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Title: SEASONAL VARIATIONS IN TIDAL DYNAMICS, WATER QUALITY, AND SEDIMENTS IN THE SIUSLAW ESTUARY

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Larry S. Slotta

Seasonal data on tides, water quality and sediments in the Siuslaw Estuary were collected. Tide and velocity data were analyzed to evaluate damping conditions in the estuary. The system was found to approximate a weakly damped standing wave. A strong relationship of damping conditions to river flow was observed. The equation of wave celerity was used to calculate the effective depth of the estuary.

Physical water quality data were examined for dependence on tidal conditions and river flow. The relationship of freshwater flow ratio to estuary stratification was evaluated. The mixing conditions in the estuary were found to vary widely with streamflow. Salinity data were used to estimate estuary flushing times.

Sediment sample data were examined for the relationship of physical parameters to distance from the estuary inlet and for seasonal changes. Grain size and other parameters were found to be

relatively constant in the main channel of the estuary within about eight miles of the inlet. Shoaling conditions in the estuary were evaluated.

Seasonal Variations in Tidal Dynamics, Water Quality and Sediments in the Siuslaw Estuary

by

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LIST OF SYMBOLS

f = fraction of fresh water in a portion of an estuary

g = gravitational acceleration

h = water depth

k = wave number = 2π/tidal wavelength

x = distance from the head of the estuary

A = estuary inlet area below Mean Sea Level

C = wave celerity

L = tidal wavelength

P = tidal prism

Q_f = amount of fresh water accumulated in a segment of an estuary

R = riverflow

S_n = mean salinity of estuarine water

S_s = salinity of seawater

T_f = flushing time

η = tidal displacement

η_o = tidal displacement at the head of the estuary

μ = tidal damping coefficient

ϕ = tidal dissipation constant

σ = 2π/tidal period

σ_{tH} = time angle of high water

SEASONAL VARIATIONS IN TIDAL DYNAMICS, WATER QUALITY AND SEDIMENTS IN THE SIUSLAW ESTUARY

I. INTRODUCTION

This study is based upon research conducted in the Siuslaw Estuary during 1973. This research was supported by Sea Grant through Oregon State University's Ocean Engineering Program.

The research was conducted in three topical areas, which were: tidal dynamics in the estuary, physical water quality, and physical properties of sediments in the estuary. In each subject area, seasonal changes were investigated. Throughout the research, emphasis was placed on developing methods for prediction of physical phenomena based on available data.

In this thesis, each subject of research concentration is separately examined. A survey of applicable literature is followed by a brief description of the field research, and a presentation of topical data and results. An overall summary is given which presents conclusions based on research findings and suggestions for further research.

A compilation of data from the 1973 studies in the Siuslaw Estuary is given in the Appendix.

II. PHYSICAL DESCRIPTION AND HISTORY

The Siuslaw Estuary is located on the Oregon coast, at latitude 44 degrees North, about 160 miles south of the Columbia River. It has no major embayments, and the estuary consists mainly of the channel of the Siuslaw River. The river has an estimated normal flow of 3,150 cubic feet per second (89.2 m^3/sec), based upon precipitation records (3). Tidewater in the estuary extends 22.5 miles (36.2 km) above the mouth (15). The surface area of the estuary has been reported by the Division of State Lands as 2245 acres (1100 hectares) at high tide (15).

Physical data on the Siuslaw Estuary are available from a variety of sources (7) (15) (17). Burt and McAllister (14) measured salinity and temperature during 1957 and 1958, and classified the estuary as stratified in January and May, partly mixed in March, and as well mixed in October. More recently, the Oregon Department of Environmental Quality (DEQ) has made periodic measurements of physical and biological water quality (17). Continuing measurements of streamflow, sediment transport, and water temperature are conducted by the U. S. Geological Survey (17).

The area was only sparsely settled until the 1880's (6). Significant development of the area did not occur until the establishment of a good road from the Willamette Valley, after 1920 (16). The present (1974) population of the area is approximately 4500 (17).

The Siuslaw Estuary has been a port for ocean commerce since the first significant settlement at Florence. The port has had engineered improvements for over half a century. The jetty system was first completed in 1917. It has been rehabilitated and extended since that date (17). At the present time, only limited industrial activity is in evidence on the estuary. Logs are rafted to forest products manufacturers, and one mill exports lumber on sea-going barges (17). The many aging pilings found in the estuary point to a great deal of log-rafting activity in the historic past.

The major water related activities on the Siuslaw Estuary include commercial and recreational fishing. These activities are seasonal, since the bar at the Siuslaw River mouth is not readily passable in winter weather conditions (17).

At present, there is not a great deal of visible pressure for extensive development of the estuary. Recent and continuing tourist-oriented development shows some sign of making the area the major tourist center of the central Oregon Coast. The estuary remains in a relatively unspoiled state. With continued emphasis on the environmental aspects of any proposed estuarine development, it may remain unspoiled for the foreseeable future.

The details of future development of the Siuslaw Estuary are uncertain. The final report of the Oregon Coastal Conservation and

Development Commission scheduled for presentation to the 1975 Legislature will make recommendations for regional planning which will have long-reaching effects on the future of all of Oregon's estuaries.

III. TIDAL DYNAMICS

Theory and Literature

Estuarine tidal mechanics theories are not sufficiently developed to provide a satisfactory analytical model of tidal effects in any real estuary. In general, the tide in the ocean at any estuary entrance acts as a forcing function, and the response of the estuary varies with the effects of geomorphology and hydrology. The effects of fluid friction tend to damp or decrease the amplitude of the tidal disturbance, while the decreasing width of the estuary tends to amplify the tidal height as the disturbance proceeds up the estuary.

The wave celerity of the tidal disturbance is controlled by the depth of the estuary according to the solitary wave celerity relationship (10):

$$C = \sqrt{g(h + \eta)}$$

Where: C = shallow water wave celerity

g = gravitational acceleration

h = undisturbed water depth

η = tidal displacement

According to this relationship, low tides are propagated into the estuary more slowly than high tides, resulting in increasing durations for ebbing tides and decreasing durations for flooding tides as the tide proceeds toward the head of the estuary (10).

Harmonic Analysis

It is considered desirable to express relationships among tidal parameters which permit prediction of tidal heights and velocities. One method of developing such relationships is to consider the tide in an estuary as two damped co-oscillating waves, one originating at the entrance and the other reflected from the head of the estuary. Using such an approach, Ippen and Harleman (10) have developed expressions that relate the relative times of high water as the tide wave propagates up the estuary, σ_{tH}, and the tidal amplitudes, to the phase change kx (where x is the distance from the head of the estuary and k is the wave number, equal to $2\pi/L$, where L is the wave length) and to a "damping coefficient" μ which specifies the change in amplitude with distance x along the estuary caused by fluid friction (5). In the relationship developed by Ippen and Harleman, the time of high water in the estuary relative to high water at the estuary head is given by:

$$\tan \sigma_{tH} = -\tan kx \tanh \mu x$$

If channel cross-section and roughness are taken as constants,

$$\mu = \frac{\phi}{2\pi k}$$

where ϕ is the "dissipation constant," a proportionality constant relating μ and k.

For an estuary where tidal ranges and times have been measured, values of ϕ and thereby μ can be determined by the use of a nomograph relating the ratio of tidal amplitude at any point in the estuary to the amplitude at tidewater, η/η_o , to the time angle σ_{tH} of high water. The nomograph uses plotted lines of equal values of ϕ and kx. In general, the relationship of η/η_o to σ_{tH} is expected to follow a line of constant ϕ for any particular estuary of constant cross-section and roughness. Such a nomograph for the Siuslaw Estuary is found later in this thesis (see Figure 7).

The damping coefficient determined by the above graphical procedure is not directly measurable, and must be inferred from tidal measurements. It will be shown in a later section that this damping coefficient may be affected by variations in freshwater inflow to the estuary.

O'Brien's Relationship

An important empirical relationship in the dynamics of tides in estuaries is the relationship of tidal prism to inlet area identified by O'Brien in 1931 (13), and later refined by O'Brien (14) and by Johnson (11). O'Brien's relationship relates the tidal prism to the inlet area of the estuary. It has proved useful in designing channel improvements, such as in spacing jetties at estuarine inlets. O'Brien's relationship (14) may be stated as:

$$A = 4.69 \times 10^{-4} P^{0.85}$$

Where A = the inlet cross-section area below Mean Sea Level in square feet

P = the volume of the tidal prism in ft^3, as measured from mean higher high water to mean lower low water. (Conversion to metric units is omitted to avoid confusion in this particular discussion.)

In O'Brien's presentation (13), the Siuslaw Estuary was one of the estuaries used in establishing the empirical relationship. O'Brien used values for the Siuslaw of

$$A = 11,100 \text{ ft}^2$$

$$P = 2.5 \text{ mi}^2 \text{ (estuary area)} \times 6.9 \text{ ft (diurnal range)}$$

$$= 17.25 \text{ ft mi}^2 = 4.81 \times 10^8 \text{ ft}^3$$

$$4.69 \times 10^{-4} P^{0.85} = 4.69 \times 10^{-4} \times 2.40 \times 10^7 = 11,240 \text{ ft}^2$$

These values showed a close correspondence to the empirical equation, within 2 percent.

The Oregon Division of State Lands has reported the areas of the estuary at mean high and mean low tides as 2,245 and 1,489 acres, respectively. O'Brien's value of 2.5 square miles would equal only 1,312 acres.

Johnson (11) reports in an inlet cross-section area of 8,330 square feet, and a tidal prism of 2.76×10^8 ft^3 (or 9.9 mi^2-ft).

Johnson suggests that O'Brien's relationship should be expressed as:

$$\frac{P}{A} = 5 \times 10^3 \, P^{0.10}$$

which is equivalent to

$$A = 2 \times 10^{-4} P^{0.9}$$

with A in square feet and P in cubic feet, and for which the tidal prism is computed for the mean tidal range. For the Siuslaw -

$$A = 8,330 \text{ ft}^2$$

$$2 \times 10^{-4} P^{0.9} = (2 \times 10^4)\,(2.76 \times 10^8)^{0.9}$$

$$= 9480 \text{ ft}^2$$

This represents a discrepancy of about 13 percent.

A comparison of reported areas of the estuary is of interest. Johnson computed the tidal prism using the mean tidal range. NOAA reports the mean tidal range as 5.0 feet for Florence. This indicates, from Johnson's data, a planform area of:

$$\frac{2.76 \times 10^8 \text{ ft}^3}{5 \text{ ft}} = 5.52 \times 10^7 \text{ ft}^2$$

$$= 1270 \text{ acres}$$

which is compared to 1312 acres from O'Brien (13). The mean of the high tide and low tide areas reported by the Oregon Division of State Lands is 1867 acres, a considerably larger value. In view of the fit of data to O'Brien's relationship, the values reported by O'Brien and by Johnson seem more reasonable.

The spacing of the jetties at the Siuslaw entrance is 745 feet (17). If the equilibrium inlet area computed from Johnson's data

(9480 ft^2) (881 m^2) is accepted, then a mean depth between the jetties of:

$$\frac{\text{Area}}{\text{Width}} = \text{depth} = \frac{9480\ ft^2}{745\ ft} = 12.7\ ft \quad (3.87\ m)$$

is to be expected. Since the stated intention of the Corps of Engineers is to maintain a 12 ft (3.66 m) (MLLW) channel at the entrance (17), the jetty spacing appears to be correctly chosen.

Tidal Velocities

An important aspect of tidal dynamics in estuaries is the time relationship of tidal height to the tidal velocity. Tidal waves in estuaries may theoretically occur as either progressive or standing waves. In a progressive wave, maximum currents and the maximum wave height occur simultaneously. In a standing wave, on the other hand, currents are zero (slack water) at the time of maximum height.

In real estuaries, neither case is likely to be observed, but some intermediate situation is found. Goodwin, Emmett and Glenne (9) found conditions in the Siletz, Yaquina, and Alsea Estuaries approximated standing waves, Blanton (1) found Coos Bay to show more nearly progressive waves.

In this study, measurements of tidal heights and velocities were made and analyzed to quantify this relationship for the Siuslaw Estuary. Presentation of these data is made in a later section. Based upon the work of other investigators (9) it was thought that it might be possible to construct a set of predictive curves of tidal amplitude ratio, defined as the local tide range divided by the predicted range at the entrance. These curves would show predicted amplitude ratio as a function of predicted range at the entrance and measured streamflow at the head of the estuary.

Such a predictive approach is presented in the section on results of the dynamics studies (Figures 5 and 6).

Field Studies

For seasonal tidal measurements on the Siuslaw Estuary during the 1973 calendar year, tide recorders were installed at the locations shown in Figure 1. In January, the sites identified as I, II, and III were used. In April, the tide recorder at II was relocated to IIA due to continuing maintenance problems associated with floating debris. Also in April, site IV, upstream of the portion of the river shown in Figure 2, was used. In August, the downstream tide recorder was relocated to IA due to the demolition of the dock at location I, and sites IIA and III were used. In November, locations IA, IIA, and III were again used.

At each seasonal interval, the tide recorders were left in place for 14 days. The resulting records and NOAA tide predictions (20) are to be found in the Appendix. The instruments used were the

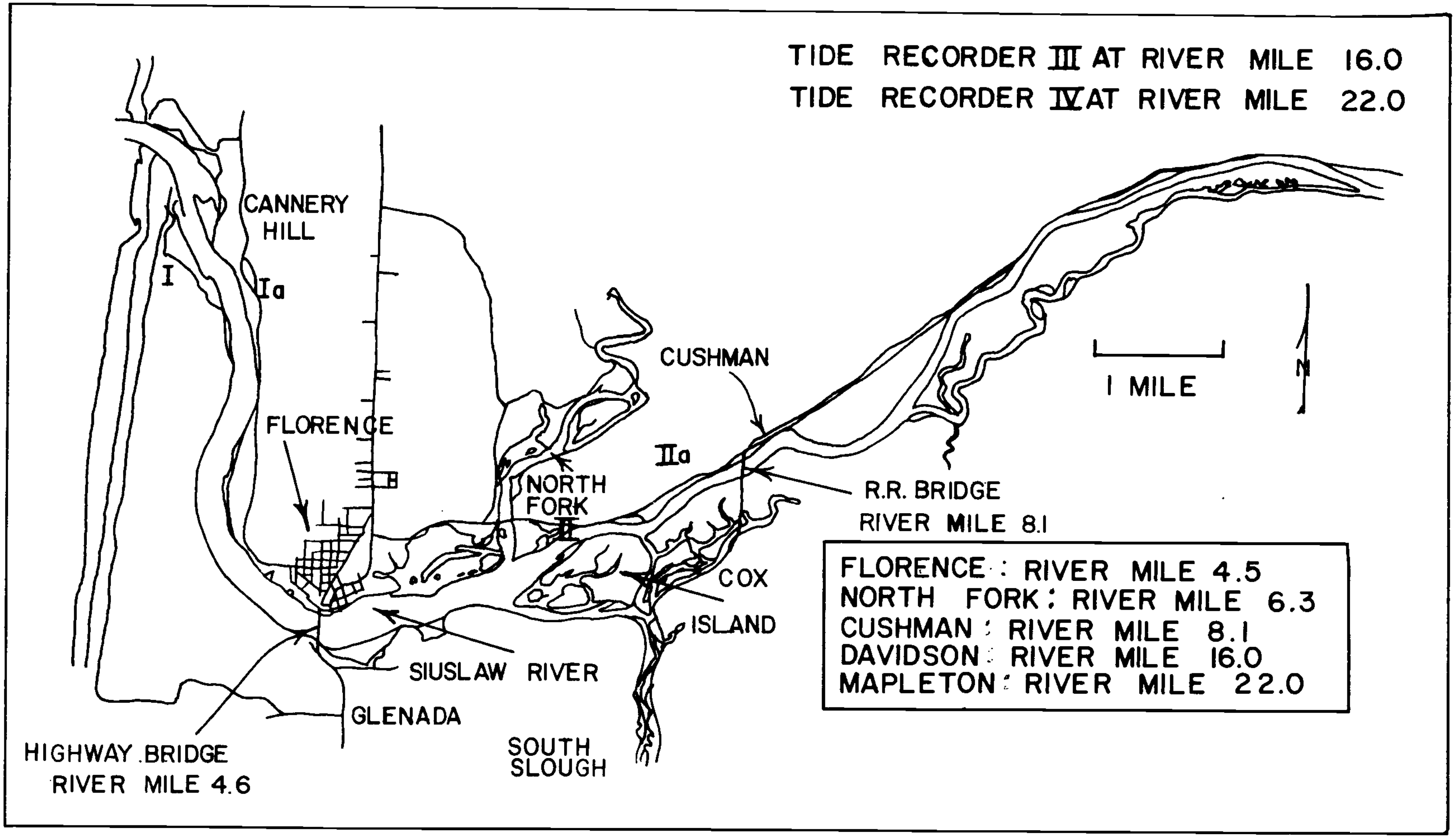

Figure 1. Map of the Siuslaw Estuary.

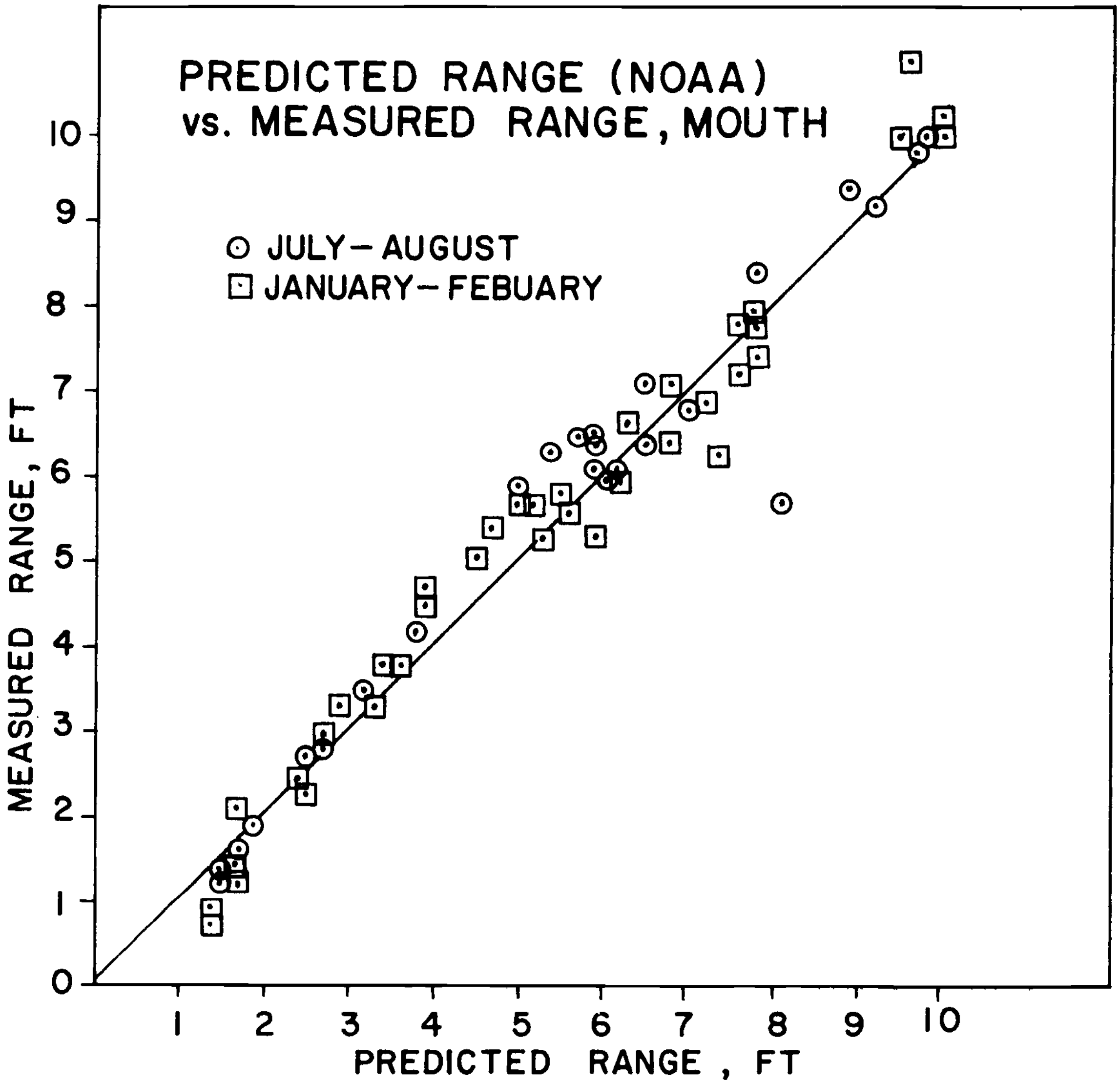

Figure 2. Predicted vs. measured tide at entrance.

Stevens type "F" or NOAA "Bubbler" type tide recorders. In general, records were read to the nearest 0.05 feet, and to the nearest 5 minutes. When reduced to tabular form the tide records were checked for consistency with NOAA predicted tides for the month, and lag times and tidal ratios were computed, using the NOAA values as a base. Discussion of this technique is found in the following section.

Velocities were measured at the cross-sections shown in Figure 1 during one day within each period of tidal measurement. For this purpose, a day with tidal height ranges approximating 6 feet (approx. 2 m) was chosen. Velocities at the indicated cross-sections were measured on both flooding and ebbing tides, attempting to measure both maximum velocity and maximum flow. Velocities were measured from small boats with Price-type meters and Savonius rotor type meters, measurements being made in 4 or 5 positions across the stream at about 5 depths for each position. A complete circuit of the cross-section required about 20 to 30 minutes, so that 4 to 10 circuits could be completed within an ebbing or flooding tide. During each measurement period, a survey of the cross-section was made to measure the location of the velocity measurement positions in the cross-section, and verify the depths at those positions. The results of the velocity measurements were integrated by a computer program, which was written by C. I. Rauw. The data acquired from the velocity measurements and the computer program used to integrate these data are found in the Appendix.

Results

The tidal measurements in these studies were over a wide range of seasonal streamflow conditions. The year 1973 presented an unusually long dry period, followed by above average rains and runoffs.

The tide records obtained were from four two-week periods, at the stations previously described. The periods were chosen to include a suitable day for current and water quality measurements. No particular attempt was made to have studies coincide with particular lunar maxima or minima, so in general the phase of the moon and its effect on the tides are not comparable from season to season. The tidal measurement periods were selected to include a day with a daylight tidal range of about 6 ft (about 2 m) so that each period of measurement included some tides of that range. The mean tidal range is reported by NOAA (20) as 5.0 feet (1.55 m).

When all the tidal height data were collected, they were tabulated, and various correlations were attempted. Some correlations were anticipated from theory and previous research. Figures 2 and 3 show the relationship of NOAA predicted tides (20) to the tides as measured near the entrance. Figure 2 shows that the relationship of predicted range to measured range is very good, with all predicted ranges (from high to low tide) within one foot of actual. Data from

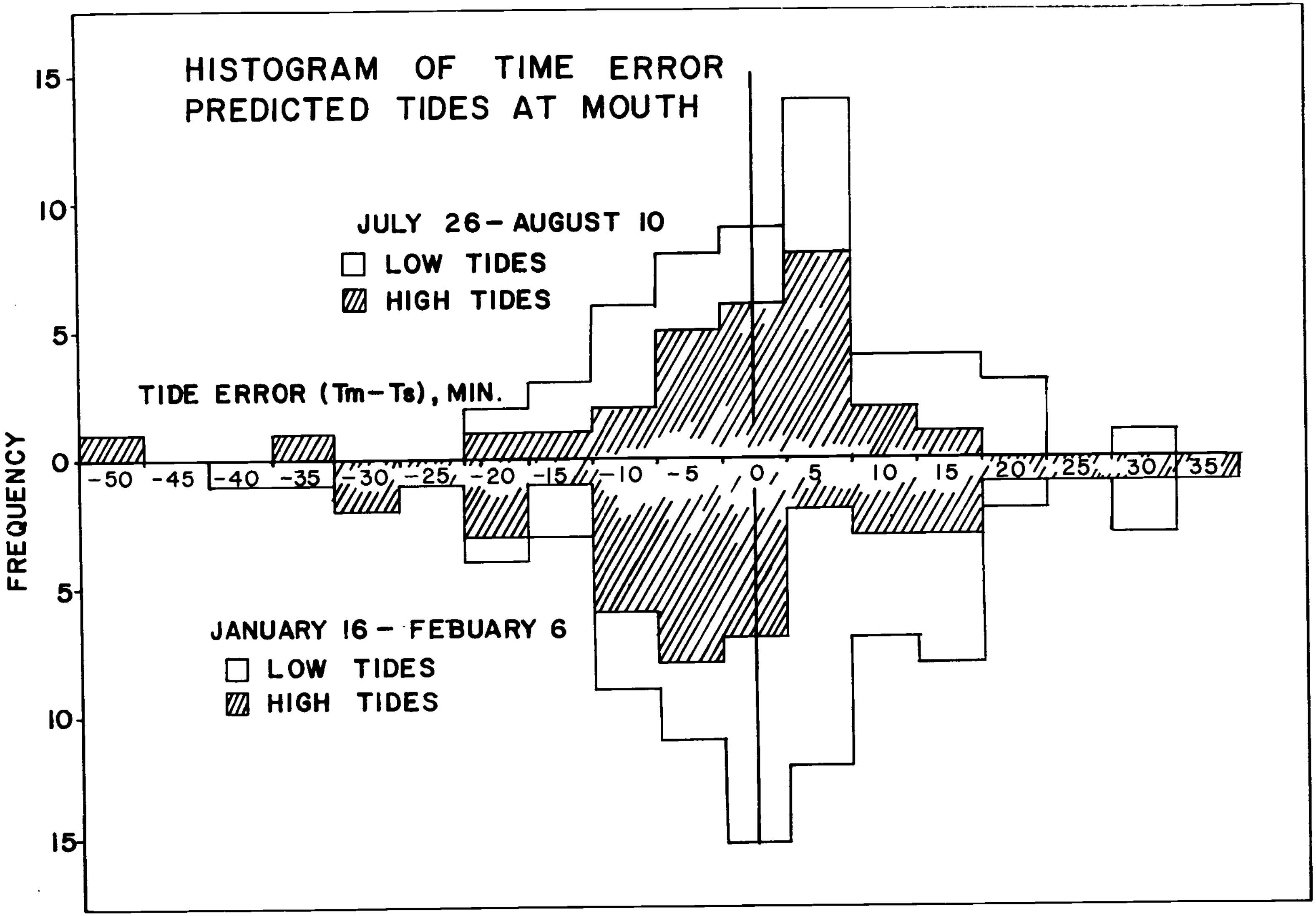

Figure 3. Histogram of time error, predicted tides

summer low streamflows and from above average winter flows are included. Figure 3 presents two histograms of the time error of tide predictions at the entrance. Considering that the time error of the tide recorders used is on the order of five minutes, the reliability of prediction shown in Figure 3 is within limits of experimental error. Since the correlation of time and range for NOAA predicted tide was found to be acceptable, tide predictions provided by NOAA were used as a base for calculation of amplification ratios and lag times.

Goodwin, Emmett, and Glenne (9) reported that amplification ratios, defined as the ratio of the range at a point within the estuary to the range at the entrance, varied with tidal range in the Siletz, Alsea, and Yaquina estuaries. They found that small ranges experienced more amplification, or less damping in these estuaries. Figure 4, showing data from the tide station at river mile 16.1, shows that it is also true for the Siuslaw Estuary in summer conditions. In other seasons, however, such a clearcut relationship is not evident. With increased freshwater flow in the rainy season, amplification factors throughout the estuary are reduced to less than one. Additionally, there is a great deal of scatter in the data, so that a trend such as that shown by Figure 4 is not evident. This scatter may be due to other factors, such as wind set and barometric pressure variation, which are more evident in winter than summer conditions. The data of Goodwin, Emmett, and Glenne (9) was taken

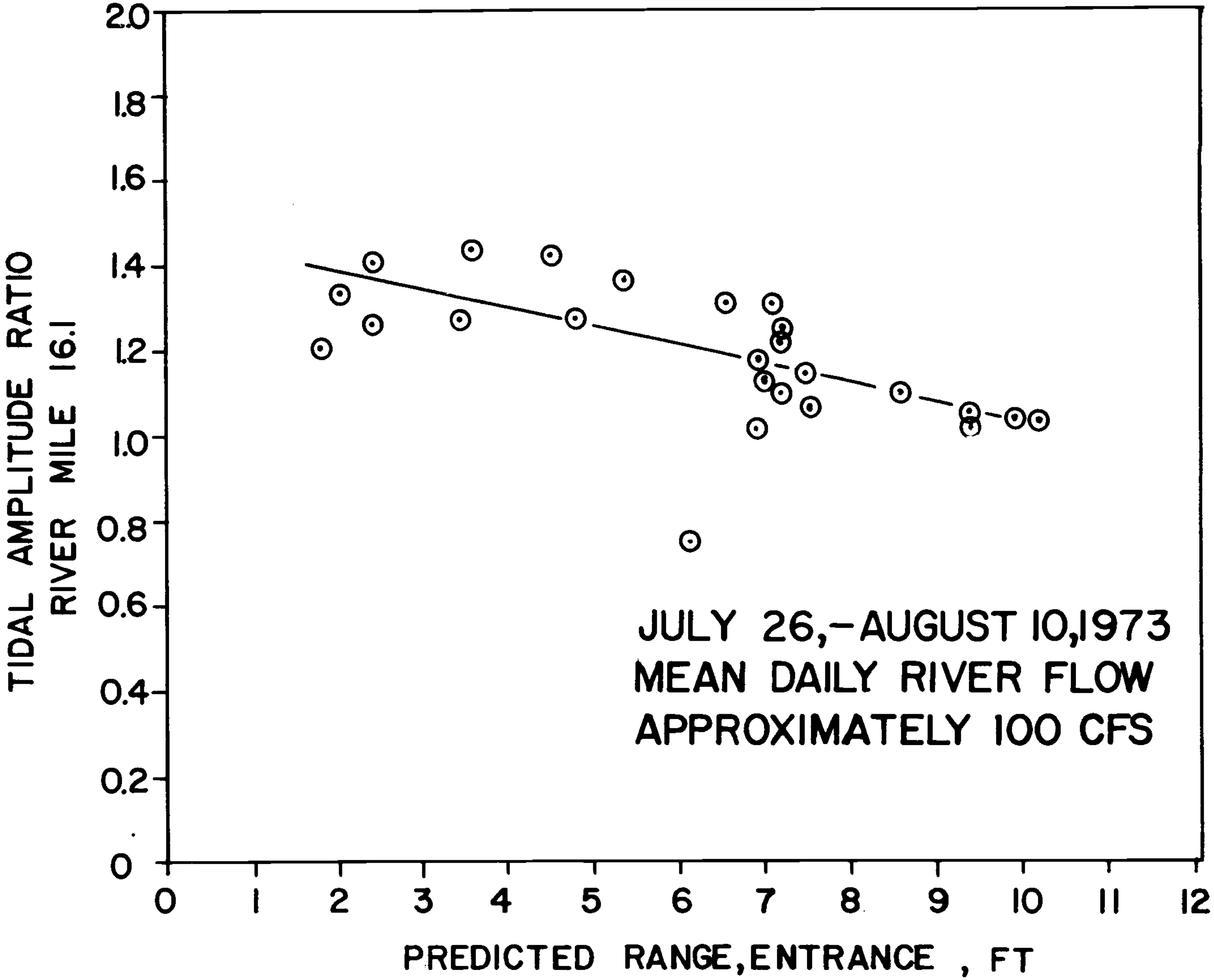

Figure 4. Variation of tidal amplitude ratio with tidal range.

in summer dry weather conditions, and may not be representative of their estuaries in other seasonal conditions.

