TECHNICAL REPORT H-73-16

ENLARGEMENT OF THE CHESAPEAKE AND DELAWARE CANAL

Hydraulic and Mathematical Model Investigation

by

M. B. Boyd, W. H. Bobb, C. J. Huval, T. C. Hill

October 1973

Sponsored by **U. S. Army Engineer District, Philadelphia**

Conducted by **U. S. Army Engineer Waterways Experiment Station**
Hydraulics Laboratory
Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

The studies reported herein were requested by the U. S. Army Engineer District, Philadelphia, in a letter dated 12 May 1970, subject: "Model Studies of Flow Conditions in Chesapeake and Delaware Canal," to the Director, U. S. Army Engineer Waterways Experiment Station (WES). The Office, Chief of Engineers, approved the study as outlined in two letters: one from WESHV, dated 27 February 1970, to the Division Engineer, North Atlantic, subject: "Computer Study of Flow Conditions in Chesapeake and Delaware Canal"; and the other from ENGCW-EH (now DAEN-CWE-H), dated 20 April 1970, to the Division Engineer, North Atlantic, subject: "Proposed Research Program for Chesapeake and Delaware Canal."

The studies were conducted in the Hydraulics Laboratory of WES during the period May 1970 to August 1972 under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory. Mr. F. A. Herrmann, Jr., Chief of the Estuaries Division, and Mr. W. H. Bobb, Chief of the Interior Channel Branch, directed the physical model study for which Mr. T. C. Hill was the Project Engineer. The computer study of flow conditions was performed by Mr. M. B. Boyd, Chief of the Mathematical Hydraulics Division, and the analytical study of salinities was done by Mr. C. J. Huval, also of the Mathematical Hydraulics Division. This report was prepared by Messrs. Boyd, Bobb, Huval, and Hill.

Mr. J. F. Phillips represented the Philadelphia District in planning and coordinating the various phases of the study. Dr. D. W. Pritchard of The Johns Hopkins University contributed much prototype data and general information pertinent to the study.

Qualified personnel from the Chesapeake Biological Laboratory

(University of Maryland), Chesapeake Bay Institute (The Johns Hopkins University), and College of Marine Studies (University of Delaware) conducted studies concurrently with those of WES.

Directors of the WES during the performance of this study and the preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
square feet	0.092903	square meters
square miles	2.58999	square kilometers
feet per second	0.3048	meters per second
cubic feet per second	0.02831685	cubic meters per second

SUMMARY

A comprehensive physical model that correctly reproduced tides, tidal currents, and density currents throughout the Chesapeake and Delaware Canal and the Delaware River was used to determine the effects of enlarging the 27-ft-deep by 250-ft-wide canal to dimensions of 35 by 450 ft on tides, currents, salinities, and the net transport of water through the canal. An existing numerical model was used for initial studies involving tides, currents, and net flow changes due to the enlargement; and a second mathematical model was developed for before-and-after salinity determinations. As of this date, the enlargement of the canal is essentially complete, except for about a 1-mile section at the eastern end; and the program included a test for this condition.

The critical value for differentiating between tests is the head differential, ΔH , which was determined by subtracting the weighted mean tide level (mtl) at Reedy Point Jetty, located at the Delaware end of the canal, from the weighted mtl at Courthouse Point located at the Chesapeake end. During periods when ΔH is positive, net flow through the canal will be eastward toward the Delaware, with the reverse occurring during periods when ΔH is negative. The Chesapeake and Delaware Canal is a very dynamic system and can experience large ΔH changes in short periods of time.

Based on the results of the physical model study, it was shown that enlargement of the canal to approximate conditions existing at the time of the study (August 1972) caused net flow to be increased by a factor of 4.8 for a mean head differential. Completion of the project will cause an additional increase in net flow, and for short periods net flows of as much as about 40,000 cfs eastward and 25,000 cfs westward can be expected. The net discharge for the 27- by 250-ft canal and a ΔH of +0.23 ft was about 900 cfs eastward. For the same ΔH and the canal enlarged to 35 by 450 ft, except for the unimproved reach from Reedy Point Bridge to the Reedy Point jetties (existing conditions), the net discharge was about 4300 cfs eastward. The net discharge for the canal completely enlarged to project dimensions (35 by 450 ft) for its entire length and a ΔH of +0.23 ft was about 7000 cfs eastward. Therefore, about 56 percent of the ultimate change in flow transfer (for mean tidal conditions) has already occurred. The increase in net flow for the canal enlarged to project dimensions as compared with the net flow for the 27- by 250-ft canal is about 780 percent for mean tide

conditions ($\Delta H = +0.30$ ft). However, ΔH is known to vary erratically between extremes of about +1.45 ft and -0.80 ft, at which values the effect of total canal enlargement on net flow is only about 250 percent. This indicates that the net flow characteristics for the small canal were greatly influenced by the density effect, which increased as the ΔH approached 0.0 ft. Therefore, when considering the total flow transfer for existing conditions as compared with the flow transfer for project dimensions, these facts must be considered.

As a result of enlarging the canal, tidal elevations in the Delaware will be increased in the reach between Artificial Island and New Castle when conditions favor a large net eastward flow, and tidal elevations in Elk River will be increased downstream to Turkey Point when conditions generate a large net westward flow. Current velocities in the canal will be increased somewhat by the enlargement. Salinities throughout the canal will be more uniform and will approximately equal the source salinity at the end of the canal with the higher mtl. Salinities in the Delaware will not be changed appreciably for conditions involving normal head differences across the length of the canal; however, significant changes in Delaware salinities will occur for short periods when the head differential across the canal is large.

A series of dye dispersion tests was conducted in the model for both the 27- by 250-ft and 35- by 450-ft canals. The tests were requested by personnel of the Chesapeake Biological Laboratory, University of Maryland, and were designed to assist them in determining the probable migration or dispersion patterns of small fish, fish eggs, and other biota transported by the currents. WES was not responsible for analysis of the data obtained from the dye tests; therefore, no discussions or interpretations concerning the test results are included in this report.

A computer study of flow conditions in the canal was made to provide information concerning the effect of channel enlargement on net flow through the canal. The study was based on the one-dimensional differential equations governing unsteady flow in open channels. Results of the computations showed that net flow through the canal is highly sensitive to small variations in head differential, and the computed changes in net flows were in close agreement with those measured in the physical model under similar conditions. Since the computation procedure used in this study could not account for variable fluid density, the actual net flows for mean tide conditions would be somewhat less than the computed values.

An analytical study of salinity intrusion was undertaken as an exploratory and development effort to complement the physical and mathematical model studies of flow conditions. The literature review showed that analytical solutions to the basic equation governing canal salinities were rather complex. Several finite-difference models have been applied to the salinity intrusion problem, but these appear to require considerable computer core memory and implementation costs. An explicit finite-difference numerical solution scheme was used to investigate salinity distributions with both steady and variable canal velocity and salinity boundary conditions. The model results are encouraging and indicate some promise for future development and use on more general estuary salinity problems.

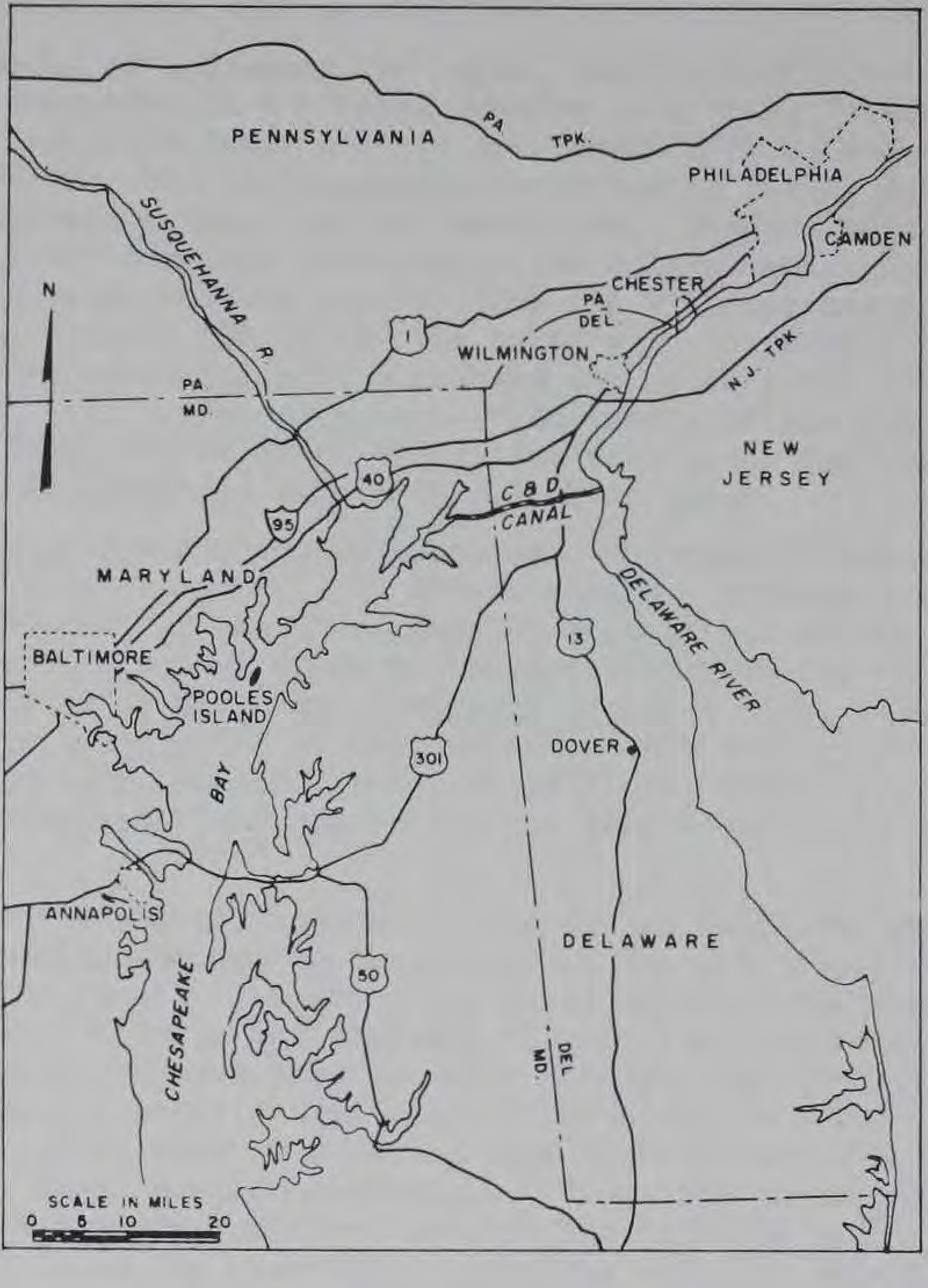

Fig. 1. Vicinity map

ENLARGEMENT OF THE CHESAPEAKE AND DELAWARE CANAL

Hydraulic and Mathematical Model Investigation

PART I: INTRODUCTION

The Prototype

Description

1. The Chesapeake and Delaware (C&D) Canal is a sea-level cut through a 14-mile* neck of land between Delaware River and the north end of Chesapeake Bay (fig. 1). The eastern entrance to the canal is at Reedy Point, Del., approximately 41 channel miles downriver from Philadelphia, Pa. At the western end, the canal enters Chesapeake Bay via Back Creek and Elk River. The original canal, opened to traffic in 1829, included three locks: two at the Delaware end and one at the Chesapeake end (fig. 2). The Federal Government acquired the canal in 1919 and by 1927 had completed conversion to a sea-level canal with a bottom width of 90 ft and a depth of 12 ft.

2. The canal was soon inadequate for the shipping carried, and in 1935 Congress authorized enlargement of the canal to 27 ft deep and 250 ft wide from the Delaware River to Elk River, and thence 27 ft deep and 400 ft wide to the vicinity of Pooles Island in upper Chesapeake Bay (fig. 3). By 1954 the canal was again considered inadequate to meet the requirements of navigation and shipping, and enlargement of the canal was authorized to a depth of 35 ft and a width of 450 ft from the Delaware River to deep water in Chesapeake Bay near Pooles Island. This revision also included modification at all bends to obtain a minimum radius of curvature of 7000 ft and the rebuilding of all bridges to obtain a minimum vertical clearance of 135 ft, along with enlargement of anchorages and stabilization and revetment of the banks. The present alignment of the enlarged canal is shown in fig. 4, along with typical

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* A table of factors for converting British units of measurement to metric units is presented on page vii.

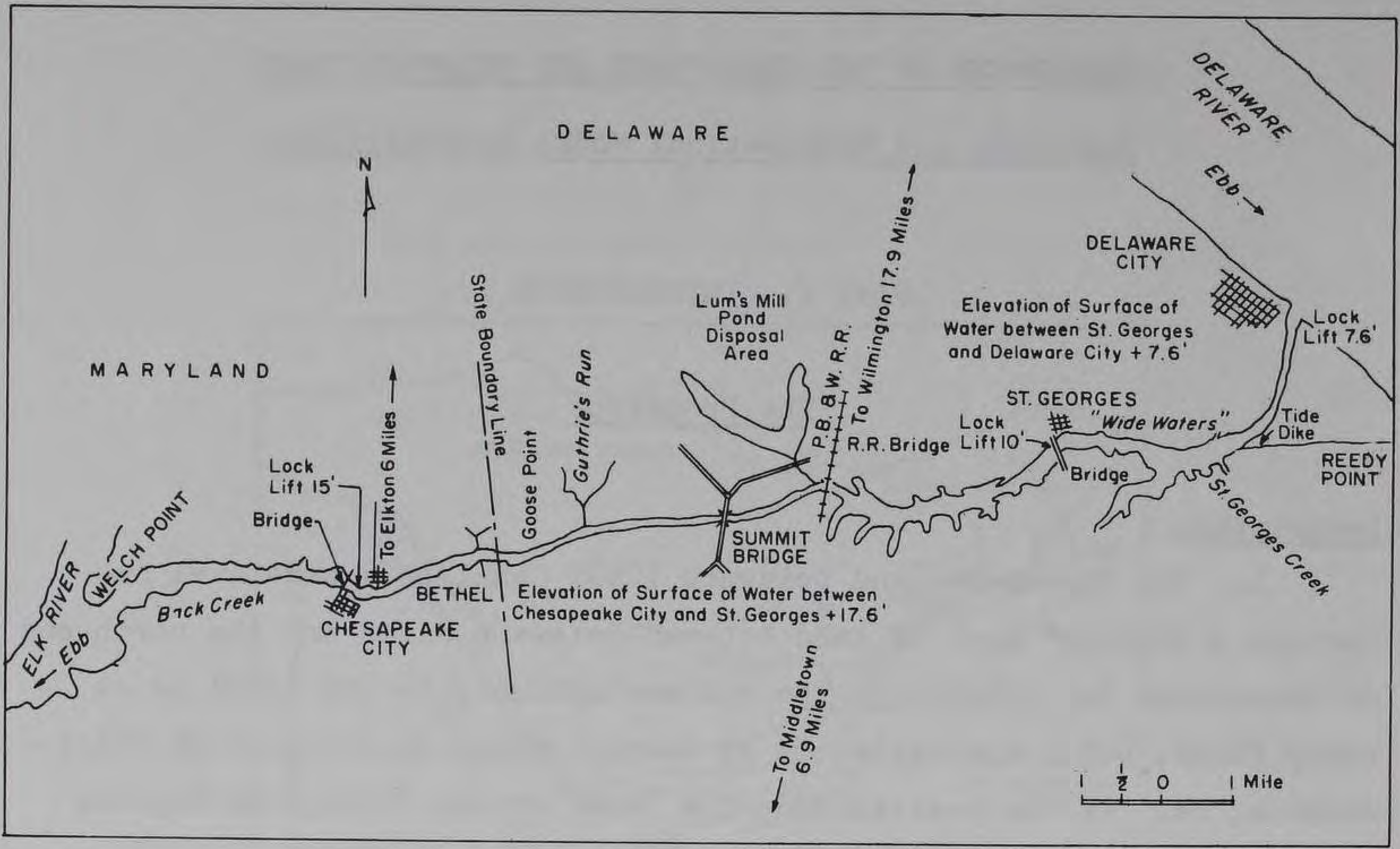


Fig. 2. Original Lock Canal

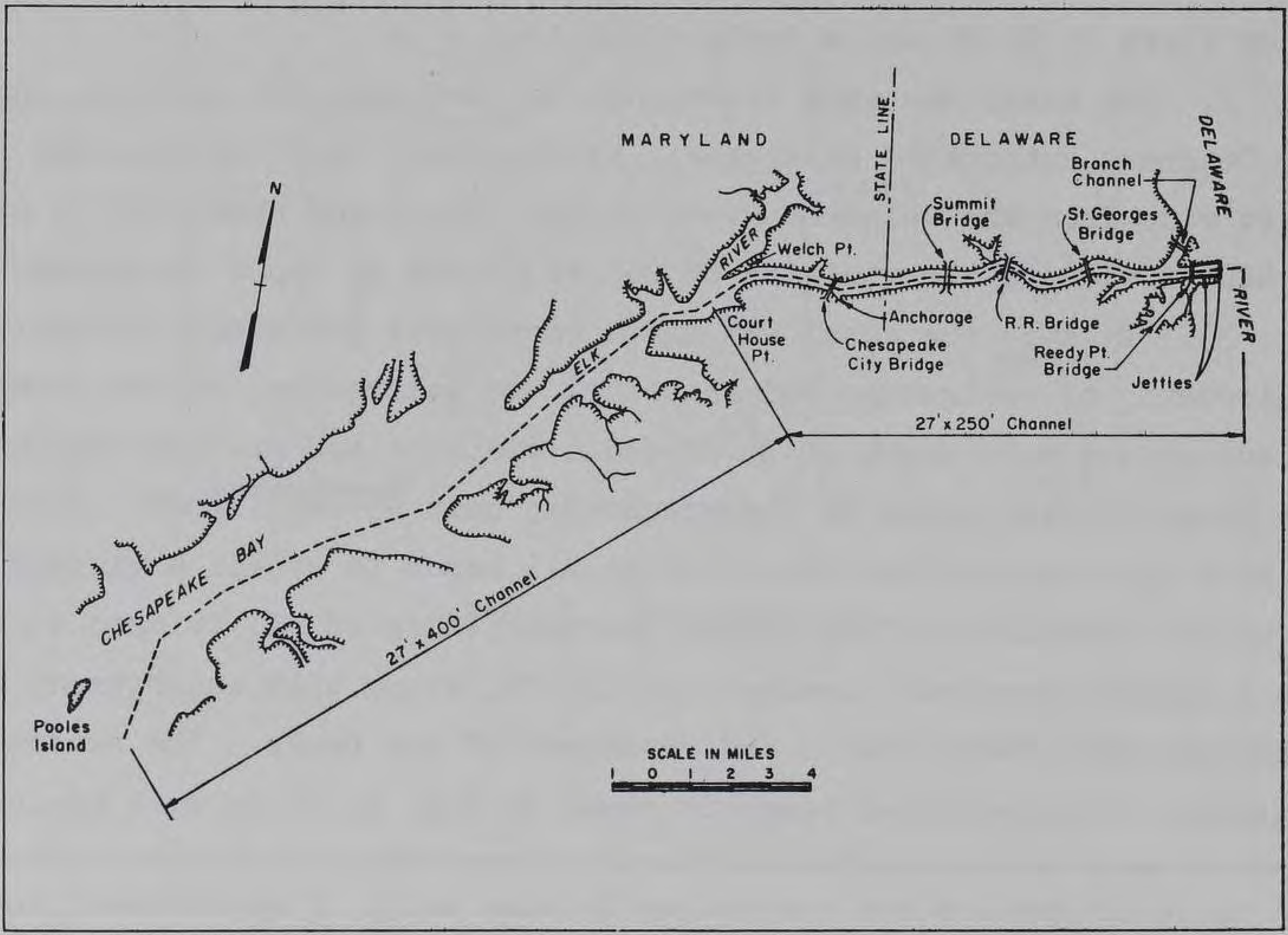
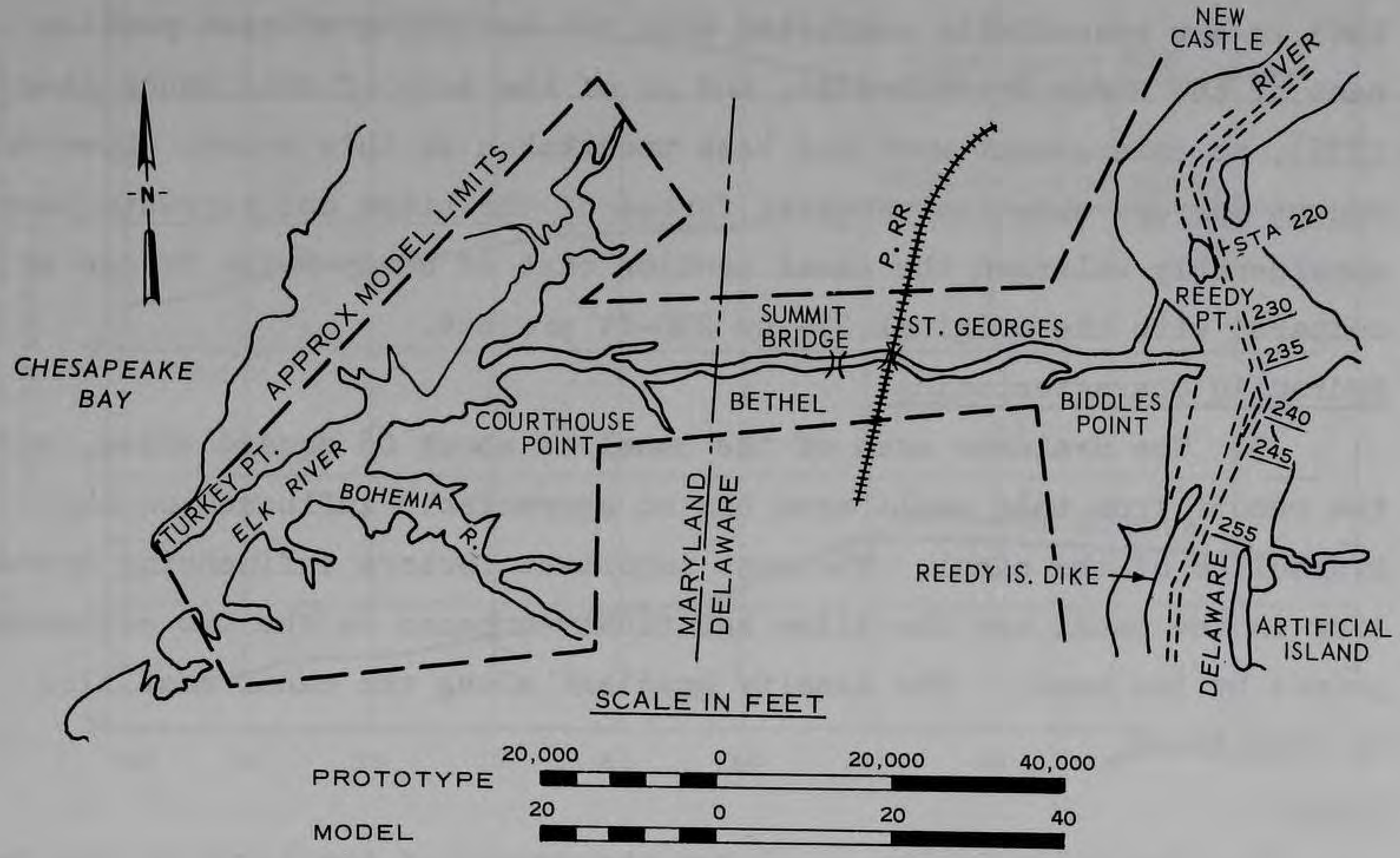
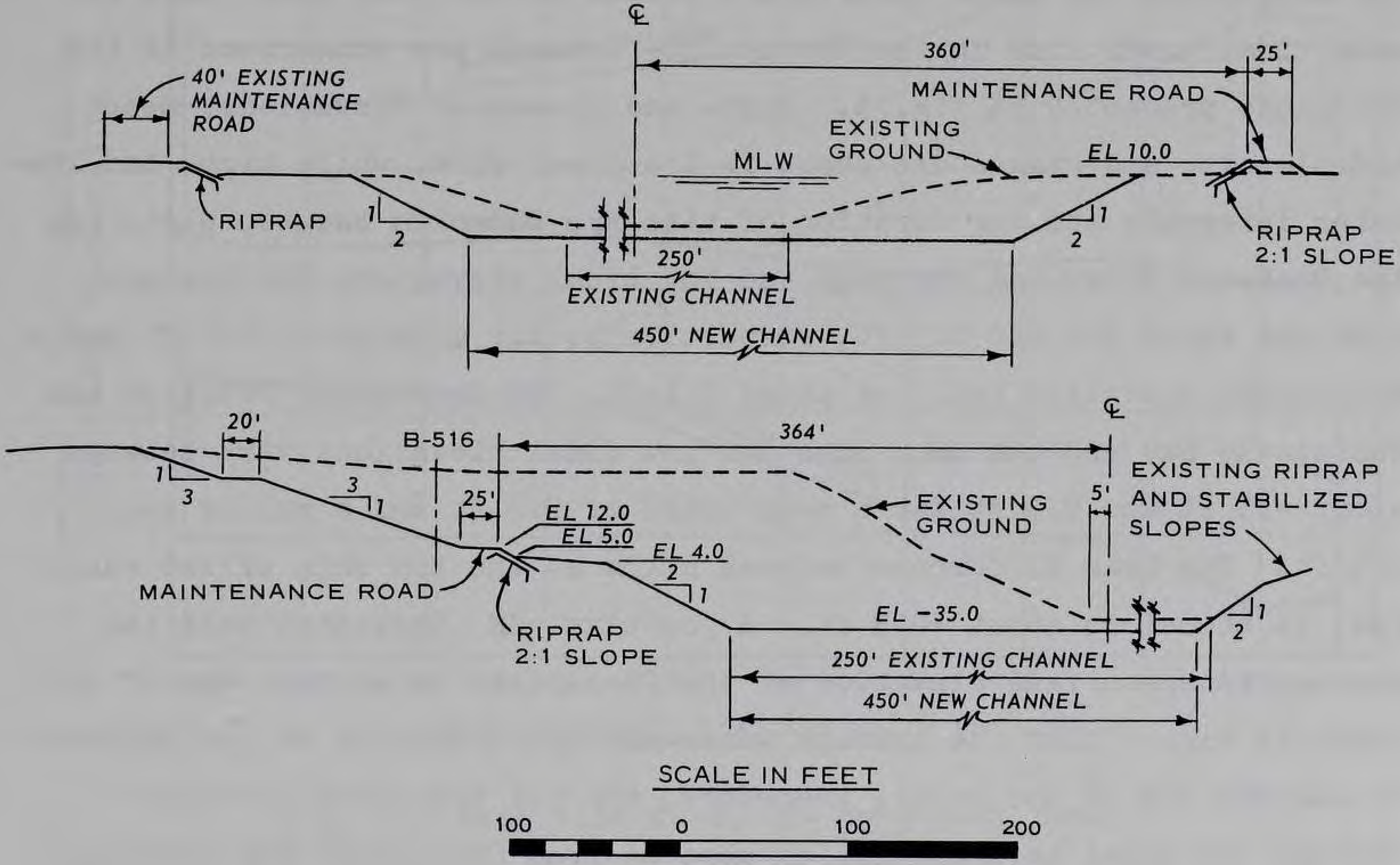


Fig. 3. Canal dimensions authorized in 1935



Present alignment of enlarged canal



Typical bank sections

Fig. 4. Present alignment and typical sections

bank sections. The enlargement authorized in 1954 and undertaken in 1963 is now essentially completed with the exception of that portion east of the Reedy Point Bridge; and as of the date of this study (Aug 1972), no enlargement work had been undertaken in this reach. However, recent surveys show that erosive forces of the tides and currents have considerably enlarged the canal section east of Reedy Point Bridge as compared with the original 27- by 250-ft project.

Hydraulic characteristics

3. The drainage area of the canal is about 65 square miles, and the runoff from this small area has no appreciable influence on the hydraulics of the canal. The most important factors influencing hydraulics in the canal are the tides and tidal currents in the two estuaries joined by the canal. The density gradient along the canal must also be considered.

Tides

4. The tides in the canal are the result of the tides at the two ends, the Delaware River tides at the east end (Reedy Point Jetty) and the Chesapeake Bay tides (Courthouse Point) at the west end. Data for mean tidal conditions in the 27- by 250-ft canal are summarized in the two plots presented in fig. 5. High- and low-water elevations, mean tide levels, and ranges are shown in the lower plot, while high- and low-water intervals and the duration of rise are shown in the top plot. At the Delaware River end the high and low tidal elevations for the mean tide are about 5.7 and 0.5 ft, respectively, for a range of 5.2 ft and a mean tidal elevation (mtl) of about 3.1 ft. At Courthouse Point at the Chesapeake Bay end the mean high and low tidal elevations vary between about 4.5 ft and 2.3 ft for a mean range of 2.2 ft and a mtl of about 3.4 ft. The mean difference between mtl's at the two ends of the canal (ΔH) is therefore about +0.3 ft. A positive ΔH indicates that the average water-surface elevation at the Chesapeake or western end of the canal is higher than the average water-surface elevation at the Delaware or eastern end of the canal; therefore, the net transport of water through the canal is from west to east or from Chesapeake Bay into Delaware River. The reverse is indicated by a negative ΔH .

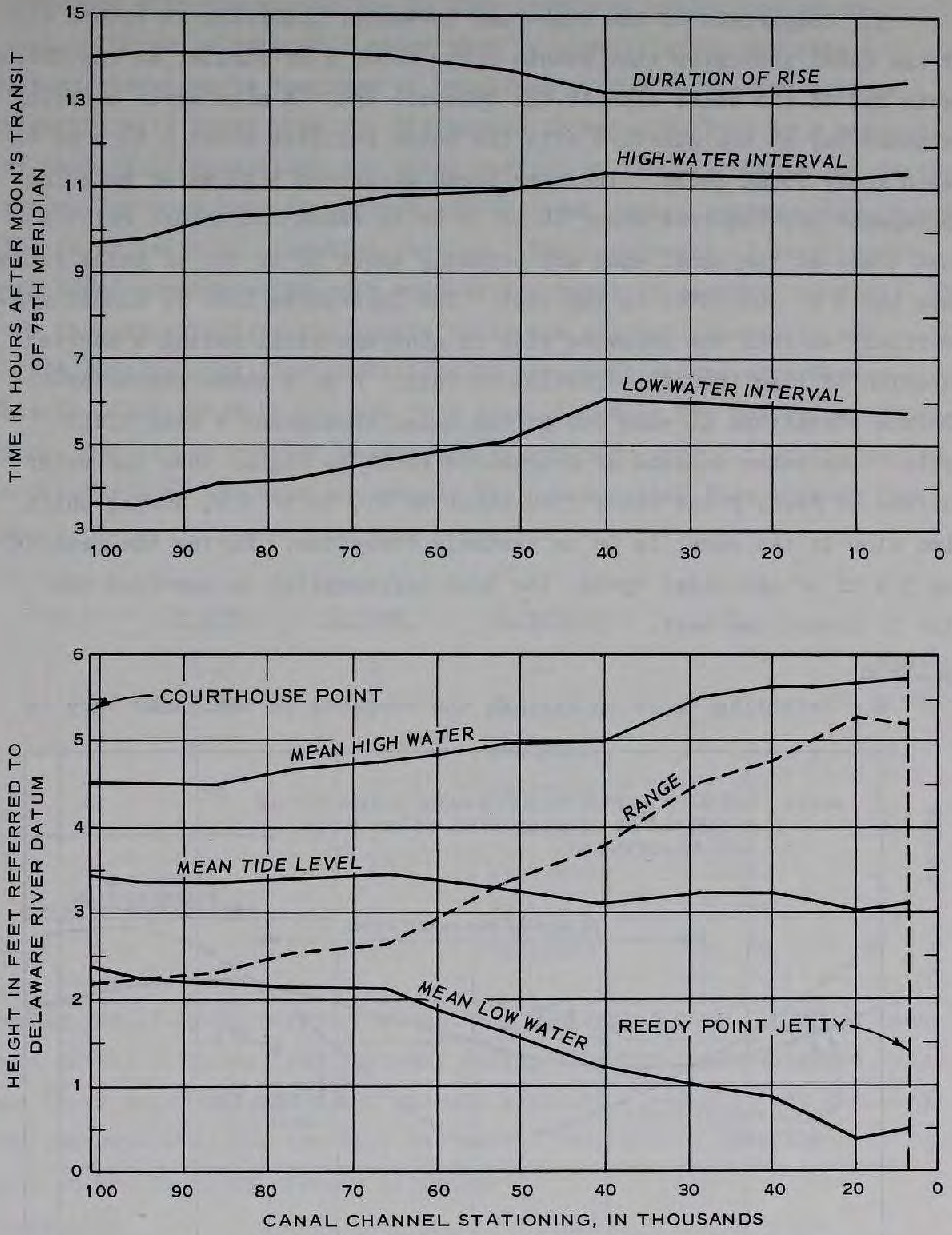


Fig. 5. Mean tide data, 27- by 250-ft canal

5. Comparison of the high- and low-water intervals at either end of the canal indicates that events occur about 2 hr earlier at the Chesapeake end of the canal than at the Delaware end. A high water entering Delaware Bay at the juncture with the ocean requires about 4 to 5 hr to reach Reedy Point Jetty. The same ocean-generated high water entering Chesapeake Bay requires about 14 to 15 hr to reach Courthouse Point so that tides at the canal ends are actually about 10 hr out of phase rather than the 2 hr indicated in the plot. The Chesapeake tide is almost symmetrical, whereas the Delaware tide is nonsymmetrical having a shorter duration of rise than the duration of fall. Fig. 6 shows the water-surface elevations at each end of the canal throughout a mean tidal cycle. The water surface at Courthouse Point is higher than the water surface at Reedy Point Jetty from about hr 2.7 to hr 9.2, during which time flow in the canal is in an easterly direction. During the remaining 5.9 hr of the tidal cycle, the head differential is reversed and flow is toward the west.

Currents

6. Referring again to fig. 6, the currents in the canal vary in

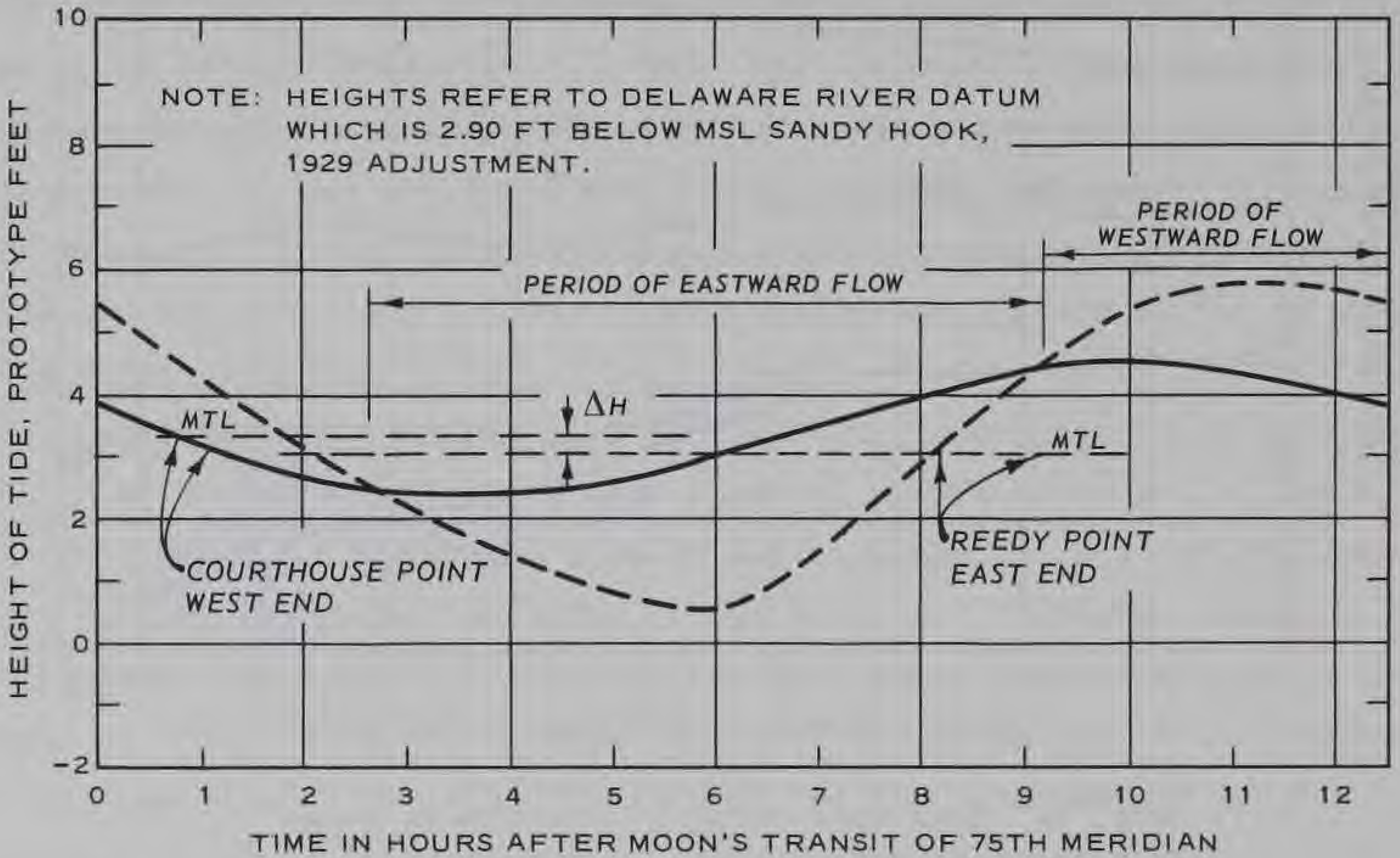


Fig. 6. Mean tides at ends of canal

accordance with the variations in tide levels at either end of the canal. Current slacks will occur when or shortly after the water-surface elevation is the same at both ends of the canal, and current strengths will occur when the difference in water surface is a maximum. For mean tidal conditions the water surface at the Chesapeake end is the highest for more than 50 percent of the tidal cycle; consequently, a net flow in an easterly direction results. The occurrence of simultaneous mean tidal conditions at both ends of the canal is somewhat unusual. The many factors affecting the source tides are subject to erratic and abrupt changes, and flow conditions in the canal change accordingly. This is illustrated by the net flow data listed in the following tabulation. Continuous current measurements were made over a 17-cycle period in October 1969 and used to compute the net nontidal flow through the canal.

Time Cycles	Duration Cycles	Direction	Net Flow cfs
1-2	2	--	0
3-5	3	Eastward	8,430
6	1	Westward	790
7-9	3	Westward	10,250
10-12	3	Eastward	10,530
13	1	Westward	3,950
14-16	3	Eastward	7,100
17	1	Westward	3,160

During the 17-cycle period the net flow was zero during 2 cycles, eastward during 9 cycles, and westward during 6 cycles. The weighted average flows were eastward 8,690 cfs and westward 6,440 cfs, not counting the two days when the net flow was zero. The erratic nature of net flow in the canal is clearly illustrated.

Salinities

7. Salinity conditions at the ends of the canal are quite different. Salinities in Chesapeake Bay in the vicinity of Turkey Point vary from fresh water during the rainy season to as much as 9.0 ppt

(total salt) after extended periods of low tributary flow with an average of about 1.3 ppt. Mixing is excellent in this vicinity, and there is essentially no density difference from surface to bottom. Average salinities in the Delaware River channel in the vicinity of the mouth of the canal vary between about 1.0 ppt and 8.0 ppt during high- and low-flow periods, respectively. Mean values are about 5.0 ppt. A longitudinal gradient of increasing salinity almost always exists from the Chesapeake end of the canal to the Delaware end. This density gradient can possibly result in a westward net flow in the canal during extended periods when the head differential across the canal is essentially zero.

The Problem

8. The need to protect and improve environmental resources has not always been given the same consideration as the need to enhance economic development. Projects authorized 10 to 20 years ago, as was the enlargement of the C&D Canal, often require additional studies with particular emphasis on environmental problems. After review of the possible effects of enlargement, it was concluded that additional studies were imperative. A plan of study designed to secure a project that will bring economic benefits to the nation and at the same time preserve and enhance the environment was adopted. The plan included the following steps: (a) field measurements and studies of tides, currents, and salinities in the canal and its approaches; (b) extension of the existing Delaware River model at WES to include the C&D Canal and Elk River to Turkey Point to permit hydraulic model tests; (c) mathematical model studies by WES; (d) hydraulic model tests of control structures by WES; (e) preliminary design of several types of control structures; and (f) ecological studies by qualified institutions using data developed from the model studies and field investigations. As of the date of this report, step (d) had not been undertaken.

Purpose of the Studies

9. It has long been realized that the net flow in the canal is of primary importance to the salinity regimes in Upper Chesapeake Bay

and Lower Delaware River. An analysis of tide and current measurements made in 1938 was done by Mr. Clarence F. Wicker of the Philadelphia District office; and the results of this work are presented in an unpublished memorandum.* Data in this memorandum support the conclusion that a net eastward flow on the order of 1000 cfs existed in the 27- by 250-ft canal at the time the measurements were made. At the time that work was done, little attention was paid to salinities and other phenomena associated with the ecology.

10. A physical model and two mathematical models were used to determine the effects of enlarging the canal on tides, currents, salinities, and net flow (steps (b) and (c) outlined in paragraph 8). The existing Delaware River model was revised to include the entire C&D Canal between Delaware River and Chesapeake Bay at Turkey Point, as shown in plate 1. The model canal was initially constructed to 27- by 250-ft project dimensions and adjusted to reproduce known hydraulic conditions, after which a series of base tests to obtain data with which to evaluate the enlargement were made. The canal was then revised to 35- by 450-ft project dimensions, except for that portion east of Reedy Point Bridge, and a comparative test was made. The enlargement was then completed so that the entire model canal was 35 ft deep and 450 ft wide, and a complete series of tests was made for comparison with similar tests made for the 27- by 250-ft canal. The mathematical model studies followed the same general pattern. A group of specialists from the University of Maryland, the University of Delaware, and The Johns Hopkins University conducted concurrent studies involving field measurements of biological activity and related physical phenomena to determine the ecological impact of the canal enlargement, as outlined in item (f) of paragraph 8. The results of their efforts will be reported separately.

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* C. F. Wicker, "Tides and Currents in Chesapeake and Delaware Canal," (unpublished), 1939, U. S. Army Engineer District, Philadelphia, Pa.

PART II: THE PHYSICAL MODEL

Description

11. The Delaware River model reproduces the entire estuary of Delaware Bay and River, beginning at Capes May and Henlopen at the downstream end and extending upstream to the head of tide at Trenton, N. J. The tidal portions of all major tributaries (Maurice, Cohansey, Salem, Christina, Schuylkill, and Rancocas Rivers) are reproduced to correct lengths and cross sections; but for convenience, portions of the tributaries have been realigned to conform to the general alignment of the main stream. The C&D Canal, beginning at its junction with the Delaware River, is reproduced to Turkey Point at the junction of Elk River and Chesapeake Bay. The limits of the area reproduced are shown in plate 1, and the C&D Canal portion is shown enlarged in insert "A." The Delaware model as originally constructed included only the eastern 3 miles of the canal; and when the model was extended to include the entire canal, it was necessary to distort two bends in the canal to keep the canal addition to the Delaware model within the existing shelter.

12. The model is constructed to linear scale ratios, model to prototype, of 1:1000 horizontally and 1:100 vertically. These scale ratios fix the following relations: slope 10:1, velocity 1:10, time 1:100, discharge 1:1,000,000, and volume 1:1,000,000,000. The salinity scale ratio required for an investigation of this type is 1:1. One prototype tidal cycle of 12 hr and 25 min is reproduced in the model in 7.45 min. The model is approximately 750 ft long and 130 ft wide at the widest point, and covers an area of about 31,000 sq ft. It is completely enclosed in a shelter to protect it from weather and to permit uninterrupted operation.

13. The entire bed of the model is molded of concrete to conform to the latest hydrographic surveys available at the time of construction. All channel shoals that existed at the times of the surveys are omitted, and the channel through shoal reaches is molded to authorized

width and depth. The model navigation channel and adjacent areas are molded in removable concrete blocks so that desired alterations in channel dimensions and locations can be made conveniently. The C&D Canal portion of the model was originally constructed to existing project dimensions (35 by 450 ft), and subsequently the 27- by 250-ft canal was constructed in block form so that verification and base tests could be conducted. Upon completion of this phase of the work, the blocks were removed and tests of the enlarged canal were made.

Appurtenances

14. The model is equipped with the necessary appurtenances to reproduce and measure all pertinent phenomena. Appurtenances used in connection with the studies reported herein include primary and secondary tide generators, tide recorders, freshwater inflow measuring devices, chemical titration equipment, salinity meters, current meters, tide gages, and Turner fluorometers for dye intensity determination. These appurtenances are described in detail in the subsequent paragraphs.

Tide generators

15. The rise and fall of the tide in the model, and the resulting flood and ebb tidal currents, are reproduced by means of a primary tide generator located at the seaward end of the model and a secondary tide generator located at the model terminus of the C&D Canal. The primary tide generator maintains a continuous imbalance between a pumped inflow of water to the model and a gravity outflow of water from the model as required to reproduce all characteristics of the prototype tides at the master tide control station (Miah Maull Shoal Light). A schematic view of the tide generating system is shown in fig. 7. The secondary tide generator, synchronized with the primary generator, is adjusted to reproduce the proper source tide at Turkey Point. The secondary tide reproducer consists of two inflow control devices, one for fresh water and one for salt water, and an automated overflow weir. Salt and fresh water are introduced at constant rates proportioned to give the

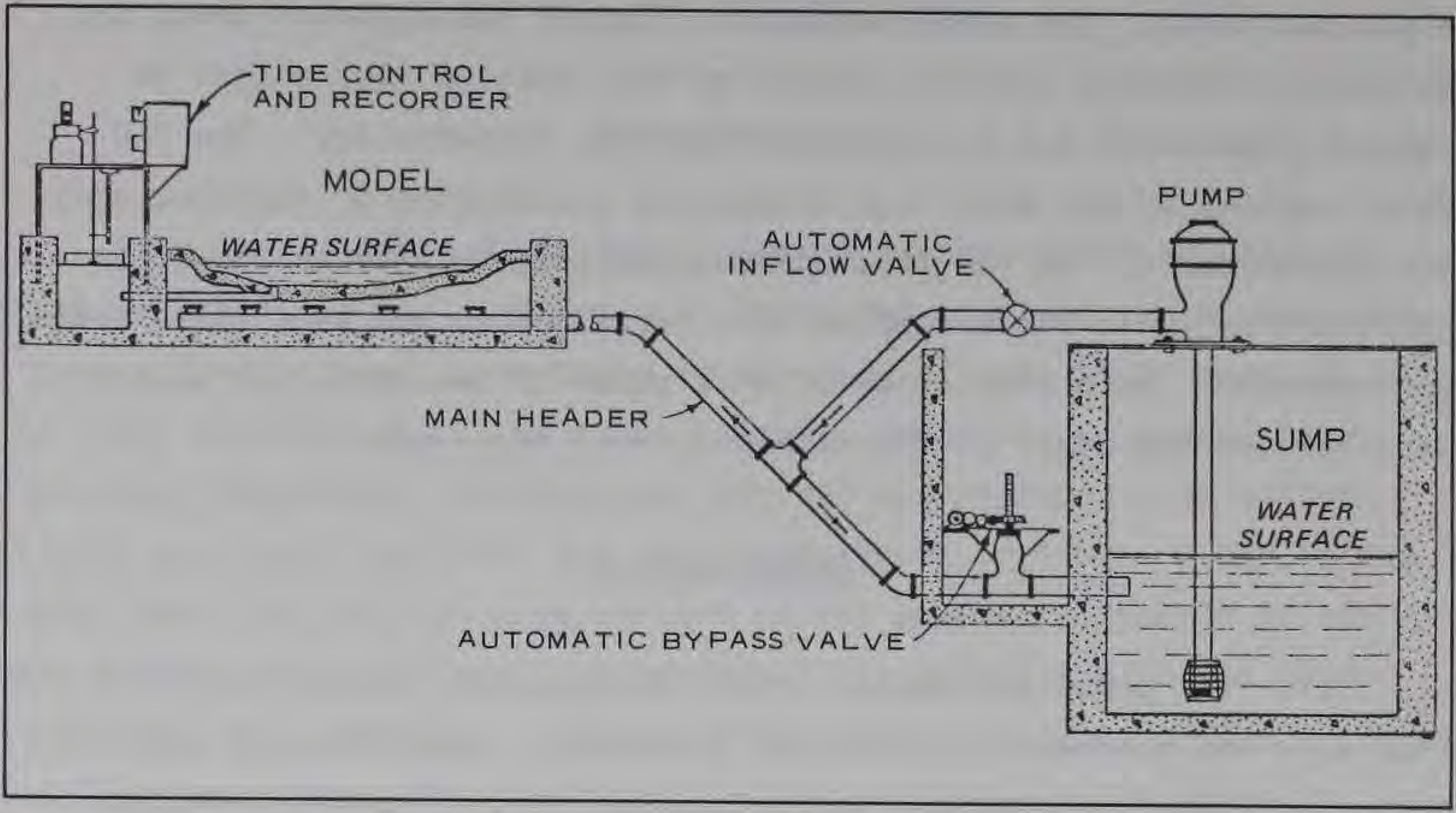

Fig. 7. Schematic view of tide generating system

desired salinity of Chesapeake Bay water at Turkey Point, generally 1250 ppm. The operation of the overflow weir is controlled by an adjustable cam and is synchronized with the primary ocean tide generator supplying Delaware Bay. The adjustable cam positions the overflow weir to cause the inflow to enter the model to create eastward flow or to cause an outflow from the model during periods when flow in the canal is westward. A schematic view of the secondary tide reproducer is shown in fig. 8.

Net flow measuring device

16. A large circular tank, 6 ft in diameter and 3 ft deep, is located to catch the discharge from the model at the Turkey Point cutoff point, as shown in fig. 8. Knowing the total imput (salt water plus fresh water) and the total volume caught in the tank during a tidal cycle, the direction and volume of net flow during a cycle can be determined. The depth of water in the tank is measured with a point gage with accuracies of ±0.001 ft. This depth is then used to compute the volumetric average net discharge in the canal for the various test

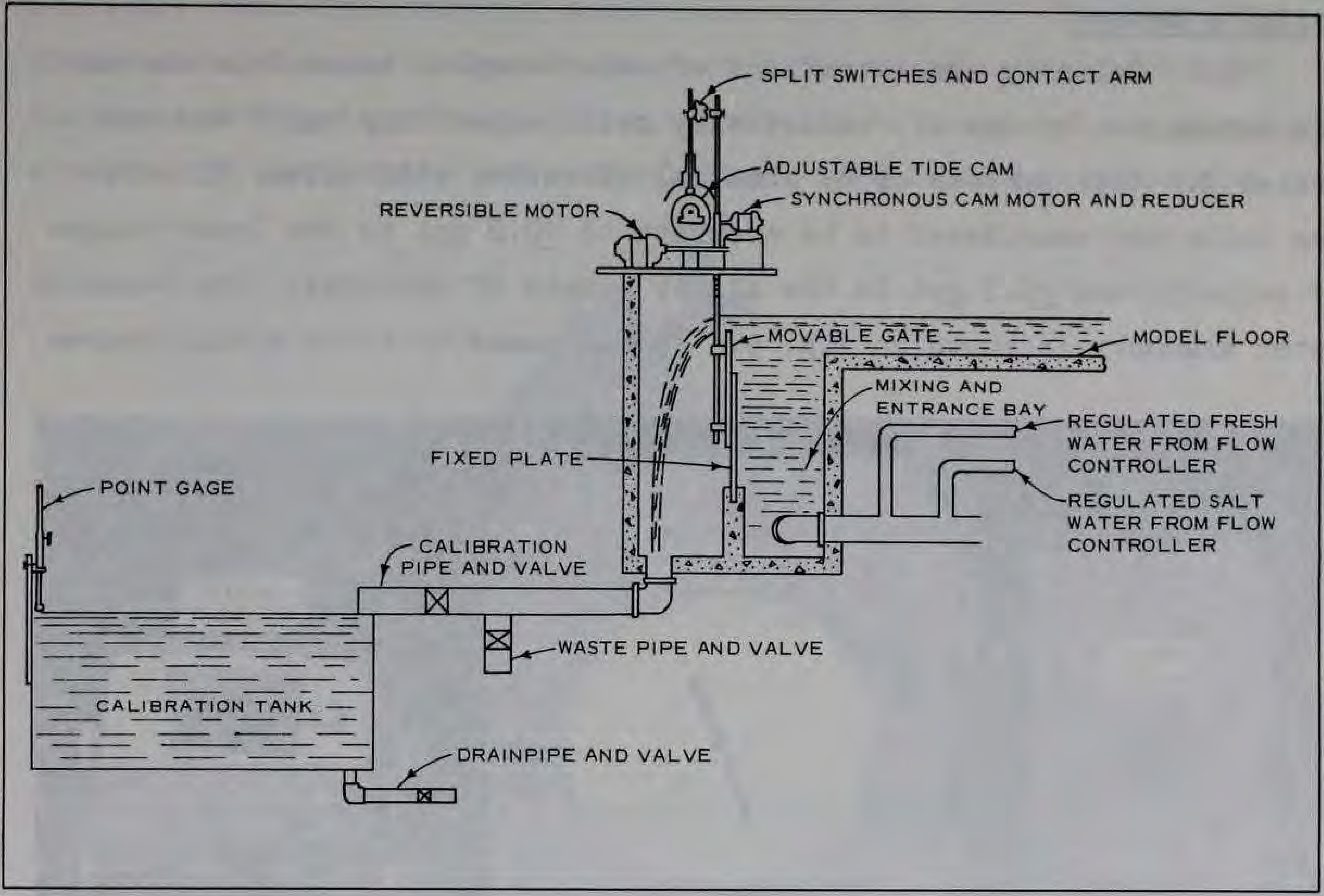

Fig. 8. Elk River tide control and calibration tank

conditions. The accuracy to which this device can measure discharge is about ±100 cfs.

Tide recorder

17. The master tide control station (Miah Maull Shoal Light) is equipped with a continuous tide recorder so that the accuracy of the model tide reproduction can be checked visually at any time.

Inflow weirs

18. The model is equipped with weirs for precise measurement of the freshwater inflow of the Delaware River at Trenton and of all major tributaries at the head of tidal influence in each stream. Each weir is adjusted to introduce the proper discharge for that particular stream, plus one-half the combined discharges of all smaller streams between it and adjacent weirs. Utilization of this method of weir operation permits reproduction of the freshwater inflows of the minor streams as well as the major streams.

Salinity meters

19. Salinity concentrations of water samples taken from the model are determined by use of conductivity cells especially built and calibrated for this purpose or by chemical titration with silver nitrate. The cells are considered to be accurate to ±0.2 ppt in the lower ranges of salinity and ±0.5 ppt in the higher ranges of salinity. The salinity meter assembly is shown in fig. 9. In all cases in which a high degree of accuracy is required, such as source salinities, chemical titration is used. The chemical titration equipment consists of a graduated burette for measuring silver nitrate volumes, a selected group of pipettes for measuring the volume of sample used, sample jars in which to perform the titration, and a supply of silver nitrate and potassium chromate for use as an end-point indicator in the titration process.

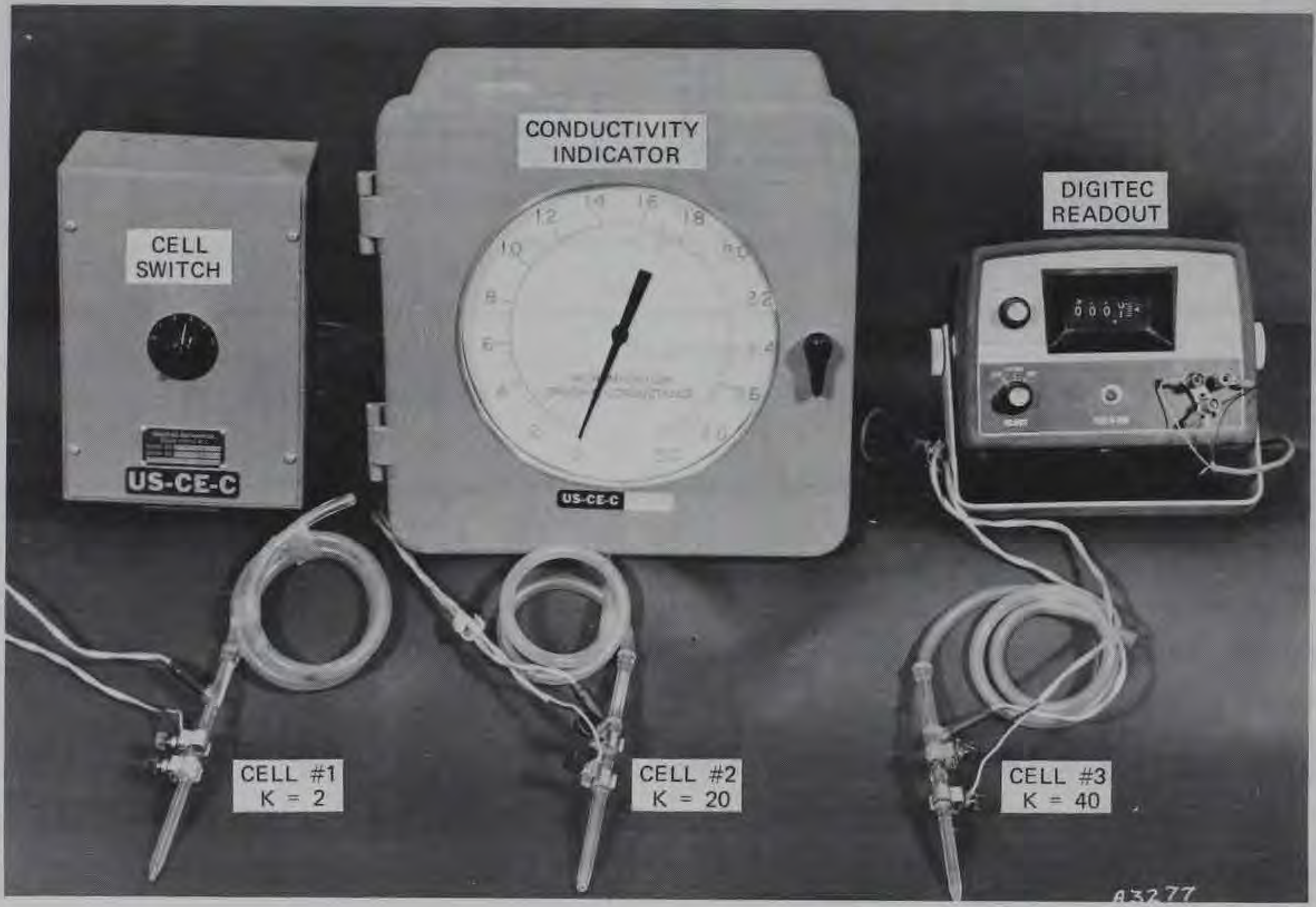

Fig. 9. Salinity meter assembly

Current meters

20. Current velocity measurements are made in the model with

miniature Price-type current meters, shown in fig. 10. The center line of the model cups on the meter is about 0.045 ft above the bottom of the meter frame; therefore, bottom velocities in the model are measured about 5.0 ft (prototype) above the bottom. Model surface velocities

Fig. 10. Miniature Price-type current meter

are measured about 3.0 ft (prototype) below the surface. The overall width of the meter is about 0.1 ft in the model, representing a horizontal width of about 100 ft in the prototype. Therefore, the distortion of area (model to prototype) results in comparing model velocities averaged over a much larger area than those of the prototype point observations. The same is true for the vertical area since the height of the cups on the meter is equivalent to about 4.0 ft prototype. Velocities are obtained by counting the number of revolutions the meter made in a 10-sec interval (model) which is equivalent to about 17 min in the prototype. The meters are calibrated frequently to ensure the accuracy of measurements and are capable of measuring actual velocities down to about 0.05 fps (0.5 fps prototype). The width of the model canal and the turbulence within the canal cause model velocity measurements to be difficult to measure.

Tide gages

21. Permanently mounted point gages are installed on the model at corresponding locations of the prototype recording tide gages used for collection of verification tide data, plus additional locations considered necessary for test purposes (see plates 1 and 2). These gages are graduated to 0.001 ft (0.1 ft prototype) and are used to measure tidal elevations throughout the model. Portable gages are used when necessary to obtain more detailed tidal data in specific reaches of the model.

Turner fluorometer (fig. 11)

22. It was necessary to determine concentrations of fluorescent

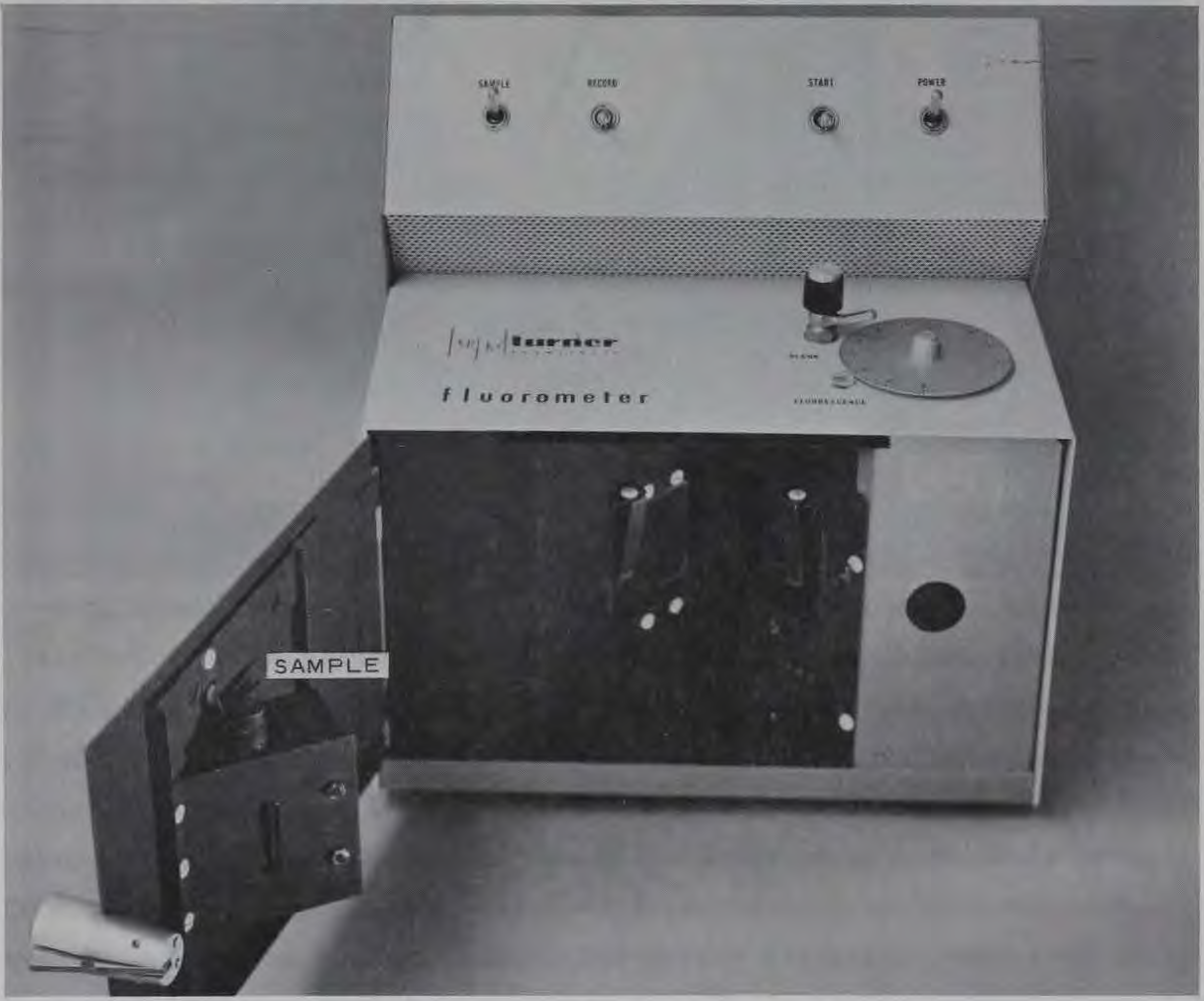

Fig. 11. Turner fluorometer

dyes introduced to determine dispersion patterns of the canal waters. All such measurements were made with a Turner fluorometer. Five-cc samples were required, and the meters were calibrated to read values between 1 and 10,000 ppb. The accuracy of the fluorometer was about ±3 percent for the range of concentrations measured.

PART III: STUDIES IN THE PHYSICAL MODEL

Hydraulic Verification

23. Verification of the model for the C&D Canal study consisted of two phases: (a) a check of the Delaware River portion of the model to assure that tidal elevations and times, current velocities and directions, and salinity characteristics were in good agreement with data from the extensive verification of the model reported in WES TM 2-337,[1] Reports 1 and 2; and (b) adjustment of the Elk River tide reproduction mechanism at the western end of the C&D Canal and the model roughness in Elk River and the canal to obtain a good reproduction of tide and current phenomena throughout the 27- by 250-ft canal measured in June 1938. No salinity data were available for verification of salinity phenomena in the canal.

Delaware River check tests

24. The results of check tests indicated significant differences in the salinity regimen in the Delaware in the vicinity of the mouth of the C&D Canal. In the original Delaware River model, the salinity of the inflow into the canal was adjusted to the average salinity (about 5.0 ppt) in the Delaware River navigation channel at about sta 235+000. This resulted in smooth profiles of salinity in the navigation channel which were in good agreement with similar prototype measurements. With the Turkey Point source salinity adjusted to 1250 ppm and with mean tides in both Chesapeake Bay and Delaware River, it was found necessary to increase the source salinity in the Delaware ocean from 28,000 ppm (used previously) to 31,000 ppm in order to again obtain acceptable salinity profiles in the Delaware. Tides and currents downstream of New Castle were then measured and found to be in good agreement with previous verification data.

Procedure for C&D Canal verification

25. The hydraulic verification of the C&D Canal was accomplished using prototype data of 7-8 June 1938, and the verification tests were preceded by a series of hydraulic adjustment tests to assure that the

Delaware Bay tide generating system was reproducing the proper tidal phenomena at Reedy Point Jetty and that the Elk River tide generating system was reproducing the proper tidal phenomena at the Chesapeake Bay (Elk River) end of the canal. These adjustments of the source tides were followed by the progressive adjustments of artificial frictional resistance elements until tidal elevations and times and current velocities and directions were in good agreement with those observed in the prototype. The artificial frictional resistance elements used in the model were 1/2-in.-wide, thin metal strips embedded in the model bed and generally extending vertically to above mean high water.

Prototype data

26. The prototype data for the 27- by 250-ft canal were measured in 1938 and included in the report prepared by Mr. Wicker and mentioned in paragraph 9.* None of the sets of data were representative of mean tidal conditions at both ends of the canal, but the 12.42-hr period beginning at low water on 7 June 1938 and ending at low water on 8 June 1938 was selected as the verification period in order to demonstrate that the model would properly reproduce tides and current velocities throughout the canal. In this report, the prototype time in lunar hours is referenced to the moon's passage of the 75th meridian, and elevations are referred to Delaware River datum which is 2.90 ft below msl at Sandy Hook, 1929 adjustment.

Tidal adjustment

27. Comparisons of prototype and model tidal elevations for 10 gage locations as shown in plate 2 are presented in plates 3-7. The gages are generally evenly spaced along the canal from Reedy Point Jetty on the east to Courthouse Point on the west. Very small adjustments were made to the prototype data in order to obtain a constant elevation for successive low waters. A close inspection of the comparisons of model versus prototype tidal data indicates differences of about 0.5 ft during the rising phase of the tide at some stations. These differences are probably due to prototype meteorological conditions not reproduced

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* See footnote reference, page 9.

in the model and inaccuracies in field measurements. The accuracy obtained in the model reproduction of the planes of high and low water, mean tide level, and range of tide for the 10 stations are shown in plate 8. A careful inspection of these data will show maximum discrepancies of less than 0.3 ft. The accuracy to which the model reproduced the times of high and low water at the stations is shown in plate 9. The maximum difference occurred at sta 40+000 and was about 45 min. The overall agreement obtained between model and prototype tides is considered satisfactory.

Adjustment of currents

28. The objective of the model current velocity adjustment was to obtain an accurate reproduction of current velocities measured in the prototype on 7 and 8 June 1938. As was necessary for the tides, minor adjustments to the prototype current velocity data were also required to correct for the semidiurnal inequality in successive low waters. The velocity data were measured at midchannel at Chesapeake City and Reedy Point Bridges at 6/10 depth. Plate 2 shows the locations of the bridges at which the verification data were measured. Plate 10 presents a comparison of model and prototype measurements, and the degree of accuracy with which the model reproduced the prototype current velocities is considered excellent. Measurements were made in the model for half-hour intervals, and a smooth curve was drawn between the points. Plate 10 shows excellent agreement between prototype and model velocities; however, this degree of reproduction could be greatly altered in the model as a result of a slight shift of the current velocity meter in the horizontal since the flow in the small model canal is very turbulent.

Adjustment of salinities

29. Salinity measurements were not available for the 27- by 250-ft canal condition used for verification. It had been determined that average salinity in Chesapeake Bay at the mouth of Elk River, the location of the model limit, was about 1250 ppm; accordingly, the source salinity at that location was maintained at 1250 ppm throughout all verification tests. The source salinity in the Delaware at the mouth of the Bay was maintained at 31,000 ppm.

Tests of 27- by 250-ft Canal

Procedure

30. During the adjustment and verification phase of the study, it became apparent that the canal was extremely sensitive to minor variations of the source tides. Great difficulty was experienced in maintaining an accurate repetition of the source tides for the prolonged periods of continuous operation necessary to obtain stable hydraulic and salinity conditions throughout the test area. Since the change in net flow through the canal is probably the most significant determination required and since the net flow is primarily a function of head differential across the canal, the tests are discussed in accordance with the various differentials selected for study. It was attempted to maintain a constant mtl in Delaware Bay (Miah Maull gage) and adjust mtl at Turkey Point to obtain the desired ΔH between Courthouse Point and Reedy Point Jetty, since this is generally what happens in the prototype. Mean tide level in the Delaware is fairly constant, whereas mtl in the Chesapeake is erratic. The maximum and minimum ΔH values tested bracket the values found in the prototype, as indicated by available data, and were +1.44 and -0.85 ft, respectively.

31. Model operation for salinity stability required a minimum of 60 tidal cycles during which time sufficient monitoring was done to demonstrate that stability had in fact been reached in the test area. The source salinities were as previously stated, 1250 ppm at Turkey Point and 31,000 ppm at the Delaware Capes. Mean freshwater inflows in the Delaware totaled 20,200 cfs at the Capes. Mean ranges of tide were reproduced in both Chesapeake Bay and Delaware River, but the ΔH across the C&D Canal was varied.

32. The first measurements usually made were of tide heights throughout the test area, followed by the measuring of currents. All measurements extended over two or more consecutive tidal cycles, and average values are reported. The hydraulic measurements usually required 40 to 50 tidal cycles, after which the net flow determinations were made using the apparatus described in paragraph 16. This operation

was performed several times, and the values were averaged. Tides at Reedy Point Jetty and Courthouse Point were monitored while flow measurements were being made.

Mean tide level $\Delta H = +0.28$ ft

33. Analysis of prototype data indicated that the long-time average mtl difference between Courthouse Point-and Reedy Point Jetty is about +0.28 ft; therefore, this condition was the first selected for testing. Tidal measurements were made at 17 stations located as shown in either plate 1 or 2. Results of the tidal observations for this condition are presented in plates 11-19, along with the tidal observations for other mtl difference conditions tested.

34. Current velocity measurements were made at six stations in the Delaware River and at seven stations in the C&D Canal and Elk River. Plate 20 shows the location of all 13 current velocity stations. Measurements were generally made at surface and bottom depths for the Delaware River stations and at surface, middepth, and bottom depths for the C&D Canal stations. Inspection of current velocities at sta A (plate 27) indicates an eastward flow for a duration of about 7 hr at both surface and bottom depths. There is evidence of a very minor density current at this station in that the occurrence of current slacks after westward and eastward flow at the surface depth is at hr 3 and 10, respectively, and at hr 2.25 and 9.25, respectively at bottom depths. The maximum eastward velocity at this station was at bottom depth and was 3.2 fps; the maximum westward velocity at this station was also at bottom depth and was 2.5 fps. Inspection of the current velocities at sta C, located near Summit Bridge (plate 29) indicates a considerably reduced density current as compared with sta A. The duration of eastward flow at sta C is about 6.5 hr. The slacks after westward and eastward flow at both the surface and bottom depths occurred at about hr 3.6 and 10.1, respectively. The maximum velocity of the eastward flow was at surface depth and was 2.9 fps, while the maximum velocity of the westward flow was also at surface depth and was 2.6 fps, indicating more uniform flow conditions in a westerly direction. Results of current velocity measurements at all stations at all depths are shown in plates 21-33.

35. Salinities were measured hourly at five of the salinity stations shown in plate 34. These measurements were made at surface and bottom depths at sta 2, A, C, D, and E; and the results are presented in plates 35-39 along with the results of similar measurements for other ΔH conditions tested. As discussed previously, the salinities in the Delaware River end of the canal are higher than salinities in the Chesapeake Bay end of the canal. However, a comparison of hourly salinities as shown in plate 35 for sta 2, located at the Reedy Point Jetty, with salinities shown in plate 36 for sta A, located about 6000 ft west of sta 2, shows some hourly salinities higher at sta A than at sta 2. This phenomenon is a result of very complex flow conditions at the eastern end of the canal. While the flow in the canal is in an eastward direction, the flow in the Delaware River is in the ebbing phase, bringing progressively less saline water from upstream in the Delaware to the canal entrance. Prior to the occurrence of slack after eastward flow in the canal, the more saline bottom layer of water in the Delaware River begins its flooding phase. A slug of heavy saline water is transported to the eastern end of the canal and begins to move along the canal bottom in a westward direction, while the surface waters of the canal are still experiencing eastward flow. When the westward flow at all depths obtains in the canal, some of the less saline water in the Delaware River is transported back into the canal so that the slug of more saline water between Reedy Point Jetty and Biddles Point is trapped between zones of less saline water for many flow situations. This peculiar flow phenomenon is further complicated by a very complex series of horizontal and vertical eddies which oscillate to various positions around the canal mouth, depending on mixing characteristics in the Delaware as affected by the canal discharge and the direction and phasing of the tidal flow. The maximum salinities at surface and bottom depths at sta 2 are 3.7 and 4.2 ppt, respectively, for conditions of $\Delta H = +0.28$ ft , while the minimum salinities at the same locations are 1.7 and 1.9 ppt, respectively. It is noted that the average salinity at bottom depth at sta 2 is about 10 percent higher than the surface salinity. The maximum salinities at surface and bottom depths at sta A are

4.1 and 4.2 ppt, respectively, while the minimum salinities are 1.5 and 2.1 ppt respectively. A review of the hourly salinities at sta C (plate 37), shows that the salinity at that location is controlled completely by the Elk River flow where a constant salinity of about 1.3 ppt was maintained. Table 1 shows the high- and low-water slack surface and bottom salinities for 18 stations located in the Delaware River and surface and bottom salinities at the current slacks following eastward and westward flow in the canal for 10 stations located in the C&D Canal. Delaware River salinity profiles for times of local current slacks for this test which involved a ΔH of +0.28 ft are shown in plate 40. The surface and bottom measurements at each station were plotted, and smooth best-fit curves were drawn. The high-water slack profiles show a slight dip at about channel sta 220, and a more pronounced dip is evident in the low-water slack profiles between sta 265 and 230. The dips are the result of the less saline C&D Canal flow entering the Delaware River. For example, plate 22 for sta 230 shows that slack after ebb occurs at about hr 7; however, if the current velocities for sta A, shown in plate 27, are studied, one sees that flow in the C&D Canal is near maximum in an eastward direction at the same time. The fresher water from Chesapeake Bay is thus still flowing into the Delaware causing the dip in salinity profile constructed for the Delaware.

36. The net flow through the canal was measured using the tank described in paragraph 16 and was found to be about 1600 cfs. In order to check this method of net flow determination, since comparatively large total volumes with respect to the net differences were involved, velocity measurements at sta A and D were used in computing the net flows at those locations. The computations required the following measurements at 30-min intervals for each station: (a) tidal elevations and (b) current velocities at the surface, middepth, and bottom stations. In addition, the cross section at each station was carefully measured and subdivided horizontally into the surface, middepth, and bottom thirds, each including a velocity station. The areas of the bottom and middepth thirds remained constant during the computation process while the area of the surface third changed according to tidal elevation and

channel width variances over the tidal cycle. The computational procedure involved multiplying the measured current velocities by the corresponding areas and adding the three results at each desired time interval over a tidal cycle. The results of these computations are a set of instantaneous discharge curves for the particular cross section and ΔH condition over a tidal cycle. The areas under the discharge versus time curves were obtained by numerical integration using Simpson's rule (fitting a parabola to the first three points, etc.). The resulting net difference between total eastward and total westward flows was divided by the duration of the tidal cycle to obtain an average net discharge. The net discharges at sta A and D were averaged to determine the net discharge through the canal, and the value for a ΔH of +0.28 ft was found to be about 1900 cfs in an eastward direction. This compared satisfactorily with the 1600-cfs value obtained by the tank method, and the tank method was judged satisfactory. Additional numerical checks were made for other ΔH conditions tested and will be summarized in a subsequent paragraph.

Mean tide level ΔH = +0.11 ft

37. The next test conducted in the C&D Canal was for a weighted mtl difference of +0.11 ft. Measurements were made at the same 17 stations, located as shown in either plate 1 or 2, that were utilized for tests involving other ΔH's . Tidal measurements are shown in plates 11-19. At the tide stations in the Delaware River, there were no pronounced differences between measurements for ΔH's of +0.11 and +0.28 ft. The most notable changes occurred in the canal, where the hourly elevations for a ΔH of +0.11 ft were generally lower than corresponding elevations for a ΔH of +0.28 ft. This was anticipated since the ΔH was altered by lowering the tidal plane at Turkey Point. A slight phase shift was noted in the tidal data, with events for a ΔH of +0.11 ft occurring earlier than corresponding events for a ΔH of +0.28 ft.

38. Current measurements were made at the 13 stations located as shown in plate 20, and the results are included in plates 21-33 along with similar measurements for the other five ΔH's tested. Minor

changes occurred in the Delaware River as would be expected; however, significant differences occurred in the C&D Canal. The most notable changes were at sta A, as shown in plate 27. Comparison of the +0.28 and +0.11 ft data shows the duration of eastward flow at surface depth was reduced from 7.0 to 6.1 hr and the duration of westward flow was increased from 5.4 to 6.3 hr, indicating a reversal in the direction of net flow. At bottom depth at sta A, the duration of eastward flow was reduced from 7.0 to 5.5 hr and the duration of westward flow was increased from 5.4 to 6.9 hr, again indicating a reversal in net flow. The magnitude of current velocities at sta A was increased in the westward direction by as much as 1.0 fps and reduced in the eastward direction a like amount compared with values for a ΔH of +0.28 ft. The greatest changes occurred at bottom depth in both directions. Proceeding in a westward direction through the C&D Canal and Elk River, there is progressively less evidence of change in current velocities as a result of decreasing ΔH from +0.28 to +0.11 ft.

39. Salinities in the C&D Canal increased at all stations and depths for the ΔH of +0.11 ft compared with similar values for a ΔH of +0.28 ft. A careful study of the hourly salinities at sta 2, A, C, D, and E, shown in plates 35-39, reveals the sensitivity of canal salinity intrusion characteristics to slight differences in mtl. Salinity values at bottom depth at sta 2 (plate 35), show a marked increase at hr 6, the time when minimum salinity might be expected for this station. The increase in salinities at that time at sta 2 is the result of the inflow of more saline water along the bottom of the canal from the Delaware River described in paragraph 35. The salinities at sta A (plate 36), indicate that for a ΔH of +0.11 ft there is a very small density gradient from surface to bottom and no notable cyclic variation in salinity as was present at this station for a ΔH of +0.28 ft. Lower salinity water that enters the canal from the Delaware River between about hr 1 and 4 does not reach sta A before the canal flow reverses direction. The maximum salinity for surface and bottom depths at sta A is 4.5 ppt for a ΔH of +0.11 ft compared with about 4.1 and 4.2 ppt, respectively, for a ΔH of +0.28 ft. The salinity values at

sta C (plate 37) were of the same order of magnitude as similar values at sta A with the minimum salinity being about 4.0 ppt on the surface. Salinities in the canal gradually decrease from east to west, but values measured at sta F (see table 1) are significantly higher than the Elk River source salinity. The salinity gradient between sta A and F is about 2.2 ppt. This indicates that the more saline Delaware River water intrudes through the canal and into Elk River for a ΔH of +0.11 ft. The presence of this salinity gradient is one explanation for having a net westward flow through the C&D Canal for a weighted mtl difference equal to or nearly zero. In such cases, the pressure gradient generated by the salinity differential between the ends of the canal is greater than the pressure gradient generated by the differential mtl and results in a net westward flow. However, the effect of this phenomenon cannot be clearly identified by inspection of the model results because of the complex tidal regimes for the two connected systems and the resulting flow characteristics previously discussed.

40. High- and low-water slack surface and bottom salinities were measured at 17 stations located in the Delaware River; and surface and bottom salinities at the current slacks after westward and eastward flow were measured at 10 stations in the C&D Canal. Results of these measurements are presented in table 1, and the results pertinent to the Delaware Estuary are presented in graphic form in plate 41. These data for $\Delta H = +0.11$ ft (plate 41) show an increase in salinity for almost all stations when compared with corresponding salinities for a ΔH of +0.28 ft (plate 40). The greatest increases were noted in the surface measurements, which would indicate a higher degree of mixing within the Delaware River. The dip in the salinity profiles discussed for the ΔH of +0.28 ft is not present in the +0.11 ft profiles. This is another indication that the net discharge through the C&D Canal is westward for a ΔH of +0.11 ft; therefore, less relatively fresh water is available from Elk River to dilute salinities in the Delaware.

41. The net discharge was measured and found to be about 600 and 740 cfs westward by the tank and numerical methods, respectively, for a ΔH of +0.11 ft, as compared with a net flow of 1600 cfs

eastward for a ΔH of +0.28 ft. This is a total change of about 2200 cfs caused by a change of only 0.17 ft in the weighted ΔH and is an indication of the sensitivity of net flow to head differences across the canal.

Mean tide level ΔH = +0.67 ft

42. Tidal observations were measured at the same stations as for the test involving a ΔH of +0.28 ft and results are shown in plates 11-19. As anticipated, tidal elevations throughout the canal were raised as a result of the increased ΔH when compared with elevations for a ΔH of +0.28 ft.

43. There were no appreciable changes in the magnitude or phases of current velocities in the Delaware River as shown in plates 21-26. The current velocities in the C&D Canal (plates 27-33) underwent considerable change as could be expected. The duration of surface eastward flow at all canal stations (except sta G) was increased by 0.5 to 2.25 hr, while the duration of bottom eastward flow was increased by 0.5 to 1.0 hr. At all stations the velocity curves were shifted toward increased eastward velocities and decreased westward velocities as compared with the results of the test for ΔH = +0.28 ft .

44. Salinities, measured at all locations shown in plate 34 in the Delaware River and C&D Canal, were decreased at almost all stations as compared with salinities for the ΔH of +0.28 ft condition. Plots of the C&D Canal salinity data are presented in plates 35-39. The maximum salinities at sta A (plate 36) for the surface and bottom depths were about 1.9 and 2.8 ppt, respectively, which is a reduction of about 2.2 ppt for the surface measurements and about 1.4 ppt for the bottom measurements as compared with the +0.28 ft values. The minimum salinity values at both depths were about 1.3 ppt which is a reduction of about 0.2 ppt at the surface and 0.8 ppt at the bottom compared with similar values for a ΔH of +0.28 ft. For a ΔH of +0.67 ft, salinities throughout most of the canal are identical with the source salinity in the Elk River, which is 1.3 ppt. The more saline Delaware River waters intruded into the canal to about sta 8. This is about 2 miles less than the intrusion length for the ΔH of +0.28 ft.

45. Salinity measurements for all stations in the Delaware River and C&D Canal for the ΔH of +0.67 ft are listed in table 1, and the Delaware River salinity profiles for times of local current slack are presented in plate 42. The profiles show a reduction of salinities for most stations compared with the similar profiles for the ΔH of +0.28 ft. The salinity profile dips in the vicinity of C&D Canal are more pronounced for this test condition as compared with the +0.28 ft test, which is an indication that a considerable amount of low-salinity water is flowing from Elk River to the Delaware. The net discharge for a weighted ΔH of +0.67 ft was determined to be about 6600 and 7300 cfs eastward by the tank and numerical methods, respectively. This is an increase of about 5000 cfs compared with the net flow eastward for a ΔH of +0.28 ft.

Mean tide level $\Delta H = +1.44$ ft

46. Tidal elevations were measured at the same stations as for the +0.28 ft ΔH condition and are shown in plates 11-19. The tidal elevations in the Delaware River from Artificial Island to New Castle were increased slightly as compared with the tides for the +0.28 ft conditions. As anticipated, those stations located in the C&D Canal and Elk River experienced marked increases in elevation compared with the +0.28 ft conditions.

47. There were no pronounced changes in the duration and magnitudes of current velocities in the Delaware River compared with similar measurements for the ΔH of +0.28 ft. Current velocities in the C&D Canal (plates 21-33) were greatly altered, with sta A showing the greatest change. The duration of surface and bottom eastward flow was increased by 0.5 to 4.5 hr, diminishing toward Turkey Point. At all stations the velocity curves were shifted toward increased eastward velocities and decreased westward velocities. The largest increase in eastward velocity (2.0 fps) occurred at the bottom at sta B.

48. Hourly salinities for sta 2, A, C, D, and E (located as shown in plate 34), were measured, and results are shown in plates 35-39. The salinities in the C&D Canal were completely controlled by the Elk River source salinity, which was 1.3 ppt. The salinities in

the Delaware River were greatly reduced from the mouth of the canal downstream to about sta 325, as shown in table 1 and plate 43, when compared with the salinities for the ΔH of +0.28 ft test. This is attributed to the large net eastward flow which was determined to be about 17,500 cfs volumetrically and 19,200 cfs numerically.

Mean tide level ΔH = -0.48 ft

49. Tide heights were again measured at the 17 stations located as shown in either plate 1 or 2, and the results are presented in plates 11-19, along with measurements for other conditions tested. For this ΔH condition, a reduction in tidal range was experienced at several stations in the Delaware River. The most noticeable reductions being at sta 220+000, New Castle, and Reedy Point Jetty where tide ranges were reduced by about 0.1 ft, as shown in plates 13 and 14. There was a slight loss of tidal range in the C&D Canal from Reedy Point westward to the Summit Bridge for a ΔH of -0.48 ft compared with similar data for a ΔH of +0.28 ft. As expected, the tidal elevations throughout the canal were lower than corresponding values for a ΔH of +0.28 ft.

50. Current velocities in the Delaware River were not greatly altered as a result of lowering the ΔH to -0.48 ft (plates 21-26). However, in the C&D Canal the current velocity magnitudes and phases underwent extreme changes (plates 27-33) compared with similar measurements for the ΔH of +0.28 ft condition. The duration of eastward flow at all canal stations was reduced by 0.5 to 2.5 hr, with the degree of change diminishing toward Turkey Point. The velocity curves were offset toward increased westward velocity and reduced eastward velocity. The greatest changes occurred at sta A where the maximum surface eastward flow was reduced by 1.2 fps and the maximum surface westward flow was increased by 0.8 fps. Comparing maximum velocities can be misleading when considering the net discharge characteristics of the canal. For example, a careful inspection of hourly current velocities for the -0.48 and +0.28 ft ΔH's shows differences of about 2.0 fps for several hours at sta A.

51. Salinities for all stations in the C&D Canal (located as

shown in plate 34) were increased as compared with the ΔH of +0.28 ft results as shown in plates 35-39. Inspection of the hourly salinities at sta 2 (plate 35) shows salinities increasing at times when minimum salinities should be experienced. This is a result of the slug inflow from the Delaware described in paragraph 35. The maximum surface and bottom salinities at sta A (shown in plate 36) were about 4.7 and 4.9 ppt, respectively, which is an increase of about 0.7 ppt at each depth as compared with salinities for the ΔH of +0.28 ft condition. Larger salinity increases were experienced throughout the remainder of the canal. The hourly salinities at sta E were a constant 4.4 ppt over the entire tidal cycle, which is an increase of about 3.0 ppt as compared with salinities for the ΔH of +0.28 ft test condition. High-water slack surface salinities in the Delaware River were increased considerably, while the bottom salinities were increased lesser amounts compared with salinities for the ΔH of +0.28 ft test. This resulted from the diversion of the fresh water from the Upper Delaware River through the canal to Chesapeake Bay and seems to indicate a higher degree of mixing throughout the Delaware River. Results of high- and low-water slack surface and bottom salinities are presented in table 1 and salinity profiles for the Delaware River are presented graphically in plate 44.

52. The net discharge for the weighted ΔH of -0.48 ft, as determined from volumes measured in the calibration tank, was about 7000 cfs westward which is a change of about 8600 cfs when compared with the net eastward flow measured for mean conditions. The net discharge as determined by the numerical method was about 7200 cfs which agrees quite closely with the volumetric determination.

Mean tide level ΔH = -0.91 ft

53. As for previous conditions tested, tide heights were measured at 17 stations located as shown in either plate 1 or 2, and these data are presented in plates 11-19. There was a reduction in tide range at several of the stations in the Delaware River and in the C&D Canal for the -0.91 ft ΔH test as compared with the +0.28 ft ΔH test. The range at Reedy Point Jetty (plate 14) was about 5.1 ft

as compared with 5.4 ft measured for the test with a ΔH of +0.28 ft. This loss of tide range extended from Reedy Point Jetty westward in the C&D Canal to about Bethel. As expected, the tidal elevations at all stations in the C&D Canal were lower than comparable elevations for the test with a ΔH of +0.28 ft.

54. Comparative current measurements made in the Delaware River and the canal are shown along with data from previous tests in plates 21-33. There was a notable change in the current velocities at all the stations in the C&D Canal (plates 27-33). The duration of eastward flow at all canal stations was reduced by about 1.0 to 4.0 hr, with the degree of change diminishing toward Turkey Point. The velocity curves were shifted toward increased westward velocity and reduced eastward velocity. The greatest changes occurred at sta A, where the maximum surface eastward velocity was reduced by 1.6 fps and the maximum surface westward velocity was increased by 1.2 fps. Careful inspection of the data for sta A shows that at some times during the tidal cycle there are 3.0 fps differences in velocities compared with similar data for a ΔH of +0.28 ft.

55. Salinity data for the ΔH = -0.91 ft condition are presented in plates 35-39, table 1, and plate 45. The salinities reached higher values in the C&D Canal for this discharge than for any condition previously tested. The maximum surface and bottom salinities at sta A (plate 36) were about 6.7 and 6.9 ppt, respectively, compared with about 4.1 and 4.2 ppt for the ΔH of +0.28 ft test condition. The salinities in the Elk River at sta E (plate 39) averaged about 6.1 ppt throughout the tidal cycle, as compared with a constant salinity of about 1.3 ppt for the ΔH of +0.28 ft. The high- and low-water slack surface and bottom measurements taken in the Delaware River (plate 45) showed a large increase in surface salinities and a lesser increase in bottom salinities. This again resulted from the diversion of additional fresh water from the Upper Delaware River through the C&D Canal to the Chesapeake Bay and seems to indicate increased mixing in the Delaware. Comparison of plates 40 and 45 shows that the salinity profiles for the surface and bottom depths were shifted upstream in the Delaware River

by considerable amounts as compared with the respective locations for the ΔH of +0.28 ft condition.

56. The net discharge for the weighted ΔH of -0.91 ft as determined volumetrically was about 11,000 cfs westward, compared with 14,400 cfs westward as determined numerically.

Additional net flow determinations

57. One of the primary concerns of the study was the development of the relation between net flow and head differential. At this stage in the program, six flow determinations had been made for the required range of head differentials; and it became apparent that additional data were needed to definitely establish the required curve. Therefore, four additional tests were made during which the controls were adjusted to obtain weighted ΔH's of +1.15, +0.35, -0.30, and -0.7 ft. The tests were conducted in exactly the same manner as the previously discussed tests; however, only the net flow and the tide at Reedy Point Jetty and Courthouse Point were measured. The net flows were determined to be about 13,500 cfs eastward, 2,000 cfs eastward, 6,000 cfs westward, and 9,500 cfs westward for the ΔH's of +1.15, +0.35, -0.30, and -0.70 ft, respectively. These data and the data obtained previously were used to construct a plot of net flow as a function of head differential (ΔH) for the 27- by 250-ft canal shown in plate 46. A similar curve for the enlarged canal is also shown in plate 46 along with results of similar tests made for various conditions in both the physical and mathematical models during the remainder of the study.

58. As previously stated, the volumetric determination of net flow involved comparatively small differences between rather large volumes of water. In order to substantiate the results of this method of determining the net flow, computations involving current velocity and area were made for sta A and D as described in paragraph 36. A comparison of the results obtained by each of the two methods is shown in plate 47. The Q versus ΔH curves shown were transposed from plate 46 and were determined by the results of the volumetric measurements, while the data points shown in plate 47 were determined by the numerical method. The plot illustrates that there would be no

significant difference in the Q versus ΔH relation established by either method. This leads to the conclusion that the curves shown are sufficiently accurate for determination of gross exchanges of water between the two bays over extended periods of time, provided reliable values for ΔH can be determined.

Elk River source salinity equals zero

59. Salinities in Chesapeake Bay at the mouth of Elk River are reduced to zero for extended periods as a result of high rates of freshwater inflow, chiefly from the Susquehanna River. It was desired to know the effects of this condition on tides, currents, and salinities in the canal; therefore, two tests were made: one for a ΔH of +0.46 and one for a ΔH of +0.55 ft. Model operating procedures were the same for these tests as previously described except that the Elk River supply was composed entirely of fresh water. Tide heights, currents, salinities, and net flows were measured at the usual locations.

60. Results of all tidal measurements for the two ΔH conditions with fresh water from the Elk River supply are presented in plates 48-56. Since none of the previous tests with a source salinity of 1250 ppm in Elk River were made for the same ΔH (+0.46 and +0.55), comparable data with a saltwater source are not shown with the results of these two tests. Evaluation of the effects of using fresh water for the Elk River supply is attempted, however. Tidal elevations were not significantly affected by the salinity changes; the only difference noted was the increase in elevations at the various stations through the C&D Canal as required to produce the desired mtl difference.

61. Current velocities for the two tests involving fresh water from the Elk River supply are presented in plates 57-68. In the Delaware River, velocities were not greatly changed for these tests as compared with measurements made during the test for an mtl difference of +0.28 ft and a source salinity of 1.3 ppt in the Elk River. However, the duration and magnitude of current velocities in the eastward direction were increased at sta A (plate 62) for the tests as compared with similar results where the ΔH's were +0.28 and +0.67 ft and the

Elk River source salinity was 1.3 ppt (plate 27). This trend was present at all stations in the C&D Canal, but the most change occurred at sta B (plates 63 and 28).

62. Perhaps the most important data collected are the hourly salinities which were measured at sta 2 and A (plates 69 and 70). The fresh water from the Elk River greatly diluted the salinity at the eastern end of the canal and in the adjacent portion of the Delaware River, which serves as the source salinity for the canal during periods when currents are in a western direction. The maximum surface and bottom salinities at sta 2 (plate 69) were about 2.2 and 2.8 ppt, respectively, for the ΔH of +0.46 ft and 1.6 and 1.2 ppt, respectively, for the ΔH of +0.55 ft, as compared with 3.6 and 4.3 ppt for the ΔH of +0.28 ft and 2.5 ppt and 3.2 ppt for the ΔH of +0.67 ft with a 1.3 ppt source salinity in the Elk River (plate 35). The minimum bottom salinity was 0.5 ppt for the ΔH of +0.46 ft and 0.0 ppt for the ΔH of +0.55 ft, as compared with minimum values of about 1.8 ppt for the ΔH of +0.28 ft and 1.3 ppt for the ΔH of +0.67 ft with an Elk River source salinity at 1.3 ppt. These same tendencies were shown for sta A (plate 70), the only difference being that the minimum salinities were 0.0 ppt for 4 to 5 hr. No salt was found west of sta 8 during either test. This reduction of salinities in the Delaware River end or eastern end of the canal is most important to an analysis of the net discharge change resulting from salinity changes. The reduced intensity of the salinity front at the eastern end of the canal offers less resistance to eastern flow and subsequently results in higher current velocities in the eastward direction at sta A than was found for a ΔH of either +0.28 ft or +0.67 ft with an Elk River source salinity of 1.3 ppt. In addition, the less intense salinity front in the eastern end of the canal provides less energy for the pressure gradient flow in the westward direction mentioned previously in paragraph 39. This loss of salinity-generated pressure gradient flow is best seen by the decrease in duration of westward flow at sta A and the decrease in magnitude of current velocities in the western direction at sta A, compared with similar measurements for the ΔH's of +0.28 and +0.67 ft for the Elk

River source salinity of 1.3 ppt. The duration of westward flow for surface and bottom depths at this station for the ΔH of +0.46 ft and +0.55 ft was about 4.5 hr compared with about 5.5 hr for the ΔH of +0.28 ft and about 4.7 hr for the ΔH of +0.67 ft with the Elk River supply adjusted to a source salinity of 1.3 ppt. The combined effects of these factors is an increase in the net discharge in the eastward direction as compared with discharges for comparable ΔH's with the Elk River source salinity at 1.3 ppt.

63. The net discharges for the ΔH of +0.46 and +0.55 ft were about 5900 and 7200 cfs, respectively, as determined volumetrically, and 6200 and 8000 cfs, respectively, as determined numerically, compared with 3700 and 4900 cfs determined volumetrically for comparable heads with the Elk River source salinity adjusted to 1.3 ppt, which is an increase in net flow of about 2200 cfs in the eastward direction in either case. The net flow values for these conditions are shown in plate 46.

Summary of important results

64. The most important results of tests conducted for the 27- by 250-ft canal are considered to be:

a. The net discharge and salinity characteristics within the canal were very sensitive to minor changes in mtl in the tidal rivers at each end of the canal.

b. The flow conditions at the Reedy Point Jetty end of the C&D Canal and adjoining Delaware River waters are very complex and dynamic and can have great influence on net discharge and flow direction in the C&D Canal. The dynamic flow condition can be greatly influenced by meteorological conditions, mtl and salinity differentials across the length of the canal, and fresh water entering the Upper Delaware River, all of which affects the salinity and currents at the eastern end of the canal.

c. When the salinity at the eastern end of the C&D Canal is appreciably higher than that at the western end, there is a net discharge in a westward direction if the tide level difference (ΔH) is minimal. This is attributed to flow induced by a longitudinal pressure gradient, which in turn is generated by a longitudinal salinity differential. The salinity gradient thus has a significant influence on the rate and direction of net flow for small mtl differentials (ΔH's).

- d. The salinity characteristics in the Delaware River and upper Chesapeake Bay in the vicinity of the canal are significantly influenced by the net tidal discharge of the C&D Canal.
- e. The net discharges for comparable ΔH's were increased when the Elk River source salinity was reduced to zero when conditions resulted in eastward flow. The fresh water from Elk River reduces the source salinity at the eastern end of the canal, thereby reducing the longitudinal salinity differential in the canal which in turn reduces the salinity-generated pressure gradient flow in a westward direction.

Tests of Existing Canal

65. Upon completion of tests of the 27- by 250-ft canal, the canal portion of the model was revised to approximate existing (1972) conditions of the canal. From Turkey Point eastward to Reedy Point Bridge, the canal was enlarged to a depth of 35 ft and a width of 450 ft, since this portion of the canal will shortly be completed to project dimensions. Further work on this project east of Reedy Point Bridge is not anticipated until FY 1974; therefore, the portion between the bridge and the end of the jetties was revised to agree with results of a Philadelphia District survey, file No. 740 dated March 1971. Results of Philadelphia District survey, file No. 750 dated 1946, were used to revise the portion from the ends of the jetties to the Delaware Navigation Channel. The unimproved section of the canal acts as a restriction or plug. After completing the tests for existing conditions, Philadelphia District survey, file No. 40600, dated November 1972 became available and was carefully checked against the March 1971 survey of the reach between the bridge and the jetties. It was concluded that the model as constructed to simulate March 1971 conditions was sufficiently close to November 1972 conditions so that any resulting hydraulic and salinity differences would not be detectable. It was also concluded that revision of the model, followed by repeating the testing program for existing conditions, was not justified and that the test results would be representative of November 1972 conditions.

66. Prior to destroying the 27- by 250-ft canal, each roughness element used in the canal was located very carefully; and upon completion of molding the enlarged section, each element was replaced in the same position. Numerical computations indicated that this amount of roughness would be satisfactory for the enlarged canal. The Elk River tide-reproducing mechanism was readjusted to reproduce the approximate mean tide at Courthouse Point used in previous tests. After this adjustment had been completed, the same testing procedures utilized for the previous tests and discussed in paragraphs 30-32 were repeated with the canal molded to existing conditions. A mean tide with a range of about 2.2 ft at Courthouse Point and a mtl difference of +0.23 ft was used.

67. Tidal heights were measured at Miah Maull in the Delaware River and at 11 stations in the C&D Canal, located as shown in plate 2, and the results are shown in plates 71-79 along with the results of similar measurements for three subsequent tests of the enlarged canal. Current velocities were measured at sta 245 and 255 in the Delaware River and sta A, C, and D in the C&D Canal and are presented in plates 84, 85, 86, 88, and 89, respectively. The measurements were for surface and bottom depths in the Delaware River and at surface, middepth, and bottom depths in the C&D Canal. Comparison of the current velocities at sta A in the unimproved area with those at sta C shows the effect of the plug or restriction on current velocities. The maximum eastward current velocities for the surface and bottom depths at sta A are 4.8 fps, while at sta C the maximum eastward velocities are 2.6 fps. The maximum westward current velocities at sta A, surface and bottom depths, are 3.4 fps while at sta C the maximums are 2.1 and 2.6 fps, respectively. The duration of eastward flow at sta A and C was about 6.75 hr. Hourly surface and bottom salinities were measured at sta 2, A, and D, as shown in plates 93, 94, and 96, along with the results of similar measurements for three subsequent tests. The maximum surface and bottom salinities at sta 2 are 3.9 and 4.2 ppt, respectively, while the minimum salinities are 1.7 and 1.6 ppt, respectively. The maximum and minimum salinities at sta A were slightly lower than those measured at sta 2. The salinities at sta D reflected no change during the tide

cycle and remained at about 1.3 ppt. The measured net discharge was about 4300 cfs in an easterly direction (see plate 46) for this mtl and canal condition. The ratio of this net discharge as compared with the 27- by 250-ft canal discharge for a comparable ΔH is about 4.8:1.0. The net discharge determined numerically for this condition was 4800 cfs eastward.

Tests of 35- by 450-ft Canal

68. After the test for existing conditions was completed, the unimproved section east of Reedy Point Bridge was enlarged, and a series of tests with the entire length of the canal enlarged to 35 by 450 ft was conducted. The model test procedures described in paragraphs 30-32 were again repeated for these tests unless so noted. No prototype tide, current, or salinity data were available for verification of the enlarged canal.

Mean tide level $\Delta H = +0.30$ ft

69. For the first test for this canal condition, the mtl difference between Courthouse Point and Reedy Point Jetty was adjusted to +0.30 ft. The net discharge in the canal for this ΔH was determined volumetrically and numerically to be about 9000 and 9500 cfs, respectively, in an eastward direction (see plates 46 and 47). Tidal measurements were made at a total of 17 stations located in the Delaware River and C&D Canal, as shown in either plate 1 or 2. Results of all tidal measurements are presented in plates 71-79.

70. Current velocities were measured at six stations in the Delaware River for surface and bottom depths and at seven stations located in the C&D Canal for surface, middepth, and bottom depths (plate 34). The duration of eastward flow at sta A for surface and bottom depths was about 7.7 hr and 7.5 hr, respectively. The maximum current velocities in the eastward direction for the surface and bottom depths for sta A (plate 86) were 3.1 and 3.5 fps, respectively. The maximum current velocities in the westward direction for surface and bottom depths were 1.7 and 2.3 fps, respectively. There was a marked

predominance of total flow in the eastward direction as compared with flow in a westward direction for the ΔH of +0.30 ft. These same general trends existed for all stations throughout the C&D Canal. Results of all current velocity measurements are presented in plates 80-92.

71. Hourly surface and bottom salinity measurements were made at sta 2, A, C, D, and E, located as shown in plate 34. The maximum surface and bottom salinities at sta 2 (plate 93) were 4.0 and 4.4 ppt, respectively, while the minimum salinities at this station for the surface and bottom depths were 1.3 and 1.7 ppt, respectively. The maximum surface and bottom salinities at sta A (plate 94) were 3.5 and 4.0 ppt, respectively, while the minimum salinity at both depths was 1.3 ppt. At sta A, there was a period of about 5.0 hr when the surface salinity was 1.3 ppt or the same as the Elk River source salinity. This same trend existed on the bottom for 4.0 hr. In the portion of the canal west of sta B, the salinity was stable throughout the tidal cycle at 1.3 ppt, the Elk River source salinity. Results of hourly salinity measurements are presented in plates 93-97. In addition to the hourly salinity measurements, high- and low-water slack surface and bottom samples were taken at 17 stations in the Delaware River, and surface and bottom samples were taken at the slack currents after eastward and westward flows at 10 stations located in the C&D Canal. The locations of these stations are shown in plate 1 or 34. Results of all slack-current salinity measurements taken for the test are presented in table 2, and the results of measurements in the Delaware are presented in plate 98 in the form of salinity profiles. As in the other salinity profiles, the points for each time and depth are plotted and smooth curves drawn through all points. There is a dip in the high-water slack, bottom curve near the C&D Canal which reflects the dilution of bottom salinity by the net flow of fresher water from Elk River.

72. Even though the very complicated and dynamic flow conditions described in paragraph 35 for the 27- by 250-ft canal still exist for the enlarged canal, there are some important differences in the salinity data. During the periods of minimum salinities at sta 2, the increase in salinities observed at about hr 6 during tests of the 27- by

250-ft canal are not evident in the data for the enlarged canal. This is a result of the great increase in the eastward net discharge, which changes the mixing characteristics at the canal mouth. This matter will be discussed in greater detail later in this report.

Discussion of effects of enlargement (ΔH = +0.30 ft)

73. In order to evaluate the effects of enlargement of the canal on the various phenomena, the results of this test involving a ΔH of +0.30 ft are compared with the results of the test for the 27- by 250-ft canal and a ΔH of +0.28 ft. The net discharge and tidal elevation data for both conditions are included in plates 46 and 101-106 along with similar comparison for other ΔH's .

74. Referring to plates 46 and 47, the net discharge for the enlarged canal for a ΔH of +0.30 ft is about 9000 and 9500 cfs eastward as determined volumetrically and numerically, respectively, as compared with about 1600 cfs eastward for the small canal. Enlargement of the canal thus resulted in an increase of about 7400 cfs when the mtl difference is about +0.30 ft.

75. Comparative tidal elevations are presented for sta 234+000 in the Delaware River and 11 canal stations from Reedy Point Jetty to Turkey Point in the Elk River (plates 101-106). The enlarged canal caused tidal elevations to increase at all locations, with maximum changes occurring during the rising phase of the tide. The increase in average elevation at Reedy Point Jetty made it necessary to adjust Courthouse Point mtl upward to obtain the required +0.30 ft ΔH . Current measurements for the two canal conditions are compared for eight locations, and the data are included in plates 107-114. At sta 234 in the Delaware River, the enlargement caused only random changes in current magnitudes. At sta A, the duration of eastward flow for the enlarged canal at surface and bottom depths was 7.75 and 7.4 hr, respectively, as compared with a duration of 7.0 hr at both depths for the small canal. Average velocities at sta A in a westward direction for the small canal were greater than those for the enlarged canal. This is a result of the fact that the salinity differential pressure gradient

effects were greater in the small canal than similar effects in the large canal. The same general tendencies are evident at other stations in the canal. Eastward velocities were consistently greater for the enlarged canal than for the small canal.

76. Comparative hourly salinities are available for five stations in the C&D Canal, and these data are included in plates 115-119 and in table 3. Hourly salinities at sta A were generally higher at surface and bottom depths for the small canal than those in the enlarged canal. Since the salinities at sta E were equal for both channel configurations, it is apparent that the salinity-induced pressure gradient flow is higher in the small canal than in the larger canal. Hourly salinity measurements at all stations through the canal west of sta A were constant at 1.3 ppt throughout the cycle. Table 3 shows that bottom salinities at current slacks at sta 2, A, 8, and B in the small canal are slightly greater than corresponding salinities in the enlarged canal. The more saline Delaware water intruded farther into the small canal than it intruded into the large canal. The differences between salinities at surface depth and bottom depth were also greater in the small canal than in the enlarged canal. Very minor changes are shown in the Delaware River high- and low-water slack salinity profiles when curves for the enlarged canal condition are compared with corresponding curves for the small canal (plates 122 and 123). However, similar salinity values were found slightly farther upstream in the Delaware River at high-water slack for the enlarged canal condition than for the small canal (i.e., the enlarged canal causes an upstream shift of the Delaware River salinity profile for the high-water slack condition). Low-water slack salinity profiles (plate 123) indicate very little change in intrusion characteristics in the Delaware for the two canal conditions.

Mean tide level $\Delta H = +1.44$ ft

77. Tidal measurements were made at the same stations used for the $\Delta H = +0.30$ ft tests (plates 71-79). The large easterly net discharge resulting from the high head differential caused a slight increase in tidal elevations in the Delaware River. The most pronounced increase was at sta 220+000 (plate 73) where elevations were generally

increased by 0.2 to 0.3 ft for the +1.44 ft ΔH condition. With a ΔH of +1.44 ft and the enlarged canal there was a net discharge in the eastern direction of 44,000 cfs (see plate 46).

78. Current velocities at sta 220, 230, 235, 240, 245, and 255 located in the Delaware River are shown in plates 80-85. Increases in velocity occurred at all stations during the ebb phase of the current, while flood tide current velocities were reduced as a result of the additional discharge from the C&D Canal. The greatest change was observed at sta 245, where the ebb velocity was increased by as much as 1.0 fps compared with similar measurements for the ΔH of +0.30 ft condition. Current velocities in the C&D Canal (plates 86-92) experienced drastic changes compared with the velocities for the ΔH of +0.30 ft condition. Inspection of velocities for sta A and B shows that the flow direction is always easterly. The maximum velocities at surface and bottom depths at sta A were 4.1 and 4.6 fps, respectively, while maximum velocities at sta B were 4.9 and 4.6 fps, respectively. These represent increases of about 1.2 fps compared with similar measurements for a ΔH of +0.30 ft. However, the increases in maximum velocities are not indicative of the maximum effects of the increased ΔH . Increases at other times during the cycle at the two stations are as much as 3.0 fps. There were periods of slight westward flow at sta C, D, E, F, and G; however, there was a great predominance of flow in the eastward direction at all these stations.

79. Hourly salinities were measured at five stations in the C&D Canal and these measurements are shown in plates 93-97. The salinity throughout the entire canal was 1.3 ppt or the same as the Elk River source salinity. Even at sta 2 there was virtually no increase in salinity at the time of westward water slack or at the time of slack after flood in the Delaware River. High- and low-water slack surface and bottom salinity measurements were made at 18 stations in the Delaware River and at 10 stations located in the C&D Canal. These measurements are shown in table 1, and plate 99 shows the salinity profile constructed from the data. The net discharge of 44,000 cfs in an eastward direction for the ΔH of +1.44 ft (47,600 cfs determined

numerically) greatly reduced the salinities in the Delaware River as compared with the ΔH of +0.3 ft. There is an indication of a higher degree stratification in the Lower Delaware (downstream from about Pea Patch Island) than for the +0.3 ft test. The dips in the profile discussed in paragraph 35 are quite apparent for this net discharge.

Discussion of effects of enlargement (ΔH = +1.44 ft)

80. The net discharge for this mtl difference in the two canals was 44,000 cfs eastward in the enlarged canal as compared with 17,500 cfs eastward in the small canal (see plate 46). The net eastward flow was thus increased by a factor of 2.5 as a result of enlarging the canal. Tidal elevation comparisons for 12 stations are presented in plates 101-106. The increased net discharge for the enlarged canal caused increases in tidal elevations in both the Delaware River and the canal as compared with corresponding elevations for the small canal. Plate 101 shows that the planes of low and high water were increased by about 0.3 ft at Reedy Point Jetty by the enlarged canal. This factor is important since mtl at Courthouse Point for the enlarged canal had to be raised to a higher elevation than was used for the small canal in order to obtain a ΔH of +1.44 ft.

81. Current velocity comparisons are shown for sta 235 in the Delaware River and seven stations in the C&D Canal in plates 107-114. At sta 235, maximum surface and bottom ebb and flood velocities were increased by about 0.5 fps by the canal enlargement. From Reedy Point Jetty westward in the canal, the effects of canal enlargement on current velocities became more pronounced. At sta A the duration of eastward flow at both surface and bottom depths was 10.5 hr for the small canal, while the flow direction was eastward over the entire cycle for the enlarged canal. Current velocities at sta A were increased by as much as 1.0 fps by the enlargement.

82. There were no major differences in salinity characteristics for the C&D Canal as a result of the enlargement as is shown in plates 115-119. The salinities for both canal conditions were controlled by the Elk River source salinity which was 1.3 ppt. Plate 120 presents

high-water slack salinity profiles for the Delaware River for the two canal conditions. The surface salinity values for the enlarged canal were reduced from about sta 225+000 downriver to Miah Maull and were increased upriver from that station. The mouth of the canal is opposite sta 234+000, and enlargement of the canal caused an increase in net eastward flow from the canal into the river. This additional inflow, which has a salinity of 1.3 ppt, caused the increase in lower salinities upstream of the mouth of the canal and the decrease in higher salinities downstream from the canal mouth. Bottom salinities were increased at all stations upstream of sta 350. These data indicate that the greatly increased inflow from the C&D Canal significantly increased the degree of stratification in the Delaware and extent of salinity intrusion at the bottom. The low-water slack salinity profiles shown in plate 121 show roughly the same effects described above for conditions at high-water slack.

<u>Mean tide level $\Delta H = -0.85$ ft</u>

83. Tidal measurements were made at 17 stations in the Delaware River and C&D Canal located as shown in either plate 1 or 2, and these data are presented in plates 71-79. Tidal elevations in the Delaware River and C&D Canal were lowered for this ΔH condition. The most pronounced reduction in elevation in the Delaware River occurred at sta 220+000 (plate 73) where tidal elevations were generally reduced by about 0.3 to 0.8 ft. Tidal elevations in the canal became progressively lower from east to west for this test as compared with similar measurements for the ΔH of +0.3 ft. At Reedy Point Jetty tidal elevations were reduced by about 0.5 ft, while those at Turkey Point were reduced by about 1.2 to 2.7 ft. As in previous tests of the enlarged channel, it was necessary to readjust the mtl at Turkey Point to achieve the desired ΔH, because of the lowered mtl at Ready Point Jetty.

84. Current velocities were measured at the usual 13 stations in the Delaware River and C&D Canal. When these velocities in the Delaware River are compared with similar measurements for $\Delta H = +0.30$ conditions (plates 80-85), it is evident that ebb currents south of the canal mouth

were reduced somewhat and that flood currents were increased slightly. However, at sta 220+000 (north of the C&D Canal), the effects were reversed. This was to be expected, since there was a large net flow westward (rather than eastward) through the canal for this condition and this net flow had to be supplied from the Delaware River. Current velocities in the canal are presented in plates 86-92. At sta A, the surface current velocities either were in a westward direction or were slack throughout the complete tidal cycle, while at the bottom depth the duration of westward flow was 7.9 hr. The duration of westward flow throughout the canal was increased by 0.5 to 5.75 hr at the surface and by 2.25 to 4.75 hr at the bottom. Maximum surface and bottom current velocities in a westward direction at sta A were 2.8 and 3.5 fps, respectively. Again the conditions in this area are the result of the complex dynamic flow regime at the eastern end of the C&D Canal. Maximum eastward velocities were reduced about 1.5 fps throughout the canal, while maximum westward velocities were increased a like amount. The net discharge was 26,200 cfs westward (see plate 46).

85. Salinities were measured at 5 stations in the canal and the results are presented in plates 93-97, and slack-water salinities at 10 stations throughout the canal are shown in table 2. Because of the large net westward flow, salinity conditions throughout the canal are dominated by conditions in the Delaware. Surface and bottom minimum salinities at sta A were 7.5 and 11.8 ppt, respectively, and maximum salinities were 13.5 and 14.2 ppt, respectively. At sta C, the hourly salinities at surface and bottom depths were nearly constant throughout the tidal cycle and were about 11.8 and 12.5 ppt, respectively. Salinities of this magnitude were found throughout the western portion of the C&D Canal and in Elk River. High- and low-water slack salinity profiles at surface and bottom in the Delaware are presented in plate 100 and table 2. The diversion of the large volume of water from the Delaware to supply the net flow in the canal caused large increases in surface and bottom salinities in the river as compared with similar values for a ΔH of +0.30 ft. The salinity front was shifted several miles upstream as a result of the flow

diversion through the canal. The greatest increase occurred in the salinities at surface depth.

Discussion of effects of enlargement (ΔH = -0.85 ft)

86. The data for the small canal which are used for comparative purposes were obtained for a ΔH of -0.91 ft condition, which is 0.06 ft lower than the -0.85 ft ΔH used for tests of the enlarged canal. The small difference in ΔH should not be of significance in determining the effects of enlargement for negative heads of this general magnitude.

87. As shown in plate 46, the net discharge for a ΔH = -0.85 ft was increased by the canal enlargement on the order of 15,700 cfs (from 10,500 to 26,200 cfs) or about 2.5 times. The enlargement also caused increased tidal range throughout the canal as shown in plates 101-106. Generally, low-water elevations were lowered, and high-water elevations were raised. At Reedy Point Jetty, the tide range was increased only by about 0.2 ft; but from St. Georges Bridge to Turkey Point, the tide range increased progressively by 0.8 to 1.4 ft. Water-surface elevations during the westward flow phase were not changed appreciably, whereas elevations at the slack periods and during the eastward flow were higher for the enlarged canal. As in previous tests of the enlarged canal, it was necessary to readjust the mtl at Turkey Point to achieve the desired ΔH , because of the raised mtl at Reedy Point Jetty.

88. The effects of the channel enlargement on velocities at sta 235 in the Delaware and at seven stations in the canal are presented in plates 107-114. Maximum current velocities at bottom depth in the Delaware at sta 235 were reduced by almost 0.5 fps as a result of enlarging the canal. At sta A, the maximum westward velocity was increased by 0.5 fps and the maximum eastward velocity was reduced by 1.0 fps. On the other hand, middepth and bottom maximum velocities were unchanged, but a phase shift resulted in altered velocities throughout most of the tidal cycle. The durations of westward flow for the enlarged canal at sta A for the surface and bottom depths were

11.4 and 8.0 hr, respectively, as compared with 9.4 and 9.0 hr in the small canal. The duration of westward flow was generally increased by about 1.0 hr. Maximum westward velocities were generally increased by about 0.5 fps at all stations by the enlarged canal. Maximum eastward velocities were reduced by about 0.5 fps in the eastern half of the canal but were increased slightly in the western half.

89. The canal enlargement caused increases in salinities of about 7.0 ppt throughout the canal for negative head situations of this magnitude as shown in table 3 and plates 115-119. Inspection of the high- and low-water slack salinity profiles for the Delaware River shown in plates 124 and 125, respectively, indicate major increases in salinities throughout the Delaware River as a result of enlarging the canal. The net discharge for the enlarged canal was 26,200 cfs westward, which exceeds the total mean freshwater inflow into the Delaware; whereas the 10,500 net westward flow for the small canal is about half the Delaware freshwater inflow. As a result, the upstream extent of saltwater intrusion in the Delaware was greatly increased.

Mean tide level $\Delta H = +0.42$ ft

90. A fourth head condition was tested primarily to obtain a fourth value for the ΔH versus net flow curve. The procedures followed were the same as for previous tests, except that the Elk River tide control was readjusted to improve the agreement between the model and prototype tides at Courthouse Point throughout the tidal cycle. This was considered necessary to assure accuracy of the weighted mtl at Courthouse Point. The results of this test of the enlarged canal were compared with similar results of the test of the small canal for which the ΔH was +0.28 ft, and only these comparisons will be discussed in this report.

91. The net discharge for the +0.42 ft ΔH condition was determined to be about 13,500 cfs eastward for the enlarged canal as compared with 3500 cfs eastward for the small canal (see plate 46). For ΔH's of this order of magnitude, the enlargement would thus cause the net eastward flow to be increased by a factor of about 3.9.

92. When the value of the measured net flow (13,500 cfs) was

added to the ΔH versus net flow curve (plate 46) and found to fall on the line established by the measurements from the other three conditions tested, it was determined that additional net flow determinations for the enlarged canal were not necessary.

93. Tide heights were measured at 15 stations located as shown in either plate 1 or 2, and are shown along with similar data for the small canal (ΔH = +0.28 ft) in plates 126-133. Tide heights in the Delaware between Artificial Island and New Castle were increased by almost 0.2 to 0.3 ft, particularly during the rising phase of the tide, as a result of the large increase in net eastward flow caused by the canal enlargement. This increase in tidal elevation also occurred throughout the canal, with the maximum effect being in the vicinity of Summit Bridge where increases of about 0.5 ft were measured.

94. Current velocities were measured at sta A, C, and D, located in the canal as shown in plate 20, and the results are shown in plates 134, 135, and 136, respectively, along with similar data for the small canal with a ΔH of +0.28 ft. Current velocities in the westward direction were generally decreased by about 0.5 fps at both surface and bottom depths at all three locations; and velocities in the eastward direction were increased at both depths by amounts up to about 1.5 fps, as a result of the canal enlargement and difference in head differentials between the two tests. The duration of eastward flow was increased by about 1.0 hr at all three locations.

95. Salinities were measured at surface and bottom depths at sta A, C, and D, and the results are presented in plates 137-139 and in table 3, along with salinities measured for the ΔH = +0.28 ft condition. Salinities throughout the enlarged canal were uniform throughout the tidal cycle at about the value of the Elk River source salinity (1.3 ppt). Slight increases above the source salinity were measured at sta A at the time of slack after westward flow, indicating that a small quantity of Delaware River water moves into the canal as far as sta A during each cycle for the enlarged canal condition. For the small canal, maximum and minimum salinities at sta A were about 4.2 and 1.4 ppt, respectively, indicating that flow from the Delaware

controlled salinity values at sta A in the small canal when ΔH was +0.28 ft.

Summary of important results

96. The most important results of tests conducted for the 35- by 450-ft canal are considered to be:

- a. The canal is very sensitive to minor mtl changes. A small change in ΔH can significantly affect the tide, both the duration and magnitude of current velocities, the salinities, and subsequently the direction and volume of the net discharge through the canal.
- b. Completion of the project (i.e., enlargement of that portion of the canal east of Reedy Point Bridge) may increase the eastward net flow for mean ΔH conditions (ΔH = +0.30 ft) by about 2000 to 3000 cfs. The net discharge for the 27- by 250-ft canal and a ΔH of +0.23 ft was about 900 cfs eastward. For the same ΔH and the canal enlarged to 35 by 450 ft, except for the unimproved reach from Reedy Point Bridge to the Reedy Point jetties (existing conditions), the net discharge was about 4300 cfs eastward. The net discharge for the canal completely enlarged to project dimensions (35 by 450 ft) for its entire length and a ΔH of +0.23 ft was about 7000 cfs eastward. Therefore, about 56 percent of the ultimate change in flow transfer (for mean tidal conditions) has already occurred. However, for the conditions tested, the density effect (caused by the longitudinal salinity gradient in the canal) was approaching the maximum for the 27- by 250-ft canal at this ΔH , and this effect greatly influences the amount and direction of the net discharge.
- c. The C&D Canal is a very dynamic system and can experience large ΔH changes in short periods of time. The increase in net flow for the canal enlarged to project dimensions as compared with the net flow for the 27- by 250-ft canal is about 780 percent for mean tide conditions (ΔH = +0.30 ft). However, ΔH is known to vary erratically between extremes of about +1.45 ft and -0.80 ft, at which values the effect of total canal enlargement on net flow is only about 250 percent. This indicates that the net flow characteristics for the small canal were greatly influenced by the density effect, which increased as the ΔH approached 0.0 ft. Therefore, when considering the total flow transfer for existing conditions as compared with the flow transfer for project dimensions, these facts must be considered.
- d. The discharge versus ΔH relation shown in plate 46 is

sufficiently accurate for reliable determination of gross exchanges of water between Chesapeake Bay and Delaware River over extended periods of time. It has been shown that ΔH is critical and the accuracy of discharge determinations is directly dependent on the accuracy of determining the average ΔH .

e. Both the vertical and horizontal flow patterns at the Reedy Point end of the canal are complex and dynamic and subject to radical changes as the net discharge fluctuates. Salinity profiles for the 27- by 250-ft and the 35- by 450-ft canals for approximate mean ΔH conditions are shown in plate 140. The maximum difference between surface and bottom salinities is about 1800 ppm at Biddles Point at slack after westward flow for both canal conditions. At the end of eastward flow no significant salinity difference existed in the enlarged canal while a maximum difference of about 800 ppm was found at Reedy Point Bridge for the 27- by 250-ft canal. The enlarged canal is hydraulically more efficient than the small canal which tends to minimize effects of the longitudinal salinity gradient. Salinities throughout the canal for negative ΔH's were increased to the approximate value of the average Delaware River source salinity, for the various negative head conditions tested as shown in plate 141. Salinities throughout the canal for positive ΔH's were reduced longitudinally and vertically to approximate the salinity of the Elk River source, about 1.3 ppt (see plate 141). This factor, coupled with flow characteristics at the confluence of the canal and the Delaware, will cause the canal net discharge to be about zero for conditions of zero mtl differential (ΔH = 0.0 ft). However, the net discharges would be increased as compared with net discharges for comparable ΔH's in the small canal. The ratio of increase, when comparing the small canal discharge with the enlarged canal discharge for a +0.30 ft ΔH , is about 5.3:1, and for ΔH's of +1.44 ft and -0.95 ft the ratios were about 2.5:1.

f. A byproduct of computing the net discharges through the canal as described in paragraph 36 was the determination of the discharge variations with respect to time throughout a tidal cycle. Discharge curves so developed for sta A for three selected conditions are shown in plate 142. The selected conditions are (a) the 27- by 250-ft canal, ΔH = +0.28 ft ; (b) the 35- by 450-ft canal unimproved east of Reedy Point Bridge, ΔH = 0.23 ft ; and (c) the 35- by 450-ft canal throughout, ΔH = +0.30 ft . The large increases in net discharge as a result of enlarging the canal are immediately apparent. Also, westward flow for existing conditions (with the unimproved reach east of Reedy Point Bridge) is greater than westward flow for the completed canal for a slightly larger ΔH . This is attributed partly to the fact that sta A is located within the limits of the unimproved reach where turbulence in the canal is at a maximum and partly to the differences in the salinity gradient for the two conditions.

g. The increased efficiency associated with canal enlargement will influence tides in Elk River, the C&D Canal, and adjacent reaches of the Delaware River to a greater extent than was previously experienced with the smaller canal. The large flows through the canal generated by relatively moderate ΔH's for the enlarged canal will significantly affect the extent of saltwater intrusion and (in some cases) the degree of stratification in the Delaware. Salinities in the canal will also be significantly affected by such conditions. Large westward net flows will increase salinities in Elk River, but the effect of large eastward net flows on salinity conditions in Upper Chesapeake Bay and Elk River could not be determined from the physical model study. However, the model tests of these large net flows were conducted for steady-state conditions at the end of a long period (100 tidal cycles or more) of sustained high net flows. It is highly unlikely that such flow conditions will be sustained for appreciable periods in the prototype; therefore, the salinity changes in the prototype (Delaware River) will be considerably less than predicted by the model.

h. The tidal elevations and phases in the Delaware River, particularly in the reach between Artificial Island and New Castle, can be affected by variations in net discharge and flow direction in the canal.

i. The enlarged canal would cause a slight increase in current velocities in the eastern direction for positive ΔH's and a slight increase in magnitudes of western velocities for negative ΔH's .

j. With the enlarged canal and a high eastward net discharge, tidal elevations and ranges will be increased slightly in the Delaware River compared with conditions for an average ΔH for the enlarged canal.

k. With the enlarged canal and a high westward net discharge, the Delaware River tidal elevations and ranges will be reduced compared with conditions for an average ΔH for the enlarged canal.

PART IV: DYE DISPERSION TESTS

97. A series of dye dispersion tests was conducted in the model for both the 27- by 250-ft (small) and the 35- by 450-ft (enlarged) canals. These tests were requested by personnel of the Chesapeake Biological Laboratory, University of Maryland, and were designed to assist in determining the probable migration patterns of small fish and the dispersion rates of fish eggs and other biota transported by the currents. It was also desired to determine the effects of canal enlargement on dispersion patterns and rates from critical areas. The major areas of concern were Upper Chesapeake Bay, Elk River, and the C&D Canal.

98. This office was not responsible for analysis of the data obtained during these tests; therefore no discussions or interpretations concerning the test results are included in this report. The personnel of the University of Maryland are responsible for this phase of the effort and the results of the model tests are included herein for the convenience of all concerned. The model test results were furnished to personnel of the Chesapeake Biological Laboratory prior to publication of this report.

Test Procedure

99. The model operating conditions were the same for these tests as described in paragraphs 30-32. The mtl difference selected for the test was +0.7 ft, for which the net eastward discharges for the small and enlarged canals were 7,000 and 21,200 cfs, respectively. After the model had reached salinity stability, slug releases of two fluorescent dyes of known concentrations were made simultaneously at Courthouse Point, in the Federal Navigation Channel, and at Summit Bridge in the C&D Canal. The locations of the injection points are shown in plate 143. The slug dye releases were made instantaneously at the time of local slack after westward flow. Middepth or surface and bottom samples were taken after each local current slack at 22 stations,

located as shown in plate 143, in both the canal and the Delaware River. The samples were subsequently analyzed to determine dye concentrations. During the tests, arrival time of the dye at each station was noted.

100. The ΔH selected for these tests resulted in large net flows from Elk River toward the Delaware and comparatively high velocities in the canal. It was found that the dyes were rapidly transported out of the test area, particularly during tests of the small canal; therefore, duplicate dye releases were made for all tests of the 27- by 250-ft canal during the eleventh cycle shown on the dye plates. Observations made between cycles 1 and 11 show dispersion of the first dye release, while subsequent measurements show dispersion of the second dye release.

Test Results

101. The results of the tests are presented as plots of dye concentrations (converted to percentages of the respective initial dye concentrations) versus time in tidal cycles after release of the dye. Curves have not been drawn between the data points. Results of tests for the Courthouse Point release and the small canal are presented in plates 144-163. Data for the Summit Bridge release and the small canal are presented in plates 164-178. Corresponding data for the enlarged canal are presented in plates 179-198, and 199-212, respectively. There are some stations shown in the location map (plate 143) for which no data plates are presented. The dye had moved past these stations before the first sample was obtained, the dye had passed the location between sampling intervals, or (in the case of some of the western stations) the eastward net flow moved the dye away from the stations. The dye limit plates described below help illustrate the rapid transport of the dye cloud.

102. Plates 213-216 are included to show the approximate locations of the dye fronts after eastward flow for both canal conditions and both injection points. In addition, some of these sketches show the approximate locations of the dye fronts in the Delaware River after

both flood and ebb current periods. The maximum number of cycles during which this phenomenon could be observed visually was three. Plates 213 and 214 present the visual dye limits observed during tests of the 27- by 250-ft canal, and 215 and 216 present similar data for the 35- by 450-ft canal. These plates were constructed from visual observations and are intended to show the general location and dispersion patterns of the dye clouds. They should by no means be considered to be exact.

PART V: COMPUTER STUDY OF FLOW IN CHESAPEAKE AND DELAWARE CANAL

103. This portion of the report concerns a computer study to determine the effect of the channel enlargement on flow conditions in the canal. The work, completed early in the overall study, provided insight concerning the sensitivity of net flow through the canal to minor variations in effective head differential. The analysis procedure used and results obtained are summarized in the following paragraphs.

Computation Procedure

104. The study utilized computer programs that solve the one-dimensional differential equations governing unsteady flow in open channels. The programs are based on an explicit finite-difference solution scheme. The term one-dimensional is used to indicate that the flow characteristics such as depth and velocity are considered to vary only in the longitudinal direction and with time. The programs are adapted from programs developed by engineers at the Tennessee Valley Authority and are briefly described in an ASCE paper, "Unsteady Flow Simulation in Rivers and Reservoirs," by Jack M. Garrison, Jean-Pierre Granju, and James T. Price, published in the Journal of the Hydraulics Division, September 1969. The programs are based on the following form of the differential equations:

$$\frac{\partial(AV)}{\partial x} + B\,\frac{\partial H}{\partial t} - q = 0 \qquad \text{CONTINUITY}$$

$$g\,\frac{\partial H}{\partial x} + V\,\frac{\partial V}{\partial x} + \frac{\partial V}{\partial t} + g\,S_F + q\,\frac{V}{A} = 0 \quad \text{MOMENTUM}$$

$$S_F = \frac{n^2 V|V|}{2.21R^{4/3}}$$

where

A = flow area, ft^2

B = surface width, ft

H = water-surface elevation

q = lateral inflow, cfs/ft

x = distance, ft

t = time, sec

g = acceleration due to gravity, ft/sec^2

n = Manning resistance coefficient

R = hydraulic radius, ft

Use of the equations in this form implies the following assumptions:

(1) Velocity is uniform in any cross section.

(2) The water surface is a horizontal line at any cross section.

(3) The axis of the channel can be developed into a straight line.

(4) The flow is gradually varied so that the vertical acceleration of the water particles may be neglected.

(5) The resistance losses can be defined by the Manning equation.

(6) The mass density is constant.

105. The initiation of an unsteady flow computation requires that the following information be available as input data:

a. Geometric data. Descriptive geometric data (elevation versus area, top width and hydraulic radius to 2/3 power) must be provided in tabular form at each computation station. Some preliminary computations were made using the idealized section for both the 27- and the 35-ft channel. Later maps and soundings furnished by the Philadelphia District were used to develop appropriate data for each reach used in the computations (for both 27- and 35-ft channels).

b. Boundary conditions. One boundary condition must be specified at each end of the computation zone. Acceptable boundary conditions are discharge versus time, elevation versus time, or a rating curve. All computations on this project involved the use of elevation versus time records at Courthouse Point on the Chesapeake Bay end of the canal and at Reedy Point on the Delaware River end of the canal. For computations that included the branch canal, an elevation versus time history was also specified at Delaware City (the Delaware end of the branch canal). A location map identifying pertinent sites in the canal area is presented as plate 217.

c. Initial conditions. Discharge and water-surface elevation must be specified at all computation stations to initiate the computation. Since this information is not known, it must be estimated. The spurious waves generated by the inaccuracies in the estimate are damped out fairly rapidly as the computation progresses in time. In this study, if the initial ΔH (end to end of canal) was small, the computation was initiated by assuming no flow in the canal. In other cases, when the initial ΔH was appreciable, a very rough calculation was made to estimate initial flow conditions along the canal.

d. Resistance coefficients. Resistance coefficients (Manning's n) must be specified for each reach. These values must be estimated for the first computation. Appropriate modifications are then made in successive computations until a satisfactory verification is accomplished.

e. Lateral flow. If present, local lateral inflows in each computation reach must be provided as a function of time. No lateral inflows were considered in this study.

Two computer programs are available, one set up to handle a single continuous canal or stream and the other applicable to situations that include one major junction. For all computations that considered only the main canal, the 18.4-mile-long computation zone between Reedy Point and Courthouse Point was divided into 46 reaches 0.4 miles long. For computations that included the branch canal, the main canal between Courthouse Point and the junction with the branch canal was divided into 41 reaches 2164.8 ft long. The main canal between the junction and Reedy Point had four reaches 2640 ft long and the branch canal had four reaches 2250 ft long. Selection of reach lengths is based on judgment and is essentially a compromise between refinement of schematization and computer time required for the computations since the permissible time step is directly related to the reach lengths selected. For the reach length selected, the well-known Courant stability criterion $\left(\Delta t \leq \frac{\Delta x}{|V| + C}\right)$, which is a necessary but not sufficient condition for stability, suggests a permissible time step of about 57 sec. A time step of 44.712 sec (1/1000 of a 12.42-hr tidal cycle) was used in all calculations.

Preliminary Computations

106. Prior to receipt of maps, etc., required to develop appropriate geometric data for the canal, four preliminary computations were made using idealized channel sections (design width and depth and 2-on-1 side slopes) to provide an indication of the sensitivity of the computation to the various input parameters. Pertinent results of these computations will be briefly summarized since they are beneficial to the proper evaluation of results from later computations. All preliminary computations used the mean tide curves at Courthouse Point and at Reedy Point as boundary conditions (curves obtained from fig. 12 of "Tides and Currents in Chesapeake and Delaware Canal," an unpublished Philadelphia District memorandum, 1939; see footnote, page 9).

107. Test 1 was for the 27- by 250-ft main channel (branch canal not considered) and a constant roughness coefficient of 0.021 throughout the canal. Several tidal cycles were run to determine the time required for the effects of inaccuracies in the initial condition estimates to disappear. Study of the results showed that the effect of initial condition errors was completely eliminated (to the last decimal place) prior to the end of the first tidal cycle and for practical purposes was negligible after the first 4 to 5 hr. This would, of course, vary depending upon how close the original estimate was to the true flow conditions. However, in all later tests, these oscillations continued to die out in approximately 4 to 5 hr. Net flow for the conditions imposed in test 1 was about 2580 cfs eastward (toward Reedy Point); net flow is defined as volume of flow eastward minus volume of flow westward divided by the tidal cycle time. Test 2 was identical with test 1 except for the roughness coefficient being increased to 0.025. This increase in roughness reduced the net flow to about 1990 cfs eastward. Test 3 was for the 35- by 450-ft channel and a constant roughness

coefficient of 0.025. For the enlarged section, net flow increased by a factor of about 2.85 to 5680 cfs.

108. One other computation was made with idealized channel sections. Test 4 was similar to test 1 except that in this test the branch canal was considered. Dimensions used for the branch canal were 8 ft deep by 50 ft wide. The Reedy Point tide was also used at Delaware City in this computation. Net flow in the canal under these conditions was about 2590 cfs which compares with about 2580 cfs when the branch canal was not considered. Results of this test suggested that although consideration of the branch canal results in a measurable effect on flow conditions near the Reedy Point end of the canal, its effects on net flow through the canal is negligible. This situation was explored further during later verification tests.

109. After geometric data were developed for the 27-ft channel as it existed in 1938-39, one other test was made with the mean tide curves prior to beginning more basic verification tests. Test 5 was identical with test 1 except that the geometric data for the irregular canal was used rather than the idealized cross sections. Net flow under these conditions was about 2400 cfs, a decrease of about 180 cfs from the net flow in test 1. Results of this test provide an order of magnitude indication of errors that might result from errors in schematization.

Verification of 1938 Field Data

110. A review of the five sets of field data collected in 1938 indicated that no one set approximated mean conditions at both ends of the canal so there was no clear-cut choice of data to use in the verification. Therefore, two sets of field data, 6-7 July 1938 and 7-8 June 1938, were worked up and used in verification efforts. The Courthouse Point and Reedy Point tide curves were used as boundary conditions for the computations. The observed water-surface elevation-time curves (hereafter called tide curves) at Chesapeake City Bridge, Summit Bridge, and St. Georges Bridge, and the observed velocity-time curves at Chesapeake City Bridge and Reedy Point Bridge were used to evaluate the

refinement of the verification. The raw field velocity data (which corresponded to the contracted areas at Chesapeake City and Reedy Point Bridges) were reduced by a factor proportional to the area reduction resulting from the bridge piers to make them comparable to the computed velocities. The reduction factor was based on the area ratios at zero elevation as shown in fig. 17 of the referenced Philadelphia District report. For tests that included the branch canal, the tide and velocity curves at Fifth Street Bridge were also used in verification evaluation. No adjustment was made to the velocity data at Fifth Street Bridge since no information was available on possible bridge pier contraction.

111. A number of tests were run to determine the roughness distribution along the canal that would result in the best overall agreement with the field data. The vast majority of these tests did not include the branch canal since its effect was minor and could be evaluated as a last step in the verification. Most tests were made with the 6-7 July 1938 data, but the final changes were made in runs with the 7-8 June 1938 data. Therefore results of test 22 with the 7-8 June 1938 data are presented first. Plate 218 presents the Courthouse Point and Reedy Point tide curves which were used as input data. Observed and computed tide curves at St. Georges Bridge, Summit Bridge, and Chesapeake City Bridge are presented in plates 219-221, respectively. Observed and computed velocity curves at Chesapeake City Bridge and Reedy Point Bridge are shown in plates 222 and 223, respectively. For this set of field data the computation began at 0800 hr on 7 June 1938 and the oscillations resulting from incorrect initial conditions disappeared by 1300 hr. Agreement between field and computed data after 1300 hr on 7 June 1938 is considered to be very good.

112. Test 23 used the same roughness adjustment with the 6-7 July 1938 data. Courthouse Point and Reedy Point tide curves for this set of data are presented in plate 224. Observed and computed tide curves at St. Georges Bridge, Summit Bridge, and Chesapeake City Bridge are shown in plates 225-227. Plates 228 and 229 present the observed and computed velocity curves at Chesapeake City and Reedy Point Bridges. The computation began at 0800 hr on 6 July 1938 and the oscillations

caused by incorrect initial conditions had disappeared by 1200 hr. Again the agreement between field and computed data is quite good. Test 25 was a similar test for the 6-7 July 1938 data with the branch canal included. Data from the Delaware hydraulic model indicated a small time lag between Reedy Point and Delaware City, so in this test the input tide curve at Delaware City was the Reedy Point curve lagged 10 min. Results from this test are plotted as dots in the plates referenced earlier in this paragraph. Elevations at St. Georges Bridge differed slightly from test 23 during portions of the tidal cycles, and velocities at Reedy Point Bridge as expected were lowered as much as 0.1 fps. However, as in the preliminary computations, consideration of the branch canal had a negligible effect on flow conditions at the Chesapeake City end of the canal. Observed and computed tide and velocity curves at Fifth Street Bridge on the branch canal are presented in plates 230 and 231, respectively. Agreement between the tide curves is quite good, but substantial phase and magnitude differences are evident on the velocity plot. In all probability, these differences are due to small deviations between the lagged Reedy Point tide curve used as input at Delaware City and the true curve at this point during the test period. No effort was made to improve this agreement since flow conditions in the branch canal have a negligible effect on the basic question of net flow through the canal. This was again confirmed by computing net flow for the tidal cycle on 7 July using the computed information from tests 23 and 25. The values for the two tests differed by about 20 cfs with the net flow being about 6240 cfs.

Computations for Mean Tides

113. The roughness adjustment used in the final verification tests (tests 22, 23, and 25) was used to compute flow conditions in the 27-ft canal when mean tide curves were imposed at Courthouse Point and at Reedy Point (test 24); the mean tide curves are shown in plate 232. A time-averaged difference between the two curves shows an average ΔH of 0.26 ft from Courthouse Point to Reedy Point. Computed tide curves

at St. Georges Bridge, Summit Bridge, and Chesapeake City Bridge are presented in plates 233-235. Mean high and low waters obtained from table 2 of the referenced report are also plotted at the appropriate times for comparison. Computed and derived (figs. 13-15 of referenced report) velocity curves at Chesapeake City Bridge and Reedy Point Bridge are plotted in plates 236 and 237. Test 24 yielded a net flow of about 2050 cfs eastward.

114. Test 27 was a similar calculation for the enlarged channel. Geometric data for the irregular 35- by 450-ft channel were used. Two assumptions are required in setting up the computation: first, enlargement of the canal does not change the mean tide curves at Courthouse Point and at Reedy Point; second the roughness adjustment developed for the 27-ft channel is still appropriate after the channel enlargement is completed. Computed discharge curves at Chesapeake City Bridge for the 27-ft channel (test 24) and the 35-ft channel (test 27) are plotted in plate 238. Net flow for test 27 was about 5460 cfs eastward indicating that the channel enlargement increased net flow by a factor of 2.66.

Discussion of Results

115. The net flow computed for mean tide conditions with the 27-ft channel (test 24) was about 2050 cfs or approximately double the net flow derived for these conditions in the referenced Philadelphia District report. Therefore, it seems appropriate to elaborate on factors affecting the evaluation of net flow. The sensitivity of the computed net flow to changes in the various input parameters will be discussed to illustrate the type of change that would be required to reduce the computed net flow by 1000 cfs.

- a. Schematization. Development of appropriate geometric data for each computation reach is certainly not a task that can be done precisely. In fact, the one source of information on cross-sectional areas in the referenced report (fig. 17, which shows areas at zero elevation at various stations along the canal) suggests that the representative sections used in this study were, in some reaches, somewhat larger than the sections at the points of measurement in the basic field study. This does not seem illogical and no adjustment was made except at Chesapeake City Bridge where the section was reduced to make velocities comparable. The developed section at Reedy Point Bridge appeared to be slightly large also, but no adjustment was made there. In spite of the approximations necessary in the schematization process, it is not believed that this process introduces any appreciable error in the computed net flow. This is substantiated by the results of test 5 which showed a change of only 180 cfs in net flow when the channel geometry was changed from idealized 27- by 250-ft sections to the irregular 27-ft channel.

b. Initial conditions. Initial flow conditions in the canal must be estimated to begin the computation. Computations using a repetitive mean tide have shown conclusively that the effect of errors in the estimated initial conditions dies out as the computation advances in time. Consequently, no error is introduced to the net flow from this input parameter.

c. Roughness coefficient. Tide and current variations at the intermediate canal stations can, of course, be materially changed by changes in roughness distribution along the canal. A number of tests were required to determine an acceptable roughness adjustment. It is conceivable that additional tests would produce some further refinement in this adjustment. However, the effect of the additional refinement on the computed net flow would be minor since net flow is more dependent on overall resistance in the canal than on minor adjustments at specific locations in the canal.

d. Boundary conditions. All computations discussed in this report used as boundary conditions the reported tide records at Courthouse Point and Reedy Point. These tide records were input to the computation exactly as shown in the field measurements and in the mean tide curves, so no error was introduced to the computation from this input parameter. However, it should be noted that a small error in establishing the zero elevation of either of these gages in the basic field studies would have a very significant effect on the computed flow conditions. For example, computations have been made with the Courthouse Point mean tide record lowered 0.2 ft and 0.1 ft to show the effect of such changes on net flow. Pertinent results are presented in the following tabulation:

	27-ft Channel			35-ft Channel	
	Mean Tide Test 24	C. Pt. Tide Lowered 0.2 ft Test 26	C. Pt. Tide Lowered 0.1 ft Test 28	Mean Tide Test 27	C. Pt. Tide Lowered 0.1 ft Test 30
Duration of eastward flow,* hr	6.51	6.02	6.27	6.53	6.28
Maximum eastward flow,* cfs	28,820	27,560	28,200	64,300	62,820
Duration of westward flow,* hr	5.91	6.40	6.15	5.89	6.14
Maximum westward flow,* cfs	26,270	27,870	27,110	53,420	55,660
Head differential ΔH ,** ft	0.26	0.06	0.16	0.26	0.16
Net flow:					
Eastward, cfs	2,050		880	5,460	2,800
Westward, cfs		290			

* At Chesapeake City Bridge.

