NOS Oceanographic Circulation
Survey Report No. 8

Chesapeake Bay Circulation Survey: 1981-1983

Rockville, MD.
August 1986

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

NOS Oceanographic Survey Report

This serious of reports presents information on circulation surveys by the National Ocean Service. Normal activity includes measurements of water flow (currents), tides, temperature, salinity, and occasionally other parameters needed for understanding the physical processes. These surveys are made primarily for the Nation's navigational waterways; however, data are also obtained to describe the circulation patterns of estuaries and harbors.

These reports offer information on sampling locations, measurement techniques, processing and analysis routine, data formats, and general information on the survey area. They do not present technical interpretations of hydrodynamics of the areas.

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No. 1 Tide and Tidal Current Observations From 1965 Through 1967 in Long Island Sound, Block Island Sound, and Tributaries. Elmo E. Long, January 1978, (PB 283-849).

No. 2 Tampa Bay Circulatory Survey 1963. Demetrio A. Dinardi, August 1978, (PB 299-163).

No. 3 Puget Sound Approaches Circulatory Survey From 1973 Through 1976. Bruce B. Parker and James T. Bruce, August 1980, (PB81 113375).

No. 4 Cook Inlet Circulatory Survey: 1973-75. Richard C. Patchen, James T. Bruce, August 1980, (PB81-245-235).

No. 5 New York Harbor Circulation Survey: 1980-81. David R. Browne and Gary Dingle, February 1983, (PB83-228-635).

No. 6 Southeast Atlantic Coast Estuaries, Sapelo Sound to St. Simons Sound, Georgia Circulation Survey: 1980. William A. Watson, January 1984, (PB86-120433).

No. 7 San Francisco Bay Area Circulation Survey: 1979-80. Joseph M. Welch, Jeffrey W. Gartner, and Stephen K. Gill, November 1985, (PB87-107181).

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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

One of the major goals of the National Ocean Service (NOS), a major element of the National Oceanic and Atmospheric Administration (NOAA), is to define the tidal circulation in the Nation's estuaries and waterways for navigation purposes. In an investigation of the historical data files at NOS, it was found that the latest circulation survey conducted in the Chesapeake Bay in 1964 was for only a small area in the Bay. The instrumentation used was outdated and the duration of observations was inadequate according to modern standards. Earlier surveys conducted in the Chesapeake Bay with even more rudimentary instrumentation and shorter observation periods took place in the 1920's and 1930's. Bathymetric changes in the Bay from natural sediment transport and dredging have changed the tidal hydrodynamics considerably since these surveys were conducted. With these considerations and in response to requests from other Federal agencies, State and local governments, and commercial and academic concerns, it was determined that the need was critical for a comprehensive circulation survey of the entire Chesapeake Bay using the vastly improved measurement technology available today. During August 1981, NOS began a 2 1/2 year circulation survey of the Chesapeake Bay from its entrance to the Susquehanna River, through the Chesapeake and Delaware Canal and into the Delaware River.

1.0 INTRODUCTION

The Chesapeake Bay, the largest estuary in the United States, has been the object of many disjointed scientific studies in the last 30 years. These efforts were inspired by the need to solve many of the natural resource, water quality, and economic problems associated with managing the Bay's multiple-use development. The complexity of the Chesapeake Bay is such that some have called it a "minor sea" in that it has its own unique internal circulation patterns, local cultural variations, a thriving water-based commerce, and a substantial tourist trade.

1.1 Background

Captain John Smith first sailed up the Chesapeake Bay in 1607 and noted "There is but one entrance by Sea into this Country, and that is at the mouth of a very goodly Bay, 18 to 20 myles broad...within is a country that may have the prerogative over the most pleasant places knowne, for the large and pleasant navigable Rivers, heaven & earth never agreed better to frame a place for man's habitation..." (Ludwigson, 1969).

While traveling along the eastern shore, Captain Smith encountered an island that was particular to his liking and named it Smith Island. This island became the home of dissident colonists in 1657 who left a colony established at St. Mary's City 23 years earlier. These watermen of Smith Island and neighboring Tangier Island remained isolated both physically and economically from mainstream America for 300 years until the Chesapeake Bay Bridge opened in 1958 linking the eastern shore with Annapolis.

The livelihood of these and other watermen is solely dependent on the oyster, blue crab, clam, striped bass and white perch crops of the Chesapeake Bay. The Maryland Department of Natural Resources reports that in 1880 the Bay yielded an oyster crop of

58,000 tons; in 1967 the annual crop was reduced to 13,000 tons. Present levels are reported to be between 6,000 and 9,000 tons. Conservation measures and regulations have been introduced and new and unusual ways to apprehend oyster and crab poachers have been used to protect the industry. Pollution from industry and increased population loading in Bay communities has posed a much more dangerous threat to the oyster, crab, and fish industry. Pollution has caused an annual fishery loss of 3 million dollars in dockside value. Several oyster bed areas in both Maryland and Virginia have been completely closed due to pollution.

Understanding the circulation patterns first described by Dr. Donald Pritchard (1955) for different locations in the Bay, i.e., three layered flow in Baltimore Harbor and cyclical two layered flow in shallower tributaries, is of vital interest to scientists and other conservation interests concerned about saving the oyster, crab and fish industry. This is but one of the reasons prompting the National Ocean Service to conduct a circulation survey in the Chesapeake Bay.

1.2 Physical Setting

The Chesapeake Bay drains expanses of six states: New York, Pennsylvania, Maryland, Virginia, West Virginia and Delaware (figure 1). The Susquehanna River accounts for over 50 percent of all fresh water entering the Bay. The Potomac and James Rivers account for 18 percent and 14 percent of fresh water inflow, respectively, while the Rappahannock and York Rivers only account for a combined 6 percent. The remaining 11 percent of fresh water inflow comes from the tributaries of the eastern shore.

The Bay is 156 nautical miles long and 25.6 nautical miles wide at its widest expanse. The Bay encompasses 2.84 million acres (11.5 billion square meters) of surface area with a volume

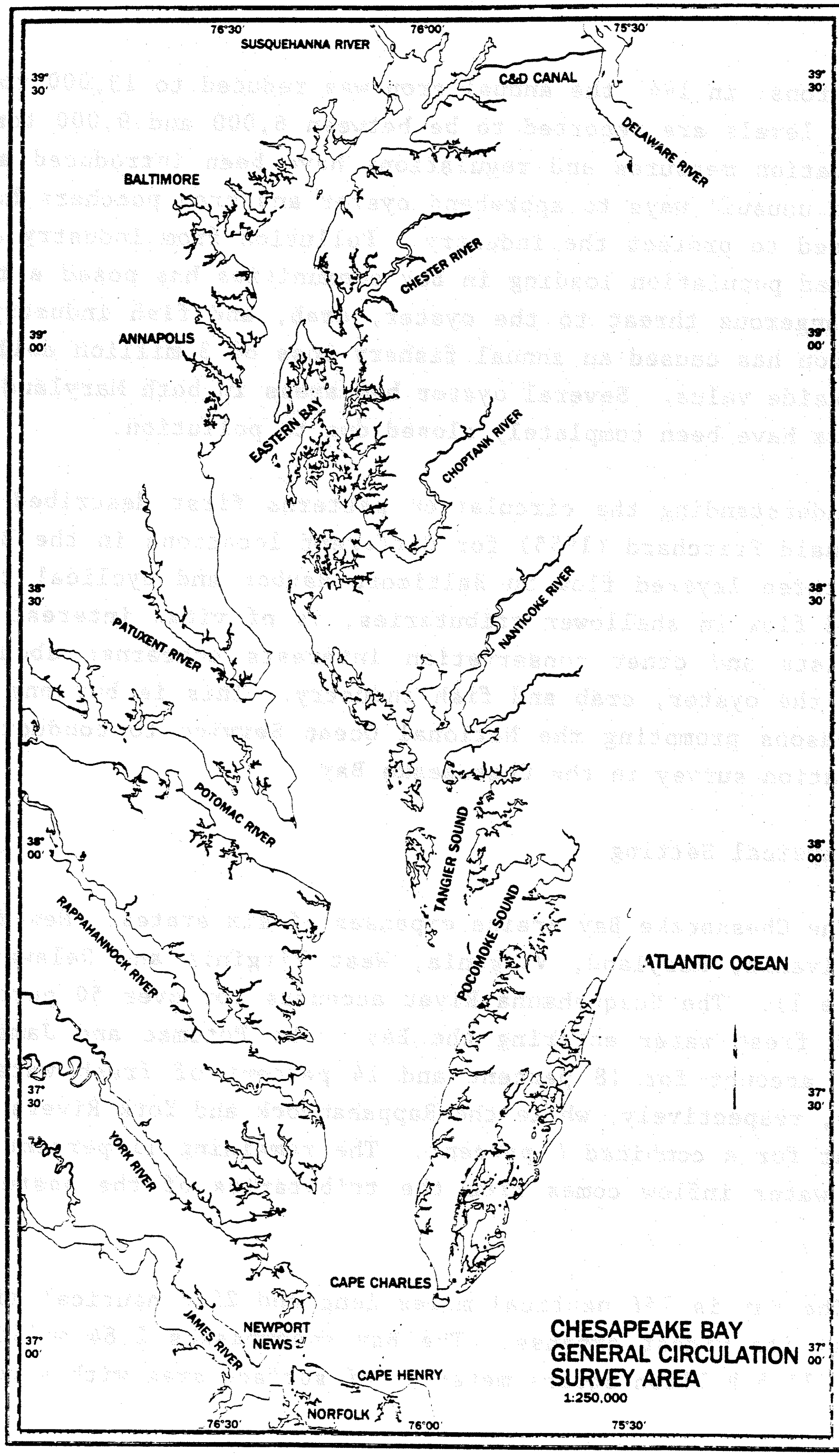

Figure 1. General Area of Chesapeake Bay Circulation Survey

of 96.8 billion cubic yards (74 billion cubic meters) of water. The average depth is approximately 27 feet (8 meters) with occasional deep channels of 175 feet (53 meters) (Hargis, 1981).

2.0 NOS CIRCULATION SURVEY

One of the major goals of the National Ocean Service (NOS), a major component of the National Oceanic and Atmospheric Administration (NOAA), is to define the tidal circulation in the Nation's estuaries and waterways for navigation purposes. NOS began a 2 1/2 year circulation survey of the Chesapeake Bay in August 1981 from its entrance to the Susquehanna River, through the Chesapeake and Delaware Canal and into the Delaware River, to respond to user needs and requests from other Federal agencies, State and local governments, and commercial and academic concerns.

2.1 Planning

A circulation survey of an estuary involves the measurement of parameters that describe or cause the water movement within the estuary. The data collected include tides, currents, water conductivity, water temperature, and meteorological parameters. In planning a survey, the object is to cover the time and spatial scales necessary for defining the tide and tidal current regime as thoroughly as available resources will allow. Current, meteorologic, conductivity/temperature/depth (CTD), and tide station locations are chosen from:

1. previous experience in the effect of physical boundaries and bathymetry on local circulation;

2. literature search on the findings of previous investigations of the survey area;

3. knowledge of circulation patterns obtained from local pilots and fishermen;

4. studying the historical data collected in that area; and

5. the special needs of supporting agencies and scientific concerns expressed at formal and informal NOS briefings.

The Chesapeake Bay circulation survey was divided into three phases representing the 3 years of operations. Planning activities for each phase included an initial field plan from the Rockville office, a presentation of this plan in briefings before representatives of Federal and State agencies, academic institutions, industry and the private sector, and a final field reconnaissance of the survey area. All phases of the program involved only the Bay proper, none of the tributaries were surveyed.

The briefing held for Phase I of the survey was attended by over 80 individuals. As a result of that briefing, a working group of 11 members (two NOAA representatives and nine extra NOAA individuals) was formed; these were in addition to the project team members. This working group provided input to NOS regarding the scientific interests of the various organizations and actual support of the program.

A result of NOS' desire to respond to the needs of outside interests was the decision on the area to be covered during Phase I of the Chesapeake Bay circulation survey. Phase I of the survey took place during August to December 1981 and was conducted between a line from Cedar Point to the Nanticoke River on the north, and a line between Smith Point and Pocomoke Sound on the south. Normally, NOS begins a survey at the entrance to an estuary and works up to the head of the estuary. However, in this case beginning the program in the middle of the Bay effected a coordinated effort with the U.S. Geological Survey (USGS) which was conducting a multiyear program in the Potomac River. NOS occupied stations in the Bay proper near the mouth of the River to supplement data collected by USGS.

Phase II of the survey was conducted from April to December 1982 covering the area between the entrance of the Chesapeake Bay northward to the Smith Point - Pocomoke Sound border. Final station locations for this area were determined after an informal meeting with the working group and a field reconnaissance by personnel from the Rockville office.

The preliminary plan for the Phase III portion of the Chesapeake Bay circulation survey was explained and comments were invited from attendees of a briefing held at the World Trade Center in Baltimore's Inner Harbor on September 13, 1982. In particular, comments and suggestions offered by the President of the Association of Maryland Pilots were invaluable in placing of a number of current stations in the northern portion of the Bay. A representative from the Maryland Department of Natural Resources (DNR) was very much interested in a proposed dumping site off Kent Island for spoils dredged from the Baltimore Harbor; there was a strong need for knowledge of the circulation there. Through a cooperative agreement with DNR, NOS agreed to upgrade a proposed 30-day current station site off Kent Island to a long-term (1 year) current station to be deployed in November 1982.

Phase III of the survey was conducted from April 1983 to December 1983 covering the area from the Cedar Point - Nanticoke River entrance boundary to the northern extent of the Bay, including Port Deposit and the Chesapeake and Delaware Canal.

2.2 Field Support

The NOAA ship FERREL was assigned the task of performing the field operations. The FERREL is a 349-gross ton, 133-foot

(40.54 m) vessel, with a 32-foot (9.75 m) beam, and draws a maximum of 7 feet (2.13 m). The FERREL carries 5 NOAA Corps Officers and 14 wage marine crew.

Current, meteorological and CTD instrumentation were calibrated before and after each phase of the survey by the NOS Test and Evaluation Laboratory at the Washington Navy Yard. The exception to this was the final calibration of instrumentation after Phase III of the survey performed by Wyle Laboratories. All calibration was done according to the procedures outlined in "Calibration Program Operation Manual For East Coast Circulatory Survey Instrumentation" by EG&G Washington Analytical Services Center, Inc.

2.3 Cooperative Agreements

In addition to the field effort conducted by the FERREL, there were four long-term current meter stations that were occupied continuously, even through the winter months. Station 40 located in the entrance to the Bay was deployed in September 1981. Station 65 located in the Wolf Trap area was deployed in December 1981. Station 36 located in mid-Bay off the mouth of the Patuxent River was deployed in September 1981. Station 121 located in the trench off Kent Island was deployed in November 1982 These stations were maintained through the winter months and, during periods when the FERREL was unavailable, by cooperative efforts with the Atlantic Marine Center, NOS, and Old Dominion University for station 40, with the Virginia Institute of Marine Science for station 65, and with the Maryland Department of Natural Resources for stations 36 and 121 (figure 5).

2.4 Survey Statistics

During the project, current meter and CTD data were collected at 132 locations (figures 5, 6, 7, 8 and 9). Tide data were collected at 9 control stations and 36 subordinate stations (figures 10, 11, 12, and 13). Meteorological data were collected at two locations during each season (figures 10, 11, and 12). Tables listing all data files for each location and times of occupation are included in this report. The final Chesapeake Bay data set consists of 685 current data files, 31 meteorological data files, 844 conductivity, temperature and depth data files, and tide data from 45 locations in the Bay.

The NOS Delaware River and Bay circulation survey carried out in 1984 and 1985 reoccupied two current stations and two tide stations in the C&D Canal, as well as two current stations in the Elk River. Details about the data from these occupations can be found in Klavans, et al (1986).

3.0 CURRENT DATA

3.1 Measurement Instrumentation

The current meters used were Grundy Model 9021-G current meters which recorded on a 3-inch diameter, 1/4-inch wide magnetic tape in 10-bit binary code. The meter serial number, current direction, current speed, temperature, sample count or time in hours and minutes, conductivity, and for some meters, pressure are recorded. The instrument is rated for 2000-meter depth service (figures 2 and 3 and table 1).

The speed sensor is a Roberts-type rotor which is oriented into the current by a relatively large tail fin. The speed is measured by the number of rotations of the rotor averaged over a 10-minute sampling period. Current direction is measured instantaneously at the end of the rotor count by comparing direction with that of magnetic north from a gimballed magnetic compass. The temperature transducer is a platinum resistance thermometer exposed to the water. The conductivity sensor is a transformer for which the outside water acts as a coupling link. The depth sensor is a bulk silicon bridge transducer with temperature compensation. A continuously running crystal oscillator ensures that the programming of sensors, sampling interval, and tape motor speed are consistent throughout the deployment. The battery is a 12V DC sealed lead storage battery.

The mooring, depicted in figure 4, is a taut-wire mooring system designed to support one to three meters on the cable. The major components are an umbilical line to a surface buoy, the subsurface buoy, a pinger, and the main cable and anchor system. The meters are attached to asymmetrical A-frames which are attached inline to the mooring cable. The meters are situated on the cable such that the surface meter is 15 feet (4.6 meters) below mean low water and the bottom meter is generally 5 feet (1.5 meters) above the bottom (Browne and Dingle, 1983).

