APPENDIX E
EXHIBIT E-1-1

1995 MONITORING RESULTS

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1995 MONITORING SUMMARY

I. INTRODUCTION

Between March and July 1995, Aubrey Consulting, Inc. (ACI) conducted a large-scale hydrodynamic survey of the portions of the Delaware Estuary surrounding the Salem Generating Station. The data collected during this period were used to generate a three-dimensional model of flow patterns near the Station. This survey was performed in response to the accumulation of detritus in the cooling water intake systems during the spring of 1994.

These data collected in 1995, in addition to providing bathymetric information, have been used for comparison to those portions of the data set, collected by Lawler, Matusky and Skelly Engineers (LMS) for the 1998 Modified Thermal Monitoring Program, that related to physical processes.

This attachment summarizes the data collection program. Details can be found in the complete report issued by Aubrey Consulting, Inc. 1995.

I.A. Objectives

The Station is located adjacent to the Delaware Estuary (Figure I-1), and utilizes Estuary water for its service water system (SWS) and circulating water system (CWS). The goal of the study was to produce comprehensive information about the hydrodynamics in the portion of the Estuary surrounding the Station. Especially detailed information was sought in the area near the intake structures and discharge piping where the converging estuarine, tidal, and Station-generated flows create complex hydrodynamic interactions.

Field observations included local observations of wind patterns, tidal elevations, currents, temperature, and conductivity (a surrogate for salinity). Appropriate data collection techniques were employed, including shipboard measurements, in situ instrument deployment, and real-time data acquisition. This report summarizes the field methodologies as well as the resulting data files. It details the types of data acquired, the collection intervals, data quality indicators, data transformation procedures, and the formats used to store the data and generate data displays.

I.B. Scope

Data collection took place within three defined regions: the far-field, near-field, and the vicinity of the Station. Note that the far-field and near-field designations differ from those used in the 1998 LMS study. The 1995 study being presented here was intended to describe circulation patterns, whereas the 1998 LMS study was focused on thermal plume transport, and these different objectives led to different study area delineation.

The far-field region contained the entire Estuary from the mouth of the Estuary to Trenton, NJ, including the Chesapeake and Delaware (C&D) Canal and lower portions of the Schuylkill River (Figure I-2). Rivers and streams that contributed less than 3% total freshwater inflow to the Estuary system were not included. For the far-field region data from other sources such as NOAA and USGS were included in the analysis.

The near-field region was defined as an approximately five-mile portion of the Estuary surrounding the Station. Its northern boundary was a line stretching across the Estuary between the northern tip of the area known as Artificial Island (where Salem is located) and the southern tip of Reedy Island. Its southern boundary stretched from the mouth of Hope Creek, NJ to Liston Point, DE (Figure I-3).

The vicinity of the Station is the region surrounding the Station's intake structures and discharge pipes (Figure I-3). This was the area for which the greatest detail of hydrodynamic circulation was sought.

The sensor systems used to collect data were technologically sophisticated and well-validated. They included current meters, tide gauges, Acoustic Doppler Current Profilers (ADCPs), salinity and temperature gauges, a fathometer, GPS (Global Positioning System) location devices and real-time atmospheric monitoring systems.

Ship-based observations were made during four surveys conducted from April to July 1995. In situ sensors were deployed between March 1995 and July 1995, and real-time acquisition of meteorological and river data continued throughout the project.

Figure I-4 shows the sensor deployment in the vicinity of the Station. Although sensors were deployed from the mouth of the Estuary to the southern end of the C&D Canal, most were centered around the vicinity of the Station.

Shipboard measurements included bathymetry, (broadband) ADCP, Conductivity-Temperature-Depth (CTD) measurements, and GPS-based location determinations for navigation. Shipboard data collection occurred principally in the near-field and the vicinity of the Station. High-resolution hourly measurements during full tidal cycles (approximately 12.4 hours) were obtained along the north and south boundaries of the near-field region, along the boundary of the vicinity of the Station, and along a northwest transect from the mouth of the Estuary to the Station.

The in situ data collection effort focused on current and tide measurements. Instrumentation included bottom-mounted current meters, high-resolution tide gauges, and real-time current monitors.

In situ current meters and tide gauges were deployed on each side of the Estuary at both the north and south boundaries of the near-field region.

In situ observations were begun in late March 1995 while Eastern Standard Time (EST) was in effect. The shipboard surveys were performed from April to June, after the shift to Eastern Daylight Time (EDT). The time standard in effect at data collection was retained in the raw data to reduce confusion. When two data sets were compared, all times were converted to EST. Data collection methods are described in greater detail below.

II. SHIPBOARD DATA COLLECTION

Four ship-based surveys were conducted during the spring and early summer, between 10 April and 23 June 1995 (Table II-1). Current, temperature, and salinity profiles were collected along the north and south boundaries of the near-field region as well as within the vicinity of the Station. Bathymetry information was collected throughout the near-field region.

Two vessels were employed. Vessel 1 was a shallow-draft, 22-foot vessel, equipped with a fathometer and CTD profiler and Vessel 2 was a 25-foot Parker, equipped with an ADCP and CTD profiler.

Both vessels carried GPS-based navigation systems to pinpoint positions of the acquired data. Instrument system schematics for the two vessels are shown in Figures II-1 and II-2.

Vessel 1 was designated a roving data collection platform, and fitted for specialized monitoring. It was used to generate a high-resolution bathymetry survey of the near-field region during the first survey period (Survey 1). Vessel 1 also was used to measure temperature and conductivity (CTD) profiles at the mouth of the Estuary during a complete tidal cycle to determine levels of salinity entering the system from the open ocean. In addition, the vessel was used to measure salinity levels from the mouth of the bay to the Station and back, to characterize the effects of vertical interactions as ocean tides meet the fresher water discharged from the Estuary during the early spring. These specialized surveys were performed only once.

CTD data were also collected aboard Vessel 1 in surveys conducted simultaneously with Vessel 2 along the near-field boundaries. During these surveys Vessel 1 traversed the northern boundary while Vessel 2 traversed the southern boundary.

Vessel 2 was designated for the regular monitoring of currents, temperature, and conductivity along the northern boundary of the near-field, the southern boundary of the near-field, and in the vicinity of the Station.

Each boundary was surveyed throughout an entire tidal cycle. For instance, the first survey day focused on the northern boundary region. The following day, the southern boundary was monitored. The third and fourth days centered on the vicinity of the Station. The fifth day was reserved for completing observations that were missed earlier because of weather and/or technical difficulties.

To assure data consistency, the following procedures were adopted. Each survey line was always traversed in the same direction. The north boundary transect extended from the New Jersey shore at the northern tip of Artificial Island to the southern shore of Reedy Island, DE, and was always traversed from New Jersey to Delaware. The south boundary line stretched from the mouth of Hope Creek, NJ, to the Delaware shore near Liston Point. That line was always traversed from Delaware to New Jersey. North boundary transects, repeated hourly, were completed in approximately 25 minutes. Due to greater length, south boundary transects, repeated every 1.5 hours, were completed in approximately 50 minutes. For the vicinity of the Station region, the outside boundary took approximately 45 minutes to traverse and the inner boundary (parallel to the Station's cooling water intake seawall) took approximately 5 minutes. Both transects in the vicinity of the Station were repeated every 1.5 hours. During their return to the transect origin, the vessels conducted CTD profiling (see Section II.C).

In order to accurately determine spatial variations in the Estuary's flow patterns, it was essential to obtain precise and accurate positioning information for every piece of data recorded on each vessel. For this purpose, an integrated navigation system was utilized.

At the core of the navigation system was a HYPACK® software package [Version 2] (Coastal Oceanographics, Inc., Middletown, CT) installed on a portable 486 laptop computer. This software displays real-time differential GPS positioning information. In addition, it assists with transect line design, horizontal datum choice, choice of data sampling rates, and graphical displays.

Fundamental to the resulting survey quality is the understanding of the horizontal datum used for positioning. All surveys were conducted using the World Geodetic Survey 1984 (WGS-84) horizontal datum as the baseline reference (expressed in U.S. survey feet). The Universal TransMercator (UTM) projection was used to generate x-y pairs from latitude/longitude pairs. Digitized maps of the survey area were input and displayed on the computer screen. Survey lines were then developed, either by the HYPACK® software as start/end points identified on the digitized map, or manually entered as latitude/longitude pairs.

The majority of GPS and other marine devices share electronic information using the National Marine Electronic Association's interfacing standards (NMEA-0183). The HYPACK® software automated the entry of requisite NMEA-0183 transfer codes and specifications assuring uninterrupted and accurate data transfers. Typically an RS-232 serial line was used for inter-device communications.

The GPS device used in this study was a Northstar 941X with differential beacon receiver (Northstar Technologies; Acton, MA). Technical specifications for the unit are listed in Postscript AA. During these surveys, GPS data were updated to the computer every two seconds. GPS satellite signals are broadcast by the Defense Department with a built-in dither designed to purposely degrade the accuracy and repeatability of positioning information. To address this, differential corrections are broadcast over radio frequencies from towers built along the coastline. Positions recorded with differential corrections are accurate to within 20 feet 95% of the time; without differential corrections, accuracies are on the order of 300 feet. Radio reception can be reduced by atmospheric static (e.g., thunderstorms) or physical obstructions. During the Estuary surveys, differential reception and, hence, positioning accuracy was occasionally lost for periods ranging from five seconds to several minutes. These losses were manifested as "differential jumps" in the transect tracklines. Such "jumps" were edited from the records during post-processing.

In addition to pinpointing data locations, the GPS navigation system helped keep the survey vessels on course. As the vessel moved across the estuary, the cursor moved in real time across the digitized map on the computer screen. Slight deviations from the transect line could be corrected immediately.

The GPS data were uploaded to both the HYPACK® PC and the ADCP laptop PC (see Section II.B.2). Navigation data uploaded to the HYPACK® computer were stored in raw data files containing time, latitude, longitude, and x-y position pairs. The raw data were stored in ASCII format. The header described the survey parameters (e.g., data, surveyor, devices used). Succeeding data rows were preceded by a data type identifier: RAW for latitude/longitude pairs, POS for x-y positioning pairs, EC1 for echosounder data (if used), TID for tide data (if used), and FIX for event mark. The computer clock time was included for each data event.

During post-processing, ACI combined the x-y position pairs with time data and, if available, depth measurements. File-naming conventions were developed and applied automatically to both raw and processed data files. The raw file convention was as follows: (transect line number)(start time)(vessel)(survey) (day). For example, raw data file 001_1642.114 references data from transect line 001 begun at 1642 (4:42 PM) by Vessel 1, during Survey 1, day 4.

In the following Sections, references to navigation log (*.LOG) files refer to the daily list of HYPACK® raw navigation data files generated for a specific survey day. The processed navigation files (x-y-time) were named according to conventions developed for the ADCP (see Section II.C.4.a). Specifically (Navigation Files Prefix) (Survey) (day) (transect line number) DAT. Thus NAV22011.DAT references the processed navigation file (NAV) for Survey 2, day 2 (22), conducted along transect line number 11 (011). The .DAT suffix indicates this is a datafile.

II.A. Bathymetry

A bathymetric survey was performed to measure depths in the near-field region between 10 and 12 April 1995 during Survey 1, using a vessel-mounted Si-Tex AVS-106 fathometer (Si-Tex Marine Electronics; St. Petersburg, FL). The system is capable of surveying depths as shallow as 2.0 feet with 0.10 foot resolution. Fathometer data were uploaded to the HYPACK® system and combined with GPS positioning information every 4.6 seconds. Specifications for the Si-Tex fathometer are listed in Postscript A. Vessel 1 was fitted for high-precision bathymetric measurements in both the deeper and shallower areas of the Estuary.

The bathymetric survey consisted of survey lines every quarter mile, running from west to east across the Estuary. These survey lines were approximately five miles long and extended from the north near-field boundary to the south near-field boundary. In addition, detailed bathymetry data were collected around Alloway Creek, Augustine Creek, Appoquinimink River, Blackbird Creek, and Hope Creek Jetty (Figure II-3).

On 14 April 1995, a high-resolution precision survey measured depths in the vicinity of the Station. Survey lines were spaced 50 feet apart with the southern portion of the line extending 300 feet beyond the intake location and the northern portion extending 300 feet beyond the discharge location. A survey of Sunken Ships Cove was combined with the survey of the vicinity of the Station, with lines spaced 100 feet apart and overlapping those for the vicinity of the Station survey.

II.B. Acoustic Doppler Current Profiling

The region of the Estuary surrounding the Station has intricate flow and circulation patterns resulting from both its natural geography and the proximity of large manmade obstructions (Sunken Ships Cove and Hope Creek Jetty). Because single-point current measurements would be inadequate, an acoustic Doppler current profiler (ADCP) was mounted aboard Vessel 2 to augment current observations and enhance understanding of Estuary geography. Vessel 2 recorded ADCP measurements while regularly traversing predefined sections of the Estuary at 60- or 90-minute intervals during complete tidal cycles of 12.42 hours. The resulting current measurements were used in concert with data from the moored current meters to analyze flow patterns in the vicinity of the Station.

II.B.1. Instrument System Description

An ADCP measures current flow by comparing high-frequency acoustic signals transmitted through the water column with the returned signal (backscattered echo). A single-frequency pulse (in this study, 1200 kHz) is emitted from a transducer at the surface. As the signal moves through the water column, it is reflected back toward the transducer by ambient scattering materials such as plankton, suspended particles, bubbles, etc. travelling through the water at the same speed as the current. The frequency of the reflected acoustic signal is compared to the frequency of the emitted signal, and the difference in frequencies (the Doppler shift) is directly proportional to the relative speed at which the scattering materials (thus, the current) are moving either toward or away from the transducer (Figure II-4).

The 1200 kHz ADCP employed in the survey was manufactured by RD Instruments (RDI) of San Diego, California [Model #BB DR1200]. The instrument consisted of four transducers placed 90 degrees apart in the horizontal plane and directed 20 degrees from the vertical axis. The ADCP profiled the entire water column by obtaining multiple independent measurements of water velocity at varying depths from the transducer.

The ADCP processes the backscatter echo frequency for each transducer, developing four independent velocity measurements. These independent velocities are then trigonometrically transformed to produce three orthogonal velocity vectors: two horizontal and one vertical for this calculation. Because only three beams are required for this calculation, the fourth beam is used to check data quality.

Depth profiles are obtained by "range-gating" the backscattered pulse, i.e., by turning the receiver on and off (gating) at regular intervals after the original pulse is emitted. Gating the return echoes creates discrete sections of the water column called depth bins. The duration of the on-off sequencing will determine the size or range of each depth bin.

Typically, a 1200 kHz ADCP can measure current speeds in depth bins as small as 25 centimeters. For this program, depth bins were set at 50 centimeters. As a result, three velocity vectors were measured for every 50-centimeter increment of the water column.

However, practical limitations (e.g., interference at both the transducer site and at the bottom) mean that accurate velocities can only be obtained starting a minimum of 50 centimeters from the transducer and ending 50 centimeters above the bottom.

The ADCP measures water velocity relative to the transducer. For a shipboard-mounted ADCP, the velocity of the transducer must be subtracted from the water velocity measurements. This is accomplished by using the Doppler shift principle to measure the velocity of the transducer relative to the bottom. Interleaving water track pulses with bottom track pulses allows the instrument to accurately measure current velocities independent of the motion of the transducer. The effects of incidental vessel motions, such as pitching and rolling in surface waves, are addressed by using an internal compass and tilt sensors.

Accuracy depends primarily on the size of the depth bin. The larger the depth bin (i.e., the longer the receiver gate remains open), the longer the echo record used to calculate the Doppler frequency shift and the more likely velocity measurements will approximate the true flow. Accuracy is also enhanced by the averaging of several successive single pulses, termed an ensemble. For the surveys in the Estuary, each ensemble consisted of five water track pulses and four bottom track pulses emitted over a 4- to 4.5-second period. The standard deviations of the current measurements are also indicative of the ADCP accuracy. Large depth bins and multiple pulse ensembles reduce variability in the data and thus reduce standard deviations. For this study, standard deviations of current measurements were on the order of 2-3 cm/sec. More information on ADCP operation is contained in Postscript B.

II.B.2. Data Collection Techniques

The ADCP was mounted to the stern of Vessel 2 on a rigid bracket. The instrument was directed downward, with the transducers approximately 25 centimeters below the water surface. Data and power were transferred from a deck unit installed within the vessel cabin. Power was supplied at 110 VAC from a portable generator. The instrument system schematic is depicted in Figure II-5. A laptop PC controlled data sampling configurations (e.g., depth bin size, ensemble averaging, water track and bottom track modes), instrument testing and initialization, and the start/stop of data logging.

Differential GPS data were logged directly through a serial port on the ADCP PC and saved as separate files independent of HYPACK® navigation data. Latitude/longitude pairs were logged together with ADCP ensemble number and computer clock time (in number of seconds after midnight; for example, 12:00 noon appeared as 43200). Due to ease of use, the HYPACK® -generated navigation (x-y-time) files were used for primary positioning information, while the ADCP-generated navigation (latitude-longitude-time) files were used for positioning quality control.

The current data for each ensemble (depth bin location, east and north components of velocity, vertical velocity, error velocity, speed, and magnitude) along with instrument-related information (individual beam echo intensities, water temperature, instrument time, tilt, heading and water depth) were stored in binary format in the raw data files.

II.B.3. File-Naming Conventions

The automatic file-naming convention for the ADCP data was as follows: (survey number)(survey day)(transect line number)(file type code).(file-size suffix). The first three characters denote the survey number; for example, Survey 4 was SV4. The fourth character represents the survey day (1 through 5). Thus SV11 would represent the first day of the first survey

Transect line numbers are shown in the next three characters. Each day's transects were numbered sequentially (001, 002, etc.) and automatically updated each time the file was opened. On occasion, files were opened and, for various logistical reasons, closed immediately, resulting in a gap in the sequential order of line numbers. No ADCP transect data were lost because of such numbering gaps.

The file type identifier is the last character file name. An "R" denotes a raw data file. An "N" denotes a navigation file.

The file-name extension indicates the size of the file. Due to the large volume of data generated during each transect, when files exceeded 200 kilobytes, data were rolled over into another data file. The first 200 kbytes of data are labeled with a .000 suffix; the second 200 kbytes of data are labeled with a .001 suffix. The file rollover was seamless, meaning no data were lost. This feature eased data handling by breaking data files into smaller, more manageable blocks.

As examples,
- File SV44005R.000 contains the first 200 kbytes of raw ADCP current data (R.000), collected on Survey 4, day 4 (SV44), during the transect of line number 5 (005).
- File SV15010N.001 contains the second 200 kbytes of ADCP navigation data (N.001) collected on Survey 1, day 5 (SV15) during the transect of line number 10 (010).

II.B.4. ADCP Data Processing

ADCP data were processed for Survey 1, day 4; Survey 2, days 2, 3, and 4; Survey 3, day 2; and Survey 4, days 2, 4, and 5 (Table II-2). These were the only days that data collection spanned the complete 12.4 hour tidal cycle. Post-processing of the ADCP data was accomplished using BBLIST® (RDI Instruments) and MATLAB® [Version 4.2] a software package by MathWorks, Inc. (Natick, MA). MATLAB® files (or .mfiles) were used to create current direction/velocity vectors and color plots of the data (see Section II.B.5).

II.B.4.a. Step One: Data Reformatting

In order to be readable by the MATLAB® program, the raw ADCP data had to be converted from binary to ASCII format. The volume of information contained in the raw files was enormous, much of it, such as instrument settings, secondary to current observations.

ACI used the RDI program, BBLIST®, to customize the ASCII output. Three different ASCII output formats were created to meet different analytic and display requirements.

In each format, data fields are identified by the ensemble number followed by the required information.

In the first format, raw ADCP data generated on the north and south boundaries were reformatted to include ensemble number, Julian day (the calendar day numbered sequentially from January 1st; e.g., February 23rd would be Julian day 54), and water temperature, along with depth profiles of east and north current velocity components, current speed, and current direction. One data field was created for every recorded ensemble. Each field consisted of 31 lines of data.

The first line contains 3 data values: ensemble number, time in decimal Julian days (the Julian day is numbered consecutively from January 1st and the decimal shows the time as a fraction of 24 hours; thus, April 11 at 15:12:32.5 EDT is decimal Julian day 101.63371), and water temperature in degrees C. The next 30 lines represent current measurements at each depth bin. The first column of lines 2 through 31 represents the center depth (in meters) of each depth bin. The top bin corresponds to a volume of water 1.5 meters to 2.0 meters from the surface and is represented as 1.75 meters. The bottom-most depth bin represents a volume of water 16.0 meters to 16.5 meters and is represented as 16.25 meters. The second through fourth columns represent east components of current velocity, north components of current velocity, and current speed, all in cm/sec. The fifth column indicates current direction, measured in degrees from due north.

Data lines 32 through 63 represent data corresponding to the second ensemble of the data file, and so on to the end of the file. No headers appear in the data file to identify the data field. Table II-3 shows an example of a single data field representing data for ensemble number 112 taken on Julian day 101.63371 (11 April 1995 at 15:12:32.5 EDT).

Estuary depths in the survey areas never exceeded 14.0 meters. Hence, a depth threshold for range-gating was set at 16.5 meters (i.e., the instrument wouldn't listen for returns beyond 16.5 meters), to assure the ADCP would always range to the bottom. Data below the actual bottom are set at 9999.0 and are eliminated during data processing.

Data generated along the vicinity of the Station boundary were displayed as vectors (arrows) representing speed (length of the arrow) and direction (direction of the arrow). Because these data took a different form in the display, the data were formatted slightly differently.

The first line included ensemble number, decimal Julian day, water temperature in degrees C, followed by four data values representing the depths of each of the transducer beams. Because the beams were angled 20 degrees from the vertical, and bottom topography varied, each beam measured a slightly different depth. An average of the four beam depths was calculated as the ensemble (or average) depth.

Lines 2-31 again reference depth profile measurements. The column identifiers are depth bin, east velocity, north velocity, speed, direction, error velocity, and "percent good". Error velocity and percent good are data quality indicators. Error velocity is calculated using the redundant fourth transducer beam, comparing velocity measurements between different beam combinations. Percent good indicates the number of pulses that used all four beams to calculate accurate velocities (as opposed to the three required). Percent good values are generally 100, except near the bottom where some pulses became contaminated by bottom interference. Values of 60% or 40% (meaning 3 out of 5 or 2 out of 5 water track pulses used 4-beam solutions) are common in near-bottom bins. If percent good values fell below 80% then the data were ignored.

The third ASCII output format was designed to verify the data quality. Included were quality indicators such as beam echo strengths, pulse-to-pulse correlation magnitude, error velocities (based on the redundant fourth transducer beam measurements), and statistical indicators.

Significant variations in data can result from both true Estuary behavior or from measurement inaccuracies due, for example, to excessive surface vessel motion, wake near the transducer at high vessel speeds, or acoustic contamination from nearby electronic instruments. Evaluating error velocities concurrently with observed current velocities will help distinguish between real variability and measurement error. Simply put, if error velocities are within two calculated standard deviations, the observations are good. If error velocities lie outside two standard deviations, the measurements are most likely contaminated by external factors.

The following are file-naming conventions and examples of reformatted ADCP data files. (Survey)(day)(transect line)(ADCP site). DAT

Thus file SV44005A.DAT contains reformatted ADCP data (.DAT) from Survey 4, day 4 (SV44) collected during the transect of line 5 (005) at either the north or south boundary of the near-field (A is used for both boundaries). Similarly, the reformatted file SV14004B.DAT contains ADCP data collected during Survey 1, day 4 (SV14) during the transect of line 4 (004) at the basin site (B).

II.B.4.b. Step Two: Merging Acoustic Doppler Current Profiler and Navigation Data

As noted above, the HYPACK®-generated navigation data proved easier to use than the ADCP-recorded information. Not only were the HYPACK® x-y pairs numerically simpler than the ADCP-generated latitude/longitude pairs, but the HYPACK®-generated data were formatted in columns, whereas the ADCP navigation file format used irregularly spaced rows, that made using the data more difficult.

A time-stamping method was used to match each ensemble with a specific x-y position pair. This method assumes that both the ADCP system clock and the HYPACK® system clock were synchronized perfectly throughout the survey. This was not always the case, because there was an offset between the two clocks which varied from day to day primarily due to inherent delays in the ADCP time command. Time differences between the two system clocks were as small as two seconds and as great as 90 seconds. To avoid difficulties during post-processing, time differences were monitored and documented manually several times during the survey.

The times were also synchronized by simultaneously sending a GPS signal to both the ADCP and HYPACK® computers at the beginning and end of each survey. The clock times assigned by each computer system to the test GPS position were compared, and appropriate time corrections were applied to that survey's data. Once times were corrected and synchronized, each ADCP ensemble (ensembles were separated by 4-4.5 seconds) was merged with the closest HYPACK® time data (where each x-y pair was separated by 2 seconds).

II.B.4.c. Step Three: Data Transformation

The along- and cross-river components of velocity usually represent more accurately the structure of water currents, particularly in rivers or estuaries that are not strictly oriented in a north-south/east-west direction. The data were therefore transformed from an earth-based (east and north) coordinate system to a locally based (upstream and cross-stream) coordinate system. Currents moving upstream (i.e., when the tide floods the Estuary) were characterized as positive, ebbing currents (i.e., flowing toward the mouth of the Estuary) were deemed negative. Positive cross-stream currents flowed toward New Jersey from the Delaware shore. Long-term current measurements are described in detail in Section III.B.

Cross-river transects on the north and south boundaries contained noise, i.e., high-frequency variability from one ensemble to the next, which sometimes obscured subtle variations in Estuary currents. This was addressed using a moving triangular filter applied across all data values.

The filter took the first seven values and weighted the center (fourth) value at 100% of its full value, adjacent values (third and fifth) at 75%, twice-removed values (second and sixth) at 50%, and thrice removed values (first and seventh) at 25%. The values they obtained were then summed and divided by four, in order to obtain a weighted average for these seven values. The same process was then carried out for the second through eighth values, and so on for the remainder of the data set.

The filter was applied to all ADCP current ensembles. The filter extended approximately 100-130 feet on each side of the central data value. The filter reduced the effect of small-scale physical oscillations of the current on the displayed data, bringing the large-scale characteristics of Estuary flow into clearer focus.

Two types of spatial averaging also were performed. The first consisted of reducing the current profiles to a limited number of vectors, in order to reveal the general structure of Estuary flow. Eleven points were defined on each of the north and south near-field boundaries, and a single current velocity was calculated for each point. To do this, several hundred ADCP ensembles were averaged both vertically and horizontally. The vertical average for the water column at a given location was the average of all current measurements at each of its depth bins. The horizontal average was performed by breaking the transect into 11 blocks, each consisting of all the ensemble positions within it. The number of ensembles assigned to each block varied by transect. This procedure resulted in one spatially-averaged current vector for each of the 22 points.

The second averaging scheme was used to visualize more clearly vertical variations in flow. Current profiles along the vicinity of the Station grid were reduced to five vertical layers. No horizontal averaging was performed, that is, all ensembles were represented. First, total water depth was established by averaging the four individual beam depths. The top layer was defined as data values within the first 12.5% of depth, the second layer was between 12.5% and 37.5% of the total depth, the third (or middle) layer 37.5% to 62.5% of the depth, the fourth layer was from 62.5% to 87.5%, and the bottom layer was from 87.5% to 100% of the total water depth.

For shallow areas, for example, Sunken Ships Cove, where depths are 5-7 feet, only one to two valid depth bins were recorded. In such areas, only the top and bottom layers were used. If three or four valid depth bins were available, the top, middle (average of the second and third valid data points), and bottom layers were presented. Valid bins numbering five or more were averaged as described above.

The results of this layering approach were plotted as colored arrows originating at a known x-y location. The plots illustrate the vertical variation of current in areas in the vicinity of the Station.

II.B.5. Sample Plots

Figures II-6 through II-11 show the velocity/direction vectors around the vicinity of the Station boundary for 25 April 1995 at 0700 to 1800 hours (survey 2, day 2). The figures portray the speed and direction of the currents for the top, middle, and bottom depth layers. The locations of the CWS and discharge pipes are shown in yellow.

Figures II-12 through II-15 show the velocity/direction vectors along a transect parallel to the intake structure screens for 25 April 1995 at 0740, 1040, 1340, and 1640 hours. The figures show the velocity and direction of the currents for the top, middle, and bottom depth layers as well as the location of the thermal plume.

Color plots, as described above, are shown in Figures II-16 through II-23 for 26 April 1995 at 0800, 1100, and 1400 hours. The plots represent flow through a cross section of the Estuary. A color scale represents the speed of the current in cm/sec. Estuarine flow is running upstream at 0800 (yellow/orange). When the velocity is negative (blue), as it is at 1400, the currents are running downstream.

II.C. Conductivity, Temperature, and Depth Measurements

Conductivity, temperature, and depth (CTD) data were required to map the spatial and temporal distribution of salinity and temperature throughout the Estuary.

II.C.1. System Description

Salinity and temperature profiles were measured using a Micro-CTD manufactured by Falmouth Scientific, Inc. (FSI, Cataumet, MA). The unit measures conductivity, from which salinity is inferred. An inductive cell allows the free flow of water through the sensing element, reducing the response delays and electrode fouling problems characteristic of traditional conductivity sensors. Temperature was measured using a highly accurate platinum resistance thermometer (±0.005°C). Depth was measured by a titanium strain gauge pressure sensor (0-200 dbar range with an accuracy of ±0.15% full scale). The unit was self-contained and used replaceable battery packs. An internal memory module held 1 megabyte of data. The electronics were housed in a Delrin (plastic) pressure case protected by a stainless steel cage. Specifications for the FSI Micro-CTD are shown in Postscript C.

A laptop PC fitted with FSI software and a generic terminal emulator controlled communications to and from the instrument.

II.C.2. Data Collection

The CTD data were collected aboard both survey vessels. Vessel 1 tracked from the mouth of the Estuary to the Station on 19 June 1995, measuring CTD profiles at 20 locations spaced approximately one mile apart. CTD profiles were obtained at four sites at the mouth of the Estuary during a single tidal cycle on 20 June 1995. Vessel 1 also monitored four sites along the southern near-field boundary (S1, S2, S3, and S4) during a full tidal cycle on 27 April and 22 June 1995 (Figure II-24).

On the same two days Vessel 2 simultaneously measured CTD profiles at four sites along the north near-field boundary (N1, N2, N3, and N4). Measurements by the two vessels were synchronized and were obtained at evenly spaced time intervals throughout the monitoring period. For example, on 27 April 1995 profiles were performed at the N4 site (Vessel 2) and S4 site (Vessel 1) at 10:23 AM, at N3 and S3 at 10:33AM, N2 and S2 at 10:42AM, and N1 and S1 at 10:51AM. Approximately 1.5 hours elapsed before the sequence was repeated.

In addition, Vessel 2 measured CTD profiles at two sites (BN, BS) in the vicinity of the Station over full tidal cycles on 25 April and 20 June 1995. Each CTD measurement, or CTD cast, was performed manually. The instrument was toggled on, allowed a one-minute wake-up delay, and lowered through the water column. Local time and water depth were recorded in the survey notes for each cast. The unit was then lifted from the bottom and pulled aboard where the switch was toggled off. Each cast took approximately two minutes. The vessel proceeded to the next site to repeat the sequence.

A raw data file was produced each survey day, containing information from all the CTD casts performed on that day. The raw files have a common .RAW suffix. Each cast was separated in the raw data file by a double row of zeros, resulting from the on/off toggle of the instrument switch.

The raw data files are formatted by data type and sample number. There are four columns in each file: conductivity (mmho/cm) in column 1 followed by temperature (°C), depth (meters), and date and time of the sample. Each row of data corresponds to a single sample. The sample rate was set at 2 kHz, meaning two samples of conductivity, temperature, depth, and date and time were written to memory every second while the instrument was submerged. The time and depth of each cast were compared to logged time and hydrostatic pressure as a way of checking data quality.

II.C.3. Conductivity/Temperature/Depth Data Processing

Post-processing of the CTD data involved splitting the raw data file into individual casts, using the FSALSOP program from FSI. FSALSOP used the conductivity data to calculate salinity values. Salinity was referenced to units of the Practical Salinity Scale (1978) (PSU-78). In addition, FSALSOP reformatted the individual data files into seven columns (scan number, conductivity, temperature, depth, date and time, salinity, and speed of sound).

In the FSALSOP-processed output files each individual cast assumed the prefix of the raw file and acquired a new suffix reflecting the order in which the casts occurred. For example, the first cast was given an .000 suffix, the second .001, etc. If 40 individual casts were performed during a day and logged in the raw data file CTDCASTS.RAW, 40 individual data files would be created by FSALSOP named CTDCASTS.000 through CTDCASTS.039.

MATLAB® was used to develop a program, CTDSPLIT.M, to split each individual CTD cast into upcast and downcast portions. Typically, oceanographers utilize only downcast data when analyzing CTD information. This is because relatively undisturbed water is measured during the downcast. However, passing an instrument down and up through the water column induces sufficient mixing to contaminate the upcast reading. CTDSPLIT discarded the upcast data and saved only the downcast data in individual data files.

The naming system for these split downcast files was as follows:

(boundary location)(site number)(data type)(cast number).(date).

For example, file N1CTD6.427 contains data from the sixth CTD cast (CTD6) conducted at site 1 on the north boundary of the near-field region (N1). The suffix shows that the data were collected on 27 April 1995 (.427).

Similarly, file BNCTD4.424 contains data from the fourth CTD cast (CTD4) conducted north of the vicinity of the Station (BN) on 24 April 1995 (.424).

II.C.4. Sample Plots

Color time series plots showing salinity and temperature variations at the south and north CTD sites in the vicinity of the Station (BS, BN) on 24 April 1995 are presented in Figures II-25 through II-28. The color plots show the range of salinity and temperature over time (bottom horizontal axis) and in relation to depth (left vertical axis). A 7-hour period is shown representing the variation in values with the tidal cycle.

Each plot shows cross-river variations in salinity measured during a single transect. The plots present a cross-section of the Estuary with Delaware on the left and New Jersey on the right. These cross-sections are considered approximations because only four CTD casts were used to calculate the salinity contours.

Figures II-29 through II-32 show hourly cross-river salinity variations at the south and north boundaries of the near-field region on 27 April 1995. Tide elevation changes for the day are included at the top of the page. All times are referenced to EDT.

Figures II-33 through II-36 depict color time series of salinity and temperature variations on 20 June 1995 at the north and south sites in the vicinity of the Station (BS, BN). The plots are similar to those described in Figures II-25 through II-28. Comparison of the two groups of figures illustrates seasonal variations in salinity and temperature.

Figures II-37 through II-39 show salinity variations at a cross-section of the mouth of the Estuary on 20 June 1995. Eleven time steps are shown. These figures were included to indicate salinity of ocean waters entering the estuarine system. Little variation is noted.

Cross-stream variations in salinity are presented for the south and north boundaries of the near-field region on 22 June 1995 in Figures II-40 through II-43. Again, these plots illustrate seasonal differences in salinity levels when compared to Figures II-29 through II-32. Tide elevations for 22 June 1995 are also shown. All times are EDT.

III. LONG-TERM MOORINGS

Long-term observations of tides and currents are essential for understanding hydrodynamic processes. For this study, *in situ* instruments were deployed at sites near the Station for the long-term measurement of currents, tides, temperatures, and salinities in the study area. Data collection efforts began during the last week of March 1995 and lasted until the end of June 1995.

III.A. Tide Measurements

III.A.1. System Description

Four tide observation gauges were placed at each corner of the near-field boundaries (Figure III-1). Station NNJ was at the northern tip of Artificial Island, Station NDEL was at Augustine Beach on the Delaware shore, Station SNJ was at the mouth of Hope Creek, and Station SDEL was near Liston Point, Delaware. A fifth gauge was deployed on the Chesapeake Bay side of the C&D Canal in Town Point Neck, MD. Specifications and deployment dates are shown in Table III-1.

Each station consisted of an SP2200 wave/tide gauge manufactured by Woods Hole Instrument Systems, Ltd (WHISL; Cataumet, MA). The instrument features a ParoScientific (Paros) Digiquartz pressure sensor with a resolution of 1 mm water and accuracy of 1 cm. Water temperatures were measured simultaneously with a Paros temperature sensor of resolution of 0.01°C and an accuracy of ±0.1°C. Technical specifications for the SP2200 are presented in Postscript D.

The instrument is self-contained. For the sampling rates chosen, battery life was estimated at three months with one Mbyte of available memory. The unit was housed in a sealed plastic pressure case and attached to an aluminum pipe. Pipes were installed in the Estuary bottom using an hydraulic pump.

Water elevations were sampled as a 7.5-minute continuous average. Values were continuously summed over the 7.5 minutes and a single mean water elevation value was recorded for that interval. There were a total of 192 data points for each day water elevation was measured.

Data recovery involved dispatching a vessel to the gauge location to remove the instrument physically from the pipe mooring, leaving the mooring in place. The instruments were first returned to shore in early May, where the preceding six weeks of monitoring data were uploaded to the PC hard disk.

Data integrity checks were performed, fresh batteries were supplied, the memory was reinitialized, and the unit was sealed for re-deployment. The gauges were returned to their moorings the following day. The gauges then recorded continuously until final recovery in late June 1995. All gauges returned 100% of the intended data.

Small differences in along- and cross-river water elevation can result in potentially large differences in flows. To address this, the absolute elevation of each gauge was surveyed using a known vertical datum prior to recovery. Surveys were conducted by Taylor, Wiseman, and Taylor (Mt. Laurel, NJ). Kinematic GPS methods were used to verify that the instrument functioned within the specified sensor accuracies (1 cm). A GPS antenna was attached to the pipe mooring for a selected period, typically 40 minutes. The distance from the pressure sensor port to the antenna was measured manually. The kinematic GPS system collected satellite information during the measurement interval and averaged the x, y, and z values to obtain a (relatively) long-period mean value. Using these data, the water elevation data from the four SP2200s were adjusted to the North American Vertical Datum 1988 (NAVD88). This survey was repeated in June 1995 to adjust for possible vertical displacement of the instrument mountings during recovery and deployment.

III.A.2. Data Processing

Uploaded water elevation data were transferred in hexadecimal format for processing and analysis. Data fields included water elevation (meters), temperature (°C), date and time, and instrument-related engineering records.

Raw data files were labeled according to the instrument identifier (usually the serial number), date of recovery (AP for April 1995, JU for June 1995) followed by a .RAW suffix. For example, data recovered from the tide gauge deployed at the northern tip of Artificial Island (Station NNJ, serial number 52019) during the first deployment period was labeled 52019AP.RAW.

Software was used to extract water elevation (in pounds per square inch [psi]), water temperature (in degrees Celsius), and date and time of each measurement from the raw data file. These extracted engineering units were saved as ASCII files.

The ASCII files contained a header identifying each column and were labeled using the same file-name conventions used for the raw data files (serial number and month of recovery), with the suffix changed to .DAT (e.g., 52019AP.DAT).

Data processing involved removing atmospheric effects from the recorded pressure measurements. The instrument measured the total pressure resulting from both water elevation and the atmosphere. Atmospheric pressure observations were obtained from outside sources (Attachment E-1) and subtracted from the total pressure readings. Resulting water pressure values were then converted to water height values based on a water density of 62.96 lbs/ft^3 (corresponding to a salinity of 6 ppt at 20°C). A constant value of water density was chosen for this conversion despite actual density variations with tides. An option for avoiding these density-induced conversion errors was to measure density (via temperature and conductivity) at the pressure port. The important issue in this conversion was not that errors might be present but rather that the salinity was likely to vary in a similar manner from one gauge location to the next. For a sensor two meters below the surface, salinity changes of 1 ppt correspond to less than 0.2 cm error in absolute water elevation measurement. These small errors were deemed acceptable.

Water heights were then adjusted to the NAVD88 datum based on survey data, resulting in the absolute water elevations. Manufacturer-supplied calibrations performed accurate temperature conversions, eliminating the need for manipulating those data.

III.A.3. Sample Plots

Water elevation and temperature were displayed in time series plots as a function of Julian day (horizontal axis) with tide level (in feet) referenced to NAVD88 (vertical axis) in Figure III-2. Temperature (°C) is the vertical axis in Figure III-3. The gap in data following Julian day 120 represents the instrument turnaround in early May.

III.B. Current Measurements

III.B.1. System Description

Estuarine currents result in part from differences in water elevation as the tide moves through the Estuary. Higher water on the southern boundary results in flows upstream; lower water at the same boundary induces an ebb, or downstream, current. Cross-channel elevation differences result in flows from one side of the Estuary to the other. Other factors such as Estuary geometry, Coriolis forces (effects of the earth's rotation), and wind can also affect circulation.

To gain an understanding of long-term current dynamics, four current meter moorings were deployed at the near-field region boundaries on each side of the navigation channel (Figure III-4). Specifications and deployment dates are listed in Table III-2.

Each mooring consisted of a SeaPac SP2000 directional current meter (WHISL; Cataumet, MA). The instrument used the well-known Marsh-McBirney (Frederick, MD) 4-inch electromagnetic current sensor. The sensor records voltage induced across electrodes created by water passing through a delimited sphere surrounding the probe (typically a 14- to 16- inch radius). The electromotive force is directly proportional to current velocity. Technical specifications for the current meters can be found in Postscript E.

The instrument is mounted vertically to a heavy, stable, tripod constructed of welded aluminum and weighing approximately 400 lbs (in air). The current probe was deployed 2 meters above the Estuary bottom. The tripod configuration is shown in Figure III-5.

The moorings were installed at each location by lowering the package from a surface vessel to mid-water, after which each instrument was released to free-fall slowly to the Estuary bottom. Mooring positions were logged using GPS.

Currents were measured using a burst average technique. Every ten minutes, the instrument began a two-minute cycle of 1 kHz current sampling. Each resulting group of 120 samples was averaged to obtain a single current velocity. The resulting sampling yielded six records per hour, representing two-minute averages every ten minutes.

The tripods were recovered using a remote mechanical release system fitted with a pre-set timer. A buoyant float with attached lightweight rope was held inside a mounted canister by a burnwire linked to the timer. At the preset time voltage sent to the burnwire chemically dissolved the constraint link. The float freely rose to the surface carrying with it the lightweight line that provided access to a heavier lifting line shackled to the top of the tripod. The lifting line was fed through the vessel winch and the tripod was hoisted aboard. Release timers were staggered over the day to facilitate recovery operations.

Upon recovery, data were uploaded to a shipboard PC. Data quality checks were performed, fresh batteries installed, and the instruments redeployed on the following day.

The initial deployment was scheduled from 29 March to 2 May 1995. Two tripods, SDEL and NDEL, were recovered on 2 May. The NDEL tripod was recovered with a broken current sensor probe. Analysis of its data indicated that the instrument had failed approximately four days prior to recovery. A backup SP2000 current meter, which had temporarily been installed in the vicinity of the Station (Section III.C.), was moved to the NDEL site to record data for the remaining deployment period. Technical problems with the two remaining tripod release systems delayed recovery of the NNJ and SNJ tripods until 18 May 1995, when they were recovered successfully by divers. These instruments were reinstalled the following day.

Final recovery of all current meter moorings was performed on 26 June 1995.

III.B.2. Data Processing

Raw current data were stored on the PC hard disk in hexadecimal format. File-naming conventions paralleled those used for the tide gauges:
(instrument serial number)(month of recovery).RAW.

For example, the raw data files from the NNJ sensor from May through June were labeled 50026JU.RAW.

Software was used to extract east velocity components, north velocity components, compass directions, temperature (°C), if a temperature sensor was used, followed by the time and date. Output files used the same file-naming convention, with the suffix changed to .DAT. For example, the above raw file, after extraction, was labeled 50026JU.DAT.

MATLAB®-ready files; matrices stripped of identifying headers, were generated for data processing. These files were named according to the following convention:

(SN) (last three digits of instrument serial number) (month of recovery).DAT.

For example, the file SN026JU.DAT represents data from the SN sensor number .026 recovered in June 1995.

A coordinate transformation was performed on the data based on their location with respect to the navigation channel. The upstream direction was defined as the central axis of the Estuary navigation channel at the tripod location, based on NOAA navigation charts. For the north tripods, the transformation angle was defined as 26 degrees to the east of north. The upstream and cross-stream velocities (V) were then calculated as:

$V_{upstream} = V_n \cdot \cos(26 \cdot \theta/180) + V_e \cdot \sin(26 \cdot \theta/180)$
$V_{cross\text{-}stream} = V_e \cdot \cos(26 \cdot \theta/180) - V_n \cdot \sin(26 \cdot \theta/180)$
Where V_n equals the uncorrected north velocity and V_e equals the uncorrected east velocity.

The Estuary axis at the south tripod locations was oriented 318 degrees east of north. Transformations for south tripod data were calculated in a similar manner.

III.B.3. Sample Plots

Current data were displayed using a polar plot showing directions and magnitudes (Figures III-6 and III-7). This type of display shows current directions over a long period of time. The associated magnitudes are represented in polar form as radii emanating from the plot origin. The polar axes are oriented with north at the top of the page and east to the right. Figure III-6 presents data from the first deployment period. Figure III-7 presents data from the final deployment period.

Data were also displayed as a standard time series for each location showing upstream and cross-stream directions. Upstream data are presented in Figure III-8. Cross-stream data are presented in Figure III-9.

Data gaps at the NNJ site from Julian day 125 to 138 represent invalid data caused by the toppling of the tripod during an unsuccessful recovery attempt on 2 May 1995. Lost data at the SDEL site from day 148 through the end of the period resulted from tripod entanglement with commercial fishing gear. This tripod had also been toppled. The data gap for the NDEL site from day 120 to 125 resulted from the broken current probe described above. The gap in the SNJ site data resulted from instrument turnaround in mid-May 1995.

III.C. Real-Time System

A Real-Time System (RTS) was installed to collect long-term current and salinity data in the Salem intake basin. The RTS was installed approximately 250 feet riverward of the intake screens.

A temporary current monitoring system was installed in the vicinity of the Station on 29 March 1995. This was the same instrument which, upon recovery, was moved to the NDEL site to replace a broken tripod at that location (Section III.B.1.) The system consisted of a TABS (Texas Automated Buoy System) surface buoy. The system included a surface SeaPac SP2000 current meter (measuring currents approximately 2 meters below the surface), connected via chain to a second SP2000 current meter and a bottom anchor. The lower instrument was located approximately 30 feet below the surface. Data from the TABS surface buoy were lost during this period due to overcharging of the solar cell batteries used to supply power to the instrument. Specifications for the SP2000 are shown in Postscript E. Data from the lower package were internally recorded at ten-minute intervals using the two-minute burst technique previously described. The lower gauge returned 100% of the desired data.

The TABS system was replaced on 3 May 1995 by a long-term system which operated until spring 1996. This system consisted of meteorological sensors (wind speed and direction) mounted at the Station on a staff above the Northern Fish Count Building located near the intake structure and oceanographic sensors (currents, tide, temperature, and conductivity) mounted on a subsurface mooring centrally located in the vicinity of the Station. A shore station inside the Northern Fish Count Building controlled system communications and data logging.

III.C.1. Meteorological Sensors

Wind speed and direction were measured by a SensorMetrics Anometer [Model 05103] (Metrics, Inc.; Lakeville, MA). Data were transferred from the sensor through a connecting cable to a SensorMetrics model ENV-50 shore station. A RS-232 cable linked the shore station to the PC. Power was preconditioned and supplied at 110 VAC. The anemometer was mounted on a staff approximately 10 meters above the water surface to a security tower located outside the Fish Count Building.

III.C.2. Oceanographic Sensors

Currents, tidal elevation, and salinity data were collected by two instrument packages in the RTS moored in the vicinity of the Station. The mooring consisted of a subsurface float with chain connecting the two instrument packages to an anchor. he system is shown in Figure III-10.

The top instrument package housed an SP2000 current meter, similar to the current meters deployed on the tripod moorings; and an FSI conductivity sensor, akin to the sensor included in the CTD instrument (Section II), that provided conductivity data through an independent data port on the SP2200. The top instrument package was located approximately 16 feet below the surface on a mean tide.

The lower instrument package contained an SP2200 current meter with an internal Paros pressure transducer. Tide information was provided by the Paros gauge. The bottom package was located approximately six feet from the basin floor, or 33 feet below the mean tide elevation.

A multi-conductor power and communications cable linked the instruments to the shore-based PC. Power was supplied at the shore station through an uninterruptable power supply designed to prevent data loss in the event of power failures.

III.C.3. Shore Station

The shore station provided system control and data management. The PC used an IBM OS/2 operating system which allowed multiple applications to run concurrently. Customized software controlled the oceanographic instruments and shore-based meteorological station. Four serial ports were connected to the two current instruments, the anemometer, and a telephone modem.

The computer monitored data detection as well as data type and validity (current, engineering, or noise). It also assigned the data to temporary storage buffers. No data-sharing protocol was required, as each serial port functioned independently. Data contained in the buffers were used to update the displays on the computer screen, and also were written to files on the hard disk. Data files stored on the hard disk contained both monitoring data and diagnostic information related to the instruments. The screen displayed Estuary currents, tidal elevation, salinity, and winds in near real time.

Currents, conductivity, and pressures were measured continuously over ten-minute intervals. At the end of each interval, the data were averaged to obtain a single value for each parameter. A communications modem was installed to allow remote access to the data over a telephone line.

The RTS logged data continuously until its retrieval in Spring 1996. Raw data files were downloaded from the on site PC hard disk for processing.

The file-naming convention was a modification of the conventions used for other SP2000 data sets. For example, data file RTJL9543.RAW refers to data from the RTS (RT), an abbreviated month of data recovery (JL for July), year of recovery (95), and instrument identifier (43 denotes serial number 2043). The .RAW suffix denotes a file in hexadecimal format. Several ASCII-formatted files resulted from processing the original raw data file (Table III-3). Currents were output as east and north components of velocity. Conductivity was used with temperature to calculate salinity using FSI software similar to that used to process the CTD psi data (See Chapter 2). Pressure was output directly as psi.

The RTS data are displayed in a similar manner to data from the tripod-moored current meters. Polar plots representing the predominant direction and speed of the currents are shown in Figure III-11. Also included are time series plots for both gauges. The top gauge (east and north velocity with salinity) is presented in Figure III-12. The bottom gauge (east and north velocity with pressure) is presented as Figure III-13.

Figure III-12 shows a decreasing salinity as the spring turns to summer. This is contrary to independent CTD observations which show salinity levels rising through this period. This decrease in salinity as measured by the conductivity sensor was due to calibration errors resulting from increased biological growth on the outside of the inductive cell. Heavy growth within the sensing volume will reduce the measured conductivity and the resulting salinity calculations. The contractor cleaned the cell in early September using divers to remove the growth, and maintenance dives were periodically carried out thereafter.

IV. METEOROLOGICAL DATA

Three meteorological data files from the vicinity of Artificial Island, compiled by the National Climatic Data Center (NCDC) in Asheville, NC, were obtained and used to correct the pressure data recorded by the SP2200 tide gauges. These NCDC data were reformatted using MATLAB® programs that converted the data into proper units and saved them as new data files. Wind speed and direction from Artificial Island from 29 March 1995 to the end of July 1995 are displayed in Figure III-14. Figure III-15 presents the atmospheric pressure with respect to wind speed.

V. CONCLUSION

This comprehensive field study amassed a library of hydrodynamic data on the portions of the Estuary immediately adjacent to the Station.

The methods employed were tailored to the information being sought, and the resulting combination of ship-based operations, long-term moorings, and real-time data acquisition provided a suite of complementary measurements that elucidated the hydrodynamics of the Estuary.

A five-mile stretch of the Estuary was examined in detail, with particular emphasis on the basins near the intake and discharge structures of the Station. Measurements of surface and interior current velocity, tidal elevation, temperature, salinity, and meteorological components were recorded, stored, and catalogued for future reference.

These data were used at the time they were compiled to model physical processes in the vicinity of the Station. They are presented here for completeness.

POSTSCRIPT A
GPS AND FATHOMETER SPECIFICATIONS
A.1 Northstar 941DX DGPS Specifications

Signal Processing

Number of Channels:	2
Frequency Range:	283.5-325.0 kHz
Tuning resolution:	< 2 Hz
Minimum Signal Strength:	1uV/m @ 100bps
Dynamic Range:	>100 dB
Adjacent Channel Rejection:	>50 dB at 1 kHz
Acquisition Time:	5 seconds, manual command 15 seconds, automatic warm start 15 minutes, automatic cold start*
Noise Blanker:	Predictive variable length
Signal Detection:	Acquisition via FLL (frequency-locked loop); tracking via PLL (phase-locked loop)

Data Processing

Demodulation:	MSK (Minimum Shift Keying)
Data Decoding:	Parallel-matched digital filters
MSK Bit Rates:	25, 50, 100, 200 (automatically selected)

Power Requirements

Power consumption:	2 Watts
Supply	12 Volts

Data Ports

DGPS Correction Output Port:	RTCM SC-104 Version 2.0-6 OF 8 RS-232-C 9600 or 4800 baud

Environmental

Whip Antenna:	
ACU:	Height: 11 inches Diameter: 2.6 inches Weight: 1.5 pounds
Antenna:	48-inch fiberglass whip (not supplied) (Shakespeare 4' #173 loaded, or Radio Shack #21-934)

EXTERNAL NORTHSTAR DGPS SPECIFICATIONS

Signal Processing

Number of Channels:	2
Frequency Range:	283.5-325.0 kHz
Tuning Resolution:	< 2 Hz
Minimum Signal Strength:	1uV/m @ 100bps
Dynamic Range:	>100 dB
Adjacent Channel Rejection:	> 50 dB at 1' kHz
Acquisition Time:	5 seconds, manual command 15 seconds, automatic warm start 15 seconds, automatic cold start*
Noise Blanker:	Predictive variable length
Signal Detection:	Acquisition via FLL (frequency-locked loop); tracking via PLL (phase-locked loop)

Data Processing

Demodulation:	MSK (Minimum Shift Keying)
Data Decoding:	Parallel-matched digital filters
MSK Bit Rates:	25, 50, 100, 200 (automatically selected)

Power Requirements

Input Voltage:	11-15 VDC
Power Consumption:	3 Watts @ 12 VDC (max.)

Data Ports

Control Input Port:	RS-232-C, RS-422 or NMEA 0183; 9600 or 4800 baud (jumper selectable)
DGPS Correction Output Port:	RTCM SC-104 Version 2.0-6 of 8 RS-232-C or RS-422 9600 or 4800 baud (jumper-selectable)
Monitor/Control Port:	Bi-directional RS-232-C at 9600 baud.

Environmental

Operating Temperatures

Receiver:	0° to 50°C
Antenna/Preamp:	-40° to +50°C

Relative Humidity

Receiver:	100%
Antenna/Preamp:	100%

Size and Weight

Receiver:	Height:	2.1 inches

	Width:	5.7 inches
	Depth:	8.3 inches
	Weight:	< 2 pounds
ACU:	Height:	11 inches
	Diameter:	2.6 inches
	Weight:	1.5 pounds

Antenna: 48-inch fiberglass whip (not supplied)
(Shakespeare 4' #173 loaded, or Radio Shack #21-934)

Status Indicator (externally-mounted Northstar Beacon Receiver only)

The LED indicator on the end panel of the Northstat Beacon Receiver is used to provide the following status information:

- LED is off while acquiring signals.
- LED is on when Channel 1 has achieved RTCM SC-104 data sync.
- LED flashes twice per second if the antenna cable is shorted or disconnected.

*Only at first turn-on after installation (time varies, depending on local beacon frequencies).

A2. Si-Tex AVS-107 Fathometer

SPECIFICATIONS

Display	6-inch monochrome display
Resolution	256 x 256 pixels
Presentation	3 shades of amber
Frequency	50, 120, or 200 kHz
Output	200 watts R.M.S. (1600 watts peak to peak)
Presentation mode	NORM, ZOOM, AUTO RANGE, AUTO ZOOM, BIG NUMBER
Depth range	5,10,20,40,80,160,320 (meters or fathoms) 10,20,40,80,160,320,640,1280 (feet)
Image speed	5 fixed speeds plus STOP
Alarms	Upper and lower bottom alarms -- fish alarm
Other functions	Gain, screen brightness, color rejection, noise rejection, STC, interference refection, measuring unit, water temperature display (*1) heading (*3), course (*3), deviation from course (*3)
Input data	NMEA-0183, NMEA-0182, KODEN-717, DC-400
Output data	NMEA-0183 (water temperature, boat speed, depth)
Power Supply	11 to 40 VDC
Power consumption	25W

Notes:

(*1): Built-in or separate SPEED/TEMP sensor is required.
(*2): Navigator is required.
(*3): DC-400 fluxgate compass is required.

POSTSCRIPT B
RDI BROADBAND ADCP SPECIFICATIONS
RDI BROADBAND ADCP
SPECIFICATIONS AND DIMENSIONS

INTRODUCTION

The ADCP emits an acoustic pulse called a *ping*. Scatterers that float ambiently with the water currents reflect some of the energy from the ping back to the ADCP. The ADCP uses the return signal to calculate a velocity. The energy in this signal is the *echo intensity*. Echo intensity is sometimes used to determine information about the scatterers.

The velocity calculated from each ping has a *statistical uncertainty*; however, each ping is an independent sample. The ADCP reduces this statistical uncertainly by averaging a collection of pings. A collection of pings averaged together is an *ensemble*. The ADCP's maximum *ping rate* limits the time required to reduce the statistical uncertainty to acceptable levels.

The ADCP does not measure velocity at a single point, it measures velocities throughout the water column. The ADCP measures velocities from its transducer head to a specified range and divides this range into uniform segments called *depth cells* (or *bins*). The collection of depth cells yields a *profile*. The ADCP produces two profiles, one for velocity and one for echo intensity.

The ADCP calculates velocity data relative to the ADCP. The velocity data have both speed and direction information. If the ADCP is moving, and is within range of the bottom, it can obtain a velocity from returns off the bottom. This is called *bottom-tracking*. The bottom-track information can be used to calculate the absolute velocity of the water. The ADCP can get absolute direction information from a heading sensor.

Table B-1 lists the specifications for all three models of ADCP's. About the specifications:

a. All these specifications assume minimal ADCP motion - pitch, roll, heave, rotation, and translation.

b. Except where noted, this specification table applies to typical setups and conditions. Typical setups use the default input values for each parameter (exceptions include Pings Per Ensemble and Number of Depth Cells). Typical conditions assume uniform seawater velocities at a given depth, moderate shear, moderate ADCP motion, and typical echo intensity levels.

c. The total measurement error of the ADCP is the sum of:

   - Long-term instrument error (as limited by instrument accuracy).
   - The remaining statistical uncertainty after averaging.
   - Errors introduced by measurement of ADCP heading and motion.

d. Because individual pings are independent, the statistical uncertainty of the measurement can be reduced according to the equation:

   Statistical uncertainty for one ping = Square-root of number of pings

Table B-1. BB ADCP Specifications

Available models	Direct-Reading (DR) Self-Contained (SC) Vessel-Mounted (VM)					
Frequency options	System (kHz)	75	150	300	600	1200
	Actual (Hz)	76.800	153.600	307.200	614.400	1.228.800

Water Velocity Measurements Relative to the ADCP

Accuracy (long term) 0.2% of measured velocity 0.2 cm/s

Precision (cm/s)

Depth cell size (m)	System frequency (kHz) 75	150	300	600	1200
0.12	----	----	----	----	----
0.25	----	----	----	----	10
0.5	----	----	----	10	4
1	----	----	10	4	2
2	----	10	4	2	1
3	15	4	2	1	----
8	5	2	1	----	----
16	3	1	----	----	----

Water-current velocity precision is the statistical uncertainty (1) of the horizontal velocities for single pings when operating in the normal mode. The precision will decrease proportional to the square root of the number of pings averaged together. Higher precision profiling modes can be used when current shear and instrument dynamics are low.

Minimum time between pings (seconds)

System frequency (kHz) 75	150	300	600	1200
1.00	0.65	0.50	0.20	0.10

Based on 1.57 ms x nominal bottom-track range

Maximum profiling range (meters)							
Frequency (kHz	75	150	300	300	600	600	1200
Beamwidth (degrees)	3	3	3	1.5	3	1.5	1.5
High-power mode	500	300	----	----	----	----	----
Low-power mode	410	230	110	130	50	60	20

Ranges are for systems using the indicated frequency, transducer beamwidth, depth cell size, and power mode in typical water conditions. Range decreases about 10% each time cell is halved.

Minimum range to start of first depth cell (meters)	System frequency (kHz)				
	75	150	300	600	1200
	8	4	2	1	0.5

Loss of profiling range near a boundary	*30° beam angle*	13.4% of range to boundary + one depth cell
	20° beam angle	6% of range to boundary + one depth cell
Number of depth cells		1 to 128 cells
Depth cell size		5 to 3200 centimeters (approx. 2 inches to 105 feet)
Velocity range		±10 m/s (horizontal)

Note: ADCP pitch and roll may reduce range.

ADCP Velocity Measurements Relative to the Bottom and Bottom Depth Measurements

Accuracy (long-term) 0.2% of measured velocity ±0.02 cm/s

Precision (Cm/s) 0.0003V + (a + 0.003V)/(1 + bAF), where:

a = 1 cm/s

b = 0.0001 kHz^{-1} m^{-1}

A = Altitude in Meters

F = System Frequency in kHz

V = Velocity in cm/s

Note: Bottom-track velocity precision is the statistical uncertainty (1) of the horizontal velocities for single pings when operating in the normal mode. The precision will decrease proportional to the square root of the number of pings averaged together.

Maximum and minimum altitudes (meters)	Frequency (kHz)	75	150	300	300	600	600	1200
	Beamwidth (degrees)	3	3	3	1.5	3	1.5	1.5
	Max. altitudes							
	High-power mode	950	525	----	----	----	----	----
	Low-power mode	850	450	225	260	95	110	35

Min. altitudes 5 3 2 2 1.4 1.4
0.8

Altitudes are for systems using the indicated frequency , transducer beamwidth, and power mode in typical seawater conditions.

Altitude accuracy (meters)	1% of measured altitude ±120/Frequency (kHz)
Velocity range	± 10 m/s (horizontal)

Echo Intensity Measurements

Accuracy	±2 dB
Profiling range (meters)	85% of water-profiling range
Number of depth cells	1 to 128 cells
Depth cell size	5 to 3200 centimeters (approx. 2 inches to 105 feet)
Dynamic range	80 dB

Data Communication

Interface	Serial communications at 300 to 115,200 baud using two RS-422 cables, or one RS-232 cable and one RS-422 cable (see Appendix-A)
Input data format	ASCII commands (see Appendix-C)
Output data format	Binary or hexadecimal-ASCII (see Appendix-D)
SC data storage capacity (Standard)	10 to 80 megabytes of solid-state memory
SC data storage	90 to 320 megabytes of solid-state memory. This optional unit fits into the power module section of the SC-BBADCP and takes up to 72 millimeters of space. You may use <u>either</u> the standard solid state memory or the optional memory pack. The units may not be combined.

Power

External

20 to 60 VDC (DR systems)
98 to 264 VAC, 50-60 Hz (DR and VM systems)
12 VDC (DR systems)

Internal (SC models)

Alkaline battery packs supplying 45 to 60 VDC

Dissipation (watts)

Source	Standby	Operate
20-60 VDC - High-power	5	300
20-60 VDC - Low-power	5	100
12 VDC	10	75
AC - High-power	10	500
AC - Low-power	10	150

Sensors

Internal

Sensor	Accuracy	Resolution
Heading	*±5°	0.2°
Tilt	±1°	0.01°
Temperature	±0.5°C	0.01°C
Depth	±1% FS	0.03% FS

10 to 10,000-M full scale (FS) depth sensors available.

• Heading accuracy assumes you are working in an environment where the horizontal magnetic field strength is 10,000 to 40,000 NT (Nano-Teslas) and the operational temperature of 0-30° C.

External

RS-485 serial interface at 300-19200 baud (future)

Environmental

Temperature

Operating: -5 to +35°C
Storage: -50 to +80°C

Humidity

Must be non-condensing

Vibration

Mets MIL-STD-167-1, type 1

Shock

20 g static

DR/SC depth ratings

200 m, 1000 m, 3000 m, or 6000 m

POSTSCRIPT C
FSI MICRO-CTD SPECIFICATIONS
Falmouth Scientific MICRO-CTD CONDUCTIVITY:

Probe:	Falmouth Scientific Inductive Conductivity Sensor	
Range:	0 - 65 mmho/cm	(0 - 6.5 S/M)
Accuracy:	±0.005 mmho/cm	(±.0005 S/M)
Stability:	±0.0005 mmho/cm/month	(±0.5 Ms/m)
Resolution:	0.0002 mmho/cm	
Sampling Rate:	Programmable 1 to 6 samples/sec	
Response:	5.0 cm (50 milliseconds @ 1 meter/second flow)	

Pressure:

Probe: Falmouth Scientific Titanium Pressure Sensor

Range:			Resolution*
	0 - 200 dbar	(300 psiA)	.0005/.002
	0 - 1000 dbar	(1500 psiA)	.003/.012
	0 - 2000 dbar	(3000 psiA)	.006/.024
	0 - 3000 dbar	(5000 psiA)	.008/.038
	0 - 7000 dbar	(10000 psiA)	.020/.087

Accuracy: ±0.12% of Full Scale

Stability: ±0.01% of F.S./month

Resolution:* 16 bits @ 6 samples/sec
18 bits @ 1 samples/sec

Sampling Rate: 1 to 6 Samples/Second Programmable

Temperature:

Probe:	Falmouth Scientific Reference Grade Platinum Resistance Thermometer or Falmouth Scientific Pressure-Protected Stabilized Thermistor (Glass)
Range:	-2° to 32° Celsius
Accuracy:	±0.005 Celsius PRT ±.010 Celsius Therm.
Stability:	±0.5 mC/m PRT ±2.0 mC/m Therm.
Resolution:	0.0001 °C
Sampling Rate:	Programmable 1 to 6 samples/sec
Response:	400 - 500 milliseconds (Platinum) 100 - 150 milliseconds (Sheathed Thermistor) (63% of Step @ 1 meter/second flow)
SEF Heating:	<0.0003 °C @ (1 meter/second flow)

POSTSCRIPT D
SEAPAC SP2200 SPECIFICATIONS
SeaPac 2200 Technical Specifications

Temperature (Pressure Sensor)		
	Sensor	Paroscientific quartz sensor
	Range	-54° to 107°C
	Accuracy	±0.1°C
	Resolution	0.01°C
Pressure		
	Sensor	Paroscientific quartz pressure sensor
	Range	0-100 psi
	Accuracy	1.0 cm
	Resolution	0.1 cm
Data Storage		
	Medium	Nonvolatile CMOS SRAM Sealed Removable Module
	Capacity	4 Mbyte (Expandable to 12 Mbytes)
	Retrieval	Stand-alone RS-232C, 300-19200 baud, w/ 16 command instruction set
	Data Security	Replaceable battery back-up, CRC generation, overwrite protection
Time Base		
	Crystal	2.097152 MHz GT-cut quartz crystal/Real Time Clock
	Stability	±1 ppm over 0 °C to +40 °C
	Accuracy	30 seconds/year
	Wave Burst Sampling	
	Burst Interval	continuous, 2 min to 24 hrs
	Scans/Burst	8 to 4096 scans (multiples of 8)
	Integration period	0.25, 0.5, 1, 2, 4, seconds
	Tide Sampling (Continuous)	
	Integration Period	3.75, 7.5, 15 minutes
Power		
	Method	SPB-50, 5 section, 50 alkaline battery pack
	Life	500 hours (all modes continuous)
Pressure Case		
	Material	6061-T6 Aluminum or PVC (Plastic)
	Oper. Depth	200 M (Deeper housings available)
	Finish	Hard-coated
	Size	11.4 cm O.D. x 140 cm long
	Weight	21 kg in air
	Maximum In-lineTension	4500 kg

POSTSCRIPT E

SEAPAC SP2000 SPECIFICATIONS

Sensors:		
	Water Velocity	
	Sensor	2-axis Marsh-McBirney 10.1 cm diameter EM sphere
	Range	±300 cm/sec
	Resolution	0.15 cm/sec (12-bits)
	Threshold	0.15 cm/sec
	Response	0.2 sec
	Error	steady-state: less than 2 cm/sec or 2% of signal
	Direction	
	Sensor	KVH Industries, Inc. digital fluxgate compass
	Resolution	±0.1 degree
	Accuracy	±0.5 degrees (after 0.5 sec of stability)
	Tilt Range	Operational ±16 degrees
	Temperature	
	Sensor	YSI Thermistor
	Range	-5° to +35°C
	Accuracy	±0.1°C
	Resolution	0.01°C)
	Sensor	Magnetek Strain Gauge
	Range	0-30, 50, 100, 200, 500, 1000, 2000, 5000, 10,000
	Accuracy	.25% of full scale
	Resolution	1:10,000
	Tilt (Optional)	
	Sensor	Accustar Dual Axis Clinometer
	Range	±20 degrees
	Accuracy	1.0 degrees
	Resolution	0.8 degrees
Data Storage		
	Medium	Nonvolatile CMOS SRAM Sealed Removable Module
	Capacity	4 Mbyte (Expandable to 12 Mbytes)
	Retrieval	Stand-alone RS-232C, 300-19200 baud, with 16-command instruction set
	Data Security	Replaceable battery back-up, CRC generation, overwrite protection
Time Base		
	Crystal	2.097152 MHz GT-cut quartz crystal/Real Time Clock
	Stability	±1 ppm over 0 °C to +40 °C
	Accuracy	30 seconds/year
	BURST SAMPLING	
	Scan Interval	1 - 3600 seconds
	Scans/Burst	1 - 4096 scans
	Burst Interval	2 - 720 minutes
	Duty Cycle	0.002% to 100% (continuous measurements)

Power

Method	SPB-50, 5 section, 50 alkaline battery pack
Life	450 (continuous mode)

Pressure Case

Material	6061-T6 Aluminum
Oper. Depth	200 M (Deeper housings available)
Finish	Hard-coated
Size	11.4 cm O.D. x 140 cm long
Weight	21 kg in air
Maximum In-line Tension	4500 kg

E-1-1 Table II-1. Ship Survey Dates 1995

Survey 1	10 April - 14 April
Survey 2	24 April - 28 April
Survey 3	5 June - 7 June
Survey 4	19 June - 23 June

E-1-1 Table II-2. ADCP Files used in Data Processing

Survey	*Day*	*Date 1995*	*No. of lines*	*No. of ADCP Files*	*No. of Nav. Files*	*Site*
1	4	April 13	27	27	27	The vicinity of the Station (along the shoreline)
2	2	April 25	26	26	26	The vicinity of the Station (13 around the basin, 13 along the shoreline)
2	3	April 26	8	8	8	South Boundary
2	4	April 27	9	9	9	North Boundary
3	2	June 6	25	25	25	The vicinity of the Station (13 around the basin, 12 along the shoreline)
4	2	June 20	20	21	20	The vicinity of the Station (10 around the basin, 10 along the shoreline)
4	4	June 22	9	9	9	North Boundary
4	5	June 23	8	8	8	South Boundary

E-1-1 Table II-3. Sample Data from ADCP Ensemble File[a]

112.00	101.63371	11.34		
1.74	-63.8	-145.3	158.69	203.7
2.24	-59.4	-136.3	148.68	203.5
2.74	-58.4	-140.7	152.34	202.5
3.24	-54.5	-136.0	146.51	201.8
3.74	-55.8	-133.8	144.97	202.6
4.24	-49.1	-123.8	133.18	201.6
4.74	-46.8	-128.0	136.29	200.1
5.24	-56.4	-126.5	138.50	204.0
5.74	-55.9	-123.1	135.20	204.4
6.24	-54.8	-115.9	128.20	205.3
6.74	-50.6	-110.6	121.63	204.6
7.24	-52.3	-108.4	120.36	205.8
7.74	-43.4	-106.5	115.00	02.2
8.24	-40.2	-109.9	117.02	200.1
8.74	-37.3	-106.5	112.84	199.3
9.24	-45.0	-107.2	116.26	202.8
9.74	-39.2	-107.6	114.52	200.0
10.24	-35.0	-102.8	108.59	198.8
10.74	-36.7	-95.5	102.31	201.0
11.24	-41.0	-91.0	99.81	204.3
11.74	-39.1	-87.4	95.75	204.1
12.24	-39.3	-82.4	91.29	205.5
12.74	-37.6	-83.8	91.85	204.2
13.24	-34.9	-81.6	88.75	203.2
13.74	-39.5	-82.9	91.83	205.5
14.24	9999.0	9999.0	9999.00	0.0
14.74	9999.0	9999.0	9999.00	0.0
15.24	9999.0	9999.0	9999.00	0.0
15.74	9999.0	9999.0	9999.00	0.0
16.24	9999.0	9999.0	9999.00	0.0

[a] The first line identifies the file (ensemble number, Julian day, water temperature in °C). For the remainder of the file, column 1 is depth (m), columns 2, 3, and 4 are east component of current velocity, north component of current velocity, and current speed, respectively, all in cm/sec. Column 5 is current direction (degrees north from due north).

E-1-1 Table III-1. SP2200 Tide Gauge Deployment Dates 1995

Site Number	Site	Longitude	Latitude	Start Time	End Time
sn52017	SDEL	39° 25.062'N	75° 32.328'W	29 March, 1300	20 April, 2245
				4 May, 1200	24 July, 1515
sn52018	SNJ	39° 26.914'N	75° 29.923'W	29 March, 1300	30 April, 2245
				4 May, 1300	24 July, 1345
sn52019	NNJ	39° 30.294'N	75° 32.286'W	29 March, 1300	30 April, 2245
				4 May, 1200	24 July, 2245
sn52020	NDEL	39° 30.509'N	75° 34.530'W	29 March, 1300	30 April, 2245
				4 May, 1200	24 July, 1545
sn52021	Chesapeake Bay	39° 30.180'N	75° 54.050'W	20 June, 1800	24 July, 1045

E-1-1 Table III-2. SP2000 Current Meter Specifications and Deployment Dates (1995)

Serial Number	Site	Longitude	Latitude	Start Time	End Time
sn50026	NNJ	39° 30.202′N	75° 32.550′W	29 March, 1300	3 May, 1740
		39° 20.206′N	75° 32.534′W	18 May, 1300	26 June, 0950
sn50027	SDEL	39° 25.442′N	75° 31.931′W	29 March, 1300	4 May, 1050
		39° 25.392′N	75° 31.858′W	5 May, 1300	27 May, 0900
sn50028	NDEL	39° 30.281′N	75° 33.397′W	29 March, 1300	30 April, 0850
sn31006	NDEL	39° 30.281′N	75° 33.695′W	5 May, 1300	26 June, 1500
sn50029	SNJ	39° 25.934′N	75° 31.290′W	29 March, 1300	17 May, 1300
		39° 25.985′N	75° 31.366′W	18 May, 1340	26 June, 1110

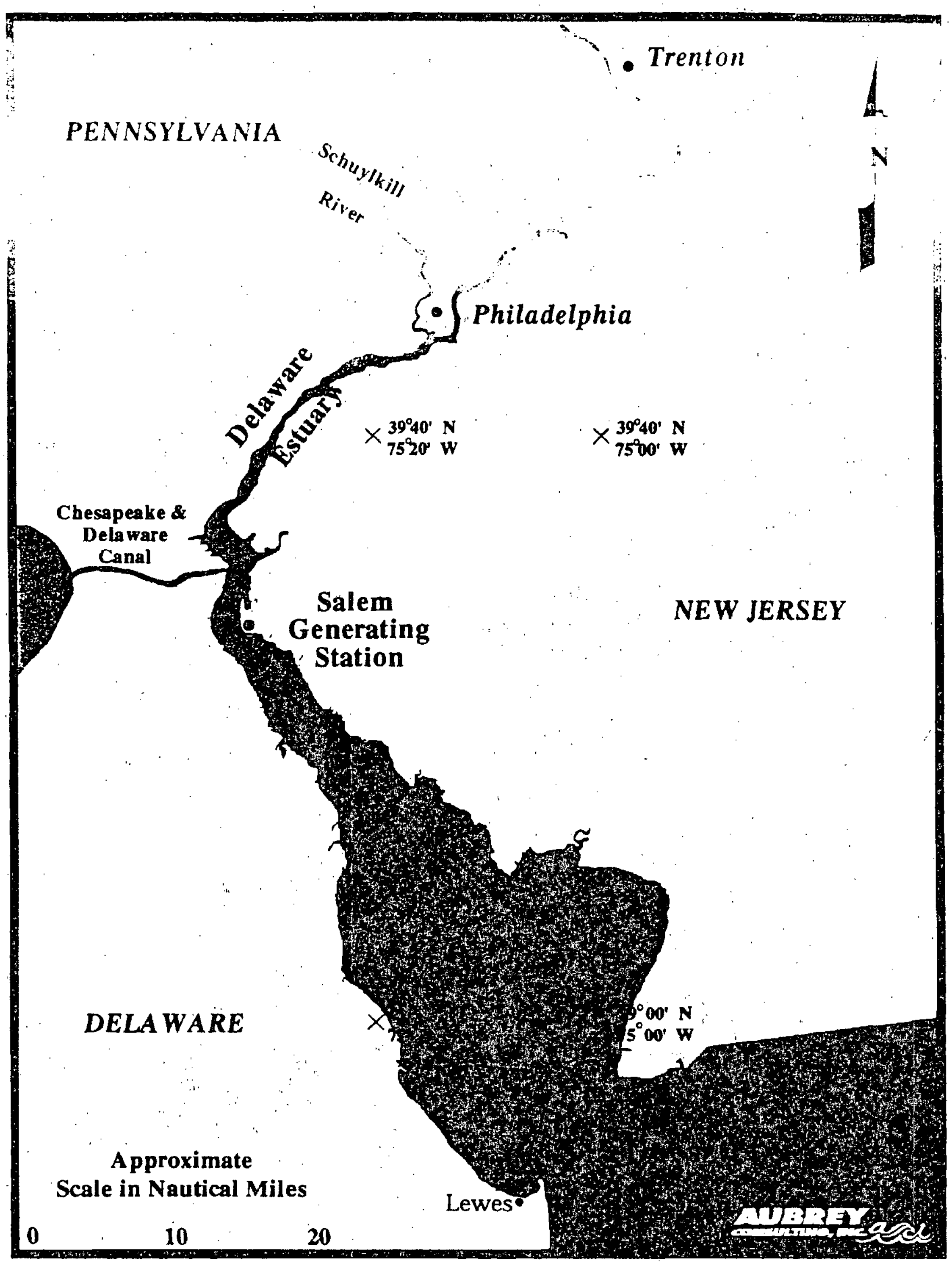
E-1-1 Table III-3. Real-Time System File Names: ASCII Files Created From Processed Raw File.

File Name	File Contents
RTJL9543.RAW	Raw hexadecimal file uploaded to the PC
RTJL9543.ENG	Engineering data record
RTJL9543.JNK	Full engineering record
RTJL9543.TEM	Two-column file of time: Column 1 = hour, Column 2 = minutes with header information
RTJL9543.HRS	Same as RTJL9543.TEM without the header data
RTJL9543.TMP	Five-column data matrix with header information; Columns 1-5 have V^e, V^n, Compass, Temperature, and Conductivity respectively
RTJL9543.VEN	The same as RTJL9543.TMP without the header data
RTJL9543.DAT	The data file to be processed by Timcon43.m
TIMCON43.M	MATLAB file which post-processes and prepares the data for plotting
HIPLOT.M	MATLAB file which plots the data for display

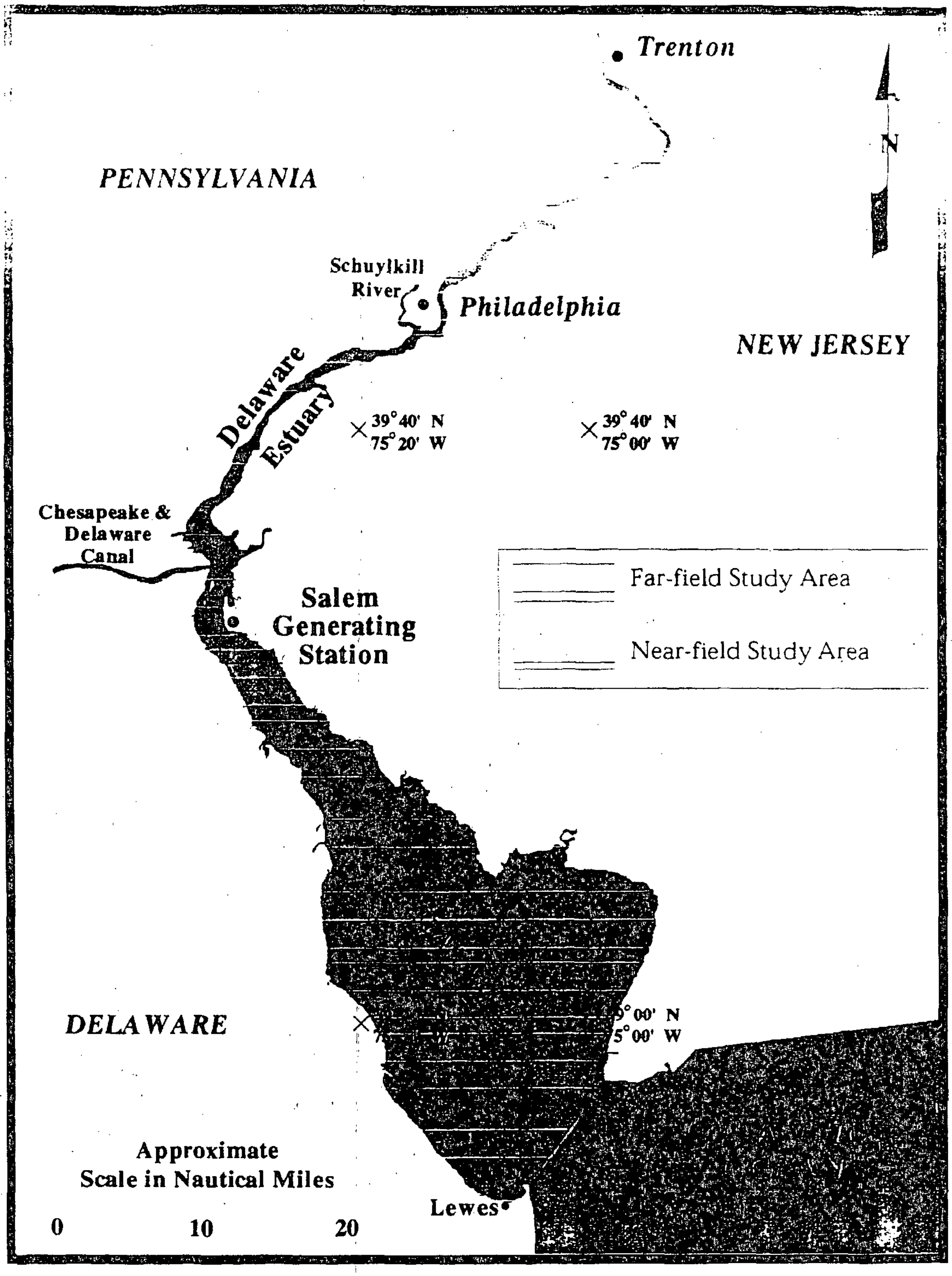
APPENDIX E
EXHIBIT E-1-1

1995 MONITORING RESULTS
REFERENCES

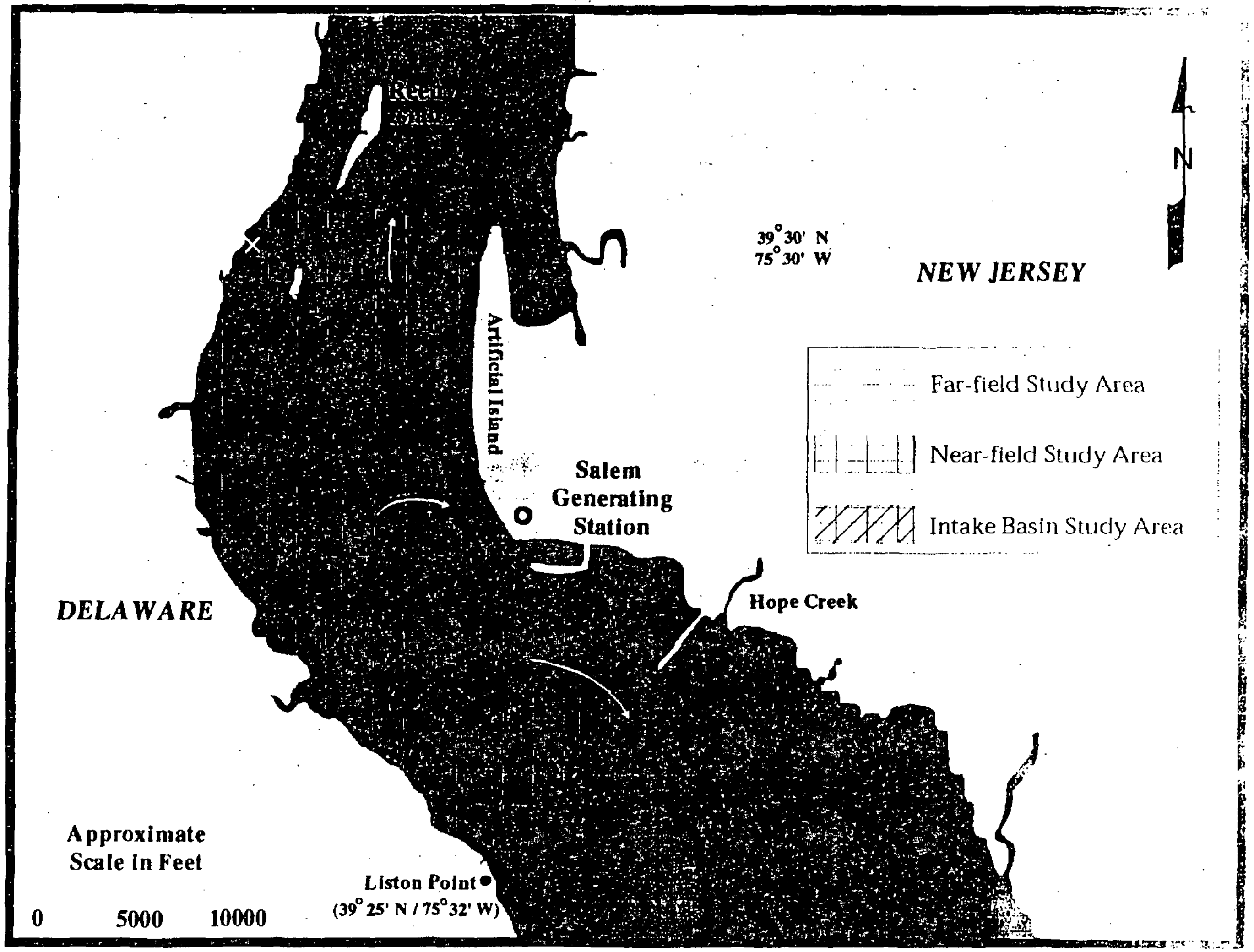
Aubrey Consulting, Inc. (ACI). 1995. Numerical Circulation Model Implementation: Salem and Hope Creek Nuclear Generating Stations Field and Data Report. East Falmouth, MA. September.



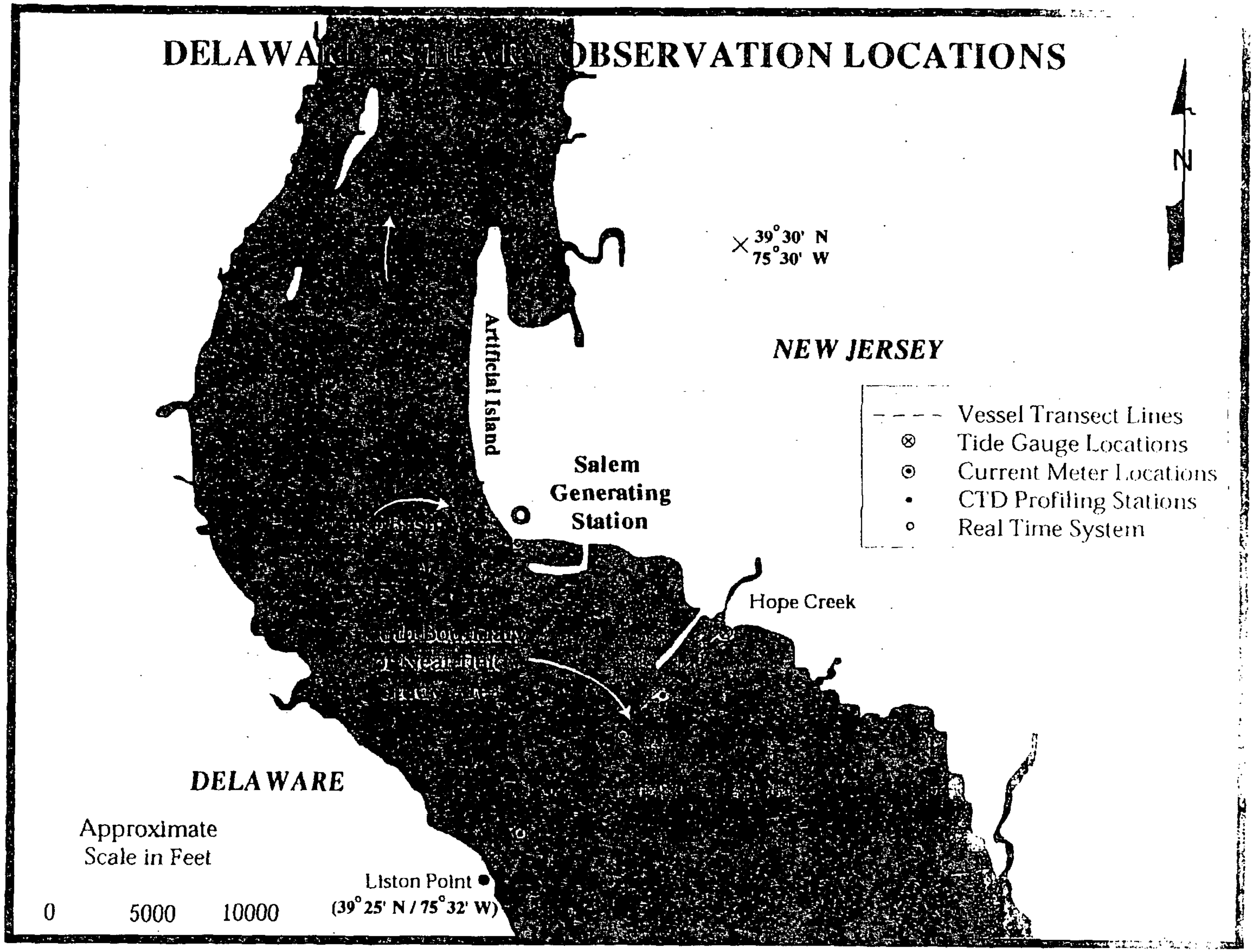
E-1-1 Figure I-1. Map of the Delaware Estuary and the relative location of the Station.



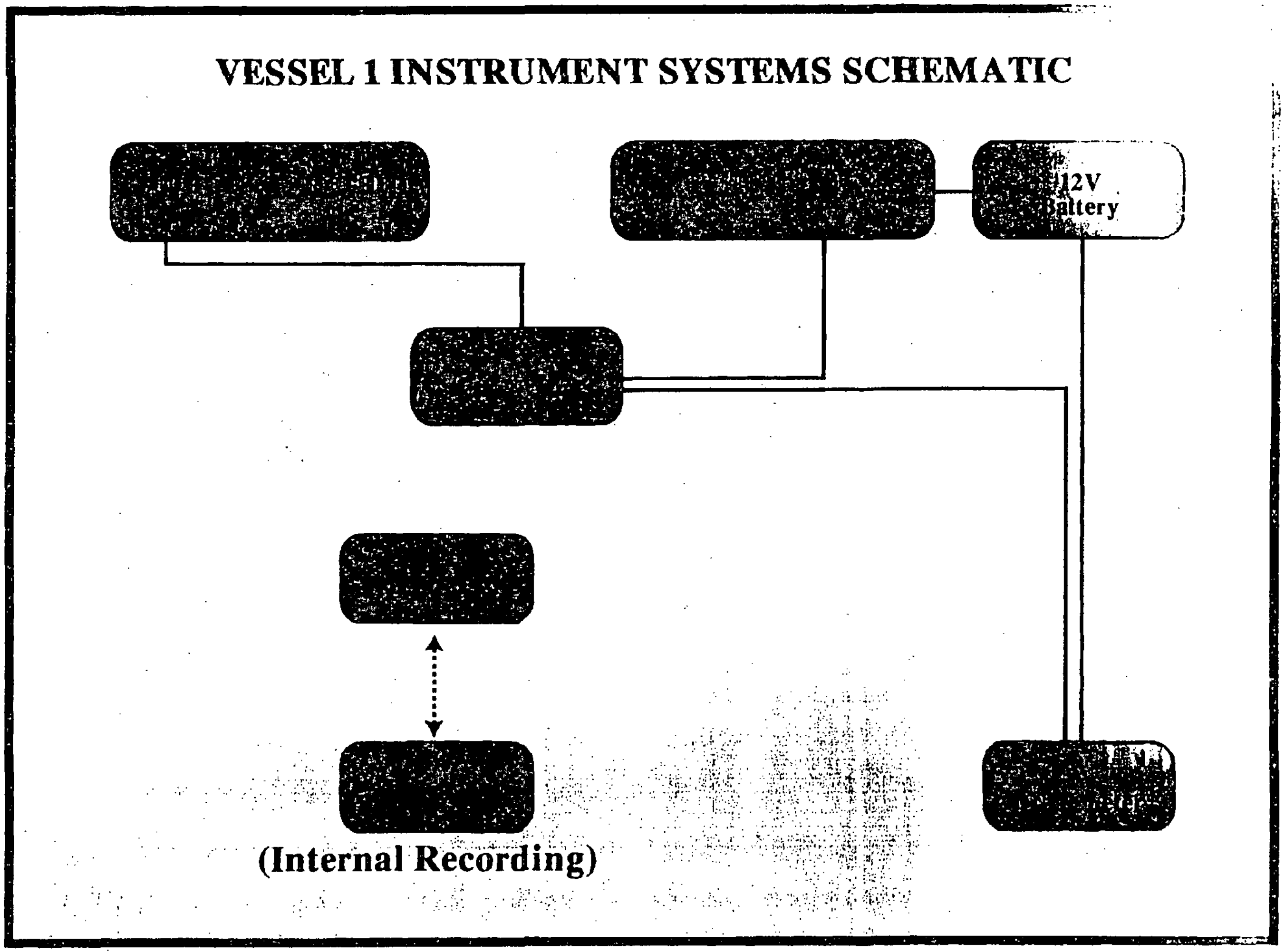
E-1-1 Figure I-2. Illustration of the far-field study area and relative location of the near-field study area. The far-field stretches from the mouth of Delaware Bay to Trenton, NJ. The Chesapeake and Delaware Canal and lower portions of the Schuylkill River are included.



E-1-1 Figure 1-3. Illustration of the near-field study area, in the vicinity of Artificial Island. The near-field limits are defined by the "north boundary" (northern tip of Artificial Island to the southern tip of Reedy Island) and by the "south boundary" (mouth of Hope Creek, NJ to Liston Point, DE). The intake basin study area is shown close to the Station.

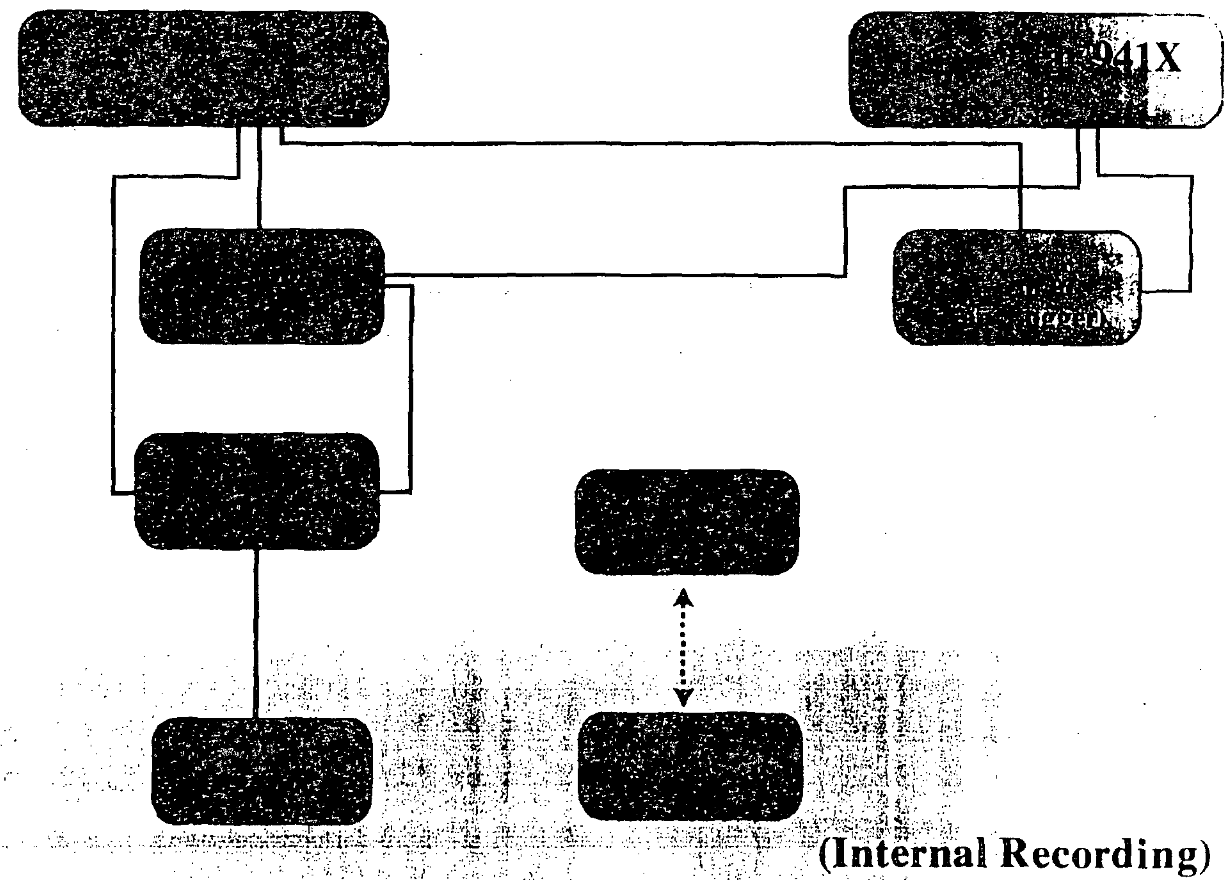


E-1-1 Figure 1-4. Locations of long-term and synoptic (survey) observations relative to the Station.

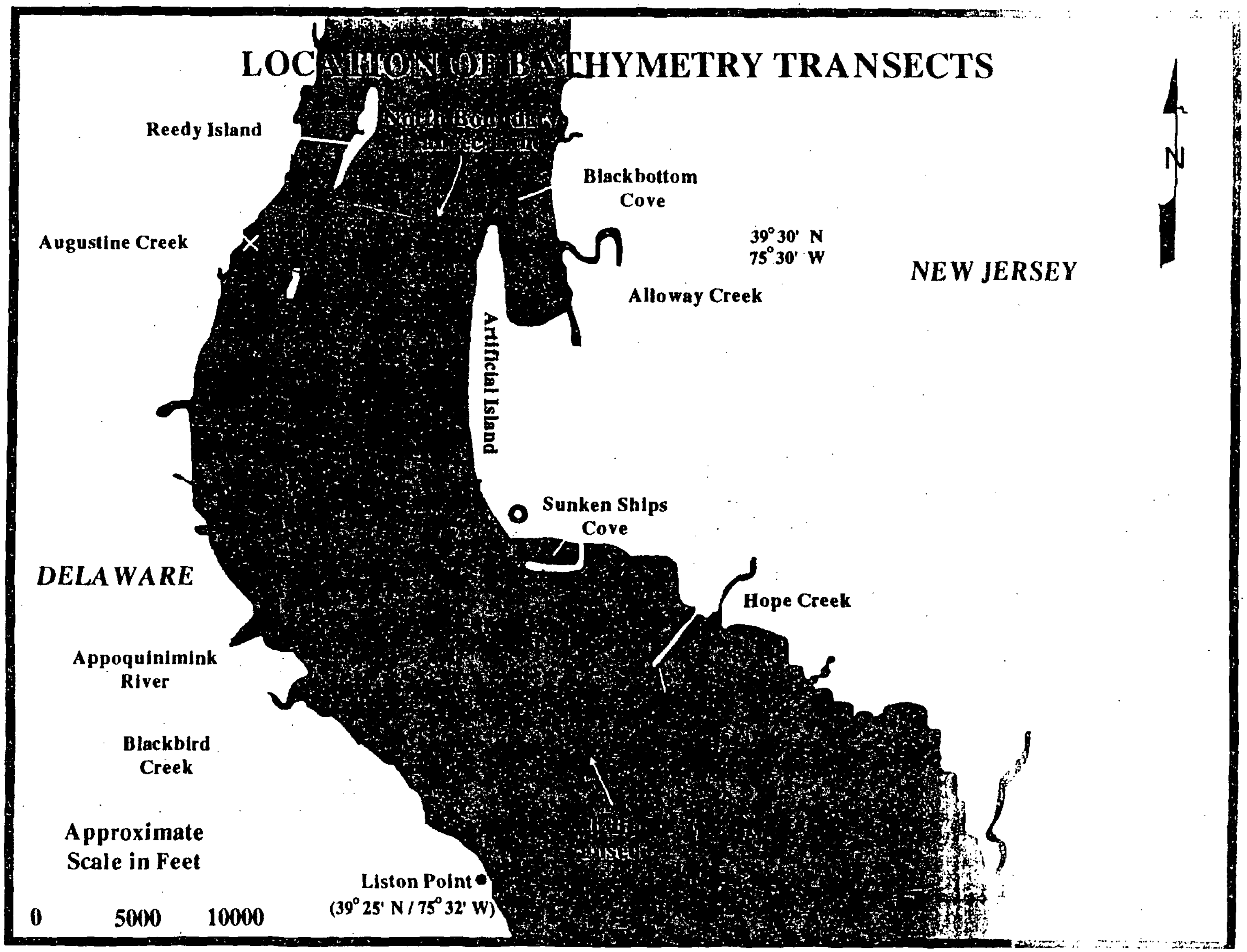


E-1-1 Figure II-1. Instrument and data systems for Vessel #1.

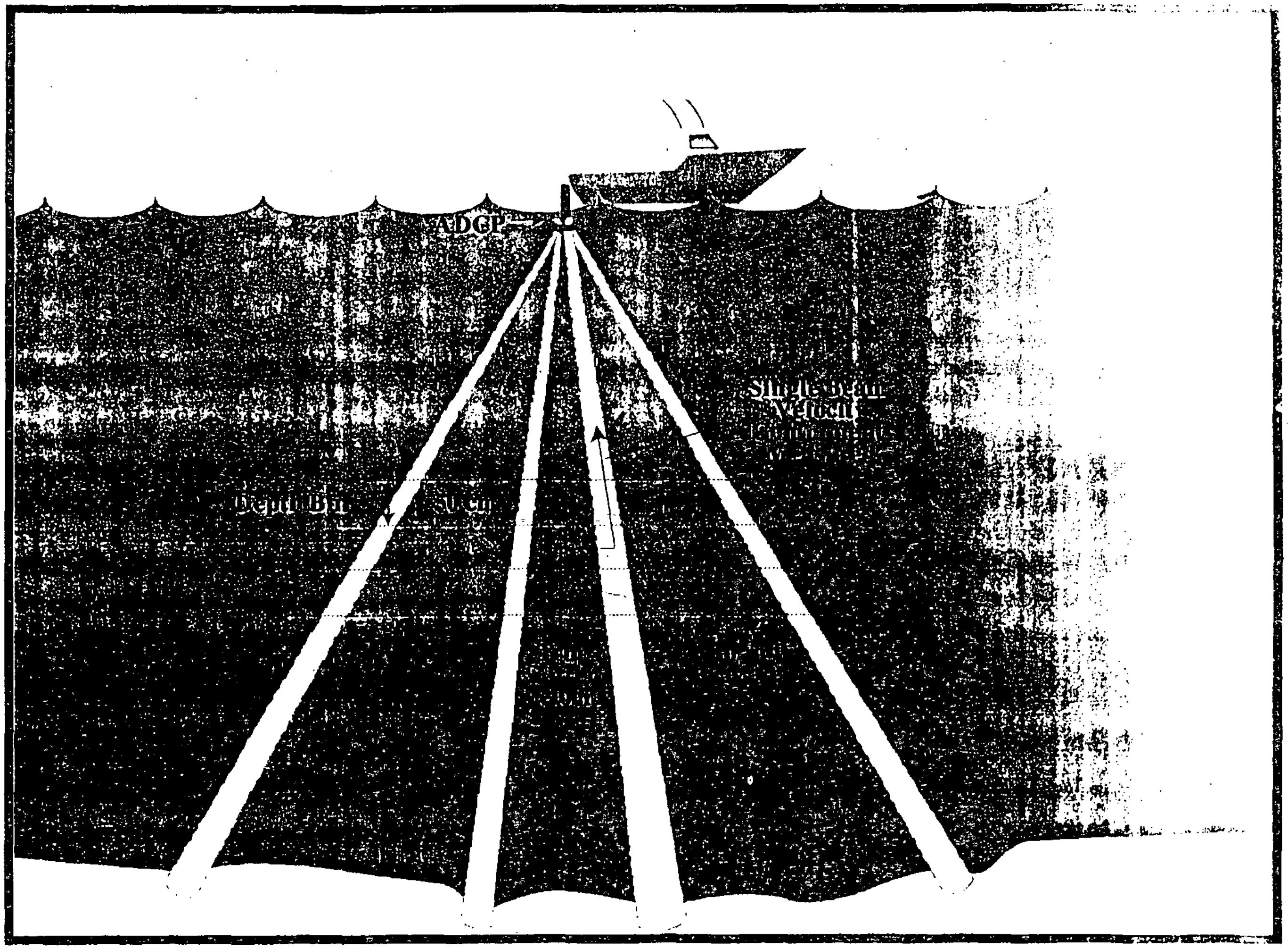
VESSEL 2 INSTRUMENT SYSTEMS SCHEMATIC



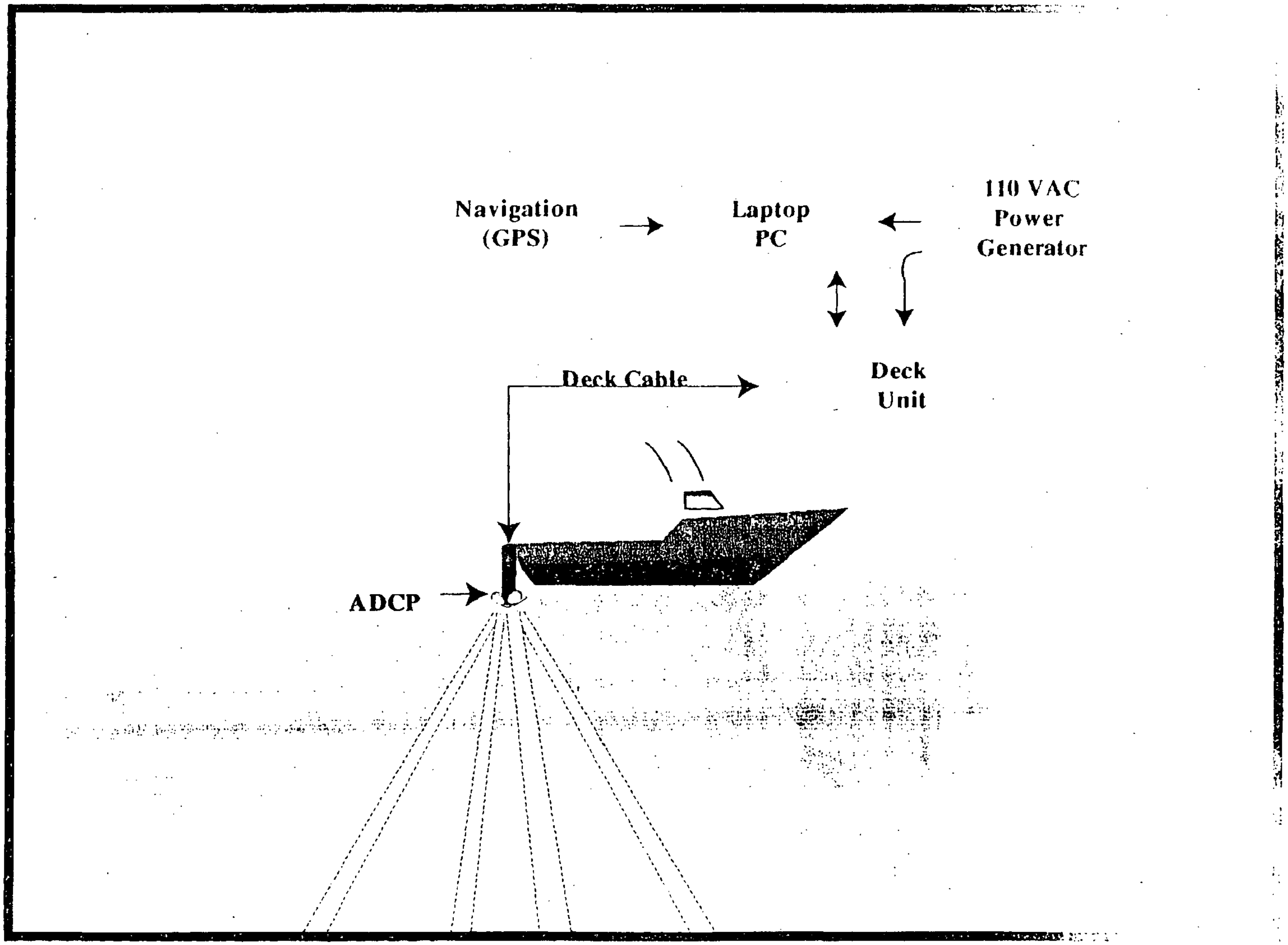
E-1-1 Figure II-2. Instrument and data systems for Vessel #2.



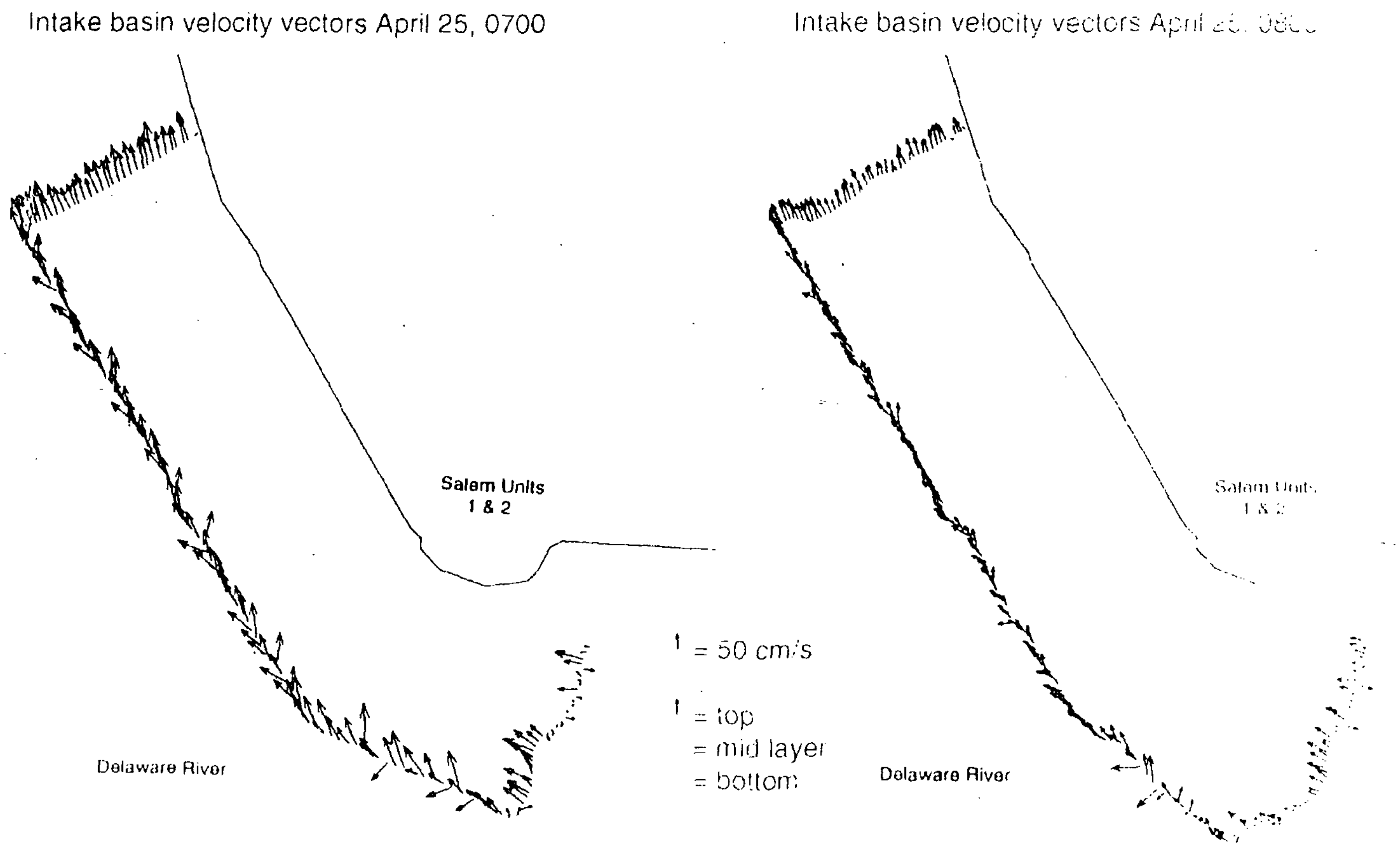
E-1-1 Figure II-3. Location of bathymetry survey transects near Artificial Island. Transect lines were spaced every 1/4 mile from the north boundary to the south boundary. Finer resolution spacing was defined for the Salem cooling water intake basin.



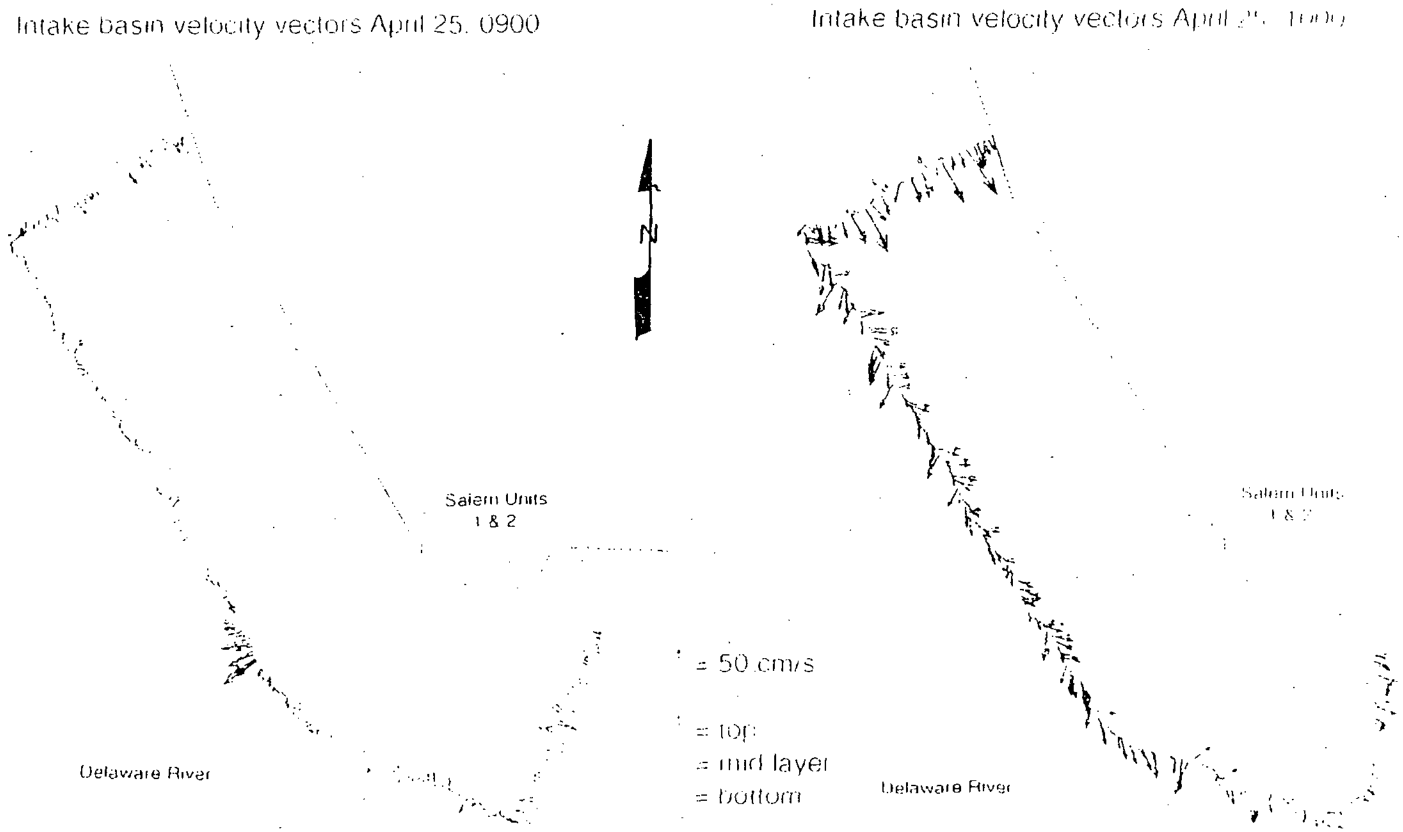
E-1-1 Figure II-4. Schematic of the ADCP mounted to the survey vessel. The ADCP uses four independent beams to sense current velocity. Acoustic signals are reflected from ambient sound scatterers in the water column; comparison of the emitted acoustic frequency with the backscattered frequency determines the doppler shift, proportional to the relative speed of the sound scatterers to the ADCP transducers. The motion of the vessel is subtracted from the current measurements by acoustic "bottom-tracking". The ADCP measures current profiles (one current measurement per 50 cm depth bin) by "range-gating" the backscattered acoustic signal. Trigonometric reduction of the four independent beam measurements produces three (x-y-z) orthogonal current velocity components.



