ANNUAL SUMMARY REPORT
FOR 1976 HYDROGRAPHIC STUDIES
OFF HAMPTON BEACH, NEW HAMPSHIRE
TECHNICAL REPORT VIII-1

PREOPERATIONAL ECOLOGICAL MONITORING STUDIES
FOR SEABROOK STATION

Conducted for

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
Manchester, New Hampshire

By

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MARCH 1979

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1.0 INTRODUCTION

Since September 1972 Normandeau Associates, Inc. (NAI) has been conducting extensive baseline hydrographic and sedimentological studies for the Public Service Company of New Hampshire's (PSC) Seabrook Station Project. These studies of a portion of the western Gulf of Maine, the coastal waters off Hampton Beach, New Hampshire, and the Hampton Harbor estuary have been designed primarily to determine year-round variability of ambient water currents, temperature, salinity, density, dissolved oxygen, tides, net circulation patterns, and winds. These studies, which represent one of the most comprehensive preoperational monitoring programs ever conducted for a proposed oceanside power plant in this country, have substantiated data previously collected by other workers and, in addition, have added much valuable new information.

1.1 STUDY AREA

The site for the proposed Seabrook Station along the southeastern coast of New Hampshire (Figure 1.1-1) is fronted by a portion of the western North Atlantic Ocean known as the Gulf of Maine. This water body is proposed to be both the primary source of cooling water for the power plant and the receiving water mass for its heated effluent.

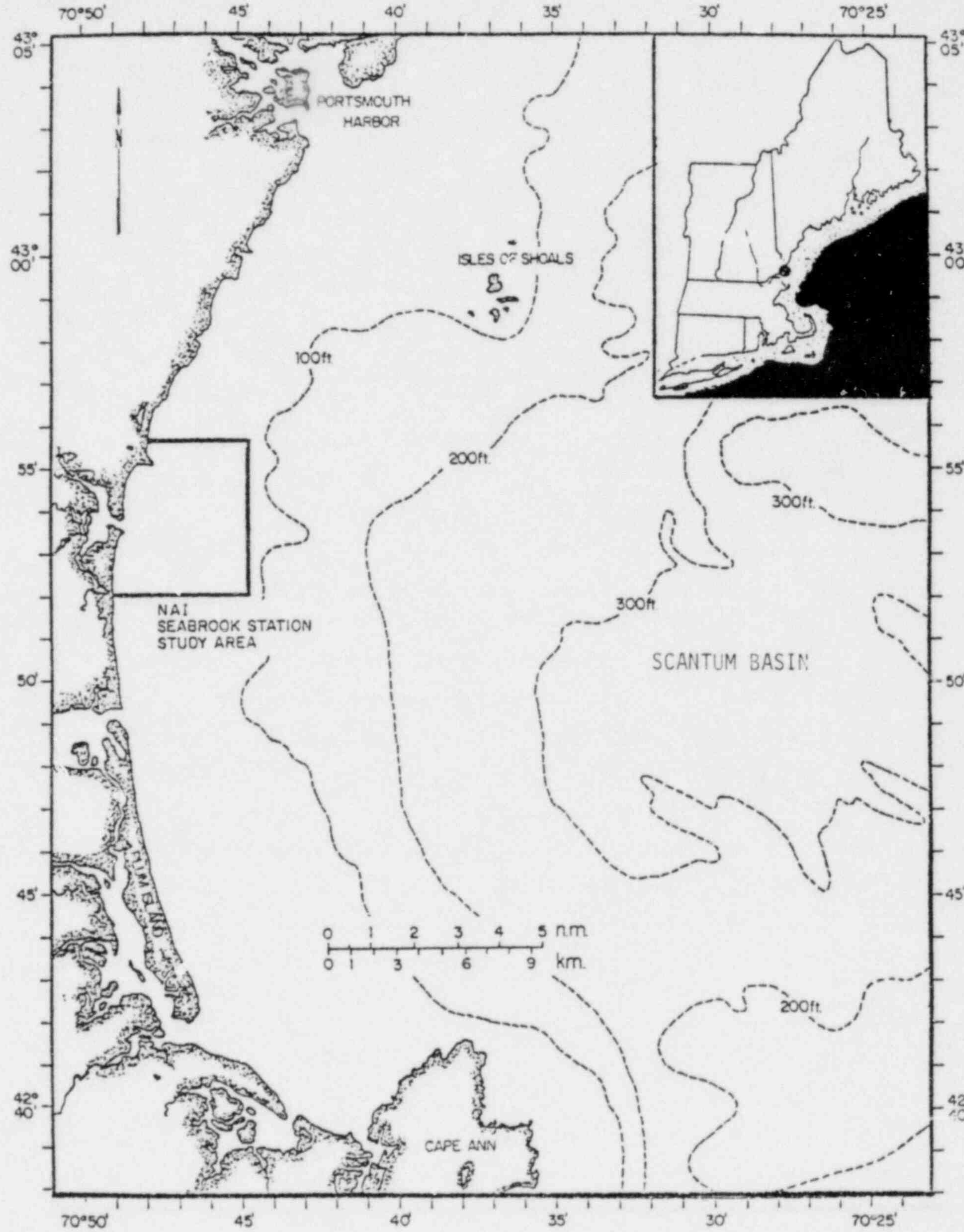

Figure 1.1-1. Location map showing NAI Seabrook Station study area off Hampton Beach and New Hampshire coastal waters. Seabrook 1976 Annual Hydrographic Report, 1979.

The Gulf of Maine forms a roughly rectangular embayment about 175 n mi (324 km) across from east to west and 100 n mi (193 km) from north to south. It stretches from Cape Cod and Nantucket Island, Massachusetts, northeastward along roughly 525 n mi (966 km) of shoreline (excluding bays and inlets) to Cape Sable, Nova Scotia. It is bordered to the south by two shallow bank areas, Georges Bank and Browns Bank which restrict water circulation with the North Atlantic and essentially enclose the Gulf as a coastal sea. The Gulf itself comprises an estimated surface area of about $49,000^2$ (36,941 n mi^2 or 126,878 km^2).

The Gulf of Maine has generally irregular bottom topography with numerous banks, sinks, and a series of large basins. The continental shelf is typically narrow, up to 13 n mi (24 km) wide. The bathymetry of the western Gulf of Maine adjacent to the coast of New Hampshire (referred to as Bigelow Bight) is dominated by two deep basins, Jeffreys Basin, which is about 600 ft (183 m) deep, and Scantum Basin, which is about 420 ft (128 m) deep (Figure 1.1-1). A broad gently-sloping shelf area with numerous local bottom irregularities, especially in the vicinity of the Isles of Shoals, lies between these basins and the coast. On the seaward side, these basins are separated from the main Gulf by a shallow rise known as Jeffreys Ledge.

1.2 PREVIOUS STUDIES

The study area off the New Hampshire coast represents a small segment of the coastal shelf zone of the Gulf of Maine in the North Atlantic Estuarine zone (U.S. Fish and Wildlife Service, 1970). Graham (1970a) has defined this coastal water as lying within 13 n mi (24 km) of the coast, being less than about 100 m (325 ft) deep and extending from the mouth of the Bay of Fundy to Cape Cod. The coastal zone is an area of mixing of ocean water entering the Gulf of Maine via the Northeast Channel and freshwater discharge. The discharge varies seasonally, but is about 100 km^3 annually (Emery and Uchupi, 1972). The Northeast Channel water has a salinity of about 34 ‰ (Bigelow, 1927) and a temperature of about 4 to 9 C (39 to 48 F; Colton and Stoddard, 1972).

The distribution of temperature and salinity of the waters in the Gulf of Maine has been studied by Bigelow (1927), Colton *et al.* (1968), Colton and Stoddard (1972), Colton (1973) and TRIGOM (1974). Numerous biological studies have been summarized in Colton (1964). Graham (1970a and 1970b) has studied the coastal waters of the Gulf of Maine from Cape Ann, Massachusetts to Machias Bay, Maine. Surface-water temperature and salinity within a 16 n mi (30 km) radius of the Merrimack River were studied by Ford (1947). Wiseman (Louisiana State University, personal communication) conducted an unpublished hydrographic study off Portsmouth Harbor in which temperature and salinity profiles were measured in the spring and summer of 1969. Shevenell (1974 and unpublished data) has studied the hydrography of the New Hampshire coastal waters in detail. His study was conducted from July 1972 to June 1973 at a grid of 16 stations centered around the Isles of Shoals. These data are summarized in NAI (1976a).

1.3 NAI STUDIES OFF HAMPTON BEACH

NAI's extensive studies since 1972, as summarized in Figure 1.12, have included: 1) continuous monitoring of currents, wind, tide and water temperature; 2) various types of hydrographic surveys (i.e., plankton cruises, slack-water surveys, anchor stations, temperature surveys and *Mya arenaria* surveys); 3) drogue tracking studies; 4) streamer observations; 5) drifter releases; 6) dye tracking; 7) suspended sediment studies; and 8) sea-floor stability studies. The results of these various studies have shown that the hydrography of the New Hampshire coastal waters is quite variable, with currents, temperature, salinity, and density showing strong seasonal changes. This variability is typical of coastal waters, where winds, tides, waves (surface and internal), bathymetry, river runoff, evaporation, precipitation, insolation, proximity to land, and advection all affect the hydrography to varying degrees in time and space.

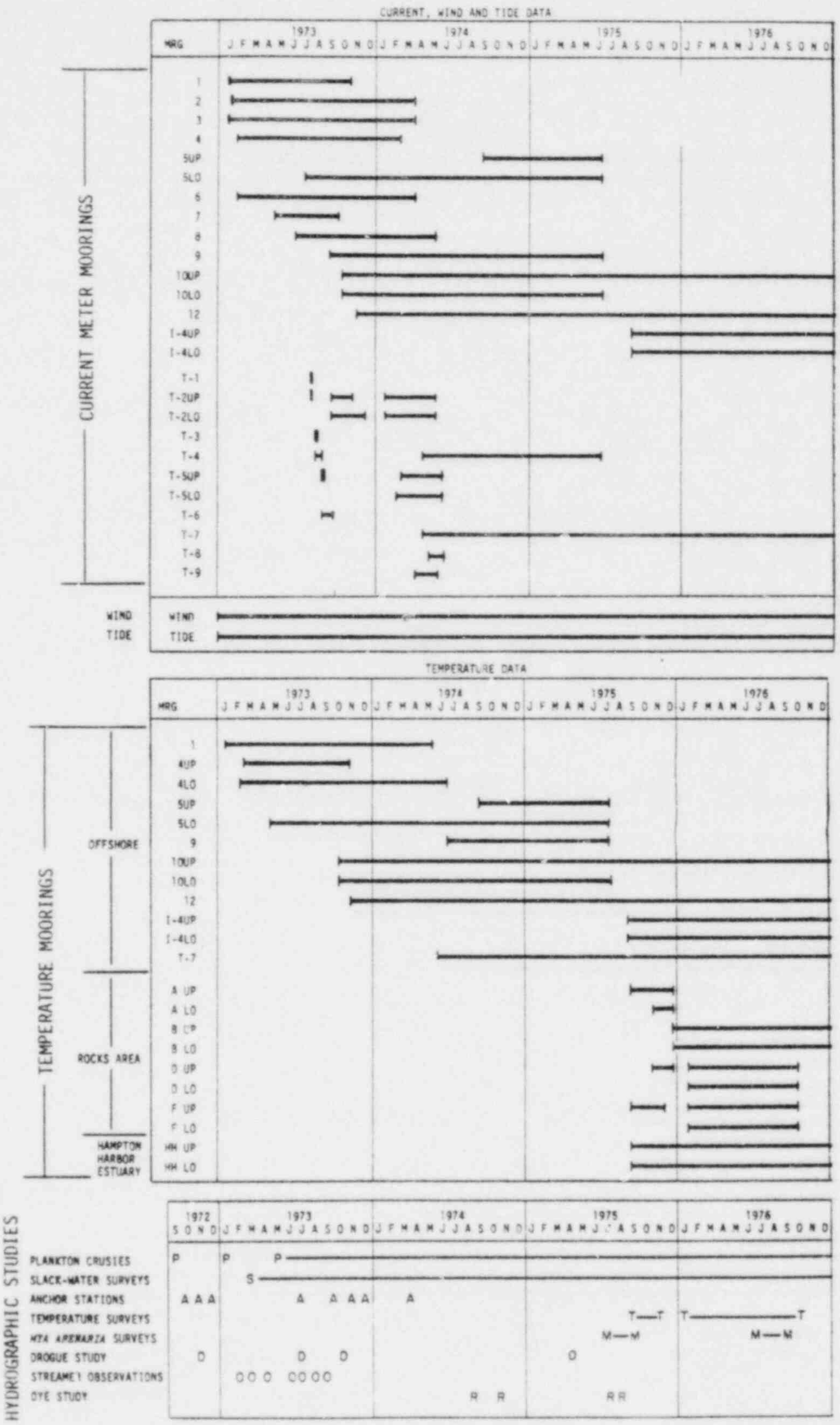

Figure 1.1-2. Diagram showing hydrographic studies which have been conducted off Hampton Beach, New Hampshire, from 1972 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

The NAI hydrographic study program has augmented concurrent NAI ecological studies and PSC engineering studies by documenting the near-shore water-mass dynamics in the vicinity of the proposed intake and discharge sites and out to 4.2 n mi (7.8 km) offshore. Data from additional stations as much as 23 n mi (43 km) offshore and both north and south of the primary study area have also documented hydrographic characteristics in much of the western Gulf of Maine.

These hydrographic studies have resulted in:

1. expanding the existing long-term data base for ambient currents and temperatures at the proposed offshore and nearshore intake sites, the proposed diffuser site, and reference moorings outside of the anticipated "near field" region (region within direct effect of the plant's circulating water system);

2. documenting the relationship between flows in the near-shore area and in the offshore area, especially as related to possible impact of plant operation, plankton entrainment effects, coastal upwelling, and other hydrographic phenomena.

3. further defining the preoperational baseline temperature conditions in the study area, especially the monthly mean of the daily maxima and the natural variability of coastal and estuarine waters.

Sedimentological studies from 1973 through 1975 have measured long-term bottom stability in the areas of the proposed intake and discharge sites off Hampton Beach and near-bottom suspended-sediment transport (NAI, 1975a).

This report presents the 1976 data and is intended to augment the previously published hydrographic summary reports: NAI Technical Report VI-8, which covered studies from September 1972 through March

1975 (NAI, 1975a); NAI Technical Report VII-2, which reported 1975 results (NAI, 1977a); and the NAI Seabrook Station Summary Document (NAI, 1977b).

2.0 MATERIALS AND METHODS

2.1 FIELD METHODS

2.1.1 Temporal Monitoring

A number of continuously recording instruments mounted on various taut moorings and platforms were deployed to monitor water currents, temperature, tide elevation and local winds in the study area (Figure 2.1-1 and Table 2.1-1). The different configurations of surface following and fixed subsurface moorings are described in detail in NAI (1977a). The three-point moored, surface following buoy systems minimized mooring watch circle and held instruments at fixed depths below the instantaneous water surface throughout the tidal cycle (examples are Moorings T-7, 12, 5 upper and I-4 upper). The subsurface moorings held instruments at depth, minimizing and absorbing induced deflections from open ocean waves (examples are Moorings 10 upper, 10 lower, I4 lower, 9 and T4). One old mooring (Mooring 5 lower) consisted of a fixed bottom tripod system ballasted with pig iron slabs and held in position with anchors (NAI, 1977a).

Currents were measured with Bendix Model Q15 or Q15 (R) geomagnetic, bidirectional, ducted current sensors with 10-ft (3-m) directional vanes and Bendix Model 270 recorder/power supply units. The Bendix system has an accuracy of ±0.05 kn (±2.6 cm/sec) for speed and ±12° for direction (Table 2.1-1). The data from these current sensors were recorded on dual channel Rustrak Model 291 DC recorders within the Bendix Model 270 housing. Bulova Model TE-11 Accutron cycle timers were installed in all recorders to provide time marks every 3 hrs on the strip charts. Electrical power was supplied with 14-day rechargeable battery packs (see complete instrument specifications, Table 2.1-1).

Water temperature was measured at selected sites with NAI Model 1000 and 1001 Temperature Monitors consisting of Rustrak Model 2133 DC recorders with matched Model 1332 thermistor probes (see Table 2.1-2 for instrument specifications).

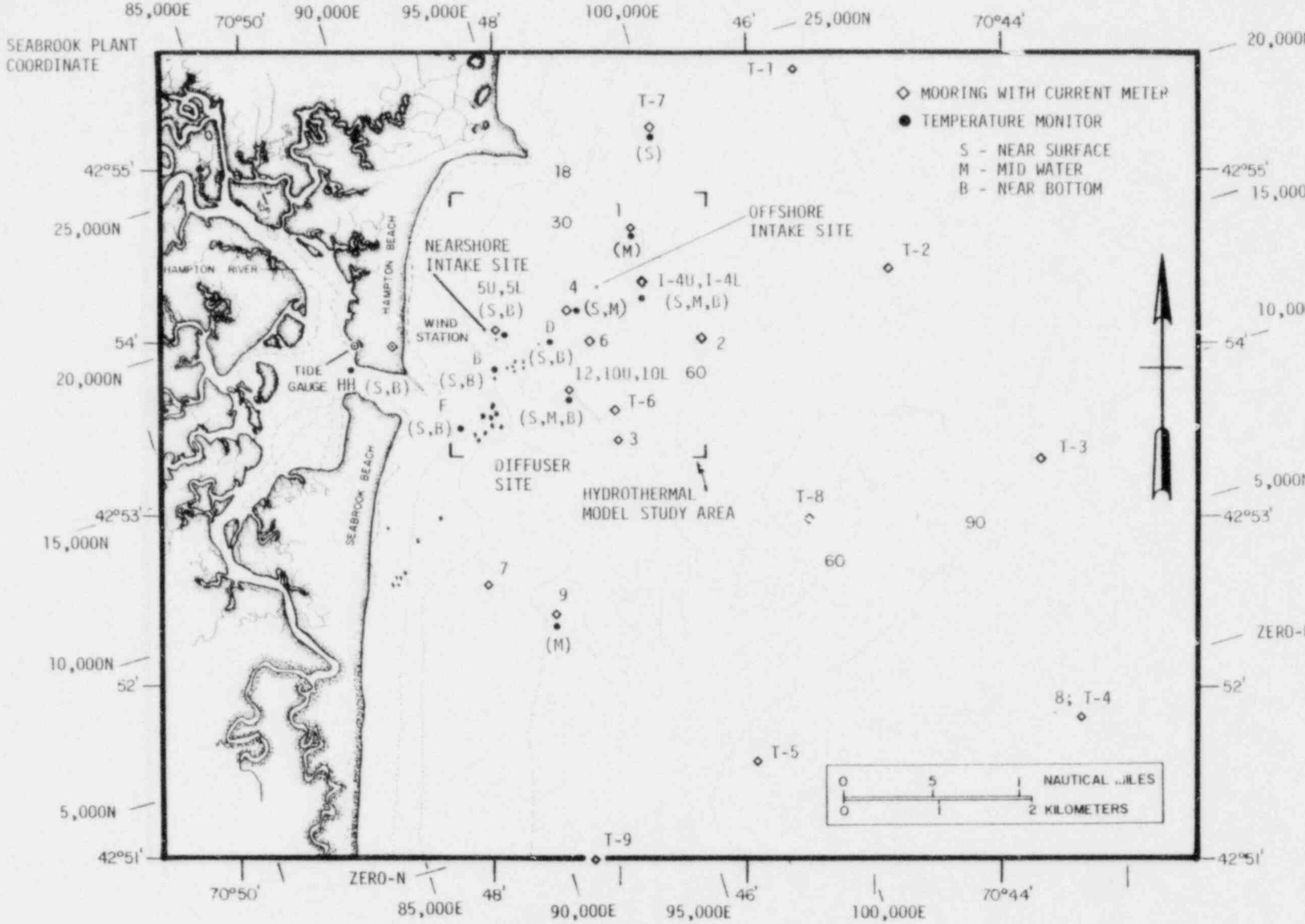

Figure 2.1-1. Location map showing all historical NAI moorings with current meters and temperature monitors in coastal waters off Hampton Beach, New Hampshire, from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

TABLE 2.1-1. OPERATIONAL DATES AND SAMPLING DEPTHS FOR 1976 NAI CURRENT METERS AND TEMPERATURE MONITORS OFF HAMPTON BEACH, NEW HAMPSHIRE. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

MOORING DESIGNATION	MOORING LOCATION LATITUDE N	MOORING LOCATION LONGITUDE W	WATER DEPTH AT MLW, FT	WATER DEPTH AT MLW, (M)	DATES OPERATIONAL, 1976	SENSOR DEPTHS BELOW INSTANTANEOUS SEA SURFACE: CURRENT METERS FT	CURRENT METERS (M)	TEMPERATURE MONITORS FT	TEMPERATURE MONITORS (M)
	Reference Site								
T-7	42°55'15"	70°46'46"	60.0	(18.3)	Jan 1 to Dec 31	5.7	(1.7)	2.0	(0.6)
	Diffuser Site								
12	42°53'43"	70°47'23"	60.0	(18.3)	Jan 1 to Dec 31	5.2	(1.6)	2.0	(0.6)
10 Upper						20.0*	(6.1)	23.0	(7.0)
	Offshore Intake Site								
I-4 Upper	42°54'20"	70°47'09"	55.0	(16.8)	Jan 1 to Dec 31	5.2	(1.6)	2.2	(0.7)
I-4 Lower						44.0*	(13.4)	48.6*	(14.8)
	Rocks Area								
B Upper	42°53'49"	70°48'00"	15.0	(4.6)	Jan 1 to Dec 31	N/A		1.0	(0.3)
B lower								13.0	(4.0)
D Upper	42°53'55"	70°47'28"	15.0	(4.6)	Feb 1 to Oct 13	N/A		1.0	(0.3)
D Lower								13.0	(4.0)
F Upper	42°53'31"	70°48'09"	15.0	(4.6)	Feb 1 to Oct 13	N/A		1.0	(0.3)
F Lower								13.0	(4.0)
	Hampton Harbor Estuary								
HH Upper	42°53'59"	70°49'09"	4.0	(1.2)	Jan 1 to Dec 31	N/A		1.0	(0.3)
HH Lower								4.0*	(1.2)
	Hampton Beach State Park								
Wind	42°53'58"	70°48'46"			Jan 1 to Dec 31	35.5	(10.8)+		
	Hampton Beach Marina								
Tide	42°54'08"	70°49'06"			Jan 1 to Dec 31				

*Depths below mean low water (MLW)

+Height above mean sea level

Tide elevation in the Hampton Harbor estuary was measured continuously at the Hampton Beach Marina (Figure 2.1-2) using a Marsh-McBirney Model 100 water-level gauge and a Rustrak Model 288 single-channel, DC strip-chart recorder. The accuracy of this system was about ±0.2 ft or 5.0 cm (Table 2.1-2). All measurements were referenced to mean low water (MLW) from surveyed bench marks keyed to the U.S. Army Corps of Engineers 1929 geodetic elevation datum.

Local wind speed and direction were measured continuously from a telephone pole located in the Hampton Beach State Park using an R.M. Young Model 6405 Field Recording wind set. The accuracy of the unit was about ±1.0 km (51.5 cm/sec) speed and ±7° direction (Table 2.1-2).

Moorings were serviced by SCUBA divers every 2 weeks, depending upon weather conditions. During each servicing period, detailed electronic tests were conducted on each *in situ* instrument to check its functioning and to detect possible instrument failure before the data were affected. Every 3 months, sensors and recorders were returned to NAI's Engineering Department instrumentation laboratory for routine maintenance, calibration, and repairs as necessary, in accordance with NAI Technical Procedures Manuals and manufacturers' specifications.

The locations of all historical offshore buoy systems from 1973 through 1976 are shown in Figure 2.1-1. The approximate latitude and longitude, water depth, sensor depths, and operational dates for all 1976 moorings are summarized in Table 2.1-1. Data collection for earlier years is summarized in Figure 1.1-2. Operational performance for each mooring is summarized in Appendix Figure 7.1-1.

2.1.2 Spatial Surveys

Monthly hydrographic surveys were conducted to measure the year-round and tidal variations in the ambient oceanographic parameters at selected stations in the coastal waters off Hampton Beach, at the

TABLE 2.1-2. SPECIFICATIONS FOR PRIMARY INSTRUMENTATION UTILIZED IN THE NAI MONITORING STUDIES OFF HAMPTON BEACH, NEW HAMPSHIRE. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

							RECORDING			
MANUFACTURER	MODEL	PARAMETER MEASURED	TYPE OF SENSOR	MEASUREMENT THRESHOLD	RANGE	ACCURACY	MEDIUM	SAMPLING PERIOD	SAMPLING FORMAT	REMARKS
CURRENT VELOCITY										
BENDIX	Q-15 Q-15H	Speed	Ducted impeller	0.04 knots	0 to 1 knots 0 to 5 knots switch selectable	± 3% or ± 0.05 kns which-ever is greater	Strip chart	16 days	Continuous	Rustrak Model 291 DC recorder
	Current Sensor and 270 Recorder	Direction	Vane with potentiometric direction transducer and compass		0° to 360°	± 12°	Strip chart	16 days	Continuous	
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day		16 days	3-hr cycling switch	3-hr event marks
BENDIX	Q-16/270	Speed	Ducted Impellor	0.04 knots	0 to 1 knot 0 to 5 knots switch selectable	±3% or ±0.05 knots which-ever is greater	Strip chart	16 days	Continuous	
		Direction	Vane with potentiometric direction trans-ducer and compass		0° to 360°	±12°	Strip chart	16 days	Continuous	
		Time	Bulova Accutron Cycle Timer	N/A	N/A	±2 sec/day		16 days	3 hour cycling switch	3-hr event marks
TEMPERATURE										
NAI	1000 Temperature Monitor	Temperature	Rustrak Model 1332 Thermistor		30 to 80 F 70 to 120 F	± 1.0 F or ± 0.46 C	Strip chart	14 days	Continuous	Rustrak Model 2133 DC recorder
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day		14 days	3-hr cycling switch	3-hr event marks
TIDE LEVEL										
MARSH-McBIRNEY Water-level Gauge	100	Tide Elevation	Gradient wire		17 ft	± 0.2 ft	Strip chart	14 days	Continuous	Rustrak model 288 DC recorder
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day		14 days	3-hr cycling switch	3-hr event marks
WIND										
R.M Young Field record-ing Wind set	6405	Speed	3 cup anemometer	1.5 kns	0 to 50 kns	± 1.0 kns	Strip chart	14 days	Continuous	Rustrak DC recorder built into unit
		Direction	Vane with potentiometer	N/A	0° to 360°	± 7°	Strip chart	14 days		
		Time	Bulova Model TE-11 Accutron Cycle Timer			± 2 sec/day		14 days	3-hr cycling switch	3-hr event marks
HYDROGRAPHIC PROFILES										
BECKMAN	RS5-3	Temperature	Thermistor		0 to 40 C	± 1.0 C	Manual Dial Reading		Continuous	
		Conductivity	Inductive		0 to 60 mmhos/cm	± 1.0 mmhos/cm				
		Salinity	D.C. Wheatstone Bridge Circuit utilizing temperature and conductivity input		0 to 40 °/oo	± 0.3 °/oo				
SALINITY										
Beckman	RS7-C	Salinity	Inductive		0-40 °/oo	±0.003 equivalent salinity	Digital Readout			Instrument measures the conductivity ratio of the sample to standard seawater

Seabrook Station intake and diffuser sites, and in the adjacent Hampton Harbor estuary.

2.1.2.1 Slack-water Surveys

As weather conditions permitted, these surveys were scheduled so as to examine typical monthly conditions, not unusual or extreme conditions, and to alternate with the plankton cruises (see Section 2.1.2.2) to maximize data coverage for each month. Each daily survey consisted of a sampling series keyed to high-water slack and a sampling series keyed to low-water slack. Each of the two sampling runs for any given survey took about 1.5 to 2.0 hrs, centered around NOAA-NOS predicted high water or low water. A fast boat was used to minimize cruising time between stations. At each station vertical profiles of temperature, conductivity and salinity were made with a Beckman RS5-3 salinometer (see Table 2.1-2 for instrument specifications). Sampling depths were: surface, 3.3 ft (1 m), 6.6 ft (2 m) and thereafter every 6.6 ft (2 m) to bottom. Duplicate water samples from near surface and near bottom were obtained at selected stations using Kemmerer or Niskin water samplers. These samples were used for laboratory determination of dissolved oxygen by azide modification of the Winkler method (U.S. Environmental Protection Agency, 1974), and of salinity with a Beckman Model RS7C Induction Salinometer referenced to standard seawater samples.

Sampling stations are shown in Figure 2.1-2. The actual sampling dates were as follows:

1976: January 29, February 27, March 26, April 21, May 26, June 18, July 20, August 24, September 21, October 28, November 22 (incomplete due to weather), December 2 (incomplete due to weather), and December 20.

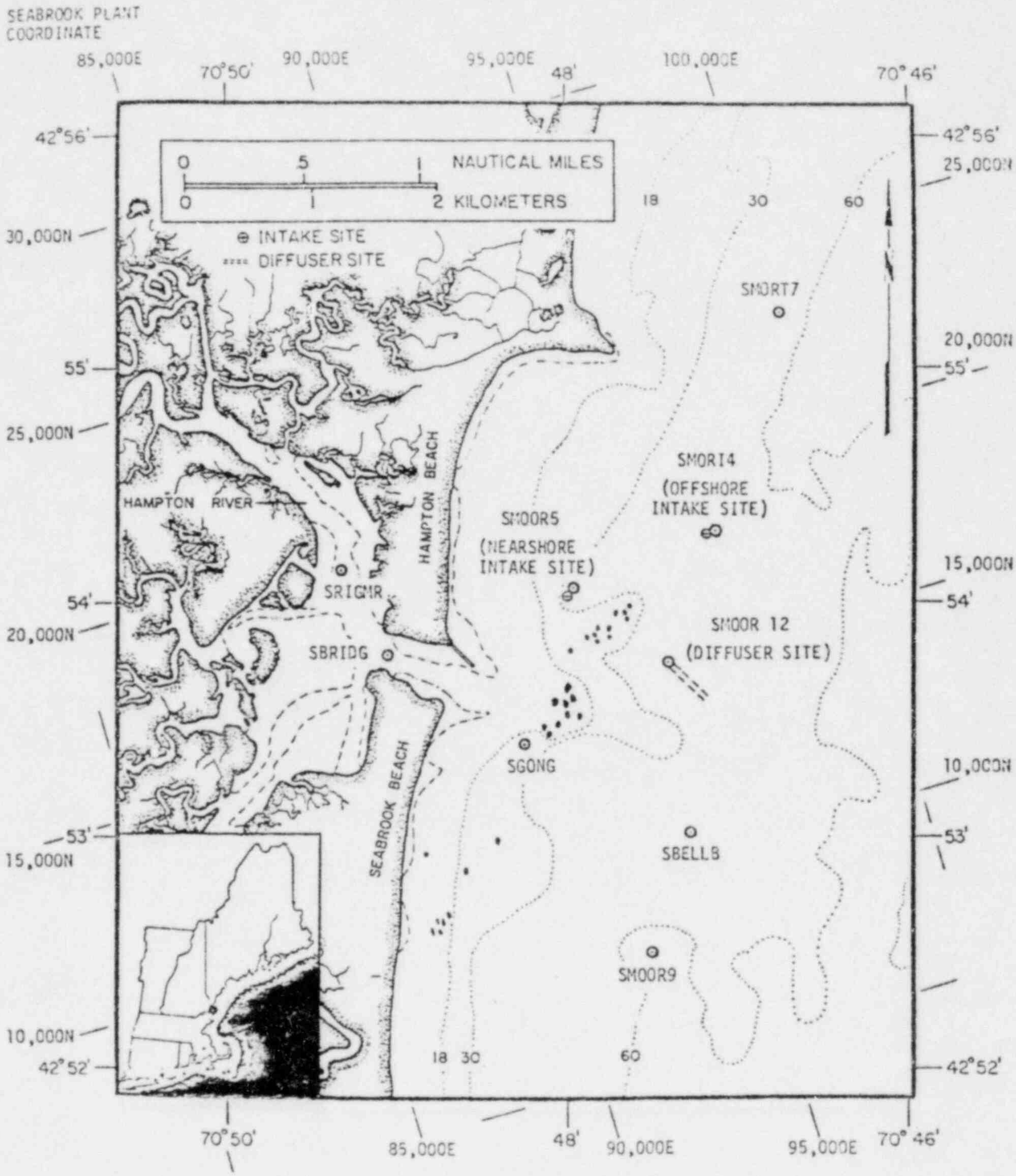

Figure 2.1-2. Location map for NAI slack-water survey sampling stations off Hampton Beach, New Hampshire, for 1976 Ecological Study Program. Seabrook 1976 Annual Hydrographic Report, 1979.

2.1.2.2 Plankton Cruises

As weather conditions permitted, plankton cruises were scheduled for alternate weeks from the slack-water runs and to avoid extremes such as storms. The stations at which no biological samples were to be collected were generally done separately, but typically within the same day.

During the cruises, water temperature, conductivity and salinity measurements were made at each station. Readings were taken at 6.6-ft (2-m) depth increments from the surface down to 132 ft (40 m) using a Beckman RS53 salinometer (see Table 2.1-2 for instrument specifications).

At each station paired water samples from near surface and near bottom were obtained using Niskin or Kemmerer water samplers. These samples were used for laboratory determination of dissolved oxygen and salinity, as described in Section 2.1.2.1.

Sampling station locations are shown in Figure 2.1-3. The sampling dates were as follows:

1976: January 15 and 16; February 10, 12 and 13; March 4; April 6; May 10; June 8; July 7; August 3; September 8 and 9; October 7; November 9; and December 6.

2.2 LABORATORY AND DATA PROCESSING METHODS

2.2.1 Temporal Monitoring Data

Current, temperature, tide elevation and wind data strip charts were all handled in the same general manner (for detailed description see NAI, 1977a). First each strip chart was carefully checked

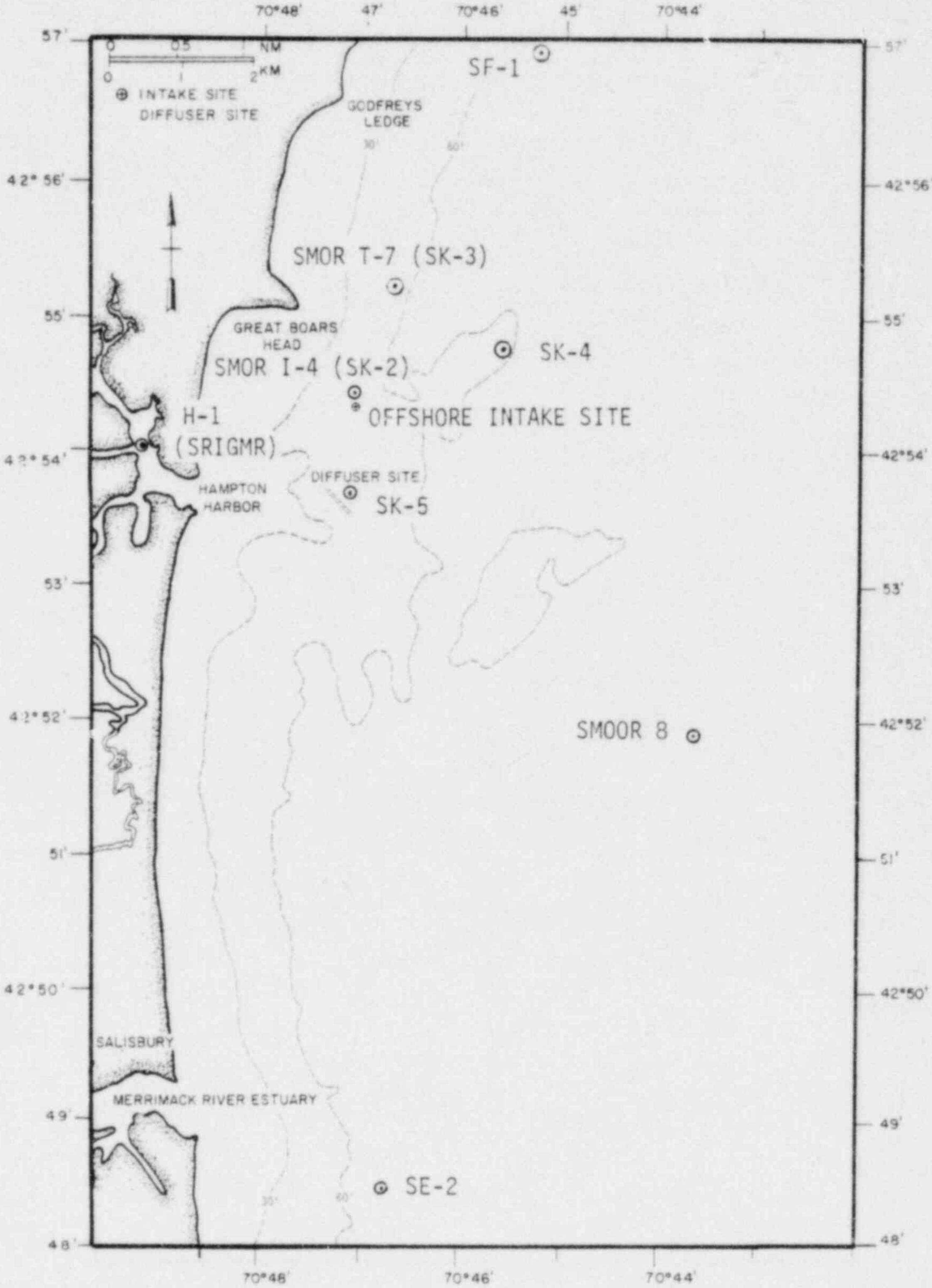

Figure 2.1-3. Location map for NAI plankton cruise sampling stations off Hampton Beach, New Hampshire, for 1976 Ecological Study Program. Seabrook 1976 Annual Hydrographic Report, 1979.

for correct start and end times, agreement with field check measurements, signs of any possible instrument malfunctions, and overall reliability. Then each strip chart was time based using the known start and end times and the 3-hr time marks. Next current and wind tapes were reduced into 20-min visual averages of speed and direction using standard conversion tables. The times and heights of each high and low water were also determined and entered onto the current and wind data sheets. Finally, data were keypunched and listed by computer to check for possible errors.

Temperature strip charts were digitized onto magnetic tape cassettes using a Numonics Model 274-133 Electronic Graphics Calculator, a Numonics Model 310 Interface and a Techtron Model 8400 Read/Write Unit. Then temperature cassette tapes were loaded onto NAI's IBM System 3 Model 12 computer for listing and editing. Data were tabulated and hourly average values were put onto punched cards.

Punched card data were processed by PSC's Engineering Department computer staff, using a st[illegible] series of plot and tabulation programs which have been deve[illegible]or their twin General Automation Model 18/30 computers.

2.2.2 Spatial Survey Data

Field hydrographic data sheets from slack-water surveys and plankton cruises were first checked for accuracy and completeness. Dissolved oxygen samples were processed in the laboratory using standard procedures (U.S. Environmental Protection Agency, 1974) and results entered onto the field sheets. Next data were keypunched and listed to check for possible errors.

Once checked for accuracy and completeness, the field data were run at PSC using their program "HYDS2". This program did the following: (1) converted depths to both ft and m, regardless of which

were input; (2) transformed temperature readings, based on instrument correction factors derived from annual laboratory calibration (NAI, 1977c); (3) converted resulting temperatures to both C and F; (4) transformed conductivity readings, based on instrument correction factors derived from annual laboratory calibration (NAI, 1977c); (5) calculated salinity from transformed temperature and conductivity; (6) calculated density or sigma-t from corrected temperature and salinity, using the Woods Hole Oceanographic Institution (WHOI) subroutine "SIGMA"; and (7) calculated the percent saturation of observed dissolved oxygen values using the equation of Gilbert *et al.* (1968).

The calculated salinity values were then compared to the reference salinity measurements obtained with the Beckman laboratory salinometer to verify the computer results. If differences of more than 0.3 to 0.4 $^{o}/oo$ were detected between the two, data were reexamined and rerun as necessary. Completed data were tabulated and manually plotted at NAI.

2.3 OTHER DATA

2.3.1 Air Temperature

Air temperature data from U.S. Weather Bureau stations at Portland, Maine and Boston, Massachusetts for 1973 through 1976 were obtained from NOAA-Environmental Data Service summaries (1973 to 1976). Monthly means of daily maximum and daily minimum temperatures were calculated from this information.

2.3.2 Regional Runoff

Mean daily and monthly average runoff data for 1973 through 1976 from the Merrimack River, the Piscataqua River basin, and the Saco River basin were obtained from the U.S. Geological Survey (1973 to 1976). These data were used to determine the approximate runoff into the western Gulf of Maine.

3.0 RESULTS

3.1 CURRENT AND WINDS

3.1.1 General

A flow classification scheme was developed for descriptive purposes in categorizing general coastal flow conditions off Hampton Beach (NAI, 1975a). Current-meter observations for each day were plotted as sequential vectors and categorized by dominant visual flow patterns using this scheme. Emphasis was placed on offshore mid-depth current meter moorings located seaward of the Outer Sunk Rocks, because these have been shown to document the general flow of water along the coast (NAI, 1977a). From this analysis the following six main types of flow have been identified (Figure 3.1-1): weak tidal flows, reversing flood- and ebb-tidal currents, moderate southward flow, strong southward flow, moderate northward flow, and strong northward flow.

3.1.2 Tidal Flows

In the absence of meteorological forcing functions, this flow type represents intervals when current-meter vectors demonstrate periodic changes in flow pattern such as flood- and ebb-tidal reversals (generally on a 6- to 7-hr basis) or a variable, weak tidal flow with periodic shifts of speed and direction.

The category of weak tidal flow represents variable conditions, but has a tendency toward periodic 180° reversals in direction. A 24-hr sequential-vector plot from August 12, 1976 illustrates this type of flow (Figure 3.1-1). This plot shows the observed 20-min average vectors of current speed and direction at each current meter for the day, referenced to Eastern Standard Time (EST). Vectors are plotted as direction toward which current was flowing.

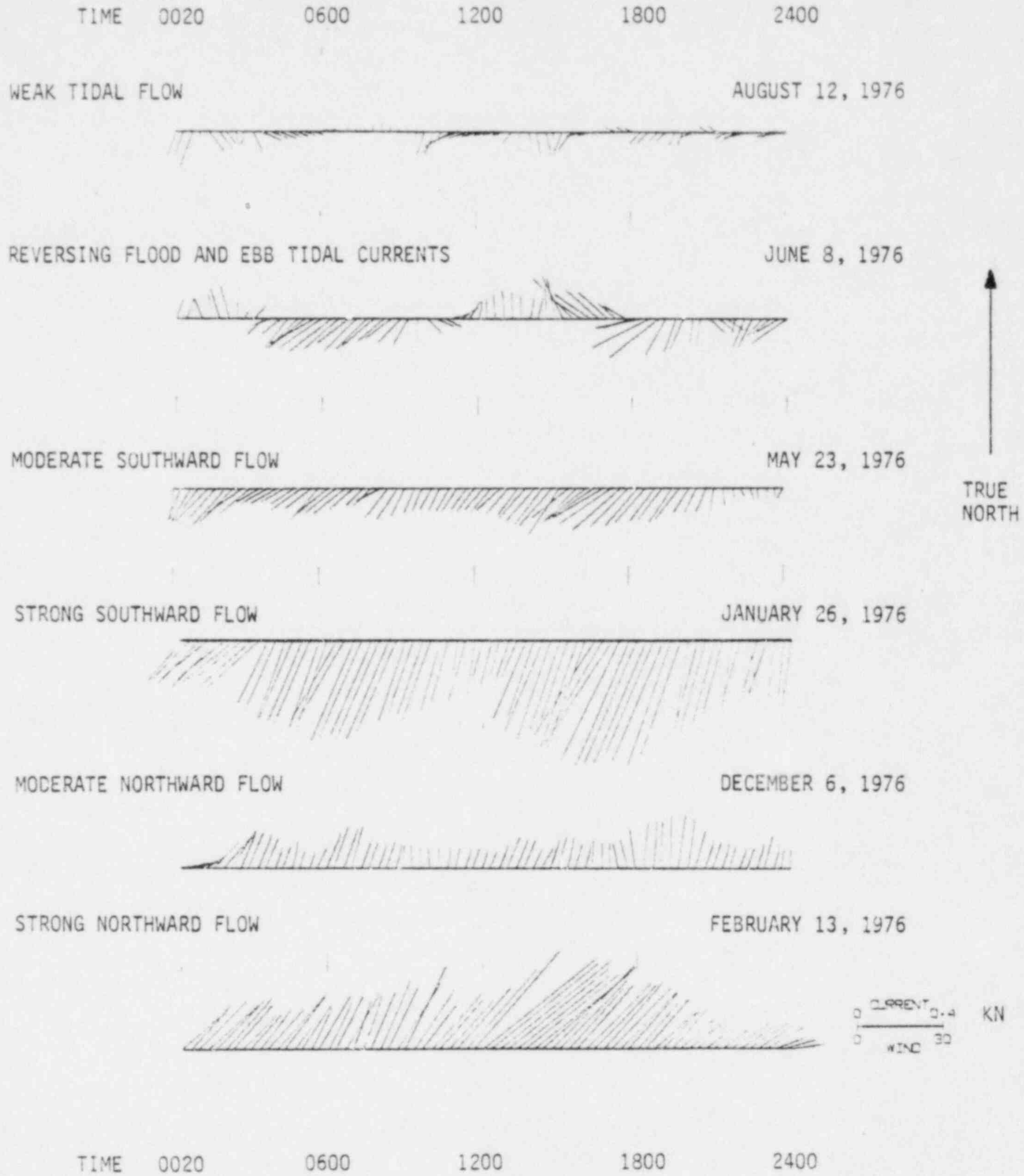

Figure 3.1-1. Examples of main types of current flows observed in coastal waters off Hampton Beach, New Hampshire (examples from 1976). Seabrook 1976 Annual Hydrographic Report, 1979.

The category of reversing flood- and ebb-tidal currents consists of strong, rhythmic sinusoidal reversals of current direction (generally at 6- to 7-hr intervals) made up of a northward-flowing, flood-tidal current and a southward-flowing, ebb-tidal current. As the flows reverse, a short period of weakening speeds or "slack" currents frequently occurs. Occasionally the currents demonstrate a more rotary character with little speed loss as direction changes. A 24-hr sequential-vector plot from June 8, 1976 illustrates this type of flow (Figure 3.1-1).

The most common type of flow in waters seaward of the Outer Sunk Rocks was transient or tidal flow, which comprised from 31.8 to 48.4 percent for 1973 to 1976 or about 40.4 percent overall (roughly one half) of the 4-year (1,437-day) study period from January 24, 1973 to December 31, 1976 (Table 3.1-1 and Figure 3.1-2). The most frequent flows of this type were reversing flood- and ebb-tidal currents, comprising from 6.6 to 34.2 percent for 1973 to 1976 or 20.7 percent overall. Weak tidal flows made up the remaining 11.9 to 27.0 percent for 1973 to 1976 or 19.7 percent overall.

3.1.3 Wind-Driven Flows

Winds play an important role in the movement of coastal waters in the study area. As a general rule, local winds push near surface waters downwind. The degree of influence of wind on water mass transport is directly related to: 1) the distance of exposed open water (fetch), 2) the duration of wind from a single direction, 3) the wind speed (stress) and 4) the water depth. Such influence first affects the topmost water, then can gradually deepen as the winds persist. Because of New Hampshire's geography and gently sloping sea-floor bathymetry, the greatest wind influence is longshore when winds blow from the north-northeast (northeaster storm) or from the south-southwest. When winds are blowing seaward, near surface waters are typically pushed offshore and a compensatory flow at depth moves landward. The strong-

TABLE 3.1-1. TABULATION OF CURRENT FLOW TYPES IN COASTAL WATERS SEAWARD OF THE OUTER SUNK ROCKS OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1973 THROUGH 1976. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

		NUMBER OF DAYS PER MONTH (PERCENTAGE)					
		TRANSIENT FLOW		STEADY STATE FLOW			
		TIDAL EFFECTS		FLOW TOWARD THE SOUTH		FLOW TOWARD THE NORTH	
MONTH	NO. OF DAYS IN MONTH	WEAK TIDAL FLOW	REVERSING FLOOD AND EBB TIDAL CURRENTS	MODERATE ABOUT 0.2-0.3 KN	STRONG GENERALLY >0.3 KN	MODERATE ABOUT 0.2-0.3 KN	STRONG GENERALLY >0.3 KN
1973							
January	7	2.0 (28.6)	0.0 (0.0)	3.0 (42.8)	2.0 (28.6)	0.0 (0.0)	0.0 (0.0)
February	28	2.0 (7.1)	8.0 (28.6)	9.0 (32.1)	8.0 (28.6)	1.0 (3.6)	0.0 (0.0)
March	31	8.0 (25.8)	6.0 (19.4)	3.5 (11.3)	10.0 (32.2)	3.5 (11.3)	0.0 (0.0)
April	30	3.0 (10.0)	9.0 (30.0)	2.0 (6.7)	5.5 (18.3)	4.0 (13.3)	6.5 (21.7)
May	31	4.0 (12.9)	16.5 (53.2)	6.0 (19.4)	4.0 (12.9)	0.5 (1.6)	0.0 (0.0)
June	30	6.0 (20.0)	12.0 (40.0)	5.5 (18.3)	4.0 (13.3)	2.5 (8.3)	0.0 (0.0)
July	31	4.5 (14.5)	20.0 (64.5)	6.0 (19.4)	0.0 (0.0)	0.5 (1.6)	0.0 (0.0)
August	31	4.5 (14.5)	13.0 (41.9)	9.0 (29.0)	3.0 (9.7)	1.5 (4.8)	0.0 (0.0)
September	30	8.5 (28.3)	16.0 (53.3)	0.0 (0.0)	2.0 (6.7)	2.5 (8.3)	1.0 (3.3)
October	31	3.0 (9.7)	9.5 (30.6)	2.0 (6.4)	4.0 (12.9)	7.5 (24.2)	5.0 (16.1)
November	30	0.5 (1.7)	3.5 (11.7)	0.5 (1.7)	0.0 (0.0)	15.5 (51.7)	10.0 (33.3)
December	31	2.5 (8.1)	3.0 (9.7)	5.5 (17.7)	2.5 (8.1)	14.0 (45.2)	3.5 (11.3)
TOTAL DAYS	341	48.5 (14.2)	116.5 (34.2)	52.0 (15.2)	45.0 (13.2)	53.0 (15.5)	26.0 (7.6)
PERCENT BY TYPE		(48.4)		(28.4)		(23.2)	
1974							
January	31	4.0 (12.9)	3.5 (11.3)	2.5 (8.1)	3.5 (11.3)	14.5 (46.8)	3.0 (9.7)
February	28	0.0 (0.0)	5.0 (17.8)	7.0 (25.0)	4.0 (14.3)	11.0 (39.3)	1.0 (3.6)
March	31	0.5 (1.6)	10.0 (32.2)	4.5 (14.5)	2.5 (8.1)	9.5 (30.6)	4.0 (12.9)
April	30	2.0 (6.7)	12.5 (41.7)	8.5 (28.3)	3.0 (10.0)	4.0 (13.3)	0.0 (0.0)
May	31	5.5 (17.7)	8.0 (25.8)	7.5 (24.2)	3.0 (9.7)	6.0 (19.4)	1.0 (3.2)
June	30	2.5 (8.3)	14.5 (48.3)	10.5 (35.0)	2.0 (6.7)	0.5 (1.7)	0.0 (0.0)
July	31	5.0 (16.1)	17.0 (54.8)	7.0 (22.6)	0.0 (0.0)	2.0 (6.4)	0.0 (0.0)
August	31	5.5 (17.7)	16.5 (53.2)	5.5 (17.7)	0.0 (0.0)	3.5 (11.3)	0.0 (0.0)
September	30	6.0 (20.0)	9.0 (30.0)	4.5 (15.0)	0.0 (0.0)	10.5 (35.0)	0.0 (0.0)
October	31	2.0 (6.4)	6.5 (21.0)	1.0 (3.2)	0.0 (0.0)	14.5 (46.8)	7.0 (22.6)
November	30	4.0 (13.3)	4.5 (15.0)	9.5 (31.7)	0.0 (0.0)	11.0 (36.7)	1.0 (3.3)
December	31	6.5 (21.0)	4.5 (14.5)	3.5 (11.3)	3.5 (11.3)	13.0 (41.9)	0.0 (0.0)
TOTAL DAYS	365	43.5 (11.9)	111.5 (30.5)	71.5 (19.6)	21.5 (5.9)	100.0 (27.4)	17.0 (4.6)
PERCENT BY TYPE		(42.5)		(25.5)		(32.0)	
1975							
January	31	3.0 (9.7)	3.5 (11.3)	10.0 (32.2)	1.0 (3.2)	12.5 (40.3)	1.0 (3.2)
February	28	5.5 (19.6)	3.0 (10.7)	6.0 (21.4)	3.0 (10.7)	10.5 (37.5)	0.0 (0.0)
March	31	7.0 (22.6)	9.0 (29.0)	4.0 (12.9)	5.5 (17.7)	4.5 (14.5)	1.0 (3.2)
April	30	9.0 (30.0)	2.0 (6.7)	8.5 (28.3)	4.0 (13.3)	5.5 (18.3)	1.0 (3.3)
May	31	9.5 (30.6)	1.0 (3.2)	15.5 (50.0)	3.0 (9.7)	1.0 (3.2)	1.0 (3.2)
June	30	9.5 (31.7)	5.0 (16.7)	8.0 (26.7)	5.5 (18.3)	2.0 (6.7)	0.0 (0.0)
July	31	12.5 (40.3)	4.0 (12.9)	7.0 (22.6)	3.5 (11.3)	4.5 (14.5)	0.0 (0.0)
August	31	12.0 (38.7)	4.0 (12.9)	7.0 (22.6)	3.5 (11.3)	4.5 (14.5)	0.0 (0.0)
September	30	4.5 (15.0)	2.5 (8.3)	3.0 (10.0)	0.0 (0.0)	15.0 (50.0)	5.0 (16.7)
October	31	9.5 (30.6)	0.0 (0.0)	3.5 (11.3)	6.0 (19.4)	11.0 (35.5)	1.0 (3.2)
November	30	5.5 (18.3)	3.0 (10.0)	4.0 (13.3)	1.0 (3.3)	13.0 (43.3)	3.5 (11.7)
December	31	10.5 (33.9)	1.0 (3.2)	10.5 (33.9)	3.0 (9.7)	5.5 (17.7)	0.5 (1.6)
TOTAL DAYS	365	98.5 (27.0)	45.0 (12.3)	84.0 (23.0)	35.5 (9.7)	88.0 (24.1)	14.0 (3.8)
PERCENT BY TYPE		(39.3)		(32.7)		(28.0)	
1976							
January	31	7.5 (24.2)	0.0 (0.0)	9.5 (30.6)	6.5 (21.0)	7.5 (24.2)	0.0 (0.0)
February	29	6.5 (22.4)	0.0 (0.0)	5.5 (19.0)	5.5 (19.0)	9.5 (32.8)	2.0 (6.9)
March	31	5.5 (17.7)	0.0 (0.0)	7.5 (24.2)	5.5 (17.7)	11.5 (37.1)	1.0 (3.2)
April	30	8.5 (28.3)	0.0 (0.0)	9.5 (31.7)	2.5 (8.3)	8.5 (28.3)	1.0 (3.3)
May	31	10.0 (32.2)	4.0 (12.9)	3.5 (11.3)	2.0 (6.4)	9.5 (30.6)	2.0 (6.4)
June	30	14.5 (48.3)	4.0 (13.3)	4.5 (15.0)	0.5 (1.7)	6.5 (21.7)	0.0 (0.0)
July	31	12.5 (40.3)	6.5 (21.0)	2.5 (8.1)	1.5 (4.8)	6.0 (19.4)	2.0 (6.4)
August	31	9.0 (29.0)	5.0 (16.1)	5.5 (17.7)	0.5 (1.6)	9.5 (30.6)	1.5 (4.8)
September	30	8.5 (28.3)	1.0 (3.3)	11.0 (36.7)	0.5 (1.7)	7.5 (25.0)	1.5 (5.0)
October	31	2.5 (8.1)	2.0 (6.4)	7.5 (24.2)	0.0 (0.0)	15.5 (50.0)	3.5 (11.3)
November	30	1.5 (5.0)	0.0 (0.0)	4.0 (13.3)	0.0 (0.0)	24.5 (81.7)	0.0 (0.0)
December	31	6.0 (19.4)	1.5 (4.8)	5.5 (17.7)	0.0 (0.0)	15.5 (50.0)	2.5 (8.1)
TOTAL DAYS	366	92.5 (25.3)	24.0 (6.6)	76.0 (20.8)	25.0 (6.8)	131.5 (35.9)	17.0 (4.6)
PERCENT BY TYPE		(31.8)		(27.6)		(40.6)	
SUMMARY: 1973 TO 1976							
TOTAL DAYS =	1437	283.0	297.0	283.5	127.0	373.5	73.0
PERCENT		(19.7)	(20.7)	(19.7)	(8.8)	(26.0)	(5.1)
PERCENT BY TYPE		(40.4)		(28.6)		(31.0)	

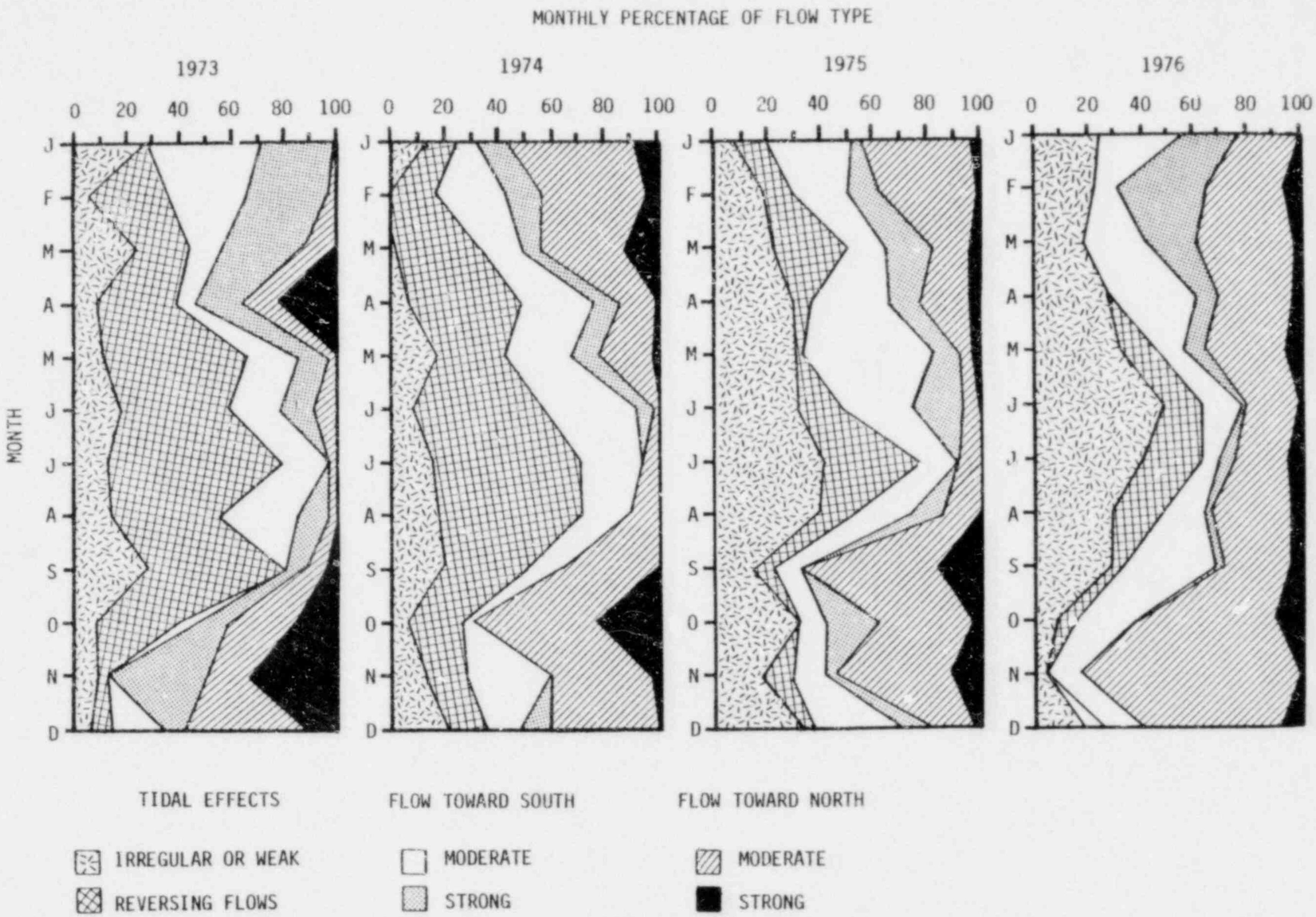

Figure 3.1-2. Distribution of monthly percentage of observed current flow types for coastal waters off Hampton Beach, New Hampshire, from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

est wind effects always accompany northeast storms because of the large fetch across the Gulf of Maine. During such storms, near surface waters are often carried southwestward at speeds of 1.0 kn (51.5 cm/sec) or more (NAI, 1975a).

3.1.3.1 Southward Flows

Under the influence of the first type of meteorological forcing function (winds from the north and northeast), southward flows are manifested by southward current vectors which show a sustained steady-state flow along the coast. Such flow essentially masks out the weaker tidal currents, frequently persisting for days at a time.

Moderate southward flows (about 0.2 to 0.3 kn or 10.3 to 15.4 cm/sec) are generally stronger than typical mean tidal current speeds. A 24-hr sequential-vector plot from May 23, 1976 illustrates this type of flow (Figure 3.1-1). Strong southward flows (greater than about 0.3 kn or 15.4 cm/sec) are faster than typical mean tidal current speeds. Such flows average 0.4 to 0.6 kn or 20.5 to 30.9 cm/sec and may occasionally exceed 1.0 kn (51.5 cm/sec). A 24-hr sequential-vector plot from January 26, 1976 illustrates this type of flow (Figure 3.1-1).

3.1.3.2 Northward Flows

Under the influence of the second type of meteorological forcing function (winds from the south and southwest), northward flows are manifested by northward current vectors which show a sustained steady-state flow along the coast. Such flow essentially masks out the weaker tidal currents, frequently persisting for days at a time.

Moderate northward flows (about 0.2 to 0.3 kn or 15.4 cm/sec) are generally stronger than typical mean tidal current speeds. A 24-hr sequential-vector plot from December 6, 1976 illustrates this type of

flow (Figure 3.1-1). Strong northward flows (greater than about 0.3 kn or 15.4 cm/sec) are faster than typical mean tidal current speeds. Such flows average 0.3 to 0.5 kn or 15.4 to 25.7 cm/sec and may occasionally exceed 1.0 kn (51.5 cm/sec). A 24-hr sequential vector plot from February 13, 1976 illustrates this type of flow (Figure 3.1-1).

In terms of actual current directions, it should be noted that the "flow toward the south" and the "flow toward the north" categories are essentially the same as the ebb or flood portions, respectively of a reversing tidal flow. The only difference is that they have persisted as a steady-state condition for a longer period.