** ΔH is time averaged difference between mean tide curves at Courthouse Point and Reedy Point.

From these results it is quite evident that net flow is very sensitive to changes of this type. Test 28 with the Courthouse Point mean tide record lowered 0.1 ft reduced the net flow to about 880 cfs eastward. Test 30 for the same tide condition and the enlarged channel showed a net flow of about 2800 cfs. One additional test was run to evaluate the effect of such a change on the agreement between computed results and field data. Test 29 was a rerun of the verification test for the 7-8 June 1938 field data (test 22) with the Courthouse Point tide record lowered 0.1 ft. Plates 239-241 show computed and field tide curves at St. Georges Bridge, Summit Bridge, and Chesapeake City Bridge, and plates 242 and 243 are plots of computed and measured velocities at Chesapeake City and Reedy Point Bridges. Comparison of these plots with those for test 22 (plates 218-223) shows no detrimental change in overall agreement; in fact, the agreement between measured and computed current velocities was improved by this adjustment in terms of both magnitude of velocity and duration of flow.

_e._ _Branch canal._ Consideration of the branch canal in the computations has a measurable effect on flow conditions in the Reedy Point end of the canal. However, several tests have shown that it has a negligible effect on flow conditions in the Chesapeake City end of the canal and on net flow. Results of two different tests that support this conclusion have been mentioned earlier in this report. Tests 1 and 4 were computations that differed only by the inclusion of the branch canal in test 4. In test 4, the Reedy Point tide was also used at the Delaware City end of the branch canal. Net flows computed from these tests differed by about 10 cfs when net flow was about 2580 cfs. Verification tests 23 and 25 for the 6-7 July 1938 field data also were similar except for inclusion of the branch canal in test 25. Since no measured tide curve was available for Delaware City, and the Delaware physical model had indicated some lag between Reedy Point and Delaware City, this test used the Reedy Point tide curve lagged 10 min. For the tidal cycle on 7 July 1938, the net flow for the two tests differed about 20 cfs when the net flow was about 6240 cfs. These results support the conclusion that the branch canal has a negligible effect on net flow through the main canal.

f. Density currents. As mentioned at the beginning of this report, the unsteady flow equations used in this study are based on the assumption of a constant fluid density throughout the computation zone. This, of course, is not a valid assumption since it is known that the salinity concentration at the Reedy Point end of the canal is normally considerably higher than that at the Courthouse Point end of the canal. The effect of possible density currents will be included in results of planned physical model tests. However, some speculation about their impact is appropriate here. It is apparent that the normal situation (high salinity at Reedy Point and low salinity at Courthouse Point) will tend to reduce an eastward net flow. It is not possible at this time to compute the precise effect of variable fluid density along the canal, but very rough calculations suggest that it may change the effective ΔH by several hundredths of a foot.

Summary and Conclusions

116. The computer study reported herein indicates that mean tide conditions at Courthouse Point and at Reedy Point (as presented in the referenced Philadelphia District report) result in a net flow of about 2050 cfs eastward through the 27-ft channel (test 24). A computation for the enlarged 35-ft channel, assuming that the mean tide curves at Courthouse Point and at Reedy Point do not change and that the roughness

adjustment developed for the 27-ft channel is still appropriate, results in a net flow of 5460 cfs eastward (test 27). These two tests and others discussed in this report are briefly described in table 4.

117. Since the computed net flow for the 27-ft channel is approximately double that derived in the original Philadelphia District study, a discussion of various factors that affect net flow was presented to provide a basis for evaluating the accuracy of the computed results. In this discussion, most factors are ruled out as having the potential to introduce significant error to the computed net flow. However, it is demonstrated that small changes in ΔH between Courthouse Point and Reedy Point result in relatively large changes in net flow through the canal. For example, if the Courthouse Point mean tide curve is lowered 0.1 ft, the computed net flows for the 27- and 35-ft channels are reduced to about 880 cfs and 2800 cfs, respectively. These computations were made to show the type of adjustment to the basic input data which would be required to bring the results of the computer study and the original Philadelphia District study into agreement. The same adjustment was made to the Courthouse Point tide record for the 7-8 June 1938 field data and a computation (test 29) made to determine how the adjustment affected the agreement between computed and measured tide and velocity data at intermediate stations along the canal. Agreement, if anything, was slightly improved as shown in plates 239-243 (compare with plates 218-223 for test 22).

118. Density currents, which are ignored in the computations reported herein, would have an effect similar to the adjustment discussed above. The higher salinity concentrations at the Delaware end of the canal make it apparent that fluid density will vary along the canal. No precise estimate of the effect of this phenomenon can be given, but very rough calculations suggest that it may reduce the effective ΔH by several hundredths of a foot. This would not account for all the change in ΔH required to bring the computed net flow into agreement with the value given in the original Philadelphia District study, but it would bring the figures considerably closer together. Results of the physical model study should provide more information on this question.

119. One other point should be made about the effect of small changes in ΔH on net flow through the canal to keep the study in perspective. Since the computed net flow is tied directly to the Courthouse Point and Reedy Point tide records, a small field error in establishing the zero elevation of either of these gages could easily account for the net flow difference discussed above. The supposition is made here that this type of error in basic field data could have existed without affecting the net flow computation in the original study since that study was based on relating velocity to difference in stage between Courthouse Point and Reedy Point and the derived relation could have compensated for the error.

120. The following observations are made in conclusion:

a. For the mean tide curves used herein, the net flow with a 27-ft channel would be something less than the 2050 cfs computed for test 24 because of the anticipated density current effects. Because of the relatively small average water-surface differential that exists for mean tide conditions (ΔH = 0.26 ft), the density current effect can cause a relatively large percentage change in net flow. For larger ΔH's the percentage influence of density currents would, of course, be much less. Computations reported herein indicate that net flow for mean tide conditions with the 35-ft channel will be about 2.6 to 3.2 times greater than for the 27-ft channel.

b. Net flow computations by the procedure used in this study are very sensitive to one common type of field error; i.e., the establishment of the zero elevation of the tide gages at Courthouse Point and at Reedy Point.

c. This study has been directed primarily toward determining the net flow that would exist if the long-term mean tides occur at Courthouse Point and at Reedy Point. It also should be noted that net flow is highly variable from cycle to cycle. No attempt has been made to establish numerical values, but a cursory inspection of the roughly 10 cycles shown in figs. 7-9 of the referenced report reveals that the net flow varies from several thousand cubic feet per second westward in some cycles to several thousands cubic feet per second eastward in other cycles.

PART VI: ANALYTICAL STUDY OF SALINITY INTRUSION

Introduction

121. As a part of the total study on physical and environmental effects to be expected by enlarging the C&D Canal, a study was conducted of the probable changes to be expected in salinities in the canal. The study included a review of previous work on salinity distributions in estuaries and an assessment of the applicability of previous analytical and mathematical models to the salinity distribution problem in the canal. Special consideration was given to the need for a predictive capability to determine salinity changes resulting from the canal enlargement. This portion of the investigation was initiated as a means of complementing the other study phases as described herein. However, the methodology to be employed was not clearly understood at the outset. It was realized, for example, that the analytical salinity intrusion portion of the study would necessarily be exploratory and developmental in character. In contrast to this study, the physical modeling methodology is well developed and the existing mathematical model to study tides, currents, and discharges has been previously developed and implemented on the accessible WES computer. Further, the unsteady-flow mathematical model had been employed on several prior studies.

122. The primary purpose of the study was to investigate possible salinity distribution effects resulting from the expected increase in net eastward (toward Delaware River) flow following the channel enlargement. An additional factor to be considered was the probable increase in salinity dispersion and mixing induced by the channel size and tidal velocity increases. A secondary goal of the project was to further the understanding of estuarine salinity distribution and to improve the analytical capability for predicting the effects of physical changes in estuarine environments.

Review of Developed Models

123. As a part of the investigation, a study was made of literature relative to salinity intrusion in estuaries. Particular attention

was paid to analytical and numerical solution approaches that could be applied to the C&D Canal problem. It was found that the analytical approaches usually involved rather drastic simplifications of ocean and upstream boundary conditions and usually assumed steady freshwater or net estuary flows. Some numerical finite-difference models were being applied to water quality and salinity problems, but these were developed for special estuary situations and flow conditions or were too complicated for possible implementation. The following summary of this study phase is given as being more representative of the sources of information rather than trying to be complete.

124. The state-of-knowledge relative to salinity intrusion and possible methods of analysis has been well summarized by Ippen[2] and in a Committee on Tidal Hydraulics Report.[3] The analytical solution of the one-dimensional estuarine convective-diffusion salinity distribution equation has been given by Ippen and Harleman[4] and checked against the WES flume model results. The analytical solution is for simplified estuarine boundary and steady net velocity conditions and does not take into account salinity variations at both estuary ends. The depth variation of salinities and currents was summarized in a subsequent report[5] which showed the complexity of specifying dispersion coefficients and the effects of stratification. Dispersion in estuaries and additional closed form solutions is given in the series of articles edited by Lauff.[6]

125. Kent[7] was one of the first to apply finite-difference techniques to constitute transport problems in estuaries. The methods developed were later applied by Pritchard[8] on the Delaware River and Boicourt[9] on the Upper Chesapeake Bay. Recently, a number of mathematical models have been based on finite-difference approximations to the convective-diffusion equations of motion for various water-quality constituents. The main aspects and state-of-the-art of estuarine modeling has been summarized[10] in a collected series of chapters by various authors. One example of these models include the "box" models developed by the Federal Water Pollution Control Administration (later EPA),[11] which has been applied to several estuaries. Another representative

model is one developed in Holland.[12] The latter model is probably the first to study the problem of coupling of the one-dimensional tidal hydraulic equations and the salinity equation. The coupled system of equations includes the longitudinal density gradient effect due to salinity differences in the momentum equation. An example of a comprehensive mathematical model is one recently developed by Fischer.[13] The model includes both one- and two-dimensional systems of coupled flow and transport equations. Running this kind of comprehensive model requires considerable computer core memory and running time costs. The logical continuation of the work at MIT and Delft is the development and refinement of the coupled tidal flow salinity model by Thatcher and Harleman.[14] The computer memory requirement for this model is about 100K bytes in active storage.

Numerical Model

Convective-diffusion equation

126. The distribution of salinity as well as pollutants in well-mixed (no density gradients) estuaries is known to be governed by a system of turbulent convective-diffusion equations analogous to Fick's diffusion laws.[2] The one-dimensional constant area form of this equation is given as

$$\frac{\partial s}{\partial t} + U_{(x,t)} \frac{\partial s}{\partial x} = \frac{\partial}{\partial x} \left(E \frac{\partial s}{\partial x} \right) \qquad (1)$$

where

s = salinity in parts per thousands or pollutant concentration

t = time

$U_{(x,t)}$ = fluid velocity in the $+x$ direction, a function of x,t

E = dispersion coefficient, in general a function of x

Fig. 12 is a definition sketch to show how this partial difference equation applies to a constant area estuary. The one-dimensional salinity representation should be readily applicable to the C&D Canal which is uniform in cross section.

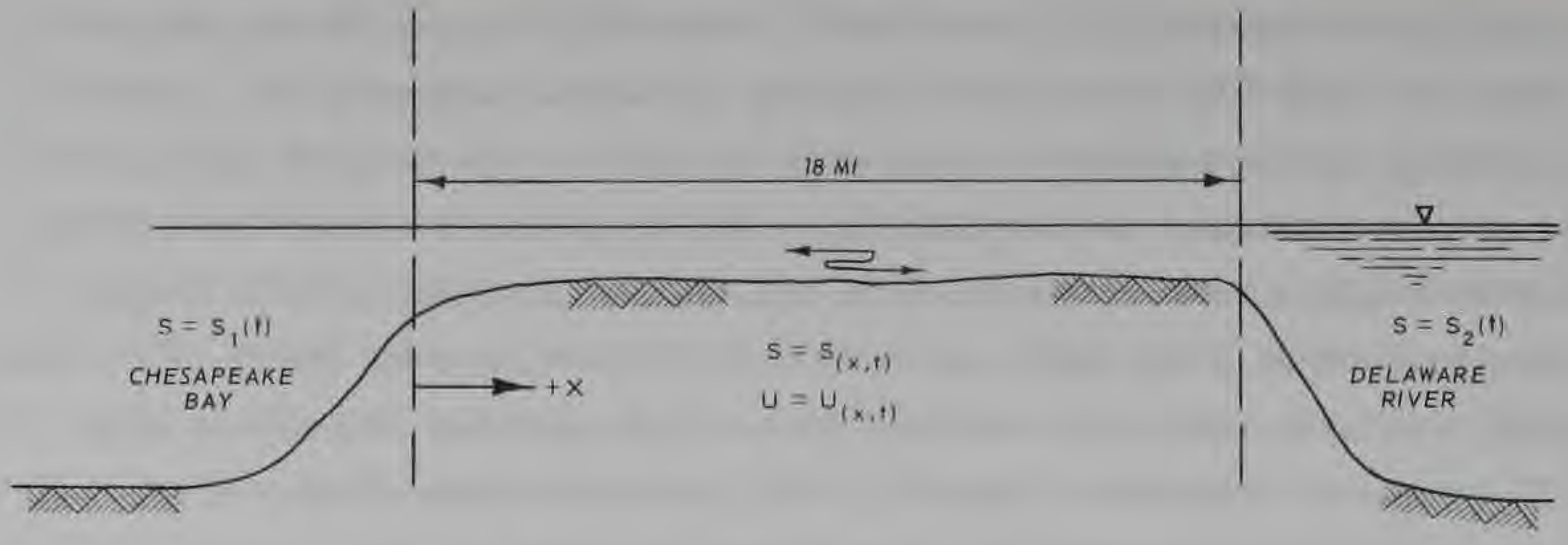

Fig. 12. Schematic of estuary

127. This partial differential equation is of the parabolic type, similar to the convective heat flow equations. Several closed-form solutions are given for constant velocity (i.e. $U \neq U_{x,t}$) in reference 2. In addition, more complicated cases are presented in reference 15. In general, closed-form solutions simply are not possible or are very complicated when the boundary or initial conditions and/or the function U relation becomes more complex. In such cases, it seems much more preferable to seek numerical solutions by means of finite-difference approximation.

Computational scheme

128. Solution of partial difference equations by numerical means can be found either by explicit or implicit methods. In general, the implicit methods require considerably more effort due to the need to solve a set of simultaneous equations (tridiagonal matrix) at each time step. As a first step in the solution of the problem, an explicit technique was employed. The formulation used is

$$\frac{S_i^{n+1} - S_i^n}{\Delta t} + U\left(\frac{S_{i+1}^n - S_{i-1}^n}{2\Delta x}\right) = E\left(\frac{S_{i+1}^n - 2S_i^n + S_{i-1}^n}{\Delta x^2}\right) \qquad (2)$$

Fig. 13 shows in a schematic way the computational grid. In this equation, both U and E are constants. The assumption of E = constant is probably acceptable for most estuary-type flows, but later a method will be presented to introduce $U = U(t)$ to make the computation more representative of the convective intratidal transport.

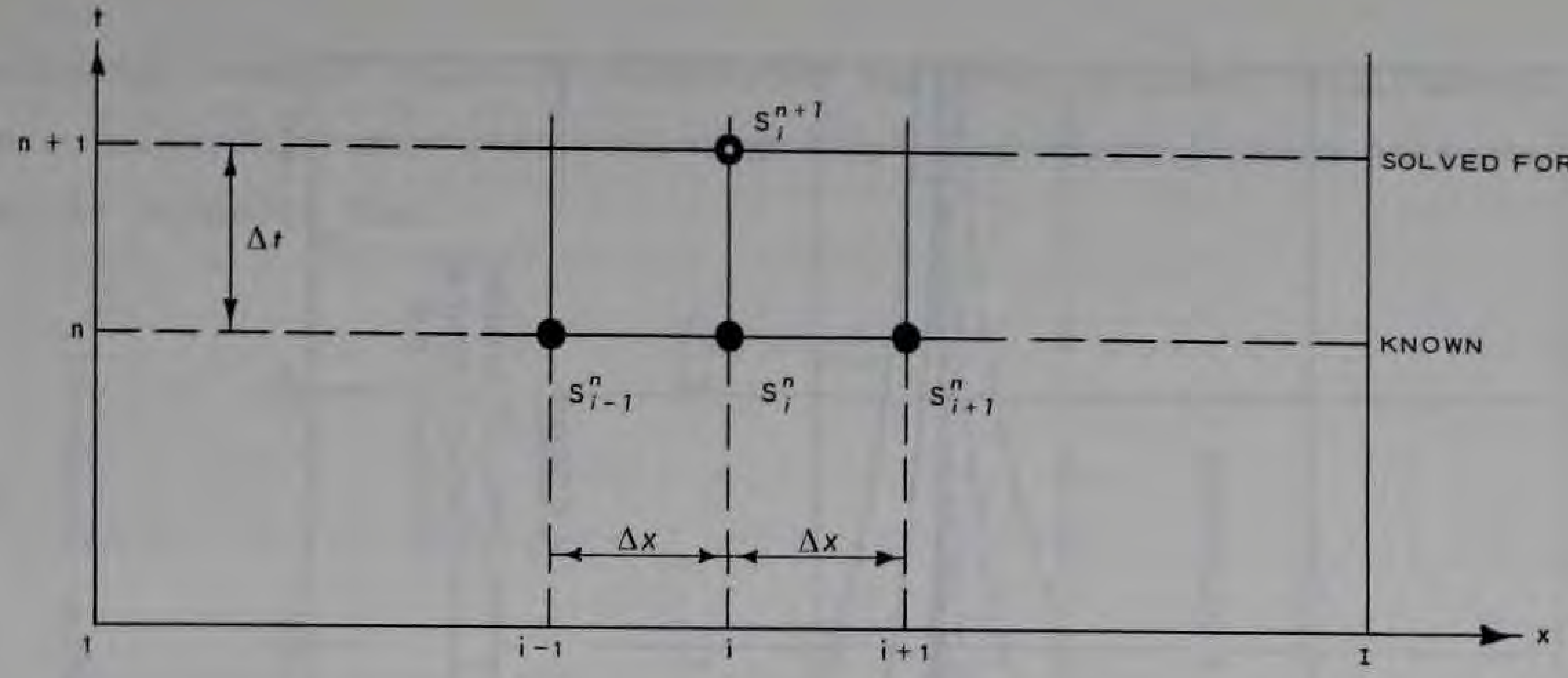

Fig. 13. Explicit scheme

129. The finite-difference equation 2 can be reduced to

$$S_i^{n+1} = S_i^n + A\left(S_{i+1}^n - 2S_i^n + S_{i-1}^n\right) - B\left(S_{i+1}^n - S_{i-1}^n\right) \tag{3}$$

where

$A = E\Delta t/\Delta x^2$

$B = U\Delta t/2\Delta x$

<u>Stability and convergence</u>

130. Explicit schemes of computation for parabolic equations are in general subject to the following two stability conditions:[16]

$$\frac{E\Delta t}{\Delta x^2} \lesssim \frac{1}{2} \tag{4}$$

and

$$\frac{U\Delta t}{\Delta x} \lesssim 1 \tag{5}$$

The satisfaction of both of these stability requirements may, in some cases, be difficult. Thus implicit schemes, which are unconditionally stable, are often preferred for computations.

131. A recent report by Leendertse,[17] however, indicates that there are error penalties to be paid by both computational methods. Fig. 14 gives a copy of a graph based on an error analysis. Of particular importance is the fact that good definition is required to

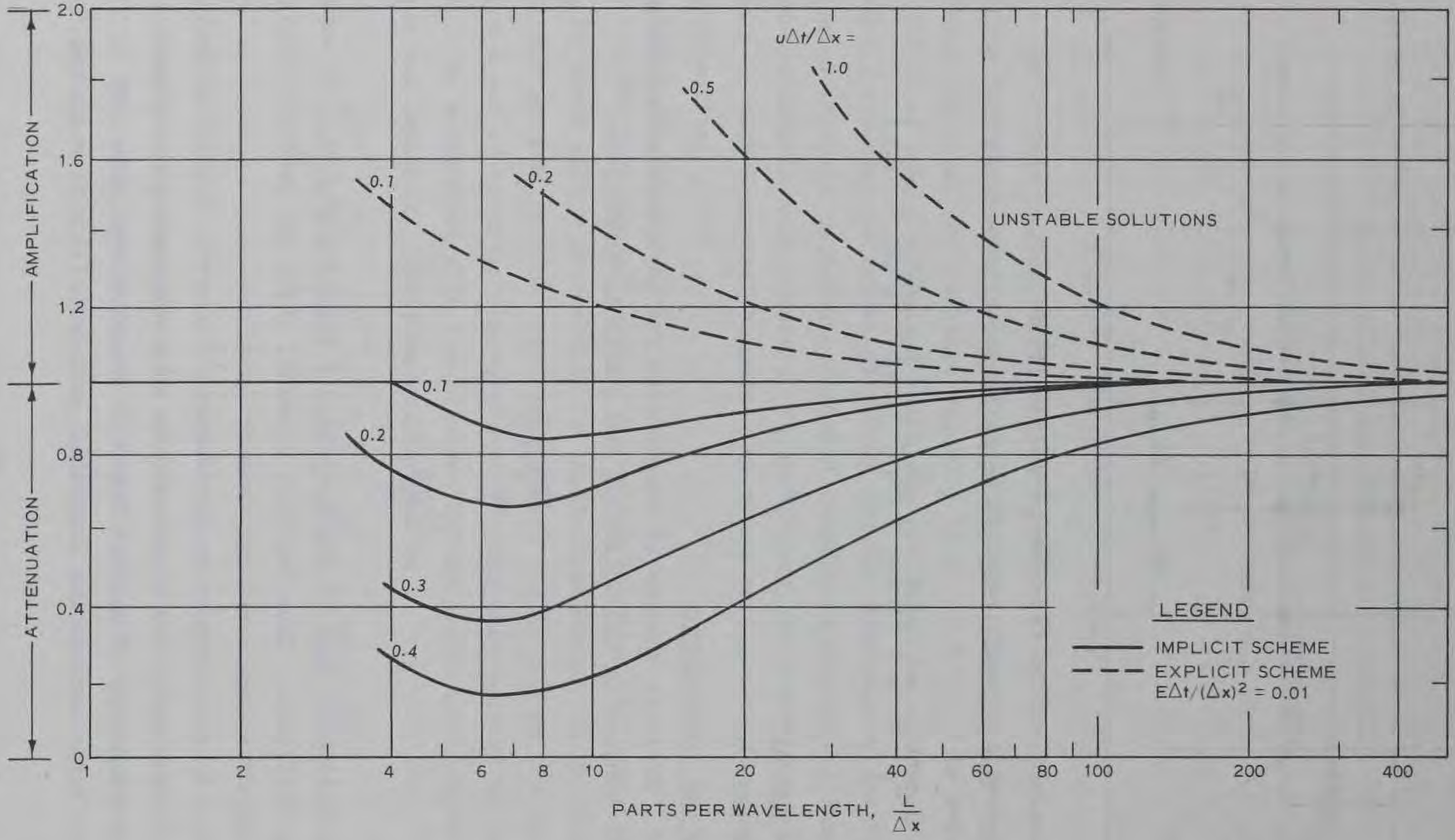

Fig. 14. Wave deformation factor of explicit and implicit schemes, after Leendertse[17]

accurately compute salinity variations and that accuracy requirements are considerably more stringent than equations 4 and 5 would indicate. Fig. 14 suggests that

$$\frac{U\Delta t}{\Delta x} \approx 0.1 \tag{6}$$

and

$$\frac{L}{\Delta x} \approx 10\text{-}20 \tag{7}$$

would be required for good salinity variation definition. The computations were planned and executed so as to keep both stability requirements (equations 4 and 5) to a very low level as suggested by fig. 14.

Tidal velocity and salinity boundary conditions

132. In general, both the estuary velocity and dispersion coefficient are functions of the longitudinal coordinate and time. It is possible to compute the tidal velocity $U_{(x,t)}$ from the full system of the tidal hydraulic equations as was done in another section of this report. In fact, as shown by Thatcher,[14] it is possible to compute the tidal hydraulics and salinity in a coupled manner and take into account the longitudinal density effect. For purposes of this report, the canal velocity was simulated by assuming a sinusoidally varying velocity of the form

$$U_t = U_{net} + U_{max} \sin \frac{2\pi t}{T} \tag{8}$$

where

U_{net} = net canal flow velocity, fps
U_{max} = maximum tidal velocity, fps
T = tidal period, 12.42 hr

This method of velocity simulation is patterned after the method used by Harleman.[18] In a similar manner, the varying salinity boundary conditions at the two canal ends can be simulated.

Dispersion coefficients

133. One of the principal problems in numerical simulation of salinity and pollutant distributions is in specifying the dispersion coefficient. This problem is especially critical for the C&D Canal study where large-scale changes in canal geometry is the principal study problem. The fundamental aspects of diffusion and dispersion have been presented[19-21] with suggestions for computations based on the Taylor type of dispersion. Field data, however, indicate large variations in dispersion coefficients. For purposes of this study, a dispersion coefficient of 10 square miles/day was selected as being representative based on published information. In a similar manner as given by Pritchard,[22] it is possible to show that the dispersion coefficient will be increased by canal enlargement. If the Taylor-type dispersion relation is assumed to be representative of the open channel dispersive process,[21] the ratio of dispersion coefficients between the 35- and 27-ft channel is

$$\begin{aligned} E_R &= U_R R_R^{5/6} \\ &= R_R^{3/2} = 1.68 \end{aligned} \tag{9}$$

The enlarged canal dispersion coefficient will, therefore, be increased from 10 square miles/day to about 16.8 square miles/day.

Computer programs

134. The computer program computed to a steady salinity value in a one-dimensional estuary with constant net flows and dispersion coefficients. Both estuary and boundary conditions were required to be steady with time.

135. A later version of the computer program allowed time varying end boundary conditions as well as time varying velocity ($U = U_t$). This was done by means of two files for SALINITY and VELOCITY. These files can either be generated by means of analytical expressions (sine functions) or from field or model data.

Example computations

136. Numerical experiments were run using the original program with a variety of values of U, E, Δx, and Δt. Fig. 15 presents a comparison of computations with two analytical solutions given in reference 15 for a finite as well as an infinitely long estuary. Both comparisons indicate that the computer program achieves acceptable accuracy.

137. Fig. 16 gives results for steady-state flows ($U = \text{const}$) and after salinity distribution had reached steady state with constant salinity boundary conditions. Eastward net flows tend to push the salinities toward the Delaware River end and westward flows toward the Chesapeake Bay end. The effect of the increased channel size (from 27 to 35 ft) is to increase the discharges from a typical value of 1000 to 2700 cfs. This increase in net flows, however, is offset by the increased dispersion and mixing in the canal. The net effect is to increase canal salinities for the expected predominant eastward net flow, if the steady flow and salinity boundary conditions are applicable.

138. The salinity boundary and canal velocity simulation conditions are shown in fig. 17. The phasing and magnitude of velocities and Delaware River source salinity were obtained by means of hydraulic model observations. The results of computations after numerical stability had been reached are shown in fig. 18. The computations indicate a reverse salinity gradient during part of the tidal cycle near the canal entrance due to the unusual phase relations between salinity variation and canal velocities.

Summary of Results

139. The literature review phase of this study showed that analytical type solutions would be very complicated for the governing convective-diffusion equation. A numerical explicit finite-difference solution of the equation was used, therefore, to simulate salinity distributions. The investigation showed that a relatively simple model of the salinity distributions can be used to study changes to be expected

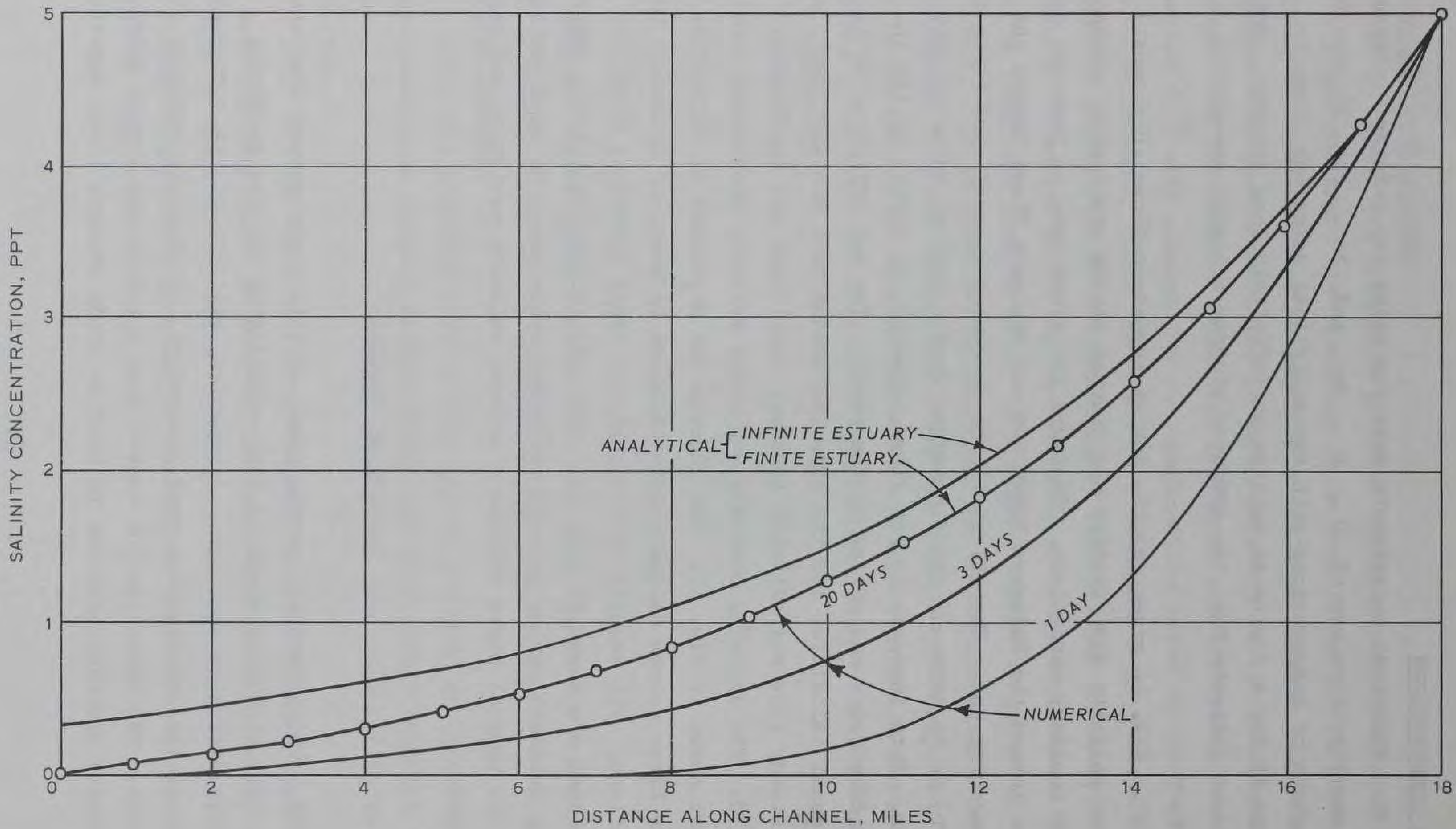

Fig. 15. Comparison of numerical and analytical solutions

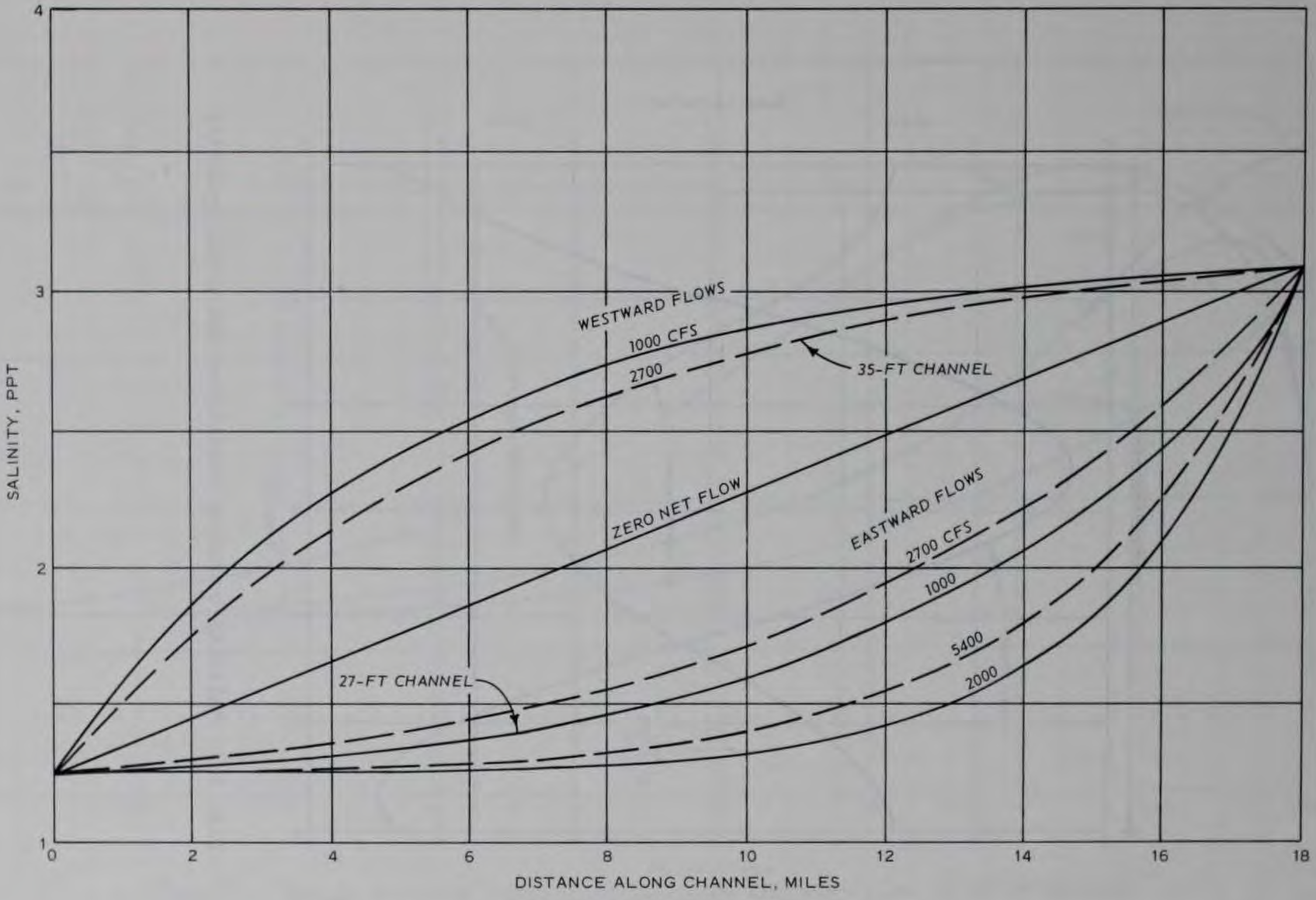

Fig. 16. Average salinities, steady-state model

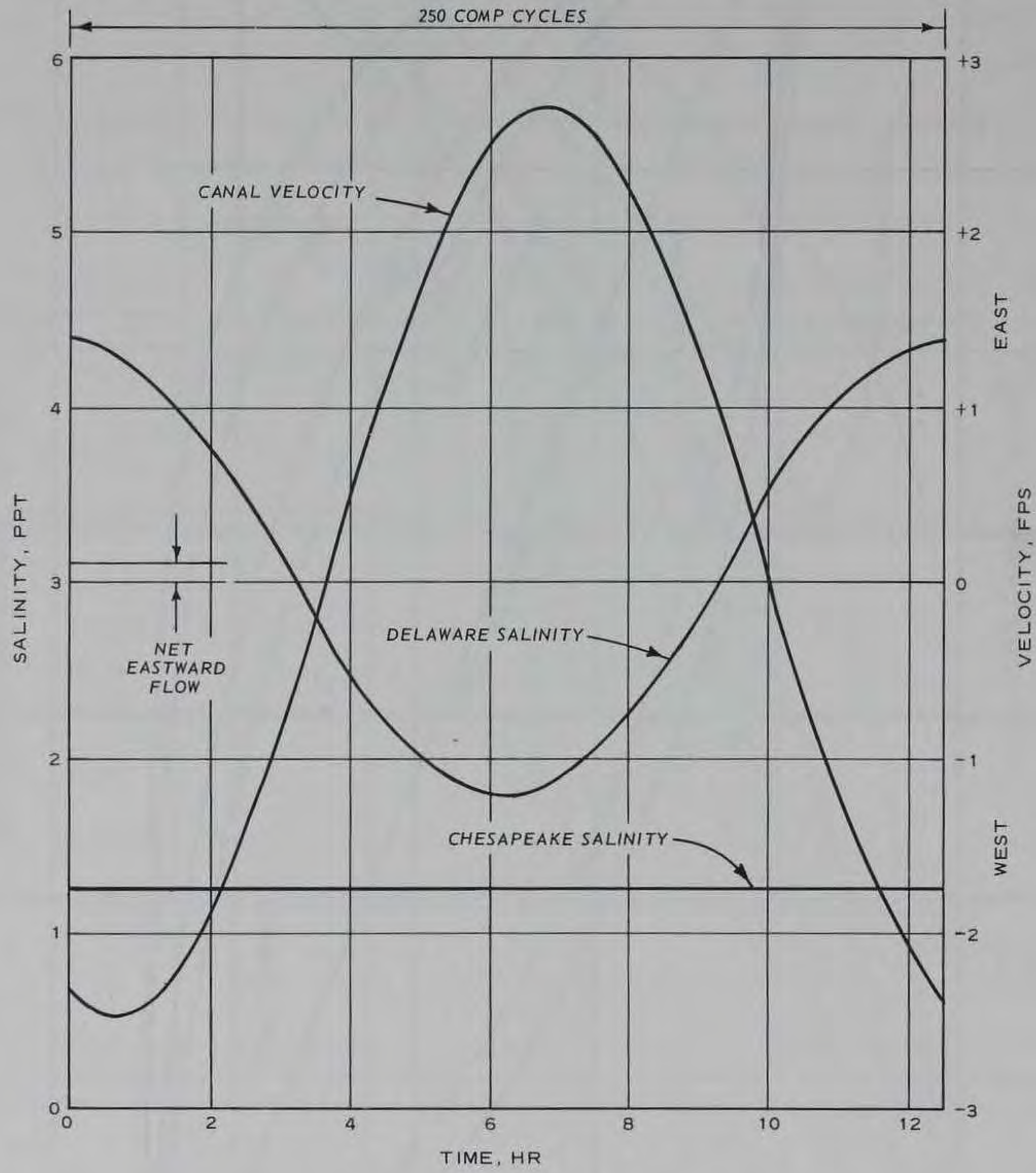

Fig. 17. Salinity boundary conditions and canal velocity

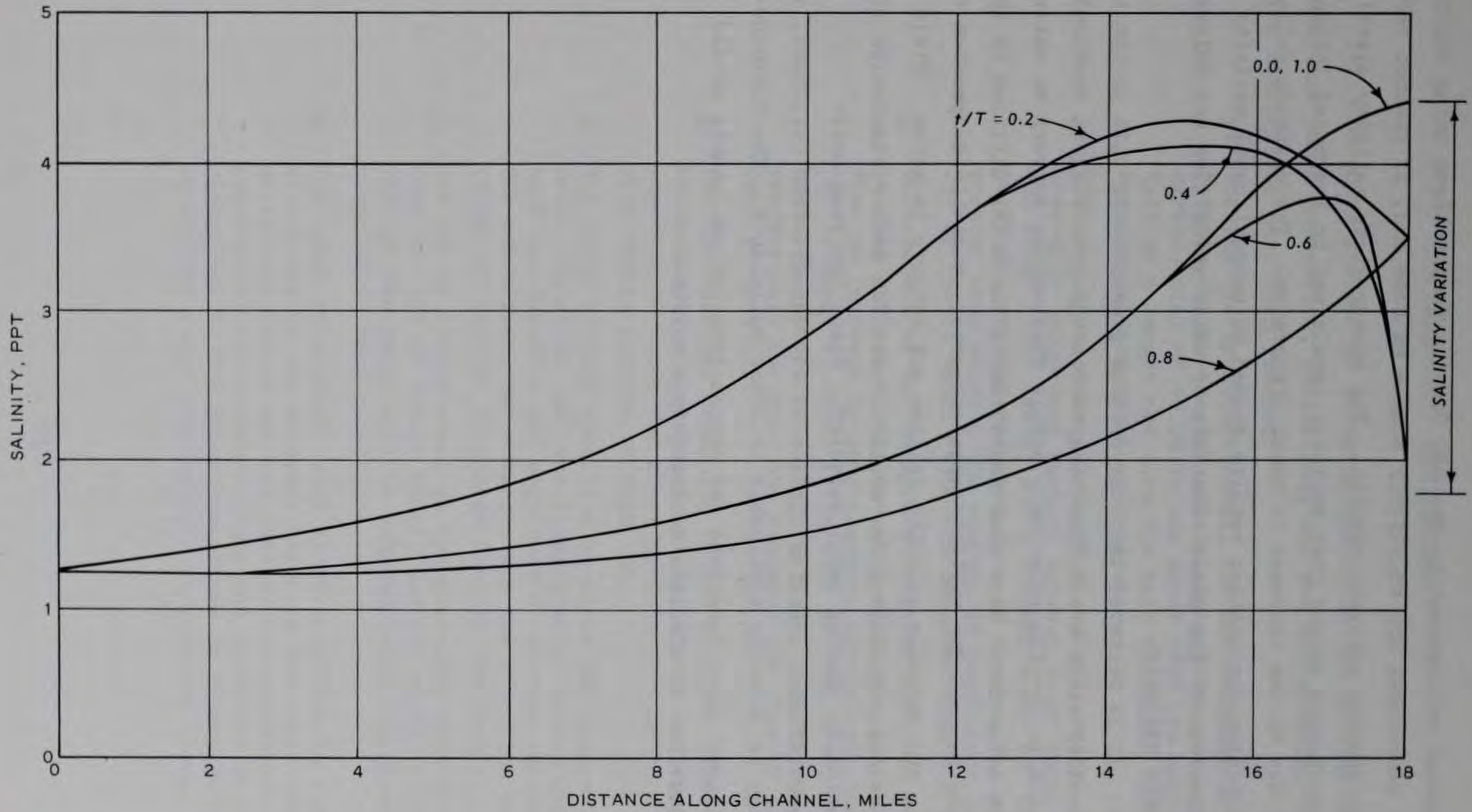

Fig. 18. Cyclic salinity variation; 1000-cfs eastward flow in 27-ft channel

due to channel enlargement in the C&D Canal. Computations using explicit numerical procedures are relatively simple to code and, if planned carefully, can provide accurate results. The steady-state salinity distribution computation showed that salinity levels may be increased through the canal due to the increase in canal dispersion. The unsteady salinity distribution computation results showed an unusual canal salinity distribution due to the phase relations of canal velocities and Delaware River source salinity.

140. It is believed that the results presented in this preliminary and exploratory study are sufficiently encouraging to suggest continuing the approach to provide relatively simple first-order answers to salinity changes in estuaries. With some improvement, the model utilized in this study could be used for variable area estuaries, variable dispersion coefficient, and variable velocity in time and estuary location. Field or computed velocity distributions could be used for better simulation of the intratidally varying canal velocity. Since the same basic convective-diffusion equation applies to any conservative pollutant, the methodology is directly applicable to other pollutants. The introduction of linear decay functions for nonconservative pollutants should also be possible to simulate decaying type pollutants.

PART VII: CONCLUSIONS

141. Based on results of tests conducted in the physical model for the various canal geometries, salinities, and mtl differences, the following conclusions have been reached:

- a. For the 27- by 250-ft canal, the net exchange of water between Chesapeake Bay and Delaware River for an mtl differential of +0.28 ft was about 1600 cfs eastward. This is a larger net flow for this condition than had been calculated previously by others.
- b. With the canal enlarged to 35 by 450 ft, except for the presently unimproved section between Reedy Point Bridge and Reedy Point Jetty, and a roughly mean ΔH of +0.23 ft, the net eastward flow is about 4.8 times greater than existed for comparable conditions in the 27- by 250-ft canal (4300 cfs compared with 900 cfs).
- c. Enlargement of the unimproved section referred to in b to full project dimensions will cause the net eastward flow to increase by approximately 160 percent when the ΔH is about +0.23 ft (from 4300 to 7000 cfs). For mean ΔH conditions ($\Delta H = +0.30$ ft) completion of the project will increase the eastward net flow by about 2000 to 3000 cfs.
- d. For the enlarged canal (35 by 450 ft), net flows up to about 40,000 cfs eastward and 25,000 cfs westward can be expected to occur for short periods of time in a normal year during periods of high ΔH .
- e. The canal is very sensitive to minor mtl changes. A small change in ΔH can significantly affect the tide, both the duration and magnitude of current velocities, the salinities, and subsequently the direction and volume of the net discharge through the canal.
- f. The 35- by 450-ft canal is hydraulically more efficient than the 27- by 250-ft canal, and net transport of water through the canal will be substantially increased for comparative head conditions.
- g. The canal enlargement will cause increases in tidal elevations in the Delaware River in the reach between Artificial Island and New Castle when conditions favor substantial net eastward flows and increases in tidal elevations in Elk River downstream to Turkey Point when conditions favor substantial net westward flows.

h. Current velocities in the canal will increase somewhat for comparable head conditions upon completion of the enlargement.

i. Enlargement of the canal tends to make the longitudinal salinity gradient more uniform throughout the canal for comparable flow conditions, and salinities throughout the canal are approximately equal to the source salinity at the end of the canal with the higher mtl.

j. For normal head differences across the enlarged canal (about +0.25 to +0.30 ft), salinities in the Delaware River will not be changed appreciably; however, local salinities (within one tidal excursion of the canal mouth) will be reduced.

k. For large head differences across the canal (on the order of +1.25 ft and -0.80 ft), salinities in the Delaware will be changed appreciably if such conditions persist for appreciable periods of time, which appears to be unlikely. Salinity measurements were made in the model for stable salinity conditions after periods of model operation equivalent to about two months. Because high ΔH periods in the prototype will be transient and of much shorter duration, it is expected that salinity changes in the Delaware River will be much less than those predicted by the steady-state tests in the physical model.

l. The discharge versus ΔH relation shown in plate 46 is sufficiently accurate for reliable determination of gross exchanges of water between Chesapeake Bay and Delaware River over extended periods of time. It has been shown that ΔH is critical and the accuracy of discharge determinations is directly dependent on the accuracy of determining the average ΔH.

142. Based on results of the mathematical model studies for the stated mean tidal conditions, the following conclusions are reached:

a. The net flow with a 27- by 250-ft canal would be somewhat less than 2050 cfs (the computed value minus the density current effects).

b. The net flow with a 35- by 450-ft canal will be about 2.6 to 3.2 times greater than for the 27- by 250-ft canal.

c. Net flows, computed by the procedure used in this study are very sensitive to one common type of field error, i.e. the establishment of the zero elevation of the tide gages at Courthouse Point and at Reedy Point.

d. Like the physical model tests, results of the computer study showed that net flow through the canal is highly sensitive to small variations in ΔH , and the net flows observed in the physical model agreed very closely with those computed for identical canal sections and similar ΔH's .

e. The steady-state salinity distribution computation showed that, due to the increase in canal dispersion, salinity levels may be increased through the canal as a result of the enlargement. The unsteady-state salinity distribution computation showed an unusual salinity distribution due to phase relations of canal velocities and Delaware River source salinity.

PART VIII: RECOMMENDATIONS

143. It is recommended that upon completion of enlargement of the canal, measurements of tides, currents, and salinities be made in the field for comparison with model predictions. A thorough analysis of the results should be made and reported for guidance in similar future situations.

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Table 1

High- and Low-Water Salinities in ppt for Various Head Differences, 27- by 250-ft Canal

Source Salinity: Delaware = 31.00 ppt, Chesapeake = 1.25 ppt

	ΔH = +1.44 ft				ΔH = +0.67 ft				ΔH = +0.28 ft			
	High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
430	24.2	29.6	22.8	24.9	24.4	28.6	22.0	25.0	25.7	28.0	23.7	25.3
350	14.7	23.6	11.4	22.6	15.8	23.2	14.0	21.3	17.6	24.0	14.8	23.4
325	11.2	19.4	8.8	15.3	15.9	21.1	11.8	19.7	15.2	20.0	12.3	21.7
310	9.0	17.6	5.4	16.0	11.8	19.5	9.3	18.2	12.6	20.7	9.6	19.5
295	8.5	16.9	2.6	5.1	11.2	18.8	5.3	7.3	13.0	19.7	6.4	10.8
280	6.2	14.9	1.6	2.6	9.3	14.4	7.2	7.4	9.0	17.3	3.7	8.1
265	4.6	11.6	0.8	1.1	8.0	13.9	2.1	3.7	8.7	14.1	2.6	4.3
250	2.5	7.3	0.7	0.8	4.5	10.5	1.4	1.6	5.8	10.1	1.7	2.0
235	1.4	1.5	0.5	0.5	3.5	4.0	0.6	0.7	4.3	4.9	1.2	1.7
220	0.8	0.8	0.1	0.2	1.5	1.9	0.3	0.3	2.5	2.8	0.6	0.6
205	0.5	0.7	0.1	0.1	1.0	1.0	0.1	0.2	1.4	1.7	0.2	0.3
190	0.4	0.4	0.3	0.2	0.7	0.6	0.1	0.1	0.9	1.2	0.1	0.2
175	0.1	0.1	0.0	0.0	0.3	0.2	0.0	0.0	0.3	0.3	0.0	0.0
160	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.0
145	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
130	0.2	0.2	0.0	0.0	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0
1	1.3	1.3	0.8	0.8	2.2	2.5	1.0	1.1	3.2	3.9	1.6	1.7
3	1.2	1.3	1.3	1.3	2.1	2.6	1.7	1.8	3.4	4.0	2.5	3.3
	Westward		Eastward		Westward		Eastward		Westward		Eastward	
2	1.2	1.2	0.8	0.9	2.4	3.2	1.0	1.2	3.7	4.4	1.6	1.9
A	1.2	1.2	1.2	1.2	1.9	2.8	1.2	1.2	4.1	4.3	1.4	2.2
8	1.3	1.3	1.3	1.3	1.3	2.0	1.3	1.2	2.0	3.8	1.4	1.6
B	1.3	1.3	1.3	1.3	1.2	1.3	1.2	1.2	1.4	1.6	1.4	1.4
C	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.3
12	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
D	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2
E	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.2	1.3	1.2	1.3
F	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3
G	1.3	1.3	1.3	1.3	1.2	1.3	1.2	1.2	--	--	--	--

(Continued)

Note: ΔH = mtl at Courthouse Point minus mtl at Reedy Island Jetty.

Table 1 (Concluded)

	ΔH = +0.11 ft				ΔH = -0.48 ft				ΔH = -0.91 ft			
	High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
430	25.6	27.7	23.8	25.5	28.8	29.4	26.2	26.8	29.9	29.9	27.6	28.8
350	17.8	22.7	16.0	21.0	19.6	23.3	17.1	21.4	20.4	22.4	22.1	25.1
325	15.2	20.6	13.6	20.0	18.7	21.2	15.1	19.2	18.7	22.6	16.7	22.6
310	13.5	20.5	10.7	18.7	16.5	20.4	13.1	19.3	17.7	21.0	14.6	19.6
295	12.3	19.5	7.0	11.5	15.1	19.2	7.9	10.6	16.1	20.4	10.6	13.0
280	12.0	18.1	5.6	11.4	12.4	16.0	5.6	6.6	15.1	18.6	7.2	9.8
265	8.9	14.6	3.1	5.1	9.9	13.7	4.3	4.1	12.5	15.3	6.8	6.9
250	6.4	10.9	2.0	2.4	6.1	8.3	2.1	2.3	9.7	11.9	3.2	4.7
235	4.9	5.6	1.2	1.2	4.8	5.7	1.1	1.1	7.1	7.9	1.8	2.0
220	3.0	3.3	0.5	0.6	3.5	3.5	--	--	5.2	5.3	0.8	0.8
205	--	--	--	--	1.8	1.9	--	--	2.2	3.4	0.6	0.7
190	1.6	1.8	0.1	0.2	0.9	1.1	0.1	0.1	1.6	1.7	0.2	0.1
175	0.4	0.4	0.0	0.0	0.4	0.3	0.1	0.0	0.6	0.7	0.3	0.1
160	0.2	0.2	0.1	0.1	0.3	0.2	0.2	0.1	0.3	0.3	0.2	0.0
145	0.3	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.4	0.2	0.2	0.1
130	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
1	4.2	4.6	1.9	1.9	4.3	4.6	1.6	1.7	5.9	6.8	2.4	2.3
3	4.4	5.2	2.1	4.1	4.7	4.7	2.2	2.5	6.0	7.3	2.7	2.6
	Westward		Eastward		Westward		Eastward		Westward		Eastward	
2	4.5	5.0	1.9	2.2	4.6	5.1	1.4	2.0	6.2	7.3	1.8	2.4
A	4.5	4.6	4.4	4.4	4.7	4.8	3.8	4.7	6.7	6.9	4.0	5.7
8	4.7	4.7	4.7	4.7	4.5	4.6	4.4	4.5	6.2	6.6	6.5	6.7
B	4.8	4.8	4.4	4.5	4.4	4.3	4.5	4.5	--	--	--	--
C	4.6	4.7	4.0	4.2	4.4	4.4	4.3	4.3	6.5	6.6	5.4	5.6
12	4.8	4.8	2.9	3.3	4.4	4.4	4.6	4.4	6.4	6.4	6.5	6.5
D	4.4	4.7	2.5	2.7	4.5	4.5	4.4	4.4	6.4	6.4	5.6	5.6
E	2.9	3.0	2.1	2.2	4.4	4.4	4.4	4.4	6.4	6.4	5.6	5.8
F	2.3	2.4	1.6	1.9	4.4	4.4	3.5	4.3	4.7	4.5	5.3	6.1
G	--	--	1.6	1.8	4.1	4.2	1.7	3.4	6.2	6.2	2.0	5.4

Table 2

High- and Low-Water Salinities in ppt for Various Head Differences, 35- by 450-ft Canal

Source Salinity: Delaware = 31.00 ppt, Chesapeake = 1.25 ppt

	ΔH = +1.44 ft				ΔH = +0.30 ft				ΔH = -0.85 ft			
	High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack		High-Water Slack		Low-Water Slack	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
430	18.1	25.9	18.0	21.6	24.6	28.6	23.9	25.2	28.9	29.1	28.6	28.7
350	9.8	21.8	10.9	20.4	16.6	24.2	15.2	22.8	26.9	27.5	24.5	26.4
325	9.2	20.4	7.3	18.7	15.1	22.5	12.2	22.0	25.3	26.6	23.3	26.1
310	6.8	19.3	4.3	18.8	13.1	22.0	10.0	21.6	23.5	25.7	21.1	24.7
295	6.3	18.3	2.3	4.8	12.9	20.8	6.3	12.6	22.8	24.4	16.8	18.6
280	4.2	15.9	3.8	4.0	10.3	19.0	5.8	10.7	20.6	23.4	13.7	19.3
265	3.4	12.9	1.2	1.1	8.2	16.1	2.3	5.0	19.4	21.5	10.6	15.8
250	1.8	10.2	1.5	1.1	6.2	12.0	2.1	2.4	15.6	10.6	7.8	13.3
235	1.3	1.2	0.7	0.8	4.2	5.4	1.4	1.6	14.8	15.7	6.0	12.7
220	0.9	1.2	0.3	0.4	2.0	2.5	0.5	0.5	9.4	11.9	3.5	6.4
205	0.8	0.9	0.2	0.2	1.7	1.7	0.2	0.4	5.3	9.9	2.6	5.8
190	0.7	0.7	0.1	0.1	1.0	1.3	0.3	0.2	3.8	7.8	1.0	1.9
175	0.3	0.2	0.0	0.0	0.5	0.4	0.1	0.1	2.9	3.8	0.4	0.5
160	0.2	0.2	0.1	0.1	0.5	0.3	0.4	0.3	1.7	2.5	0.2	0.2
145	0.1	0.1	0.0	0.0	0.2	0.1	0.0	0.1	0.8	1.2	0.2	0.2
130	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.1
1	1.3	1.3	1.1	1.2	2.5	3.5	1.7	1.6	12.1	13.6	6.2	6.3
3	1.3	1.3	1.1	1.2	3.5	3.7	3.4	3.8	12.2	13.6	6.7	7.9
	Westward		Eastward		Westward		Eastward		Westward		Eastward	
2	1.3	1.3	1.3	1.3	3.9	4.3	1.3	1.7	13.2	15.1	6.7	7.4
A	1.3	1.3	1.3	1.3	3.5	4.1	1.3	1.3	13.6	15.2	7.5	12.8
8	1.3	1.3	1.3	1.3	1.6	3.3	1.3	1.3	13.2	13.4	11.5	13.4
B	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.0	13.7	11.9	13.4
C	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.0	13.2	11.2	11.4
12	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.0	13.0	11.0	11.0
D	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.2	13.1	11.0	11.4
E	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.2	13.2	11.2	11.3
F	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.7	12.1	5.2	11.6
G	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	10.3	12.0	2.7	11.8

Note: ΔH = mtl at Courthouse Point minus mtl at Reedy Island Jetty.

Table 3

Salinities After Slack for Various ΔH's , 27- by 250-ft and 35- by 450-ft Canal

Source Salinity: Delaware = 31.00 ppt, Chesapeake = 1.25 ppt

	35- by 450-ft Canal		27- by 250-ft Canal		35- by 450-ft Canal		27- by 250-ft Canal		35- by 450-ft Canal		27- by 250-ft Canal	
	ΔH = +1.44 ft		ΔH = +1.44 ft		ΔH = +0.30 ft		ΔH = +0.28 ft		ΔH = -0.85 ft		ΔH = -0.91 ft	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
					Slack After Westward Flow							
2	1.3	1.3	1.2	1.2	3.9	4.3	3.7	4.4	13.2	15.1	6.2	7.3
A	1.3	1.3	1.2	1.2	3.5	4.1	4.1	4.3	13.6	15.2	6.7	6.9
8	1.3	1.3	1.3	1.3	1.6	3.3	2.0	3.8	13.2	13.4	6.2	6.6
B	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.6	13.0	13.7	--	--
C	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.0	13.2	6.5	6.6
12	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.0	13.0	6.4	6.4
D	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.2	13.1	6.4	6.4
E	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	13.2	13.2	6.4	6.4
F	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.7	12.1	6.2	6.2
G	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	10.3	12.0	4.5	4.7
					Slack After Eastward Flow							
2	1.3	1.3	0.8	0.9	1.3	1.7	1.6	1.9	6.7	7.4	1.8	2.4
A	1.3	1.3	1.2	1.2	1.3	1.3	1.4	2.2	7.5	12.8	4.0	5.7
8	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.6	11.5	13.4	6.5	6.7
B	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	11.9	13.4	--	--
C	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.2	11.4	5.4	5.6
12	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.0	11.0	6.5	6.5
D	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.0	11.4	5.6	5.6
E	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	11.2	11.3	5.6	5.8
F	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	5.2	11.6	5.3	6.1
G	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2.7	11.8	2.0	5.4

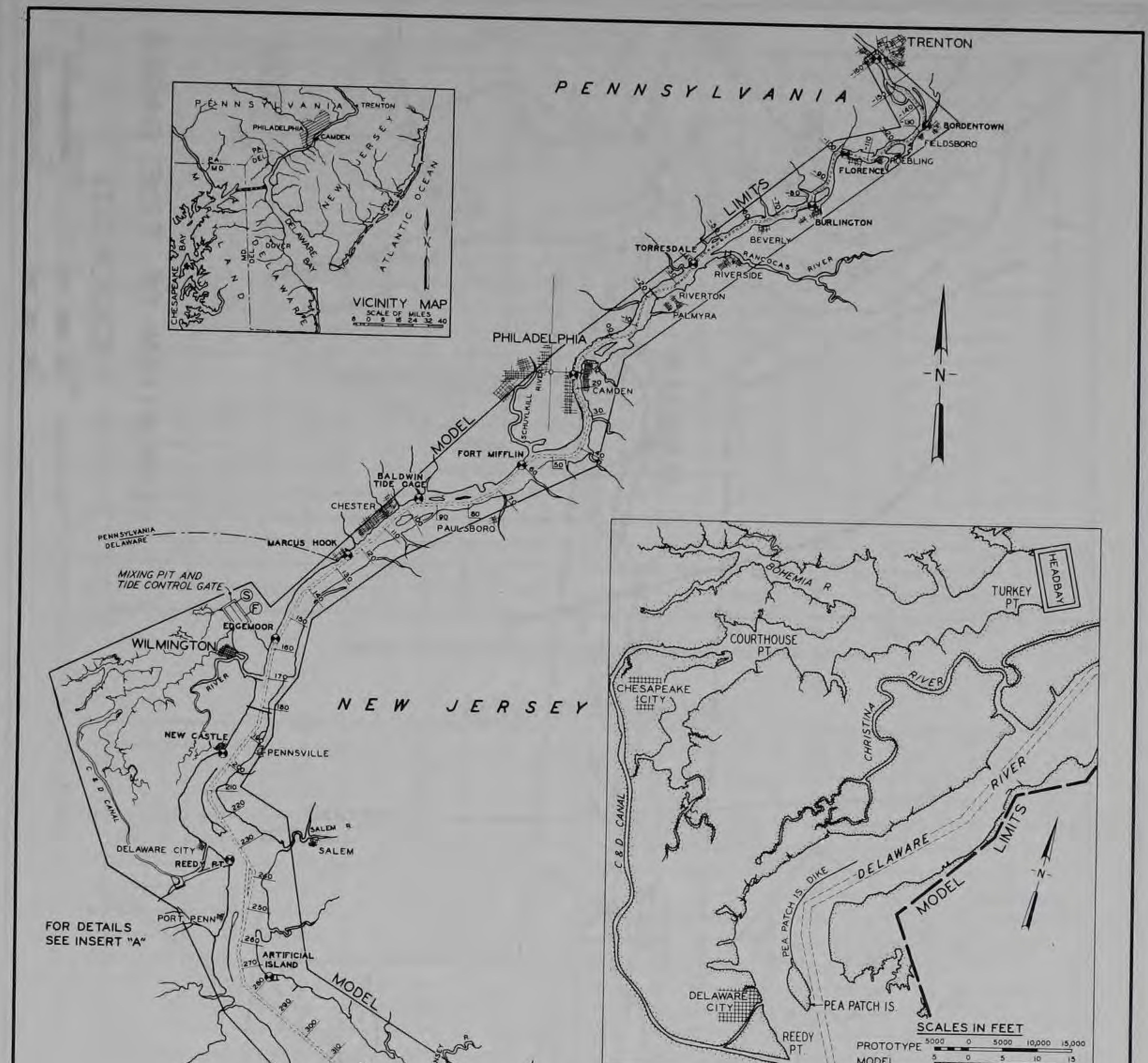
Note: ΔH = mtl at Courthouse Point minus mtl at Reedy Point Jetty. Sampling station locations are shown in plate 34. Salinity in total salt ppt.

Table 4

Description of Computer Tests Reported

Test No.	Test Conditions						
	Main Canal				Branch Canal		
	Geometry	Roughness	Courthouse Point Tide	Reedy Point Tide	Geometry	Roughness	Delaware City Tide
1	Idealized 27-ft channel	0.021	Mean tide	Mean tide	--	--	--
2	Idealized 27-ft channel	0.025	Mean tide	Mean tide	--	--	--
3	Idealized 35-ft channel	0.025	Mean tide	Mean tide	--	--	--
4	Idealized 27-ft channel	0.021	Mean tide	Mean tide	Idealized 8-ft channel	0.21	Reedy Point mean tide
5	Irregular 27-ft channel	0.021	Mean tide	Mean tide	--	--	--
22	Irregular 27-ft channel	Variable along canal*	7-8 June 1938	7-8 June 1938	--	--	--
23	Irregular 27-ft channel	Variable along canal*	6-7 July 1938	6-7 July 1938	--	--	--
24	Irregular 27-ft channel	Variable along canal*	Mean tide	Mean tide	--	--	--
25	Irregular 27-ft channel	Variable along canal*	6-7 July 1938	6-7 July 1938	Idealized 8-ft channel	0.020	Reedy Point 6-7 July 1938, tide lagged 10 min
26	Irregular 27-ft channel	Variable along canal*	Mean tide lowered 0.2 ft	Mean tide	--	--	--
27	Irregular 35-ft channel	Variable along canal*	Mean tide	Mean tide	--	--	--
28	Irregular 27-ft channel	Variable along canal*	Mean tide lowered 0.1 ft	Mean tide	--	--	--
29	Irregular 27-ft channel	Variable along canal*	7-8 June 1938 tide lowered 0.1 ft	7-8 June 1938	--	--	--
30	Irregular 35-ft channel	Variable along canal*	Mean tide lowered 0.1 ft	Mean tide	--	--	--

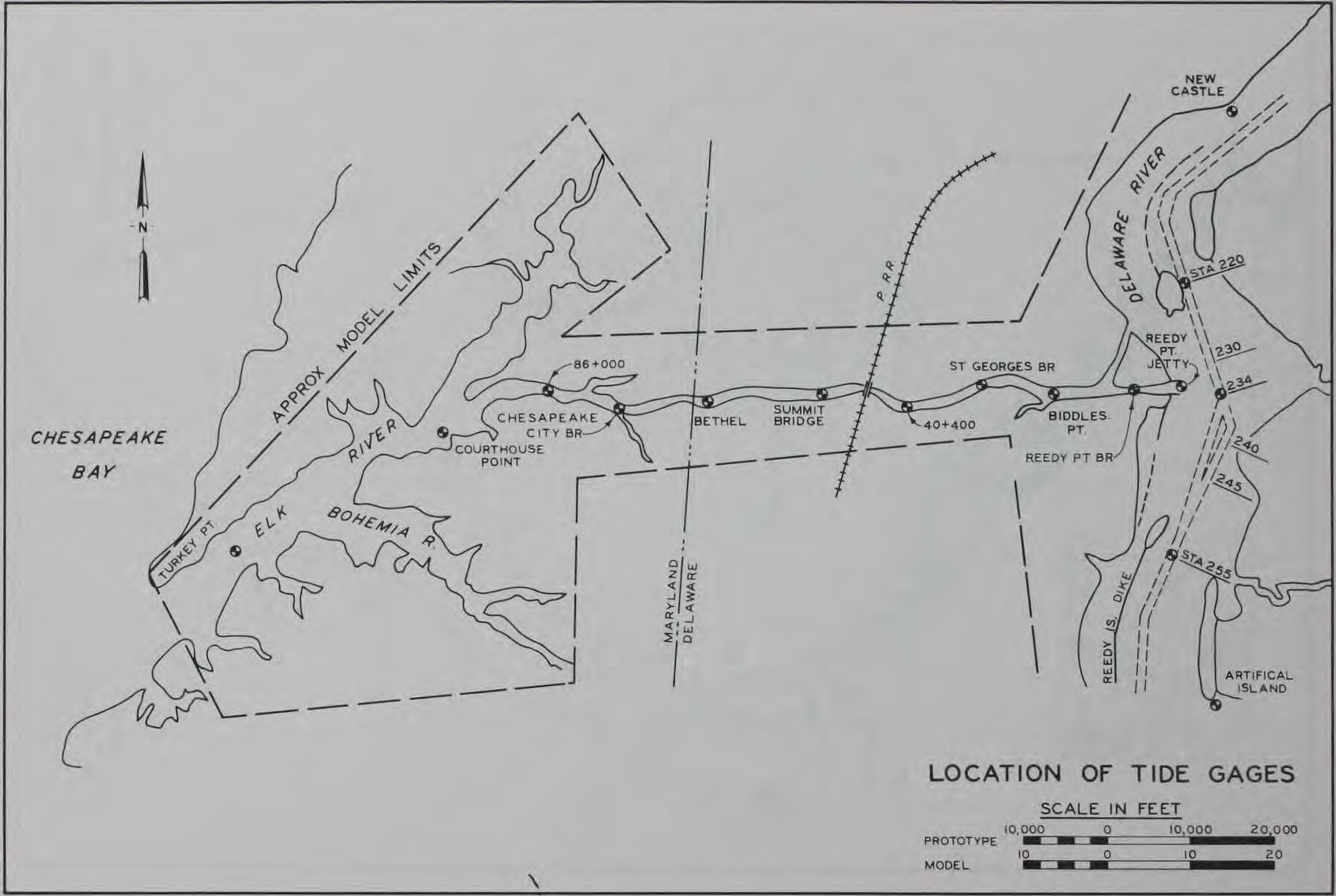
* Roughness variation along canal was as follows: n = 0.020 from mile 0.7 to mile 4.7 , n increasing from 0.020 to 0.025 between mile 4.7 and mile 7.1 , n = 0.025 from mile 7.1 to mile 15.1 , and n decreasing from 0.025 to 0.022 between mile 15.1 and mile 19.1.



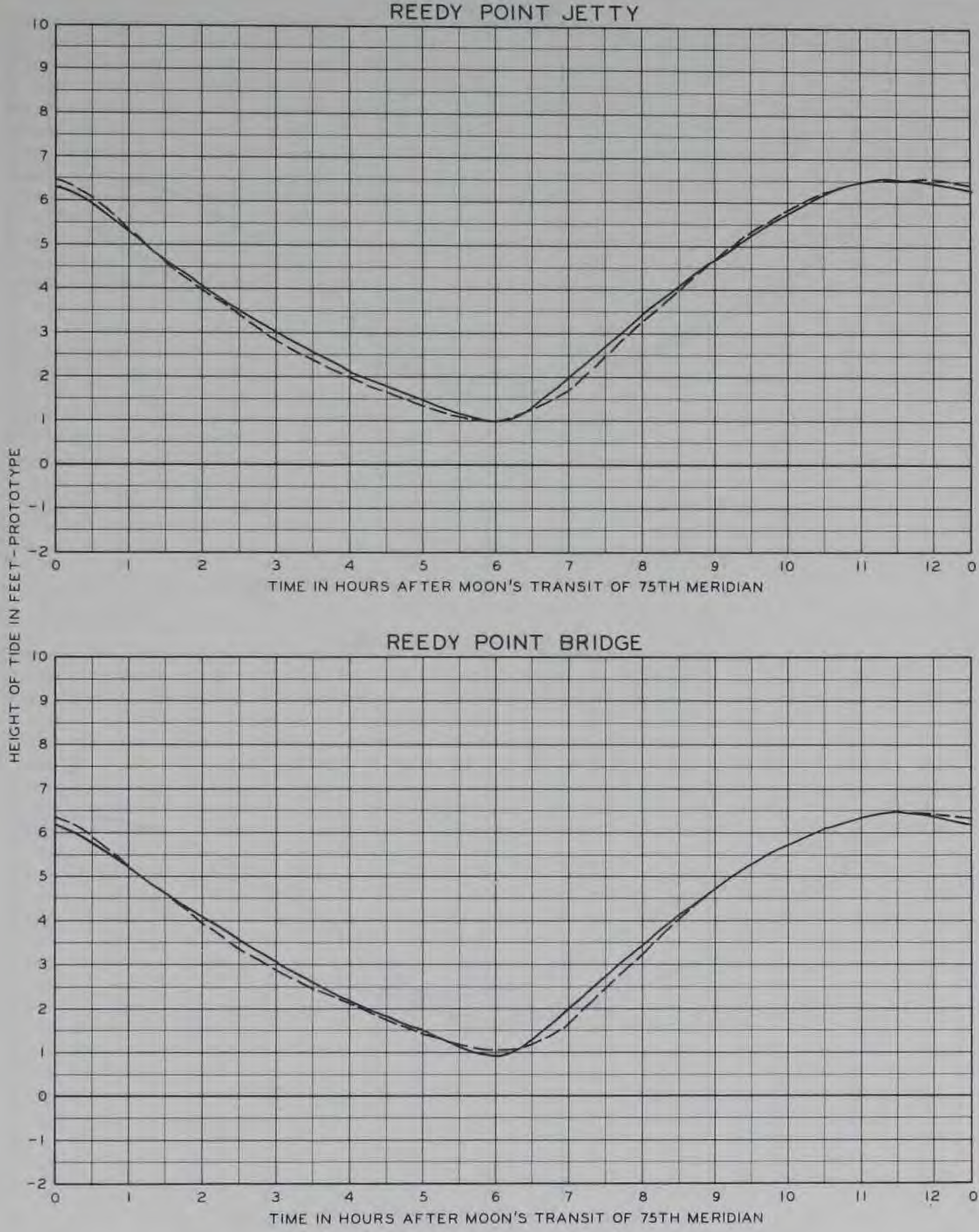
DELAWARE RIVER AND
C AND D CANAL STUDIES

LOCATION MAP

PLATE 1



LOCATION OF TIDE GAGES



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

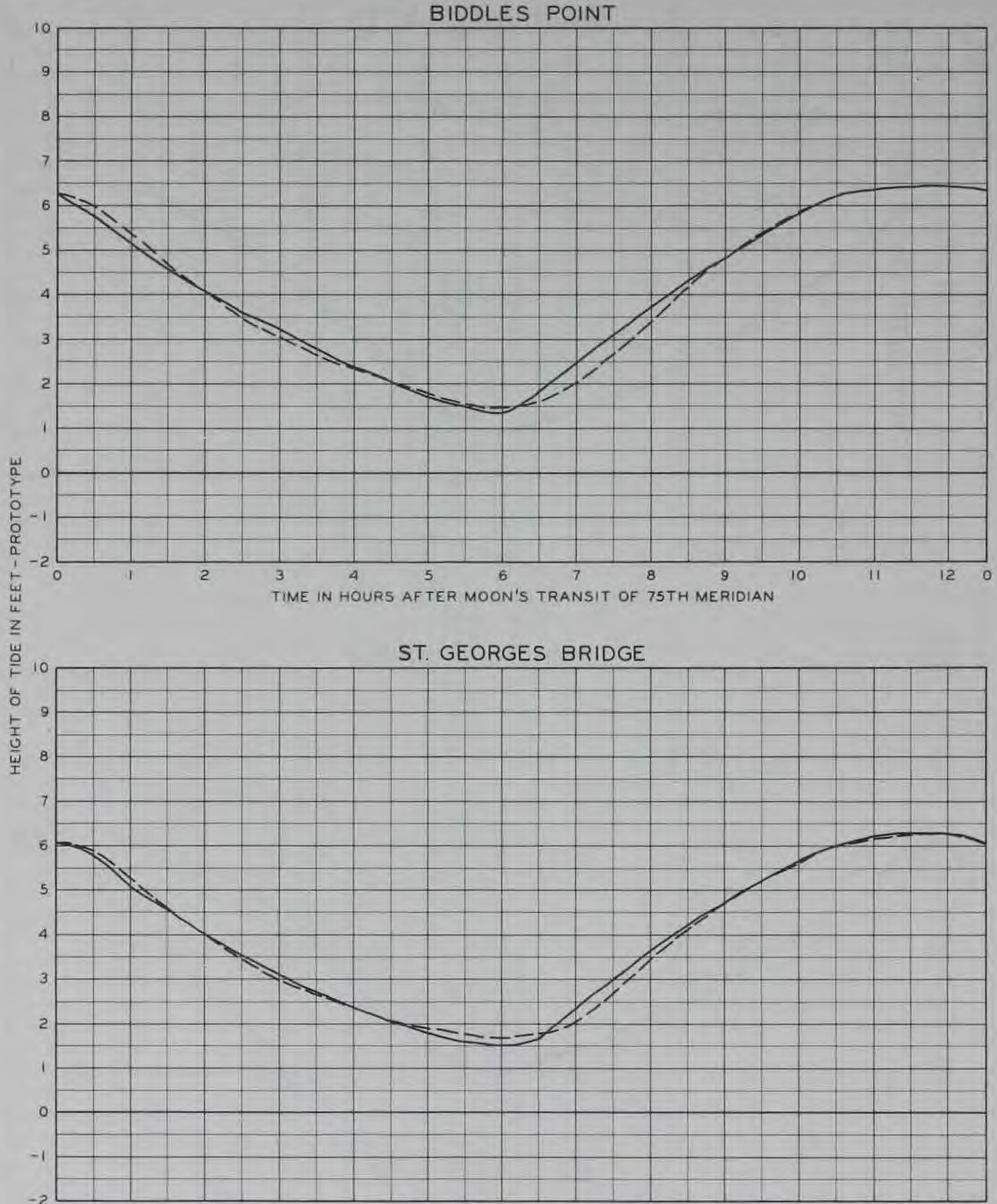
LEGEND

——— PROTOTYPE
– – – – MODEL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

VERIFICATION
TIDAL HEIGHTS

STATIONS REEDY POINT JETTY
AND REEDY POINT BRIDGE


BIDDLES POINT

ST. GEORGES BRIDGE

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

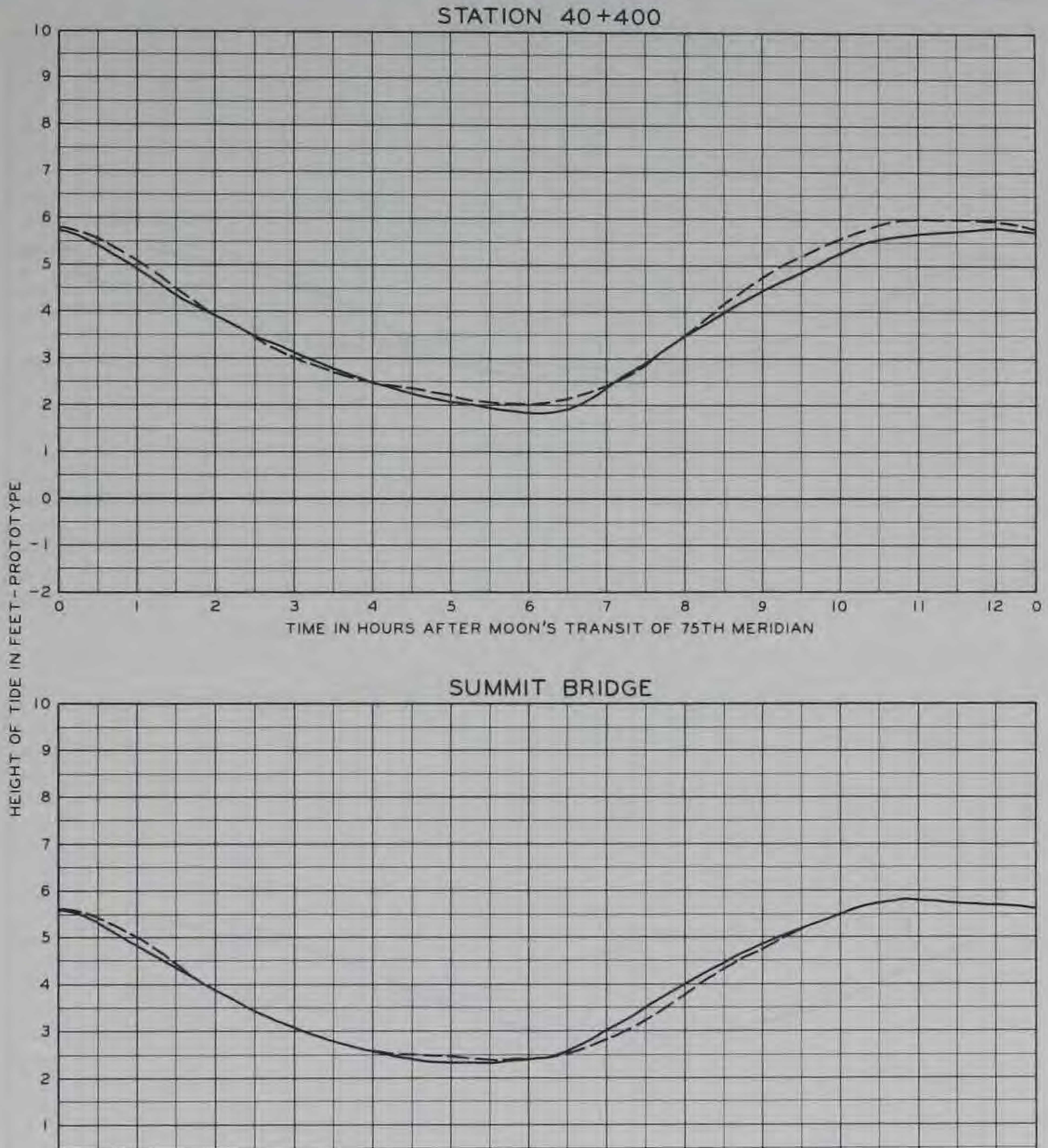
——————— PROTOTYPE
— — — — MODEL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

VERIFICATION
TIDAL HEIGHTS

STATIONS BIDDLES POINT
AND ST. GEORGES BRIDGE

PLATE 4



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

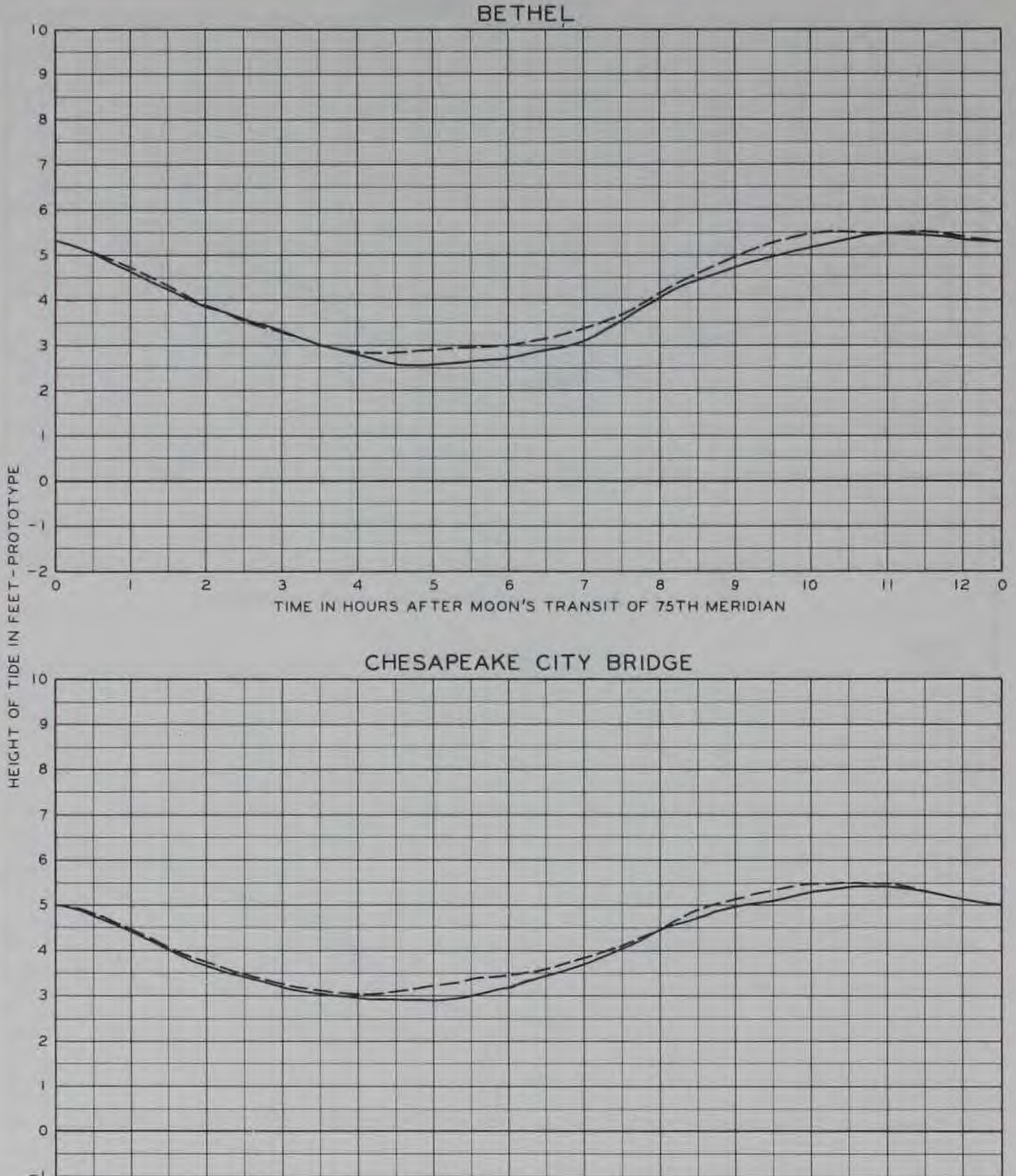
LEGEND

——— PROTOTYPE
– – – – MODEL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

VERIFICATION TIDAL HEIGHTS

STATIONS 40 + 400 AND
SUMMIT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

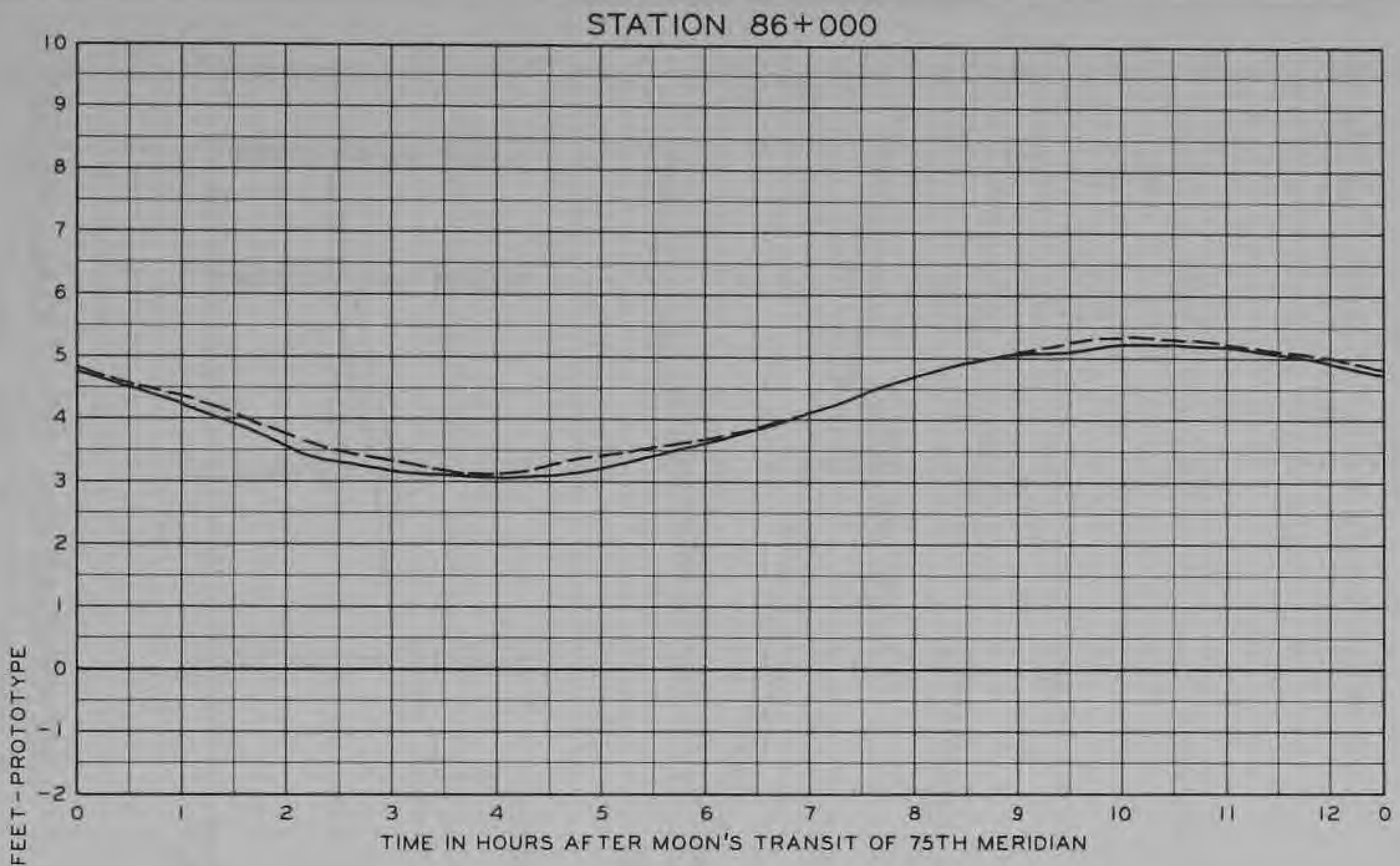
——— PROTOTYPE
– – – – MODEL

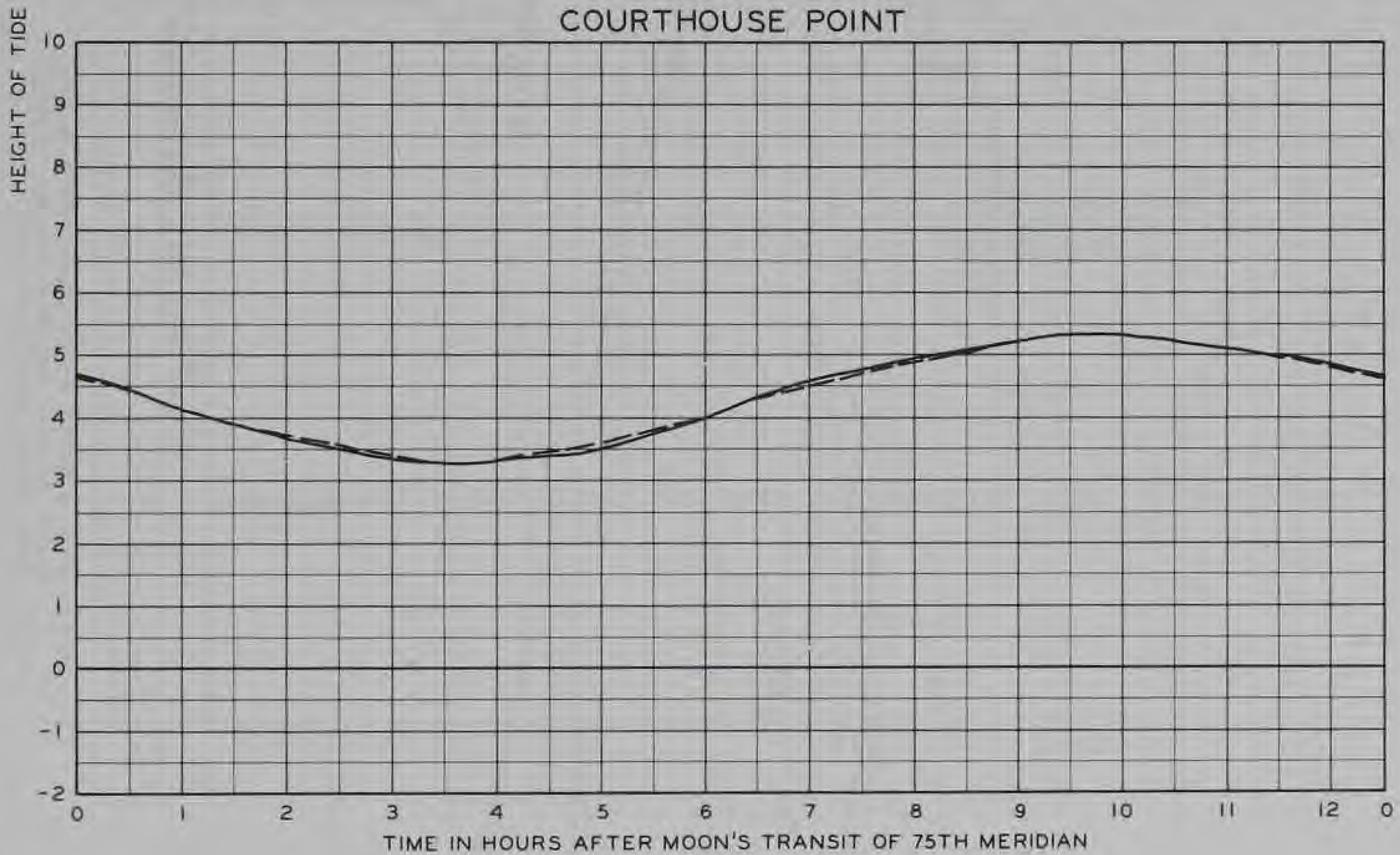
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

VERIFICATION TIDAL HEIGHTS

STATIONS BETHEL AND
CHESAPEAKE CITY BRIDGE

PLATE 6





TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

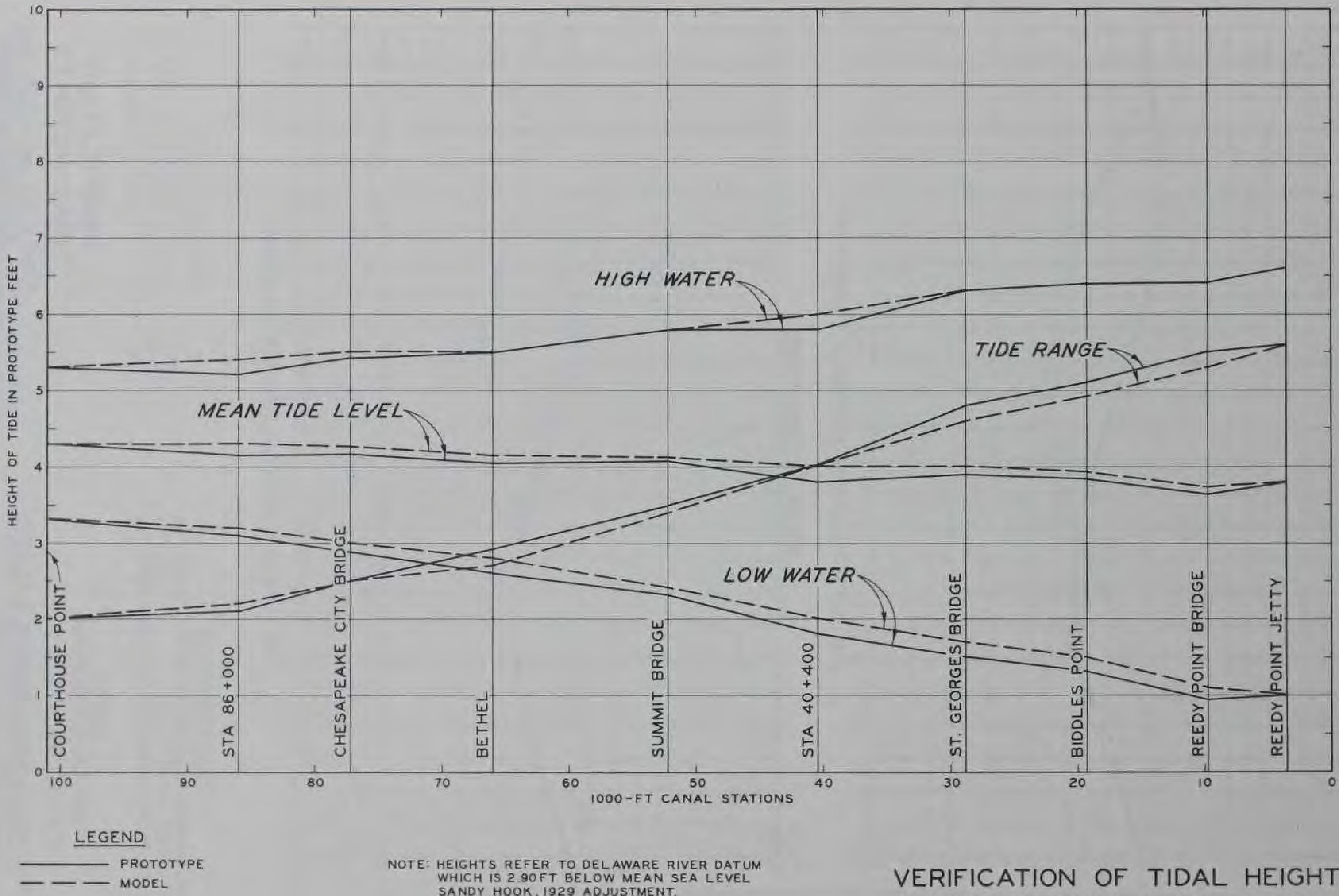
LEGEND

——— PROTOTYPE
– – – – MODEL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

VERIFICATION TIDAL HEIGHTS

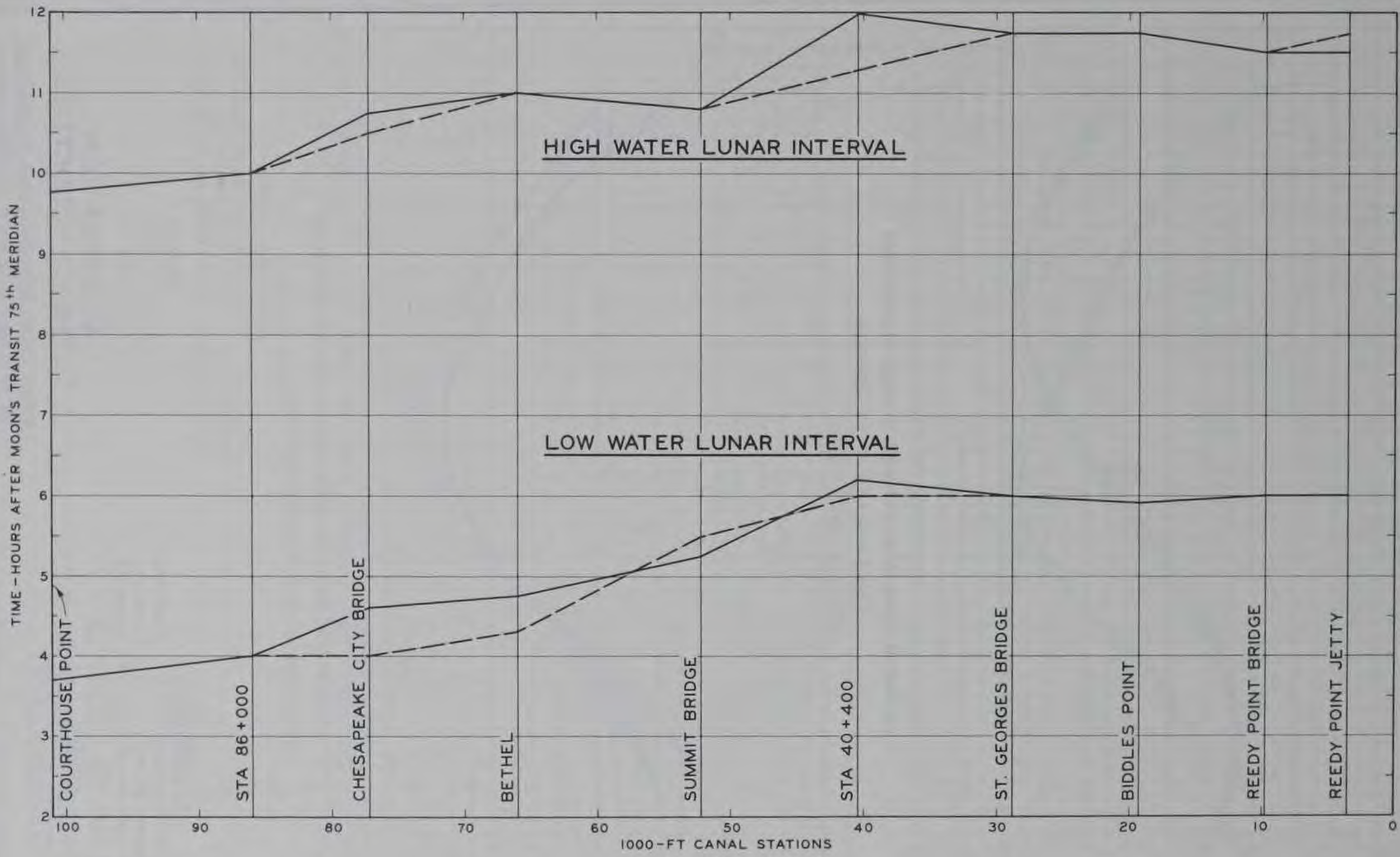
STATIONS 86+000 AND
COURTHOUSE POINT



NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FT BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

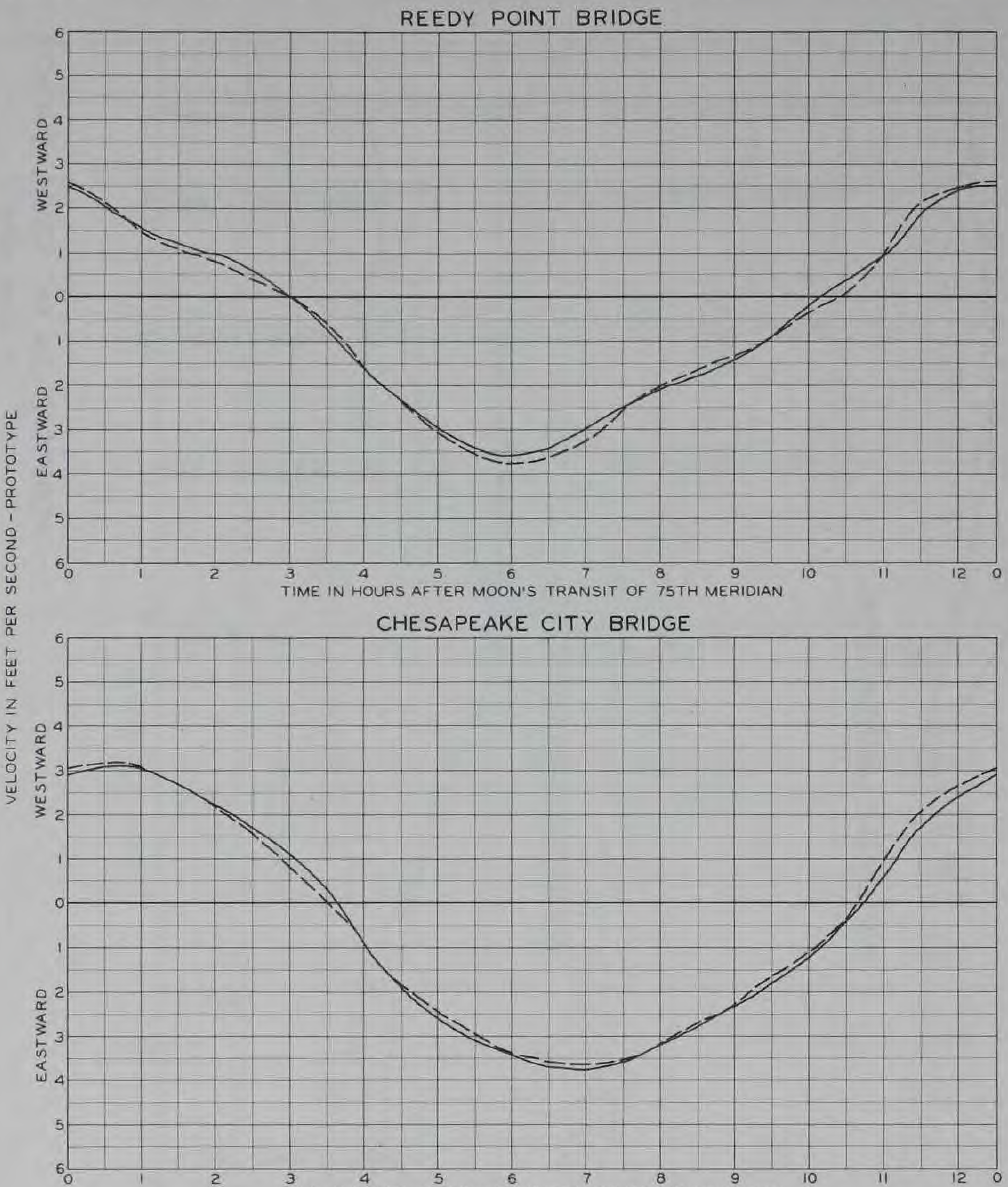
VERIFICATION OF TIDAL HEIGHTS

7 JUNE 1938



VERIFICATION OF TIDAL EVENTS

7 JUNE 1938



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

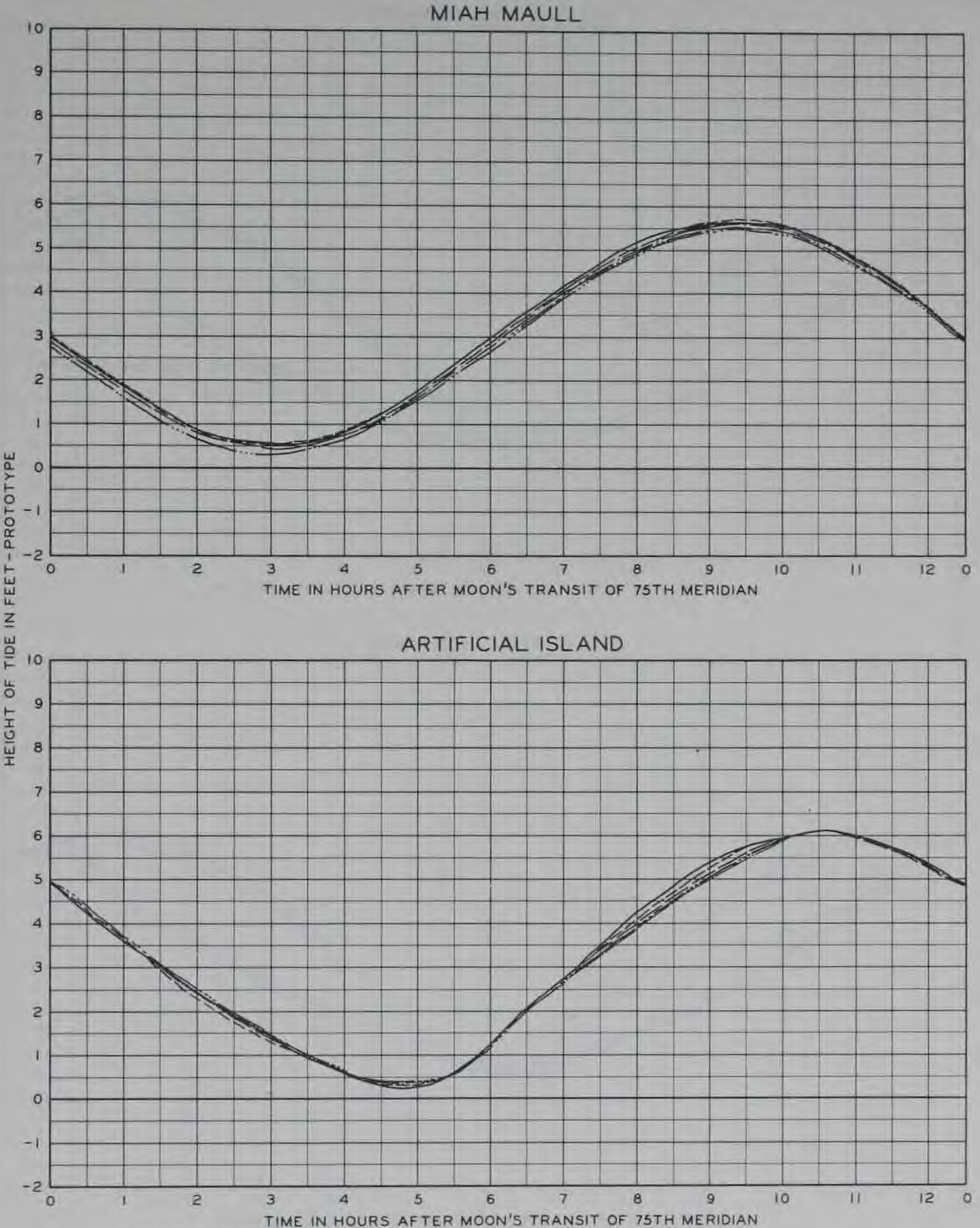
——— PROTOTYPE
– – – – MODEL

NOTE: OBSERVATIONS MADE AT 6/10 DEPTH.

VERIFICATION CURRENT VELOCITIES

STATIONS REEDY POINT BRIDGE
AND CHESAPEAKE CITY BRIDGE

PLATE 10



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

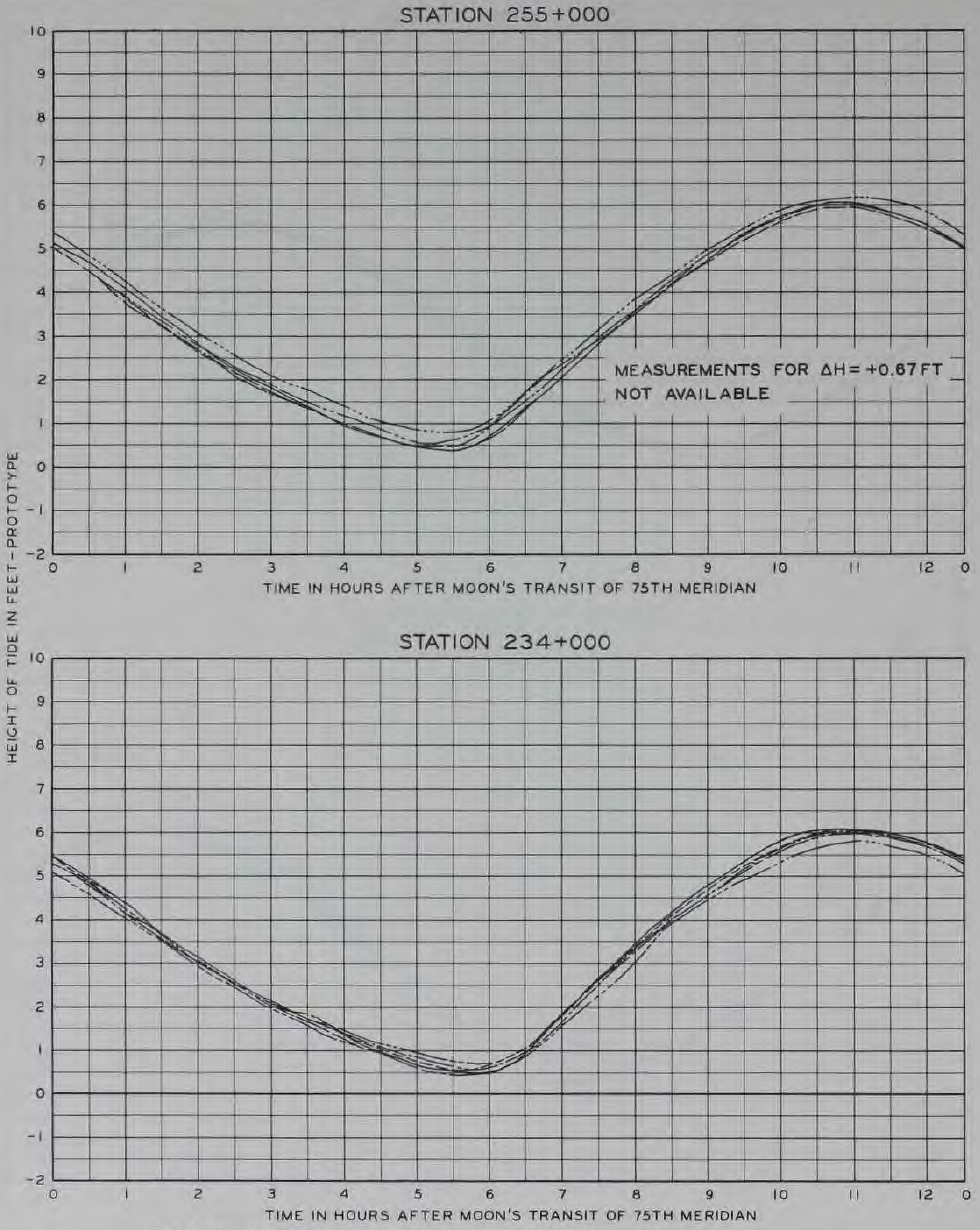
———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

MIAH MAULL AND ARTIFICIAL ISLAND

PLATE 11



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

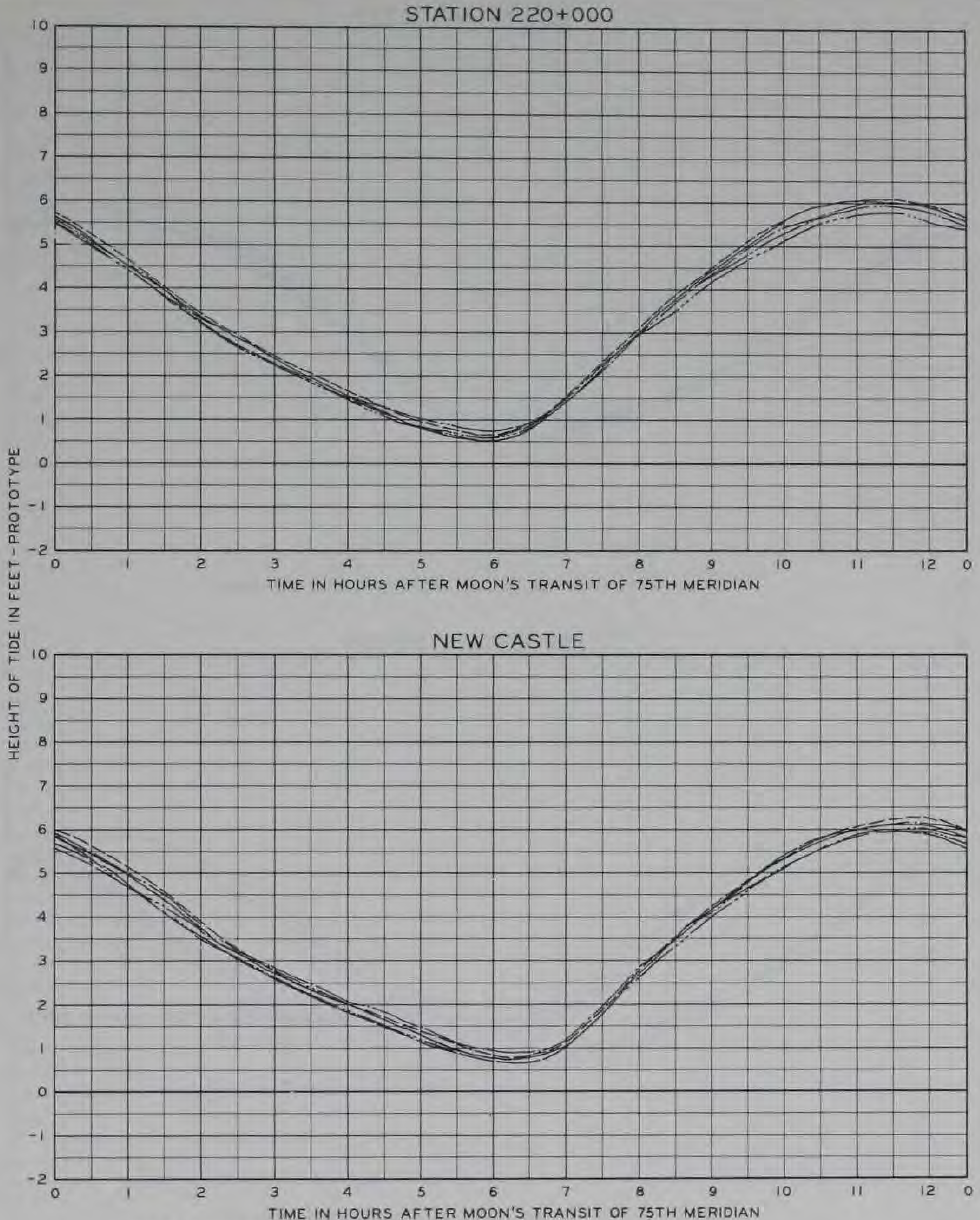
——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – ΔH = +0.67 FT
— · — ΔH = +1.44 FT
— ·· — ΔH = −0.48 FT
— ··· — ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

STATIONS 255+000 AND 234+000

PLATE 12



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

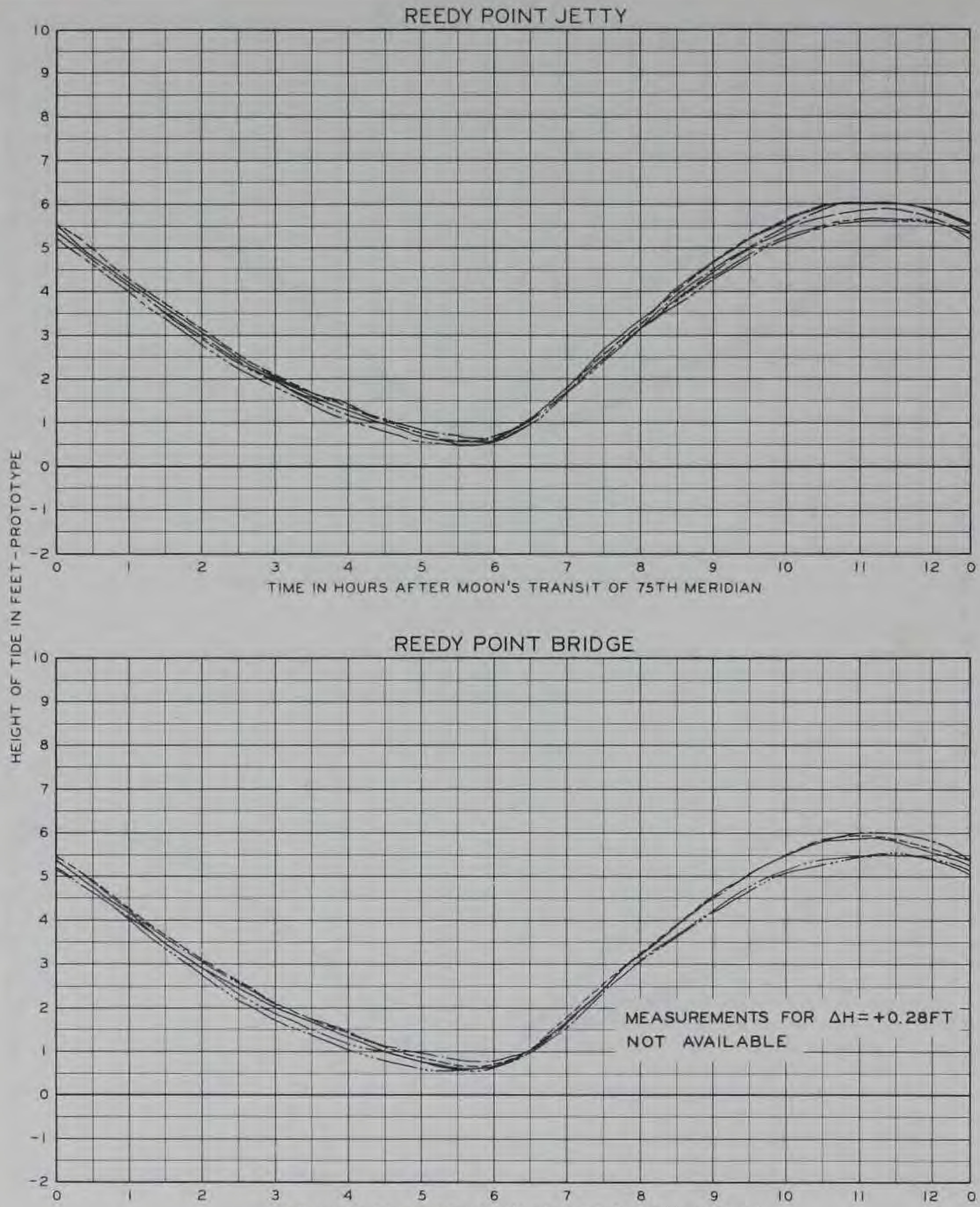
LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

STATION 220+000 AND NEW CASTLE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .....31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

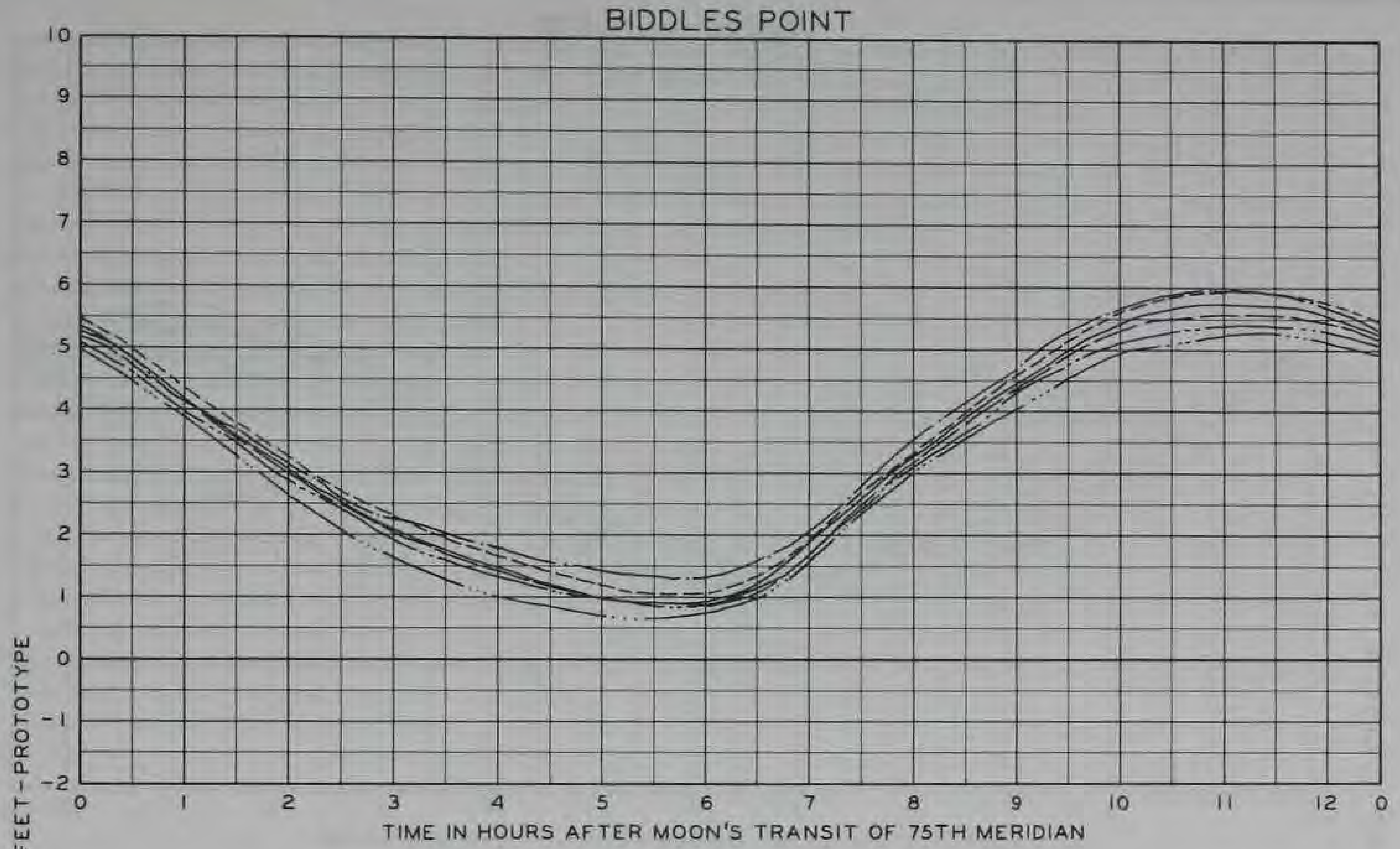
LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

REEDY POINT JETTY AND BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY......31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

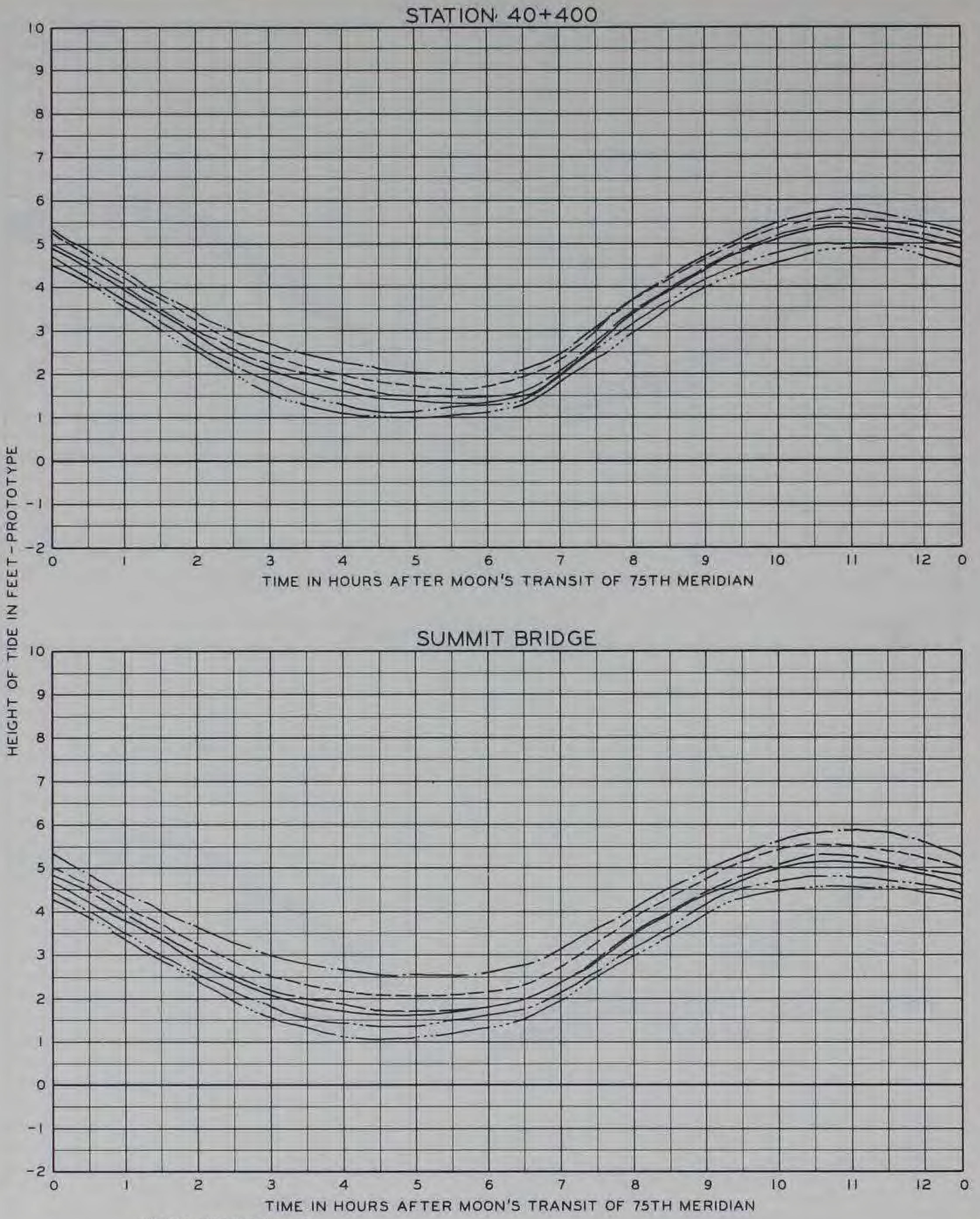
LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

BIDDLES POINT AND ST GEORGES BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

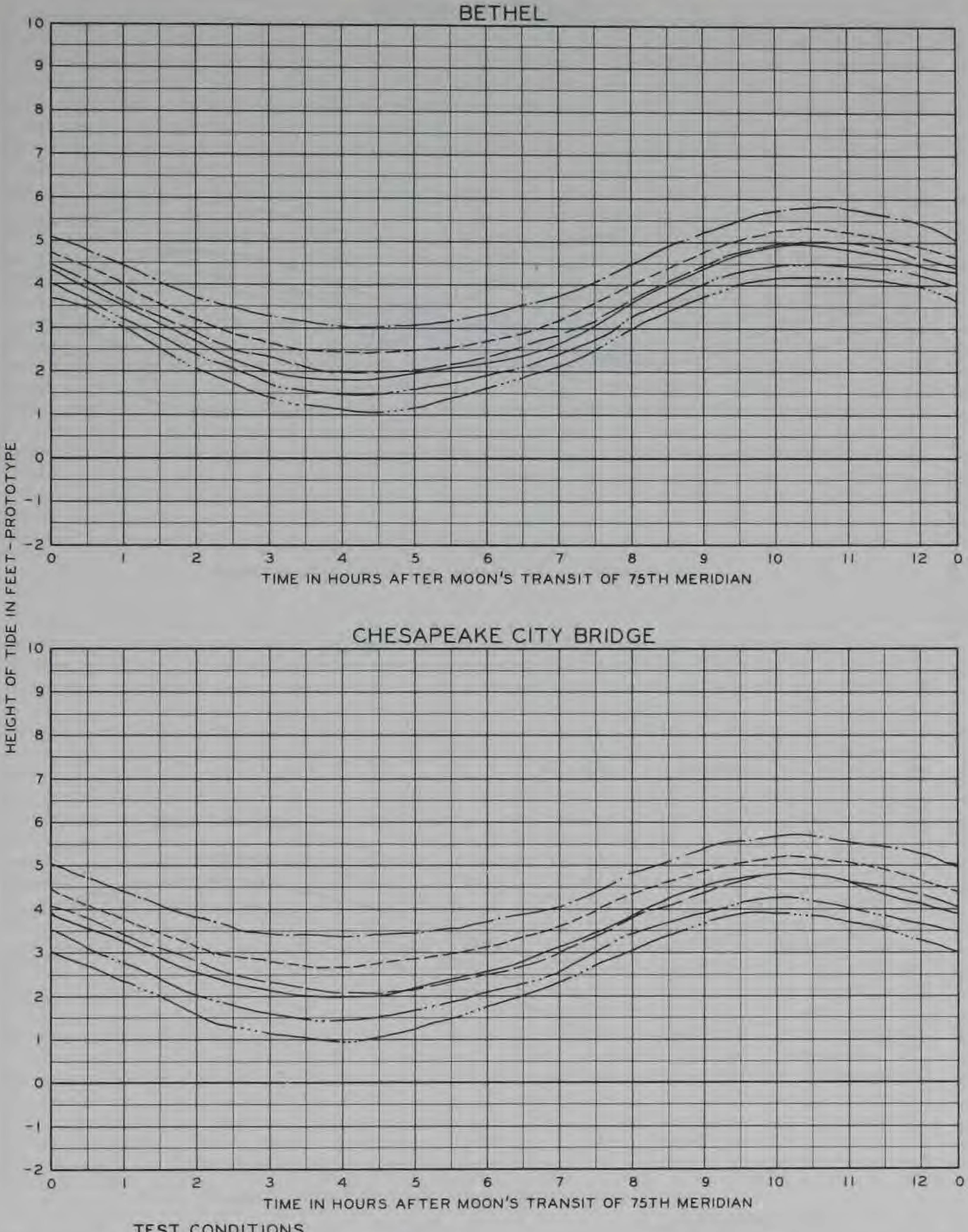
LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

STATION 40+400 AND SUMMIT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

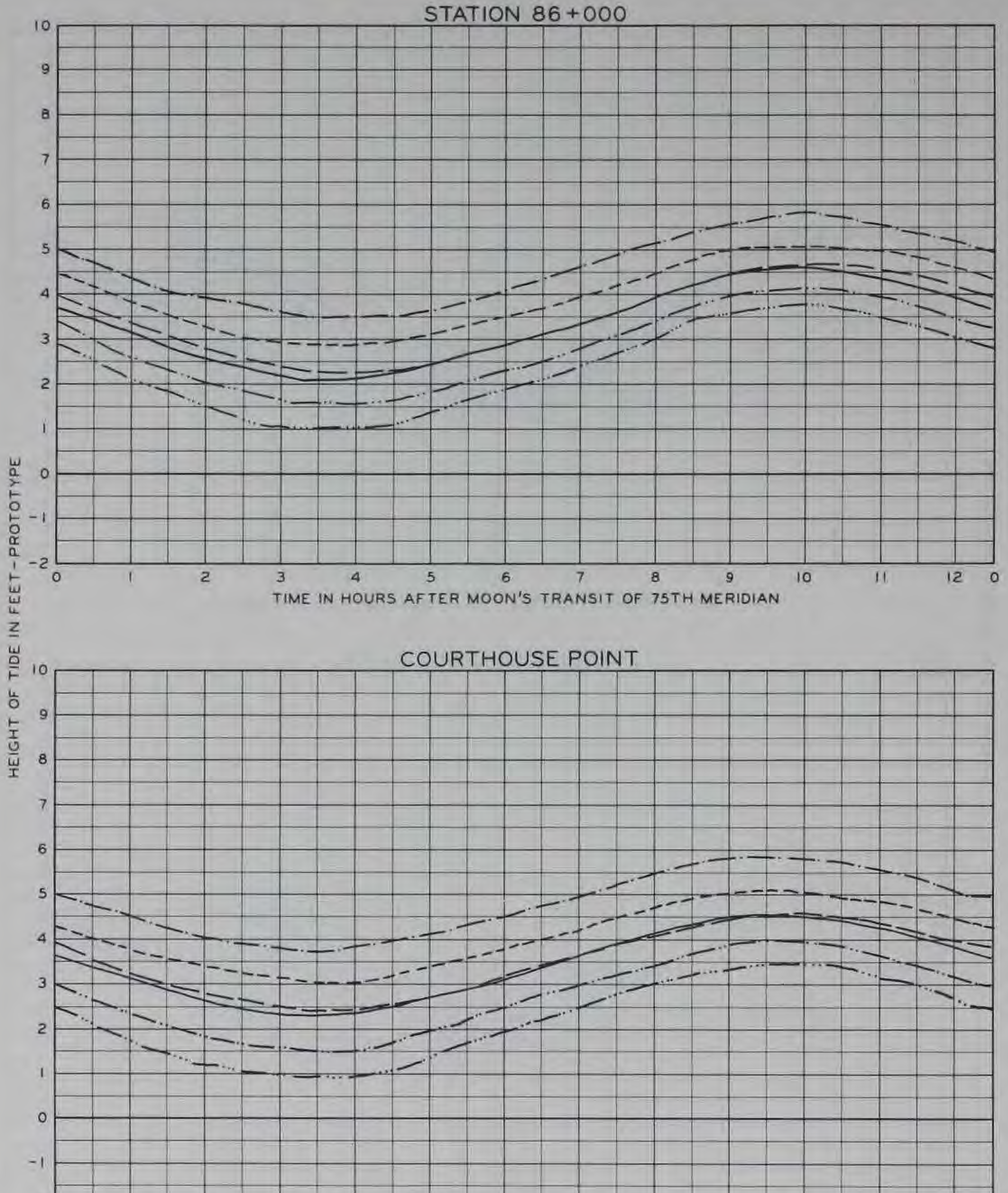
———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

BETHEL AND CHESAPEAKE CITY BRIDGE

PLATE 17



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY ..... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

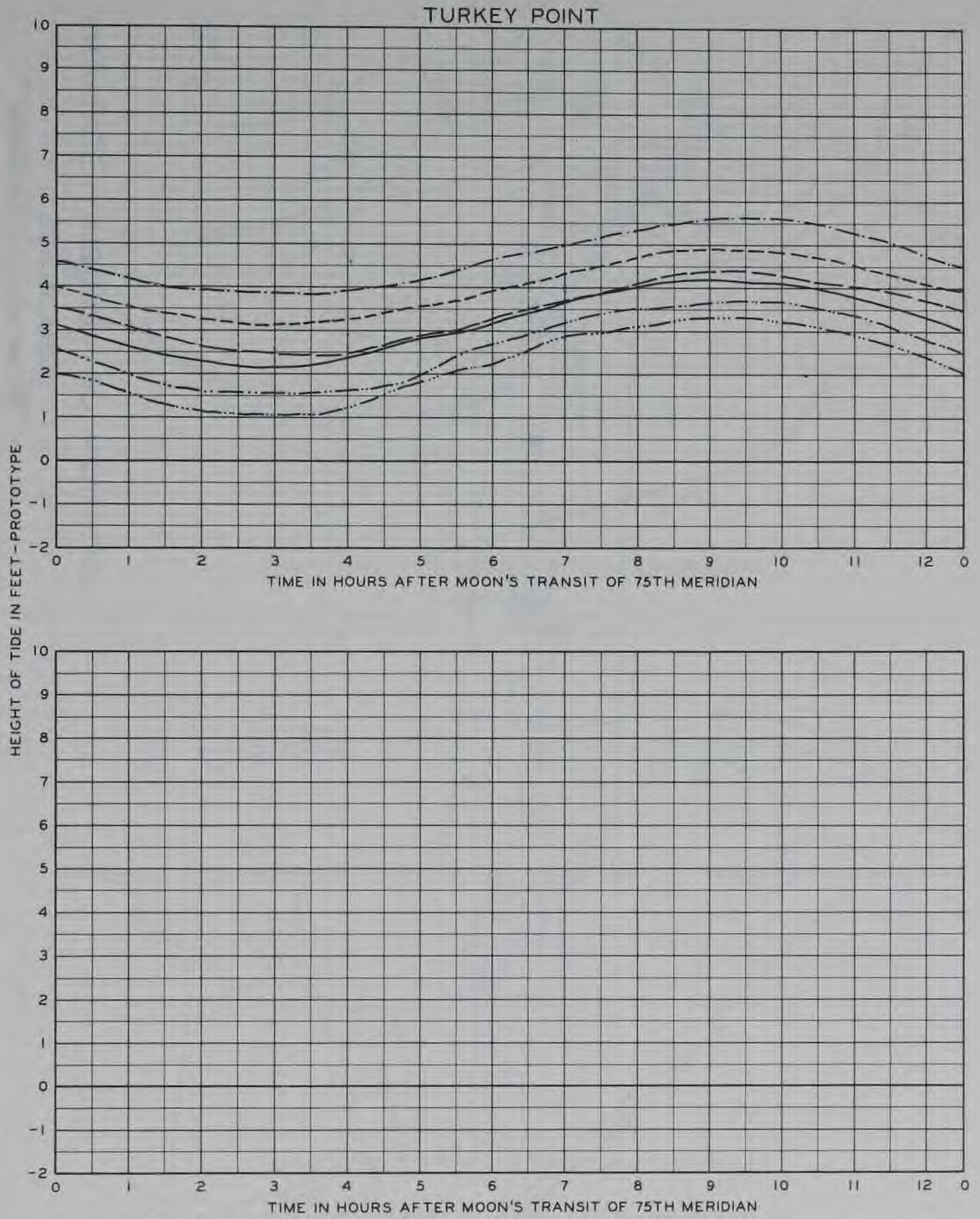
———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

STATION 86+000 AND COURTHOUSE POINT

PLATE 18



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

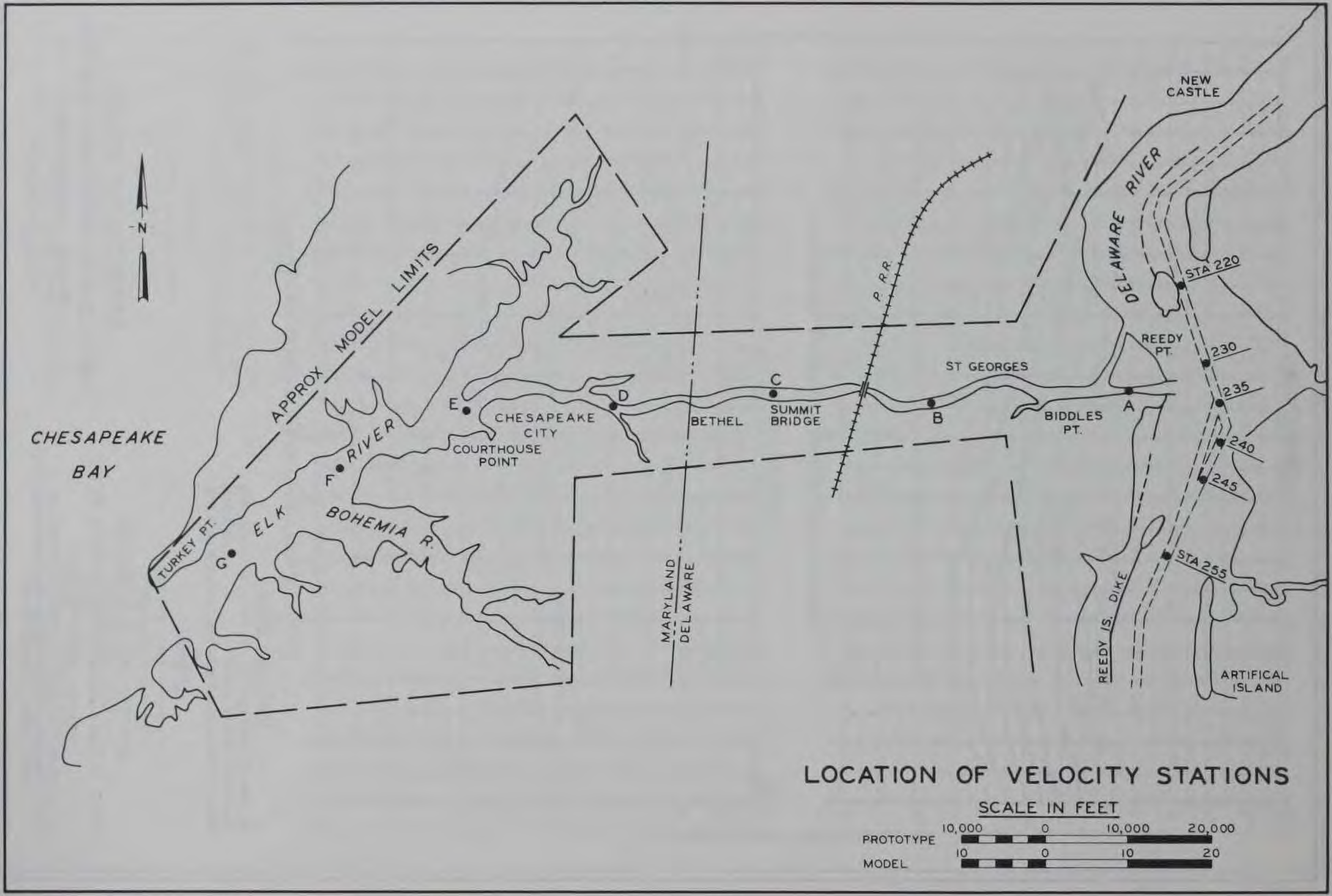
LEGEND

——— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

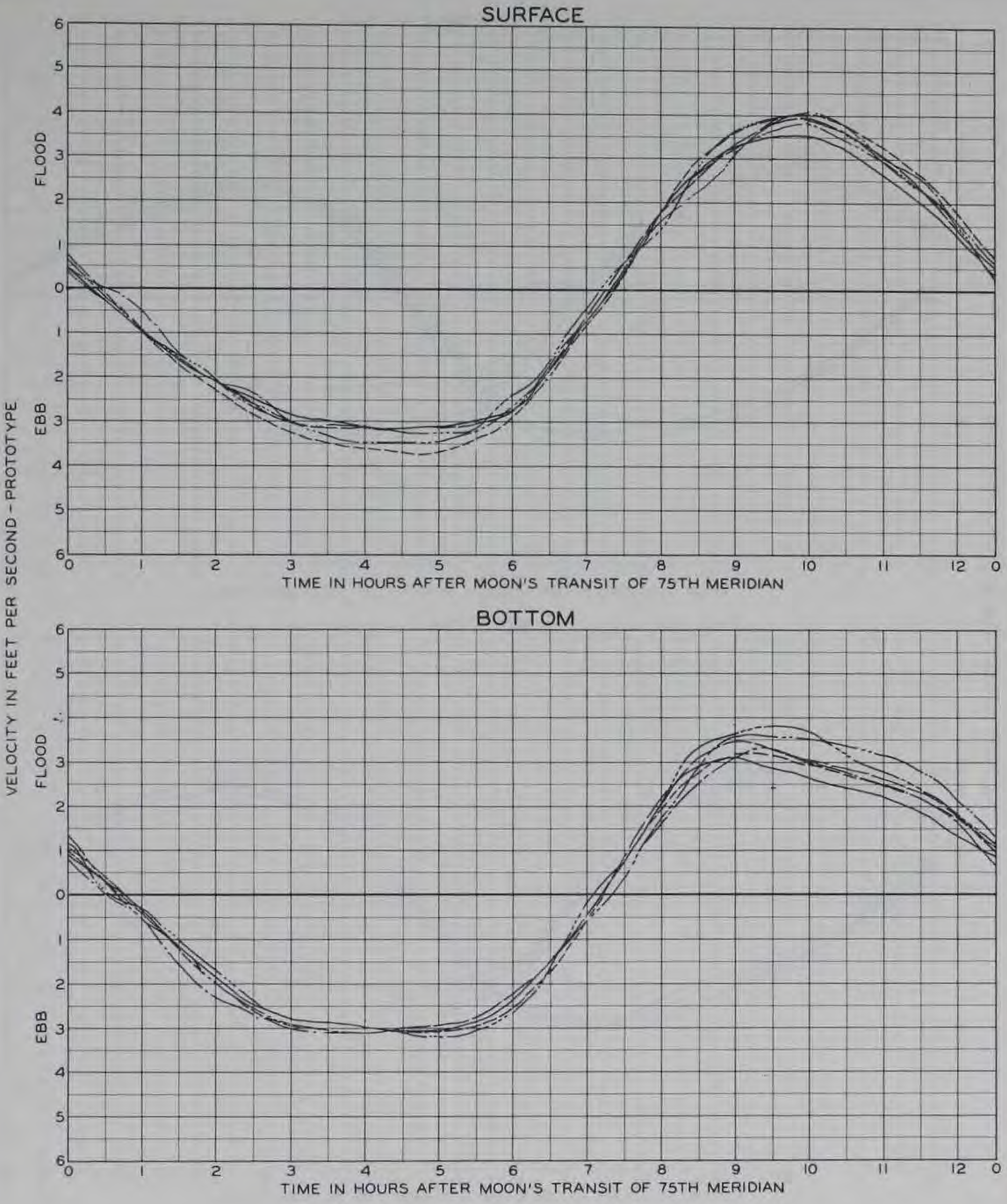
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM
WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL
SANDY HOOK, 1929 ADJUSTMENT.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS