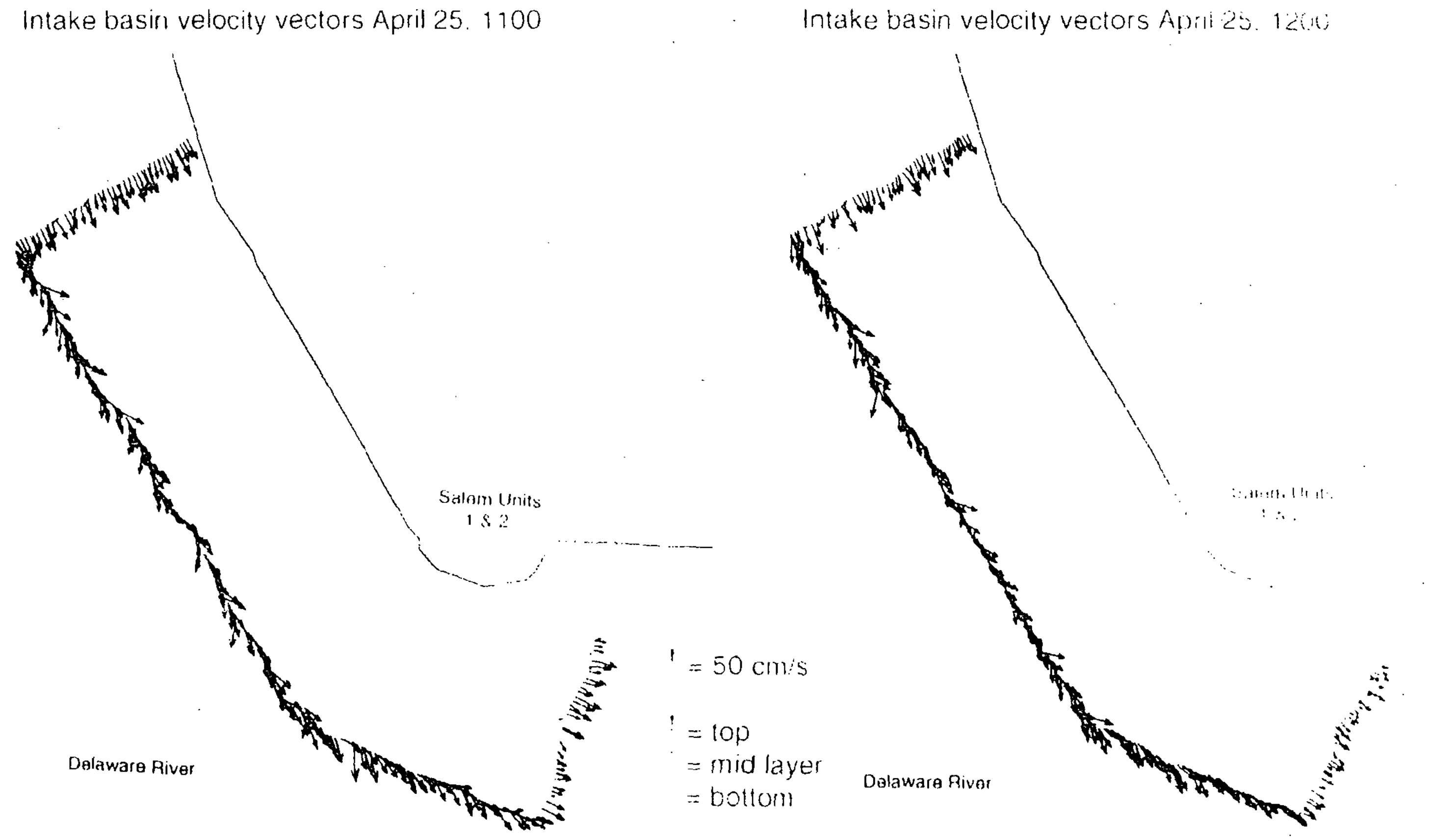
E-1-1 Figure II-5. Schematic of the ADCP shipboard system. The system features the (submerged) ADCP instrument, deck unit, ADCP laptop computer, GPS navigation device, and power.



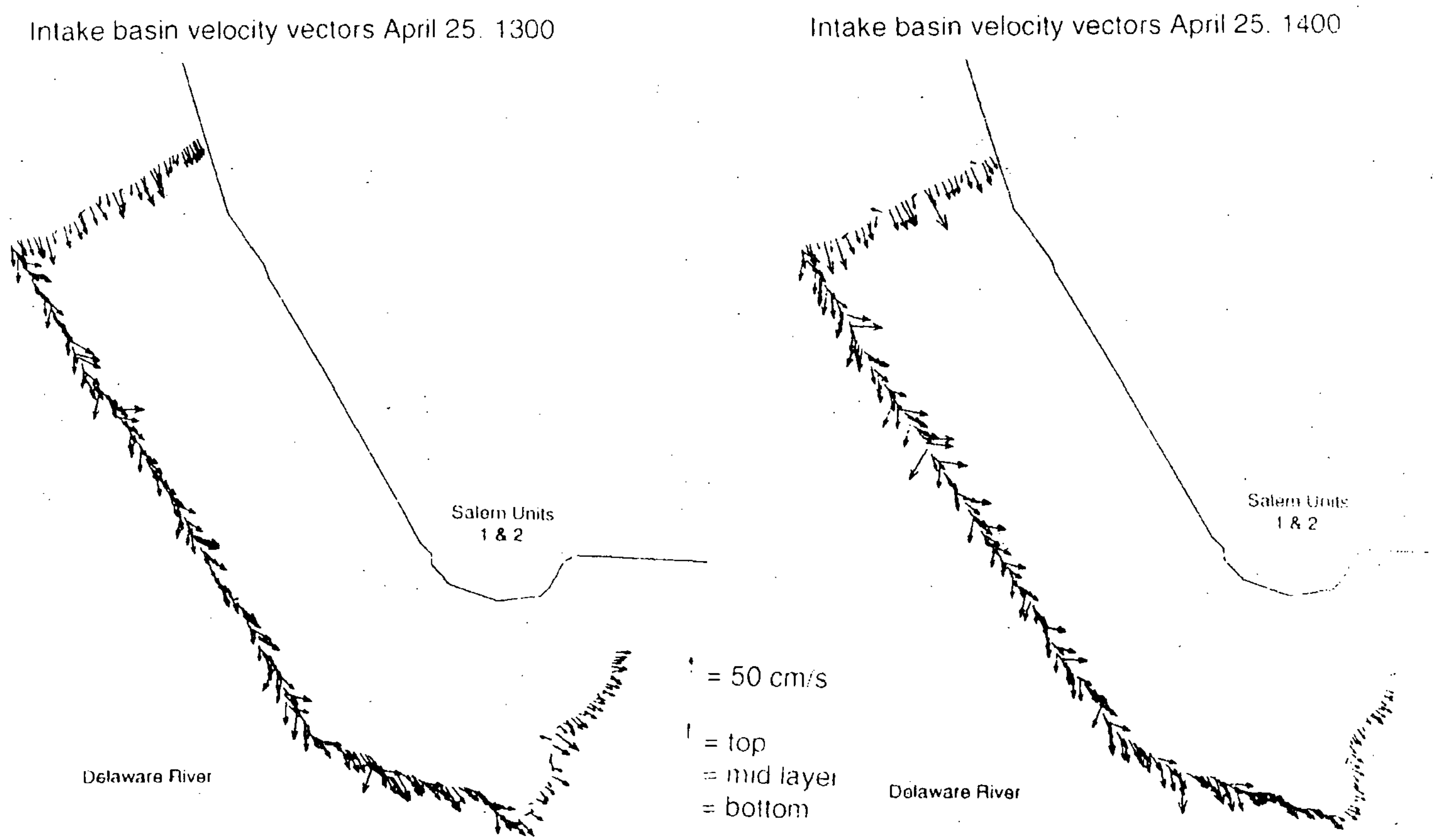
E-1-1 Figure II-6. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 0700 (EDT) and 0800 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



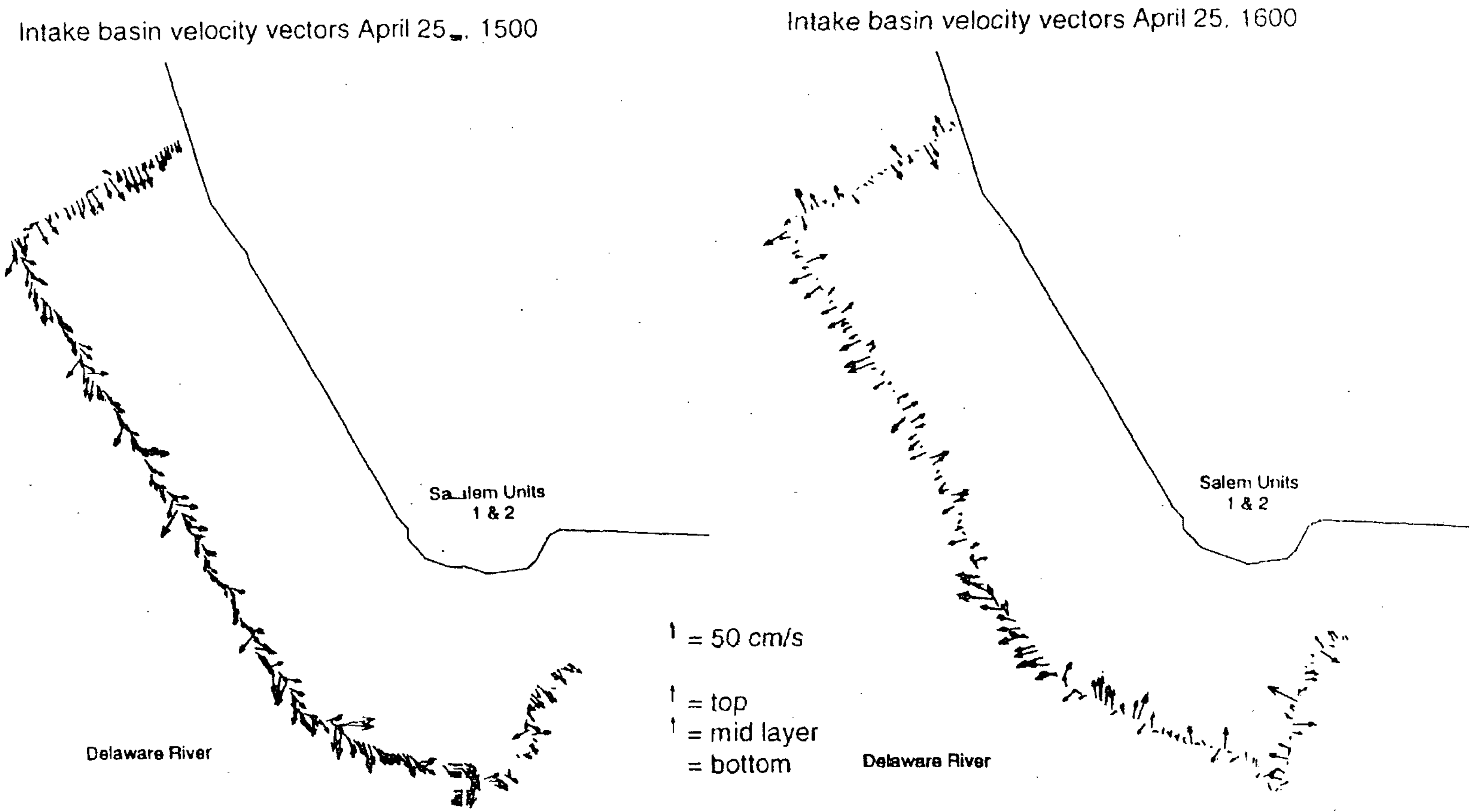
E-1-1 Figure II-7. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 0900 (EDT) and 1000 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



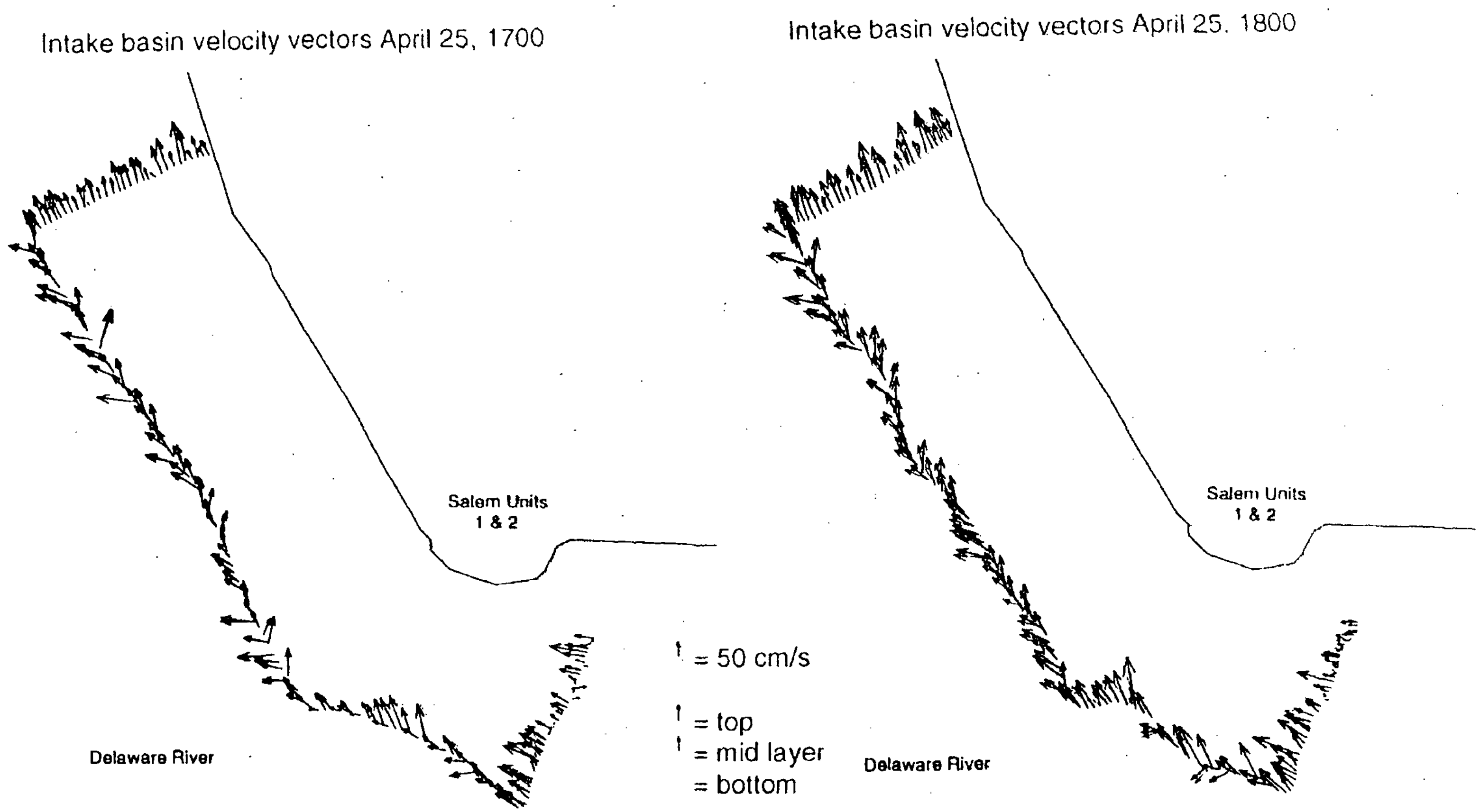
E-1-1 Figure II-8. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 1100 (EDT) and 1200 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



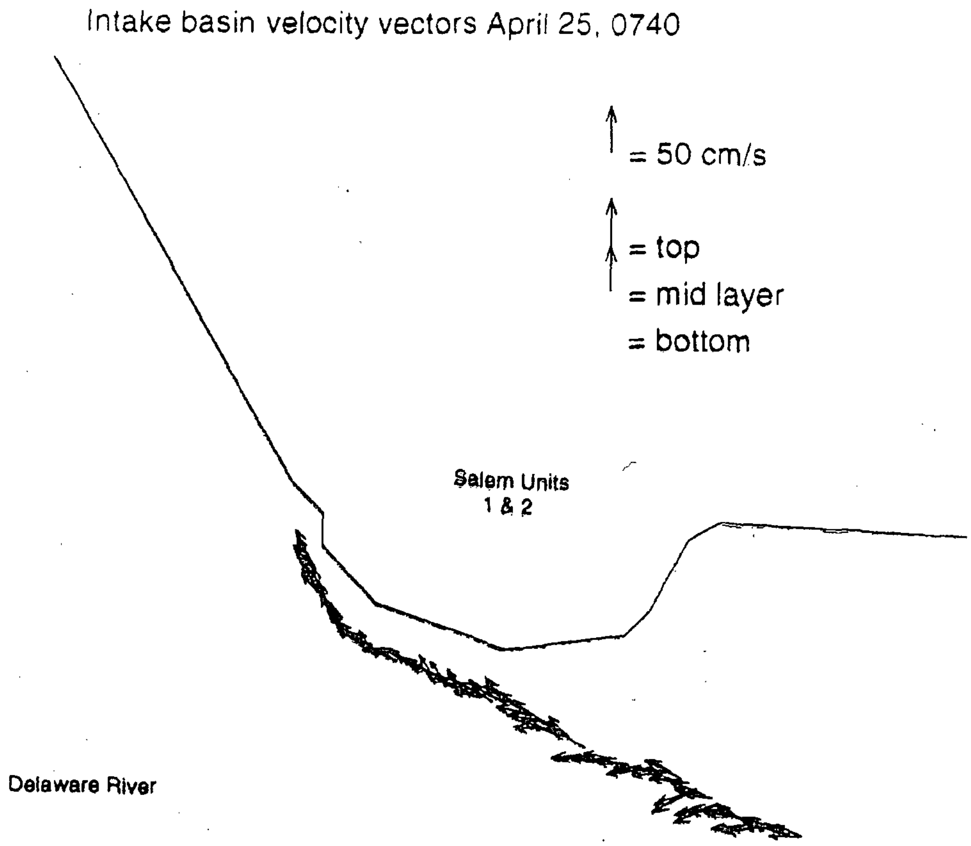
E-1-1 Figure II-9. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 1300 (EDT) and 1400 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



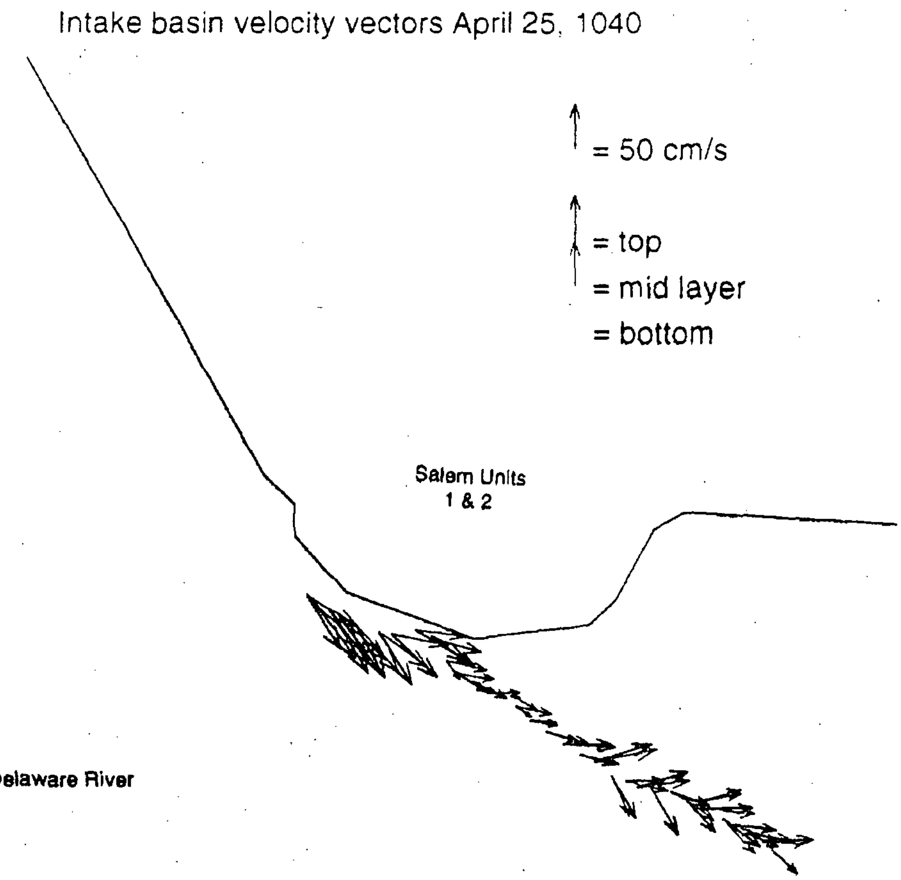
E-1-1 Figure II-10. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 1500 (EDT) and 1600 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



E-1-1 Figure II-11. Current vectors at the outer boundary of the intake basin as measured by the ADCP for 1700 (EDT) and 1800 (EDT) on 25 April 1995. Each arrow represents the speed and direction of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.

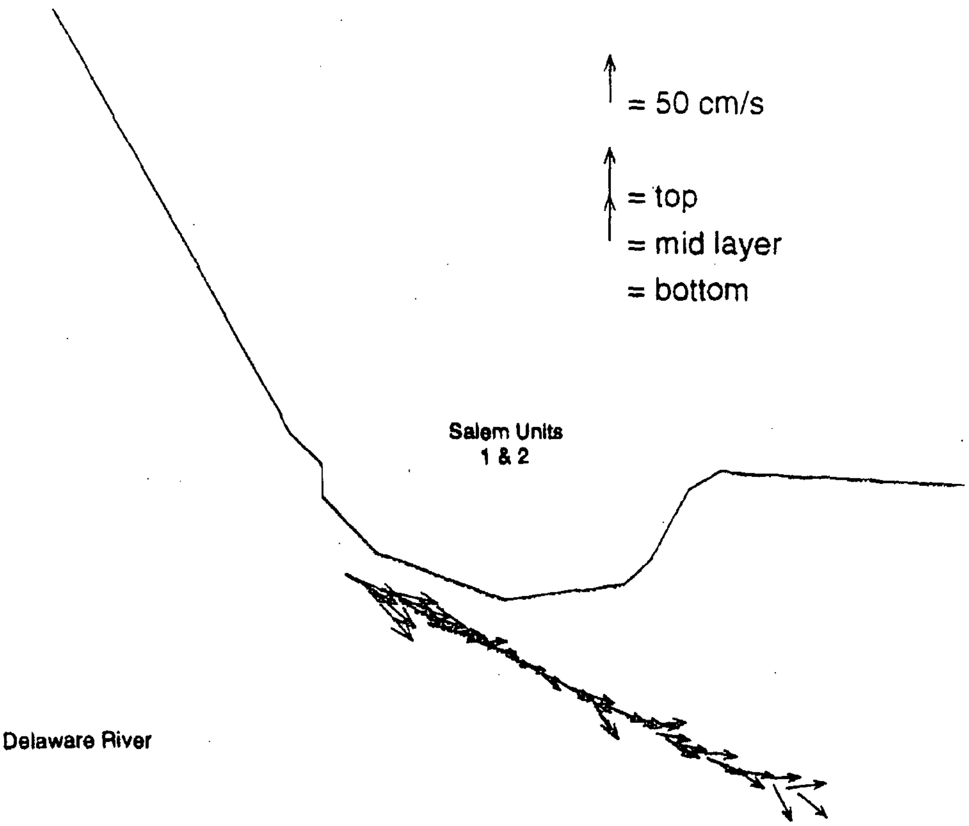


E-1-1 Figure II-12. Current vectors along a survey transect parallel to the Salem cooling water intake structure seawall as measured by the ADCP at 0740 (EDT) on 25 April 1995. Each arrow represents the speed and directon of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.

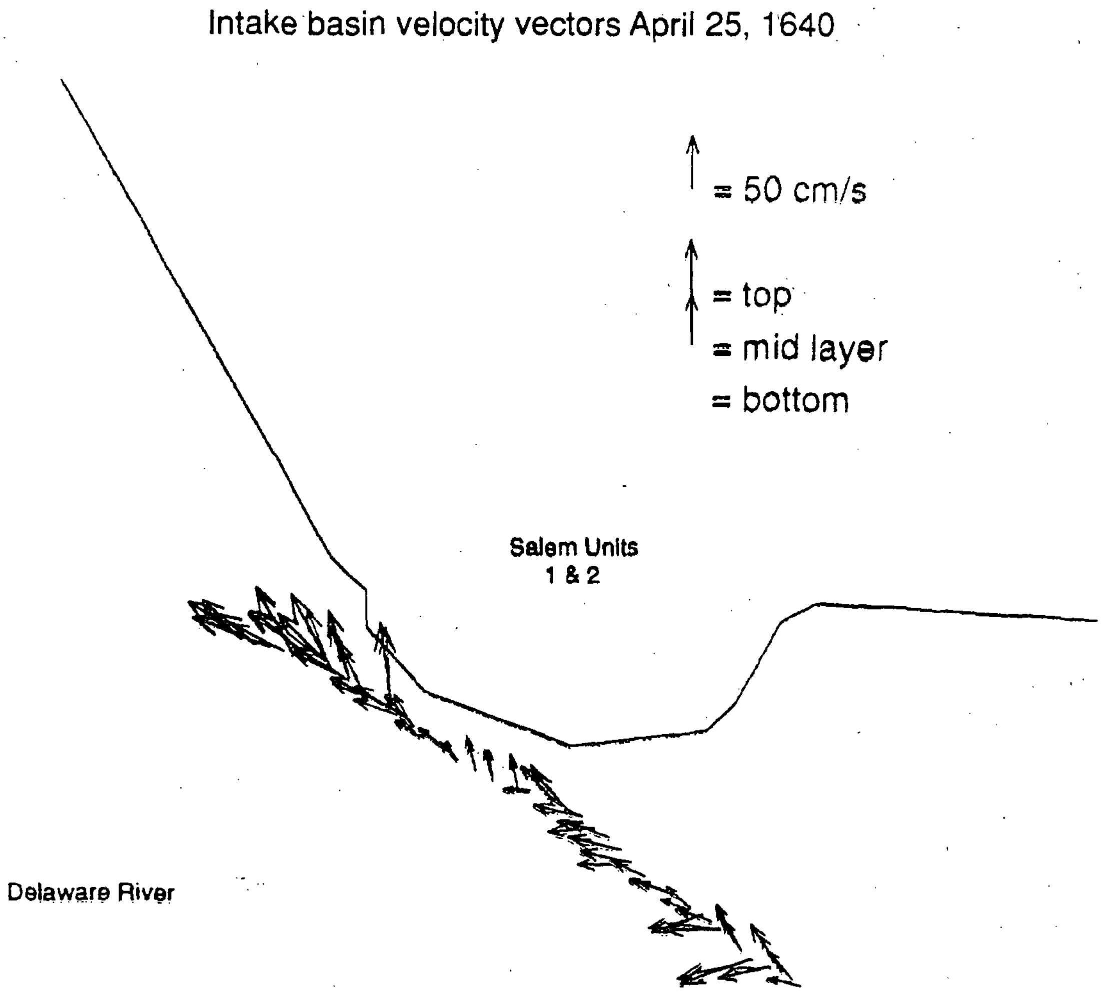


E-1-1 Figure II-13. Current vectors along a survey transect parallel to the Salem cooling water intake structure seawall as measured by the ADCP at 1040 (EDT) on 25 April 1995. Each arrow represents the speed and directon of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.

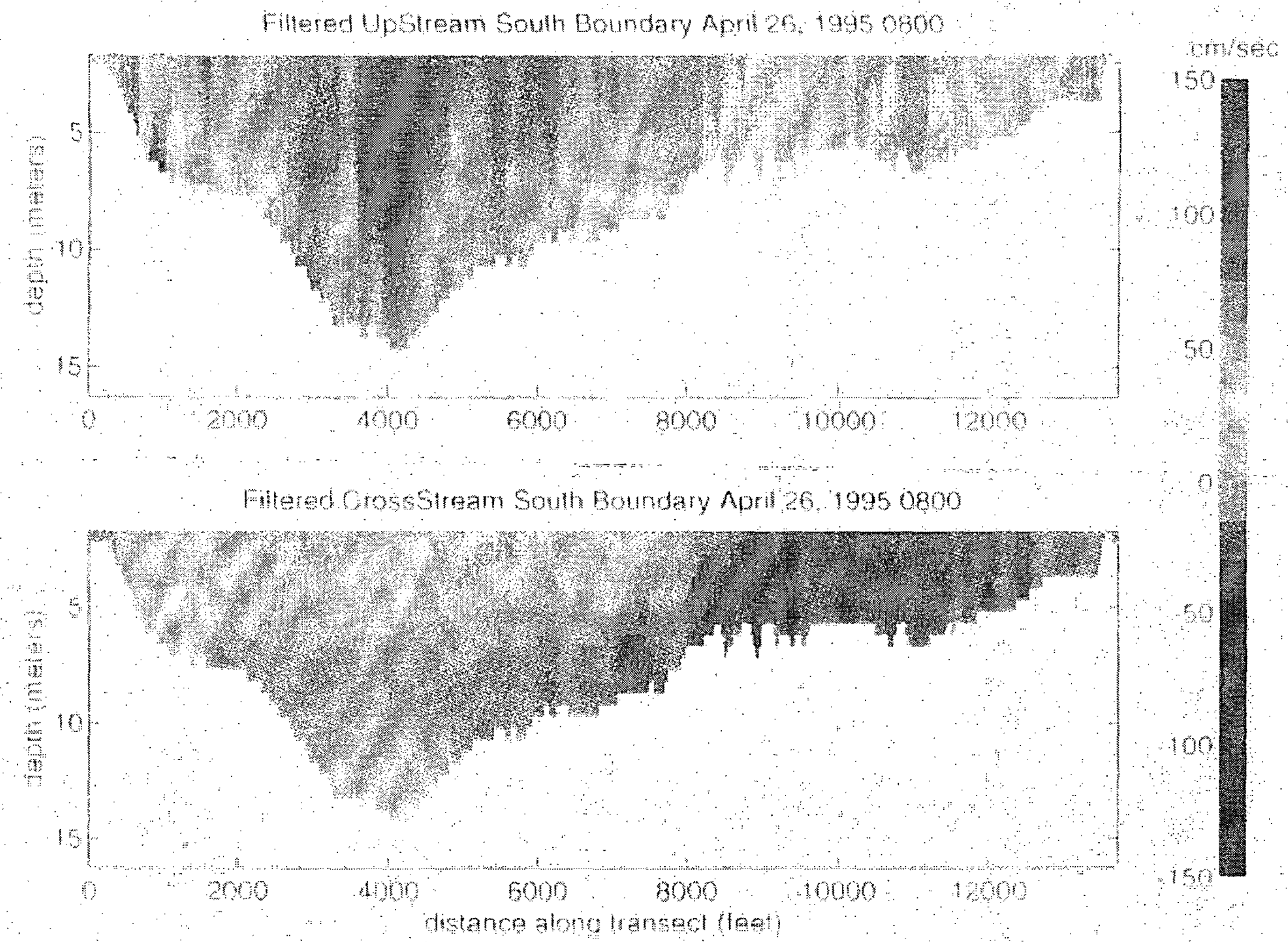
Intake basin velocity vectors April 25, 1340



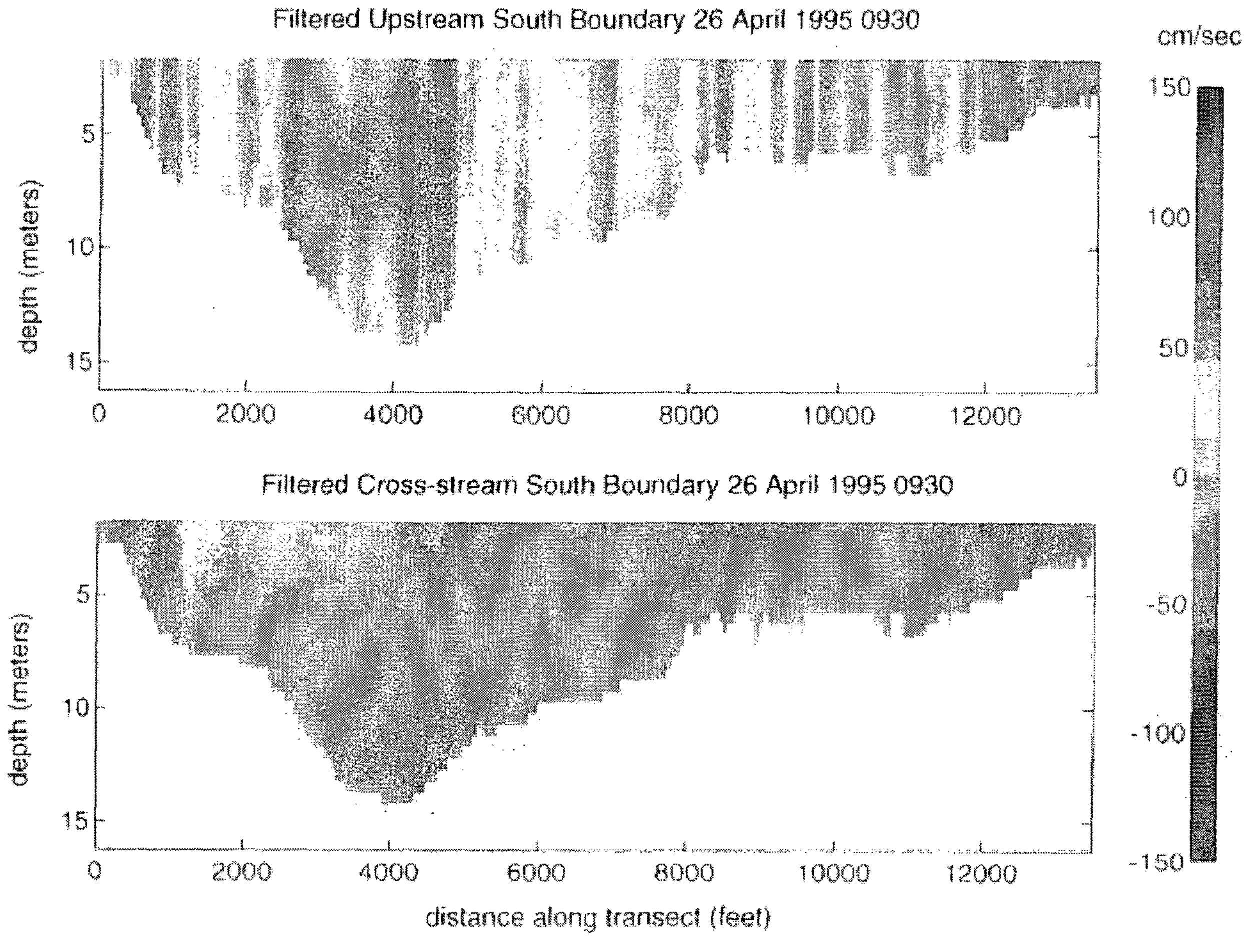
E-1-1 Figure II-14. Current vectors along a survey transect parallel to the Salem cooling water intake structure seawall as measured by the ADCP at 1340 (EDT) on 25 April 1995. Each arrow represents the speed and directon of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



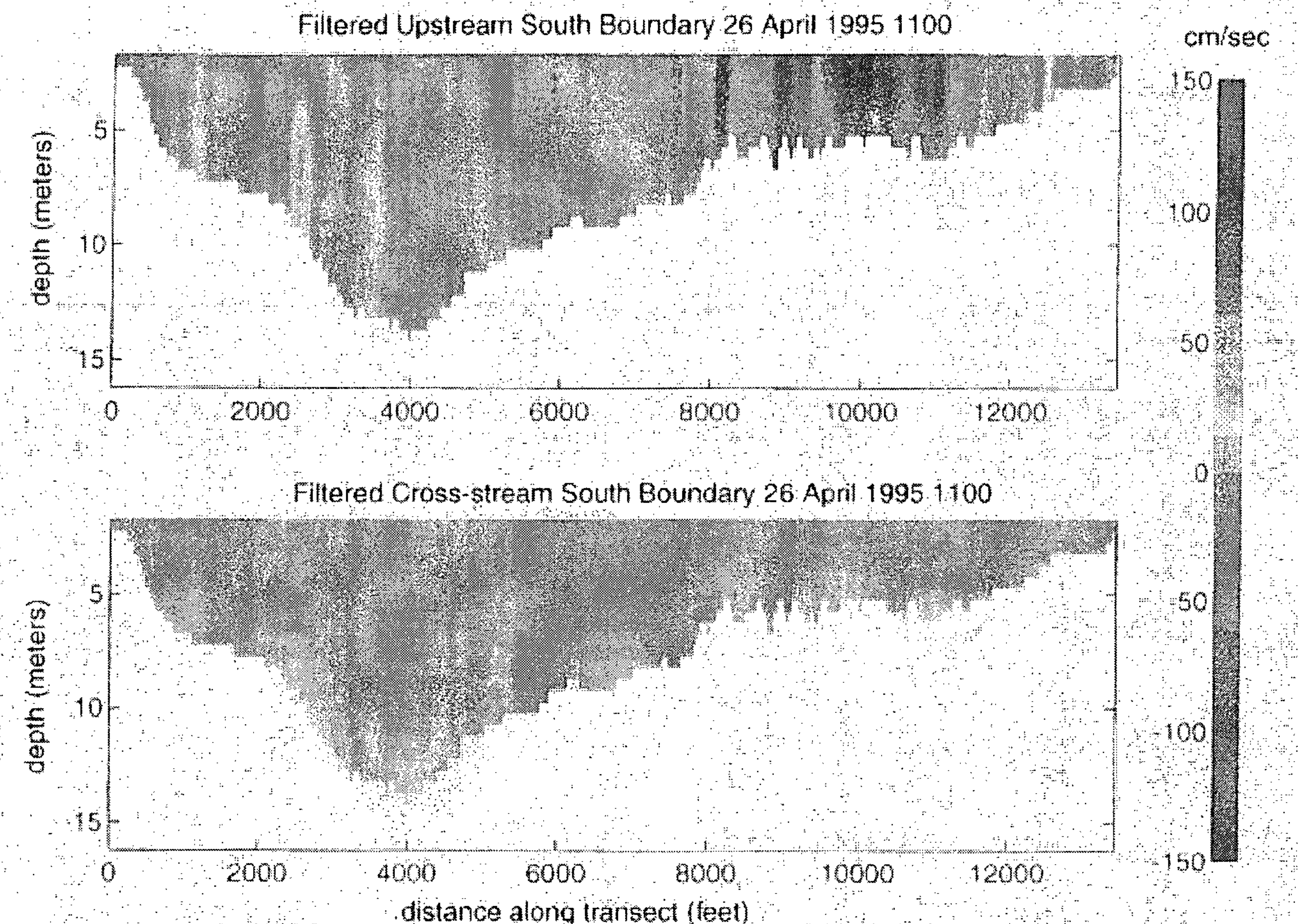
E-1-1 Figure II-15. Current vectors along a survey transect parallel to the Salem cooling water intake structure seawall as measured by the ADCP at 1640 (EDT) on 25 April 1995. Each arrow represents the speed and directon of the current. Black arrows represent surface currents, red arrows represent currents at mid-depth, and yellow arrows represent currents near the bottom. The approximate location of the Salem cooling and service discharge is depicted as the yellow circle within the grid. The shoreline is depicted by the black line to the right of the vectors.



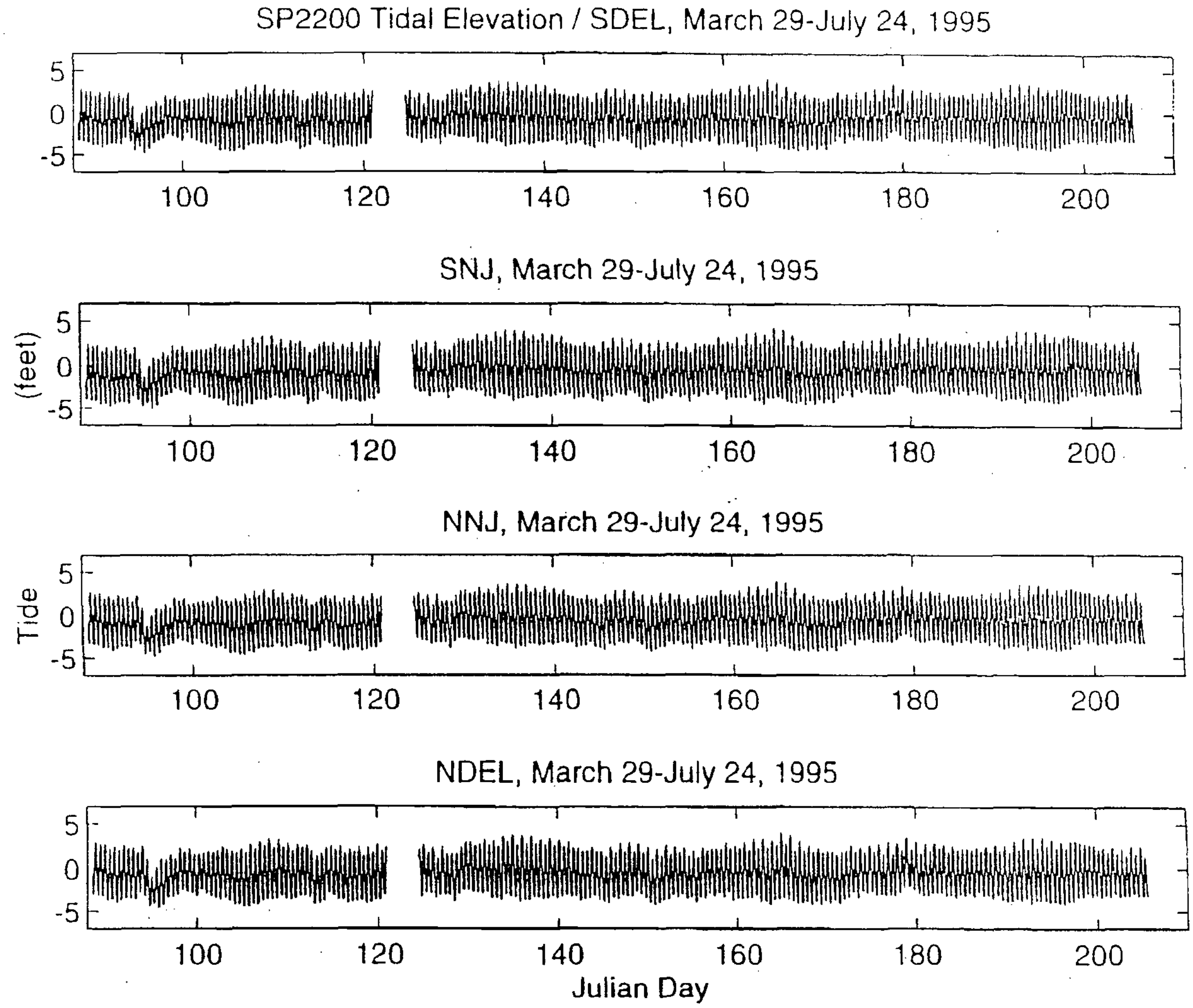
E-1-1 Figure II-16. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 0800 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay; negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



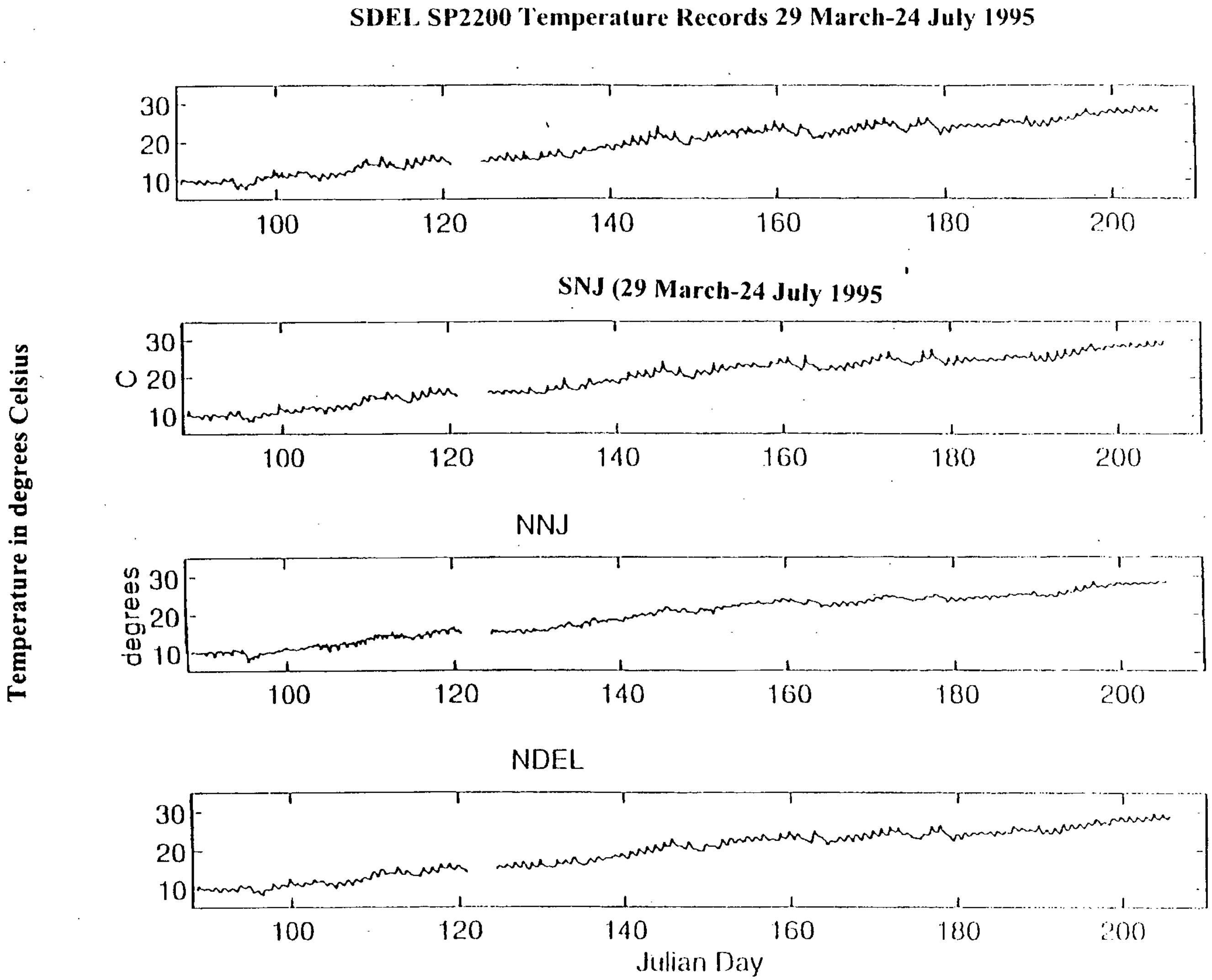
E-1-1 Figure II-17. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 0930 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



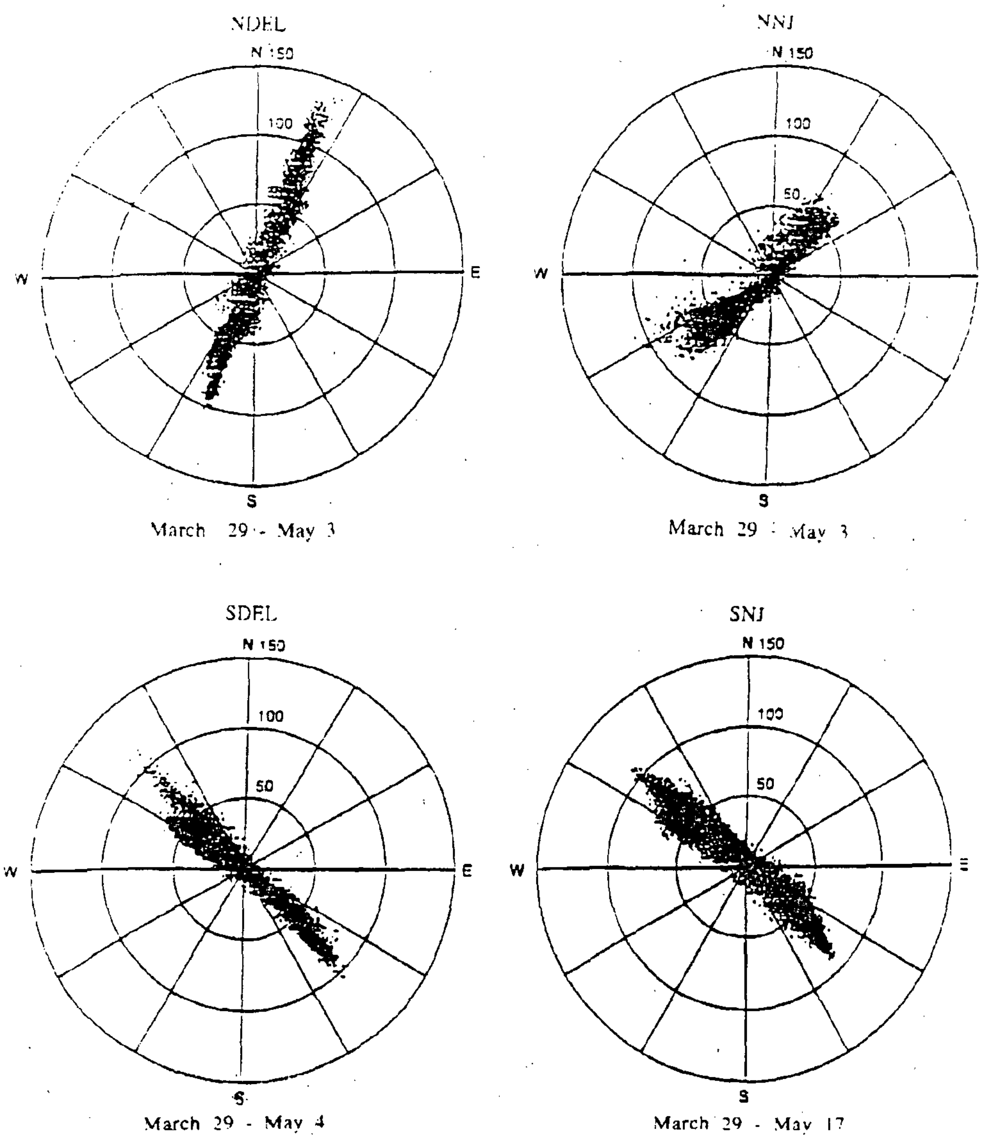
E-1-1 Figure II-18. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1100 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



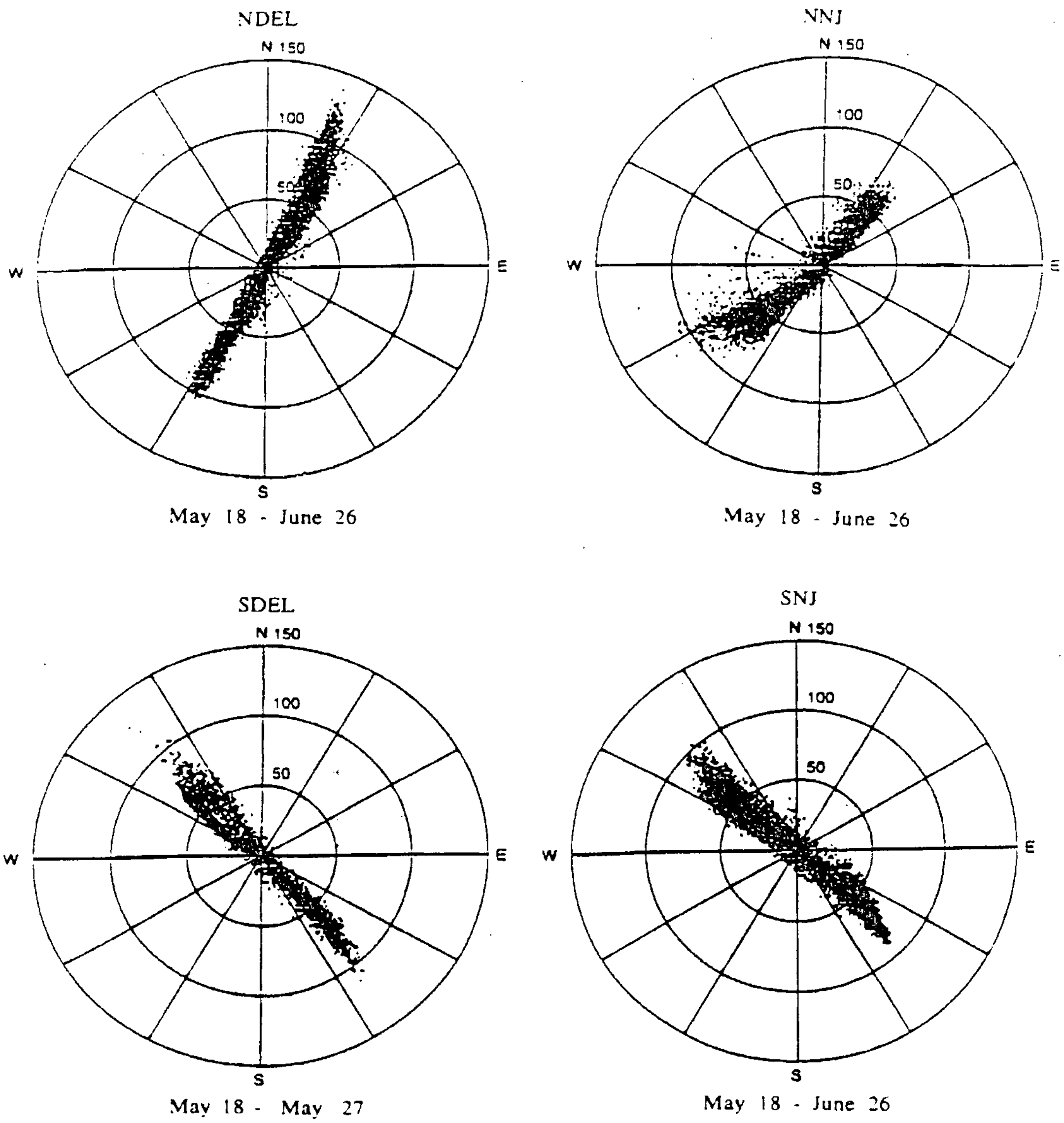
E-1-1 Figure III-2. Time-series of tidal elevations at four locations in the Delaware Estuary system from 29 March 1995 (Julian day 88) to 24 July 1995 (Julian day 205). Elevations are referenced to NAD 88 (North American Datum 1988). The gap in data represents the instrument turnaround operation performed 3–4 May 1995.



E-1-1 Figure III-3. Time series of water temperature at four locations in the Delaware Estuary system 29 March 1995 (Julian Day 88) to 24 July 1995 (Julian Day 205).

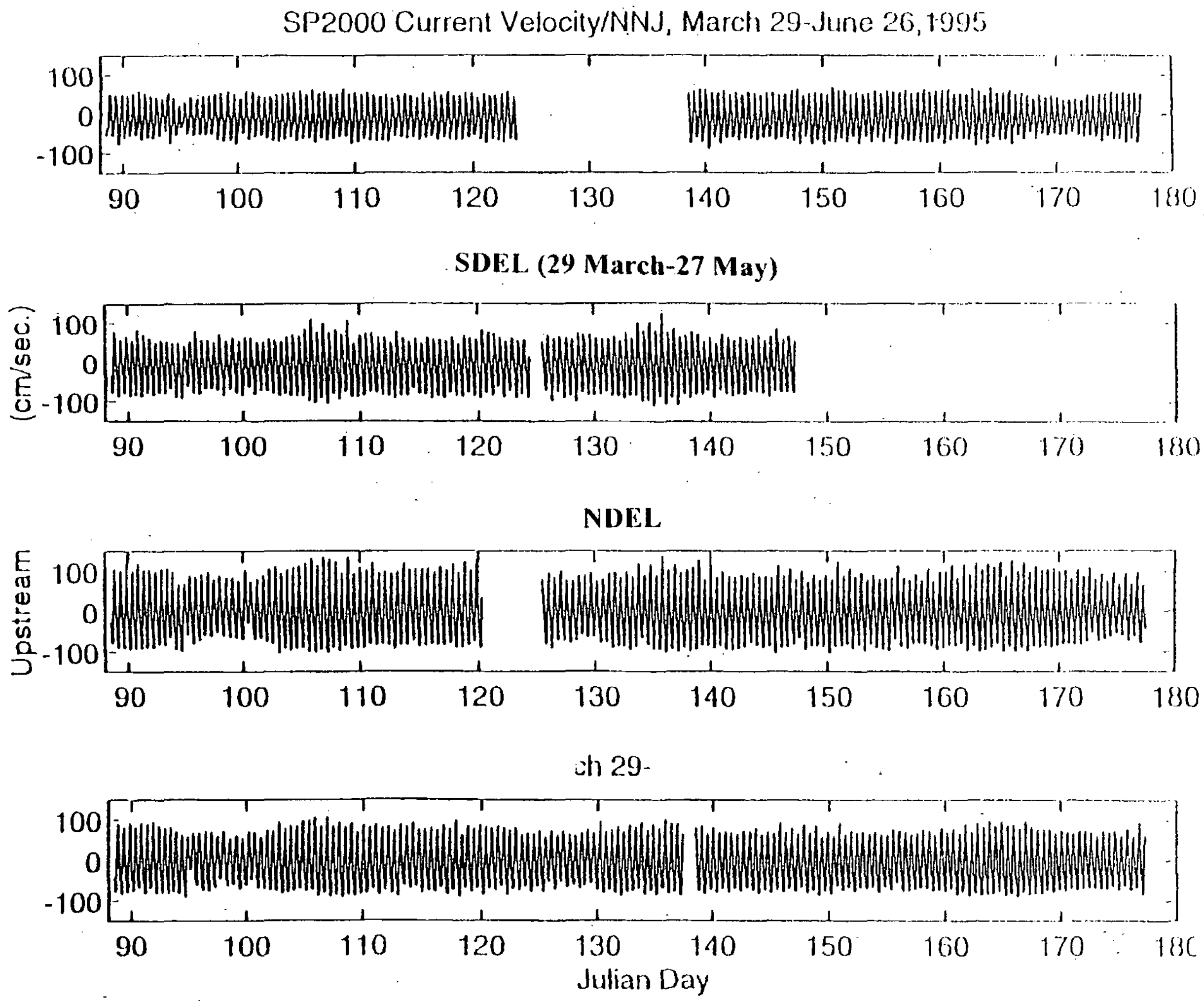


E-1-1 Figure III-6. Polar plots of currents at four locations in the Delaware Estuary system from 29 March to 17 May 1995. The spokes of the plot indicate direction of the current; the concentric circles represent speed of the current. Units of speed are cm/sec. The currents were measured two meters off the river bottom using the SP2000 current meter.

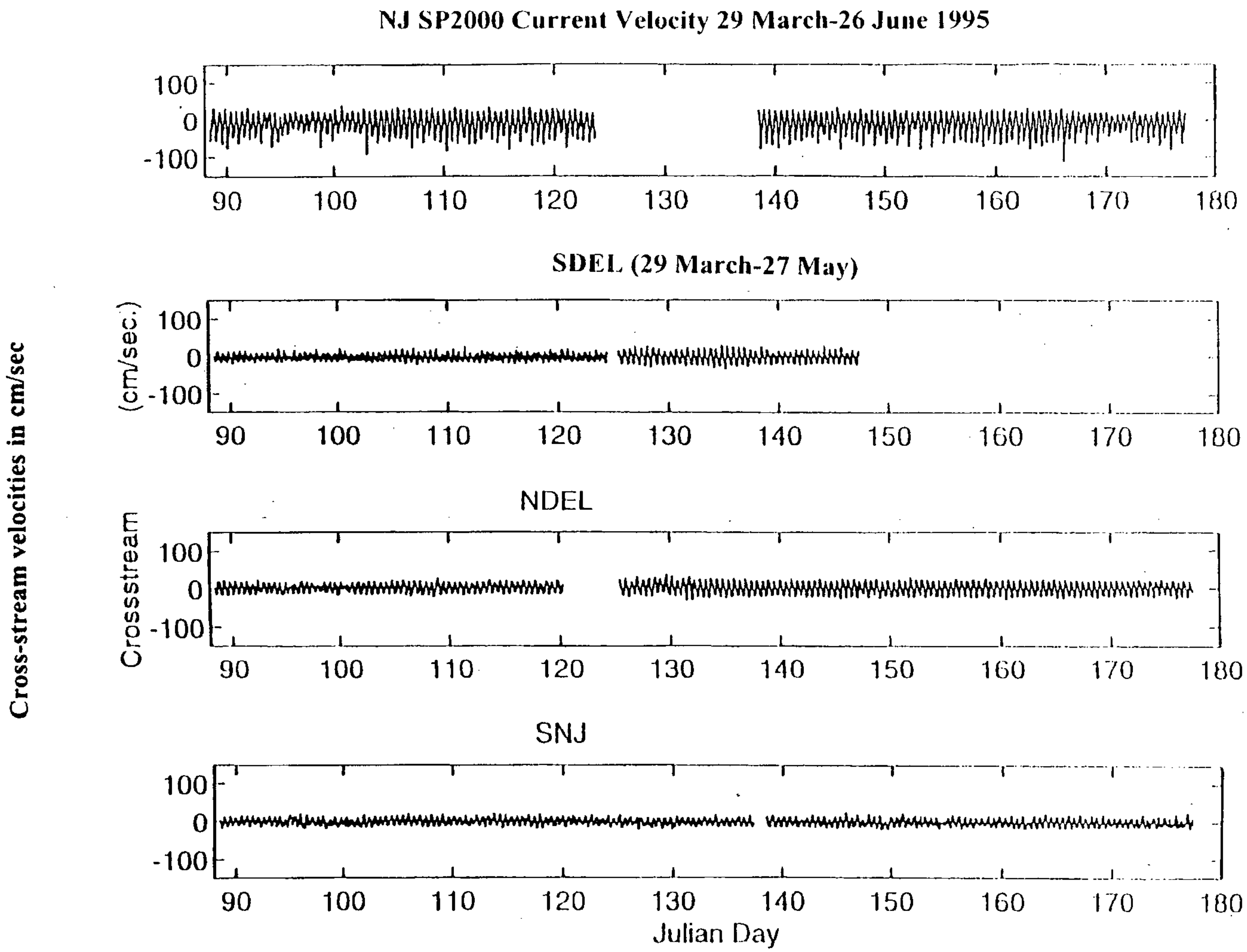


E-1-1 Figure III-7. Polar plots of currents at four locations in the Delaware Estuary System from 18 May to 26 June 1995. The spokes of the plot indicate direction of the current; the concentric circles represent speed of the current. Units of speed are cm/sec. The currents were measured two meters off the river bottom using SP2000 current meters.

NNJ SP2000 Current Velocity 29 March-26 June 1995



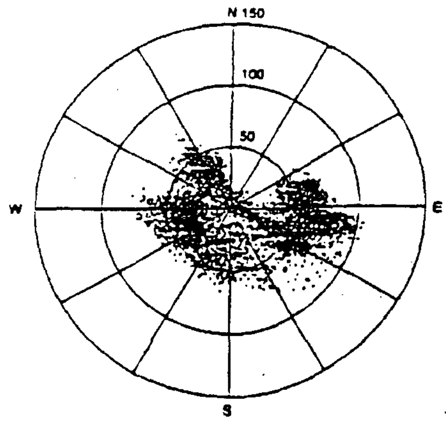
E-1-1 Figure III-8. Time series of the upstream component of current velocity at four locations in the Delaware Estuary system from 29 March 1995 (Julian Day 88) to 26 June 1995 (Julian Day 177). Positive upstream currents flow approximately in the northerly direction. Units of velocity are cm/sec.



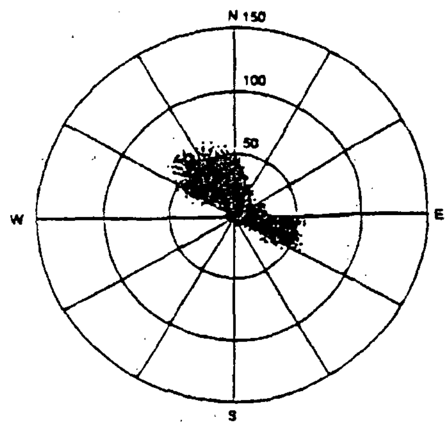
E-1-1 Figure III-9. Time series of the cross-stream component of current velocity at four locations in the Delaware Estuary system from 29 March 1995 (Julian Day 88) to 26 June 1995 (Julian Day 177). Positive cross-stream currents flow approximately in the easterly direction (from Delaware to New Jersey). Units of velocity are cm/sec.

REAL-TIME SYSTEM CURRENT MEASUREMENTS
(15 May - 5 July 1995)

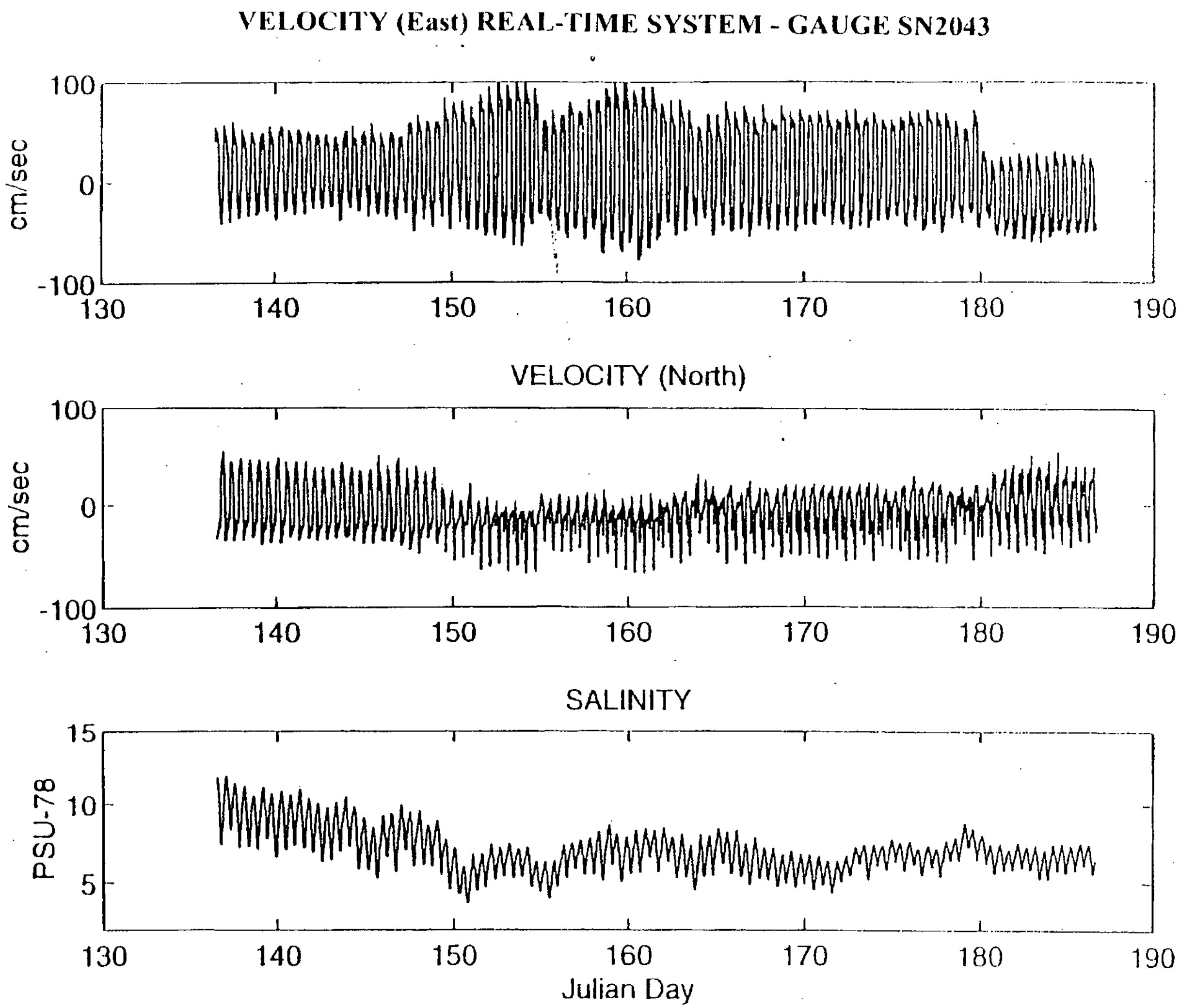
SN2043 (Top) GAUGE



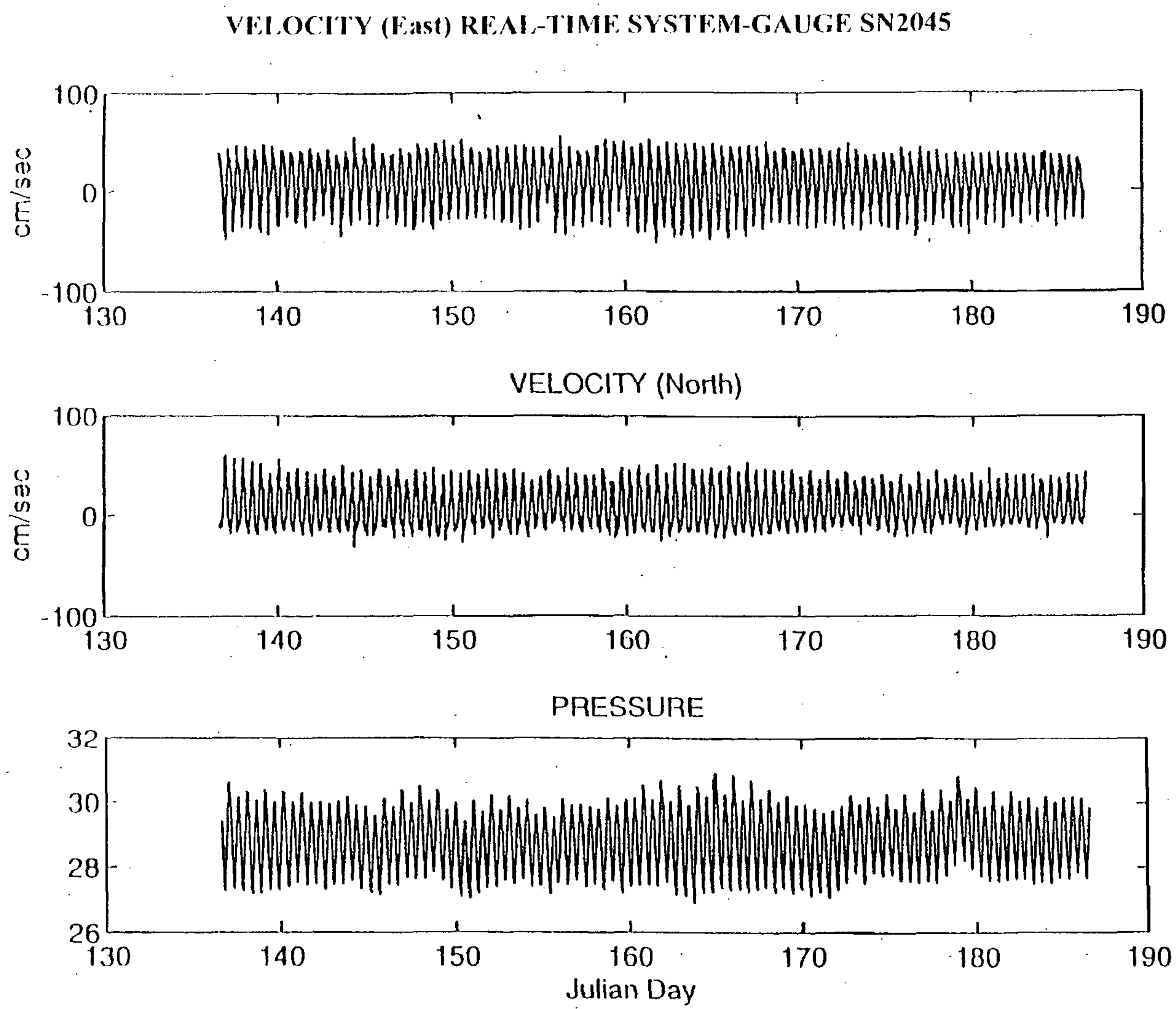
SN2045 (Bottom) GAUGE



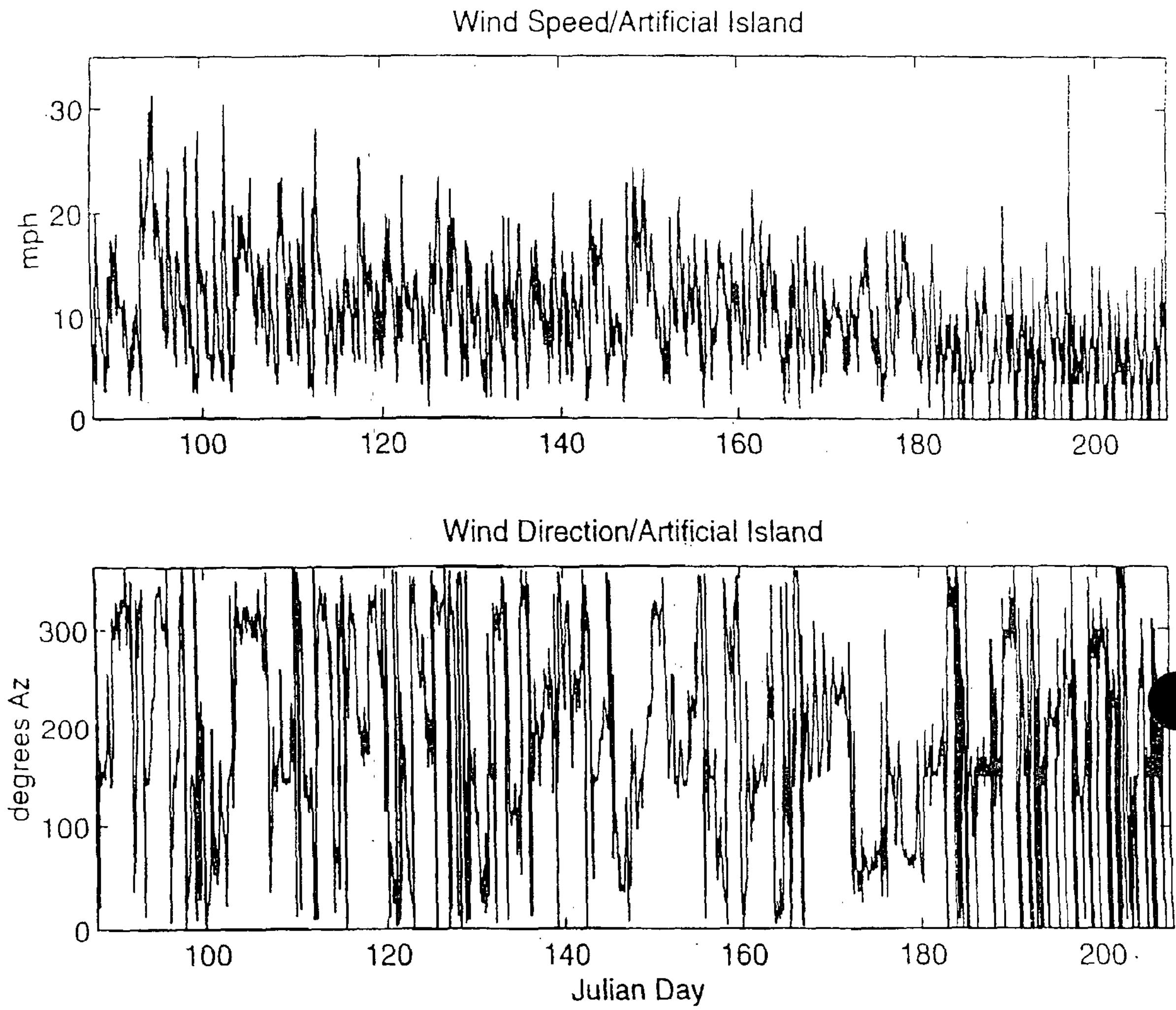
E-1-1 Figure III-11. Polar plots of currents as measured by the Real-time System current meters. The spokes of the plot indicate direction of the current; the concentric circles represent speed of the current. Units of speed are cm/sec. SN2043 (top) gauge currents were measured approximately 26 feet off the bottom; SN2045 (bottom) currents were measured approximately 6 feet off the river bottom.



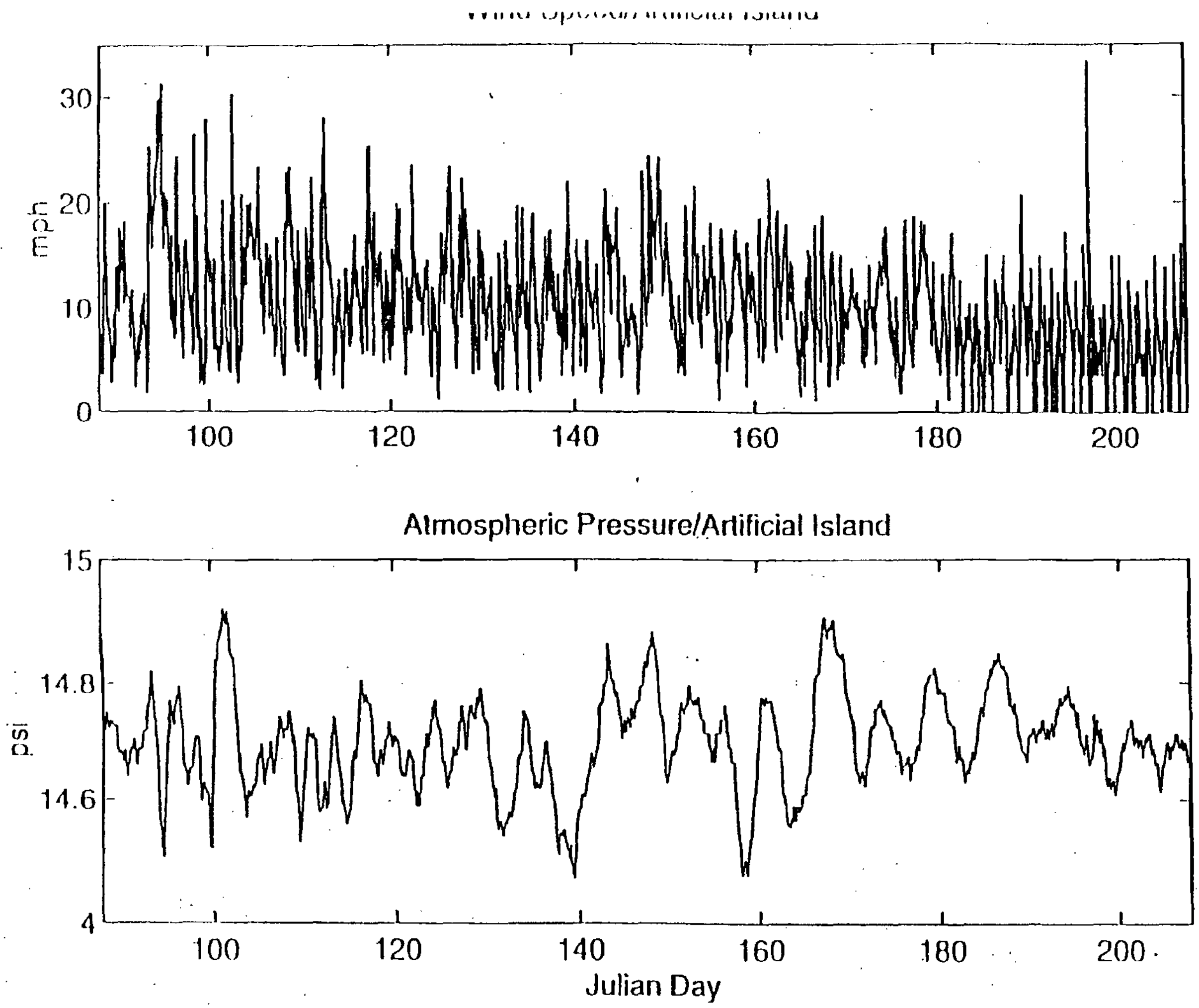
E-1-1 Figure III-12. Time series of east and north components of velocity and salinity as measured by SN2043 (top) gauge of the Real-Time System. Measurements were made from 16 May to 5 July 1995.



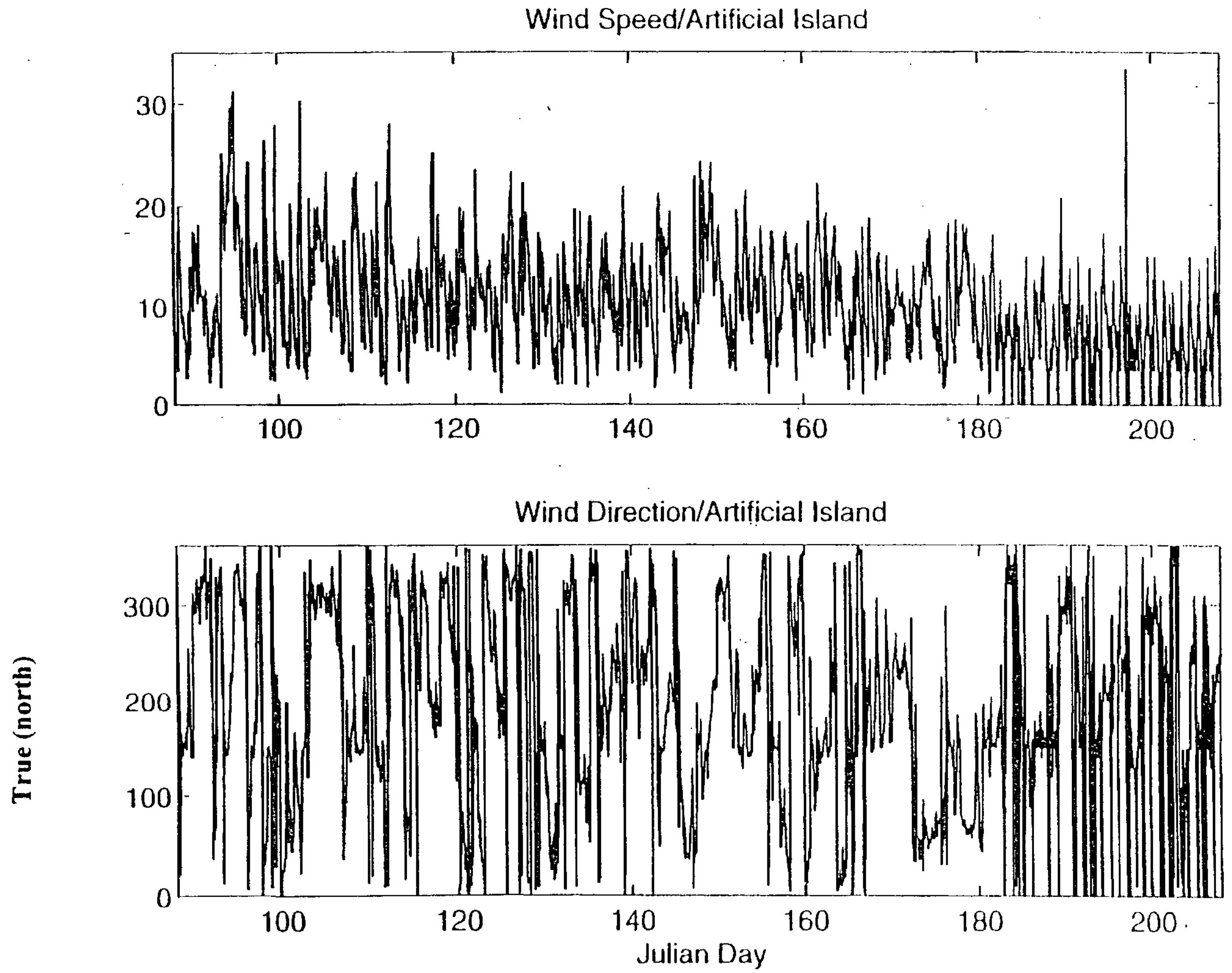
E-1-1 Figure III-13. Time series of east and north components of velocity and hydrostatic pressure as measured by SN2045 (bottom) gauge of the Real-Time System. Measurements were made from 16 May to 5 July 1995. Pressure (tide) is in pounds per square inch (psi).



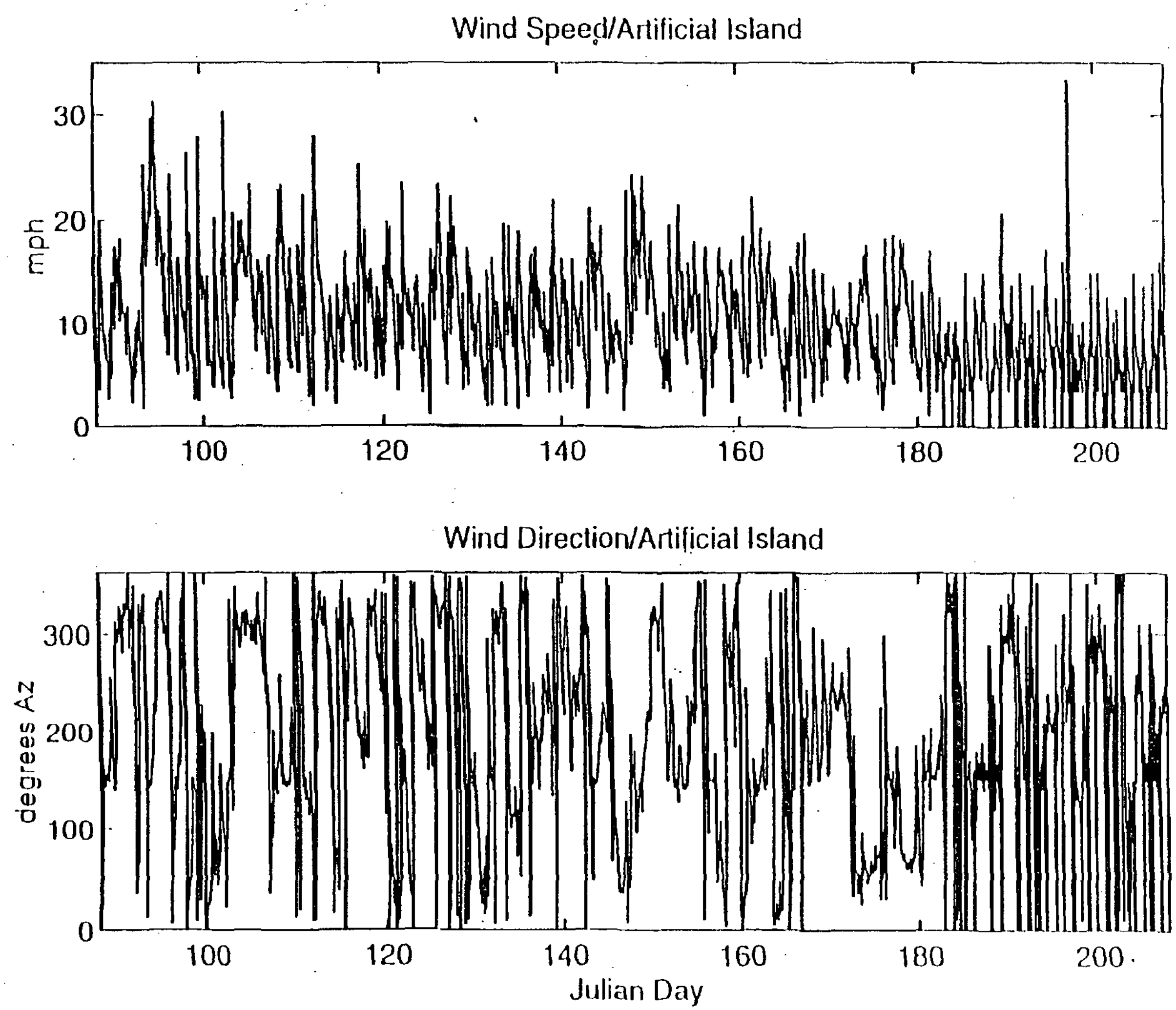
E-1-1 Figure III-14. Wind speed and direction at Artificial Island 29 March 1995 to 24 July 1995.



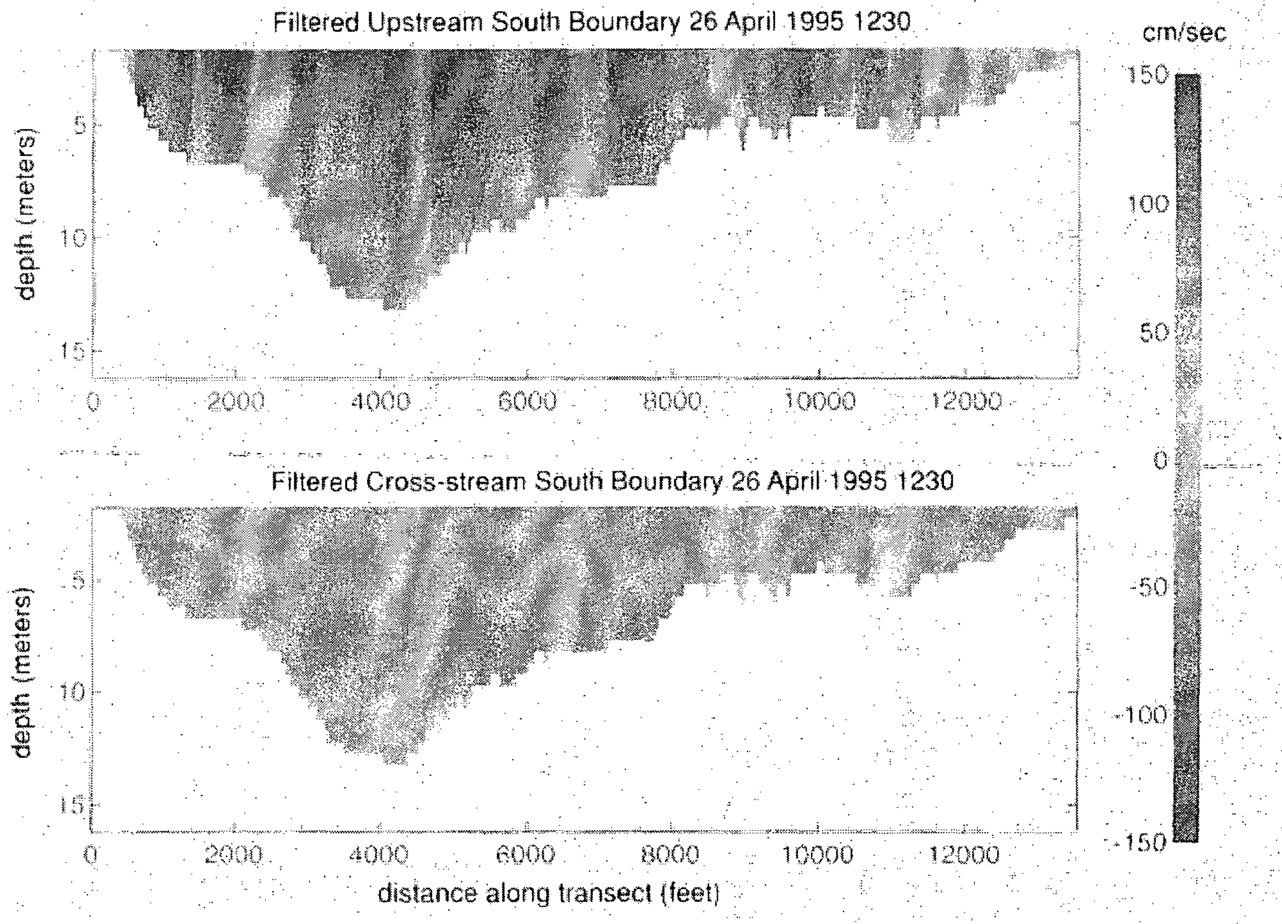
E-1-1 Figure III-15. Wind speed and atmospheric pressure at Artificial Island 29 March 1995 to 24 July 1995. Wind speed is in miles per hour and atmospheric pressure is in pounds per square inch.



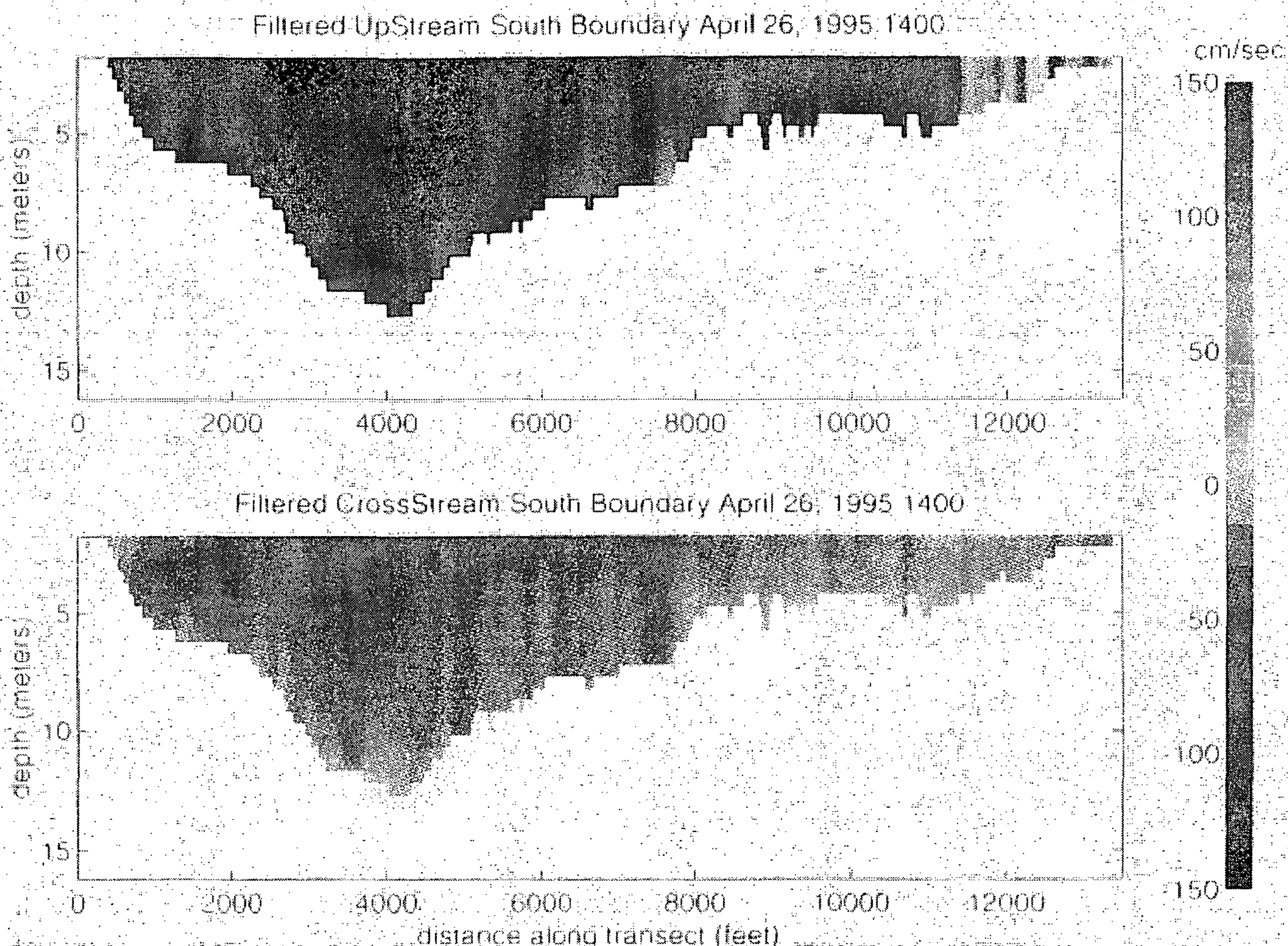
E-1-1 Figure IV-1. Wind speed and direction at Artificial Island 29 March 1995 to 24 July 1995.



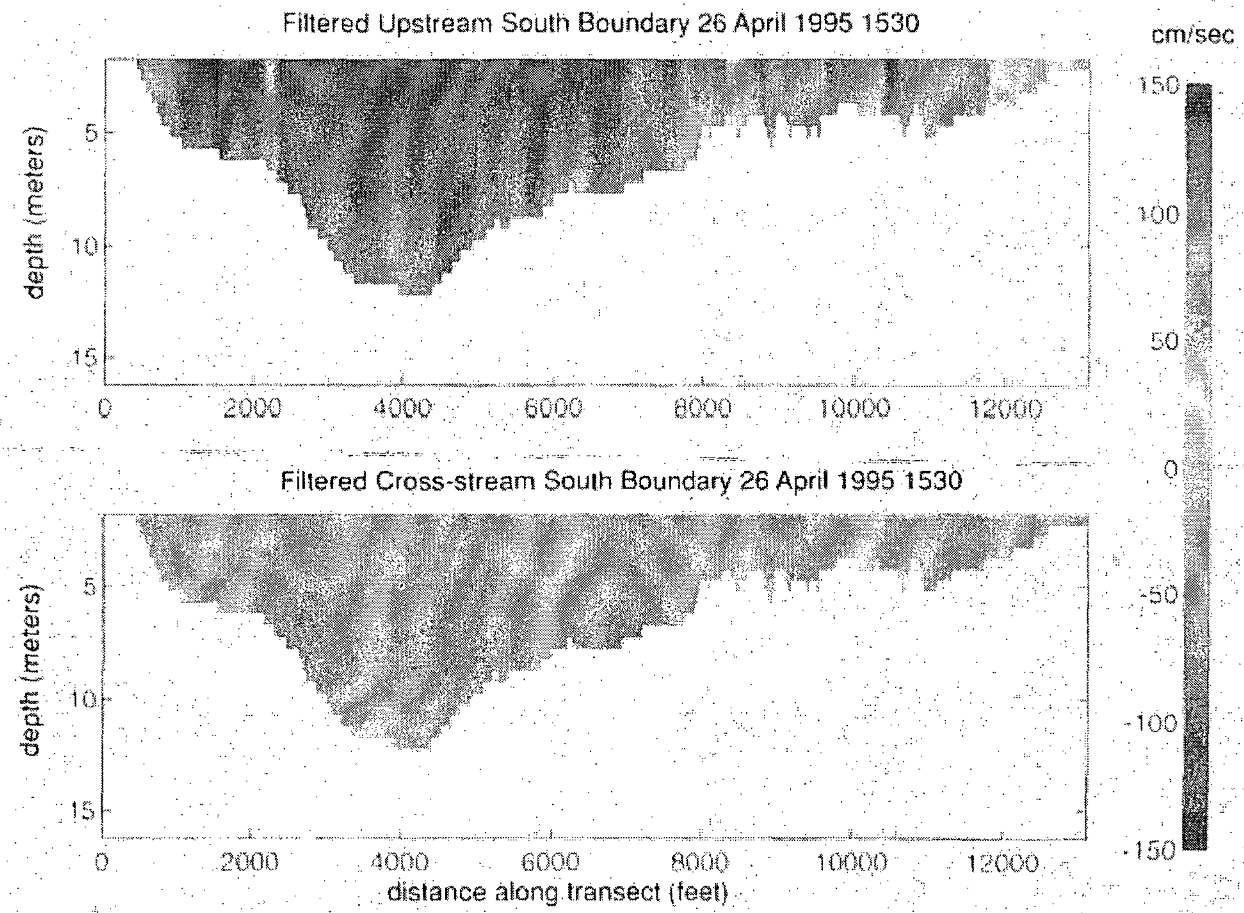
E-1-1 Figure IV-2. Wind speed and atmospheric pressure at Artificial Island 29 March 1995 to 24 July 1995. Wind speed is in miles per hour and atmospheric pressure is in pounds per square inch.



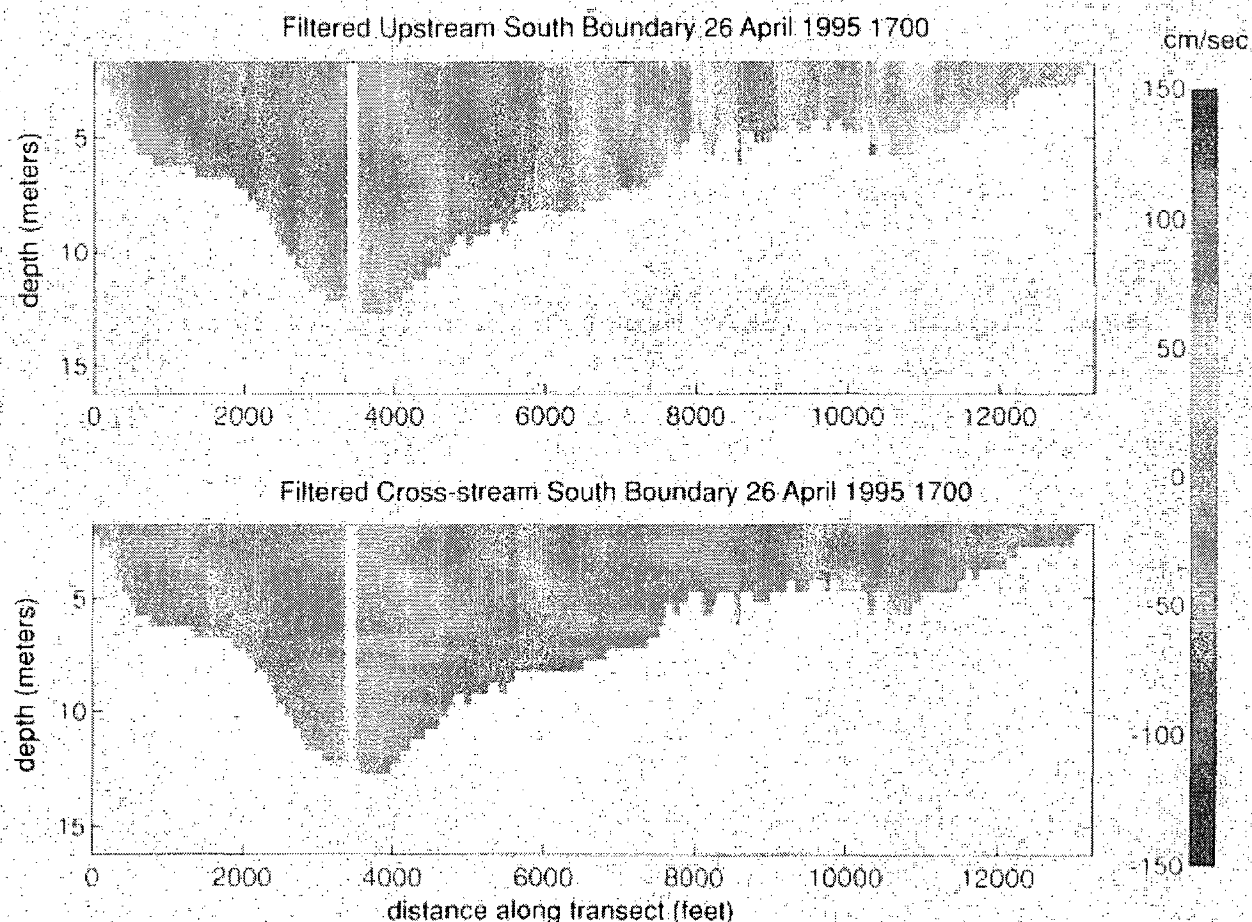
E-1-1 Figure II-19. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1230 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



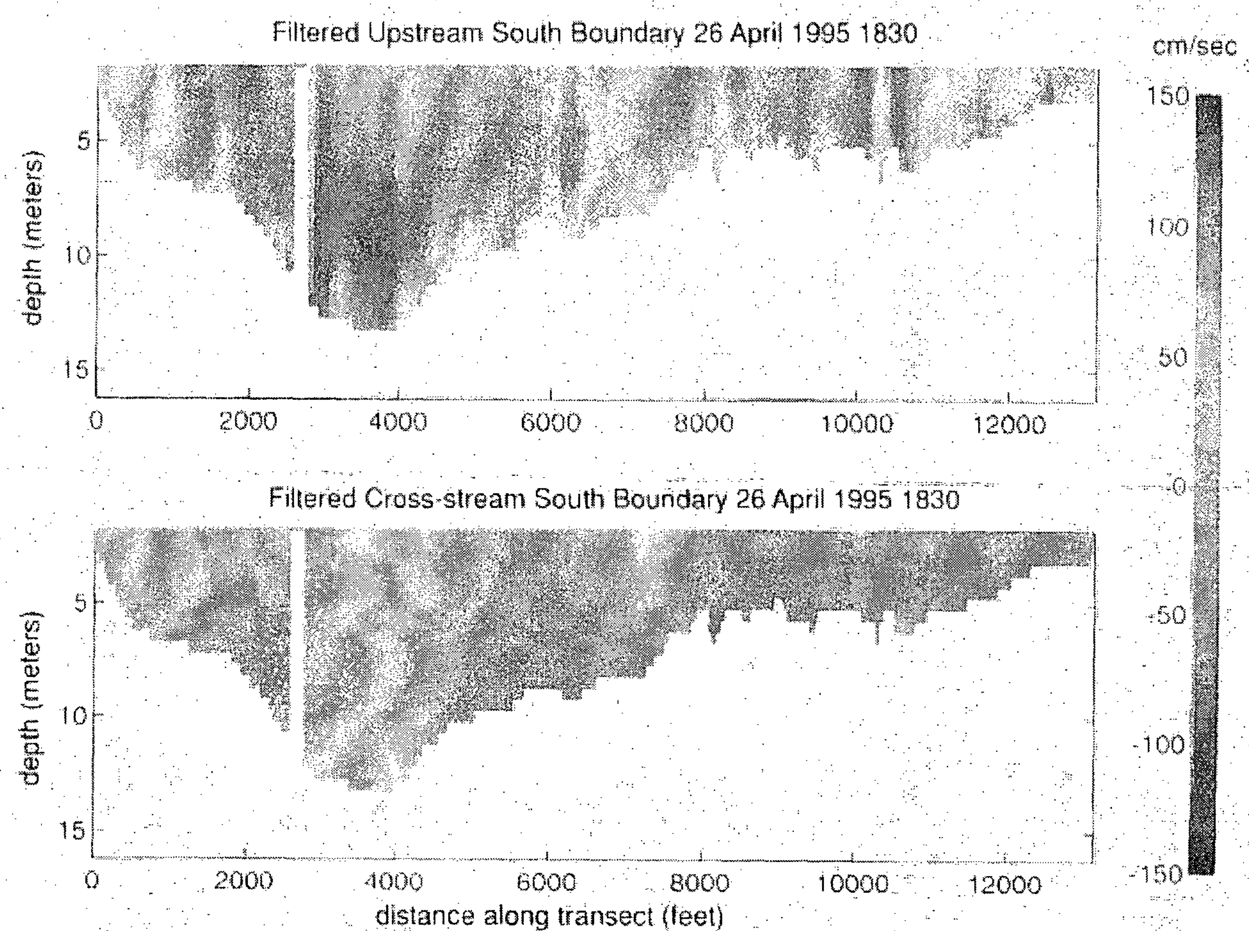
E-1-1 Figure II-20. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1400 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay; negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



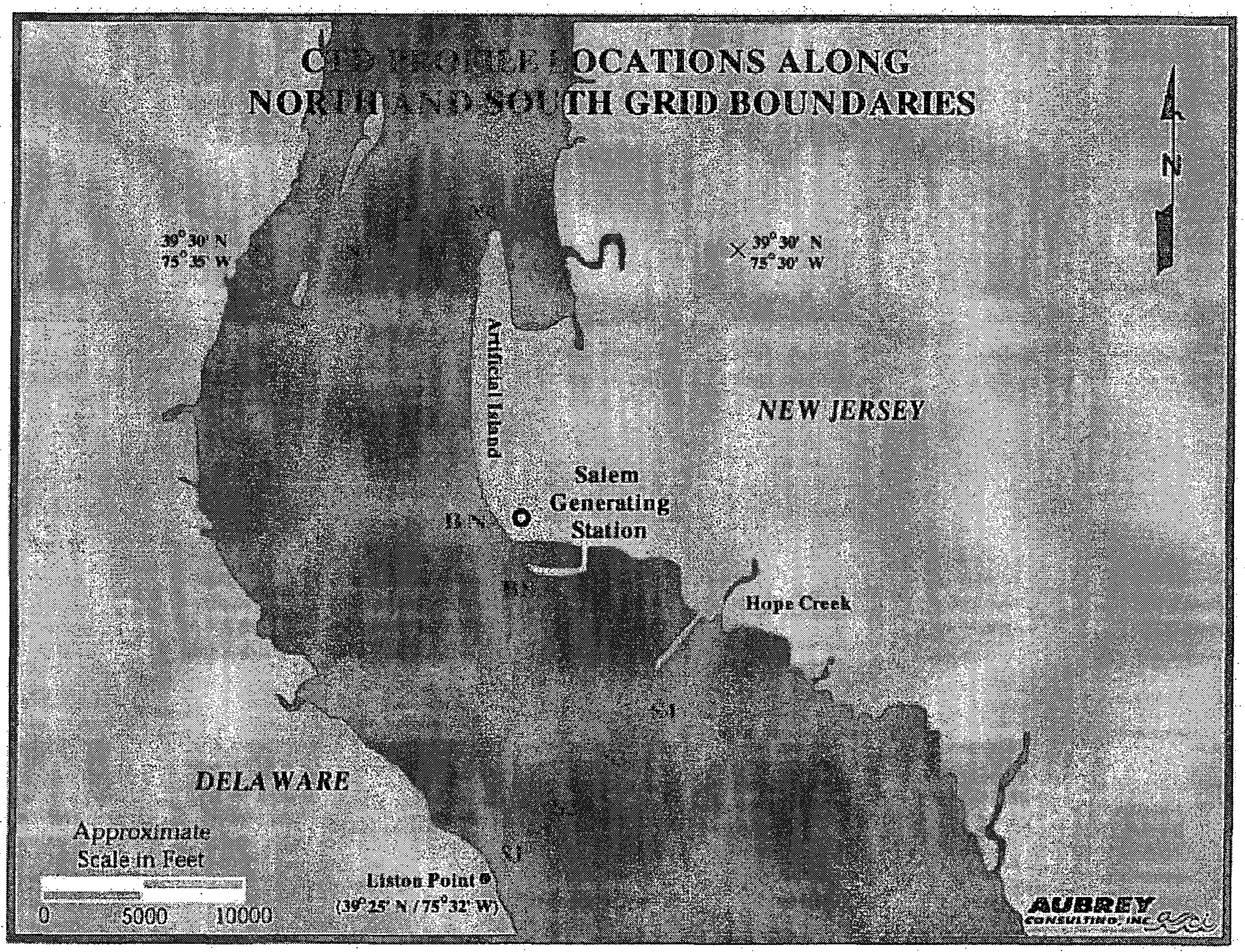
E-1-1 Figure II-21. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1530 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



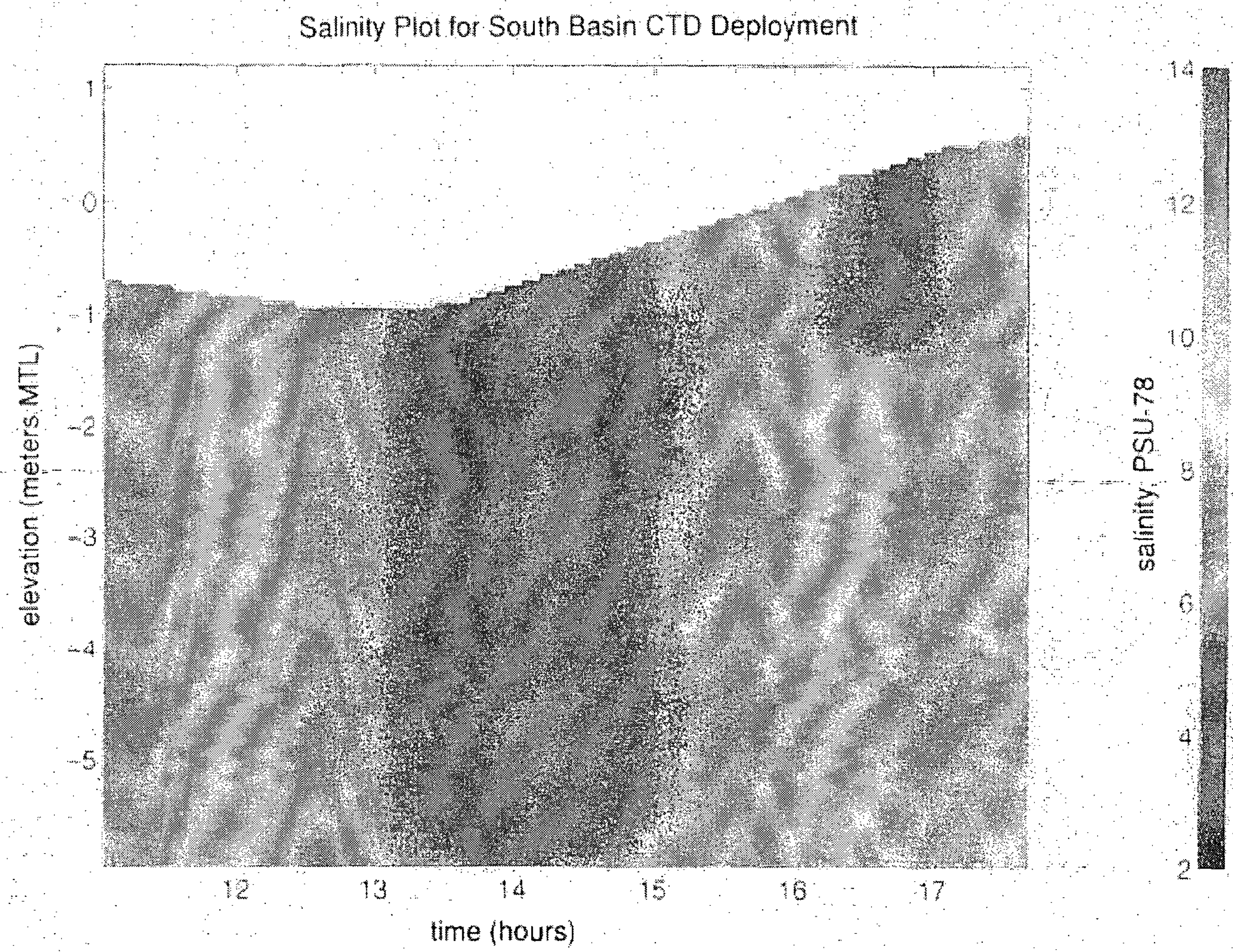
E-1-1 Figure II-22. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1700 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



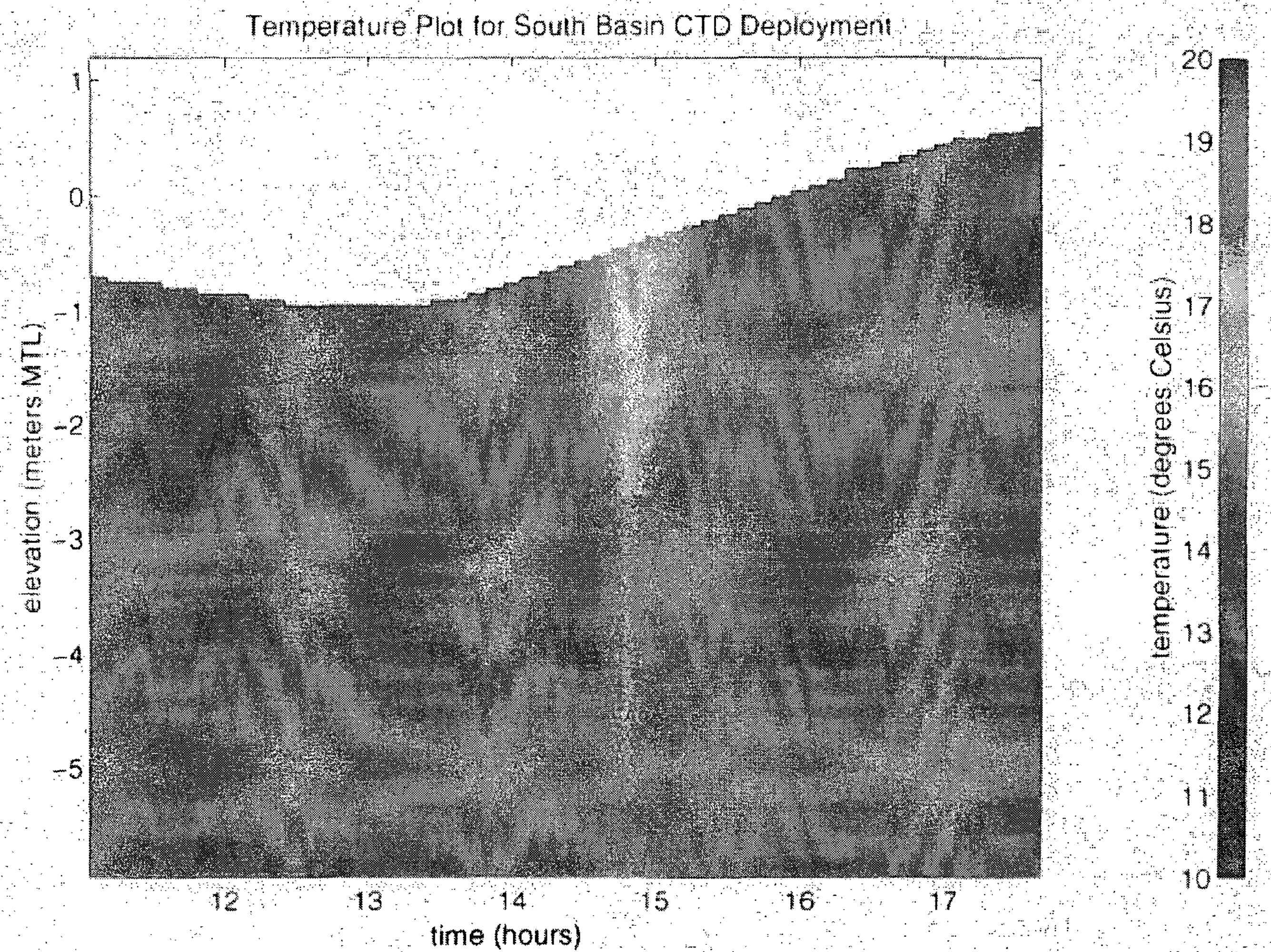
E-1-1 Figure II-23. Color plot of upstream (top) and cross-stream (bottom) velocity along a survey transect of the south near-field boundary as measured by the ADCP at 1830 (EDT) on 26 April 1995. The plot depicts currents through a cross-section of the river; the Delaware shore is to the left of the plot and New Jersey to the right. The color bar to the right indicates the magnitude of the current. Positive upstream (flood) currents flow away from the mouth of the Bay, negative (ebb) currents flow to the mouth of the Bay. Positive cross-stream currents flow toward the east (New Jersey). The bottom contour of the river cross-section is represented in white. The vertical axis represents depth from the surface of the water; the horizontal axis represents distance along the transect. The data have been filtered to remove excessive measurement noise.