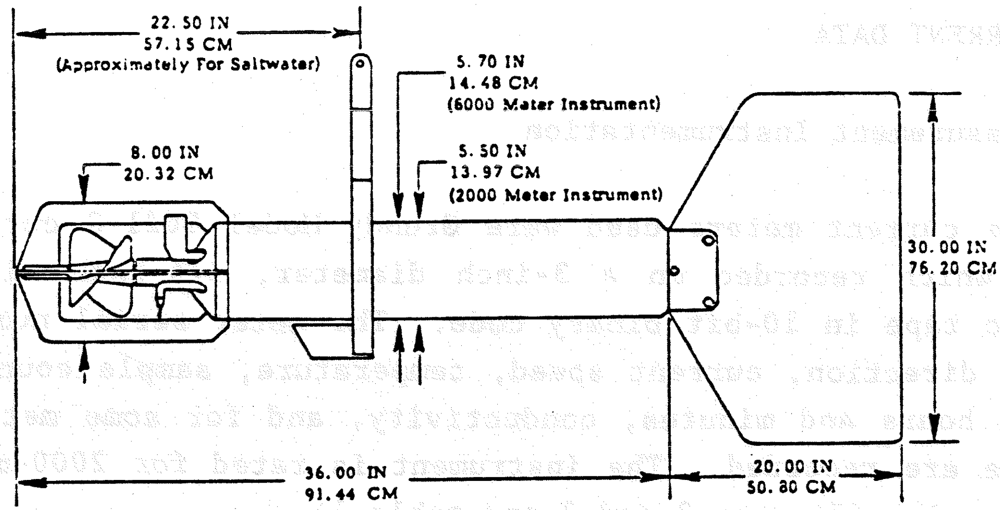

Figure 2. Grundy 9021 G Current Meter Dimensions

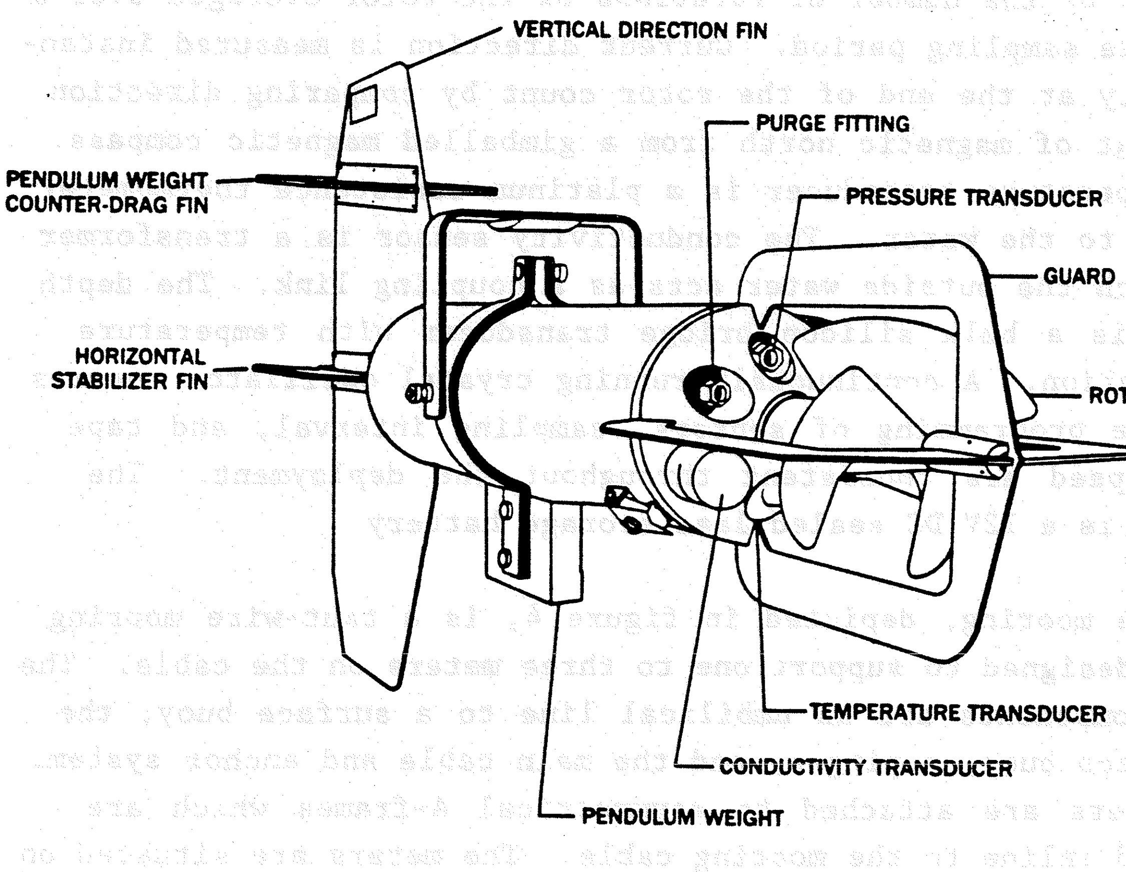

Figure 3. Grundy 9021 G Current Meter

Table 1. Manufacturer's Specifications for the Grundy 9021 G Current Meter (Plessy Environmental Systems Corp., 1977)

Current Speed Sensor

Speed Range: 2.5 to 500 cm/sec (approximately 0.05 to 10 knots)
Starting Velocity: 1.5 cm/sec
Accuracy: ±2 cm/sec or 2%, whichever is greater

Current Direction Sensor

Type: Vane
Magnetic direction: 0° to 360° continuous
Minimum movement velocity: Less than 30 mm/sec
Compass resolution: ±1°
Compass precision: ±3°
Allowable Pitch & Roll: ±30° from horizontal

cm) Recording System
Type: ¼ inch magnetic tape
cm) Format: Digital, serial form
Storage capacity: 70,000 words (or 10,000 seven word samples)
Resolution: 0.1%
Drive: Brushless stepper motor

Timing Mechanism

Type: Solid state clock
m; Timing interval: Programmable 0.5 to 75 minutes
Precision: Better than ±2 sec/day from -5°C to +40°C

Sampling

Parameters to be measured: 6 data channels plus identification number
Measuring speed: 0.6 sec per line. measurement
Rate: Continuous or preset by timing mechanism for 0.8 to 120 samples per hour (sample intervals 0.5 to 75 min.)

Magnetic Tape

Standard ¼ in magnetic tape on a 3 inch spool can be used. To obtain the data storage capacity of 70,000 words, 600 ft of triple-play tape is necessary.

Dimensions

Diameter: 5.5 in (14 cm) for 2000 m depth capability; 5.7 in (15 cm) for 6000 m
Width: 8 in (20 cm)
Height: (instrument and fin): 24 in (61 cm)
Length (instrument and fin): 56 in. (142 cm)
Height overall (including suspension frame): 96 in (244
Length overall (including suspension frame): 76 in (193

Weight

Instrument
In air: 51 lb (23 Kg) for 2000 m; 56 lb (25 Kg) for 6000 m
Instrument (including suspension frame)
In air: 75 lb (34 Kg) for 2000
90 lb (41 Kg) for 6000 m from
In water: 46 lb (21 Kg) for 2000 m; 60 lb (28 Kg) for 6000 m

Suspension System

Mounting: In-line splice or clamp on.
Gimbal: Active ball bearing, low torque gimbal not subjected to tensile stress from mooring
Tilt (maximum): Independent of mooring line angle up to 30° from vertical.
Material: 316 stainless steel
Tensile strength: 9000 lbs (4100 Kg)

Sample count: optional
Sample interval in minutes:
$\frac{N \times T}{8}$, where
N=number of parameters
T=number of days to record-not to exceed 180

Telemetering System

Type: Acoustic
Frequency: 32,768 Hz (nominal)
Telemetering speed: 0.6 sec per measurement
Range: Approximately 800 m depending on conditions

Electronics

Circuits: All solid state
Power: 12v sealed, lead-acid battery; rechargeable with Model 8021 charger

Operating Environonements

Medium: Saline or fresh water
Operating temperature range: -5°C to +40°C
Storage temperature range: -30°C to +40°C
Maximum operating depth: 2000m (6000 m optional)
Maximum pressure: 3000 psi (9000 psi optional)

(for spliced mounting)

Optional Measurands

Temperature
Range: -2° to 35°C
Precision: ±0.1°C
Response time: 15 sec for 99% response
Conductivity
Range: 0 to 60 mmho/cm (other ranges available on special order)
Precision: ±0.12 mmho/cm
Response time: 4 sec
Depth/Pressure
Precision: ±0.5% of full scale
Response time: 10 m sec

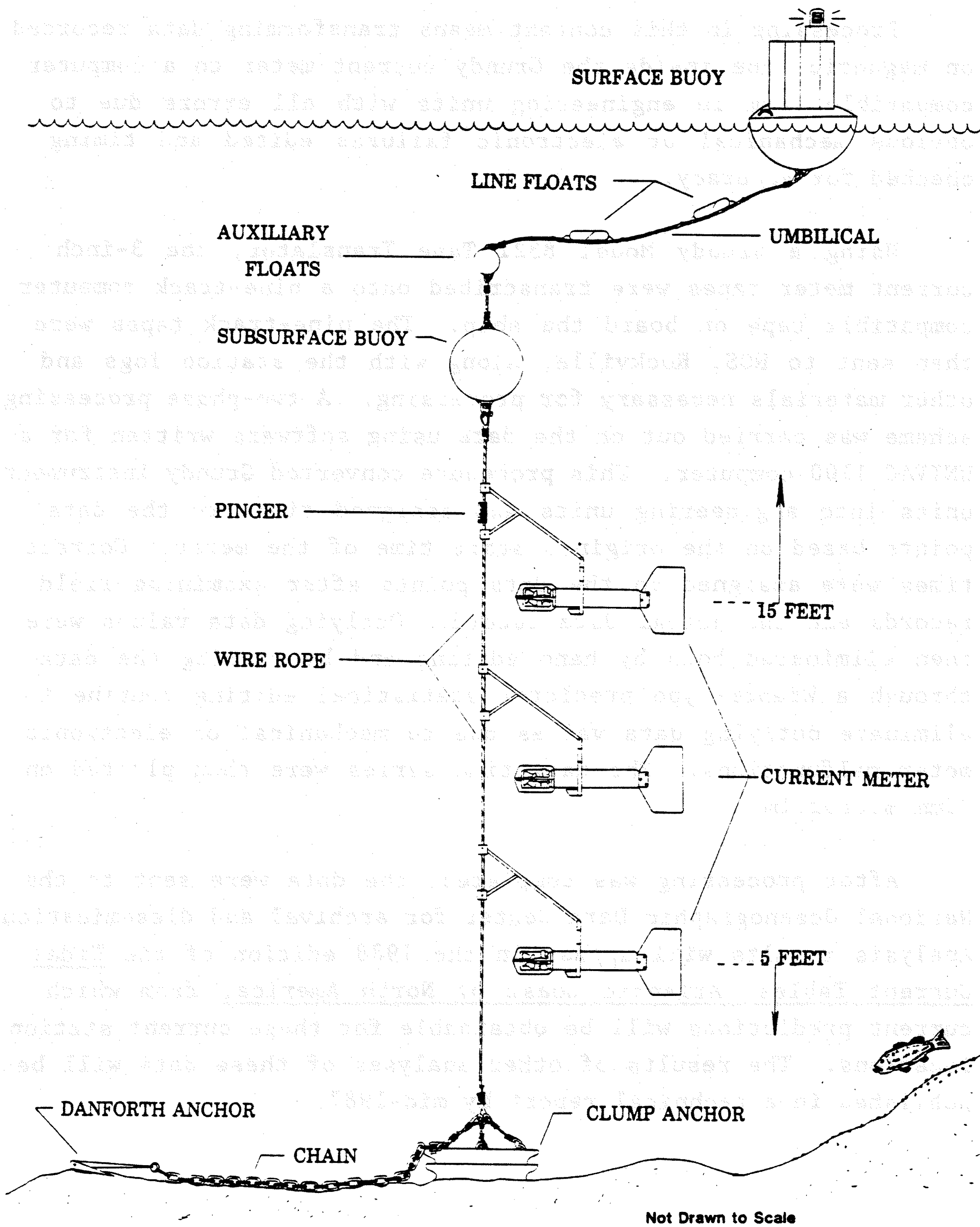

Figure 4. Current Meter Taut-Wire Mooring System

3.2 Processing Procedures

Processing in this context means transforming data recorded on magnetic tape inside the Grundy current meter to a computer compatible form in engineering units with all errors due to obvious mechanical or electronic failures edited and timing checked for accuracy.

Using a Grundy Model 8321 Tape Translator, the 3-inch current meter tapes were transcribed onto a nine-track computer compatible tape on board the ship. The nine-track tapes were then sent to NOS, Rockville, along with the station logs and other materials necessary for processing. A two-phase processing scheme was carried out on the data using software written for a UNIVAC 1100 computer. This procedure converted Grundy instrument units into engineering units and assigned times to the data points based on the original start time of the meter. Correct times were assigned to the data points after examining field records and the actual data record. Outlying data values were then eliminated both by hand editing and by running the data through a Wiener-type predictor statistical editing routine to eliminate outlying data values due to mechanical or electronic meter malfunctions. The data time series were then plotted on 35mm microfilm.

After processing was completed, the data were sent to the National Oceanographic Data Center for archival and dissemination. Analysis results will appear in the 1988 edition of the Tidal Current Tables, Atlantic Coast of North America, from which current predictions will be obtainable for these current station locations. The results of other analyses of these data will be published in a technical report by mid-1987.

3.3 Current Stations

The locations of current stations deployed in all three phases of the Chesapeake Bay survey are shown in figures 5 through 9. Long-term current stations deployed throughout the survey are depicted in figure 5. Phase I current station locations are depicted in figure 7. Phase II current station locations are depicted in figure 6. Phase III current station locations are depicted in figures 8 and 9. Information on each station, latitude, longitude, meter depth, station depth, and duration of observations is given in table 2. Scheduling for all phases of the survey was based of the desire for simultaneous observations within the constraints of field logistics.