Figures 5 and 6 show another presentation of the amplification of tidal effects in the estuary. In this case, an average amplification ratio was computed by averaging the magnitude of both rising and falling tidal ranges for a particular day, then computing the ratio of the average range at the indicated locations to the average range at the entrance. This is presented in Figures 5 and 6 plotted versus the mean daily river flow as measured at Mapleton. In this way, data based on the same time periods could be compared. The plotted lines of Figures 5 and 6 demonstrate that the average amplification ratio, as computed, remains constant up to about 3000 cfs of mean daily flow, then sharply declines. The normal flow of the Siuslaw River is 3150 cfs (3). From this, it might be hypothesized that, since the river channel is formed by its normal flow, that at flows above this value, it is flowing above its normal channel, experiencing different frictional conditions than in normal or lesser flows. This might explain the increased damping of tidal effects, especially in the upper estuary associated with high streamflows. It is also true that larger streamflows are associated with higher flow velocities and steeper gradients of the water surface profile which might affect damping.

Figure 7 shows the relationship of amplification to phase lag for

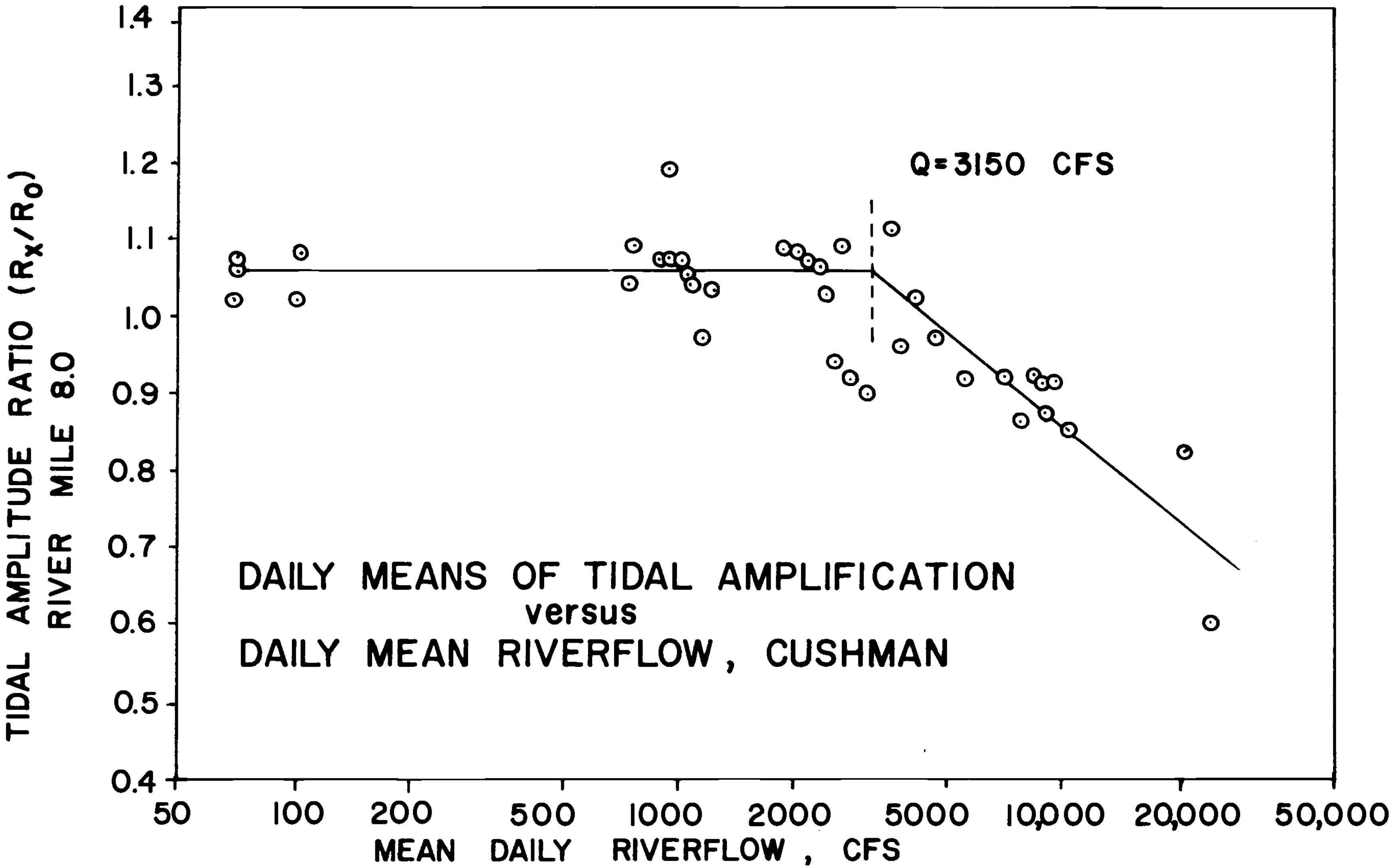

Figure 5. Tidal amplification vs. riverflow, Cushman

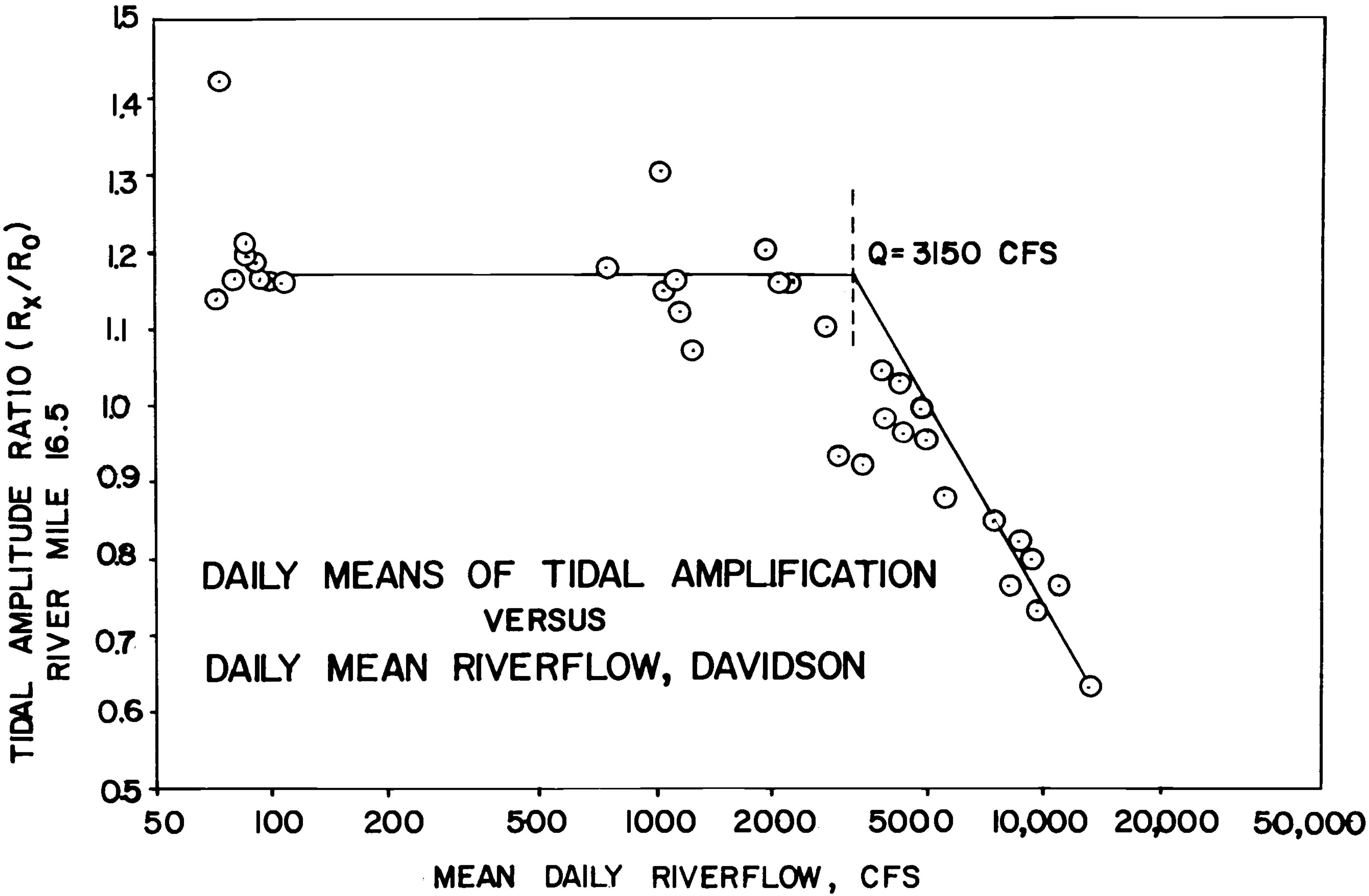

Figure 6. Tidal amplification vs. riverflow, Davidson.

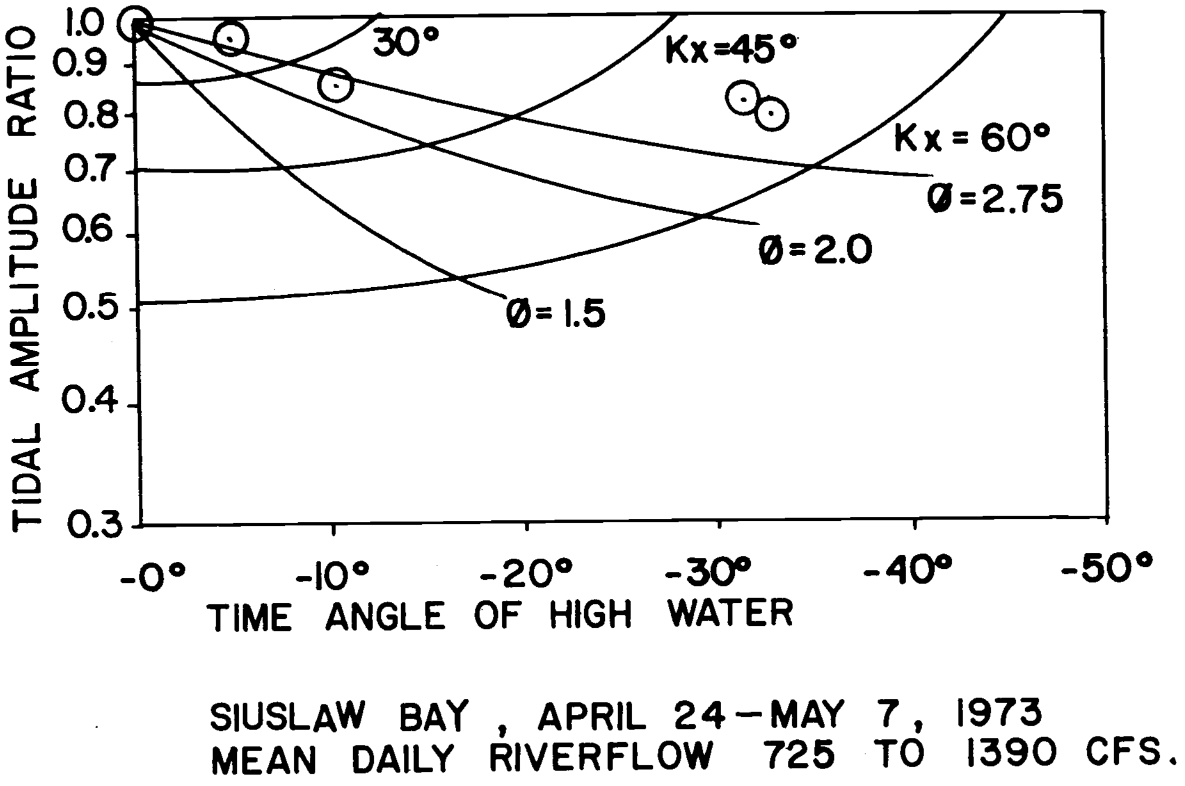

Figure 7. Nomograph for determination of damping coefficient.

the period of tidal measurement in April and May 1973. From this figure it is possible to compute a value of the damping coefficient, μ. Since the mean daily freshwater flow was less than the normal flow during this period of tidal measurement, the value of μ would not be representative for greater streamflows, however.

During 1972, the Oregon State University Ocean Engineering Program engaged in studies of surface velocity patterns in the Siuslaw Estuary. Dye tracers were placed on the water surfce, and documented by a series of timed aerial photographs. Data digitized from the photographs was subjected to computer analysis. Computer output in both digital and graphic form provided measured velocities and dispersion coefficients (21). An example of the graphic output is provided in Figure 8.

Based on similar field research, Boley (2) found that circulation patterns in the Alsea Estuary varied widely between flooding and ebbing tides. In the Siuslaw, which has a narrower, more riverine morphology, such results were not anticipated. In fact, examination of the data from the 1972 circulation studies shows that maximum velocities in flood and ebb are observed at similar locations. The surface velocity patterns are those expected in a fluvial channel. In general, velocity maxima are found at mid-channel, and on the concave banks in channel bends. Reduced velocities are observed where the estuary broadens in the vicinity of Florence.

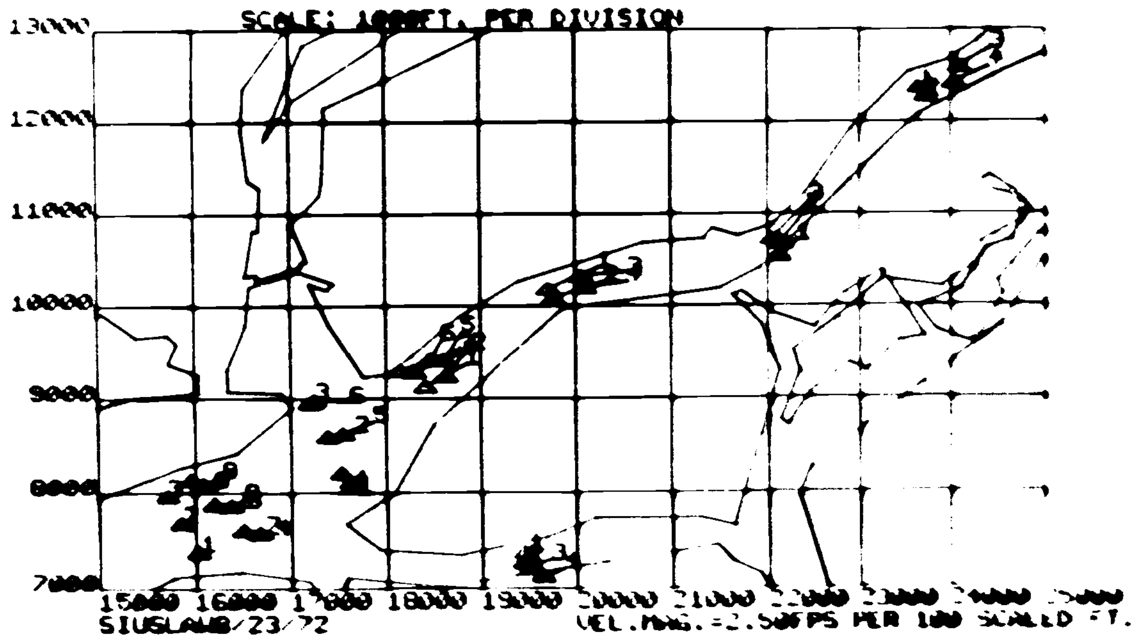

Figure 8. Computer presentation of measured velocity, mouth of North Fork.

In the tidal channels near Cox Island, it was noted that velocities are not in phase with velocity patterns in the main channel. In fact, surface flow may still be flooding in the Slough south of Cox Island when ebb flow is observed in the main channel north of the island.

Figure 9 shows velocity and flow data obtained from measurements at the upstream current station as related to tidal height at the recorder near the same location for the day of January 31. The figure is representative of the data obtained from velocity measurement. Other such presentations are found in the Appendix. The data obtained indicate that, on the days considered, which deliverately show only a limited variety of tidal ranges, maximum flow and velocity occur about 3 hours after tidal height maxima. As anticipated, this indicates that the tidal movement progresses as a wave intermediate in character between a progressive and a standing wave, approximating a damped standing wave.

Figures 10, 11, and 12 show plotted points of predicted tidal height versus measured travel time to the indicated locations for high and low tides. The notable scatter of the plotted points indicate that other factors are involved in the relationship of these variables. As discussed previously, it was anticipated that low tides would experience longer travel times in the estuary than high tides (5). Figures 10, 11, and 12 tends to verify this expectation. From Figure 10, we may use the travel time to compute mean depths for the estuary. A

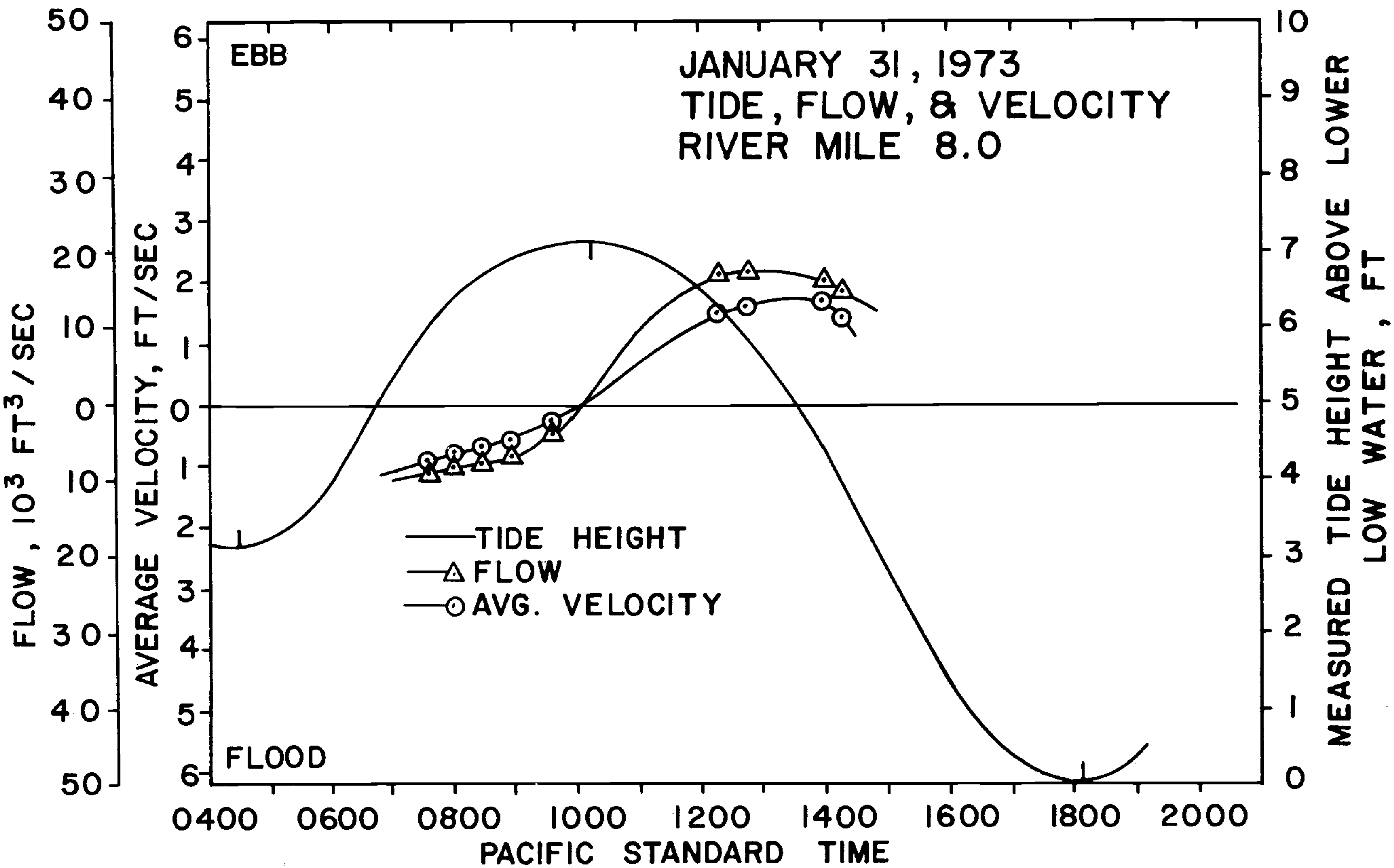

Figure 9. Velocity, flow and tides, river mile 8.0, January 31.

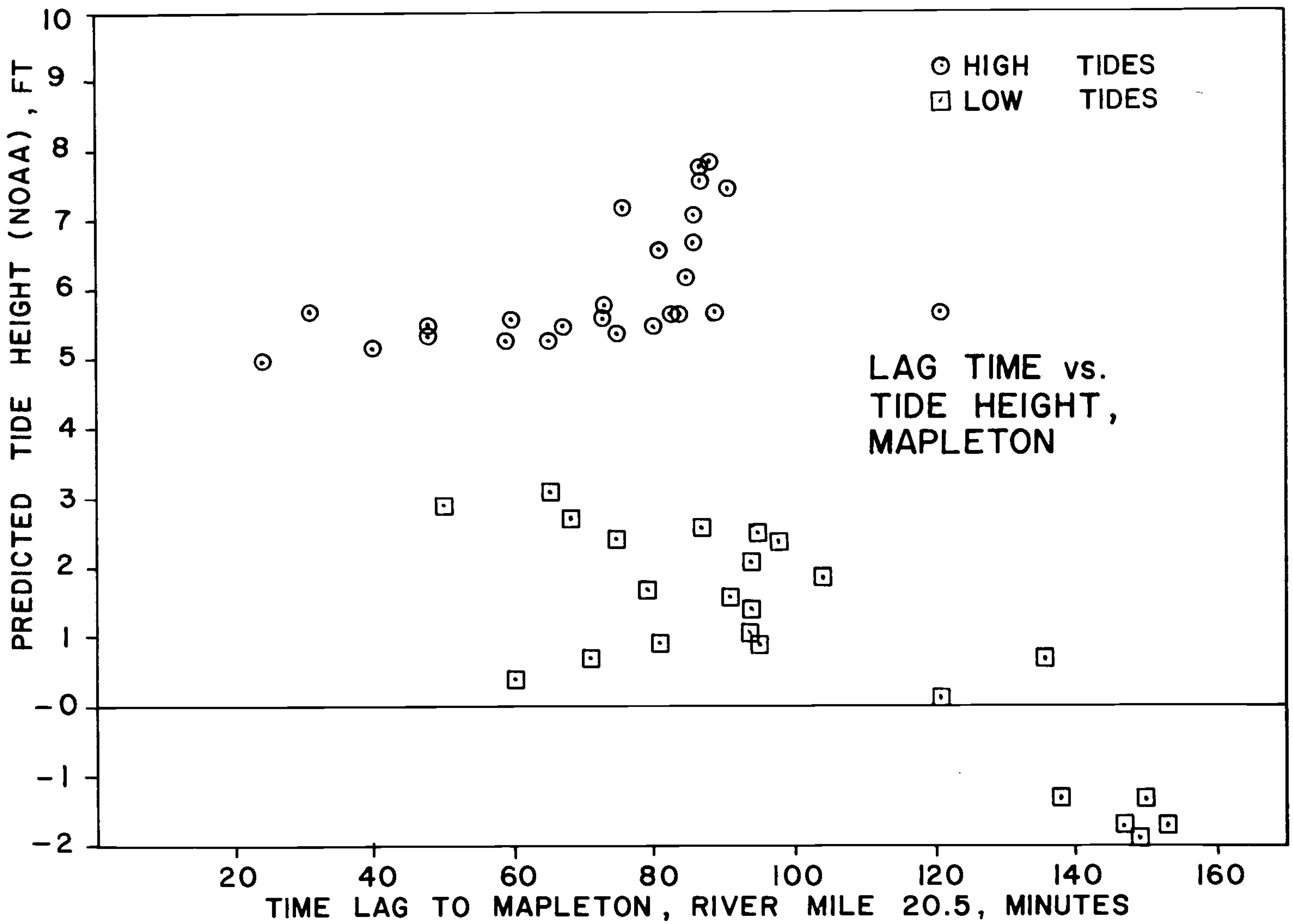

Figure 10. Lag time vs. tide height, Mapleton.

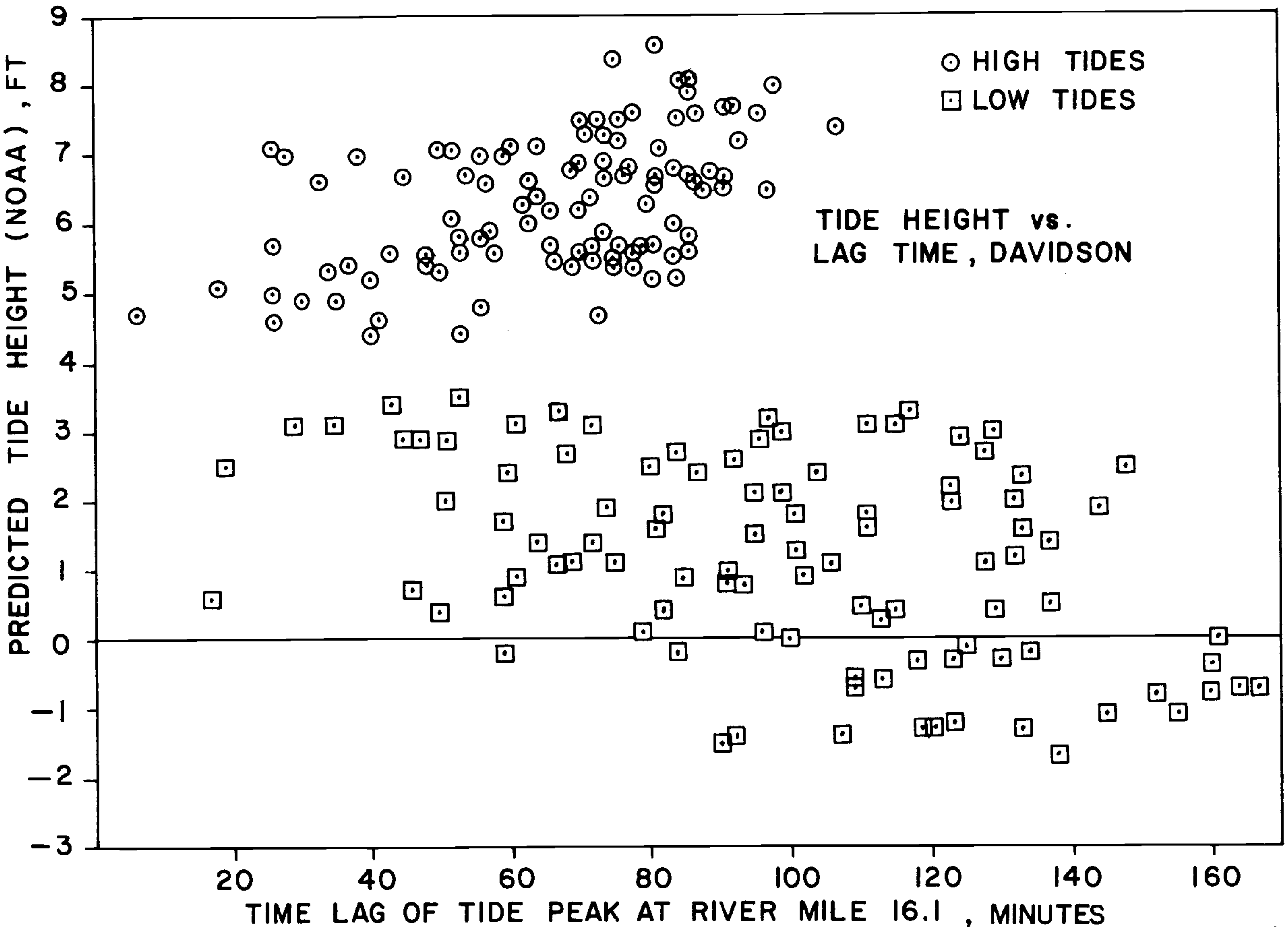

Figure 11. Lag time vs. tide height, Davidson.

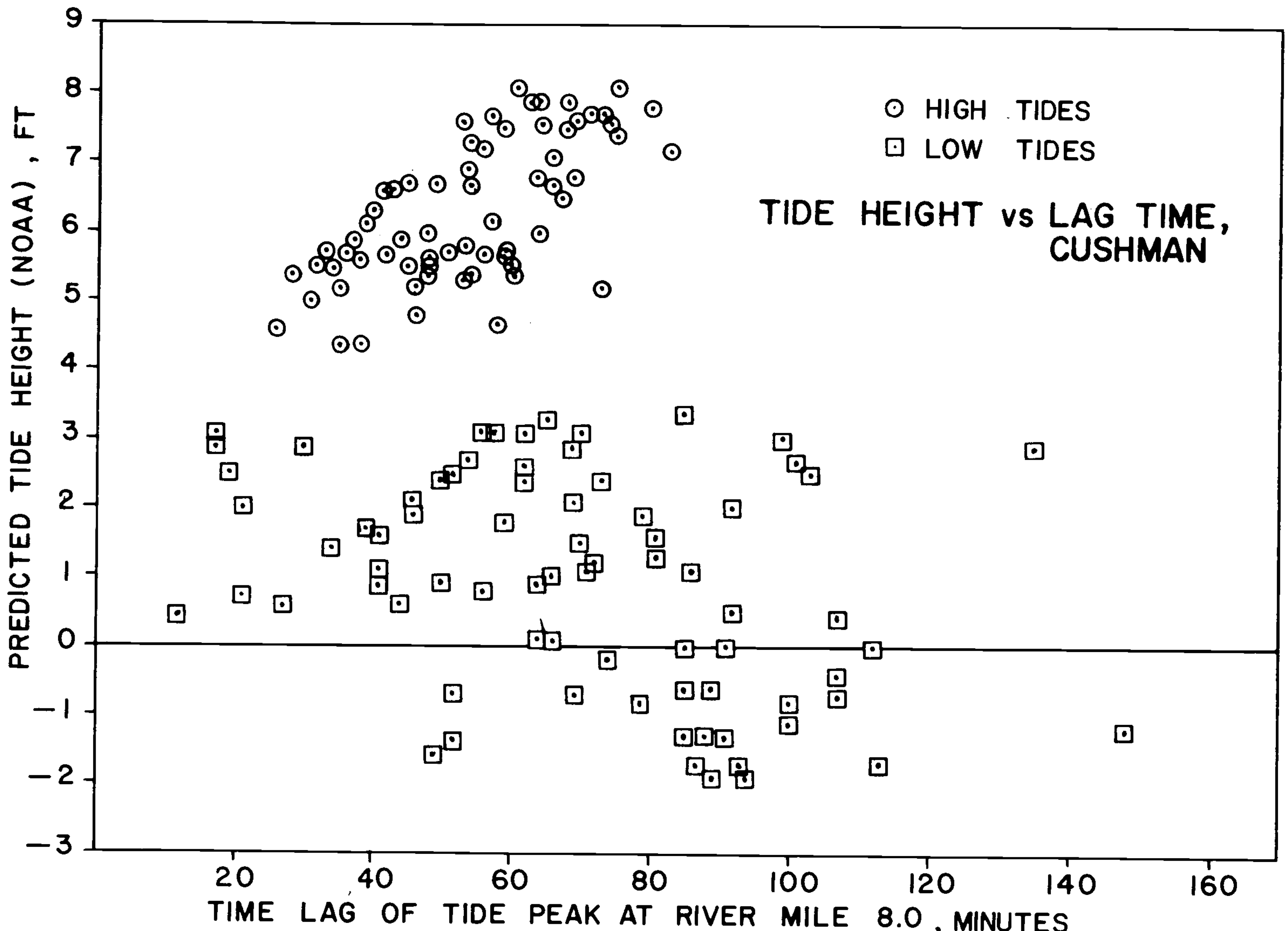

Figure 12. Lag time vs. tide height, Cushman.

high tide of 7.0 feet is seen to require 85 minutes to arrive at Mapleton, river mile 20.5, so the wave celerity can be expressed as:

$$C = \frac{\text{Distance}}{\text{time}} = \frac{20.5 \text{ miles}}{1.42 \text{ hours}} = 14.5 \text{ mph} = 21.3 \text{ ft/sec}$$

(6.5 m/sec)

since

$$C = \sqrt{g(h + \eta)},$$

$$h + \eta = \frac{C^2}{g}$$

$$h + \eta = \frac{(21.3)^2}{32.2 \text{ ft}} = \frac{454}{32.2} = 14.1 \text{ ft} \quad (4.3 \text{ m})$$

For a low tide of minus 1.0 foot, a travel time of 140 minutes is required, giving C = 12.9 ft/sec (3.94 m/sec) and h + = 5.2 ft (1.59 m). These calculations show a computed difference of 8.9 feet (2.71 m) for a stated difference of 8.0 feet (2.44 m) which is within reasonable limits. The mean depth is computed to be approximately 6 feet (approx. 2 meters), which is also reasonable. Johnson (11) reports the mean depth below mean sea level as 7 feet.

