NOAA Technical Memorandum NOS OES

EFFECTS OF THE JANUARY 1992 ATLANTIC OCEAN COASTAL STORM ON WATER LEVELS

DATA REPORT

MAY 1992

OCEAN AND LAKE LEVELS DIVISION
OFFICE OF OCEAN AND EARTH SCIENCES
NATIONAL OCEAN SERVICE
ROCKVILLE, MARYLAND 20852

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ACKNOWLEDGEMENTS

This report was prepared by Stephen K. Gill and Dale H. Deitemyer, Tidal Analysis Branch, Ocean and Lake Levels Division. It represents the cumulative efforts of Atlantic Operations Section personnel stationed in Chesapeake, VA, and headquarters personnel of the Ocean and Lake Levels Division located in Rockville, MD, who are responsible for operating and maintaining the tide stations, and for the priority collection, processing and analysis of data and information.

EFFECTS OF JANUARY 1992 ATLANTIC OCEAN COASTAL STORM ON WATER LEVELS

DATA REPORT

I. INTRODUCTION

This report documents the water levels observed during the formation and decay of the early January 1992 coastal storm that severely affected the coastal areas of Virginia, Delaware, Maryland, and New Jersey.

The Ocean and Lake Levels Division (OLLD), Office of Ocean and Earth Sciences (OES), National Ocean Service (NOS) operates and maintains water level measurement stations; collects, processes, and analyzes data; and produces standard time series and water level datum products. The OLLD operates the National Water Level Observation Network (NWLON), a network of approximately 200 long-term continuously operating stations in the U.S. coastal ocean, territories, and possessions, including the Great Lakes and their connecting channels and also installs, operates and maintains short term water level stations for various special projects for other federal and state agencies.

This report contains information from selected NWLON stations and special project stations in operation during the January 1992 coastal storm. The maximum water level heights recorded during the storm are reported and compared to the maximum historical water level heights observed over the period of record at each location. Storm surge, as defined in this report, is the difference between observed and predicted water level heights. Predicted water levels are computed using standard NOS harmonic analysis and tide prediction algorithms. The comparisons between predicted and observed water levels are presented in a set of time series plots. Characteristics of the response of water levels to the storm at each location are shown in this report as time series plots of the storm surge.

This storm had especially devastating effects on the open ocean coasts of Virginia, Maryland, Delaware and New Jersey. The center of the northward moving storm turned north-westward and made landfall on the Maryland and Delaware ocean coast on January 4, 1992. The water level measurement stations suffered varying degrees of damage during this particular storm from the high water levels and the high waves. The Ocean City tide station was completely destroyed when the offshore end of the Ocean City Pier on which it was located was destroyed. Other nearby stations had relatively minor damage.

Appendix 1 includes a copy of the National Weather Service (NWS) Weekly Series of Daily Weather Maps (January 2 through January 5, 1992) showing the daily progression of the storm event and includes a plot of the wind speed, wind gust and barometric pressure as recorded by the ancillary sensors at the Chesapeake Bay Bridge Tunnel tide station. Appendix 2 is a set of station location chartlets for each station listed.

II. MAXIMUM HEIGHTS AND DATUM RELATIONSHIPS

Table I includes the following information for the storm: the date, time and height of the maximum water level heights above Mean Lower Low Water (MLLW), Mean Higher High Water (MHHW), and National Geodetic Vertical Datum (NGVD); the date and height of the maximum historical water level heights above MLLW; and the Mean Great Diurnal Range (GT). The MLLW and MHHW datums are based on the 1960-78 National Tidal Datum Epoch. MLLW is the reference datum in tidal areas for NOAA nautical charts and the NOS published tide prediction tables.

The tides in this study area are classified semidiurnal; i.e two high waters and two low waters each tidal day. Although the inequality in the heights of the two high waters each tidal day and the inequality in the heights of the two low waters each tidal day are small, they can be significant in terms of storm surge (e.g., if the maximum storm surge coincides with a higher high water or a lower high water). The diurnal high water and diurnal low water inequalities in the study area range from 0.10 to 0.40 foot. The MHHW datum is the average of the higher high water heights observed each tidal day and MLLW is the average of the lower low water heights observed each tidal day. The mean Great Diurnal Range is the difference in height between MHHW and MLLW. Height comparisons to MHHW and the mean Diurnal Range of tide are provided to put the effects of this particular storm in context with the normal excursion of the tide from MLLW up to MHHW at each location.

The maximum historical values are based on the entire period of record for each location. These periods are quite different for each station. The maximum historical observed water height was exceeded at only one location (Wachapreague, VA). However, this station has a relatively short historical record of 13 years. The maximum heights during the storm were within 0.50 foot of the historical maximums at several of the longer operating stations (Lewes, DE (72 yrs.); Cape May, NJ (26 yrs.); and Lewisetta, VA (21 yrs.)).

TABLE I. MAXIMUM OBSERVED WATER LEVEL HEIGHTS AND HISTORICAL DATA COMPARISON

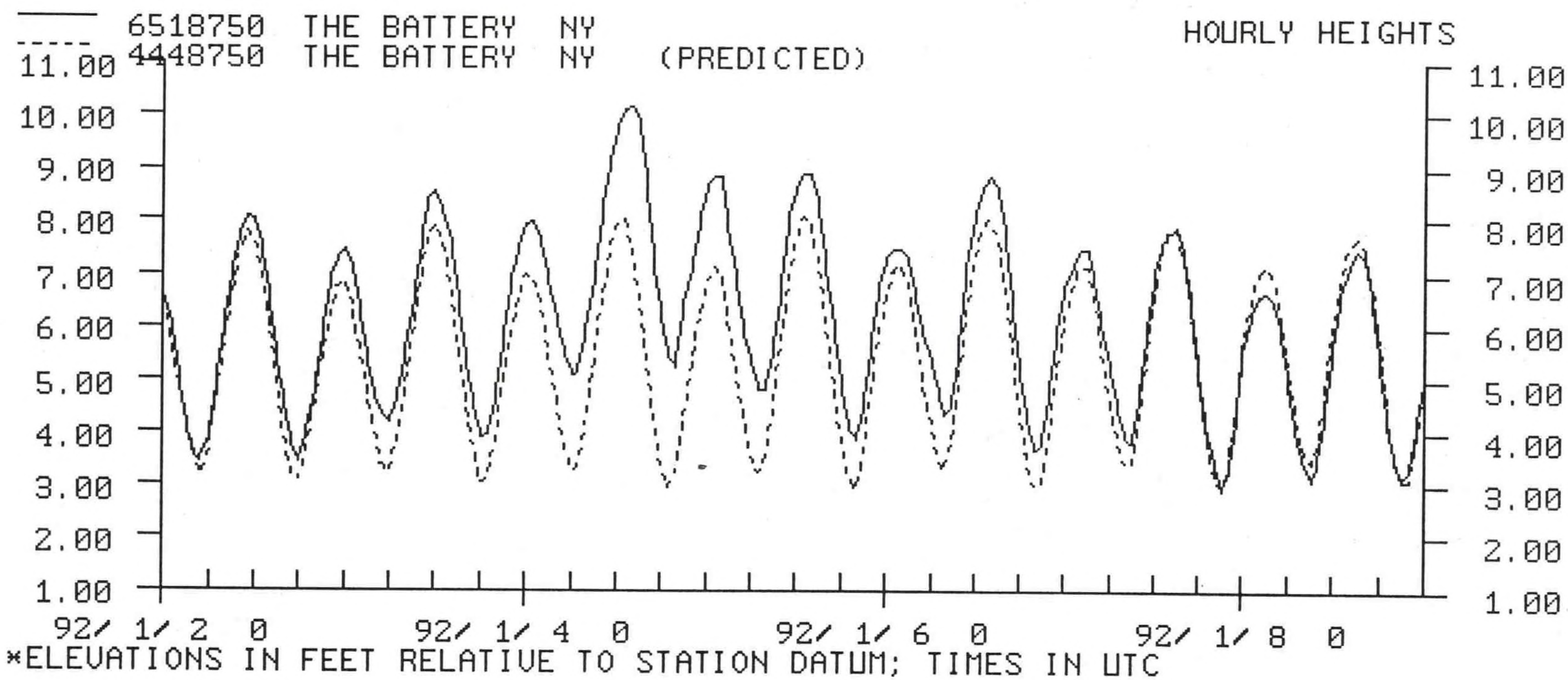
STATION	DATE/TIME (mon/day)	OBSERVED HIGHEST HEIGHT ABOVE MLLW	MHHW	NGVD	HISTORICAL HEIGHT ABOVE MLLW DATE (mon/yr)	HGT.	DIURNAL RANGE
The Battery, NY	1/4 0812	7.09	1.97	5.21	9/60	10.23	5.12
Sandy Hook, NJ	1/4 0730	7.48	2.28	5.71	3/62	10.33	5.20
Atlantic City, NJ	1/4 0730	7.18	2.50	5.54	9/44	9.20	4.68
Cape May, NJ	1/4 0806	8.82	3.31	6.82	9/85	9.09	5.51
Philadelphia, PA	1/4 1354	8.58	1.83	6.29	11/50	10.79	6.75
Lewes, DE	1/4 0748	9.02	4.29	7.30	3/62	9.49	4.73
Ocean City, MD	station destroyed				9/85	7.54	3.96
Baltimore, MD	1/4 2000	3.19	1.53	2.91	8/33	7.93	1.66
Annapolis, MD	1/4 1836	2.74	1.31	2.58	8/33	6.40	1.43
Solomons Is., MD	1/4 1112	3.44	1.93	3.09	8/55	4.53	1.51
Wachapreague, VA	1/4 0742	8.95	4.35	-	10/80	8.33	4.60
Kiptopeake, VA	1/4 0836	5.80	2.77	4.37	3/62	7.41	3.03
Colonial Beach, VA	1/4 1430	3.99	2.02	3.51	9/79	4.36	1.97
Lewisetta, VA	1/4 1218	3.50	1.97	3.22	3/83	3.62	1.53
Hampton Roads, VA	1/4 0900	5.31	2.51	4.14	8/33	8.39	2.80
Ches. Bay Brdg. Tun., VA	1/4 0618	5.59	2.64	-	4/78	6.36	2.95
Duck Pier, NC	1/4 0624	5.68	1.92	4.10	11/81	6.48	3.76
Cape Hatteras, NC	1/4 0712	5.09	1.56	3.73	9/85	5.84	3.53

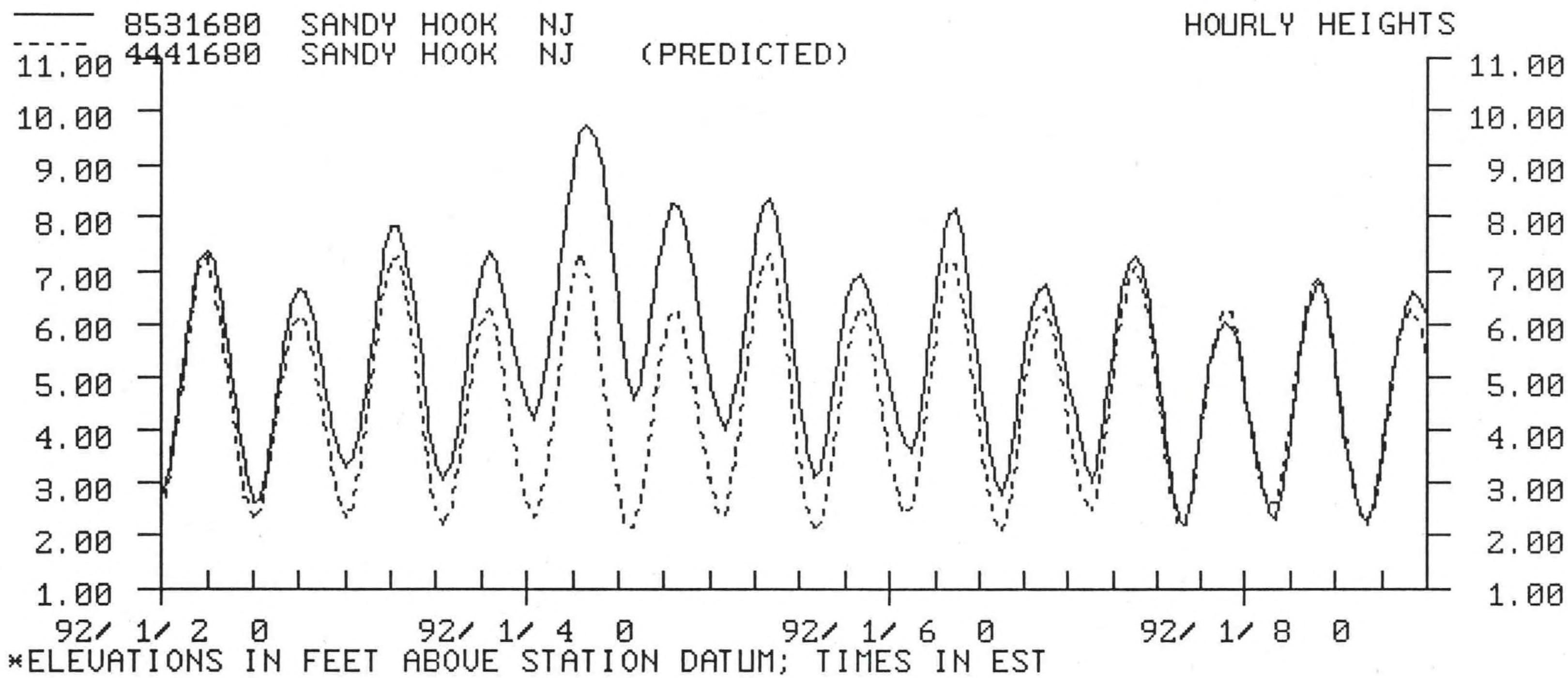
NOTES:
Heights are in feet; Times are in EST.

III. COMPARISON PLOTS: OBSERVED VS. PREDICTED

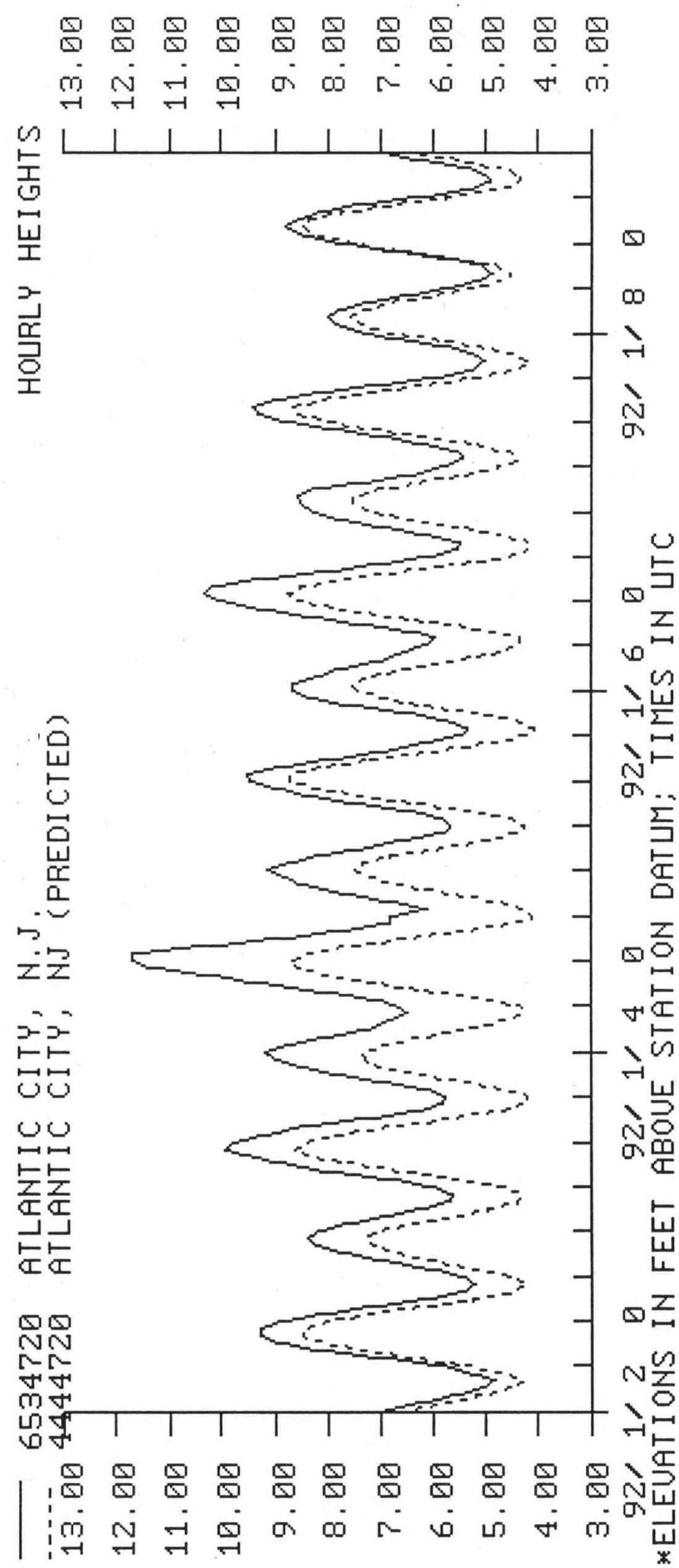
This section presents plots of the observed and predicted hourly height time series for each station from which the storm surge signatures in Section IV were derived. The effects of the timing and magnitude of the storm on the observed water levels are clearly seen when compared to the predicted water level. The reference datum and time zone are shown on each plot. EST is Eastern Standard Time; UTC is Universal Time Coordinates; and GMT is Greenwich Mean Time.

In most tidal areas, the maximum height is strongly tied to the timing of the storm relative to the phases of the tide. Storms that coincide with perigee and/or syzygy (new or full moon) will tend to have more devastating effects. This storm did occur around the time of the new moon (January 4), however the effects of stronger tide producing forces due to the new moon were partially mitigated by the phasing with apogee of the moon (moon furthest away in the monthly elliptical orbit) on January 6. The maximum storm surge effects coincided with the mid-day high tide on January 4.

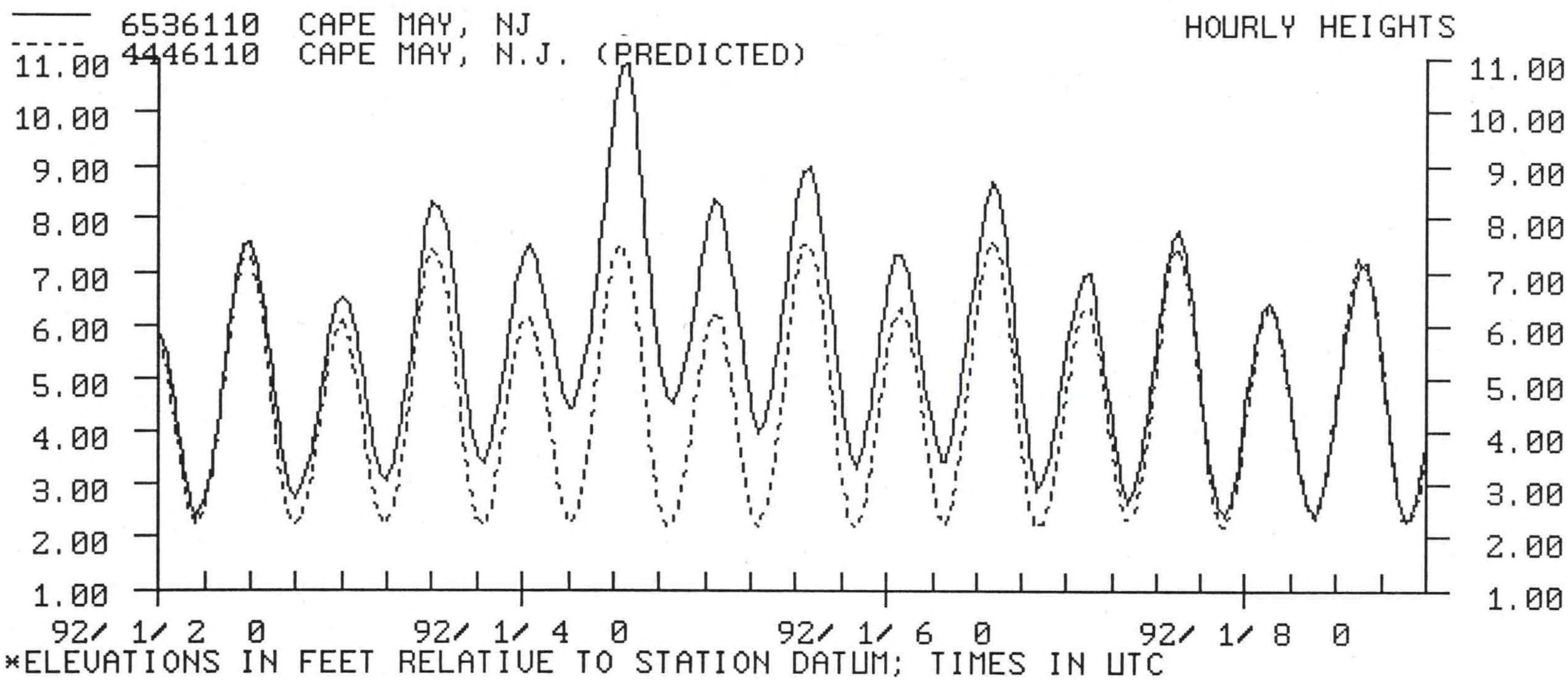

6518750 THE BATTERY NY
4448750 THE BATTERY NY (PREDICTED)
HOURLY HEIGHTS
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

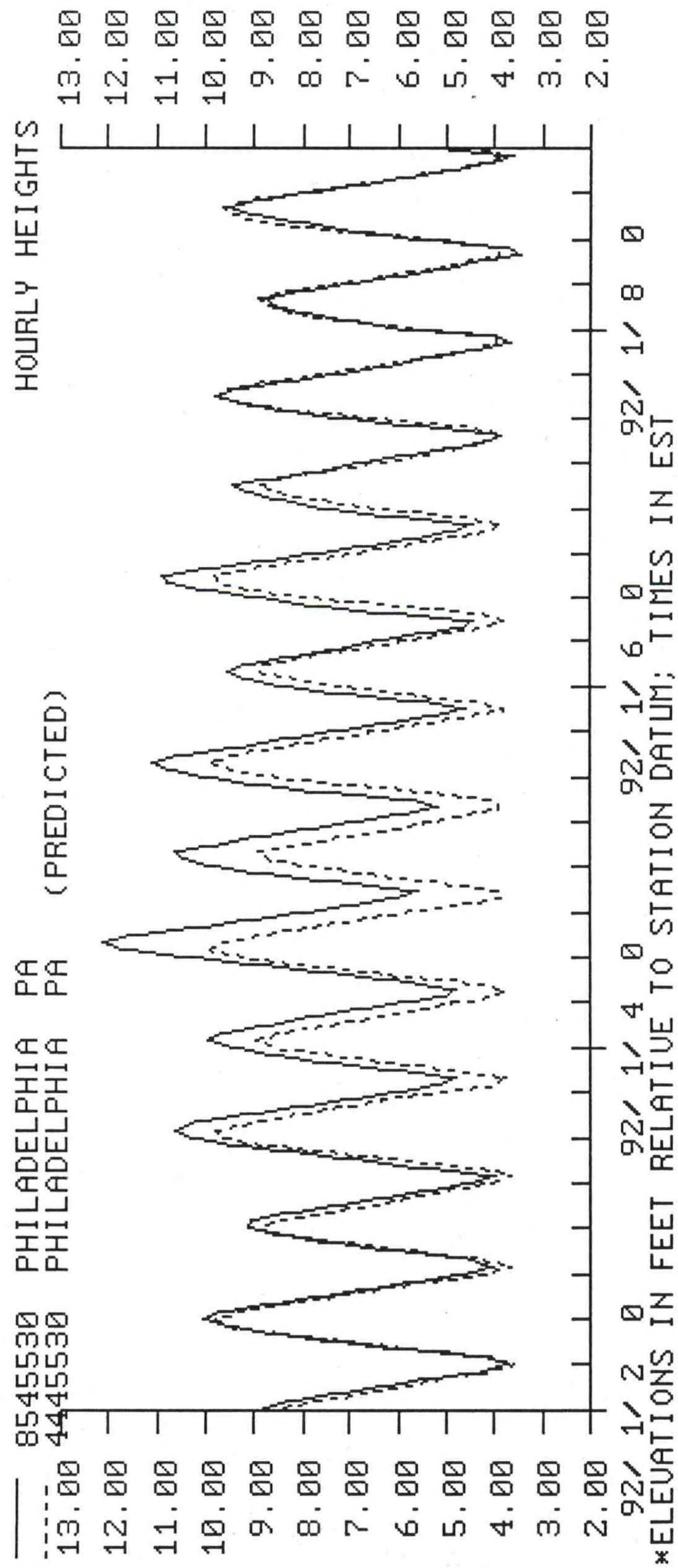


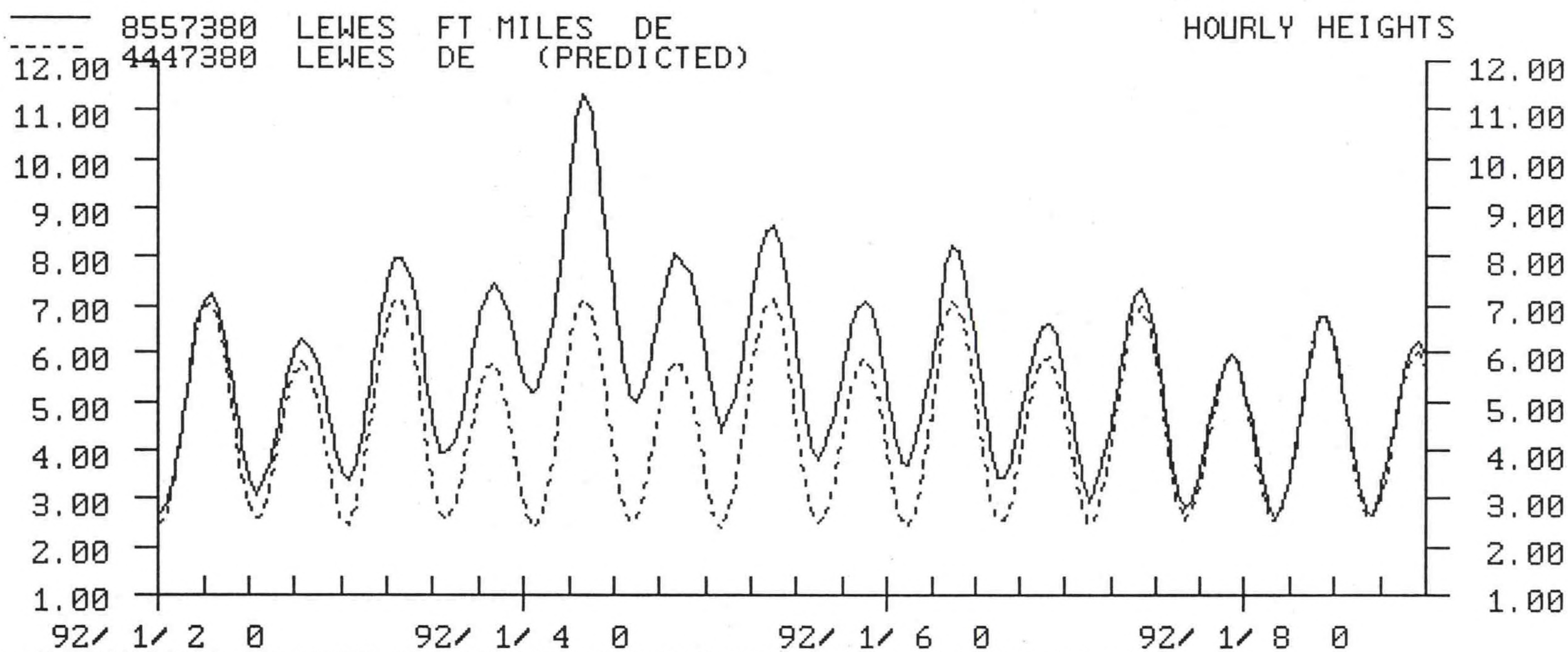
8531680 SANDY HOOK NJ
4441680 SANDY HOOK NJ (PREDICTED)
HOURLY HEIGHTS
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET ABOVE STATION DATUM; TIMES IN EST