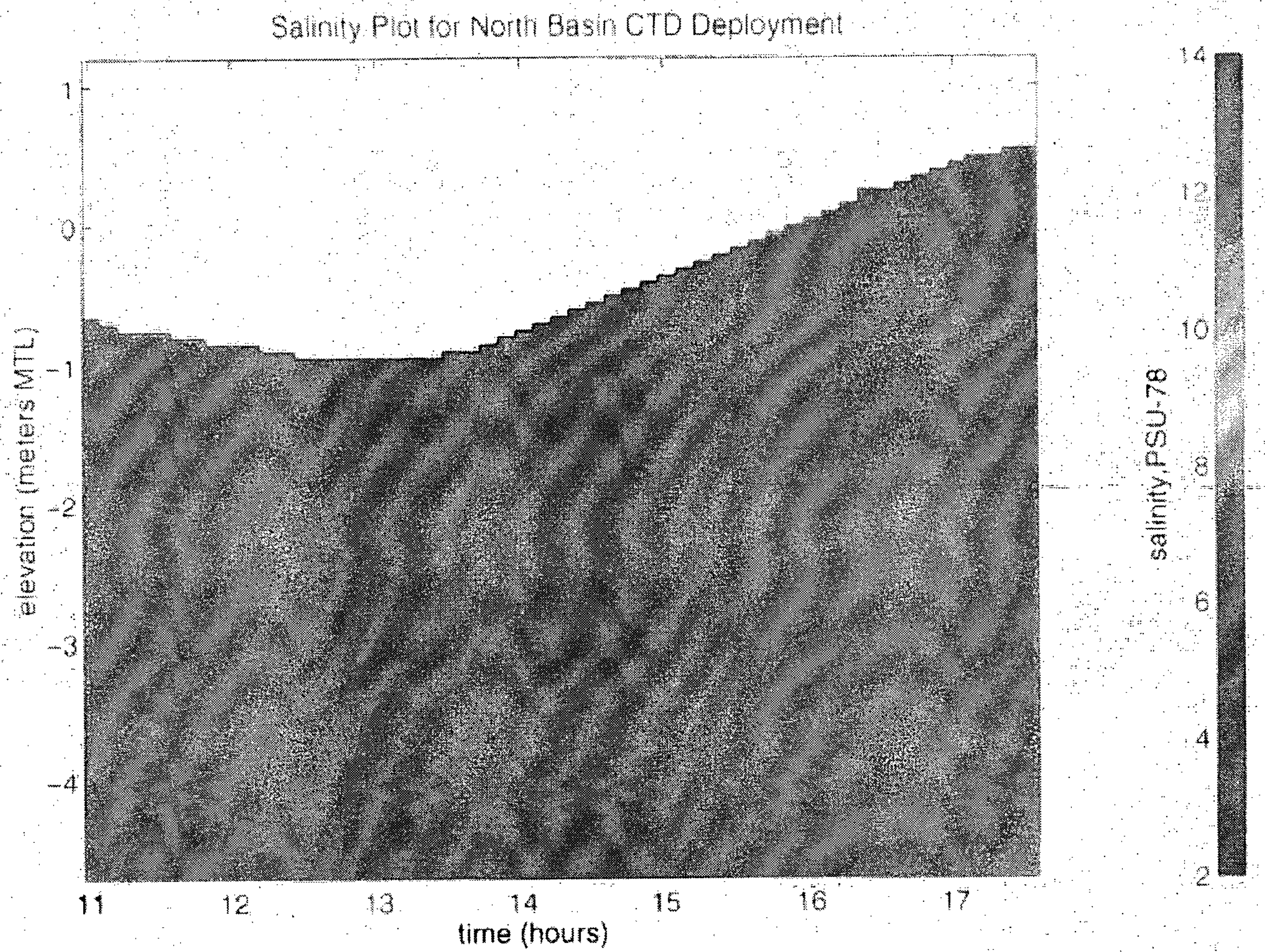
E-1-1 Figure II-24. Location map depicting the CTD observation sites in the Delaware Estuary. These sites were located on the north and south boundaries of the near-field study area as well as the BN and BS CTD sites within the intake basin. CTD profiles taken at these sites over tidal cycles were used to develop an understanding of the spatial and temporal variability of temperature and salinity in the Delaware River.



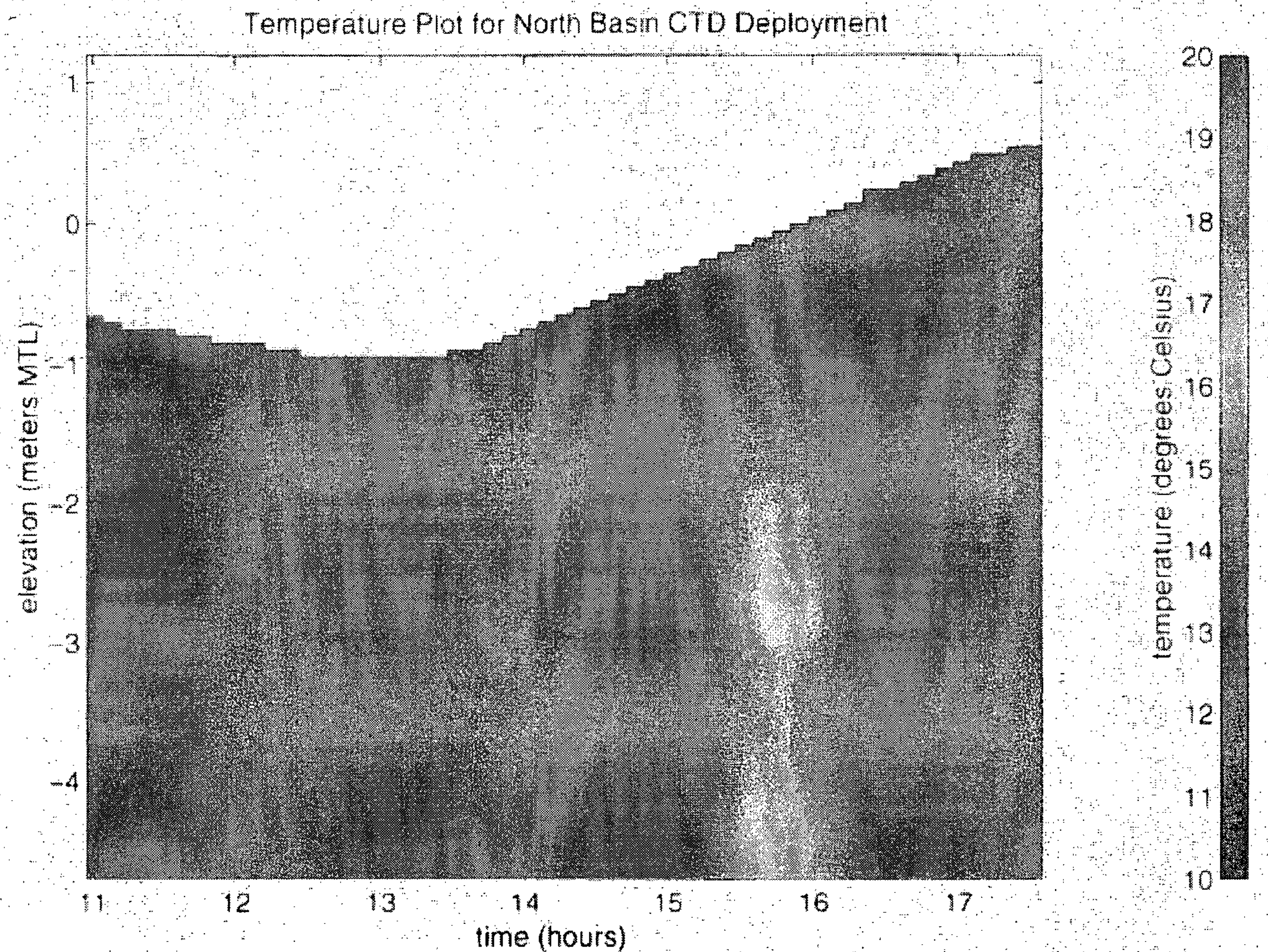
E-1-1 Figure II-25. Color time-series plot of salinity variations at the BS site for 24 April 1995. Color indicates the magnitude of salinity represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses. Salinity begins to approach a maximum at high tide (1800).



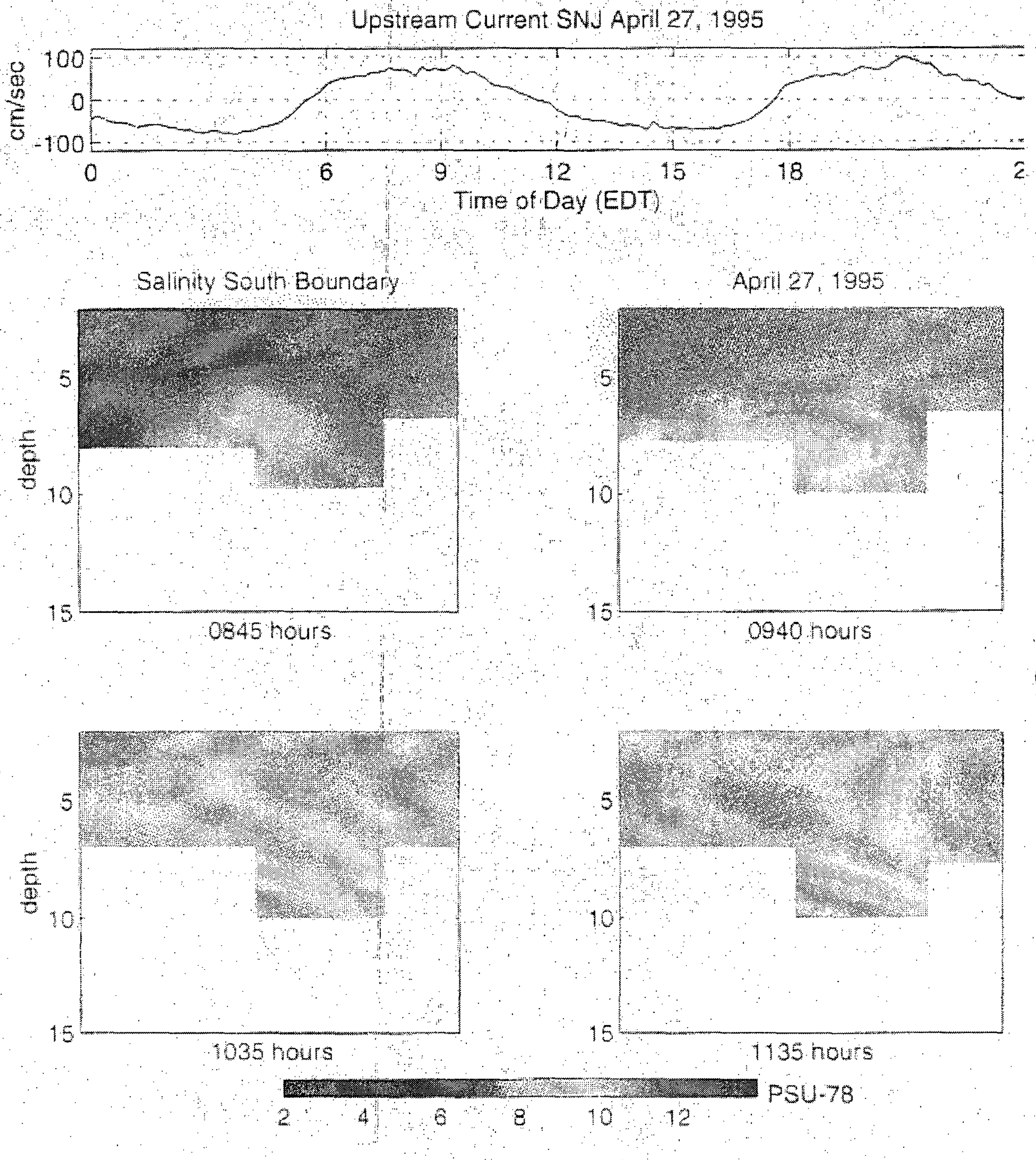
E-1-1 Figure II-26. Color time-series plot of temperature variations at the BS site for 24 April 1995. Color indicates the magnitude of temperature represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses.



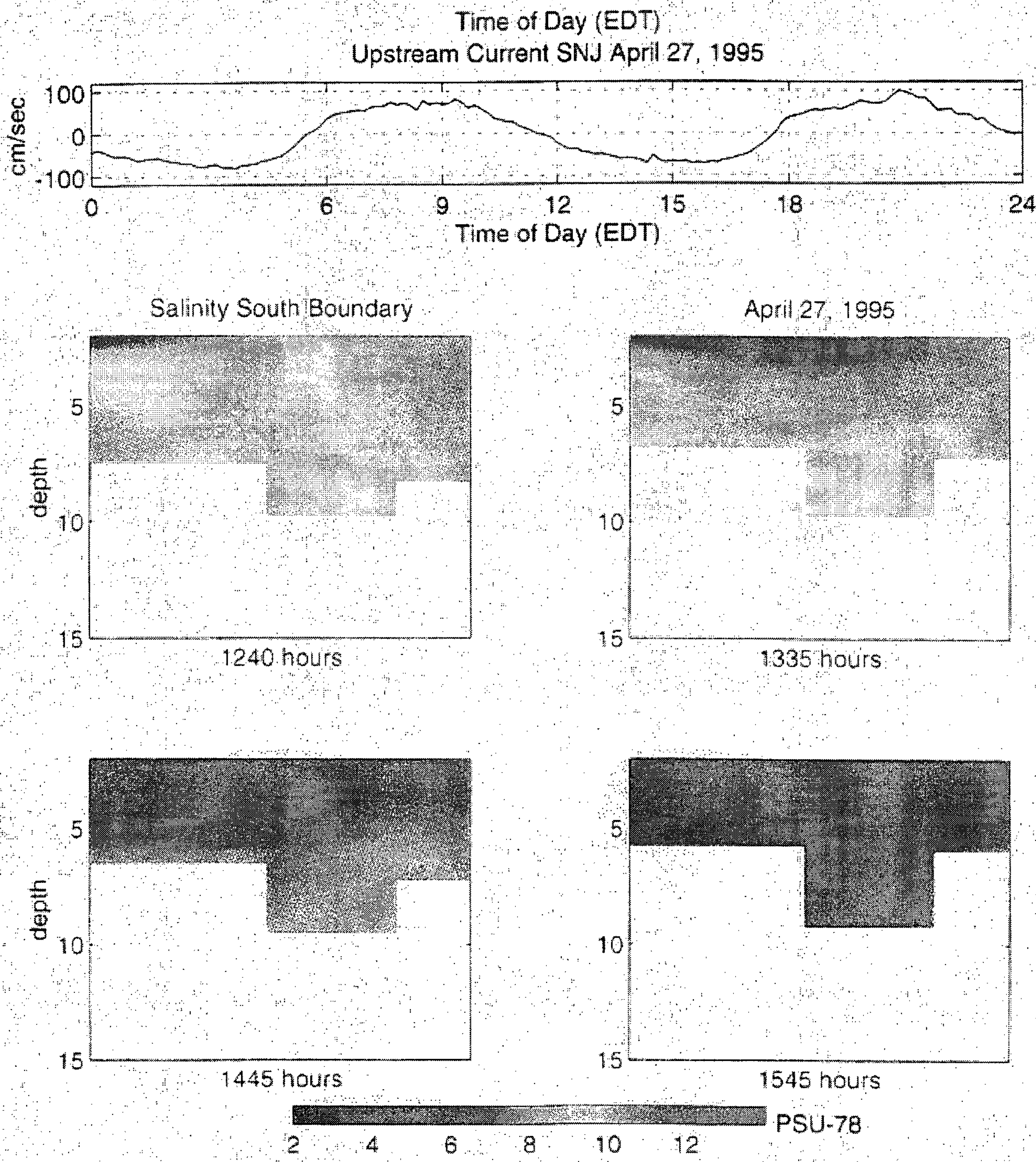
E-1-1 Figure II-27. Color time-series plot of salinity variations at the BN site for 24 April 1995. Color indicates the magnitude of salinity represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses. Salinity begins to aproach a maximum at high tide (1800).



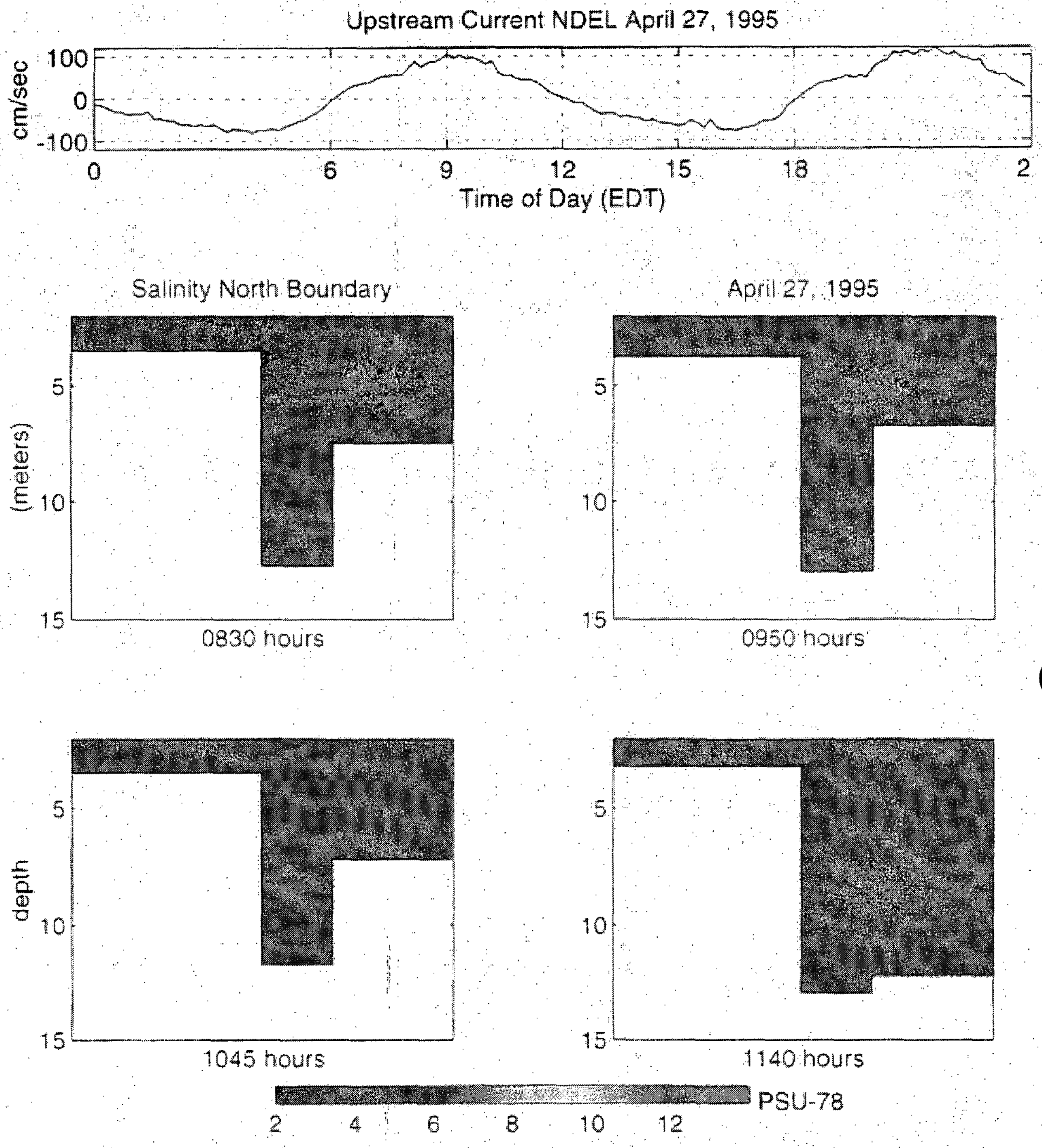
E-1-1 Figure II-28. Color time-series plot of temperature variations at the BN site for 24 April 1995. Color indicates the magnitude of temperature represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses.



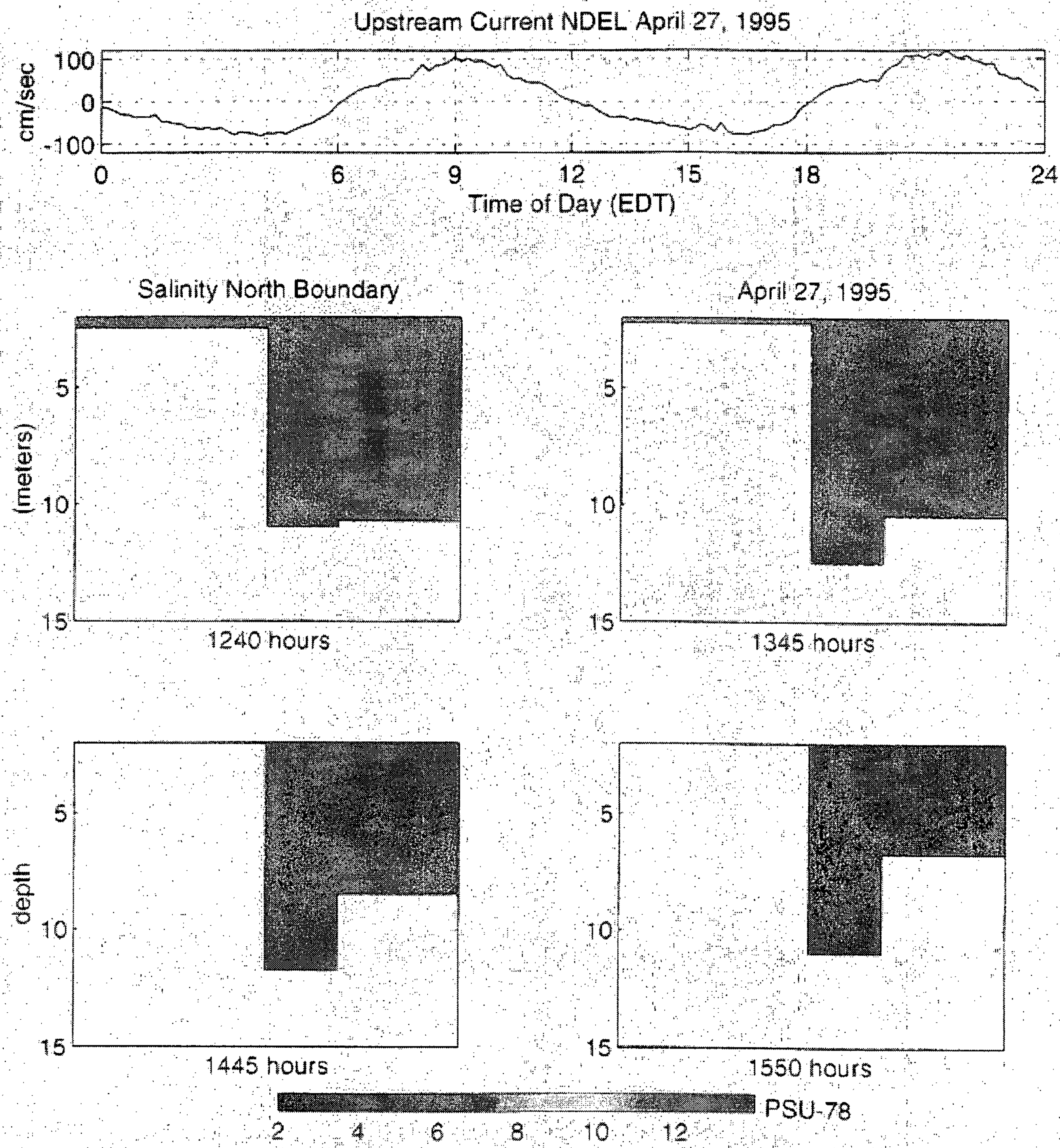
E-1-1 Figure II-29. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 0845 to 1135 on 27 April 1995. Each plot represents measurements at S1, S2, S3, and S4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



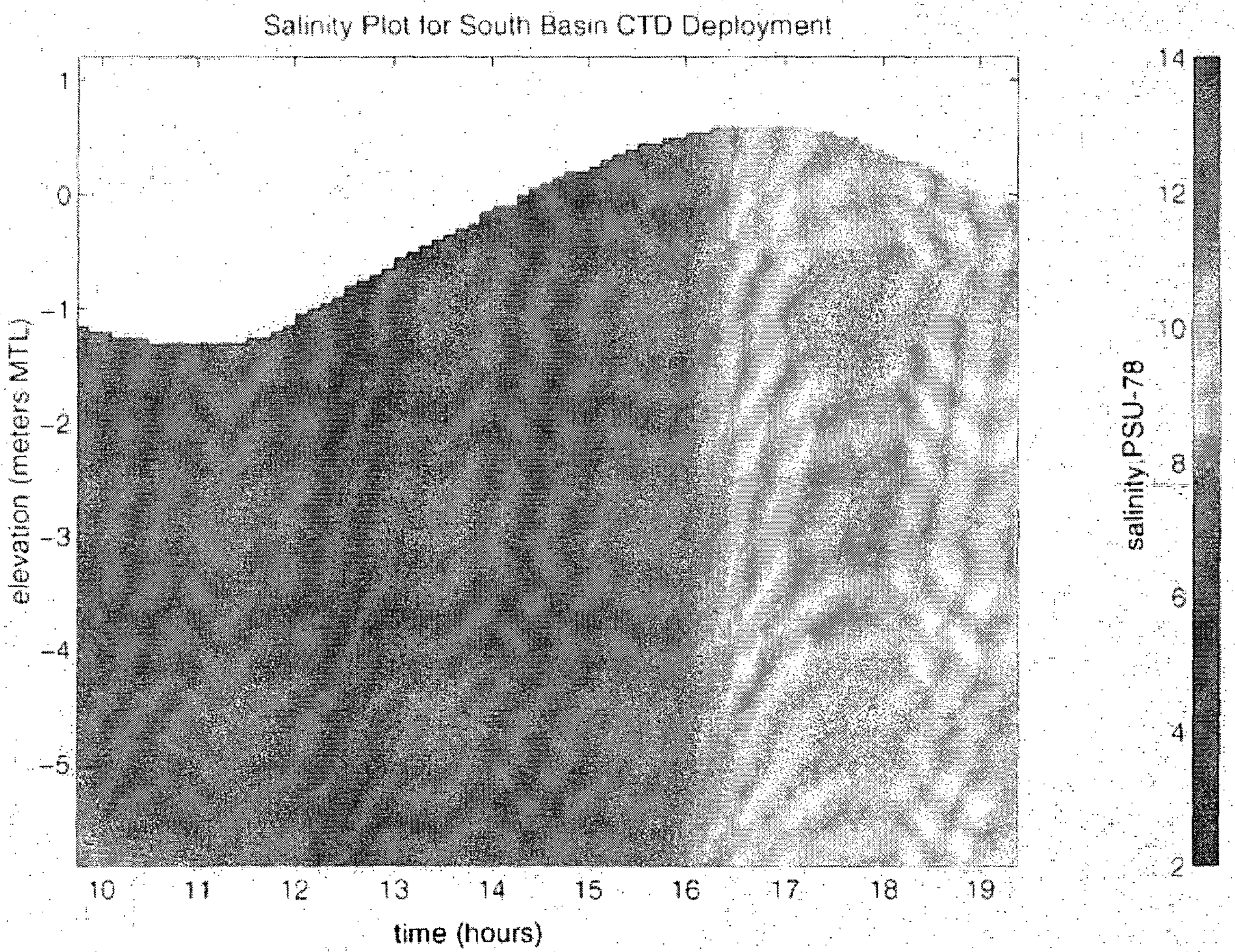
E-1-1 Figure II-30. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 1240 to 1545 on 27 April 1995. Each plot represents measurements at S1, S2, S3, and S4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



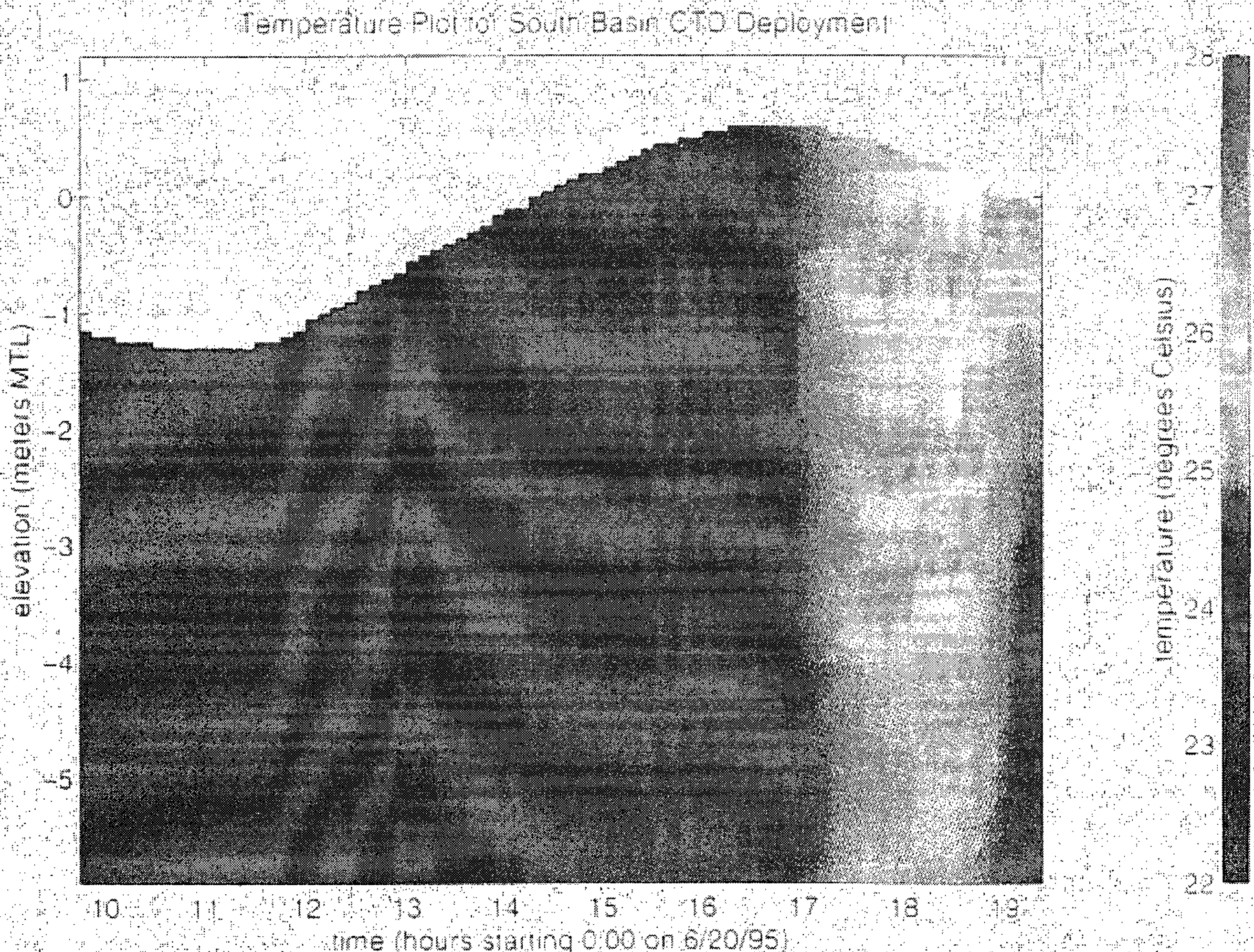
E-1-1 Figure II-31. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 0830 to 1140 on 27 April 1995. Each plot represents measurements at N1, N2, N3, and N4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



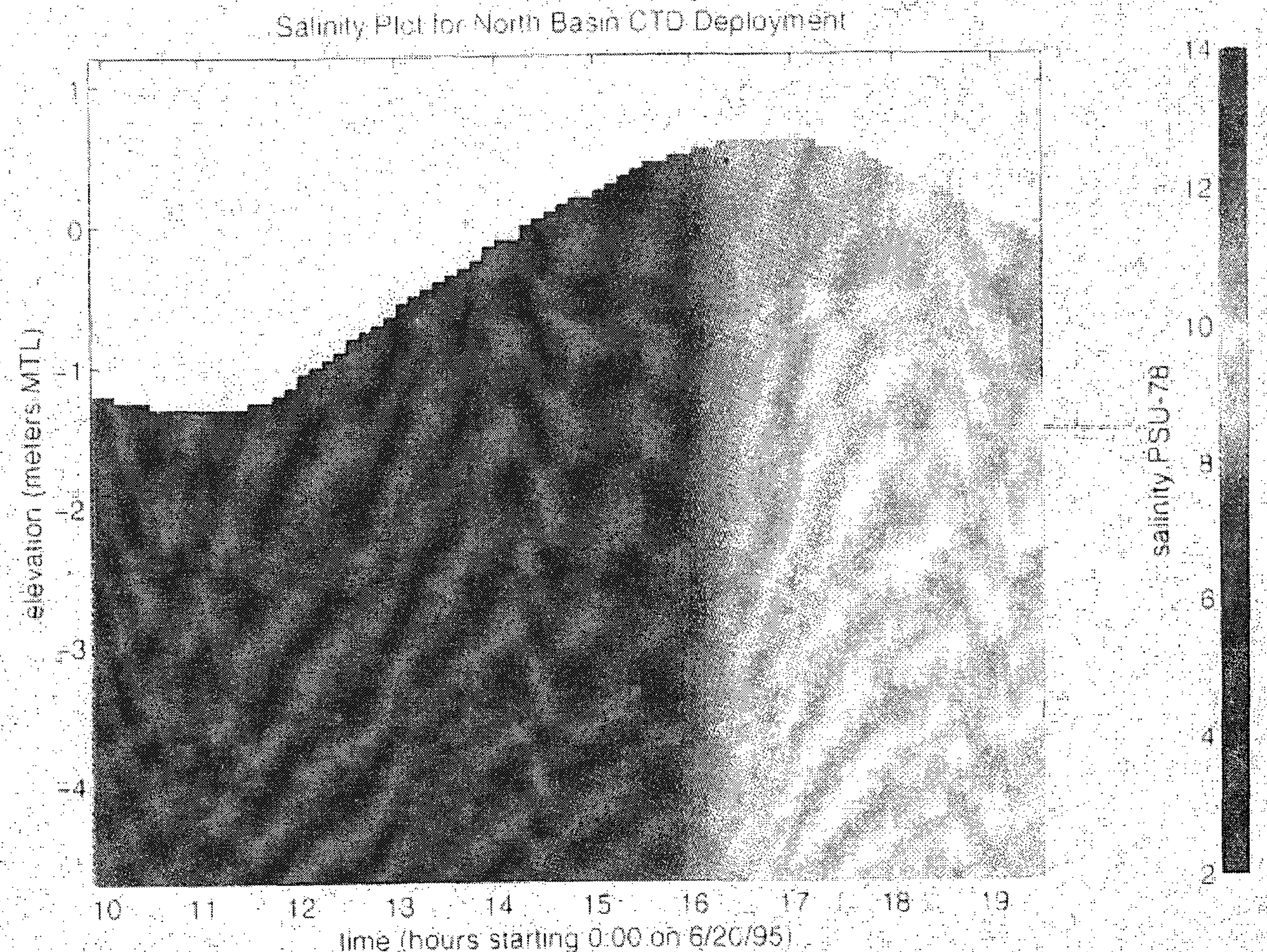
E-1-1 Figure II-32. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 1240 to 1550 on 27 April 1995. Each plot represents measurements at N1, N2, N3, and N4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



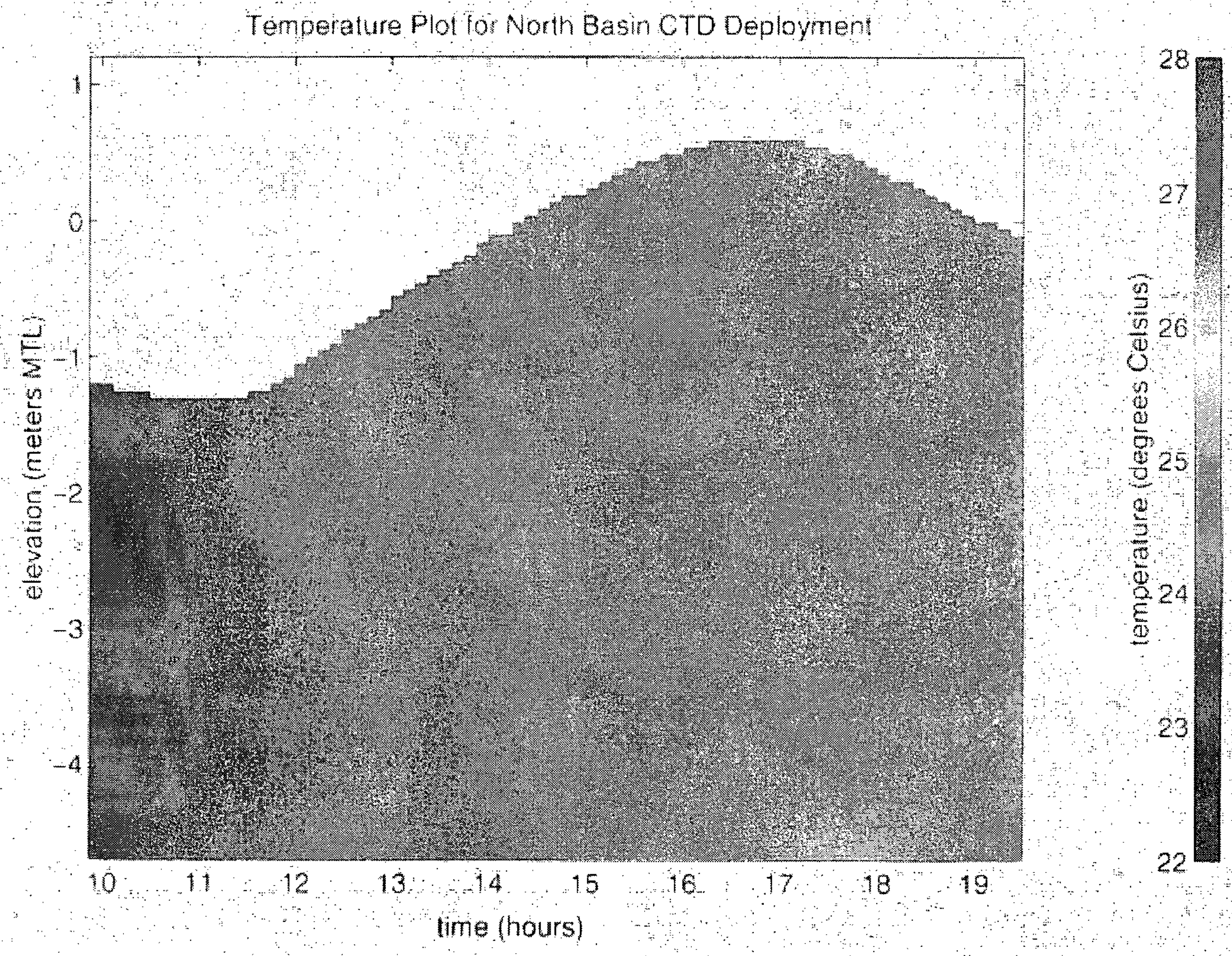
E-1-1 Figure II-33. Color time-series plot of salinity variations at the BS site for 20 June 1995. Color indicates the magnitude of salinity represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses. Salinity approaches a maximum just past high tide (1900).



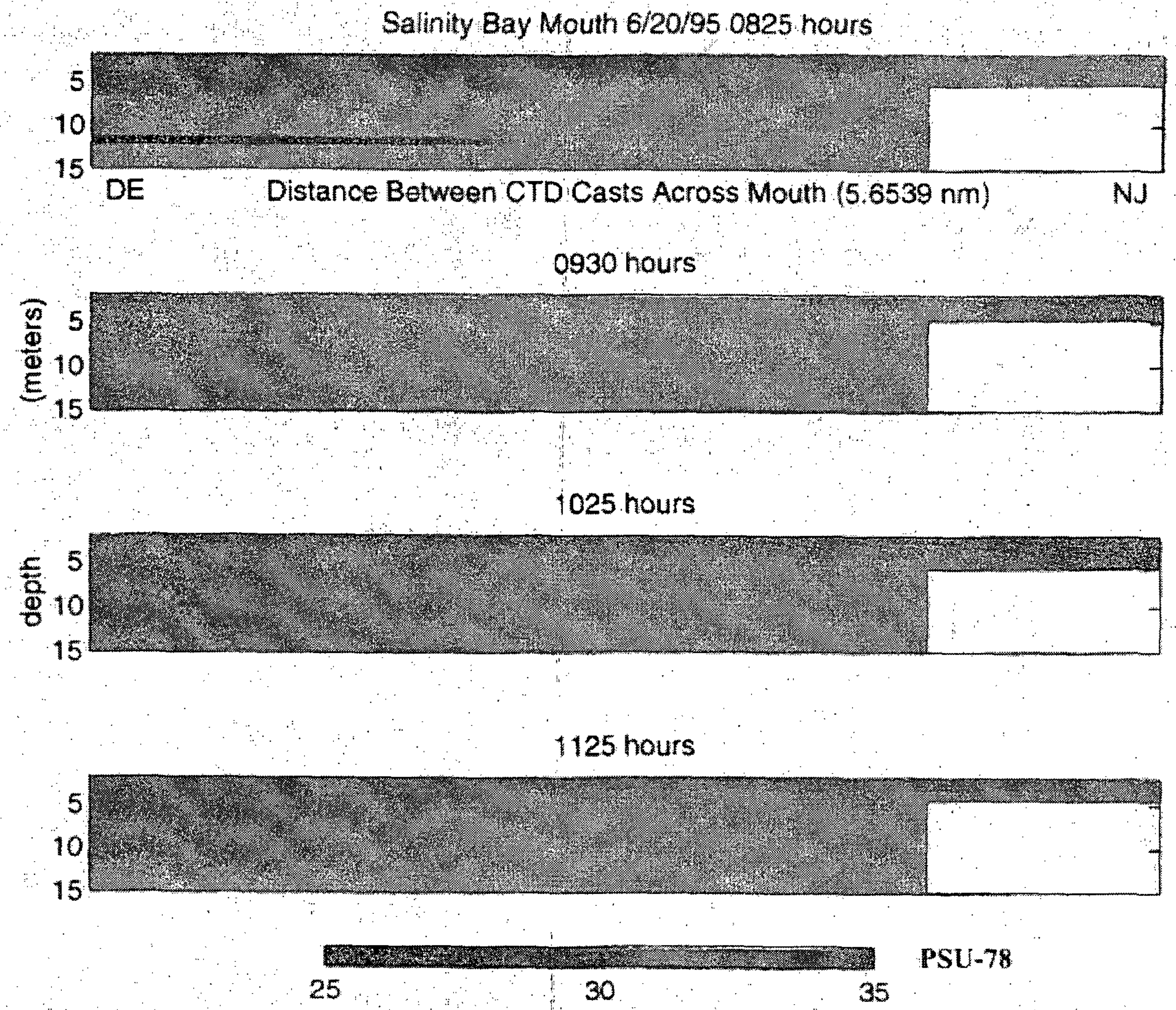
E-1-1 Figure II-34. Temperature plot for South Basin CTD Deployment. Color time-series plot of temperature variations at the BS site for 20 June 1995. Color indicates the magnitude of temperature represented by the color bar to the right. The vertical axis is depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses.



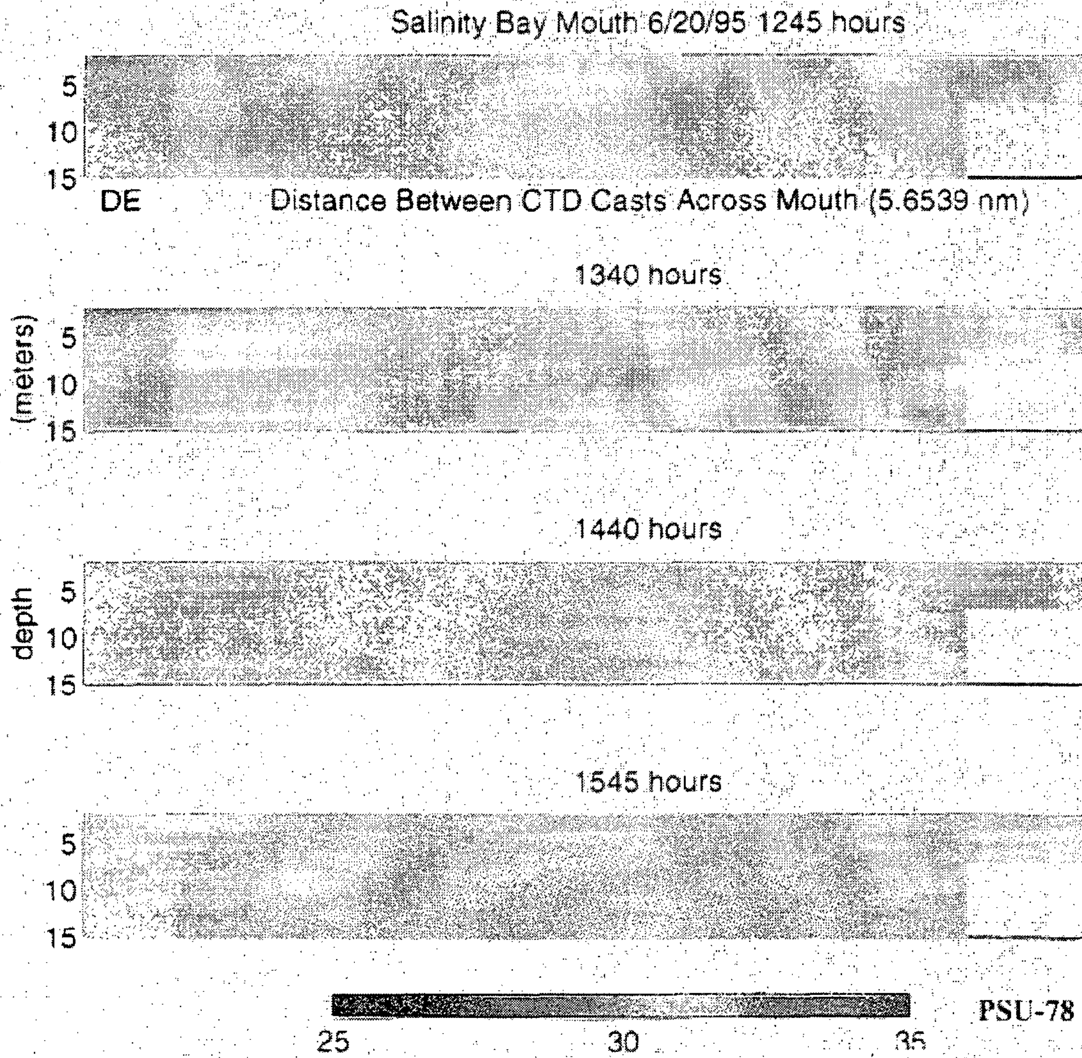
E-1-1 Figure II-35. Color time-series plot of salinity variations at the BN site for 20 June 1995. Color indicates the magnitude of salinity represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses. Salinity approaches a maximum just past high tide (1900).



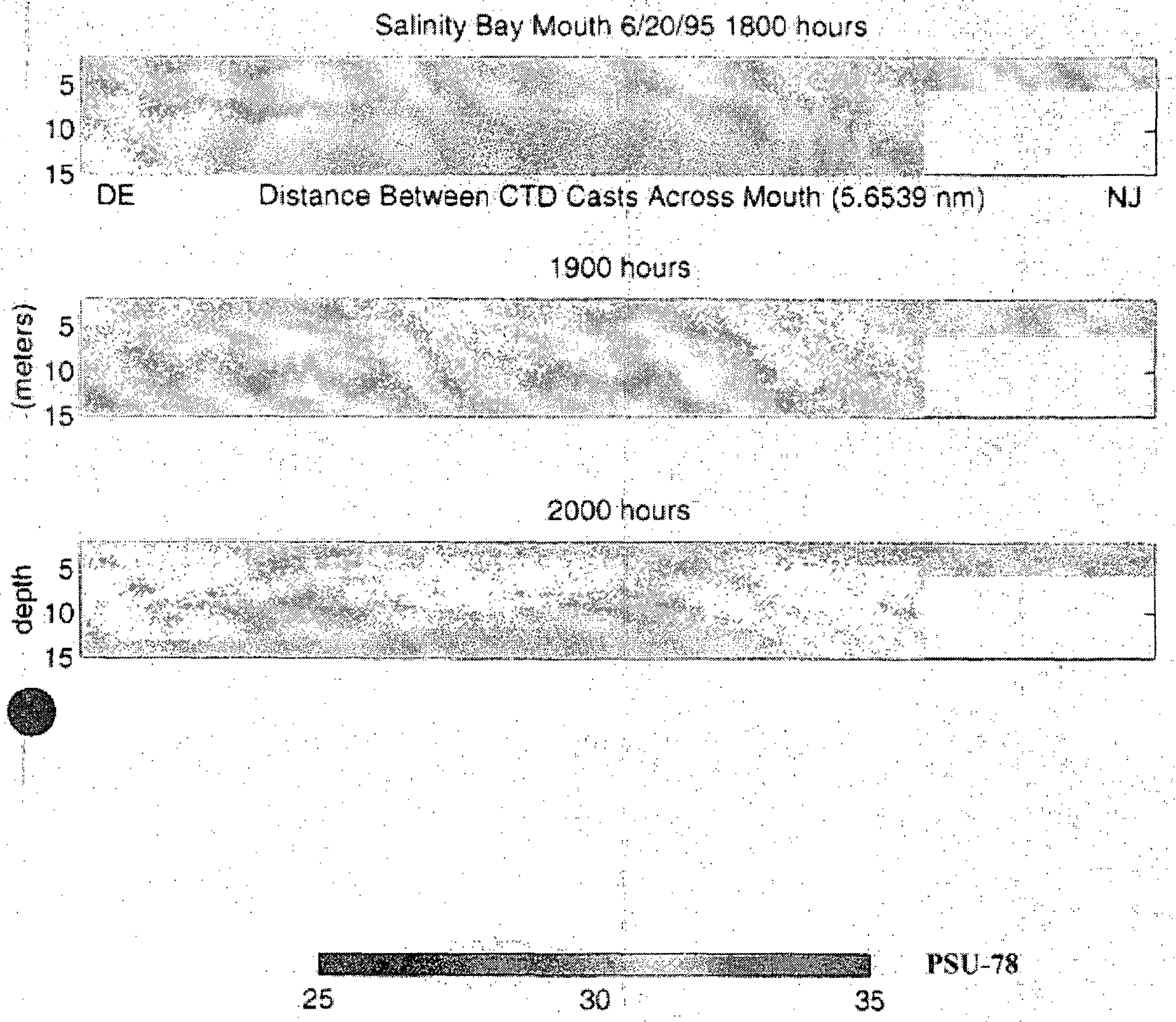
E-1-1 Figure II-36. Color time-series plot of temperature variations at the BN site for 20 June 1995. Color indicates the magnitude of temperature represented by the color bar to the right. The vertical axis represents depth from mean tide level. The horizontal axis represents time of day (EDT). Tide elevation is represented by the rise of the water surface as the day progresses.



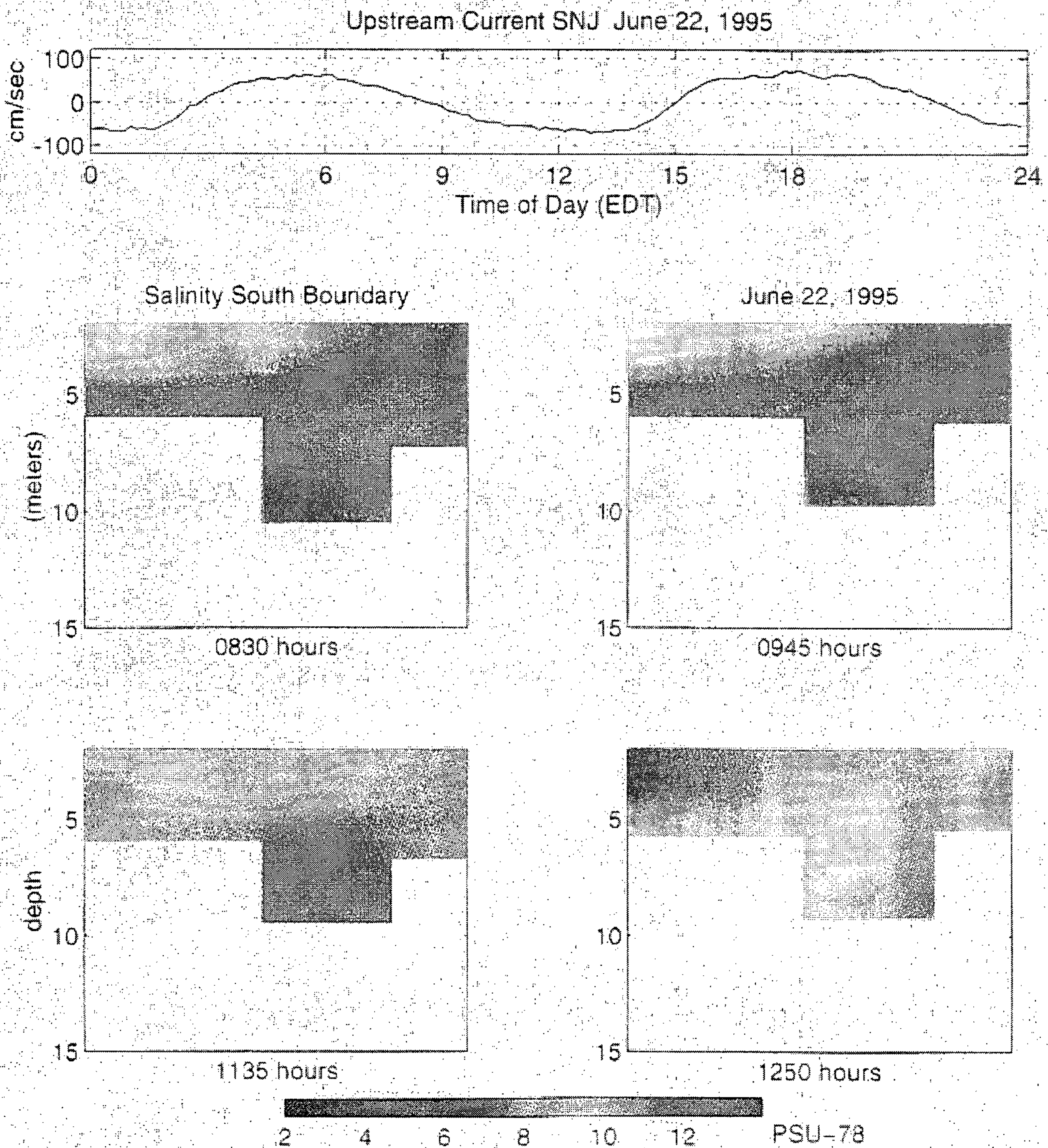
E-1-1 Figure II-37. Sequential measurements of cross-stream variability of salinity at the mouth of Delaware Bay from 0825 to 1125 (EDT) on 20 June 1995. Each plot represents measurements at four sites for a single transect. The plot represents a coarse cross-section of the Bay. Lewes, Delaware is to the left, Cape May, New Jersey is to the right. The data represents baseline salinity levels entering the system on this day.



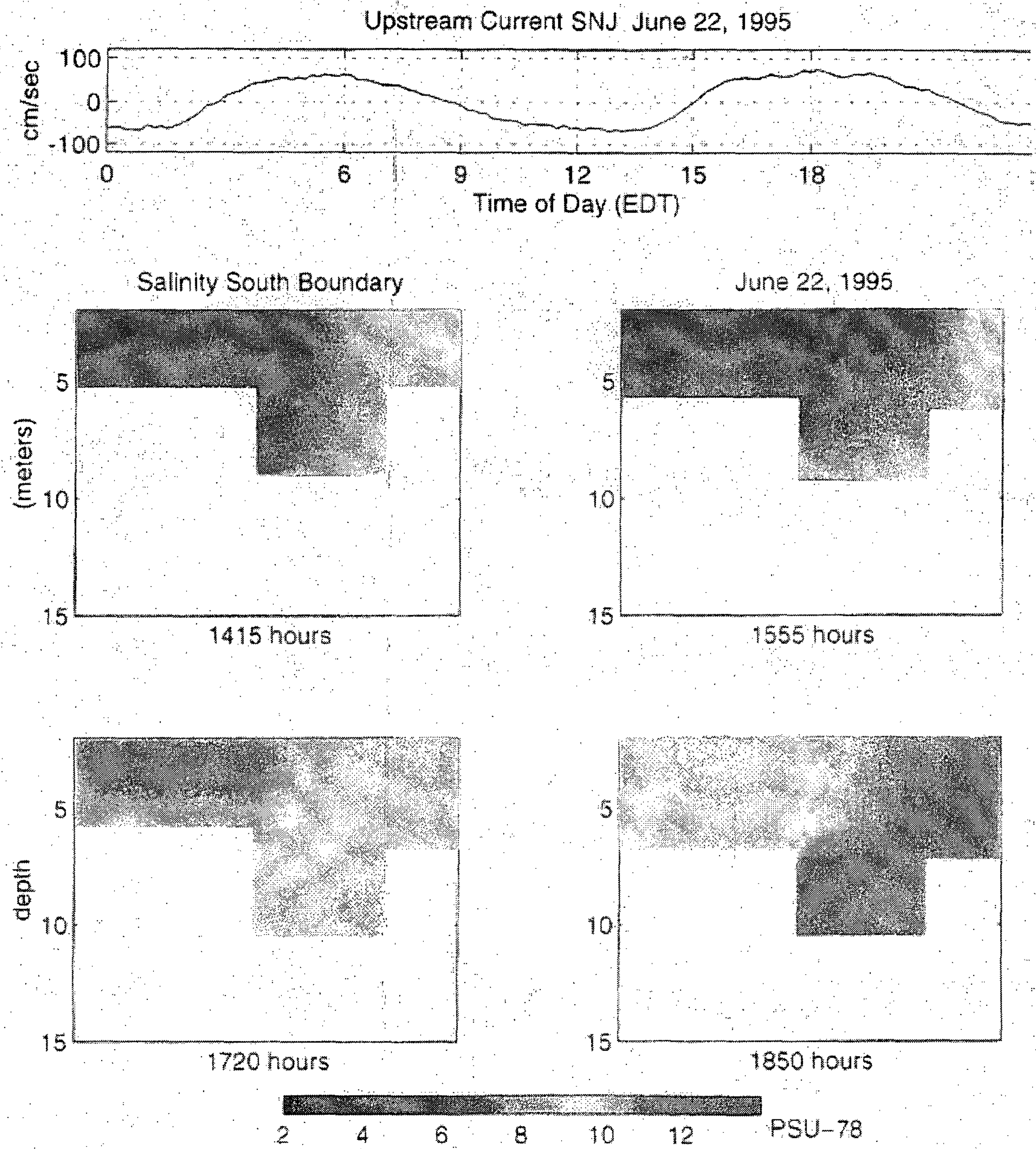
E-1-1 Figure II-38. Sequential measurements of cross-stream variability of salinity at the mouth of Delaware Bay from 1245 to 1545 (EDT) on 20 June 1995. Each plot represents measurements at four sites for a single transect. The plot represents a coarse cross-section of the Bay. Lewes, Delaware is to the left, Cape May, New Jersey is to the right. The data represents baseline salinity levels entering the system on this day.



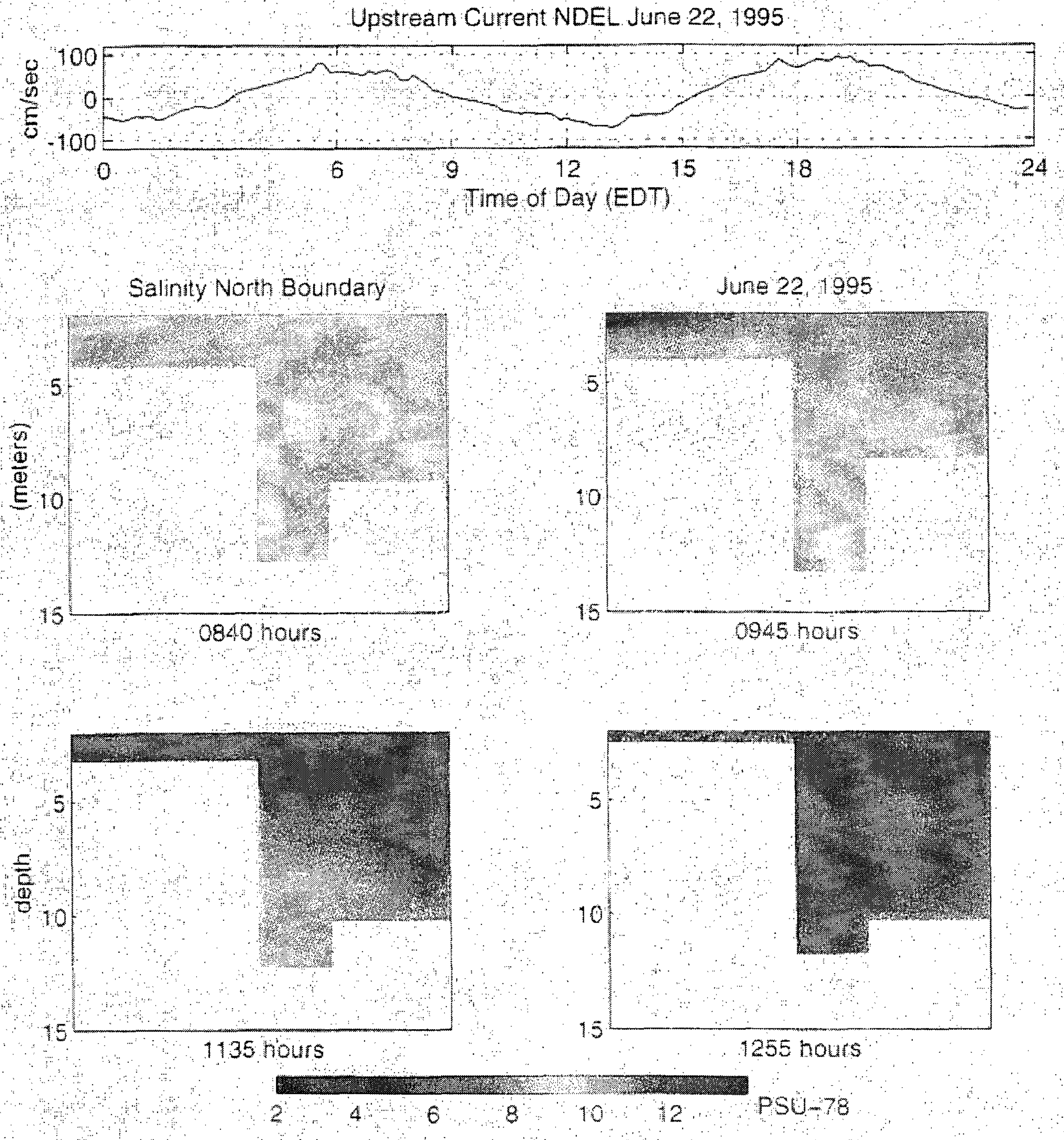
E-1-1 Figure II-39. Sequential measurements of cross-stream variability of salinity at the mouth of Delaware Bay from 1800 to 2000 (EDT) on 20 June 1995. Each plot represents measurements at four sites for a single transect. The plot represents a coarse cross-section of the Bay. Lewes, Delaware is to the left, Cape May, New Jersey is to the right. The data represents baseline salinity levels entering the system on this day.



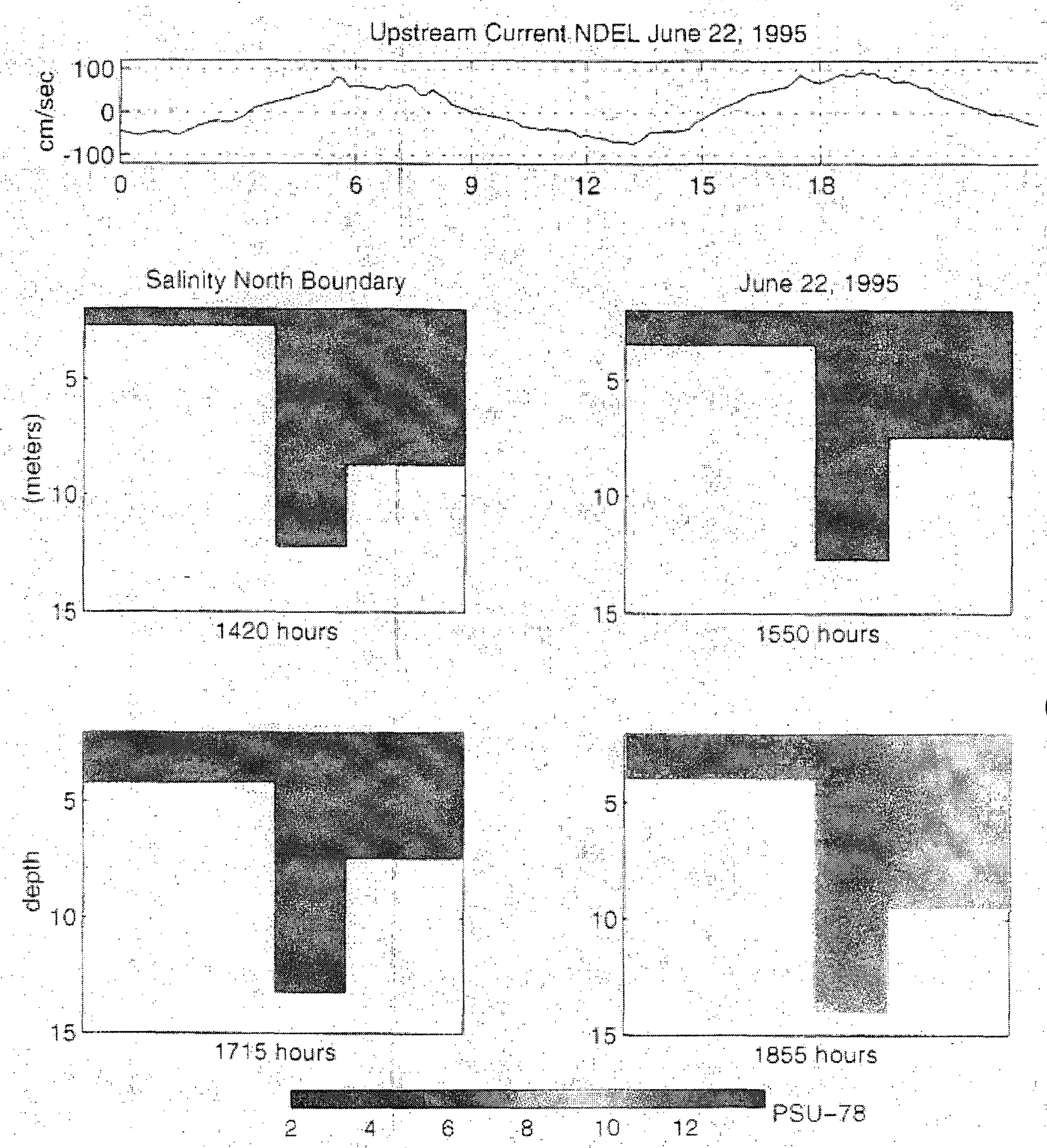
E-1-1 Figure II-40. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 0830 to 1250 on 22 June 1995. Each plot represents measurements at S1, S2, S3, and S4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot of each transect represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



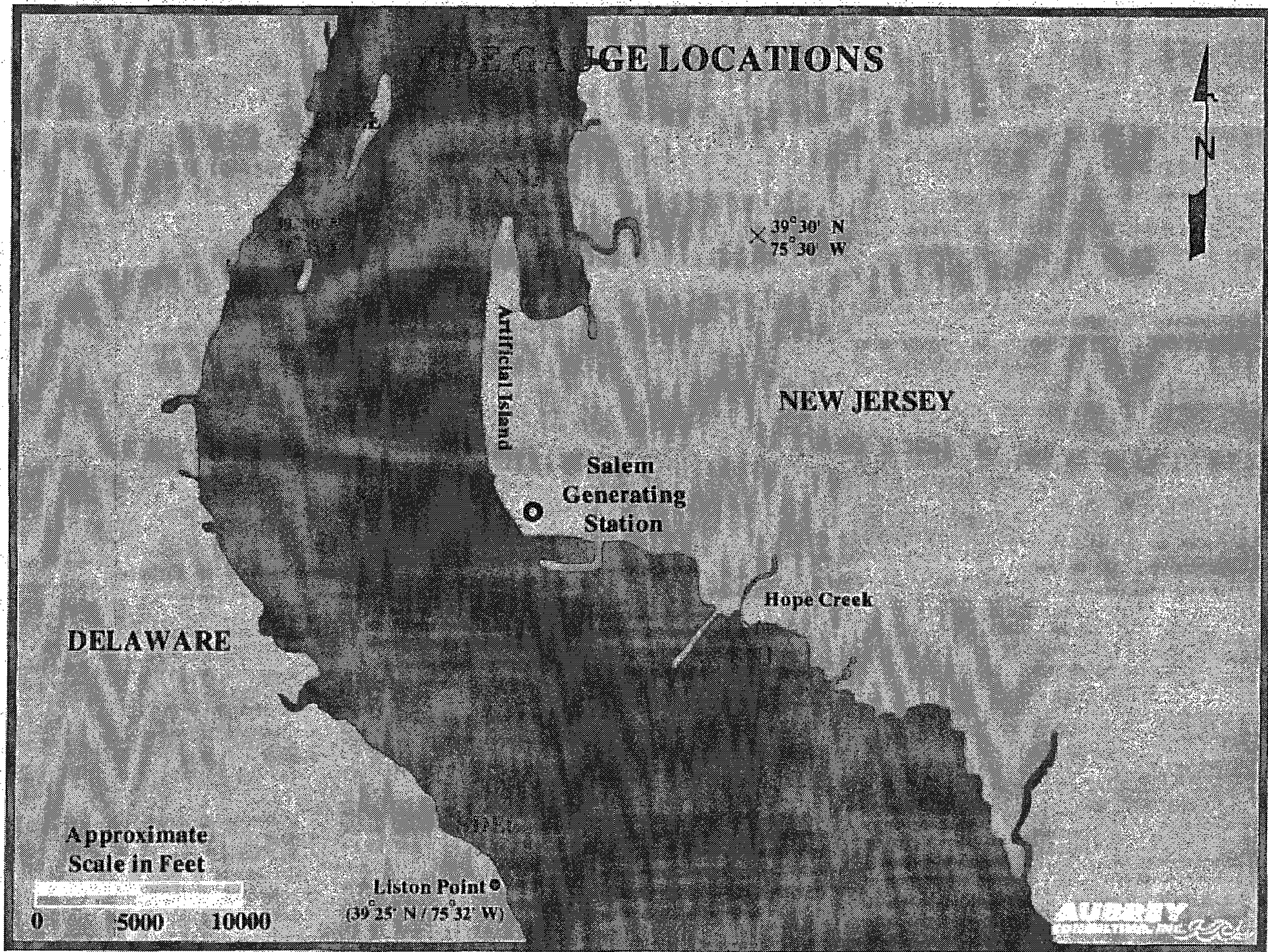
E-1-1 Figure II-41. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 1415 to 1850 on 22 June 1995. Each plot represents measurements at S1, S2, S3, and S4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot of each transect represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



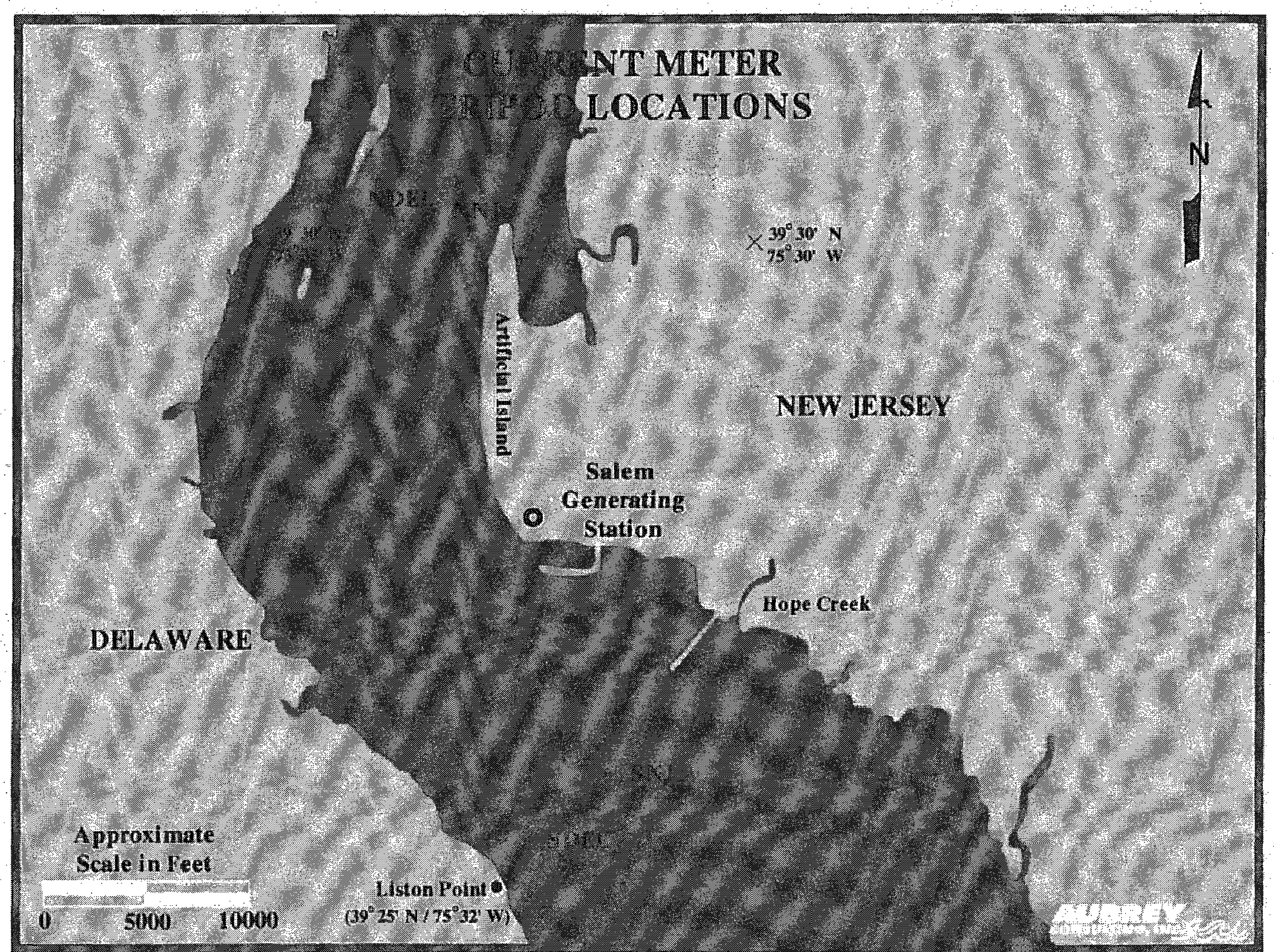
E-1-1 Figure II-42. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 0840 to 1255 on 22 June 1995. Each plot represents measurements at N1, N2, N3, and N4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot of each transect represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



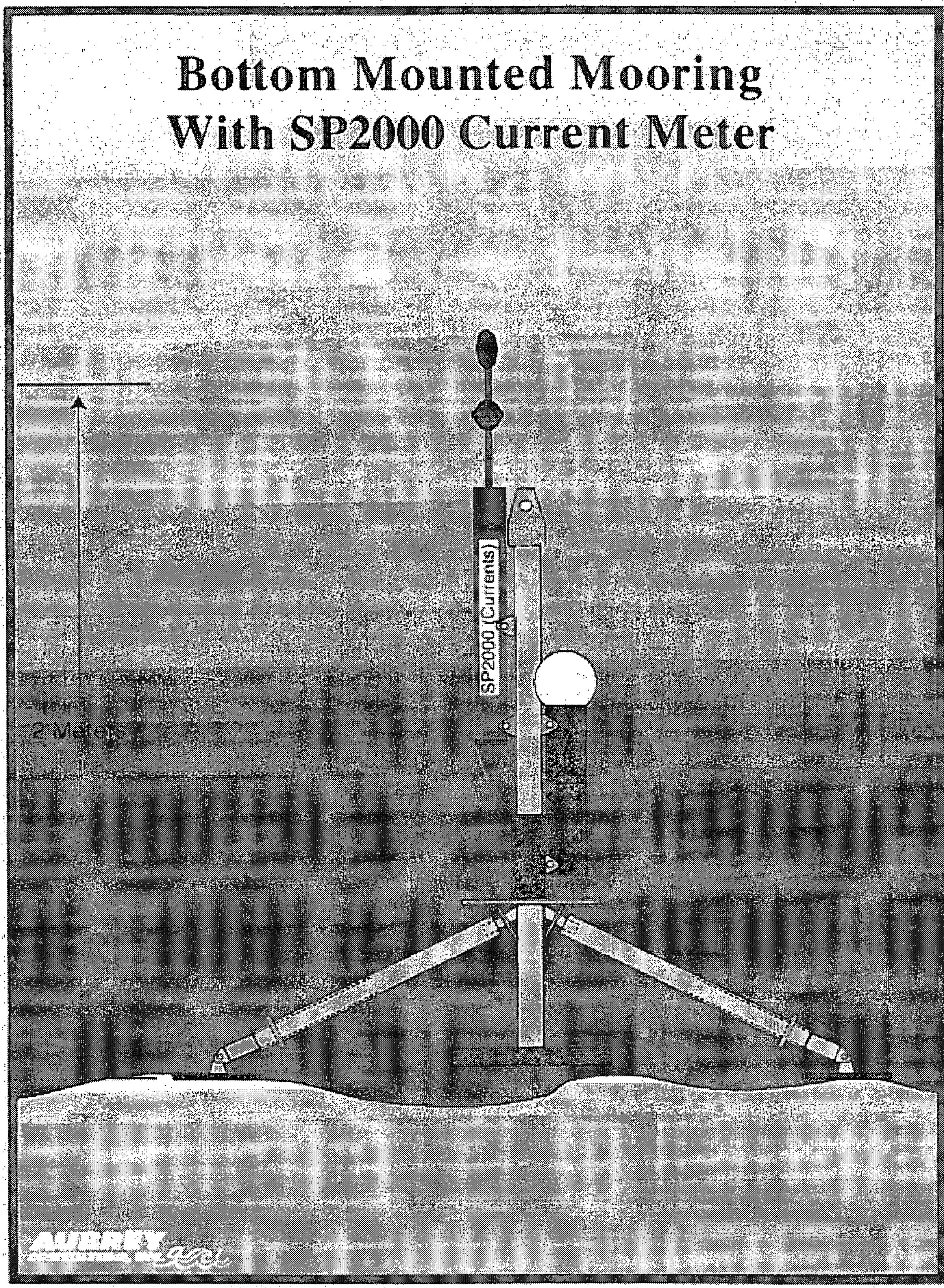
E-1-1 Figure II-43. Sequential measurements of cross-stream variability of salinity at the south boundary of the near-field study area from 1420 to 1855 on 22 June 1995. Each plot represents measurements at N1, N2, N3, and N4 sites for a single transect. The time of each transect is listed below the plot referenced to Eastern Daylight Time (EDT). The plot of each transect represents a coarse cross-section of the river. Delaware shore is to the left, New Jersey to the right. Tide elevation for the day is presented at the top of the page in EDT.



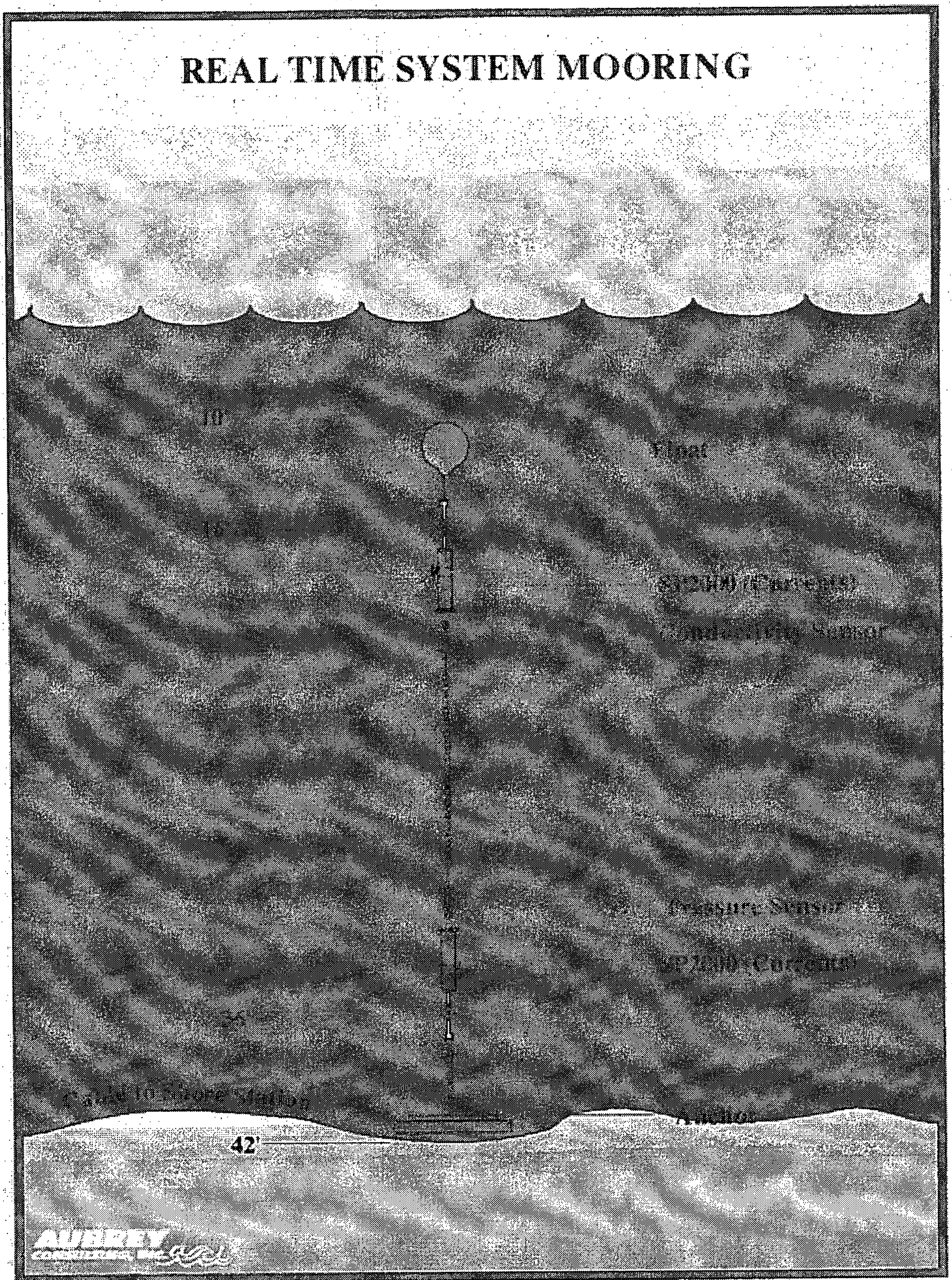
E-1-1 Figure III-1: Location of SP2200 Tide gauges in the near-field study area. Data were recorded at these locations from 29 March 1995 to 24 July 1995.



E-1-1 Figure III-4. Location of SP2000 current meter tripods in the near-field study area. Data were recorded at these locations from 29 March 1995 to 26 June 1995.



E-1-1 Figure III-5 A schematic of the SP2000 current meter tripods illustrating location of the current sensor off the estuary bottom.



E-1-1 Figure III-10. Schematic of the Real Time System (RTS) oceanographic mooring. Two instruments, SN2043 at the top and SN2045 at the bottom, transfer data to the shore station computer through the transfer cable along the estuary bottom. The system was installed 3 May 1995 and recovered in Spring 1996.

PSE&G

ESTUARY ENHANCEMENT PROGRAM

Public Service Electric and Gas Company
Biological Monitoring Program
1997 Annual Report

(Chapter 11 Only)

Part #2182-J
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CHAPTER 11

THERMAL MONITORING

11.0 THERMAL MONITORING BACKGROUND

Pursuant to Part IV-B/C Section H.6(a). of the Salem Generating Station (SGS) New Jersey Pollutant Discharge Elimination System (NJPDES) Permit No. NJ0005622 Public Service Electric & Gas Company (PSE&G) is required to perform a Thermal Monitoring Program (TMP) as a component of the Biological Monitoring Program. Portions of the TMP known as the thermal surveys of the Delaware River (the River) were conducted by Lawler, Matusky & Skelly Engineers LLP (LMS) for PSE&G.

Since the time of acceptance (April, 1996) of the Original TMP, the PSE&G prepared a Modified Thermal Monitoring Program (Modified TMP), which was submitted by PSE&G on 25 March 1998 and accepted by the NJDEP in May, 1998. The Modified TMP was mandated by the unscheduled and extended outages experienced at SGS Units 1 and 2 since late spring of 1995. Unit No. 2 returned to steady state full power operation in mid-October 1997. Unit No. 1 returned to steady state full power operation in May 1998.

PSE&G took advantage of the extended outage and conducted a survey of the spatial distribution of ambient river temperatures (Ambient Survey) in July, 1997. A thermal monitoring survey was conducted shortly after Salem Unit No. 2 returned to steady state full power operation (Single Unit Survey) in October, 1997. The Modified TMP makes reference to these two early surveys and their use in the new monitoring paradigm for thermal modeling presented in response to the SGS outages.

The two monitoring components, the Ambient Survey and the Single Unit Survey, were conducted using the methods described below.

The specific purposes of the Ambient Survey and/or the Single-Unit Survey were to:

- Collect data on the spatial distribution of naturally occurring river water temperature in the Delaware Estuary in the vicinity of the Salem plant,

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- Collect additional data for the calibration and verification of the far-field hydrodynamic model,

- Provide data for application of the models to characterize the thermal plume,

- Collect data to improve our physical understanding of thermal inputs from shallow marshes surrounding the SGS, and

- Support the biothermal assessment through improved understanding of thermal processes in the River, using both observational data and calibrated/verified model output

11.1 AMBIENT SURVEY

11.1.1 OBJECTIVES

The Ambient Survey took place from 11 through 16 July 1997, when the SGS had not been discharging heated cooling water for nearly two years due to extended outages. The objective of the Ambient Survey was to obtain data on the spatial temporal variability of Delaware River water temperature in the absence of the SGS thermal discharge.

The field measurements represent data both from instruments at mooredstations, as well as mobile sampling by surface vessels equipped with oceanographic instruments. Moored instruments were deployed concurrently for a five-day period from 11 through 15 July 1997. The mobile sampling was conducted on 14 and 15 July 1997, encompassing the full semidiurnal tidal cycles on each day. Meteorological data were collected at PSE&G's Artificial Island meteorological station prior to and during the Ambient Survey.

Ancillary data collected by U.S. Government agencies during the Ambient Survey are presented in this report. These data include tidal water surface elevation measured by the National Oceanic and Atmospheric Administration (NOAA) and river flow gauged by the U.S. Geological Survey (USGS).

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The purpose of this portion of the report is to describe the methods and materials employed to collect the data (Section 11.1.2) and to present the data for the Ambient Survey (Section 11.1.3). Analysis and interpretation of these Ambient Survey data, conducted as part of the ongoing hydrothermal modeling, will be provided in the permit renewal submittal (March 1999).

11.1.2 METHODS AND MATERIALS

11.1.2.1 Overview of survey components

The Delaware River Study Area covered by the Ambient Survey extends 12 nautical miles upstream and downstream of the SGS (Figure 11-1). The two major river-related elements of the Ambient Survey are:

> Mobile sampling - three survey boats occupied river transects on the Delaware River on 14 July 1997 and transects at the mouths of four tributary creeks on 15 July 1997.
>
> Moored stations - oceanographic equipment was deployed at two river stations and at the mouths of three tributary creek stations from 11 through 15 July 1997.

The methods and measurement equipment used for the mobile sampling and at the moorings are described in the next two sections. The manufacturers and model numbers of the equipment used and the manufacturer's specified accuracy are summarized in Table 11-1. The calibration of the equipment is summarized in Table 11-2.

11.1.2.2 Mobile Sampling

Three survey boats occupied five river transects positioned at the SGS, and at 6 and 12 nautical miles upstream (positive) and downstream (negative) of the SGS (Figure 11-2). In addition, transects at the mouths of four tributaries - Salem River, Mad Horse Creek, Hope Creek and Alloway Creek - were completed during 15 July 1997.

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Each boat was equipped with a differential global positioning system receiver (DGPS), a conductivity/temperature/depth profiler (CTD), an Acoustic Doppler Current Profiler (ADCP), and a personal computer (PC) to record the data. The configuration of the measurement and data recording equipment with the power supplies is shown schematically in Figure 11-3. An ADCP measures and records a profile of three-dimensional water currents at discrete vertical intervals between the sea surface and the bottom using acoustic sensing. A CTD measures and records the water conductivity, temperature, and depth of the instrument at programmable depth intervals. Salinity is computed from the observed conductivity and temperature using internationally accepted formulae. The DGPS makes use of radio positioning information transmitted by U.S. Department of Defense satellites and by U.S. Coast Guard radio beacons to geographically position the receiver, typically to within 2 to 3 m. DGPS positions are calculated roughly every 2 sec.

Three parameters were monitored in a two-step procedure at each transect. First, temperature and conductivity (for calculation of salinity) were measured near the water surface (at a depth of 1 to 2 ft), at multiple locations along each transect. While the boat was underway along the transect, ADCP observations were made simultaneously at multiple depth levels throughout the water column. Second, vertical profiles of temperature and conductivity were measured at up to eight stations on each transect by lowering the CTD through the water. This monitoring sequence was repeated along each transect during four tidal phases on 14 July 1997: ebbing tide, slack water following ebb tide (end of ebb – EOE), flooding tide, and slack water following flood tide (end of flood – EOF).

11.1.2.3 Moored Stations

Oceanographic instruments were moored at five stations in the vicinity of the SGS (Figure 11-4):

- Mooring E;
- Mooring H;
- Mad Horse Creek mouth;
- Hope Creek mouth; and
- Alloway Creek mouth.

All five stations were equipped with instruments measuring and recording water conductivity, temperature, and dissolved oxygen (DO) concentration. Salinity was computed from the conductivity and temperature observations, as discussed above. Each station had a Conductivity/Temperature/Dissolved Oxygen (CT/DO) instrument and data logger located near the water surface, near mid-water, and near the bottom (Figure 11-5). The moorings also had redundant thermistors at each depth at all stations. The moorings were deployed on 11 July 1997 and retrieved on 16 July 1997.

A tide gauge was installed at the SGS barge slip. The vertical position of the gauge was surveyed to convert measured depth to water surface elevation relative to North American Vertical Datum (NAVD). Local surveyors (Taylor Wiseman and Taylor) used differential leveling to transfer an elevation from PSE&G Control Network Monument Artis 2 to the SGS barge slip and then checked the level using the Artis 3 monument to within 0.01 ft.

The CT/DO instrument was a YSI Model 600XLM, the thermistors were Onset Optic Stowaways, and the tide gauge was a Coastal Leasing MicroTide. All values of manufacturer's specified accuracy are listed in Table 11-1.

11.1.2.4 Ancillary Data Collected by NOAA, USGS and PSE&G

The contractor collated the following ancillary data collected by the USGS, NOAA and PSE&G as part of their respective routine environmental monitoring programs.

- Water surface elevation as gauged continuously by NOAA at four locations within the Delaware River Estuary:

NOAA STATION	RIVER MILE
Lewes, Breakwater Harbor	0.0
Cape May	1.2
Reedy Point	58.2
Philadelphia	98.3

- Freshwater flow of the Delaware River at Trenton, New Jersey, as gauged by the USGS (Gauge No. 01463500).

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- PSE&G meteorological observations near the SGS on Artificial Island including:

  - Air temperature
  - Air pressure
  - Atmospheric radiation
  - Relative humidity
  - Wind speed and direction

11.1.3 RESULTS

11.1.3.1 Overview of Data

Ambient Survey data are presented in five sections:

1. Mobile survey measurements
2. Moored station measurements
3. Tide data
4. Tributary creek flow and heat fluxes
5. Ancillary meteorological and hydrological data

11.1.3.2 Mobile Survey Measurements

11.1.3.2.1 Vertical profiles of salinity and temperature. Vertical profiles of conductivity and temperature of the Delaware River were measured at four phases of the semidiurnal tide on 14 July 1997. Salinity was calculated from these data. Results are presented by showing location where vertical profiles were taken, temperature profiles corresponding to those locations, and salinity profiles. Data plots are arranged in rows corresponding to the five transects from north to south (i.e., +12 nautical miles, +6 NM, 0 NM, -6 NM, and –12 NM). Each column corresponds to a profile along the transect, either to the west, center, or east of the navigation channel. Each phase describes a two-hour interval relative to the NOAA predicted tidal elevation phase at Artificial Island. Transect stations not sampled, because of field logistical problems, are indicated by a missing plot.

The 12 figures selected as representative of the mobile survey vertical are:

TIDAL PHASE	STATION LOCATIONS	TEMPERATURE	SALINITY
EOF	Fig. 11-6	Fig. 11-7	Fig. 11-8
Ebb	Fig. 11-9	Fig. 11-10	Fig. 11-11
EOE	Fig. 11-12	Fig. 11-13	Fig. 11-14
Flood	Fig. 11-15	Fig. 11-16	Fig. 11-17

11.1.3.2.2 Temperature of water surface. To show variation of temperature across the study area, the lowest surface temperature measured during the entire mobile survey (reference temperature) was subtracted from all other measured temperatures, and depicted on four oversized figures:

TIDAL PHASE	FIGURE NO.
EOF	11-18
Ebb	11-19
EOE	11-20
Flood	11-21

The lowest surface temperature (reference temperature) observed during all four tidal phases was at the transect location -12 NM.

11.1.3.2.3 Velocity. River current velocities measured using ADCPs are presented as cross-sectional plots for the five transects, arranged from the most upstream transect at the top of the page to the most downstream transect at the bottom of the page. The four figures showing the river cross-sectional velocity are:

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TIDAL PHASE	FIGURE NO.
EOF	11-22
Ebb	11-23
EOE	11-24
Flood	11-25

The transects were not measured simultaneously, since the vessels had to proceed from one transect to another. Therefore, the data from different transects were not collected synoptically during any single phase of the tide.

Color represents the magnitude and direction of velocity perpendicular to the river transect (that is, along-channel speed). The color-coded scale on each figure differs to accentuate the lateral and longitudinal variability in velocity for each transect sample. The river discharge along each transect was computed using the velocity and associated cross-sectional. The estimated discharge is presented on each figure.

11.1.3.3 Moored Station Measurements

11.1.3.3.1 Vertical profiles of temperature, salinity, and dissolved oxygen. The data recorded at surface, mid-water, and bottom levels at the five moored stations during the 2-hr tidal phase intervals defined for the 14 July 1997 survey are presented as a series of vertical profiles. The minimum, maximum, and mean at the three depths are shown as end bars and a solid circle, respectively, in each plot. Each temperature bar is computed using both the CT/DO and the thermistor measurements at each depth level. Similar presentations of salinity and dissolved oxygen data are also made. The 12 figures showing the data for the two river and three marsh creek mouth moored stations are:

Tidal	Temperature	Salinity	DO
EOF	Fig. 11-26	Fig. 11-	Fig. 11-34
Ebb	Fig. 11-27	Fig. 11-	Fig. 11-35
EOE	Fig. 11-28	Fig. 11-	Fig. 11-36
Flood	Fig. 11-29	Fig. 11-	Fig. 11-37

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DO data failing QA/QC, included the mid-water measurements at Hope Creek and the surface observations at Mad Horse Creek. The symptoms suggest a meter malfunction. The DO meter at the surface of Mad Horse Creek apparently malfunctioned on 12 July 1997 (see Section 11.1.3.3.2). All other DO measurements in the Delaware River and Alloway and Hope creeks were consistently close to saturation.

11.1.3.3.2 *Time series in temperature, salinity, and dissolved oxygen* The time series of temperature, salinity and DO data recorded at individual CT/DO instruments are presented in the following figures:

Station	Temperature	Salinity	DO
Delaware E	Fig. 11-38	Fig. 11-43	Fig. 11-48
Delaware H	Fig. 11-39	Fig. 11-44	Fig. 11-49
Alloway Creek	Fig. 11-40	Fig. 11-45	Fig. 11-50
Hope Creek	Fig. 11-41	Fig. 11-46	Fig. 11-51
Mad Horse *Creek*	Fig. 11-42	Fig. 11-47	Fig. 11-52

The DO data also passed QA/QC, except at Mad Horse Creek following 12 July 1997, and the mid-water DO data at Hope Creek (see previous section).

11.1.3.4 Tide Data

The water surface elevation measurements recorded by NOAA at Lewes, Cape May, Reedy Point, and Philadelphia and by PSE&G at the SGS are shown as Figure 11-53. The lower plot in this figure shows the tides on 14 July 1997. The average tidal range for the six days of measurement and 14 July 1997 shows a general increase from the mouth of the river to Philadelphia (Figure 11-54). The lag in the time of high and low water relative to the mouth of the River is shown in the lower plot of this figure. For

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comparison, NOAA tidal forecasts, based on long-term tidal records for the five river stations (referred to previously), are presented in Figures 11-55 and 11-56. The tidal range and times of low and high water predicted by NOAA generally match the observed data.

11.1.3.5 Hydrological and Meteorological Data

The time series flow in the Delaware River observed at the USGS Trenton gauging station and the meteorological data observed at the Artificial Island station for the period just prior to and during the Ambient Survey are shown in Figure 11-57. The two weeks prior to and including the 14 and 15 July 1997 mobile survey were periods of generally fair weather.

Daily maximum air temperatures ranged from the mid-70s to the low-90s, and the overnight low temperatures ranged from the mid-60s to the mid-70s. The barometric pressure record suggests that a relatively stable air mass occupied the region during the entire period, with no storms or frontal movements, and the wind speeds and directions were correspondingly moderate and steady. The Artificial Island rain gauge recorded no rainfall during the two-week period prior to and including the mobile survey.

Delaware River flows for the two weeks prior to the mobile survey ranged between 3000 and 4000 cfs, typical of a period of little regional rainfall. According to the USGS Water Resources Data, New Jersey 1996, the long-term mean river flow at the Trenton gauge during July is 7104 cfs.

11.1.3.6 Summary of Survey Results

The data collected during the Ambient Survey provide a characterization of ambient river conditions in the vicinity of SGS. In general, the data passed QA/QC procedures (with few exceptions as noted in the text), and are therefore usable in defining background summer, low river flow conditions.

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11.2 SINGLE-UNIT SURVEY

11.2.1 OBJECTIVES

The second thermal survey took place between 21 and 30 October 1997, a period when only one (Salem Unit No. 2) of the two power generating units was operating. This thermal survey had as its objective the collection of data to support the far-field hydrodynamic modeling.

As with the Ambient Survey, moored stations and mobile surveys were included as the means of data collection. However, the scope of this survey surpassed that of the Ambient Survey in several aspects. It included:

- A greater number of moored stations were installed
- Initial conditions were sampled at the beginning of survey
- Additional tide gauges were installed
- A bottom-mounted ADCP was deployed
- Additional boats participated in the mobile survey

The primary components of the Single-Unit Survey included:

- Initial conditions survey
- Tidal boundary survey
- Tide gauges
- Moored stations
- Fixed-station ADCP
- Mobile survey of river
- Mobile survey of marsh mouths
- Ancillary data

Section 11.2.2 describes the methods and materials employed to collect the data. The data for the Single-Unit Survey are presented in Section 11.2.3. Analysis and interpretation of the Single-Unit Survey data will be conducted as part of the ongoing hydrothermal modeling and will be described in the March 1999 permit renewal submittal.

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11.2.2 METHODS AND MATERIALS

11.2.2.1 Overview of Survey Components

The Single-Unit Survey covered the Delaware River from Trenton, New Jersey, to the mouth of Delaware Bay at Cape May, New Jersey. However, measurements were concentrated on the reach that extends 12 NM upstream and downstream of SGS. The overall sampling scheme consisted of moored oceanographic meters deployed at selected locations to record data during, before and after a period when mobile surveys took place. A timeline of the survey components is shown in Figure 11-58. The major components of the Single-Unit Survey included:

Initial Conditions Survey – Vertical profiles of conductivity (salinity) and temperature were measured at 16 stations spaced at 5- to 10-nmile increments between river miles 0 and 120 using two boats on 21 October 1997.

Tidal Boundary Survey – Vertical profiles of conductivity and temperature were measured at three locations spaced along the Delaware River mouth during flood using one boat on 27 October 1997.

Tide Gauges – Water surface elevations were measured at six locations between 14 and 28 October 1997.

Moored stations – Meters were deployed at three depth levels at moorings set at 24 locations to measure temperature at all locations and conductivity (salinity) and DO at selected locations between 21 and 31 October 1997.

Bottom Mounted ADCP – Current velocity was measured at one location near the discharge between 16 and 18 October 1997.

Mobile surveys – Five survey boats occupied river transects on 28 October 1997.

Mobile surveys of marsh mouth - The four tributaries of the Delaware River covered by the Ambient Survey were also monitored during the Single-Unit Survey and were conducted at the mouths of four tributaries on 29 October 1997

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Ancillary data – Various ancillary oceanographic and meteorological data from available sources were compiled to support the data collection effort.

The methods and measurement equipment used for these survey components are described in the following sections. The manufacturer and model number of the equipment used and the manufacturer's specified accuracy are summarized in Table 11-3. The calibration of the equipment used in the Single-Unit Survey is summarized in Table 11-4.

11.2.2.2 Initial Conditions Survey

Calculation of river temperatures and hydrodynamics using the hydrothermal model of the Delaware River requires initial conditions as input to the model. The initial conditions for the one-week survey period were measured on 21 October 1997. Conductivity (salinity) and temperature were measured throughout the water column using Falmouth Scientific Inc. CTDs at 16 locations along the navigation channel from the Delaware River mouth to Trenton, at river mile (RM) locations: 0, 10, 20, 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, 100, 110, and 120 (Figure 11-59). One vessel covered from the Delaware River mouth to RM40 and the second vessel covered from RM45 to RM120.

11.2.2.3 Tidal Boundary Survey

Vertical profiles of conductivity and temperature were measured at three locations spaced along the Delaware River mouth during flood using one boat on 27 October 1997.

Three tide-gauges were occupied as part of the tidal boundary survey component; locations of the gauges are shown on Figure 11-60.

11.2.2.4 Tides Gauges

Tide gauges were installed by LMS at six stations along the Delaware River:

- Cape May
- Woodland Beach (near Ship John Shoal)

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- Salem Barge Slip
- Western C&D Canal
- Eastern C&D Canal (Reedy Point)
- Marcus Hook

In addition, NOAA maintains continuously-recording tide gauges at four locations (see Section 11.1.2.4). The locations of the 10 tide gauging stations are shown in Figure 11-61.

11.2.2.5 Moored Stations

Moorings equipped to measure certain parameters were installed at twenty-four stations in the river and at the mouths of three tributaries (see Figures 11-5 and 11-62). The oceanographic parameters measured at these stations varied as follows:

Temperature, conductivity, and DO	-	five stations (same locations as Ambient Survey stations)
Temperature and conductivity	-	nine stations
Temperature	-	ten stations

The sensors for temperature and/or CT/DO deployed at surface, mid-water, and bottom positions for each moored station are listed in Table 11-5.

All moorings were deployed between 15 and 16 October 1997. Two of the 24 moorings were lost during the deployment; the remaining 22 moorings were retrieved between 31 October and 4 November 1997.

11.2.2.6 Fixed Station ADCP

An ADCP was deployed by divers in the vicinity of SGS's discharge on 16 October 1997. The location of the ADCP is shown on Figure 11-66 After deployment an electrical cable on the unit frayed, presumably by its motion and contact with mooring hardware. This the frayed cable resulted in termination of data logging on 18 October 1997. The ADCP was retrieved on 30 October 1997.

11.2.2.7 Mobile Surveys

Five survey boats occupied the transects shown in Figures 11-63, 11-64 and 11-65. Two boats occupied the same transects during each of four tidal phases sampled on 28 October 1997:

Boat Number 4 – Transects +6 and + 12 NM
Boat Number 5 – Transects –6 and –12 NM

The transects covered by the remaining three boats depended on the tide. Boats 2 and 3 covered the river east of the navigation channel and were generally upstream and downstream, respectively, of SGS during ebb and flood tide. The transects these two boats occupied shifted upstream for the EOF phase and downstream for the EOE phase to track the higher temperatures that were likely within the thermal plume. Boat 1 occupied the 0 NM transect (full width of the river) during all four tidal phases and was used as a "rover" to delineate the thermal plume in the vicinity of the discharge (Figure 11-65).

All boats were equipped with DGPS receivers, a CTD, and a PC, as described previously (Section 11.1.2.2 and Figure 11-3). Sampling for temperature and conductivity was performed two ways: (1) temperature and conductivity (salinity) measurements were obtained from a depth of 1 to 2 ft (near water surface) as the boat traveled along the transects, and (2) vertical profiles of temperature and salinity at a number of stations when the boat was stopped. For sampling method 1, the three boats closest to the SGS thermal discharge (Boats 1, 2, and 3) were equipped with Ocean Temperature Modules (OTM). The three boats measured temperature as they were underway along the transects, whereas Boats 4 and 5 were required to stop periodically to take near-surface temperature measurements. The OTM equipment allowed more frequent measurements in the vicinity of the discharge, where larger horizontal temperature gradients occur. For sampling method 2, the CTD was lowered at vertical profiling stations from each of the five vessels, and recorded data from the water surface to the bottom at closely spaced, but discrete, depth intervals.

Boats 1, 4, and 5 were also equipped with ADCPs to measure current velocity at various depth strata.

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Due to high winds and accompanying rough water, some transects were not occupied.

11.2.2.8 Mobile Surveys of Marsh Mouths

The four tributaries of the Delaware River covered by the Ambient Survey (Salem River, Mad Horse Creek, Hope Creek, and Alloway Creek) were also monitored during the Single-Unit Survey. The CT/DO meters on Boats 1 and 4 (see Table 11-3) were used to measure temperature, conductivity (salinity), DO, and current velocity during four tidal phases on 29 October 1997.

11.2.2.9 Ancillary Data

The Delaware River data routinely collected by NOAA, USGS, and PSE&G, which were described in Section 11.1.2.4, were also collected during the Single-Unit Survey.

11.2.3 RESULTS

11.2.3.1 Overview of Data

The data recorded during the Single-Unit Survey were downloaded and compiled. All data were subjected to QA/QC procedures. Data missing from the two lost moorings and abbreviated measurements by the bottom ADCP represent a approximately 1% of the data collected, thus providing sufficient data to support thermal modeling.

The results of the field measurements are presented graphically in the following subsections.

11.2.3.2 Initial Conditions Survey

The vertical profiles of temperature at the 16 stations along the River are presented in Figures 11-66 and 11-67. The vertical profiles of salinity are shown in Figures 11-68 and 11-69.

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11.2.3.3 Tidal Boundary Survey

Vertical profiles of temperature and salinity are presented for three stations at the mouth of the River along the model boundary transect. The plots of temperature and salinity data taken at five time intervals during flood tide are shown in Figures 11-70 and 11-71, respectively.

11.2.3.4 Tide Gauges

The water surface elevations measured at six tide gauge stations installed for the Single-Unit Survey were converted to the common datum (NAVD) by surveying from a vertical control benchmark. In addition, data recorded by NOAA at their four tidal gauging stations were also converted to NAVD. The tidal variations in water surface elevation between 21 October and 1 November 1997 at these 10 stations are shown in Figures 11-72 and 11-73 The time series during the mobile survey of 28 October 1997 are shown in Figures 11-74 and 11-75.

The average and minimum/maximum ranges in tide between high and low water are shown for the 11-day period and the single day in Figure 11-76. The tidal elevation time delay, or phase lag from the mouth upstream to Philadelphia, is shown similarly in Figure 76.

11.2.3.5 Moored Stations

22 of the 24 moorings set in the River and at the mouths of tributaries were retrieved; moorings 8 and 21 were lost. Three of the 66 retrieved meters had data losses due to instrument malfunction:

Mooring 3	surface
Mooring 3	bottom
Mooring 10	surface

Two instruments sampled at the wrong sampling rate (12 hrs. instead of 10 minutes):

Mooring 3	mid-water
Mooring 4	mid-water

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The temperature, salinity and dissolved oxygen data are presented graphically in two ways: vertical profiles and time series.

The vertical profiles of temperature, salinity, and DO are presented as sets of five figures for each tidal phase. Each tidal phase presents data from different locations, and includes temperature, salinity, and dissolved oxygen monitoring results:

Tidal Phase	Location	Temperature		Salinity	DO
Flood	Fig. 11-77	Fig. 11-78	Fig. 11-79	Fig. 11-80	Fig. 11-81
EOF	Fig. 11-77	Fig. 11-82	Fig. 11-83	Fig. 11-84	Fig. 11-85
Ebb	Fig. 11-77	Fig. 11-86	Fig. 11-87	Fig. 11-88	Fig. 11-89
EOE	Fig. 11-77	Fig. 11-90	Fig. 11-91	Fig. 11-92	Fig. 11-93

The mean value of each 2-hr interval is shown as a dot and the minimum and maximum values are shown as the ends of horizontal bars. Data availability is tabulated in Table 11-5.

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The time series of temperature, salinity, and DO are shown for all 22 moored stations:

Station	Temperature	Salinity	DO
1	Fig. 11-94	Fig. 11-95	Fig. 11-96
2	Fig. 11-97	Fig. 11-98	
3	Fig. 11-99	Fig. 11-100	
4	Fig. 11-101	Fig. 11-102	
5	Fig. 11-103	Fig. 11-104	
6	Fig. 11-105	Fig. 11-106	
7	Fig. 11-107	Fig. 11-108	
9	Fig. 11-109	Fig. 11-110	
10	Fig. 11-111	Fig. 11-112	
Alloway Creek	Fig. 11-113	Fig. 11-114	Fig. 11-115
Hope Creek	Fig. 11-116	Fig. 11-117	Fig. 11-118
Mad Horse Creek	Fig. 11-119	Fig. 11-120	
E	Fig. 11-121	Fig. 11-122	Fig. 11-123
H	Fig. 11-124	Fig. 11-125	Fig. 11-126
I	Fig. 11-127		
K	Fig. 11-128		
V	Fig. 11-129		
L	Fig. 11-130		
N	Fig. 11-131		
22	Fig. 11-132		
23	Fig. 11-133		
24	Fig. 11-134		

The DO data at the bottom of Alloway Creek and the surface of Hope Creek are suspect. Similarly, the bottom DO at Station E appears questionable. All other data passed QA/QC checks.

11.2.3.6 Fixed Station ADCP

The current speed and direction measured by the bottom-mounted ADCP at 5-ft depth intervals are shown in Figure 11-135. This gauge was deployed near the discharge location.

11.2.3.7 Mobile Survey of River

The measurements taken during the mobile survey of the Delaware River on 28 October 1997 are presented as plots of surface isotherms and as vertical profiles. The surface temperature plots for each of the four tidal phases cover the full 24-mile extent of the river, as well as a close-up of the vicinity of the SGS discharge. The eight figures showing surface temperatures are:

Tidal Phase	Full Extent	Close-up
Flood	Fig. 11-136	Fig. 11-137
EOF	Fig. 11-138	Fig. 11-139
Ebb	Fig. 11-140	Fig. 11-141
EOE	Fig. 11-142	Fig. 11-143

The vertical profiles of temperature and salinity are shown as sets of five figures for each tidal phase: location of vertical profile stations, and two figures each of temperature profiles and salinity profiles at representative stations:

Tidal Phase	Location	Temperature		Salinity	
Flood	Fig. 11-144	Fig. 11-145	Fig. 11-146	Fig. 11-147	Fig. 11-148
EOF	Fig. 11-149	Fig. 11-150	Fig. 11-151	Fig. 11-152	Fig. 11-153
Ebb	Fig. 11-154	Fig. 11-155	Fig. 11-156	Fig. 11-157	Fig. 11-158
EOE	Fig. 11-159	Fig. 11-160	Fig. 11-161	Fig. 11-162	Fig. 11-163

The current velocity data measured along the five river transects are presented as cross-sectional plots, showing only the along-river component:

Tidal Phase	Figure No.
Flood	Fig. 11-164
EOF	Fig. 11-165
Ebb	Fig. 11-166
EOE	Fig. 11-167

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Since the measurements along the transects did not occur at the exact same time within the local tidal cycle, the data cannot be compared visually in a quantitative fashion.

11.2.3.8 Mobile Surveys of Marsh Mouth

The temperature and salinity data recorded during the marsh mouth surveys are presented as vertical profiles:

Location	Temperature	Salinity
Salem River	Fig. 11-168	Fig. 11-169
Alloway Creek	Fig. 11-170	Fig. 11-171
Hope Creek	Fig. 11-172	Fig. 11-173
Mad Horse Creek	Fig. 11-174	Fig. 11-175

The water discharge into and out of the four tributaries was calculated using the measured current velocity and cross-sectional area during each measurement interval.

11.2.3.9 Ancillary Data

The meteorological data collected by PSE&G during the Single-Unit Survey include:

- Wind speed and direction
- Air temperature
- Barometric pressure
- Solar radiation
- Dew point temperature
- Cloud cover

These data are shown graphically in Figure 11-176. Hourly precipitation data also collected at PSE&G's monitoring station show rainfall on five days during the survey period:

Day in October 1997	Rainfall (in.)
19	0.12
24	0.10
25	0.77
26	0.56
27	0.06

These meteorological data show a storm preceding the mobile survey. The flow in the Delaware River at Trenton increased on 25 October 1997 and then decreased on 28 October 1997 according to USGS river-gauging data (Figure 11-177).