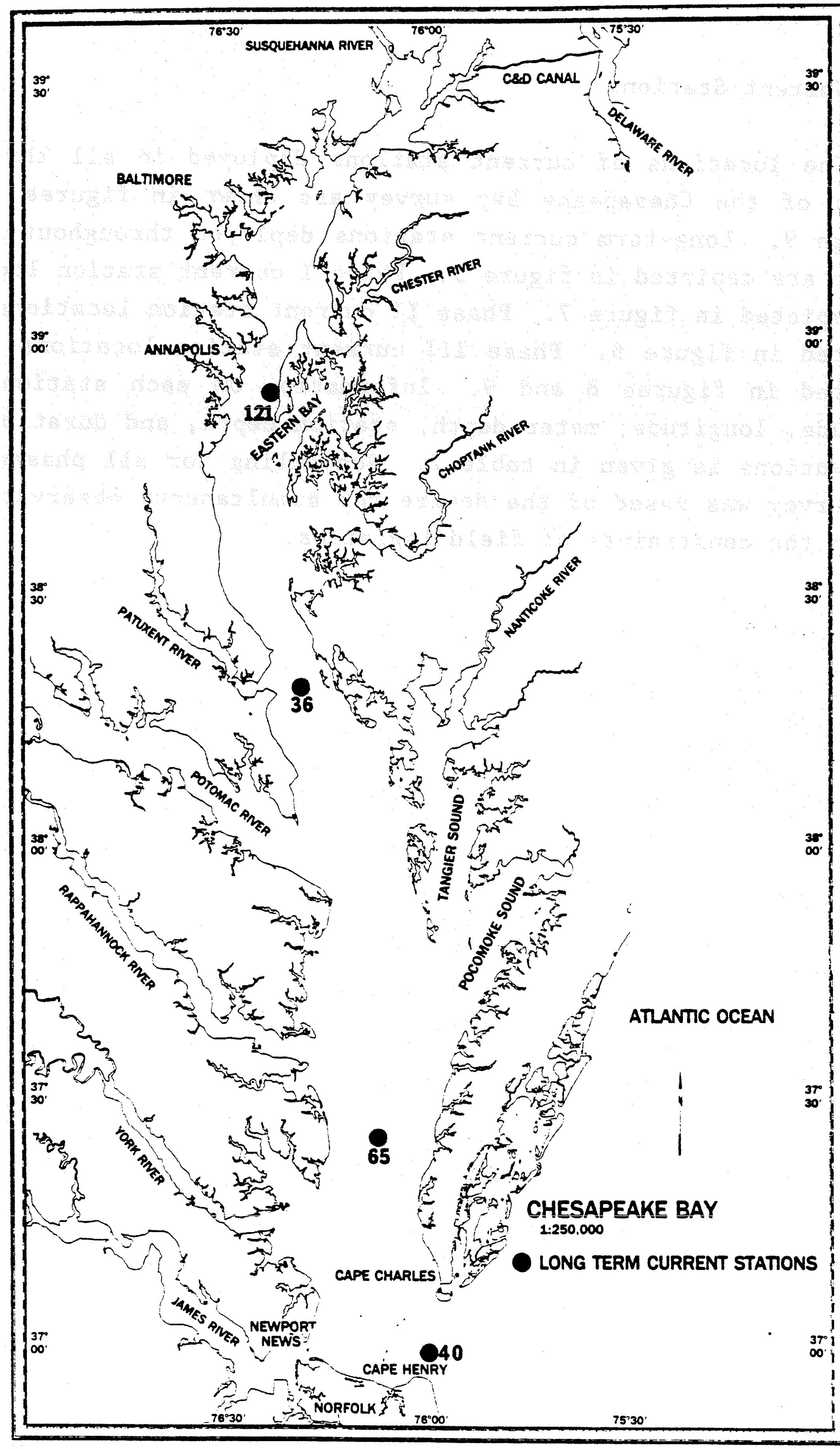

Figure 5. Long Term Current Stations

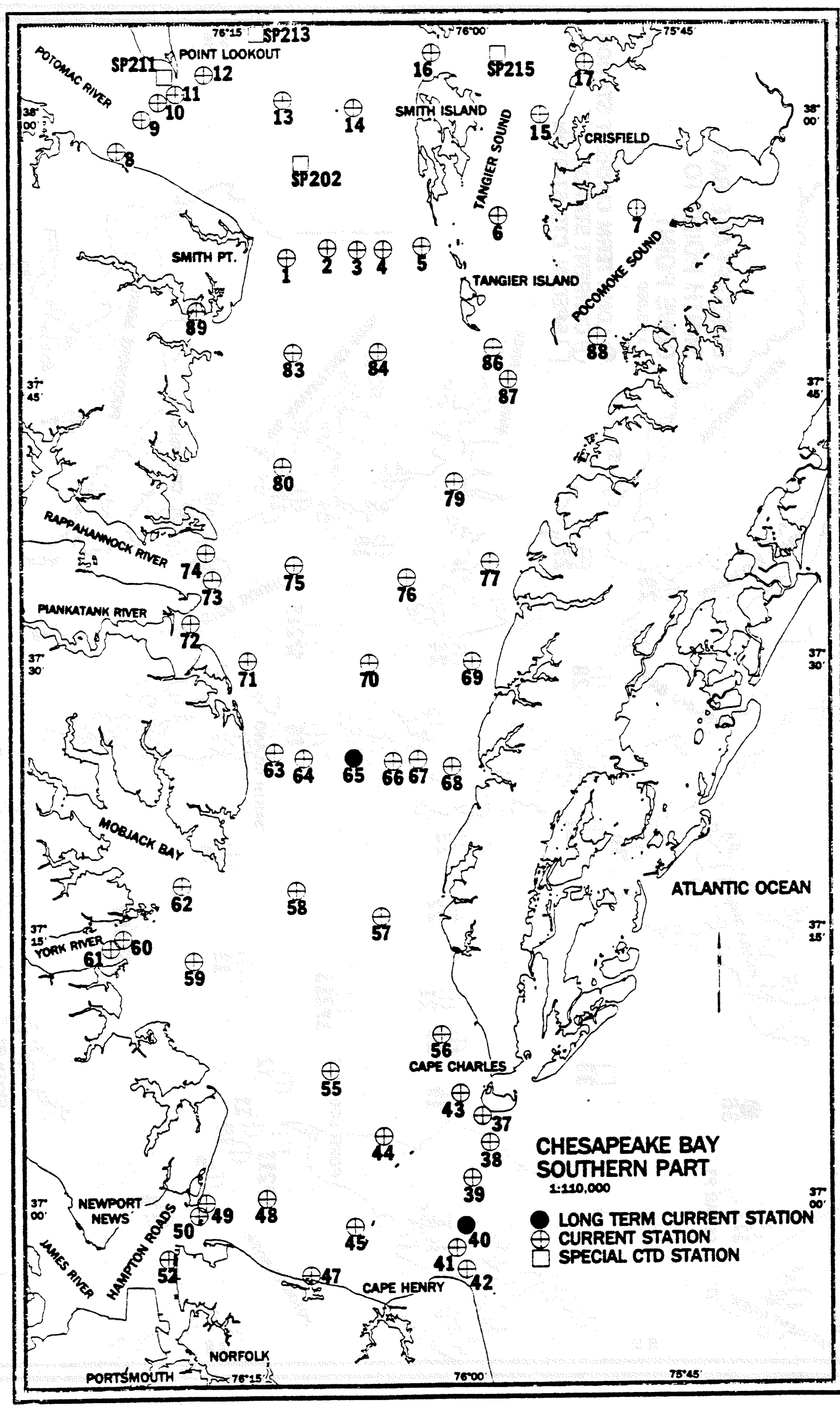

Figure 6. Current and CTD Stations - Phase II Area

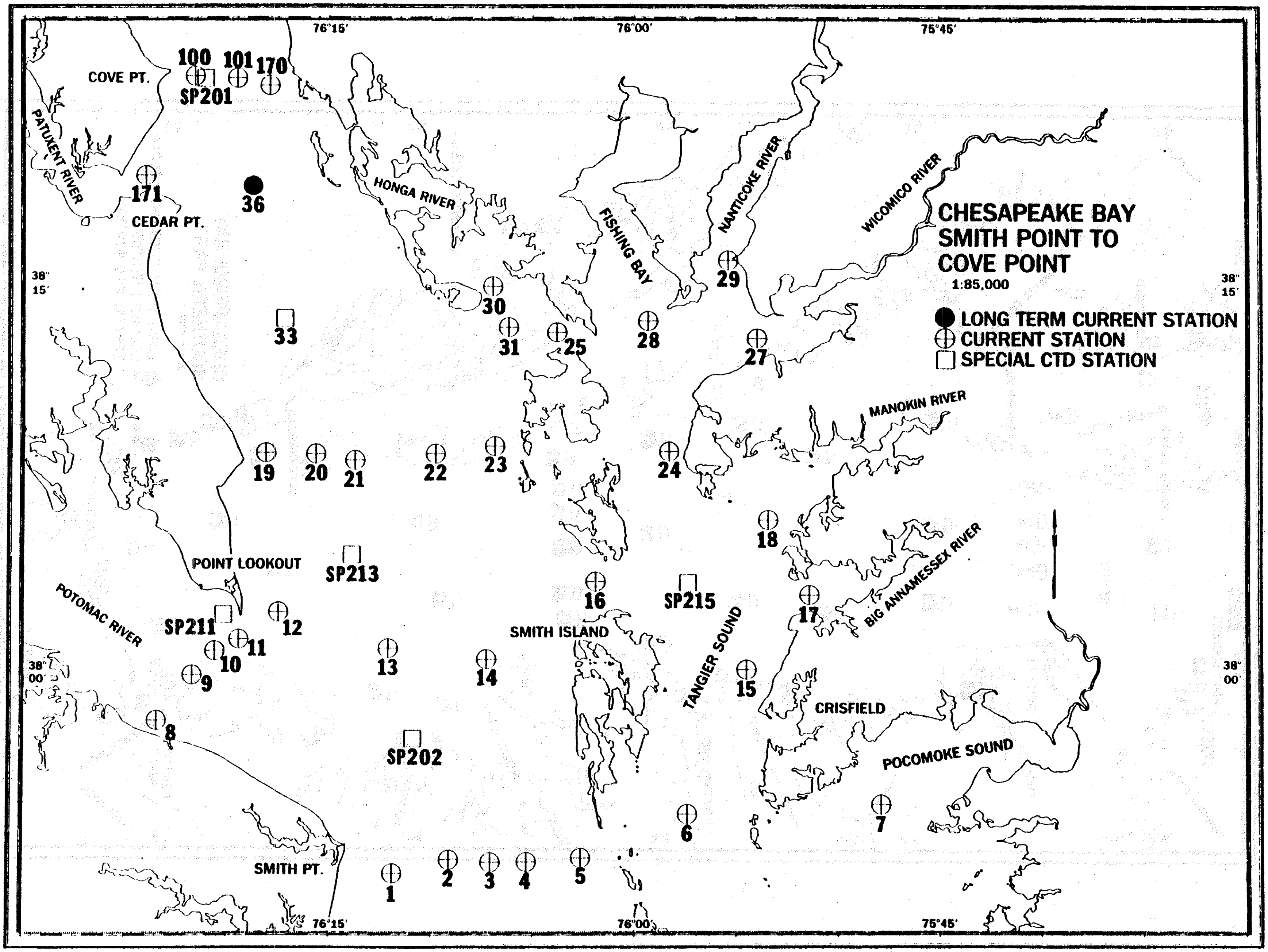

Figure 7. Current and CTD Stations - Phase I Area

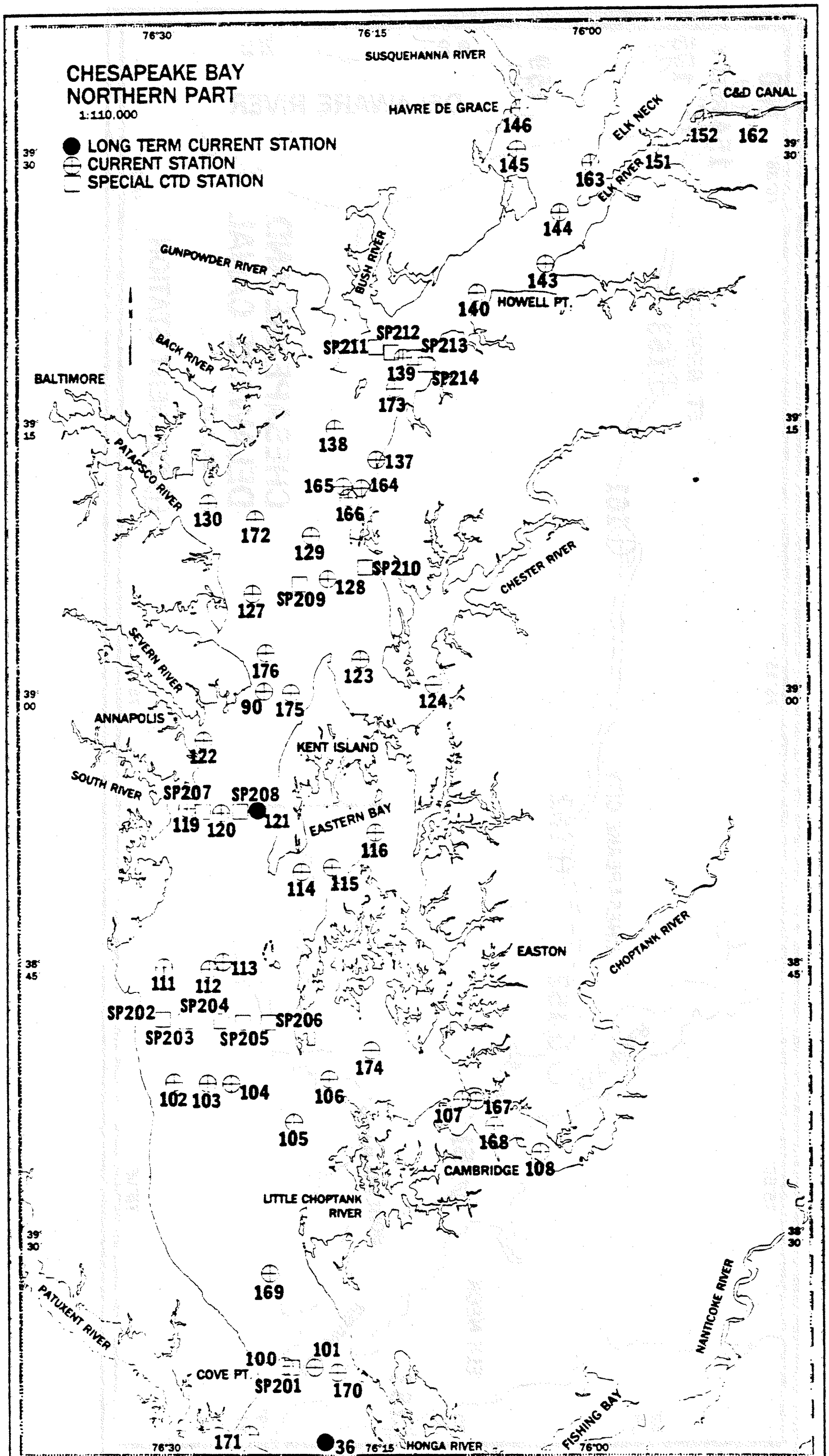

Figure 8. Current and CTD Stations - Phase III Area

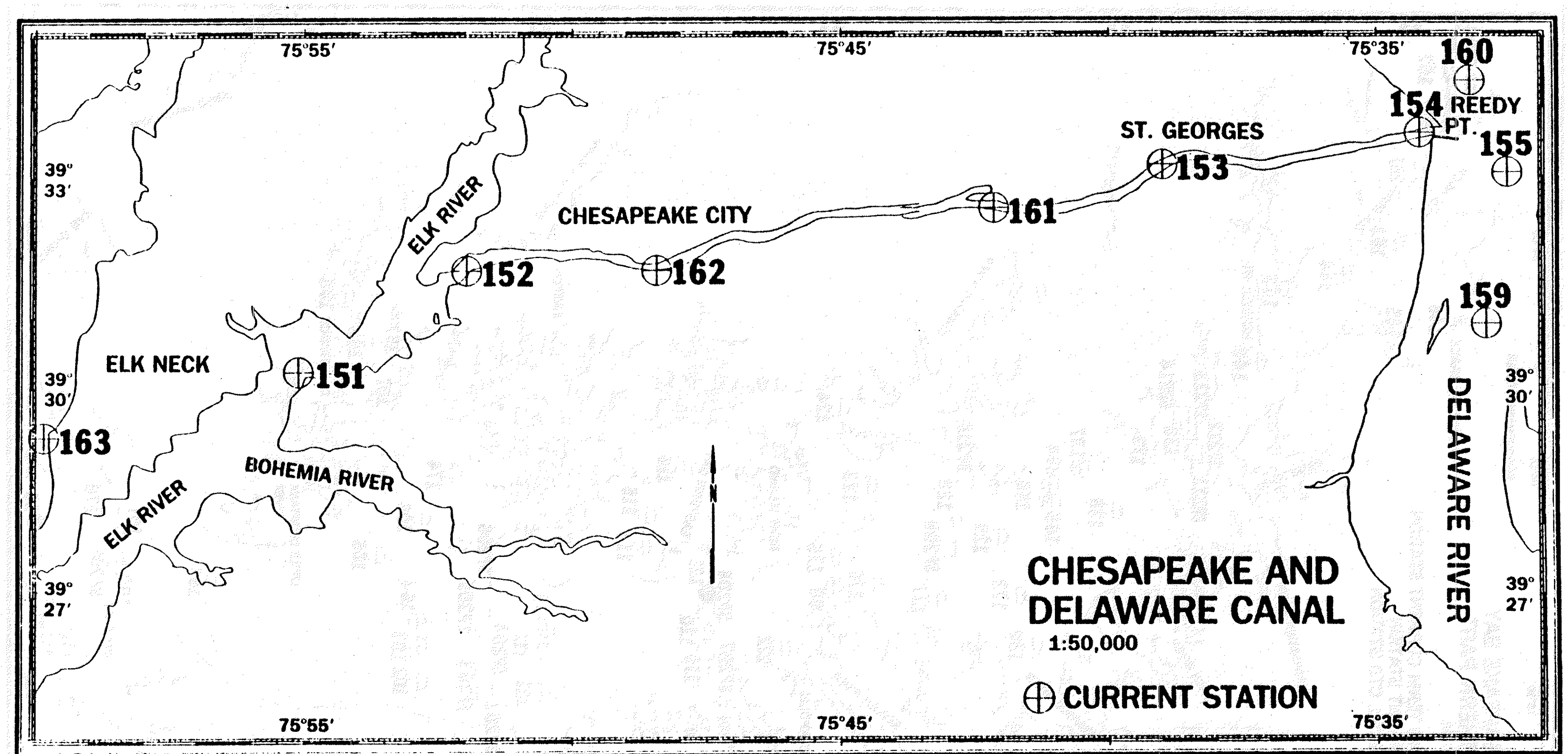

Figure 9. Current and CTD Stations - Phase III Area - Continued

Table 2. INDEX OF CURRENT METER STATIONS

Sta. No.	Location Lat (N)	Location Long (W)	Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
1	37 52.23	76 11.90	11.5	5.0	09/09/81	09/24/81	15
2T	37 52.75	76 09.12	73.0	58.0	09/09/81	09/24/81	13
2T	"	"	73.7	58.0	09/22/81	10/13/81	21
2T	37 52.63	76 09.08	73.6	58.0	10/31/81	11/02/81	10
2T	37 52.57	76 09.22	75.3	58.0	11/02/81	11/17/81	15
2M	37 52.75	76 09.12	73.0	33.0	09/09/81	09/22/81	13
2M	"	"	73.0	33.0	09/22/81	10/13/81	21
2M	37 52.63	76 09.08	73.6	33.0	10/13/81	11/02/81	20
2M	37 52.57	76 09.22	75.3	33.0	11/02/81	11/17/81	15
2B	37 52.75	76 09.12	73.0	5.0	09/09/81	09/22/81	13
2B	"	"	73.7	5.0	09/22/81	10/13/81	21
2B	37 52.63	76 09.08	73.6	8.0	10/13/81	11/02/81	20
2B	37 52.57	76 09.22	75.3	8.0	11/02/81	11/17/81	15
3T	37 52.65	76 07.08	38.6	24.0	09/09/81	09/22/81	13
3T	"	"	37.9	24.0	09/22/81	10/13/81	21
3B	"	"	38.6	5.0	09/09/81	09/24/81	13
3B	"	"	37.9	5.0	09/22/81	10/31/81	21
4T	37 52.67	76 05.30	29.5	15.0	09/08/81	09/24/81	14
4B	"	"	29.1	5.0	09/22/81	10/09/81	17
5	37 52.83	76 02.65	10.9	5.0	09/08/81	09/24/81	16
6T	37 54.50	75 57.42	94.5	80.0	09/09/81	09/30/81	21
6T	"	"	"	80.0	09/30/81	10/15/81	15
6T	37 54.07	75 57.50	94.9	79.0	10/14/81	11/02/81	19
6M	37 54.50	75 57.42	94.5	55.0	09/09/81	09/30/81	21
6M	"	"	"	55.0	09/30/81	10/15/81	15
6M	37 54.07	75 57.50	94.9	54.0	10/14/81	11/02/81	19

