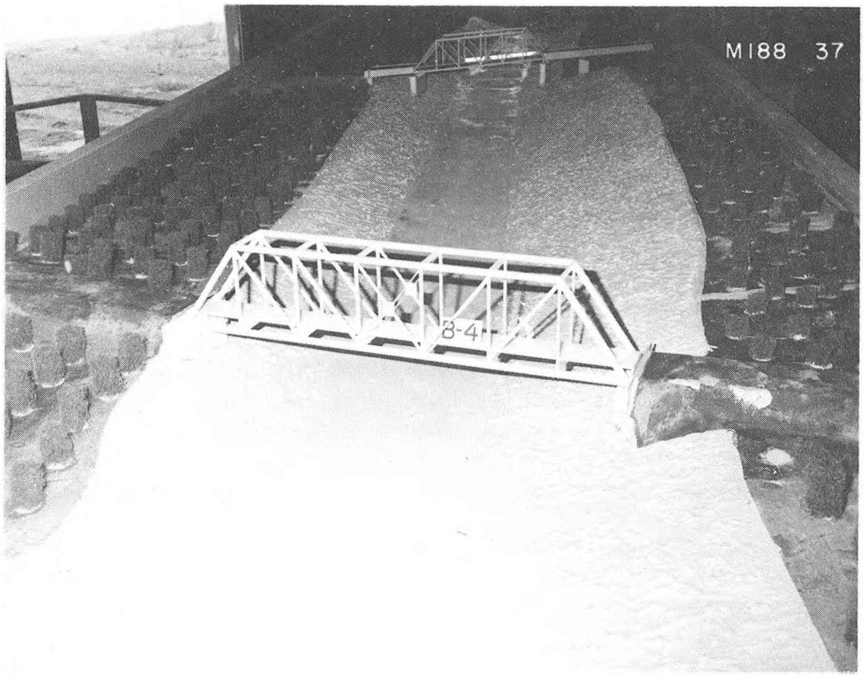


Before verification of channel

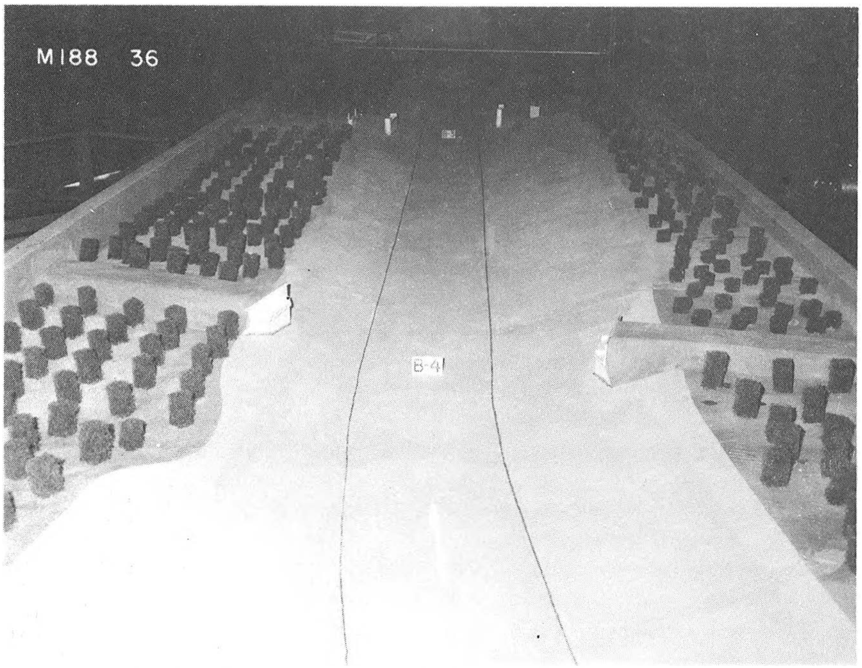
Photograph 8. Bridges B-5 and B-6 and adjacent channel



Photograph 9. Transition and grouted riprap section at downstream end of concrete channel

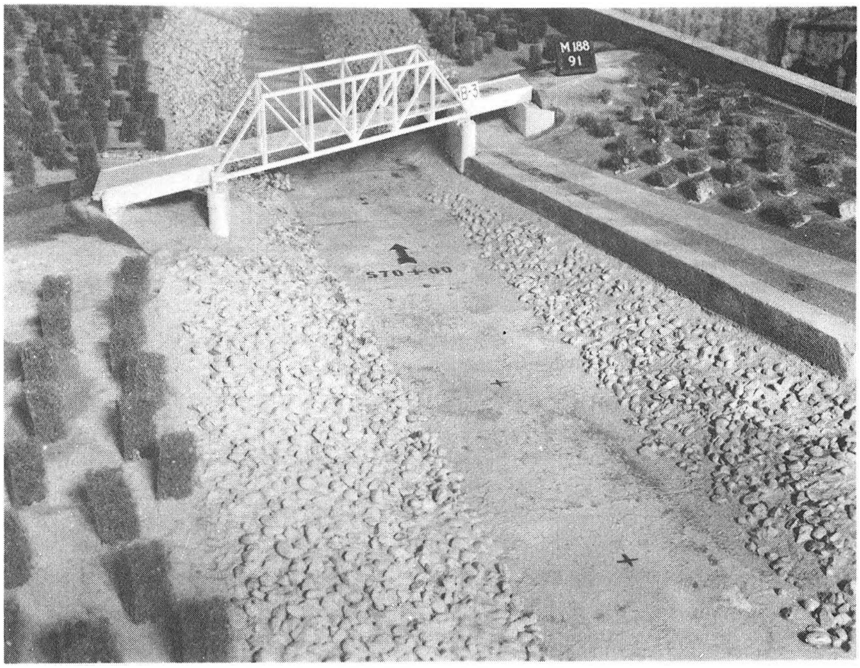


After verification of channel

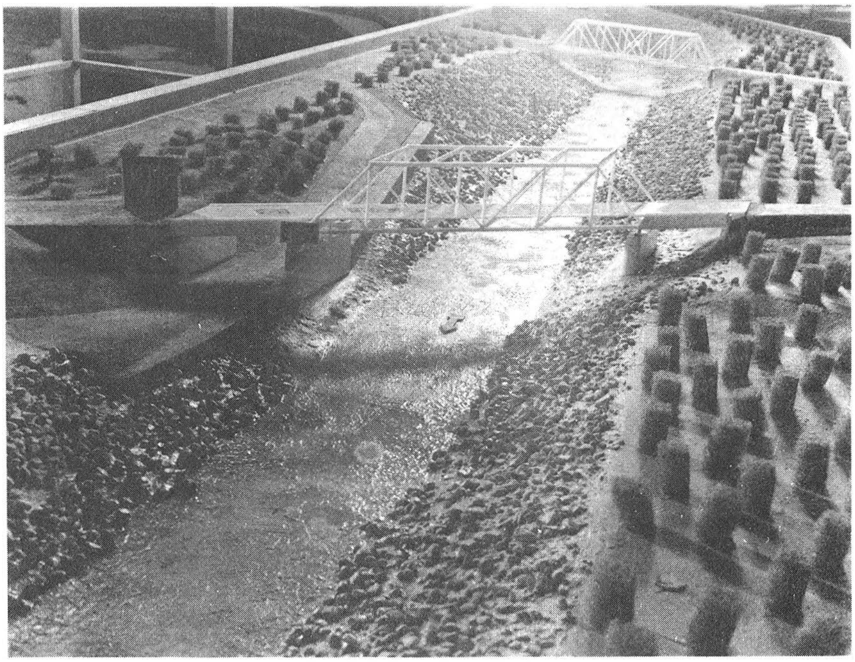


Before verification of channel

Photograph 10. Bridge B-4 and adjacent channel



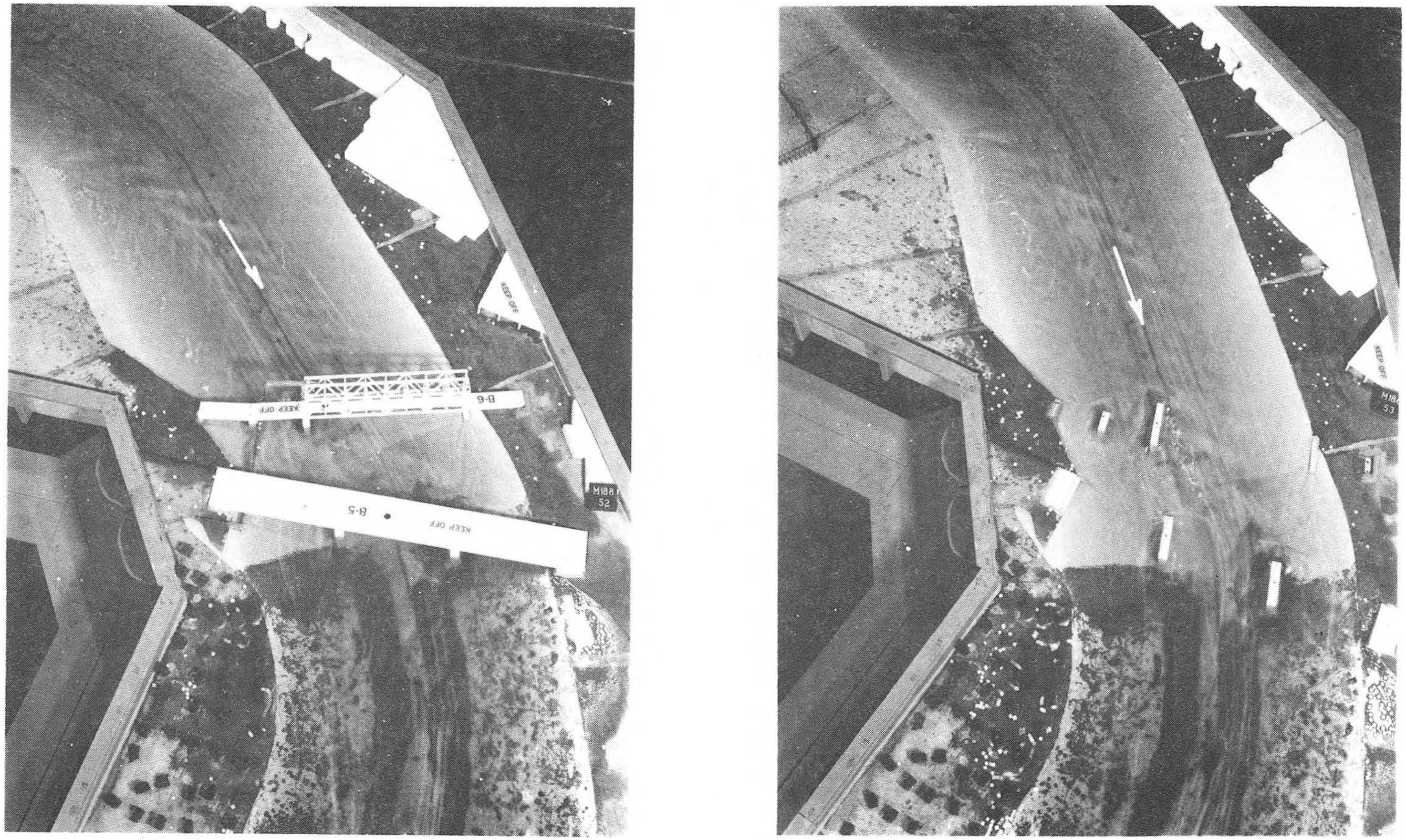
Looking downstream



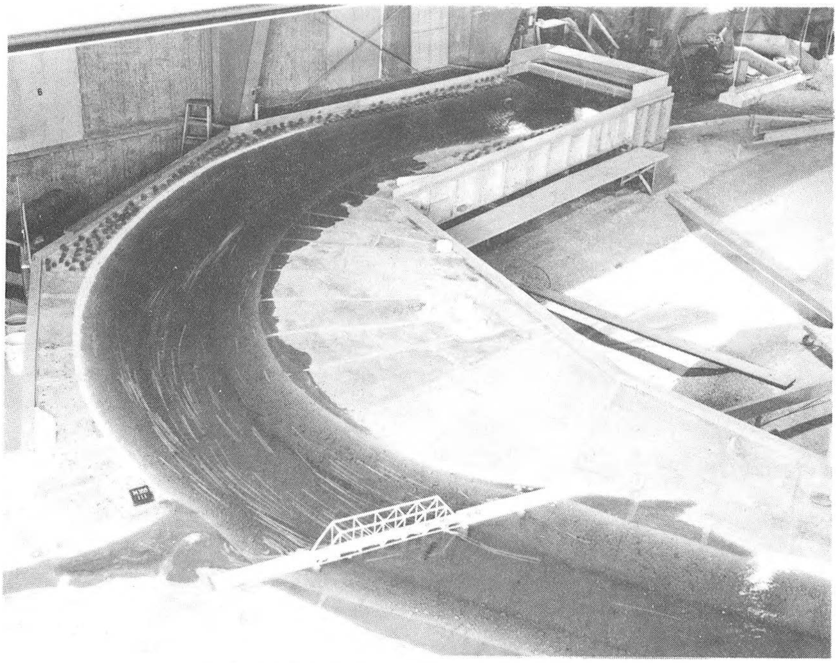
Looking upstream

Photograph 11. Bridge B-3 and adjacent channel

Photograph 12. Verified concrete channel at station 535+00, rolling mill building and flood wall in foreground



Photograph 13. Flow conditions along right bank at station 541+00 (upper left) prior to realignment of bank and at bridges B-5 and B-6. Discharge of 35,000 cfs with Missouri River at 10-year discharge

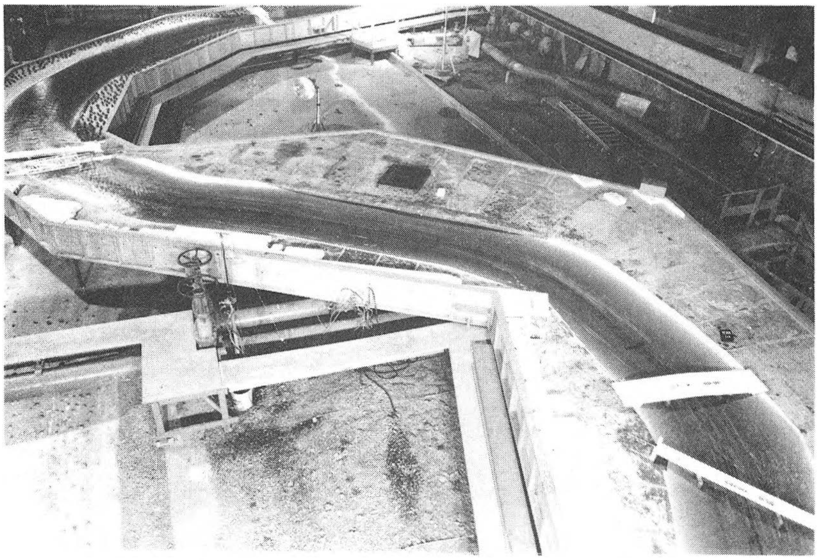


Upstream from bridge B-10

From bridge B-10 to B-8

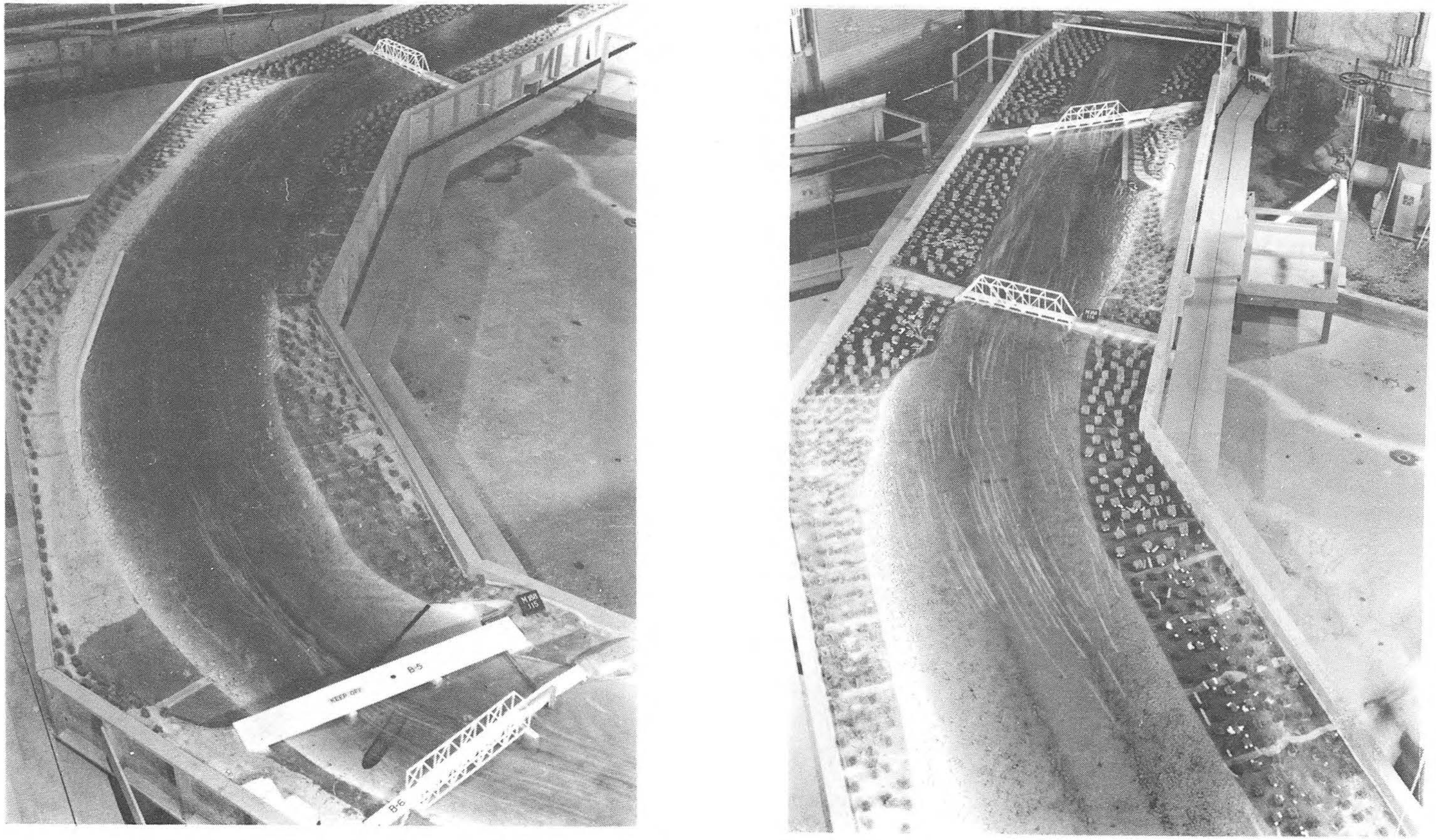
Photograph 14. Flow conditions with discharge of 35,000 cfs and Missouri River at 10-year discharge

From bridge B-8 to B-7



From bridge B-7 to B-6

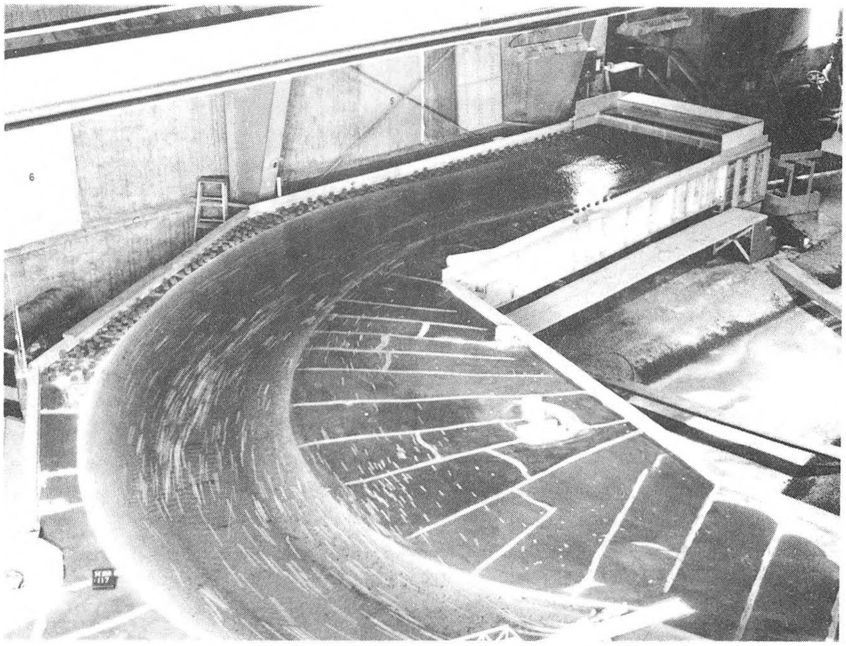
Photograph 15. Flow conditions with discharge of 35,000 cfs and Missouri River at 10-year discharge



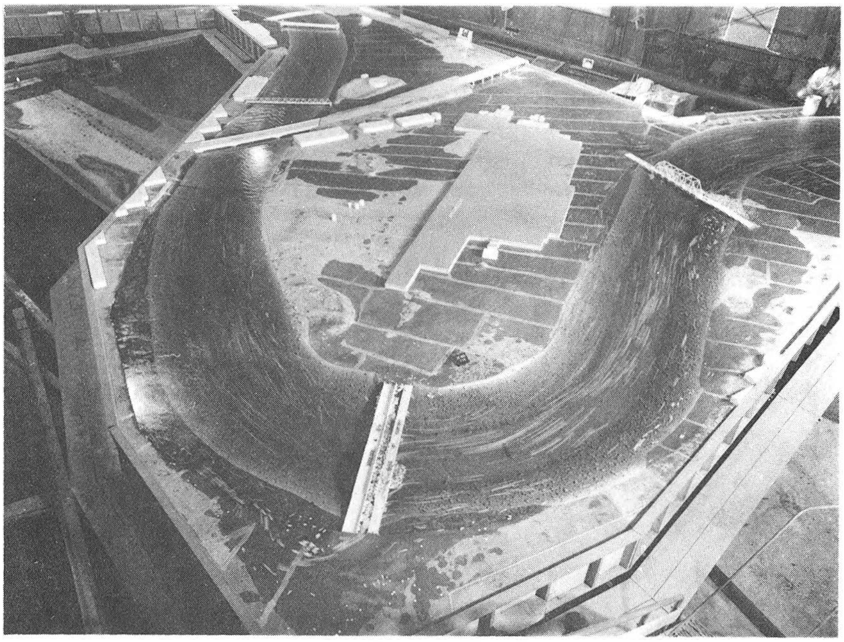
From bridge B-6 to B-4

At bridges B-4 and B-3

Photograph 16. Flow conditions with discharge of 35,000 cfs and Missouri River at 10-year discharge

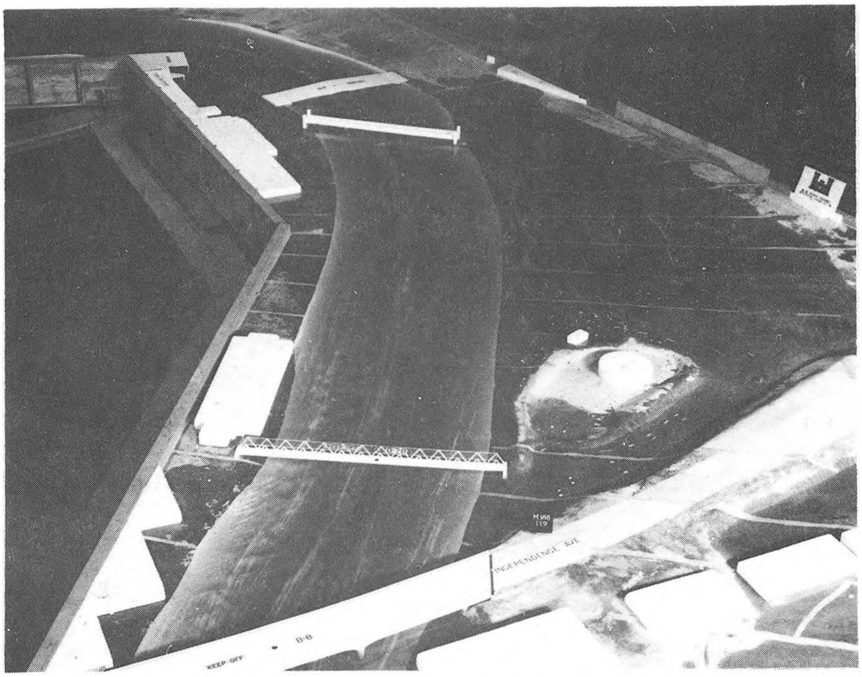


Upstream from bridge B-10



From bridge B-10 to B-8

Photograph 17. Flow conditions with discharge of 42,000 cfs and Missouri River at 10-year discharge

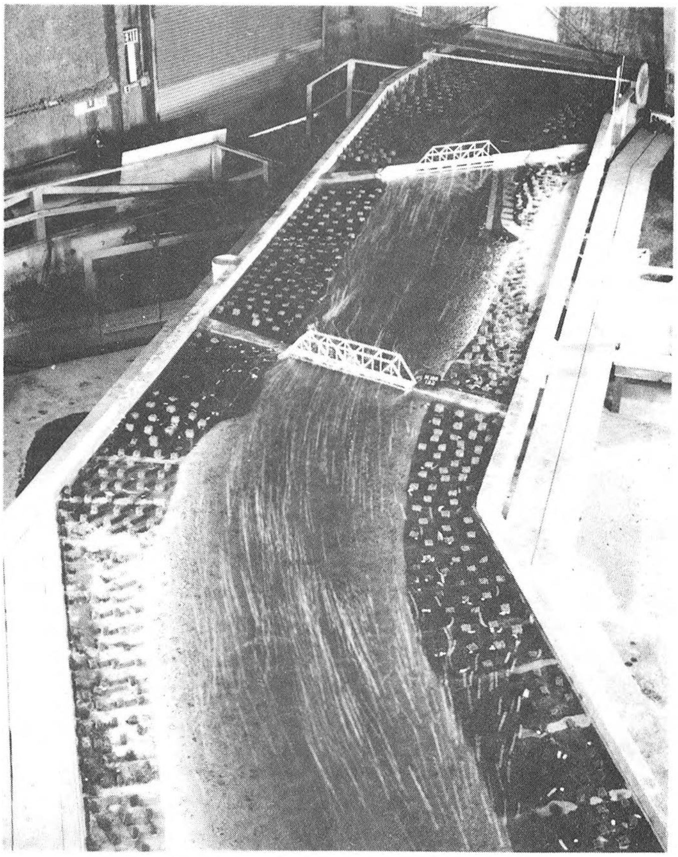


From bridge B-8 to B-7

From bridge B-7 to B-5

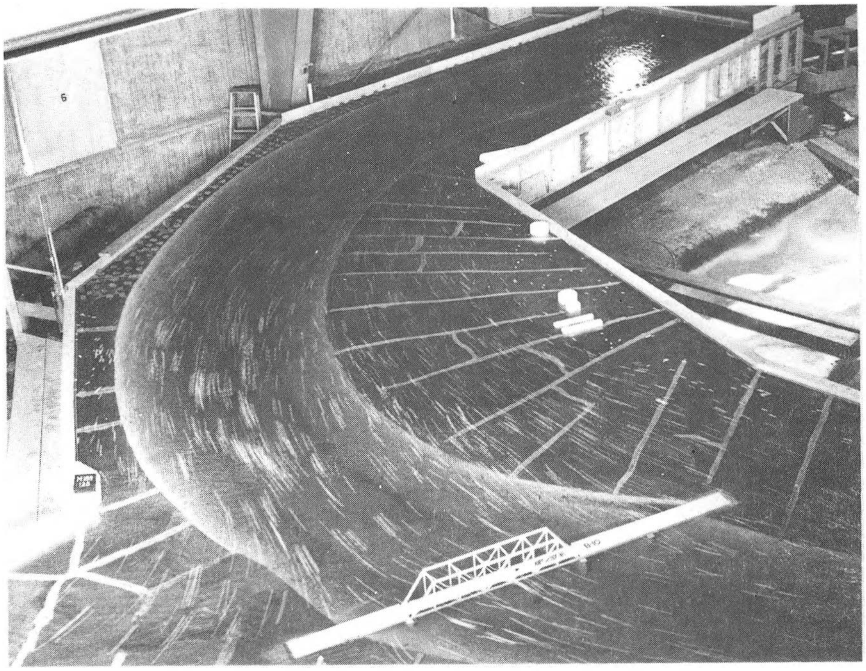
Photograph 18. Flow conditions with discharge of 42,000 cfs and Missouri River at 10-year discharge

From bridge B-5 to B-4

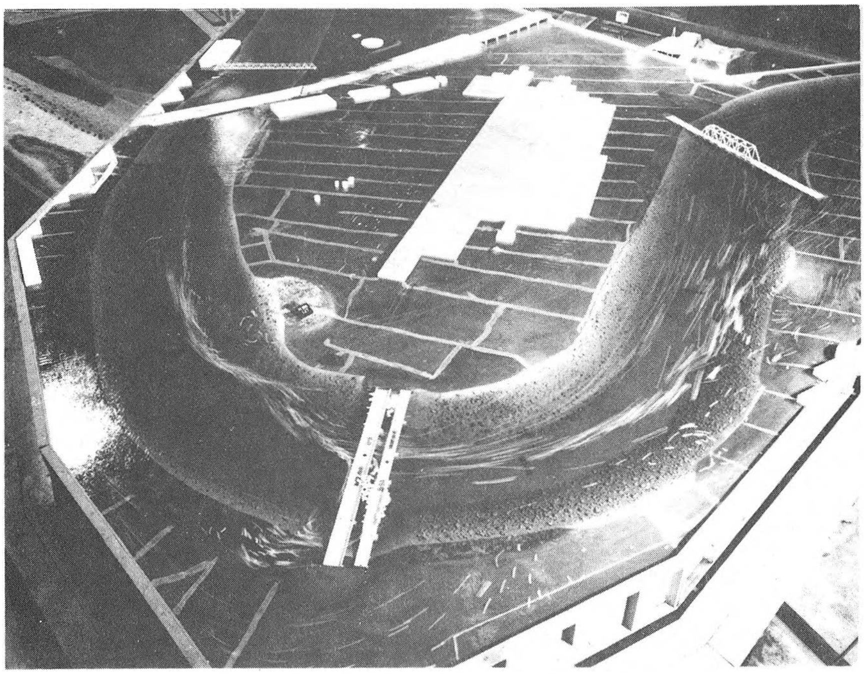


At bridges B-4 and B-3

Photograph 19. Flow conditions with discharge of 42,000 cfs and Missouri River at 10-year discharge

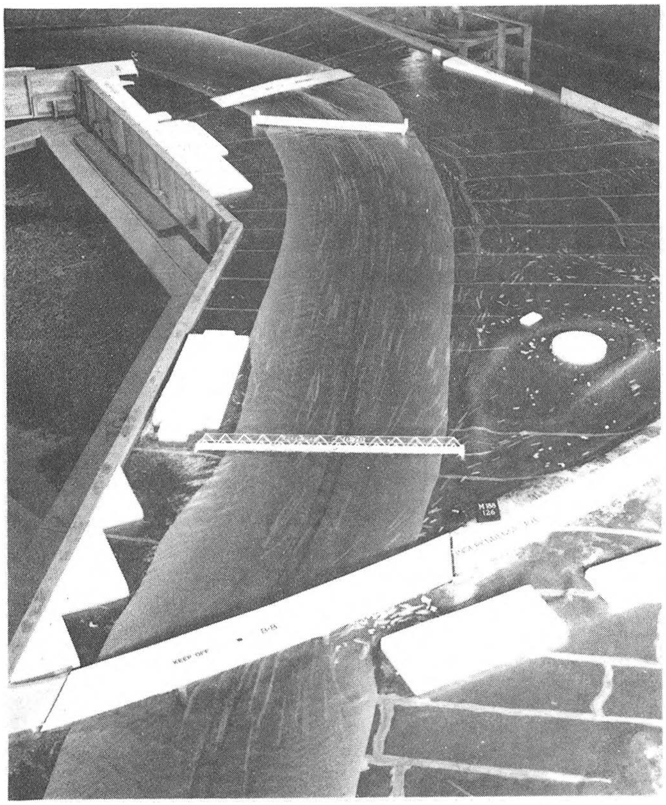


Upstream from bridge B-10

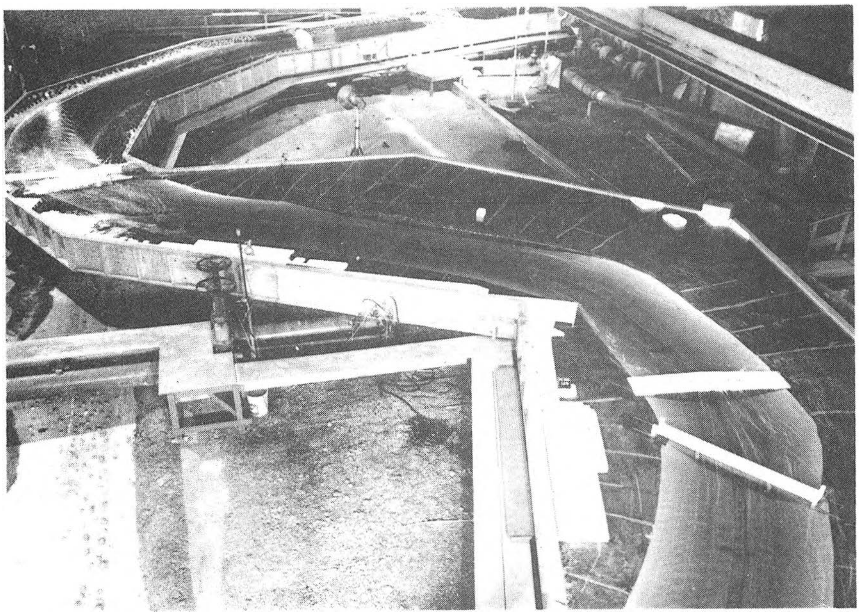


From bridge B-10 to B-8

Photograph 20. Flow conditions with discharge of 52,800 cfs and Missouri River at 10-year discharge

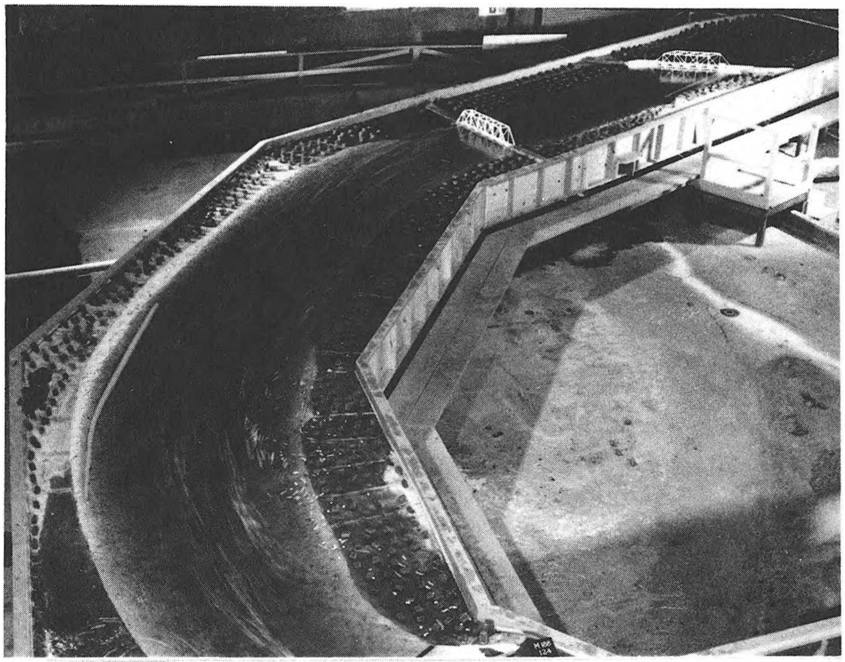


From bridge B-8 to B-7

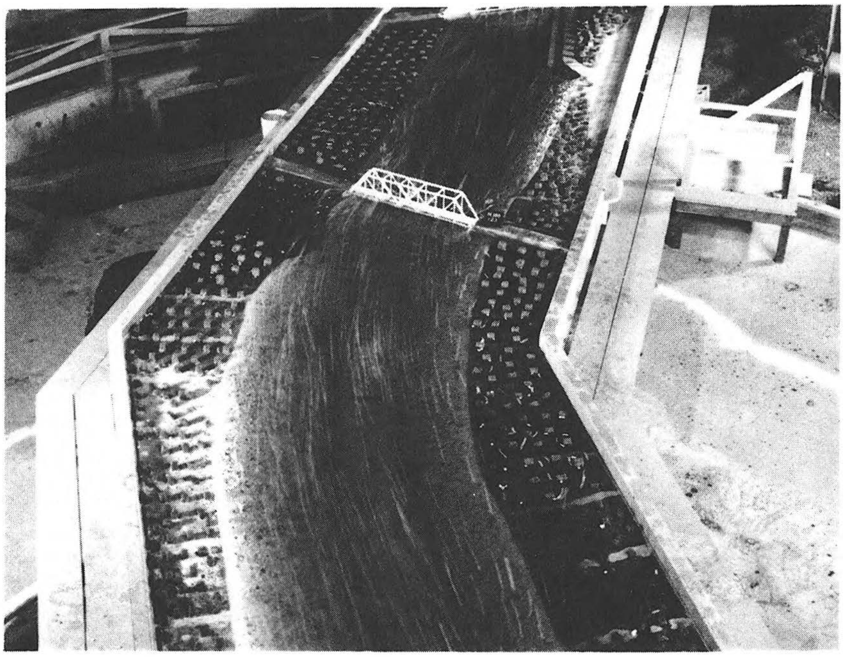


From bridge B-7 to B-5

Photograph 21. Flow conditions with discharge of 52,800 cfs and Missouri River at 10-year discharge