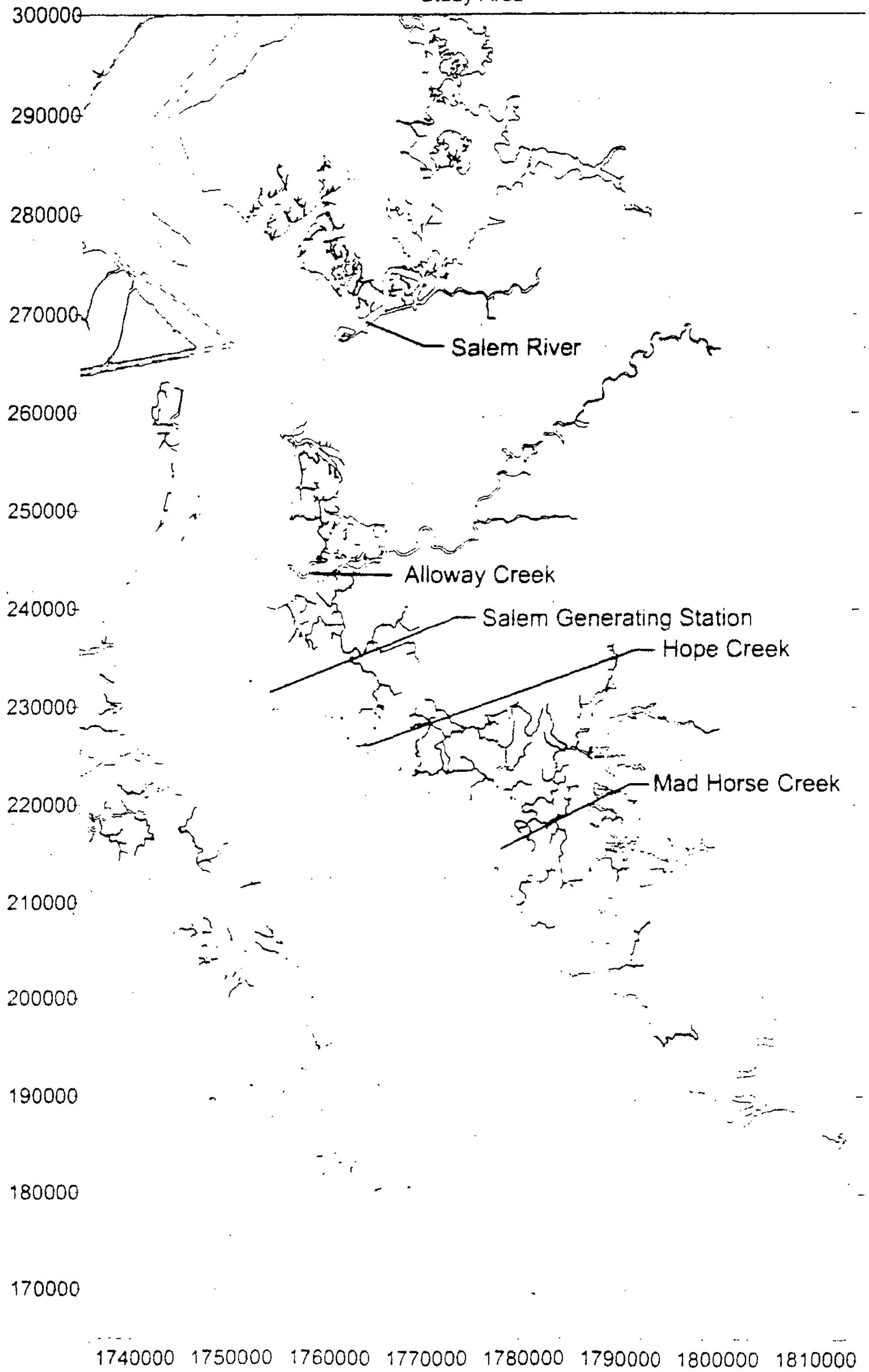
11.2.3.10 Summary of Survey Results

The data collected during the Single-Unit Survey met the survey objective and contributes data and information useful for the nearfield and farfield models. Small data gaps identified in this report pose no significant risk to the modeling success.

11.3 LITERATURE CITED

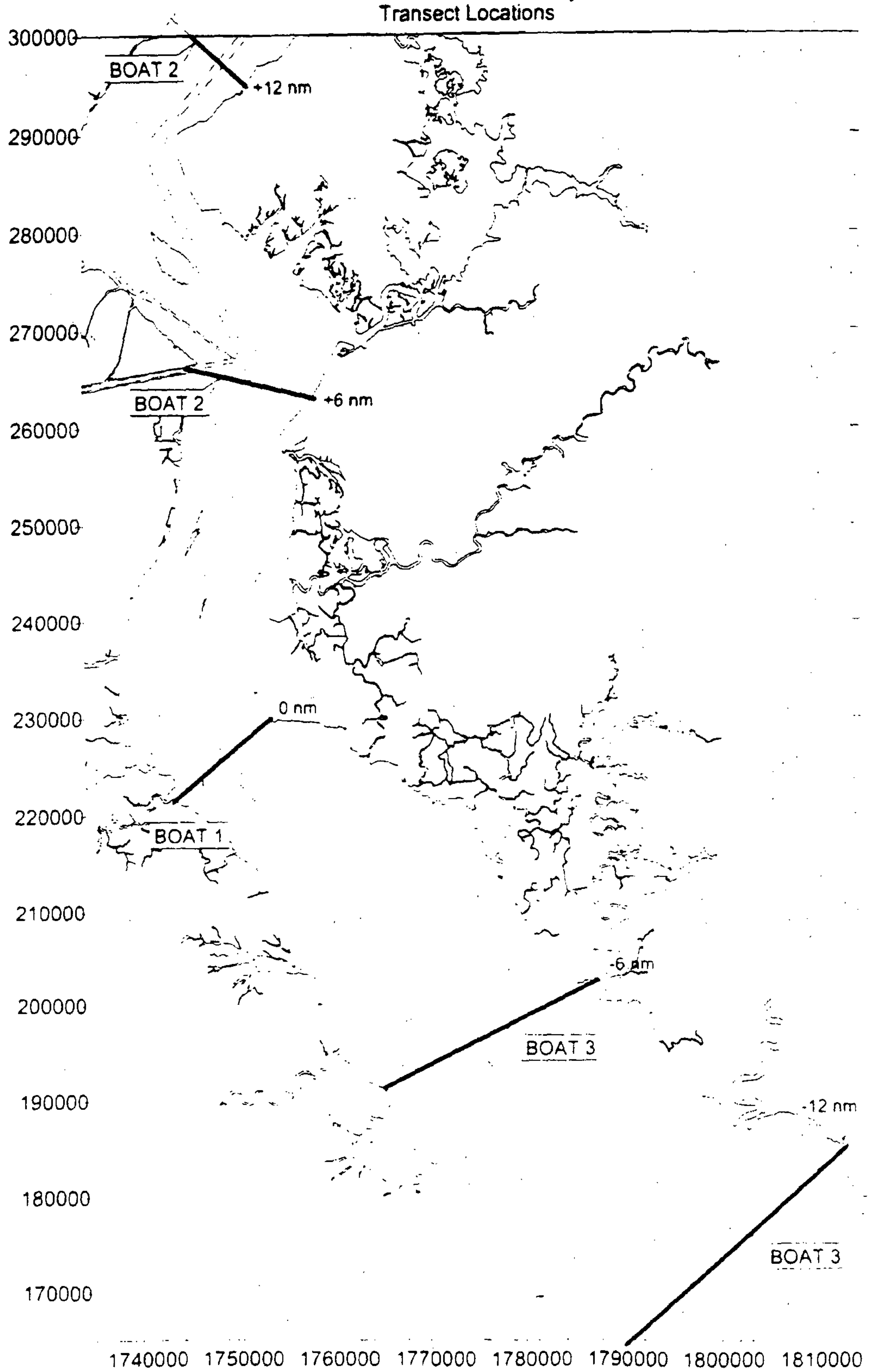
U.S. Environmental Protection Agency (EPA). 1985. Rates, Constants and Kinetics Formulations in Surface Water Quality Modeling (second edition). EPA/600/3-85/040.

Figure 11-1
PSE&G Ambient Survey
Study Area



305

Figure 11-2
PSE&G Ambient Survey
Transect Locations



306

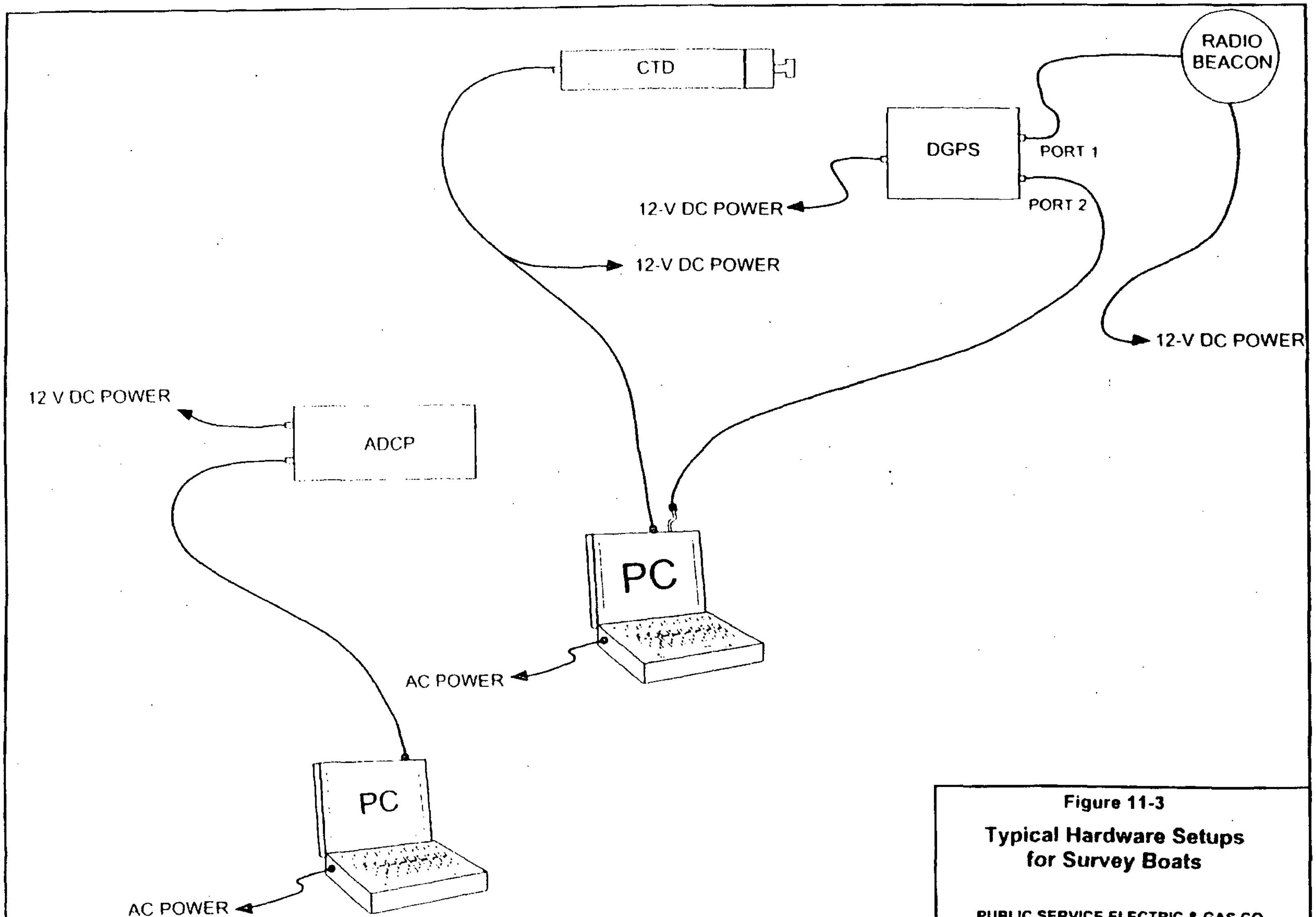


Figure 11-3

Typical Hardware Setups for Survey Boats

PUBLIC SERVICE ELECTRIC & GAS CO.

LMS Lawler, Matusky & Skelly Engineers LLP
One Blue Hill Plaza • Pearl River, New York 10965

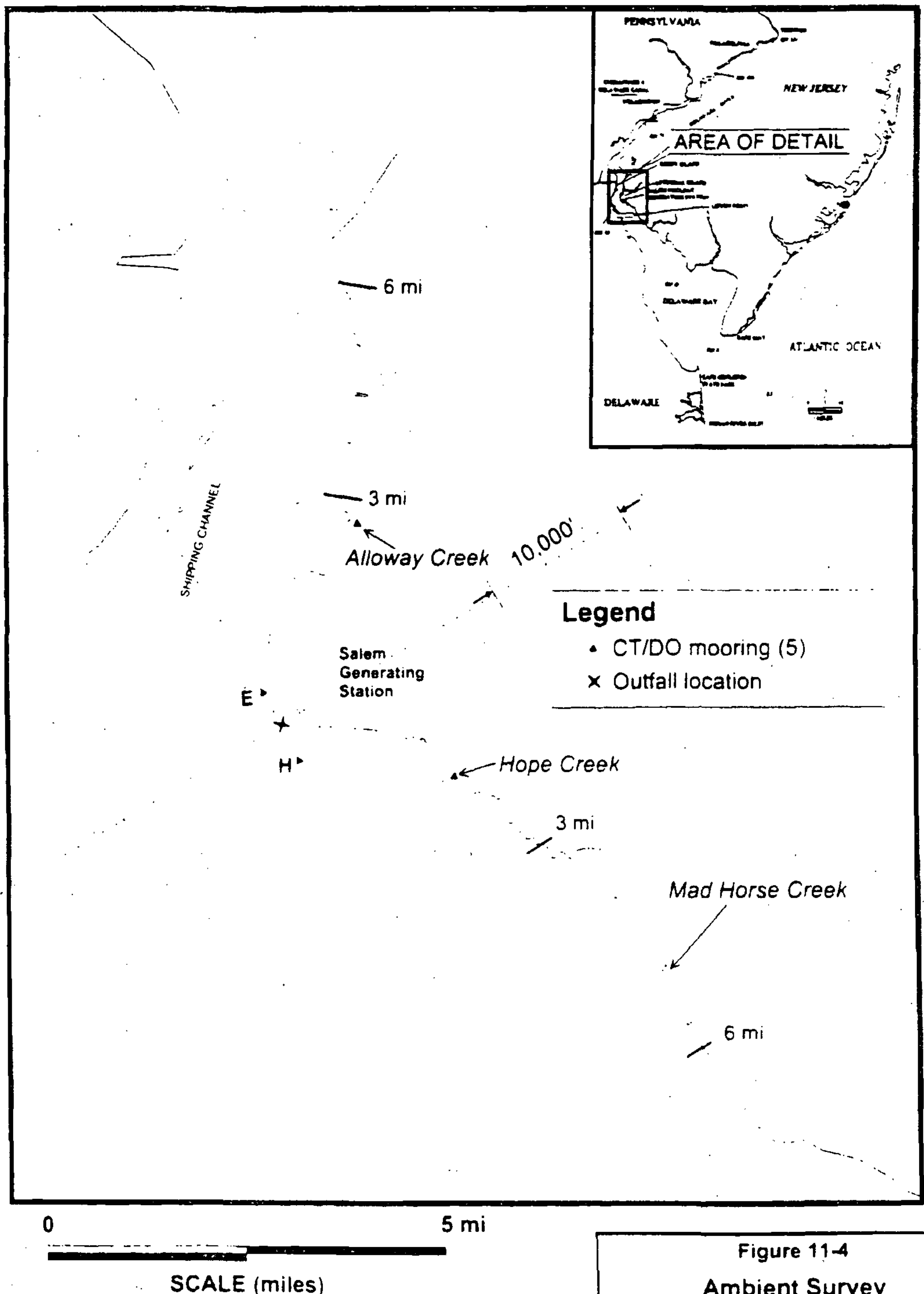


Figure 11-4

Ambient Survey Moored Station Locations

PUBLIC SERVICE ELECTRIC & GAS CO.

LMS Lawler, Matusky & Skelly Engineers LLP
One Blue Hill Plaza · Pearl River New York 10965

022-mac.csf

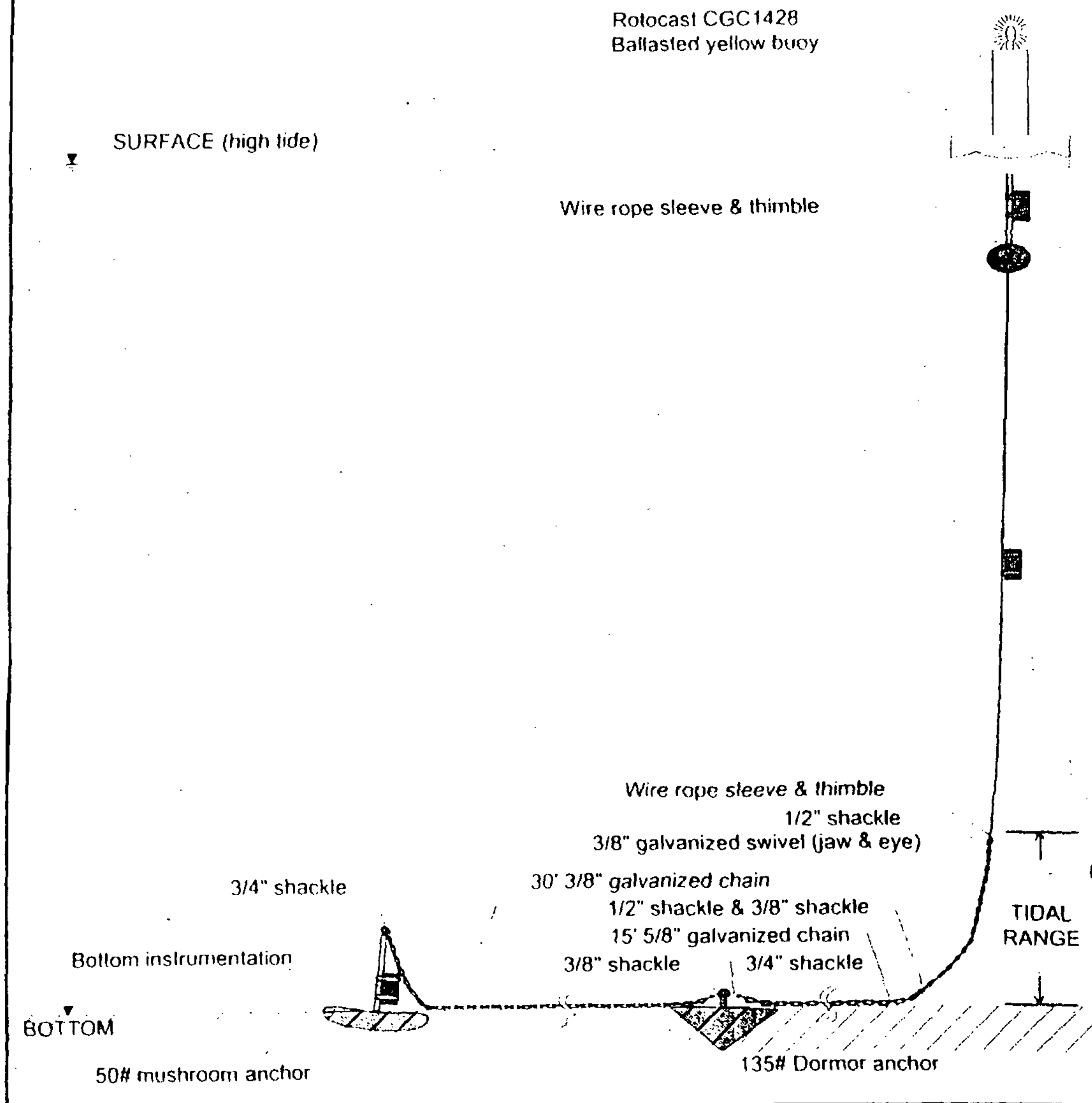


Figure 11-5

Revised Mooring Configuration

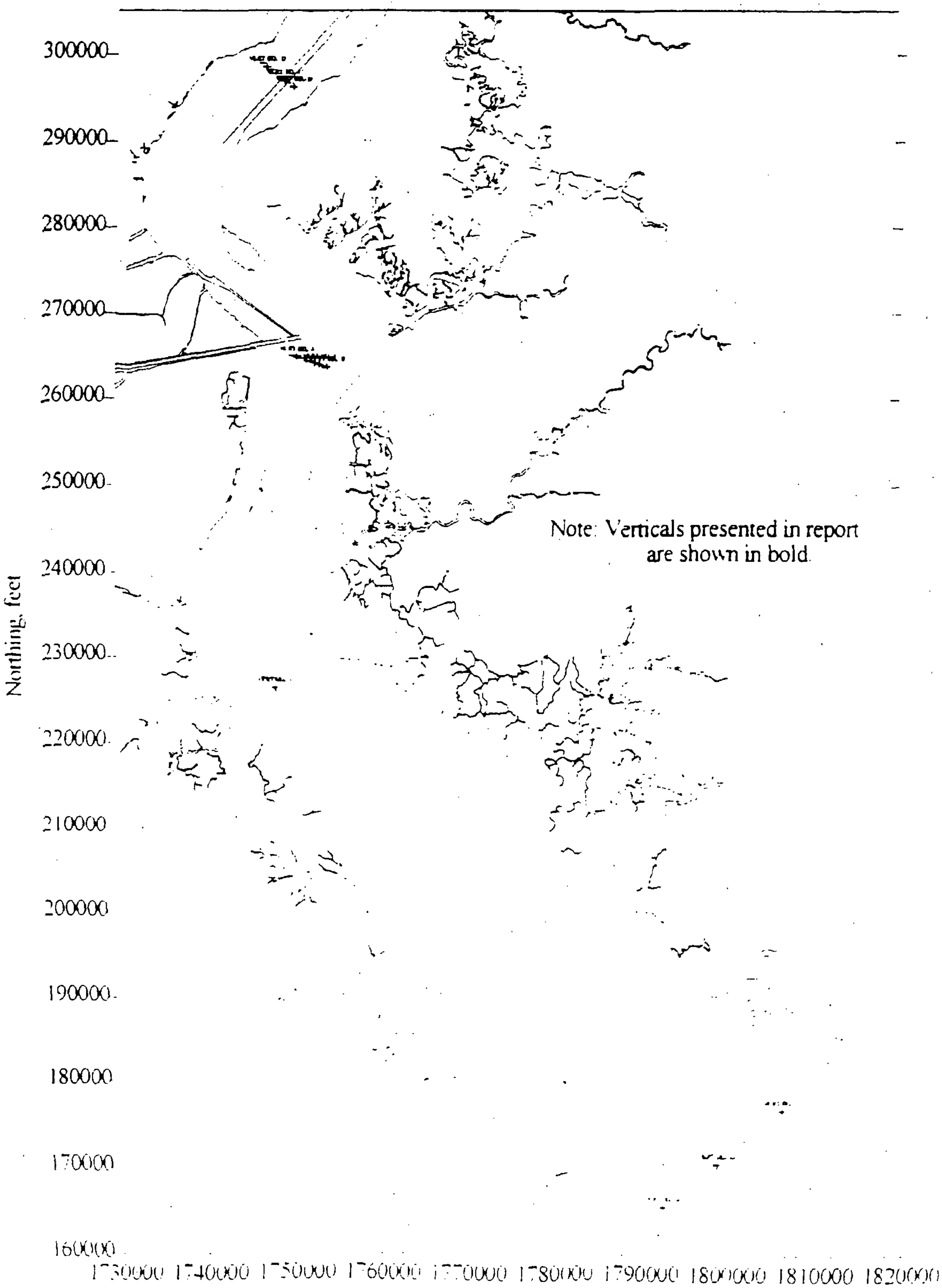
PUBLIC SERVICE ELECTRIC & GAS CO.

LMS Lawler, Matusky & Skelly Engineers LLP
One Blue Hill Plaza · Pearl River, New York 10965

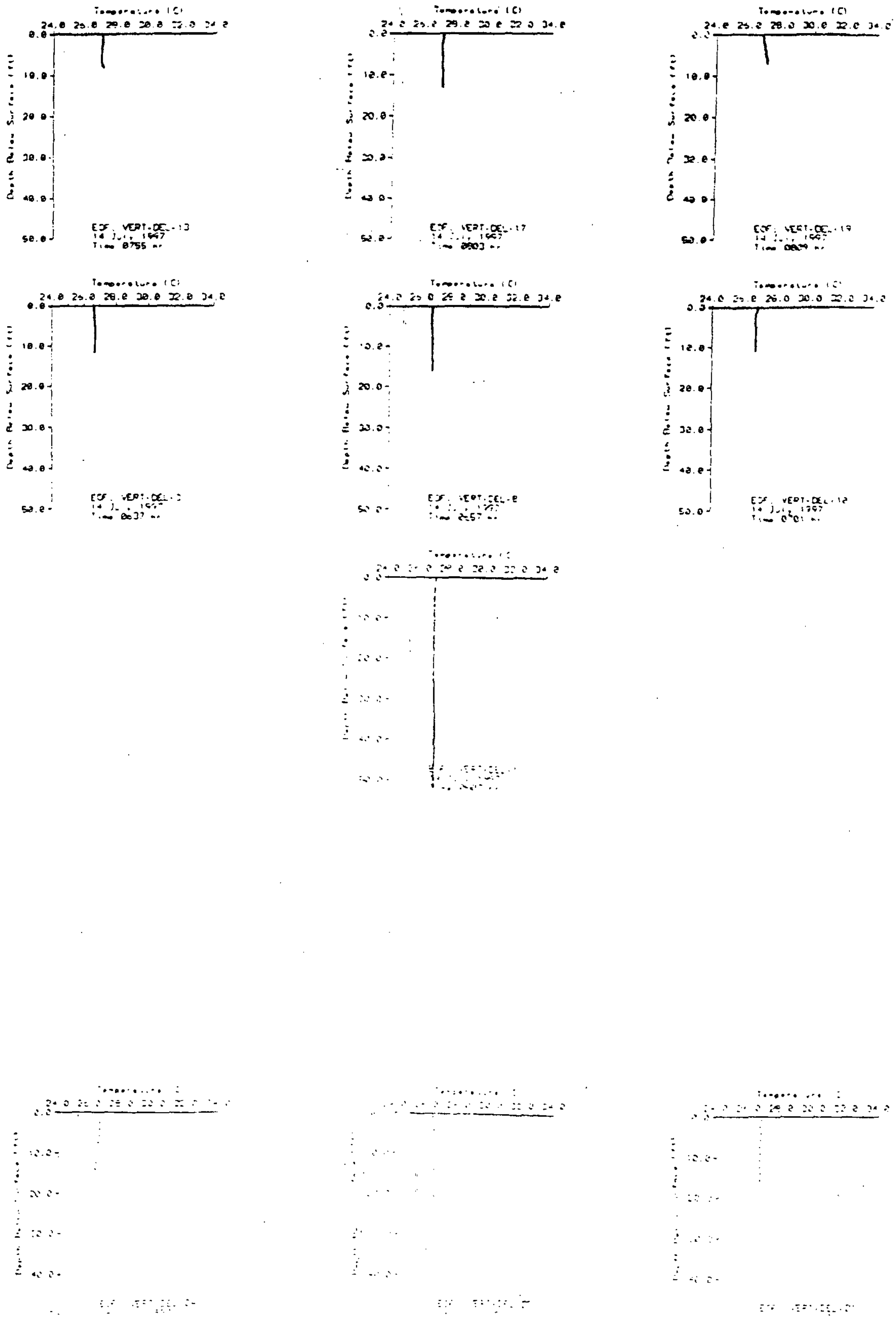
309

Part #2182-L
48d

PSE&G Ambient Survey
Vertical Locations
14 July 1997; EOF Phase

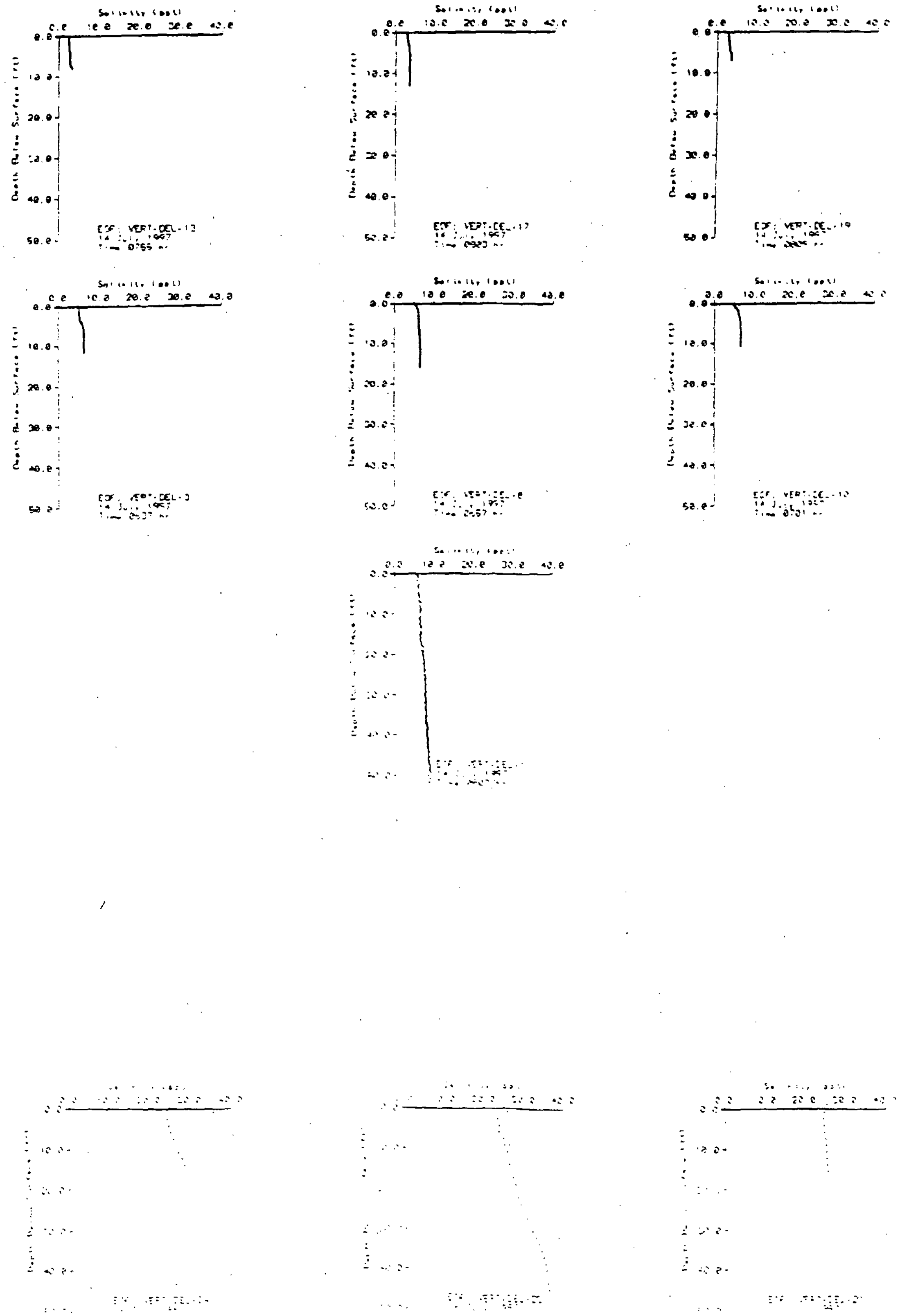


PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles
EOF Phase [06:22 - 08:22 (est)]



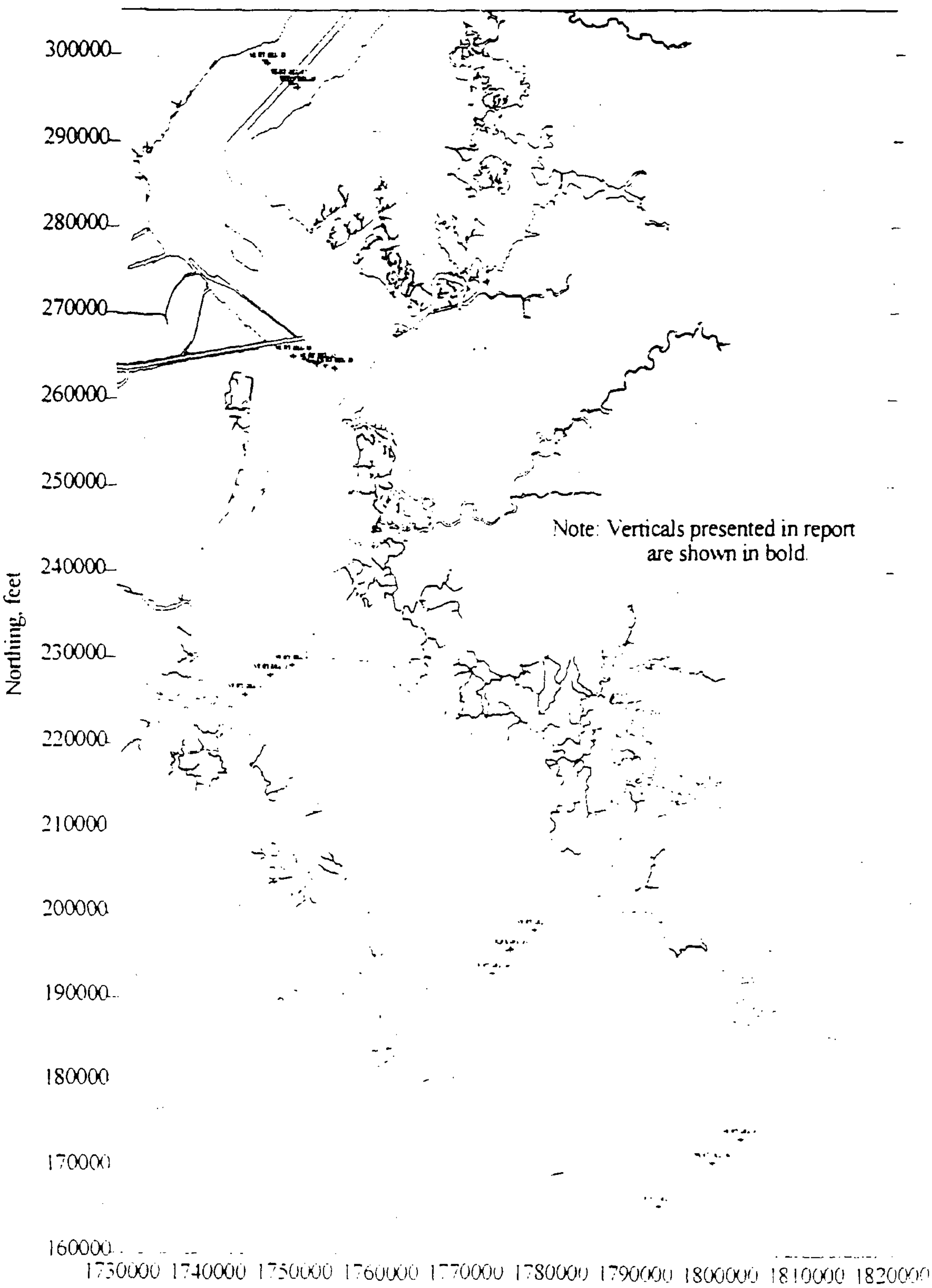
Figure

PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles
EOF Phase [06:22 - 08:22 (est)]



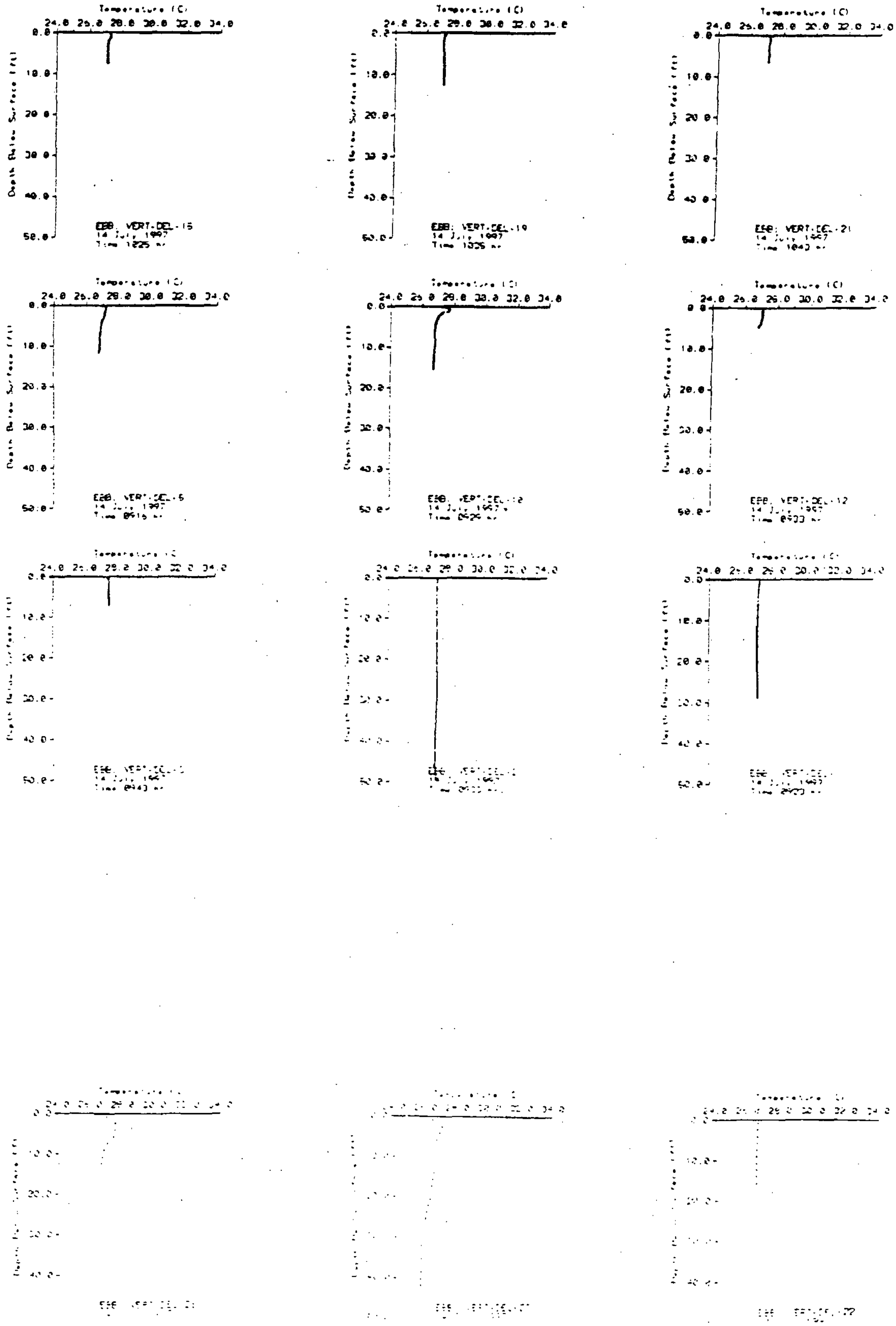
312

PSE&G Ambient Survey
Vertical Locations
14 July 1997; Ebb Phase



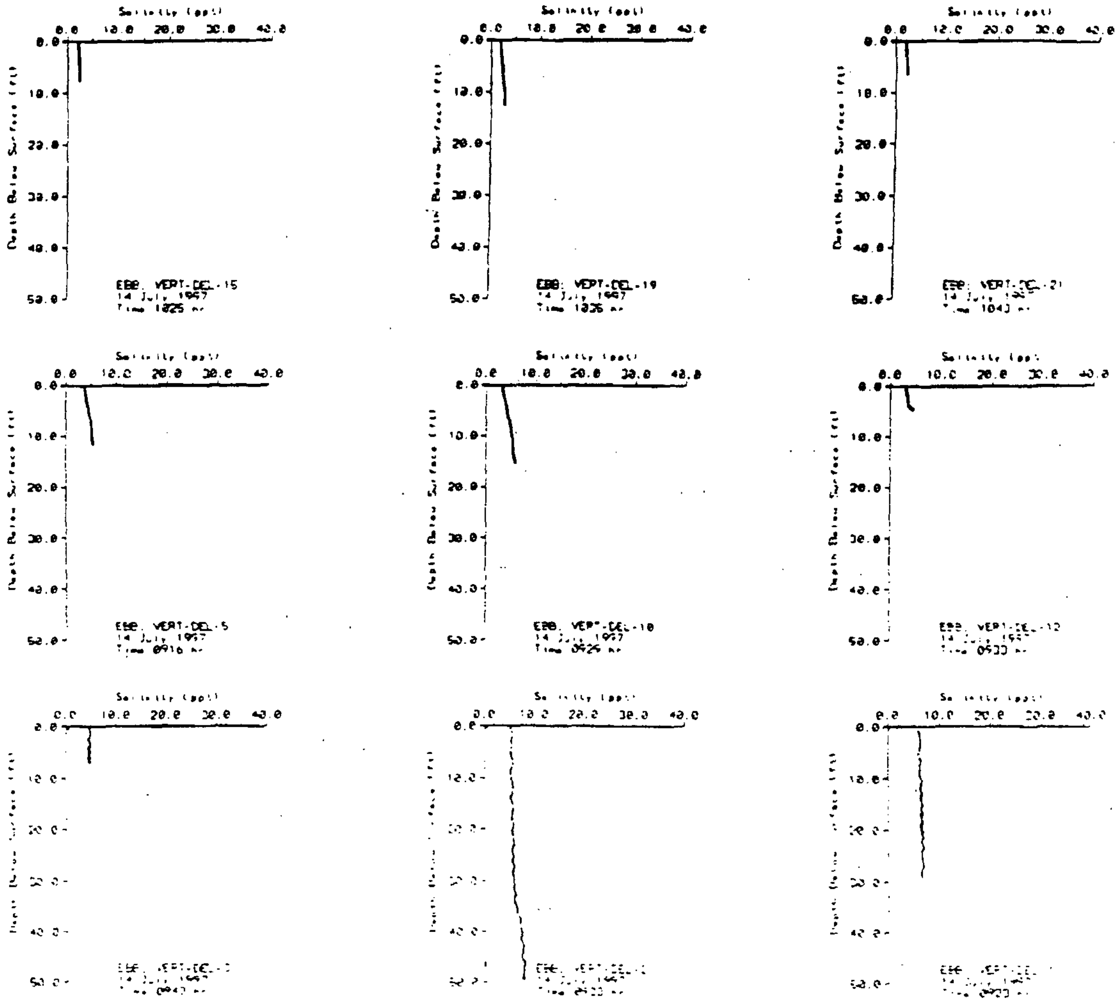
313

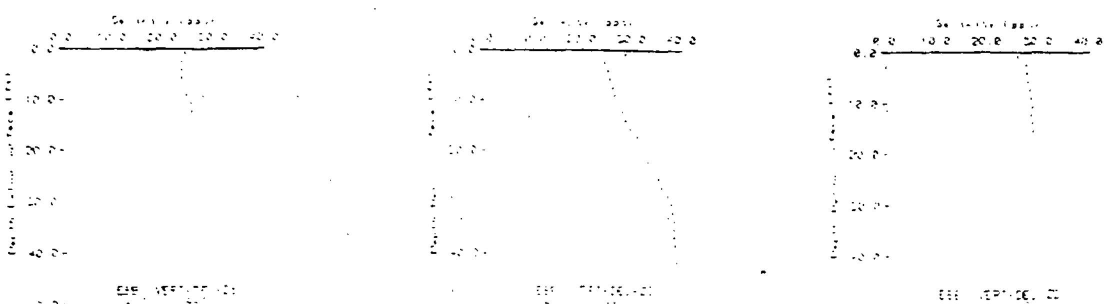
PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles
Ebb Phase [09:51 - 11:51 (est)]



314

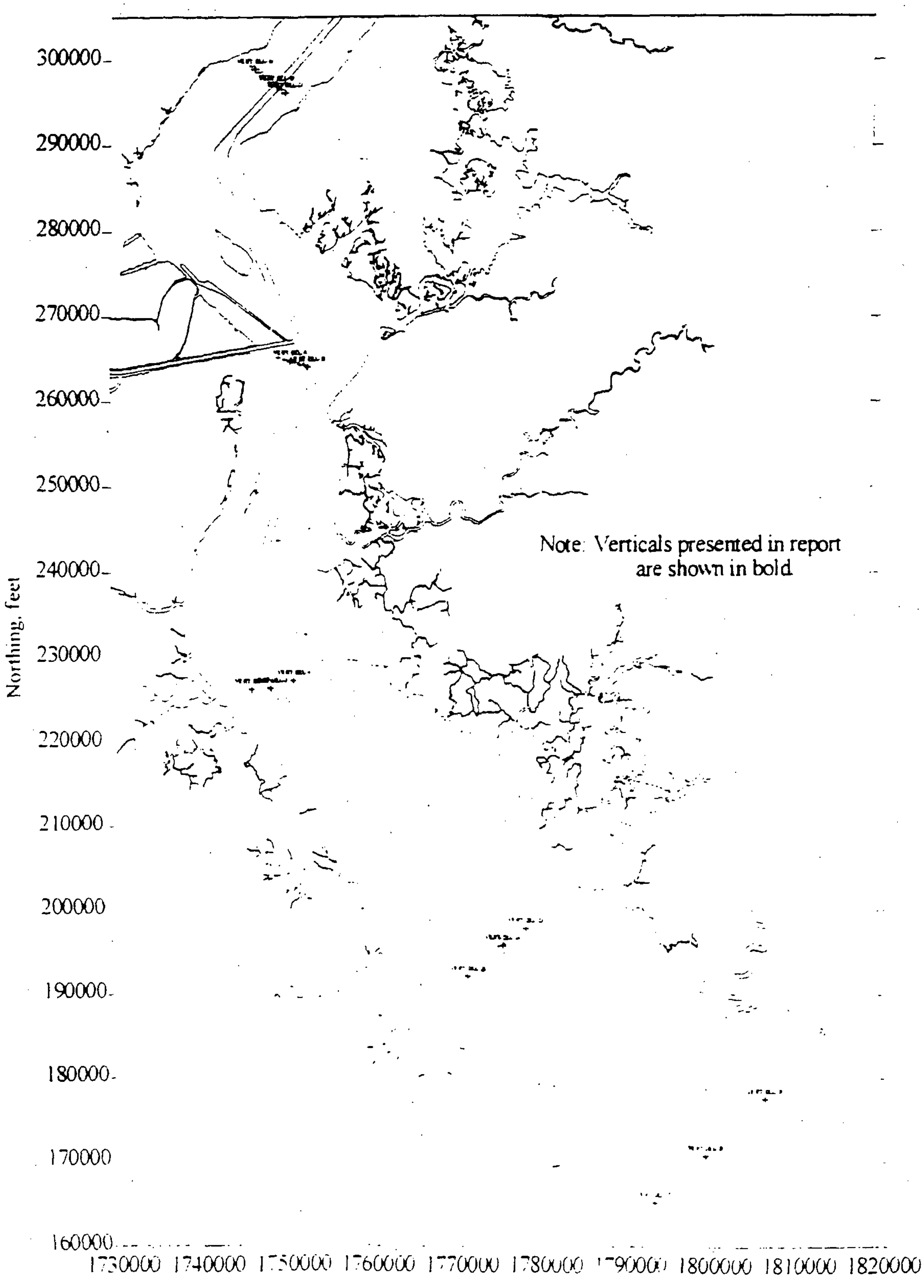
PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles
Ebb Phase [09:51 - 11:51 (est)]





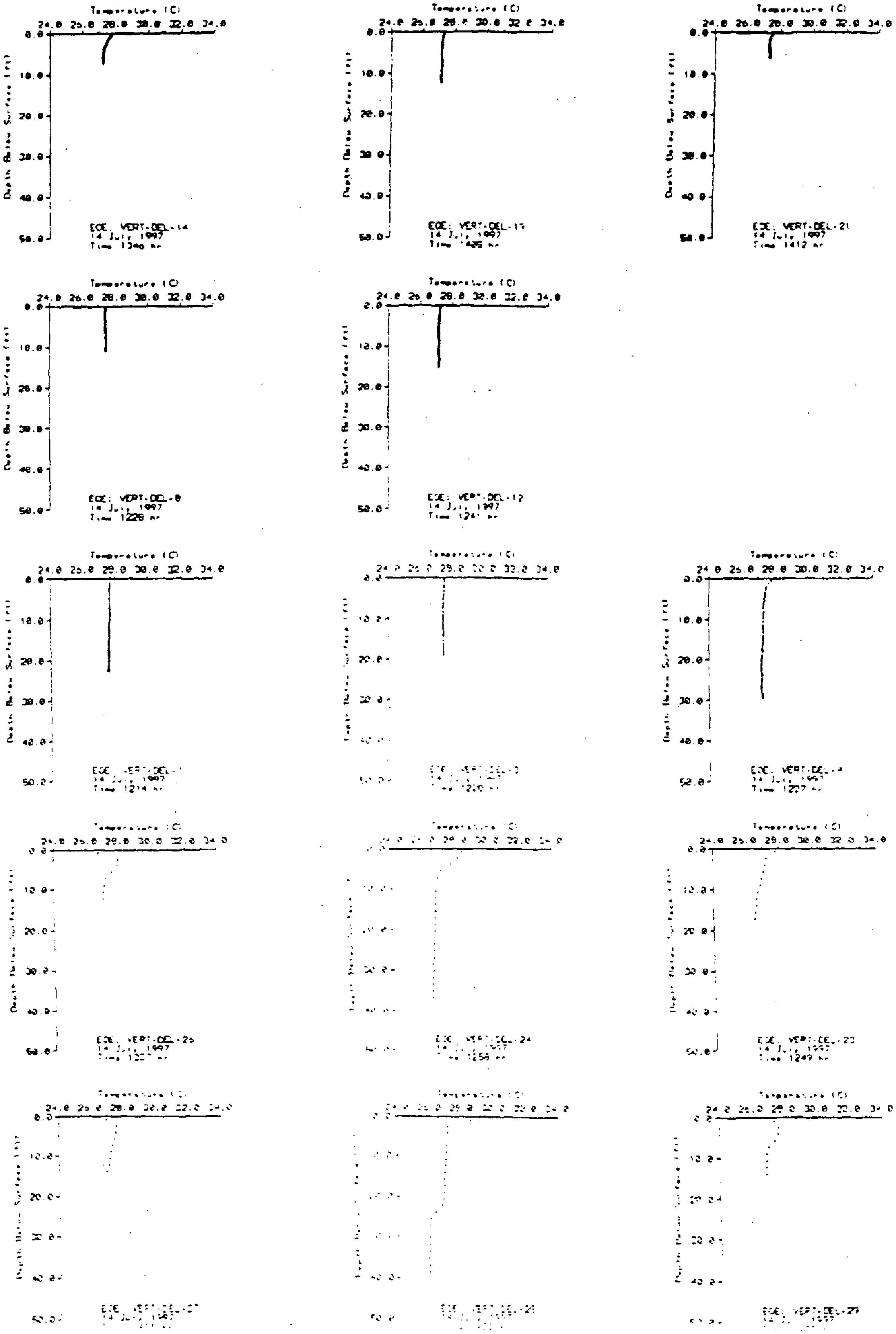
315

PSE&G Ambient Survey
Vertical Locations
14 July 1997; EOE Phase



316

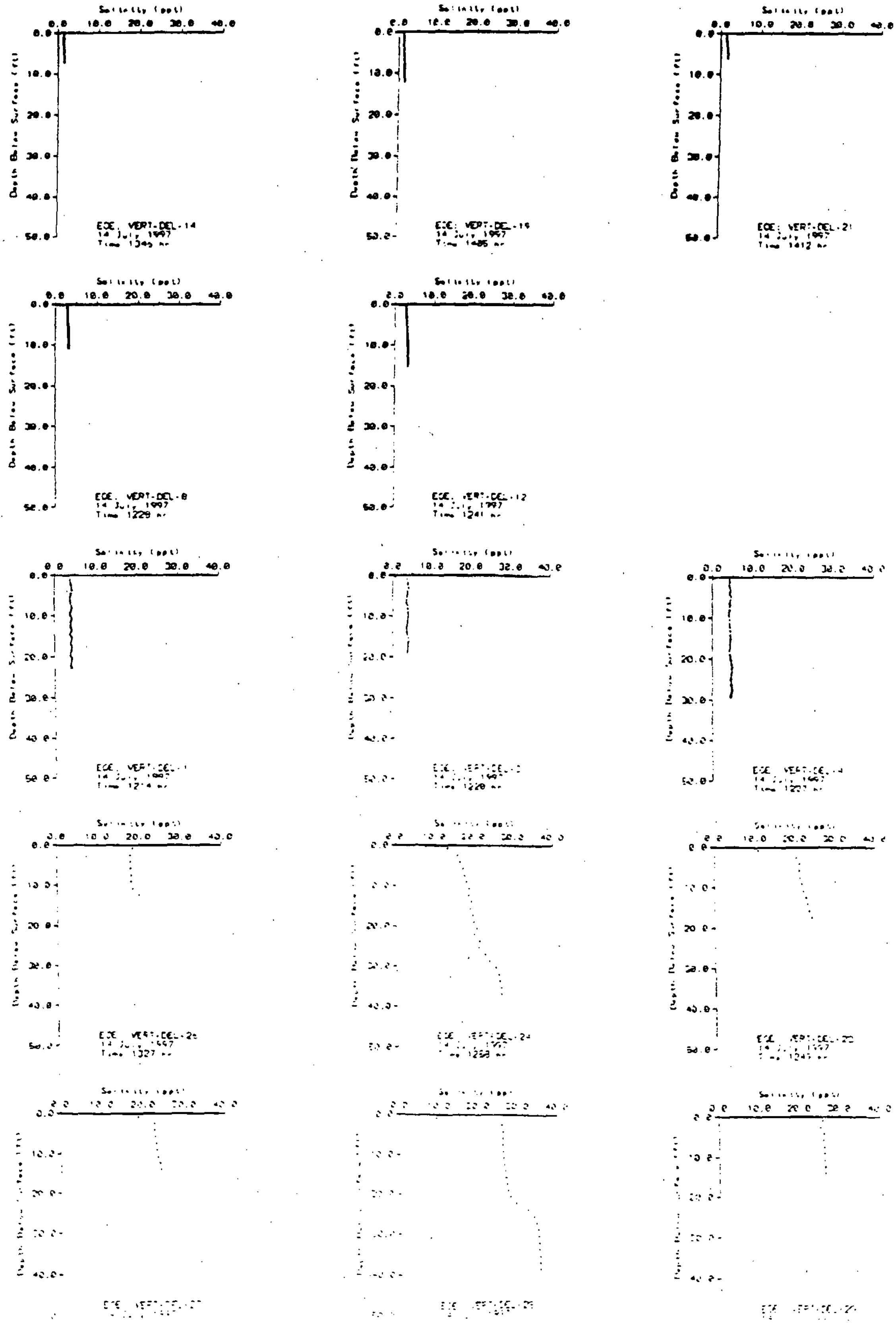
Figure [illegible]
PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles
EOE Phase [12:39 - 14:39 (est)]



317

Figure

PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles
EOE Phase [12:39 - 14:39 (est)]



318

PSE&G Ambient Survey
Vertical Locations
14 July 1997; Flood Phase

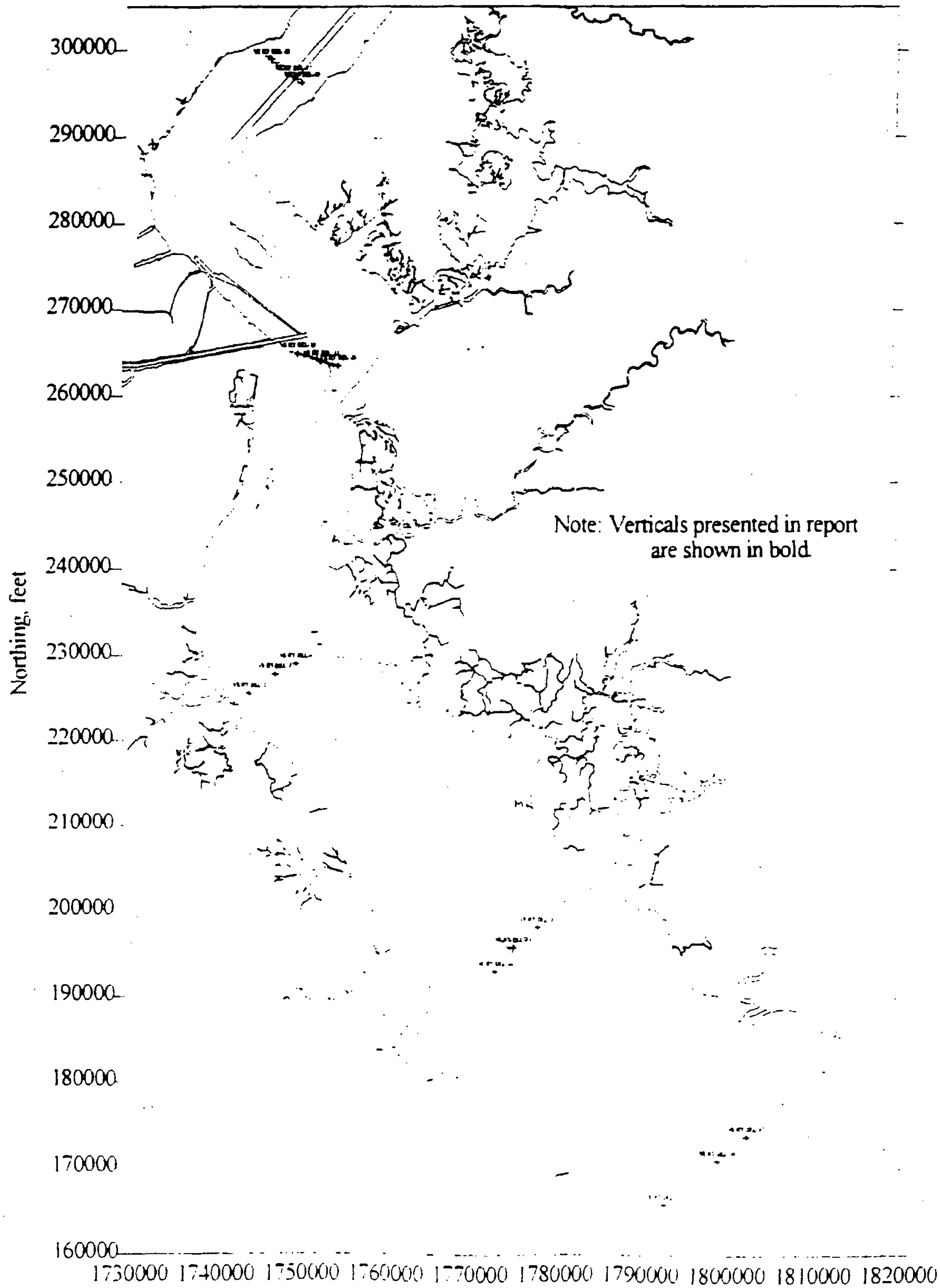
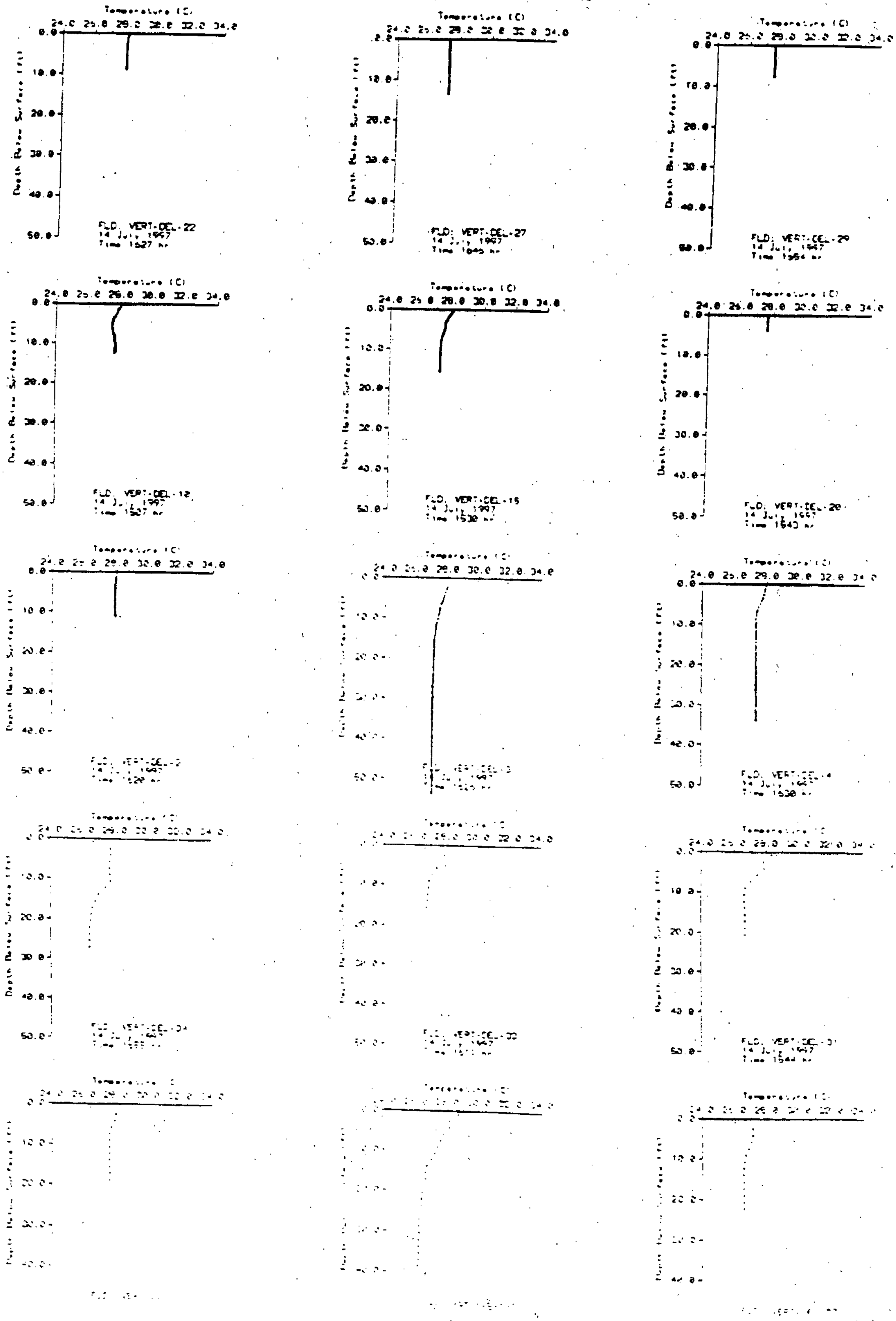


Figure 11-16

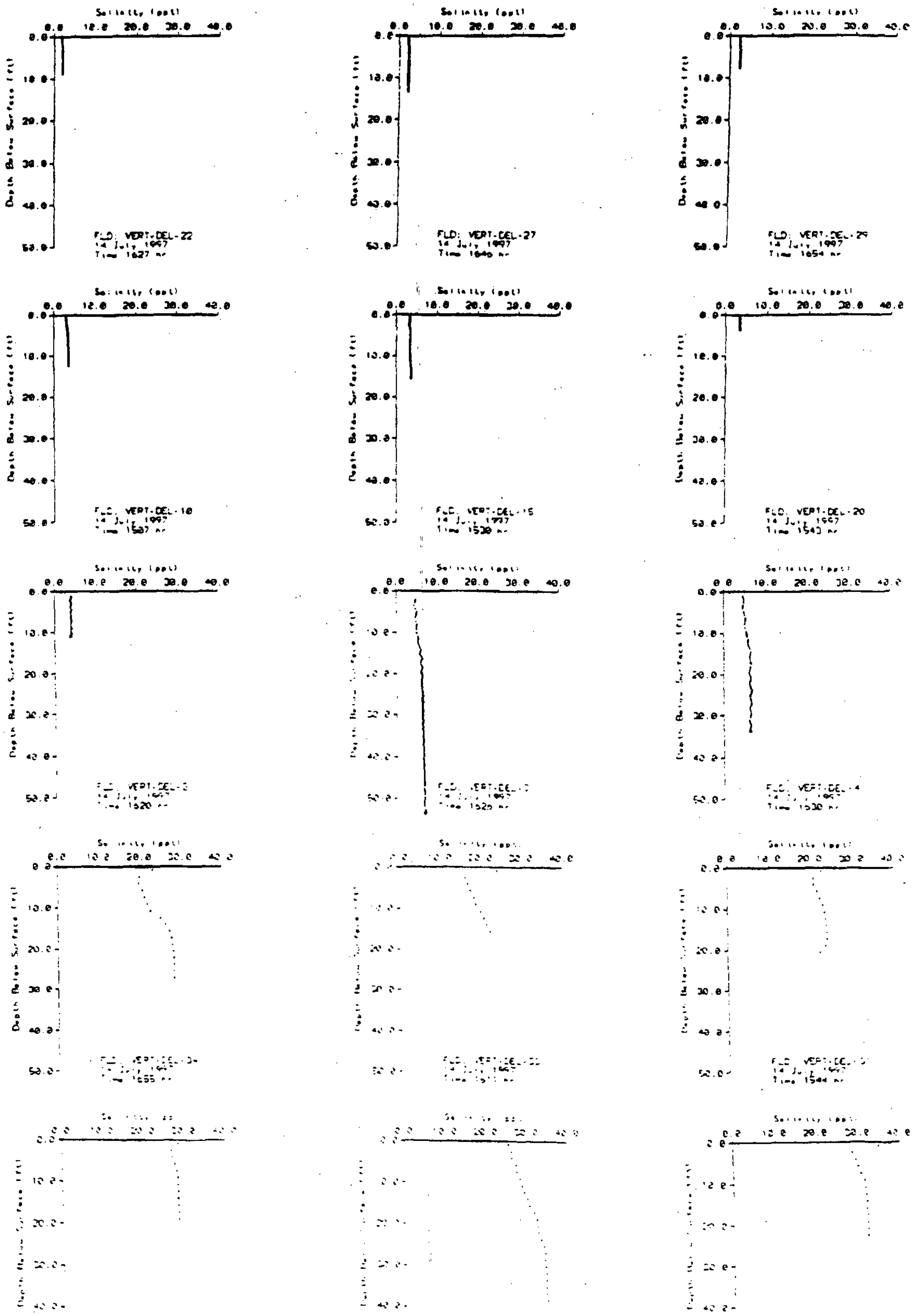
PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles
Flood Phase [16:15 - 18:15 (est)]

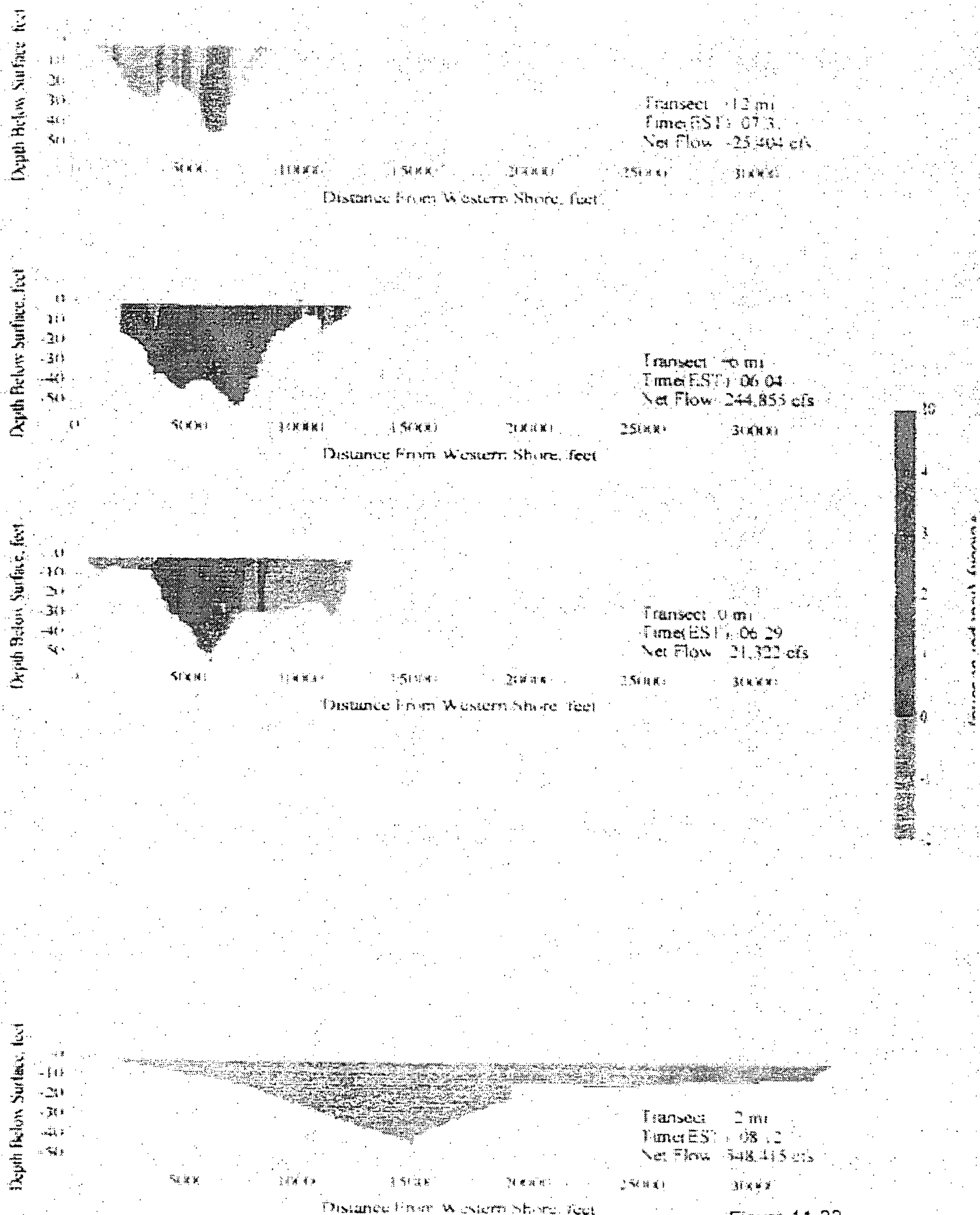


320

Figure 11-17

PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles
Flood Phase [16:15 - 18:15 (est)]





Note: Velocities are in fps.

Figure 11-22

PSE&G Ambient Survey: 14 July 1997
Delaware River Velocity Profiles
EOF PHASE [06:22-08:22 (est)]

326

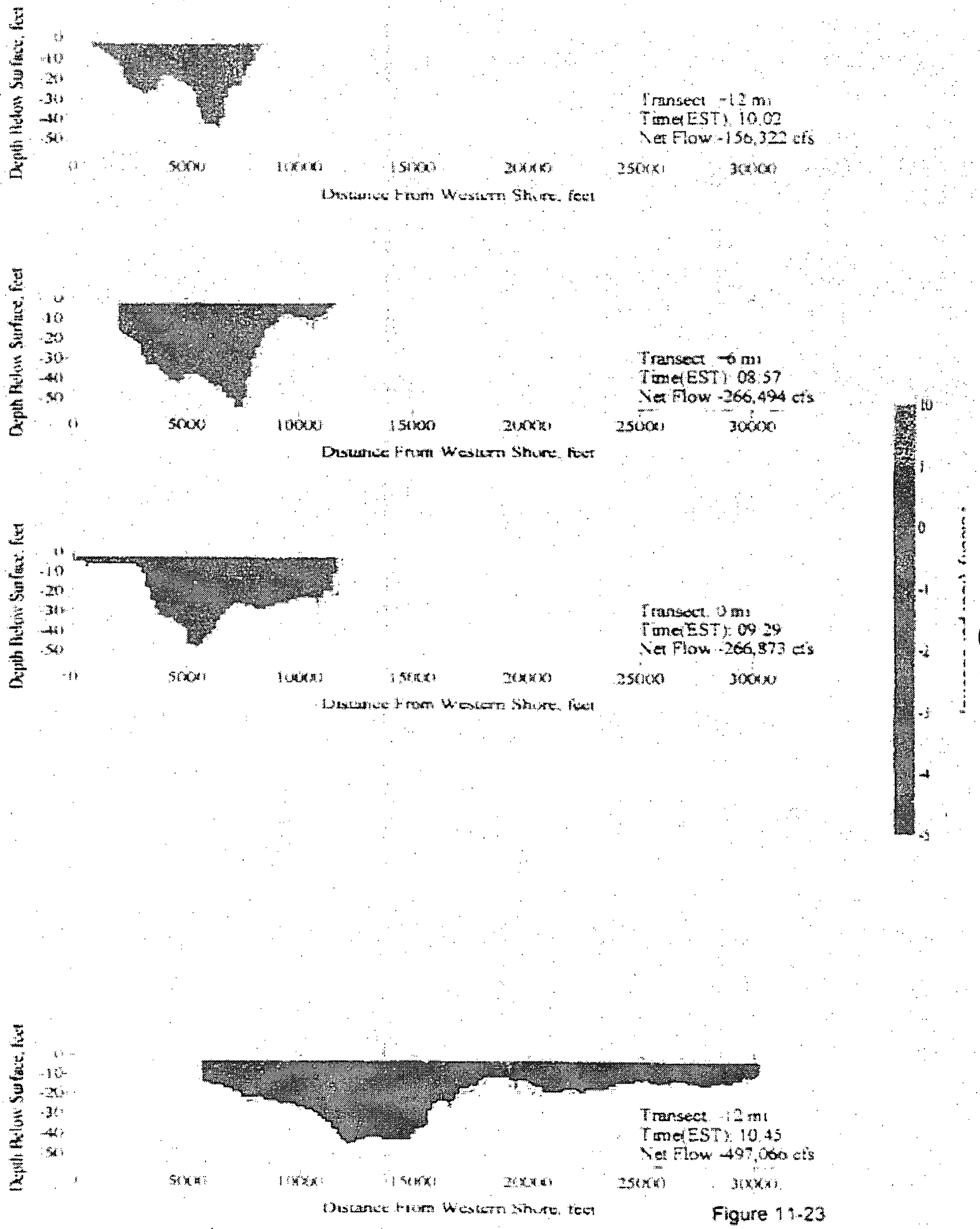


Figure 11-23

PSE&G Ambient Survey: 14 July 1997
Delaware River Velocity Profiles
EBB PHASE [09:51-11:51 (est)]

Note: Velocities are in fps.

32

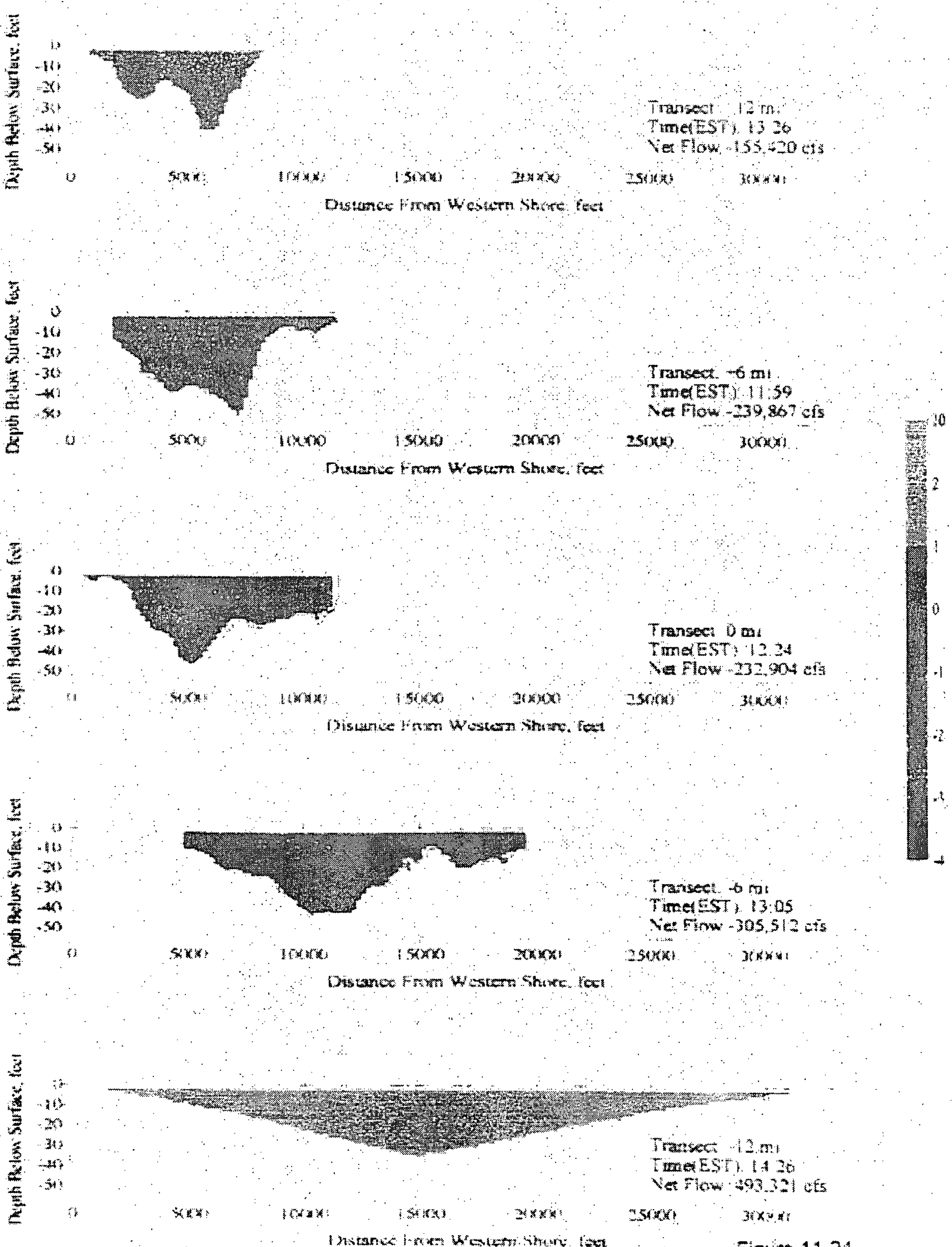


Figure 11-24

PSE&G Ambient Survey: 14 July 1997
Delaware River Velocity Profiles
EOE PHASE [12:39-14:39 (est)]

Note: Velocities are in fps.

328

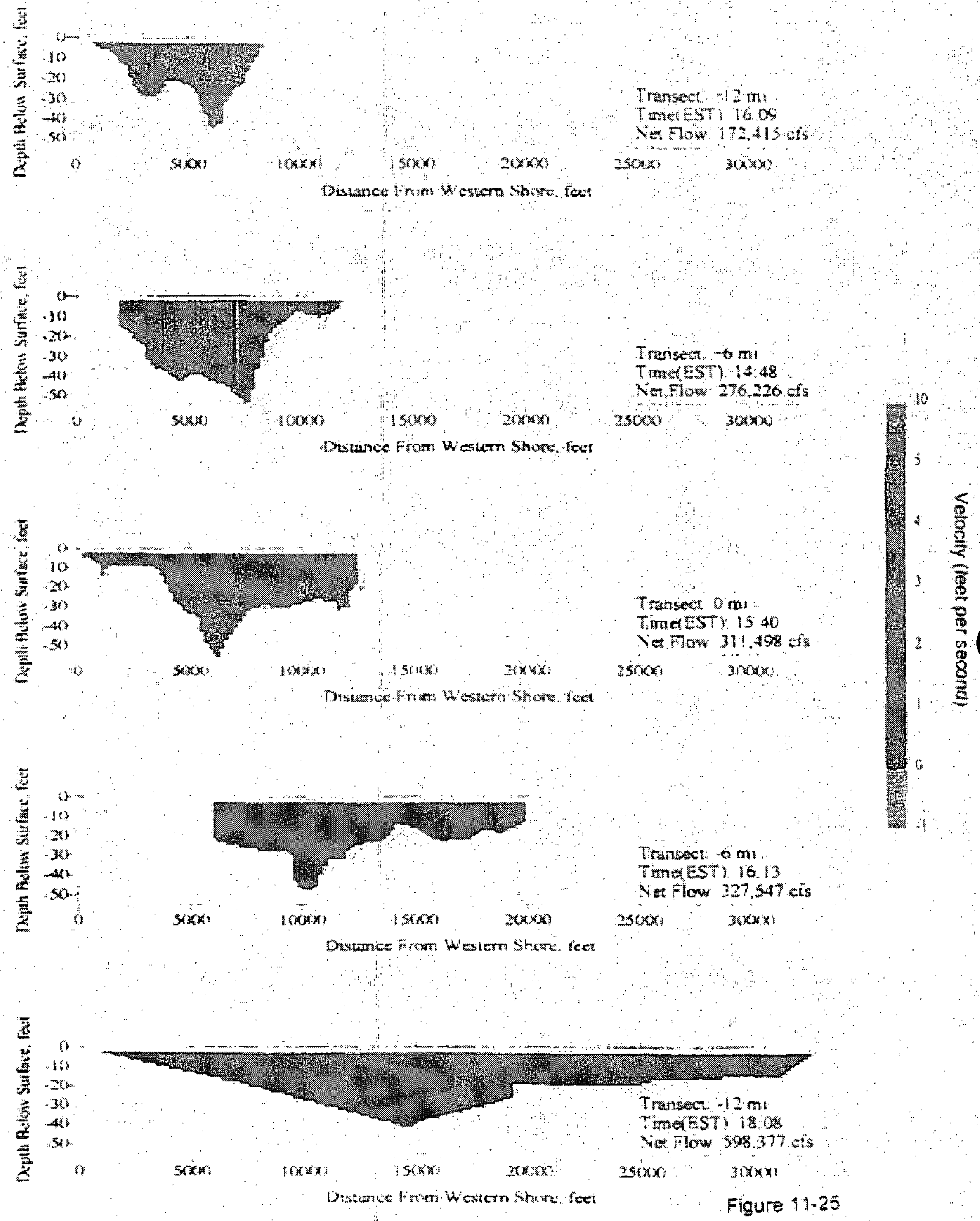


Figure 11-25

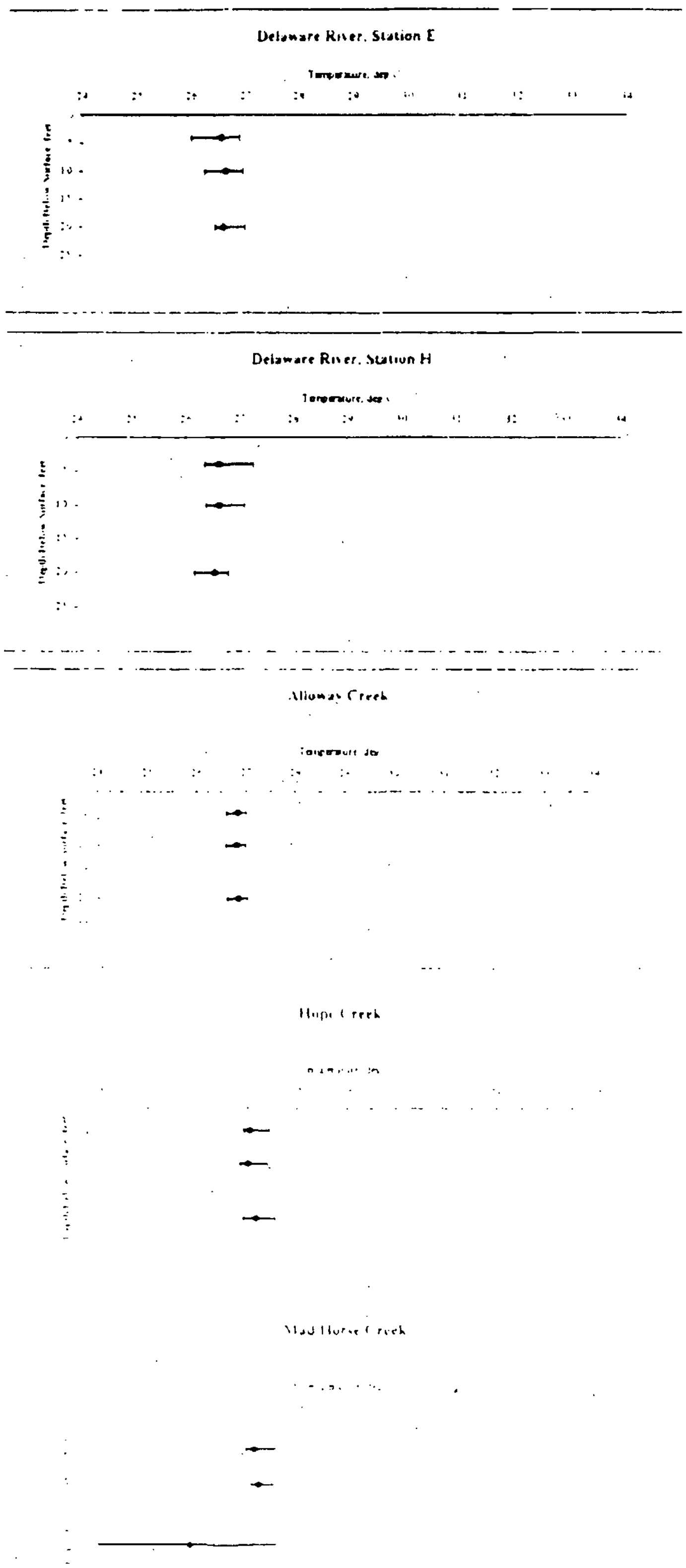
PSE&G Ambient Survey; 14 July 1997
Delaware River Velocity Profiles
FLOOD PHASE [16:15-18:15 (est)]

Note: Velocities are in fps.

32c

Figure 11-26

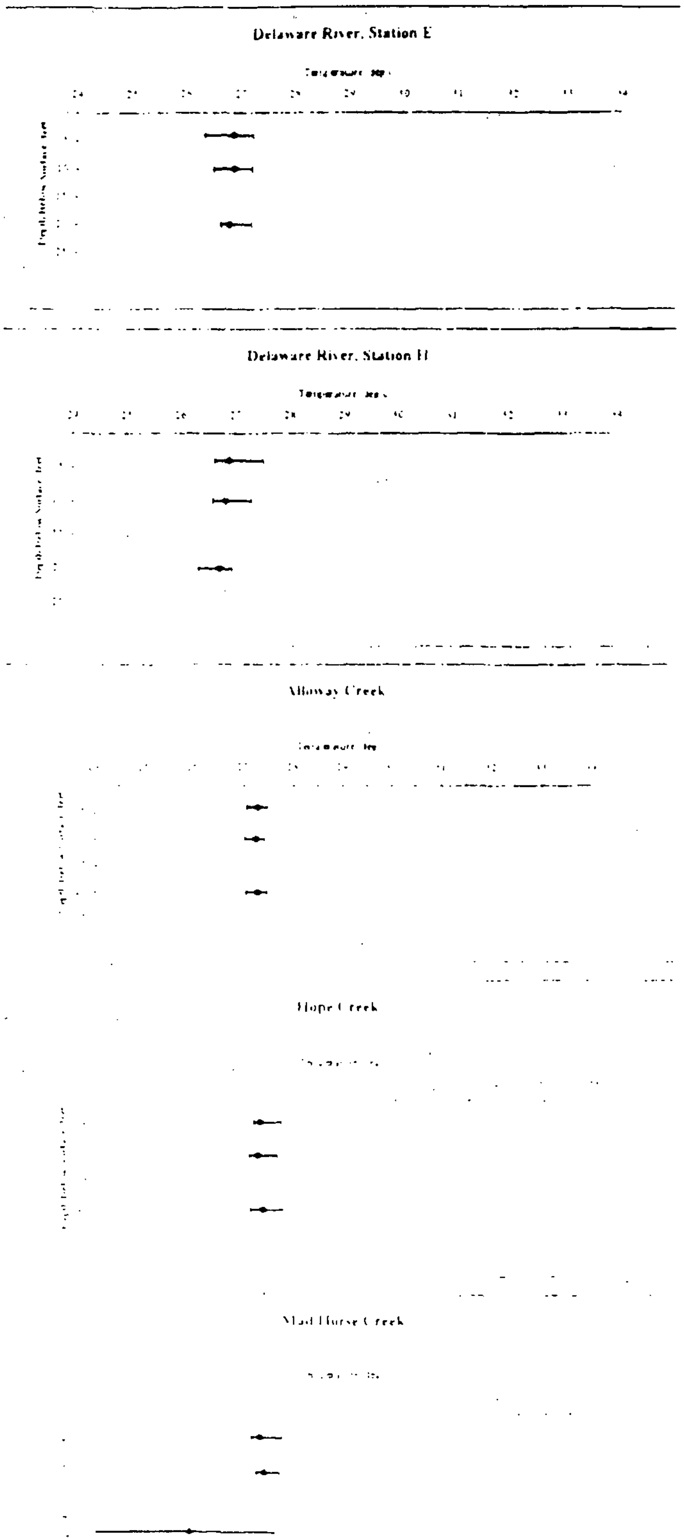
PSE&G Ambient Survey: 14 July 1997
Temperature Vertical Profiles (Moorings)
EOF Phase (06:22 - 08:22)



330

Figure 11-27

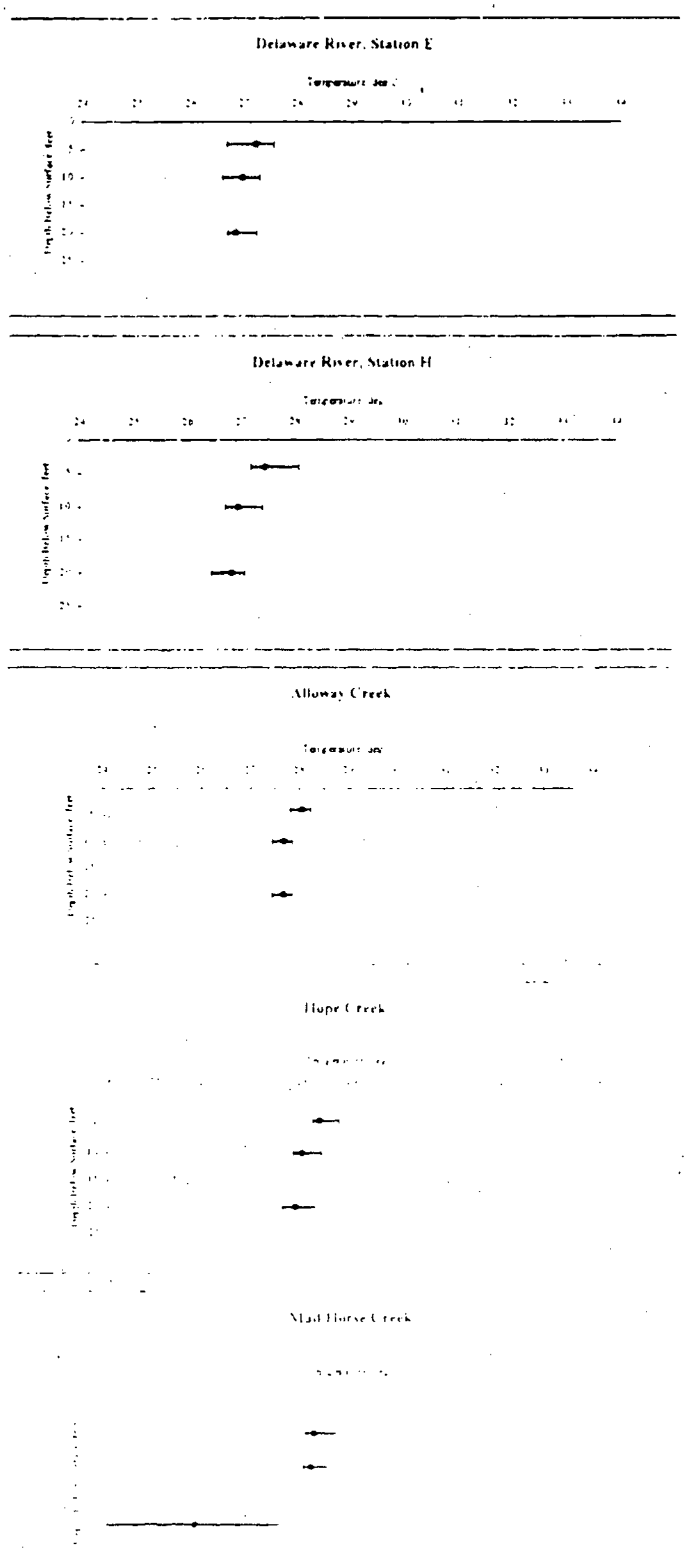
PSE&G Ambient Survey: 14 July 1997
Temperature Vertical Profiles (Moorings)
Ebb Phase (09:51 - 11:51)



331

Figure 11-28

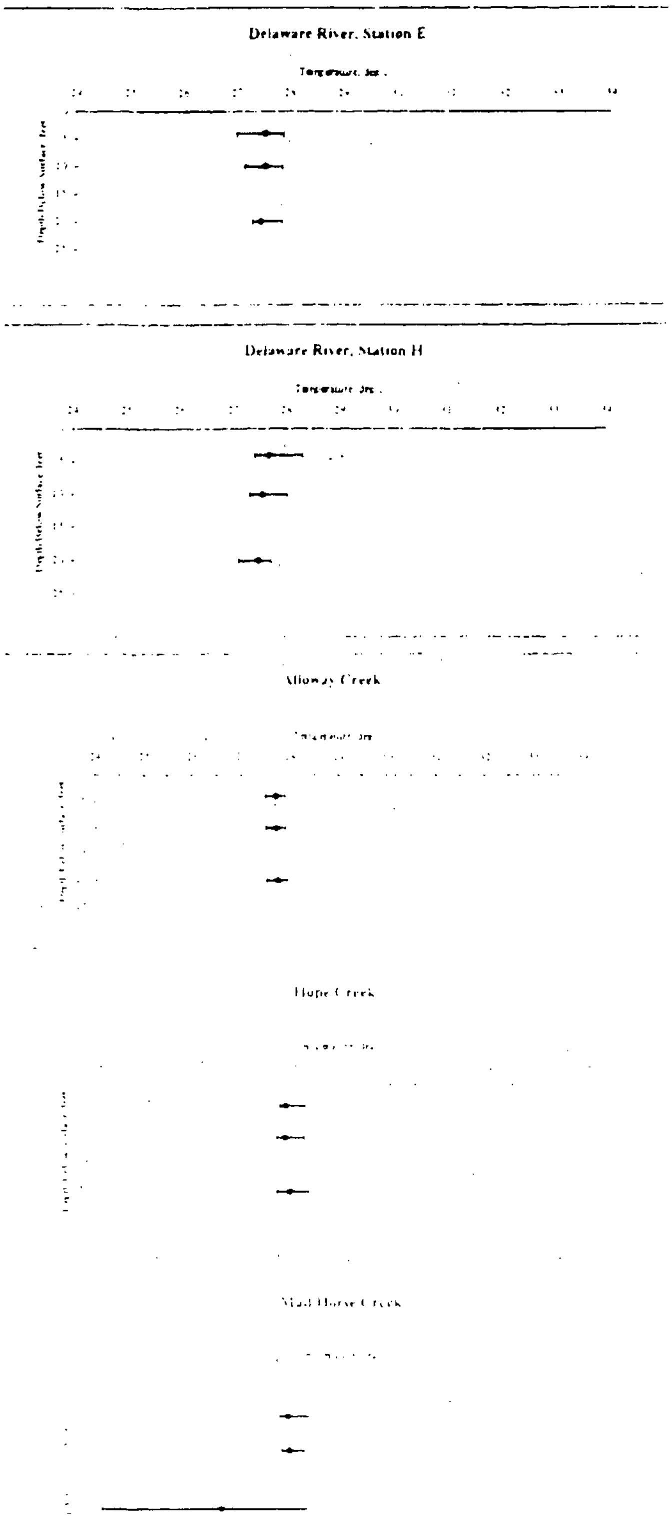
PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles (Moorings)
EOE Phase (12:39 - 14:39)



332

Figure 11-29

PSE&G Ambient Survey; 14 July 1997
Temperature Vertical Profiles (Moorings)
Flood Phase (16:15 - 18:15)

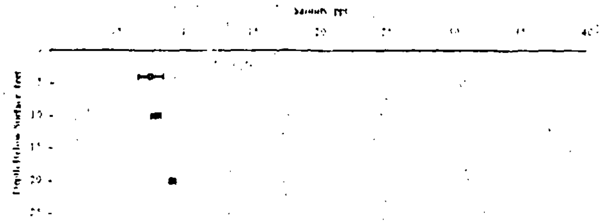


333

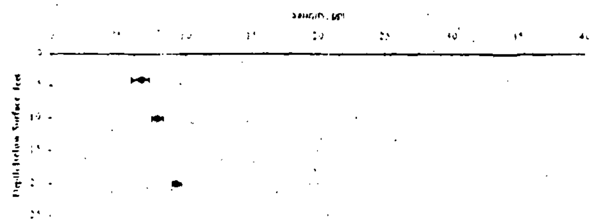
Figure 11-30

PSE&G Ambient Survey: 14 July 1997
Salinity Vertical Profiles (Moorings)
EOF Phase (06:22 - 08:22)

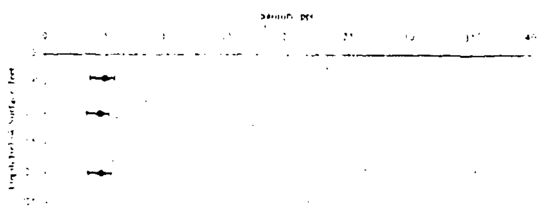
Delaware River, Station E



Delaware River, Station H



Alloway Creek



Hope Creek

Mad Horse Creek

334

Figure 11-31

PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles (Moorings)
Ebb Phase (09:51 - 11:51)

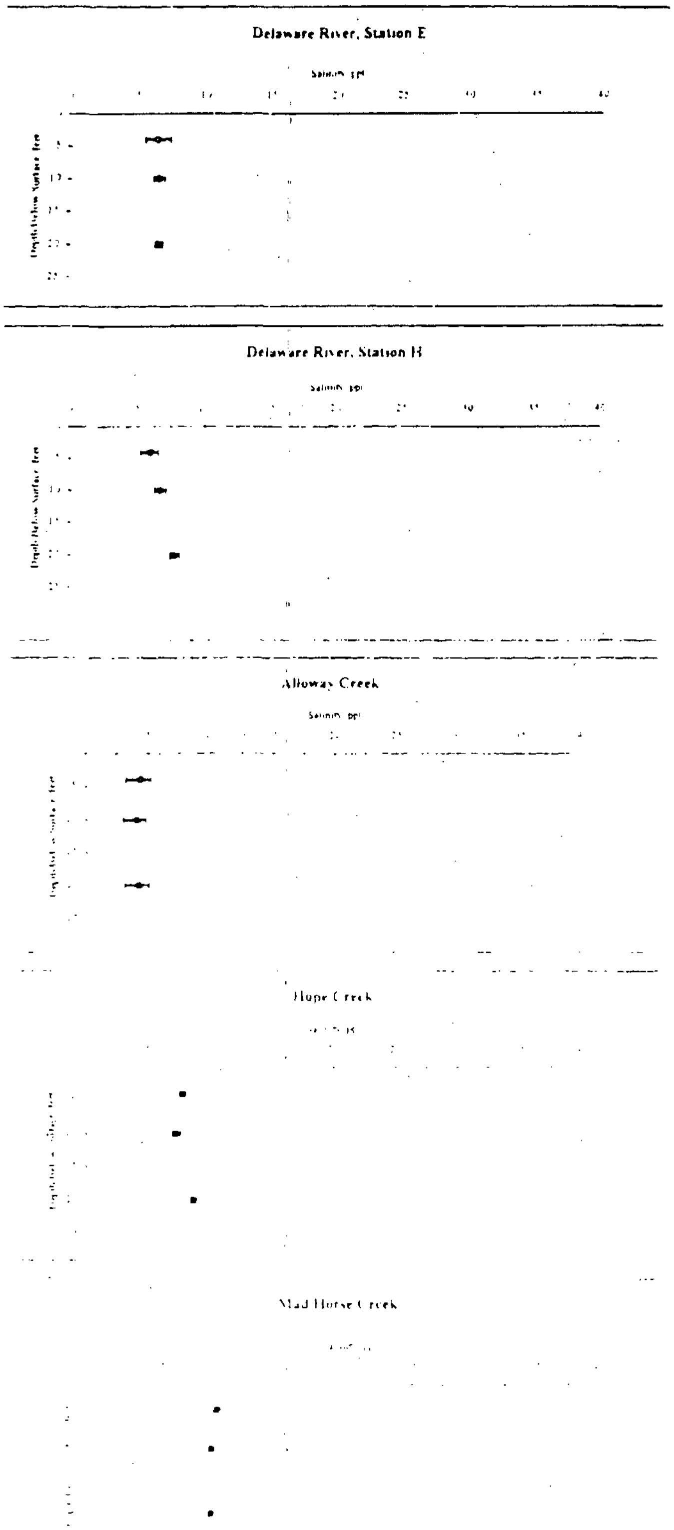


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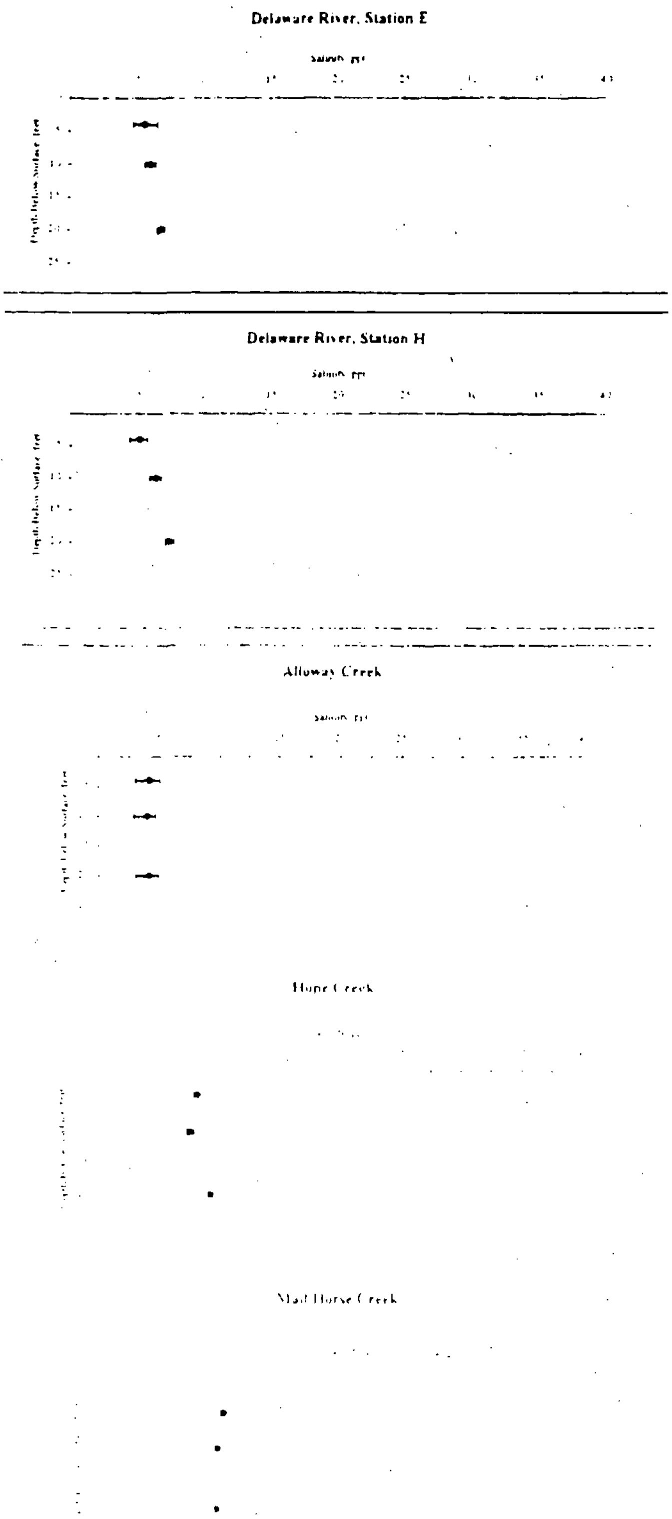
Figure 11-32

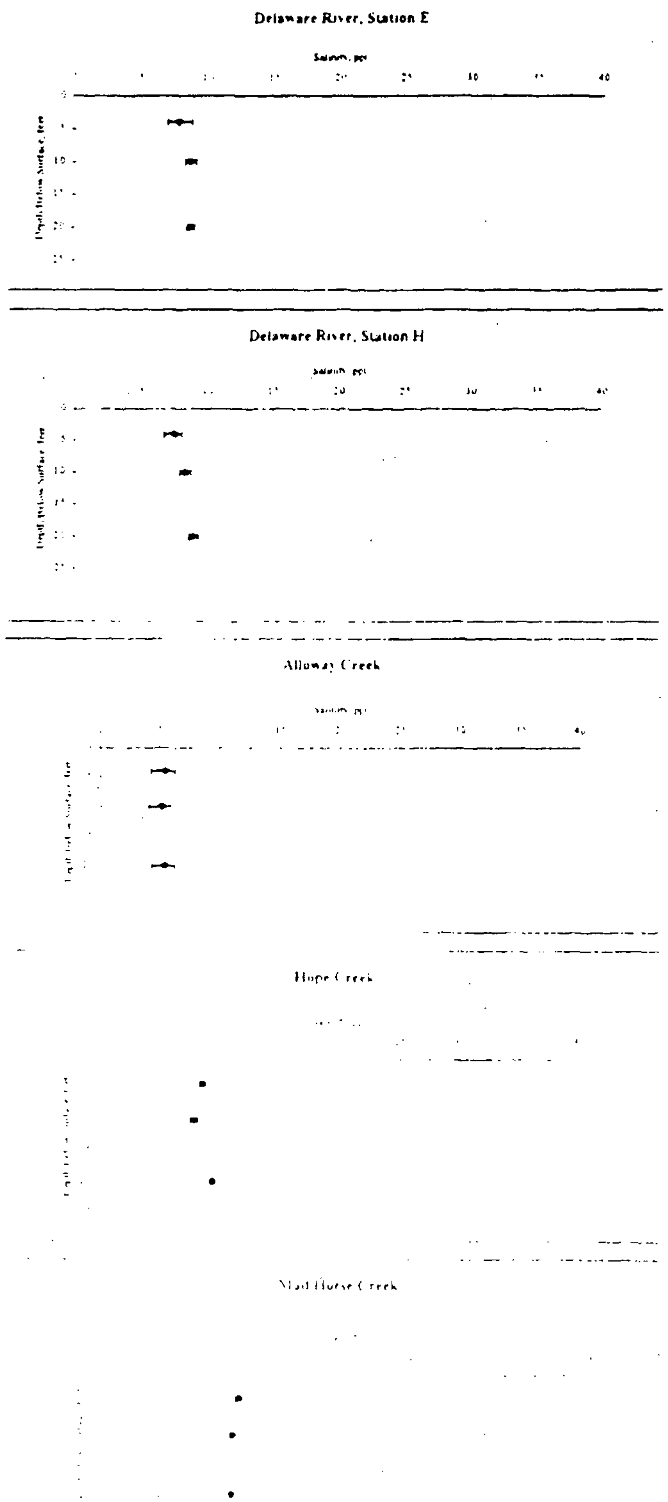
PSE&G Ambient Survey; 14 July 1997
Salinity Vertical Profiles (Moorings)
EOE Phase (12:39 - 14:39)



336

Figure 11-33

PSE&G Ambient Survey: 14 July 1997
Salinity Vertical Profiles (Moorings)
Flood Phase (16:15 - 18:15)



337

PSE&G Ambient Survey; 14 July 1997
Dissolved Oxygen Vertical Profiles (Moorings)
EOF Phase (06:22 - 08:22)

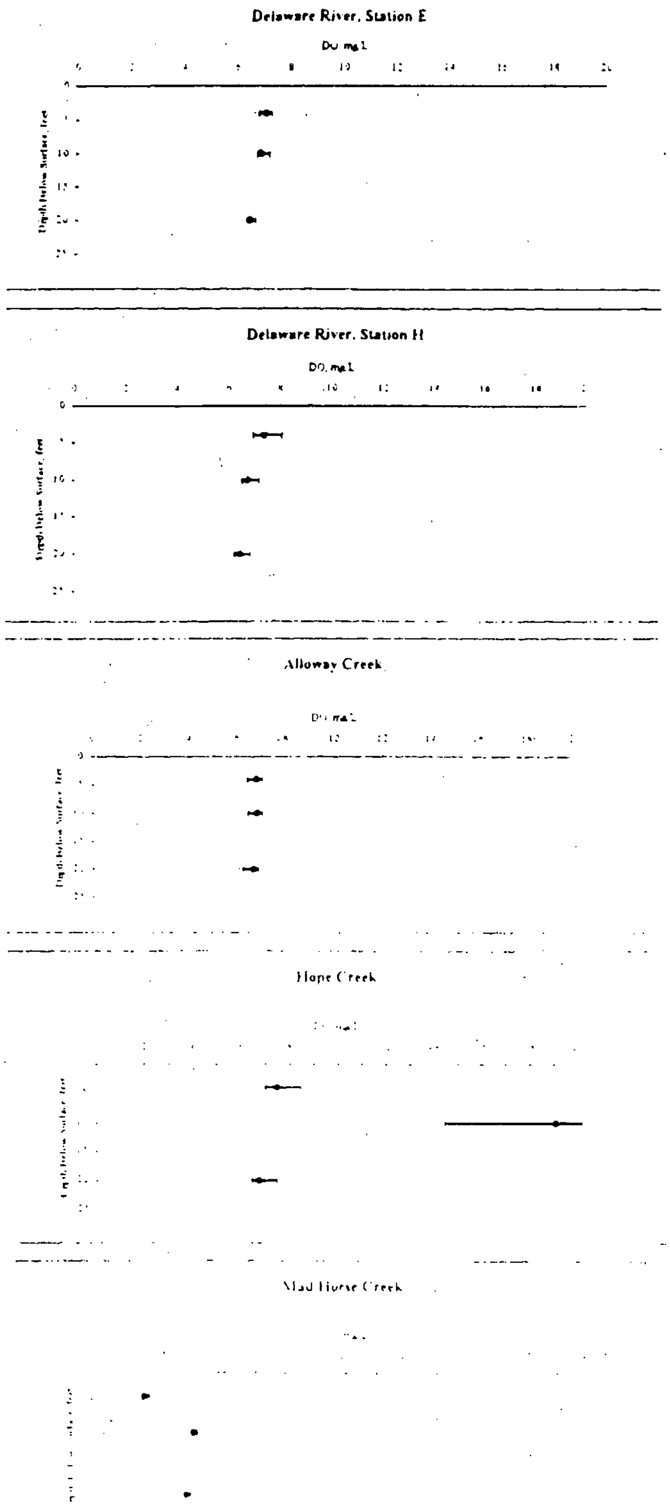


Figure 11-35

PSE&G Ambient Survey; 14 July 1997
Dissolved Oxygen Vertical Profiles (Moorings)
Ebb Phase (09:51 - 11:51)

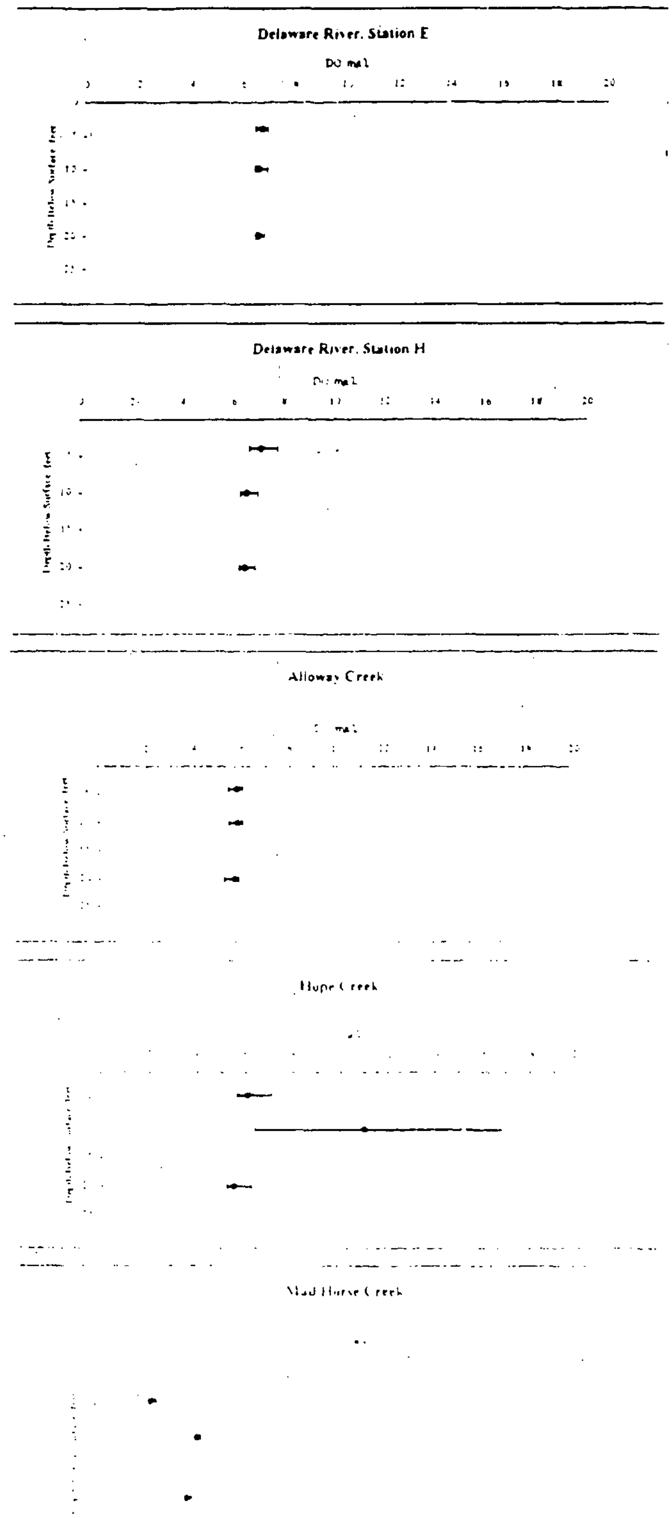


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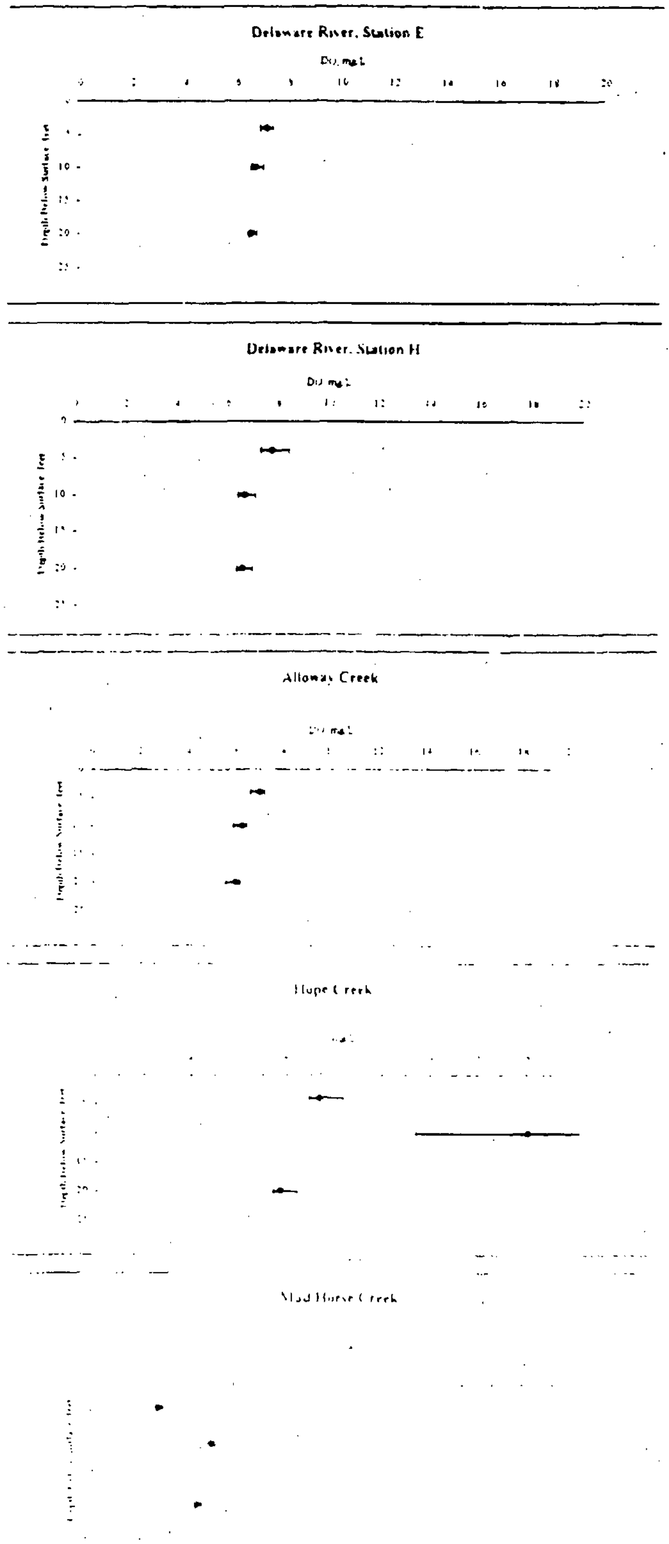
Figure 11-36