The broad scatter in the plotted data of Figures 10, 11, and 12 is not well understood. In examining the tidal data, the travel time of the tides is seen to have no trend with respect to freshwater inflow, except for an increased time lag at extremely high flows. The data within the main bodies of plotted points in Figures 10, 11, and 12 do not appear to vary as a function of streamflow.

IV. WATER QUALITY

Theory and Literature

Physical water quality of the Siuslaw Estuary has been studied by Burt and McAllister (4) and by Giger (7) among others. Based upon their salinity measurements in 1957 and 1958 Burt and McAllister classified the Siuslaw Estuary as a two-layered system during January and May, as a partly-mixed system in March, and as a well-mixed system in October.

In general, a well-mixed estuary is one dominated by tidal forces, where freshwater flow is relatively unimportant. A partially mixed estuary, usually defined as one where vertical salinity differences exceed 1% (5), is one where both freshwater and tidal flows are important. A stratified estuary is one which is dominated by freshwater flow. Simmons (5) has found that when the flow ratio (the ratio of river flow per tidal cycle to the tidal prism) is 1.0 or greater, the estuary is fully stratified. When the flow ratio is about 0.25 the estuary is partly-mixed and when the flow ratio is less than about 0.1 the system is well-mixed.

The flow ratio cannot completely describe the circulation of the estuarine system, however. The bathymetry of the estuary also has important effects. The width and depth of the estuary, as well as the flow ratio, determine the amount of mixing which a particular tidal rise or fall will produce in the water column (5).

The stratification or mixing of an estuary will vary from season to season as the freshwater inflow changes. This is especially true in estuaries such as the Siuslaw, where river flow may vary by a factor of 500 from rainy to dry seasons. In fact, the flow ratio of the Siuslaw Estuary varies from less than 0.001 in the summer low flows to greater than 0.35 in some winter runoffs. Thus, the degree of mixing in the estuary is expected to vary from complete mixing to an almost fully stratified system.

Of the physical water quality variables measured in this study, salinity is most definitive in terms of mixing. Salt is a conservative substance in estuarine processes, while dissolved oxygen, turbidity, pH, and heat (as measured by water temperature) may individually not be conserved in processes in the estuarine system.

Dissolved oxygen may be added by photosynthesis or surface aeration, or subtracted by microbiological decomposition of organic material. In a pristine estuary, dissolved oxygen is expected to be near the saturation level. The saturation level varies with temperature and salinity, decreasing with both increasing salinities and temperatures. During sunlight periods in low-velocity portions of the estuary, photosynthetic action of aquatic organisms may raise dissolved oxygen above the saturation level.

Turbidity may be associated with either suspended sediments from marine or riverine sources, or with plankton. Sediments may settle out of the water column in areas of low velocity, be re-suspended by higher velocities, or flocculated by increasing salinity, increasing settling velocities. Growth of planktonic organisms may be affected by salinity, temperature, or the pre-existing turbidity.

The pH of riverine waters is normally very slightly acidic (approximately 6.9), while the pH of undiluted near-surface seawater is about 8.4. The pH of estuarine waters is expected to vary within this range, effected by biochemical processes in the estuary.

Temperatures of offshore ocean waters vary in a complicated relationship with ocean currents, local wind induced current systems, and coastal upwelling. River water temperatures vary from below freezing in winter to over 20 degrees C in summer (17). Heat is added to the estuarine system by solar radiation, by transfer of heat from the atmosphere, and other transfers of heat.

Physical water quality measurements, described in the next section, were taken on the Siuslaw Estuary to verify and quantify the qualitative concepts outlined above.

Another important concept, related to the flow ratio, is the flushing time for the estuary. The flushing time is defined as the time for some particular incremental volume of freshwater to be carried through the estuary to the ocean. The flushing time may be more or less accurately predicted by several methods, either semi-analytical or numerical. The flushing time varies with streamflow, decreasing for increased river discharge. Ketchum (5) has estimated flushing time as

$$T_f = \frac{Q_f}{R}$$

Where Q_f is the total amount of river water accumulated in the whole or a section of the estuary, and R is the river flow.

The normal flow of the Siuslaw River is about 3150 cubic feet/second (89.2 m^3/sec) (3).

The quantity of freshwater in any section of the estuary may be computed by using a fractional freshwater concentration

$$f = \frac{S_s - S_n}{S_s}$$

where S_s is the salinity of undiluted seawater and S_n is the mean salinity of a given segment of the estuary. From this

$$Q_f = fV$$

where V is the volume of the segment in question. It should be noted that salinity measurements are required to use this method of estimating flushing times. Such an estimate, based on salinity data from these studies, is presented in a later section of this thesis.

Field Studies

Water quality measurements were accomplished on four days, chosen to represent four different seasonal conditions of the estuary. Since tides on the Oregon coast vary widely, and it was desired to identify seasonal effects, a tidal range approximating 6 feet (2 meters) was selected for study during each season. Exact conditions of tide and streamflow for each measurement date are identified in Table I.

Water quality measurements and sampling were conducted at high and low tides, commencing at the entrance. The sampling boat then proceeded upstream, mocing with the tide, sampling and measuring at selected sites, taking about 90 minutes to reach Cushman, at river mile 8.1.

Using the Hydrolab instrument system, in situ measurements were made of temperature, dissolved oxygen, pH, and conductivity. Using a bottle sampler, samples of water were taken for laboratory analysis to confirm field measurements of dissolved oxygen and salinity (conductivity), and for laboratory measurement of turbidity.

Laboratory measurements of salinity were conducted with a Plessey Environmental Systems Portable Salinometer. Confirmation of field dissolved oxygen was by Winkler titration (19). Turbidity measurements were made by Hach Laboratory Turbidimeter.

In each season, sampling was repeated at the same sites, located approximately 1 mile (1.6 km) apart along the main channel of the estuary and in the North Fork and South Slough channels. Samples were taken at the bottom, mid-depth, and surface at each

Table I. Water Sampling Dates and Conditions

Date	Freshwater Flow at Mapleton (Daily Mean) CFS	NOAA Predictions, Entrance High Tide FT	Low Tide FT	Range FT
1-30-73	2480	7.3	0.1	7.2
5-3-73	933	5.7	-1.7	7.4
8-2-73	82	6.8	0.0	6.8
11-19-73	4700	7.0	1.2	6.2

station. *In situ* measurements were made at the same depths, and at other intermediate depths if extreme gradients or other phenomena of interest were present.

The dissolved oxygen probe used in the Hydrolab system is affected by the conductivity of the water, so corrections for conductivity were applied in evaluating the field data.

The results of the water quality field work are presented in the following section. In the graphical presentation of dissolved oxygen and salinity data, the points plotted represent laboratory measurements. In any case, where laboratory information was lacking for individual points, Hydrolab field data was used, corrected by the difference between the means of the two data groups.

A complete tabulation of field and laboratory data is presented in the Appendix.

Results

Water quality sampling and measurement was carried out on the dates and under the conditions shown in Table I. Figures 13, 14, 15, and 16 display the salinities measured at the bottom, mid-depth, and surface for each season and station. In general, these presentations of data show a well-mixed condition. A few significant exceptions are to be noted, however. In Figure 13, displaying the salinities measured on January 30, 1973, some vertical salinity gradient is

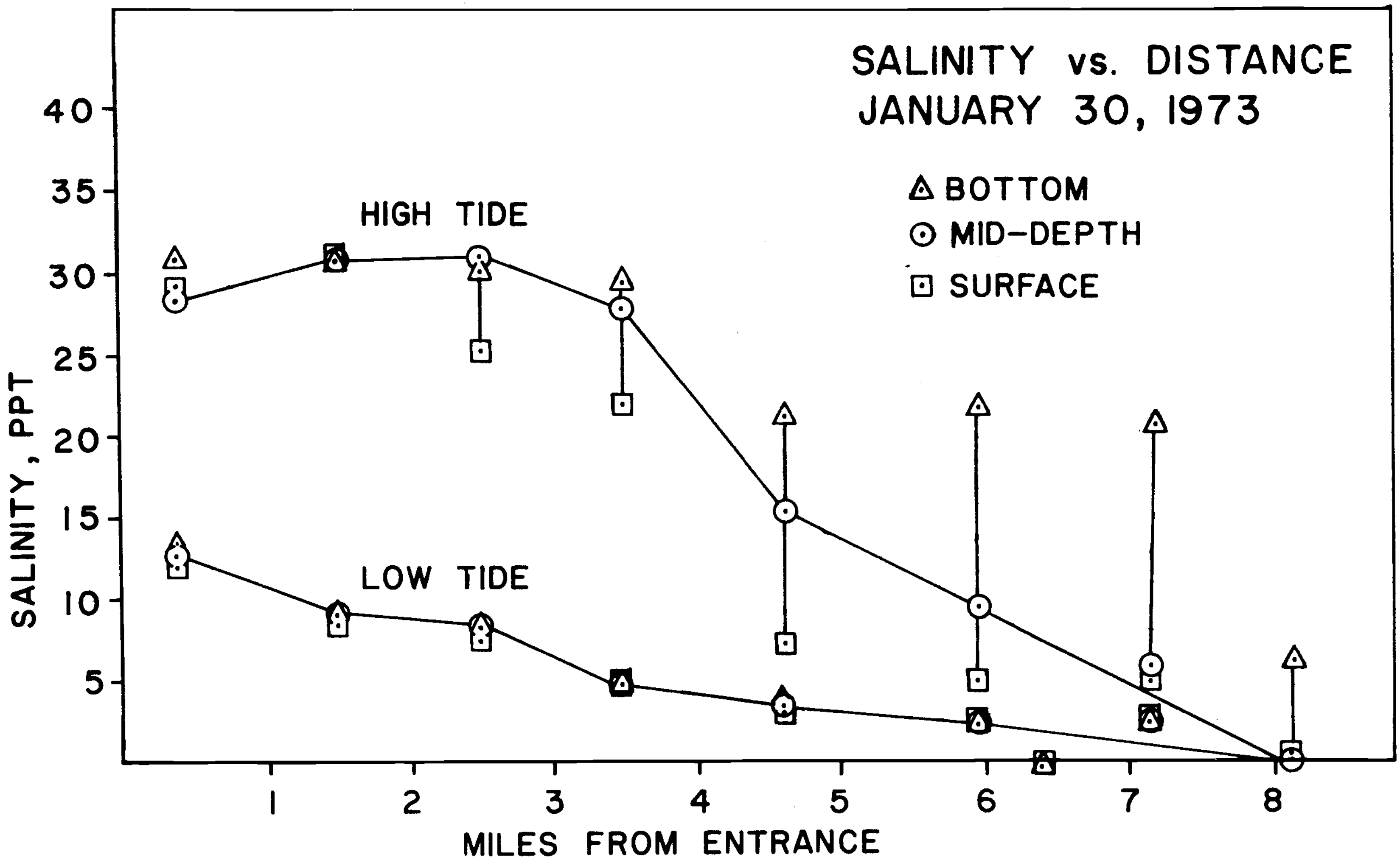

Figure 13. Salinity vs. distance, January 30, 1973

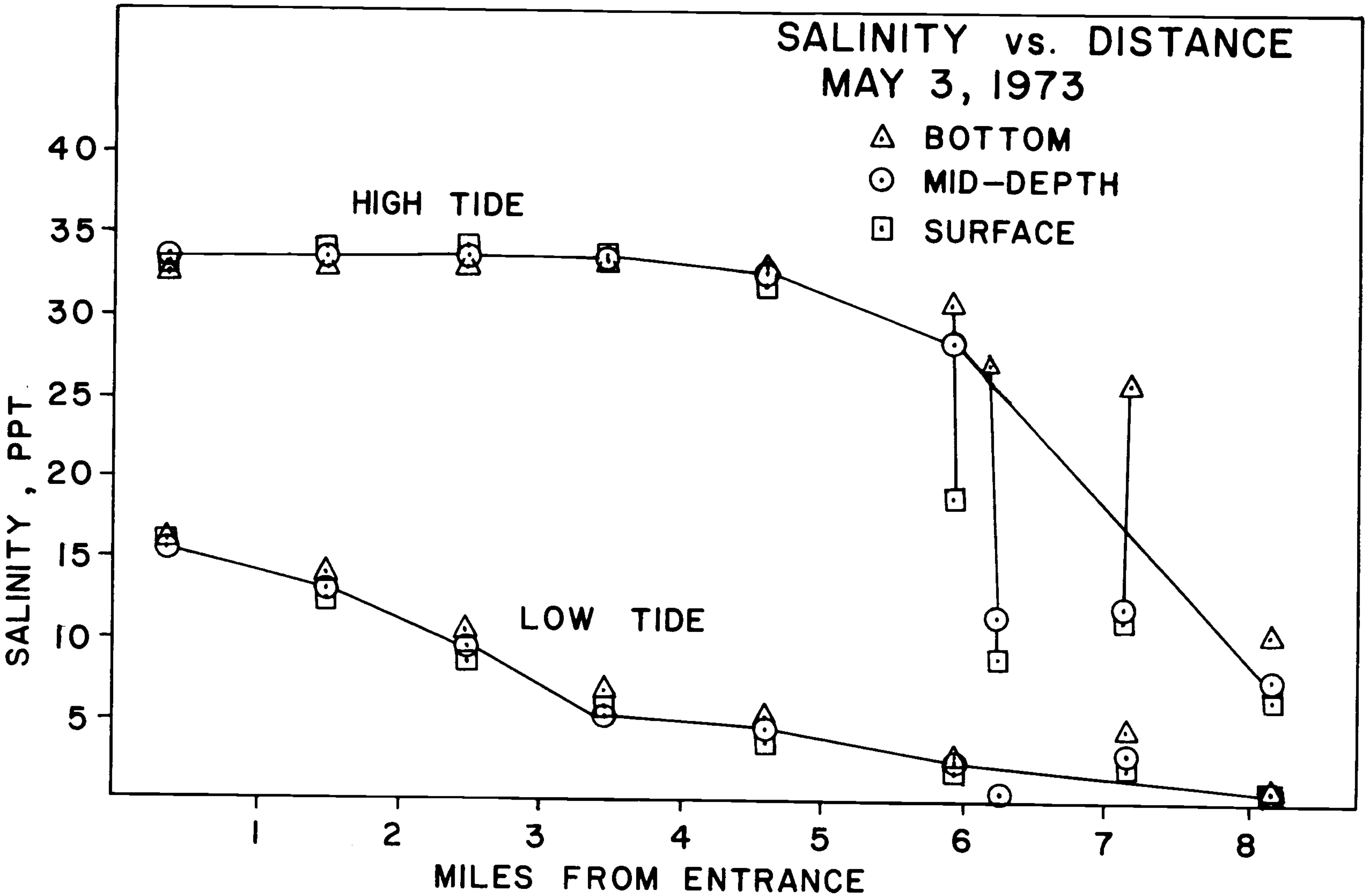

Figure 14. Salinity vs. distance, May 3, 1973.

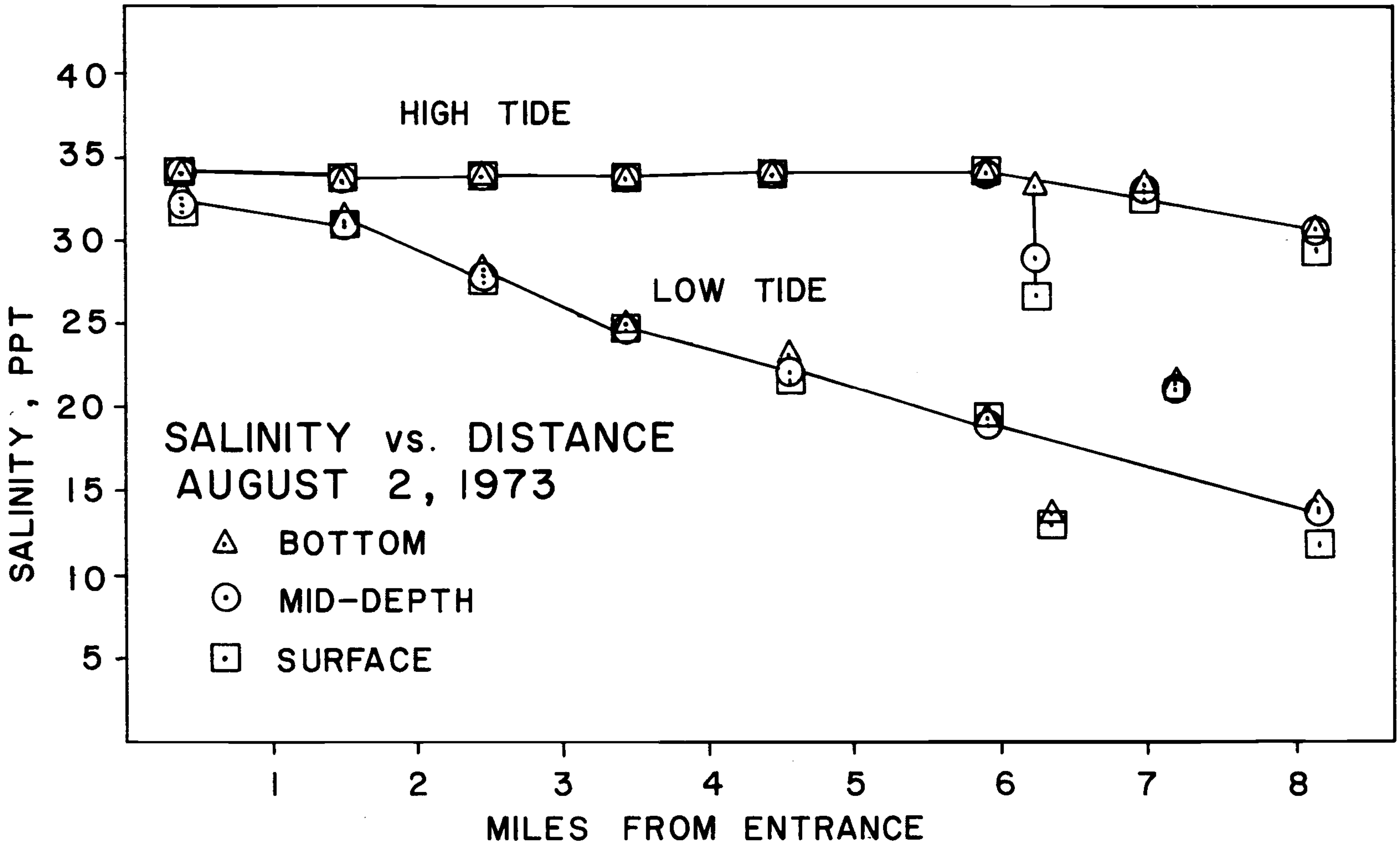

Figure 15. Salinity vs. distance, August 2, 1973.

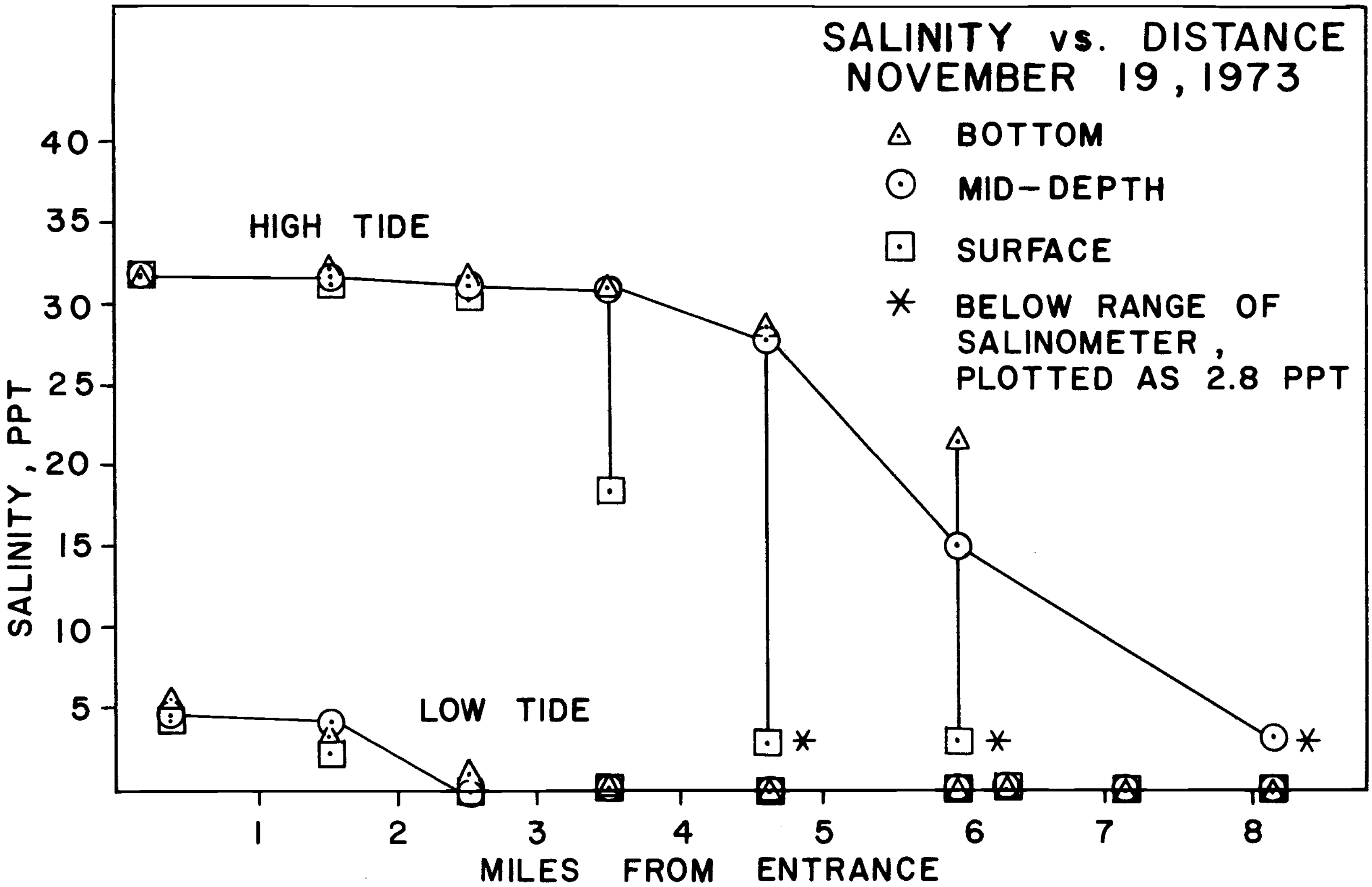

Figure 16. Salinity vs. distance, November 19, 1973.

observed at high tide above river mile 2.5. In Figure 14, displaying the salinities measured on May 3, 1973, only a single measuring station on the main channel, at river mile 5.9, shows any significant vertical salinity gradient. The two off-channel stations in the North Fork of the Siuslaw and South Slough show relatively high salinity at depth, with significant gradients. This is evidenced only at high tide. The data from August 2, 1973, as presented in Figure 15, shows no significant vertical salinity gradients, and also shows relatively high salinities throughout the portion of the estuary where measurements were made. In Figure 16, in which data from measurements taken November 19, 1973 are displayed, the largest vertical salinity gradient observed during this study is shown at river mile 4.6, with essentially freshwater found at the surface, and a salinity of 28.5 PPT at the bottom. This figure also shows the extremely low salinities observed at low tide on this day, with entirely freshwater to be found from river mile 2.5 upward.

The results observed from Figures 13 through 16 are consistent with expectations. The days of observation for which freshwater inflow was relatively small, in May and August, show relatively complete mixing. With a larger freshwater inflow, the data from January show some vertical gradients of salinity. The data from November, with the largest freshwater inflow for which water quality measurements were made, shows the greatest evidence of stratification. This tends to demonstrate that the highest level of mixing occurs when the flow regime within the estuary is dominated by tidal effects, with more stratification to be expected when fresh-water flow is increased.

Figures 17, 18, 19, and 20 display the dissolved oxygen levels measured at the bottom, mid-depth, and surface for each station and season. For visual reference, the saturation dissolved oxygen level for the measured surface salinity and temperature is plotted on Figures 17, 18, and 19. An instrument failure resulting in a lack of temperature data precluded such a plotting on Figure 20. It should be noted that for the purpose of making a more readable presentation of the data, the ordinates of Figures 17 through 20 are truncated at various levels.

In general, it is to be observed that as the surface saturation dissolved oxygen level decreases with increasing surface salinity downstream, the measured dissolved oxygen levels decrease at a parallel rate. Figures 16 and 17 exemplify such a trend. As noted above, Figure 19 does not have saturation levels plotted. Figure 19 displays an apparent anomaly of supersaturation. No rationalization of this phenomenon is proposed.

Figures 21, 22, and 23 display the temperatures measured at the bottom, mid-depth, and surface for each station and season. No data are presented for the November 19, 1973 water quality

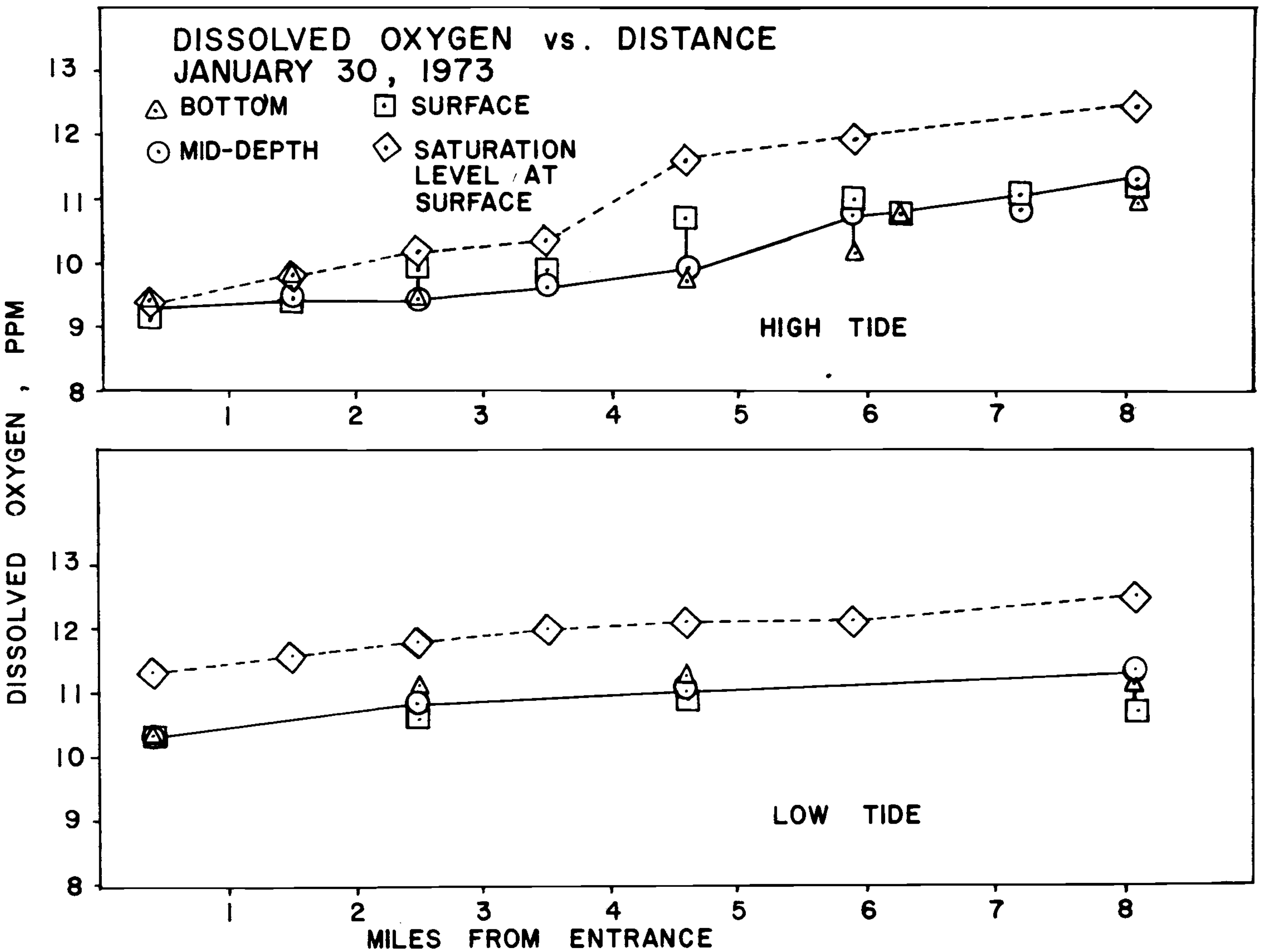

Figure 17. Dissolved oxygen vs. distance, January 30, 1973.