The steady-state flows toward the south and the north were about equally distributed, being 25.5 to 32.7 percent or 28.6 percent overall for the former and 23.2 to 40.6 percent or 31.0 percent overall for the latter; Table 3.1-1 and Figure 3.1-2). The southerly flows, which occurred roughly one fourth of the year, were generally the result of northeasterly storms and occasional periods of north to northwesterly winds. Such flows essentially masked out the tidal currents and frequently persisted unabated for days at a time. Moderate southward flows comprised about 15.2 to 23.0 percent for 1973 to 1976 or 19.7 percent overall. Strong flows comprised 5.9 to 13.2 percent or 8.8 percent overall. Correspondingly, the northward flows generally occurred during the remaining one-fourth of the year in conjunction with strong south-to-southwest winds or as possible seiching in the western Gulf of Maine following storm surges. Moderate northward flows comprised about 15.5 to 35.9 percent or 26.0 percent overall, whereas strong flows were observed about 3.8 to 7.6 percent or 5.1 percent overall (Table 3.1-1).

3.1.3.3 Comparison With Flow Patterns of Other Years

As during previous years, transient flows in 1976 were most prevalent during summer months, when meteorological conditions tend to be fairly stable (Figure 3.1-2). The northerly flows were most preva-

lent during the late fall and winter months. October, November and December 1976 showed a predominance of northward flows, more so than during any of the previous years of observations (overall northward flow of 40.6 percent). During 1976, the southerly flows occurred about equally during almost every month of year, reflecting the periodic passage of eastward-moving low-pressure systems and associated northeasterly wind events.

3.1.4 Wind Conditions

Four years of summary wind data collected at Hampton Beach State Park from January 24, 1973 through December 19, 1976 (Figure 3.1-3) illustrate that predominant winds (about 23 percent of the time) have been from the west at a mean speed of 7.3 kns (3.8 m/sec). Winds from the southwest and northwest are next most common, with mean speeds to 7.9 kns and 6.4 kns, respectively (4.1 and 3.3 cm/sec). Highest speeds have been from the northeast (mean speed of 8.6 kns or 4.4 m/sec), but such winds are not prevalent. Overall data are tabulated in Figure 7.3-1.

Annual wind variations over the period from November 30, 1975 through December 19, 1976 are shown in Figure 3.1-4. During the winter months predominant winds were from the northwest and west at mean speeds of 8.6 kns and 11.9 kns, respectively (4.4 and 6.1 cm/sec). Strongest winds were from the northeast and east (mean speeds up to 13.5 kns or 6.9 m/sec). During the spring of 1976, winds were somewhat calmer and southwesterly winds were more prevalent. In the summer, west and southwest winds predominated, but mean speeds were much lower than they had been earlier in the year (7.2 to 8.6 kns or 3.7 to 4.4 m/sec). Winds at this time of the year are generally light and variable, with less tendency for any preferential directions (Figure 7.2-1). In the fall, winds picked up again with strongest gusts coming in from the southwest (mean speeds up to 10.2 kns or 5.2 cm/sec). In summary, winds at Hampton Beach vary considerably from month to month, but overall patterns from year to year have been fairly consistent (Figure 7.2-1).

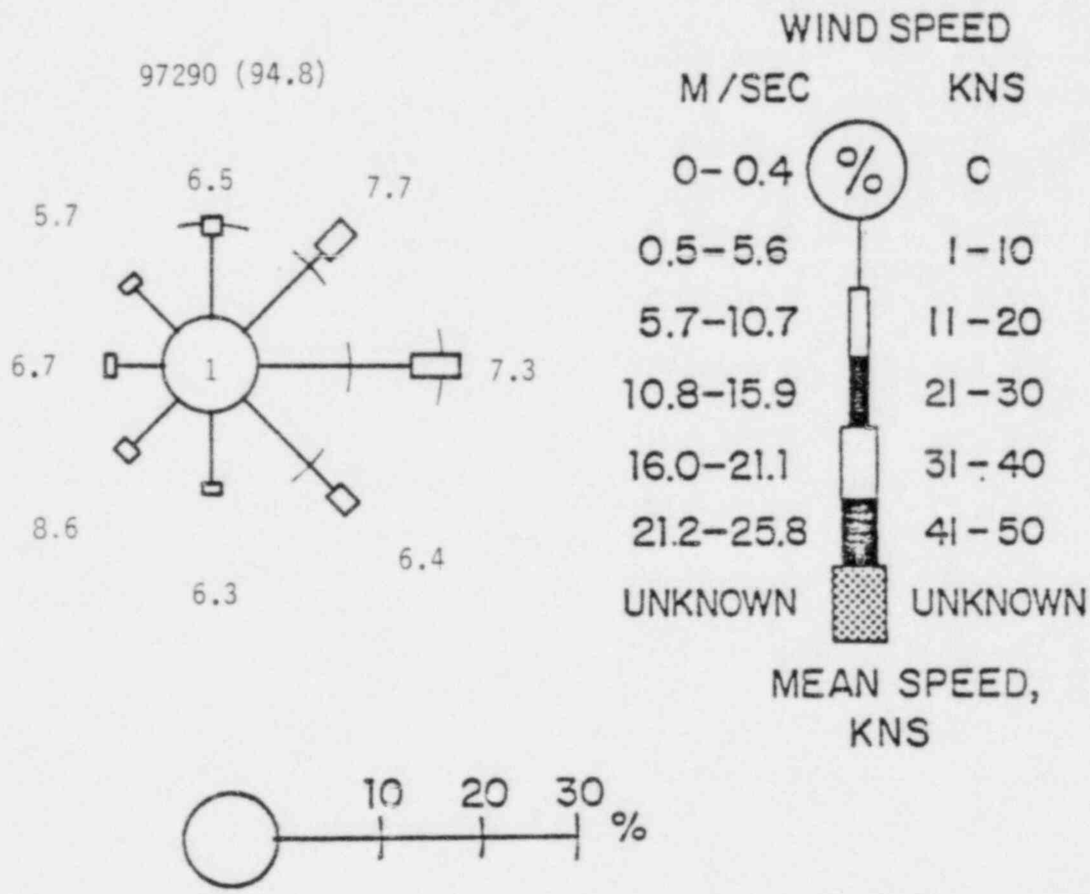

Figure 3.1-3. Rose diagram showing percentage-frequency of wind (direction toward which wind was blowing) measured by NAI at Hampton Beach, New Hampshire from January 24, 1973 to December 19, 1976. Total possible 20-min observations for period = 102,784. Seabrook 1976 Annual Hydrographic Report, 1979.

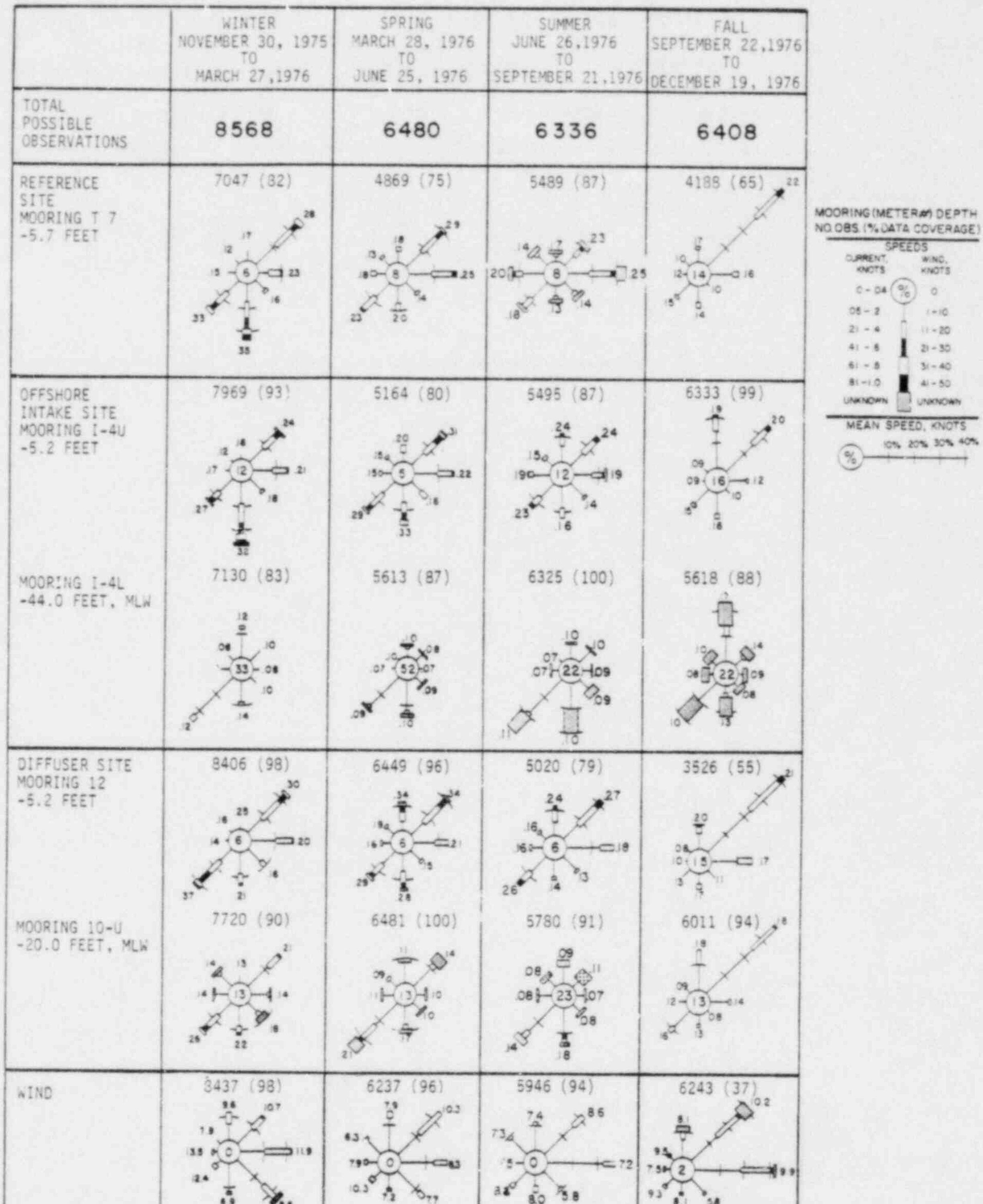

Figure 3.1-4. Rose dia,rams of currents and local winds off Hampton Beach, New Hampshire, for the winter, spring, summer and fall seasons of 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

3.1.5 Spatial Current Conditions

Regional current flow patterns northward or southward along the coast tend to be consistent from site to site for any particular depth. Because of wind influence, strongest flows always occur closest to the surface.

3.1.5.1 Diffuser Site

Coastal flows at the diffuser site located about 1 n mi (2 kn) off Hampton Beach (Figure 2.1-1) have shown pronounced variations with season and with depth. Near surface flows at Mooring 12 have been generally strong, with a pronounced bimodality toward the northeast and south. At Mooring 10 upper, located about mid-depth, currents have been somewhat weaker, but overall patterns have been similar to Mooring 12. Near bottom at Mooring 10 lower, flows have been quite weak, generally toward the west and northwest due to local topography and compensatory landward flows.

I. SEASONAL VARIATIONS IN FLOW PATTERNS

During the winter months, winds and storms generally play a dominant role in coastal circulation in the waters off Hampton Beach, New Hampshire and in the western Gulf of Maine. The current patterns observed during the winter months of 1976 (lunar months November 30, 1975 to March 27, 1976; Figure 3.1-4) were quite similar to those observed during the winters of 1973, 1974 and 1975 (NAI, 1975a)*. Dominant winds were from the west and northwest at mean speeds of 11.9 kns (6.1 m/sec) and 8.6 kns (4.4 m/sec), respectively. Strongest winds

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* Note that rose diagrams represent direction toward which current was flowing or wind was blowing. See figure legends for additional details.

were from the northeast and east at mean speeds of 12.4 kn (6.4 m/sec) and 13.5 kn (6.9 m/sec), respectively. This distribution was similar to wintertime wind conditions of previous years (Figure 7.2-1).

At Mooring 12, prevalent flow toward the northeast and east at mean speeds of 0.20 to 0.30 kn (10.4 to 15.4 cm/sec) was observed. These flows were nearly balanced by south-to-southwesterly currents averaging 0.21 to 0.37 kn (10.8 to 19.0 cm/sec), as illustrated by the pronounced bimodality of the rose diagrams. The alternating northward and southward wind-driven flows is clearly shown in the data from February 1 to 16, 1976 (Figure 3.1-5). During the winter of 1974, flows were northward or southward, with little southwestward flow. In 1975, flows had a strong north and northeastward component (Figure 7.2-2).

Deeper in the water column at Mooring 10 upper, flows in other directions were more evident; however, the prevailing currents were still toward the northeast and the southwest. These flows had mean speeds of 0.21 kn (10.8 cm/sec) and 0.26 kn (13.4 cm/sec), respectively. This pattern was quite similar to flows observed during previous winters (Figure 7.2-3).

Near bottom at Mooring I-4 lower, overall currents have been much weaker with lower mean speeds and with 33 percent of the observations falling below threshold of the current sensor (NAI, 1977a). Nevertheless, predominant flows were still toward the southwest (mean speed of 0.12 kn or 6.2 cm/sec) and the north (also 0.12 kn or 6.2 cm/sec).

During the spring months, storms generally continue to play an important role in coastal circulation with the tides beginning to show more of an influence, especially during periods of calm weather. Dominant winds are still from the western quadrant, but stronger components from the northeast and southeast are observed (Figure 7.2-2 and PSC, 1973). The predominant near-surface current flows (Mooring 12) in the spring (lunar months of March 28 to June 7, 1976; Figure 3.1-4) were

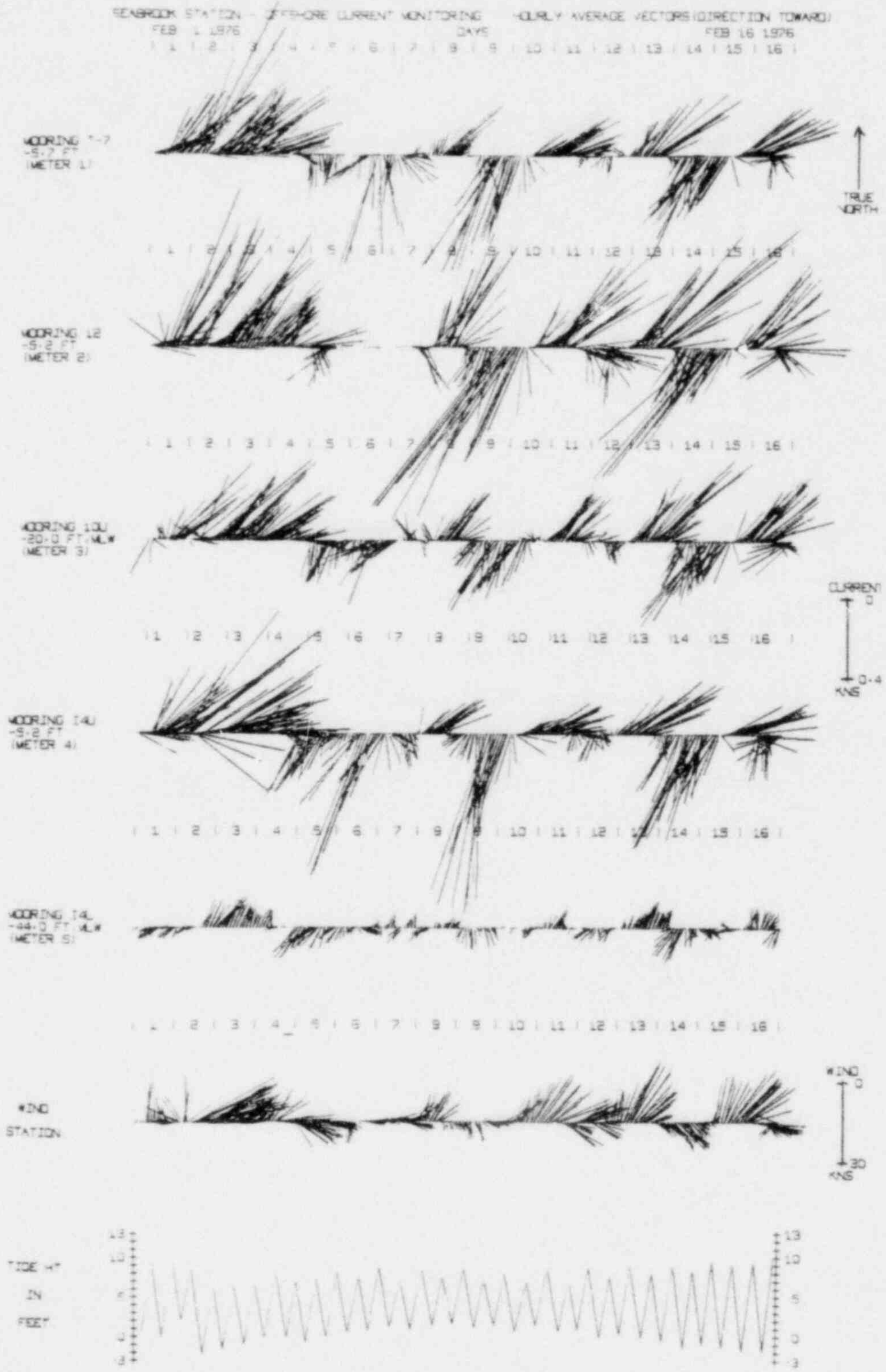

Figure 3.1-5. Typical wintertime hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for February 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1978.

generally toward the south and southwest quadrants, at about the same mean speeds (about 0.28 to 0.29 kn or 14.4 to 14.9 cm/sec) as equivalent flows during the preceding winter months. Northeastward currents were nearly as common as in the winter, but their mean speeds were greater (0.34 kn or 17.5 cm/sec). This bimodal pattern was primarily the result of combined effects of northeasterly and southwesterly storm winds, which pushed nearshore waters either southward or northward along the coast. The annual peak in development of the southerly flow of the counterclockwise Gulf of Maine gyre also typically occurs during the late spring (largely as a consequence of spring runoff). This phenomenon reinforced the southward net drift of coastal waters at this time of year. The influence of tides during the calmer atmospheric periods between storms was apparent from the more equal flow distributions in the various direction classes (Figure 7.2-2).

Flows at the diffuser site showed pronounced shearing. This was illustrated by the weaker mean speeds (about 0.21 kn or 10.8 cm/sec southward and 0.14 kn or 7.2 cm/sec northeastward) and higher percent calm (Figure 3.1-4) at Mooring 10 upper (at about -20.0 ft or 6.1 m below MLW). Nevertheless, predominant mid-depth and near-bottom flows were still toward the southwest (Figure 7.2-3).

During the summer months, storms are less frequent and less intense, making tidal effects more apparent. The wind pattern also becomes quite different, with most of the winds either from the southwest, northwest or the southeast at relatively slow speeds (Figure 7.2-1 and PSC, 1973). Typically, winds blow onshore during the day and offshore at night under the influence of the thermal differential between the land and the sea. During the summer months of 1976 (lunar months of June 26 to September 21, 1976; Figure 3.1-4) flows at the diffuser site were generally weak and variable in all directions. This distribution was because of increased dominance of tidal effects. At Mooring 12, occasional summertime northeast storms accounted for the strong southwestward component (mean speed of 0.26 kn or 13.4 cm/sec). During the summer, observed current speeds weaker than 0.05 kn (2.6 cm/sec) occurred

more frequently than during other times of the year. During periods of tidal domination, flows alternated between northward flood and southward ebb, but there was generally a net residual drift of 2 to 3 n mi (4 to 6 kn) per day southward along the coast as part of the counterclockwise Gulf of Maine gyre. This tidal oscillation is clearly shown in the data from July 17 to 31, 1976 (Figure 3.1-6). Nevertheless, note that several periods of strong winds masked the tidal influence, causing strong northward flows (July 21 to 24) and strong northward flows (July 30 and 31). Flows showed considerable variation from one depth to another at the diffuser site. Near surface at Mooring 12, northeasterly and southwesterly flows were nearly balanced. Speeds were below 0.05 kn (2.6 cm/sec) during only 6 percent of the summer. At Mooring 10 upper located at mid-depth, flow was more southerly and about 23 percent of the speeds were below 0.05 kn (2.6 cm/sec). This pattern has remained consistent from summer to summer (Figures 7.2-2 and 7.2-3).

Storms begin to intensify during the fall season, with dominant winds generally from the northwest and secondary components from the northeast and southwest (Figure 7.2-1 and PSC, 1973). During the fall of 1976 (lunar months September 22 to December 19, 1976) both the predominant and the strongest winds were from the west and southwest at mean speeds of 9.9 to 10.2 kns (51.0 to 52.5 m/sec; Figure 3.1-4). Currents were generally quite different from those observed during other seasons, apparently as a result of southwest winds and breakdown in the flow of the Gulf of Maine gyre. Distinct shearing along the halocline and thermocline separating the upper and lower portions of the water column was observed, especially during the early fall as the Gulf of Maine began to cool.

Near-surface currents at Mooring 12 tended to follow the wind, whereas flows at depth were more influenced by the tides and occasional compensatory flows during stormy periods. Mooring 12 showed about 41 percent of flows toward the northeast at a mean speed of 0.21 kn (10.8 cm/sec). Remaining flows in the other directions were somewhat weaker (about 0.08 to 0.17 kn or 4.1 to 8.7 cm/sec). Flows slightly deeper at

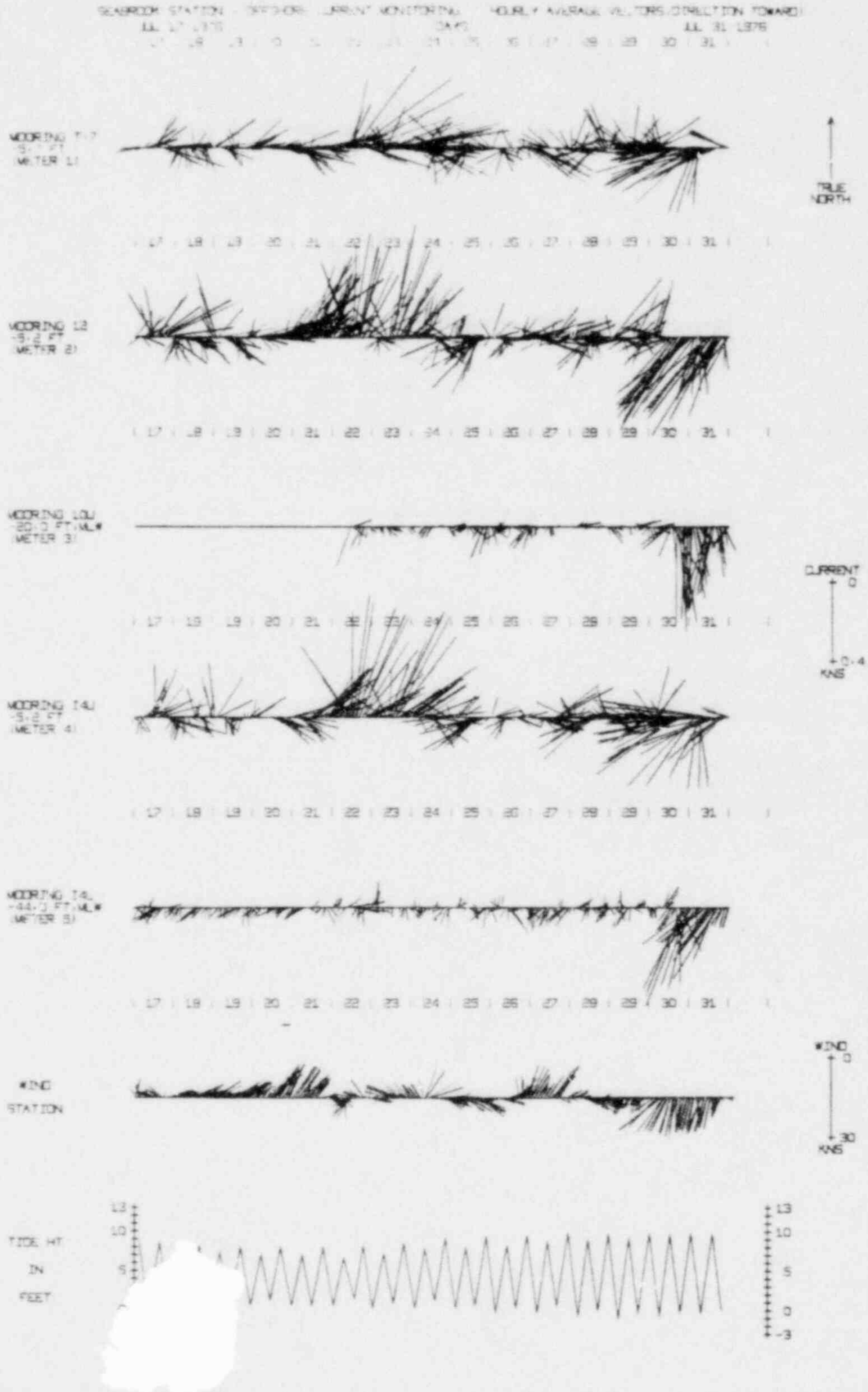

Figure 3.1-6. Typical summertime hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for July 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1978.

Mooring 10 upper showed a similar pattern, but overall speeds were slightly weaker (Figure 3.1-4). Thus, for all of the fall months in 1973 through 1976, predominant flows at this location have generally been toward the northeast. In 1974 and 1975 some strong southeastward and southwestward flows were also observed (Figures 7.2-2 and 7.2-3).

II. OVERALL FLOW PATTERNS

Summary tabulations of Mooring 12 data from November 16, 1973 to December 19, 1976 showed that about 9 percent of the flows were less than 0.05 kn (2.6 cm/sec), or essentially below the starting threshold of the Bendix Q-15 current meter (Figure 7.3-2). These data showed a pronounced bimodality toward the northeast and the south. About 46 percent of the flows were 0.05 to 0.2 kn (2.6 to 10.3 cm/sec), with gradually decreasing percentages up to about 1 percent for 0.81 to 1.0 kn or 41.7 to 51.5 cm/sec.

Slightly deeper at Mooring 10 upper, about 18 percent of the flows were 0.04 kn (2.0 cm/sec) or less (Figure 7.3-3). The directional data showed a similar bimodality to the flows at Mooring 12 except that the northeastern quadrant was less dominant. The majority of flows (60 percent) were in the 0.05 to 0.2 kn (2.6 to 10.3 cm/sec) speed class.

Near bottom at Mooring 10 lower, observed flows were much weaker (49 percent were 0.04 kn or 2.0 cm/sec and less) and the dominant flows were toward the west and northwest (NAI, 1977a). This pattern appeared to be due to effects of local bottom topography and compensatory landward flows similar to the trajectory data from sea-bed drifters (NAI, 1975a and 1975b). About 45 percent of all flows were in the 0.05 to 0.2 kn (2.6 to 10.3 cm/sec) class.

3.1.5.2 Offshore Intake Site

Although less data have been collected at the offshore intake site than at some other locations off Hampton Beach (Figures 1.1-2 and 2.1-1), there is sufficient information to show that the flow patterns are basically the same as at the diffuser site. This similarity illustrates the influence of the coastline, tides and local winds, all combining to cause longshore flows of nearshore waters either northward or southward.

I. SEASONAL VARIATIONS IN FLOW PATTERNS

During the winter of 1976, the near-surface current patterns at Mooring I-4 upper were quite similar to those at Mooring 12 (Figure 3.1-4). Mean speeds were slightly lower, the percentage of flows below current meter threshold was slightly higher (12 percent versus 6 percent for Mooring 12), and flows were more southward, probably because this location is outside the influence of local bedrock outcropping on the sea floor (such as the influence the Sunk Rocks have on Mooring 12). Monthly rose diagrams for the same period are shown in Appendix Figure 7.2-4. Near-bottom flows at Mooring I-4 lower were much weaker (33 percent were below 0.05 kn or 2.6 cm/sec) and predominantly toward the southwest (Figures 3.1-4 and Appendix Figure 7.2-5).

During the spring season of 1976, near-surface flows at Mooring I-4 upper were nearly identical to those at Mooring 12 (Figures 3.1-4 and Appendix Figure 7.2-4). Near-bottom flows were much weaker than during the winter (52 percent were below 0.05 kn or 2.6 cm/sec), but still primarily toward the south and southwest (Figures 3.1-4 and Appendix Figure 7.2-5).

Summer season flows at the offshore intake site during 1976 showed much-weaker near-surface currents than earlier in the year (12 percent below 0.05 kn or 2.6 cm/sec) and a greater tidal influence with

nearly equal flows in every direction (Figures 3.1-4 and Appendix Figure 7.2-4). Near-bottom flows continued to show south to southwestward storm-driven currents superimposed on weak tidal flows (Figure 3.1-4 and Appendix Figure 7.2-5).

In the fall of 1976, near-surface flows at this location were predominantly toward the north and northeast, in response to regional wind patterns (Figures 3.1-4 and Appendix Figure 7.2-4). Near-bottom flows showed both the northward storm-driven influence and the south-to-southwestward "northeaster" storm influence (Figures 3.1-4 and Appendix Figure 7.2-5).

II. OVERALL FLOW PATTERNS

Summary tabulations of Mooring I-4 upper data from September 4, 1975 to December 19, 1976 showed that near-surface flows have been predominantly southward and northeastward (Appendix Figure 7.3-4). About 10 percent have been below 0.05 kn or 2.6 cm/sec, about 46 percent have been 0.05 to 0.2 kn (2.6 to 10.3 cm/sec), about 29 percent have been 0.21 to 0.4 kn (10.8 to 20.6 cm/sec) and about 15 percent were 0.41 to 1.0 kn (21.1 to 51.5 cm/sec).

Over a similar time period, near-bottom flows at Mooring I-4 lower have been much weaker and predominantly southwestward (Appendix Figure 7.3-5). About 34 percent have been below current meter threshold speed (0.05 kn or 2.6 cm/sec), about 59 percent have been 0.05 to 0.2 kn (2.6 to 10.3 cm/sec), and only about 7 percent from 0.21 to 1.0 kn (10.8 to 51.5 cm/sec). These data show good agreement with earlier observations from old NAI Mooring 1 at about the same location and depth (NAI, 1975a) and are consistent with the general patterns of near bottom water movement as deduced from sea-bed drifter studies.

3.1.5.3 North of Diffuser and Intake Sites

At Mooring T-7, located northeast of Great Boars Head, flow patterns were very similar to those observed at Moorings 12, I-4 upper and 10 upper (Figures 3.1-4 and 7.2-6). Flows during the winter of 1976 were predominantly northeastward and south-to-southwestward, with about 6 percent of flows weaker than 0.05 kn (2.6 cm/sec). Springtime flows were also northeastward and southwestward with a pronounced offshore or eastward component (which was also evident at Mooring I-4 upper). Flows during the summer of 1976 were tidally dominated with more eastward and westward flows than is typically observed (Figure 7.2-6). In the fall of 1976, flows were strongly northeastward, as at Moorings I-4 upper, 12 and 10 upper (Figure 3.1-4). Summary data from April 16, 1974 through December 19, 1976 show that about 13 percent of the time current speeds were 0.04 kn (2.0 cm/sec) or less (Figure 7.3-6). About 55 percent of the flows were 0.05 to 0.2 kn (2.6 to 10.3 cm/sec) and 32 percent were 0.21 to 10. kn (10.8 to 51.5 cm/sec).

3.1.5.4 South of Diffuser and Intake Sites

Flows at Moorings 7 and 9, which were located south of the primary study area (Figure 2.1-1), have been very similar to those previously described. Observed flows in this area have been strongly bimodal toward the north and the south to southwest. This information further confirms the consistent pattern of flows from site to site along the coast and from near surface to near bottom (NAI, 1977a).

3.1.5.5 Offshore Flows

Year-round current meter data collected at Mooring T-4 at a distance of 4.1 n mi (7.6 km) off Hampton Beach in 132 ft (40.2 m) of water (at MLW) also showed pronounced seasonal variations (NAI, 1977a).

Near surface flows at 20 ft (6.1 m) below MLW showed the northward flows typical of fall, the bimodal northward and southward currents typical of winter, and the strong southward currents typical of spring, caused primarily by the Gulf of Maine gyre and northeast storm winds (Bumpus and Lauzier, 1965 and Csanady, 1974). By late summer and early fall, the northerly flows were again observed (NAI, 1977a). The data also showed periodic "coupling" of nearshore waters to offshore waters, forming storm-driven coastal boundary layers.

3.1.6 Net Wind Displacement and Stress

Wind measurements in the Hampton Beach area from January 1973 through December 1976 were compiled to determine net monthly transport or displacement (referenced toward which the wind was blowing). The onshore/offshore or east/west components show that the wind blows predominantly offshore (Figure 3.1-7). Greatest wind transport was seen in the fall and winter months (up to 150 n mi or 278 km per day in February 1976). During the late spring of the first three years of studies, there was a short period of onshore net transport (up to about 25 n mi or 46.3 km/day in June 1974). This phenomenon was not observed during 1976.

The longshore or north/south transport components show a more complex pattern (Figure 3.1-7). During the winter months, wind transport has been generally southward (up to 69 n mi or 127.8 km/day in February 1973), except for February and March of 1976 when it was northward. The spring and early summer months have generally shown a northward component of longshore wind transport (up to 85 n mi or 157.5 km/day in May 1976). During the fall and early winter, conditions have varied from year to year. That is, 1973 showed southward transports (up to 25 n mi or 46.3 km/day), 1974 showed northward transports (up to 40 n mi or 74.1 km/day), 1975 showed both northward and southward transports and 1976 had strongly northward wind transports (up to 75 n mi or 139.0 km/day). Thus, these wind data document a general seasonality and a close link to coastal currents, but no clear correlation to overall

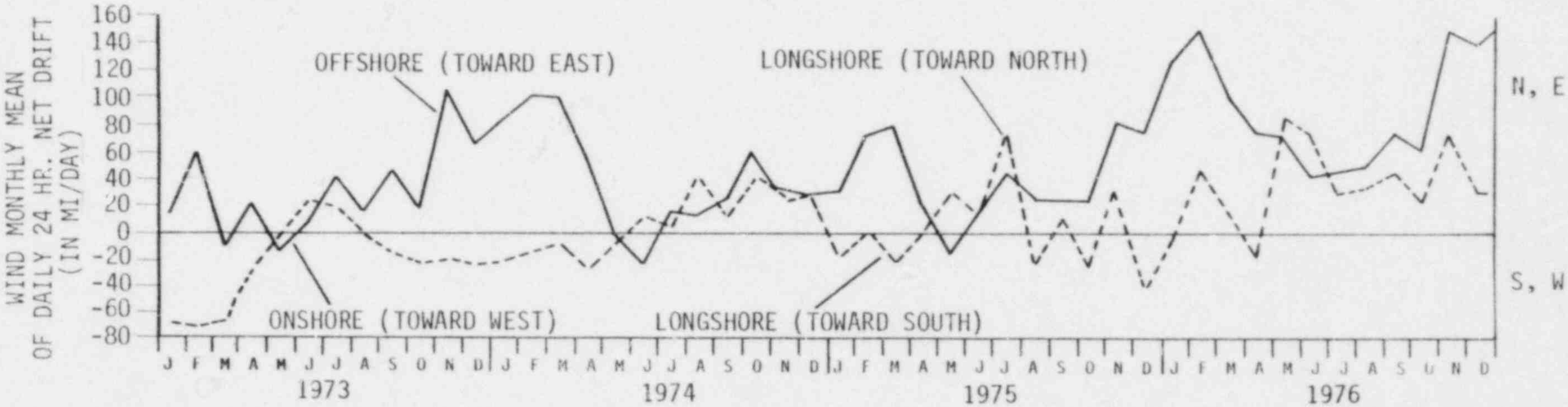

Figure 3.1-7. Plot of monthly mean onshore/offshore and longshore components of daily 24 hour wind net drift. Seabrook 1976 Annual Hydrographic Report, 1979.

temperature, salinity and density stratification (NAI, 1977a). Because previous NAI studies (1975a) have shown a much closer relationship between winds and short-term hydrographic variations (especially, stormy periods), it appears that monthly means are a little too coarse for such analyses.

Mean wind stress data for 1973 through 1975 have showed that the strongest wind stresses generally occur in the spring, with a secondary peak in the fall (NAI, 1977a). This pattern corresponds closely to the onshore/offshore net drift pattern, wherein the periods of strong wind stress seem to have a predominantly offshore component (Figure 3.1-7). Such periods also have a typically southward component. Thus, the greatest wind stress effect seems to have a southeastward net displacement, in agreement with prevailing winds for the region.

3.1.7 Net Drift Patterns in Coastal Waters

3.1.7.1 General Net Drift Patterns

Daily water current net drift or coastal water mass displacement measurements (24-hr vector average based on actual 20-min observations of current speed and direction) further demonstrate the dynamic nature of the waters off Hampton Beach. Regardless of actual flow type (i.e., weak tidal flow, reversing flood and ebb-tidal currents, moderate or strong southward flows, and moderate or strong northward flows), the coastal currents are such that for any given day there is always some net residual non-tidal drift. Thus, nearshore flows may generally be conceptualized as somewhat discrete entities, often moving alternately northward or southward independent of water masses further offshore (which have greater freedom of motion in the east/west direction).

3.1.7.2 Historical Trends in Drift Patterns

Daily (24 hr) net-drift data (longshore or north-south components* averaged over 3-day periods for ease in presentation) collected from mid-depth current meters off Hampton Beach during 1973 through 1976 are summarized in Figure 3.1-8. Data from the summer season, when tidal flows are more prevalent and entrainment impacts of power plant operation potentially the greatest, show typical net drift rates of at least 1 to 2 n mi per day and numerous periods of much greater net drift. Periods of large net drift are in apparent response to storm effects.

Although conditions from year to year have varied slightly, a general summertime pattern has been observed all 4 years. During both June and July of all 4 years, predominant net drift was southward except for about 4 to 5 days of northward drift. In August 1973 there was very little northward drift, in August 1974 about 5 to 6 days, and in August 1975 and 1976 about 10 to 12 days. During September 1973 and 1976 there was about 6 to 8 days of northward net drift, in 1974 about 21 days, and in 1975 about 27 days. These data show that periods of relatively small net drift lasting several days at a time occur periodically during the summer season. However, such quiescent periods alternate with periods of strong flow, lasting for days at a time and resulting in large scale net displacement of nearshore waters.

Another technique for graphically depicting net residual drift in the ocean is to prepare progressive vector plots of current speed and direction. Current vectors are plotted sequentially from tip to tail, based on the assumption that water at a given depth or current-meter location behaves as a layer, free to move horizontally in any direction independent of bottom frictional effects. This technique is often utilized for deep ocean currents, many hundreds of n mi or km from shore. However, one must be careful when using this procedure with shallow

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* In calculating the longshore components of net d[illegible] directional axis was rotated 10° east of north to approx[illegible] orientation of the New Hampshire coastline.

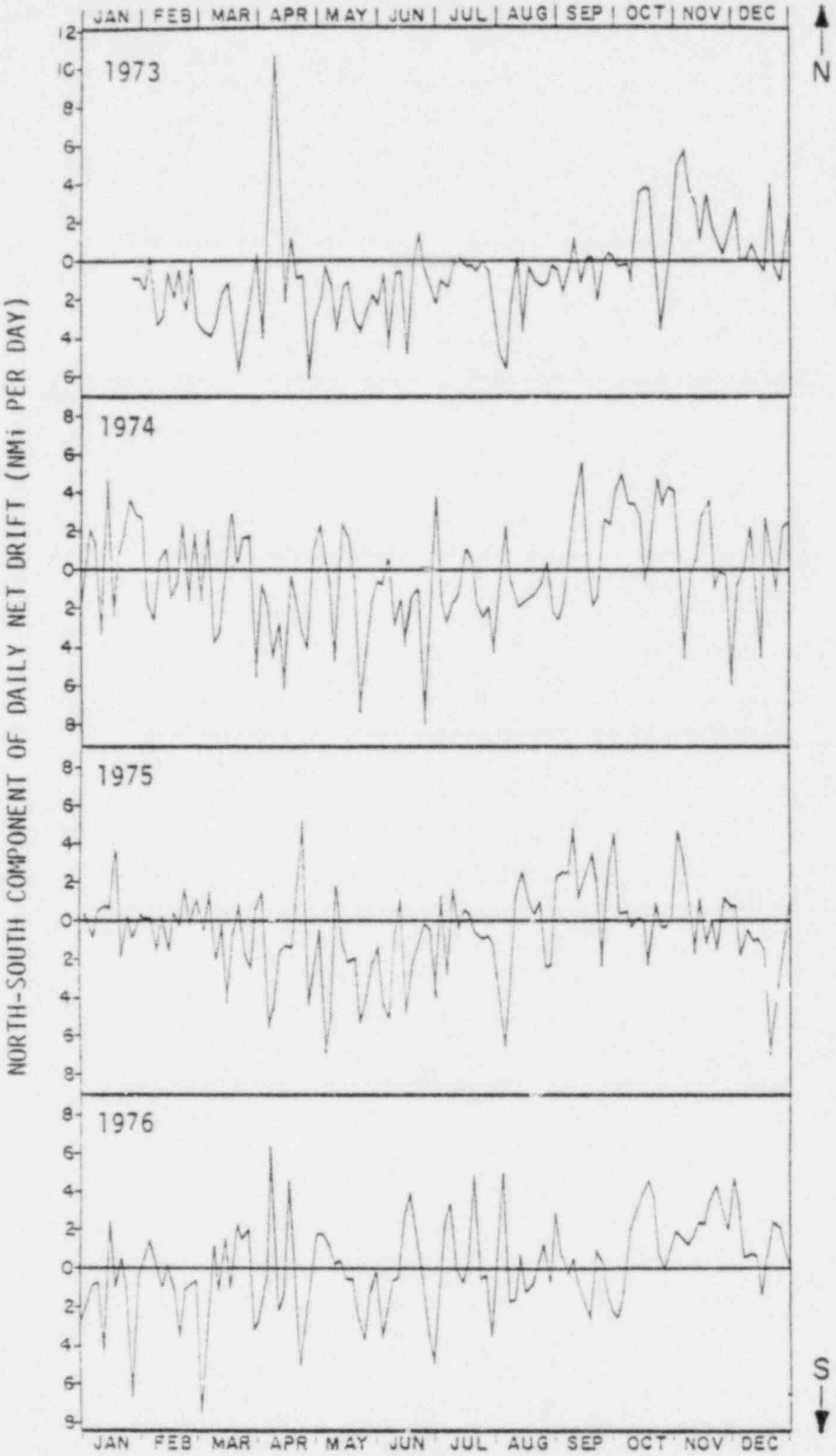

Figure 3.1-8. Plot of daily net drift of longshore (north-south) components averaged over 3-day periods from mid-depth current meters off Hampton Beach, New Hampshire, 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

water, such as the near shore data NAI has collected off Hampton Beach. Flows past a given current sensor are often significantly altered further up coast or down coast in response to the effects of local bottom topography. Because of this, progressive vectors can be misleading. Nevertheless, progressive vector diagrams represent a means of depicting gross drift patterns. Representative vector plots of mid-depth current meter readings from the summers of 1973 through 1976 (Appendix 7.4) document the variability of day-to-day flows. The typical pattern is one of strong southward (or northward) flows parallel to the coast, a consequence of strong longshore wind stress events. Mid-depth current meter data from a typical mid-summer day with southward tidal-driven flows shows a characteristic clockwise rotary motion (Figure 3.1-9). In contrast, summertime data with northward tidal-driven flows show a characteristic counterclockwise rotary motion (Figure 3.1-10). Both of these days showed considerable net displacement of coastal waters (2 to 3 n mi or 3.7 to 5.6 km), even in the absence of meteorological forcing functions. As has been previously observed (NAI, 1975a and 1977a), cross-covariance analyses of kinetic energy densities have shown high positive correlation with near surface currents lagging 2 to 6 hrs behind major wind shifts.

3.2 TEMPERATURE

3.2.1 Temperature Patterns at the Diffuser Site

Offshore water temperatures at the diffuser site show pronounced daily, seasonal and annual variability. Mean monthly near-surface measurements from Mooring 12 (-3 ft or 0.9 m below instantaneous sea surface) during 1976 showed lowest values in January (36.6 F or 2.6 C) and highest values in August (62.6 F or 17.0 C; Figure 3.2-1). Overall summary data from November 9, 1973 through December 31, 1976 show that lowest temperatures typically occur in February, lagging about

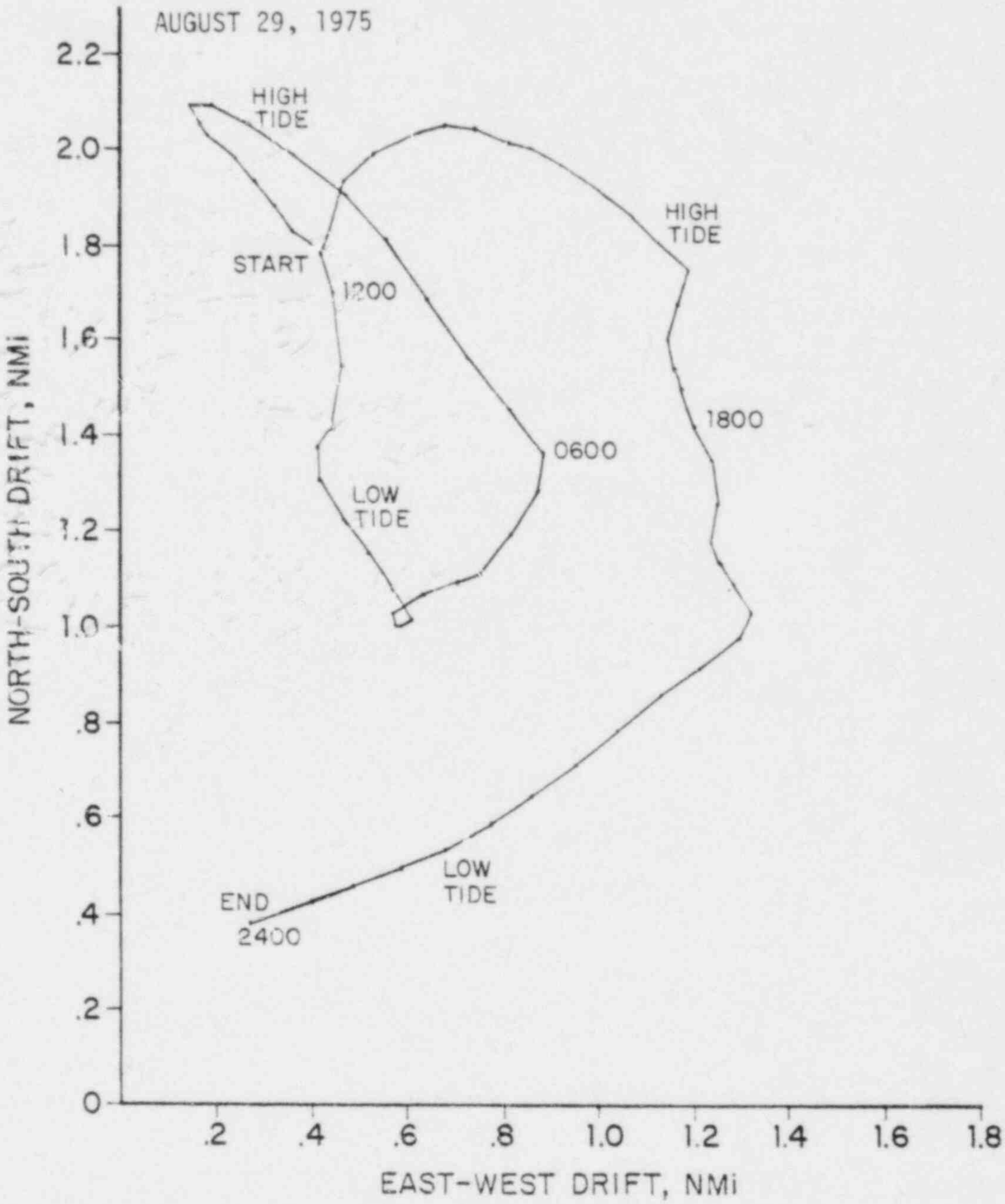

Figure 3.1-9. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for August 29, 1975. Seabrook 1976 Annual Hydrographic Report, 1979.

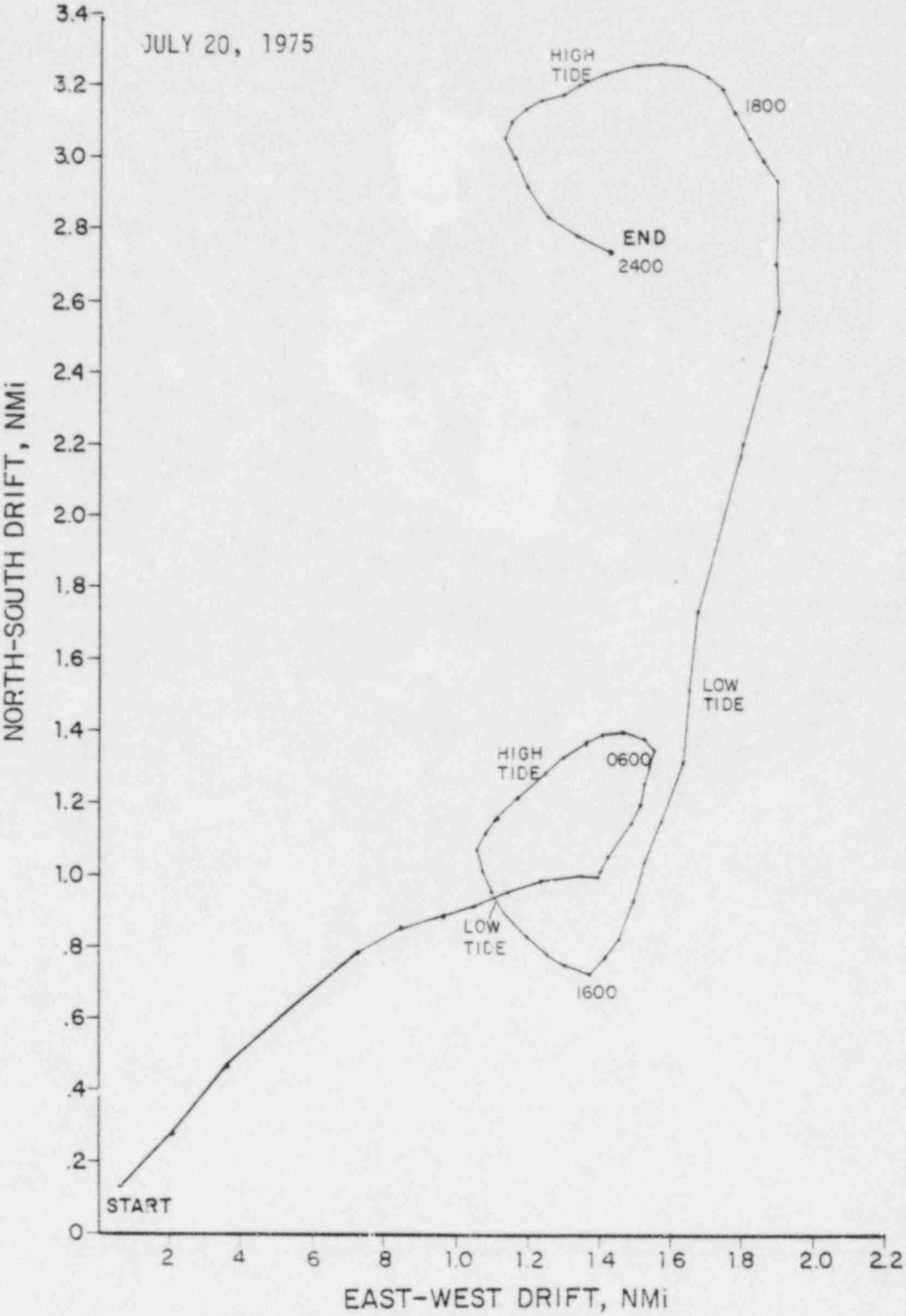

Figure 3.1-10. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for July 20, 1975. Seabrook 1976 Annual Hydrographic Report, 1979.

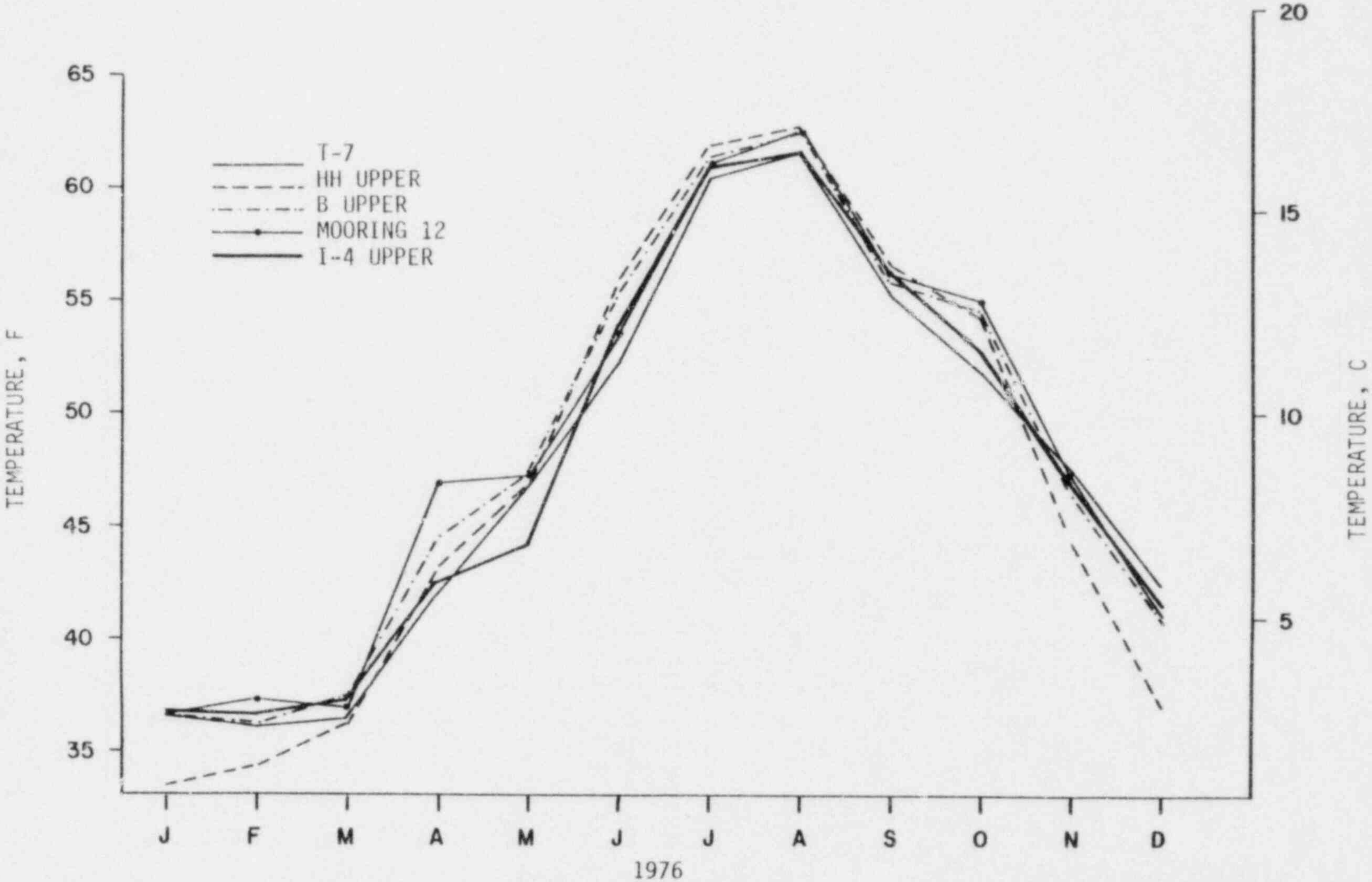

Figure 3.2-1. Monthly mean near-surface water temperature for selected moorings off Hampton Beach, New Hampshire, during 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

30 days behind the coldest air temperatures (Figure 7.5-1).* During April, May and June, temperatures rose rapidly with highest temperatures generally being reached during August. During late September and early October, temperatures began to decrease. Note that the months of February and April of 1976 were both slightly warmer than has been previously observed for these months, whereas the other months were close to expected values based on historical data.

The ambient variability in terms of the differential between observed daily maxima and minima is striking (Figure 3.2-2). These data document daily variations from 1.0 to 10.9 F (0.5 to 6.0 C) in the summer and from 1.0 to 6.9 F (0.5 to 3.8 C) in the winter.

Slightly deeper at Mooring 10 upper (-20.0 ft or 6.1 m below MLW), an annual pattern similar to that at Mooring 12 was observed (Figure 3.2-3). Lowest mean monthly temperatures were observed in February (36.6 F or 2.6 C) while warmest temperatures occurred in August (51.3 F or 10.7 C). Overall summertime temperatures at this depth were about 2.0 F (1.1 C) colder than near surface at Mooring 12. Mean wintertime temperatures were quite similar, ranging from about 1.0 F (0.6 C) warmer in February to 1.0 F (0.6 C) colder in March. Both moorings showed April 1976 was about 4.0 F (2.2 C) warmer than previous years (Figure 7.5-2).

Although no near bottom temperature measurements were obtained at the diffuser site during 1976, historical data from Mooring 10 lower (-41.0 ft or 12.5 m below MLW) show that this same basic pattern of annual variability has been observed during earlier years (NAI, 1977a). Wintertime temperatures have been similar to those at Moorings 12 and 10 upper, reflecting isothermal conditions characteristic of this time of the year (Figure 7.5-3). Warmest summer temperatures occurred later than at the other moorings (during September rather than August) and were 6 to 8 F (3.3 to 4.4 C) colder. The daily wintertime variability

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* These figures summarize the overall monthly means of the daily maxima and daily minima and indicate the maximum and minimum temperatures ever observed during each month of any year. Mean monthly temperatures for 1976 are also shown.

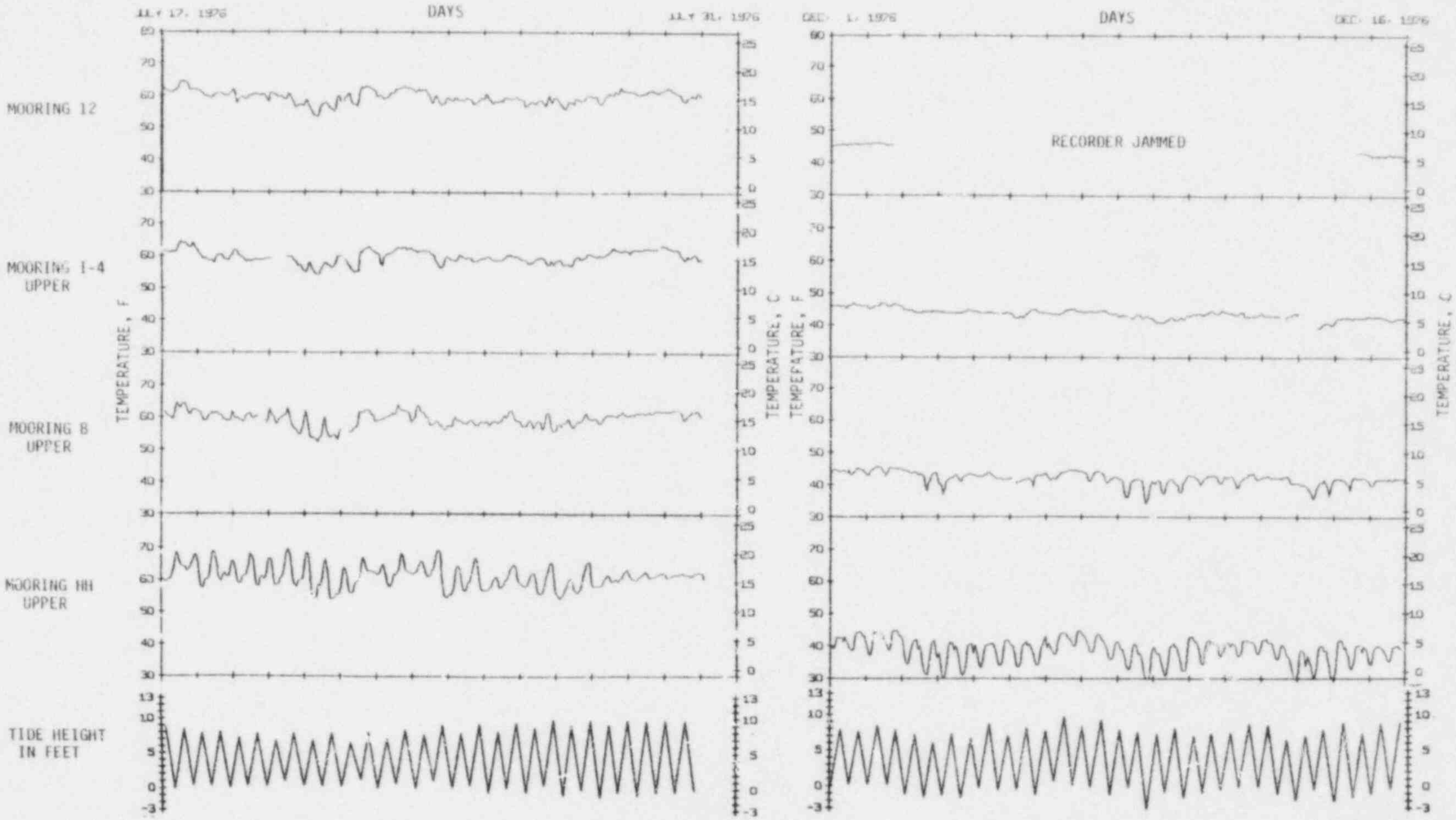

Figure 3.2-2. Represenative summertime (July 17 to 31, 1976) and wintertime (December 1 to 16, 1976) plots of hourly average near surface temperature data from the diffuser site (Mooring 12), intake site (Mooring I-4 Upper), Rocks area (Mooring B), and Hampton Harbor estuary (Mooring HH Upper); tide heights shown along bottom. Seabrook 1976 Annual Hydrographic Report, 1979.

