MODEL STUDIES OF STEELE BAYOU DRAINAGE STRUCTURE AND OUTLET CHANNEL AND REPAIRS TO OUTLET CHANNEL

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Outlet channel degradation is typical downstream of all hydraulic structures which discharge into the Yazoo River from the Yazoo backwater area. Since completion of each drainage structure on the Yazoo backwater area, there has been a continuous instability problem in each downstream outlet channel.

After the severe flood outflows during the spring of 1983, significant bottom scouring and bank sloughing were noted in Steele Bayou Outlet Channel. Model studies were conducted to define performance of the existing stilling basin and causes of problems in the outlet channel and to develop practical modifications that will permit the structure and outlet channel to perform satisfactorily for all anticipated flow and operational conditions.

PROJECT LOCATION

Steel Bayou Drainage Structure is the major outlet structure in the Yazoo Backwater Project. The Yazoo Backwater Area is located in west-central Mississippi and lies generally between the east bank Mississippi River levee on the west and the hills on the east. (See Plate 1) The area extends northward from Vicksburg some 60 miles to the latitude of Hollandale and Belzoni, Mississippi. Major streams within the Yazoo Backwater area are Big Sunflower and Little Sunflower Rivers, Collins and Deer Creeks and Steele Bayou.

Interior drainage is evacuated into the Yazoo River by drainage structures at Steele Bayou (Mile 9.8), Collins Creek (Mile 29.2), and Little Sunflower River (Mile 33.0). (See Plate 1) Also there is one structure for water quality and mitigation of fish and wildlife in the Eagle Lake area.

Another major component of the project is a two hundred foot bottom width channel connecting the Little Sunflower and Steele Bayou ponding areas near their confluence with the Yazoo River.

DESCRIPTION OF STEELE BAYOU DRAINAGE STRUCTURE

The structure is 600 feet west of Steele Bayou and some 3200 feet to the north of where the bayou flows into the Yazoo River. The structure consists of four vertical lift gates 30 feet x 22.5 feet, a concrete paved approach channel, and a stilling basin. The steel gates are used to close off Steele Bayou from the Little Sunflower River. The longitudinal length of the structure is 300 feet, consisting of 120-foot concrete paved approach apron, a 53-foot gate structure, a 40-foot chute, and a 78-foot stilling basin. Energy dissipation is enhanced by two rows of baffle piers in the stilling basin and a stepped endsill. (See Plate 2) Construction of the drainage structure was begun on 22 July 1965 and completed on 17 January 1969. The structure provides protection for agricultural lands.

ORIGINAL HYDRAULIC DESIGN CONDITIONS

The structure was designed to pass a maximum of 45,000 cfs and to pass 19,000 cfs with a hydraulic head of 1-foot at sump level elevation 82.5 feet NGVD. The maximum sump level for the design flood (1927 flood under present conditions) is elevation 96.9 feet NGVD. On the assumption that future conditions may justify pumping which would lower the sump level, a sump elevation of 92.0 feet NGVD was adopted for design flood conditions. The maximum sump level for minimum tailwater conditions is elevation 85.0 feet NGVD. The design flood tailwater level is elevation 107.0 feet NGVD. The minimum Yazoo River level at the mouth of Steele Bayou is elevation 43.0 feet NGVD. The approach channel is of the same size (200 feet bottom width) and capacity as the channel connecting the Sunflower and Steele Bayou sumps. The connecting channel has an elevation of 60.0 feet NGVD. The length of the stilling basin and adjacent riprap is designed for maximum flow at minimum head (maximum velocity 12.5 feet per second) for durations of time applicable to the project. The discharge channel will be of the same cross section dimensions as the approach channel (200 feet bottom width at elevation 55).

PROBLEMS SINCE CONSTRUCTION

The outlet channel at Steele Bayou was originally paved with riprap for a distance of 200 feet below the endsill. The channel was sand overlaid with a clay cap (See Plate 3) which tied into the existing riprap below the stilling basin. Within 2 years after completion, channel scour was noted downstream of the existing riprap in the outlet channel.

The channel bottom deteriorated from approximately elevation 55 to elevation 35. This deterioration started below the riprap and continued to the Yazoo River with a large energy hole downstream of the existing riprap. (See Plate 4)

The outlet channel continued to deteriorate and scallop until large scale eddies, standing waves, and vortices breached the access road during the spring runout of 1983. (See Plates 5 & 6)

MODEL USED IN STUDIES

Three types of models were used to determine hydraulic deficiencies with the structure and to determine the best outlet channel repairs.

Section Model

Using a 1-foot wide flume, a two-dimensional section model was constructed at a scale of 1:48. This model represented approximately one gate width and a 48-foot wide approach channel, stilling basin, and outlet channel. Inlet flow was calibrated with varying tailwaters in the model.

Types of hydraulic jumps which were occurring within the existing stilling basin under various inflow and tailwater conditions were determined.

Low tailwaters approximately 53-60 feet allowed violent hydraulic jumps to occur over the insills and transmitted large scale turbulence below the stilling basin. With large flows and excessively low tailwaters, the jump was noted to sweep out of the stilling basin.

With moderate tailwaters approximately 63-76 feet, a good strong hydraulic jump occurred over the baffle blocks and minimum turbulence was noted in the downstream outlet channel. The hydraulic jump was not observed outside the stilling basin with moderate tailwaters in the section model.

At approximately 78-100 feet, excessively high tailwaters appeared in the section model. As the tailwater significantly increased, the hydraulic jump in the stilling basin began to drown out and allowed standing waves to leave the stilling basin. With excessive submergence on the stilling basin, the hydraulic jump was completely drowned causing the stilling basin to provide minimal energy dissipation of the flow.