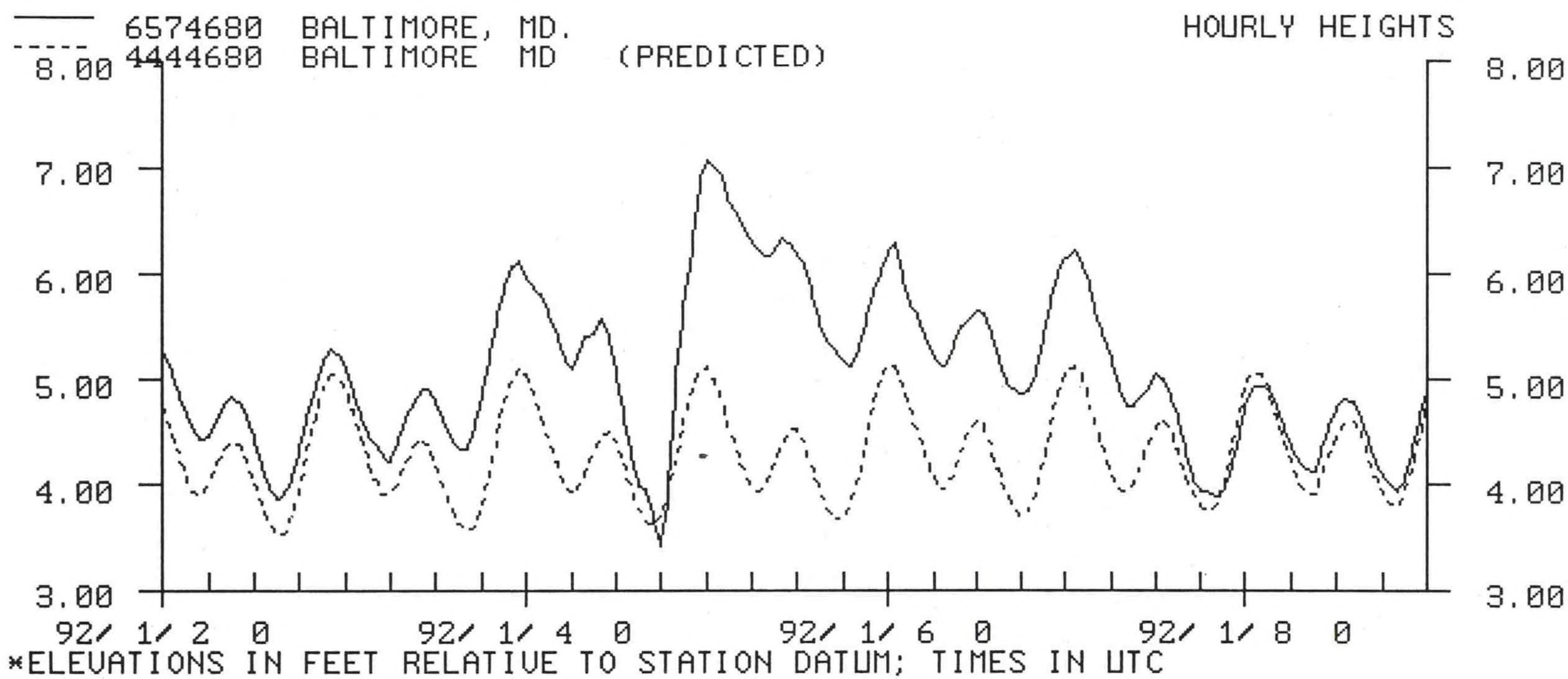
HOURLY HEIGHTS
6534720 ATLANTIC CITY, N.J.
4444720 ATLANTIC CITY, NJ (PREDICTED)
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET ABOVE STATION DATUM; TIMES IN UTC

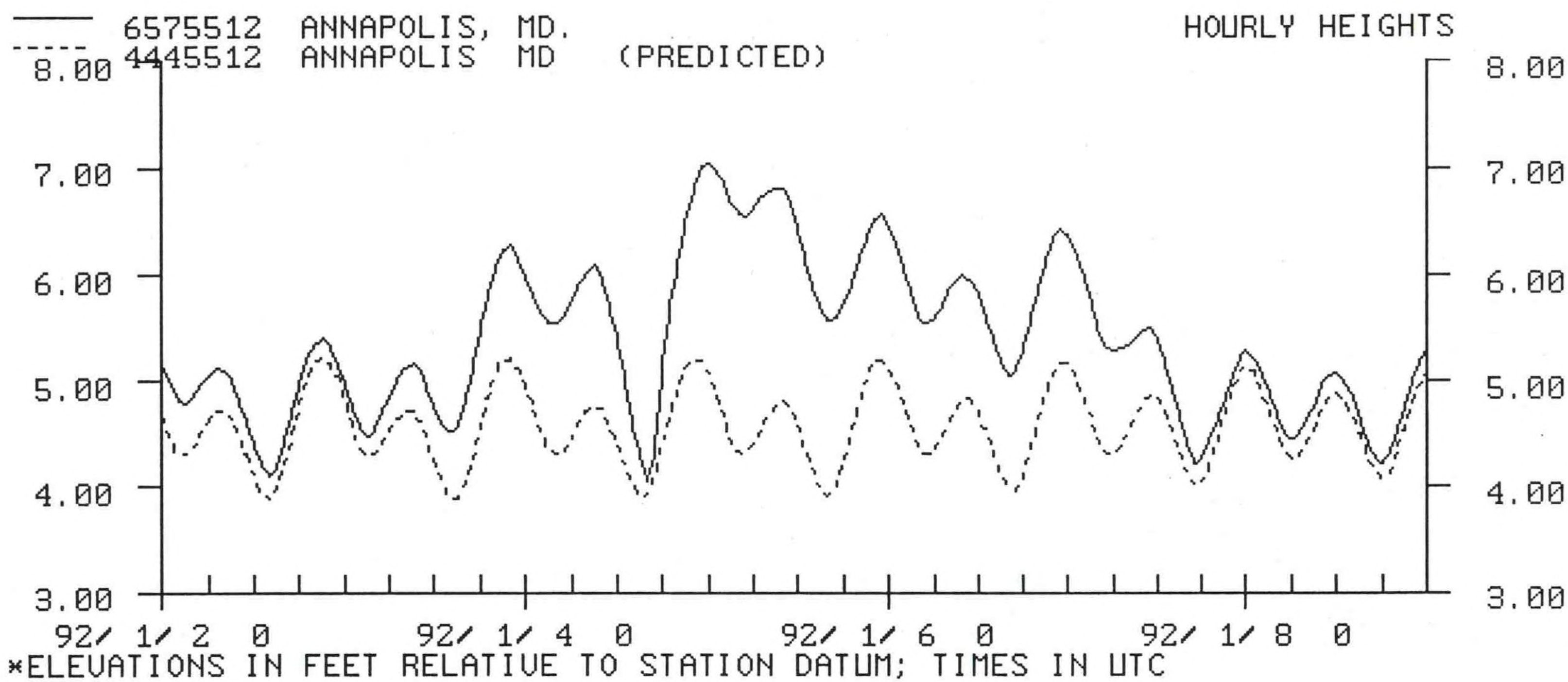

6536110 CAPE MAY, NJ
4446110 CAPE MAY, N.J. (PREDICTED)
HOURLY HEIGHTS
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

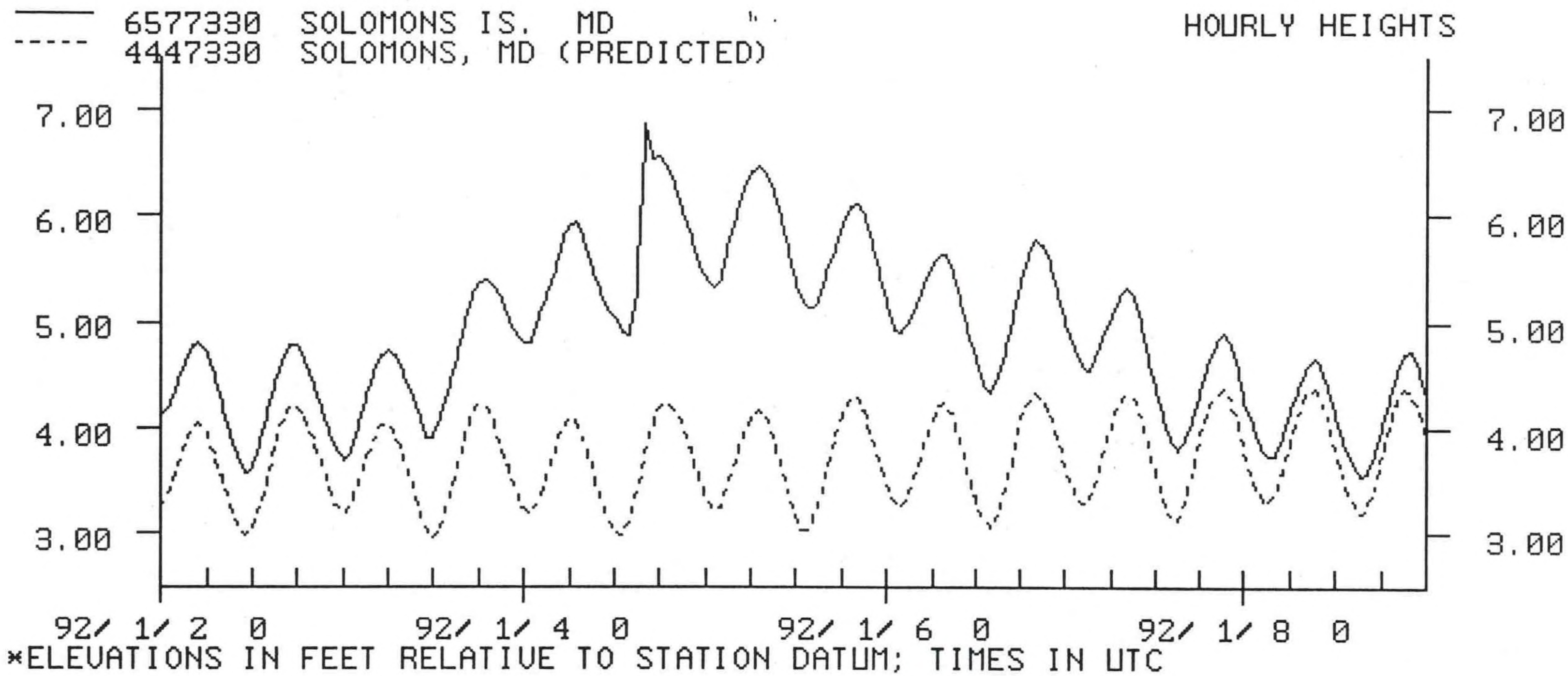

8545530 PHILADELPHIA PA
4445530 PHILADELPHIA PA (PREDICTED)
HOURLY HEIGHTS
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST

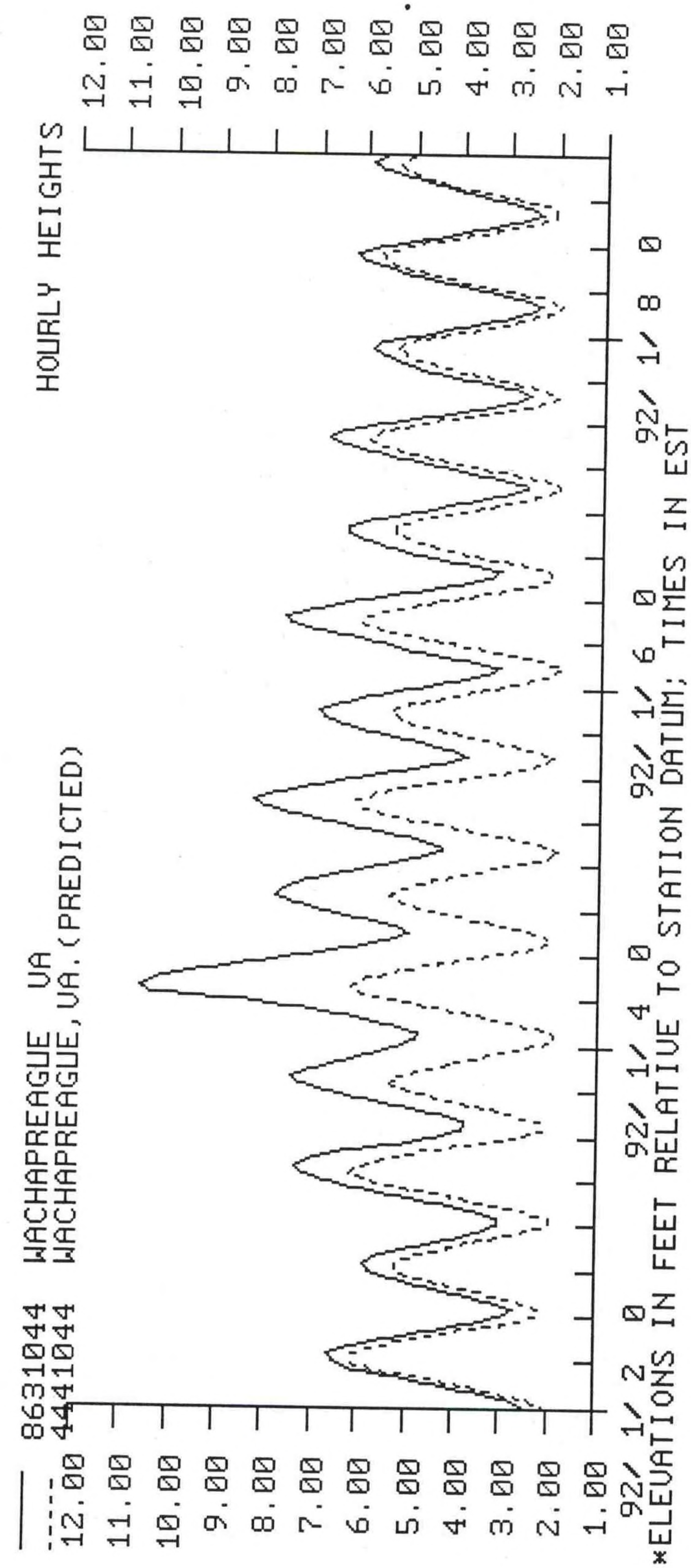


*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST

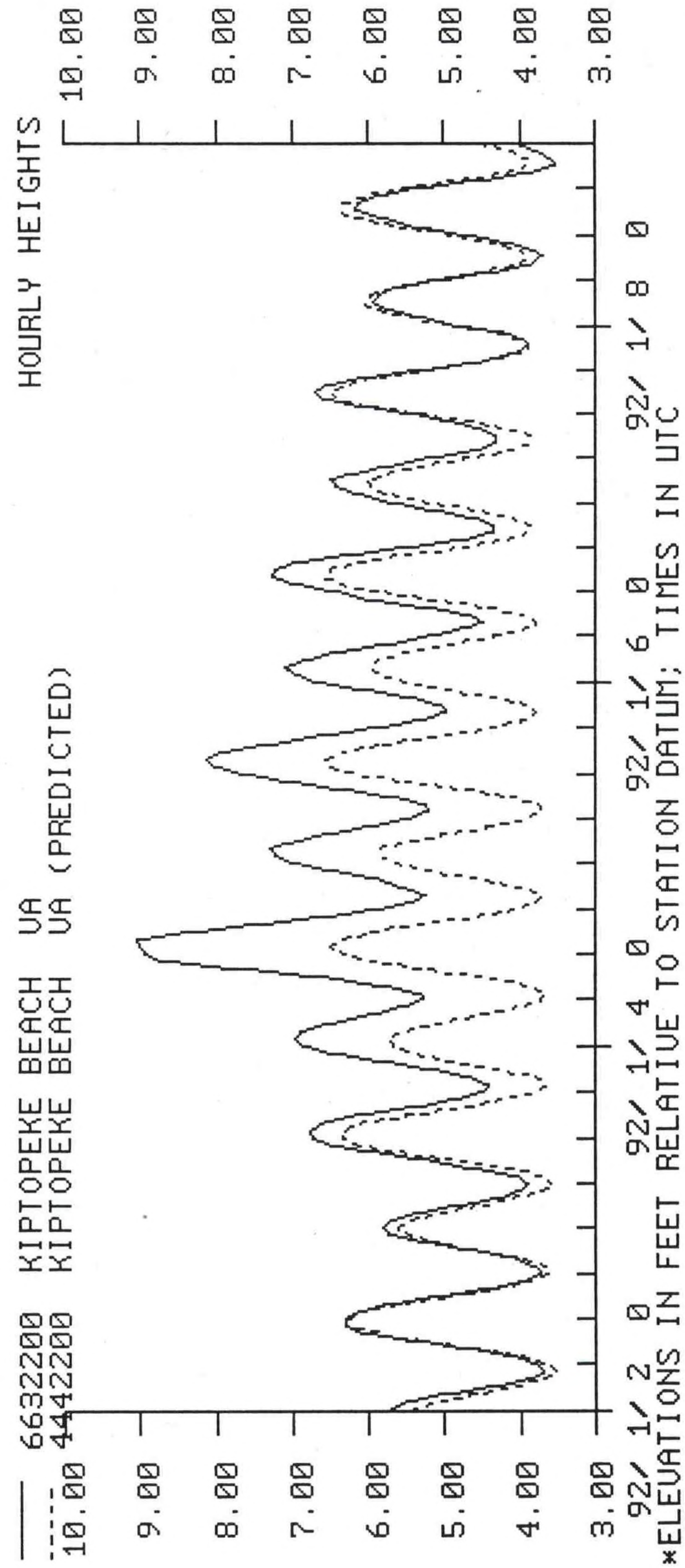

6574680 BALTIMORE, MD.
4444680 BALTIMORE MD (PREDICTED)
HOURLY HEIGHTS
8.00
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

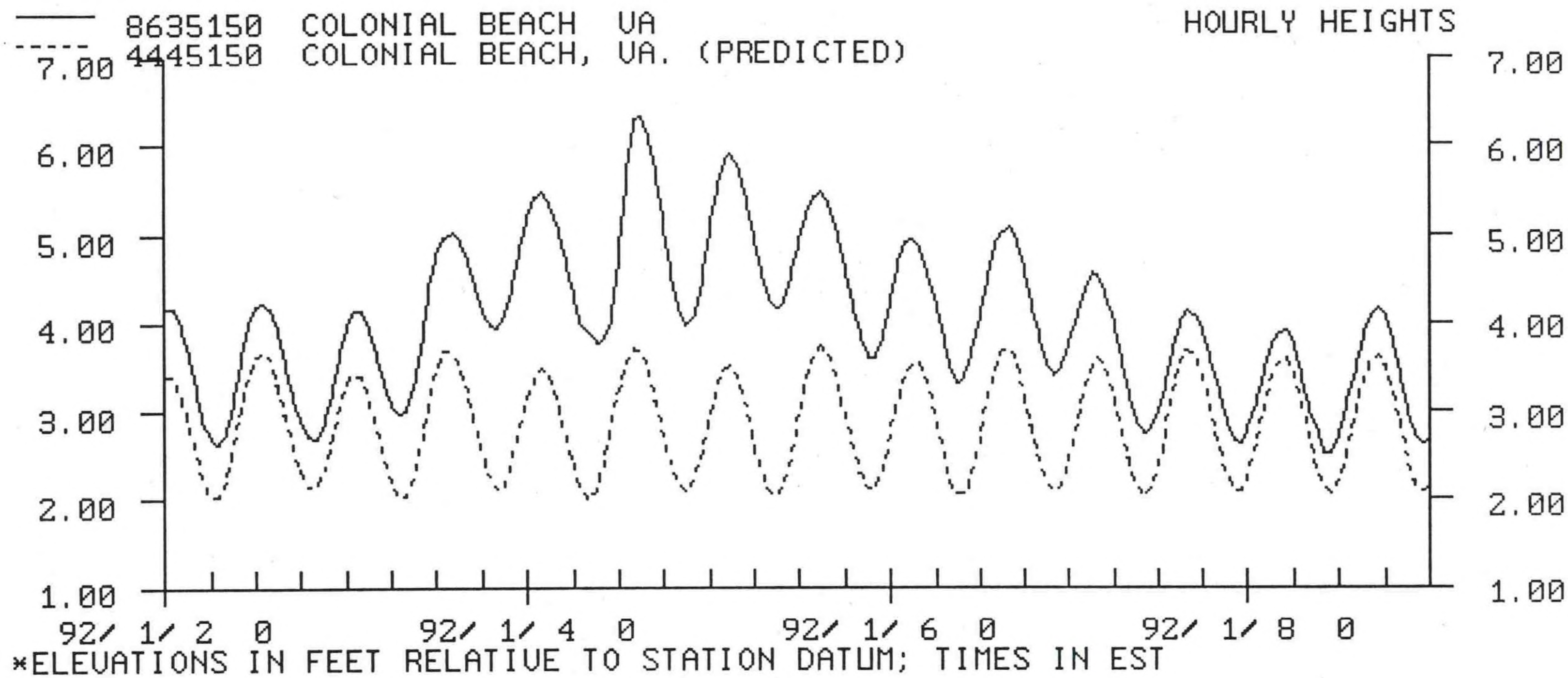

6575512 ANNAPOLIS, MD.
4445512 ANNAPOLIS MD (PREDICTED)
HOURLY HEIGHTS
8.00
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

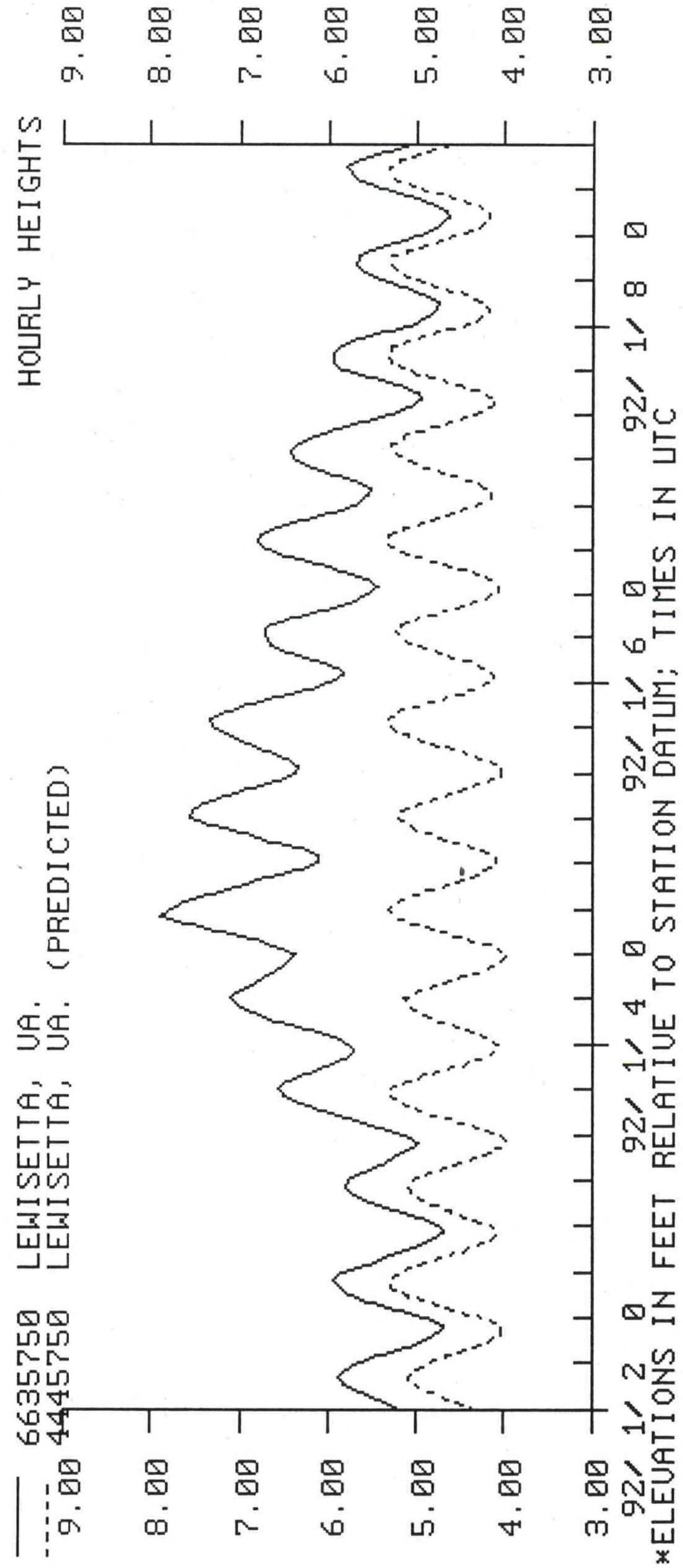

6577330 SOLOMONS IS. MD
4447330 SOLOMONS, MD (PREDICTED)
HOURLY HEIGHTS
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