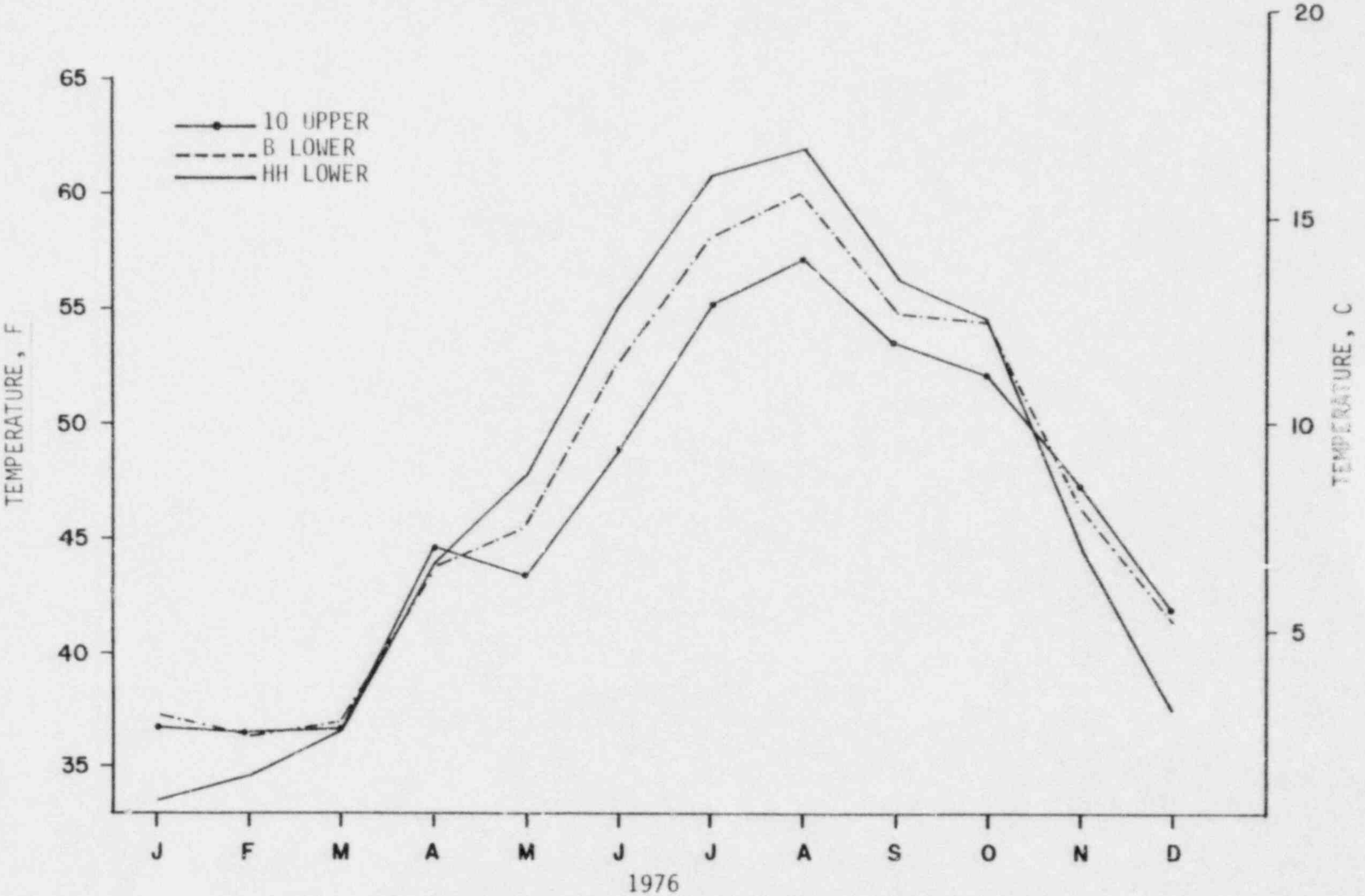

Figure 3.2-3. Monthly mean mid-depth water temperature for selected moorings off Hampton Beach, New Hampshire, during 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

of 1.0 to 4.9 F (0.5 to 2.7 C) was about the same as near surface at Mooring 12. Daily summertime temperatures were less variable (generally 0.0 to 5.9 F or 0.0 to 3.3 C).

Summary plots of the monthly mean of the daily maxima, daily mean and daily minima of near surface temperatures (Moorings 12 and I-4 upper) and near bottom temperatures (Moorings 10 lower and I-4 lower) from April 1973 through December 1976 show consistent trends from year to year (Figure 3.2-4). Highest temperatures occurred during September 1973 and lowest temperatures occurred during January 1976. During 1975, peak temperatures at both near surface and near bottom were observed in August, whereas during other years near-bottom temperatures tended to lag 1 to 2 months behind (such as in 1974). Mean annual near surface water temperatures* have remained fairly constant over this period: 51.5 F or 10.8 C for 1973 (incomplete year as data began in early April), 48.5 F or 9.2 C for both 1974 and 1975, and 49.4 F or 9.7 C for 1976 (Figure 3.2-4).

Temperature measurements from the monthly slack water surveys provide an additional framework for the continuous data observations. Measurements made at Mooring 12 during 1976 for near surface and near bottom at both high and low water showed that late January was the coldest part of the year and that peak temperatures occurred in late August (Figure 3.2-5). No distinct pattern of temperature differences between high water and low water was evident. These surveys show a general pattern of colder near surface temperatures at low water during the winter months (caused by cold ebb tidal waters flushing from Hampton Harbor and adjacent estuaries), and at high water during the summer months (caused by the offshore waters being colder than the warmed ebb tidal plumes from Hampton Harbor and adjacent estuaries). Thus, on the flooding tide during the winter, near surface waters tend to become warmer. During the summer they tend to become colder, as water from

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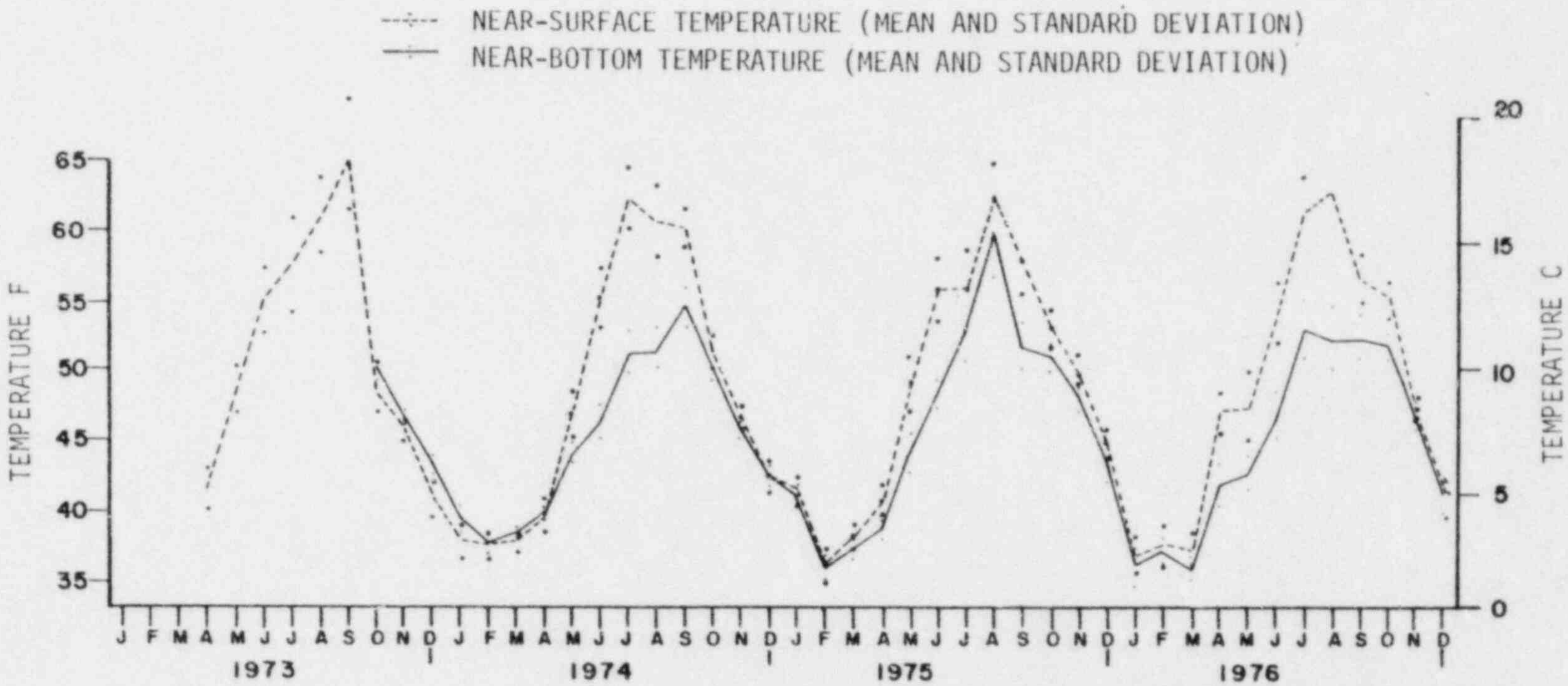
* Average of mean monthly values weighted by the number of days for which data were actually acquired.



Fiugre 3.2-4. Monthly mean temperature and standard deviation for near-surface waters (Moorings 12 and I-4 upper) and near-bottom waters (Moorings 10 lower and I-4 lower) off Hampton Beach, New Hampshire, from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

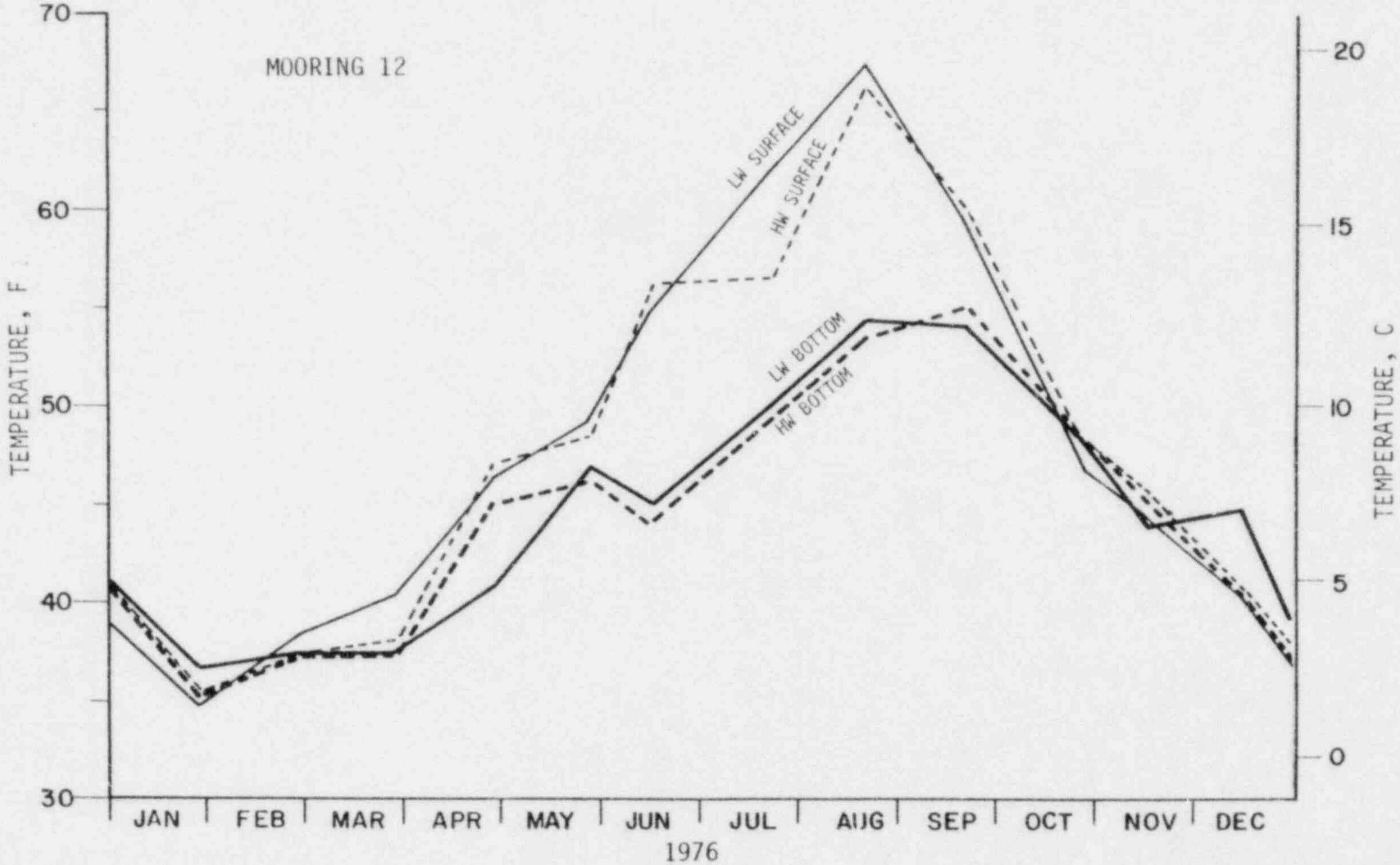


Figure 3.2-5. Monthly temperature observations at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack-water surveys (both low water, LW and high water, HW). Seabrook 1976 Annual Hydrographic Report, 1979.

offshore displaces water closer to shore. Near bottom waters showed less variability with a tendency for low water conditions to be slightly warmer than high water conditions (Figure 3.2-5).

Mean monthly temperature profiles from high-water slack for all of the offshore stations during 1976 are shown in Figure 3.2-6. Starting in November and December with essentially homogeneous thermal conditions from near surface to near bottom averaging around 40.0 to 45.0 F (4.4 to 7.2 C), temperatures dropped sharply in the early winter. Coldest temperatures were observed during late January, lagging about 30 days behind the minimum atmospheric temperature observed during the year. At this time there was also some thermal inversion of coastal waters, wherein the near surface temperatures were several degrees colder than those at depth because of radiational cooling.

Starting with isothermal conditions in March, the water column showed a gradual warming trend as the spring season progressed (Figure 3.2-6). By May and June, the development of the seasonal thermocline (a layer of water with a more intensive vertical gradient in temperature than that found in layers above or below it), was well along. By mid-summer the coastal waters showed a strong thermal stratification with a variation of up to 13.0 F (7.2 C) between near surface and near bottom depths. Maximum near-surface temperatures occurred during August, lagging about 30 days behind the maximum atmospheric temperatures observed during the year. During September and early October, the stratification broke down rapidly and temperatures became more homogeneous from near surface to near bottom.

3.2.2 Temperature Patterns at the Offshore Intake Site

Although temperature data from near surface at the offshore intake site (Mooring I-4 upper at -2.2 ft or 0.7 m below surface) and near bottom (Mooring I-4 lower at -48.6 ft or 14.8 m below MLW) have been collected for a shorter period of time than at other locations,

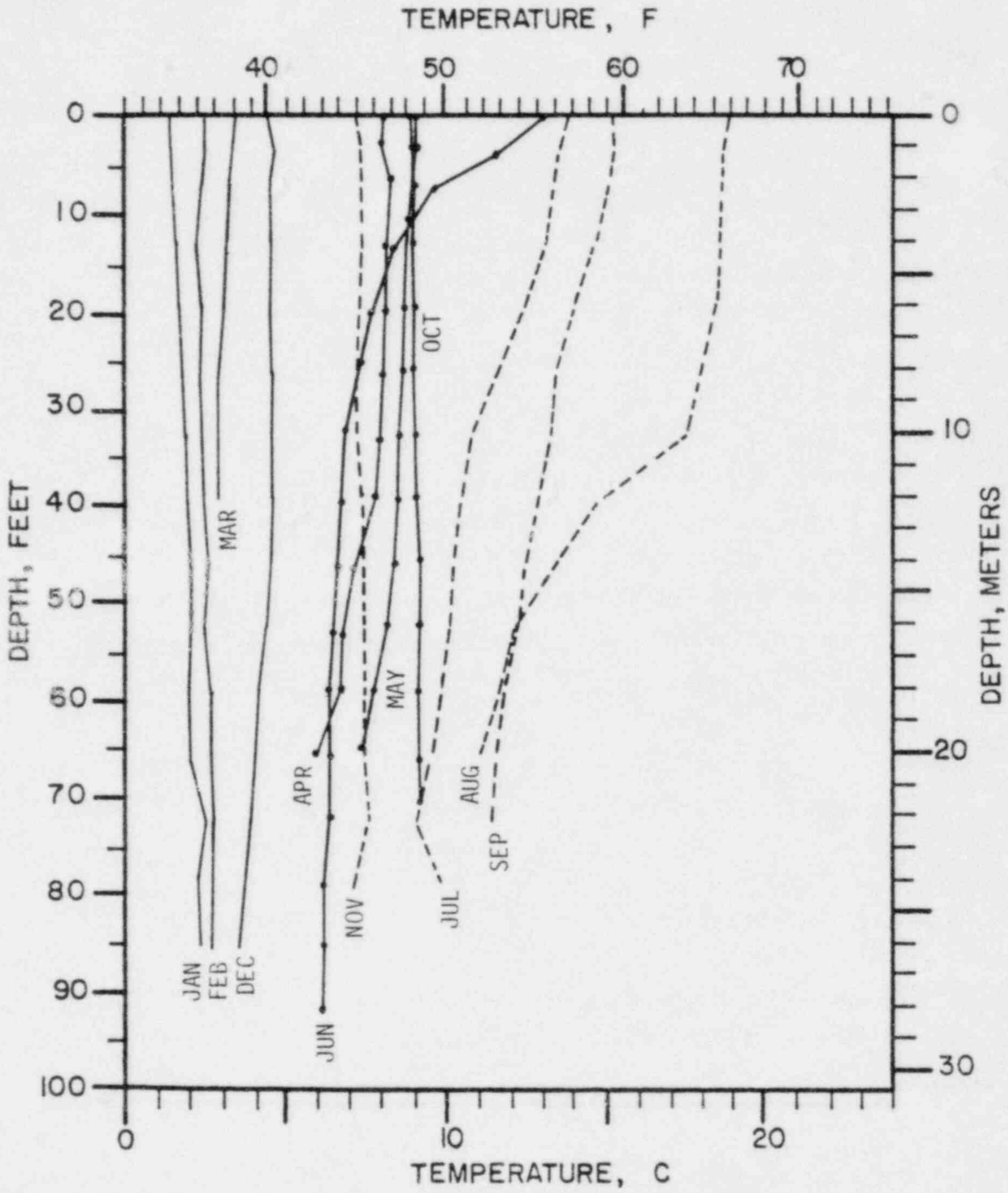


Figure 3.2-6. Mean temperature profiles taken at high-water slack from coastal waters off Hampton Beach, New Hampshire, during 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

both of these moorings have showed trends similar to those observed at the diffuser site. Mean monthly near-surface measurements from Mooring I-4 upper during 1976 showed lowest values in February (36.7 F or 2.6 C) and peak values in August (61.6 F or 16.4 C; Figure 3.2-1).

Springtime temperatures in April and May were about 3 to 4 F (1.7 to 2.2 C) colder than those observed at Mooring 12. Overall summary data from August 29, 1975 to December 31, 1976 are shown in Figure 7.5-4. Daily summertime temperature variations at this location can range up to 12.0 F (6.7 C) whereas wintertime variations can be up to as much as 8.9 F (4.9 C). Representative data from July and December 1976 are shown in Figure 3.2-2.

Mean monthly near-bottom measurements from Mooring I-4 lower during 1976 showed coldest values in March (35.7 F or 2.1 C) and peak values in July (52.7 or 11.5 C; Figure 3.2-7). Note that temperatures remained warm for almost 4 months, before finally starting to cool back down in late October and early November. Overall summary data from August 28, 1975 to December 31, 1976 is shown in Appendix Figure 7.5-5.

3.2.3 Temperature Patterns North of the Diffuser and Intake Sites

At Mooring T-7 located northeast of Great Boars Head, the same general pattern of minimum near surface values in February and maximum values in August was documented as at other near surface moorings (Figure 3.2-1). Note that the mean monthly temperatures from April through October 1976 were warmer than during previous years (Figure 7.5-6).

3.2.4 Temperature Patterns South of the Diffuser and Intake Sites

Historical data from Mooring 9 (June 27, 1974 to June 18, 1975; Figure 1.1-2) located off Seabrook Beach (location map, Figure

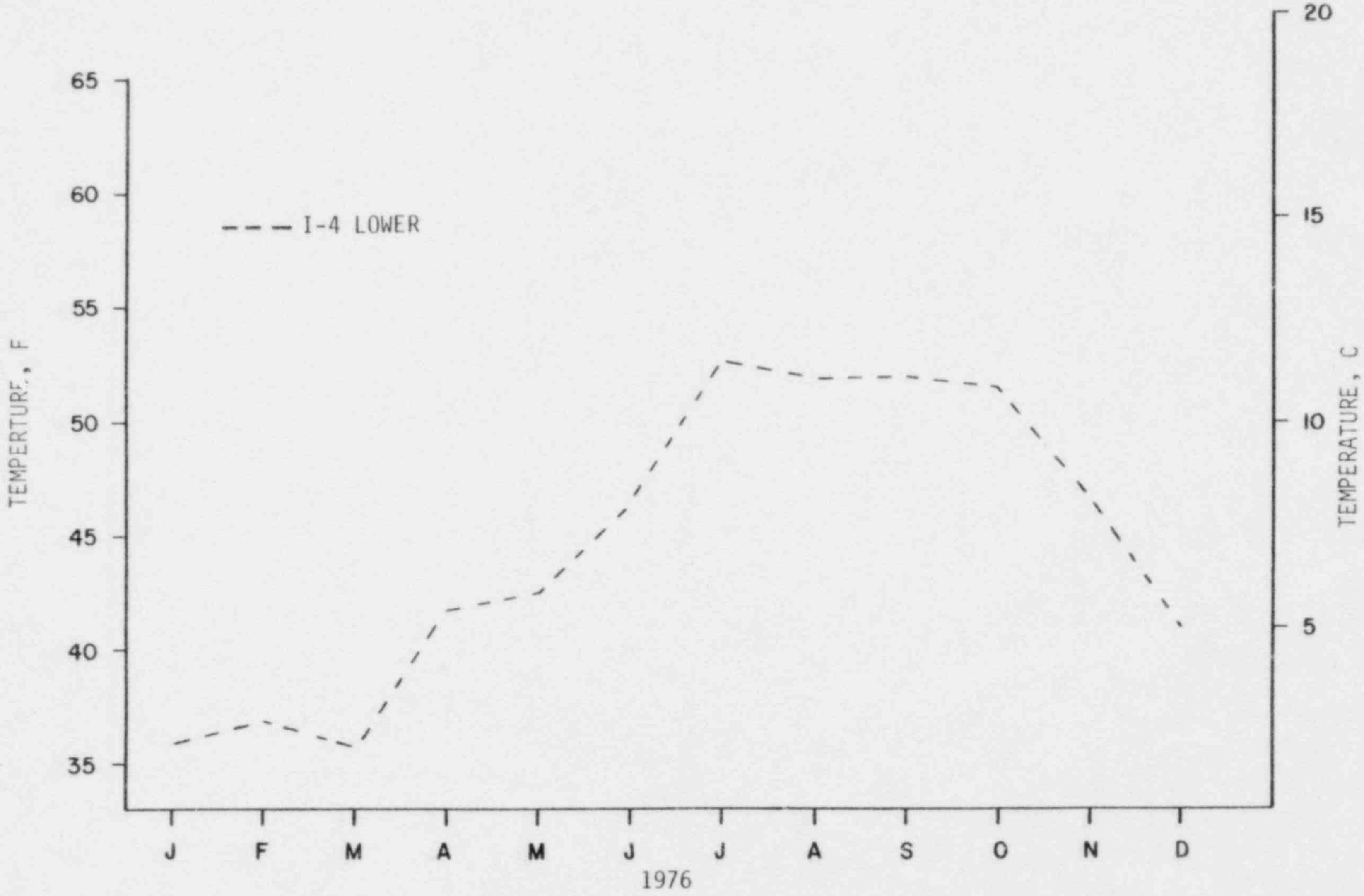


Figure 3.2-7. Monthly mean near-bottom water temperature from Mooring I-4 lower off Hampton Beach, New Hampshire, during 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

2.1-1) at -37.0 ft (11.3 m) below MLW showed the same general range of temperature and annual variability as at Mooring 10 lower (NAI, 1977a).

3.2.5 Temperature Patterns Around the Inner and Outer Sunk Rocks

As part of special temperature studies which were initiated late in 1975, continuous measurements were obtained at several locations and depths around Inner and Outer Sunk Rocks as well as in Hampton Harbor estuary. In general, these data showed much greater variability than at any of the other monitoring locations. Near surface data from Mooring B upper, located west of the Outer Sunk Rocks, showed daily ranges of from 2.0 to more than 12.0 F (1.1 to 6.7 C) in the summer and 1.0 to 5.9 F (0.5 to 3.3 C) in the winter. Plots of typical summertime and wintertime data are shown in Figure 3.2-2. Mean monthly near-surface measurements from Mooring B upper during 1976 showed lowest values in February (36.3 F or 2.4 C and peak values in August (62.5 F or 16.9 C; Figure 3.2-1). Overall data from September 11, 1975 to December 31, 1976 is summarized in Figures 3.2-8 and 7.5-7.

Near bottom temperatures in the same area (Mooring B lower at -13.0 ft or 4.0 m below MLW) closely followed near surface temperatures (Figures 3.2-8 and Appendix Figure 7.5-8). Wintertime temperatures averaged about 1.0 F (0.6 C) warmer on the bottom than near the surface, whereas summertime temperatures averaged about 3.0 F (1.7 C) colder on the bottom. Spring and fall temperatures were essentially isothermal (Figures 3.2-3 and 3.2-8).

3.2.6 Temperature Patterns in the Hampton Harbor Estuary

The waters of the Hampton Harbor estuary show the most variation of any location in the Hampton Beach area. Mean monthly near-surface measurements from Mooring HH upper (-1.0 ft or 0.3 m below instantaneous sea surface) during 1976 showed lowest values in January (33.5 F

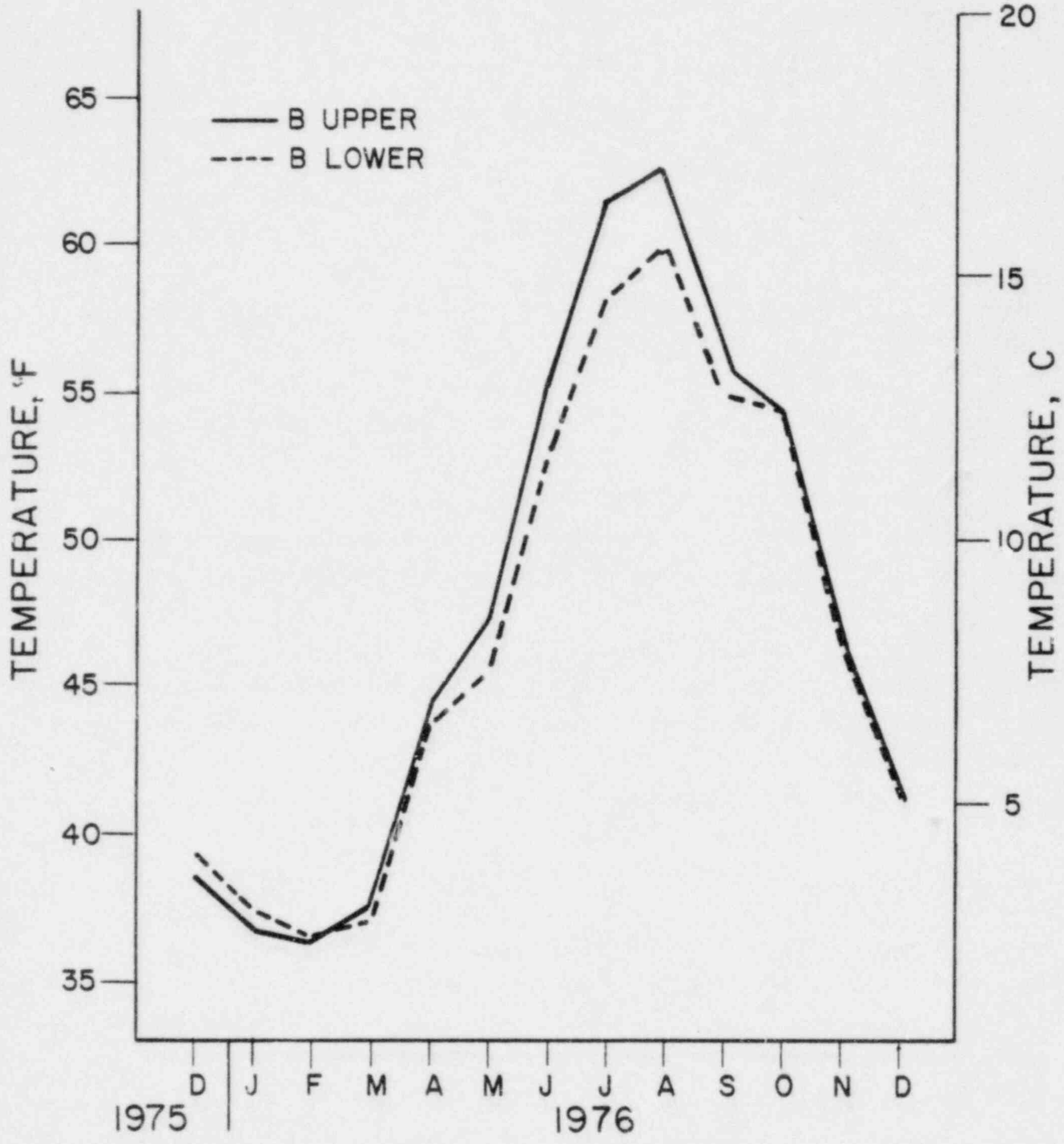


Figure 3.2-8. Monthly mean near-surface and mid-depth water temperatures from the Sunk Rocks (Mooring B) off Hampton Beach, New Hampshire, from 1975 and 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

or 0.8 C) and highest values in August (62.7 F or 17.1 C; Figure 3.2-1). Note that this mooring was colder than all the other near surface moorings during the winter months but warmer than all the others during the summertime. All available Mooring HH upper data from September 11, 1975 to December 31, 1976 are summarized in Figures 3.2-9 and Appendix Figure 7.5-9.

Near-bottom measurements from Mooring HH lower at -4.0 ft or 1.2 m below MLW closely parallel those from Mooring HH upper (Figures 3.2-3 and Appendix Figure 7.5-10). Mean monthly temperature data from 1976 showed that the near-bottom wintertime temperatures within the estuary were consistently colder than mid-depth waters offshore, whereas in the summertime they were warmer (Figure 3.2-3). Summary data from September 11, 1975 to December 31, 1976 show that estuarine waters are vertically well mixed throughout most of the year. At the wintertime extreme, near-surface waters average about 0.3 F (0.2 C) colder than near bottom, whereas in the summer they average about 0.7 F (0.4 C) warmer than near bottom (Figure 3.2-9). Observed temperatures have ranged from a low of 27.0 F (-2.8 C) to a high of 72.5 F (22.5 C).

Variations in hourly average temperatures further document the dynamic nature of these waters. Ambient variability within the estuary has ranged from 3.0 to more than 12.0 F (1.7 to 6.7 C) in the winter; and from 5.0 to more than 12.0 F (2.8 to 6.7 C) in the summer. Examples of typical summertime and wintertime conditions are illustrated in Figure 3.2-2. Lowest temperatures each day occur near high tide, whereas highest temperatures typically occur around low tide, under the influence of the ebbing tide. It appears that the ebb tidal prism discharges out toward the Inner and Outer Sunk Rocks in a manner such that peak temperatures occur first at Mooring B, then at Mooring F and finally at Mooring HH (for example, July 20, 1976 in Figure 3.2-10). Typical mid-summer data from offshore moorings, moorings in the Rocks area, and moorings in the Hampton Harbor estuary show changes of at least 2 to 6 F (1.1 to 3.3 C) within 1 hr, 5 to 12 F (2.8 to 6.7 C) within a tidal cycle (12.8 hrs) and 5 to 13 F (2.8 to 7.2 C) over a day.

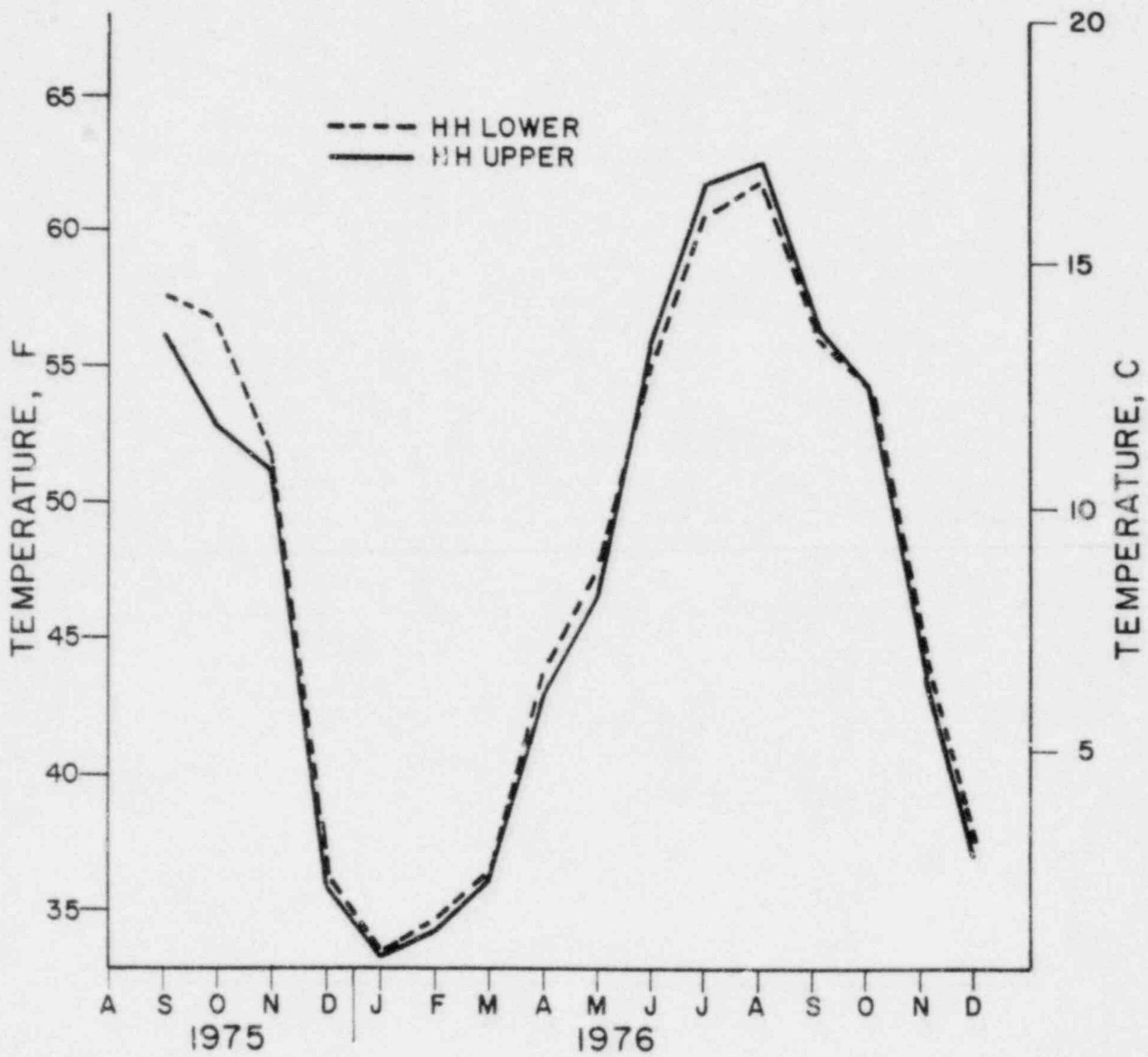


Figure 3.2-9. Monthly mean near-surface and near-bottom water temperatures from the Hampton Harbor estuary (Mooring HH) during 1975 and 1976. Seabrook 1976 Annual Hydrographic Summary Report, 1979.

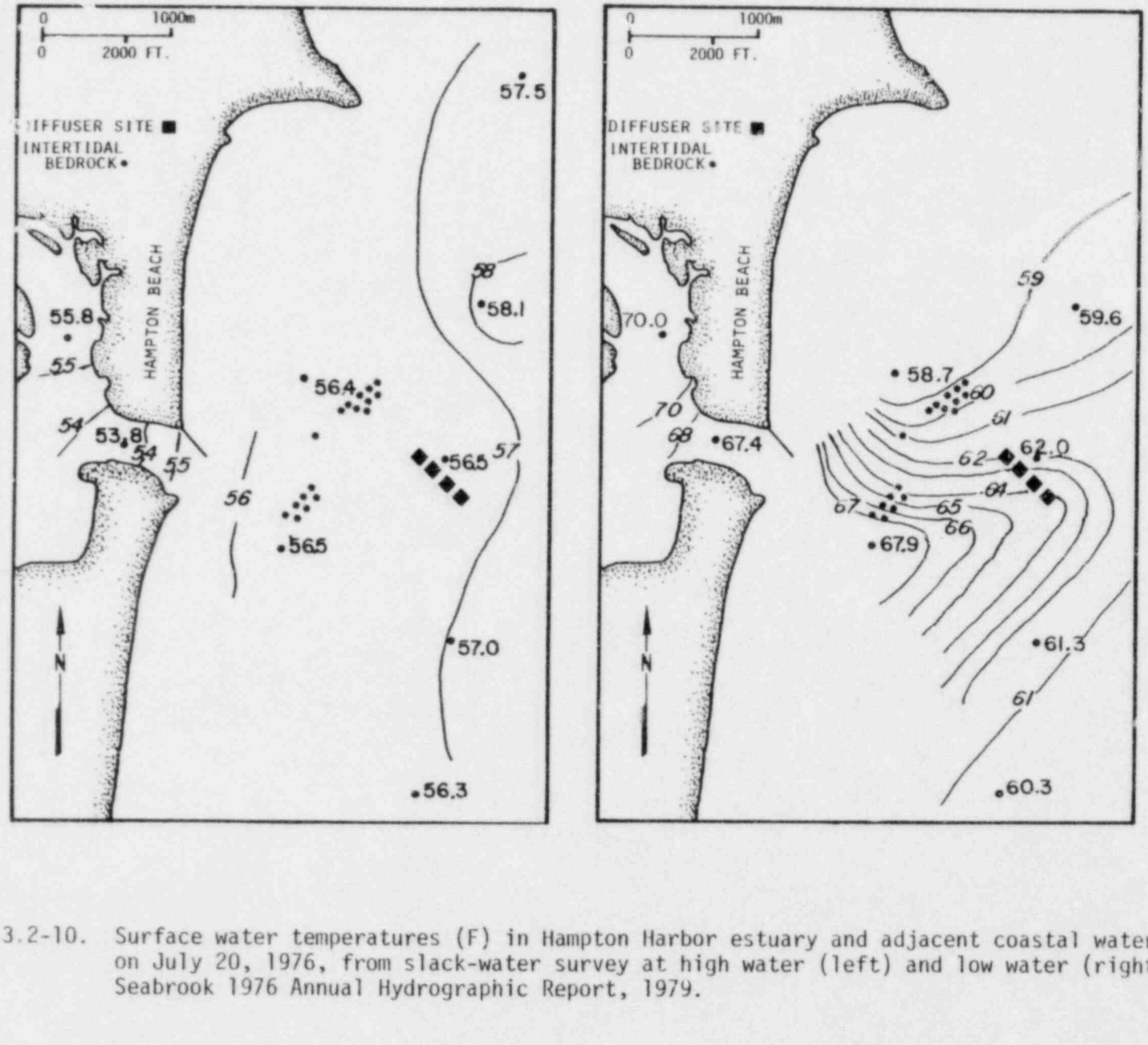


Figure 3.2-10. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on July 20, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

Such variability is due to the continuous complex interaction of factors including: discharge of local estuaries, runoff, precipitation, winds, tides, storms, currents, upwelling, downwelling, turbulence and the like.

3.2.7 Spatial Conditions

Near-surface temperature measurements obtained from slack-water surveys and plankton cruises further document the dynamic nature of these waters. Data from the former highlight the variability between tidal cycles (Figures 3.2-10 to 13), whereas the latter emphasize the variability along the coast from Rye Harbor southward to the Merrimack River (Figures 3.2-14 to 17).

Selected surveys from 1976 illustrate the variability of near-surface waters over a typical year. The slack-water survey of January 29, 1976 (Figure 3.2-11) showed fairly isothermal conditions around high water (34.8 to 35.7 F or 1.6 to 2.1 C); however, at low water, estuarine temperatures were only 32.0 F (0.0 C) and offshore conditions were more variable, because of residual ebb-tidal discharges into coastal waters. Late winter conditions were isothermal, but in the spring the estuary and offshore waters began to warm up. The April 21, 1976 slack-water survey (Figure 3.2-12) showed estuarine waters to be about 7.5 F (4.2 C) warmer than the isothermal offshore waters (46.1 to 47.7 F or 7.8 to 8.7 C). On the May 10, 1976 plankton cruise (Figure 3.2-14), measurements showed cold water in Hampton Harbor, fairly isothermal conditions offshore and a warm pocket off the mouth of the Merrimack River.

During early summer (plankton cruise of July 7, 1976; Figure 3.2-15), nearshore coastal waters were fairly isothermal; however, waters further offshore and in the estuary were both slightly warmer. This pattern appears to persist throughout the summer, as further illustrated by the slack-water survey of July 20, 1976 (Figure 3.2-10), the plankton cruise of September 8, 1976 (Figure 3.2-16), and the slack-

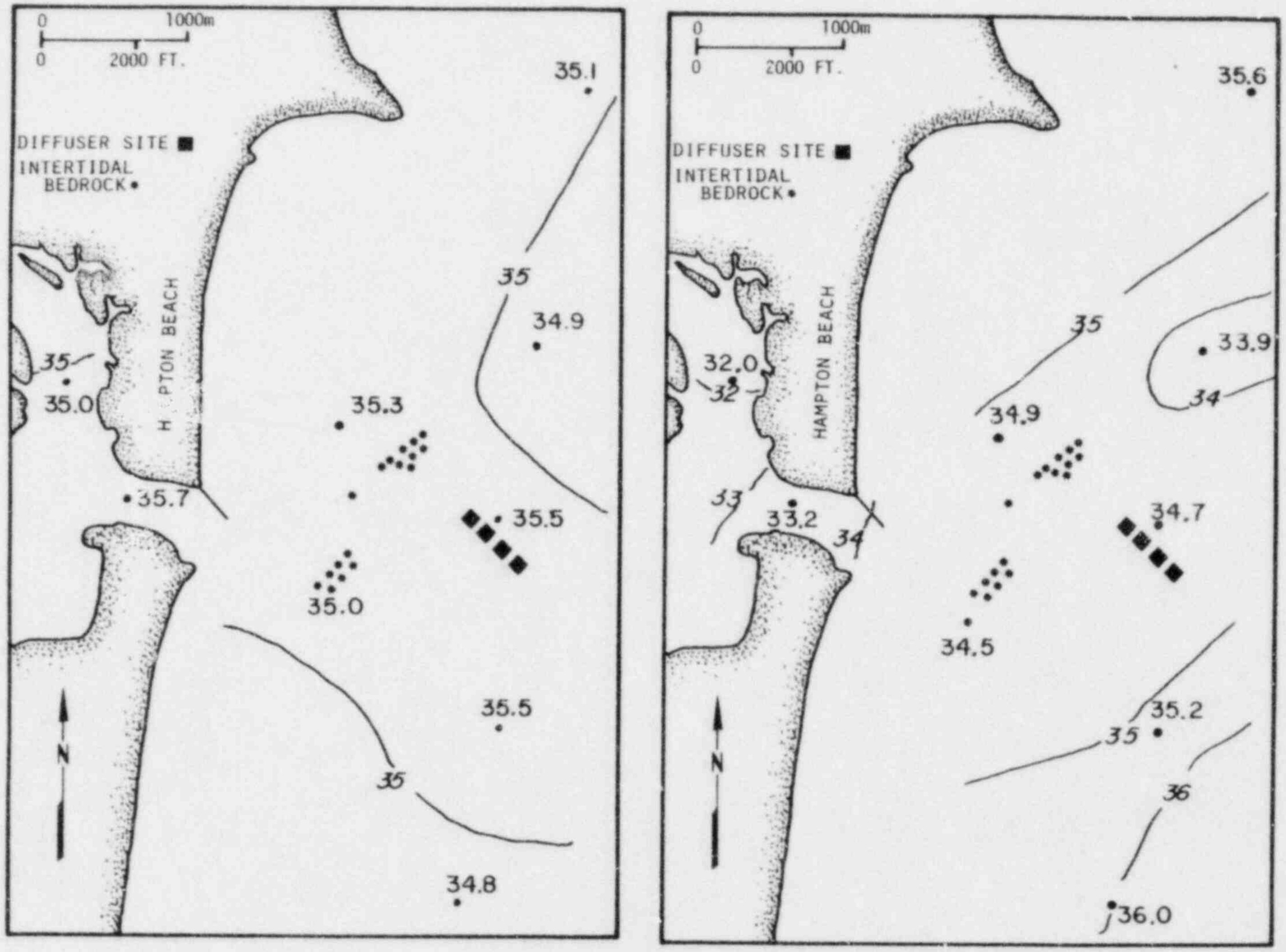


Figure 3.2-11. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on January 29, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

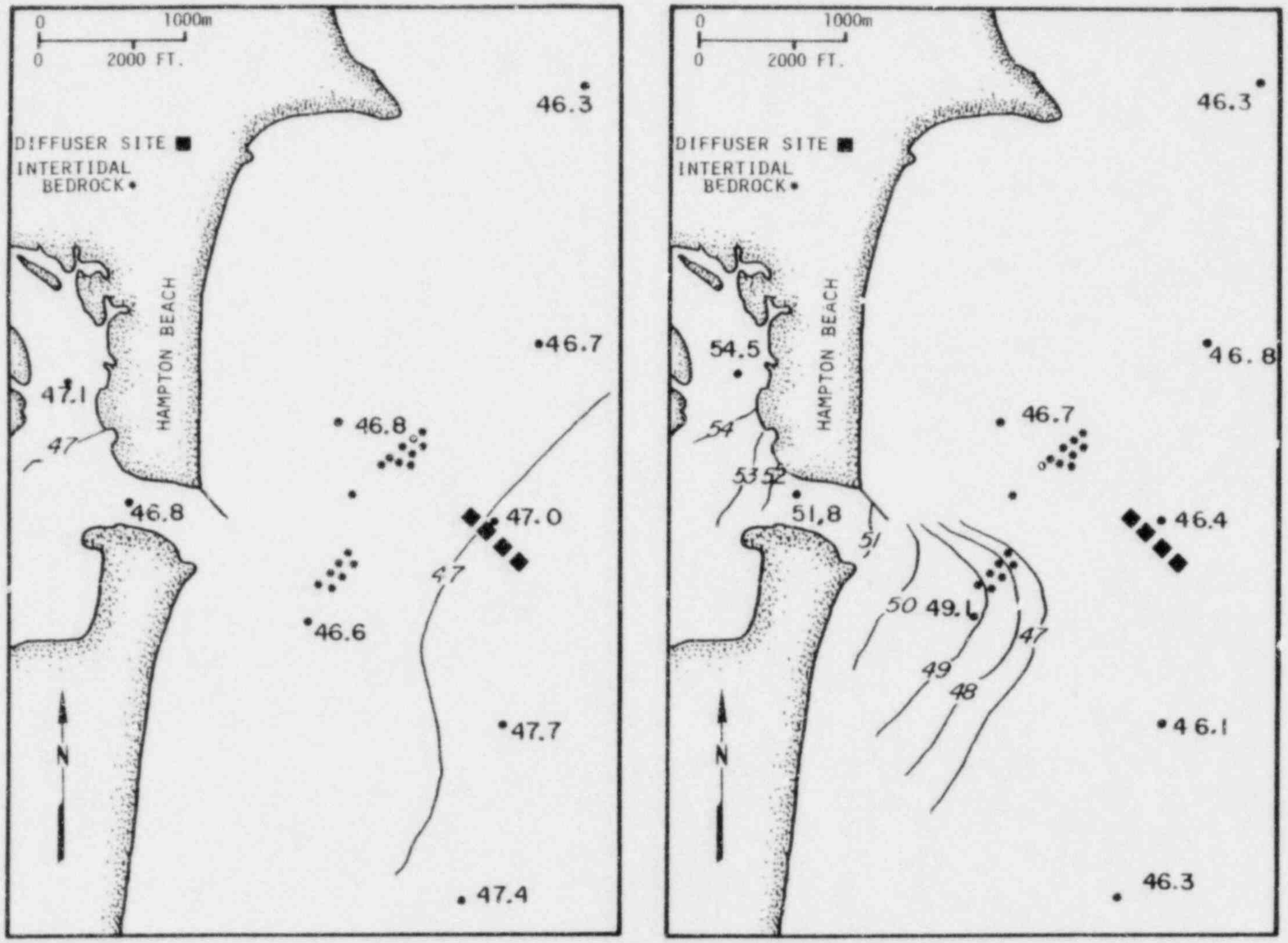


Figure 3.2-12. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on April 21, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

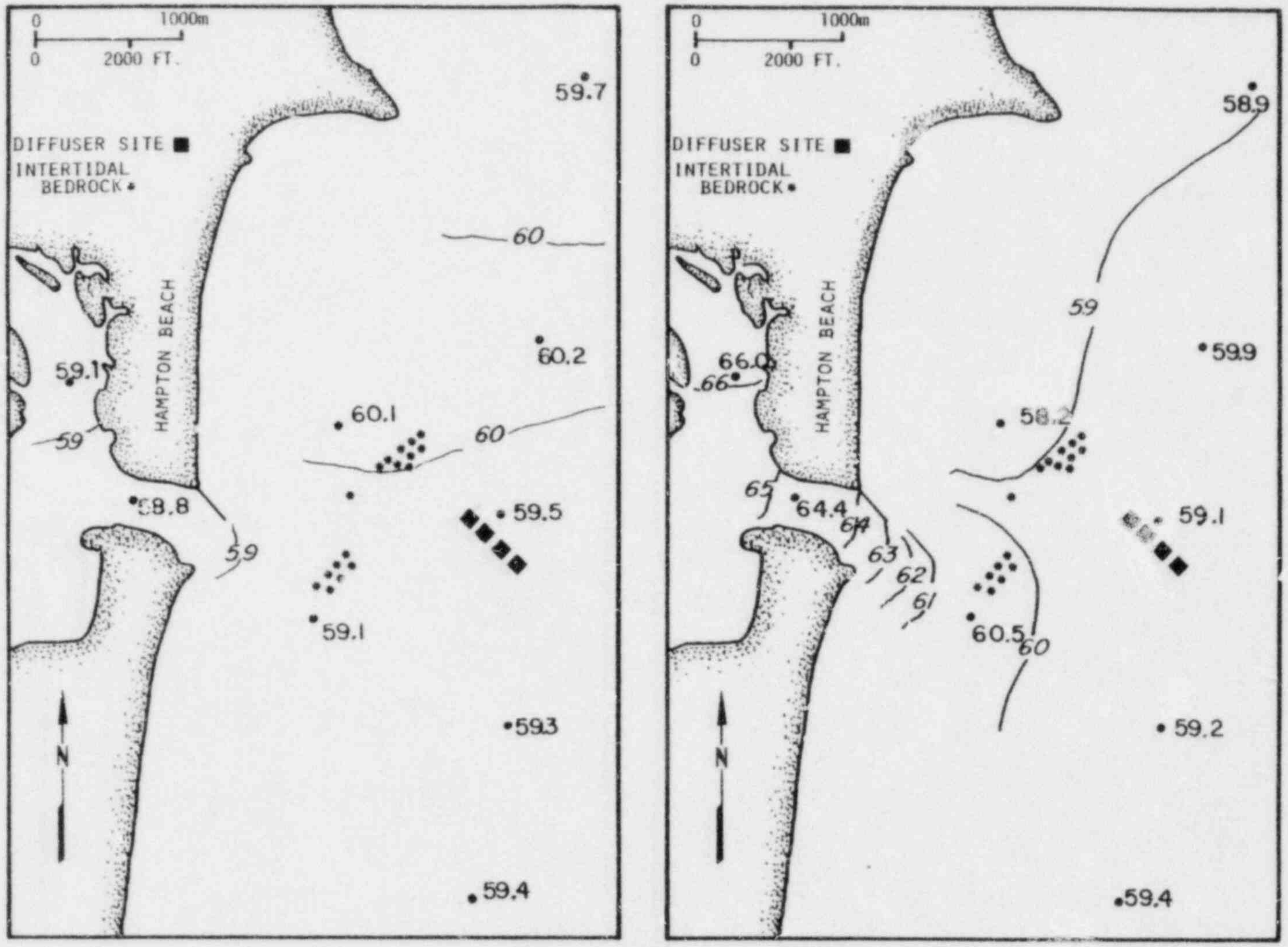


Figure 3.2-13. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on September 21, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

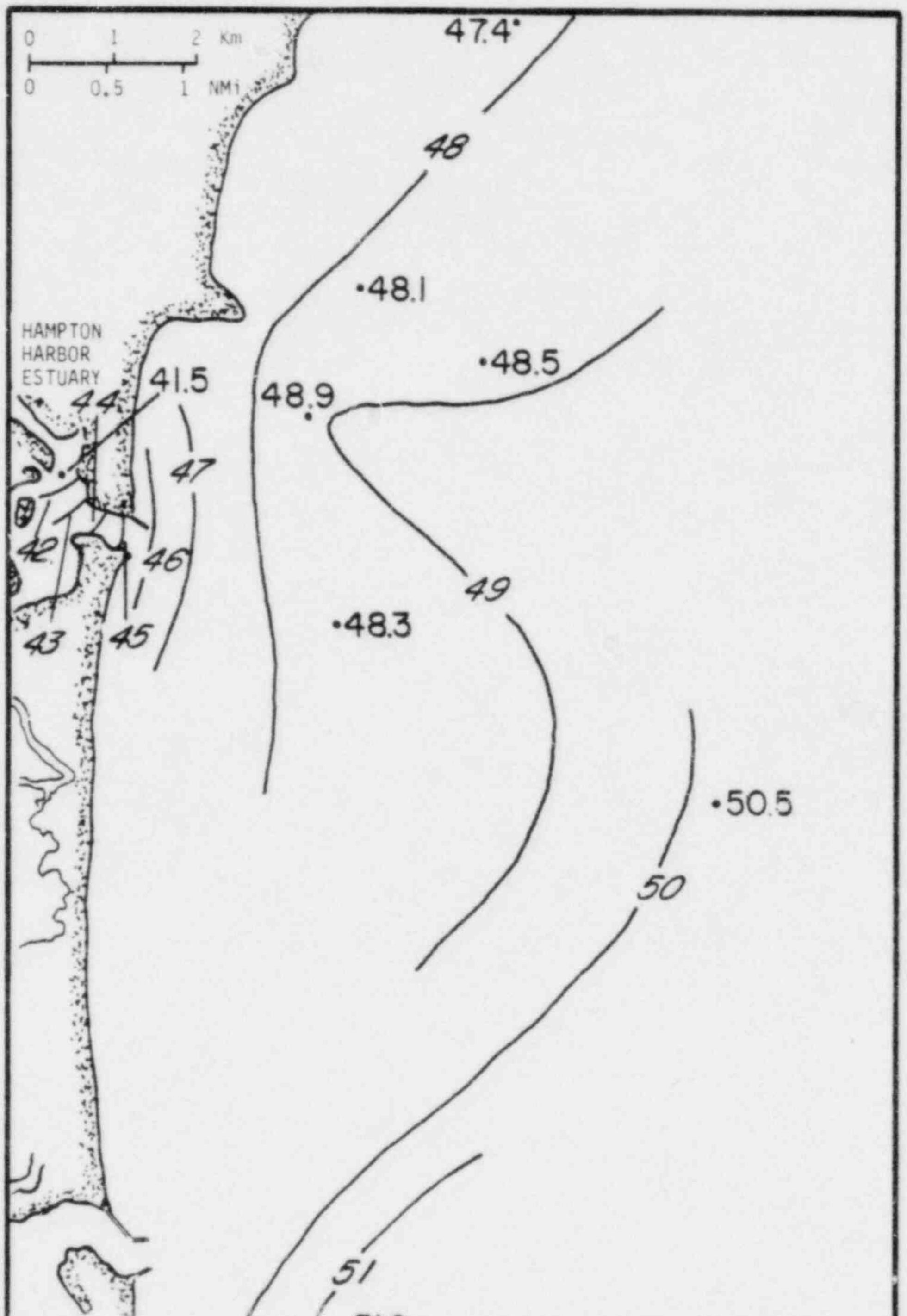


Figure 3.2-14. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on May 10, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

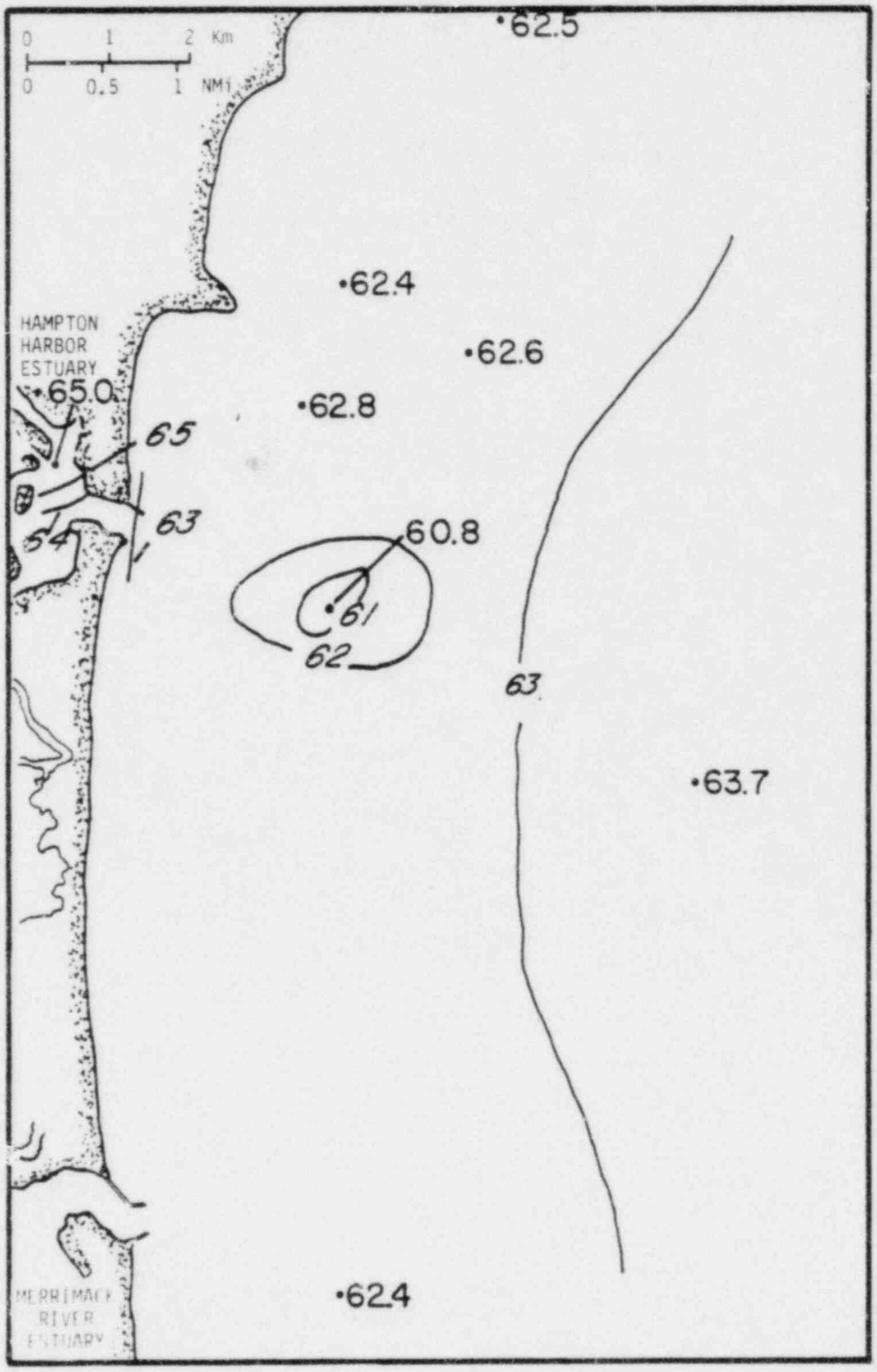


Figure 3.2-15. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on July 7, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

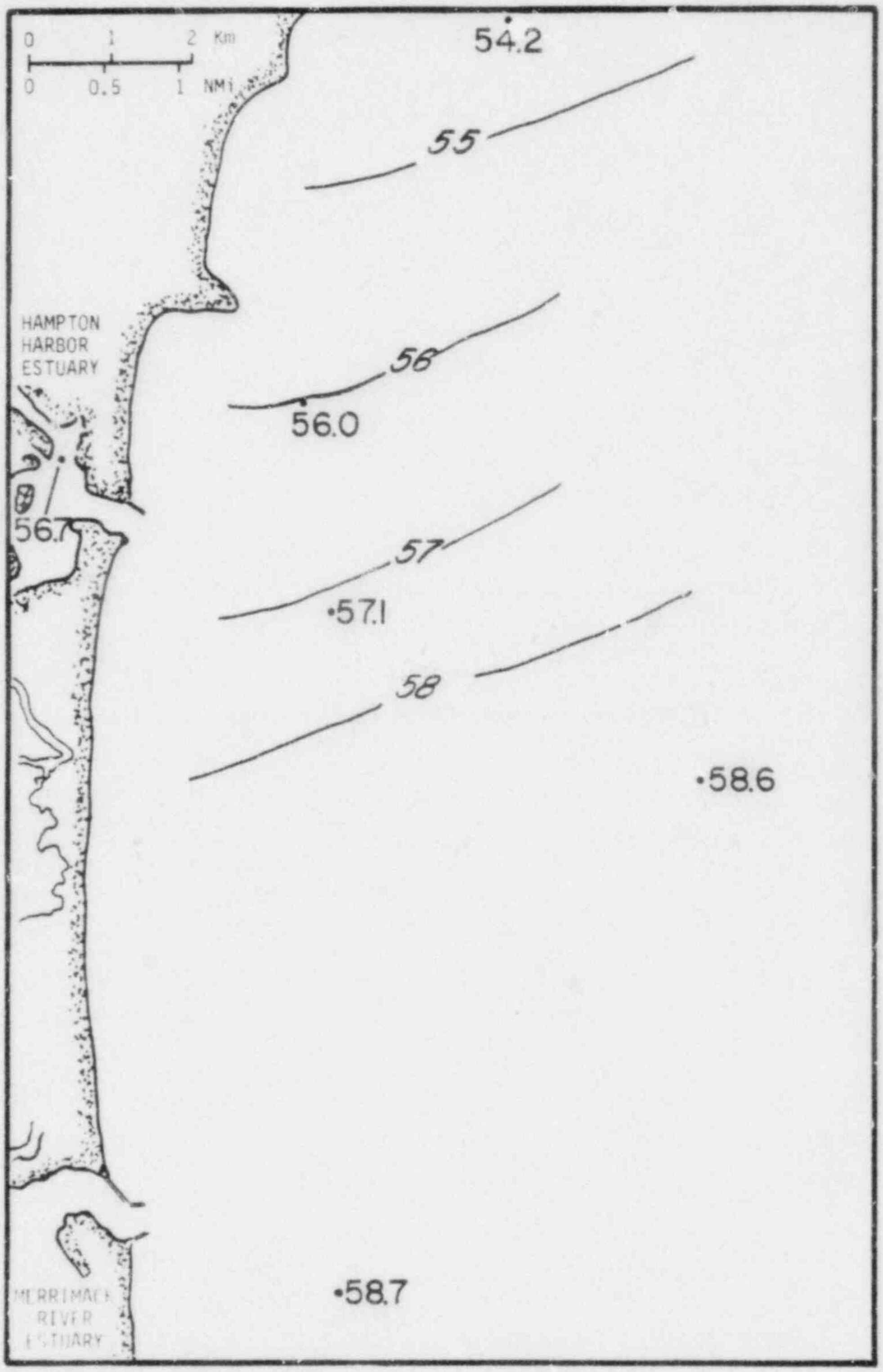


Figure 3.2-16. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on September 8, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

water survey of September 21, 1976 (Figure 3.2-13). These data suggest that radiational heating is greatest within the estuary and out at some distance offshore. Because of vertical mixing and storm effects, near-shore waters tend to be slightly colder. Fall storms help break down the thermocline, and by early December (plankton cruise of December 6, 1976; Figure 3.2-17), the estuary starts to be colder again.