The sectional model was also utilized to determine if any structural modifications could be made to the stilling basin to increase its performance over the wide range of tailwaters. Some examples of improvements tested were various baffle heights and floating and fixed type baffles to disperse the standing waves downstream.

When baffle heights were increased 10-20 feet, stronger jumps were obtained with low and moderate tailwaters. These occurred over the baffle blocks and not the endsill as with the existing structure. Various floating and fixed baffle plates were tested to disperse the standing waves which occurred with totally submerged tailwater conditions. These were determined to be impractical due to height requirements and cost. Higher baffles and floating types baffles were determined to decrease outflow from the structure which is unacceptable.

The section model is relatively inexpensive to construct and test, but only two-dimensional flow characteristics are observed.

Mathematical Model

HEC-2 backwater computation mathematical models were set up for the original, existing, and modified cross sections. The limits of these models were from the confluence of the Yazoo River to the endsill of the structure. The data obtained from the models were channel capacities, velocities in the channel and water surface elevations.

The math models indicated super critical flow occurring in the downstream outlet channel with minimum tailwater. A comparison of minimum tailwater rating curves is presented in Plate 7.

These types of mathematical models are inexpensive and less time-consuming as compared with any type of physical model. The fault of this mathematical model is that only velocities and water surfaces are obtained with no directional indications available. This type model does not address vortices, eddies or return flow.

Structural Model

A 1:36 scale model was constructed to reproduce adequate approach and exit areas, the entire structure, and riprap protection as existed in the outlet channel. The approach and overbank areas were molded of sand- cement mortar to sheet-metal templates. The structure was formed with sheet metal and plywood. (See Plate 8)

This model allowed full evaluation of the performance of the structure and entrance and exit channels at the same time with three-dimensional flow.

After calibration of the model, it was determined the hydraulic jump would sweep out of the stilling basin or occur over the endsill under proper tailwater conditions (See Plates 9 & 10) as previously indicated by other models.

Numerous structural and outlet channel modifications were evaluated. As discussed in the section model, different height baffles (See Plate 11) and fixed and floating baffle plates were evaluated in the structural model. No baffle configurations produced acceptable levels of energy dissipation without channel alterations.

In the effort to disperse large eddies, numerous spur dike alignments were added in the scalloped area on each side of the outlet channel. It was determined that return flows could be significantly reduced with proper spur dike alignment, but large scale turbulence and eddies still existed which attacked the dikes and the downstream channel. Uneven gate openings magnified the vortices and turbulences with the spur dikes on the scalloped area downstream. No spur dike positioning with or without structural changes produced acceptable flow conditions on the downstream outlet channel.

Using sandbags, longitudinal dikes were placed in the scalloped area of the outlet channel, leaving the bottom elevation as it existed. Longitudinal dikes significantly reduced return flows and eddies in the outlet channel for all tailwater conditions and narrowed the range of tailwater elevations which allowed the hydraulic jump to leave the stilling basin. Large scale turbulence was reduced but not eliminated.

Longitudinal dikes enhanced the performance of the stilling basin and outlet channel better than any alternate configuration studied. Sandbags were removed from the model and the fixed mortar channel was replaced with a movable bed. The dikes were constructed of riprap with 1 on 3 side slopes and realigned parallel to each other. (See Plate 12) The existing channel bottom was capped with riprap.

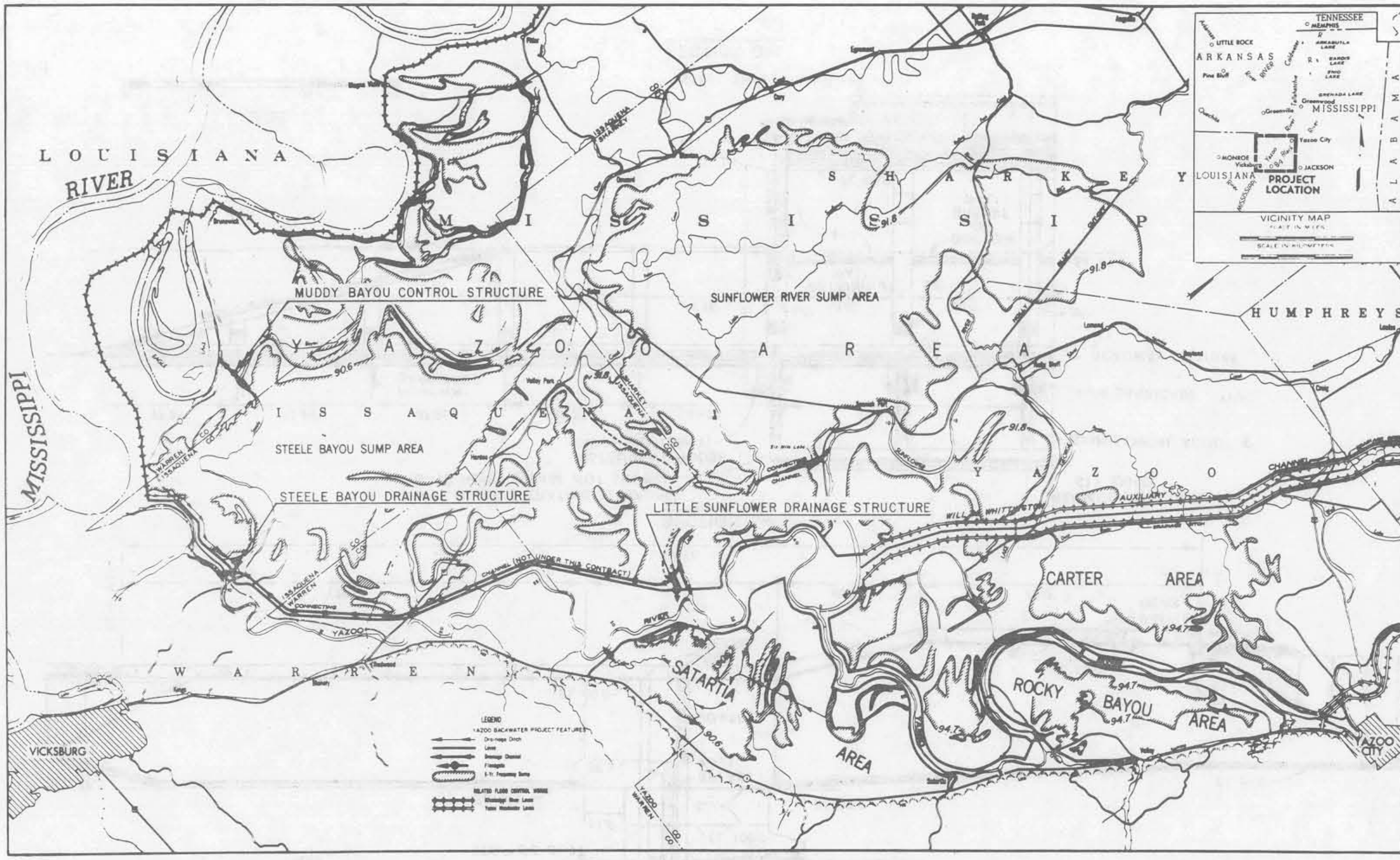
Testing indicated good flow alignment with minimal eddies and return flows but large boils and turbulences still existed in the outlet channel. Recommendations were made to raise the channel bottom to reduce the turbulence. The channel bottom, previously at approximate elevation 35, was raised to elevation 45 and capped with riprap. (See Plate 13) Turbulence was tremendously decreased and minimal. No eddies were observed in the prismatically formed channel. This modification provided a solution to the majority of the hydraulic problems occurring at the structure and in the outlet channel.

