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GROUTING OF SCOURED FOUNDATION OLD RIVER LOW SILL STRUCTURE, LOUISIANA

by

Hugh K. Wilson

Concrete Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

December 1978
Final Report

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In the emergency grouting operations at the Old River Low Sill Structure, Louisiana, in late 1973 and early 1974, the Concrete Laboratory of the U. S. Army Engineer Waterways Experiment Station was responsible for (a) development of a series of grout mixtures for placement in scoured areas, (b) supervision of mixing and placement of the grout mixtures, (c) development of instrumentation for monitoring uplift pressure and grout levels and locations beneath the structure, (d) the actual monitoring of uplift pressure and grout levels during grouting

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operations, and (e) determining the physical properties of field-placed grout. It is believed, after many check borings, that the physical properties of the field-placed grout closely match the design criteria, and the scoured areas have been successfully replaced.

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Preface

The work performed by the U. S. Army Engineer Waterways Experiment Station (WES) in connection with the emergency grouting of Old River Low Sill Structure, Louisiana, was accomplished during the last two months of 1973 and the first two months of 1974 for the U. S. Army Engineer District, New Orleans (NOD), Lower Mississippi Valley Division (LMVD), under the direction of Mr. E. B. Kemp III, NOD, and responsible staff members of the LMVD and NOD. The Atlas Construction Co. and the Alabama Waterproofing Co. rendered excellent cooperation, logistical support, and assistance to WES during this operation.

The WES participation in this operation was under the direction of Mr. Bryant Mather, Chief, Concrete Lab (CL), and under the supervision of Messrs. J. M. Polatty and R. A. Bendinelli, CL. Laboratory and field operations were performed under direct supervision of Messrs. D. Foster, NOD, and J. A. Boa, Jr., J. V. Maggio, O. K. Loyd, H. K. Wilson, and D. L. Ainsworth, all of CL, WES. Mr. Wilson prepared this report.

Directors of WES during the conduct of the work and the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Mr. F. R. Brown was Technical Director.

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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
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
cubic yards	0.7645549	cubic metres
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre
pounds per cubic foot	16.01846	kilograms per cubic metre
cubic feet	0.02831685	cubic metres

GROUTING OF SCOURED FOUNDATION, OLD RIVER LOW SILL STRUCTURE, LOUISIANA

Introduction

Background

1. The Old River Low Sill Structure (Figure 1) is located approximately 154 miles* upstream of New Orleans, Louisiana, on the west bank of the Mississippi River. It is an 11-gated, pile-founded, 600-ft-long structure, and was completed in 1960 as part of a project to prevent the capture of the Mississippi River by the Atchafalaya River.

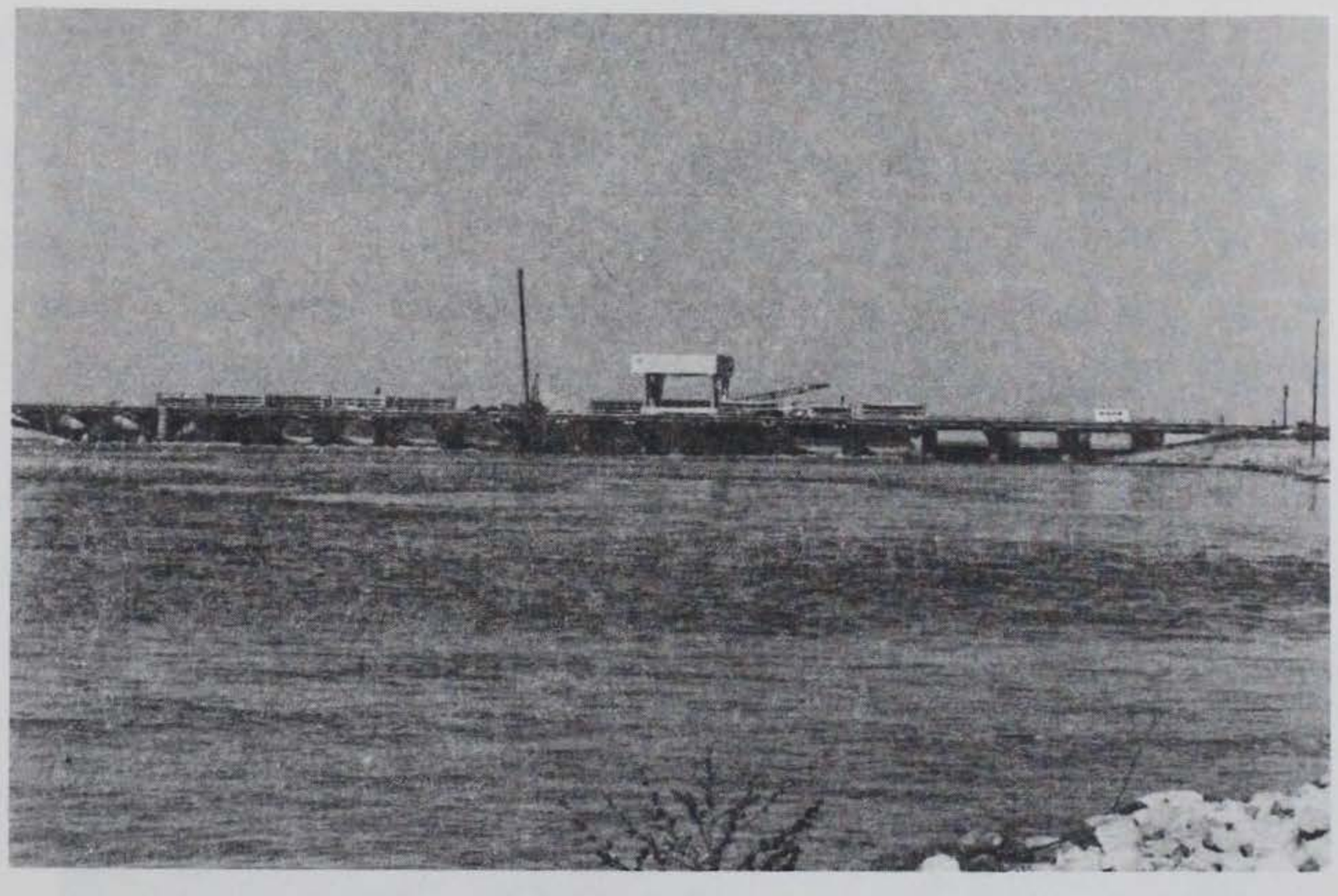

Figure 1. Old River Low Sill Structure

2. In 1952, a study conducted by the U. S. Army Corps of Engineers revealed that the Atchafalaya River would capture over 40 percent of the flow of the Mississippi River by 1971. Once this capture occurred it would only be a matter of time before the Atchafalaya River

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

would be carrying the majority of the Mississippi River flow with disastrous results downriver on both the Mississippi and Atchafalaya Rivers.

3. The project to prevent capture of the Mississippi River by the Atchafalaya River consisted of an overbank structure to accommodate high water flows; a low sill structure to control the amount of flow between the Mississippi River and the Atchafalaya River; a lock for navigation between the Mississippi, Red, and Atchafalaya Rivers; and a closure dam to seal Old River. The entire project was completed in July 1963.

4. During the 1973 flood at Old River Low Sill Structure an eddy developed behind the southeast wing wall, and in April 1973 the major portion of this wing wall collapsed. Surveys of the forebay indicated a large scour hole, maximum depth -65 ft,* had formed in front of gate bays 8-11. The immediate repair consisted of placing riprap in the scour hole in the forebay area and the construction of a rock dike to replace the collapsed wing wall (Figure 2).