3.2.8 Air Temperature

Although NAI has not monitored air temperature in the study area, data from U.S. Weather Bureau stations to the north at Portland, Maine, and to the south at Boston, Massachusetts, bracket local conditions in the Hampton Beach area. Monthly means of the daily maximum and minimum air temperatures from these stations for 1973 to 1976 (NOAA-Environmental Data Service, 1973 to 1976) show that July generally was the warmest month and February the coldest (Figure 3.2-18). Seasonal patterns have varied somewhat from year to year for each station.

For example in the summertime at Boston, 1975 appears to have been the warmest summer with a July monthly mean of daily maxima of 85 F (29.5 C) and a July monthly mean of daily minima of 68 F (20 C). Peak temperatures other years occurred in June (1976), July (1973 and 1975), and August (1974). To the north at Portland, the warmest summer appears to have been 1973 with a July monthly mean of daily maxima of 80 F (26.7 C) and a July monthly mean of daily minima of 62 F (16.7 C). Peak temperatures other years occurred in June (1976) and July (1973, 1974 and 1975). The most anomalous year was 1976 when peak minimum values occurred in June and peak minimum values occurred in August.

Wintertime temperature patterns have been more consistent. At both Portland and Boston, January 1976 was the coldest month; monthly means of daily minima were 7 F (-13.9 C) and 18 F (-7.8 C), respectively, with daily maxima of 27 F (-2.8 C) and 35 F (1.7 C), respectively. For all the other years under discussion, February was consistently the coldest month (Figure 3.2-18).

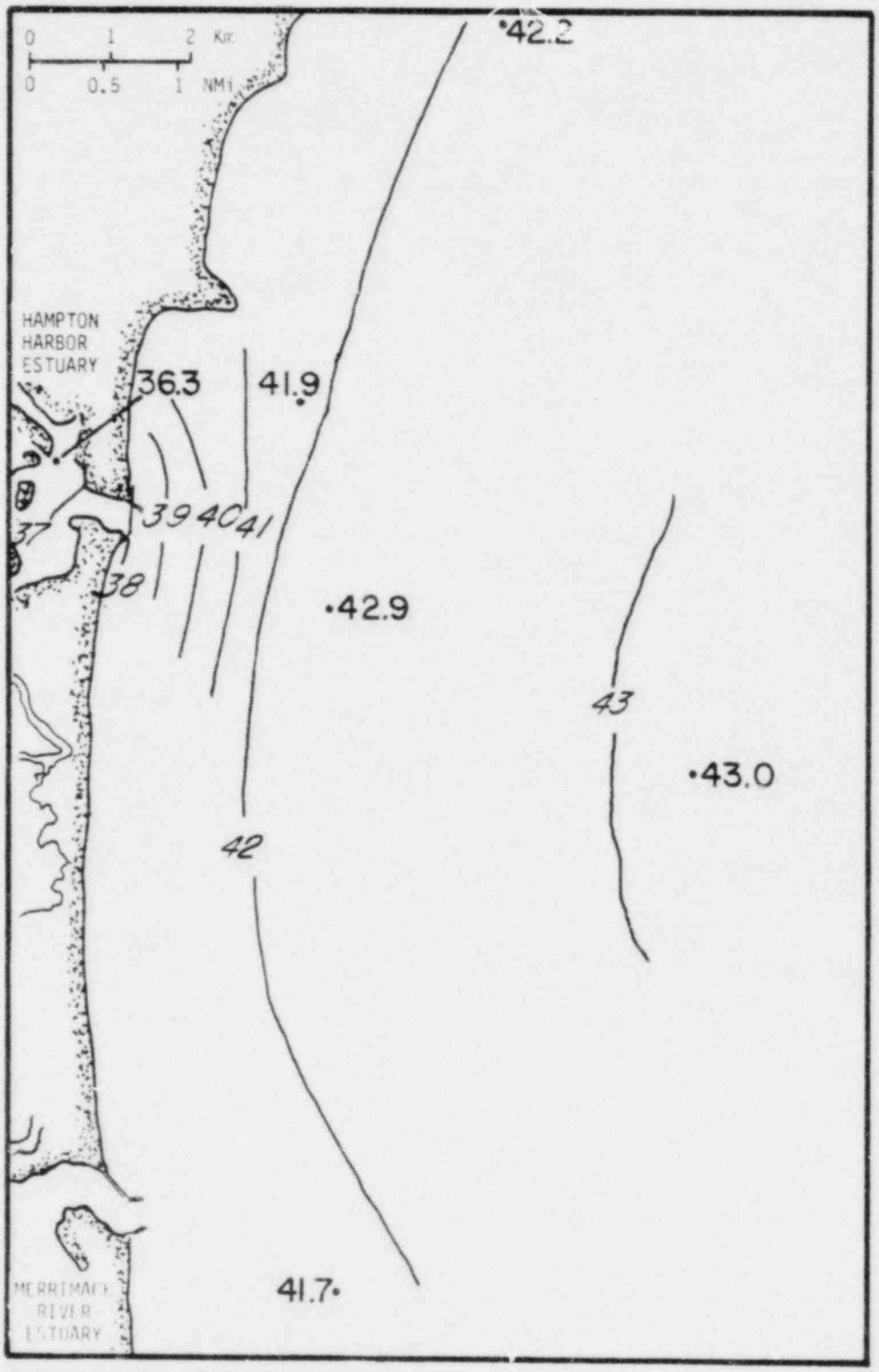


Figure 3.2-17. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on December 6, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

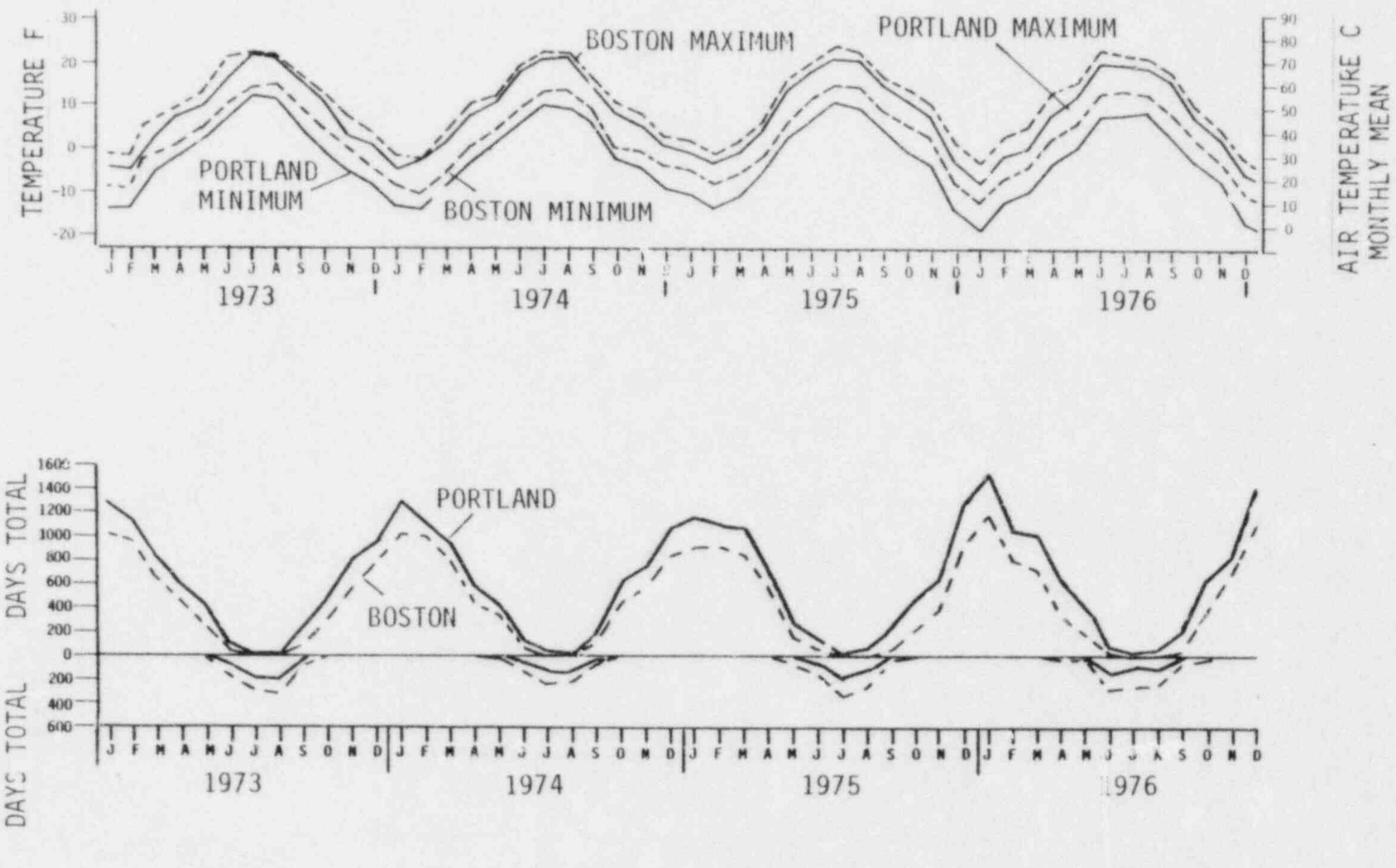


Figure 3.2-18. Monthly mean of daily maximum and minimum air temperatures, and heating and cooling degree days measured at U.S. Weather Bureau stations at Boston, Mass., and Portland, Maine from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

Comparing the two stations during the summer months, the monthly means of the daily maxima at Boston were 1 to 6 F (0.6 to 3.3 C) warmer than those at Portland, whereas the monthly means of the daily minima were up to 10 F (5.5 C) warmer. During the winter months, Boston's monthly means of the daily maxima were up to 10 F (5.5 C) warmer than Portland's; the minima were up to 12 F (6.7 C) warmer.

Total monthly heating and cooling degree days (based on 60 F or 15.5 C) from U.S. Weather Bureau stations at Boston and Portland for 1973 through 1976 are summarized in Figure 3.2-18. The highest total degree days have occurred during January of all four years, with 1976 appearing to be the coldest. The pattern of cooling degree days has been somewhat variable, with peak cooling degree days having occurred during August of 1973, July of 1974 and 1975, and June of 1976.

3.3 SALINITY

3.3.1 Salinity Patterns at the Diffuser Site

Near surface and near bottom measurements made at Mooring 12 during 1976 for both high and low water show a gradual rise through the year (Figure 3.3-1). The winter and spring data showed considerable variability. From August through December, salinities became less variable and rose from around 32.2 °/₀₀ up to about 34.0 °/₀₀. Lowest mean near surface values were 29.8 °/₀₀ in late January and 30.3 °/₀₀ in mid-May. Near bottom salinities were slightly higher and much less variable, ranging from 31.3 °/₀₀ in April up to 34.0 °/₀₀ in December. In general, lowest salinities were observed at low water, reflecting the influence of runoff from coastal embayments.

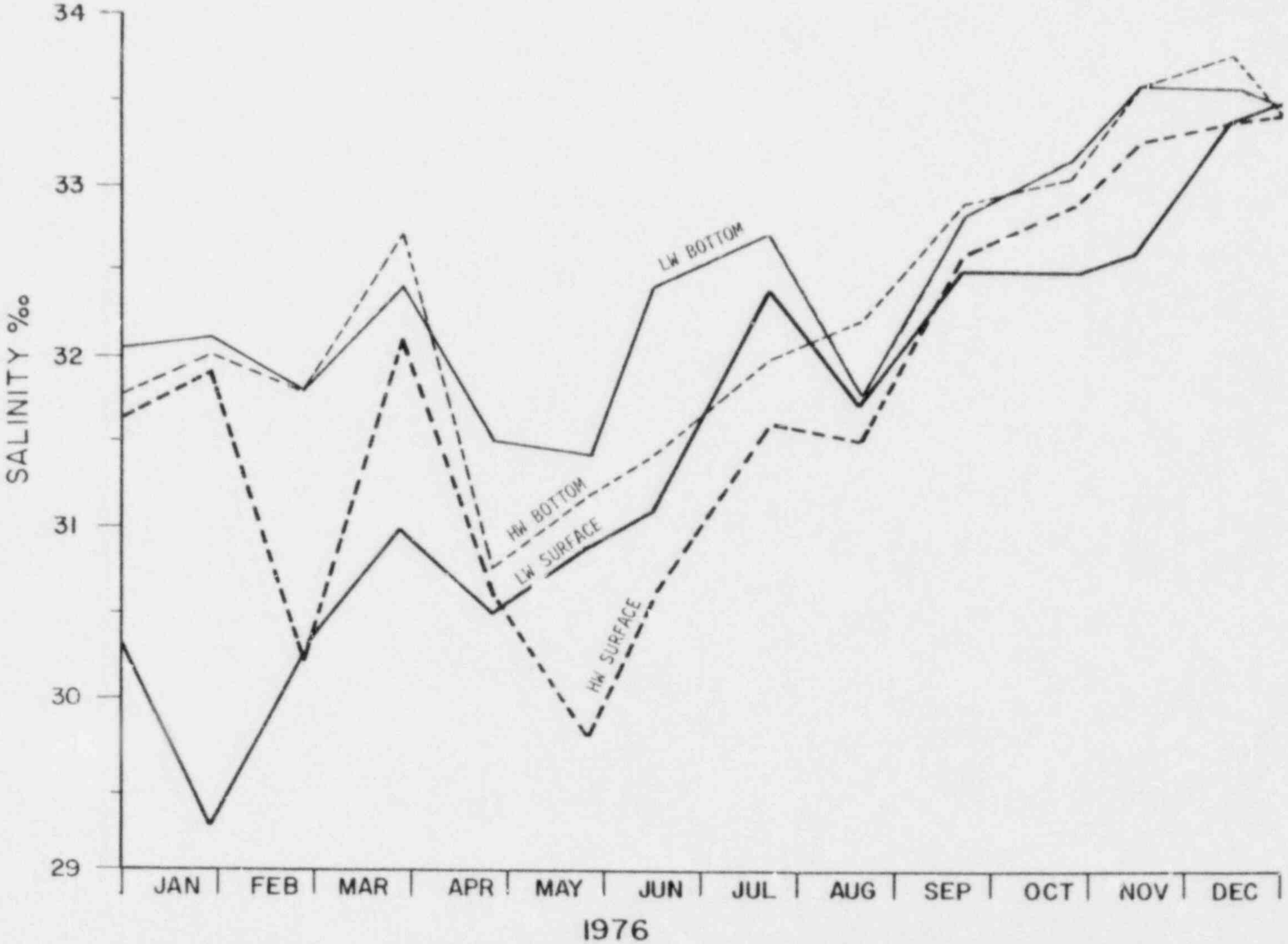


Figure 3.3-1. Monthly salinity observations (^{o}/oo) at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack-water surveys (both low water, LW and high water, HW). Seabrook 1976 Annual Hydrographic Report, 1979.

3.3.2 Mean Salinity Profiles

Mean monthly salinity profiles from high-water slack for all of the offshore stations during 1976 are shown in Figure 3.3-2. Beginning in January with a mean salinity of around 32.0 $^{\circ}/_{\circ\circ}$, salinities increased during the winter with near-surface values always being less than those at depth. From February through May, mean salinities dropped sharply to 30.2 $^{\circ}/_{\circ\circ}$ and lower, forming a pronounced halocline. This phenomenon was a result of spring run-off into the western Gulf of Maine. During the summer months, salinities increased again and the halocline was less evident. In September, October and November, increased runoff reestablished the halocline again, showing surface-to-bottom variations of up to 0.5 $^{\circ}/_{\circ\circ}$ (Figure 3.3-2). In the late fall, the onset of more intense winter storms (in the absence of the seasonal thermocline and decreased runoff) brought increased vertical mixing and return to the typical isohaline conditions of December (which averaged 33.3 $^{\circ}/_{\circ\circ}$).

3.3.3 Spatial Conditions

Near-surface salinity measurements obtained from slack-water surveys and plankton cruises further document the dynamic nature of these waters. Salinity data from the slack-water surveys emphasize the variability between tidal cycles, whereas the plankton cruise data highlight the variability along the coast from Rye Harbor southward to the Merrimack River.

Selected surveys from 1976 illustrate the variability of near-surface waters over a typical year. The mid winter survey of January 15, 1976 (Figure 3.3-3) showed the effect of regional runoff from the Merrimack River (23.1 $^{\circ}/_{\circ\circ}$ at the mouth) and Hampton Harbor (19.3 $^{\circ}/_{\circ\circ}$). Northward blowing winds apparently had carried this freshened water up to a point off Hampton Beach. However, from Great Boars Head on northward, surface salinities were high (32.0 $^{\circ}/_{\circ\circ}$). About 2 weeks later (January 29, 1976), ebb tidal salinities in Hampton Harbor were again

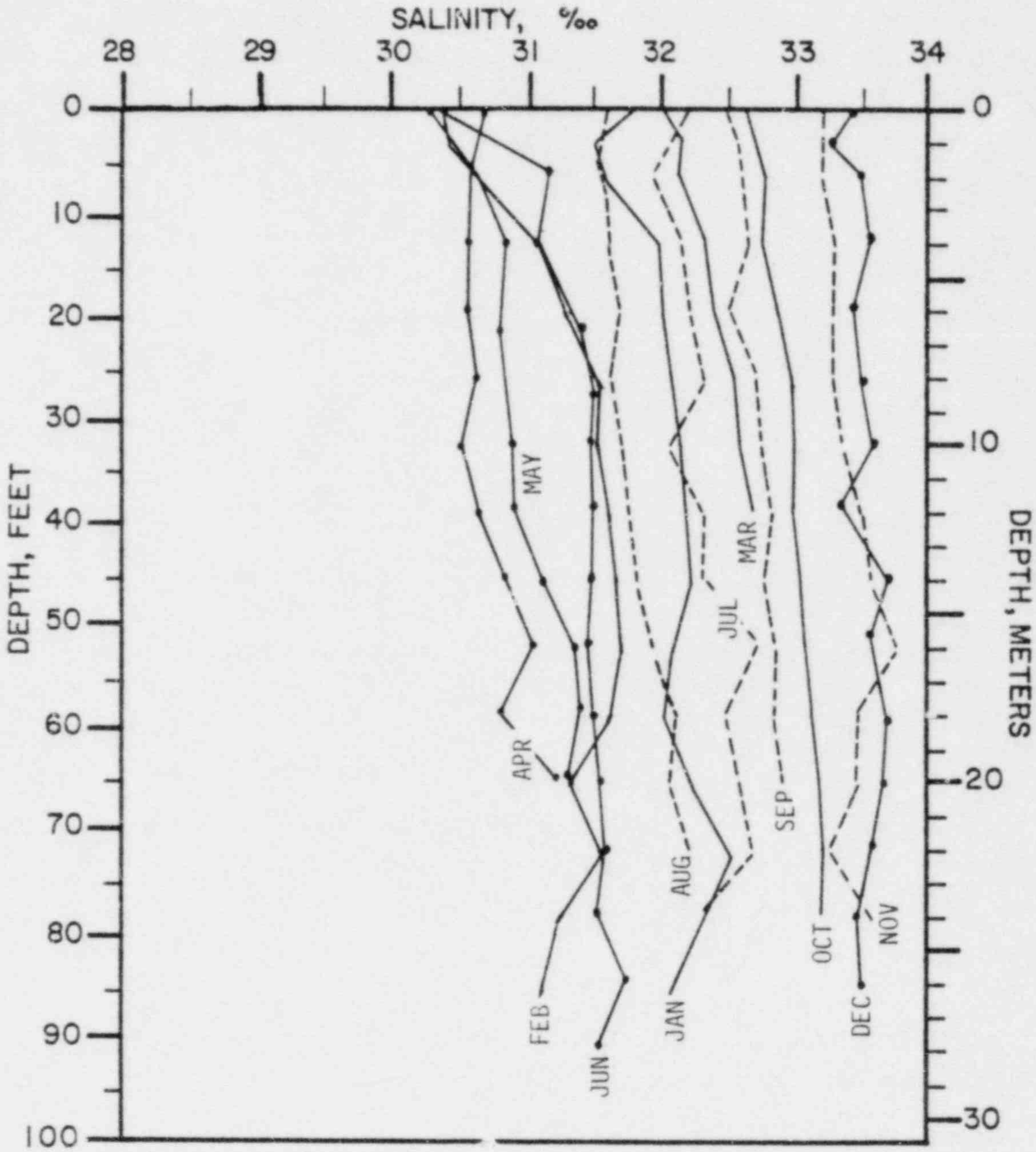


Figure 3.3-2. Mean salinity profiles taken at high-water slack from coastal waters off Hampton Beac.. ,ew Hampshire, during 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

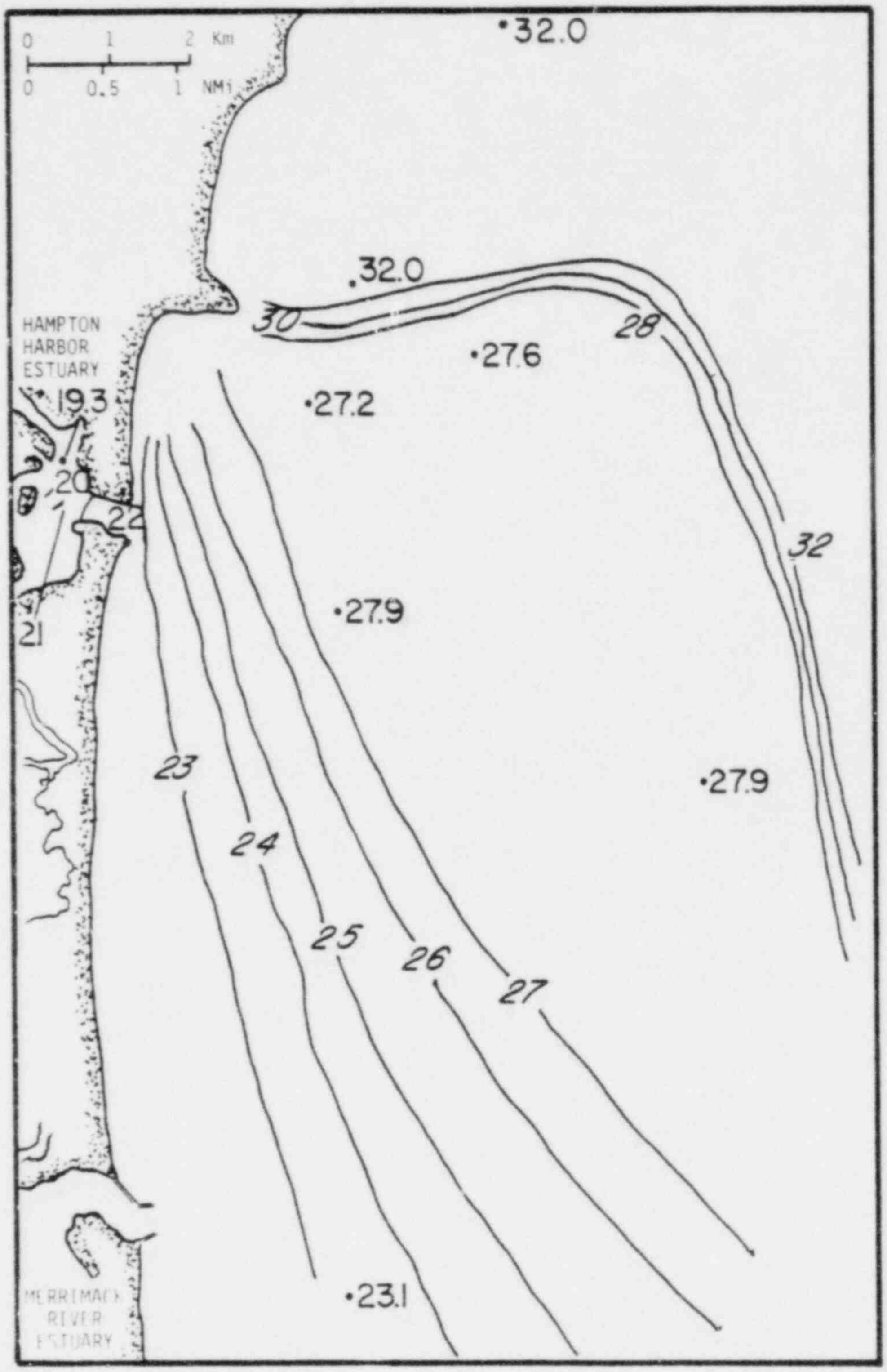


Figure 3.3-3. Surface salinity ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on January 15, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

very low (19.5 $^{\circ}/_{\circ\circ}$); with the high water condition surface salinities rose back up to 31.4 to 32.0 $^{\circ}/_{\circ\circ}$ (Figure 3.3-4).

By April spring runoff conditions had caused a general lowering of coastal salinities. For example, the April 21, 1976 slack-water survey showed typical coastal salinities of 30.1 to 31.0 $^{\circ}/_{\circ\circ}$ and an ebb tidal low of 28.0 $^{\circ}/_{\circ\circ}$ (Figure 3.3-5). The May plankton cruise again showed strong runoff from the Merrimack River with surface salinities down to 22.5 $^{\circ}/_{\circ\circ}$ and typical coastal values of about 30.0 $^{\circ}/_{\circ\circ}$ (Figure 3.3-6).

With drier summer weather, coastal salinities began rising again. Plankton cruise data from July 7, 1976 showed nearshore values of 31.2 to 31.7 $^{\circ}/_{\circ\circ}$ and an offshore low of 30.8 $^{\circ}/_{\circ\circ}$ (Figure 3.3-7). The slack water survey of July 20, 1976 (Figure 3.3-8) showed even higher values, up to 32.7 $^{\circ}/_{\circ\circ}$.

Typical fall season data further document this continuing rise in salinity. The plankton cruise from September 8, 1976 (Figure 3.3-9) showed a low off the Merrimack (30.8 $^{\circ}/_{\circ\circ}$), higher values to the north (31.8 to 32.2 $^{\circ}/_{\circ\circ}$) off Hampton Beach, and slightly lower salinities offshore (31.8 $^{\circ}/_{\circ\circ}$). The October 28, 1976 slack-water survey (Figure 3.3-10) showed coastal salinities of 31.8 $^{\circ}/_{\circ\circ}$ up to 33.1 $^{\circ}/_{\circ\circ}$.

In summary, the slack water surveys showed generally uniform near-surface salinities; however, in Hampton Harbor estuary, values as low as 19.5 $^{\circ}/_{\circ\circ}$ were observed. These surveys documented salinity variations of as much as 12.0 $^{\circ}/_{\circ\circ}$ at one station within the estuary over a single tidal cycle (January 29, 1976); more typical variations were 2.0 to 4.0 $^{\circ}/_{\circ\circ}$ between tidal cycles. Monthly plankton cruise data showed lowest salinities were generally in Hampton Harbor or off the mouth of the Merrimack River estuary (down to 20.8 $^{\circ}/_{\circ\circ}$ on February 10, 1976). Salinity values at stations off Hampton Beach were generally homogeneous. Studies by Manohar-Maharaj and Beardsley (1973) have shown that the Merrimack River is the largest source of freshwater input in the western Gulf of Maine.

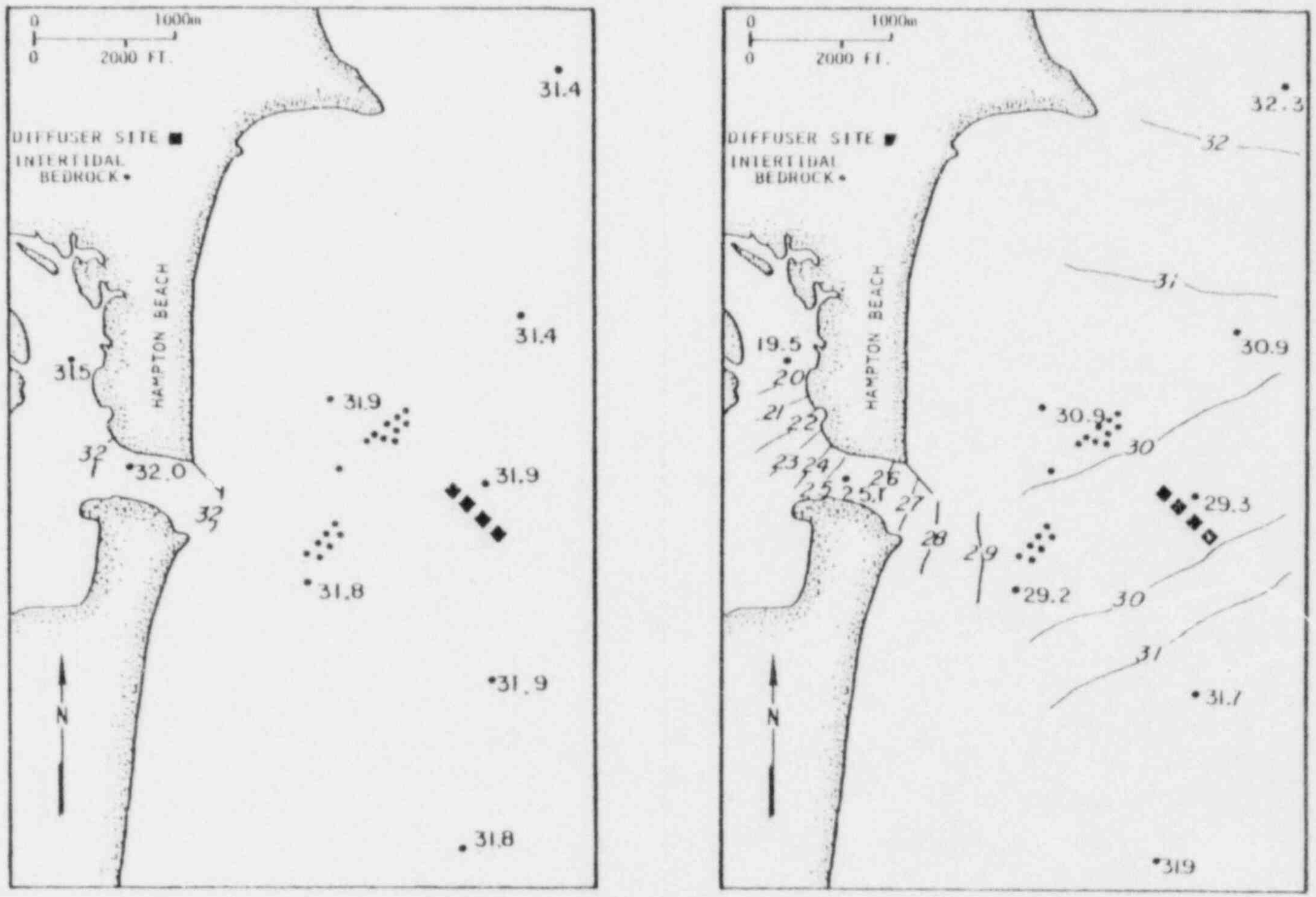


Figure 3.3-4. Surface salinities ($^{0}/oo$) in Hampton Harbor estuary and adjacent coastal waters on January 29, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

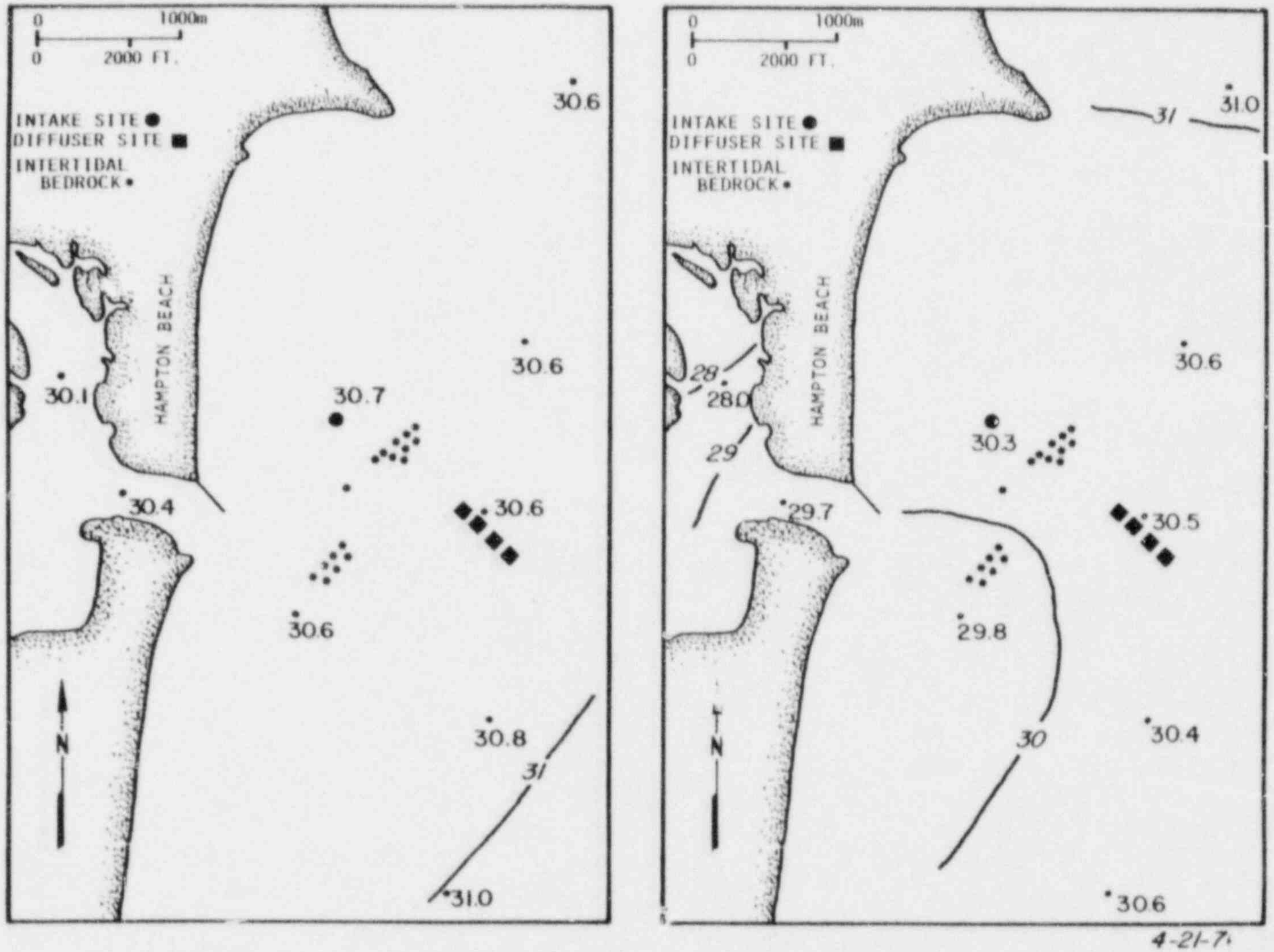


Figure 3.3-5. Surface salinities ($^{0}/oo$) in Hampton Harbor estuary and adjacent coastal waters on April 21, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

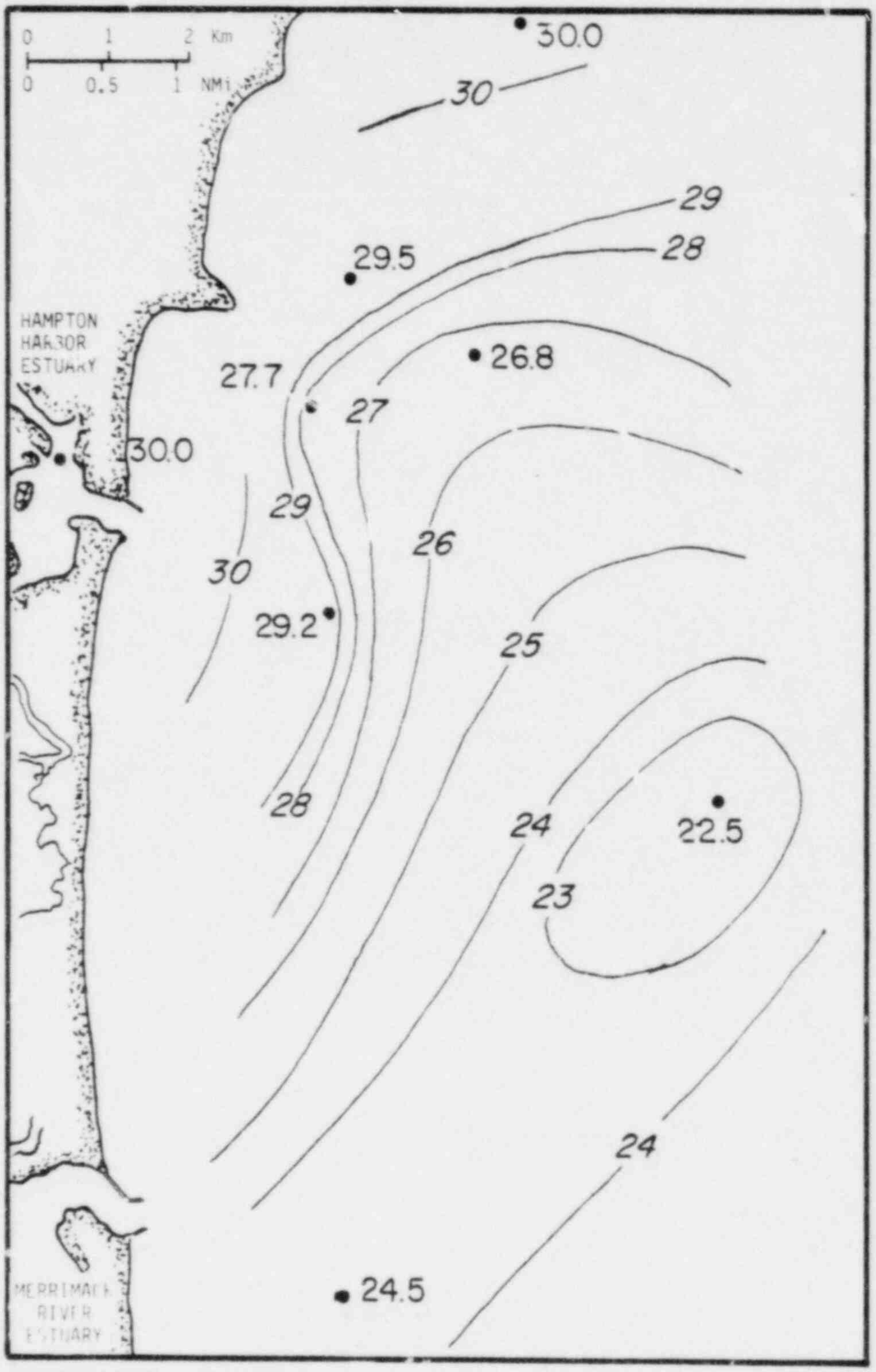


Figure 3.3-6. Surface salinity (°/oo) in Hampton Harbor estuary and adjacent coastal waters on May 10, 1976 from planktcn cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

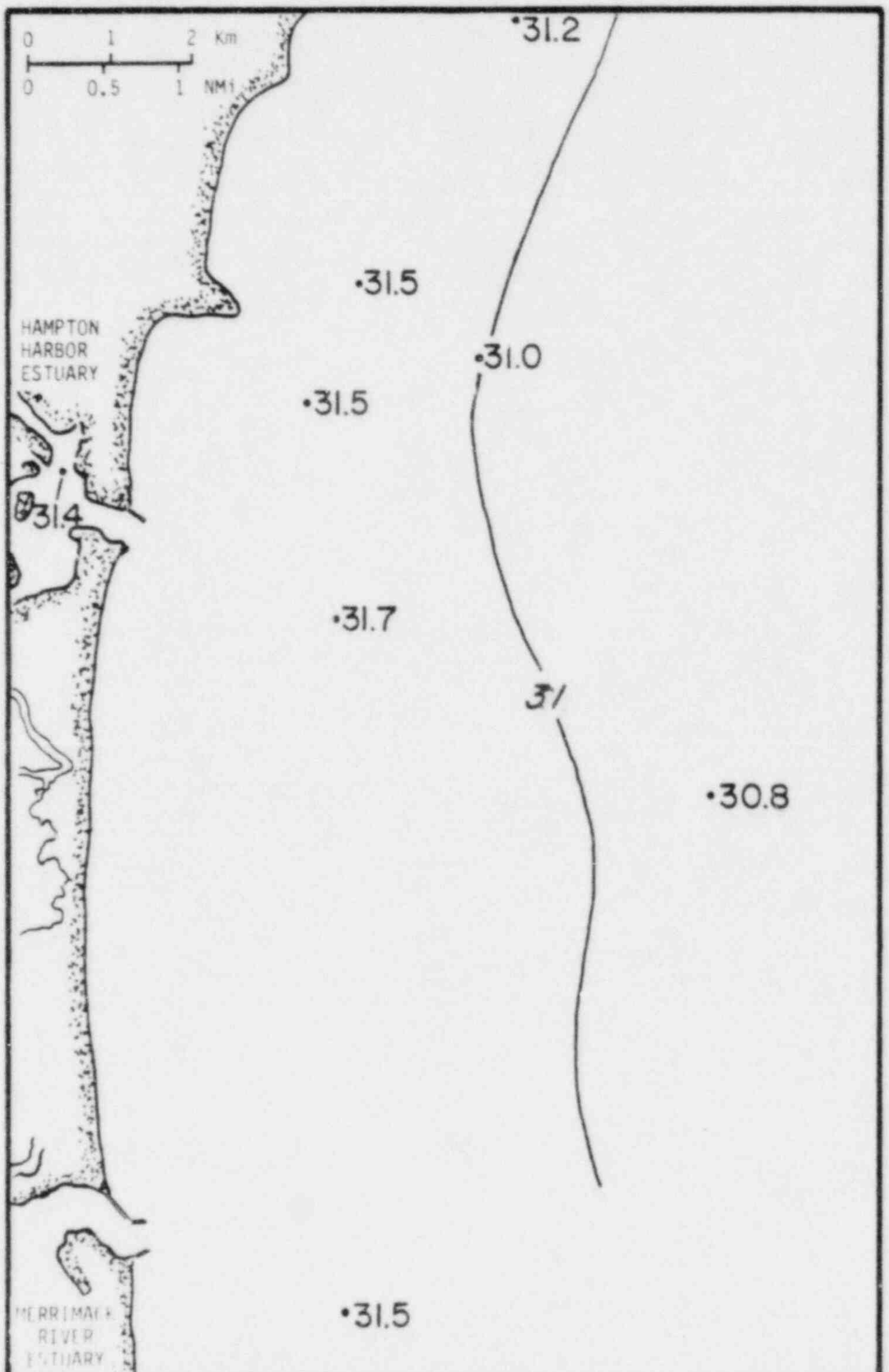


Figure 3.3-7. Surface salinity ($^{0}/oo$) in Hampton Harbor estuary and adjacent coastal waters on July 7, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

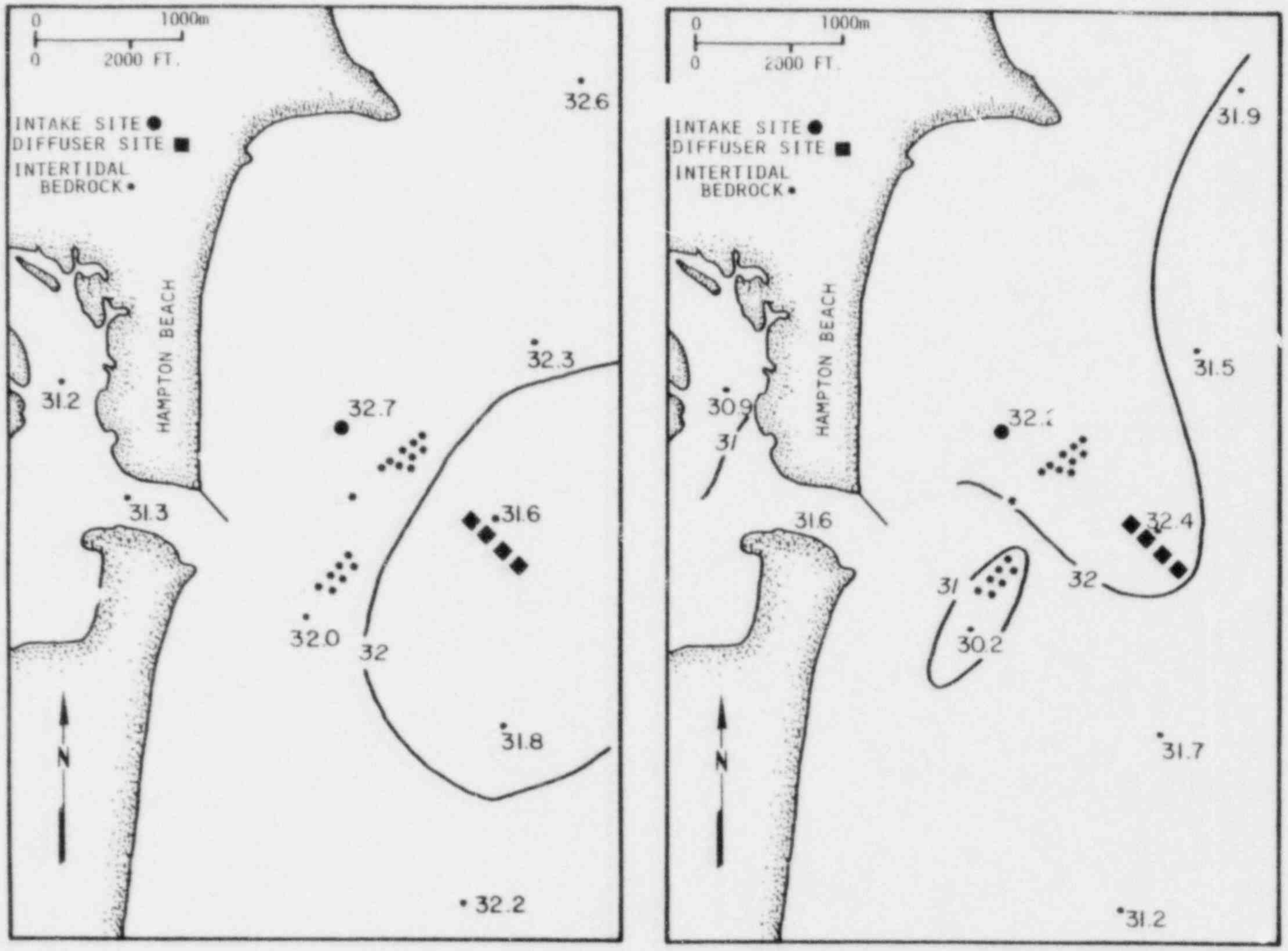


Figure 3.3-8. Surface salinities ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on July 20, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

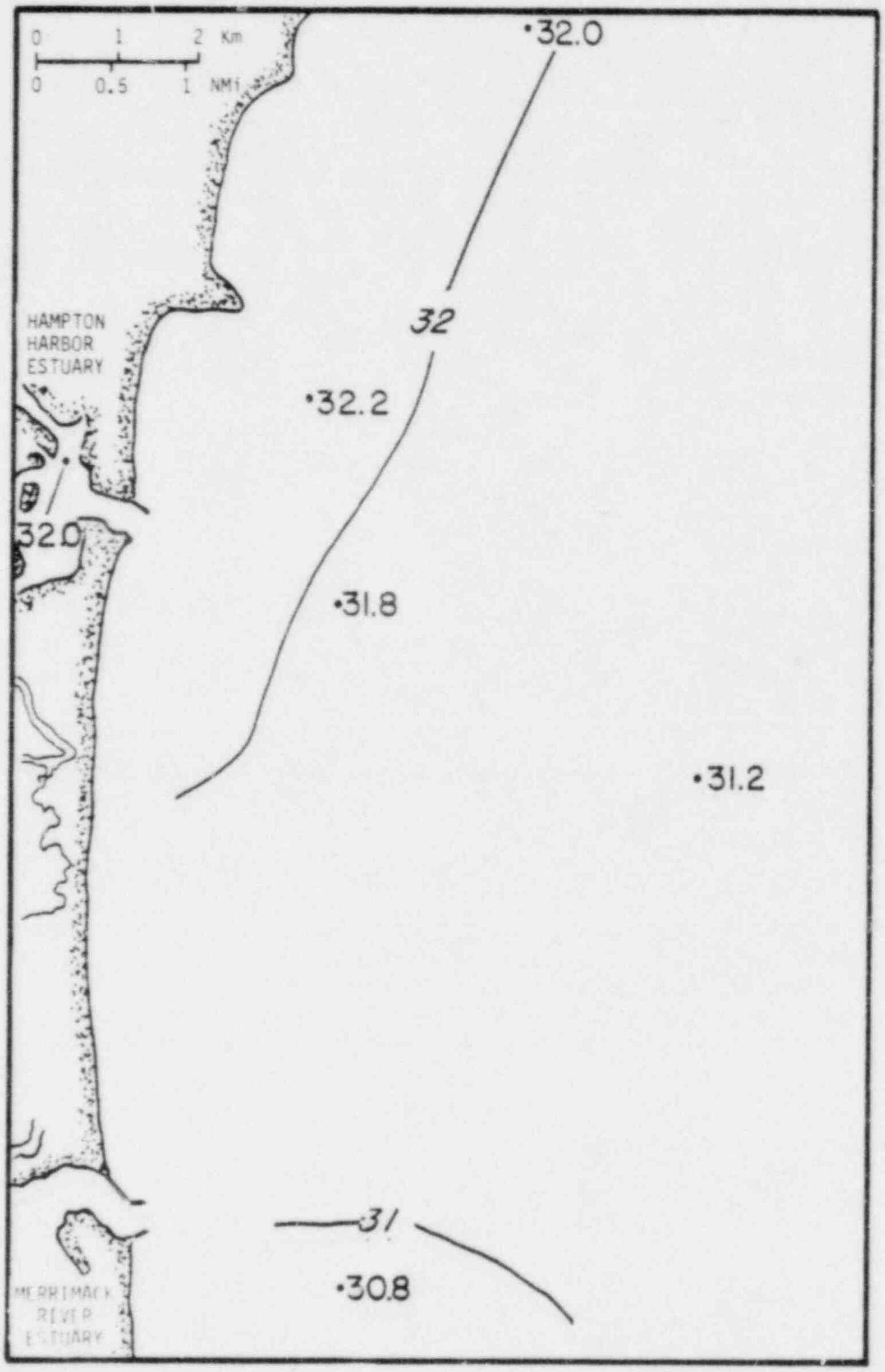


Figure 3.3-9. Surface salinity ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on September 8, 1976 from plankton cruise measurements. Seabrook 1976 Annual Hydrographic Report, 1979.

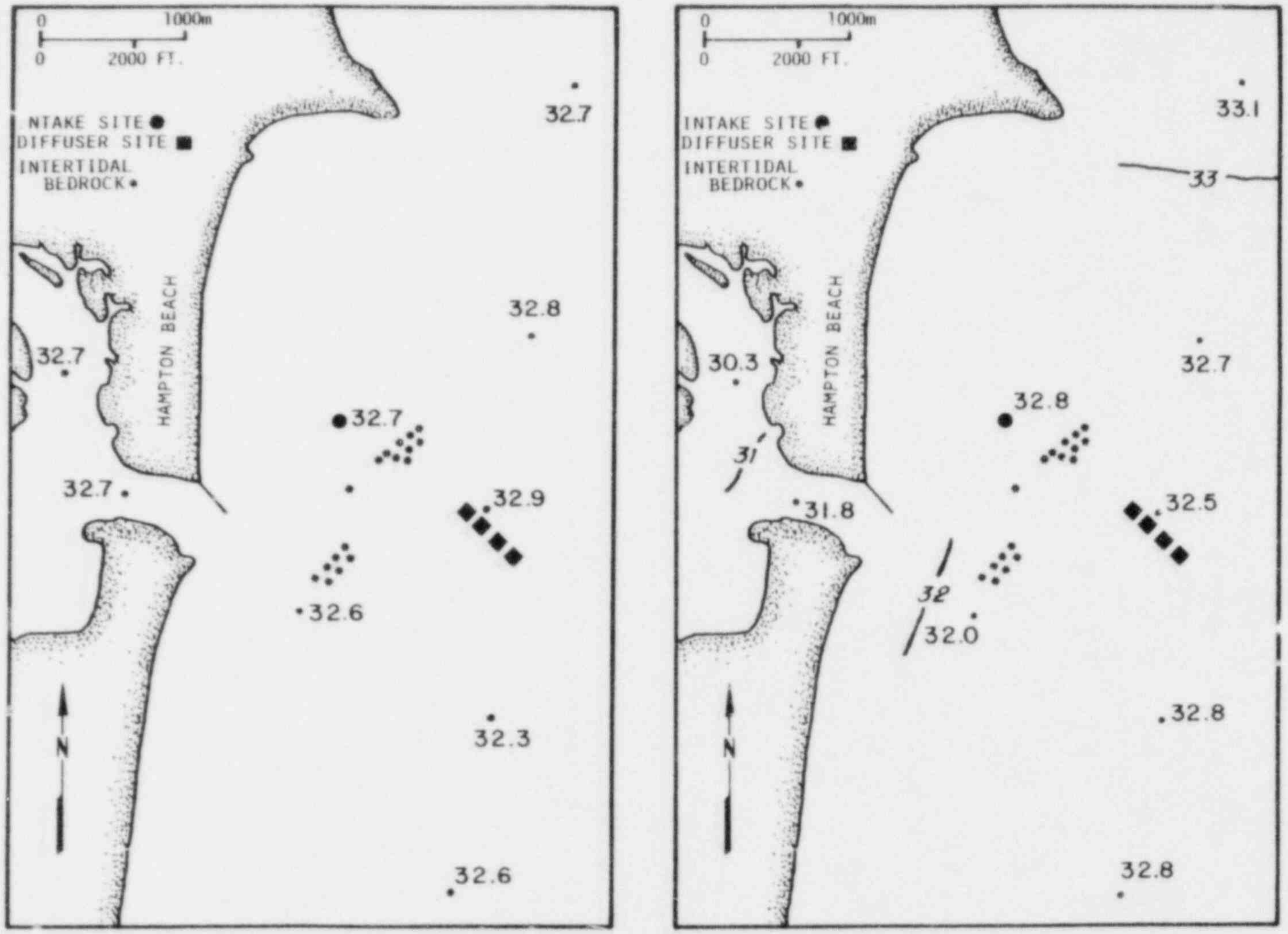


Figure 3.3-10. Surface salinities ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on October 28, 1976, from slack-water survey at high water (left) and low water (right). Seabrook 1976 Annual Hydrographic Report, 1979.

3.3.4 Relationship of Regional Runoff to Coastal Salinities

Salinities of coastal waters in the western Gulf of Maine are strongly influenced by regional runoff and river discharge (Graham, 1970b). For the region from Cape Ann, Massachusetts northward to Cape Elizabeth, Maine, about 90 percent of the drainage basin is comprised of the Merrimack River, Piscataqua River and Saco River systems. Mean monthly discharge data from the most downstream U.S. Geological Survey gauging stations on each basin were compiled to determine approximate runoff into the coastal waters for 1973 through 1976 (Figure 3.3-11). These data show a close relationship to NAI's mean near surface and mean near bottom salinities* observed during each hydrographic cruise over the same period. Peak discharge, which was observed in April 1973, caused a dramatic lowering of salinities (near surface values down to 27.0 °/₀₀ and near bottom values down to 29.6 °/₀₀). Note that the freshening lagged about 1 to 2 months behind the peak runoff. Similar freshening was observed in May 1976, but discharge was not as great. Other major freshening events were observed in July 1973; January, June and August, 1974; March and May 1975; and January 1976 (Figure 3.3-10). Highest salinities generally occurred during the late fall and early winter (up to 34.0 °/₀₀ in December 1976).

3.4 DENSITY

Density of water determined at atmospheric pressure ($\rho = 0$) or sigma-t measurements† from the monthly slack water surveys and the

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* Mean of all available data from each given day including both high water and low water measurements from slack-water surveys.

† The abbreviated way of writing density is $\sigma_t = (\rho_{s,t,o} - 1) \times 10^3$ so that density of 1.02570 would equal σ_t of 25.70. Density is affected in varying degrees by changes in ambient temperature and salinity. Changes in salinity have a relatively greater impact on density variation than changes in temperature. The same degree of change in salinity will affect the density more at lower temperatures than at higher.

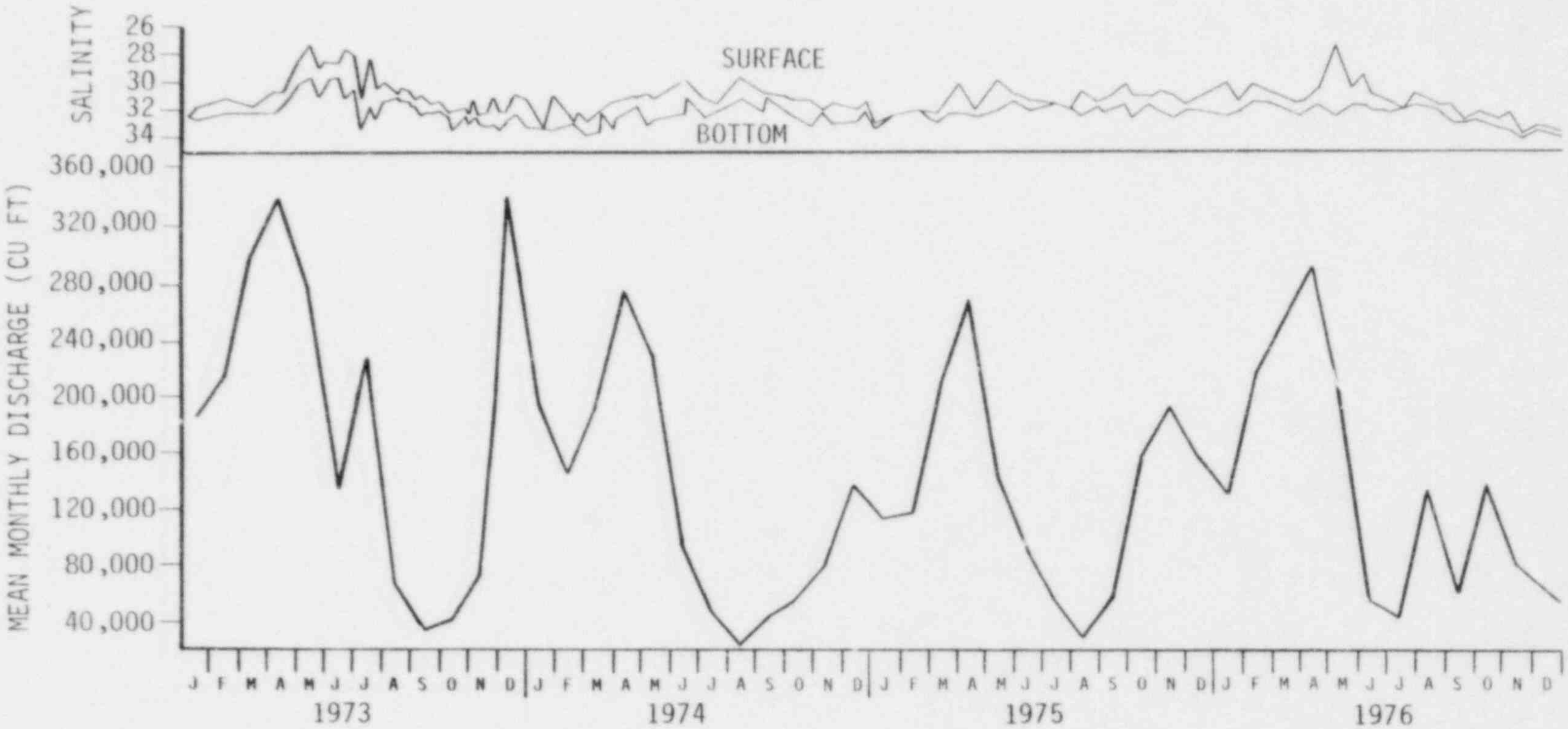

Figure 3.3-11. Plots of mean near-surface and near-bottom salinities from hydrographic surveys of coastal waters off Hampton Beach, New Hampshire, and mean monthly discharge from the Merrimack, Piscataqua and Sacco Rivers combined for 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

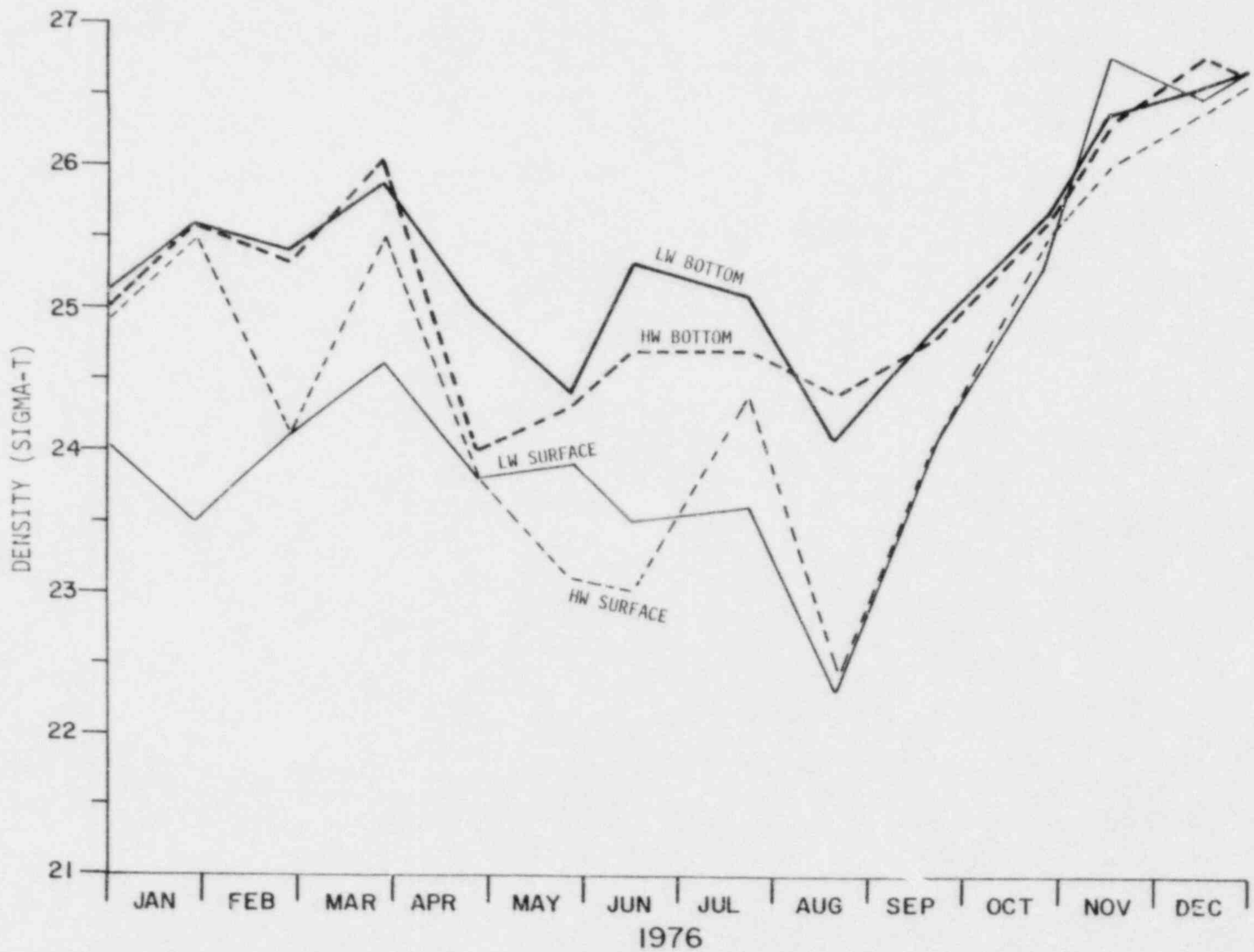

Figure 3.4-1. Monthly density of sigma-t observations at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack-water surveys (both low water, LW and high water, HW). Seabrook 1976 Annual Hydrographic Report, 1979.

plankton cruises provide additional framework for the data discussed in preceding sections. Measurements made at Mooring 12 during 1976 for near surface and near bottom at high water and at low water are presented in Figure 3.4-1. Near surface waters showed considerable variability, ranging from 22.3 in late August to 25.5 in January and March. Near bottom waters were much more uniform, averaging from 24.0 to about 26.8, but following a trend similar to the near surface waters. Both showed a gradual rise from August through December. As with the salinity data, lowest values were generally observed at low water, reflecting the influence of the ebb tidal flows from Hampton Harbor and adjacent estuaries.