Structural models are time-consuming and very costly in comparison to math models or section models, but detail solutions can be better provided. The amount and accuracy of data collected is significantly increased with a structural model.

DISCUSSION

Due to the cost of longitudinal dikes, the side slopes were increased to one vertical on 2 horizontals with a bottom width of 120 feet at elevation 45. The increased side slopes provide the same nonturbulent flow and eliminate the eddies over a wide range of flow conditions. With a large enough discharge and unusually low tailwater, hydraulic jump could occur out of the stilling basin. These tailwaters are very unlikely to occur, and discharges will be limited through the structure when minimal tailwaters are present.

Hydraulic deficiencies of Steele Bayou Drainage Structure were defined in the Outlet Channel, not the structure. With proper tailwater, the stilling basin performs adequately.



PROJECT LOCATION MAP

SCALE IN MILES

PLATE 1

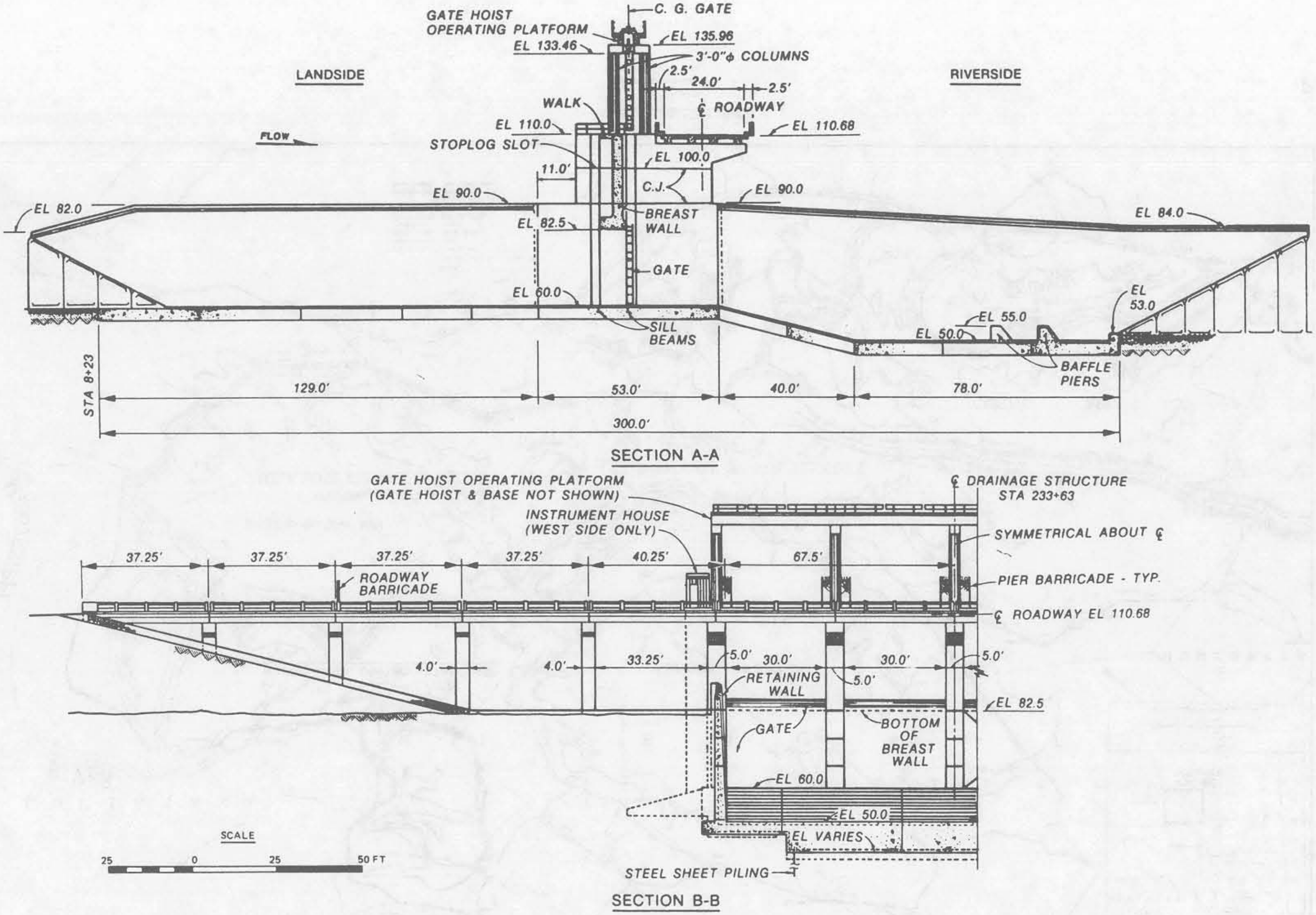

GATE HOIST OPERATING PLATFORM
C. G. GATE
EL 133.46
EL 135.96
3'-0"φ COLUMNS
2.5'
24.0'
2.5'
℄ ROADWAY
LANDSIDE
RIVERSIDE
WALK
EL 110.0
EL 110.68
FLOW
STOPLOG SLOT
EL 100.0
11.0'
C.J.
EL 90.0
EL 90.0
EL 82.0
EL 82.5
BREAST WALL
EL 84.0
GATE
EL 60.0
SILL BEAMS
EL 55.0
EL 50.0
EL 53.0
BAFFLE PIERS
STA 8+23
129.0'
53.0'
40.0'
78.0'
300.0'
SECTION A-A
GATE HOIST OPERATING PLATFORM (GATE HOIST & BASE NOT SHOWN)
℄ DRAINAGE STRUCTURE STA 233+63
INSTRUMENT HOUSE (WEST SIDE ONLY)
SYMMETRICAL ABOUT ℄
37.25'
37.25'
37.25'
37.25'
40.25'
67.5'
ROADWAY BARRICADE
PIER BARRICADE - TYP.
℄ ROADWAY EL 110.68
4.0'
4.0'
33.25'
5.0'
30.0'
30.0'
5.0'
5.0'
RETAINING WALL
EL 82.5
GATE
BOTTOM OF BREAST WALL
EL 60.0
EL 50.0
EL VARIES
SCALE
25 0 25 50 FT
STEEL SHEET PILING
SECTION B-B