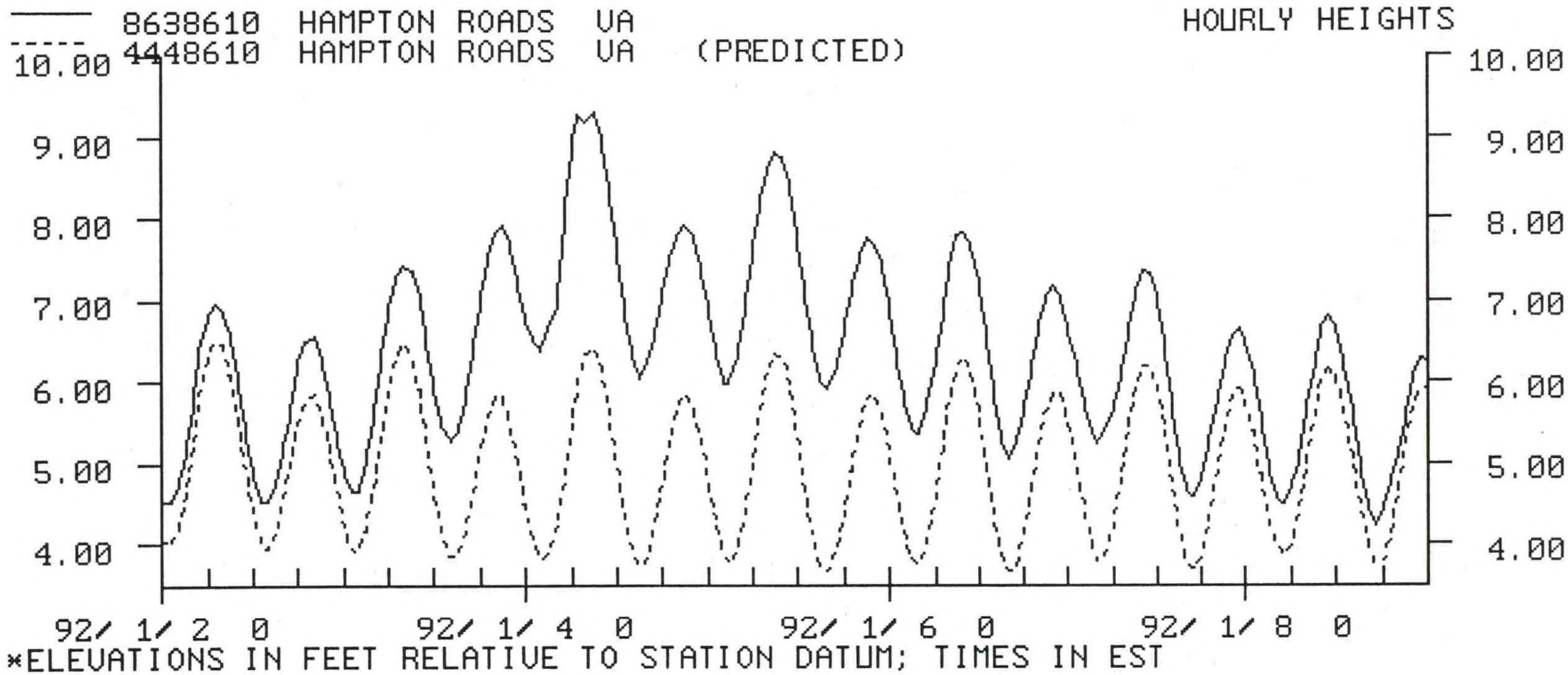


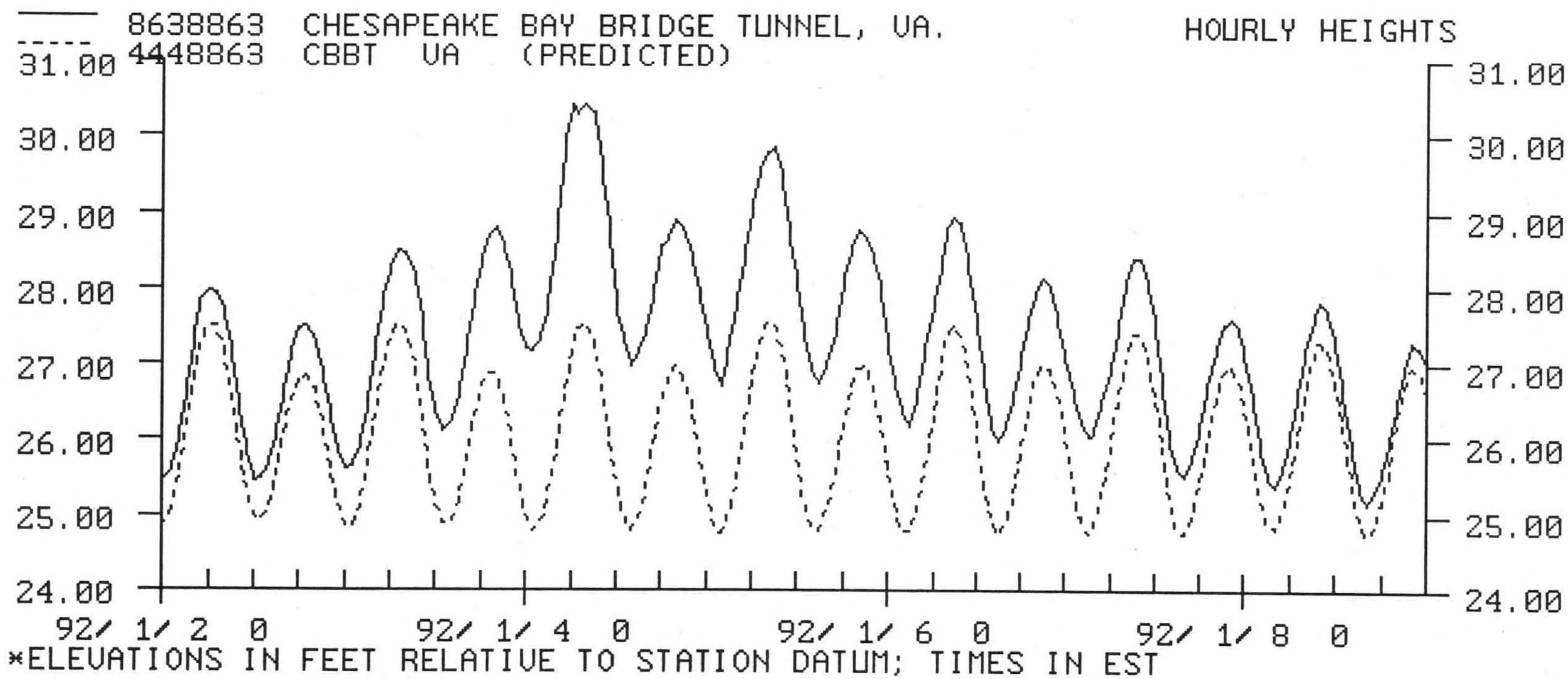
8631044 WACHAPREAGUE VA
4441044 WACHAPREAGUE,VA.(PREDICTED)
HOURLY HEIGHTS
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST

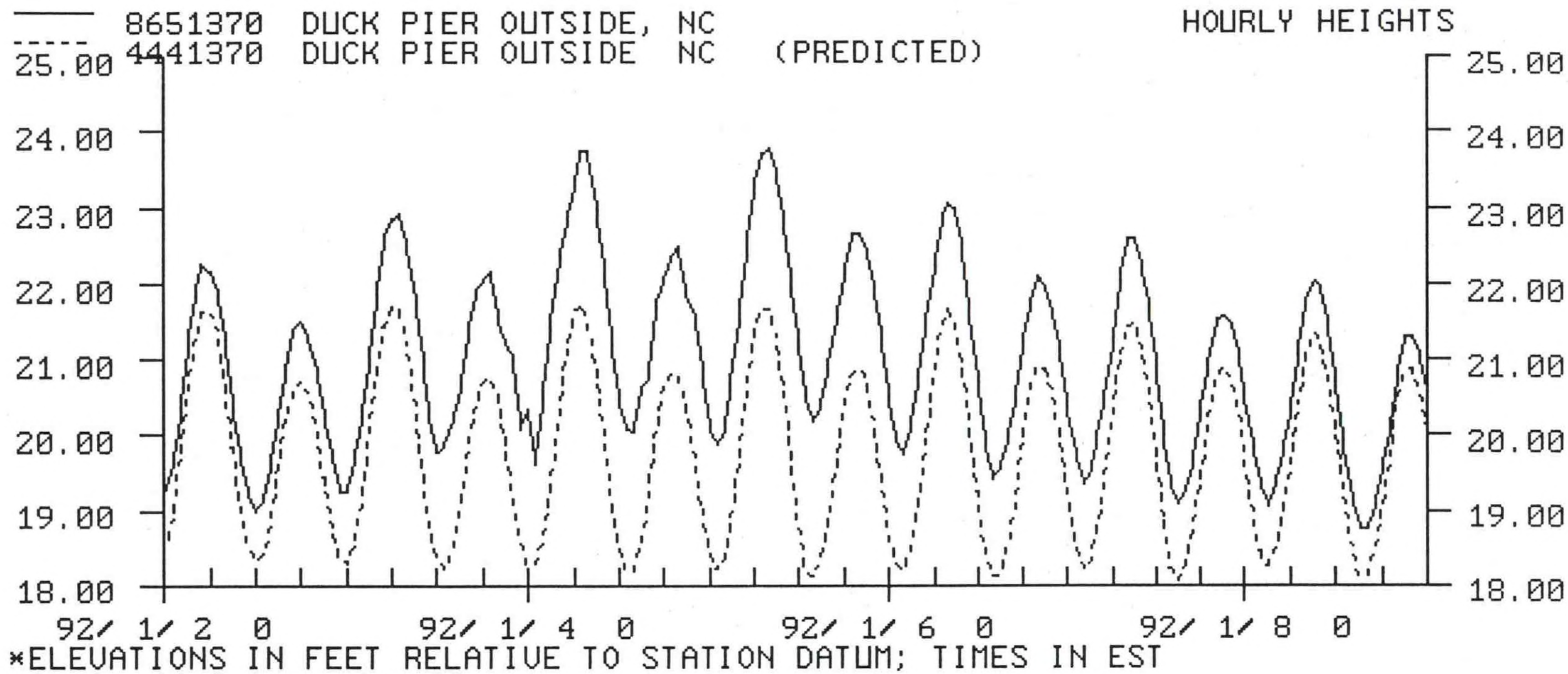

6632200 KIPTOPEKE BEACH VA
4442200 KIPTOPEKE BEACH VA (PREDICTED)
HOURLY HEIGHTS
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC

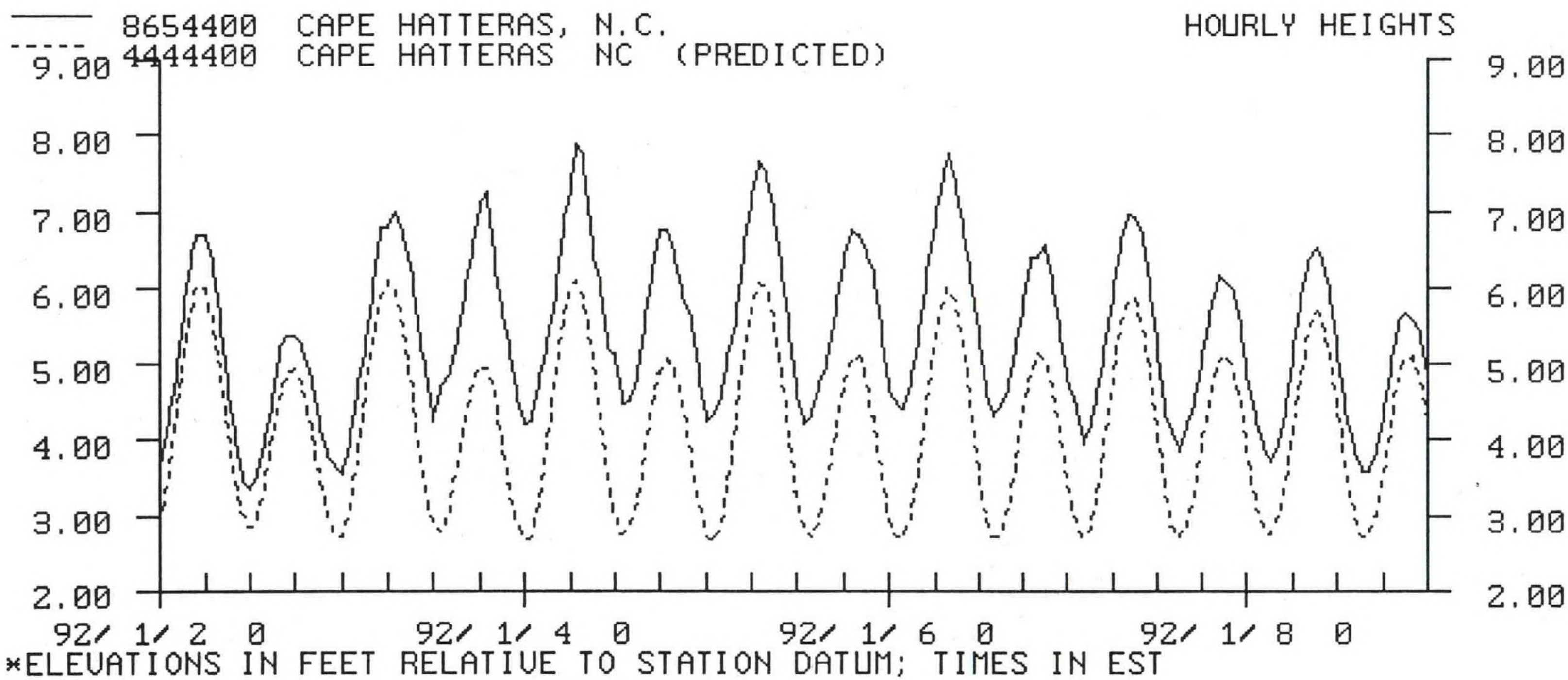

8635150 COLONIAL BEACH VA
4445150 COLONIAL BEACH, VA. (PREDICTED)
HOURLY HEIGHTS
7.00
6.00
5.00
4.00
3.00
2.00
1.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST


6635750 LEWISETTA, VA.
4445750 LEWISETTA, VA. (PREDICTED)
HOURLY HEIGHTS
9.00
8.00
7.00
6.00
5.00
4.00
3.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN UTC


8638610 HAMPTON ROADS VA
4448610 HAMPTON ROADS VA (PREDICTED)
HOURLY HEIGHTS
10.00
9.00
8.00
7.00
6.00
5.00
4.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST


8638863 CHESAPEAKE BAY BRIDGE TUNNEL, VA.
4448863 CBBT VA (PREDICTED)
HOURLY HEIGHTS
31.00
30.00
29.00
28.00
27.00
26.00
25.00
24.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST


8651370 DUCK PIER OUTSIDE, NC
4441370 DUCK PIER OUTSIDE NC (PREDICTED)
HOURLY HEIGHTS
25.00
24.00
23.00
22.00
21.00
20.00
19.00
18.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST


8654400 CAPE HATTERAS, N.C.
4444400 CAPE HATTERAS NC (PREDICTED)
HOURLY HEIGHTS
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
92/ 1/ 2 0
92/ 1/ 4 0
92/ 1/ 6 0
92/ 1/ 8 0
*ELEVATIONS IN FEET RELATIVE TO STATION DATUM; TIMES IN EST

IV. STORM SURGE CHARACTERISTICS

Information on the maximum storm surge measured at each station is found in Table II. Storm surge is defined as the difference between the observed and predicted water level heights. Predicted water level heights are computed using standard NOS harmonic analysis and prediction algorithms. The timing of the maximum storm surge is largely dependent upon the timing of interaction of the tide and the storm passage, and the maximum storm surge may not coincide with the occurrence of a predicted tidal high water. Table II provides the following information for each station: the date and time of the maximum storm surge; the observed height of the water above MLLW at that time; the predicted height of the water above MLLW at that time; and the storm surge value (observed minus predicted heights).

Time series of the storm surge are constructed by subtracting the predicted time series from the observed time series. Figures 1 through 4 are simultaneous plots of the storm surge for various geographical regions for a nine-day time period centered around the time period of the storm. All of the figures use the same vertical scale (in feet) so that the magnitude of the surge can be put into perspective between stations and regions. Table II and the figures show that storm surge values over 4.50 feet occurred at Lewes, DE and Wachapreague, VA; locations closest to the storm center as it made landfall. Storm surge above 3.00 feet were observed at all coastal stations locations in southern Chesapeake Bay and along the Atlantic Coasts from Virginia up to New Jersey and New York Harbor.

Storm surge plots of the closest stations to the landfall of the storm depict signatures similar to those found during hurricane events (Figure 1). The signatures show a pronounced sharp peak at the time of landfall superimposed on a lower frequency surge. Figure 2 shows the significant effects of the storm in Upper and Lower New York Harbor as well as the effects in the upper Delaware Bay system as seen at Philadelphia. The storm surge maxima at the stations in the upper Chesapeake Bay showed varying responses to the changing wind and pressure fields as the storm passed. Figure 4 shows the decreasing effects of the storm proceeding south along the coast from the Chesapeake Bay entrance.

The storm surge plots for many of the stations show some degree of periodicity at the tidal frequencies. This is attributed to the process of the subtraction of two sinusoidal curves (predicted and observed) that are slightly out of phase because of the storm, and to the effect of the prolonged storm surge in modifying the normal sinusoidal shape of the observed tide curve. An extreme example of the residual periodicity is found at Philadelphia. Philadelphia normally has a complex tide curve due to the shallow water and frictional effects, and the addition of the timing of the storm surge and the tide causes significant time-varying changes in the frictional drag incurred. There was no smoothing of observed data prior to computing the storm surge values for plotting in Figures 1 through 4.

Figures 5 and 6 show the results of applying a filter to smooth the storm surge plots so that the low frequency signature can be resolved through the high frequency noise. A low-pass 13-hour Doodson filter was applied to the hourly storm surge data to produce the plots in Figure 5. Doodson's filters were developed for smoothing the tidal components from hourly records. The 13-hour filter window length is appropriate for studying the longer term storm surge oscillations before and after landfall, but is too long of a window for studying the maximum storm effects because the narrow (short term) storm surge peaks are filtered out. Filtering is especially beneficial in studying storm surge effects when working with residuals such as those found at Philadelphia.

The storm surge plots are generally consistent with the meteorological information found in the appendices. The NWS maps show that there were actually a series of offshore low pressure centers during this time period, with one of the most intense centers moving westward and making landfall on January 4. The storm surge plots generally show a secondary oscillation after the main storm surge event that are consistent with the secondary increase in wind speed at Chesapeake Bay Bridge Tunnel on January 5. The storm surge plots of the upper Chesapeake Bay stations found in Figure 3 show a significant anomaly from the others with a significant decrease in the surge prior to the maximum surge. This is probably in response to the shift in direction of the strong winds as the main storm center passed inland up the Delaware Bay.

TABLE II. MAXIMUM STORM SURGE INFORMATION

STATION	DATE/TIME (mon/day hrs.min.)	HEIGHT ABOVE MLLW OBSERVED	PREDICTED	DIFFERENCE
The Battery, NY	1/4 1012	6.66	3.19	3.47
Sandy Hook, NJ	1/4 1012	6.35	2.65	3.70
Atlantic City, NJ	1/4 0730	7.38	4.02	3.36
Cape May, NJ	1/4 0900	8.77	5.06	3.71
Philadelphia, PA	1/4 1442	8.24	5.55	2.69
Lewes, DE	1/4 0748	9.19	4.62	4.57
Ocean City, MD	station destroyed			
Baltimore, MD	1/5 0048	2.44	0.14	2.30
Annapolis, MD	1/4 2254	2.29	0.04	2.25
Solomons Is., MD	1/4 1100	3.41	0.46	2.95
Wachapreague, VA	1/4 0742	8.99	4.25	4.74
Kiptopeake, VA	1/4 0606	5.47	2.61	2.86
Colonial Beach, VA	1/4 1430	3.99	1.35	2.64
Lewisetta, VA	1/4 1148	3.45	0.67	2.78
Hampton Roads, VA	1/4 0600	4.90	1.41	3.49
Ches. Bay Brdg. Tun., VA	1/4 0506	5.21	1.67	3.54
Duck Pier, NC	1/4 0430	4.89	2.43	2.46
Cape Hatteras, NC	1/3 1900	4.44	2.14	2.30

NOTES:
Storm surge is the difference between observed and predicted heights; Heights are in feet; MLLW is Mean Lower Low Water datum; Times are in EST