3.5 DISSOLVED OXYGEN

The monthly slack water surveys and plankton cruises have documented the dissolved oxygen conditions in coastal waters. Measurements made at Mooring 12 during 1976 for near surface and near bottom at both high and low water are presented in Figure 3.5-1. Highest values were observed during the late winter, spring and early summer (about 10.0 to 11.7 mg/l), whereas lowest values occurred during the late summer and fall (down to 6.7 mg/l in August). No consistent pattern was observed between tidal stage or water depth, suggesting that dissolved oxygen follows a seasonal cycle related to planktonic photosynthesis, temperature and salinity. During the winter and spring, it was essentially homogeneously distributed, but near surface waters had higher concentrations during the summer.

The percentage saturation of dissolved oxygen for Mooring 12 over the same time period is summarized in Figure 3.5-2. During the winter and spring, concentrations gradually rose from about 97 percent to around 112 percent. Over the summer, near surface waters were highly supersaturated (up to 124 percent), whereas near bottom waters were generally undersaturated (down to 76 percent). Lowest overall concentrations were in November (mean of about 87 percent). Again, no consistent difference between tidal stage or water depth values was observed.

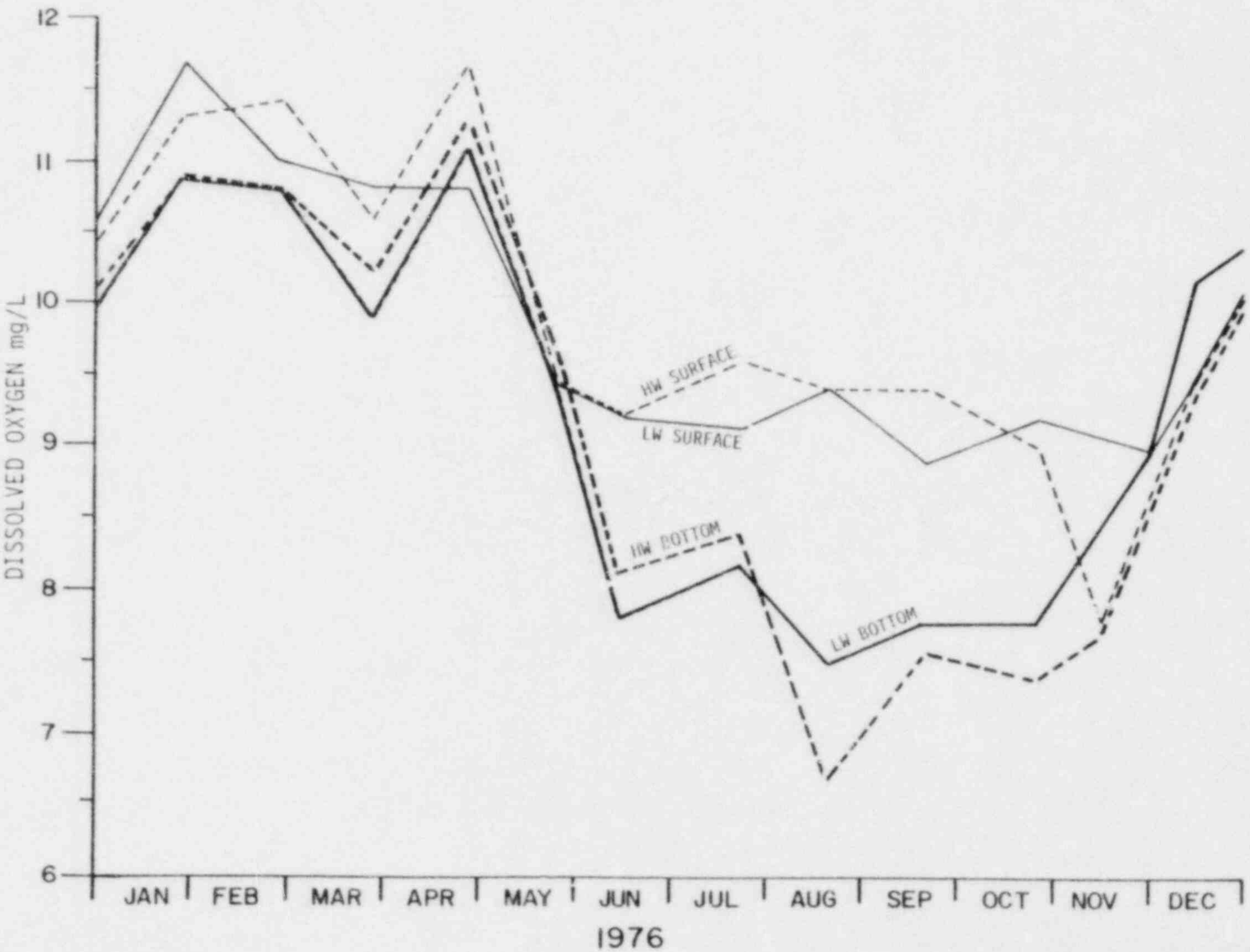

Figure 3.5-1. Monthly dissolved oxygen observations (mg/l) at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack-water surveys (both low water, LW and high water, HW). Seabrook 1976 Annual Hydrographic Report, 1979.

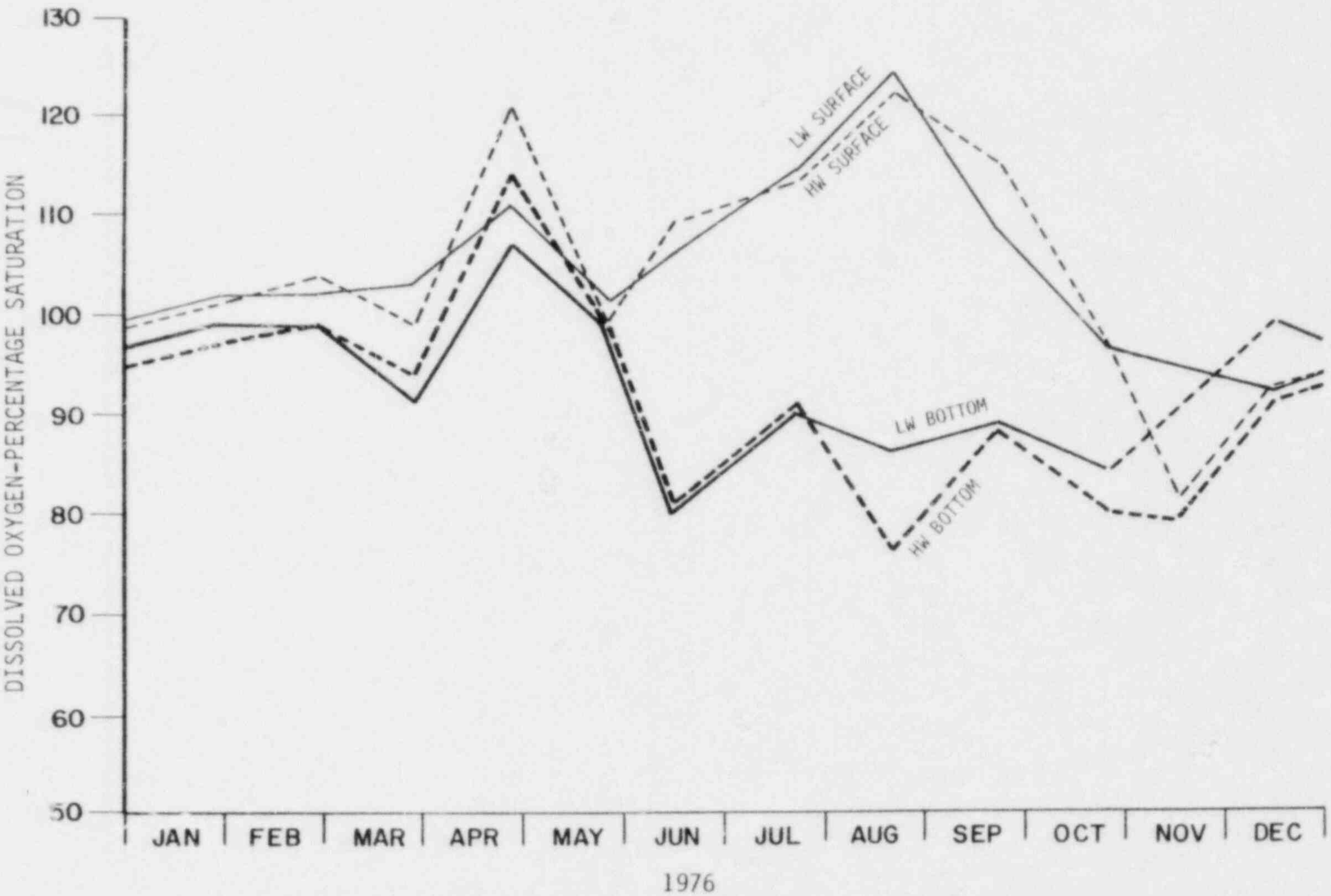

Figure 3.5-2. Monthly dissolved oxygen percentage saturation at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack-water surveys (both low water, LW and high water, HW). Seabrook 1976 Annual Hydrographic Report, 1979.

3.6 TIDES

Tide height in the Hampton Harbor estuary was measured continuously during 1976 at the Hampton Beach Marina (location map, Figure 2.1-1). These data were utilized primarily in determining actual times and heights of high and low water in the study area and for documenting periods of abnormally high tides which frequently accompany major storms. Plots of tide height over typical summertime and wintertime lunar months are shown in Figure 3.6-1. In this study program, the years were subdivided into lunar months based on a 1- to 2-day period preceding the new moon. During this interval, National Oceanic and Atmospheric Administration-National Ocean Survey (NOAA-NOS) predicted that the tide heights would be close to the mean for the estuary. From this dividing point, the monthly lunar cycle proceeds as follows: spring tide conditions (new moon), neap tide conditions (first quarter), spring tide conditions (full moon), and neap tide conditions (last quarter). Based on these criteria, the lunar months lasted from 29 to 31 days. The NAI-observed tide data showed close argreement with the NOAA-NOS tide table predictions (NOAA-NOS, 1976). In general, the mean tide range was about 8.3 ft (2.5 m). Spring tides ranged as high as 12.5 ft (3.8 m), whereas neap tides ranged as low as 6.0 ft (1.8 m). These tides are of the mixed, semi-diurnal type with a small (1 to 2 ft or 0.3 to 0.6 m) diurnal inequality which is most pronounced during spring tides (Figure 3.6-1). In the summer months, the highest spring tides occur with the full moon, whereas in the winter months the highest spring tides occur with the new moon.

The change in tide height (high or low water) and tidal current direction generally occurs 15 to 30 min earlier offshore than inside Hampton Harbor. Measurements of tide heights and times of high and low water at the mouth of the estuary in August 1974 showed that recorded heights at the Hampton Beach Marina were as much as 6 in (15.2 cm) higher and occurred 3 to 10 min later (NAI, 1975a).

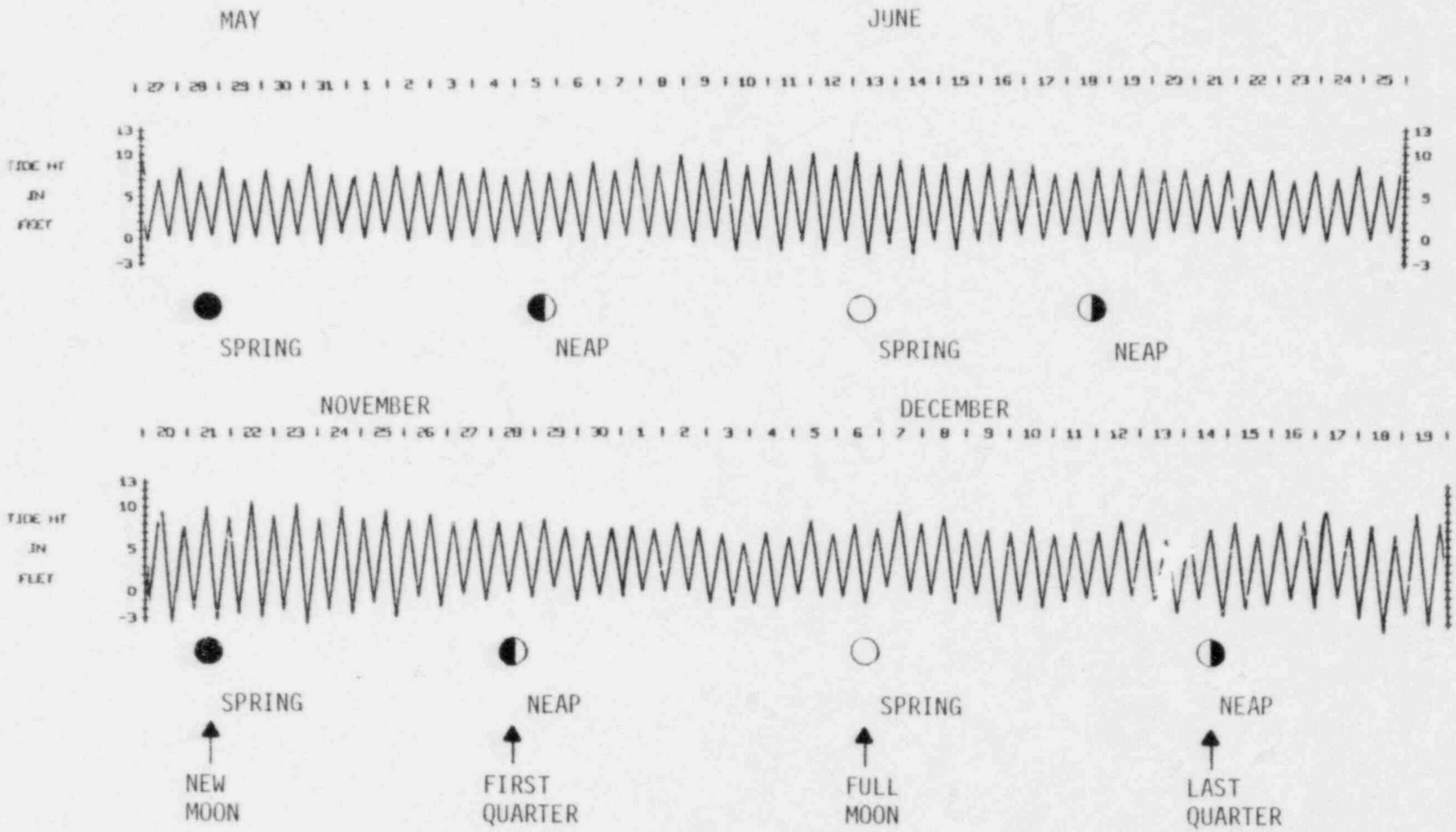

Figure 3.6-1. Plot of high-water and low-water tide heights in the Hampton Harbor estuary during typical 1976 summertime and wintertime lunar months. Seabrook 1976 Annual Hydrographic Report, 1979.

4.0 DISCUSSION

4.1 STORM EFFECTS

4.1.1 General Storm Patterns

Winds have a major influence in near surface water mass transport, especially in areas close to shore. When prevailing winds move near surfa ters away from the coast, subsurface waters move upward to replac them, a process called "upwelling", which is responsible for bringing nutrients into the more productive nearshore areas. Upwelling has been documented in the western Gulf of Maine by Longard and Banks, (1952), Graham (1970a), Kangas and Hufford (1974), Hartwell (1975) and NAI (1975a). Conversely, when winds are onshore, the opposite process of "downwelling", or plunging of coastal waters seaward along the bottom, can occur (NAI, 1975a). Strongest wind effects always accompany northeast storms. During these storms, near surface waters are often carried southward at speeds of 1.0 kn (51.5 cm/sec) or more.

Based on the four years of continuous current-meter data presented in previous sections and results of concurrent drifter releases (NAI, 1975a and 1975b), it appears that storms and associated winds play a key role in the large scale water mass displacement of the western Gulf of Maine and appear to help drive the general counterclockwise circulation of the Gulf of Maine gyre, as described by the work of Bigelow (1927), Day (1958), Bumpus and Lauzier (1965), Graham (1970a), and Bumpus (1973). In general, low-pressure systems moving across the region cause the stormiest conditions and the most significant wind stress effects in nearshore waters (Beardsley and Butman, 1974). Two basic patterns have been observed over the years.

The first pattern is that occurring when a low-pressure system moves slowly northeastward some 50 to 100 n mi (93 to 185 km) off the Atlantic coast, over Georges Bank and on past the Maritime Provinces (Figure 4.1-1). The counterclockwise wind circulation of such storms

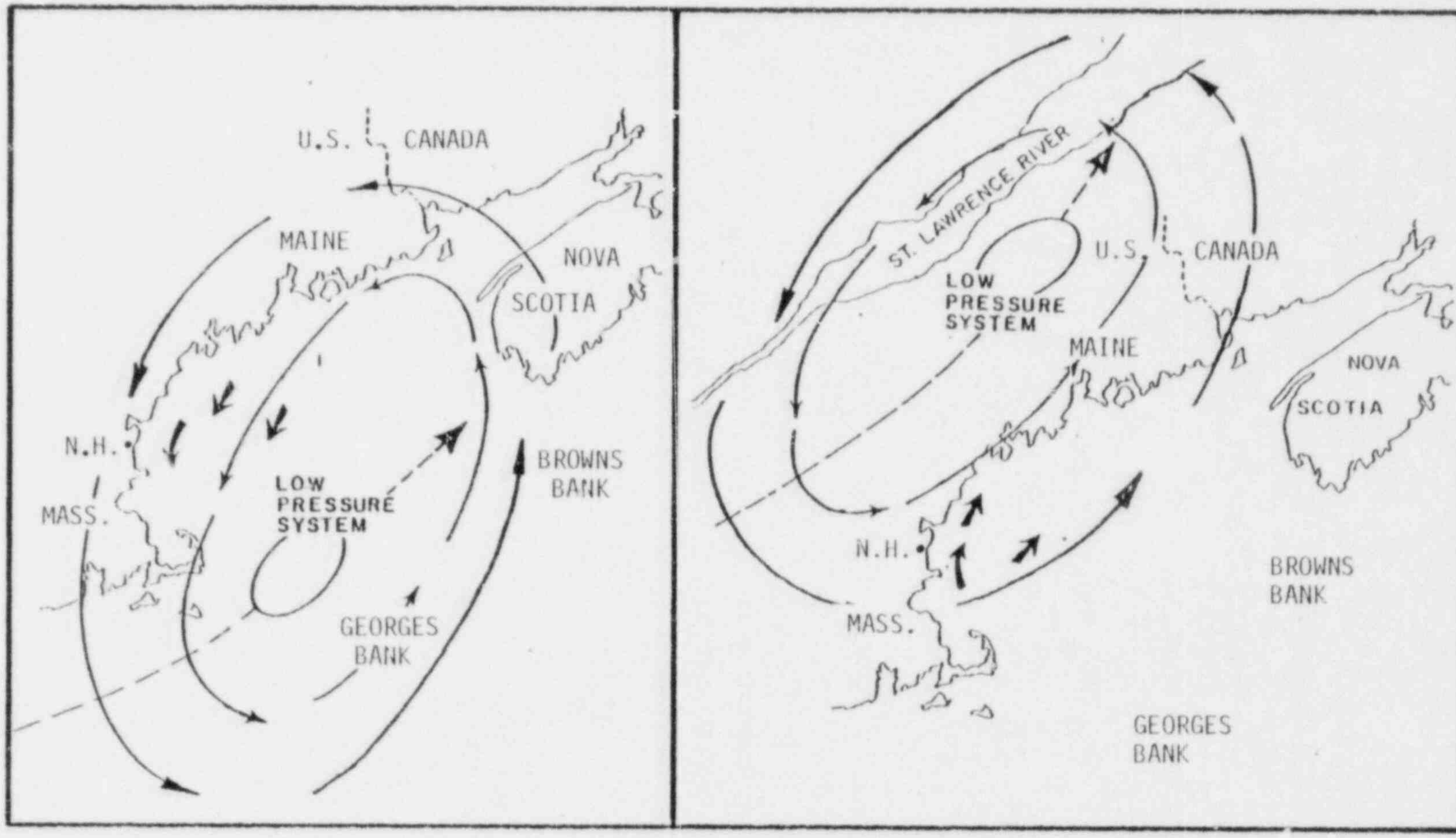

Figure 4.1-1. Diagrammatic representation of low-pressure systems and accompanying wind patterns from storms moving up off the coast and up the St. Lawrence River Valley illustrating effects on coastal flows in the western Gulf of Maine. Seabrook 1976 Annual Hydrographic Report, 1979.

means that winds from the north or northeast blow from across the Gulf of Maine, lashing the coast as a typical "nor'easter" or northeast storm. Such storms have long been recognized as most significant along this coast, especially from the standpoint of beach erosion (Hayes and Boothroyd, 1969) and seem to consistently result in strong southward flows along the coast (NAI, 1975a and 1975b; Hartwell, 1976).

The second pattern is that occurring when a low-pressure system moves slowly northeastward over the Great Lakes, up the St. Lawrence River valley, and over eastern Canada out to sea (Figure 4.1-1). In this instance, the winds in the Gulf are from the southwest, south or southeast and typically result in northward flows along the coast.

In both cases, nearshore waters seem to respond very quickly to the storm winds, probably because of the relative shallowness along the coast. Frequently, ambient coastal flows may be directly opposite to the storm-generated currents. These opposite nearshore and offshore flows may continue for a period of a day or two. Eventually the storm effects become dominant (provided the storm has been strong and persistent enough) and both nearshore and offshore flows become coupled, flowing in the same direction. Once the storm passes, the nearshore waters are again the first to return to more normal conditions (Hartwell, 1976).

This phenomenon creates coastal jets or pulses of flow which frequently dominate coastal circulation. Such coastal jets have been described by Csanady (1972) in Lake Ontario (which is somewhat smaller than the Gulf of Maine) and by Scott and Csanady (1976) in their studies of nearshore currents off Long Island. If wind stress has been strong and persistent enough, such jets expand seaward, causing nearshore and offshore water masses to become "coupled". Shearing between the two is also important and at times flows can be quite complex.

4.1.2 Model of Northeasterly Storm Build-up and Dissipation

Based on analysis of over one-hundred northeasterly storms, a simple model for the typical pattern of storm buildup and dissipation has been developed (Figure 4.1-2). In the "storm phase", ambient temperatures and salinity often create a stratified condition comprising an upper layer and a lower layer. The shallow waters are especially susceptible to wind shear effects and constitute a "nearshore" zone. Waters further seaward are called the "offshore" zone. In the absence of a storm, transient or tidal effects predominate.

In the "early storm phase", wind stress effects begin, waves start building up, vertical mixing near shore is initiated, and upper and lower layers become coupled. The nearshore zone exhibits southward flow, whereas the offshore zone continues to show residual tidal effects (Figure 4.1-2).

In the "intense storm phase", the upper and lower layers, as well as the nearshore and offshore zones, become coupled. Strong southward currents predominate with storm surge and coastal flooding, beach erosion, bottom sediment transport, and sand wave migration (Figure 4.1-2).

Finally, with the "post storm phase", currents have shifted to cause downwelling along the coast; however, residual momentum persists, especially in the offshore zone. The upper and lower layers remain coupled, but the nearshore zone and the offshore zone decouple. The nearshore zone returns to tidal flows, whereas the residual storm-driven flows in the offshore zone may persist for several more days.

4.1.3 Storms During 1976

During 1976, there was a series of major northeaster storms which caused periodic surges in coastal flows, large waves and some

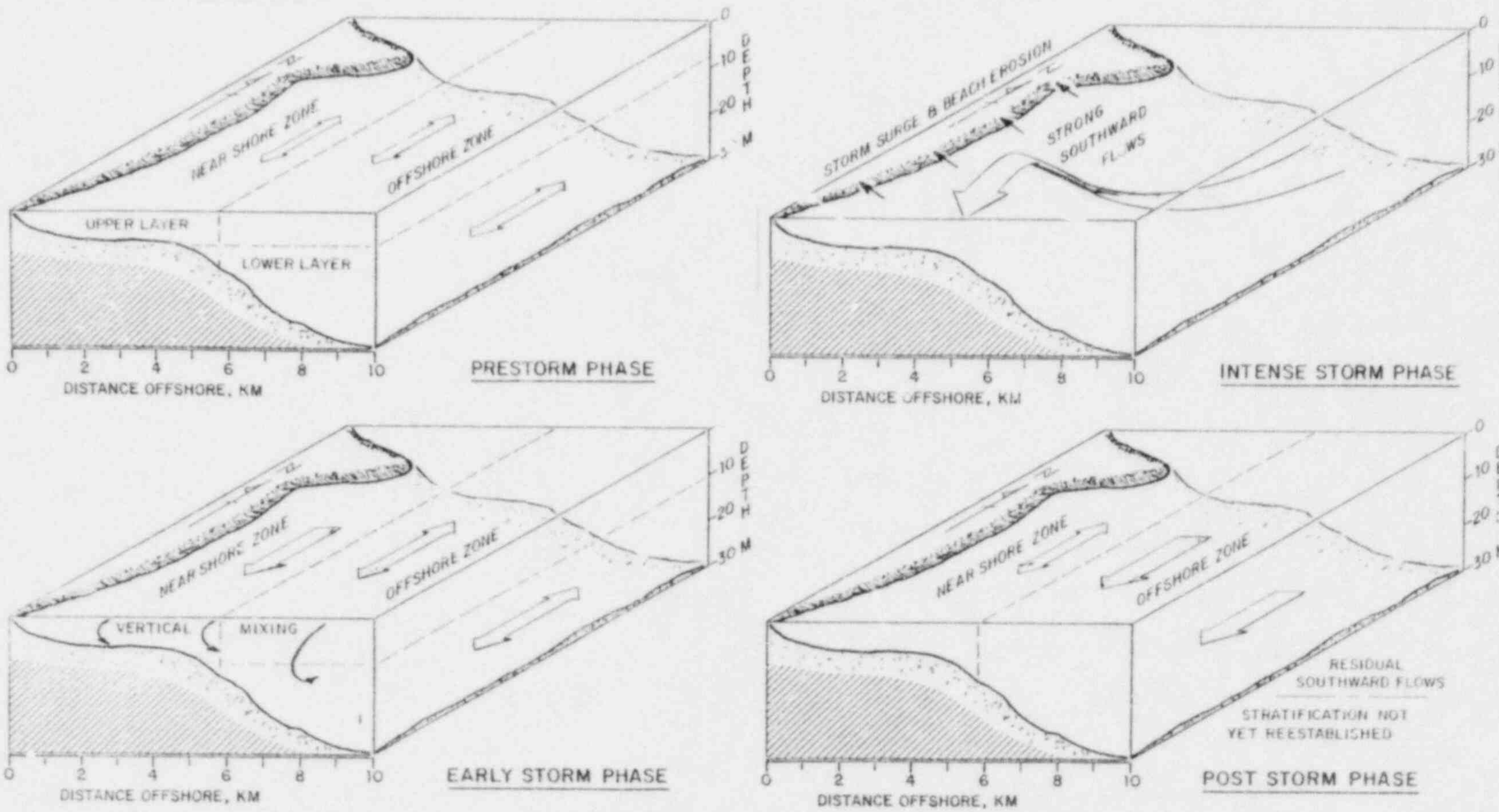

Figure 4.1-2. Diagram illustrating the four phases of northeasterly storm buildup and dissipation in the western Gulf of Maine. Seabrook 1976 Annual Hydrographic Report, 1979.

beach erosion events. Numerous weaker storms also occurred (Table 4.1-1 and Appendix 7.6). January, February, March and April were the storm-iest months, but at least one northeaster occurred every month of the year (also see Figure 3.1-2).

4.1.4 Comparison With Historical Trends

We are not aware that any of the 1976 storms set any U.S. Weather Bureau records. Rather the patterns observed during this year were similar to those observed during previous years (Figure 3.1-2). Other studies in the western Gulf of Maine (for example, NAI, 1974 in Casco Bay, Maine; Cox, 1975 in Massachusetts Bay; Kangas and Hufford, 1974 in Massachusetts Bay; and EG&G, 1976 off Salisbury Beach and Plymouth, Massachusetts) have also showed that periodic storm events drive coastal currents southward or northward along the coast, depending upon wind direction. Such events typically affect the entire coastal region from Cape Elizabeth to Cape Cod, resulting in major displacements of large volumes of water.

4.2 ANNUAL CYCLE OF TEMPERATURE/SALINITY DISTRIBUTION AND WATER MASS

The coastal waters off Hampton Beach and in the western Gulf of Maine, out to at least 9 n mi (17 km) offshore, undergo an annual cycle which is representative of the natural variability of temperate coastal seas, caused by factors such as: tides, winds, solar radiation, waves, storms, upwelling, downwelling, rainfall, evaporation, and estuarine thermal plumes. The Gulf of Maine waters can be grouped into four water masses: surface (MSW), intermediate (MIW), bottom (MBW) and Georges Bank (GBW), based on Hopkins and Garfield (1978). These are represented diagrammatically in Figure 4.2-1. The Seabrook study area is primarily within the MSW mass.

TAB'E 4.1-1. DATES OF MAJOR AND LESS IMPORTANT STORMS DURING 1976. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

1976	MAJOR STORMS	LESS IMPORTANT STORMS
January	8 & 9, 22 to 29	1, 11 to 13, 18, 31
February	17 & 18, 25 & 26	5 to 7, 9, 14
March	2 to 5, 29 to 31	
April	1, 19 to 23, 25 & 26	
May		21 & 22; 25 & 26
June		27 & 28
July	1 & 2	30 & 31
August		7
September		17 to 19; 28
October	26 to 28	1 to 6
November		1, 6, 29
December		8 & 9, 13 & 14, 16, 18 & 19, 21, 29 & 30

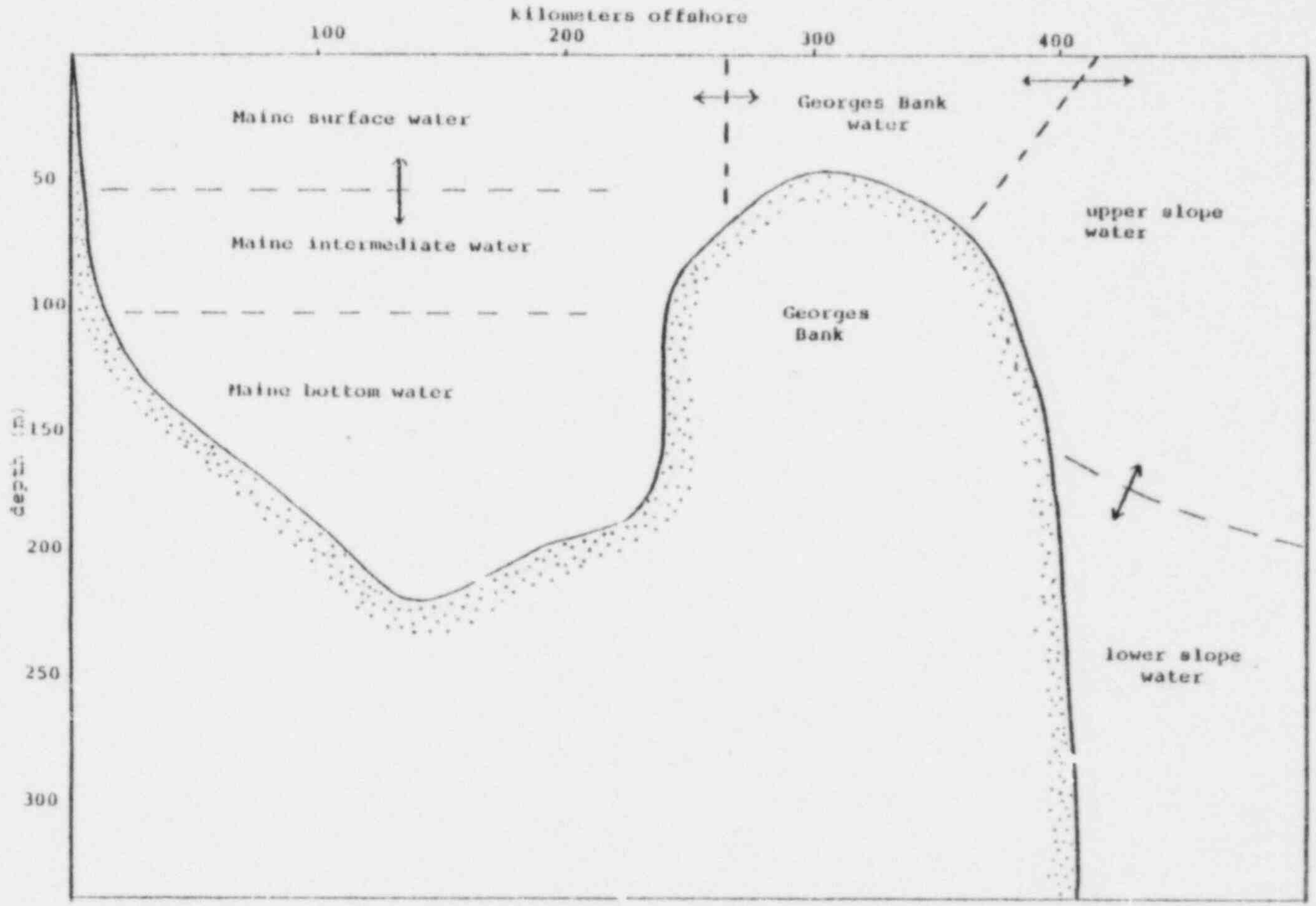

Figure 4.2-1. Water mass schematic of the Gulf of Maine from Hopkins and Garfield, 1978. Seabrook 1976 Annual Hydrographic Report, 1979.

In general, the Gulf of Maine is exposed to three source water masses: Western Scotian Shelf Water (WSSW) lying off the coast of Nova Scotia, Upper Slope Water (USW) overlying the continental slope region, and Lower Slope Water (LSW) at depth on the continental slope (Hopkins and Garfield, 1978). Freshwater inflow from the Gulf of St. Lawrence causes seasonal salinity minima along the Nova Scotian coast, reflecting a westward advection of the St. Lawrence discharge; but it is uncertain how much of this water enters the Gulf of Maine (Sutcliffe *et al.*, 1976). Thus, river runoff into the Gulf of Maine appears to be the major influence on coastal salinities.

The following descriptions are from Hopkins and Garfield (1978):

4.2.1 Maine Surface Water (MSW)

The MSW commonly has salinities between 31 and 33 °/₀₀. In the nearshore regions, salinities may be reduced to less than 30 °/₀₀. The temperature range of about 34 to 63 F (1 to 17 C) reflects the seasonal heating and cooling cycle. The surface T-S properties along the coast of Maine are influenced by the eastward decrease in runoff and the eastward increase in tidal mixing. Such tidal mixing tends to cause lower surface temperatures as well as higher salinities.

4.2.2 Maine Intermediate Water (MIW)

The MIW is a low salinity, temperature minimum water. The salinities are too low to be of offshore origin, and the water mass volume shows seasonal fluctuation, suggesting local coastal effects. The possibilities are water from the Scotian Shelf having salinities lowered by the St. Lawrence discharge, local coastal Maine waters cooled during the winter, or both. During the winter, the MIW characteristics converge with the MSW, but during spring the two water masses diverge as

the MSW freshens and warms. The MIW is the remnant water mass from the previous winter. It does not lose its identity during summer heating because the mixing processes associated with cooling extend deeper than do those associated with warming. The MIW core is found between about 165 and 325 ft (50 and 100 m), the lower limit and volume dependent upon seasonal production.

4.2.3 Maine Bottom Water (MBW)

The MBW is a warmer, higher salinity water than the MIW. It occupies the depths between the MIW and the bottom. By definition its water type is unaffected by air-sea interaction (i.e., because the direct effects are absorbed by the MIW). The only offshelf exposure (below about 250 ft or 75 m) occurs through the Northeast Channel where the sill is about 800 ft or 240 m. This permits entry into the Gulf of Maine of slope water of both the warmer (USW) and cooler (LSW) variety (Figure 4.3-1). No published account of the MBW distribution and its Slope Water content exists. However, Figure 4.2-2 shows that the separation between USW and LSW that exists close to the Northeast Channel disappears for stations well into the Gulf, i.e., the MBW. The position of the MBW on the T-S diagram intermediate between the MIW and the USW and LSW implies mixing between these three water masses.

4 2.4 Georges Bank Water (GBW)

The GBW has been designated a separate water mass on the basis that lateral homogeneity commonly does not extend beyond Georges Bank. The position of GBW on the T-S diagram (Figure 4.2-2) implies closer association with interior Gulf of Maine waters than exterior. This is more clearly indicated by the salinities, which over an annual cycle remain remarkably constant (about 32.5 $^{\circ}/_{\circ\circ}$). For comparison the Gulf of Maine waters at a depth greater than 164 ft or 50 m average 32.35 ± .35 $^{\circ}/_{\circ\circ}$ while offshore averages 33.67 ± 1.03 $^{\circ}/_{\circ\circ}$. The increasing

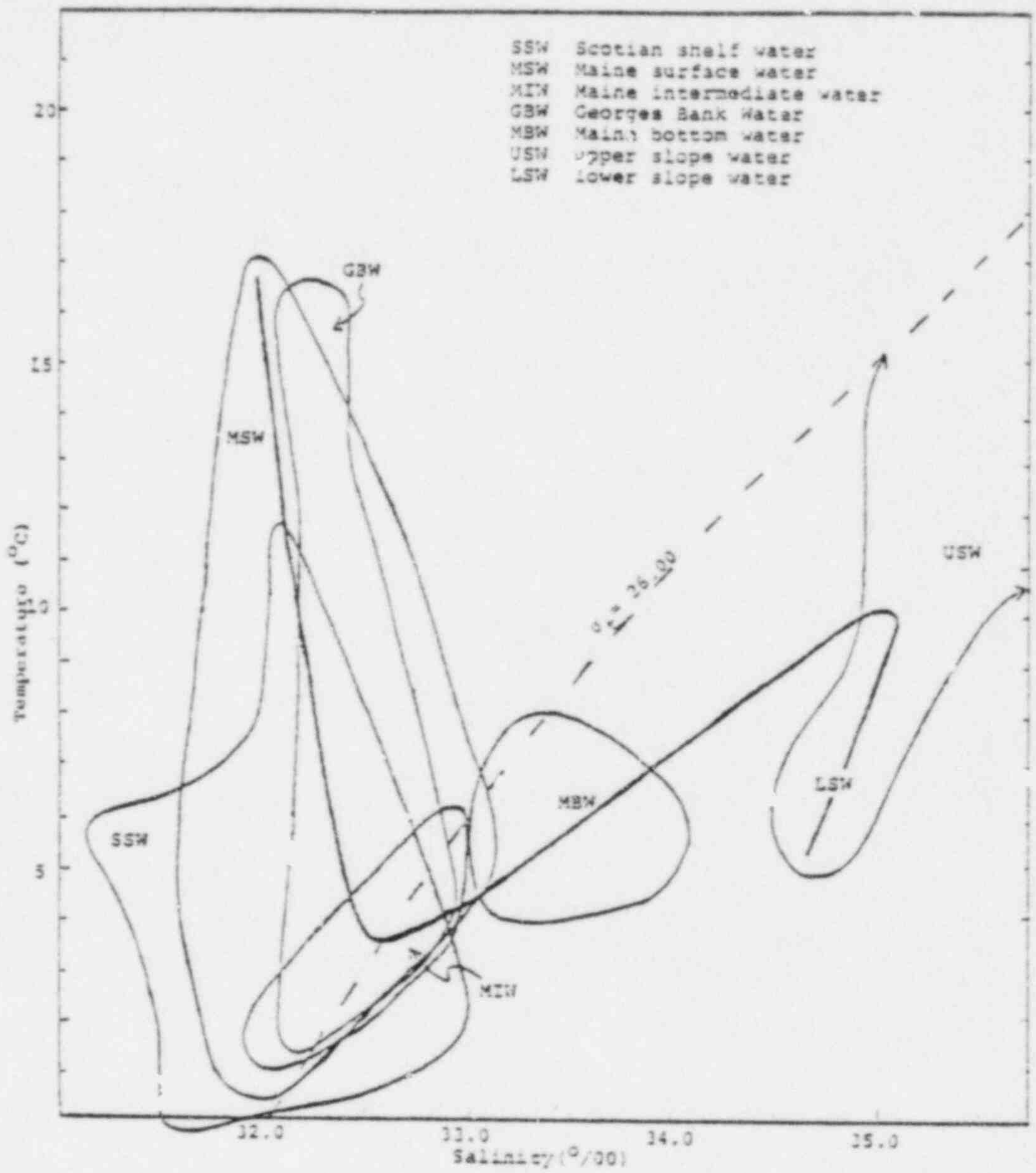

Figure 4.2-2. Schematic Gulf of Maine T-S Diagram with data from Colton *et al.*, (1968) for December 1965 through September 1966 from Hopkins and Garfield, 1978. Seabrook 1976 Annual Hydrographic Report, 1979.

salinity of the GBW from the base salinity of the MSW could come from either the admixture of offshore surface water or from deeper Gulf of Maine waters.

4.2.5 Upper Slope Water (USW) and Lower Slope Water (LSW)

The USW and the LSW refer to the two subsurface water masses found over the continental slope (Figure 4.2-2). The description and definition of these water masses is not clear and in the region of Georges Bank there has been the least treatment of all, because the region falls at the southern end of Canadian interest and at the northern end of U.S. attention. Gatien (1976) separates the Slope Waters by distinguishing between those dominated by the Gulf Stream and those dominated by the Labrador Current, calling them Warm Slope Water and Labrador Slope Water, respectively. The Slope Water off the Scotian Shelf is more completely discussed by McLellan (1957) and Lee (1970).

4.2.6 Coastal Waters off Hampton Beach, New Hampshire

In the portion of the MSW which NAI has been studying, the freshwater input is either mixed with salt water in estuaries before it reaches the Gulf of Maine proper or falls as rain across the Gulf. The salinity of this estuarine input varies considerably, depending primarily upon the size of the drainage basin. The largest source of fresh water runoff in this portion of the western Gulf of Maine is the Merrimack River (Manohar-Maharaj and Beardsley, 1973). Other sources include the Great Bay System (including the Piscataqua River), the Hampton Harbor estuary, Parker River estuary and Essex River estuary (see Figure 1.1-1). These estuaries typically release waters as fresh as about 20 °/₀₀, causing a well-defined coastal halocline during much of the year. Offshore these waters become diluted with higher salinity waters.

Seasonal variations in nearshore water temperatures are primarily the result of air-sea heat transfer and circulation patterns. The circulation affects temperature by: (1) lateral displacement of water masses and (2) vertical motion such as upwelling or turbulent mixing by storms and waves (Sverdrup *et al.*, 1942 and Smith, 1973).

This annual progression or cycle is primarily manifested in the ambient variations in temperature and salinity which may be used to define six distinct water masses over the course of the year. This cycle, documented by the NAI hydrographic data from 1972 through 1975, was developed using the nomenclature of Shevenell presented in NAI (1976a). The cycle is as follows (Figure 4.2-3):

4.2.6.1 December Water Mass

Beginning in December, waters in the study area typically show a vertical homogeneity from near surface to near bottom. Temperatures range from about 40.6 to 44.5 F (4.8 to 7.0 C) and salinities average from about 31.1 to 33.2 °/₀₀. This vertical uniformity probably results from atmospheric cooling and vertical mixing of the MSW and MIW in the water column, associated with breakdown of the seasonal thermocline, rising of the halocline and increased intensity of major winter storms. Apparently, at this time of year the halocline is not well enough established to restrict vertical mixing.

4.2.6.2 Winter Water Mass

From January through March, both near-surface and near-bottom waters undergo pronounced cooling, down to about 41.0 to 35.6 F (6.0 to 2.0 C). Through much of the winter, near-surface temperatures are slightly cooler than those of near-bottom waters, resulting in a weak reversed or negative thermal stratification. Coldest temperatures generally occur during January and February, lagging about 30 days

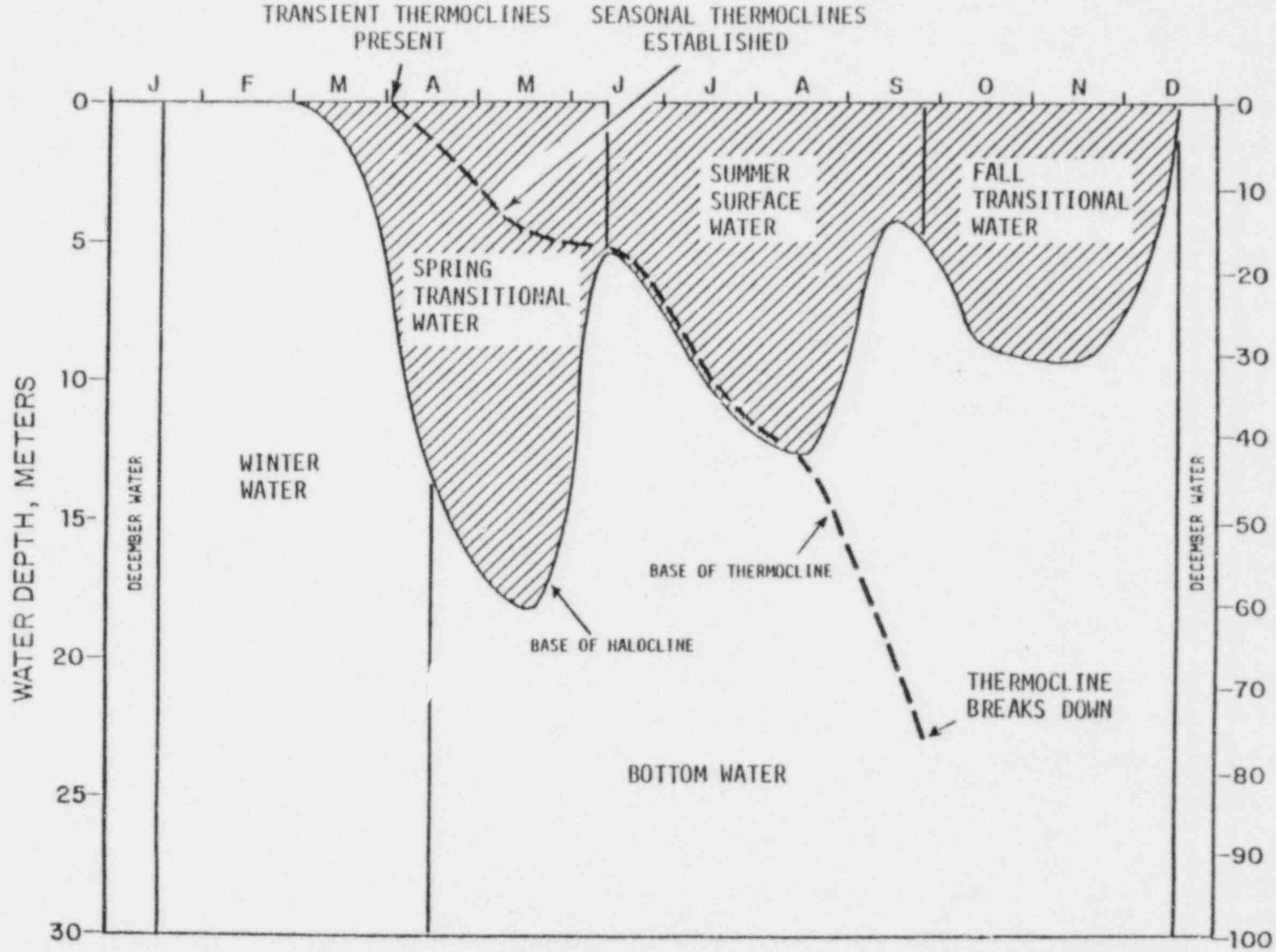

Figure 4.2-3. Annual cycle of water mass types based on temperature and salinity variations in waters off the New Hampshire coast and in the western Gulf of Maine. Seabrook 1976 Annual Hydrographic Report, 1979.

behind the minimum atmospheric temperatures observed during the year. Salinities remain about the same as in the December Water Mass (about 31.1 to 33.6 °/₀₀). Thus, at this time of the year, coastal waters are well mixed both horizontally and vertically (combination of MSW and MIW).

4.2.6.3 Spring Transitional Water Mass

Fresh water runoff, coupled with atmospheric heating and decrease in storm frequency, causes major changes in the temperature and salinity characteristics of the near surface MSW, whereas only minor effects are observed in the deeper MIW. In March, the development of the surface layer is typically initiated by an increase in freshwater runoff which lowers salinity in the surface waters and promotes stabilization of the water column. The characteristics of the Winter Water Mass are maintained in the deep water as the Transitional Water Mass develops. In early April, atmospheric warming promotes development of the annual thermocline. Initially, the depth of the thermocline coincides with the depth of the halocline, suggesting that the warming of the surface waters occurs after the surface layer has been established by river runoff. The gradually rising temperatures average about 39.2 to 50.5 F (4.0 to 10.3 C) with highest values in June. Salinities show a marked decrease from those of the Winter Water Mass, down to about 27.7 to 31.0 °/₀₀. This results from spring runoff and leads to the development of a sharp halocline which typically is most pronounced during May. During periods of high estuarine discharge, salinities also tend to show a gradient perpendicular to the shoreline (i.e., salinities increase with increasing distance offshore).

4.2.6.4 Summer Surface Water Mass

During late spring, near surface salinities begin to increase again after the peak of spring runoff has passed. By June, the thermo-

cline and halocline coincide again and the Summer Surface Water Mass becomes established. Temperatures show a sharp increase over those of the Spring Transitional Water Mass (about 53.2 to 68.5 F or 11.8 to 20.3 C). Maximum temperatures generally occur during August, lagging about 30 days behind the maximum atmospheric temperatures observed during the year. Salinities show an average rise of about 1 ‰ (about 28 to 32 ‰). This salinity increase is primarily due to decreased fresh water discharge to the Gulf of Maine and increased evaporation. By late summer, the thermocline continues to deepen, whereas the halocline gets shallower again.

4.2.6.5 Bottom Water Mass

The Bottom Water Mass (actually the upper portion of the MIW) is observed from April through November, but typically can be divided into three phases which correspond closely to the various Surface Water Masses. April and May typically show a warming trend (about 38.5 to 43.2 F or 3.6 to 6.2 C) and moderate salinities (about 29.9 to 32.2 ‰). From June to September, temperatures increase to about 44.2 to 53.2 F (6.8 to 11.8 C), but salinities remain about the same (about 30.9 to 32.4 ‰). During October and November, temperatures decrease again (about 51.4 to 45.3 F or 10.8 to 7.4 C), whereas salinities increase to about 32.2 to 32.9 ‰.

4.2.6.6 Fall Transitional Water Mass

Development of this water mass generally occurs when the halocline is re-established by a secondary pulse of fresh water discharge into the Gulf of Maine. By this time of year, the progressive deepening of the thermocline brought on by increased major storm activity generally carries it to the bottom. Temperatures decrease from about 55.4 to 44.2 F (13.0 to 6.8 C) and salinities average 30.8 to 32.0 ‰. By November, there is no thermal stratification and the halocline becomes

shallower again (reunificat‿ı of MSW and MIW). By December, maximum homogeneity is evident th‿ ıghout the water column with no distinguishable surface layer. Thus, the development and maintenance of the surface layer is a result of low salinity water being discharged from the estuaries, rather than the presence of a thermocline. The freshened surface layer persists in the fall, even though there was a lack of thermal stratification. Thus by early December, the December Water Mass becomes re-established and the annual cycle begins again.

4.3 HYDROGRAPHIC TRENDS FROM 1973 THROUGH 1976

Various hydrographic and meterological parameters measured in the study area from 1973 through 1976 were analyzed in order to determine possible interrelationships among the following: monthly mean of daily 24-hr wind net displacement or drift, daily net drift of longshore (north-south) mid-depth current components, percentage occurrence of coastal flow types, monthly mean of the daily maximum and daily minimum air temperatures, heating and cooling degree days, monthly mean of near surface and near bottom water temperatures, mean of near surface and near bottom salinities, and mean monthly regional discharge (Figure 4.3-1). Results were compiled on a seasonal basis.

4.3.1 Winter Season

The winter months are characterized by stormy seas, predominantly offshore winds, alternating northward and southward coastal currents, with only few quiescent periods of predominantly tidal influence. January and February were the coldest months, with the winter of 1975 and 1976 the most severe of those studied. Peak heating degree day totals have been observed during January of all four years. Coldest water temperatures tended to lag about 30 days behind the coldest air temperatures, with 1975 to 1976 also showing the coldest water temp-

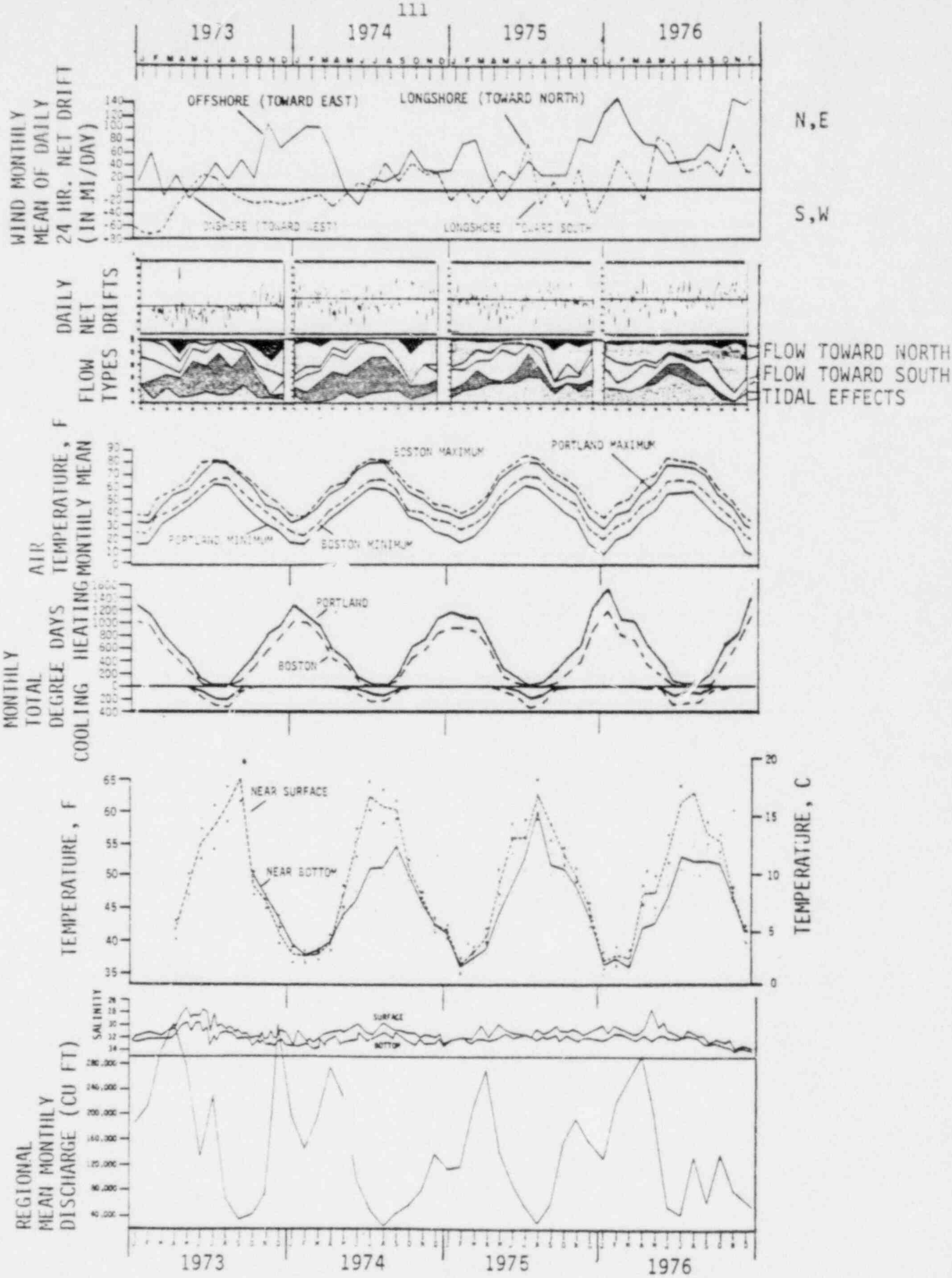

Figure 4.3-1. Wind net drifts, current net drifts, current flow types, air temperature, degree days, water temperature, coastal salinities and regional runoff from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1978.

eratures of those years studied. Wintertime salinities tended to be quite high due to minimal seasonal runoff. The winter of 1976 to 1977 appears to have had the highest overall salinities.

4.3.2 Spring Season

The spring months are transitional from the storminess of winter to the weaker tidal dominance of the summer. Runoff increases dramatically, lowering coastal salinities, and helping to set in motion the strong southward flows of the counterclockwise Gulf of Maine gyre. Winds and coastal flows have a strong southwestward component. Starting in late March and early April, water temperatures gradually warm up.

4.3.3 Summer Season

The summer months have few storms and coastal flows reflect rotary tidal flows northward and southward parallel to the coast. Warmest air temperatures generally occur in July or early August, whereas peak water temperatures tend to lag about a month later. Warmest near surface temperatures were measured during September 1973, whereas warmest near bottom temperatures were observed during 1975. Peak cooling degree days have been observed during August of 1973, July of 1974 and 1975, and June of 1976.

4.3.4 Fall Season

Warm summertime temperatures persist into the fall until storms break down thermal stratification and vertical mixing re-establishes isothermal and isohaline conditions. Coastal currents are typically northward following seasonal wind patterns. By late fall, the "December Water Mass" conditions are set up and the seasonal cycle begins again.

5.0 SUMMARY

The results of the hydrographic studies off Hampton Beach, New Hampshire, from September 1972 through December 1976 can be summarized as follows:

5.1 CURRENTS

These coastal waters are very dynamic and some advective flow is always evident. Tidal flows are prevalent in the absence of meteorological forcing functions. These flows occur either as flood- and ebb-tidal reversals (generally on a 6- to 7-hr basis) or as a variable, weak tidal flow with periodic shifts in speed and direction. Mean speeds average 0.1 to 0.2 kn. Such flows have comprised about 40 percent overall for the four years of study. Wind-driven currents can easily overpower tidal flows, causing either southward or northward currents which often persist for days at a time. Mean speeds average 0.3 to 0.6 kn but can exceed 1.0 kn during storms. For the four-year study period such flows have comprised 29 percent and 31 percent overall for southward and northward, respectively.

5.2 WIND

Wind and associated storms which accompany passage of low-pressure systems play an important role in driving coastal water flows either southward or northward. Over the four-year study period, predominant winds have been from the west (about 23 percent). The next most common directions are northwest and southwest (18 and 17 percent, respectively. Highest mean speeds have been from the northeast (8.6 kn).

Storms and associated winds play a key role in the large scale water mass displacement of the western Gulf of Maine and appear to help drive the general counterclockwise circulation of the Gulf of Maine gyre.

In general, low-pressure systems moving across the region cause the stormiest conditions and the most significant wind stress effects in nearshore waters. Typical northeaster storms show a pattern which has been divided into the following phases: prestorm, early storm, intense storm and post storm. During 1976 January to April was the stormiest period, but at least one northeaster occurred every month of the year.

5.3 TEMPERATURE

Water temperatures show pronounced daily, seasonal and annual variability. Coldest temperatures typically occur in February, lagging about 30 days behind the coldest air temperatures. During the spring months temperatures gradually rise and the seasonal thermocline becomes established. By mid summer the thermocline may be 30 to 40 ft (9 to 12 m) thick). Highest temperatures are generally reached during August. Temperature data show daily variations of 1 to 11 F (0.5 to 6 C) during the summertime and 1 to 7 F (0.5 to 4 C) during the wintertime. During 1976 near-surface temperatures ranged from 33 to 63 F (0.5 to 17.2 C), whereas near-bottom temperatures ranged from 35.5 to 52.5 F (1.9 to 11.4 C).

5.4 SALINITY

The salinity measurements from 1976 showed a gradual rise through the year. Beginning in January with a mean salinity of around 32.0 ‰, salinities increased during the winter with near-surface values always being less than those at depth. From February through May, seasonal runoff lowered salinities sharply and a pronounced halocline formed. By early summer the halocline weakened and salinities started rising again. In September, October and November, increased runoff reestablished the halocline, showing vertical variations of at least 0.5 ‰. In the late fall intense storms and vertical mixing brought a return to isohaline conditions averaging 3.3 ‰. Field data show that the Merrimack River plays an important role in regional salinity distributions.

5.5 DENSITY

Near surface waters showed considerable variability, ranging from 22.3 in late August to 25.5 in January and March. Near bottom waters were much more uniform, averaging from 24.0 to about 26.8, but following a trend similar to the near surface waters. Both showed a gradual rise from August through December. As with the salinity data, lowest values were generally observed at low water, reflecting the influence of the ebb tidal flows from Hampton Harbor and adjacent estuaries.

5.6 DISSOLVED OXYGEN

Highest values were observed during the late winter, spring and early summer (about 10.0 to 11.7 mg/l), whereas lowest values occurred during the late summer and fall (down to 6.7 mg/l in August). No consistent pattern was observed between tidal stage or water depth, suggesting that dissolved oxygen follows a seasonal cycle related to planktonic photosynthesis, temperature and salinity. During the winter and spring, it was essentially homogeneously distributed, but near surface waters had higher concentrations during the summer. Winter and spring percentage saturation ranged from 97 to 112 percent. In the summertime, near surface waters became highly supersaturated (up to 124 percent), whereas near bottom waters were generally undersaturated (down to 76 percent). In November the lowest overall concentrations were observed (mean of about 87 percent).

5.7 TIDES

Tides in Hampton Harbor are of the mixed, semi-diurnal type with a small (1 to 2 ft or 0.3 to 0.6 m) diurnal inequality which is most pronounced during spring tides. The mean tide range was about 8.3 ft (2.5 m). Spring tides ranged as high as 12.5 ft (3.8 m), whereas neap tides ranged

as low as 6.0 ft (1.8 m). In the summer months, the highest spring tides occur with the full moon, whereas in the wintermonths the highest spring tides occur with the new moon.