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
6B	37	54.50	75	57.42	94.5	5.0	09/09/81	09/30/81	21
6B		"		"	"	5.0	09/30/81	10/15/81	15
6B	37	54.07	75	57.50	94.9	8.0	10/14/81	11/02/81	19
7	37	54.87	75	47.92	11.5	5.0	09/02/81	09/29/81	27
8	37	58.12	76	23.50	15.4	5.0	09/24/81	10/14/81	20
9T	37	59.87	76	21.75	37.9	24.0	09/23/81	10/08/81	15
9T		"		"	39.6	24.0	10/08/81	10/28/81	20
9B		"		"	"	5.0	09/23/81	10/08/81	15
9B		"		"	39.6	5.0	10/08/81	10/28/81	20
10T	38	00.80	76	20.62	52.5	38.0	09/08/81	09/21/81	13
10T		"		"	"	"	09/21/81	10/08/81	17
10T		"		"	"	"	10/08/81	10/27/81	19
10T		"		"	53.6	"	10/27/81	11/11/81	15
10T	38	00.76	76	20.82	54.6	"	11/11/81	11/16/81	5
10T	38	00.80	76	20.62	52.5	"	10/14/81	11/02/81	19
10T	38	00.75	76	20.57	52.5	"	11/02/81	11/17/81	15
10B	38	00.80	76	20.62	52.5	5.0	09/21/81	10/08/81	17
10B		"		"	53.6	5.0	10/27/81	11/11/81	15
10B	38	00.76	76	20.82	54.6	5.0	11/11/81	12/02/81	21
10B	38	00.75	76	20.57	52.5	8.0	11/02/81	11/17/81	15
11T	38	01.25	76	19.45	47.8	33.0	09/23/81	10/08/81	15
11T		"		"	48.7	33.0	10/08/81	10/27/81	19
11B		"		"	47.8	5.0	09/23/81	10/08/81	15
11B		"		"	48.7	5.0	10/08/81	10/27/81	19
12T	38	02.30	76	17.50	36.0	19.0	11/16/81	12/02/81	16
12B		"		"	35.2	5.0	10/13/81	10/30/81	17
12B		"		"	36.0	5.0	11/16/81	12/02/81	16

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
13T	38	00.88	76	12.12	63.5	48.0	10/13/81	10/30/81	17
13T		"		"	64.0	48.0	11/16/81	12/01/81	15
13M	38	00.88	76	12.12	64.0	23.0	11/16/81	12/01/81	15
13B		"		"	"	5.0	10/13/81	10/30/81	17
13B		"		"	"	5.0	11/16/81	12/01/81	15
14T	38	00.45	76	07.28	37.0	19.0	10/13/81	10/30/81	17
15T	38	00.05	75	54.52	97.9	83.0	09/09/81	09/30/81	21
15M		"		"	"	58.0	09/09/81	09/30/81	21
15B		"		"	"	5.0	09/09/81	09/30/81	21
16	38	03.45	76	01.93	14.8	5.0	09/25/81	10/14/81	19
17	38	02.93	75	51.45	17.5	5.0	11/12/81	12/01/81	19
18	38	05.82	75	53.48	25.3	5.0	11/12/81	12/01/81	16
19	38	08.43	76	18.13	22.6	5.0	10/29/81	11/13/81	15
20T	38	08.38	76	15.67	44.0	29.0	10/14/81	10/27/81	13
20T		"		"	"	29.0	10/27/81	11/13/81	17
20B		"		"	"	5.0	10/14/81	10/27/81	13
20B		"		"	"	5.0	10/27/81	11/13/81	17
21T	38	08.13	76	13.75	97.0	82.0	10/14/81	10/27/81	13
21T		"		"	99.2	82.0	10/27/81	11/13/81	17
21M		"		"	97.0	57.0	10/14/81	10/27/81	13
21M		"		"	99.2	57.0	10/27/81	11/13/81	17
21B		"		"	97.0	5.0	10/14/81	10/27/81	13
21B		"		"	99.2	5.0	10/27/81	11/13/81	17

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
22	38	08.38	76	09.80	26.0	10.0	11/13/81	11/30/81	17
23	38	08.67	76	06.87	17.8	5.0	11/03/81	11/13/81	10
24T	38	08.45	75	58.33	47.3	32.0	10/30/81	11/12/81	13
24T		"		"	47.0	32.0	11/12/81	12/01/81	19
24B		"		"	47.3	5.0	10/30/81	11/12/81	13
24B		"		"	47.0	5.0	11/12/81	12/01/81	19
25	38	13.05	76	03.83	21.0	7.0	11/13/81	11/30/81	17
27	38	12.80	75	54.02	14.8	5.0	11/12/81	11/30/81	18
28T	38	13.48	75	59.37	24.7	10.0	11/12/81	11/30/81	18
28B		"		"	24.7	5.0	11/12/81	11/30/81	18
29T	38	15.80	75	55.43	42.3	24.0	11/12/81	11/30/81	18
29B		"		"	42.3	5.0	11/12/81	11/30/81	18
30B	38	14.82	76	06.97	31.8	5.0	10/29/81	11/13/81	15
31	38	13.25	76	06.20	22.9	8.0	10/29/81	11/13/81	15
36T	38	18.67	76	18.78	54.8	40.0	09/03/81	09/21/81	18
"		"		"	54.6	40.0	09/21/81	10/08/81	17
"		"		"	55.9	40.0	10/08/81	10/27/81	19
"		"		"	57.0	40.0	10/27/81	11/11/81	15
"	38	18.72	76	18.72	55.4	40.0	11/11/81	11/30/81	19
"	38	18.70	76	18.73	55.3	40.0	11/30/81	12/07/81	17
"		"		"	55.3	40.0	12/21/81	02/08/82	49
"		"		"	55.3	40.0	03/01/82	04/13/82	43
"		"		"	55.9	40.0	04/13/82	05/05/82	22
"		"		"	55.9	40.0	05/05/82	05/20/82	15
"		"		"	56.7	40.0	05/20/82	06/07/82	18
"		"	76	18.77	57.5	40.0	06/07/82	06/24/82	17

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)	Location Long (W)	Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
36T	38 18.70	76 18.77	57.5	40.0	07/13/82	07/28/82	15
"	"	"	"	"	07/28/82	08/17/82	20
"	"	"	"	"	08/17/82	08/27/82	10
"	"	"	"	"	08/27/82	09/13/82	17
"	"	"	"	"	09/29/82	10/14/82	15
"	"	"	"	"	10/14/82	10/28/82	14
"	38 18.73	76 18.75	56.0	"	11/09/82	12/08/82	29
"	"	"	"	"	12/08/82	01/10/83	33
"	"	"	55.1	"	01/10/83	02/17/83	38
"	"	"	"	"	03/23/83	04/05/83	13
"	"	"	"	"	06/03/83	06/17/83	14
"	"	"	"	"	06/17/83	07/05/83	18
"	"	"	"	"	07/05/83	07/22/83	17
"	"	"	"	"	08/01/83	08/18/83	17
"	"	"	"	"	08/18/83	09/06/83	19
"	"	"	55.5	"	09/07/83	09/20/83	13
"	"	"	56.4	"	09/20/83	10/07/83	17
"	"	"	56.5	"	10/07/83	10/20/83	13
"	"	"	56.5	"	10/20/83	11/07/83	18
"	"	"	57.1	"	11/07/83	11/15/83	8
"	"	"	57.1	"	11/15/83	12/05/83	20
36M	38 18.72	76 18.77	57.5	18.0	06/07/83	06/24/83	17
36B	38 18.67	76 18.78	54.8	5.0	09/03/81	09/21/81	18
"	"	"	54.6	5.0	09/21/81	10/08/81	17
"	"	"	55.9	5.0	10/08/81	10/27/81	19
"	"	"	57.0	5.0	10/27/81	11/11/81	15
"	38 18.72	76 18.72	55.4	5.0	11/11/81	11/30/81	19
"	38 18.70	76 18.73	55.3	5.0	11/30/81	12/07/81	7
"	"	"	"	5.0	12/21/81	01/08/82	17
"	"	"	55.9	8.0	04/13/82	04/27/82	14
"	"	"	55.9	8.0	05/05/82	05/20/82	15
"	"	"	56.7	8.0	05/20/82	06/07/82	18
"	"	76 18.77	57.5	8.0	06/07/82	06/24/82	17
"	"	"	"	8.0	06/24/82	07/13/82	19

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
36B	38	18.70	76	18.77	57.5	8.0	07/13/82	07/28/82	15
"		"		"	"	8.0	07/28/82	08/17/82	20
"		"		"	"	8.0	08/27/82	09/13/82	17
"		"		"	"	8.0	09/13/82	09/29/82	16
"		"		"	"	8.0	09/29/82	10/14/82	15
"		"		"	"	8.0	10/28/82	11/09/82	12
"		"		"	55.1	8.0	01/10/83	02/17/83	38
36B	38	18.73	76	18.75	55.1	8.0	02/17/83	03/23/83	34
36B		"		"	56.9	8.0	03/20/83	04/05/83	13
36B	38	18.72	76	18.73	"	8.0	06/17/83	07/05/83	18
36B		"		"	"	8.0	07/05/83	07/22/83	17
36B		"		"	"	8.0	07/22/83	08/01/83	10
36B		"		"	"	8.0	08/01/83	08/18/83	17
36B		"		"	"	8.0	08/18/83	09/07/83	20
36B		"		"	55.5	8.0	09/07/83	09/20/83	13
36B		"		"	56.4	8.0	09/20/83	10/07/83	17
36B		"		"	56.5	8.0	10/07/83	10/20/83	13
36B		"		"	56.5	8.0	10/20/83	11/07/83	18
36B		"		"	57.1	8.0	11/07/83	12/05/83	28
37	37	04.85	75	58.83	24.7	10.0	05/12/82	05/24/82	12
37		"		"	"	10.0	06/03/82	06/15/82	12
38T	37	03.27	75	58.33	33.3	17.0	05/12/82	06/03/82	22
38T	37	03.37		"	32.2	17.1	06/03/82	06/15/82	12
38B		"		"	33.3	8.0	05/12/82	06/03/82	22
38B		"		"	32.2	8.0	06/03/82	06/15/82	12
39	37	01.40	75	59.55	19.9	5.0	05/12/82	06/03/82	22
39		"		"	19.3	5.0	06/03/82	06/15/82	12
40T	36	58.77	75	59.98	42.0	27.0	09/15/81	10/21/81	36
"		"		"	"	"	10/21/81	12/17/81	57
"		"		"	"	"	12/17/81	01/18/82	32
"		"		"	"	"	01/29/82	03/11/82	41

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
40T	36	58.78	75	59.93	42.0	27.0	03/29/82	04/15/82	17
"		"		"	41.0	"	04/15/82	05/04/82	19
"		"		"	41.9	"	05/04/82	05/12/82	8
"		"		"	41.7	"	05/12/82	06/03/82	22
"		"	75	59.88	41.3	"	06/03/82	06/15/82	12
"		"		"	41.0	"	06/15/82	07/02/82	17
"		"		"	"	"	07/02/82	07/14/82	12
"		"		"	"	"	07/14/82	07/29/82	15
"		"		"	"	"	07/29/82	08/13/82	15
"		"		"	"	"	08/13/82	08/28/82	15
"		"		"	"	"	08/28/82	09/12/82	15
"		"		"	"	"	09/12/82	09/28/82	16
"		"		"	"	"	09/28/82	10/19/82	21
"		"		"	41.4	"	10/19/82	11/03/82	15
"		"		"	42.5	"	11/03/82	11/18/82	15
"		"		"	42.6	"	11/18/82	11/30/82	12
"		"		"	41.8	"	11/30/82	12/22/82	22
"		"		"	"	"	12/22/82	01/14/83	23
"		"		"	"	"	01/14/83	02/10/83	27
"		"		"	"	"	02/10/83	03/04/83	22
"		"		"	"	"	03/04/83	03/23/83	19
"		"		"	40.7	"	03/23/83	04/21/83	29
"		"		"	"	"	04/04/83	05/11/83	20
"		"		"	"	"	05/11/83	05/24/83	13
"		"		"	"	"	06/13/83	07/11/83	28
"		"		"	"	"	07/11/83	08/15/83	35
"		"		"	"	"	08/15/83	09/13/83	29
"		"		"	"	"	09/13/83	10/17/83	34
"		"		"	"	"	10/17/83	11/18/83	32
"		"		"	"	"	11/18/83	12/08/83	20
40B	36	58.77	75	59.98	42.0	5.0	09/15/81	10/21/81	36
"		"		"	"	5.0	10/21/81	12/17/81	57
"		"		"	"	5.0	12/17/81	12/23/81	6
"		"		"	"	5.0	01/18/82	02/08/82	37
"	36	58.78	75	59.93	"	5.0	02/24/82	03/29/82	33

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
40B	36	58.78	75	59.93	42.0	5.0	03/29/82	04/15/82	17
"	36	58.80		"	41.9	8.0	05/04/82	05/12/82	8
"		"		"	41.7	8.0	05/12/82	06/03/82	22
"		"	75	59.88	41.3	8.0	06/03/82	06/15/82	12
"		"		"	"	8.0	07/02/82	07/14/82	12
"		"		"	"	8.0	07/14/82	07/29/82	15
"		"		"	"	8.0	07/29/82	08/13/82	15
"		"		"	"	8.0	08/13/82	08/28/82	15
"		"		"	"	8.0	08/28/82	09/12/82	15
"		"		"	"	8.0	09/12/82	09/28/82	16
"		"		"	"	8.0	09/28/82	10/19/82	21
"		"		"	41.4	8.0	10/19/82	11/03/82	15
"		"		"	42.5	8.0	11/03/82	11/18/82	15
"		"		"	42.6	8.0	11/18/82	11/30/82	12
"		"		"	41.8	8.0	11/30/82	12/15/82	15
"		"		"	"	8.0	12/22/82	01/14/83	23
"		"		"	"	8.0	02/10/83	03/04/83	22
"		"		"	"	8.0	03/04/83	03/23/83	19
"		"		"	40.7	8.0	03/23/83	04/21/83	29
"		"		"	"	8.0	04/21/83	05/11/83	20
"		"		"	"	8.0	05/11/83	06/13/83	33
"		"		"	"	8.0	06/13/83	07/11/83	28
"		"		"	"	8.0	07/11/83	08/15/83	35
"		"		"	"	8.0	08/15/83	09/13/83	29
"		"		"	"	8.0	09/13/83	10/17/83	34
"		"		"	"	8.0	10/17/83	11/18/83	32
"		"		"	"	8.0	11/18/83	12/08/83	20
41T	36	57.53	76	00.63	61.8	47.0	05/12/82	06/03/82	22
41T		"	76	00.68	61.7	47.0	06/03/82	06/15/82	12
41M		"	76	00.63	61.8	23.0	05/12/82	06/03/82	22
41M		"	76	00.68	61.7	23.0	06/03/82	06/15/82	12
41B		"	76	00.63	61.8	8.0	05/12/82	06/03/82	22
41B		"	76	00.68	61.7	8.0	06/03/82	06/15/82	12

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
42T	36	56.33	75	59.98	46.1	31.0	05/12/82	06/03/82	22
42B	36	56.33	75	59.88	46.1	8.0	05/12/82	06/03/82	22
42B	36	56.27	76	00.00	45.7	8.0	06/03/82	06/15/82	12
43T	37	06.10	76	00.33	29.8	14.0	05/11/82	06/02/82	22
43B		"		"	"	8.0	05/11/82	05/19/82	8
43B		"		"	"	8.0	05/19/82	06/02/82	14
44T	37	03.40	76	05.58	42.4	29.0	05/27/82	06/02/82	16
44T	37	03.73	76	05.58	46.5	28.0	11/03/82	11/18/82	15
44B	37	03.40	76	05.58	42.4	8.0	05/11/82	05/27/82	16
44B	37	03.40	76	05.58	42.4	8.0	05/27/82	06/02/82	6
44B	37	03.73	76	05.58	46.5	8.0	11/03/82	11/18/82	15
45T	36	58.73	76	07.57	53.2	38.0	05/11/82	06/02/82	22
45B		"		"	"	8.0	05/11/82	06/02/82	22
47	36	56.05	76	10.60	23.1	8.0	05/12/82	06/02/82	21
48T	37	00.32	76	13.60	51.4	36.0	06/02/82	06/18/82	16
48B		"		"	"	8.0	06/02/82	06/18/82	16
49T	37	00.12	76	17.72	94.0	81.0	06/02/82	06/18/82	16
49M		"		"	"	46.0	06/02/82	06/18/82	16
49M		"		"	"	46.0	06/18/82	07/06/82	18
49B		"		"	"	8.0	06/02/82	06/18/82	16
49B		"		"	"	8.0	06/18/82	07/06/82	18
50T	36	59.42	76	18.23	51.9	37.0	06/16/82	07/06/82	20