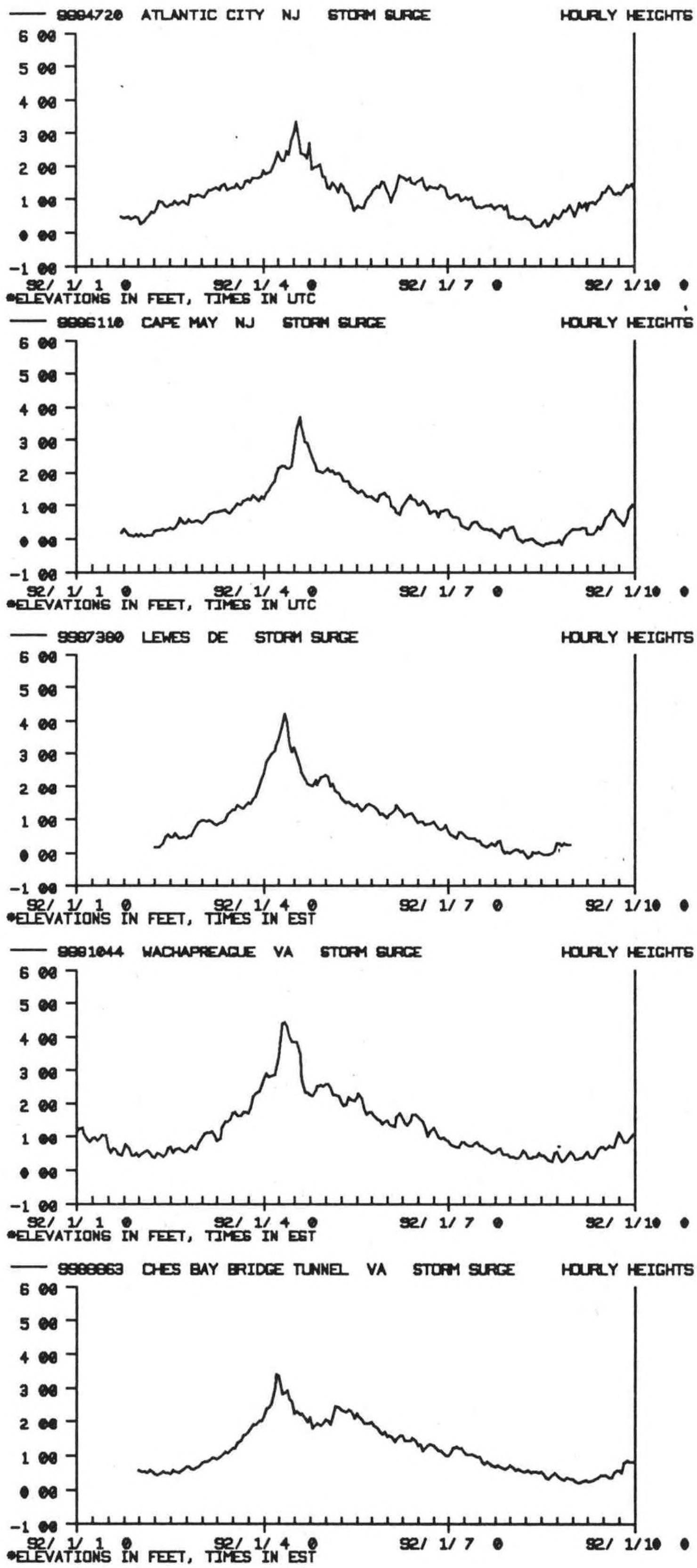


FIGURE 1. STORM SURGE PLOTS, JANUARY 1992 STORM ATLANTIC CITY TO CHESAPEAKE BAY ENTRANCE

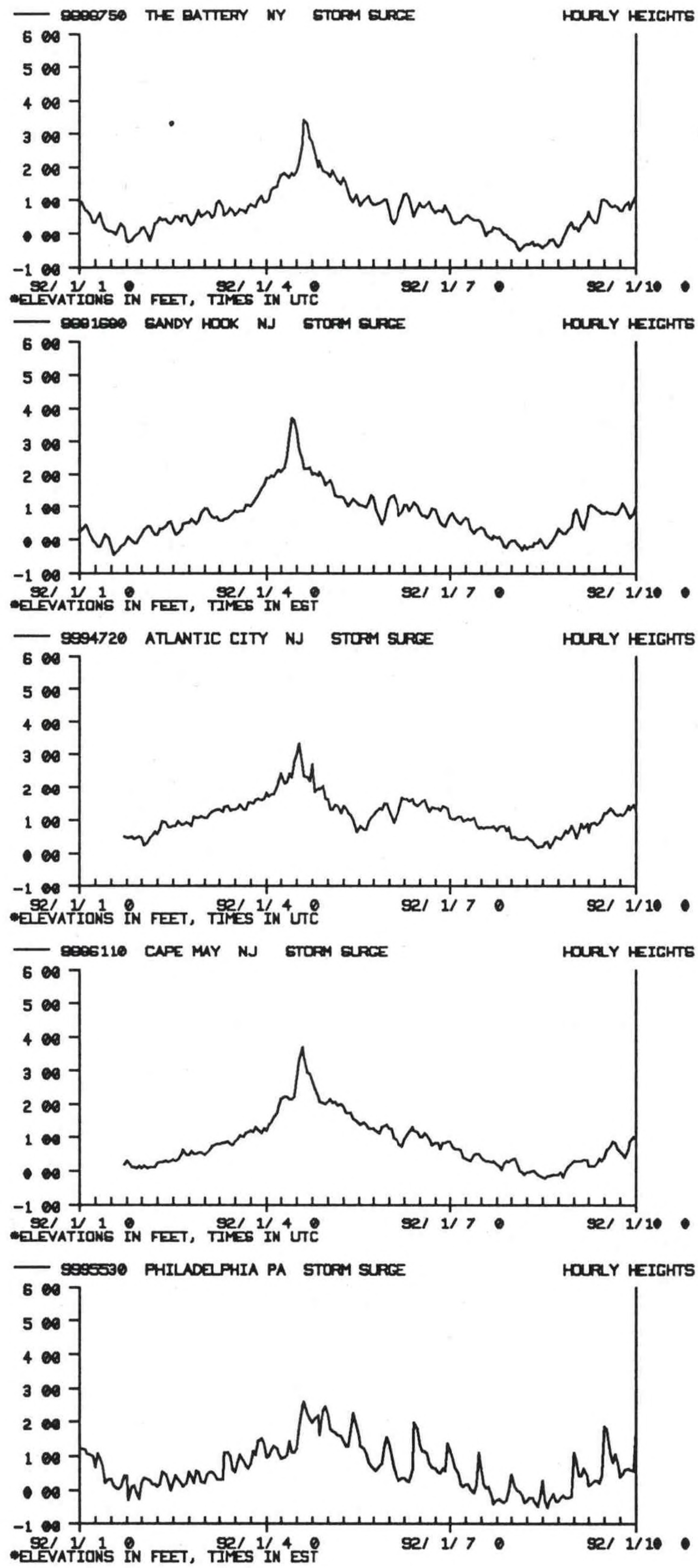


FIGURE 2. STORM SURGE PLOTS, JANUARY 1992 COASTAL STORM NEW YORK HARBOR TO DELAWARE BAY

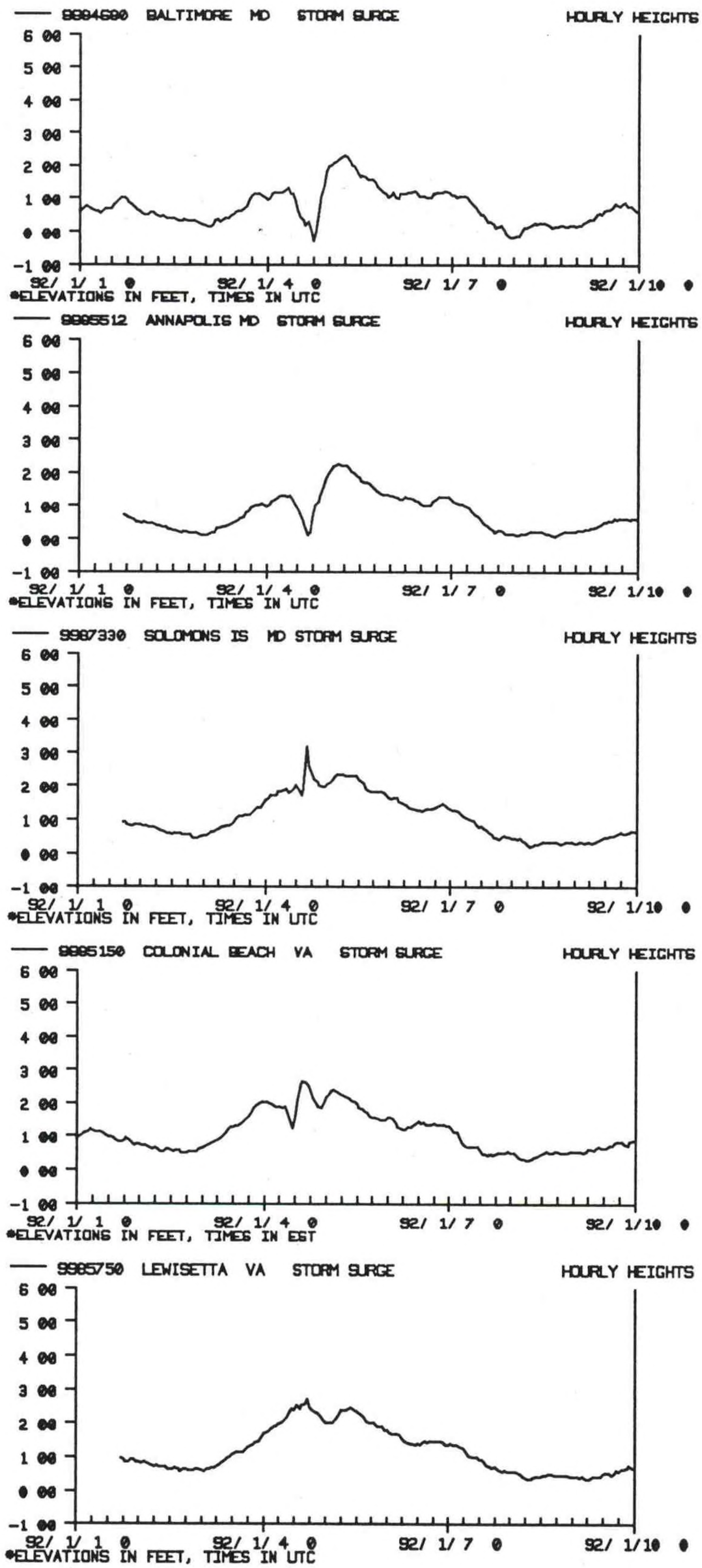


FIGURE 3. STORM SURGE PLOTS, JANUARY 1992 COASTAL STORM UPPER CHESAPEAKE BAY

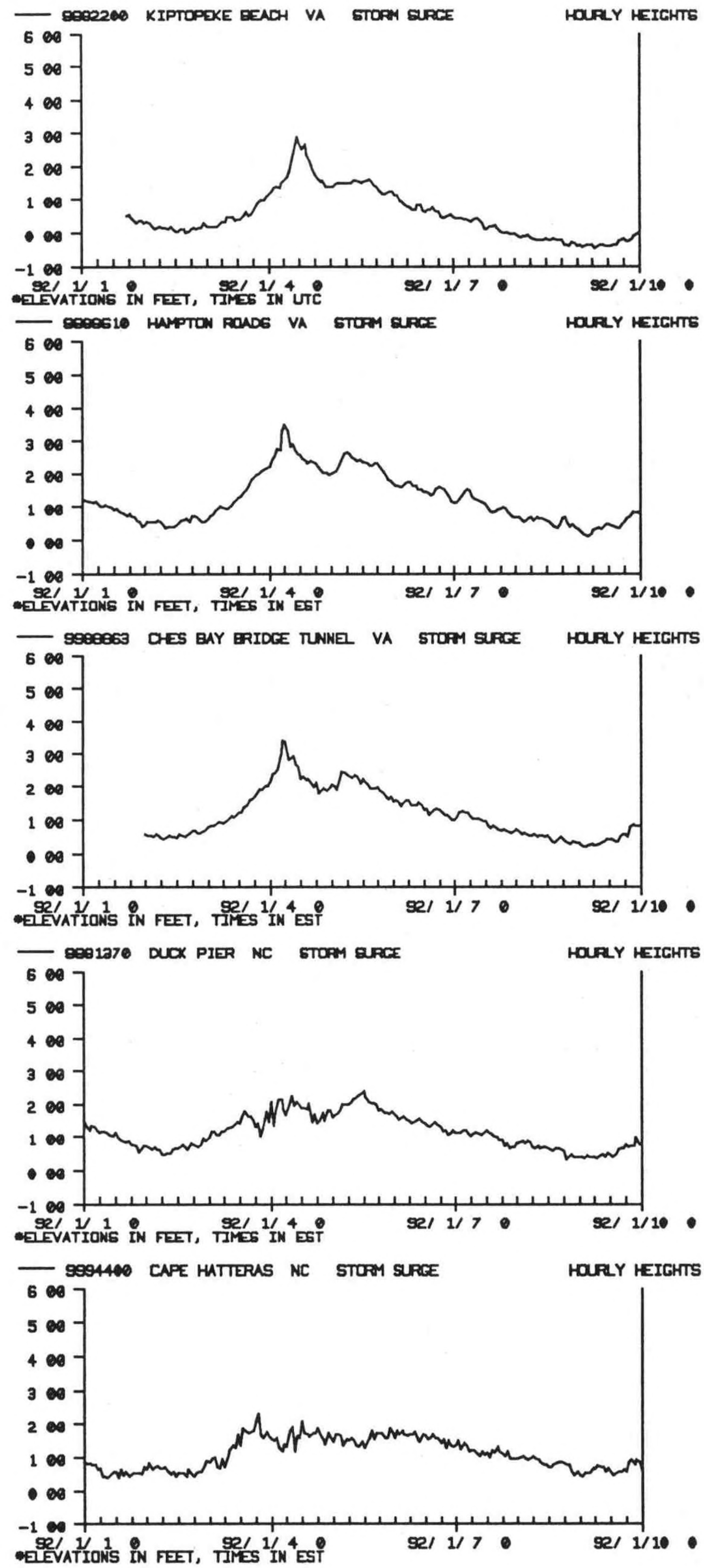
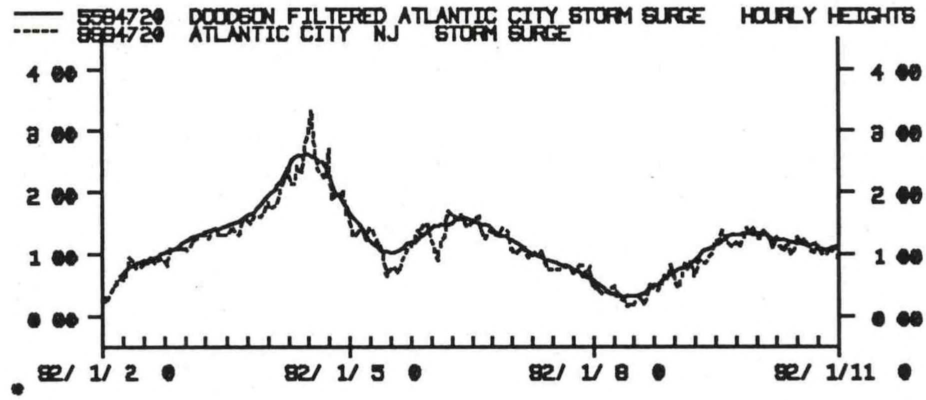
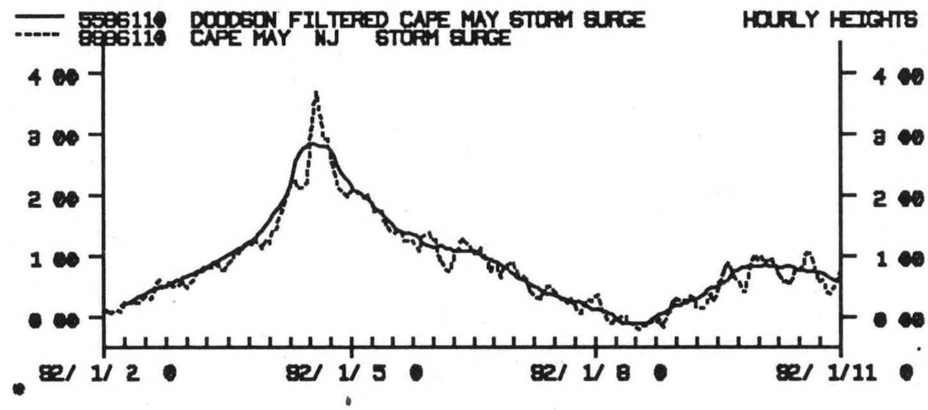


FIGURE 4. STORM SURGE PLOTS, JANUARY 1992 COASTAL STORM SOUTHERN CHESAPEAKE BAY TO THE NORTH CAROLINA COAST





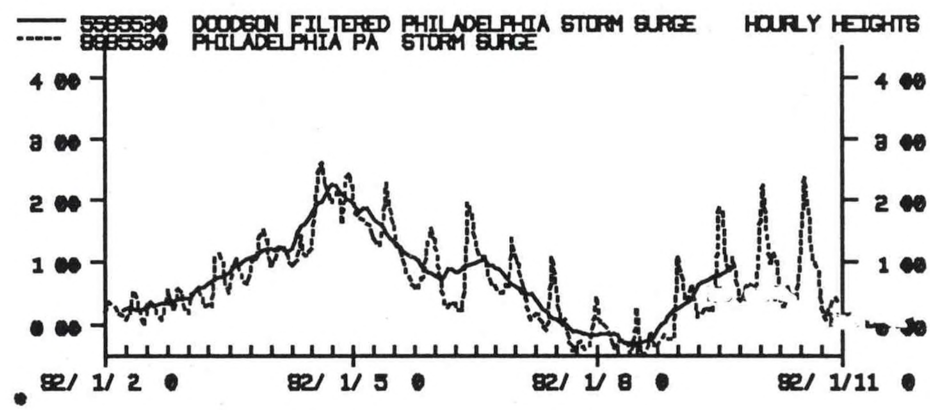


FIGURE 5. COMPARISON OF HOURLY STORM SURGE WITH DOODSON FILTERED STORM SURGE USING 13-HOUR WINDOW

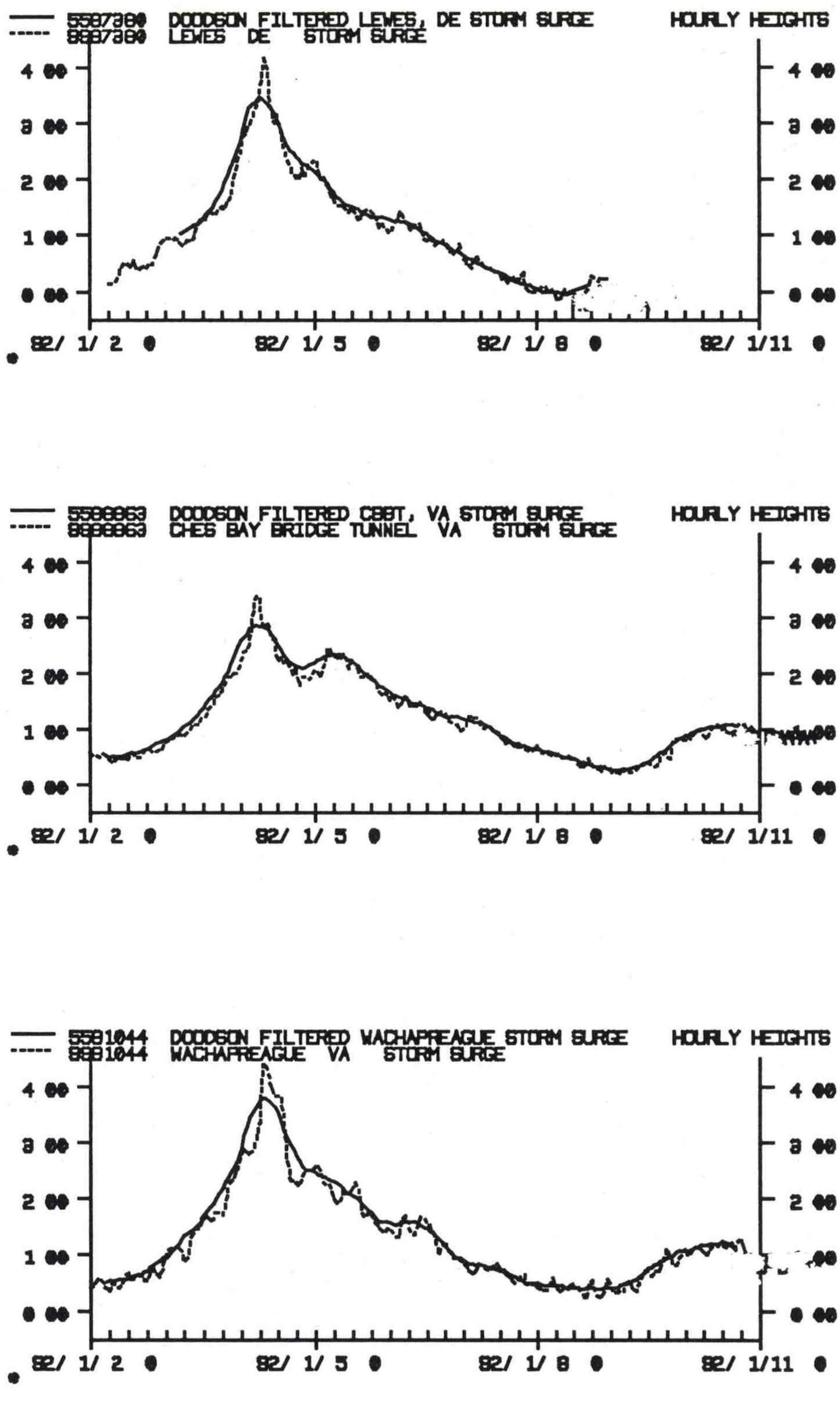


FIGURE 6. COMPARISON OF HOURLY STORM SURGE AND DOODSON FILTERED STORM SURGE USING 13-HOUR WINDOW

V. SUMMARY

The continuous operation of the National Water Level Observation Network (NWLON) has resulted in an important data set documenting the effects of an unusual coastal storm on water levels in the U.S. coastal ocean. Although not a hurricane, this storm was a significant storm event in the history of the Virginia, Maryland, Delaware, and New Jersey coastal zone.

Maximum recorded historical highest water levels were exceeded at one of the NWLON stations (Wachapreague, VA). Although historical levels were not exceeded at the stations with the longer historical records, the maximum levels did come within 0.50 foot of the historical maxima at several locations (Lewes, DE; Cape May, NJ; and Lewisetta, VA). The maximum storm surge values (observed minus predicted water levels) of over 4.5 feet were also measured at Lewes and Cape May with several stations having values over 3.0 feet. Significant storm surge values were observed at NWLON stations as far south as Cape Hatteras, NC. The storm destroyed the NOAA tide station when the offshore end of the Ocean City Pier was destroyed.

Storm surge signatures derived from subtracting predicted from observed water levels generally show a steep rise to the maximum surge early on January 4, with a slower fall and evidence of a secondary oscillation at several locations. Notable exceptions are the storm surge signatures in the upper Chesapeake Bay, which exhibit a strong oscillation prior to the maximum surge due to shifts in wind direction as the storm center passed to the north. A 13-hour Doodson filter can be used to effectively smooth the high frequency noise found in the signatures.

Preliminary data recorded during the storm were provided to the U.S. Army Corps of Engineers, the National Weather Service, and to FEMA. Information on tidal datums, storm surge, and time series from the stations listed in this report and from other NOS stations can be obtained from:

NOAA/National Ocean Service
Office of Ocean and Earth Sciences
Ocean and Lake Levels Division
Products and Services Branch, N/OES23
6001 Executive Blvd.
Rockville, MD 20852

Telephone: (301) 443-8467
FAX: (301) 443-1920

VI. APPENDICES

1. Storm Track Information from National Weather Daily Weather Maps Weekly Series and Ancillary Wind Measurements from the NOAA Chesapeake Bay Bridge Tunnel tide station.

2. Set of tide station location chartlets.

APPENDIX 1

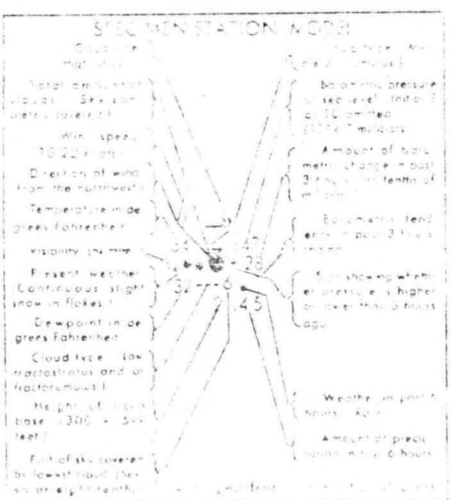
National Oceanic and Atmospheric Administration • National Weather Service • National Meteorological Center
Meteorological Operations Division & Climate Analysis Center

daily weather maps

Weekly Series **DECEMBER 30, 1991 – JANUARY 5, 1992**

The charts in this publication are the principal charts of the former Weather Bureau publication, "Daily Weather Map." They are the Surface Weather Map, the 500-Millibar Height Contours chart, the Highest and Lowest Temperatures chart, and the Precipitation Areas and Amounts chart. All charts for each day are arranged on a single page. They are derived from operational weather maps prepared by the National Meteorological Center, National Weather Service. The symbols on the Surface Weather Map and the 500-Millibar Height Contours chart are standard international symbols. Copies of an explanatory sheet are available from the Climate Analysis Center (address below). NOAA is responsible for managing, printing, and distributing these maps. The contents may be reprinted freely, with proper credit.

Orders for annual subscriptions and single copies may be sent to Daily Weather Maps, Climate Analysis Center, Room 808 World Weather Building, Washington, D.C. 20233.



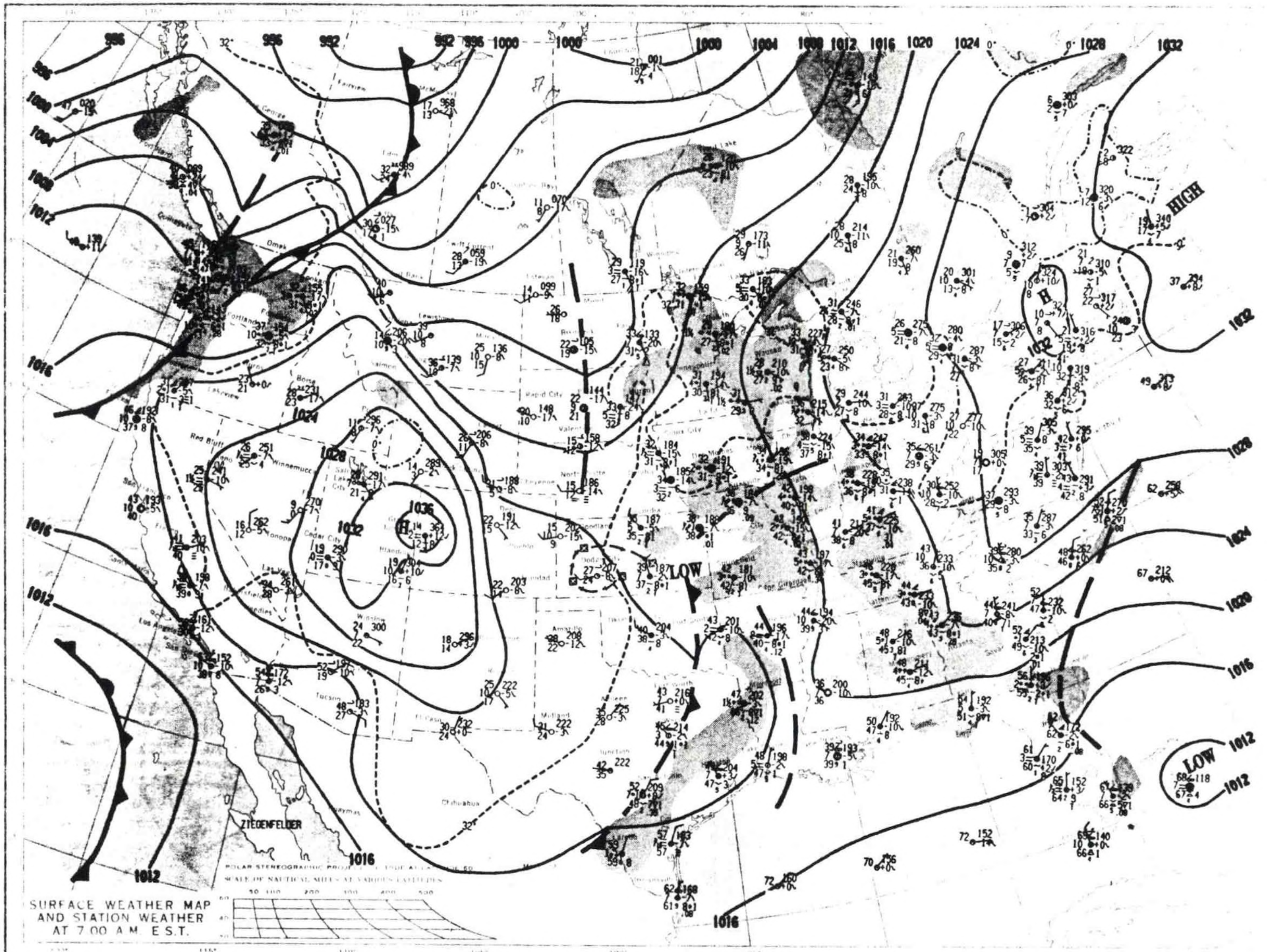
The price of the Daily Weather Maps is $60 per year for domestic mailing, $75 per year for foreign mailing and $1.50 for single issues. Only checks or money orders (including international postal money orders), made payable to the Department of Commerce, NOAA, are acceptable.

The Surface Weather Map shows station data and the analysis for 7:00 a.m., EST. Tracks of well-defined low pressure areas are indicated by a chain of arrows; locations of these centers at 6, 12, and 18 hours preceding map time are indicated by small white crosses in black squares. Areas of precipitation are indicated by shading. The weather reports printed here are only a fraction of those on which the analyses are based. Occasional apparent discrepancies between the printed station data and the analyses result from the absence of station reports not included here because of lack of space.

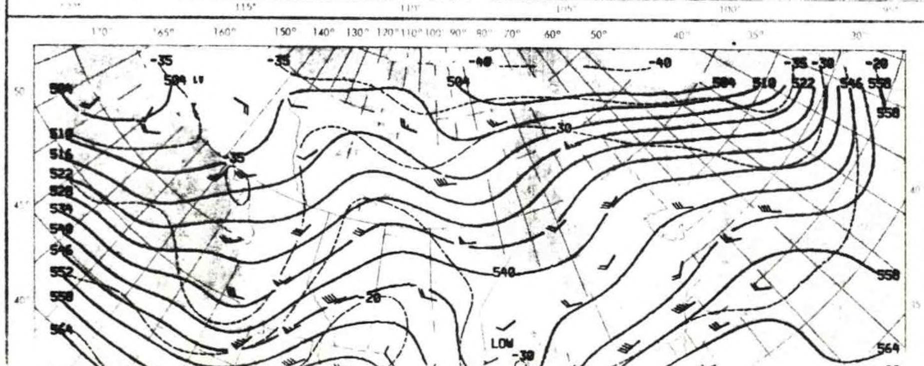
The 500-Millibar Height Contours chart shows height contours and isotherms of the 500-millibar surface at 7:00 a.m., EST. Height contours are shown as continuous lines labeled in dekameters above sea level. Isotherms are shown as dashed lines labeled in degrees Celsius. Arrows show the wind direction and speed at the 500-millibar level.