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APPENDIX 7.1

PERCENT RECOVERY OF DATA

a. CURRENT METER AND WIND
b. TEMPERATURE (% RECOVERY)

TABLE 7.1-1. OPERATIONAL PERFORMANCE OF NAI CURRENT METERS AND WIND STATION OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1976. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

MOORING DESIGNATION	DATES OPERATIONAL 1976	TOTAL POSSIBLE OBSERVATIONS	ACTUAL VECTOR OBSERVATIONS	DIRECTION ONLY OBSERVATIONS	SPEED ONLY OBSERVATIONS	NO DATA
T-7	Jan 1 to Dec 31	26352	18423	866	695	6368
12	Jan 1 to Dec 31	26352	21054	485	252	4561
10 upper	Jan 1 to Dec 31	26352	22687	2776	0	889
I-4 Upper	Jan 1 to Dec 31	26352	23445	195	0	2712
I-4 Lower	Jan 1 to Dec 31	26352	19270	4295	0	2787
Current Meter Total		131760	104879	8617	947	17317
Percentage Recovery			79.6%	6.5%	0.7%	13.2%
			86.1%			
Wind Total	Jan 1 to Dec 31	26352	24877	746	0	729
Percentage Recovery			92.4%	2.8%	0%	2.8%
			97.2%			

TABLE 7.1-2. OPERATIONAL PERFORMANCE OF NAI TEMPERATURE MONITORS OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1976. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

MOORING OR TEMPERATURE MONITOR DESIGNATION	DATES OPERATIONAL, 1976	TOTAL POSSIBLE DAYS	DAYS DATA OBTAINED	DAYS NO DATA OBTAINED
T-7	Jan 1 to Dec 31	366	348	18
12	Jan 1 to Dec 31	366	293	73
10 Upper	Jan 1 to Dec 31	366	327	39
I-4 Upper	Jan 1 to Dec 31	366	333	33
I-4 Lower	Jan 1 to Dec 31	366	334	32
B Upper	Jan 1 to Dec 31	366	301	65
B Lower	Jan 1 to Dec 31	366	279	87
D Upper	Feb 1 to Oct 13	256	210	46
D Lower	Feb 1 to Oct 13	256	216	40
F Upper	Feb 1 to Oct 13	256	201	55
F Lower	Feb 1 to Oct 13	256	201	55
HH Upper	Jan 1 to Dec 31	366	324	42
HH Lower	Jan 1 to Dec 31	366	322	44
Total		4318	3689	629
Percentage			85.4%	14.6%

APPENDIX 7.2

MONTHLY ROSE DIAGRAMS

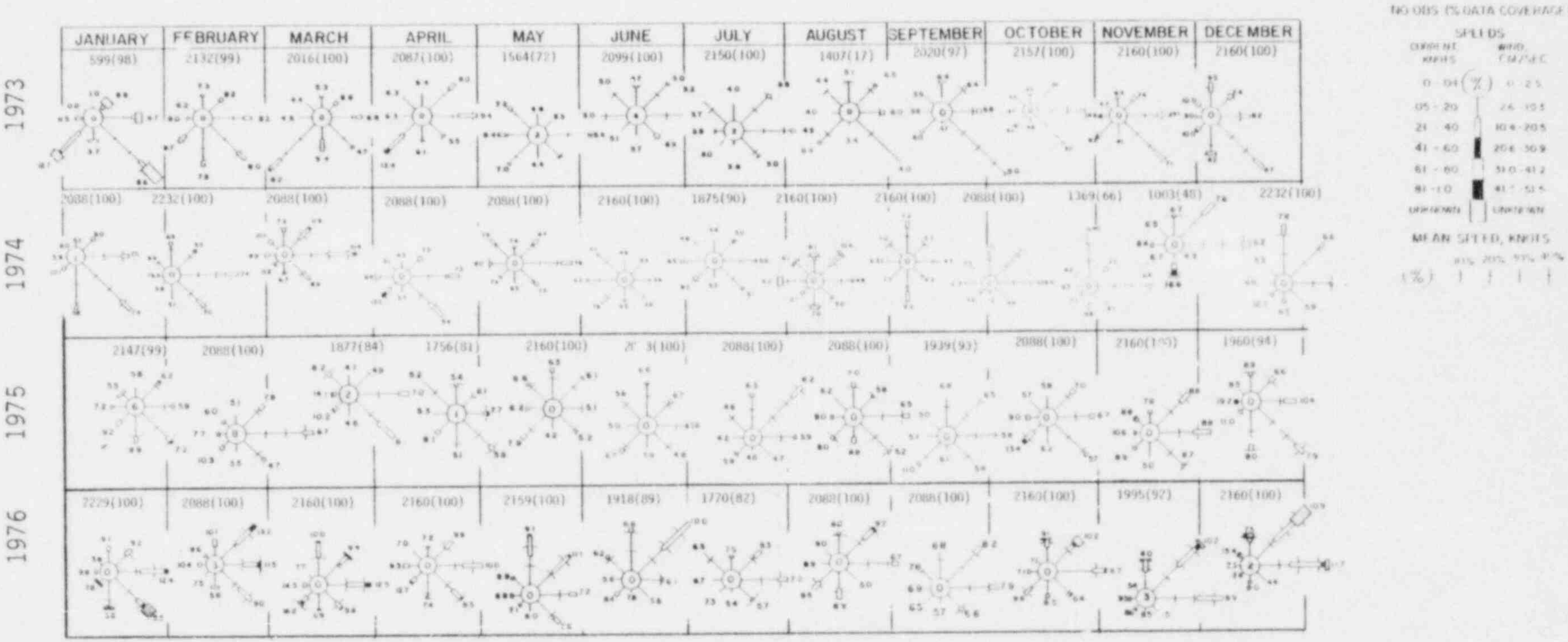

Figure 7.2-1. Summary rose diagrams of wind data measured by NAI at Hampton Beach, New Hampshire, from 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

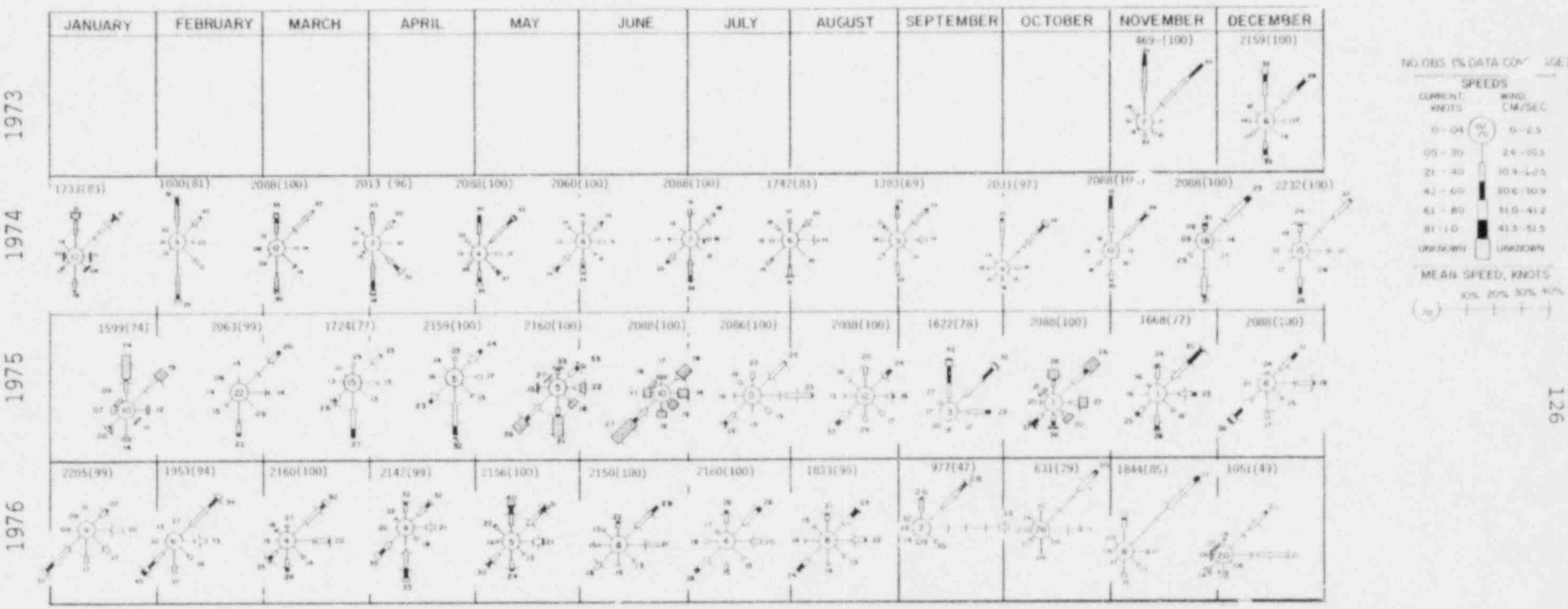

Figure 7.2-2. Summary rose diagrams of near-surface currents at NAI Mooring 12 (-5.2 ft or 1.6 m below surface) off Hampton Beach, New Hampshire for 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

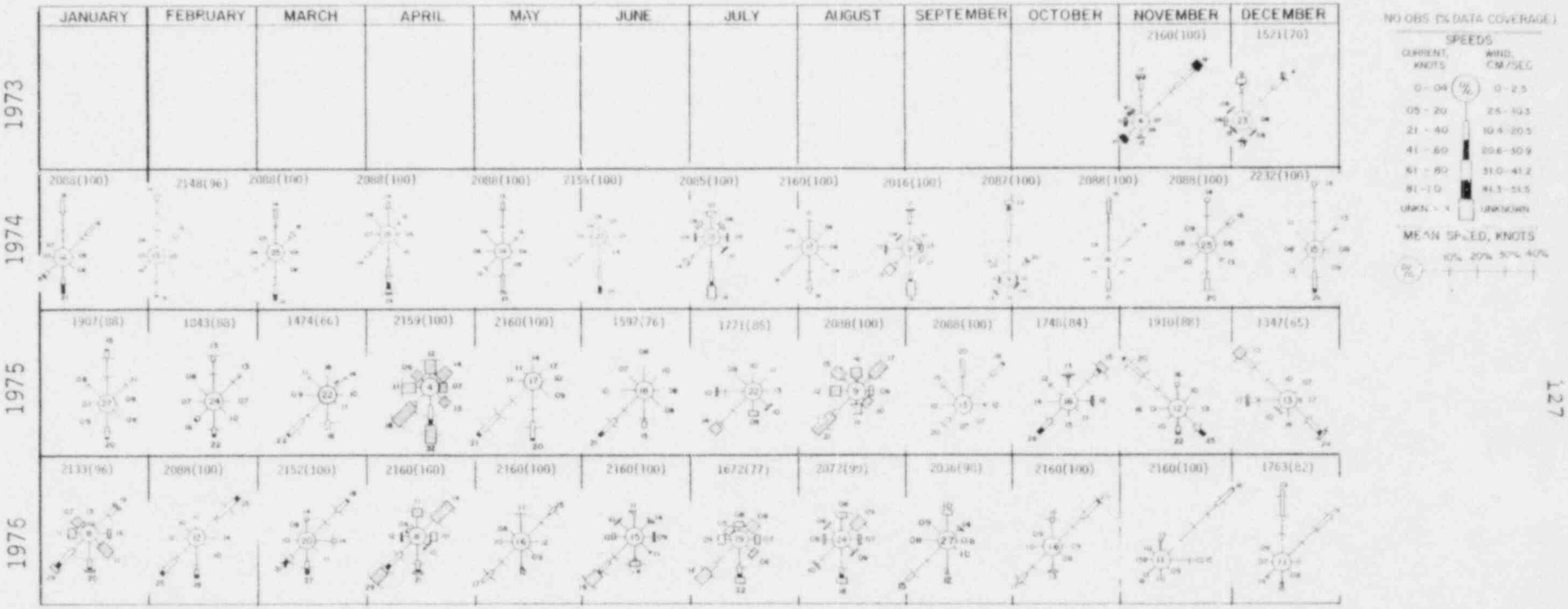

Figure 7.2-3. Summary rose diagrams of near-surface currents at NAI Mooring 10 upper (-20.0 ft or 6.1 m below MLW) off Hampton Beach, New Hampshire for 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

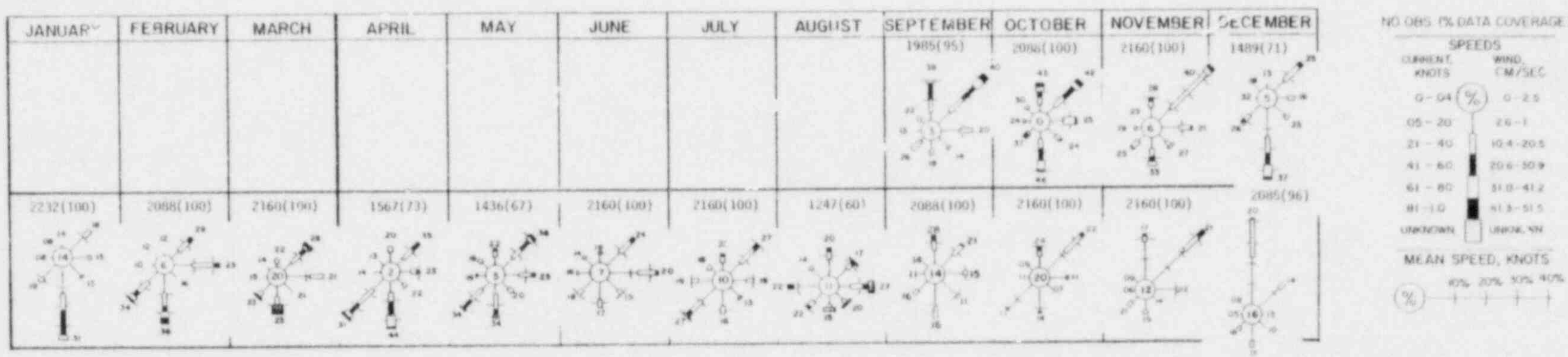

Figure 7.2-4. Summary rose diagrams of near-surface currents at NAI Mooring I-4 upper (-5.2 ft or 1.6 m below surface) off Hampton Beach, New Hampshire for 1973 through 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

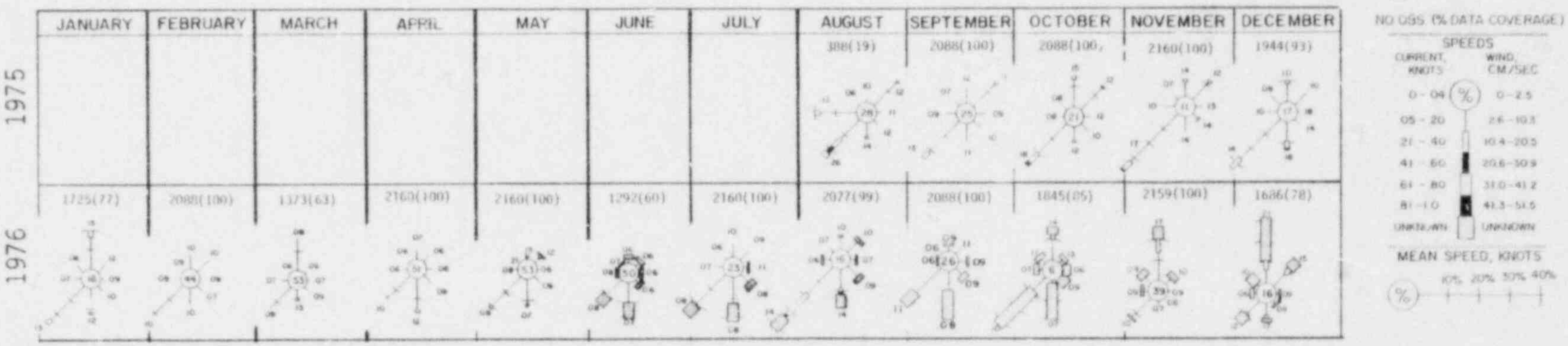

Figure 7.2-5. Summary rose diagrams of near-surface currents at NAI Mooring I-4 lower (-44.0 ft or 13.4 m below MLW) off Hampton Beach, New Hampshire for 1975 and 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

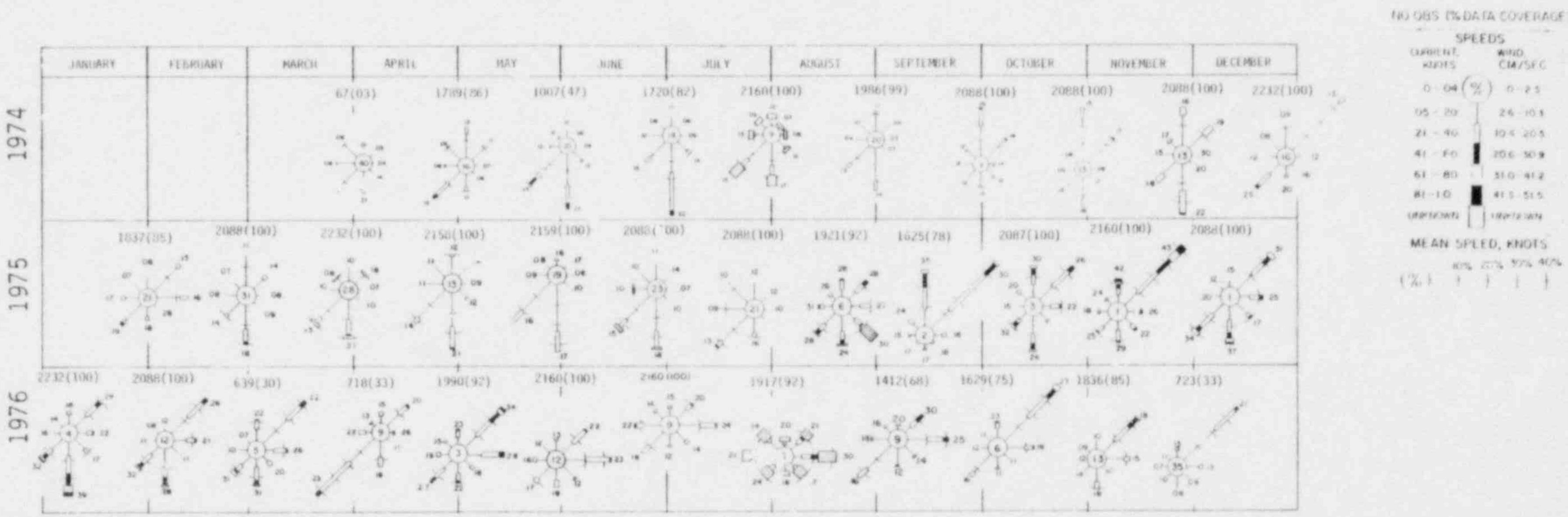

Figure 7.2-6. Monthly rose diagrams of near-surface currents at NAI Mooring T-7 for 1974 through 1976. Seabrook Annual Hydrographic Report, 1979.

APPENDIX 7.3

OVERALL DATA TABULATIONS

TABLE 7.3-1. PERCENTAGE-FREQUENCY TABULATION OF WIND FROM WIND STATION AT HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM JANUARY 24, 1973 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
Calm	127	210	264	200	106	54	67	54	1	1,083	1.1
0-10	8,758	11,528	16,704	13,911	6,500	5,772	5,111	6,861	0	75,145	77.9
11-20	1,818	4,259	4,888	2,736	1,110	2,242	921	662	2	18,638	19.3
21-30	84	310	383	99	52	408	156	55	0	1,547	1.6
31-40	1	11	20	5	16	26	10	3	0	92	0.1
41-50	0	0	0	0	2	0	2	0	0	4	0.0
Direction Only	159	401	96	257	123	84	60	60	0	1,240	0.0
Total	10,947	16,719	22,355	17,308	7,909	8,586	6,327	7,695	3	97,749	100.0
Percent Frequency	11.2	17.1	22.9	17.6	8.1	8.8	6.5	7.8	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 102,784

VECTOR OBSERVATIONS = 96,506 (93.9%)

DIRECTION ONLY OBSERVATIONS = 1,240 (1.2%)

SPEED ONLY OBSERVATIONS = 3 (0.0%)

NO DATA = 5,035 (4.9%)

TABLE 7.3-2. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING 12 OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM NOVEMBER 16, 1973 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.00-0.04	531	881	975	948	922	743	617	582	6	6,205	8.9
0.05-0.20	3,391	7,026	5,289	3,874	5,090	3,853	1,924	1,905	47	32,399	46.4
0.21-0.40	3,274	7,131	3,084	991	3,584	2,943	516	622	38	22,183	31.8
0.41-0.60	1,380	2,249	273	149	1,321	1,382	37	101	0	6,892	9.9
0.61-0.80	290	447	10	75	371	395	0	22	0	1,610	2.3
0.81-1.00	139	110	4	30	101	130	0	3	0	517	0.7
Direction Only	466	652	393	273	452	563	153	164	0	3,116	0.0
Total	9,471	18,496	10,028	6,340	11,841	10,009	3,247	3,399	91	72,922	100.0
Percent Frequency	13.0	25.4	13.8	8.7	16.3	13.7	4.4	4.7	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 81,361

VECTOR OBSERVATIONS = 69,715 (85.8%)

DIRECTION ONLY OBSERVATIONS = 3,116 (3.8%)

SPEED ONLY OBSERVATIONS = 91 (0.0%)

NO DATA = 8,439 (10.4%)

TABLE 7.3-3. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING 10 UPPER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM OCTOBER 12, 1973 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.00-0.04	2,604	2,144	1,375	1,206	1,155	1,389	1,373	1,854	9	12,569	17.7
0.05-0.20	8,463	7,970	2,705	3,170	6,231	6,839	3,164	4,056	2	42,600	60.0
0.21-0.40	2,599	3,038	250	365	3,359	3,131	217	529	1	13,489	19.0
0.41-0.60	189	262	6	97	869	525	18	36	0	2,002	2.7
0.61-0.80	10	10	0	0	203	100	0	6	0	329	0.5
0.81-1.00	4	0	0	0	26	20	0	0	0	50	0.1
Direction Only	960	1,447	482	625	1,050	1,565	706	790	0	7,625	0.0
Total	14,289	14,871	4,818	5,463	12,893	13,569	5,478	7,271	12	78,664	100.0
Percent Frequency	18.2	18.9	6.1	6.9	16.4	17.3	7.0	9.2	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 83,881

VECTOR OBSERVATIONS = 71,027 (84.7%)

DIRECTION ONLY OBSERVATIONS = 7,625 (9.1%)

SPEED ONLY OBSERVATIONS = 12 (0.0%)

NO DATA = 5,217 (6.2%)

TABLE 7.3-4. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING I-4 UPPER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM SEPTEMBER 4, 1975 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.00-0.04	303	474	506	440	480	362	231	317	0	3,113	10.1
0.05-0.02	1,904	2,724	2,324	1,636	2,236	1,890	799	808	0	14,339	46.4
0.21-0.40	1,168	2,426	1,422	486	1,519	1,346	241	252	0	8,860	28.7
0.41-0.60	465	1,101	205	76	685	483	68	36	0	3,119	10.1
0.61-0.80	101	302	22	40	508	125	11	14	0	1,123	3.6
0.81-1.00	43	147	3	13	120	29	0	2	0	357	1.1
Direction Only	13	52	32	11	124	38	9	4	0	283	0.0
Total	3,997	7,226	4,532	2,702	5,672	4,273	1,359	1,433	0	31,194	100.0
Percent Frequency	12.8	23.2	14.5	8.7	18.2	13.7	4.3	4.6	0	0	100.0

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 34,056

VECTOR OBSERVATIONS = 30,911 (90.8%)

DIRECTION ONLY OBSERVATIONS = 283 (0.8%)

SPEED ONLY OBSERVATIONS = 0 (0.0%)

NO DATA = 2,862 (8.4%)

TABLE 7.3-5. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING I-4 LOWER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM AUGUST 28, 1975 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.00-0.04	1,164	1,406	901	970	1,241	1,583	916	905	0	9,086	33.5
0.05-0.02	2,457	2,152	680	1,070	2,529	5,778	803	640	0	16,109	59.4
0.21-0.40	457	178	31	48	255	686	34	7	0	1,696	6.3
0.41-0.60	18	2	0	3	49	124	1	0	0	197	0.7
0.61-0.80	0	0	0	0	2	14	0	0	0	16	0.1
0.81-1.00	0	0	0	0	4	7	0	0	0	11	0.0
Direction Only	618	329	188	352	1,177	1,146	223	262	0	4,295	0.0
Total	4,714	4,067	1,800	2,443	5,257	9,338	1,977	1,814	0	31,410	100.0
Percent Frequency	15.0	12.9	5.7	7.8	16.7	29.7	6.4	5.8	0	0	100.0

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 34,529

VECTOR OBSERVATIONS = 27,115 (78.5%)

DIRECTION ONLY OBSERVATIONS = 4,295 (12.4%)

SPEED ONLY OBSERVATIONS = 0 (0.0%)

NO DATA = 3,119 (9.1%)

TABLE 7.3-6. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING T-7 OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM APRIL 16, 1974 TO DECEMBER 19, 1976.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE

SPEED, KNOTS	N 338-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.00-0.04	1,103	1,236	756	865	919	864	842	1,066	1	7,652	12.9
0.05-0.20	4,502	5,959	2,497	2,310	5,683	5,977	3,012	2,780	9	32,729	55.2
0.21-0.40	1,415	3,511	1,814	595	3,425	2,630	586	399	0	14,375	24.2
0.41-0.60	319	1,086	378	70	707	624	109	39	0	3,332	5.6
0.61-0.80	85	347	37	24	210	183	22	12	0	920	1.5
0.81-1.00	40	158	1	6	91	59	0	0	0	355	0.6
Direction Only	124	172	248	333	263	368	178	222	0	1,908	0.0
Total	7,588	12,469	5,731	4,203	11,298	10,705	4,749	4,518	10	61,271	100.0
Percent Frequency	12.4	20.3	9.4	6.8	18.4	17.5	7.8	7.4	0	0	100.0

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 70,455

VECTOR OBSERVATIONS = 59,353 (84.2%)

DIRECTION ONLY OBSERVATIONS = 1,908 (2.8%)

SPEED ONLY OBSERVATIONS = 10 (0.0%)

NO DATA = 9,184 (13.0%)

APPENDIX 7.4

PROGRESSIVE VECTOR PLOTS

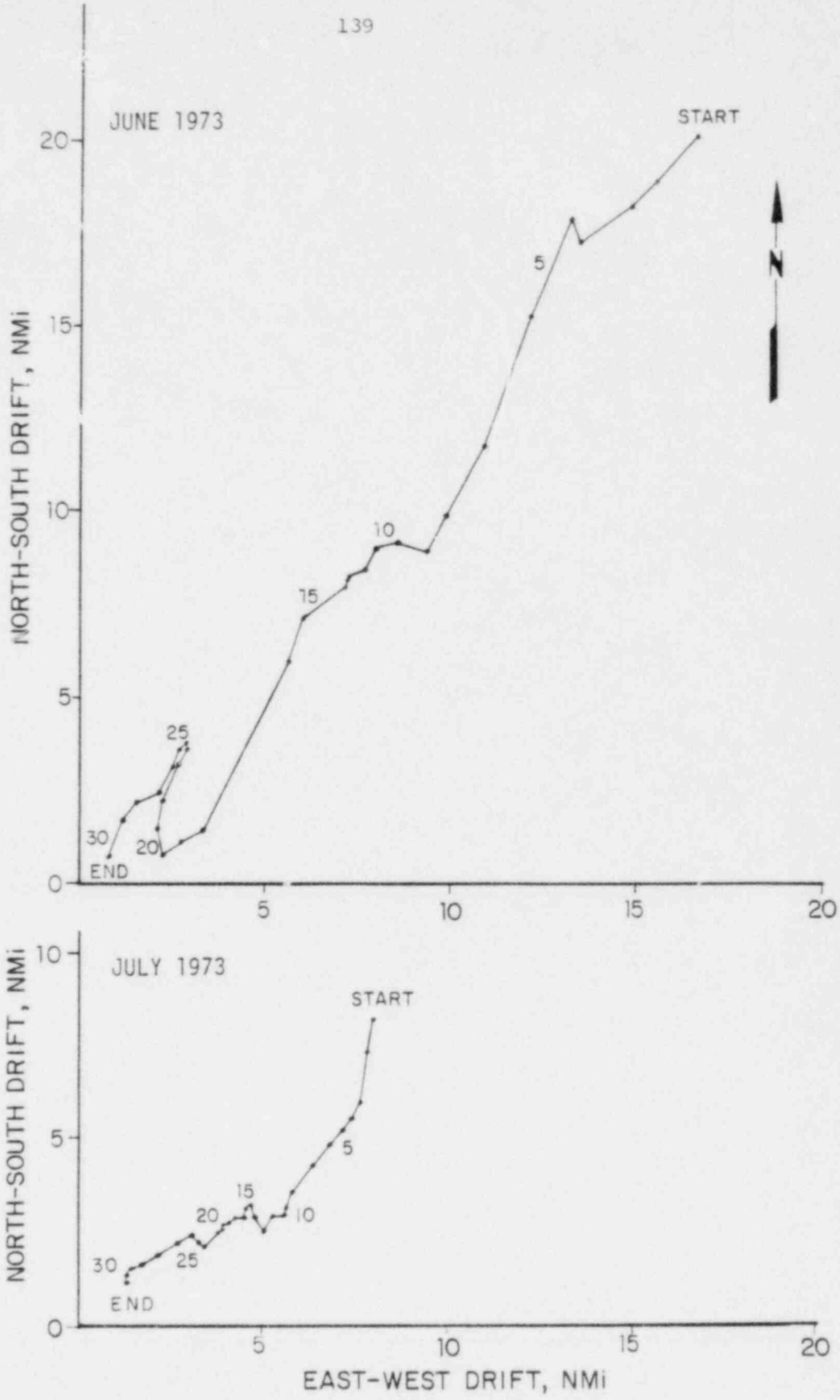

Figure 7.4-1. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 4 at -23 ft. below MLW) for June and July, 1973. Seabrook 1976 Annual Hydrographic Report, 1979.

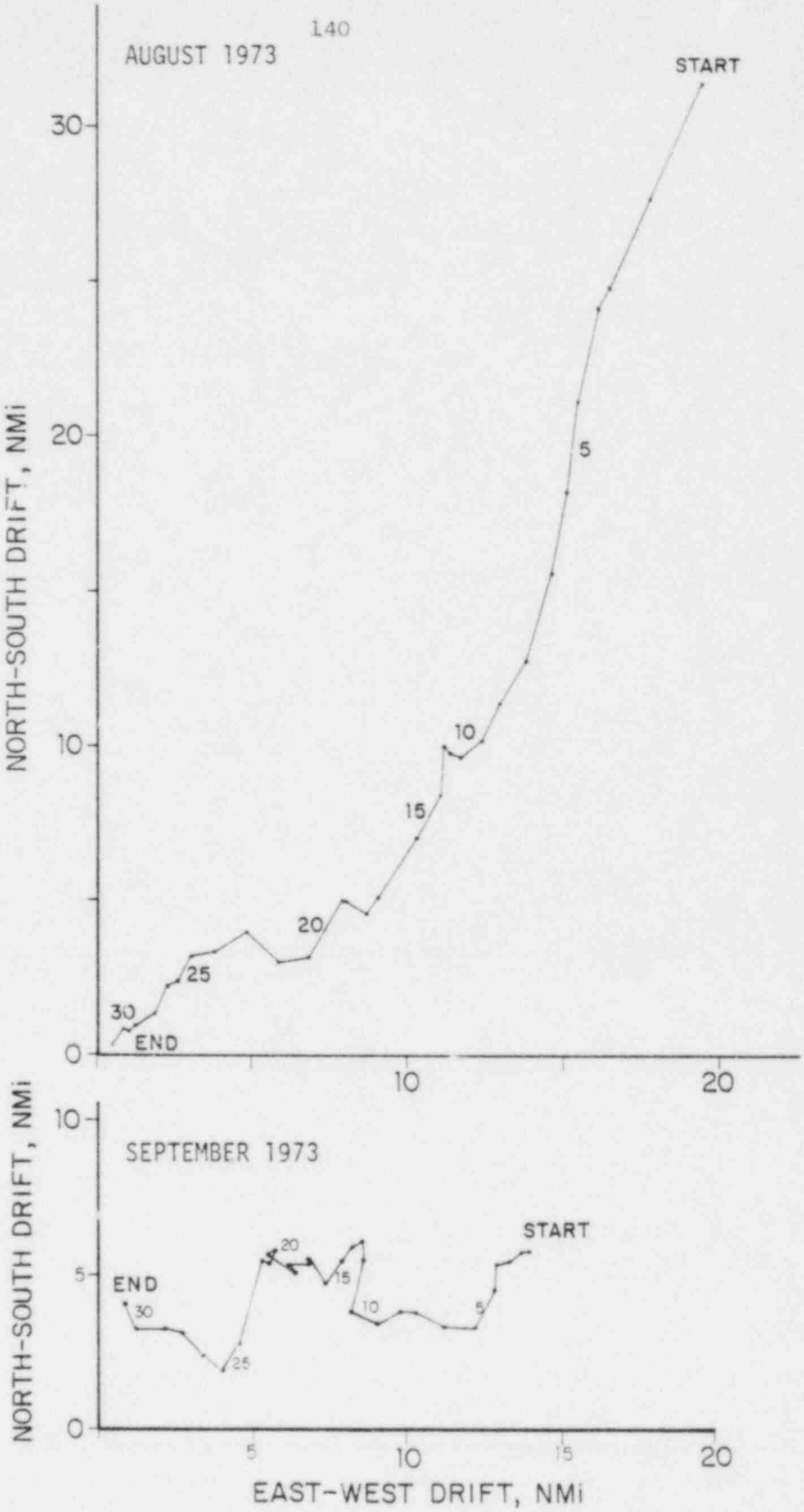

Figure 7.4-2. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 4 at -23 ft. below MLW) for August and September, 1973. Seabrook 1976 Annual Hydrographic Report, 1979.

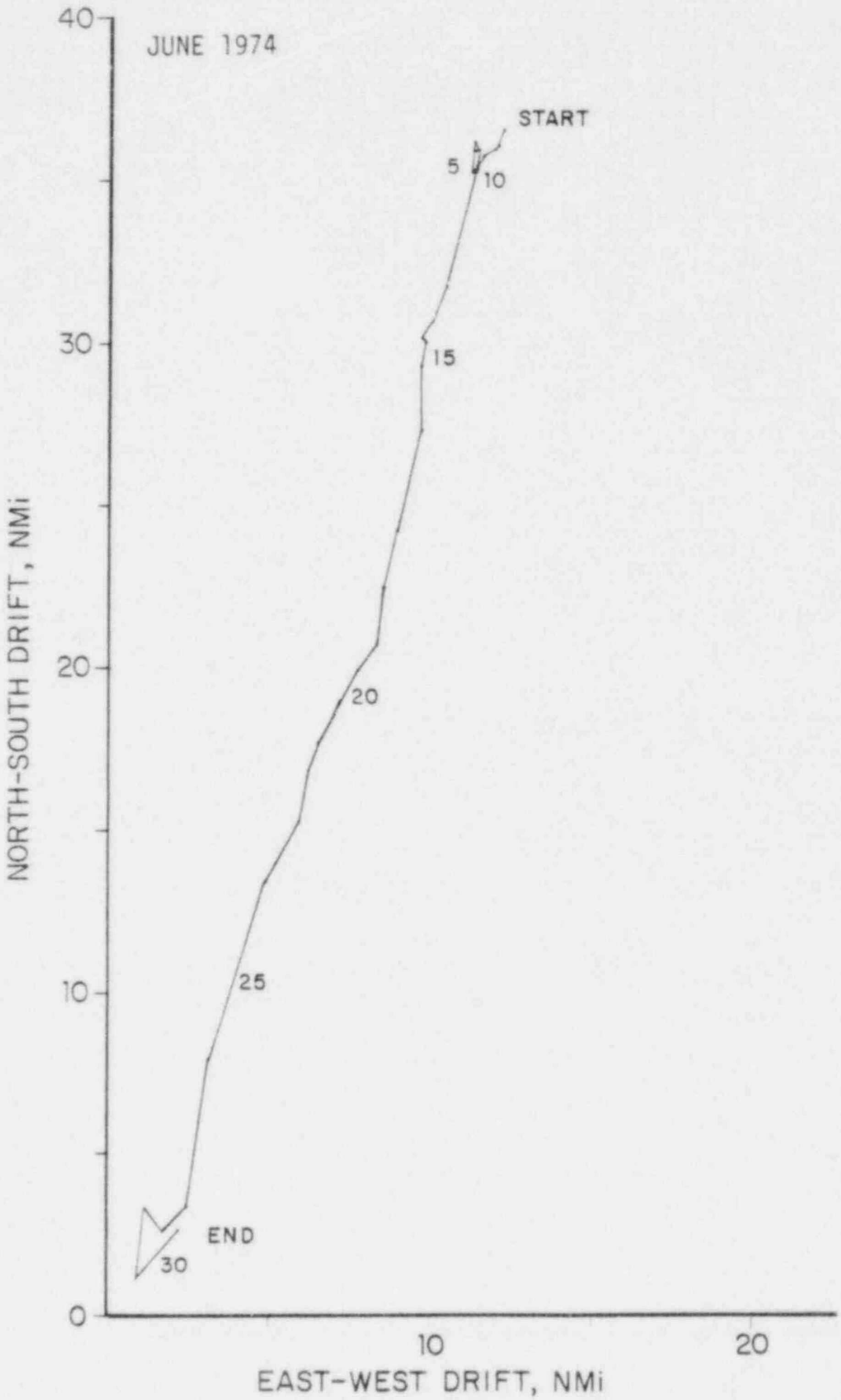

Figure 7.4-3. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -13 ft. below MLW) for June, 1974. Seabrook 1976 Annual Hydrographic Report, 1979.

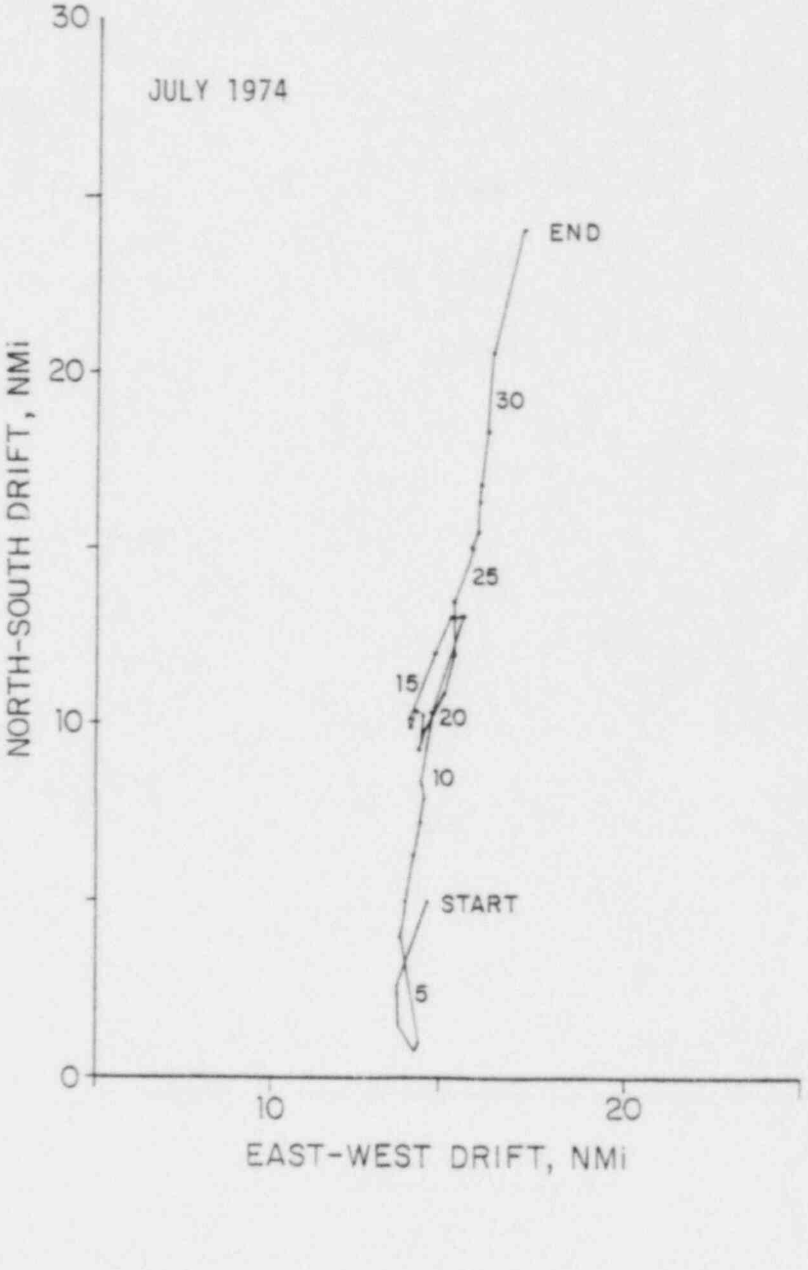

Figure 7.4-4. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -13 ft. below MLW) for July 1974. Seabrook 1976 Annual Hydrographic Report, 1979.

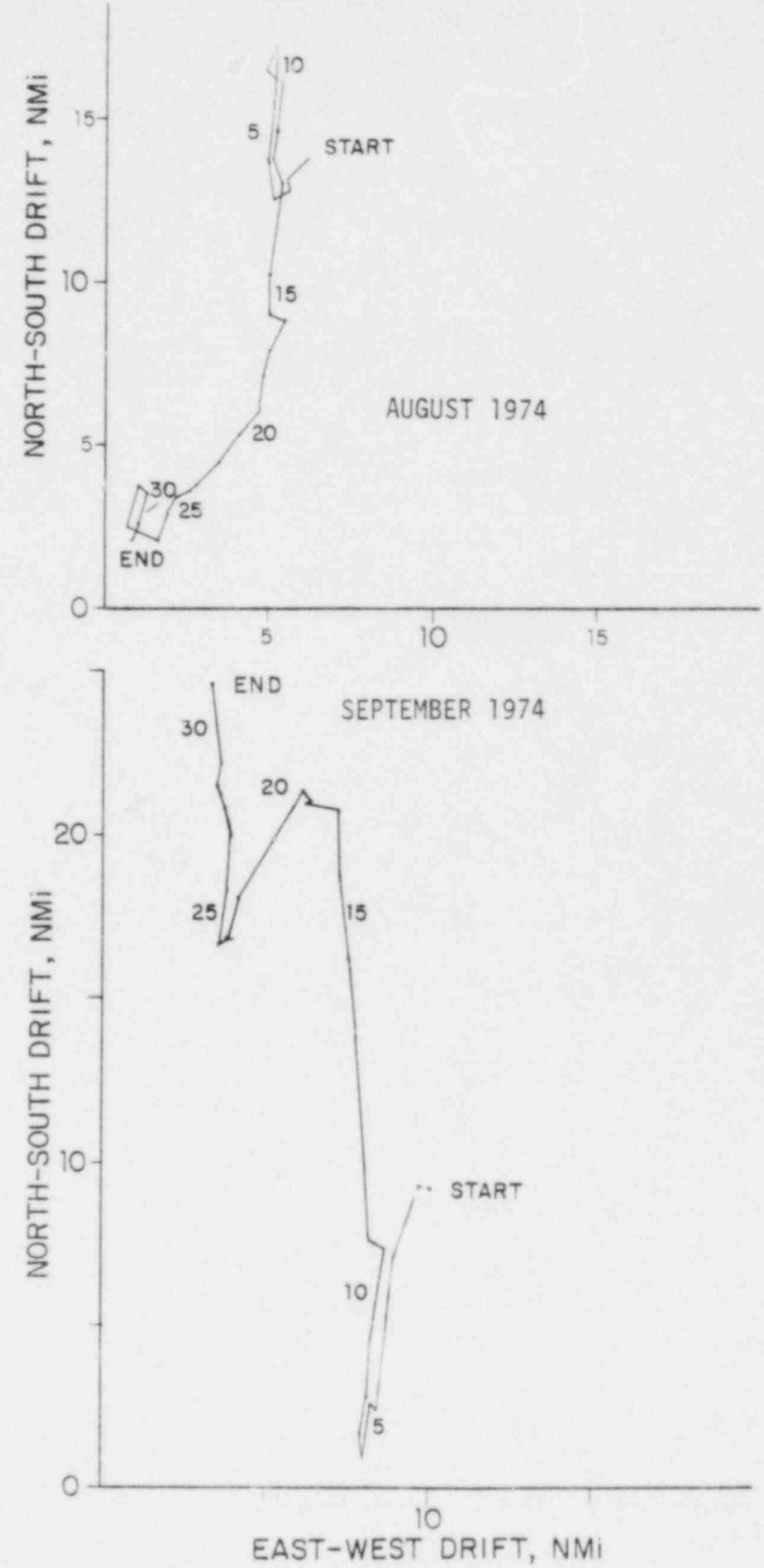

Figure 7.4-5. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -13 ft. below MLW) for August and September, 1974. Seabrook 1976 Annual Hydrographic Report, 1979.

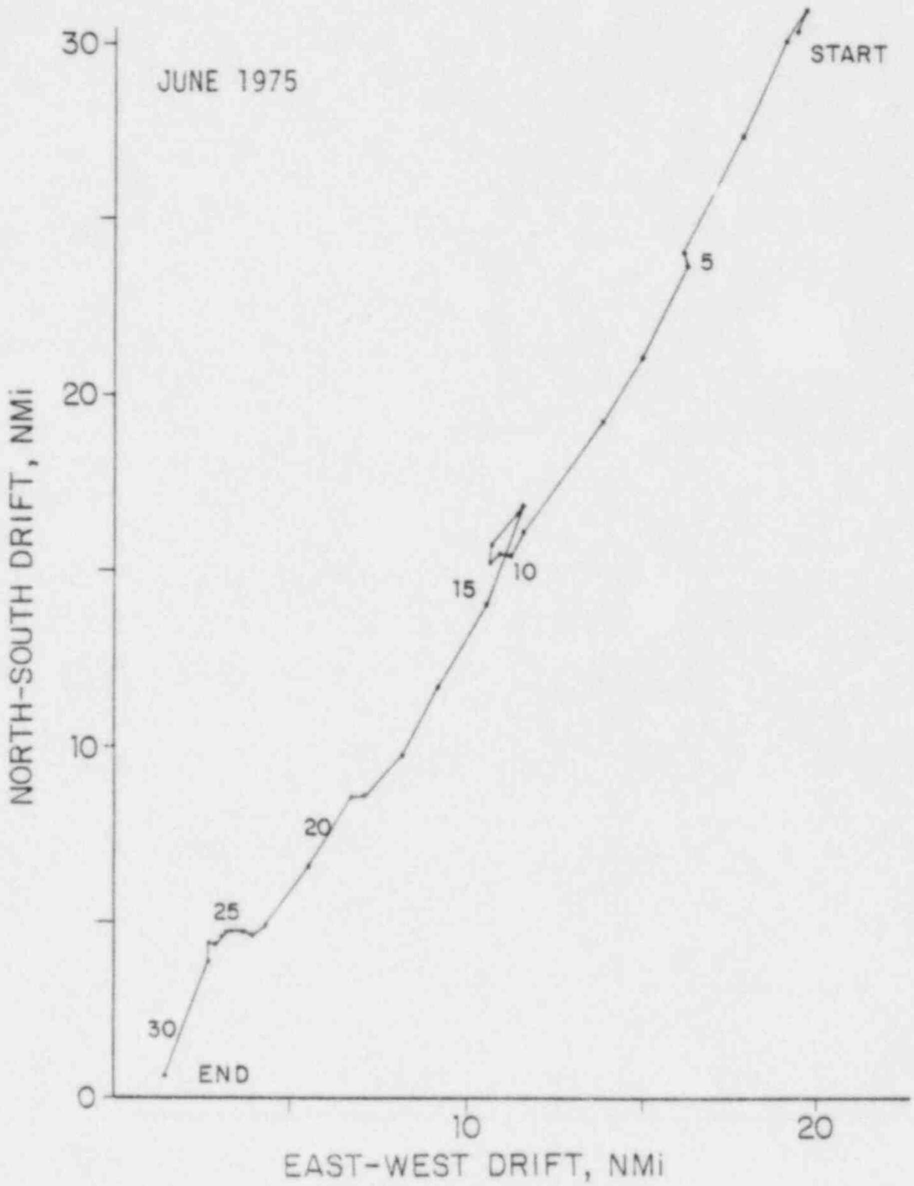

Figure 7.4-6. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -13 ft. below MLW) for June, 1975. Seabrook 1976 Annual Hydrographic Report, 1979.

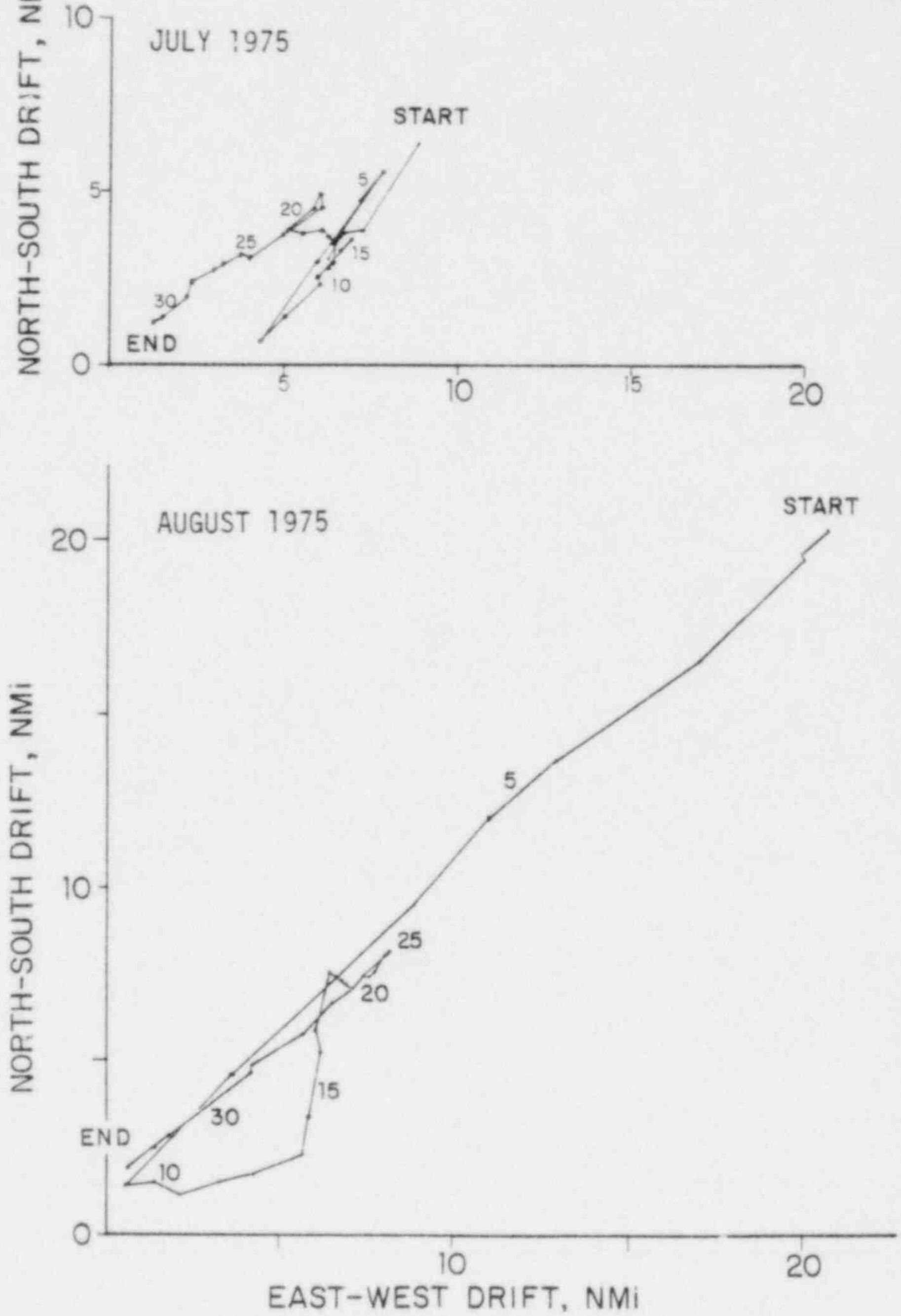

Figure 7.4-7. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for July and August, 1975. Seabrook 1976 Annual Hydrographic Report, 1979.

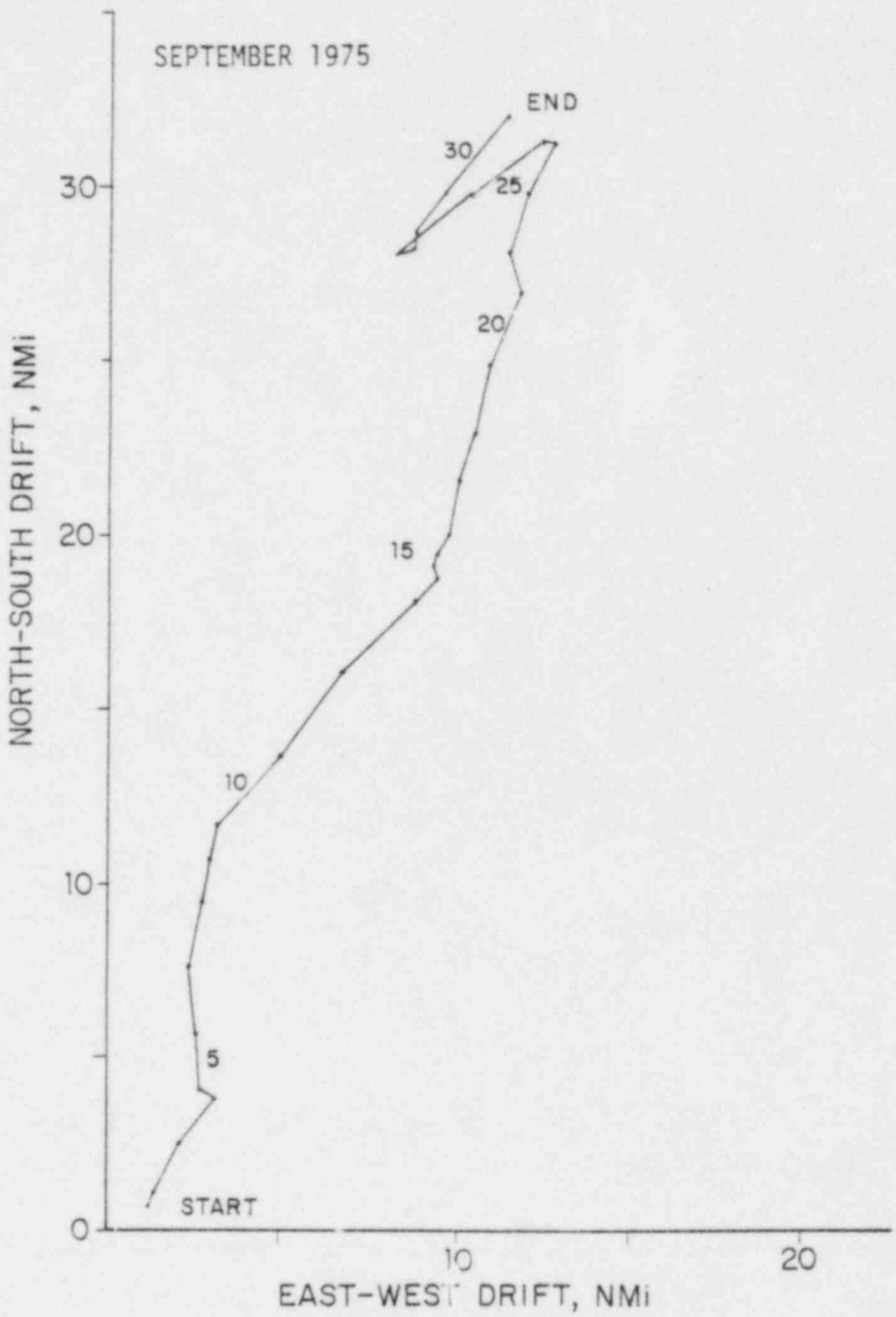

Figure 7.4-8. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for September, 1975. Seabrook 1976 Annual Hydrographic Report, 1979.