TURKEY POINT



LOCATION OF VELOCITY STATIONS



TEST CONDITIONS

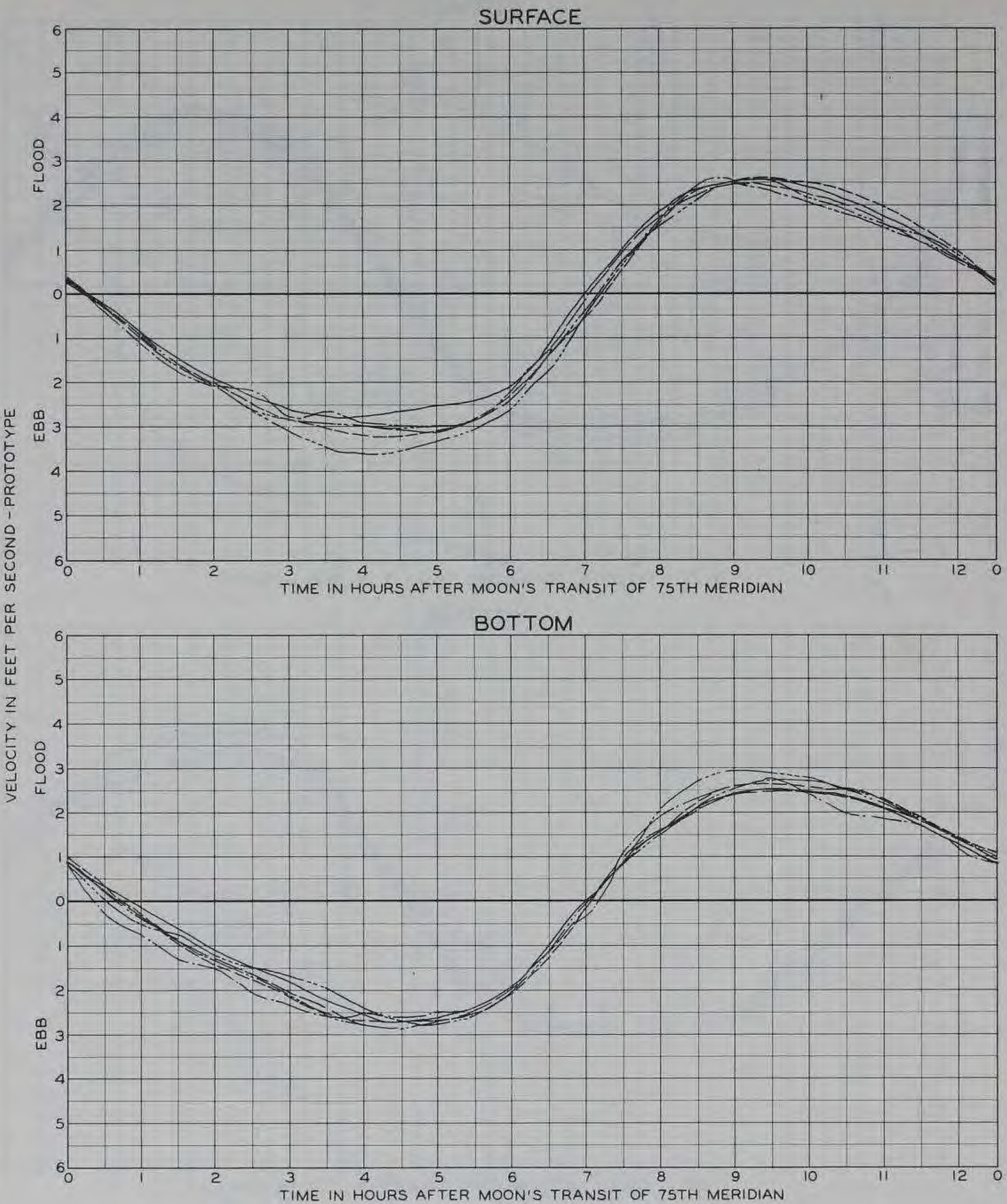
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——— ΔH = + 0.11 FT
— — ΔH = + 0.28 FT
– – – ΔH = + 0.67 FT
—·— ΔH = + 1.44 FT
—··— ΔH = − 0.48 FT
—···— ΔH = − 0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION 220



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

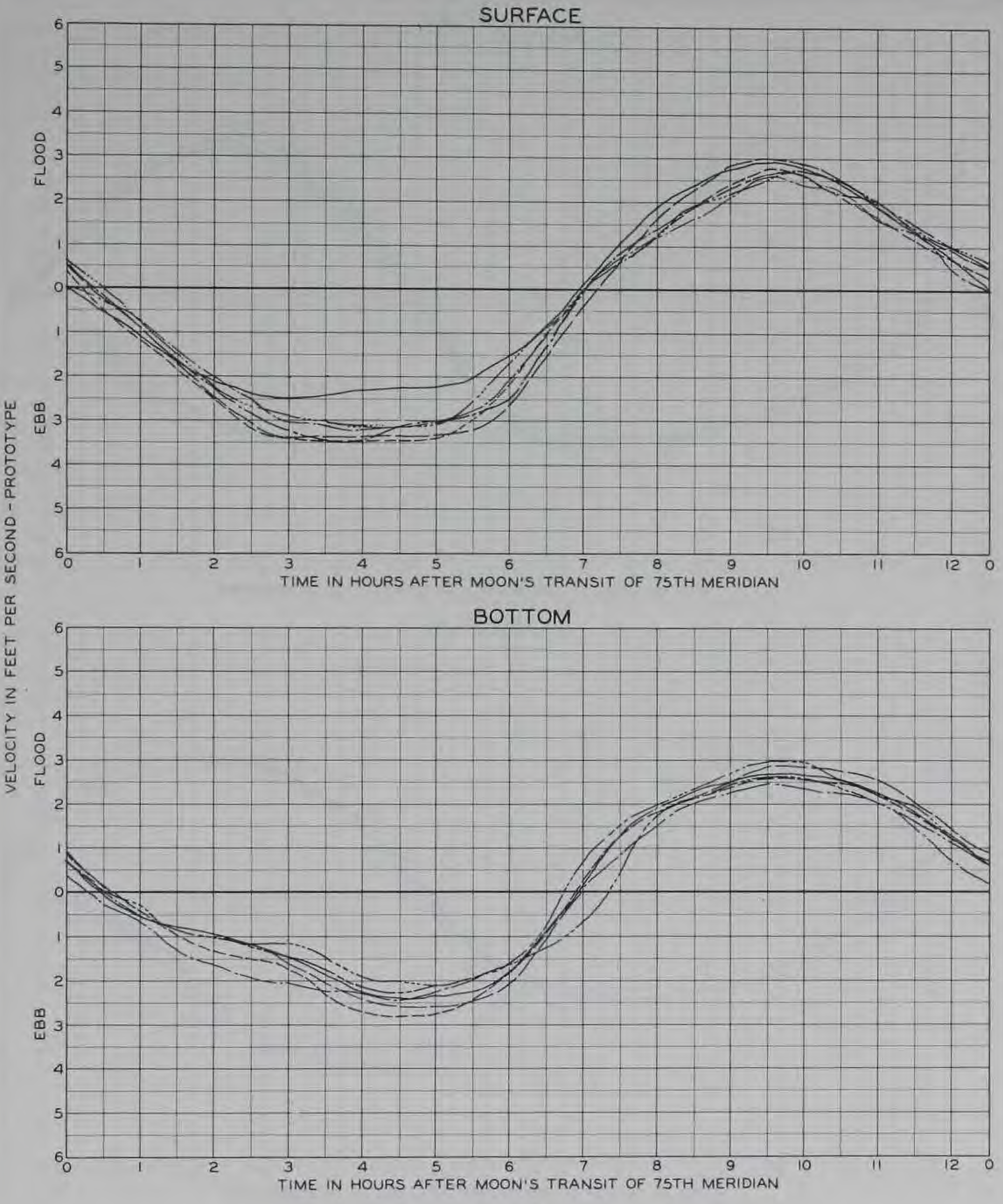
LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION 230

PLATE 22



TEST CONDITIONS

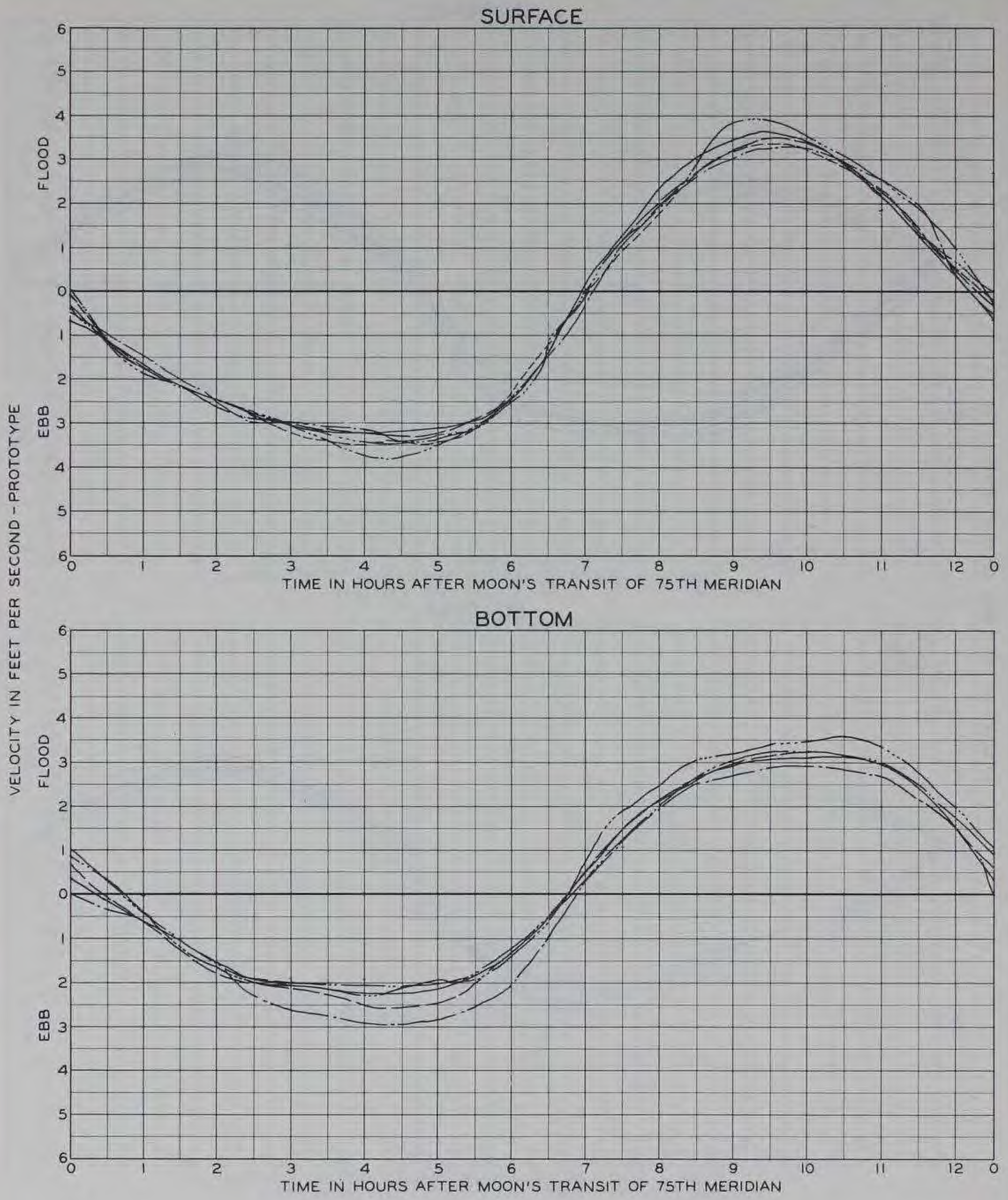
DELAWARE RIVER SOURCE SALINITY..... 31,000 PPM
ELK RIVER SOURCE SALINITY............ 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——————— ΔH = +0.11 FT
——— ——— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——— · ——— ΔH = +1.44 FT
——— ·· ——— ΔH = −0.48 FT
——— ··· ——— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION 235



TEST CONDITIONS

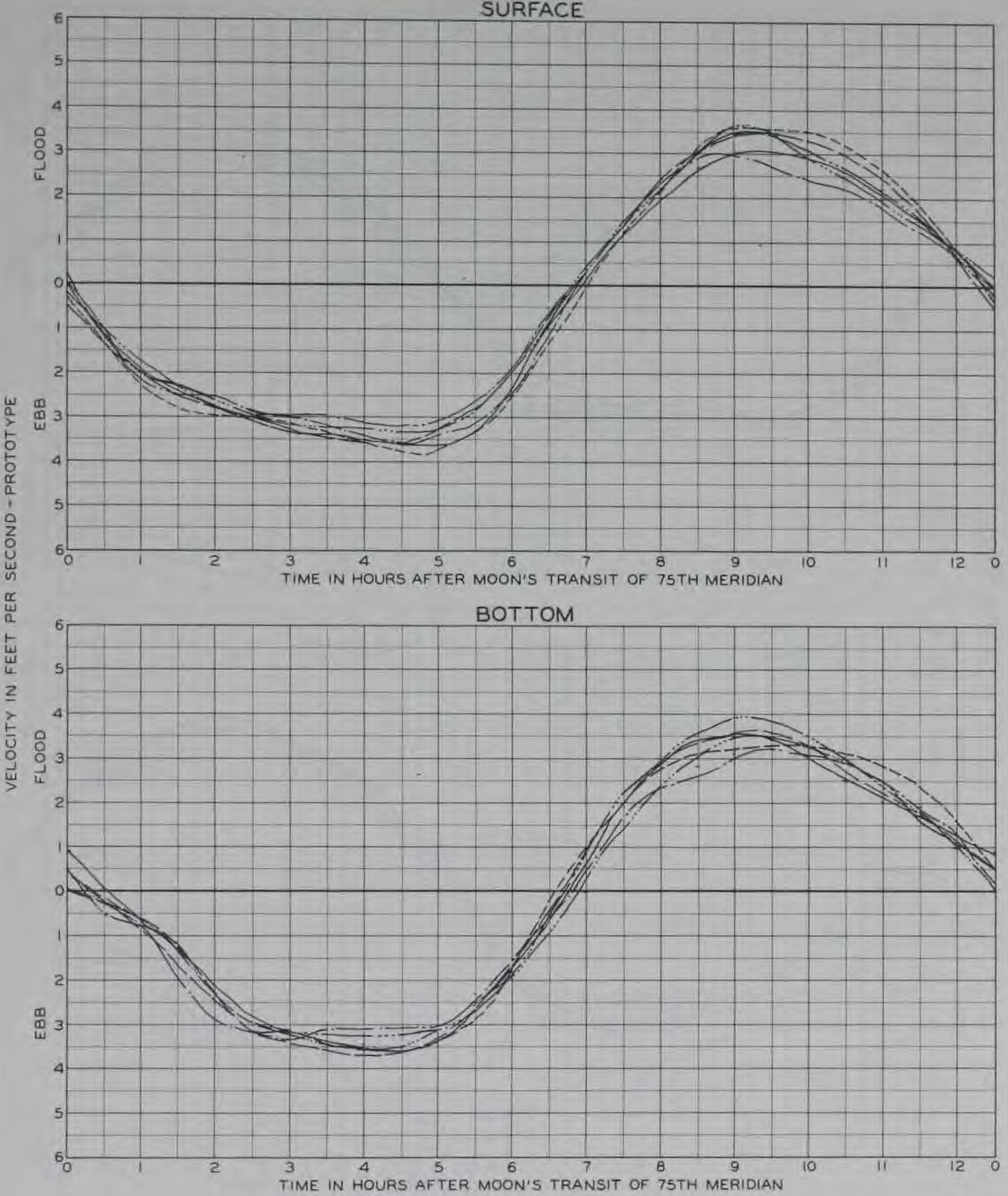
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

ΔH = +0.11 FT
ΔH = +0.28 FT
ΔH = +0.67 FT
ΔH = +1.44 FT
ΔH = −0.48 FT
ΔH = −0.91 FT

EFFECTS OF MEAN
TIDE LEVEL DIFFERENCES ON
CURRENT VELOCITIES
STATION 240

PLATE 24



TEST CONDITIONS

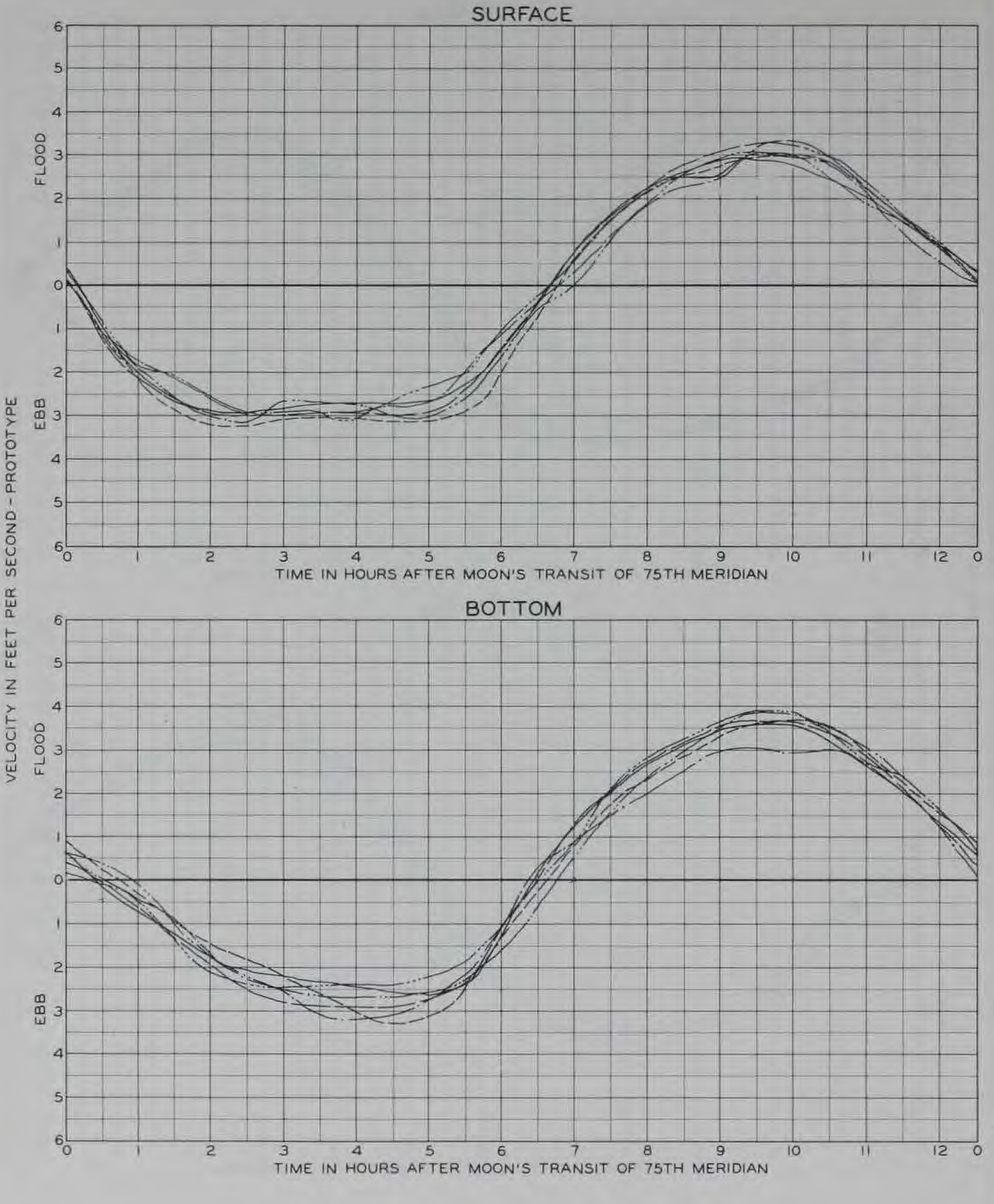
DELAWARE RIVER SOURCE SALINITY ..... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION 245



TEST CONDITIONS

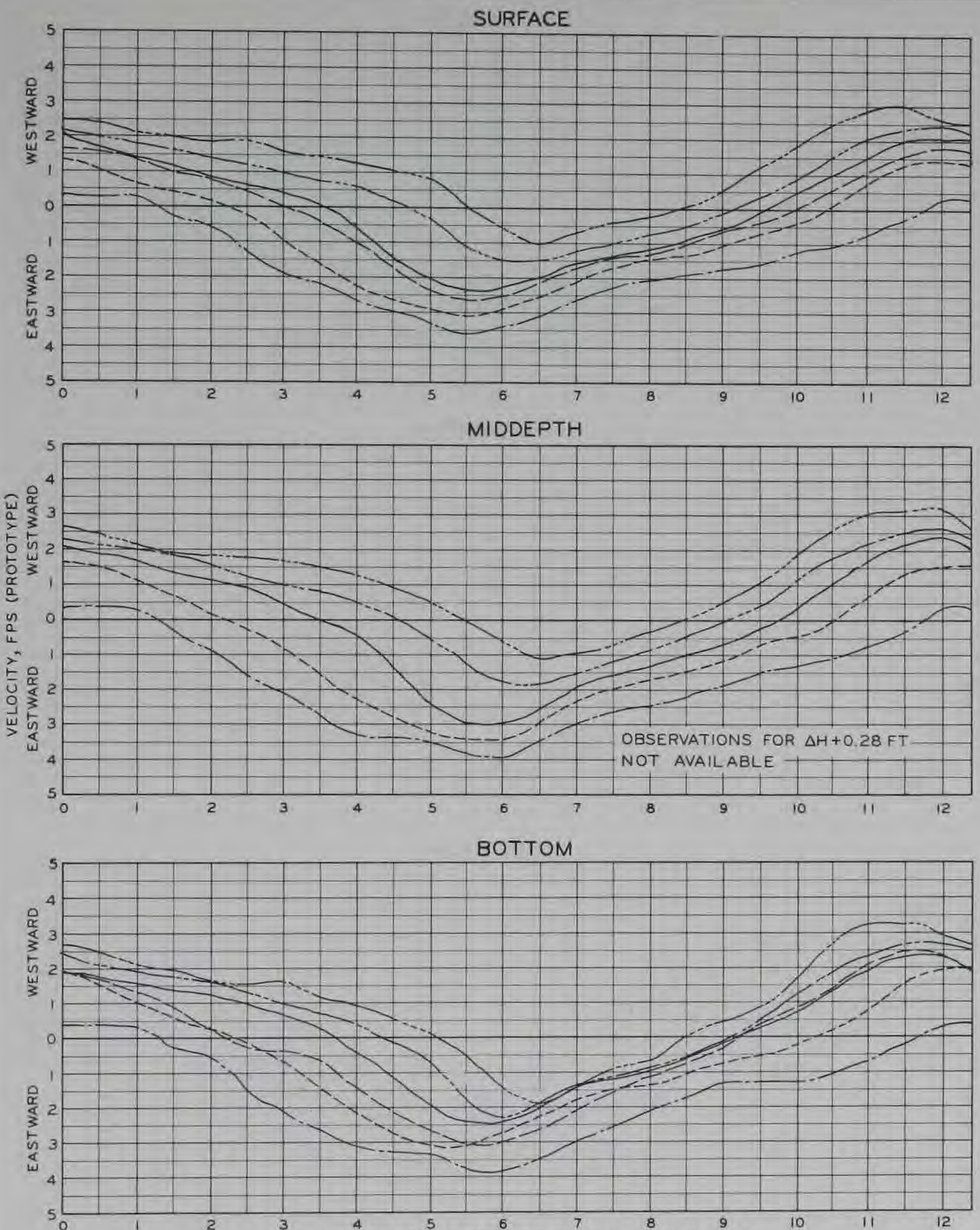
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——————— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION 255



TEST CONDITIONS

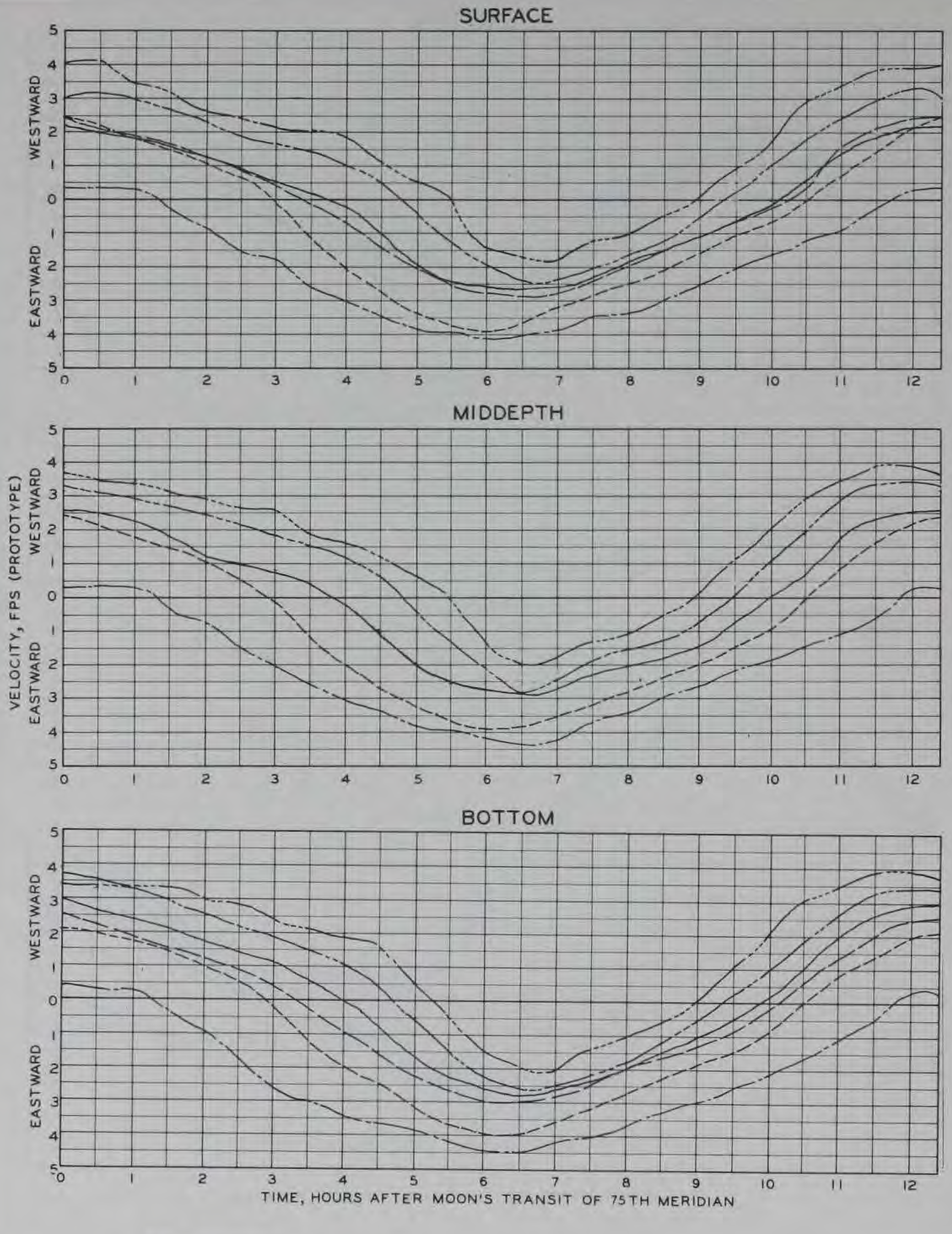
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

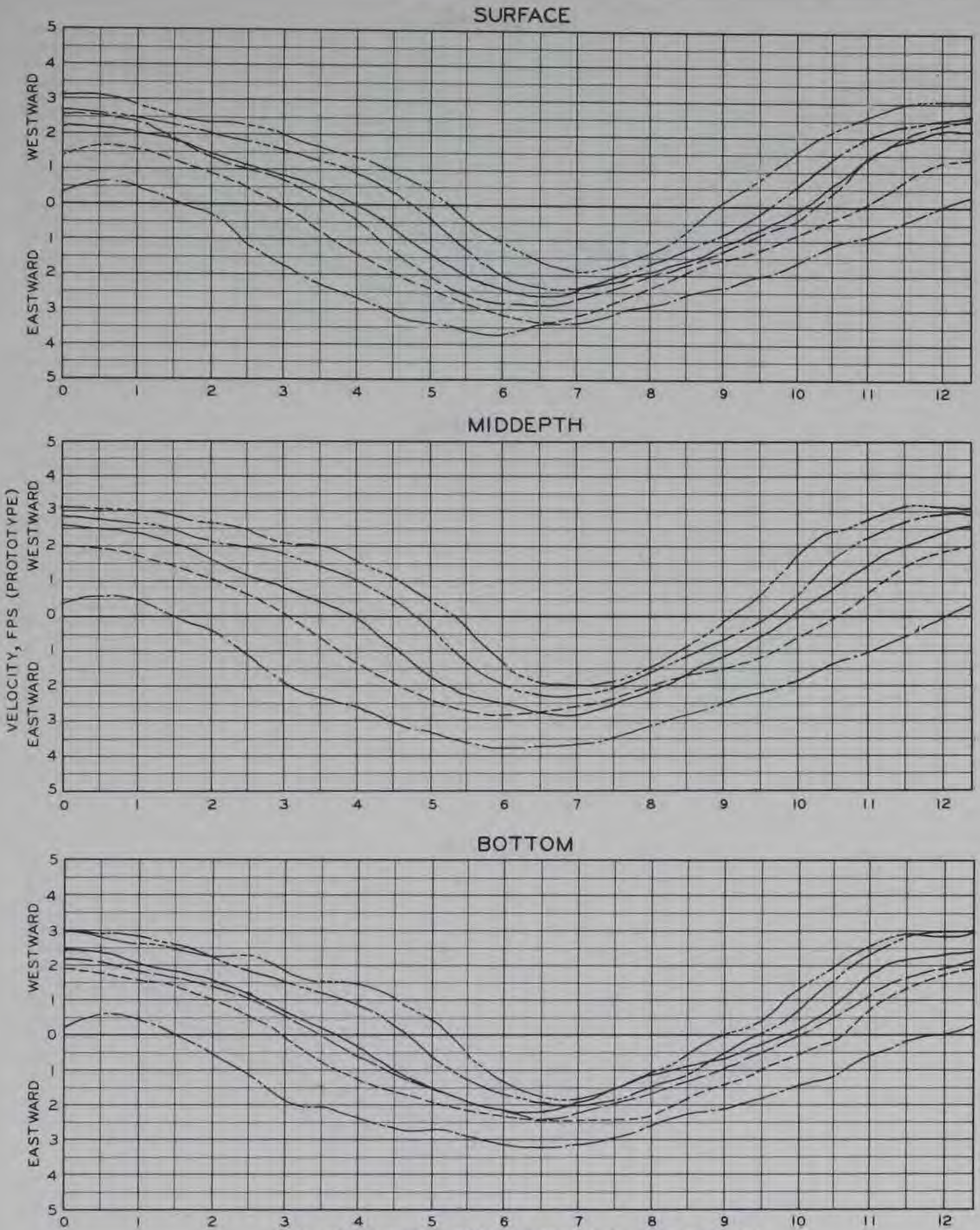
LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION B

PLATE 28



TEST CONDITIONS

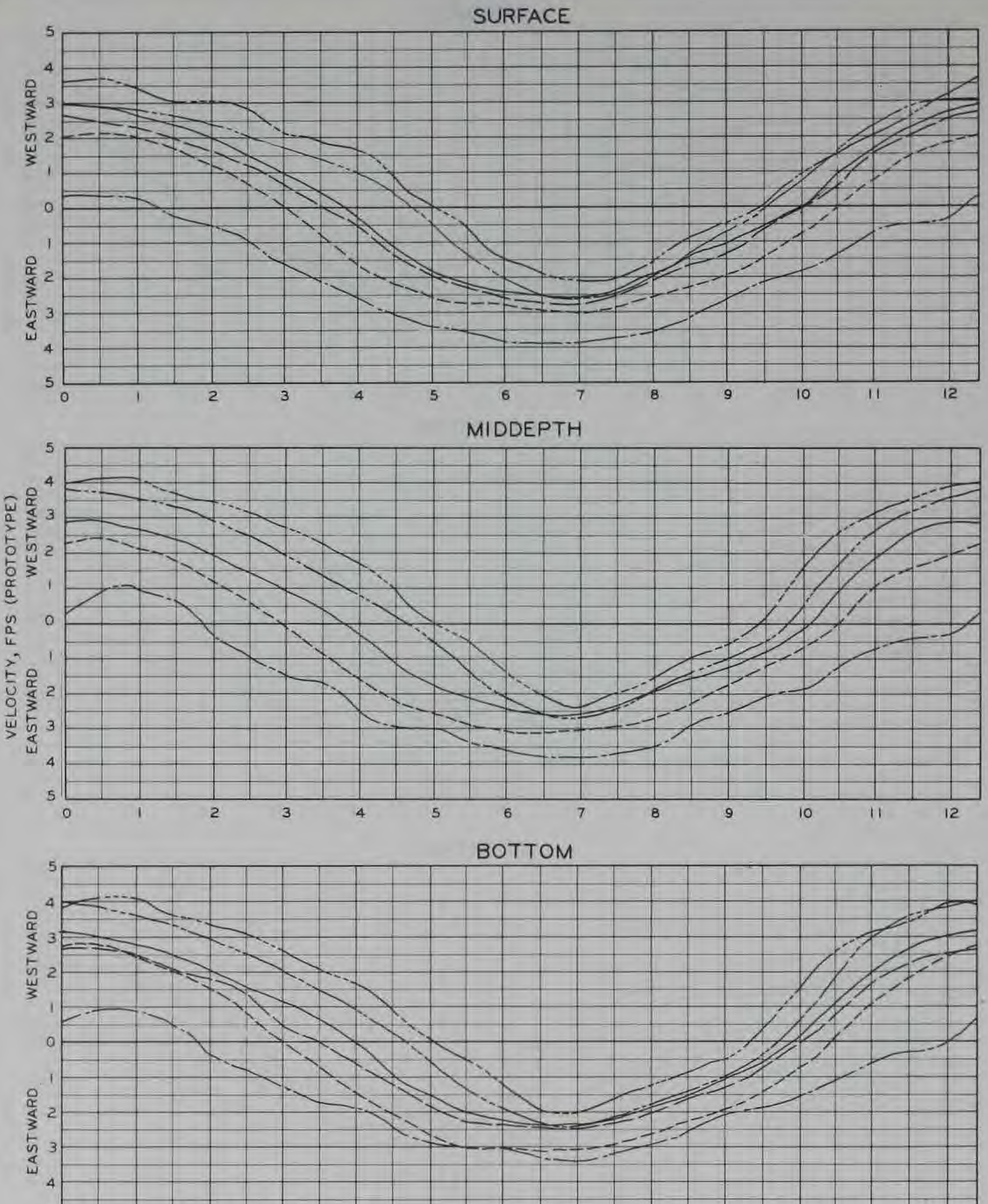
DELAWARE RIVER SOURCE SALINITY .....31,000 PPM
ELK RIVER SOURCE SALINITY ....1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..........1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

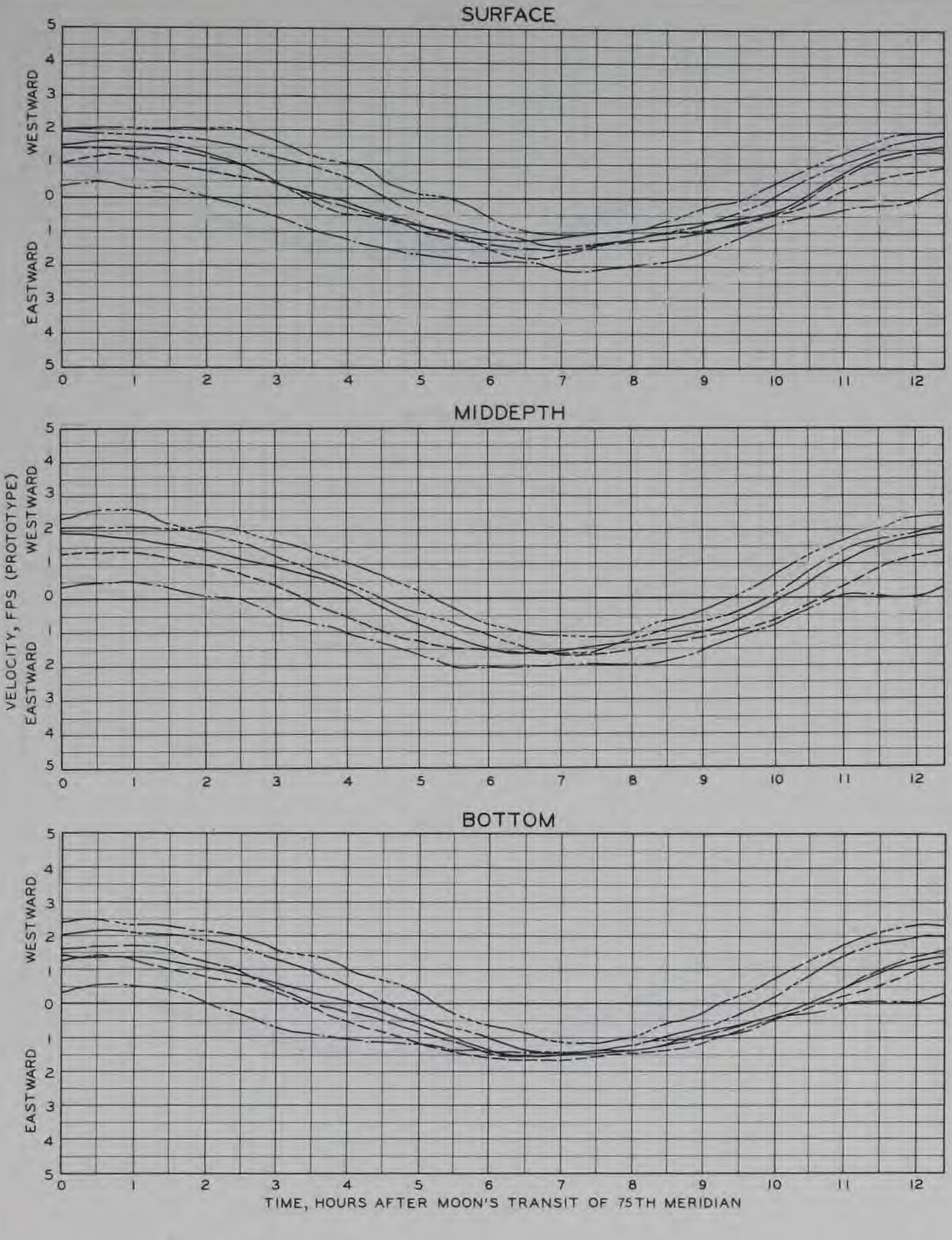
LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION D

PLATE 30



TEST CONDITIONS

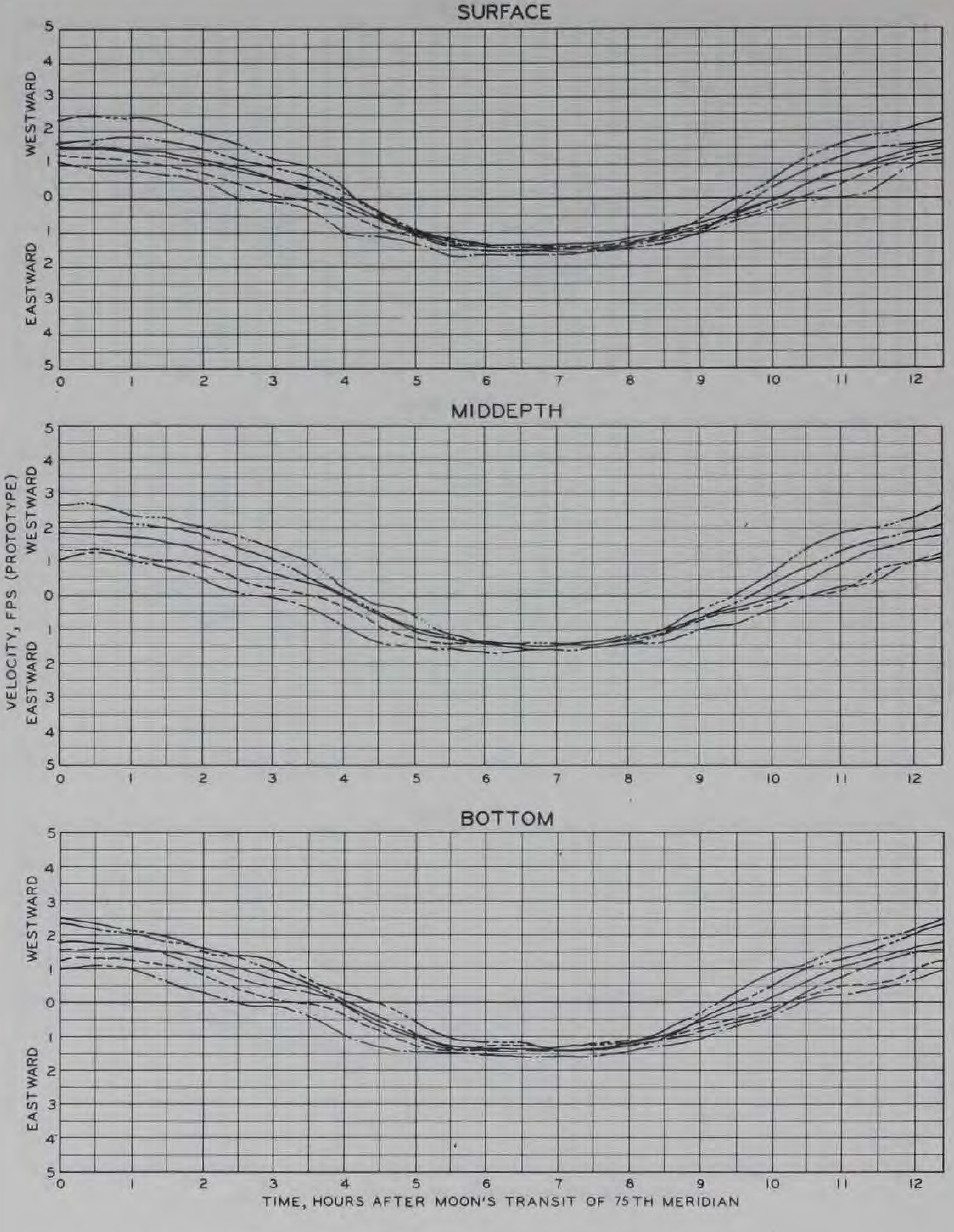
DELAWARE RIVER SOURCE SALINITY..... 31,000 PPM
ELK RIVER SOURCE SALINITY.............. 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION E



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

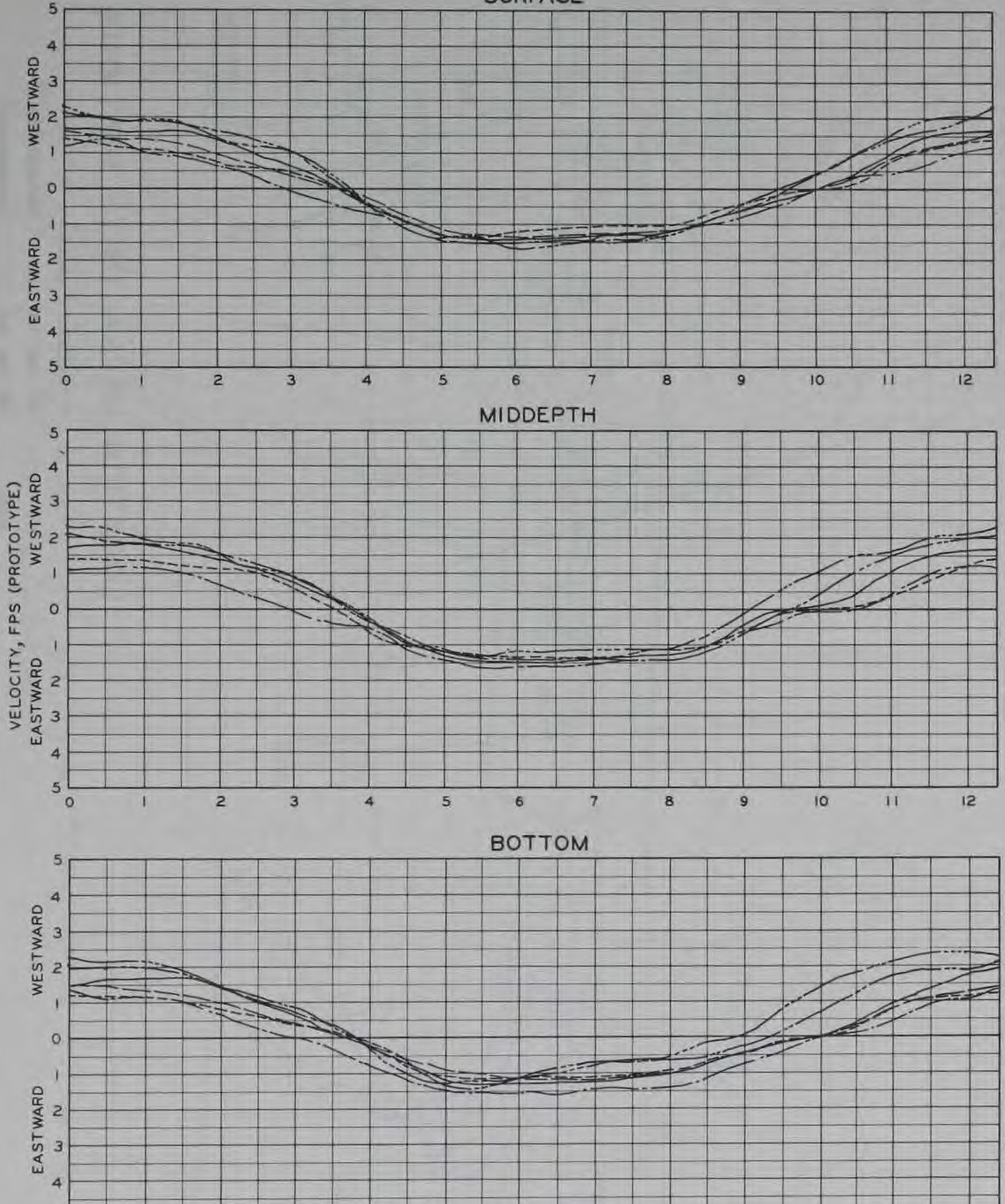
LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
– – – – ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION F

PLATE 32



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..........1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

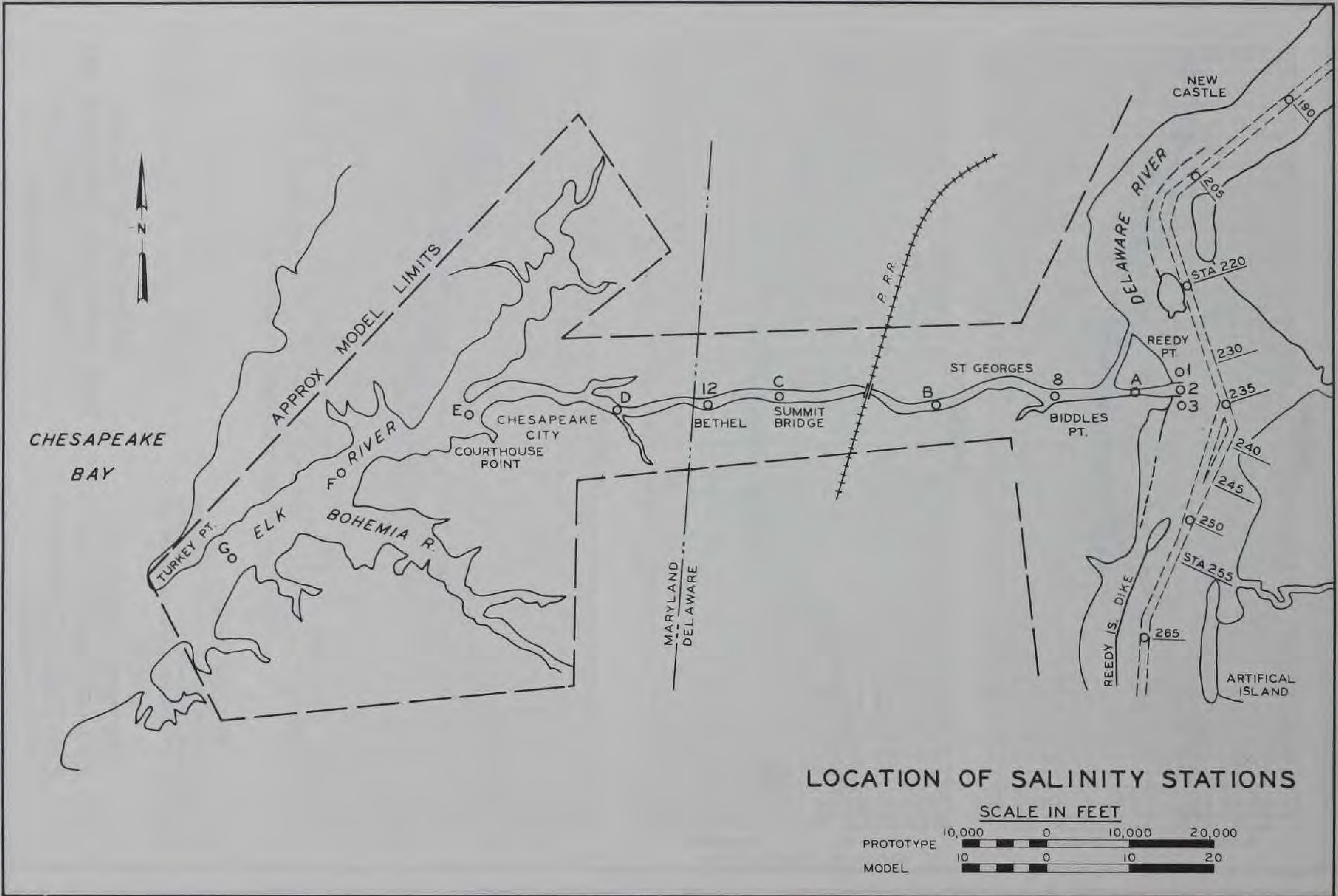
LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

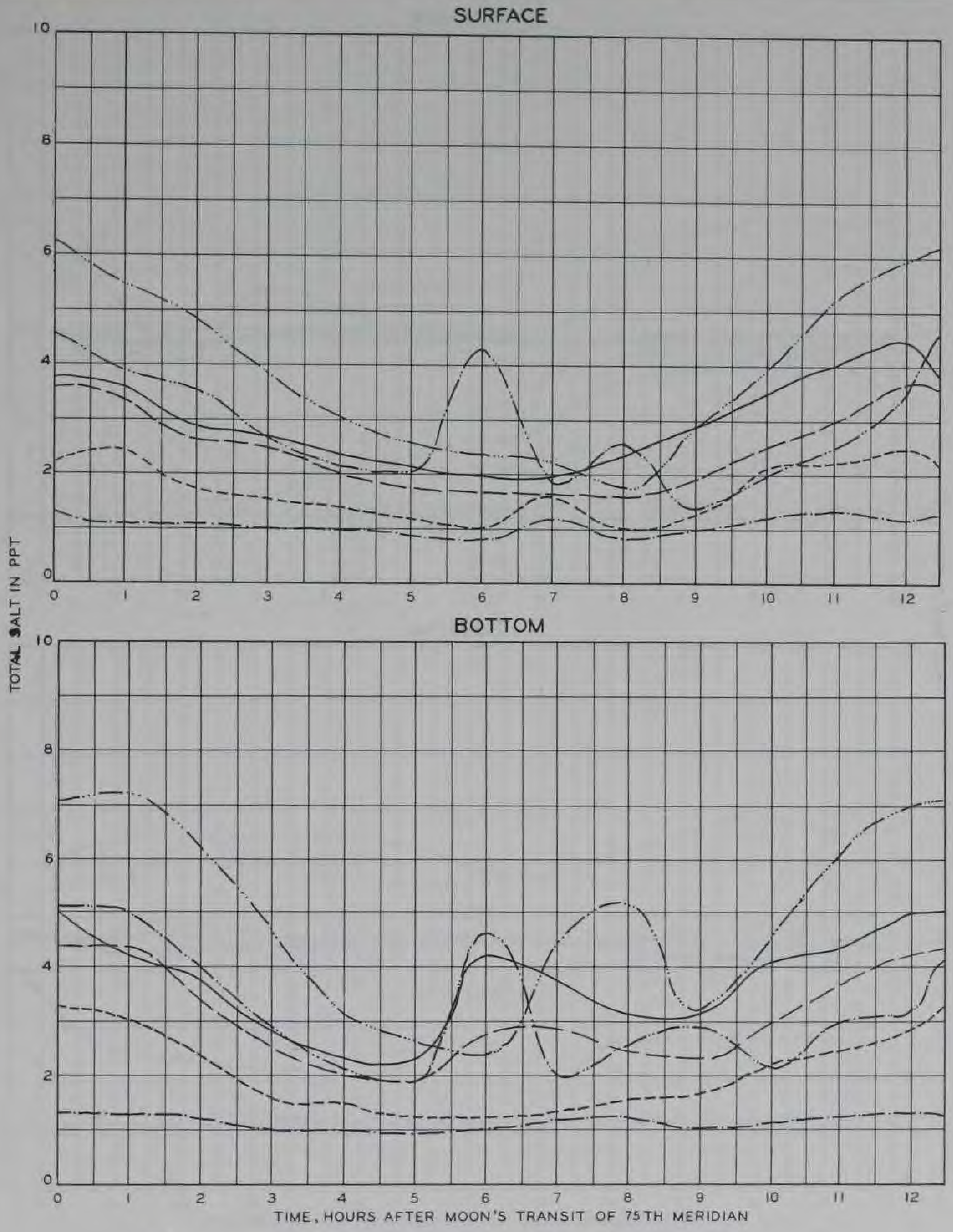
EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES

STATION G

PLATE 34



LOCATION OF SALINITY STATIONS



TEST CONDITIONS

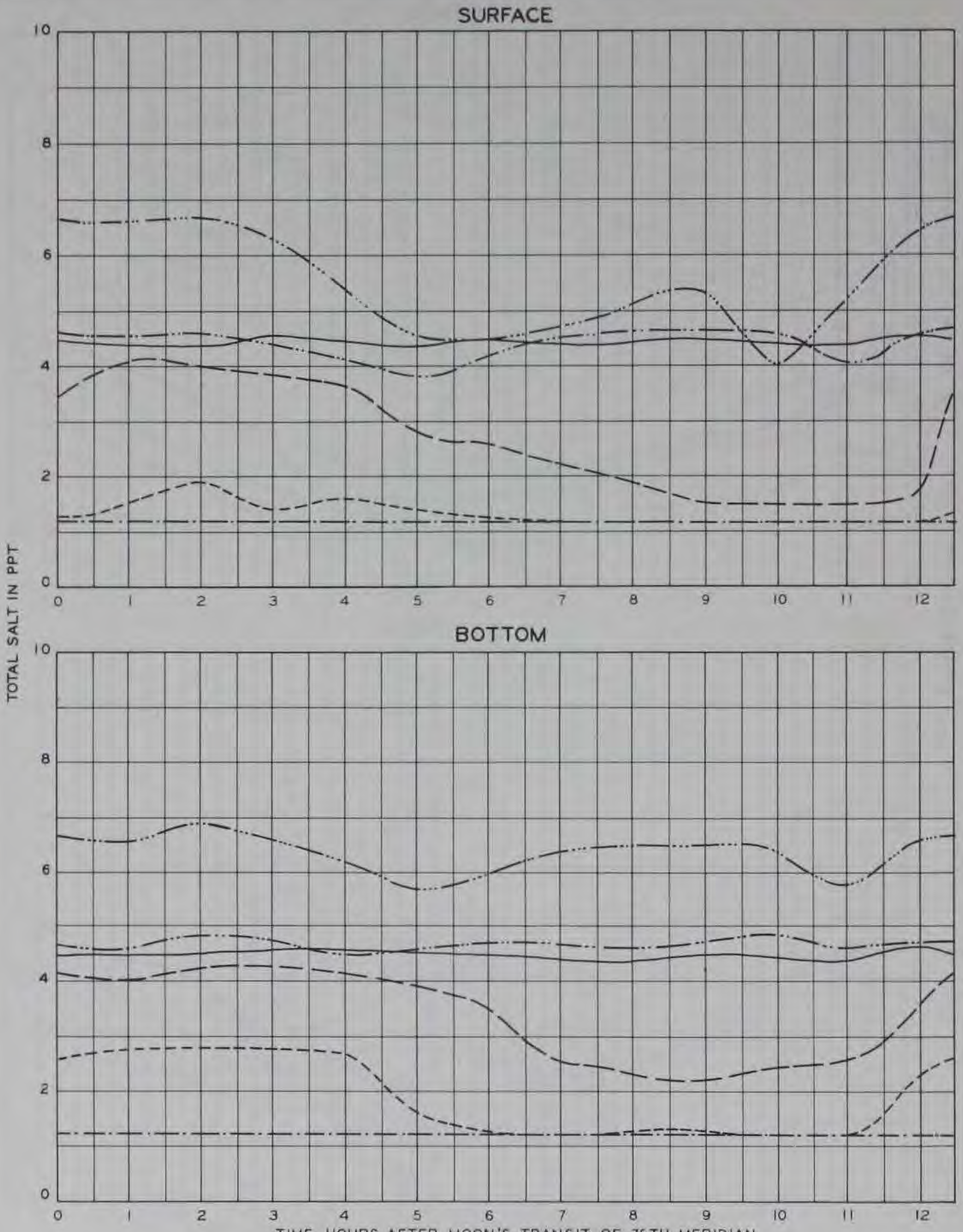
DELAWARE RIVER SOURCE SALINITY . . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES

STATION 2



TEST CONDITIONS

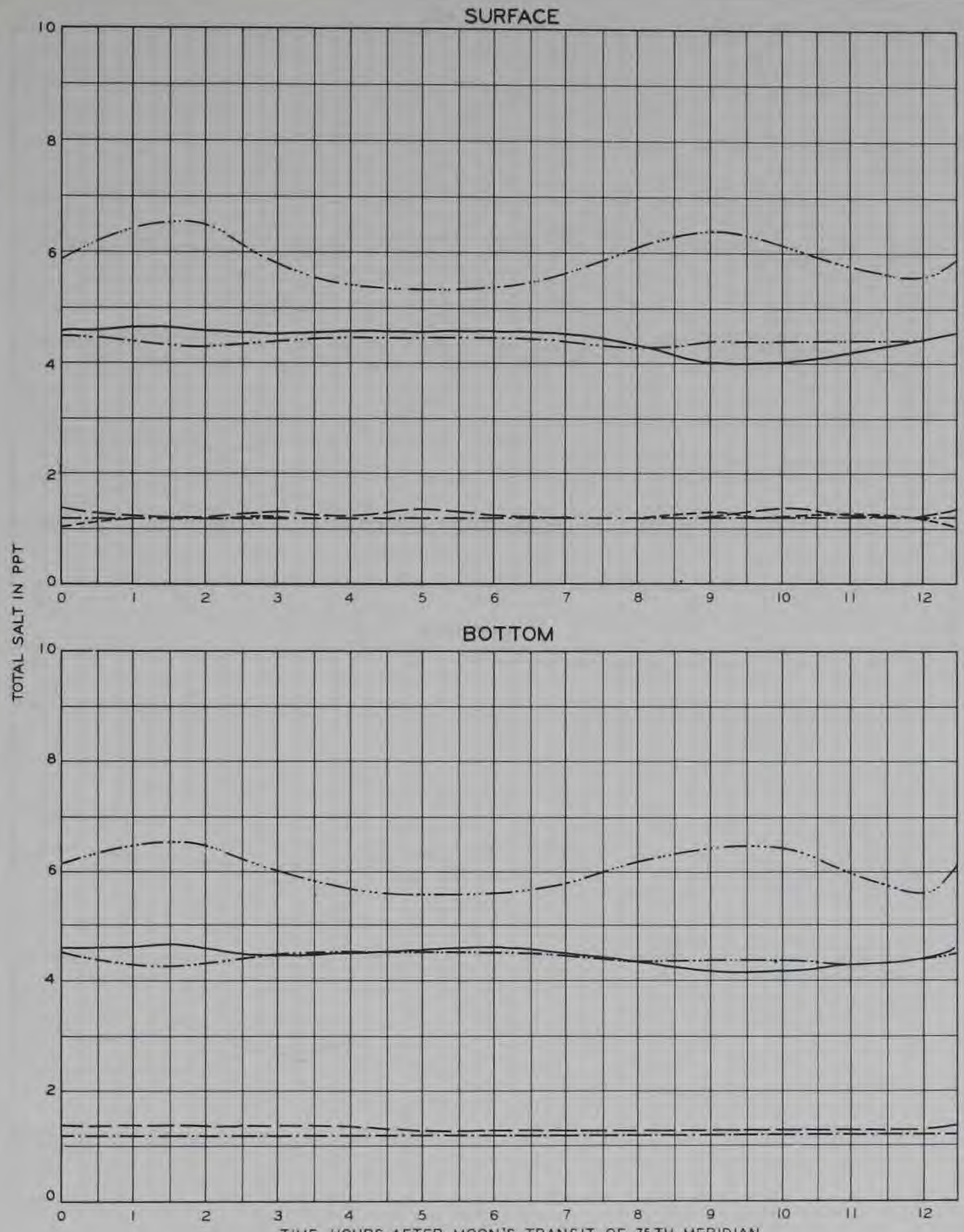
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = + 0.11 FT
—— —— ΔH = + 0.28 FT
— — — ΔH = + 0.67 FT
—·— ΔH = + 1.44 FT
—··— ΔH = − 0.48 FT
—···— ΔH = − 0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES

STATION A



TEST CONDITIONS

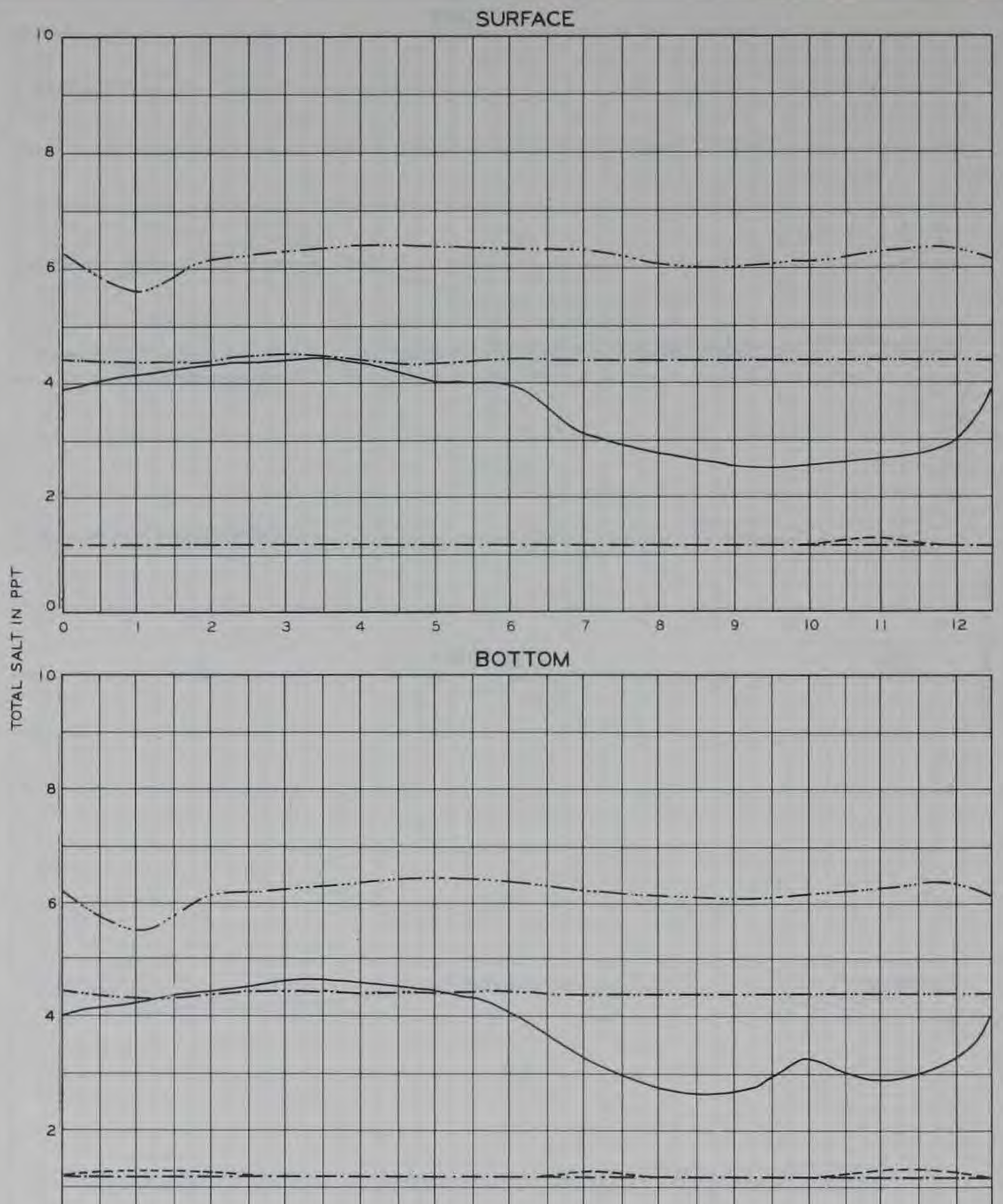
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

———— ΔH = +0.11 FT
—— —— ΔH = +0.28 FT
— — — — ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES

STATION C



TEST CONDITIONS

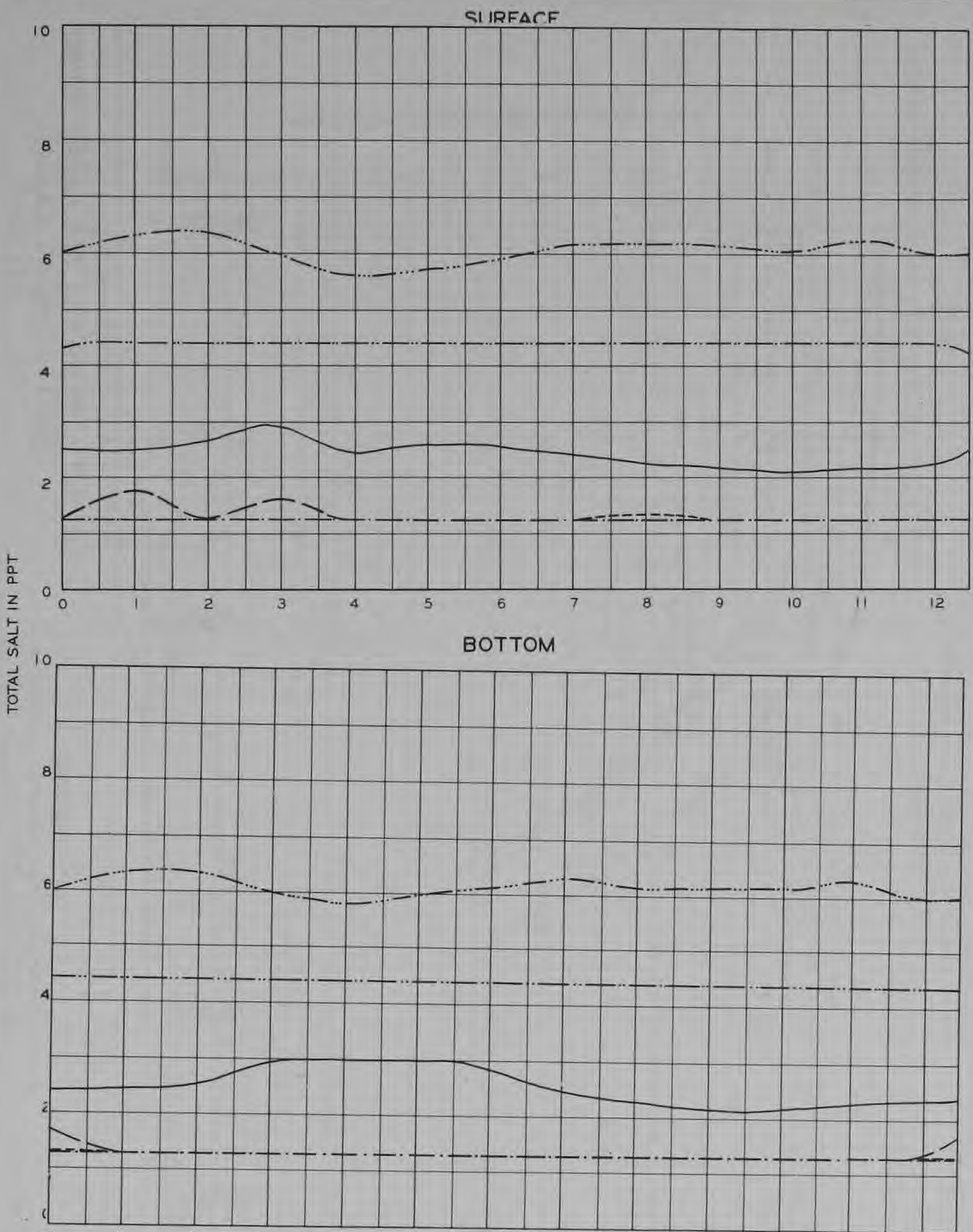
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——— ΔH = +0.11 FT
— — ΔH = +0.28 FT
— — — ΔH = +0.67 FT
—·— ΔH = +1.44 FT
—··— ΔH = −0.48 FT
—···— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES

STATION D



TEST CONDITIONS

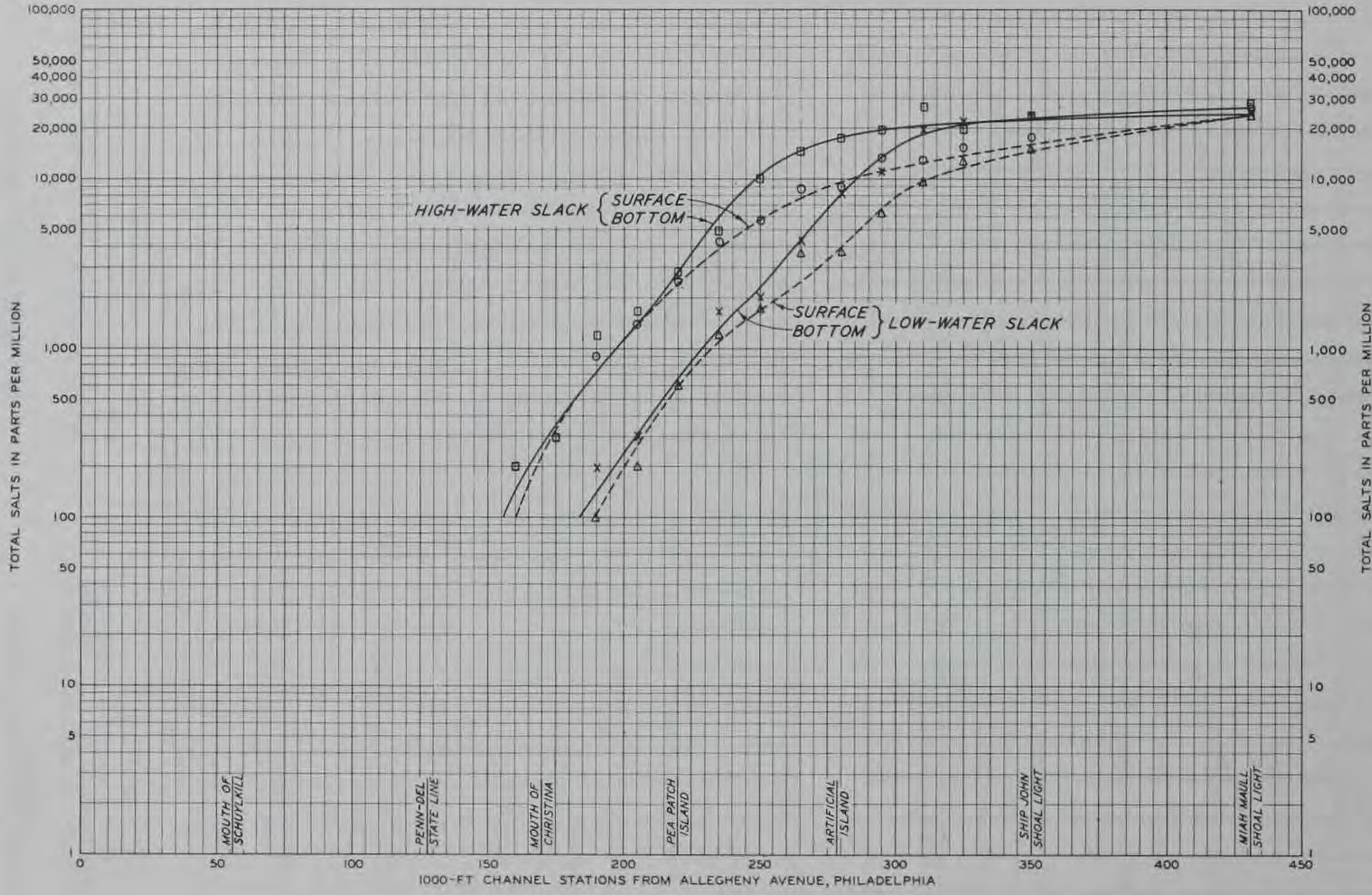
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

——————— ΔH = +0.11 FT
——— ——— ΔH = +0.28 FT
—— —— —— ΔH = +0.67 FT
——·—— ΔH = +1.44 FT
——··—— ΔH = −0.48 FT
——···—— ΔH = −0.91 FT

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES

STATION E



LEGEND

- - - - - SURFACE
———— BOTTOM

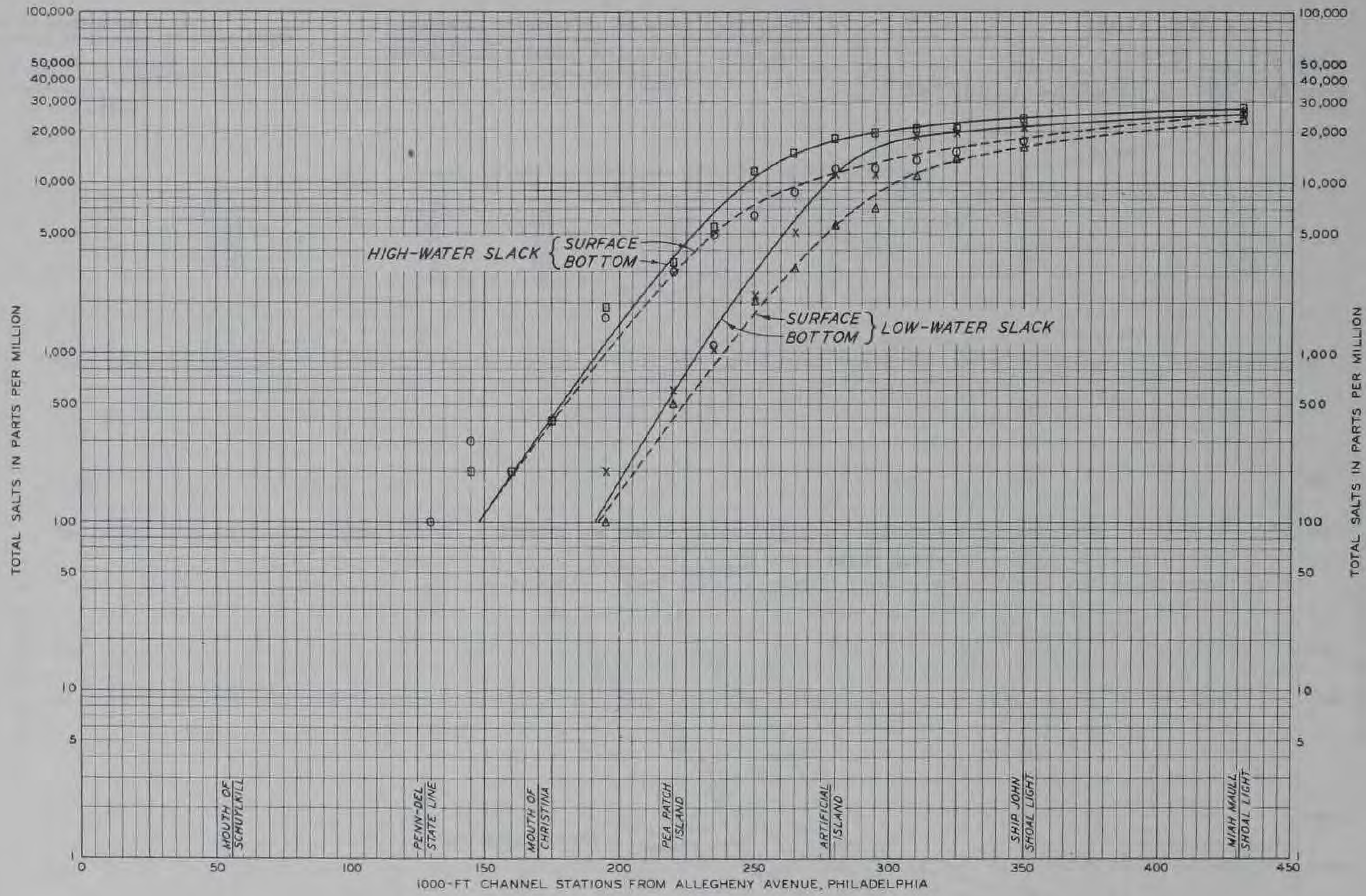
NOTE. ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY....................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL

ΔH = +0.28 FT



LEGEND

- - - - - SURFACE
———— BOTTOM

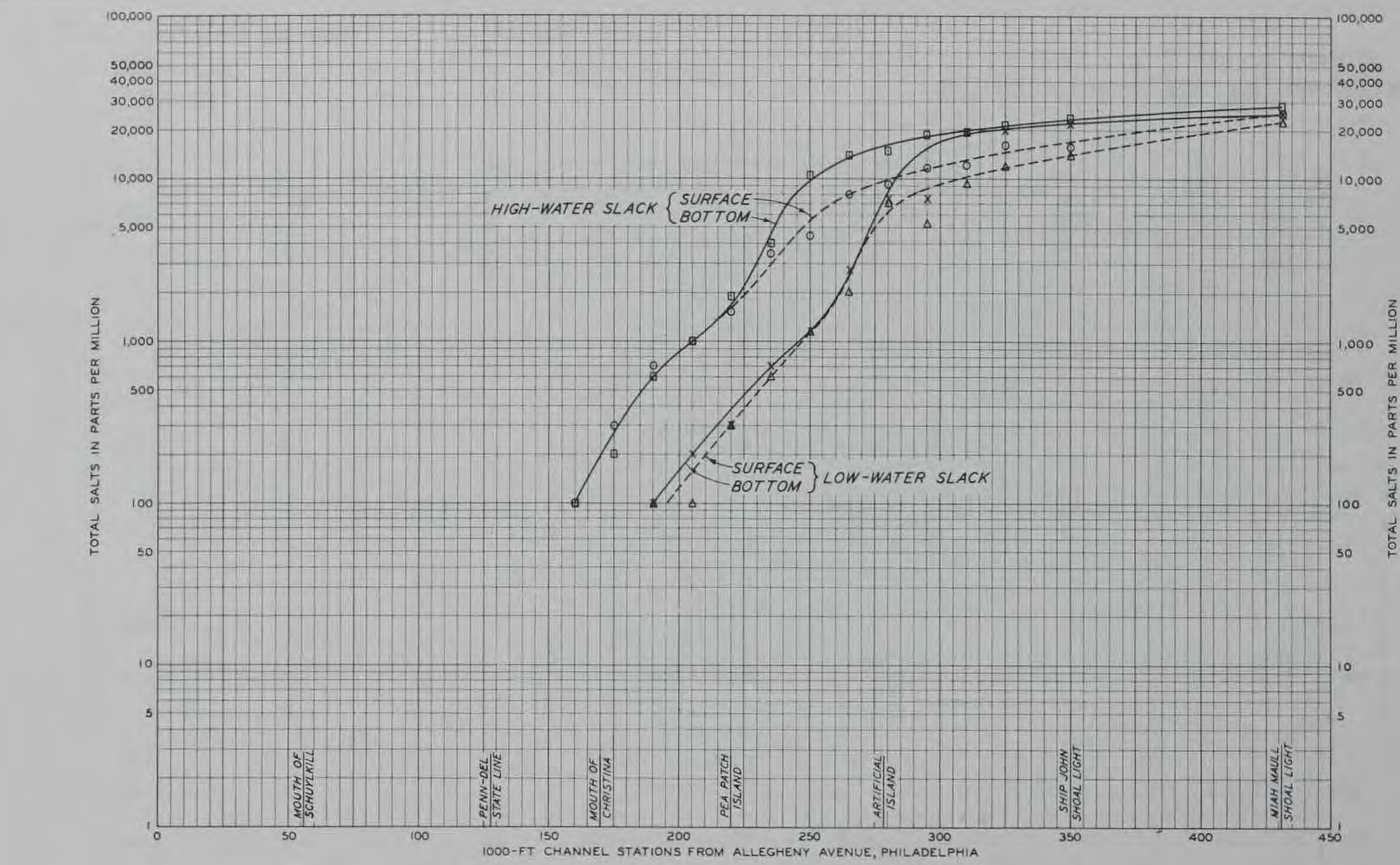
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY...................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL

ΔH = +0.11 FT



LEGEND

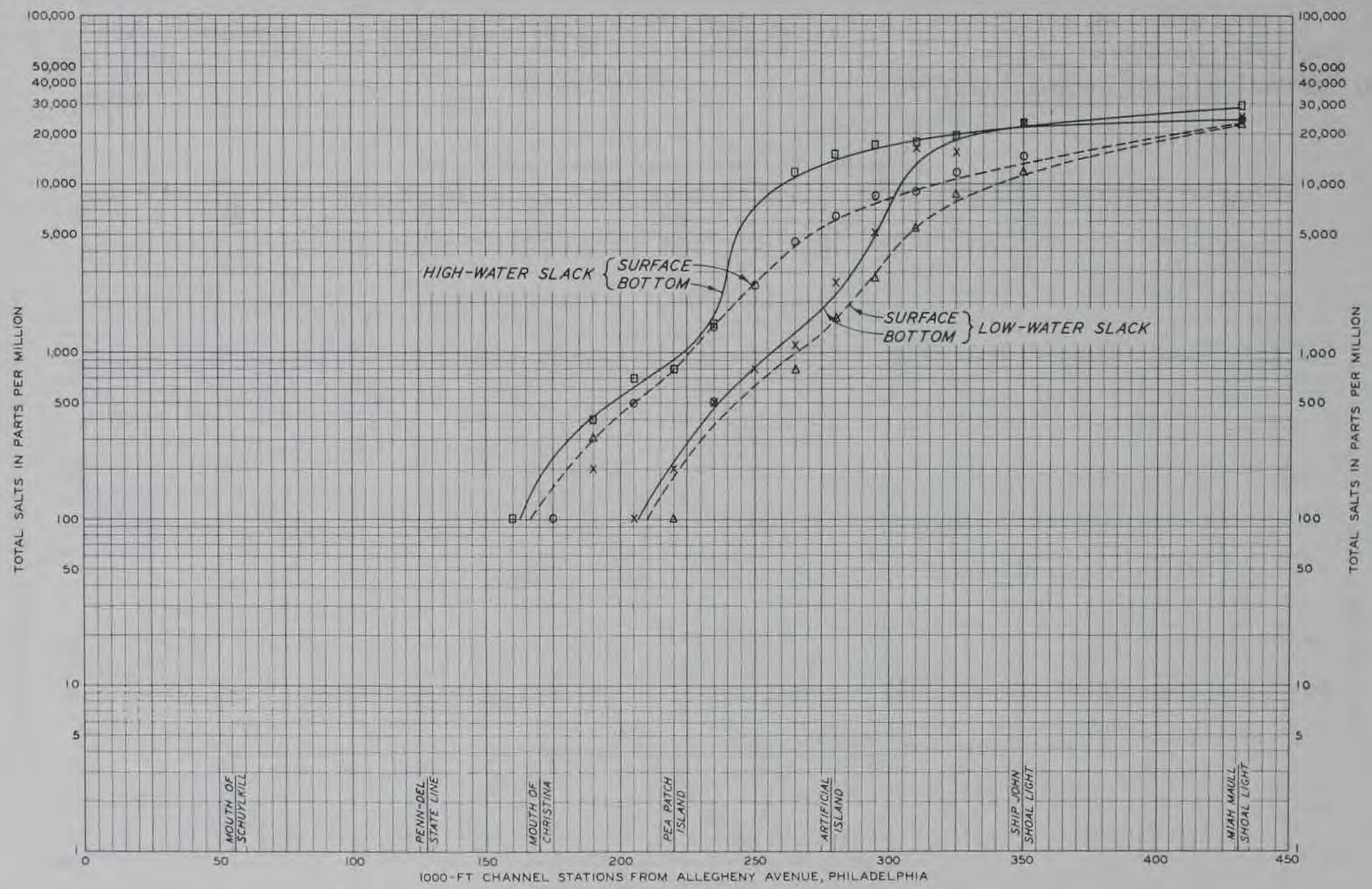
- - - - - SURFACE
———— BOTTOM

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY...................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES ...20,200 CFS

SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL
ΔH = +0.67 FT



LEGEND

- - - - - SURFACE
——— BOTTOM

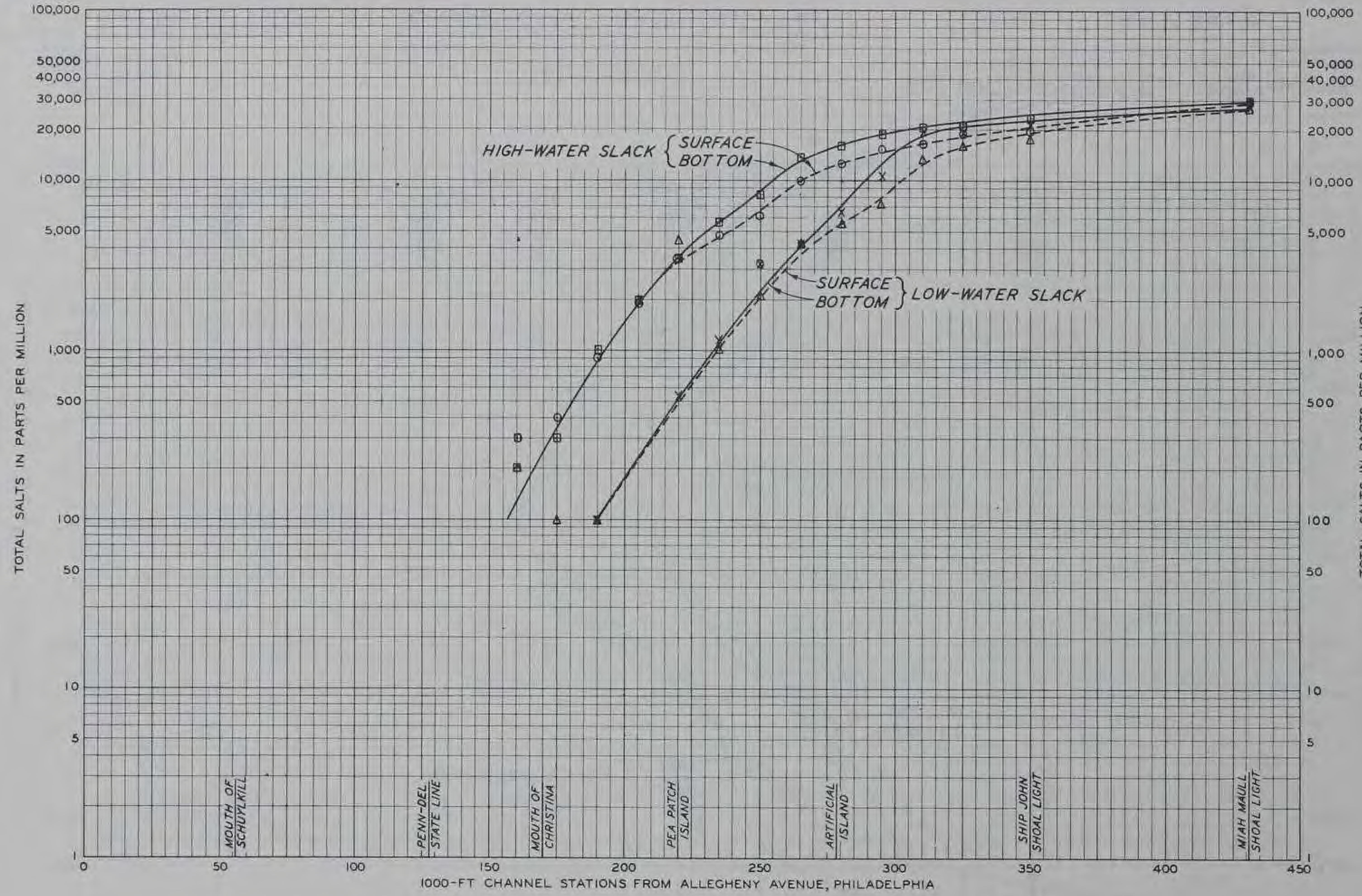
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY......................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL

ΔH = +1.44 FT



LEGEND

- - - - - SURFACE
——— BOTTOM

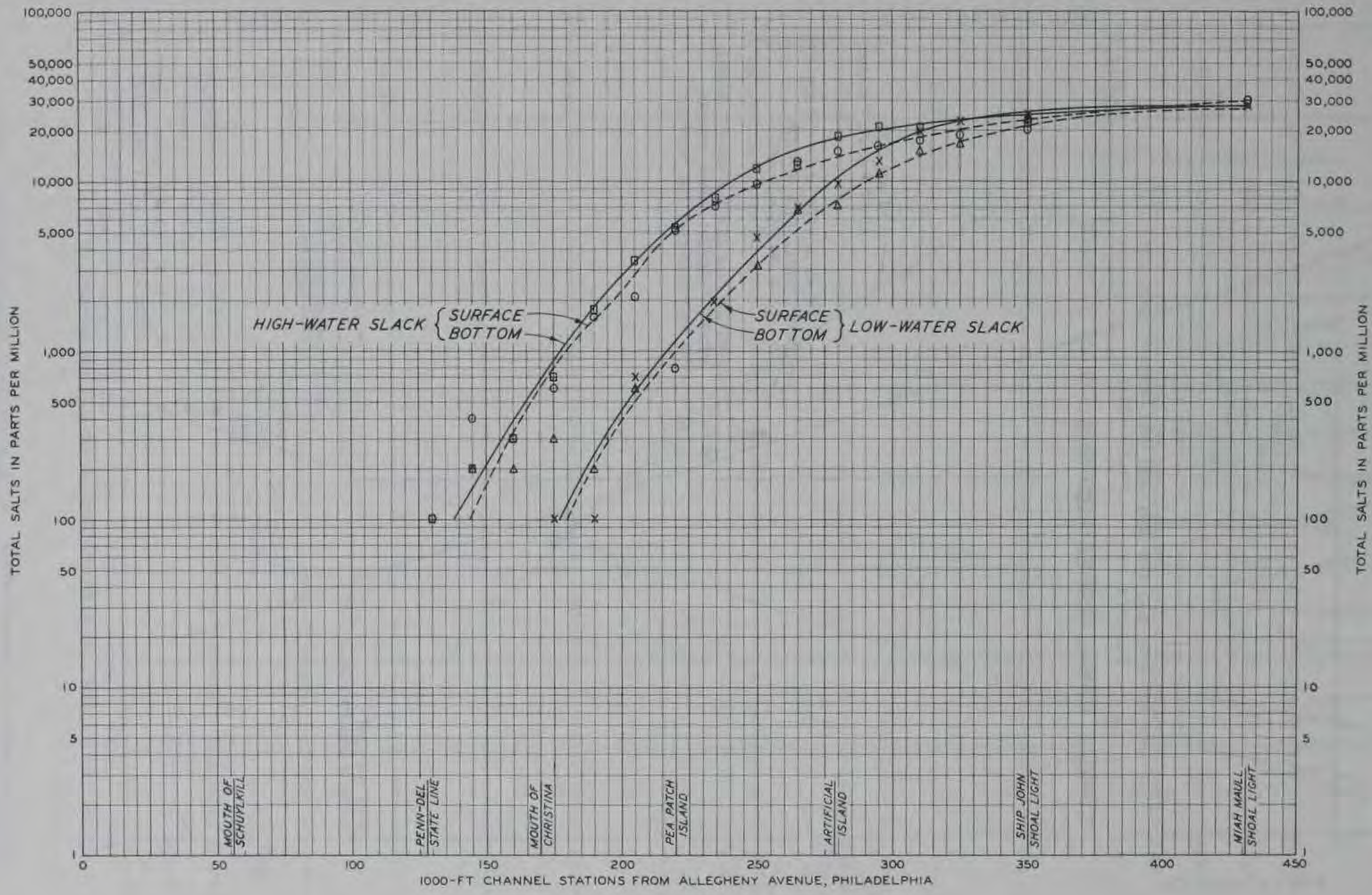
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY....................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL

ΔH = −0.48 FT



LEGEND

- - - - - SURFACE
——— BOTTOM

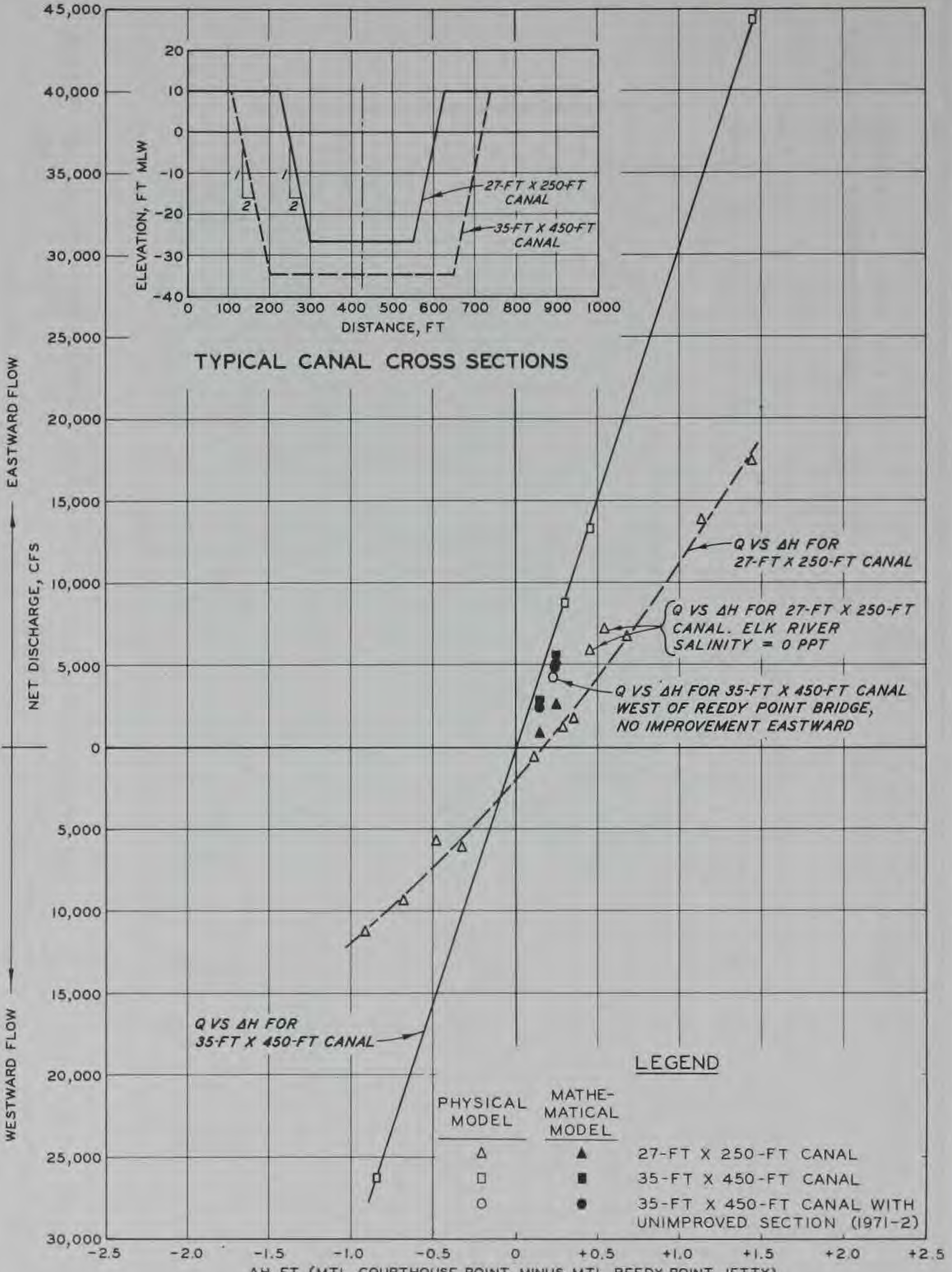
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY....................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

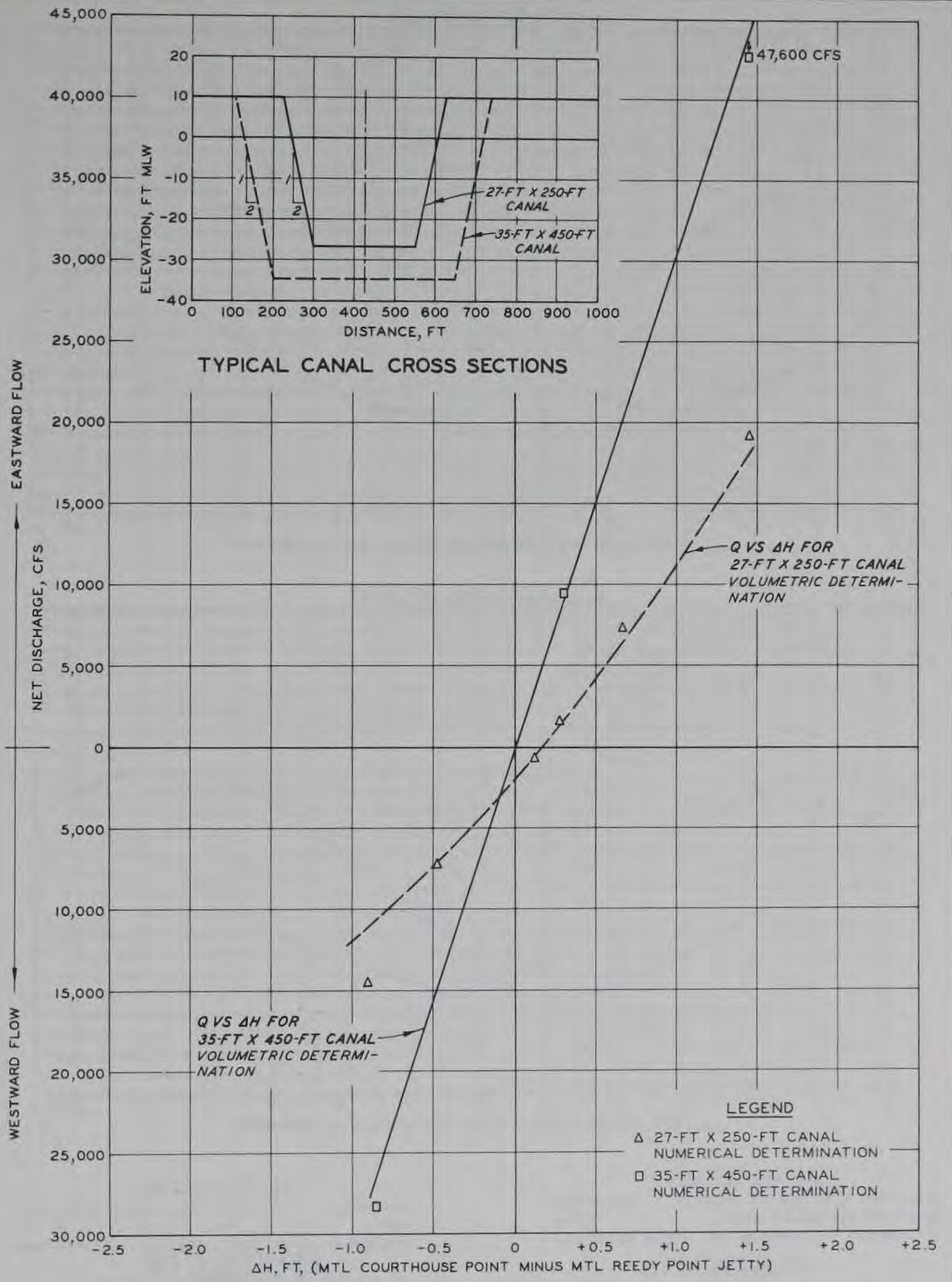
SALINITY PROFILES DELAWARE RIVER
27 FT X 250 FT CANAL

ΔH = −0.91 FT



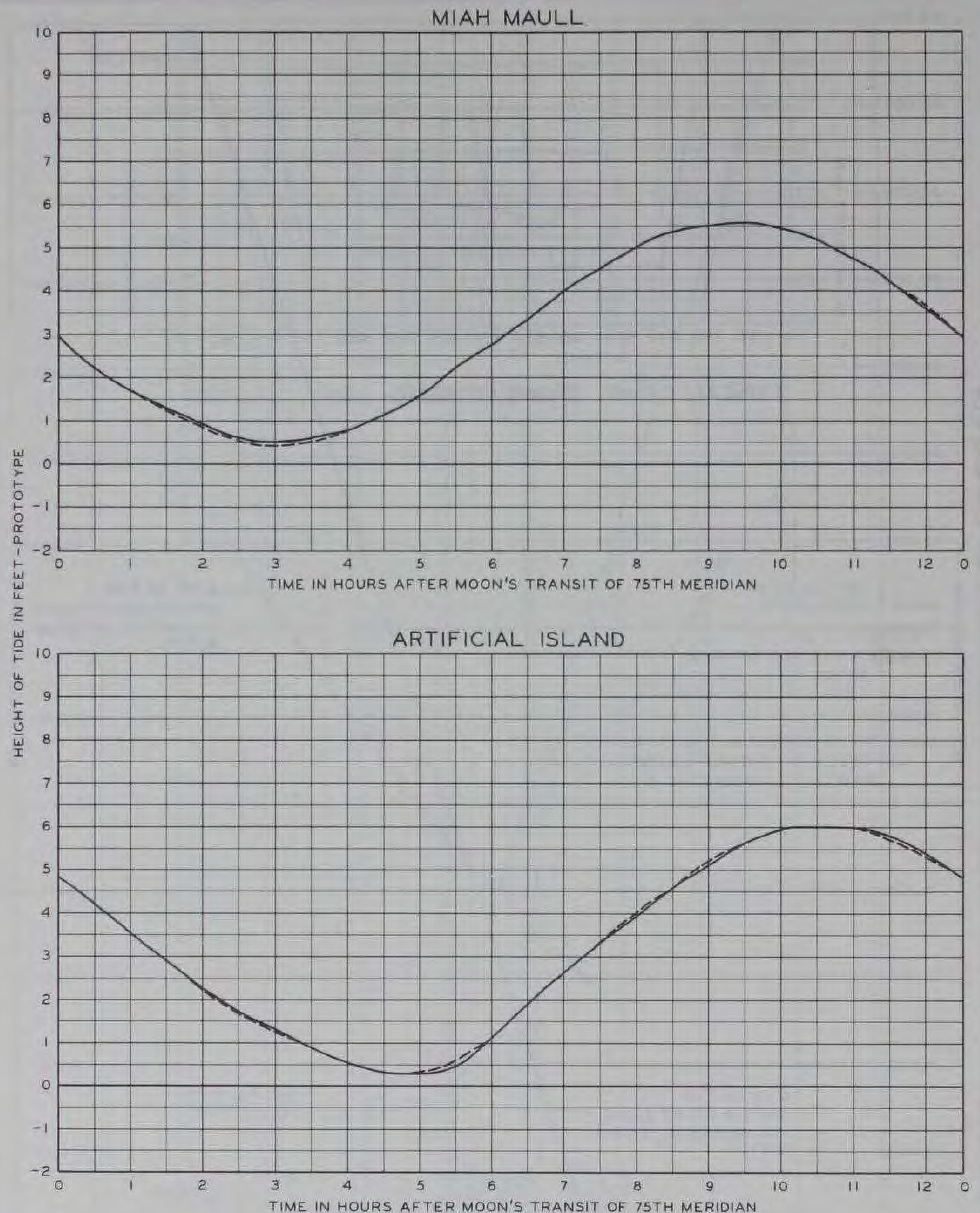
NOTE: TIDE HEIGHTS USED TO COMPUTE MEAN
TIDE LEVELS REFER TO DELAWARE RIVER
DATUM WHICH IS 2.90 FT BELOW MSL
SANDY HOOK, 1929 ADJUSTMENT.

EFFECT OF
CANAL ENLARGEMENT
ON NET DISCHARGE



NOTE: TIDE HEIGHTS USED TO COMPUTE MEAN TIDE LEVELS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FT BELOW MSL SANDY HOOK, 1929 ADJUSTMENT.

COMPARISON OF VOLUMETRIC AND NUMERICAL DETERMINATION OF NET DISCHARGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

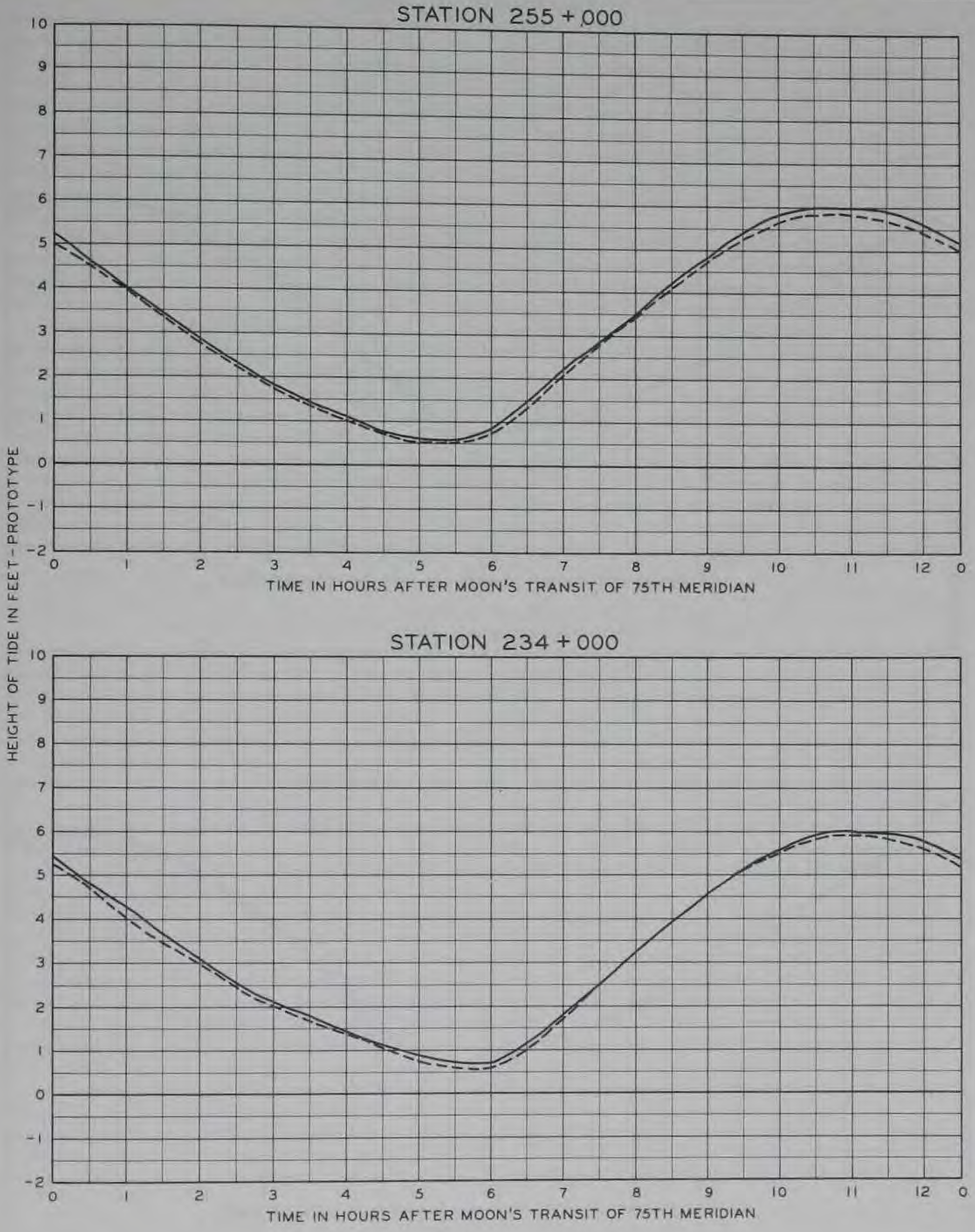
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS MIAH MAULL AND ARTIFICIAL ISLAND



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

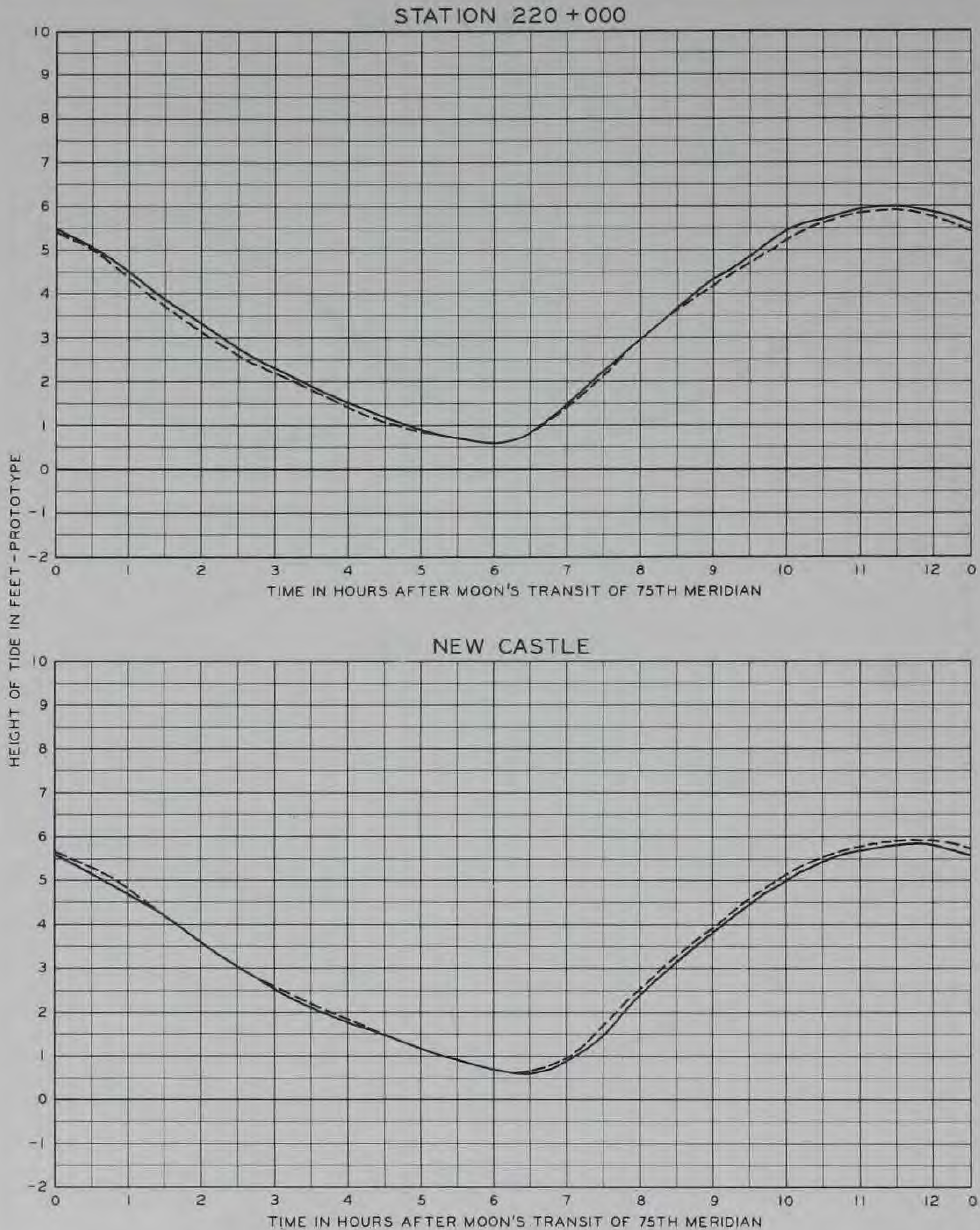
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS 255+000
AND 234+000



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

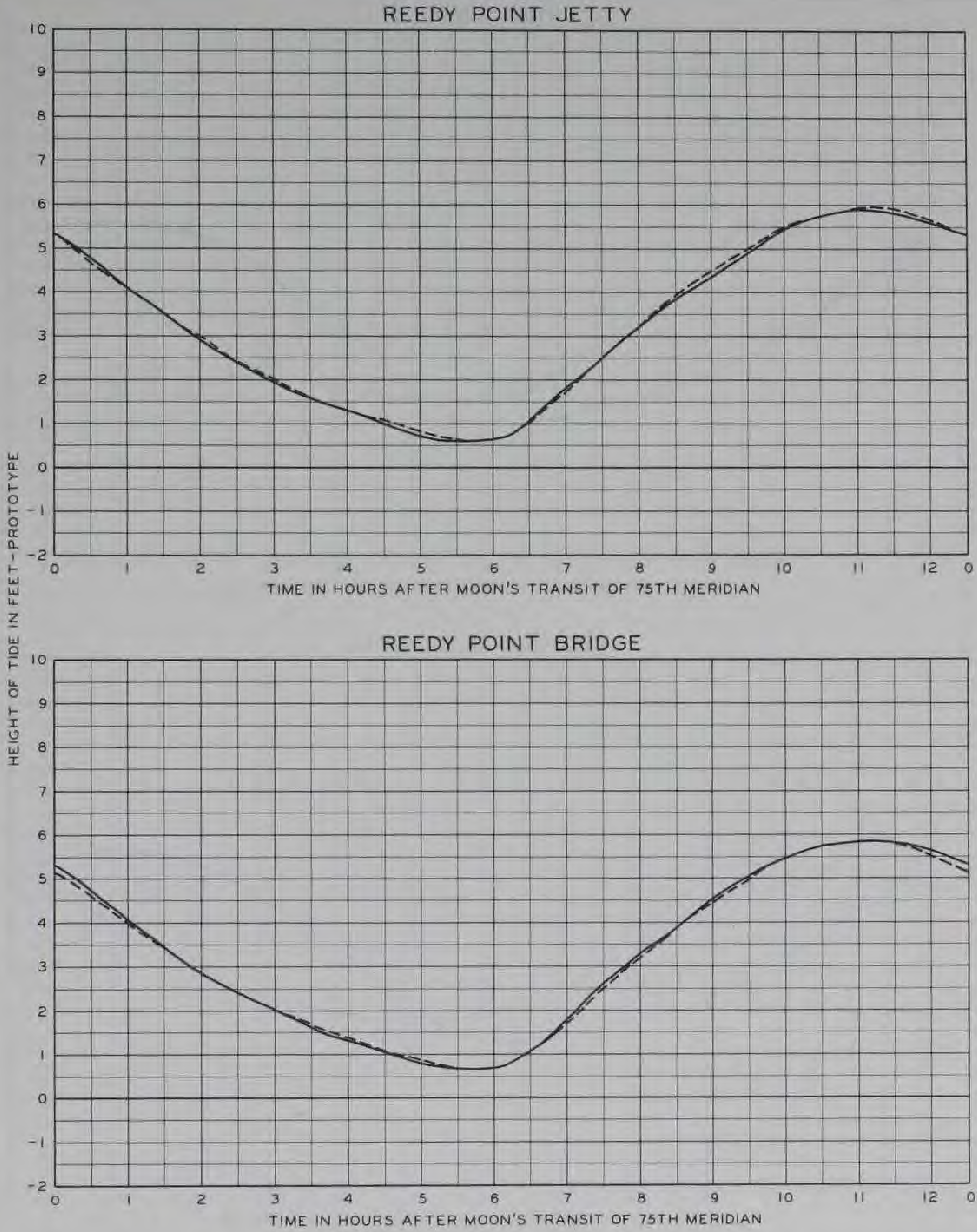
LEGEND

———————	ΔH = +0.46 FT
– – – – –	ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF
ELK RIVER SALINITY
ON TIDAL HEIGHTS
FOR 27 FT X 250 FT CANAL

STATIONS 220 + 000
AND NEW CASTLE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

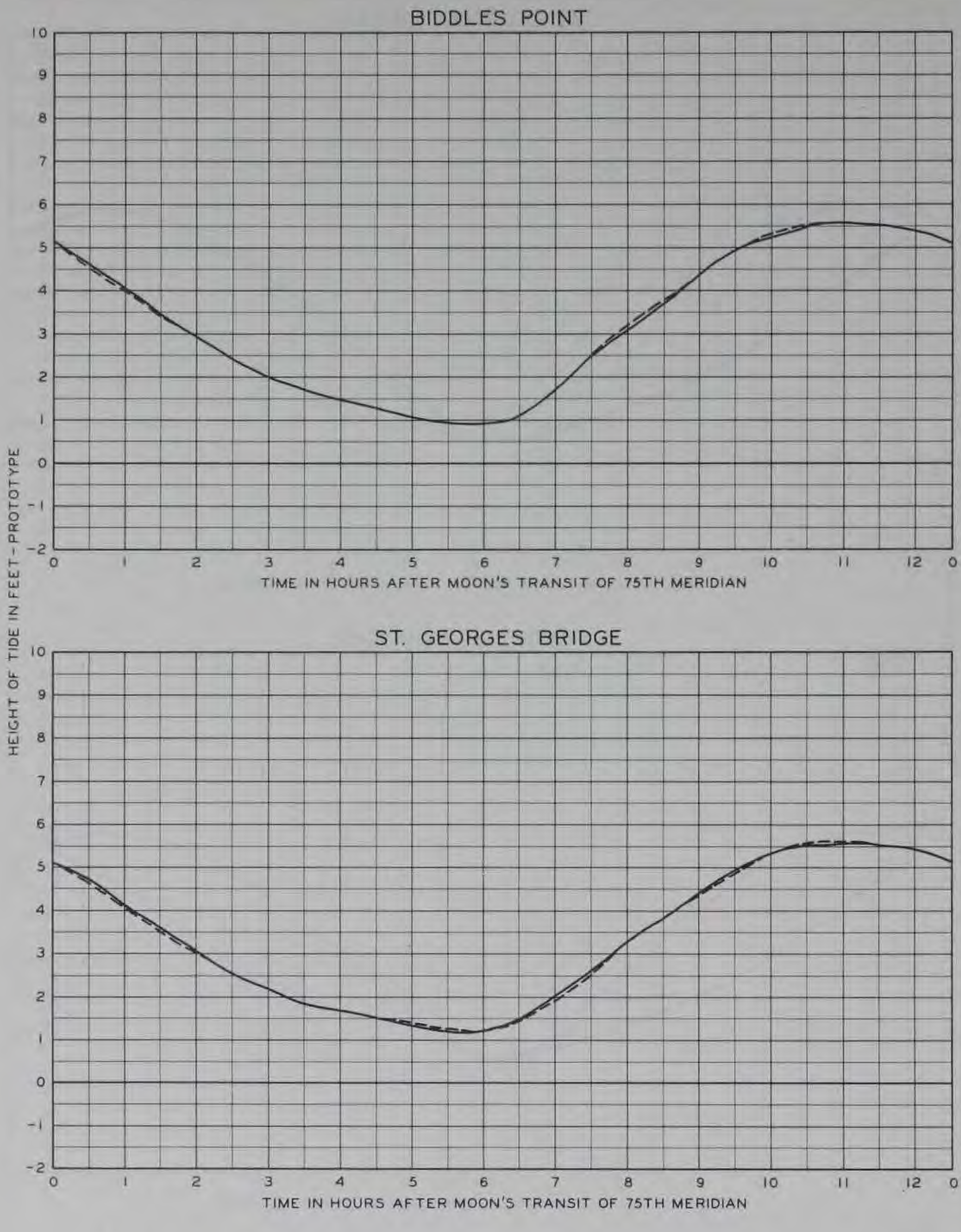
LEGEND

——— $\Delta H = +0.46$ FT
– – – – $\Delta H = +0.55$ FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS REEDY POINT JETTY
AND REEDY POINT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

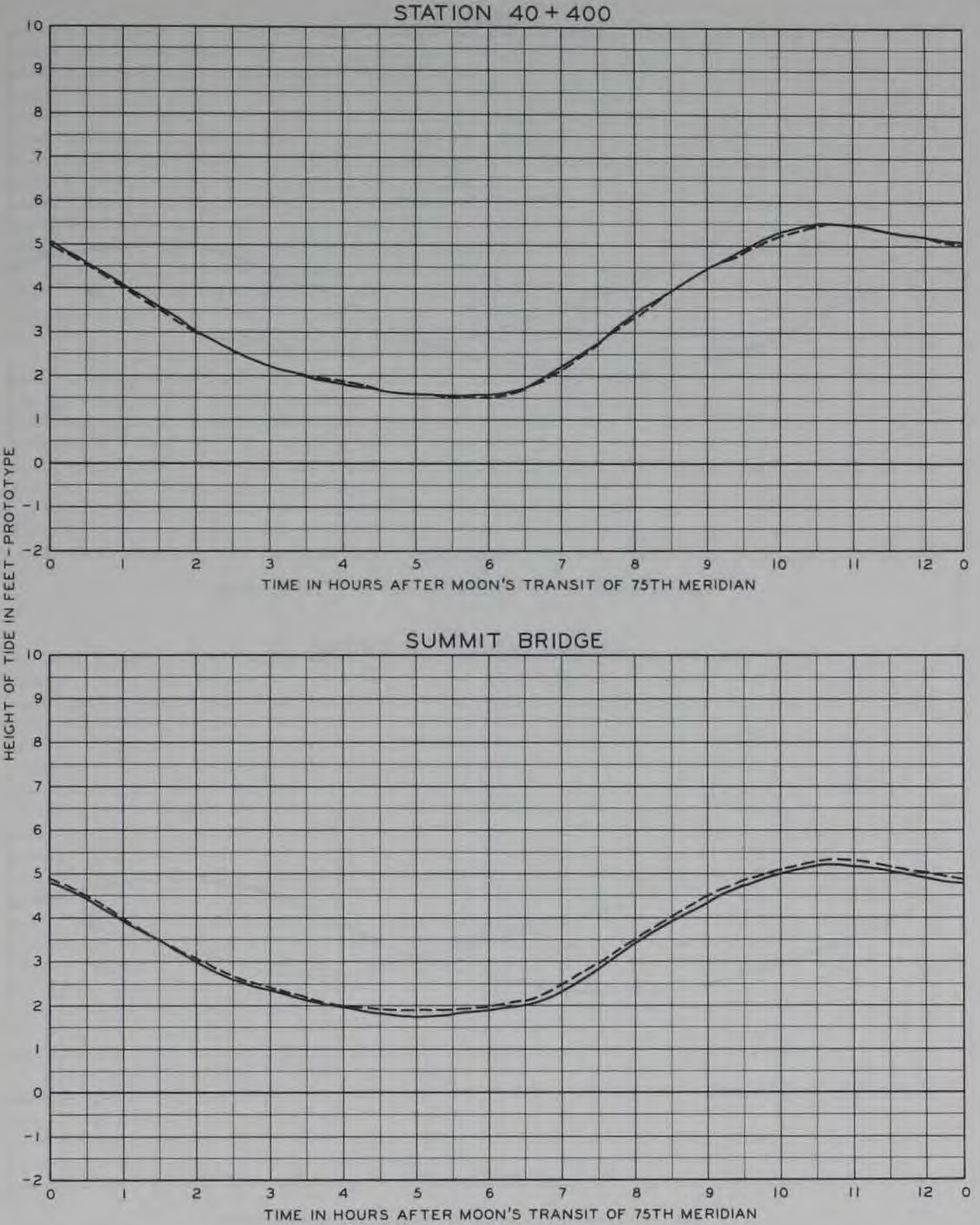
———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS BIDDLES POINT AND ST. GEORGES BRIDGE

PLATE 52



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

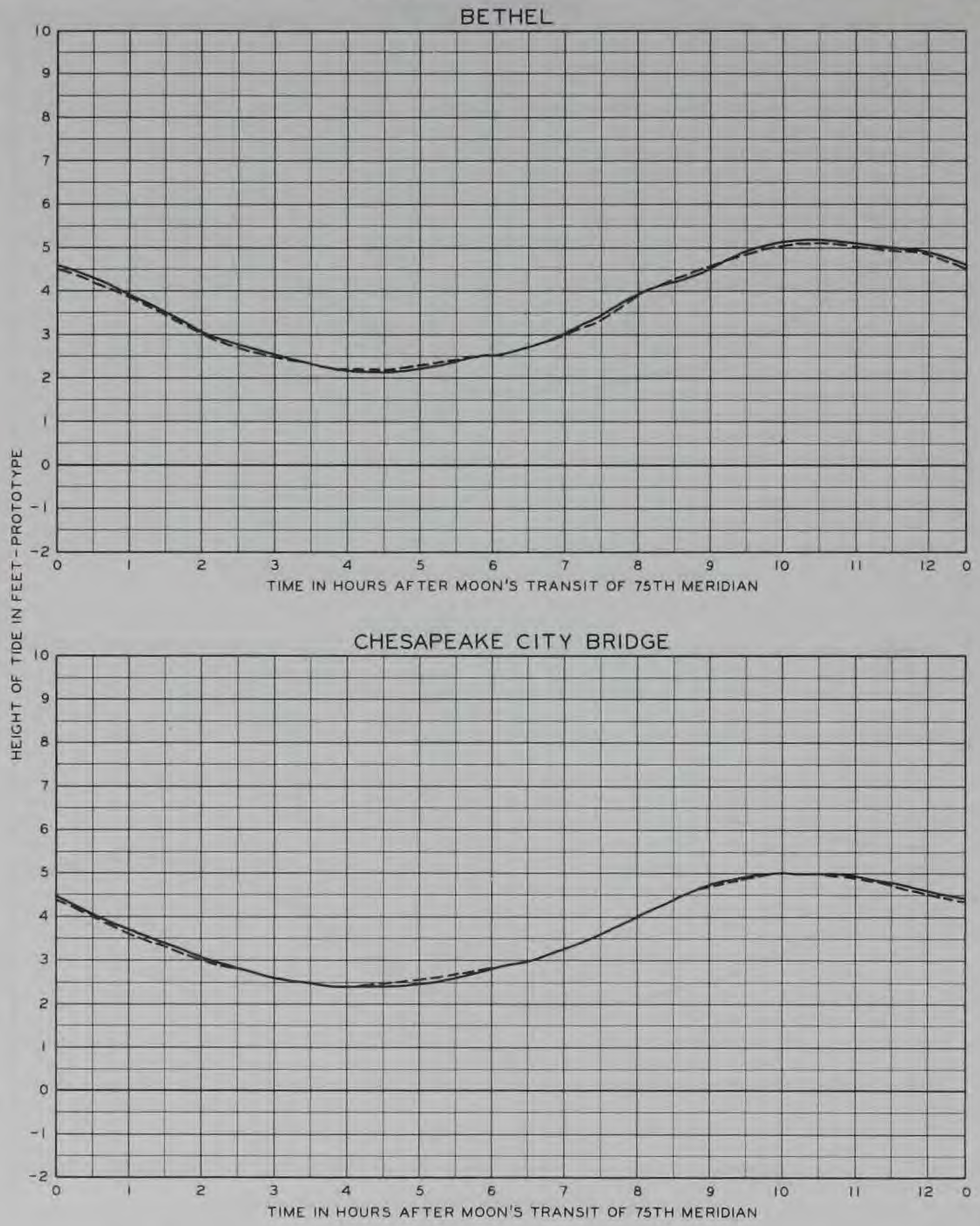
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS 40 + 400
AND SUMMIT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

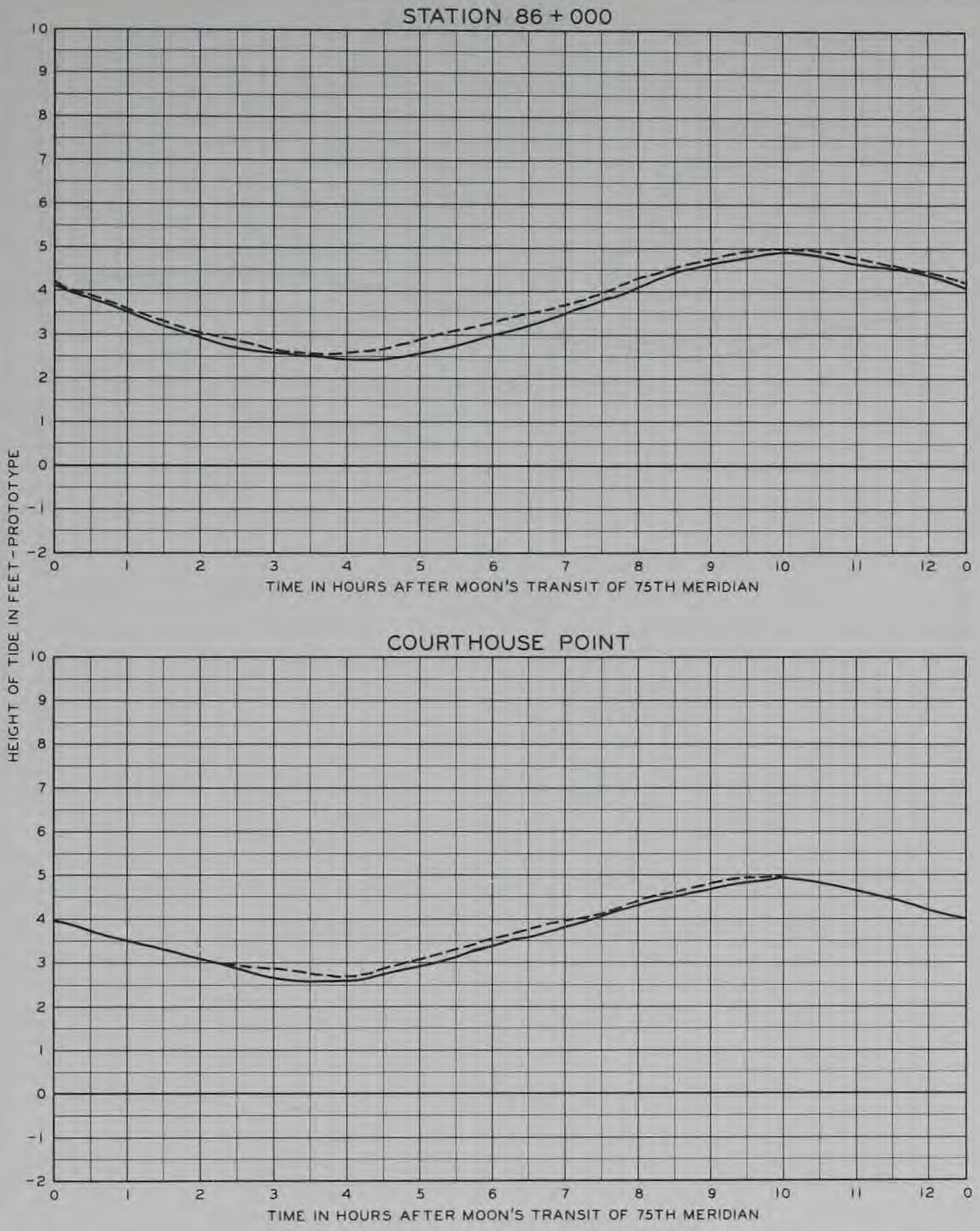
LEGEND

———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS BETHEL AND CHESAPEAKE CITY BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

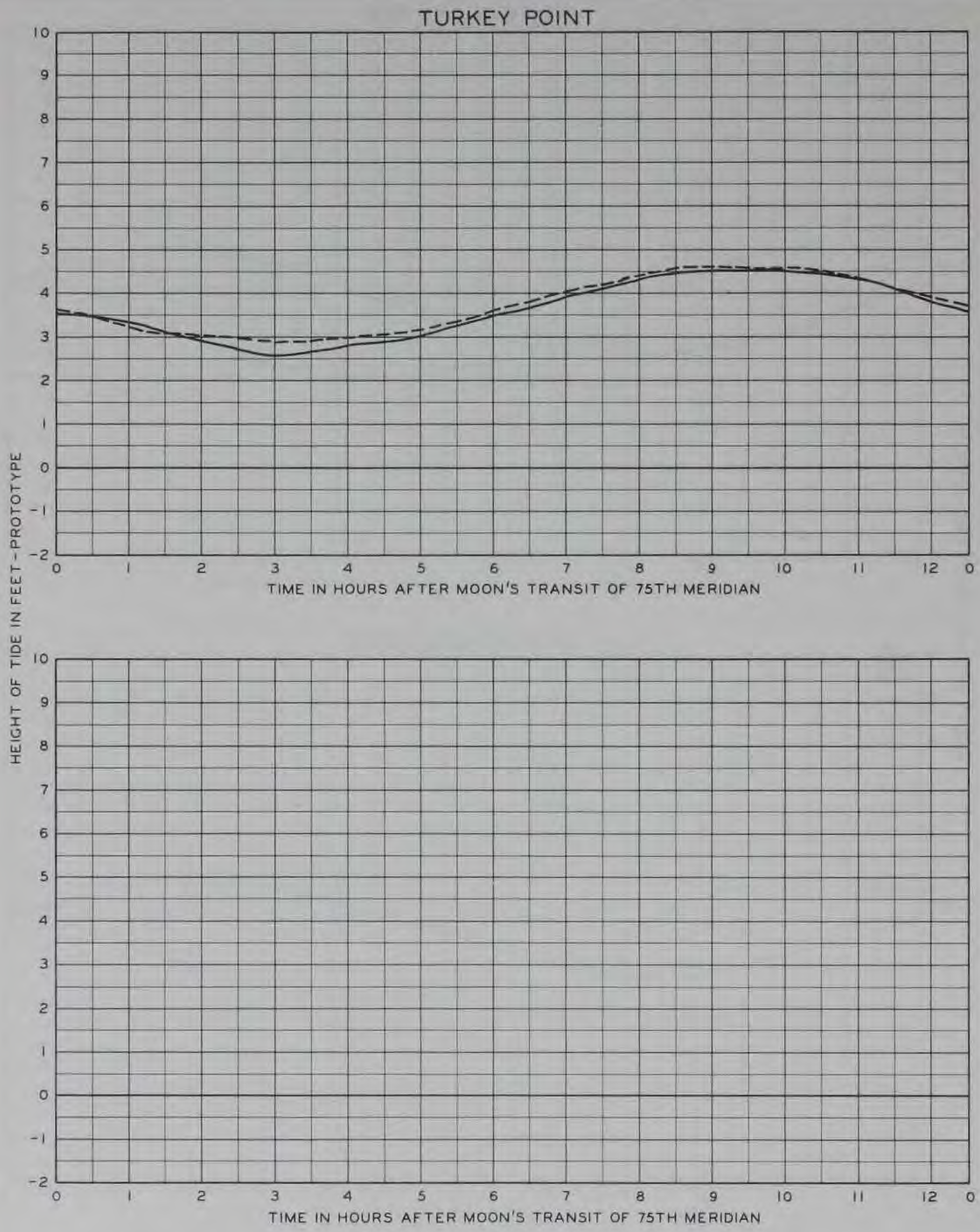
LEGEND

———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATIONS 86 + 000 AND COURTHOUSE POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

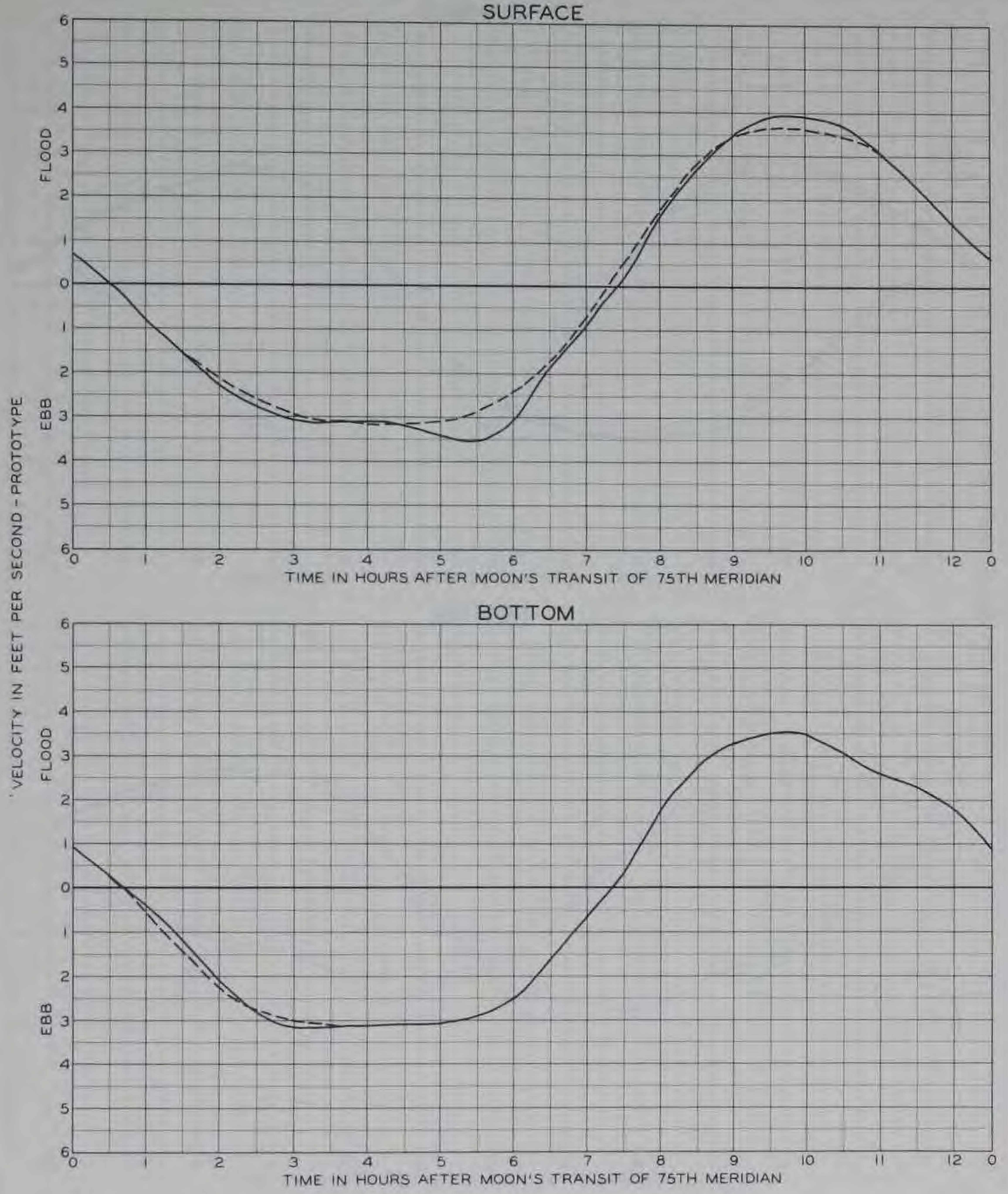
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON TIDAL HEIGHTS FOR 27 FT X 250 FT CANAL

STATION TURKEY POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

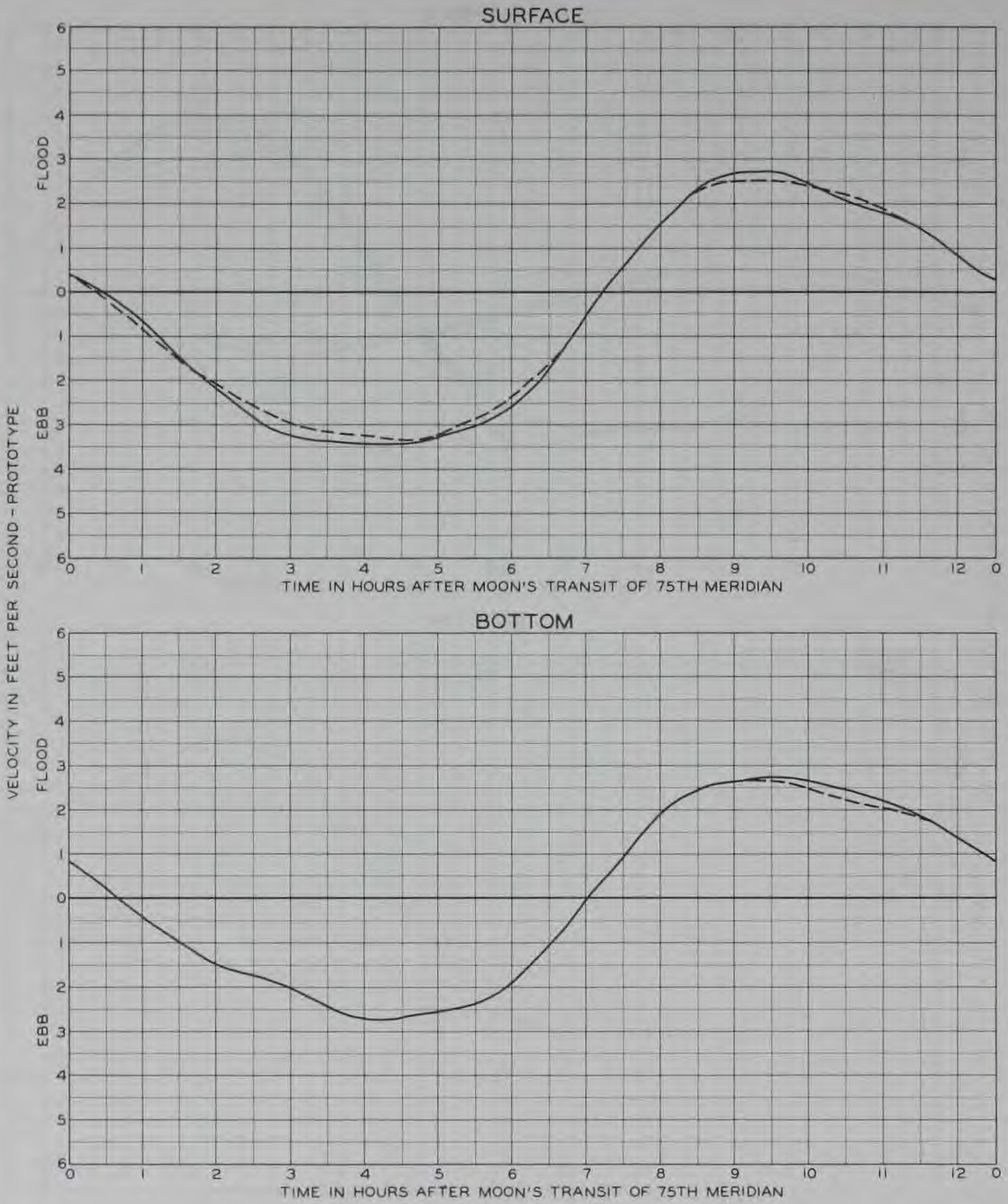
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: **ΔH** = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION 220



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

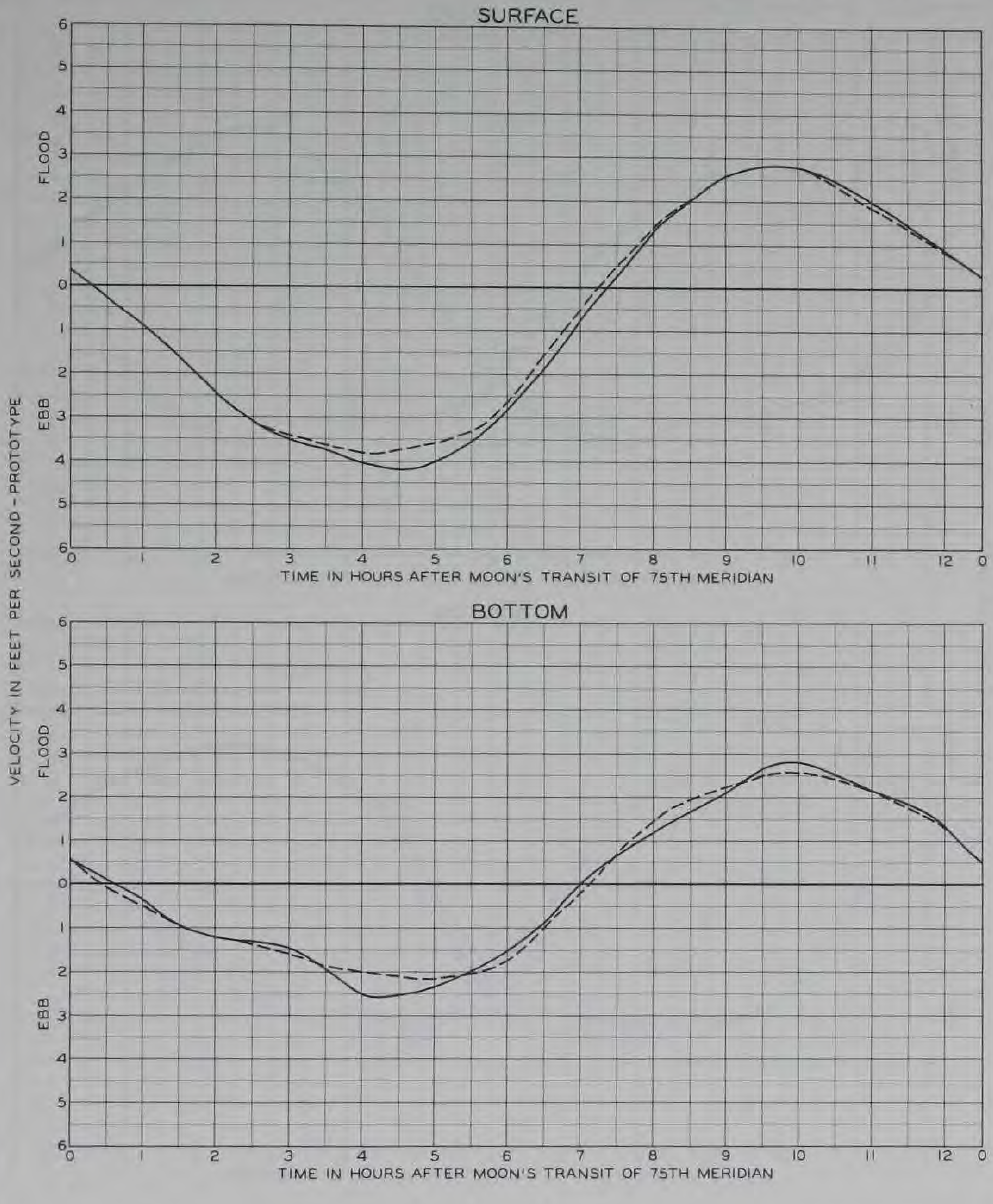
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION 230