PLATE 2

CENTERLINE PROFILE OF STEELE BAYOU OUTLET CHANNEL

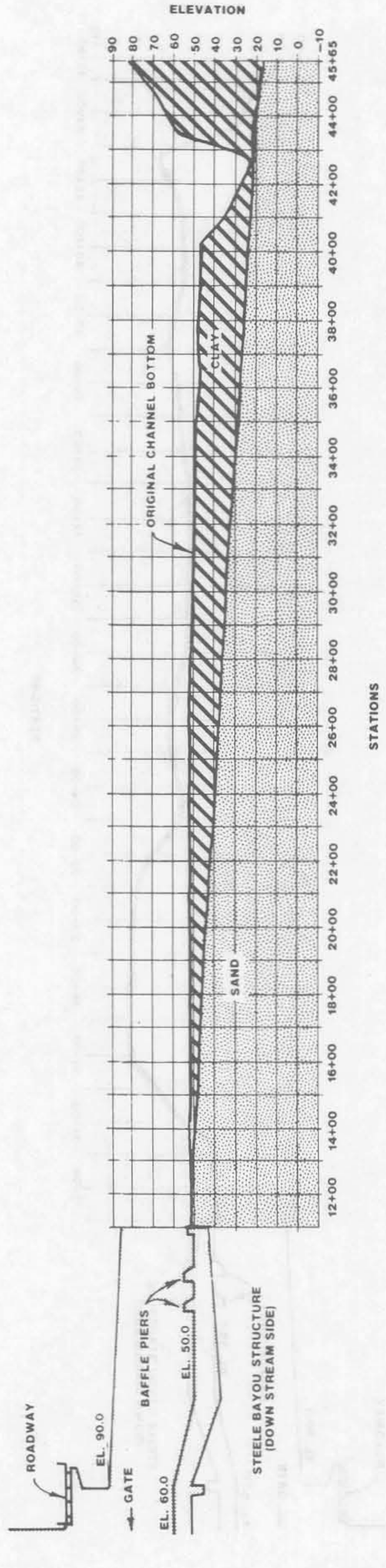


PLATE 3

CENTERLINE PROFILE OF STEELE BAYOU OUTLET CHANNEL

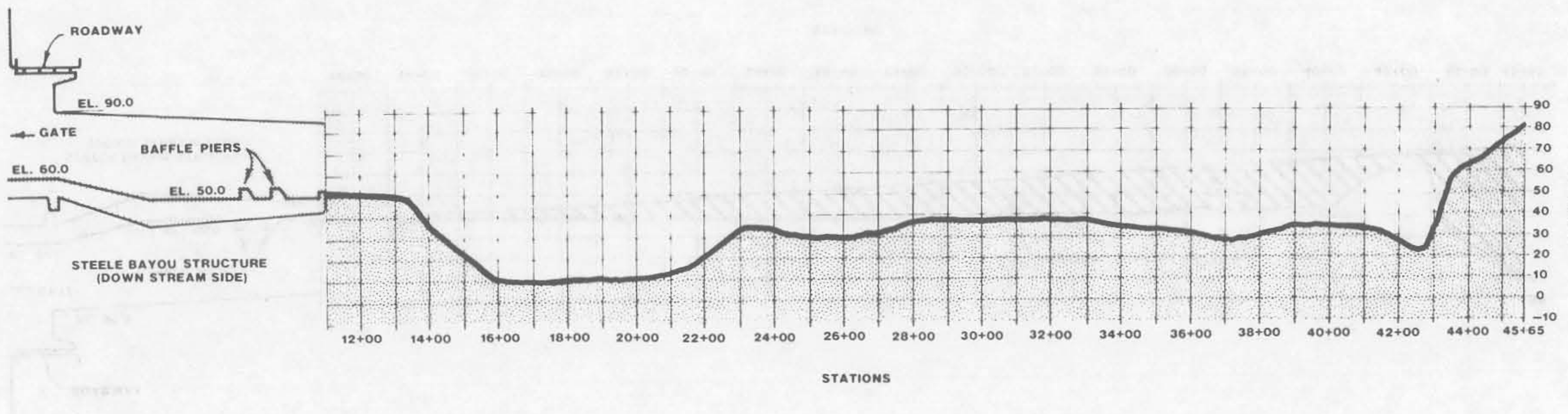
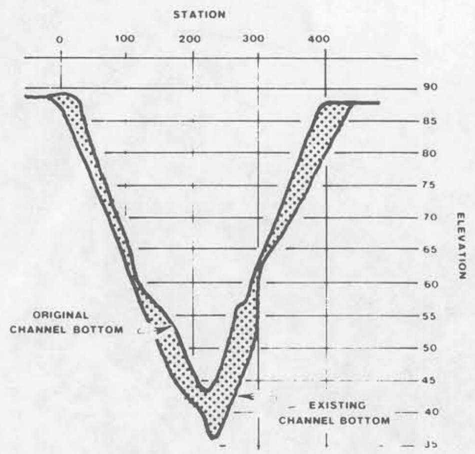
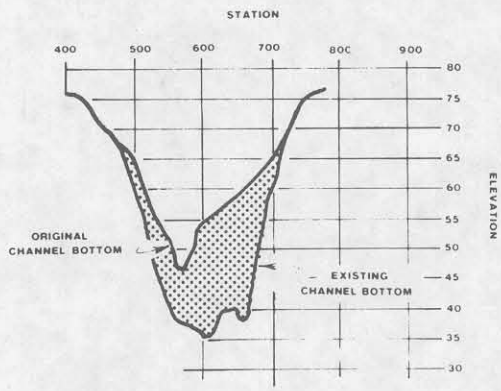