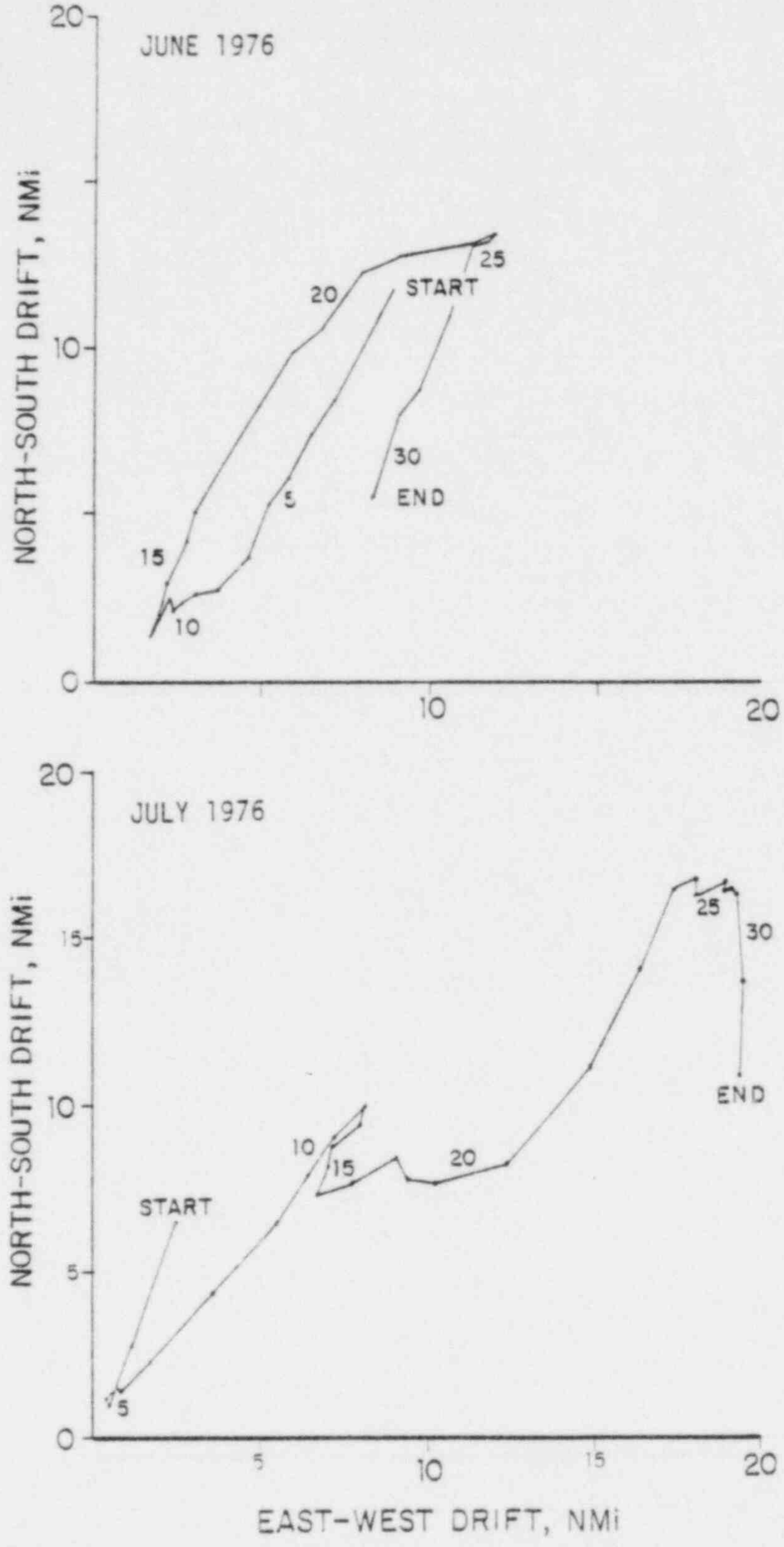

Figure 7.4-9. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for June and July, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

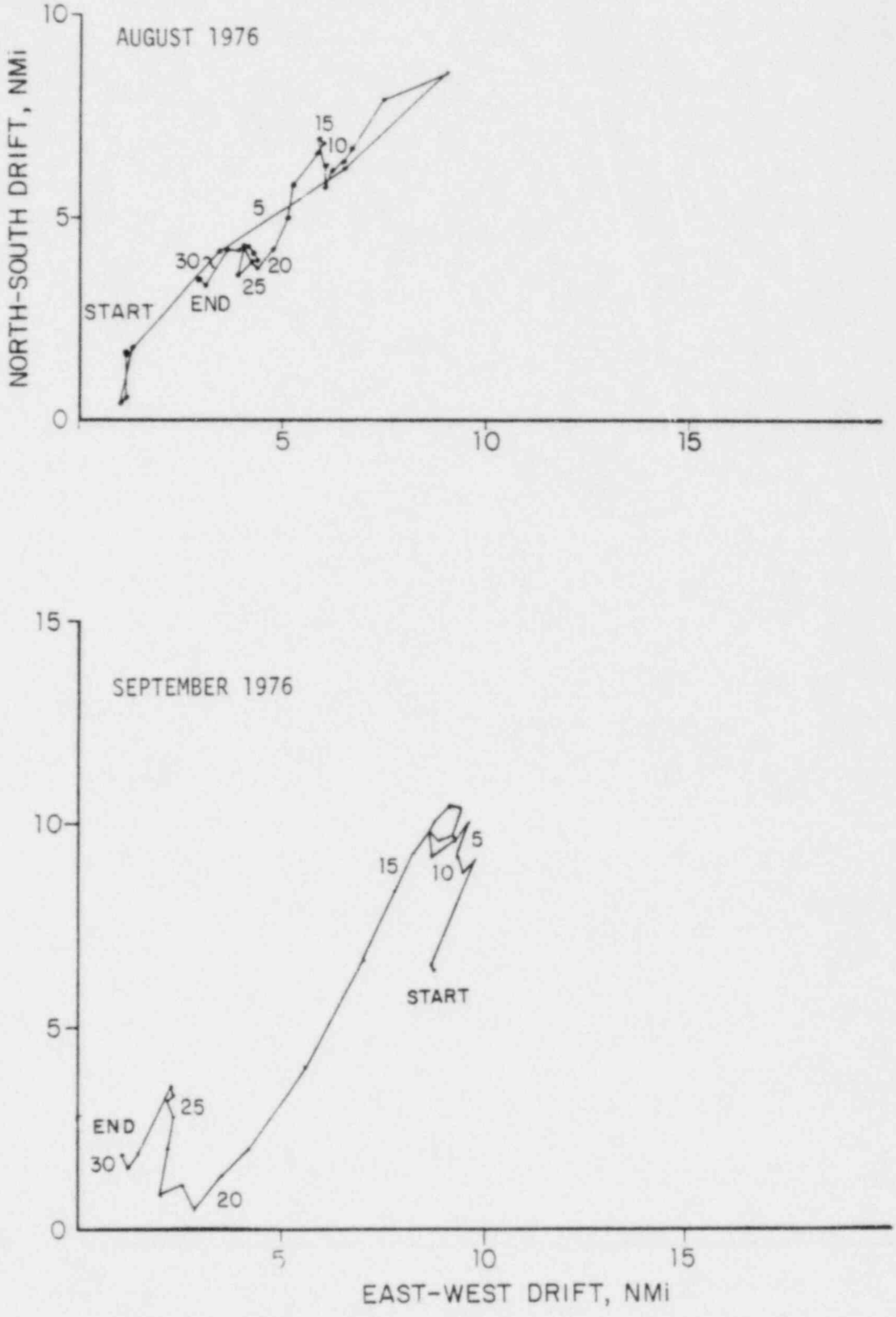

Figure 7.4-10. Progressive vector plots of 24-hour net drift from a mid-depth current meter (Mooring 10 upper at -20 ft. below MLW) for August and September, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

APPENDIX 7.5

SUMMARY TEMPERATURE PLOTS

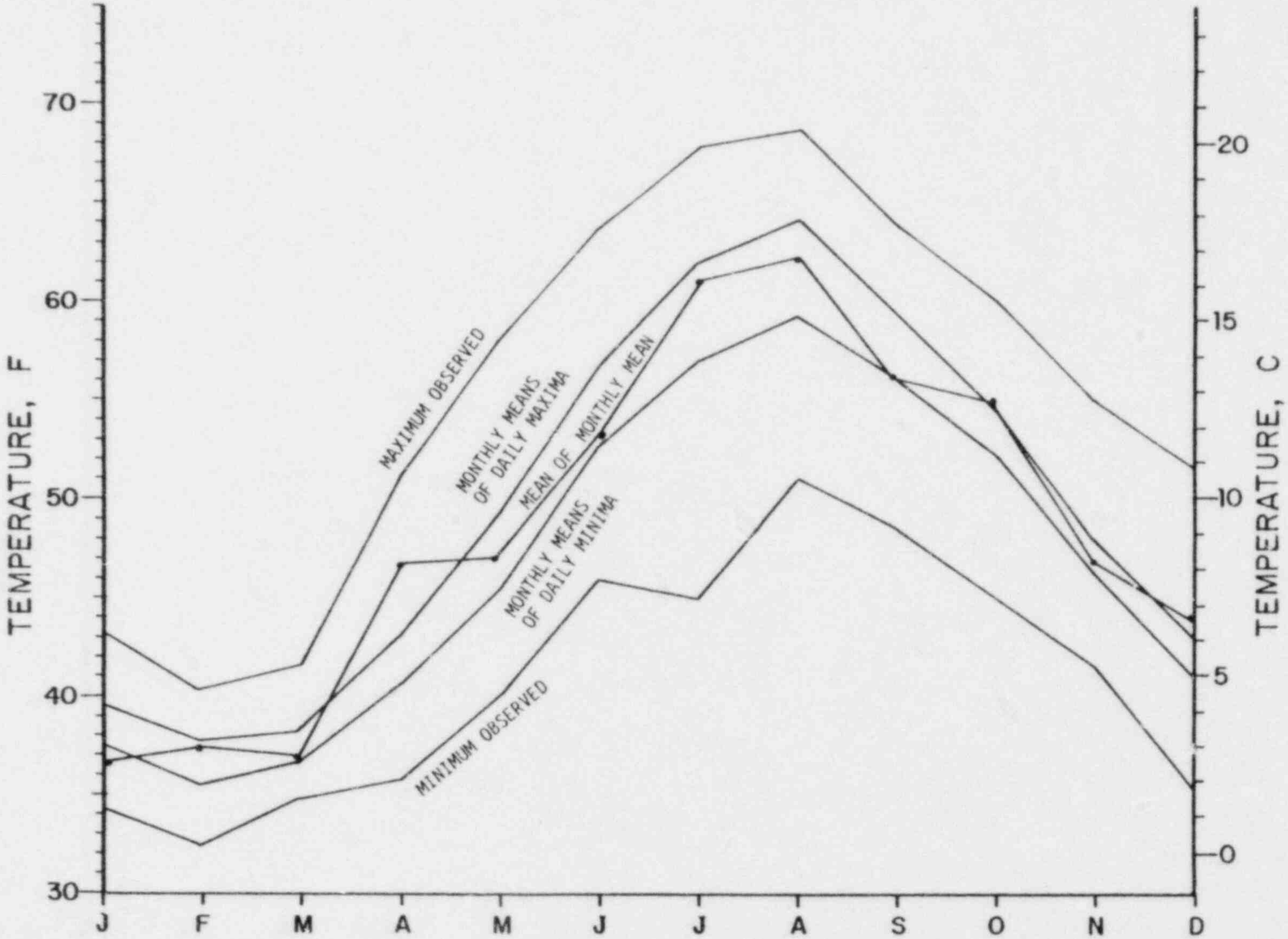

Figure 7.5-1. Monthly summary temperature data from Mooring 12 showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from November 9, 1973 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

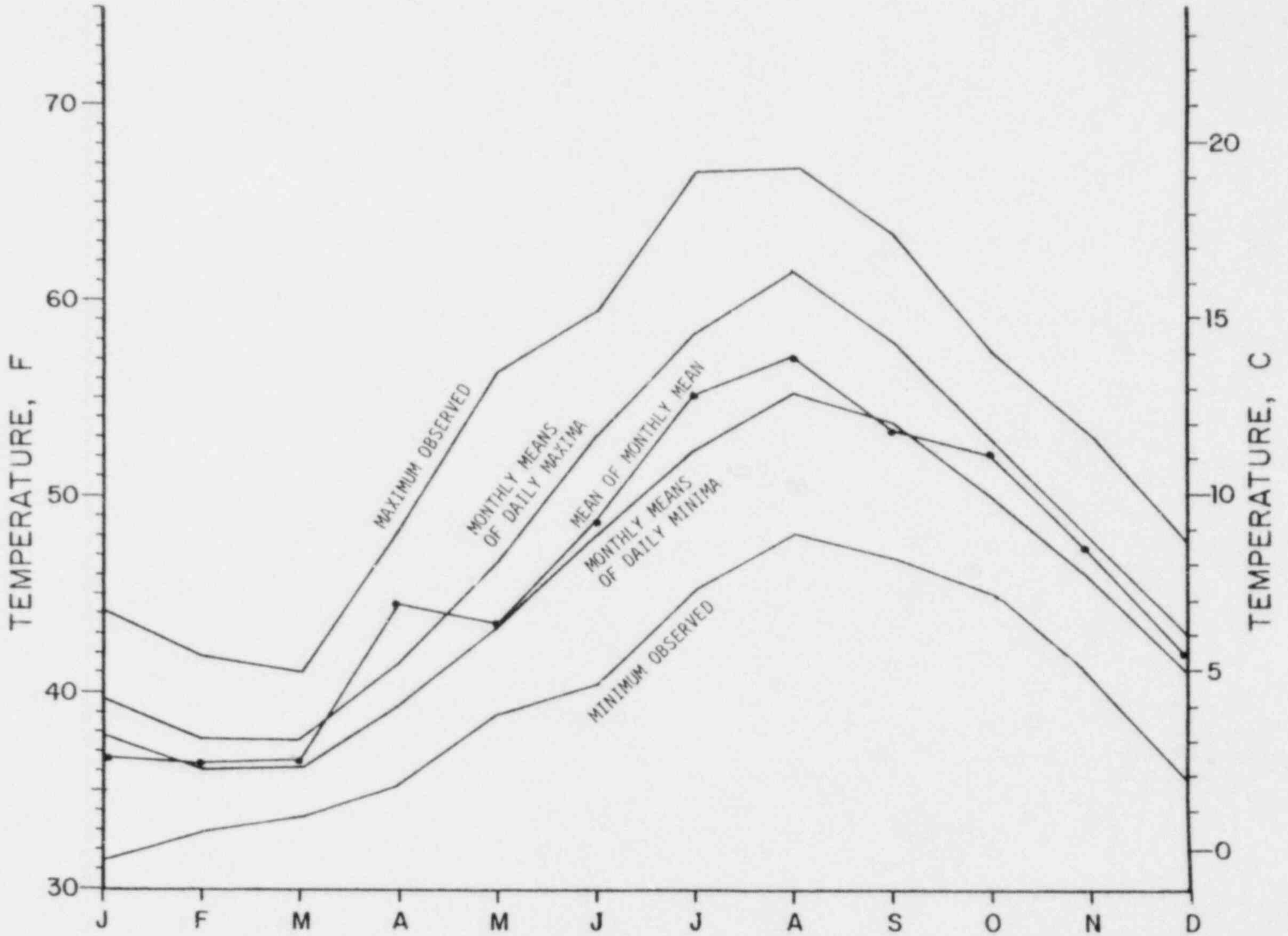

Figure 7.5-2. Monthly summary temperature data from Mooring 10 upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from October 19, 1973 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

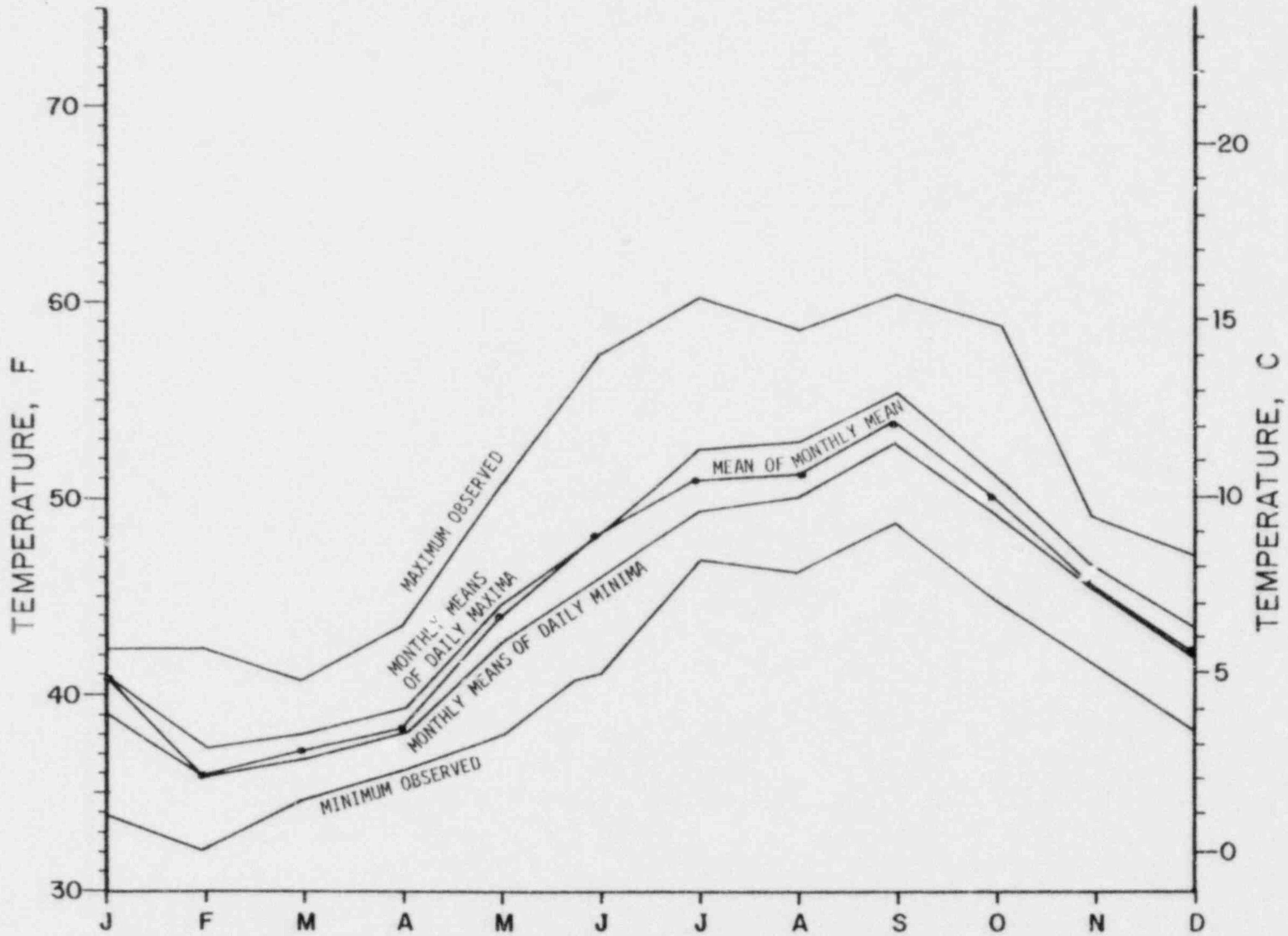

Figure 7.5-3. Monthly summary temperature data from Mooring 10 lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from October 20, 1973 to June 24, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

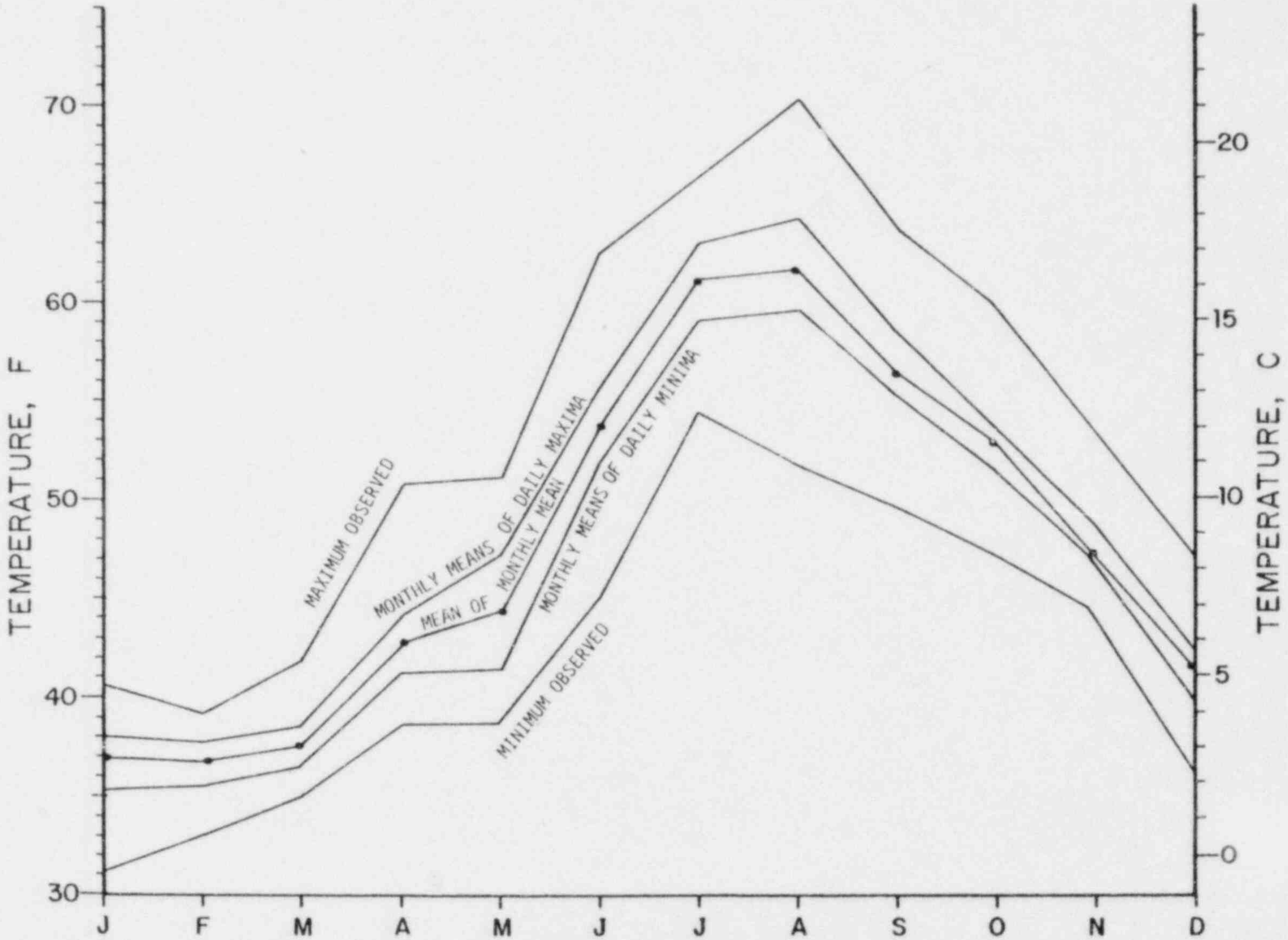

Figure 7.5-4. Monthly summary temperature data from Mooring I-4 upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from September 5, 1975 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

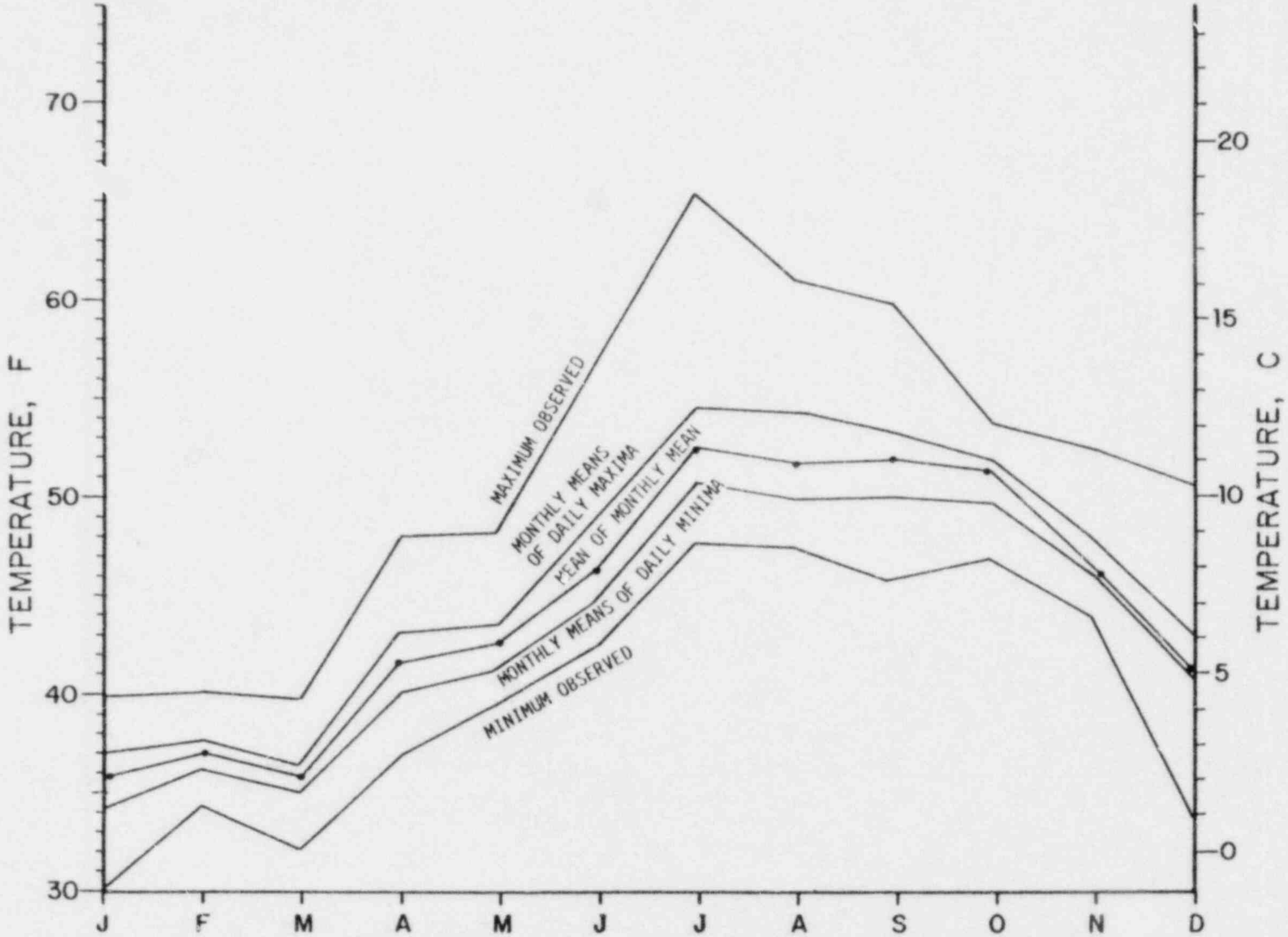

Figure 7.5-5. Monthly summary temperature data from Mooring I-4 lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from September 5, 1975 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

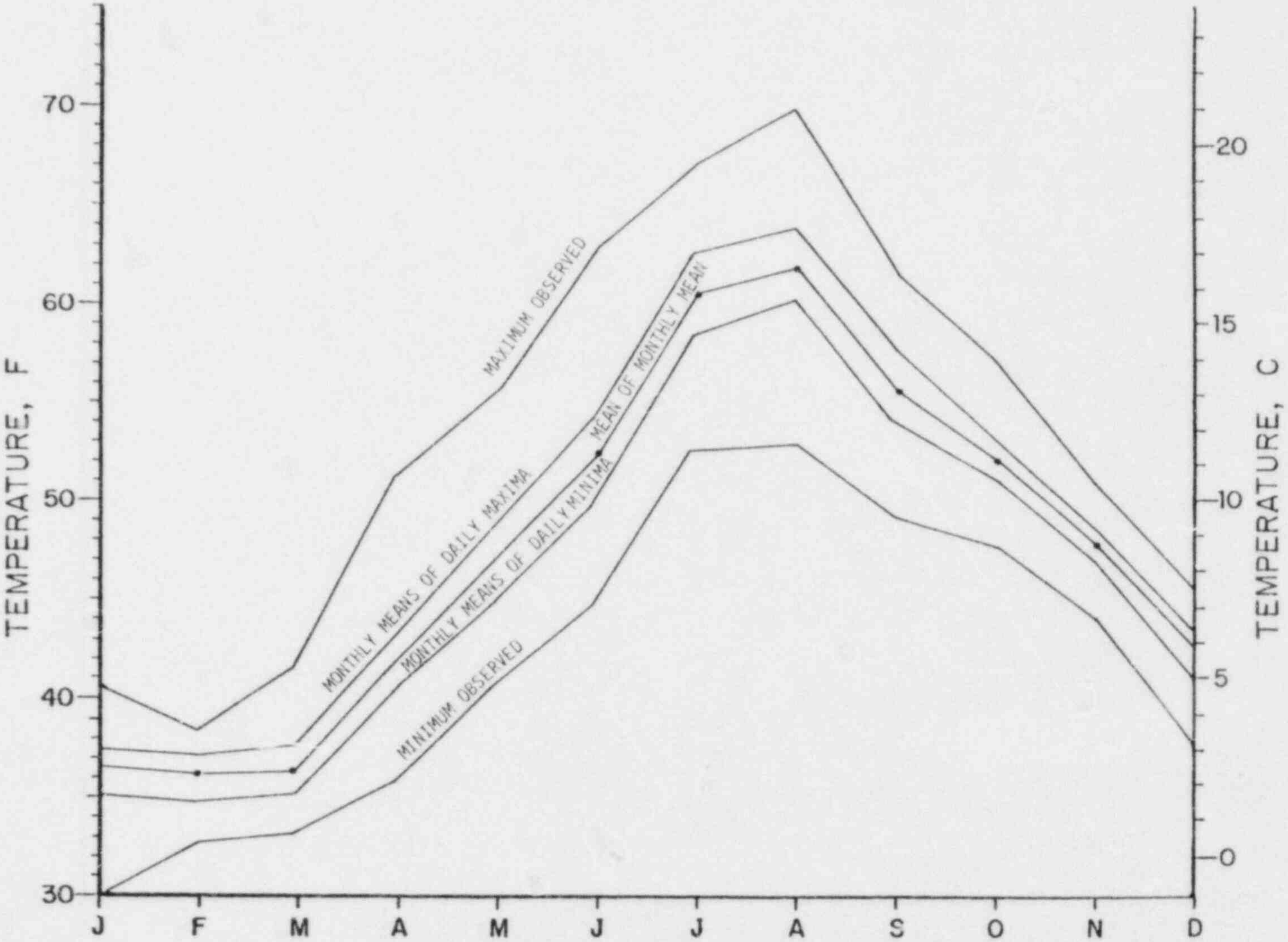

Figure 7.5-6. Monthly summary temperature data from Mooring T-7 showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from July 1, 1975 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

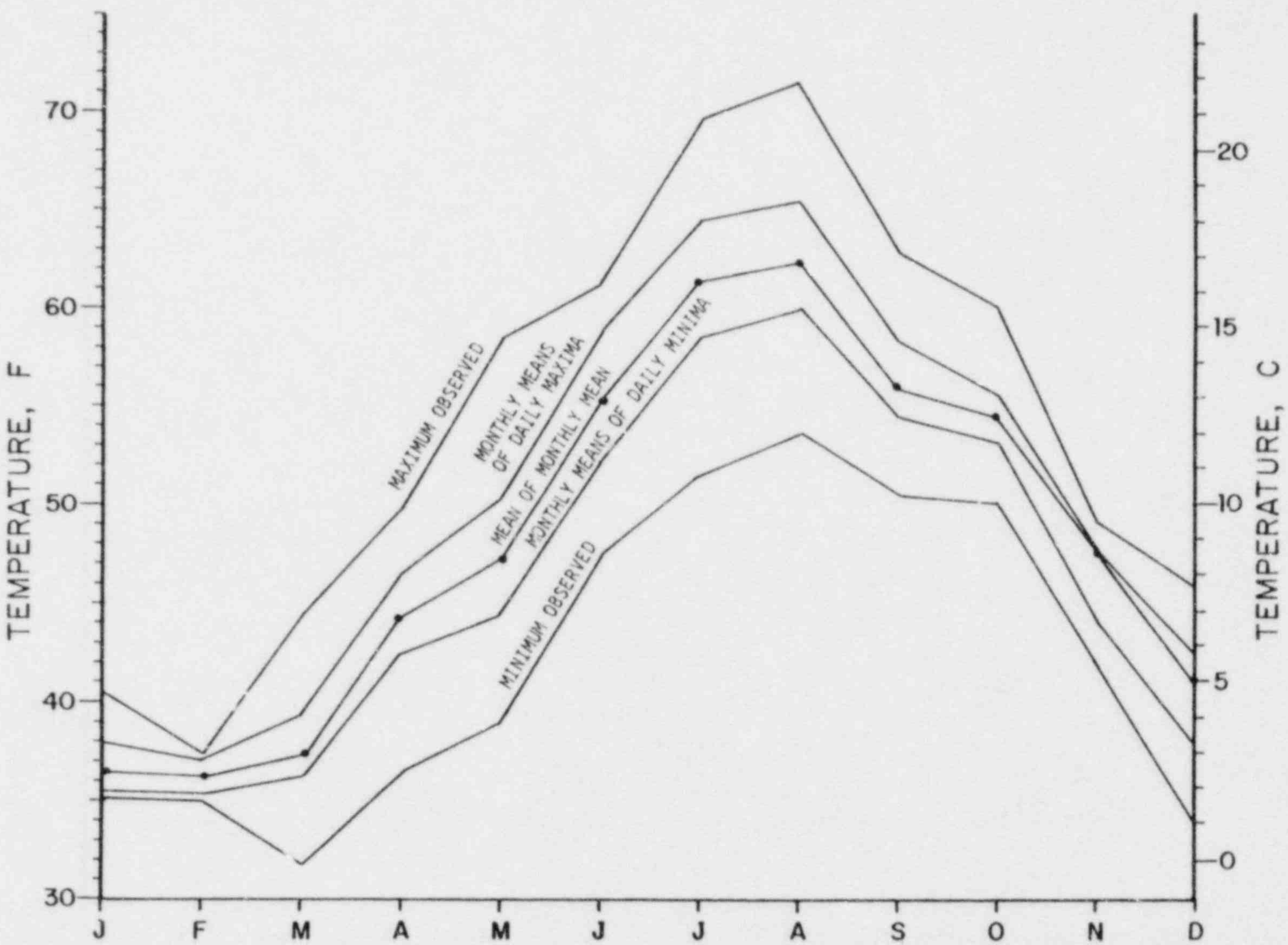

Figure 7.5-7. Monthly summary temperature data from Mooring B upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from January 1, 1976 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

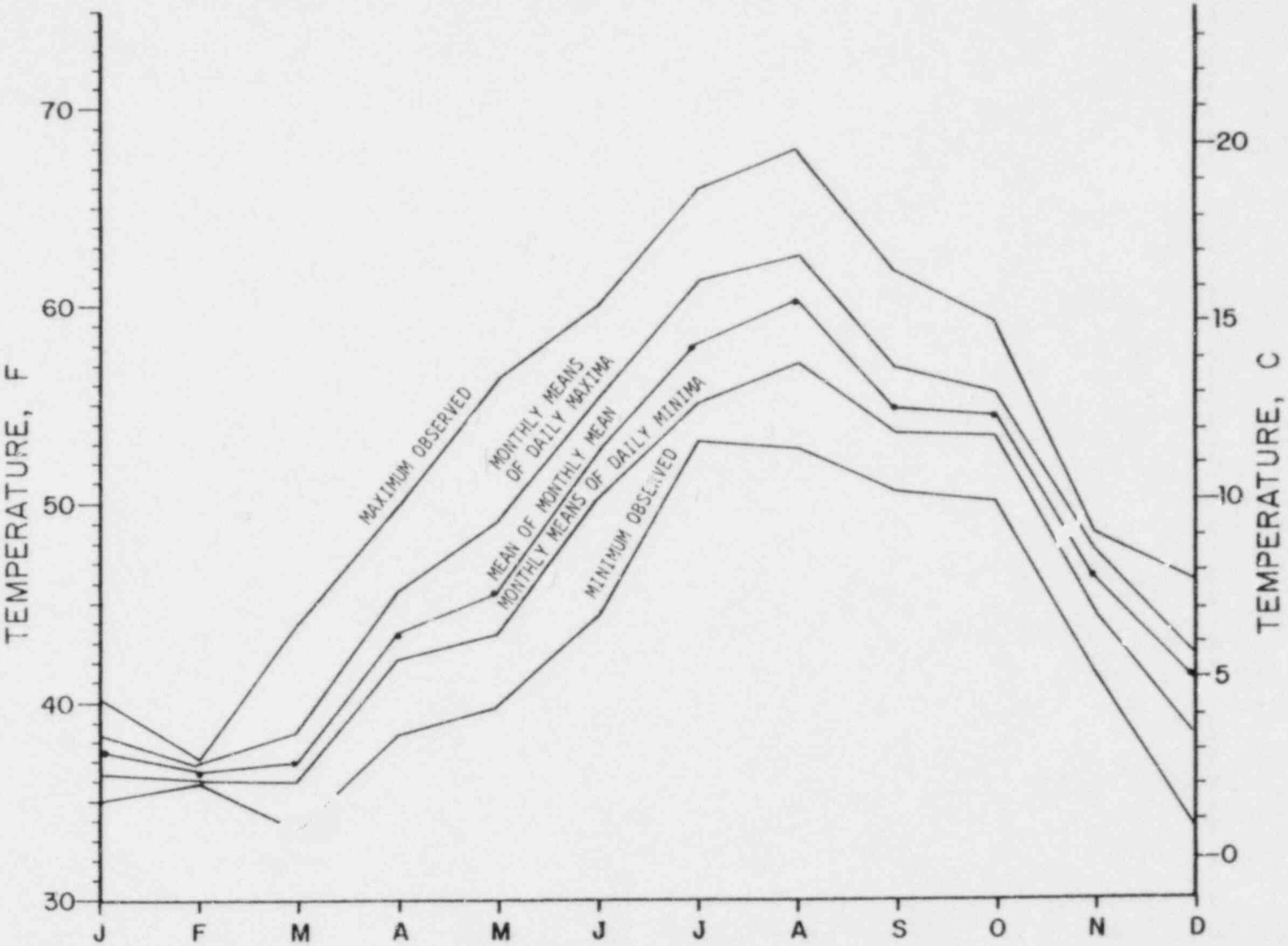

Figure 7.5-8. Monthly summary temperature data from Mooring B lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from January 1, 1976 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

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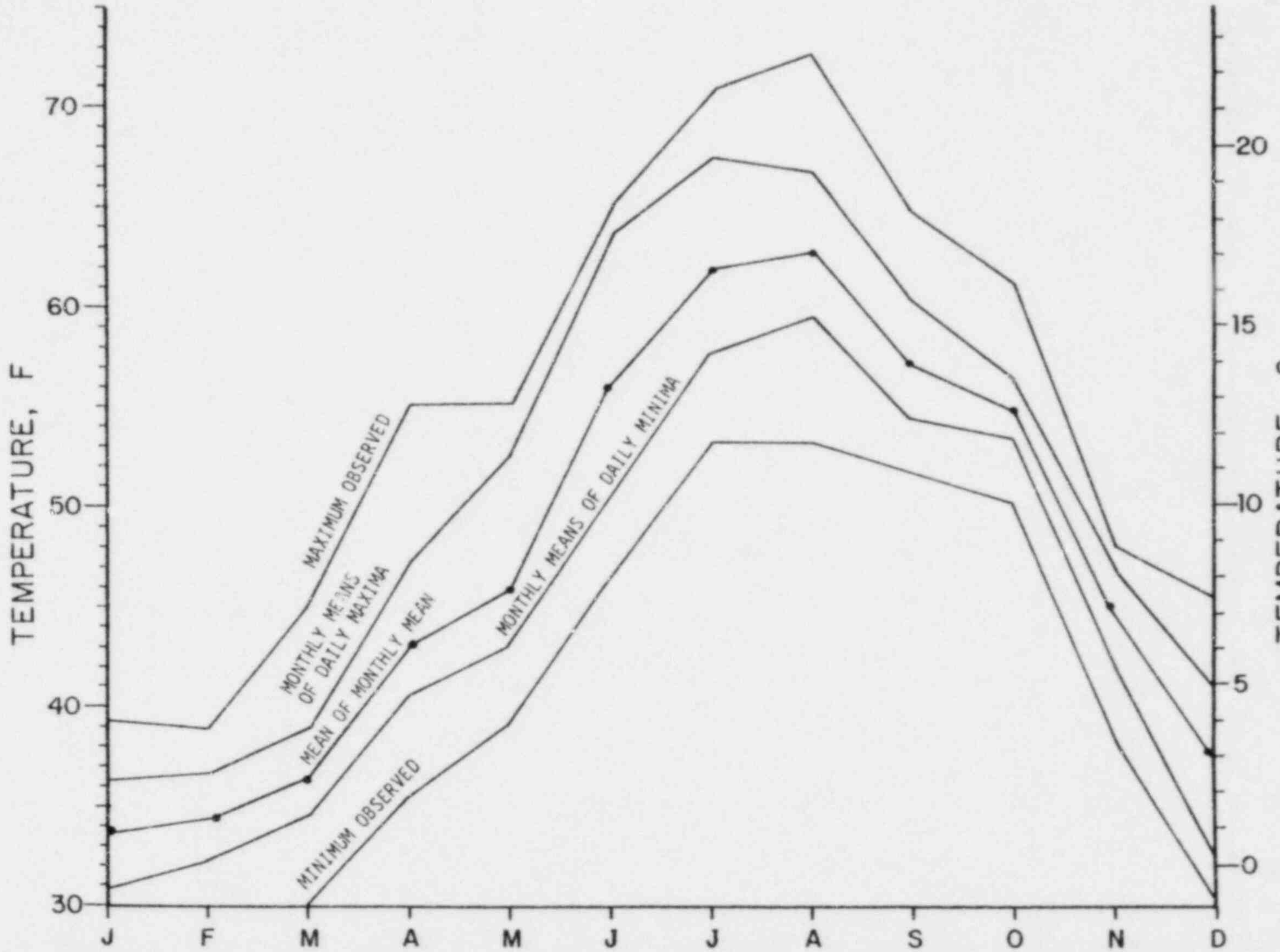

Figure 7.5-9. Monthly summary temperature data from Mooring HH upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from January 1, 1976 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

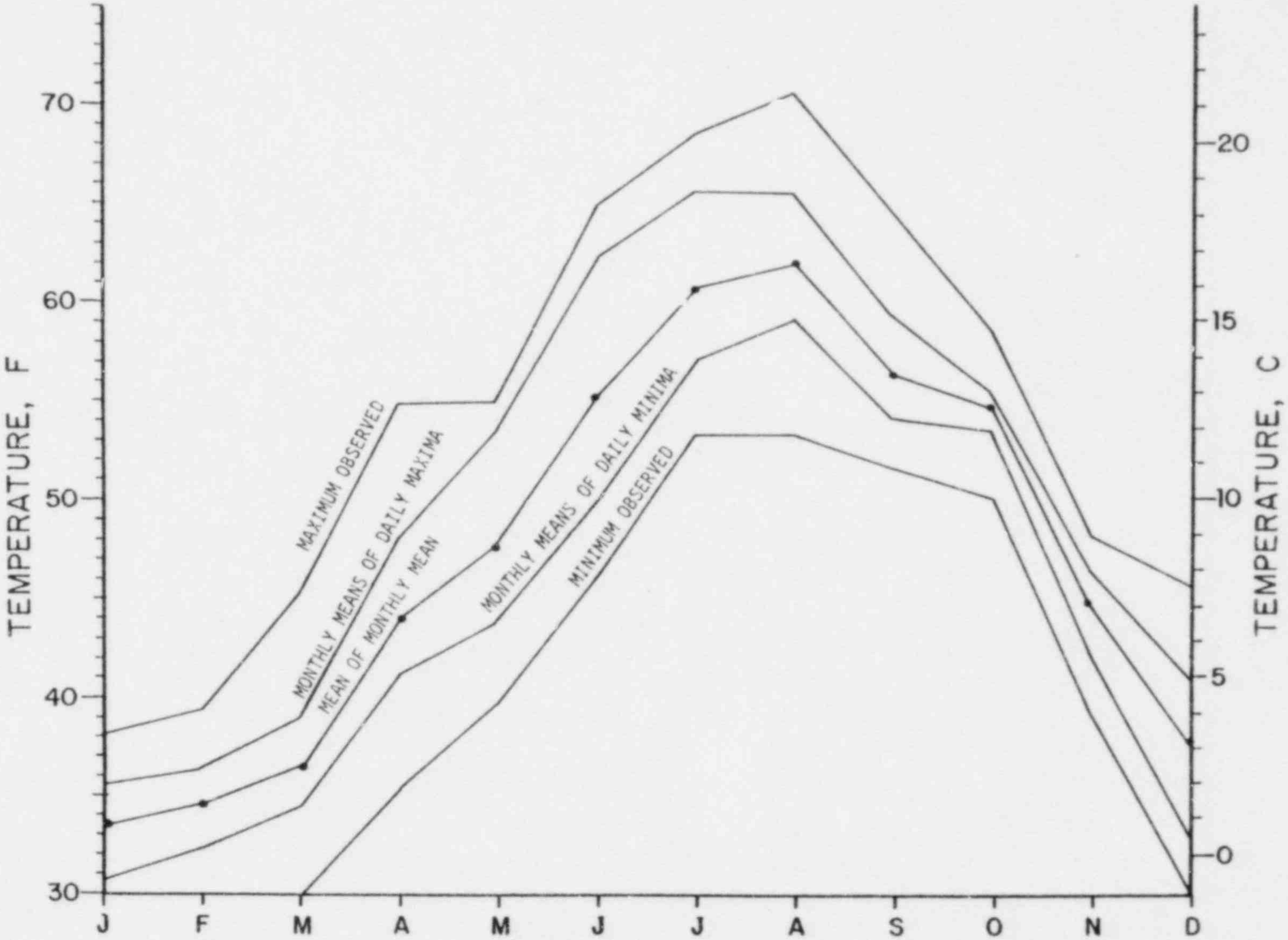

Figure 7.5-10. Monthly summary temperature data from Mooring HH lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1976), monthly mean of daily minima, and minimum ever observed from January 1, 1976 to December 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

APPENDIX 7.6

SUMMARY SEQUENTIAL VECTOR PLOTS

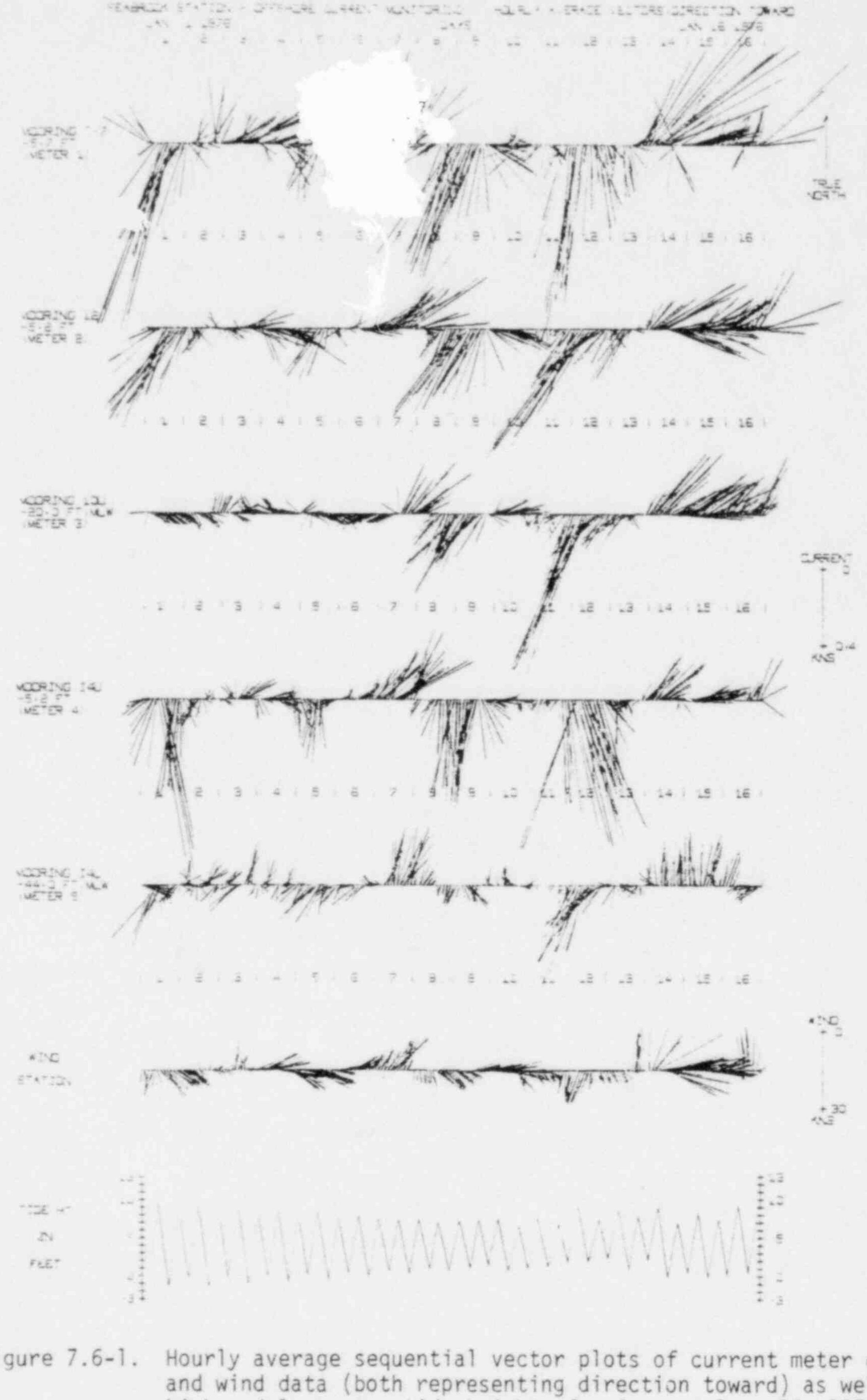

Figure 7.6-1. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for January 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

Figure 7.6-2. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for January 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

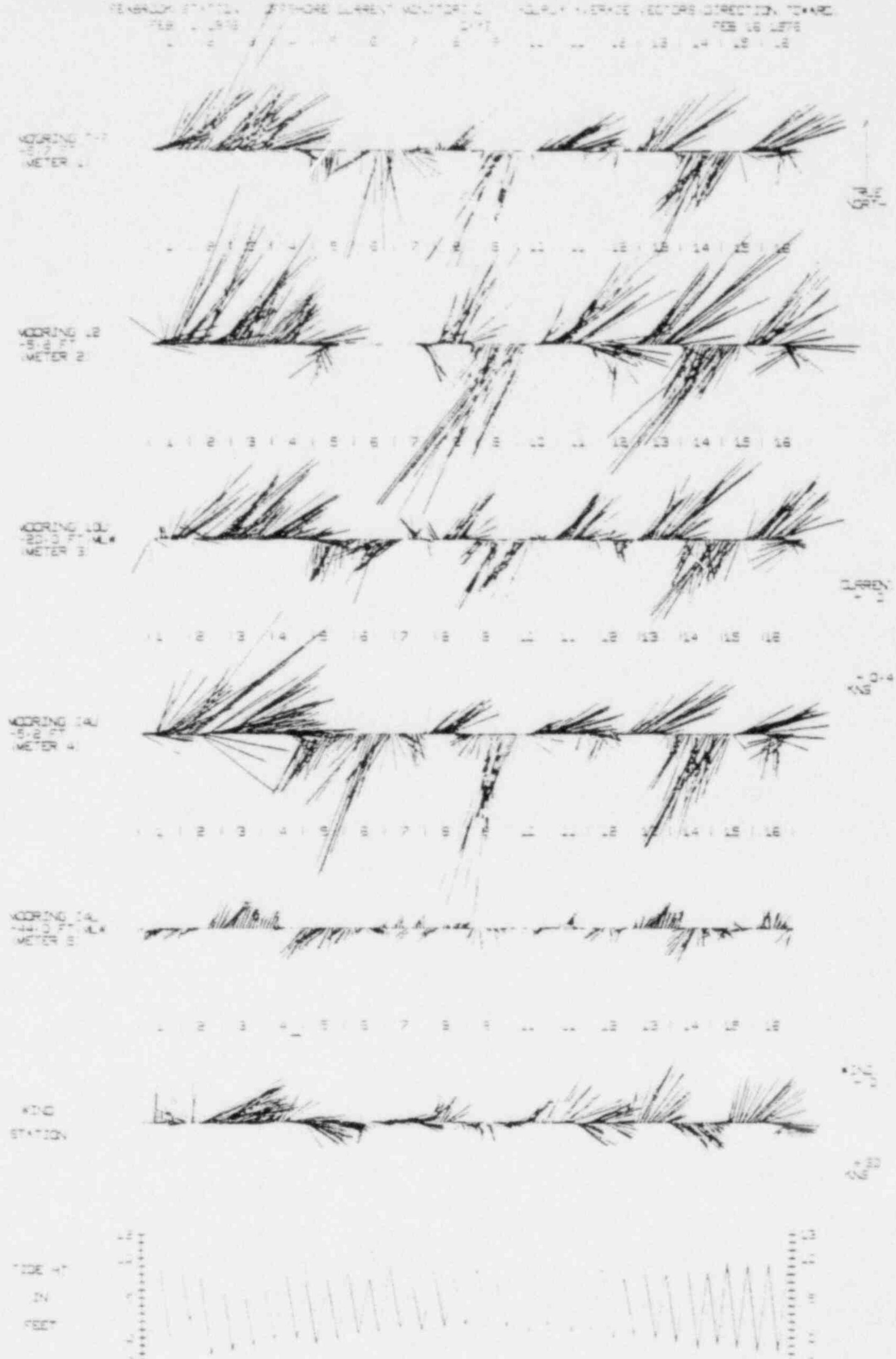

Figure 7.6-3. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for February 1 to 16, 1976. 'eabrook 1976 Annual Hydrograohic Report, 1979.

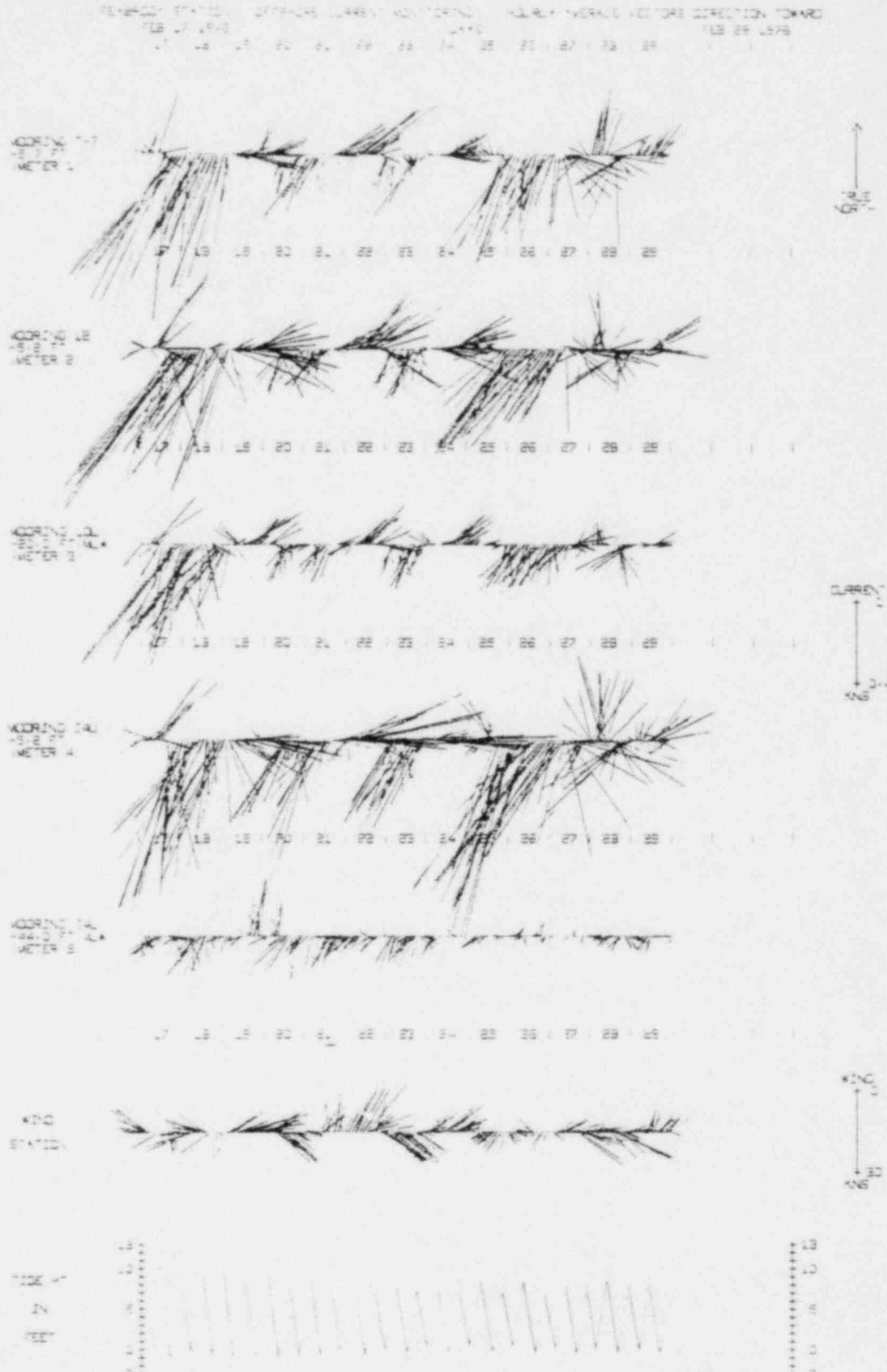

Figure 7.6-4. Hourly average sequent'al vector plots of current meter data and wind data (both re,resenting direction toward) as well as high and low water tide heights for February 17 to 29, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

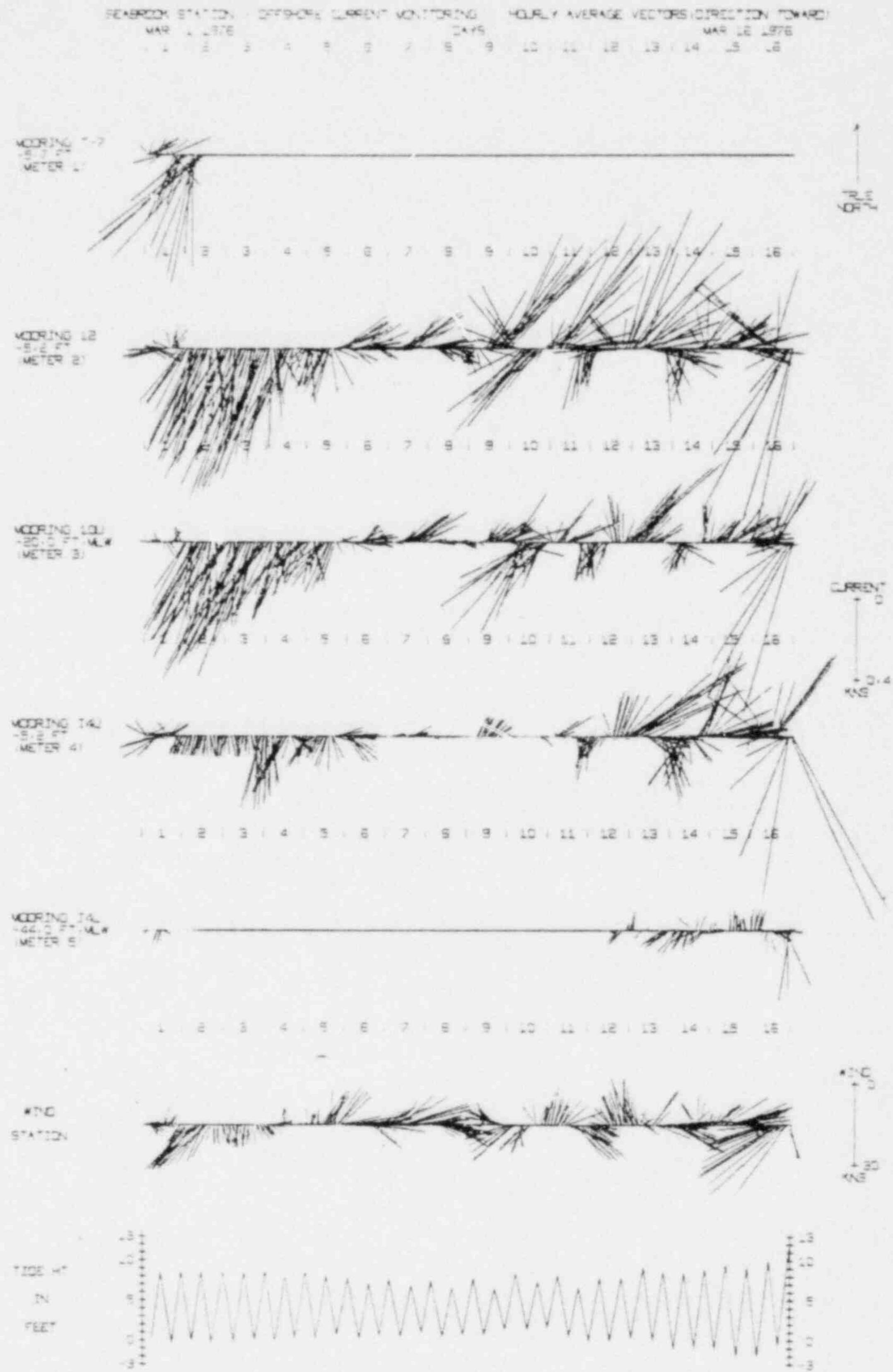

Figure 7.6-5. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for March 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

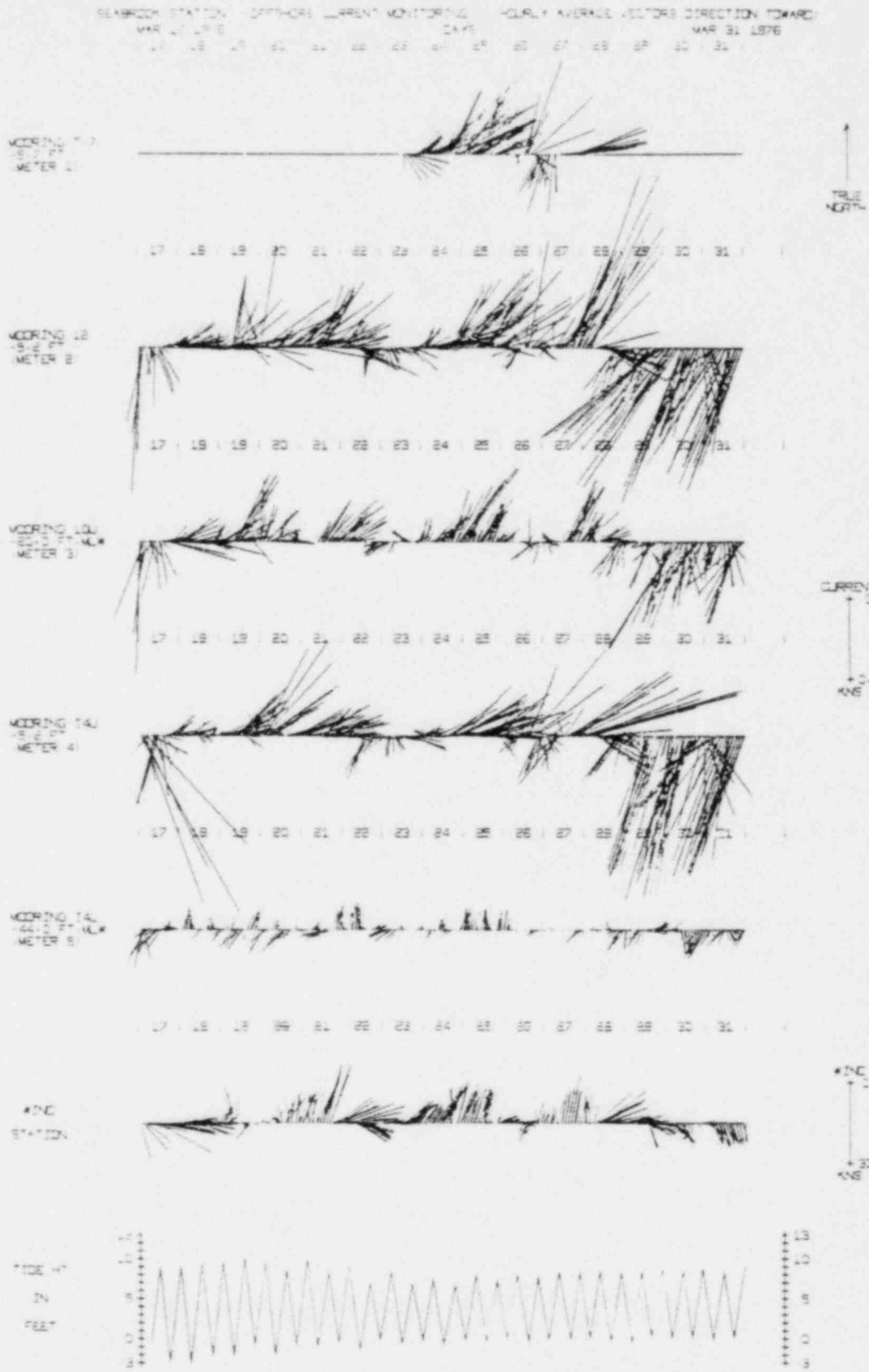

Figure 7.6-6. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for March 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

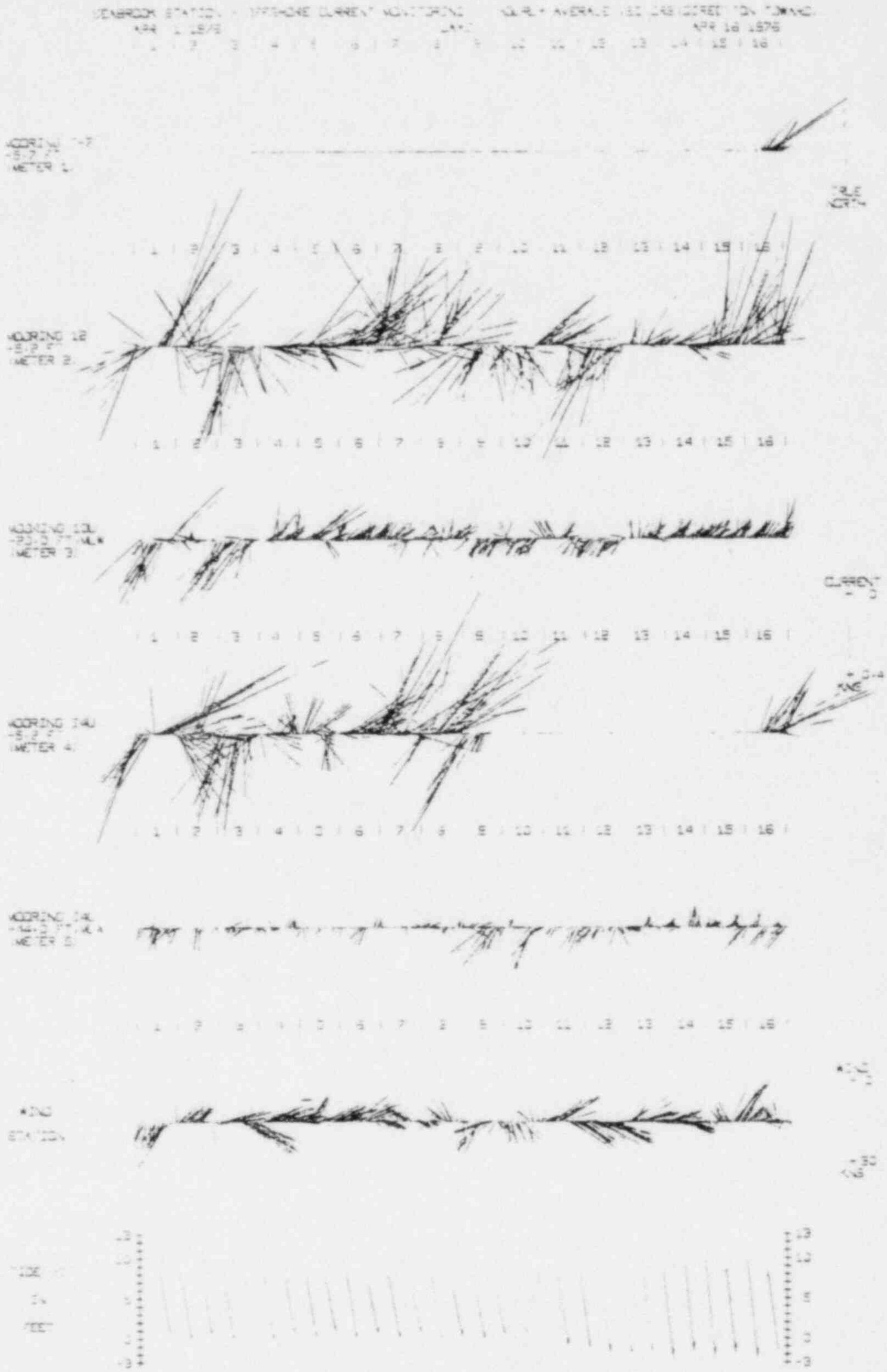

Figure 7.6-7. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for April 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