Figure 2. Rock dike and remainder of collapsed wing wall (lower right)

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* All elevations (el) cited herein are in feet referred to mean sea level.

5. Because of the magnitude of the scour hole (depth of -65 ft immediately in front of the forebay sheet piling which extends to a depth of -36 ft), an immediate investigation of the foundation beneath the structure and the stilling basin was initiated by the U. S. Army Engineer District, New Orleans.

6. With the help of U. S. Army Engineer District, Mobile, crews and drill rigs, the investigation beneath the structure and stilling basin was begun in late September 1973. The drill rigs were truck-mounted, skid-mounted, and mounted on self-elevating barges or regular spud barges. Between 23 September 1973 and 8 February 1974, 48 borings were made (Figure 3). By mid-October, the extent of the limits of the scour had been defined using drill rigs, downhole TV cameras, and sounding equipment, but the exact dimensions would not be known until a later date.

Objective and scope of WES participation

7. The U. S. Army Engineer Waterways Experiment Station (WES) was given the primary mission of (a) developing grout or concrete mixtures to be used for replacing the eroded foundation material, (b) investigating possible means of placing these mixtures, and (c) designing instrumentation for monitoring the uplift pressures and grout levels and locations.

8. The peculiarities of this project required that special grout mixtures and instrumentation be designed for special uses and locations.

Grout Mixtures

Design criteria

9. Certain criteria for proportioning the grout mixtures to be used at Old River Low Sill Structure had to be met; these were:

a. A nonsanded, medium cement content, low-strength slurry-type grout mixture was proportioned for incorporating the muck material into the grout and to prevent the segregation and dilution of the bulk filler grout which was to be subsequently placed.

b. A sanded, low cement content grout mixture having low

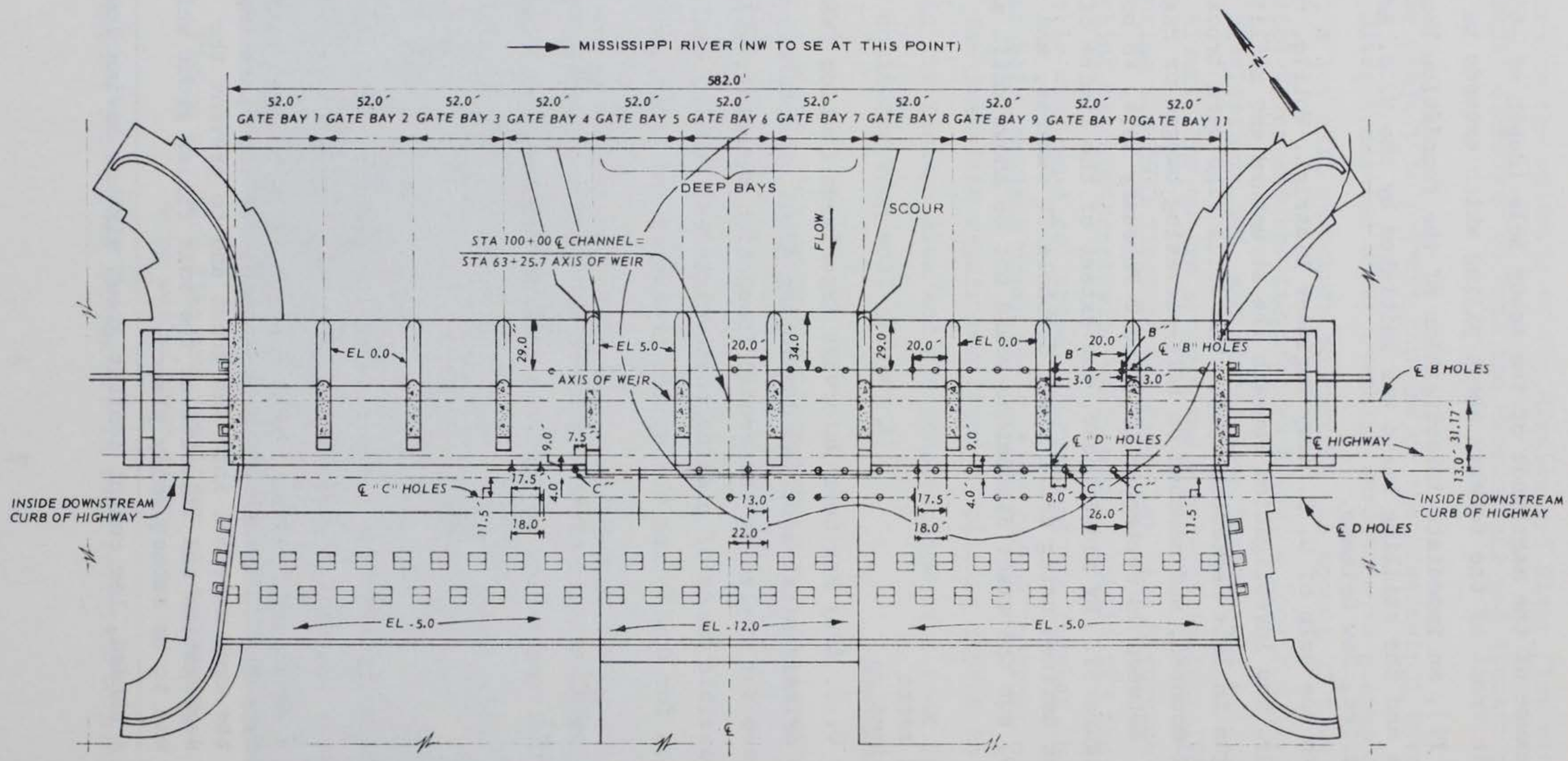


Figure 3. Top view of structure showing location and extent of scour and locations of B-, C-, and D-line borings

bond and compressive strengths was proportioned to be used as a bulk filler of the scoured area.

c. A nonsanded grout having a high cement content and a high compressive strength was proportioned to be used as a cap to insure bond between the underside of the structure sill and the bulk grout and to prevent erosion by channeling.

d. All grout mixtures had to be self-leveling, highly pumpable, and heavy enough to be placed in wet, sluggish environments.

Materials and laboratory mixtures

10. Materials were obtained from local sources for use in the laboratory proportioning work.

11. Masonry sand and Type I cement were secured to match as closely as possible actual materials to be used. Barite and bentonite (Aqua-Gel) were purchased from Baroid, a division of the National Lead Co.

12. During September and October 1973, different materials and approximately 30 mixtures were proportioned and examined for compliance with design criteria. Ultimately, mixture designs designated OR-13, OR-5, and OR-23 were selected for the incorporation of muck, bulk filler, and capping mixtures, respectively. The mixture proportions are presented in the following tabulation.

Materials	Mixture Designations, Dry Batch (SSD)*		
	OR-5	OR-13	OR-23
Cement, Type I Portland, lb/yd^3	281.61	563.49	1088.10
Sand (masonry), lb/yd^3	875.07	--	--
Barite, lb/yd^3	851.85	--	892.89
Bentonite (Aqua-Gel), lb/yd^3	75.60	59.94	92.34
Water, lb/yd^3	1028.97	1199.80	1088.10
Theoretical unit weight, lb/ft^3	115.4	111.3	117.1
Theoretical cement factor, bags/yd^3	3.0	6.0	11.6
Water-cement ratio, by weight	3.65	2.13	1.00

* Saturated surface dry.