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
50B	36	59.42	76	18.23	51.9	8.0	06/16/82	07/06/82	20
52T	36	57.03	76	20.32	50.3	37.0	06/16/82	06/30/82	14
52B		"		"	"	8.0	06/16/82	06/28/82	12
55T	37	07.38	76	09.20	40.5	27.0	06/02/82	06/16/82	14
55T	37	07.43	76	09.27	39.8	27.0	06/16/82	07/06/82	20
55B	37	07.38	76	09.20	40.5	8.0	06/02/82	06/16/82	14
55B	37	07.43	76	09.27	39.8	8.0	06/16/82	07/06/82	20
56	37	09.37	76	01.60	22.9	9.0	06/17/82	07/06/82	19
57T	37	15.95	76	05.67	101.3	87.0	04/26/82	05/11/82	15
57T	37	15.87	76	05.62	102.5	86.0	11/08/82	11/30/82	22
57M	37	15.95	76	05.67	101.3	62.0	04/26/82	05/11/82	15
57M	37	15.87	76	05.62	102.5	61.0	11/08/82	11/20/82	22
57B	37	15.87	76	05.62	102.5	8.0	11/08/82	11/30/82	22
58T	37	17.40	76	11.45	41.5	26.0	04/26/82	05/11/82	15
58B		"		"	"	8.0	04/26/82	05/11/82	15
59T	37	13.55	76	18.47	37.9	23.0	06/15/82	06/30/82	15
59T		"		"	37.0	23.0	07/22/82	08/09/82	18
60T	37	14.80	76	23.28	53.9	40.0	06/14/82	07/06/82	22
60T		"		"	52.4	40.0	07/06/82	07/21/82	15
60M		"		"	53.9	15.0	06/14/82	07/06/82	22
60M		"		"	52.4	15.0	07/06/82	07/21/82	15
60B		"		"	53.9	5.0	06/23/82	07/06/82	13

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
60B	37	14.80	76	23.38	52.4	5.0	07/06/82	07/23/82	15
61T	37	14.28	76	24.13	36.5	22.0	07/06/82	07/21/82	15
61B		"		"	"	8.0	07/06/82	07/21/82	15
62	37	17.70	76	19.25	24.5	9.0	06/15/82	06/30/82	15
63	37	25.00	76	12.90	16.7	5.0	07/21/82	08/09/82	19
64	37	24.67	76	10.90	32.3	17.0	04/27/82	05/10/82	13
64		"	76	10.57	31.3	16.0	07/07/82	07/21/82	14
64		"		"	"	16.0	07/21/82	08/09/82	19
65T	37	24.68	76	07.48	41.1	26.0	12/08/81	01/06/82	29
65T		"		"	"	26.0	01/06/82	01/15/82	9
65T		"		"	"	26.0	01/25/82	02/23/82	29
65T		"		"	"	26.0	02/23/82	03/10/82	14
65T		"		"	"	26.0	03/10/82	04/08/82	29
65T	37	24.70	76	07.40	"	26.0	04/08/82	04/26/82	18
65T		"		"	"	26.0	04/26/82	05/10/82	14
65T	37	24.70		"	"	26.0	05/10/82	05/27/82	17
65T		"		"	"	26.0	05/27/82	06/15/82	19
65T		"		"	"	26.0	06/15/82	07/07/82	22
65T	37	24.80		"	"	26.0	07/07/82	07/21/82	14
65T		"		"	40.0	26.0	08/09/82	08/24/82	15
65T		"		"	40.0	26.0	08/24/82	09/11/82	18
65T		"		"	"	26.0	09/11/82	09/27/82	16
65T		"		"	41.1	26.0	09/27/82	10/15/82	18
65T		"		"	41.5	26.0	10/15/82	11/03/82	19
65T		"		"	41.2	26.0	11/18/82	12/01/82	13
65T		"		"	"	26.0	12/01/82	01/06/83	36
65T	37	24.80	76	07.40	41.2	26.0	01/06/83	02/03/83	28
65T		"		"	"	26.0	02/24/83	03/30/83	34
65T		"		"	"	26.0	03/30/83	04/04/83	5

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
65T	37	24.80	76	07.40	41.2	26.0	04/04/83	05/11/83	37
65T		"		"	"	26.0	05/11/83	06/09/83	29
65T		"		"	"	26.0	06/09/83	07/13/83	34
65T		"		"	"	26.0	07/13/83	08/09/83	27
65T		"		"	"	26.0	08/09/83	09/06/83	28
65T		"		"	"	26.0	09/06/83	10/03/83	27
65T		"		"	"	26.0	10/03/83	11/01/83	29
65T		"		"	"	26.0	11/01/83	11/17/83	16
65T		"		"	"	26.0	11/17/83	12/07/83	20
65B	37	24.70		"	"	8.0	05/10/82	05/27/82	17
65B		"		"	"	8.0	05/27/82	06/15/82	19
65B		"		"	"	8.0	06/15/82	07/07/82	22
65B	37	24.80		"	"	8.0	07/07/82	07/21/82	14
65B		"		"	40.0	8.0	07/21/82	08/09/82	19
65B		"		"	40.0	8.0	08/09/82	08/24/82	15
65B		"		"	40.0	8.0	08/24/82	09/11/82	18
65B		"		"	40.0	8.0	09/11/82	09/27/82	16
65B		"		"	41.4	8.0	09/27/82	10/15/82	18
65B		"		"	41.2	8.0	11/03/82	11/18/82	15
65B		"		"	"	8.0	11/18/82	12/01/82	13
65B		"		"	"	8.0	12/01/82	01/06/83	36
65B		"		"	"	8.0	03/30/83	04/04/83	5
65B	37	24.80	76	07.40	41.2	8.0	04/04/83	05/11/83	37
65B		"		"	"	8.0	05/11/83	06/09/83	29
65B		"		"	"	8.0	06/09/83	07/13/83	34
65B		"		"	"	8.0	07/13/83	08/09/83	27
65B		"		"	"	8.0	08/09/83	09/06/83	28
65B		"		"	"	8.0	10/03/83	11/01/83	29
65B		"		"	"	8.0	11/17/83	12/07/83	20
65M	37	24.67	76	07.57	40.3	18.0	04/08/82	04/27/82	19
65M	37	24.70	76	07.60	41.0	18.0	04/27/82	05/10/82	13
65M	37	24.67	76	07.70	39.5	17.0	07/07/82	07/22/82	15
65M		"		"	40.5	17.0	07/22/82	08/09/82	18

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
65M	37	24.67	76	07.70	40.5	11.0	07/22/82	08/09/82	18
66T	37	24.50	76	04.80	72.3	56.0	04/08/82	04/22/82	14
66T		"		"	"	56.0	04/22/82	04/26/82	4
66T		"	76	04.85	72.2	57.0	04/26/82	05/10/82	14
66T		"	76	05.00	"	56.0	07/07/82	07/09/82	2
66T		"	76	05.00	"	56.0	07/09/82	07/22/82	13
66T		"		"	71.2	56.0	07/22/82	08/09/82	18
66M	37	24.50	76	04.80	72.3	31.0	04/08/82	04/26/82	18
66M		"	76	04.85	72.2	32.0	04/26/82	05/10/82	14
66M		"	76	05.00	71.0	31.0	07/07/82	07/22/82	15
66M		"	76	05.00	71.2	31.0	07/22/82	08/09/82	18
66B	37	24.50	76	04.80	72.3	5.0	04/16/82	04/26/82	10
66B		"	76	04.85	72.2	8.0	04/26/82	05/10/82	14
66B		"	76	05.00	71.0	8.0	07/07/82	07/22/82	15
66B		"		"	71.2	8.0	07/22/82	08/09/82	18
67T	37	24.60	76	03.10	39.5	25.0	04/27/82	05/10/82	13
67T	37	24.50	76	03.83	37.4	23.0	07/07/82	07/22/82	15
67T		"		"	"	23.0	07/22/82	08/09/82	18
67B	37	24.50	76	03.83	"	8.0	07/22/82	08/09/82	18
68	37	24.30	76	00.70	"	5.0	04/14/82	04/27/82	13
68	37	24.33	76	00.80	"	5.0	05/04/82	05/10/82	6
68	37	24.20	76	00.78	20.6	5.0	07/07/82	07/22/82	15
68	37	24.20	76	00.78	20.0	5.0	07/22/82	08/09/82	18
69	37	29.97	75	59.37	21.2	8.0	07/21/82	08/10/82	20
70T	37	29.90	76	06.40	37.0	23.0	06/01/82	06/21/82	20
70T	37	29.90	76	06.40	37.0	23.0	06/21/82	07/07/82	16
70T	37	29.70	76	06.50	36.5	23.0	07/07/82	07/21/82	14
70T		"		"	"	23.0	07/21/82	08/10/82	20

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
70B	37	29.90	76	06.40	37.0	8.0	06/01/82	06/21/82	20
70B	37	29.70	76	06.50	36.5	8.0	07/07/82	07/21/82	14
70B		"		"	"	8.0	07/21/82	08/10/82	20
71	37	30.03	76	14.70	21.6	6.0	07/21/82	08/10/82	20
72	37	32.13	76	18.57	20.4	5.0	04/09/82	04/27/82	18
73	37	34.53	76	17.08	28.2	8.0	08/09/82	08/25/82	16
74T	37	36.00	76	17.50	43.8	28.0	04/09/82	04/16/82	7
74T		"		"	"	"	04/16/82	04/27/82	11
74T		"		"	44.0	"	04/27/82	05/11/82	14
74B	37	36.0	76	17.50	43.8	5.0	04/16/82	04/27/82	11
74B	37	36.00	76	17.50	44.0	8.0	04/27/82	05/11/82	14
75T	37	35.30	76	11.50	43.3	29.0	08/10/82	08/25/82	15
75B		"		"	"	8.0	08/10/82	08/25/82	15
76T	37	34.60	76	03.80	41.2	27.0	08/10/82	08/25/82	15
76B		"		"	"	8.0	08/10/82	08/25/82	15
77	37	35.45	75	58.10	25.5	9.0	08/10/82	08/25/82	15
79T	37	39.85	76	00.52	45.9	33.0	08/11/82	08/26/82	15
79B	37	39.85	76	00.52	45.9	8.0	08/11/82	08/26/82	15
80T	37	40.70	76	12.25	41.4	28.0	08/10/82	08/24/82	14
80T		"		"	"	28.0	10/13/82	11/01/82	19
80B	37	40.70	76	12.25	"	8.0	08/10/82	08/24/82	15
80B		"		"	41.4	8.0	10/13/82	11/01/82	19

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
80B	37	40.70	76	12.25	42.8	8.0	11/01/82	11/16/82	15
83T	37	47.00	76	11.50	100.7	87.0	10/13/82	11/01/82	19
83T		"		"	100.9	87.0	11/01/82	11/16/82	15
83M		"		"	100.7	62.0	10/13/82	11/01/82	19
83M		"		"	100.9	62.0	11/01/82	11/16/82	15
83B		"		"	100.7	8.0	10/13/82	11/01/82	19
83B		"		"	100.9	8.0	11/01/82	11/16/82	15
84T	37	47.03	76	05.68	36.0	21.0	11/01/82	11/17/82	16
84B		"		"	"	8.0	11/01/82	11/17/82	16
86T	37	47.25	75	57.83	102.4	86.0	10/14/82	11/02/82	19
86T		"		"	"	86.0	11/02/82	11/17/82	15
86M		"		"	"	61.0	11/02/82	11/17/82	15
86B		"		"	"	8.0	10/14/82	11/02/82	19
86B		"		"	"	8.0	11/02/82	11/17/82	15
87	37	45.50	75	56.80	25.7	11.0	10/14/82	10/27/82	13
87		"		"	"	11.0	10/27/82	11/02/82	6
88T	37	47.85	75	50.67	90.7	66.0	10/14/82	11/04/82	21
88T	37	47.62	75	50.83	88.7	76.0	11/04/82	11/17/82	13
88M	37	47.85	75	50.67	90.7	41.1	10/14/82	11/04/82	21
88M	37	47.62	75	50.83	88.7	51.0	11/04/82	11/17/82	13
88B	37	47.85	75	50.67	90.7	8.0	10/14/82	11/04/82	21
89	37	49.33	76	18.07	20.4	8.0	08/11/82	08/26/82	15

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
90T	39	00.32	76	22.80	47.7	33.0	07/19/83	08/04/83	16
90T		"		"	46.9	33.0	08/04/83	08/22/83	18
90T		"		"	47.8	33.0	08/22/83	09/07/83	16
90B		"		"	47.7	5.0	07/19/83	08/04/83	16
90B		"		"	46.9	5.0	08/04/83	08/22/83	18
90B		"		"	47.8	5.0	08/22/83	09/07/83	16
100T	38	22.88	76	21.62	47.7	32.0	10/07/83	10/24/83	17
100T		"		"	48.5	32.0	10/24/83	11/07/83	14
100T		"		"	47.7	32.0	11/19/83	12/05/83	16
100B		"		"	48.5	8.0	10/24/83	11/07/83	14
100B		"		"	47.7	8.0	11/07/83	12/05/83	28
101T	38	22.80	76	19.52	102.7	88.0	10/20/83	11/07/83	18
101T		"		"	"	88.0	11/07/83	11/28/83	21
101M	38	22.80	76	19.52	102.7	63.0	10/20/83	11/07/83	18
101M		"		"	"	73.0	11/07/83	11/25/83	18
101B		"		"	"	5.0	10/20/83	11/07/83	18
101B		"		"	"	5.0	11/07/83	11/28/83	21
102T	38	38.70	76	29.23	32.6	18.0	09/20/83	10/06/83	16
102T		"		"	33.4	18.0	11/08/83	11/13/83	5
102B		"		"	33.4	5.0	11/13/83	11/28/83	15
103T	38	38.63	76	26.88	39.1	22.0	09/20/83	10/06/83	16
103T		"		"	39.5	22.0	11/08/83	11/28/83	20
103B		"		"	39.5	5.0	11/15/83	11/28/83	13
104T		"		"	82.5	65.0	10/03/83	10/20/83	17

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
104M	38	38.63	76	26.88	81.3	40.0	09/20/83	10/05/83	15
104M		"		"	82.5	40.0	10/05/83	10/20/83	15
104M		"		"	82.1	40.0	11/08/83	11/22/83	14
104B		"		"	81.3	5.0	09/20/83	10/05/83	15
104B		"		"	82.5	5.0	10/07/83	10/20/83	13
104B		"		"	82.1	5.0	11/08/83	11/28/83	20
105	38	36.43	76	20.88	31.7	12.0	09/20/83	10/06/83	16
106T	38	38.83	76	18.75	50.1	35.0	10/06/83	10/24/83	18
106T		"		"	50.0	35.0	10/24/83	11/15/83	22
106B		"		"	50.0	5.0	10/24/83	11/01/83	8
106B		"		"	50.0	5.0	11/01/83	11/15/83	14
107T	38	37.70	76	09.10	28.8	12.0	10/05/83	10/25/83	20
107B		"		"	"	5.0	10/05/83	10/25/83	20
108T	38	34.78	76	03.67	40.3	22.0	10/25/83	11/10/83	16
108B		"		"	40.3	5.0	10/25/83	11/10/83	16
111	38	45.10	76	29.93	24.7	10.0	09/21/83	10/06/83	15
112T	38	44.98	76	26.73	52.9	38.0	09/21/83	10/06/83	15
112B		"		"	"	5.0	09/21/83	10/06/83	15
113T	38	45.37	76	25.77	97.2	83.0	09/08/83	09/22/83	14
113T		"		"	98.4	83.0	09/22/83	10/18/83	16
113M	38	45.37	76	25.77	97.8	48.0	08/22/83	09/08/83	17
113M		"		"	97.2	48.0	09/08/83	09/22/83	14
113M		"		"	98.4	48.0	09/22/83	10/15/83	23