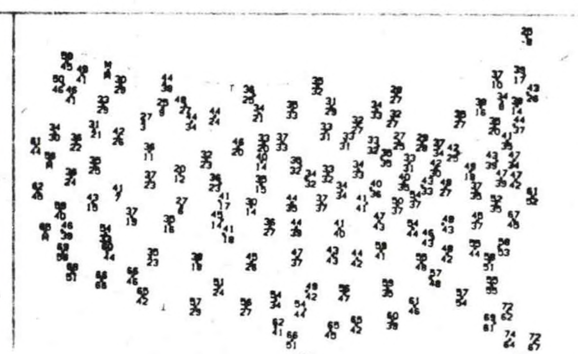
The Highest and Lowest Temperature chart shows the maximum temperature for the 12-hour period ending 7:00 p.m. EST of the previous day and the minimum temperature for the 12-hour period ending 7:00 a.m. EST. The names of the reporting points are shown on the Surface Weather Map. The maximum temperature is plotted above the station location, and the minimum temperature is plotted below.

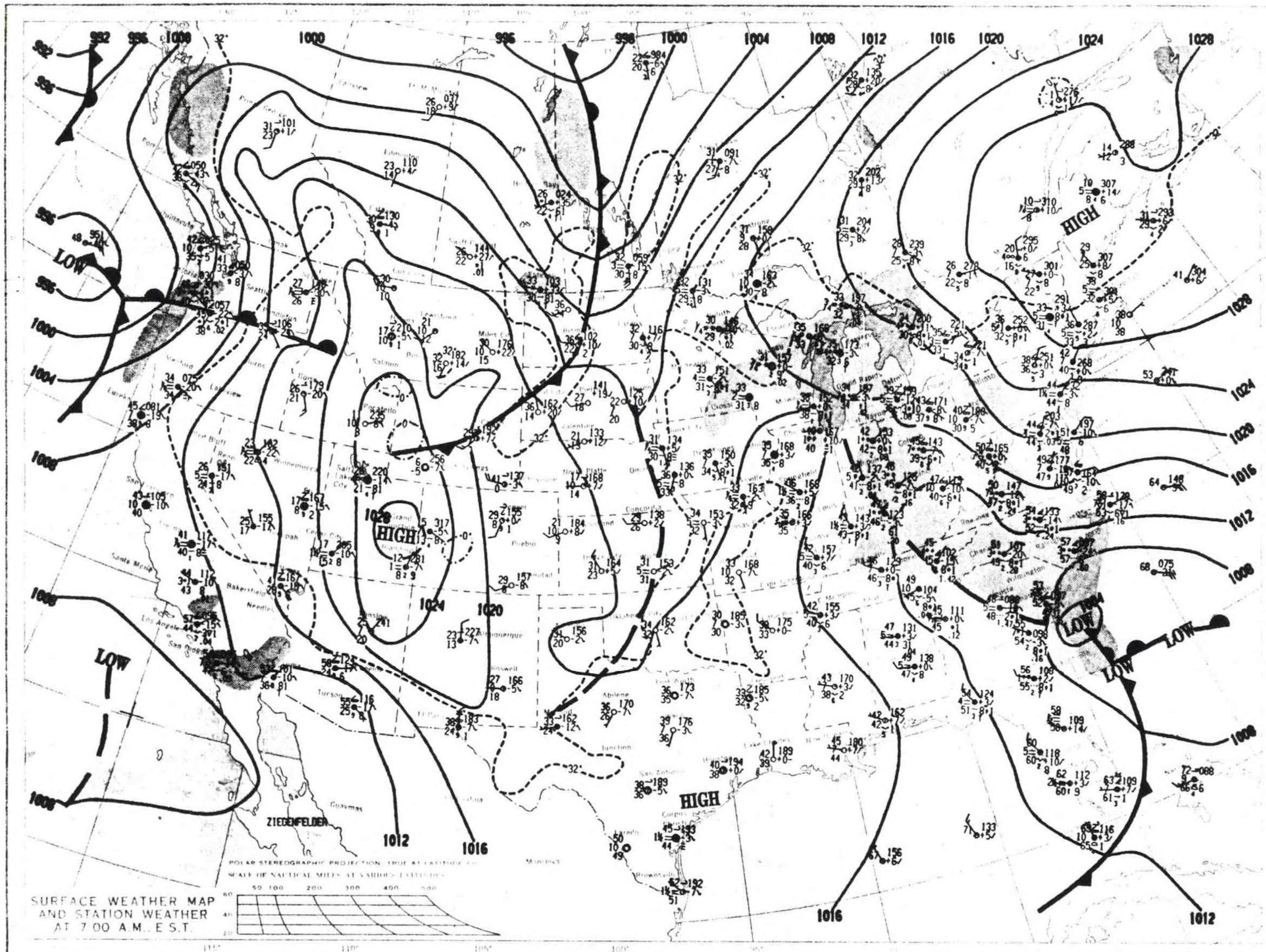
The Precipitation Areas and Amounts chart shows areas (shaded) that had precipitation during the 24 hours ending at 7:00 a.m., EST, with amounts to the nearest hundredth of an inch. Incomplete totals are underlined. "T" indicates a trace of precipitation. Dashed lines, in season, show the depth of snow on the ground in inches at 7:00 a.m., EST.

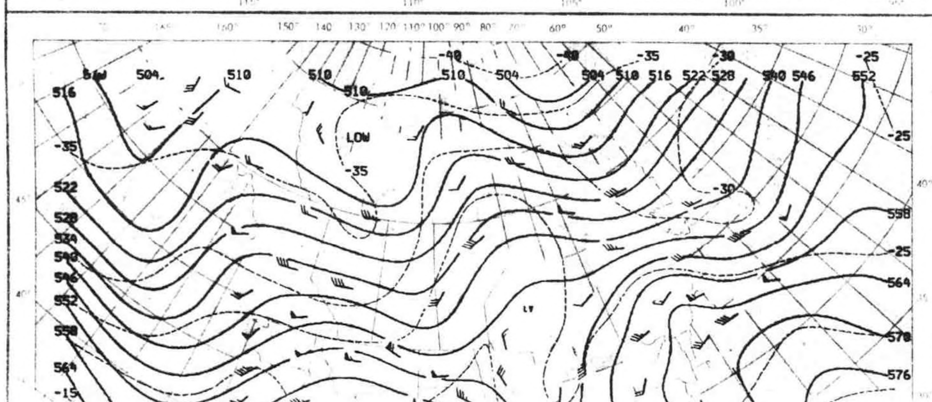


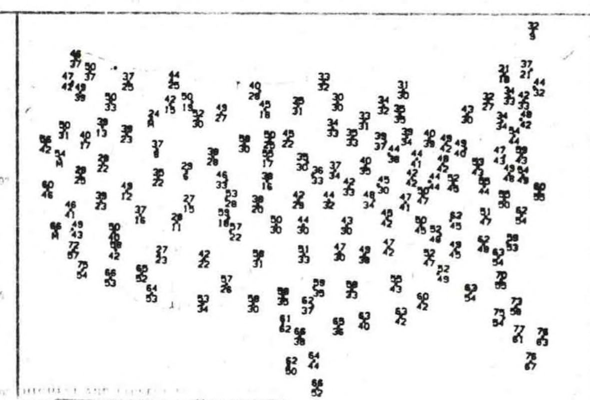
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.

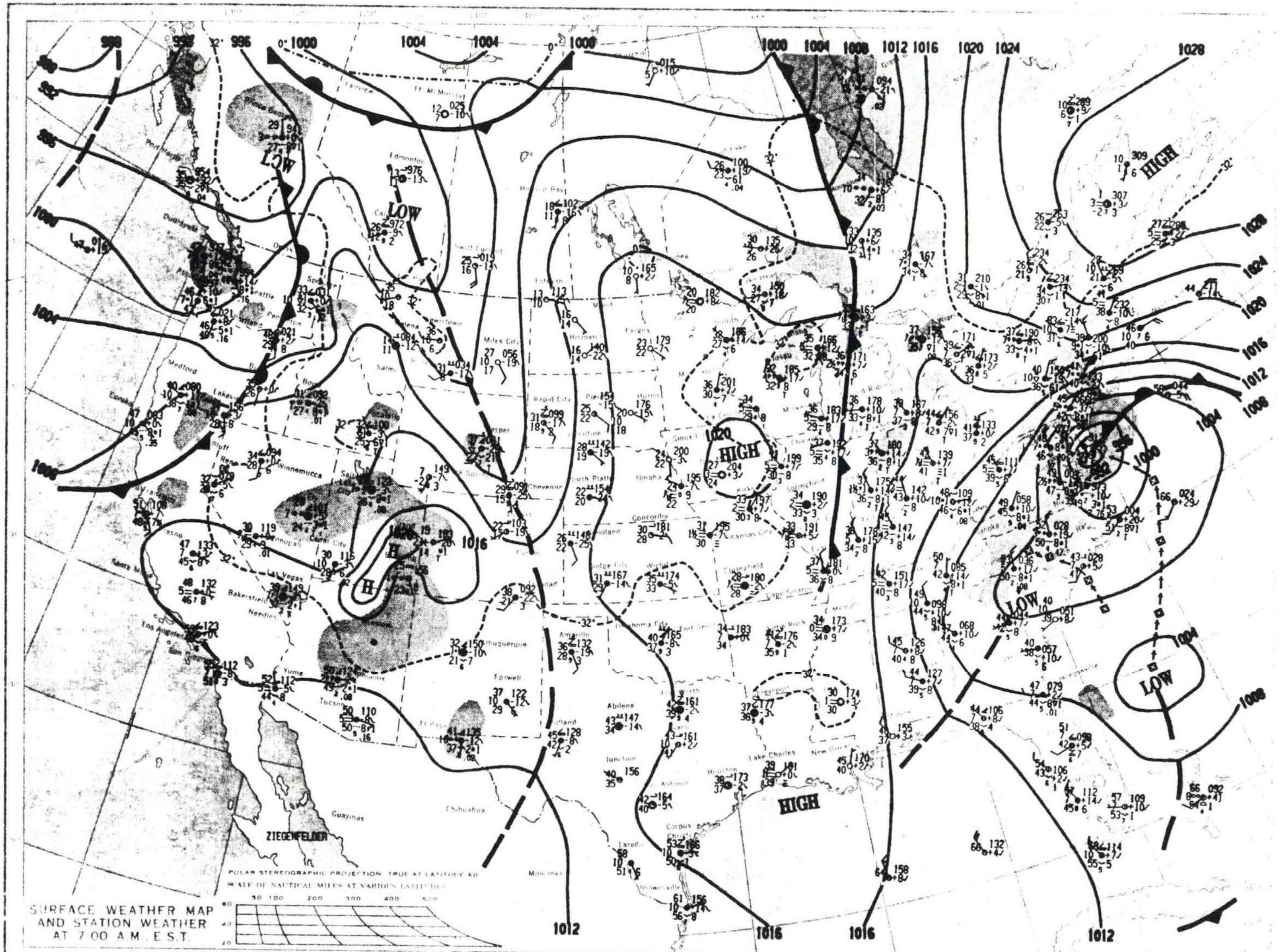


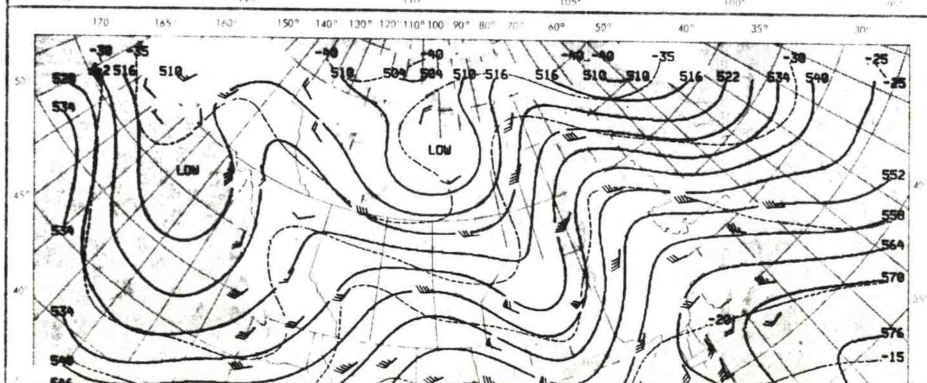


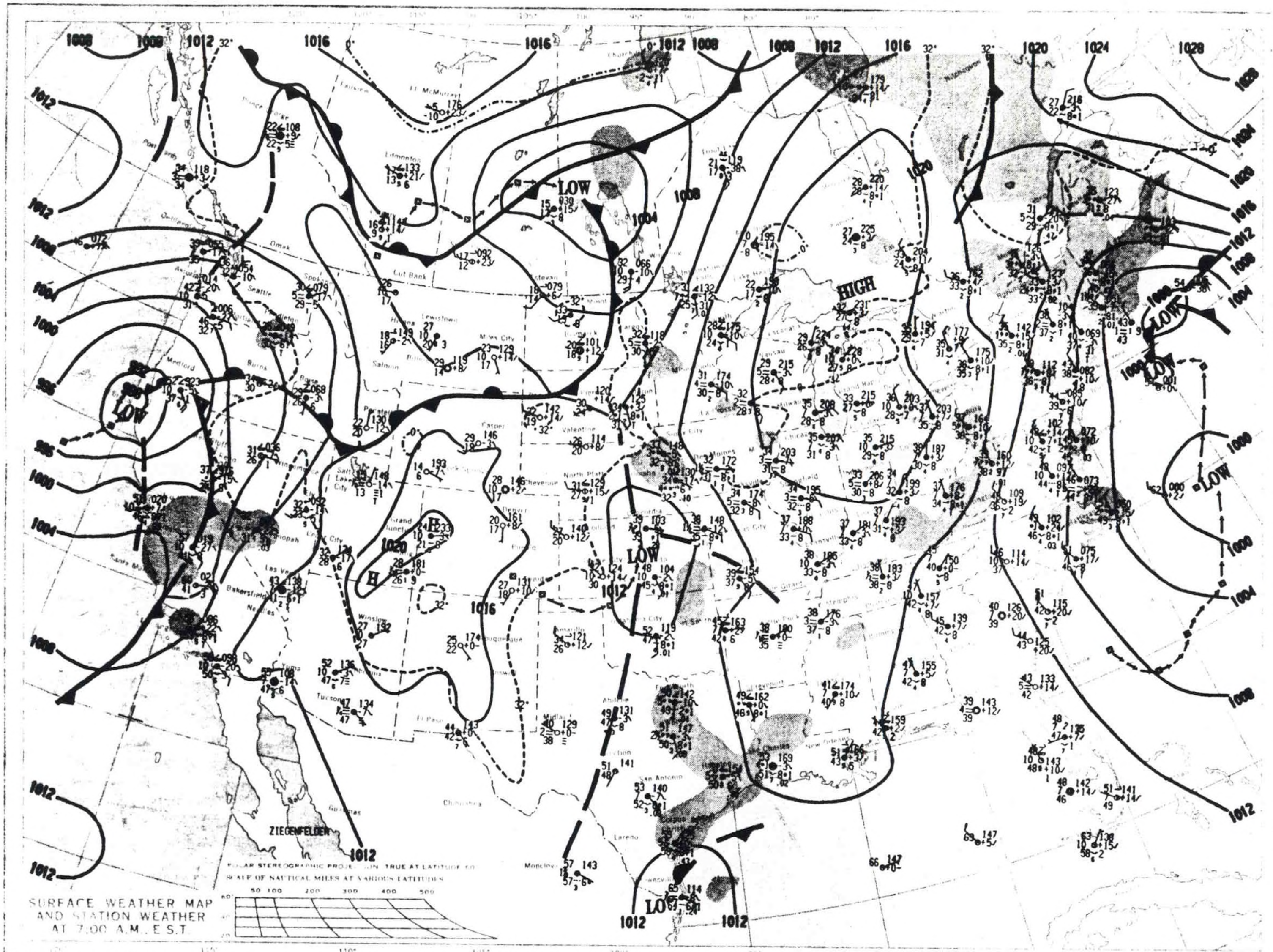

SURFACE WEATHER MAP
AND STATION WEATHER
AT 7:00 A.M., E.S.T.
HIGH
LOW
ZIEGENFELDER

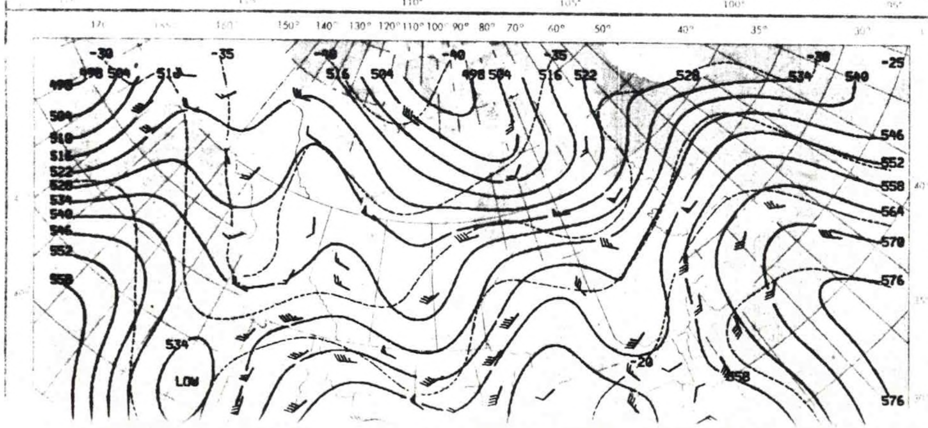


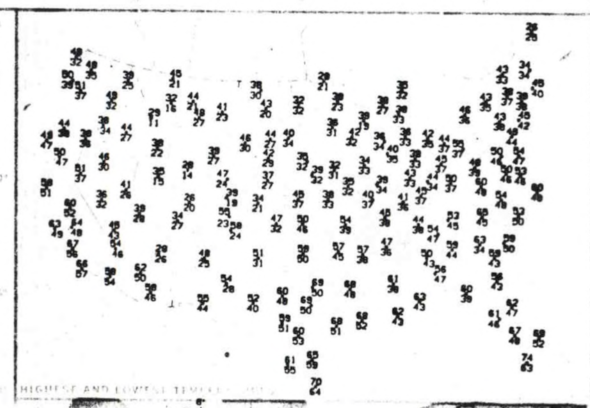



SURFACE WEATHER MAP
AND STATION WEATHER
AT 7:00 A.M. E.S.T.
POLAR STEREOGRAPHIC PROJECTION TRUE AT LATITUDE 60
SCALE OF NAUTICAL MILES AT VARIOUS LATITUDES
HIGH
LOW
ZIEGENFELDER

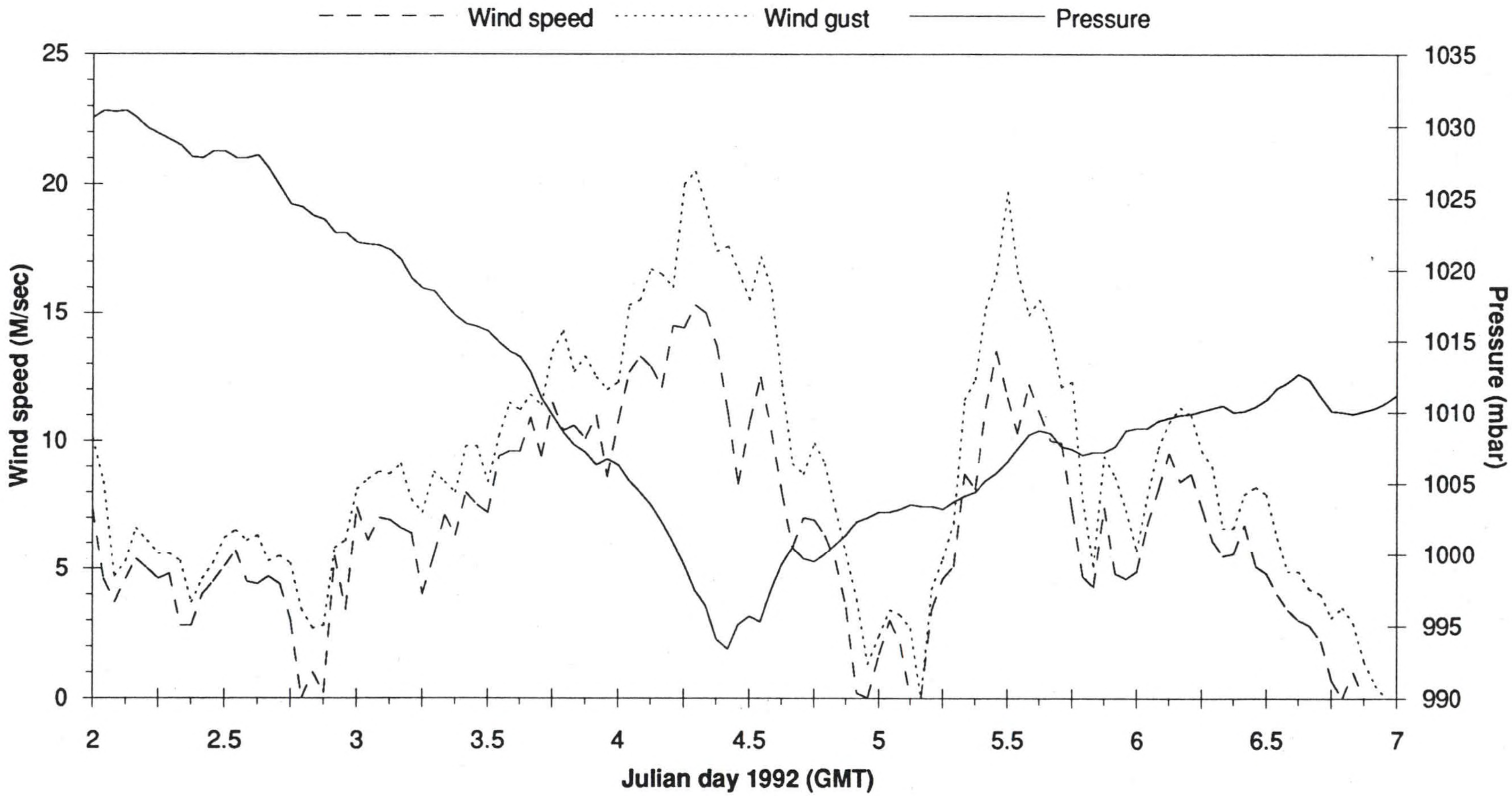

LOW


SURFACE WEATHER MAP
AND STATION WEATHER
AT 7:00 A.M. E.S.T.
POLAR STEREOGRAPHIC PROJECTION TRUE AT LATITUDE 60
SCALE OF NAUTICAL MILES AT VARIOUS LATITUDES
HIGH
LOW
ZIEGENFELDER