PLATE 4

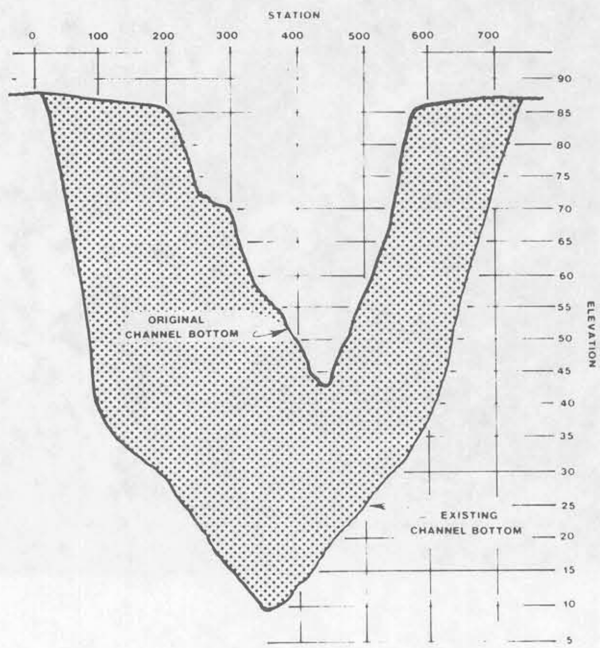
CROSS SECTION OF STEELE BAYOU



MILE 0.04



MILE 0.20

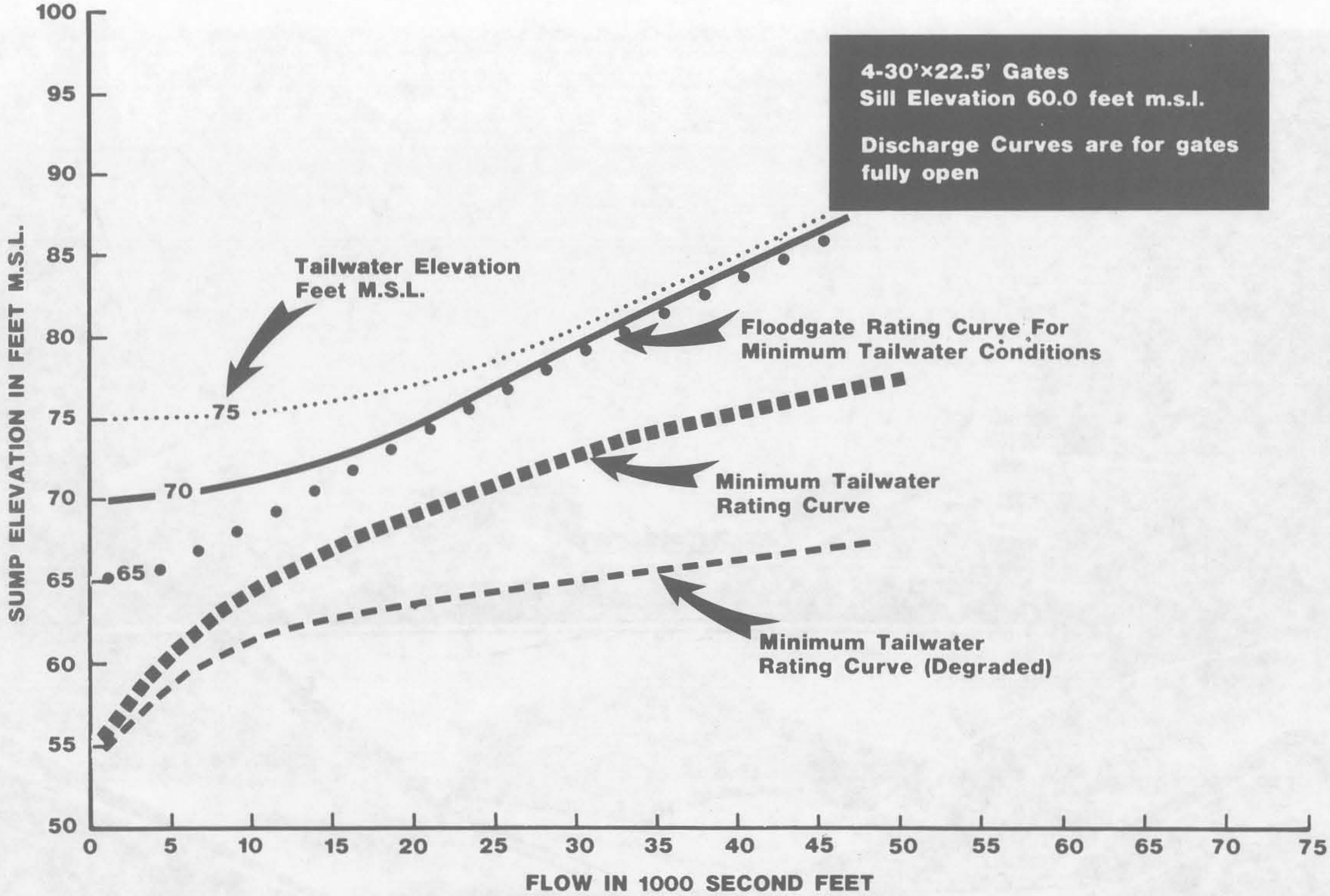


MILE 0.42

PLATE 5