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
113B	38	45.37	76	25.77	97.8	8.0	08/22/83	09/08/83	17
113B		"		"	97.2	8.0	09/08/83	09/22/83	14
113B		"		"	98.4	8.0	09/22/83	10/06/83	14
114T	38	50.33	76	20.25	38.9	24.0	08/04/83	08/22/83	18
114T		"		"	38.3	24.0	08/22/83	09/08/83	17
114B		"		"	38.3	5.0	08/22/83	09/08/83	17
115	38	50.57	76	18.13	23.4	10.0	08/22/83	09/08/83	17
116T	38	52.50	76	15.00	41.6	27.0	08/04/83	08/22/83	18
116T		"	76	15.12	41.1	27.0	08/22/83	09/08/83	17
119	38	53.88	76	28.23	16.9	5.0	07/19/83	07/31/83	12
119	38	53.95	76	28.33	16.6	5.0	08/04/83	08/12/83	8
120T	38	53.62	76	25.83	38.4	22.0	07/19/83	08/04/83	16
120B		"		"	38.4	5.0	07/19/83	08/04/83	16
121T	38	53.75	76	23.28	78.5	57.0	11/09/82	12/06/82	27
121T		"		"	"	57.0	12/06/82	01/10/83	35
121T		"		"	"	57.0	01/10/83	02/15/83	36
121T		"		"	"	57.0	02/15/83	03/21/83	34
121T		"		"	"	57.0	03/21/83	04/05/83	15
121T		"	76	23.36	79.5	59.0	04/05/83	04/18/83	13
121T		"		"	"	"	04/18/83	05/06/83	18
121T		"		"	"	"	05/06/83	05/26/83	20
121T		"		"	"	"	06/09/83	06/20/83	11
121T		"		"	"	"	06/20/83	07/05/83	15
121T		"		"	"	"	08/04/83	08/22/83	18
121T		"		"	"	"	08/22/83	09/07/83	16
121T		"		"	"	"	09/07/83	09/22/83	15
121T		"		"	"	"	09/22/83	10/05/83	13
121T		"		"	"	"	10/05/83	10/24/83	19

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
121T	38	53.75	76	23.36	79.5	59.0	10/24/83	11/08/83	15
121T		"		"	"	"	11/08/83	11/22/83	14
121T		"		"	"	"	11/22/83	12/05/83	13
121M	38	53.75	76	23.28	78.5	39.0	11/09/82	12/06/82	27
121M		"		"	"	39.0	12/06/82	01/10/83	35
121M		"		"	"	39.0	03/21/83	04/05/83	15
121M		"	76	23.36	79.5	41.0	04/05/83	04/18/83	13
121M		"		"	"	41.0	04/18/83	05/06/83	18
121M		"		"	"	41.0	05/06/83	05/26/83	20
121M		"		"	"	41.0	06/09/83	06/20/83	11
121M		"		"	"	41.0	06/20/83	07/05/83	15
121M		"		"	"	41.0	07/05/83	07/19/83	14
121M		"		"	"	41.0	07/19/83	08/04/83	16
121M		"		"	"	41.0	08/04/83	08/22/83	18
121M		"		"	"	41.0	08/22/83	09/07/83	16
121M		"		"	"	41.0	09/22/83	10/05/83	13
121M		"		"	"	41.0	10/05/83	10/24/83	19
121M		"		"	"	41.0	01/01/83	11/22/83	14
121M		"		"	"	41.0	11/22/83	12/05/83	13
121B	38	53.75	76	23.28	78.5	8.0	11/09/82	12/06/82	27
121B		"		"	"	8.0	12/06/82	01/10/83	35
121B		"		"	"	5.0	01/10/83	02/15/83	36
121B		"		"	"	5.0	02/15/83	03/21/83	34
121B		"	76	23.36	79.5	8.0	04/05/83	04/18/83	13
121B		"		"	"	8.0	04/18/83	05/06/83	18
121B		"		"	"	8.0	05/06/83	05/26/83	20
121B		"		"	"	8.0	06/09/83	06/20/83	11
121B		"		"	"	8.0	06/20/83	07/05/83	15
121B		"		"	"	8.0	07/05/83	07/19/83	14
121B		"		"	"	8.0	07/19/83	08/04/83	16
121B		"		"	"	8.0	08/22/83	09/07/83	16
121B		"		"	"	8.0	09/07/83	09/22/83	15
121B		"		"	"	8.0	09/22/83	10/05/83	13
121B		"		"	"	8.0	10/05/83	10/24/83	19

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
121B	38	53.75	76	23.36	79.5	8.0	10/24/83	11/08/83	15
121B		"		"	"	8.0	11/08/83	11/22/83	14
121B		"		"	"	8.0	11/22/83	12/05/83	13
122	38	57.63	76	27.05	20.3	5.0	07/20/83	08/04/83	15
123	39	02.05	76	16.07	20.5	5.0	07/19/83	08/03/83	15
123		"		"	"	5.0	08/03/83	08/19/83	16
123		"		"	"	5.0	08/19/83	09/07/83	19
124T	39	00.63	76	10.95	44.9	29.0	07/19/83	08/03/83	15
124B		"		"	"	5.0	07/19/83	08/03/83	15
127	39	05.68	76	23.58	42.0	24.0	07/19/83	08/03/83	15
127		"		"	41.9	25.0	08/03/83	08/19/83	16
128T	39	06.48	76	18.32	31.8	18.0	07/19/83	08/03/83	15
128T		"		"	31.6	18.0	08/03/83	08/19/83	16
128B		"		"	31.8	5.0	07/19/83	08/03/83	15
128B		"		"	31.6	5.0	08/03/83	08/19/83	16
129	39	08.85	76	19.48	32.2	14.0	06/30/83	07/18/83	18
129		"		"	31.4	14.0	07/18/83	08/03/83	16
130	39	10.70	76	26.65	20.3	5.0	06/15/83	06/29/83	14
130		"		"	20.8	5.0	06/29/83	07/18/83	19
137T	39	13.03	76	14.90	39.4	25.0	06/15/83	06/29/83	14
137T		"		"	40.3	25.0	06/29/83	07/18/83	19
137B		"		"	39.4	5.0	06/15/83	06/29/83	14
137B		"		"	40.3	5.0	06/29/83	07/18/83	19
138	39	14.78	76	17.80	20.7	6.0	06/15/83	06/30/83	15
138		"		"	20.4	6.0	06/30/83	07/18/83	18

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
139	39	18.70	76	13.00	25.6	8.0	04/06/83	04/11/83	5
139		"	76	13.03	24.8	8.0	06/15/83	06/29/83	14
139		"	76	13.03	24.6	8.0	06/29/83	07/18/83	19
139		"	76	13.03	24.0	6.0	09/07/83	09/22/83	15
140	39	22.23	76	07.80	31.1	16.0	05/13/83	05/31/83	18
143	39	23.78	76	03.02	23.3	9.0	05/13/83	05/31/83	18
143		"		"	22.5	9.0	05/31/83	06/13/83	13
144	39	26.60	76	02.03	14.0	5.0	05/11/83	05/25/83	13
145	39	30.08	76	05.00	14.7	5.0	05/10/83	05/25/83	15
145		"		"	14.1	5.0	05/25/83	06/09/83	15
146	39	32.33	76	04.80	15.0	5.0	04/13/83	04/26/83	13
146	39	32.38	76	04.63	15.3	5.0	04/26/83	05/10/83	14
146		"		"	15.3	5.0	05/10/83	05/25/83	15
151T	39	30.23	75	55.12	38.4	21.0	04/12/83	04/27/83	15
151T		"		"	38.4	21.0	04/27/83	05/11/83	14
151T		"		"	38.8	21.0	05/11/83	05/31/83	20
151T		"		"	39.2	21.0	05/31/83	06/06/83	6
151B	39	30.23	75	55.12	38.4	9.0	04/12/83	04/27/83	15
151B		"		"	"	9.0	04/27/83	05/11/83	14
151B		"		"	38.8	9.0	05/11/83	05/31/83	20
151B		"		"	39.2	9.0	05/31/83	06/14/83	14
152T	39	31.67	75	51.97	34.0	26.0	05/12/83	05/31/83	19
152B	39	31.67	75	51.97	"	9.0	05/18/83	05/31/83	13
152B	39	31.62	75	52.22	38.5	9.0	05/31/83	06/14/83	14
152B		"		"	40.0	9.0	09/07/83	09/22/83	15
153T	39	33.17	75	39.00	43.0	25.0	04/12/83	04/27/83	15

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
154T	39	33.62	75	34.20	42.6	24.0	04/12/83	04/27/83	15
154T		"		"	"	24.0	05/03/83	05/12/83	9
154T		"		"	37.8	28.0	09/07/83	09/22/83	15
155T	39	33.05	75	32.58	48.7	32.0	04/26/83	05/02/83	6
155T		"		"	44.4	32.0	05/02/83	05/24/83	22
155T		"		"	44.5	32.0	05/24/83	06/14/83	21
155B	39	33.05	75	32.58	"	5.0	04/21/83	04/26/83	5
155B		"		"	44.4	5.0	05/02/83	05/24/83	22
155B		"		"	44.5	5.0	05/24/83	06/11/83	18
159	39	30.88	75	32.97	43.3	30.0	05/11/83	06/01/83	21
159		"		"	43.3	30.0	06/01/83	06/14/83	13
160T	39	34.37	75	33.27	34.8	20.0	04/12/83	04/23/83	11
160T		"		"	36.2	20.0	04/26/83	05/04/83	8
160T		"		"	34.1	20.0	05/04/83	05/24/83	20
160B		"		"	34.8	5.0	04/12/83	04/26/83	14
160B		"		"	36.2	5.0	04/26/83	05/04/83	8
161T	39	32.55	75	42.15	42.6	26.0	04/12/83	04/27/83	15
161T		"		"	"	26.0	04/27/83	05/12/83	15
161B		"		"	"	9.0	04/12/83	04/20/83	8
161B		"		"	"	9.0	04/21/83	04/27/83	6
162T	39	31.67	75	48.43	46.3	20.0	04/12/83	04/27/83	15
162T		"		"	43.4	20.0	04/27/83	05/12/83	15
162B		"		"	46.3	9.0	04/12/83	04/27/83	15
162B		"		"	43.4	9.0	04/27/83	05/12/83	15
163	39	29.30	75	59.85	13.7	5.0	05/12/83	05/25/83	13
164	39	11.47	76	15.95	28.3	13.0	06/15/83	06/28/83	13

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
164	39	11.47	76	15.95	27.9	13.0	06/29/83	07/12/83	13
164		"		"	"	13.0	07/12/83	07/18/83	6
165	39	11.57	76	17.22	20.3	5.0	06/15/83	06/29/83	14
165	39	11.57	76	17.22	20.0	5.0	06/29/83	07/12/83	13
166T	39	10.95	76	16.87	35.1	18.0	06/15/83	06/29/83	14
166T		"		"	35.6	18.0	06/29/83	07/18/83	19
166B		"		"	35.1	10.0	06/15/83	06/29/83	14
166B		"		"	25.6	10.0	06/29/83	07/18/83	19
167	38	37.63	76	08.15	35.9	18.0	10/25/83	11/07/83	13
168	38	36.23	76	06.87	12.3	5.0	09/20/83	10/05/83	15
168		"		"	"	5.0	10/05/83	10/25/83	20
169T	38	28.03	76	22.60	71.6	57.0	10/07/83	10/20/83	13
169T		"		"	71.9	57.0	10/20/83	11/07/83	18
169M		"		"	71.6	32.0	10/07/83	10/20/83	13
169M		"		"	71.9	32.0	10/20/83	11/07/83	18
169B		"		"	71.6	5.0	10/07/83	10/20/83	13
169B		"		"	71.9	5.0	10/20/83	11/07/83	18
170	38	22.52	76	17.92	20.7	5.0	10/20/83	11/07/83	18
170		"		"	"	5.0	11/07/83	11/28/83	21
171T	38	19.08	76	24.07	46.4	33.0	10/07/83	10/24/83	17
171T		"		"	43.7	33.0	10/24/83	11/07/83	14
171B	38	19.08	76	24.00	46.4	5.0	10/07/83	10/24/83	17
171B		"		"	43.7	5.0	10/24/83	11/07/83	14
172	39	09.78	76	23.38	21.7	8.0	06/15/83	06/30/83	15

Table 2. INDEX OF CURRENT METER STATIONS - continued

Sta. No.	Location Lat (N)		Location Long (W)		Water Depth at MLW (ft)	Meter Ht. above bottom (ft)	Series Begins (Date)	Series Ends (Date)	Length of Series (Days)
173	39	16.97	76	13.57	21.8	6.0	06/15/83	06/20/83	15
173		"		"	"	6.0	06/20/83	06/29/83	9
173		"		"	21.7	6.0	06/29/83	07/18/83	19
174	38	40.43	76	15.45	19.1	5.0	09/21/83	10/06/83	15
175T	39	00.22	76	20.93	45.6	31.0	06/29/83	07/19/83	20
175T		"		"	"	31.0	07/19/83	08/04/83	16
175B		"		"	"	5.0	06/29/83	07/19/83	20
175B		"		"	"	5.0	07/19/83	08/04/83	16
176T	39	02.42	76	22.67	42.6	28.0	07/19/83	08/03/83	15
176B		"		"	"	5.0	07/19/83	08/03/83	15

4.0 CONDUCTIVITY AND TEMPERATURE DATA

4.1 Measurement Instrumentation

The Grundy 9400 CTD profiling system was used for long period (13-hour time series) observations at a few single station sites, observations at stations forming a linear transect, and single casts at current meter station sites. This unit is lowered and raised in the water column making incremental measurements of conductivity and temperature with depth. The 9400 CTD unit uses a platinum resistance thermometer to sense temperature, an inductive transformer to sense conductivity, and a bonded strain gage to sense pressure (Frey and Appell, 1981). The outputs from the sensors are transmitted via a single conductor cable to the Grundy Model 8400 data logger on board ship. The data logger processes the data which are then recorded on 9-track magnetic tape by a Kennedy Model 9800 tape recorder. The CTD data are forwarded to NOS in this form for further processing. This tape, when listed on paper output on the PDP/11/34 minicomputer, provides header information and data in the form of depth, conductivity, and temperature. Further processing of data yields salinity, which is calculated from temperature and conductivity, and Sigma-T, calculated from salinity and temperature (table 3).

The temperature and conductivity sensors of the Grundy 9021-G current meter provide a time series of measurements of these parameters at each station meter depth. The sampling rate is every 10 minutes, the same as that for current speed and current direction (Browne and Dingle, 1983).

4.2 Processing Procedures

Processing CTD data recorded by the Grundy 9400 CTD profiler consists of running the data through interactive programs in sequence. The 9400 data tapes are first read and a listing of the data is produced. The data are then converted to engineering

Table 3. Manufacturer's Specifications for the Model 9400 CTD System (Plessy Environmental Systems Corp., 1977)

Parameter	Measurand		
	Conductivity	Temperature	Pressure
Measurement Range	0 to 60 mmho/cm	-2°C to 35°C	600 meters (profiling) 300 meters (moored)
Accuracy (See Note 1)	±0.03 mmho.cm	±0.02°C	±0.25% of full scale
Output Signal Frequency	4,995-7901 Hz	2,127-4193 Hz	9712-11,288 Hz
Resolution	0.0001 mmho/cm	0.0001°C	0.0002% FS
Time Constant	0.1 sec	0.35 sec	0.1 sec

Frame	
Dimensions	12 in (30.48 cm) dia x 16 in (40.64 cm) high
Weight	26 lb (11.8 Kg) in air; 18 lb (8.2 Kg) in water
Material	Stainless steel
Power Requirements	150 to 250 ma constant current at a minimum of 33 vdc plus cable drop, i.e., voltage = 33v + cable resistance x 0.25

Note: 1. Accuracy is based upon a 1-sigma distribution of errors, e.g., in a random sampling, the stated accuracy will occur approximately 67% of the time.

units, edited for bad values, and header information inserted, including local meteorological information. The data are then converted to NODC format.

Temperature and conductivity data measured by the Grundy 9021-G current meter are recorded along with the current speed and direction for each sampling interval. These data are processed the same way as the current data except for statistical editing.

4.3 CTD Field Program

CTD casts were taken twice at all current stations, once during slack before flood, and once during slack before ebb during current station deployment or recovery operations.

CTD transects were conducted to follow the progression of the tidal wave in order to examine the water density structure of the survey area at the two extremes of the tide. CTD transects consist of casts taken at preselected current station locations (or special CTD cast stations denoted by "SP") forming a line either crossing the Bay or along the longitudinal axis of the Bay. All transects were conducted during slack water before flood and again during slack water before ebb. CTD transect locations and dates are given in table 4.

Table 4. Chesapeake Bay Circulation Survey CTD Transects

Year	Transect Number	Current/CTD Stations	Month
1981	1	1, 2, 3, 4, 5	September
	2	2, SP202, 13, SP213, 20, 33, 36	October
	3	8, 9, 10, 11, SP211	October
	4	19, 20, 21, 22, 23	October, November
	5	6, 15, SP215, 24, 26	October
1982	1	63, 64, 65, 66, 67, 68	April, May, July
	2	37, 38, 39, 40, 41, 42	May, June
	3	40, 44, 55, 58, 65, 75, 80, 83, 2	October
1983	1	154, 153, 161, 162, 152, 15	September
	2	SP211, SP212, 139, SP213, SP214	September
	3	127, SP209, 128, SP210	September
	4	119, SP207, 120, SP208, 121	September
	5	SP202, SP203, SP204, SP205, SP206	September
	6	100, SP201, 101, 170	September
	7	100, 101, 170, 102, 103, 104	November
	8	105,104, 103, 102, 111, 112	September

Data from 13-hour time series CTD casts will be used to investigate the tidal influences on the density structure and the influence of the density structure on the circulation. Each series consists of half-hourly casts from the surface to near bottom depths at one location.

CTD time series casts were taken as follows:

Year	Current (CTD) station	Month/Day
1981	10	September 17
	36	September 21, 22
	2	September 22, 23, 25
	6	September 30
		October 14, 15
1982	65	April 13, 14, 28
		June 7, 8, July 21, 22
	40	May 23, 24, June 3, 4
	49	June 16, 17
	73	August 9, 10
	83	October 14, 15
	86	November 1, 2
1983	36	September 11, 12
	121	September 12, 13
	139	October 13, 14

CTD stations are the same as current stations except where indicated by the letters "SP" before the station number. The locations of these stations are presented in figures 6 through 9.