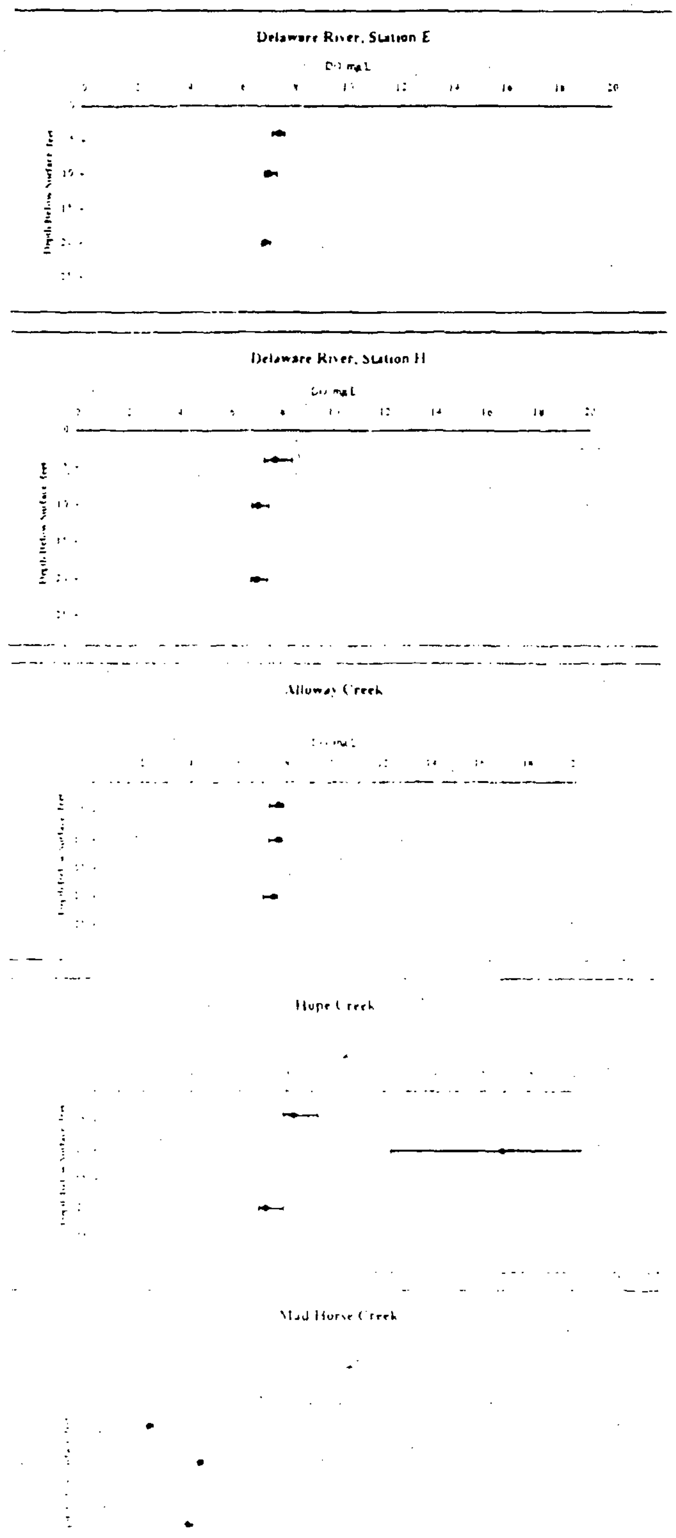
PSE&G Ambient Survey; 14 July 1997
Dissolved Oxygen Vertical Profiles (Moorings)
EOE Phase (12:39 - 14:39)



340

Figure 11-37

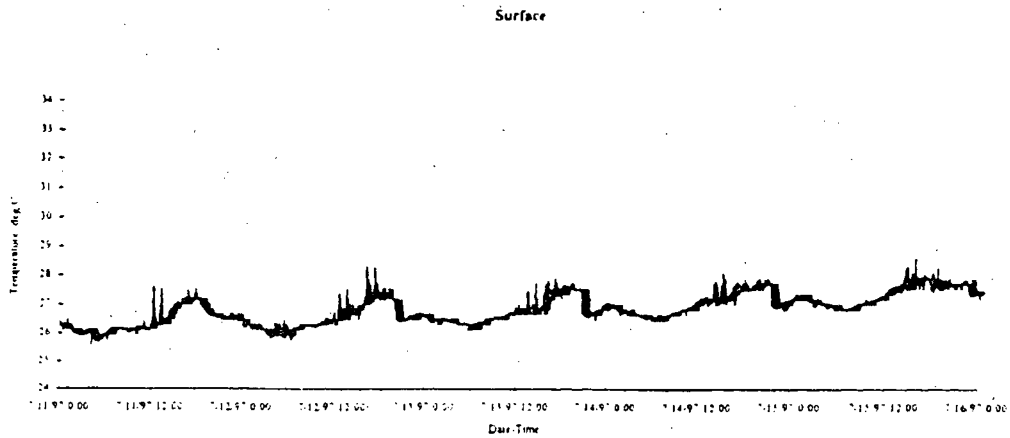
PSE&G Ambient Survey; 14 July 1997
Dissolved Oxygen Vertical Profiles (Moorings)
Flood Phase (16:15 - 18:15)

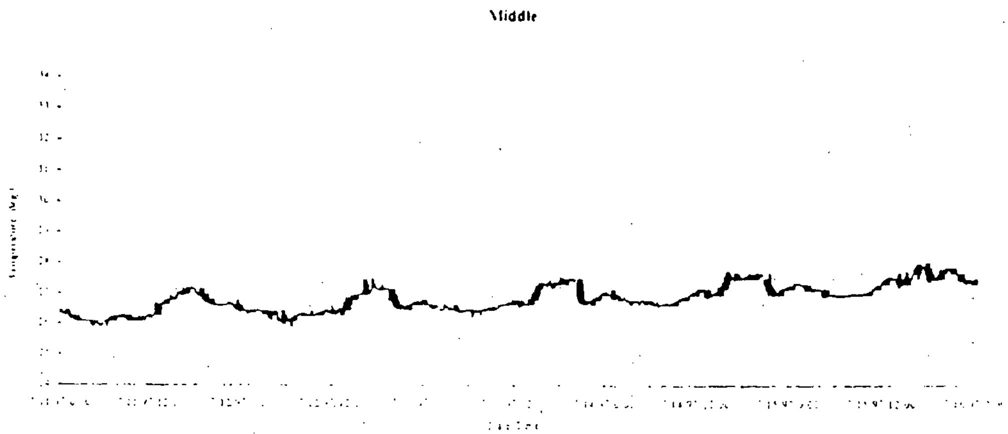


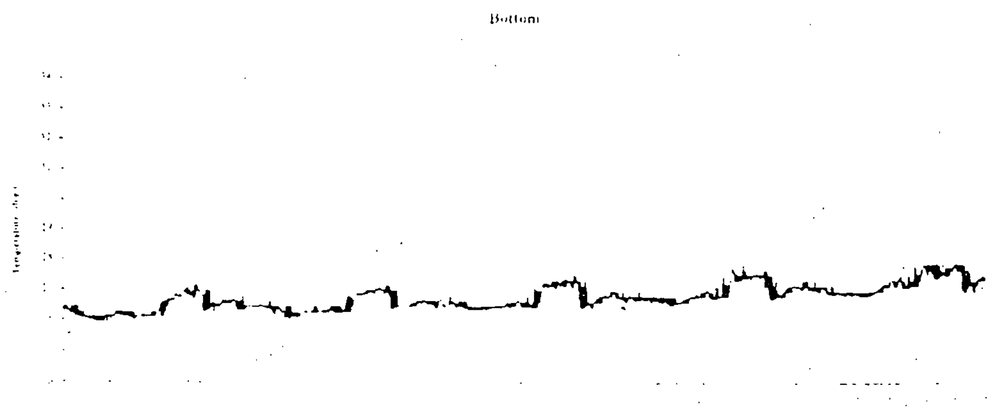
341

Figure 11-38

PSE&G Ambient Survey; 11-16 July 1997
Temperature Temporal Profiles (Moorings)
DELAWARE E





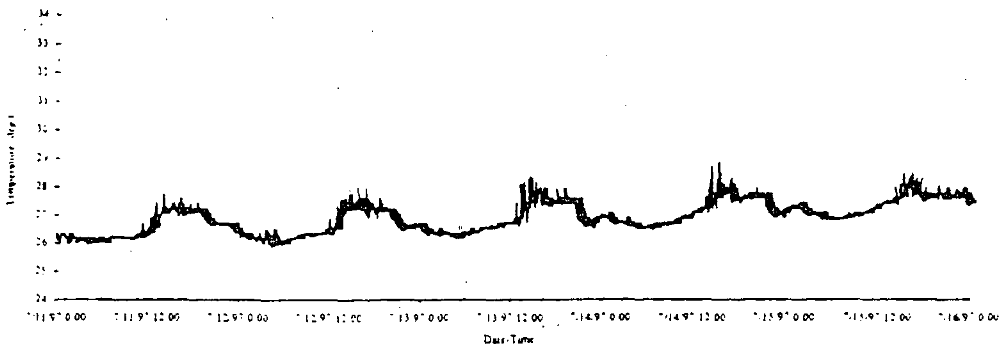


342

Figure 11-39

PSE&G Ambient Survey; 11-16 July 1997
Temperature Temporal Profiles (Moorings)
DELAWARE H

Surface



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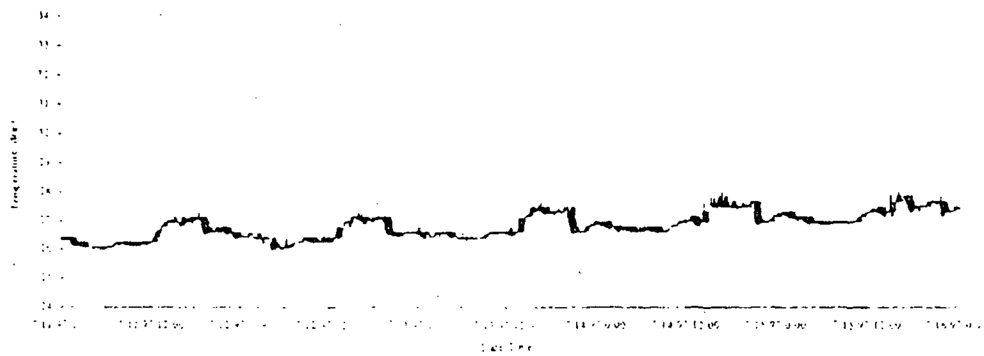
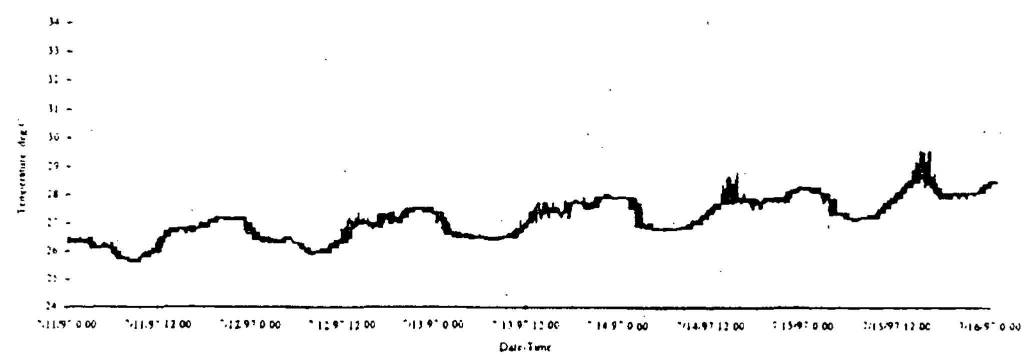


Bottom

Figure 11-40

PSE&G Ambient Survey: 11-16 July 1997
Temperature Temporal Profiles (Moorings)
ALLOWAY CREEK

Surface



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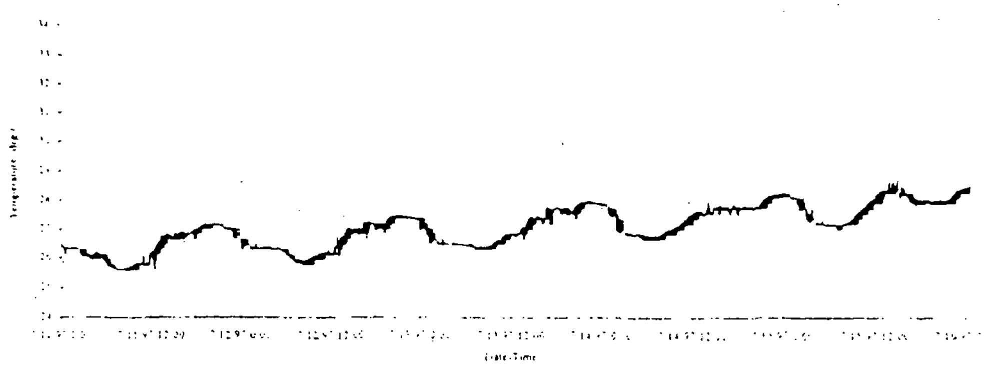

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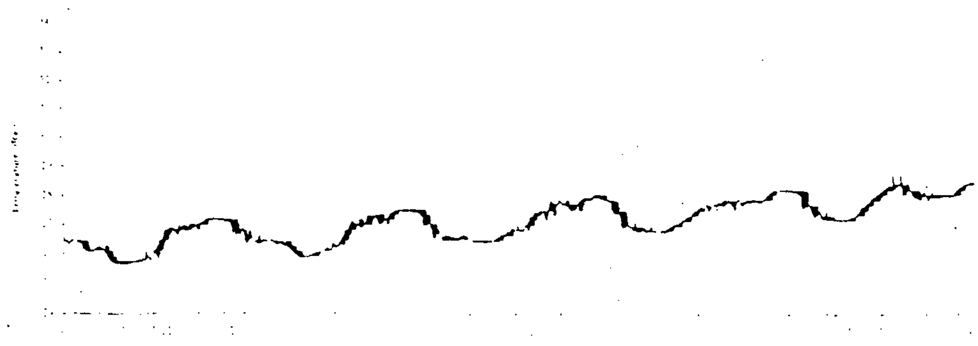


344

Figure 11-41

PSE&G Ambient Survey: 11-16 July 1997
Temperature Temporal Profiles (Moorings)
HOPE CREEK

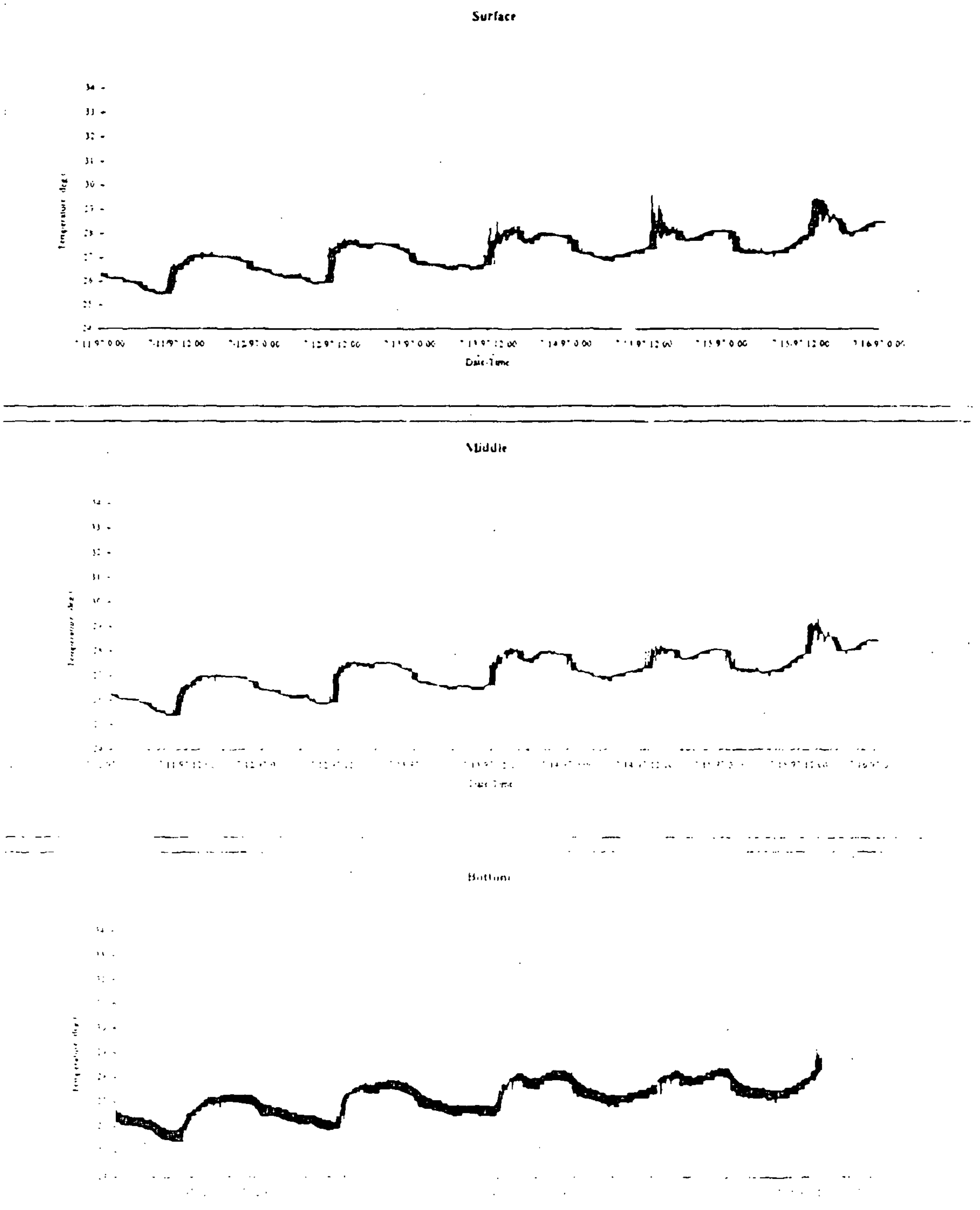
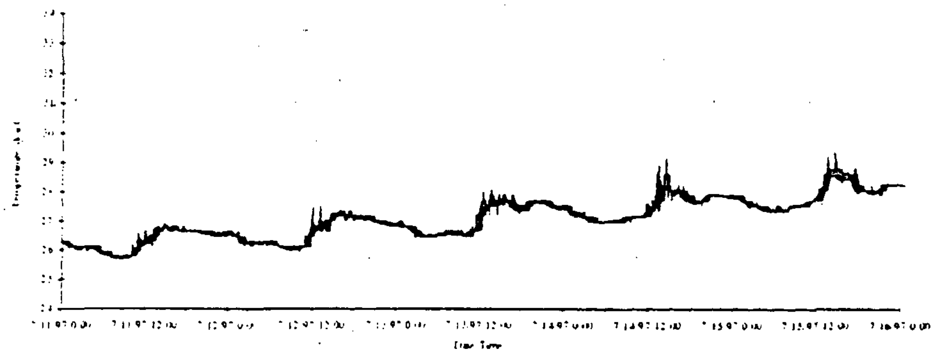


Figure 11-42

PSE&G Ambient Survey: 11-16 July 1997
Temperature Temporal Profiles (Moorings)
MADHORSE CRK

Surface



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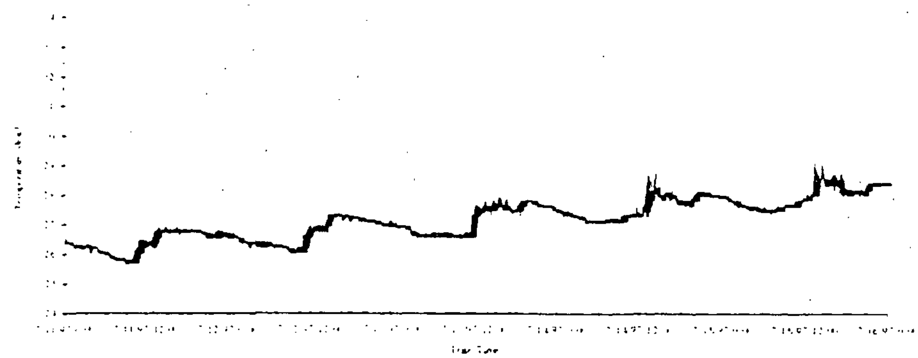

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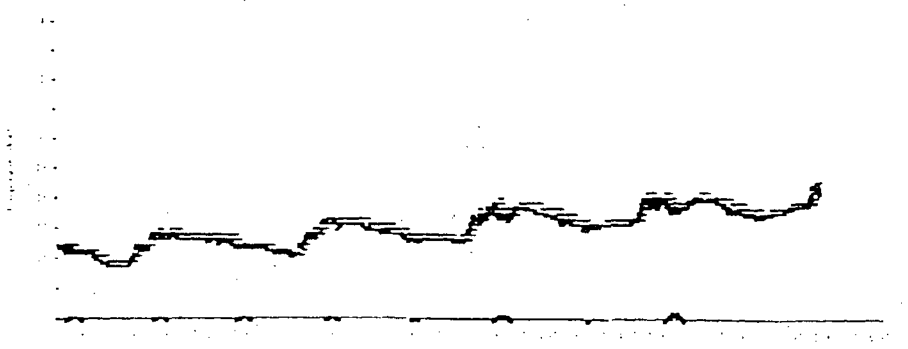
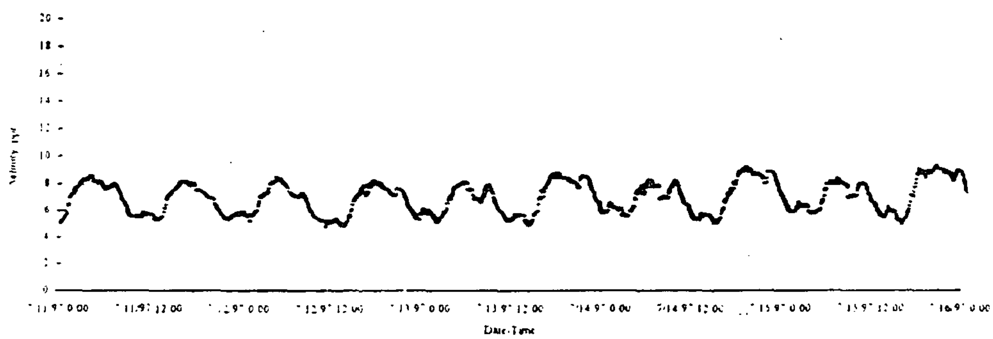


Figure 11-43

PSE&G Ambient Survey: 11-16 July 1997
Salinity Temporal Profiles (Moorings)
DELAWARE E

Surface



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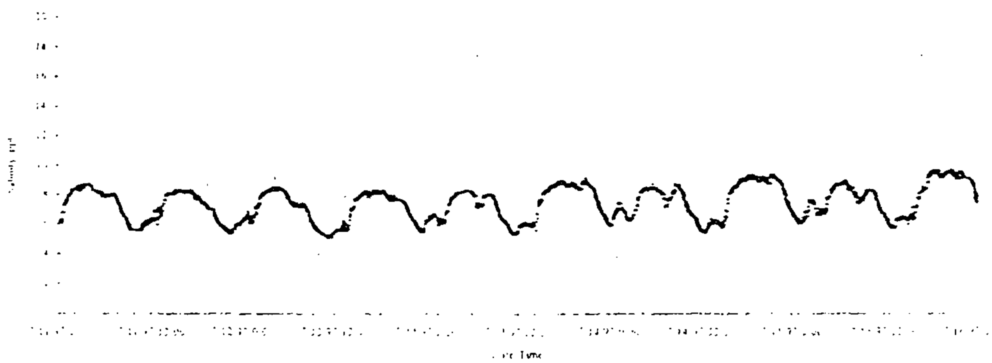

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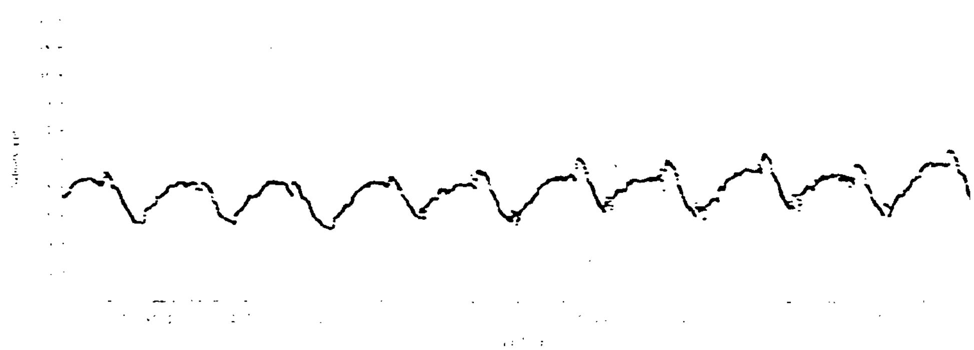
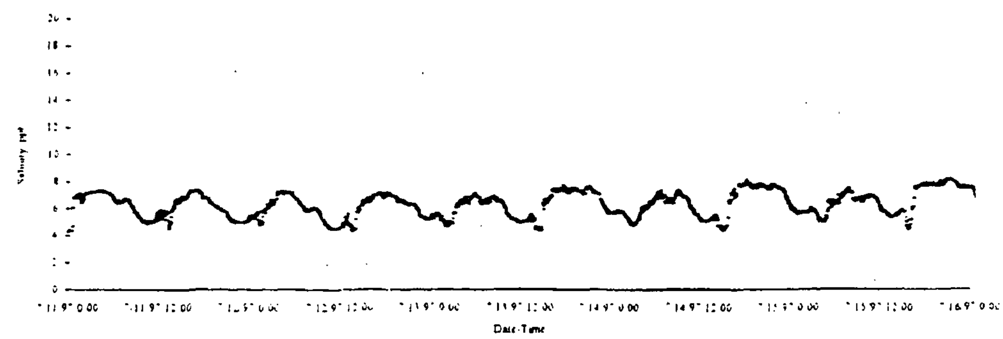


347

Figure 11-44

PSE&G Ambient Survey: 11-16 July 1997
Salinity Temporal Profiles (Moorings)
DELAWARE II

Surface



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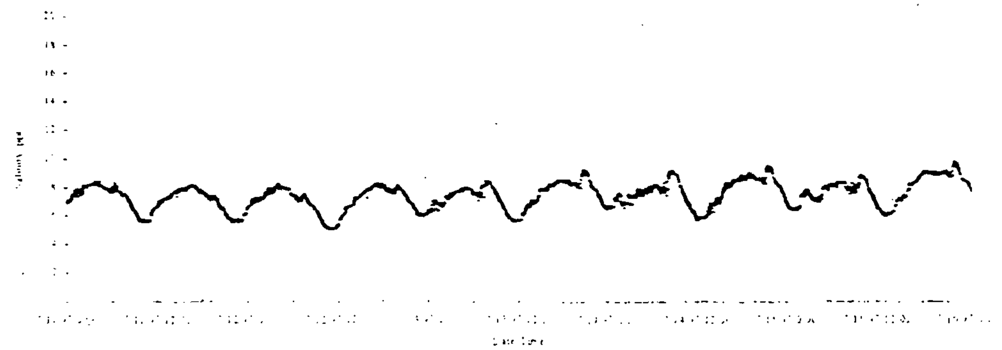

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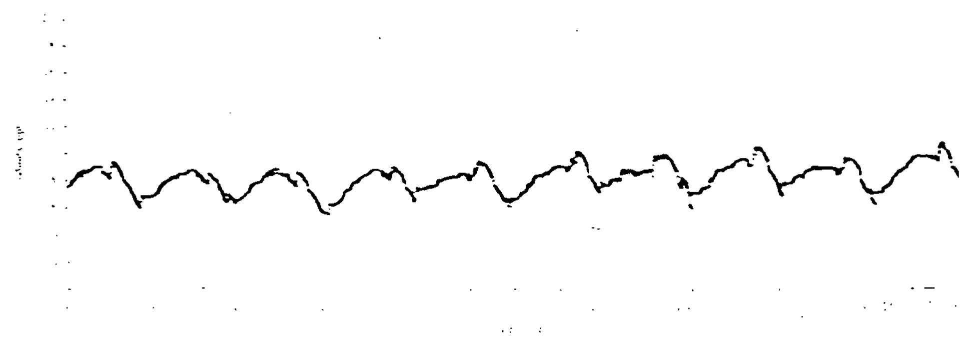
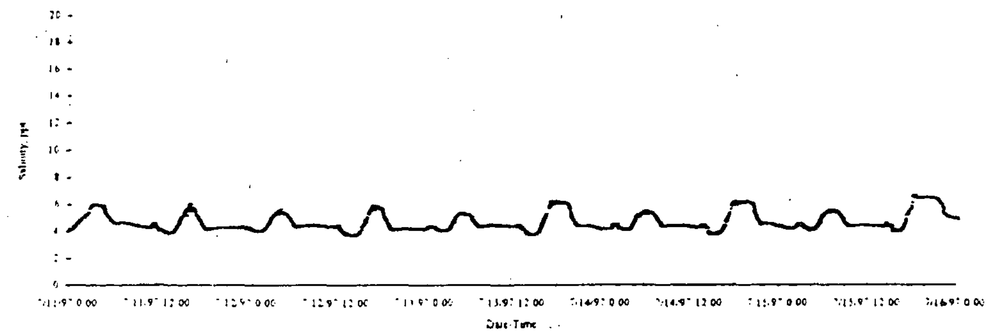


348

Figure 11-45

PSE&G Ambient Survey; 11-16 July 1997
Salinity Temporal Profiles (Moorings)
ALLOWAY CREEK

Surface



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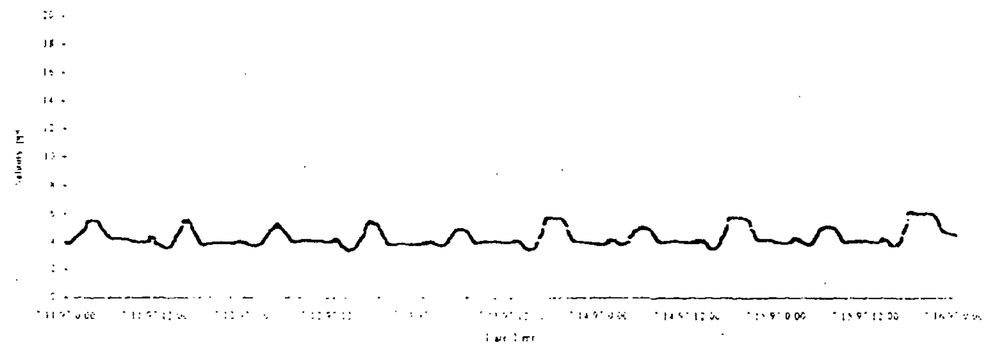

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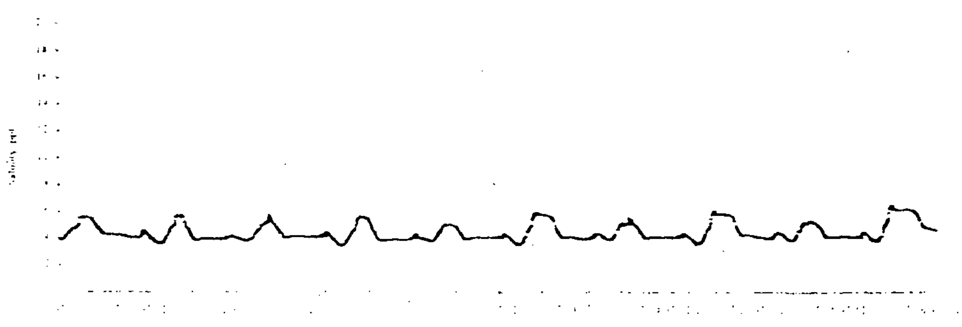
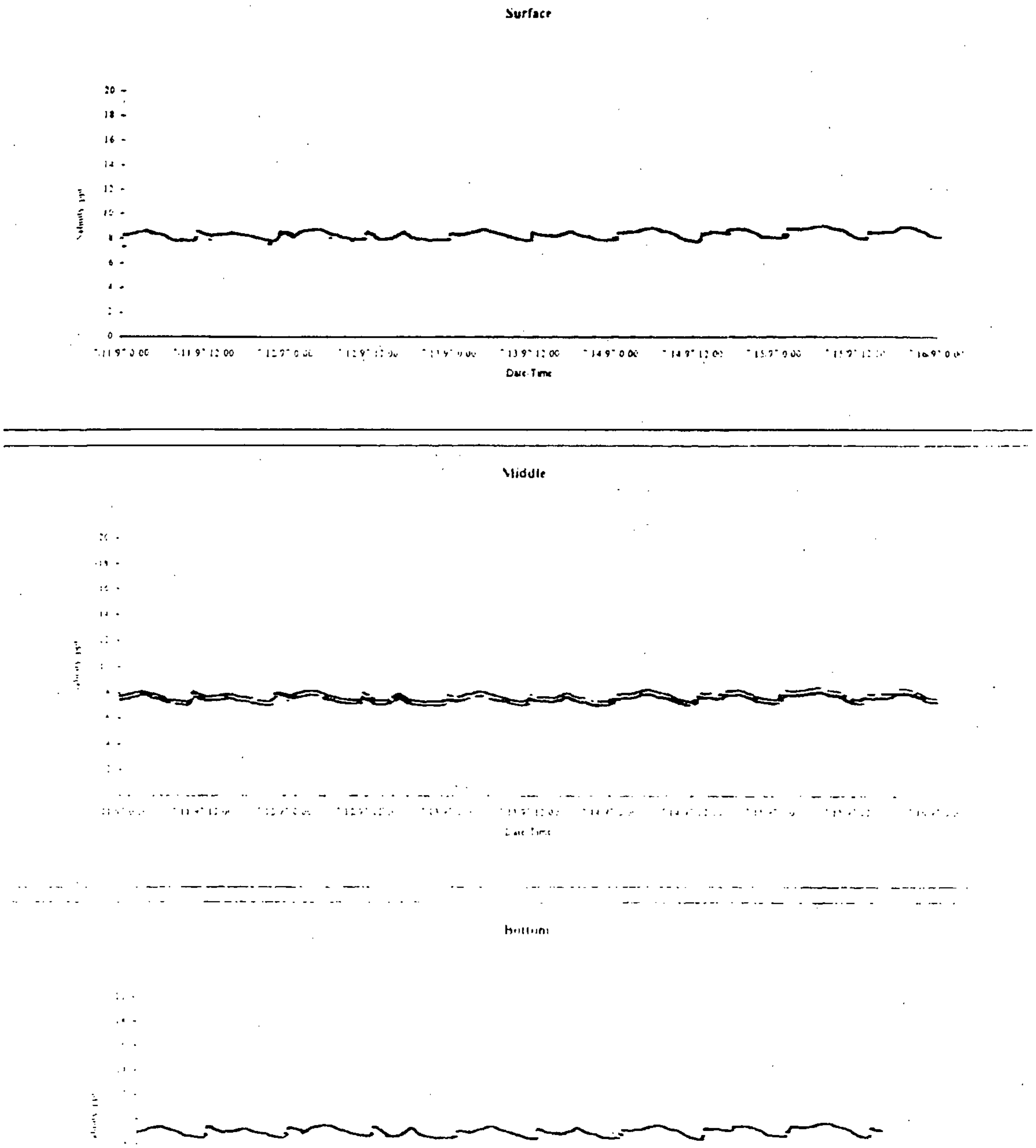


Figure 11-46

PSE&G Ambient Survey; 11-16 July 1997
Salinity Temporal Profiles (Moorings)
HOPE CREEK



350

Figure 11-47

PSE&G Ambient Survey; 11-16 July 1997
Salinity Temporal Profiles (Moorings)
MADHORSE CRK

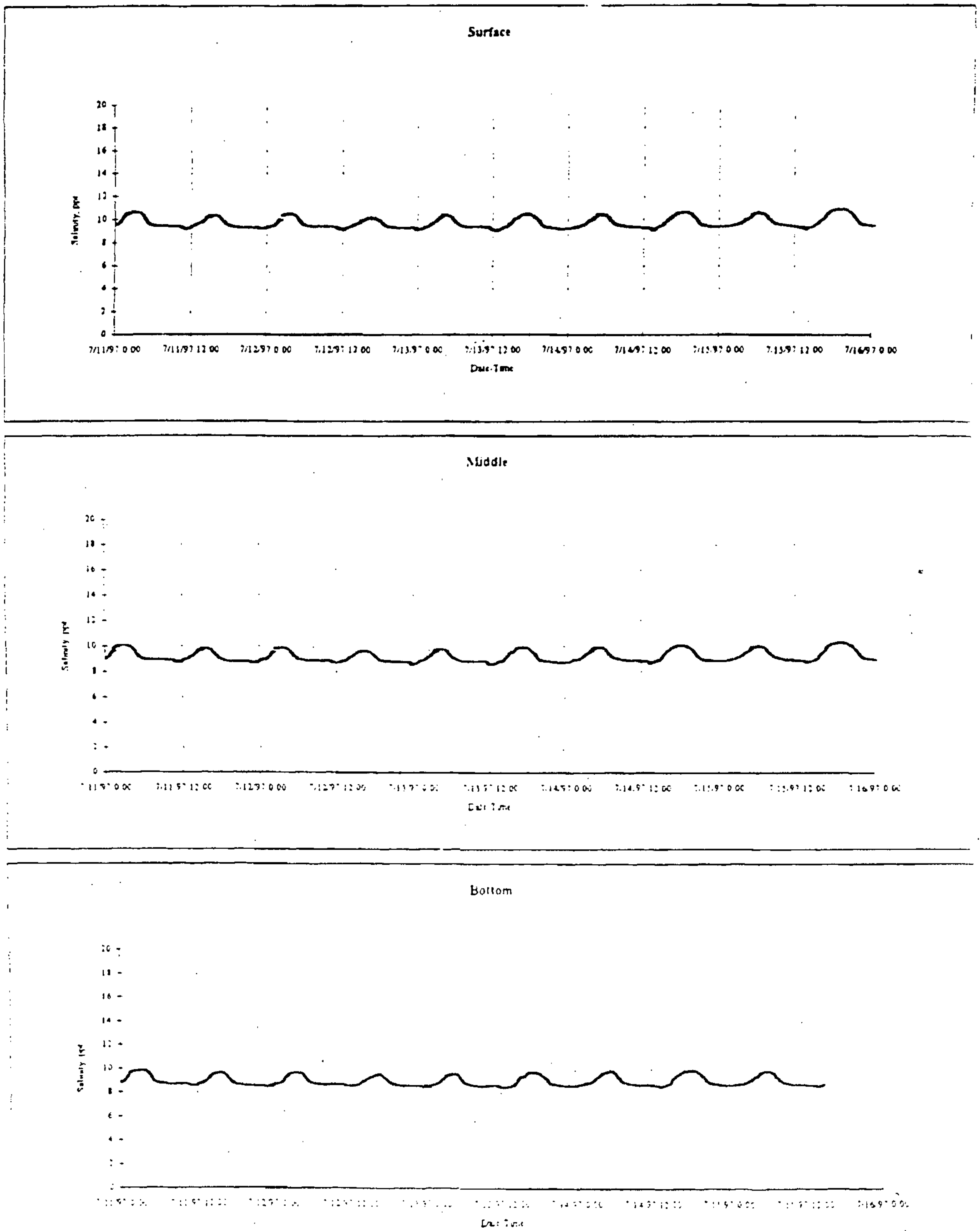
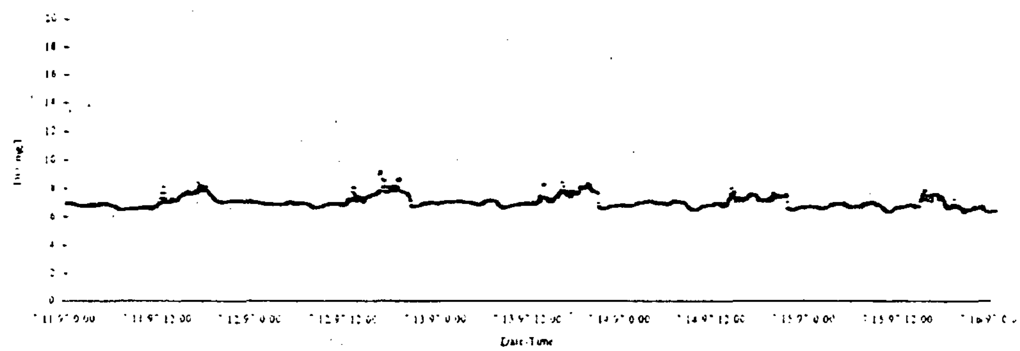


Figure 11-48

PSE&G Ambient Survey; 11-16 July 1997
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE E

Surface



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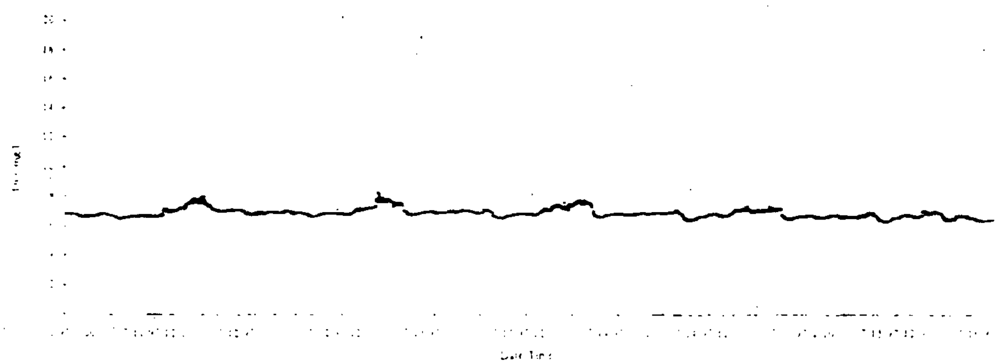

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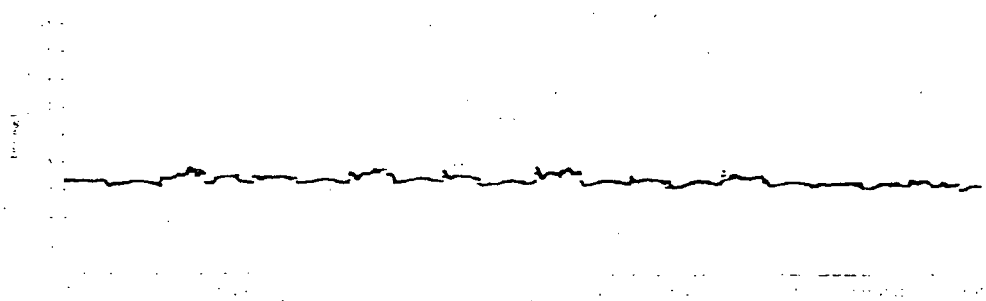

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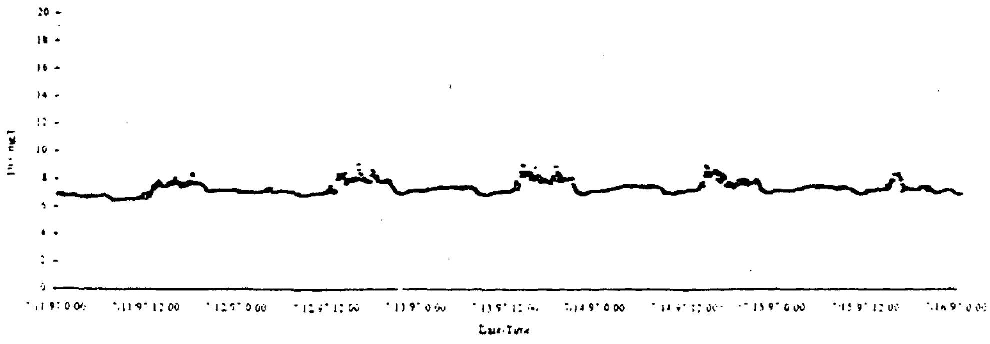
Figure 11-49

PSE&G Ambient Survey; 11-16 July 1997
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE H

Surface



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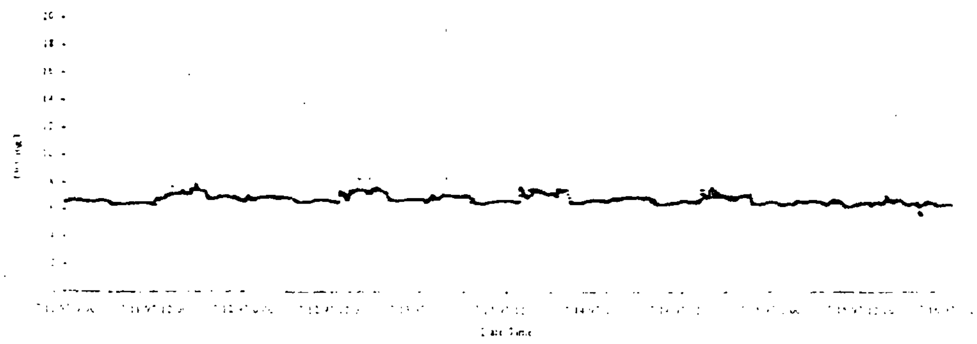

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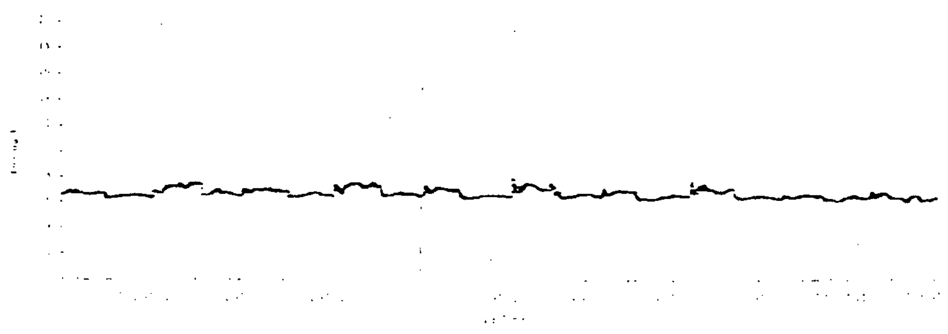

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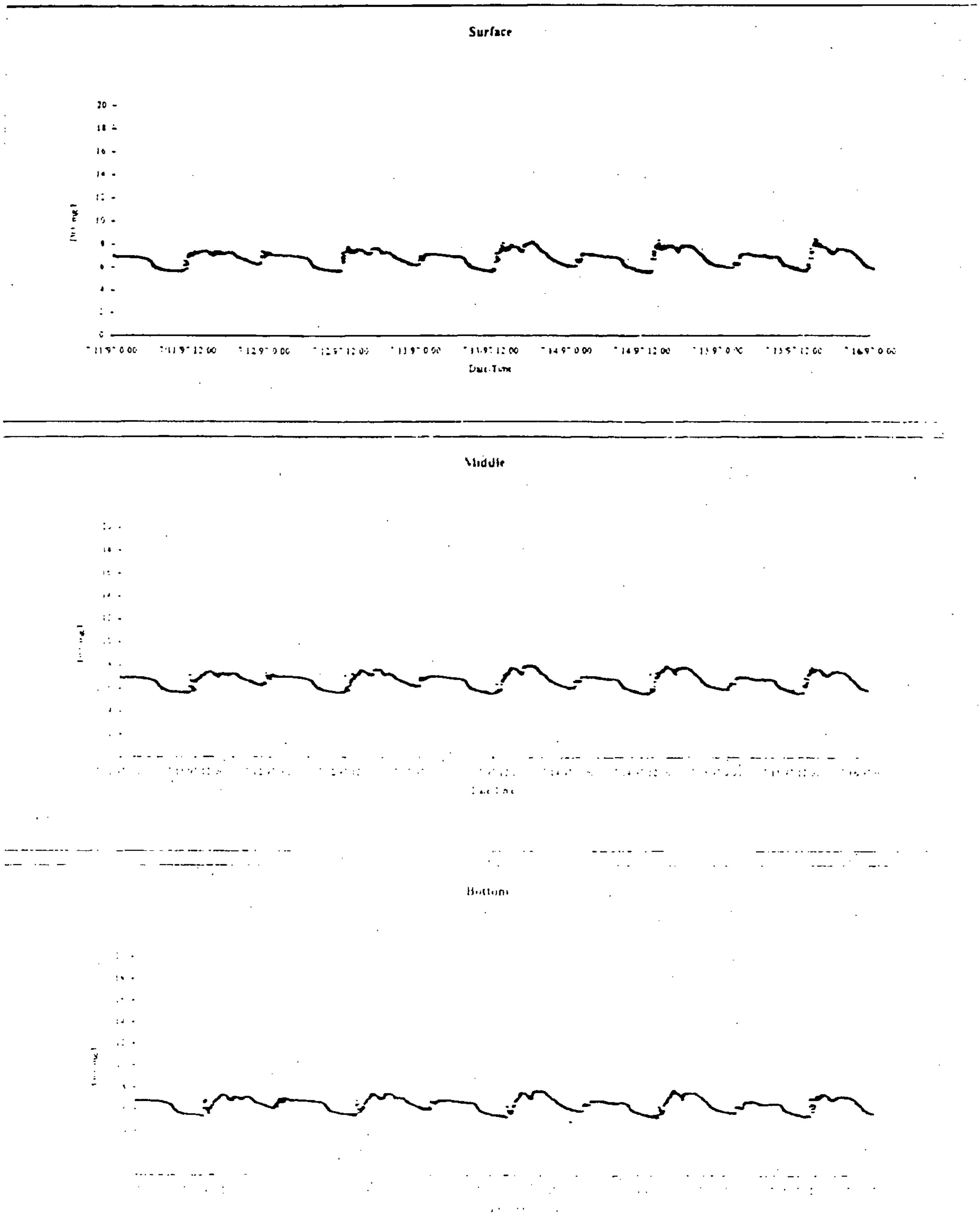
Figure 11-50

PSE&G Ambient Survey; 11-16 July 1997
Dissolved Oxygen Temporal Profiles (Moorings)
ALLOWAY CREEK



354

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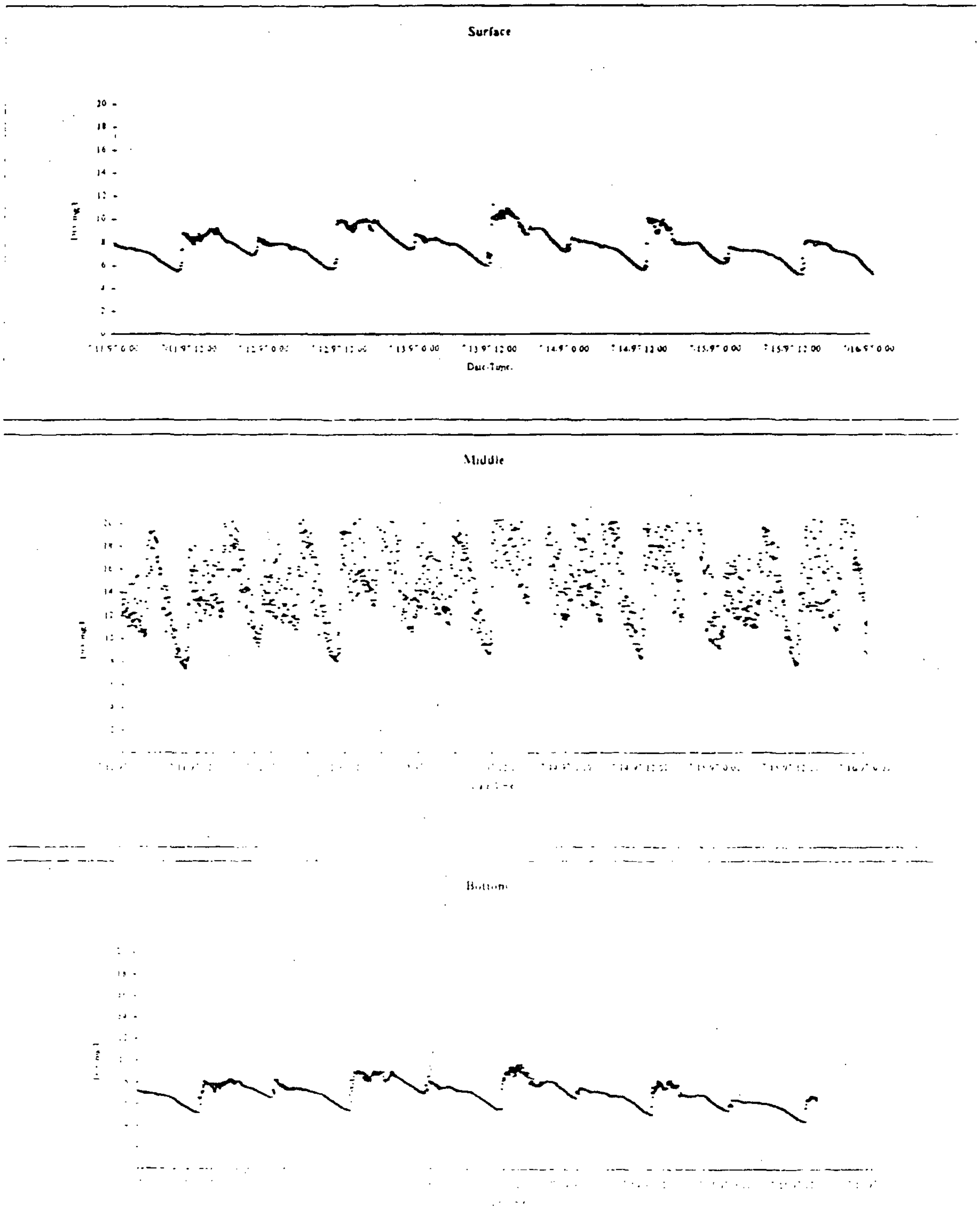
48e

Figure 11-51

PSE&G Ambient Survey; 11-16 July 1997
Dissolved Oxygen Temporal Profiles (Moorings)
HOPE CREEK

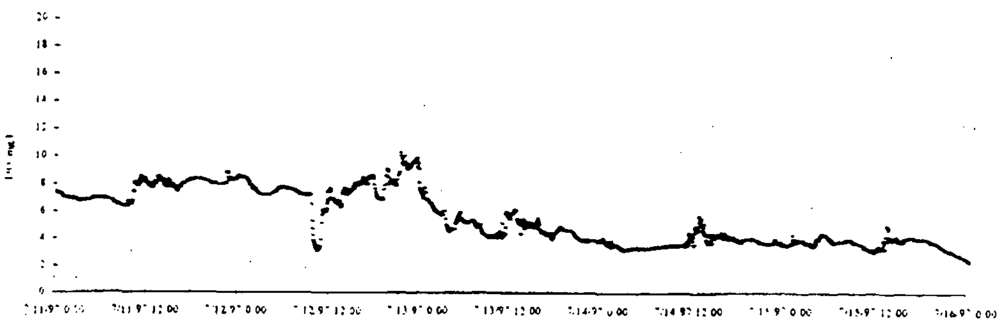


355

Figure 11-52

PSE&G Ambient Survey; 11-16 July 1997
Dissolved Oxygen Temporal Profiles (Moorings)
MADHORSE CRK

Surface



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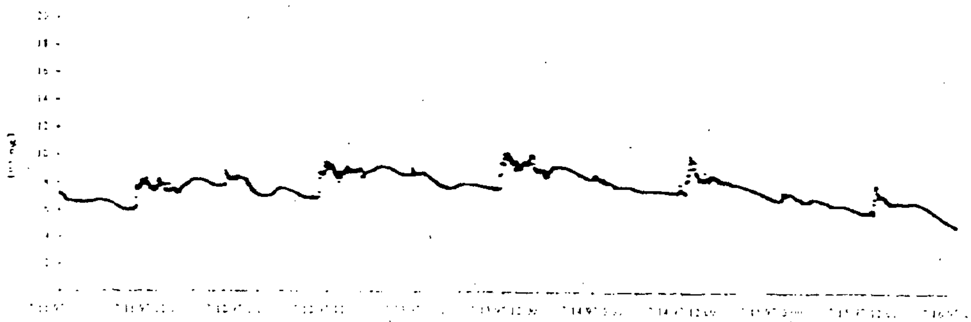

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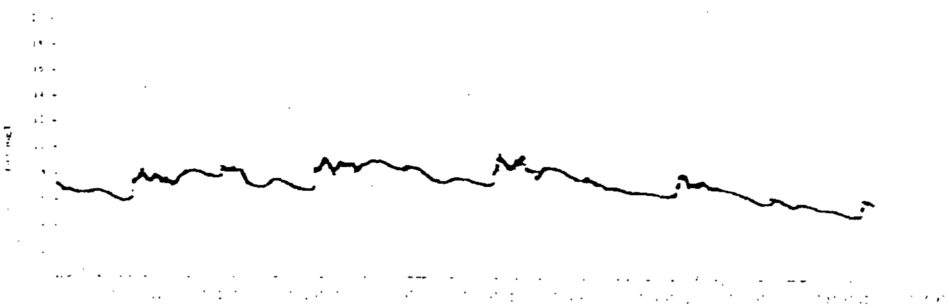

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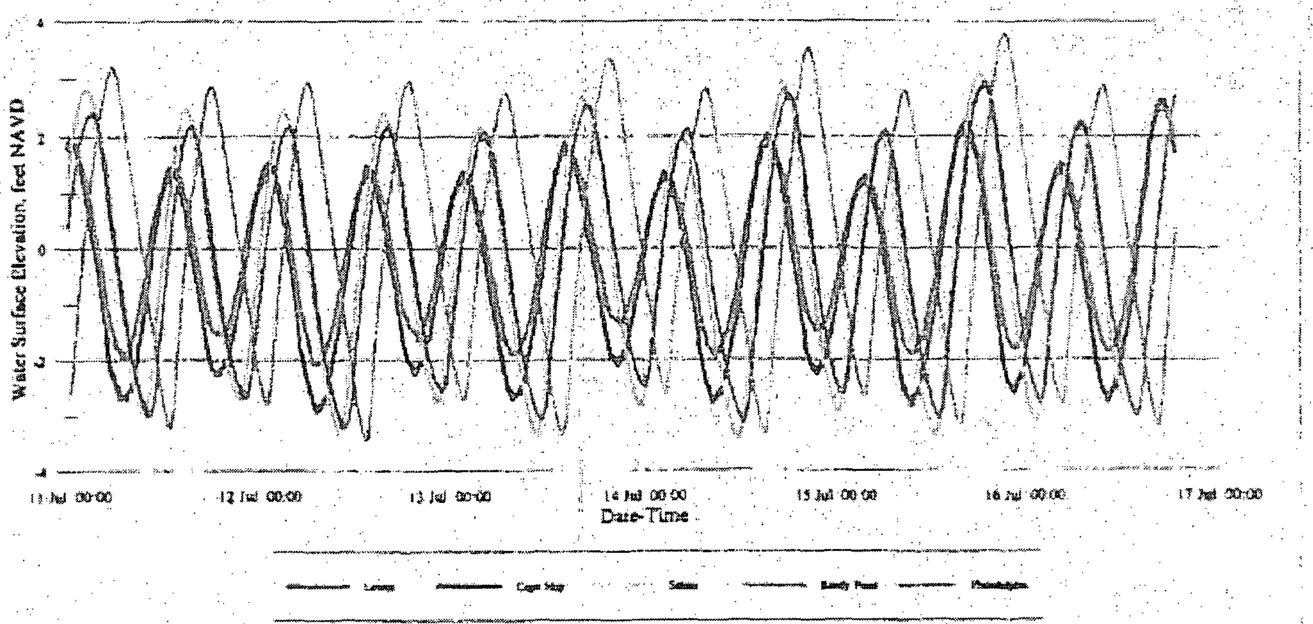
Figure 11-53

PSE&G Ambient Survey; July 1997
Delaware River Tide Gages
Temporal Variation

11 July 1997 - 16 July 1997



14 July 1997

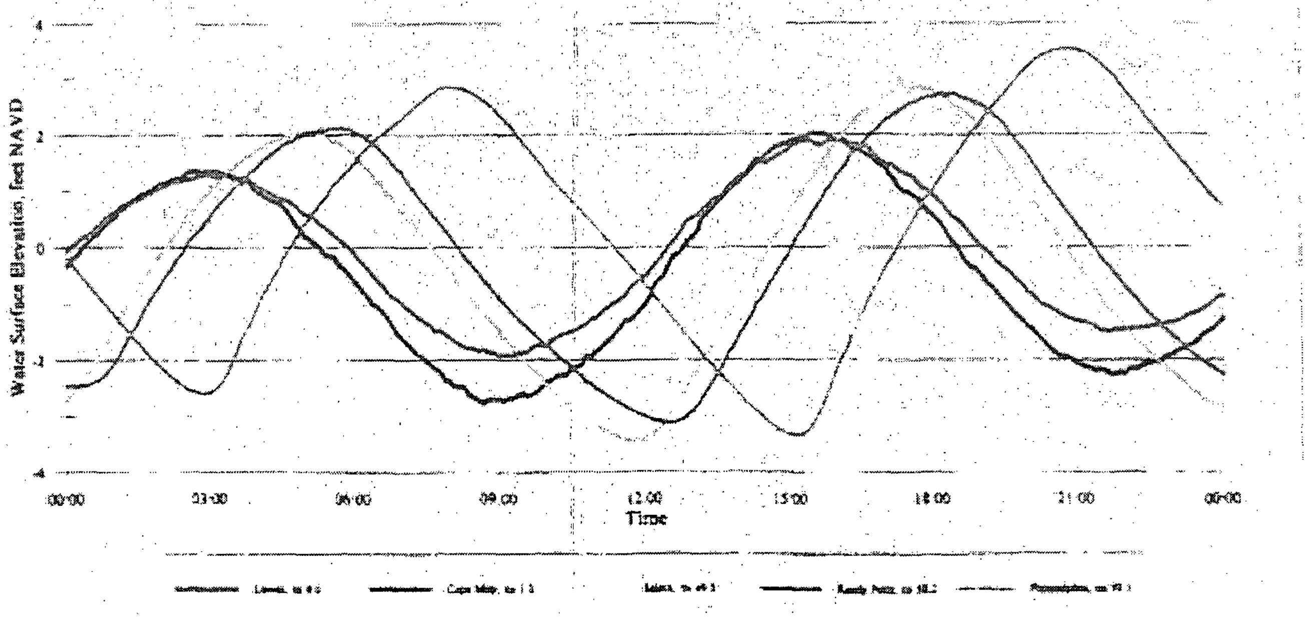


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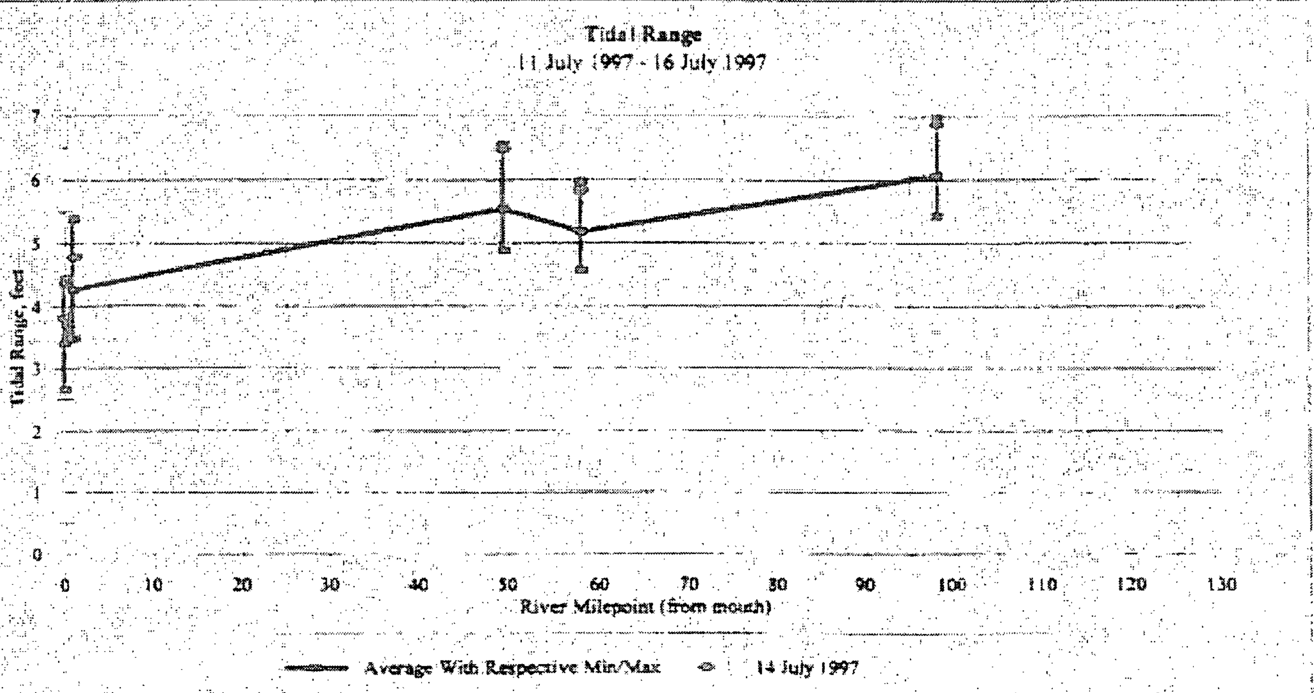
Figure 11-54

PSE&G Ambient Survey: July 1997
Delaware River Tide Gages
Spatial Variation



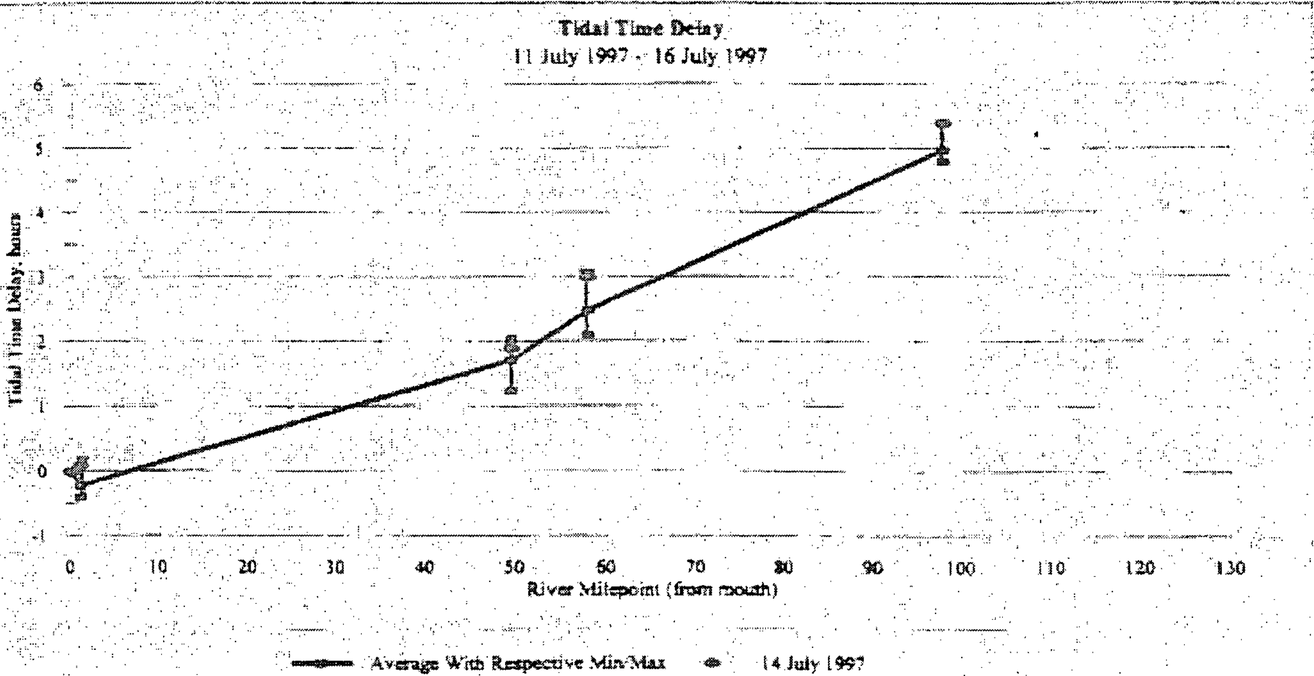
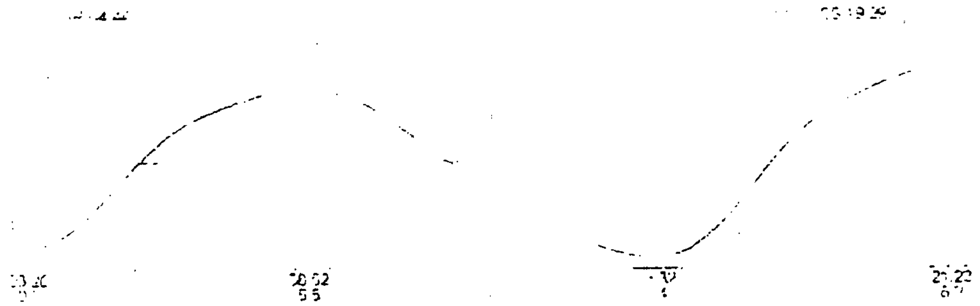


Figure 11-55

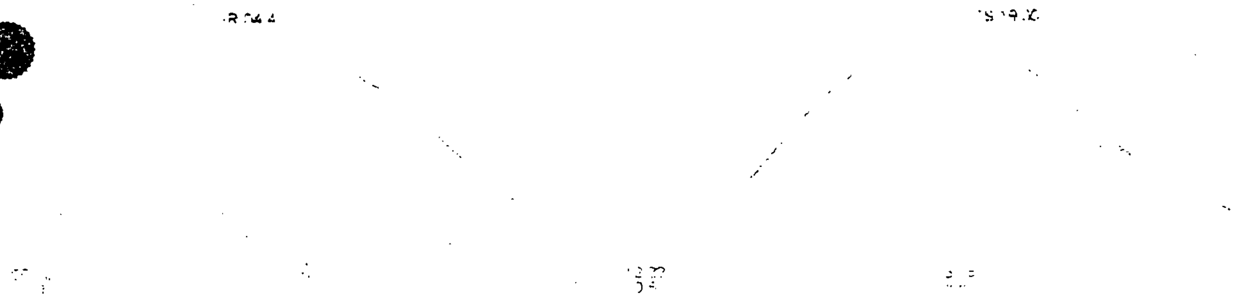
Tides-PHILADELPHIA, Municipal Pier

Monday July 14, 1997



Tides-REEDY POINT

Monday July 14, 1997



Tides-Artificial Island, Salem Nuclear Plant N J

Monday July 14 1997

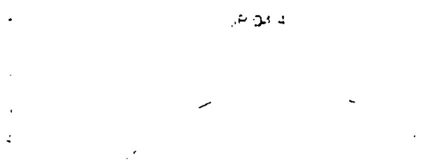


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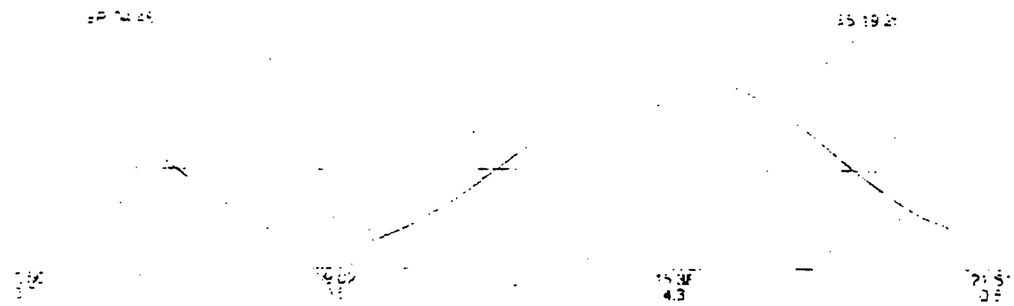
Figure 11-56

Tides-BREAKWATER HARBOR

Monday July 14, 1997



Tides-Cape May Ferry Terminal, New Jersey

Monday July 14, 1997

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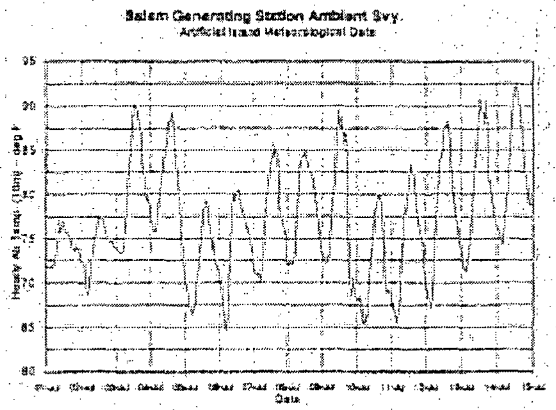
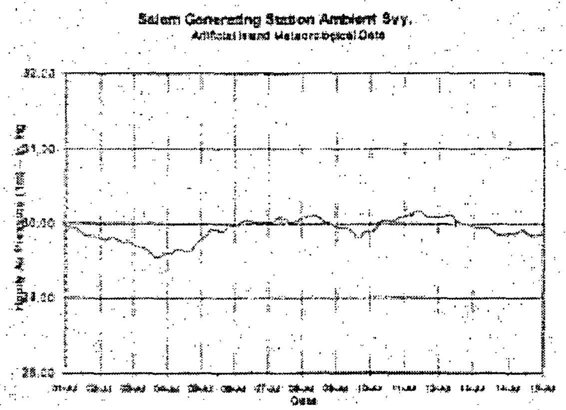
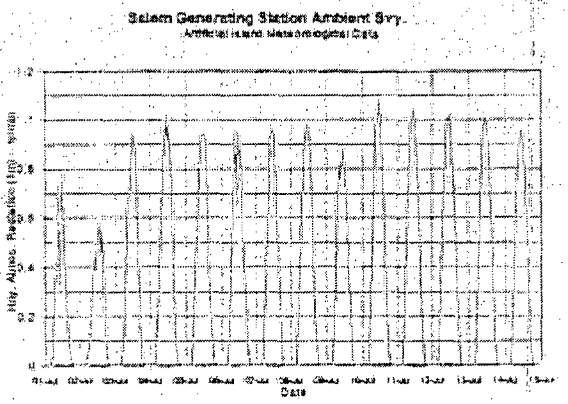
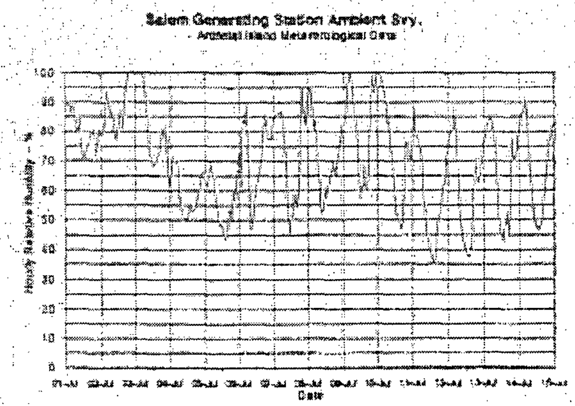
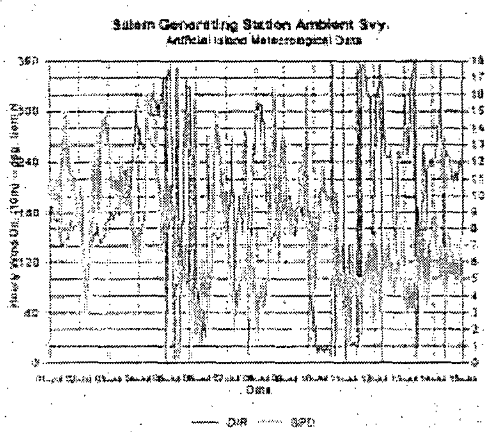
Figure 11-57


Salem Generating Station Ambient Svy.
Artificial Island Meteorological Data
Date


Salem Generating Station Ambient Svy.
Artificial Island Meteorological Data
Date


Salem Generating Station Ambient Svy.
Artificial Island Meteorological Data
Date


Salem Generating Station Ambient Svy.
Artificial Island Meteorological Data
Date


Salem Generating Station Ambient Svy.
Artificial Island Meteorological Data
Date
DIR
SPD

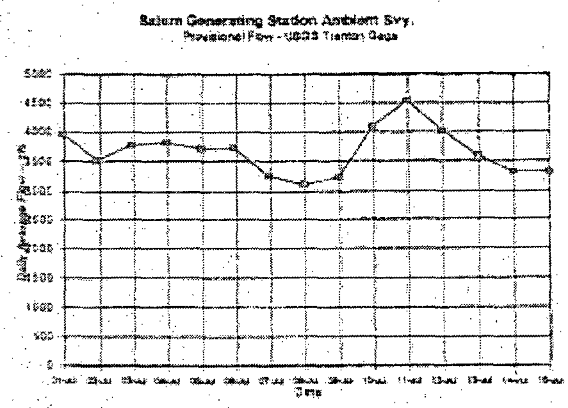

Salem Generating Station Ambient Svy.
Provisional Flow - USGS Trenton Gage
Date

Figure 11-58. Timeline of 1-Unit survey components

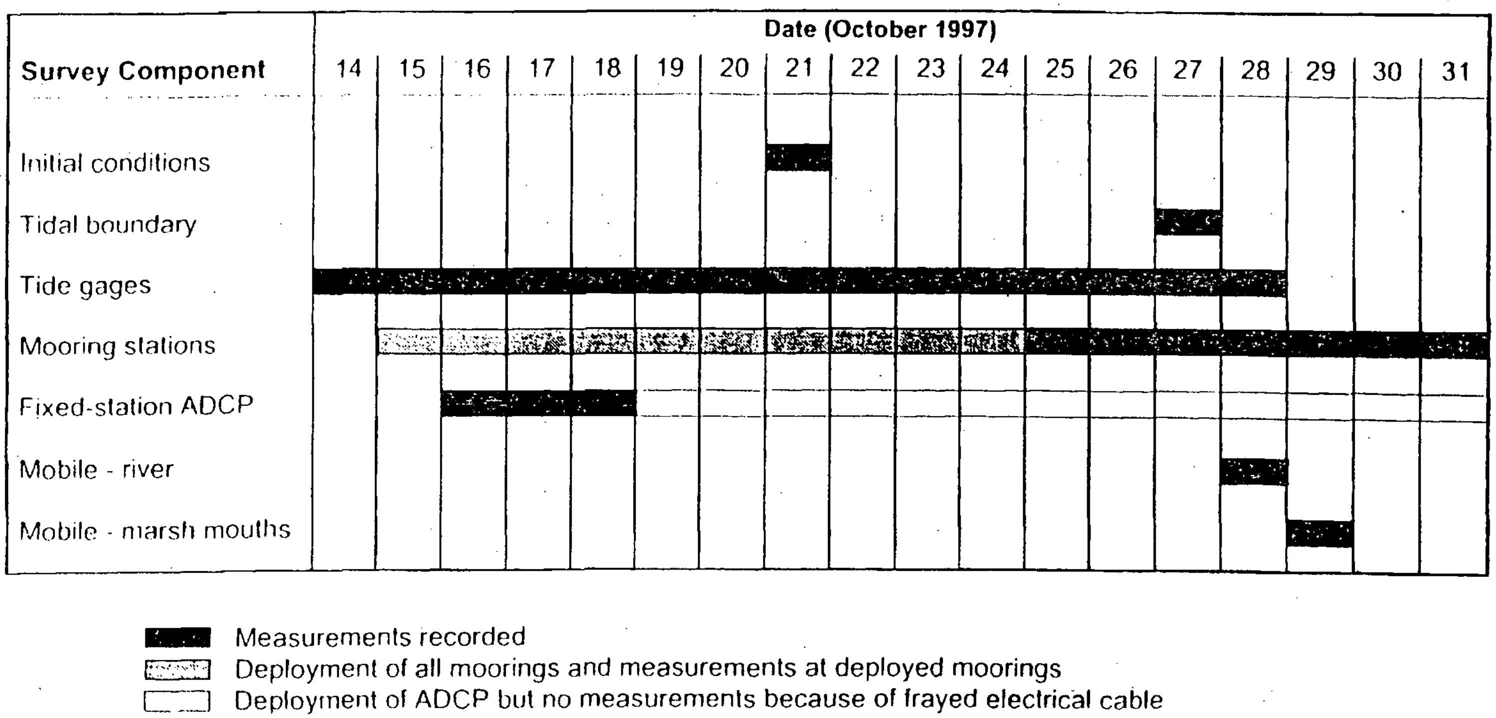


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Figure 11-59

Location of Initial Conditions Stations

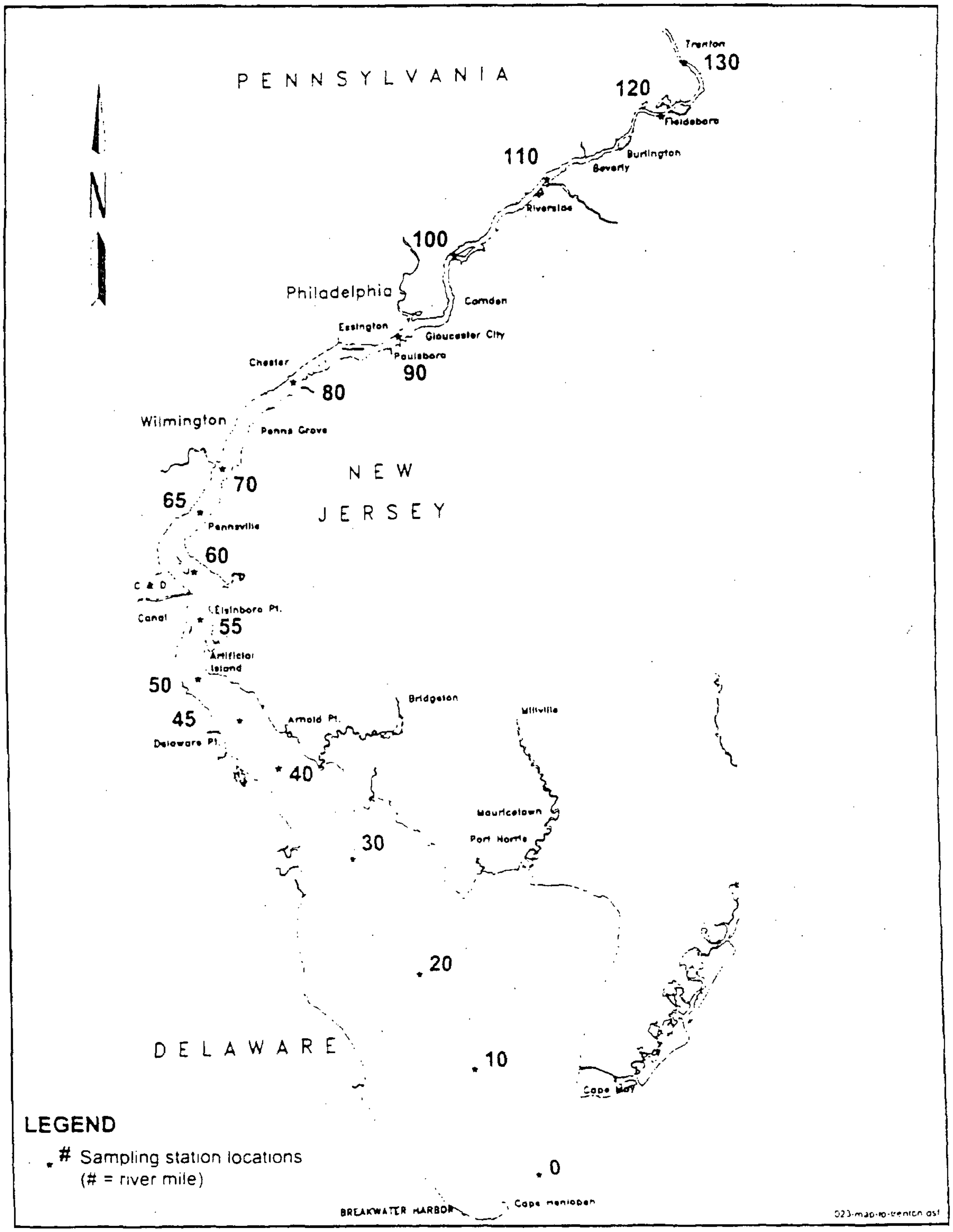

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Figure 11-60
Tidal Boundary Condition Stations

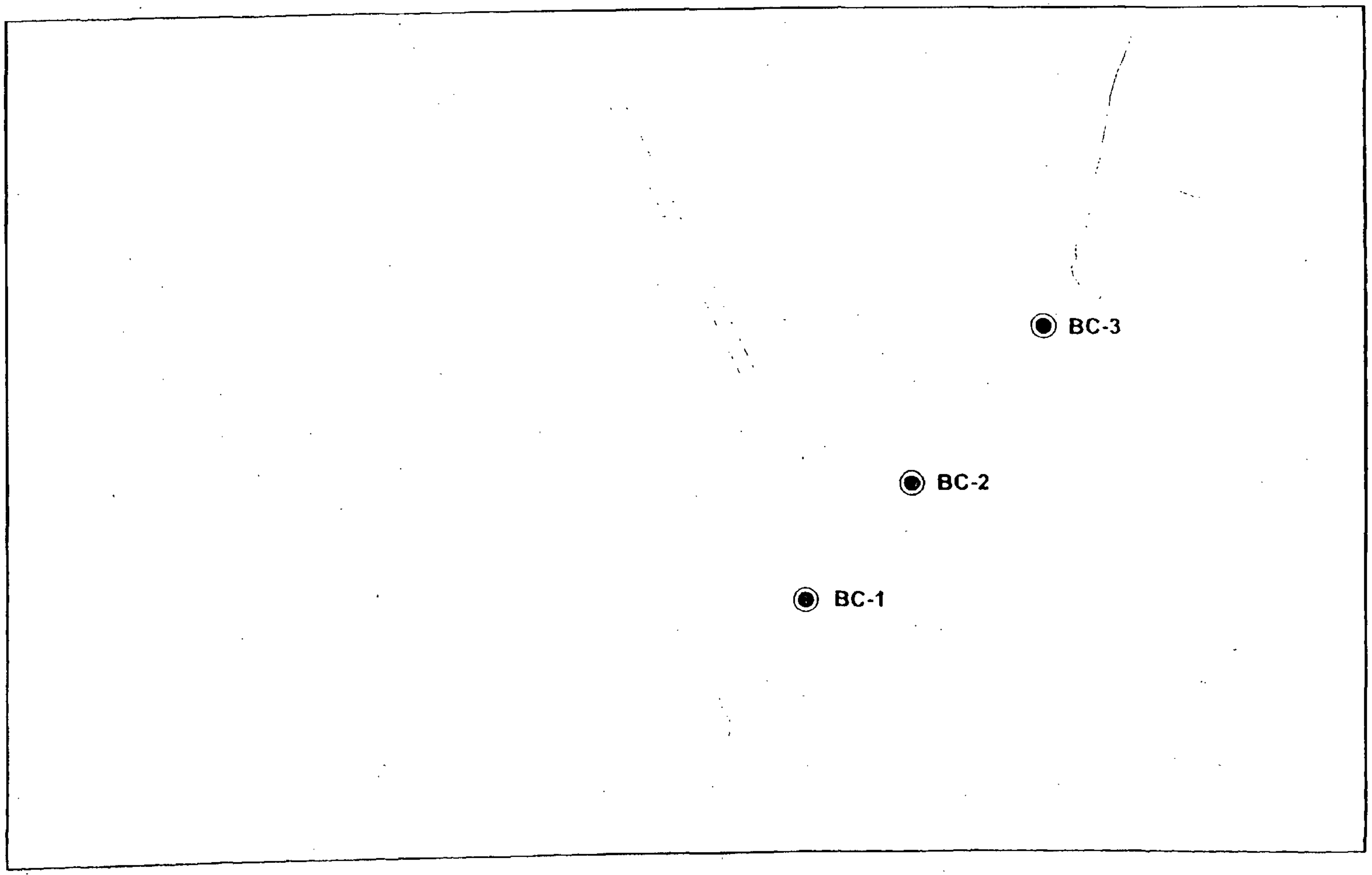

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Figure 11-61

PSE&G 1-Unit Survey; 28 October 1997
Delaware River / C&D Canal Tide Gages

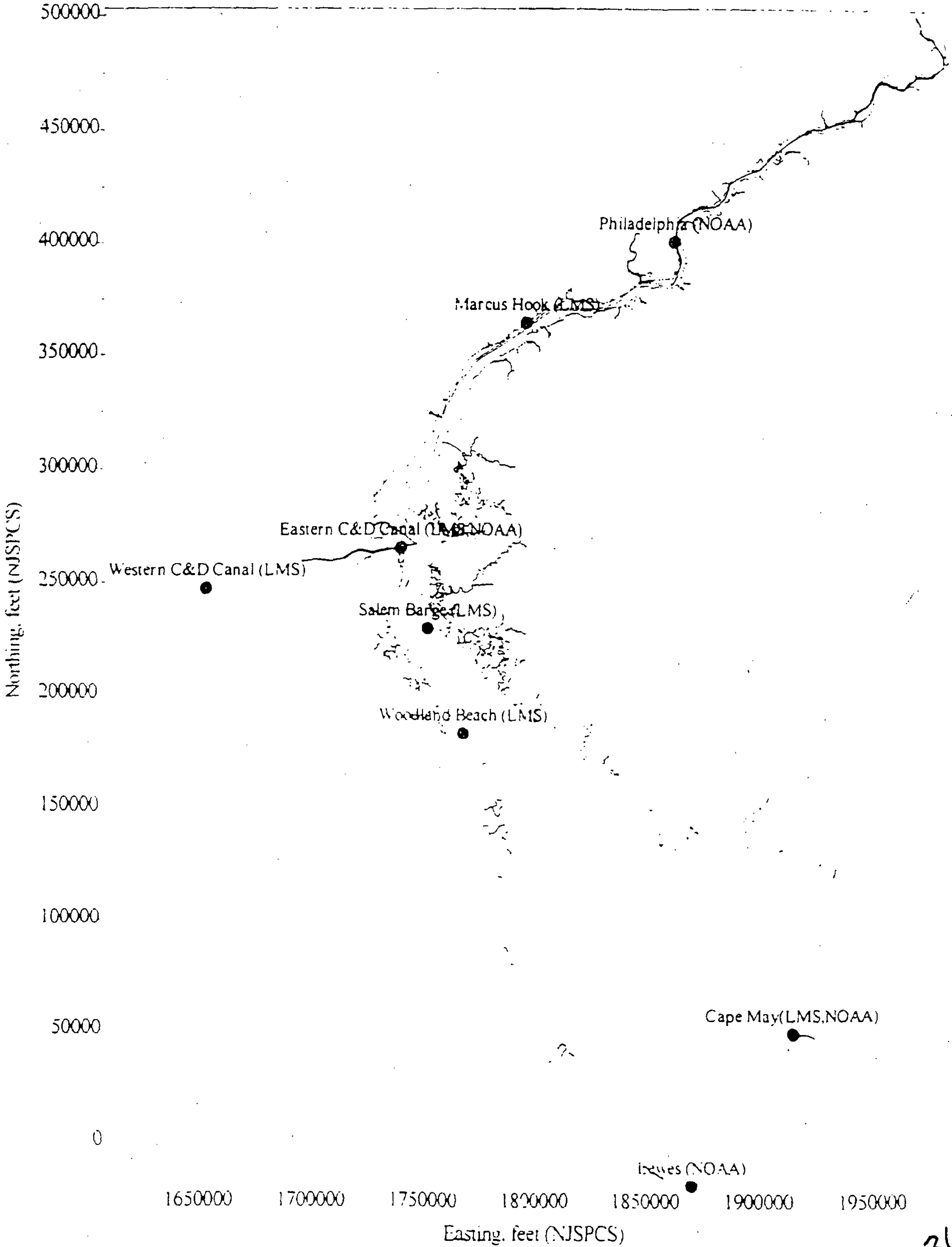

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Figure 11-62
PSE&G 1-Unit Survey: 28 October 1997
Moorings and ADCP Stations

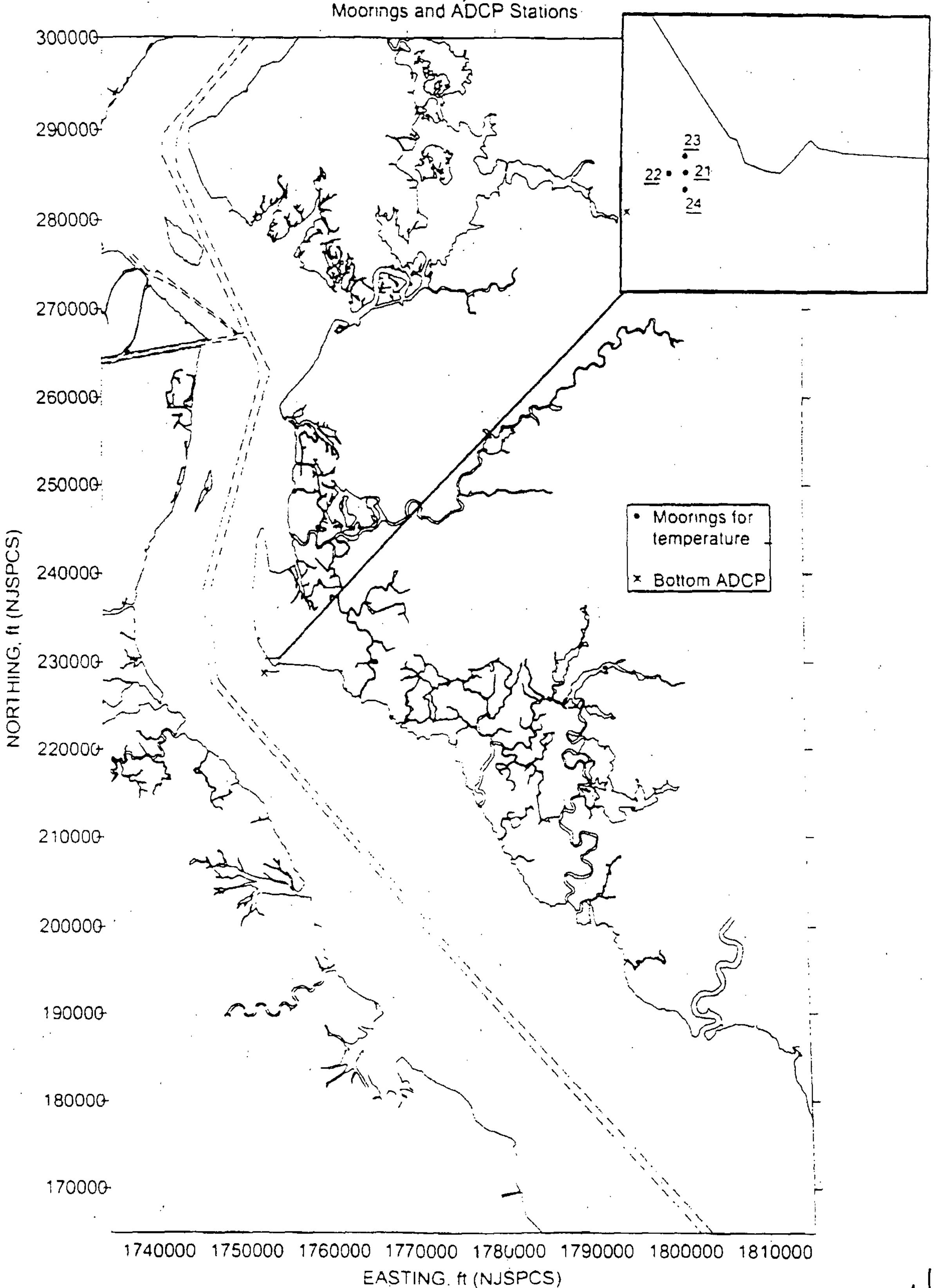

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Figure 11-63
PSE&G 1-Unit Survey
EOF Transect Locations

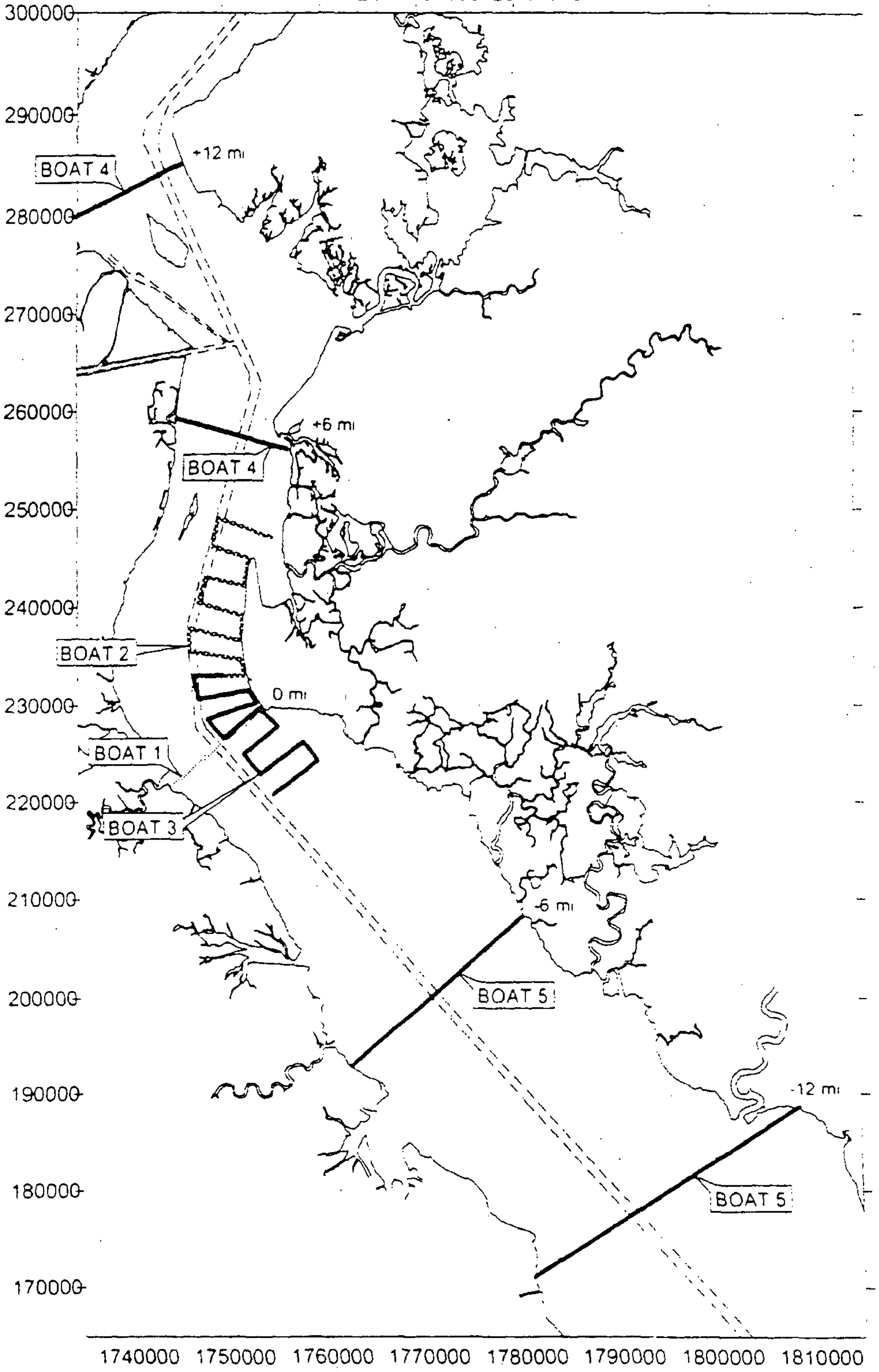

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Figure 11-64
PSE&G 1-Unit Survey
EOE Transect Locations

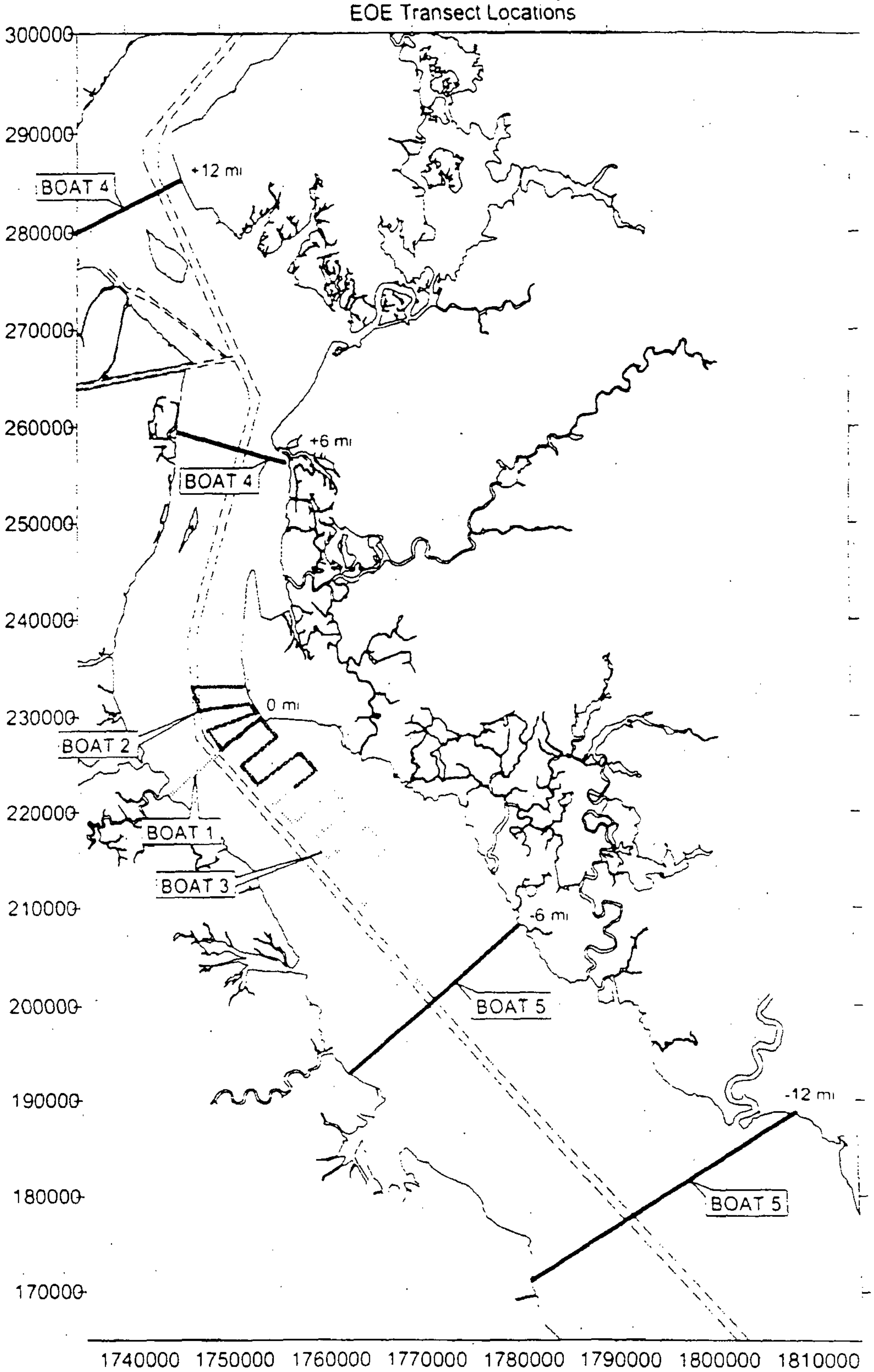

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Figure 11-65
PSE&G 1-Unit Survey
Ebb/Flood Transect Locations

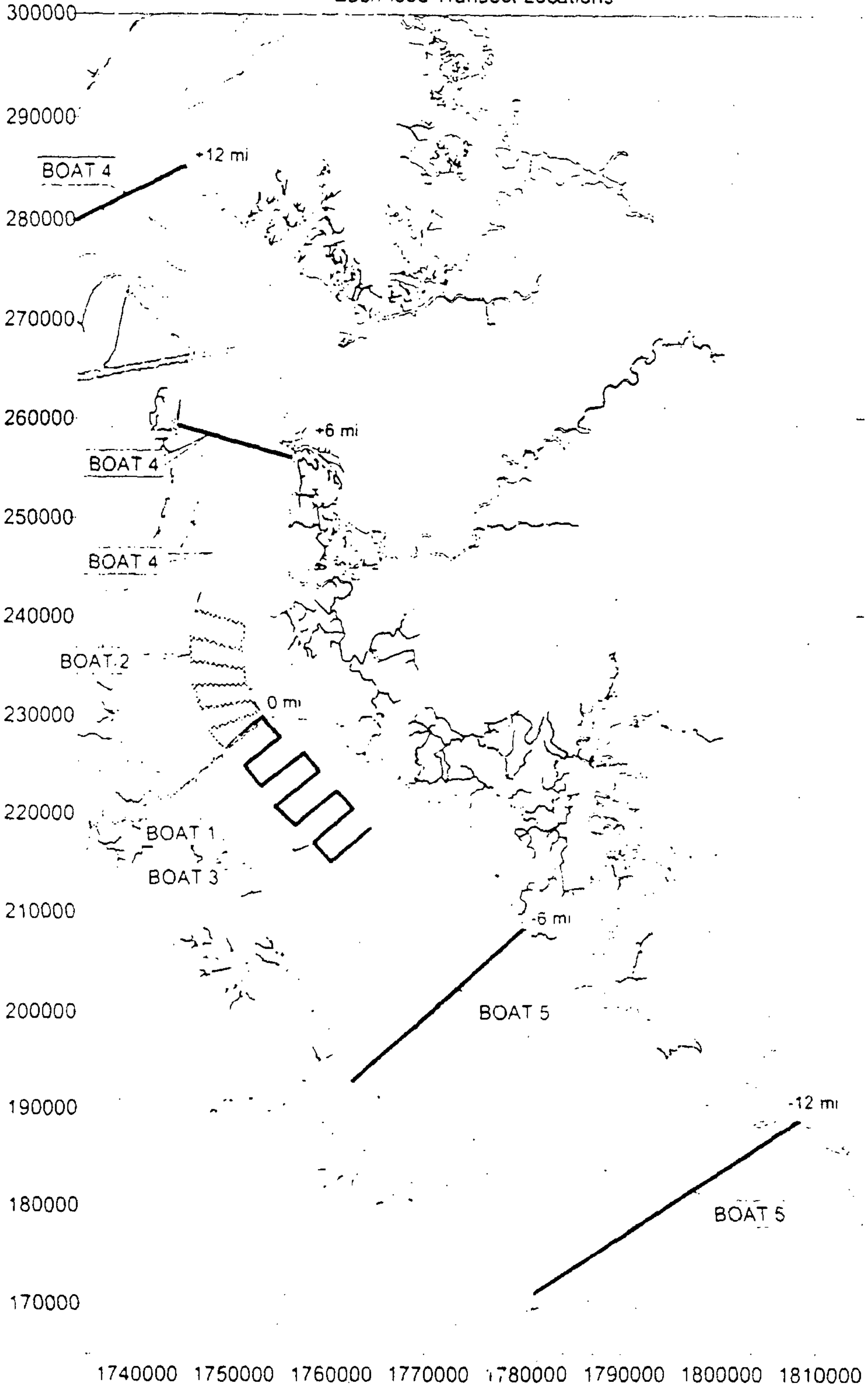

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Figure 11-66

PSE&G 1-Unit Survey: 21 October 1997
Vertical Temperature Profiles
Initial Conditions

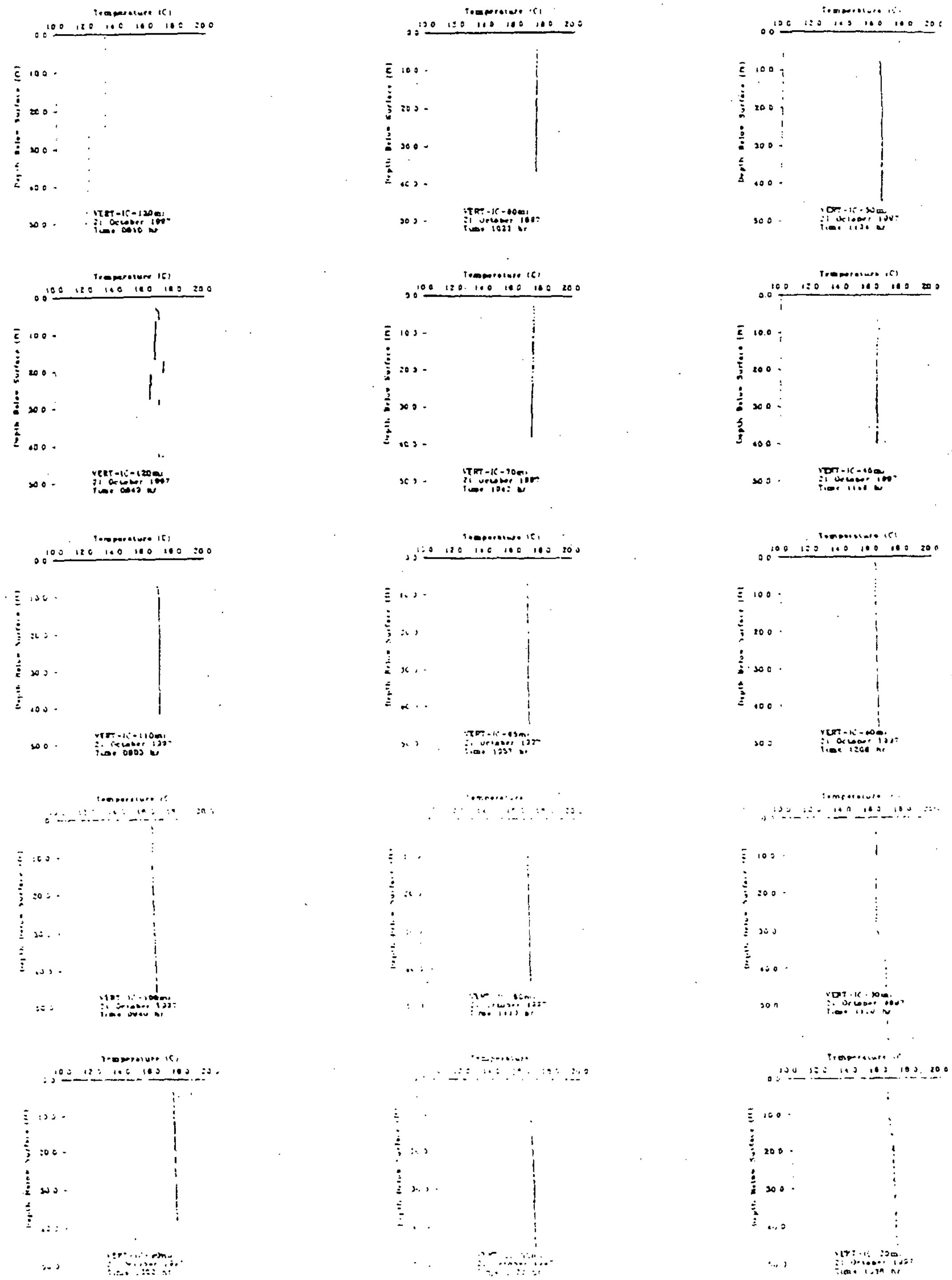

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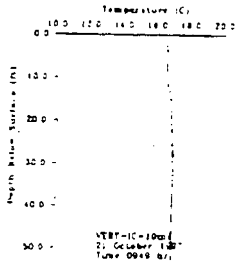
Figure 11-67

PSE&G 1-Unit Survey: 21 October 1997
Vertical Temperature Profiles
Initial Conditions



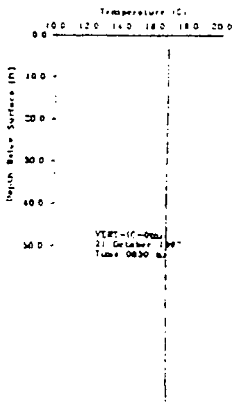


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Figure 11-68

PSE&G 1-Unit Survey: 21 October 1997
Vertical Salinity Profiles
Initial Conditions

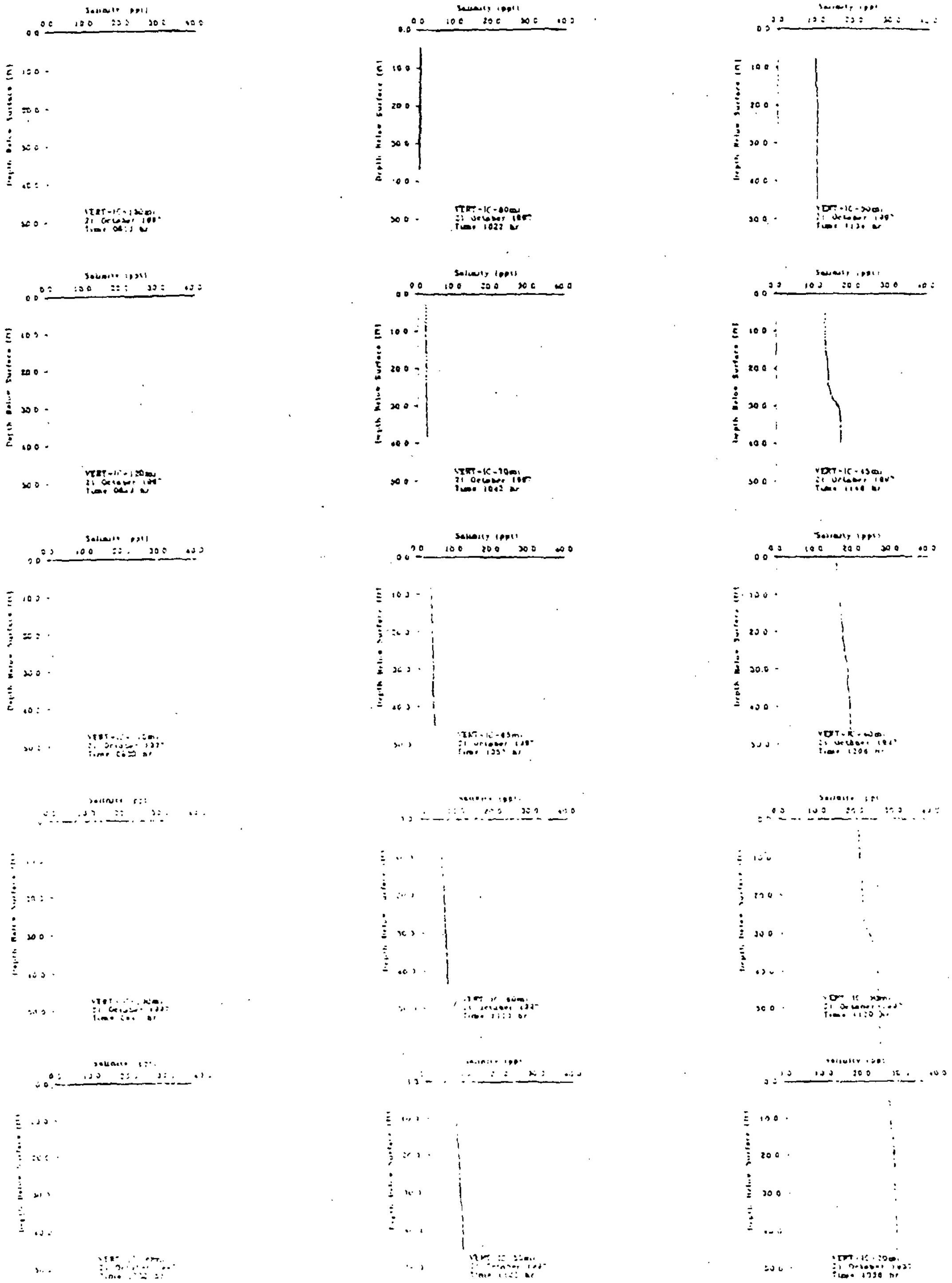

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Figure 11-69

PSE&G 1-Unit Survey; 21 October 1997
Vertical Salinity Profiles
Initial Conditions

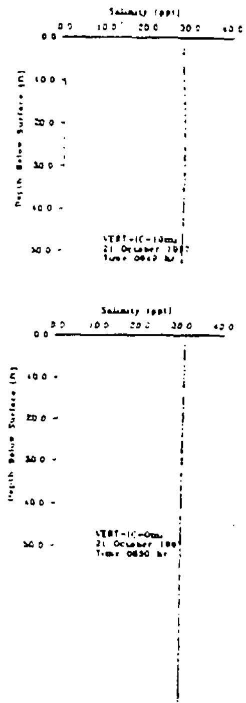

Figure 11-70

PSE&G 1-Unit Survey: 27 October 1997
Vertical Temperature Profiles
Tidal Boundary Conditions