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

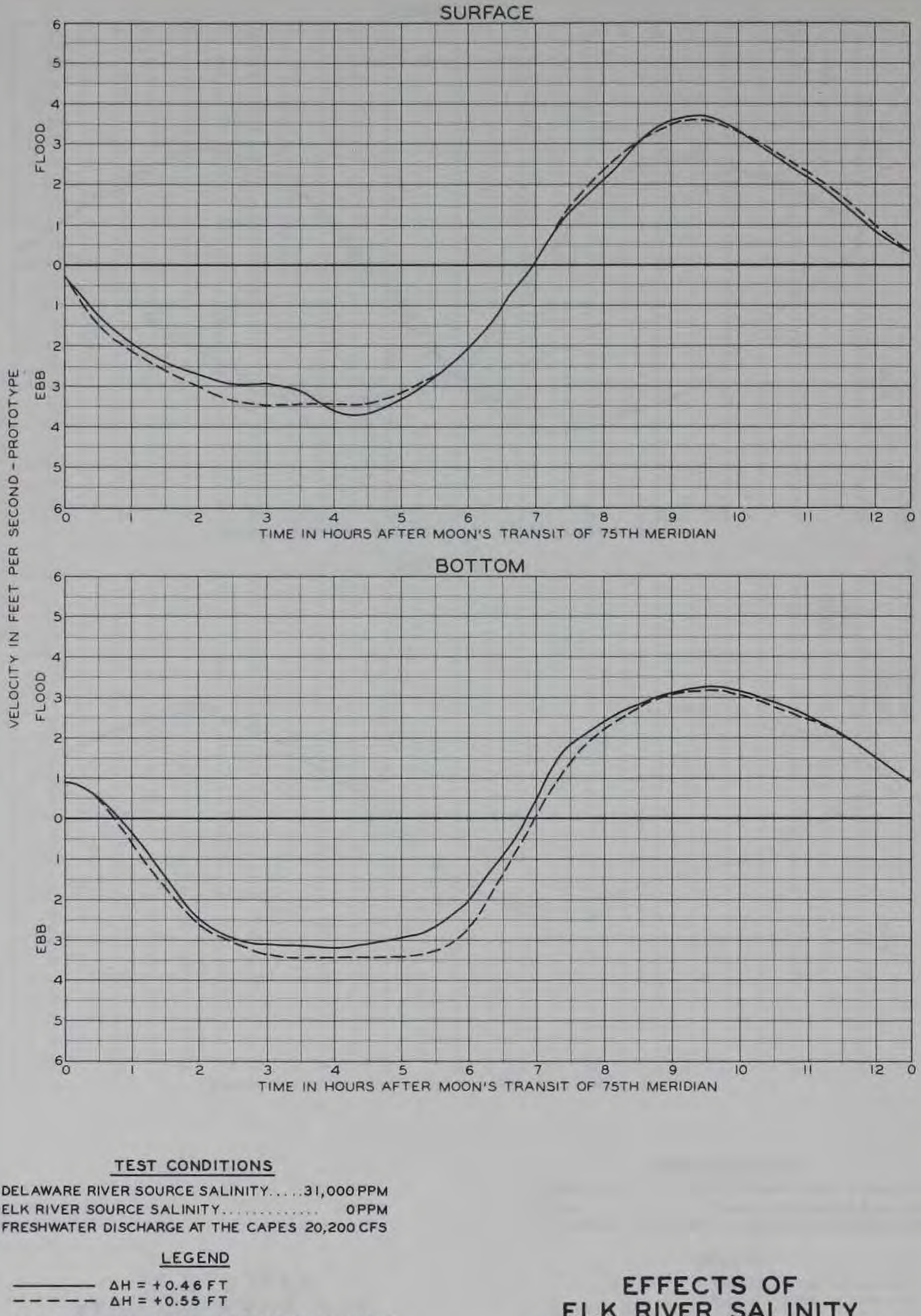
LEGEND

——— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION 235



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

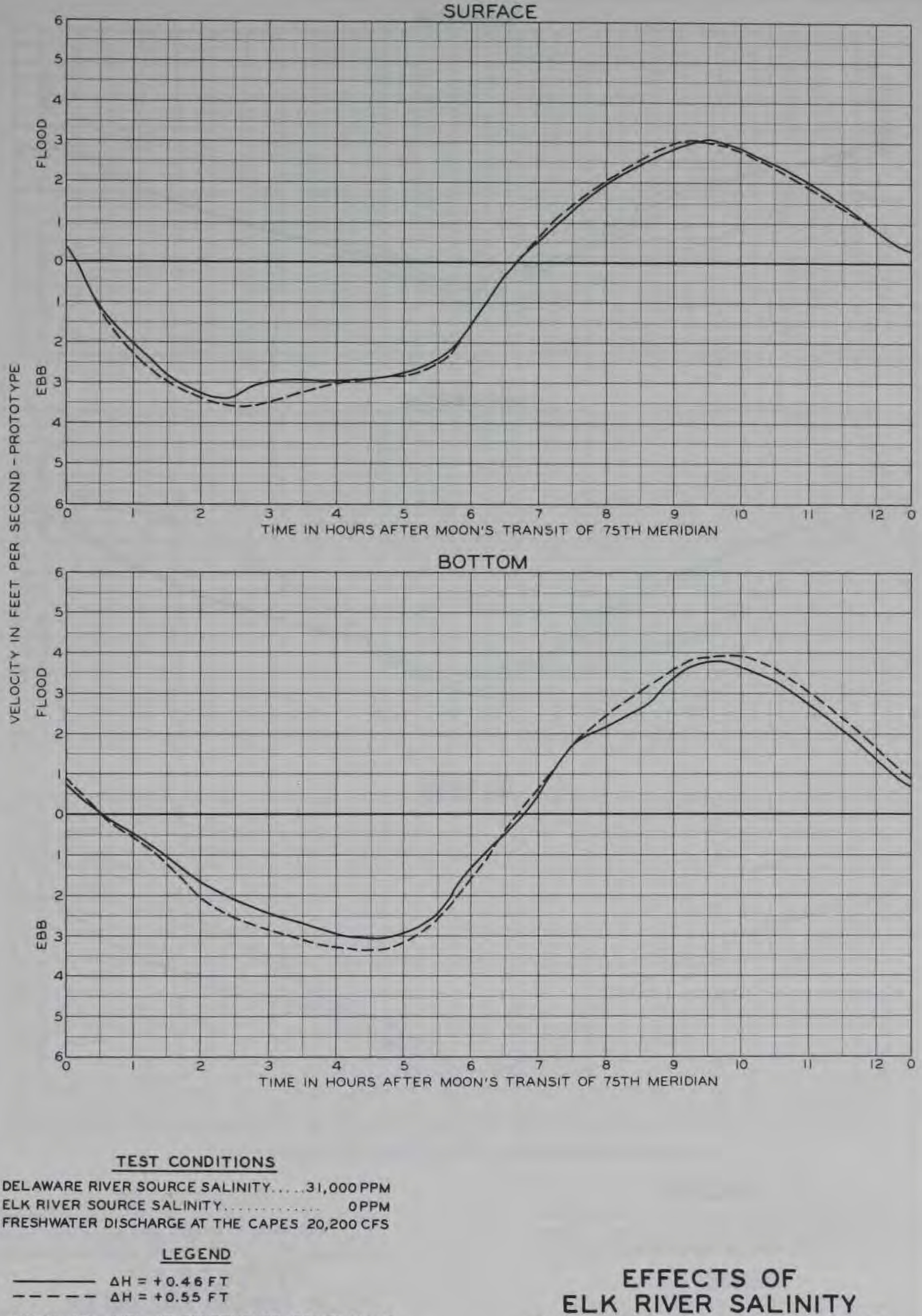
LEGEND

———	ΔH = +0.46 FT
– – – – –	ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION 245



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............ 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

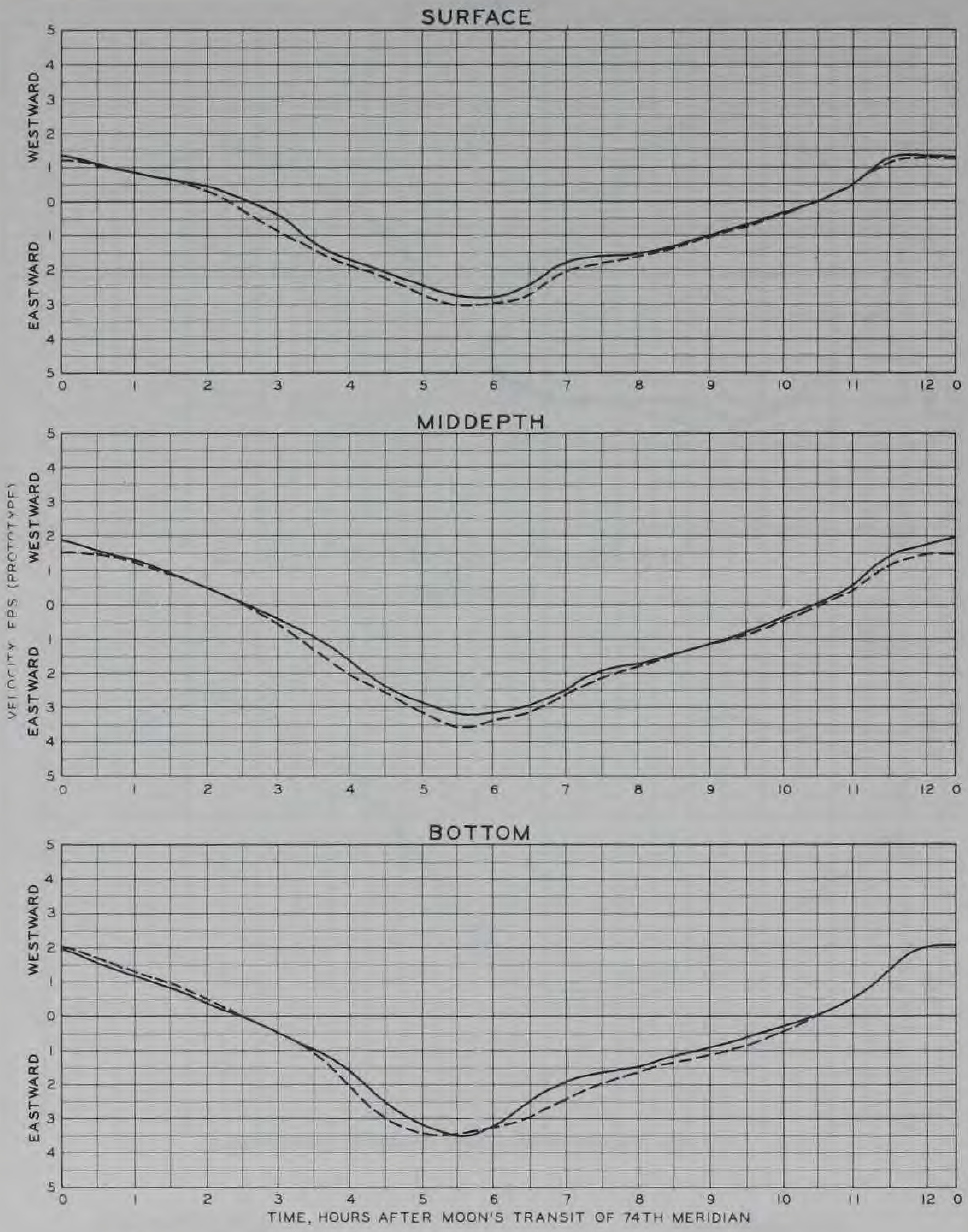
LEGEND

——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION 255



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

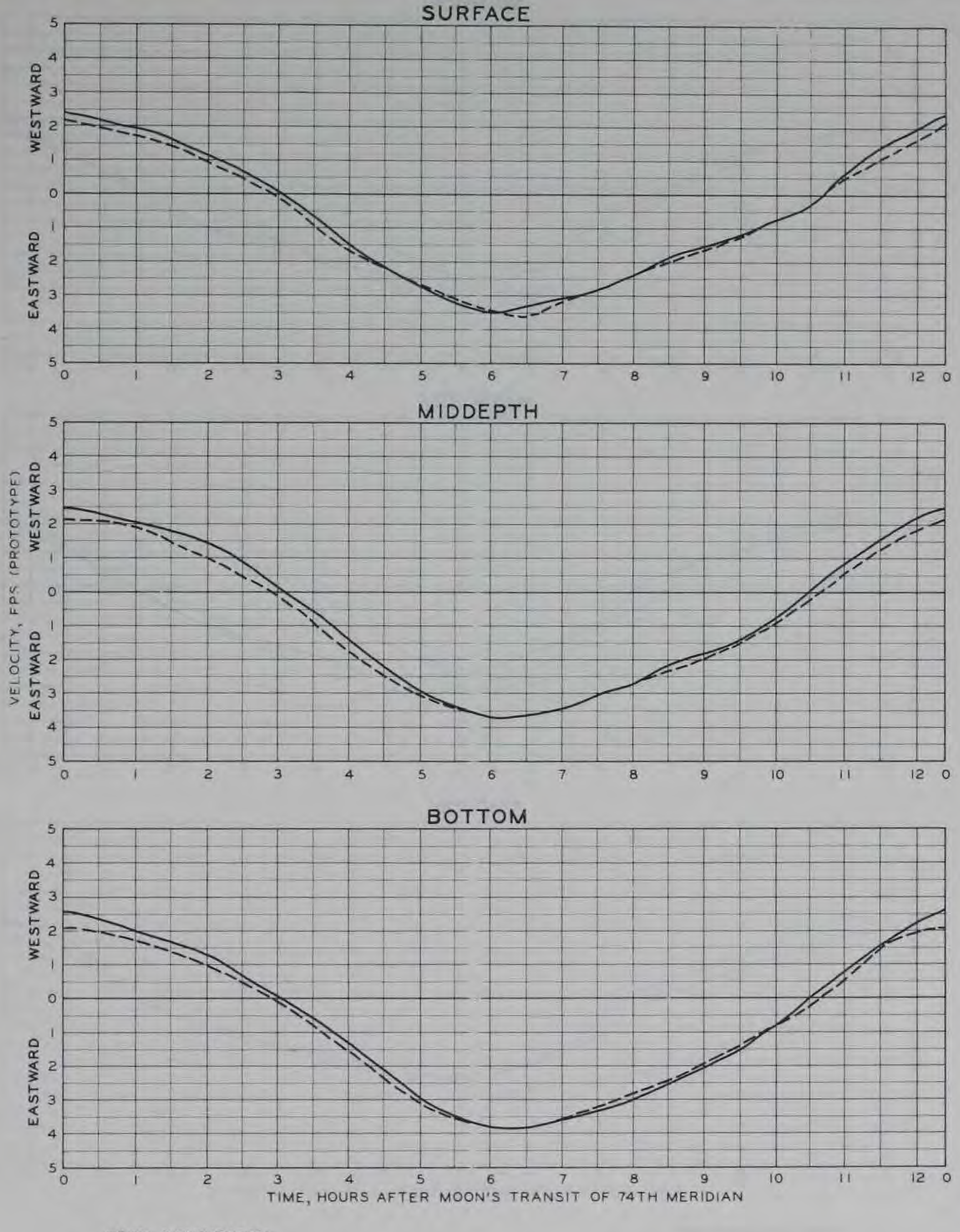
——— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

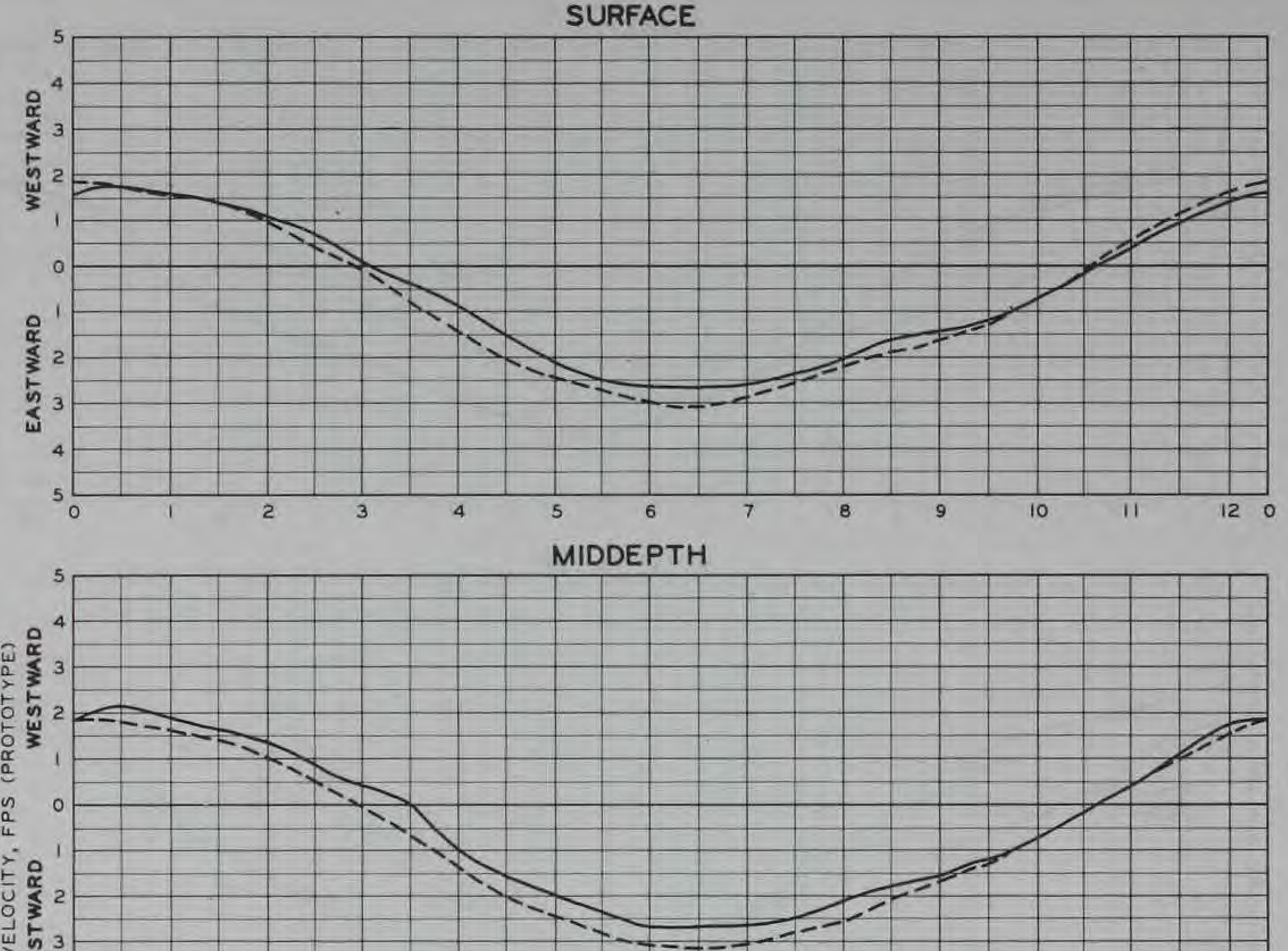
——— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION B



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

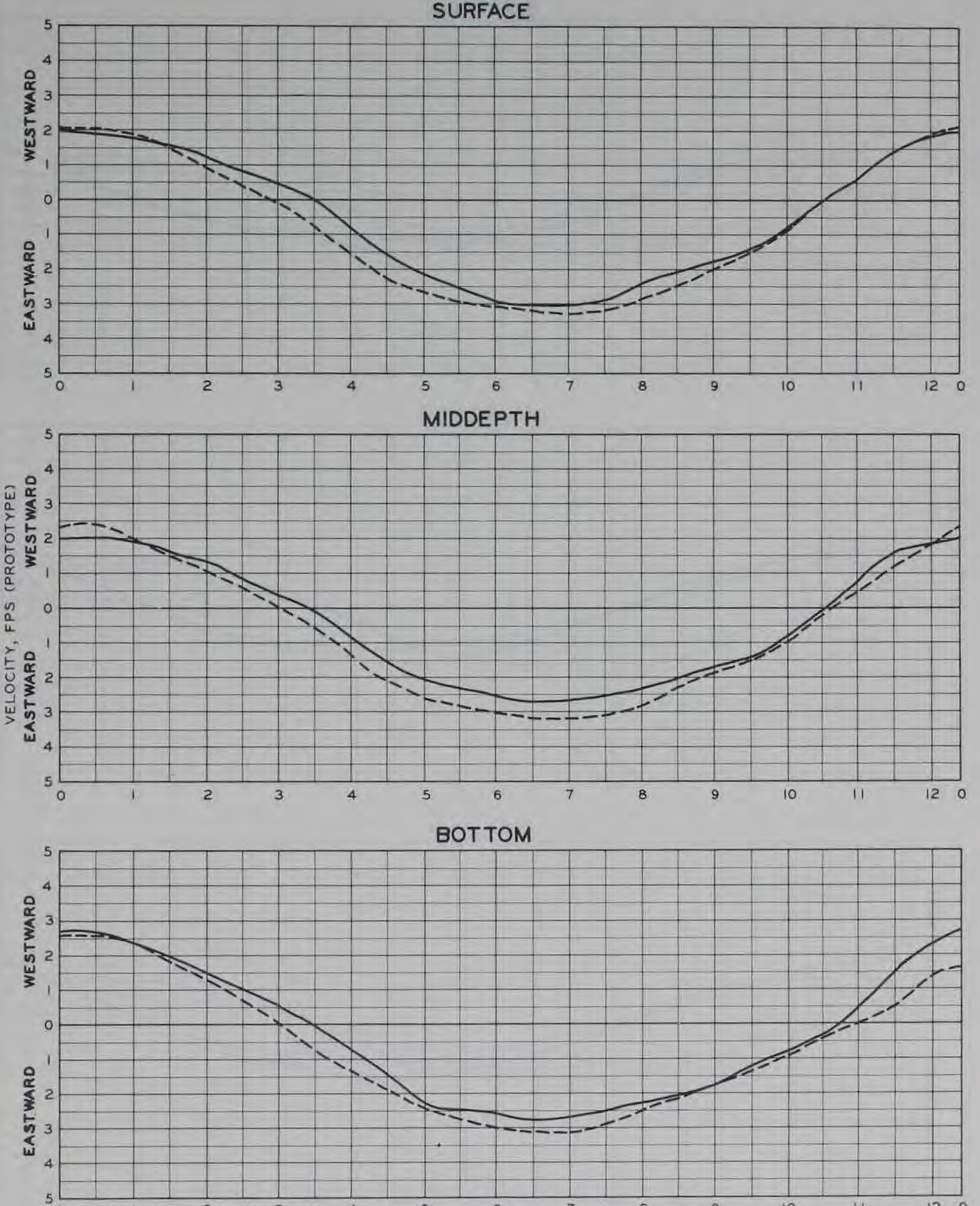
——— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION C

PLATE 64



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY......31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

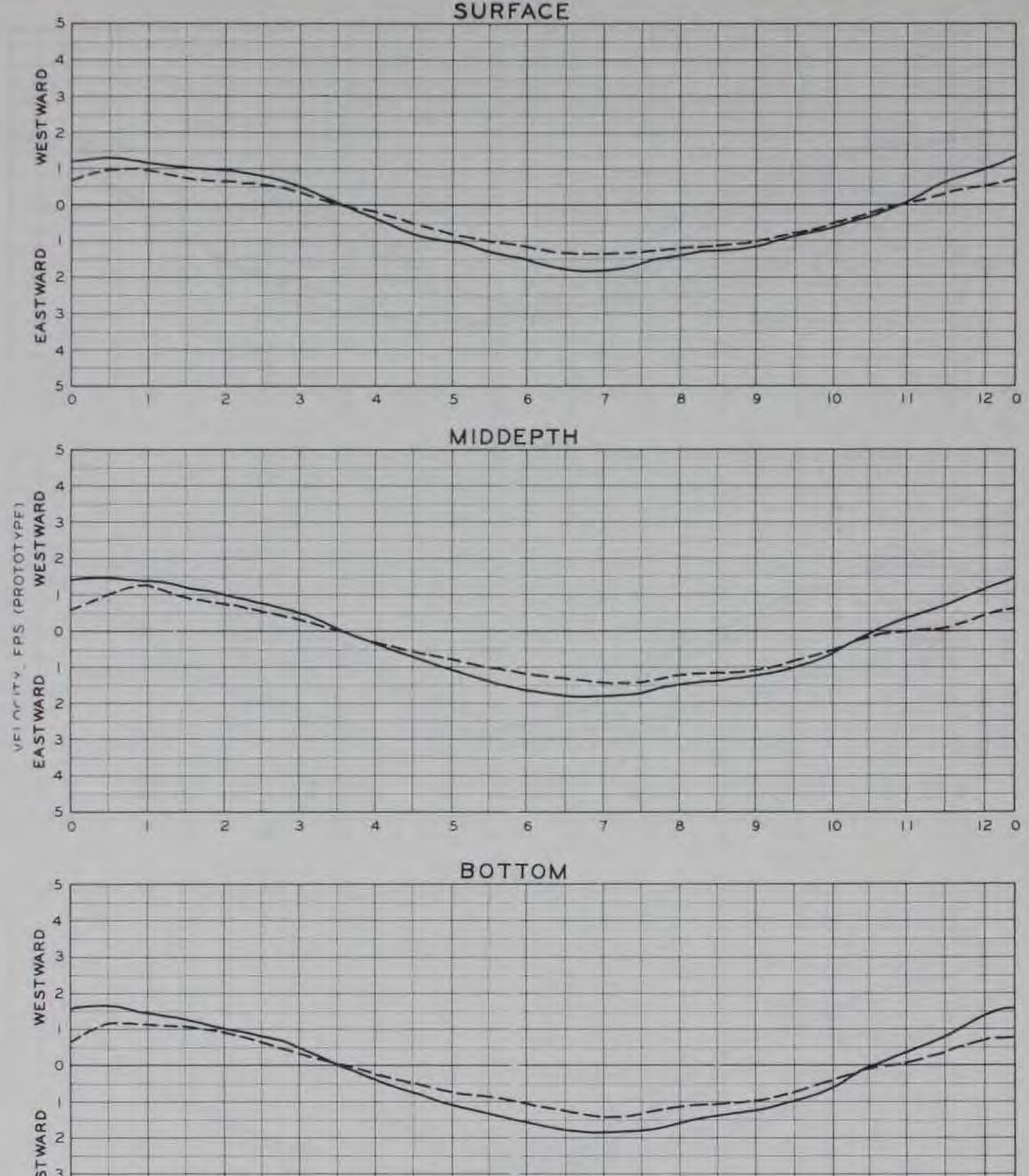
LEGEND

———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION D



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

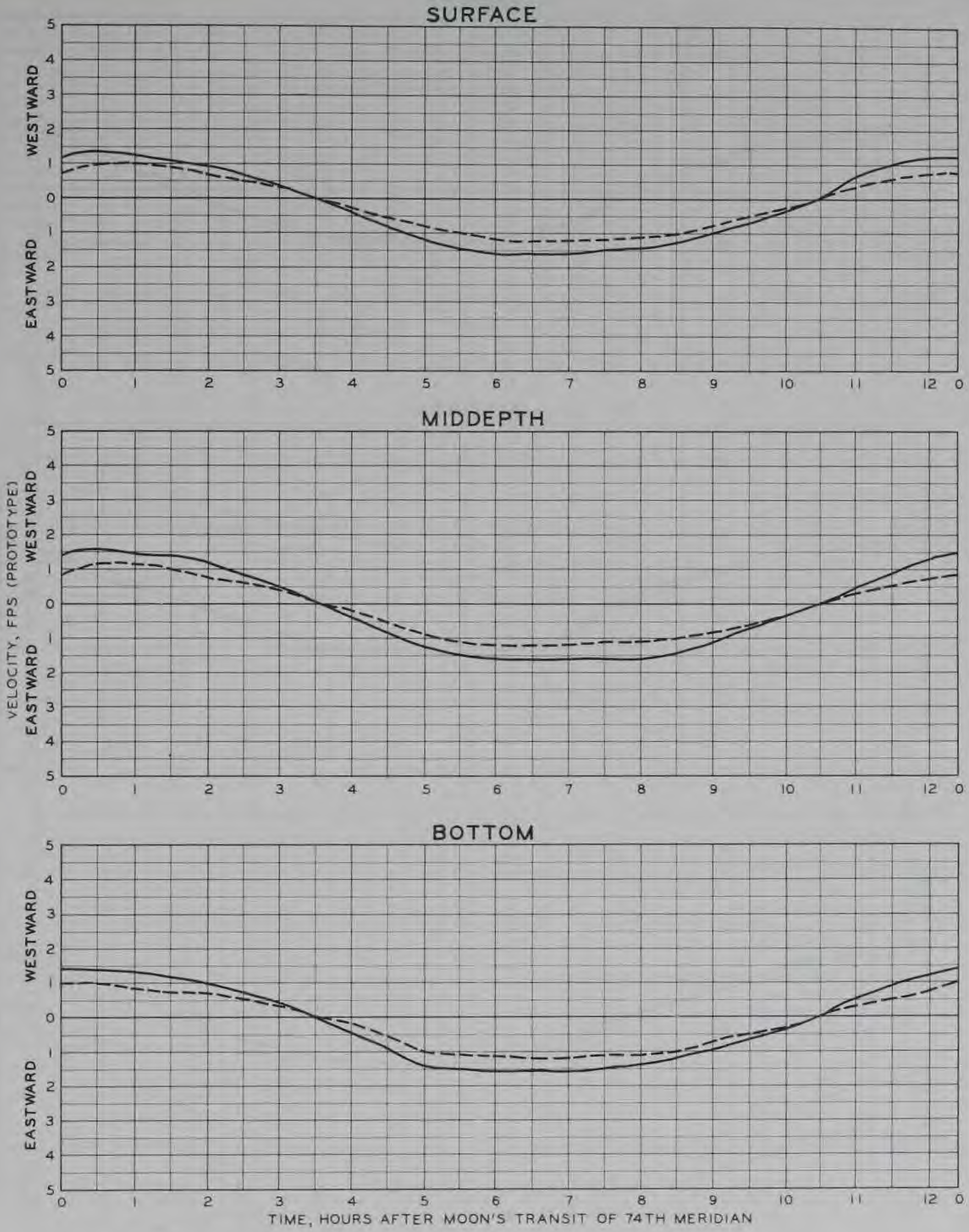
——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF
ELK RIVER SALINITY
ON CURRENT VELOCITIES
FOR 27 FT X 250 FT CANAL

STATION E



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

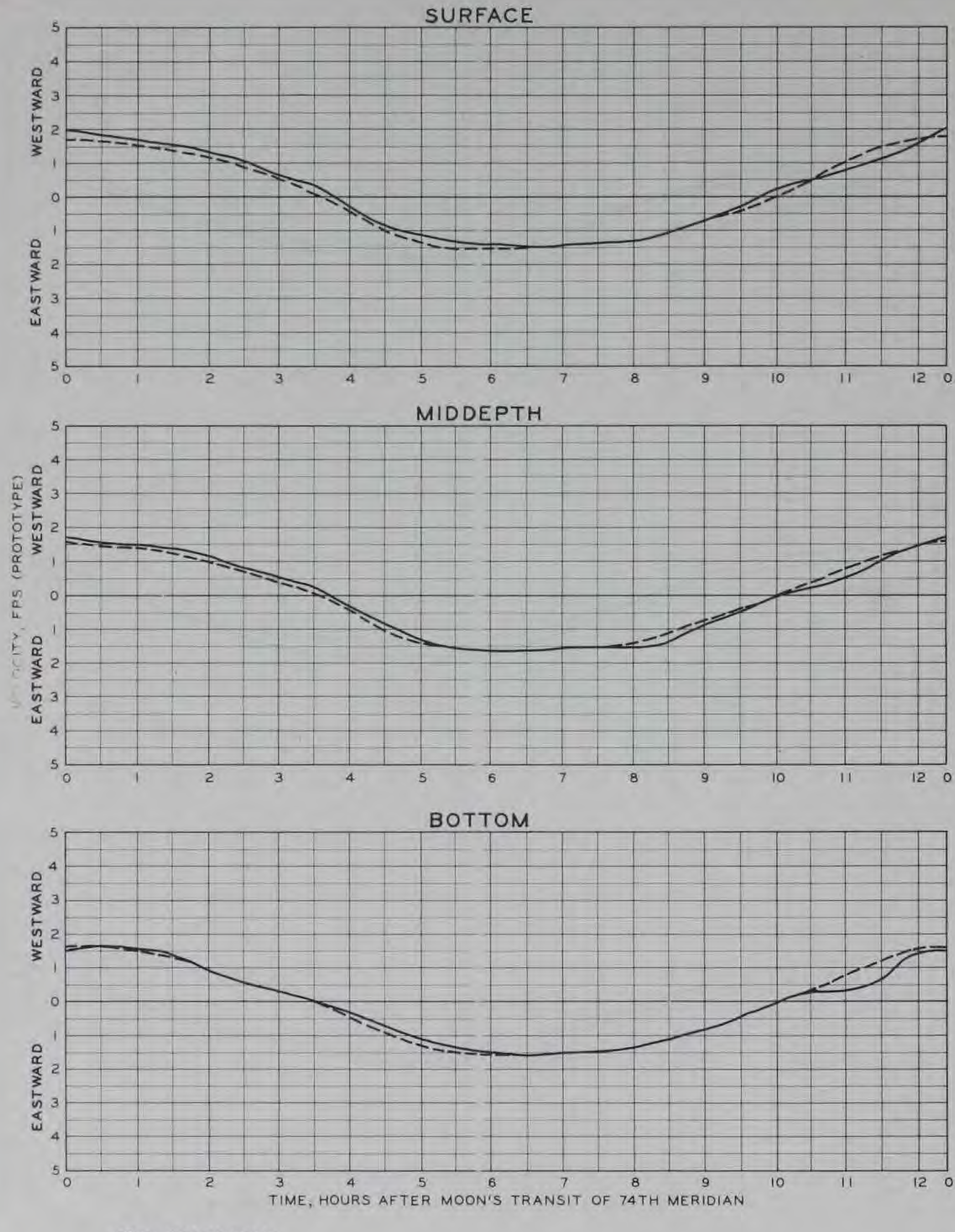
———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION F



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

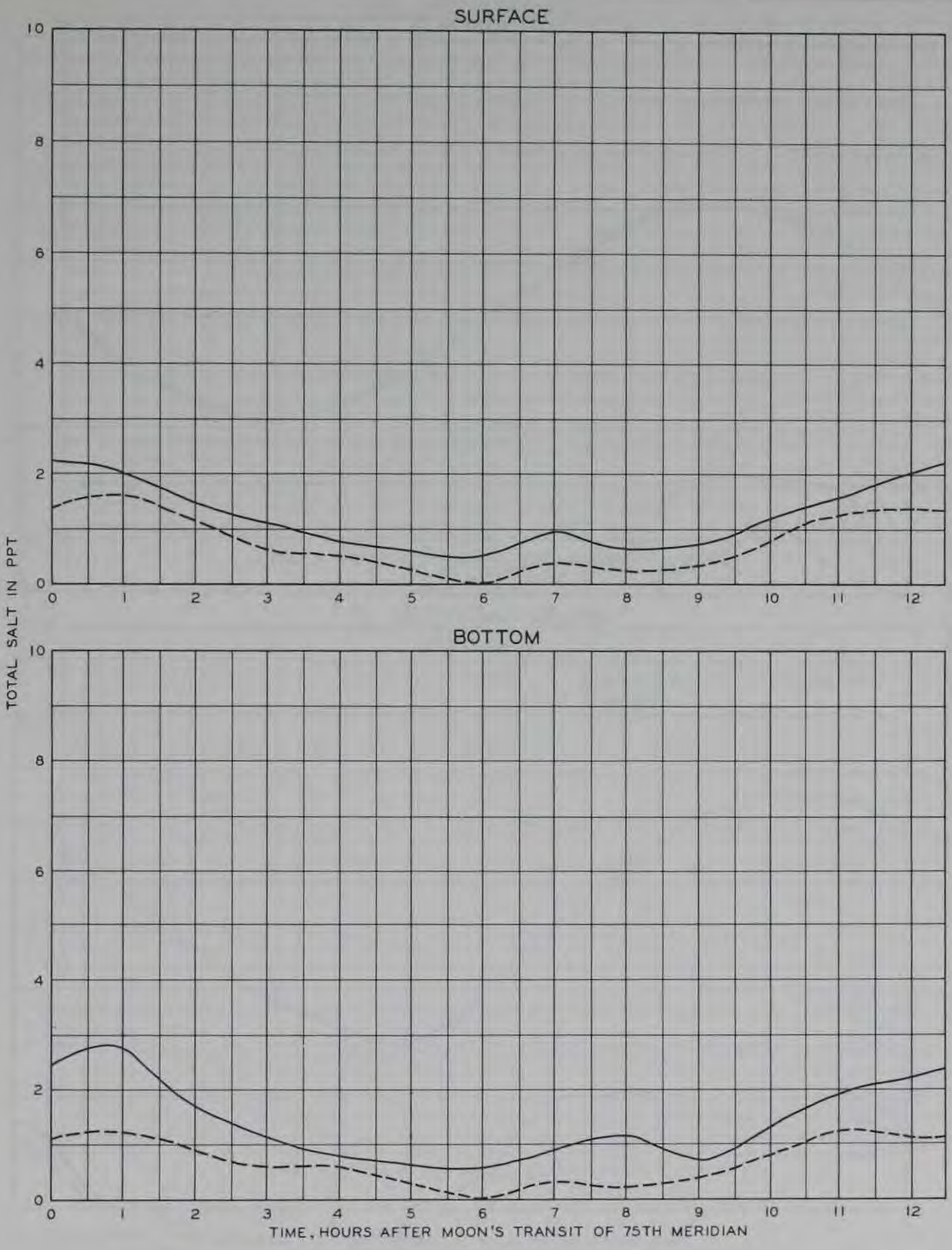
——— ΔH = +0.46 FT
– – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF ELK RIVER SALINITY ON CURRENT VELOCITIES FOR 27 FT X 250 FT CANAL

STATION G



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............. 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

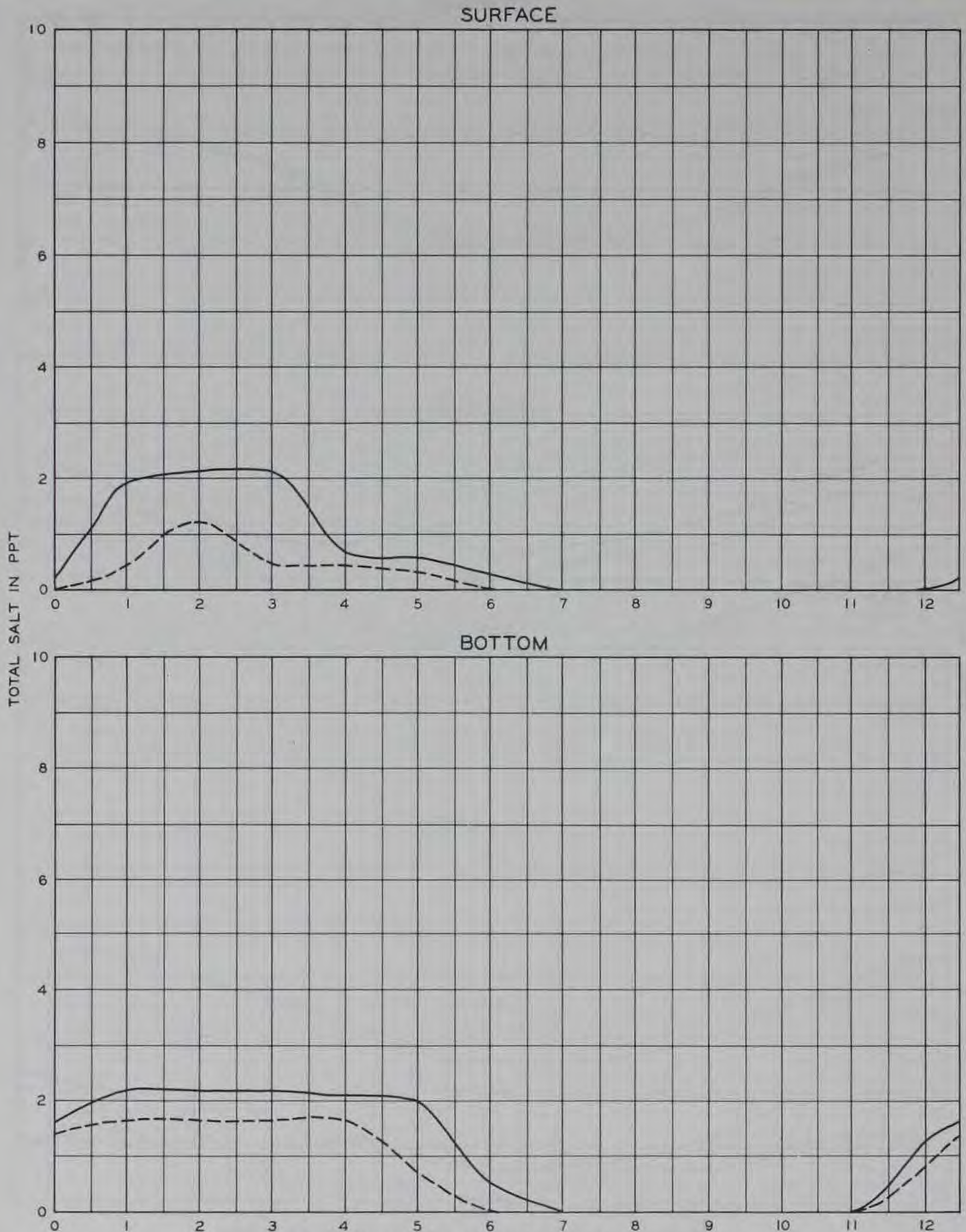
LEGEND

———— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF DENSITY ON ELK RIVER SUPPLY ON SALINITIES FOR 27 FT X 250 FT CANAL

STATION 2



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............ 0 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

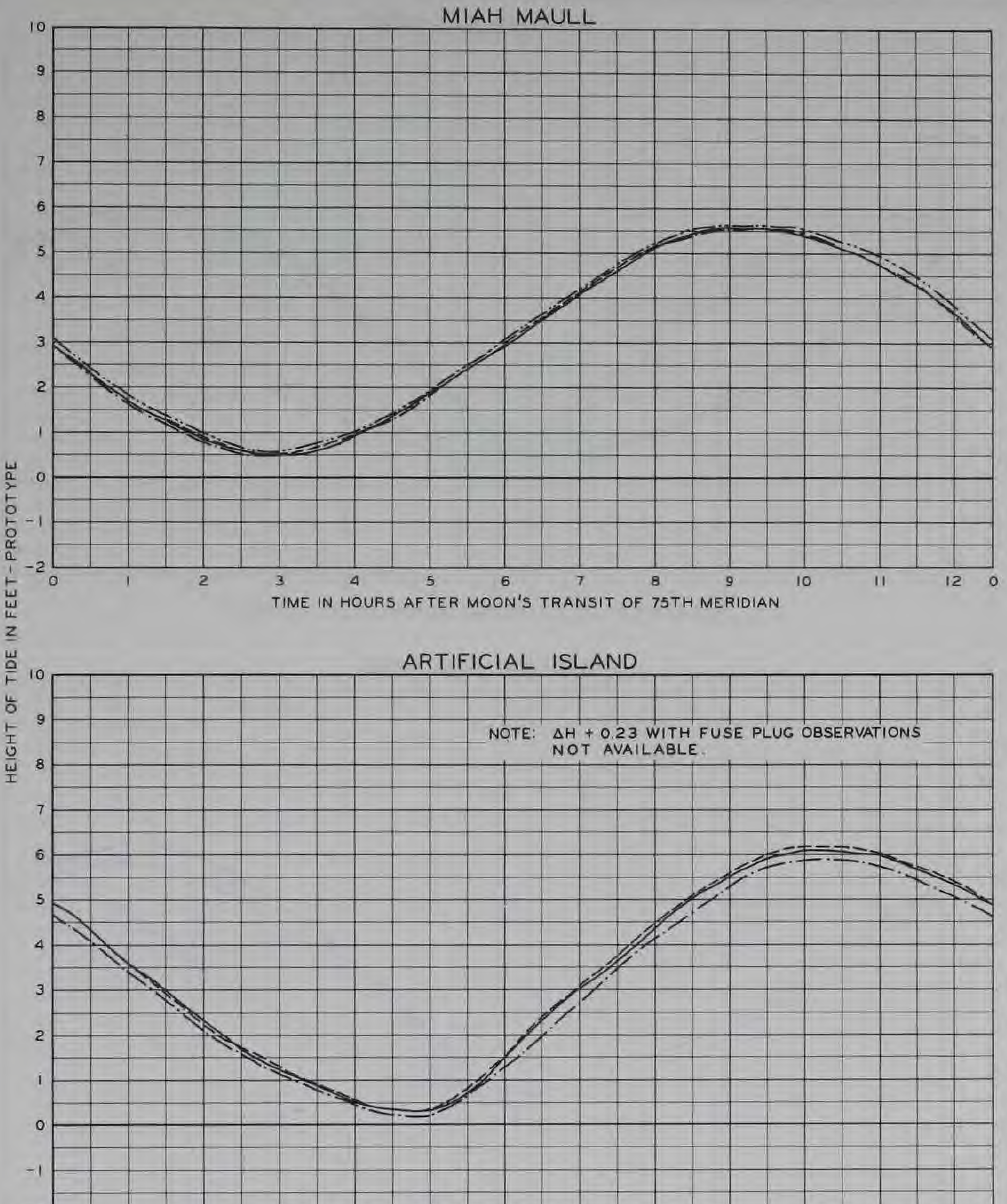
LEGEND

——— ΔH = +0.46 FT
– – – – – ΔH = +0.55 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF DENSITY ON ELK RIVER SUPPLY ON SALINITIES FOR 27 FT X 250 FT CANAL

STATION A



NOTE: ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS NOT AVAILABLE.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

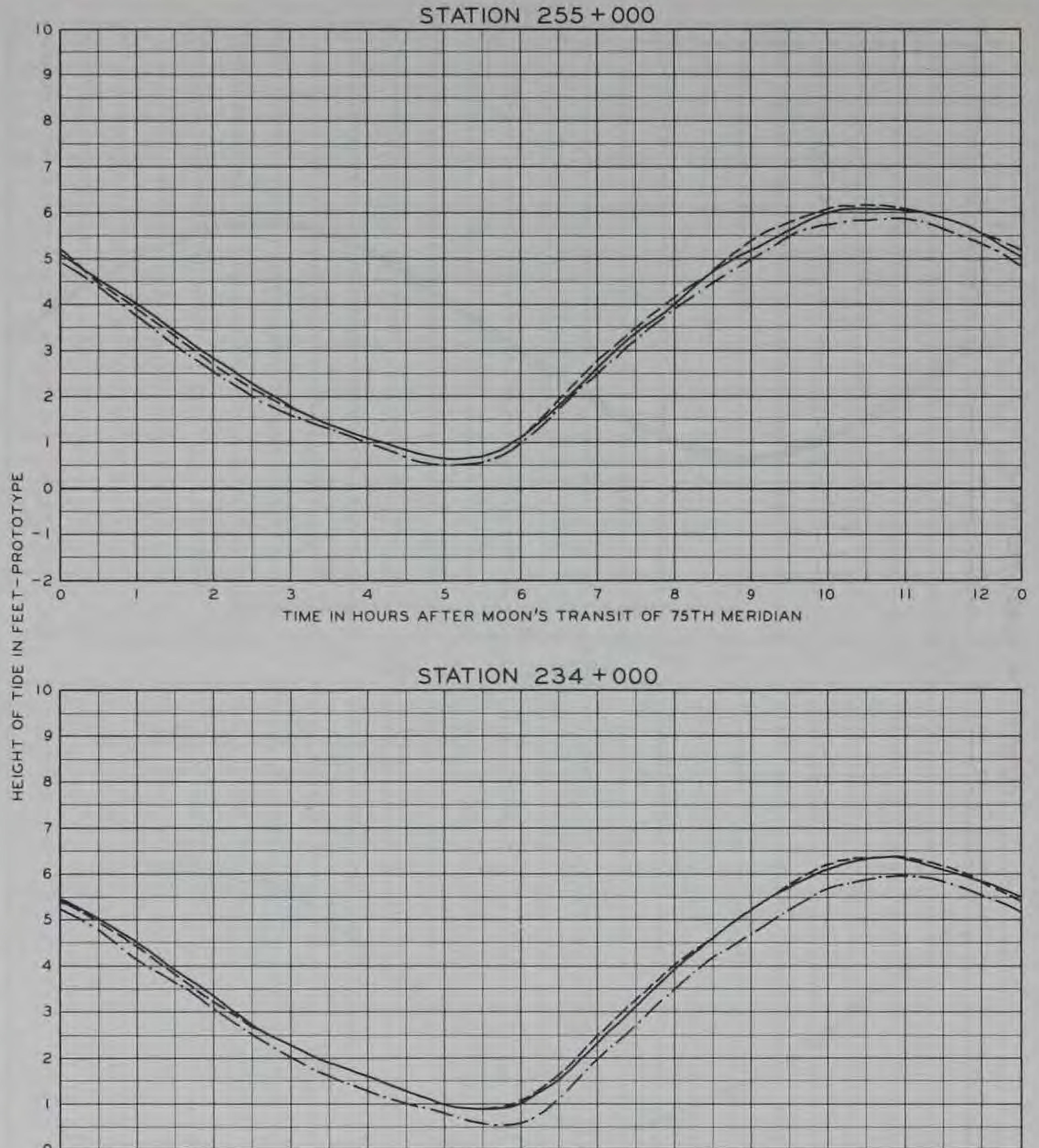
LEGEND

– – – – – ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS MIAH MAULL AND
ARTIFICIAL ISLAND



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

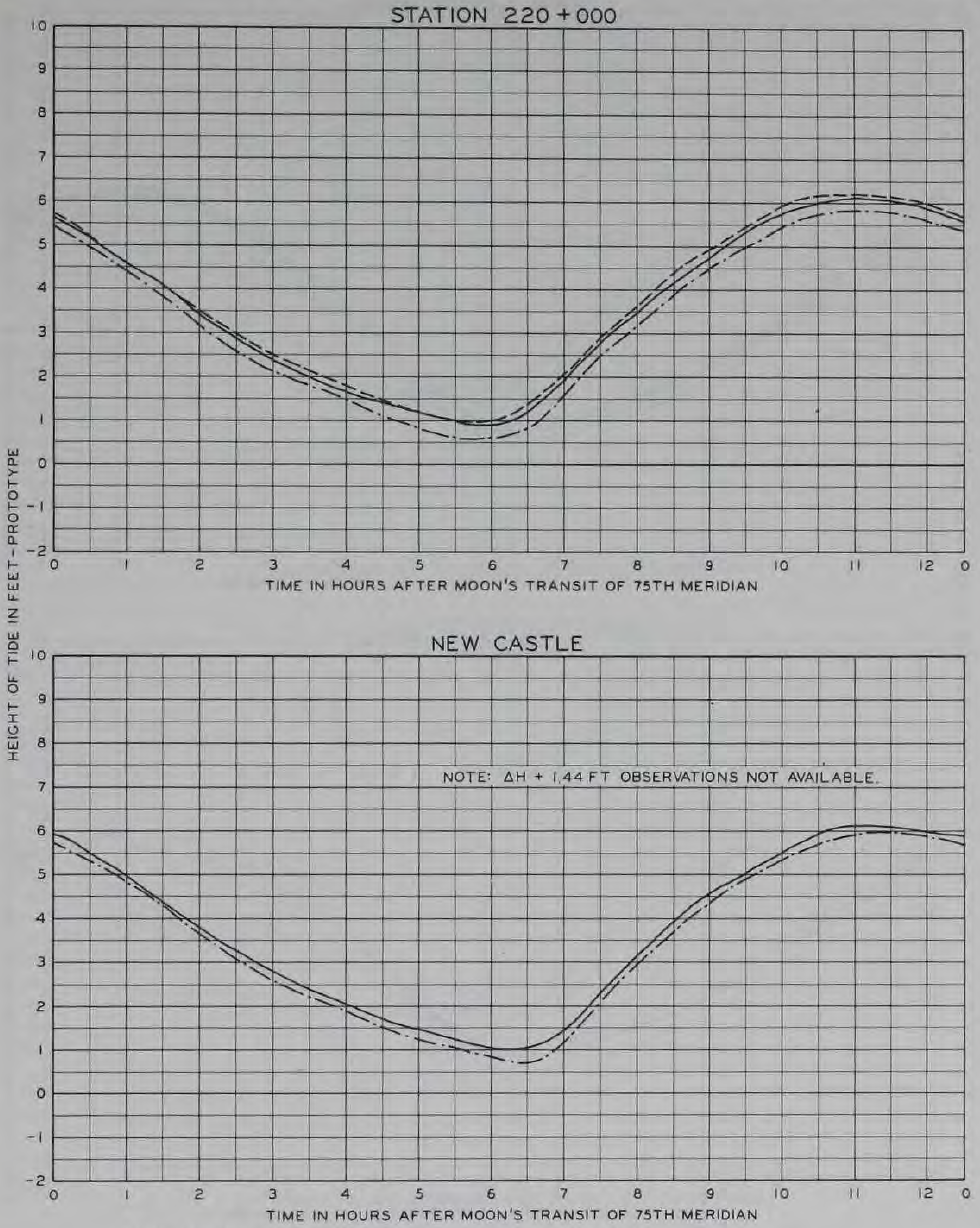
LEGEND

– – – – ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·—— ΔH = − 0.85 FT
—··—— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS 255 + 000
AND 234 + 000



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY ..... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

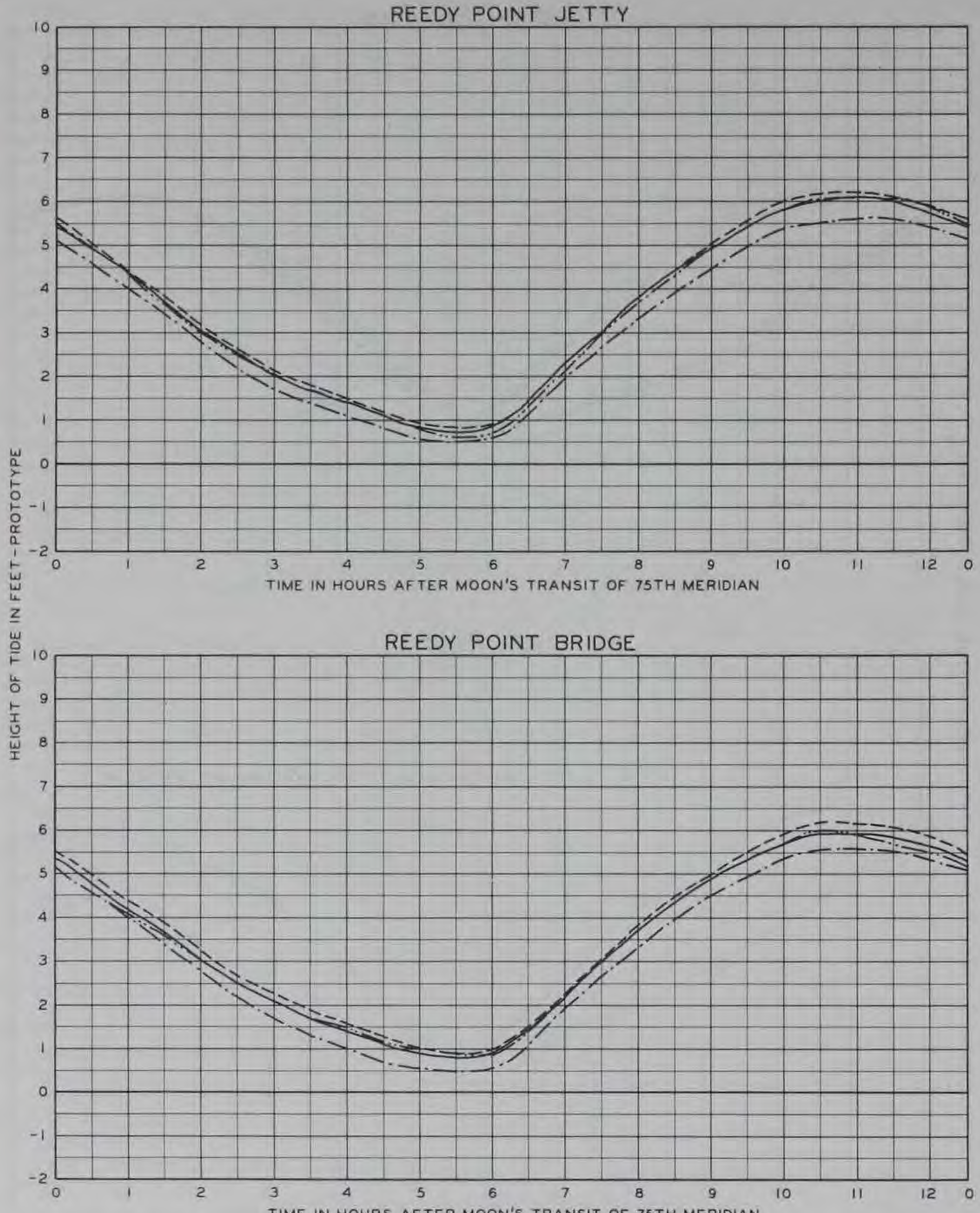
LEGEND

– – – – – ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS 220 + 000 AND NEW CASTLE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

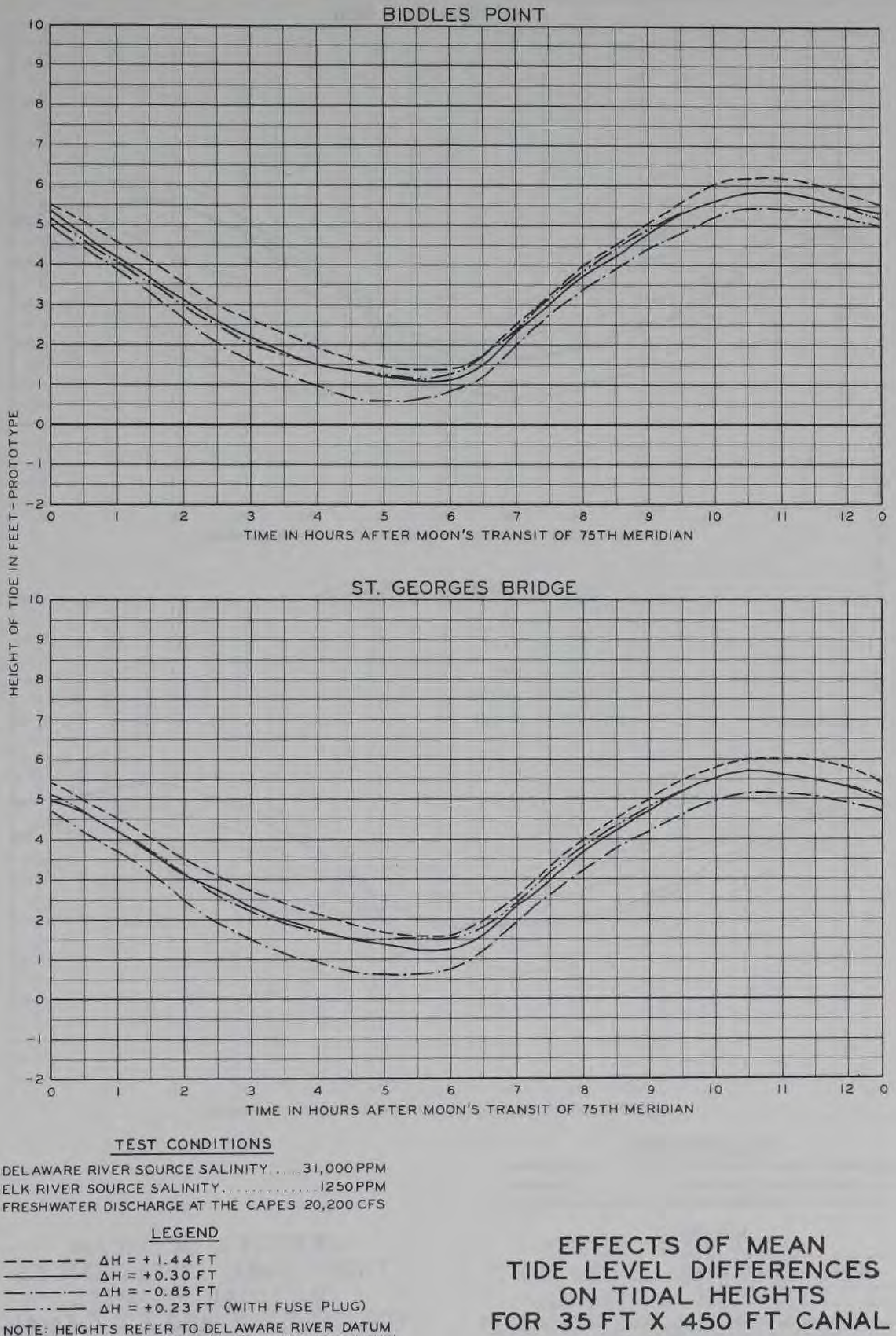
LEGEND

- – – – – ΔH = +1.44 FT
- ——— ΔH = +0.30 FT
- —·—·— ΔH = −0.85 FT
- —··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS REEDY POINT JETTY AND REEDY POINT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY ..... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

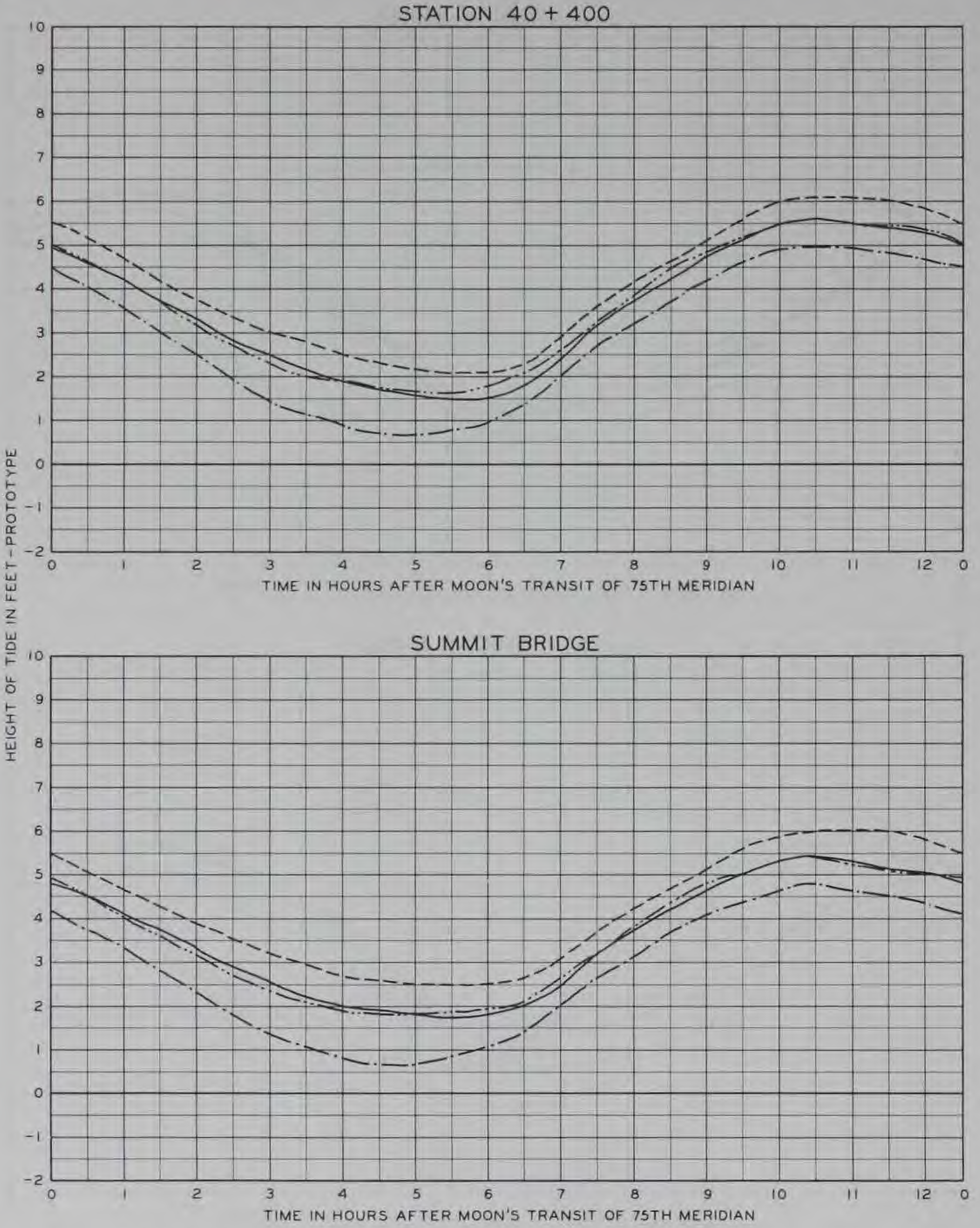
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = -0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS BIDDLES POINT
AND ST. GEORGES BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

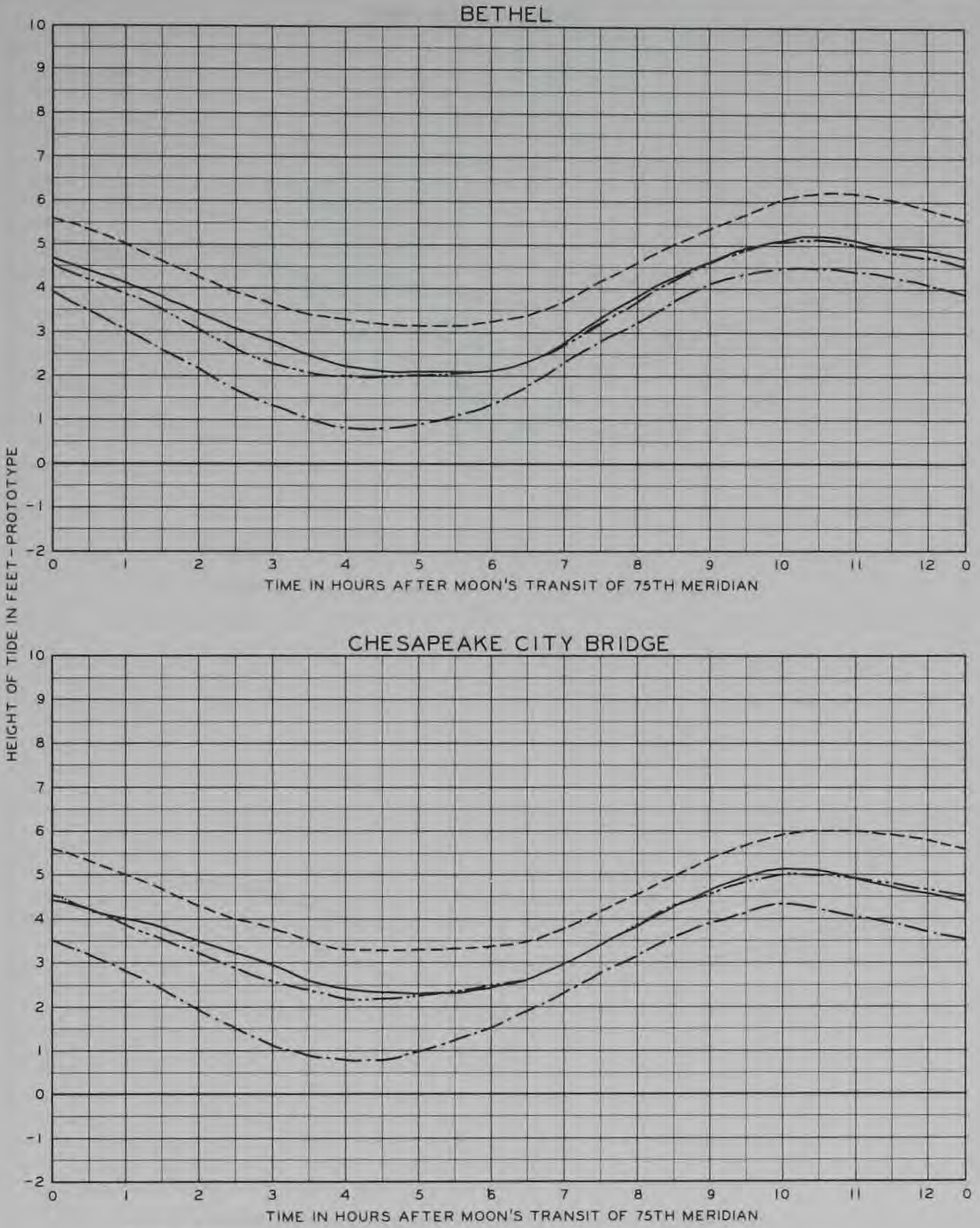
LEGEND

- - - - - ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·—·— ΔH = - 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS 40 + 400 AND SUMMIT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

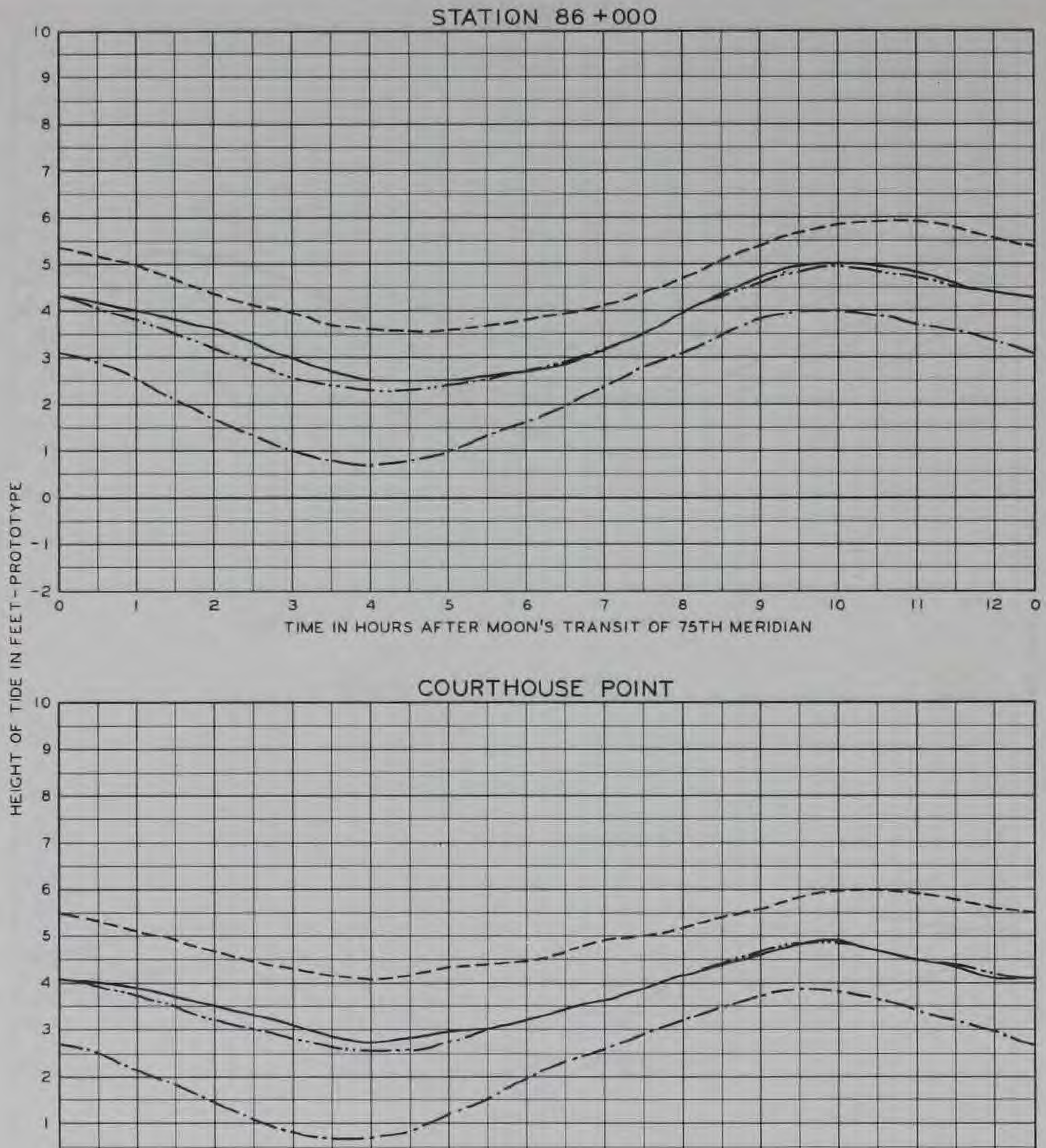
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS BETHEL AND
CHESAPEAKE CITY BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

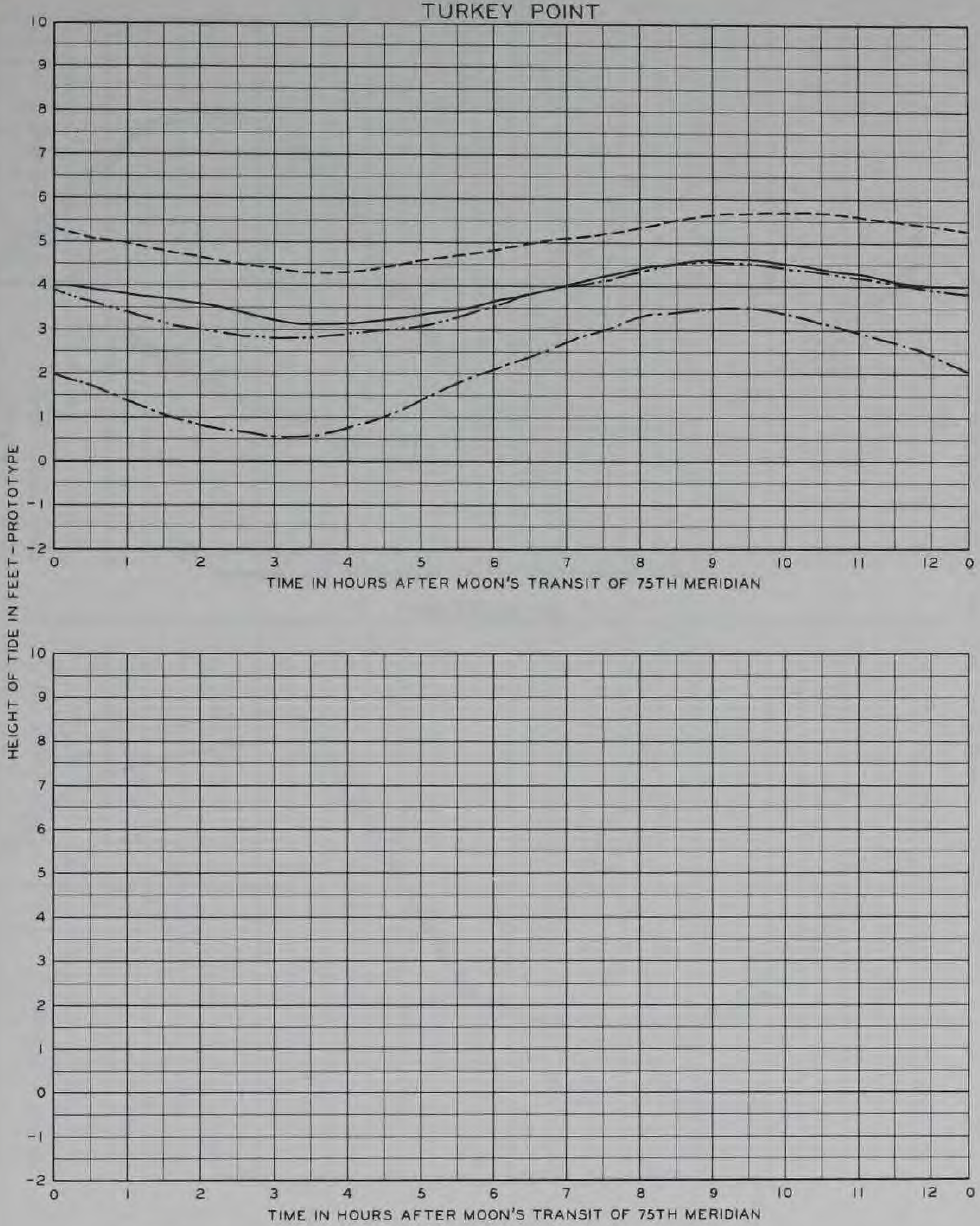
LEGEND

- - - - - ΔH = +1.44 FT
——— ΔH = +0.30 FT
—·—·— ΔH = -0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATIONS 86+000 AND COURTHOUSE POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

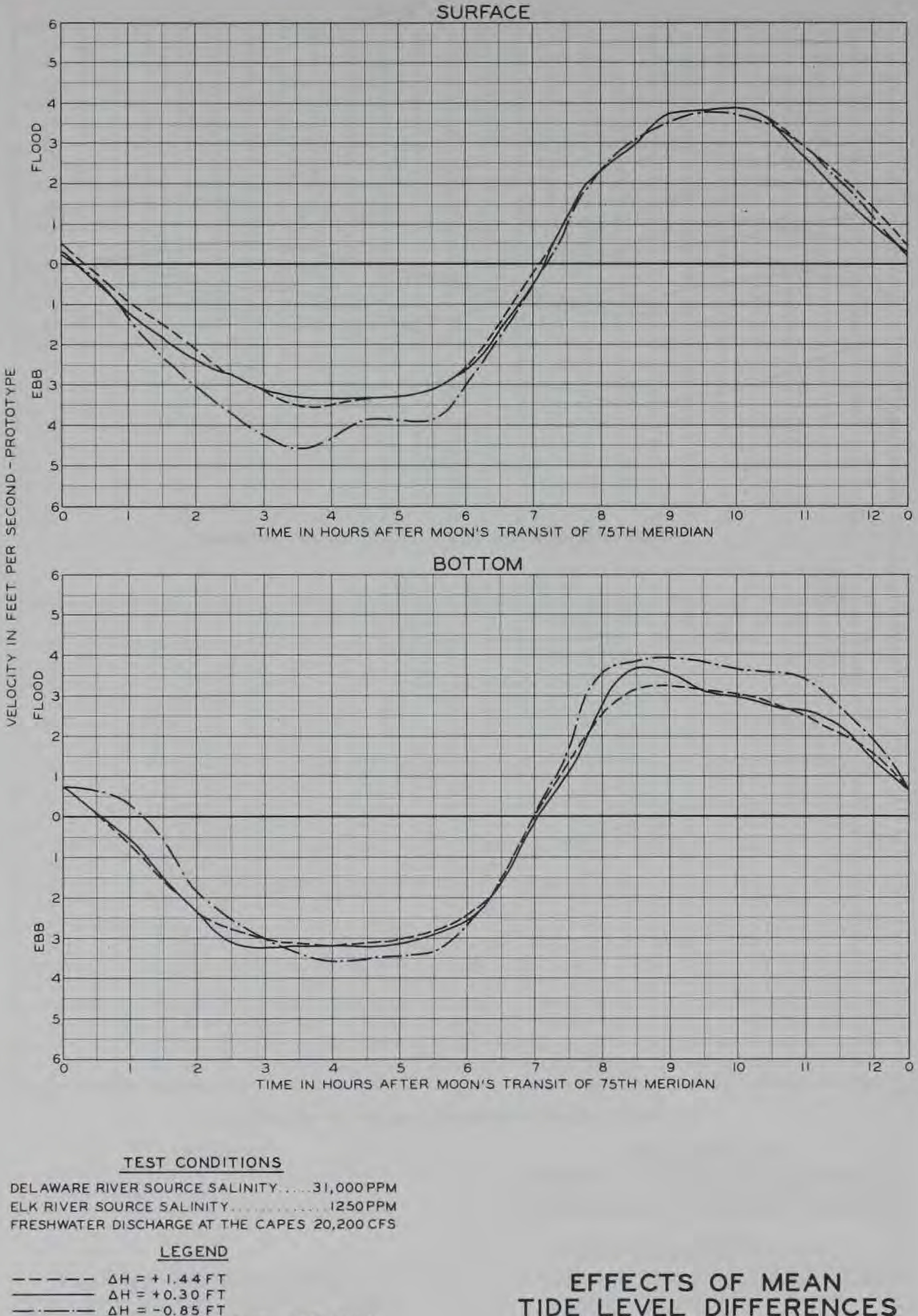
LEGEND

– – – – – ΔH = +1.44 FT
——— ΔH = +0.30 FT
—·—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON TIDAL HEIGHTS FOR 35 FT X 450 FT CANAL

STATION TURKEY POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

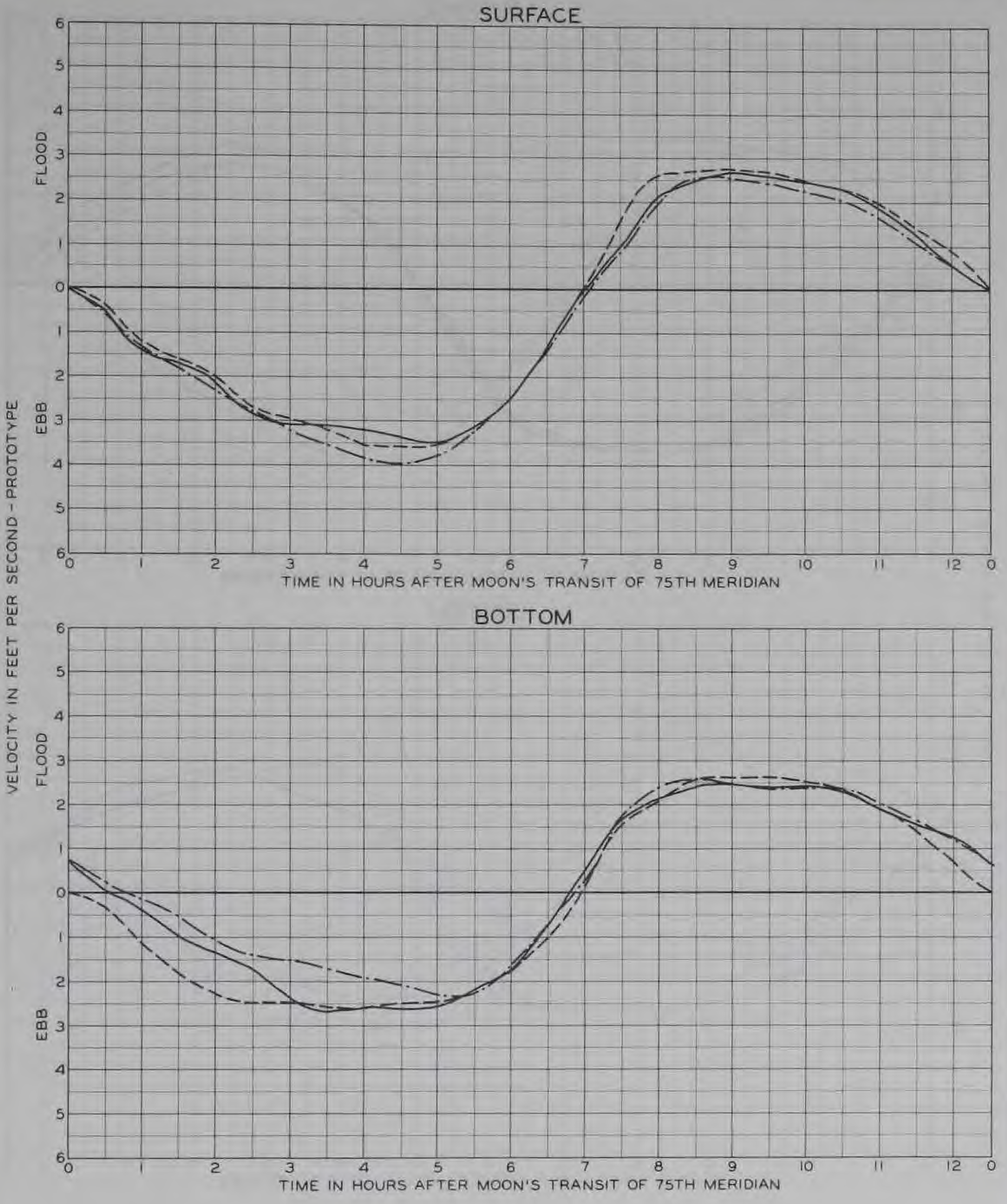
LEGEND

- — — — — ΔH = + 1.44 FT
- ———— ΔH = + 0.30 FT
- —·—— ΔH = − 0.85 FT
- —··—— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 220



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

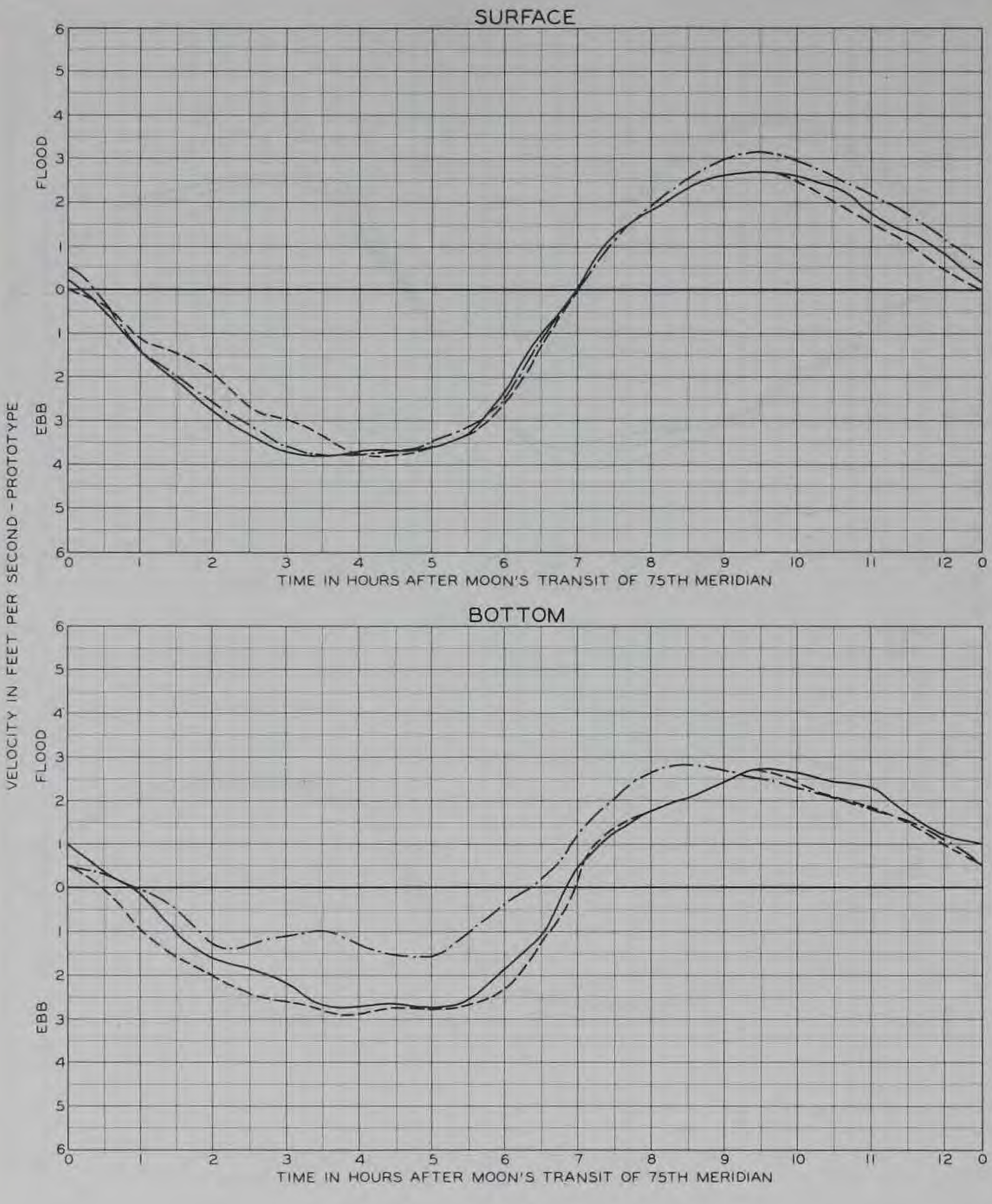
LEGEND

- – – – – ΔH = + 1.44 FT
- ——— ΔH = + 0.30 FT
- —·—·— ΔH = − 0.85 FT
- —··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 230



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

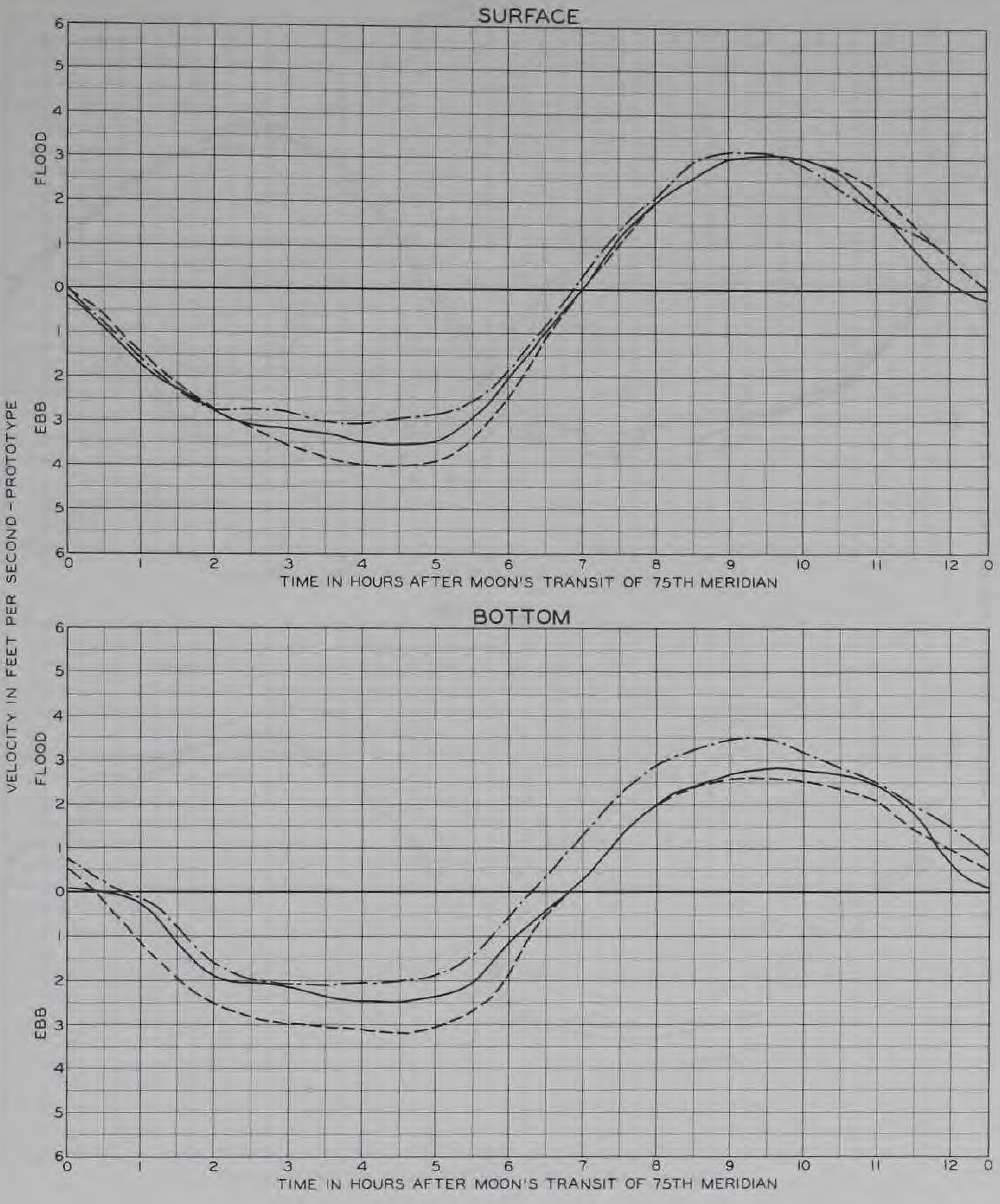
LEGEND

– – – – – ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 235



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

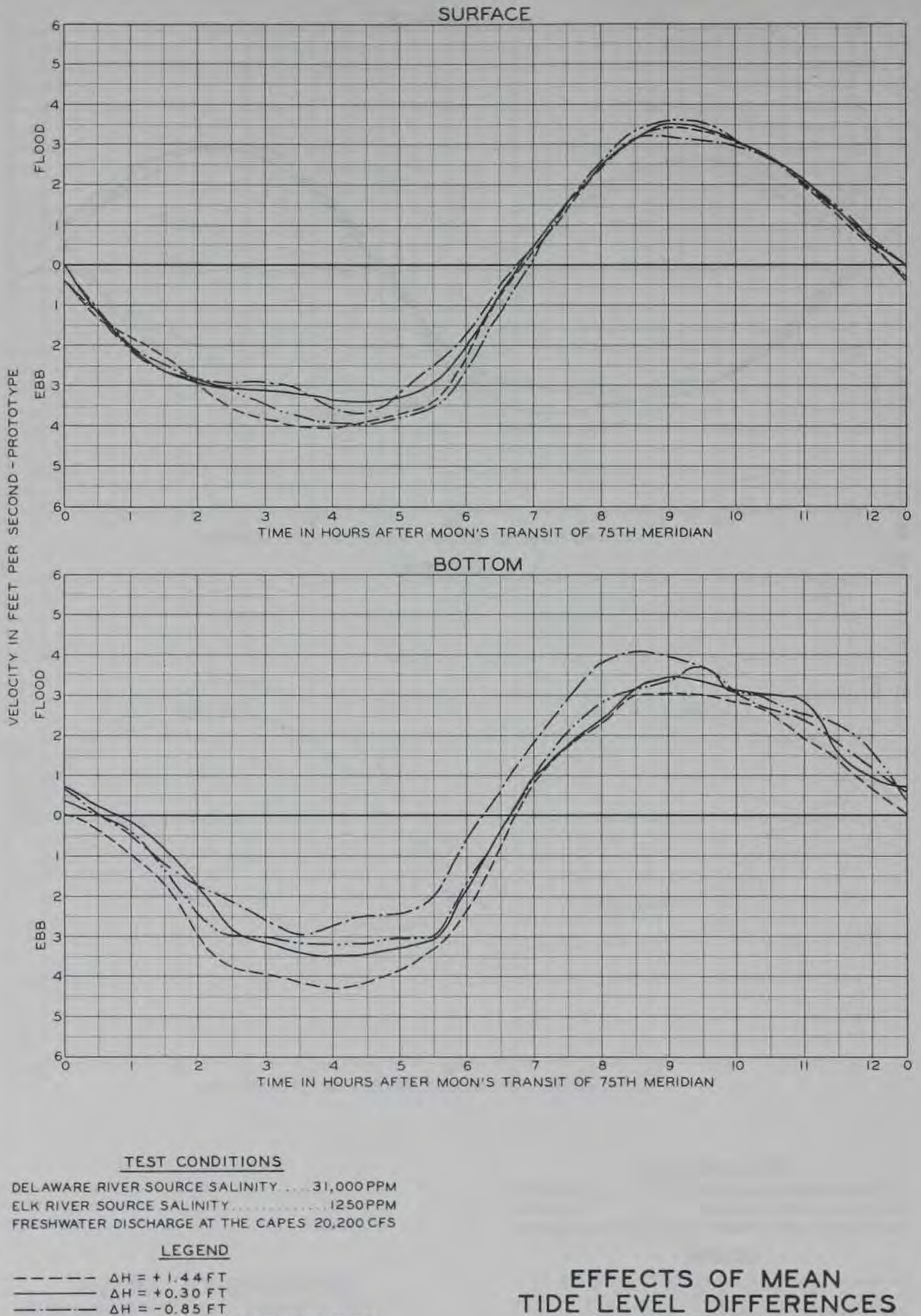
LEGEND

– – – – – ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 240



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . . 31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

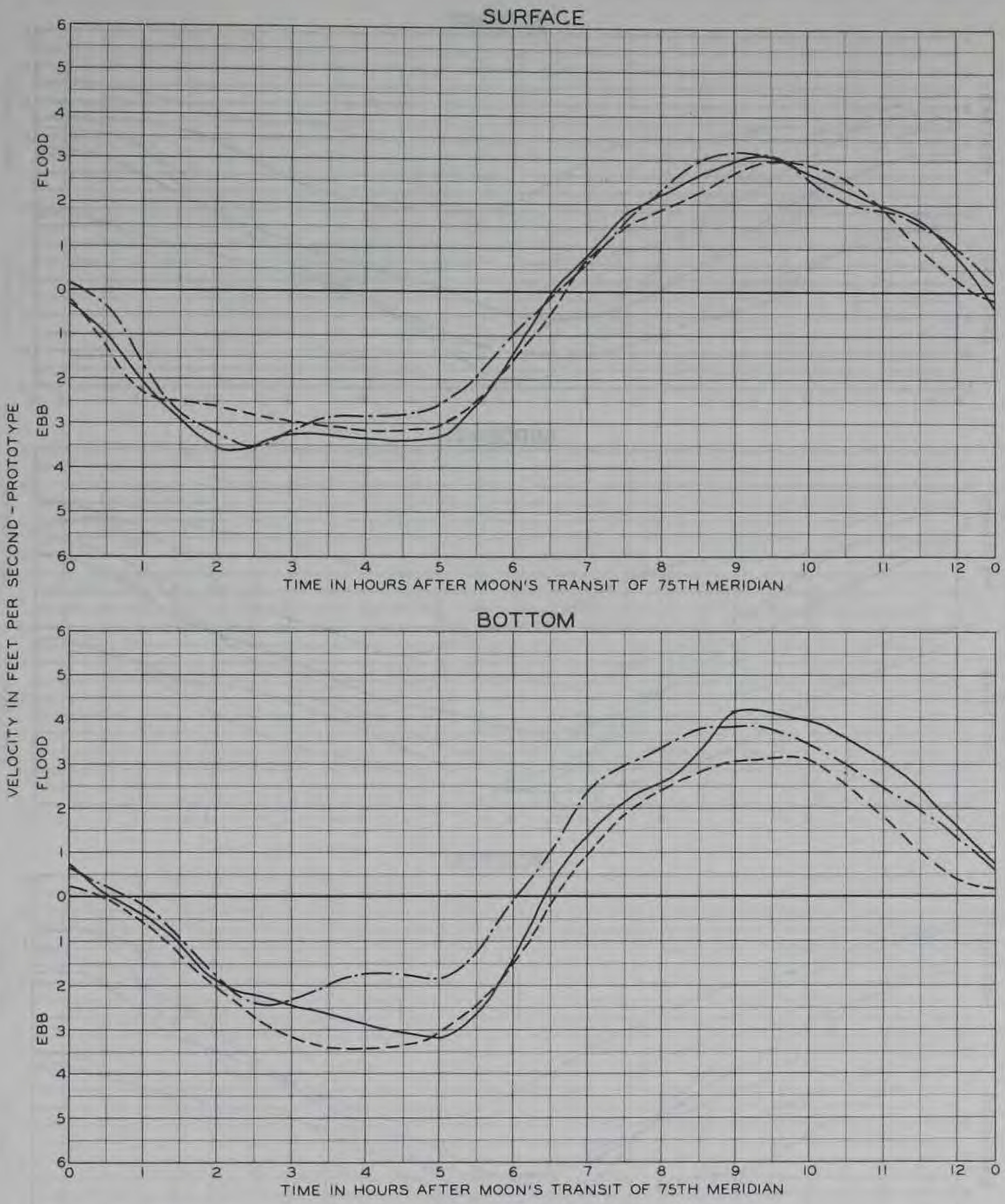
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = + 0.30 FT
—·—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 245



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

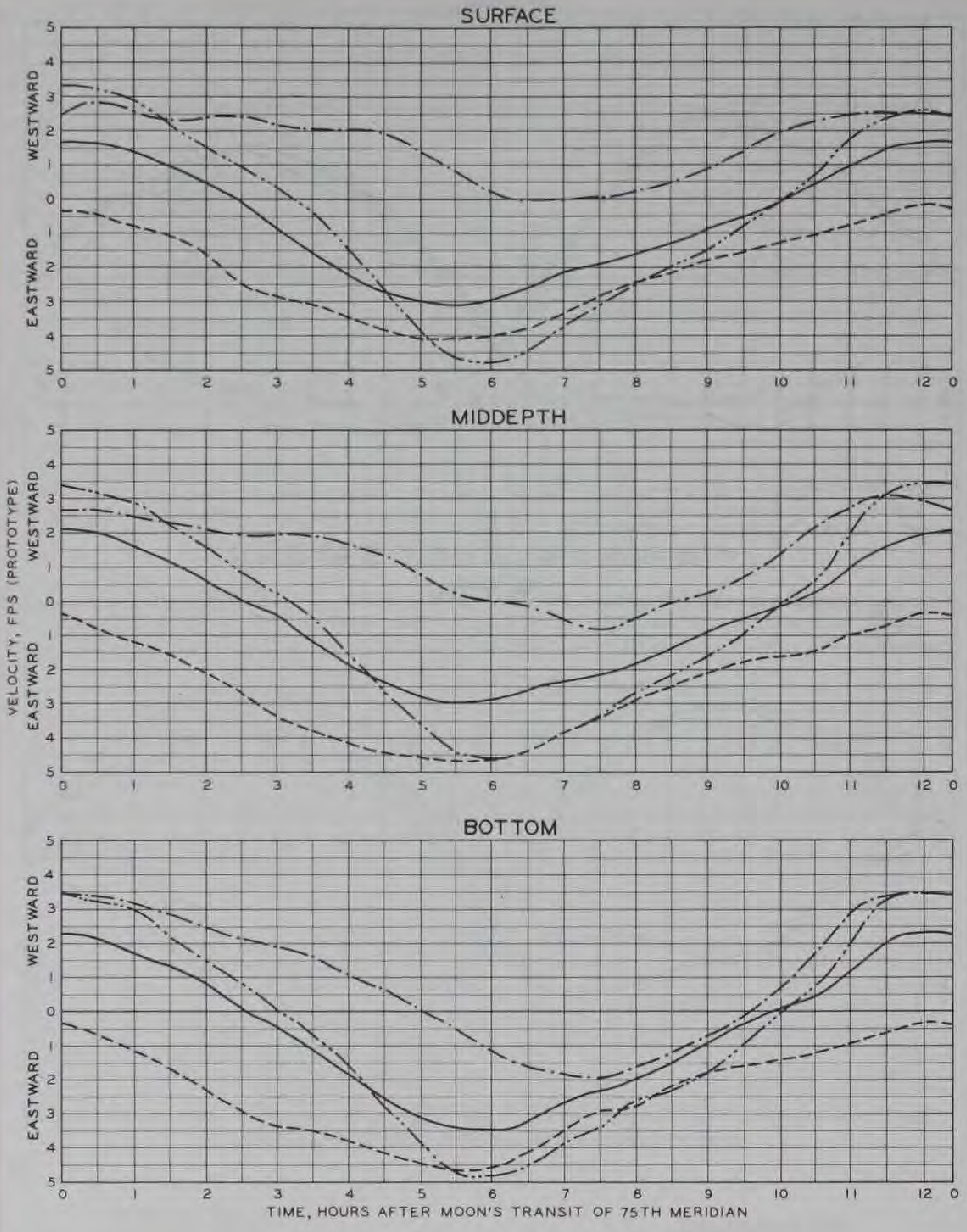
LEGEND

– – – – – ΔH = + 1.44 FT
——————— ΔH = + 0.30 FT
—·——·— ΔH = − 0.85 FT

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION 255



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY. . . . .31,000 PPM
ELK RIVER SOURCE SALINITY. . . . . .1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

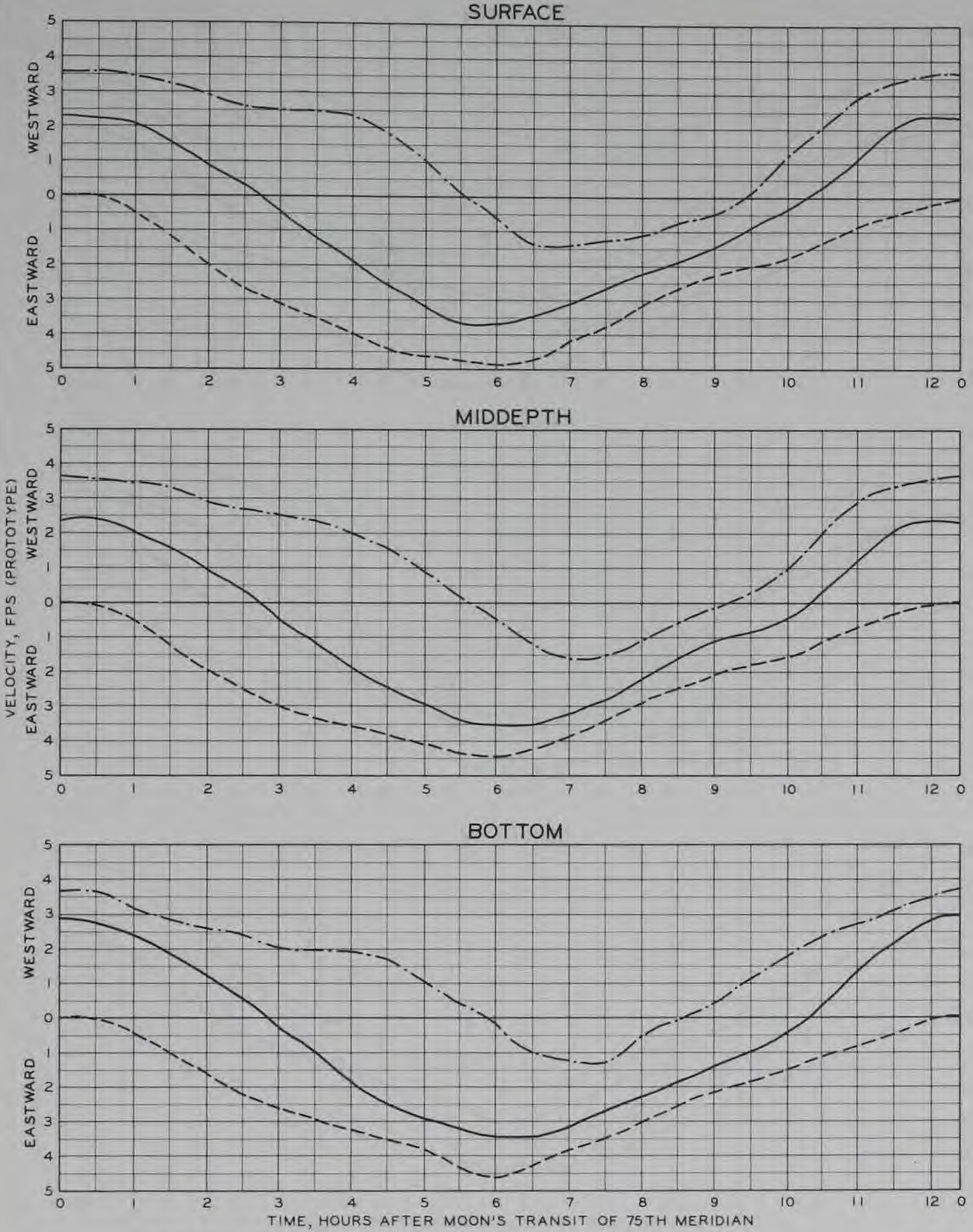
LEGEND

– – – – – ΔH = +1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION A


SURFACE

MIDDEPTH

BOTTOM

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

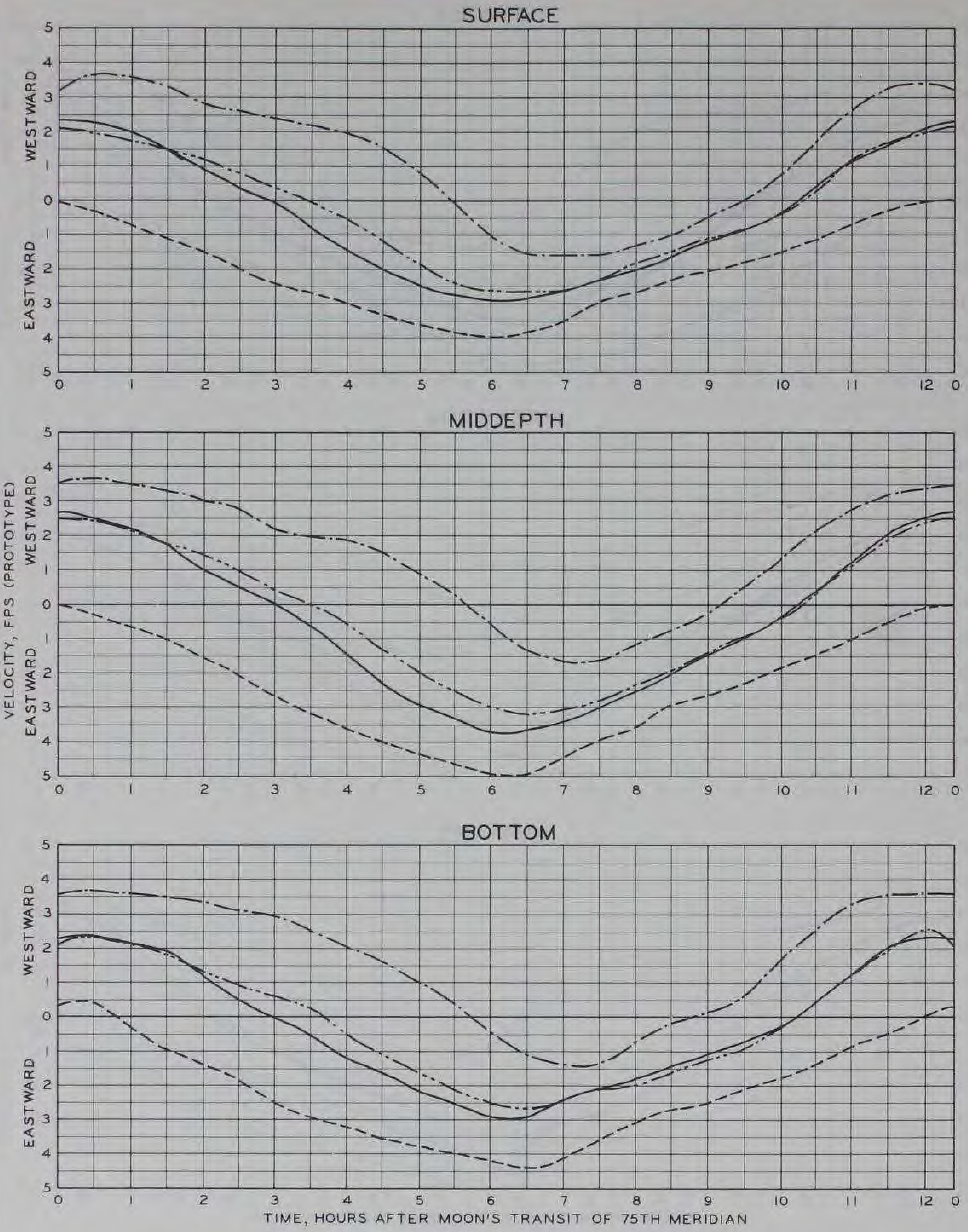
LEGEND

- – – – – ΔH = + 1.44 FT
- ——— ΔH = +0.30 FT
- —·— ΔH = −0.85 FT
- —··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION B



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

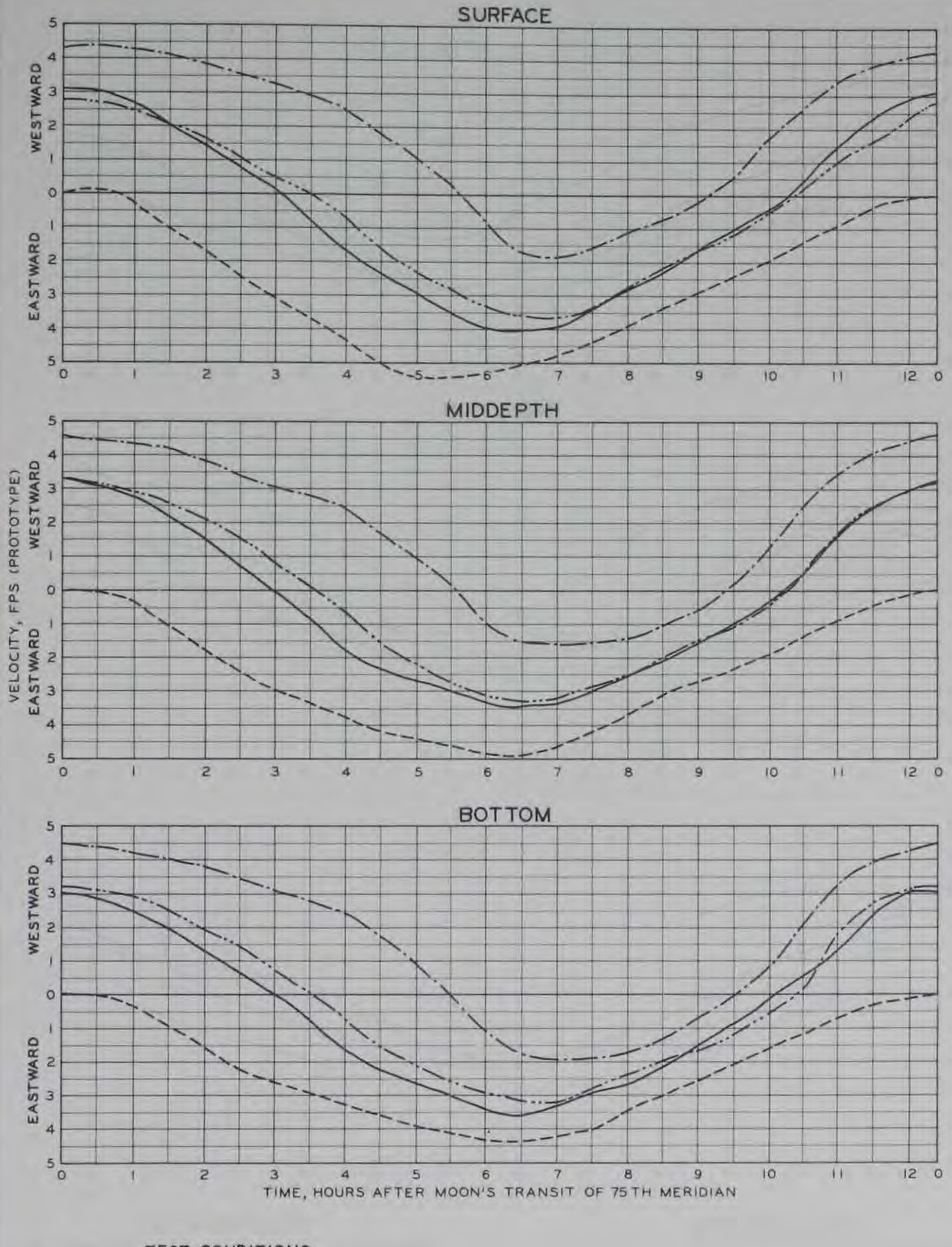
LEGEND

- - - - - ΔH = + 1.44 FT
——— ΔH = + 0.30 FT
—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

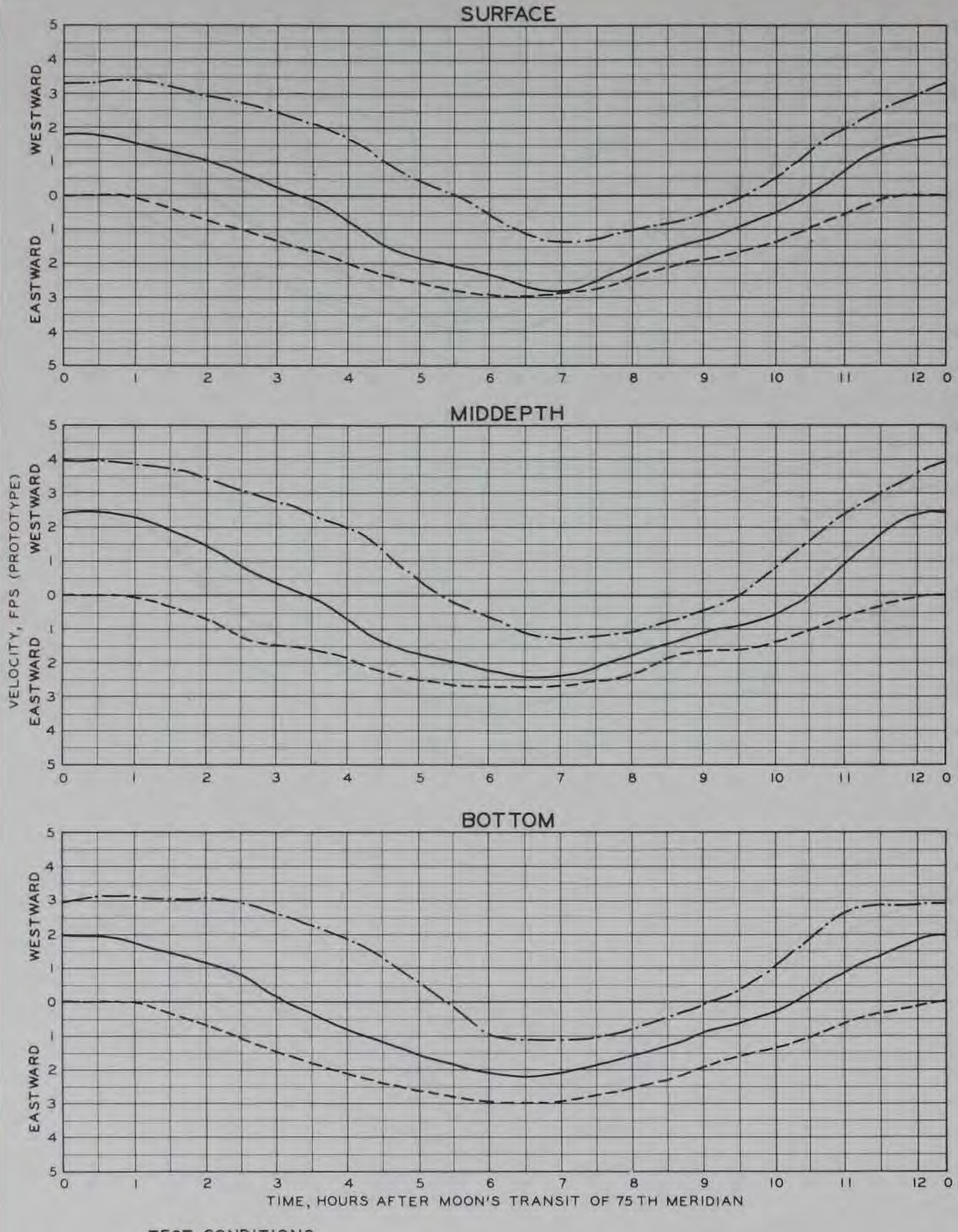
LEGEND

- – – – – ΔH = +1.44 FT
- ——— ΔH = +0.30 FT
- —·—·— ΔH = −0.85 FT
- —··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION D



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

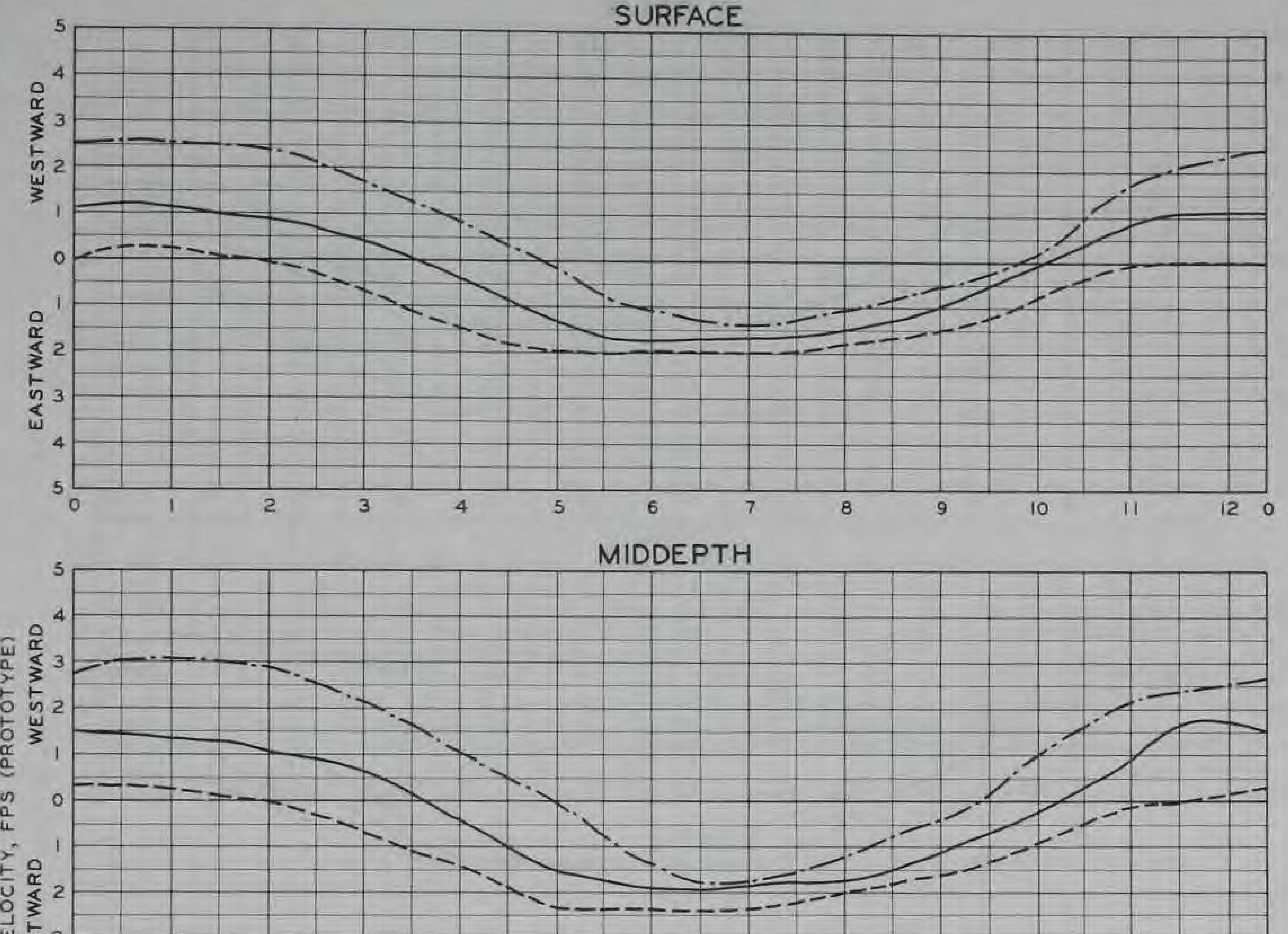
LEGEND

– – – – – ΔH = + 1.44 FT
——— ΔH = +0.30 FT
—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION E



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

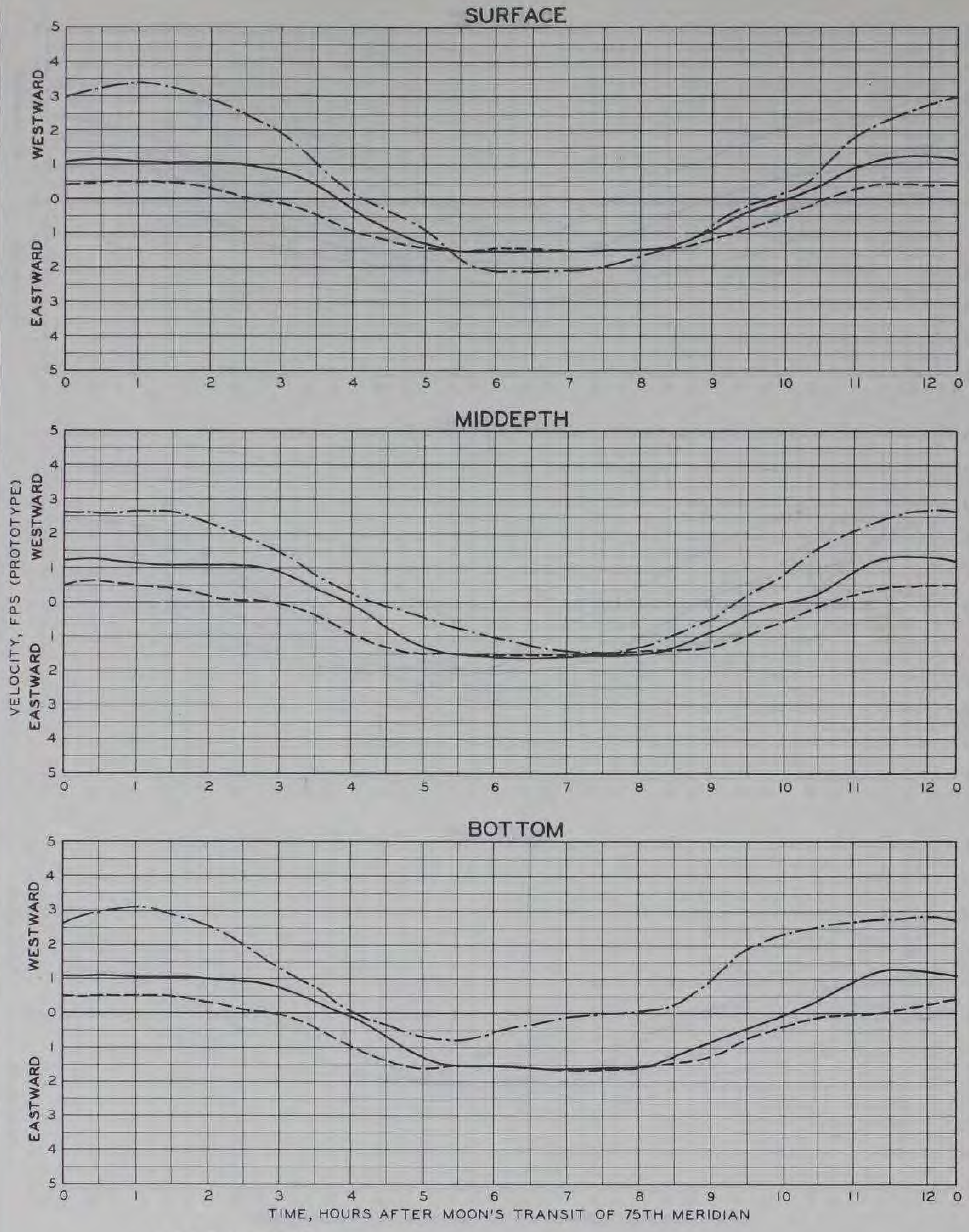
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = –0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION F



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

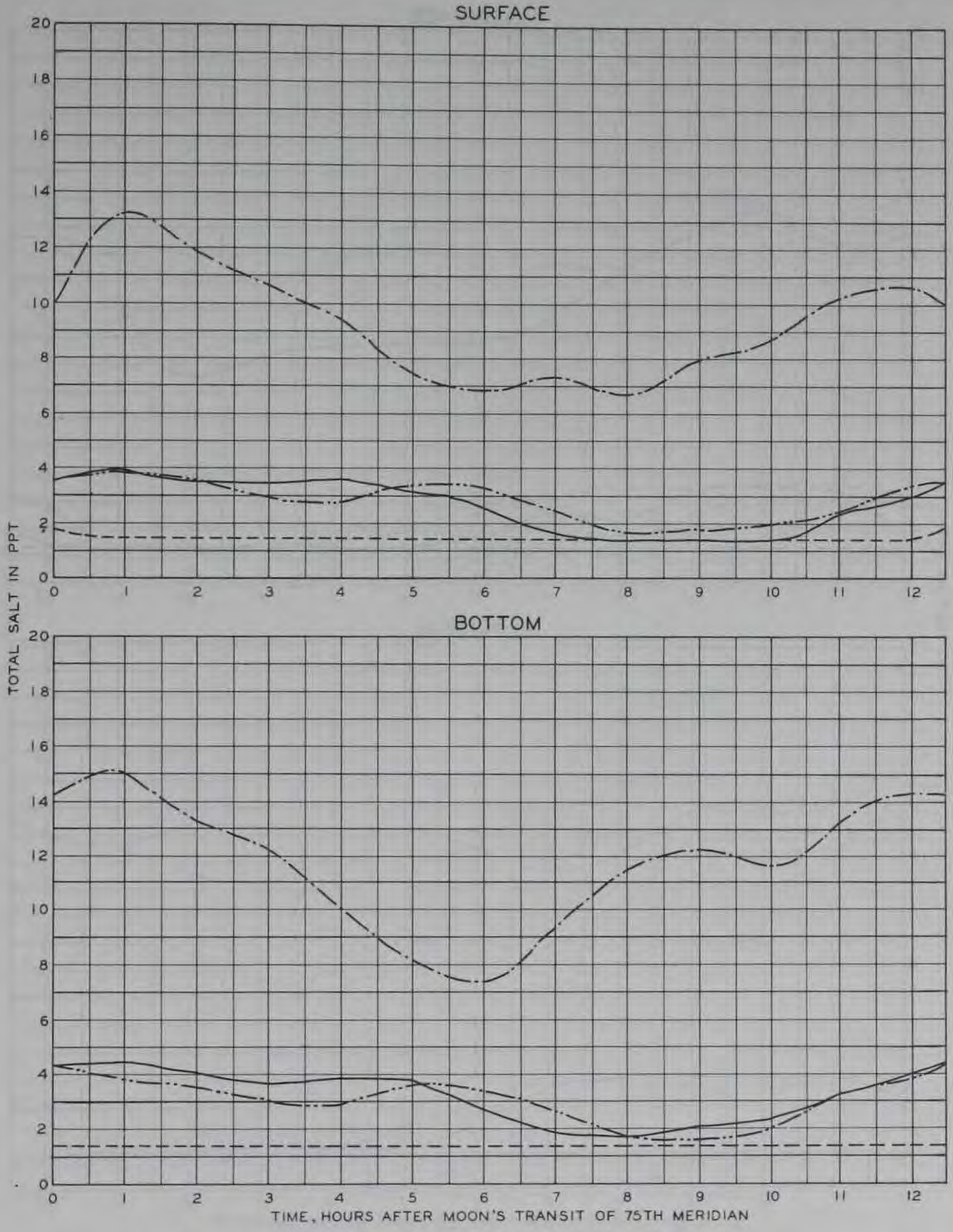
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = + 0.30 FT
—·—·— ΔH = − 0.85 FT
—··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON CURRENT VELOCITIES FOR 35 FT X 450 FT CANAL

STATION G



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY..... 31,000 PPM
ELK RIVER SOURCE SALINITY.............. 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

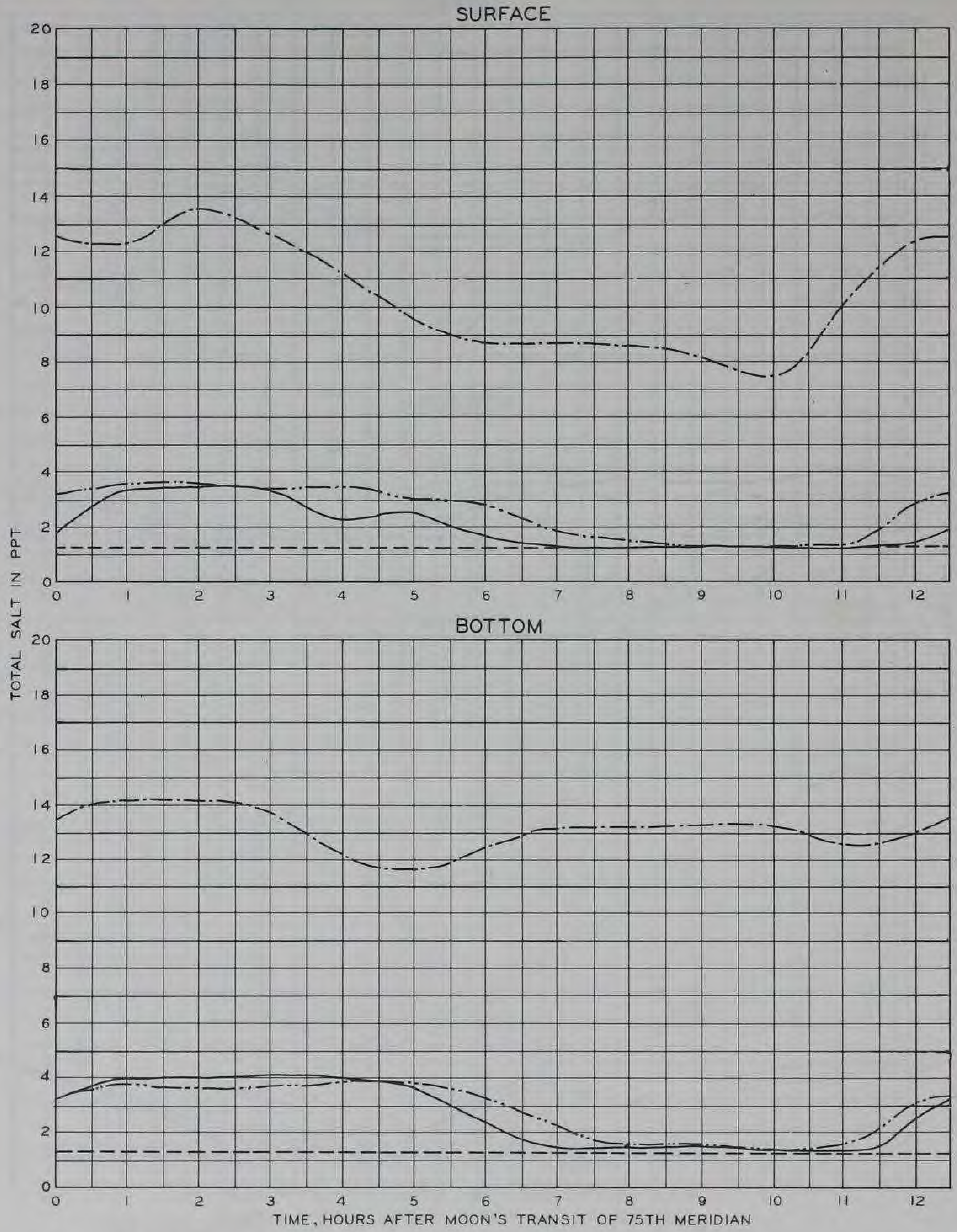
LEGEND

- – – – – ΔH = +1.44 FT
- ——— ΔH = +0.30 FT
- —·—·— ΔH = −0.85 FT
- —··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES FOR 35 FT X 450 FT CANAL

STATION 2



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

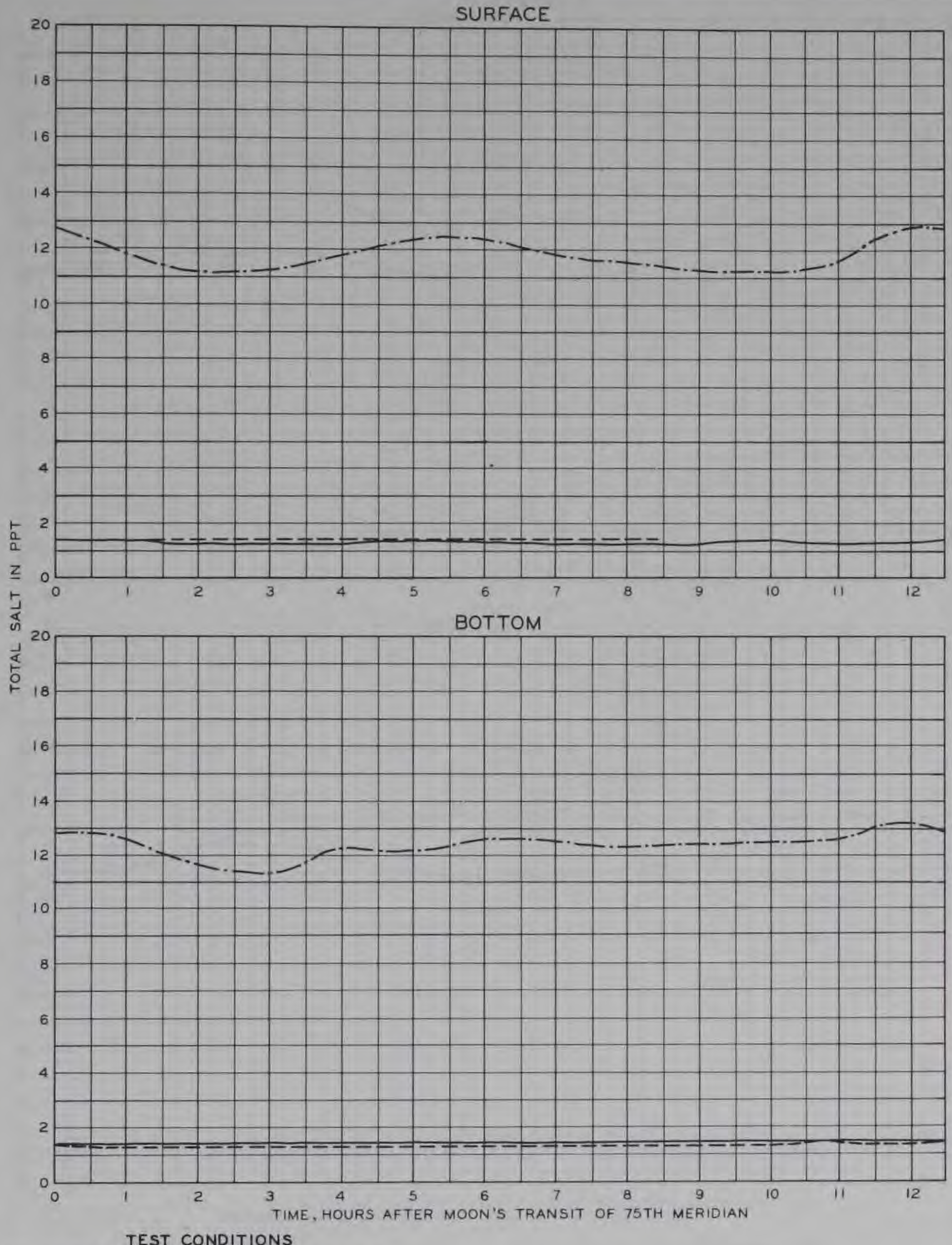
LEGEND

– – – – – ΔH = + 1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = -0.85 FT
—··—— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES FOR 35 FT X 450 FT CANAL

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

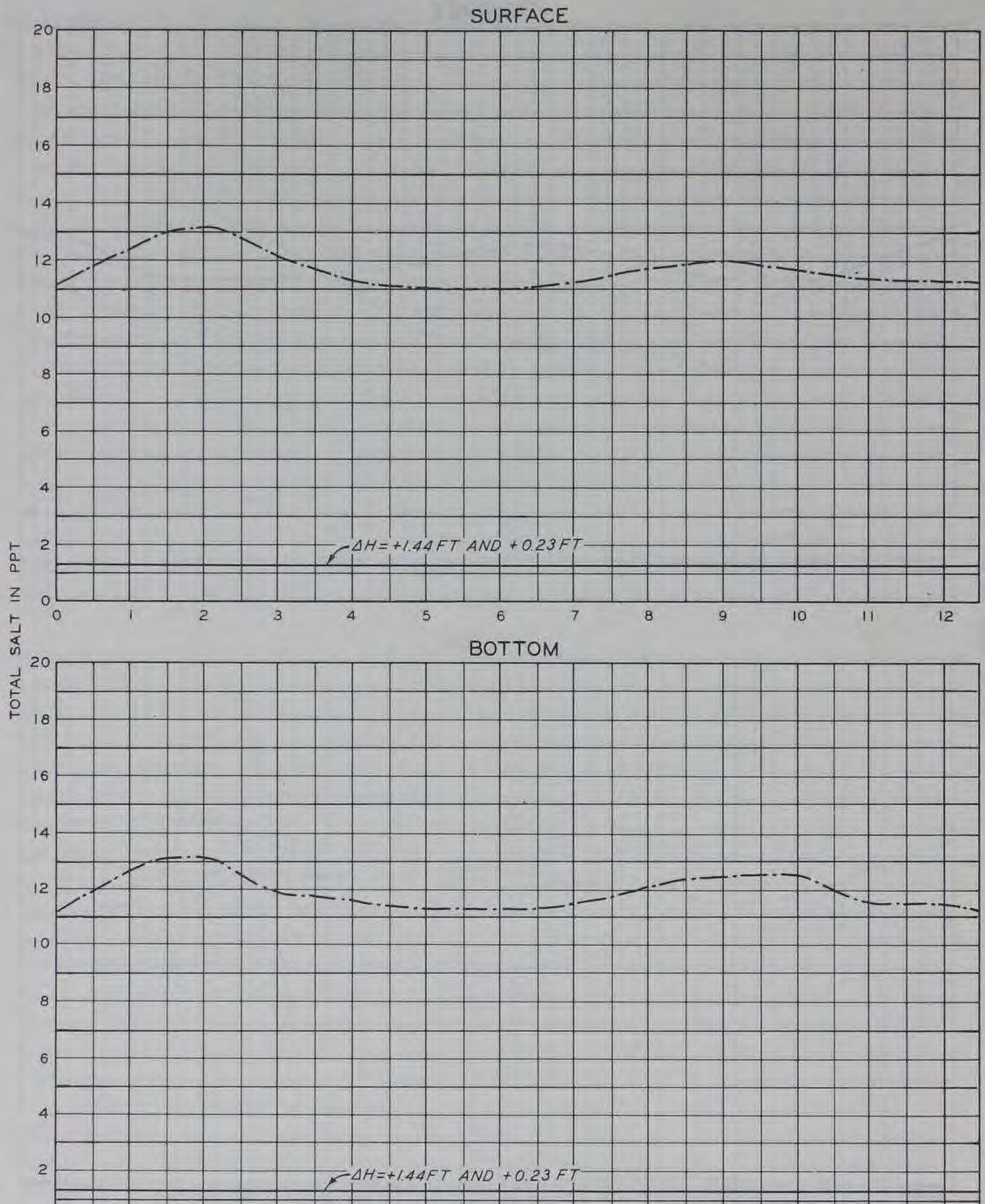
LEGEND

– – – – ΔH = +1.44 FT
——— ΔH = +0.30 FT
—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES FOR 35 FT X 450 FT CANAL

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

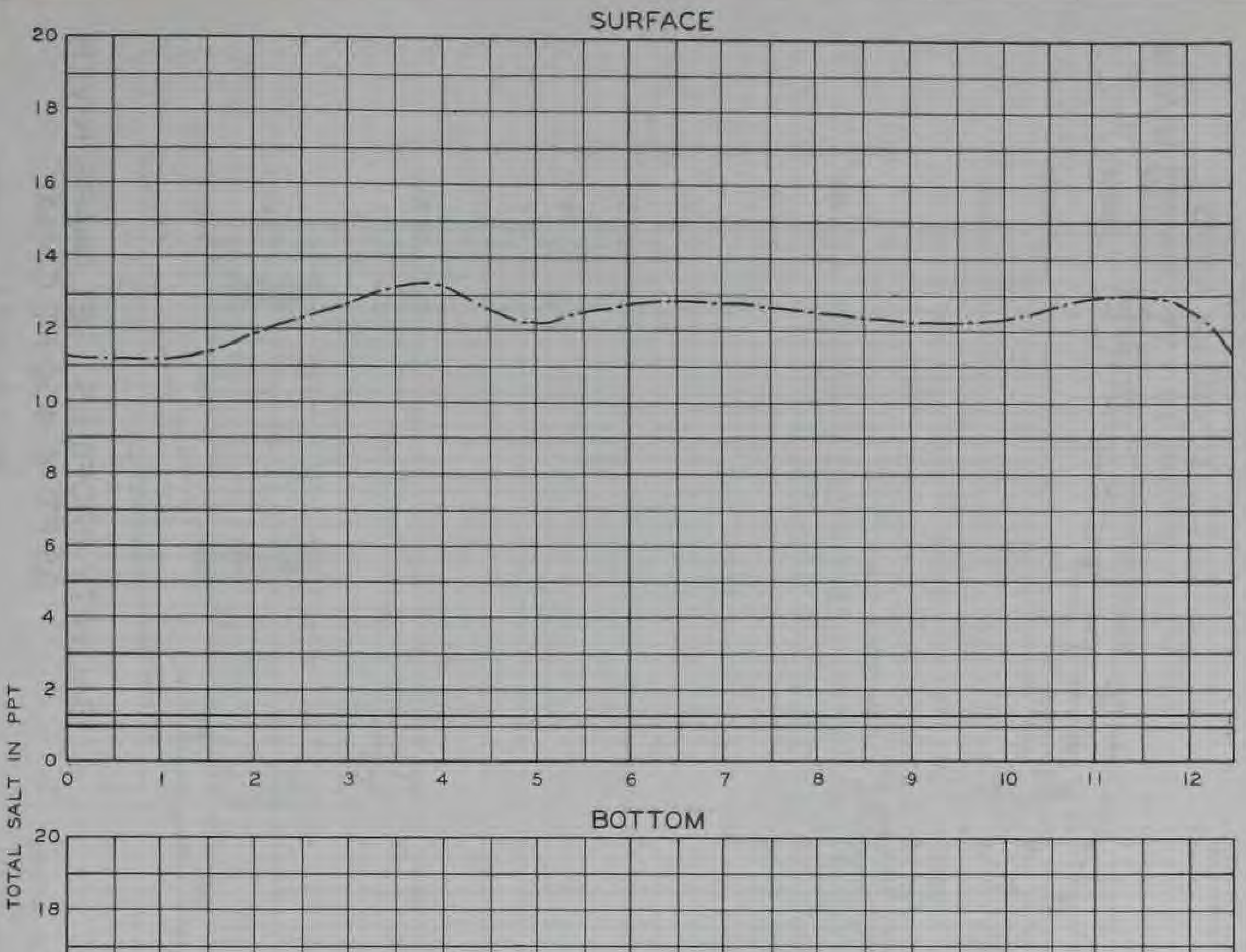
– – – – – ΔH = + 1.44 FT
———— ΔH = +0.30 FT
—·—·— ΔH = −0.85 FT
—··— ΔH = +0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES FOR 35 FT X 450 FT CANAL

STATION D

PLATE 96



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

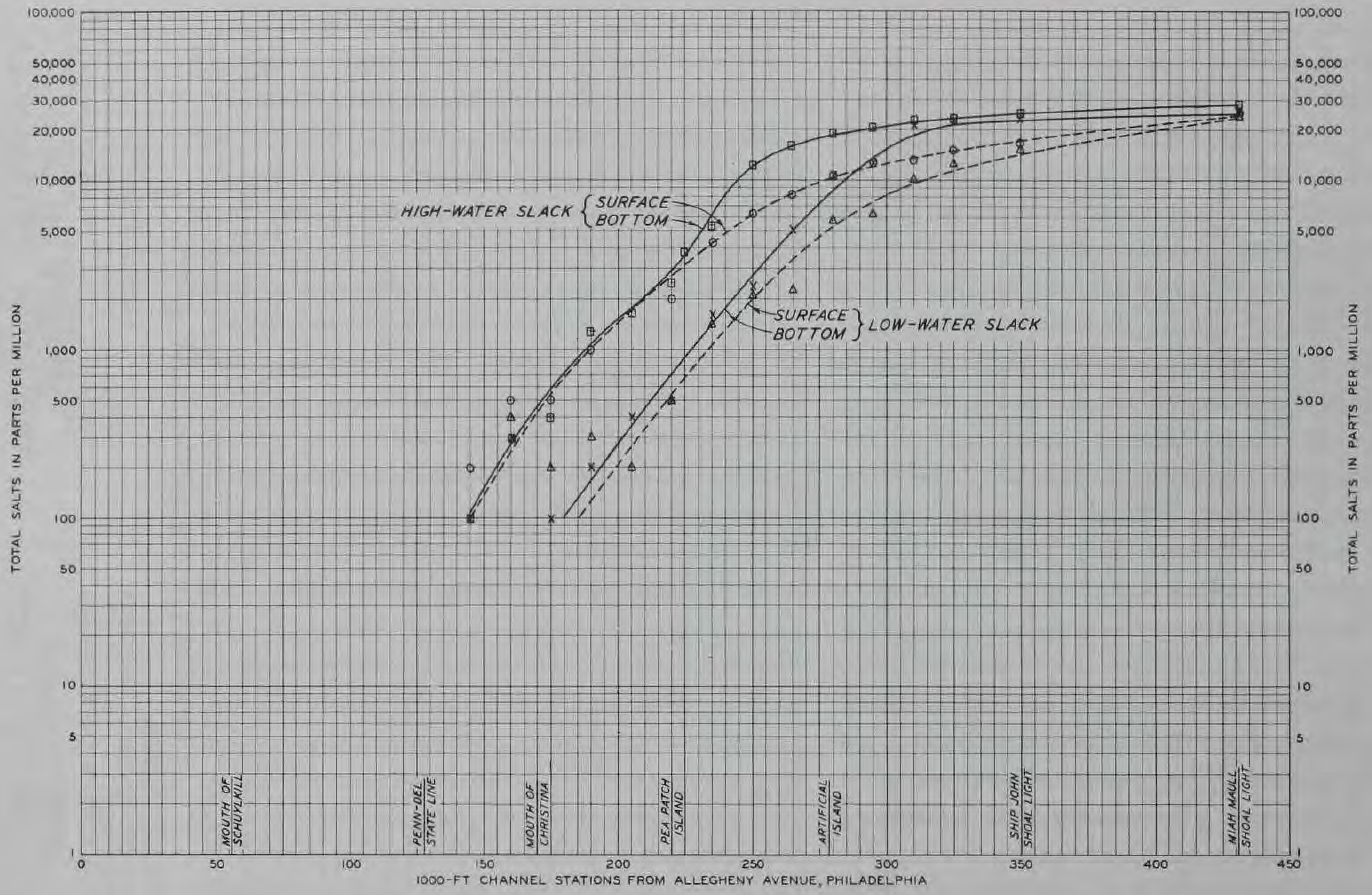
LEGEND

- – – – – ΔH = + 1.44 FT
- ——— ΔH = + 0.30 FT
- —·—·— ΔH = − 0.85 FT
- —··— ΔH = + 0.23 FT (WITH FUSE PLUG)

NOTE: ΔH MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.
ΔH + 0.23 WITH FUSE PLUG OBSERVATIONS
NOT AVAILABLE.