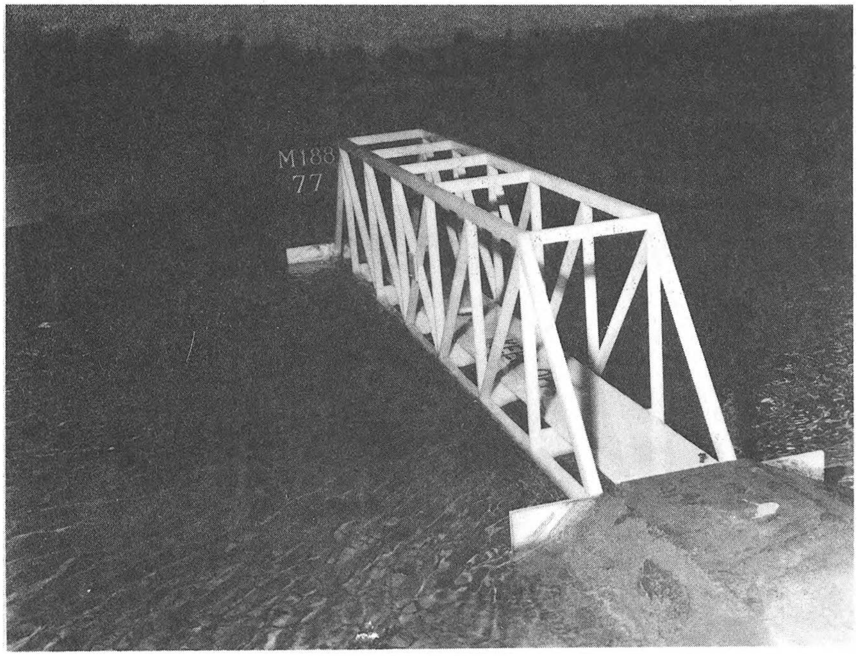


From bridge B-5 to B-3

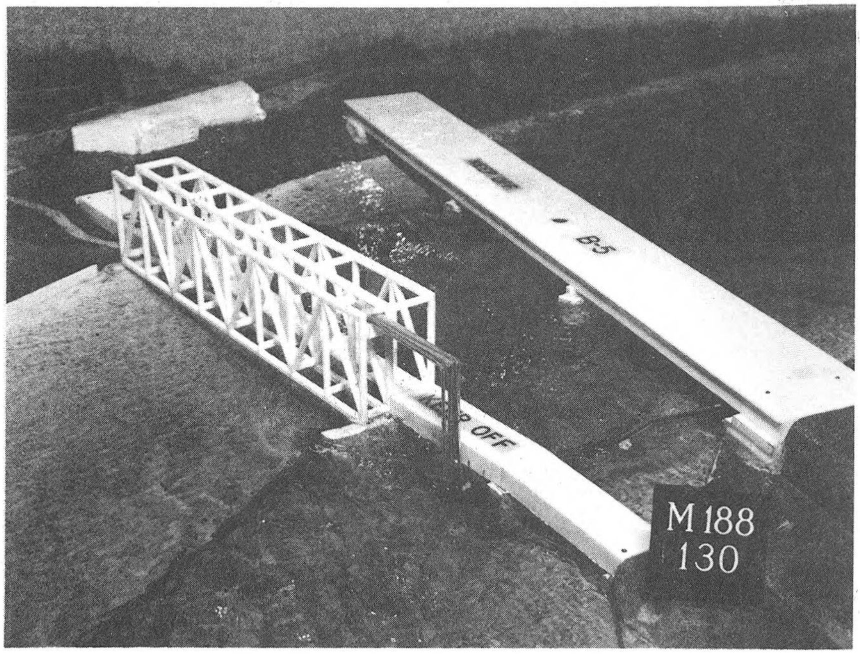


At bridge B-4

Photograph 22. Flow conditions with discharge of 52,800 cfs and Missouri River at 10-year discharge

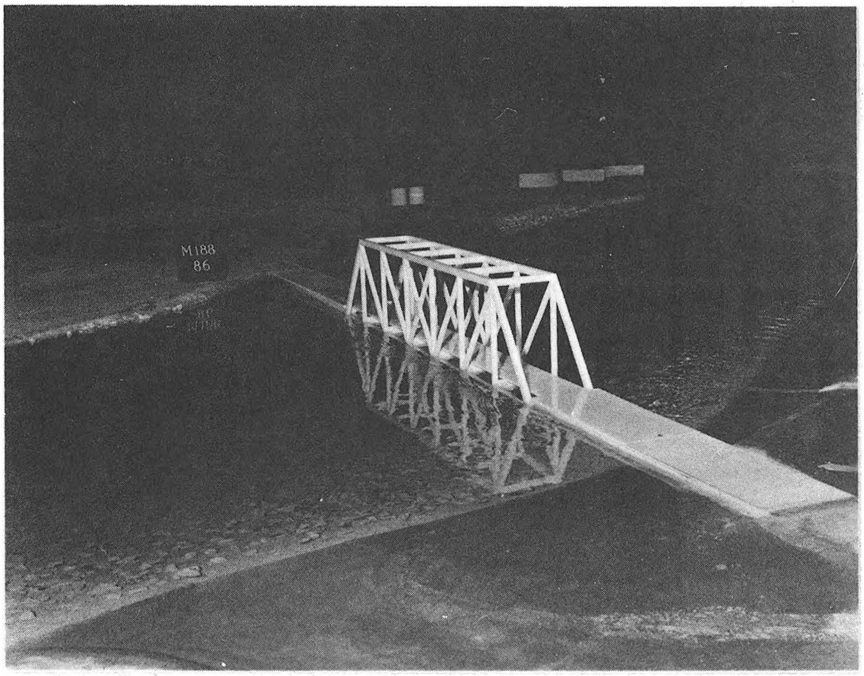


Bridge B-4



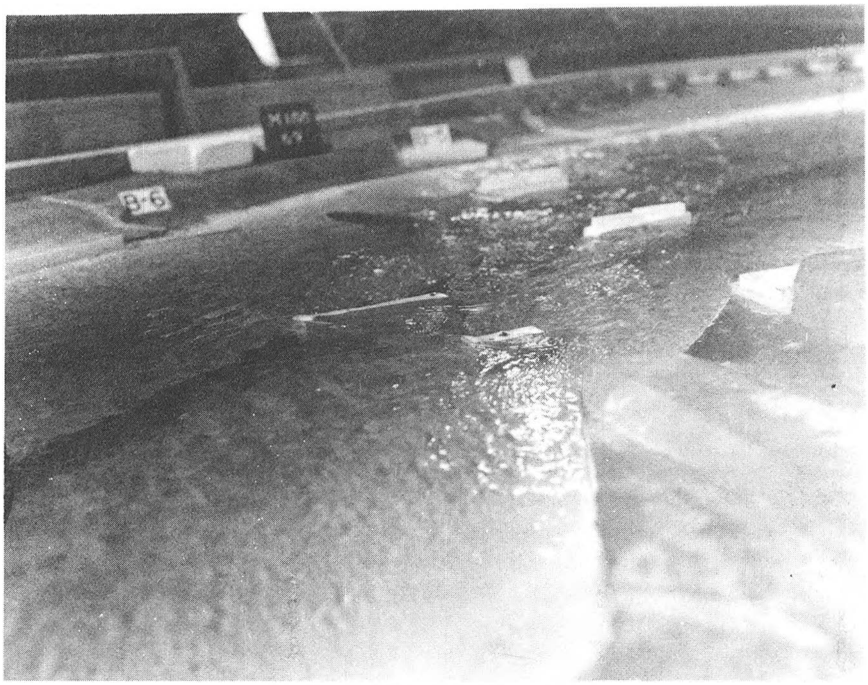
Bridges B-5 and B-6

Photograph 23. Flow conditions with discharge of 35,000 cfs and Missouri River at 10-year discharge



Bridge B-10

Photograph 24. Flow conditions with discharge of 35,000 cfs and Missouri River at 10-year discharge



Looking downstream

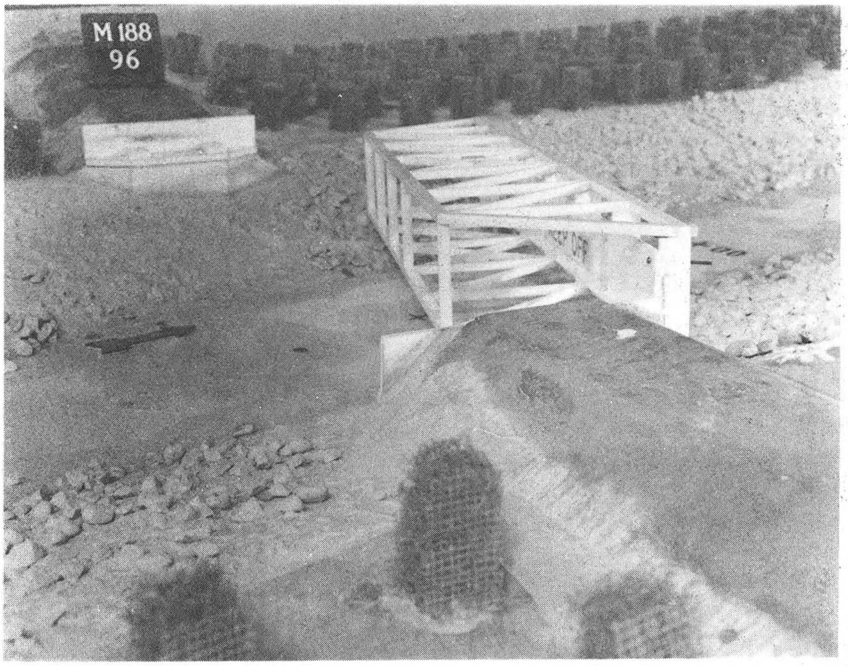
Looking upstream

Photograph 25. Flow around existing piers of bridges B-5 and B-6, discharge of 35,000 cfs with Missouri River at 10-year discharge

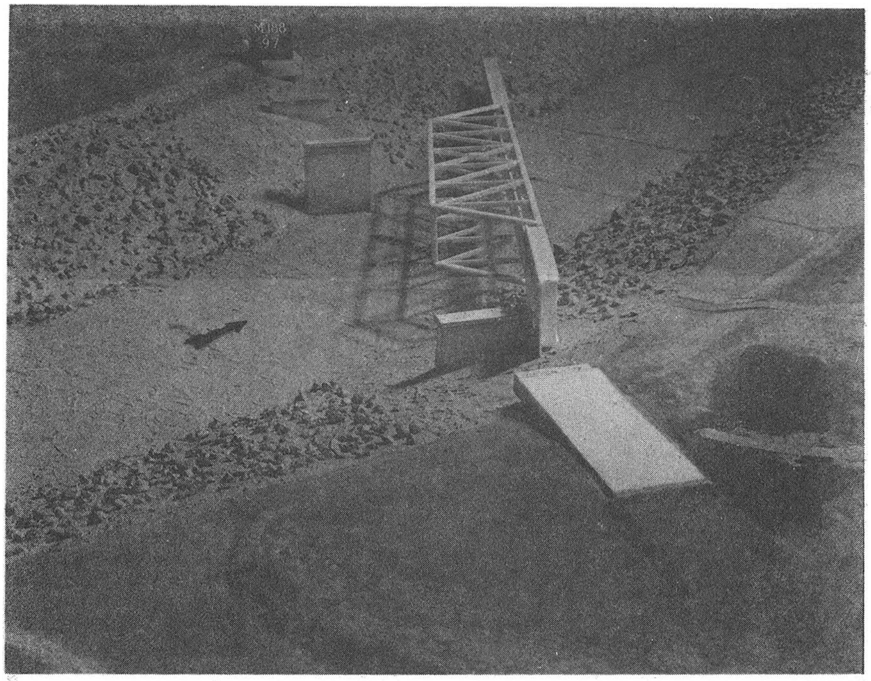
Looking downstream

Looking upstream

Photograph 26. Flow around existing piers of bridges B-5 and B-6, discharge of 35,000 cfs with minimum tailwater

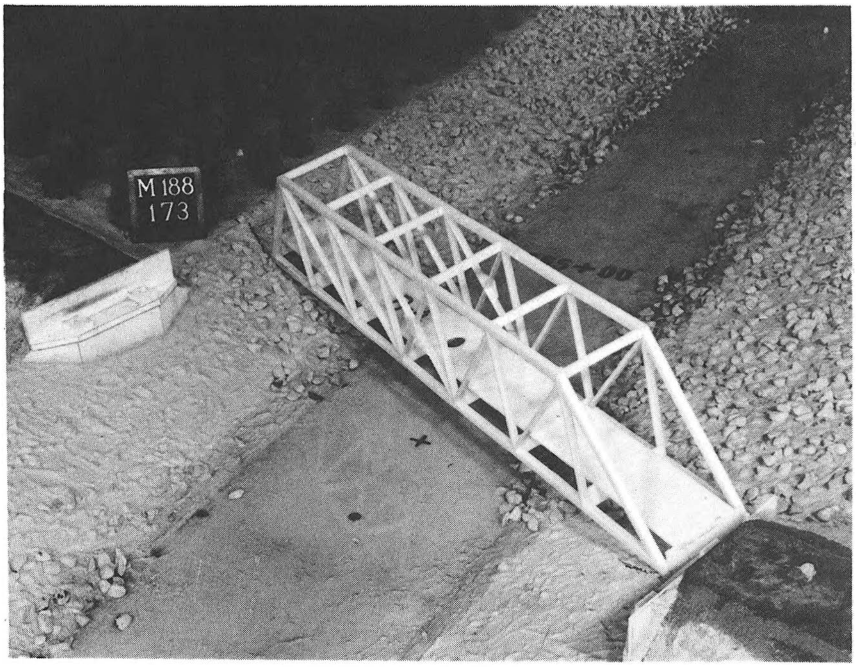


Bridge B-4

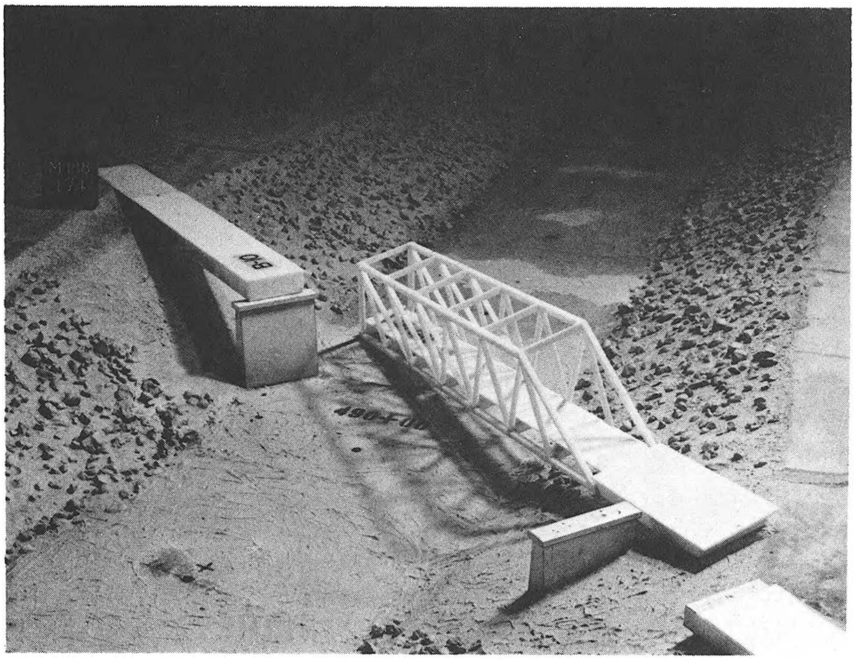


Bridge B-10

Photograph 27. Bridges swept from piers into channel on their sides



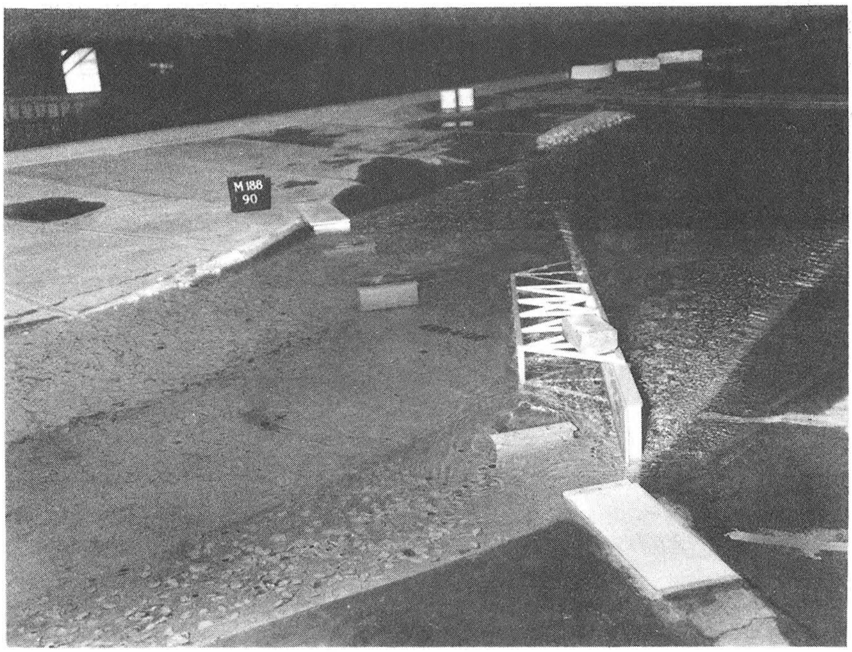
Bridge B-4



Bridge B-10

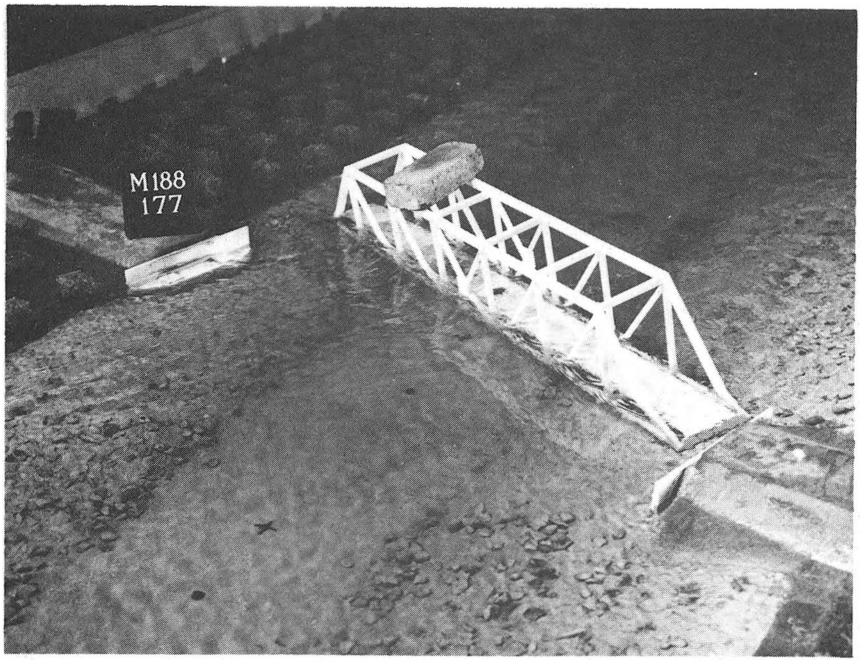
Photograph 28. Bridges swept from piers into channel in upright position

Bridge B-4

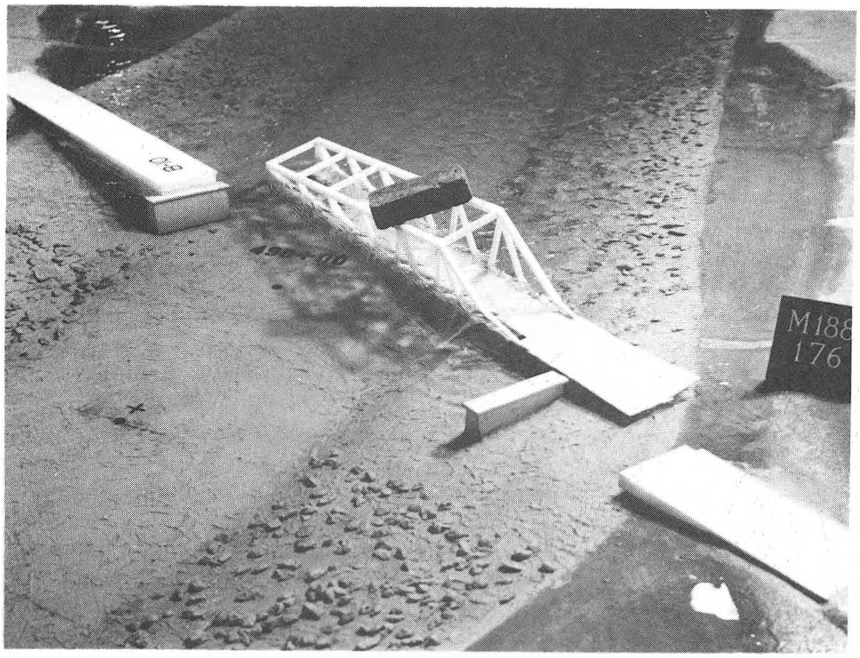


Bridge B-10

Photograph 29. Bridges swept from piers into channel on their sides. Discharge of 35,000 cfs with Missouri River at 10-year discharge.

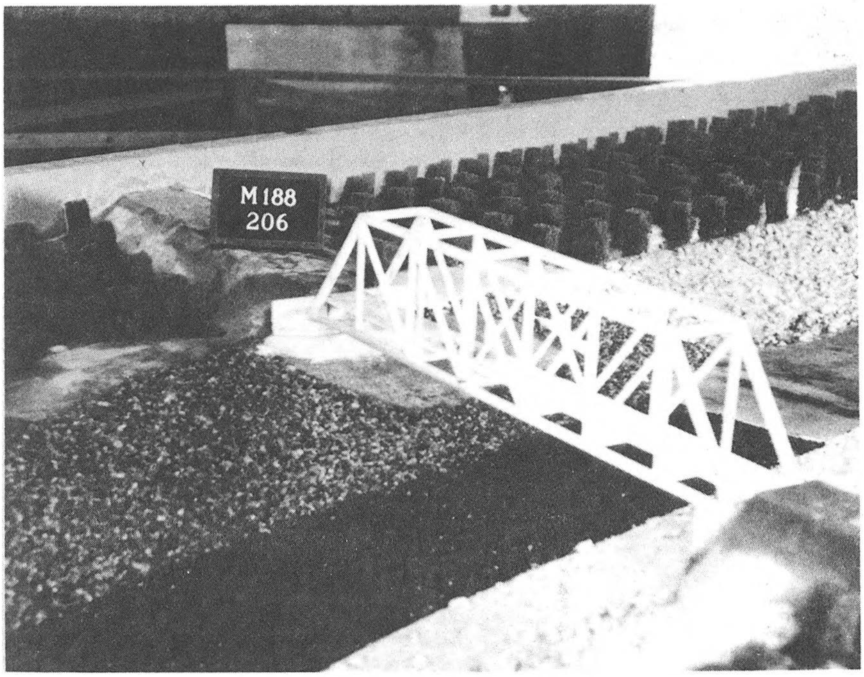


Bridge B-4

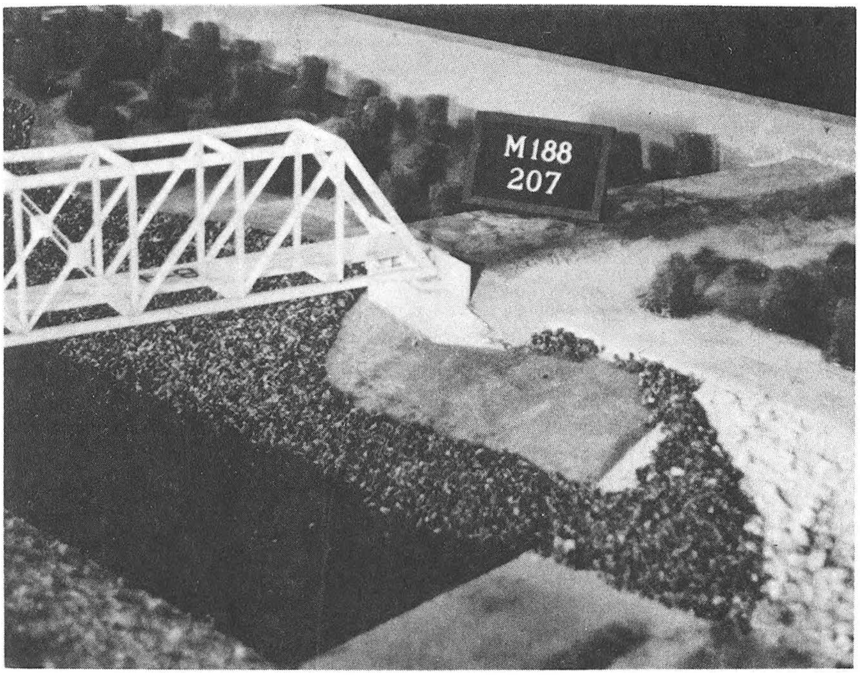


Bridge B-10

Photograph 30. Bridges swept from piers into channel in upright position. Discharge of 35,000 cfs with Missouri River at 10-year discharge.

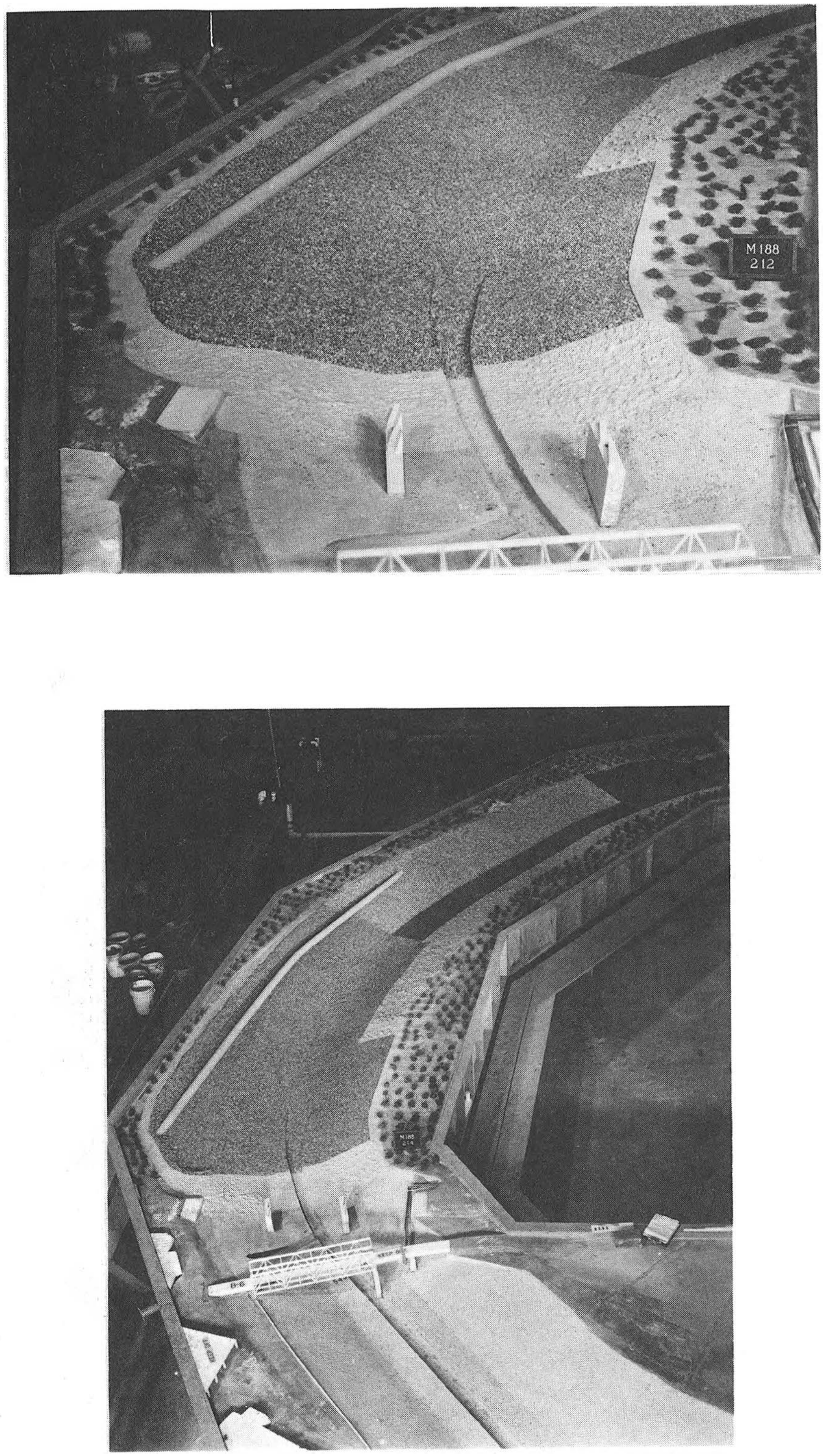


Looking downstream



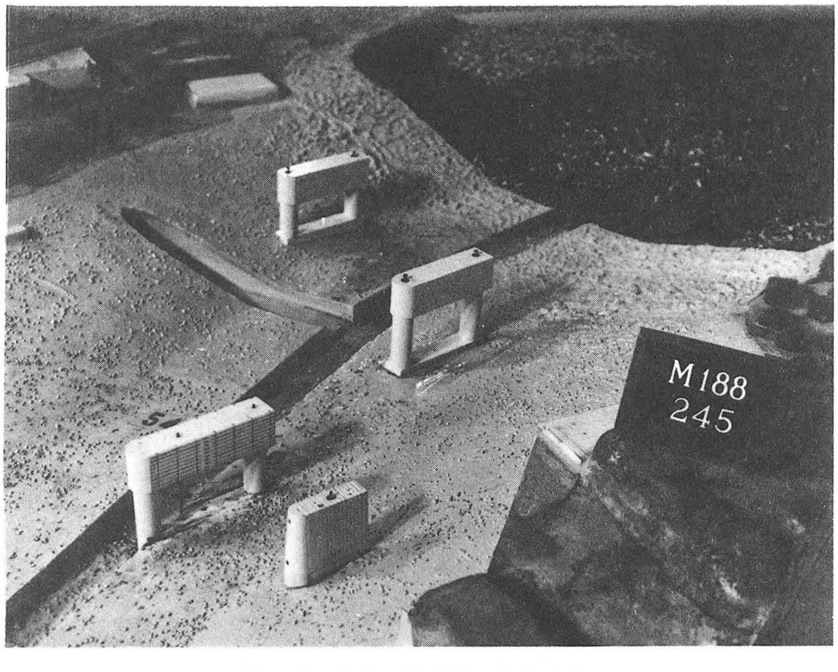
Looking upstream

Photograph 31. Failure of 18-inch riprap at left abutment of bridge B-4 after a discharge of 54,000 cfs with minimum tailwater



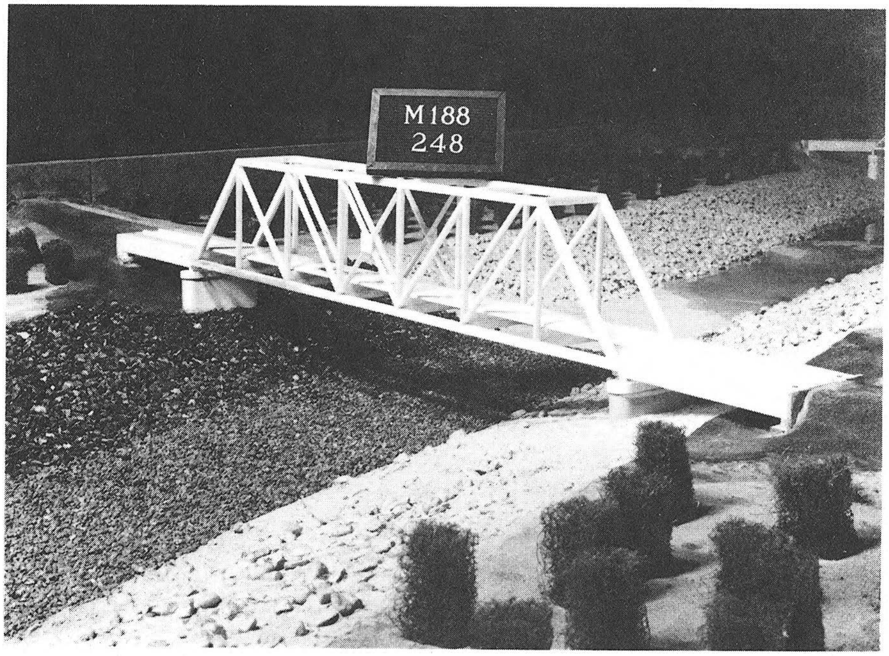
Photograph 32. Revised transition and channel at downstream end of concrete channel. Looking downstream, superstructure of bridge B-5 removed.

Existing

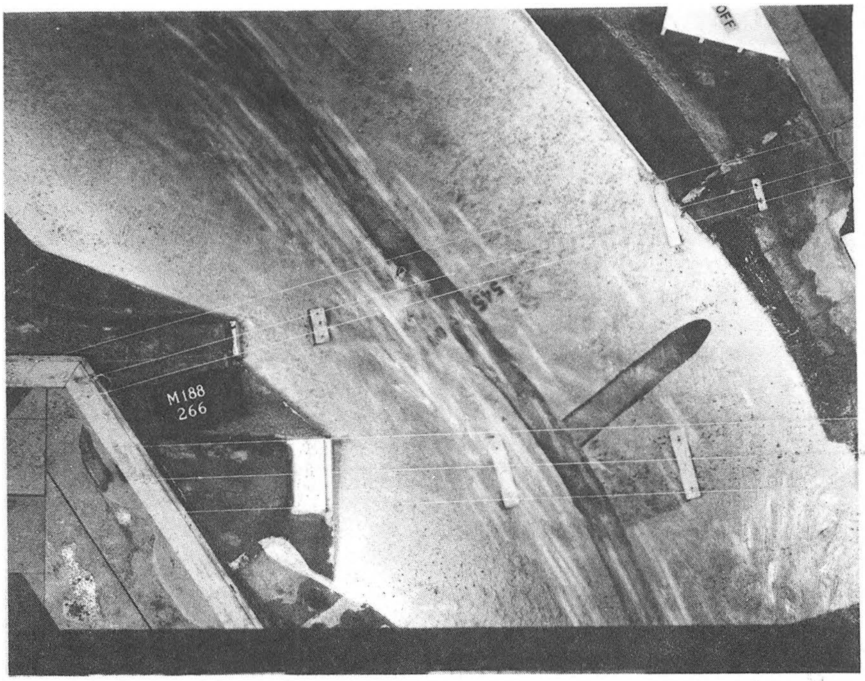


Proposed revision

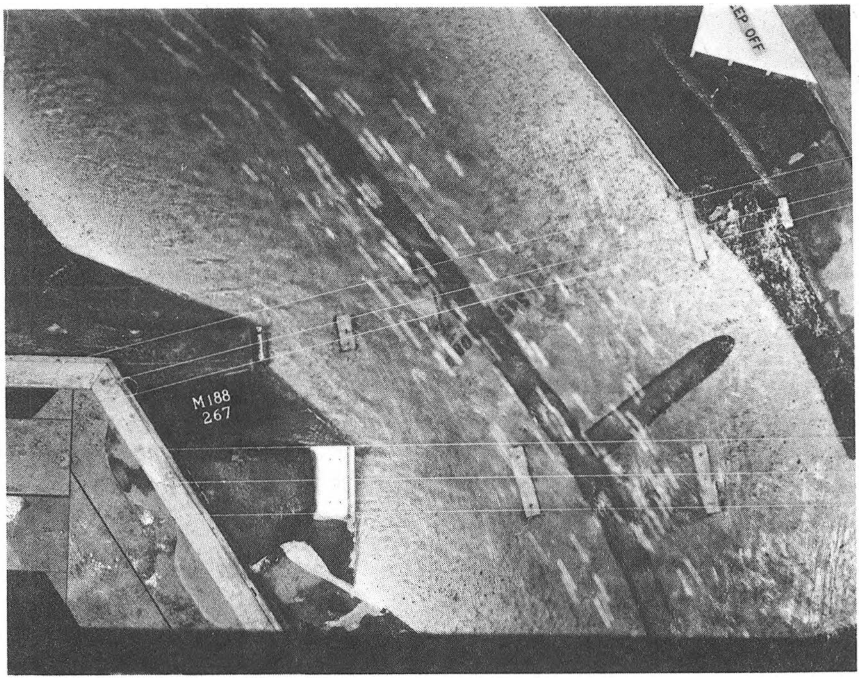
Photograph 33. Piers of bridges B-5 and B-6. Looking downstream, bridge B-6 in foreground.