Laboratory-simulated field conditions

13. Concepts and ideas on types of mixtures and methods of placement were received from many sources.

14. One such concept was a high-slump concrete mixture with pea gravel or 9.5-mm (3/8-in.) maximum size aggregate to be placed by the tremie method.

15. A laboratory-controlled, field-simulated test was conducted using a high-slump concrete and tremie in a water-filled sump (Figures 4 and 5). Several problems surfaced during this test: (a) the lack of self-leveling properties, (b) the possibility of the mixture segregating and diluting, and (c) the actual handling of such a long tremie led to the decision to use highly pumpable, self-leveling, sanded and nonsanded grout mixtures.

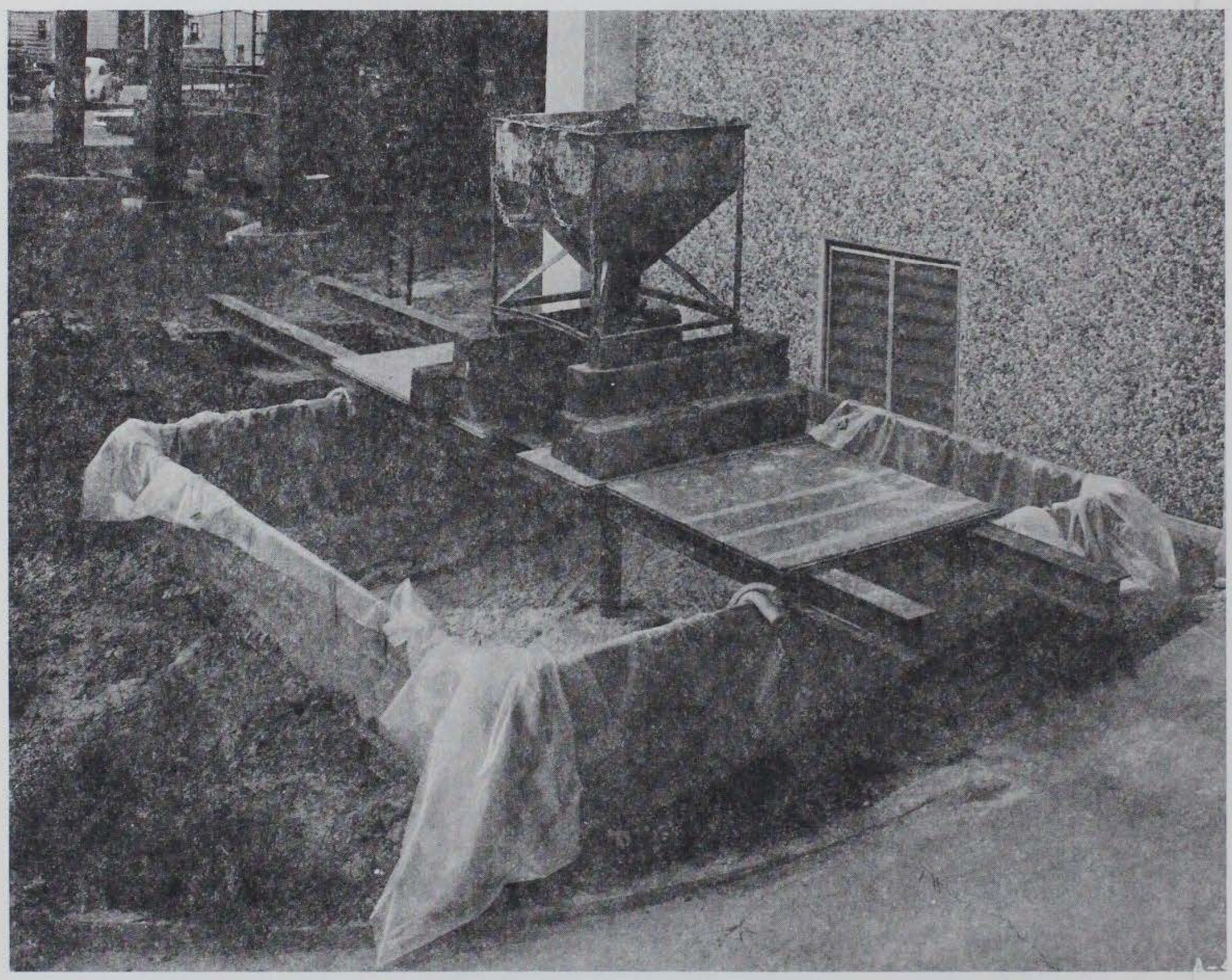


Figure 4. Field-simulated tremie placement test

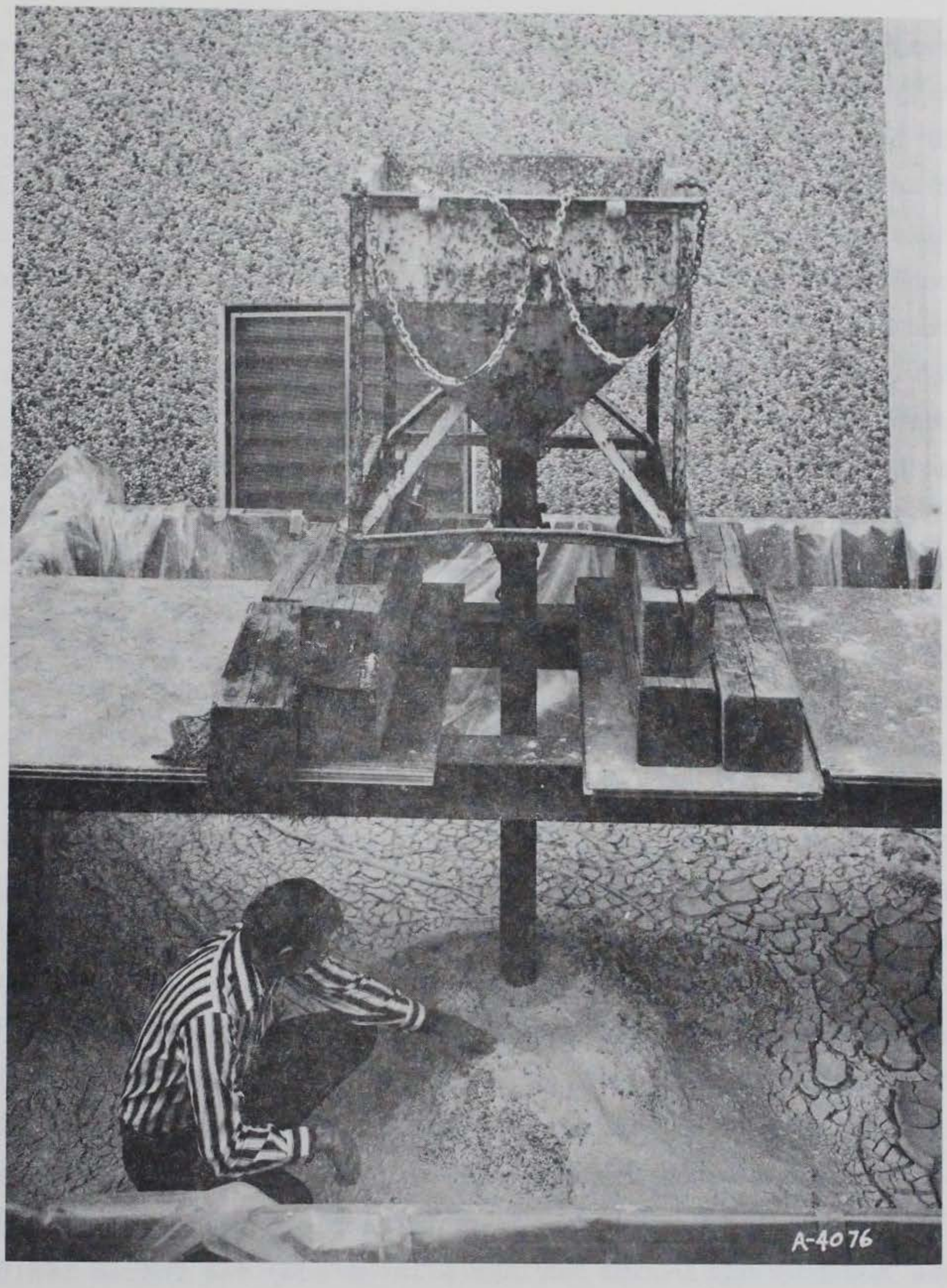


Figure 5. Close-up of tremie mixture showing lack of self-leveling properties and segregation and dilution