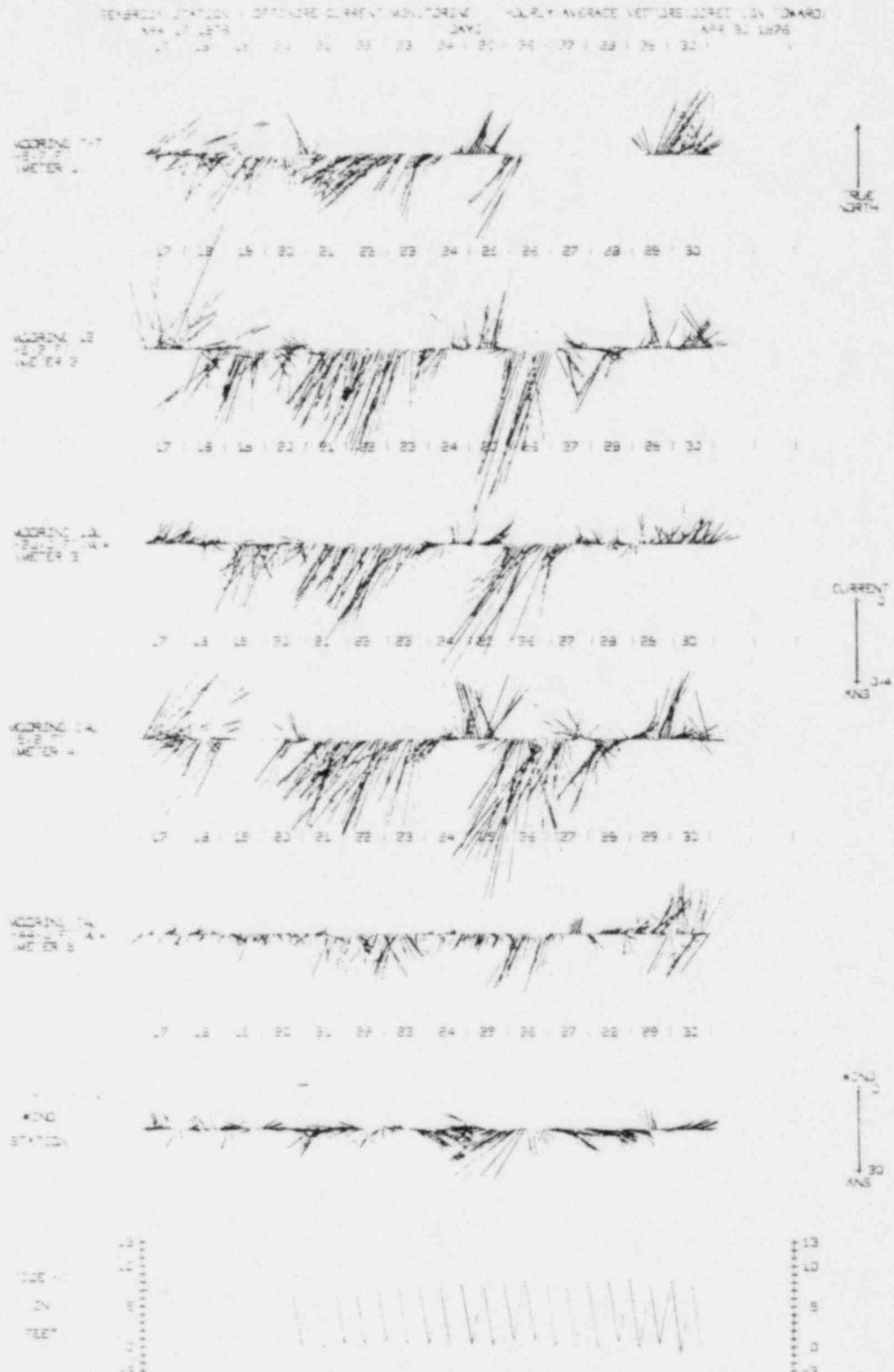

Figure 7.6-8. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for April 17 to 30, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

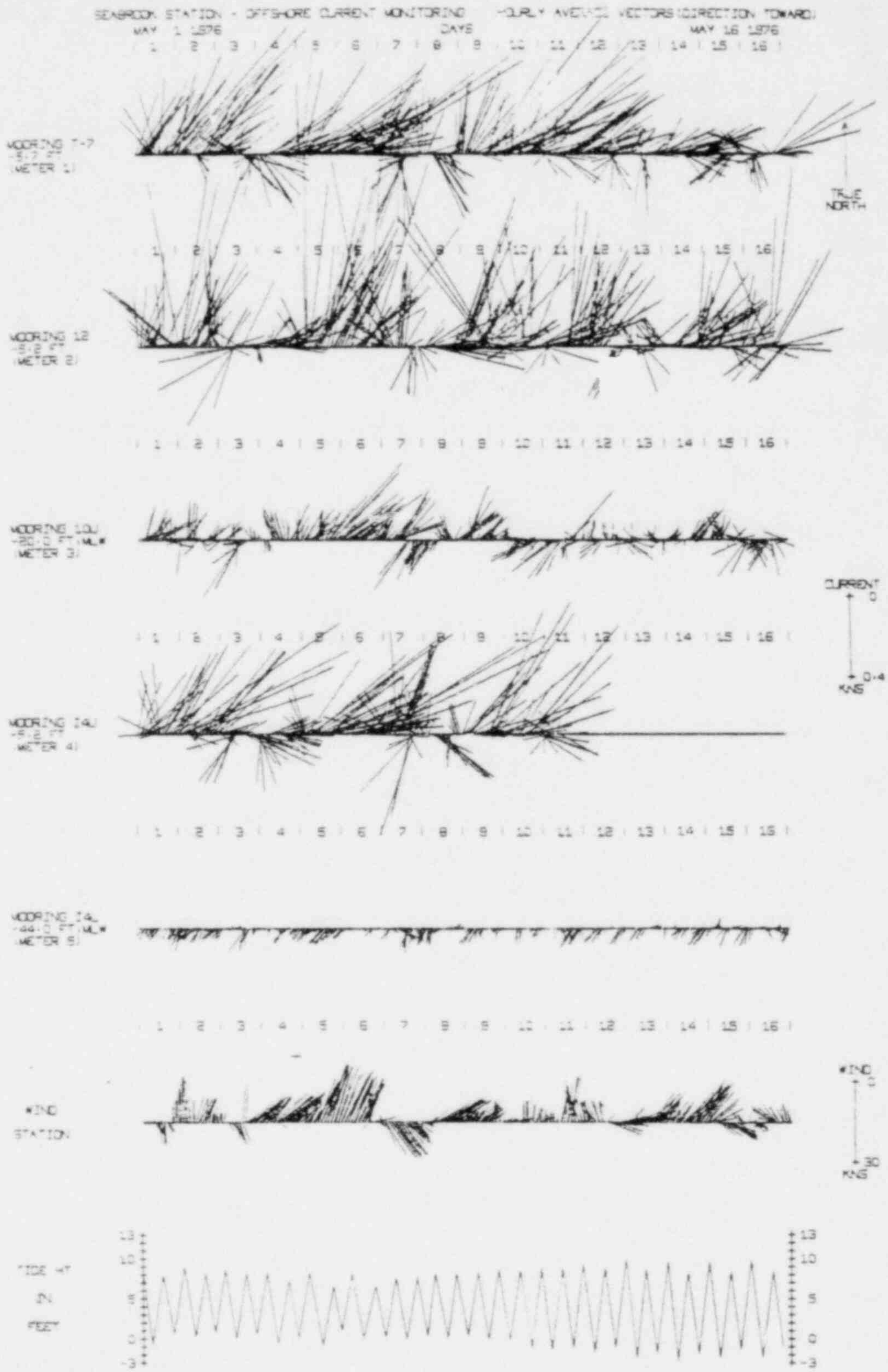

Figure 7.6-9. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for May 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

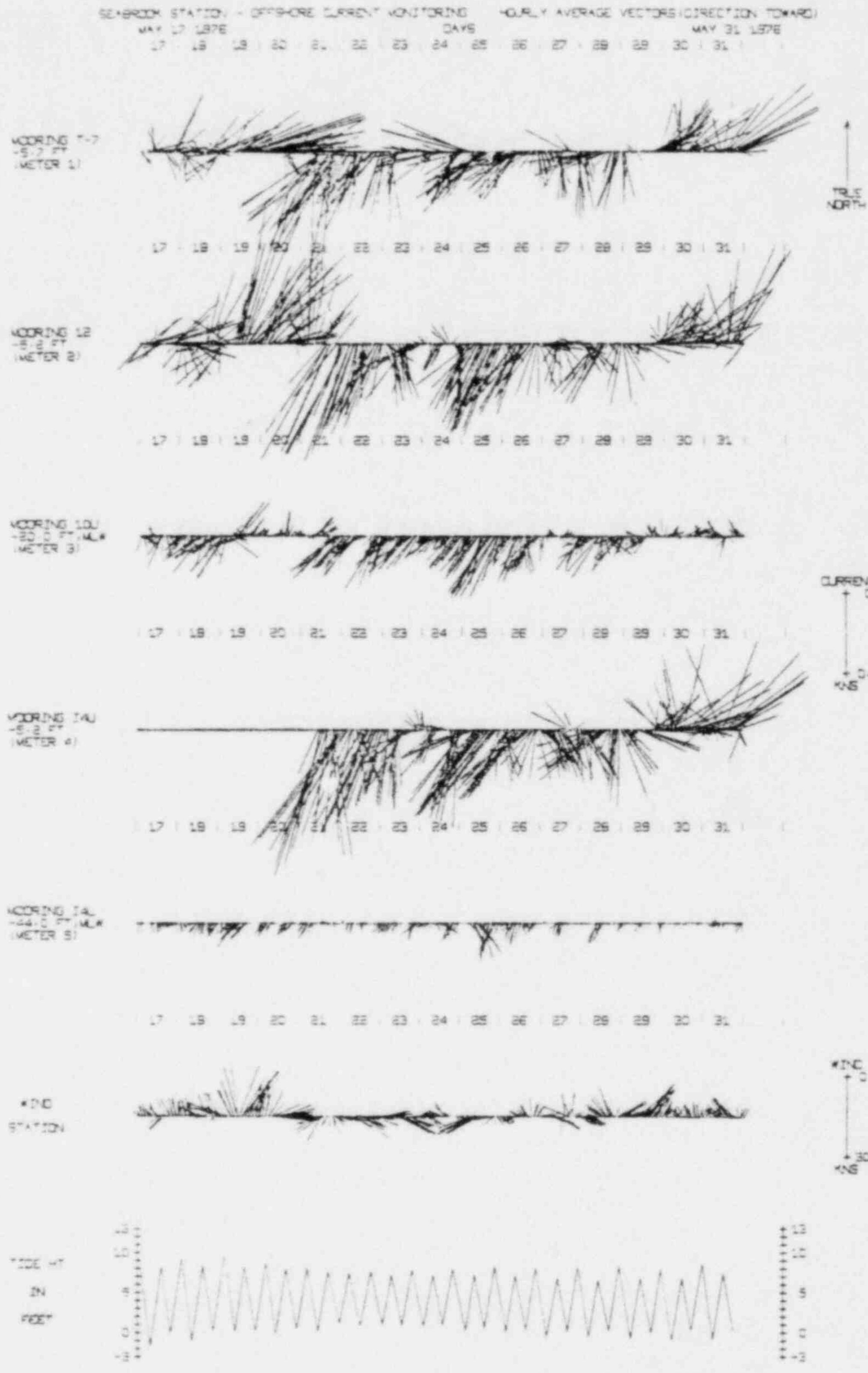

Figure 7.6-10. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for May 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

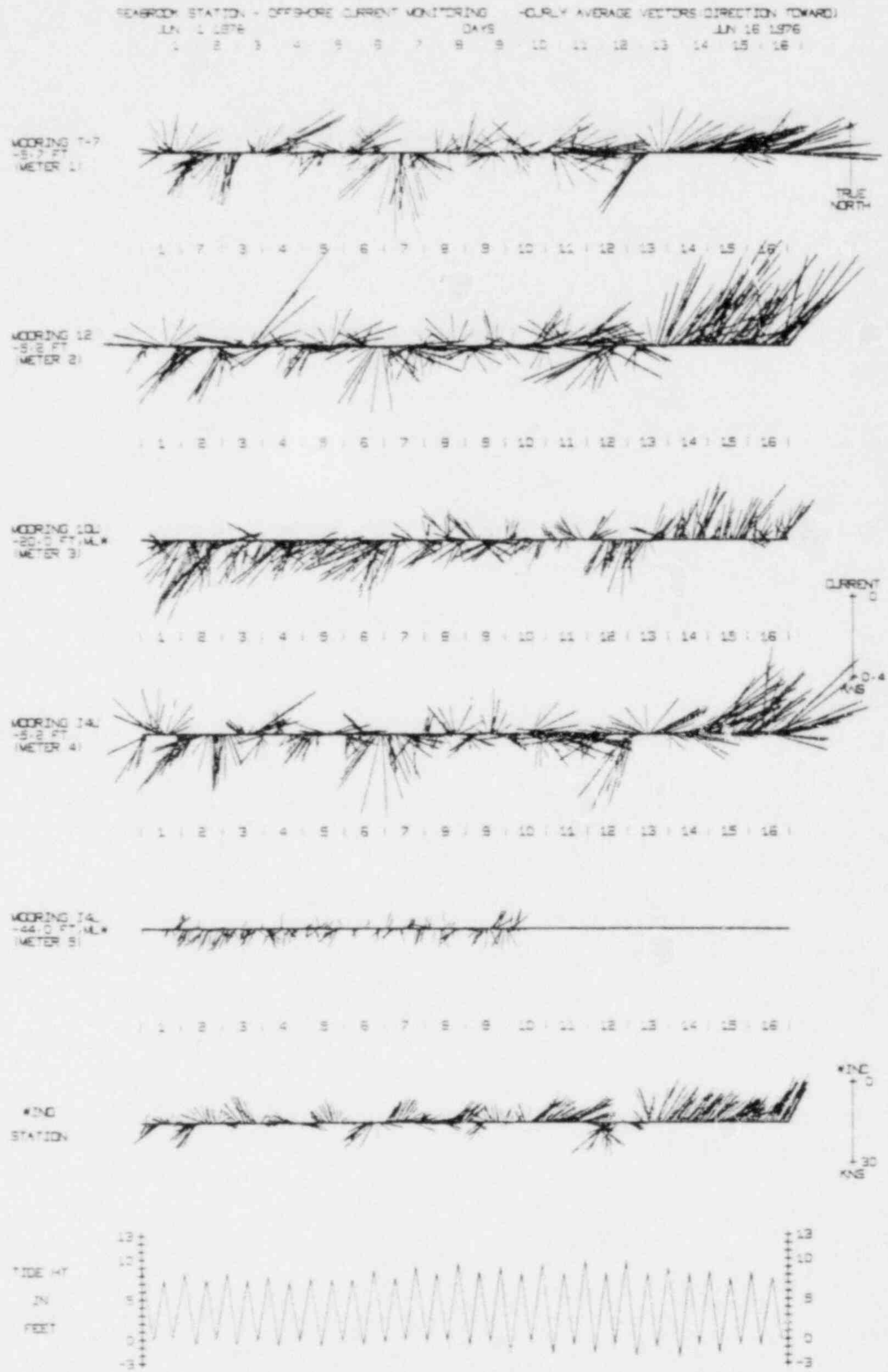

Figure 7.6-11. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for June 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

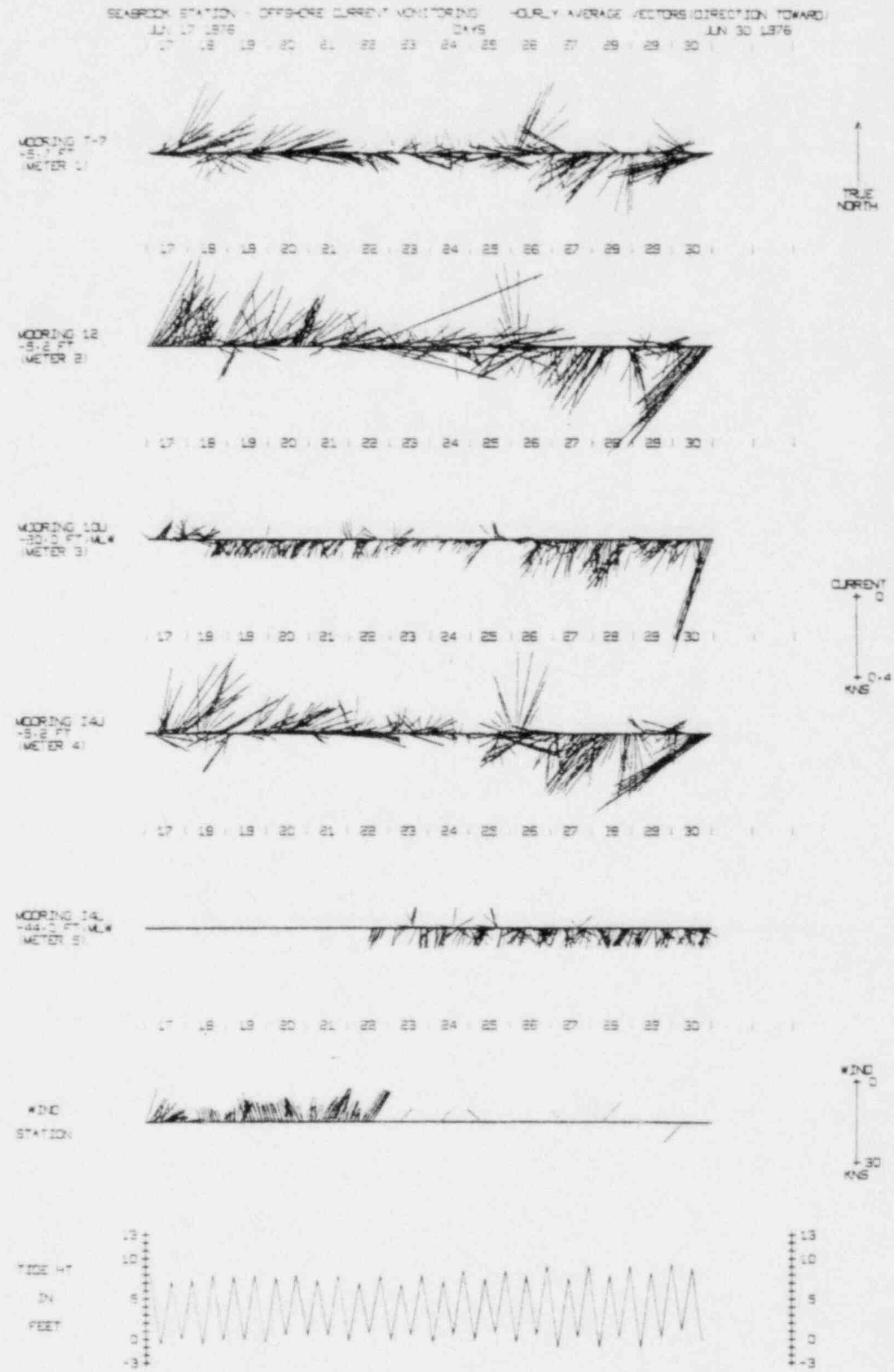

Figure 7.6-12. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for June 17 to 30, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

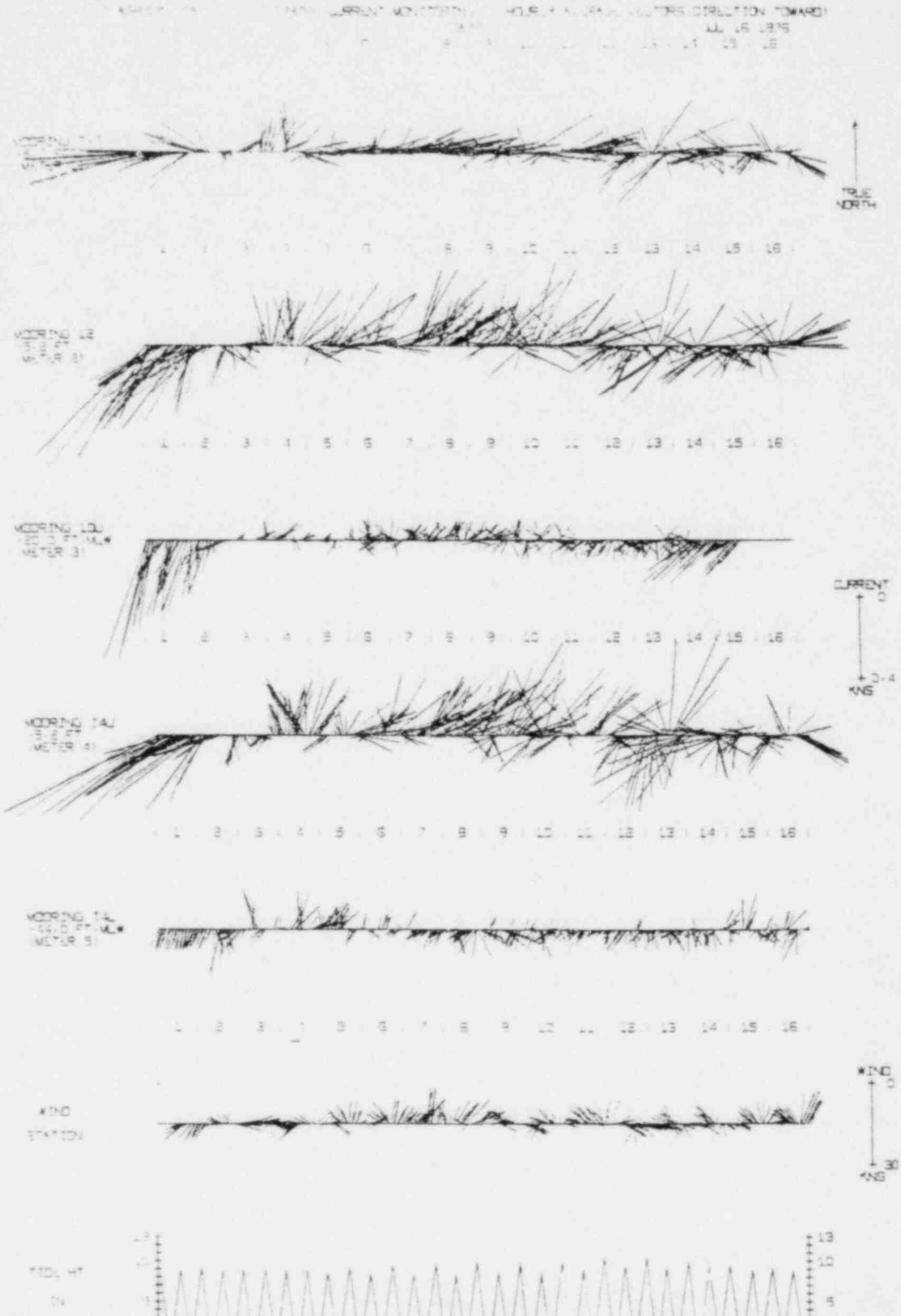

Figure 7.6-13. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for July 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

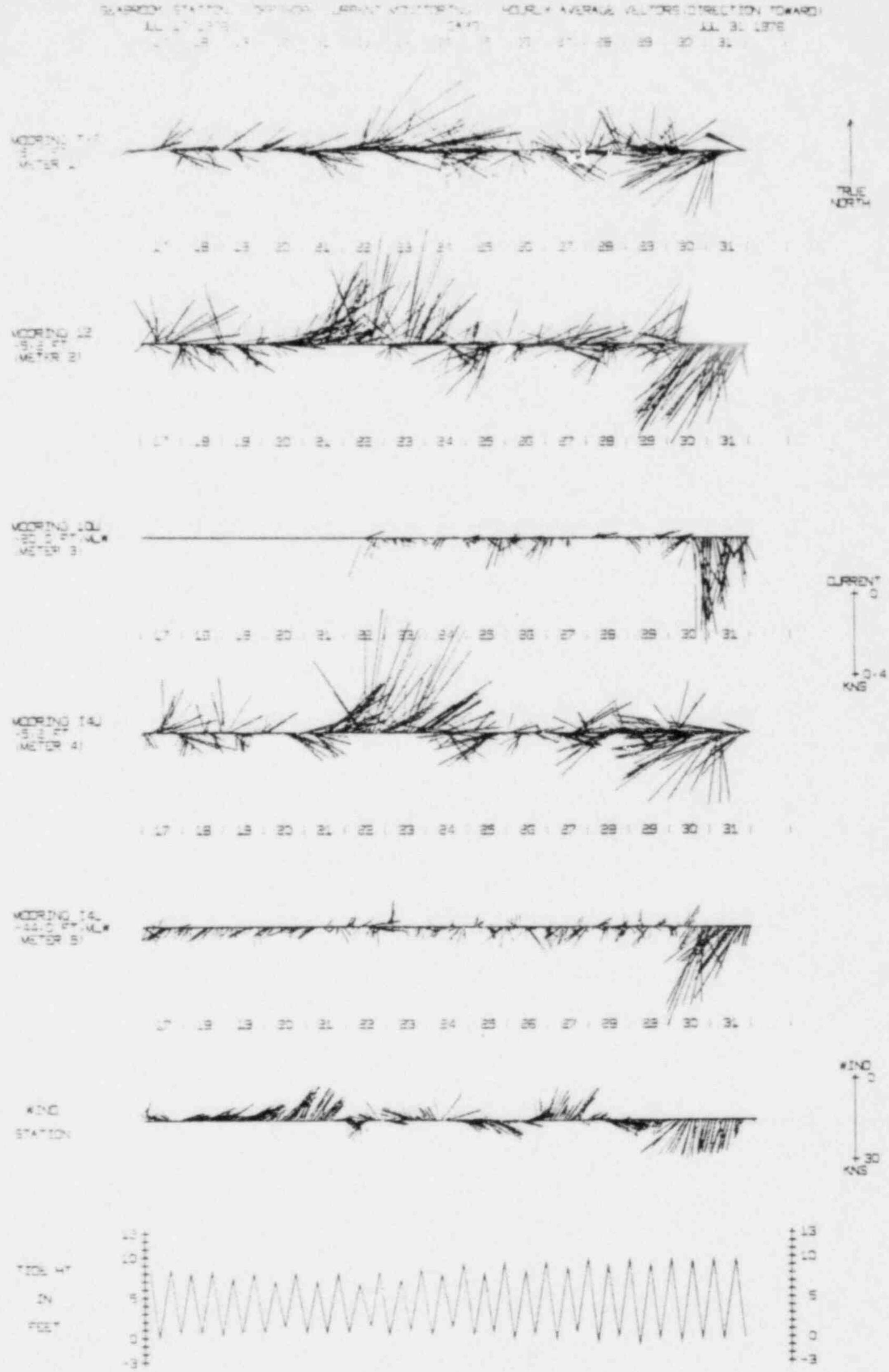

Figure 7.6-14. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for July 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

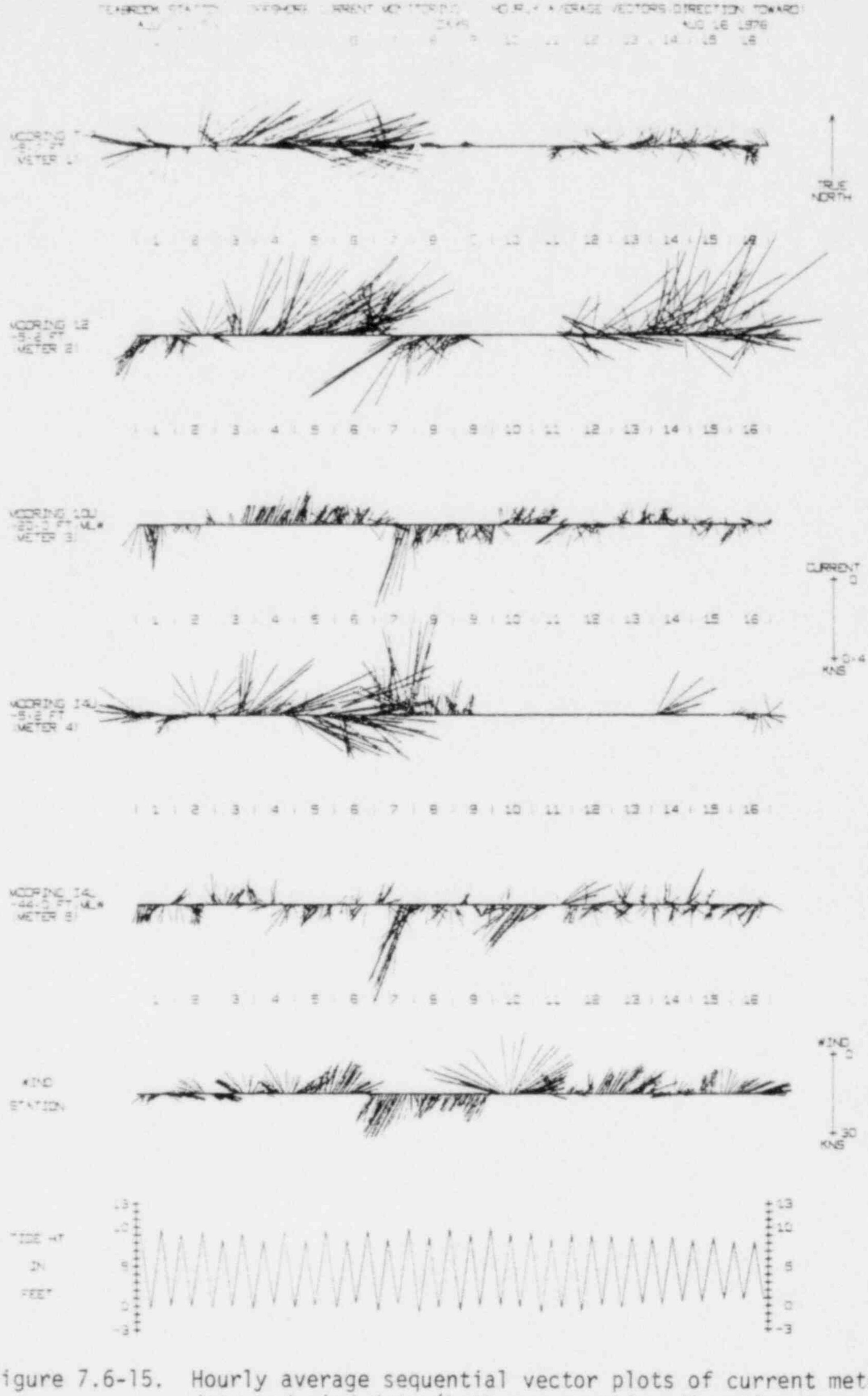

Figure 7.6-15. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for August 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

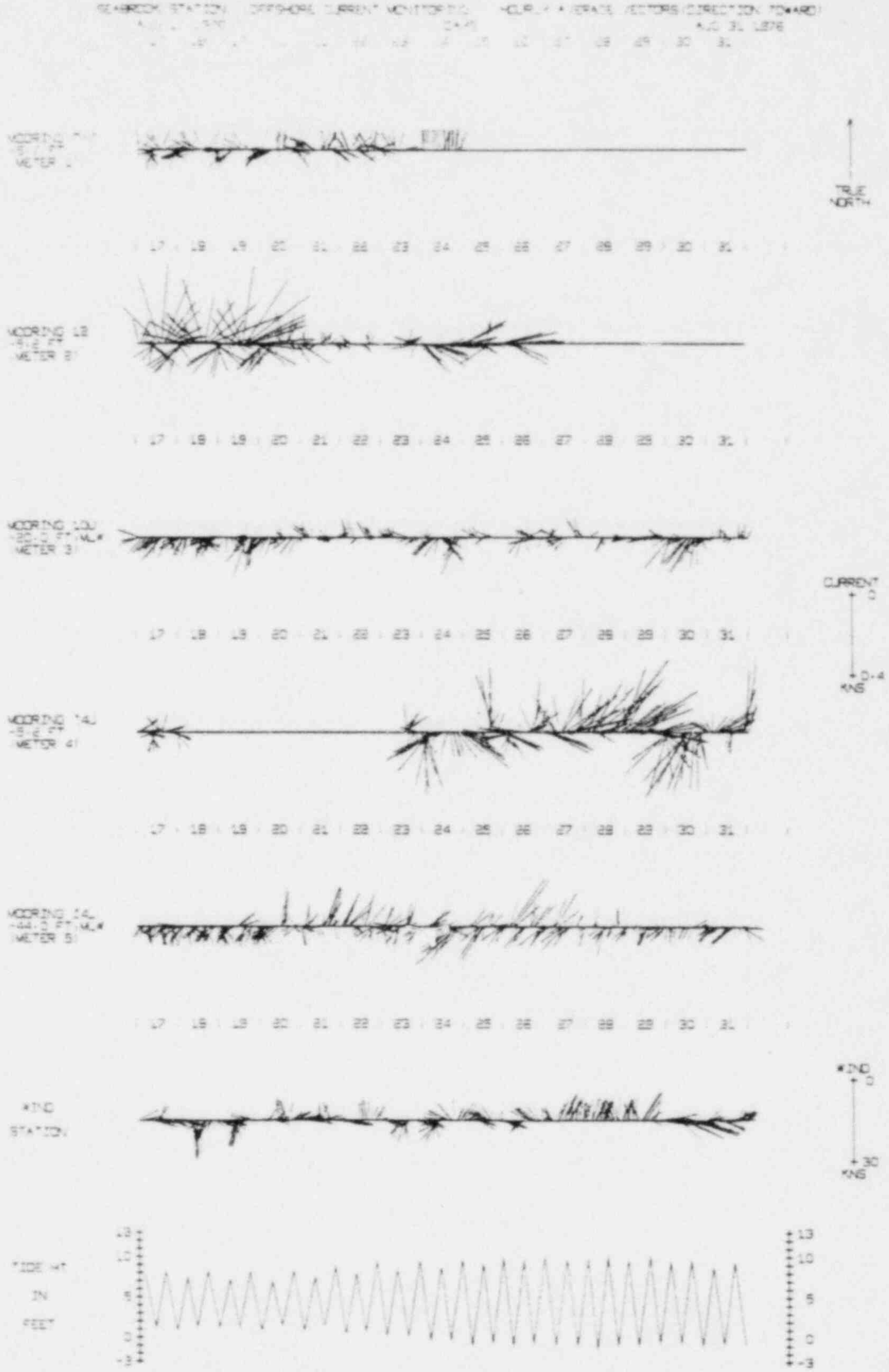

Figure 7.6-16. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for August 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

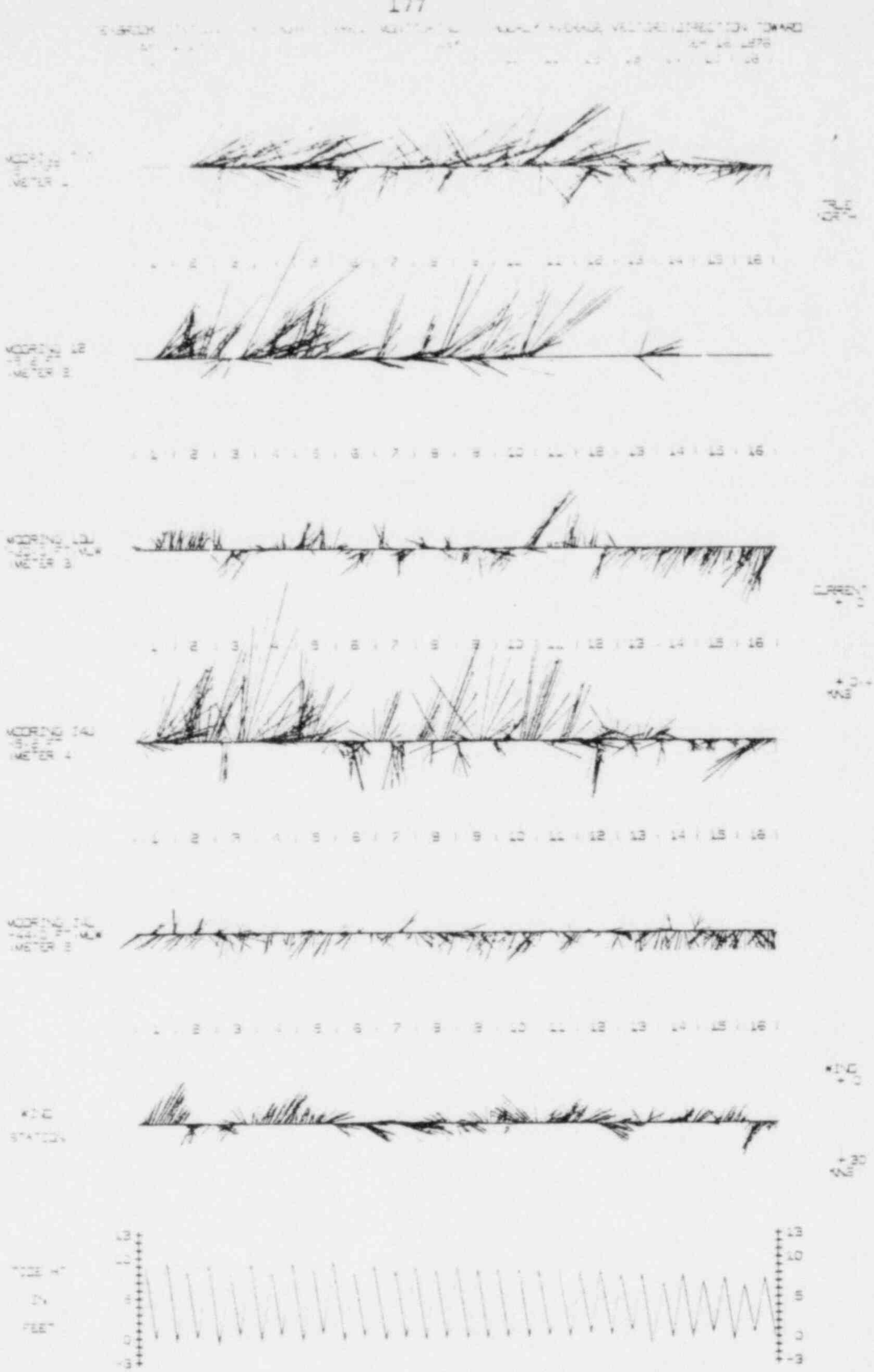

Figure 7.6-17. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for September 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

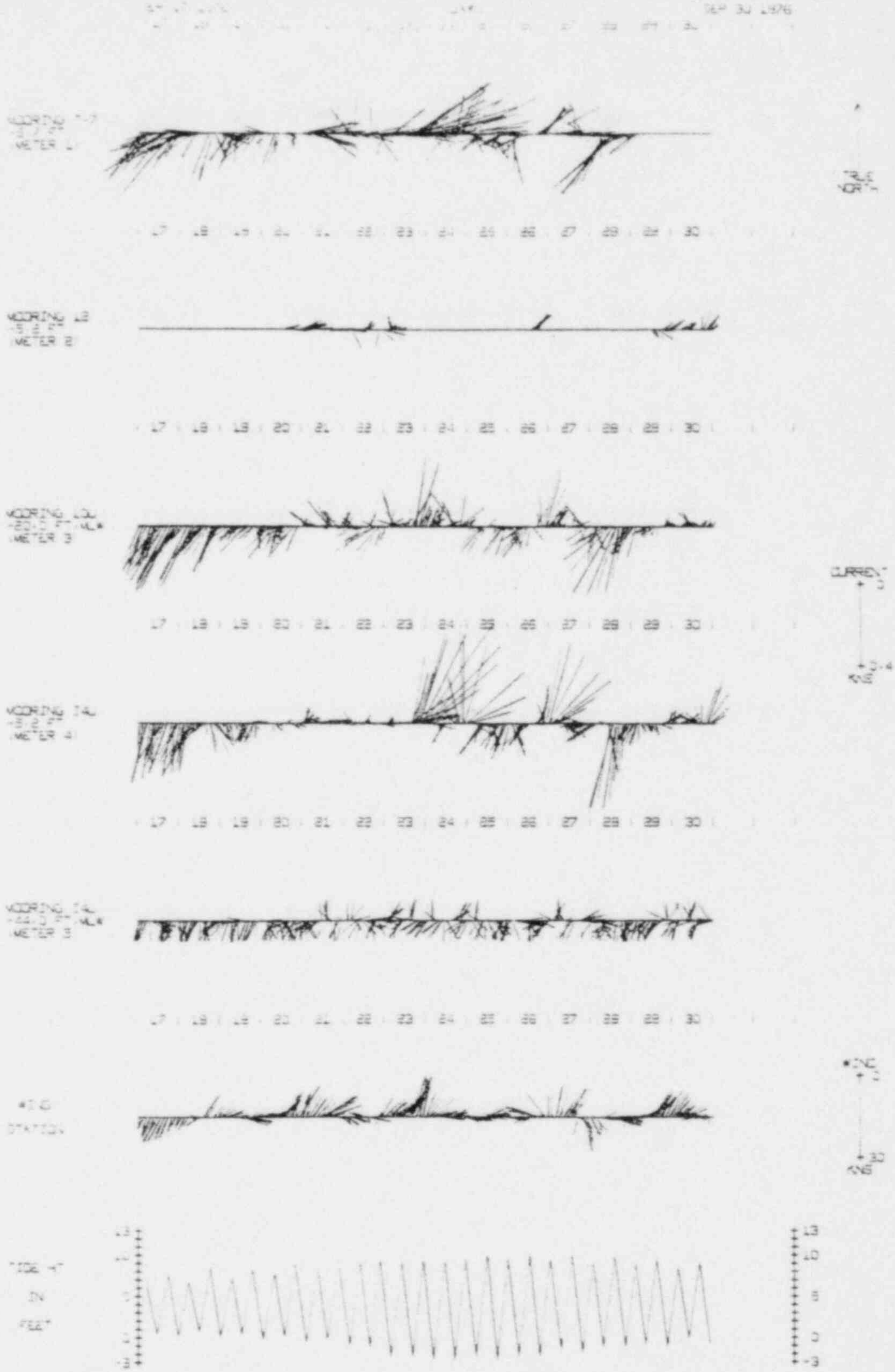

Figure 7.6-18. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for September 17 to 30, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

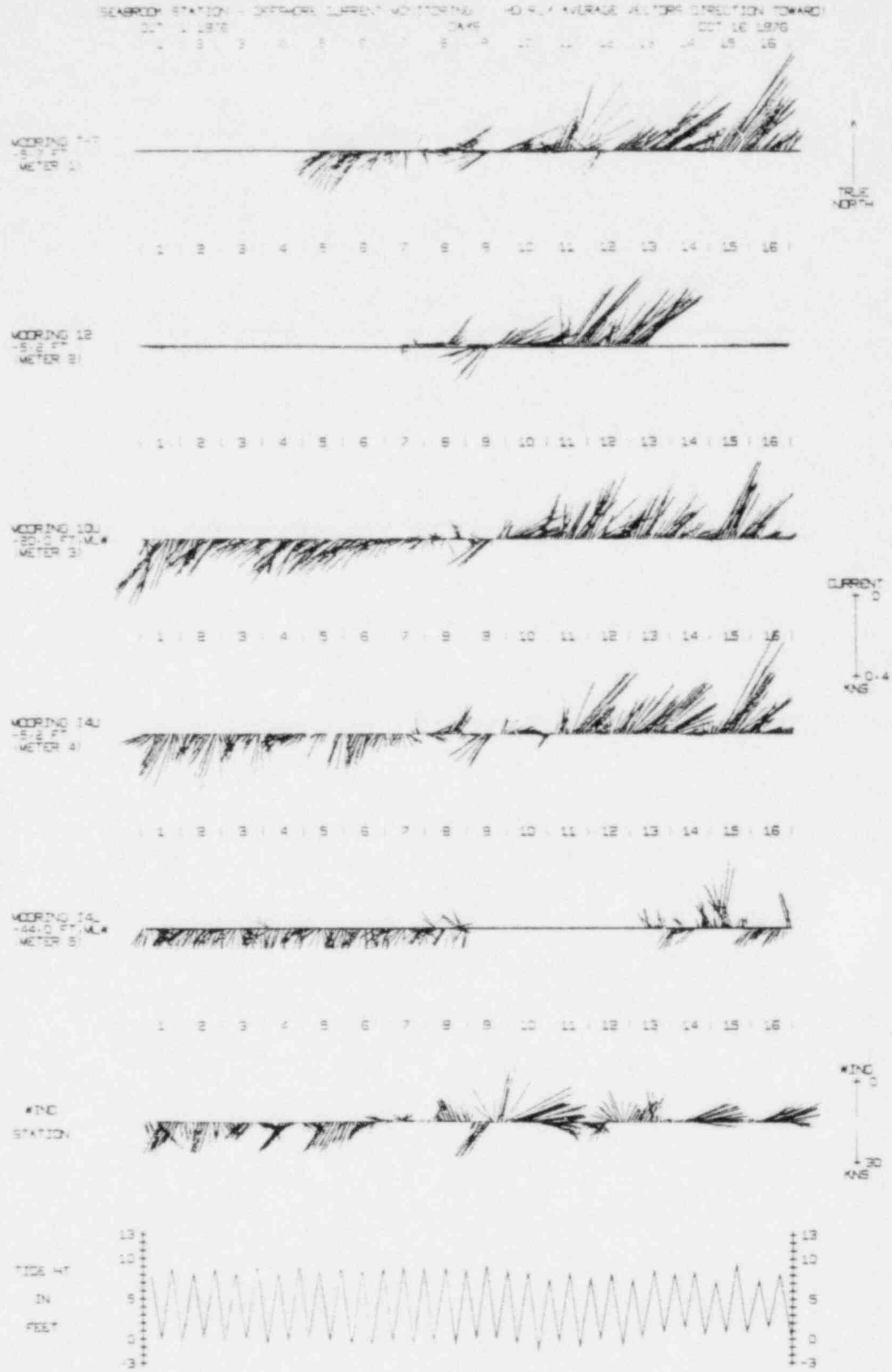

Figure 7.6-19. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for October 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

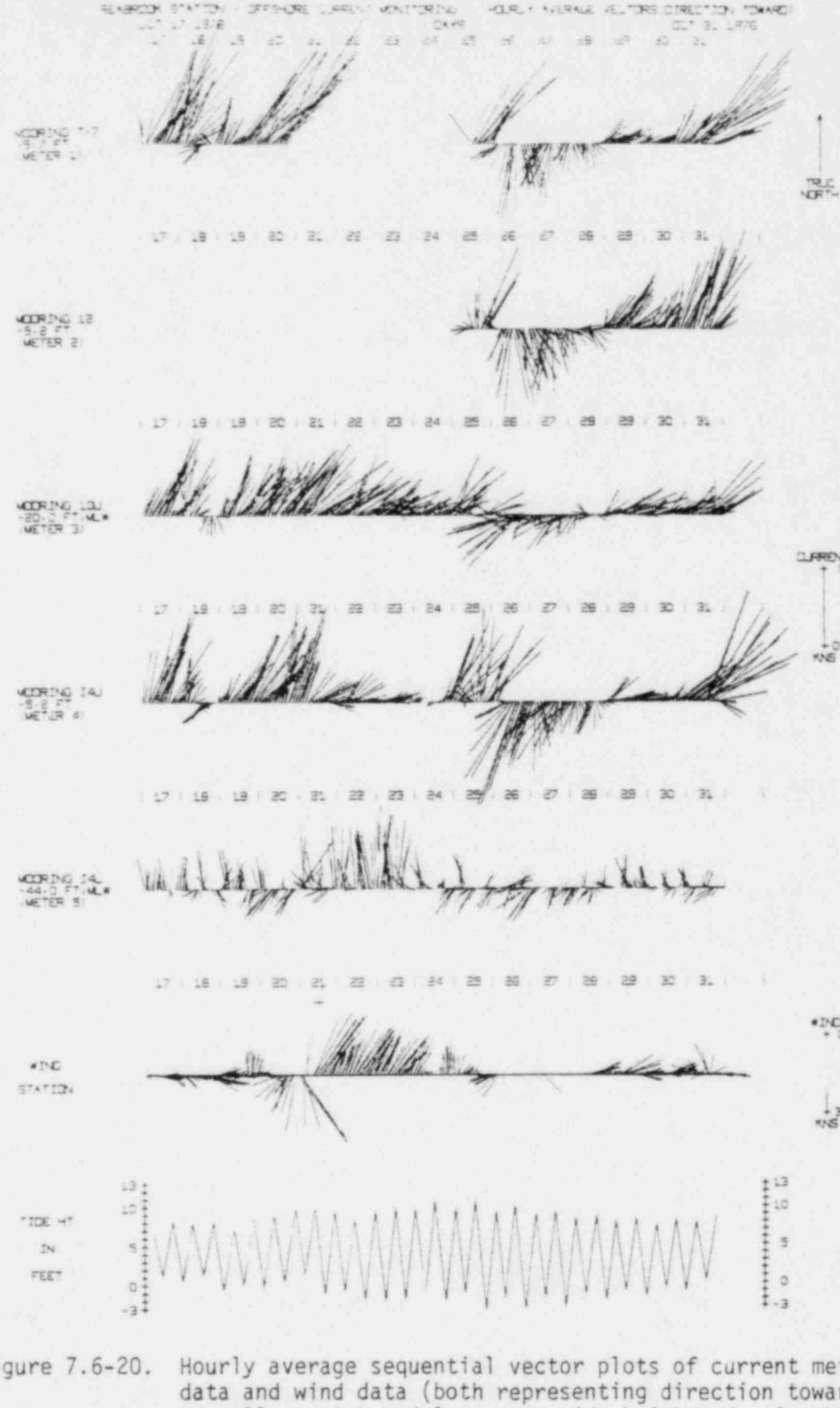

Figure 7.6-20. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for October 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

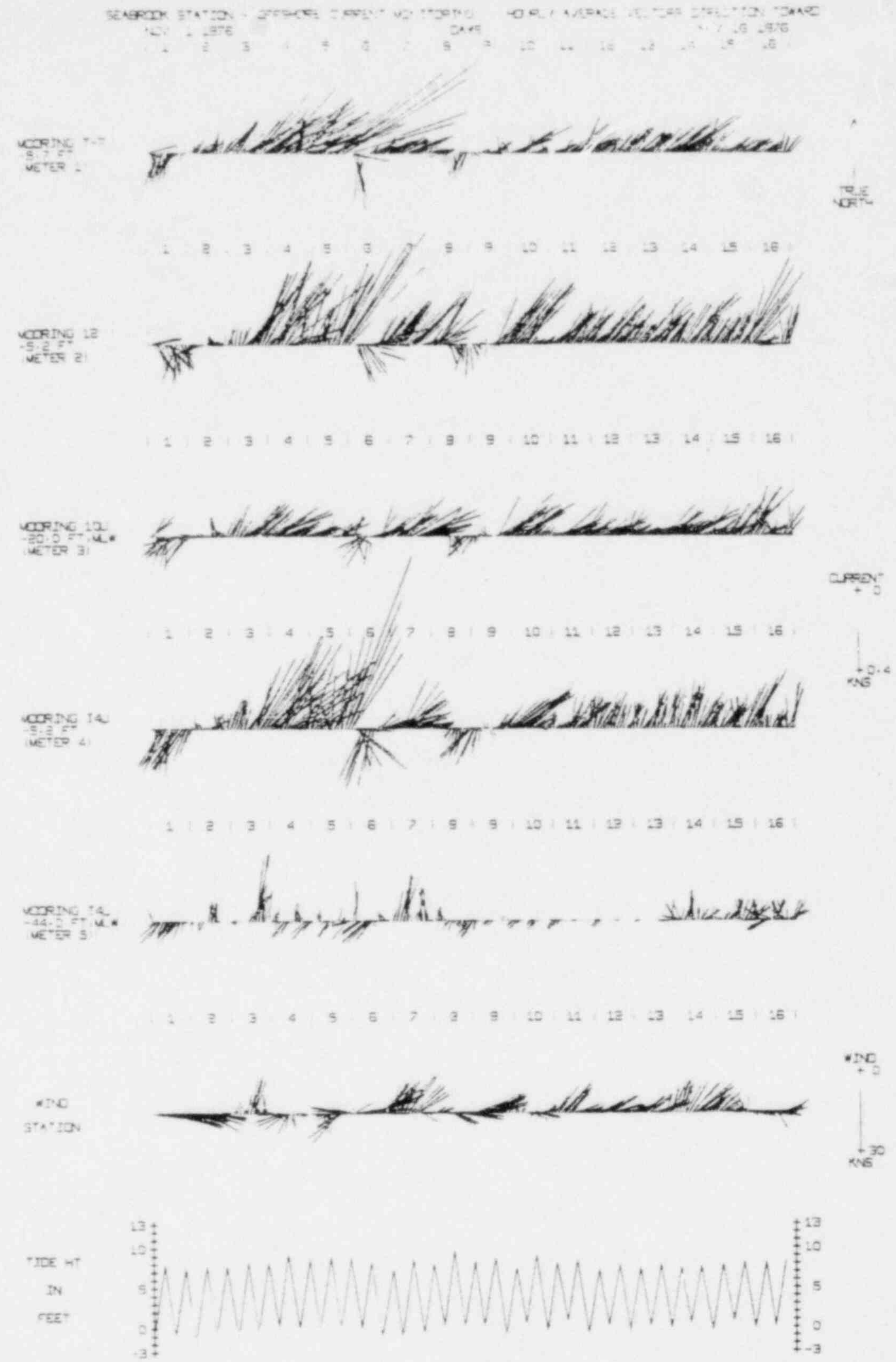

Figure 7.6-21. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for November 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

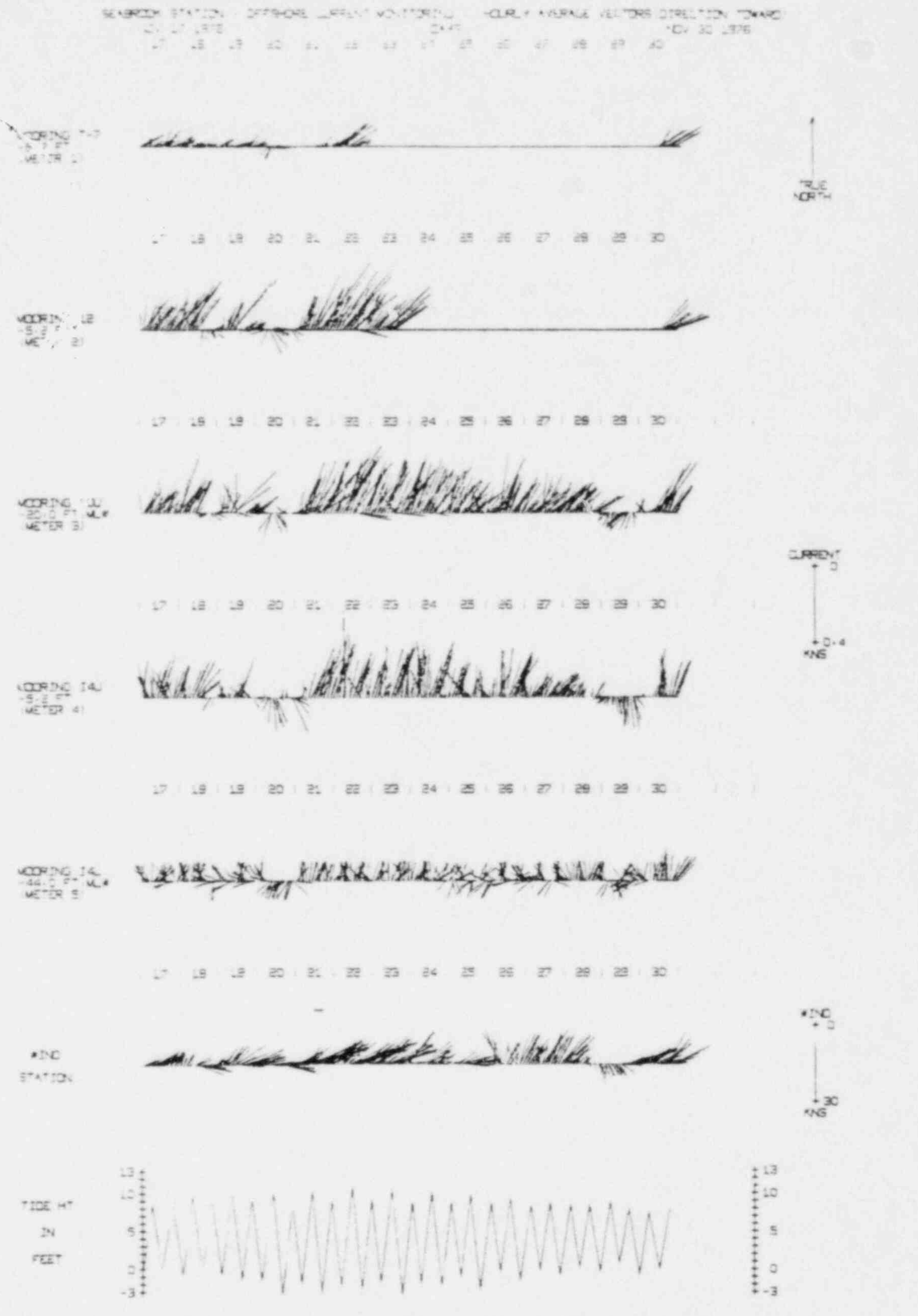

Figure 7.6-22. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for November 17 to 30, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

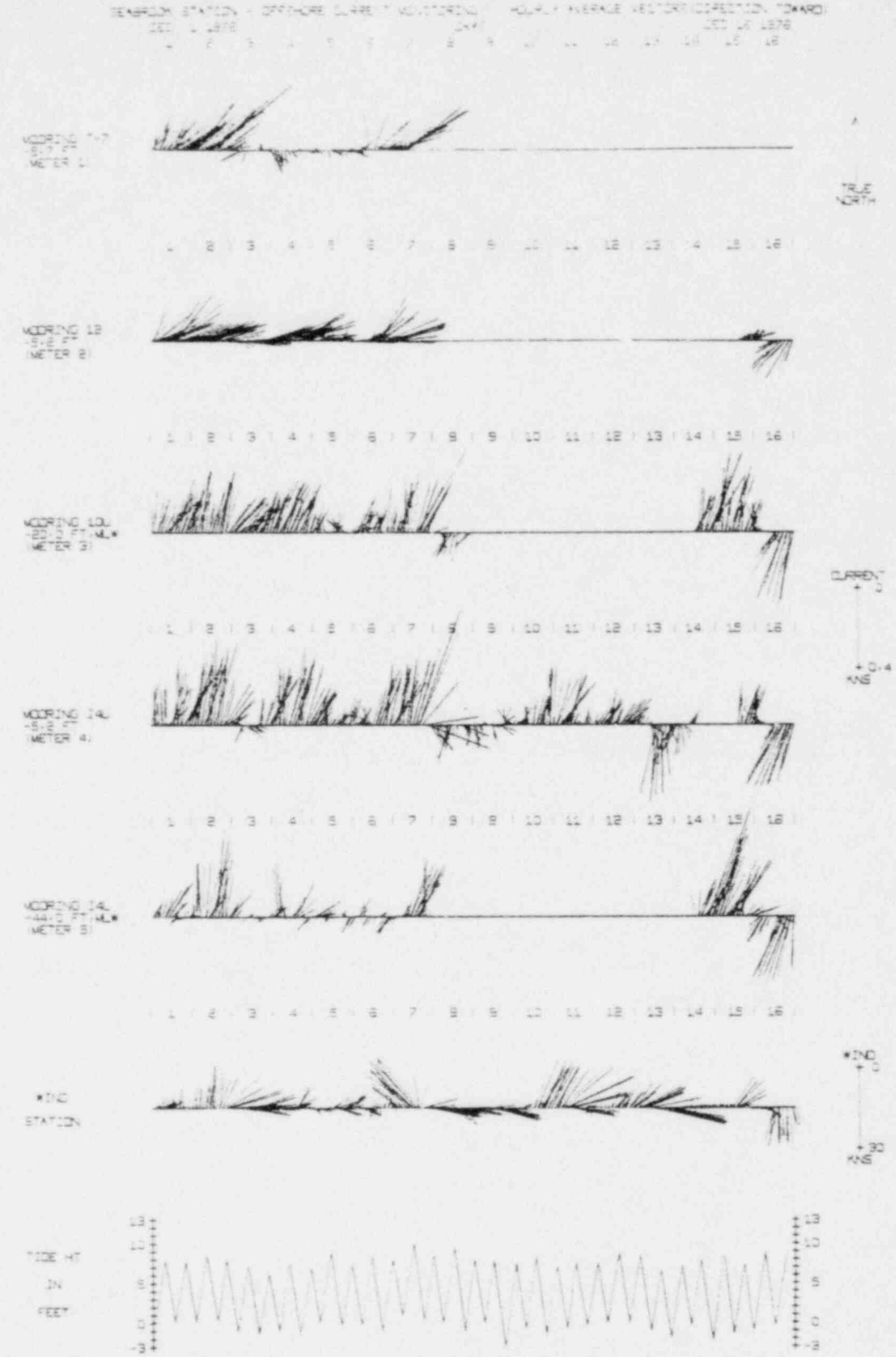

Figure 7.6-23. Hourly average seouential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for December 1 to 16, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.

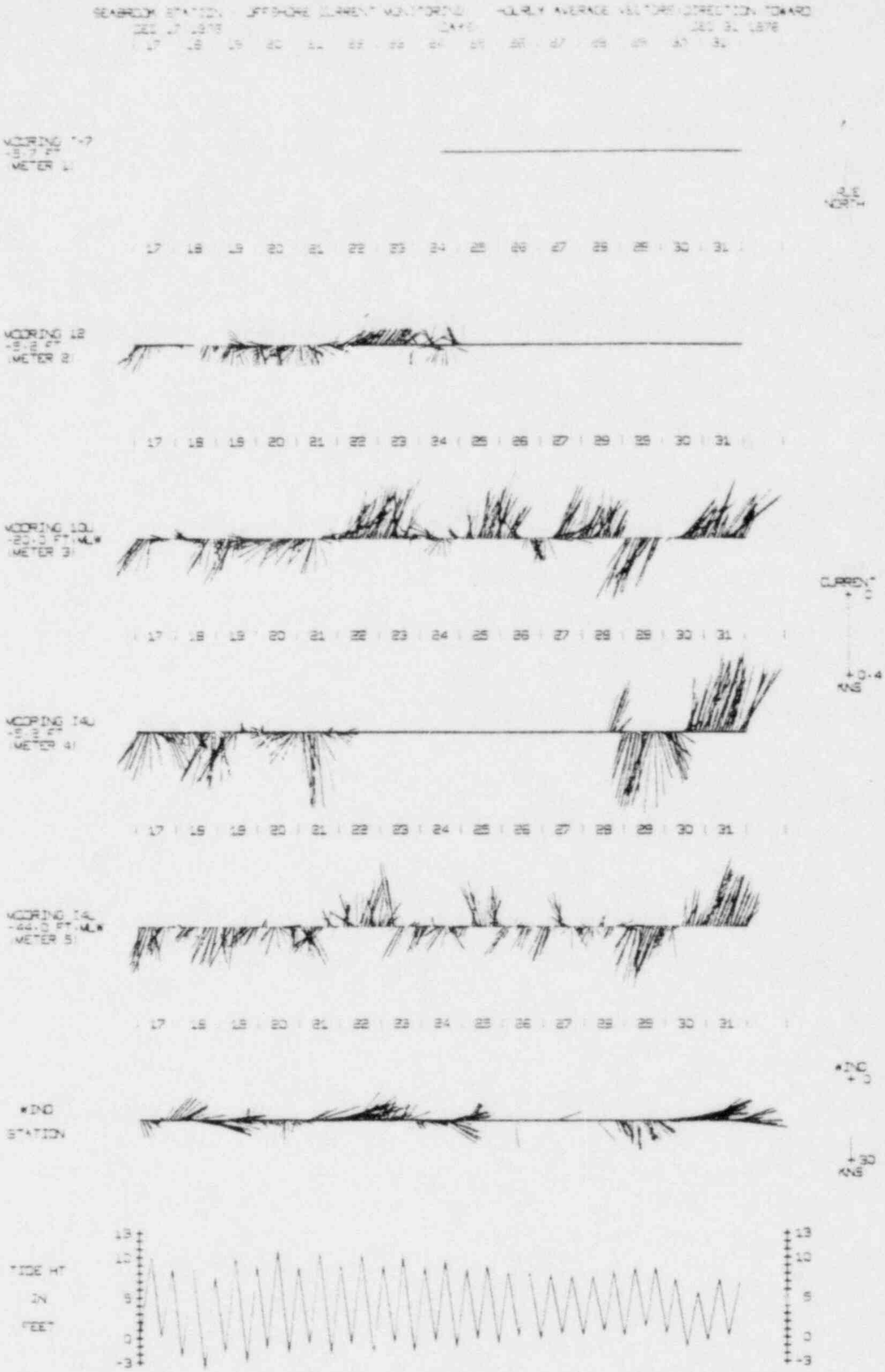

Figure 7.6-24. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for December 17 to 31, 1976. Seabrook 1976 Annual Hydrographic Report, 1979.