Photograph 34. Revised bridge B-4 (end spans added) looking downstream

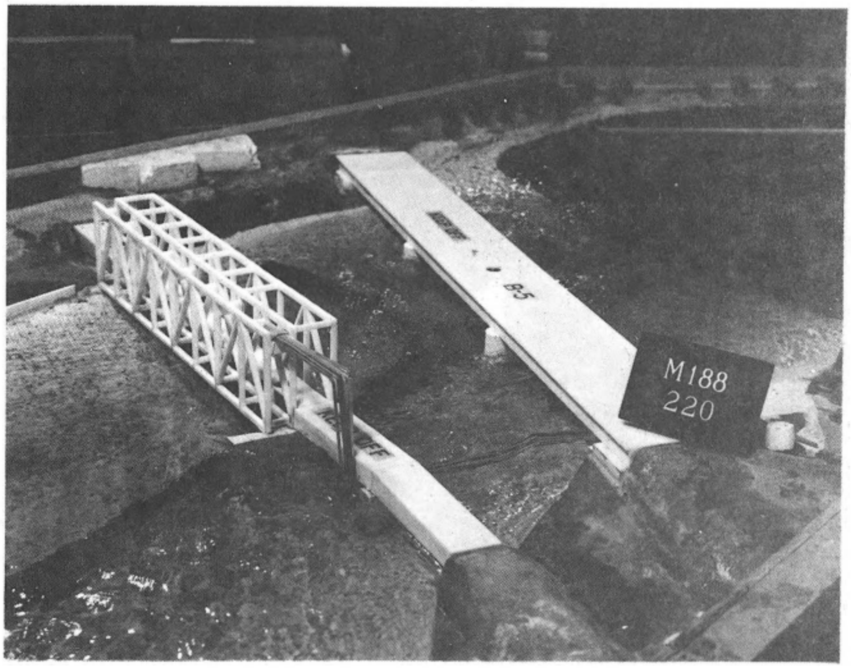


Discharge 35,000 cfs

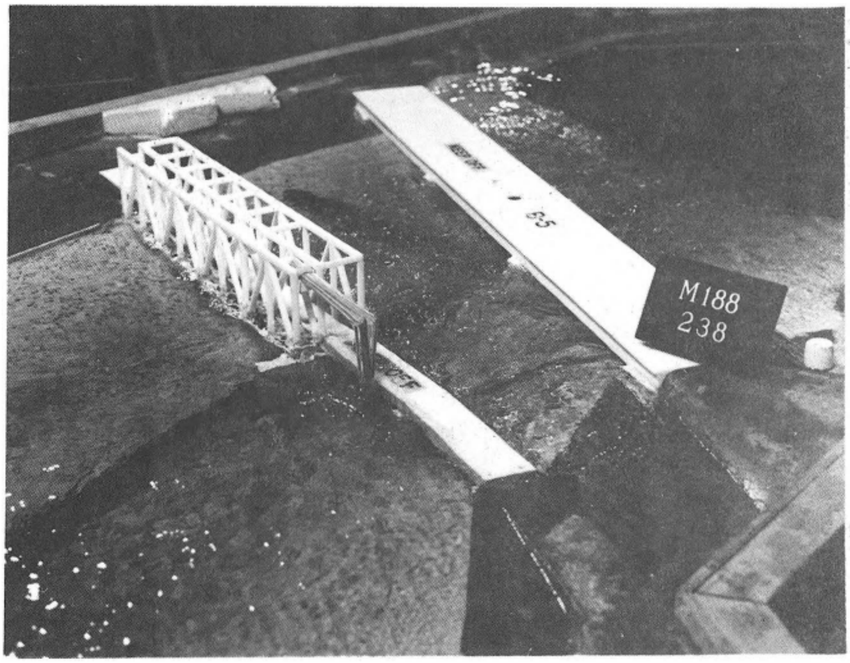


Discharge 52,800 cfs

Photograph 35. Flow conditions at bridges B-5 and B-6 with piers removed from channel, Missouri River at 10-year discharge (flow shown from top to bottom of photographs)

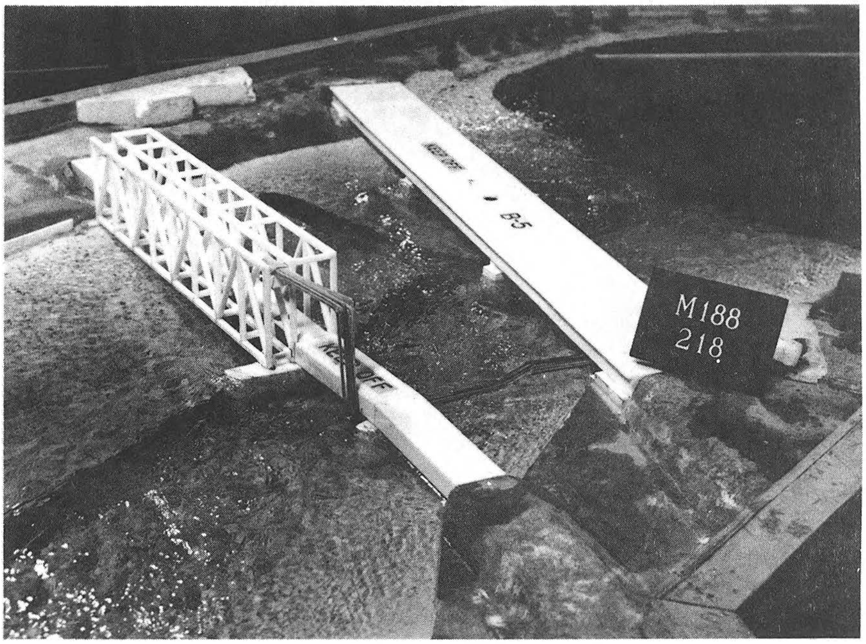


Discharge 35,000 cfs

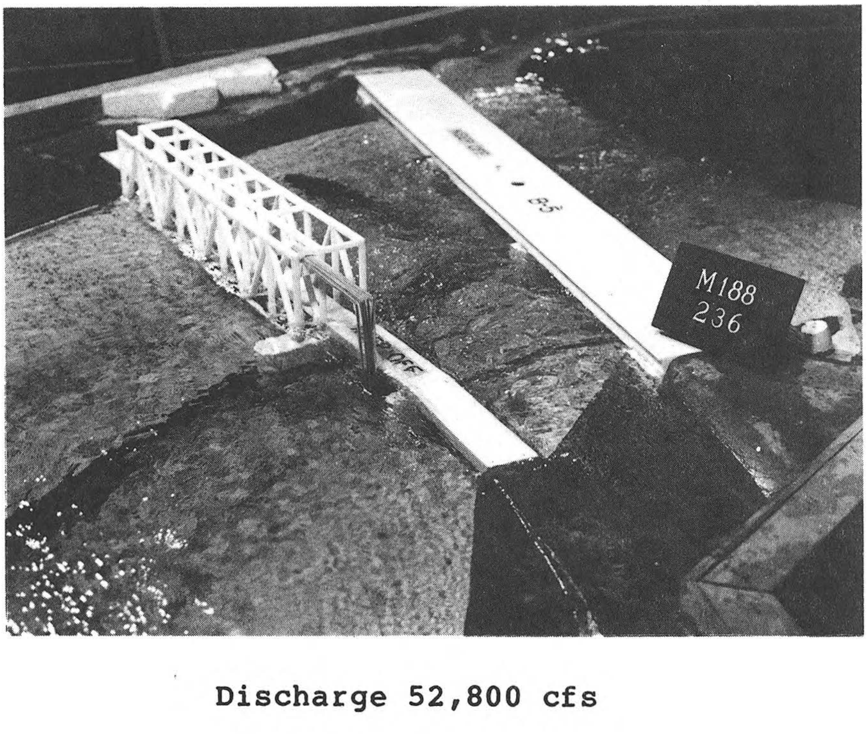


Discharge 52,800 cfs

Photograph 36. Flow conditions at bridges B-5 and B-6 with revised piers of bridge B-5 and existing piers of bridge B-6. Missouri River at 10-year discharge.

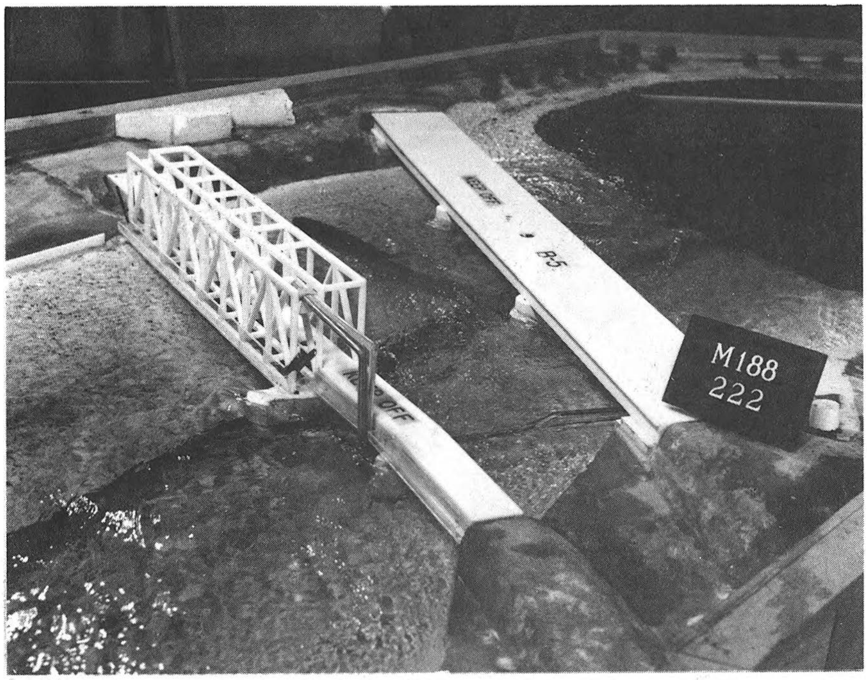


Discharge 35,000 cfs

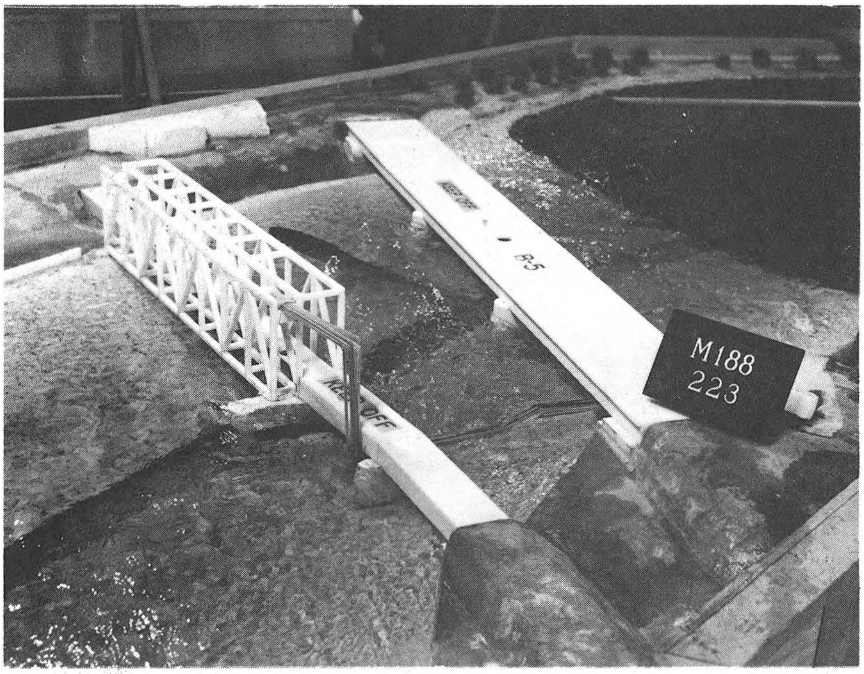


Discharge 52,800 cfs

Photograph 37. Flow conditions at bridges B-5 and B-6 with revised piers of bridge B-6. Missouri River at 10-year discharge.

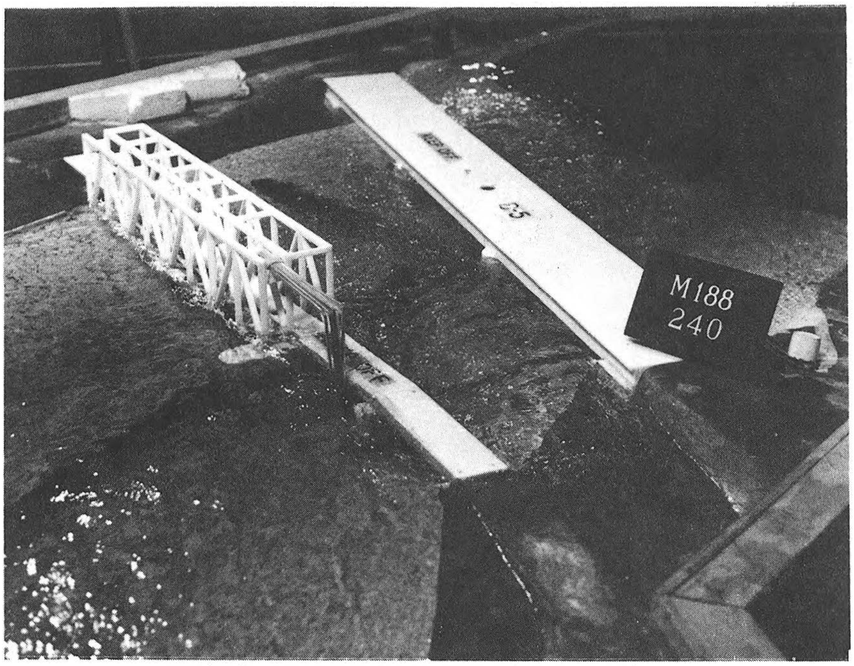


With existing bridge B-4

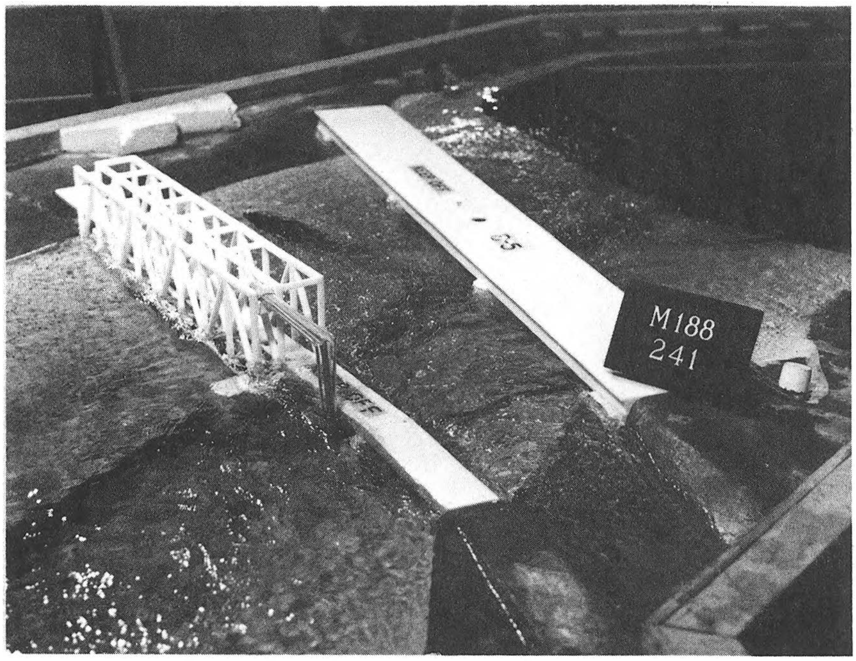


With revised bridge B-4

Photograph 38. Flow conditions at bridges B-5 and B-6 with revised piers of both bridges. Discharge of 35,000 cfs with Missouri River at 10-year discharge.

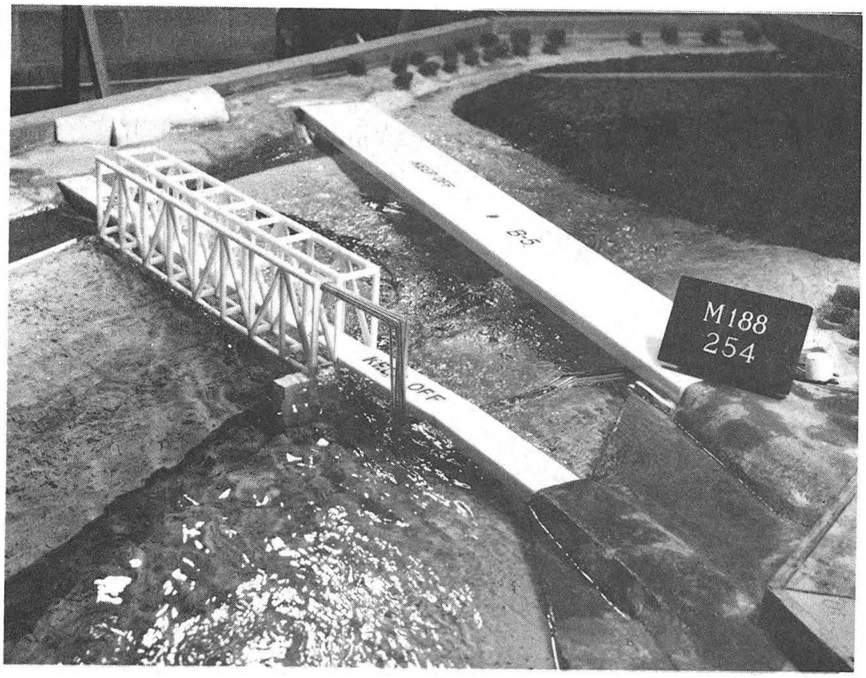


With existing bridge B-4

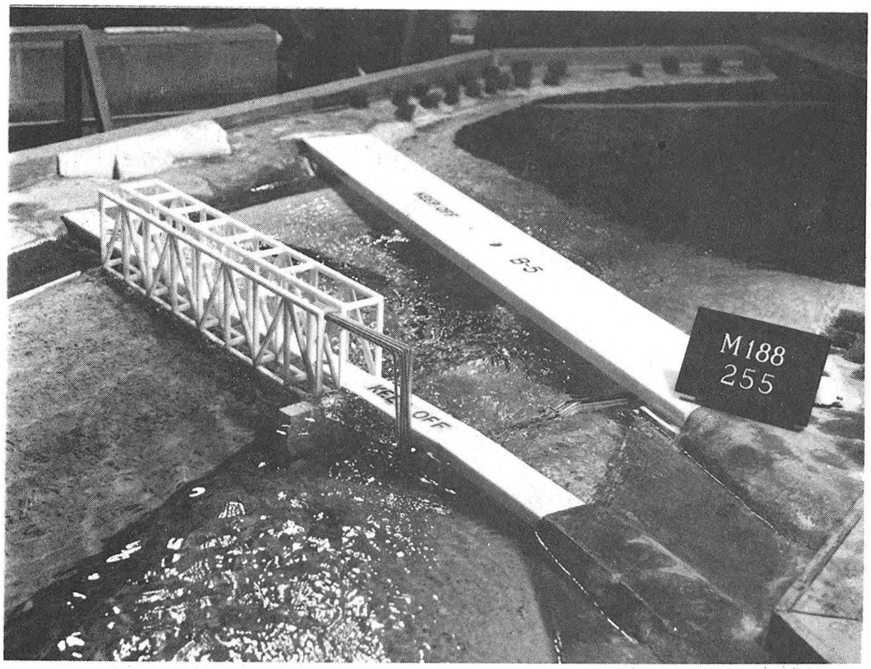


With revised bridge B-4

Photograph 39. Flow conditions at bridges B-5 and B-6 with revised piers of both bridges. Discharge of 52,800 cfs with Missouri River at 10-year discharge.

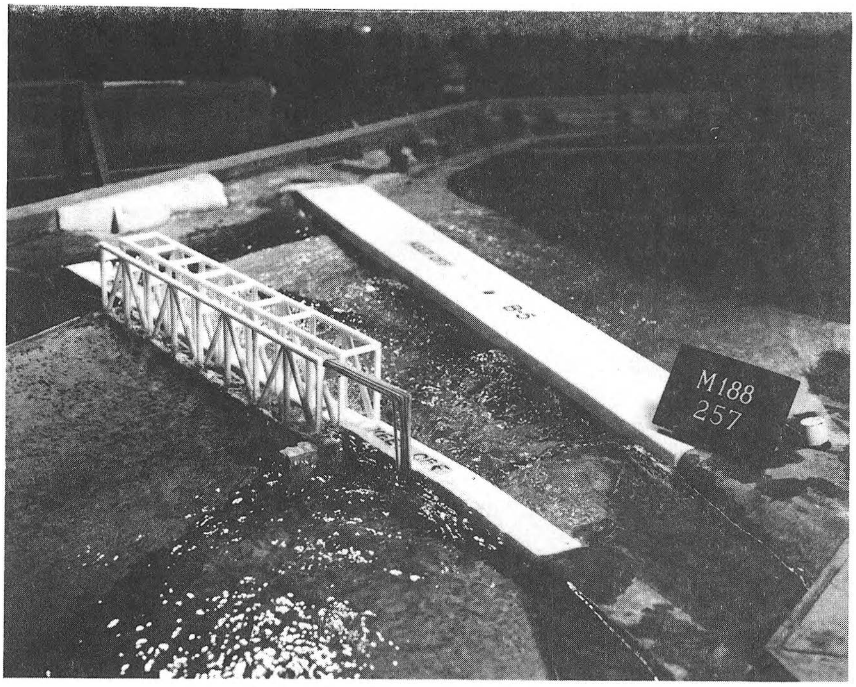


With existing bridge B-4

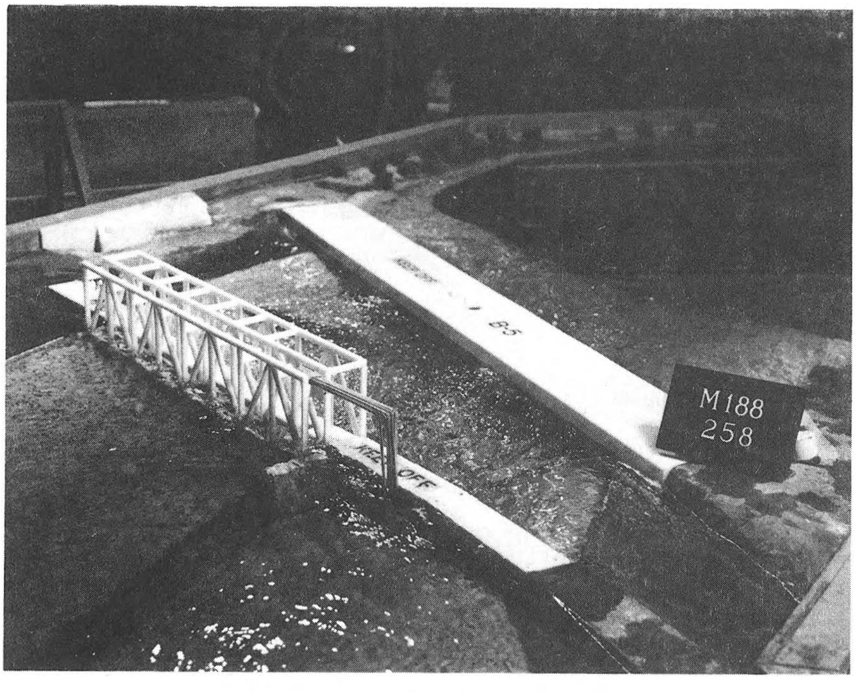


With revised bridge B-4

Photograph 40. Flow conditions at bridges B-5 and B-6 with existing piers, discharge of 42,000 cfs with Missouri River at 10-year discharge

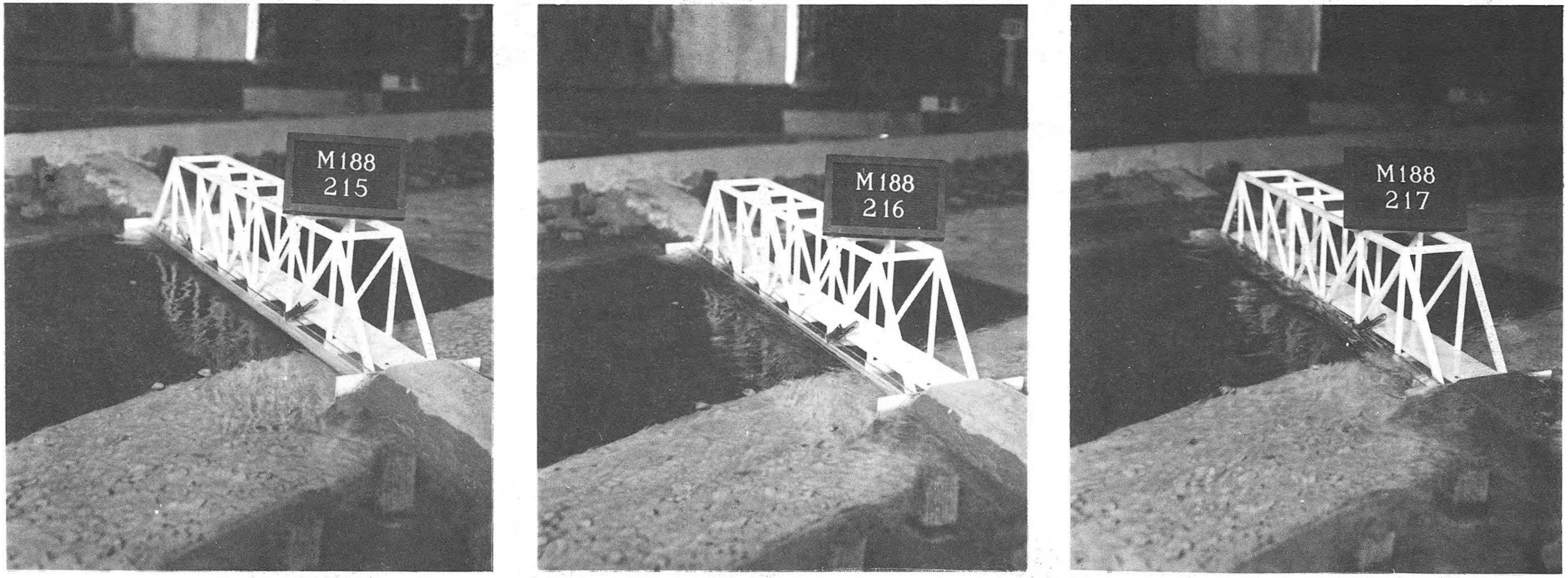


With existing bridge B-4



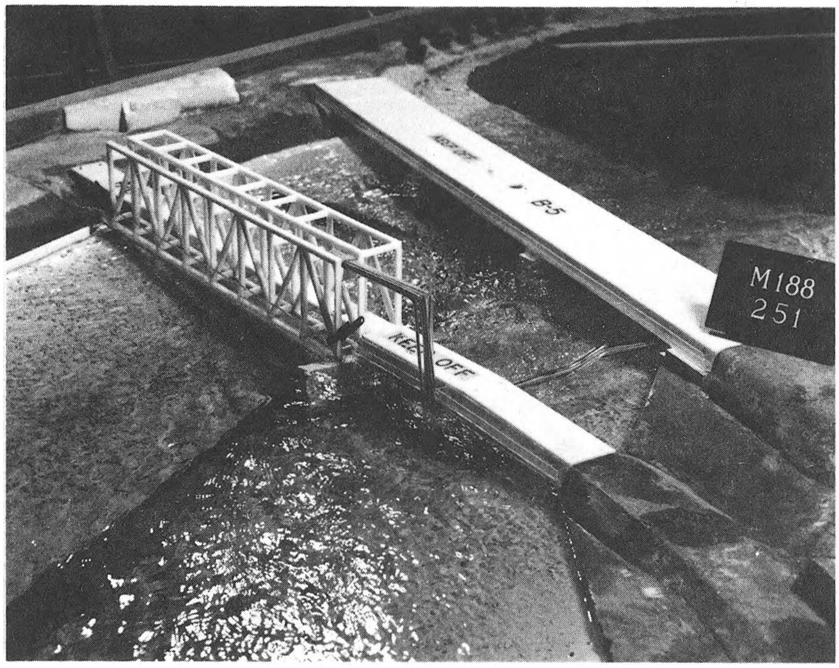
With revised bridge B-4

Photograph 41. Flow conditions at bridges B-5 and B-6 with existing piers. Discharge of 52,800 cfs with Missouri River at 10-year discharge.

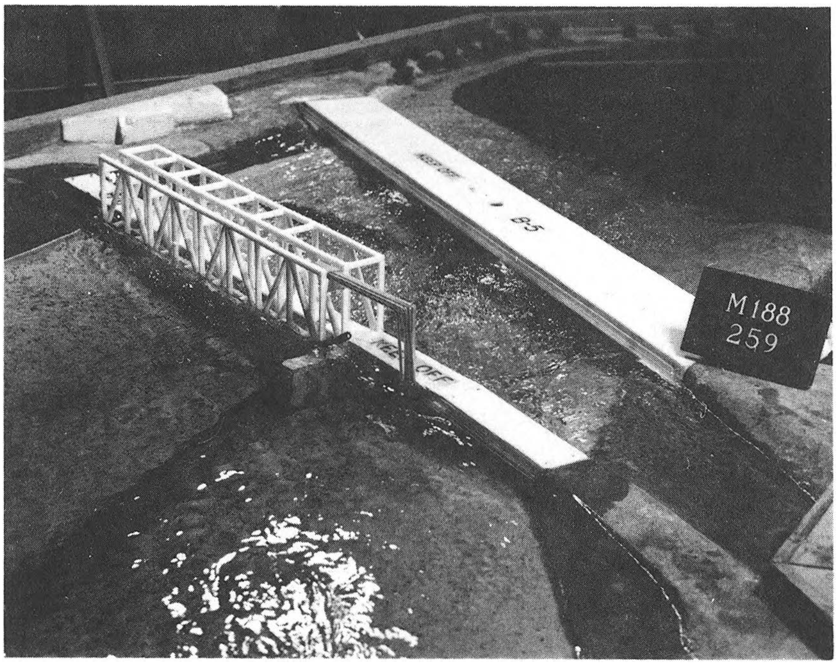


Discharge 35,000 cfs **Discharge 42,000 cfs** **Discharge 52,800 cfs**

Photograph 42. Flow conditions with streamlining cowl on bottom girder of bridge B-4. Missouri River at 10-year discharge.

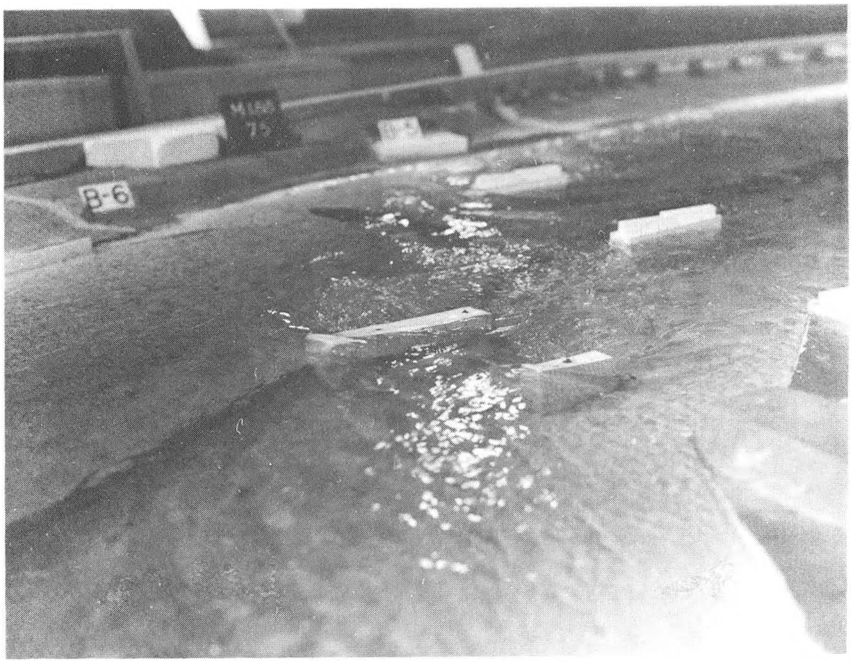


Discharge 35,000 cfs



Discharge 52,800 cfs

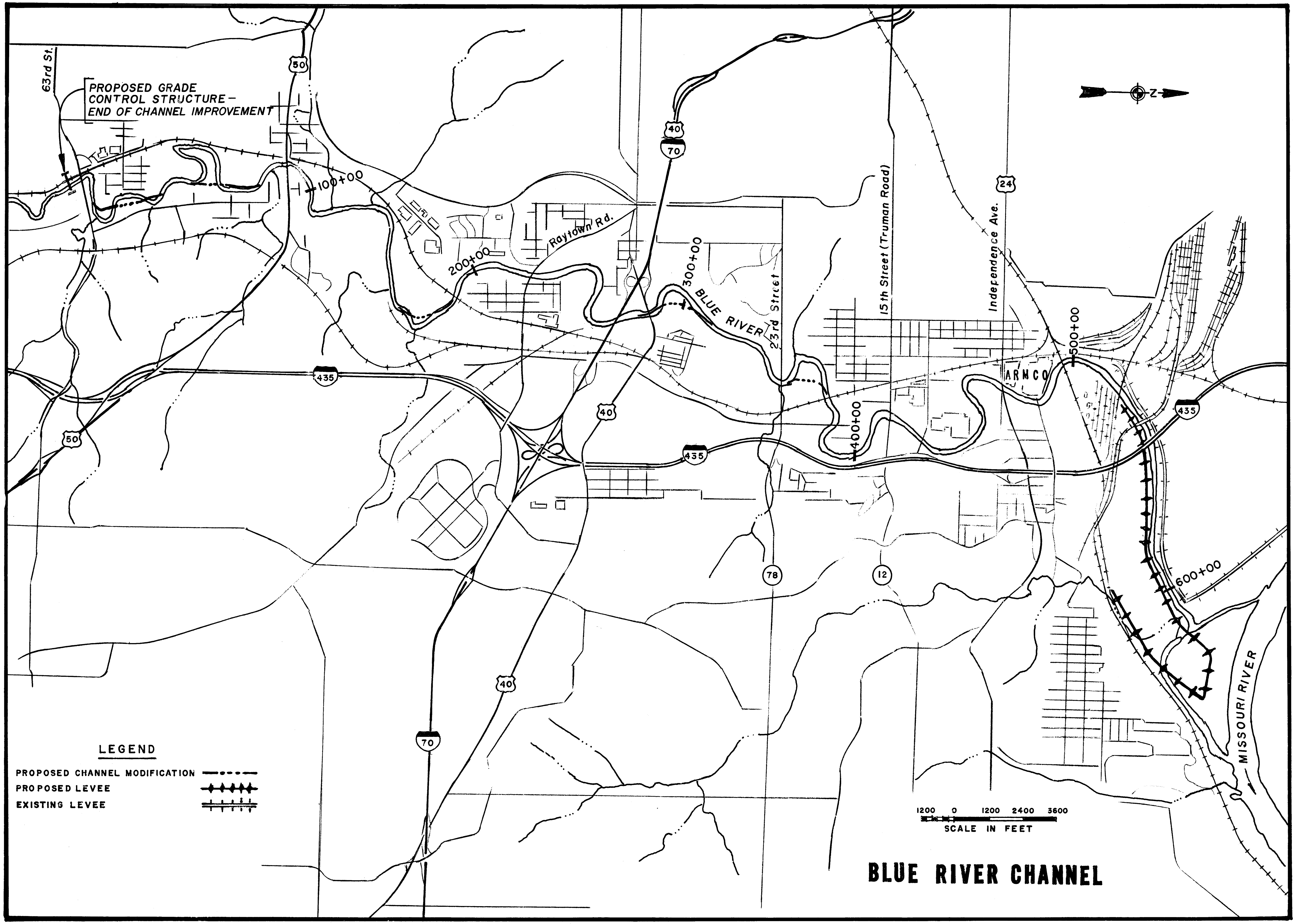
Photograph 43. Flow conditions at bridges B-5 and B-6 with streamlining cowl on bottom girders of bridges B-4, B-5, and B-6. Missouri River at 10-year discharge.



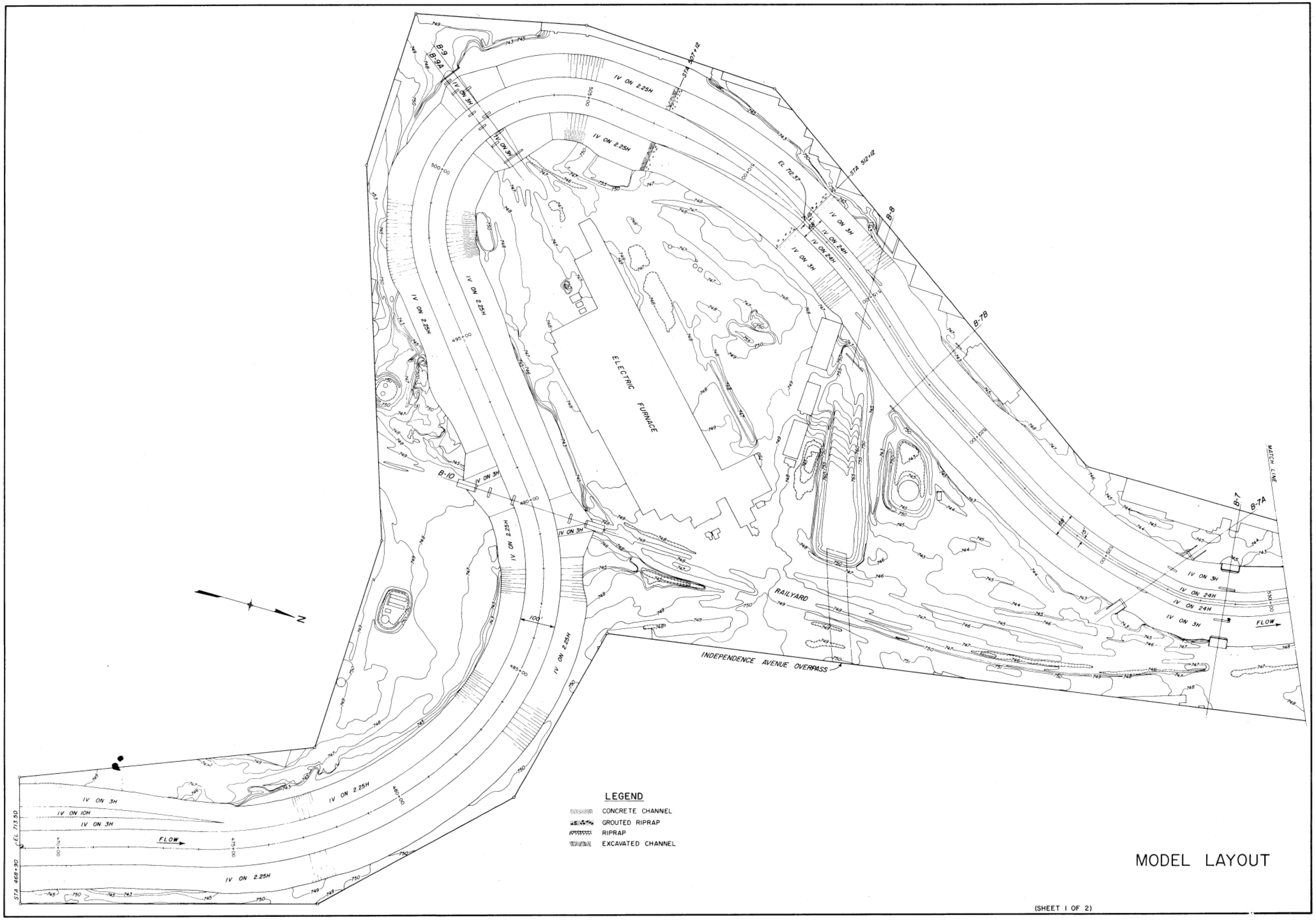
Looking downstream

Looking upstream

Photograph 44. Flow conditions at bridges B-5 and B-6 with revised pier 2 of bridge B-6. Discharge of 35,000 cfs with Missouri River at 10-year discharge.