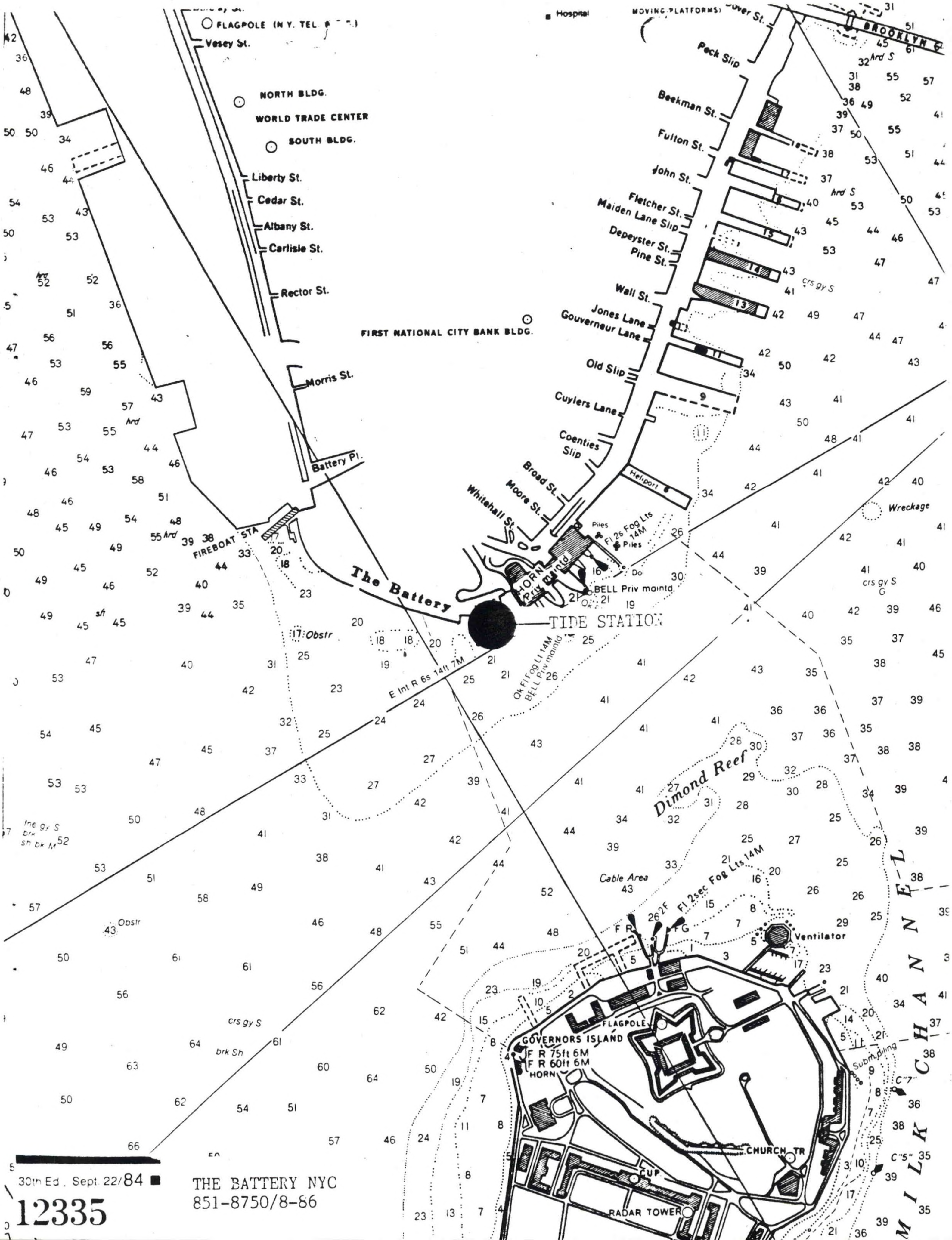



HIGHEST AND LOWEST TEMPERATURES

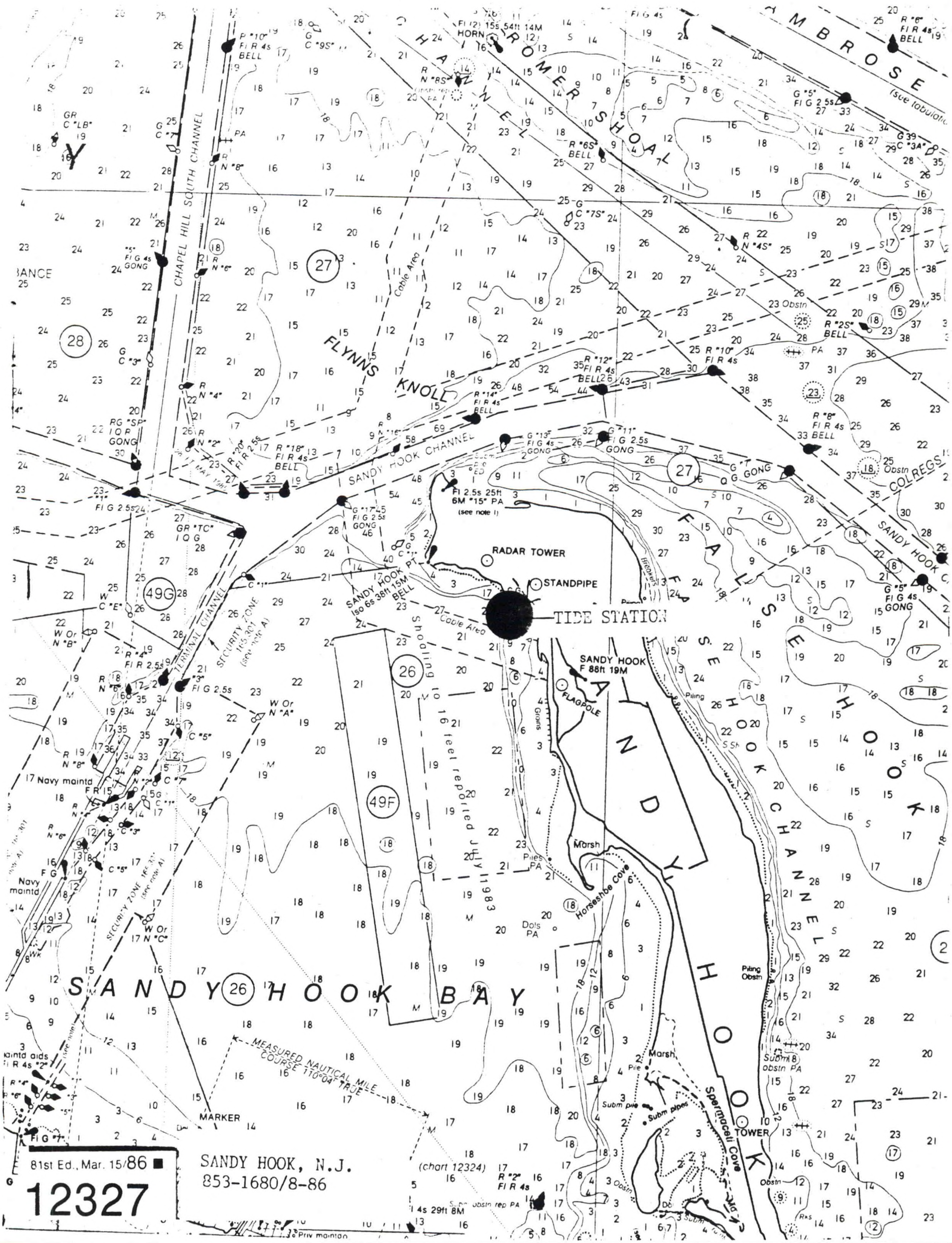
Station: 8638863 CBBT, VA
Wind speed, gust and Barometric pressure for 2 Jan - 6 Jan 1992



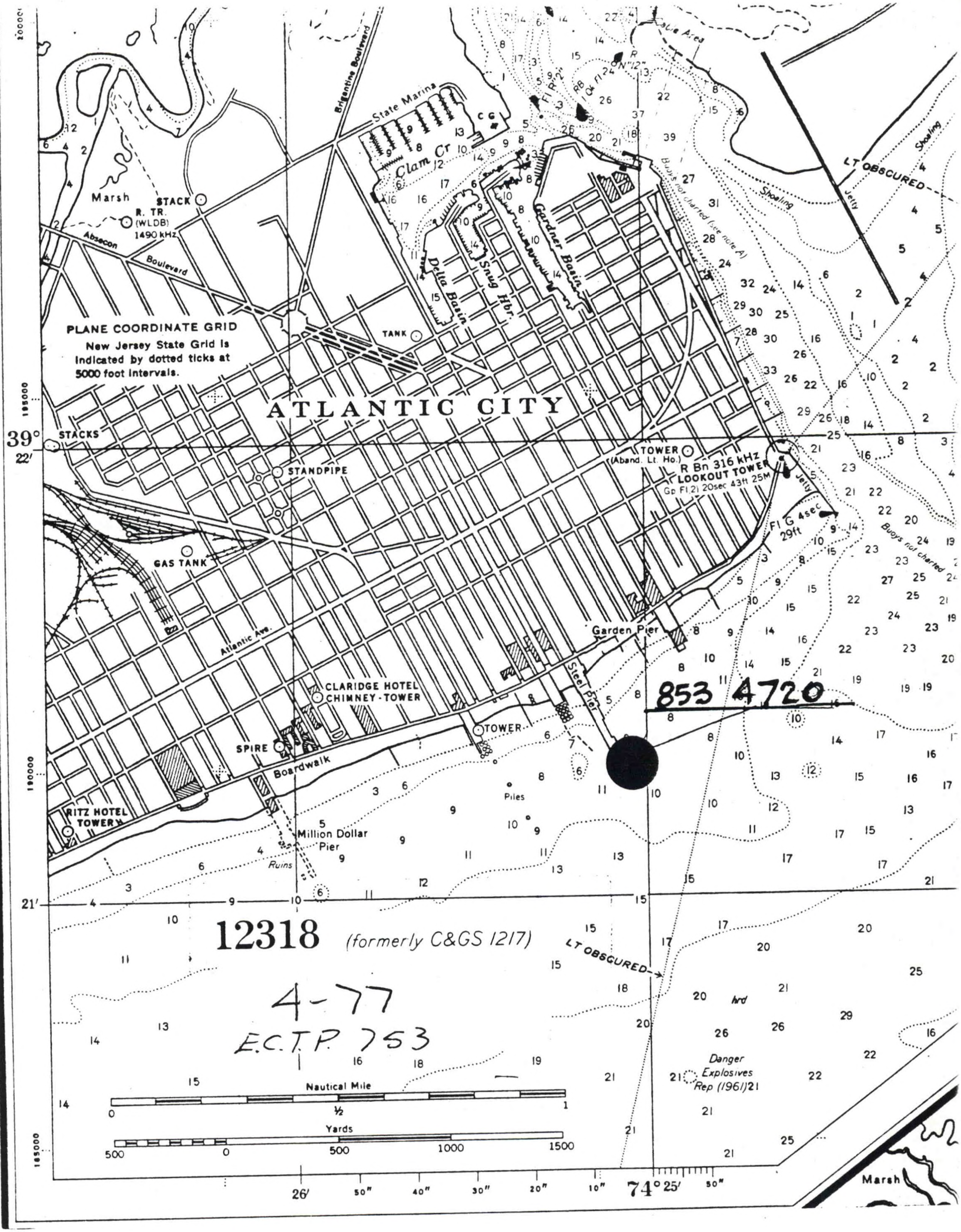
APPENDIX 2



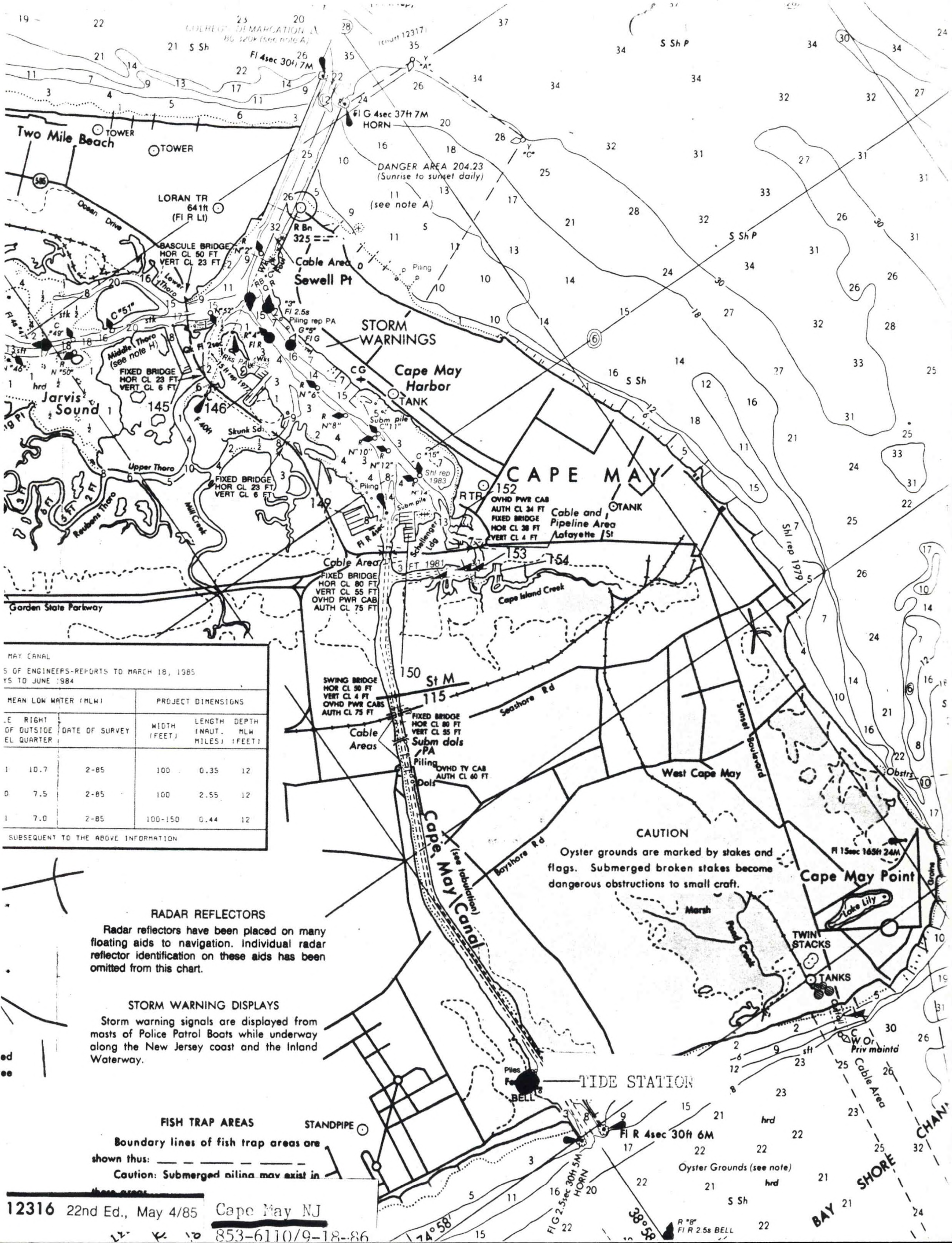
FLAGPOLE (N.Y. TEL.
Vesey St.
Hospital
MOVING PLATFORMS
Dover St.
BROOKLYN
NORTH BLDG.
WORLD TRADE CENTER
SOUTH BLDG.
Liberty St.
Cedar St.
Albany St.
Carlisle St.
Rector St.
Morris St.
Battery Pl.
FIRST NATIONAL CITY BANK BLDG.
Peck Slip
Beekman St.
Fulton St.
John St.
Fletcher St.
Maiden Lane Slip
Depeyster St.
Pine St.
Wall St.
Jones Lane
Gouverneur Lane
Old Slip
Cuylers Lane
Coenties Slip
Broad St.
Moore St.
Whitehall St.
Heliport
FIREBOAT STA
The Battery
HORN Priv maintd
Fl 2s Fog Lts 14M
Piles
BELL Priv maintd
TIDE STATION
17 Obstr
E Int R 6s 14ft 7M
Ok Fl Fog Lt 14M BELL Priv maintd
Wreckage
crs gy S
Dimond Reef
Cable Area
Fl 2sec Fog Lts 14M
Ventilator
FLAGPOLE
GOVERNORS ISLAND
F R 75ft 6M
F R 60ft 6M
HORN
Subm piling
CHURCH TR
CUP
RADAR TOWER
BUTTERMILK CHANNEL
fne gy S brk sh bk M
crs gy S
brk Sh
43 Obstr
30th Ed., Sept. 22/84
12335
THE BATTERY NYC
851-8750/8-86



SANDY HOOK, N.J.
853-1680/8-86



ATLANTIC CITY
PLANE COORDINATE GRID
New Jersey State Grid is indicated by dotted ticks at 5000 foot intervals.
Marsh
STACK
R. TR. (WLDB) 1490 kHz
Absecon Boulevard
Brigantine Boulevard
State Marina
Clam Cr
C G
Delta Basin
Snug Hbr.
Gardner Basin
TANK
STACKS
STANDPIPE
GAS TANK
Atlantic Ave.
CLARIDGE HOTEL CHIMNEY-TOWER
SPIRE
Boardwalk
TOWER
RITZ HOTEL TOWER
Million Dollar Pier
Ruins
Piles
Steel Pier
Garden Pier
TOWER (Aband. Lt. Ho.)
R Bn 316 kHz
LOOKOUT TOWER
Gp Fl 2) 20sec 43ft 25M
Fl G 4sec 29ft
Jetty
Shoaling
LT OBSCURED
Buoys not charted
853 4720
12318 (formerly C&GS 1217)
4-77
E.C.T.P. 753
Danger Explosives Rep (1961)
Nautical Mile
Yards
39° 22′
21′
26′
74° 25′
Marsh



MAY CANAL
S OF ENGINEERS-REPORTS TO MARCH 18, 1985
YS TO JUNE 1984

MEAN LOW WATER (MLW)		PROJECT DIMENSIONS		
..E RIGHT OF OUTSIDE ..EL QUARTER	DATE OF SURVEY	WIDTH (FEET)	LENGTH (NAUT. MILES)	DEPTH MLW (FEET)
I 10.7	2-85	100	0.35	12
D 7.5	2-85	100	2.55	12
I 7.0	2-85	100-150	0.44	12

SUBSEQUENT TO THE ABOVE INFORMATION

CAUTION

Oyster grounds are marked by stakes and flags. Submerged broken stakes become dangerous obstructions to small craft.

RADAR REFLECTORS

Radar reflectors have been placed on many floating aids to navigation. Individual radar reflector identification on these aids has been omitted from this chart.

STORM WARNING DISPLAYS

Storm warning signals are displayed from masts of Police Patrol Boats while underway along the New Jersey coast and the Inland Waterway.

FISH TRAP AREAS

Boundary lines of fish trap areas are shown thus: — — — — —

Caution: Submerged piling may exist in these areas.

12316 22nd Ed., May 4/85

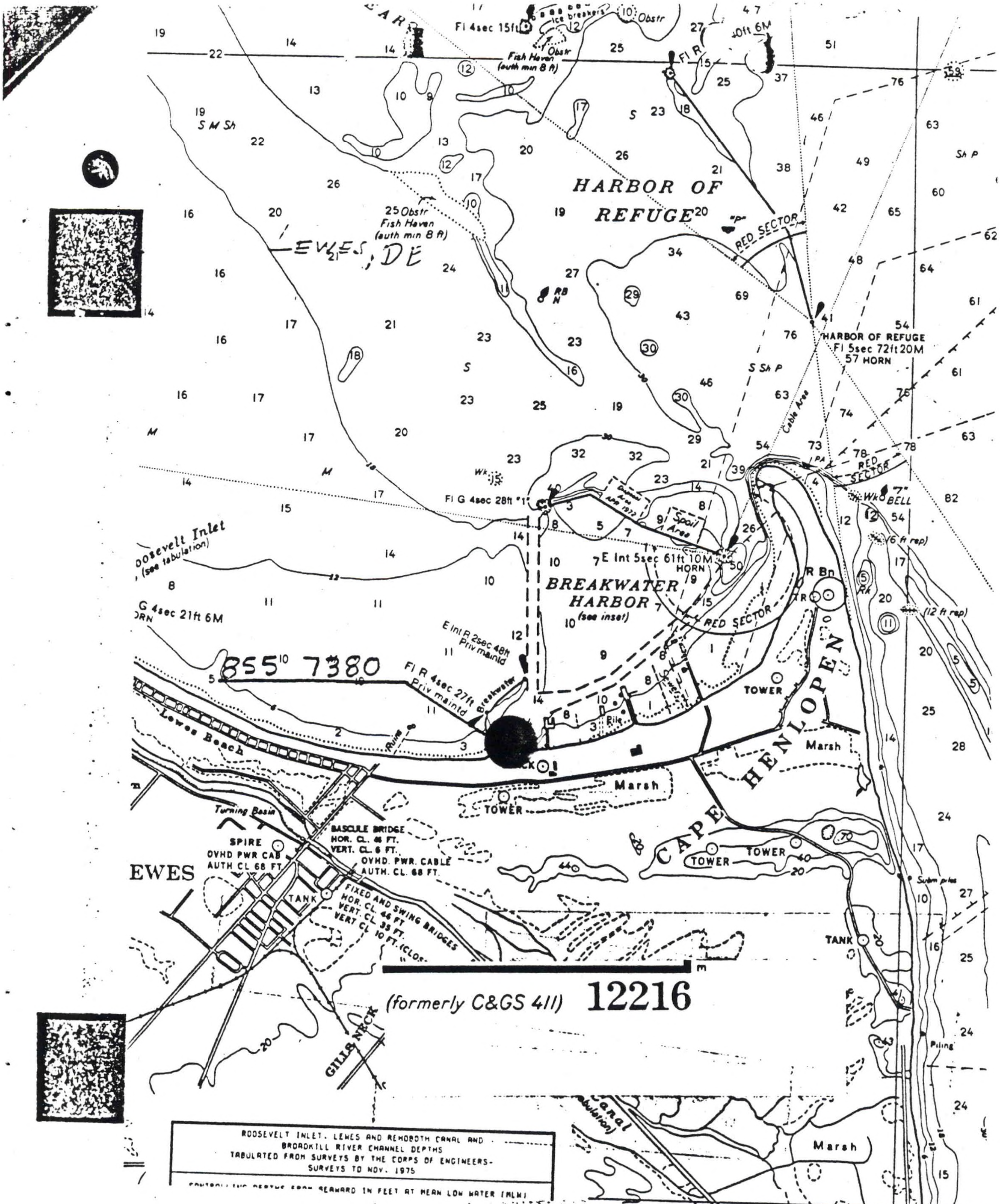
Cape May NJ
853-6110/9-18-86

UNITED STATES – EAST COAST
PENNSYLVANIA – NEW JERSEY
DELAWARE RIVER
PHILADELPHIA AND CAMDEN

(Philadelphia and Camden Waterfronts)

12313

SOUNDINGS IN FEET - SCALE 1:15,000


HARBOR OF REFUGE
LEWES, DE
HARBOR OF REFUGE
Fl 5sec 72ft 20M
57 HORN
RED SECTOR
Fish Haven (auth min 8 ft)
25 Obstr
Fl 4sec 15ft
Fl G 4sec 28ft "1"
E Int 5sec 61ft 10M HORN
BREAKWATER HARBOR (see inset)
Spoil Area
Roosevelt Inlet (see tabulation)
G 4sec 21ft 6M
855 7380
E Int R 2sec 48ft Priv maintd
Fl R 4sec 27ft Priv maintd
Breakwater
Lewes Beach
Marsh
TOWER
Turning Basin
BASCULE BRIDGE HOR. CL. 46 FT. VERT. CL. 6 FT.
SPIRE
OVHD PWR CAB AUTH CL 68 FT.
OVHD. PWR. CABLE AUTH. CL. 68 FT.
LEWES
TANK
FIXED AND SWING BRIDGES HOR. CL. 46 FT. VERT. CL. 35 FT. VERT. CL. 10 FT. (CLOS.
CAPE HENLOPEN
R Bn
"7" BELL
(6 ft rep)
(12 ft rep)
Subm piles
Piling
GILLS NECK
(formerly C&GS 411) 12216
ROOSEVELT INLET, LEWES AND REHOBOTH CANAL AND BROADKILL RIVER CHANNEL DEPTHS
TABULATED FROM SURVEYS BY THE CORPS OF ENGINEERS-SURVEYS TO NOV. 1975
CONTROLLING DEPTHS FROM SEAWARD IN FEET AT MEAN LOW WATER (MLW)