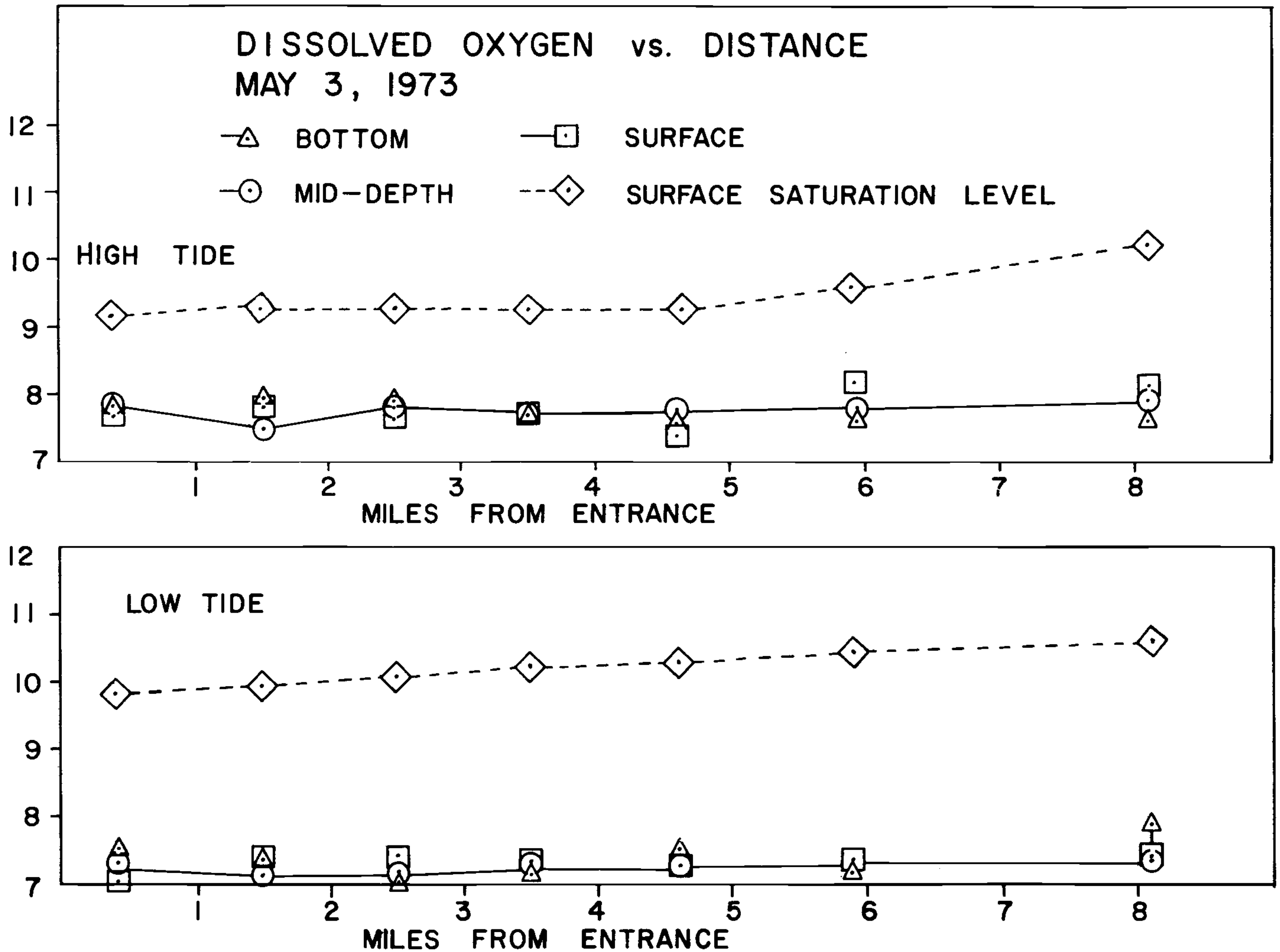

Figure 18. Dissolved oxygen vs. distance, May 3, 1973.

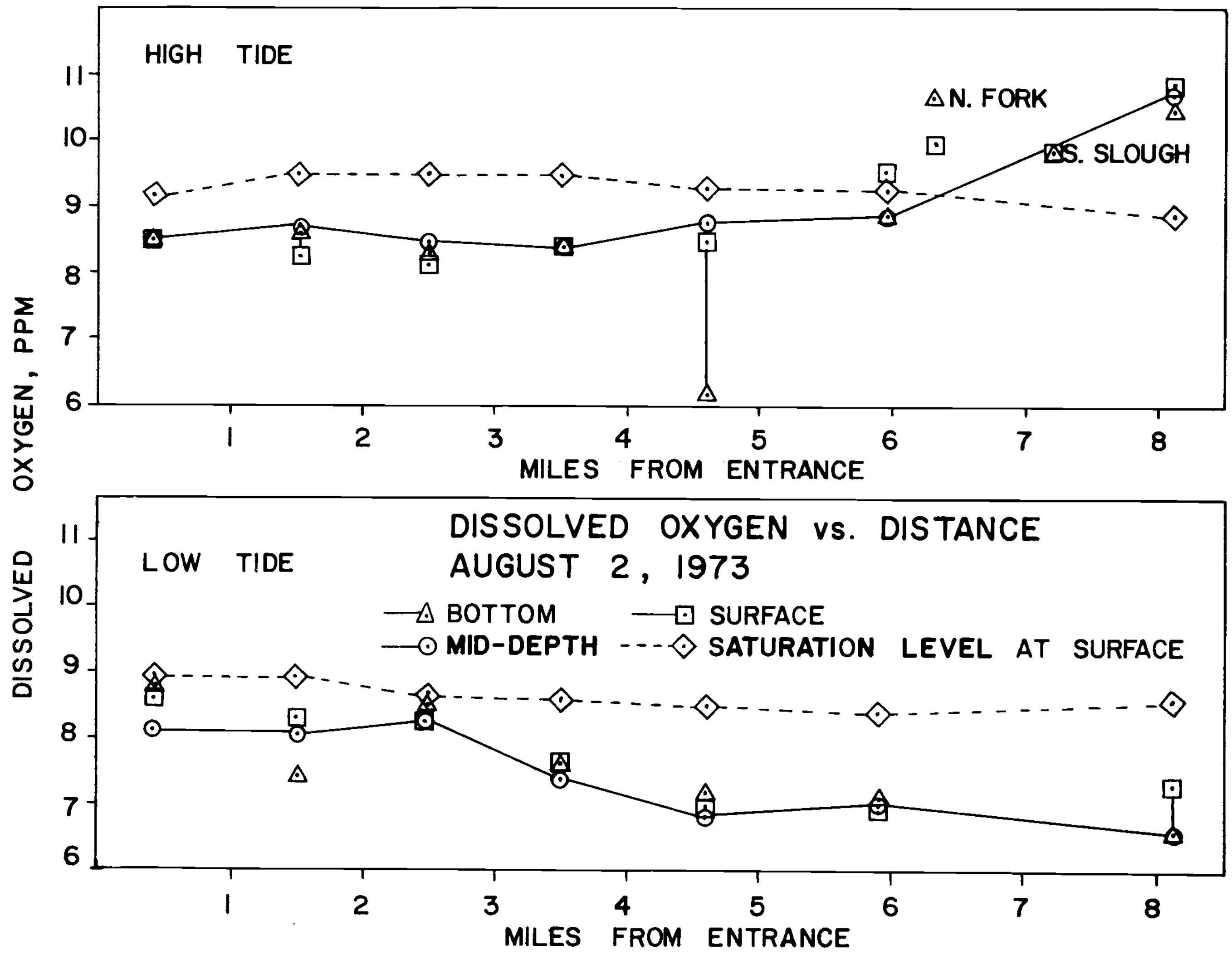

Figure 19. Dissolved oxygen vs. distance, August 2, 1973.

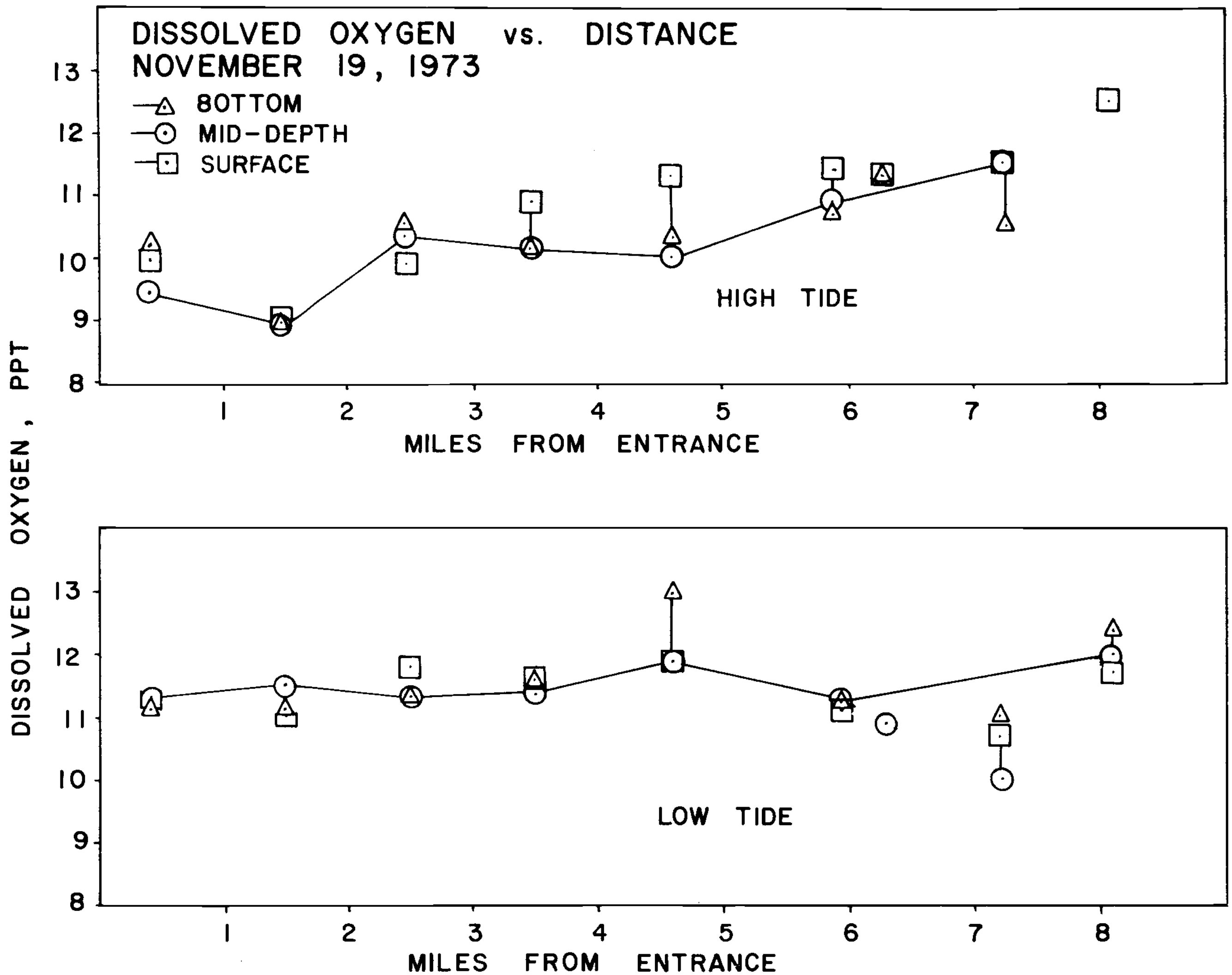

Figure 20. Dissolved oxygen vs. distance, November 19, 1973.

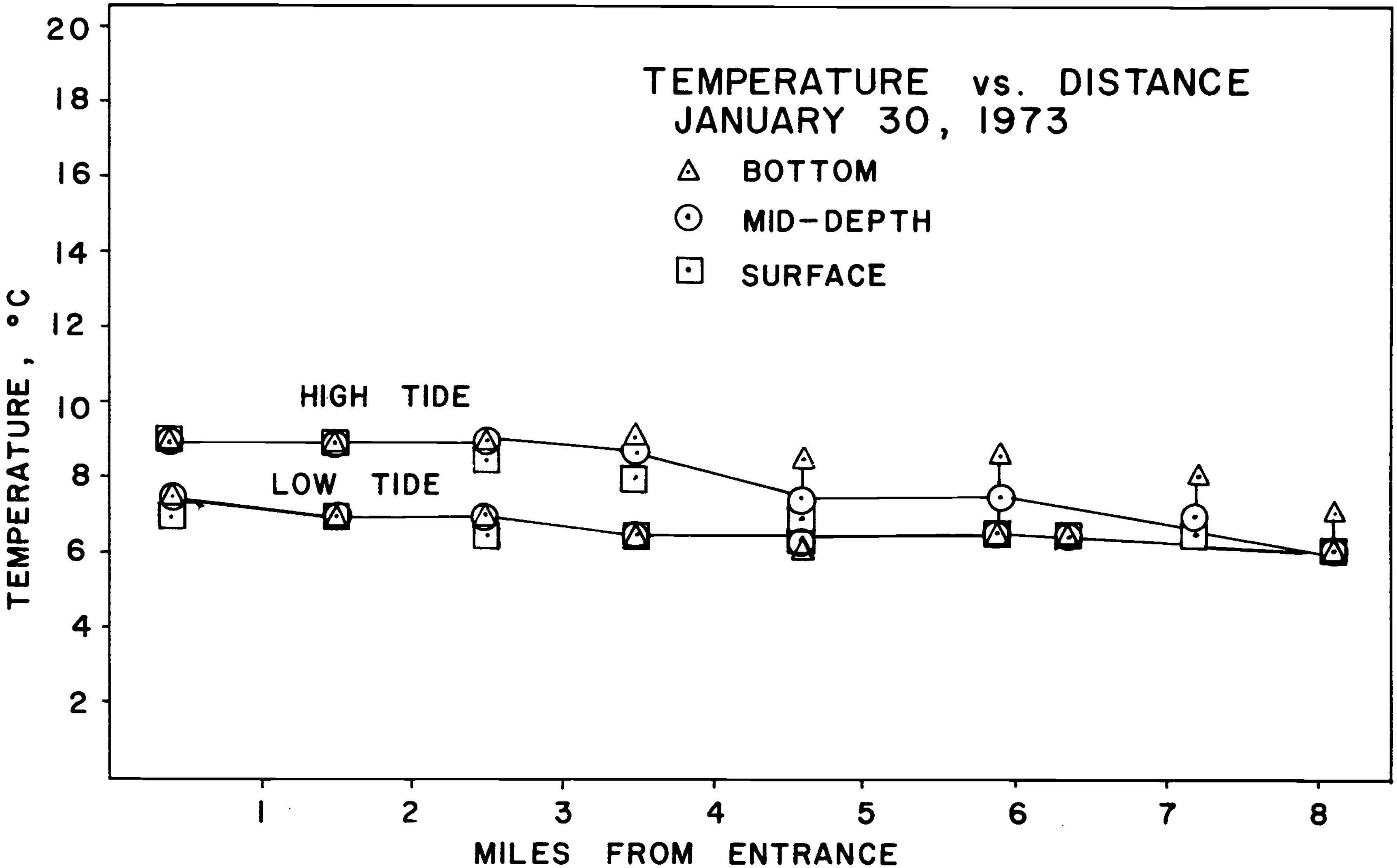

Figure 21. Temperature vs. distance, January 30, 1973.

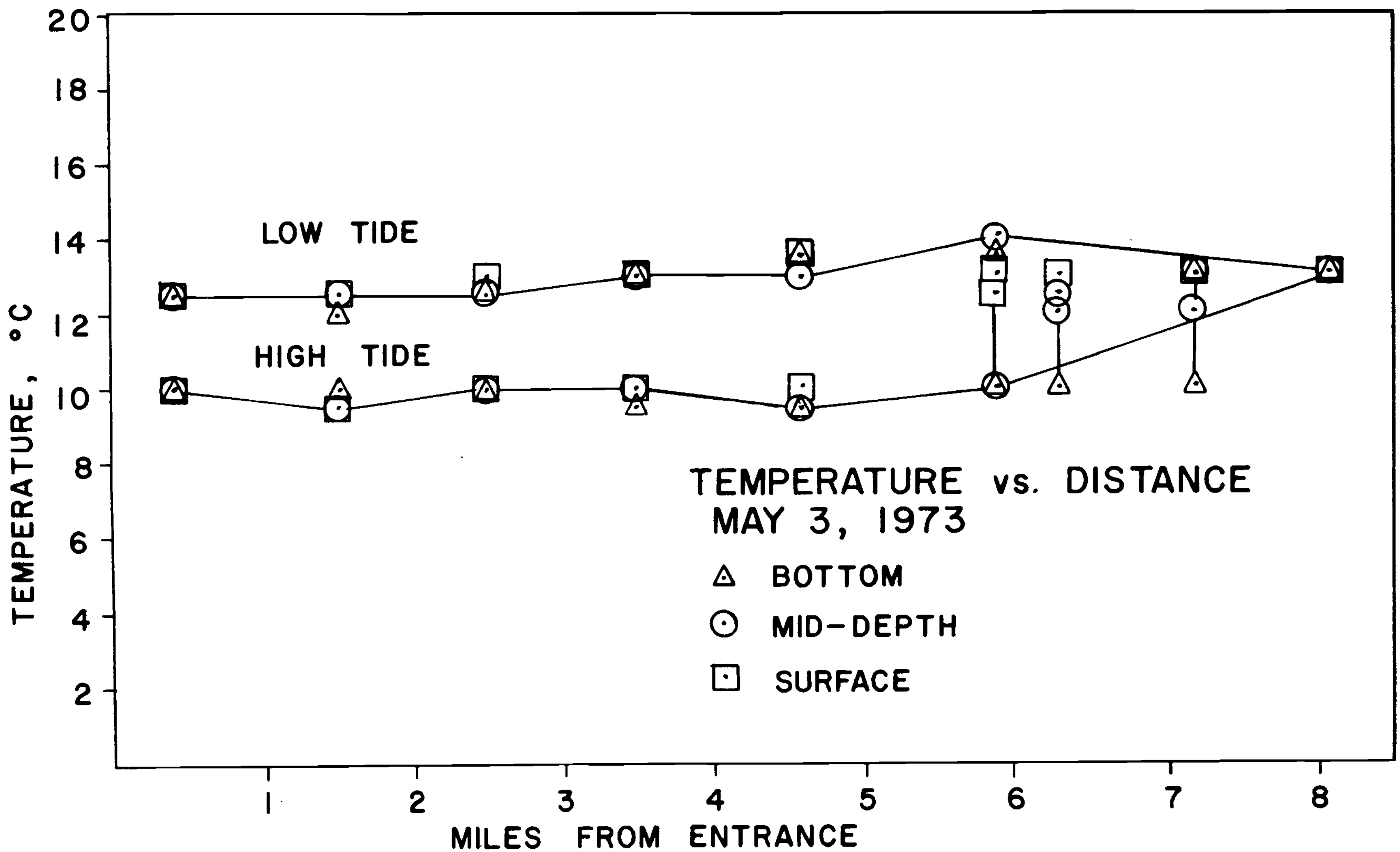

Figure 22. Temperature vs. distance, May 3, 1973.

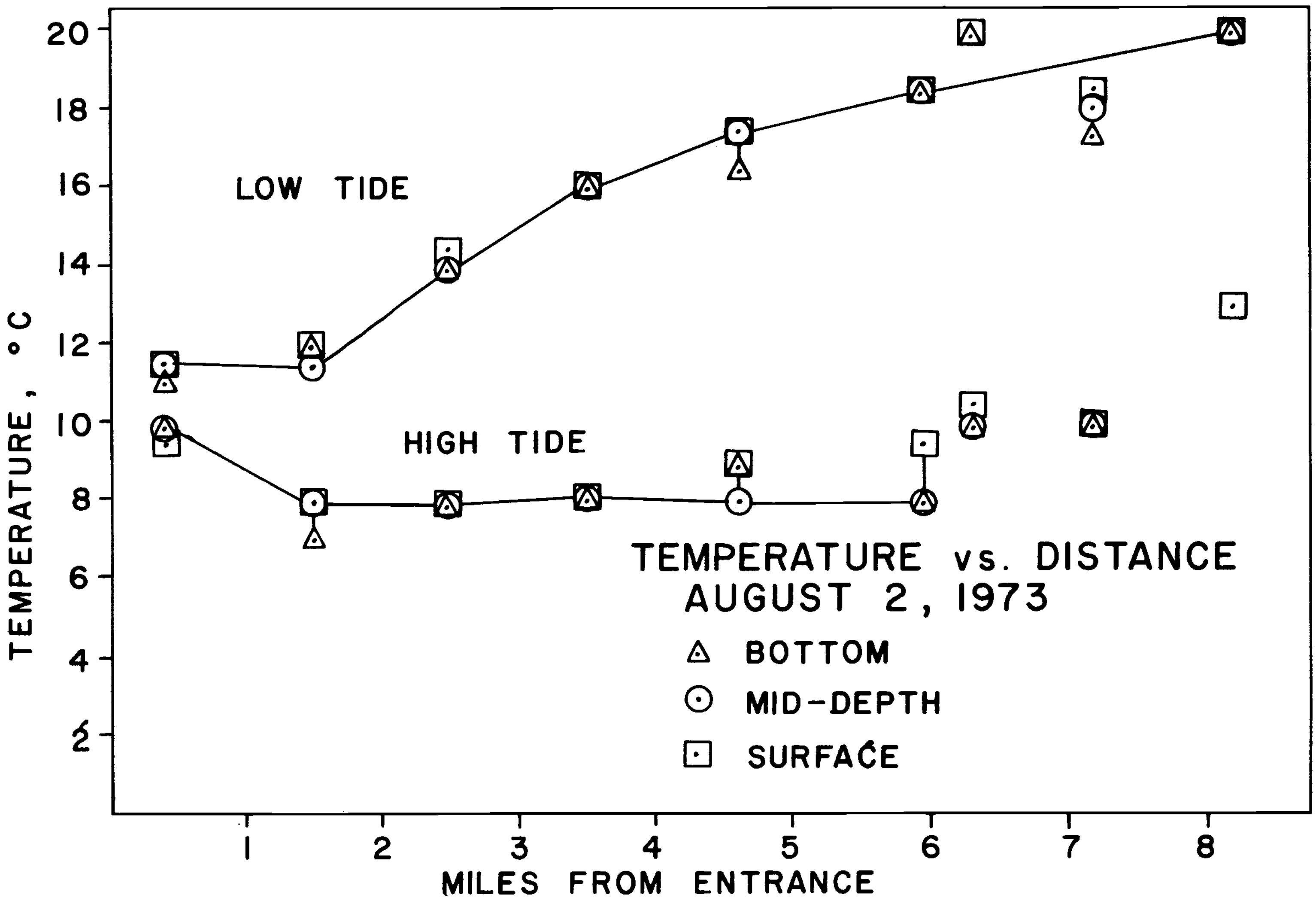

Figure 23. Temperature vs. distance, August 2, 1973.

measurements, due to an instrument failure.

In each of the three instance presented in Figures 21, 22, and 23, a significant temperature difference is noted between the high tide and low tide measurements. In no case was there a large vertical temperature gradient observed along the main channel.

The temperature data from August 2, 1973, as presented in Figure 23, when correlated with the salinity data presented in Figure 15, indicates that the ocean water temperature was nearly 8 degrees C, while the temperature of the freshwater inflow from the Siuslaw River was a minimum of 20 degrees C. The plotted values for high tide in Figure 23 show a continuous horizontal temperature gradient from river mile 2.5 to the upstream end of the measurement.

Figures 24, 25, 26, and 27 display turbidites of mid-depth water samples for each station and season. Turbidity measurement with the techniques available at present (see section on field studies) is not extremely precise. The data shown in Figures 24 through 27 show considerable scatter due to experimental error, which limits the possibility of reaching conclusions based upon the data presented.

One observation based on the turbidity measurements presented in Figures 24 through 27 is that general turbidity levels in the portion of the estuary observed are quite low. No value of over 10 Jackson Turbidity Units was observed. On each day of observation, a definable difference of turbidity exists between high tide and low tide

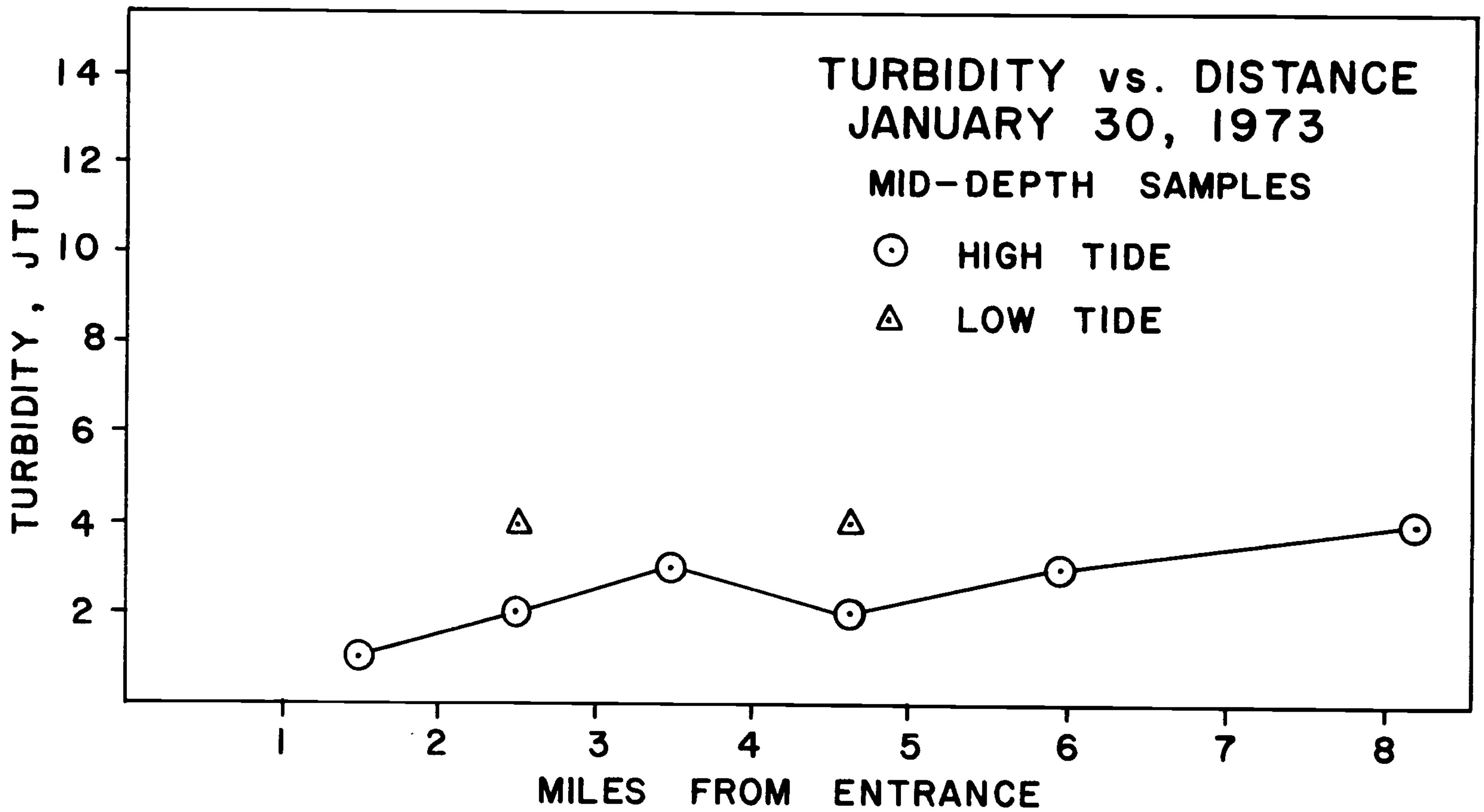

Figure 24. Turbidity vs. distance, January 30, 1973.