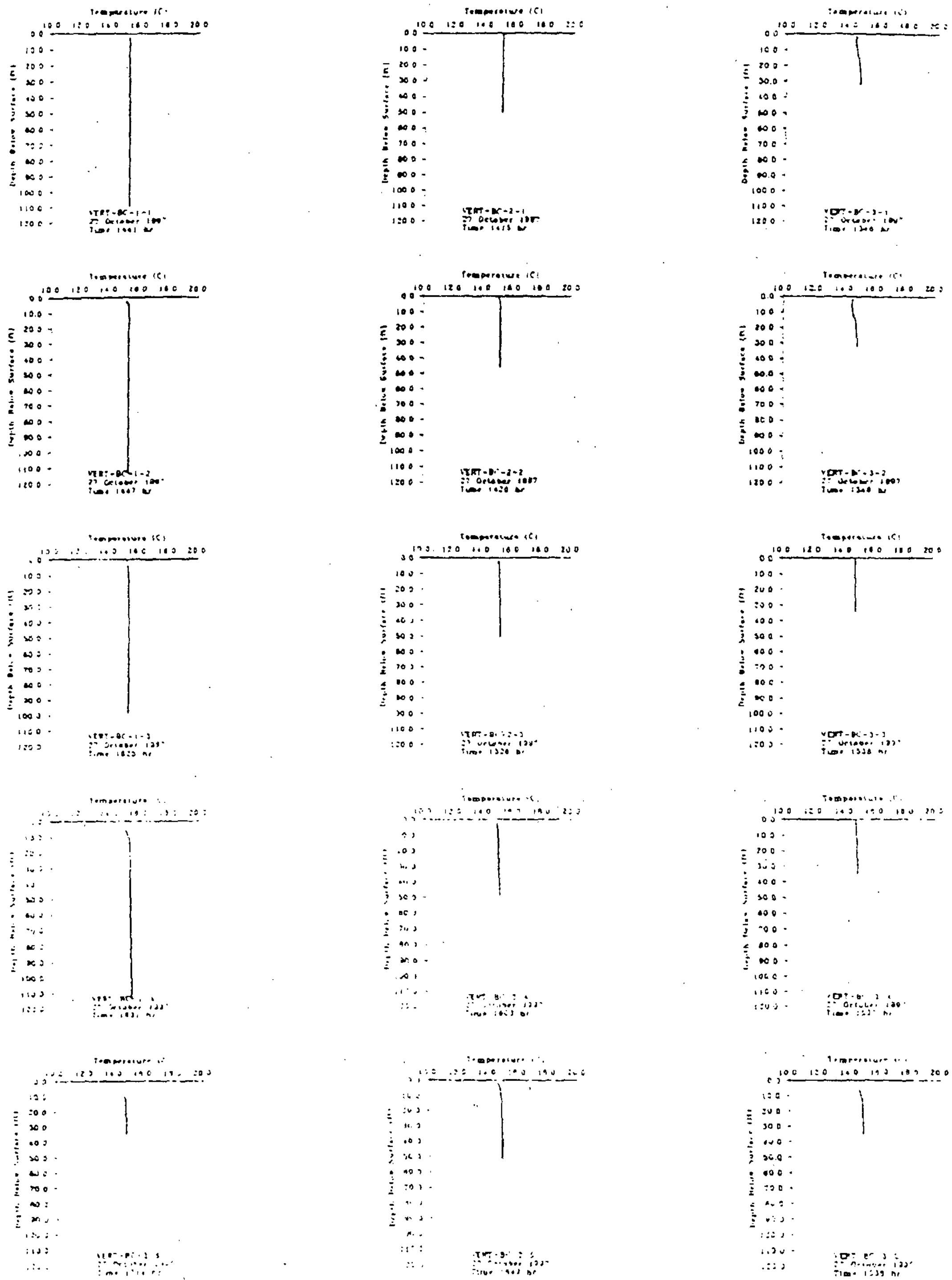

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Figure 11-71

PSE&G 1-Unit Survey: 27 October 1997
Vertical Salinity Profiles
Tidal Boundary Conditions

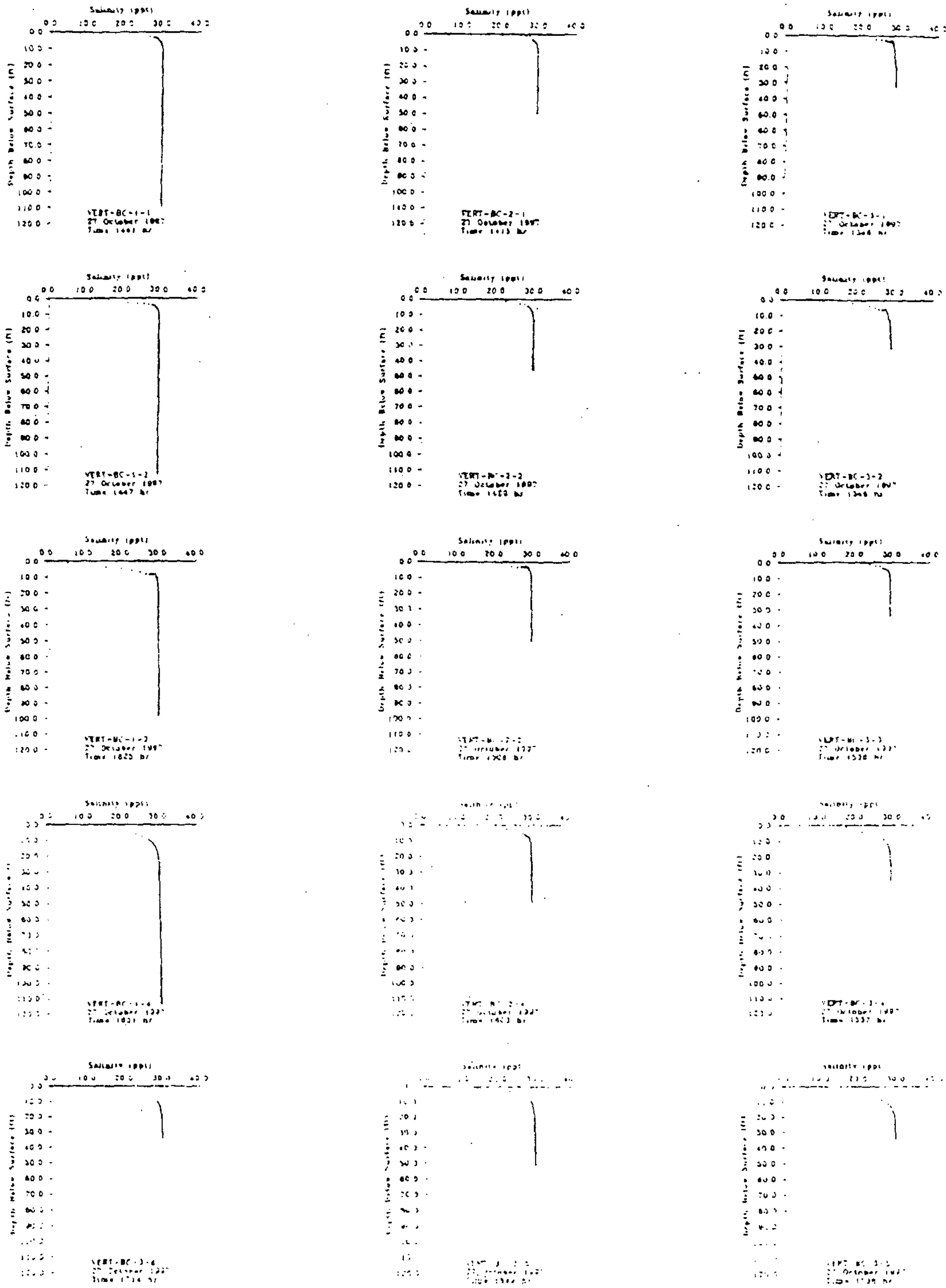

Figure 11-72

PSE&G 1-Unit Survey: October 1997
Delaware River/ C&D Canal Tide Gages
Temporal Variation

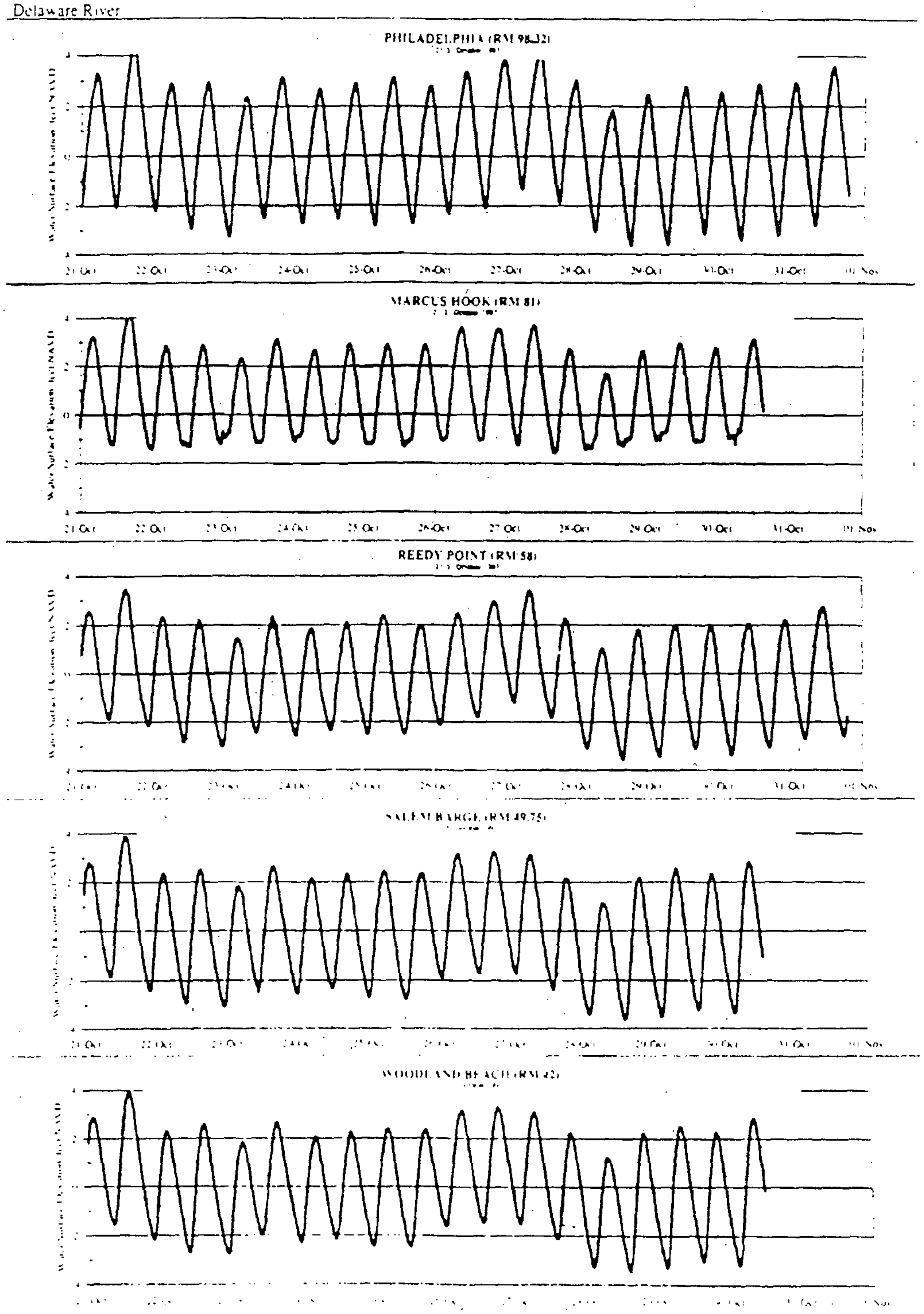

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Figure 11-73

PSE&G 1-Unit Survey: October 1997

Delaware River/ C&D Canal Tide Gages

Temporal Variation

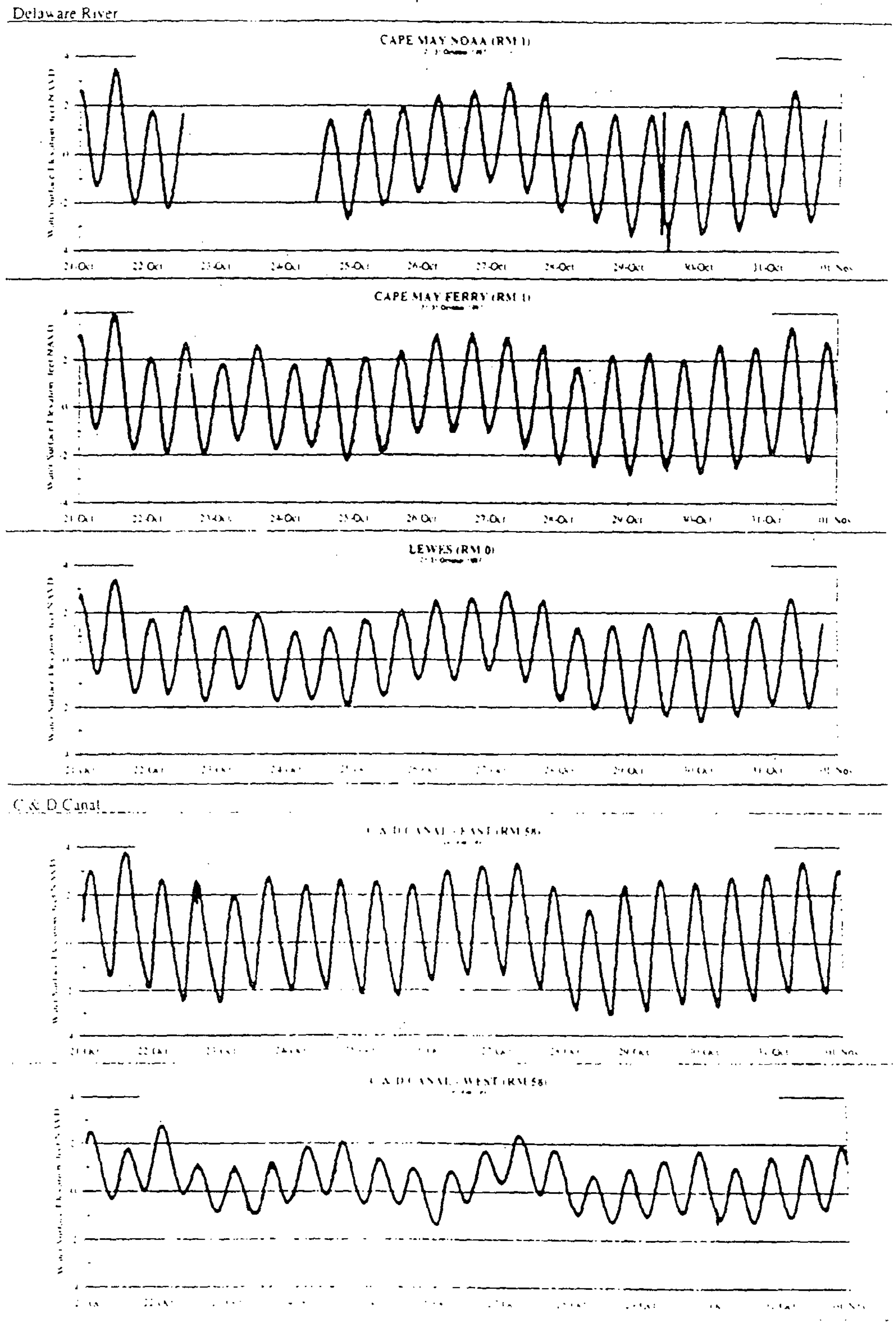

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Figure 11-74

PSE&G 1-Unit Survey: 28 October 1997
Delaware River/ C&D Canal Tide Gages
Temporal Variation

Delaware River

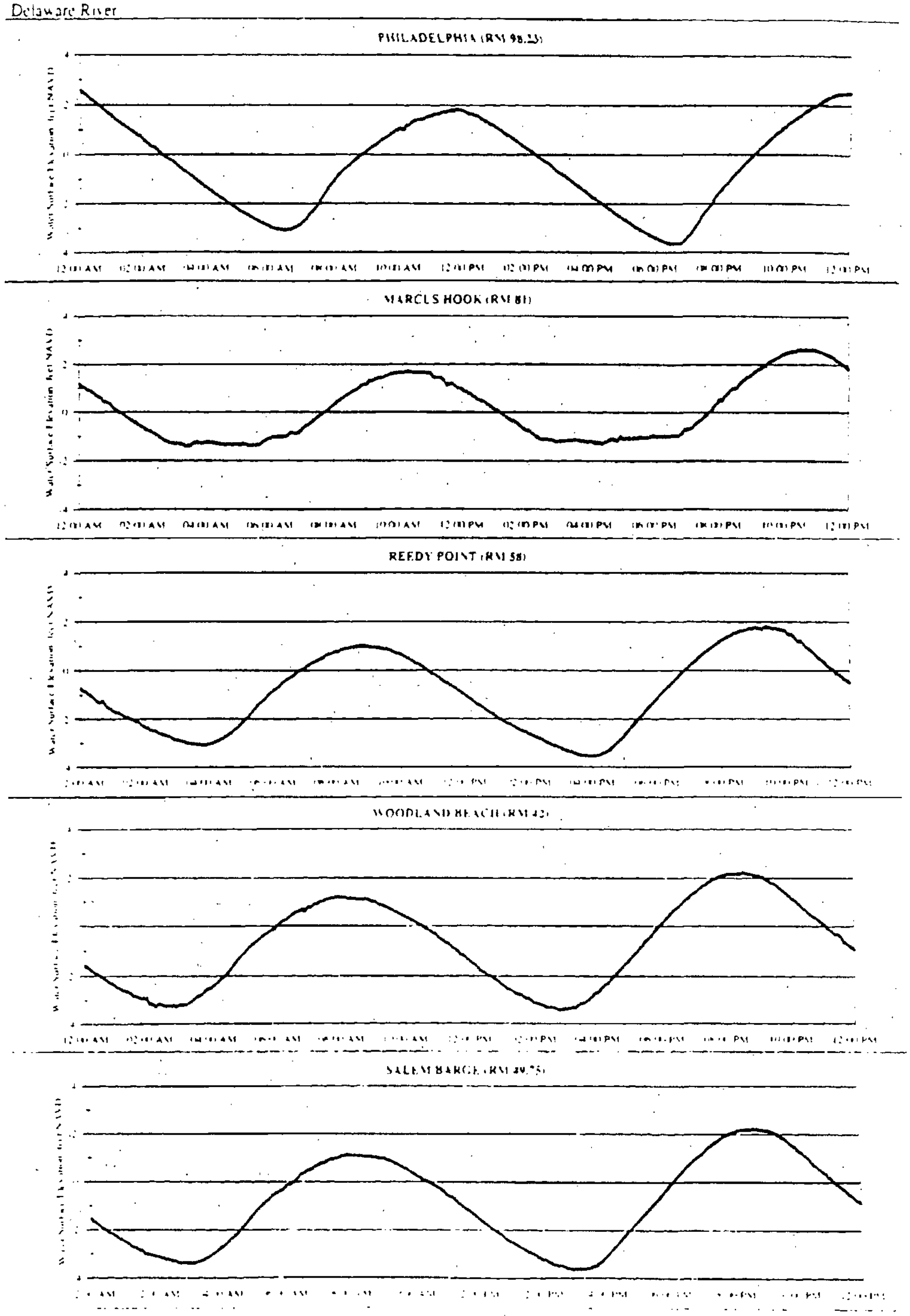

Figure 11-75

PSE&G 1-Unit Survey, 28 October 1997

Delaware River/ C&D Canal Tide Gages

Temporal Variation

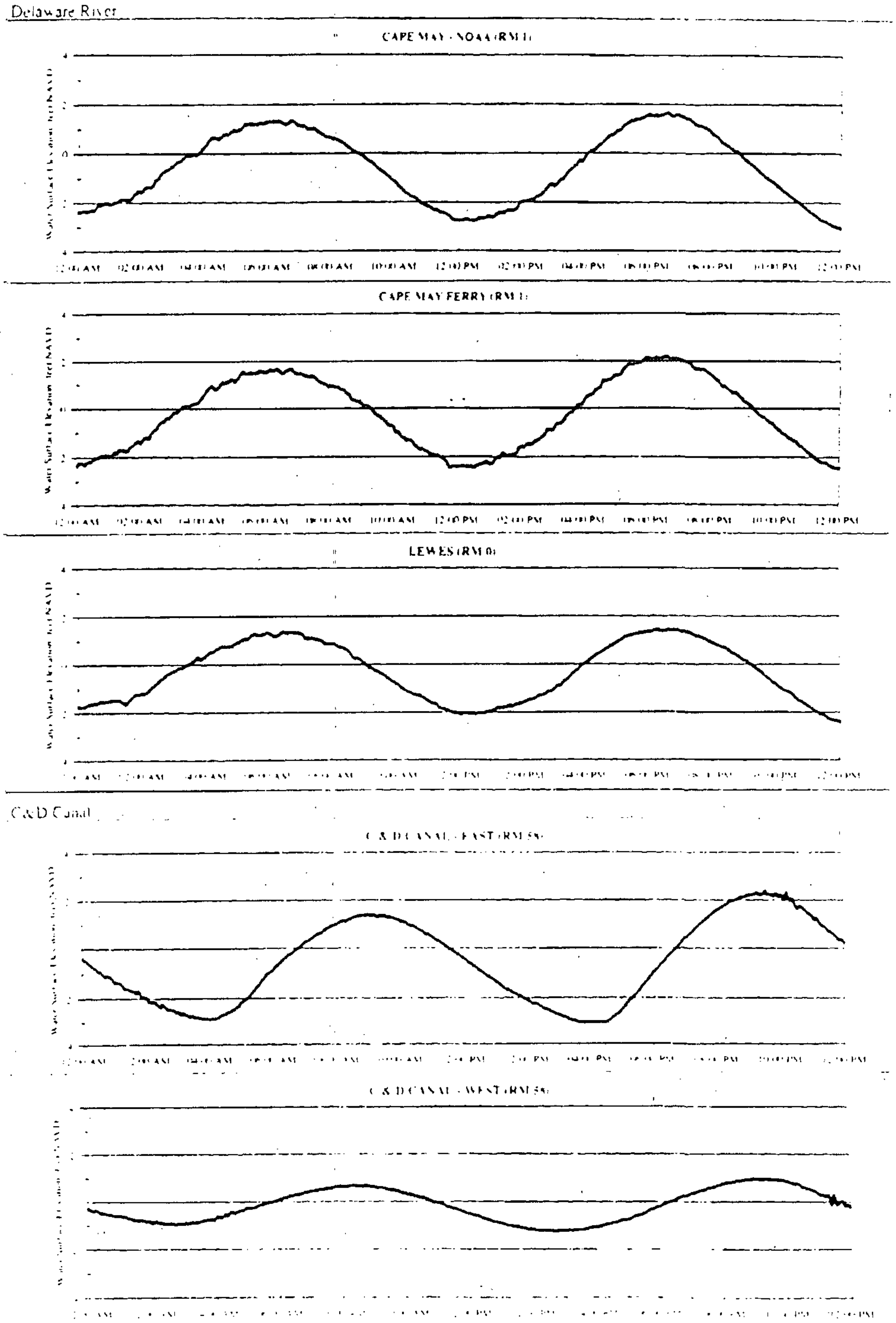

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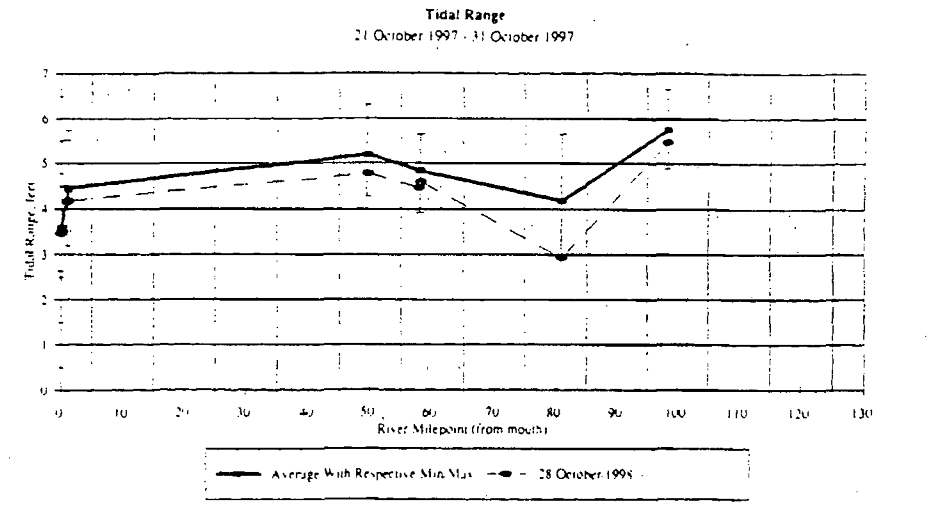
Figure 11-76

PSE&G 1-Unit Survey: October 1997
Delaware River Tide Gages
Spatial Variation



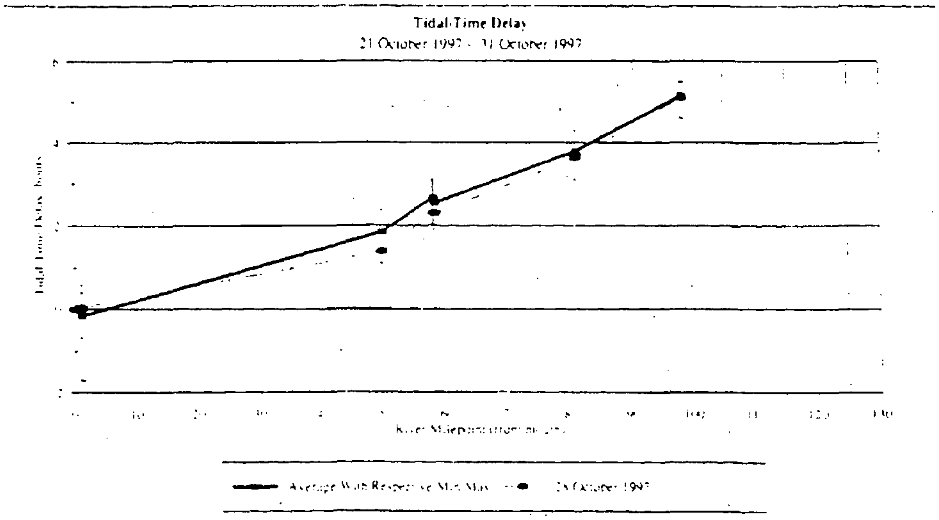


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Figure 11-77
PSE&G 1-Unit Survey
Ebb/Flood Transect Locations

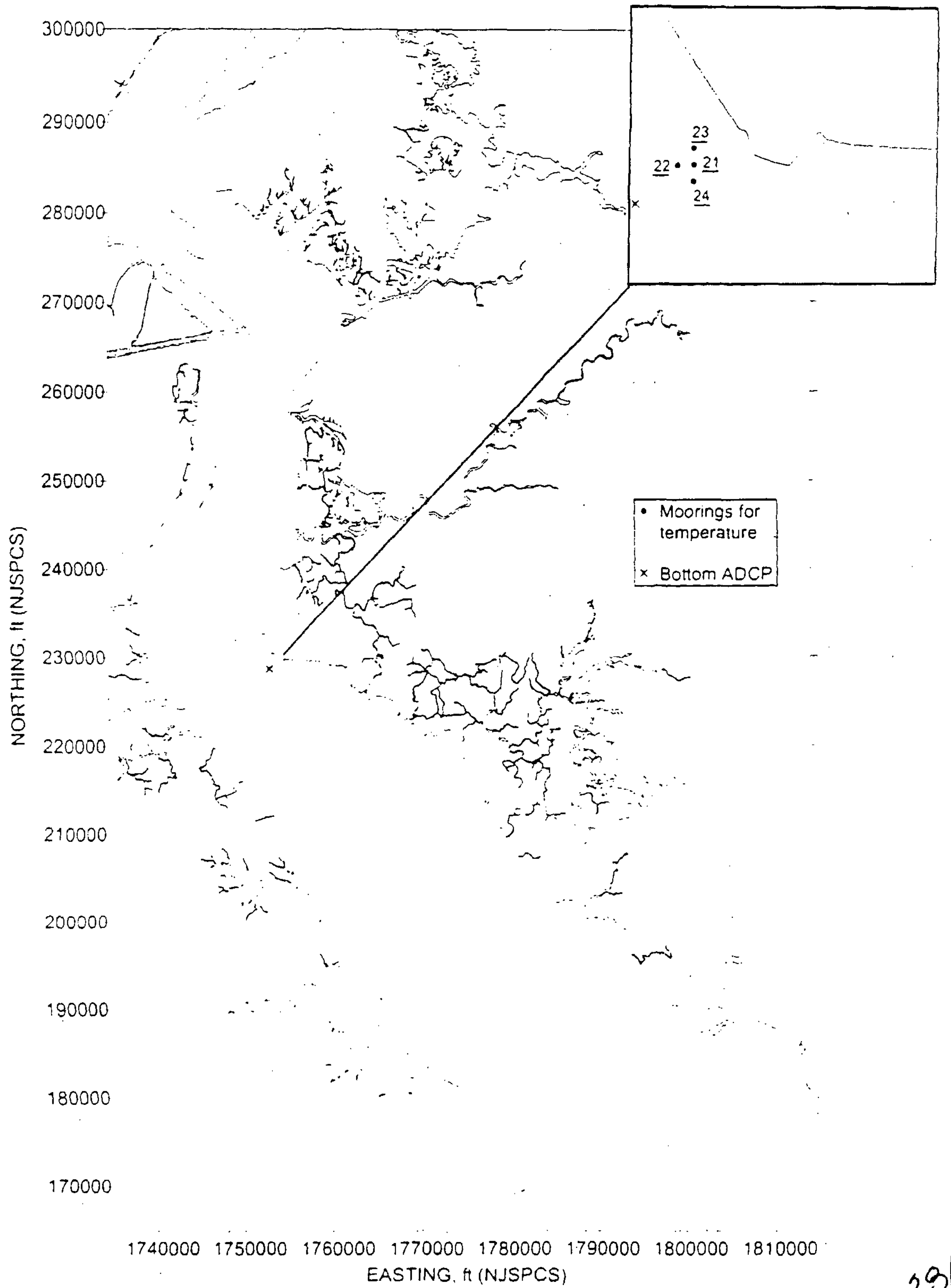

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Figure 11-78

PSE&G 1-Unit Survey; 28 October 1997
Temperature Vertical Profiles (Moorings)
Flood Phase (06:30 - 08:30)

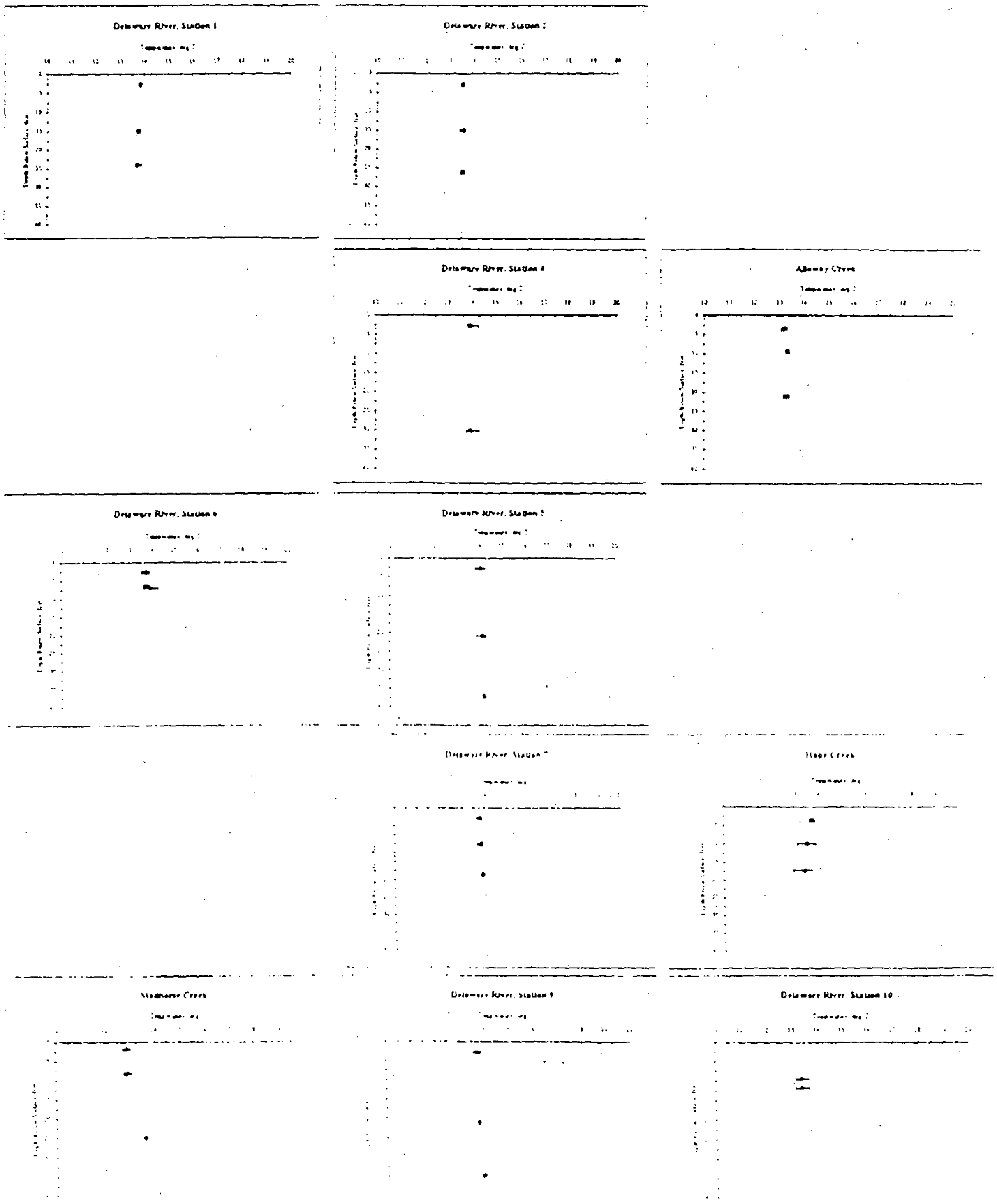
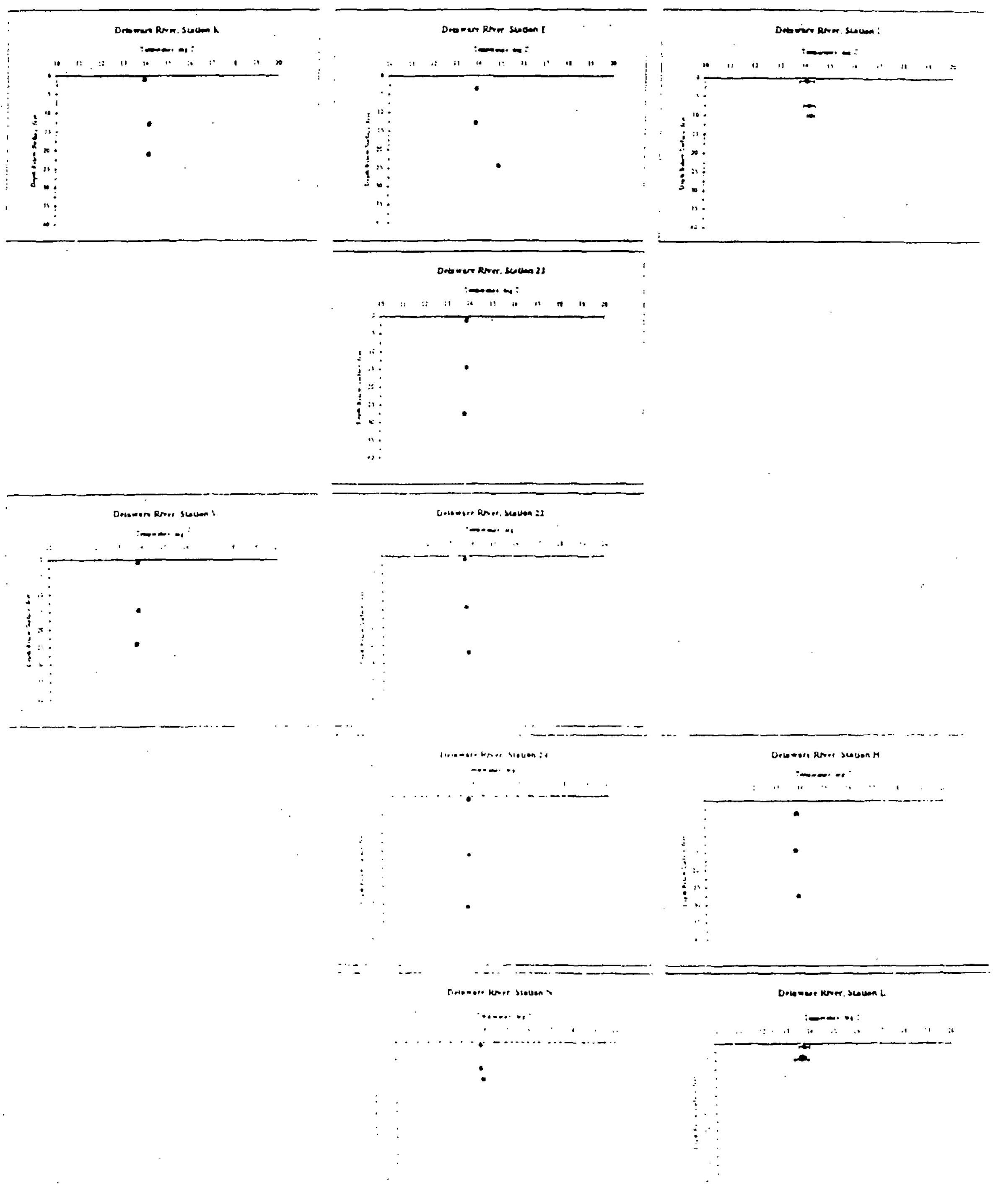


Figure 11-79

PSE&G 1-Unit Survey: 28 October 1997
Temperature Vertical Profiles (Moorings)
Flood Phase (06:30 - 08:30)



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48 b

Figure 11-80

PSE&G 1-Unit Survey, 28 October 1997
Salinity Vertical Profiles (Moorings)
Flood Phase (06:30 - 08:30)

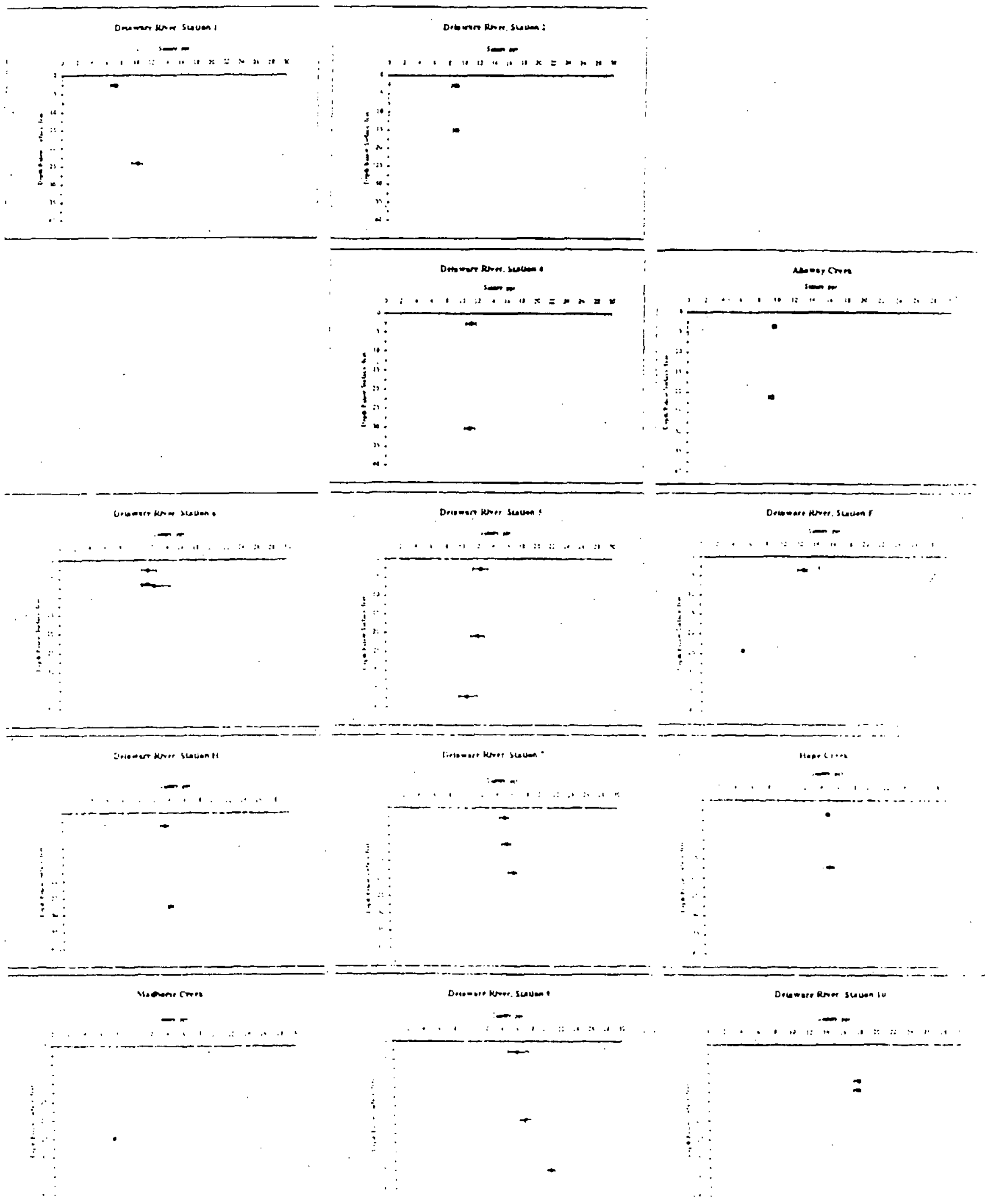
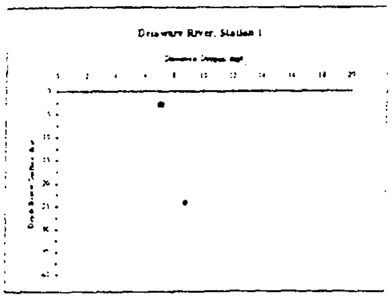
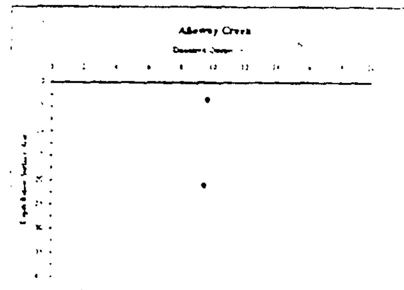
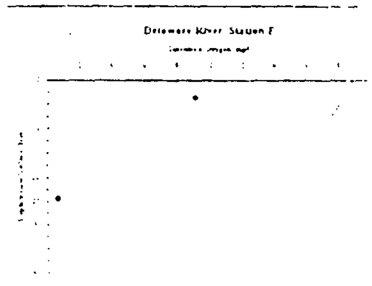


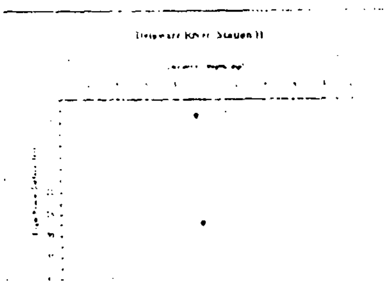
Figure 11-81

PSE&G 1-Unit Survey: 28 October 1997
Dissolved Oxygen Vertical Profiles (Moorings)
Flood Phase (06:30 - 08:30)









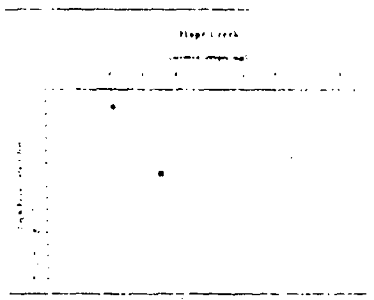


Figure 11-82

PSE&G 1-Unit Survey: 28 October 1997
Temperature Vertical Profiles (Moorings)
EOF Phase (09:10 - 11:10)

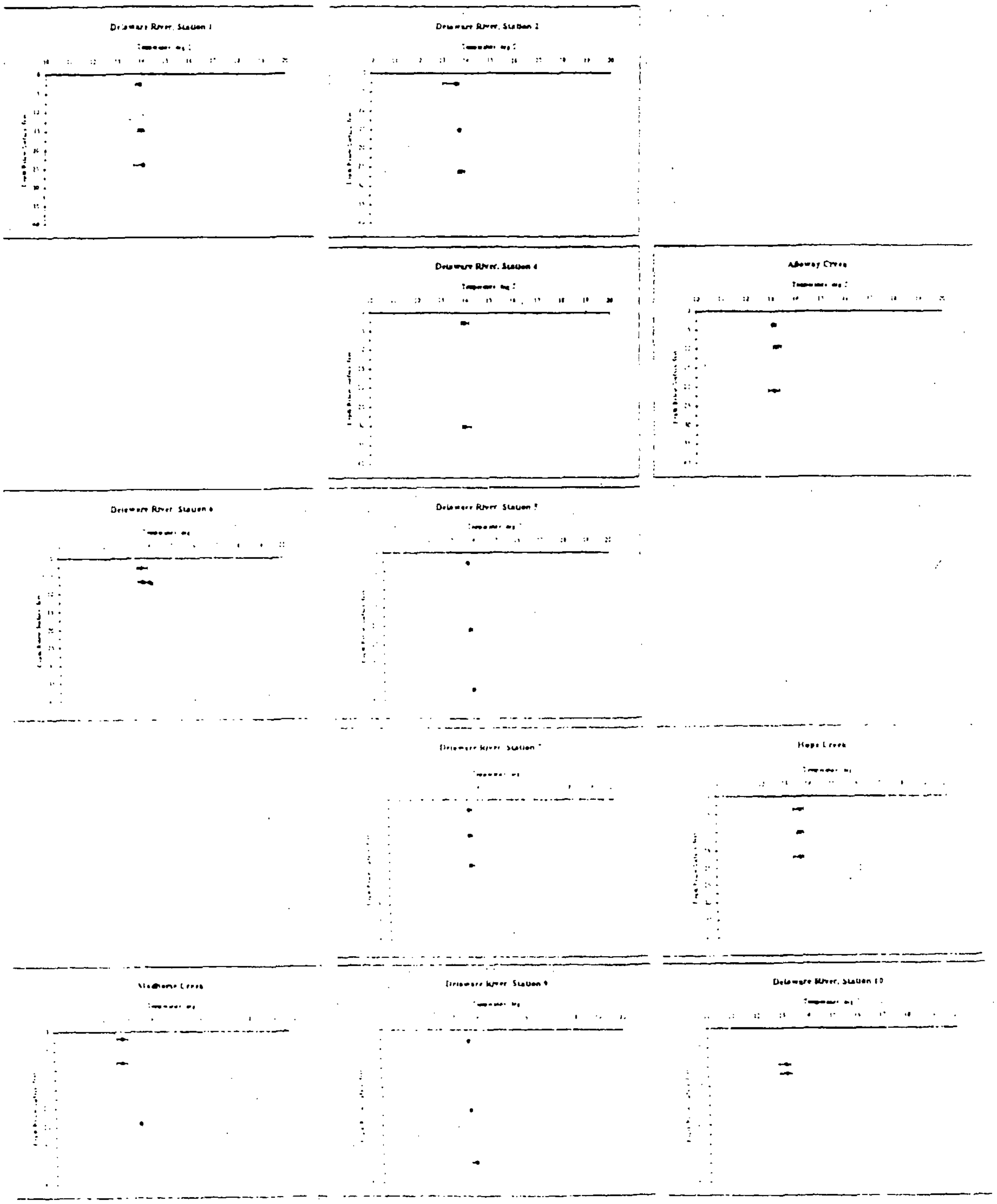


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Figure 11-83

PSE&G 1-Unit Survey: 28 October 1997
Temperature Vertical Profiles (Moorings)
EOF Phase (09:10 - 11:10)

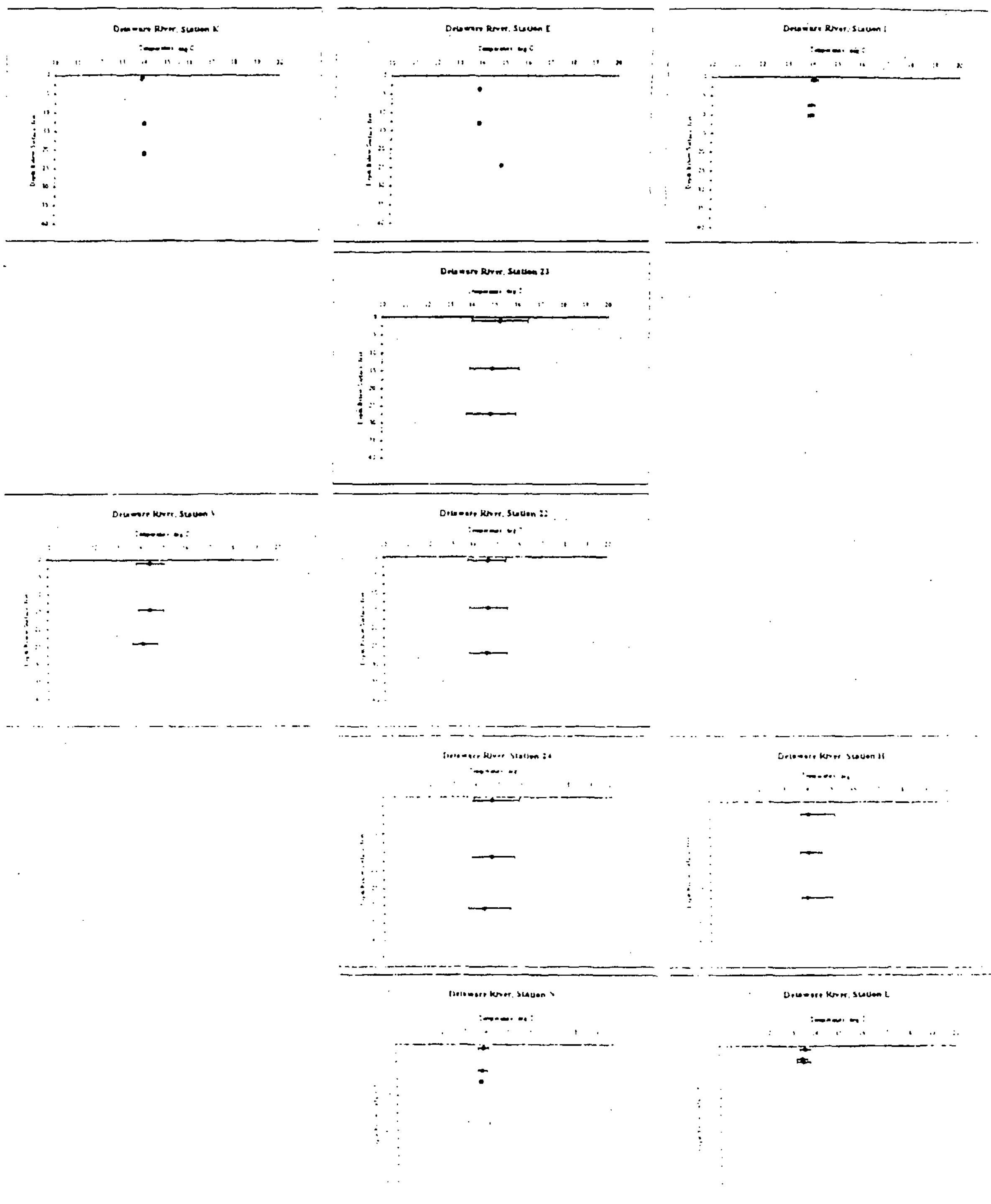

Figure 11-84

PSE&G 1-Unit Survey; 28 October 1997
Salinity Vertical Profiles (Moorings)
EOF Phase (09:10 - 11:10)

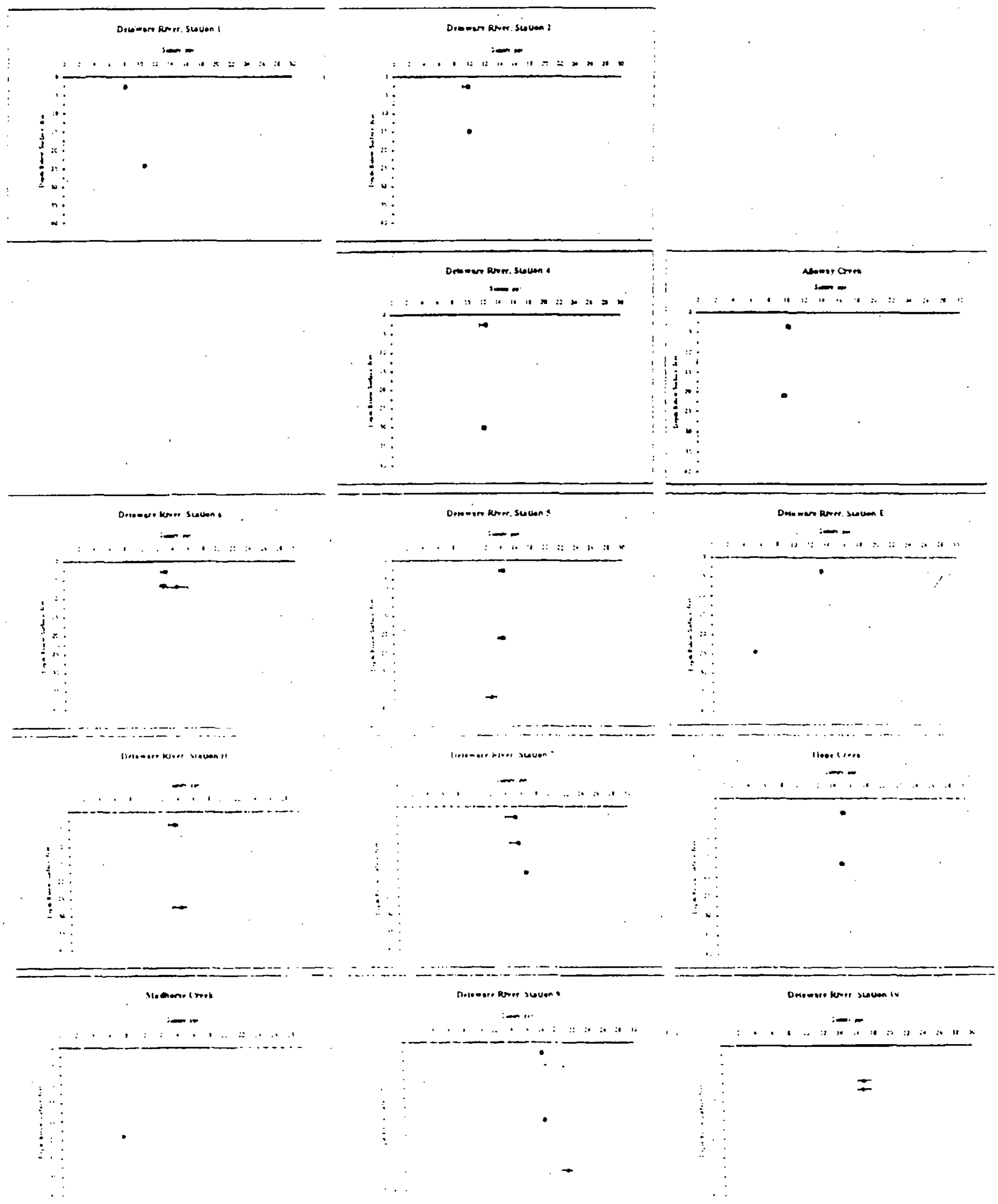

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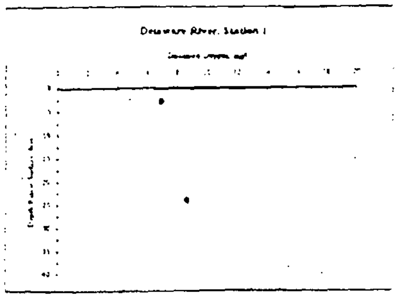
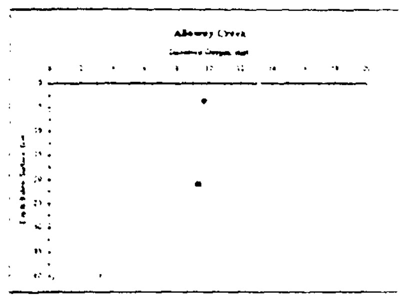
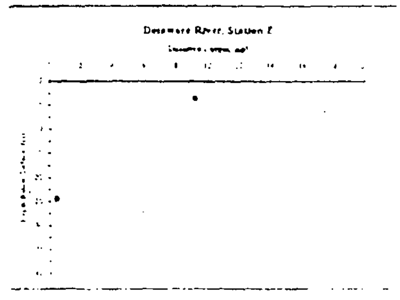
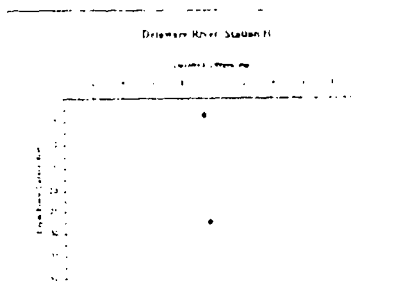
Figure 11-85

PSE&G 1-Unit Survey; 28 October 1997
Dissolved Oxygen Vertical Profiles (Moorings)
EOF Phase (09:10 - 11:10)









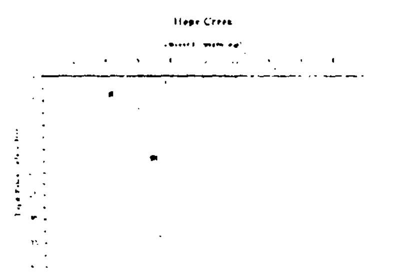


Figure 11-86

PSE&G 1-Unit Survey; 28 October 1997
Temperature Vertical Profiles (Moorings)
EBB Phase (12:25 - 13:25)

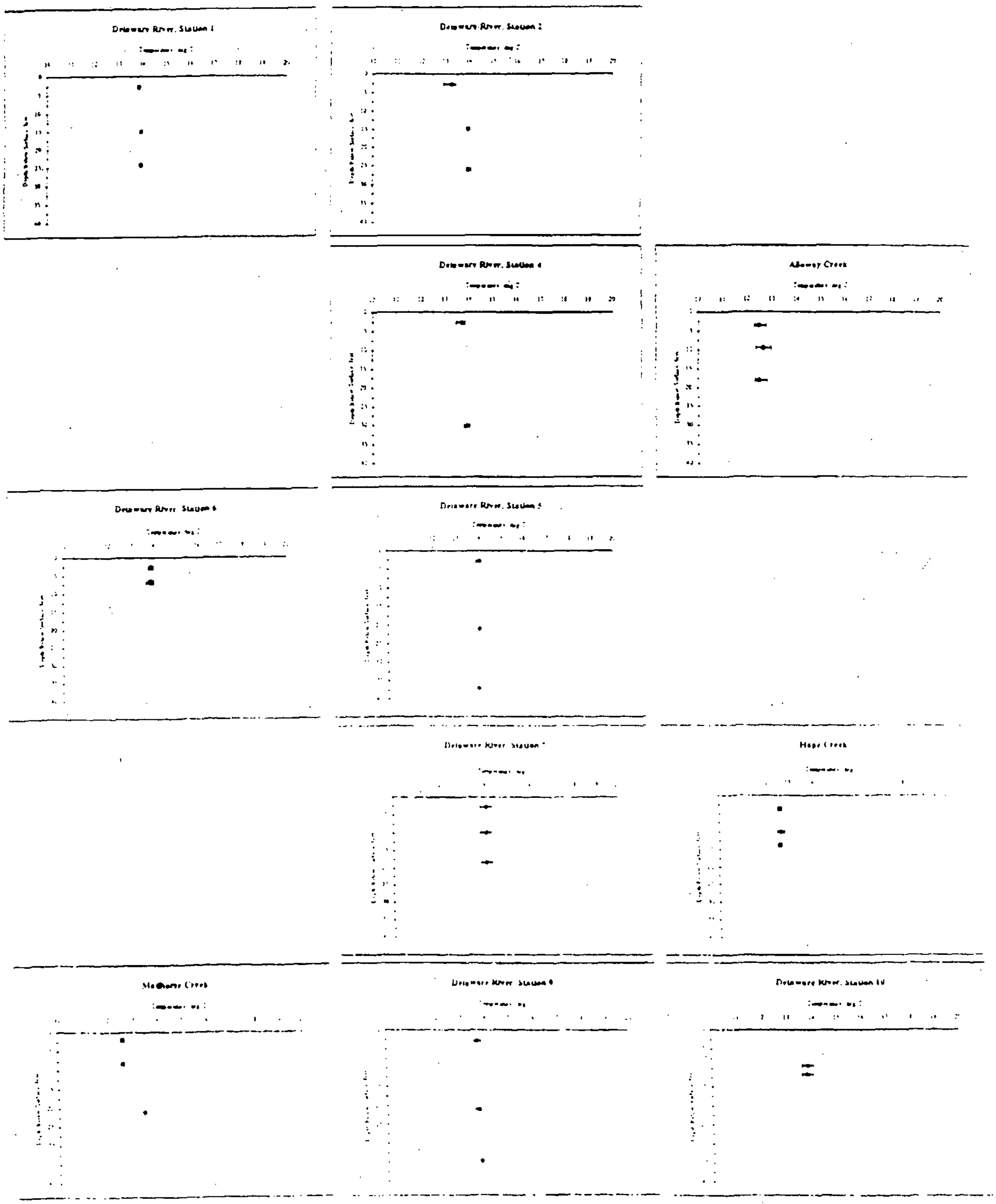


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Figure 11-87

PSE&G 1-Unit Survey; 28 October 1997
Temperature Vertical Profiles (Moorings)
EBB Phase (12:25 - 13:25)

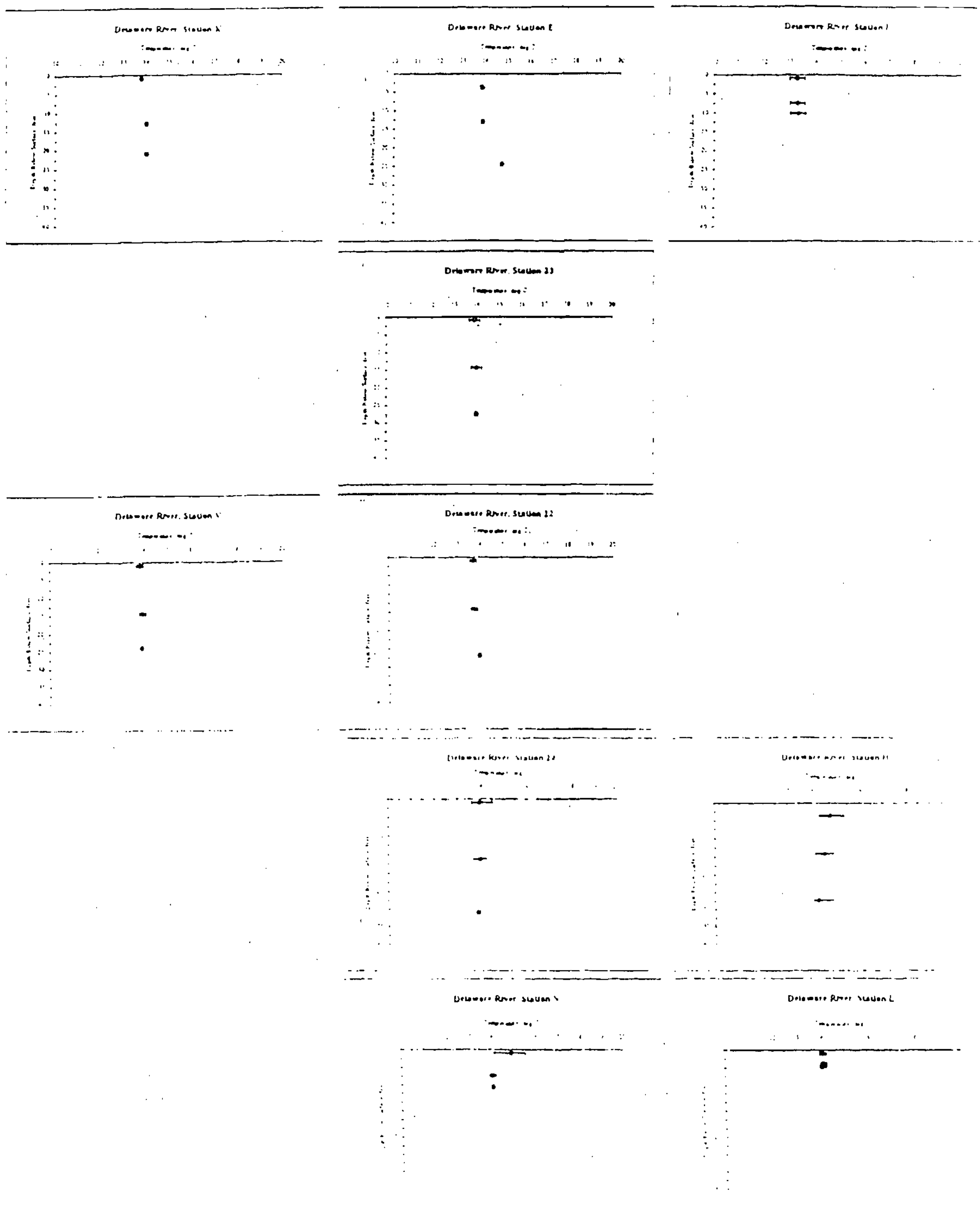

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Figure 11-88

PSE&G 1-Unit Survey; 28 October 1997
Salinity Vertical Profiles (Moorings)
EBB Phase (12:25 - 13:25)

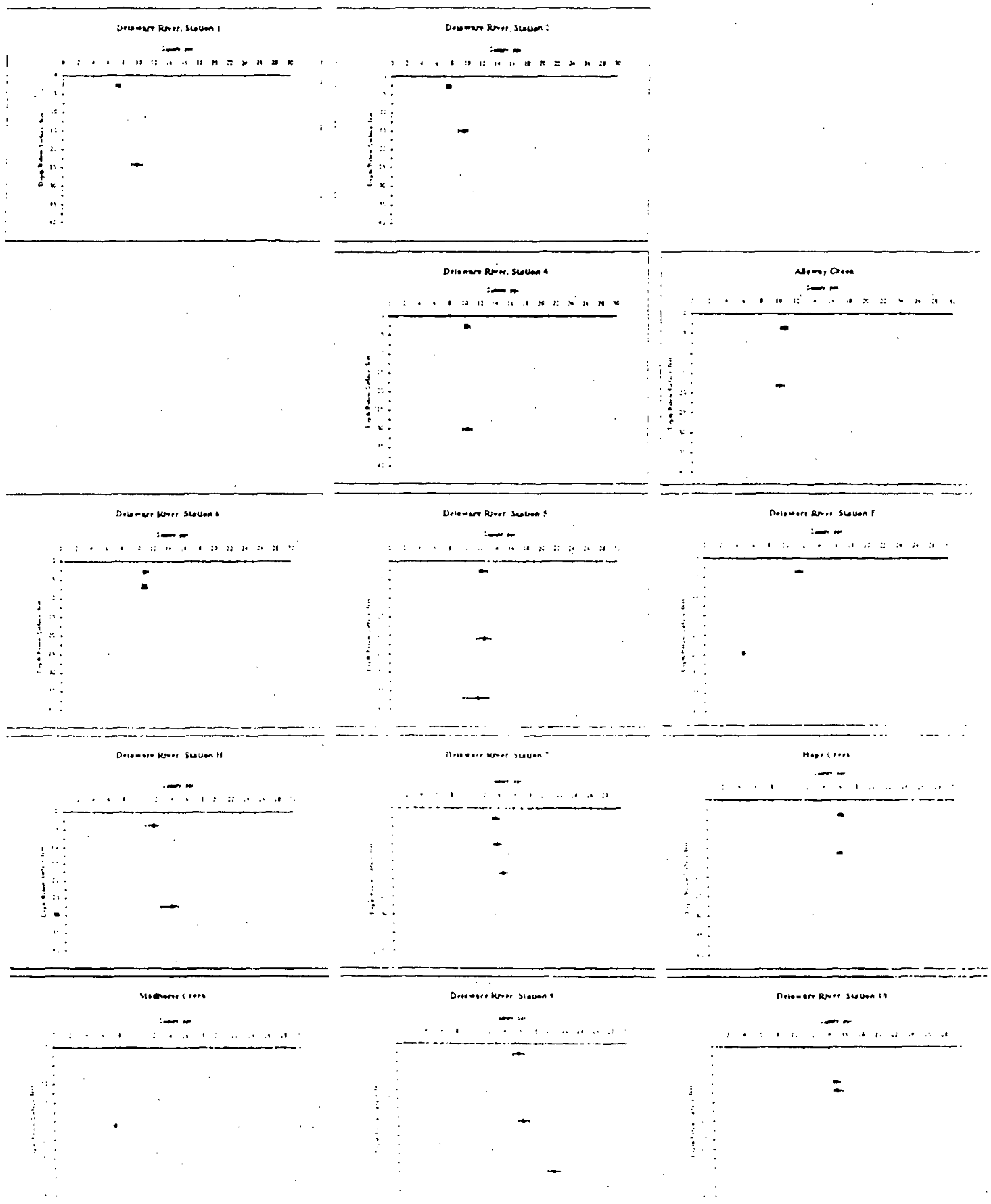
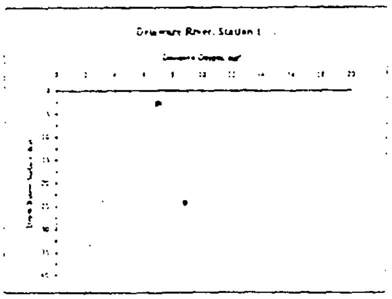
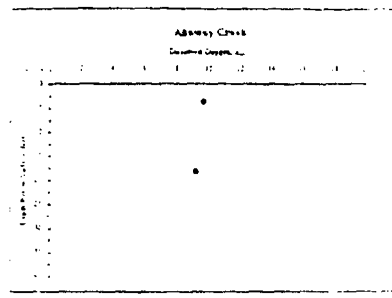
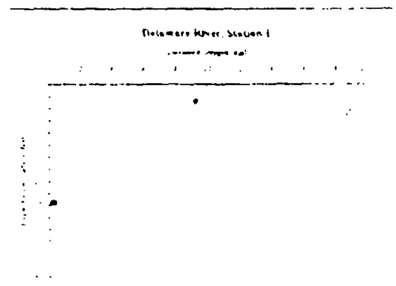


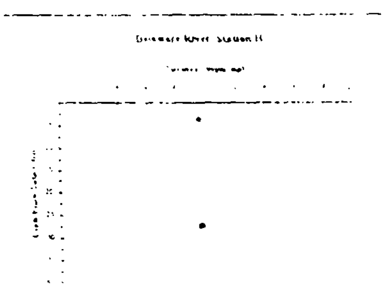
Figure 11-89

PSE&G 1-Unit Survey; 28 October 1997
Dissolved Oxygen Vertical Profiles (Moorings)
EBB Phase (11:25 - 13:25)









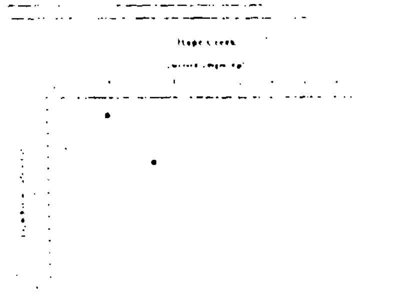


Figure 11-90

PSE&G 1-Unit Survey: 28 October 1997
Temperature Vertical Profiles (Moorings)
EOE Phase (16:15 - 18:15)

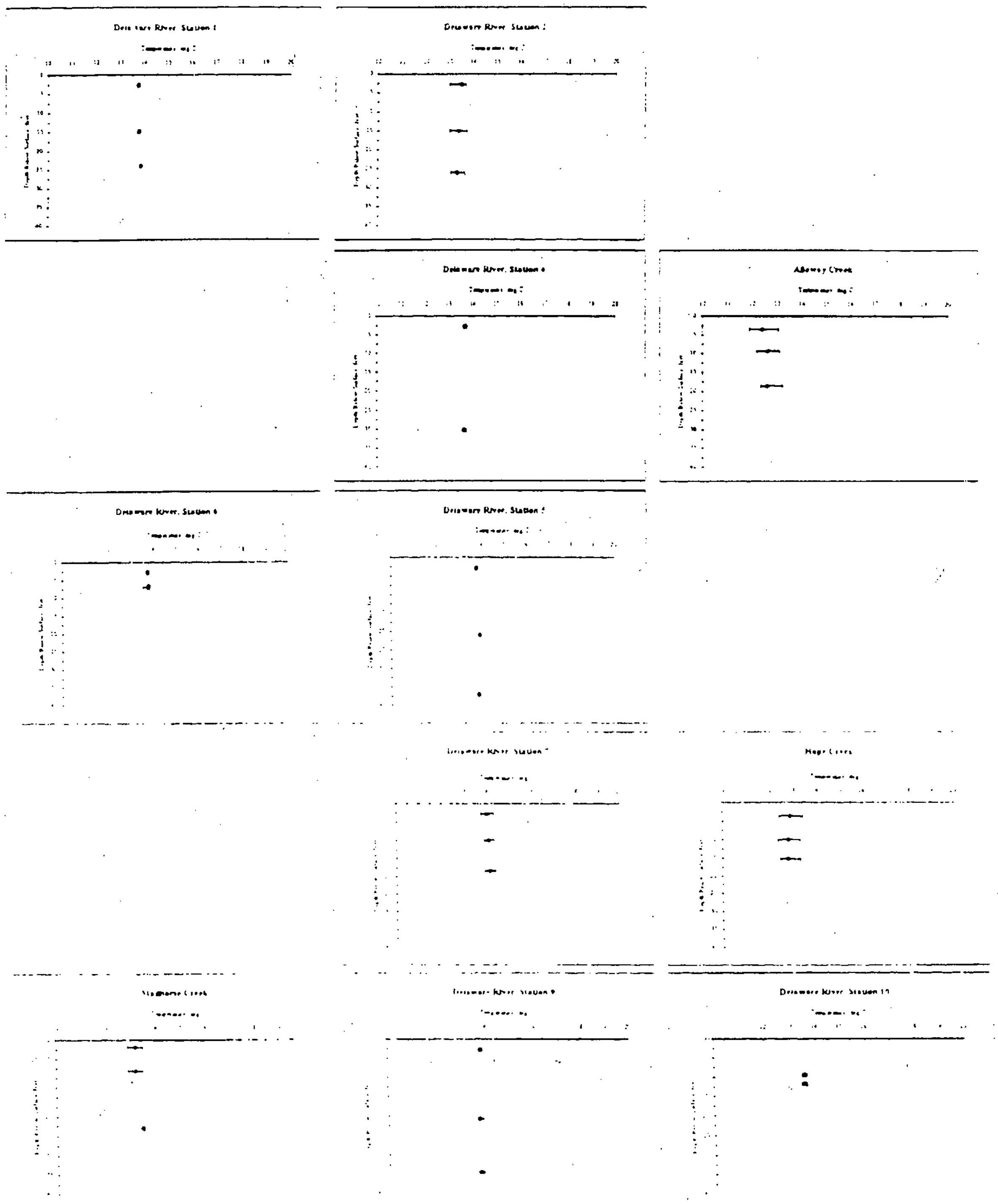


Figure 11-91

PSE&G 1-Unit Survey; 28 October 1997
Temperature Vertical Profiles (Moorings)
EOE Phase (16:15 - 18:15)

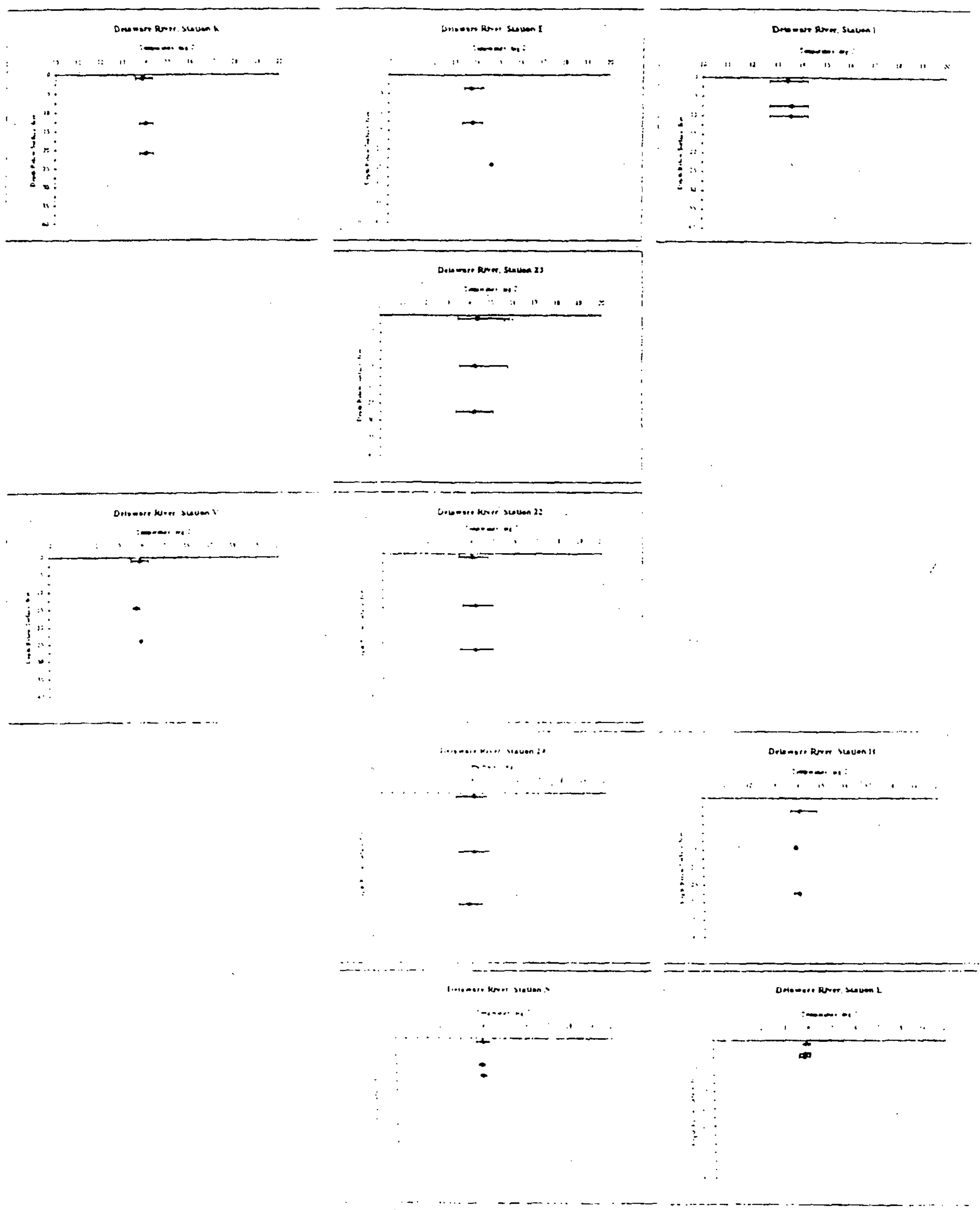


Figure 11-92

PSE&G 1-Unit Survey, 28 October 1997
Salinity Vertical Profiles (Moorings)
EOE Phase (16:15 - 18:15)

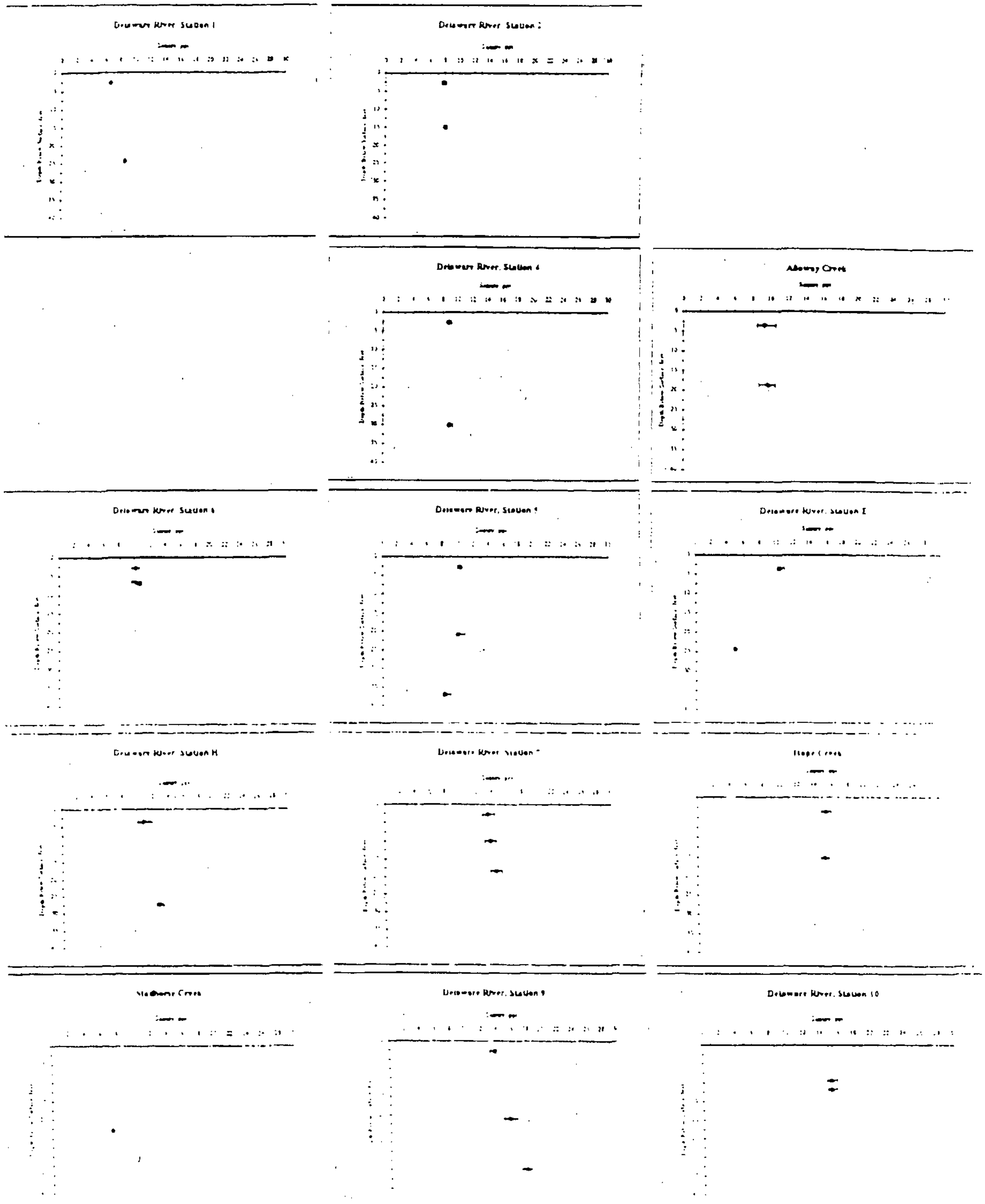
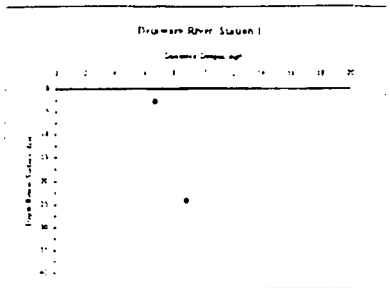
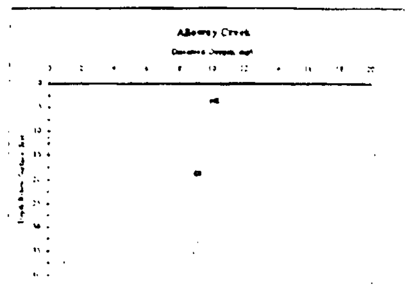
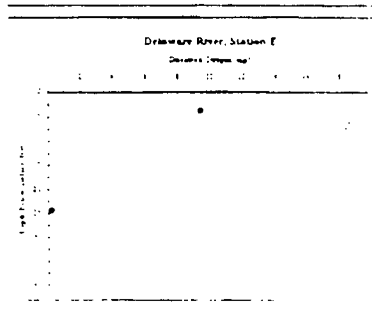


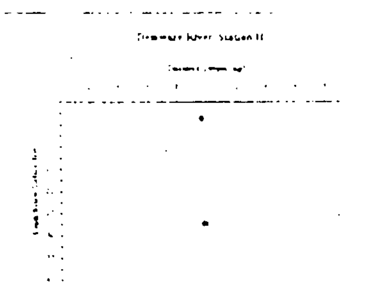
Figure 11-93

PSE&G 1-Unit Survey; 28 October 1997
Dissolved Oxygen Vertical Profiles (Moorings)
EOE Phase (16:15 - 18:15)









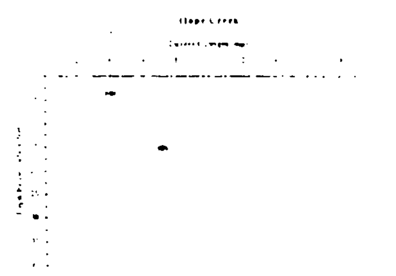
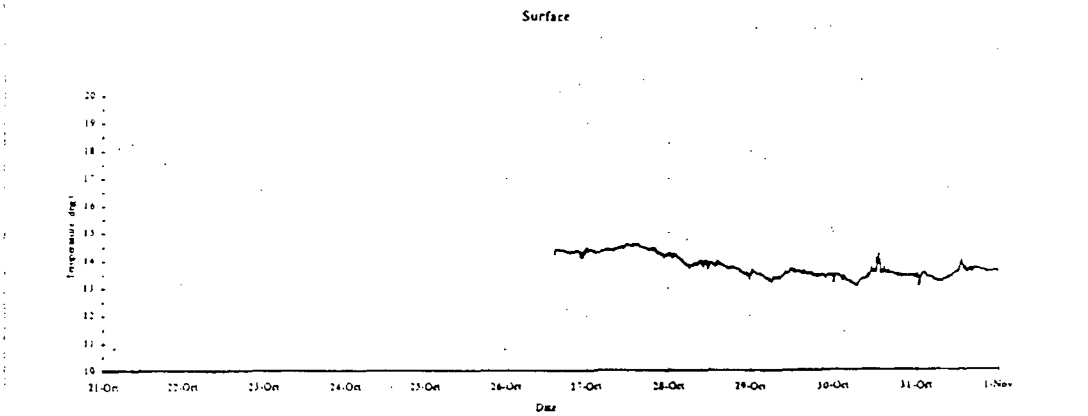
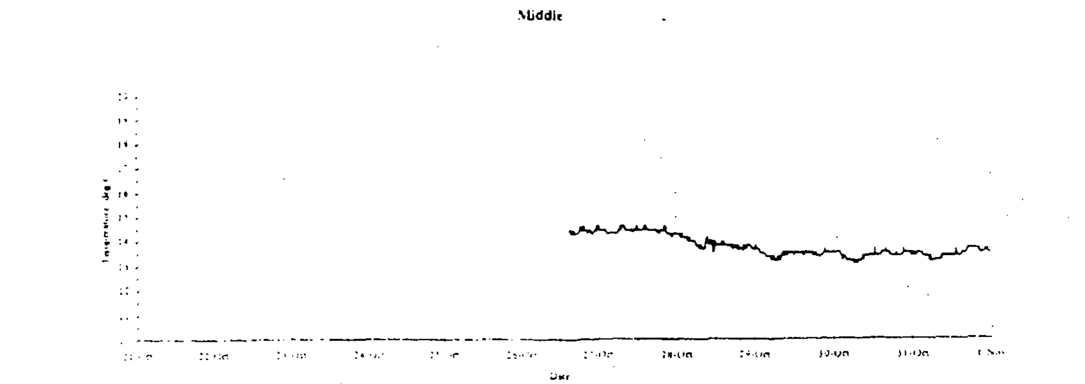


Figure 11-94

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-1





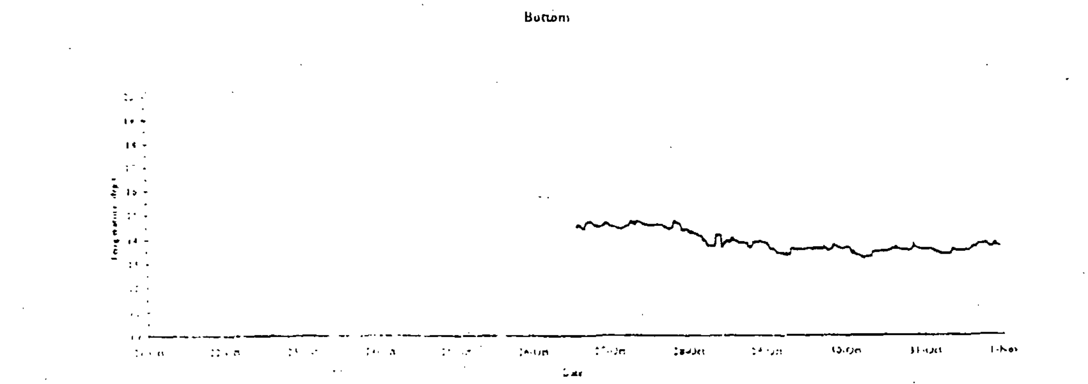


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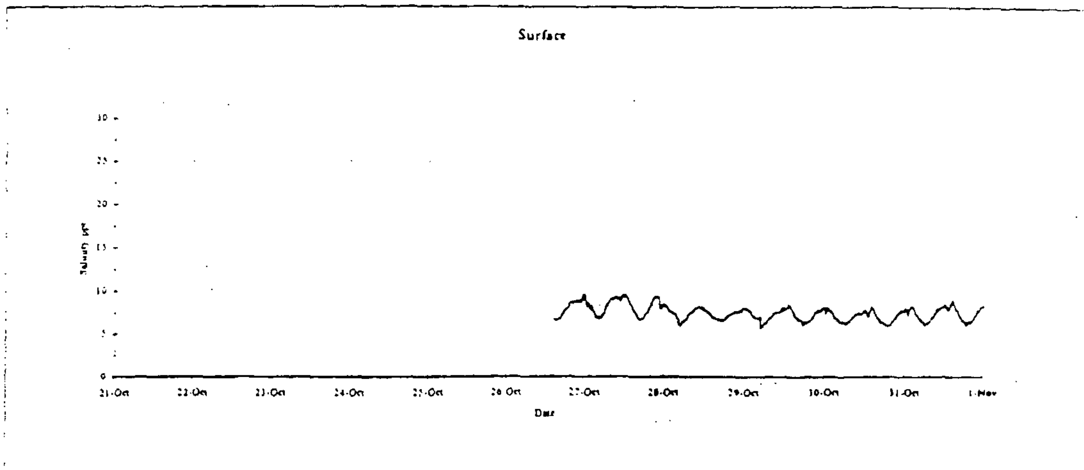
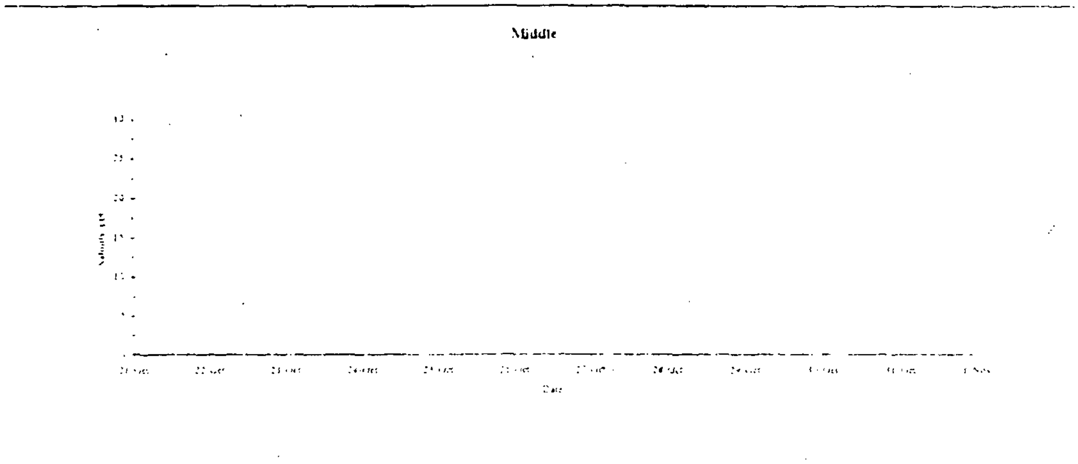
Figure 11-95

PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-1





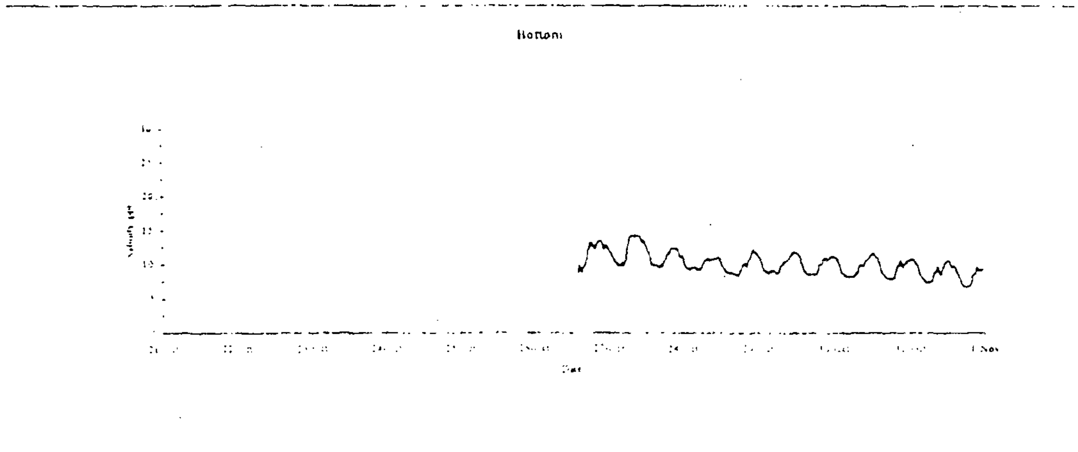


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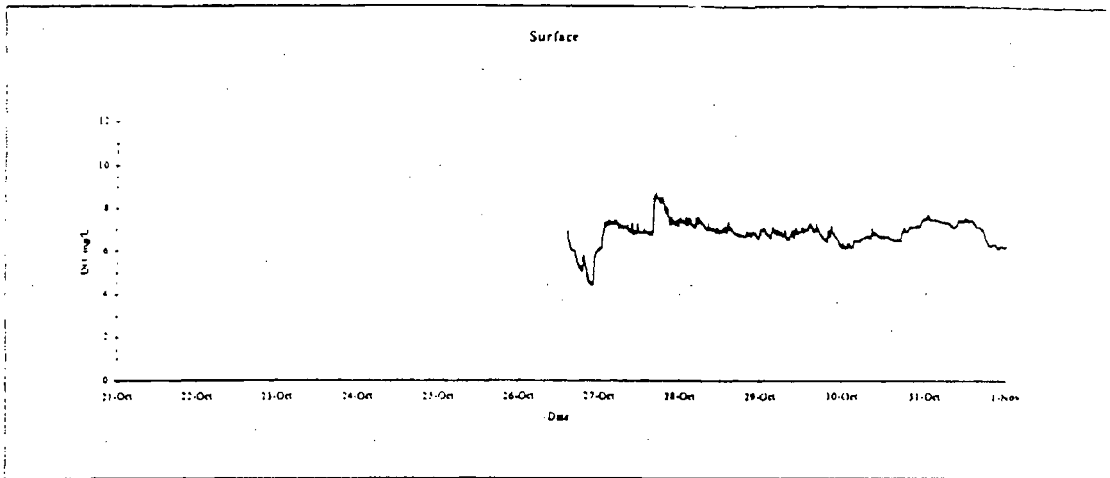
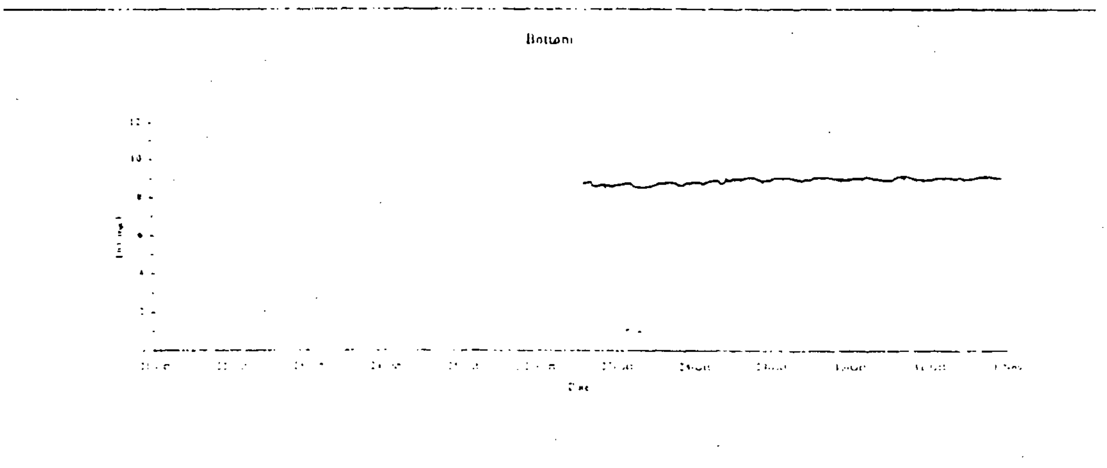
Figure 11-96

PSE&G 1-Unit Survey; 21 - 31 October 1997
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-1



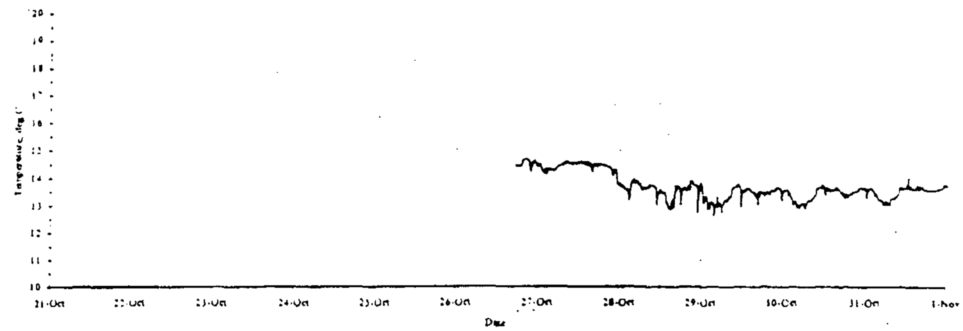


400

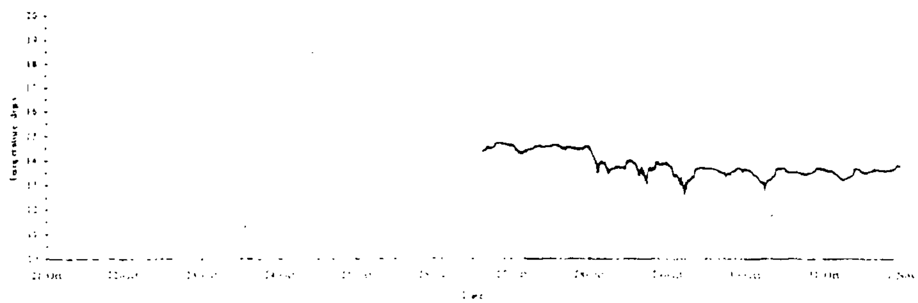
Figure 11-97

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-2

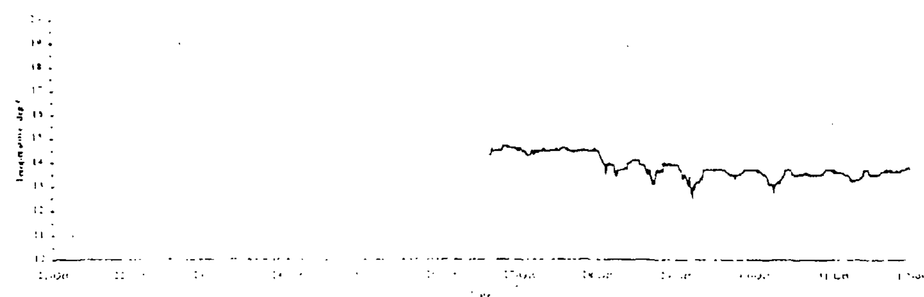
Surface



Middle



Bottom



401

Figure 11-98

PSE&G 1-Unit Survey: 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-2

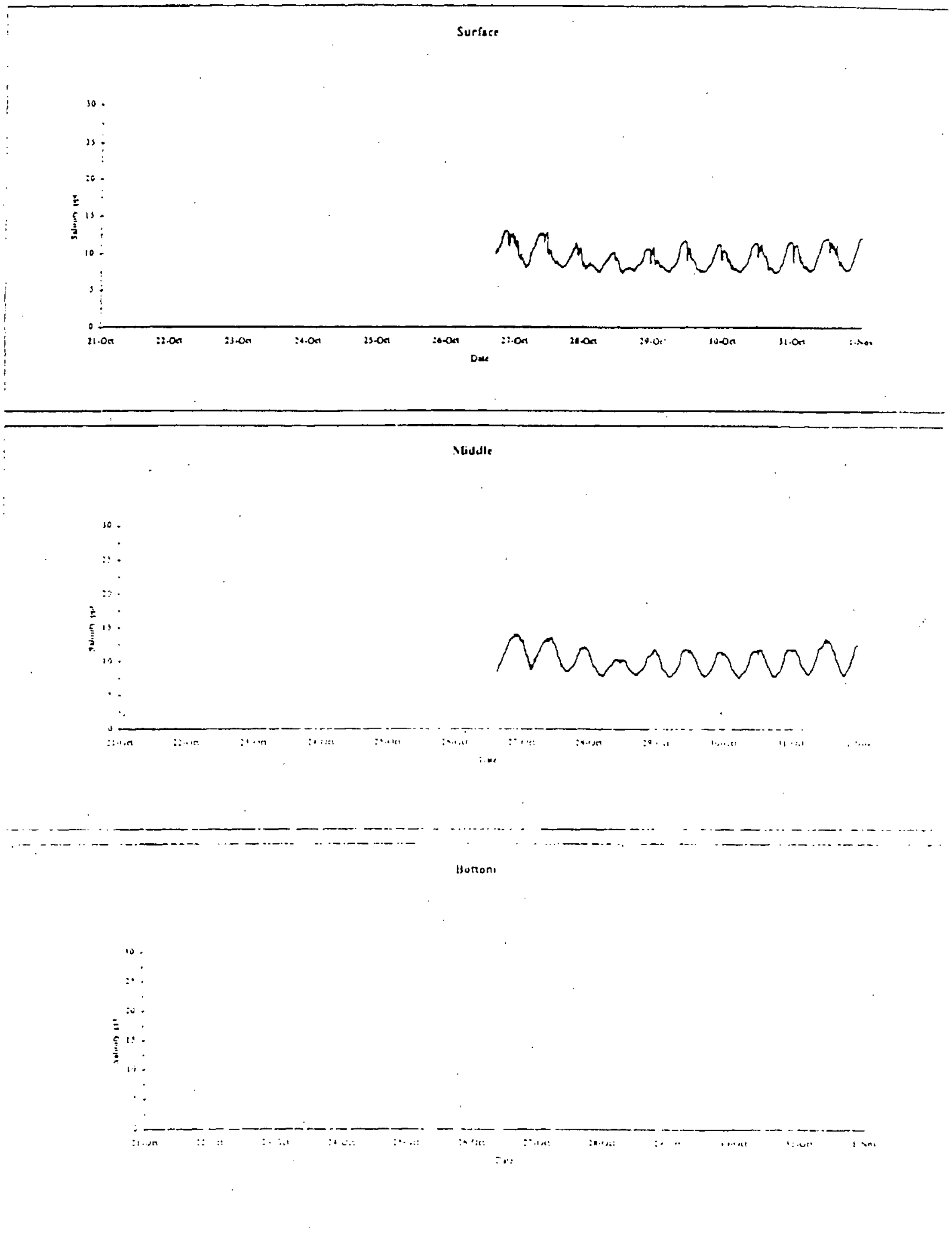
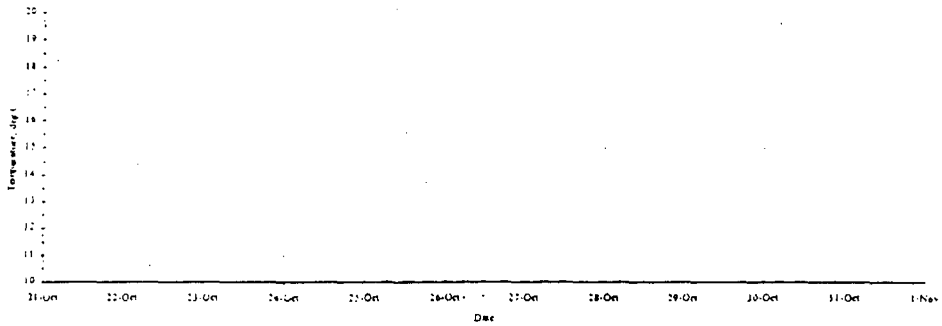


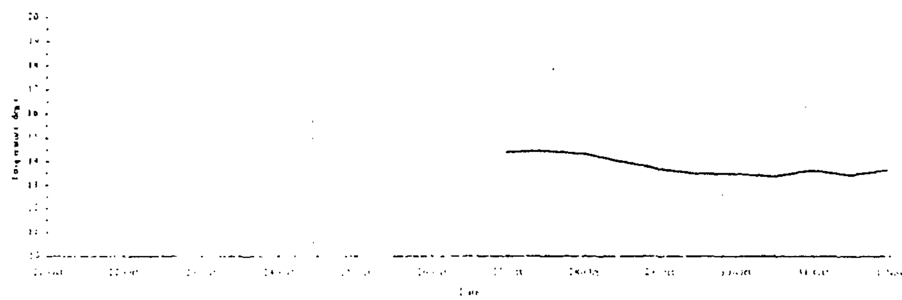
Figure 11-99

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-3

Surface



Middle



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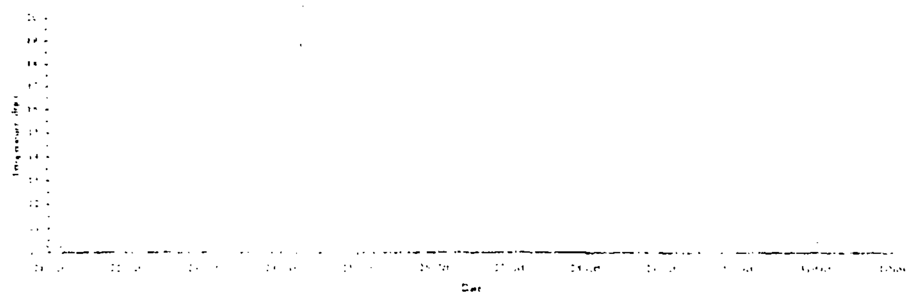
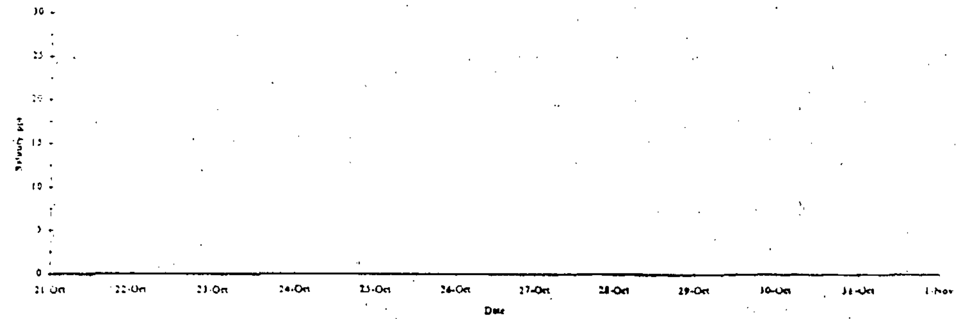


403

Figure 11-100

PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-3

Surface



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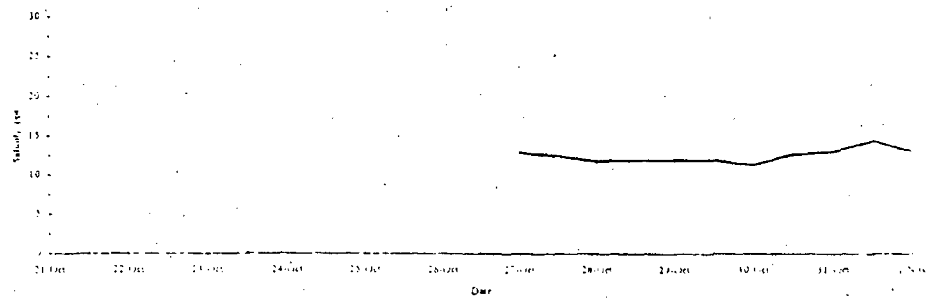

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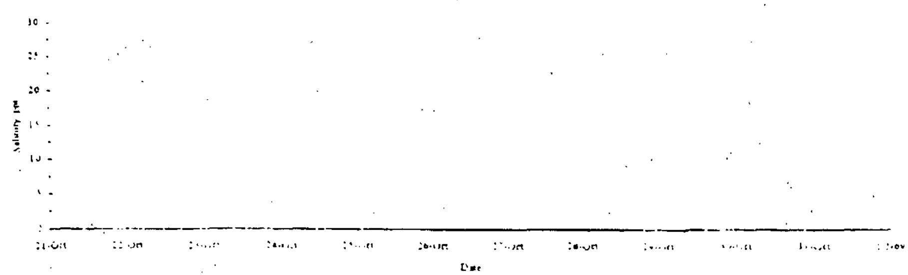
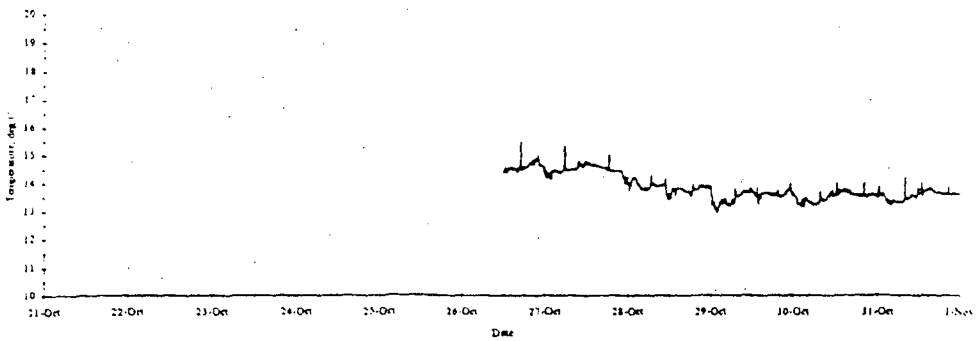


404

Figure 11-101

PSE&G 1-Unit Survey: 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-4

Surface



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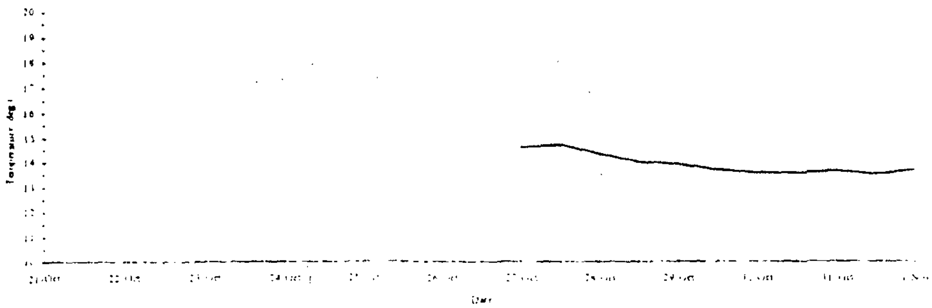


Bottom

405

Figure 11-102

PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-4

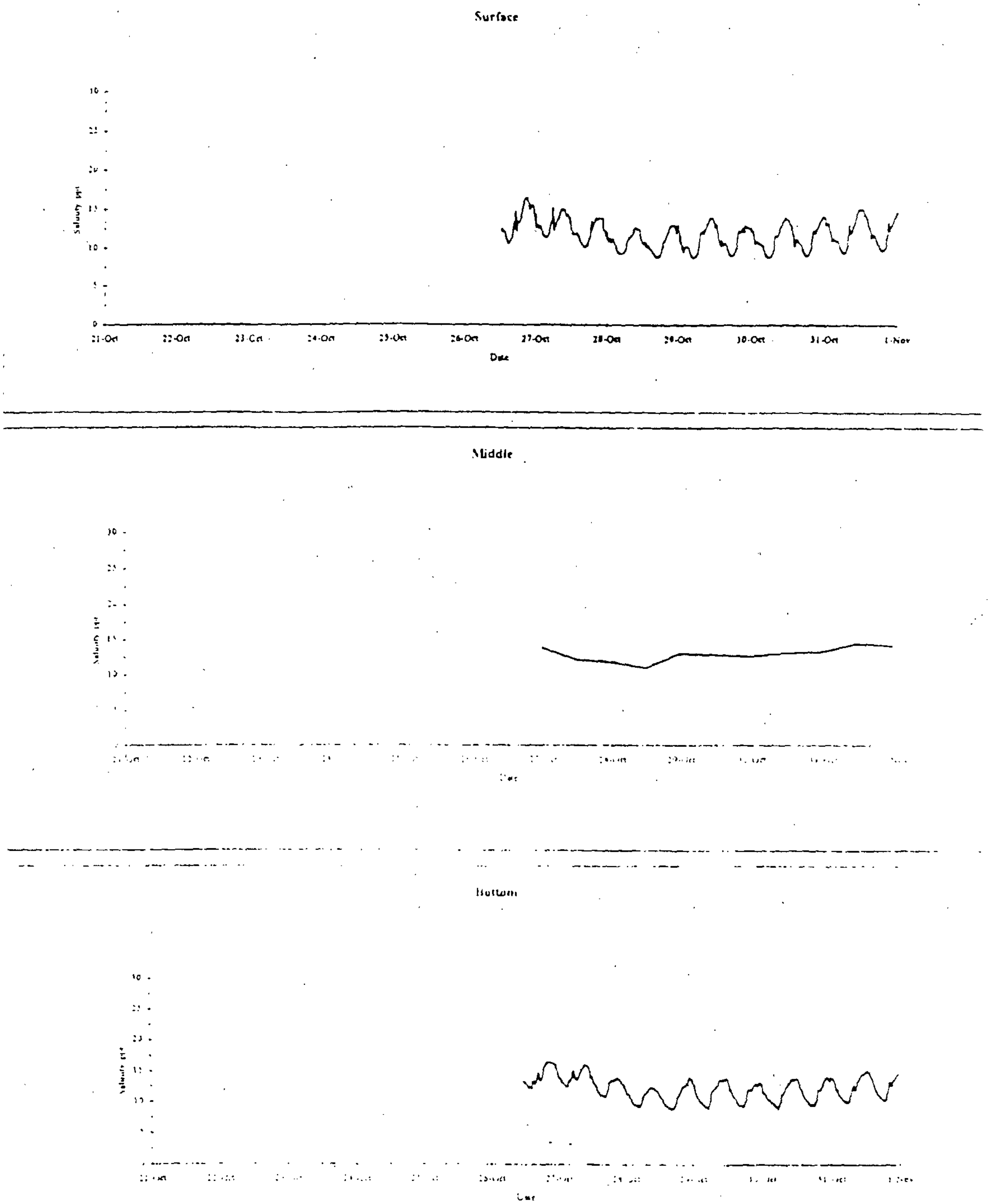
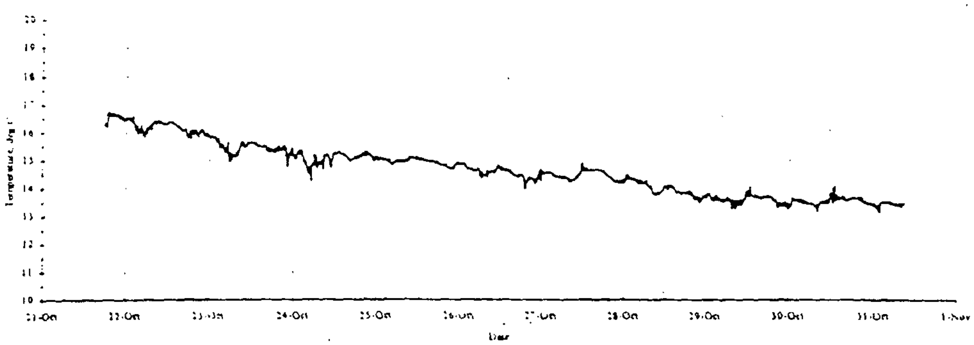


Figure 11-103

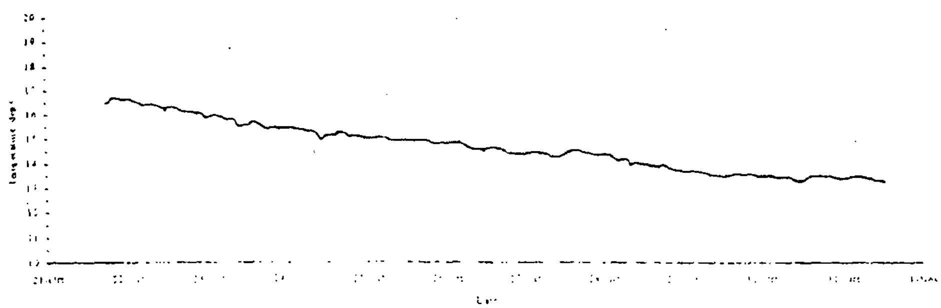
PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-5