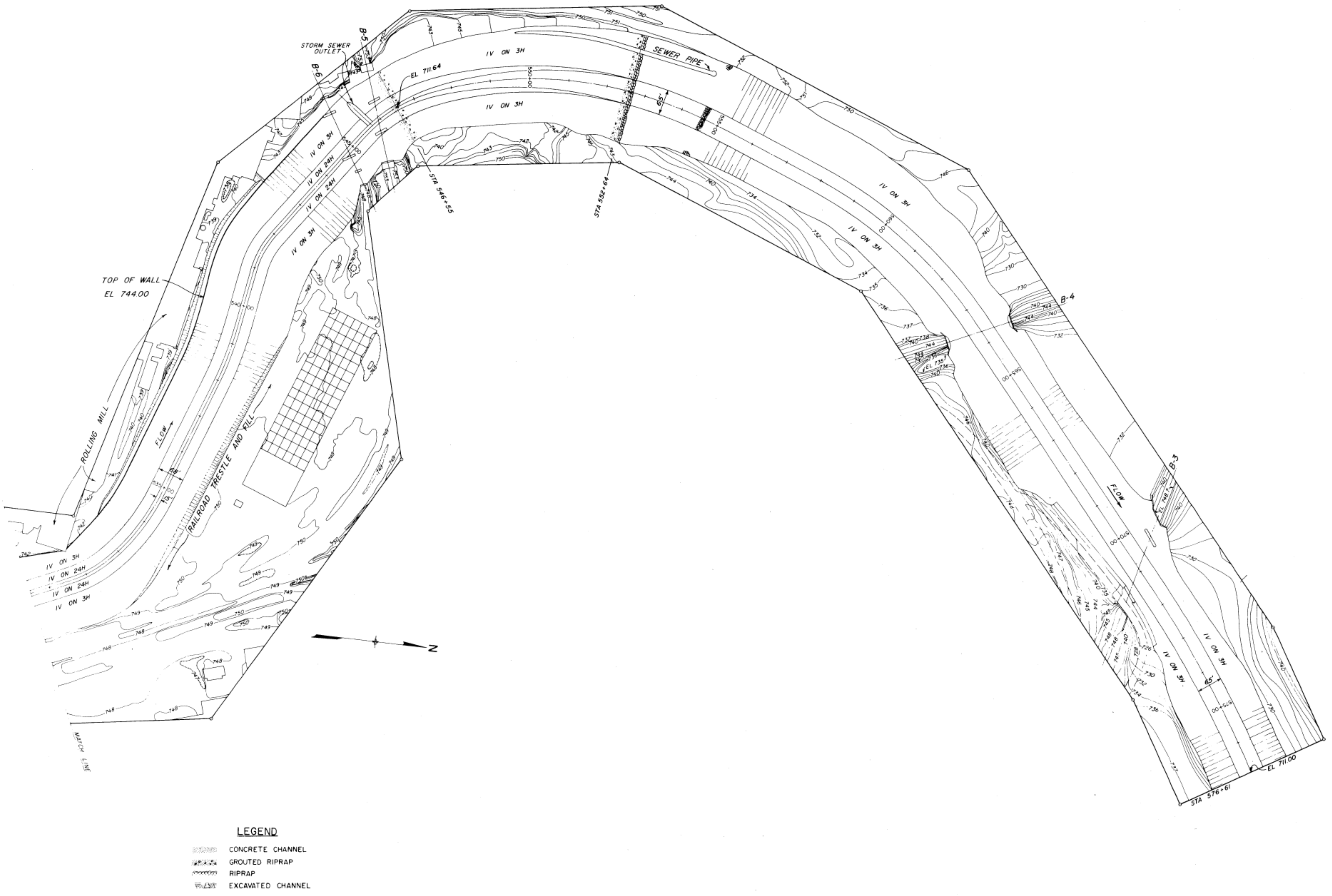


BLUE RIVER CHANNEL



MODEL LAYOUT

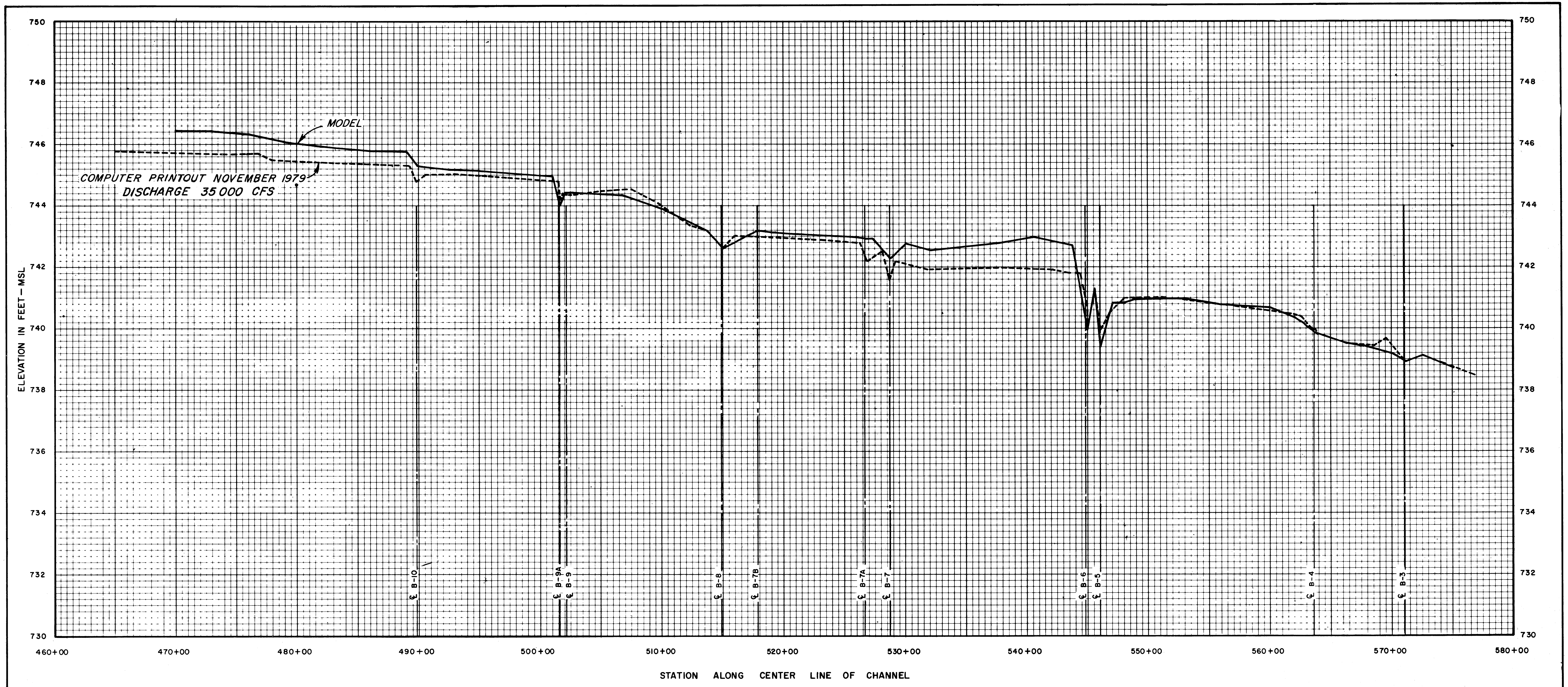
(SHEET 1 OF 2)



MODEL LAYOUT

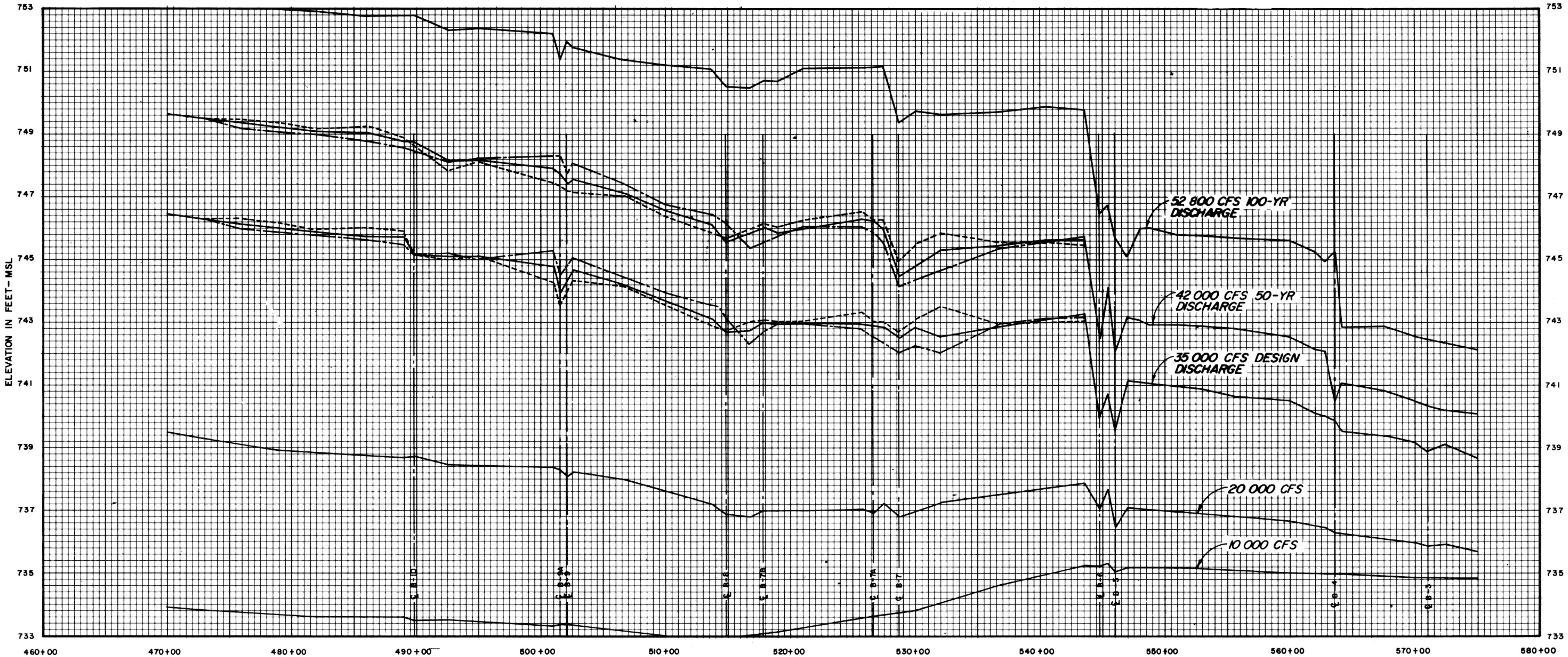
(SHEET 2 OF 2)

PLATE 3



WATER SURFACE PROFILE ALONG CENTER LINE
VERIFICATION OF CHANNEL

PLATE 4



STATION ALONG CENTER LINE OF CHANNEL

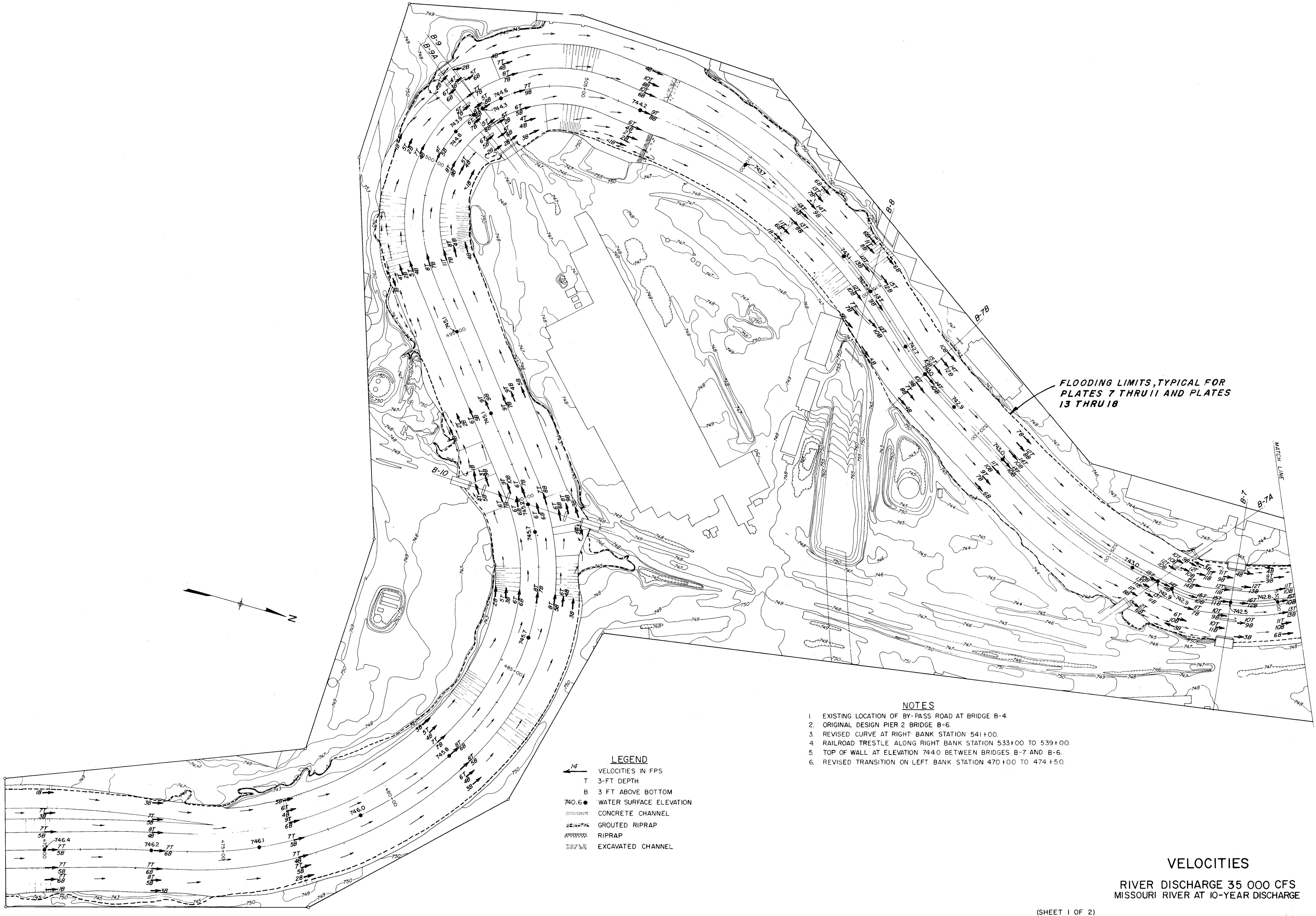
NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-3
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6
3. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00
4. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6

LEGEND

——— CENTERLINE
- - - - - RIGHT BANK
—·—·— LEFT BANK

WATER SURFACE PROFILES
MISSOURI RIVER AT 10-YEAR DISCHARGE



FLOODING LIMITS, TYPICAL FOR PLATES 7 THRU 11 AND PLATES 13 THRU 18

LEGEND

← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER SURFACE ELEVATION
░	CONCRETE CHANNEL
▓	GROUTED RIPRAP
▨	RIPRAP
▤	EXCAVATED CHANNEL

NOTES

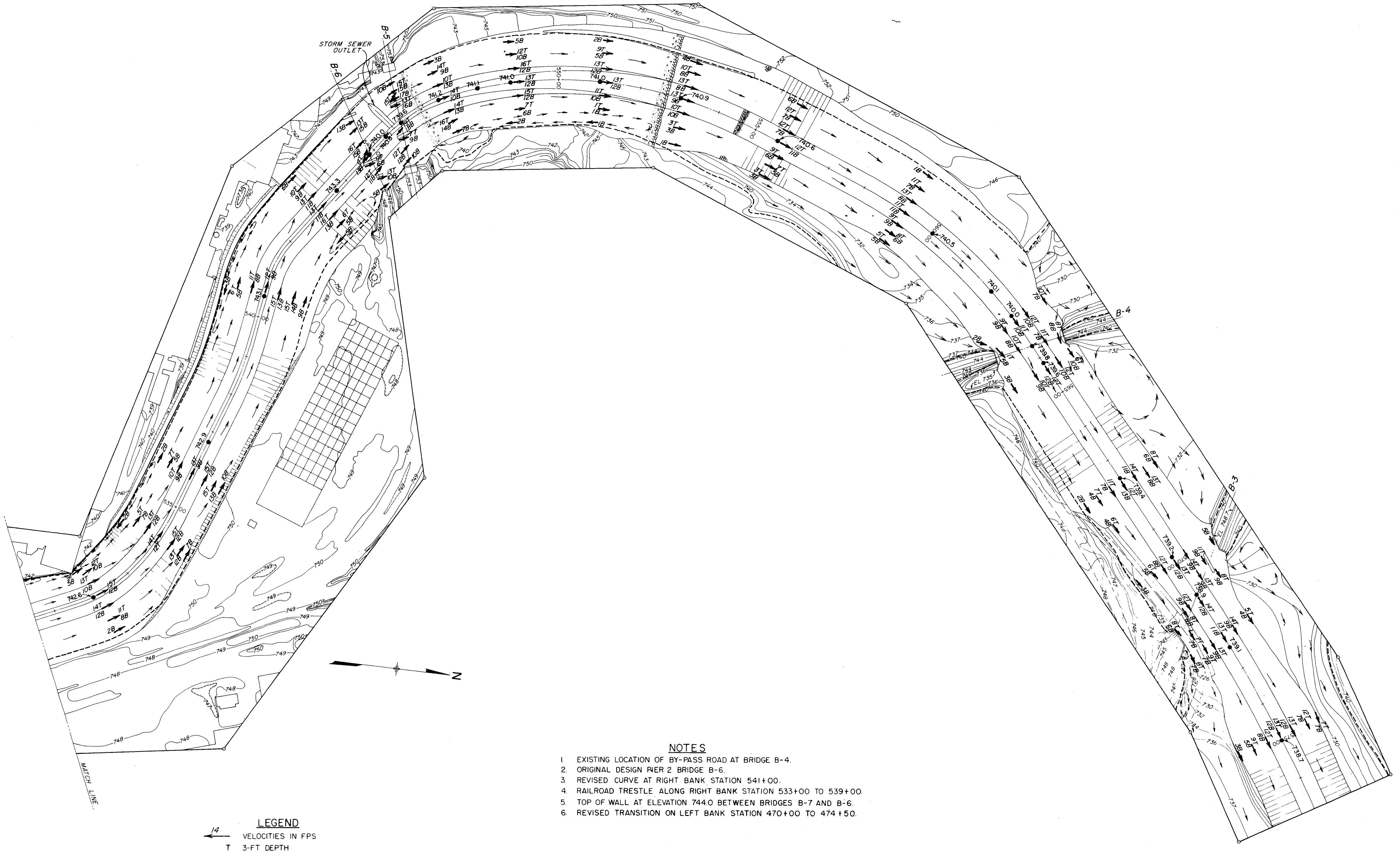
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 35 000 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 1 OF 2)

PLATE 6



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

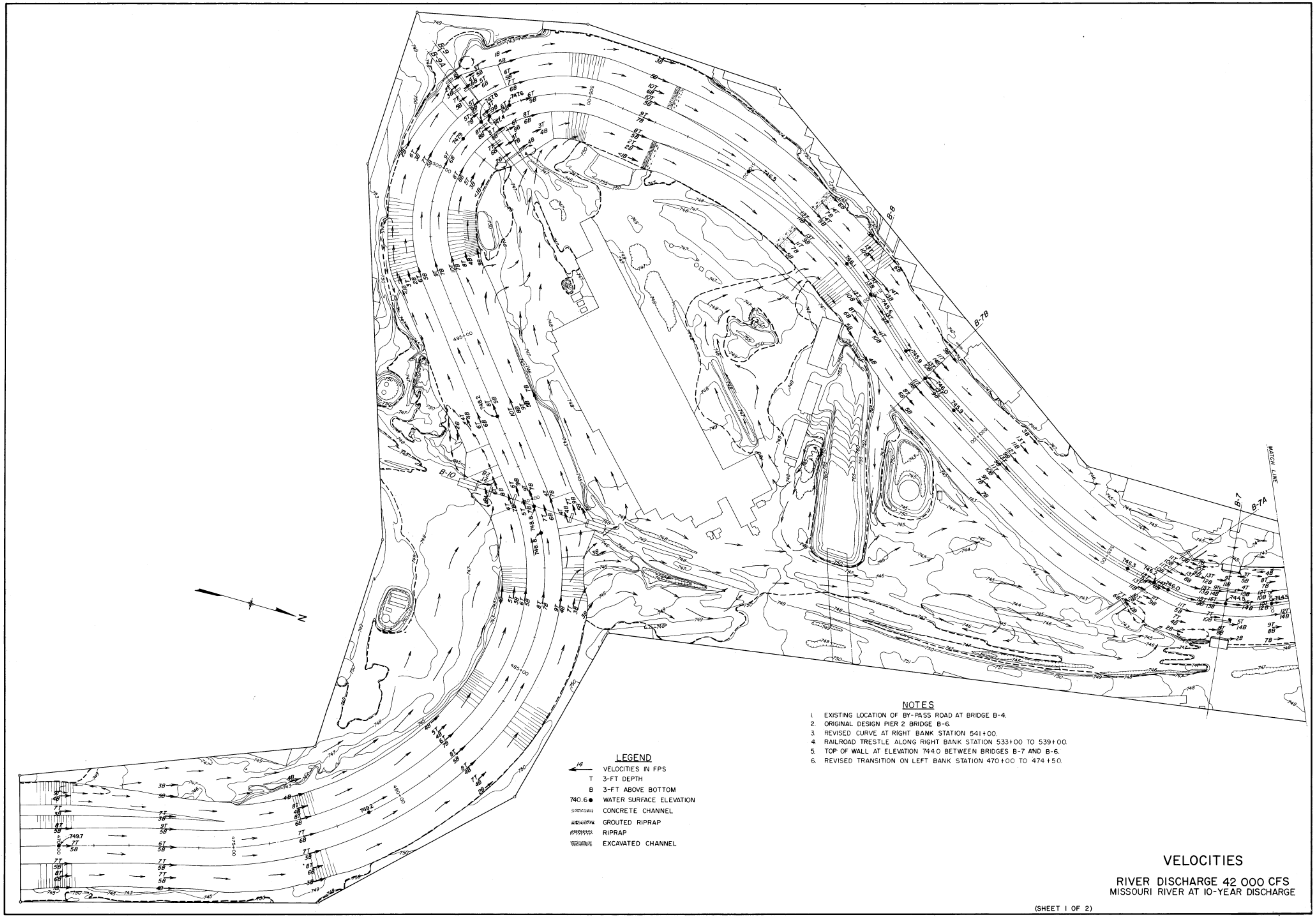
← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER-SURFACE ELEVATION
░	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▤	EXCAVATED CHANNEL

VELOCITIES

RIVER DISCHARGE 35 000 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 2 OF 2)

PLATE 7



LEGEND

← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3-FT ABOVE BOTTOM
740.6 ●	WATER SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

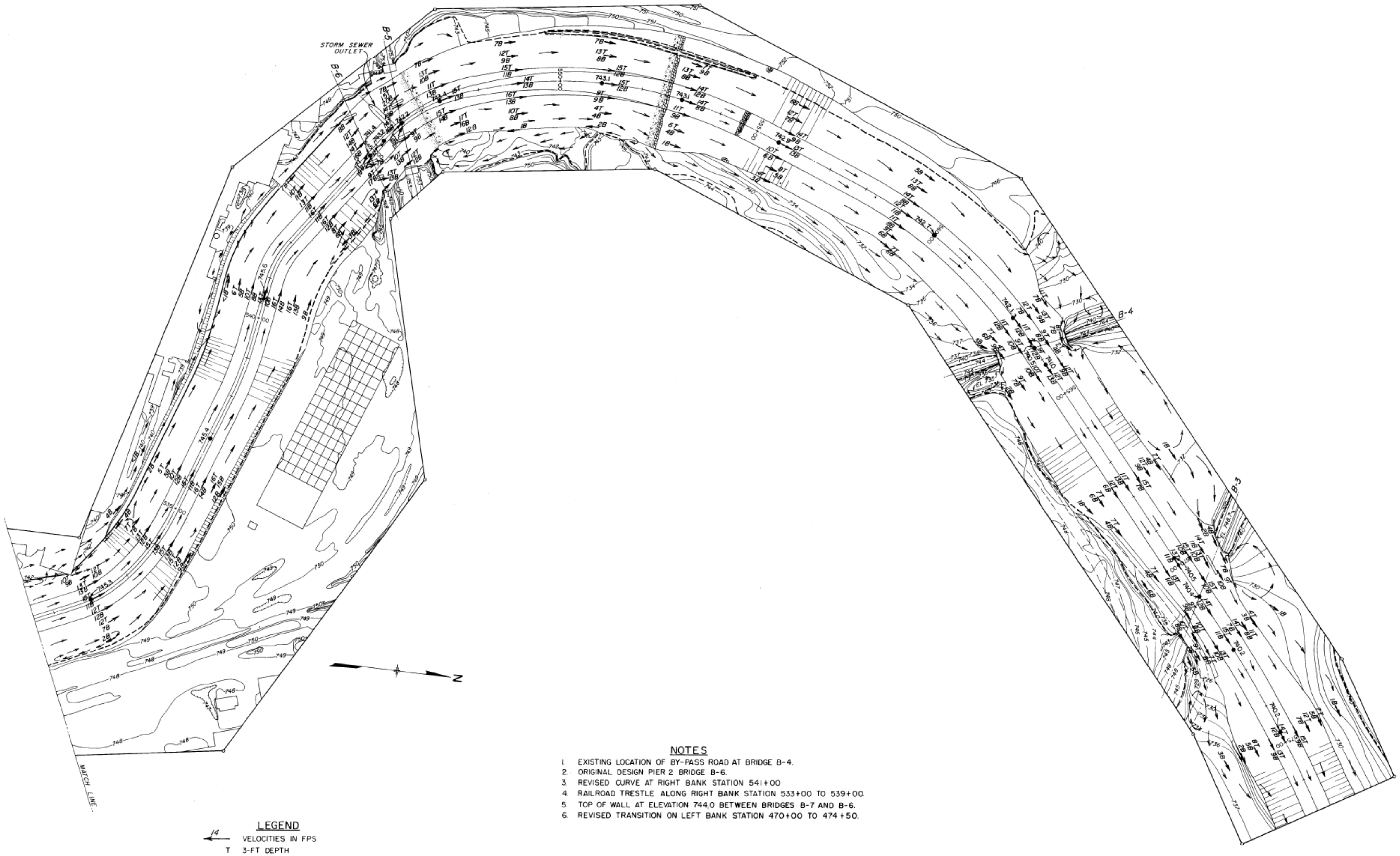
NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 42 000 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 1 OF 2)



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

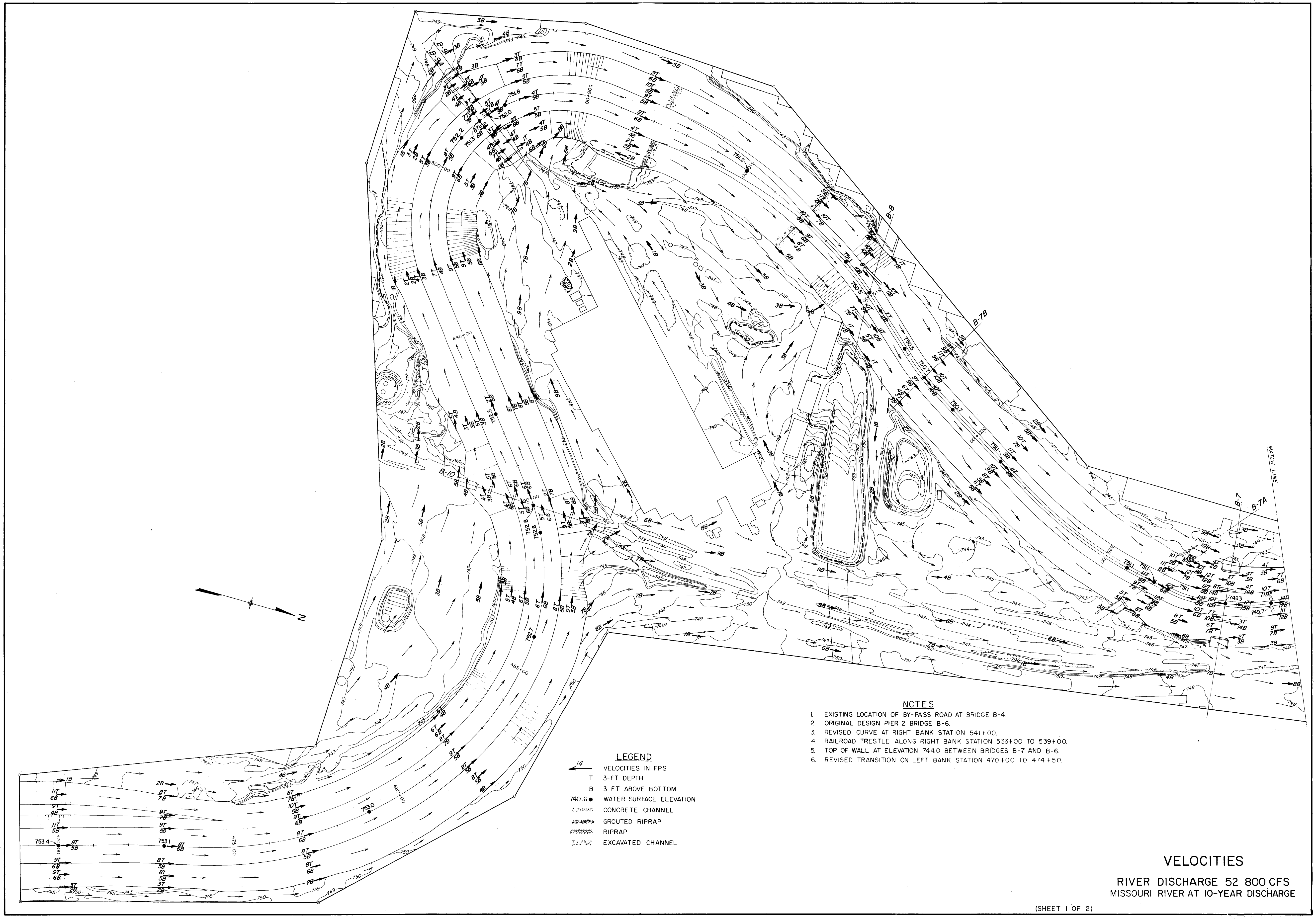
14 ←	VELOCITIES IN FPS
T	3-FT DEPTH
B	3-FT ABOVE BOTTOM
740.6 ●	WATER-SURFACE ELEVATION
░	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▤	EXCAVATED CHANNEL

VELOCITIES

RIVER DISCHARGE 42 000 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 2 OF 2)

PLATE 9



LEGEND

← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER SURFACE ELEVATION
░	CONCRETE CHANNEL
▓	GROUTED RIPRAP
▨	RIPRAP
▧	EXCAVATED CHANNEL

NOTES

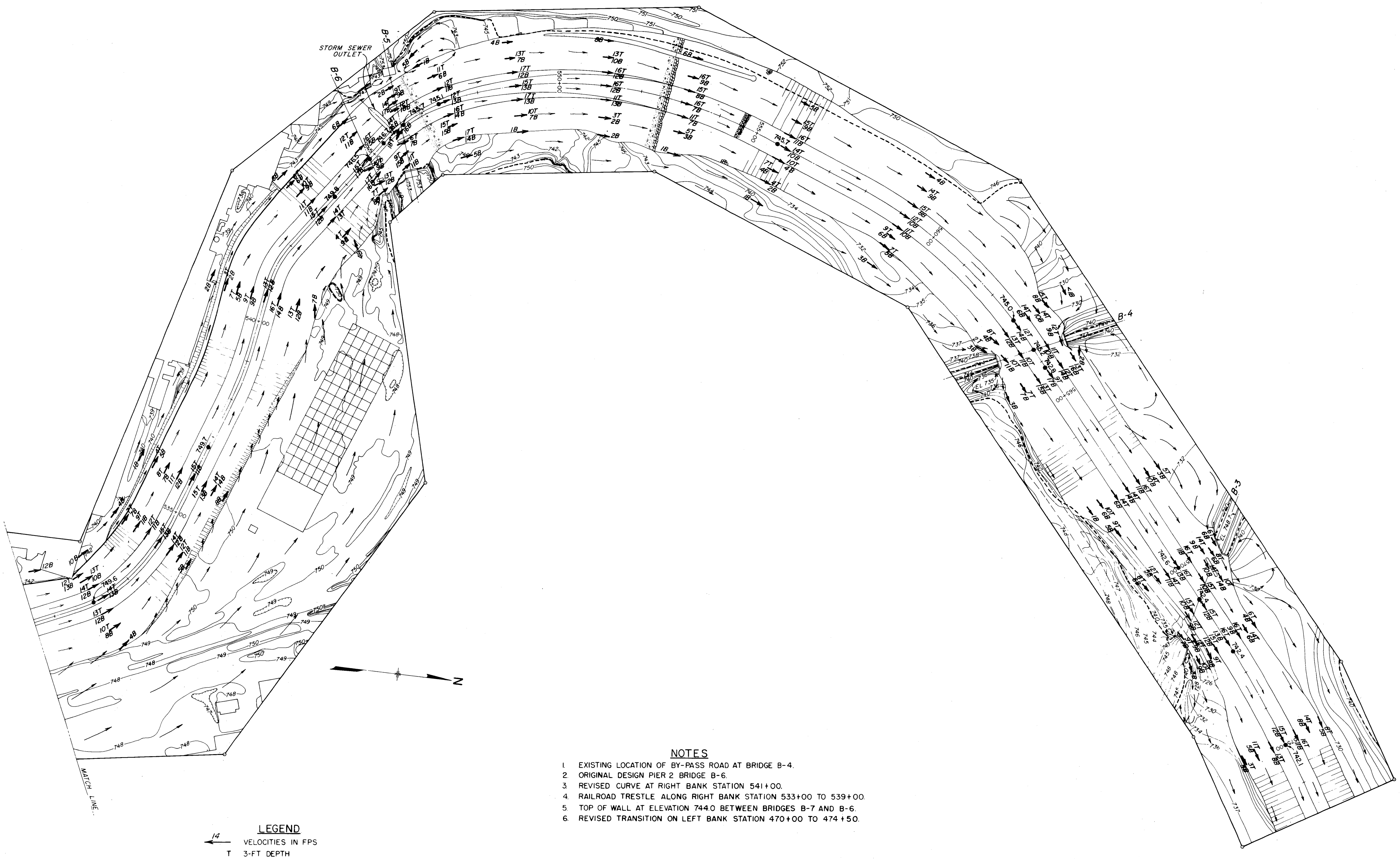
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 52 800 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 1 OF 2)

PLATE 10



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

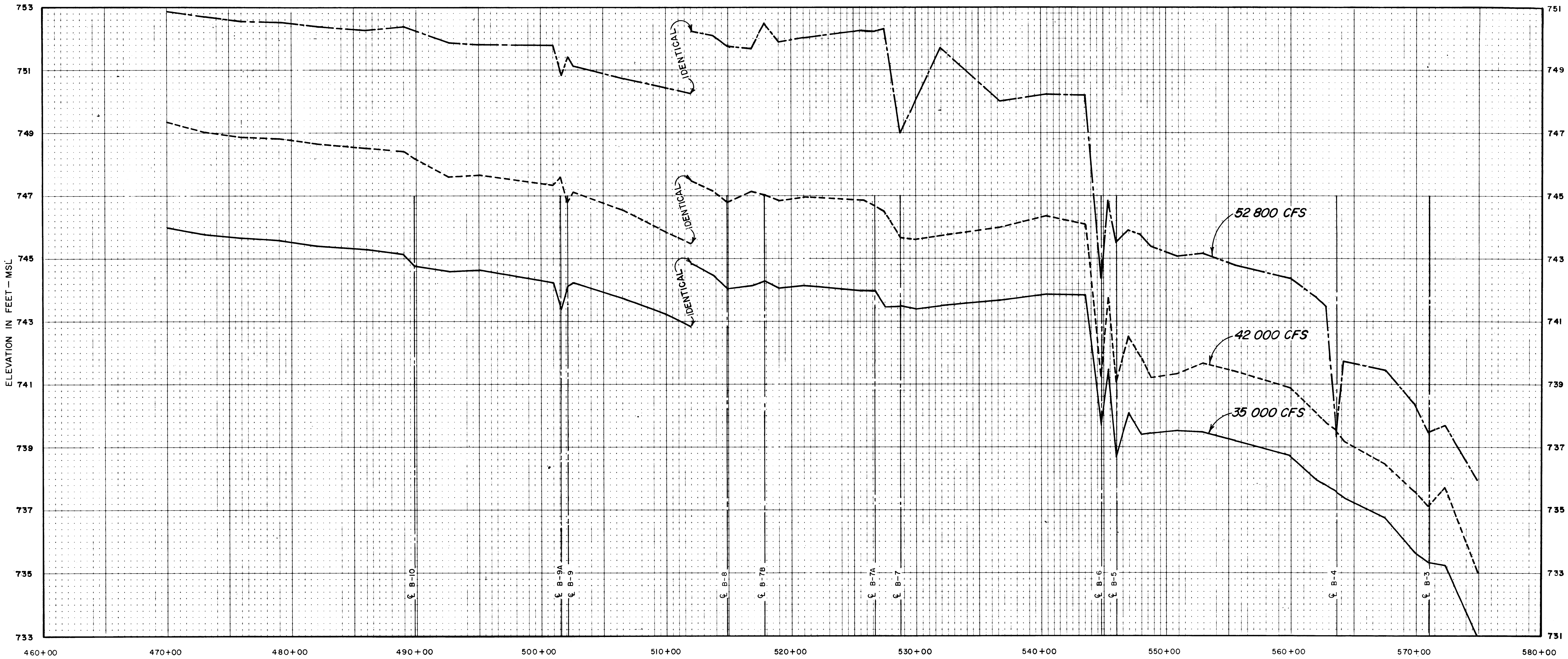
14 ←	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER-SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

VELOCITIES

RIVER DISCHARGE 52 800 CFS
MISSOURI RIVER AT 10-YEAR DISCHARGE

(SHEET 2 OF 2)

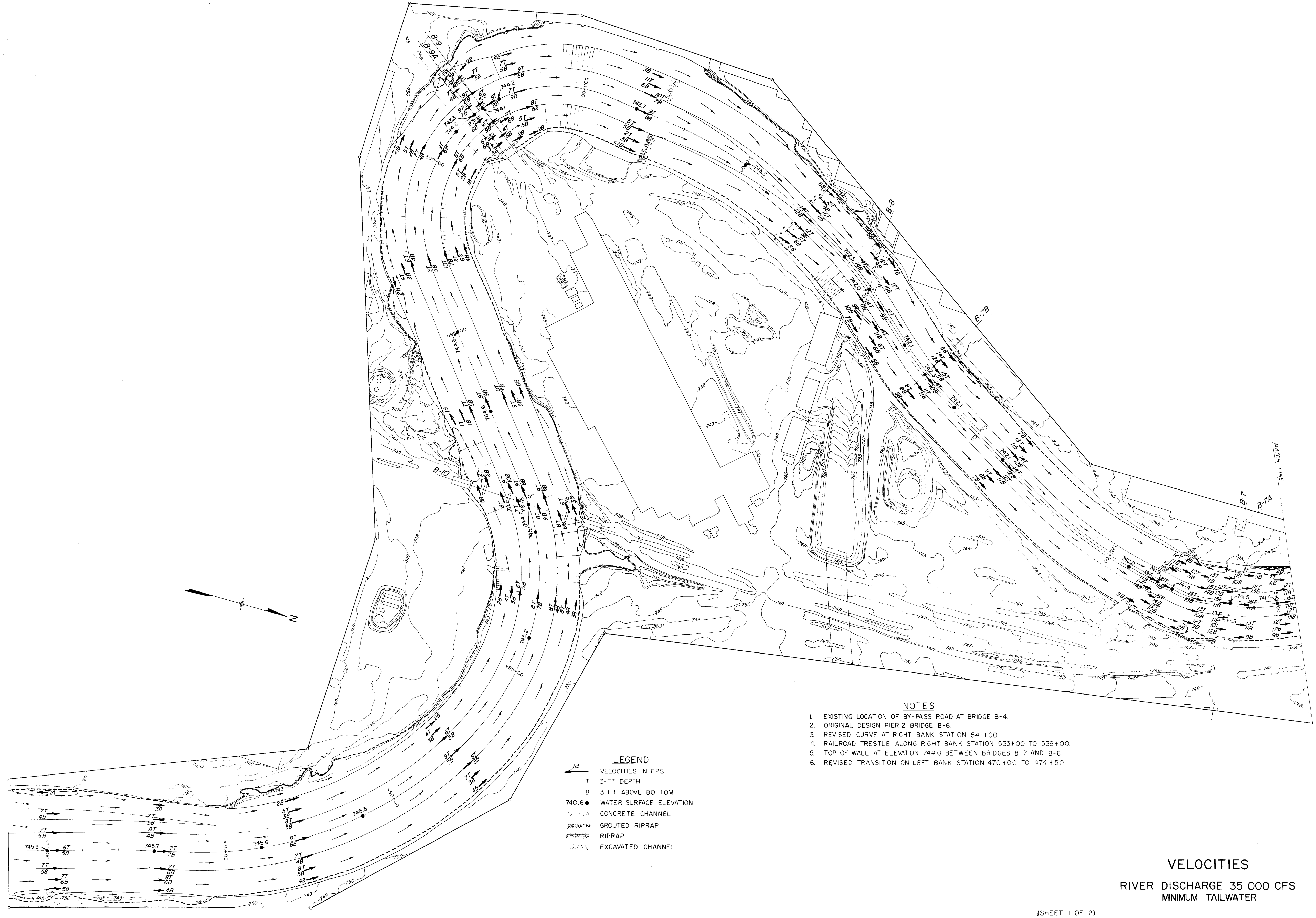
PLATE 11



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-3.
2. ORIGINAL DESIGN PIER 2, BRIDGE B-6.
3. RAILROAD TRESTLE ALONG RIGHT BANK, STATIONS 533+00 TO 539+00.
4. TOP OF WALL AT EL 744.0 BETWEEN BRIDGES B-7 AND B-6.