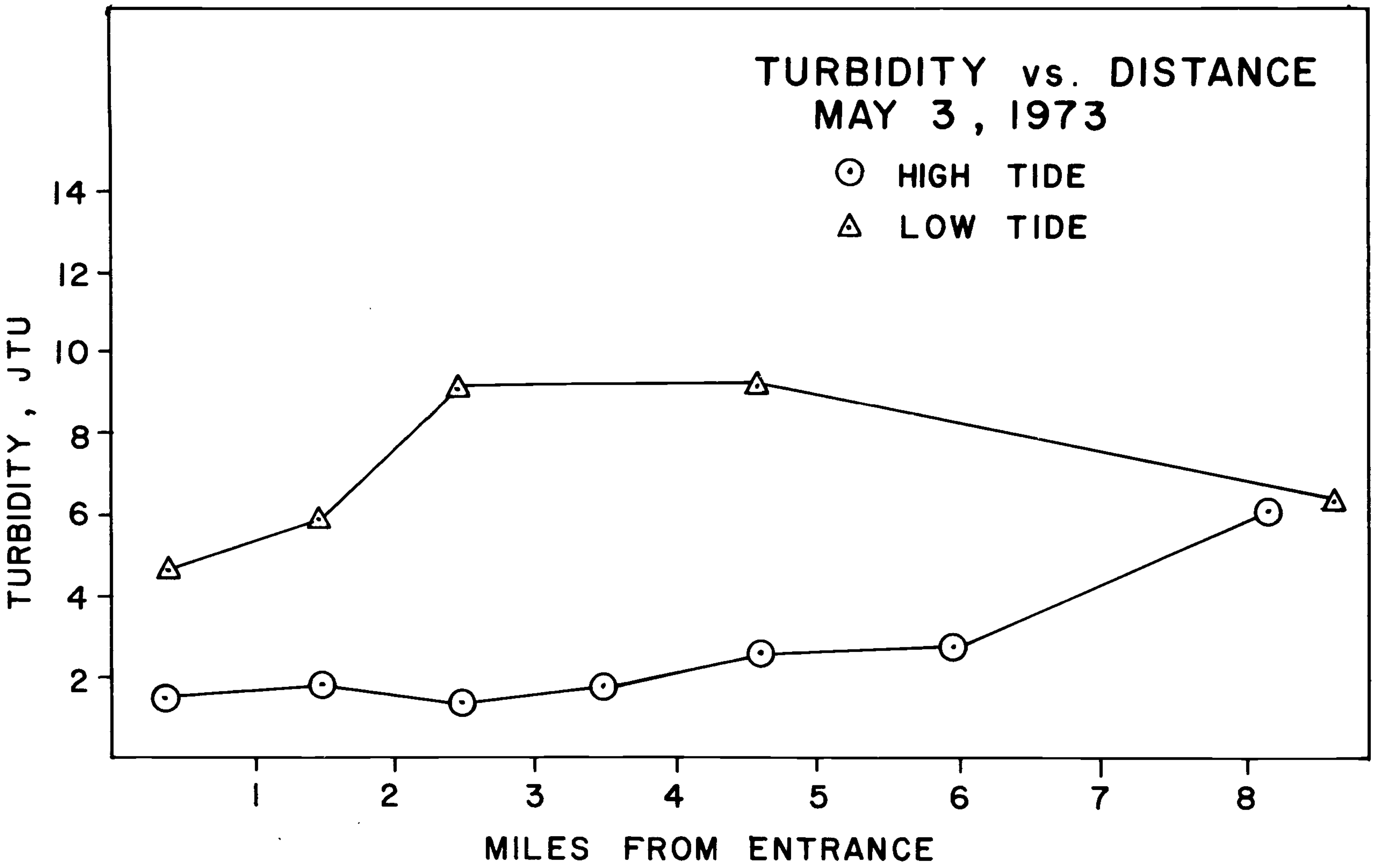

Figure 25. Turbidity vs. distance, May 3, 1973

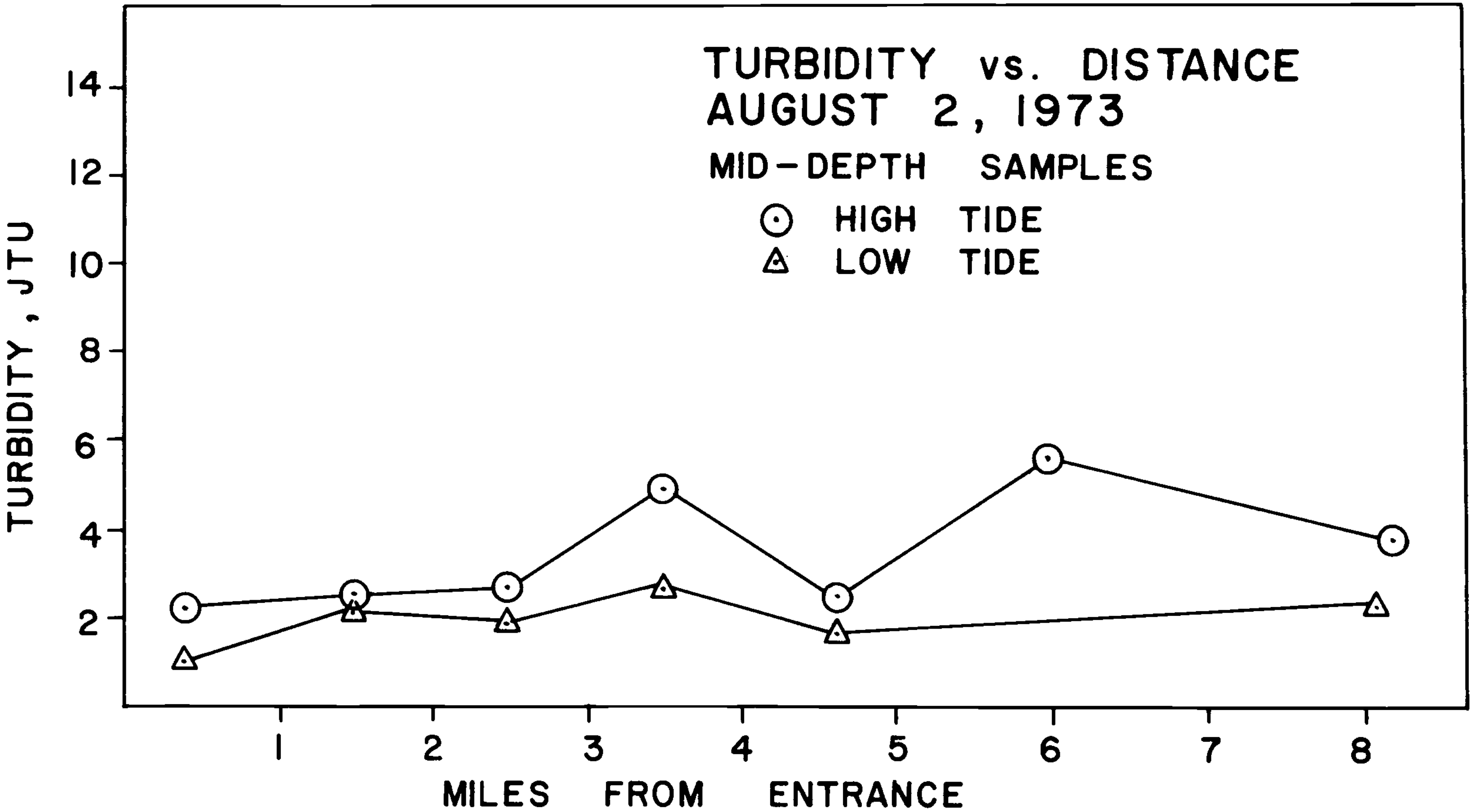

Figure 26. Turbidity vs. distance, August 2, 1973

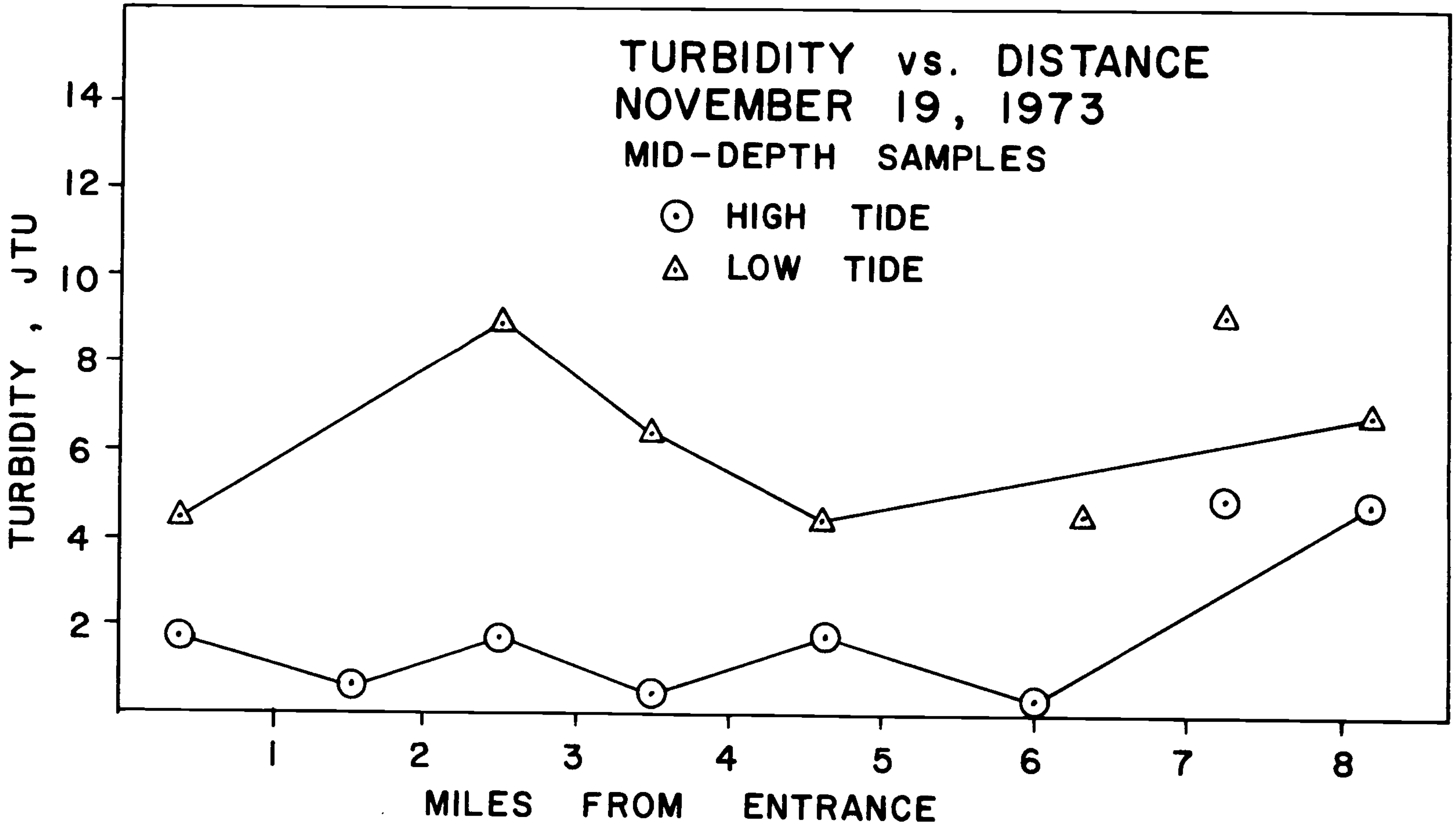

Figure 27. Turbidity vs. distance, November 19, 1973

samples. For the samples from January, April, and November, the turbidity of the low tide, low salinity water mass is greater than the turbidity of the high tide, high salinity water mass. For the August samples, the turbidity of the high tide, high salinity water mass is greater. A possible explanation of these results might be that for the January, April, and November samples, representing periods of relatively high river flow, show relatively higher turbidites associated with large quantities of sediment transported by the river system. The August samples, representing a period of relatively low river flow, and also higher ocean temperatures, show relatively higher turbidites associated with organic materials from increased plankton growth in the offshore zone.

No graphic presentation of pH data has been included. Examination of pH data, found in Table IV, in the Appendix, reveals no significant trends. Variations in pH were small relative to the precision of available pH instrumentation. The pH of all samples was approximately 7.0, and no trends with location or time were observed.

In obtaining the measurements and samples reported in Figures 13 through 27, no precise system of navigation was used to insure repeatability of sampling location. Samples were taken in the vicinity of some landmark, such as a bouy, bridge, or piling. As a result, considerable variability of depth resulted between observations for each season are displayed in Figure 28. Separate presentations for

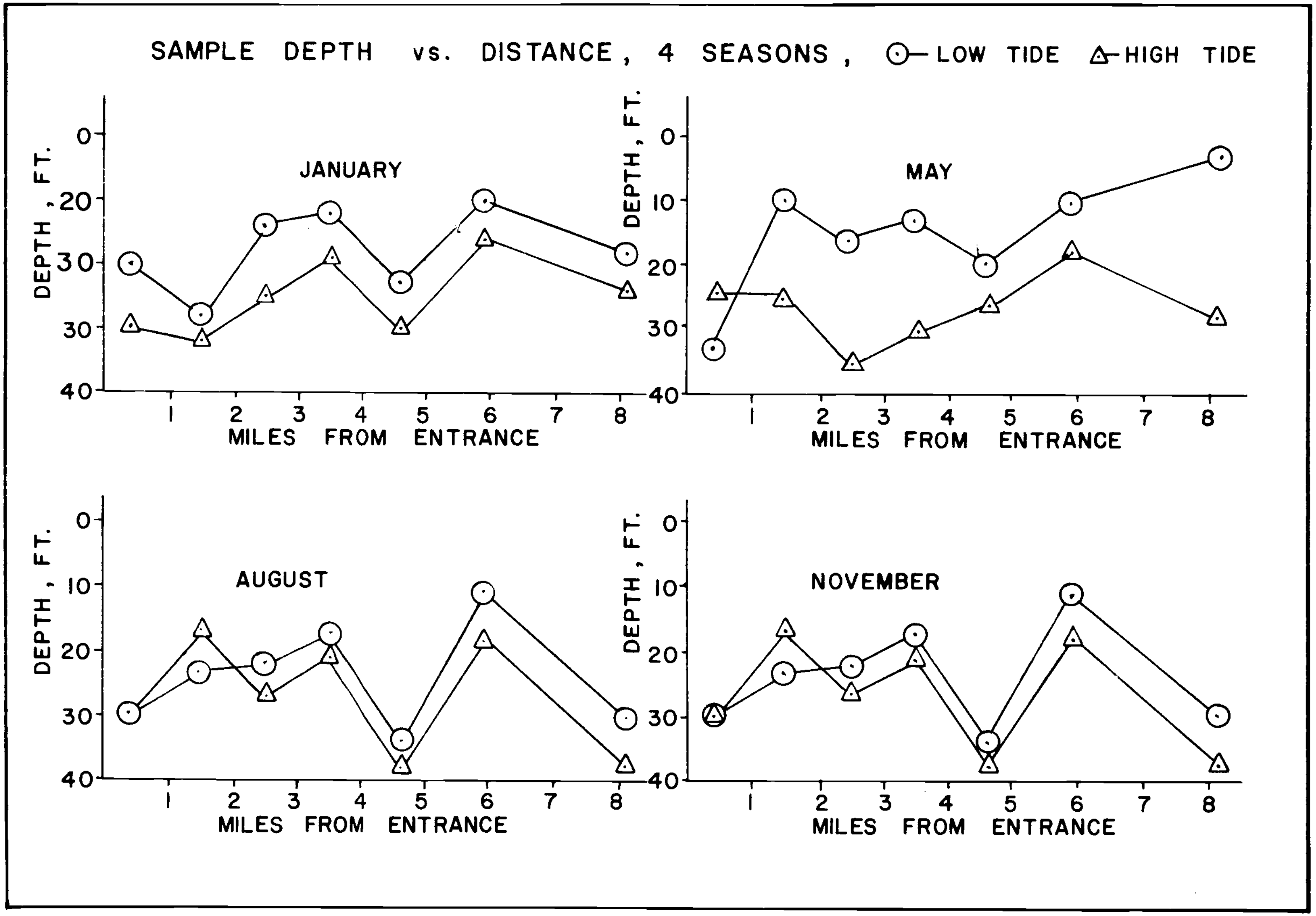

Figure 28. Sampling depths for all sampling dates.

each season were adopted to minimize confusion of plotted lines.

As discussed previously, the concept of flushing time is an important one in estuarine dynamics. Using the mean daily flow, and salinity data from the low tide water quality measurements of January 30, 1973 a flushing time may be computed.

$$R = 2480\ ft^3/sec = 70.4\ m^3/sec$$

$$S_s = 35\ ppt$$

$$S_n = 5\ ppt$$

$$f = \frac{35-5}{35} = \frac{6}{7}$$

Volume (entrance to Cushman) = $1.9 \times 10^8 ft^3$ (estimated) = $5.4 \times 10^6 m^3$

(f) x (Volume) = $Q_f = 1.6 \times 10^8 ft^3 = 4.5 \times 10^6 m^3$

$$T_f = \frac{1.6 \times 10^8}{2.5 \times 10^3} = 0.64 \times 10^5\ sec$$

$$= 0.75\ days$$

Similarly, the data presented in Table II were calculated for each day of water quality sampling. It should be noted that these values of estimated flushing time are representative only of the conditions of tide and streamflow for which they were calculated.

Table II. Calculated Flushing Times

Date	Tide Range (NOAA Predicted) FT	Freshwater Flow at Mapleton (Daily Mean) CFS	Estimated Flushing Time Days
1-30-73	7.2	2480	0.75
5-3-73	7.4	933	2.0
8-2-73	6.8	82	11.6
11-19-73	6.2	4700	0.46

V. SEDIMENTS

Theory

Sediments in estuaries are subject to a number of forces which affect their distribution. Estuarine sediments are generally from two sources; they are carried by the river system from an origin in the watershed, or they are carried by waves and tidal action from the littoral zone.

In general, sediments of marine origin are to be expected in the area of the estuary nearest the mouth, sediments of fluviatile origin are expected in the upper reaches of the estuary, and a zone of mixed sediments is anticipated in-between (12).

Sediments of fluviatile origin are found in suspension in the fresh riverine water which enters the estuary. These sediments are generally clays of various types. The surface chemistry of the clay minerals is such that the increased salinity which is encountered in the estuarine environment causes the clay particles to flocculate. The flocs have a much larger effective size than the originally suspended clay particles, and start to settle out of the stream wherever salinity is first encountered. The deposition of these sediments in the benthic zone is influenced by velocity and salinity patterns in the area where appreciable salinity is first encountered by river-carried sediments (10).

In the Siuslaw Estuary, river flow varies from less than 100 cfs (2.8 m^3/sec) to over 20,000 cfs (566 m^3/sec) (17), and tide ranges vary dramatically from spring tides to neap tides (20). This means that the distribution of salinity in the estuary, which is dependent on both tidal conditions and freshwater flow, varies over a wide range. The deposition of riverine sediments also is expected to vary with the conditions of streamflow and tides.

In the Yaquina Estuary, Kulm and Byrne (12) found that the three realms of deposition were: 1) marine, from the entrance 1.5 miles (2.4 km) into the estuary; 2) fluviatile, from the freshwater head of the estuary to within 6 miles (9.6 km) from the entrance; and 3) the marine-fluviatile realm between 1.5 and 6.0 miles from the entrance. The Yaquina Estuary, however, experiences significantly less freshwater input than the Siuslaw, which drains a watershed three times as large into a much smaller estuary.

Sediments are monitored daily by the U. S. Geological Survey at its station on the Siuslaw River near Mapleton. Sediment transport as measured by this station indicates a wide variation of transport rates, from less than 0.5 tons/day (454 kg/day) to over 4000 tons/day (3.63 x 10^6 kg/day) (17).

It should be noted that periods of maximum sediment transport correspond to maximum river flow, and therefore to conditions of highest ebb tide velocities and minimum salinity in the estuary. This means that sediments delivered by the river might be passed through the estuary with no opportunity for settling or deposition in the estuary.

Several investigators (10) have theorized that in cases where a well-defined saline wedge occurs in an estuary, deposition will be expected where the upstream end of the saline intrusion is found. This effect is not expected to be of importance in the Siuslaw Estuary, since it forms a two-layered system only at certain times (4), and the saline wedge is subject to wide variations in its intrusion due to the tides (7).

Corps of Engineers records, as quoted by Pearcy et al. (17) indicate that most sediment deposition which required dredging has been in the entrance channel. This material has been readily identifiable as fine sand of marine origin. This is consistent with the results reported by Kulm and Byrne (12) at Yaquina.

Generally, the expected distribution of sediments in Siuslaw would be marine sands near the mouth, fluviatile clays near the freshwater head of the estuary, and a zone of mixed sediments between those two areas.

Field Studies

Sediment samples were taken in the estuary in January and in June 1973. Core samples were taken by a gravity coring device from a pontoon craft. The gravity coring device was constructed by S. Crane.

The sediment cores were sealed in transparent acrylic core liners and transported back to the Ocean Engineering soils laboratory in Corvallis. There they were extruded from their liners in sections of 4 inch (10.16 cm) lengths. These segments were air-dryed, then weighed.

Portions of these segments were then separated for analyses of grain size, volatile solids and, in selected cases, specific gravity. The analysis of grain size was conducted in accordance with ASTM Standards (18) by hydrometer technique and sieving. Volatile solids analysis was performed by oven drying at 110 degrees C to eliminate hygroscropic moisture, then burning in a 600 degree C oven to oxidize any volatile materials, weighing the sample after each procedure. Specific gravity of some selected samples was performed by water displacement in a pre-calibrated pyncnometer, in accordance with ASTM standards (18). Only the uppermost 4 inches (10.16 cm) of each core taken was analyzed for the purposes of the present research. From the known volume of the sample, the air-dryed weight, and the specific gravity, the porosity of each sample was computed. Grain size distribution and other data for each sample analyzed are to be found in the Appendix.

A presentation of the most significant results is to be found in the following section.

Sampling Results

Figure 29 indicates the mean grain size of the sediment in the uppermost 4 inches of core samples collected at locations indicated in Figures 29 through 32. The mean size throughout the area studied is seen to be approximately 0.25 mm, with a few exceptions. This size is typical of littoral sediments on the Oregon coast (31). Four points are significantly below the main grouping of data. The two points representing the samples from the upper portion of the South Slough, opposite river mile 7.3 of the main channel, show a much smaller mean grain size, indicating that relatively low flow velocities prevail in this backwater area. The lowest point at river mile 8.1 represents a sample taken at the boat dock at Cushman, less than a hundred feet from the main channel. This indicates the possible variation of grain size transverse to the direction of flow. The single point at river mile 1.7 may also indicate this sort of variation, or a local anomaly.

The general trend of the mean grain size of the sample from June is below that of the samples from January. This might indicate deposition of fine material as flow velocities decrease due to reduced runoff volume. This is most evident in the samples from river mile 4.5 and above river mile 6.0.

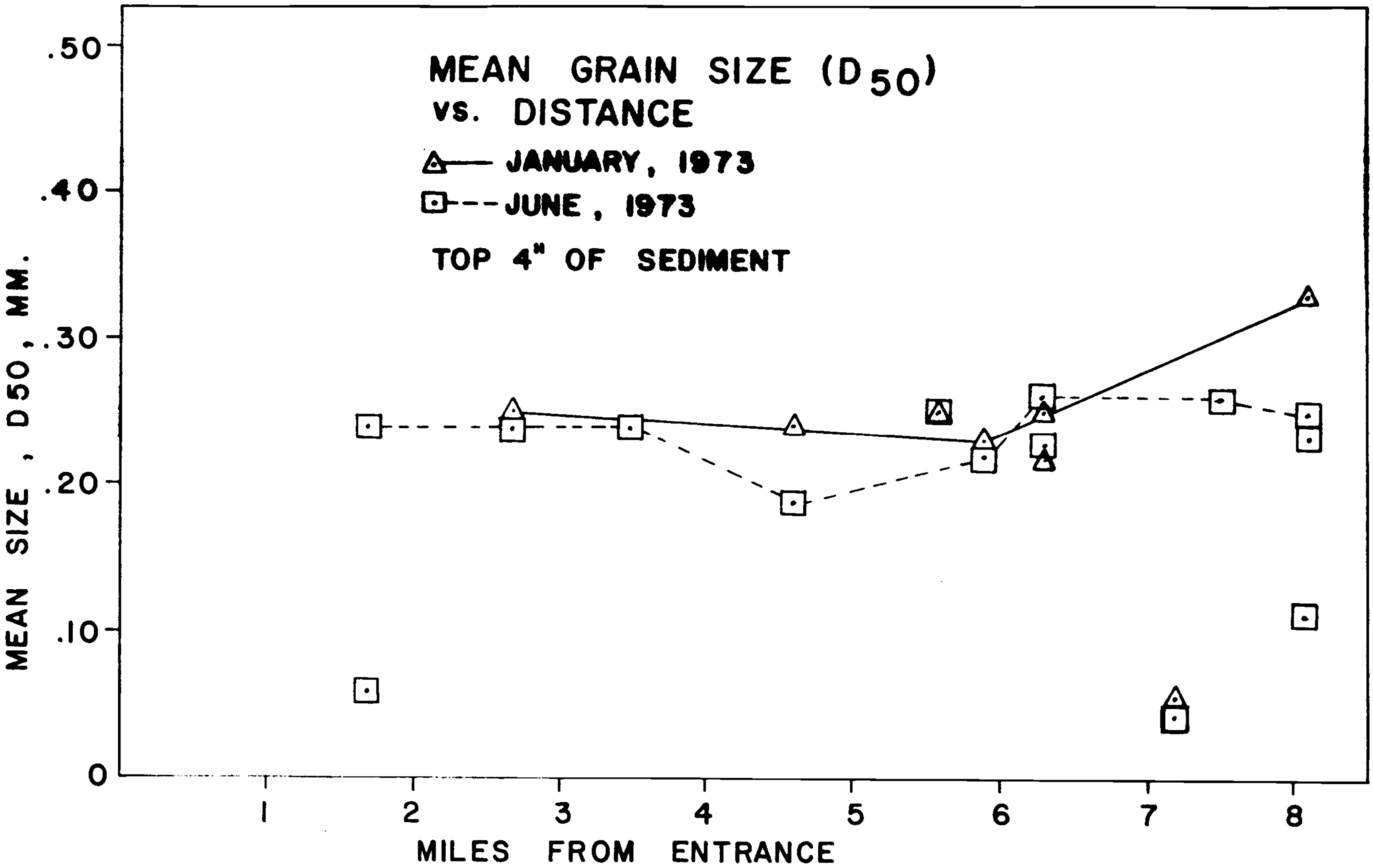

Figure 29. D_{50} vs. river mile.

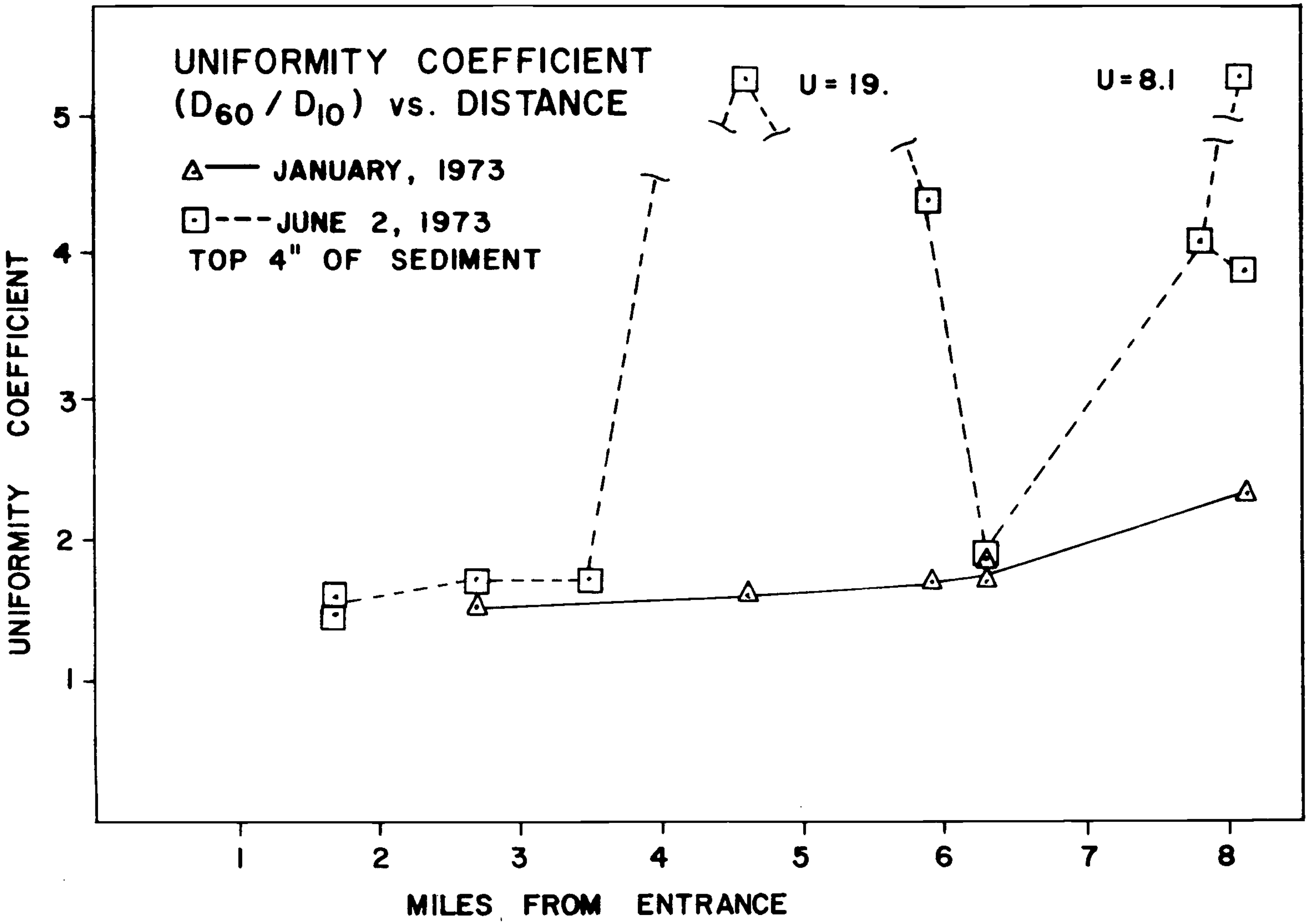

Figure 30. Uniformity coefficient vs. river mile.

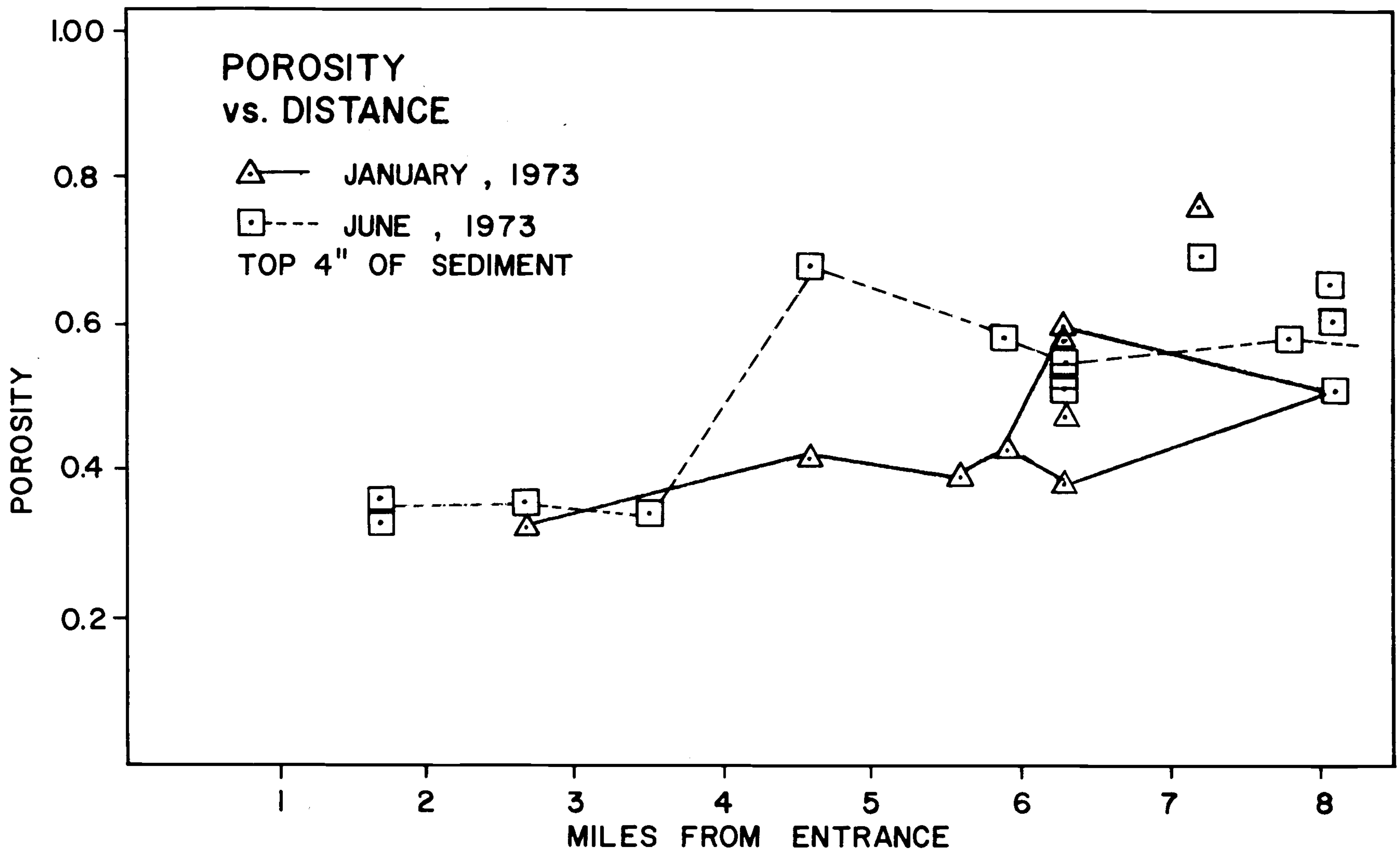

Figure 31. Sediment porosity vs. river mile.