5.0 METEOROLOGICAL DATA

5.1 Measurement Instrumentation and Processing

The meteorological data were collected by self-contained Aanderaa meteorological stations, which consist of a six-channel data logger and a program wiring board housed in a base cabinet. Wind speed and direction sensors were mounted at 7 to 13 meters above the water surface, temperature sensors on mast arms below that, and the pressure sensor within the base housing.

All sensors transmit analog signals to the data logger via the programming board. The Aanderaa data logger, which is powered by an internal 9-volt battery, digitized the analog signals to 10-bit binary words and stored them on 1/4-inch reel-to-reel magnetic tape. Additional batteries were provided via connector ports on the programming board to insure proper operation of the data logger for longer operating periods. The first channel of the data logger is reserved for the reference number of the data logger, and the remaining channels are available for data input. The data loggers are programmed by internal quartz-crystal clocks at selectable sampling intervals.

The wind speed sensor is a three-cup anemometer which measures averaged and maximum wind speed. The direction sensor consists of a vane which is coupled to a compass with a potentiometer ring in the sensor housing. At the time of recording, the compass is clamped and the direction reading is recorded as the potentiometer setting. The temperature sensor is a platinum thermal resistor, and the barometric pressure sensor is an aneroid barometer. The manufacturers specifications for the Aanderaa Meteorological System are listed in table 5.

Throughout the study period, all data loggers were set at a sampling rate of six observations per hour. The time series data sets include time averaged wind speed and instantaneous readings of wind direction, air temperature, barometric pressure, and the maximum wind speed observed during the sampling period.

5.2 Meteorological Stations

As described by Wang (1979), wind forcing has a significant effect on the overall circulation of the Chesapeake Bay. He observed that a strong wind speed at a prevailing direction can totally override tidal and density induced circulation patterns in the Bay.

The need for high quality wind data was considered sufficiently critical to have two Aanderaa Meteorological stations deployed during each phase of the survey. Station locations, vertical position and duration of observations are indicated in table 6. Station locations are also indicated in figures 10-12.

Table 5. Manufacturer's Specification for Aanderaa Meteorological System (Welch et al, 1985)

Weight

Recording unit: 4 kg

Dimensions

Recording unit length: 38 cm
Recording unit diameter: 14 cm
Housing: 1 m x 25 cm x 25 cm
Wind sensors at 10 m above water.

Materials

Data logger: PVC plastic, nickel plated, bronze, acrylic.
Mast and housing: aluminum

Measuring Ranges and Accuracies

Wind speed: threshold 30-50 cm/sec ±2% of full scale.
Direction: 0-360° ±5° magnetic
Temperature: -44.05-44.09°C ±0.25°C
Pressure: 720-1070 mbar ±0.67% of full scale.

Measuring System

Rotary encoder system with sequential measuring of 6 channels by self-balancing bridge. Bridge is balanced in ten binary steps and gives a 10-bit binary word for each channel.
Measuring speed: 4.0 sec/channel
The channels are: Reference number, Average Speed, Maximum Speed, Direction, Temperature, Pressure.

Recording System

Serial recording of 10-bit binary words on 0.6 cm magnetic tape by use of short and long pulses. Total storage capacity: 5,000 samplings
Tape: 183 m on 7.6 cm spool

Clock

Accuracy: ±2 sec/day over temperature range 0-20°C.

Sampling Intervals

180, 60, 30, 20, 15, 10, 5, 2.5, 1, and 0.5 min according to interval selected.

External Triggering

Is possible by applying a 6 volt positive pulse to programming board.

Batteries

Main battery: Tudor 9T1 or similar battery (9 volt battery 63 x 50 x 80 mm, nonmagnetic).

Table 6. METEOROLOGICAL STATION INDEX

1981

STATION	LAT.	LONG.	H.T. ABOVE SURFACE (M)	START	STOP	DAYS OF OBSERVATIONS
Point Lookout	38°01'36"	76°19'18"	11.0	09/03	10/04	31
				10/04	11/05	32
				11/05	12/02	27
Holland Island Bar Light	38°04'06"	76°05'48"	10.5	08/29	10/04	36
				10/04	11/05	32
				11/05	12/02	27

1982

STATION	LAT.	LONG.	H.T. ABOVE SURFACE (M)	START	STOP	DAYS OF OBSERVATIONS
York Spit	37°12'36"	76°15'18"	10.0	05/21	06/14	24
				06/14	07/10	26
				07/10	08/12	33
				08/12	09/07	26
				09/07	10/02	35
				10/02	11/08	27
				11/08	11/24	16
Windmill Pt.	37°35'48"	76°14'12"	13.0	05/17	06/14	28
				06/14	07/10	26
				08/08	09/07	30
				09/07	09/27	20

1983

STATION	LAT.	LONG.	H.T. ABOVE SURFACE (M)	START	STOP	DAYS OF OBSERVATIONS
Pooles Island	39°15'42"	76°16'42"	10.0	03/19	04/14	26
				04/14	05/10	26
				05/10	06/02	23
				06/02	07/05	33
				07/05	08/01	27
				08/01	08/31	30
				08/31	09/14	14
				10/31	11/22	22
				11/22	12/02	10
Herring Bay	38°44'21"	76°30'50"	7.0	03/15	04/18	34
				04/29	05/26	27
				05/26	06/17	22
				06/17	07/12	25
				08/09	08/25	16
				08/25	08/26	01
				08/26	08/30	04
				10/18	11/08	21
				11/08	12/01	23

6.0 TIDE DATA

6.1 Instrumentation and Processing

Two types of tide gages were used during the Chesapeake Bay circulation survey: an ADR (Analog-Digital-Recorder) and a Bubbler (gas purged). The specifications for these gages are given in table 7.

The ADR gage records every 6 minutes on foil-backed paper tape, which is processed using a mechanical translator and computers. The steps in processing are generally: (1) logging the 6-minute samples on computer-compatible magnetic tape; (2) deriving hourly values from these (by picking the nearest 6-minute value to the hour) and storing them on cards and tape and in tabulated form; and (3) tabulating high and low waters, various tidal datums (e.g., mean high water, mean low water, and mean sea level), and other relevant parameters.

The bubbler gage produces a continuous analog plot on a 6-inch strip chart. Resolution is not as good as with the ADR and generally only high and low waters and various tidal datums are tabulated. Hourly values are sometimes determined for special needs using a bubbler marigram scanner, which digitizes the data at visually selected points.

Processed monthly tabulations (high and low waters and tidal datums) from each station are verified for staff-marigram relationship, and equivalent 19-year mean values are computed through simultaneous comparison with the appropriate tide control station. Tidal bench mark elevations are established by referencing these bench marks to the computed tidal datums. New elevations for historical bench marks are used to check any vertical land movement that may have occurred. The relationships between tidal datums and the National Geodetic Vertical Control

Table 7. Manufacturer's Specifications for the ADR and Bubbler Tide Measurement Systems

ADR (Analog-Digital Recorder)

Manufacturer: Fischer - Porter
Range: 0-99.99 feet
Precision: ± 1/2 binary count
Recorder: Foil-backed paper tape (punch)
Record Format: Binary - decimal code
Sampling Rate: 6-minute intervals
Duration: Chart - 3 months
Chart drive, battery - 3 months
Processing: Mechanical translator
Mode of Operation: Float movement is translated into binary code and recorder on paper tape.

Bubbler (Gas Purged)

Manufacturer: Bristol
Range: 0-10 feet to 0-50 feet
Precision: 1 percent of full scale
Recorder: 6-inch strip chart
Record Format: Analog, curvilinear
Sampling Rate: Continuous
Duration: Chart - 1 month
Chart drive, spring wound - 8 days
Processing: Visual
Mode of Operation: Compressed nitrogen is purged through the system, actuating a pressure-sensitive element, which measures water level fluctuations.

Network are also computed when level connections can be made to geodetic bench marks.

Tide data are further analyzed using: (1) 29-day Fourier harmonic analyses; (2) least-squares harmonic analyses (for 1-year series); (3) nonharmonic comparison analyses relating a short period station to a longer period control station; (4) various filtering and spectral techniques; and (5) FR80 microfilm plotting. The harmonic constants obtained from item (2) can be used to make predictions for table 1 of the Tide Tables, East Coast of North and South America including Greenland. Results from items (1), (2), and (3) can be used in table 2 of this same publication.

6.2 Tide Stations

The locations of tide gages occupied during the Chesapeake Bay circulation survey are shown in figures 10 through 13; table 8 gives the latitude and longitude and dates of occupation of each tide station. All stations were occupied for at least 30 days and some were in place for one or more years. The shorter period tide stations were usually installed simultaneously with nearby current stations.

Tide stations were installed by the NOAA Ship FERREL. Before a tide gage was installed, a reconnaissance of the proposed site was carried out to determine the availability of structures for the gage, water depth, the recovery of old bench marks, and possible sites for new bench marks. During installation, differential levels were run from the tide staff to established bench marks and, whenever possible, to the National Geodetic Vertical Control Network.