Instrumentation

16. In order to adequately monitor uplift pressures and grout levels, a sophisticated instrumentation program was developed and monitored by personnel of the Engineering Physics Branch, Concrete Lab, WES. The uplift pressures were measured using CEC strain gage pressure gages

with a range of 0-50 psi, installed in waterproof housings, and located immediately beneath the concrete slab. Grout monitoring devices consisted of two electrodes spaced approximately 1-1/2 in. apart, protruding from an encapsulated body containing the electrode wires, and also steel balls necessary to provide weight. These gages measured the different conductivity exhibited by air, water, muck, and grout, and were calibrated such that full-scale (10-in.) deflection on the recorder was obtained with the gage in air and half-scale (5-in.) deflection with the gage inserted in water. With this calibration, grout deflection was indicated by a 1-in. deflection from zero, water contaminated with cement by a 1-1/2-in. to 3-in. deflection, and muck by a 3- to 4-in. deflection. Strong water current was indicated by a 6- to 7-in. deflection. A WES report to be published in the near future will more fully describe the instrumentation systems used on this project.

Field Operations

Site investigation

17. As stated previously, the investigation to determine the presence of a void or voids under the Old River Low Sill Structure was begun in September 1973 with Mobile District drill crews and rigs. Borings were drilled from spud barges, self-elevating barges, and from the structure itself. The borings drilled from the structure were unique. The drill bit and drill stem had to be suspended 74 ft through air and water. Even with the gates closed in the working area, considerable water turbulence was encountered; the water along the B-line borings (Figure 3) moved down the face of the closed gates to the open gates, and along C- and D-line borings a large eddy was formed behind these closed gates.

18. To protect the drill bit and stem while drilling, a large 10- to 12-in. ID casing was set on top of the structural slab. This enabled the driller to start and drill an 8-in.-diam hole to a depth of 1.5 ft. A small 6-in. ID casing was then set in the 1.5-ft hole down through the larger 10- to 12-in. casing. With this smaller casing in place, the drilling was resumed with a 5.5-in.-diam bit through the structural slab.

19. After completing the boring the larger casing was pulled and used to start another boring. In the B and D lines, the smaller casing was secured to the bridge deck before the drill platform was relocated over another drilling location. The casings along C line were left standing through a hole in the bridge deck (Figure 6).

20. By mid-November 1973 the extent of the scour area had been defined. Figure 3 shows the extent of the scour and Figures 7-9 show the profiles along the B, C, and D lines, respectively. Note on B and D lines the depth of scour below the forebay sheet piling (B line) and tailbay sheet piling (D line).

21. By early February 1974 some 48 borings had been drilled. Figure 3 shows the drill pattern of each gate bay as well as the complete south end of the structure.

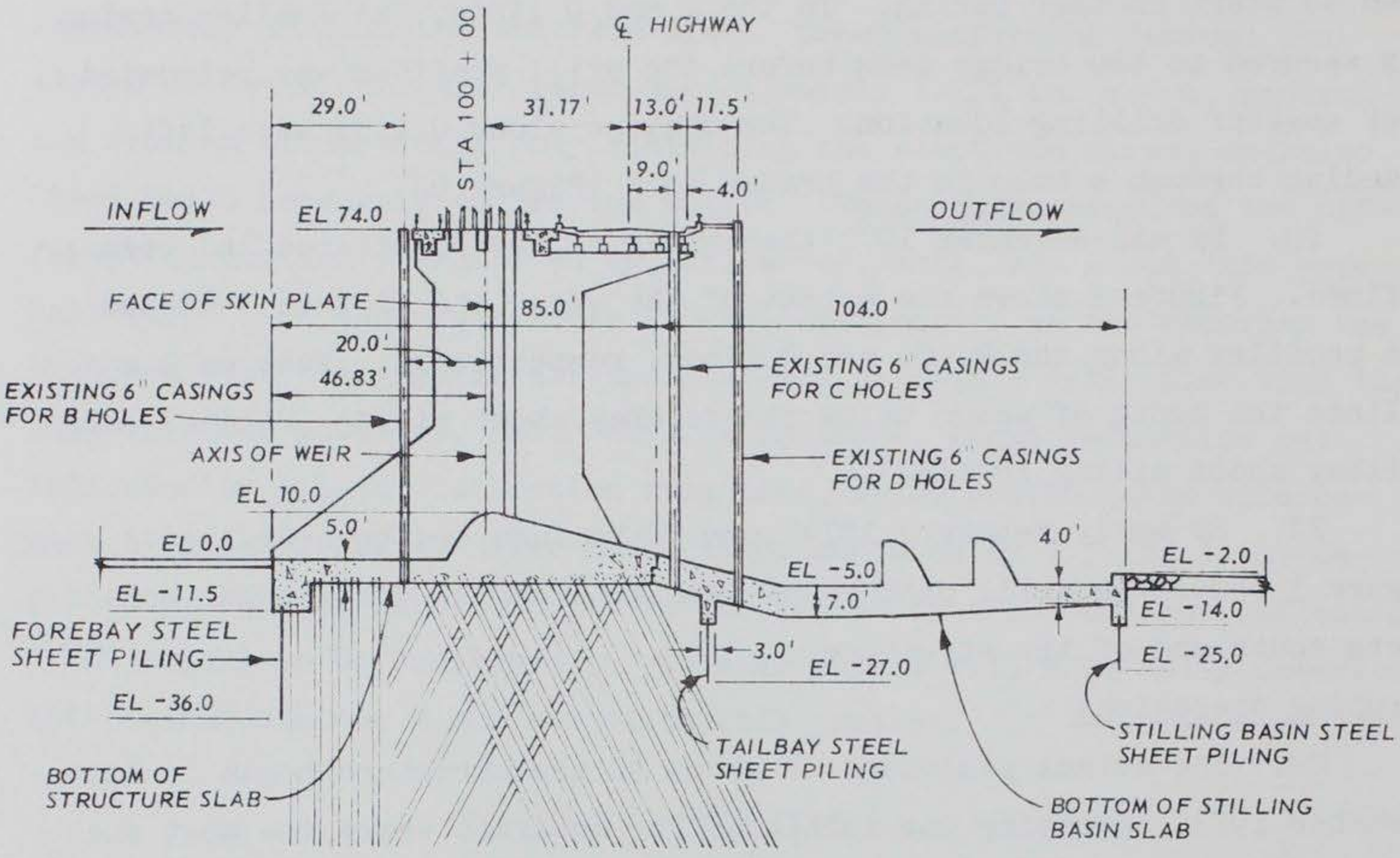
Grouting operations

22. The actual placement of grout in the structure began in late November 1973. Grouting was initiated in the areas where the most muck and the deepest scour occurred.