WATER SURFACE PROFILE ALONG CENTER LINE
MINIMUM TAILWATER



LEGEND

← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

NOTES

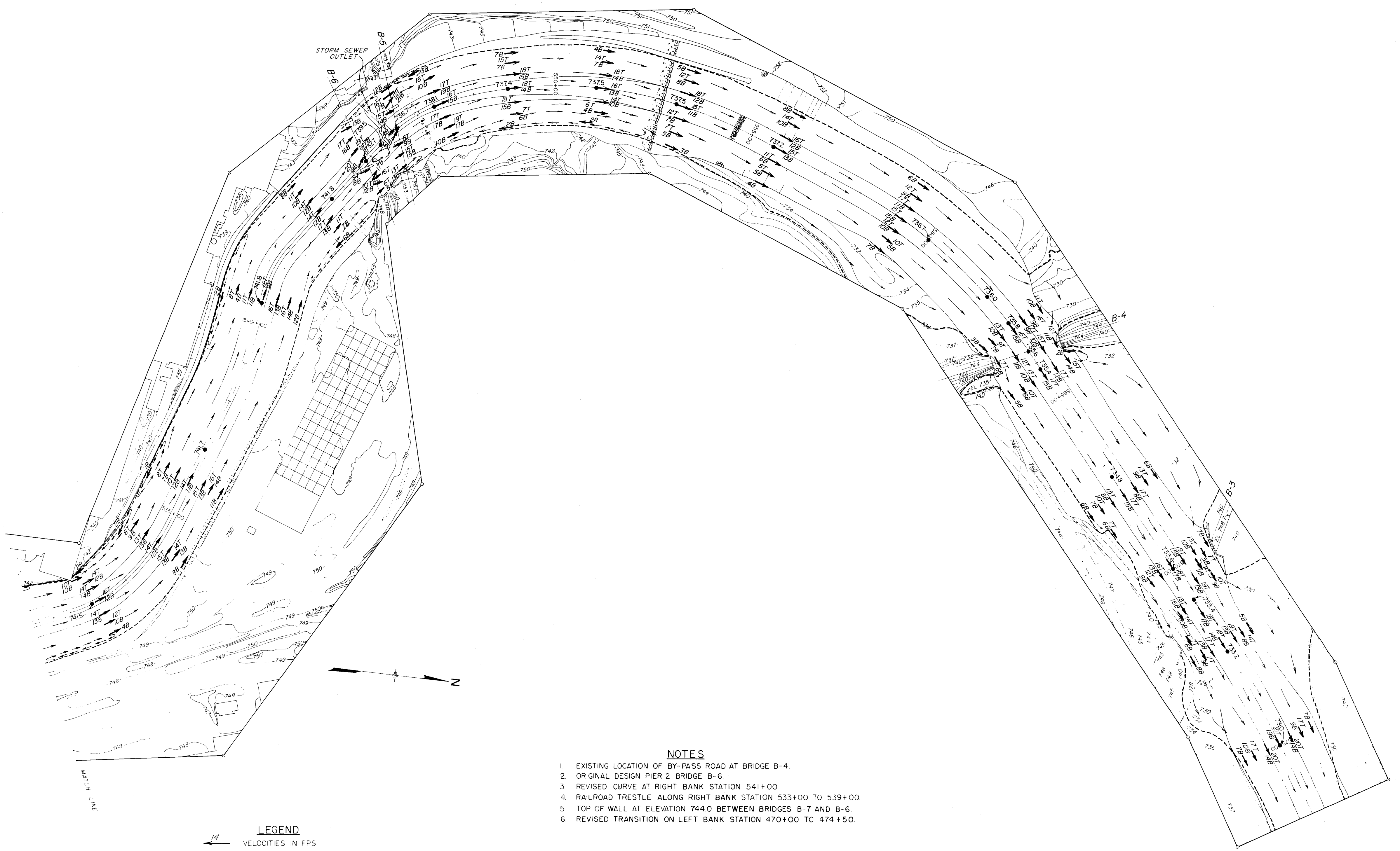
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER

(SHEET 1 OF 2)

PLATE 13



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

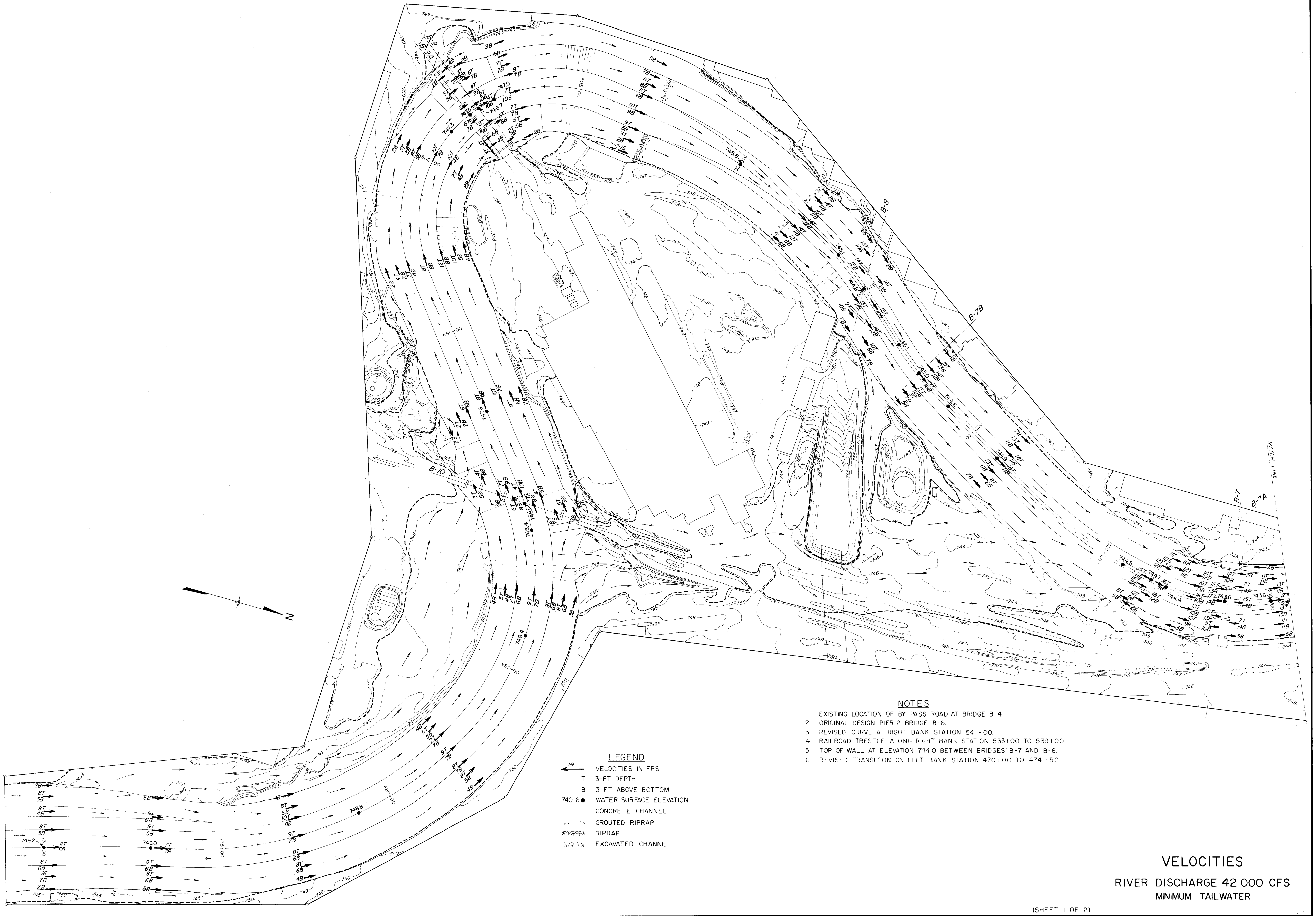
← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER-SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

VELOCITIES

RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER

(SHEET 2 OF 2)

PLATE 14



NOTES

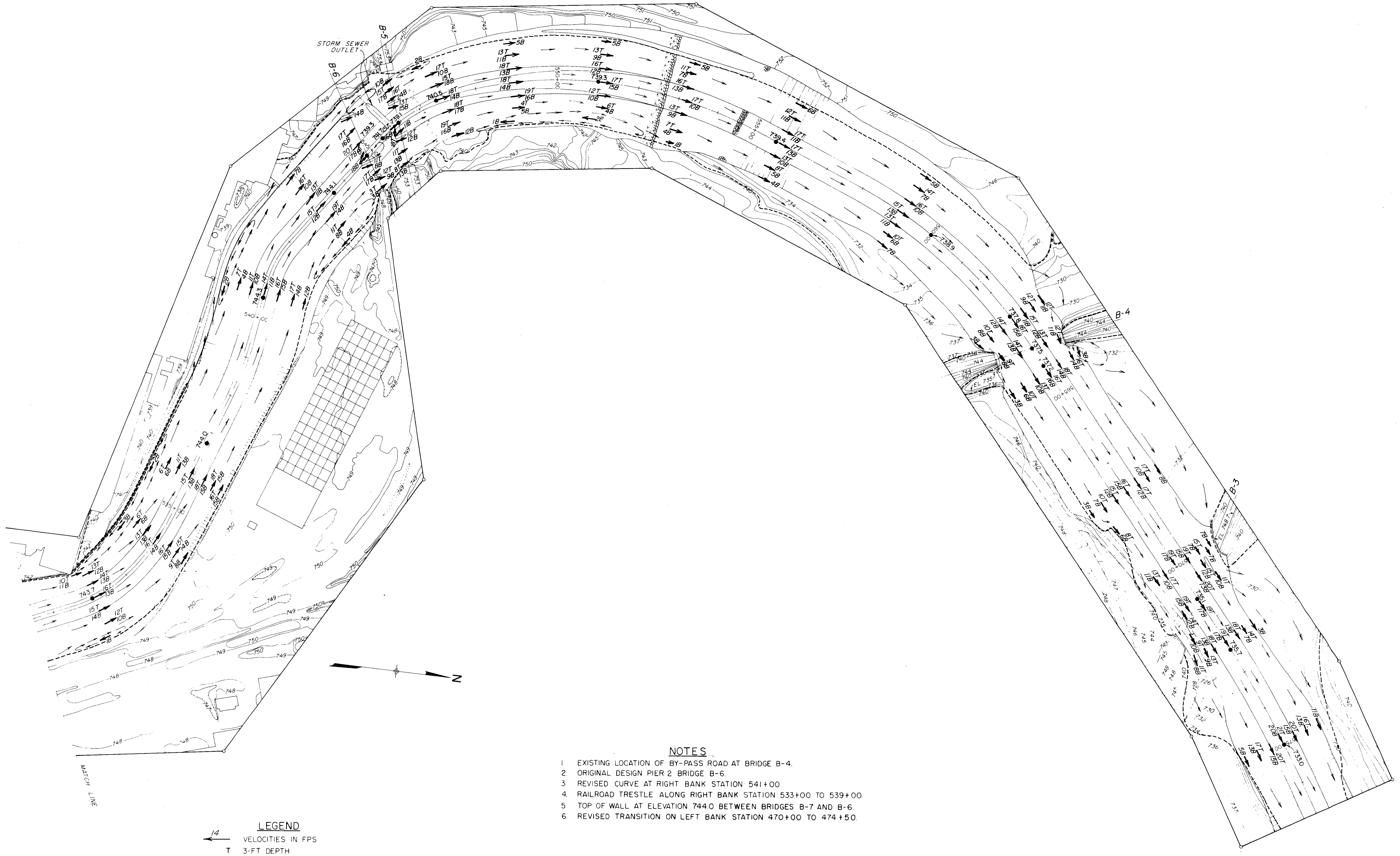
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 42 000 CFS
MINIMUM TAILWATER

(SHEET 1 OF 2)

PLATE 15



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740 6 ●	WATER-SURFACE ELEVATION
░	CONCRETE CHANNEL
▒	GROUTED RIPRAP
▒	RIPRAP
▨	EXCAVATED CHANNEL

VELOCITIES

RIVER DISCHARGE 42 000 CFS

MINIMUM TAILWATER

(SHEET 2 OF 2)

PLATE 16

LEGEND

14 ←	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740.6 ●	WATER SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

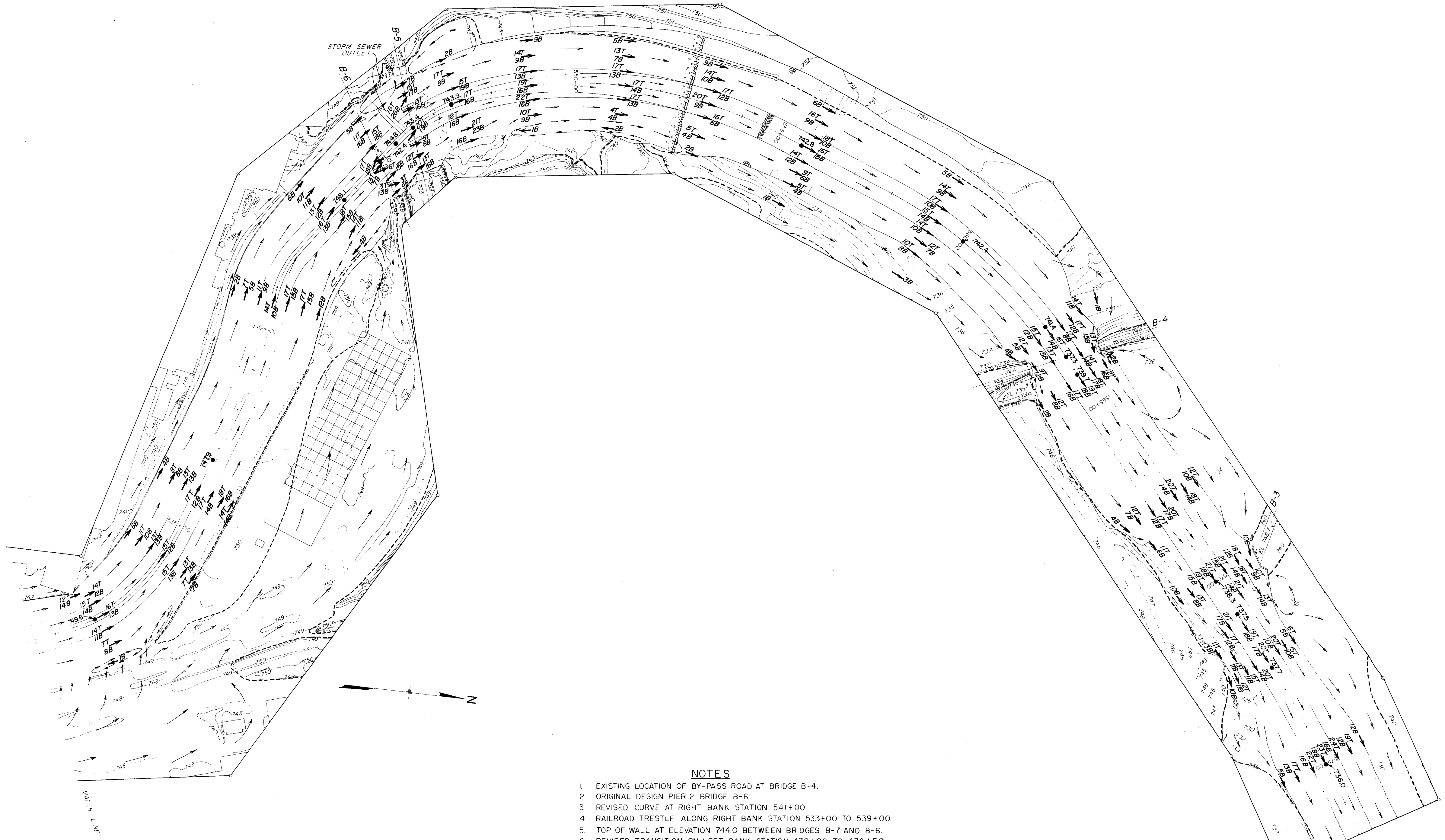
NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00.
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

VELOCITIES

RIVER DISCHARGE 52 800 CFS
MINIMUM TAILWATER

(SHEET 1 OF 2)



NOTES

1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-4.
2. ORIGINAL DESIGN PIER 2 BRIDGE B-6.
3. REVISED CURVE AT RIGHT BANK STATION 541+00
4. RAILROAD TRESTLE ALONG RIGHT BANK STATION 533+00 TO 539+00.
5. TOP OF WALL AT ELEVATION 744.0 BETWEEN BRIDGES B-7 AND B-6.
6. REVISED TRANSITION ON LEFT BANK STATION 470+00 TO 474+50.

LEGEND

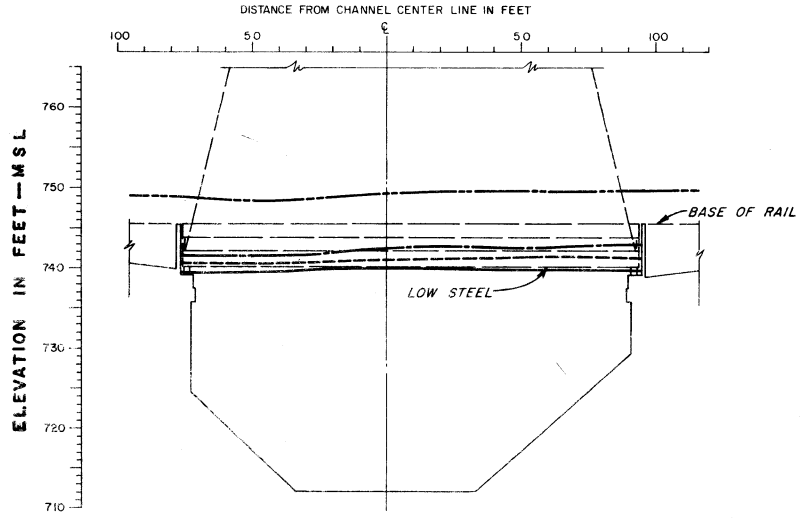
← 14	VELOCITIES IN FPS
T	3-FT DEPTH
B	3 FT ABOVE BOTTOM
740 6 ●	WATER-SURFACE ELEVATION
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP
▨	RIPRAP
▨	EXCAVATED CHANNEL

VELOCITIES

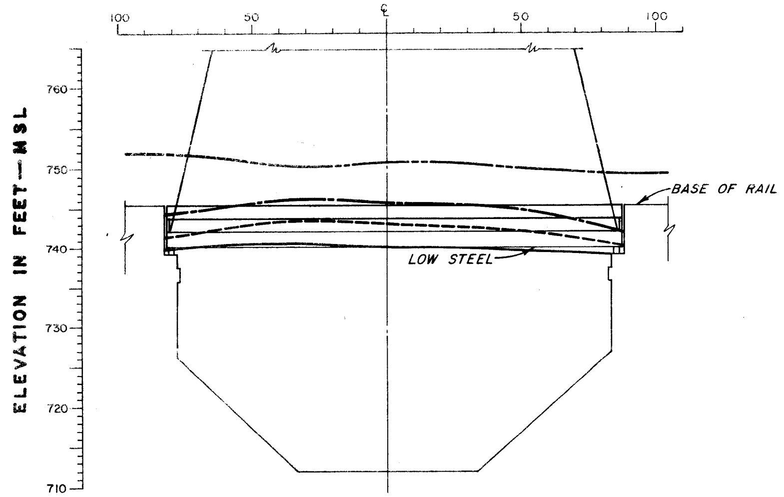
RIVER DISCHARGE 52 800 CFS
MINIMUM TAILWATER

(SHEET 2 OF 2)

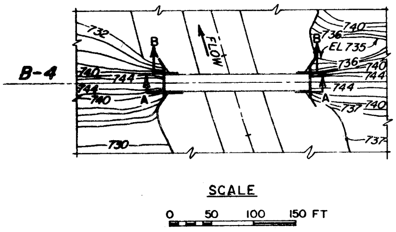
PLATE 18



SECTION B-B



SECTION A-A

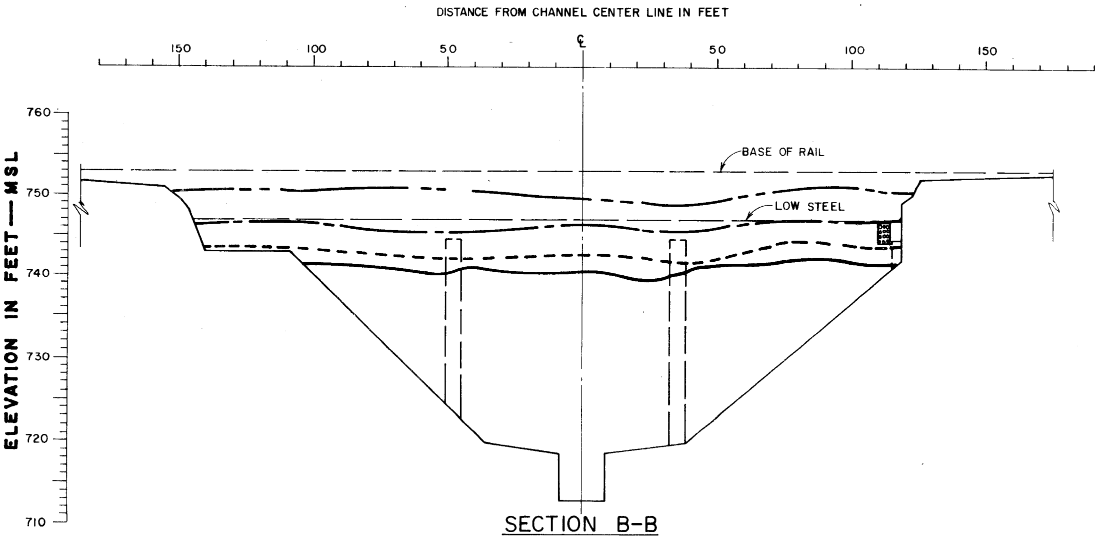


LOCATION OF CROSS SECTIONS

LEGEND

—— 35 000 CFS-DESIGN DISCHARGE
------ 42 000 CFS-50-YEAR DISCHARGE
—-— 52 800 CFS-100-YEAR DISCHARGE
—--— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-4



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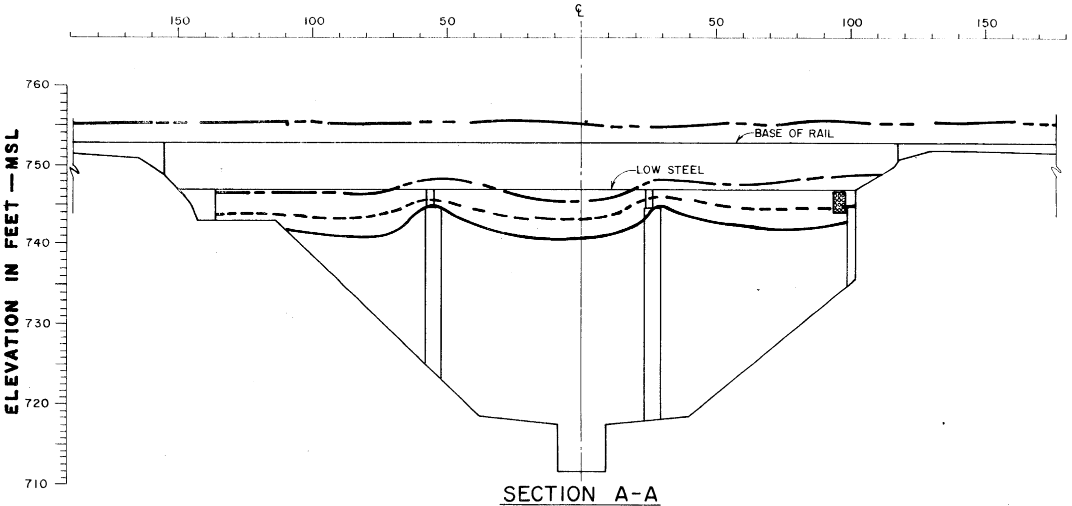

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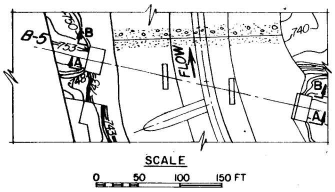


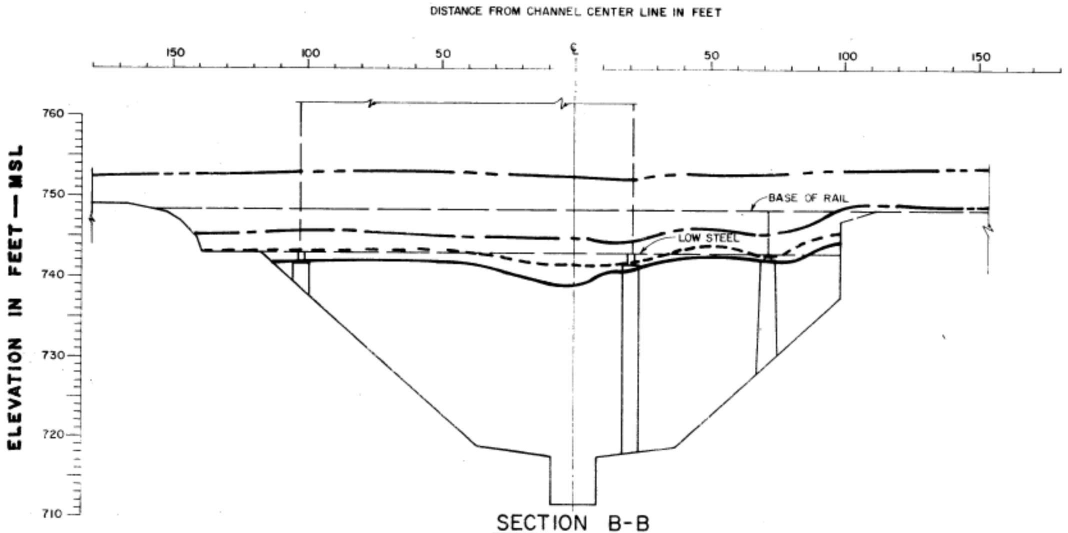
LOCATION OF CROSS SECTIONS

LEGEND

——— 35 000 CFS-DESIGN DISCHARGE
------ 42 000 CFS-50-YEAR DISCHARGE
—-— 52 800 CFS-100-YEAR DISCHARGE
—-— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-5

PLATE 20



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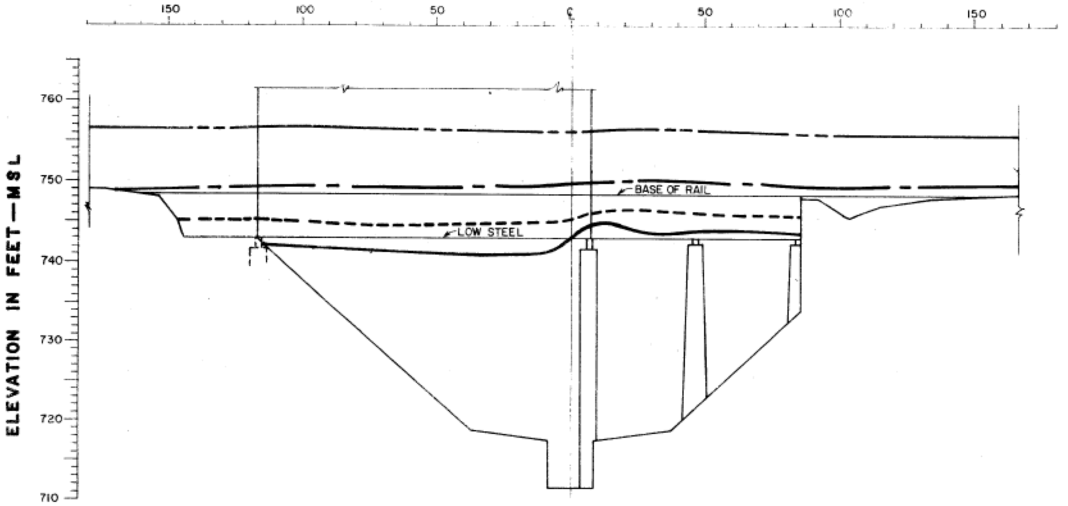

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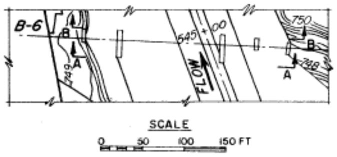


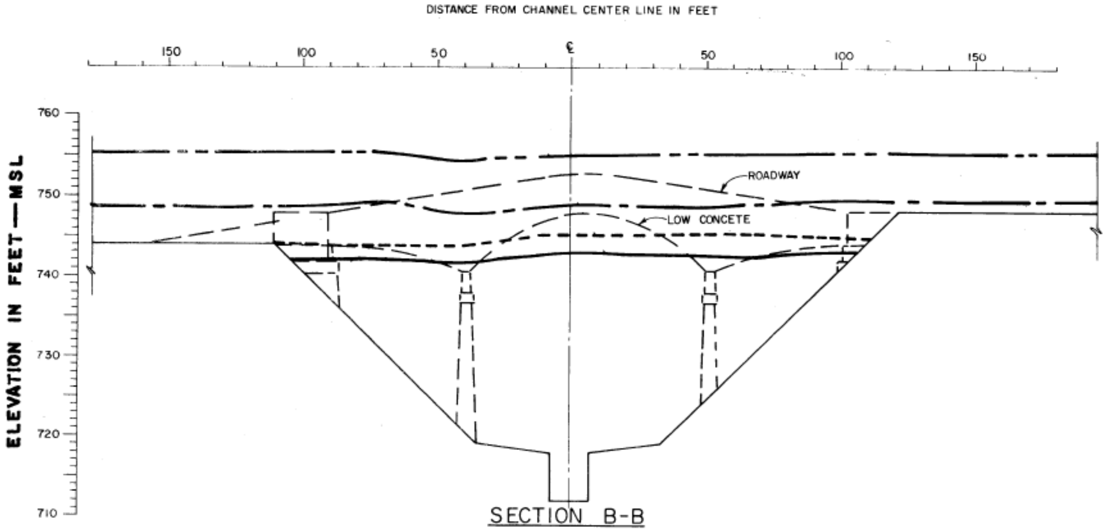
LOCATION OF CROSS SECTIONS

LEGEND

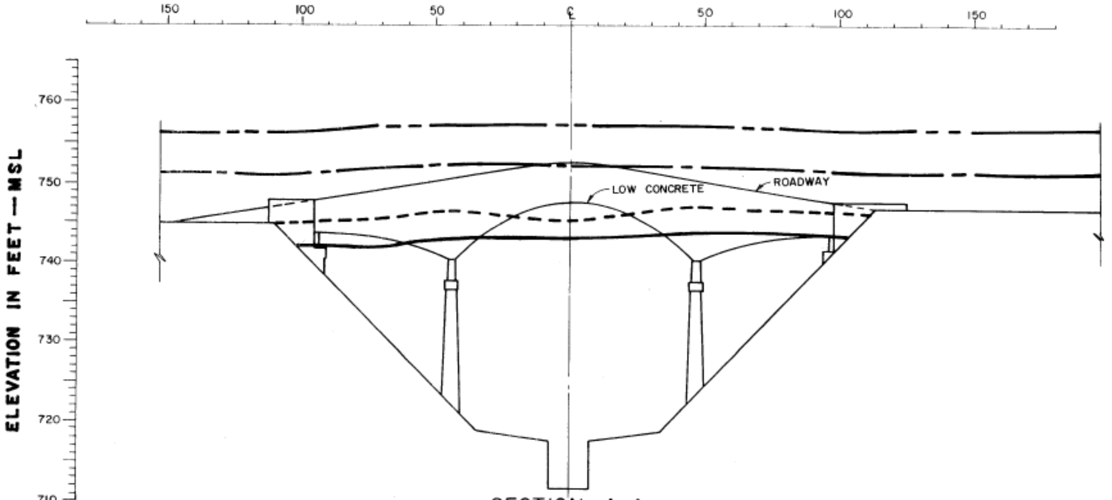
- ——— 35 000 CFS-DESIGN DISCHARGE
- ------ 42 000 CFS-50-YEAR DISCHARGE
- —-— 52 800 CFS-100-YEAR DISCHARGE
- —--— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-6

PLATE 21



SECTION B-B



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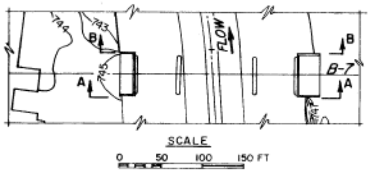


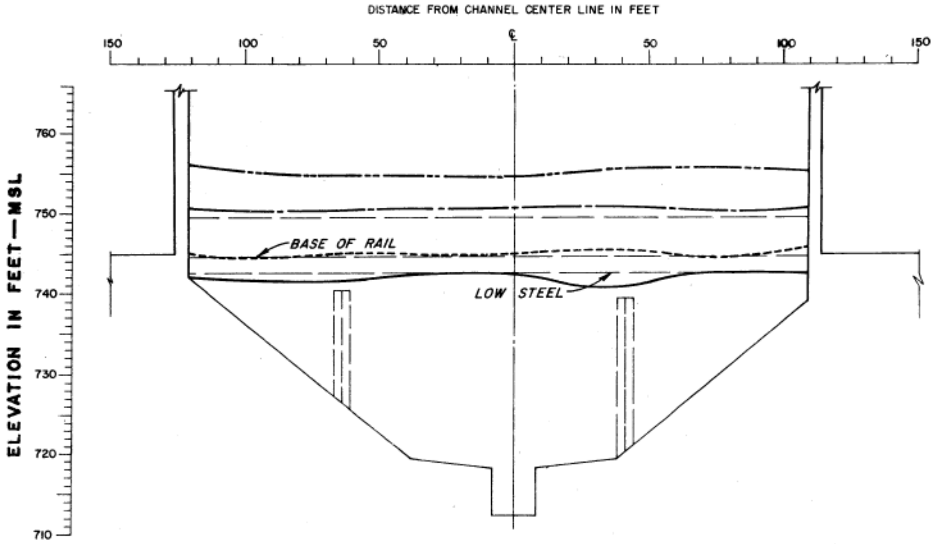
LOCATION OF CROSS SECTIONS

LEGEND

- ——— 35 000 CFS-DESIGN DISCHARGE
- - - - - - 42 000 CFS-50-YEAR DISCHARGE
- —·—— 52 800 CFS-100-YEAR DISCHARGE
- —··—— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-7

PLATE 22



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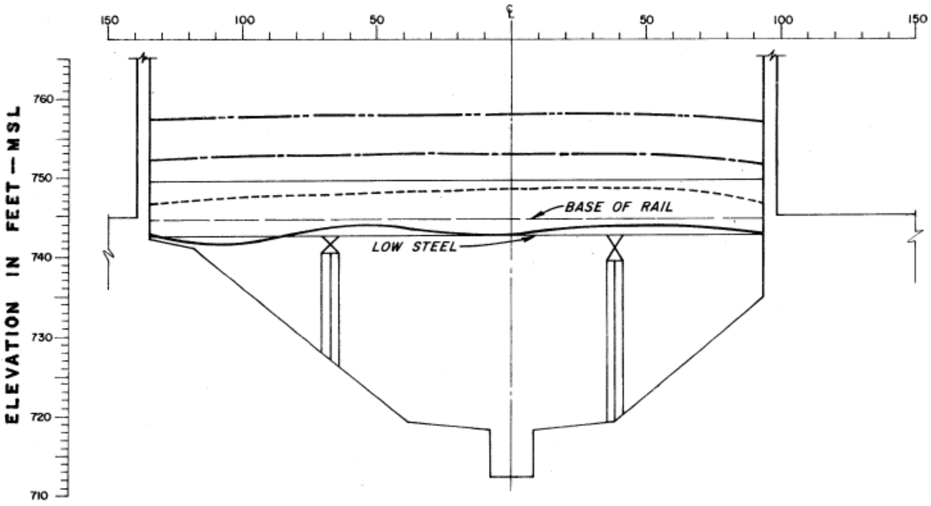

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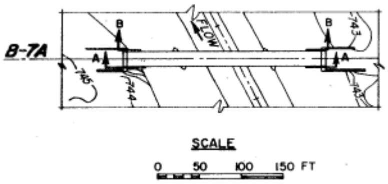
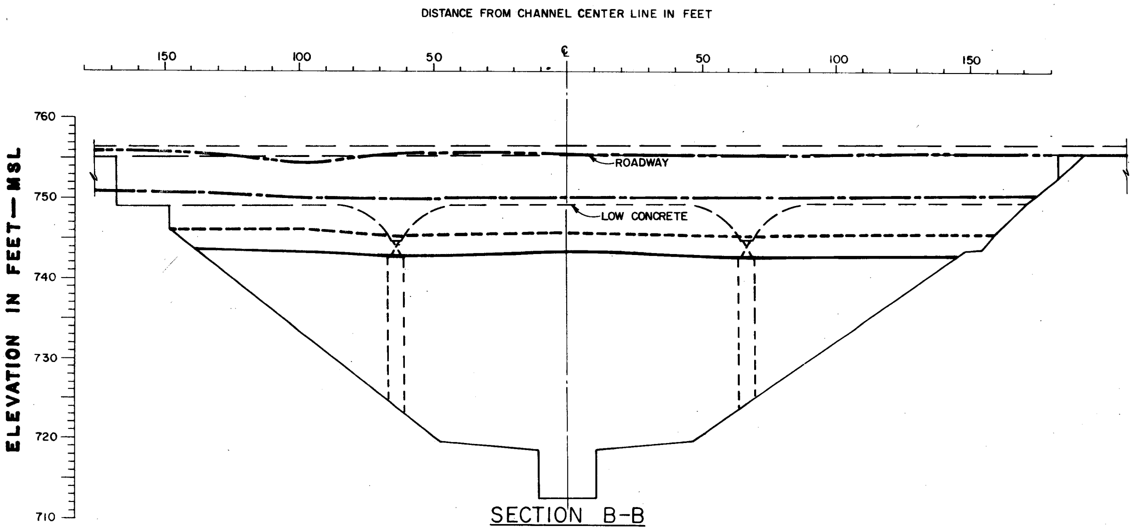