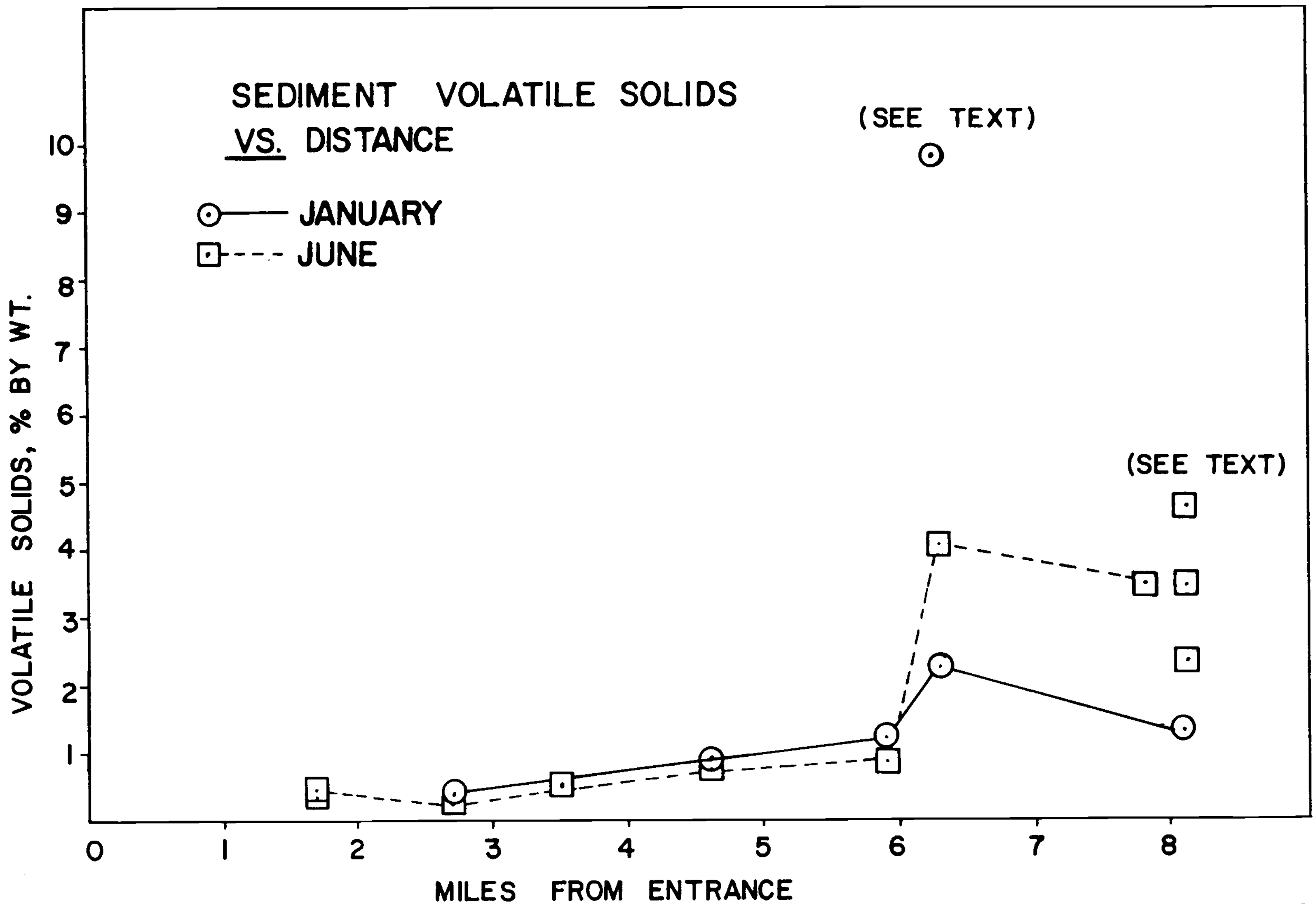

Figure 32. Volatile solids vs. river mile.

Figure 30 shows the uniformity coefficient of the same core samples for which mean grain size was indicated in Figure 29. This measure is more sensitive to the presence of moderate percentages of fine-grain sizes. Comparison of the curves from January and June clearly indicates that some significant amount of fine sediments have been deposited in some areas. The lack of such deposition evidenced by the sample from river mile 6.3 might be explained by the shallower depths and consequent higher bottom velocities found in the vicinity of the mouth of the North Fork.

Figure 31 displays porosity of this same group of samples. Porosities for the January samples are reasonably consistent, with a high point found at river mile 6.3, in an area which had been dredged during the previous summer. This increased porosity might be explained by the disturbance of the bottom sediments due to the dredging operations. From September 8 through September 20, 1972, the hydraulic dredge POLHEMUS owned by Willamette Western Corporation, removed 32,983 cubic yards (25,249 m^3) between river mile 6.15 and river mile 6.45. The mouth of the North Fork Siuslaw River is at river mile 6.3.

For the June samples, the porosity in the vicinity of river mile 6.3 is almost unchanged from January, but porosities immediately above and below that area are greatly increased. For the June data, the locations of high uniformity coefficient in Figure 30 coincide with the high porosity values in Figure 31. This may be interpreted to indicate that newly deposited fine-grained sediments are in a less consolidated state, resulting in a higher measured porosity.

Figure 32 shows volatile solids contents of the samples as measured by the method previously described. It may be noted that there is a strong correlation between the porosities shown in Figure 31 and the volatile solids content shown in Figure 32. This may be explained as an effect of gross particles of organic material interfering with compaction of the sediments. Another possible explanation might be that the porosity calculation is based on a value of specific gravity for the soil solids which is larger than that of organic material (18). This causes the calculated porosity to be unrealistically high when significant qualities of organic material are present. Figure 32 also shows higher volatile solids values are found in the upstream portion of the area studied. This corresponds to the portion of the estuary which is more visibly riverine in character. Log rafting activity is prevalent in this portion of the estuary, and wood chips were visible in some core samples. The one extremely high observed value of volatile solids content, at river mile 6.3, was evidently an isolated concentration of wood chips.

Volatile solids content is seen to decrease to very low values in the sandy downstream reaches of the estuary.

VI. SUMMARY AND CONCLUSIONS

The results of the tidal dynamics study are somewhat mixed. It was shown that damping conditions varied greatly with streamflow, especially when river flow exceeded the normal flow. Observed travel times of high and low tides were found to be within expected ranges, but a considerable amount of unexplained variability was found. Some factors in this variability may be wind induced local changes in tidal action, short term variability in river flows not indicated by the mean daily flows which were used, and the influence of the North Fork Siuslaw River, the relatively small flow of which was not considered in the analysis of the data.

In the study of water quality, the results found were consistent with the theory of flow ratios (5). The Siuslaw Estuary, under typical seasonal freshwater flows, was found to be partly mixed in high river flow conditions and average tides, with mixing becoming more complete with lower streamflows. With neap tide ranges and typical rainy season runoffs the system may become fully stratified on some occasions.

Dissolved oxygen levels were found to be consistently near saturation values throughout the estuary, and oxygen depletion is not considered to be a problem in this estuarine system.

Turbidity was uniformly low during measurement periods, but observations were not made during the largest runoff, nor during the first large runoff of the season, so no sweeping negative generalization is justified.

Sediment analysis in the lower reaches of the estuary showed sands of presumably marine origin through about the lower five miles of the estuary, with a mixed marine fluviatile zone near the mouth of the North Fork Siuslaw River.

Seasonal differences in porosity and uniformity indicata a probable area of low-flow shoaling near the mouth of the North Fork. The recently required dredging of that area tends to confirm this as a shoaling area. Sediment sampling did not extend upstream far enough to include the expected zone of fluviatile sediments.

Caution must be exercised in evaluating the results of this research. The water quality measurements were not selected for specific portions of the lunar cycle. The sediment samples were taken only in the lower estuary, in only two seasons, in a year of atypical runoff patterns. Although the relationships and concepts developed in this study are considered valid and valuable, they should be applied with caution.

An avenue of future research may be in numerical modeling of physical phenomena in estuaries. The model proposed by Goodwin (8) might be verified for the Siuslaw Estuary. The present study has shown that tidal dynamics in the Siuslaw Estuary are dominated by inertial effects in low streamflow conditions, and by friction at high streamflows. Goodwin's model might assist in more precise prediction of these effects.

It is suggested that future research on the Siuslaw Estuary be concentrated on a specific parameter or process, rather than attempting, as these studies have, to cover a broad range of physical qualities over an expanse of area and time. It is hoped that this research has added to the available knowledge of estuarine behavior, and has provided a basis for hypotheses for future, more detailed research.

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APPENDIX

Table III. Predicted and Measured Tides

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
1-16	6440		+5.2		5.1		5.0		5.2		
		0910	(8.4)	0925	H	1000	H	1025	H		
			-9.5		10.0		9.6		7.45		
		1645	(-1.1)	1650	L	1810	L	1910	L		
			+6.9		6.7		5.9		5.25		
		2329	(5.8)	2330	H	2350	H	0025	H		
1-17	7350		-2.7		2.95		3.1		2.95		
		0409	(3.1)	0415	L	0435	L	0600	L		
			+5.5		5.65		5.4		5.35		
		1009	(8.6)	1030	H	1055	H	1130	H		
			-10.0		10.0		-		7.6		
		1733	(-1.4)	1735	L		L	1920	L		
1-18	6180		+7.6		7.75		-		5.8		
		0014	(6.2)	0005	H		H	0120	H		
			-3.3		3.3				3.4		
		0509	(2.9)	0530	L		L	0645	L		
			+5.7		6.3				-		
		1059	(8.6)	1105	H		H		H		
			-10.0		10.25						
		1817	(-1.4)	1845	L		L		L		
1-19	5740		+7.9		7.4						
		0053	(6.5)	0050	H		H		H		
			-3.9		4.7						
		0603	(2.6)	0620	L		L		L		
			+5.8		5.7						
		1150	(8.4)	1155	H		H		H		
			-9.6		10.9						
		1859	(-1.2)	1905	L		L		L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
1-20	5030		+7.9								
		0132	(6.7)		H		H		H		
			-4.3								
		0656	(2.4)		L		L		L		
			+5.6								
		1240	(8.0)		H		H		H		
			-8.8								
		1938	(-0.8)	1935	L		L	2210	L		
1-21	4660		+7.7		+8.0				+6.5		
		0210	(6.9)	0145	H		H	0320	H		
			-4.7		-5.4				-5.15		
		0747	(2.2)	0745	L		L	0950	L		
			+5.2		+5.3				+5.1		
		1328	(7.4)	1325	H		H	1450	H		
			-7.6		-7.8				-7.9		
		2016	(-0.2)	2015	L		L	2230	L		
1-22	4060		+7.2		+7.65				+6.75		
		0246	(7.0)	0240	H		H	0345	H		
			-5.0		-5.7				-5.6		
		0842	(2.0)	0850	L		L	1045	L		
			+4.7		+4.95				+4.9		
		1418	(6.7)	1420	H		H	1535	H		
			-6.3		-6.65				-6.2		
		2054	(0.4)	2105	L		L	2305	L		
1-23	3490		+6.7		+7.3				+6.8		
		0321	(7.1)	0330	H		H	0425	H		
			5.2		-5.7				-5.75		
		0938	(1.9)	0940	L		L	1120	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
1-23	3490		+4.1						+4.9		
		1512	(6.0)		H		H		H		
			-4.9						-4.9		
		2130	(1.1)		L		L		L		
1-24	3620		+6.0		+6.25		+6.4		+6.55		
		0400	(7.1)	0355	H	0445	H	0500	H		
			-5.3		-5.3		-5.5		-5.6		
		1034	(1.8)	1045	L	1120	L	1215	L		
			+3.6		+3.3		+4.6		+3.65		
		1608	(5.4)	1636	H	1650	H	1645	H		
			-3.6		-3.8		-3.8		-3.85		
		2208	(1.8)	2158	L	2245	L	2330	L		
1-25	4230		+5.3		+5.1		+5.1		+5.05		
		0438	(7.1)	0440	H	0500	H	0530	H		
			-5.5		-5.8		-5.7		-5.6		
		1139	(1.6)	1120	L	1215	L	1330	L		
			+3.3		+2.95		+3.5		+2.8		
		1725	(4.9)	1721	H	1745	H	1800	H		
			-2.5		-2.25		-2.5		-2.6		
		2250	(2.4)	2240	L	2320	L	2350	L		
1-26	3750		+4.6		+4.35		+4.4		+4.45		
		0522	(7.0)	0535	H	0550	H	0550	H		
			-5.6		-5.6		-5.75		-5.6		
		1248	(1.4)	1210	L	1325	L	1405	L		
			+3.2		+3.1		+3.05		+3.1		
		1859	(4.6)	1850	H	1900	H	1925	H		
			-1.7		-1.25		-1.5		-1.65		
		2339	(2.9)	2305	L	0005	L	0030	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	Range (Height) (ft)	Site I, IA Time	Range (ft)	Site II, IIA Time	Range (ft)	Site III Time	Range (ft)	Site IV Time	Range (ft)
1-27	3210		+4.1		3.7		3.95		4.05		
		0612	(7.0)	0605	H	0630	H	0640	H		
			-5.9		5.3		5.5		5.55		
		1358	(1.1)	1405	L	1420	L	1505	L		
			+3.6		3.6		3.9		3.60		
		2039	(4.7)	2040	H	2030	H	2045	H		
1-28	2830		-1.4		0.7		0.9		1.05		
		0038	(3.3)	0025	L	0050	L	0145	L		
			+3.7		3.15		3.3		3.4		
		0707	(7.0)	0655	H	0730	H	0745	H		
			-6.2		6.0		6.0		6.0		
		1457	(0.8)	1440	L	1500	L	1630	L		
			+4.1		3.85		4.15		3.7		
		2155	(4.9)	2220	H	2350	H	2225	H		
1-29	2540		-1.4		0.85		1.1		1.3		
		0148	(3.5)	0200	L	0215	L	0255	L		
			+3.6		3.15		3.3		3.55		
		0805	(7.1)	0805	H	0835	H	0855	H		
			-6.8		6.4		6.5		6.7		
		1545	(0.4)	1545	L	1700	L	1740	L		
			+4.8		4.6		4.6				
		2247	(5.2)	2245	H	2300	H		H		
1-30	2480		-1.7		1.4		1.6				
		0254	(3.5)	0330	L	0350	L		L		
			+3.8		3.4		3.6				
		0857	(7.3)	0905	H	0930	H		H		
			-7.2		-6.9		6.75				
		1631	(0.1)	1645	L	1749	L	1745	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
1-30	2480		+5.3		5.1		5.6		4.75		
		2322	(5.1)	2250	H	2350	H	2340	H		
1-31	2710		-1.7		2.1		2.2		2.15		
		0347	(3.4)	0350	L	0425	L	0430	L		
			+4.0		3.6		3.75				
		0942	(7.4)	0955	H	1020	H		H		
			-7.6		7.2		6.9				
		1708	(-0.2)	1715	L	1810	L	1807	L		
			+5.8		5.65		5.4		5.5		
		2354	(5.6)	2345	H	0020	H	0047	H		
2-1	2560		-2.4		2.45		3.8		3.1		
		0436	(3.2)	0450	L	0535	L	0612	L		
			+4.3		4.15		4.4		4.7		
		1024	(7.5)	1005	H	1110	H	1137	H		
			-7.8		7.8		7.35		7.45		
		1744	(-0.3)	1735	L	1850	L	1947	L		
2-2	2360		+6.2		6.75		6.45		6.6		
		0023	(5.9)	0005	H	0105	H	0137	H		
			-2.9		3.3		3.5		3.85		
		0518	(3.0)	0515	L	0600	L	0657	L		
			+4.6		4.6		4.7		5.05		
		1103	(7.6)	1100	H	1150	H	1230	H		
			-7.8		7.45		8.0		7.45		
		1815	(-0.3)	1830	L	1935	L	2025	L		
2-3	2180		+6.4		6.7		6.35		6.6		
		0048	(6.1)	0030	H	0135	H	0140	H		
			-3.4		3.8		4.05		4.4		
		0601	(2.7)	0615	L	0655	L	0725	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
2-3	2180		4.8		4.95		5.2		5.6		
		1145	(7.5)	1115	H	1240	H	1255	H		
			-7.8		7.9		7.65		7.9		
		1847	(-0.3)	1850	L	2015	L	2045	L		
2-4	2020		+6.6		6.9		6.7		6.85		
		0113	(6.3)	0100	H	0210	H	0215	H		
			-3.9		4.5		4.65		5.05		
		0641	(2.4)	0710	L	0740	L	0825	L		
			+4.9		5.2		5.45		5.75		
		1224	(7.3)	1225	H	1235	H	1335	H		
			-7.4		6.25		7.4		7.6		
		1915	(-0.1)	1911	L	2034	L	2120	L		
2-5	1880		+6.7		7.1		6.7		6.95		
		0137	(6.6)	0125	H	0230	H	0210	H		
			-4.5		5.05		5.2		5.65		
		0725	(2.1)	0730	L	0810	L	0900	L		
			+5.0		5.25		5.45		6.85		
		1303	(7.1)	1255	H	1400	H	1425	H		
			-6.8		7.1		6.85		7.15		
		1947	(0.3)	1945	L	2055	L	2140	L		
2-6	1800		+6.5		7.3		7.0		7.35		
		0203	(6.8)	0200	H	0305	H	0320	H		
			-5.0		5.7		5.8		6.3		
		0809	(1.8)	0810	L	0908	L	1000	L		
			+4.9		5.5		5.53		6.0		
		1349	(6.7)	1400	H	1455	H	1510	H		
			-6.0								
		2019	(0.7)		L		L		L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	Range (Height) (ft)	Site I, IA Time	Range (ft)	Site II, IIA Time	Range (ft)	Site III Time	Range (ft)	Site IV Time	Range (ft)
4-24	1390										
		1821	(5.0)	1802	H	1852	H	1847	H	1845	H
			-1.9		1.65		2.0		2.32		2.4
		2315	(3.1)	2247	L	2332	L	2347	L	0020	L
4-25	1300		+2.6		2.25		2.6		2.85		2.85
		0434	(5.7)	0432	H	0507	H	0500	H	0505	H
			-5.3		4.90		5.3		5.52		5.45
		1210	(0.4)	1147	L	1222	L	1300	L	1210	L
			+4.8		4.70		4.8		5.26		5.1
		1910	(5.2)	1910	H	1945	H	1950	H	1950	H
4-26	1230		-2.3		2.10		2.5		2.77		2.75
		0035	(2.9)	0025	L	0105	L	0120	L	0125	L
			+2.5		2.10		2.5		2.7		2.70
		0547	(5.4)	0540	H	0615	H	0635	H	0635	H
			-4.8		4.55		4.8		4.95		4.90
		1303	(0.6)	1255	L	1330	L	1320	L	1405	L
			+4.9		4.60		5.1		-		5.30
		1952	(5.5)	1957	H	2040	H	2040	H	2040	H
4-27	1170		-3.1		2.85		3.45		3.5		3.50
		0145	(2.4)	0147	L	0235	L	0245	L	0300	L
			+2.9		2.4		2.80		3.05		3.10
		0706	(5.3)	0705	H	0705	H	0740	H	0805	H
			-4.6		4.2		4.55		4.75		4.70
		1354	(0.7)	1335	L	1415	L	1440	L	1505	L
			+5.1				5.15		5.52		5.40
		2027	(5.8)		H	2120	H	2120	H	2140	H
4-28	1100		-4.1				4.35		4.77		4.90
		0241	(1.7)		L	0320	L	0340	L	0400	L

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	Range (Height) (ft)	Site I, IA Time	Range (ft)	Site II, IIA Time	Range (ft)	Site III Time	Range (ft)	Site IV Time	Range (ft)
4-28	1100		+3.6		-		3.75		4.12		4.1
		0820	(5.3)		H	0913	H	0910	H	0925	H
			-4.4				4.55		4.80		4.7
		1439	(0.9)		L	1520	L	1540	L	1600	L
			+5.3				5.35		5.70		5.8
		2100	(6.2)		H	2157	H	2210	H	2225	H
4-29	1070		-5.3				5.55		5.97		6.0
		0335	(0.9)		L	0425	L	0500	L	0510	L
			+4.5				4.8		5.25		5.2
		0925	(5.4)		H	1025	H	1040	H	1040	H
			4.3				4.6		5.0		5.0
		1521	(1.1)	1505	L	1602	L	1630	L	1655	L
			+5.6		6.0		6.0		6.55		6.6
		2134	(6.7)	2135	H	2240	H	2300	H	2300	H
4-30	1020		-6.6		6.8		6.75		7.3		7.3
		0419	(0.1)	0420	L	0525	L	0605	L	0620	L
			+5.4		5.7		5.8		6.23		6.3
		1025	(5.5)	1018	H	1125	H	1140	H	1145	H
			-4.1		4.5		4.45		5.10		5.2
		1606	(1.4)	1600	L	1640	L	1710	L	1740	L
			+5.7		6.45		6.25		6.83		6.8
		2209	(7.1)	2205	H	2315	H	2235	H	2335	H
5-1	987		-6.4		8.15		7.75		8.3		8.2
		0504	(-0.7)	0507	L	0615	L	0655	L	0720	L
			+5.0		6.8		6.50		7.02		7.00
		1121	(5.7)	1110	H	1220	H	1240	H	1250	H
			-4.1		4.50		4.70		5.35		5.4
		1649	(1.6)	1640	L	1730	L	1810	L	1820	L

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
5-1	987		+5.9		6.5		6.55		7.13		7.20
		2244	(7.5	2240	H	2352	H	0000	H	0015	H
5-2	957		-8.8		9.3		8.65		9.13		9.1
		0550	(-1.3)	0550	L	0715	L	0750	L	0820	L
			+7.0		7.45		7.0		7.45		7.5
		1214	(5.7)	1205	H	1310	H	1330	H	1335	H
			-3.8		4.1		4.5		4.95		5.2
		1731	(1.9)	1727	L	1817	L	1845	L	1905	L
			+5.9		6.5		6.6				7.3
		2323	(7.8)	2315	H	0035	H		H	0050	H
5-3	933		-9.5		10.15		9.3				9.7
		0637	(-1.7)	0630	L	0810	L		L	0910	L
			+7.4		8.25		7.55				8.1
		1307	(5.7)	1253	H	1403	H		H	1430	H
			-3.6		3.65		4.35				5.1
		1816	(2.1)	1812	L	1902	L	1945	L	1950	L
5-4	926		+5.8		6.55		6.70				7.3
		0006	(7.9)	0000	H	0110	H		H	0135	H
			-9.8		10.75		9.65				10.1
		0726	(-1.9)	0705	L	0900	L		L	0955	L
			+7.6		8.45		7.45				8.0
		1401	(5.7)	1338	H	1500	H		H	1525	H
			-3.3		3.8		4.08				4.9
		1902	(2.4)	1902	L	1950	L		L	2040	L
5-5	781		+5.5		5.85		6.0				6.6
		0052	(7.9)	0055	H	0155	H		H	0220	H
			-9.8		10.45		9.55				9.99
		0816	(-1.9)	0810	L	0945	L		L	1045	L

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
5-5	781	1457	+7.5 (5.6)	1500	9.2 H	1545	7.3 H	1615	H	1610	7.85 H
		1955	-3.1 (2.5)	2010	3.6 L	2047	3.95 L	2115	4.6 L	2130	4.65 L
5-6	748	0141	+5.1 (7.6)	0145	4.9 H	0250	5.8 H		H	0303	6.30 H
		0908	-9.3 (-1.7)	0903	9.8 L	1035	9.15 L		L	1135	9.5 L
		1553	+7.2 (5.5)	1535	H	1638	7.05 H	1705	H	1700	7.7 H
		2053	-2.9 (2.6)	2100	3.20 L	2155	3.6 L	2225	4.2 L	2220	6.3 L
5-7	725	0234	+4.6 (7.2)	0235	4.75 H	0330	5.0 H	0350	6.65 H	0350	5.0 H
		1002	-8.5 (-1.3)	1005	8.8 L	1130	8.35 L	1215	8.87 L	1220	8.8 L
		1655	+6.9 (5.6)					1805	7.37 H	1755	7.4 H
		2202	-2.9 (2.7)					2310	3.80 L	2310	4.0 L
5-8	746	0339	+3.9 (6.6)					0500	5.20 H	0500	5.2 H
		1100	-7.4 (-0.8)								
		1754	+6.5 (5.7)								
		2323	-3.2 (2.5)								

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
7-26	109										
		2039	(7.9)	2045	H	2147	H	2205	H		
7-27	103		-9.2		9.2		8.9		9.4		
		0416	(-1.3)	0415	L	0547	L	0615	L		
			+6.5		6.9		6.9		7.05		
		1059	(5.2)	1055	H	1145	H	1220	H		
			-2.5		2.7		3.2		3.6		
		1536	(2.7)	1540	L	1630	L	1700	L		
			+5.4		5.4		5.5		6.1		
		2139	(8.1)	2145	H	2240	H	2305	H		
7-28	101		-9.7		9.8		8.5				
		0506	(-1.6)	0510	L	0555	L		L		
			+7.2		7.7		6.65				
		1144	(5.6)	1150	H	1235	H	1310	H		
			-3.2		3.5		3.8		4.5		
		1638	(2.4)	1655	L	1740	L	1805	L		
			+5.7		5.8		6.2		6.7		
		2235	(8.1)	2240	H	2350	H	0000	H		
7-29	96		-9.8		10.0		9.5		10.2		
		0552	(-1.7)	0555	L	0745	L	0810	L		
			+7.7		8.2		7.4		8.4		
		1226	(6.0)	1225	H	1330	H	1350	H		
			-3.9		4.5		4.5		5.35		
		1736	(2.1)	1745	L	1845	L	1915	L		
			+5.9		6.3				6.95		
		2327	(8.0)	2335	H		H	0105	H		
7-30	92		-9.5		10.0				9.9		
		0635	(-1.5)	0635	L		L	0805	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
7-30	92		+7.8		8.6				8.4		
		1305	(6.3)	1255	H	1345	H	1425	H		
			-8.1		5.4		5.2		6.1		
		1831	(1.8)	1850	L	1930	L	2012	L		
7-31	89		+5.9		6.4		6.3		7.0		
		0019	(7.7)	0031	H	0130	H	0150	H		
			-8.9		9.4		8.8		9.4		
		0717	(-1.2)	0726	L	0945	L	0920	L		
			+7.7		8.6				8.5		
		1342	(6.5)	1231	H		H	1510	H		
			-5.0		5.9				6.55		
		1925	(1.5)	1931	L	2035	L	2100	L		
8-1	86		+5.7		6.2				6.75		
		0112	(7.2)	0117	H		H	0245	H		
			-7.8		8.4				8.6		
		0756	(-0.6)	0817	L	0925	L	0945	L		
			+7.3		8.1				8.25		
		1419	(6.7	1417	H		H	1550	H		
			-5.4		6.3				7.1		
		2019	(1.3)	2022	L	2140	L	2200	L		
8-2	82		+5.2		5.9				6.4		
		0204	(6.5)	0213	H		H	0335	H		
			-6.5		7.1				7.5		
		0835	(0)	0838	L	0930	L	1015	L		
			+6.8		7.6				8.2		
		1456	(6.8)	1453	H		H	1625	H		
			-5.7		6.5				7.2		
		2114	(1.1)	2128	L	2225	L	2300	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
8-3	79		+4.7		5.2				5.8		
		0259	(5.8)	0304	H		H	0425	H		
			-5.1		5.6						
		0914	(0.7)	0909	L		L		L		
			+6.2		6.8						
		1536	(6.9)	1534	H	1630	H	1650	H		
			-5.9		6.5				7.2		
		2214	(1.0)	2214	L	2320	L	2345	L		
8-4	77		+4.2		4.8				5.3		
		0357	(5.2)	0410	H	0510	H	0520	H		
			-3.8		4.2				4.85		
		0953	(1.4)	1010	L		L	1105	L		
			+5.4		5.9				4.65		
		1616	(6.8)	1615	H	1725	H	1740	H		
			-5.9		6.4		6.5		7.2		
		2316	(0.9)	2311	L	0020	L	0040	L		
8-5	76		+3.8		4.1		4.25		4.7		
		0512	(4.7)	0501	H	0610	H	0625	H		
			-2.7		2.8		2.6		3.45		
		1034	(2.0)	1026	L	1055	L	1125	L		
			+4.7		5.0		4.65		5.6		
		1701	(6.7)	1706	H	1750	H	1815	H		
8-6	73		-5.9		6.1		6.3		6.95		
		0024	(0.8)	0012	L	0120	L	0155	L		
			+3.6		3.9		4.1		7.6		
		0642	(4.4)	0637	H	0720	H	0735	H		
			-1.9		1.9		1.9		2.4		
		1126	(2.5)	1122	L	1145	L	1145	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
8-6	73		+4.2		3.1		4.25		4.75		
		1751	(6.7)	1752	H	1845	H	1845	H		
8-7	70		-6.1		6.0		6.25		6.9		
		0131	(0.6)	0123	L	0215	L	0230	L		
			+3.8		3.8		4.2		4.6		
		0815	(4.4)	0818	H	0850	H	0855	H		
			-1.5		1.2		1.5		1.8		
		1228	(2.9)	1213	L	1245	L	1315	L		
			+3.7		3.3		3.6		4.1		
		1847	(6.6)	1833	H	1930	H	1950	H		
8-8	72		-6.2		6.1		6.4		7.0		
		0233	(0.4)	0224	L	0420	L	0355	L		
			+4.2		4.3		4.65		5.1		
		0934	(4.6)	0859	H	1000	H	1015	H		
			-1.5		1.4		1.6		2.0		
		1334	(3.1)	1404	L	1430	L	1435	L		
			+3.5		3.2		3.5		3.9		
		1948	(6.6)	1929	H	2030	H	2045	H		
8-9	72		-6.5		6.4		6.7		7.2		
		0326	(0.1)	0305	L	0430	L	0445	L		
			+4.7		4.8		5.1		5.5		
		1024	(4.8)	1020	H	1110	H	1120	H		
			-1.7		1.6		2.0		2.40		
		1438	(3.1)	1500	L	1530	L	1550	L		
			+3.7		3.2		3.6		4.05		
		2041	(6.8)	2035	H	2145	H	2150	H		
8-10	72		-7.0		6.8		6.9		7.55		
		0411	(-0.2)	0355	L	0525	L	0535	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Times	Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
11-13	10,400										
		0230	(5.4)		H		H		H		
			3.0								
		0724	(2.9)		L		L		L		
			5.2								
		1310	(8.1)		H		H		H		
			9.5								
		2038	(-1.4)		L	2230	L	2310	L		
11-14	10,200		7.3				5.73		4.62		
		0323	(5.9)		H	0400	H	0420	H		
			2.9				3.42		3.06		
		0821	(3.0)		L	1000	L	1030	L		
			4.7				3.82		3.43		
		1403	(7.7)		H	1500	H	1535	H		
			8.8				5.50		5.45		
		2130	(-1.1)		L	2310	L	0005	L		
11-15	20,100		7.1				6.04		5.09		
		0422	(6.0)		H	0510	H	0525	H		
			2.9				2.76		1.27		
		0928	(3.1)		L	1030	L	0957	L		
			4.1				4.12				
		1502	(7.2)		H	1625	H		H		
			7.8				3.60				
		2227	(-0.6)		L	2352	L	0020(?)	L		
11-16	23,600		6.7				2.98				
		0521	(6.1)		H	0600	H		H		
			3.2				2.53				
		1045	(2.9)		L	1300	L		L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	Range (Height) (ft)	Site I, IA Time	Range (ft)	Site II, IIA Time	Range (ft)	Site III Time	Range (ft)	Site IV Time	Range (ft)
11-16	23,600		+3.6				1.47				
		1608	(6.5)			1715	H	1745	H		
			-6.5				4.38		3.67		
		2323	(0.0)			0115	L	0300	L		
11-17	12,10		+6.5						2.52		
		0610	(6.4)				H	0720	H		
			-3.9						3.17		
		1209	(2.5)			1352	L	1437	L		
			+3.4				2.58		1.94		
		1731	(5.9)			1815	H	1845	H		
11-18	7,040		-5.4				4.44		3.92		
		0020	(0.5)			0152	L	0237	L		
			+6.2				5.16		4.40		
		0705	(6.7)			0750	H	0750	H		
			-4.8				5.00		4.73		
		1326	(1.9)			1445	L	1550	L		
			+3.6				3.15		2.82		
		1903	(5.5)			1937	H	2027	H		
11-19	4,700		-4.4				4.19		3.94		
		0114	(1.1)			0240	L	0322	L		
			+5.9				5.70		5.43		
		0754	(7.0)			0850	H	0850	H		
			-5.8				5.83		5.80		
		1433	(1.2)			1545	L	1645	L		
			+4.2				4.62		4.55		
		2028	(5.4)			2122	H	2137	H		
11-20	5,490		-3.8				3.02		3.05		
		0209	(1.6)			0330	L	0422	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
11-20	5490		+5.7				5.62		5.68		
		0836	(7.3)			0930	H	0950	H		
			-6.8				5.60		5.20		
		1530	(0.5)			1515	L	1720	L		
			+4.9				4.50		4.24		
		2142	(5.4)			2230	H	2300	H		
11-21	9080		-3.4				3.30		2.97		
		0258	(2.0)			0430	L	0510	L		
			+5.5				4.40		4.13		
		0916	(7.5)			1015	H	1040	H		
			-7.5				6.40		5.33		
		1619	(0.0)			1750	L	1900	L		
			+5.5				4.80		3.56		
		2243	(5.5)			2315	H	2350	H		
11-22	9500		-3.1				3.01		2.54		
		0347	(2.4)			0500	L	0600	L		
			+5.2				4.71		4.12		
		0952	(7.6)			1045	H	1110	H		
			-8.0				6.81		5.85		
		1705	(-0.4)			1852	L	1945	L		
			+6.0				4.92		3.97		
		2337	(5.6)			0015	H	0035	H		
11-22	7590		-2.9				3.10		2.84		
		0429	(2.7)			0610	L	0637	L		
			+5.0				5.08				
		1027	(7.7)			1140	H		H		
			-8.4				7.05				
		1743	(-0.7)			1930	L	2030	L		