EFFECTS OF MEAN TIDE LEVEL DIFFERENCES ON SALINITIES FOR 35 FT X 450 FT CANAL

STATION E



LEGEND

----- SURFACE
——— BOTTOM

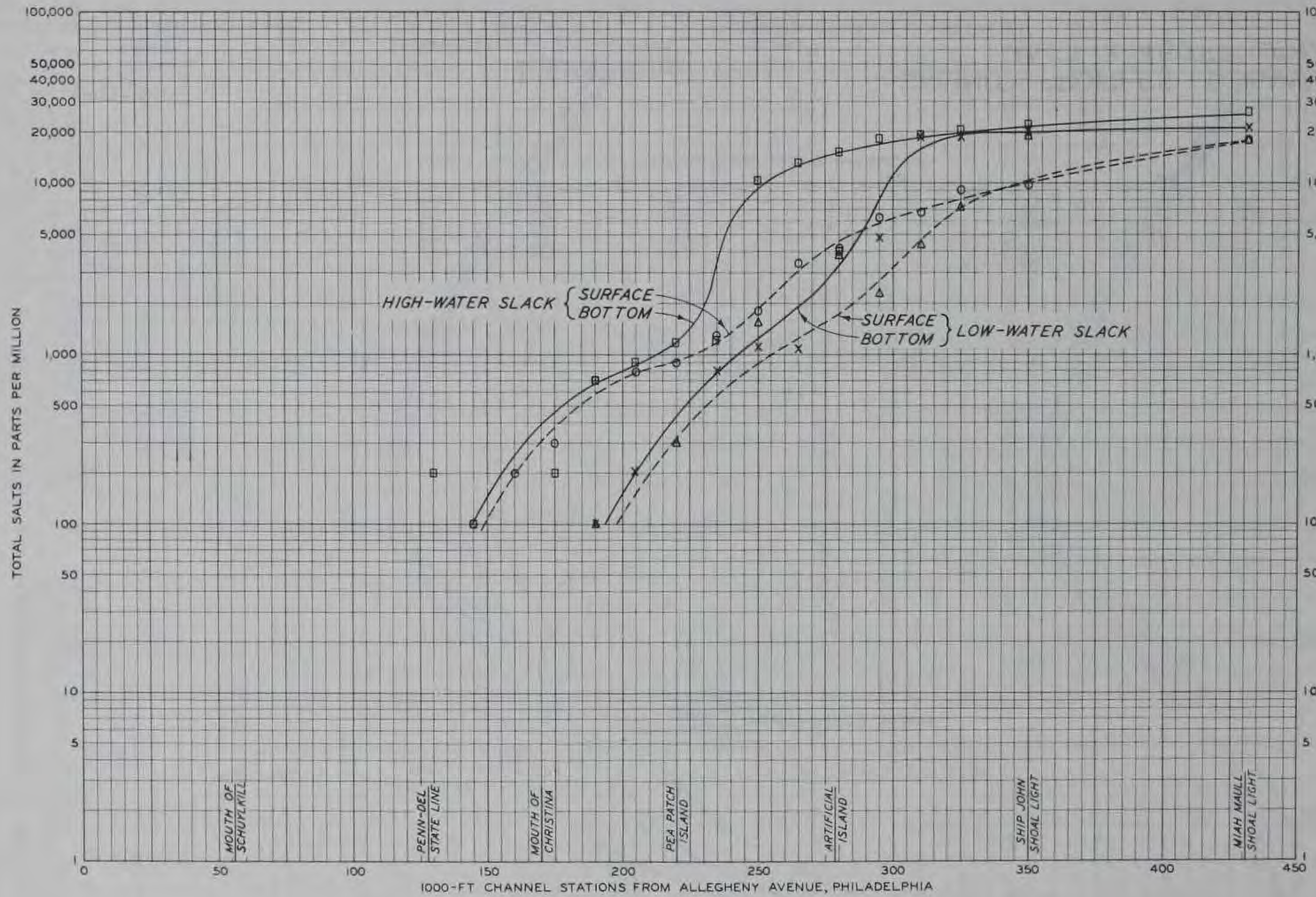
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY...................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
35 FT X 450 FT CANAL

ΔH = +0.30 FT



LEGEND

- - - - - SURFACE
——— BOTTOM

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY

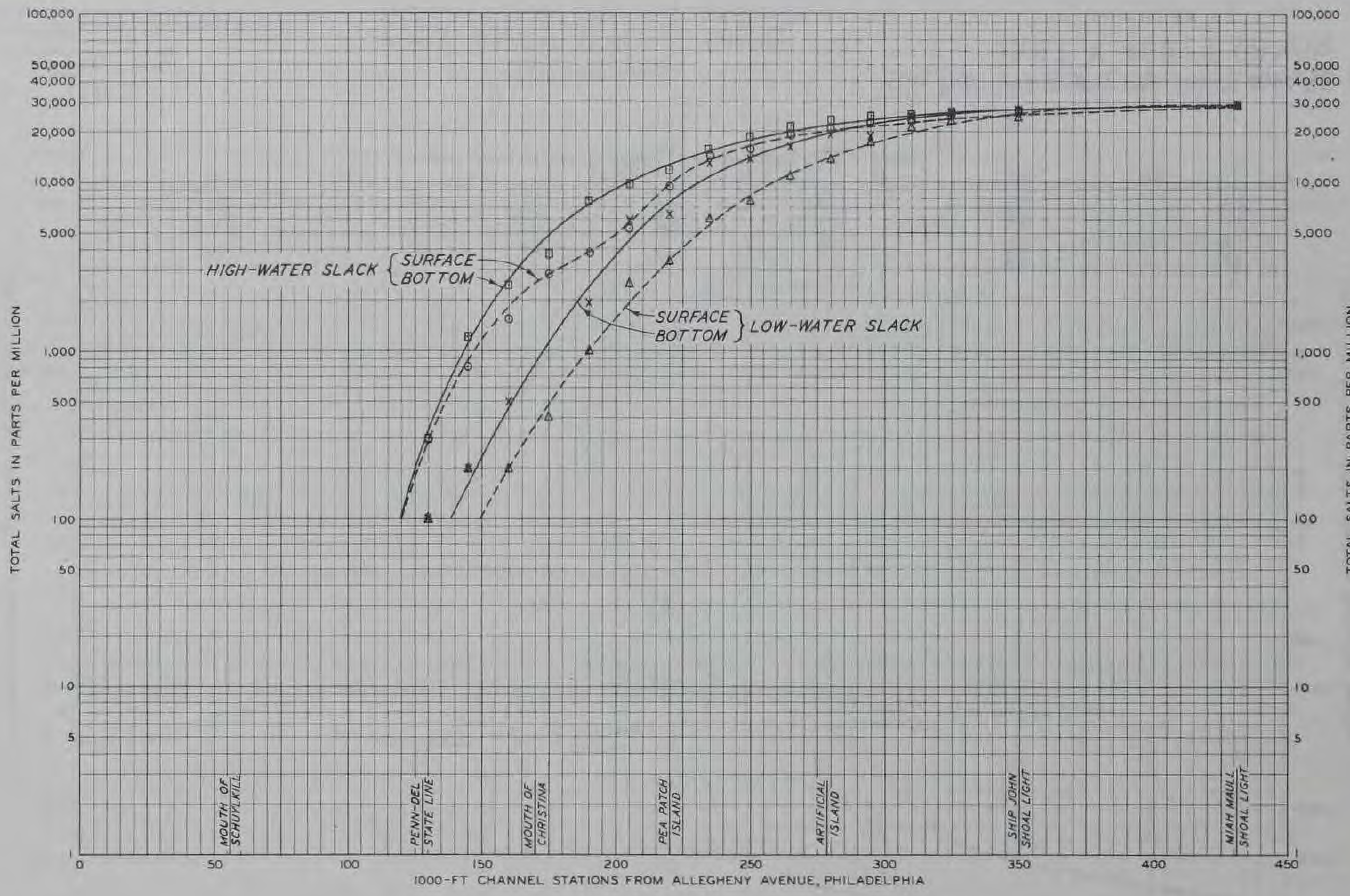
TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY....................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
35 FT X 450 FT CANAL

ΔH = +1.44 FT

PLATE 100



LEGEND

----- SURFACE
——— BOTTOM

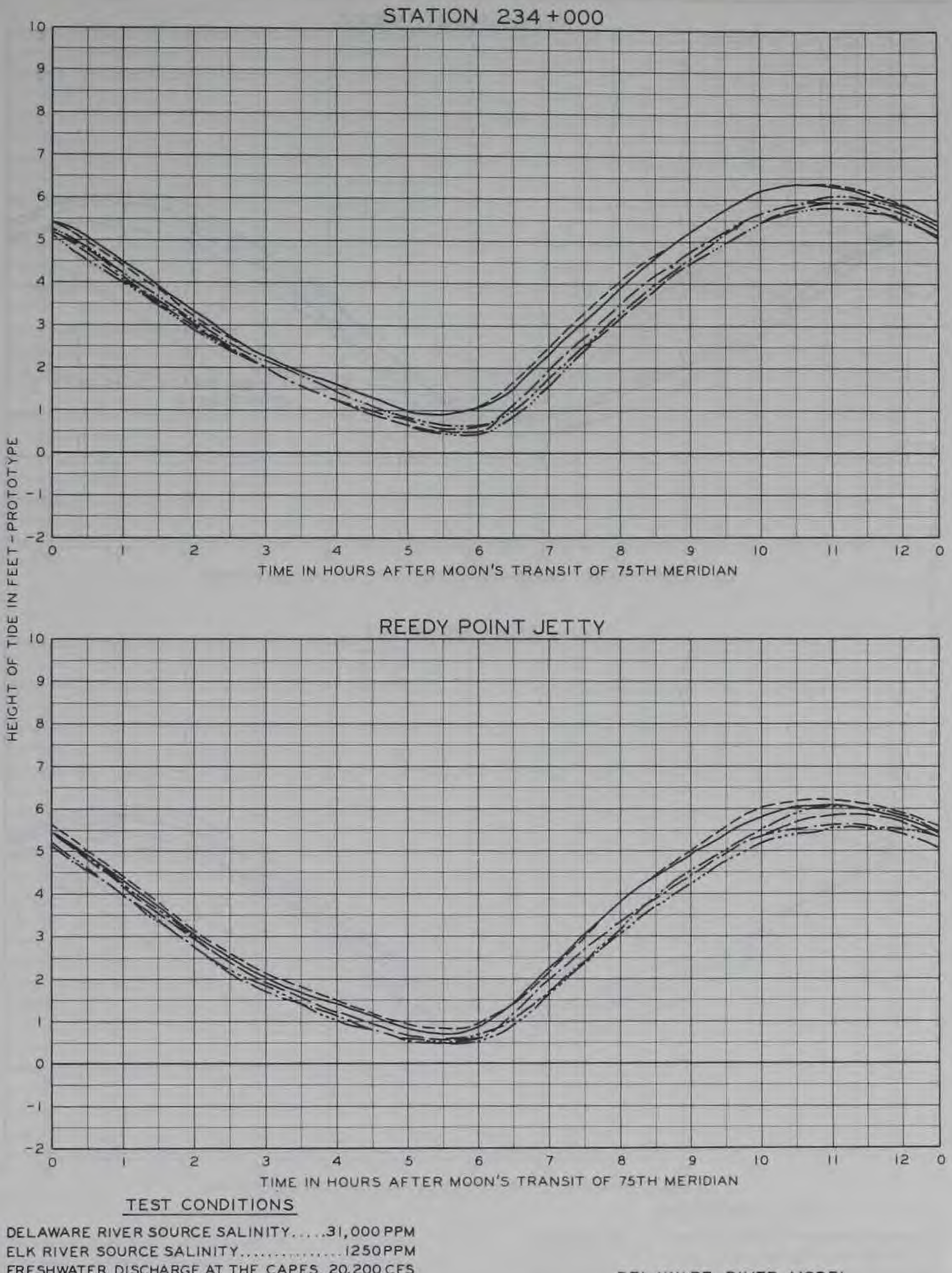
NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.........31,000 PPM
ELK RIVER SOURCE SALINITY..................1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES....20,200 CFS

SALINITY PROFILES DELAWARE RIVER
35 FT X 450 FT CANAL

ΔH = −0.85 FT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

– – – – ΔH = +1.44 FT ⎤
——— ΔH = +0.30 FT ⎬ 35 FT CANAL
–·–·– ΔH = -0.85 FT ⎦
–··– ΔH = +1.44 FT ⎤
— — ΔH = +0.28 FT ⎬ 27 FT CANAL
–···– ΔH = -0.91 FT ⎦

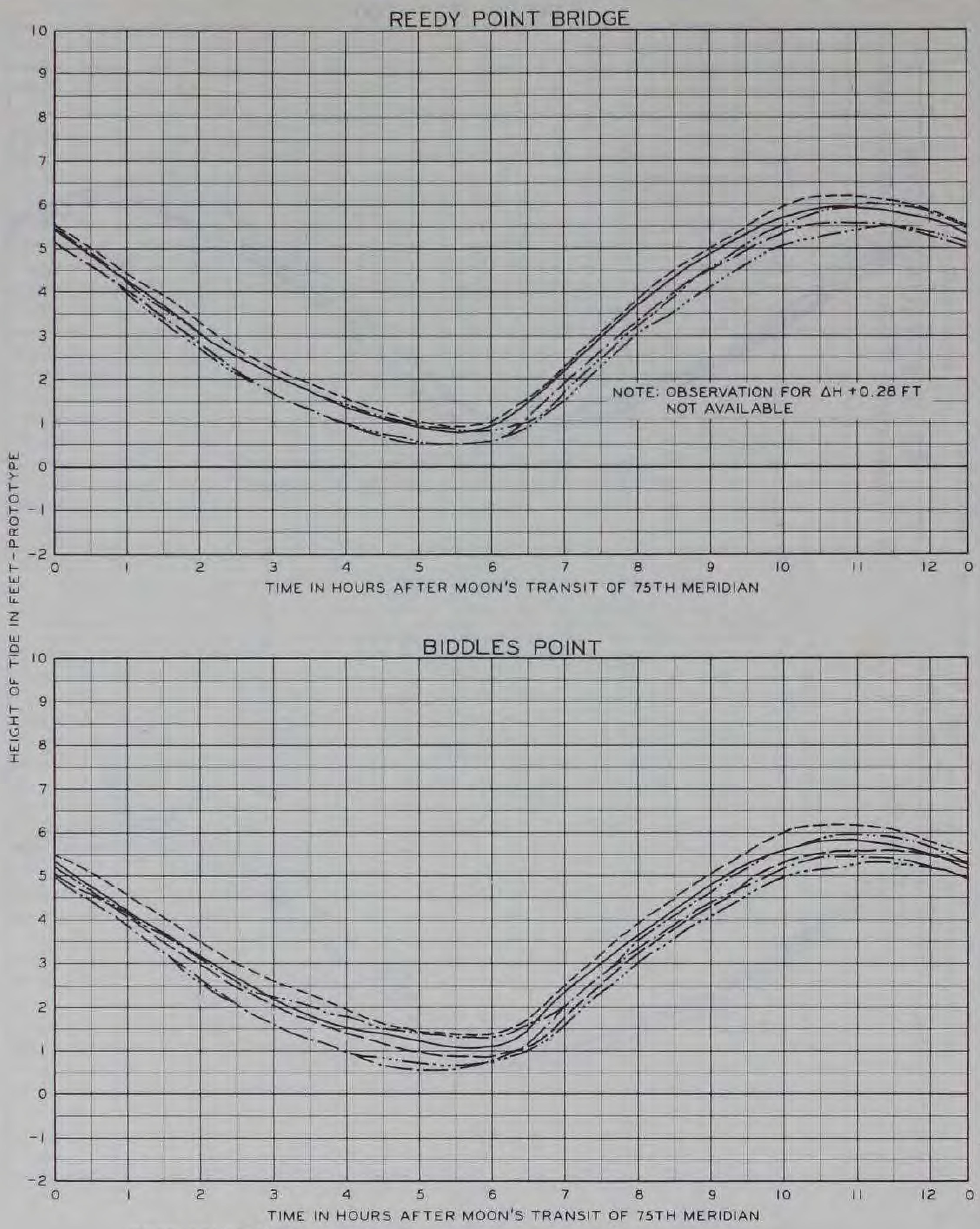
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS 234 + 000 AND
REEDY POINT JETTY



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

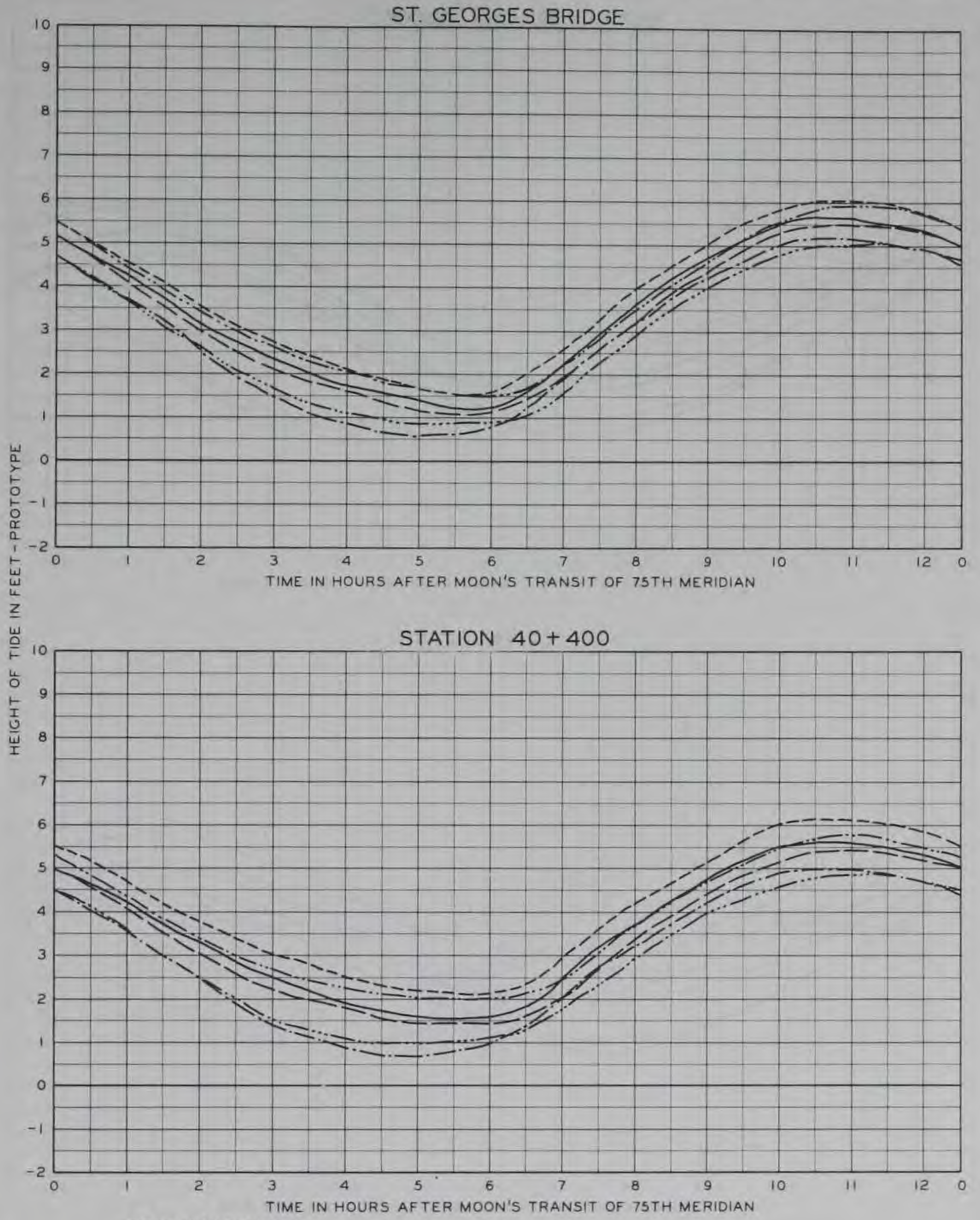
Line	ΔH	Canal
– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
–·–·–	ΔH = −0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
—···—	ΔH = −0.91 FT	

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS REEDY POINT BRIDGE
AND BIDDLES POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

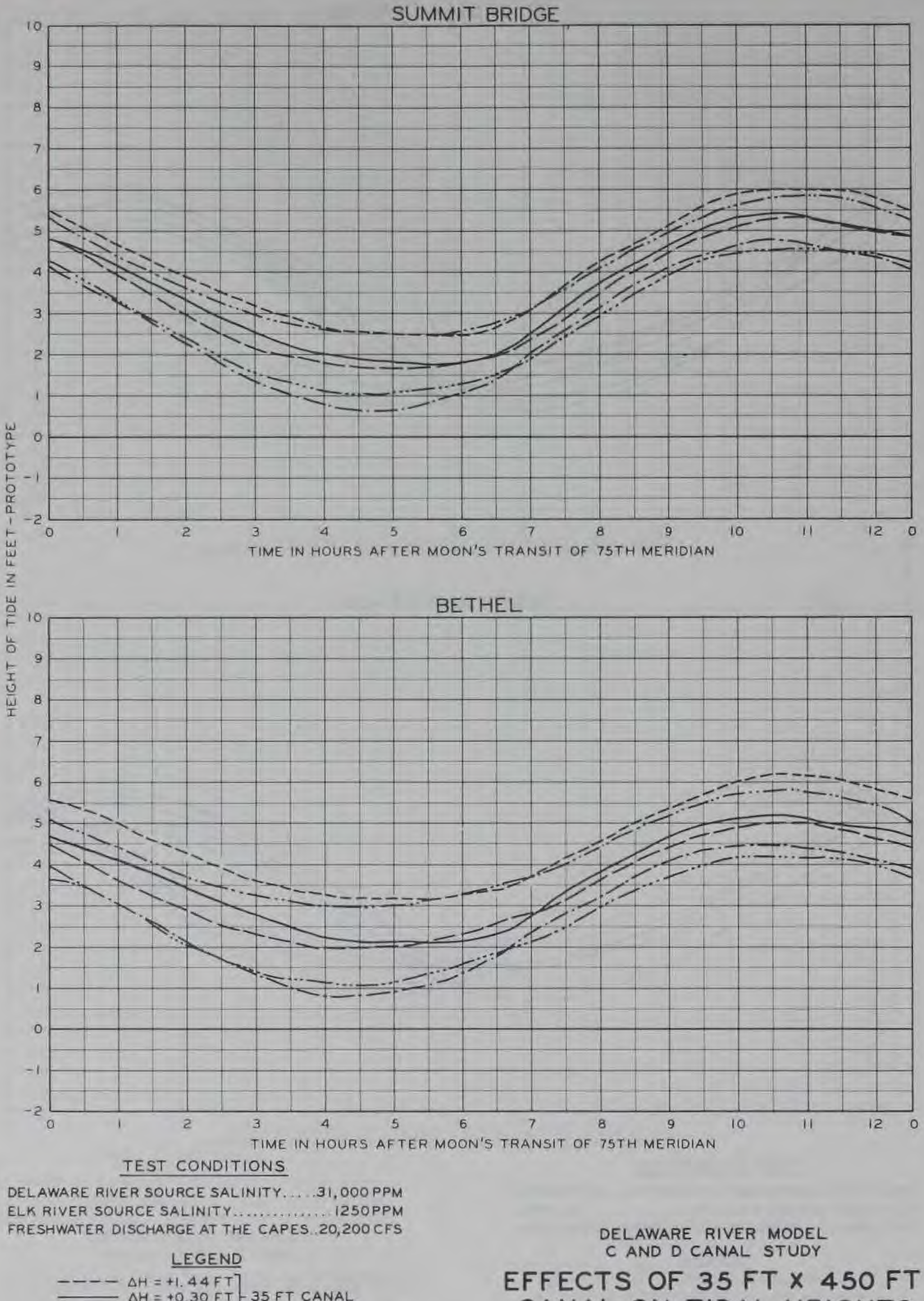
Line	ΔH	Canal
– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
–·—·–	ΔH = -0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
— —	ΔH = +0.28 FT	
—···—	ΔH = -0.91 FT	

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS ST. GEORGES BRIDGE
AND 40 + 000



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

– – – – $\Delta H = +1.44$ FT ⎤
——— $\Delta H = +0.30$ FT ⎬ 35 FT CANAL
–·–·– $\Delta H = -0.85$ FT ⎦
—··— $\Delta H = +1.44$ FT ⎤
— — $\Delta H = +0.28$ FT ⎬ 27 FT CANAL
—···— $\Delta H = -0.91$ FT ⎦

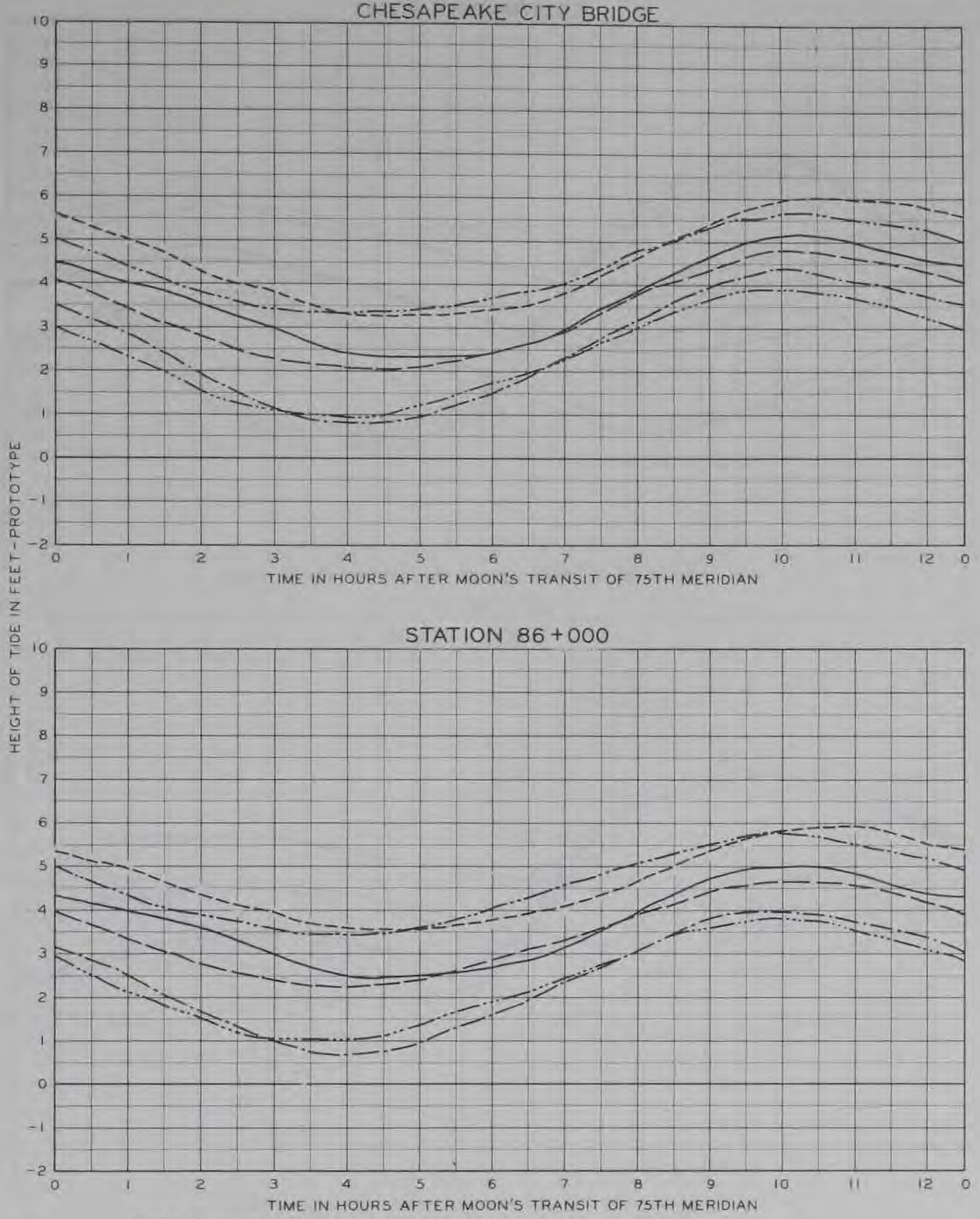
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS SUMMIT BRIDGE
AND BETHEL

PLATE 104



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY . . . .31,000 PPM
ELK RIVER SOURCE SALINITY . . . . 1250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

Line	ΔH	Canal
– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
–·–·–	ΔH = -0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
—···—	ΔH = -0.91 FT	

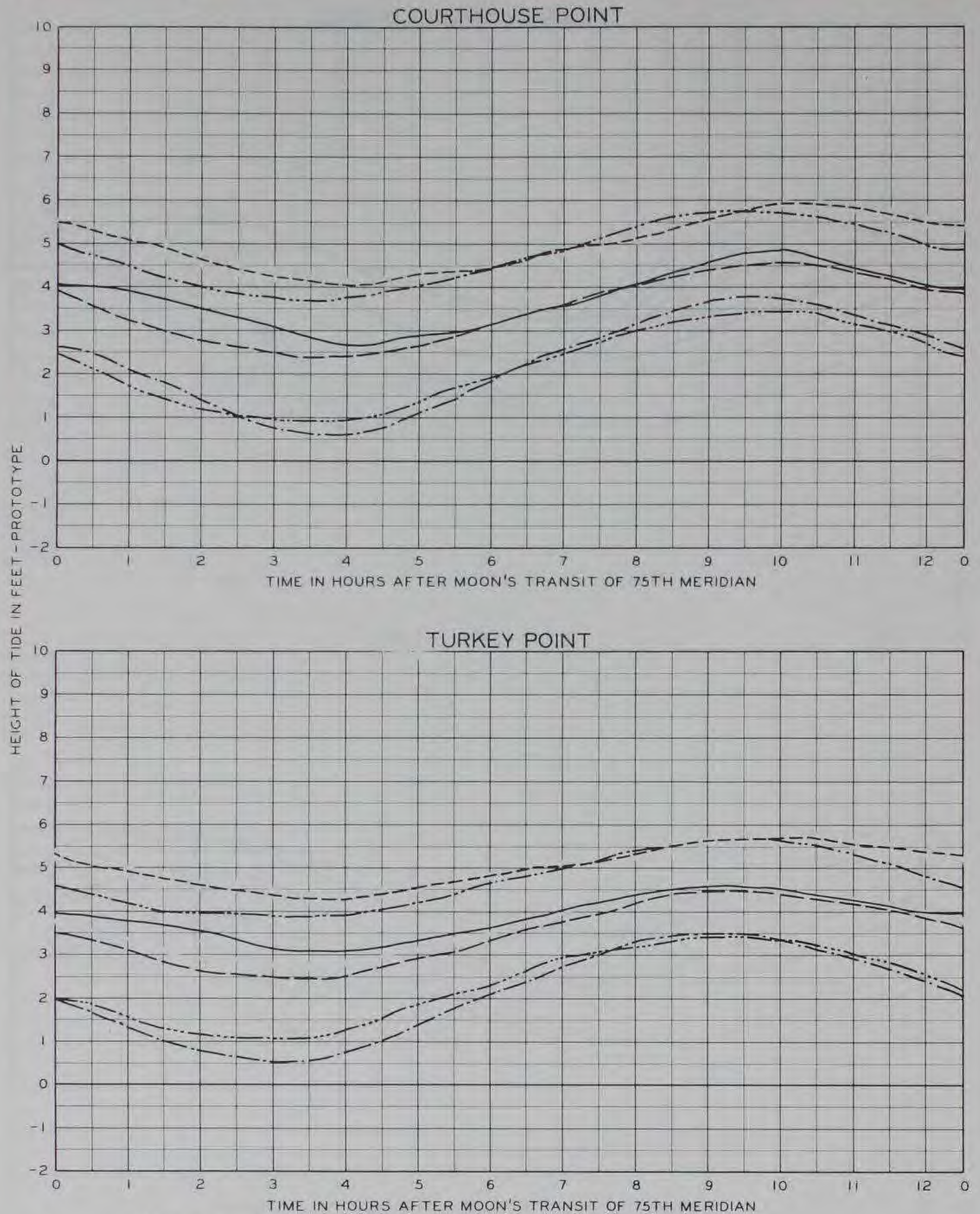
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS CHESAPEAKE CITY
BRIDGE AND 86 +000



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

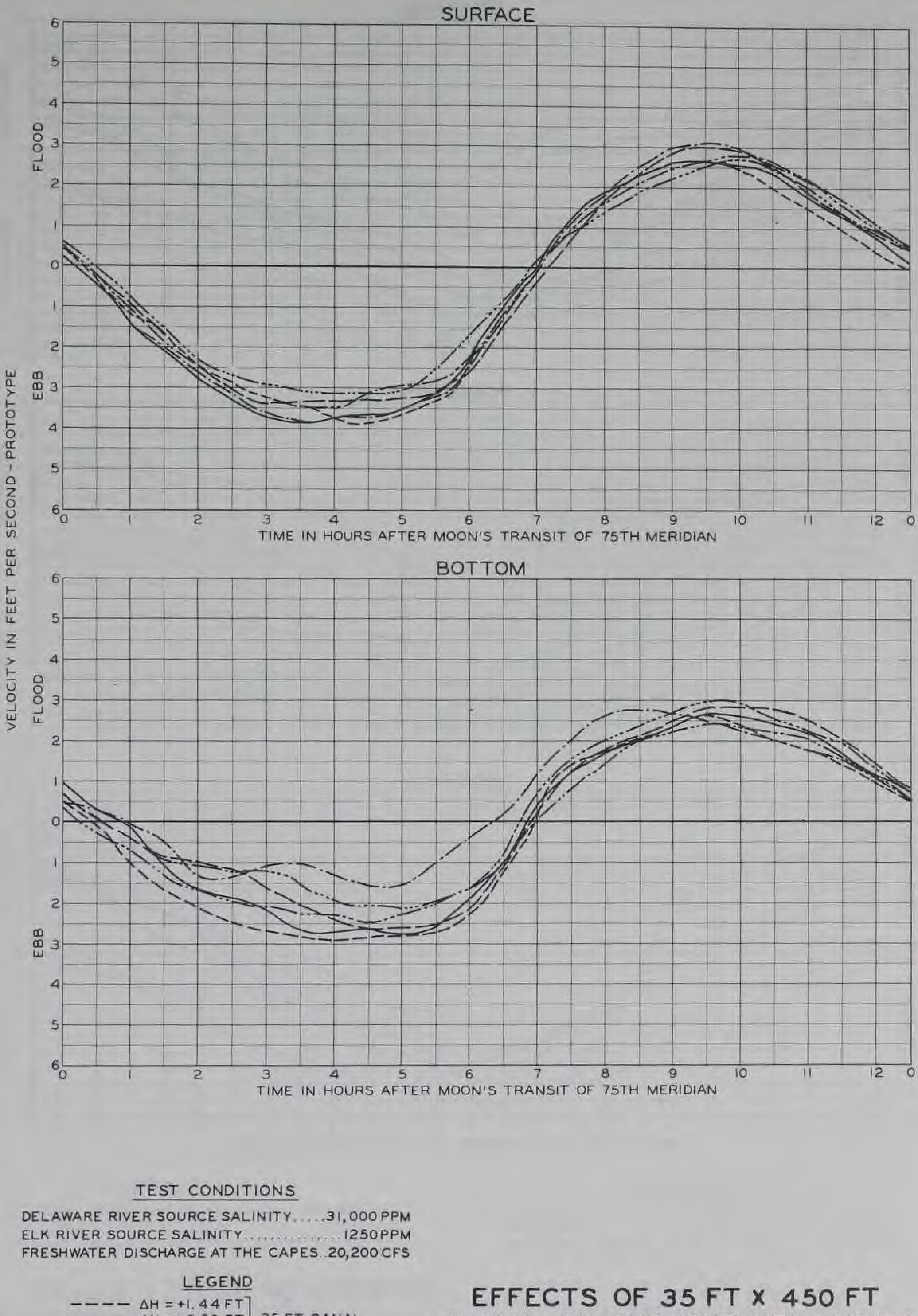
– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
–·–·–	ΔH = -0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
—···—	ΔH = -0.91 FT	

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.
ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON TIDAL HEIGHTS FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATIONS COURTHOUSE POINT
AND TURKEY POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

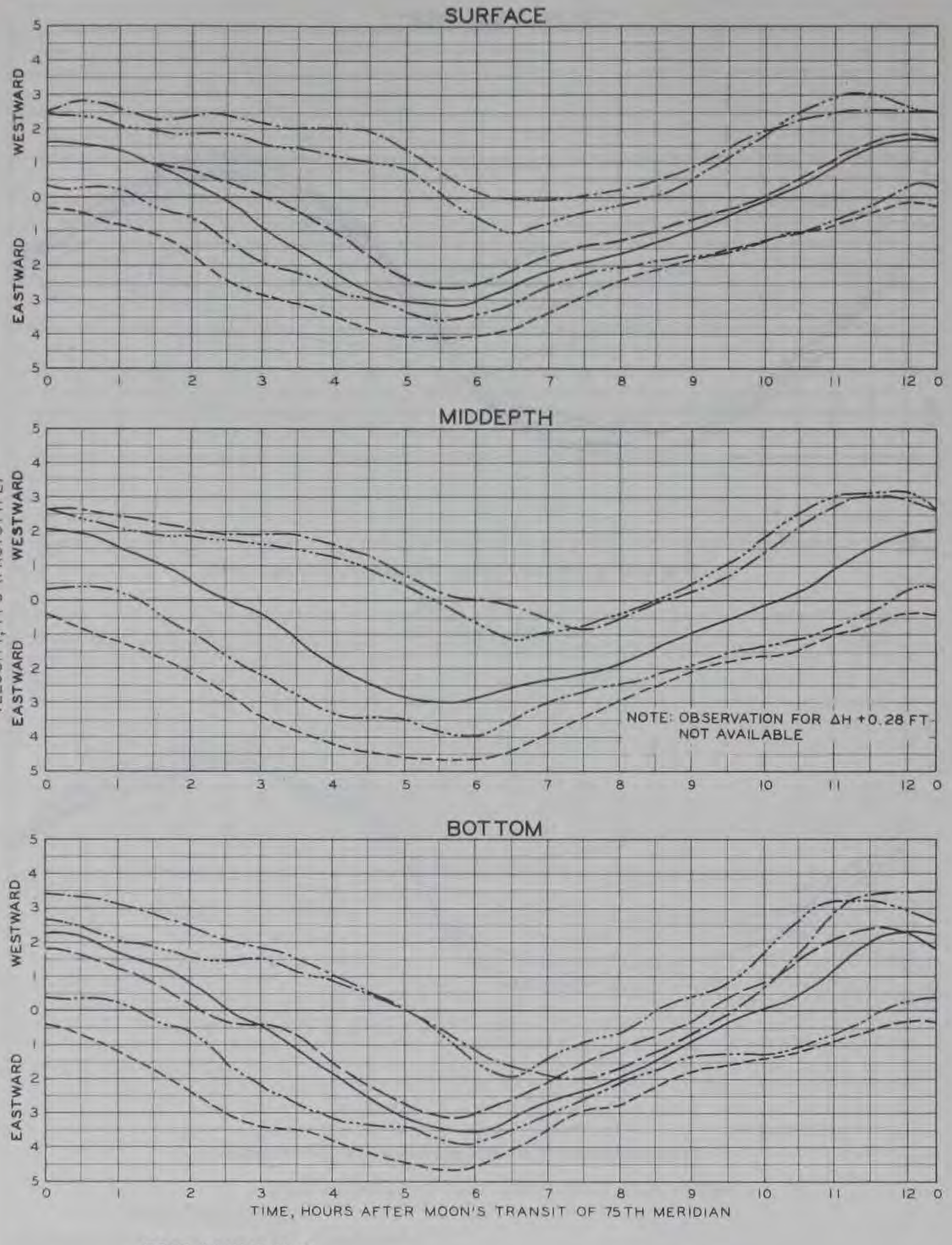
LEGEND

– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
–·–·–	ΔH = −0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
—···—	ΔH = −0.91 FT	

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT x 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION 235



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY................1250 PPM
FRESHWATER DISCHARGE AT THE CAPES .20,200 CFS

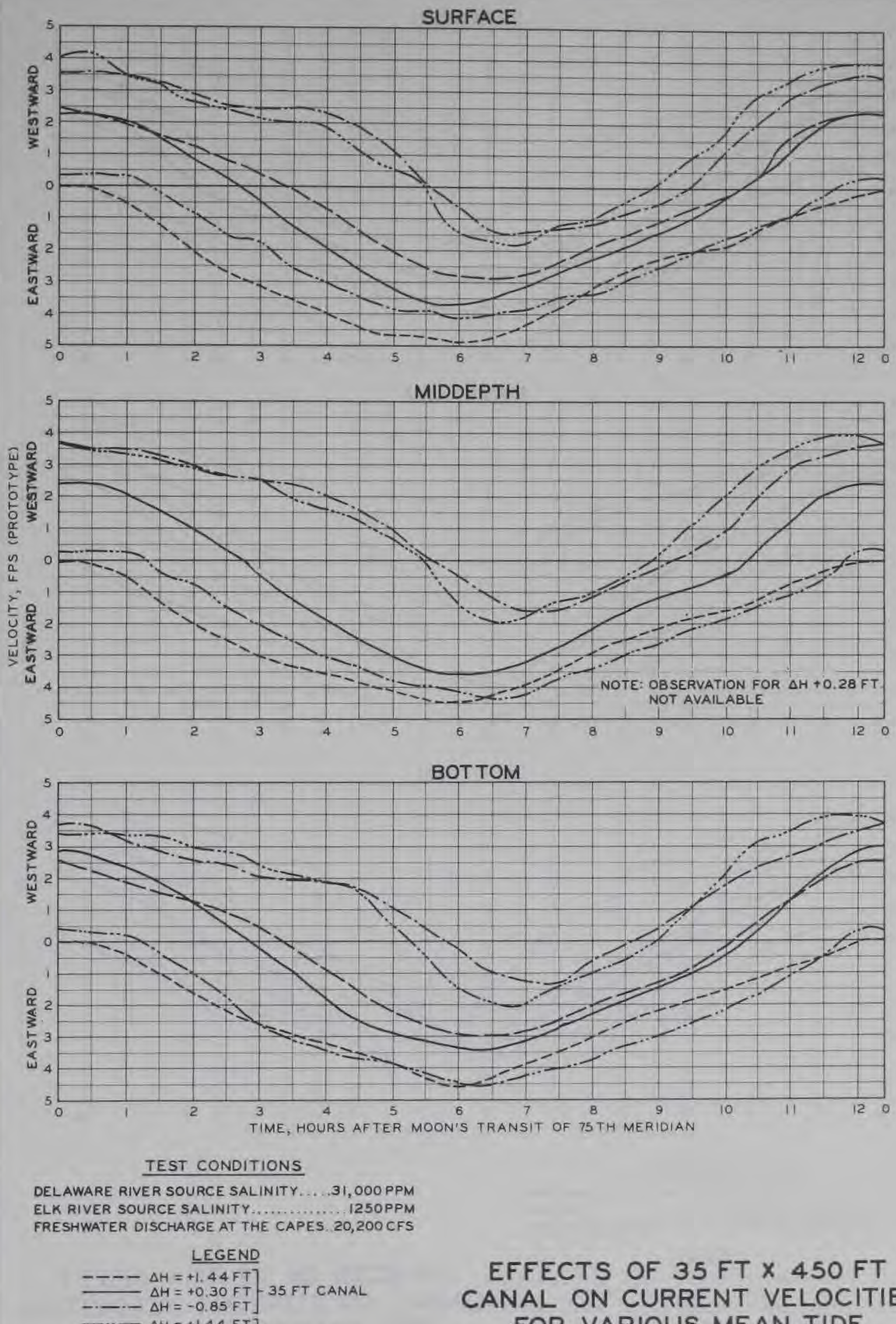
LEGEND

- ---- ΔH = +1.44 FT ⎤
- ——— ΔH = +0.30 FT ⎬ 35 FT CANAL
- —·—·— ΔH = −0.85 FT ⎦
- —··— ΔH = +1.44 FT ⎤
- —— ΔH = +0.28 FT ⎬ 27 FT CANAL
- —···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT X 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION A



TEST CONDITIONS

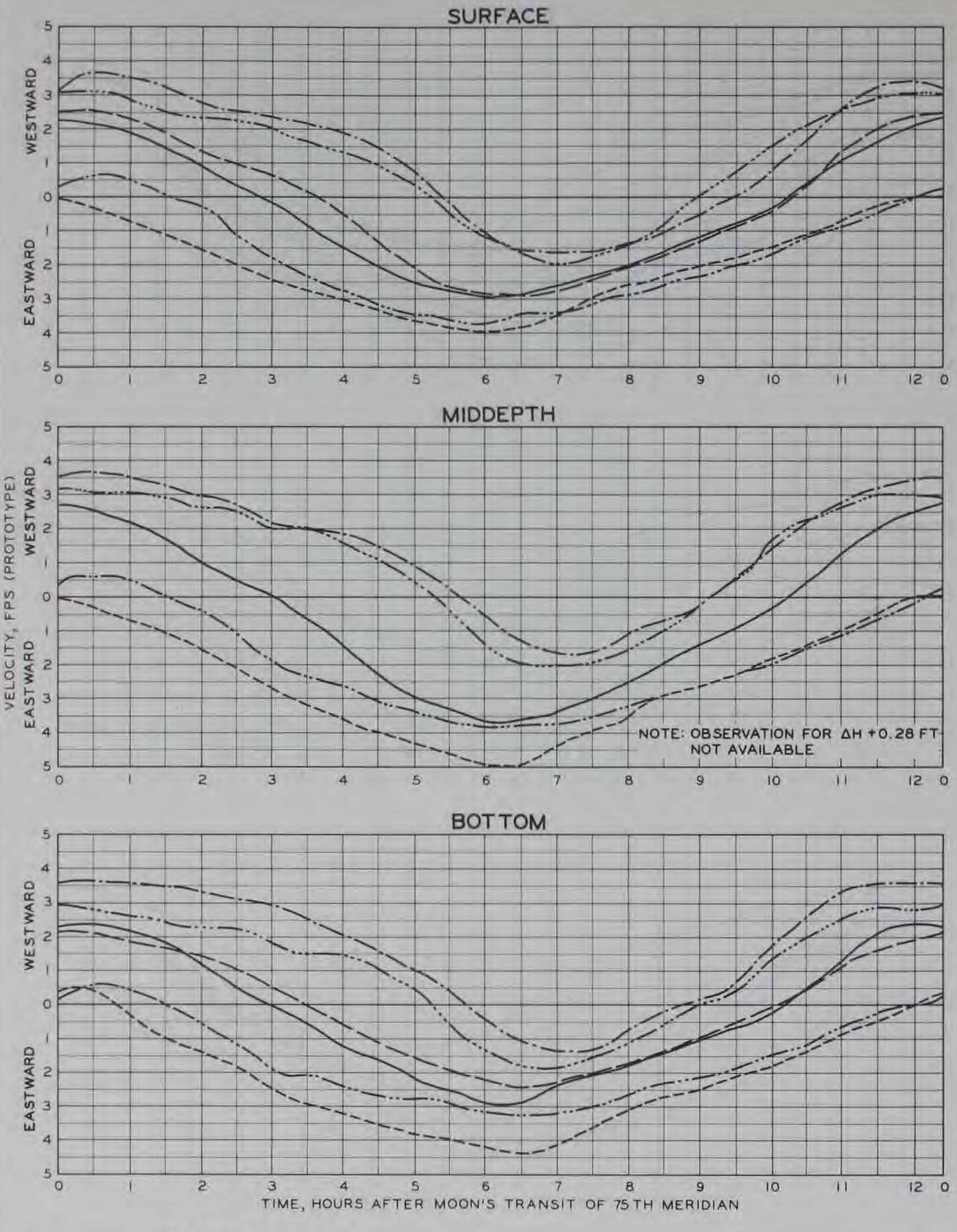
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

- – – – ΔH = +1.44 FT } 35 FT CANAL
- ——— ΔH = +0.30 FT } 35 FT CANAL
- –·—·– ΔH = -0.85 FT } 35 FT CANAL
- —··— ΔH = +1.44 FT } 27 FT CANAL
- — — ΔH = +0.28 FT } 27 FT CANAL
- —···— ΔH = -0.91 FT } 27 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT
MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT X 450 FT
CANAL ON CURRENT VELOCITIES
FOR VARIOUS MEAN TIDE
LEVEL DIFFERENCES
STATION B



TEST CONDITIONS

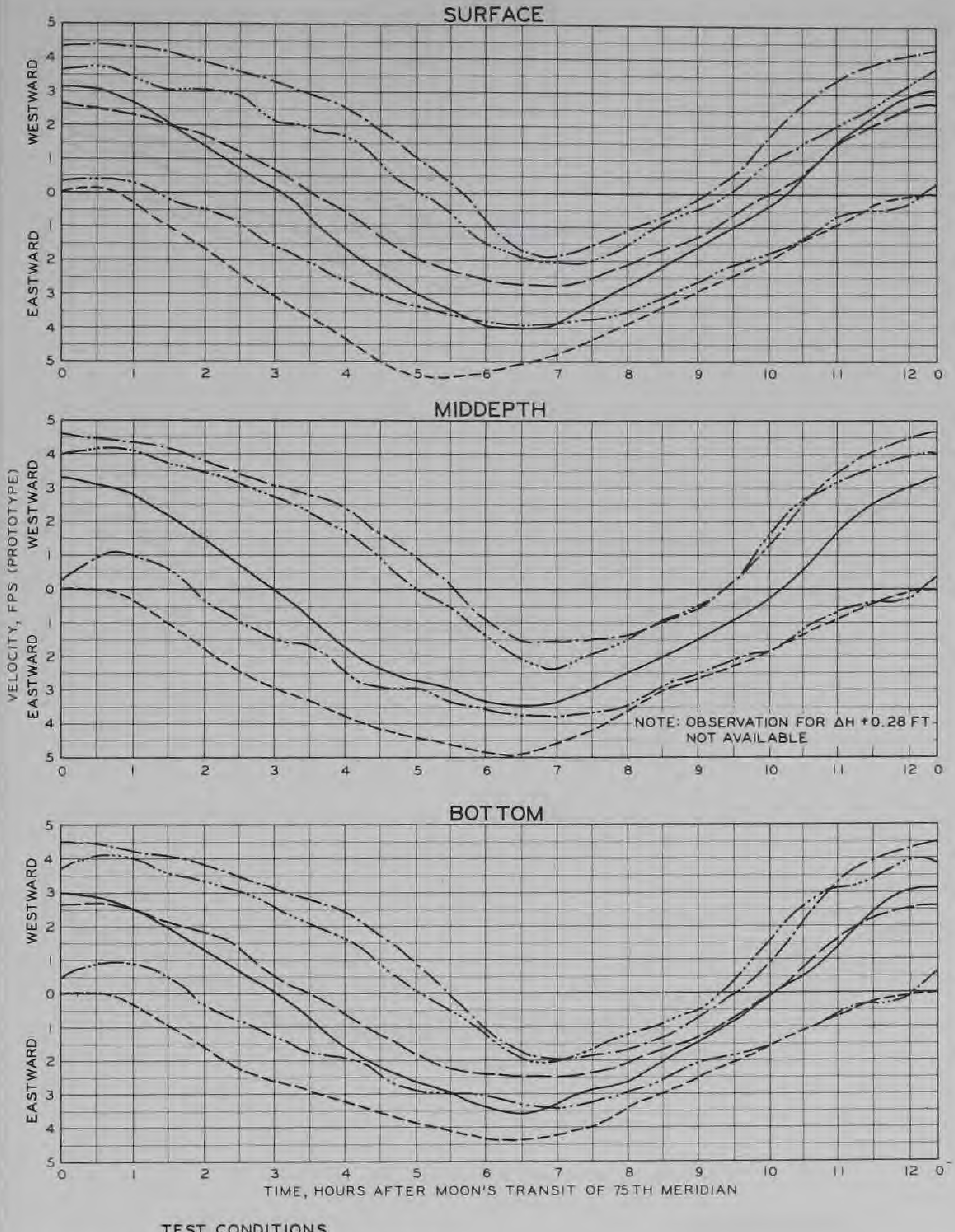
DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

- – – – – ΔH = +1.44 FT ⎤
- ——— ΔH = +0.30 FT ⎬ 35 FT CANAL
- –·–·– ΔH = −0.85 FT ⎦
- —··— ΔH = +1.44 FT ⎤
- —— — ΔH = +0.28 FT ⎬ 27 FT CANAL
- —···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT X 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES
STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

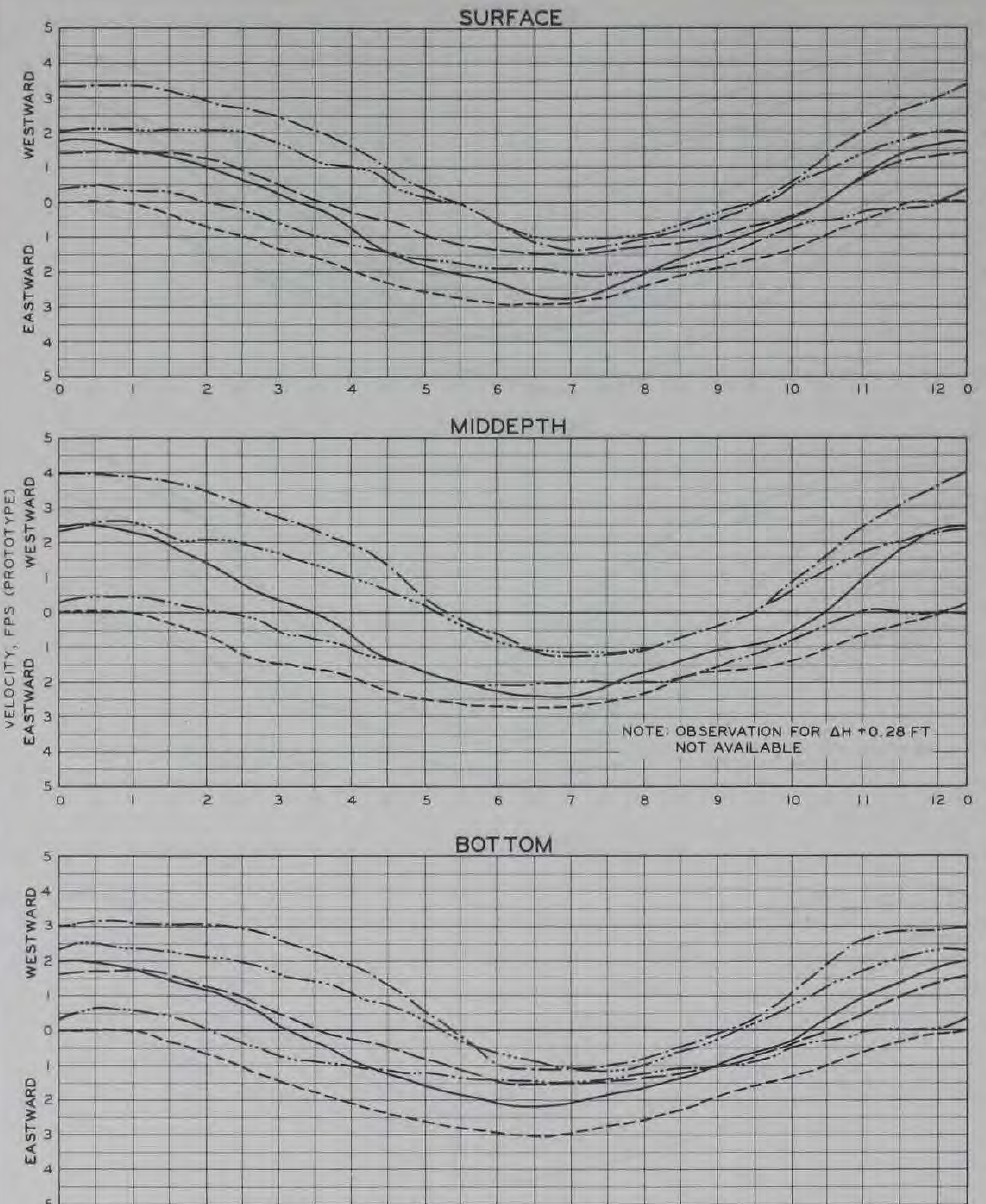
LEGEND

– – – –	ΔH = +1.44 FT	35 FT CANAL
————	ΔH = +0.30 FT	
–·–·–	ΔH = −0.85 FT	
–··–··	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
–···–	ΔH = −0.91 FT	

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT X 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION D



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1250PPM
FRESHWATER DISCHARGE AT THE CAPES. 20,200 CFS

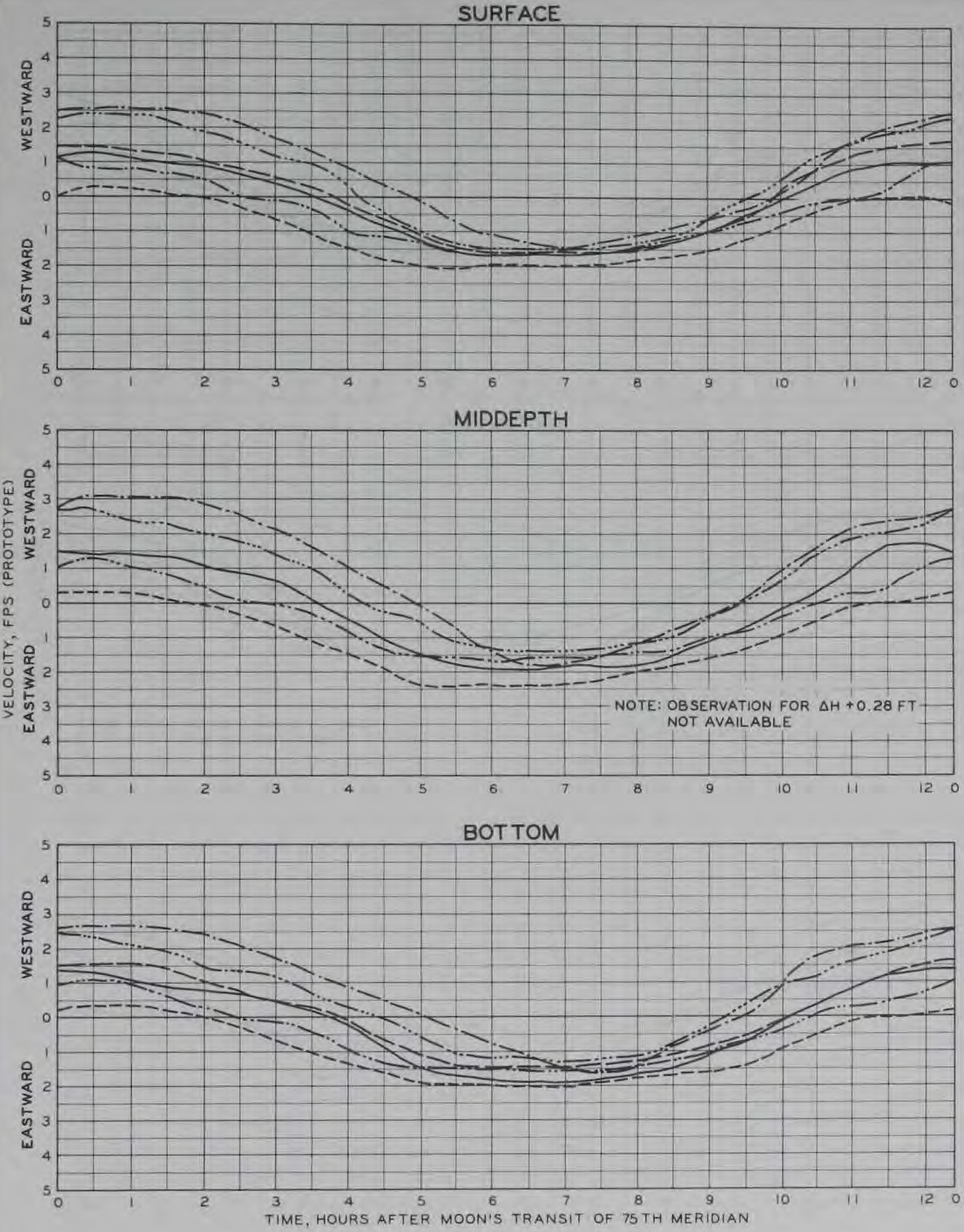
LEGEND

Line	ΔH	Canal
----	ΔH = +1.44 FT	35 FT CANAL
——	ΔH = +0.30 FT	
-·-·-	ΔH = -0.85 FT	
—··—	ΔH = +1.44 FT	27 FT CANAL
— —	ΔH = +0.28 FT	
—···—	ΔH = -0.91 FT	

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT x 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION E



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

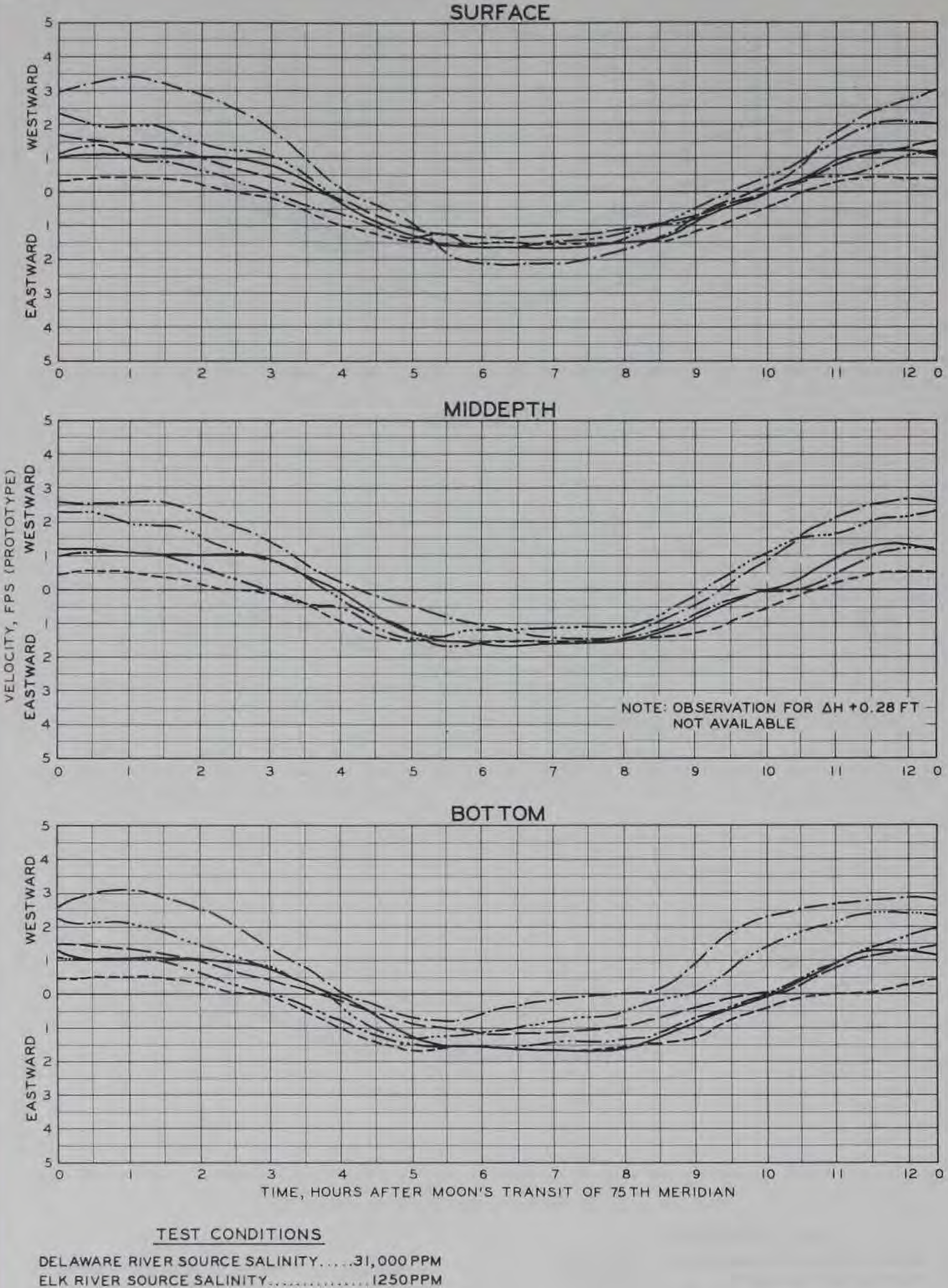
LEGEND

---- ΔH = +1.44 FT ⎤
—— ΔH = +0.30 FT ⎬ 35 FT CANAL
–·–·– ΔH = -0.85 FT ⎦
—··— ΔH = +1.44 FT ⎤
— — ΔH = +0.28 FT ⎬ 27 FT CANAL
—···— ΔH = -0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT X 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION F



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

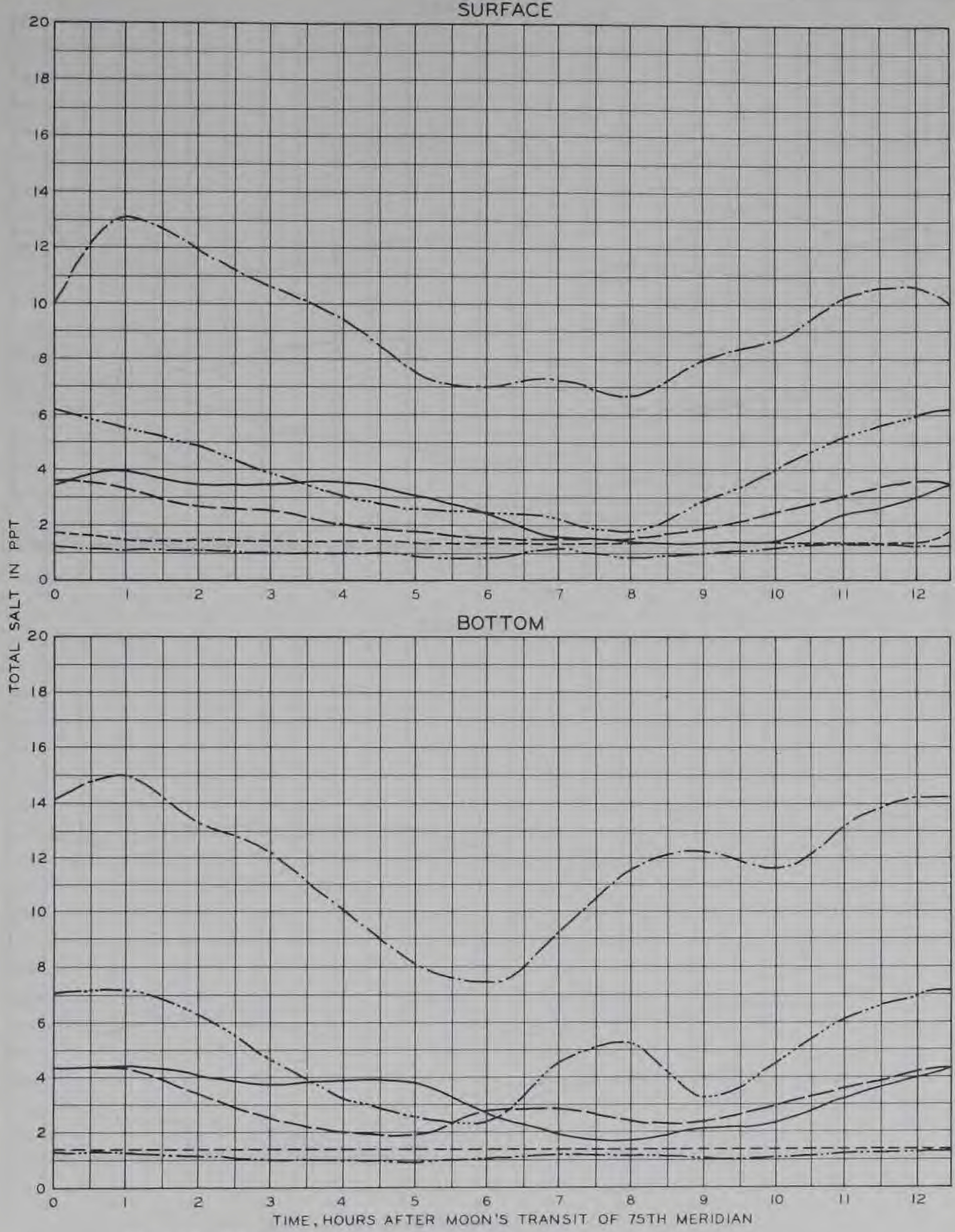
LEGEND

---- ΔH = +1.44 FT ⎤
—— ΔH = +0.30 FT ⎬ 35 FT CANAL
—·—·— ΔH = −0.85 FT ⎦
—··— ΔH = +1.44 FT ⎤
—— ΔH = +0.28 FT ⎬ 27 FT CANAL
—···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF 35 FT x 450 FT CANAL ON CURRENT VELOCITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION G



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

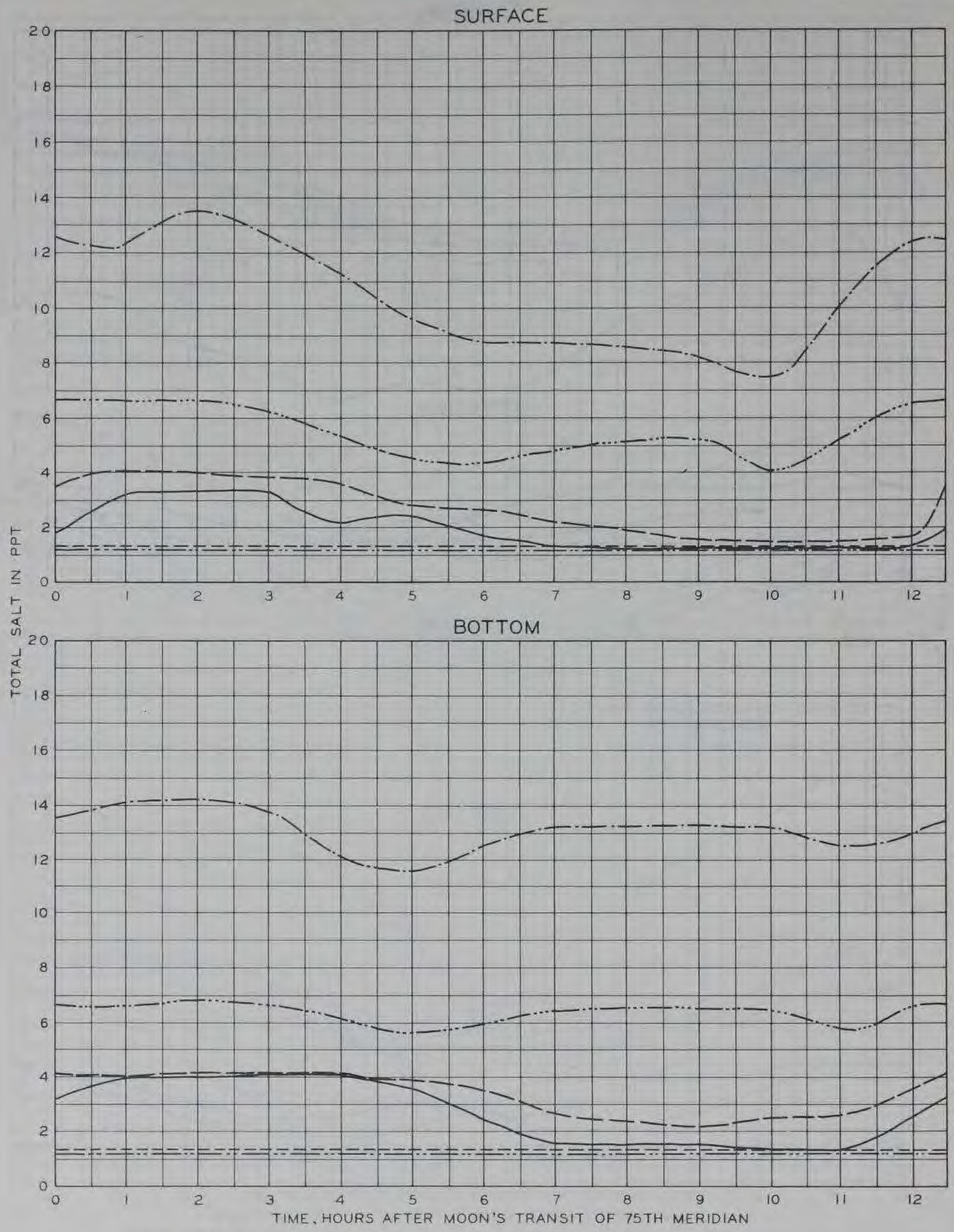
ΔH = +1.44 FT
ΔH = +0.30 FT } 35 FT CANAL
ΔH = −0.85 FT
ΔH = +1.44 FT
ΔH = +0.28 FT } 27 FT CANAL
ΔH = −0.91 FT

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON SALINITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION 2



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

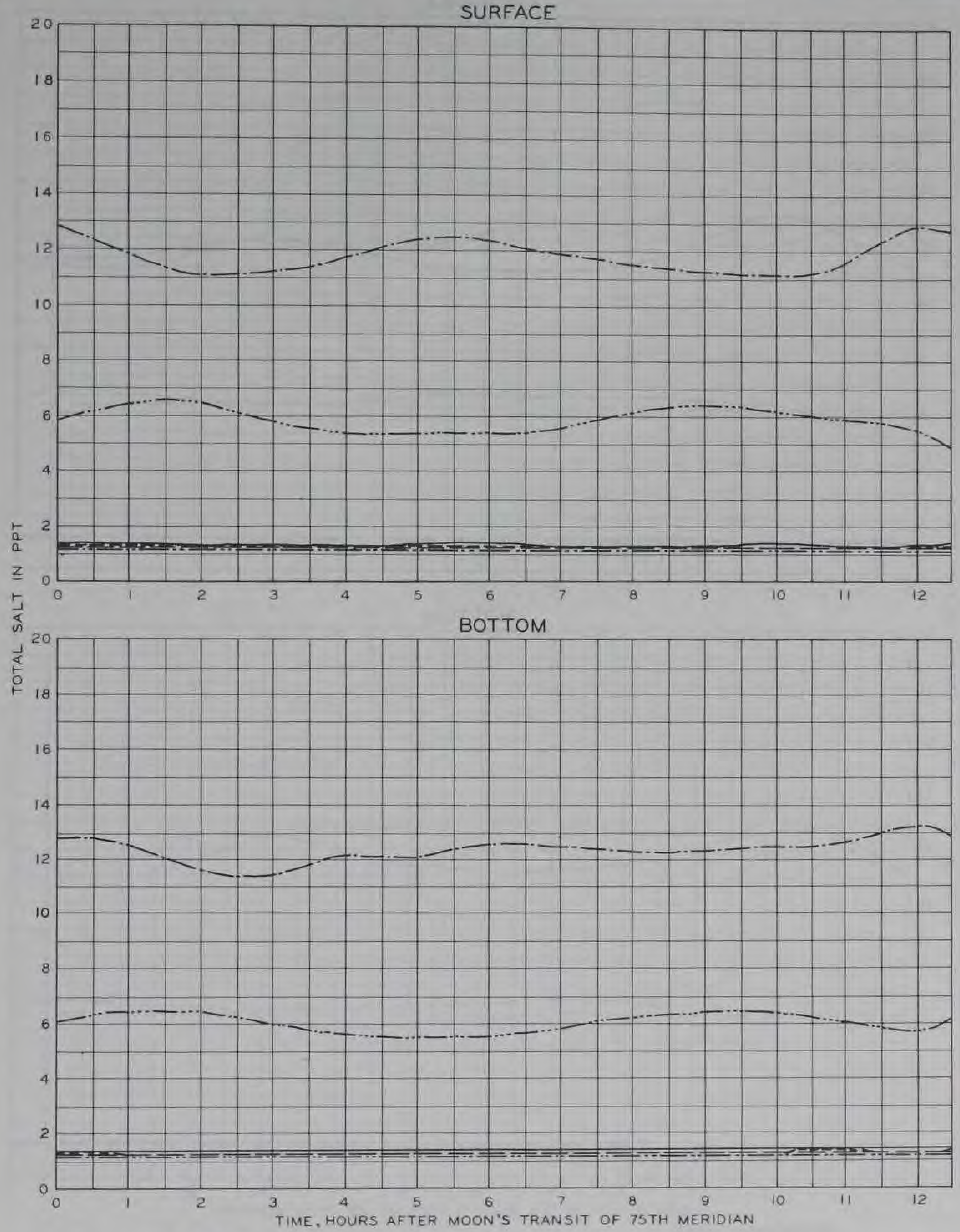
Line	ΔH	Canal
– – – –	ΔH = +1.44 FT	35 FT CANAL
———	ΔH = +0.30 FT	
—·—·—	ΔH = −0.85 FT	
—··—··—	ΔH = +1.44 FT	27 FT CANAL
—— ——	ΔH = +0.28 FT	
—···—···—	ΔH = −0.91 FT	

NOTE: ΔH = MTL AT COURTHOUSE POINT
MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON SALINITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

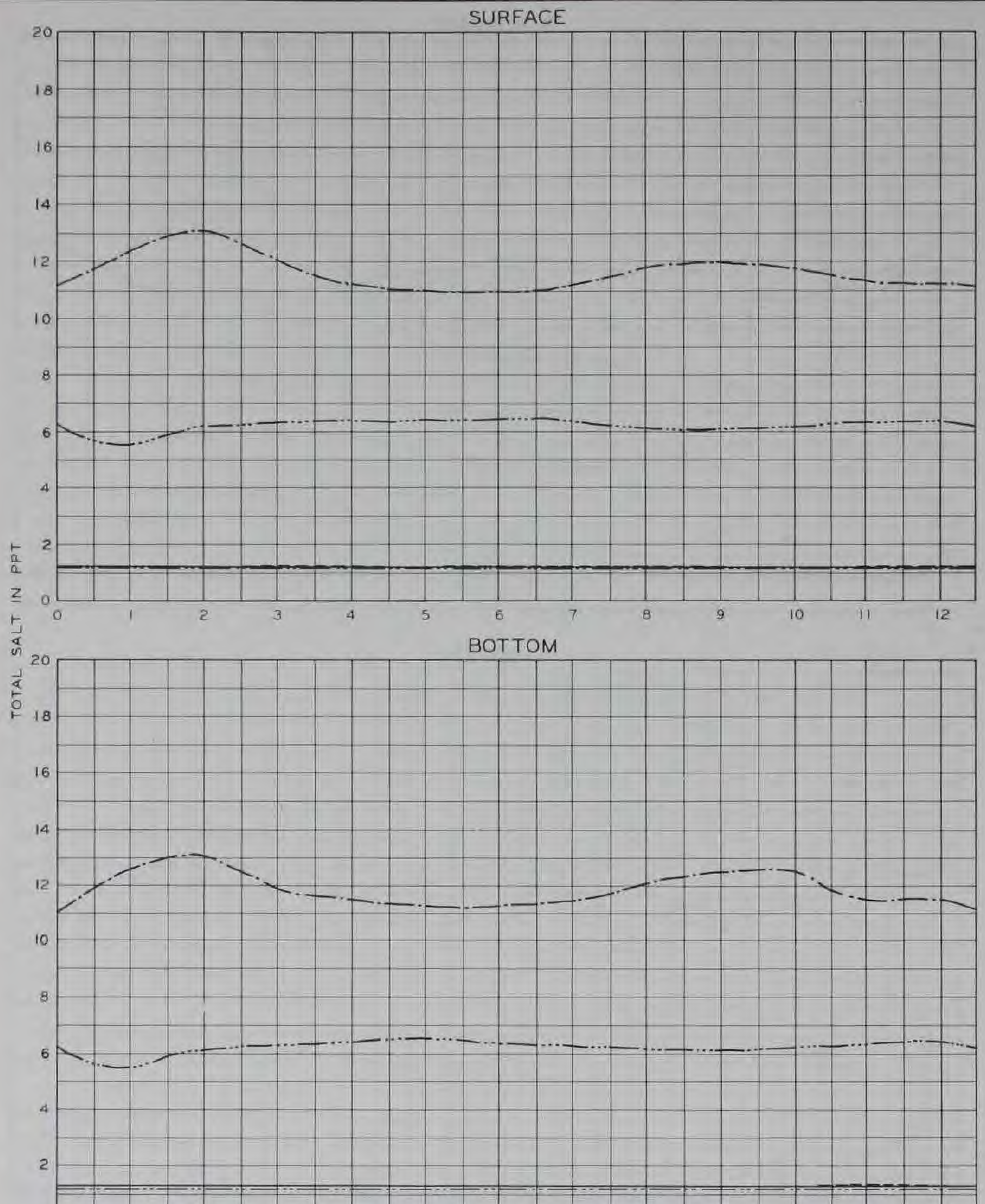
- – – – ΔH = +1.44 FT ⎤
- ——— ΔH = +0.30 FT ⎬ 35 FT CANAL
- —·—·— ΔH = −0.85 FT ⎦
- —··— ΔH = +1.44 FT ⎤
- —— —— ΔH = +0.28 FT ⎬ 27 FT CANAL
- —···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON SALINITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

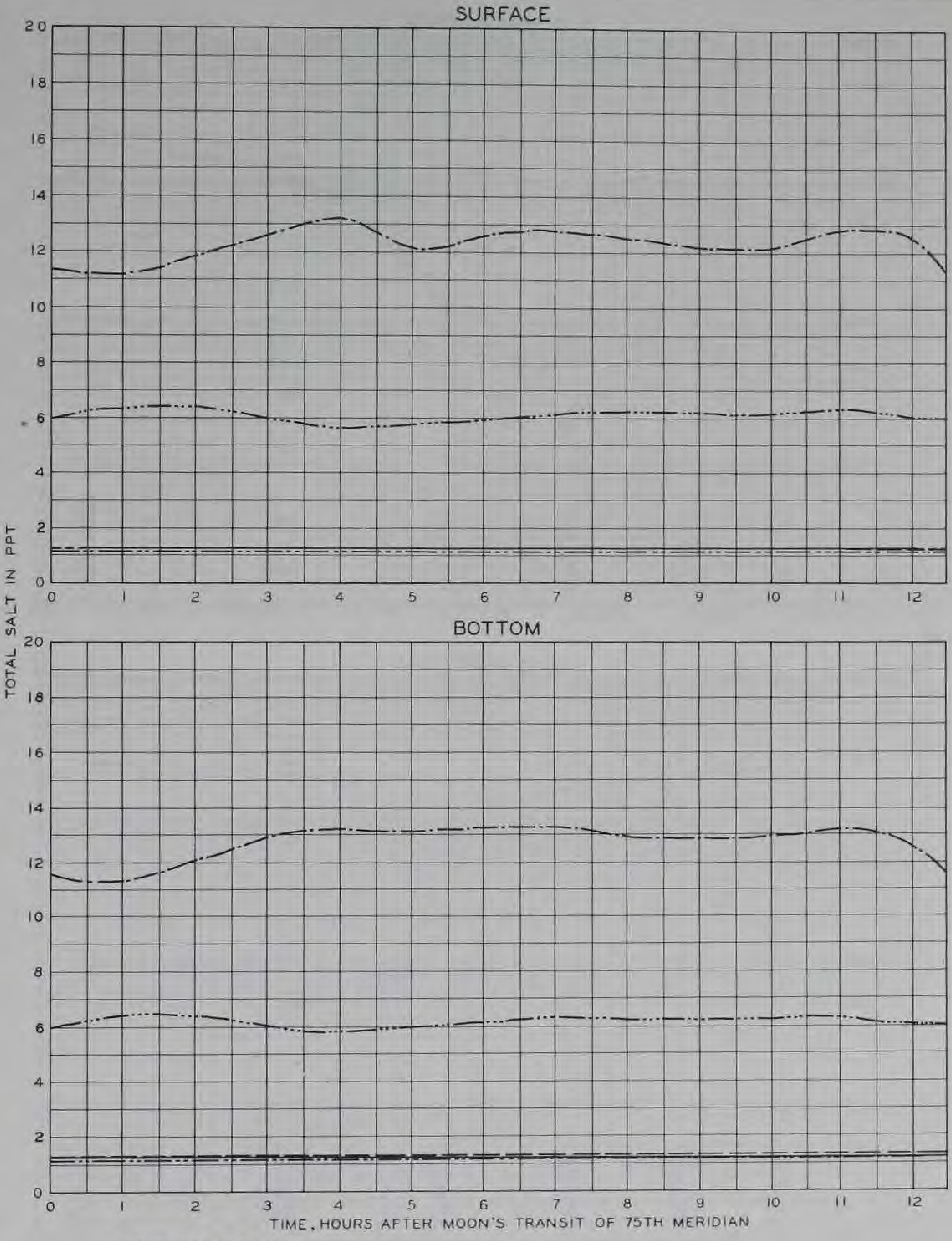
- – – – – ΔH = +1.44 FT ⎤
- ——— ΔH = +0.30 FT ⎬ 35 FT CANAL
- –·–·– ΔH = −0.85 FT ⎦
- —··— ΔH = +1.44 FT ⎤
- —— —— ΔH = +0.28 FT ⎬ 27 FT CANAL
- —···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.
ΔH = +0.28 OBSERVATIONS FOR 27 FT × 250 FT CANAL NOT AVAILABLE FOR STATION D.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON SALINITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION D



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1250 PPM
FRESHWATER DISCHARGE AT THE CAPES..20,200 CFS

LEGEND

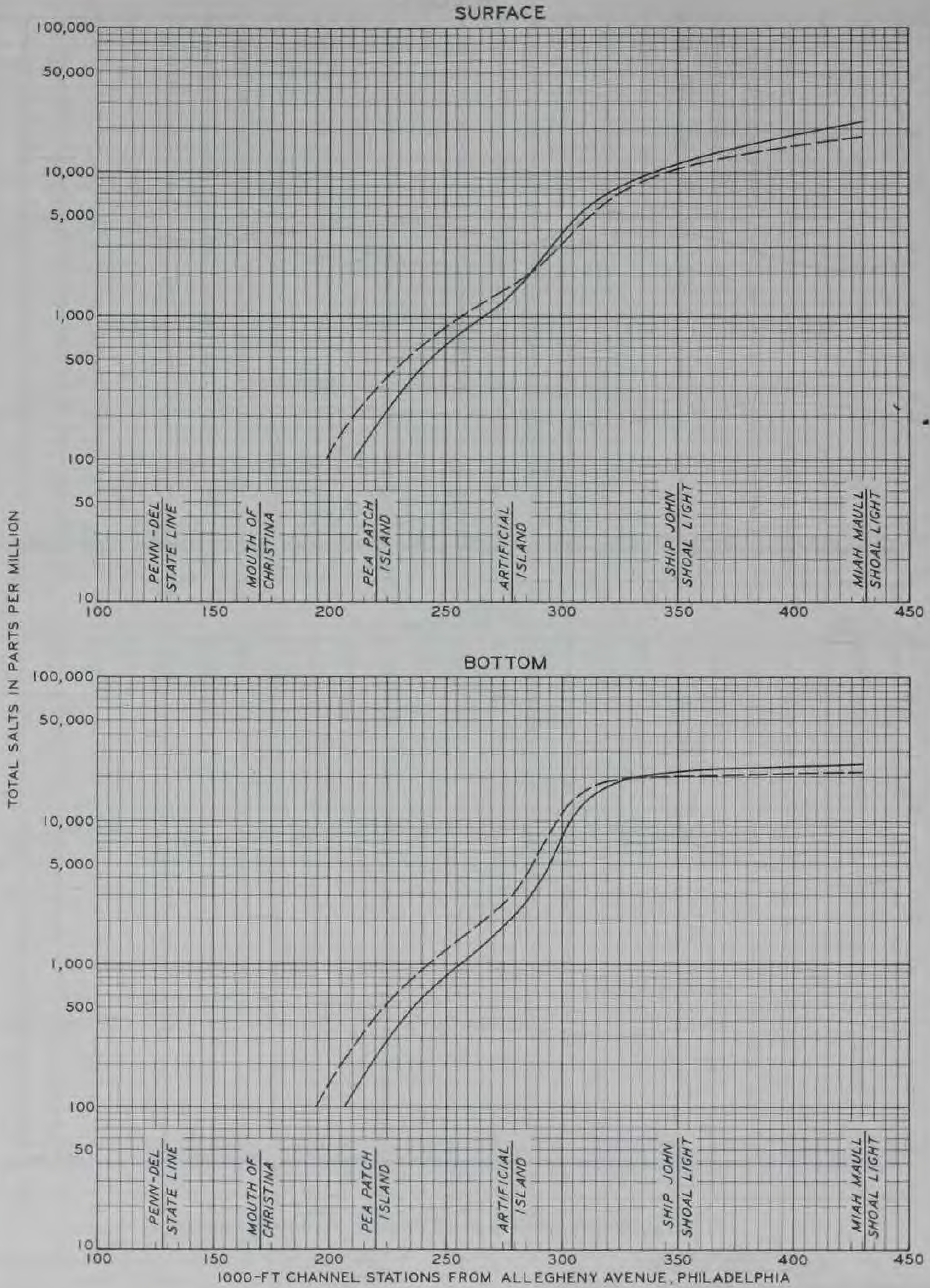
---- ΔH = +1.44 FT ⎤
——— ΔH = +0.30 FT ⎬ 35 FT CANAL
—·—·— ΔH = −0.85 FT ⎦
—··— ΔH = +1.44 FT ⎤
—— —— ΔH = +0.28 FT ⎬ 27 FT CANAL
—···— ΔH = −0.91 FT ⎦

NOTE: ΔH = MTL AT COURTHOUSE POINT
MINUS MTL AT REEDY POINT JETTY.

DELAWARE RIVER MODEL
C AND D CANAL STUDY

EFFECTS OF 35 FT X 450 FT CANAL ON SALINITIES FOR VARIOUS MEAN TIDE LEVEL DIFFERENCES

STATION E



LEGEND

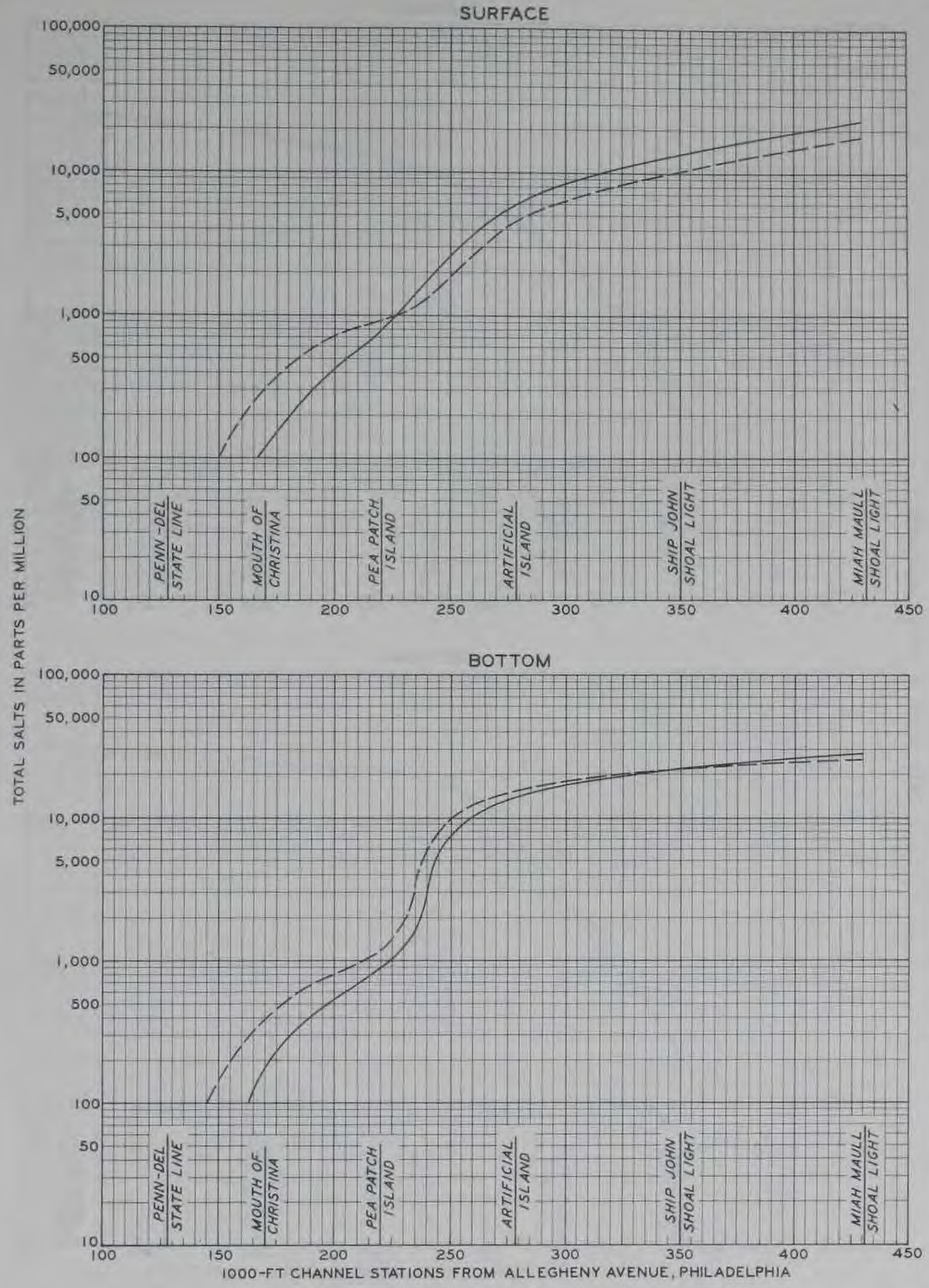
—— ΔH = +1.44 FT, 27 FT x 250 FT CANAL
– – – – ΔH = +1.44 FT, 35 FT x 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES ..... 20,200 CFS

EFFECTS OF 35 FT x 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = +1.44 FT
HIGH-WATER SLACK
SURFACE AND BOTTOM DEPTH



LEGEND

——— ΔH = +1.44 FT, 27 FT × 250 FT CANAL

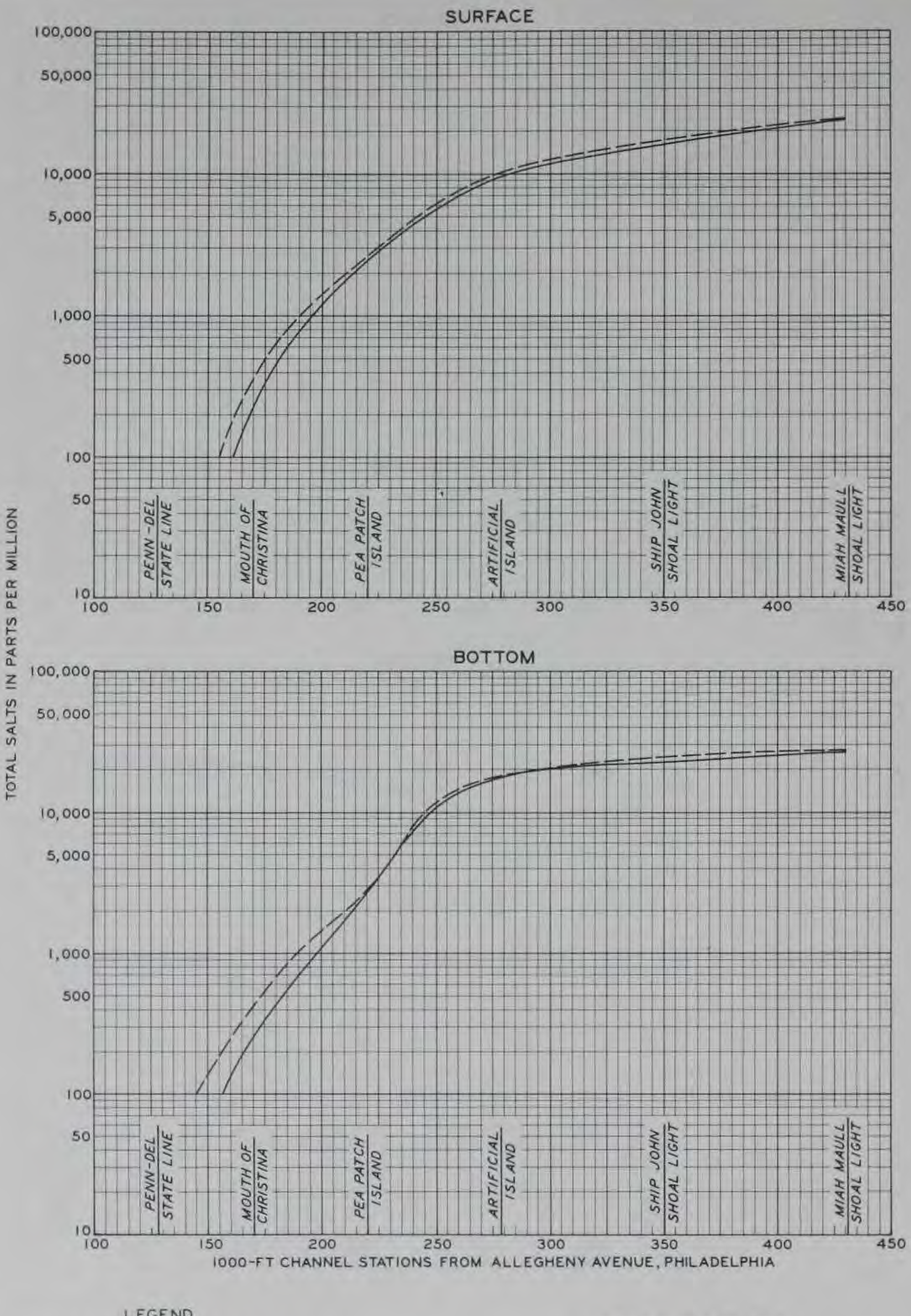
- - - - ΔH = +1.44 FT, 35 FT × 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY	31,000 PPM
ELK RIVER SOURCE SALINITY	1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES	20,200 CFS

EFFECTS OF 35 FT × 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = +1.44 FT
LOW-WATER SLACK
SURFACE AND BOTTOM DEPTH



LEGEND

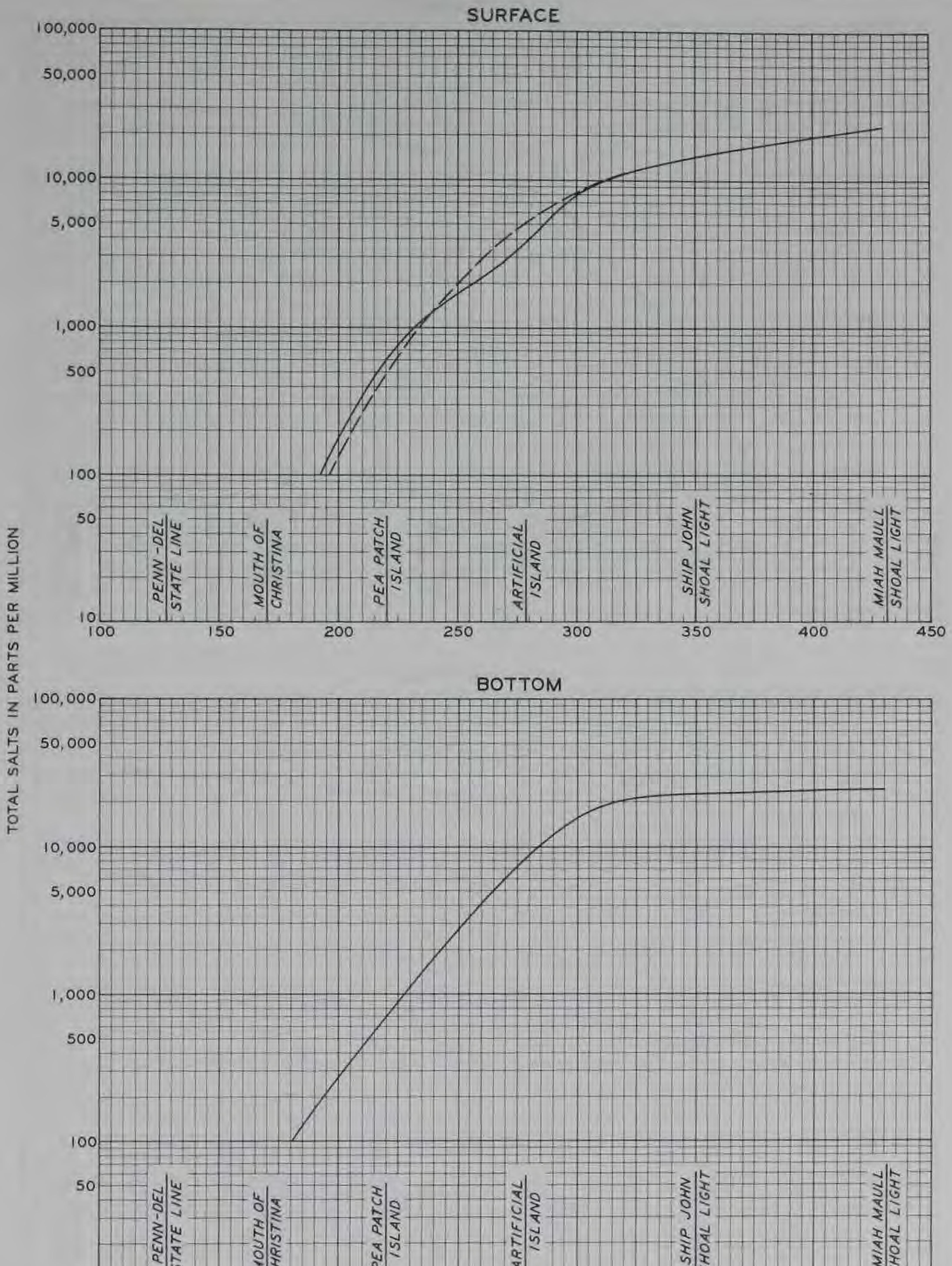
——— ΔH = +0.28 FT, 27 FT x 250 FT CANAL
– – – – ΔH = +0.30 FT, 35 FT x 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY .... 31,000 PPM
ELK RIVER SOURCE SALINITY .... 1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES ..... 20,200 CFS

EFFECTS OF 35 FT x 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = +0.30 FT AND ΔH = +0.28 FT
HIGH-WATER SLACK
SURFACE AND BOTTOM DEPTH



LEGEND

——— ΔH = +0.28 FT, 27 FT x 250 FT CANAL

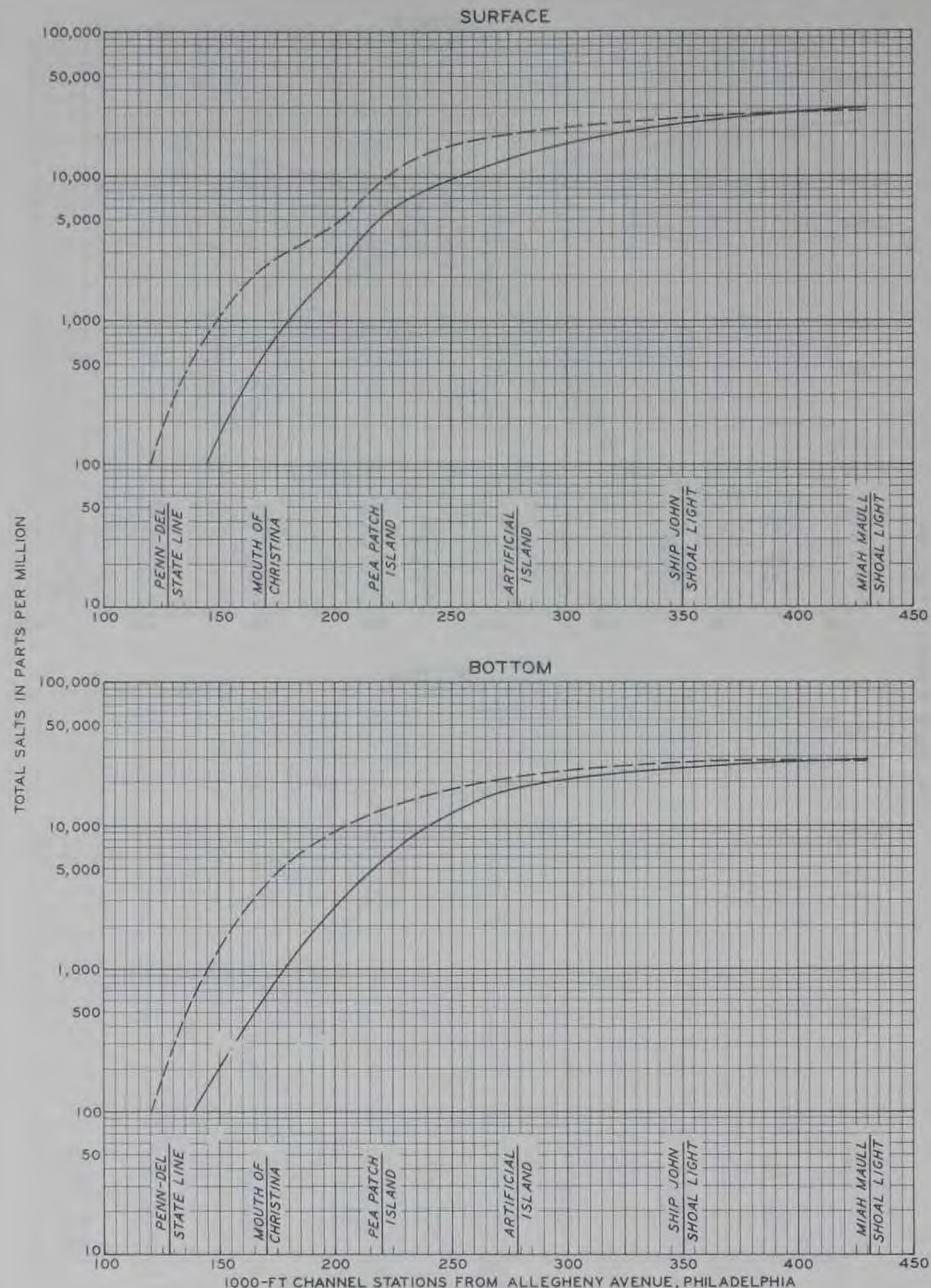
– – – – ΔH = +0.30 FT, 35 FT x 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY	31,000 PPM
ELK RIVER SOURCE SALINITY	1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES	20,200 CFS

EFFECTS OF 35 FT x 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = +0.30 FT AND ΔH = +0.28 FT
LOW-WATER SLACK
SURFACE AND BOTTOM DEPTH



LEGEND

——— ΔH = -0.91 FT, 27 FT x 250 FT CANAL

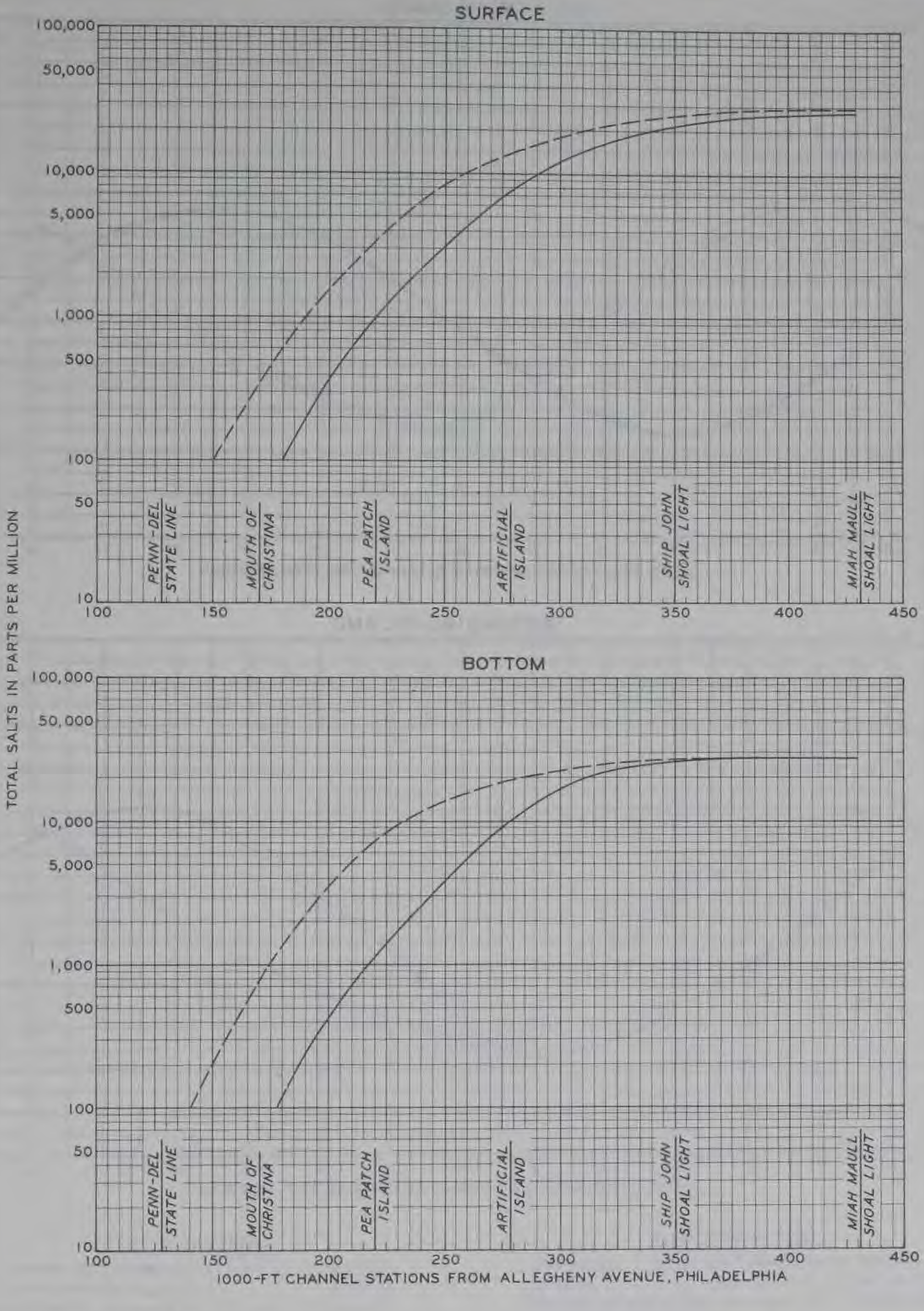
– – – – ΔH = -0.85 FT, 35 FT x 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY ········ 31,000 PPM
ELK RIVER SOURCE SALINITY ················ 1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES ···· 20,200 CFS

EFFECTS OF 35 FT x 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = -0.91 FT AND ΔH = -0.85 FT
HIGH-WATER SLACK
SURFACE AND BOTTOM DEPTH



LEGEND

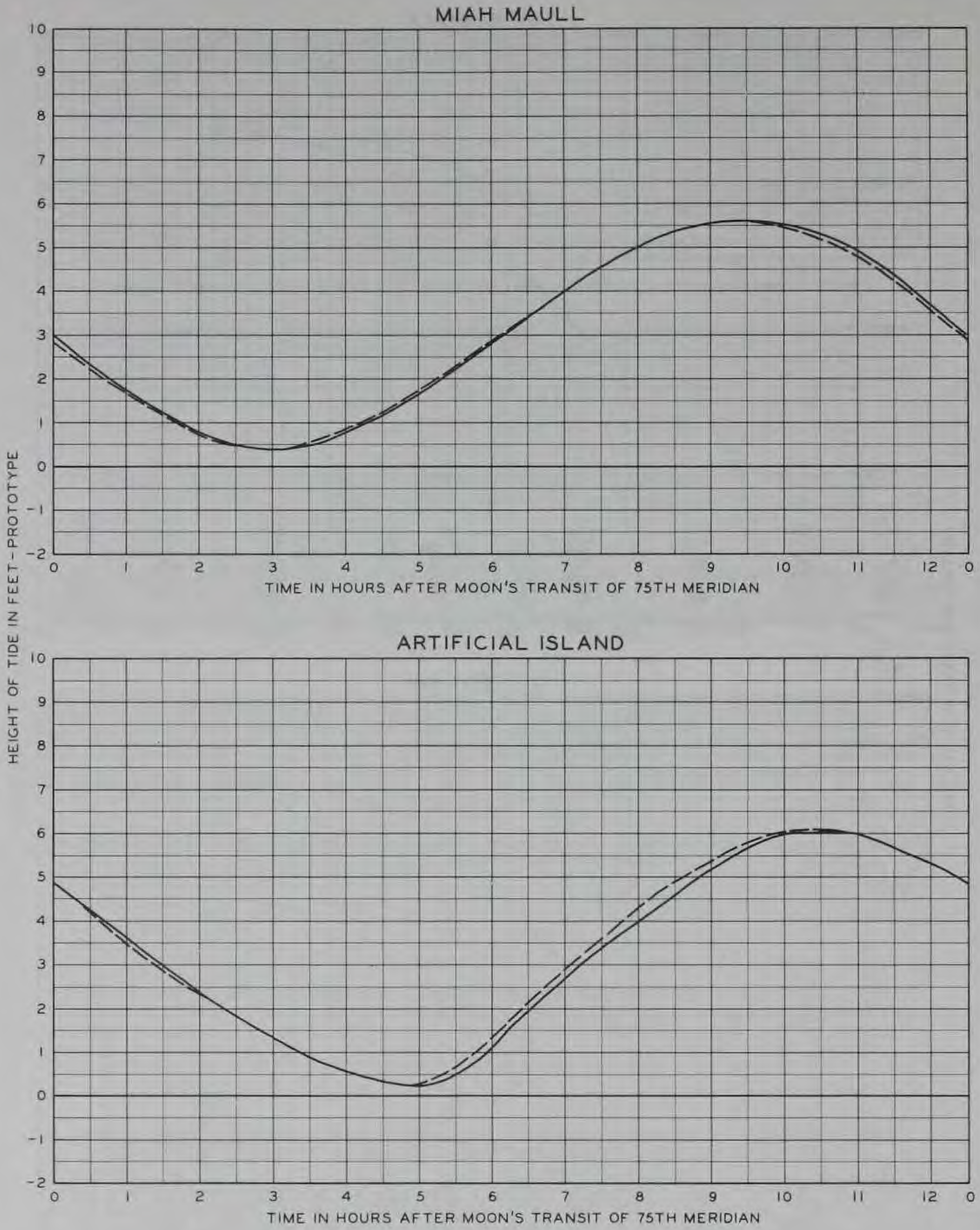
——— ΔH = −0.91 FT, 27 FT × 250 FT CANAL
– – – – ΔH = −0.85 FT, 35 FT × 450 FT CANAL

TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY	31,000 PPM
ELK RIVER SOURCE SALINITY	1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES	20,200 CFS

EFFECTS OF 35 FT x 450 FT CANAL ON SALINITIES - DELAWARE RIVER

ΔH = −0.91 FT AND ΔH = −0.85 FT
LOW-WATER SLACK
SURFACE AND BOTTOM DEPTH



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

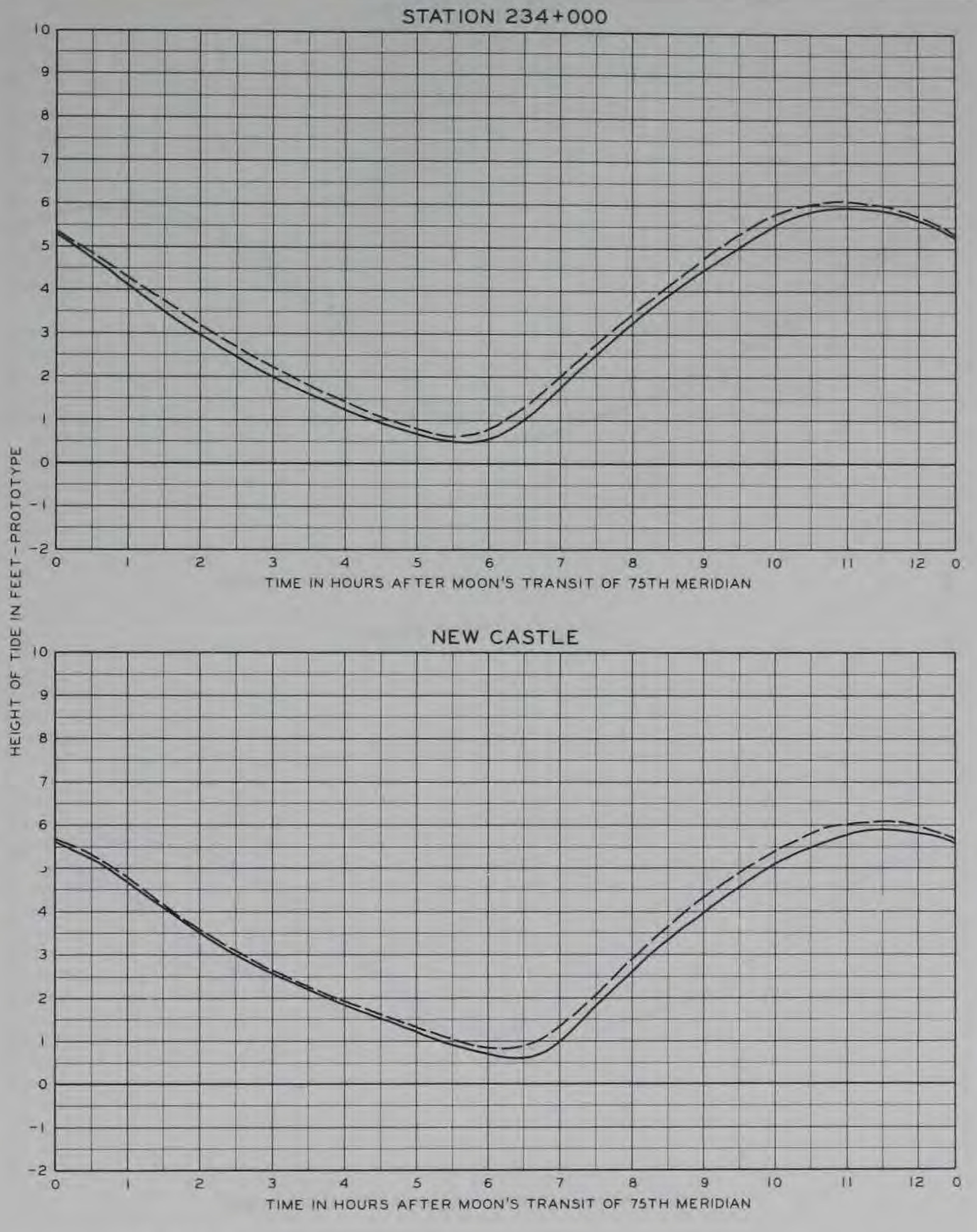
- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
———— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS MIAH MAULL AND ARTIFICIAL ISLAND



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

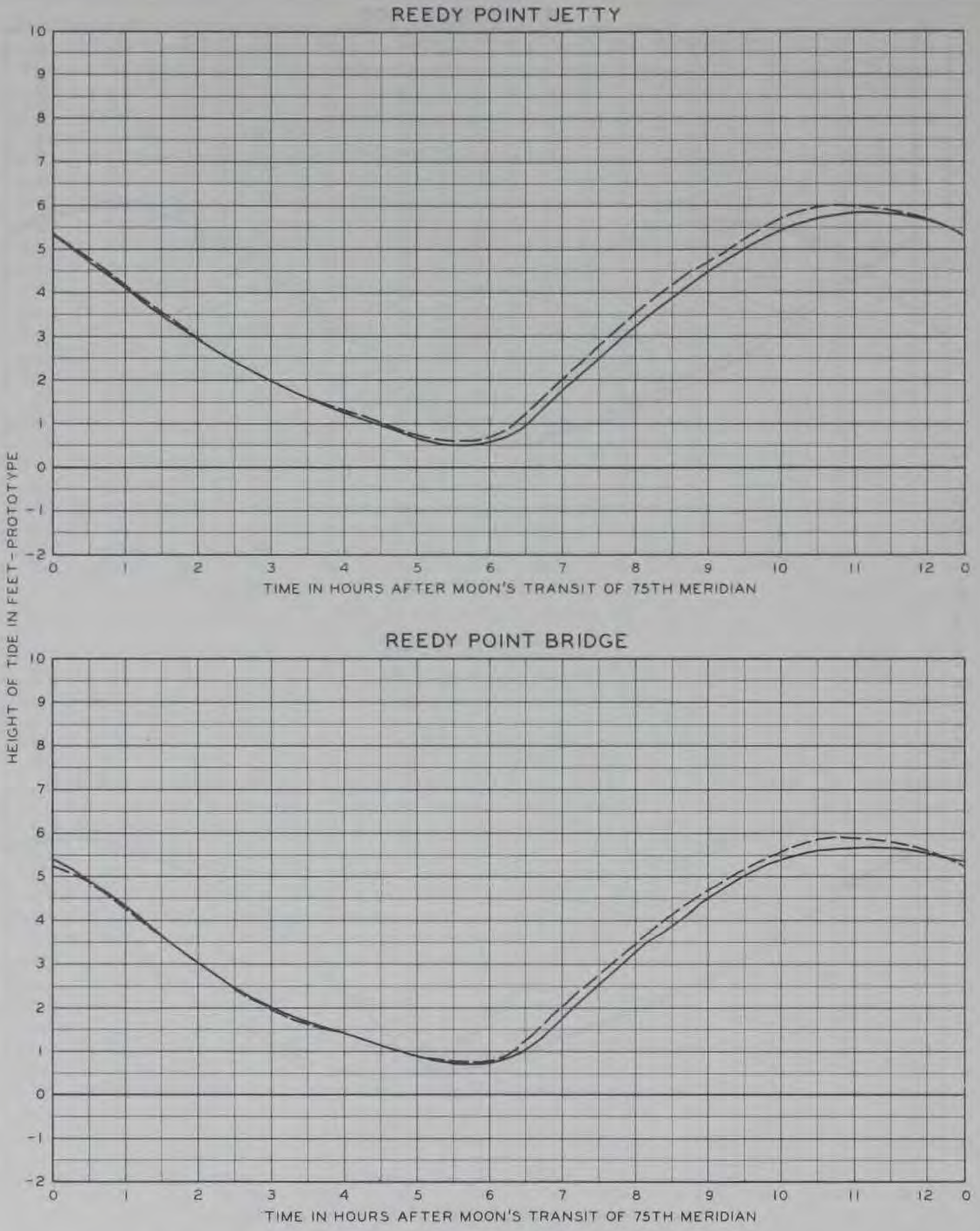
– – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
———— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS 234+000
AND NEW CASTLE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

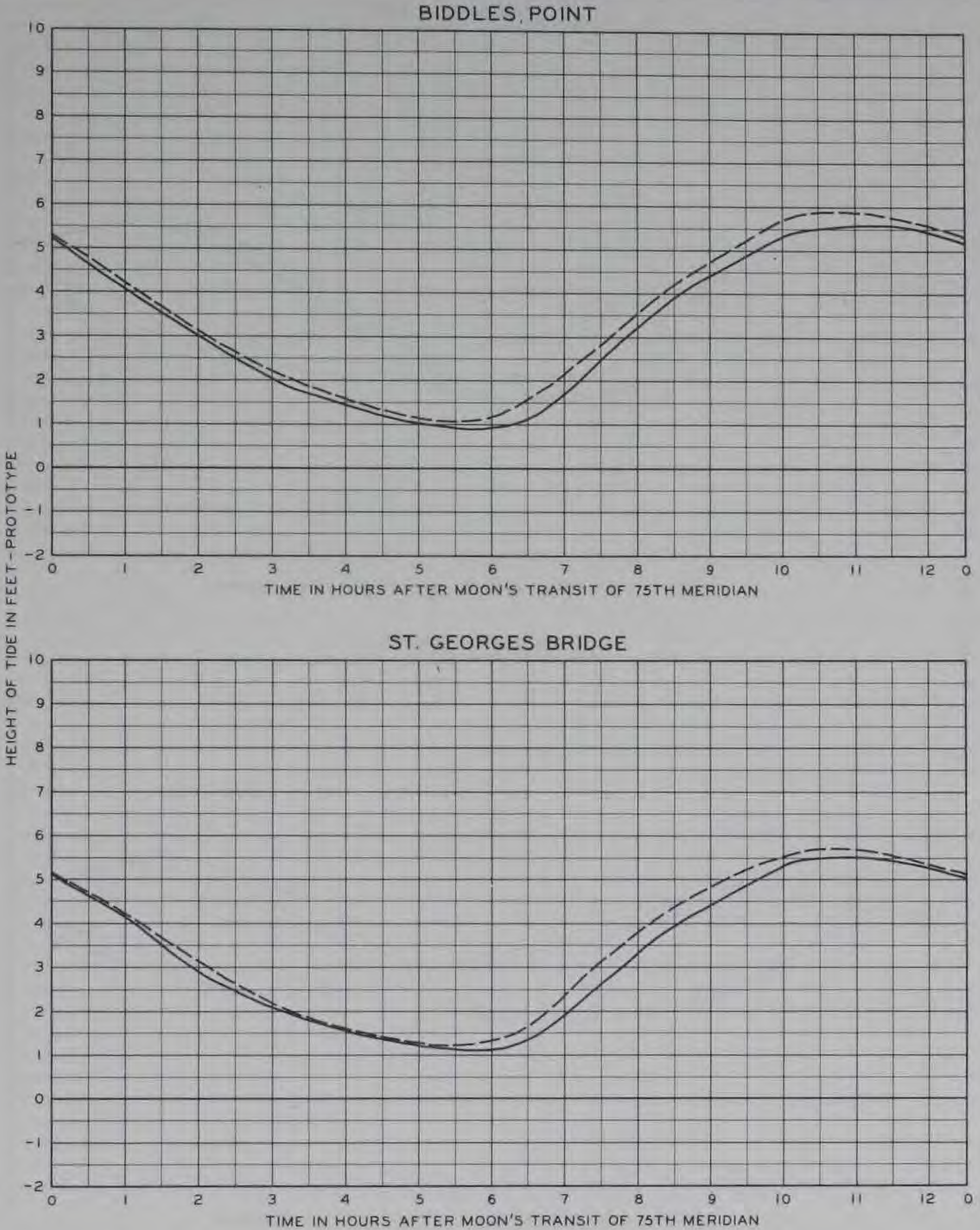
NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS REEDY POINT JETTY
AND REEDY POINT BRIDGE

PLATE 128



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

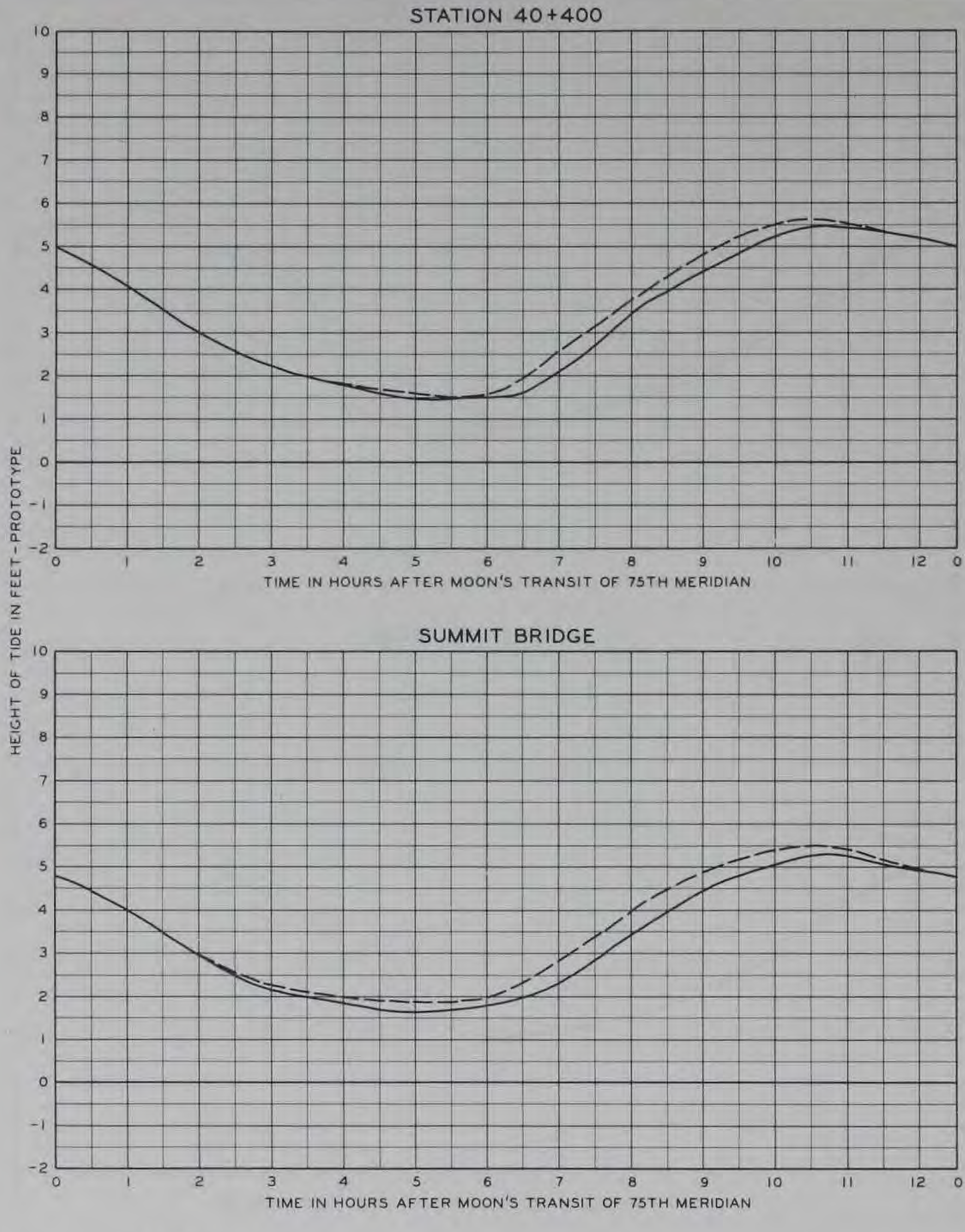
– – – – – $\Delta H = +0.42$ FT 35 FT X 450 FT CANAL
———— $\Delta H = +0.28$ FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY

EFFECTS OF
CANAL ENLARGEMENT ON
TIDAL HEIGHTS

STATIONS BIDDLES POINT
AND ST. GEORGES BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

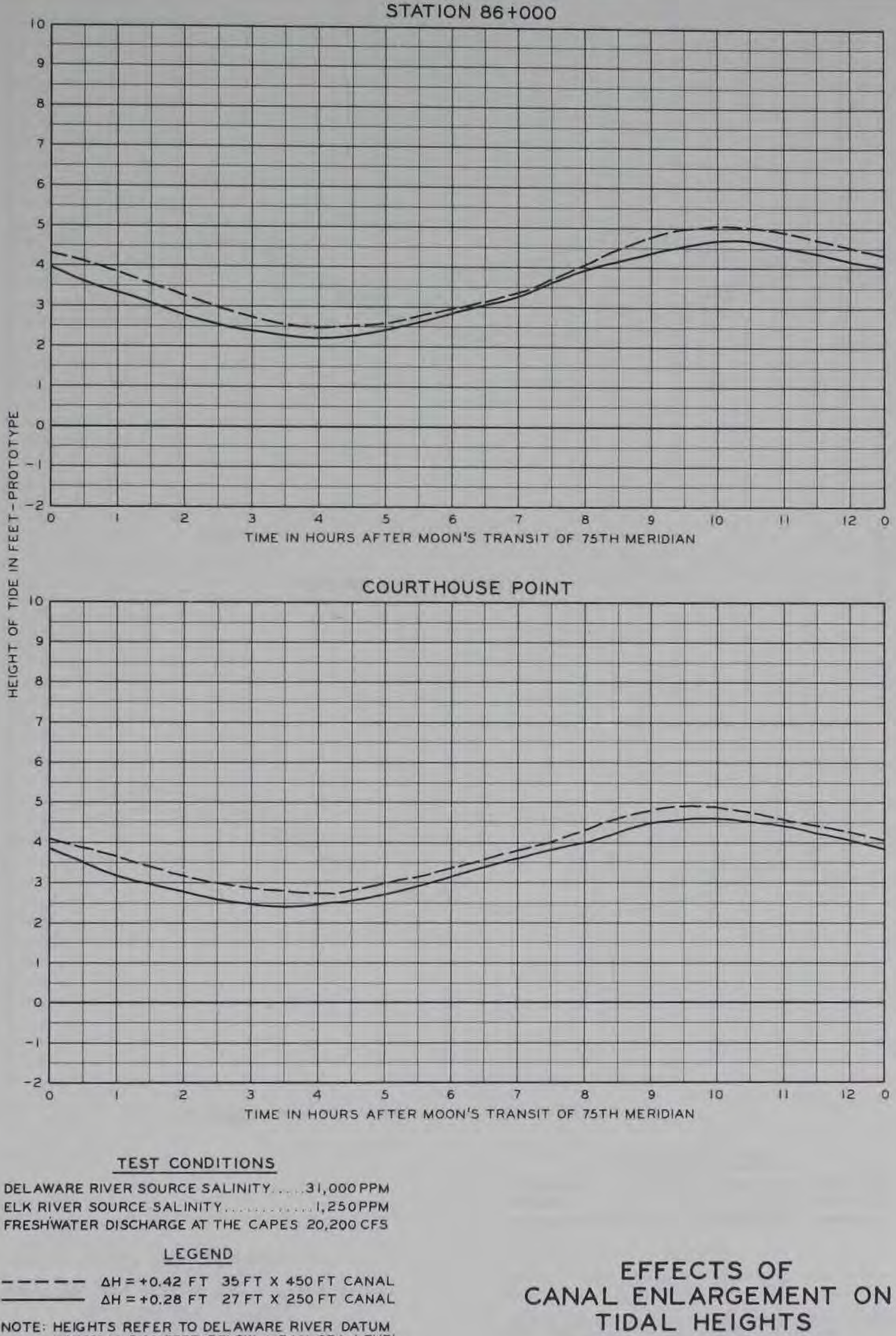
– – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
———— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS 40+400 AND SUMMIT BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

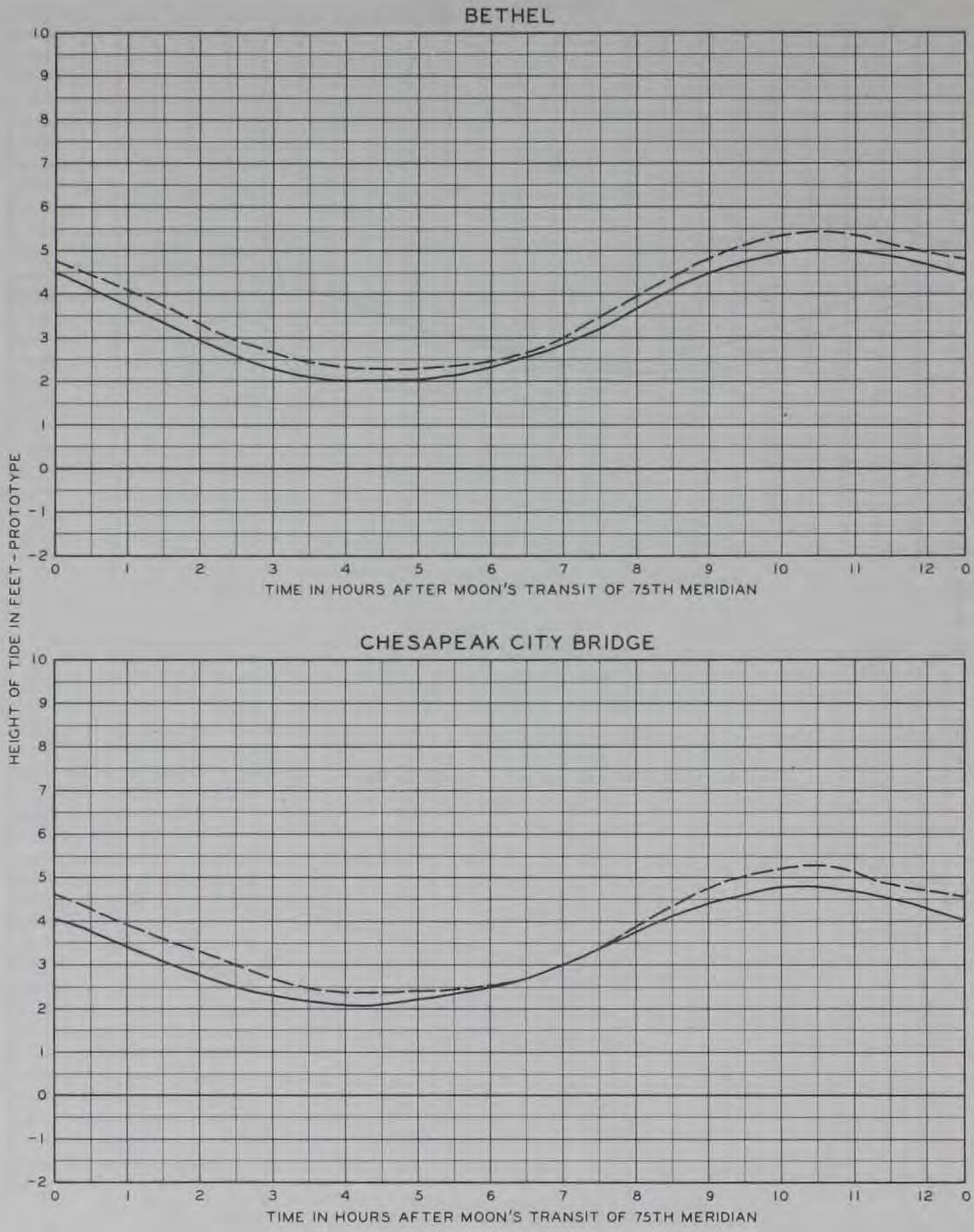
– – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
———— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS 86+000 AND
COURTHOUSE POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

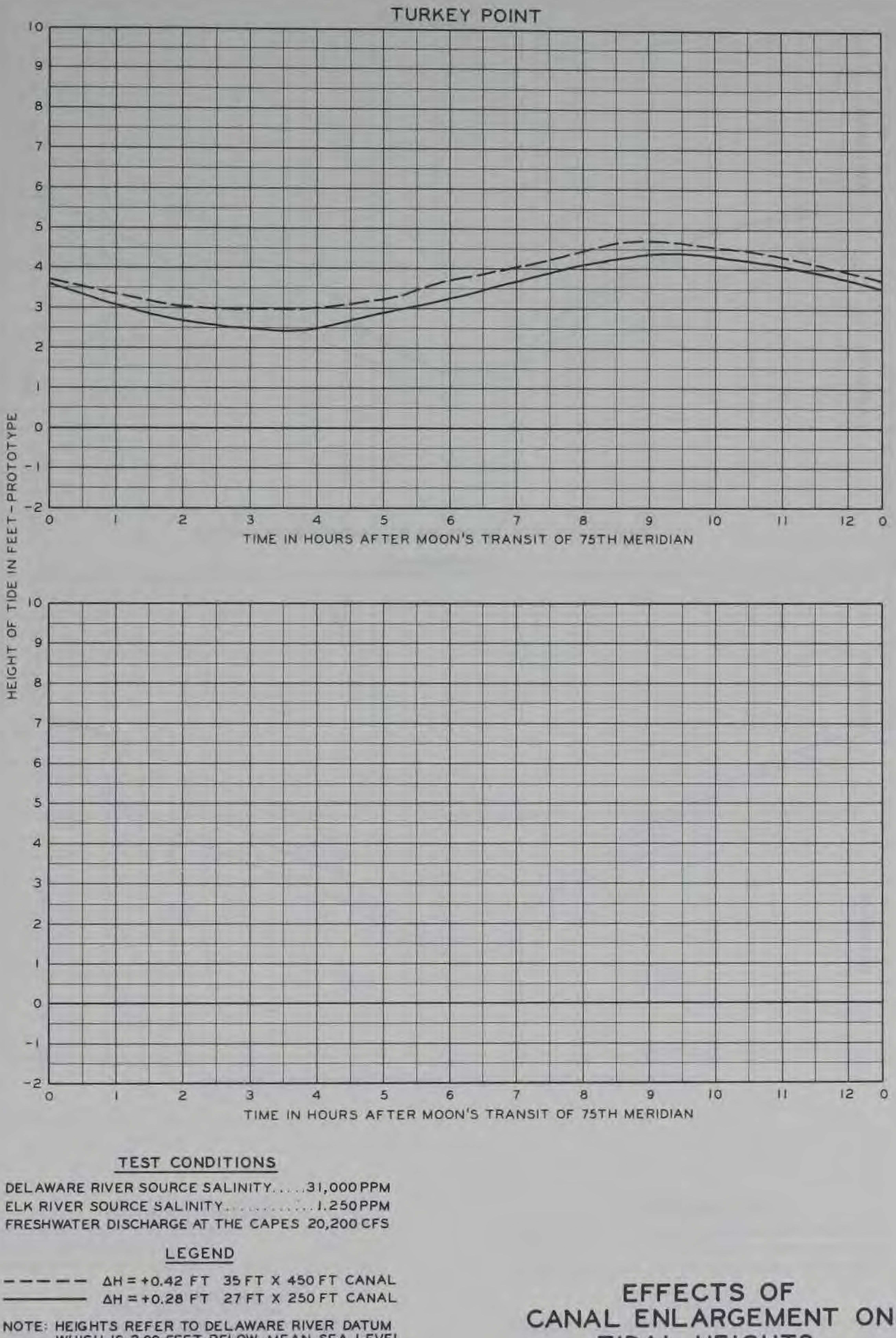
- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATIONS BETHEL AND
CHESAPEAKE CITY BRIDGE



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY..............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

LEGEND

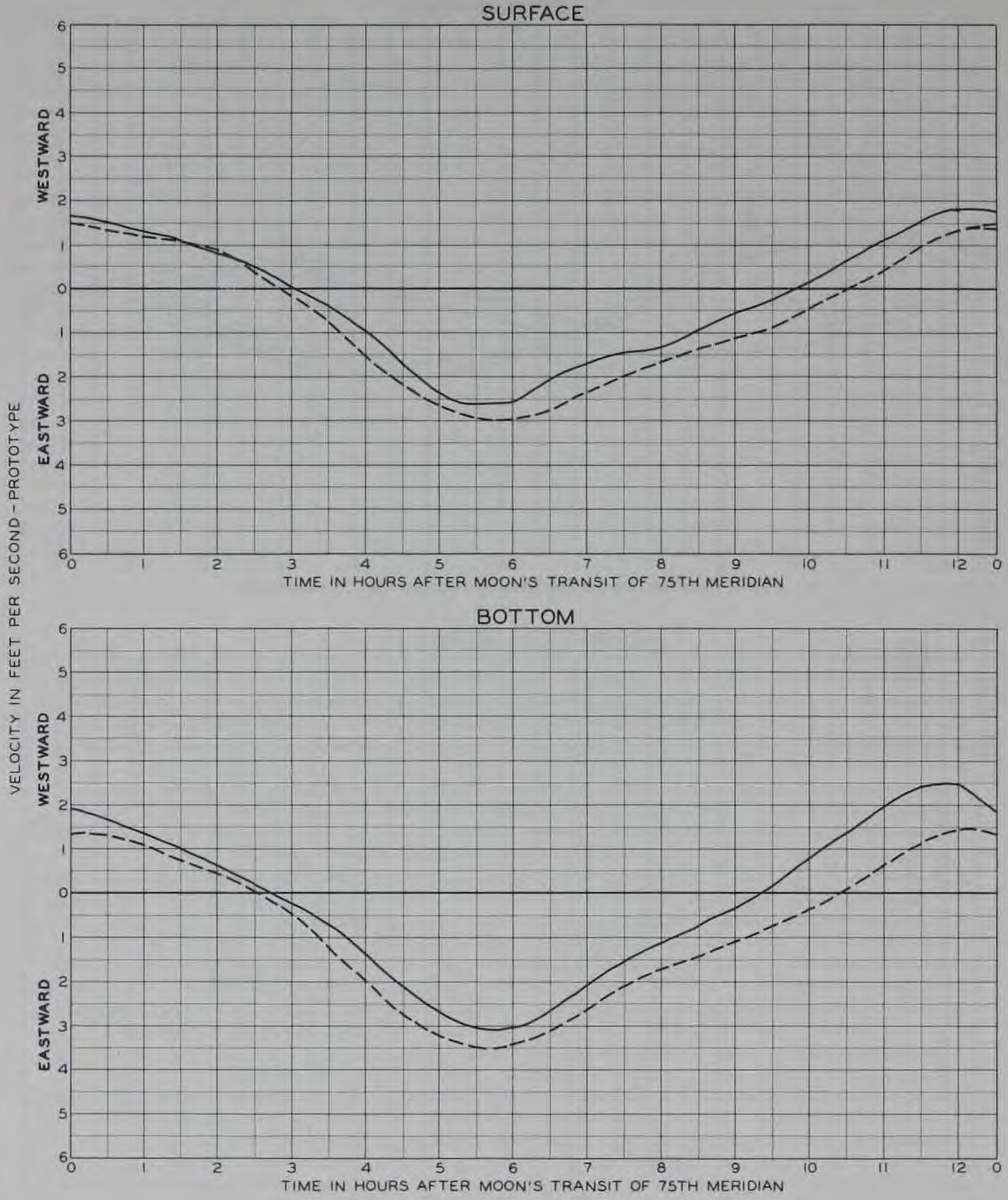
– – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
———— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: HEIGHTS REFER TO DELAWARE RIVER DATUM WHICH IS 2.90 FEET BELOW MEAN SEA LEVEL SANDY HOOK, 1929 ADJUSTMENT.

ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON TIDAL HEIGHTS

STATION TURKEY POINT



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY......31,000 PPM
ELK RIVER SOURCE SALINITY..............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

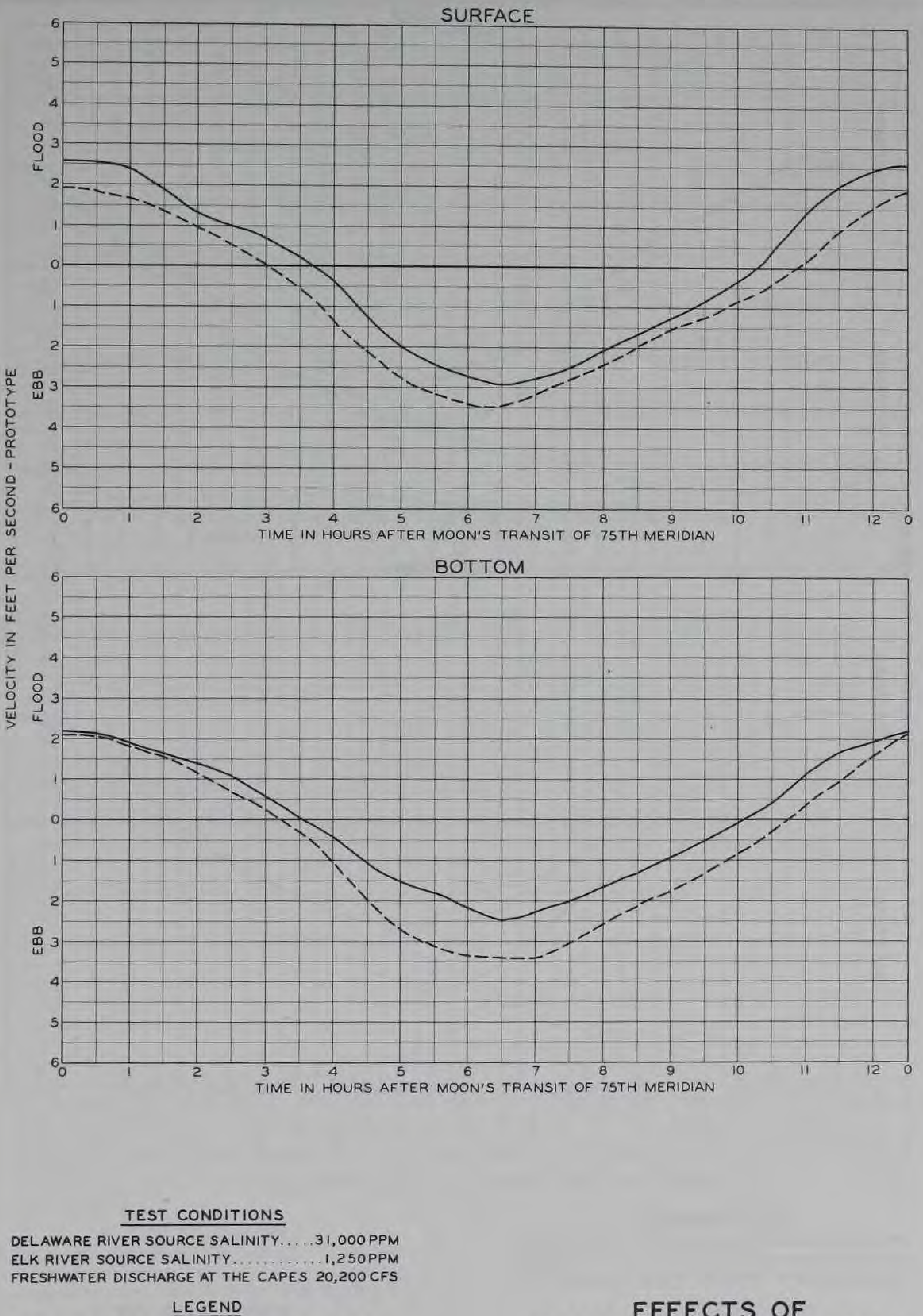
LEGEND

– – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON CURRENT VELOCITIES

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

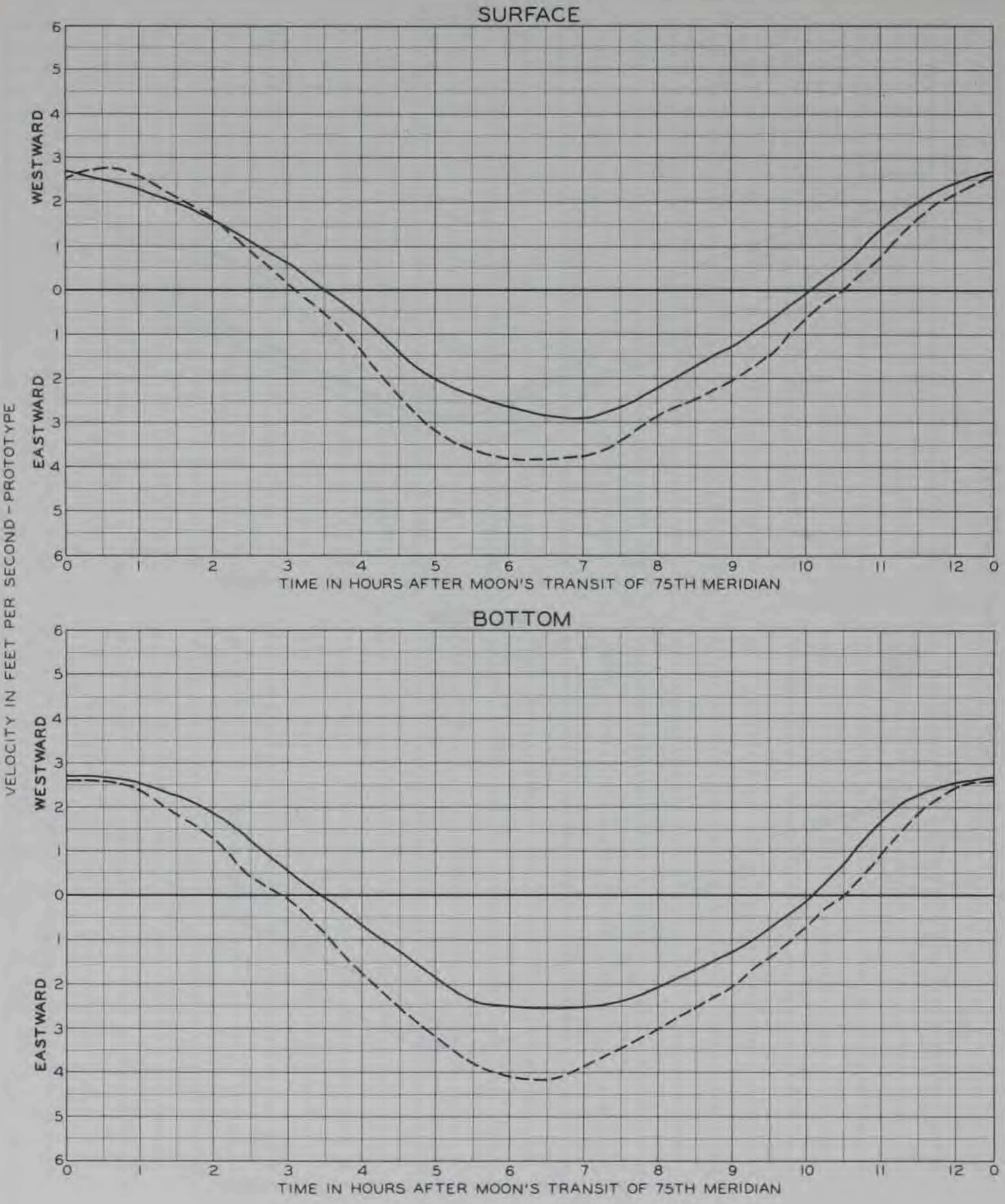
LEGEND

- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON CURRENT VELOCITIES

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY...............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

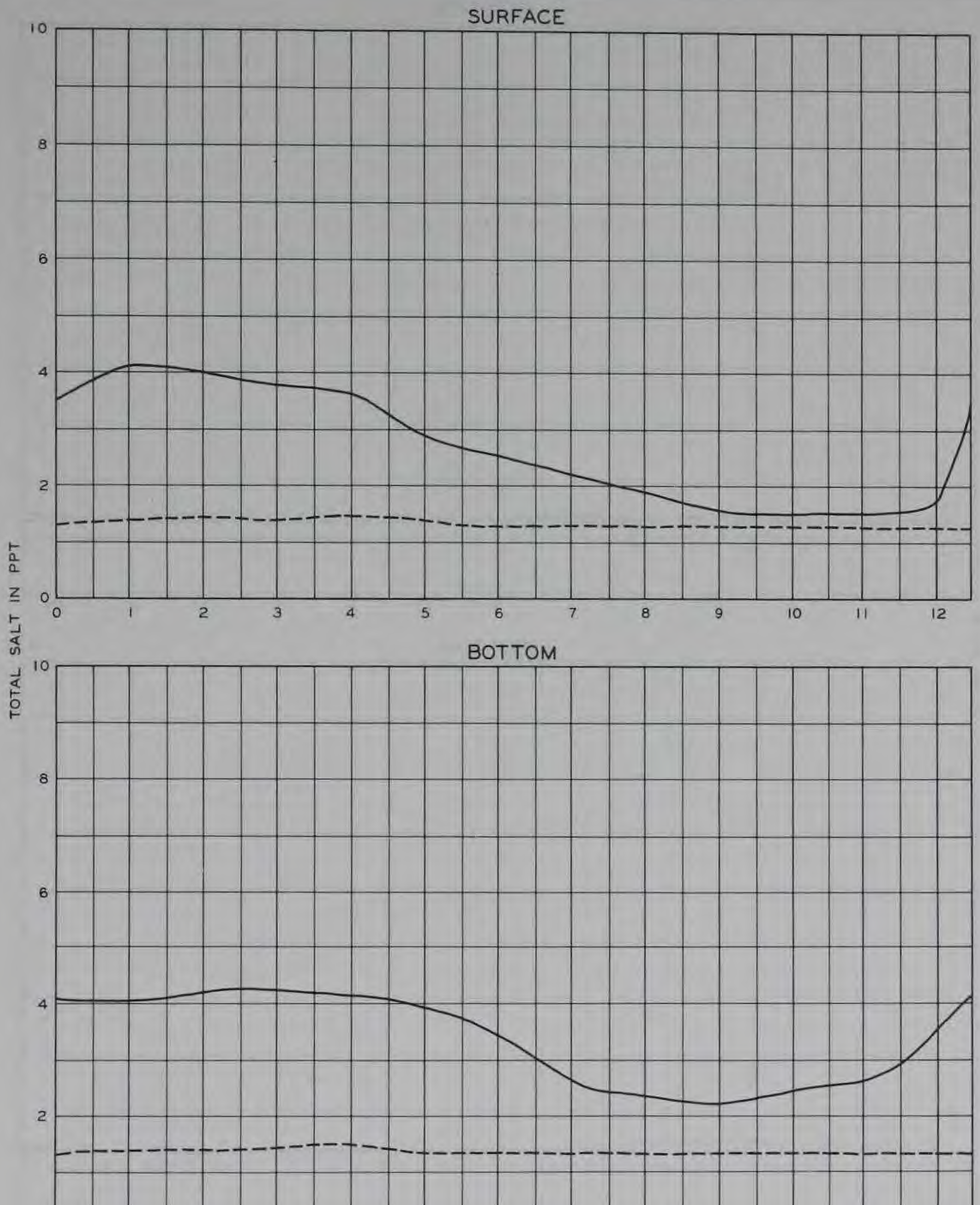
LEGEND

– – – – –	ΔH = +0.42 FT 35 FT X 450 FT CANAL
———	ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON CURRENT VELOCITIES

STATION D



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

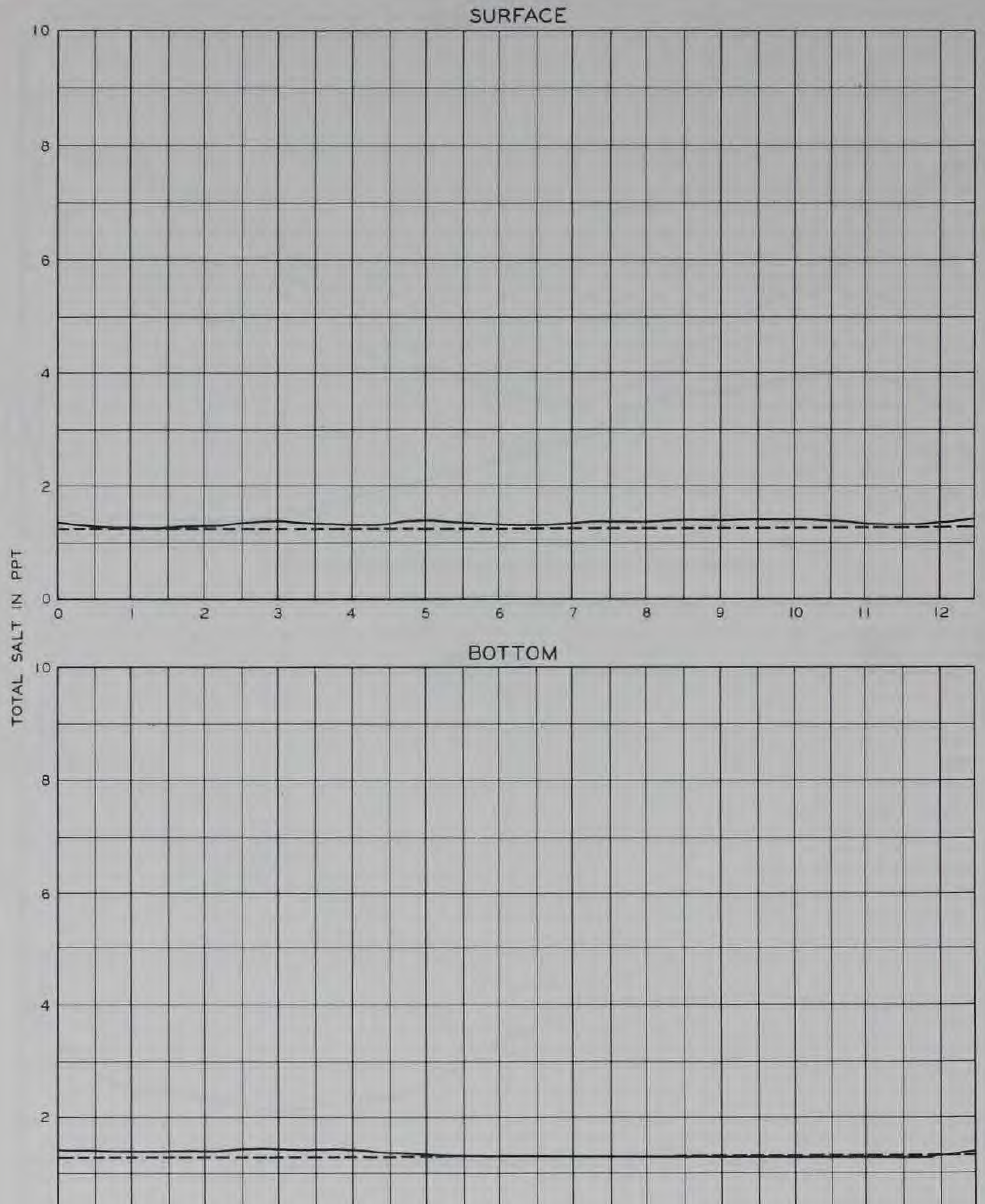
LEGEND

- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON SALINITIES

STATION A



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY.............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

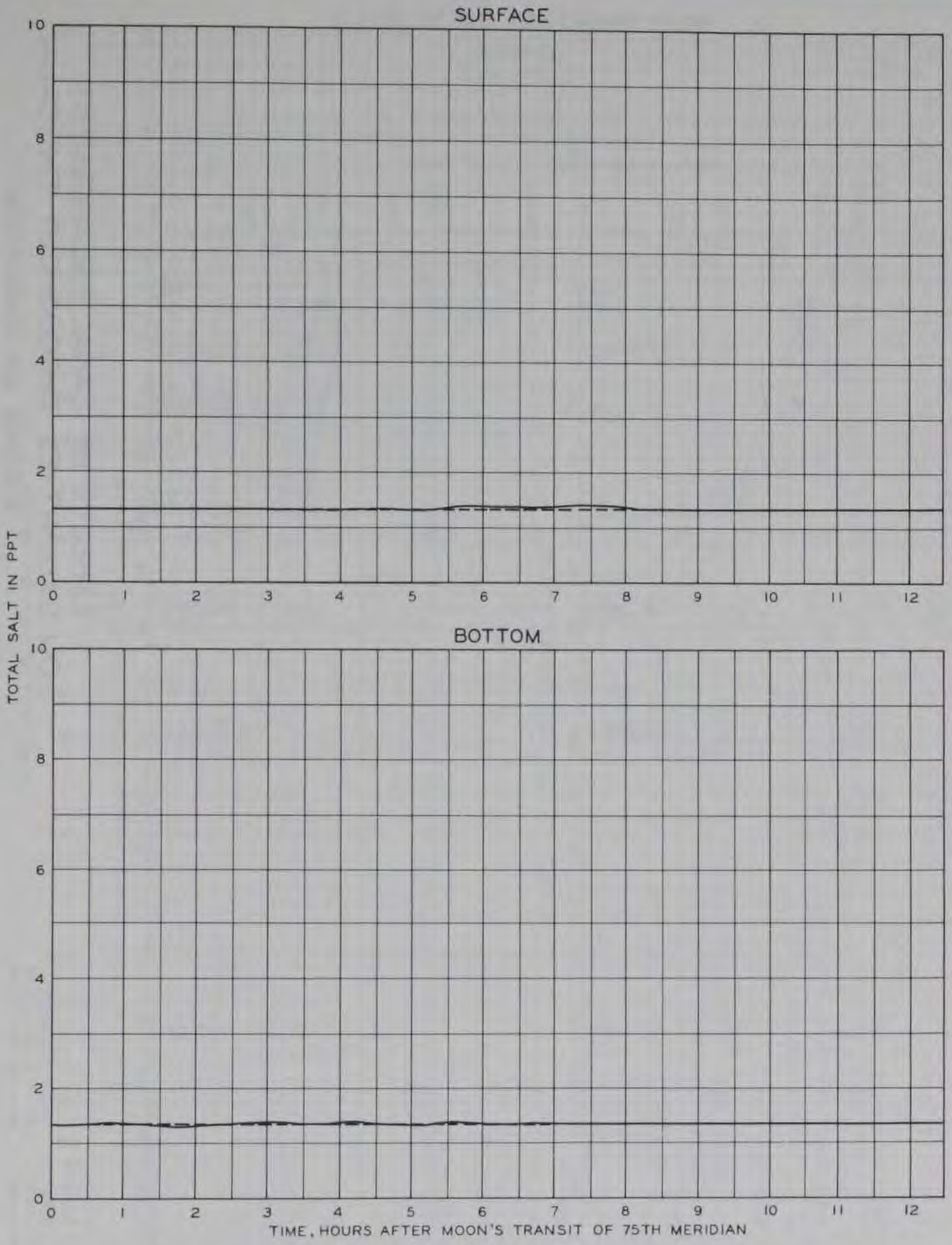
LEGEND

- - - - - ΔH = +0.42 FT 35 FT X 450 FT CANAL
——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

EFFECTS OF CANAL ENLARGEMENT ON SALINITIES

STATION C



TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY.....31,000 PPM
ELK RIVER SOURCE SALINITY............1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES 20,200 CFS

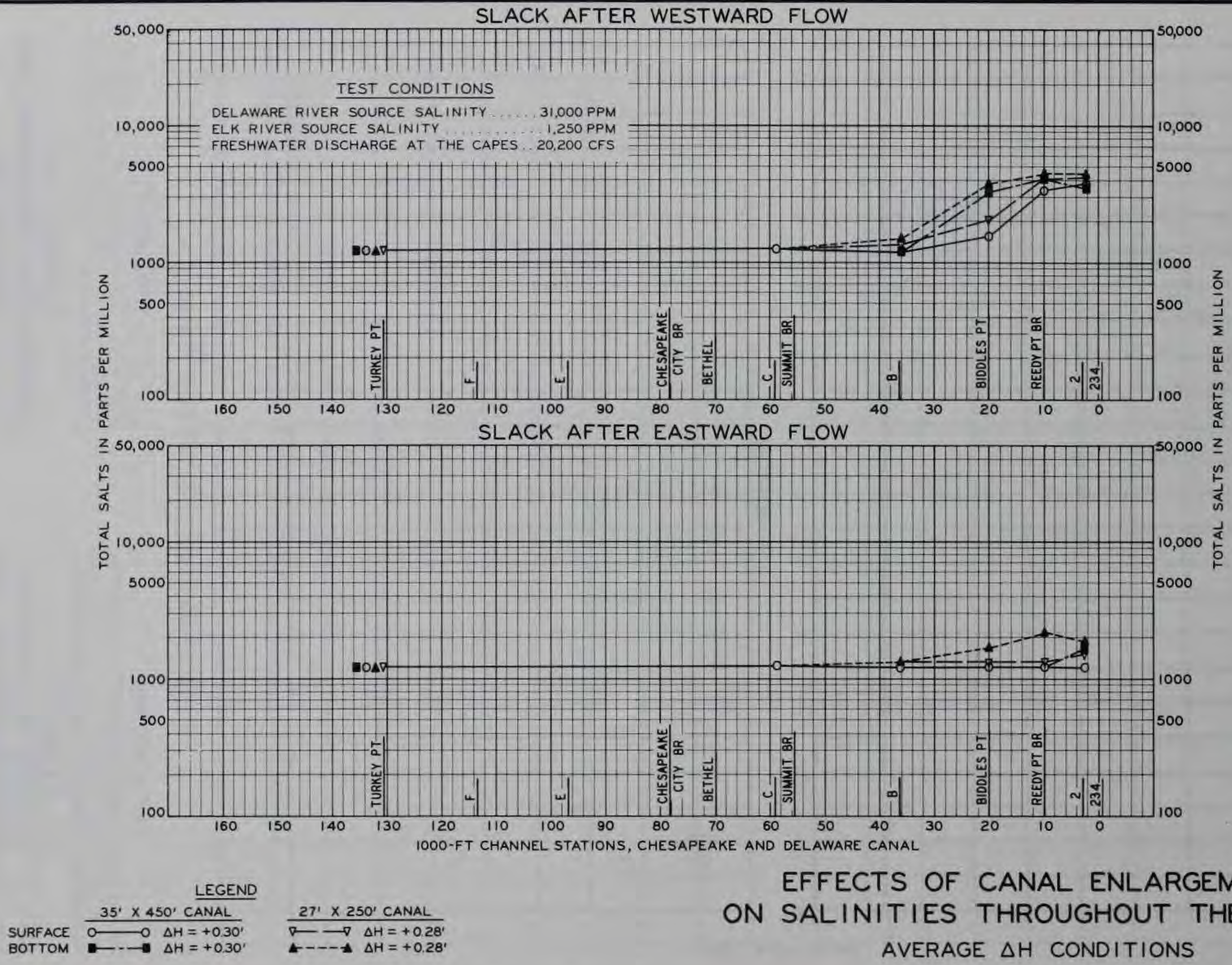
LEGEND

- – – – – ΔH = +0.42 FT 35 FT X 450 FT CANAL
- ——— ΔH = +0.28 FT 27 FT X 250 FT CANAL

NOTE: ΔH = MTL AT COURTHOUSE POINT MINUS
MTL AT REEDY POINT JETTY.

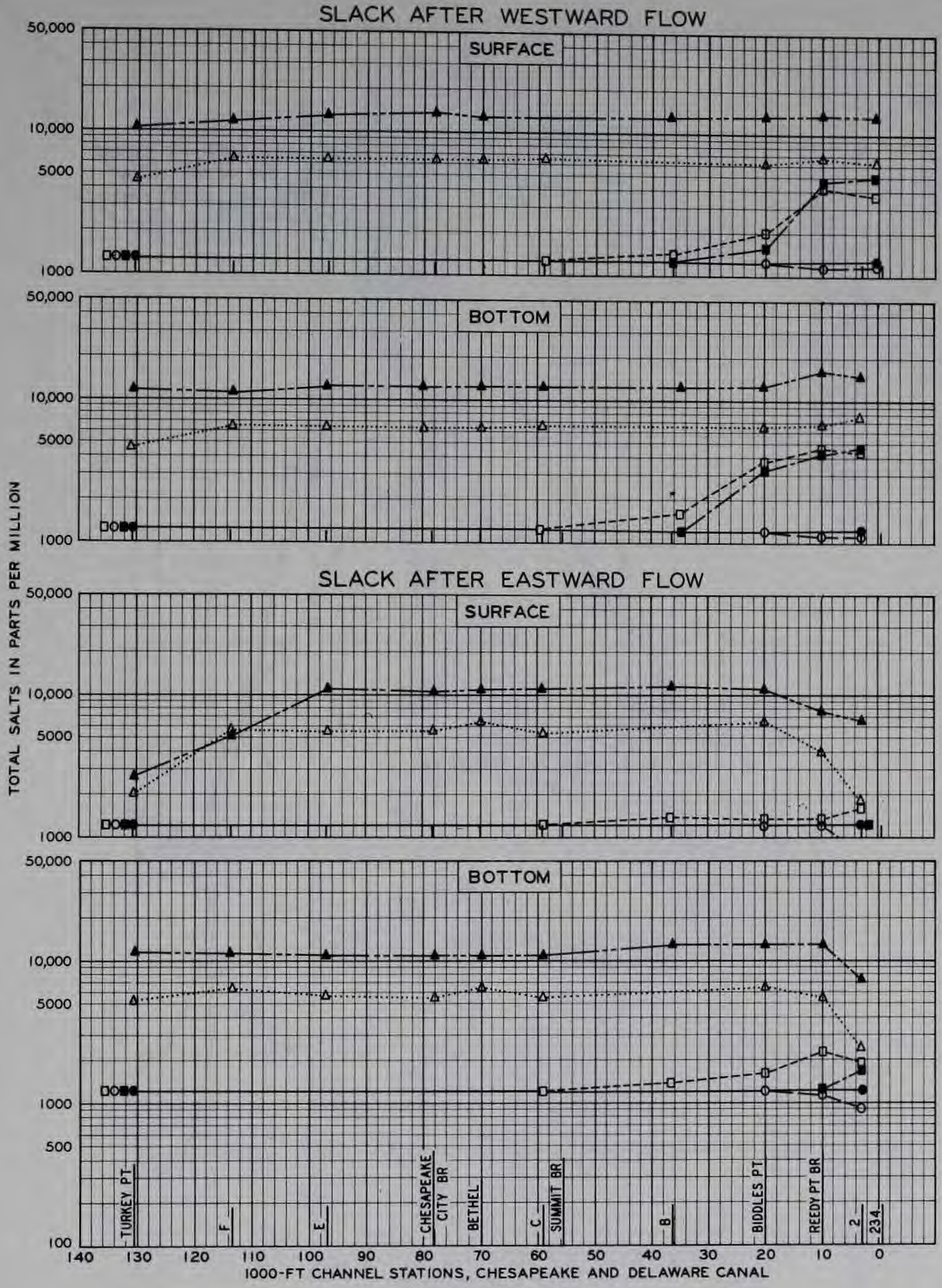
EFFECTS OF CANAL ENLARGEMENT ON SALINITIES

STATION D



EFFECTS OF CANAL ENLARGEMENT ON SALINITIES THROUGHOUT THE CANAL

AVERAGE ΔH CONDITIONS
]



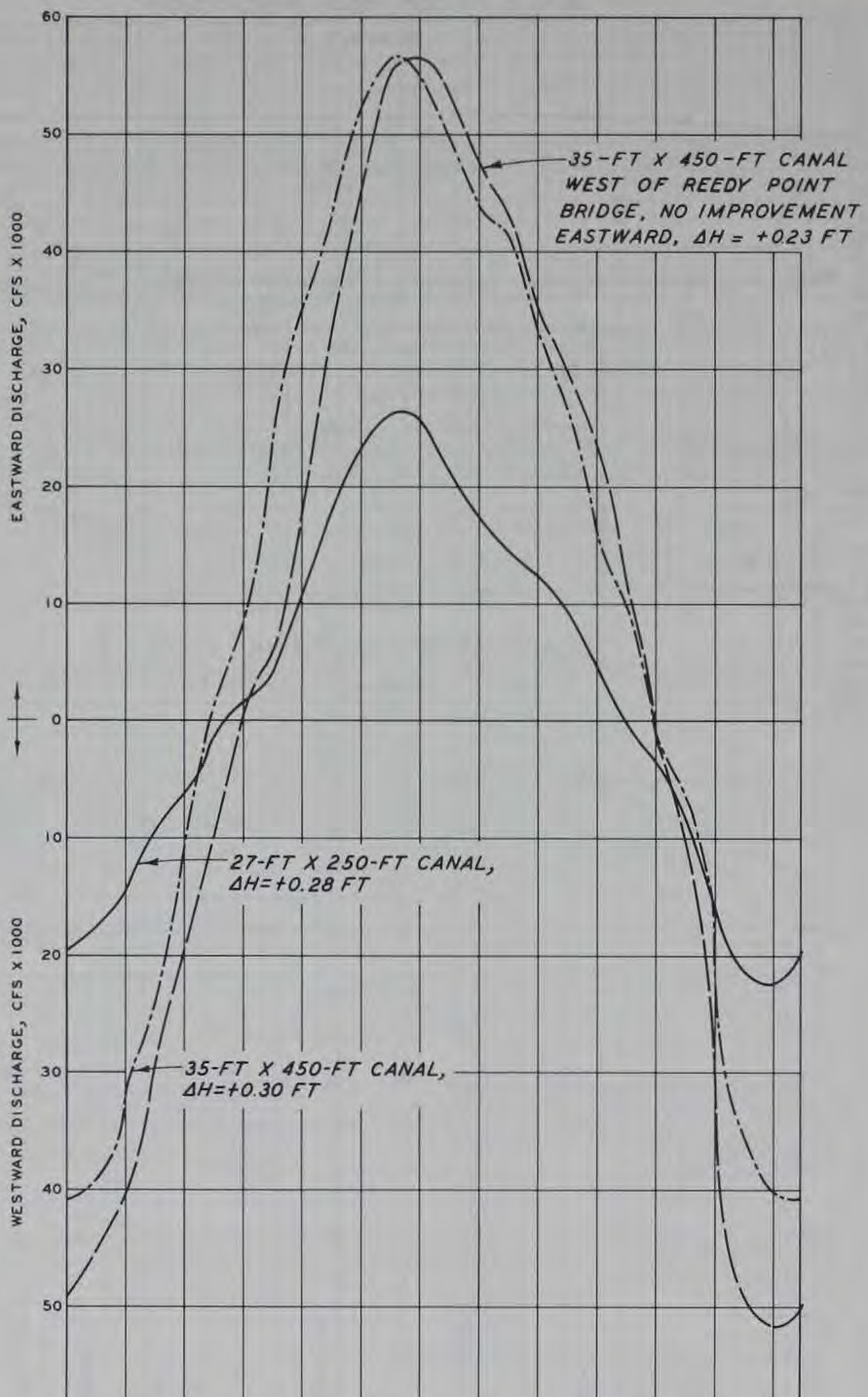
TEST CONDITIONS

DELAWARE RIVER SOURCE SALINITY ......31,000 PPM
ELK RIVER SOURCE SALINITY .... 1,250 PPM
FRESHWATER DISCHARGE AT THE CAPES ... 20,200 CFS

LEGEND

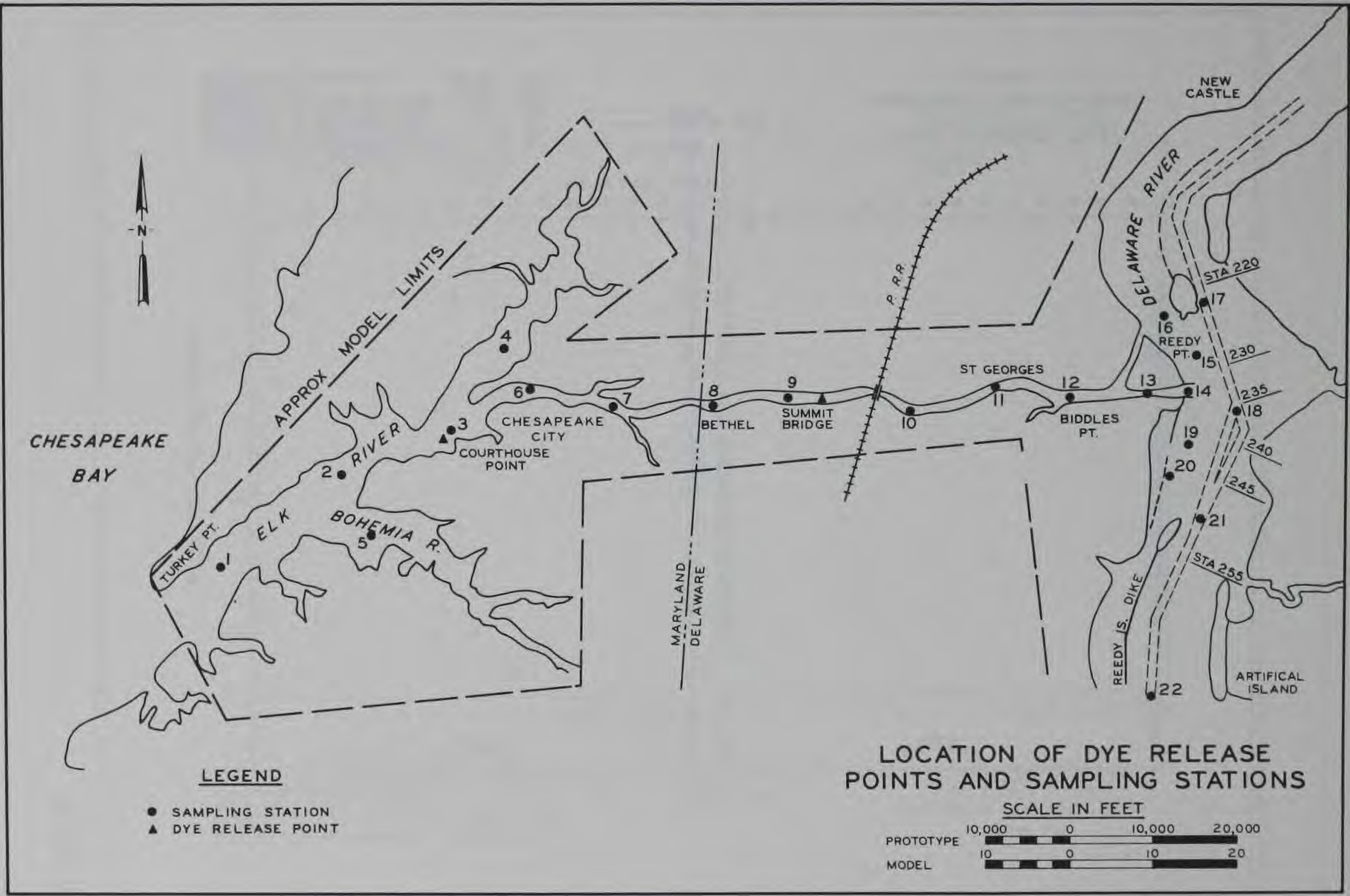
35' X 450' CANAL	27' X 250' CANAL
●——● ΔH = +1.44'	○——○ ΔH = +1.44'
■-·-■ ΔH = +0.30'	□----□ ΔH = +0.28'
▲-·-▲ ΔH = −0.85'	△.........△ ΔH = −0.91'

EFFECT OF CANAL ENLARGEMENT ON SALINITIES THROUGHOUT THE CANAL



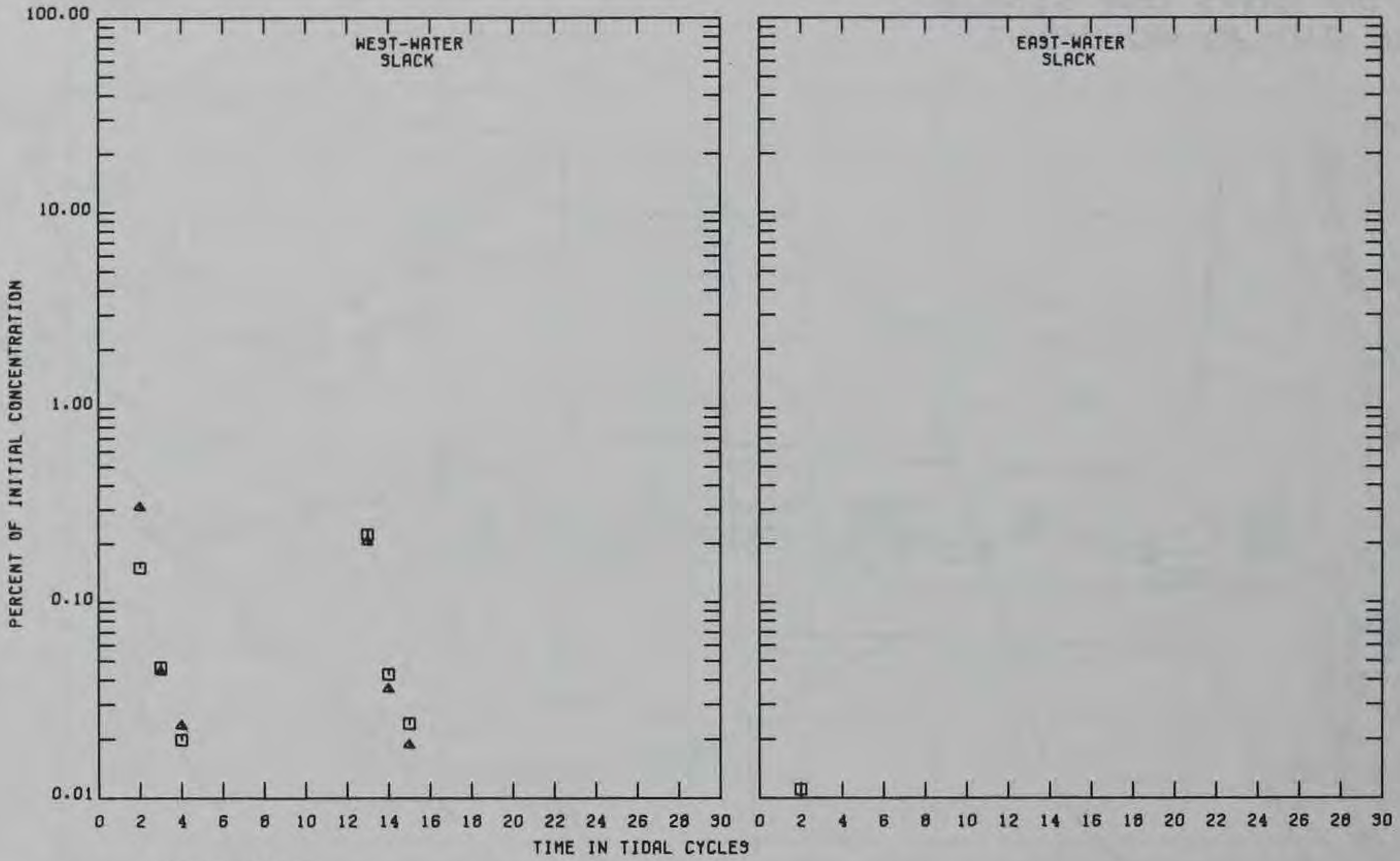
EFFECTS OF CANAL ENLARGEMENT ON DISCHARGE AT STATION A

NUMERICAL DETERMINATION



LOCATION OF DYE RELEASE POINTS AND SAMPLING STATIONS

PLATE 144



TEST CONDITIONS

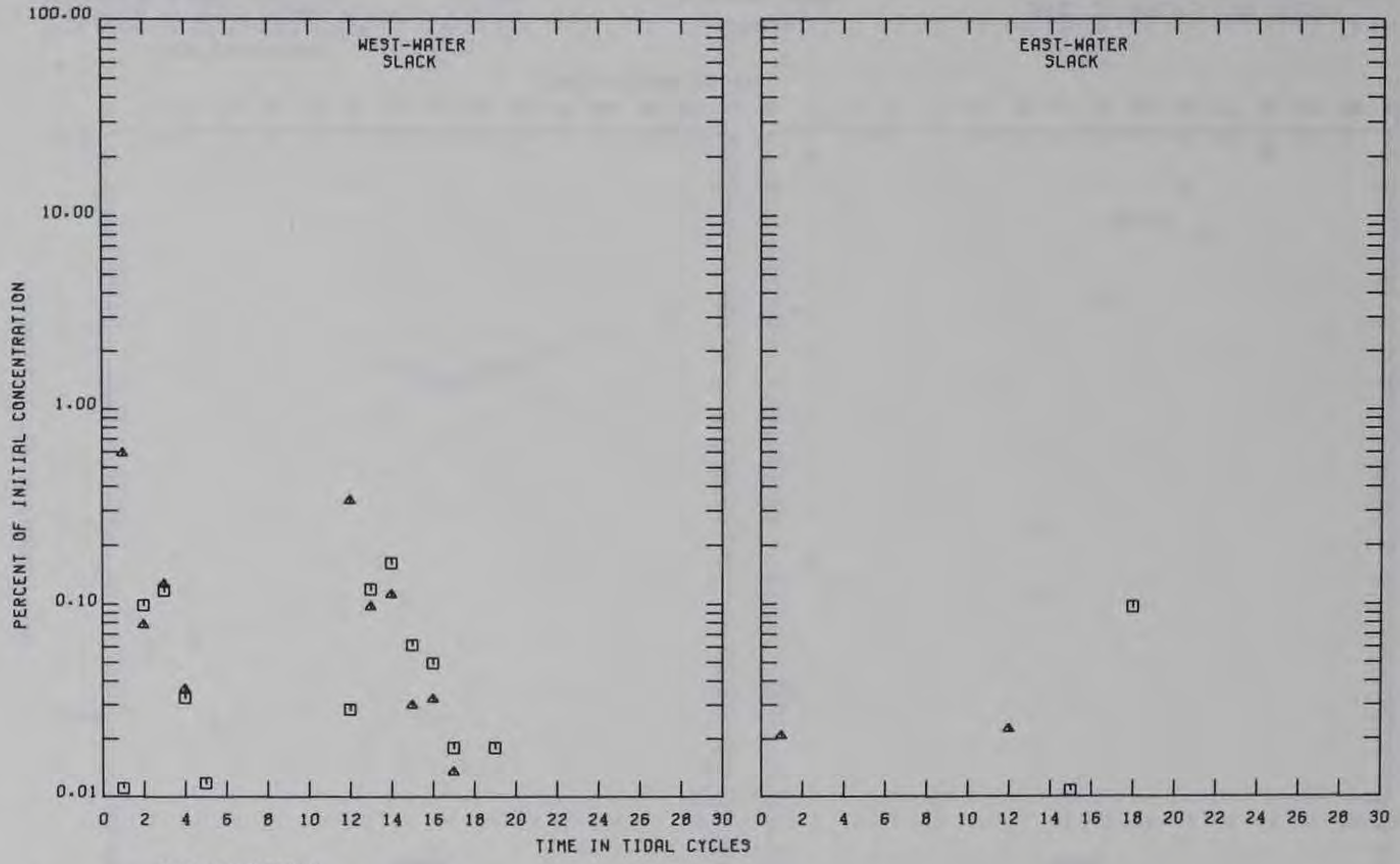
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 2



TEST CONDITIONS

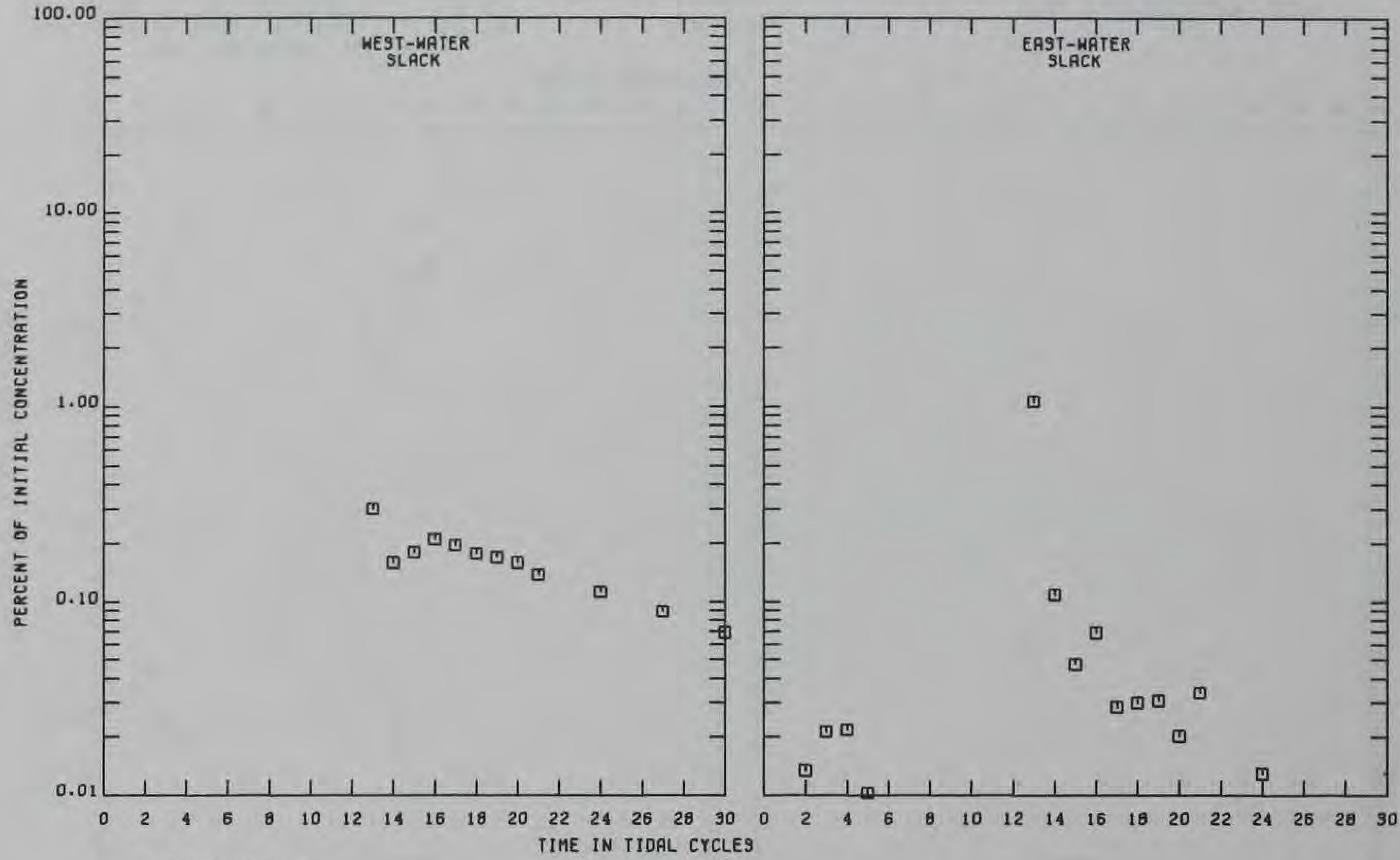
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344,200	PPB

LEGEND

☐ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 3

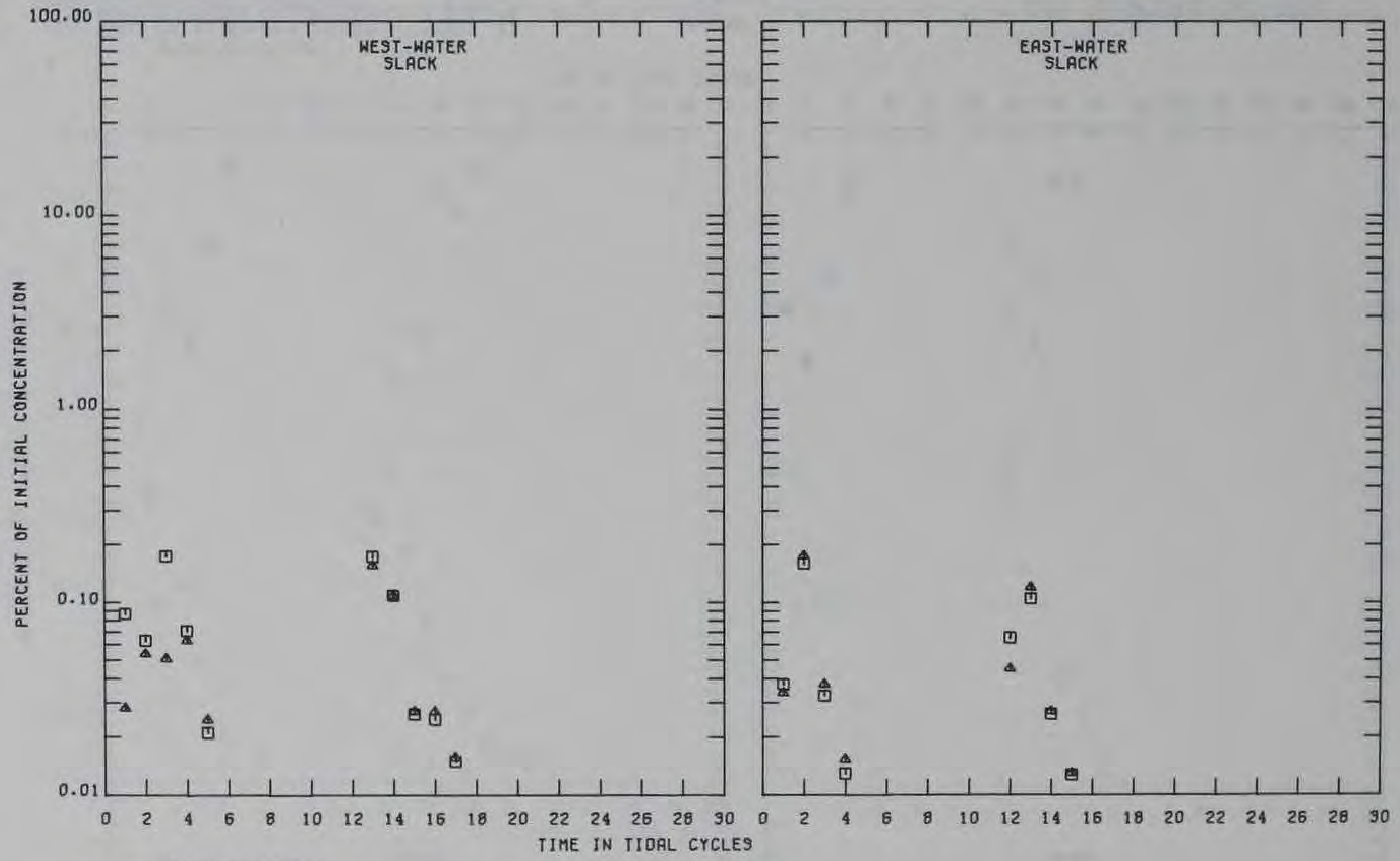


TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344,200	PPB

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 4 MID-DEPTH



TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

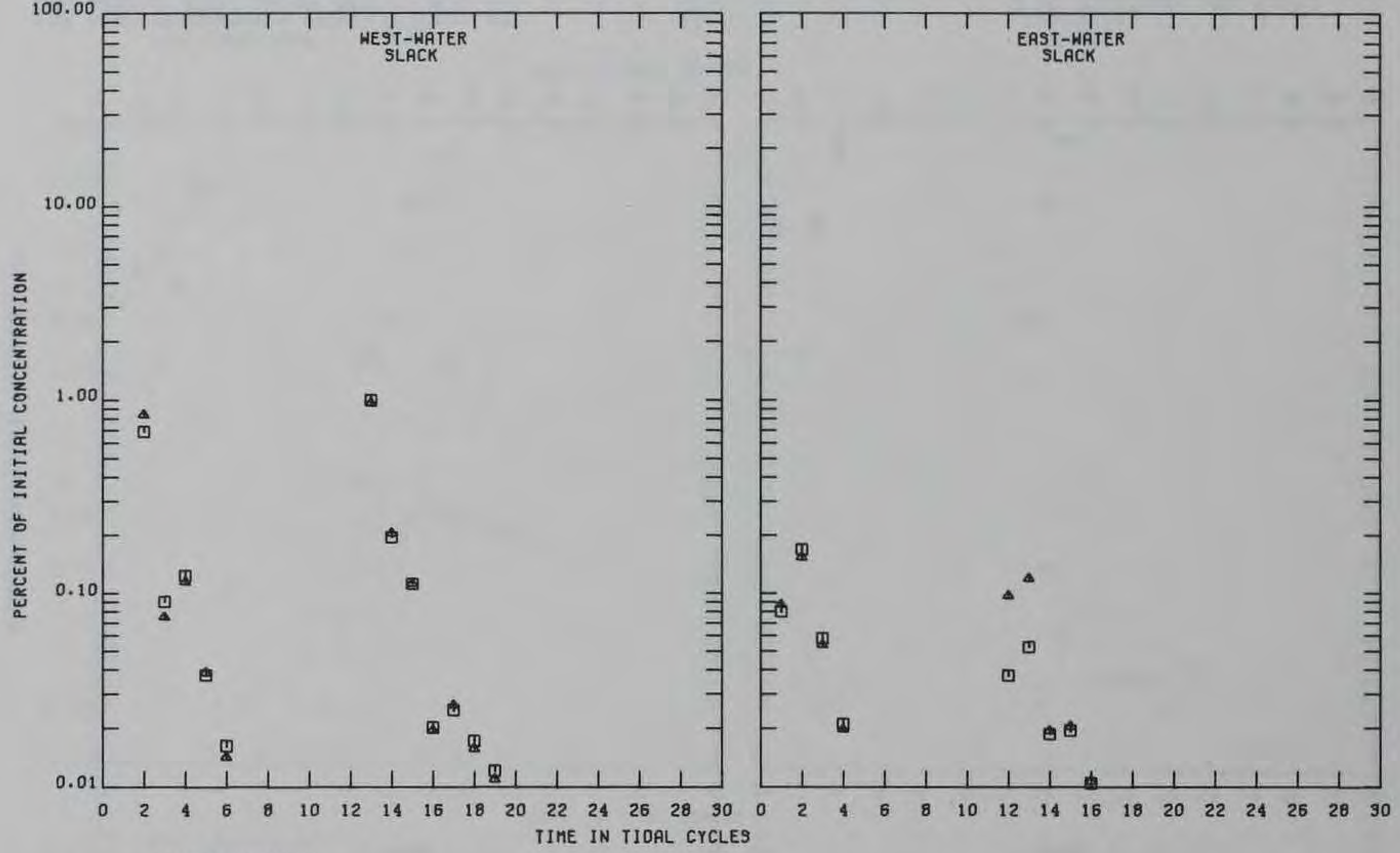
LEGEND

☐ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 6

PLATE 147



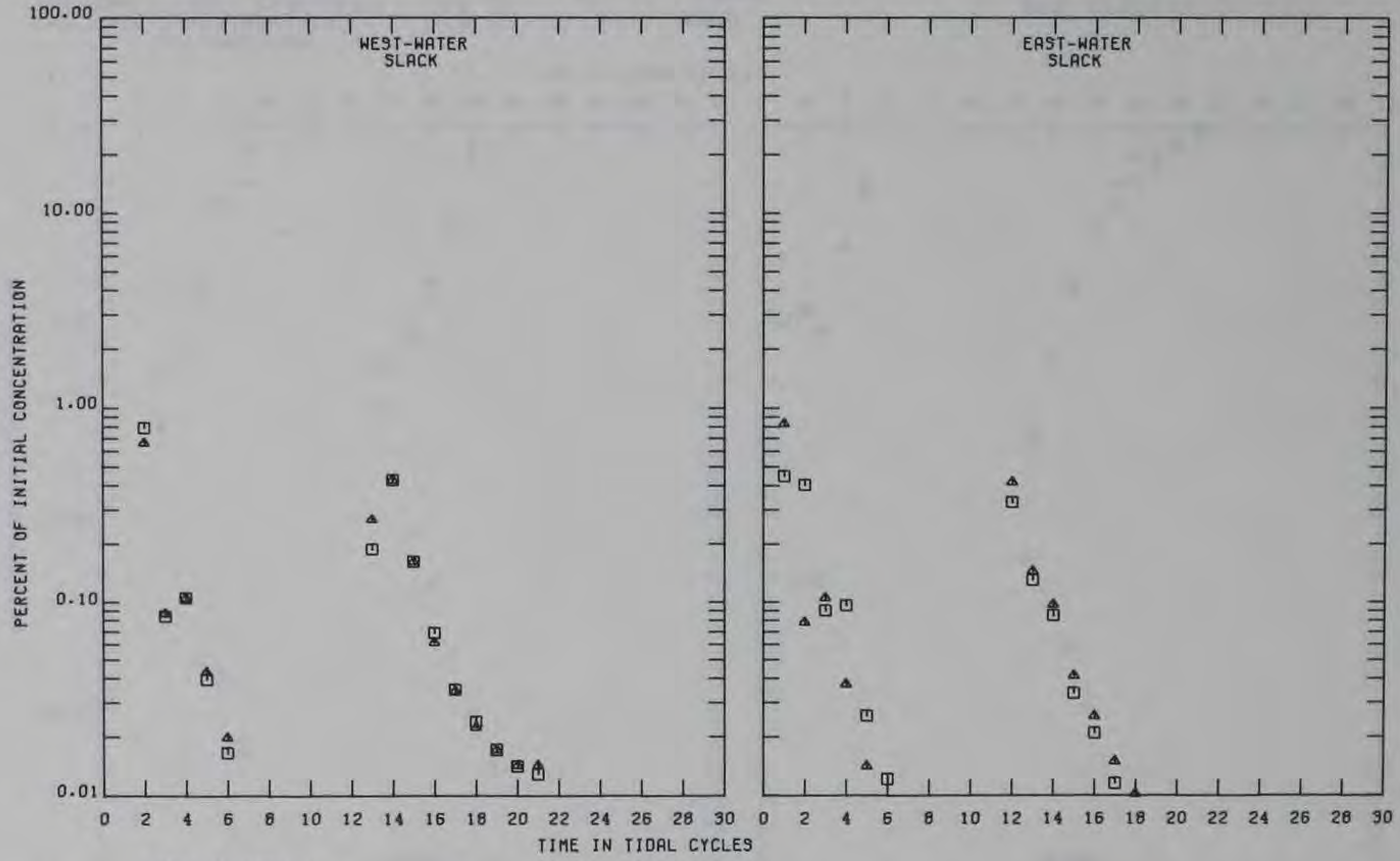
TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT
STATION 7



TEST CONDITIONS

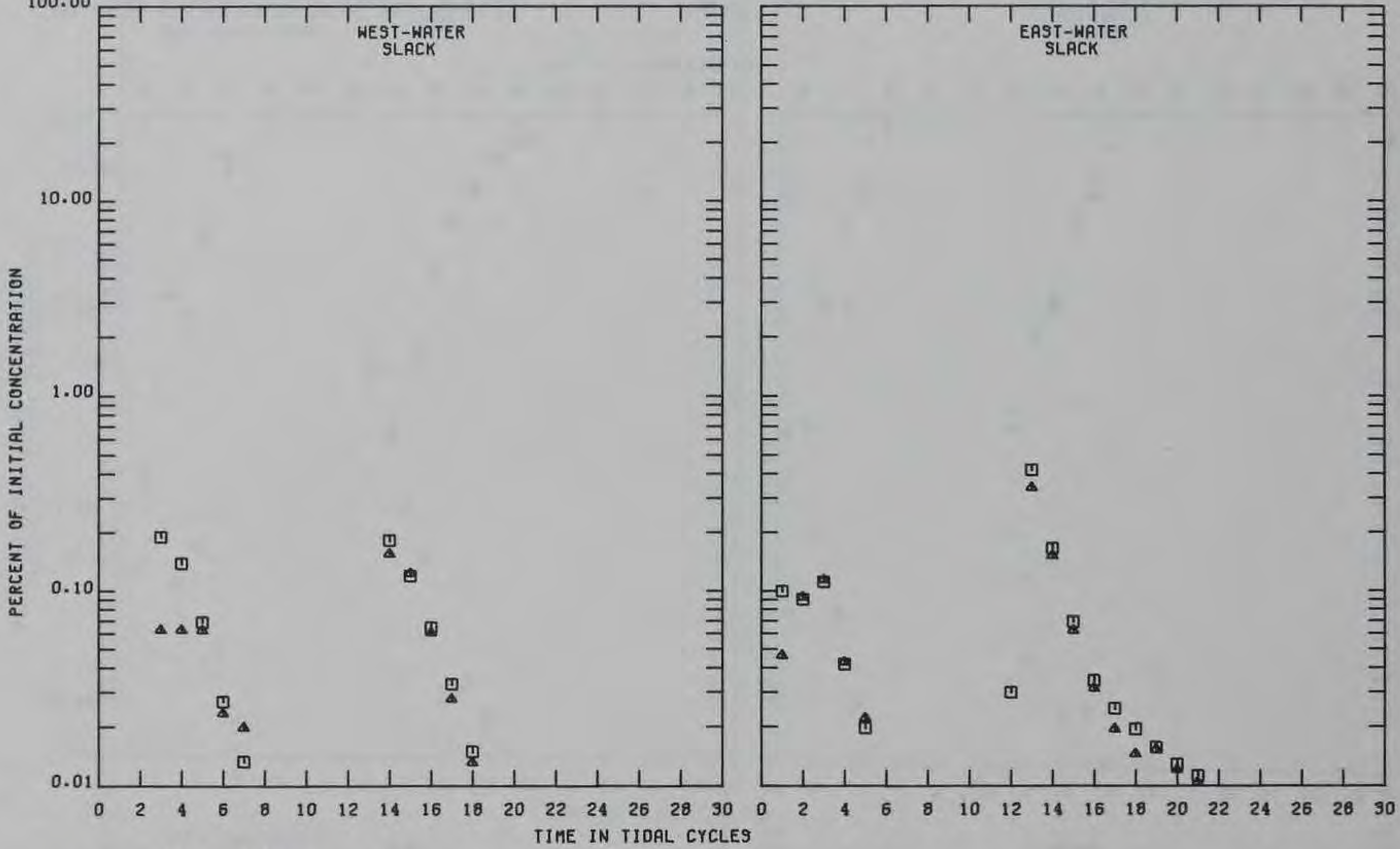
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 8

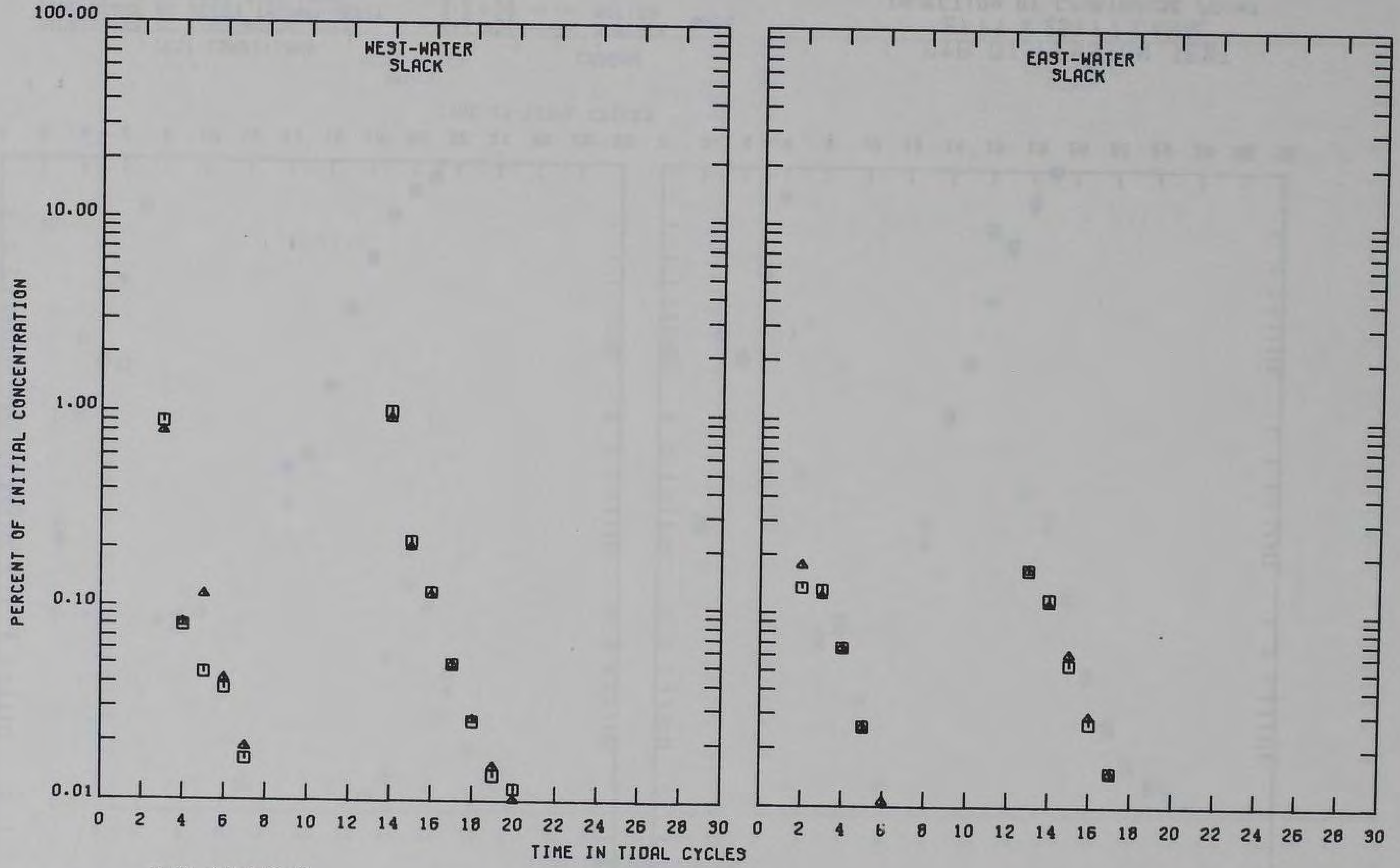


TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 9



TEST CONDITIONS

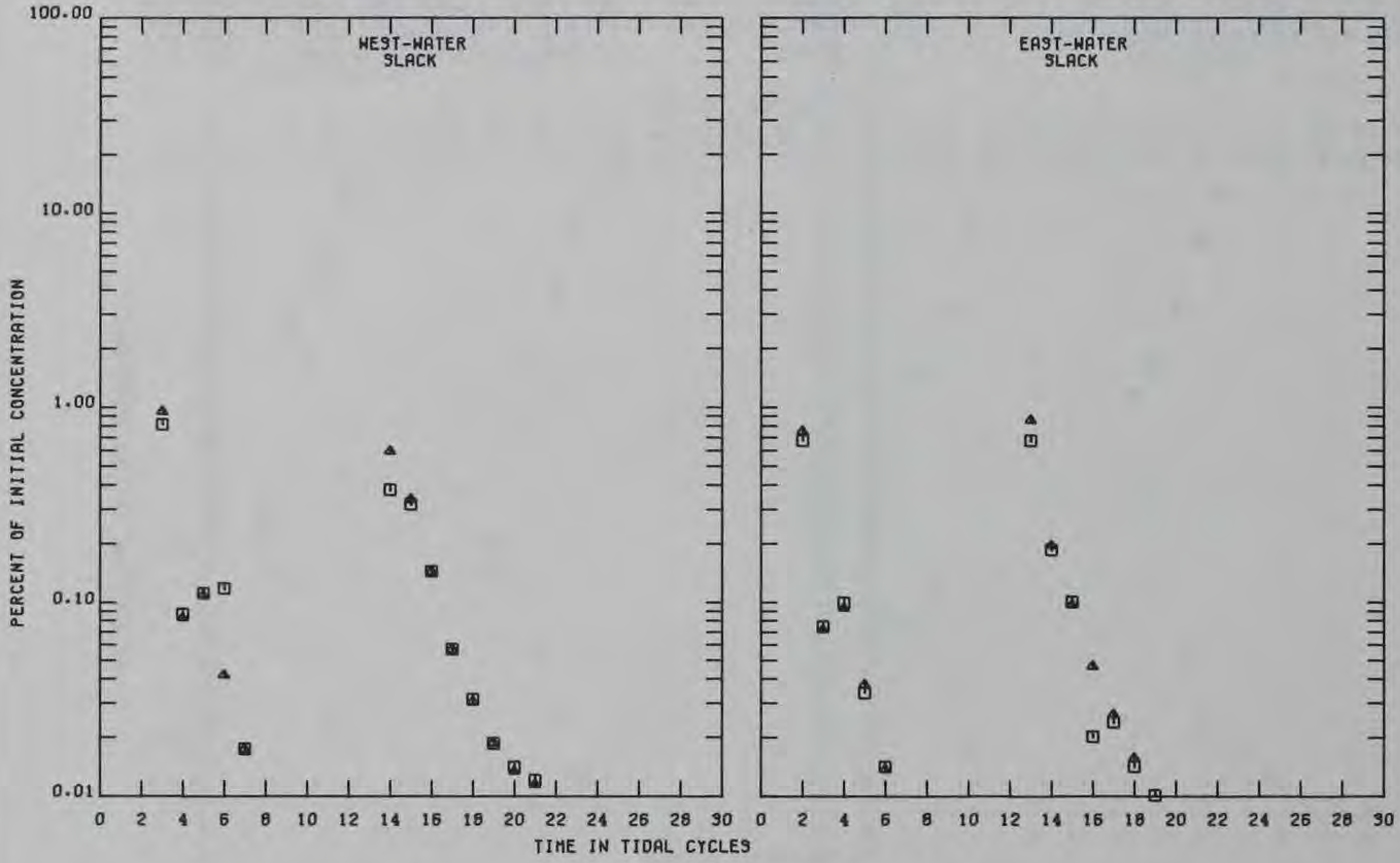
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 10



TEST CONDITIONS

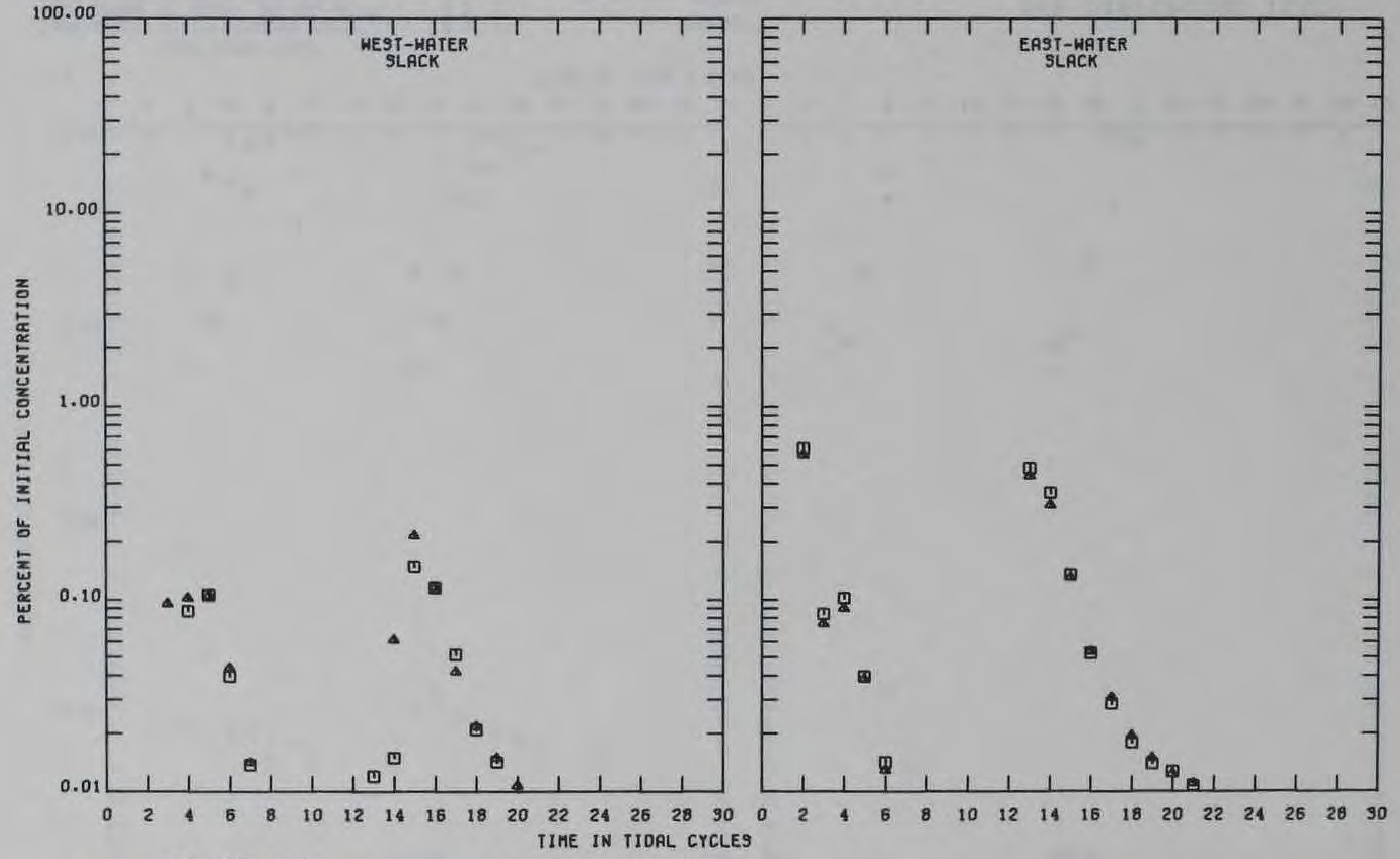
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	88200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTR		

LEGEND

□ ——— SURFACE
▲ — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 11



TEST CONDITIONS

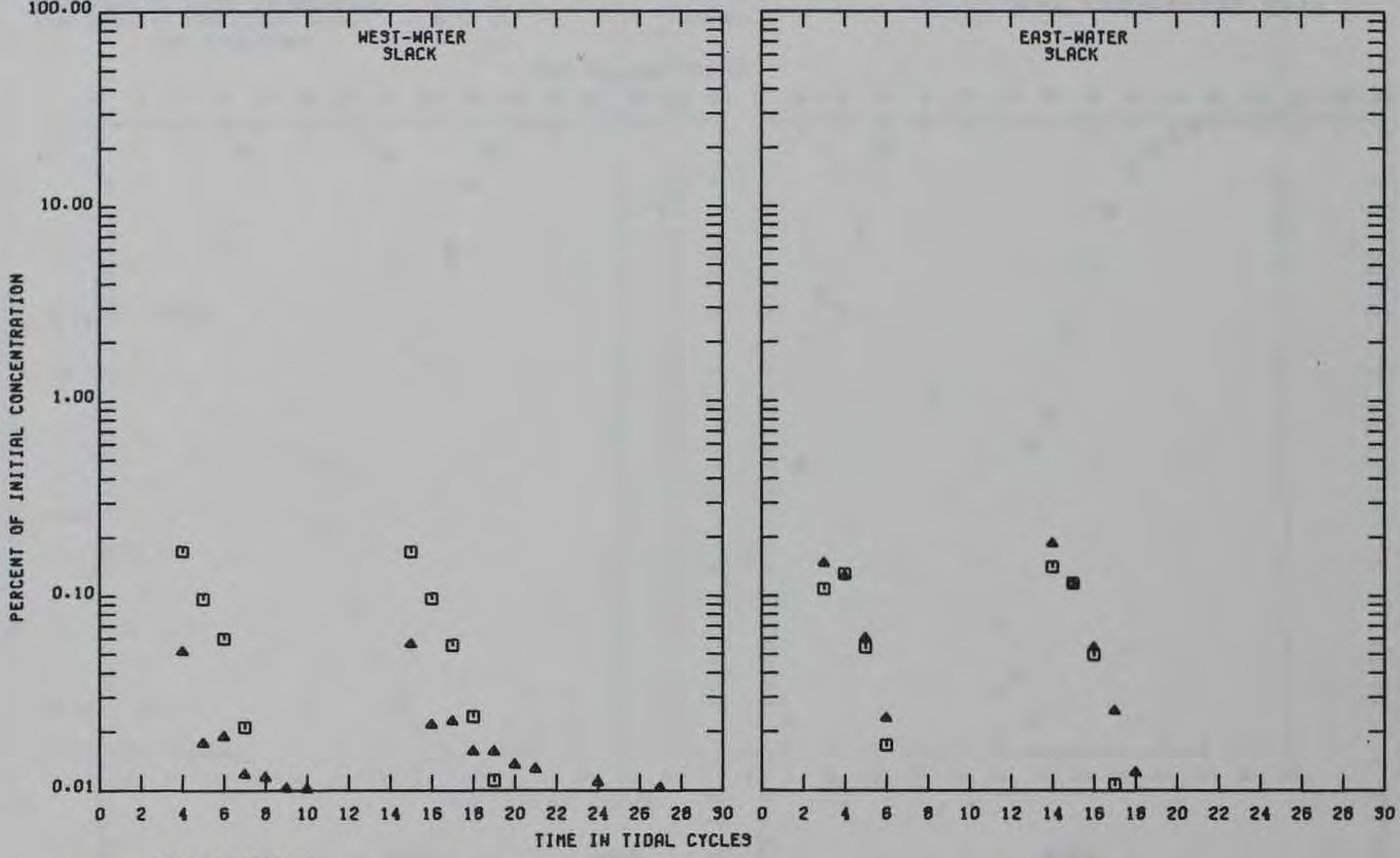
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 12



TEST CONDITIONS

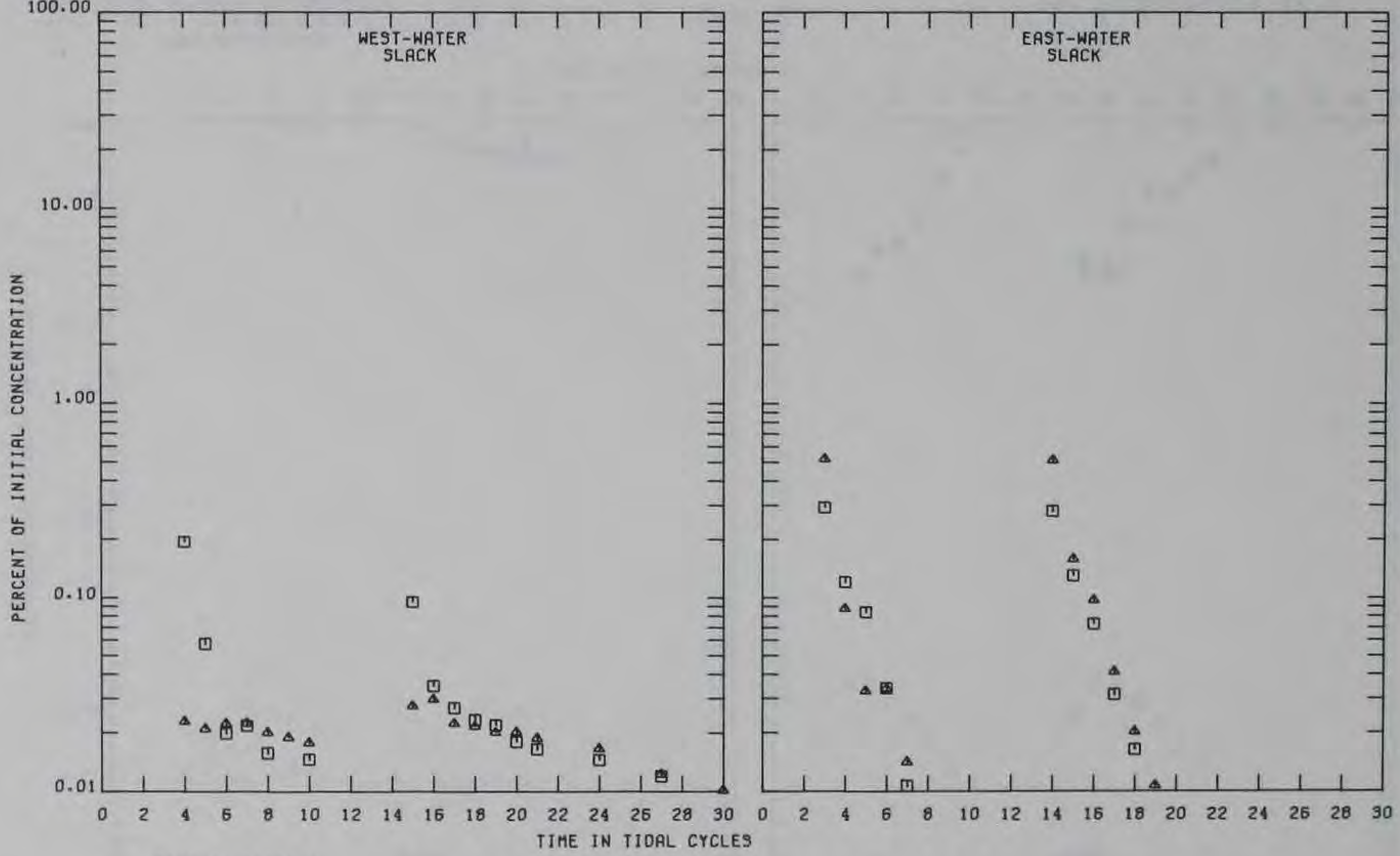
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 13



TEST CONDITIONS

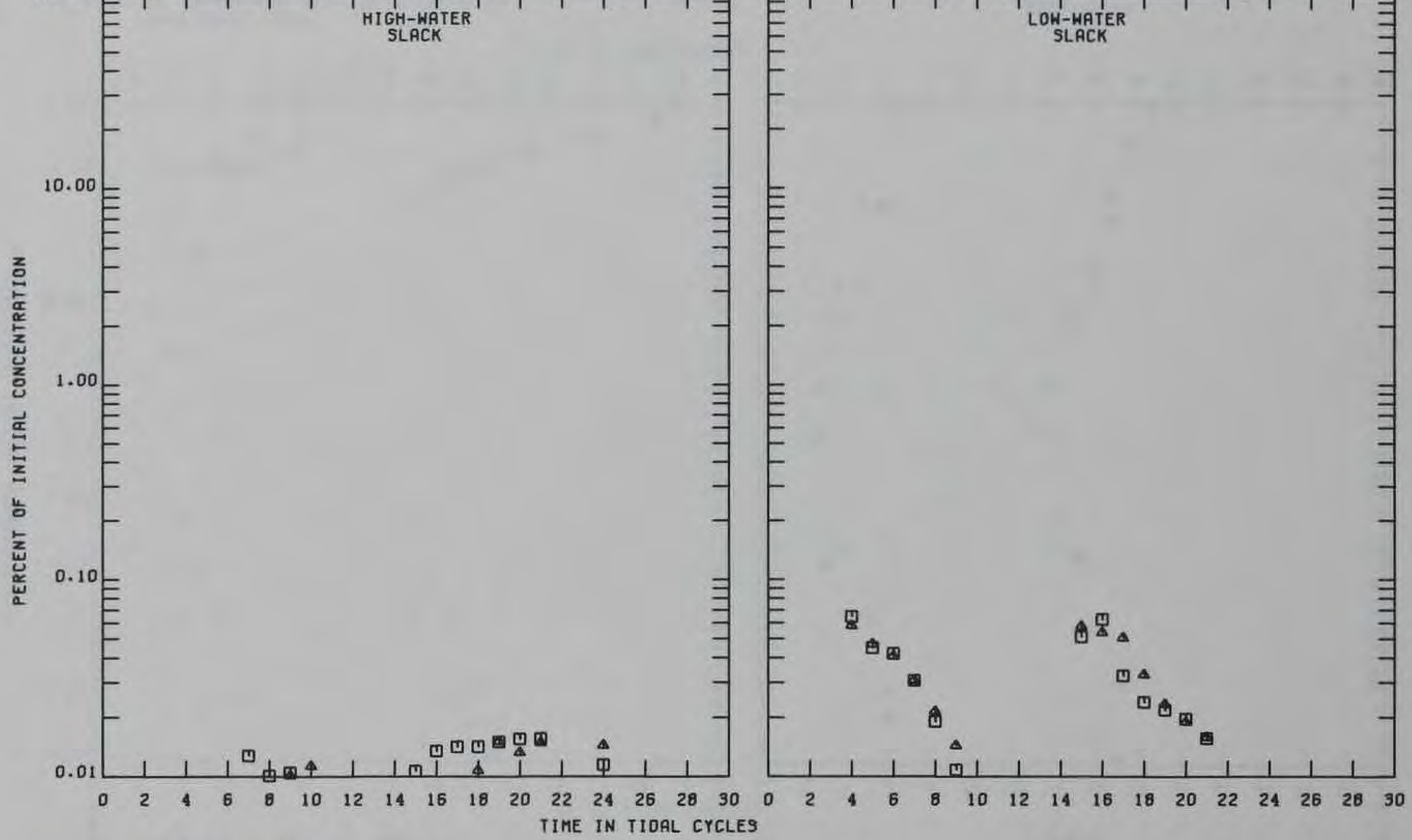
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

⊡ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 14



TEST CONDITIONS

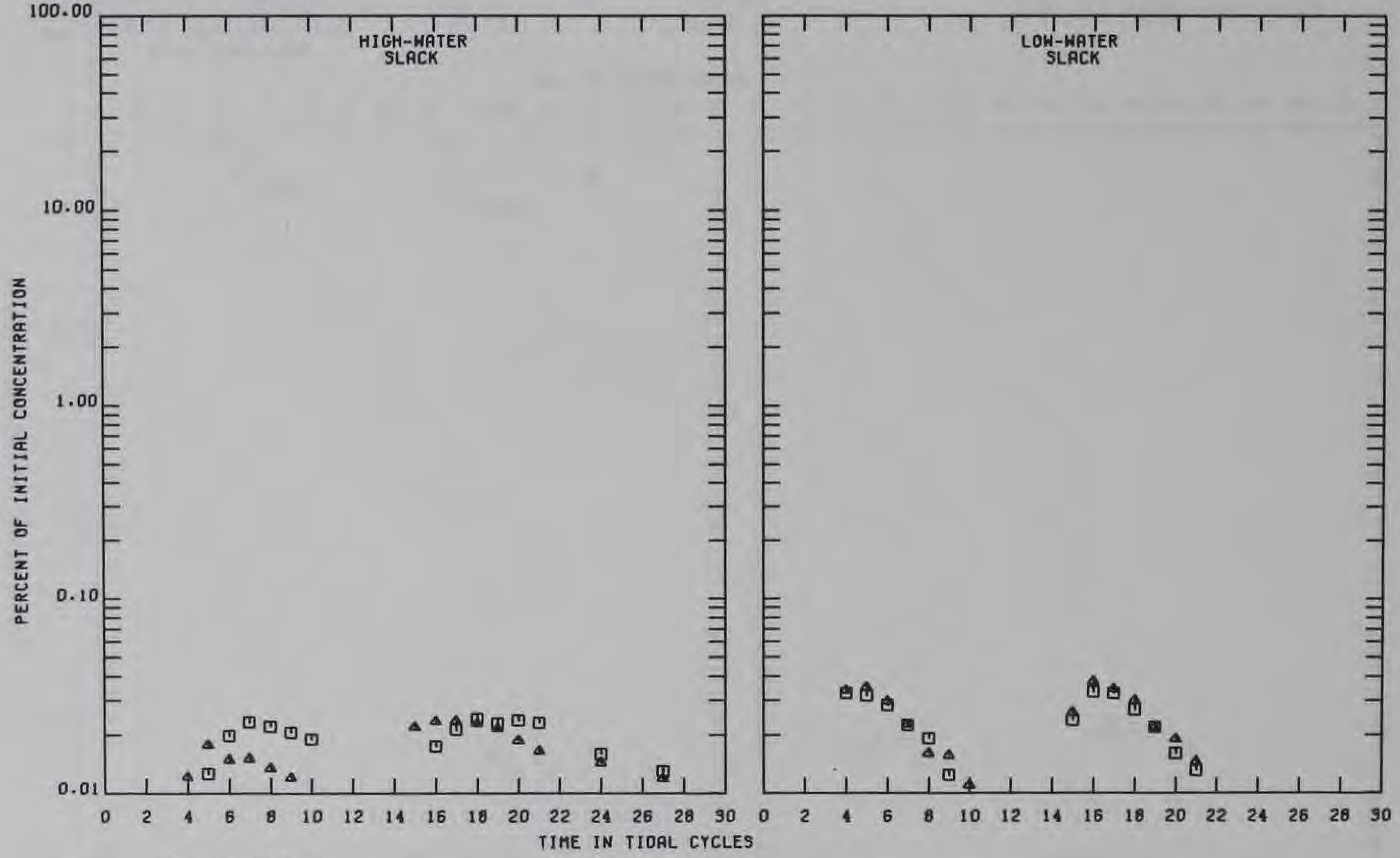
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344,200	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 15



TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 16

TEST CONDITIONS

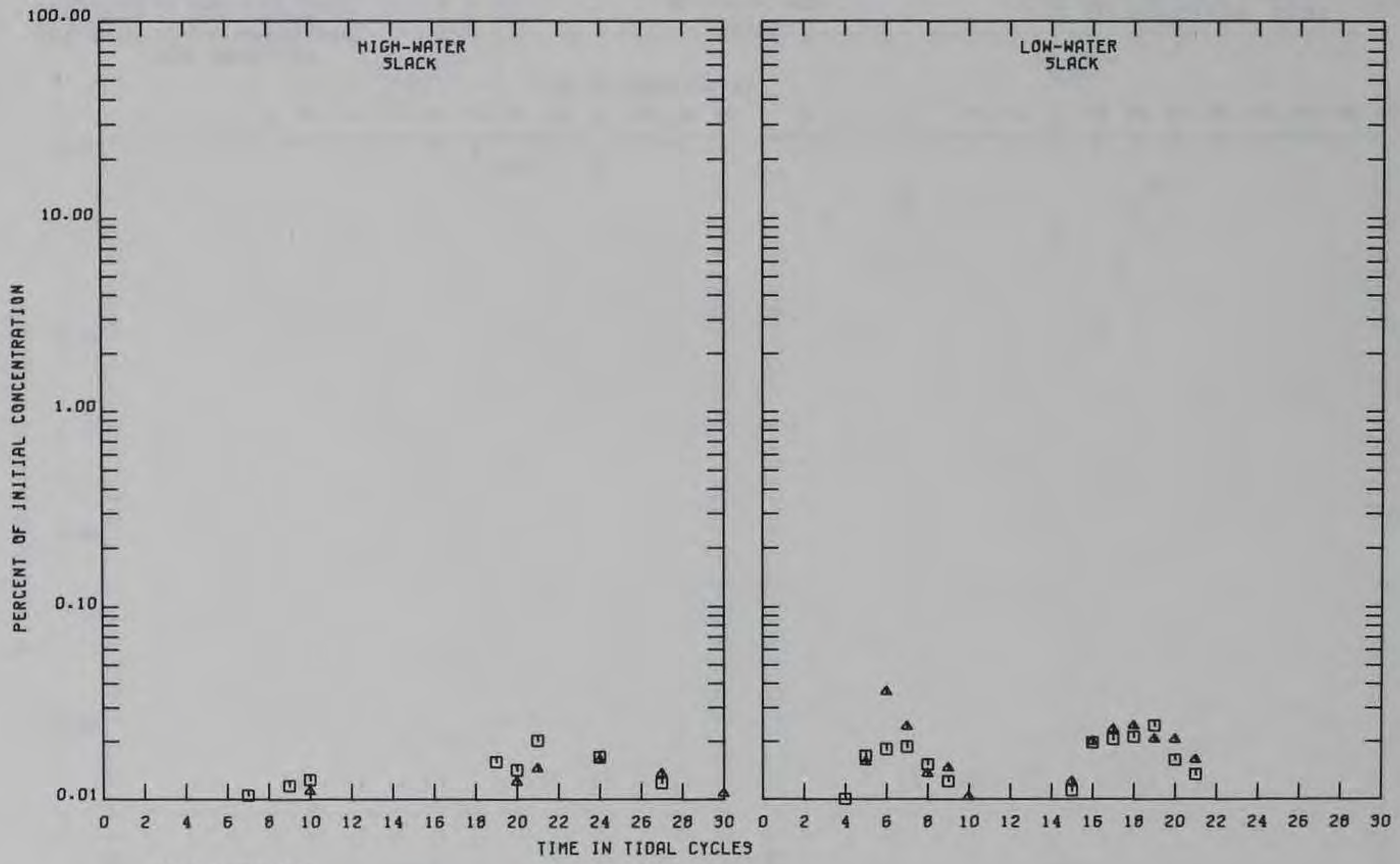
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 17



TEST CONDITIONS

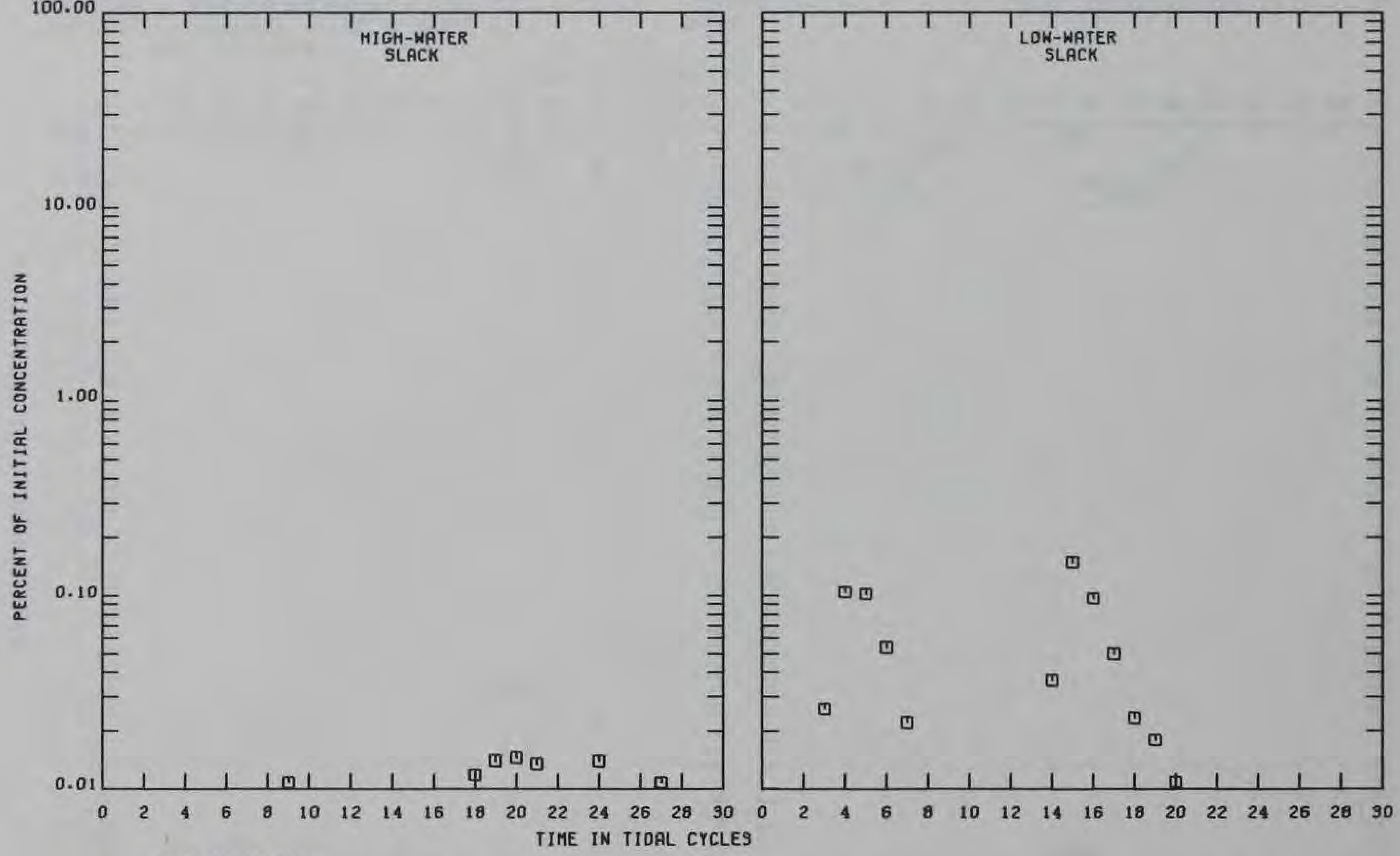
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

◻ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 18



TEST CONDITIONS

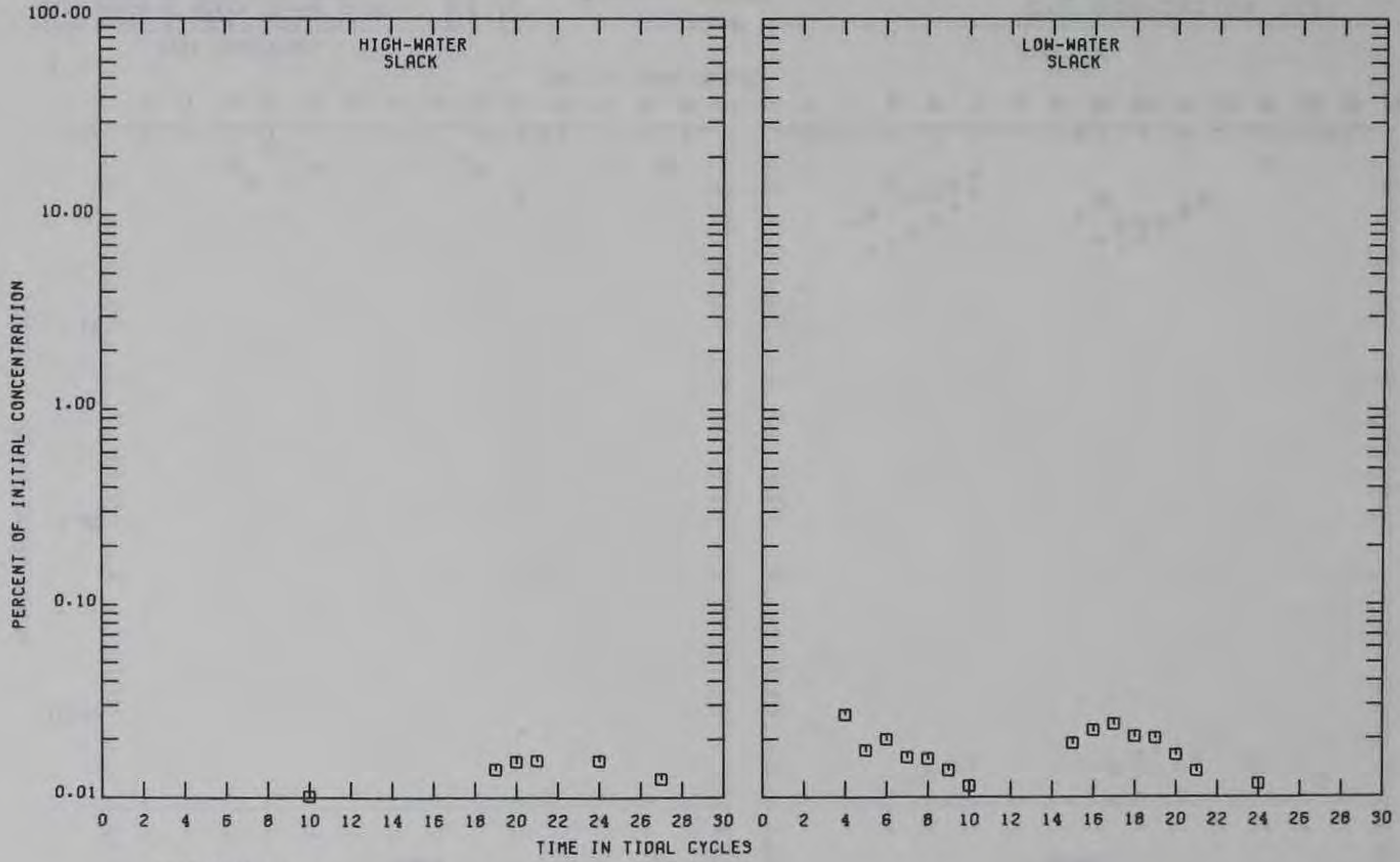
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

□ ——— BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 19 MID-DEPTH



TEST CONDITIONS

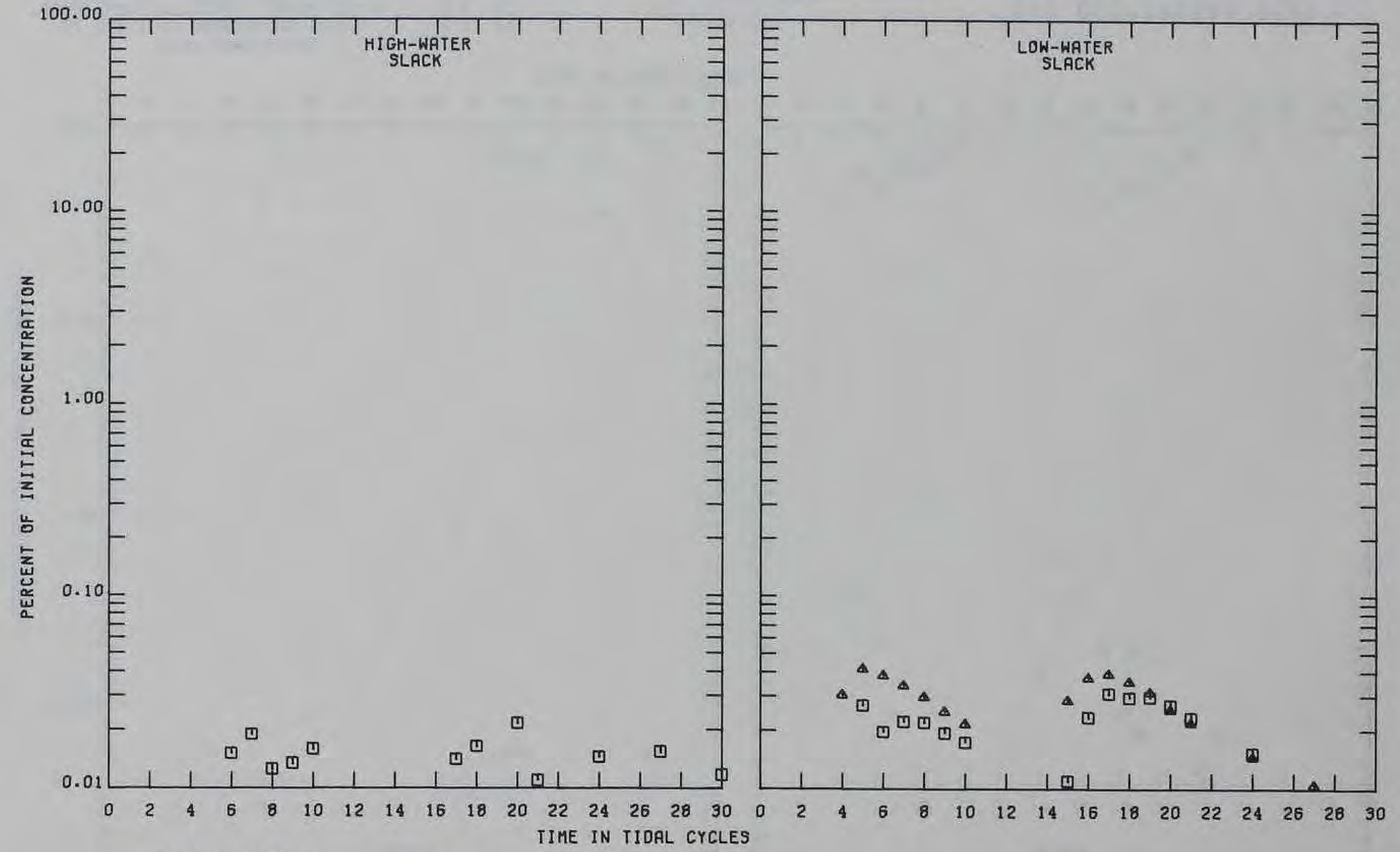
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344,200	PPB

LEGEND

□ ——— BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 20 MID-DEPTH



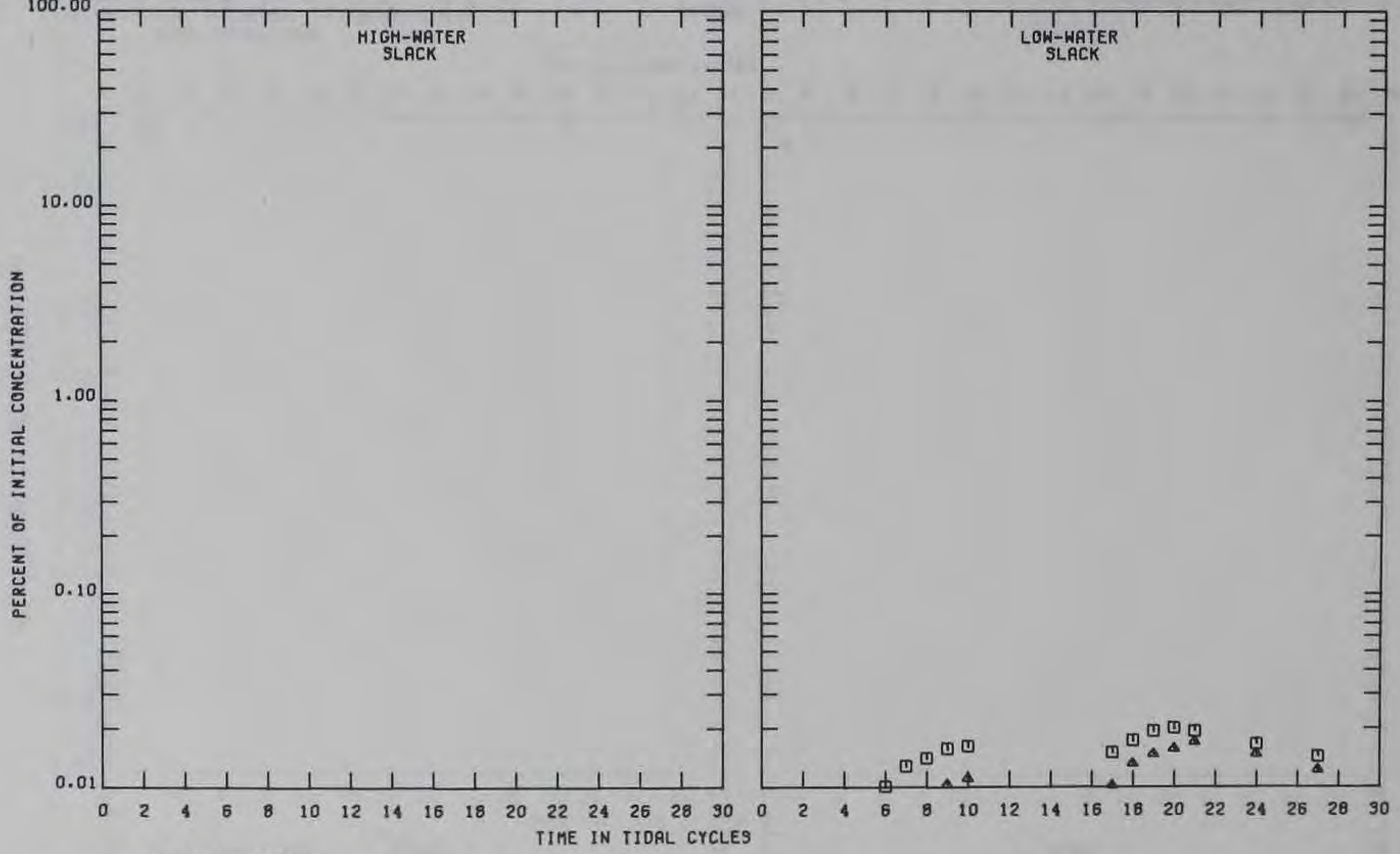
TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	344,200	PPB

LEGEND

⊡ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT
STATION 21



TEST CONDITIONS

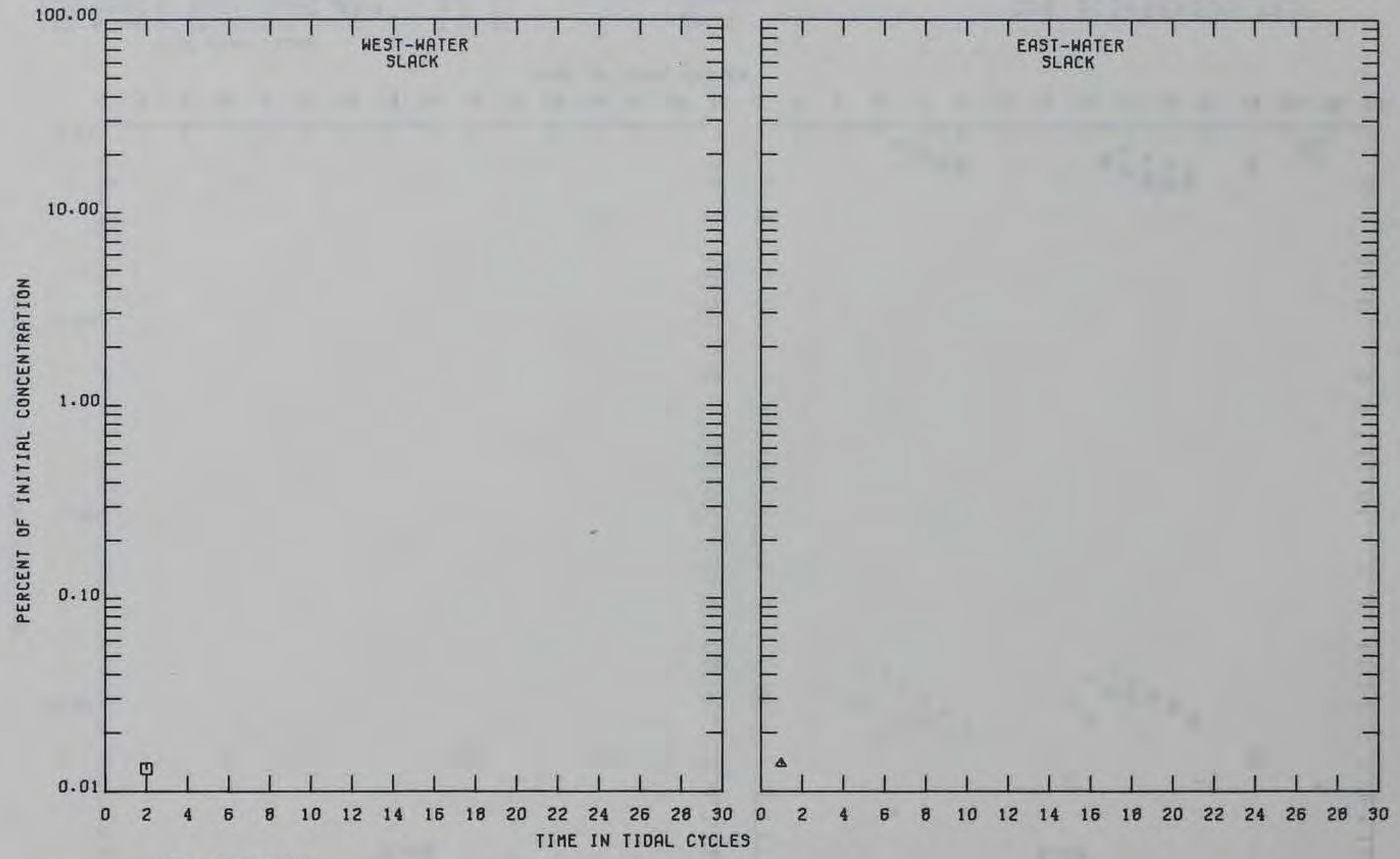
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	344.200	PPB

LEGEND

☐ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 22



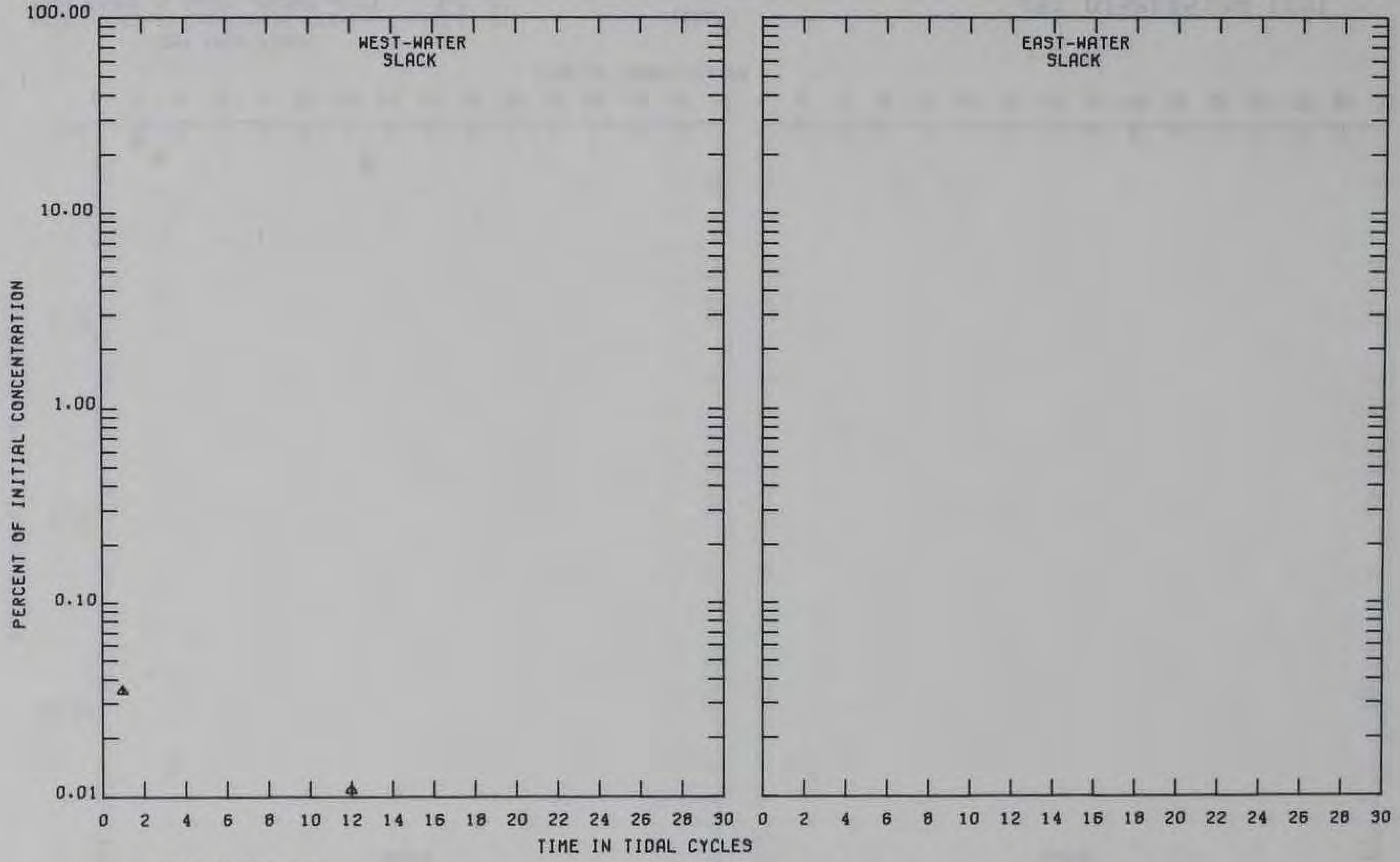
TEST CONDITIONS		
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 8



TEST CONDITIONS

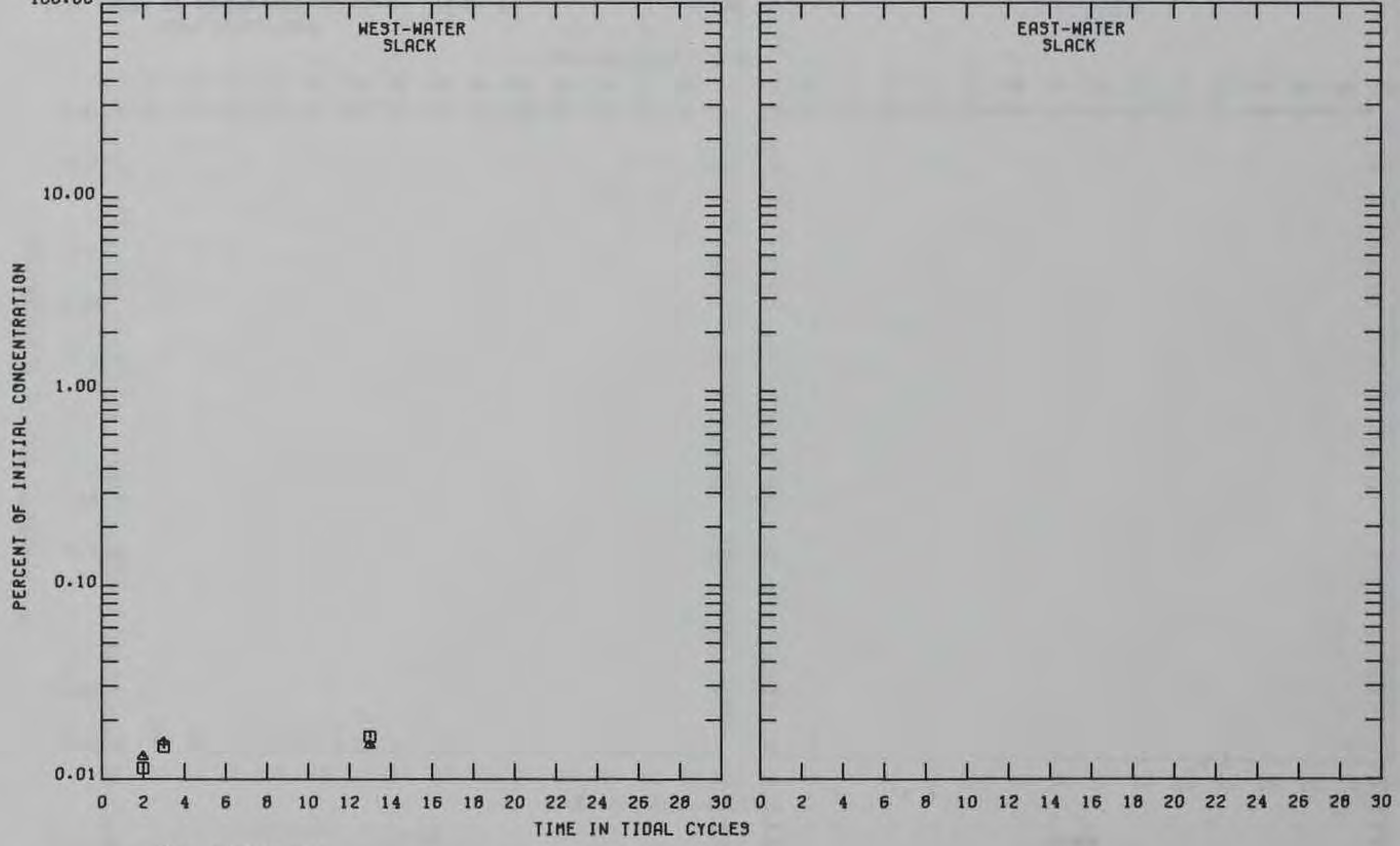
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE BASE
△ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 9



TEST CONDITIONS

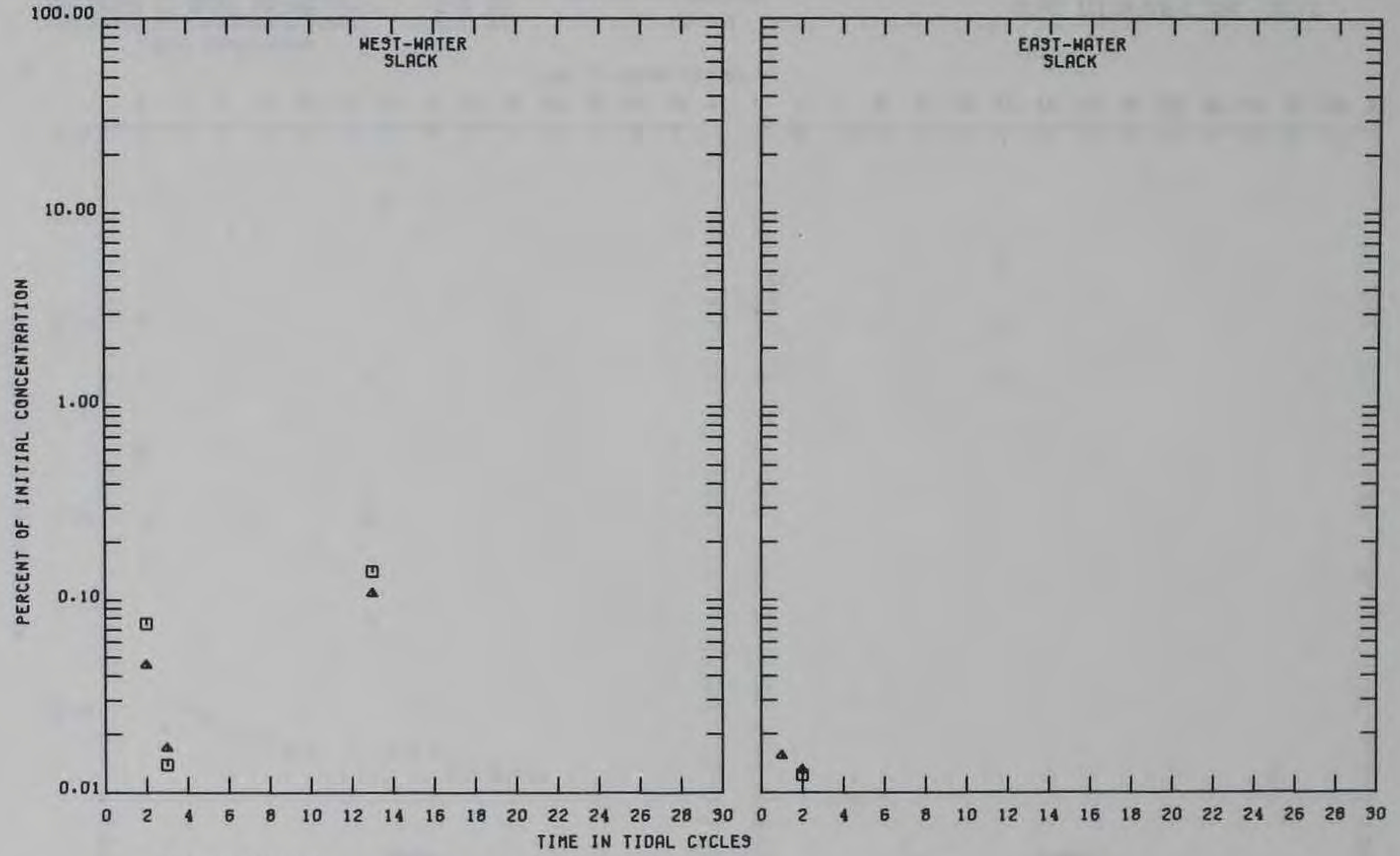
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 10



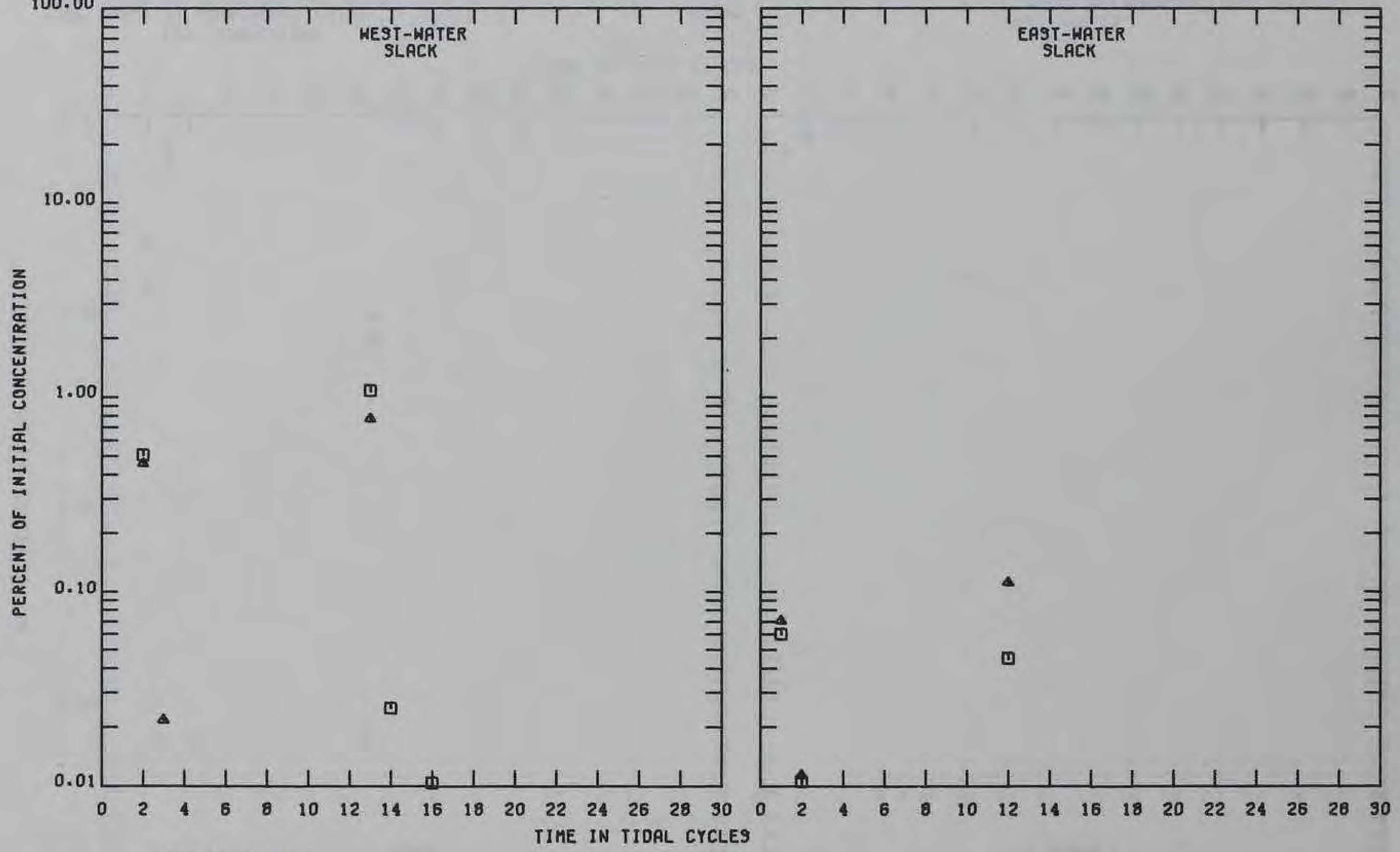
TEST CONDITIONS		
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

◻ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 11



TEST CONDITIONS		
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

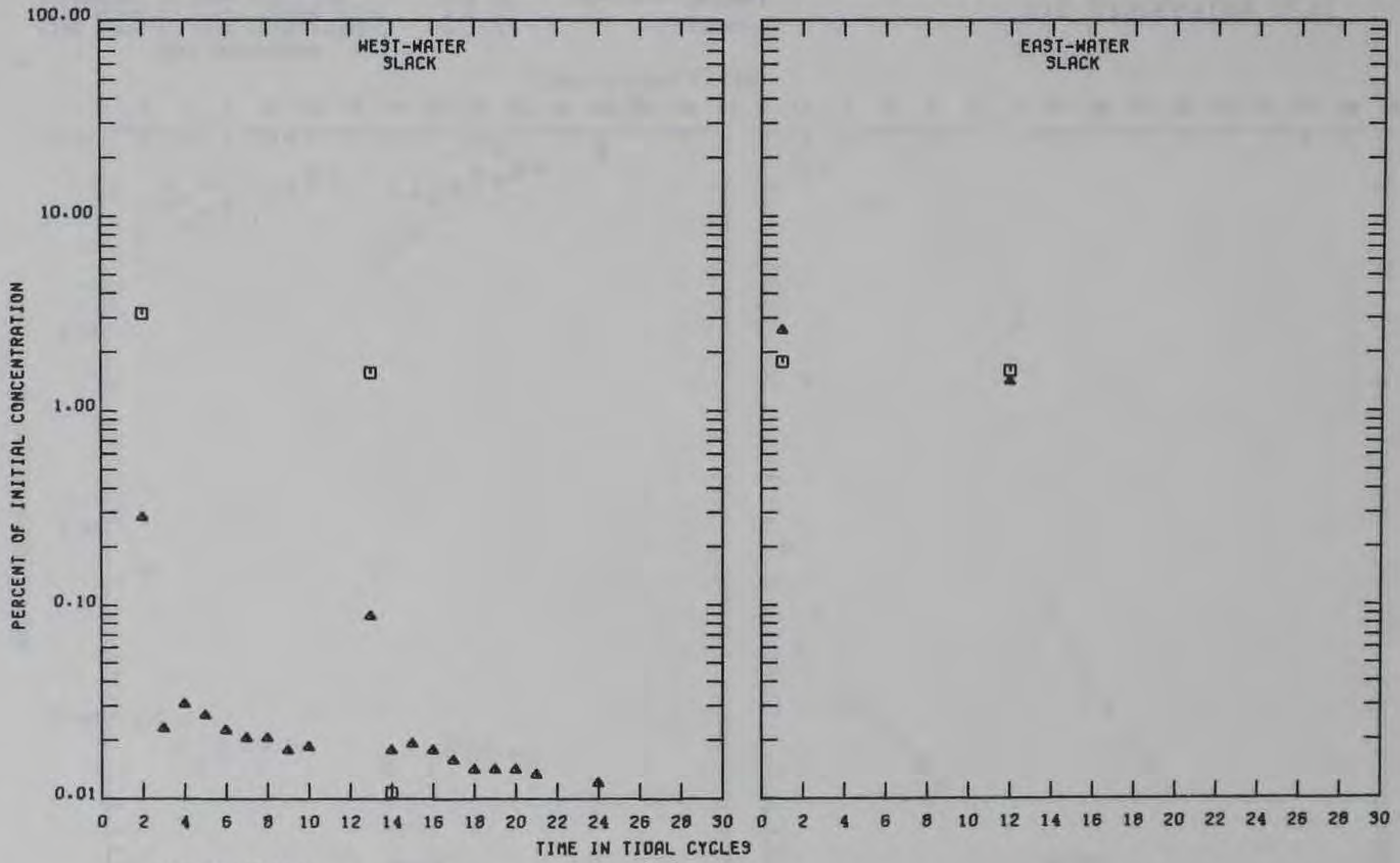
LEGEND

□ ——— SURFACE
▲ — — — BOTTOM

BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 12



TEST CONDITIONS

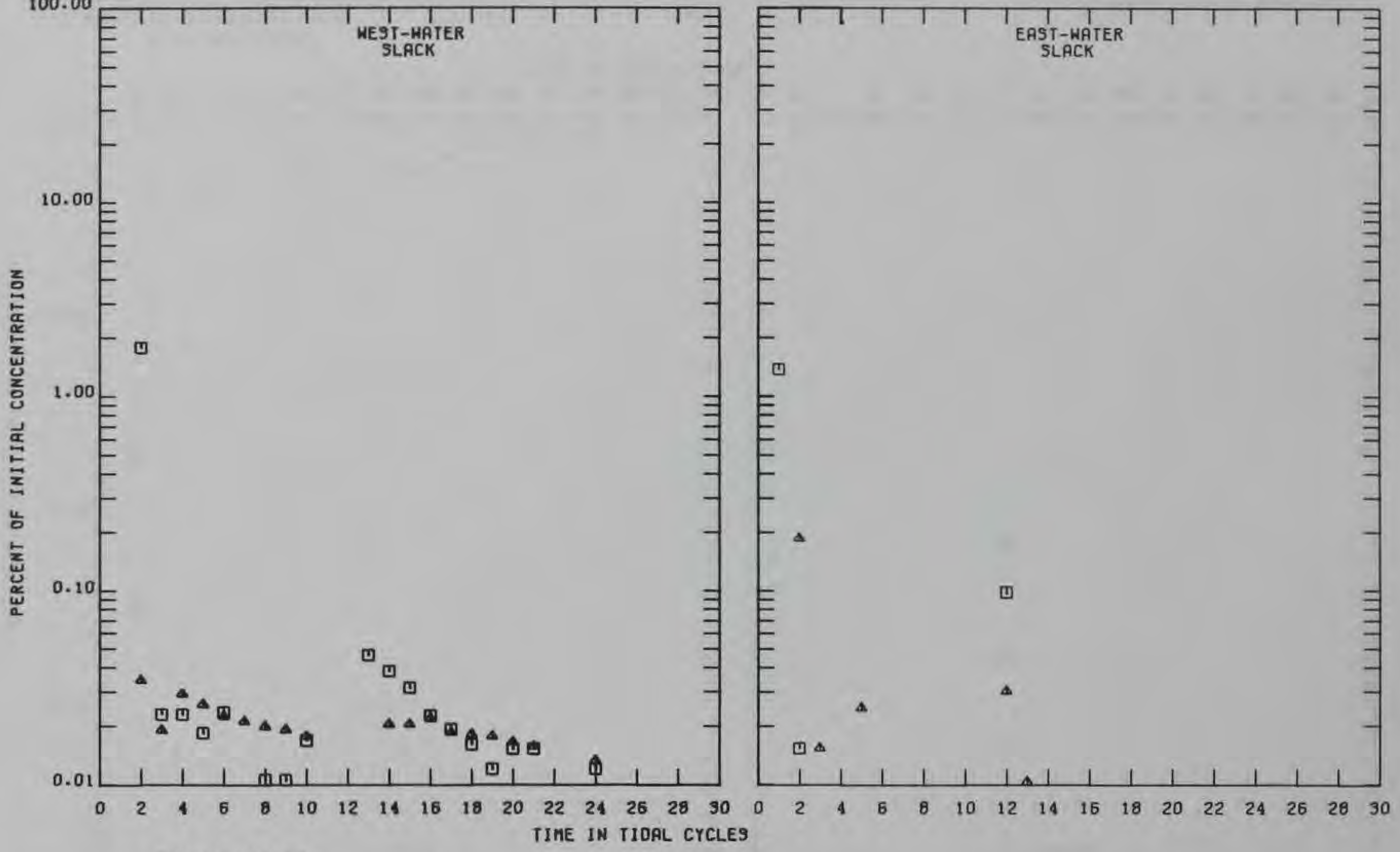
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 13



TEST CONDITIONS

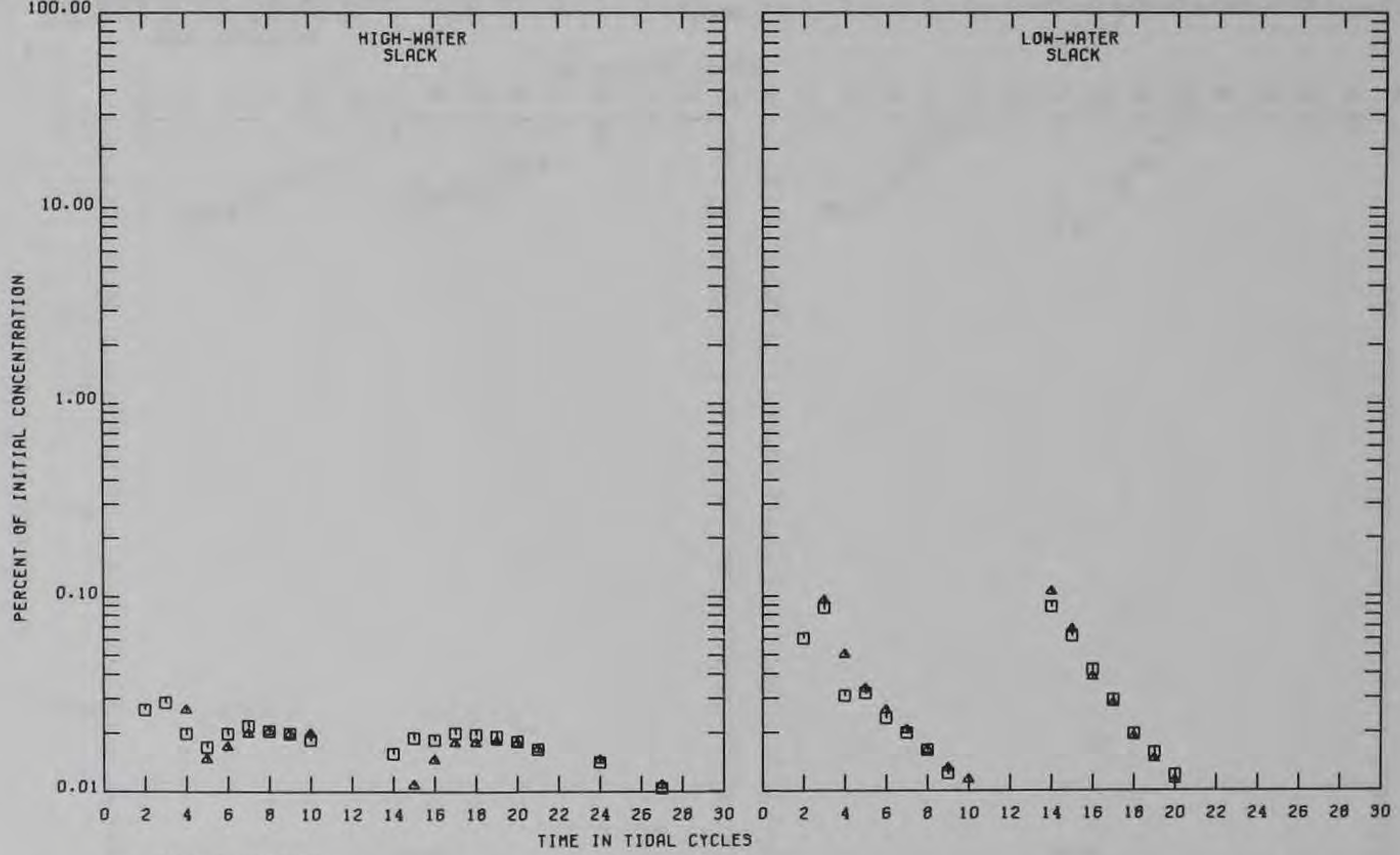
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 14



TEST CONDITIONS

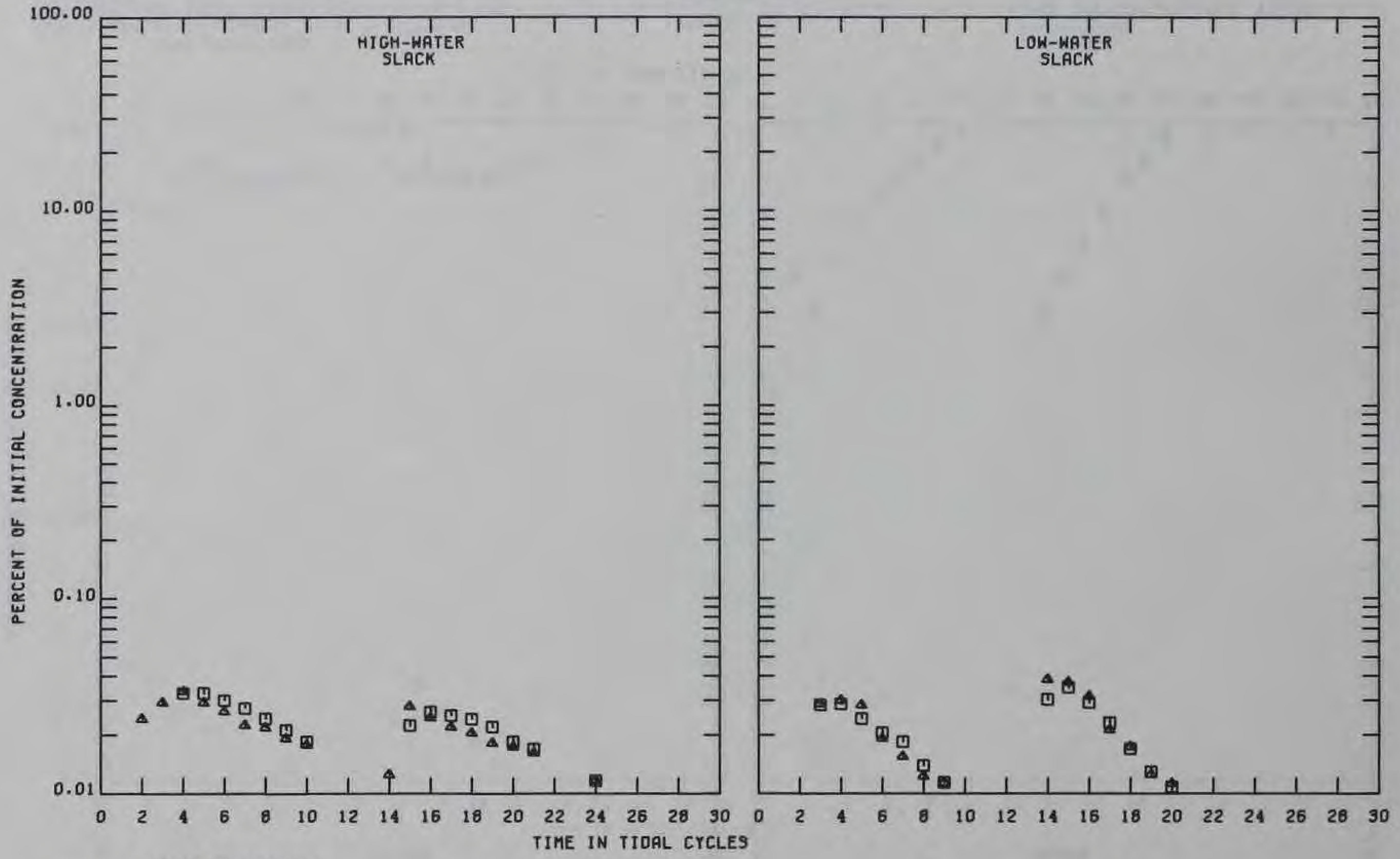
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE BASE
△ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 15



TEST CONDITIONS

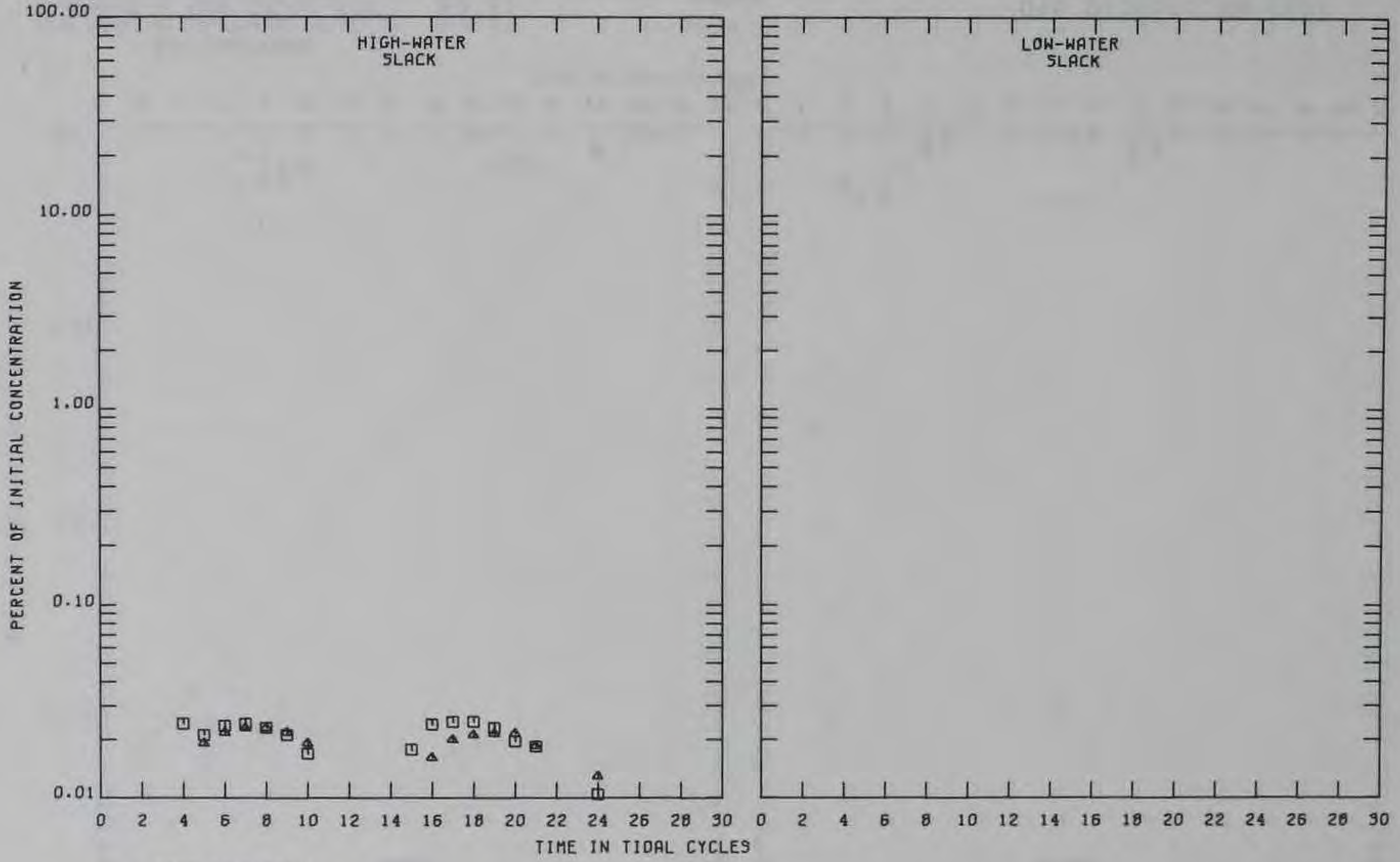
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 16