LOCATION OF CROSS SECTIONS

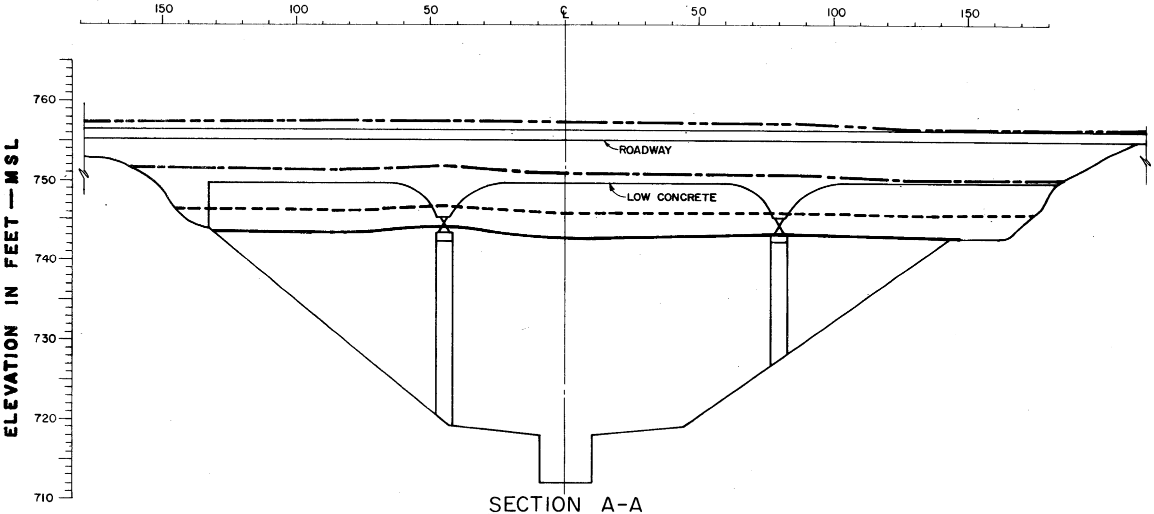
LEGEND

———— 35 000 CFS-DESIGN DISCHARGE
------ 42 000 CFS-50-YEAR DISCHARGE
—·—— 52 800 CFS-100-YEAR DISCHARGE
—··— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-7A



SECTION B-B



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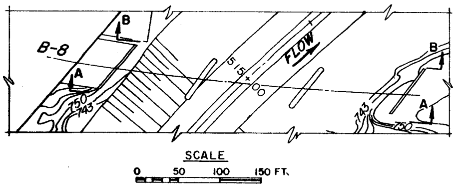
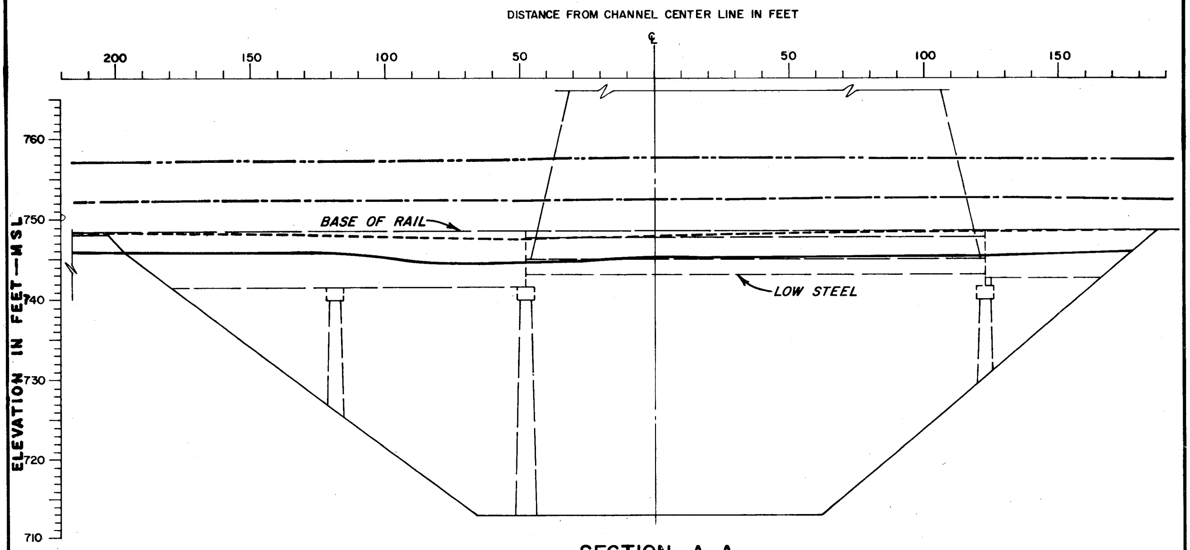


LOCATION OF CROSS SECTIONS

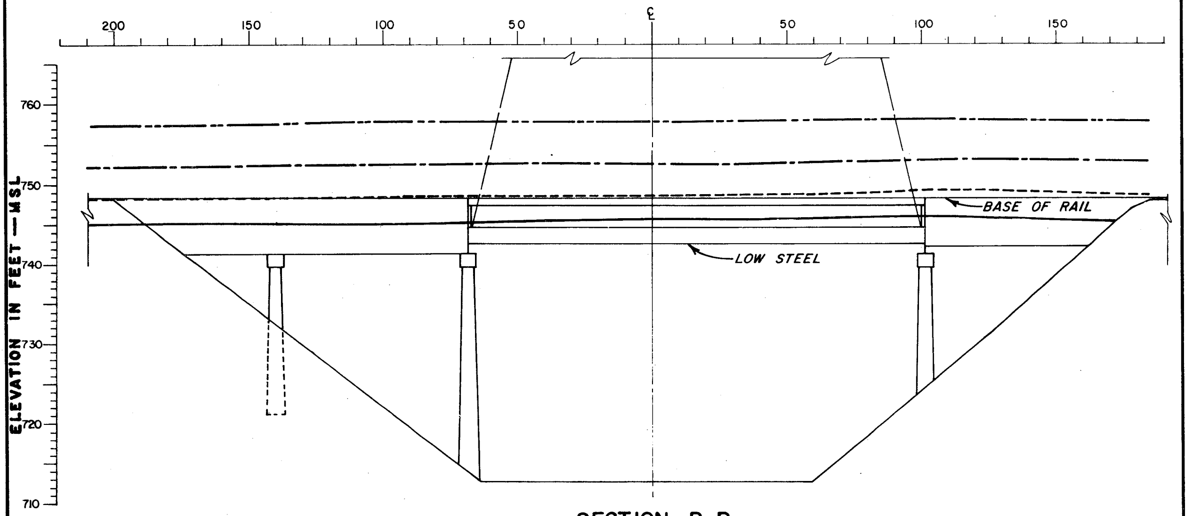
LEGEND

——	35 000 CFS-DESIGN DISCHARGE
------	42 000 CFS-50-YEAR DISCHARGE
—-—	52 800 CFS-100-YEAR DISCHARGE
—--—	71 000 CFS

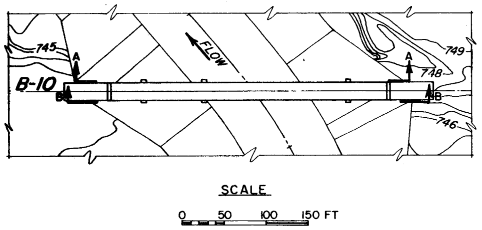
WATER SURFACE CROSS SECTIONS
BRIDGE B-8



SECTION A-A



SECTION B-B

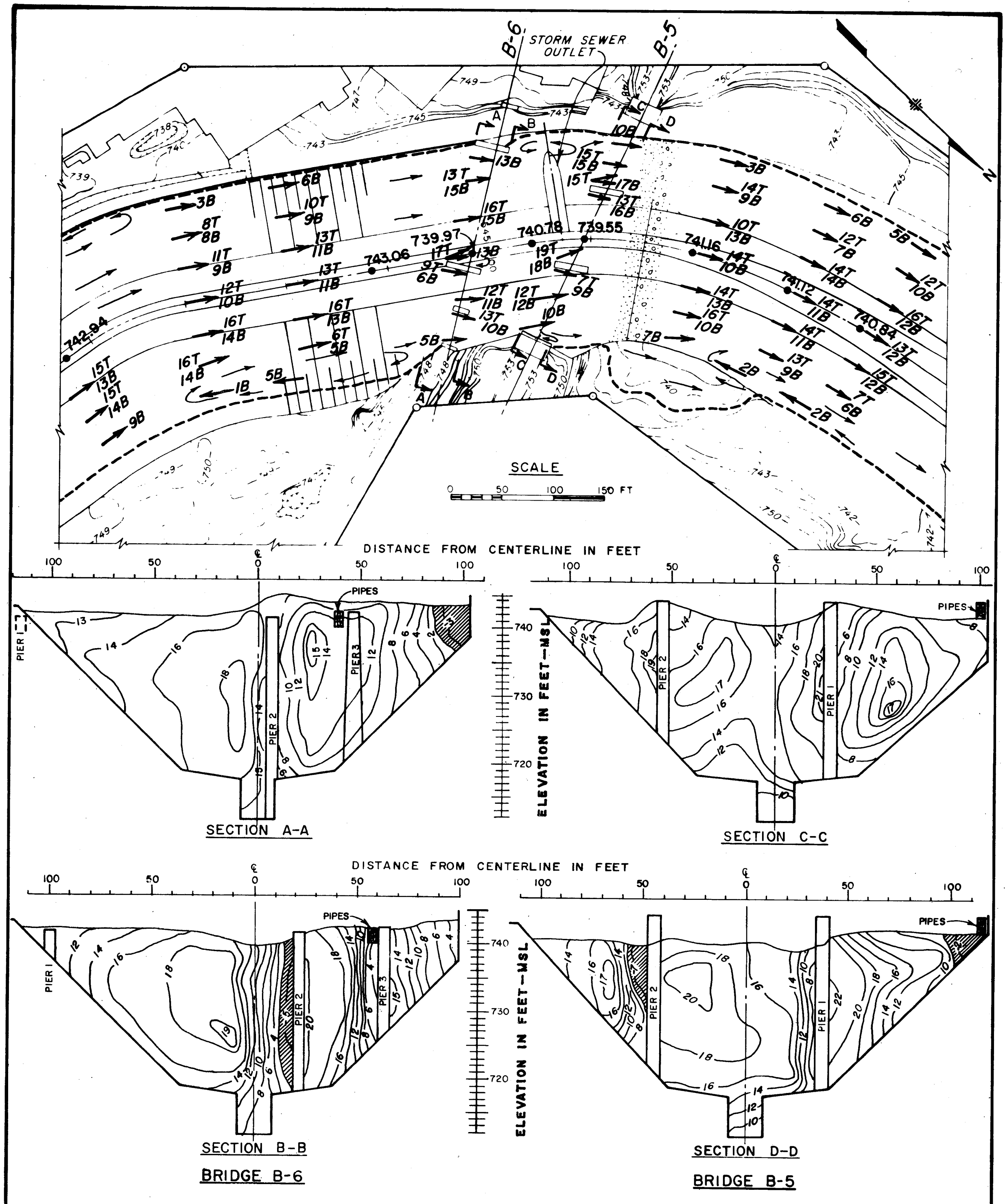


LOCATION OF CROSS SECTIONS

LEGEND

- ——— 35 000 CFS-DESIGN DISCHARGE
- ------ 42 000 CFS-50-YEAR DISCHARGE
- —·—· 52 800 CFS-100-YEAR DISCHARGE
- —··— 71 000 CFS

WATER SURFACE CROSS SECTIONS
BRIDGE B-10



ORIGINAL PIER DESIGN

LEGEND

14 ← VELOCITIES IN FPS

-3 UPSTREAM VELOCITIES IN FPS

T 3-FT DEPTH

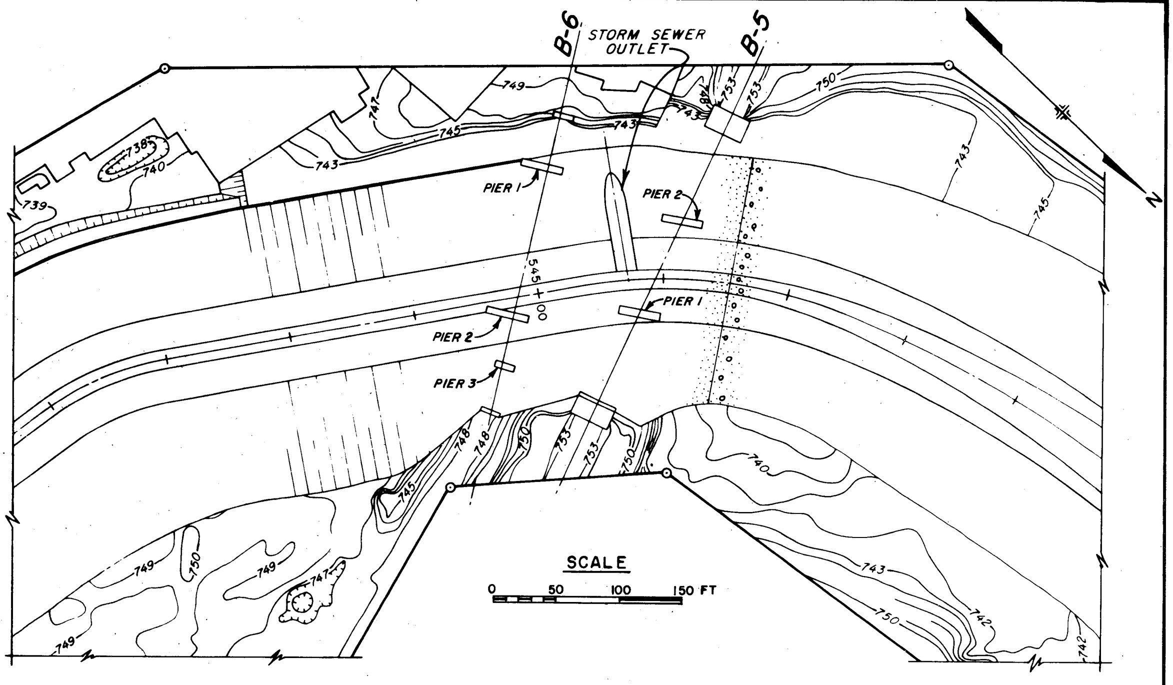
B 3-FT ABOVE BOTTOM

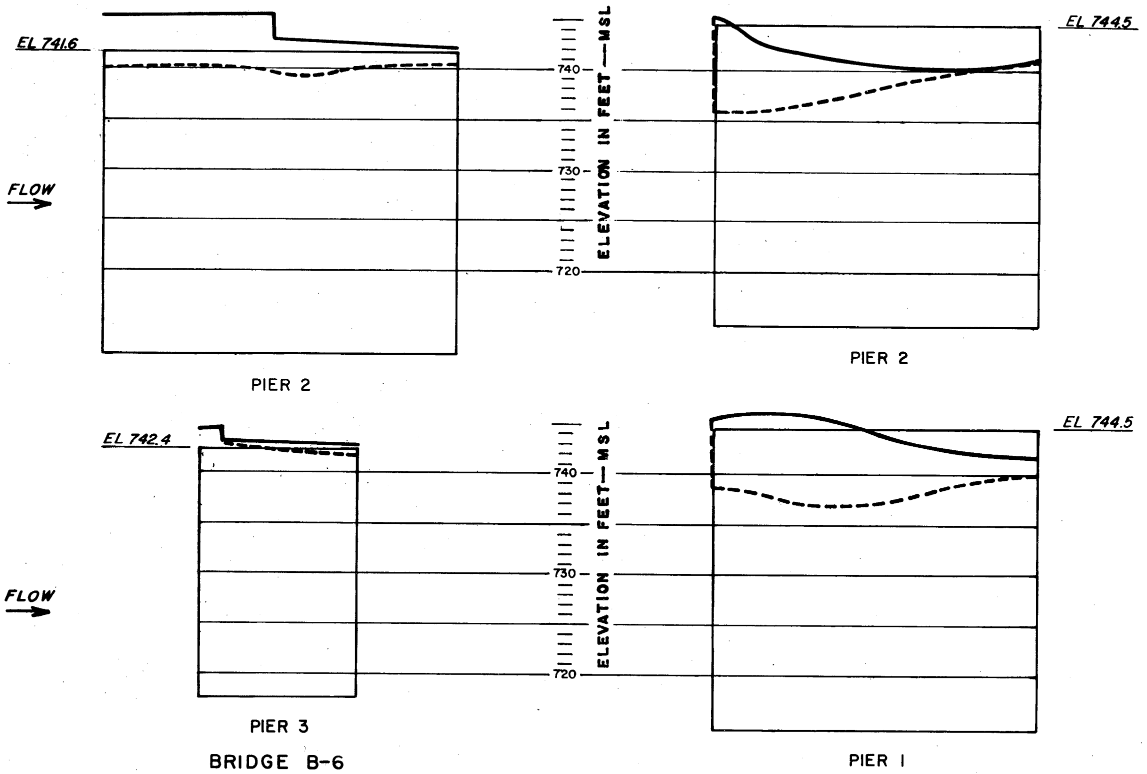
743.06 ● WATER-SURFACE ELEVATION FT

▨ CONCRETE CHANNEL

▨ GROUTED RIPRAP

FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
DESIGN TAILWATER





PIER 2

PIER 2

PIER 3

BRIDGE B-6

PIER 1

BRIDGE B-5

ORIGINAL PIER DESIGN

LEGEND

— AVERAGE WATER SURFACE ALONG RIGHT SIDE PIER

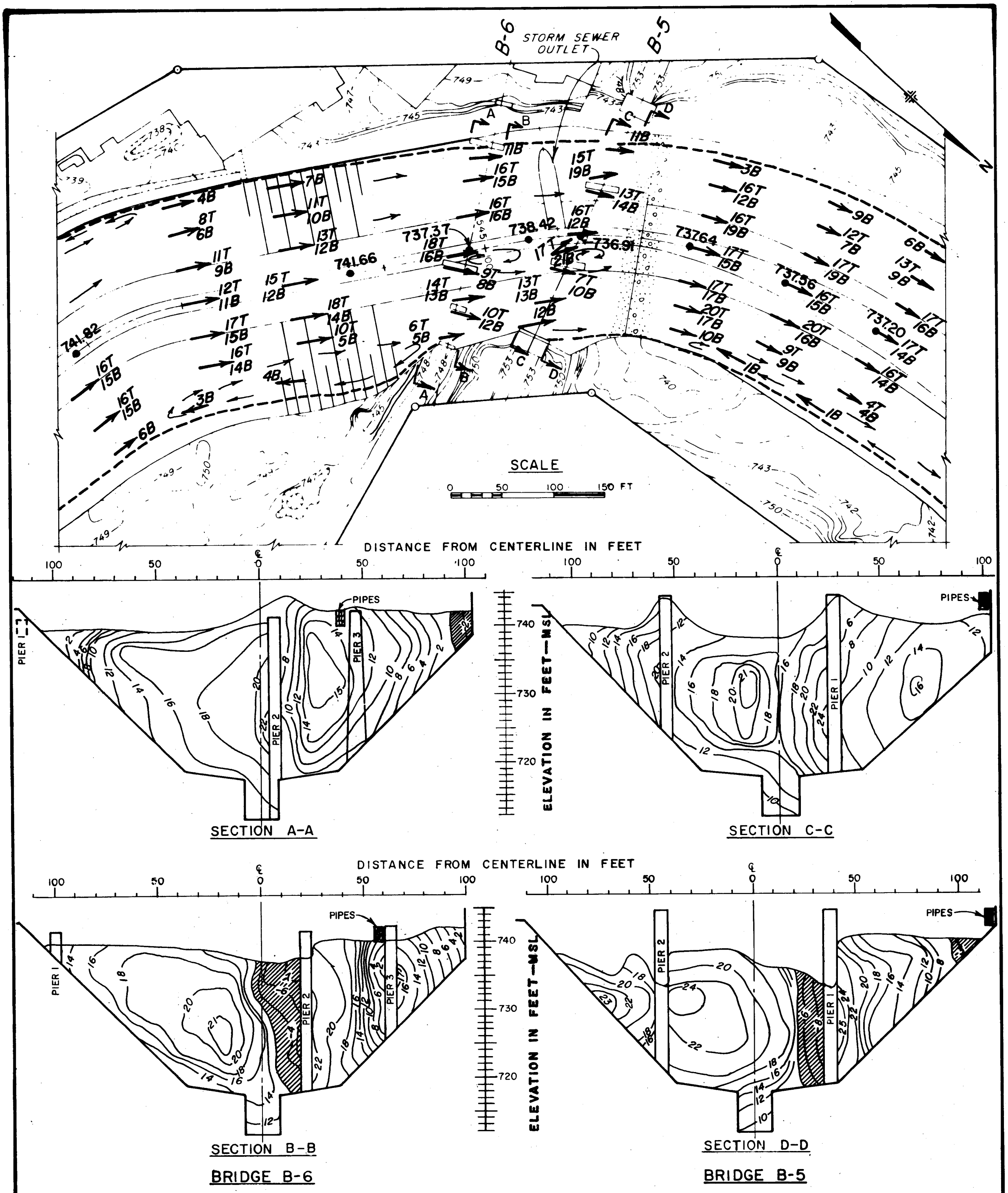
- - - - AVERAGE WATER SURFACE ALONG LEFT SIDE PIER

░ CONCRETE CHANNEL

▨ GROUTED RIPRAP

WATER SURFACE PROFILE
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
DESIGN TAILWATER

PLATE 27

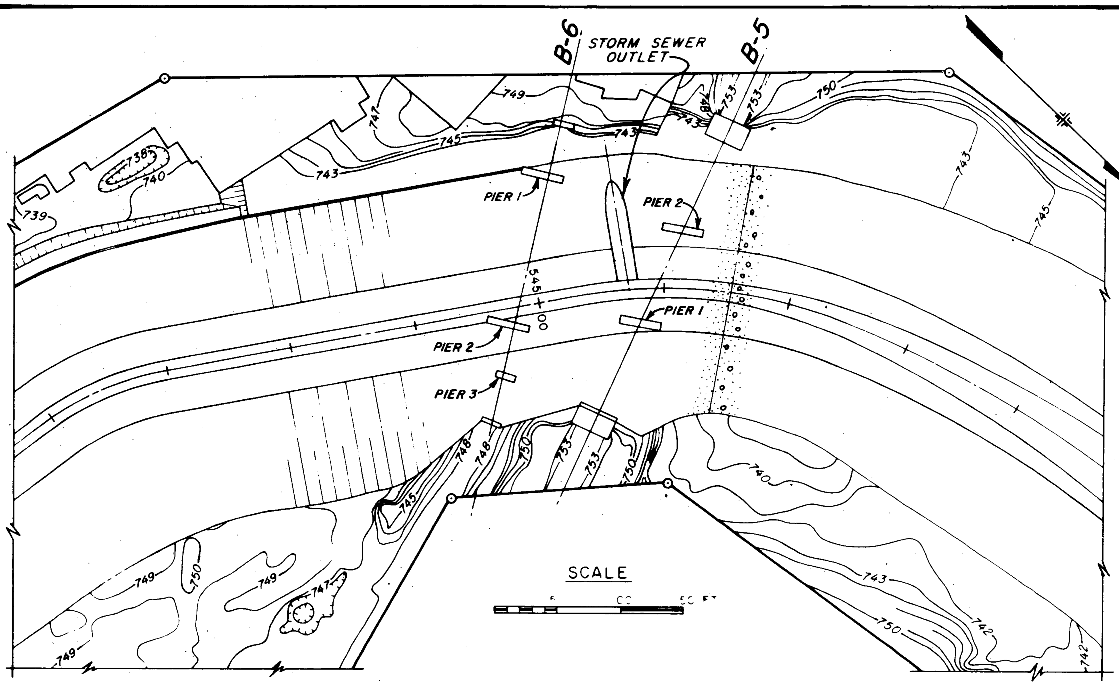


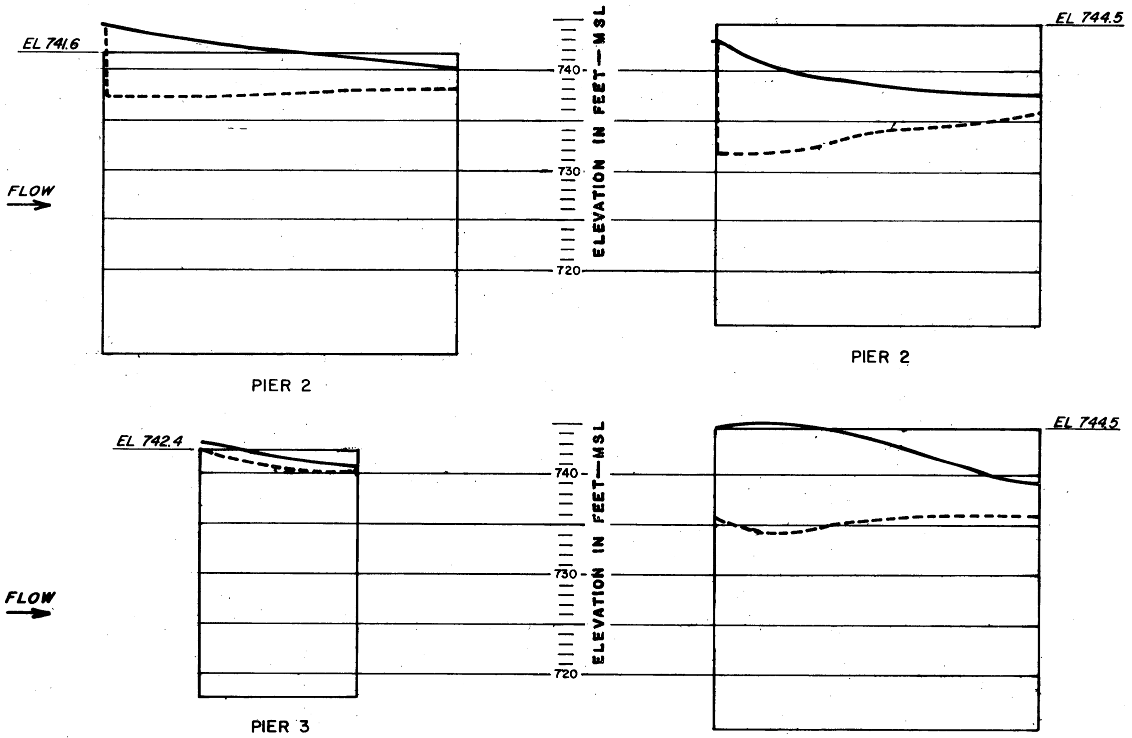
ORIGINAL PIER DESIGN

LEGEND

14 ←	VELOCITIES IN FPS
-3	UPSTREAM VELOCITIES IN FPS
T	3-FT DEPTH
B	3-FT ABOVE BOTTOM
743.06 ●	WATER-SURFACE ELEVATION FT
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP

FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER





PIER 2

PIER 2

PIER 3

BRIDGE B-6

PIER 1

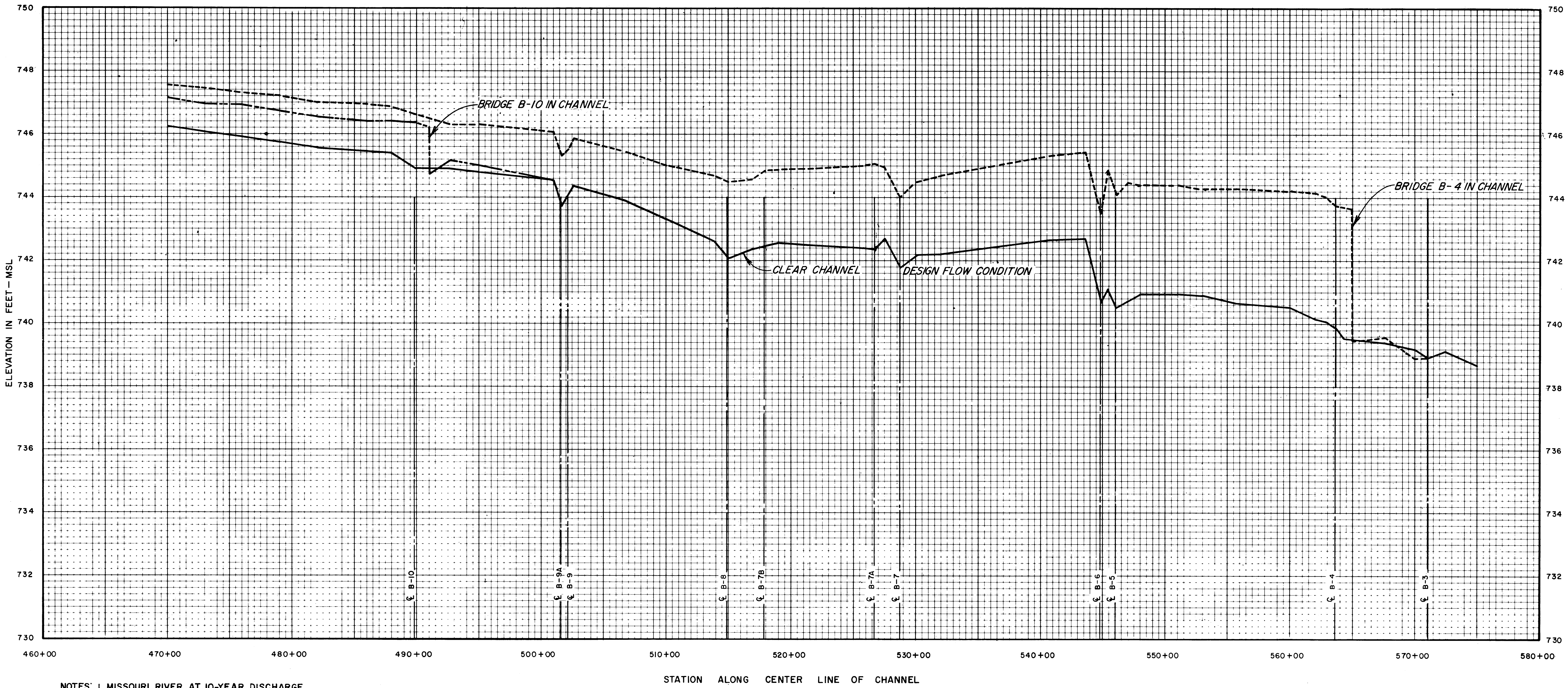
BRIDGE B-5

ORIGINAL PIER DESIGN

LEGEND

▬ AVERAGE WATER SURFACE ALONG RIGHT SIDE PIER
---- AVERAGE WATER SURFACE ALONG LEFT SIDE PIER
▨ CONCRETE CHANNEL
▨ GROUTED RIPRAP

WATER SURFACE PROFILE
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER

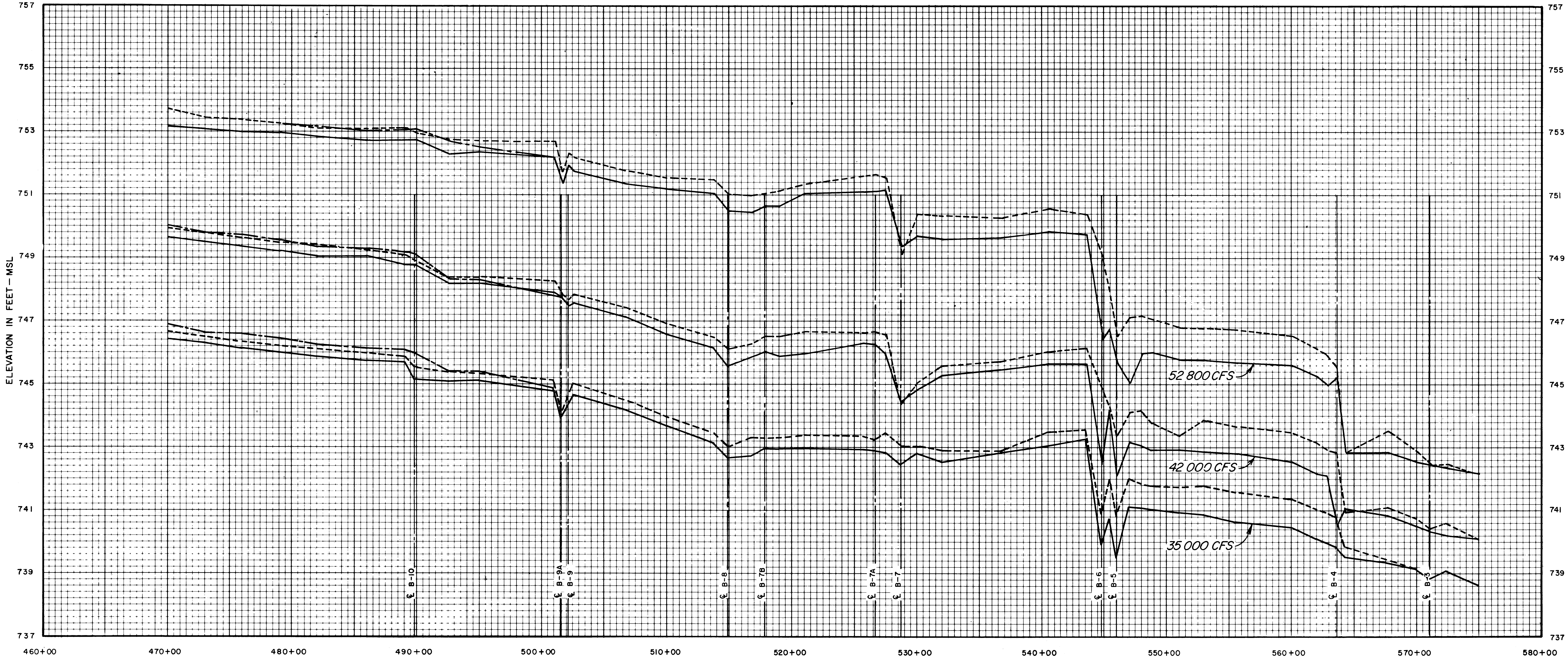


NOTES: 1. MISSOURI RIVER AT 10-YEAR DISCHARGE.
2. BRIDGE B-6 WITH MODIFIED PIER 2.

RIVER DISCHARGE 35 000 CFS

WATER SURFACE PROFILE ALONG CENTER LINE
COLLAPSE OF BRIDGES B-4 AND B-10 INTO CHANNEL
BRIDGES LYING ON SIDES

PLATE 30



NOTES

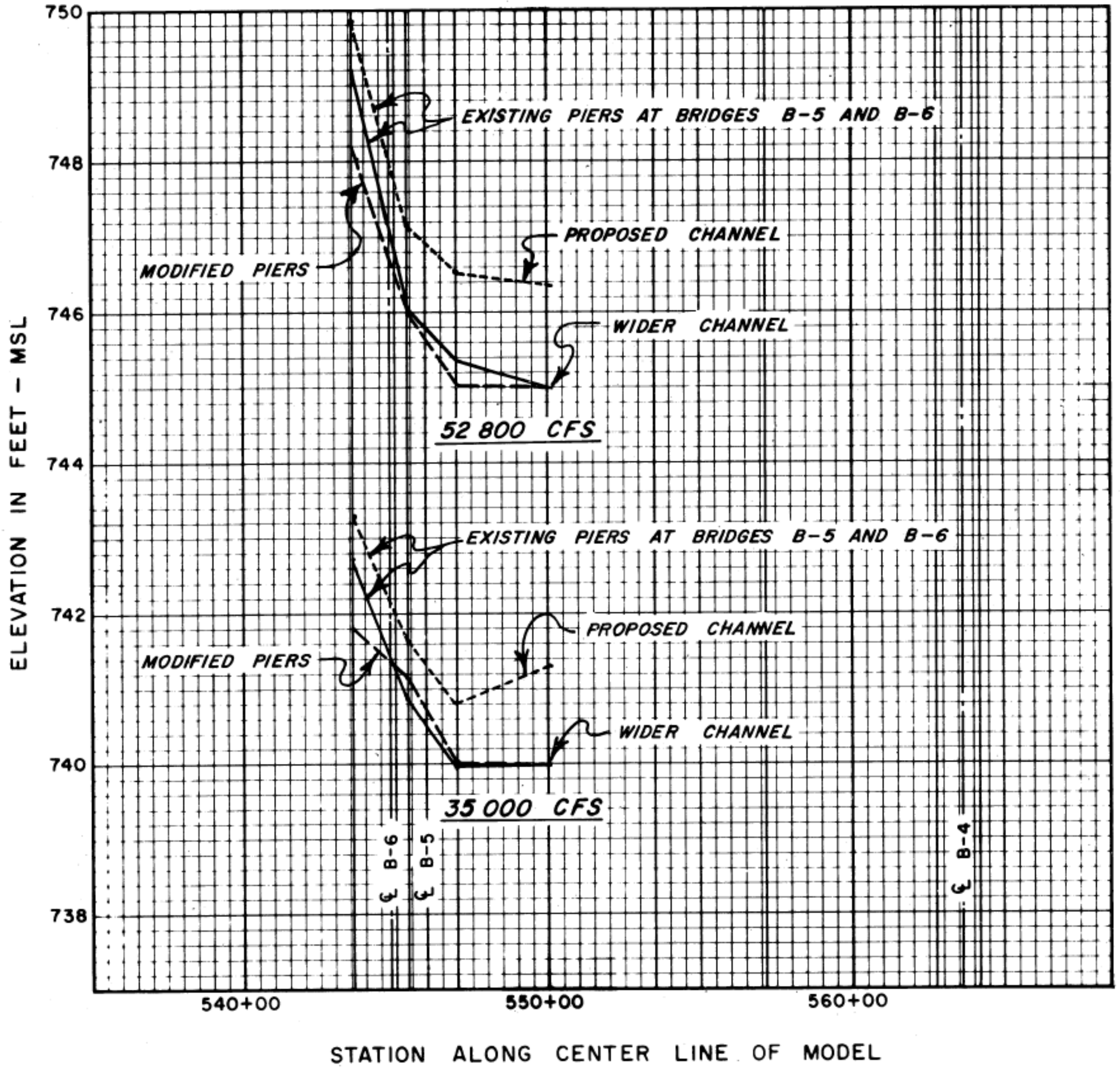
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-3.
2. ORIGINAL DESIGN PIER 2, BRIDGE B-6.
3. RAILROAD TRESTLE ALONG RIGHT BANK, STATIONS 533+00 TO 539+00.
4. TOP OF WALL AT EL 744.0 BETWEEN BRIDGES B-7 AND B-6.