Surface



Middle

Bottom

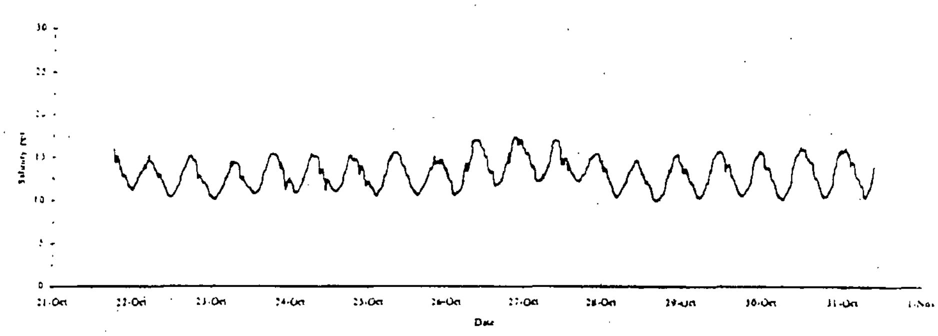


407

Figure 11-104

PSE&G 1-Unit Survey: 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-5

Surface



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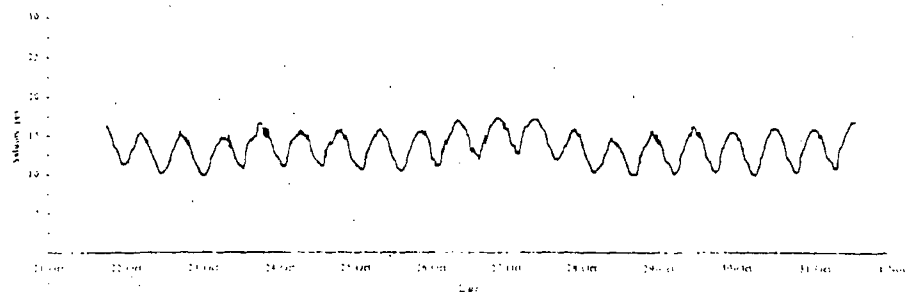

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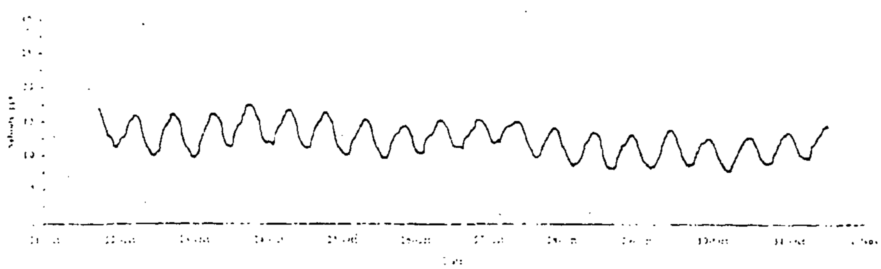
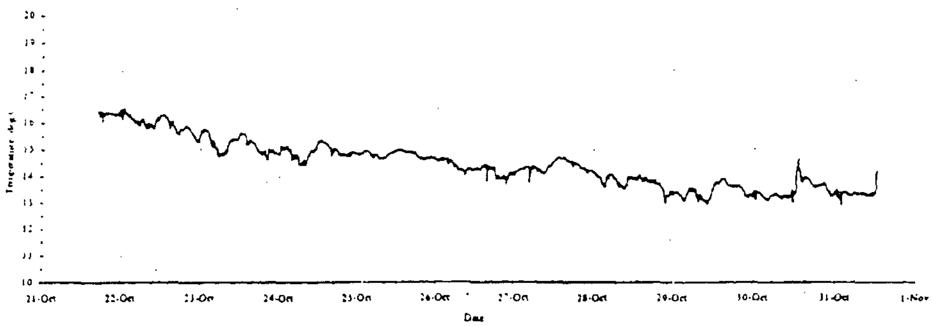


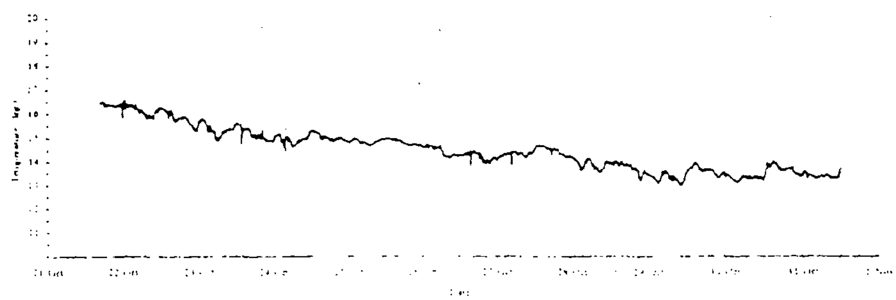
Figure 11-105

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-6

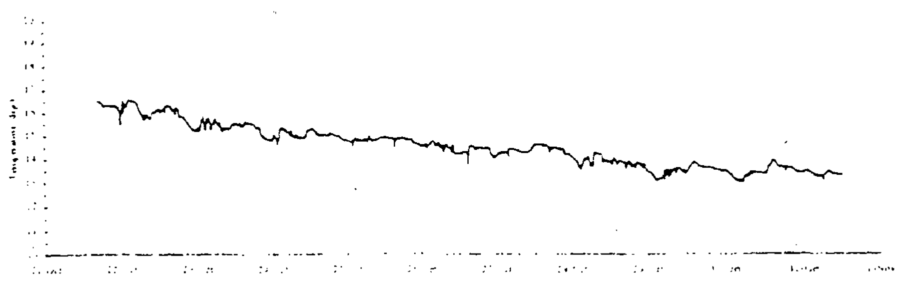
Surface



Middle



Bottom



40

Figure 11-106

PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-6

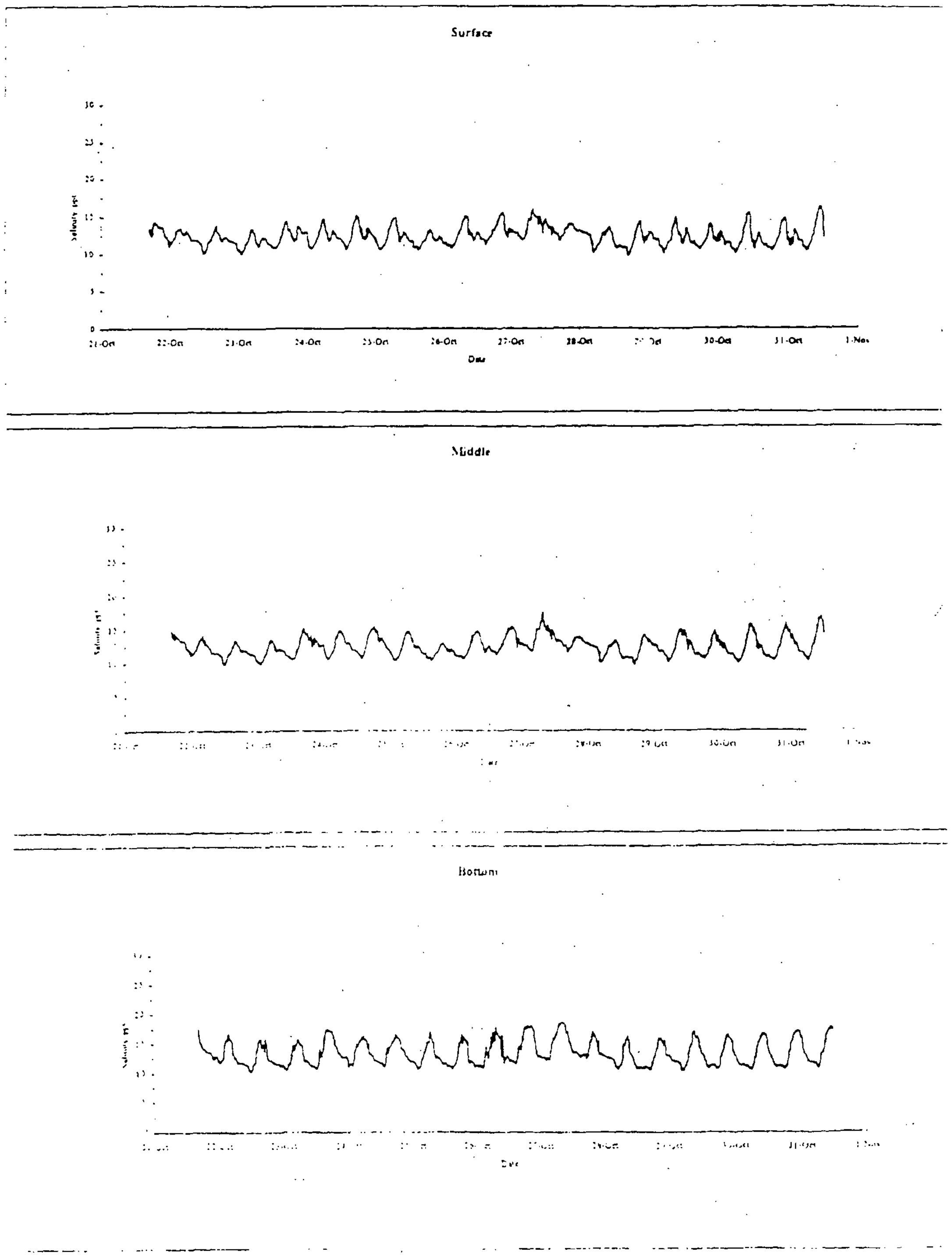


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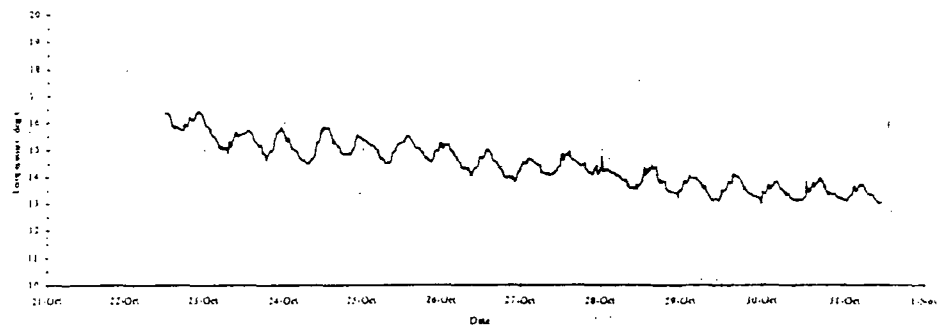
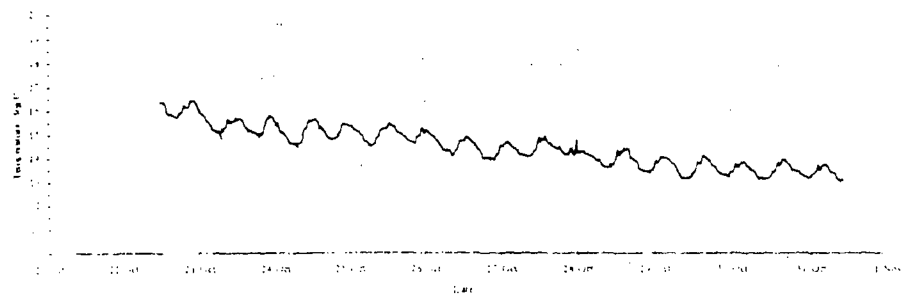
Figure 11-107

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-7

Surface



Middle



Bottom

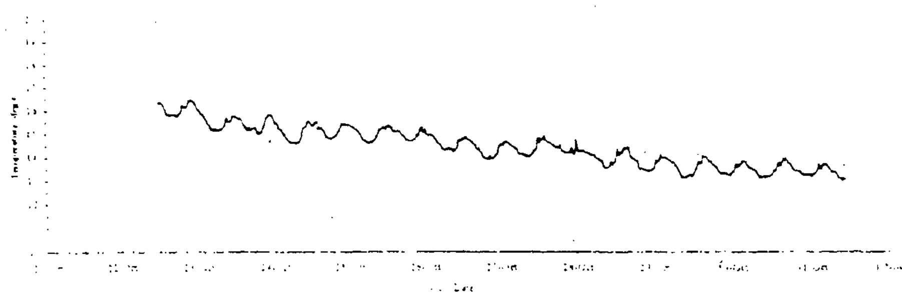
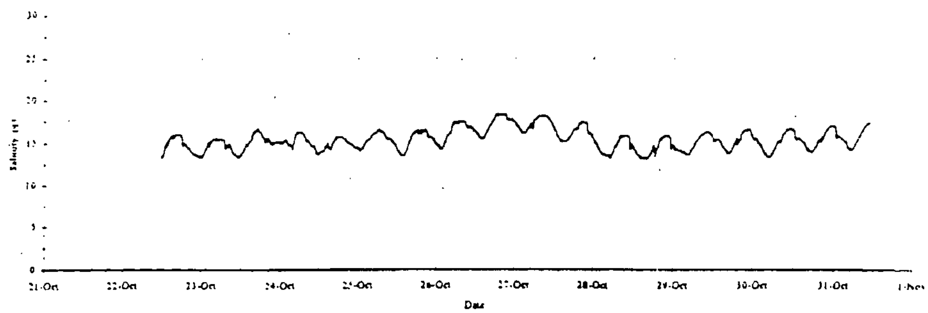


Figure 11-108

PSE&G 1-Unit Survey: 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-7

Surface



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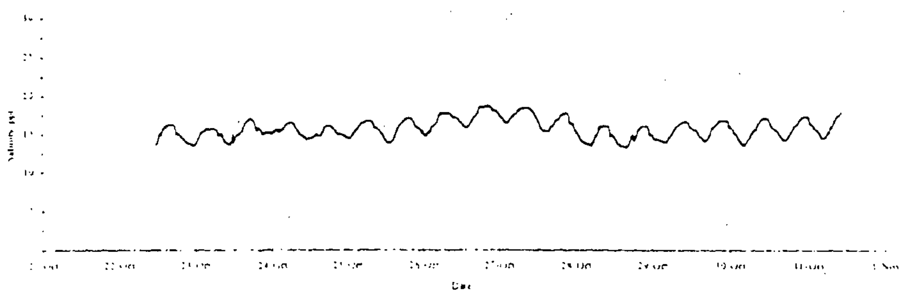

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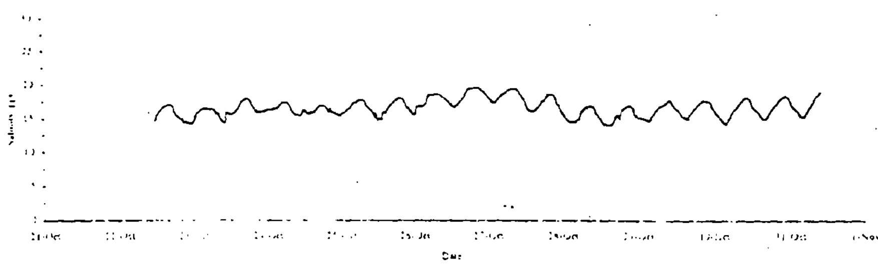

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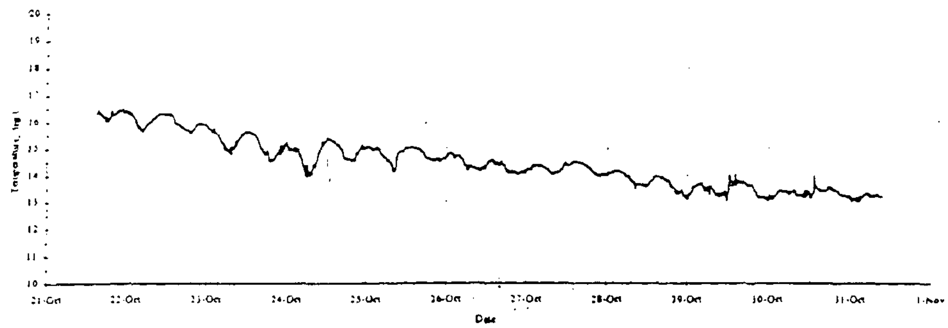
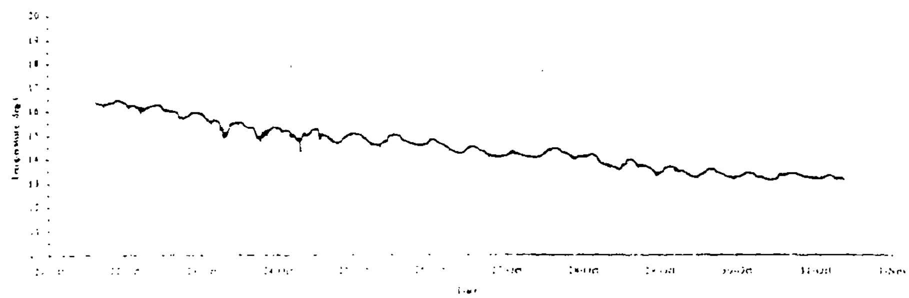
Figure 11-109

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-9

Surface



Middle



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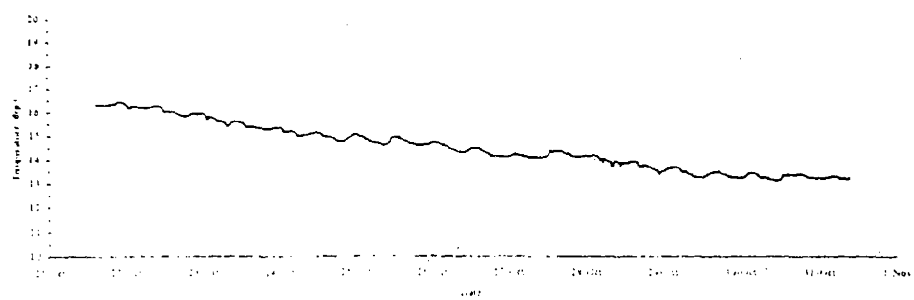

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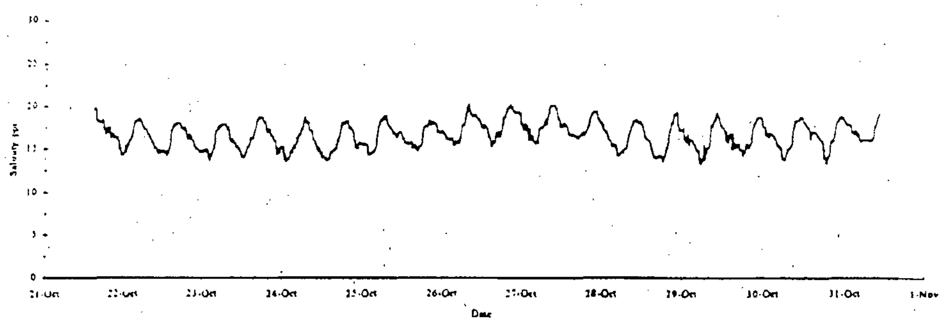
Figure 11-110

PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-9

Surface



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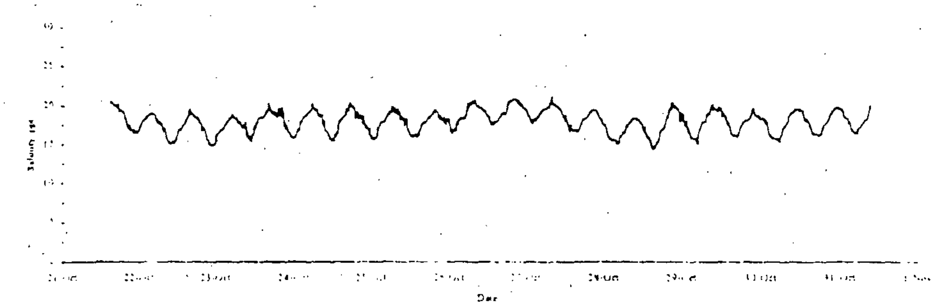

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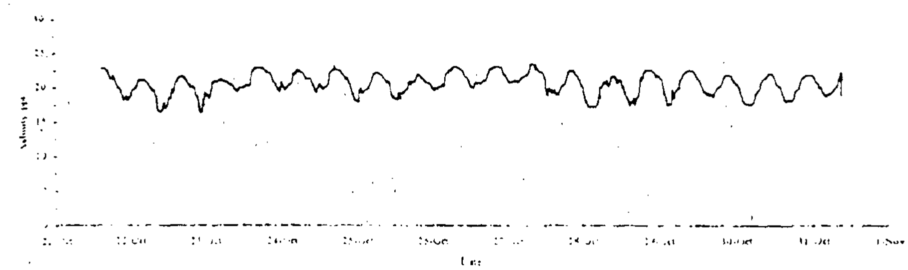

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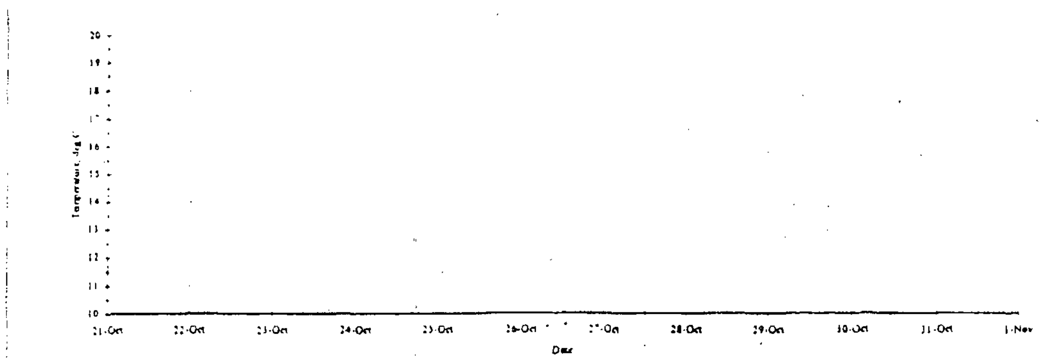
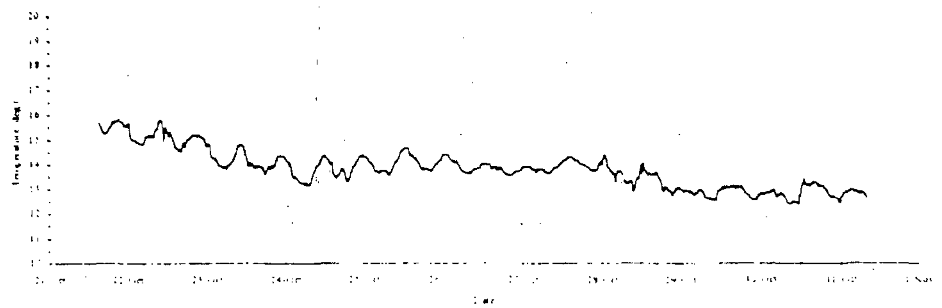
Figure 11-111

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-10

Surface



Middle



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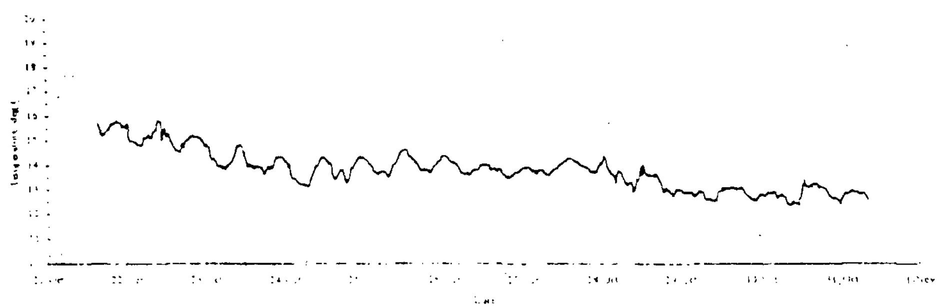
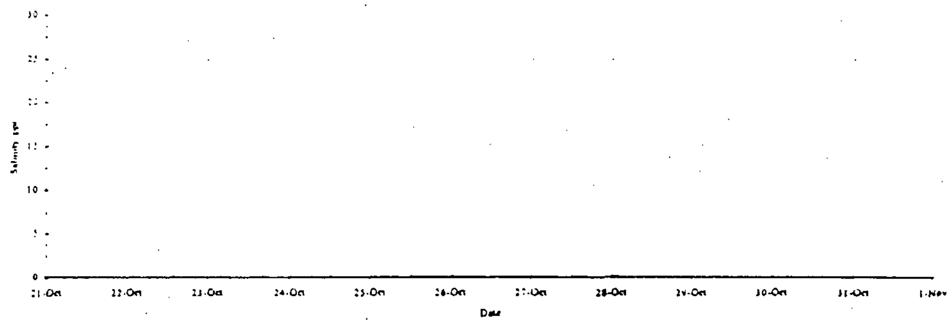


Figure 11-112

PSE&G 1-Unit Survey: 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-10

Surface



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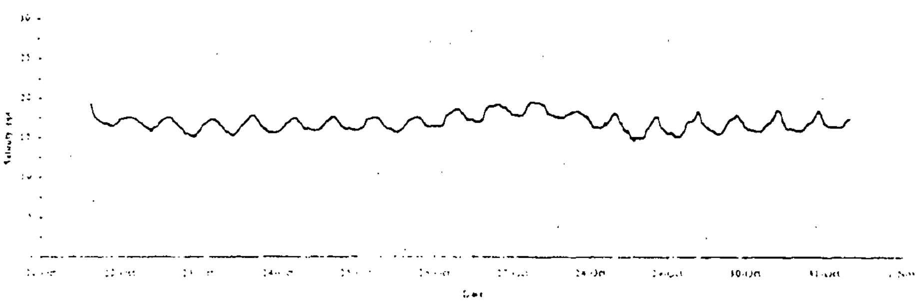

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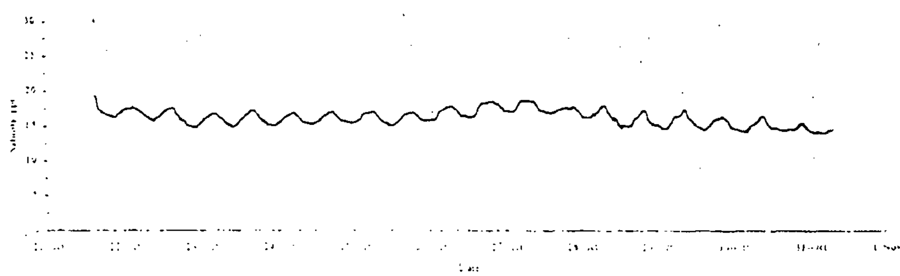
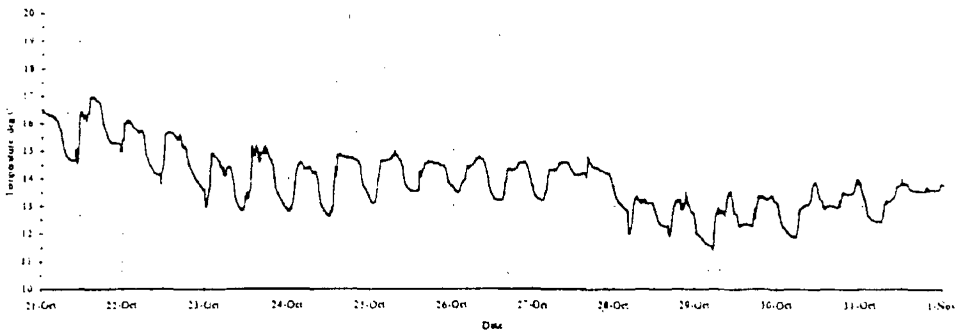


414

Figure 11-113

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
ALLOWAYCRK

Surface



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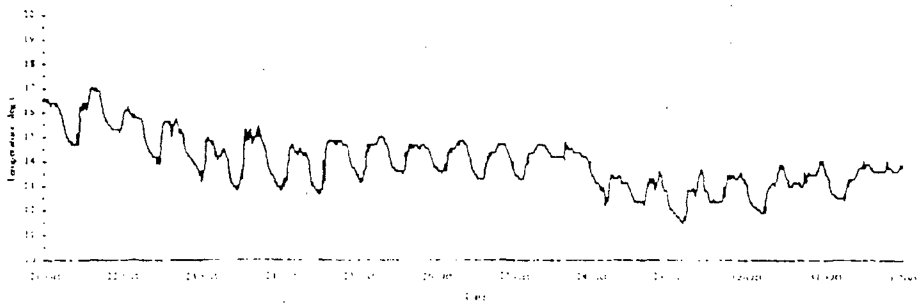

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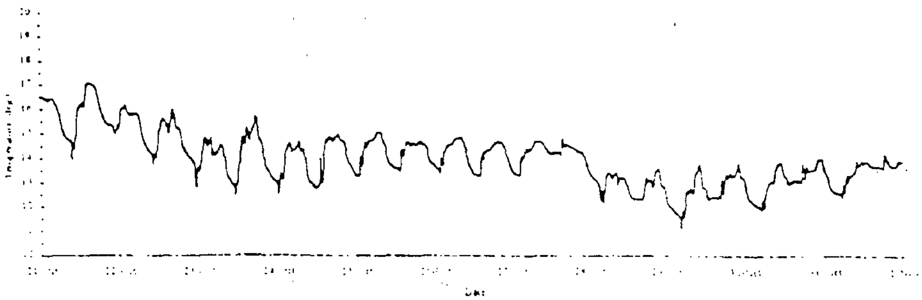
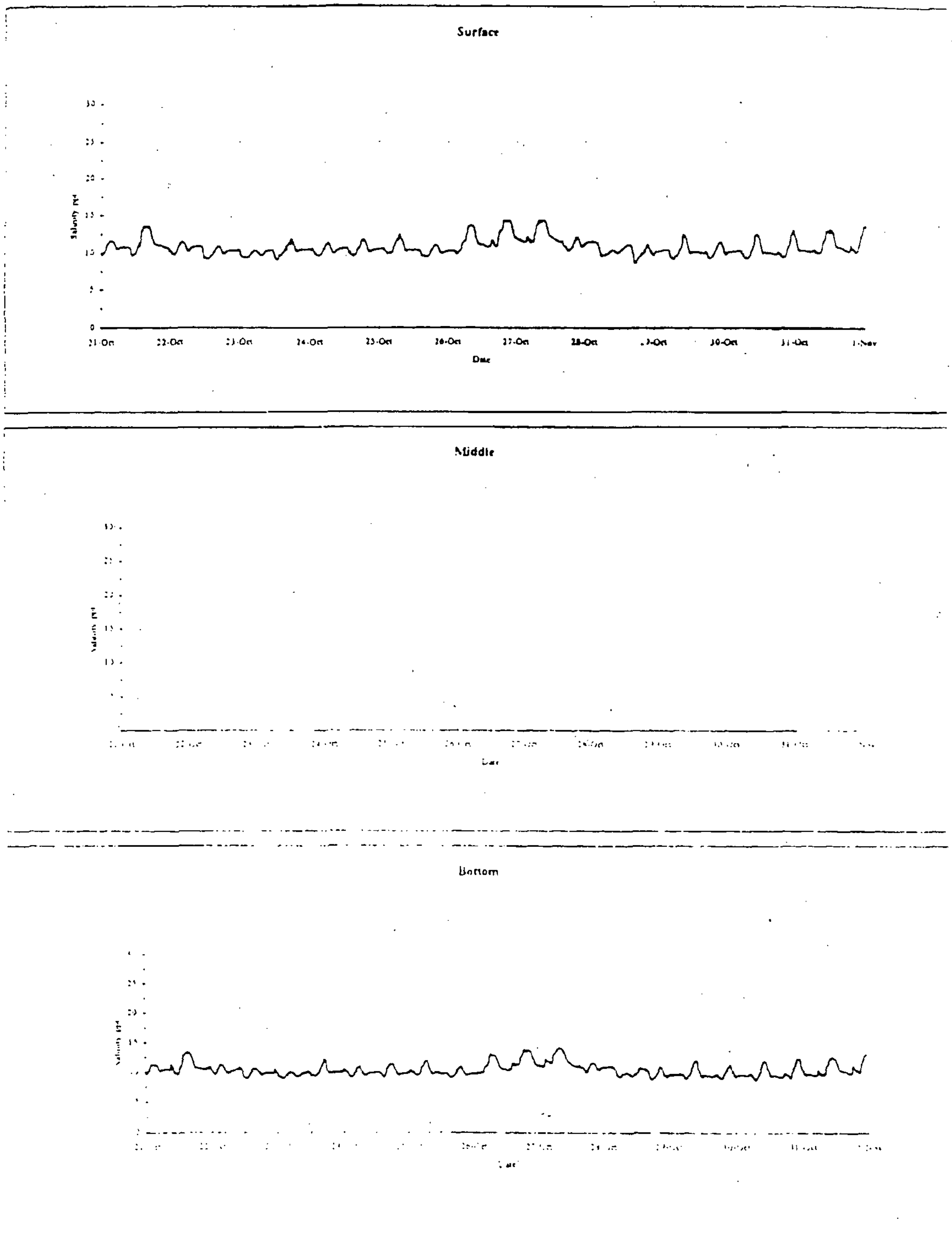


417

Figure 11-114

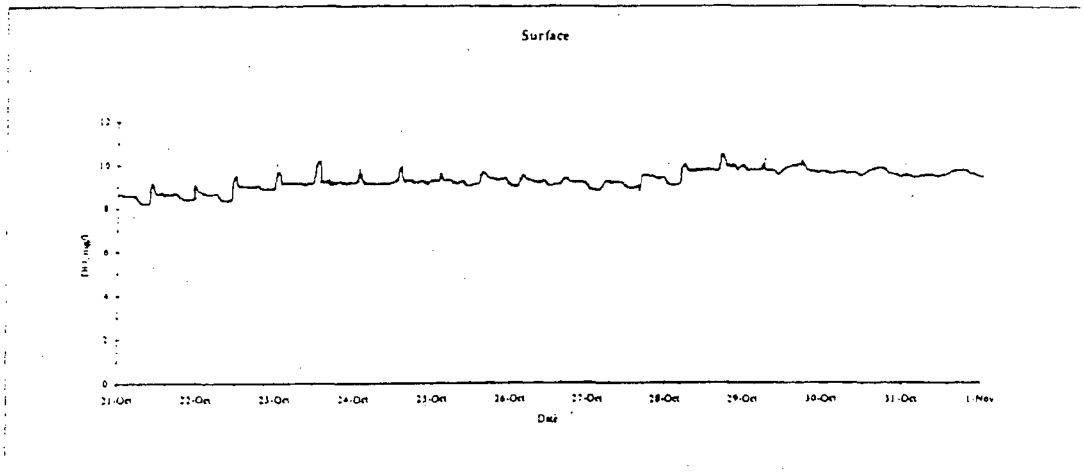
PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
ALLOWAYCRK

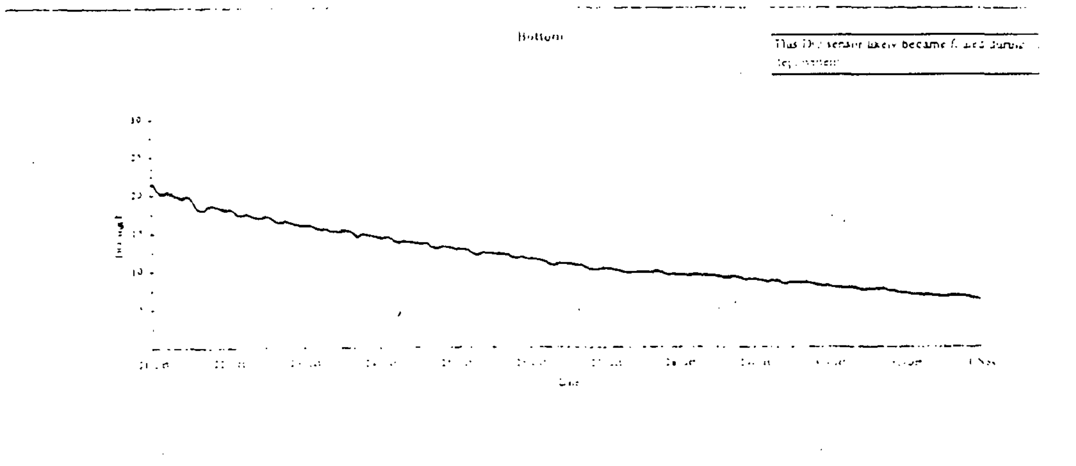


418

Figure 11-115

PSE&G 1-Unit Survey: 21 - 31 October 1997
Dissolved Oxygen Temporal Profiles (Moorings)
ALLOWAYCRK



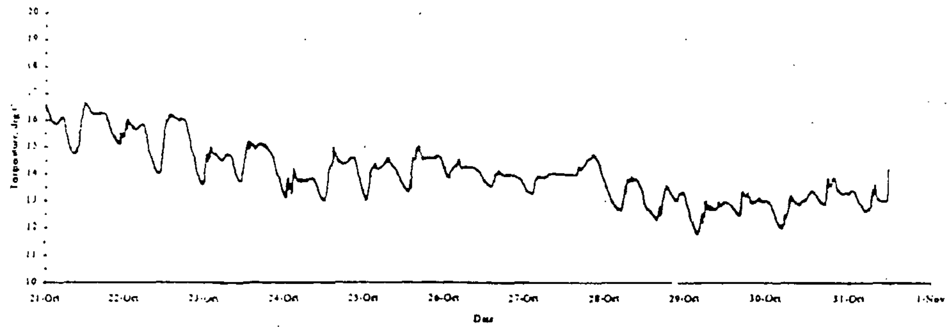


419

Figure 11-116

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
HOPECREEK

Surface



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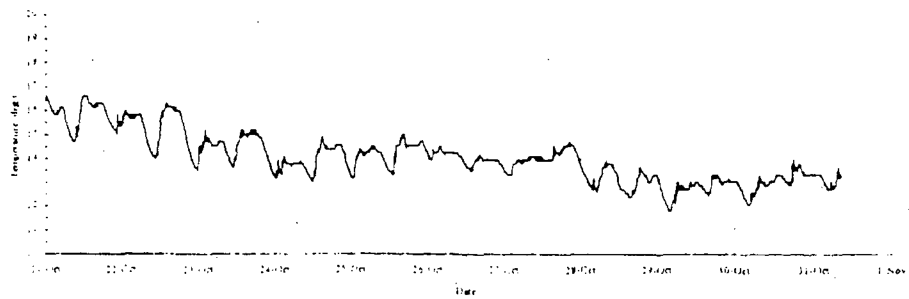

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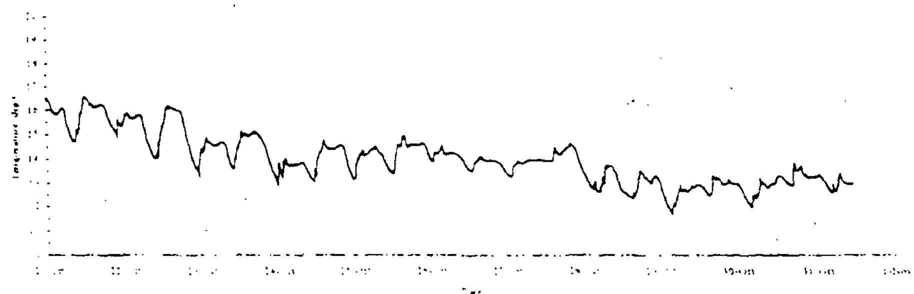


421

Figure 11-117

PSE&G 1-Unit Survey: 21 - 31 October 1997

Salinity Temporal Profiles (Moorings)

HOPECREEK

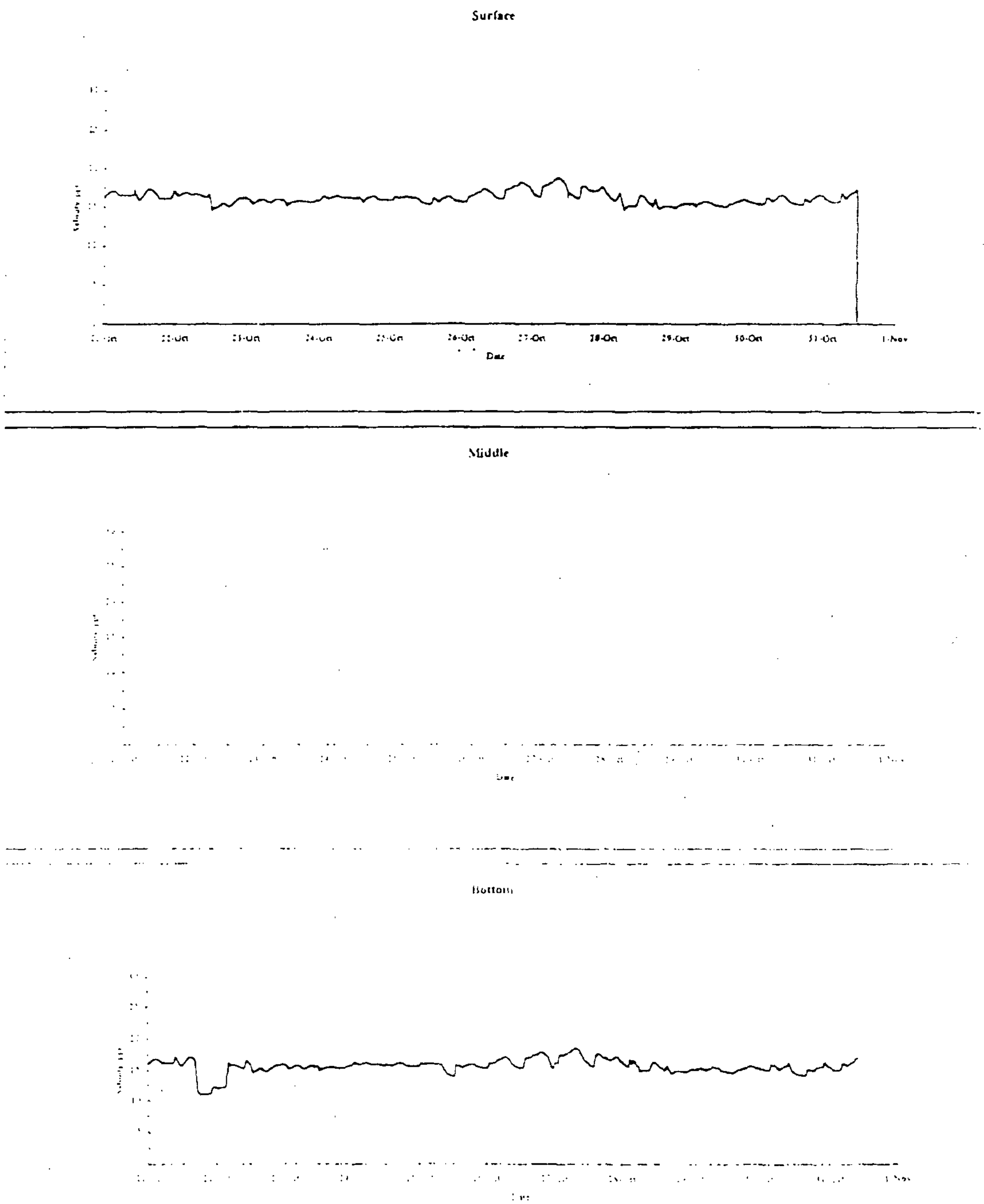
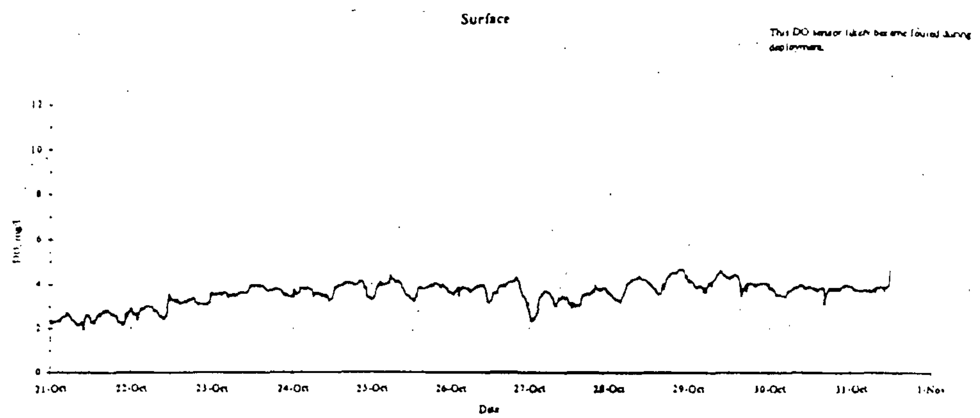


Figure 11-118

PSE&G 1-Unit Survey; 21 - 31 October 1997
Dissolved Oxygen Temporal Profiles (Moorings)
HOPECREEK



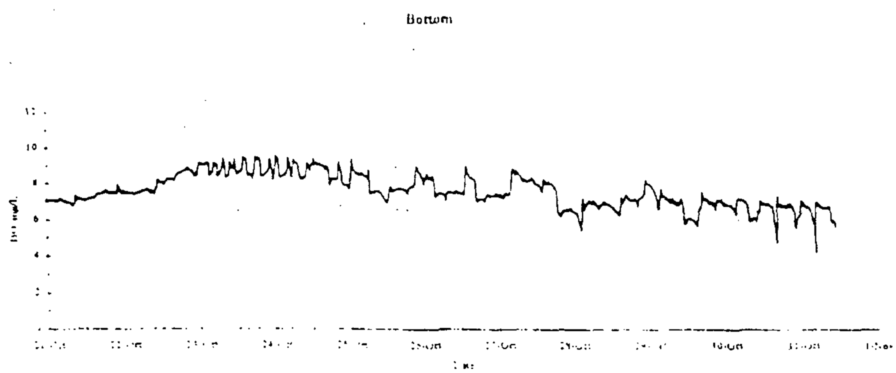
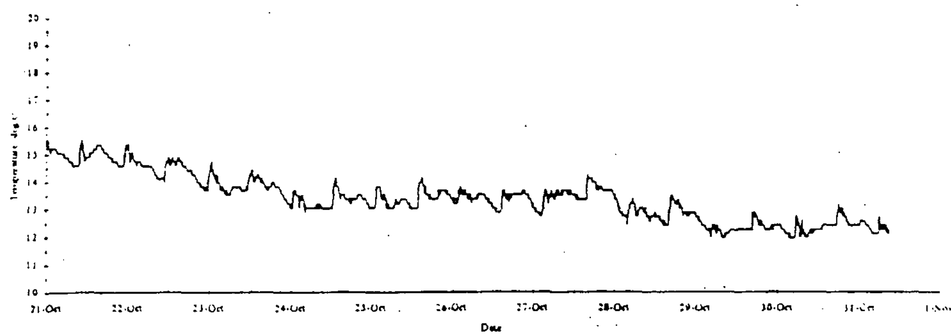


Figure 11-119

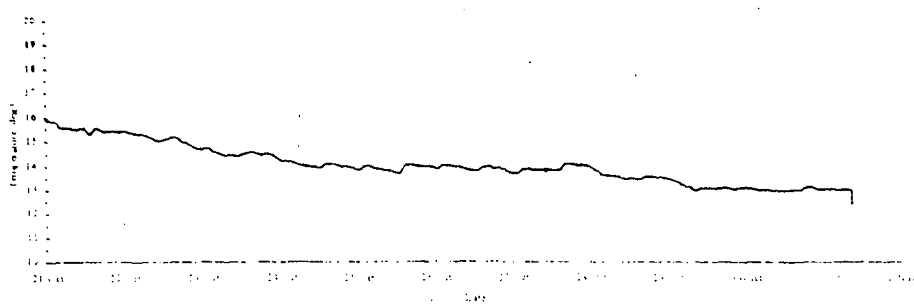
PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
MADHORSECRK

Surface



Middle

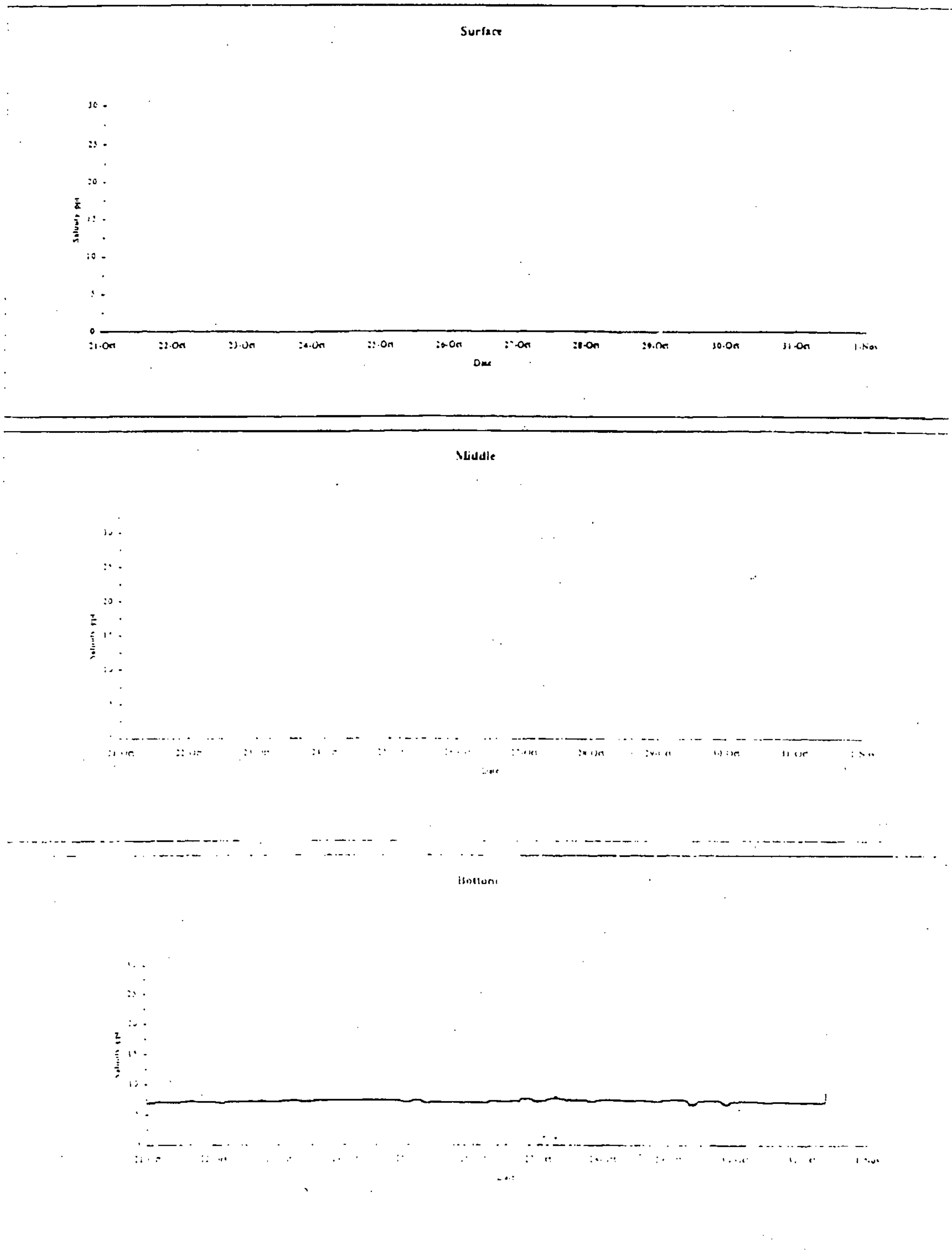
Bottom



42?

Figure 11-120

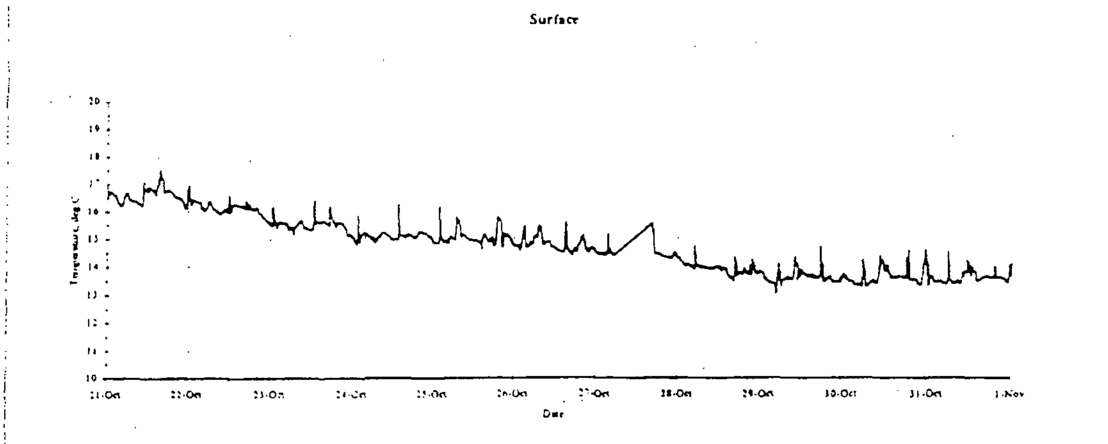
PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
MADHORSECRK

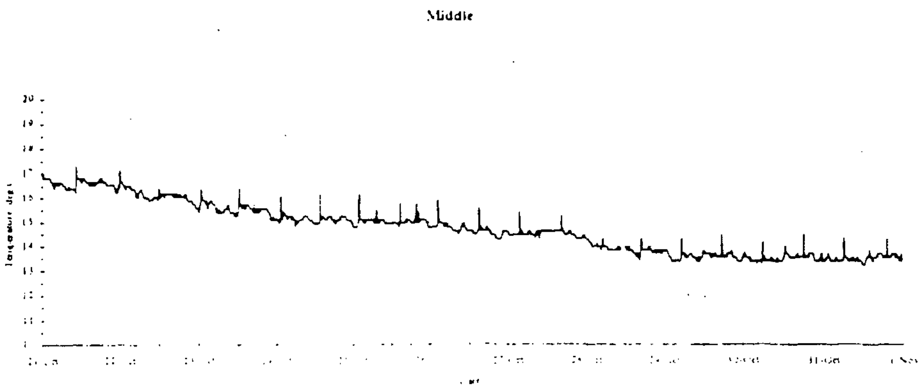


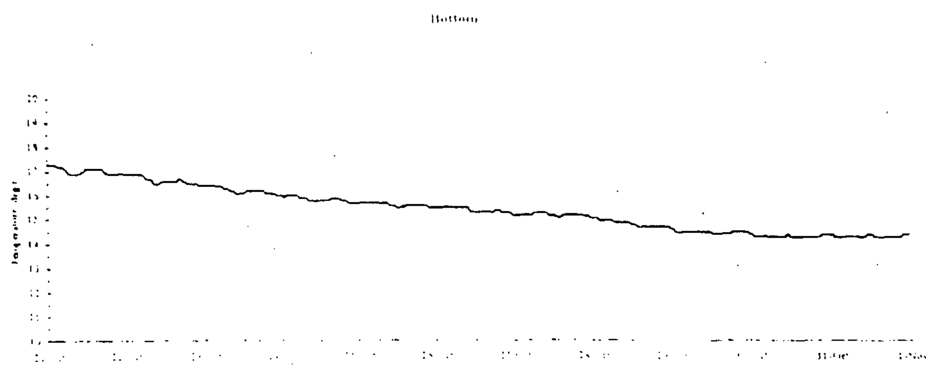
42

Figure 11-121

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-E





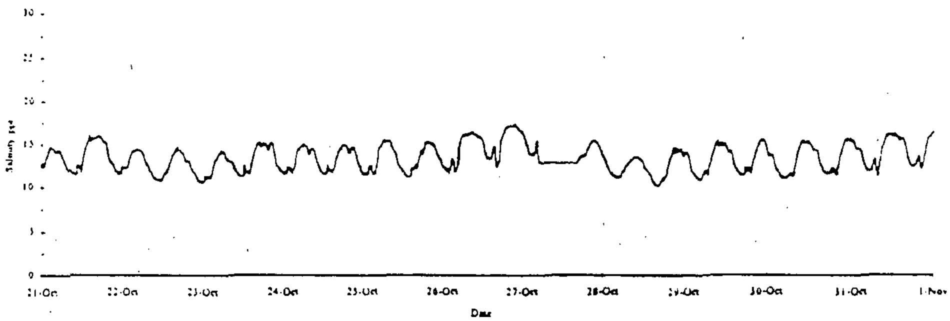


42

Figure 11-122

PSE&G 1-Unit Survey: 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-E

Surface



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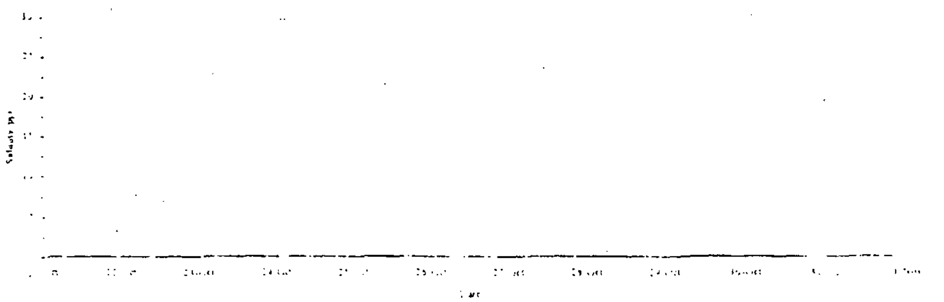

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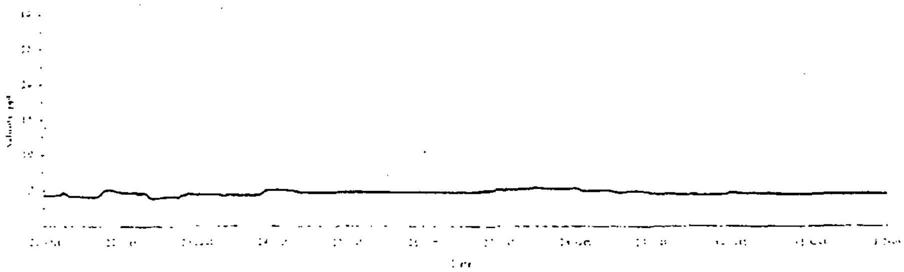
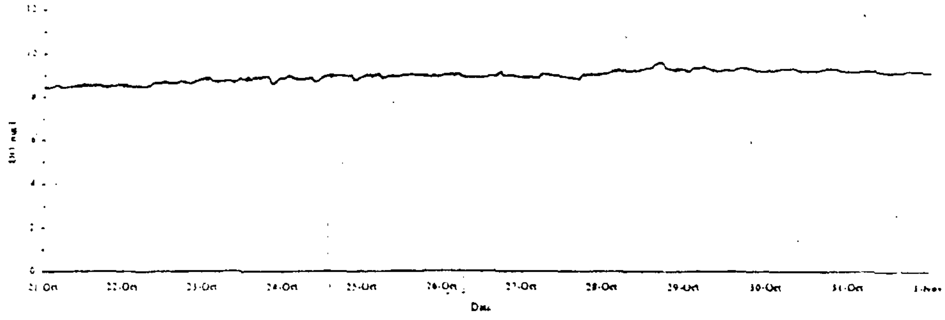


42

Figure 11-123

PSE&G 1-Unit Survey; 21 - 31 October 1997
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-E

Surface



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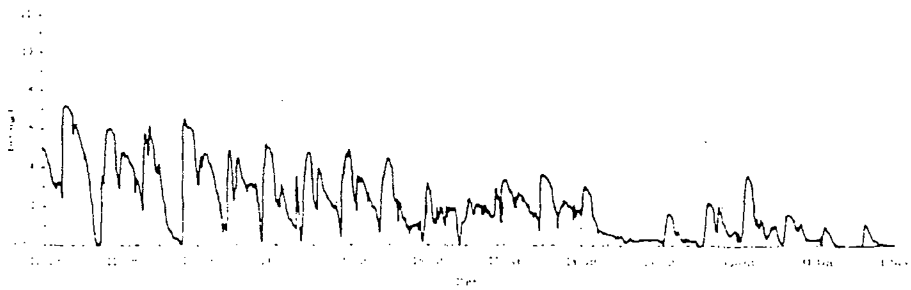
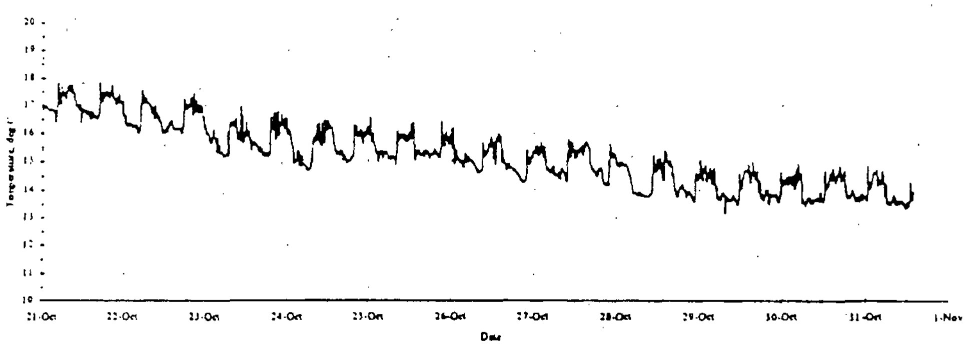


42

Figure 11-124

PSE&G 1-Unit Survey: 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-H

Surface



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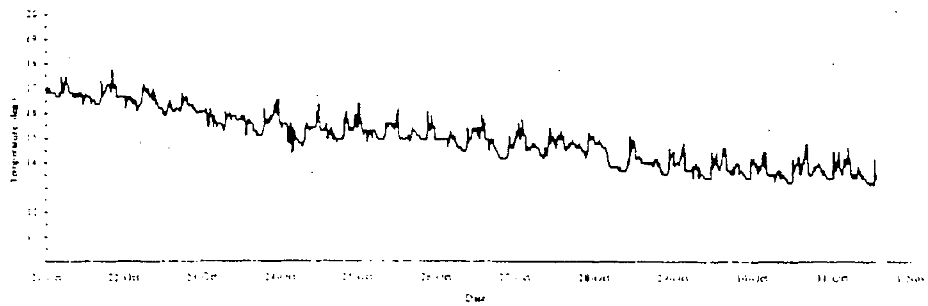
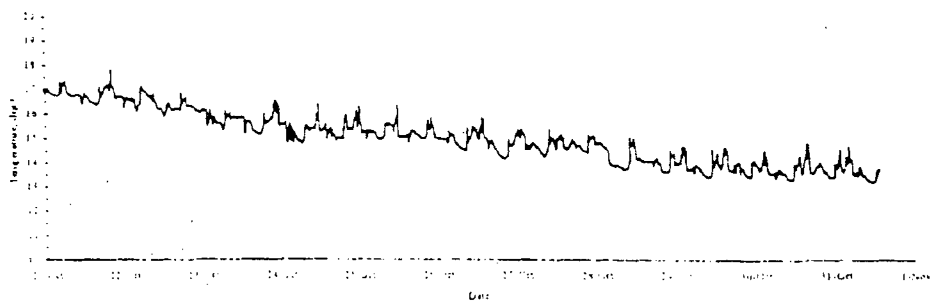


Bottom

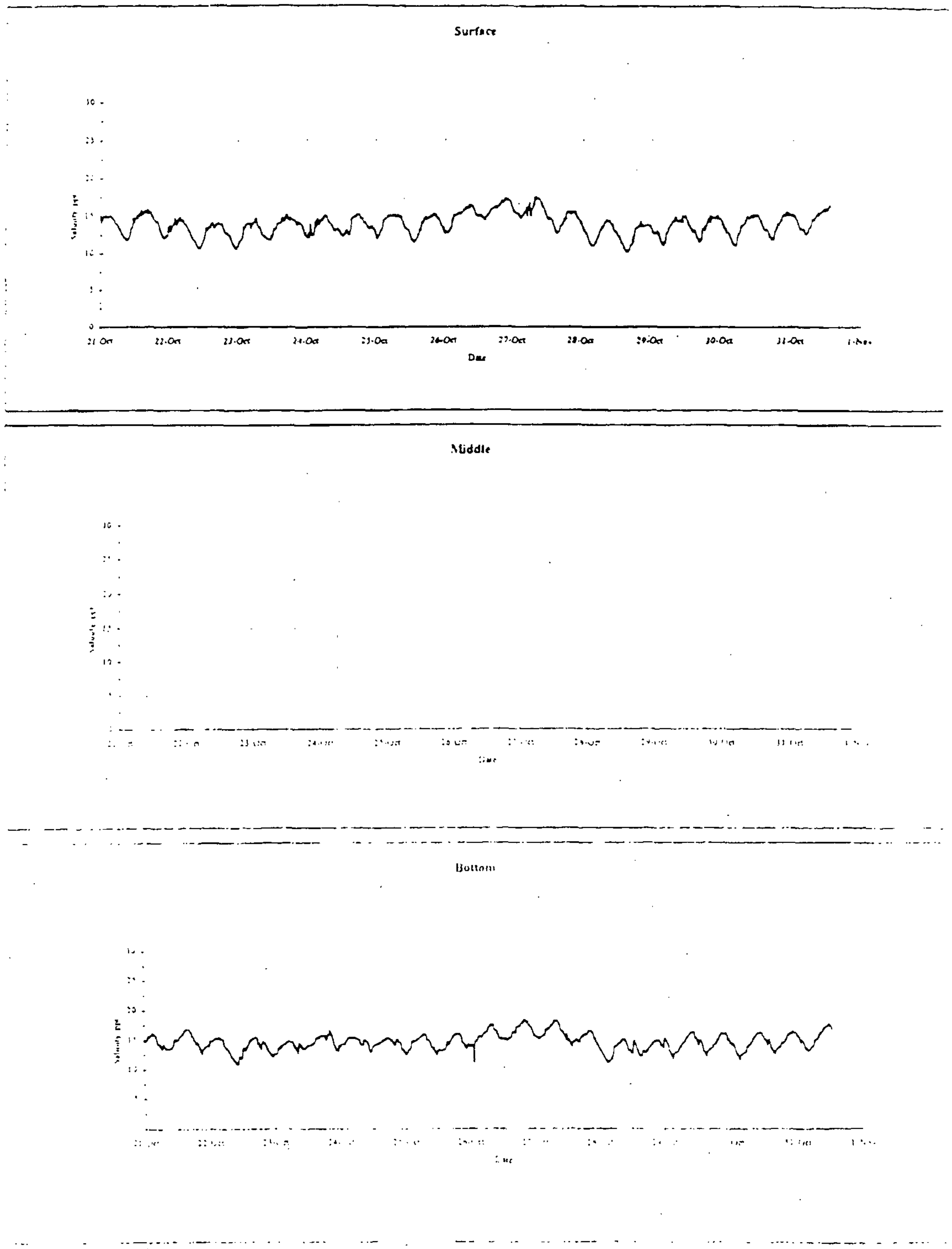


46

Part #2182-0
490

Figure 11-125

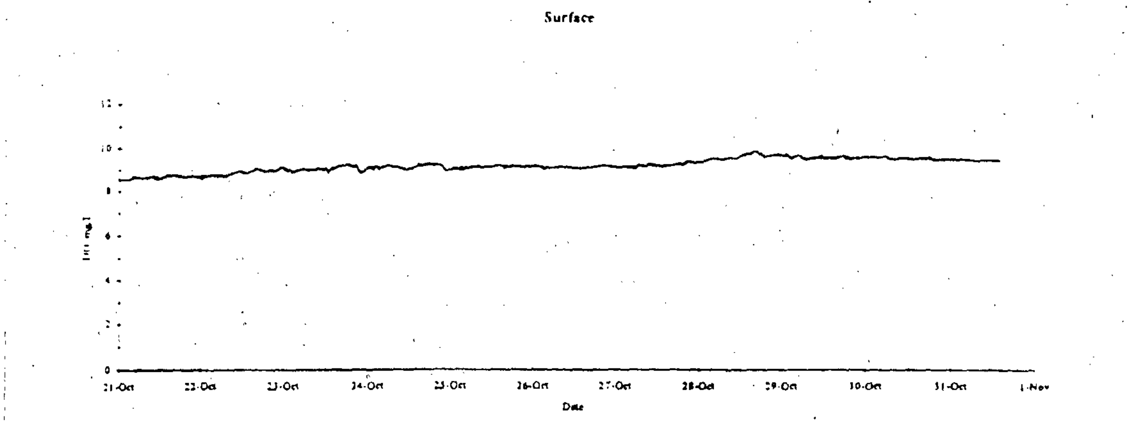
PSE&G 1-Unit Survey; 21 - 31 October 1997
Salinity Temporal Profiles (Moorings)
DELAWARE-H

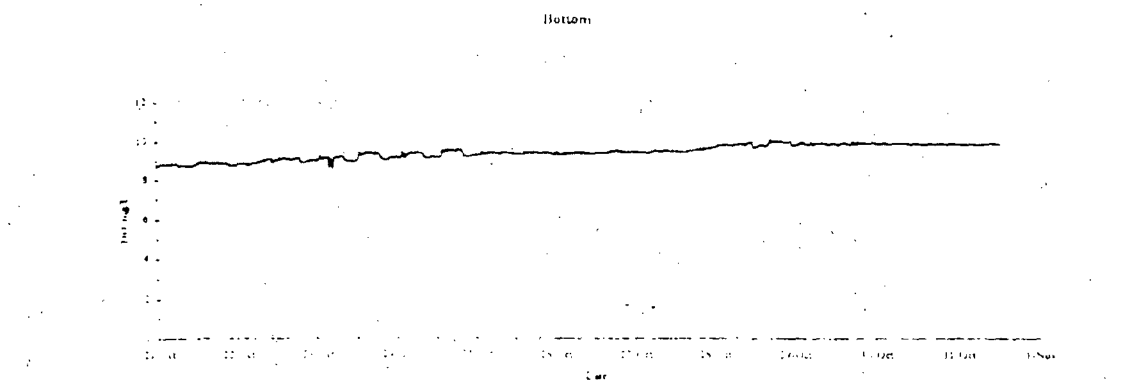


4

Figure 11-126

PSE&G 1-Unit Survey; 21 - 31 October 1997
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-II



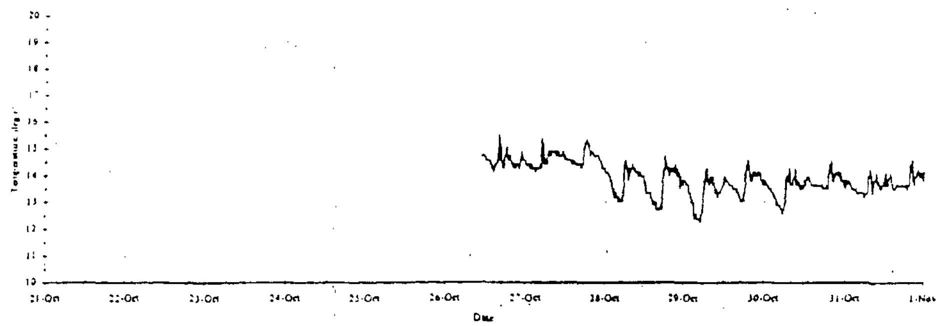


42

Figure 11-127

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-1

Surface



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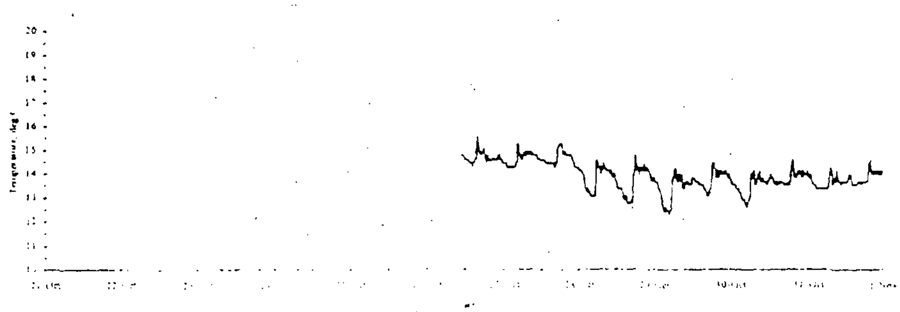

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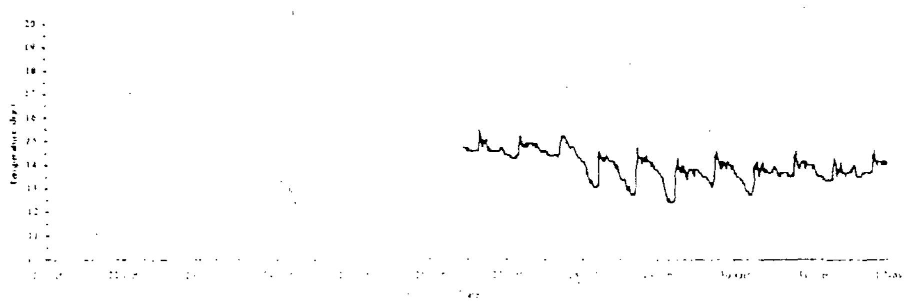
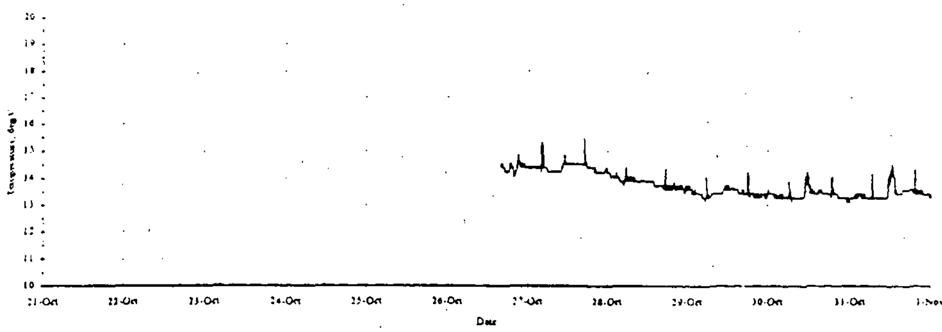


43

Figure 11-128

PSE&G 1-Unit Survey: 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-K

Surface



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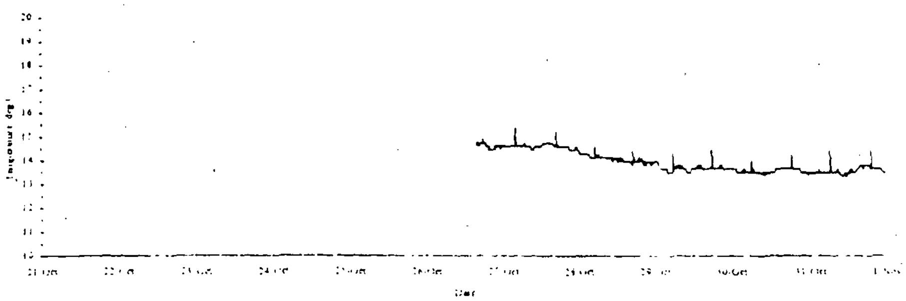

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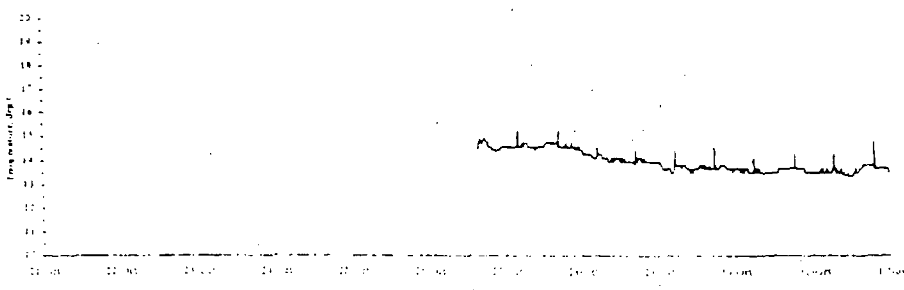
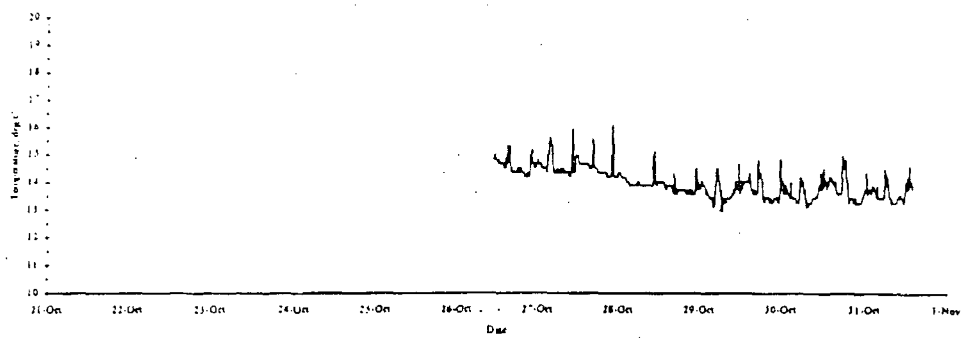


43

Figure 11-129

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-V

Surface



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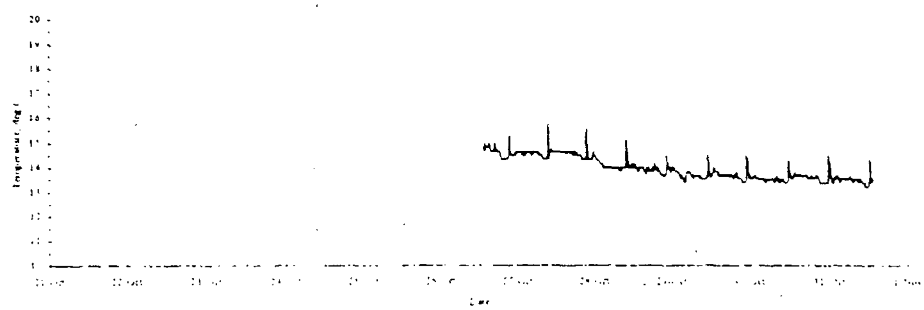

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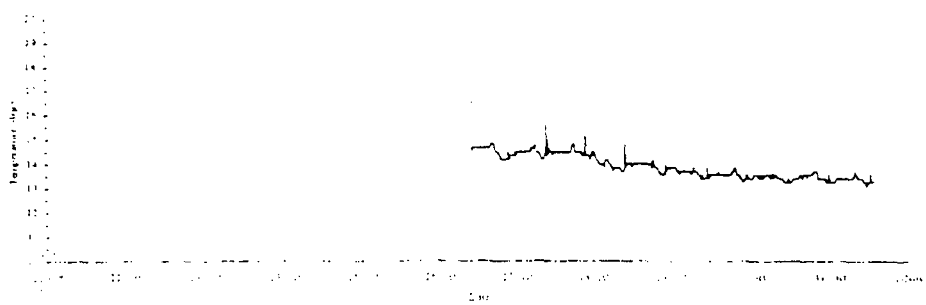
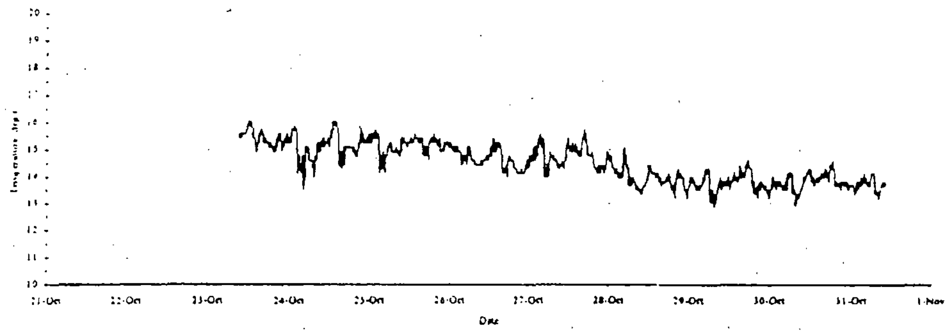


42

Figure 11-130

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-L

Surface



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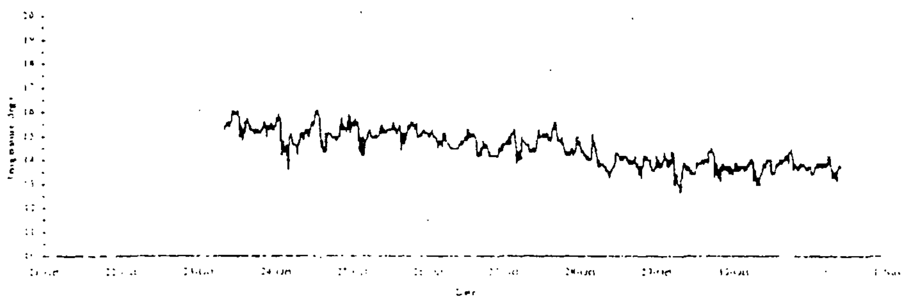

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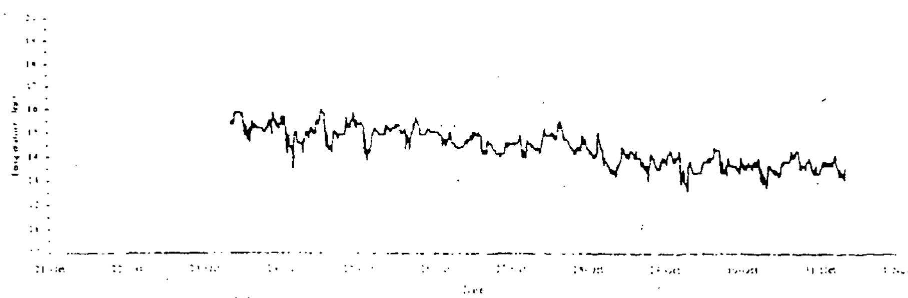
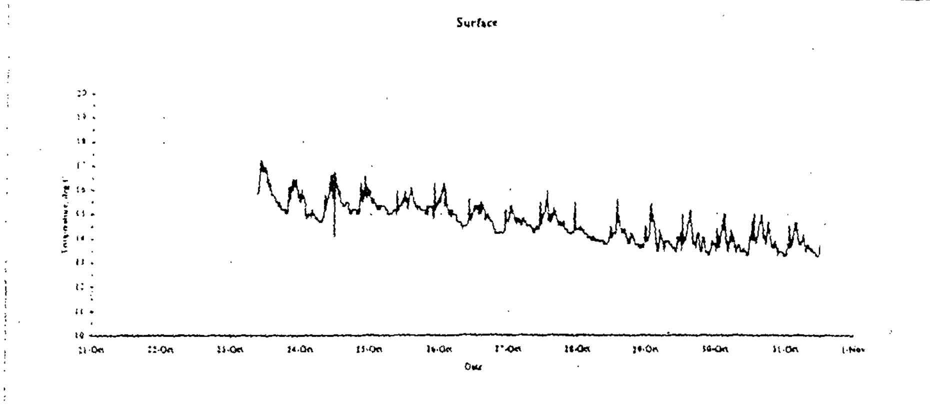
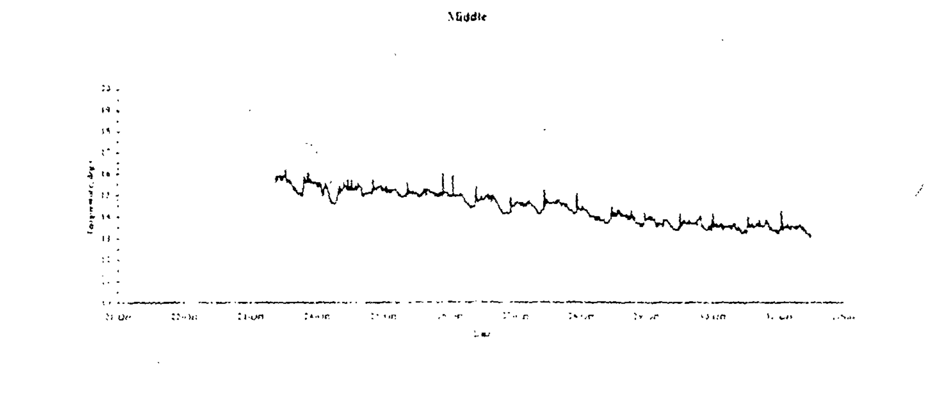


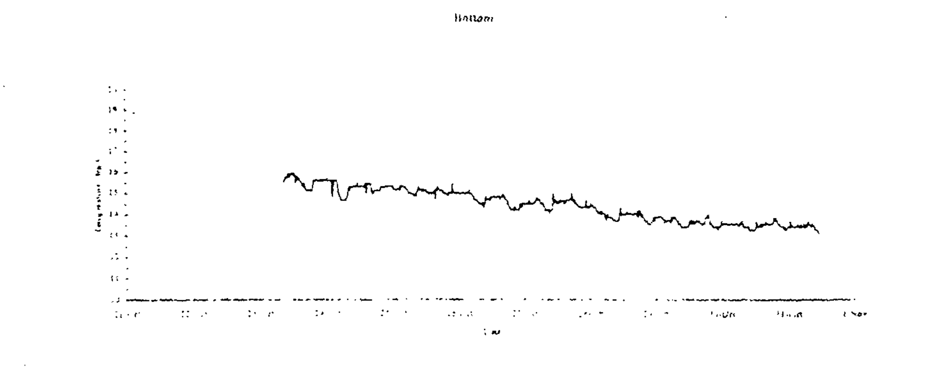
4?

Figure 11-131

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-N





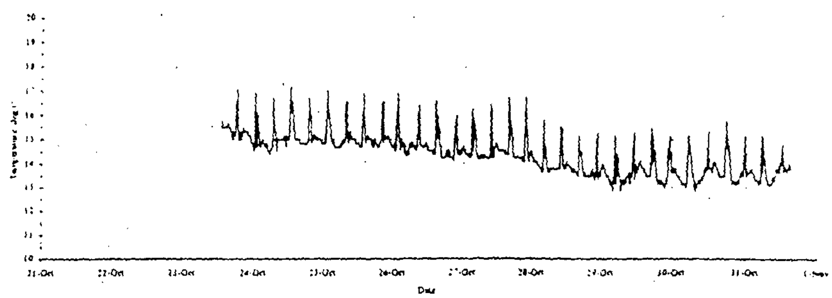


43E

Figure 11-132

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-22

Surface



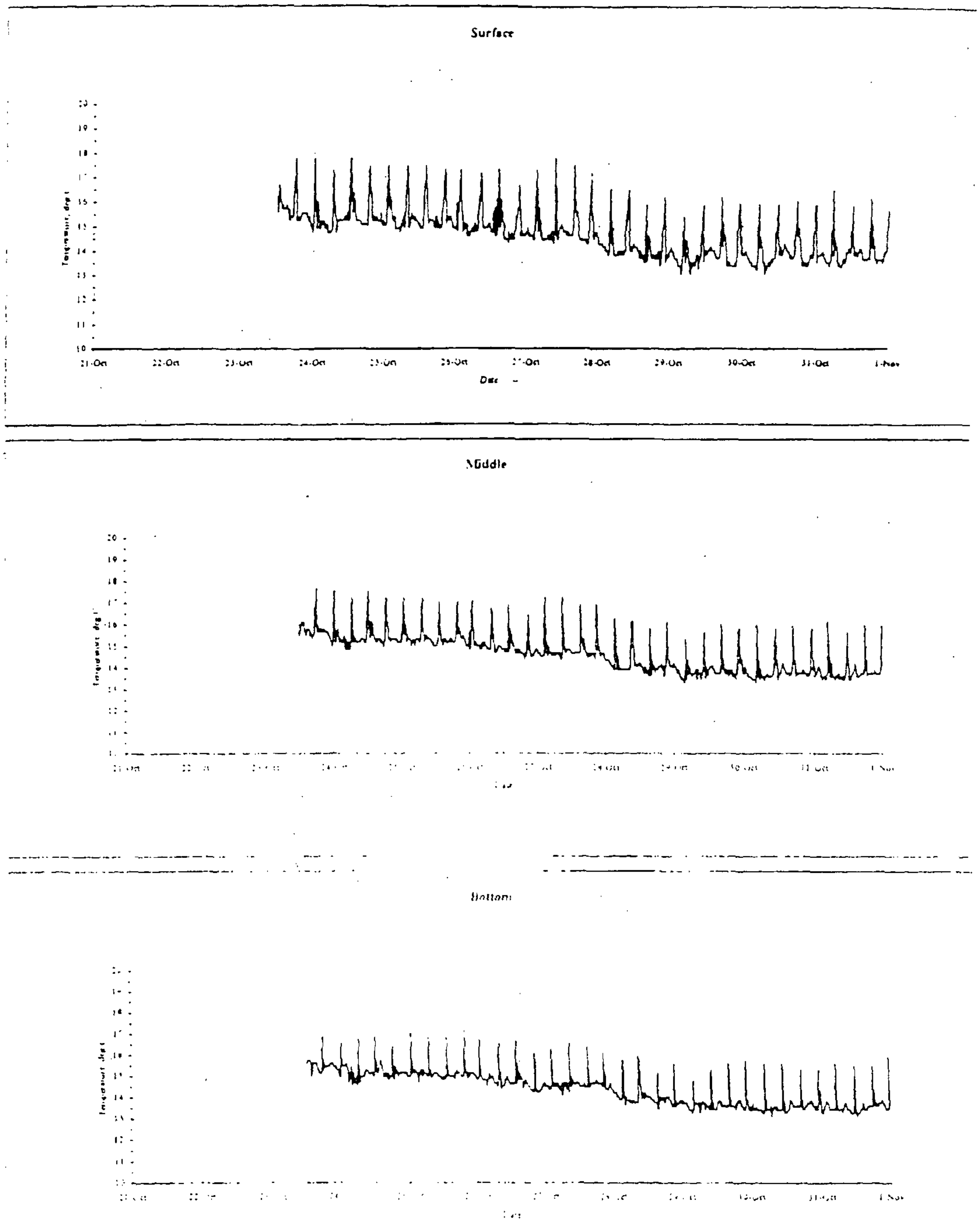
Middle

Bottom

431

Figure 11-133

PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-23

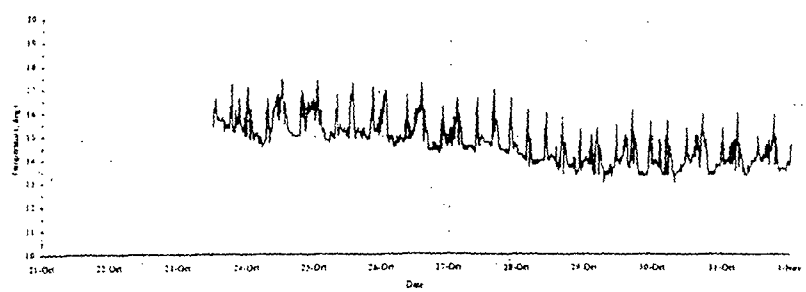


43

Figure 11-134

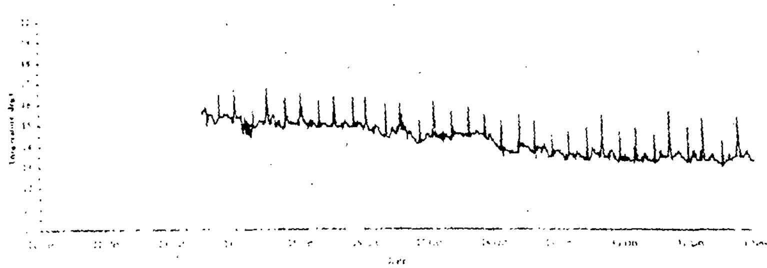
PSE&G 1-Unit Survey; 21 - 31 October 1997
Temperature Temporal Profiles (Moorings)
DELAWARE-24

Surface



Middle

Bottom

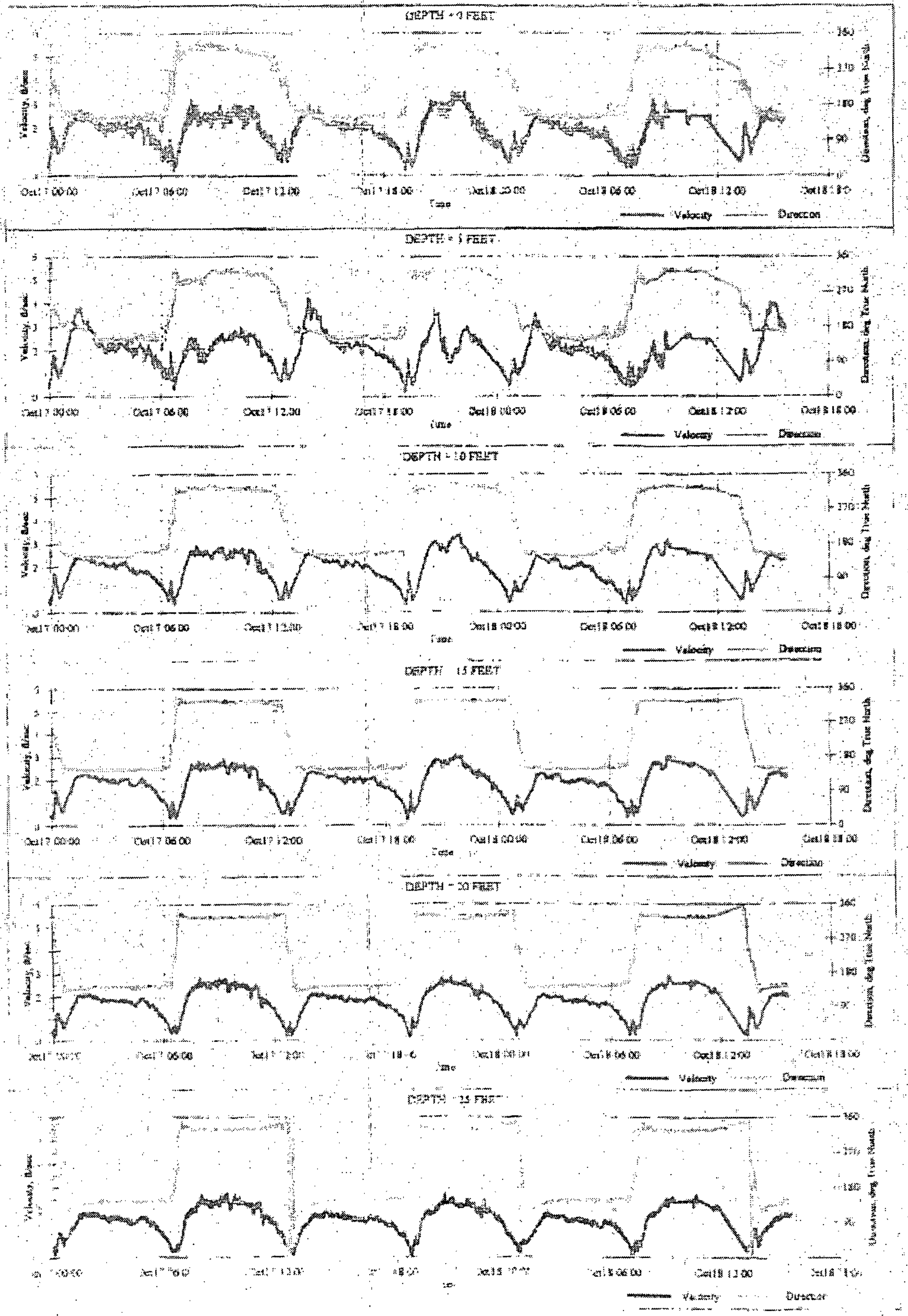


43E

Figure 11-135

PSE&G 1-Unit Survey, October 1997

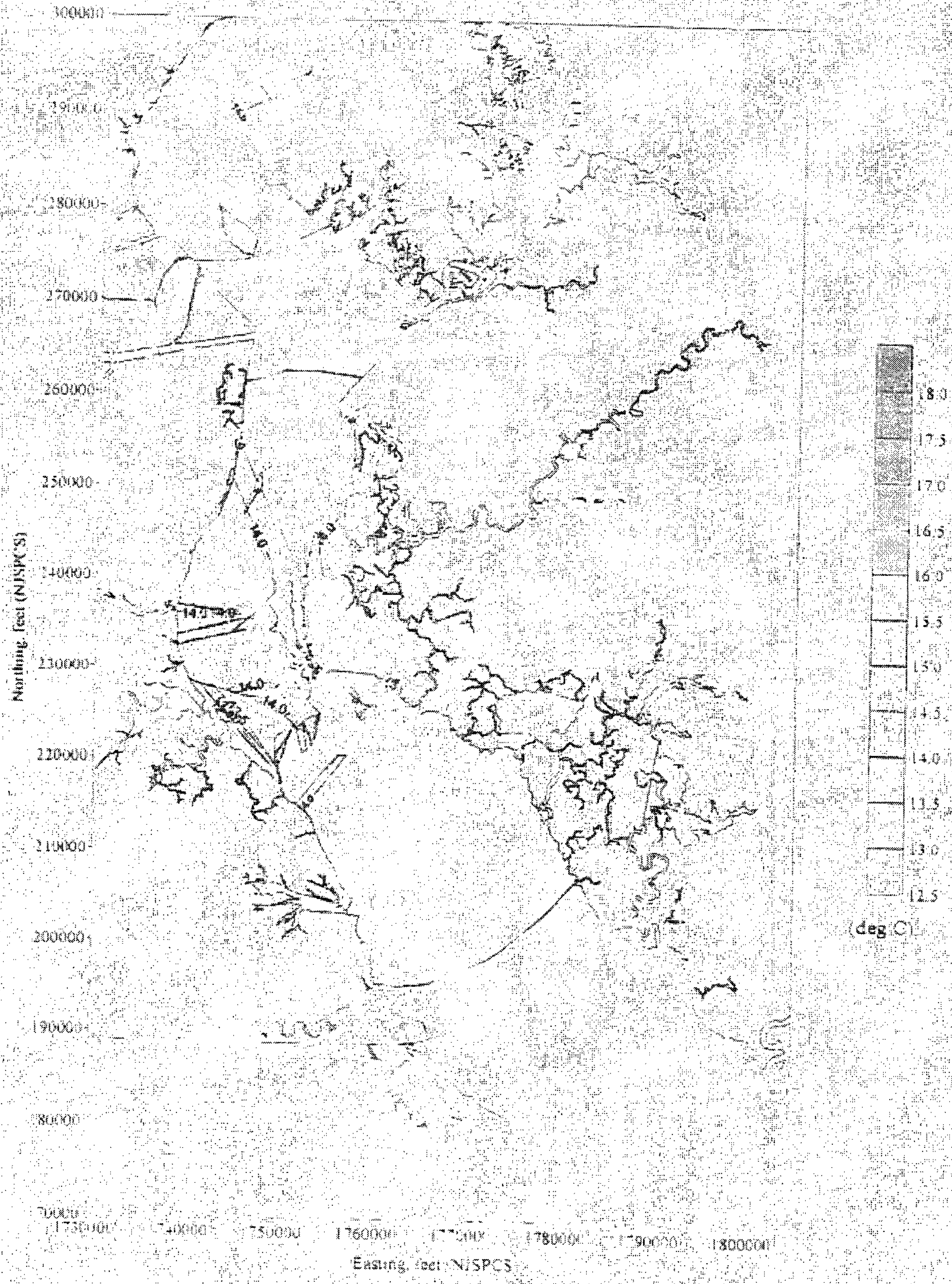
Vertical Velocity Profile Near Discharge



4

Figure 11-136

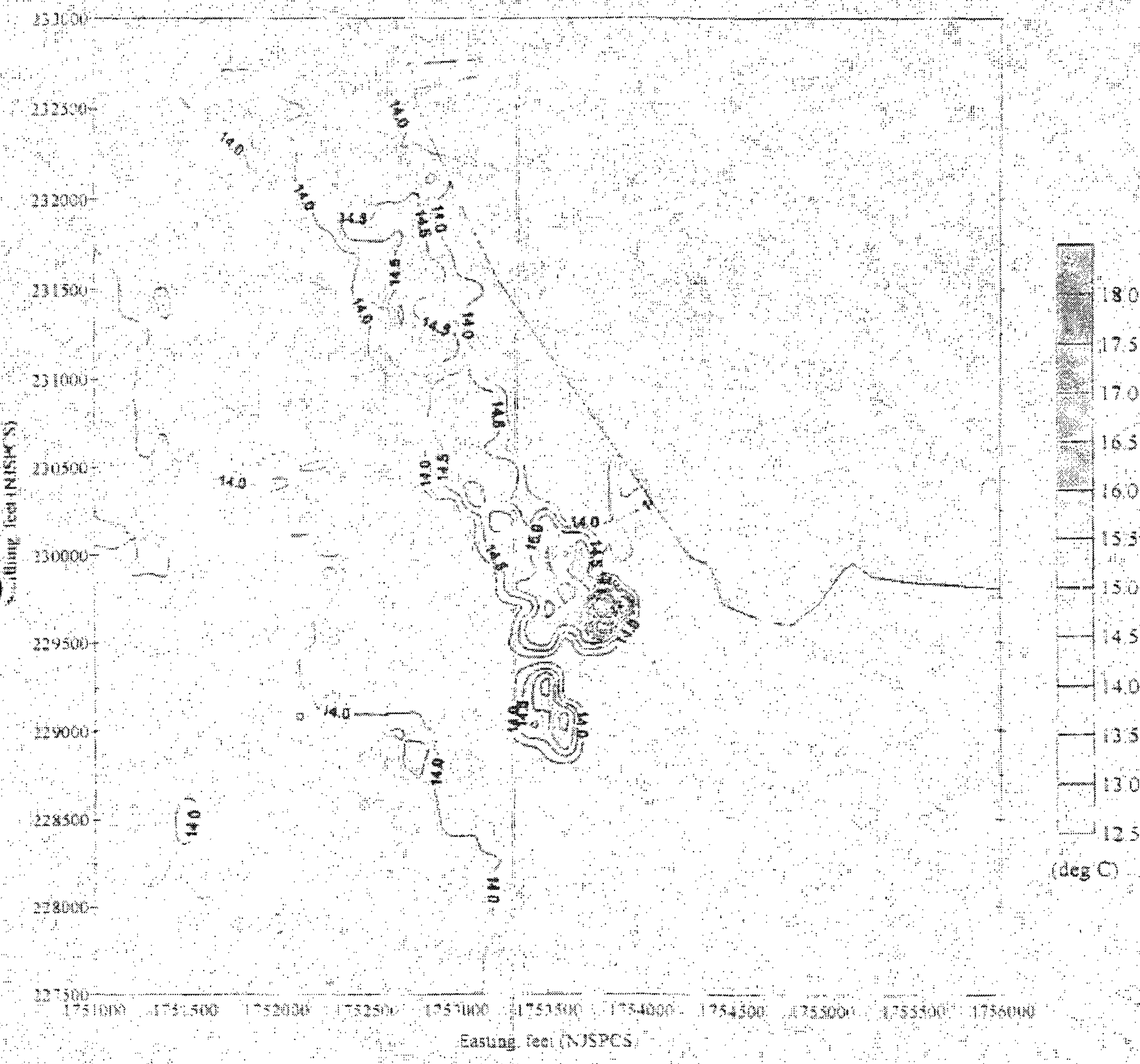
PSE&G 1-Unit Survey: 28 October 1997
Surface Temperature Profiles
FLOOD Phase (06:30 - 08:30)



440

Figure 11-137

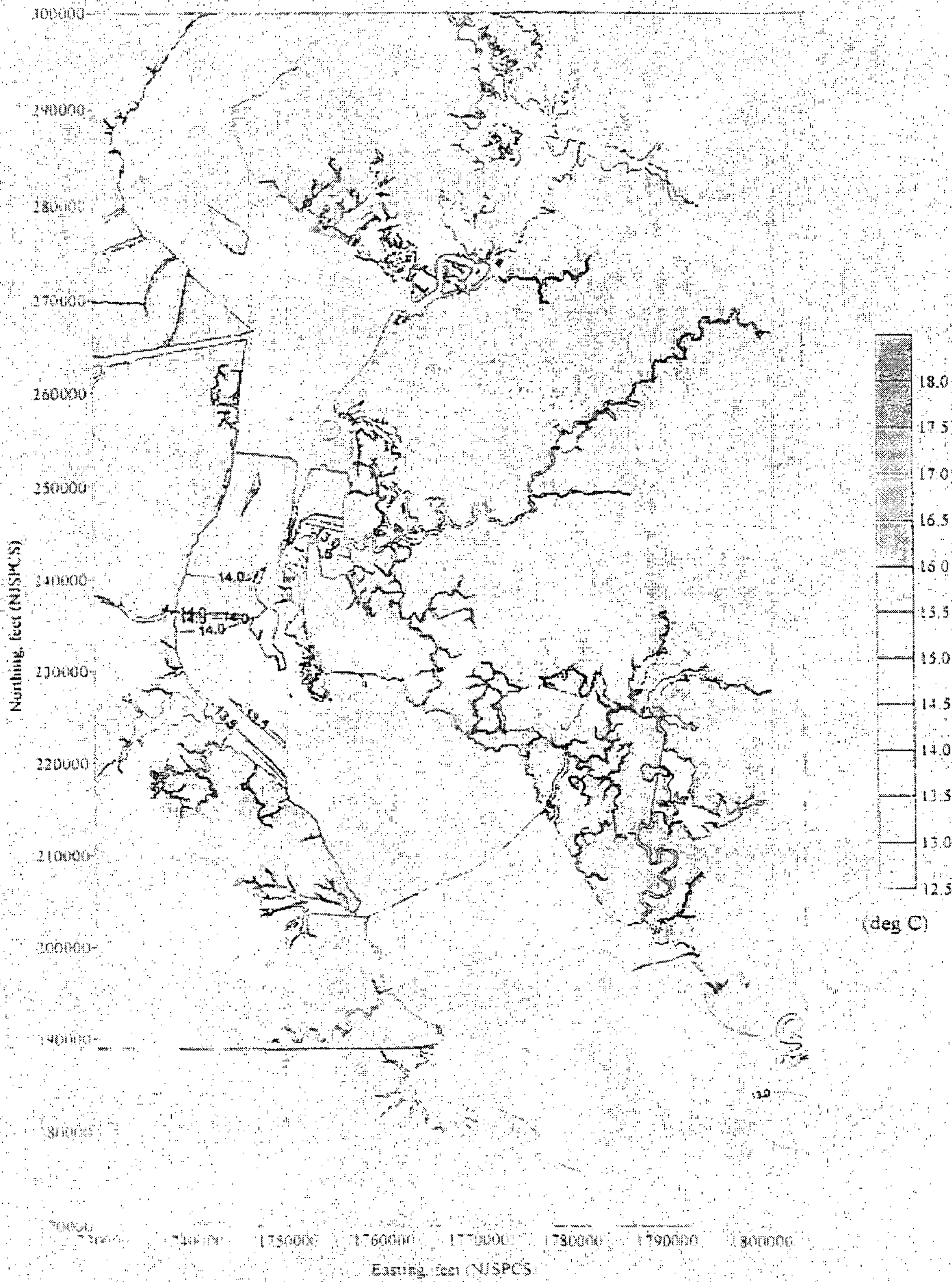
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
FLOOD Phase (06:30 - 08:30)



441

Figure 11-138

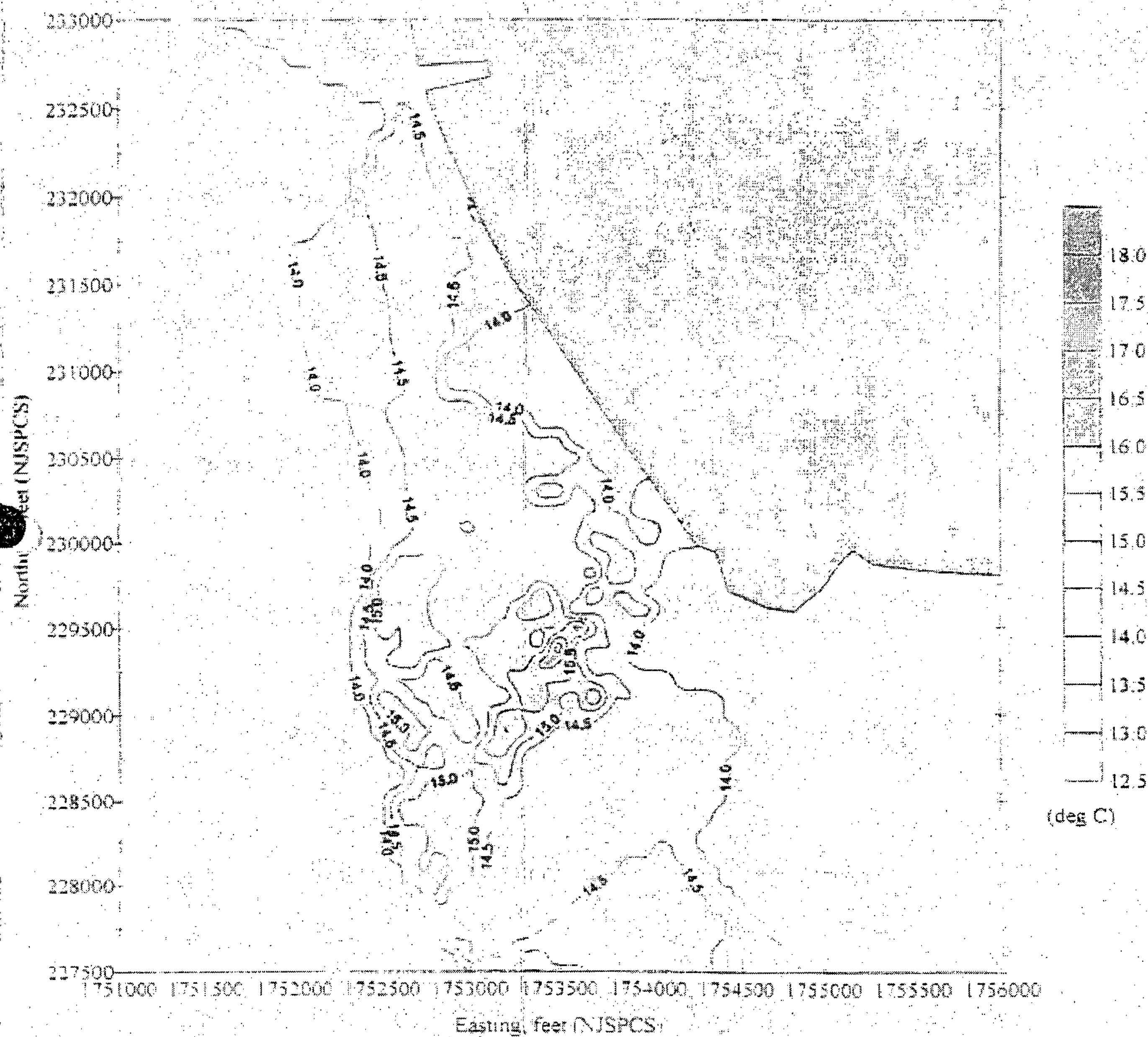
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EOF Phase (09:10 - 11:10)



442

Figure 11-139

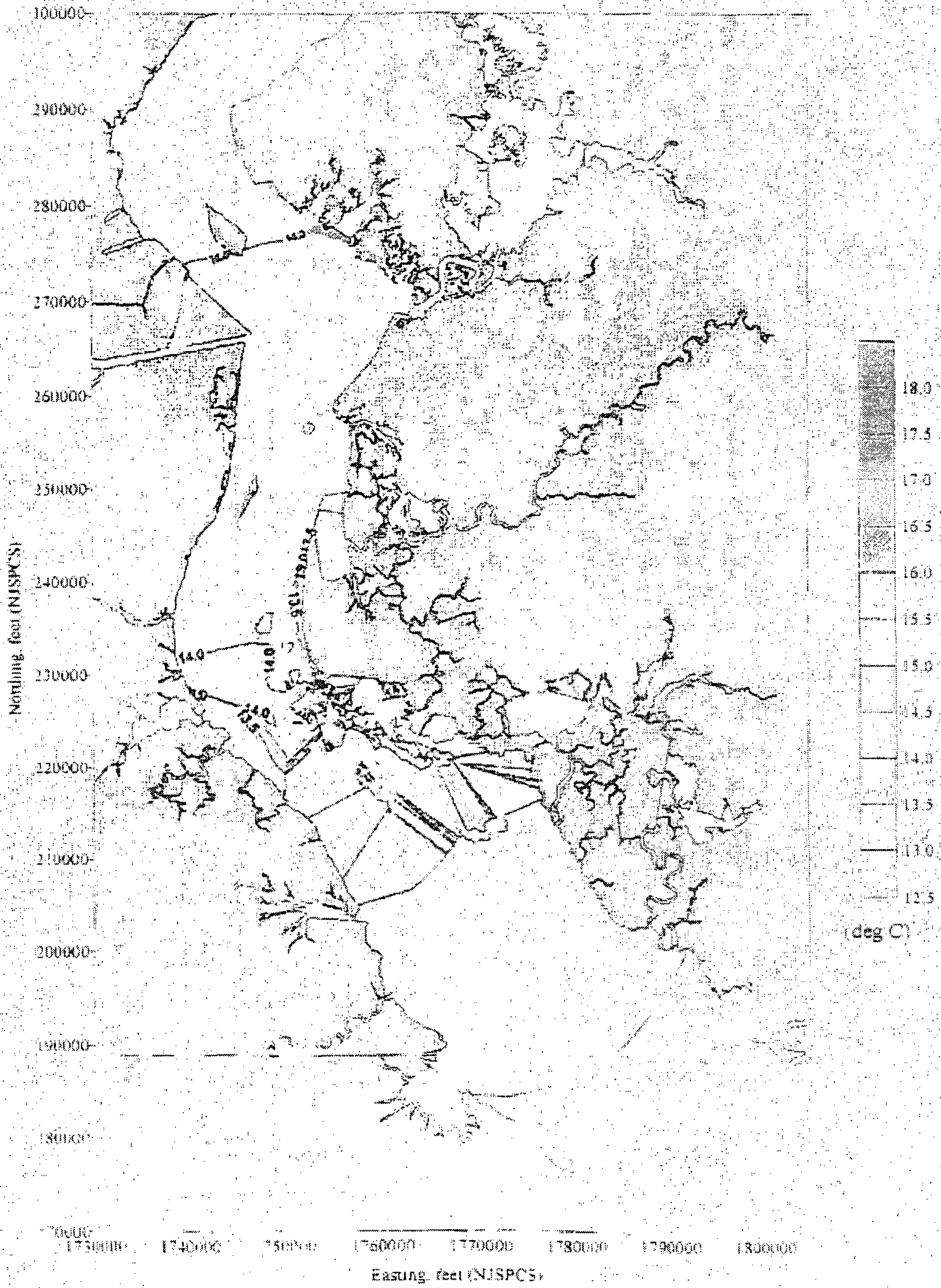
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EOF Phase (09:10 - 11:10)



443

Figure 11-140

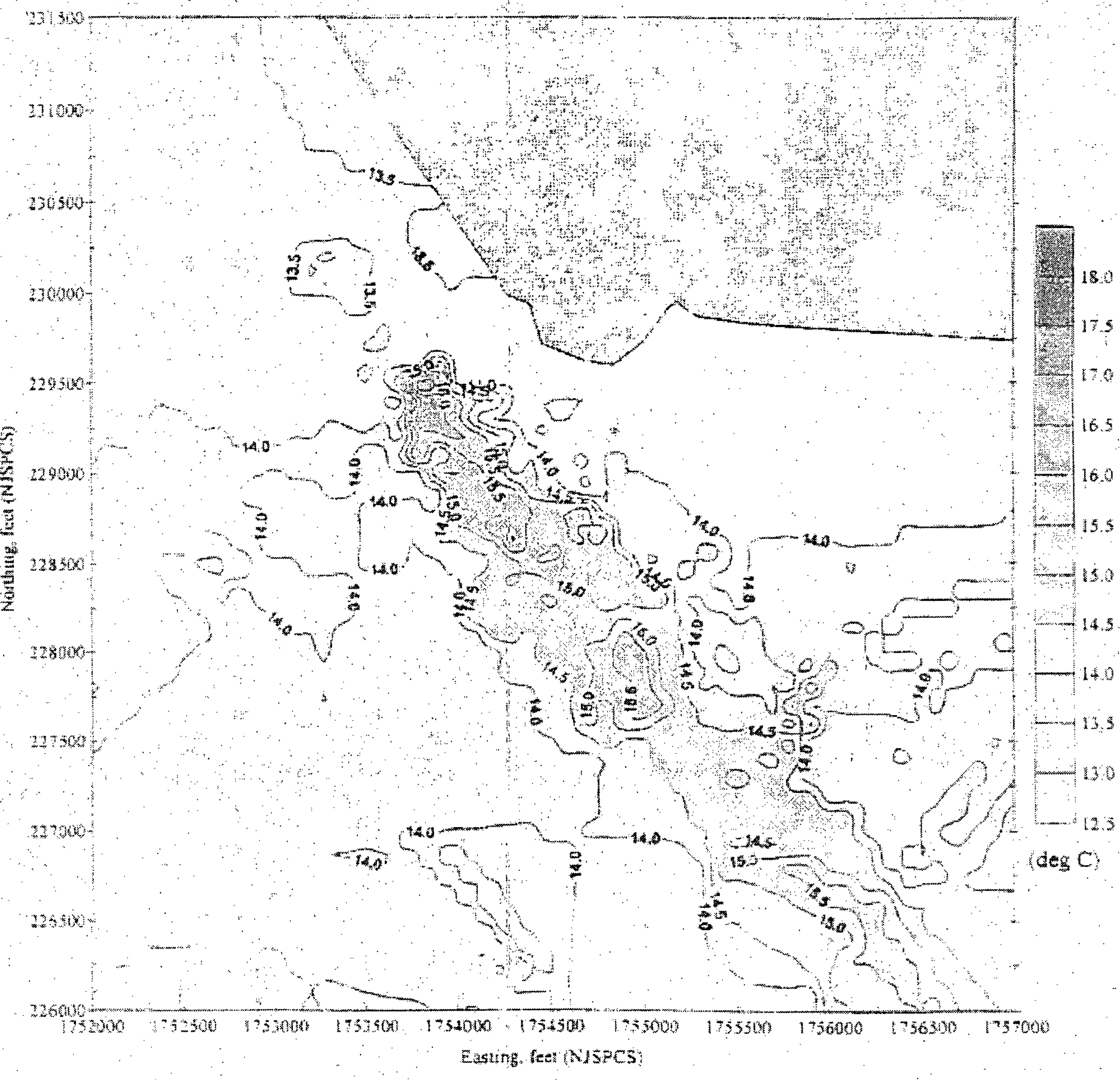
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EBB Phase (12:25 - 14:25)