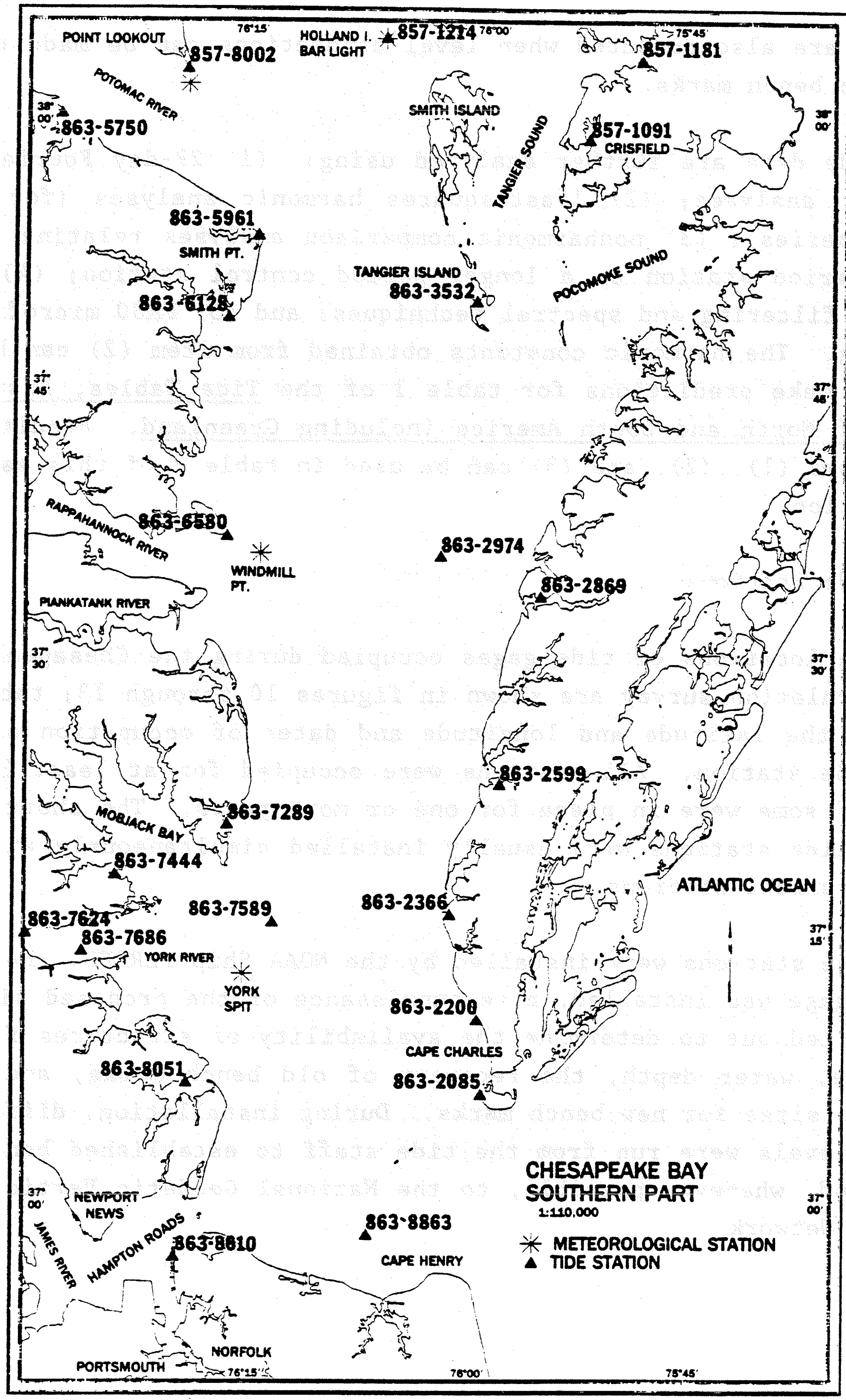

Figure 10. Tide and Meteorological Stations - Phase II Area

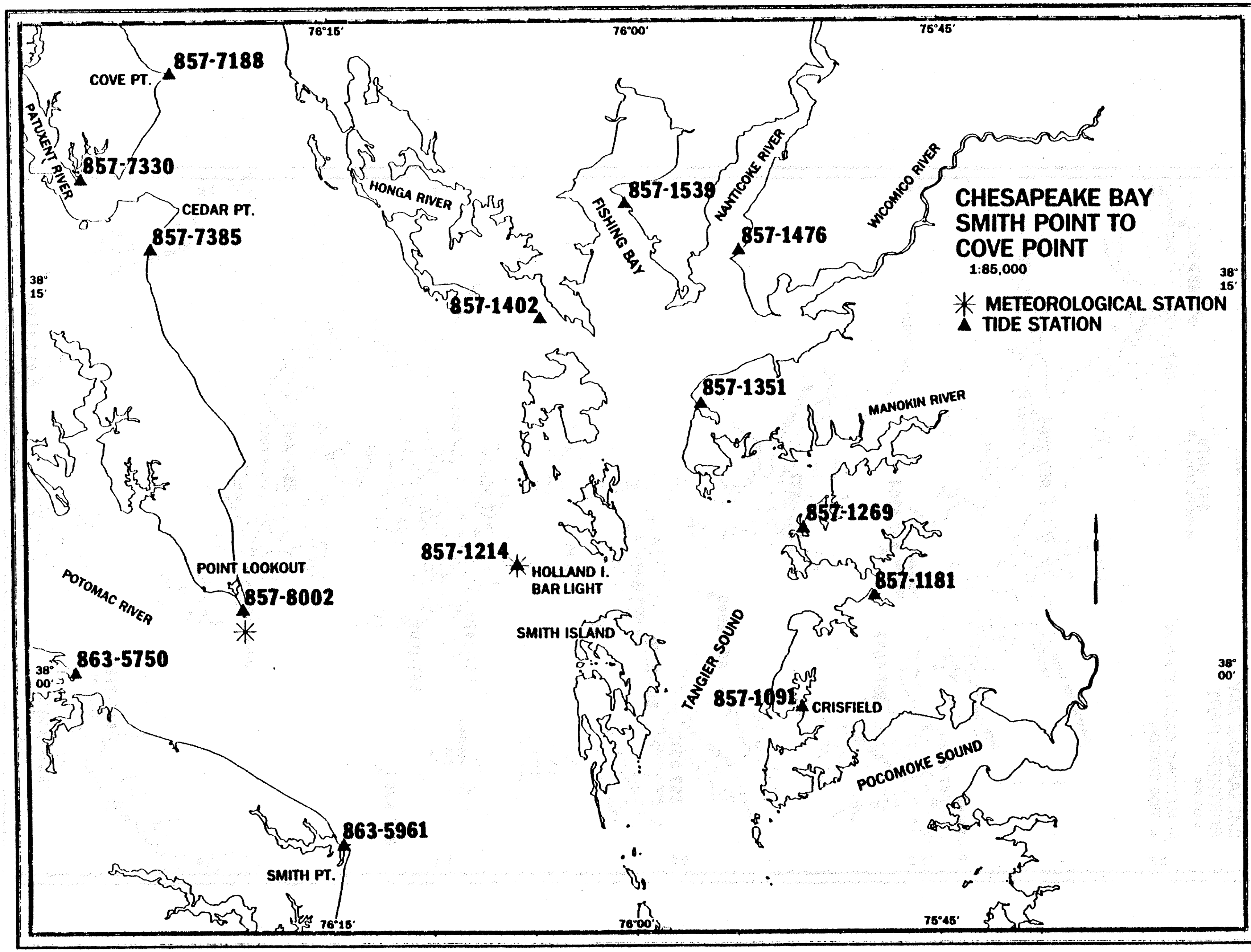

Figure 11. Tide and Meteorological Stations - Phase I Area

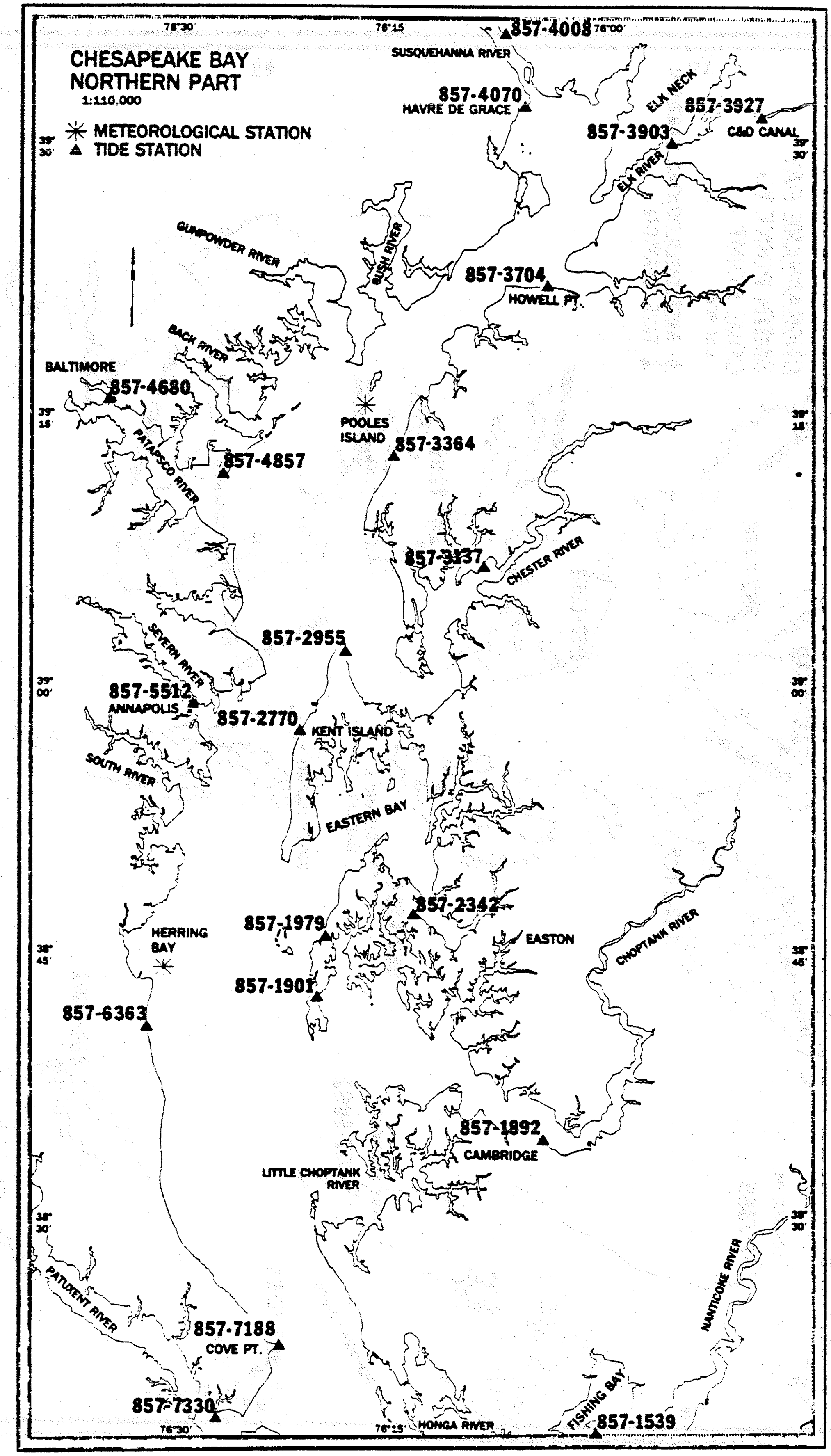

Figure 12. Tide and Meteorological Stations - Phase III Area

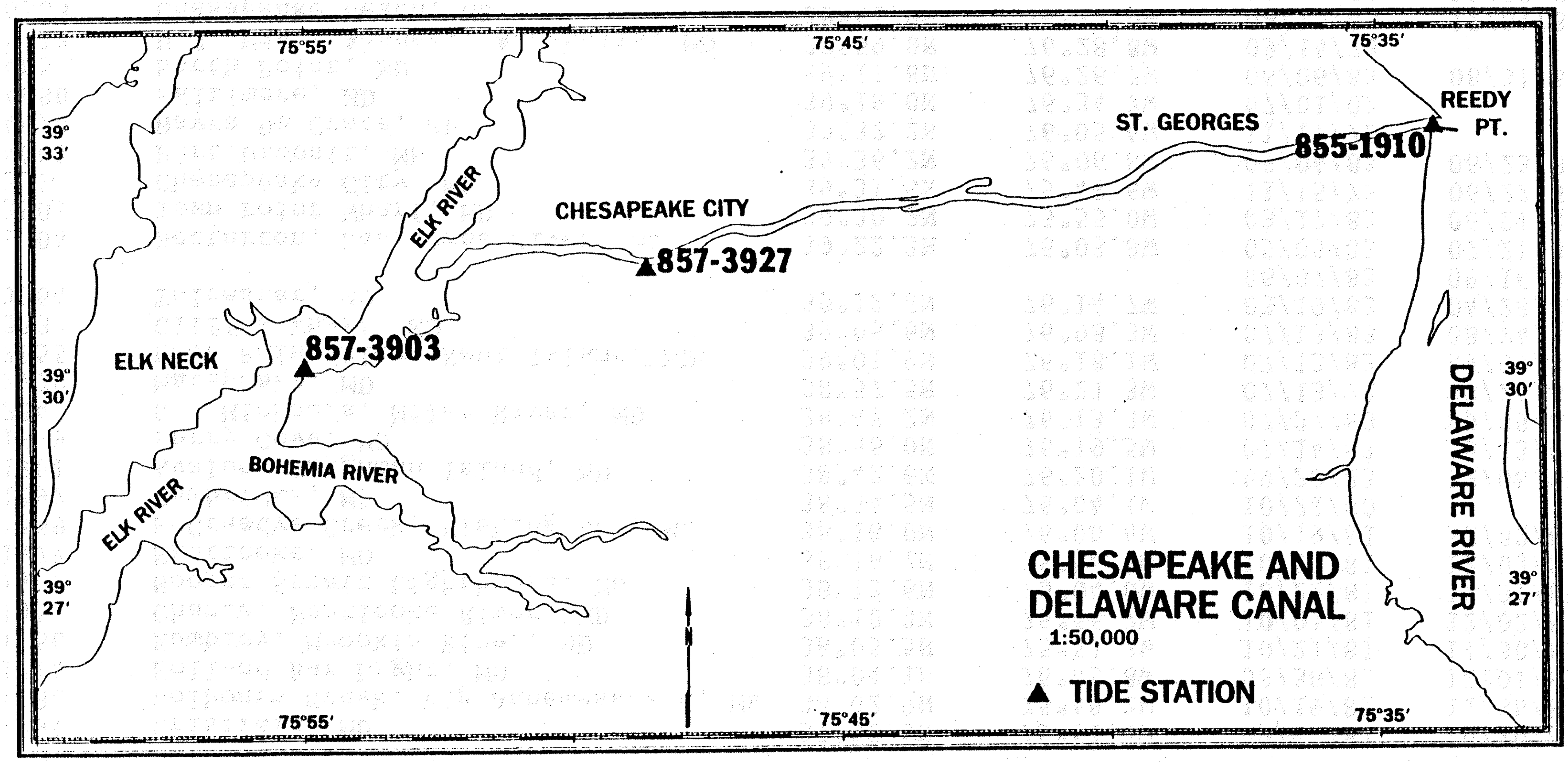

Figure 13. Tide and Meteorological Stations - Phases III Area - Continued

Table 8. INDEX OF TIDE STATIONS

Station ID Number	Tide Station Name	Latitude	Longitude	*Install Date	*Removal Date
8571091	Crisfield, MD	37°58.6N	75°51.8W	09/01/81	10/20/81
8571181	Colbourn Creek, Big Annemessex R, MD	38°02.9N	75°48.2W	10/19/81	11/30/81
8571214	Holland Bar Light, MD	38°04.1N	76°05.8W	08/30/81	12/01/81
8571266	Rumbley, Manokin River, MD	38°05.5N	75°51.7W	10/21/81	11/30/81
8571351	Chance, Nanticoke River, MD	38°10.3N	75°56.7W	10/01/81	12/02/81
8571402	Hooper Strait Lighthouse, MD	38°13.6N	76°04.6W	10/22/81	12/01/81
8571477	Nanticoke, MD	38°16.2N	75°54.8W	10/21/81	12/03/81
8571559	McCreadys Creek, Fishing Bay, MD	38°18.0N	76°00.4W	10/19/81	12/02/81
8571892	Cambridge, MD	38°34.5N	76°04.1W	10/21/80	
8571901	Avalon, Tilghman Island, MD	38°42.6N	76°20.1W	09/28/83	12/08/83
8571979	Ferry Cove, MD	38°46.0N	76°19.5W	07/14/83	10/13/83
8572342	St. Michaels, Miles River, MD	38°47.2N	76°13.3W	07/27/83	09/09/83
8572770	Matapeake, MD	38°57.5N	76°21.3W	07/13/72	08/24/84
8572955	Love Point Pier, Kent Island, MD	39°01.9N	76°18.1W	07/13/83	09/09/83
8573137	Cliff's Wharf, MD	39°06.6N	76°08.3W	07/13/83	08/24/83
8573364	Tolcester, MD	39°12.8N	76°14.7W	03/19/83	04/28/83
				06/07/83	09/16/83
8573704	Betterton, Sassafras River, MD	39°22.3N	76°03.8W	05/05/83	07/21/83
8573903	Town Point Wharf, MD	39°30.2N	75°55.0W	03/17/83	06/21/83
8573927	Chesapeake City, MD	39°31.6N	75°48.6W	11/15/72	06/22/83
8574008	Port Deposit, MD	39°36.2N	76°06.8W	05/04/83	06/23/83
8574070	Havre De Grace, MD	39°32.2N	76°05.4W	11/17/72	
8574680	Baltimore, MD	39°16.0N	76°34.7W	07/01/02	
8574857	North Point, MD	39°11.8N	76°26.7W	06/06/83	08/31/83
8575512	U.S. Naval Academy, Annapolis, MD	38°59.0N	76°28.8W	09/14/78	
8576363	Chesapeake Beach, MD	38°41.0N	76°32.0W	08/15/83	12/01/83
8577188	Cove Point, MD	38°23.1N	76°22.9W	10/12/83	12/02/83
8577330	Solomons Island, MD	38°19.0N	76°27.2W	11/05/37	
8577385	Navy Seaplane Basin Boathouse, MD	38°16.3N	76°23.8W	08/28/81	12/03/81
8578002	Point Lookout, MD	38°02.4N	76°19.4W	10/05/81	12/04/81
8632085	Fishermans Island, VA	37°05.8N	75°59.0W	03/16/82	11/22/82
8632200	Kiptopeke Beach, VA	37°10.0N	75°59.3W	08/22/51	

Table 8. INDEX OF TIDE STATIONS - continued

Station ID Number	Tide Station Name	Latitude	Longitude	*Install Date	*Removal Date
8632366	Cape Charles HBR (U.S. G. Wharf) VA	37°15.8N	76°01.2W	03/16/82	07/12/82
8632599	Mattawoman Creek, VA	37°23.3N	75°57.8W	03/16/82	12/09/82
8632869	Gaskins Pt., Occohannock Creek, VA	37°33.4N	75°55.0W	07/12/82	09/02/82
8632974	Rappahannock Shoal, VA	37°35.6N	76°01.9W	06/24/83	10/31/83
8633532	Tangier Island, VA	37°49.7N	75°59.5W	08/27/81	10/30/81
8635750	Lewisetta, Potomac River, VA	37°59.8N	76°27.8W	10/20/70	
8635961	Smith Point, VA	37°53.3N	76°14.5W	08/26/81	10/17/81
				10/06/82	11/22/82
8636128	Fleet Pt. Great Wicomico River, VA	37°48.8N	76°16.5W	07/26/82	11/21/82
8636580	Wind Mill Marina, VA	37°36.7N	76°16.5W	03/10/82	09/29/82
				04/21/83	10/31/83
8636581	Windmill Point, VA (Backup)	37°36.9N	76°18.1W	06/28/83	10/31/83
8637289	New Point, VA	37°20.8N	76°16.4W	03/09/82	11/24/82
8637444	Browns Bay, Mobjack Bay, VA	37°18.0N	76°24.0W	06/08/82	07/20/82
8637589	New Pt. Comfort Shoal, (Backup), VA	37°15.4N	76°13.3W	05/29/81	09/10/81
8637624	Gloucester Point, VA	37°14.8N	76°30.0W	05/16/50	
8637686	Yorktown, York River, VA	37°13.8N	76°26.2W	06/07/82	07/27/82
8638051	Messick Point, Back River, VA	37°06.5N	76°19.1W	06/05/82	07/12/82
8638610	Hampton Roads, Sewells Point, VA	36°56.8N	76°19.9W	07/01/27	
8638863	Chesapeake Bay Bridge Tunnel, VA	36°58.0N	76°06.8W	01/26/76	

* Installation and removal dates do not imply continuous good data or the actual length of the data series.

7.0 HISTORICAL DATA

7.1 Current Data

The NOS has collected current data in the Chesapeake Bay and its tributaries since the early 1900's. The early surveys were designed to fulfill specific requirements for relatively small areas. Not until the 1981-1983 survey was there a systematic survey of the entire Bay. Duration of observations for the early stations was generally 1 to 5 days. The instruments used were primarily current poles, Price current meters, and Roberts radio current meters. The resulting data records were processed and analyzed manually. The records are archived at NOS in the form of hand plotted time series graphs.

Information concerning historical methods of current measurement can be found in Manual of Current Observations, U.S. Coast and Geodetic Survey, S.P. 215, 1950. Predictions and mean values for some of these historical current stations can be found in Tidal Current Tables, Atlantic Coast of North America, published by NOS.

Historical data may be obtained by writing NOAA/NOS, Director, Office of Oceanography and Marine Assessment, 6001 Executive Boulevard, Rockville, Maryland 20852.

7.2 Tide Data

In contrast to historical current data, the historical tide data set is rather extensive. Although some records date prior to 1900, the major efforts in tide measurement occurred in the mid-1940's, mid-1950's and mid-to late 1970's. The duration of observations range from 2 weeks to several months to 1 year for subordinate tide stations and decades for control tide stations. Clock-wound portable and standard automatic tide gages, and gas-purging pressure gages were the tide measurement instrumentation used in efforts prior to the surveys of the 1970's.

The 1981-1983 Chesapeake Bay circulation survey tide data acquisition effort gave NOS and users simultaneous tide measurements with current measurements and updated tide predictions and tidal datums in the Bay.

Descriptions of historic tide measuring devices can be found in Manual of Tide Observation, U.S. Coast and Geodetic Survey, Pub. 30-1, 1965, or in Tidal Datum Planes, U.S. Coast and Geodetic Survey, S.P. 135, 1951. Predictions and mean ranges for some of these historical tide stations can be found in Tide Tables, East Coast of North and South America Including Greenland, published by NOS.

These data may be obtained by writing NOAA/NOS, Director, Office of Oceanography and Marine Assessment, 6001 Executive Boulevard, Rockville, Maryland 20852.

8.0 NOS PRODUCTS

Standard NOS products resulting from the Chesapeake Bay circulation survey includes the updating of predictions for table 1 entries of the Tide and Tidal Current Tables, Atlantic Coast of North America. Predictions for the reference current station at the entrance of the Bay (sta. 40) will be updated from analysis of approximately 11 months of data. The old reference station "Baltimore Harbor Approach" is being replaced as a reference current station by current station No. 121 located off Kent Island in the Bay proper. Predictions for this reference station will be based on analysis of approximately 8 months of data.

Table 2 entries in the tide and tidal current tables will be increased in number and upgraded from analyses of data series much more accurate and of longer duration than of observations obtained at these station entry sites in the past. These analyses tied in with updated predictions for the two reference stations will provide for a dramatic increase in the accuracy of the tide and tidal current predictions throughout the Bay proper.

An NOS technical report describing the tidal hydrodynamics of the Chesapeake Bay based on the data set from the circulation survey is forthcoming.

A circulation atlas describing the total current regime in the Chesapeake Bay is proposed to be published. It will describe the circulation of the Bay in response to astronomical conditions, water density changes, and changing climatic conditions. The date of publication has not yet been established.

The entire data set, except tide data, was sent to and is available from the National Oceanographic Data Center, Page Building #1, 2001 Wisconsin Avenue, N.W., Washington, D.C. 20235. Tide data may be obtained from the Director, Office of Oceanography and Marine Assessment 6001 Executive Boulevard, Rockville, Maryland 20852.

ACKNOWLEDGEMENTS

The largest and most thorough circulation survey data set ever obtained in the Chesapeake Bay was secured through the professional efforts of the officers and crew of the NOAA Ship FERREL under the successive commands of Cdr. Donnie Spillman and Cdr. Kurt Schnebele.

Special thanks goes to Messrs. Fred Ganjon, Richard Hogan and Kenny O'Dell of the Automated Cartographic Production Group. The charts of Chesapeake Bay, with and without station plots, were constructed in an expeditious and professional manner, through the willingness of Messers. Ganjon and Hogan to share their resources and the special talents of Mr. O'Dell.

Members of the Office of Oceanography and Marine Assessment who contributed to the planning and office direction of the three phase circulation survey in the Chesapeake Bay are Dr. Bruce Parker, Messrs. David Browne and Richard Patchen, and Lt. Gary Petrae.

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