LEGEND

——— CLEAR CHANNEL
- - - - BRIDGE B-4 IN CHANNEL
— - — BRIDGE B-10 IN CHANNEL

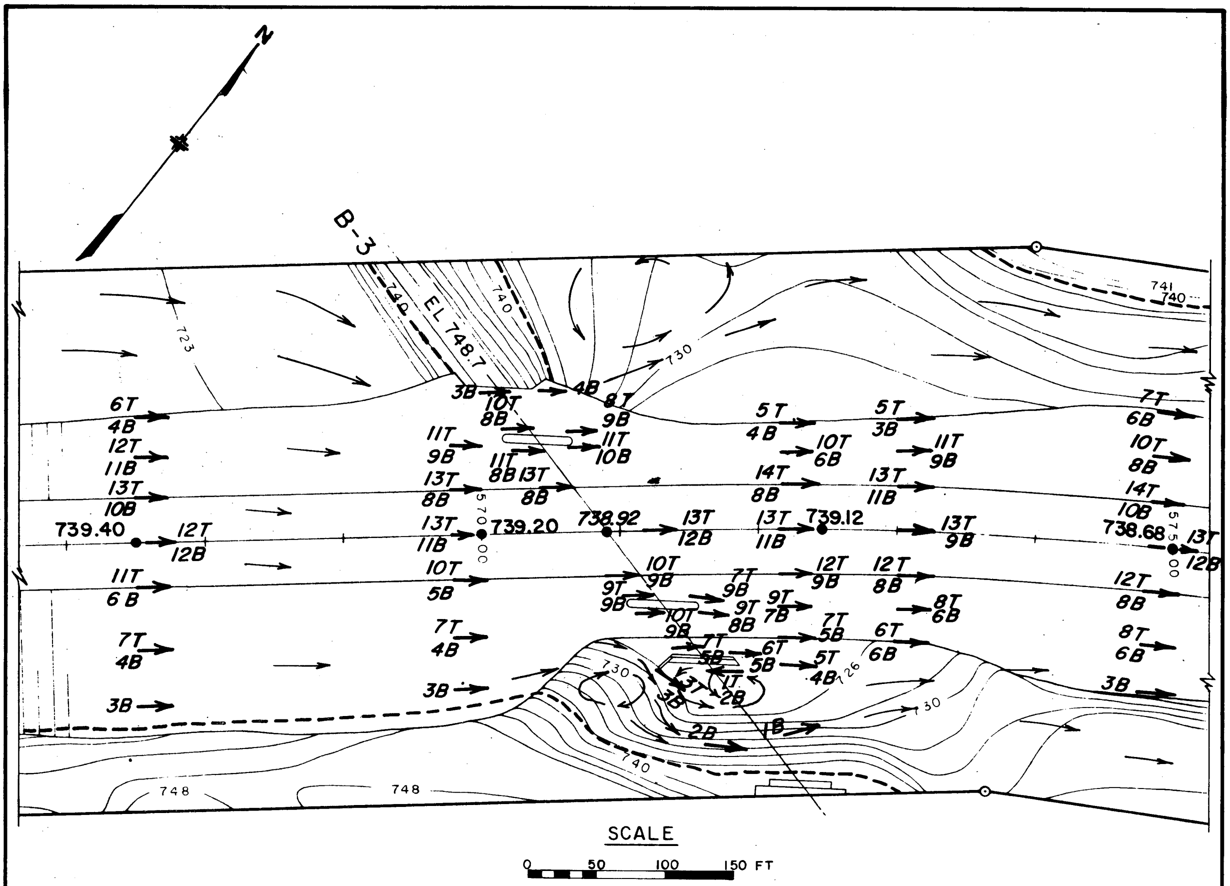
WATER SURFACE PROFILE ALONG CENTER LINE
COLLAPSE OF BRIDGES B-4 AND B-10 INTO CHANNEL
BRIDGES UPRIGHT

PLATE 31



WATER SURFACE PROFILE ALONG CENTER LINE

EFFECT OF WIDER DOWNSTREAM
CHANNEL AT BRIDGES B-5 AND B-6



LEGEND

14 VELOCITIES IN FPS

T 3-FT DEPTH

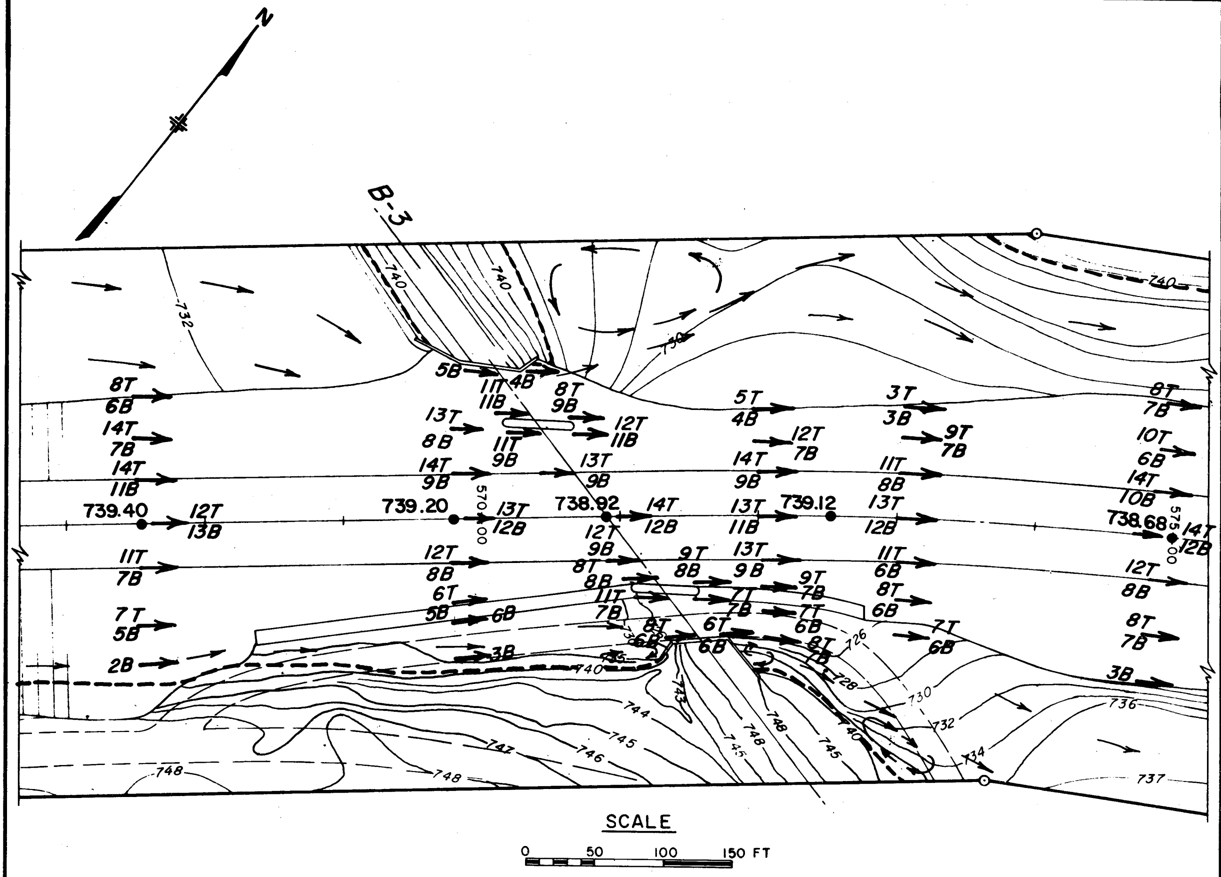
B 3 FT ABOVE BOTTOM

740.64● WATER SURFACE ELEVATION

ORIGINAL DESIGN ARMCO ROADWAY

FLOW CONDITIONS AT
BRIDGE B-3
RIVER DISCHARGE 35000 CFS
DESIGN TAILWATER

PLATE 33



EXISTING ARMCO ROADWAY

LEGEND

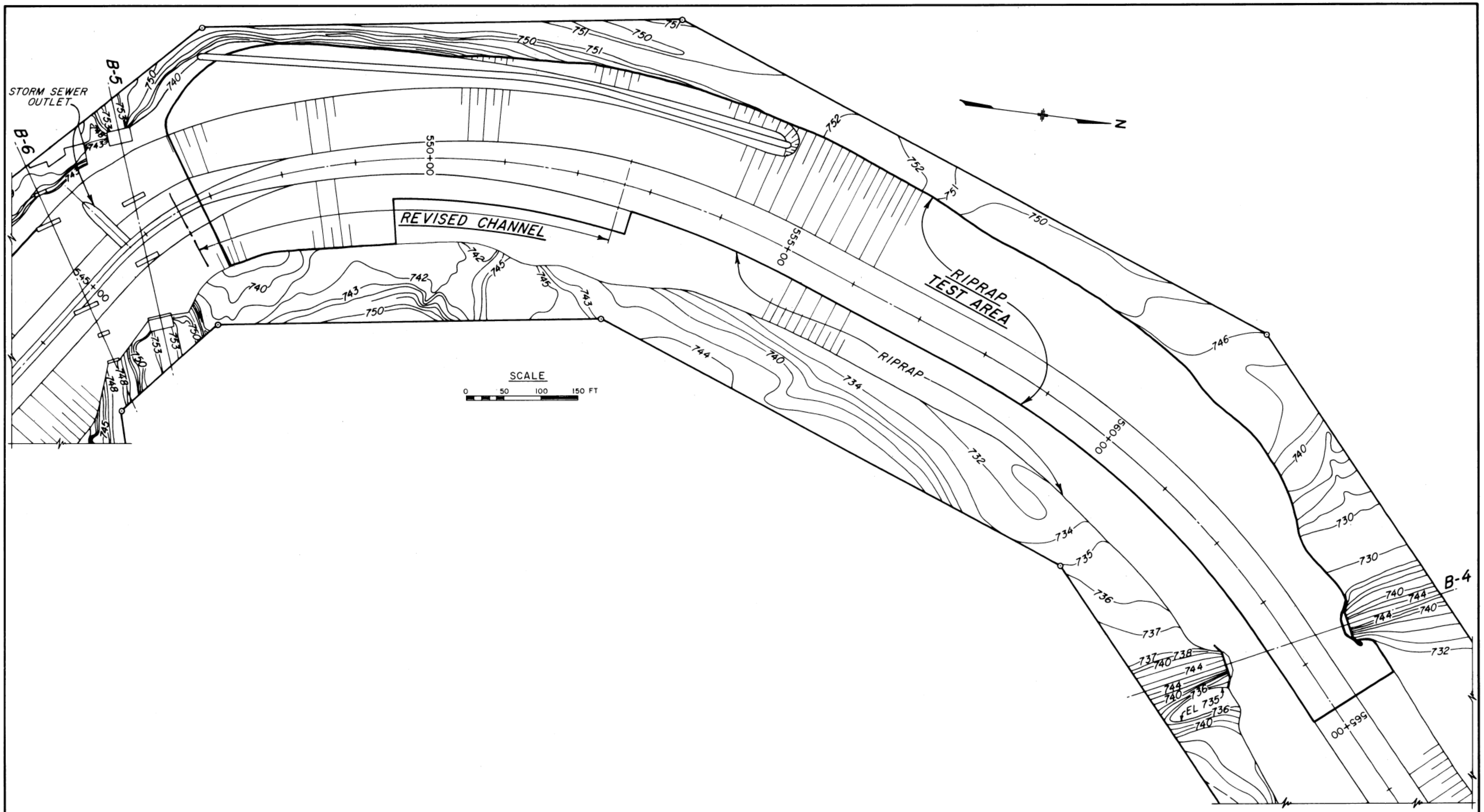
← 14 VELOCITIES IN FPS

T 3-FT DEPTH

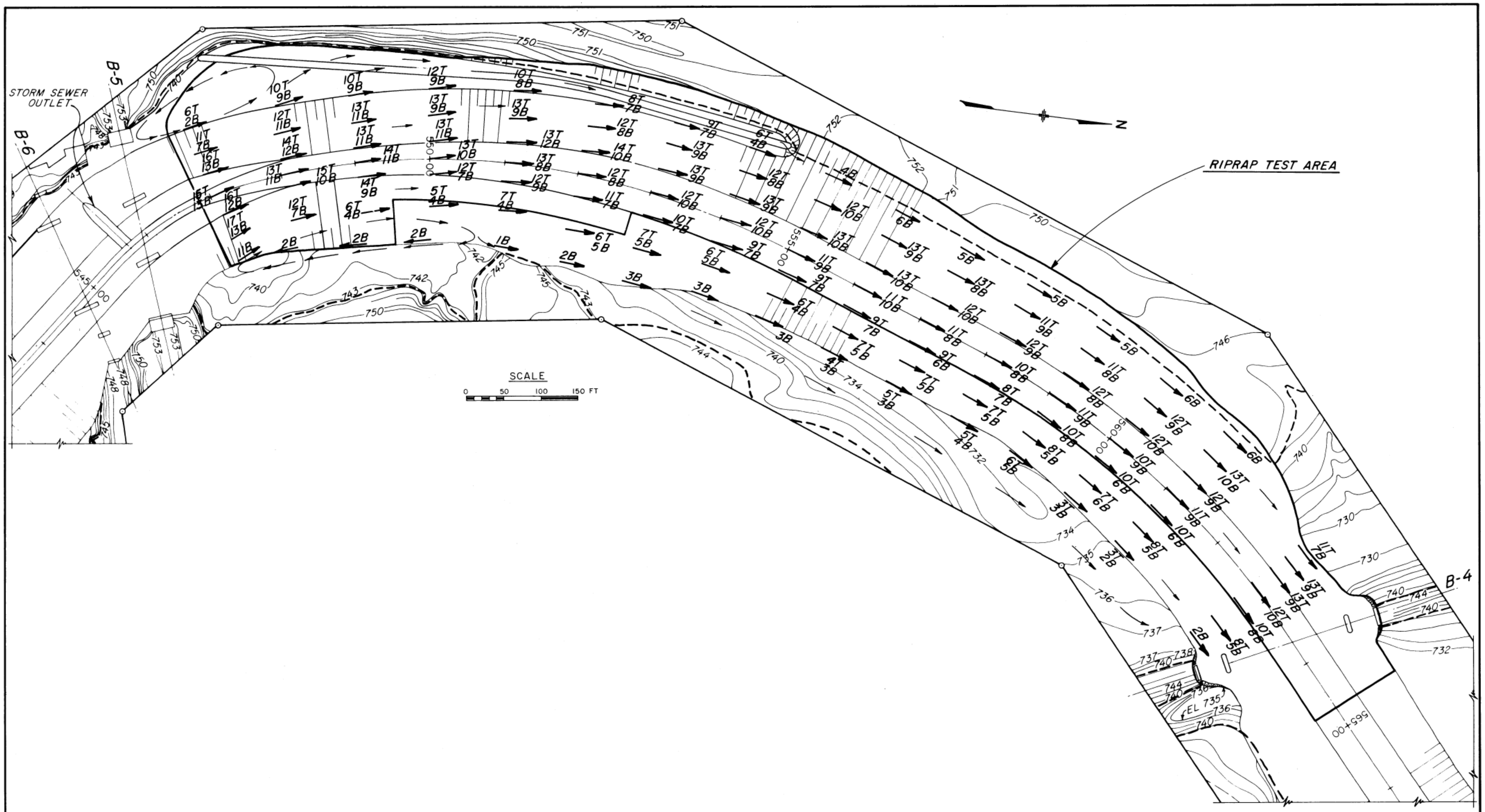
B 3 FT ABOVE BOTTOM

740.64 ● WATER SURFACE ELEVATION

FLOW CONDITIONS AT
BRIDGE B-3
RIVER DISCHARGE 35000 CFS
DESIGN TAILWATER



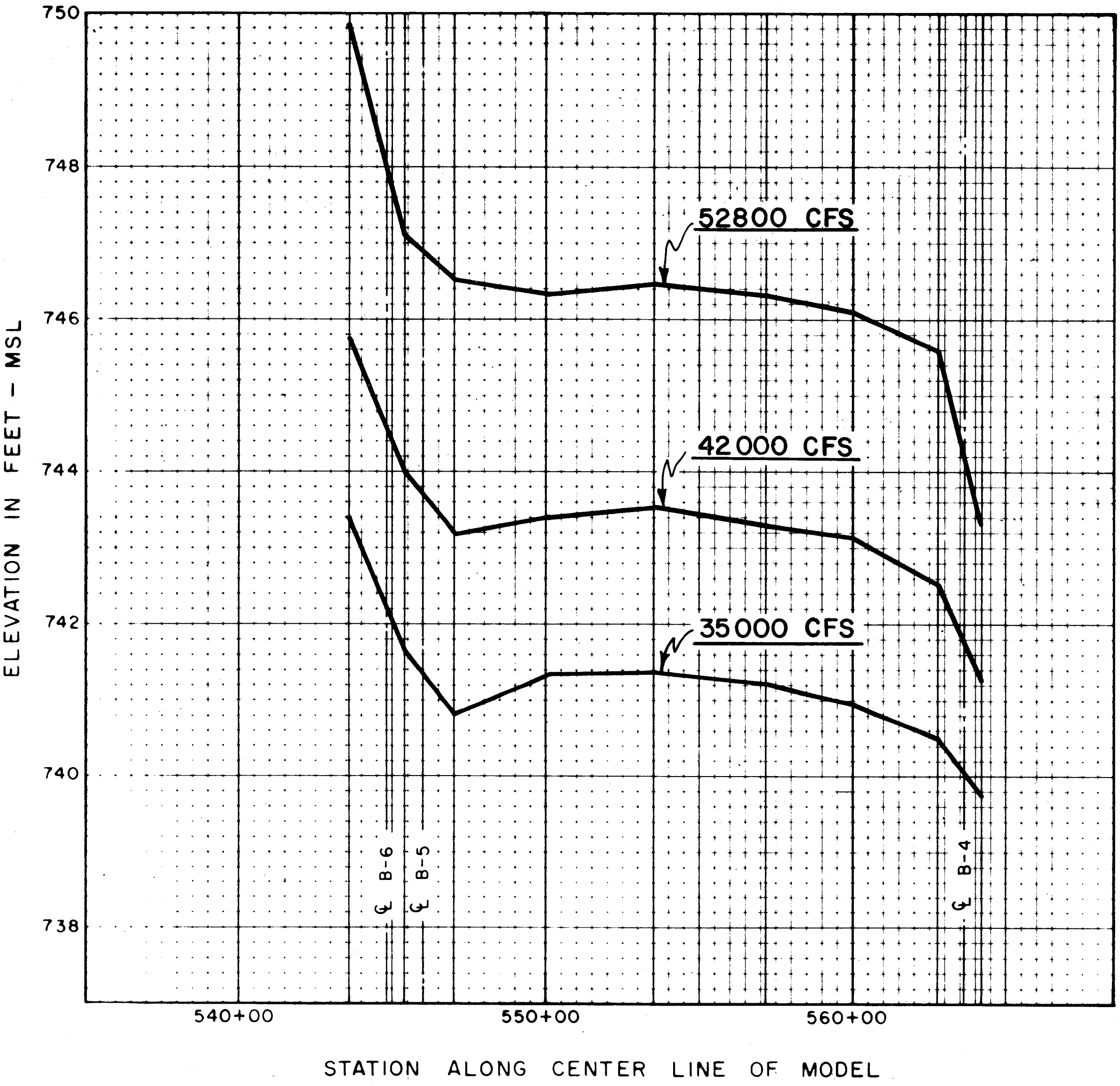
REVISED CHANNEL STA 546+55 TO
552+64 AND RIPRAP TEST AREA



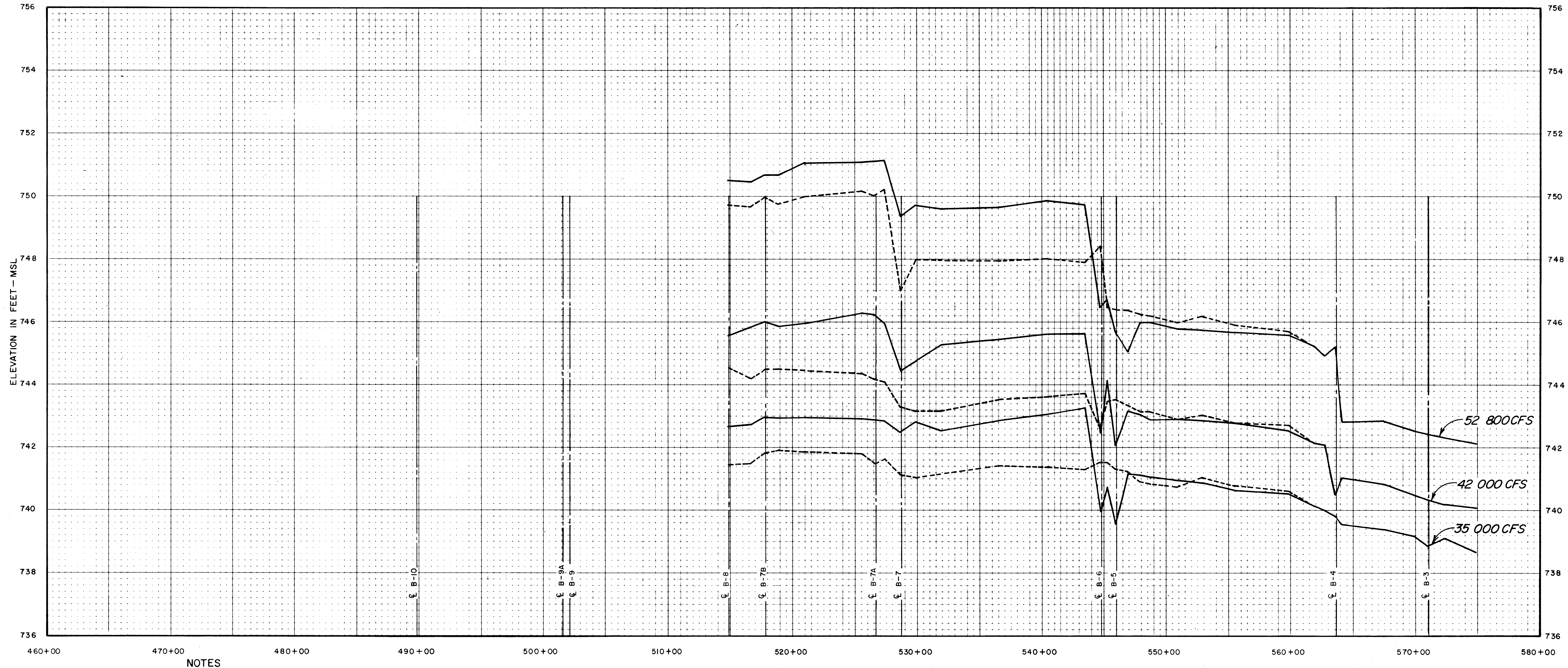
LEGEND

- ←14 VELOCITIES IN FPS
- T 3-FT DEPTH
- B 3 FT ABOVE BOTTOM

FLOW CONDITIONS
STATIONS 547+00 TO 563+00
REVISED RIPRAPPED CHANNEL
RIVER DISCHARGE 42 000 CFS
DESIGN TAILWATER



WATER SURFACE PROFILE ALONG CENTER LINE
EXISTING PIERS AT BRIDGES B-5 AND B-6
EXISTING BRIDGE B-4



NOTES

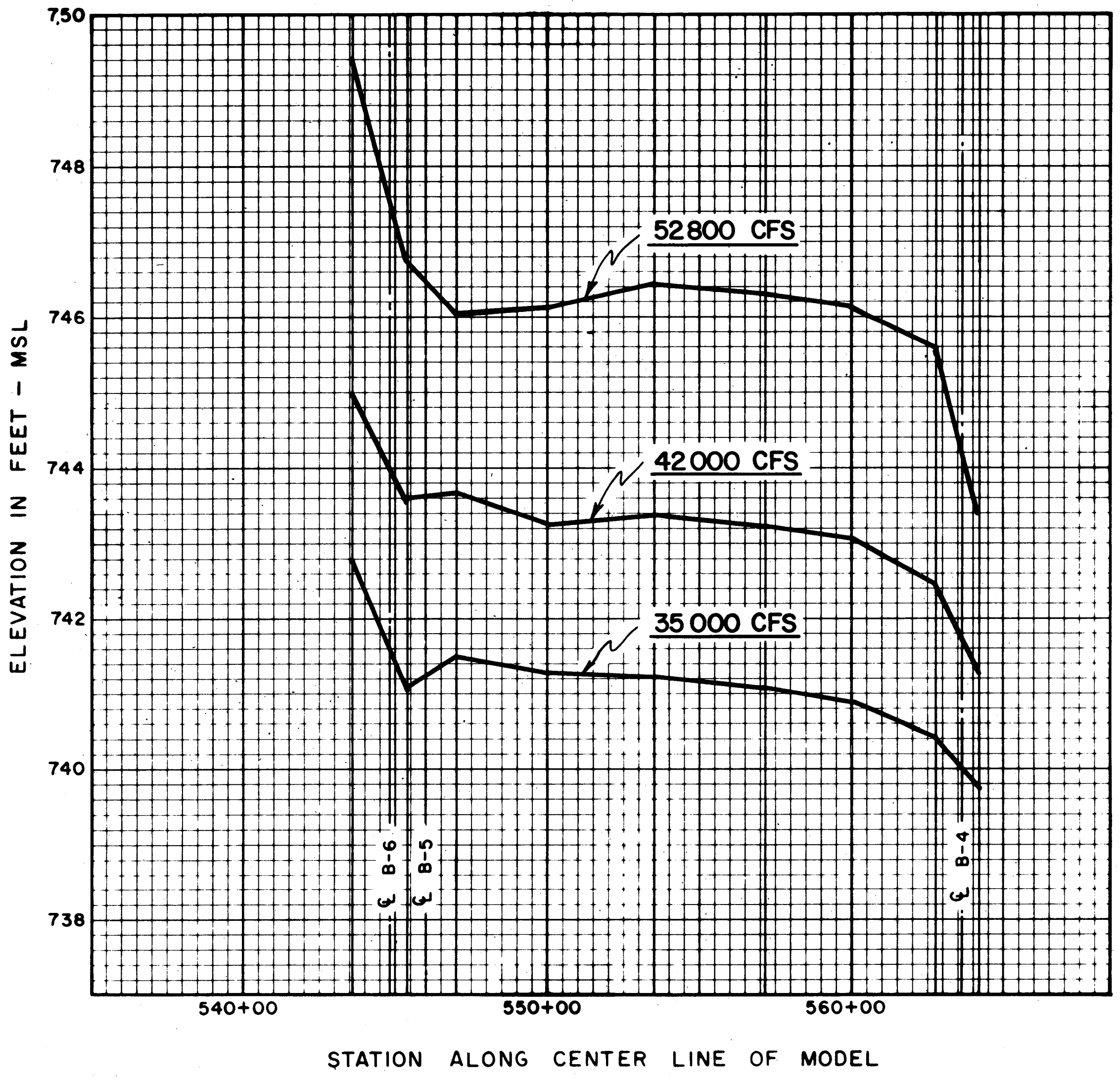
1. EXISTING LOCATION OF BY-PASS ROAD AT BRIDGE B-3.
2. MISSOURI RIVER AT 10-YEAR DISCHARGE.
3. RAILROAD TRESTLE ALONG RIGHT BANK STATIONS 533+00 TO 539+00.
4. TOP OF WALL AT EL 744.0 BETWEEN BRIDGES B-7 AND B-6.

LEGEND

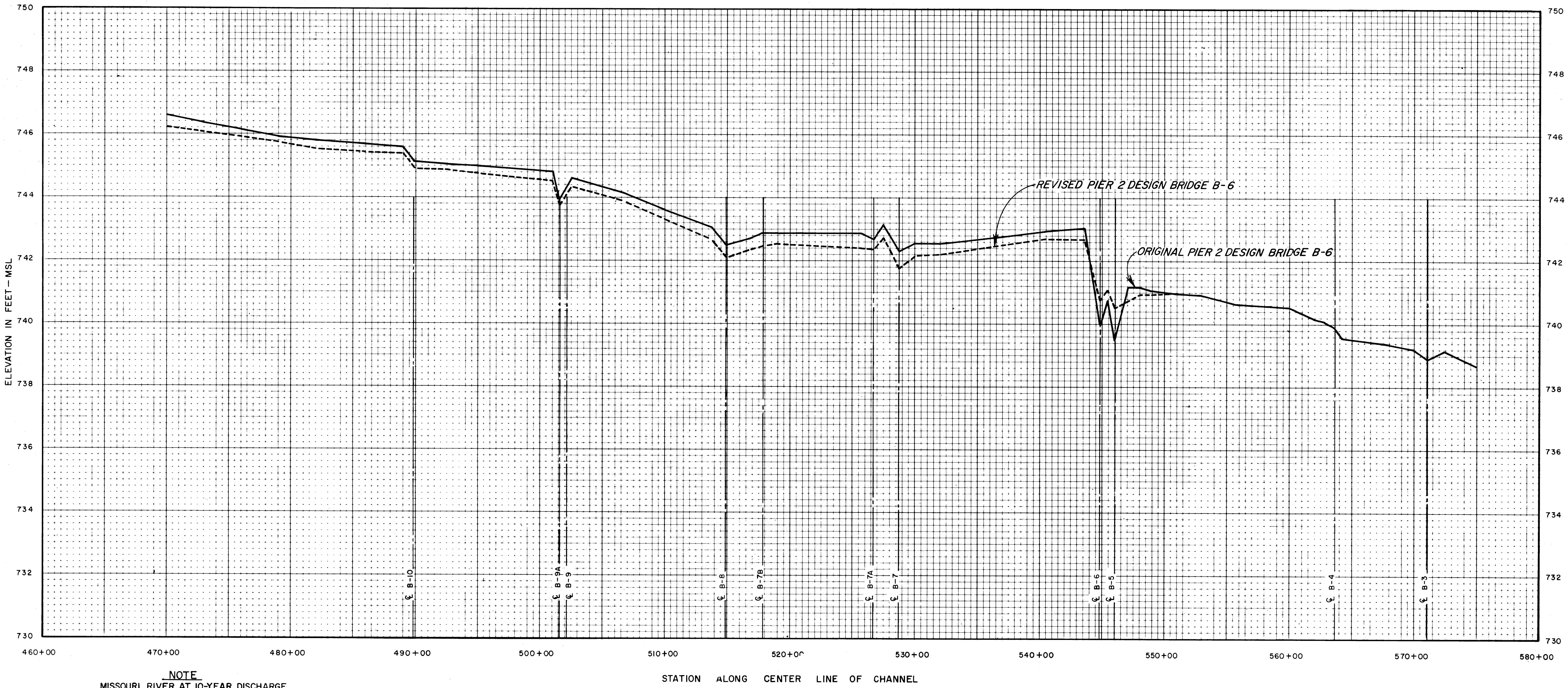
——— ORIGINAL DESIGN PIERS INSTALLED

- - - - PIERS REMOVED

WATER SURFACE PROFILE ALONG CENTER LINE
EFFECT OF PIER REMOVAL BRIDGES B-5 AND B-6



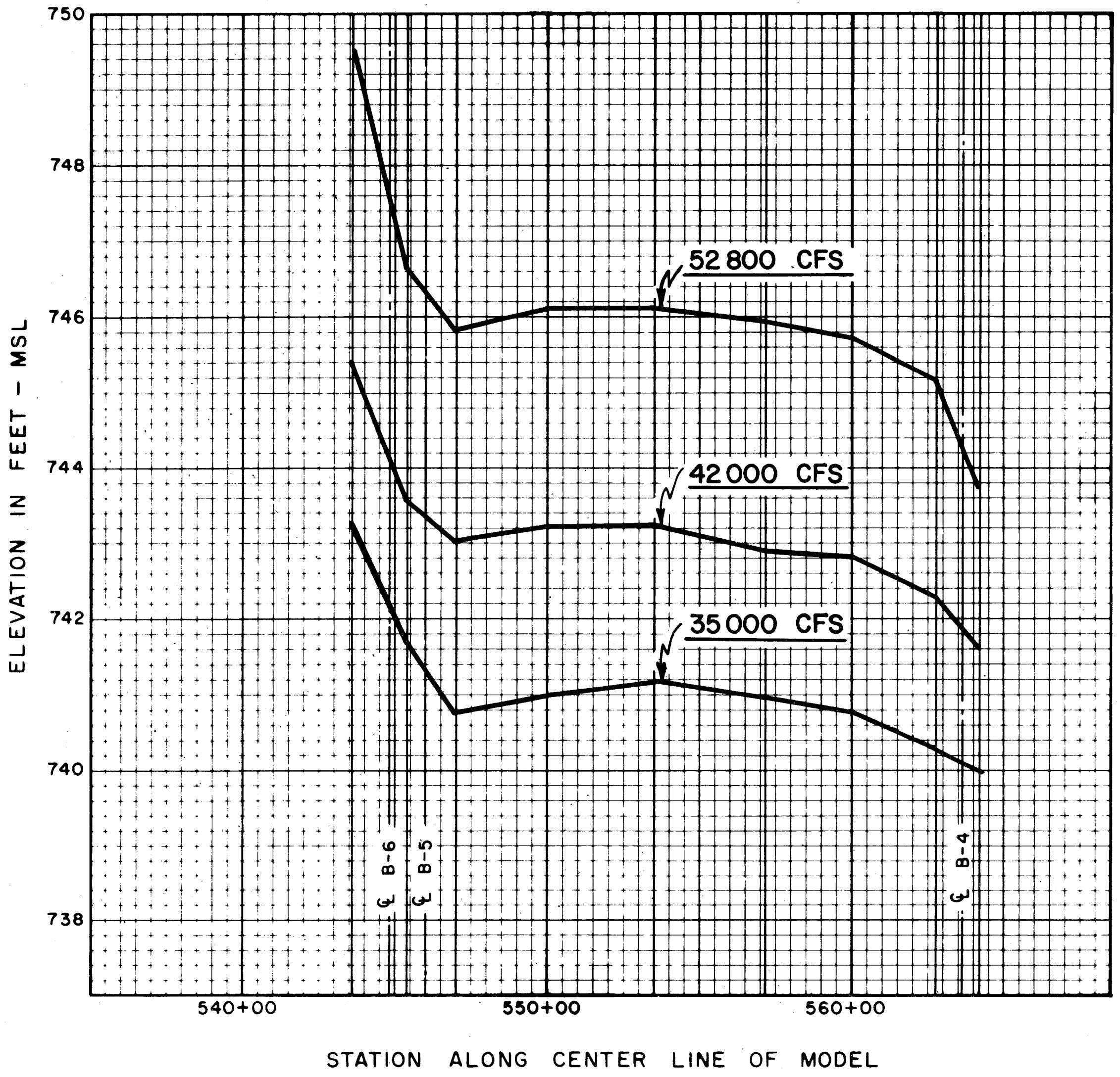
WATER SURFACE PROFILE ALONG CENTER LINE
MODIFIED PIERS AT BRIDGE B-5



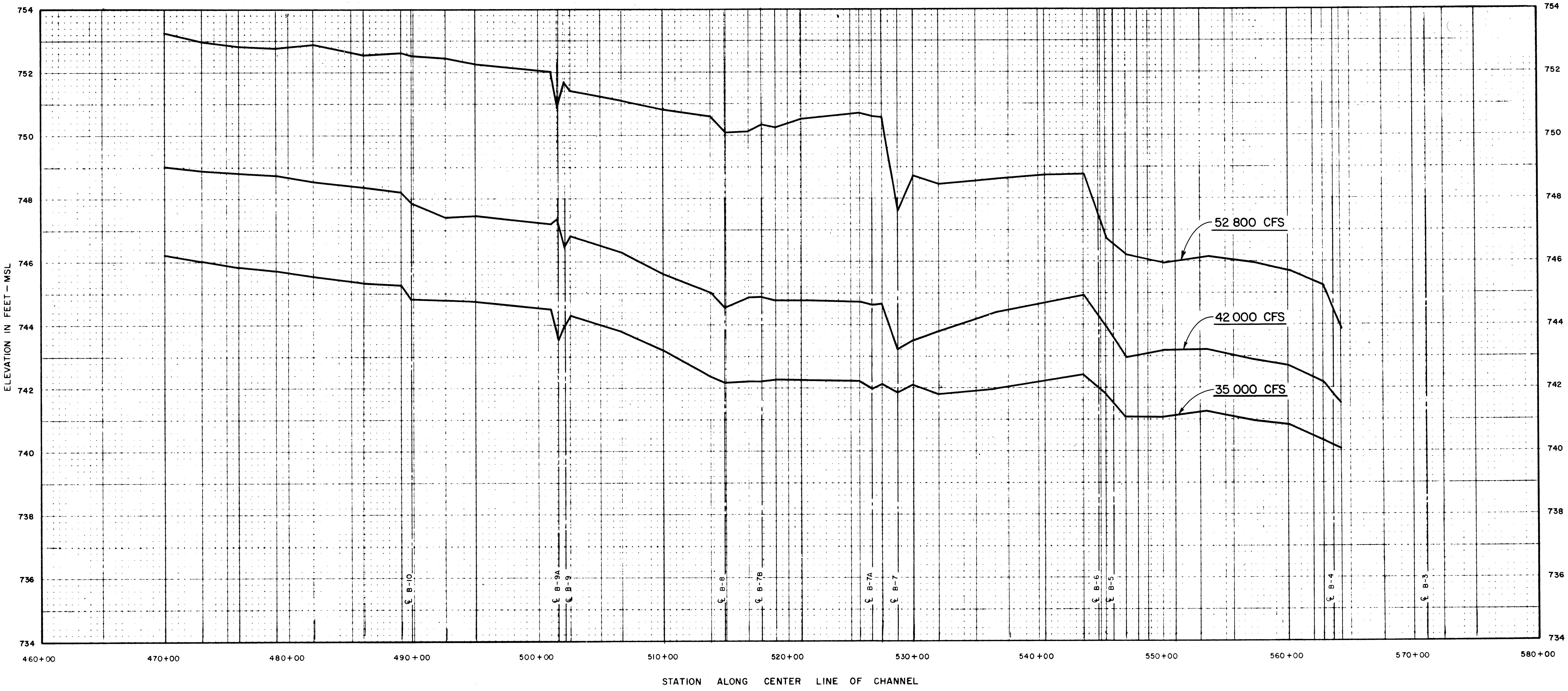
NOTE
MISSOURI RIVER AT 10-YEAR DISCHARGE