PLATE 6

PLATE 7



DISCHARGE RATING CURVE

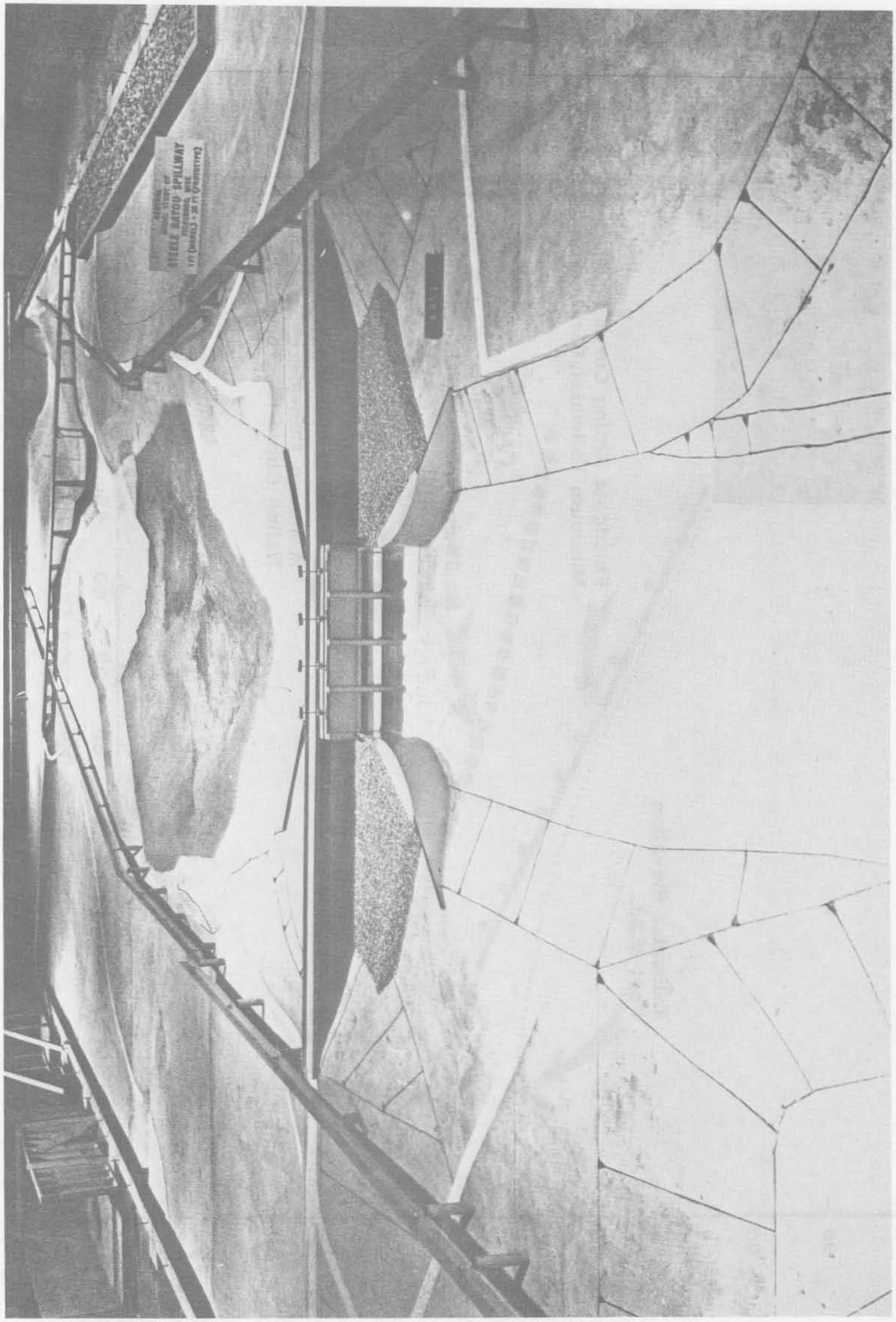


PLATE 8

PLATE 9

PLATE 10

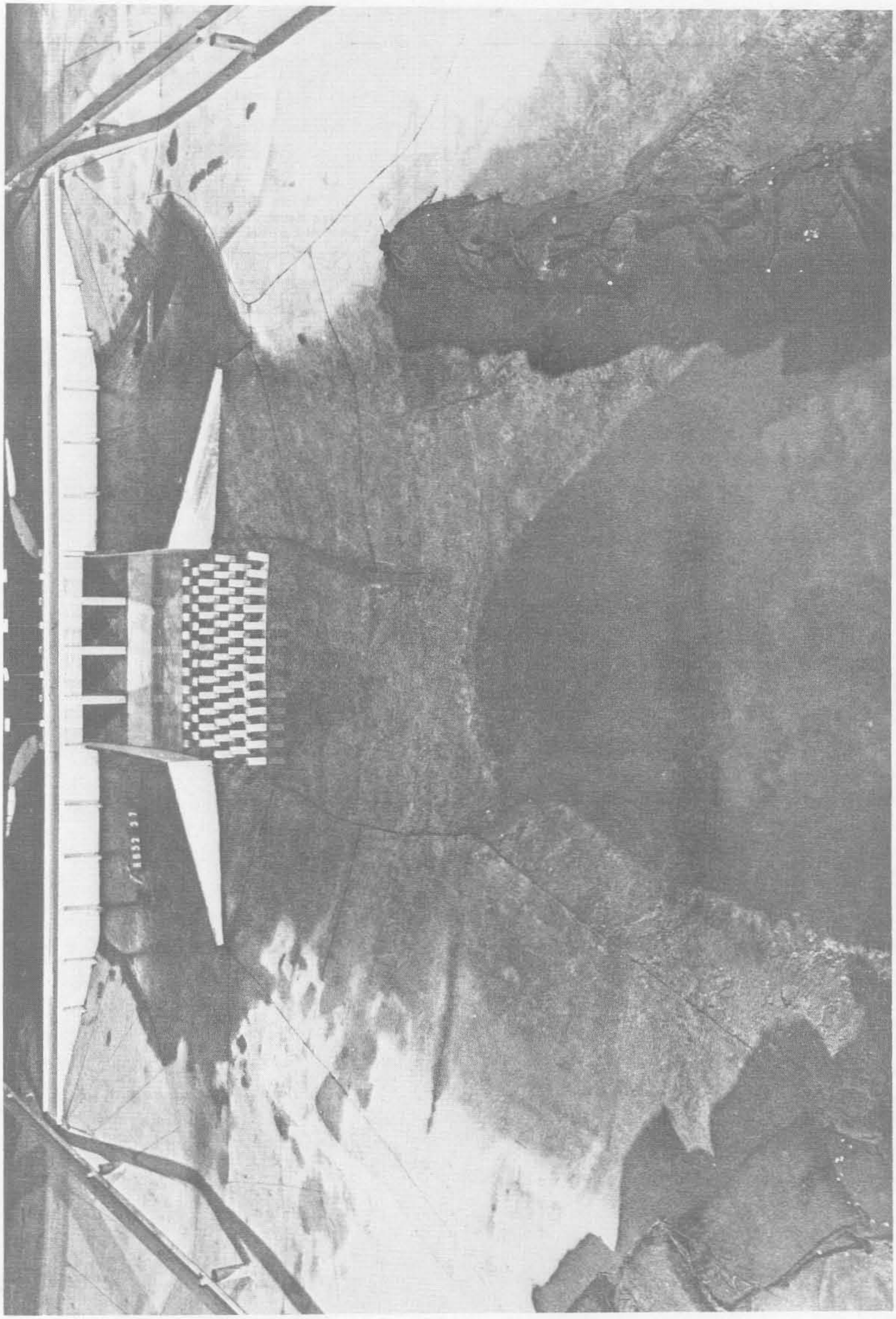