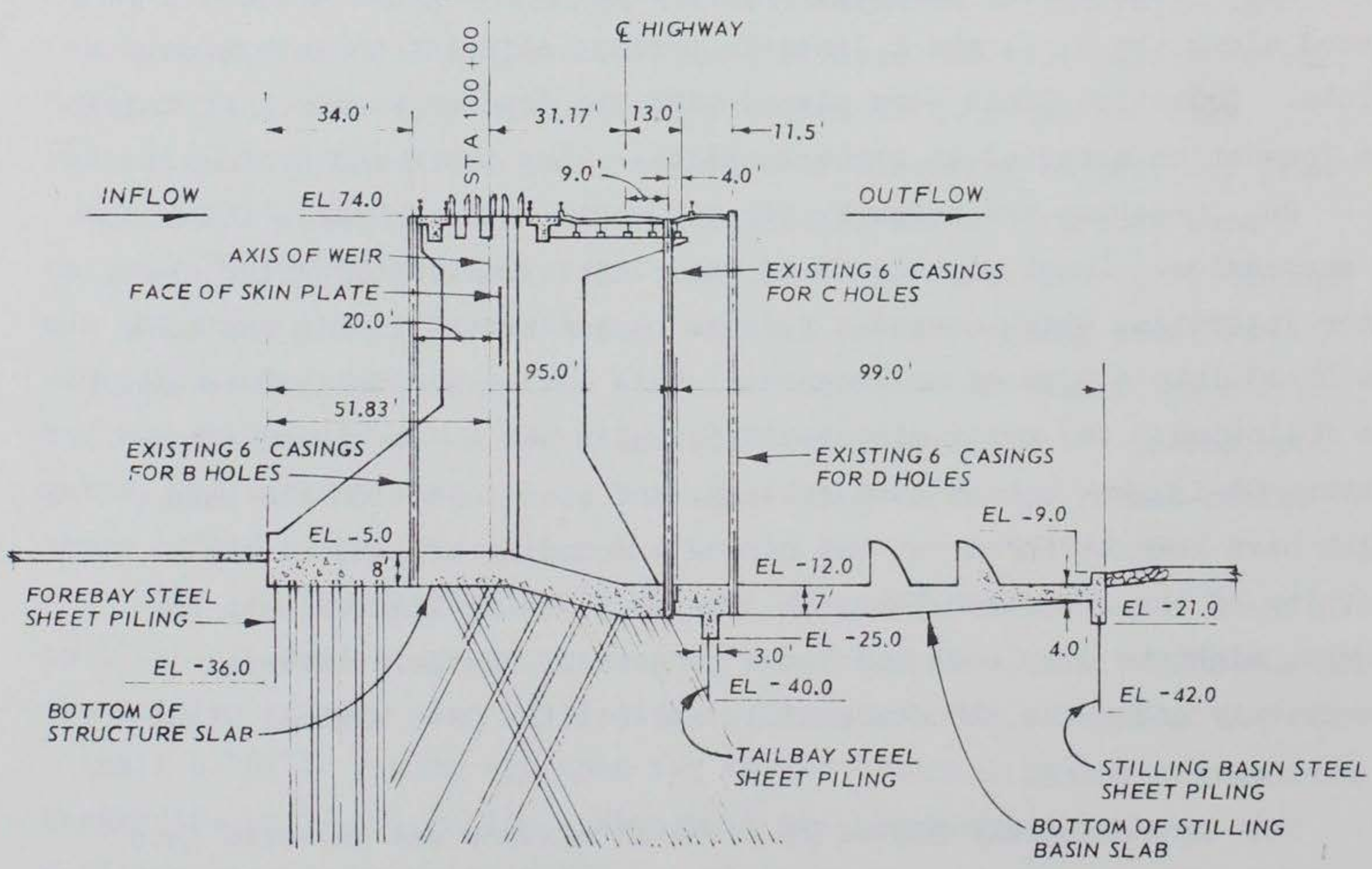
23. Prior to the pumping, pressure gages and grout detectors were placed along the B, C, and D lines in borings adjacent to injection points. Injection lines were placed with the discharge ends 1 ft from the foundation material at three locations along the B and C lines.

24. Grouting was begun by first pumping water to place the muck in suspension. Grout mixture OR-13 was placed immediately after the water injection, which caused a turbulence and served to mix the muck and OR-13 into a type of soil cement. This mixing was desired to avoid the following: (a) grout mixture OR-5, which was to be placed after mixture OR-13, had a high sand content, and upon injection the sand might have been stripped out and caused a mounding of sand in the vicinity of the injection line, (b) the muck, being lighter than the grouts, might be displaced and leave pockets of unstable material immediately under the structure sill, and (c) the OR-5 mixture might be seriously diluted.

25. Approximately 300 cu yd of OR-13 mixture was injected into the B and C lines and immediately followed by mixture OR-5. While



GATE BAYS 1-4 AND 8-11



GATE BAYS 5-7

Figure 6. Profile of structure and locations of B-, C-, and D-line borings at gate bays 1-11