TEST CONDITIONS

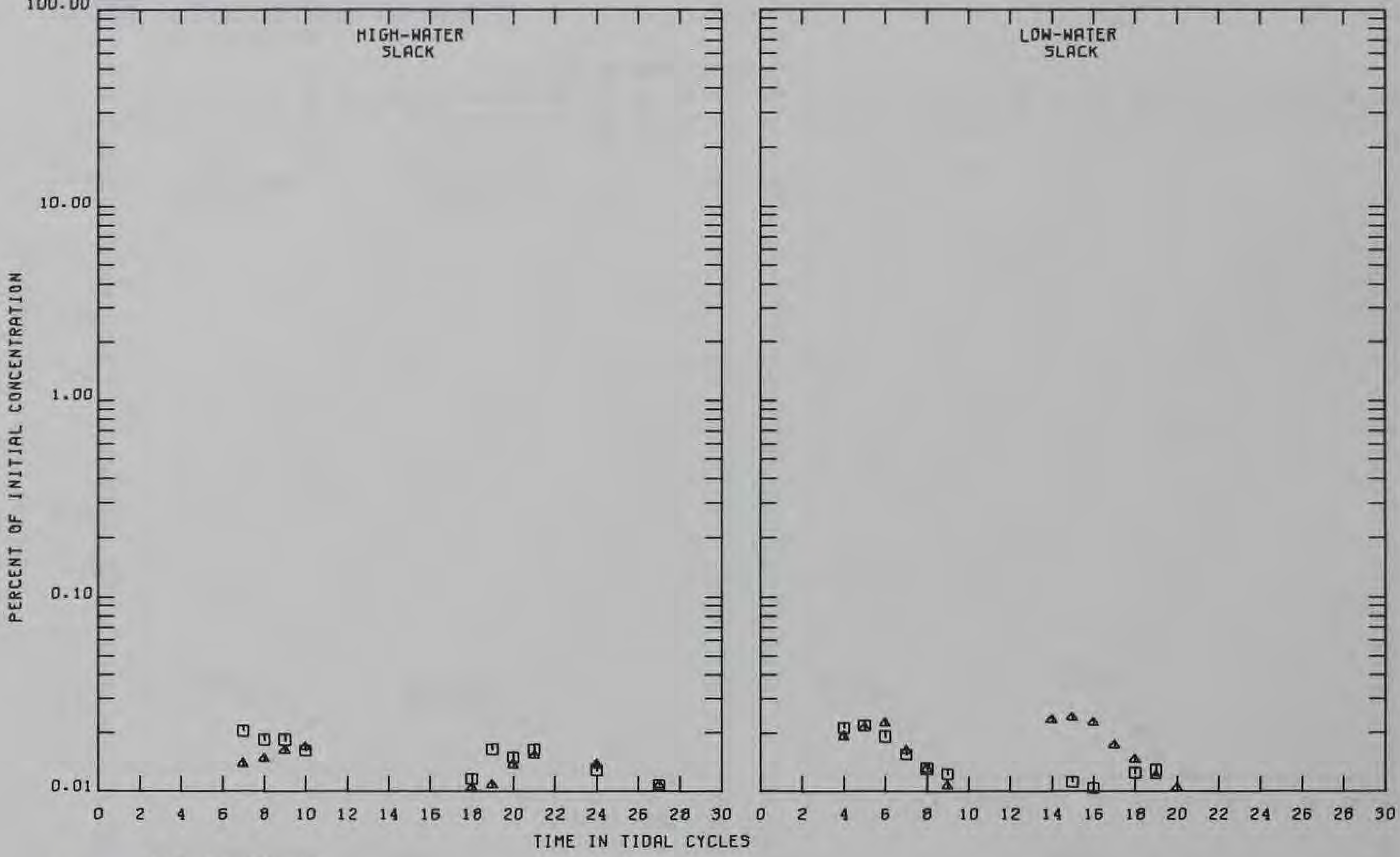
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

LEGEND

⊡ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 17



TEST CONDITIONS

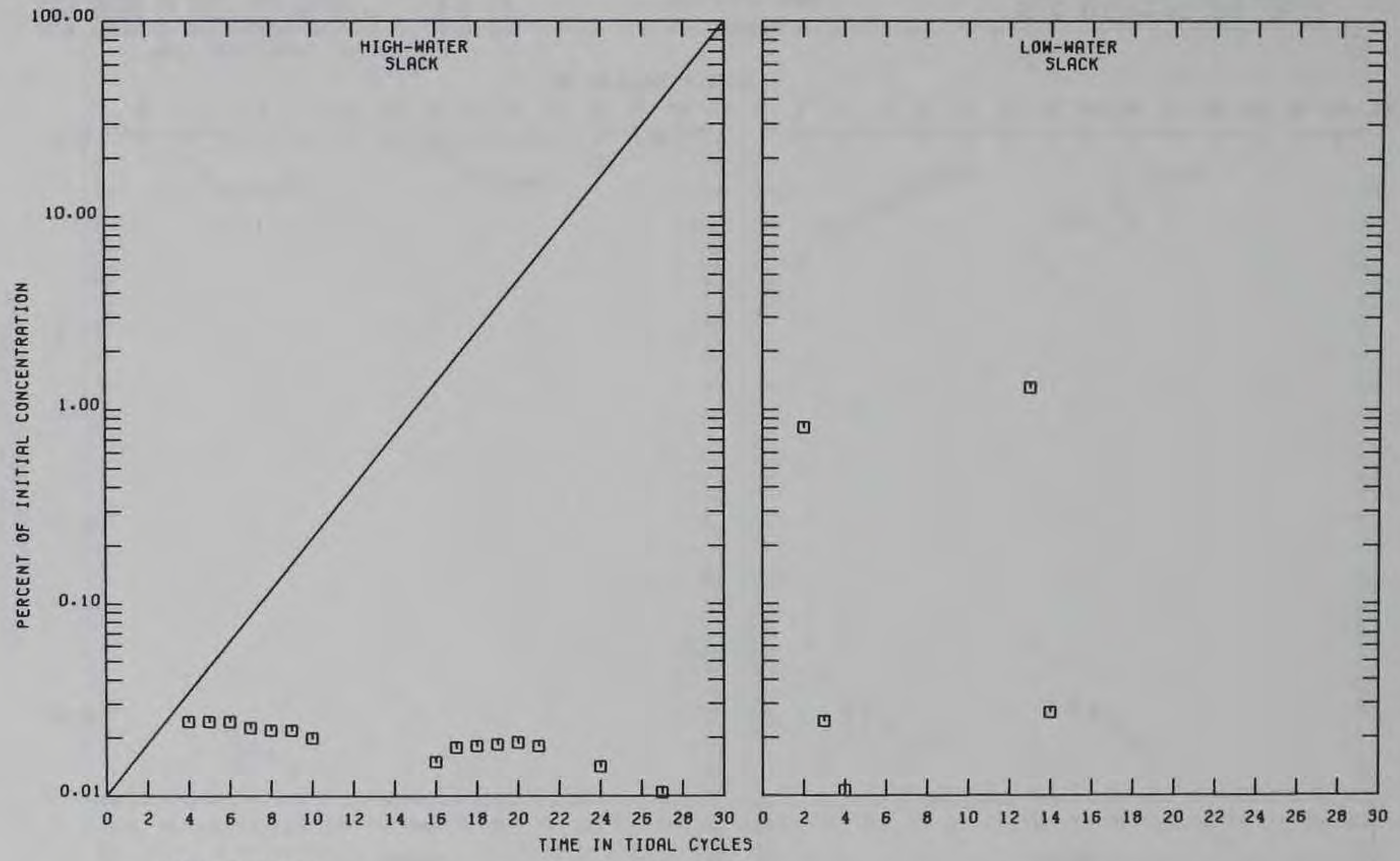
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 18



TEST CONDITIONS

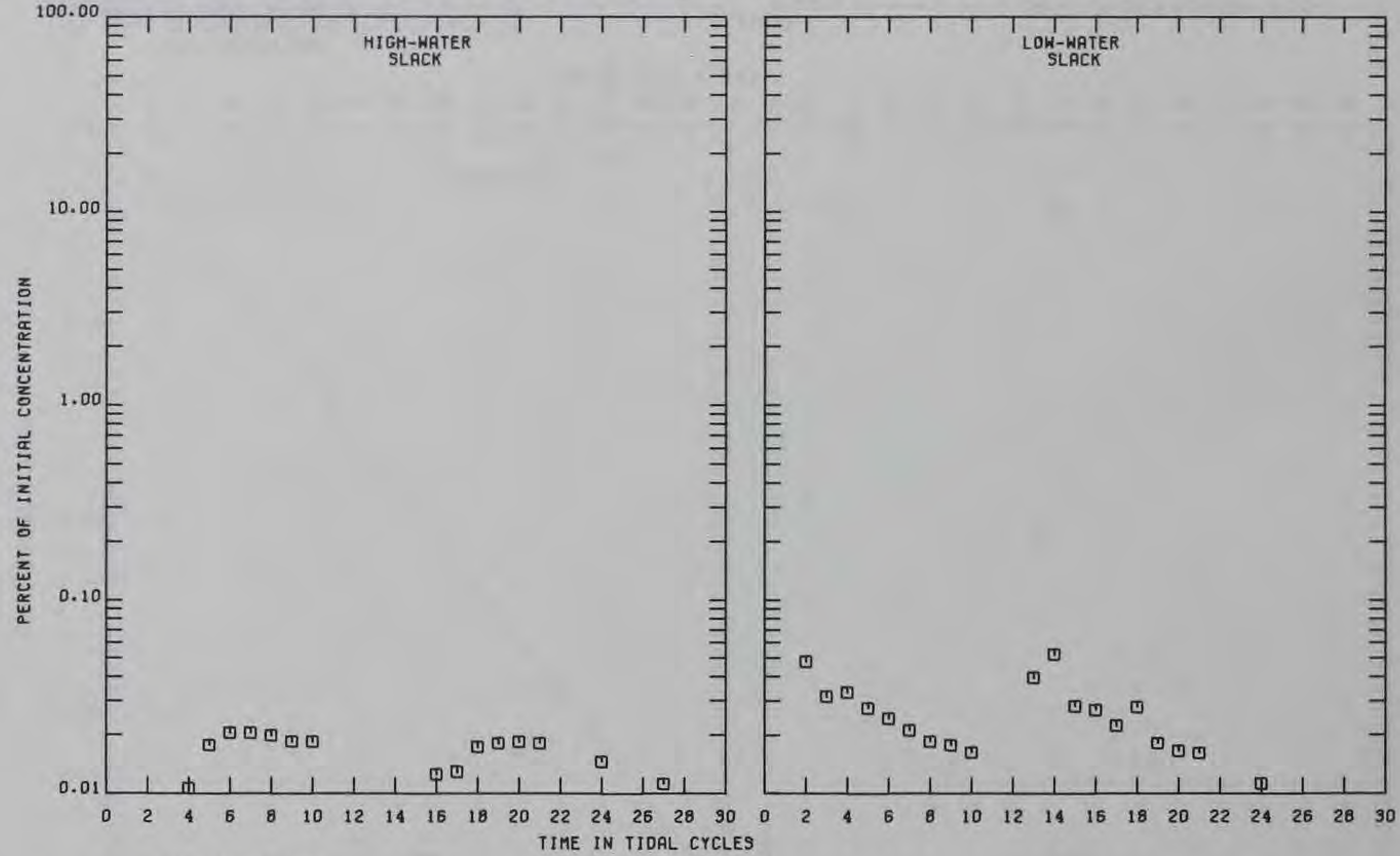
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

LEGEND

▢ ——— BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 19 MID-DEPTH

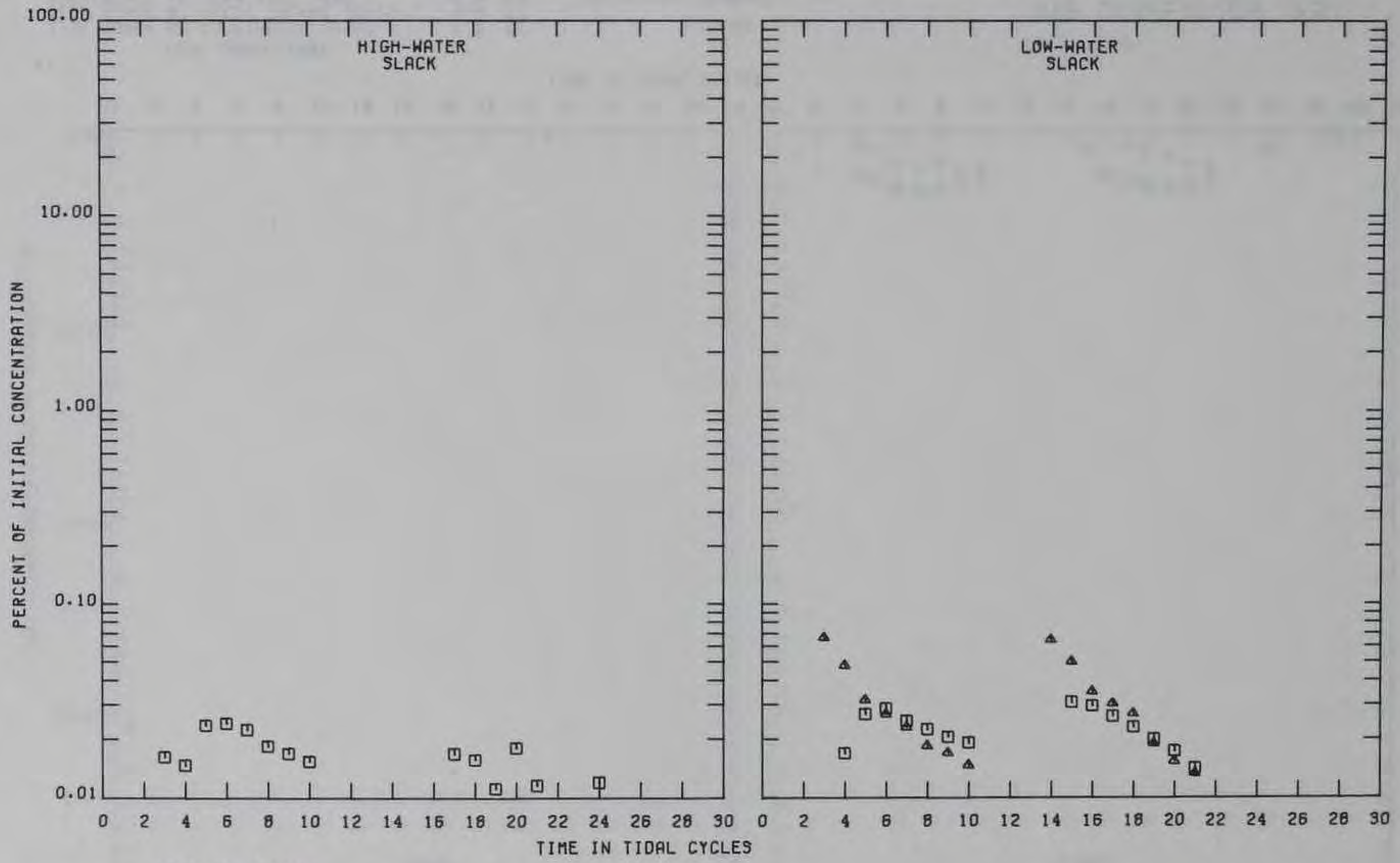


TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 20 MID-DEPTH



TEST CONDITIONS

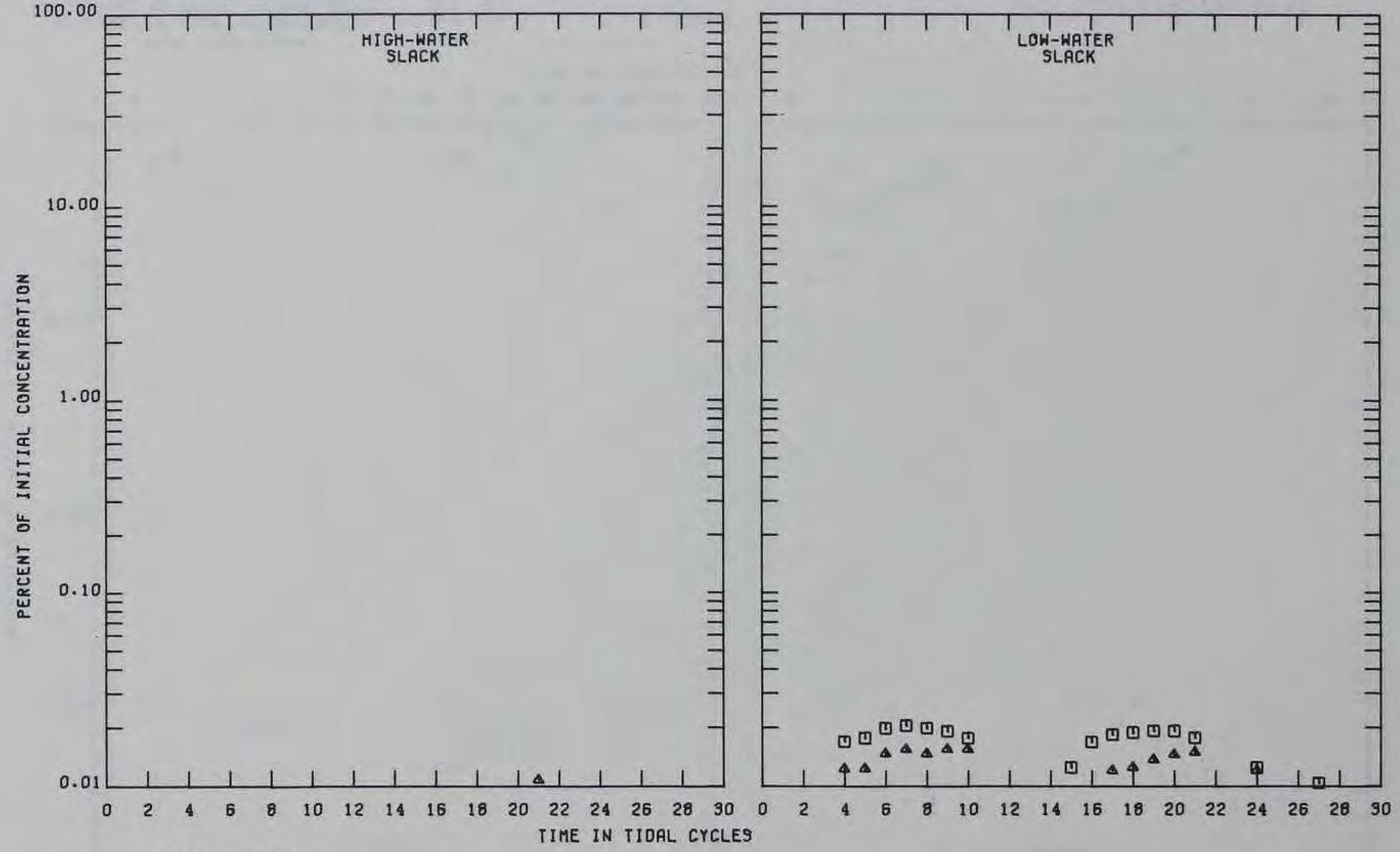
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	315,600	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 21



TEST CONDITIONS

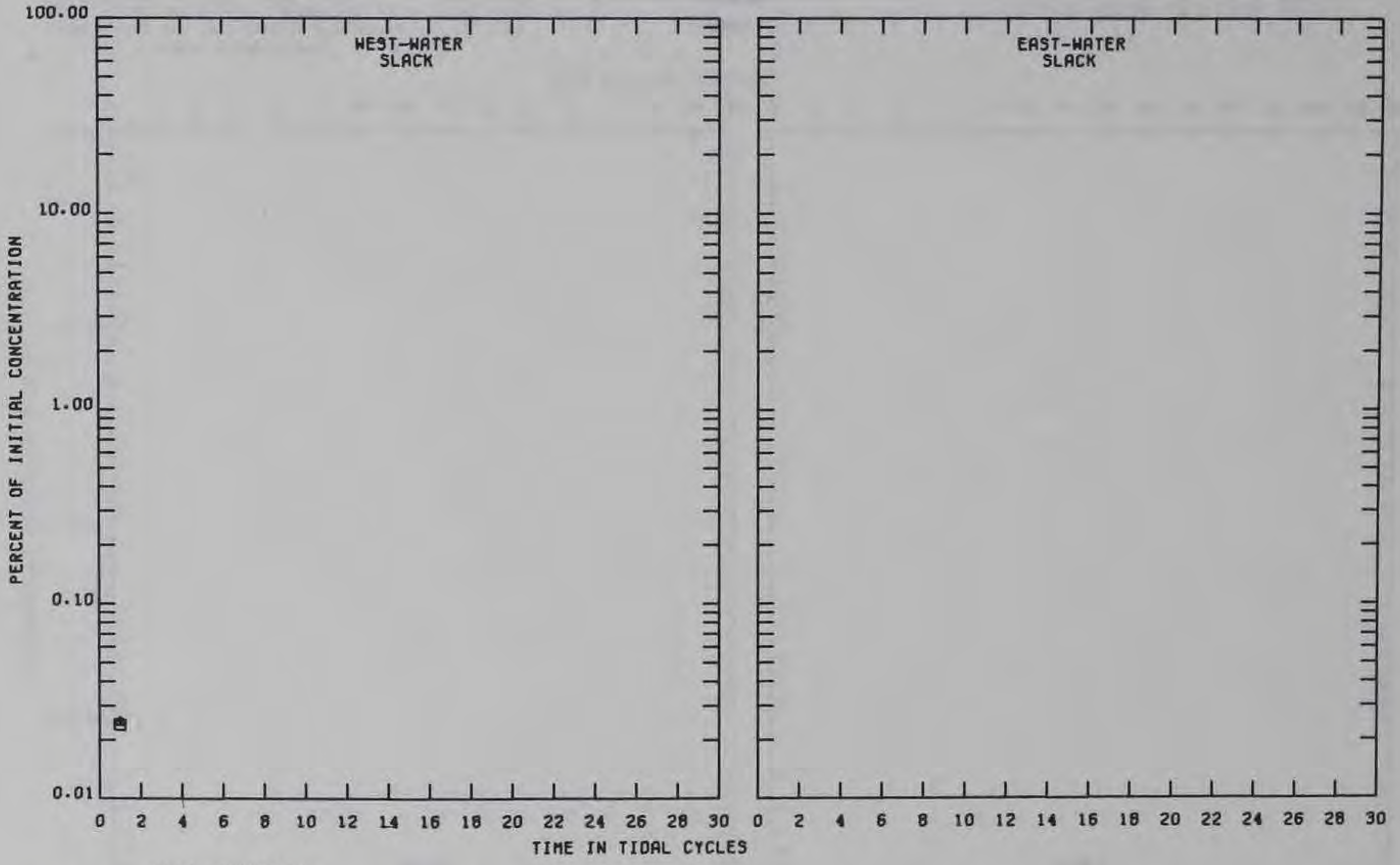
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	7000	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	315.600	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
27 FT X 250 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 22



TEST CONDITIONS

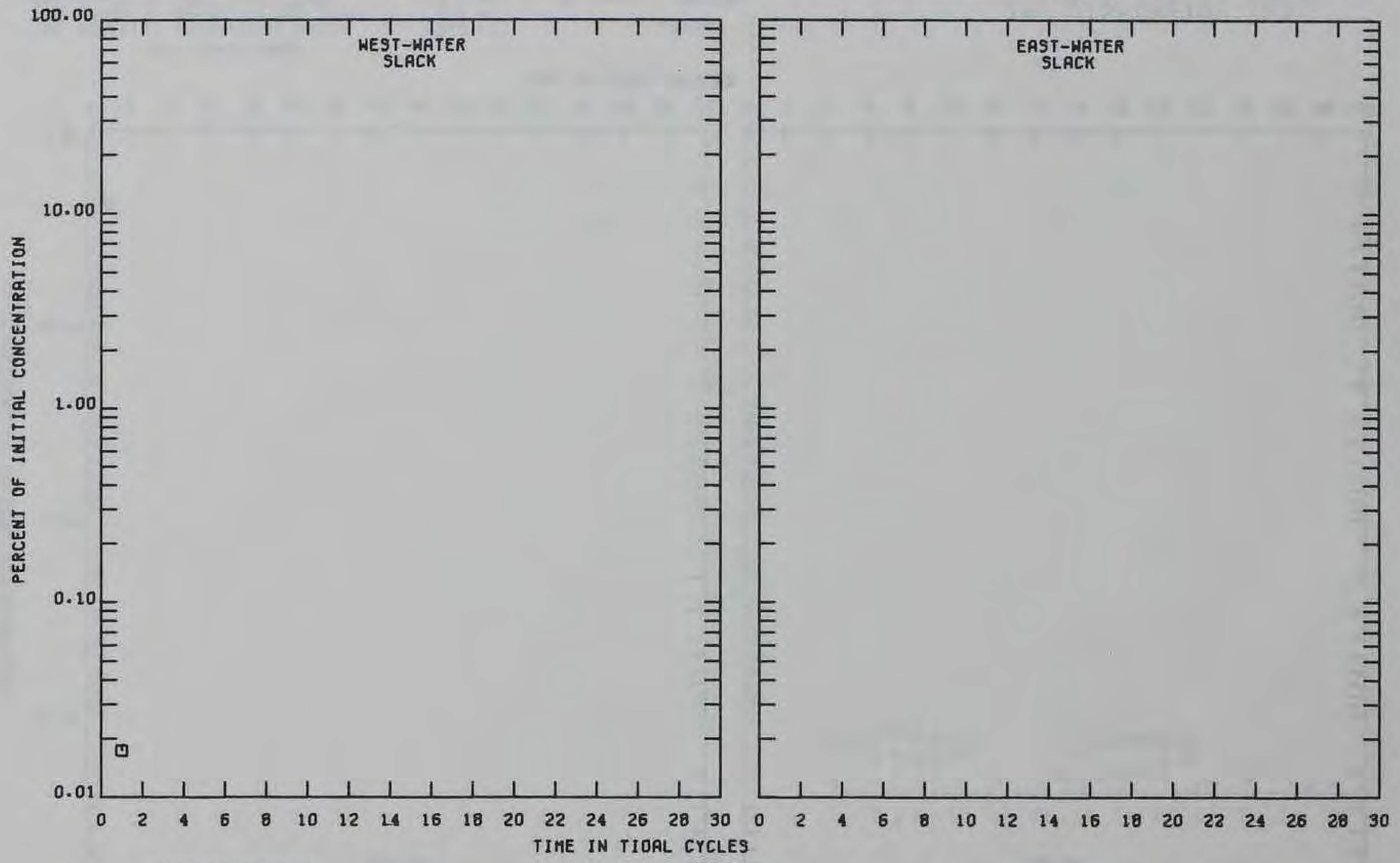
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 2



TEST CONDITIONS

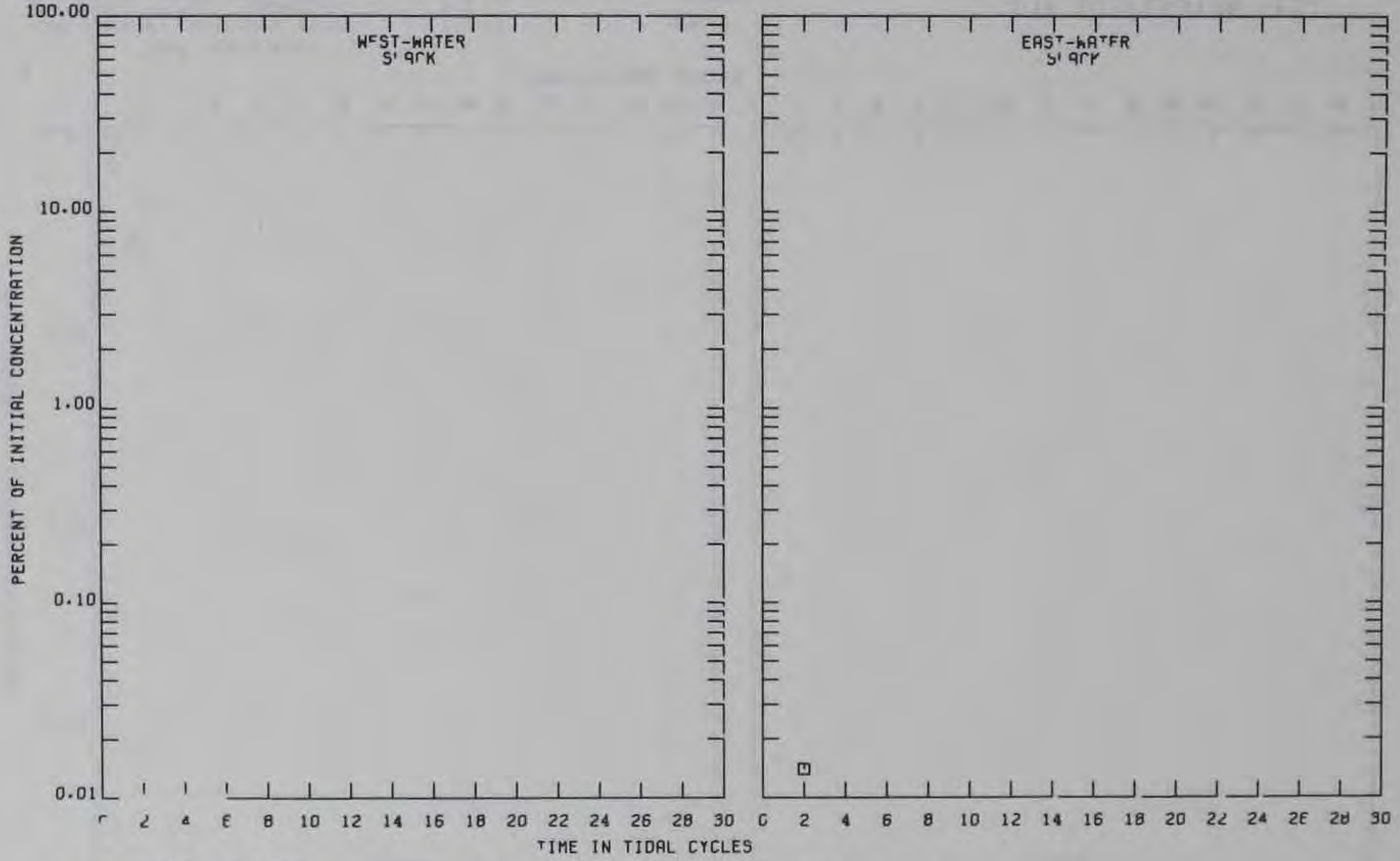
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 3



TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

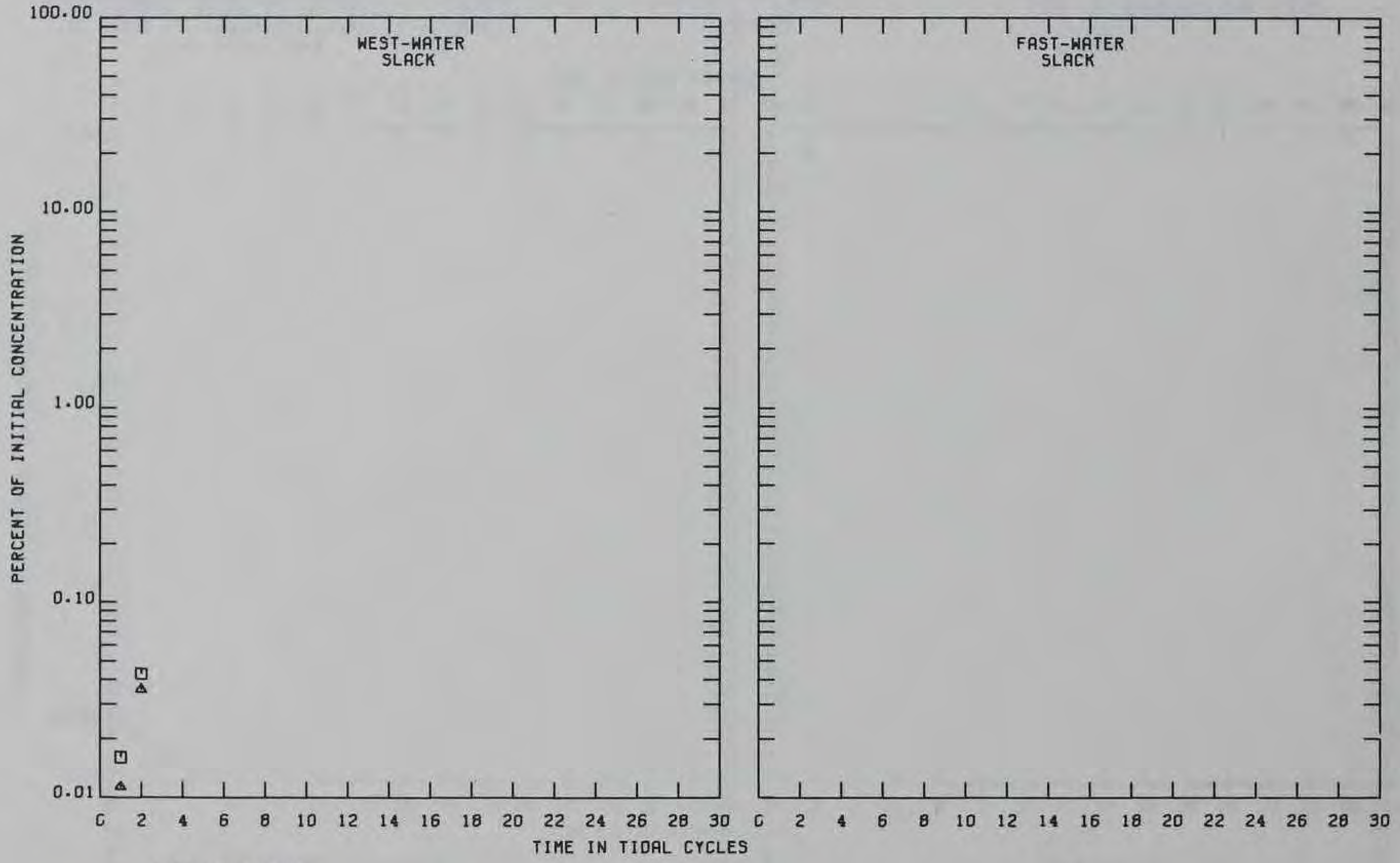
LEGEND

▢ ——— BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 4 MID-DEPTH

PLATE 182



TEST CONDITIONS

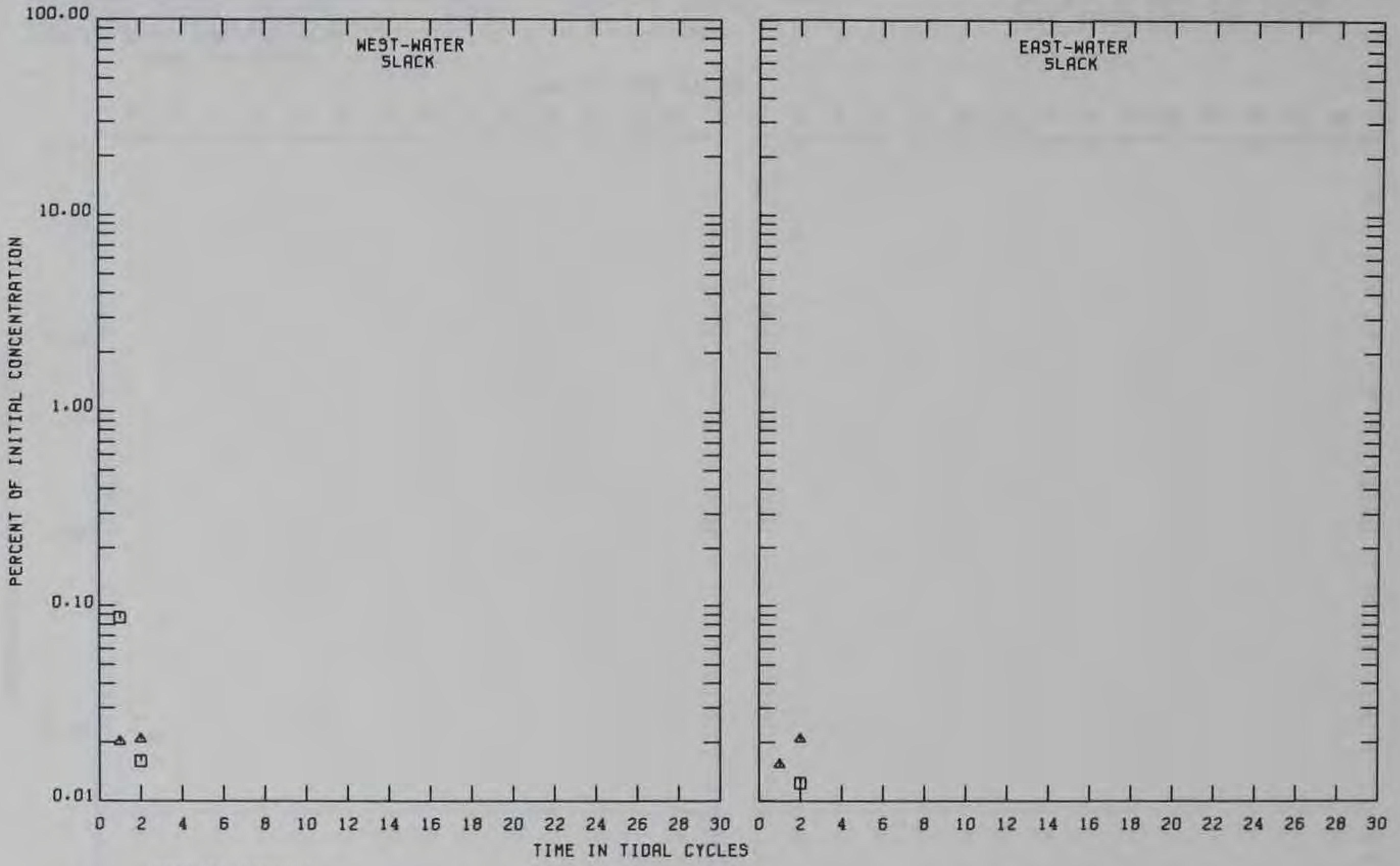
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 6



TEST CONDITIONS

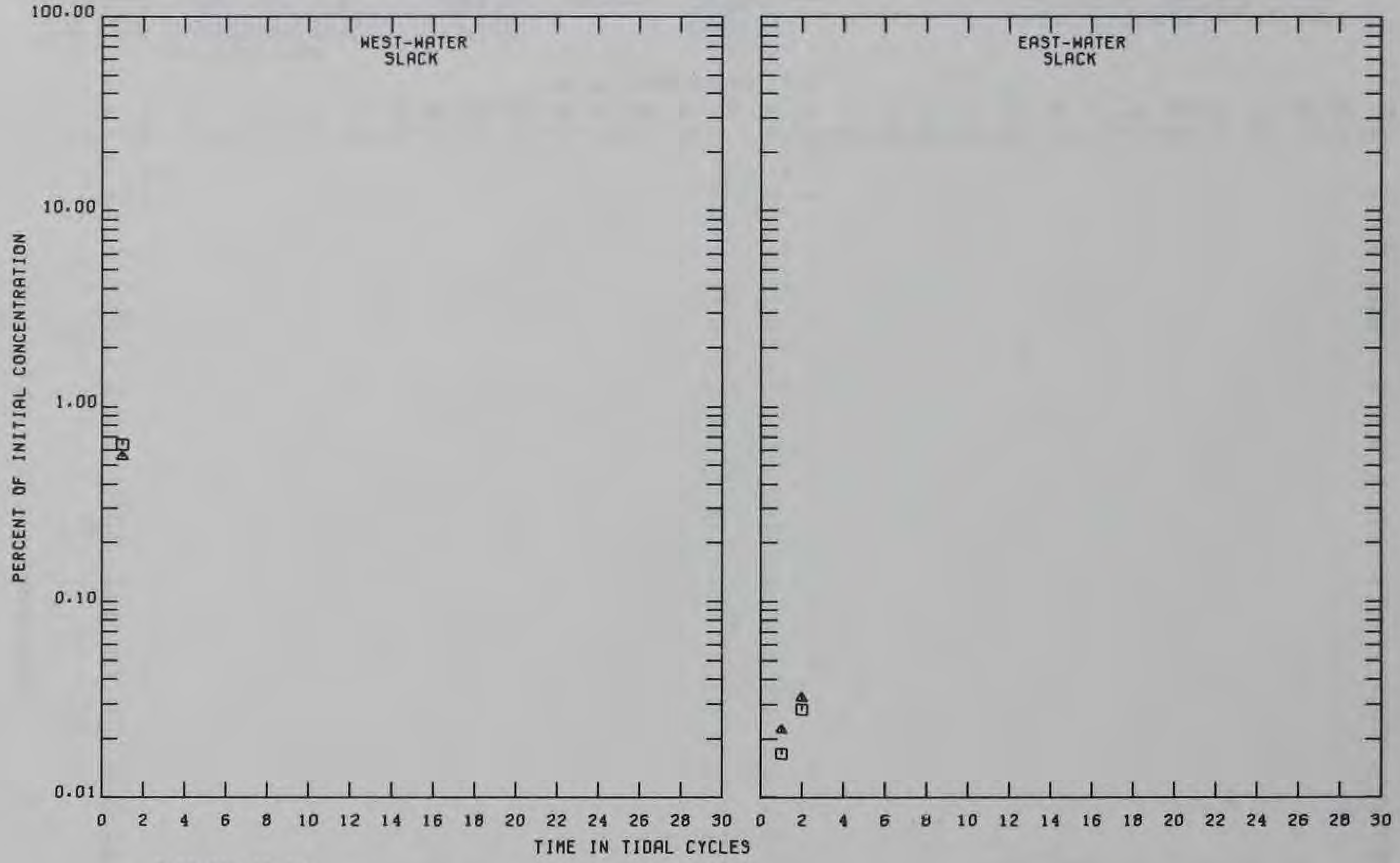
TIDE RANGE AT COURTHOUSE POINT	2.2 FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5 FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7 FT
NET CANAL DISCHARGE (EASTWARD)	21,200 CFS
DELAWARE RIVER COMBINED INFLOW	20,200 CFS
OCEAN SALINITY	31,000 PPM
INITIAL DYE CONCENTRATION	384,000 PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 7

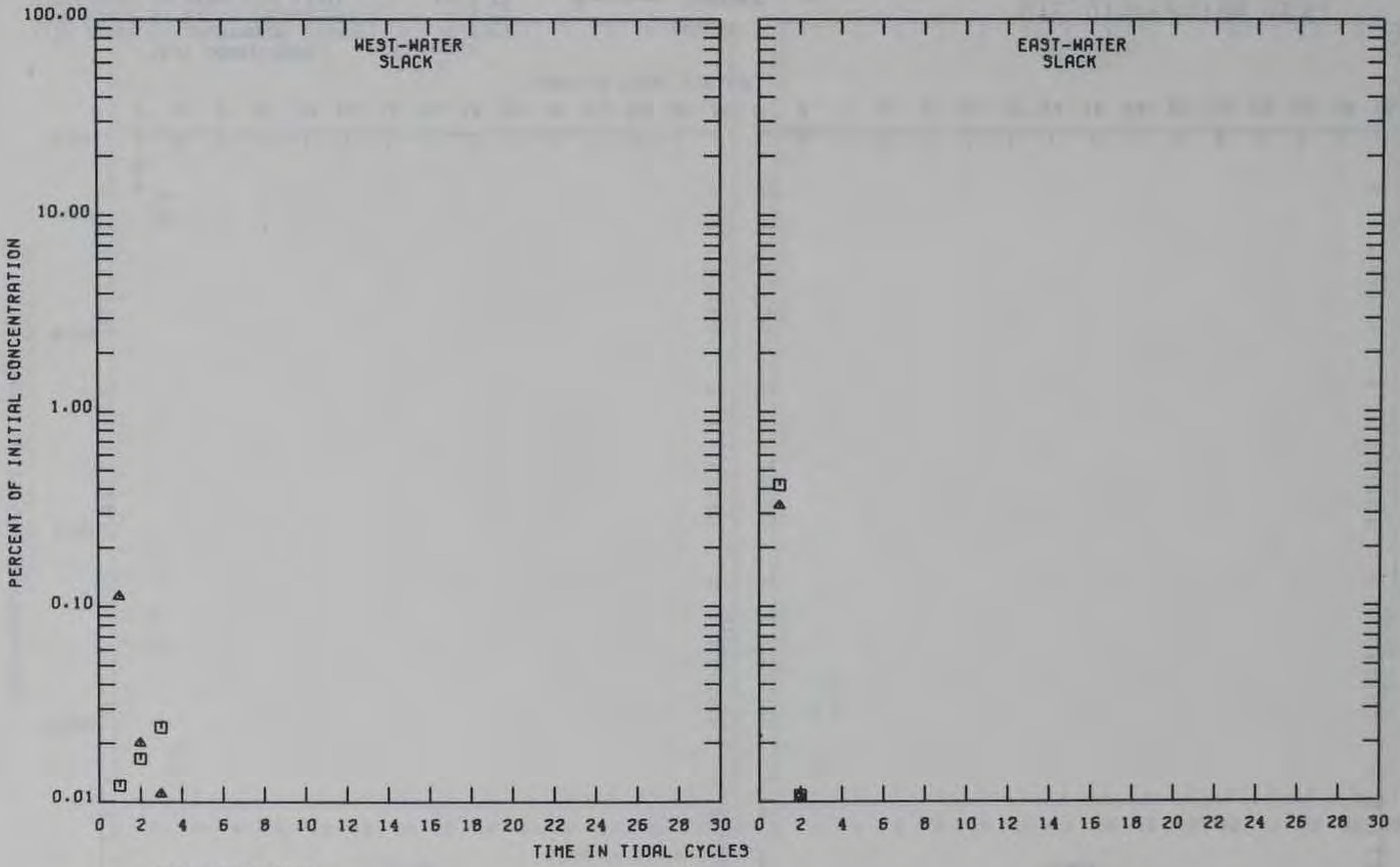


TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 8



TEST CONDITIONS

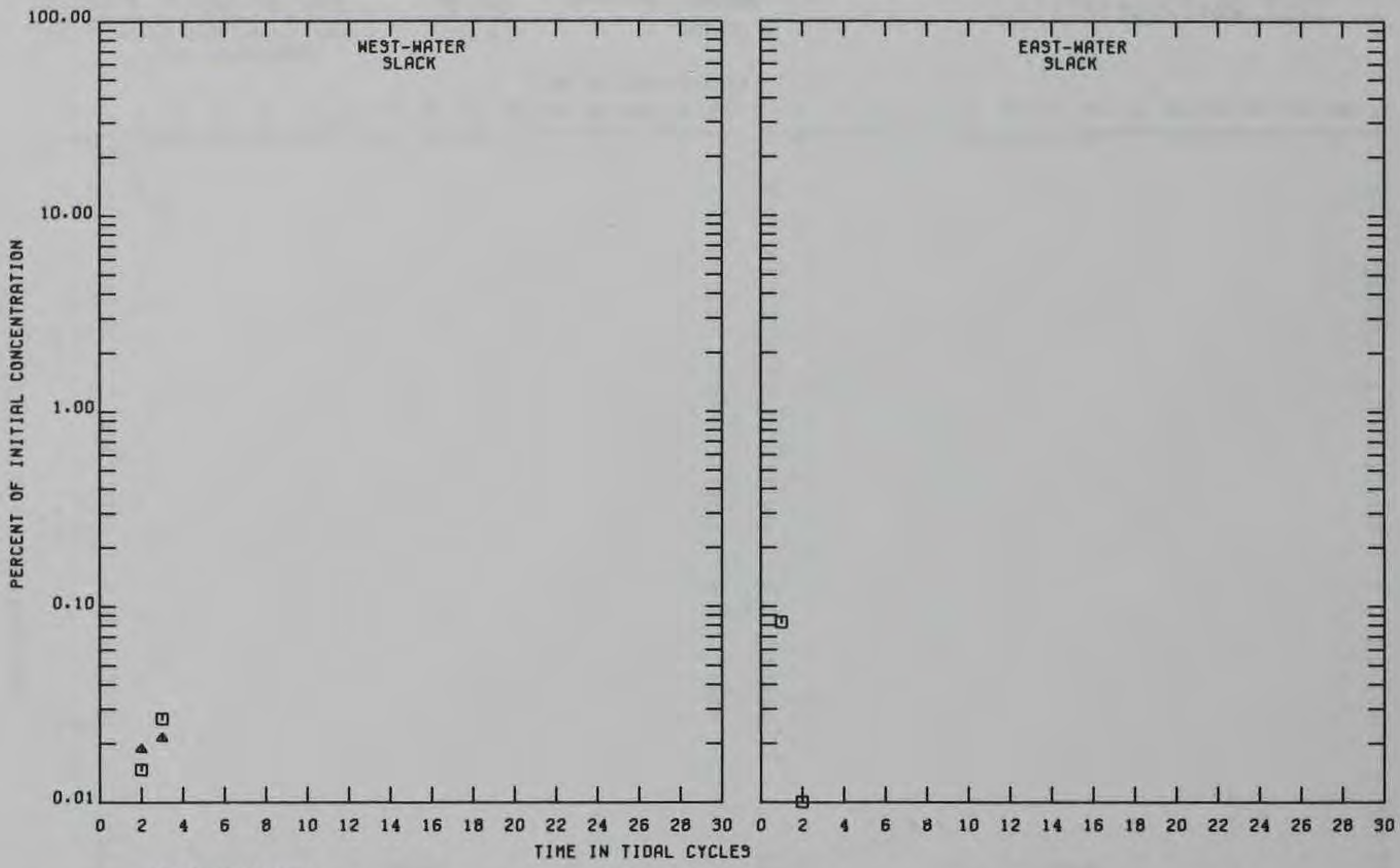
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

◻ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 9



TEST CONDITIONS

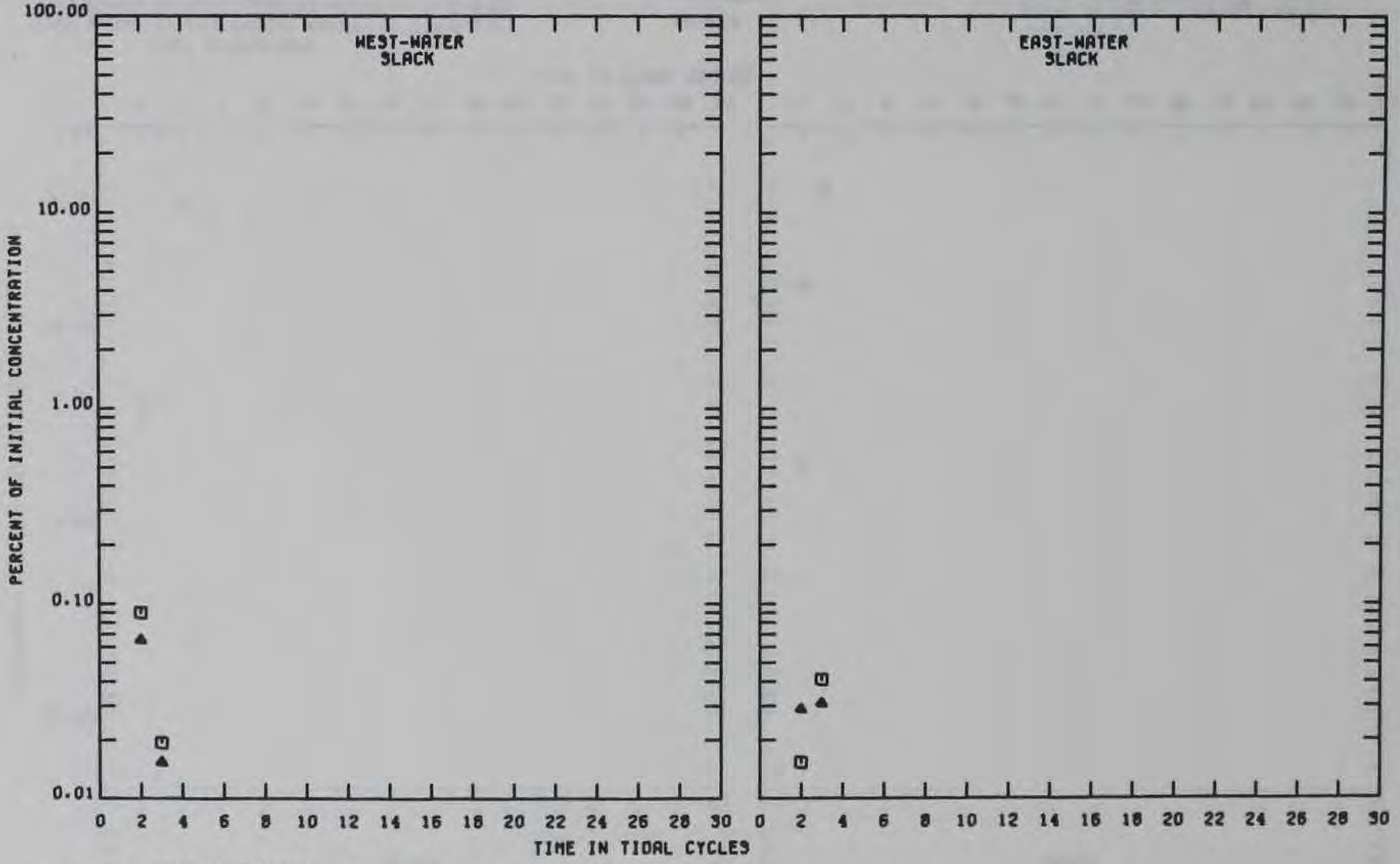
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	984.000	PPB

LEGEND

⊡ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 10



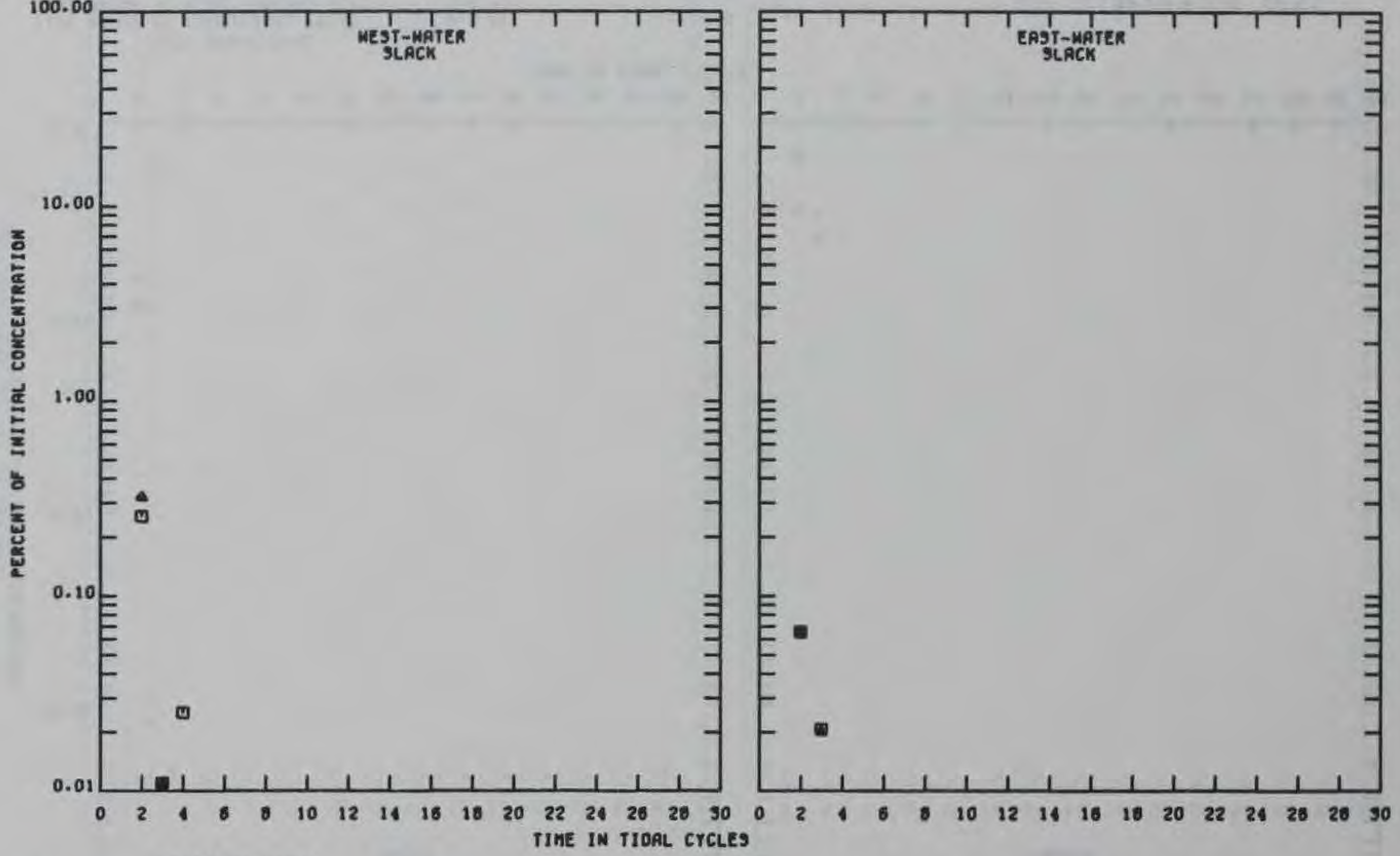
TEST CONDITIONS		
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 11



TEST CONDITIONS

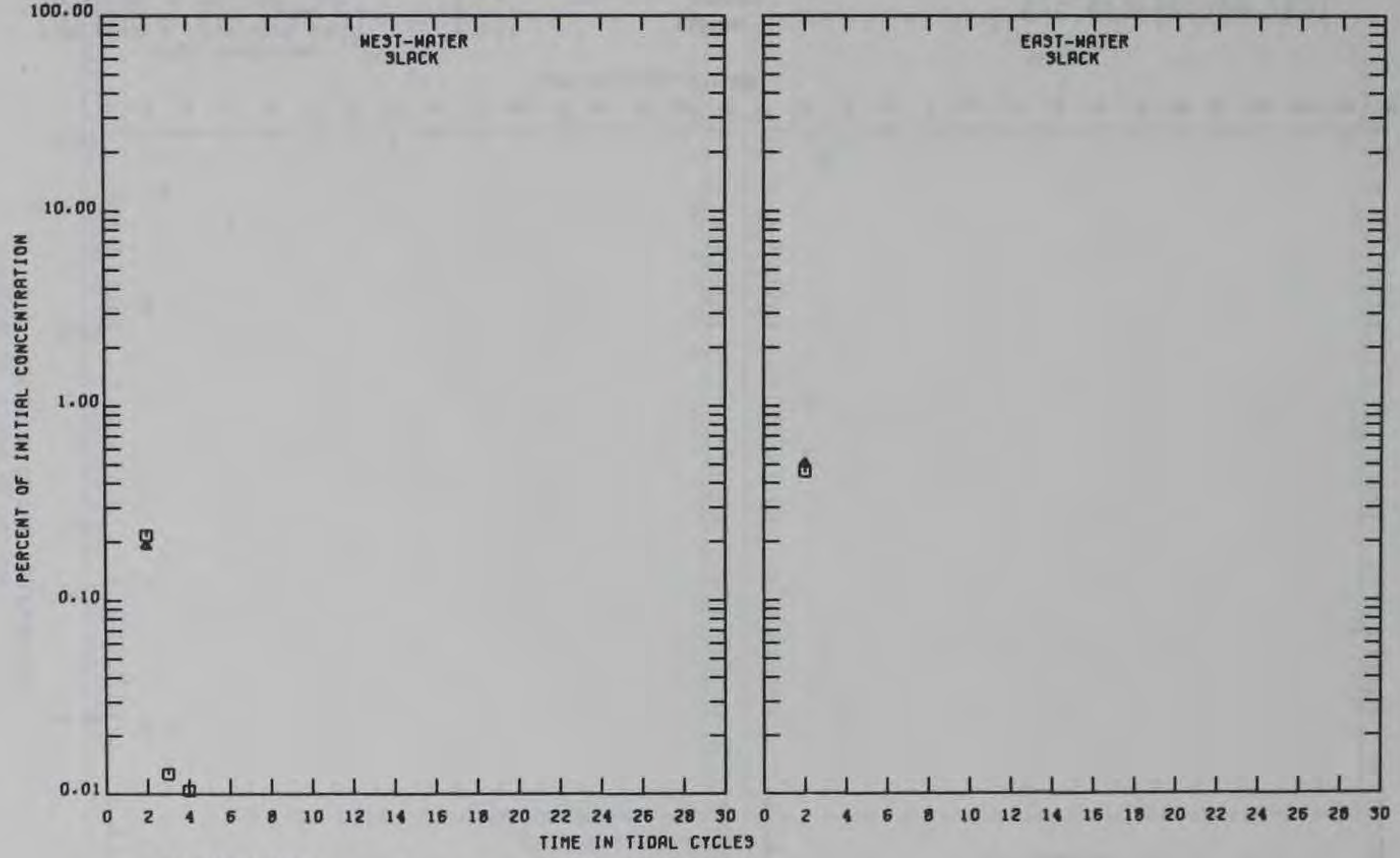
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

▢ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 12



TEST CONDITIONS

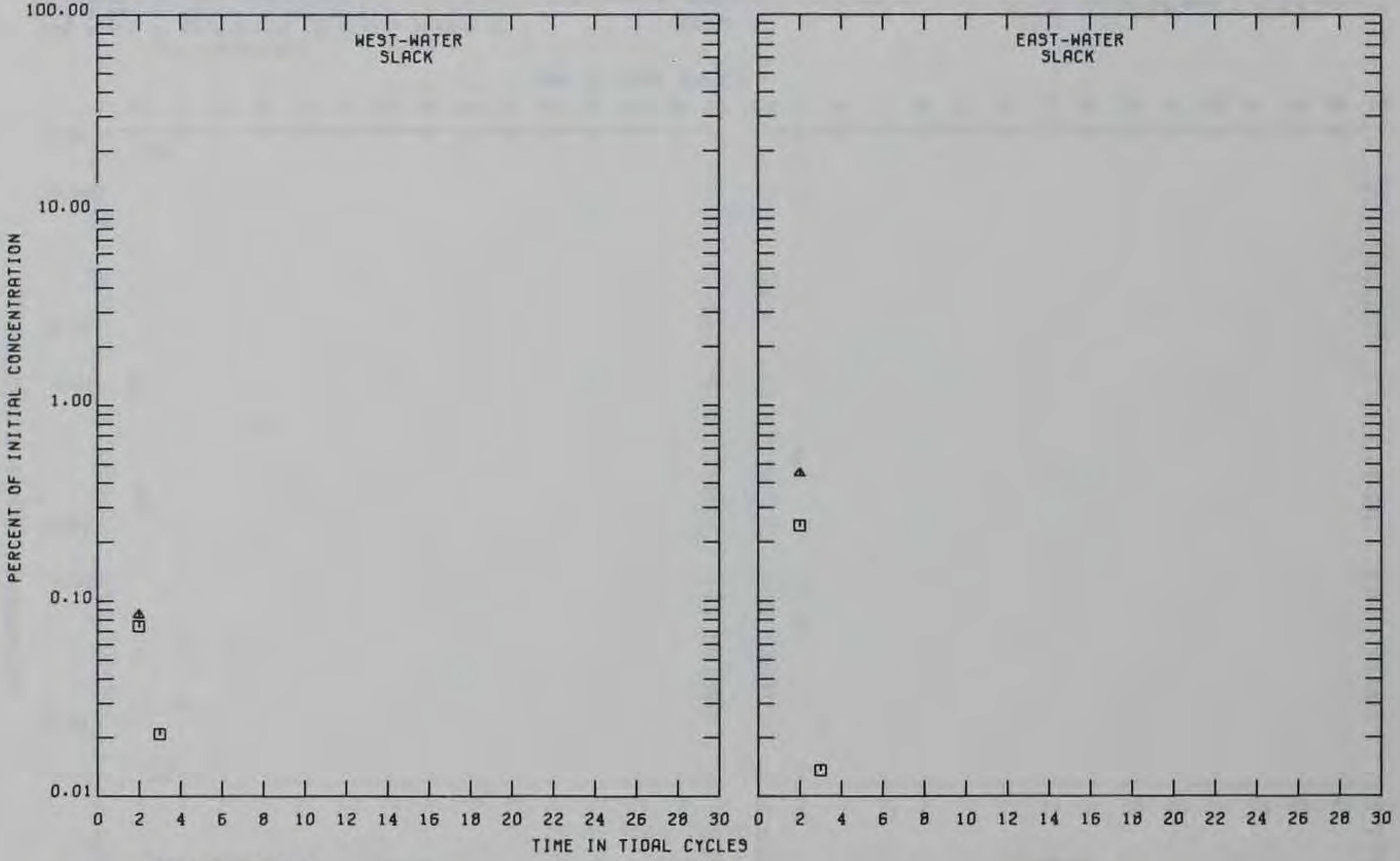
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 13



TEST CONDITIONS

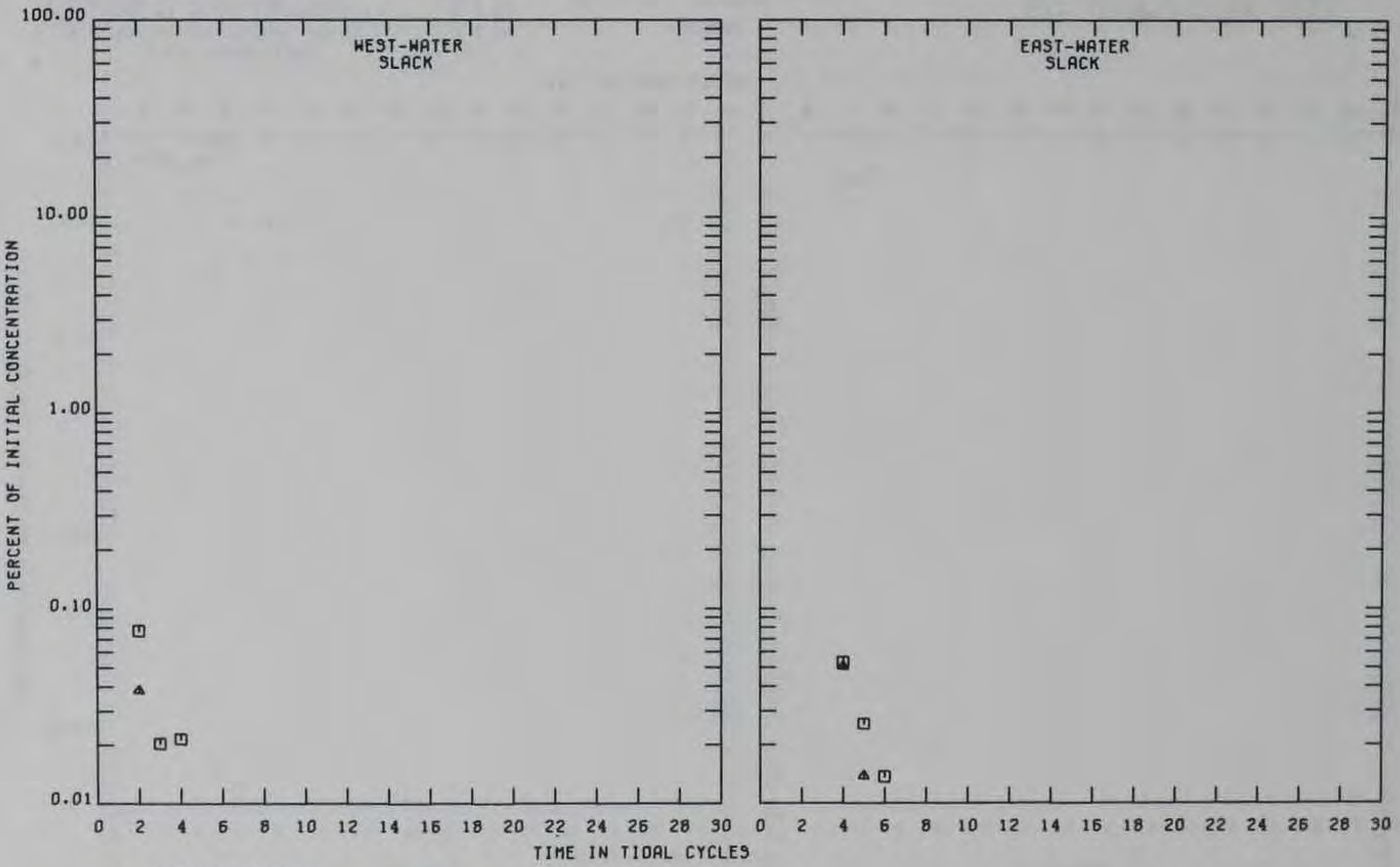
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384,000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 14



TEST CONDITIONS

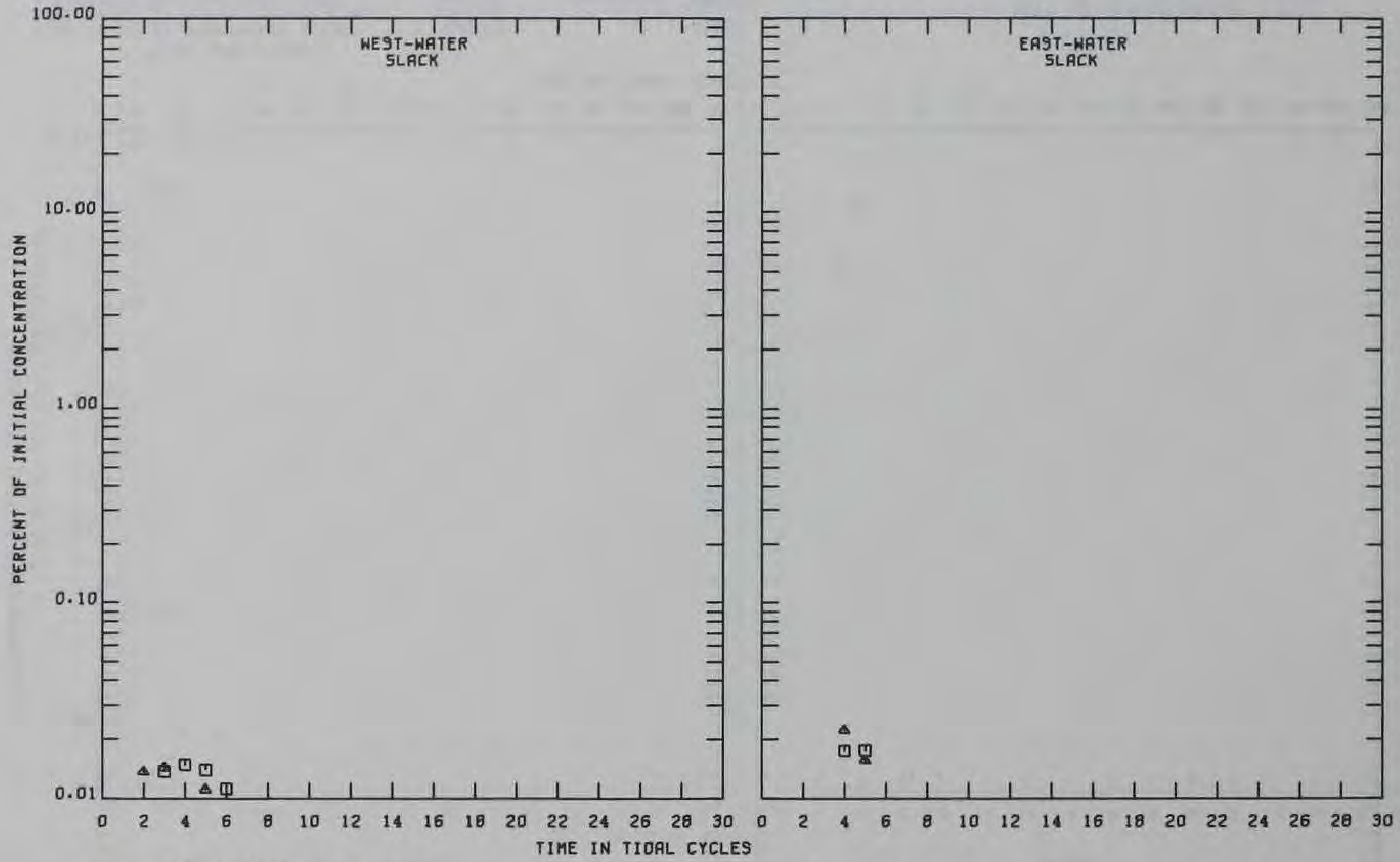
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384,000	PPB

LEGEND

☐ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 15

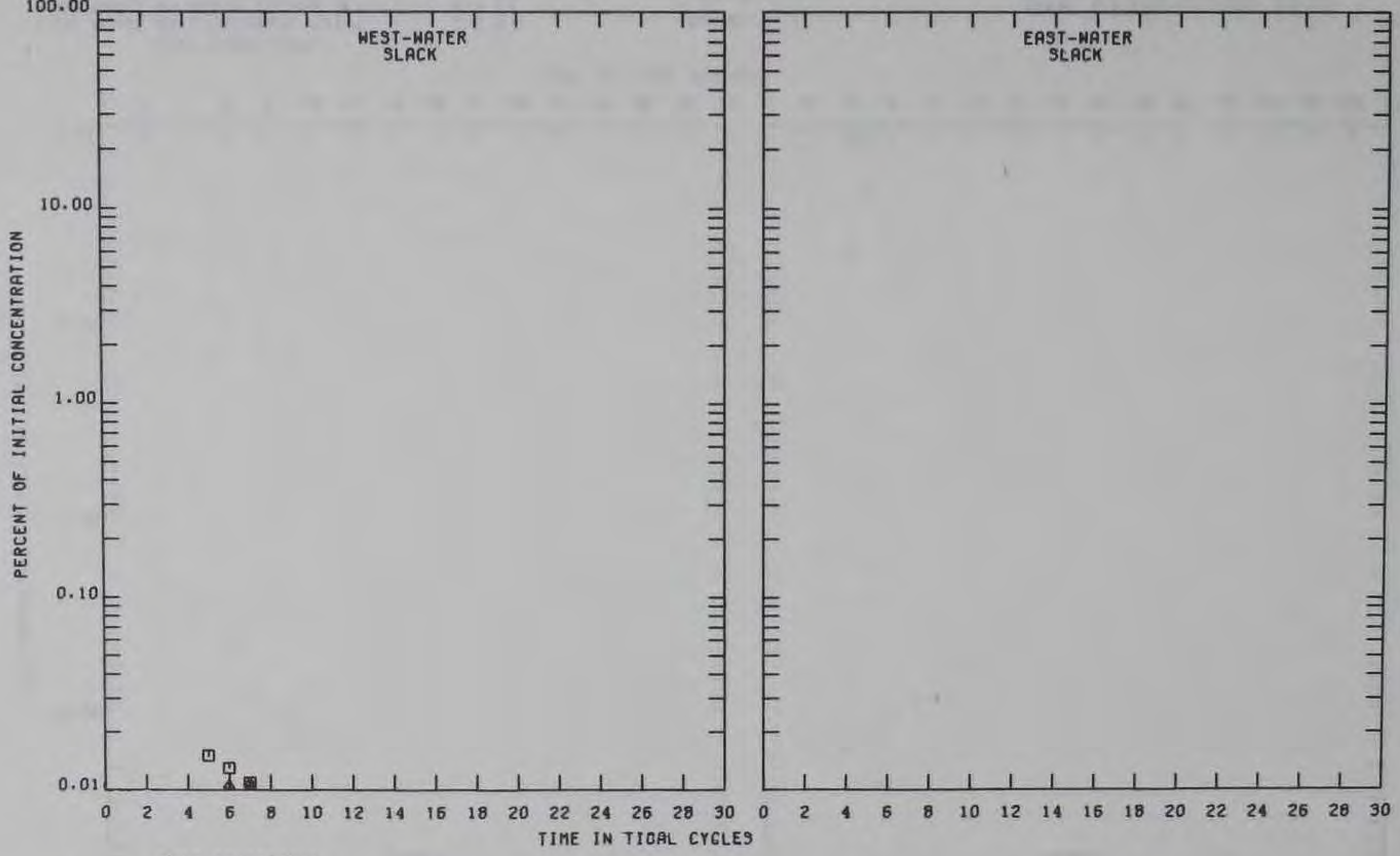


TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	984.000	PPB

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 16



TEST CONDITIONS

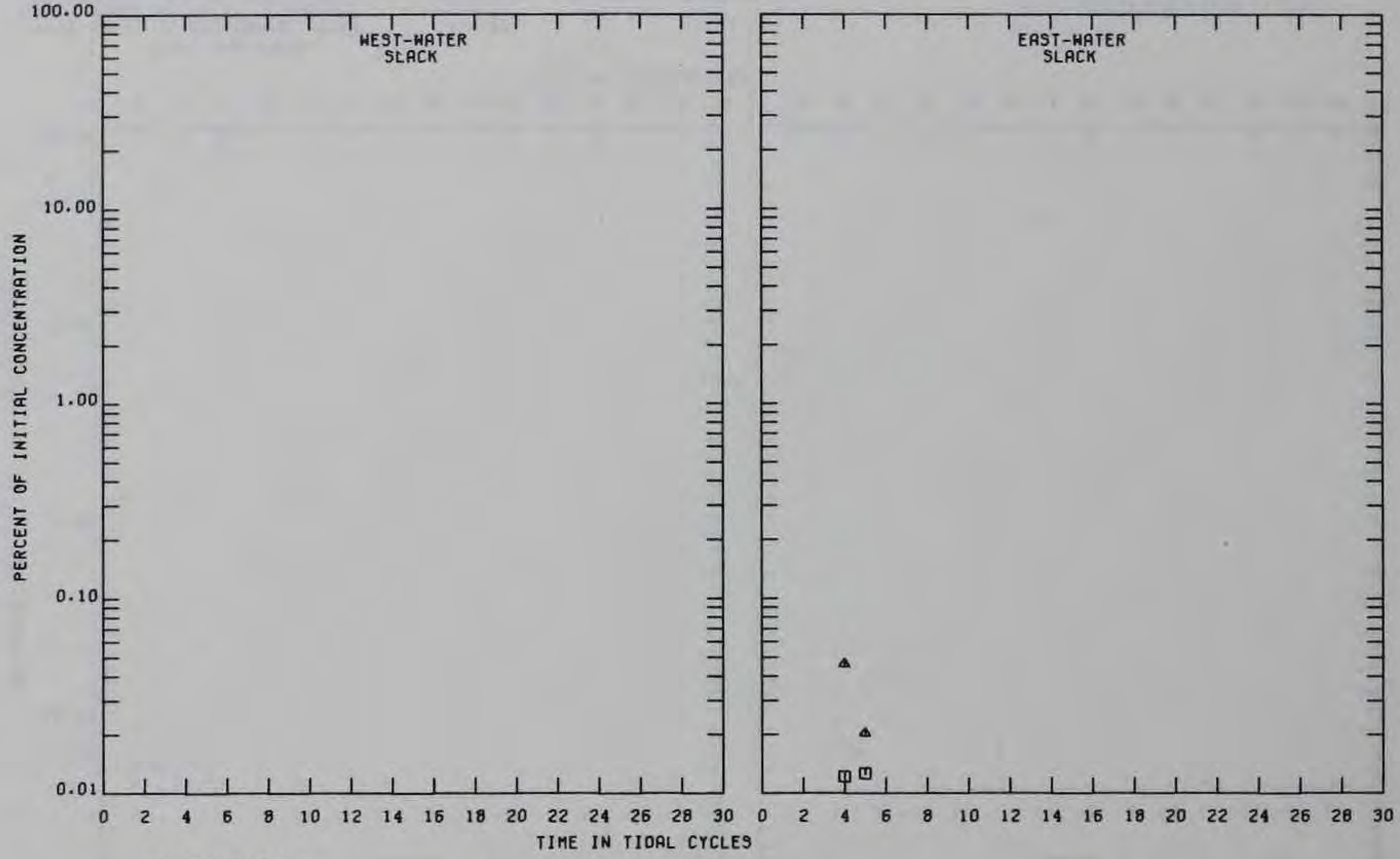
TIDE RANGE AT COURTHOUSE POINT	2.2 FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5 FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7 FT
NET CANAL DISCHARGE (EASTWARD)	21.200 CFS
DELAWARE RIVER COMBINED INFLOW	20.200 CFS
OCEAN SALINITY	31.000 PPM
INITIAL DYE CONCENTRATION	384.000 PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 17



TEST CONDITIONS

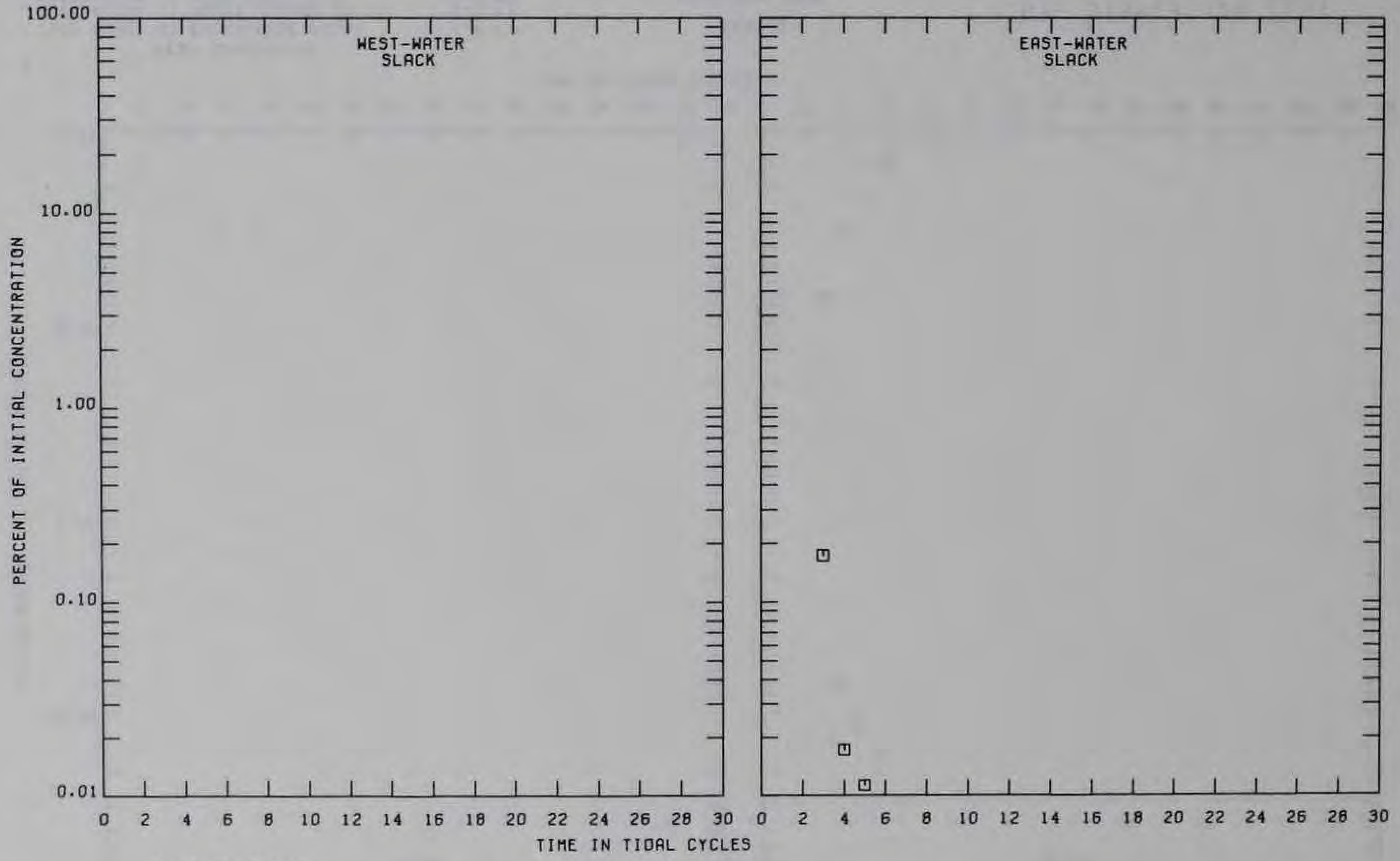
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 18



TEST CONDITIONS

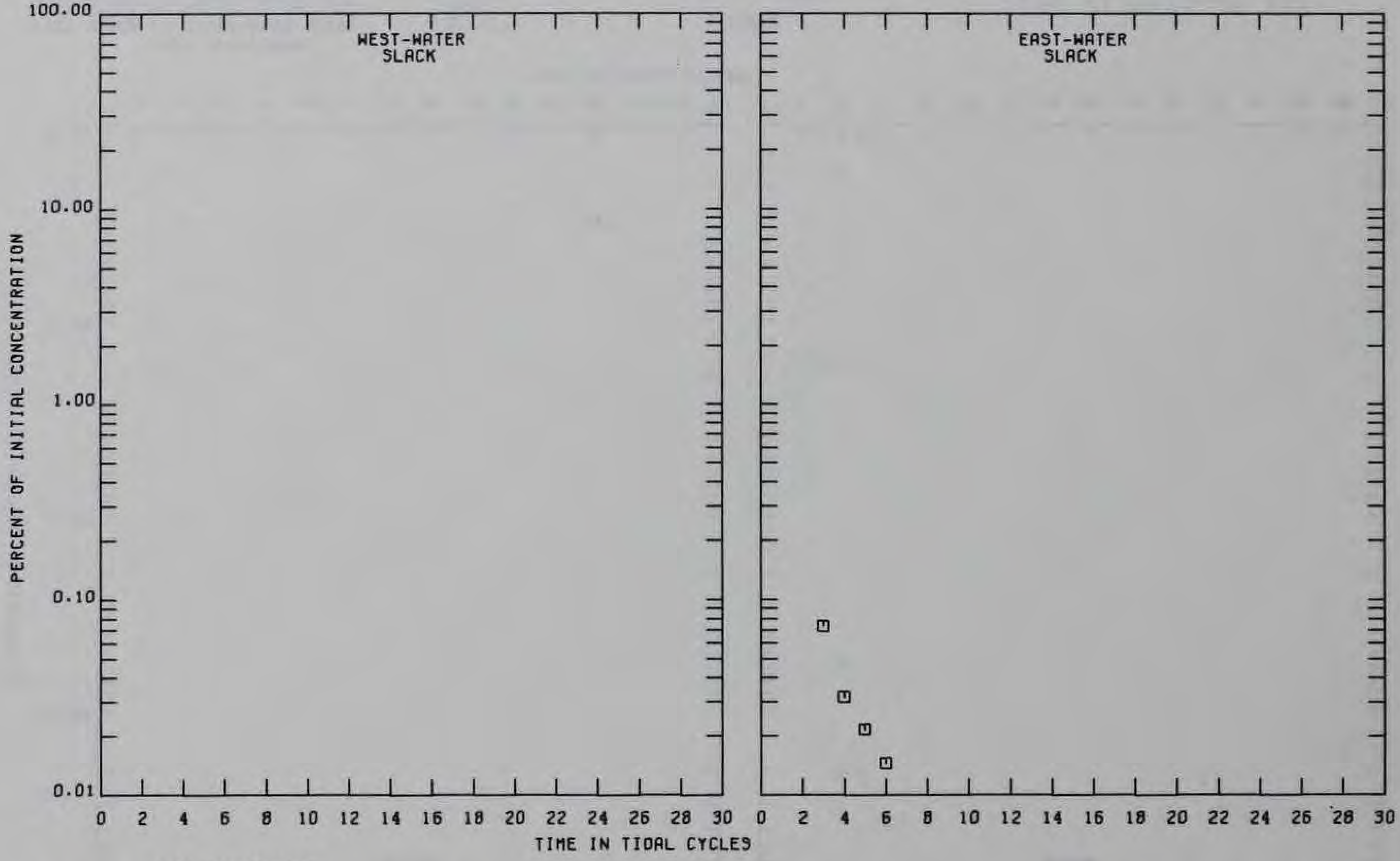
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

□ ——— BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 19 MID-DEPTH



TEST CONDITIONS

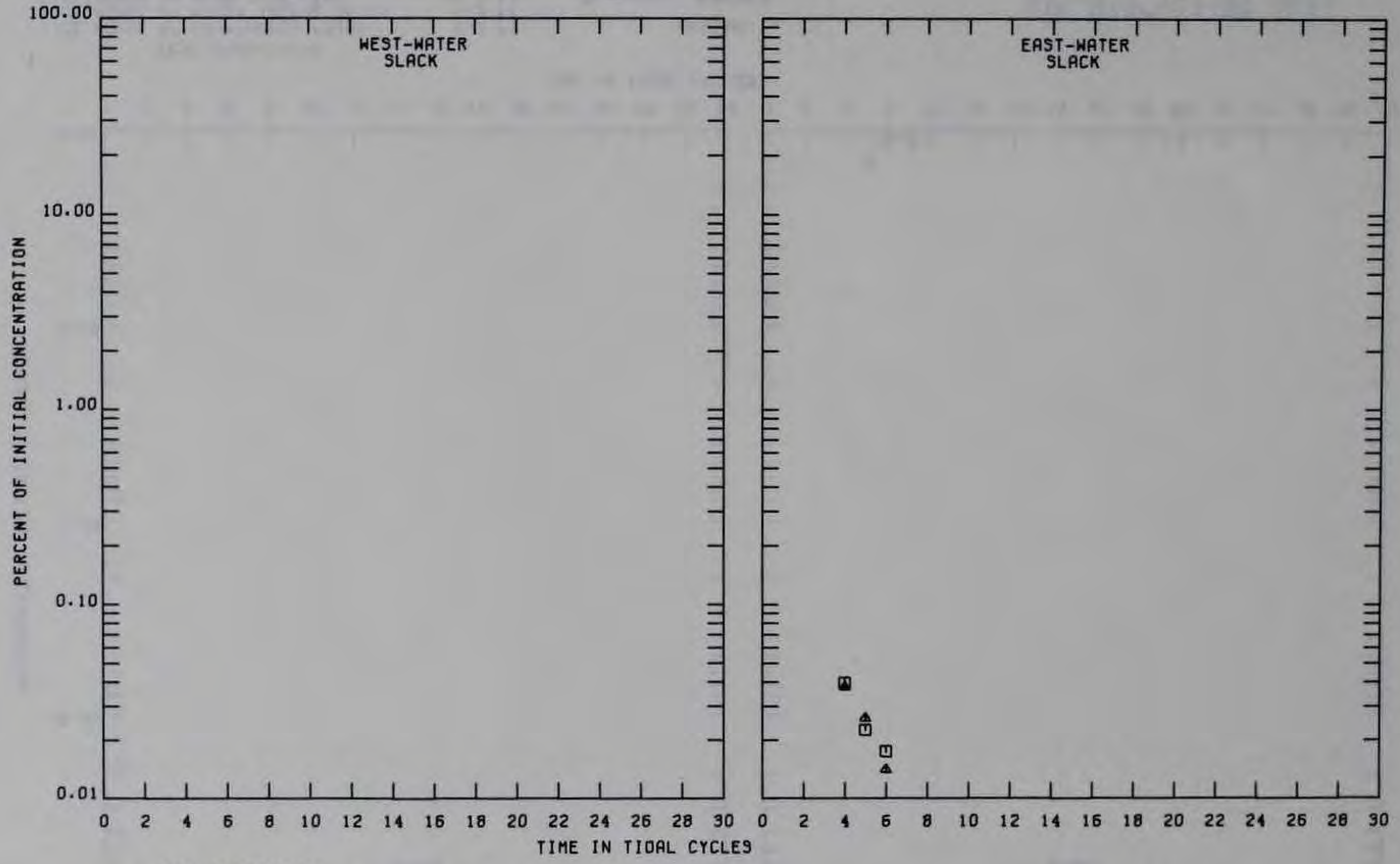
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21.200	CFS
DELAWARE RIVER COMBINED INFLOW	20.200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	384.000	PPB

LEGEND

▢ ——— BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 20 MID-DEPTH



TEST CONDITIONS

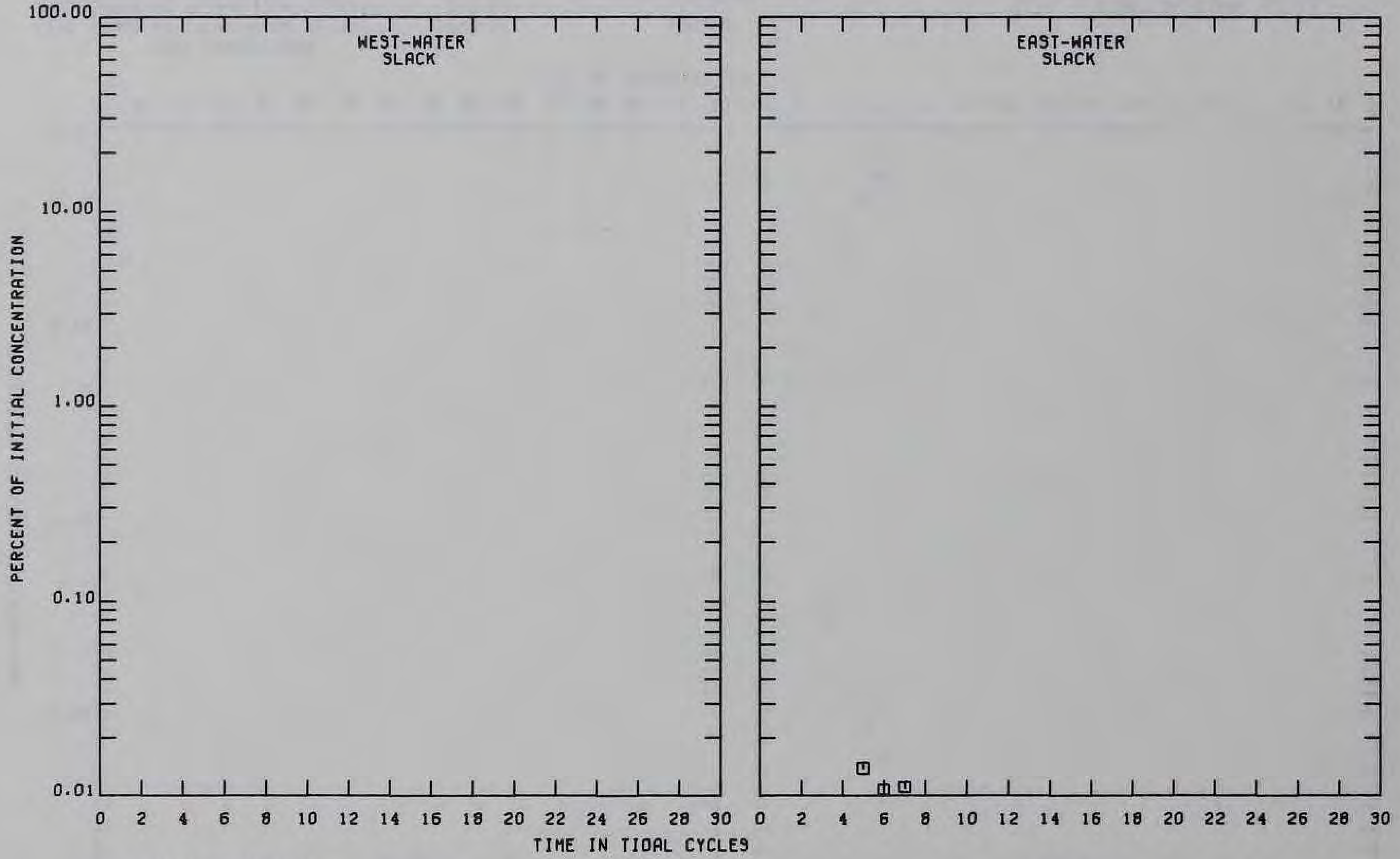
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384,000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 21



TEST CONDITIONS

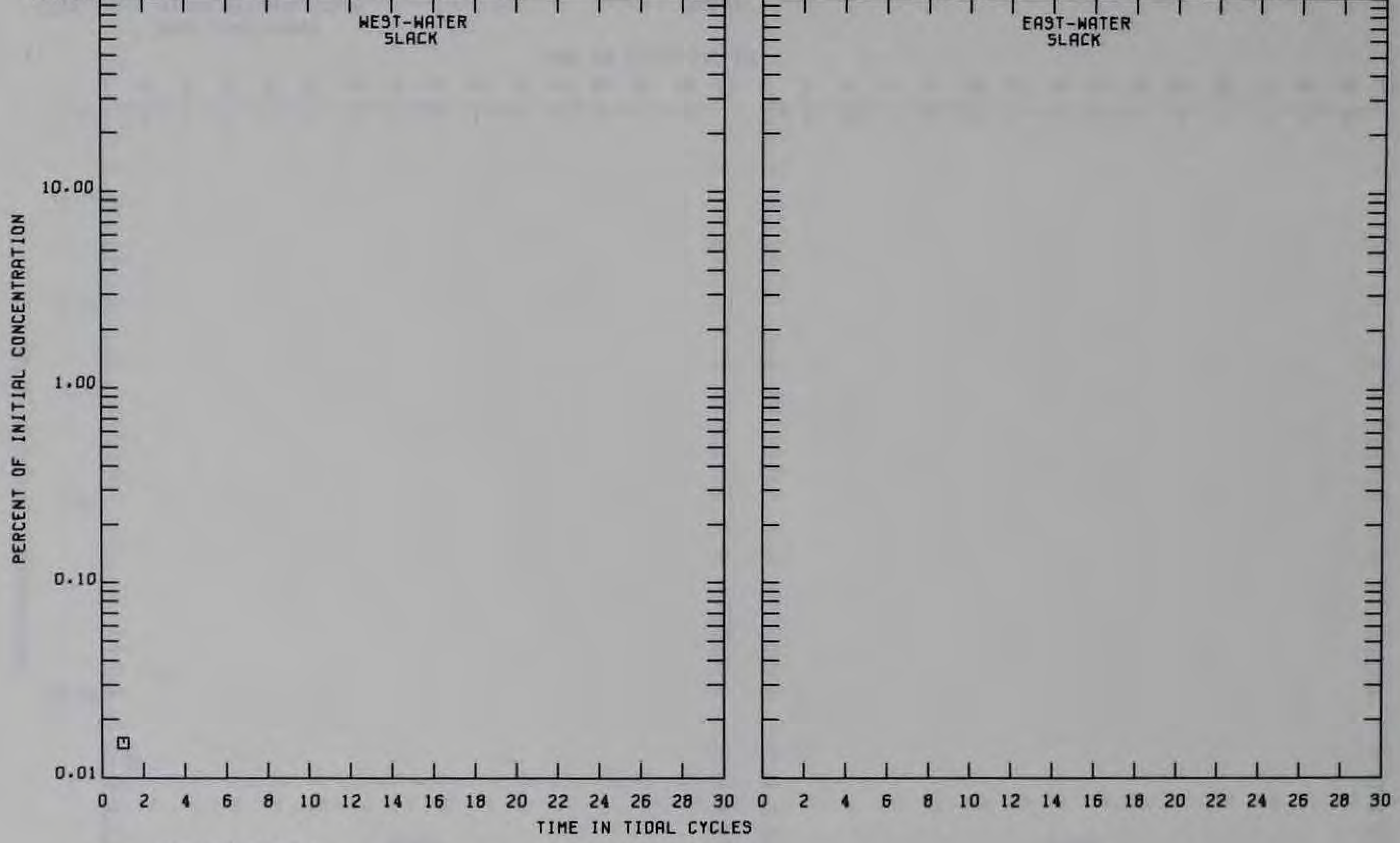
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE LEVEL	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	384,000	PPB

LEGEND

⊡ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT COURTHOUSE POINT

STATION 22



TEST CONDITIONS

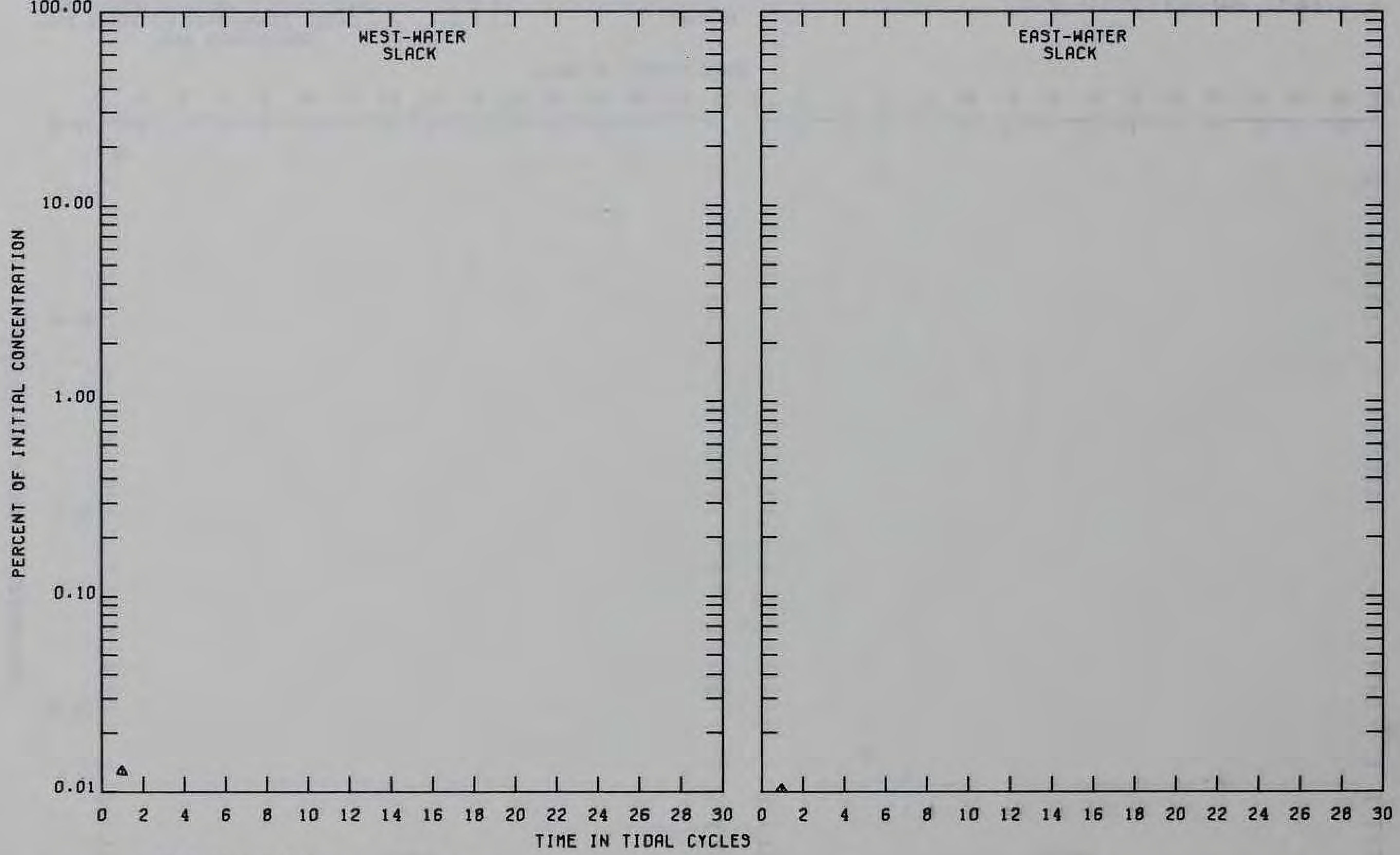
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

□ ——— SURFACE BASE
△ — — — BOTTOM

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 8



TEST CONDITIONS

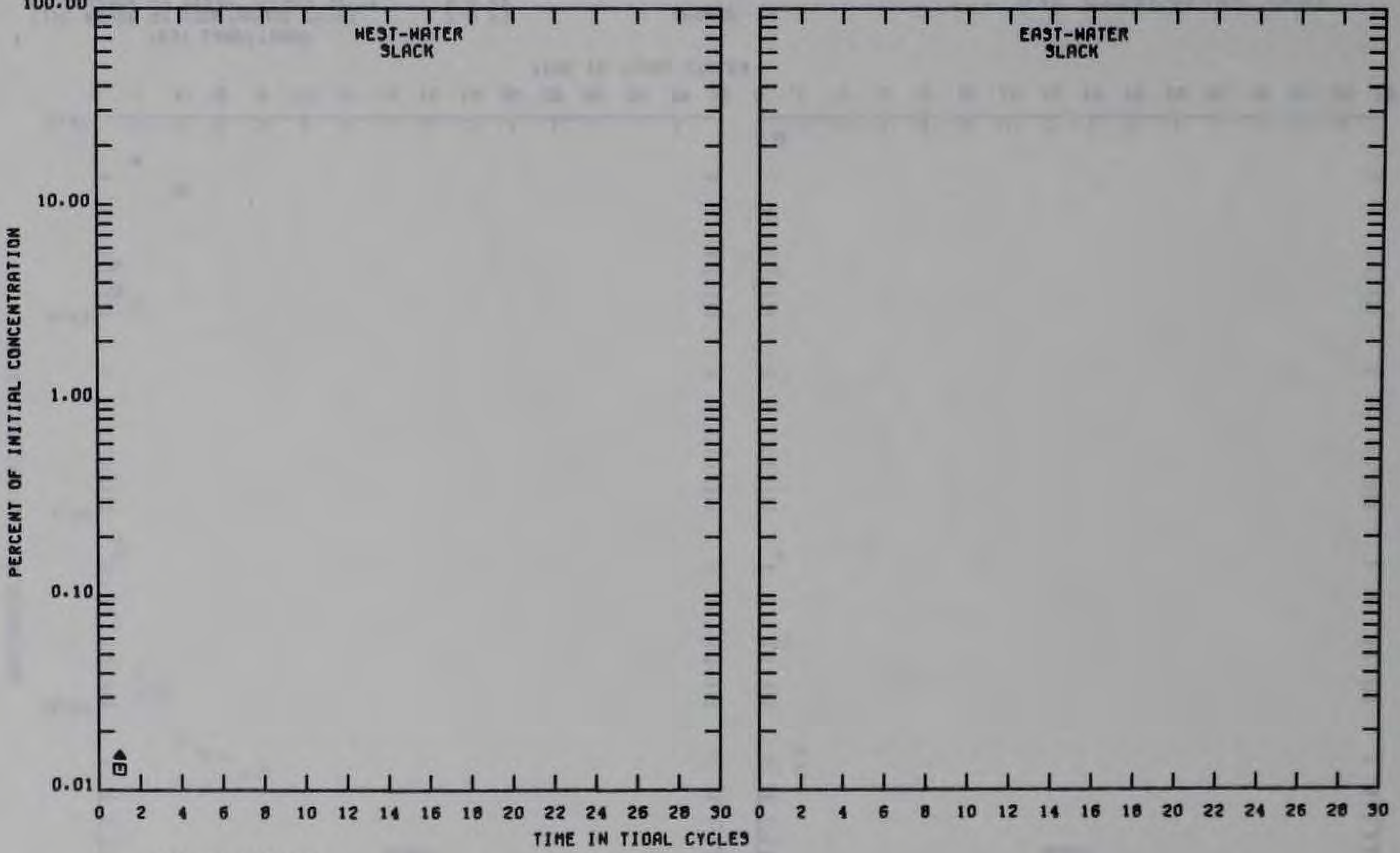
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	330.000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 9



TEST CONDITIONS

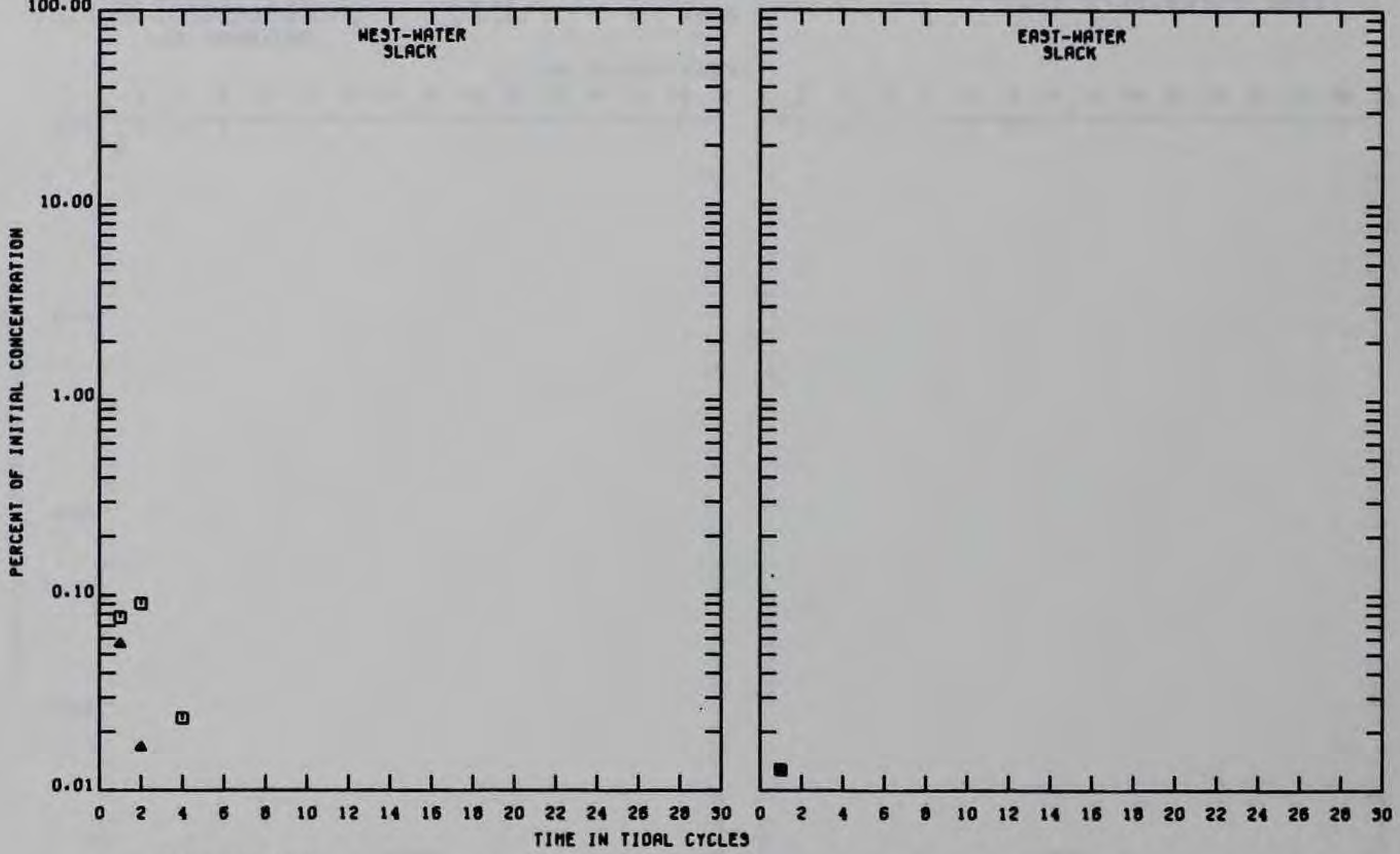
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	330.000	PPB

LEGEND

⊡ ——— SURFACE BASE
▲ — — — BOTTOM

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 11



TEST CONDITIONS

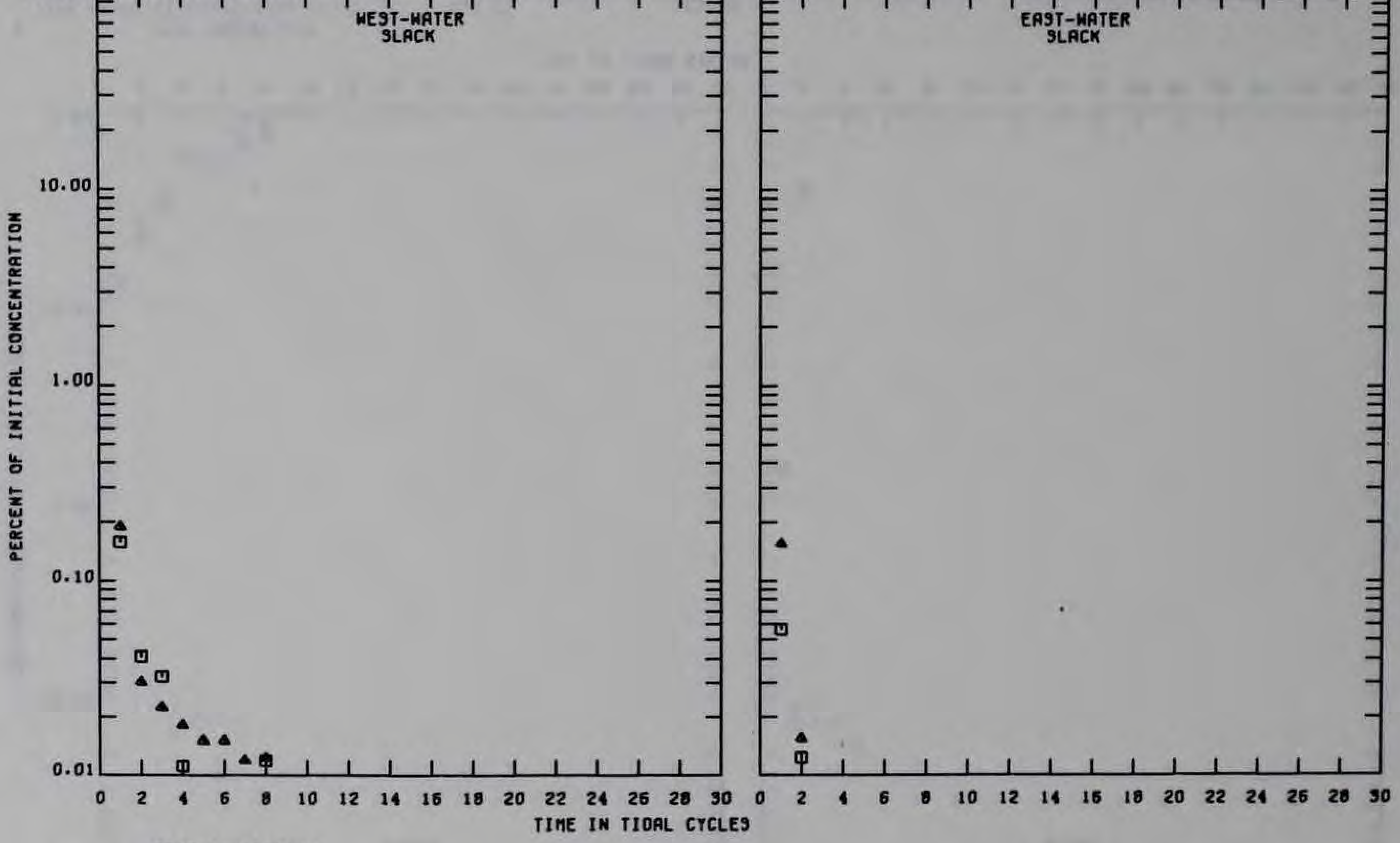
TIDE RANGE AT COURTHOUSE POINT	2.2 FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5 FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7 FT
NET CANAL DISCHARGE (EASTWARD)	21,200 CFS
DELAWARE RIVER COMBINED INFLOW	20.200 CFS
OCEAN SALINITY	31.000 PPM
INITIAL DYE CONCENTRATION	330.000 PPB

LEGEND

▣ ——— SURFACE
▲ – – – BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 12



TEST CONDITIONS

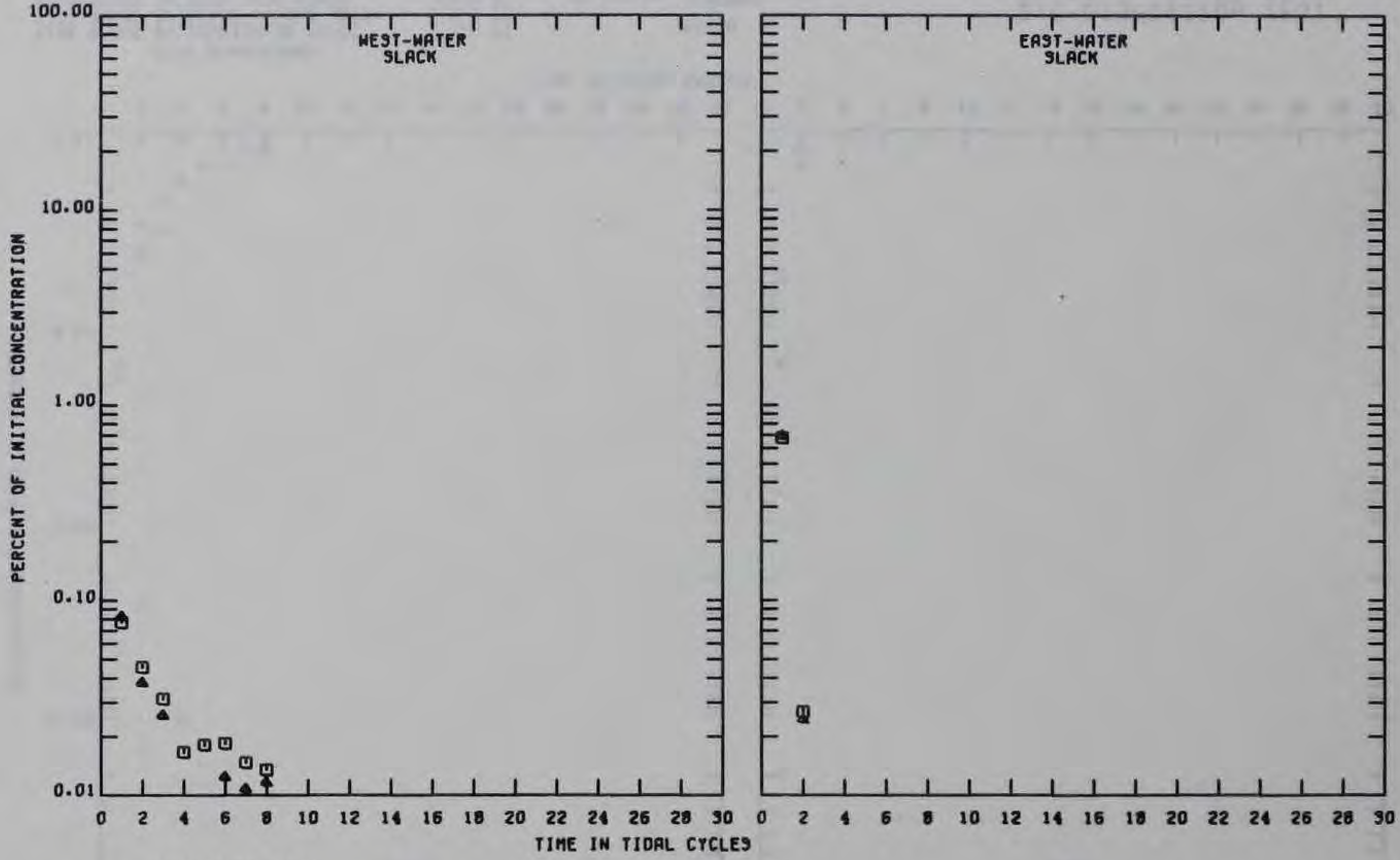
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE
STATION 13

PLATE 203



TEST CONDITIONS

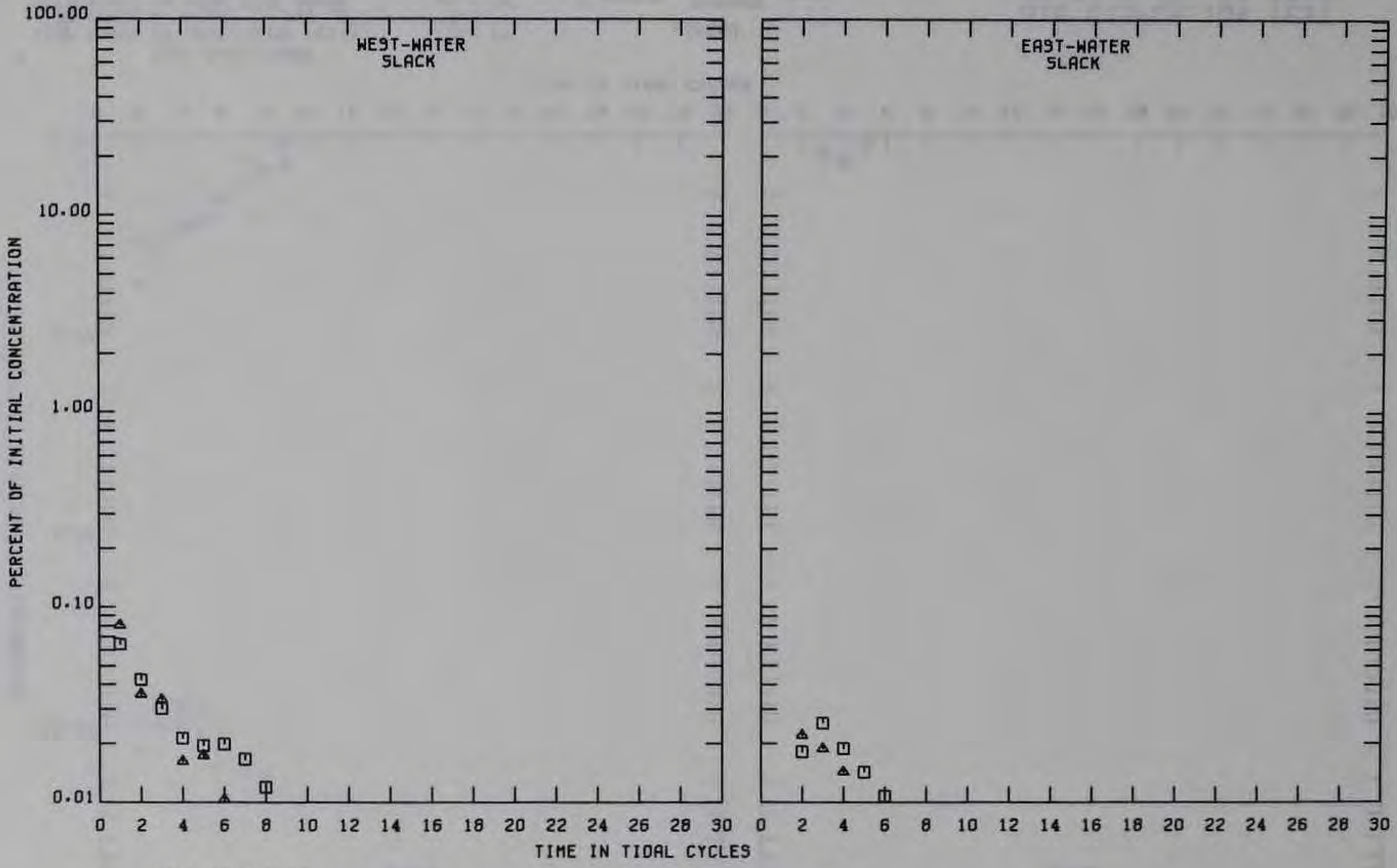
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	330.000	PPB

LEGEND

⊡ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 14



TEST CONDITIONS

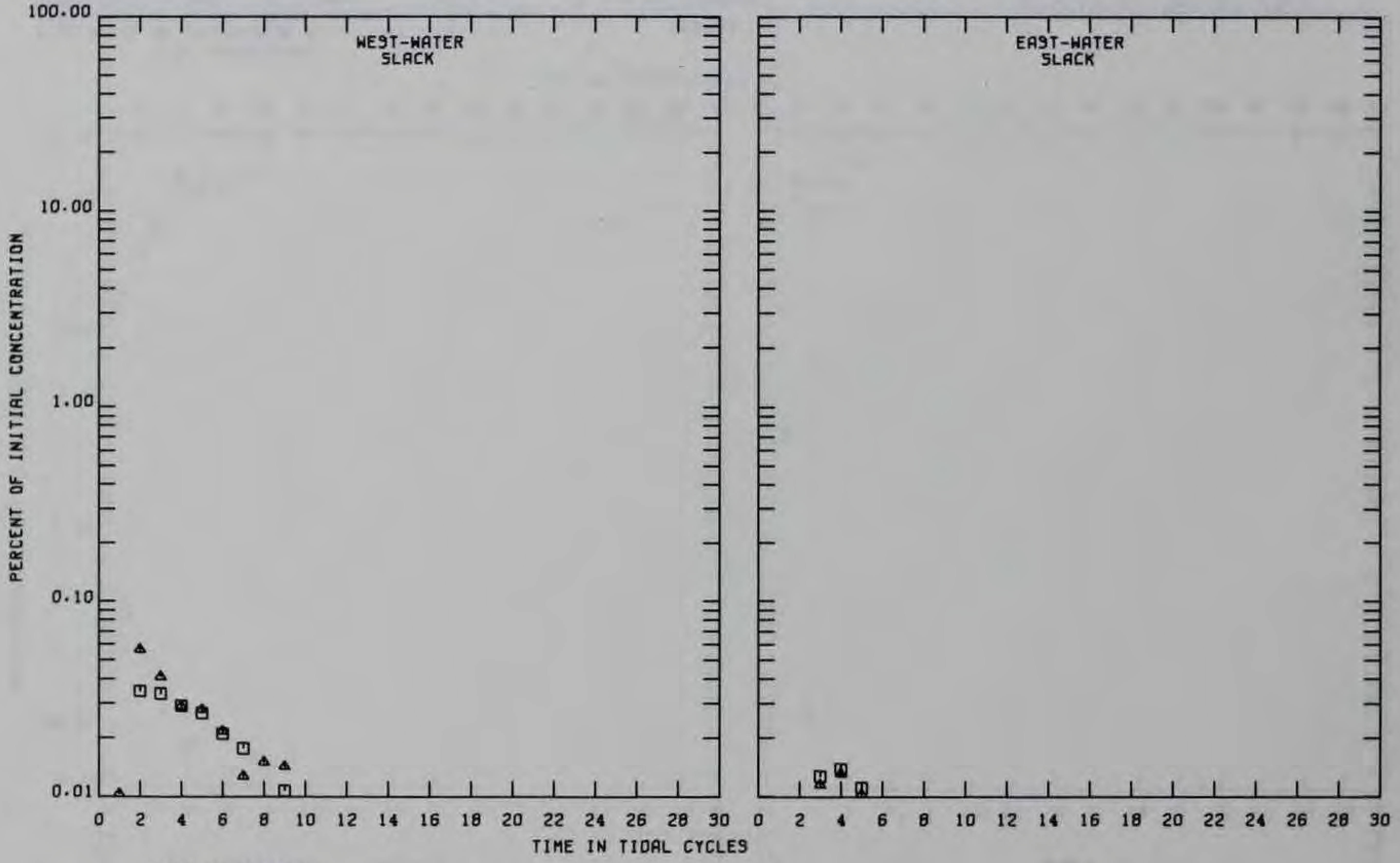
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	330.000	PPB

LEGEND

□ ——— SURFACE
△ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 15



TEST CONDITIONS

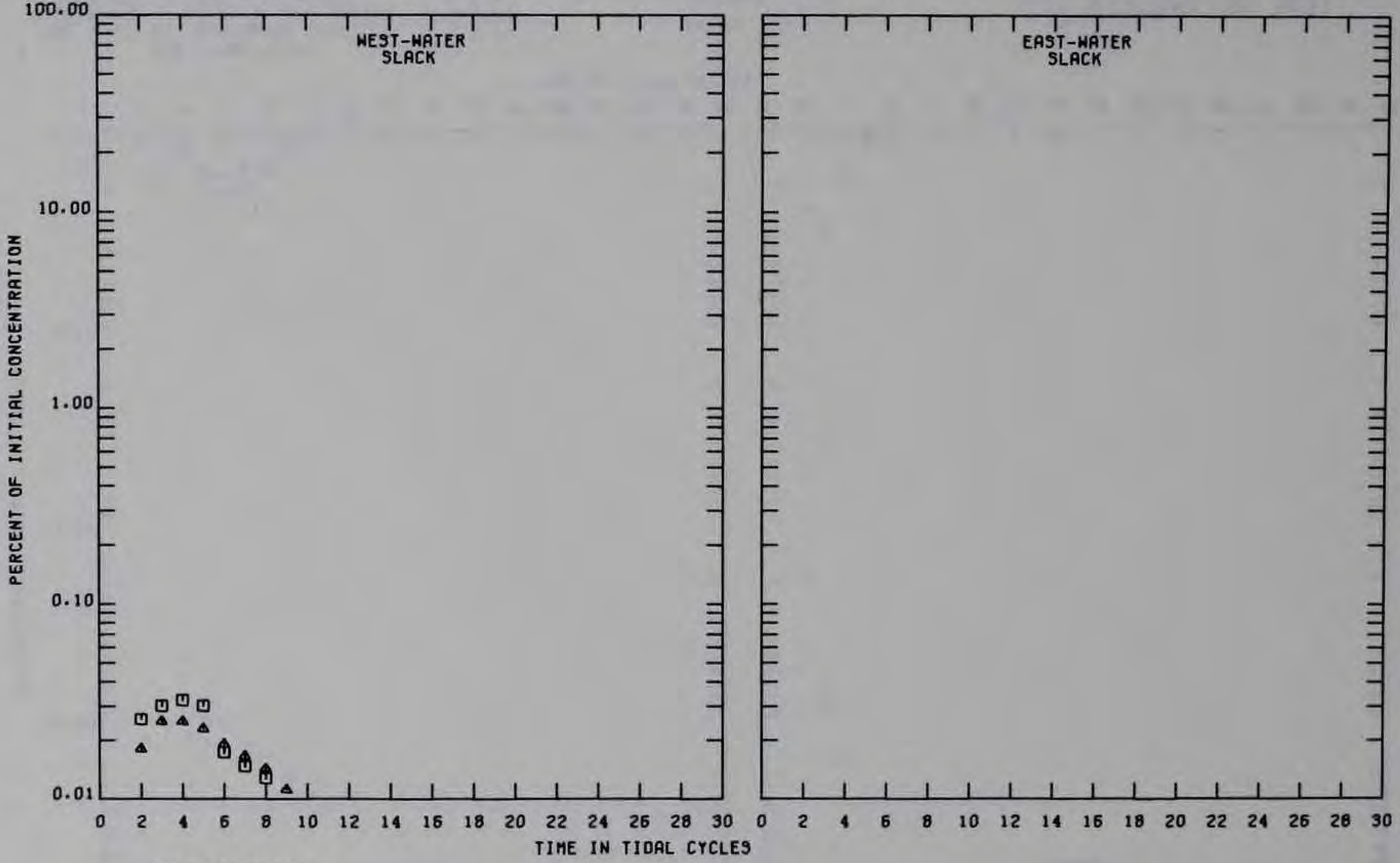
TIDE RANGE AT COURTHOUSE POINT	2.2 FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5 FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7 FT
NET CANAL DISCHARGE (EASTWARD)	21,200 CFS
DELAWARE RIVER COMBINED INFLOW	20.200 CFS
OCEAN SALINITY	31.000 PPM
INITIAL DYE CONCENTRATION	330.000 PPB

LEGEND

□ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 16



TEST CONDITIONS

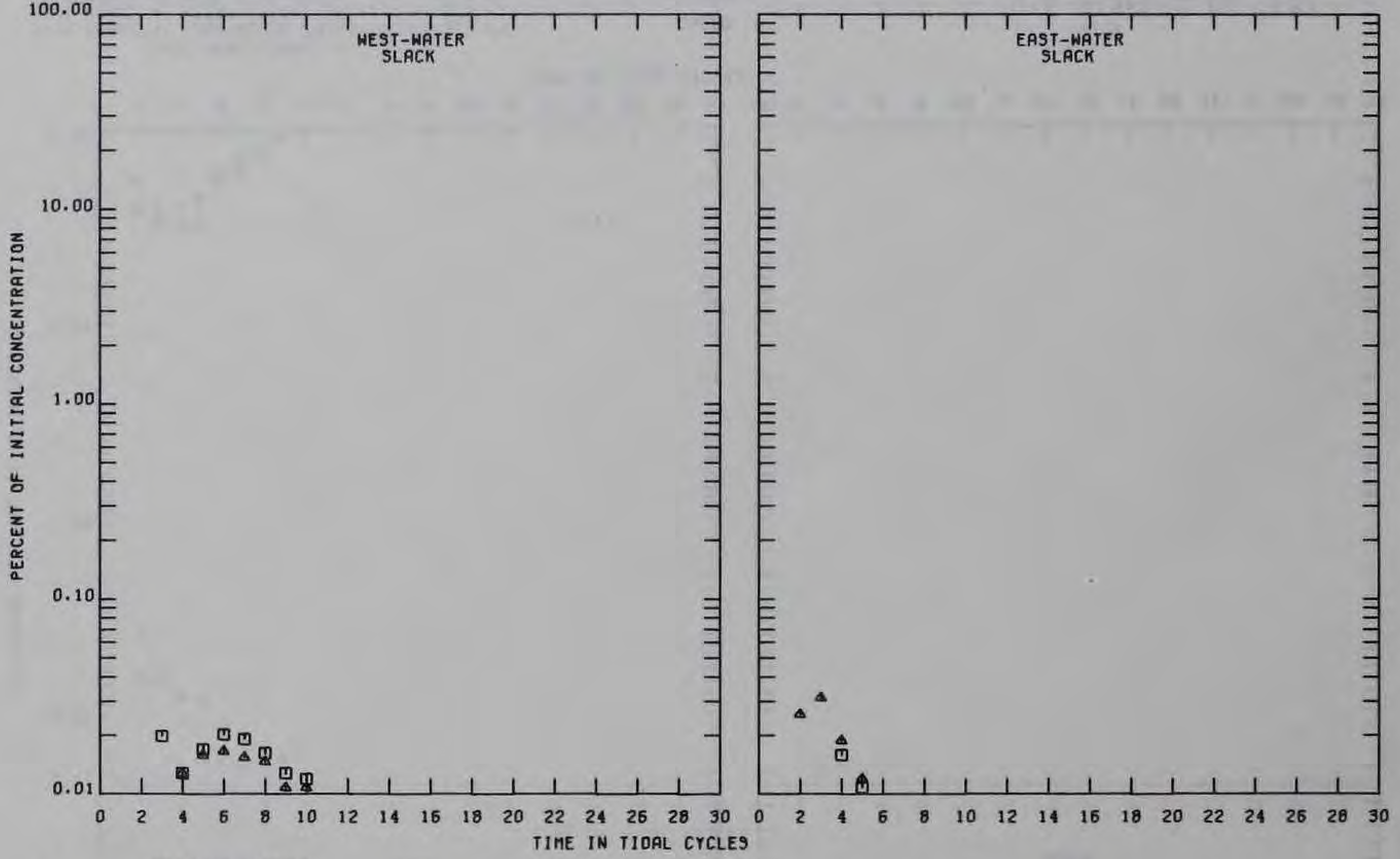
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

□ ———	SURFACE	BASE
▲ — — —	BOTTOM	

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 17



TEST CONDITIONS

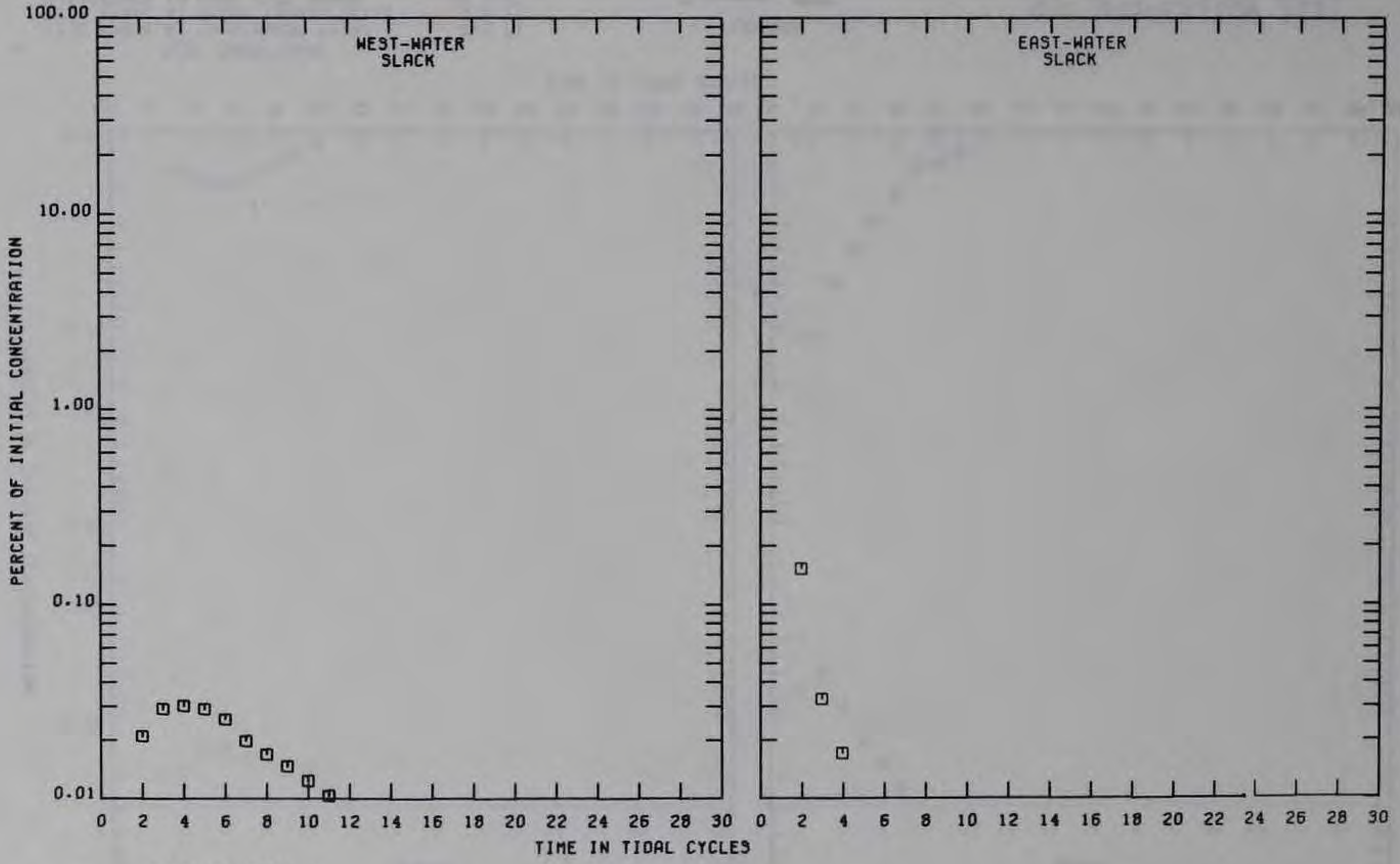
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 18



TEST CONDITIONS

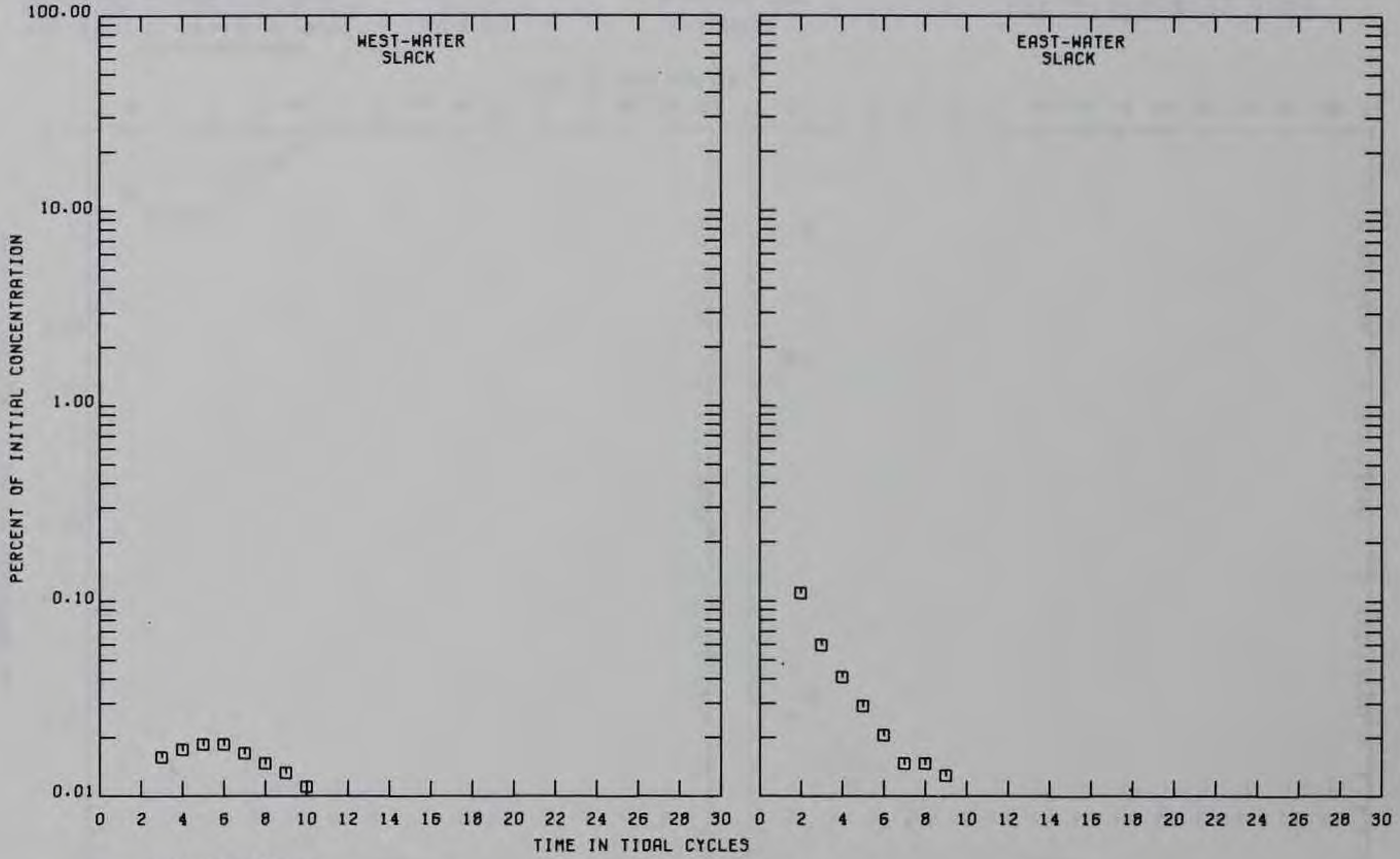
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

□ ——— BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

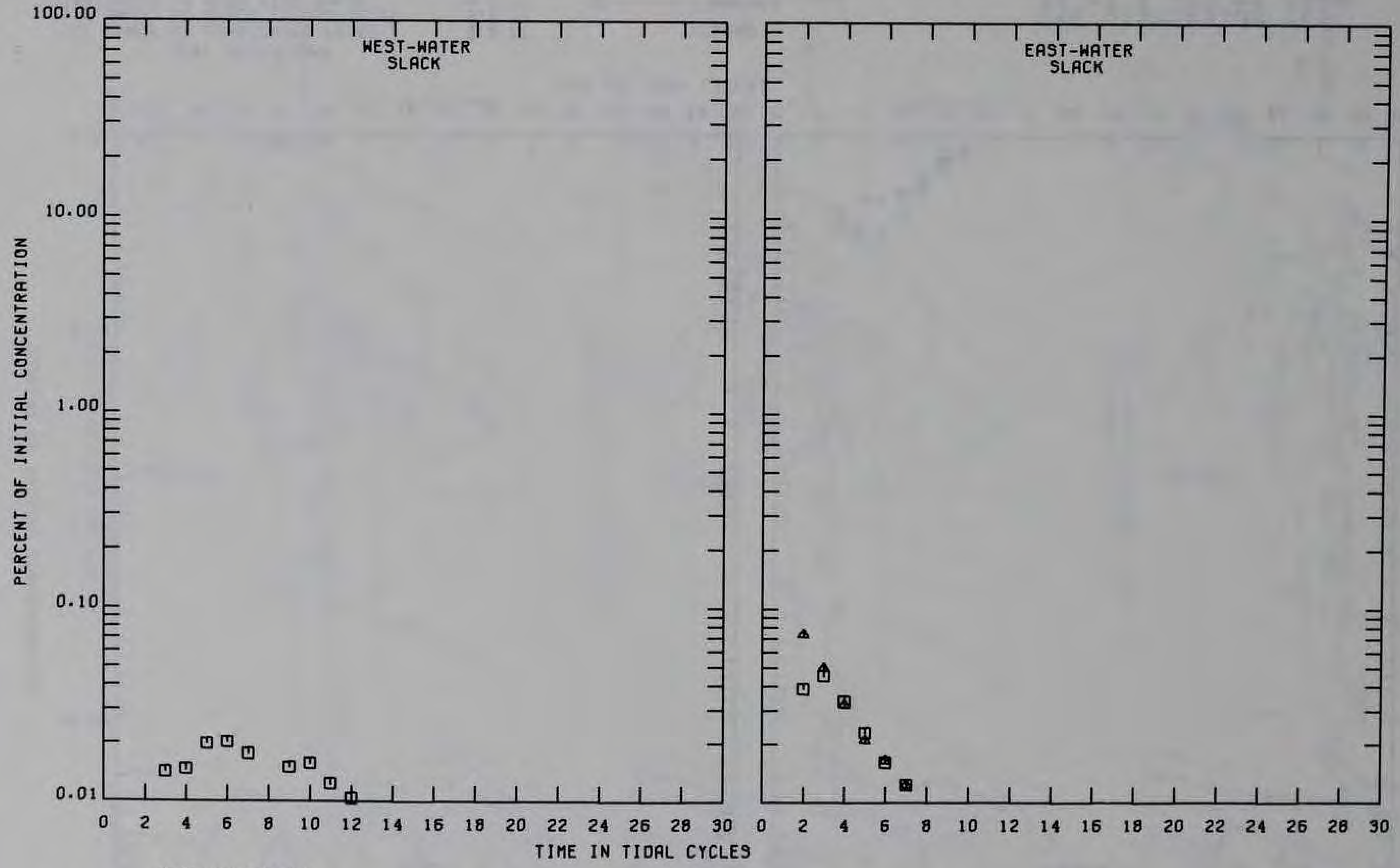
STATION 19 MID-DEPTH



TEST CONDITIONS

TIDE RANGE AT COURTHOUSE POINT	2.2 FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5 FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7 FT
NET CANAL DISCHARGE (EASTWARD)	21,200 CFS
DELAWARE RIVER COMBINED INFLOW	20,200 CFS
OCEAN SALINITY	31,000 PPM
INITIAL DYE CONCENTRATION	330,000 PPB