5/86

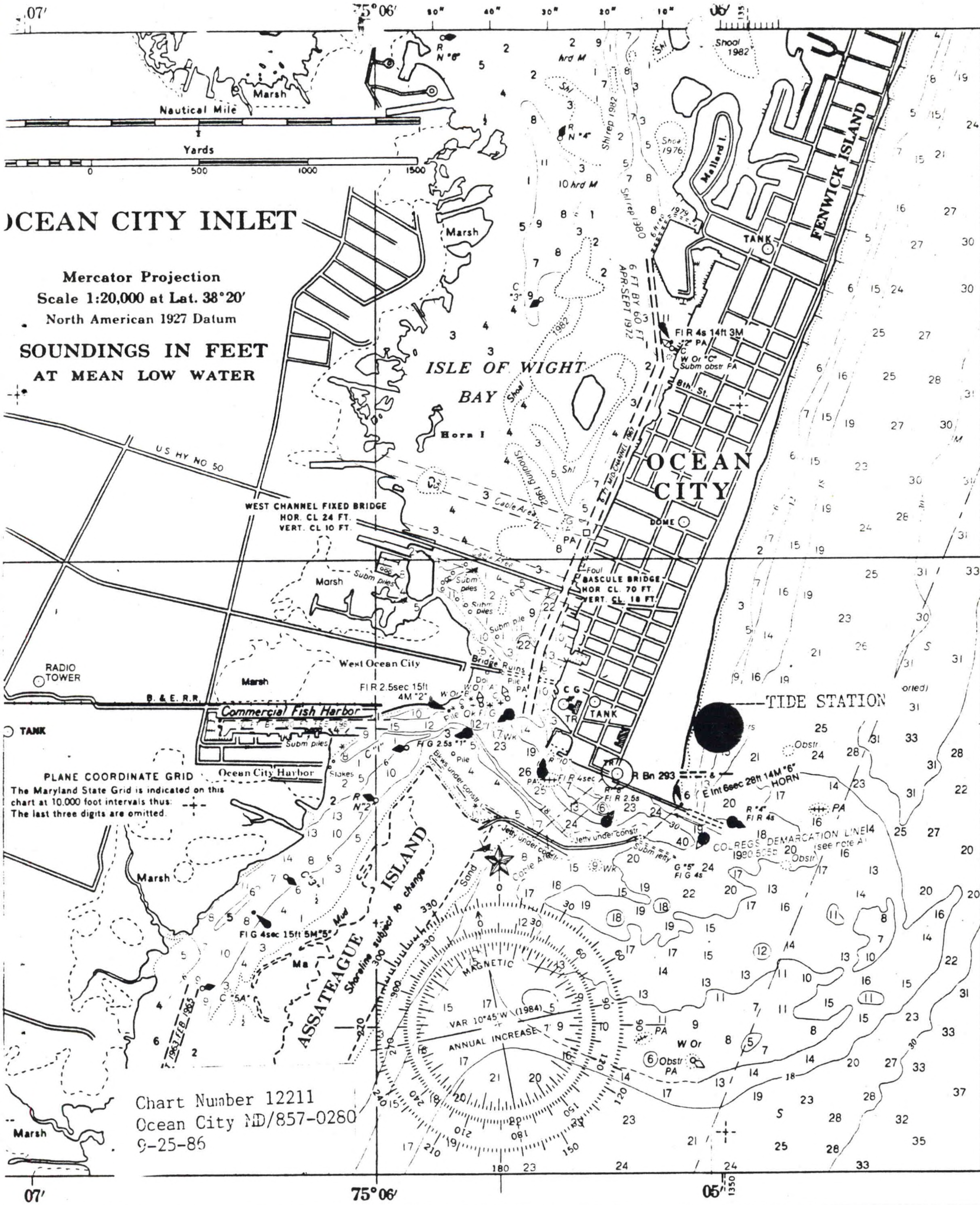
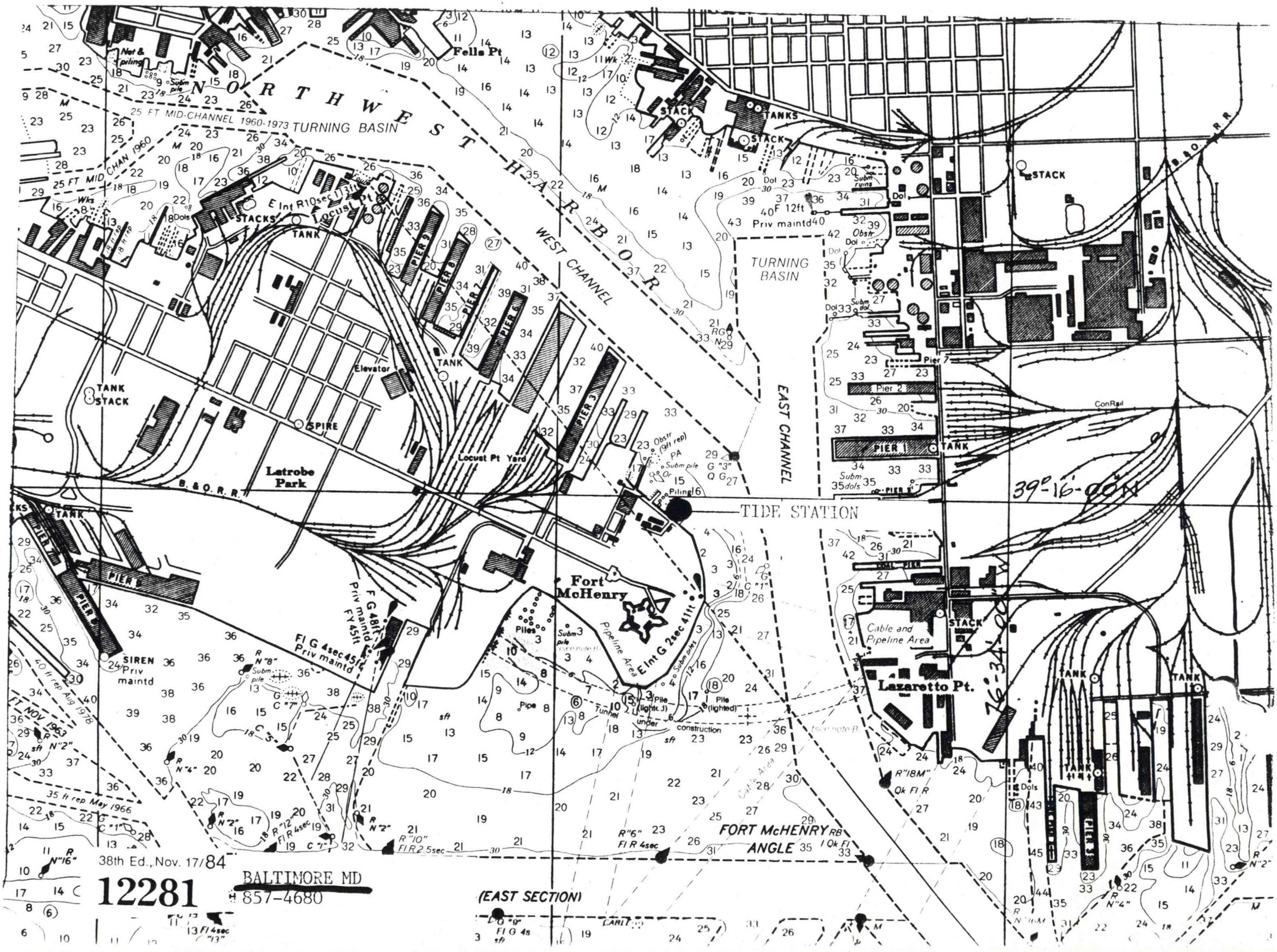
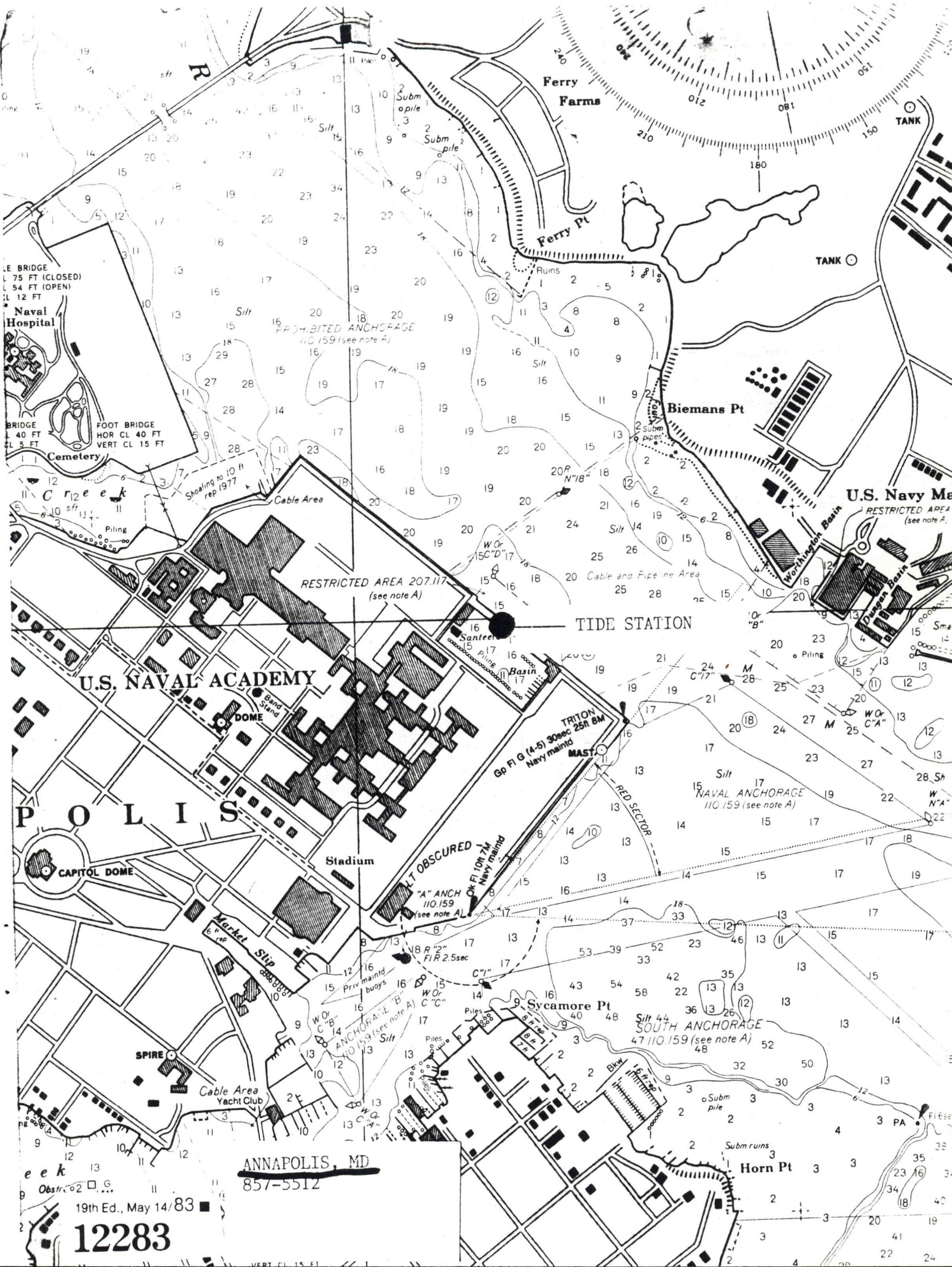


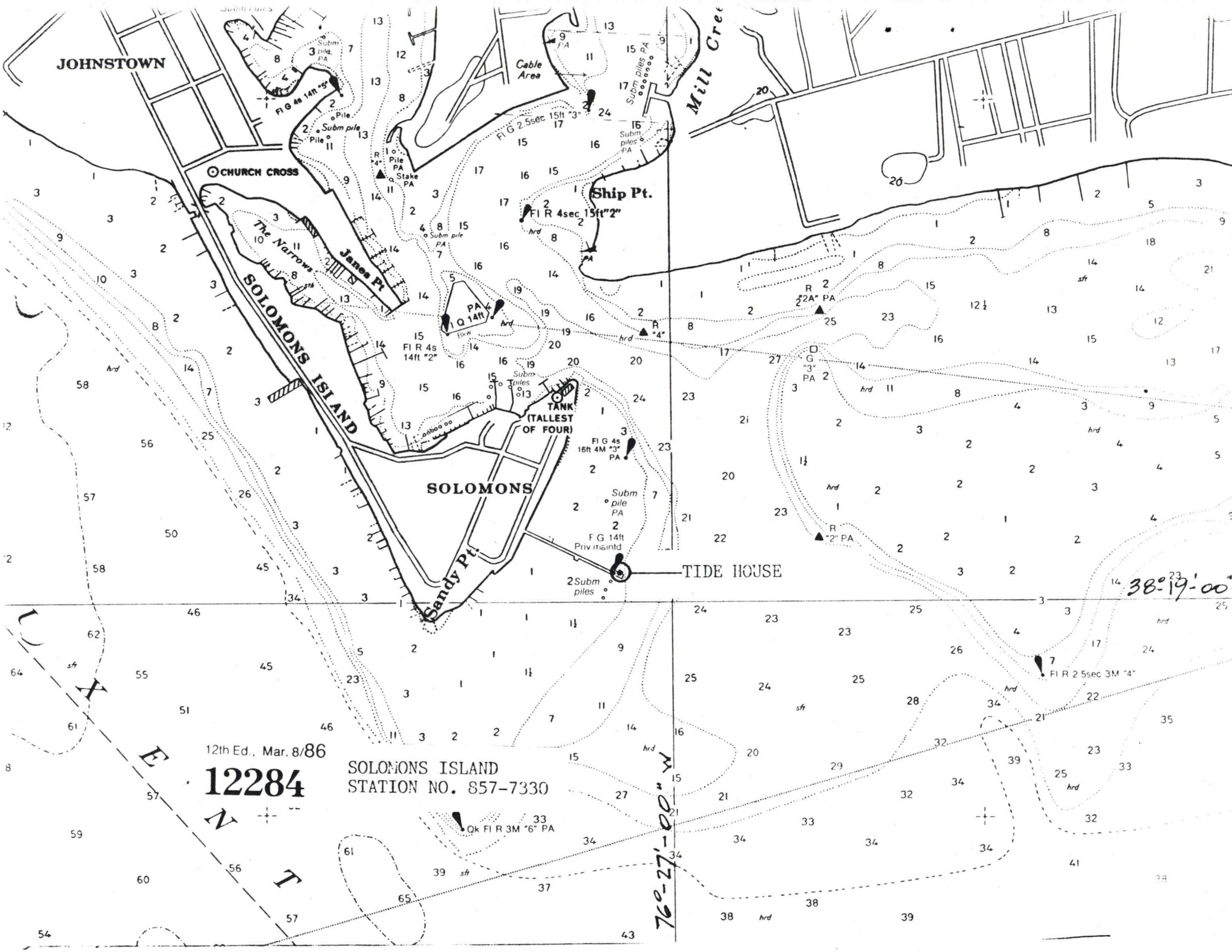
Chart Number 12211
Ocean City MD/857-0280
9-25-86



NORTHWEST HARBOR
TURNING BASIN
25 FT MID-CHANNEL 1960-1973
25 FT MID CHAN 1960
WEST CHANNEL
EAST CHANNEL
TURNING BASIN
TIDE STATION
Fells Pt
Locust Pt
Locust Pt Yard
Latrobe Park
Fort McHenry
Pipeline Area
Lazaretto Pt.
Cable and Pipeline Area
FORT McHENRY ANGLE
(EAST SECTION)
PIER 1
Pier 2
PIER 3
PIER 6
PIER 7
PIER 8
PIER 9
B. & O. R.R.
ConRail
Elevator
SPIRE
TANK
STACK
STACKS
TANKS
SIREN Priv maintd
F G 48ft Priv maintd FY 45ft
Fl G 4sec 45ft Priv maintd
E Int G 2sec 41ft
40 ft rep Aug 1978
35 ft rep May 1966
FT NOV 1963
39°-16'-00"N
76°-34'-00"W
38th Ed., Nov. 17/84
12281
BALTIMORE MD
857-4680



Ferry Farms
Ferry Pt
Ruins
TANK
Biemans Pt
Subm pipes
Subm pile
U.S. Navy Ma
RESTRICTED AREA (see note A)
Worthington Basin
Dungan Basin
PROHIBITED ANCHORAGE 110.159 (see note A)
Silt
Naval Hospital
FOOT BRIDGE HOR CL 40 FT VERT CL 15 FT
Cemetery
Shoaling to 10 ft rep 1977
Cable Area
Piling
RESTRICTED AREA 207.117 (see note A)
TIDE STATION
Santee Basin
U.S. NAVAL ACADEMY
Band Stand
DOME
TRITON Gp Fl G (4+5) 30sec 25ft 8M Navy maintd
MAST
RED SECTOR
NAVAL ANCHORAGE 110.159 (see note A)
Cable and Pipeline Area
POLIS
CAPITOL DOME
Stadium
LT OBSCURED
"A" ANCH 110.159 (see note A)
Qk Fl 10ft 7M Navy maintd
Market Slip
R "2" Fl R 2.5sec
Priv maintd buoys
ANCHORAGE "B" 110.159 (see note A)
Sycamore Pt
SOUTH ANCHORAGE 47 110.159 (see note A)
SPIRE
Cable Area
Yacht Club
Subm ruins
Horn Pt
ANNAPOLIS, MD
857-5512
19th Ed., May 14/83
12283



JOHNSTOWN
CHURCH CROSS
The Narrows
Janes Pt
SOLOMONS ISLAND
SOLOMONS
Sandy Pt
Ship Pt.
Mill Cre
Cable Area
TANK (TALLEST OF FOUR)
TIDE HOUSE
F G 14ft Priv maintd
Fl G 4s 16ft 4M "3" PA
Fl R 4s 14ft "2"
Fl R 4sec 15ft "2"
Fl G 2.5sec 15ft "3"
Fl G 4s 14ft "5"
Fl R 2.5sec 3M "4"
Qk Fl R 3M "6" PA
38°19'00"
76°27'00"W
12th Ed., Mar. 8/86
12284
SOLOMONS ISLAND
STATION NO. 857-7330
U X E N T

NATIONAL OCEAN SERVICE

ED STATES – EAST COAST
VIRGINIA

OTEAGUE INLET
TO
IACHIPONGO INLET

Mercator Projection
Scale 1:80,000 at Lat. 37°40′
North American 1927 Datum

SOUNDINGS IN FEET
AT MEAN LOW WATER

TIDAL INFORMATION

	Height referred to datum of soundings (MLW)		
	Mean High Water	Mean Tide Level	Mean Low Water
	feet	feet	feet
ılet	2.6	1.3	0.0
	3.6	1.8	0.0
	4.0	2.0	0.0

HEIGHTS

Heights in feet above Mean High Water.

AUTHORITIES

ıy and topography by the National Ocean Service, Geodetic Services with additional data from the Corps of ɪological Survey, and U.S. Coast Guard.

ols and Abbreviations see Chart No. 1
ɛgulations for Preventing Collisions at Sea, 1972.
ıes are shown thus: — — — — — —