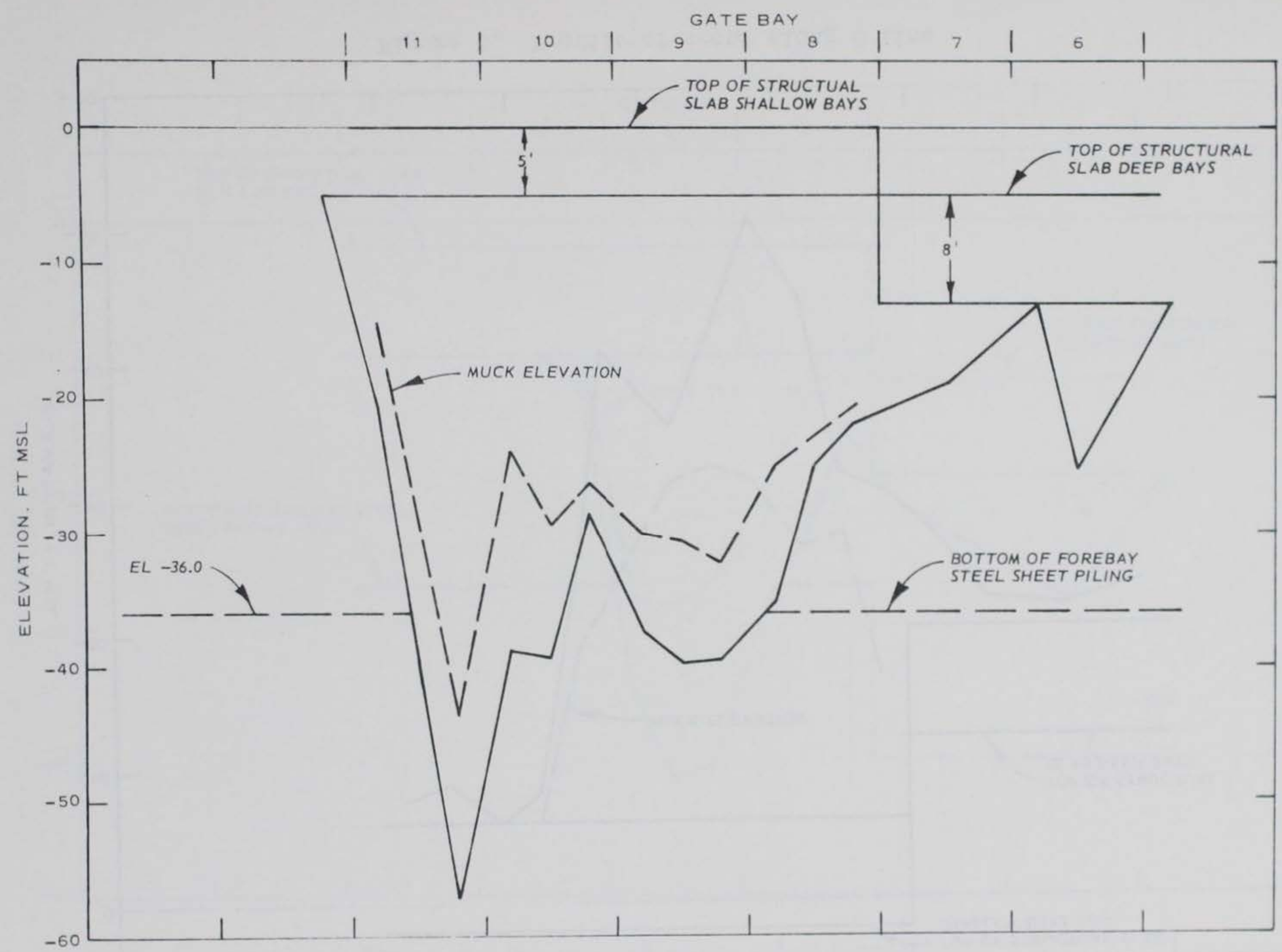


Figure 7. Profile of scour area along B line

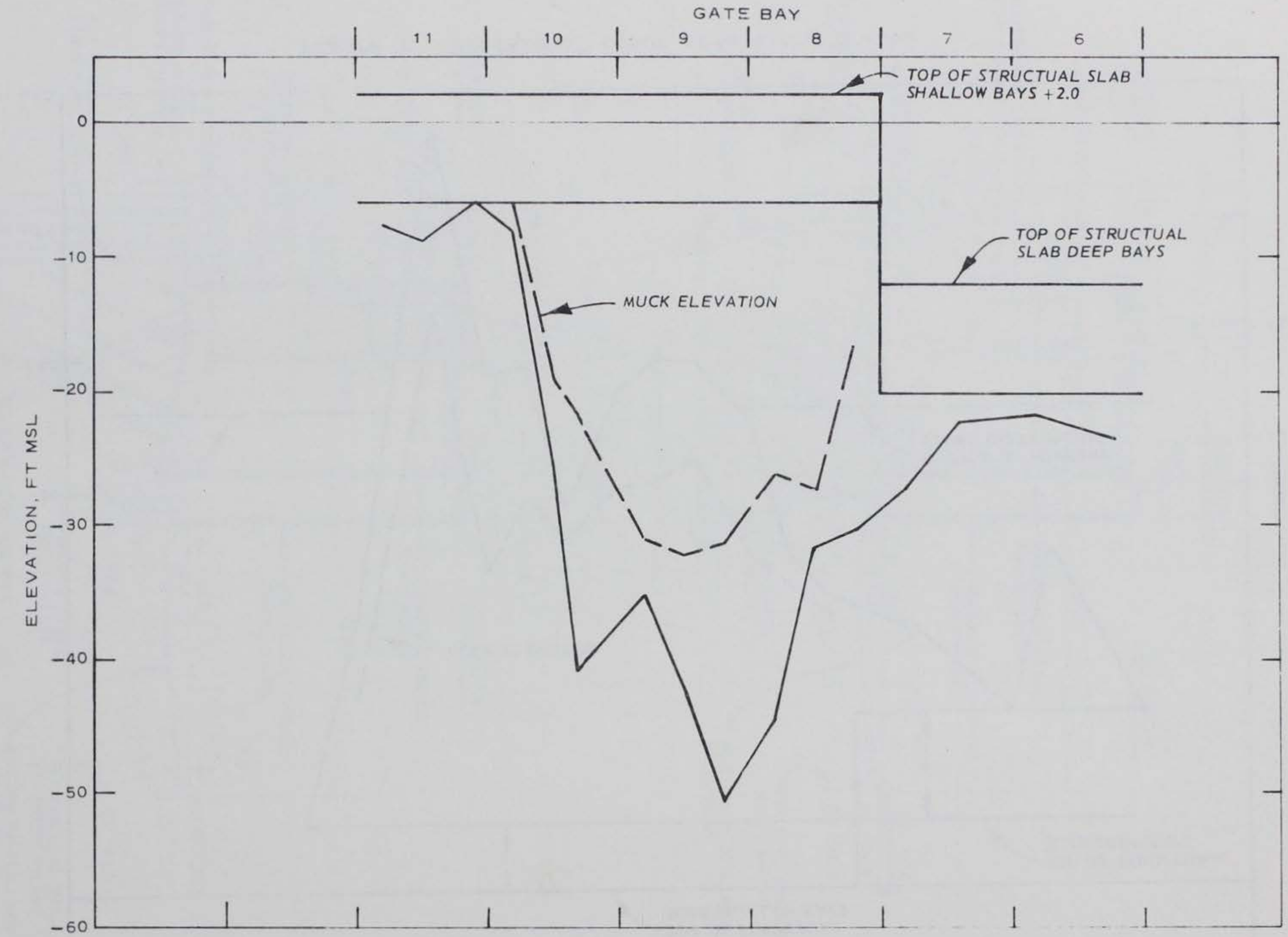


Figure 8. Profile of scour along C line

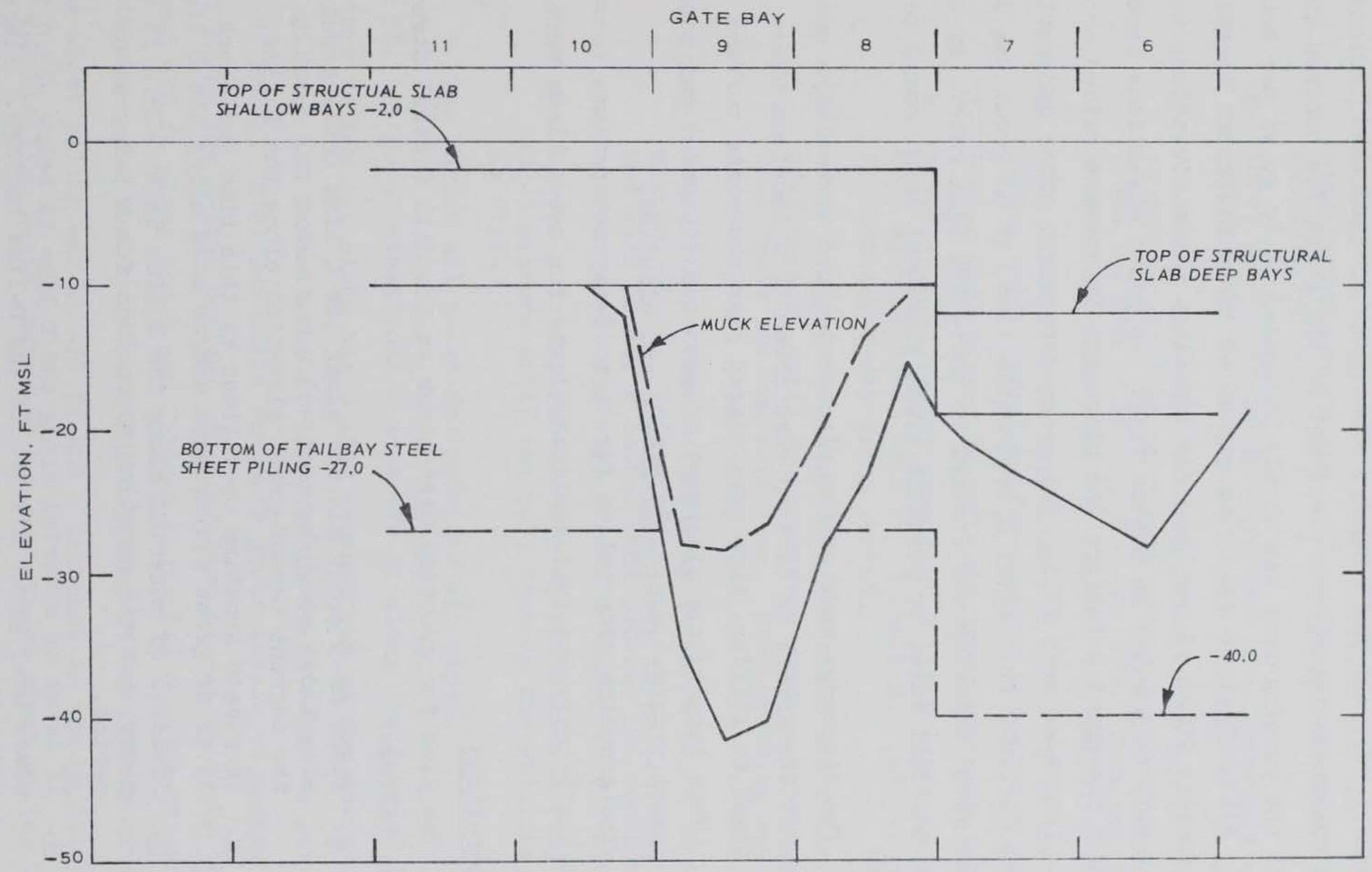


Figure 9. Profile of scour along D line

mixture OR-13 was being injected and as the injection of mixture OR-5 began, the pumping rates were approximately 40 cu yd per hour and uplift pressures were watched closely. There was no indicated increase of uplift pressures during the placement of the first few hundred cubic yards, and the pumping rate was slowly increased to 60 cu yd per hour.

26. Although grout was being placed at three different locations at approximately 20 cu yd per hour per location, grout elevations were watched closely to prevent an uneven fill. As grout elevations were eased upward the grout detectors and placement lines were raised or relocated to insure an even fill. The grout detectors, after indicating grout, were lifted 1 ft. After a reasonable time, if no grout was detected, the grout detector was lowered to check the fill rate. By this procedure, the fill rate, or possible grout placement loss, could be determined.

27. The discharge ends of the placement lines were always under the surface of the grout, or if they were moved to a location where the grout had begun to stiffen, they were placed just above the surface of the grout. This insured the placement of good quality grout and minimized the possibility of grout segregation and dilution.

28. The grouting plan called for 4- to 5-day setup times between stages. Actually only two full-scale shutdowns for setup times were necessary.

Plan of operations

29. The plan for grouting operations at Low Sill Control Structure was as follows:

a. Place OR-5 grout mixture along the C line until grout elevations reach between -23.0 and -22.0 ft, which is the current top-of-grout elevation along the B line.

b. Terminate grouting operations at this time and check level of grout and/or muck and/or sand along the D line.

c. If level of material along the D line is at -23.0 ft or above, suspend grouting operations for a 5-day setup period.

d. If level of material along the D line is below -23.0 ft, place OR-5 grout mixture in the D-line borings. Place grout at a very slow rate until the grout level reaches -23.0 ft. Then terminate grout operations.

e. If grouting is necessary in the D-line borings, the time it takes to accomplish this will constitute part or all of the 5-day setup time in the B and C lines.

f. During the 5-day setup time, initiate and complete plugging operations on the well relief system beneath the stilling basin.

g. Carry on the plugging operations simultaneously with the grouting in the D line, if such grouting is necessary.

h. After the material in the B and C lines has been allowed to set up for 5 days, resume grouting operations on the B and C lines using the OR-5 mixture. Continue grouting to approximately -18.0 ft beneath the stilling basin.

i. When grout reaches approximately -18.0 ft in the B and C lines, halt operations for another 5-day setup period.

j. During this period do not pump grout into any holes.

k. After 5 days, resume grouting in the B and C lines with OR-5 mixture until -8.0 ft is reached. Halt operations for another 5-day setup period.

l. After 5 days, resume grouting in the B and C lines with OR-5 mixture until grout surface reaches approximately 1 ft below the concrete base. Stop grouting operations and observe a 5-day setup time.