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE
STATION 20 MID-DEPTH



TEST CONDITIONS

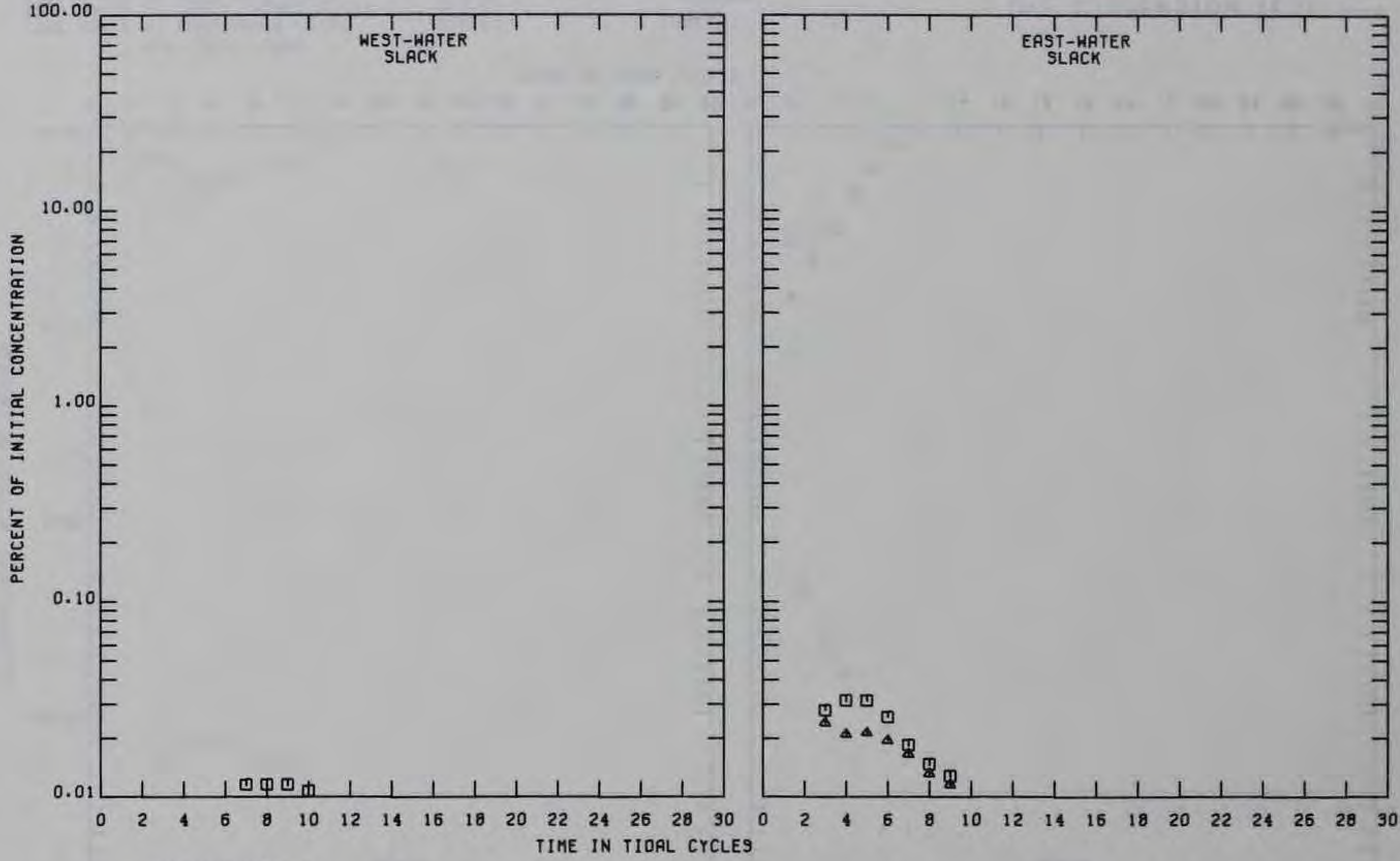
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31,000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

□ ——— SURFACE BASE
△ — — — BOTTOM

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

STATION 21



TEST CONDITIONS

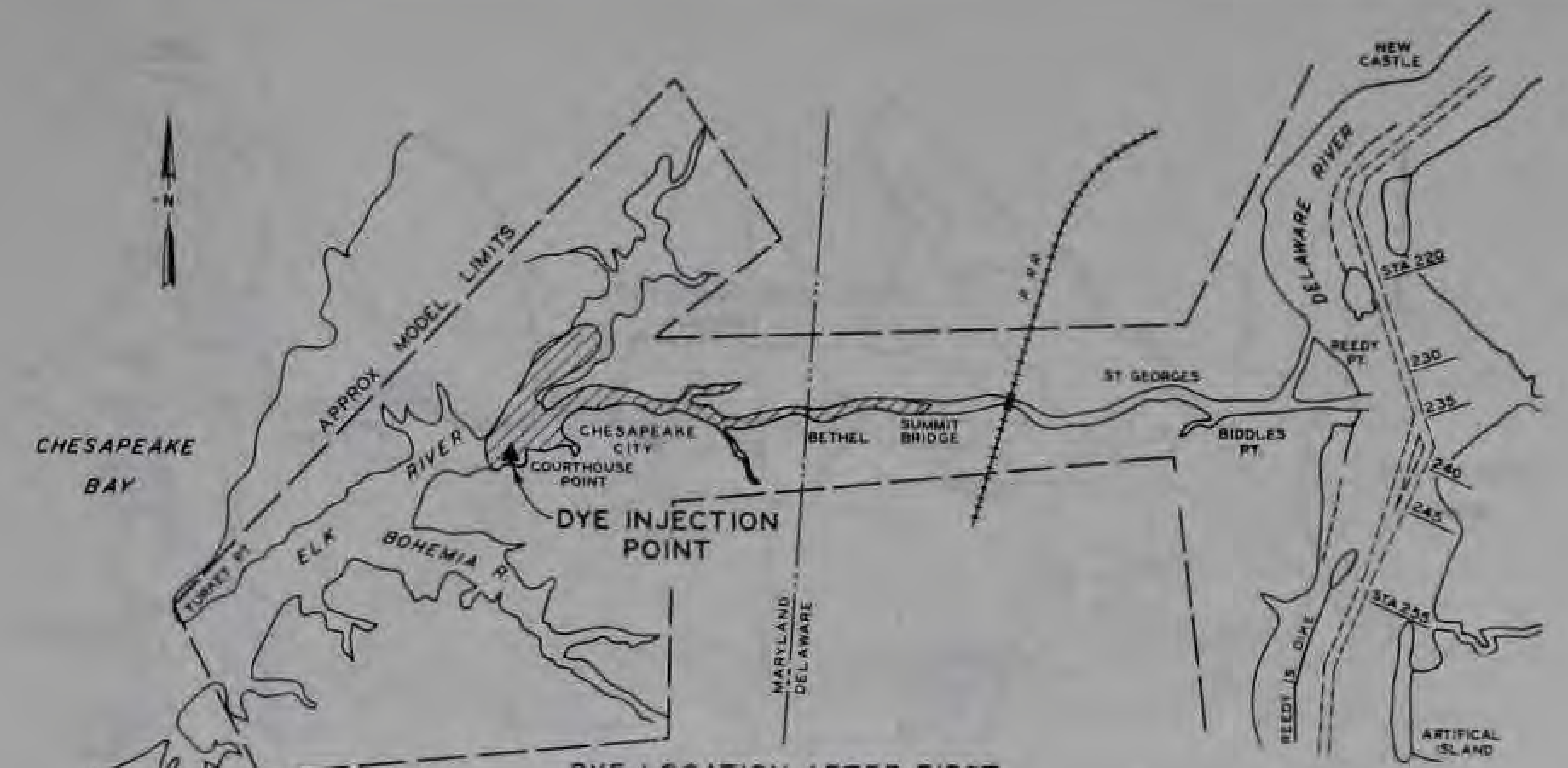
TIDE RANGE AT COURTHOUSE POINT	2.2	FT
TIDE RANGE AT REEDY ISLAND JETTY	5.5	FT
DIFFERENCE IN MEAN TIDE RANGE	+0.7	FT
NET CANAL DISCHARGE (EASTWARD)	21,200	CFS
DELAWARE RIVER COMBINED INFLOW	20,200	CFS
OCEAN SALINITY	31.000	PPM
INITIAL DYE CONCENTRATION	330,000	PPB

LEGEND

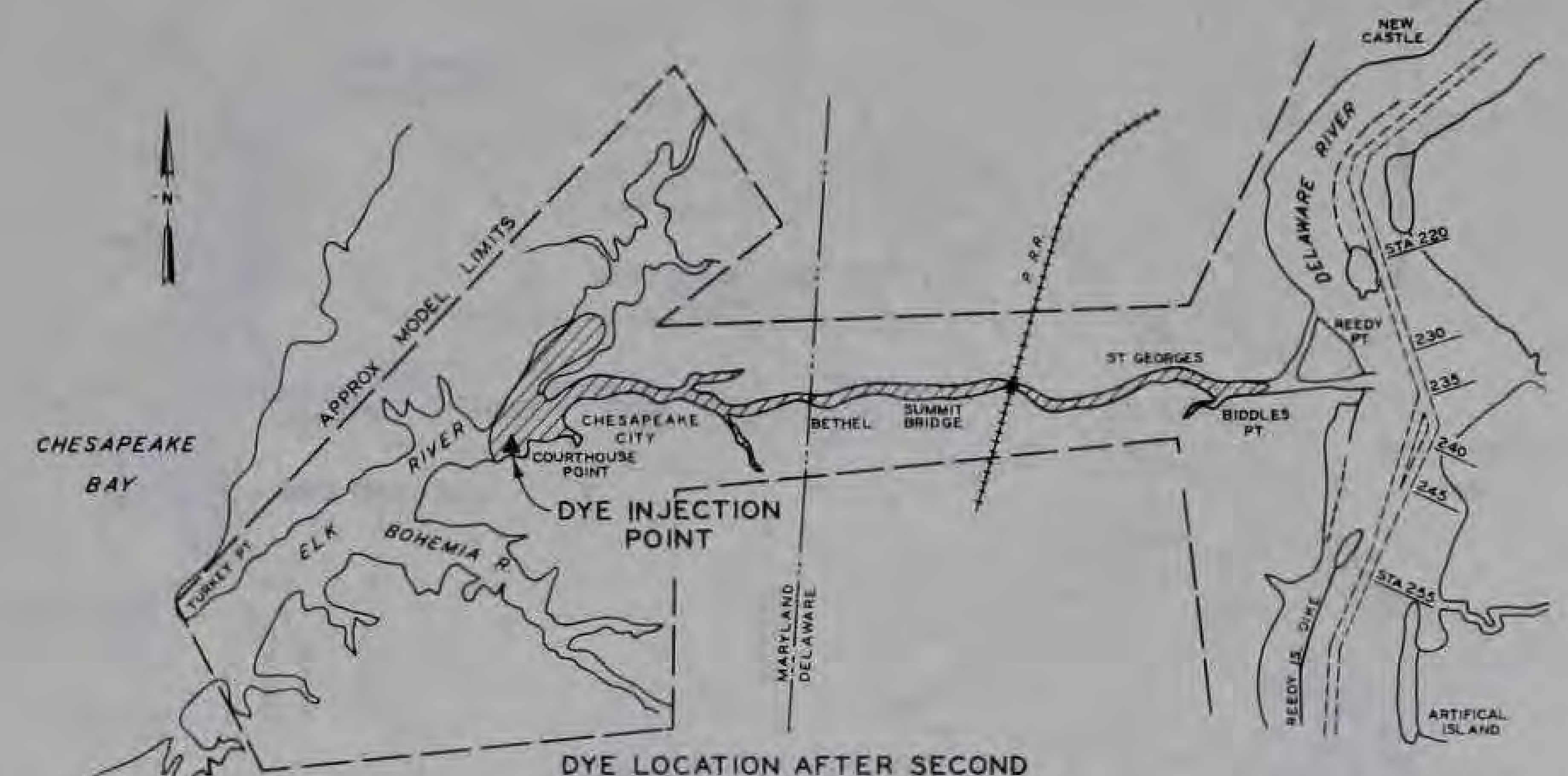
□ ——— SURFACE
▲ — — — BOTTOM
BASE

DYE DISPERSION TEST
35 FT X 450 FT CANAL
INJECTION AT SUMMIT BRIDGE

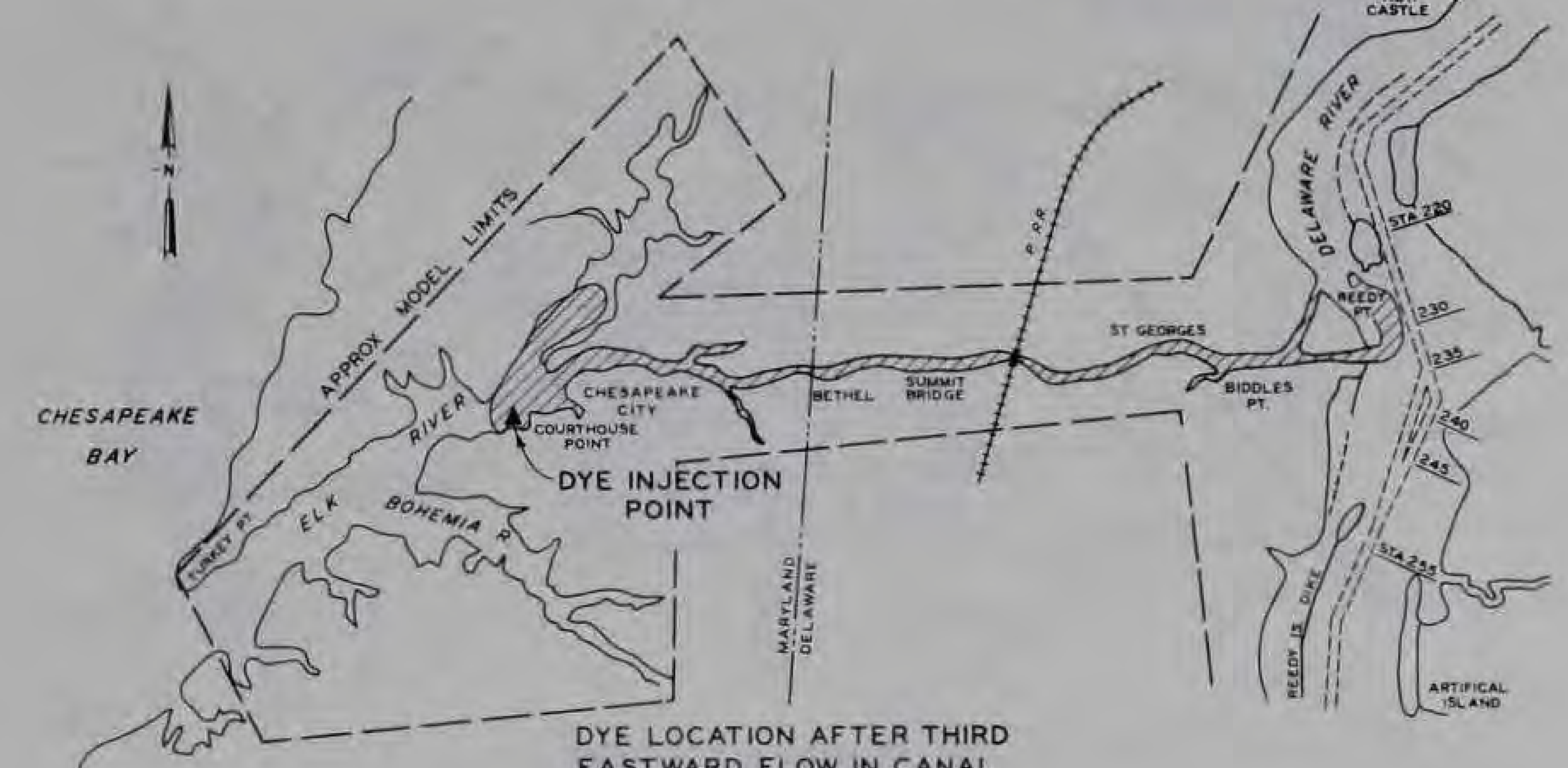
STATION 22



DYE LOCATION AFTER FIRST
EASTWARD FLOW IN CANAL



DYE LOCATION AFTER SECOND
EASTWARD FLOW IN CANAL



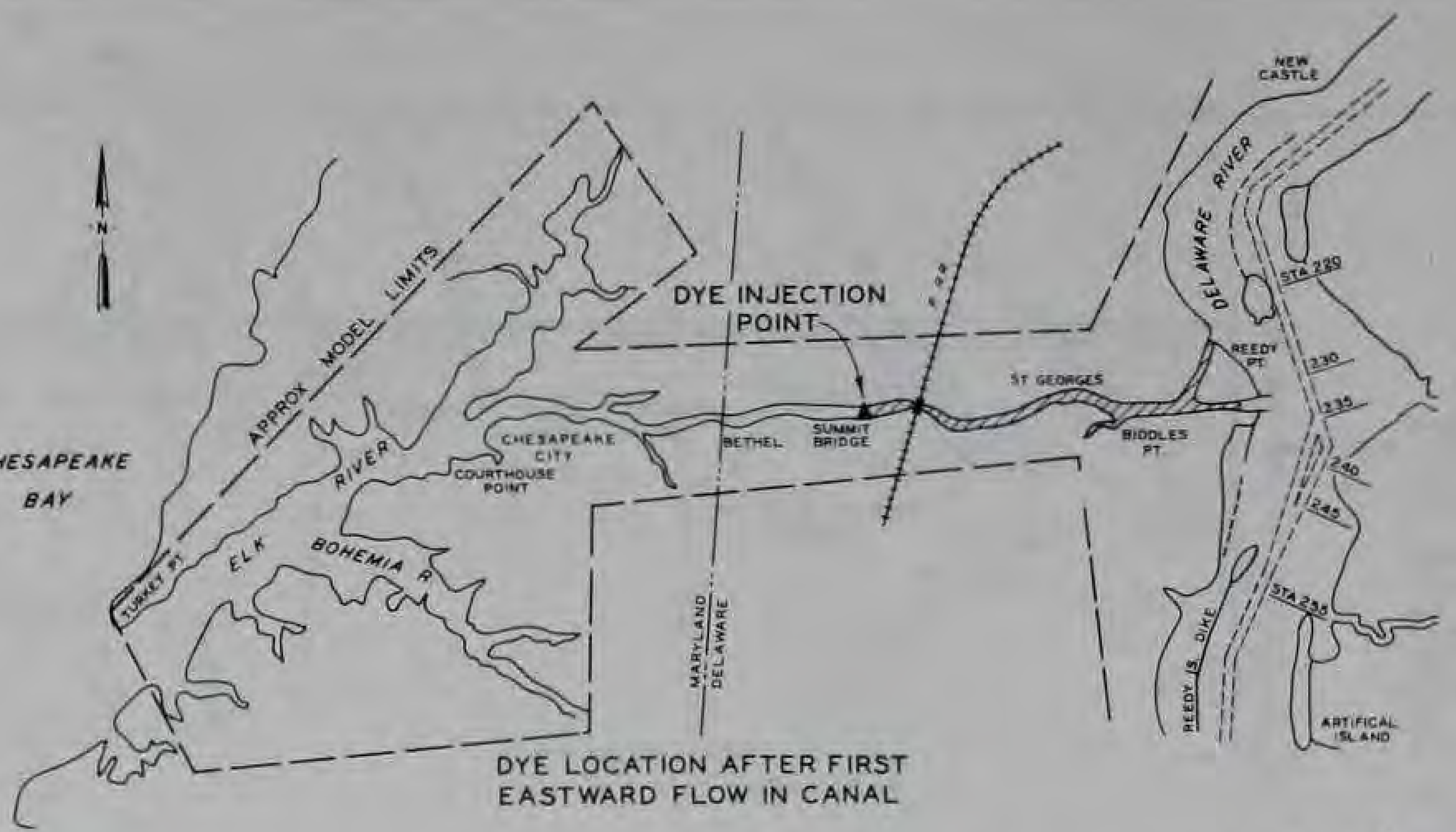
DYE LOCATION AFTER THIRD
EASTWARD FLOW IN CANAL

LOCATIONS OF DYE FRONTS
27 FT x 250 FT CANAL
COURTHOUSE POINT INJECTION

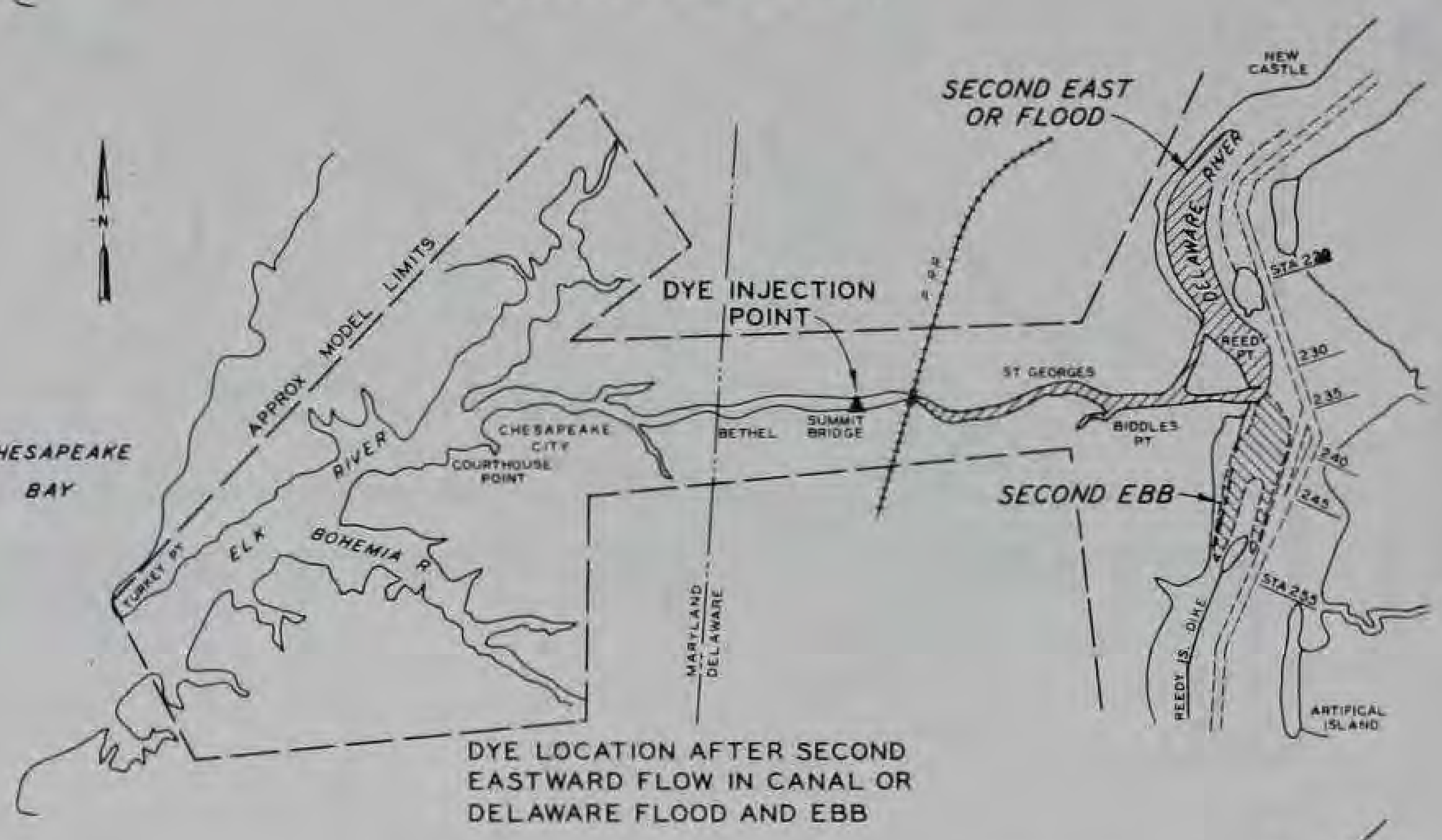
SCALES IN FEET

PROTOTYPE 20,000 0 20,000 40,000

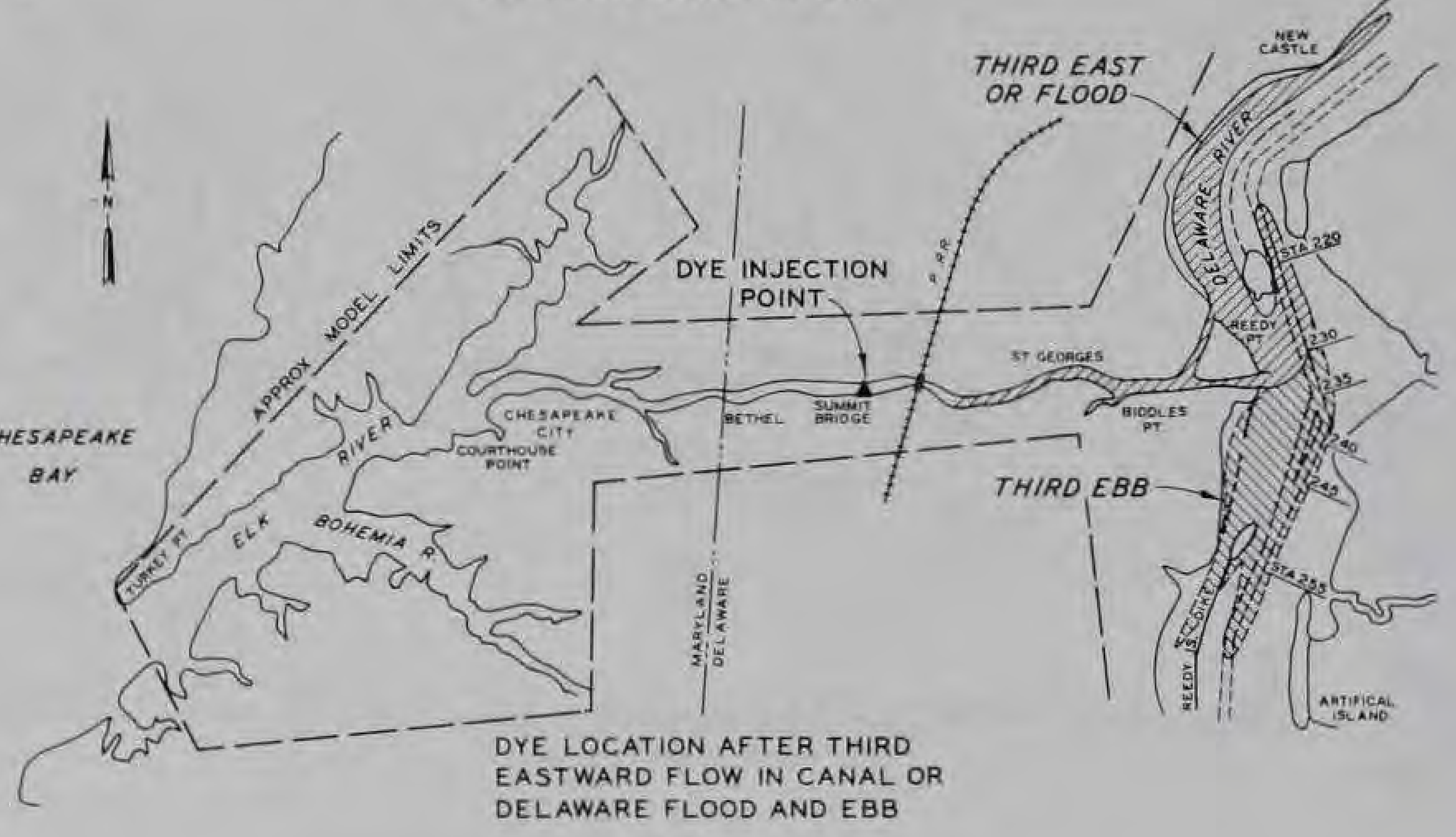
MODEL 20 0 20 40



DYE LOCATION AFTER FIRST EASTWARD FLOW IN CANAL



DYE LOCATION AFTER SECOND EASTWARD FLOW IN CANAL OR DELAWARE FLOOD AND EBB



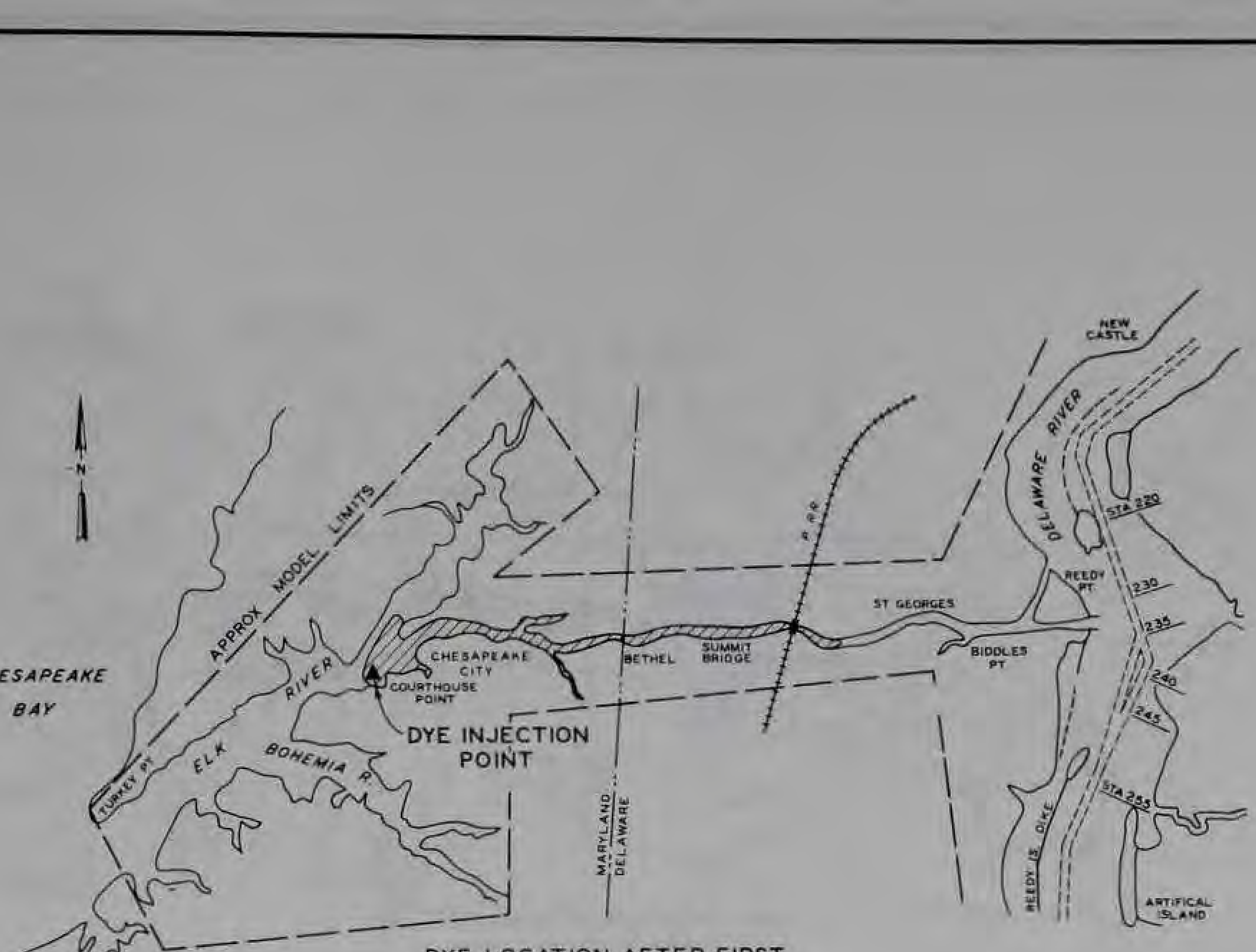
DYE LOCATION AFTER THIRD EASTWARD FLOW IN CANAL OR DELAWARE FLOOD AND EBB

LOCATIONS OF DYE FRONTS
27 FT x 250 FT CANAL
SUMMIT BRIDGE INJECTION

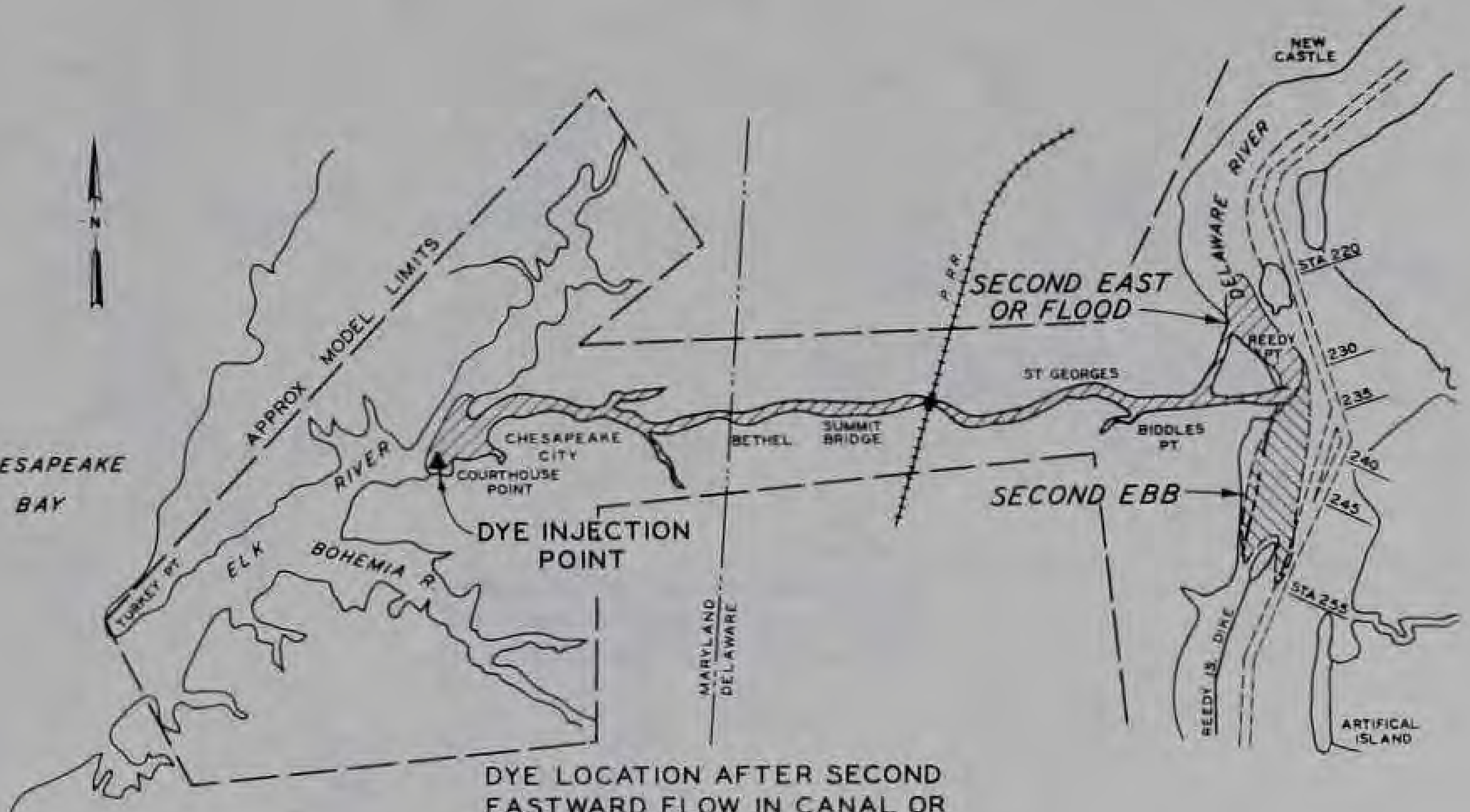
SCALES IN FEET

PROTOTYPE 20,000 0 20,000 40,000

MODEL 20 0 20 40



DYE LOCATION AFTER FIRST
EASTWARD FLOW IN CANAL

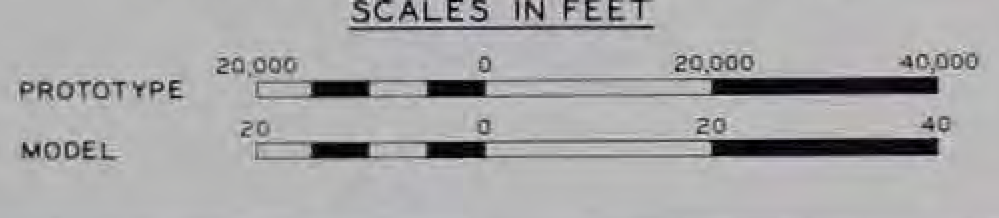


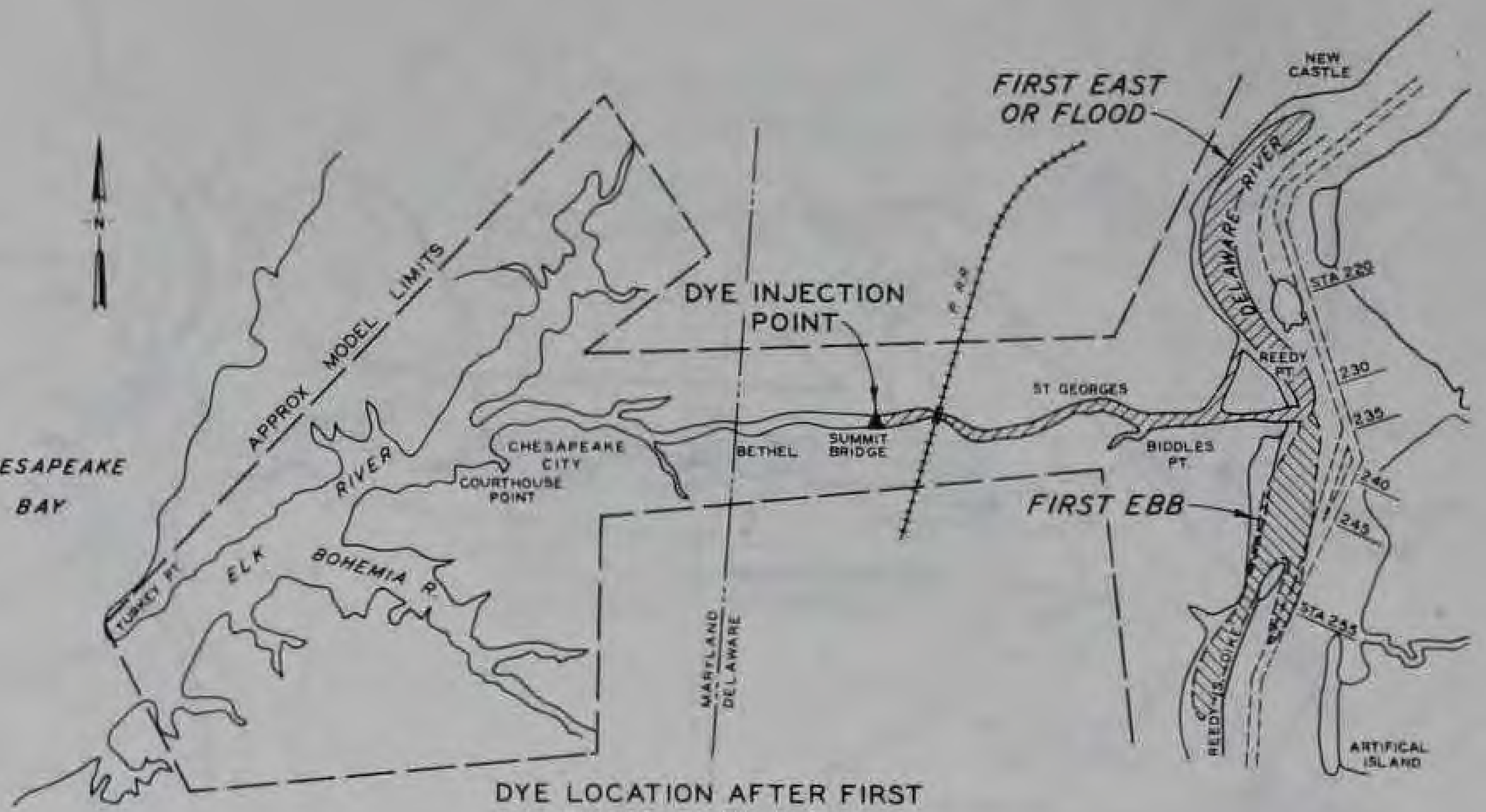
DYE LOCATION AFTER SECOND
EASTWARD FLOW IN CANAL OR
DELAWARE FLOOD AND EBB

LOCATIONS OF DYE FRONTS
35 FT x 450 FT CANAL

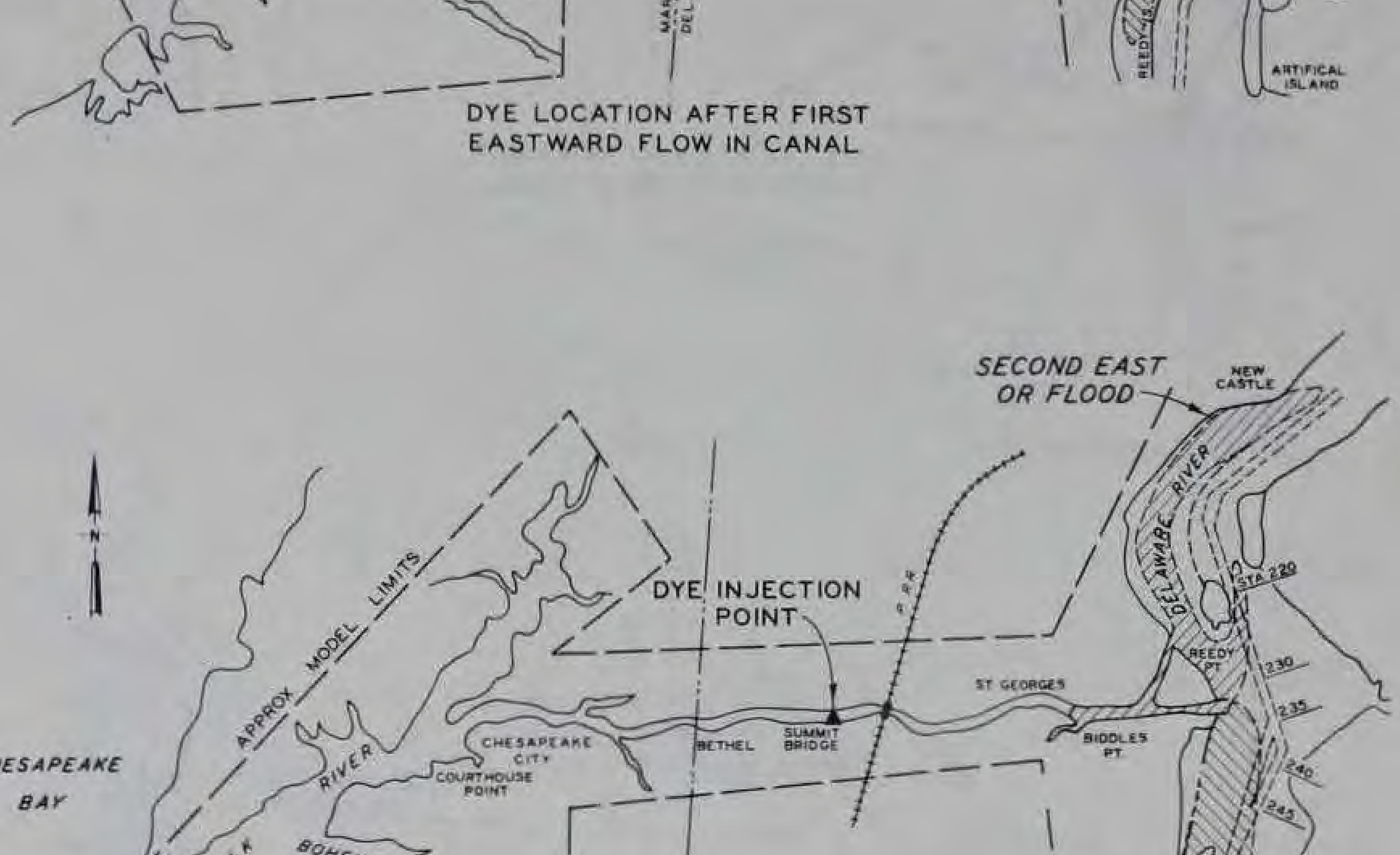
COURTHOUSE POINT INJECTION

SCALES IN FEET





DYE LOCATION AFTER FIRST EASTWARD FLOW IN CANAL



DYE LOCATION AFTER SECOND EASTWARD FLOW IN CANAL OR DELAWARE FLOOD AND EBB

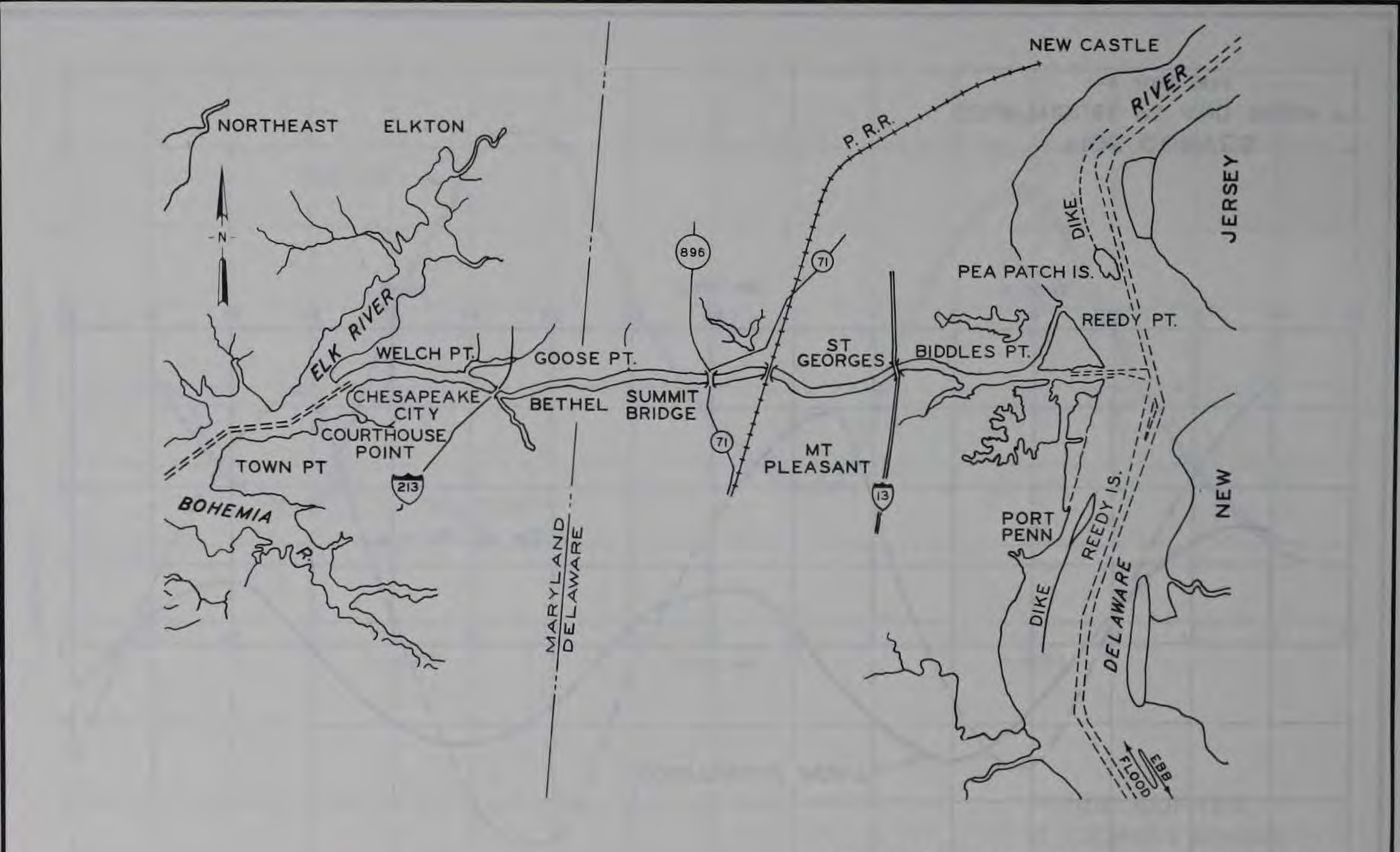
LOCATIONS OF DYE FRONTS
35 FT x 450 FT CANAL
SUMMIT BRIDGE INJECTION

SCALES IN FEET

PROTOTYPE 20,000 0 20,000 40,000

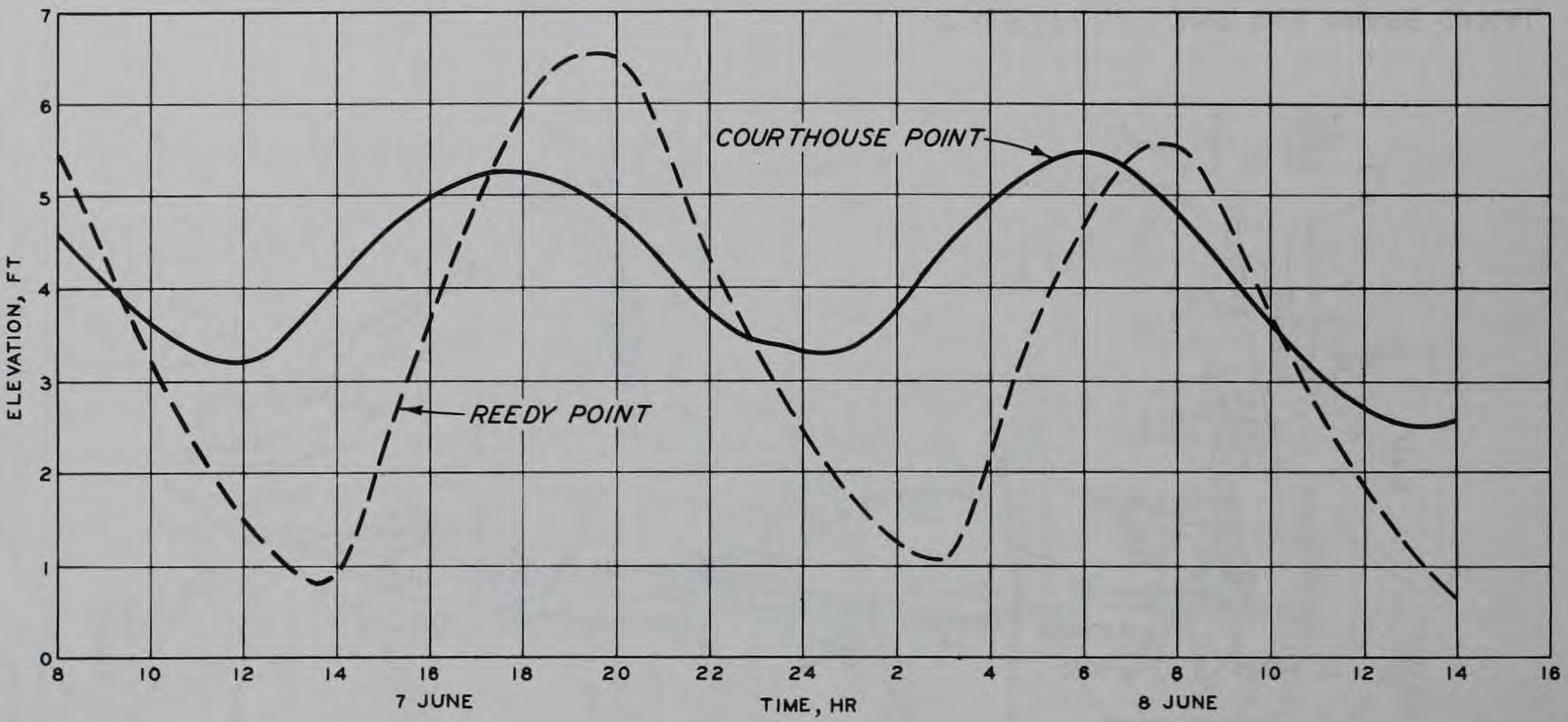
MODEL 20 0 20 40

PLATE 216

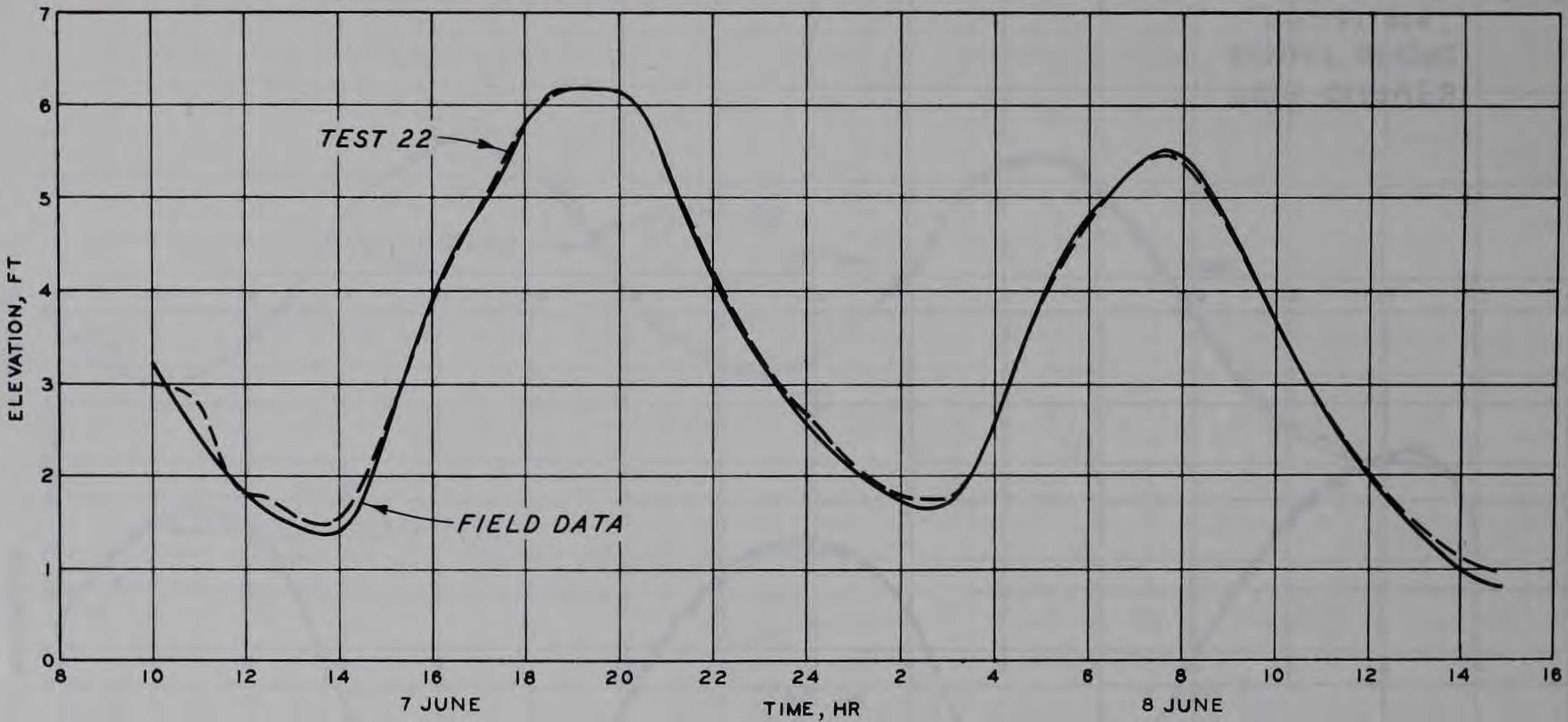


CHESAPEAKE AND DELAWARE CANAL

PLATE 217



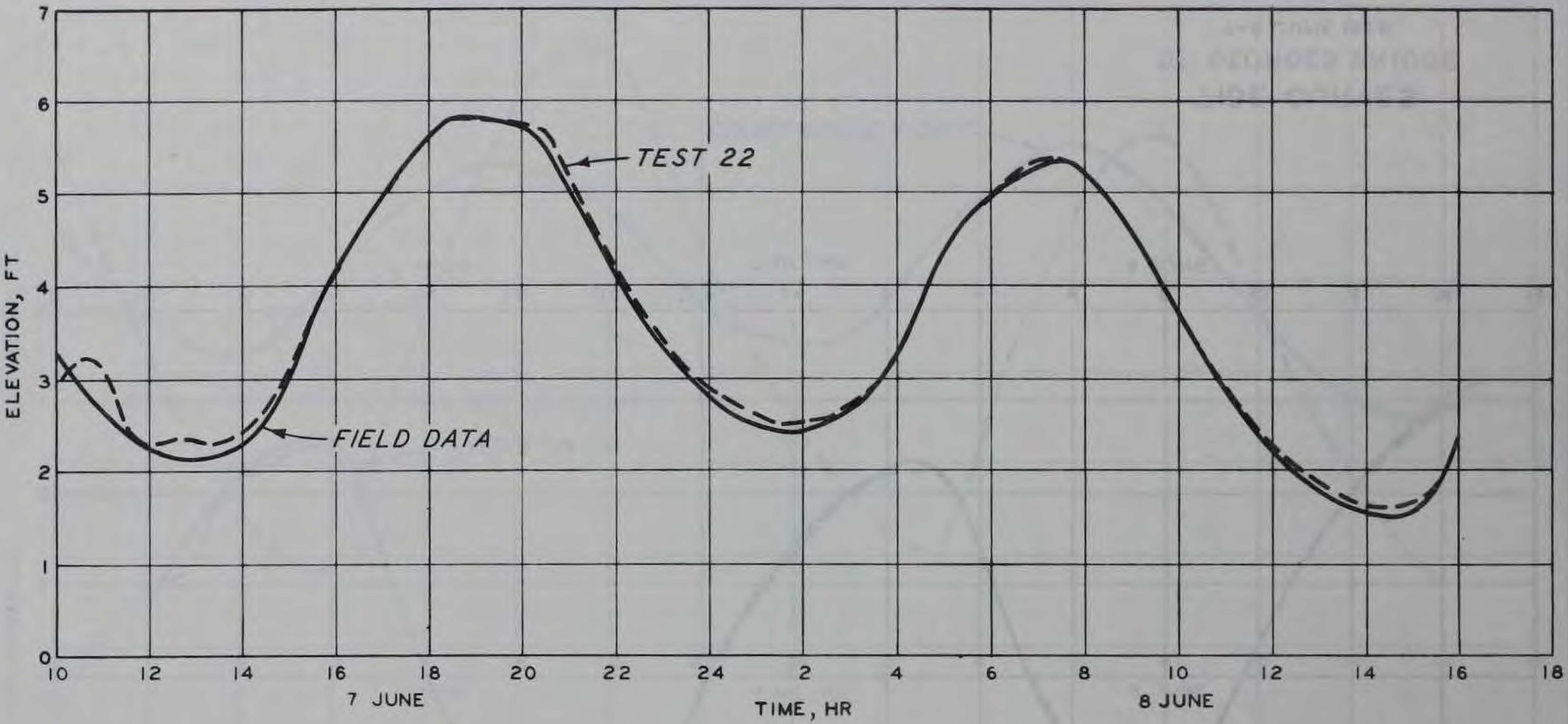
TIDE CURVES
COURTHOUSE PT AND REEDY PT
7-8 JUNE 1938



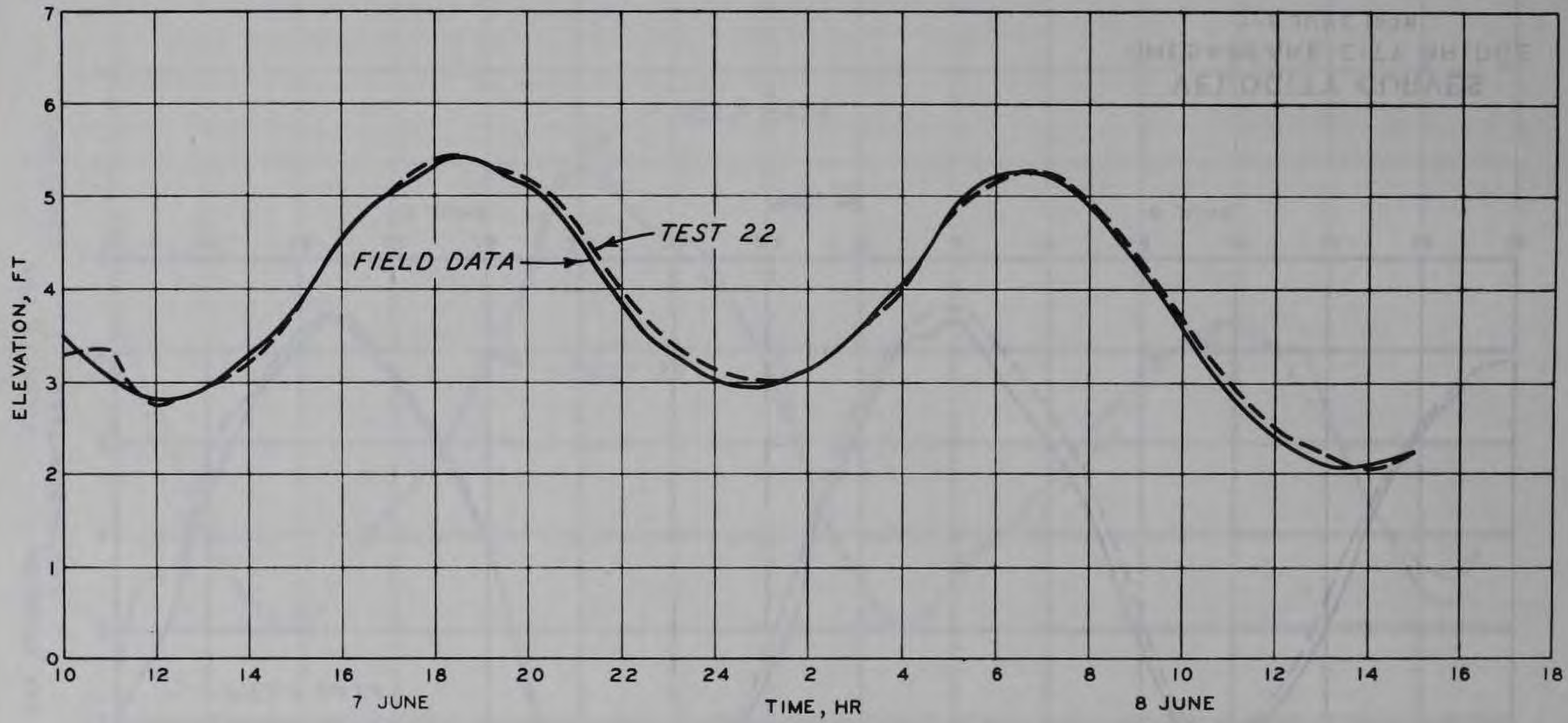
TIDE CURVES

ST. GEORGES BRIDGE

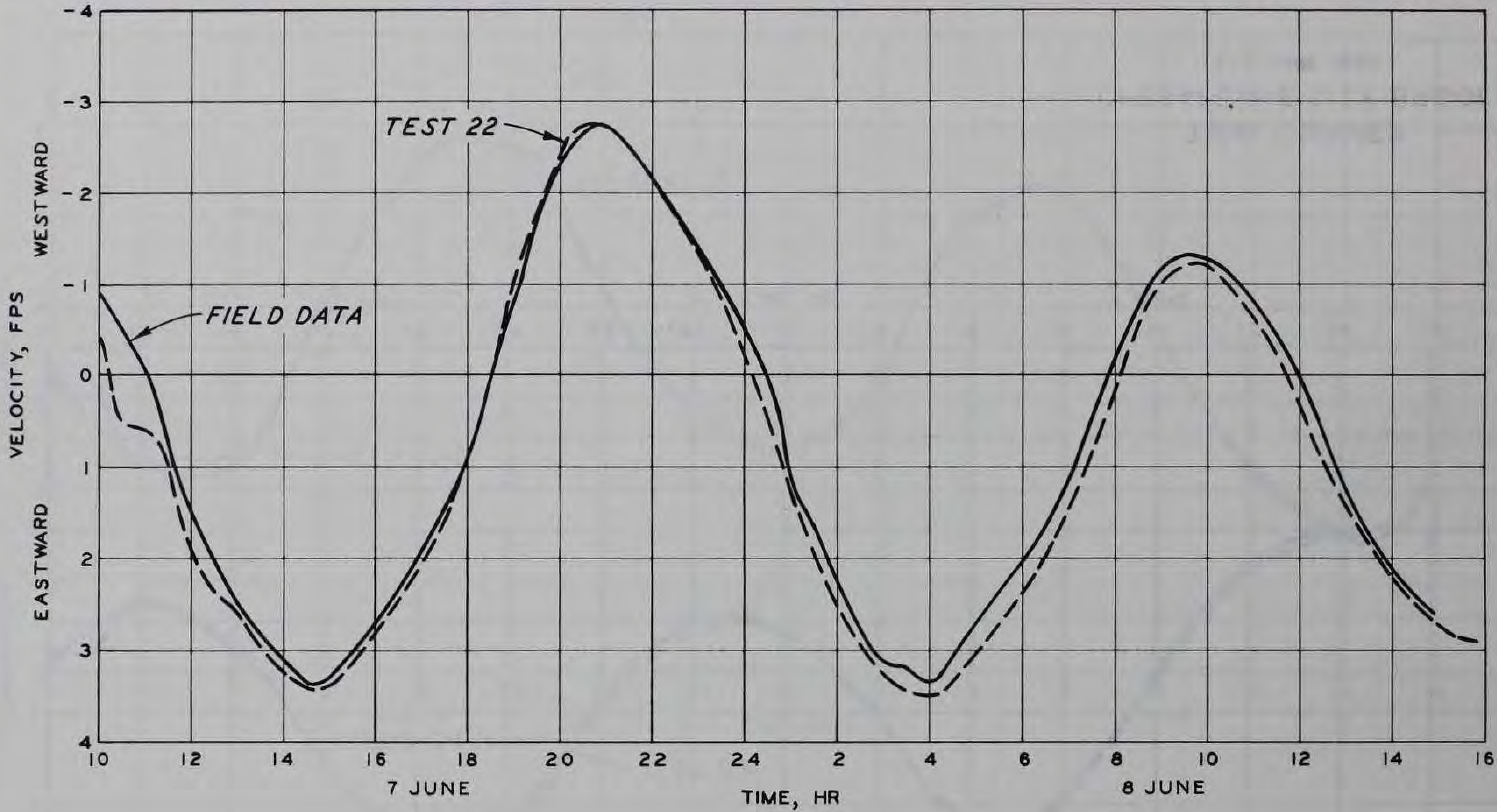
7-8 JUNE 1938



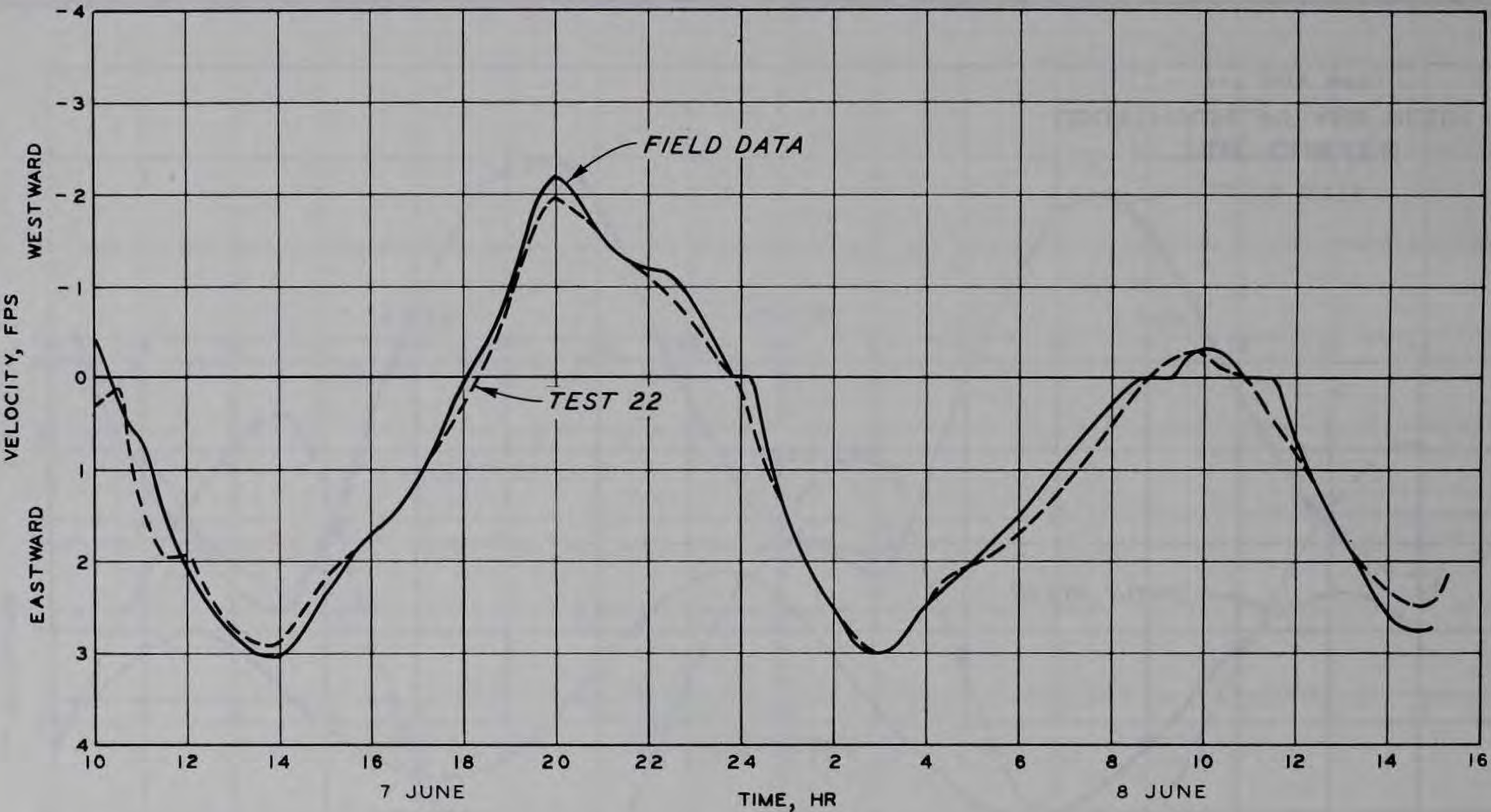
TIDE CURVES
SUMMIT BRIDGE
7-8 JUNE 1938



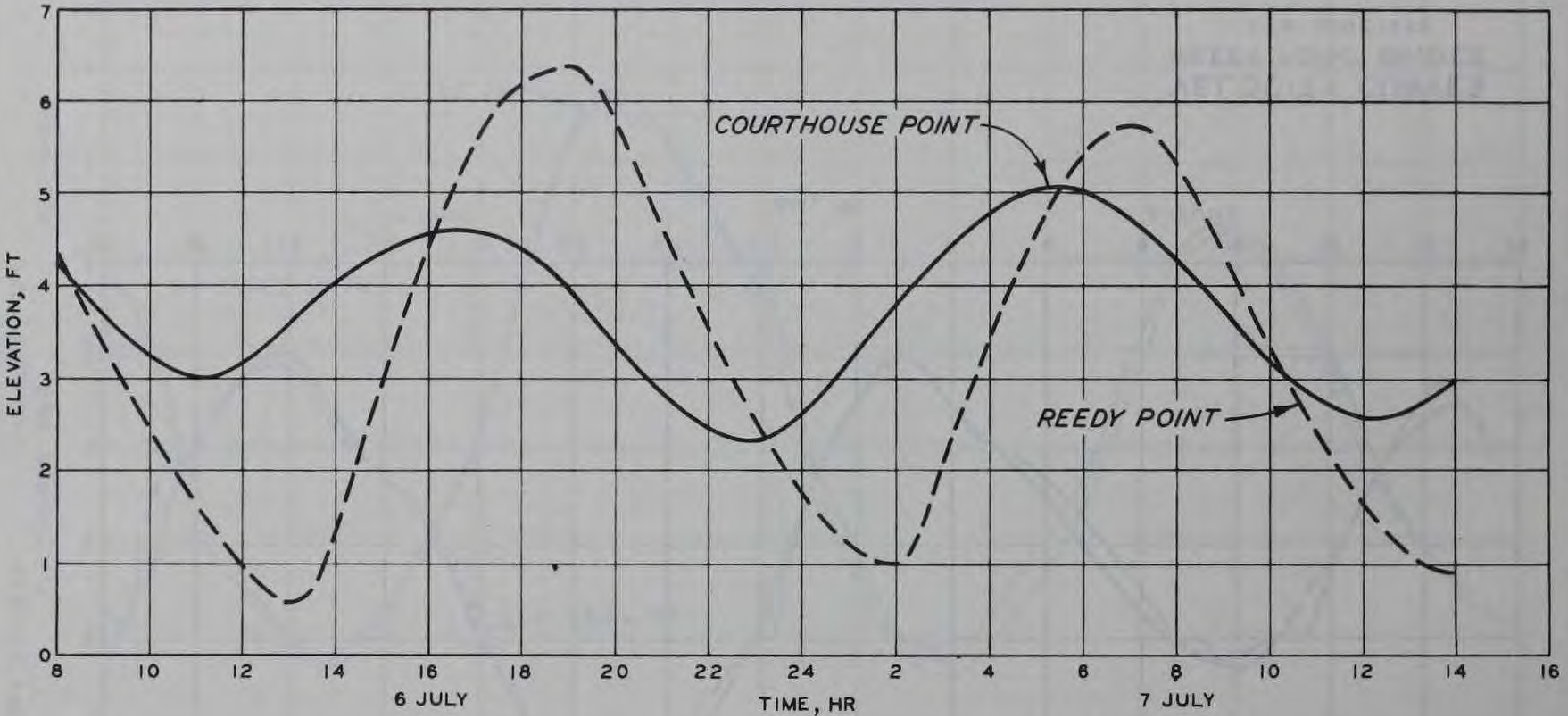
TIDE CURVES
CHESAPEAKE CITY BRIDGE
7-8 JUNE 1938



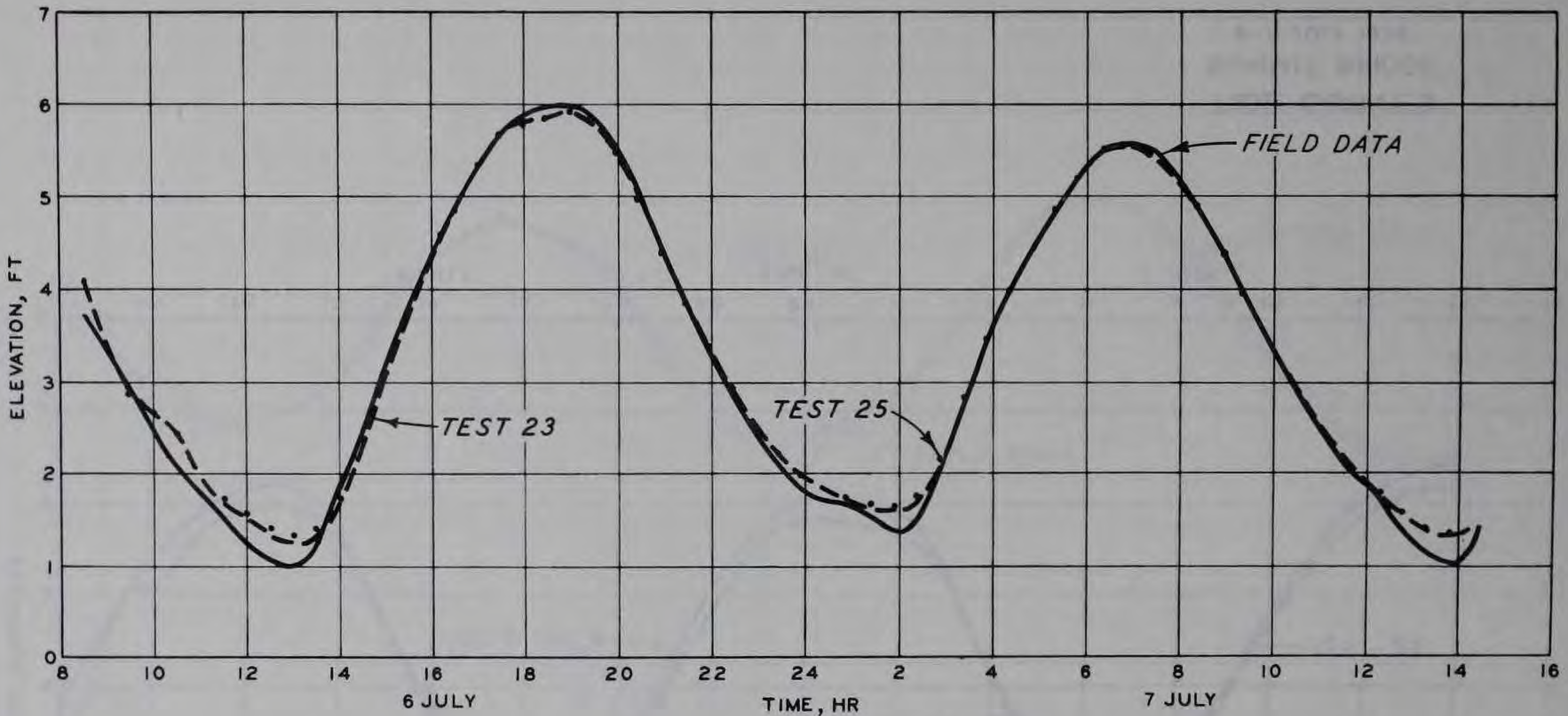
VELOCITY CURVES
CHESAPEAKE CITY BRIDGE
7-8 JUNE 1938



VELOCITY CURVES
REEDY POINT BRIDGE
7-8 JUNE 1938



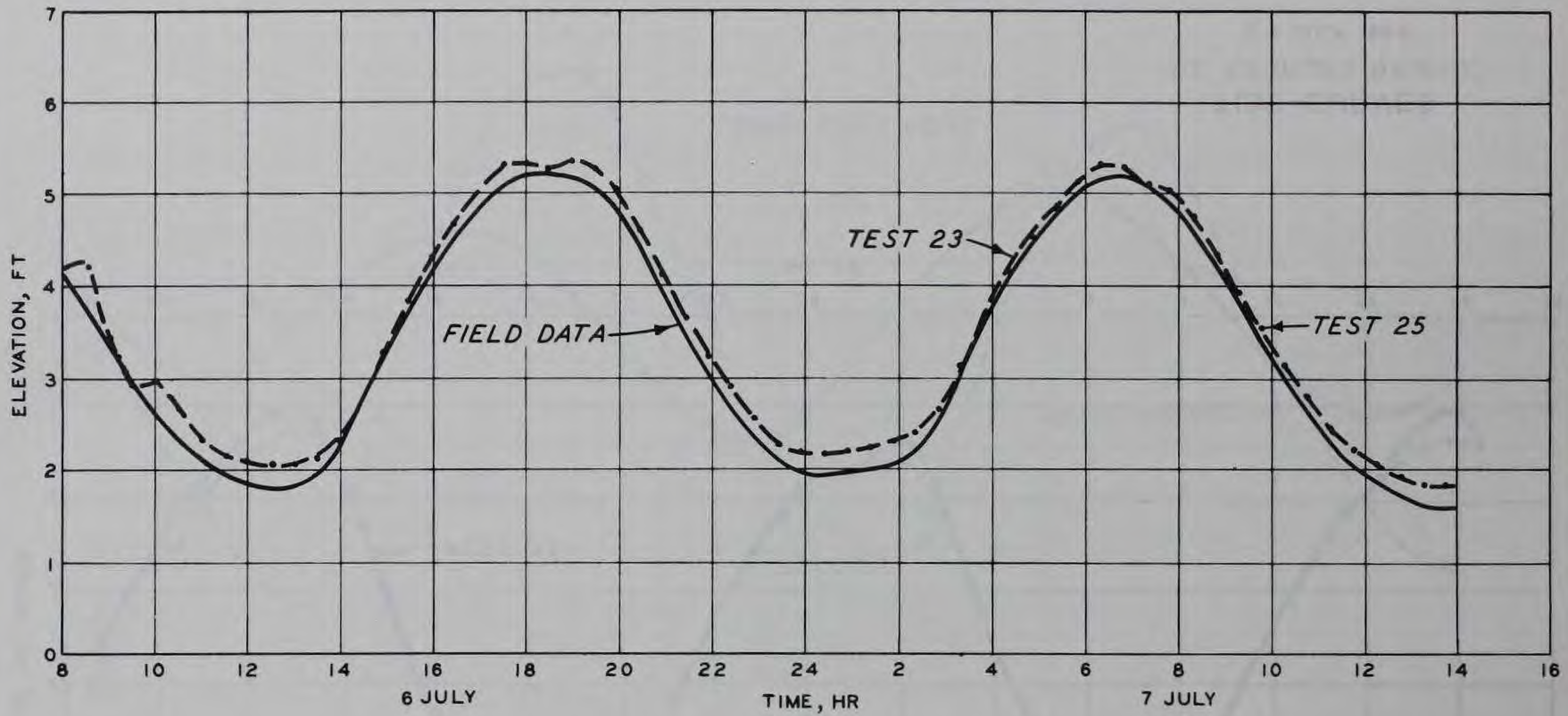
TIDE CURVES
COURTHOUSE PT AND REEDY PT
6-7 JULY 1938



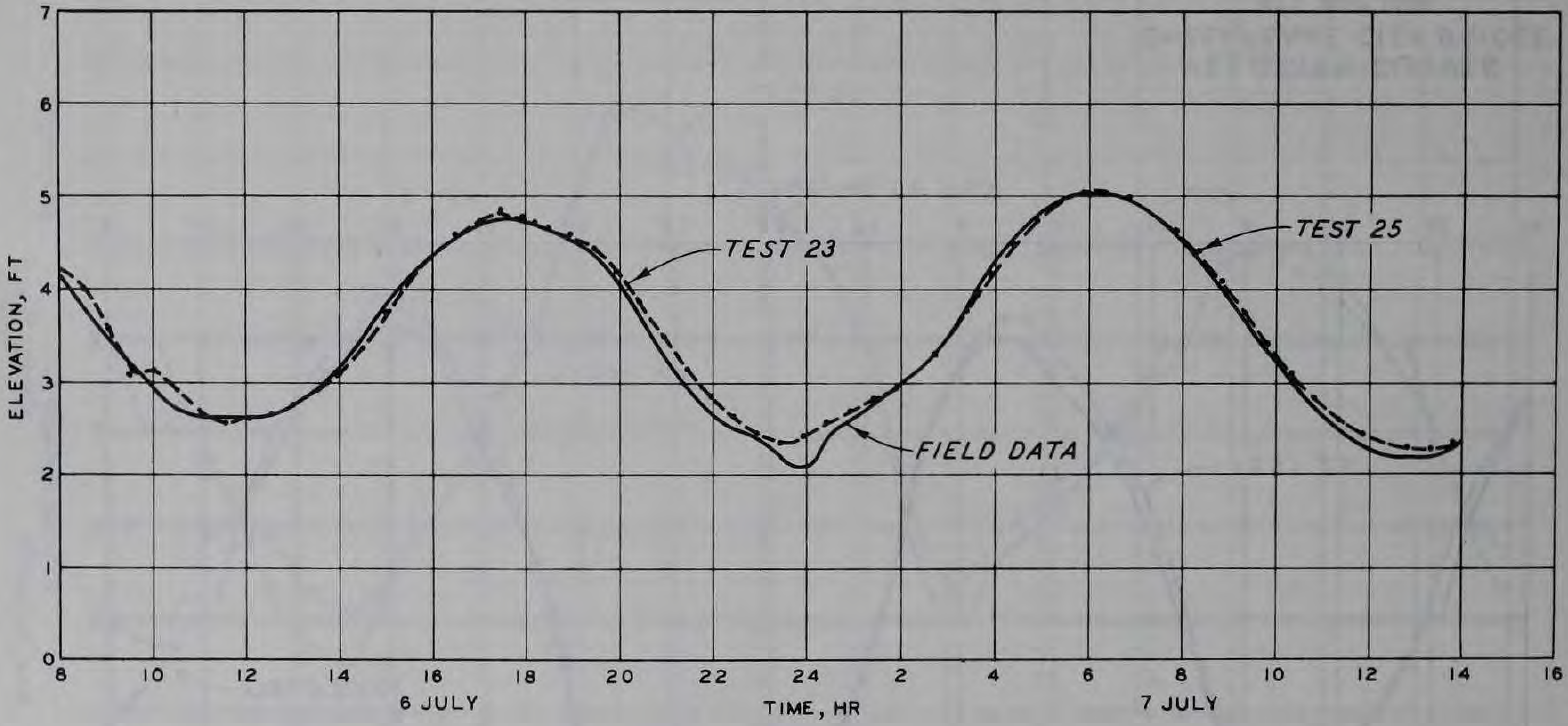
TIDE CURVES

ST. GEORGES BRIDGE

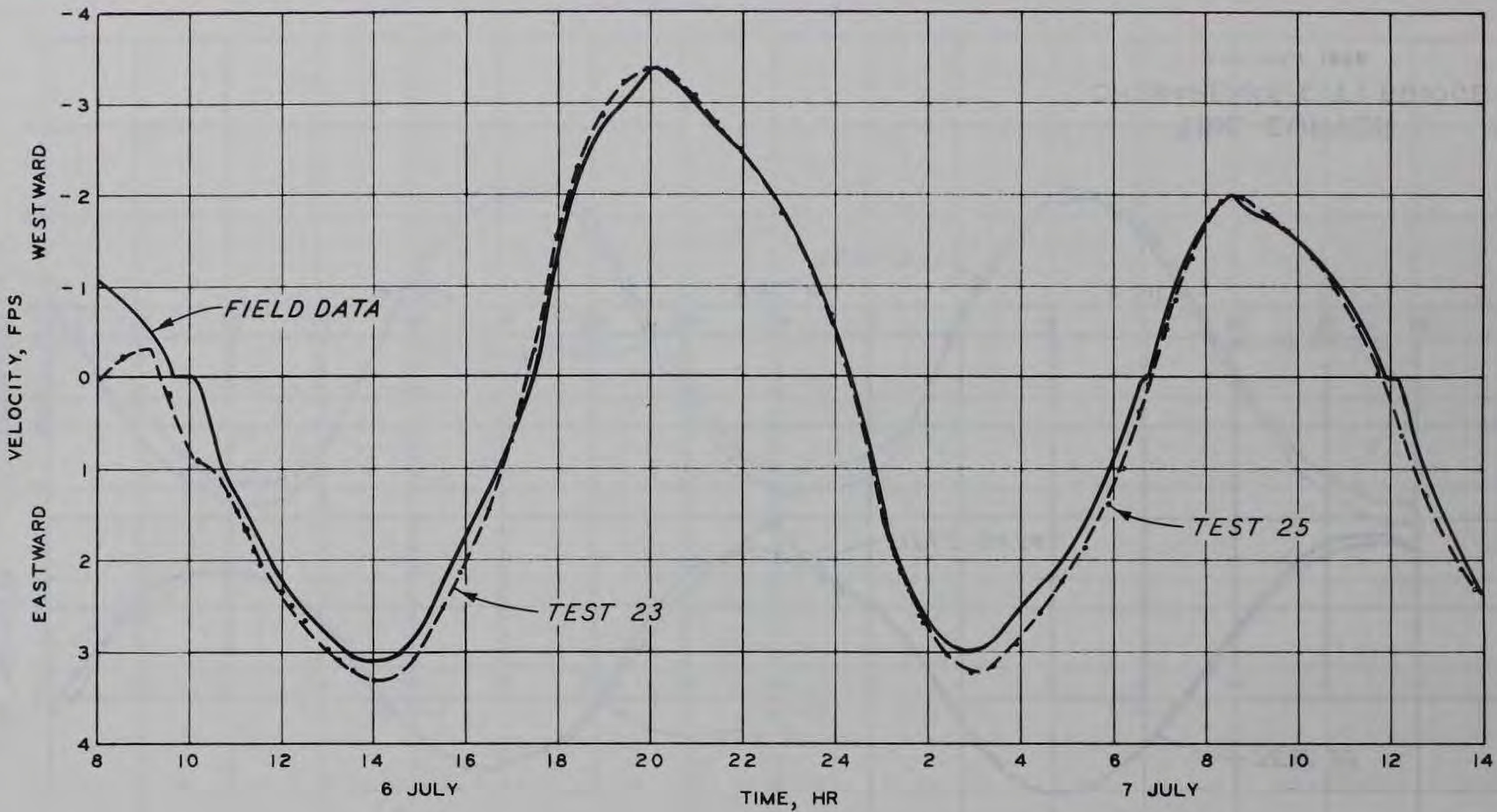
6-7 JULY 1938



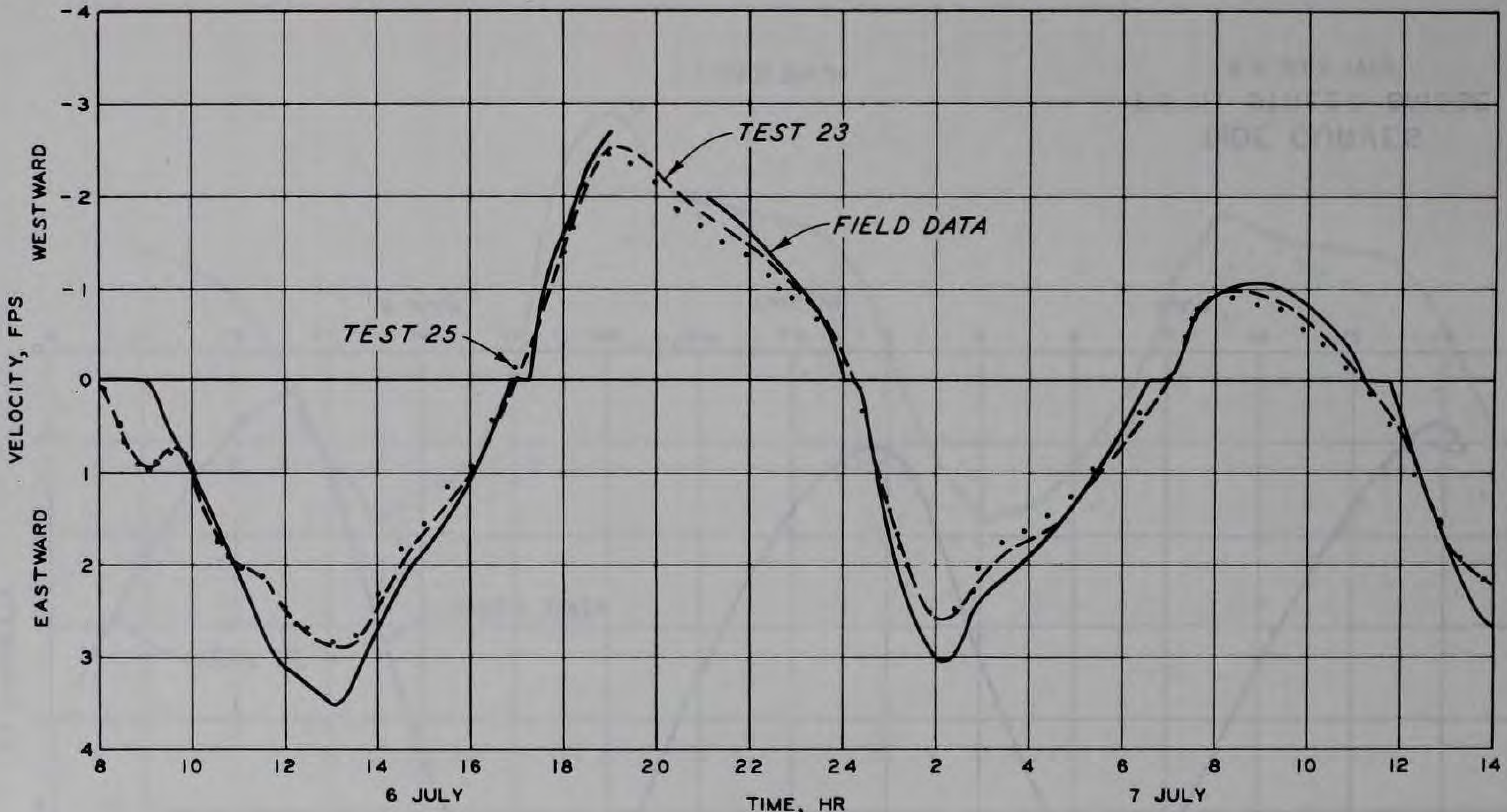
TIDE CURVES
SUMMIT BRIDGE
6-7 JULY 1938



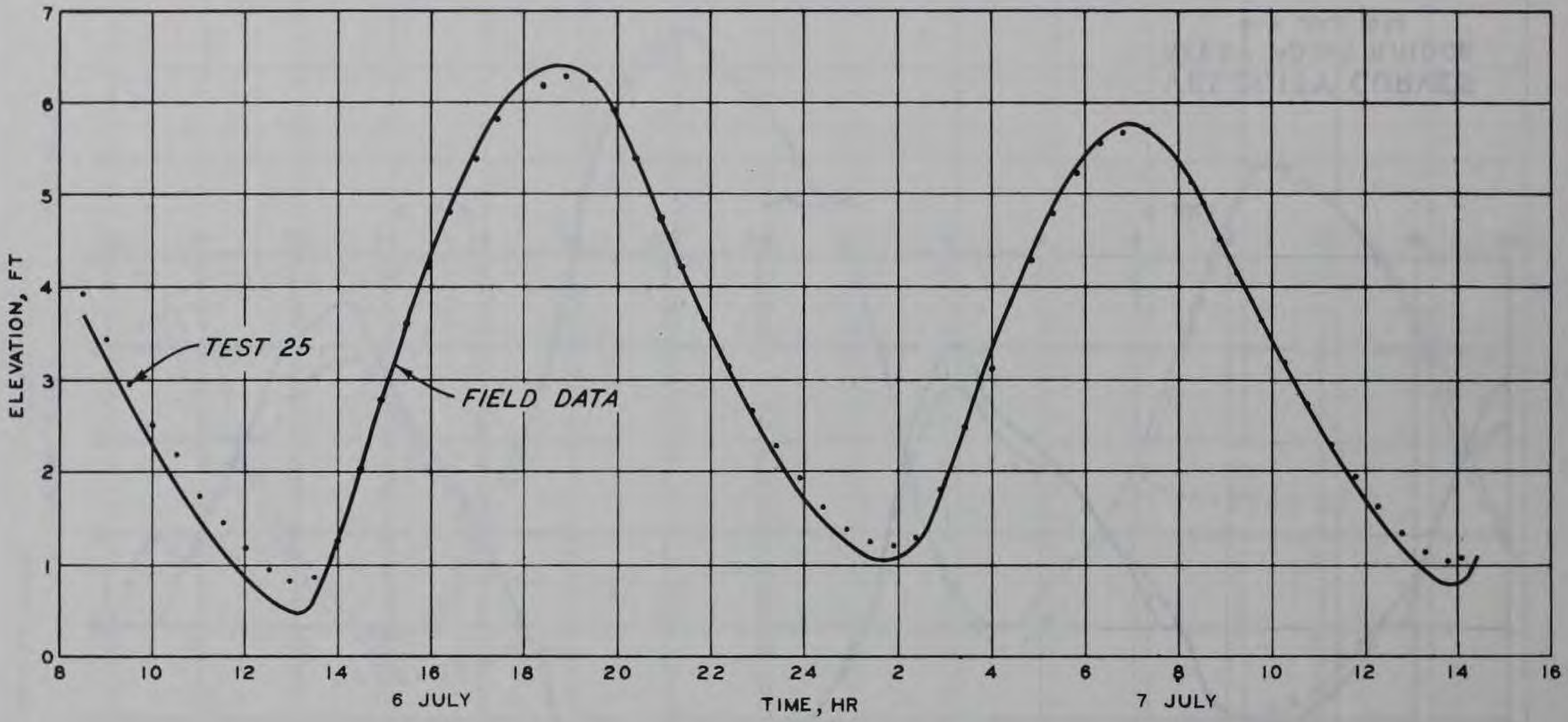
TIDE CURVES
CHESAPEAKE CITY BRIDGE
6-7 JULY 1938



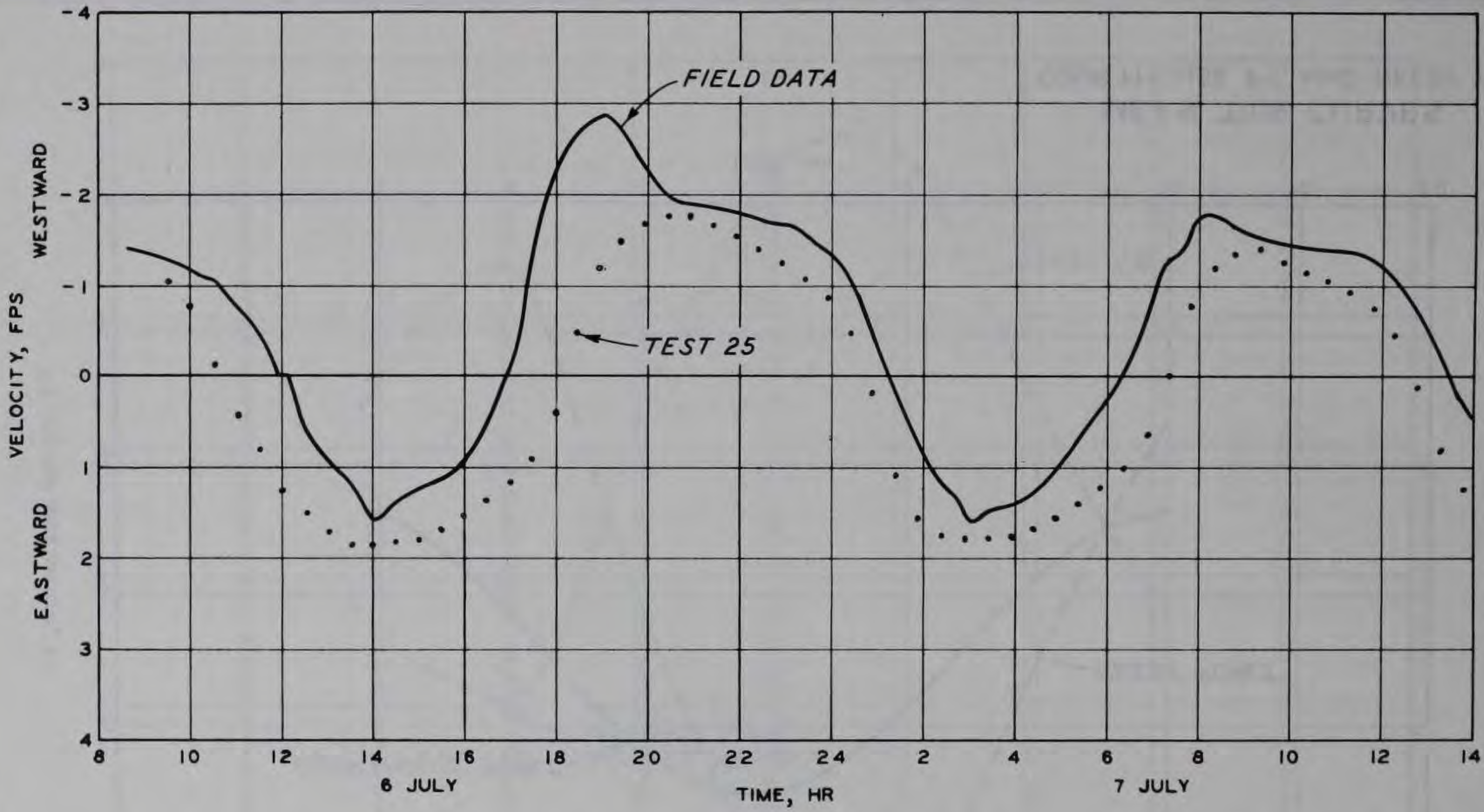
VELOCITY CURVES
CHESAPEAKE CITY BRIDGE
6-7 JULY 1938



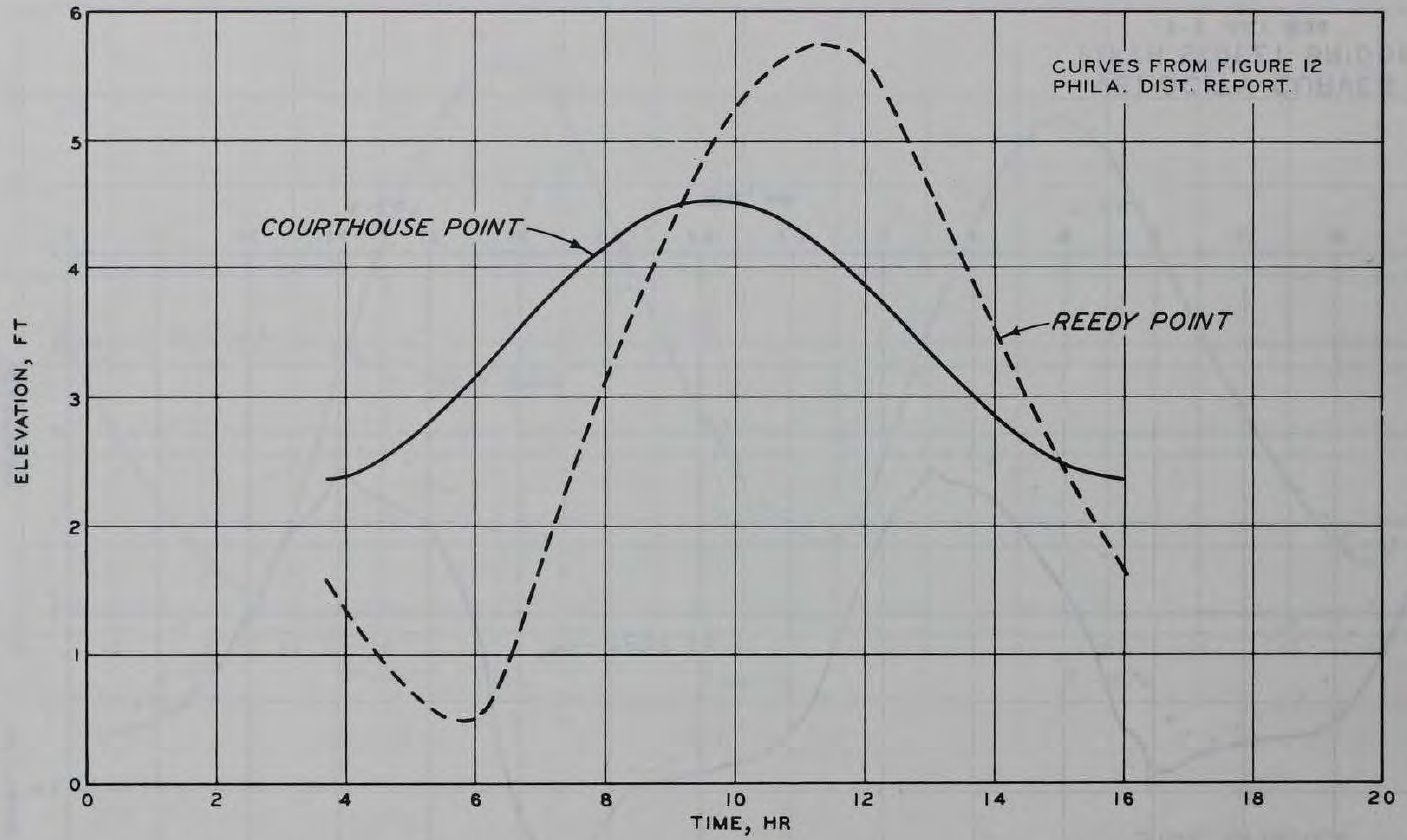
VELOCITY CURVES
REEDY POINT BRIDGE
6-7 JULY 1938



TIDE CURVES
FIFTH STREET BRIDGE
6-7 JULY 1938

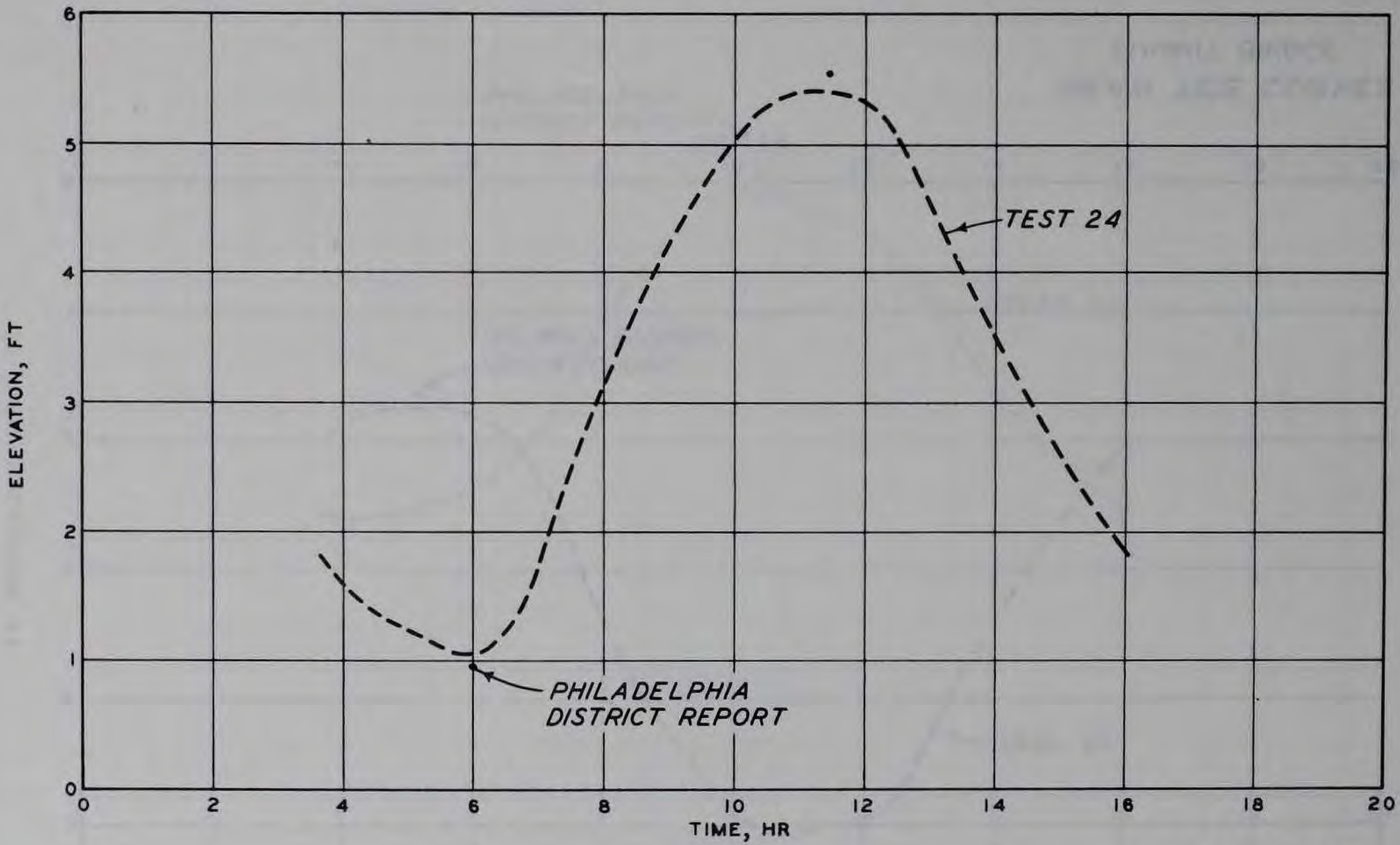


VELOCITY CURVES
FIFTH STREET BRIDGE
6-7 JULY 1938

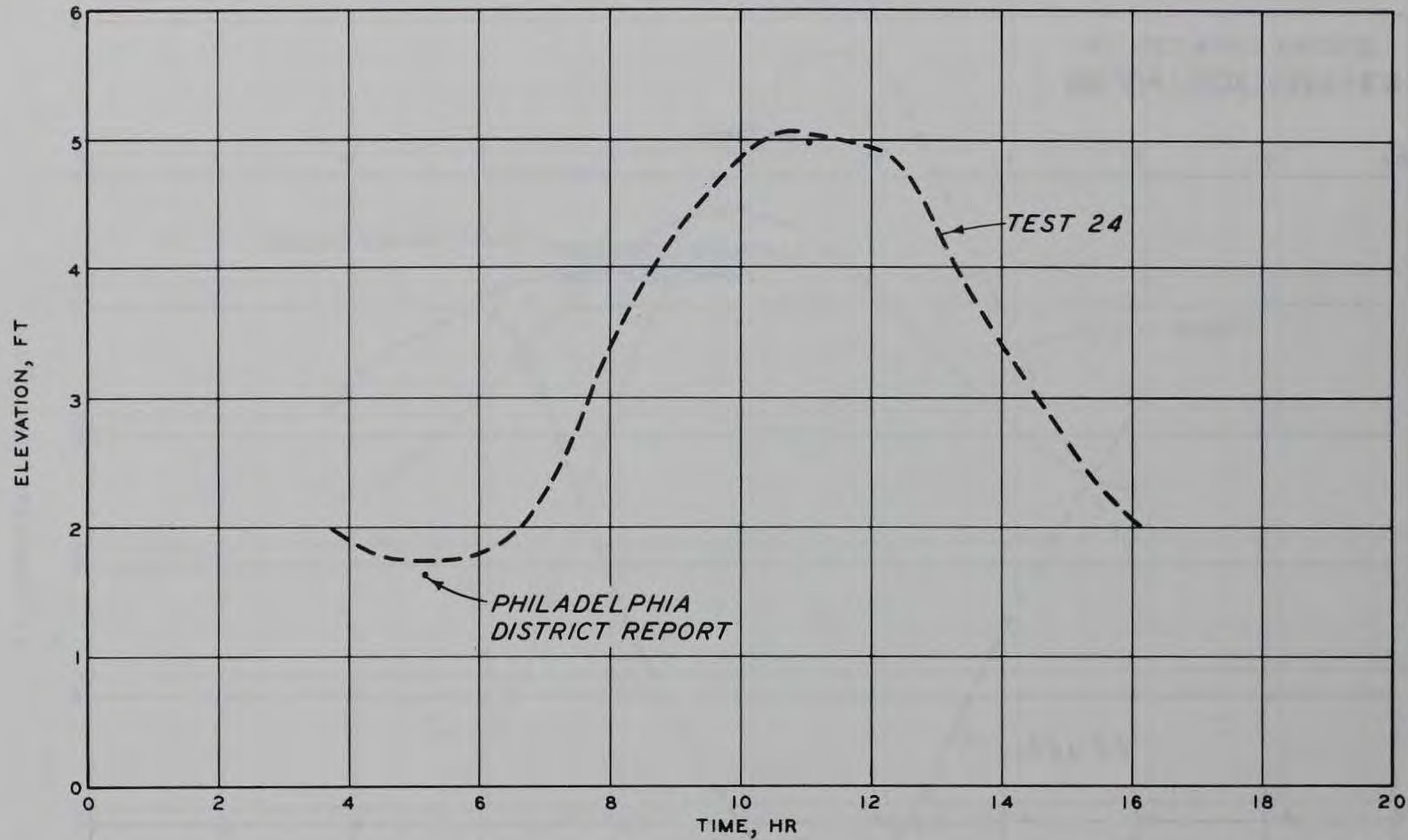


CURVES FROM FIGURE 12
PHILA. DIST. REPORT.

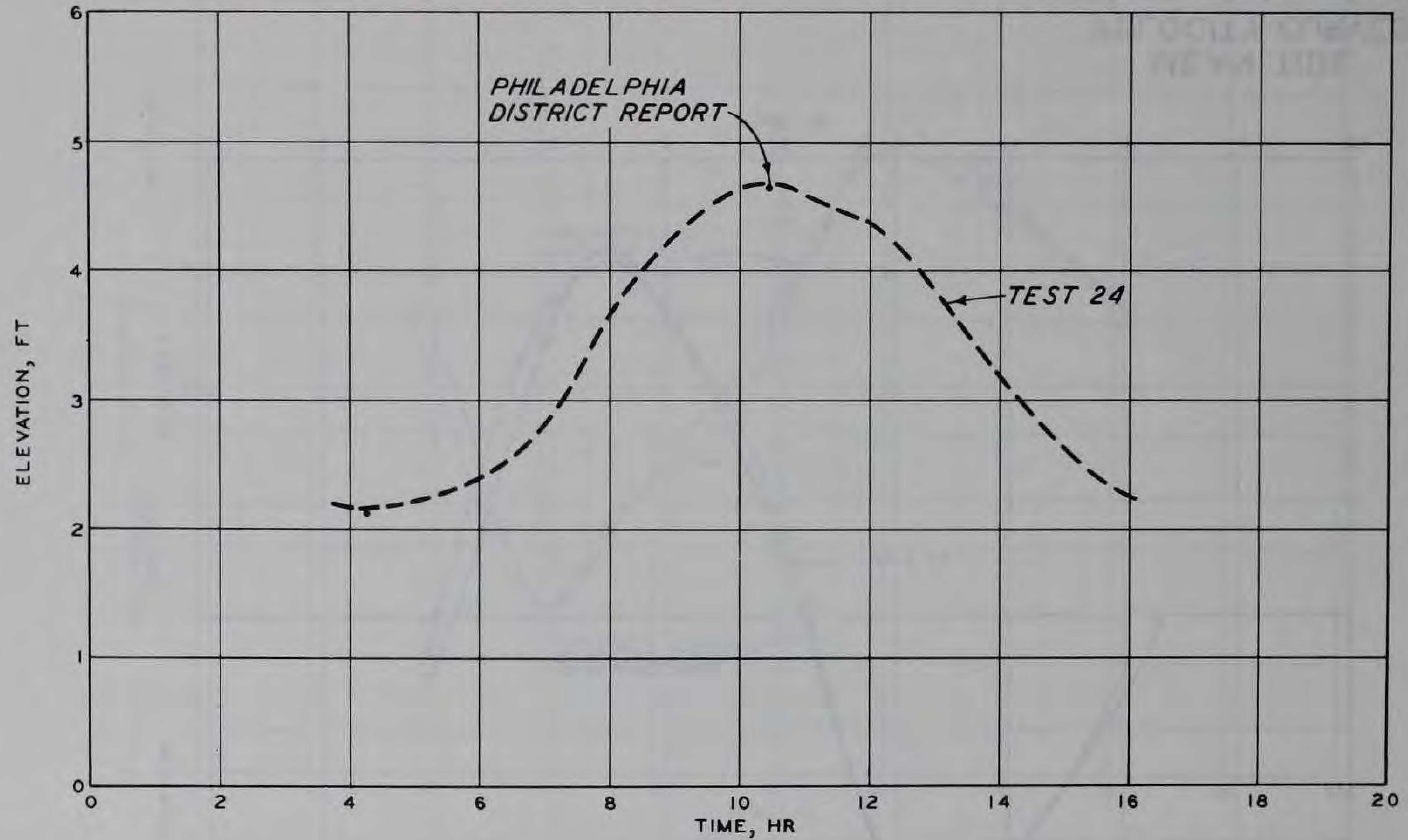
MEAN TIDE CURVES
COURTHOUSE PT AND REEDY PT



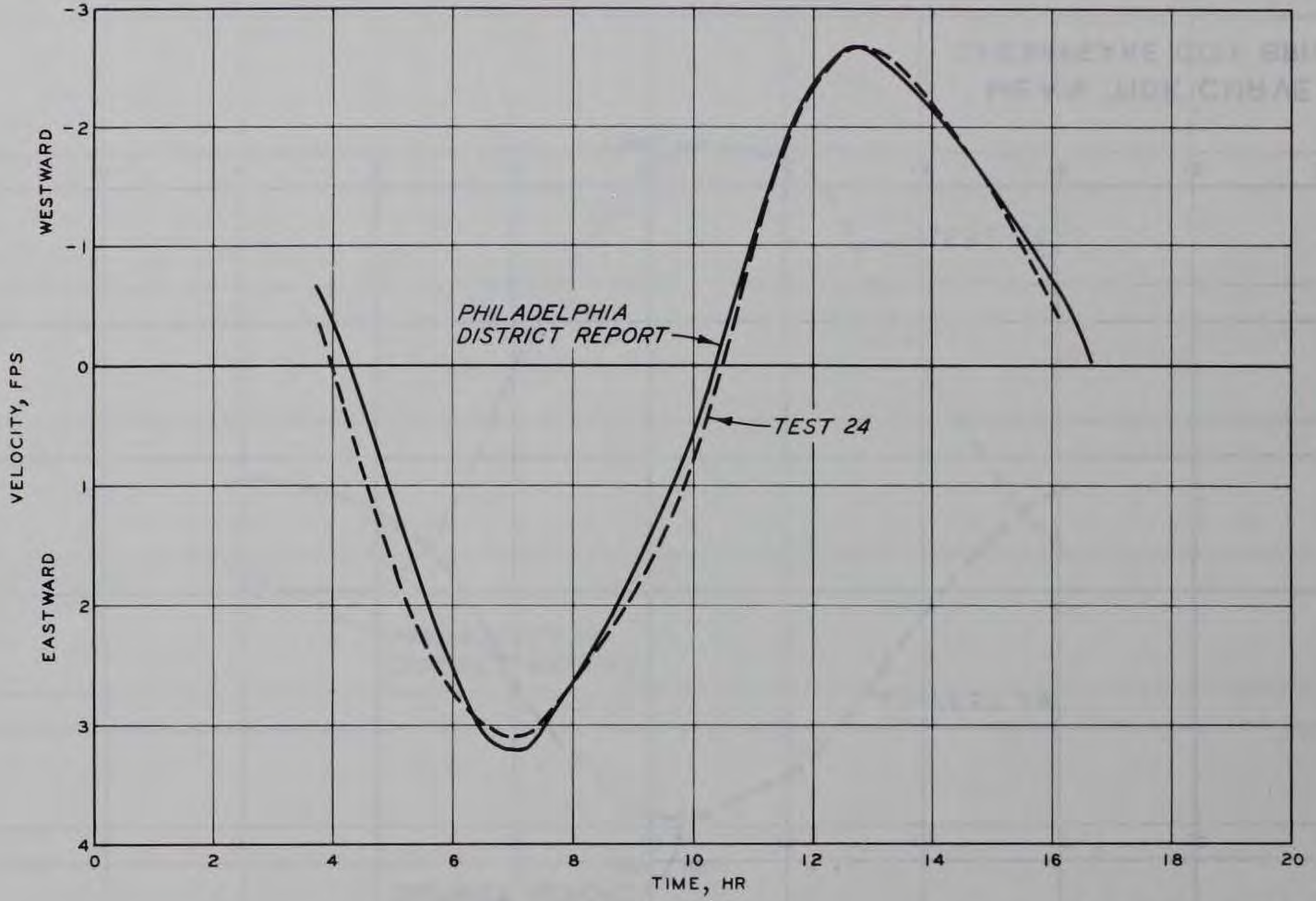
MEAN TIDE CURVES
ST. GEORGES BRIDGE



MEAN TIDE CURVES
SUMMIT BRIDGE

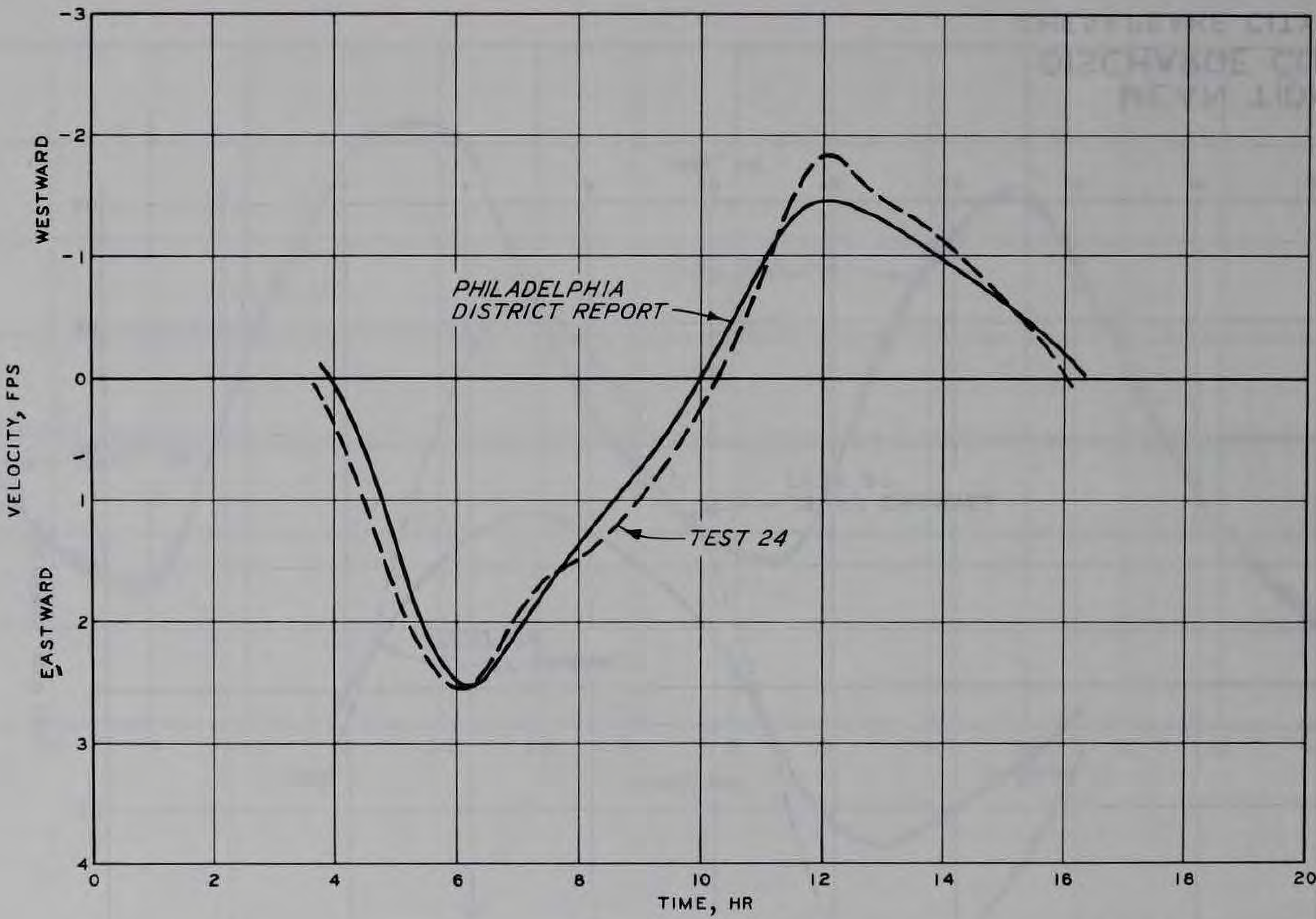


MEAN TIDE CURVES
CHESAPEAKE CITY BRIDGE



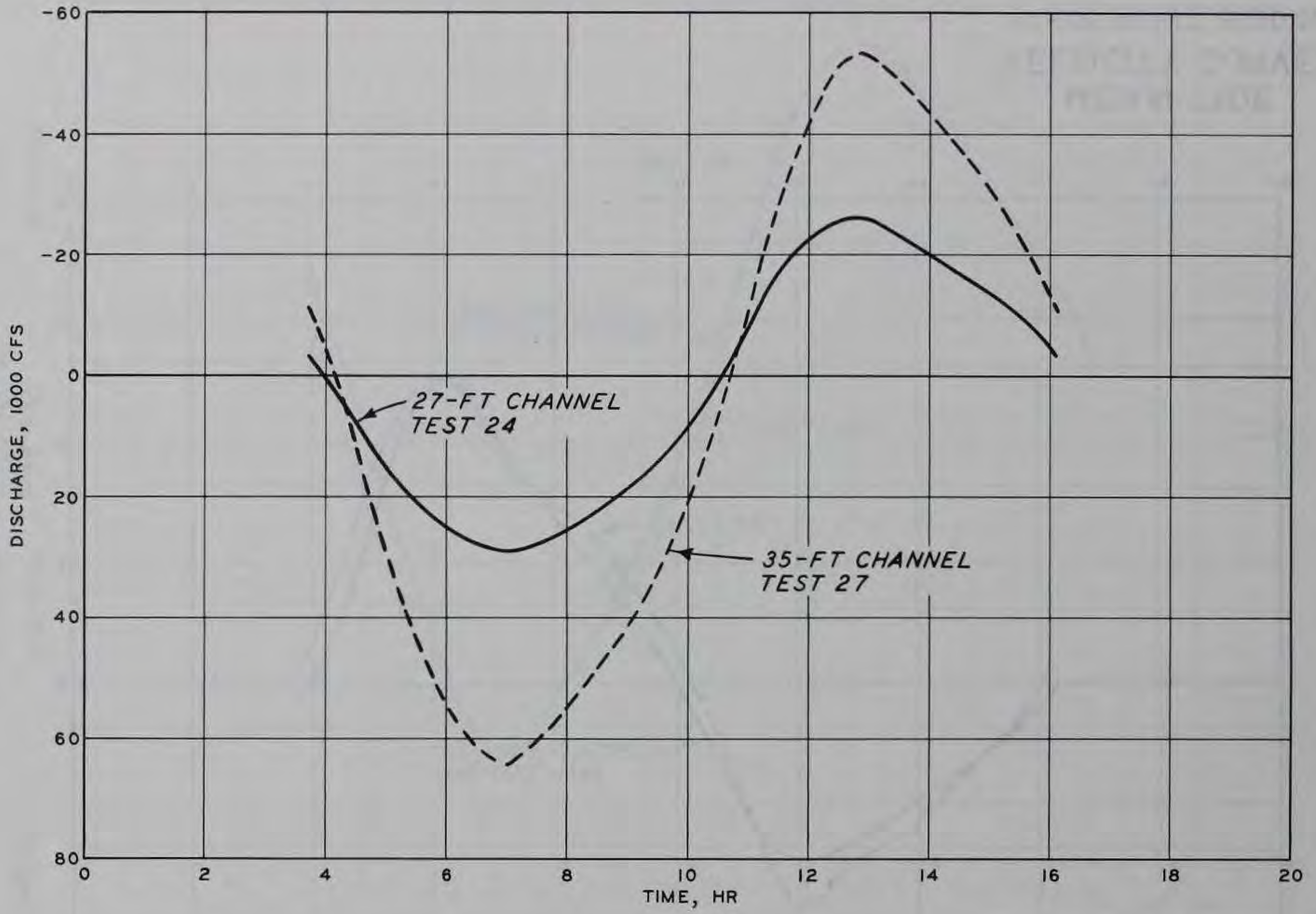
MEAN TIDE VELOCITY CURVES

CHESAPEAKE CITY BRIDGE

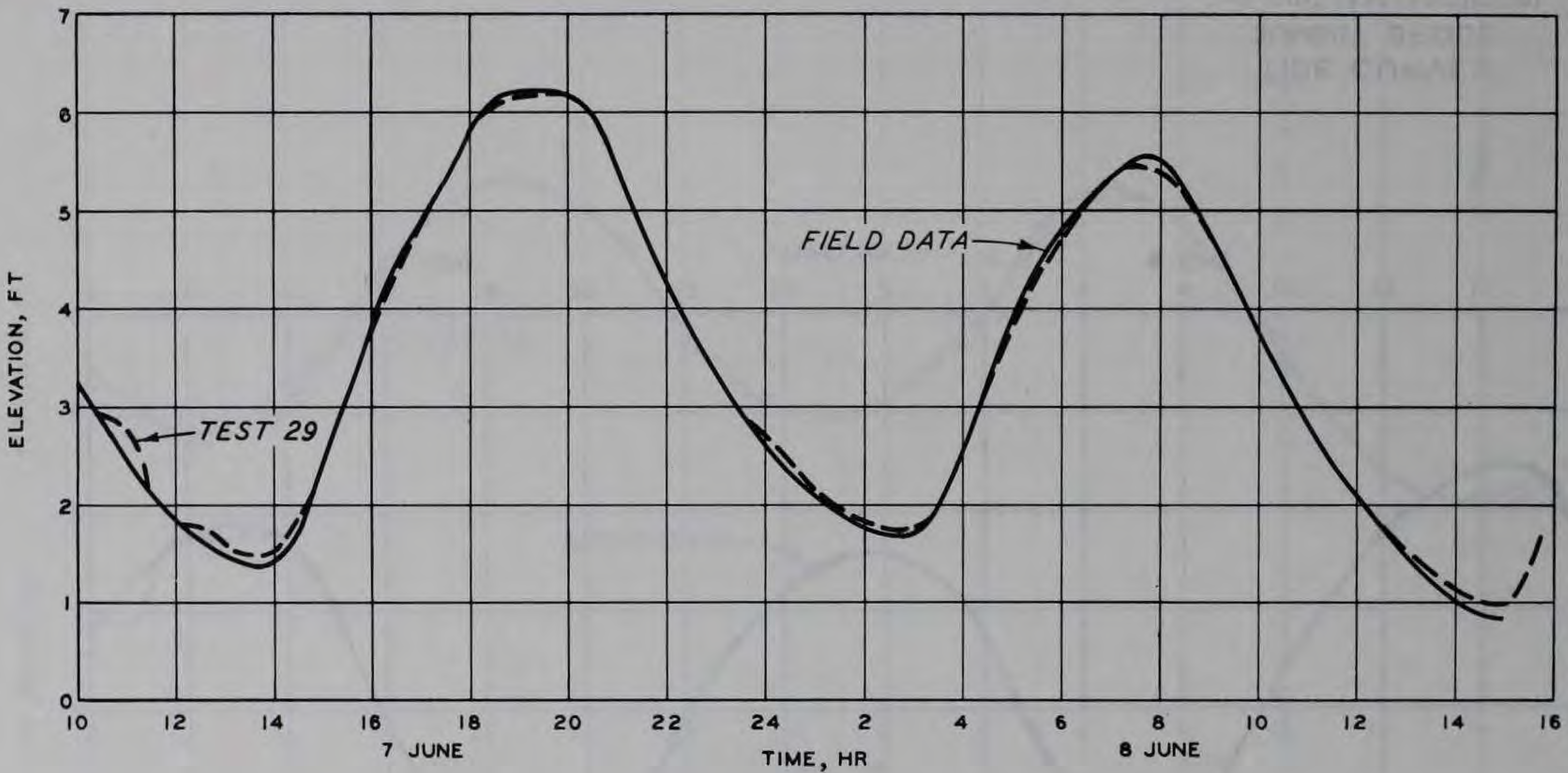


MEAN TIDE VELOCITY CURVES

REEDY POINT BRIDGE

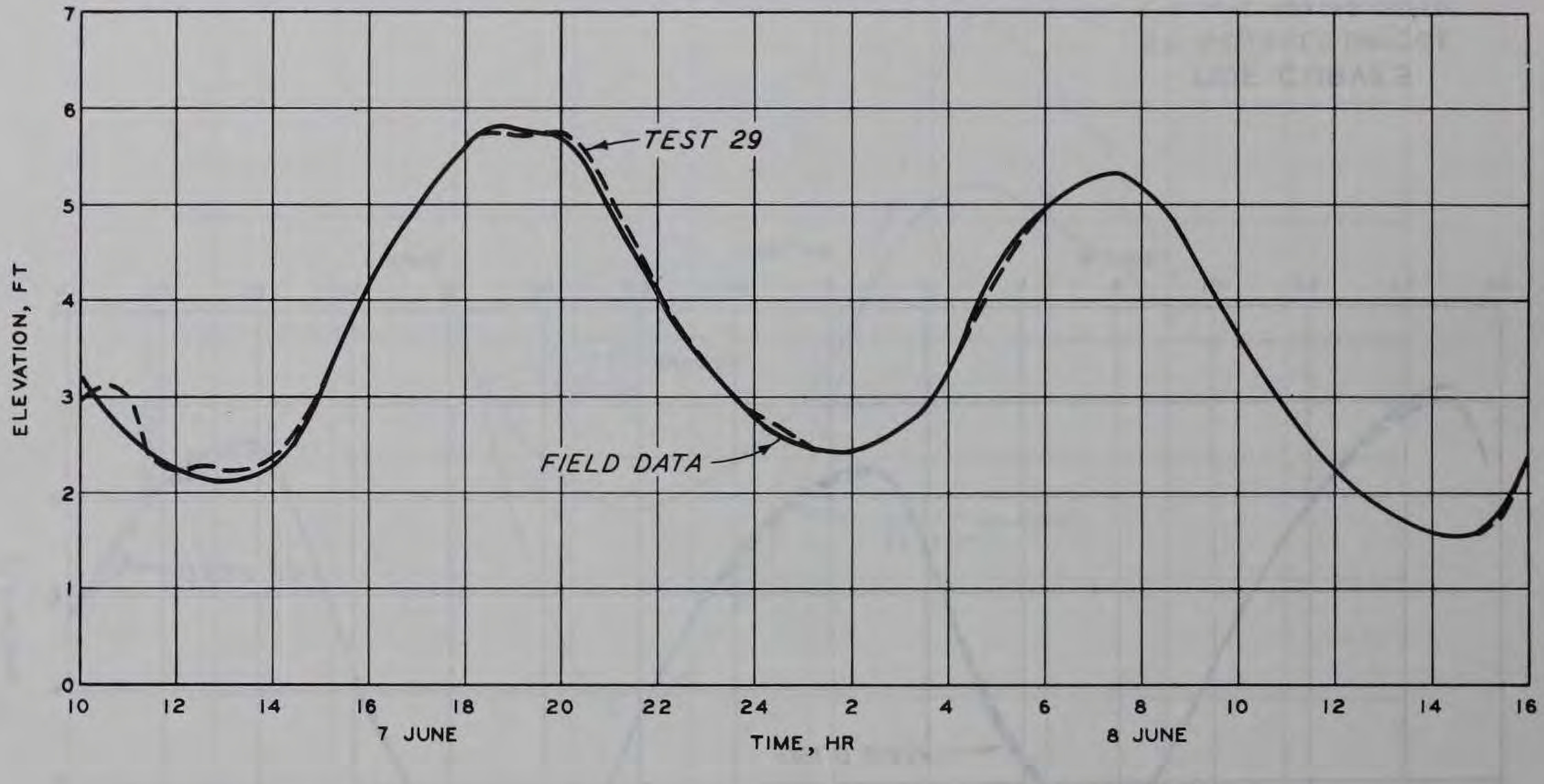


MEAN TIDE
DISCHARGE CURVES
CHESAPEAKE CITY BRIDGE

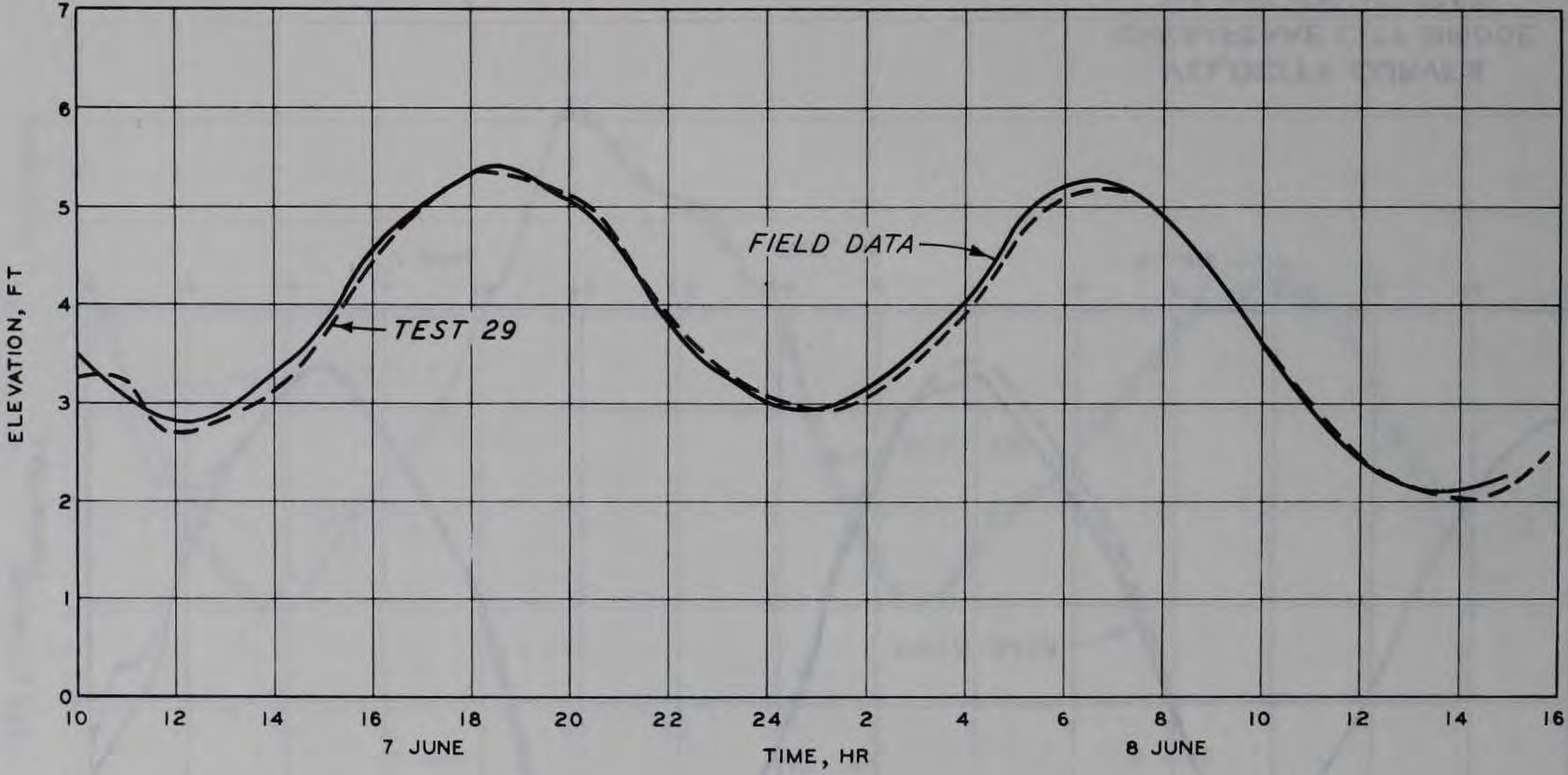


TIDE CURVES

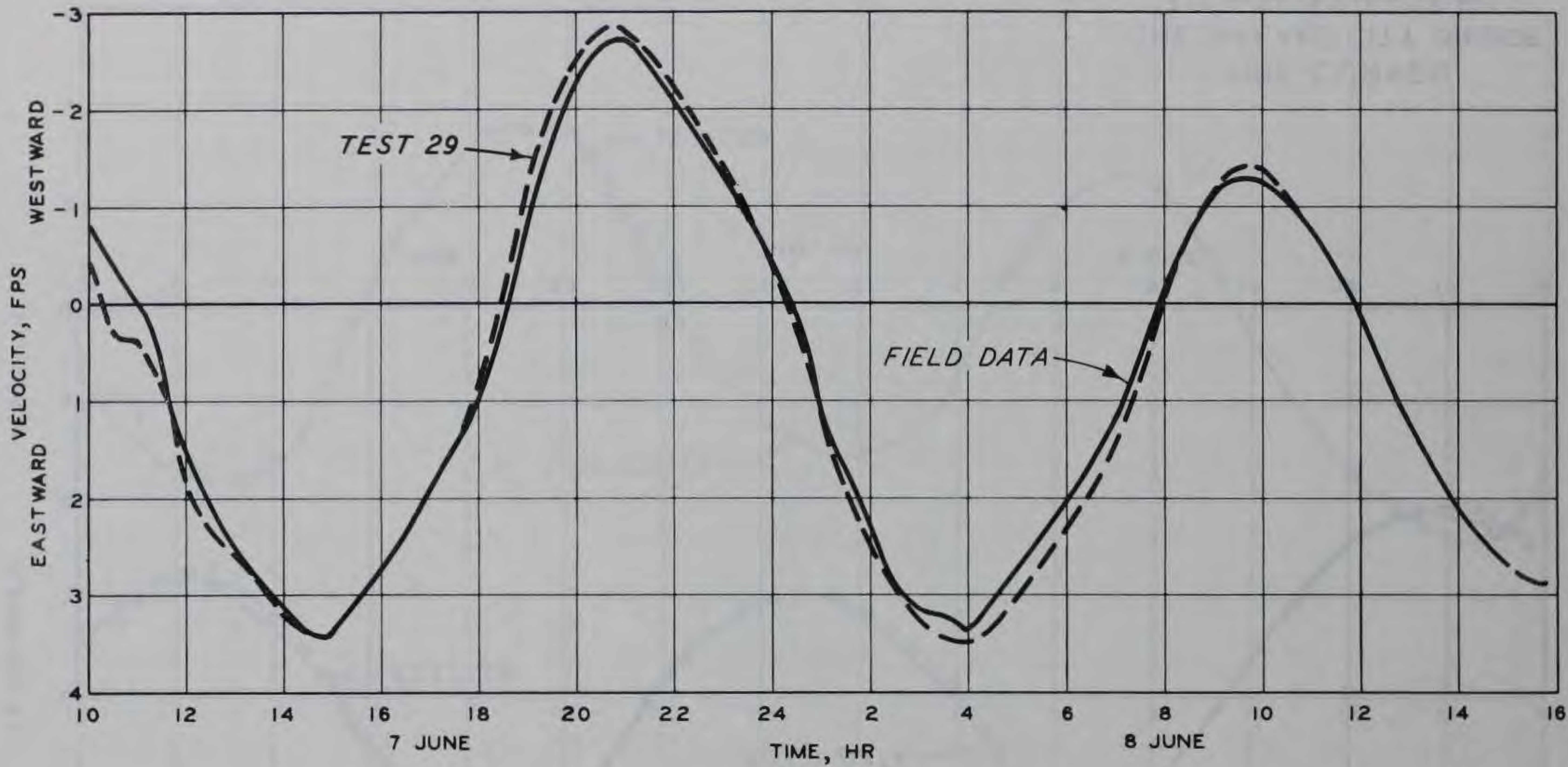
ST. GEORGES BRIDGE
7-8 JUNE 1938 (ADJUSTED)



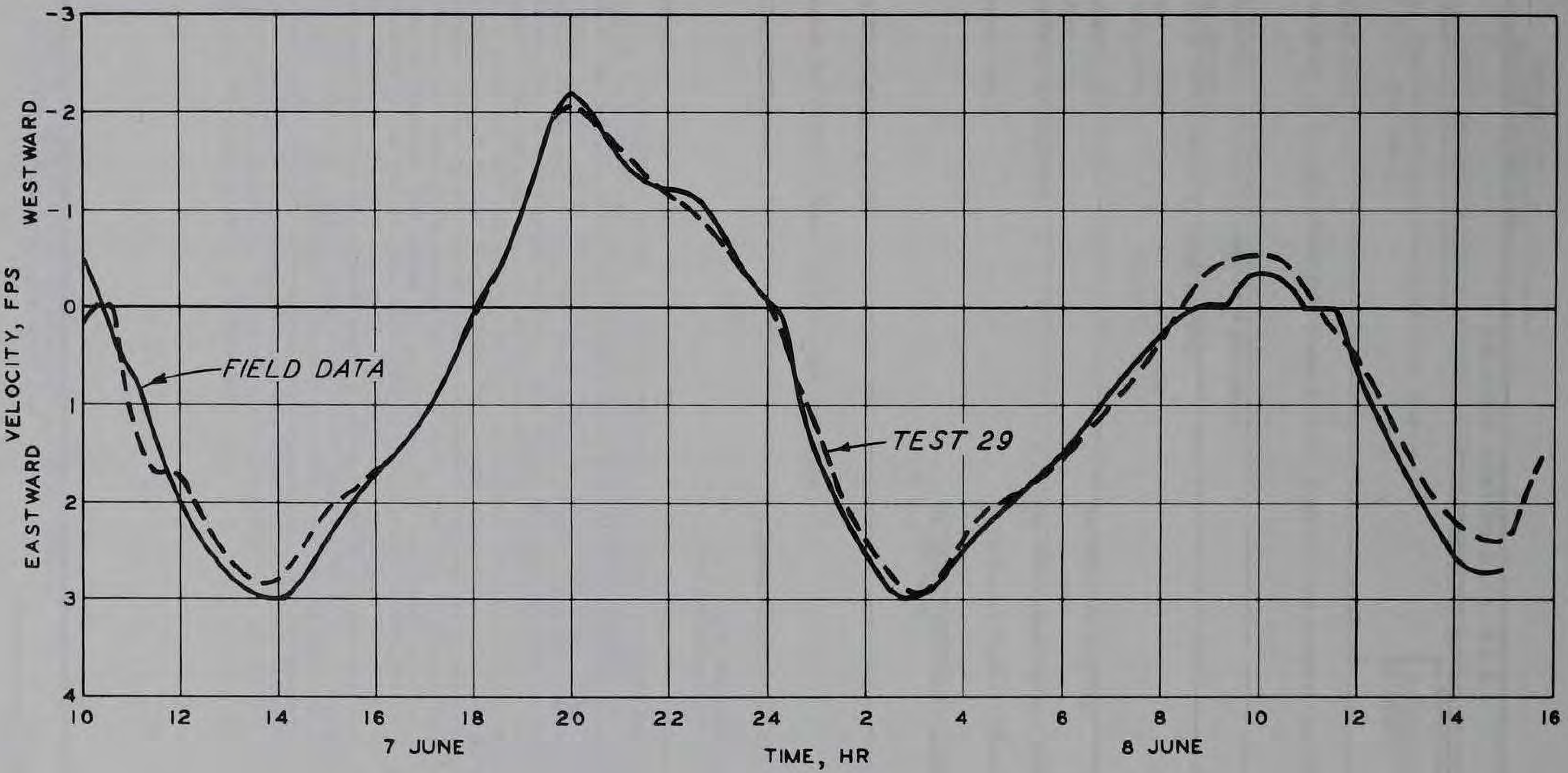
TIDE CURVES
SUMMIT BRIDGE
7-8 JUNE 1938 (ADJUSTED)



TIDE CURVES
CHESAPEAKE CITY BRIDGE
7-8 JUNE 1938 (ADJUSTED)



VELOCITY CURVES
CHESAPEAKE CITY BRIDGE
7-8 JUNE 1938 (ADJUSTED)



VELOCITY CURVES
REEDY POINT BRIDGE
7-8 JUNE 1938 (ADJUSTED)

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U. S. Army Engineer Waterways Experiment Station Vicksburg, Mississippi	**2a. REPORT SECURITY CLASSIFICATION** Unclassified **2b. GROUP**

3. REPORT TITLE

ENLARGEMENT OF THE CHESAPEAKE AND DELAWARE CANAL; Hydraulic and Mathematical Model Investigation

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final report

5. AUTHOR(S) *(First name, middle initial, last name)*

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6. REPORT DATE October 1973	**7a. TOTAL NO. OF PAGES** 436	**7b. NO. OF REFS** 22
8a. CONTRACT OR GRANT NO. **b. PROJECT NO.**	**9a. ORIGINATOR'S REPORT NUMBER(S)** Technical Report H-73-16	
c. **d.**	**9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)***	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	**12. SPONSORING MILITARY ACTIVITY** U. S. Army Engineer District Philadelphia, Pennsylvania

13. ABSTRACT

Enlargement of the sea-level C&D Canal connecting Chesapeake Bay and Delaware River from 27 by 250 ft to 35 by 450 ft, undertaken in 1954, was essentially complete by 1970 except for about a 2-mile reach at the Delaware River end. Concern about effects of the enlargement on the environmental and biological systems led to the decision to leave the unimproved reach intact, pending completion of extensive environmental studies. The study program included field measurements, physical and mathematical model studies, and ecological studies. This report is concerned with the model studies. The existing Delaware River model was extended to include the 27- by 250-ft C&D Canal and Elk River and the propagation of tides and currents in the addition was verified. Tides, currents, salinities, and discharges were then measured for various head differentials across the canal. The canal was first enlarged to existing conditions (35 by 450 ft, except for the unimproved reach at the Delaware end) and subsequently to project conditions and comparative measurements were made. The critical phenomenon affecting flow in the canal is head differential (ΔH) across the canal produced by Chesapeake Bay tides at the western end and Delaware River tides at the eastern end. The canal is a very dynamic system and can experience large ΔH changes daily. Net flow is toward the lower tide level and enlargement from 27 by 250 ft to August 1972 conditions caused net flow to be increased by a factor of about 4.8 and completion of enlargement will cause additional increases. Dye dispersion tests were made for 27 by 250 ft and completed canal conditions and a mean ΔH. An existing numerical model based on the one-dimensional unsteady flow equations was used for initial studies concerning net flow changes due to the enlargement. A relatively simple numerical model was developed, tested against known analytical solutions, and applied to show expected salinity changes after enlargement and a reversed salinity gradient near the eastern end of the canal in agreement with field and physical model measurements.

DD FORM 1 NOV 65 **1473** REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chesapeake and Delaware Canal						
Hydraulic models						
Mathematical models						
Sea level canals						

Unclassified
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