RIVER DISCHARGE 35 000 CFS

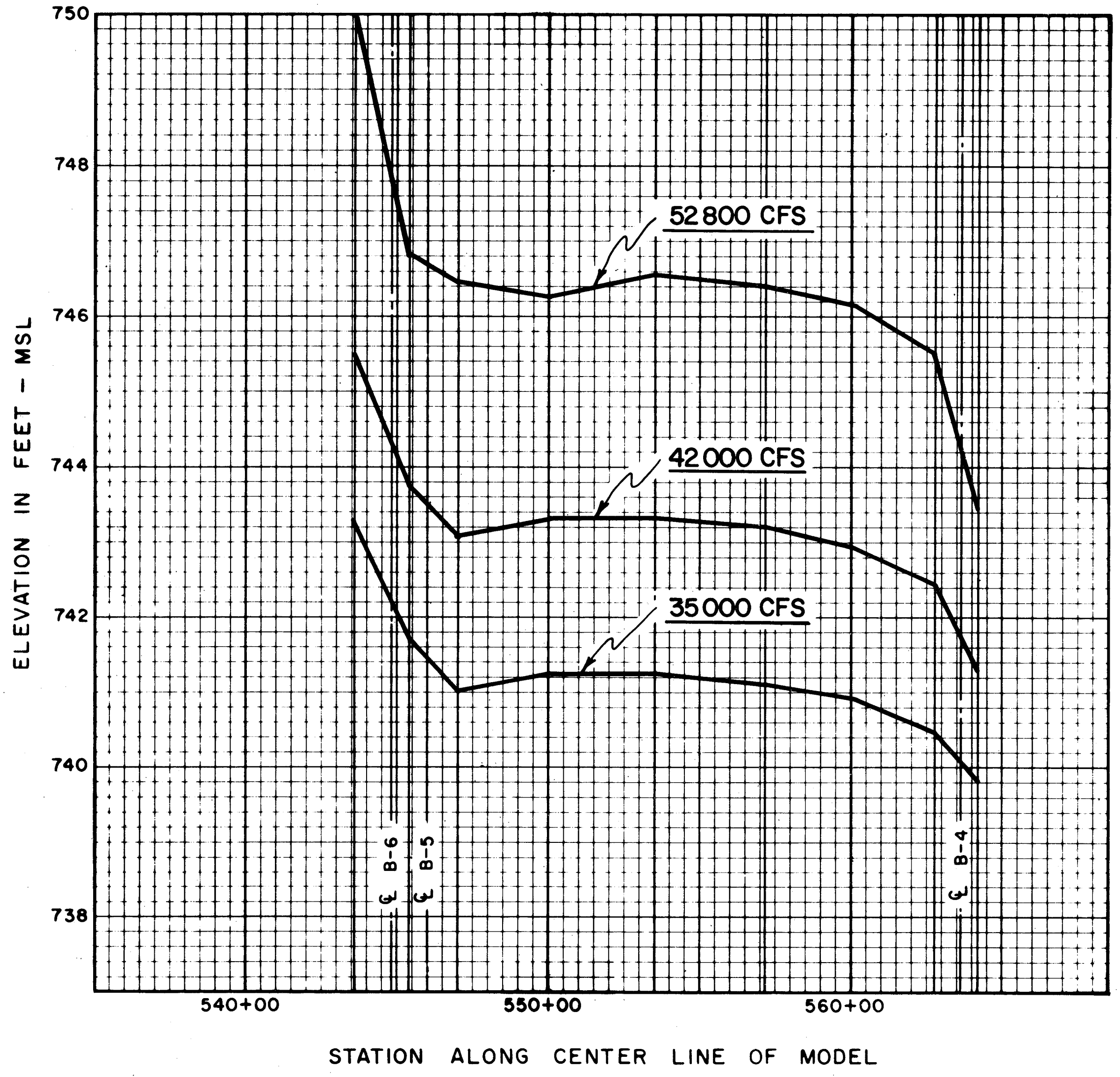
WATER SURFACE PROFILE ALONG CENTER LINE
EFFECT OF MODIFIED PIER 2 BRIDGE B-6



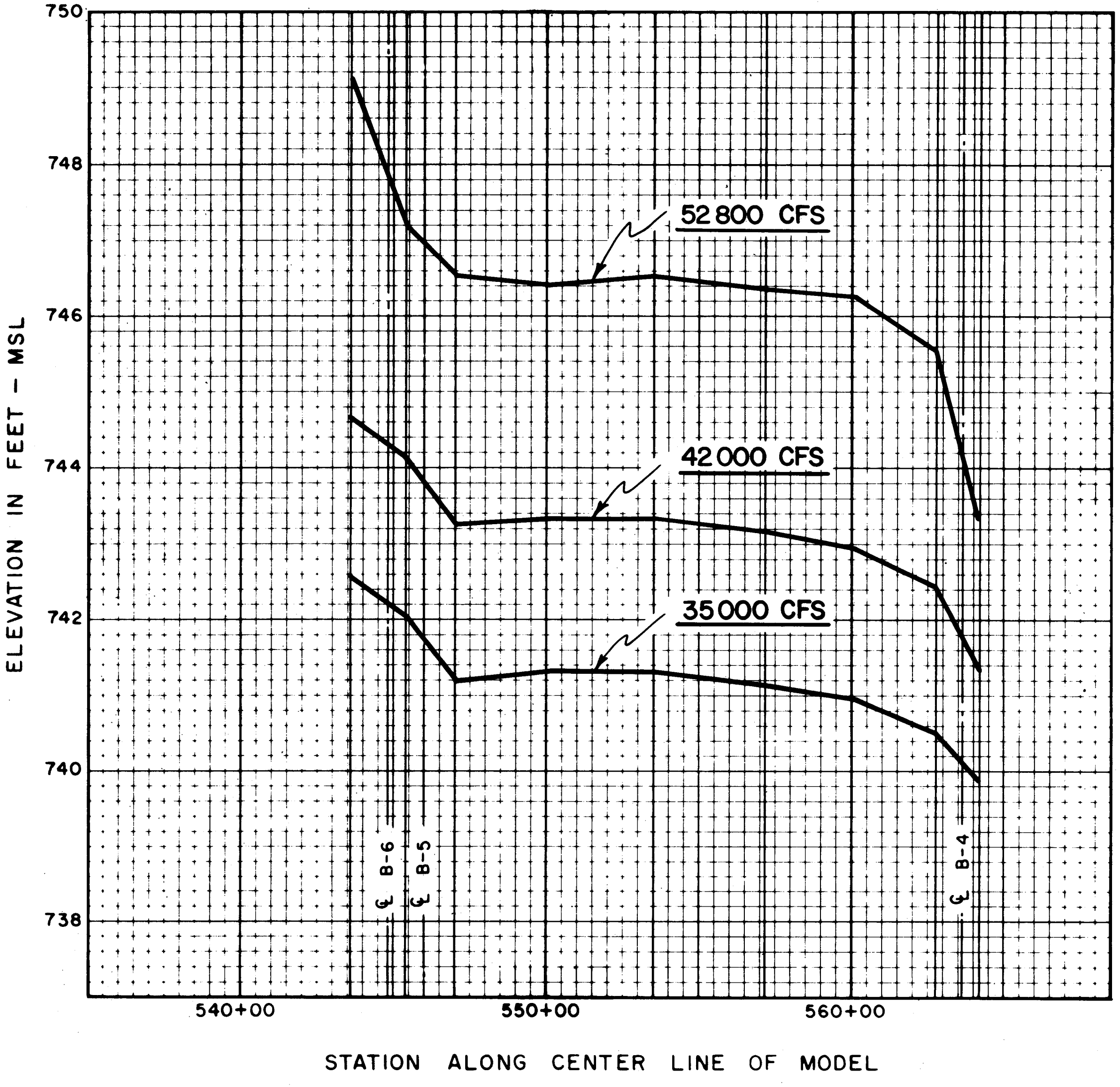
WATER SURFACE PROFILE ALONG CENTER LINE
EXISTING PIERS AT BRIDGES B-5 AND B-6
REVISED BRIDGE B-4



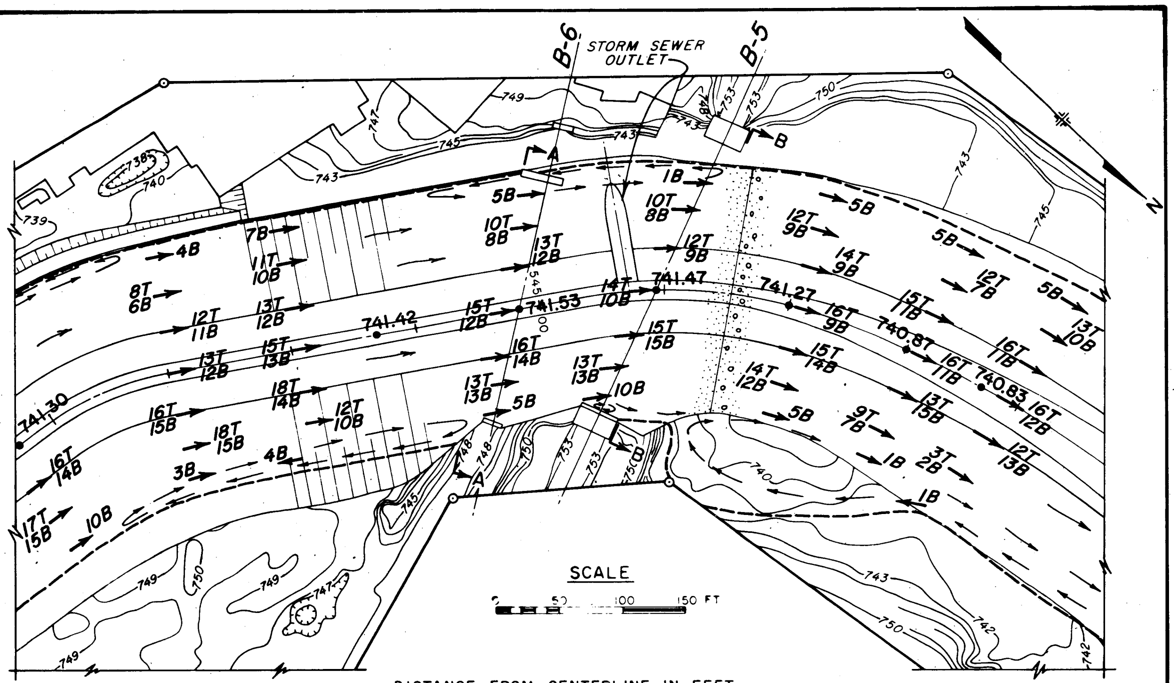
WATER SURFACE PROFILE ALONG CENTER LINE
MODIFIED PIERS AT BRIDGES B-5 AND B-6
REVISED BRIDGE B-4

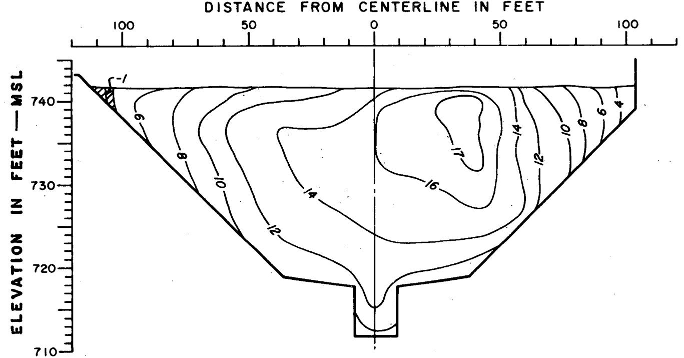


WATER SURFACE PROFILE ALONG CENTER LINE
EXISTING PIERS AT BRIDGES B-5 AND B-6
COWLED BEAMS ON BRIDGES B-4, B-5, AND B-6



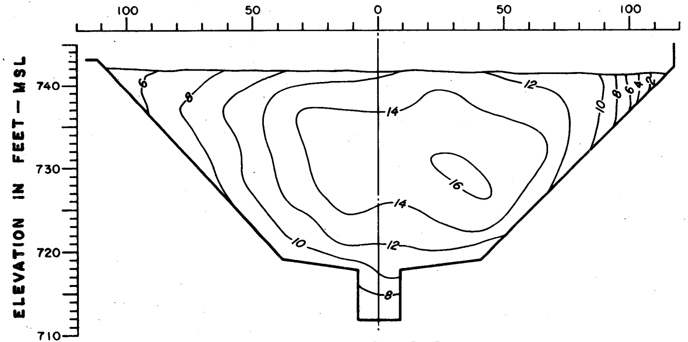
WATER SURFACE PROFILE ALONG CENTER LINE
MODIFIED PIERS AT BRIDGES B-5 AND B-6
COWLED BEAMS ON BRIDGES B-4, B-5, AND B-6





SECTION A-A

BRIDGE B-6



SECTION B-B

BRIDGE B-5

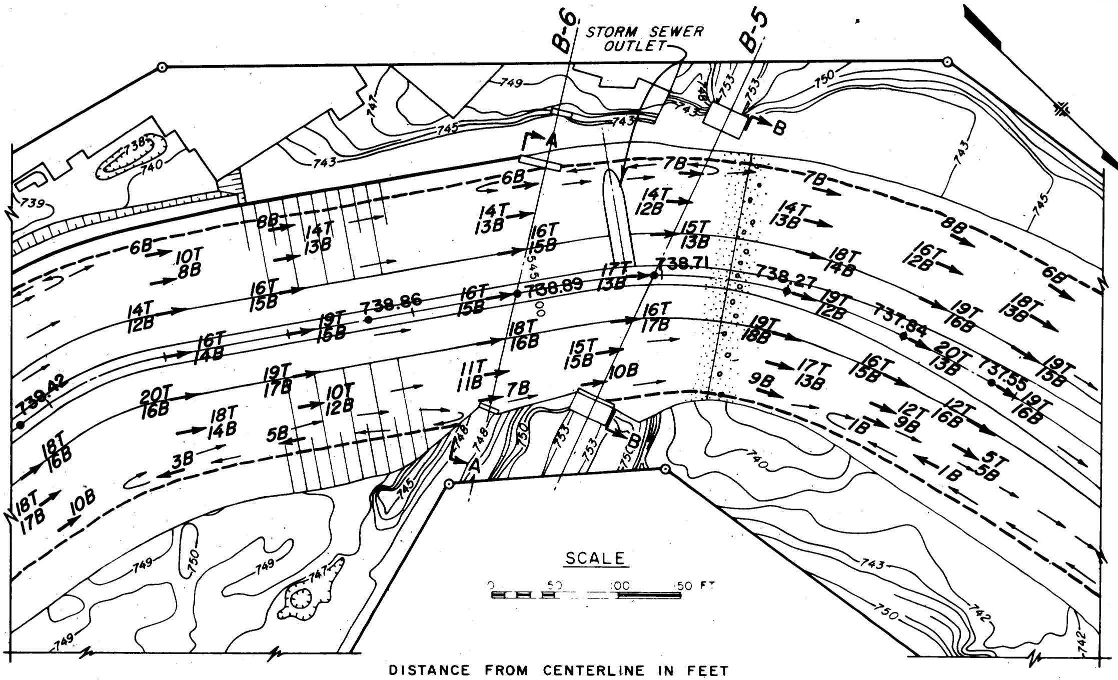
PIERS REMOVED

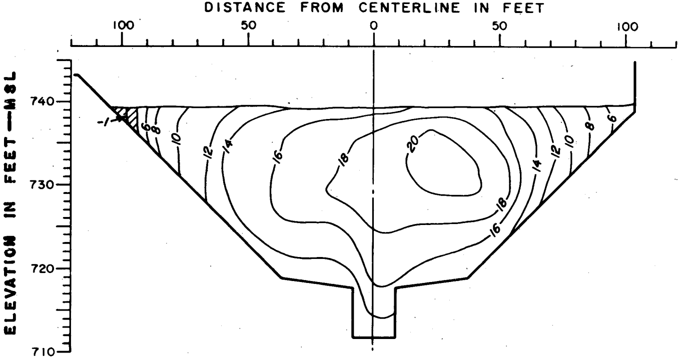
LEGEND

14 ← VELOCITIES IN FPS
-3 UPSTREAM VELOCITIES IN FPS
T 3-FT DEPTH
B 3-FT ABOVE BOTTOM
743.06 ● WATER-SURFACE ELEVATION FT
▨ CONCRETE CHANNEL
▨ GROUTED RIPRAP

FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
DESIGN TAILWATER

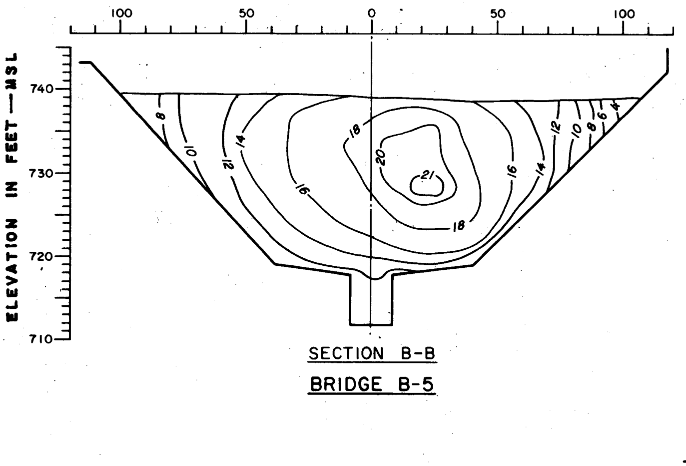
PLATE 45





SECTION A-A

BRIDGE B-6



SECTION B-B

BRIDGE B-5

PIERS REMOVED

LEGEND

14 ← VELOCITIES IN FPS

-3 UPSTREAM VELOCITIES IN FPS

T 3-FT DEPTH

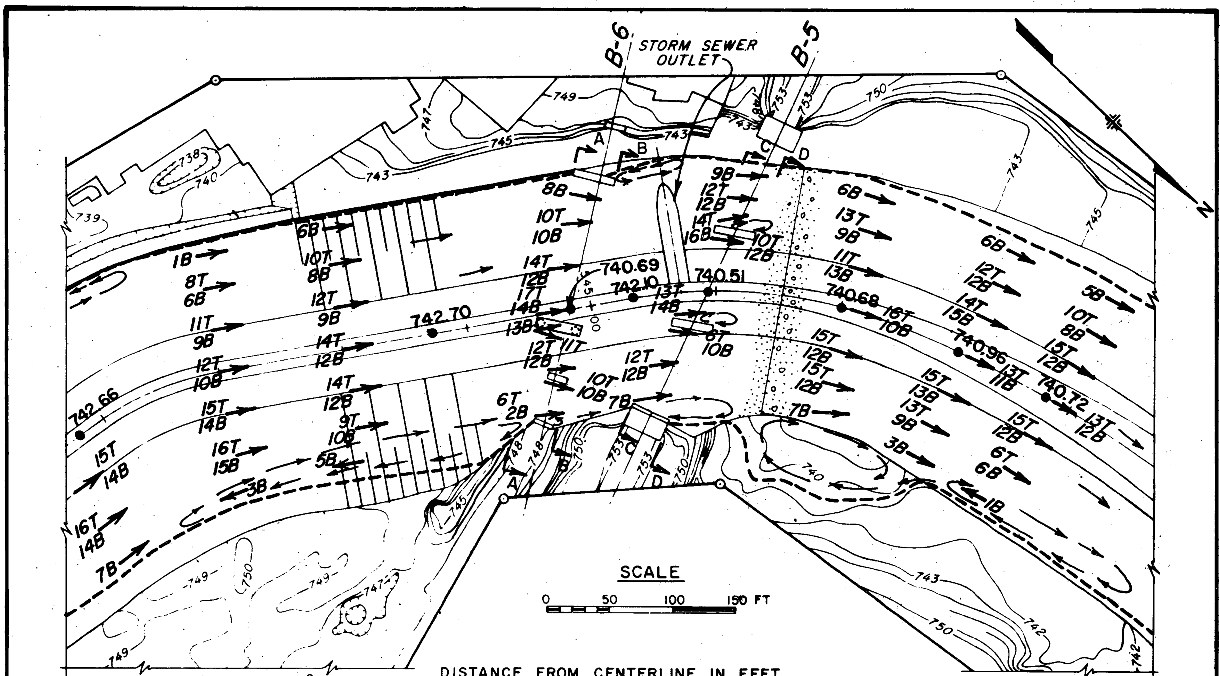
B 3-FT ABOVE BOTTOM

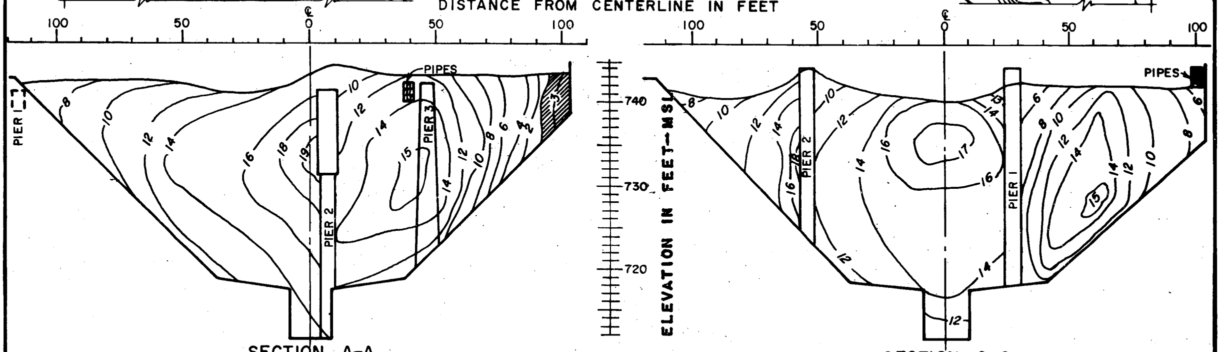
743.06 ● WATER-SURFACE ELEVATION FT

▨ CONCRETE CHANNEL

▨ GROUTED RIPRAP

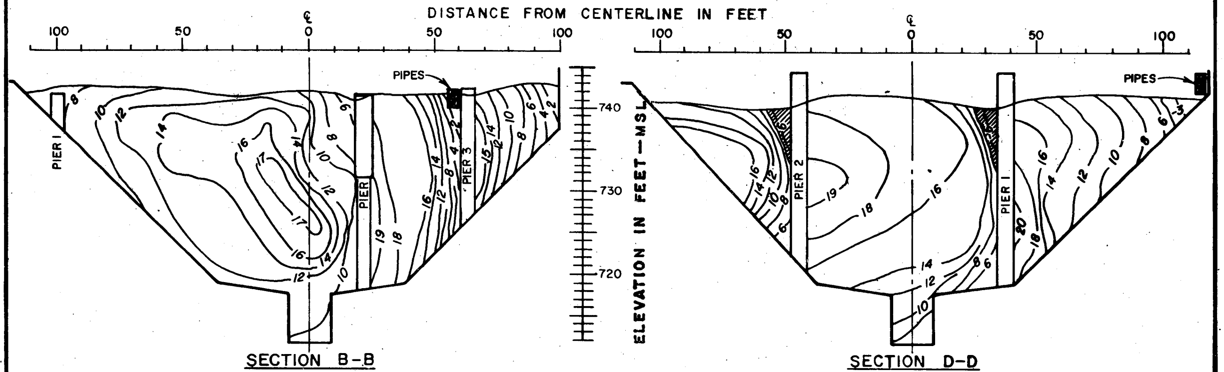
FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER





SECTION A-A

SECTION C-C



SECTION B-B

BRIDGE B-6

SECTION D-D

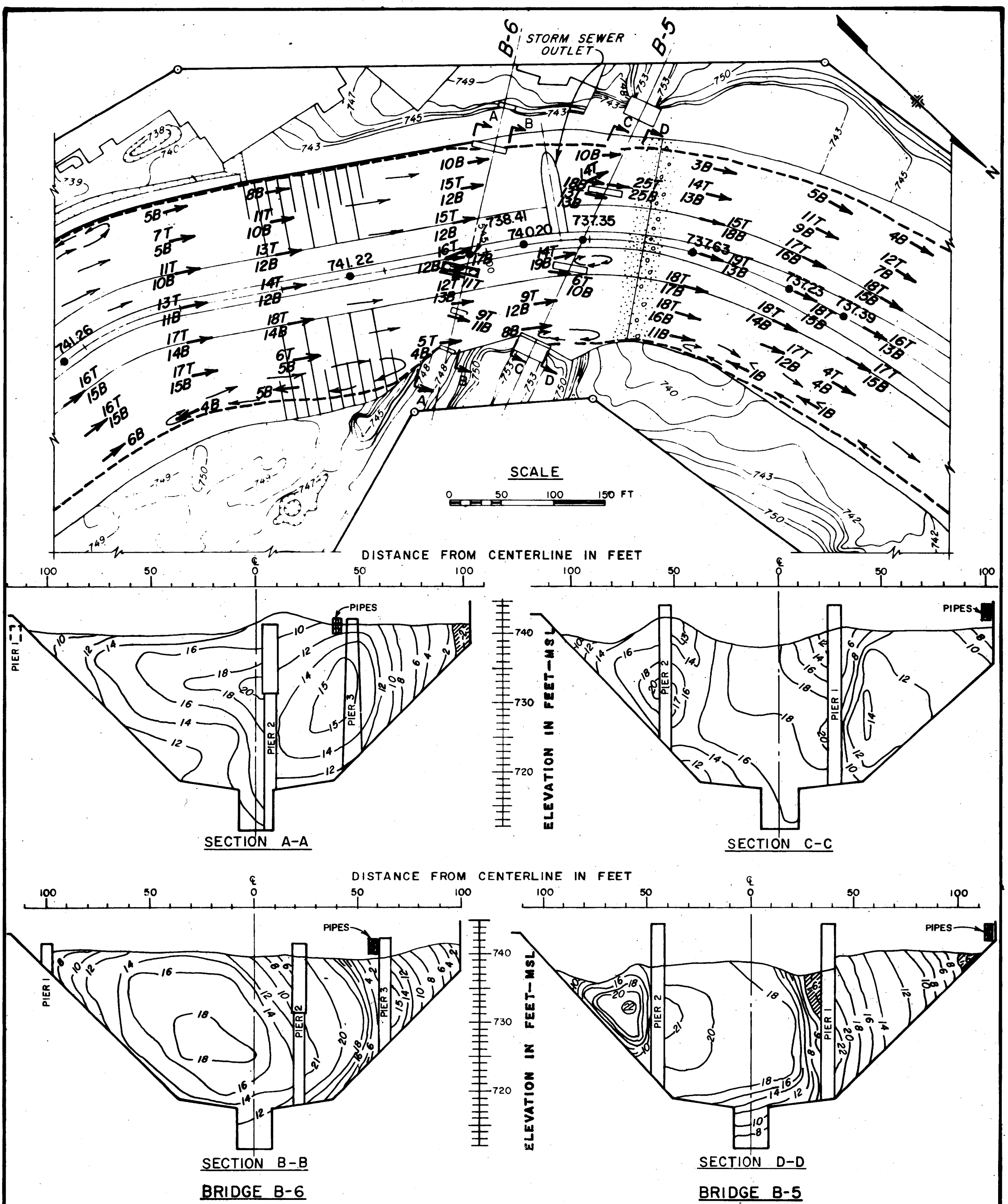
BRIDGE B-5

ALTERNATE PIER 2 DESIGN
BRIDGE B-6

LEGEND

14 ← VELOCITIES IN FPS
-3 UPSTREAM VELOCITIES IN FPS
T 3-FT DEPTH
B 3-FT ABOVE BOTTOM
743.06 ● WATER-SURFACE ELEVATION FT
▨ CONCRETE CHANNEL
▨ GROUTED RIPRAP

FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
DESIGN TAILWATER



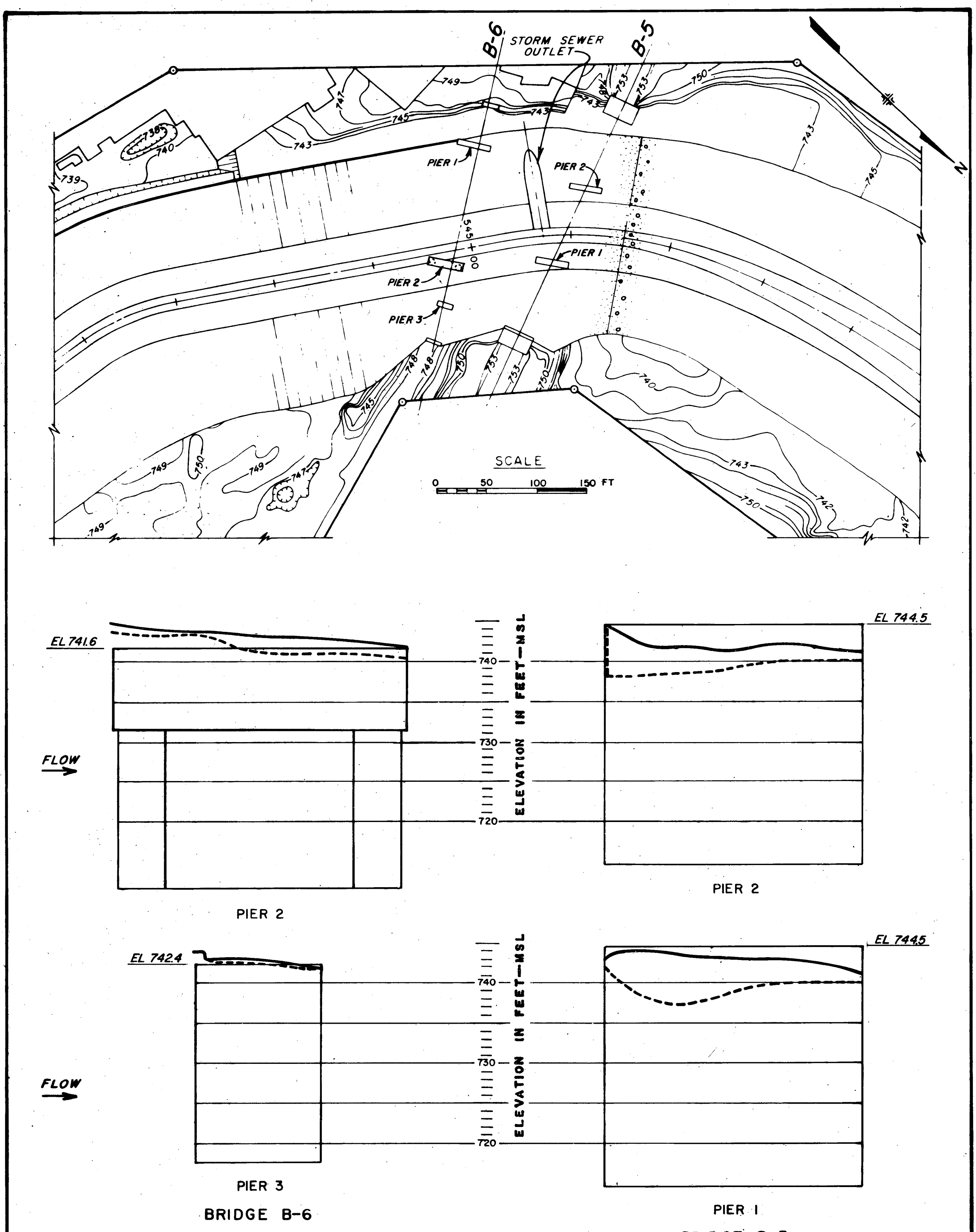
ALTERNATE PIER 2 DESIGN
BRIDGE B-6

LEGEND

← 14	VELOCITIES IN FPS
-3	UPSTREAM VELOCITIES IN FPS
T	3-FT DEPTH
B	3-FT ABOVE BOTTOM
743.06 ●	WATER-SURFACE ELEVATION FT
▨	CONCRETE CHANNEL
▨	GROUTED RIPRAP

FLOW CONDITIONS
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER

PLATE 48

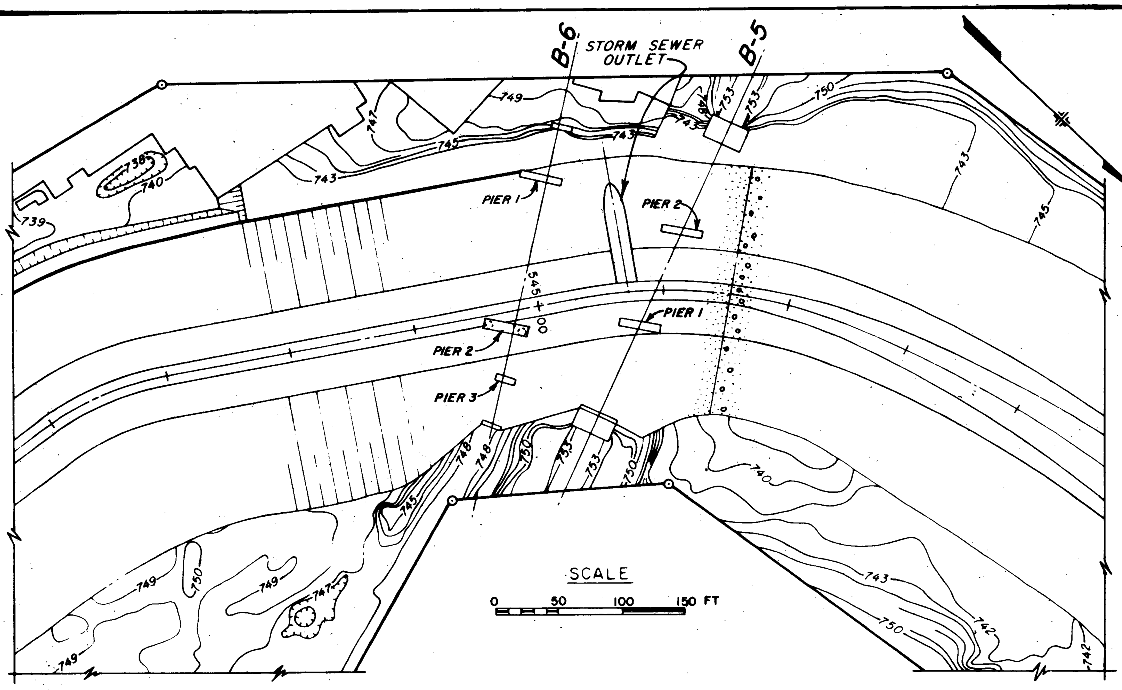


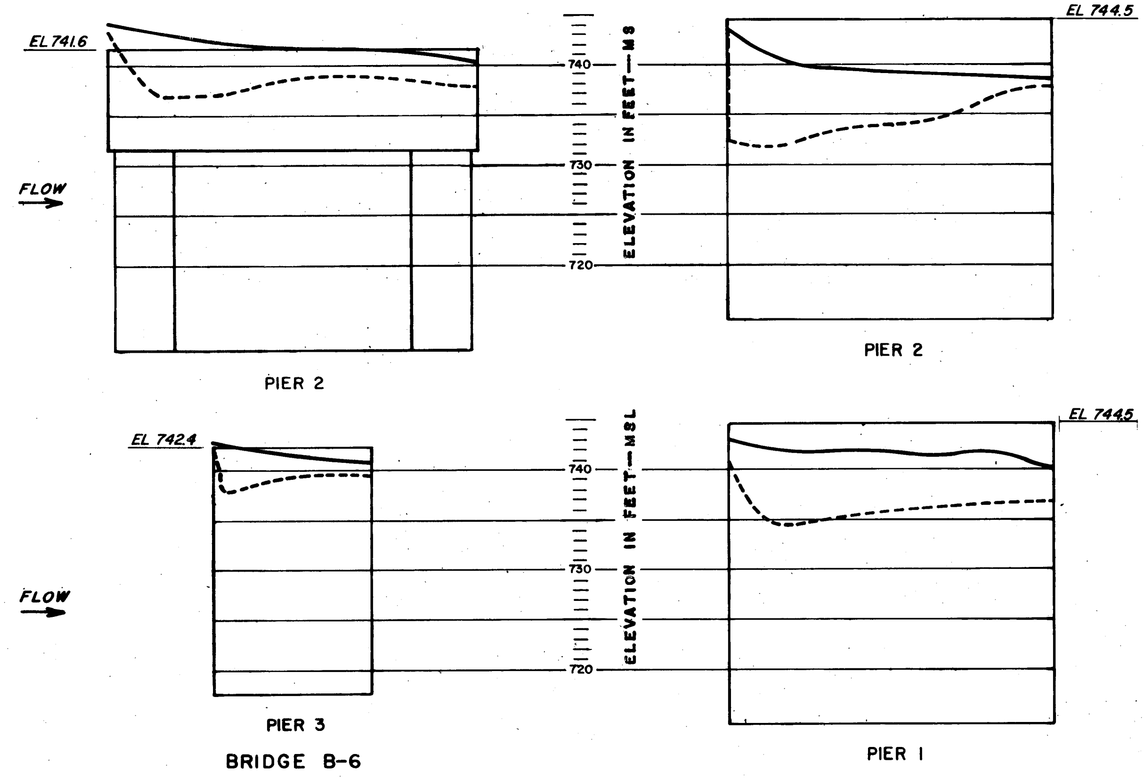
LEGEND

- ——— AVERAGE WATER SURFACE ALONG RIGHT SIDE PIER
- - - - - AVERAGE WATER SURFACE ALONG LEFT SIDE PIER
- ░ CONCRETE CHANNEL
- ▨ GROUTED RIPRAP

WATER SURFACE PROFILE
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
DESIGN TAILWATER

PLATE 49





PIER 2

PIER 2

PIER 3

BRIDGE B-6

PIER 1

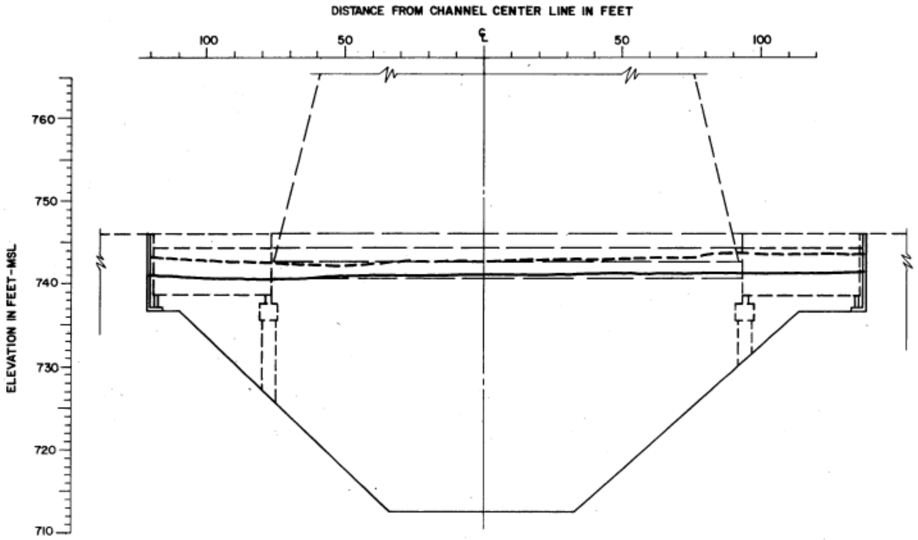
BRIDGE B-5

ALTERNATE PIER 2 DESIGN
BRIDGE B-6

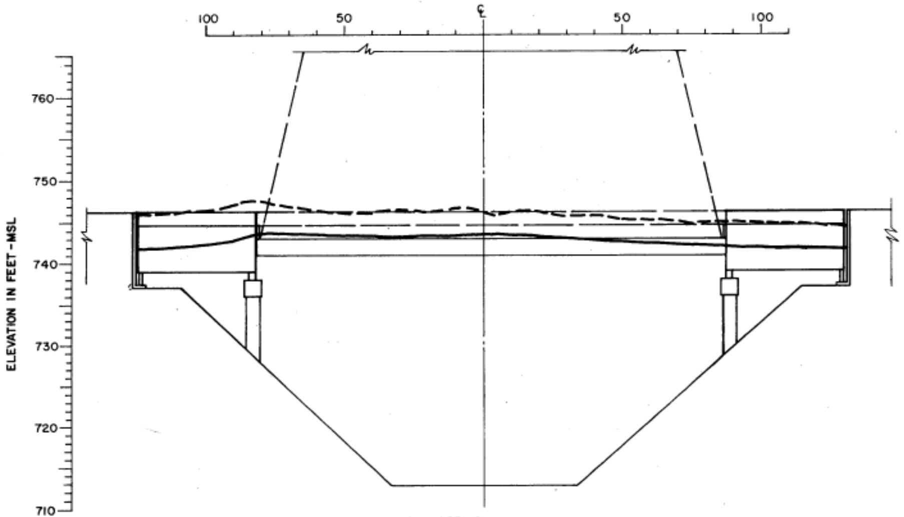
LEGEND

▬	AVERAGE WATER SURFACE ALONG RIGHT SIDE PIER
----	AVERAGE WATER SURFACE ALONG LEFT SIDE PIER
░	CONCRETE CHANNEL
▓	GROUTED RIPRAP

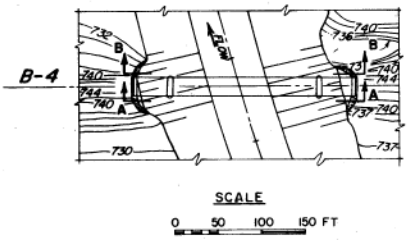
WATER SURFACE PROFILE
BRIDGES B-5 AND B-6
RIVER DISCHARGE 35 000 CFS
MINIMUM TAILWATER



SECTION B-B



SECTION A-A



LOCATION OF CROSS SECTIONS

LEGEND

—— 42 000 CFS-50-YEAR DISCHARGE

– – – – 52 800 CFS-100-YEAR DISCHARGE

WATER SURFACE CROSS SECTIONS
REVISED BRIDGE B-4