Table III. Continued

Date	Mean Daily Flow, Mapleton (CFS)	NOAA Pred. Tides, Entrance Time	NOAA Pred. Tides, Entrance Range (Height) (ft)	Site I, IA Time	Site I, IA Range (ft)	Site II, IIA Time	Site II, IIA Range (ft)	Site III Time	Site III Range (ft)	Site IV Time	Site IV Range (ft)
11-24	7730		+6.4				5.10		4.40		
		0024	(5.7)			0100	H	0130	H		
			-2.8				2.80		2.50		
		0511	(2.9)			0620	L	0715	L		
			+4.7				3.95		3.55		
		1101	(7.6)			1215	H	1237	H		
			-8.4				6.72		5.81		
		1821	(-0.8)			1940	L	2152	L		
11-25	8320		+6.5				5.80		5.06		
		0109	(5.7)			0200	H	0230	H		
			-2.6				2.53		2.35		
		0550	(3.1)			0700	L	0745	L		
			+4.5				4.47		4.20		
		1133	(7.6)			1237	H	1300	H		
			-8.4				6.80		5.74		
		1857	(-0.8)			2037	L	2137	L		
11-26	8830		+6.5				5.15		4.16		
		0148	(5.7)			0230	H	0300	H		
			-2.4				2.50		2.18		
		0625	(3.3)			0730	L	0822	L		
			+4.1				4.05		3.60		
		1205	(7.4)			1320	H	1352	H		
			-8.1				6.70		5.82		
		1923	(-0.7)			2115	L	2207	L		
11-27	9030		+6.3				5.55		4.75		
		0227	(5.6)			0300	H	0310	H		
			-2.2				3.05				
		0705	(3.4)			0830	L		L		

Velocity Integration Program

```
        PROGRAM ESFLODAT
C       PROGRAM ESTUARY FLOW DATA
        DIMENSION XB(10),YB(10),YA(10),X(10),W(10)
        DIMENSION V(10,10,10),D(10,10,10),TAVG(10)
        INTEGER Q,S,P
C       N = NO. OF BATHY WIDTHS
138     WRITE(61,38)
38      FORMAT(IX,'ENTER NO OF BATHY WIDTHS - FORMAT IX,I2')
        READ(60,9)N
        WRITE(61,9)N
        CALL TEST(I)
        IF(I) 144,144,138
9       FORMAT(1X,I2)
144     WRITE(61,145)
145     FORMAT(1X,'ENTER JMAX,KMAX - FORMAT 1X,2I2')
        READ(60,130)JMAX,KMAX
130     FORMAT(1X,3I2)
        WRITE(61,130)JMAX,KMAX
        CALL TEST(I)
        IF(I) 139,139,144
139     WRITE(61,39)
39      FORMAT(1X,'ENTER WID & DEP FOR EACH STA - FORMAT 1X, 20F
4.0')
        READ(60,10) (XB(I),YB(I),I = 1,N)
        WRITE(61,10) (XB(I),YB(I),I = 1,N)
        CALL TEST(I)
        IF(I) 141,141,139
10      FORMAT(1X,20F4.0)
141     WRITE(61,41)
41      FORMAT(1X,'ENTER THE AVE TIME OF EACH PASS - FORMAT 1X,
10F5.2')
```

Velocity Integration Program, continued

```
      READ(60,12)(TAVG(I),I = 1,KMAX)
      WRITE(61,12) (TAVG(I),I = 1,KMAX)
      CALL TEST(I)
      IF(I) 142,142,141
12    FORMAT(1X,10F5.2)
142   CONVRT=0.
      WRITE(61,109)
109   FORMAT(1X,'TYPE: 01 IF VEL DAT IS CLICKS/SEC--00 IF KNO
TS')
      READ(60,110)Q
      IF(Q) 111,111,112
111   CONVRT = 1.68
      GO TO 108
112   CONVRT = 0.0742
      GO TO 108
110   FORMAT(1X,I1)
108   READ(20,13) (((V(I,J,K),I = 1,10),J = 1,JMAX),K = 1,KMAX)
      READ(30,13) (((D(I,J,K),I = 1,10),J = 1,JMAX),K = 1,KMAX)
13    FORMAT(1X,10F6.2)
      WRITE(61,36)
36    FORMAT(1X,'PASS',3X,'FLOW RATE',2X,'UAVE',3X,
    C 'CROSS-SECTIONAL AREA',3X,'AVE TIME')
      WRITE(61,37)
37    FORMAT(10X,'(CFS)',4X,'(FPS)',7X,'(SQ FT)',11X,'OF PASS
')
      IMAX = JMAX
      S = 1
      DXN =0.
      DX1 = 0.
      DX2 = 0.
      K = 1
```

Velocity Integration Program, continued

```
34    I = 0
      J = 1
      ASUM = 0.0
      QSUM = 0.0
      UAVE = 0.0
      P = 0
14    I = I + 1
      IF(D(I,J,K) - 99. )14,15,15
15    DX1 = XB(1)*( (D(I-1,J,K)/YB(1) ) -1. )
      I = 0
16    I = I + 1
      IF(D(I,IMAX,K) = 99. )16,17,17
17    DXN = (XB(N) - XB(N-1) )*( (D(I - 1,IMAX,K)/YB(N-1) ) - 1. )
      DX2 = DX1 + DXN
      M = 0
18    M = M + 1
      X(M) = XB(M) + DX1
      IF(M-N)18,19,19
19    X(M) = XB(M) + DX2
      M = 0
22    M = M + 1
      IF(M - 1)20,20,21
20    W(M) =(X(M + 1) )/2.
      GO TO 22
21    IF(M - N)42,31,31
42    W(M) = (X(M+1) - X(M - 1) )/2.
      GO TO 22
31    I = 0
26    I = I + 1
      IF(I - 1)24,24,25
24    IF(D(I + 1,J,K)-99. )71,70,70
```

Velocity Integration Program, continued

```
70    YA(I) = D(I,J,K)
      GO TO 72
71    YA(I) = (D(I,J,K) + D(I + 1,J,K) )/2.
      GO TO 26
25    IF(D(I + 1,J,K) - 99. )27,28,28
27    YA(I) = (D(I + 1,J,K) - D (I - 1,J,K) )/2.
      GO TO 26
28    YA(I) = (D(I,J,K) - D(I - 1,J,K) )/2.
72    P = P + 1
      I = 0
29    I = I + 1
      AREA = W(P)*YA(I)
      ASUM = ASUM + AREA
      DQ = AREA * V(I,J,K)*CONVRT
      QSUM = QSUM + DQ
      IF (D(I + 1,J,K) - 99. )29,30,30
30    J = J + 1
      IF (J - IMAX)31,31,32
32    UAVE = QSUM/ASUM
      WRITE(61,33)S, QSUM, UAVE,ASUM, TAVG(S)
33    FORMAT(2X,I2,2X,F10.1,4X,F3.1,6X,F10.1,7X,F8.2)
      K = K + 1
      S = S + 1
      IF(K - KMAX)34,34,35
35    CALL EXIT
      END
      SUBROUTINE TEST(I)
      READ(60,100)I
100   FORMAT(1X,I1)
      RETURN
      END
```

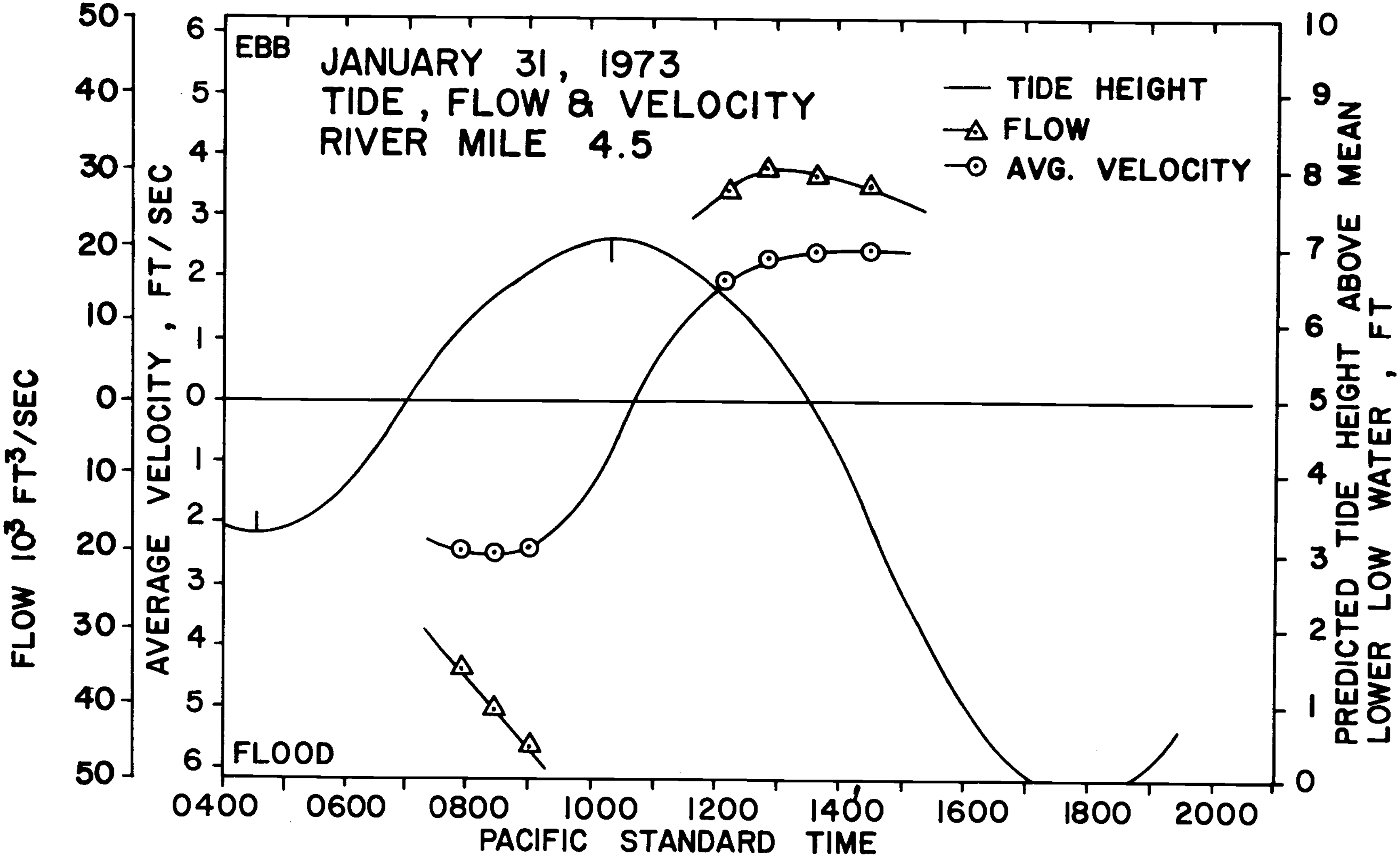

Figure 33. Velocity, flow and tides, river mile 4.5, January 31.

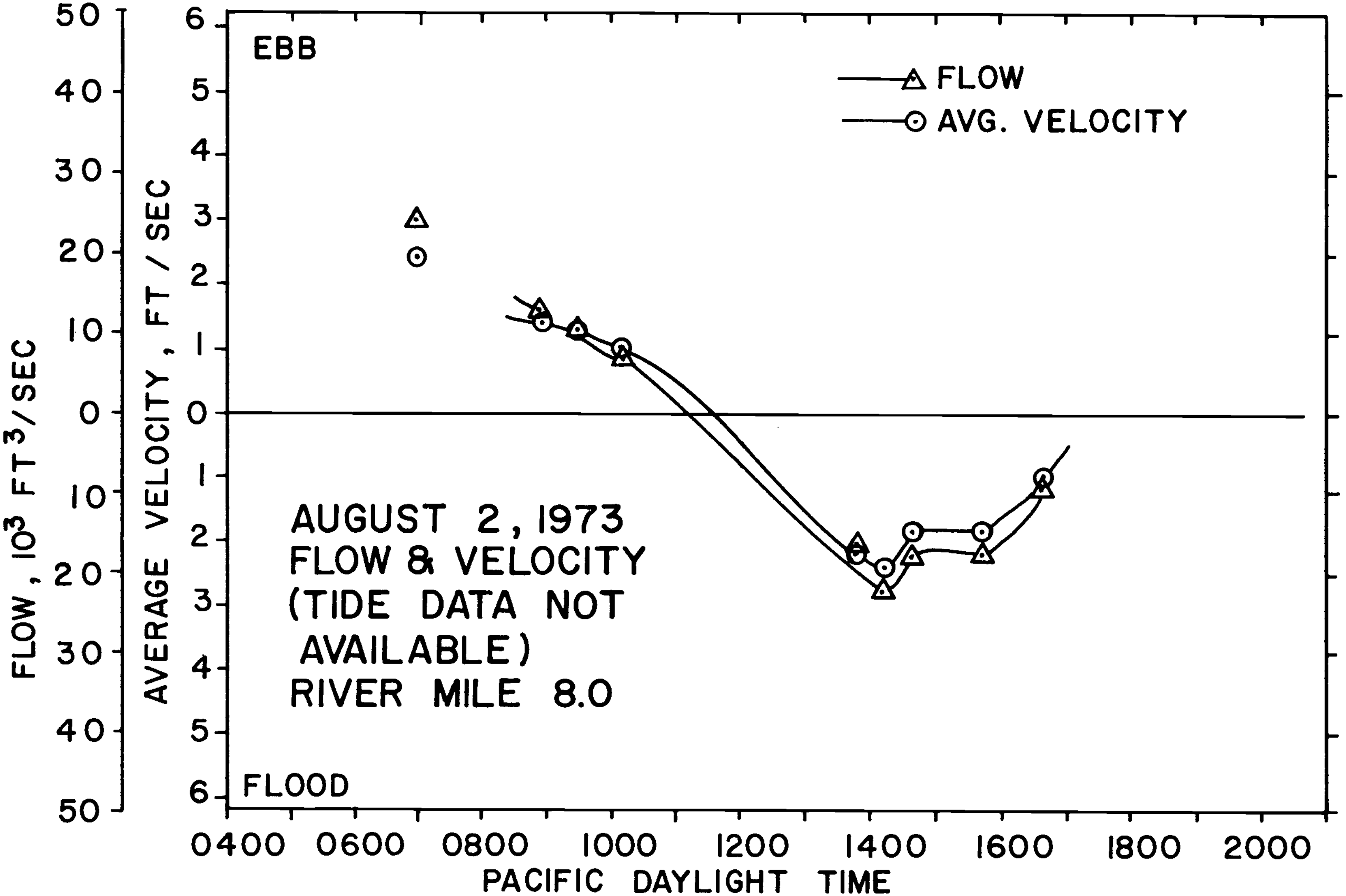

Figure 34. Velocity and flow, river mile 8.0, August 2.

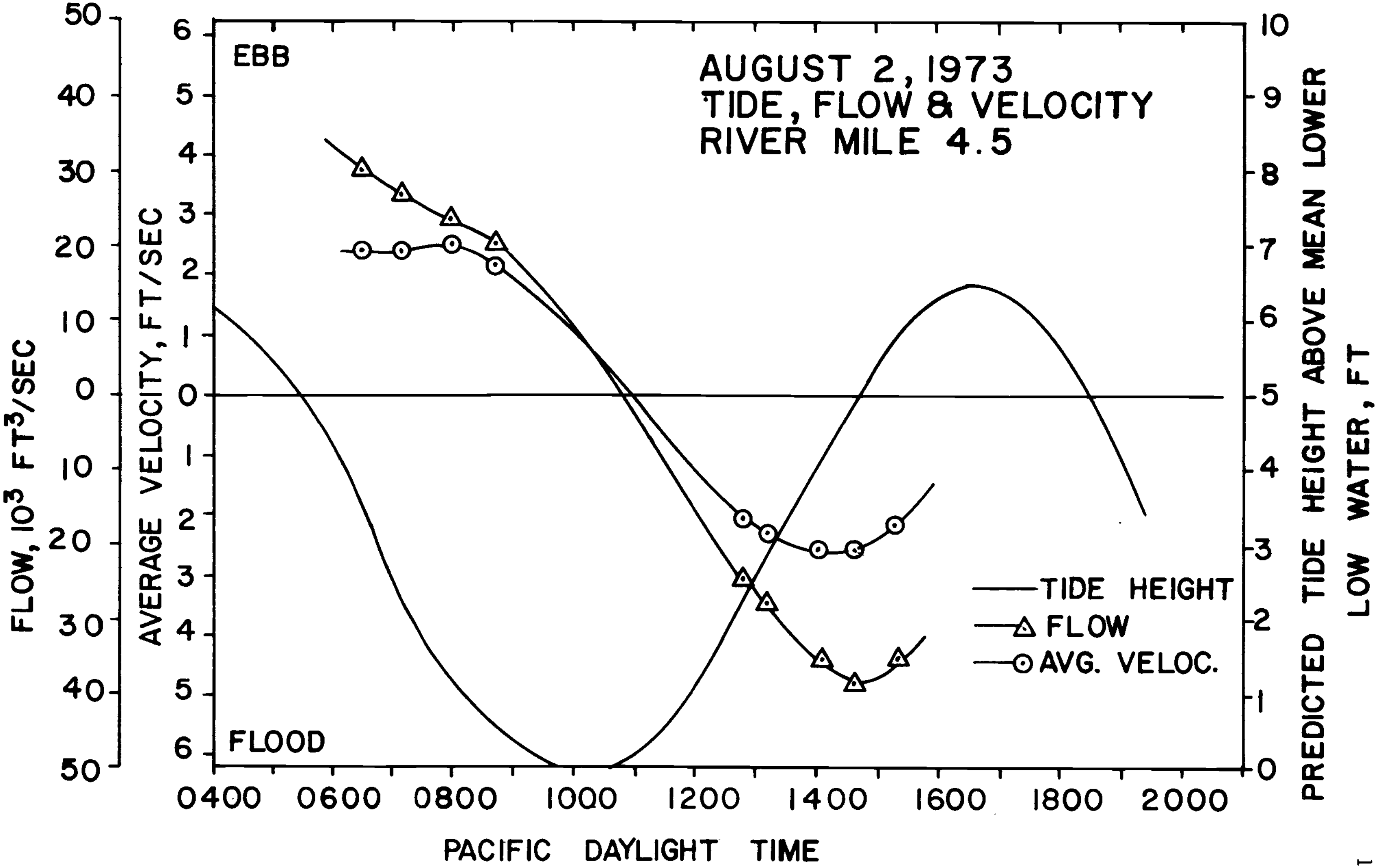

Figure 35. Velocity, flow, and tides, river mile 4.5, August 2.

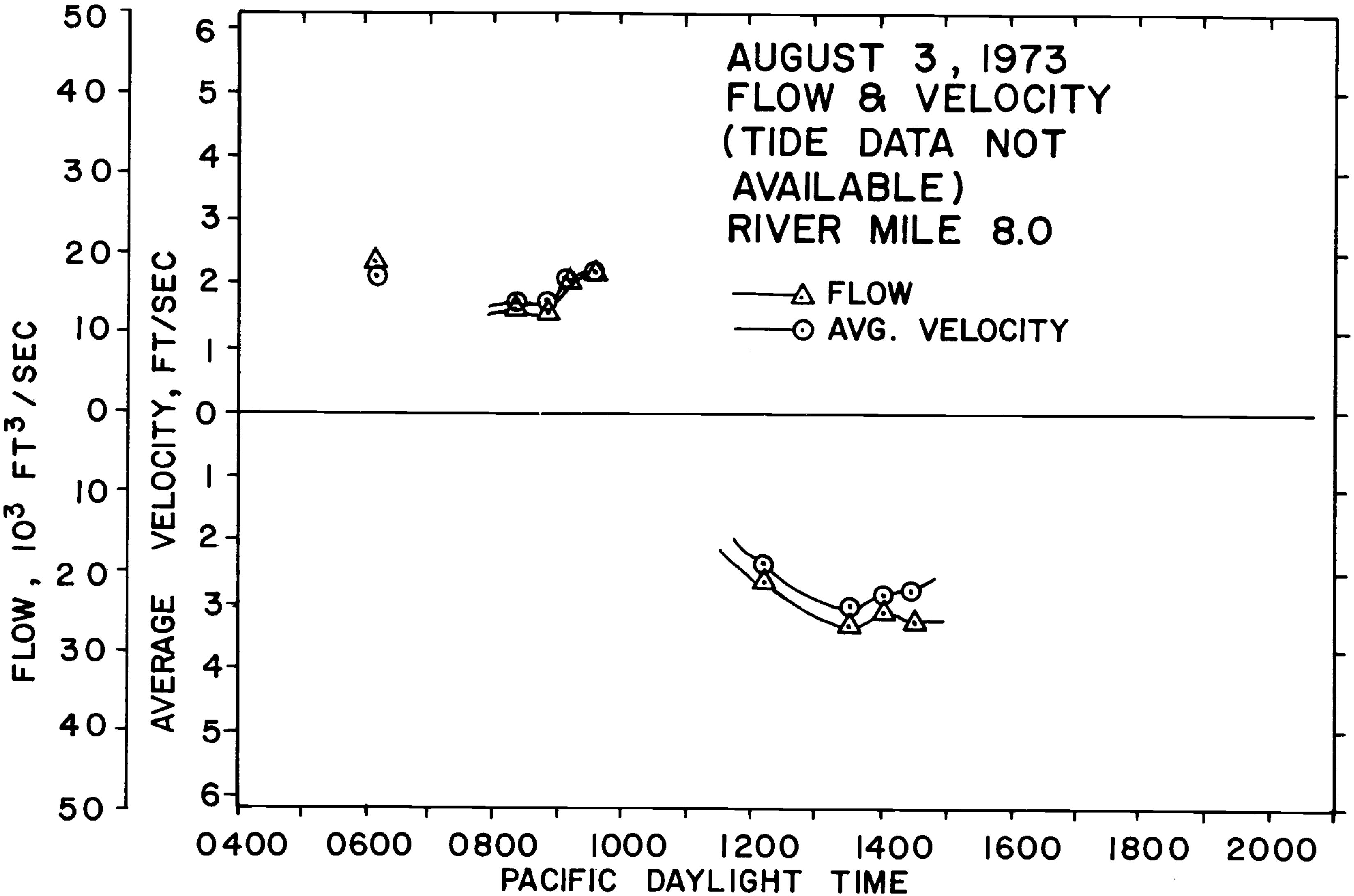

Figure 36. Velocity and flow, river mile 8.0, August 3.

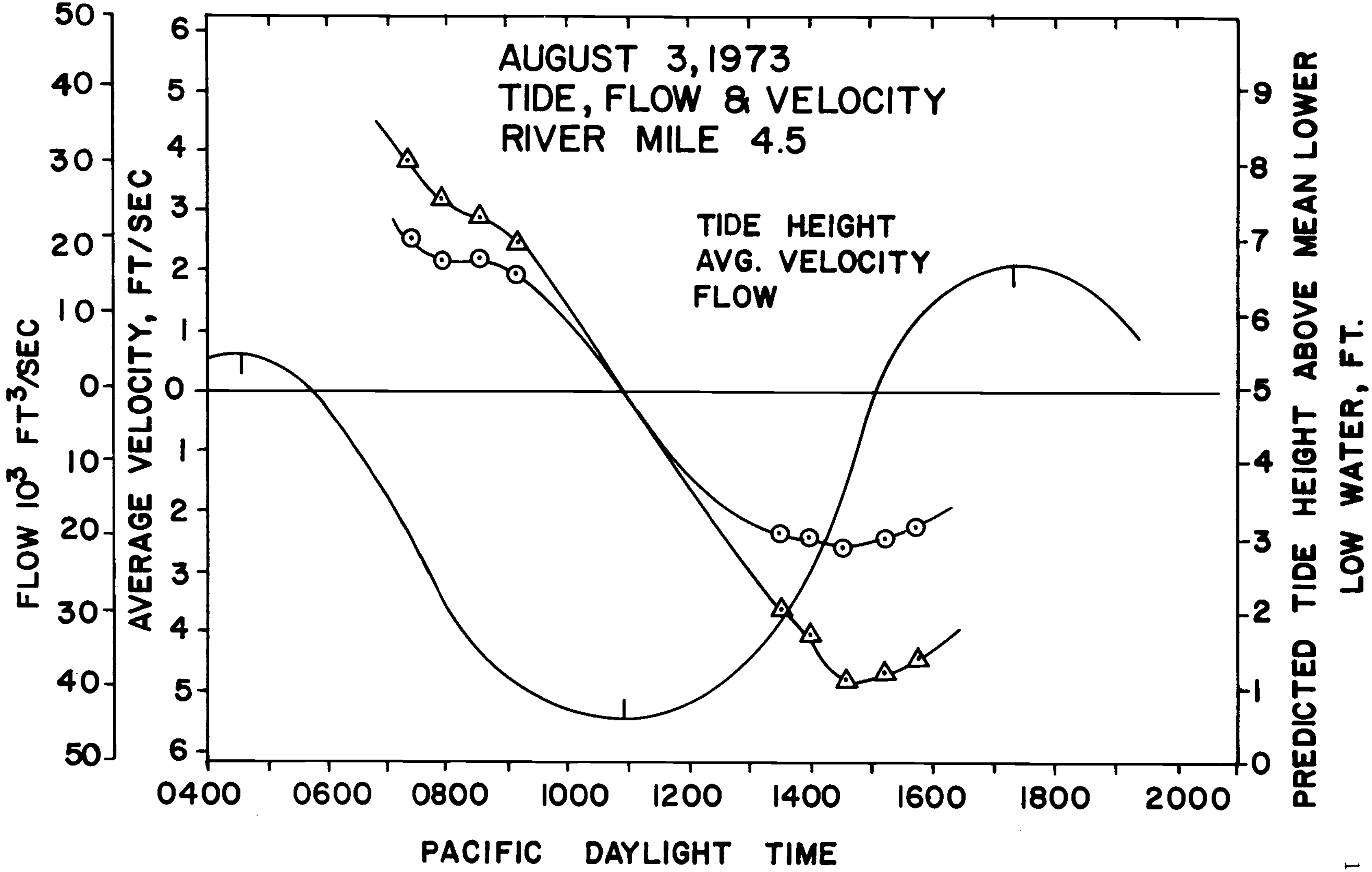

Figure 37. Velocity, flow and tides, river mile 4.5, August 3.

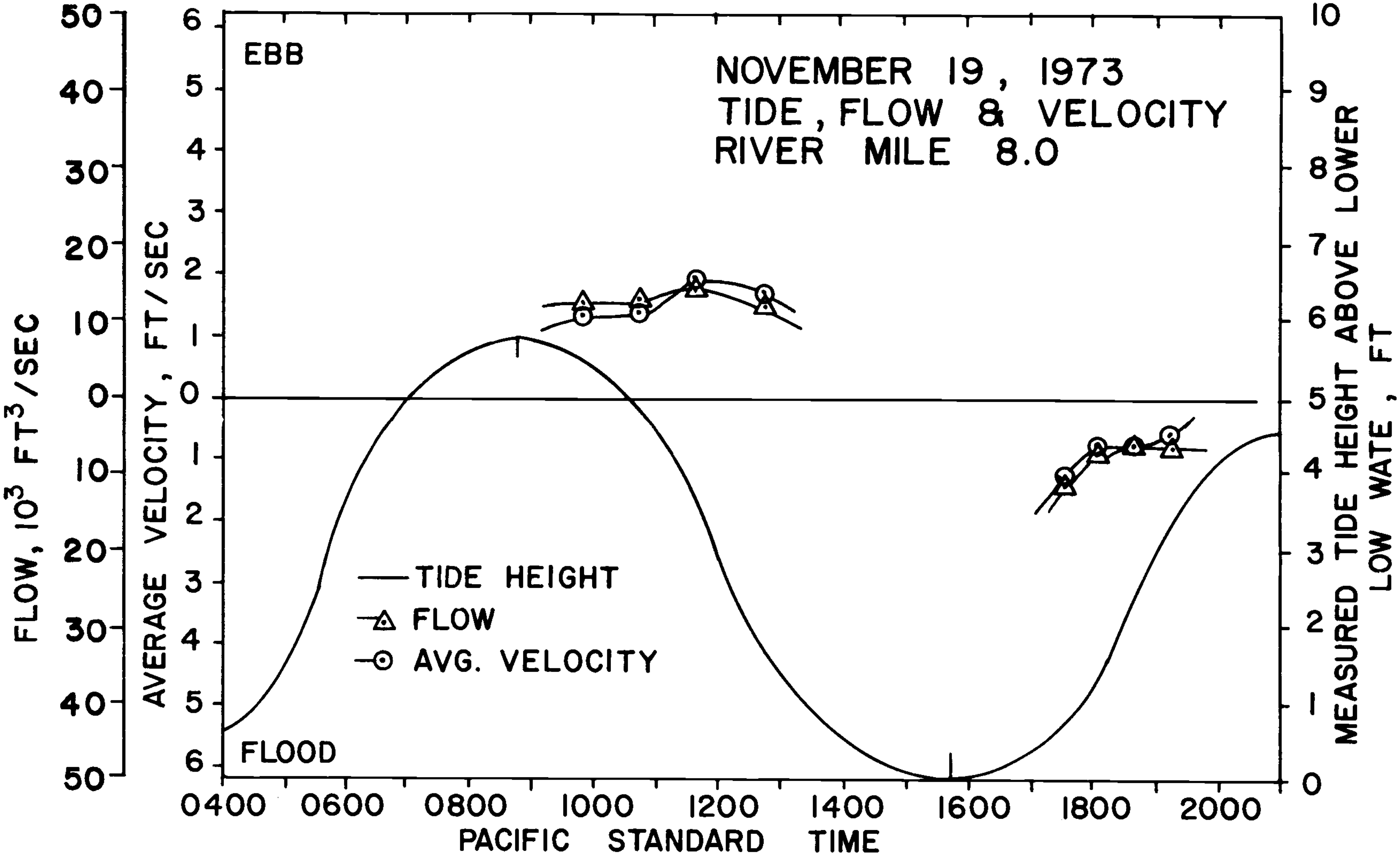

Figure 38. Velocity, flow and tides, river 8.0, November 19.