PLATE 11

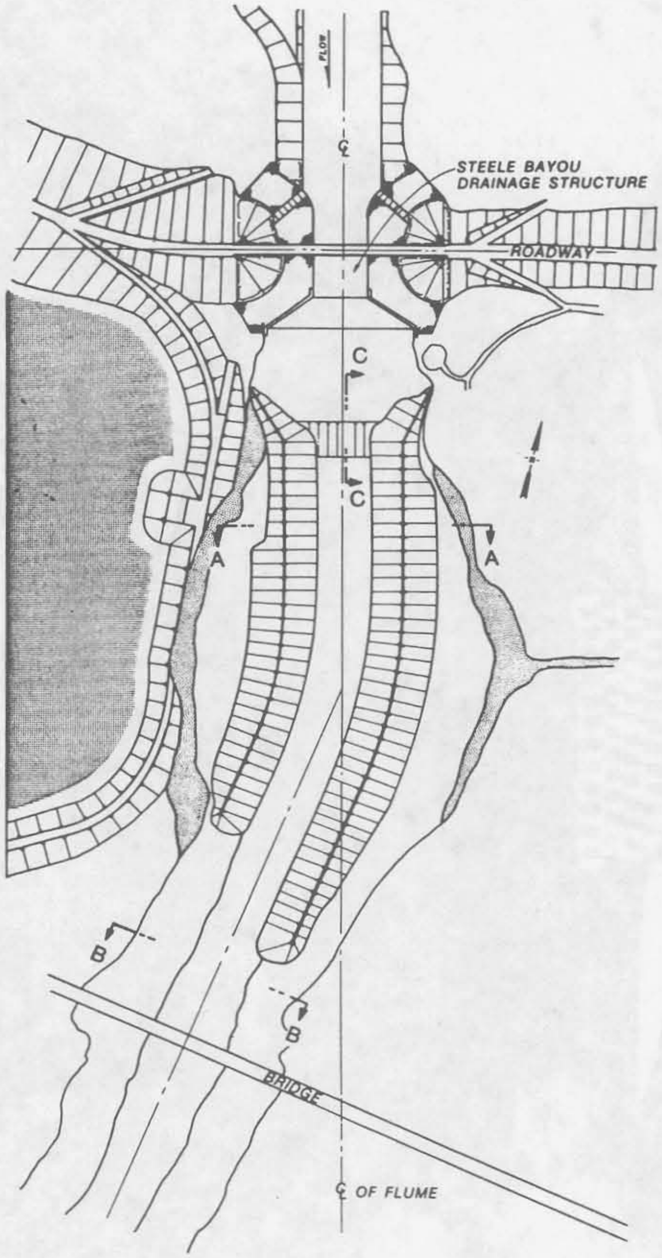

FLOW
STEELE BAYOU
DRAINAGE STRUCTURE
ROADWAY
C
C
A
A
B
B
BRIDGE
℄ OF FLUME

PLATE 12

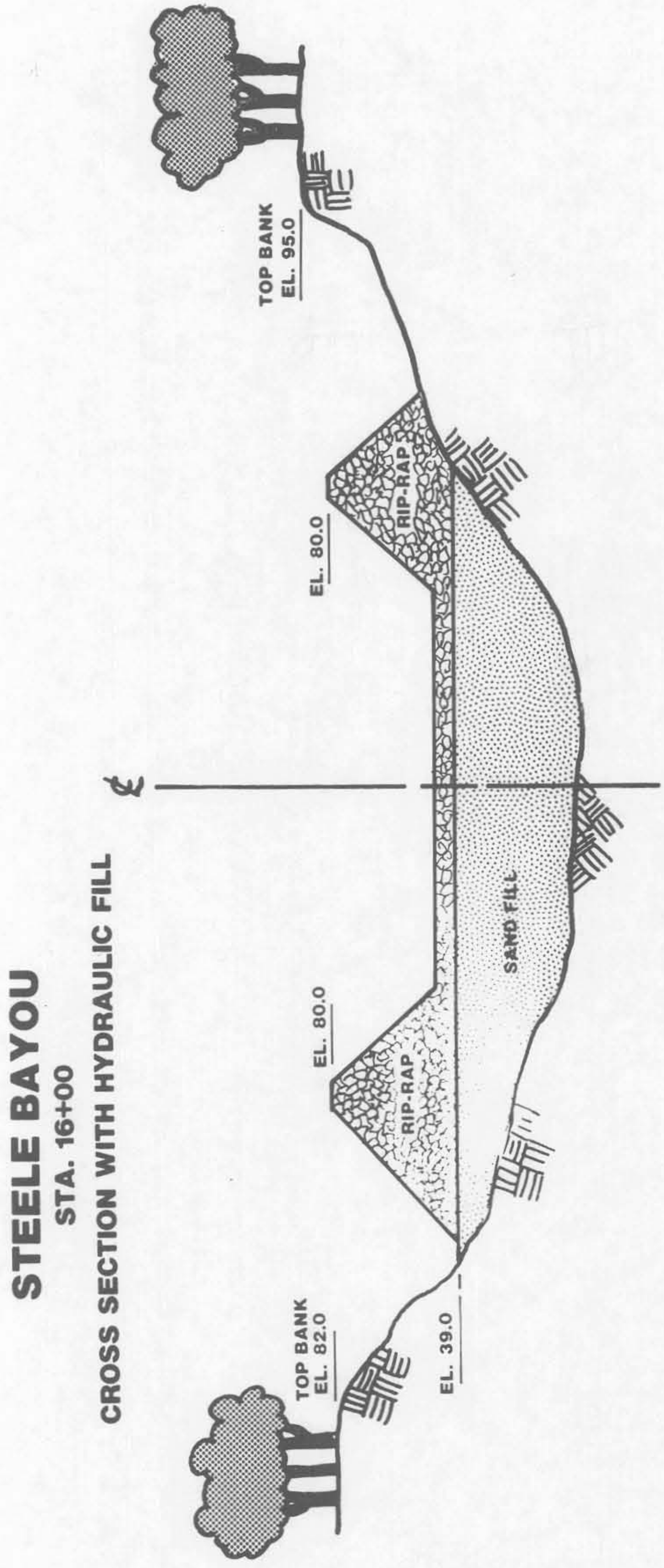

STEELE BAYOU
STA. 16+00
CROSS SECTION WITH HYDRAULIC FILL
TOP BANK
EL. 82.0
EL. 39.0
EL. 80.0
RIP-RAP
SAND FILL
EL. 80.0
RIP-RAP
TOP BANK
EL. 95.0

PLATE 13