m. After 5 days, resume grouting in the B and C lines using mixture OR-23. This mixture has a higher cement content and will create a better bond between the concrete slab and the grout and will create a "cap-off" effect.

n. Resume grouting immediately in the D-line boring with OR-5 mixture until the void beneath the stilling basin is filled.

o. Grout all holes and retrieve all pipes.

30. As grout elevations neared -20 ft along the B and C lines, detectors in borings along the D line (downstream of the downstream sheet pilings and beneath the stilling basin slab) began to give indications of grout. A closer check revealed grout levels at approximately -17 ft along the D-line boring. An elevation of -17 ft along the D line and -20 ft along the B and C lines indicated a surge of grouting materials beneath the downstream sheet pilings. The bottom of the downstream sheet piling was at -27 ft and a decrease in the uplift pressure under the stilling basin indicated the downstream sheet piling had been anchored in grout. A setup period was effected and grouting resumed

in the B- and C-line borings and the grout level raised to a varying level of -15 to -18 ft. It was noticed that the grout level in boring 8C' had not been rising with the other borings. A careful check along the D line revealed no additional buildup in grout since the initial surge.

31. During the attempt to fill boring 8C' several things were tried. SIKA 4A, an accelerator, and regulated-set cement were added to the OR-5 mixture and pumped at a rapid rate and then followed by the regular OR-5 mixture, to no avail. A large quantity of tracer dye was used attempting to determine the location of the grout being placed. No traces of dye were ever found. It was decided to bring the grout level up along the D line to equalize the pressure along the downstream sheet piling between the C and D lines. The grout level in the D line was brought up to -13 ft, 1 ft beneath the stilling basin slab, with the OR-5 mixture. With grout levels at -13 ft along the D line, uplift pressures under the stilling basin slab dropped to and remained at tailwater pressures.

32. Grouting was then shifted back to C-line borings in an attempt to fill 8C'. Some 400 to 500 cu ft of foam rubber squares, 1 ft by 1 ft by 6 in., were forced down boring 8C' and a special mixture of diesel fuel, cement, bentonite, and IMCO cellophane flakes were placed immediately following the foam rubber cubes. This was mixed in blending pots on the bridge and the IMCO flakes (lost circulation material) were dispersed by hand into the blender pots (Figure 10) in order to get as much into the grout as possible and it still be successfully pumped. Approximately 30 cu yd of this mixture was placed and followed immediately by placement of OR-5. After a short period of accelerated placement the grout in 8C' began to rise. When the grout level in 8C' reached -12 ft, a 5-day setup time was put into effect. After 5 days, placement was begun again using mixture OR-5 along B and C lines in gate bays 8-10. Placement of OR-5 continued until grout elevations reached -6 to -9 ft, 1 to 4 ft below the structural slab, except in boring 8C' which was still at -12 ft, 7 ft below the structural slab. To allow another setup time for mixture OR-5 beneath gate bays 8-10 along B and