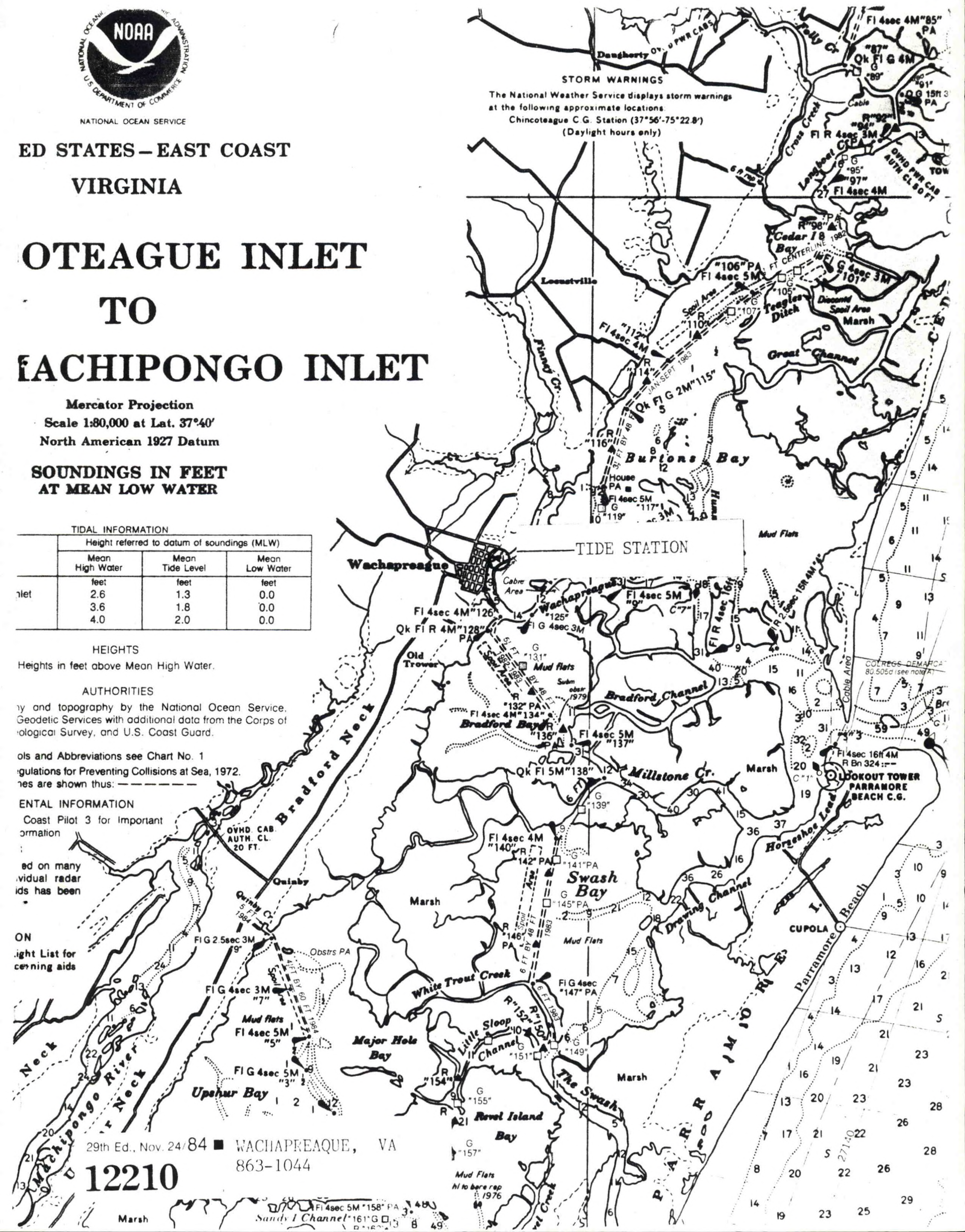
ENTAL INFORMATION

Coast Pilot 3 for Important ɔrmation

ed on many ıvidual radar ıds has been

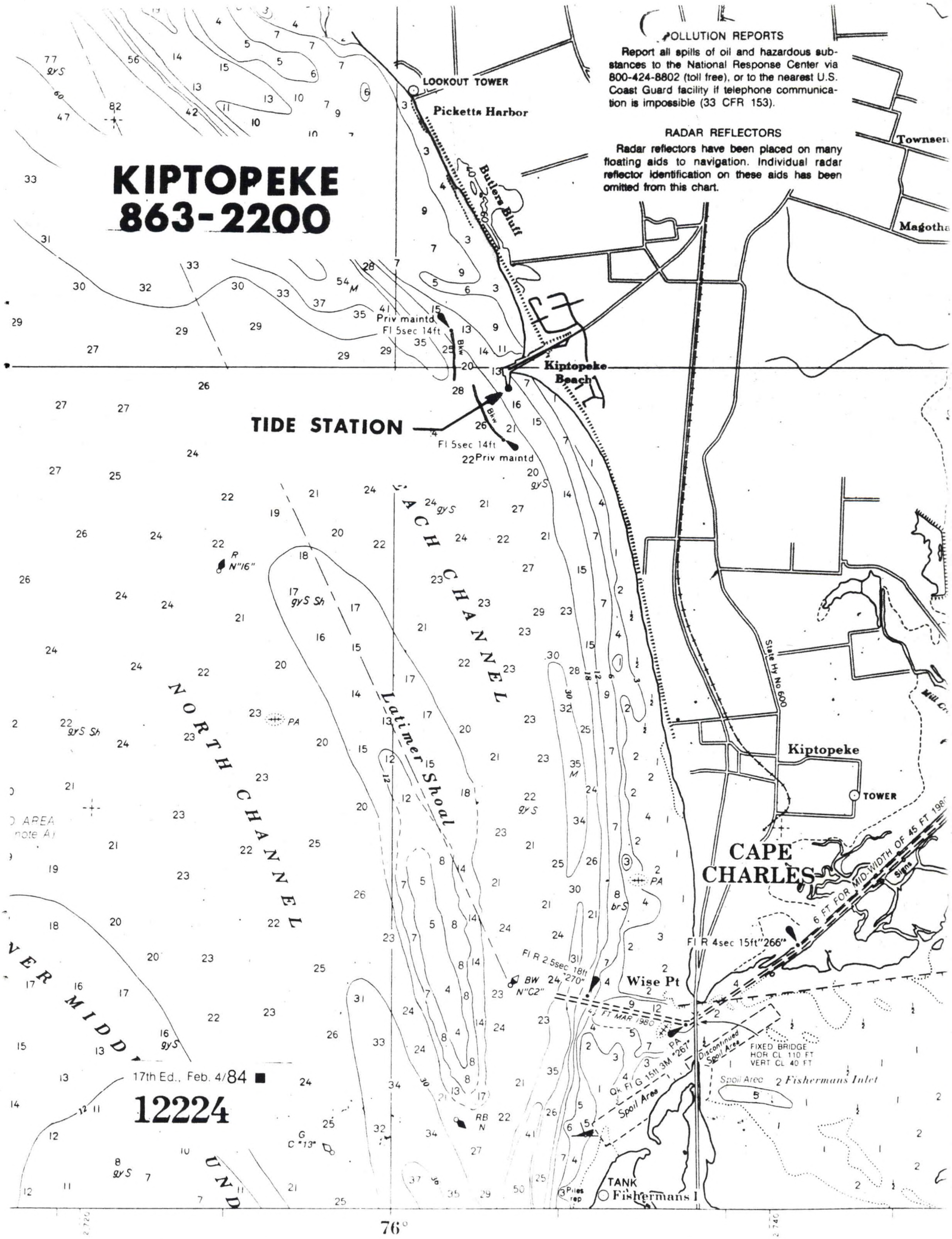
ON

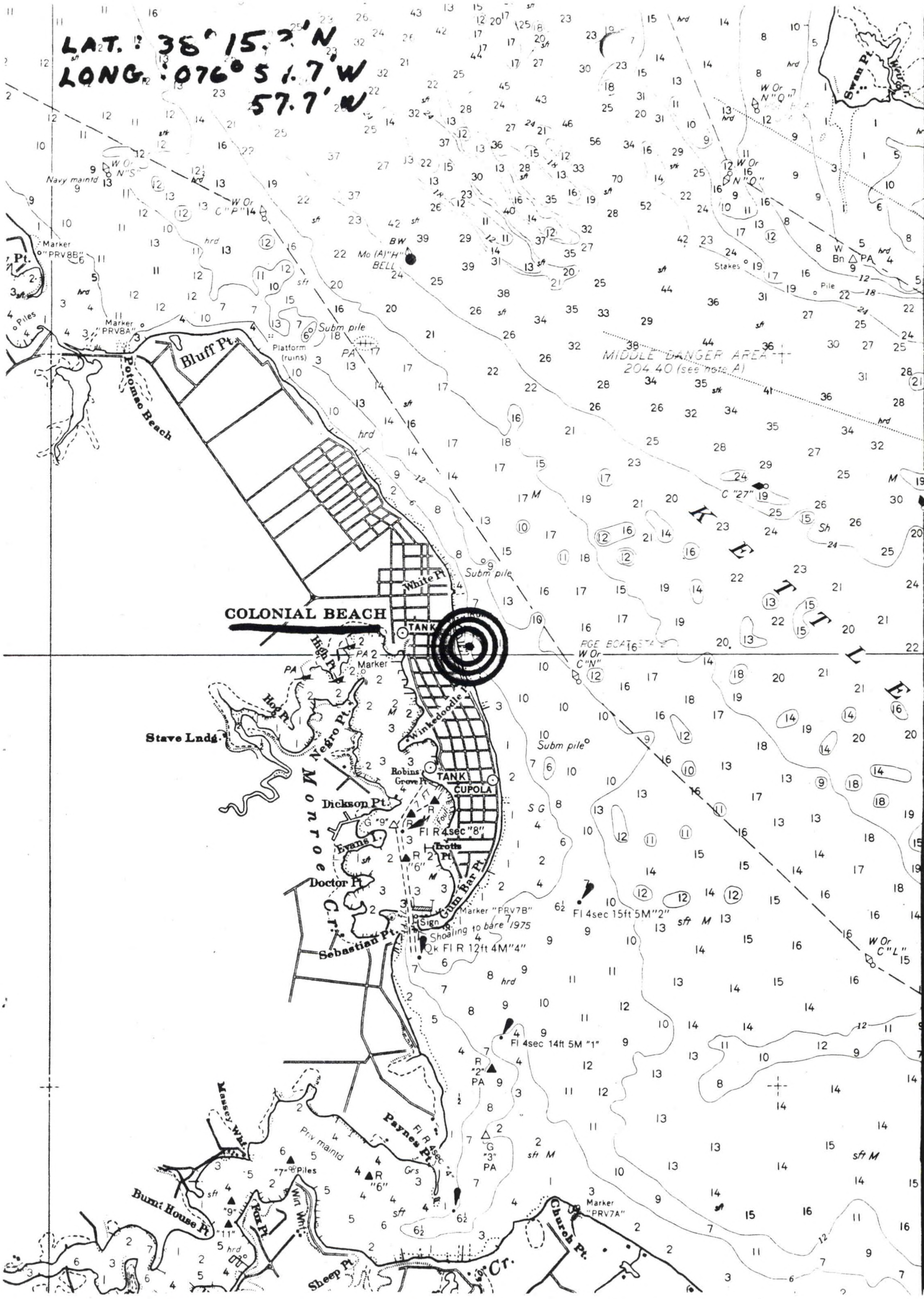
ıght List for cerning aids

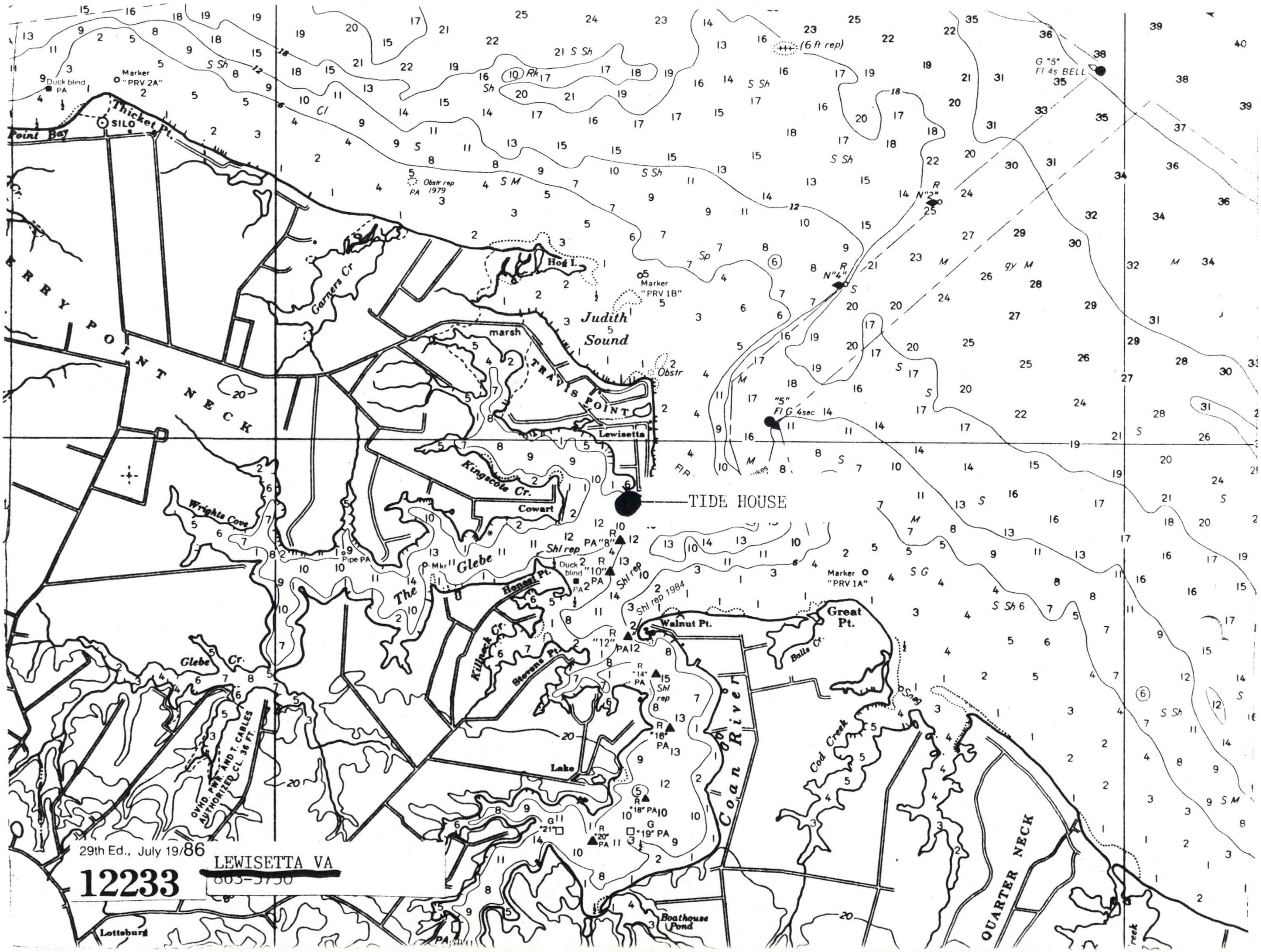


29th Ed., Nov. 24/84 ■ WACHAPREAQUE, VA
863-1044

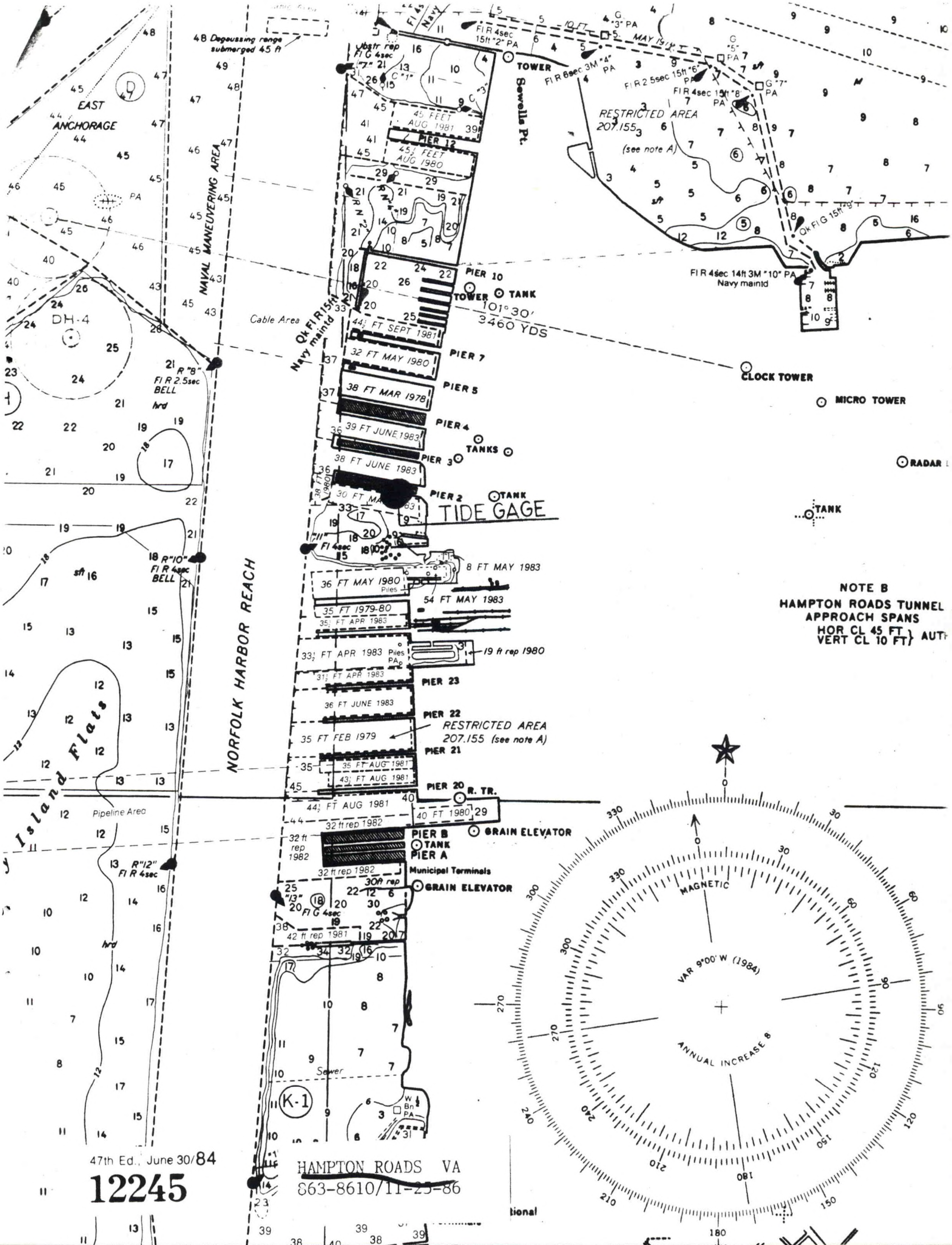
12210


KIPTOPEKE
863-2200
POLLUTION REPORTS
Report all spills of oil and hazardous substances to the National Response Center via 800-424-8802 (toll free), or to the nearest U.S. Coast Guard facility if telephone communication is impossible (33 CFR 153).
RADAR REFLECTORS
Radar reflectors have been placed on many floating aids to navigation. Individual radar reflector identification on these aids has been omitted from this chart.
LOOKOUT TOWER
Picketts Harbor
Butlers Bluff
Townsen
Magotha
Priv maintd
Fl 5sec 14ft
Kiptopeke Beach
TIDE STATION
Fl 5sec 14ft
Priv maintd
NORTH CHANNEL
Latimer Shoal
State Hy No 600
Kiptopeke
TOWER
CAPE CHARLES
6 FT FOR MID-WIDTH OF 45 FT 1980
Fl R 4sec 15ft "266"
Fl R 2.5sec 18ft "270"
BW N"C2"
Wise Pt
FT MAR 1980
Qk Fl G 15ft 3M "267"
Discontinued Spoil Area
FIXED BRIDGE
HOR CL 110 FT
VERT CL 40 FT
Spoil Area
Fishermans Inlet
Spoil Area
TANK
Fishermans I
Piles rep
RB N
G C "13"
17th Ed., Feb. 4/84
12224
76°

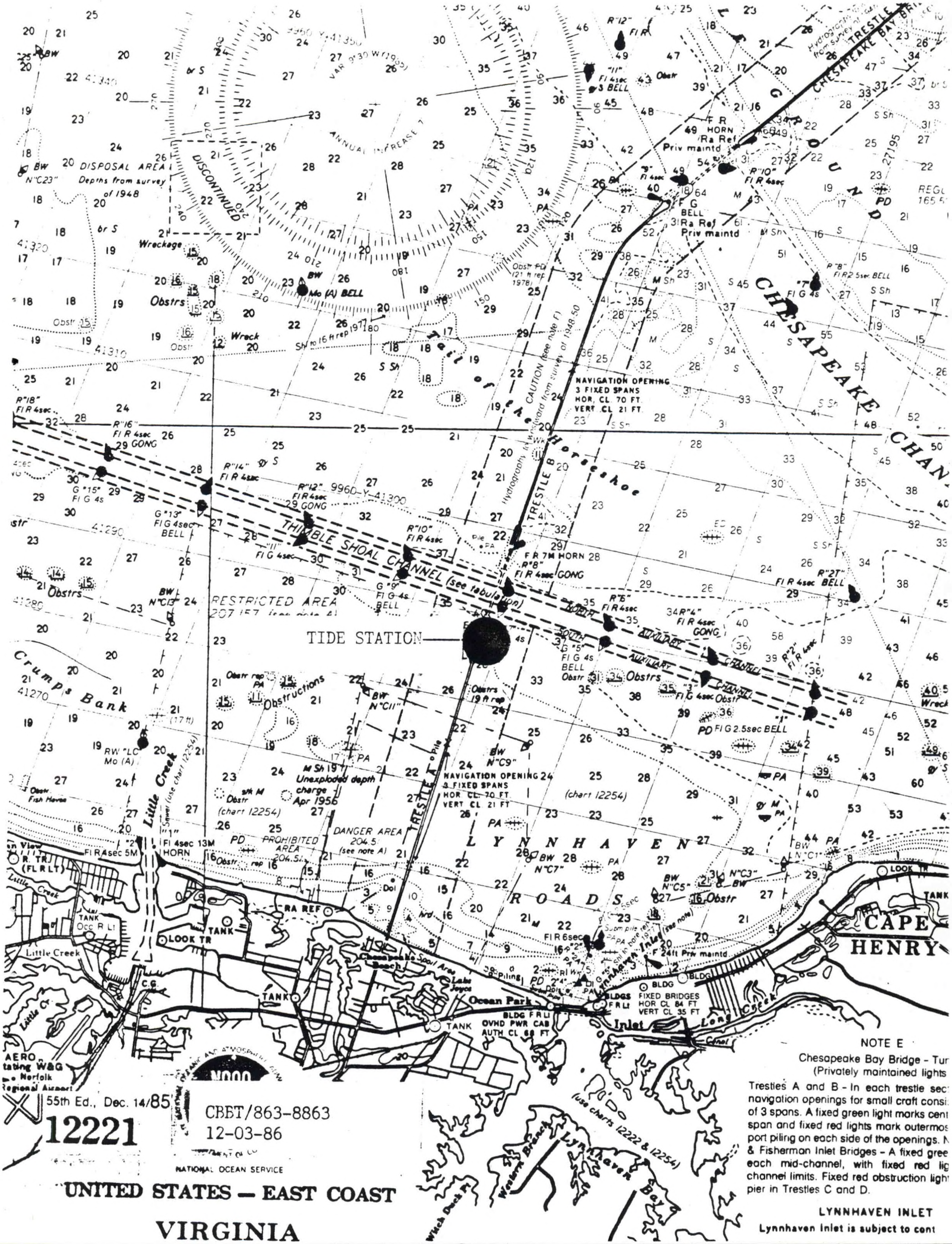

LAT.: 38° 15.?'N
LONG.: 076° 51.7'W
57.7'W
COLONIAL BEACH
Bluff Pt.
Potomac Beach
White Pt.
TANK
Winkedoodle Pt.
Stave Lndg.
Hog Pt.
Negro Pt.
High Pt.
Monroe Cr.
Robins Grove Pt.
TANK
CUPOLA
Dickson Pt.
Evans Pt.
Doctor Pt.
Trotts Pt.
Gum Bar Pt.
Sebastian Pt.
Paynes Pt.
Massey Whf.
Burnt House Pt.
Fox Pt.
Wirt Whf.
Sheep Pt.
Church Pt.
Swan Pt.
KETTLE
MIDDLE DANGER AREA
204.40 (see note A)
Marker "PRV8B"
Marker "PRV8A"
Marker "PRV7B"
Marker "PRV7A"
Navy maintd
Platform (ruins)
Subm pile
BW Mo (A) "H" BELL
Fl 4sec 15ft 5M "2"
Qk Fl R 12ft 4M "4"
Fl 4sec 14ft 5M "1"
Fl R 4sec "8"
Shoaling to bare 1975
Prv maintd
Piles
Stakes



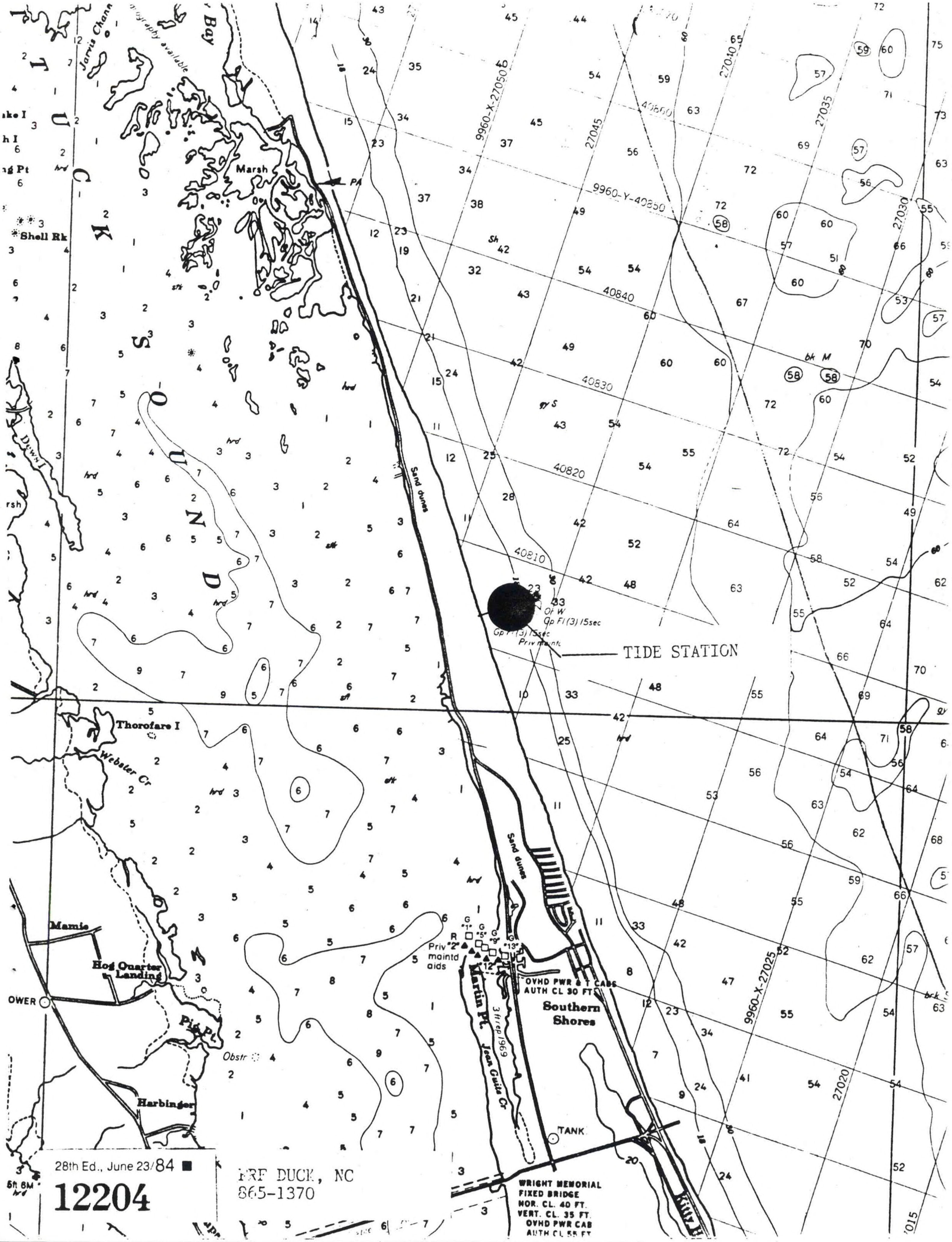
TIDE HOUSE
Judith Sound
Travis Point
Lewisetta
Hog I.
Thicket Pt.
Point Bay
Garners Cr
Kingscote Cr.
Cowart
Wrights Cove
The Glebe
Glebe Cr.
Hones Pt.
Killpeck Cr.
Stevens Pt.
Walnut Pt.
Great Pt.
Balls Cr.
Cod Creek
Coan River
Quarter Neck
Boathouse Pond
Lake
Lottsburg
Marker "PRV 1A"
Marker "PRV 1B"
Marker "PRV 2A"
G "5" Fl 4s BELL
"5" Fl G 4sec
OVHD PWR. AND T. CABLES AUTHORIZED CL. 36 FT.
29th Ed., July 19/86
12233
LEWISETTA VA



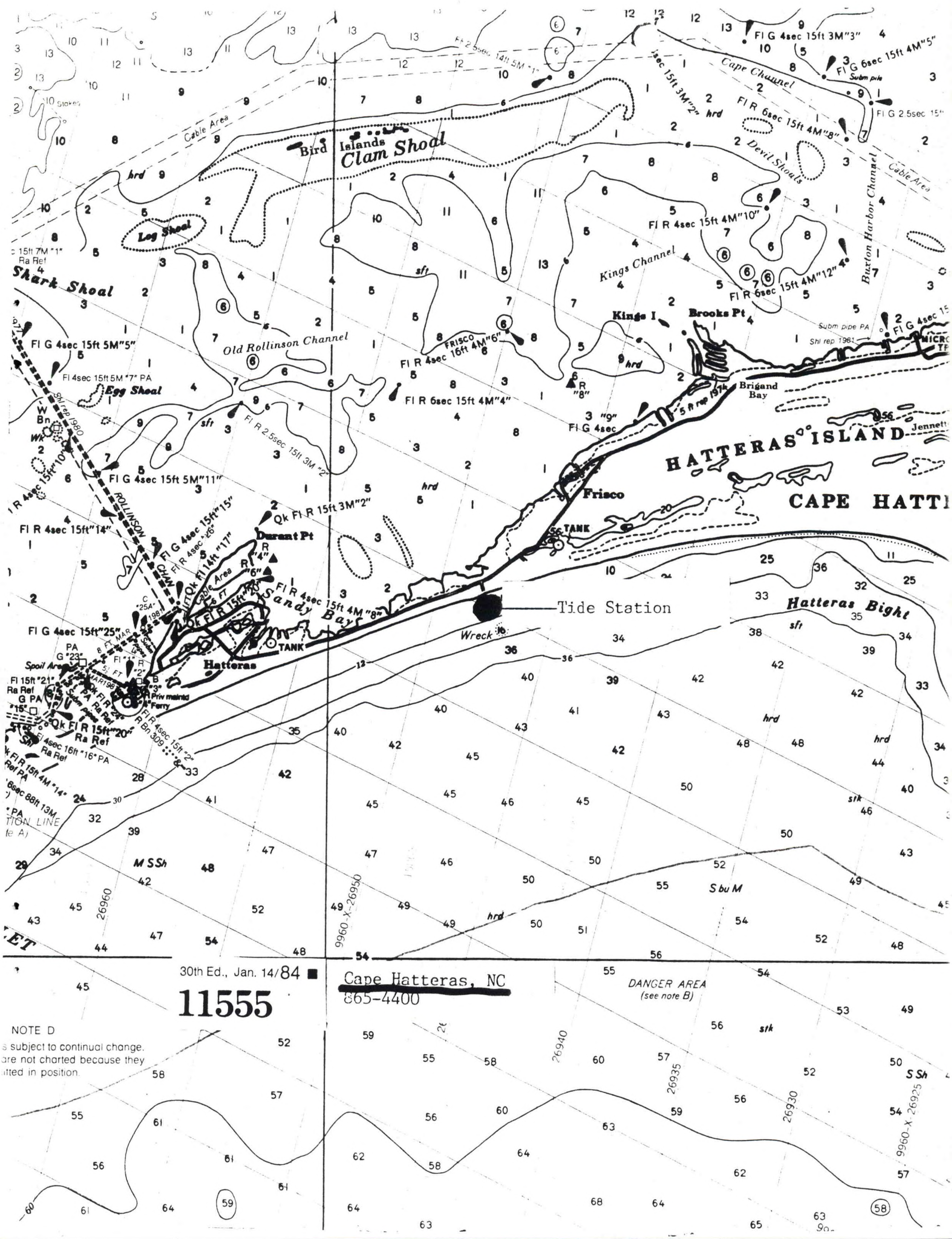
48 Degaussing range submerged 45 ft
EAST ANCHORAGE
DH-4
NAVAL MANEUVERING AREA
Cable Area
NORFOLK HARBOR REACH
Island Flats
Pipeline Area
R "8" Fl R 2.5sec BELL
R "10" Fl R 4sec BELL
R "12" Fl R 4sec
Qk Fl R 15ft Navy maintd
TOWER
Sewells Pt.
RESTRICTED AREA 207.155 (see note A)
45 FEET AUG 1981
PIER 12
45 1/2 FEET AUG 1980
PIER 10
TOWER
TANK
101°30'
3460 YDS
44 1/2 FT SEPT 1981
32 FT MAY 1980
PIER 7
38 FT MAR 1978
PIER 5
39 FT JUNE 1983
PIER 4
TANKS
38 FT JUNE 1983
PIER 3
PIER 2
TANK
TIDE GAGE
CLOCK TOWER
MICRO TOWER
RADAR
TANK
8 FT MAY 1983
36 FT MAY 1980
54 FT MAY 1983
35 FT 1979-80
35 1/2 FT APR 1983
33 1/2 FT APR 1983
19 ft rep 1980
31 1/2 FT APR 1983
PIER 23
36 FT JUNE 1983
PIER 22
RESTRICTED AREA 207.155 (see note A)
35 FT FEB 1979
PIER 21
35 FT AUG 1981
43 1/2 FT AUG 1981
PIER 20
R. TR.
44 1/2 FT AUG 1981
40 FT 1980
32 ft rep 1982
PIER B
TANK
PIER A
GRAIN ELEVATOR
Municipal Terminals
GRAIN ELEVATOR
30ft rep
42 ft rep 1981
Sewer
K-1
NOTE B
HAMPTON ROADS TUNNEL
APPROACH SPANS
HOR CL 45 FT
VERT CL 10 FT
MAGNETIC
VAR 9°00'W (1984)
ANNUAL INCREASE 8'
47th Ed., June 30/84
12245
HAMPTON ROADS VA
863-8610/11-25-86



TIDE STATION
THIMBLE SHOAL CHANNEL (see tabulation)
NORTH AUXILIARY CHANNEL
SOUTH AUXILIARY CHANNEL
CHESAPEAKE CHANNEL
CHESAPEAKE BAY BRIDGE TRESTLE
TRESTLE A
TRESTLE B
Tail of the Horseshoe
Crumps Bank
DISPOSAL AREA
Depths from survey of 1948
DISCONTINUED
RESTRICTED AREA 207.157 (see note A)
DANGER AREA 204.5 (see note A)
PROHIBITED AREA 204.51
NAVIGATION OPENING
3 FIXED SPANS
HOR. CL. 70 FT.
VERT. CL. 21 FT.
CAUTION (see note F)
Unexploded depth charge Apr 1956
Obstructions
Wreckage
Wreck
(chart 12254)
L Y N N H A V E N
R O A D S
Little Creek
Chesapeake Beach
Ocean Park
Lynnhaven Inlet
Long Creek
CAPE HENRY
FIXED BRIDGES
HOR CL 84 FT
VERT CL 35 FT
OVHD PWR CAB AUTH CL 68 FT
(use charts 12222 & 12254)
Western Branch
Lynnhaven Bay
Witch Duck Pt
Norfolk Regional Airport
VAR 9°30'W (1985)
ANNUAL INCREASE 7'
55th Ed., Dec. 14/85
12221
CBBT/863-8863
12-03-86
NATIONAL OCEAN SERVICE
UNITED STATES — EAST COAST
VIRGINIA
NOTE E
Chesapeake Bay Bridge - Tur
(Privately maintained lights
Trestles A and B - In each trestle sec
navigation openings for small craft consi
of 3 spans. A fixed green light marks cent
span and fixed red lights mark outermos
port piling on each side of the openings. N
& Fisherman Inlet Bridges - A fixed gree
each mid-channel, with fixed red lig
channel limits. Fixed red obstruction light
pier in Trestles C and D.
LYNNHAVEN INLET
Lynnhaven Inlet is subject to cont



CURRITUCK SOUND
Jarvis Chann
Marsh
Shell Rk
Sand dunes
TIDE STATION
Of W
Gp Fl (3) 15sec
Priv maintd
9960-X-27050
9960-Y-40850
9960-X-27025
40840
40830
40820
40810
Thorofare I
Webster Cr
Mamie
Hog Quarter Landing
OWER
Pig Pt
Obstr
Harbinger
Martin Pt
Jean Guite Cr
Priv maintd aids
OVHD PWR & T CABS AUTH CL 30 FT
Southern Shores
TANK
WRIGHT MEMORIAL FIXED BRIDGE
HOR. CL. 40 FT.
VERT. CL. 35 FT.
OVHD PWR CAB
AUTH CL 55 FT
28th Ed., June 23/84
12204
FRF DUCK, NC
865-1370


Tide Station
30th Ed., Jan. 14/84
11555
Cape Hatteras, NC
865-4400
HATTERAS ISLAND
CAPE HATT
Clam Shoal
Bird Islands
Log Shoal
Shark Shoal
Egg Shoal
Old Rollinson Channel
Kings Channel
Cape Channel
Devil Shoals
Buxton Harbor Channel
Kings I
Brooks Pt
Brigand Bay
Frisco
Durant Pt
Sandy Bay
Hatteras
Hatteras Bight
Wreck
TANK
Cable Area
ROLLINSON CHN
Spoil Area
Priv maintd Ferry
DANGER AREA
(see note B)
NOTE D
s subject to continual change.
are not charted because they
itted in position.
Jennett