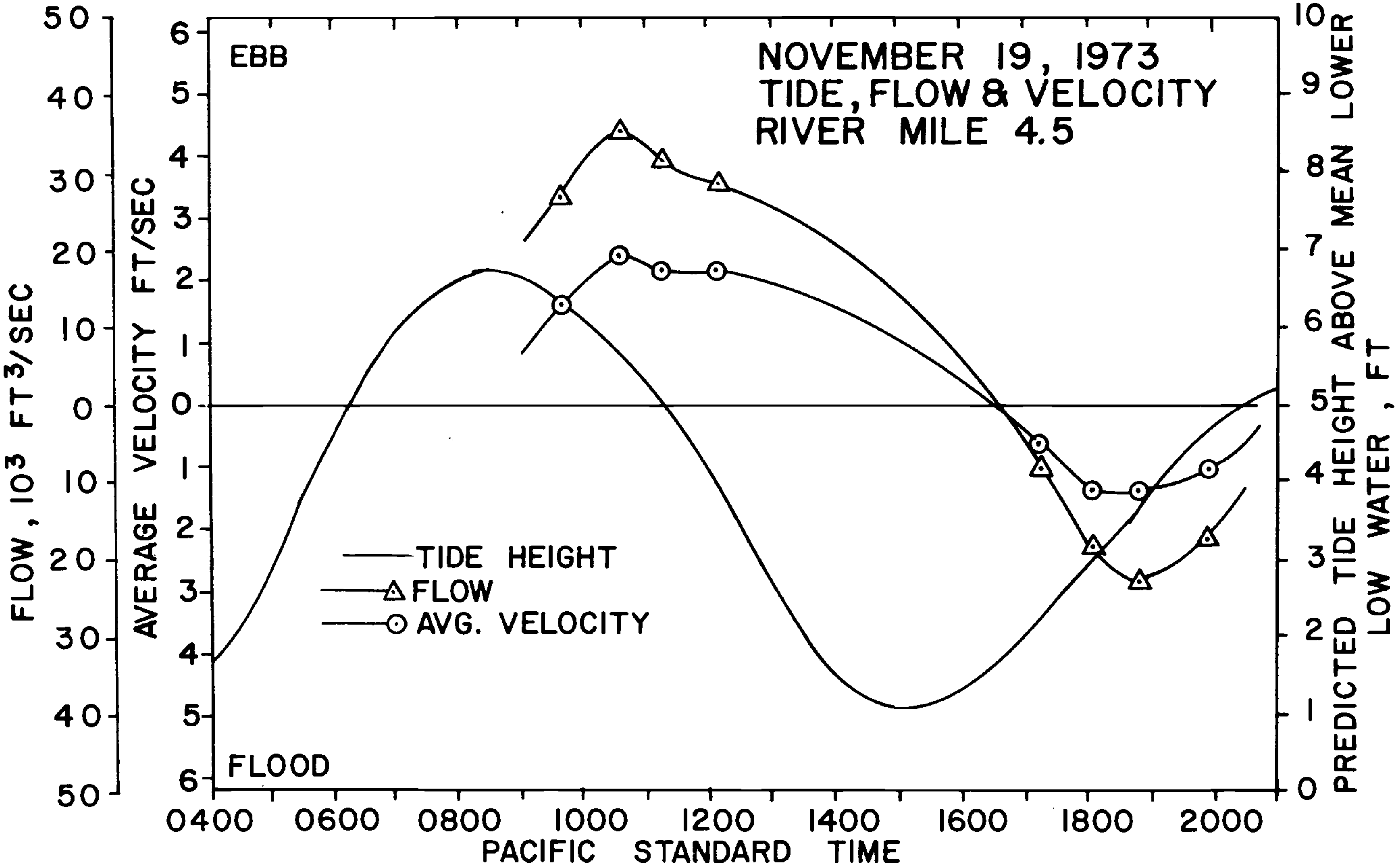

Figure 39. Velocity, flow and tides, river 4.5, November 19.

Table IV. Water Quality Data

January 30, 1973
High Tide

Station Time River Mile	Depth (Ft)	Field Measurements: Temp. (°C)	Field Measurements: Dissolved Oxygen (ppm)	Field Measurements: Salinity (ppt)	Field Measurements: pH	Laboratory Measurements: Dissolved Oxygen (ppm)	Laboratory Measurements: Salinity (ppt)	Laboratory Measurements: pH	Laboratory Measurements: Turbidity (JTU)
Sta. 1	20	9.0	8.6	28.3	8.2	9.5	30.8	7.5	2
0955	10	9.0	8.6	28.3	8.2	-	-	-	-
R.M. 0.4	2	9.0	8.6	28.3	8.2	9.1	29.2	7.5	3
Sta. 2	26	9.0	8.2	27.6	8.2	9.7	30.9	8.0	4
	18	9.0	8.4	27.6	8.2	-	-	-	-
1030	13	-	-	-	-	9.4	30.9	7.6	1
R.M. 1.5	10	9.1	8.5	27.6	8.2	-	-	-	-
	2	9.0	8.7	26.6	8.1	9.3	30.9	8.0	2
Sta. 3	26	9.0	8.3	26.6	8.2	9.4	30.2	7.4	3
1045	18	9.0	8.3	26.6	8.2	-	-	-	-
R.M. 2.5	13	-	-	-	-	9.4	30.9	7.9	2
	10	9.0	8.4	24.0	8.2	-	-	-	-
	2	8.5	8.7	22.0	8.2	9.9	25.0	7.9	2
Sta. 4	25	9.0	8.2	25.5	8.2	-	29.4	7.9	2
1110	15	8.7	8.2	25.5	8.2	-	-	-	-
R.M. 3.5	12	-	-	-	-	9.6	27.8	6.8	3
	10	8.7	8.3	24.4	8.2	-	-	-	-
	5	8.7	8.4	23.3	8.2	-	-	-	-
	2	8.0	8.7	18.5	8.2	9.9	22.0	7.4	2
Sta. 5	30	8.5	8.2	22.0	8.2	9.7	21.3	7.7	5
1145	20	8.5	8.4	19.9	8.2	-	-	-	-
R.M. 4.6	15	7.5	8.9	11.8	8.2	9.9	15.4	7.5	2
	10	7.0	9.3	8.1	7.9	-	-	-	-
	5	7.0	9.6	6.3	7.9	-	-	-	-
	1	7.0	9.7	6.3	7.8	10.7	7.3	7.2	12

Table IV. Continued

January 30, 1973
High Tide

Station Time River Mile	Depth (Ft)	Field Measurements Temp. (°C)	Field Measurements Dissolved Oxygen (ppm)	Field Measurements Salinity (ppt)	Field Measurements pH	Laboratory Measurements Dissolved Oxygen (ppm)	Laboratory Measurements Salinity (ppt)	Laboratory Measurements pH	Laboratory Measurements Turbidity (JTU)
Sta. 6	16	8.5	8.5	22.0	8.2	10.1	22.0	7.8	2
1225	10	7.5	8.8	10.5	8.2	-	10.5	-	-
R.M. 5.9	8	-	-	-	-	10.7	-	6.1	3
	5	6.5	9.3	6.9	7.9	-	6.9	-	-
	1	6.5	9.6	6.3	7.9	11.0	6.3	-	-
Sta. 7	15	8.0	8.6	17.1	8.8(?)	-	10.7	-	-
S. Slough	12	6.5	8.5	5.8(?)	8.2	-	-	-	-
1240	10	7.0	8.7	10.5	8.4	-	-	-	-
R.M. 7.2	8	-	-	-	-	10.8	5.7	7.2	3
	6	6.5	8.9	4.7	8.0	-	-	-	-
	4	6.5	9.2	4.1	5.9(?)	-	-	-	-
	1	6.5	9.4	4.1	5.8(?)	11.0	4.6	6.9	-
Sta. 8	10	-	-	-	-	10.7	< 2.8	-	-
N. Fork	1	-	-	-	-	10.7	< 2.8	6.9	3
1400									
R.M. 6.3									
Sta. 9	30	7.0	8.3	11.8	8.2	10.9	6.1	-	-
1300	20	6.0	9.1	1.2	7.6	-	-	-	-
R.M. 8.1	15	-	-	-	-	11.3	< 2.8	6.4	4
	10	6.0	9.5	0.9	7.4	-		-	-
	1	6.0	9.7	0.5	7.3	11.1	< 2.8	-	-

Table IV. Continued

January 30, 1973 Low Tide		Field Measurements				Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 1	25	7.5	9.6	11.8	8.4	10.3	13.3	-	-
1530	15	7.5	8.9	11.2	8.3	-	-	-	-
R.M. 0.4	10	-	-	-	-	10.3	12.8	-	-
	5	7.5	8.7	11.2	8.2	-	-	-	-
	1	7.0	8.9	10.5	8.2	10.3	12.3	-	-
Sta. 2	26	7.0	9.5	9.2	8.9(?)	-	-	-	-
1545	15	7.0	9.2	9.2	8.5	-	-	-	-
R.M. 1.5	8	7.0	9.2	8.6	8.4	-	-	-	-
	1	7.0	9.2	8.6	8.3	-	-	-	-
Sta. 3	20	7.0	9.9	6.9	8.0	11.1	8.3	-	-
1555	15	7.0	9.4	6.9	8.0	-	-	-	-
R.M. 2.5	10	-	-	-	-	10.8	8.3	7.3	4
	7	7.0	9.4	6.9	8.0	-	-	-	-
	1	6.5	9.4	6.3	7.9	10.7	7.6	-	-
Sta. 4	18	6.5	9.7	4.7	8.9(?)	-	-	-	-
1615	12	6.5	9.3	4.7	8.4	-	-	-	-
R.M. 3.5	5	6.5	9.3	4.7	8.2	-	-	-	-
	1	6.5	9.3	4.7	8.1	-	-	-	-
Sta. 5	24	6.0	9.5	2.9	7.7	11.0	3.8	-	-
1635	18	6.0	9.4	2.9	7.7	-	-	-	-
R.M. 4.6	12	6.5	9.4	2.9	7.6	11.2	3.5	7.2	4
	6	6.5	9.5	2.9	7.6	-	-	-	-
	1	6.5	9.5	2.9	7.6	10.9	3.2	-	-

Table IV. Continued

Station Time River Mile	Depth (Ft)	Temp. (°C)	Field Measurements Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Laboratory Measurements Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
January 30, 1973 Low Tide									
Sta. 6	8	6.5	9.7	2.3	8.5	-	-	-	-
1645	5	6.5	9.8	2.3	7.8	-	-	-	-
R.M. 5.9	1	6.5	9.8	2.3	7.8	-	-	-	-
Sta. 7	10	6.5	9.8	2.3	8.6	-	-	-	-
S. Slough	5	6.5	9.7	2.3	8.4	-	-	-	4
1700	1	6.5	9.7	2.3	8.2	-	-	-	-
R.M. 7.2									
Sta. 9	24	6.0	9.7	1.2	8.0	11.1	<2.8	-	-
1715	15	6.0	9.8	0.6	7.8	-	-	-	-
R.M. 8.1	12	-	-	-	-	11.3	<2.8	7.2	-
	10	6.0	9.6	0.4	7.7	-	-	-	-
	5	6.0	9.6	0.3	7.6	-	-	-	-
	1	6.0	9.8	0.3	7.6	10.7	<2.8	-	-
May 3, 1973 Low Tide									
Sta. 1	20	12.5	9.6	12.5	7.8	7.3	15.9	7.2	4.5
0815	10	12.5	9.7	13.0	7.8	7.2	15.4	7.6	4.7
R.M. 0.4	1	12.5	10.0	12.5	7.8	7.1	33.5(?)	7.6	7.6
Sta. 2	28	12.0	9.8	11.5	7.8	7.3	13.4	7.8	8.0
0845	14	12.5	9.7	11.0	7.8	7.1	13.0	7.7	6.0
R.M. 1.5	1	12.5	9.9	10.5	7.8	7.3	12.8	7.7	5.1

Table IV. Continued

May 3, 1973
Low Tide

Station Time River Mile	Depth (Ft)	Temp. (°C)	Field Measurements: Dissolved Oxygen (ppm)	Field Measurements: Salinity (ppt)	Field Measurements: pH	Laboratory Measurements: Dissolved Oxygen (ppm)	Laboratory Measurements: Salinity (ppt)	Laboratory Measurements: pH	Laboratory Measurements: Turbidity (JTU)
Sta. 3	14	12.5	9.8	8.0	7.6	7.0	10.1	7.6	7.8
0855	7	12.5	9.7	8.0	7.6	7.1	9.7	8.4	9.2
R.M. 2.5	1	12.0	9.8	8.0	7.6	7.3	9.6	7.8	5.8
Sta. 4	12	13.0	9.6	6.0	7.6	7.1	7.0	7.6	12.0
0912	6	13.0	9.5	5.5	7.4	-	-	-	-
R.M. 3.5	1	13.0	9.2	5.5	7.4	7.3	6.5	8.8	8.0
Sta. 5	23	13.5	9.7	5.0	7.4	7.4	5.0	7.9	13.0
0929	12	13.0	9.4	4.5	7.5	7.2	4.5	7.6	9.2
R.M. 4.6	1	13.5	9.9	3.5	7.4	7.2	3.8	8.6	8.5
Sta. 6	10	13.5	9.8	3.0	7.4	7.2	3.0	7.7	13.0
0940	5	14.0	9.8	2.5	7.3	-	-	-	-
R.M. 5.9	1	13.0	9.8	2.5	7.4	7.3	<2.8	8.9	29.0
Sta. 7	9	13.0	8.4	7.0	7.3	6.2	7.7	7.6	18.0
1002	5	13.0	.9.6	3.0	7.1	-	-	-	-
S. Slough	1	13.0	9.9	2.0	7.2	7.2	<2.8	6.8	14.5
R.M. 7.2									
Sta. 8									
0953	1.5	12.0	9.8	0.5	7.2	-	-	-	-
N. Fork									
R.M. 6.3									

Table IV. Continued

May 3, 1973 Low Tide			Field Measurements			Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 9	18	13.0	9.6	0.5	7.2	-	-	-	-
1018	9	13.0	9.9	0.5	6.9	-	-	-	-
R.M. 8.1	1	13.0	10.0	0.5	6.9	-	-	-	-
Sta. 10	17	13.5	10.3	0	7.3	7.0	<2.8	7.1	5.5
R.M. 9.0	8	13.5	9.8	0	7.0	7.2	<2.8	7.3	6.2
	1	13.5	9.9	0	7.0	7.6	<2.8	6.9	4.5
May 3, 1973 High Tide									
Sta. 1	30	10.0	10.0	24.0(?)	8.2	7.8	33.6	7.9	2.3
1517	15	10.0	10.3	30.5	8.2	7.8	33.7	8.0	1.5
R.M. 0.4	1	10.0	10.3	29.0	8.1	7.7	33.7	7.9	5.0
Sta. 2	31	10.0	9.8	30.5	8.2	7.9	33.5	7.6	3.0
1534	15	9.5	10.3	29.0	8.2	7.5	33.6	7.9	1.8
R.M. 1.5	1	9.5	10.8	30.0	8.2	7.8	33.6	8.0	1.3
Sta. 3	25	10.0	10.0	30.0	8.2	7.9	33.6	8.0	2.9
1549	12	10.0	10.2	30.5	8.2	7.8	33.7	8.0	1.4
R.M. 2.5	1	10.0	10.8	30.5	8.2	7.7	33.7	8.0	1.6
Sta. 4	14	9.5	10.0	28.5	8.1	7.7	33.6	7.9	2.0
1602	10	10.0	10.3	29.0	8.1	7.7	33.6	8.0	1.7
R.M. 3.5	1	10.0	10.5	29.0	8.2	7.7	33.5	8.0	1.6

Table IV. Continued

May 3, 1973 High Tide			Field Measurements			Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 5	30	9.5	10.1	29.0	8.2	7.6	32.8	8.0	2.5
1620	15	9.5	10.1	28.5	8.1	7.7	32.9	8.6	2.5
R.M. 4.6	1	10.0	10.4	27.5	8.1	7.4	21.1	8.2	2.0
Sta. 6	16	10.0	10.1	27.5	8.1	7.7	30.9	8.1	3.7
1630	8	10.0	10.4	27.5	8.2	7.8	28.7	8.1	2.8
R.M. 5.9	1	12.5	12.3	16.0	8.2	8.2	19.1	8.1	3.7
Sta. 7	15	10.0	8.8	26.0	8.0	7.3	26.3	8.0	4.0
1700	7	12.0	11.1	12.0	8.2	-	-	-	-
S. Slough	1	13.0	12.1	9.0	8.2	8.4	10.8	8.1	4.5
R.M. 7.2									
Sta. 8	7	10.0	9.5	26.5	8.0	-	-	-	-
1449	3	12.5	12.5	11.5	8.3	-	-	-	-
N. Fork	1	13.0	13.0	9.0	8.4	-	-	-	-
R.M. 6.3									
Sta. 9	24	13.0	11.2	8.0	8.0	7.6	10.6	8.0	7.4
1715	12	13.0	11.1	6.5	8.0	7.9	7.7	7.9	6.0
R.M. 8.1	1	13.0	9.6	5.5	8.2	8.1	6.3	8.4	6.2
Sta. 10	20	12.5	10.3	1.5	7.6	7.7	<2.8	8.0	11.0
1735	10	12.5	10.3	1.5	7.6	8.4	<2.8	7.8	8.5
R.M. 9.0	1	13.0	10.2	1.5	7.4	7.6	<2.8	7.6	7.0

Table IV. Continued

August 2, 1973 Low Tide			Field Measurements			Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 1	33	11.0	8.4	28.0	7.7	8.7	32.5	7.5	4.6
0825	15	11.5	8.5	29.0	7.9	8.1	32.3	7.6	1.1
R.M. 0.4	1	11.5	8.7	27.0	7.8	8.6	32.2	7.6	1.8
Sta. 2	10	12.0	8.6	28.0	8.0	7.4	31.2	7.6	2.8
0940	5	11.5	8.9	28.0	7.9	8.1	30.9	7.6	2.3
R.M. 1.5	1	12.0	8.8	28.0	7.9	8.3	31.0	7.5	1.4
Sta. 3	16	14.0	8.1	25.5	7.6	8.5	28.6	7.3	2.1
0925	8	14.0	8.6	18.5	7.6	8.3	28.4	7.4	2.0
R.M. 2.5	1	14.5	8.2	24.5	7.6	8.3	28.2	7.5	3.2
Sta. 4	15	16.0	7.0	31.0	7.5	7.6	24.9	7.6	1.4
0946	12	16.0	7.4	22.0	7.4	7.4	24.9	7.3	2.7
R.M. 3.5	1	16.0	7.5	22.0	7.4	7.6	25.0	7.2	1.1
Sta. 5	20	16.5	7.5	21.0	7.4	7.2	23.8	7.2	3.9
1004	10	17.5	7.2	20.0	7.2	6.9	22.2	7.2	1.8
R.M. 4.6	1	17.5	6.7	19.0	5.3	7.1	21.9	7.2	2.4
Sta. 6	10	18.5	6.8	17.0	7.2	7.1	19.4	7.1	3.7
1020	5	18.5	6.5	17.0	7.1	-	-	-	-
R.M. 5.9	1	18.5	6.3	16.5	7.0	7.0	19.3	7.2	2.2
Sta. 7	8	17.5	5.2	18.5	7.0	6.0	21.6	8.2	3.1
1040	4	18.0	4.6	18.5	7.0	-	-	-	-
S. Slough	1	18.5	5.1	18.5	7.0	5.7	21.2	7.0	1.7
R.M. 7.2									

Table IV. Continued

August 2, 1973 Low Tide Station Time River Mile	Depth (Ft)	Temp. (°C)	Field Measurements Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Laboratory Measurements Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 8	3	20.0	8.0	12.0	7.1	8.3	13.3	7.2	1.2
1128	1	20.0	7.7	12.0	7.1	8.1	13.1	7.2	1.6
N. Fork									
R.M. 6.3									
Sta. 9	29	20.0	6.0	14.0	7.0	6.6	14.0	7.0	2.1
1156	14	20.0	6.2	12.0	7.0	6.6	13.5	7.1	2.4
R.M. 8.1	1	20.0	6.8	10.5	7.0	7.3	12.0	7.1	1.7
August 2, 1973 High Tide									
Sta. 1	24	9.5	7.5	29.0	7.8	8.5	33.8	7.6	1.2
1458	12	9.5	8.0	30.0	7.8	8.5	33.9	7.5	2.2
R.M. 0.4	1	9.8	8.3	30.0	7.9	8.5	33.8	7.6	3.1
Sta. 2	24	7.0	7.9	24.0(?)	7.6	8.6	33.9	7.6	1.9
1515	12	8.0	8.2	30.0	7.8	8.7	33.8	7.7	2.5
R.M. 1.5	1	8.0	8.5	30.0	7.8	8.2	33.8	6.9	3.2
Sta. 3	36	8.0	7.8	30.0	7.8	8.3	34.0	7.7	0.8
1531	18	8.0	8.0	30.0	7.8	8.5	33.9	7.6	2.7
R.M. 2.5	1	8.0	8.3	30.0	7.8	8.2	33.9	7.6	2.8
Sta. 4	30	8.0	7.8	30.0	7.8	8.4	33.9	7.6	2.6
1545	15	8.0	8.2	30.0	7.8	8.4	33.9	7.2	5.0
R.M. 3.5	1	8.0	8.3	30.0	7.8	8.4	33.9	7.7	3.0

Table IV. Continued

August 2, 1973 High Tide			Field Measurments			Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 5	26	9.0	7.9	30.0	7.8	6.2	34.0	7.6	3.5
1604	13	8.0	7.8	30.0	7.9	8.8	34.0	7.3	2.5
R.M. 4.6	1	9.0	8.4	29.0	7.9	8.5	33.9	6.8	3.8
Sta. 6	18	8.0	8.2	30.0	7.8	8.9	33.9	7.4	4.2
1616	9	8.0	8.3	30.0	7.9	8.9	-	7.6	5.8
R.M. 5.9	1	9.5	8.3	30.0	7.9	9.6	32.4	7.6	3.5
Sta. 7	17	10.0	9.4	29.0	7.9	9.9	33.4	7.6	4.2
1631	8	10.0	9.4	28.0	7.9	-	33.5	7.6	4.0
S. Slough	1	10.0	9.4	28.0	7.9	1.0	33.2	7.8	4.2
R.M. 7.2									
Sta. 8	12	10.5	10.0	29.0	8.0	10.7	33.0	7.6	3.5
1650	7	10.0	10.4	29.0	7.9	-	-	-	-
N. Fork	1	10.0	11.1	28.0	7.9	10.0	27.0	7.6	3.8
R.M. 6.3									
Sta. 9	28	-	-	-	-	10.5	30.4	7.6	4.5
1717	14	-	-	-	-	10.8	30.6	7.7	3.8
R.M. 8.1	1	13	-	-	7.8	10.9	29.3	7.6	3.1

Table IV. Continued

November 19, 1973 High Tide		Field Measurements				Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 1	30	(Instrument Inoperative)				10.1	31.9	7.9	1.2
0732	15					9.4	31.8	8.4	1.7
R.M. 0.4	1					10.0	31.8	8.4	1.2
Sta. 2	17					9.9	31.8	7.6	1.9
0751	8					9.9	31.6	8.0	0.6
R.M. 1.5	1					10.0	31.7	7.3	1.8
Sta. 3	27					10.5	31.6	8.1	2.0
0800	14					10.3	31.2	7.9	1.8
R.M. 2.5	1					9.9	30.2	8.2	1.7
Sta. 4	21					10.1	30.9	7.8	1.2
0813	10					10.1	30.7	7.8	0.4
R.M. 3.5	1					10.9	18.3	7.3	0.7
Sta. 5	38					10.3	28.5	7.6	1.4
0822	20					10.0	27.8	8.0	1.8
R.M. 4.6	1					11.3	<2.8	8.1	1.5
Sta. 6	18					10.7	21.9	7.1	1.9
0907	9					10.9	15.2	7.7	0.4
R.M. 5.9	1					11.4	<2.8	7.6	5.0
Sta. 7	17					10.5	11.5	7.4	2.0
0926	8					11.5	<2.8	7.0	5.0
S. Slough	1					11.5	<2.8	6.8	5.4
R.M. 7.2									

Table IV. Continued

November 19, 1973 High Tide		Field Measurements				Laboratory Measurements			
Station Time River Mile	Depth (Ft)	Temp. (°C)	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Dissolved Oxygen (ppm)	Salinity (ppt)	pH	Turbidity (JTU)
Sta. 8	7	(Instrument Inoperative)				11.3	<2.8	6.4	2.8
0917									
N. Fork	1					11.3	<2.8	7.1	5.8
R.M. 6.3									
Sta. 9	38					-	<2.8	7.0	6.8
0950	20					-	<2.8	7.0	4.9
R.M. 8.1	1					12.5	<2.8	6.8	1.9
November 19, 1973 Low Tide									
Sta. 1	30	-	8.8	4.6	7.4	11.1	5.4	7.0	2.9
1449	15	-	8.7	4.5	7.4	11.3	7.8	7.2	4.5
R.M. 0.4	1	-	8.8	4.0	7.3	11.2	4.5	7.1	2.8
Sta. 2	23	-	9.0	3.0	7.2	11.1	3.2	7.1	15.0
1439	13	-	9.0	3.9	7.2	11.5	<2.8	-	-
R.M. 1.5	1	-	9.0	2.2	7.2	11.0	<2.	6.9	5.4
Sta. 3	22	-	9.2	0.6	7.0	11.3	<2.	7.5	22.0
1512	11	-	9.1	0	7.0	11.3	<2.	7.1	9.0
R.M. 2.5	1	-	9.0	0	7.0	11.8	<2.	7.2	9.6
Sta. 4	17	-	9.3	0	6.8	11.6	<2.	5.9	8.5
1523	8	-	9.2	0	6.8	11.4	<2.	7.2	6.5
R.M. 3.5	1	-	9.2	0	6.8	11.6	<2.	7.1	9.0

Table IV. Continued

November 19, 1973
Low Tide

Station Time River Mile	Depth (Ft)	Temp. (°C)	Field Measurements: Dissolved Oxygen (ppm)	Field Measurements: Salinity (ppt)	Field Measurements: pH	Laboratory Measurements: Dissolved Oxygen (ppm)	Laboratory Measurements: Salinity (ppt)	Laboratory Measurements: pH	Laboratory Measurements: Turbidity (JTU)
Sta. 5	34	-	9.3	0	6.8	13.0	<2.	6.7	9.0
1544	17	-	9.2	0	6.7	11.9	<2.	7.2	4.5
R.M. 4.6	1	-	9.1	0	6.7	11.9	<2.	7.2	3.8
Sta. 6	11	-	8.9	0	6.7	11.3	<2.	6.5	3.7
1559	5	-	8.6	0	6.6	11.3	<2.	-	-
R.M. 5.9	1	-	8.5	0	6.5	11.1	<2.	-	-
Sta. 7	13	-	8.6	0	6.8	11.0	<2.	7.1	10.0
1630	7	-	8.2	0	6.7	10.0	<2.	7.2	9.3
S. Slough	1	-	8.1	0	6.6	10.7	<2.	6.8	9.5
R.M. 7.2									
Sta. 8									
1615	2	-	9.0	0	6.6	10.4	<2.	7.3	4.7
N. Fork									
R.M. 6.3									
Sta. 9	30	-	9.2	0	6.8	12.4	<2.	6.8	7.0
1655	15	-	9.1	0	6.7	12.0	<2.	7.2	7.0
R.M. 8.1	1	-	9.2	0	6.7	11.7	<2.	7.3	8.0

Table V. Sediment Test Data

Sample A = Jan. B = June	Location (River Mile)	D_{90} (mm)	D_{60} (mm)	D_{50} (mm)	D_{10} (mm)	U (D_{60}/D_{10})	Porosity (%)	Volatile Solids (%)
20A04	R.M. 8.1 RR Bridge	0.75	0.39	0.33	0.17	2.3	50.7	1.29
21A04	R.M. 7.2 S. Slough	0.15	0.07	0.055	0.0039	17.9	76.3	7.73
22A04	R.M. 6.3 Dredge site	0.40	0.27	0.25	0.16	1.69	57.5	2.24
23A04	R.M. 6.3 Dredge site	0.40	0.28	0.25	0.15	1.86	59.3	9.60
24A04	R.M. 5.9	0.40	0.27	0.25	0.16	1.69	43.5	1.20
25A04	R.M. 6.3 S. Slough	0.36	0.26	0.22	0.10	2.60	47.6	1.84
26A04	R.M. 6.3 N. Fork	0.37	0.27	0.25	0.17	1.59	47.3	0.57
27A04	R.M. 6.3 N. Fork	0.37	0.27	0.25	0.17	1.59	38.6	0.83
28A04	R.M. 5.6 N. Slough	0.37	0.27	0.25	0.18	1.50	39.4	0.65
29A04	R.M. 4.6	0.37	0.27	0.24	0.17	1.59	41.8	0.94
30A04	R.M. 2.7	0.37	0.27	0.25	0.18	1.50	33.5	0.34

Table V. Continued

Sample A = Jan. B = June	Location (River Mile)	D_{90} (mm)	D_{60} (mm)	D_{50} (mm)	D_{10} (mm)	U (D_{60}/D_{10})	Porosity (%)	Volatile Solids (%)
Dredge Spoils		0.37	0.27	0.25	0.17	1.59	--	1.14
18B04	R.M. 8.1 off-channel	0.31	0.13	0.11	0.016	8.12	65	4.62
19B04	R.M. 8.1 RR Bridge	0.58	0.29	0.23	0.050	5.80	52	2.29
20B04	R.M. 8.1 RR Bridge	0.61	0.29	0.25	0.075	3.87	60	3.46
21B04	R.M. 7.2 S. Slough	0.29	0.11	0.088	0.013	8.46	69	5.88
22B04	R.M. 6.3	0.47	0.30	0.26	0.16	1.88	54	4.04
24B04	R.M. 5.4	0.37	0.24	0.22	0.055	4.36	58	0.87
25B04	R.M. 6.3 S. Slough	0.37	0.25	0.23	0.15	1.67	51	1.64
26B04	R.M. 6.3 N. Fork	0.36	0.26	0.24	0.16	1.62	52	1.33
27B04	R.M. 6.3 N. Fork	0.47	0.29	0.25	0.16	1.81	54	0.94
29B04	R.M. 4.6	0.40	0.23	0.19	0.012	19.2	68	0.73
30B04	R.M. 2.7	0.38	0.27	0.24	0.16	1.69	35	0.39

Table V. Continued

Sample A = Jan. B = June	Location (River Mile)	D_{90} (mm)	D_{60} (mm)	D_{50} (mm)	D_{10} (mm)	U (D_{60}/D_{10})	Porosity (%)	Volatile Solids (%)
32B04	R.M. 7.8	0.80	0.31	0.26	0.075	4.13	58	3.45
33B04	R.M. 3.5	0.39	0.27	0.24	0.16	1.69	34	0.50
34B04	R.M. 1.7	0.37	0.28	0.24	0.17	1.65	34	0.43
35B04	R.M. 1.7	0.35	0.063	0.058	0.042	1.50	35	0.34