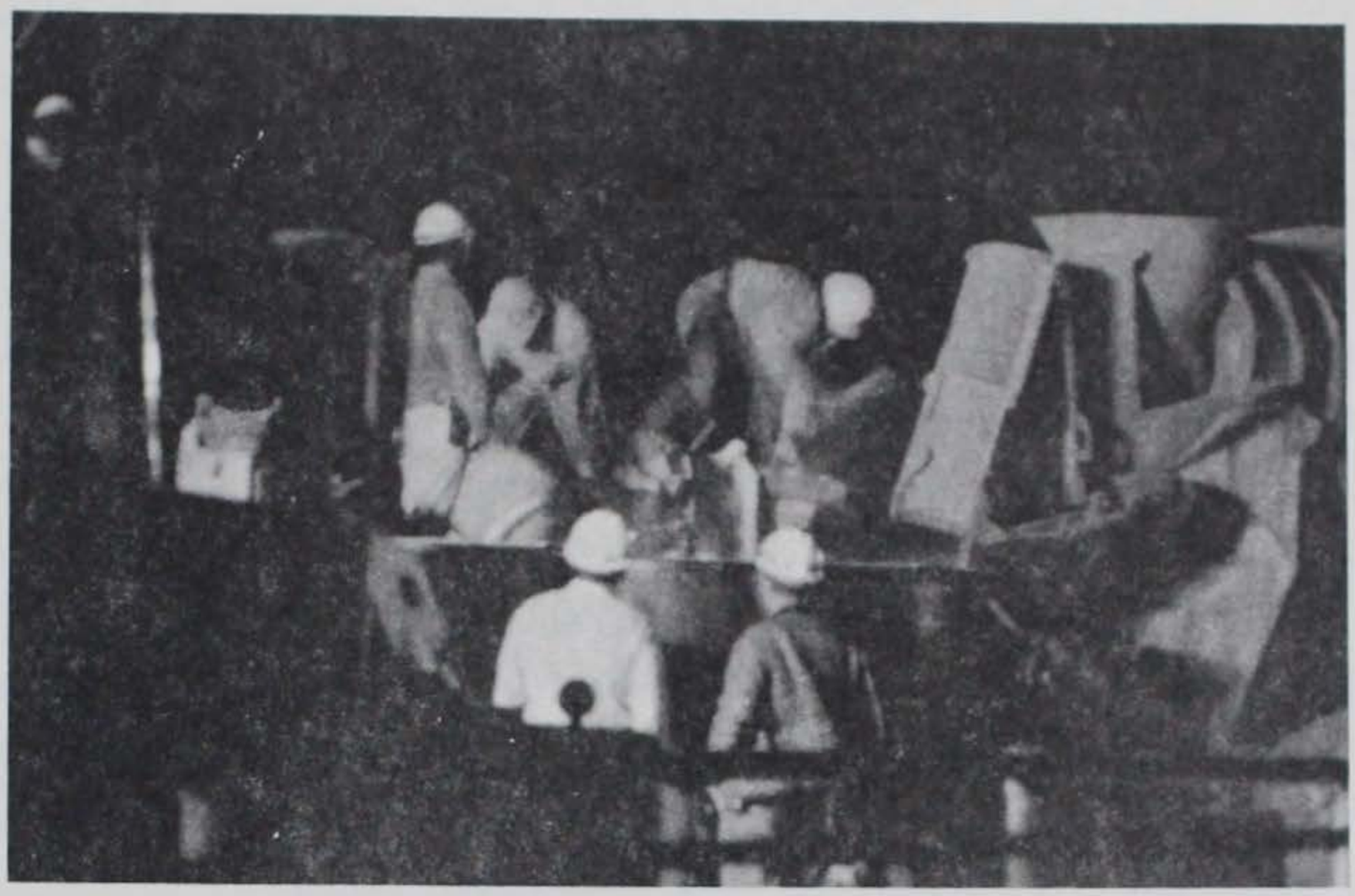


Figure 10. Mixing of IMCO flakes in blending pots

C lines, grouting operations were shifted to D-line borings behind gate bays 8-10 for topping off. Placement of OR-23 was begun and the D line behind gate bays 8-10 was topped off. Grouting was then resumed in borings along the B and C lines of gate bays 8-10 with mixture OR-23. Placement of mixture OR-23 was continued until grout elevations in all borings of B and C lines in gate bays 8-10 were at 0.0 ft, the top of the structural slab.

33. After several days of closely monitoring grout elevations in gate bays 8-10, several check borings were drilled along B, C, and D lines. The cores taken from these check borings indicated competent grout emplaced from directly beneath the structural slab to the contact with foundation material--the extent of the original scour. The complete absence of muck in these borings indicated the successful incorporation of the muck with mixture OR-13.

34. After the grouting of the check boring holes, the casings along the B, C, and D lines in gate bays 9 and 10 were removed and drilling and grouting operations were shifted to gate bays 6 and 7 where preliminary drilling indicated a small scour. As more drilling along

the B, C, and D lines in gate bays 6 and 7 was completed, the scour was bracketed and was found to be shallow (a maximum of 7 ft in boring 7C'). Due to the shallowness (7 ft), it was decided to use the top-off mixture OR-23 for grouting in gate bays 6 and 7. Initial grouting in borings 7C and 7C" failed to raise the level of grout. Approximately 15 cu ft of foam rubber cubes and approximately 30 cu yd of the diesel fuel-bentonite-cement mixture was placed and followed immediately by mixture OR-13. The grout levels began to rise and placement of mixture OR-23 was continued until all borings in gate bays 6 and 7 were topped off. Check borings in gate bays 6 and 7 indicated good grout columns similar to those found in gate bays 8-10. Check borings were soon made in gate bays 11 and 5 with no open cavity or muck encountered. With the completion of check borings of gate bays 5 and 11 the emergency operations at Old River Low Sill Structure were considered ended.

35. The sequence of events for placement of the various grout mixtures beneath Old River Low Sill Structure from stockpiles of dry materials required (a) a concrete batch plant, (b) ready-mix transit trucks, (c) agitator-holding tanks, and (d) pumps. The concrete batch plant, vitally necessary for required volumes and quality control, charged the ready-mix transit trucks with the proper quantities of dry materials and mixture water. The ready-mix transit trucks mixed and delivered the grout mixture to the agitator-holding tanks. The tanks were large enough to hold and slowly agitate approximately 10 cu yd of grout. Pumps then pulled the grout from the tanks and discharged it beneath the structure at specified pump pressures.

Results of Operations

36. In the emergency grouting operations at the Old River, Louisiana, Low Sill Structure in late 1973 and early 1974, the Concrete Laboratory of the WES was responsible for (a) development of a series of grout mixtures for placement in scoured areas, (b) supervision of mixing and placement of the grout mixtures, (c) development of instrumentation for monitoring uplift pressure and grout levels and locations

beneath the structure, (d) the actual monitoring of uplift pressure and grout levels during grouting operations, and (e) determining the physical properties of field-placed grout. It is believed, after many check borings, that the physical properties of the field-placed grout closely match the design criteria, and the scoured areas have been successfully replaced.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Wilson, Hugh K
Grouting of scoured foundation, Old River Low Sill Structure, Louisiana / by Hugh K. Wilson. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
23 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; C-78-19)
Prepared for U. S. Army Engineer District, New Orleans, New Orleans, Louisiana.

1. Foundations. 2. Grouting. 3. Grouts. 4. Old River Low Sill Structure. 5. Scour. I. United States. Army. Corps of Engineers. New Orleans District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; C-78-19.
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