444

Figure 11-141

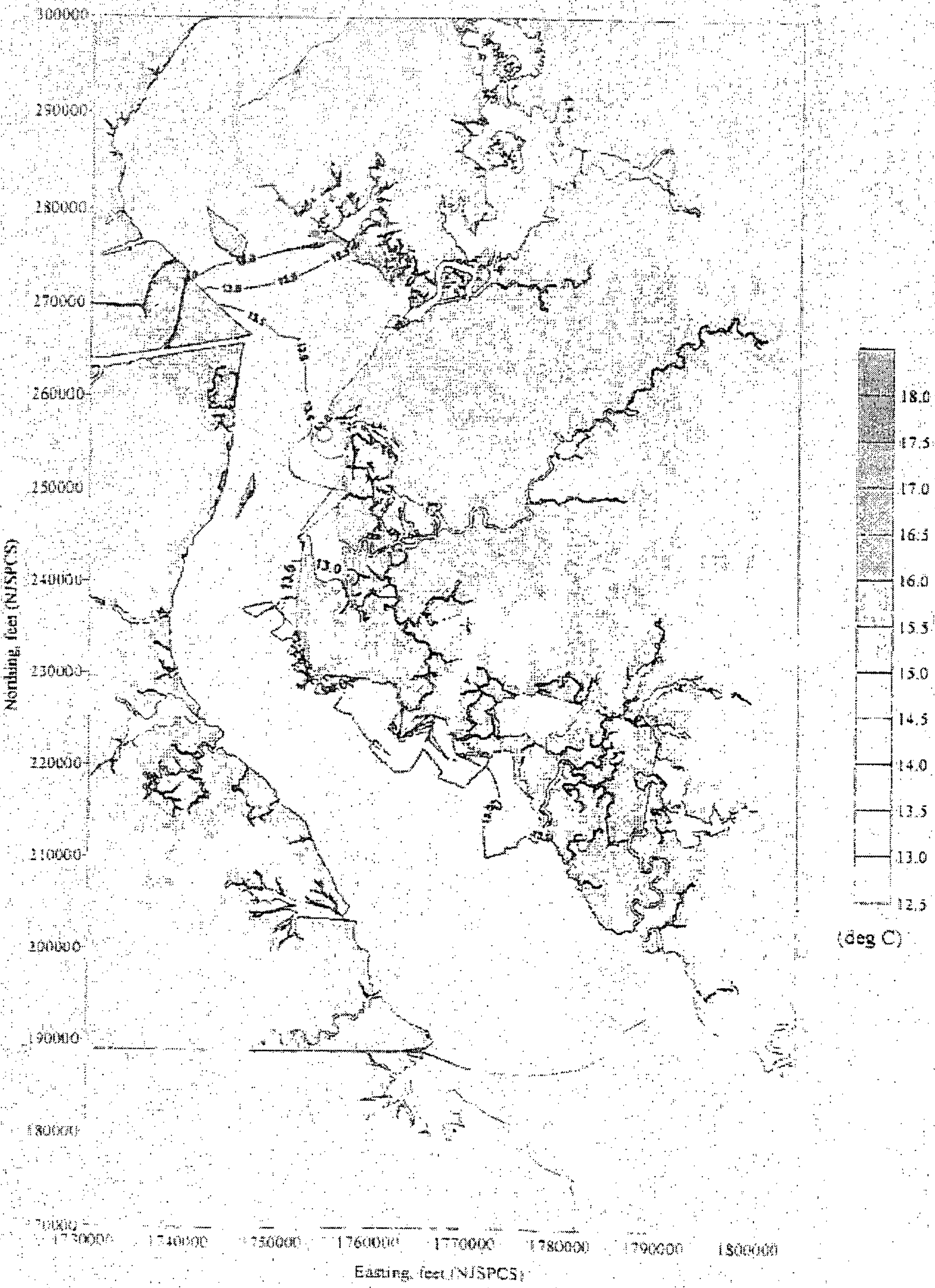
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EBB Phase (12:25 - 14:25)



445

Figure 11-142

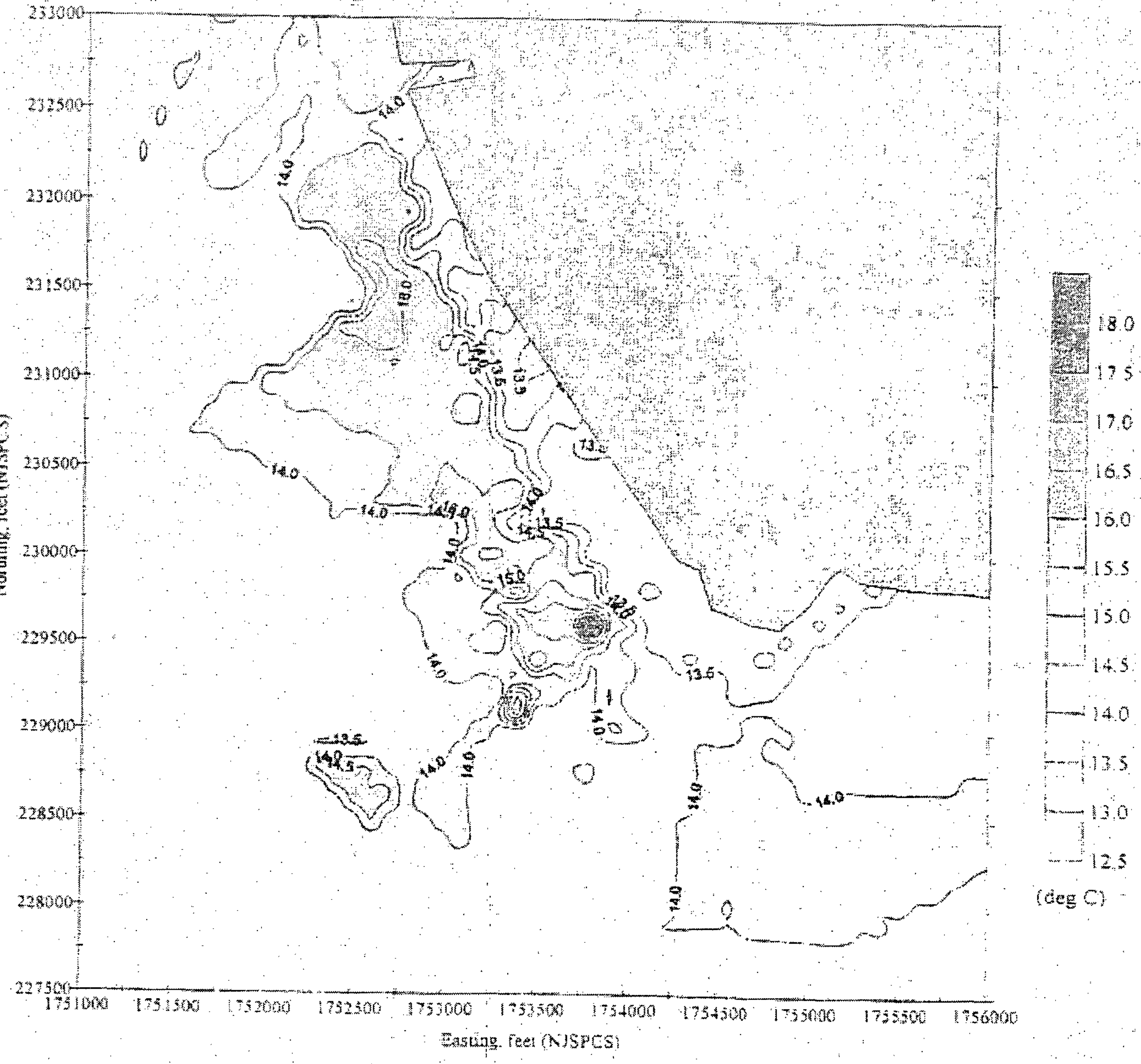
PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EOE Phase (16:15 - 18:15)



446

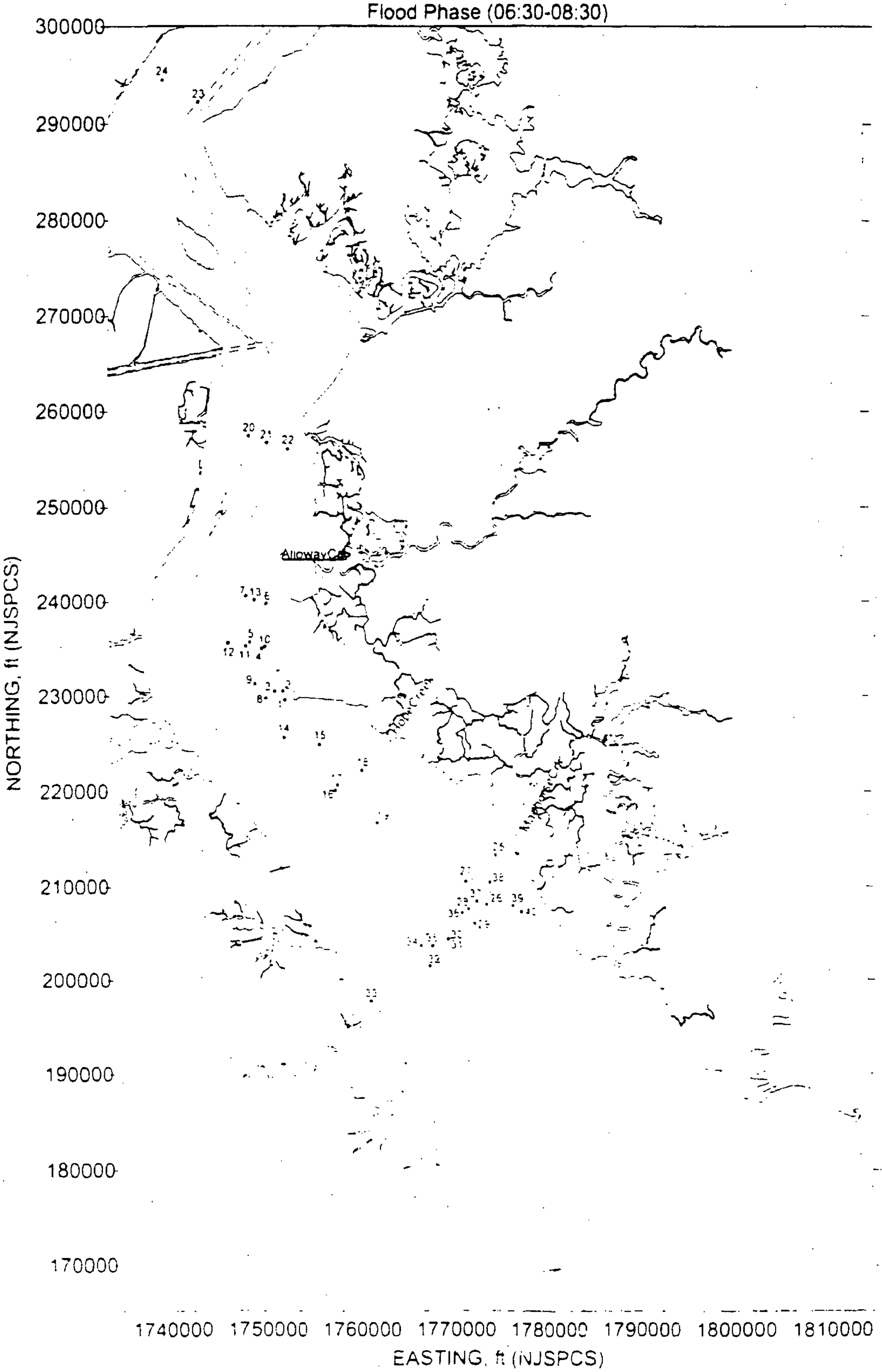
Figure 11-143

PSE&G 1-Unit Survey; 28 October 1997
Surface Temperature Profiles
EOE Phase (16:15 - 18:15)



44

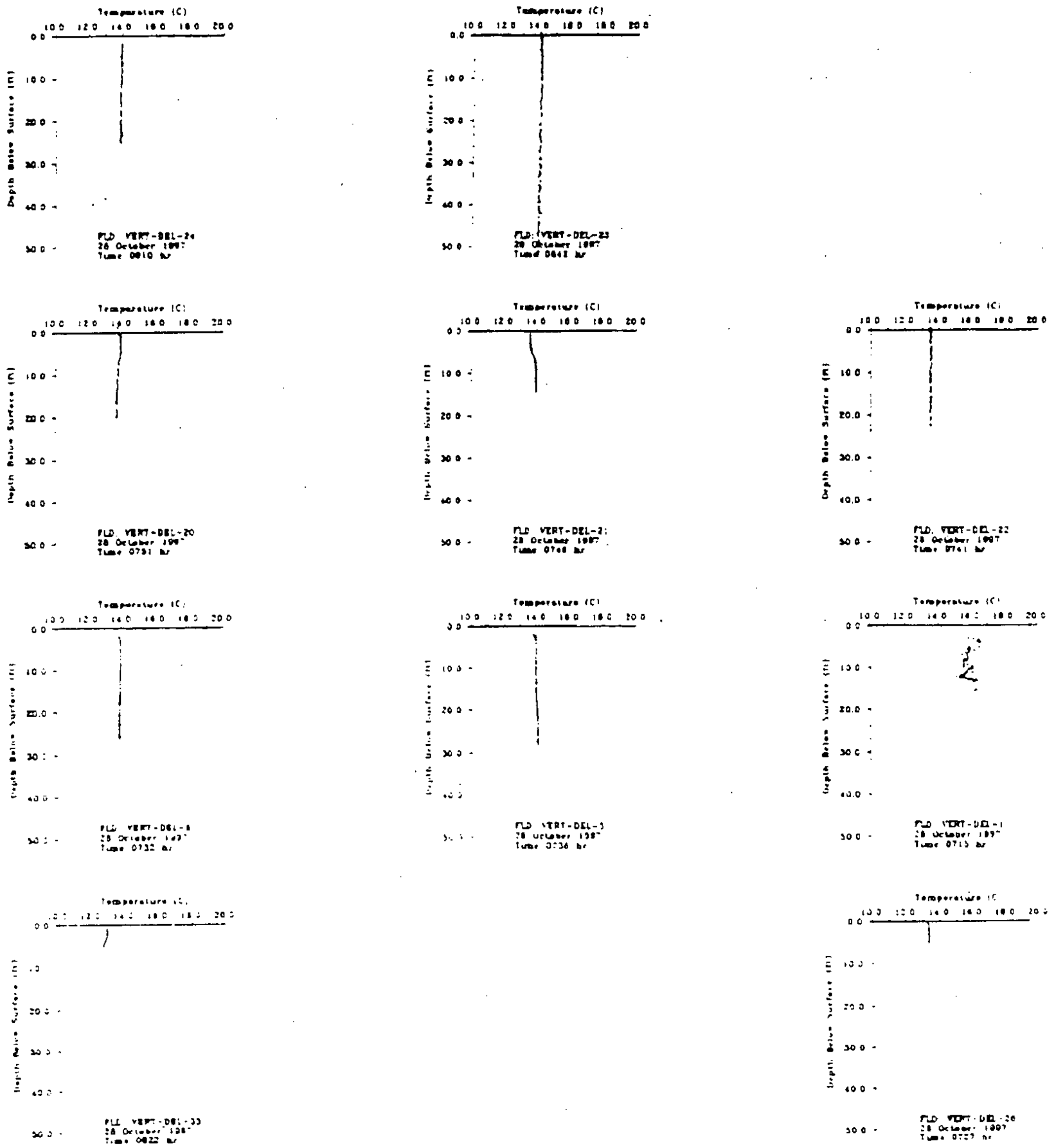
Figure 11-144
PSE&G 2-Unit Survey
Vertical Profile Locations
Flood Phase (06:30-08:30)



448

Figure 11-145

PSE&G 1-Unit Survey; 28 October 1997
Vertical Temperature Profiles
FLD Phase (06:30 – 08:30)



449

Figure 11-146
PSE&G 1-Unit Survey; 28 October 1997
Vertical Temperature Profiles
FLD Phase (06:30 - 08:30)

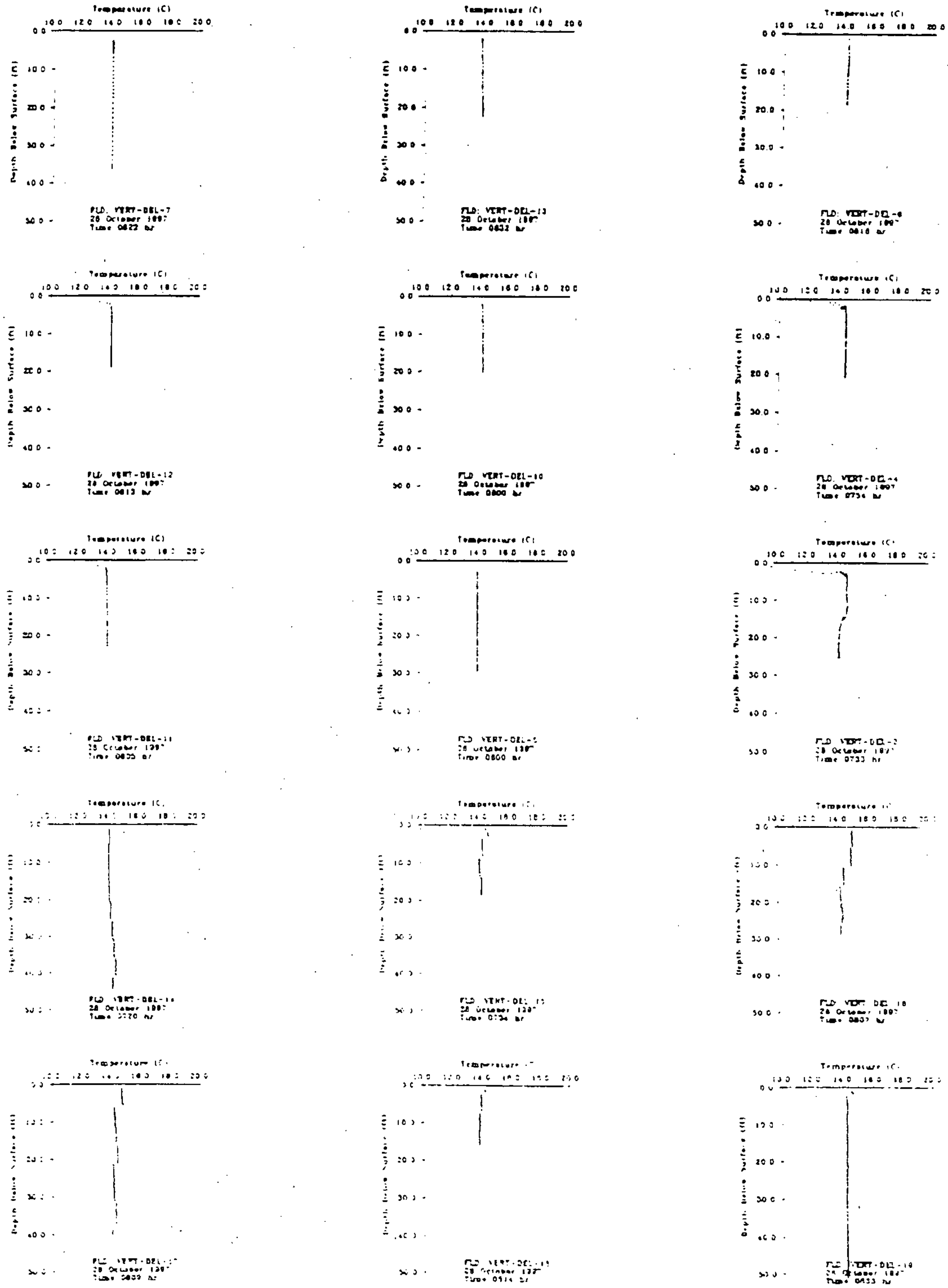


Figure 11-147

PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
FLD Phase (06:30 - 08:30)

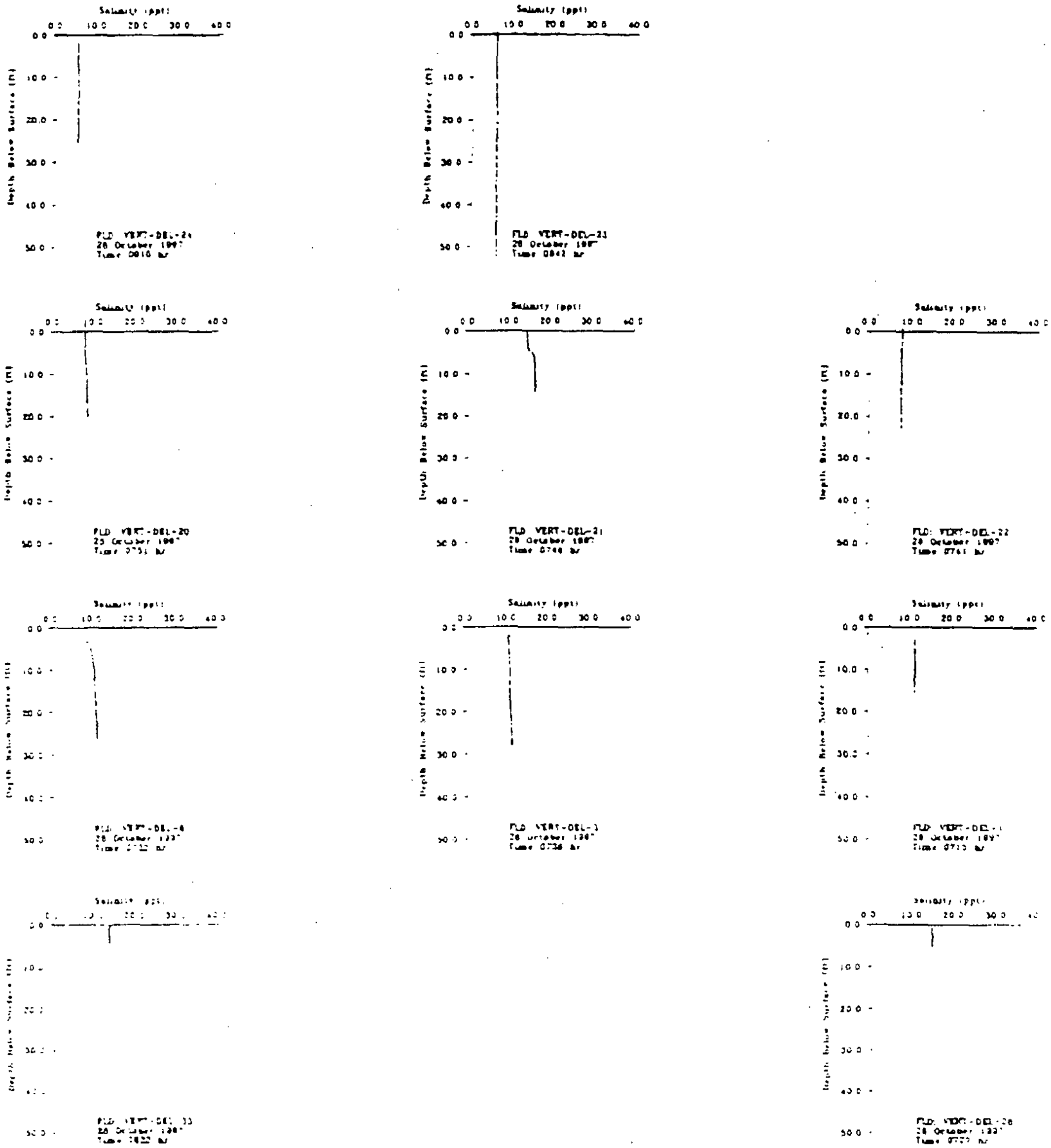


Figure 11-148

PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
FLD Phase (06:30 - 08:30)

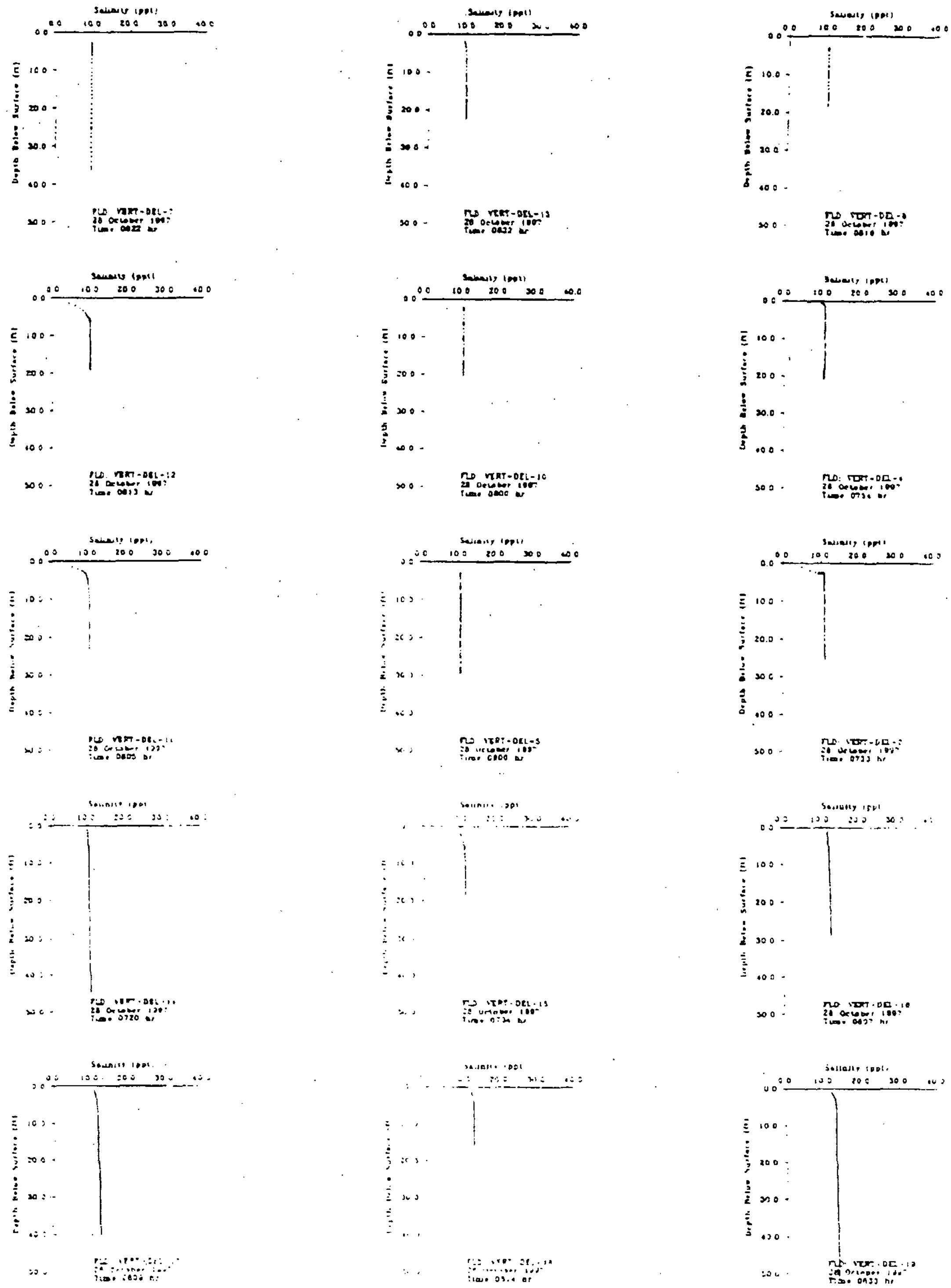
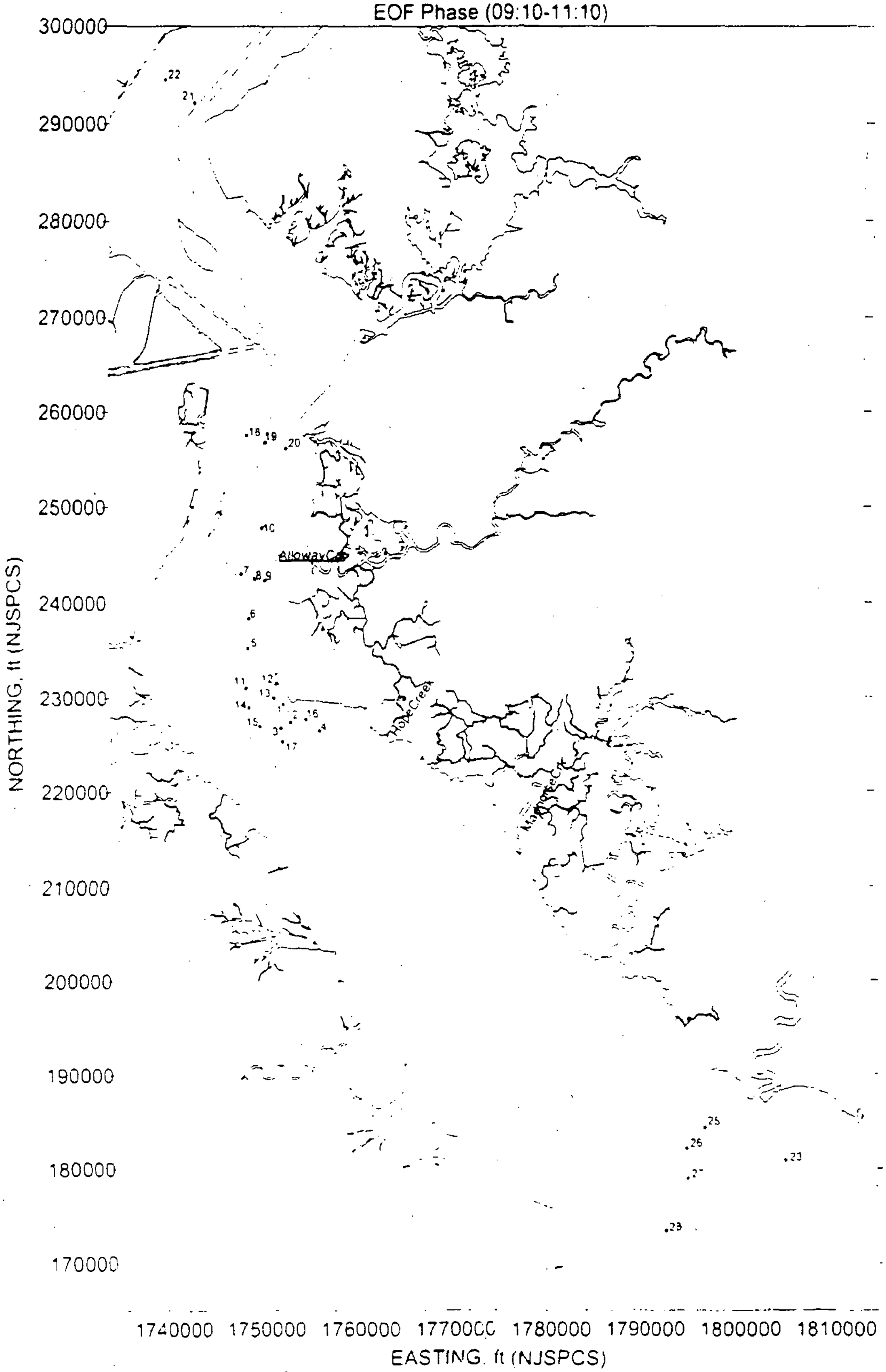


Figure 11-149
PSE&G 2-Unit Survey
Vertical Profile Locations
EOF Phase (09:10-11:10)



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PSE&G 1-Unit Survey: 28 October 1997
Vertical Temperature Profiles
EOF Phase (09:10 - 11:10)

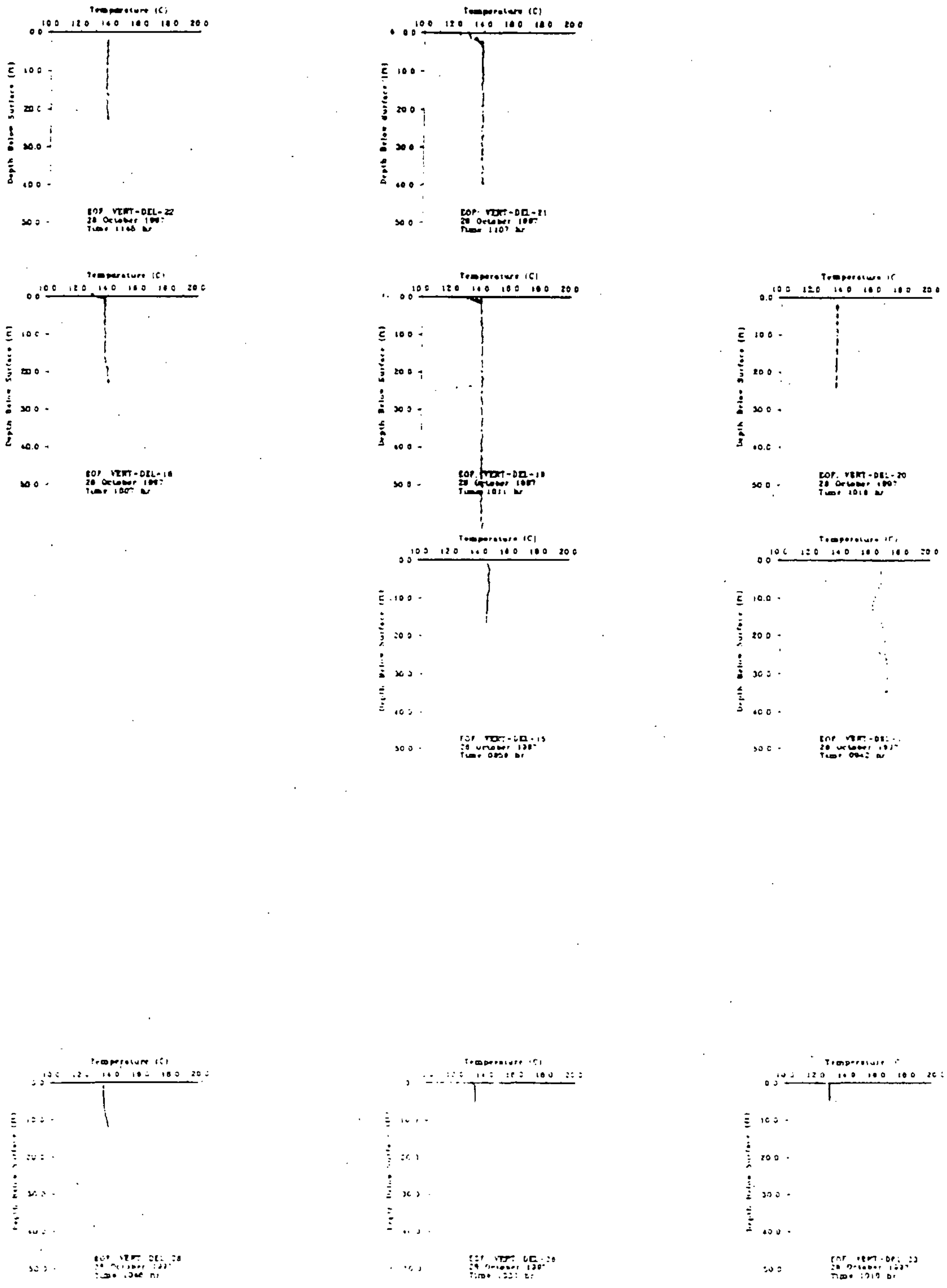

Figure 11-151

PSE&G 1-Unit Survey: 28 October 1997
Vertical Temperature Profiles
EOF Phase (09:10 - 11:10)

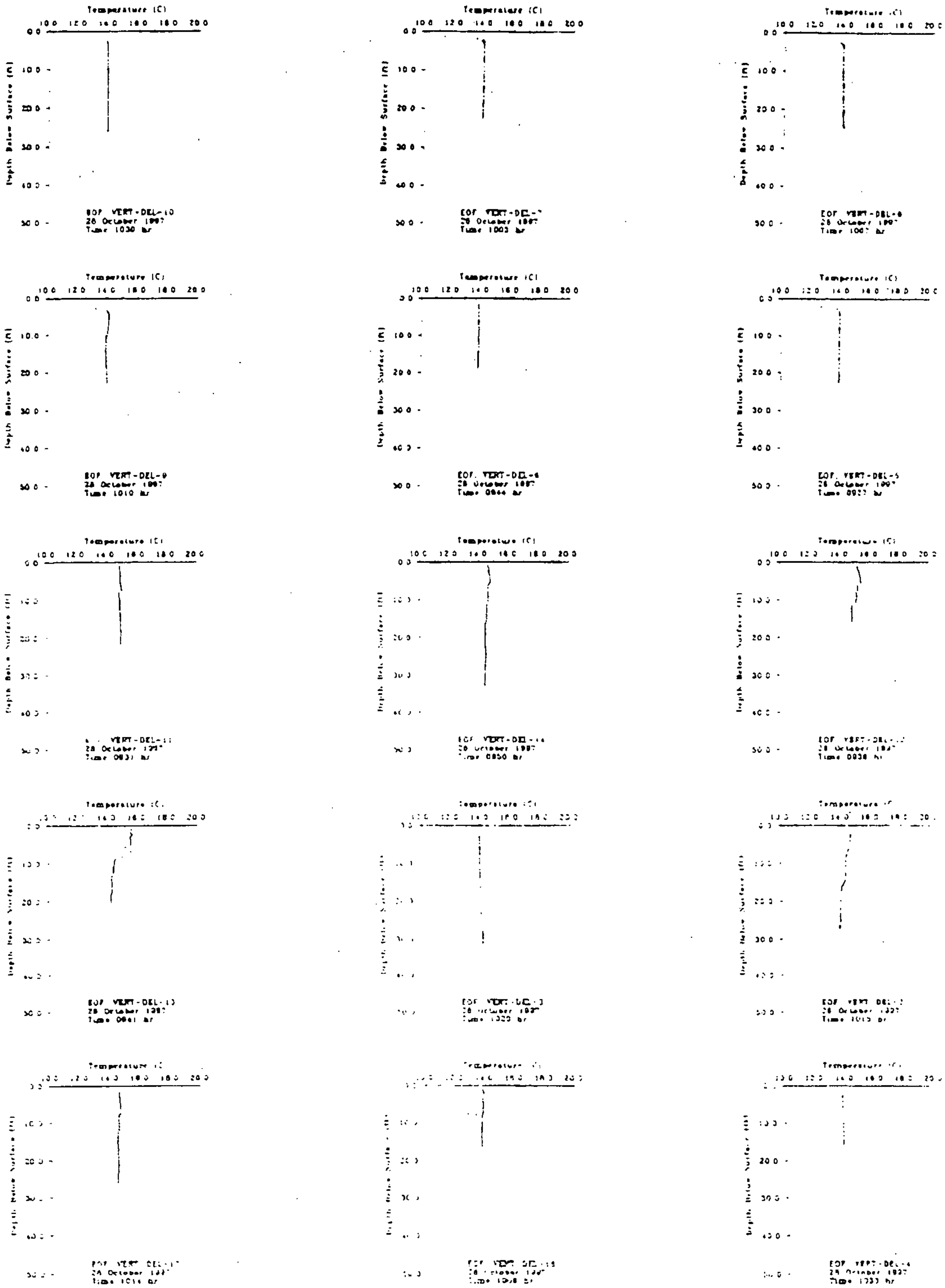

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Figure 11-152
PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
EOF Phase (09:10 - 11:10)

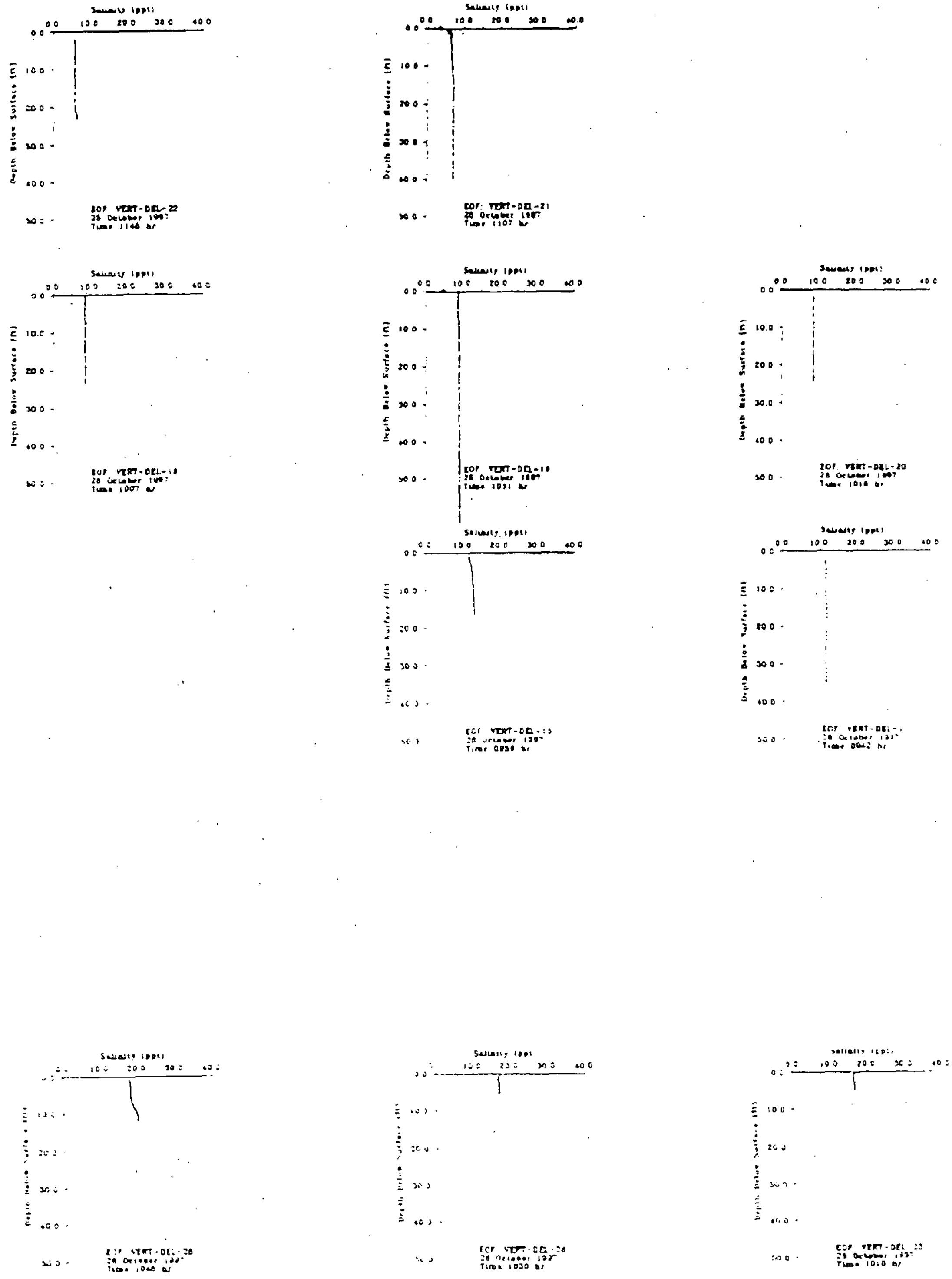

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Figure 11-153

PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
EOF Phase (09:10 - 11:10)

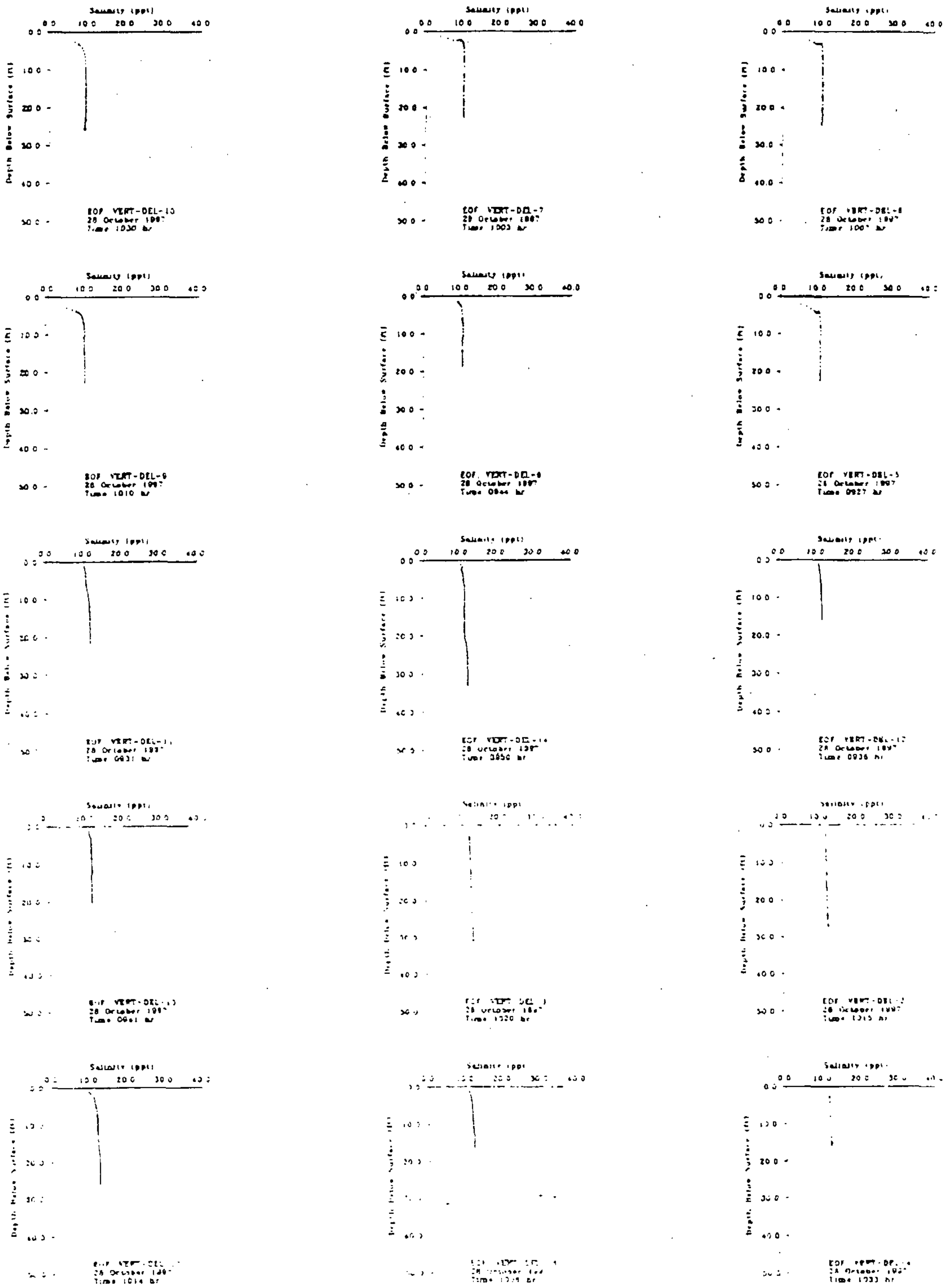

Figure 11-154
PSE&G 2-Unit Survey
Vertical Profile Locations
Ebb Phase (12:25-14:25)

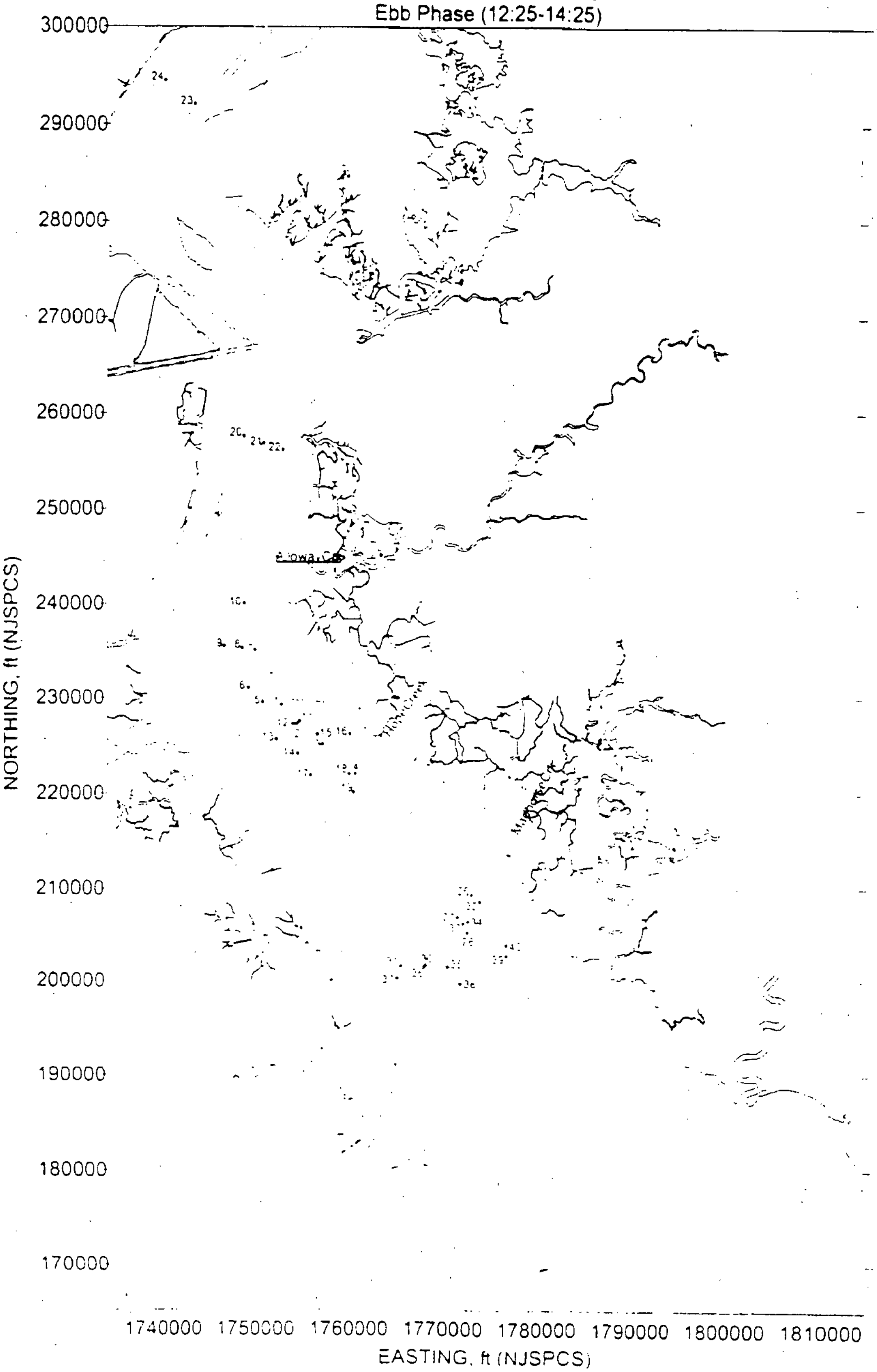

Figure 11-155

PSE&G 1-Unit Survey: 28 October 1997
Vertical Temperature Profiles
EBB Phase (12:25 - 14:25)

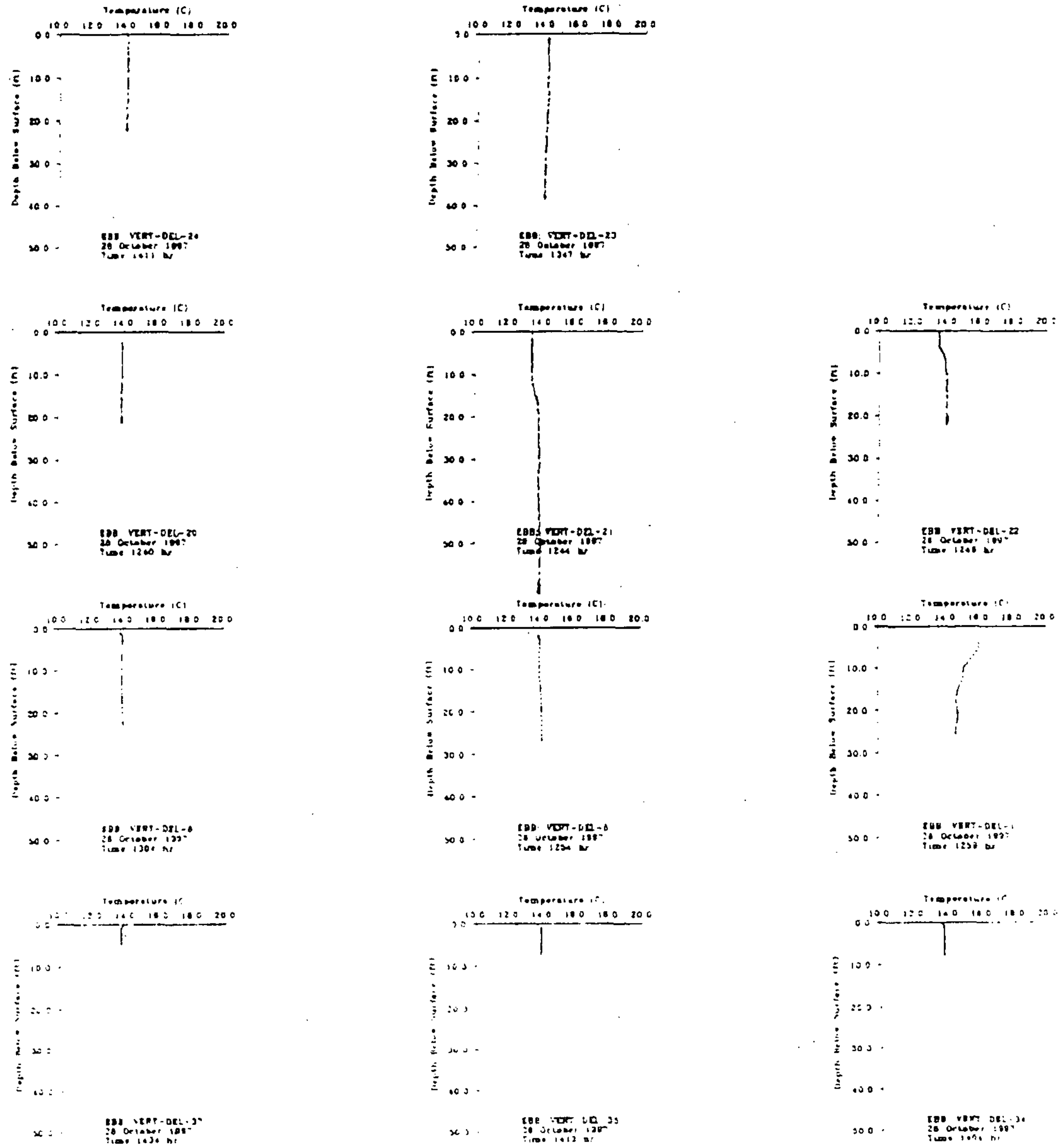

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Figure 11-156

PSE&G 1-Unit Survey; 28 October 1997
Vertical Temperature Profiles
EBB Phase (12:25 - 14:25)

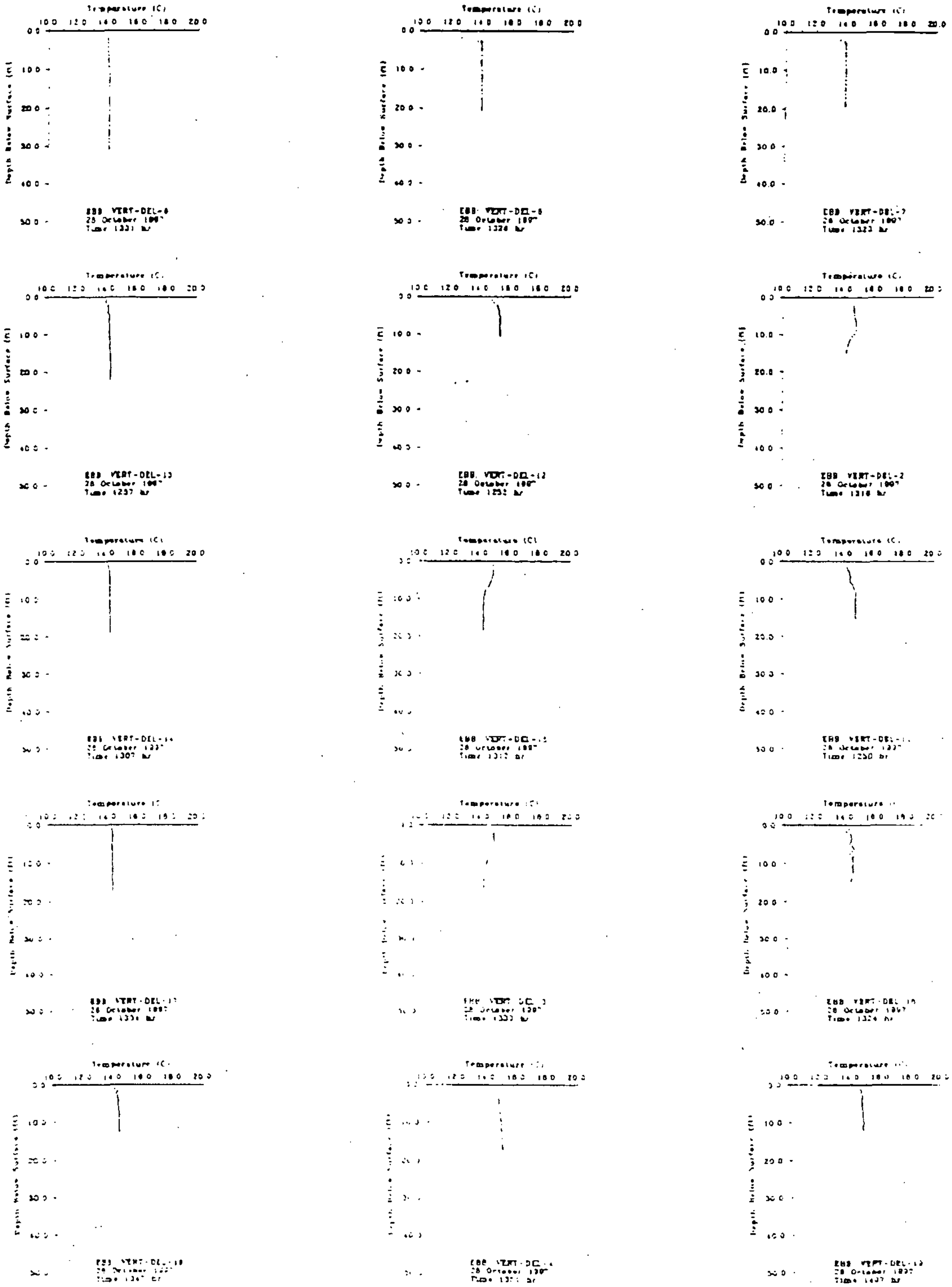

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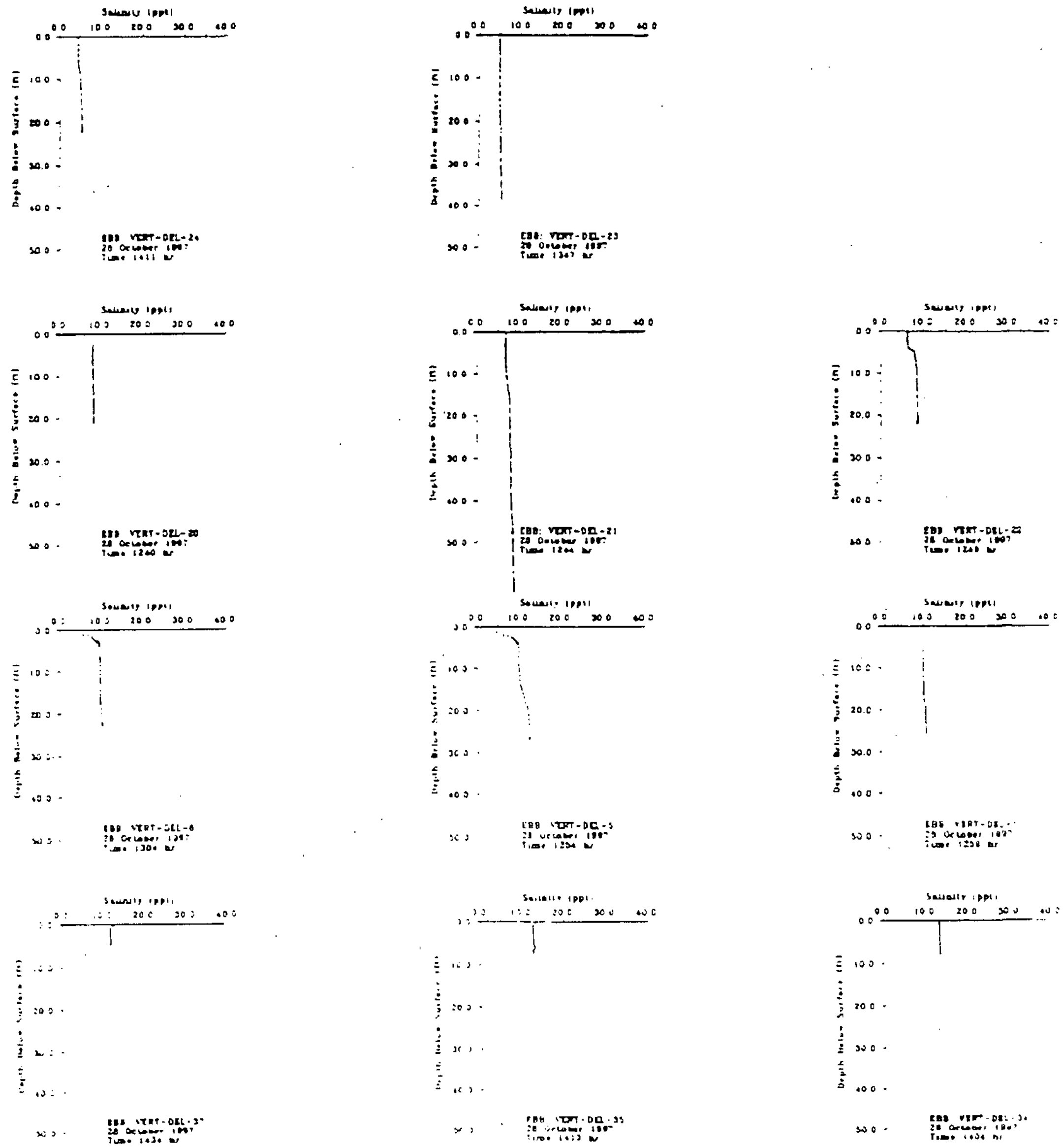
Figure 11-157

PSE&G 1-Unit Survey; 28 October 1997

Vertical Salinity Profiles

EBB Phase (12:25 - 14:25)



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PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
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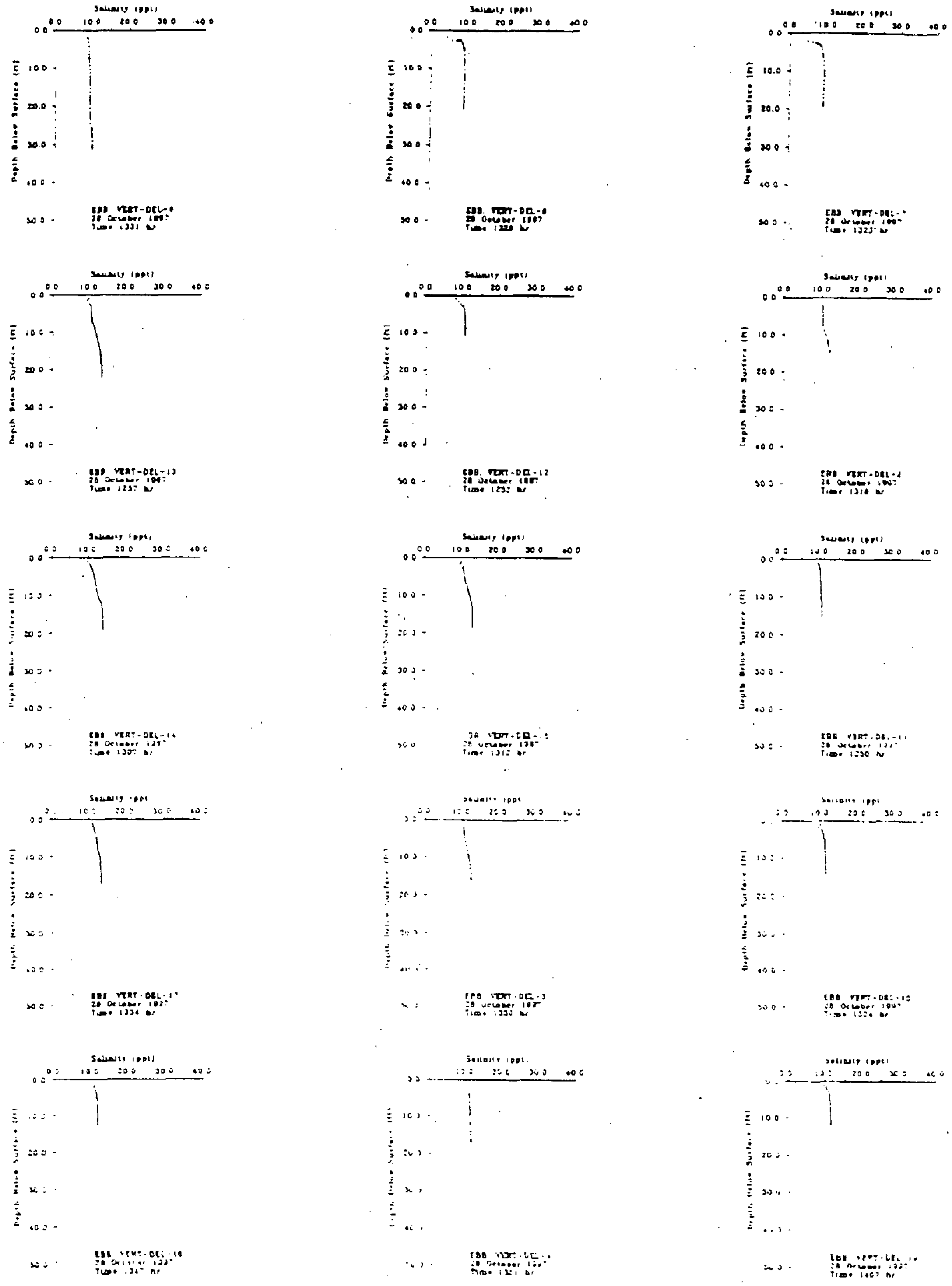

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Figure 11-159
PSE&G 2-Unit Survey
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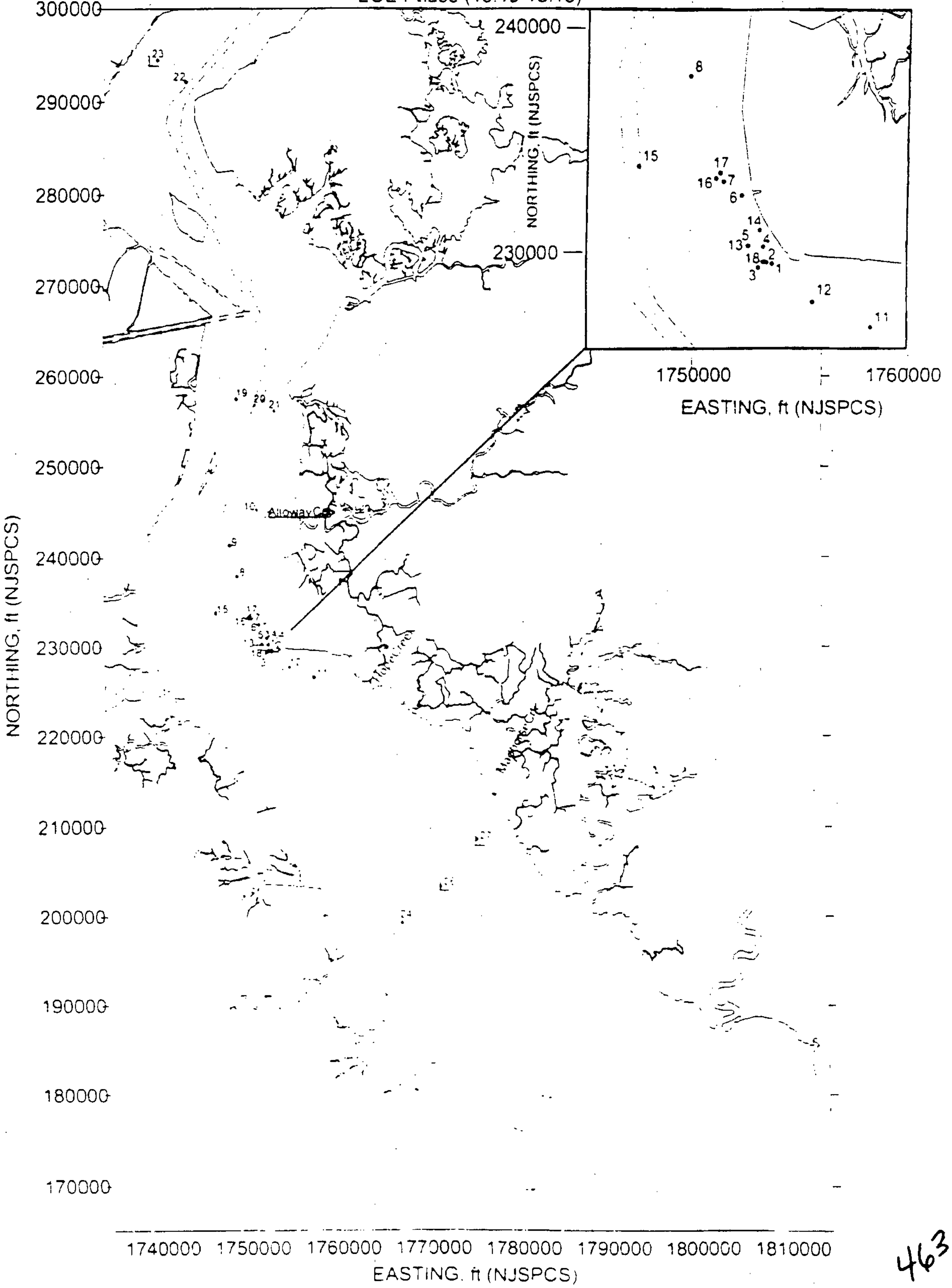

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PSE&G 1-Unit Survey; 28 October 1997
Vertical Temperature Profiles
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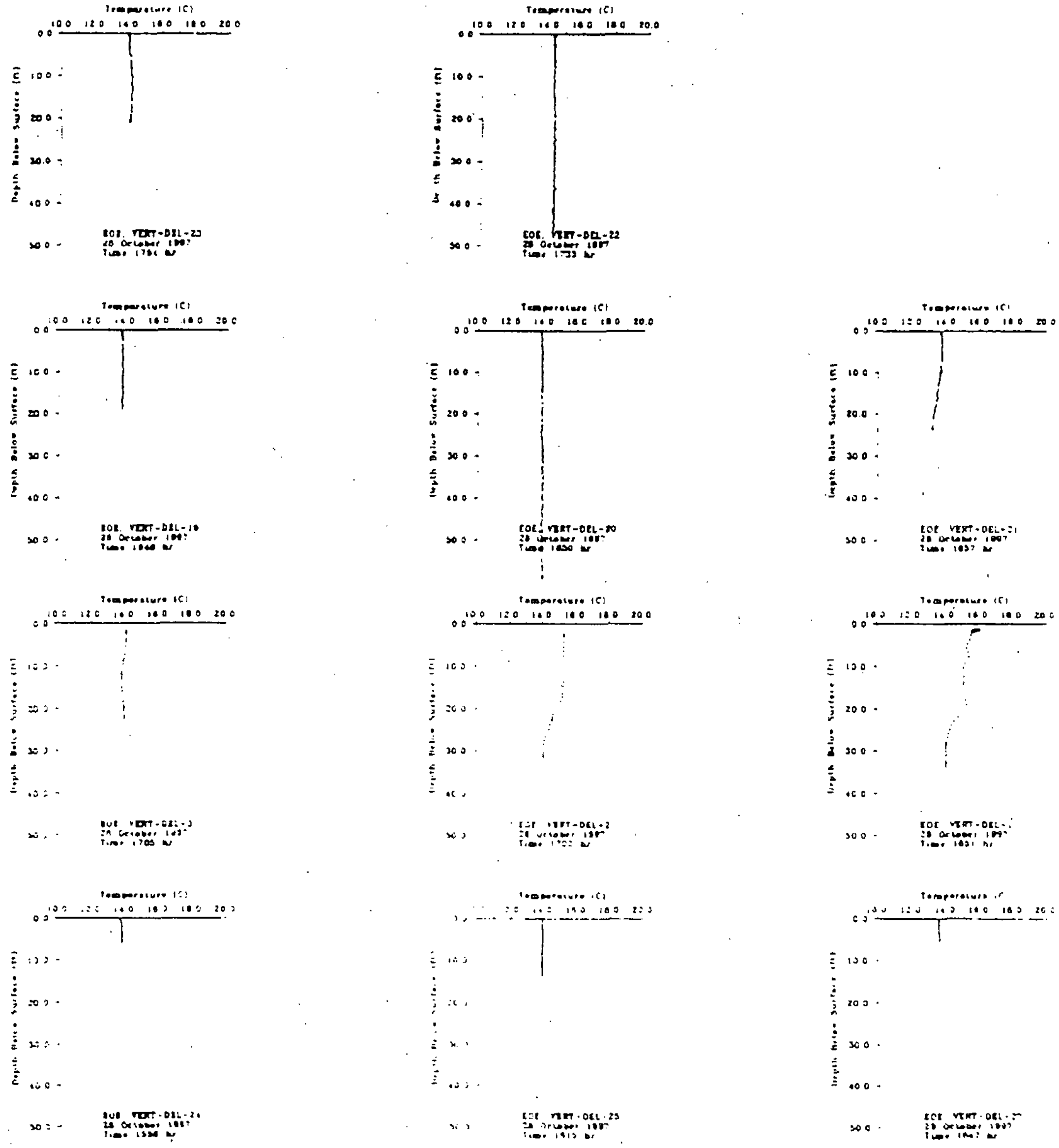

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Figure 11-161
PSE&G 1-Unit Survey, 28 October 1997
Vertical Temperature Profiles
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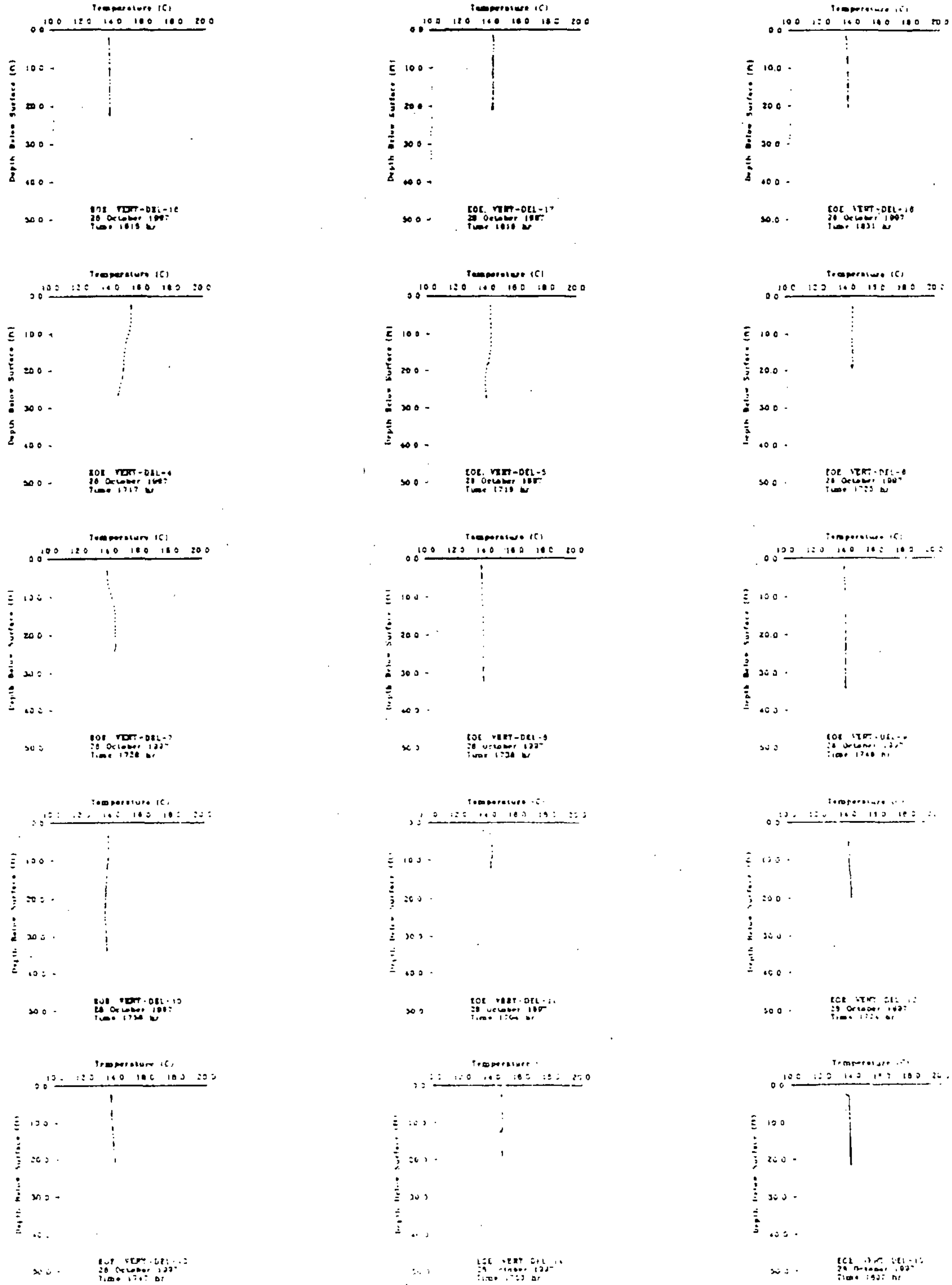
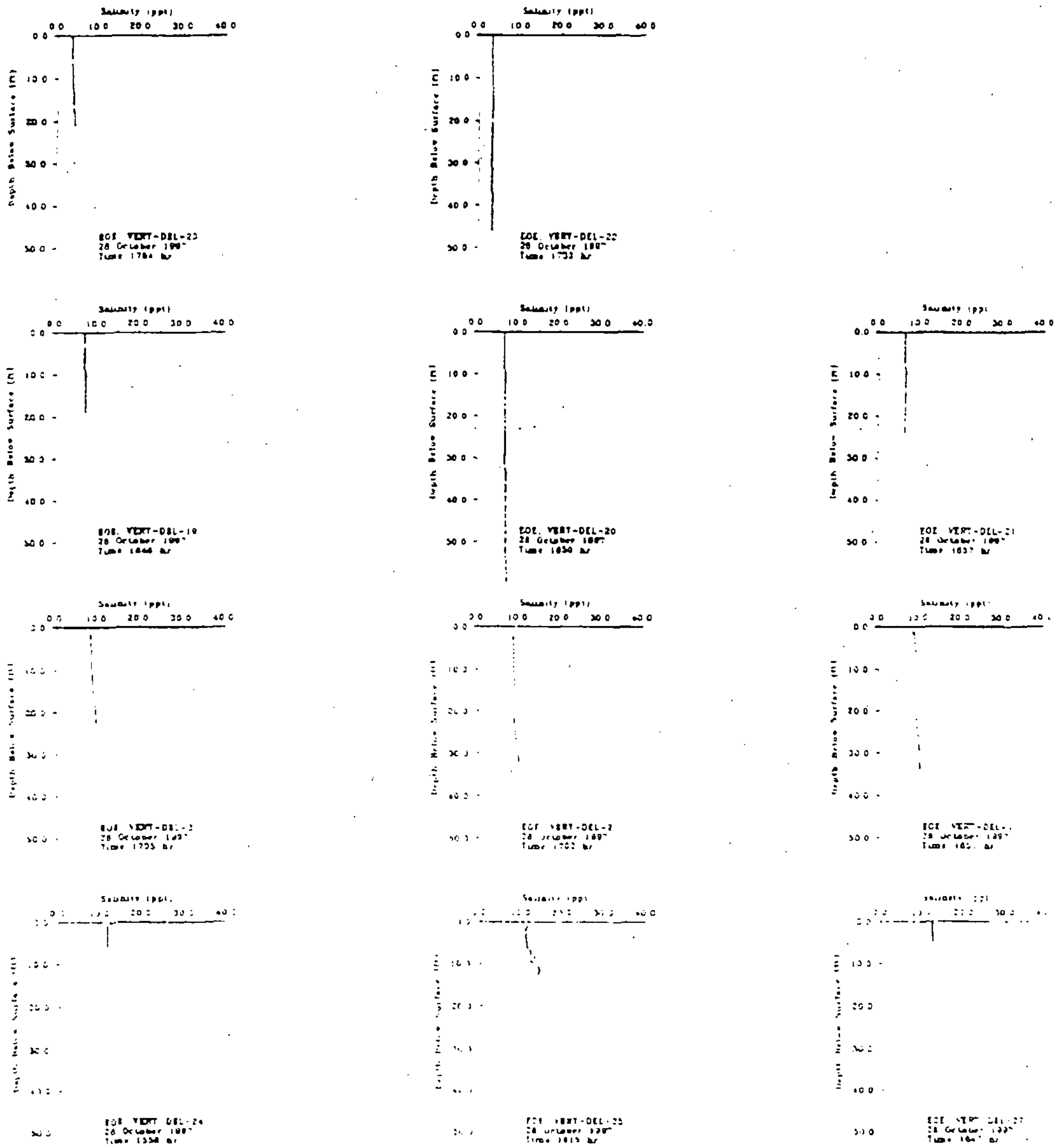


Figure 11-162

PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
EOE Phase (16:15 - 18:15)



4do

Figure 11-163

PSE&G 1-Unit Survey: 28 October 1997
Vertical Salinity Profiles
EOE Phase (16:15 - 18:15)

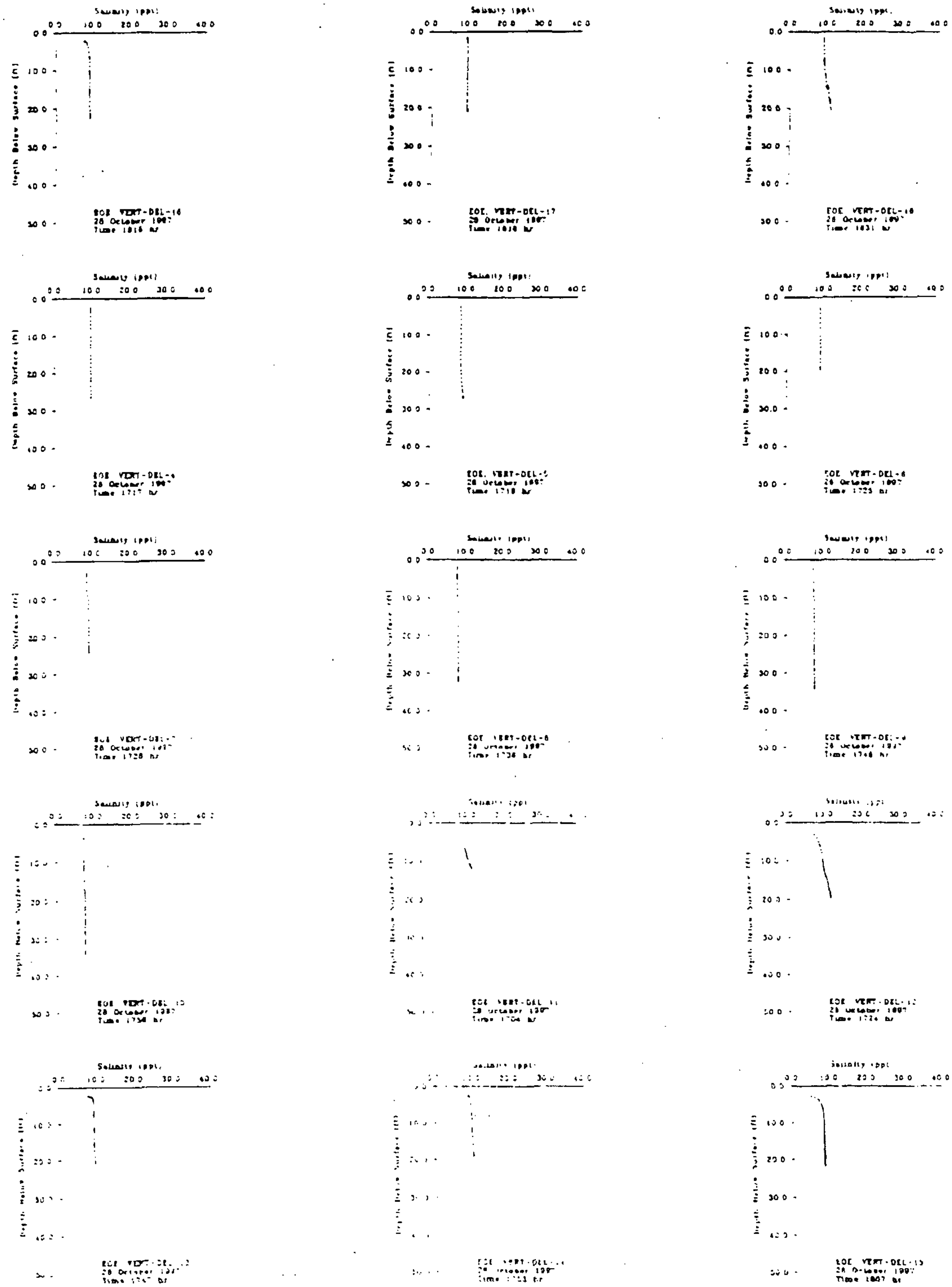
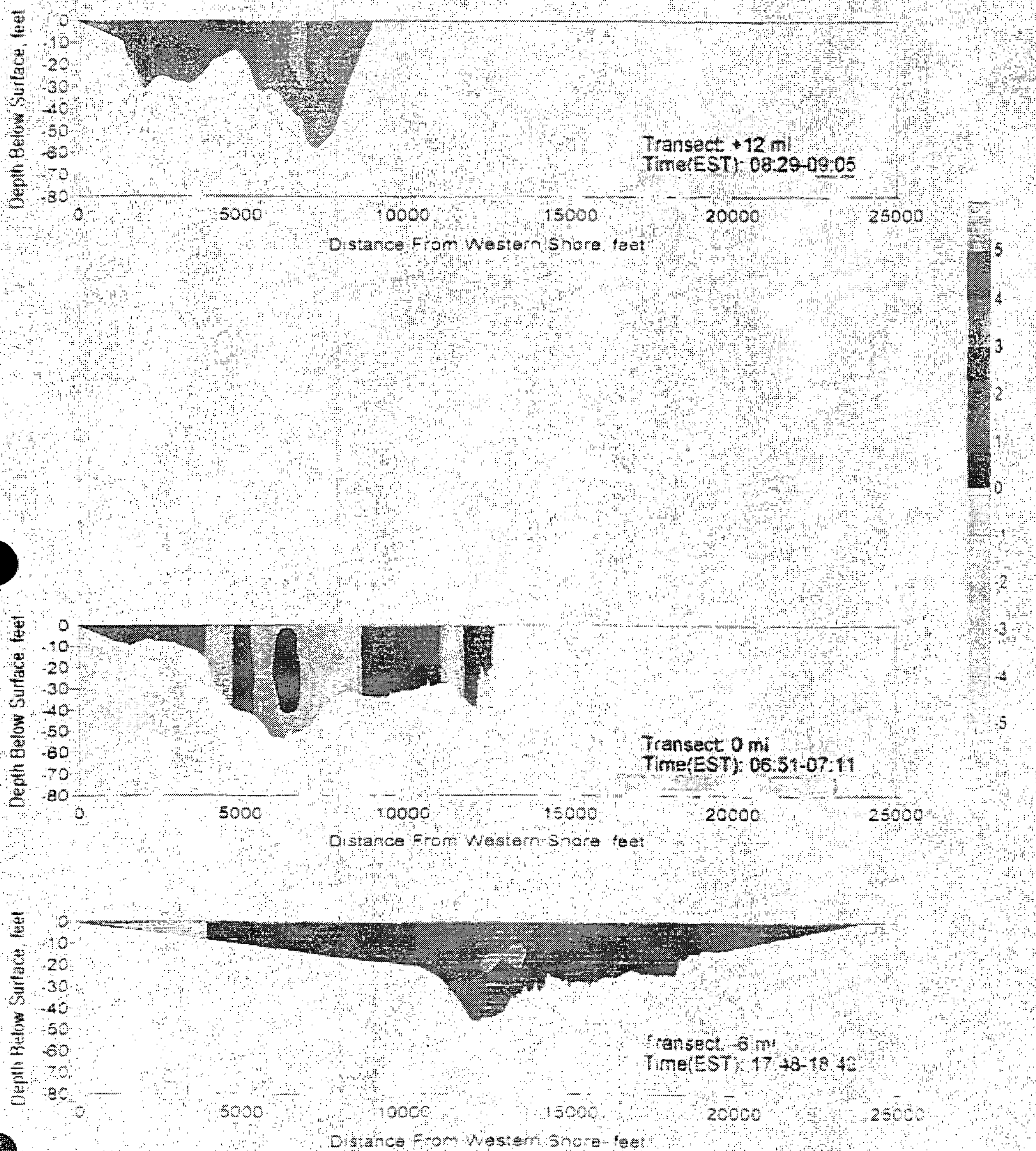


Figure 11-164
PSE&G 1-Unit Survey; 28 October 1997
Delaware River Velocity Profiles
FLOOD PHASE [06:30-08:30 (est)]



Note: Velocities are in fps.

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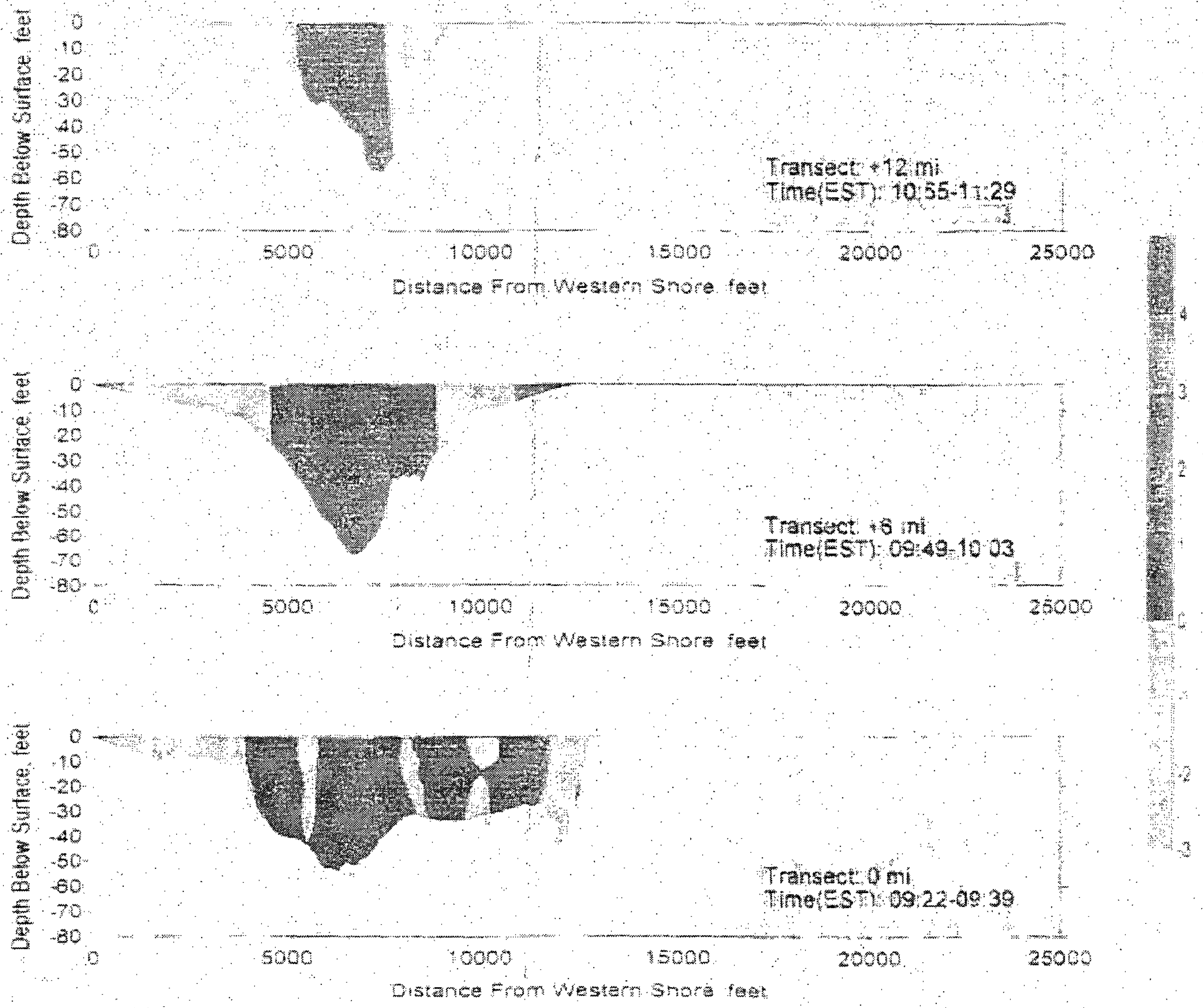
Figure 11-165

PSE&G 1-Unit Survey; 28 October 1997
Delaware River Velocity Profiles
EOF PHASE [09:10-11:10 (est)]



Note: Velocities are in fps.

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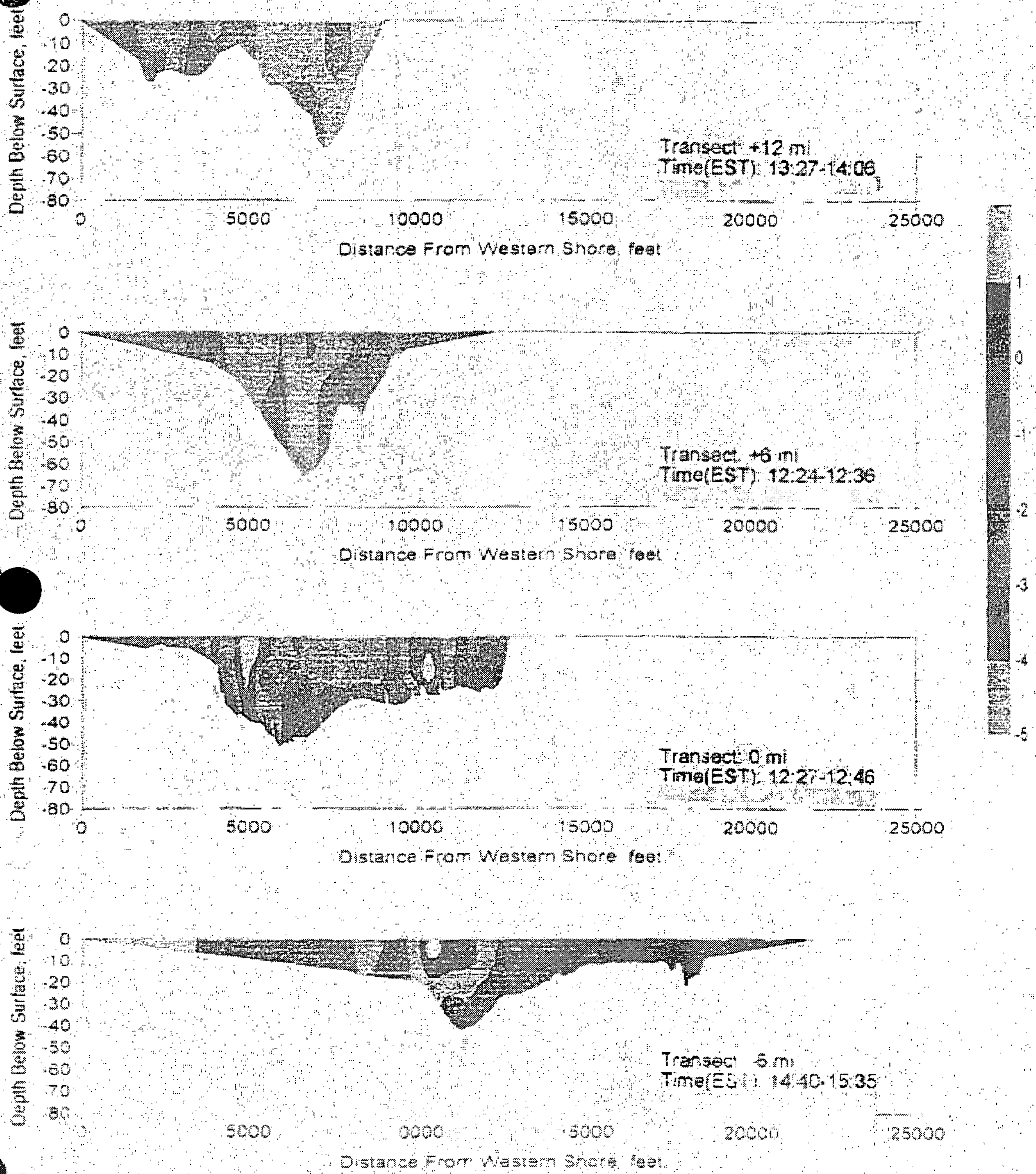
Figure 11-166

PSE&G 1-Unit Survey; 28 October 1997
Delaware River Velocity Profiles
EBB PHASE [12:25-14:25 (est)]



Note: Velocities are in fps.

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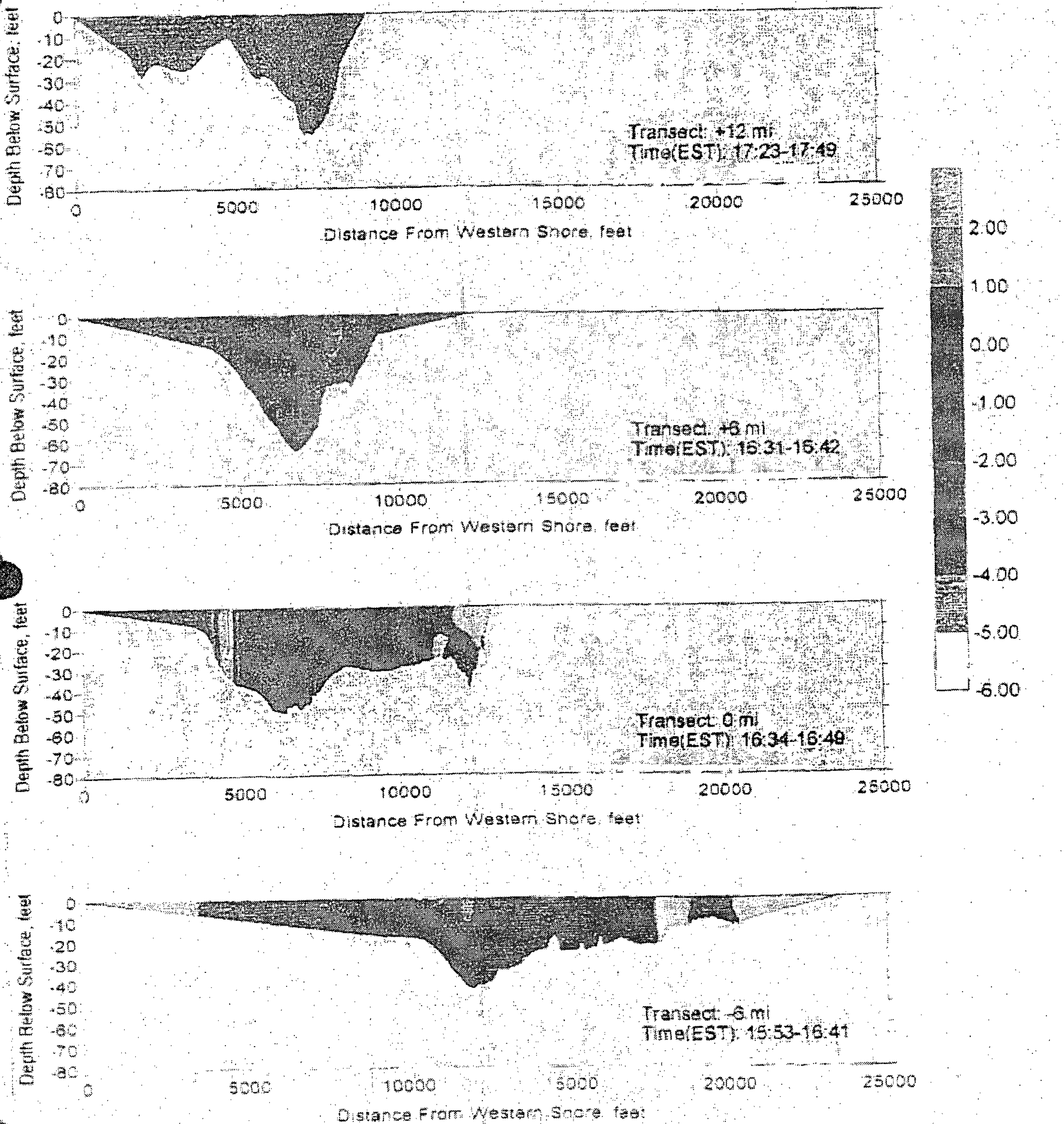
Figure 11-167

PSE&G 1-Unit Survey; 28 October 1997
Delaware River Velocity Profiles
EOE PHASE [16:15-18:15 (est)]



Note: Velocities are in fps.

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Figure 11-168

PSE&G 1-Unit Survey; 29 October 1997
Vertical Temperature Profiles
Salem River

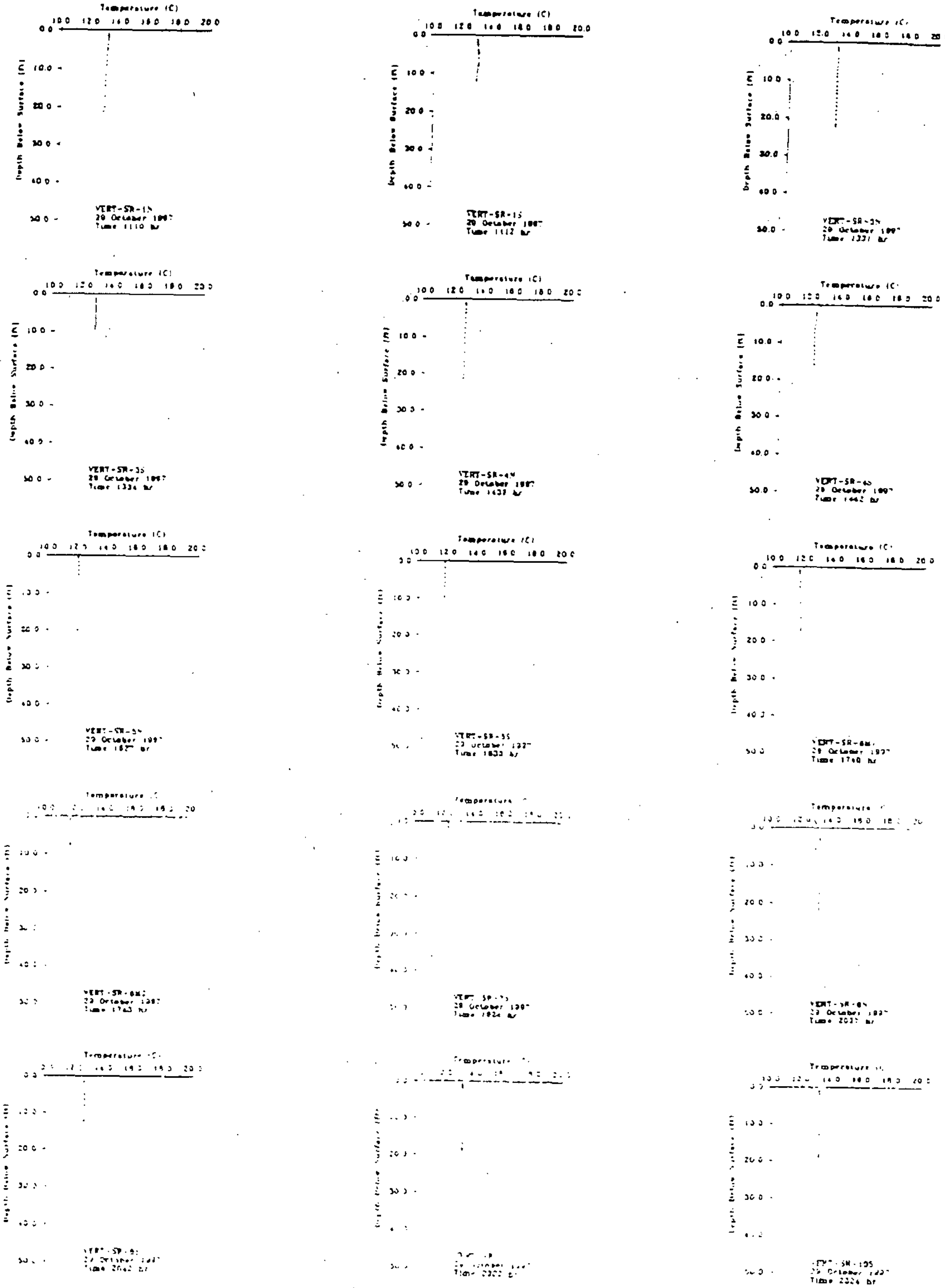

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Figure 11-169
PSE&G 1-Unit Survey: 29 October 1997
Vertical Salinity Profiles
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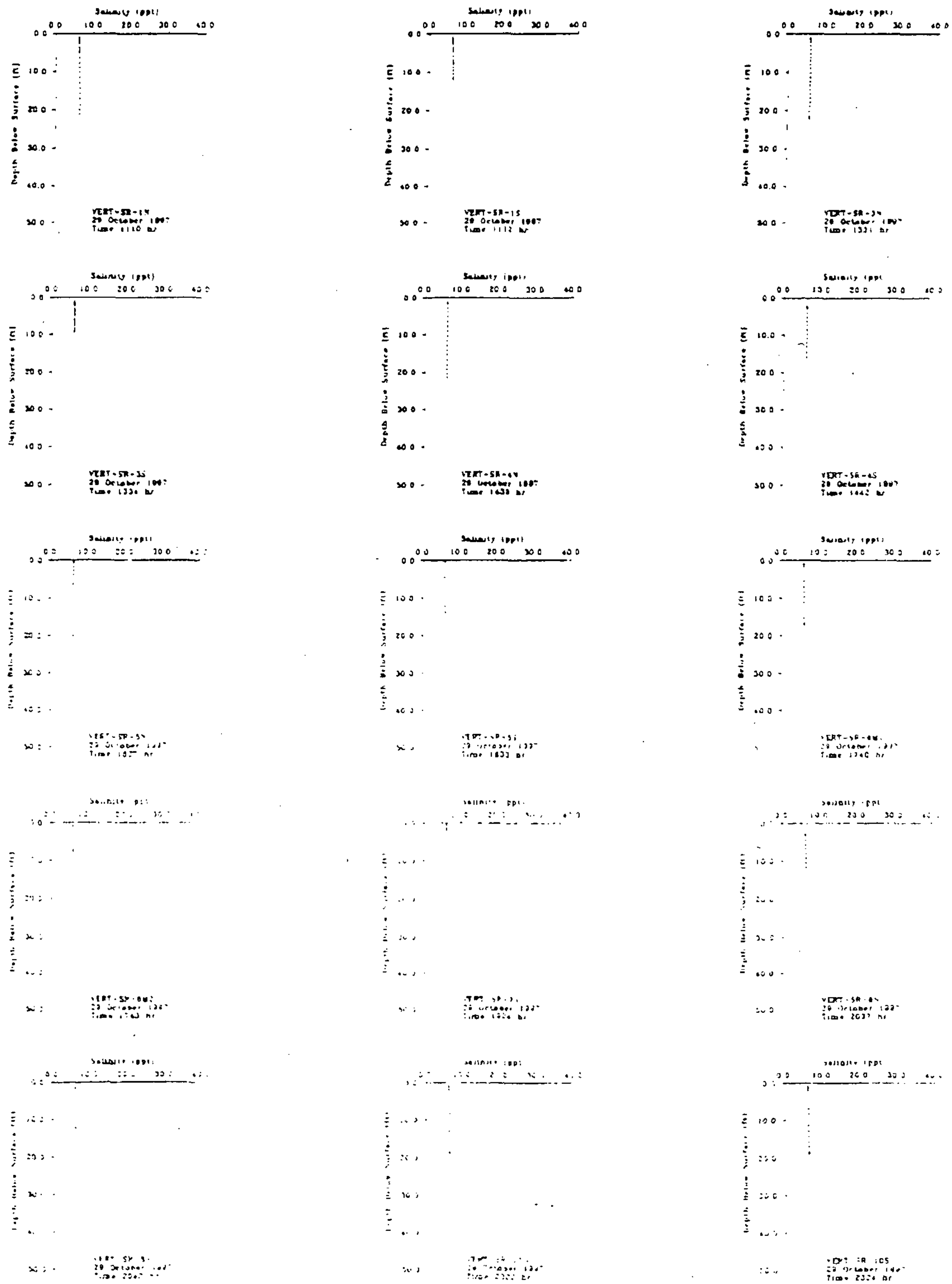

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Figure 11-170

PSE&G 1-Unit Survey: 29 October 1997
Vertical Temperature Profiles
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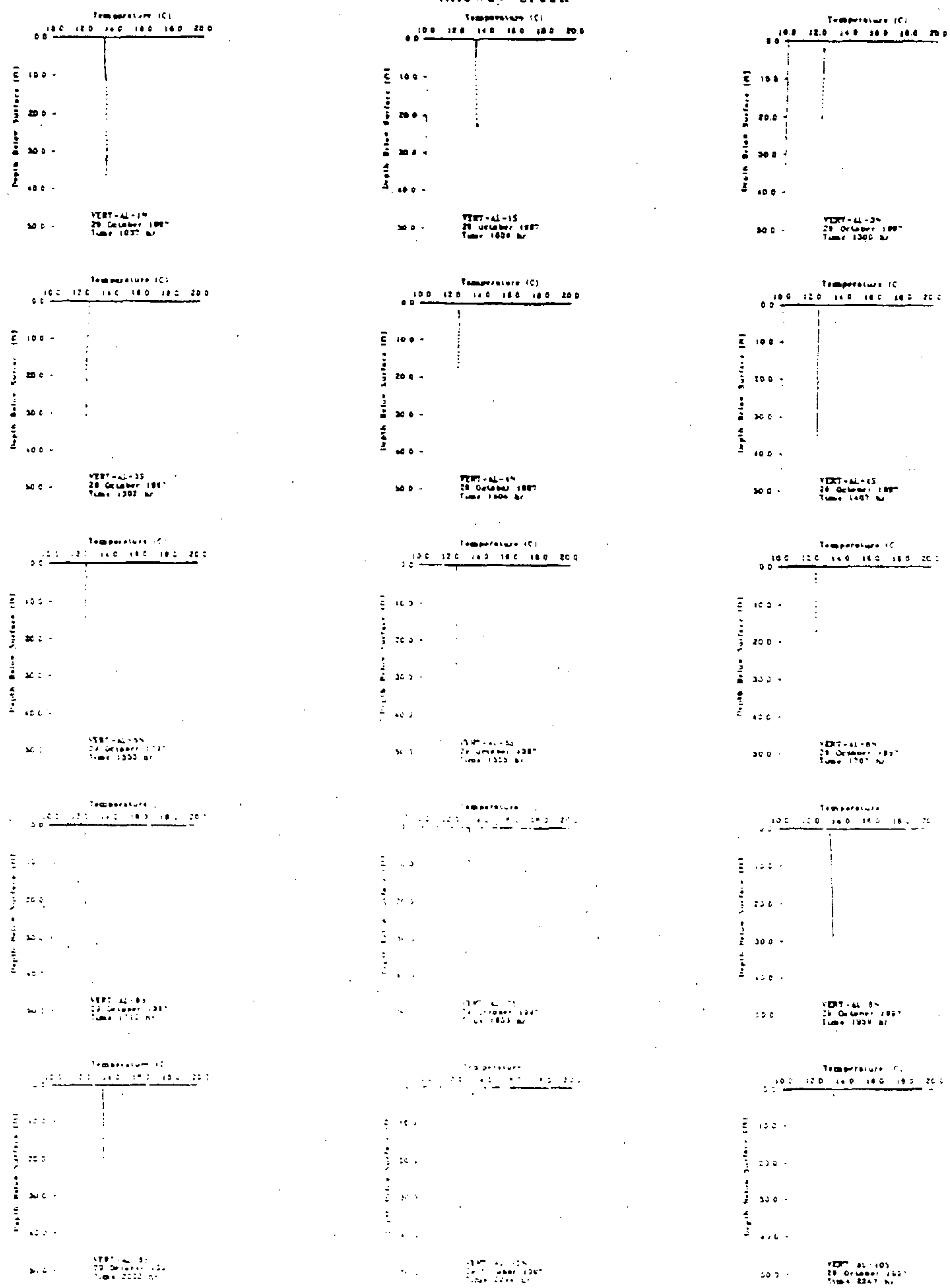

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PSE&G 1-Unit Survey: 29 October 1997
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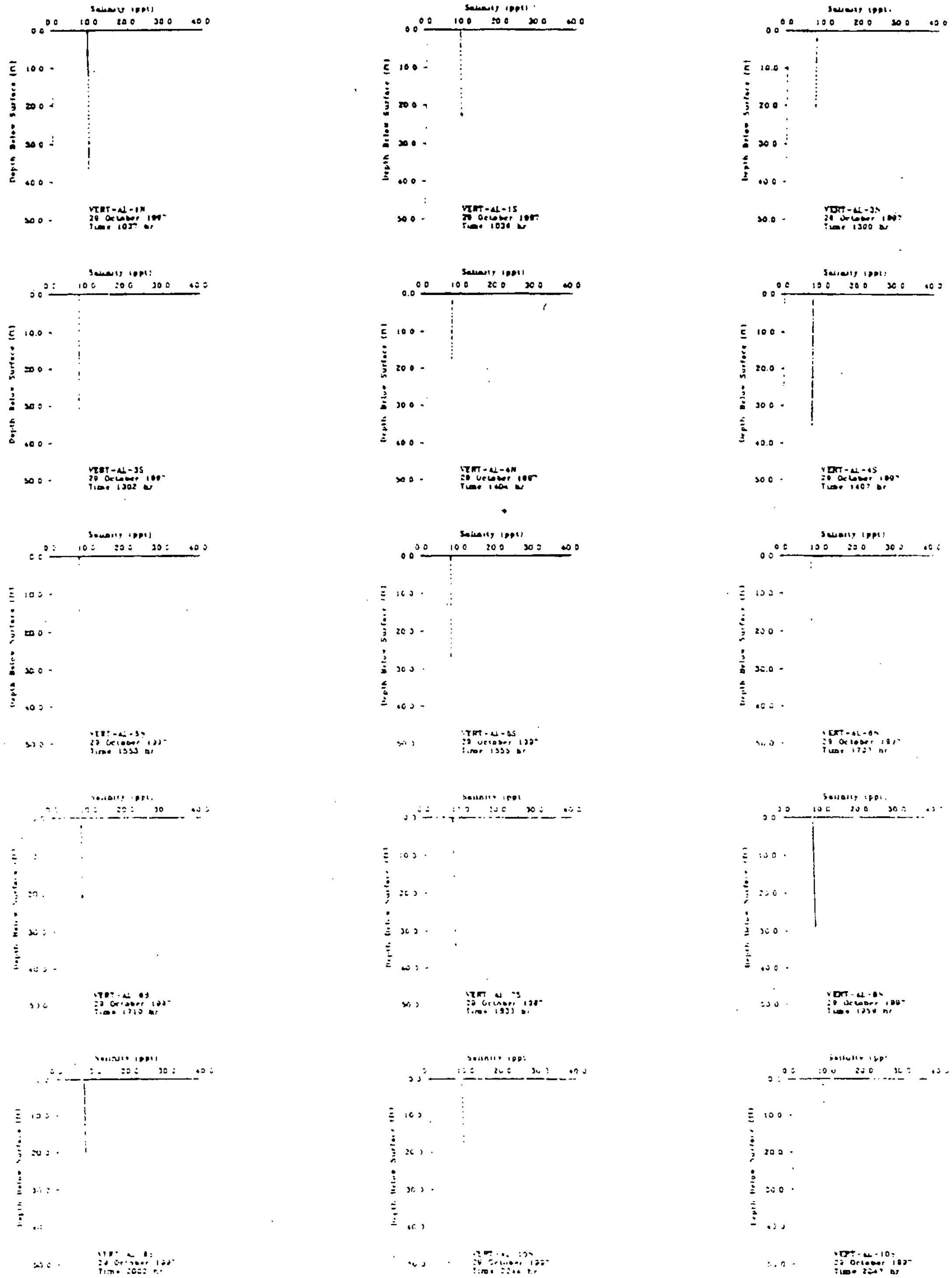

Figure 11-172
PSE&G 1-Unit Survey: 29 October 1997
Vertical Temperature Profiles
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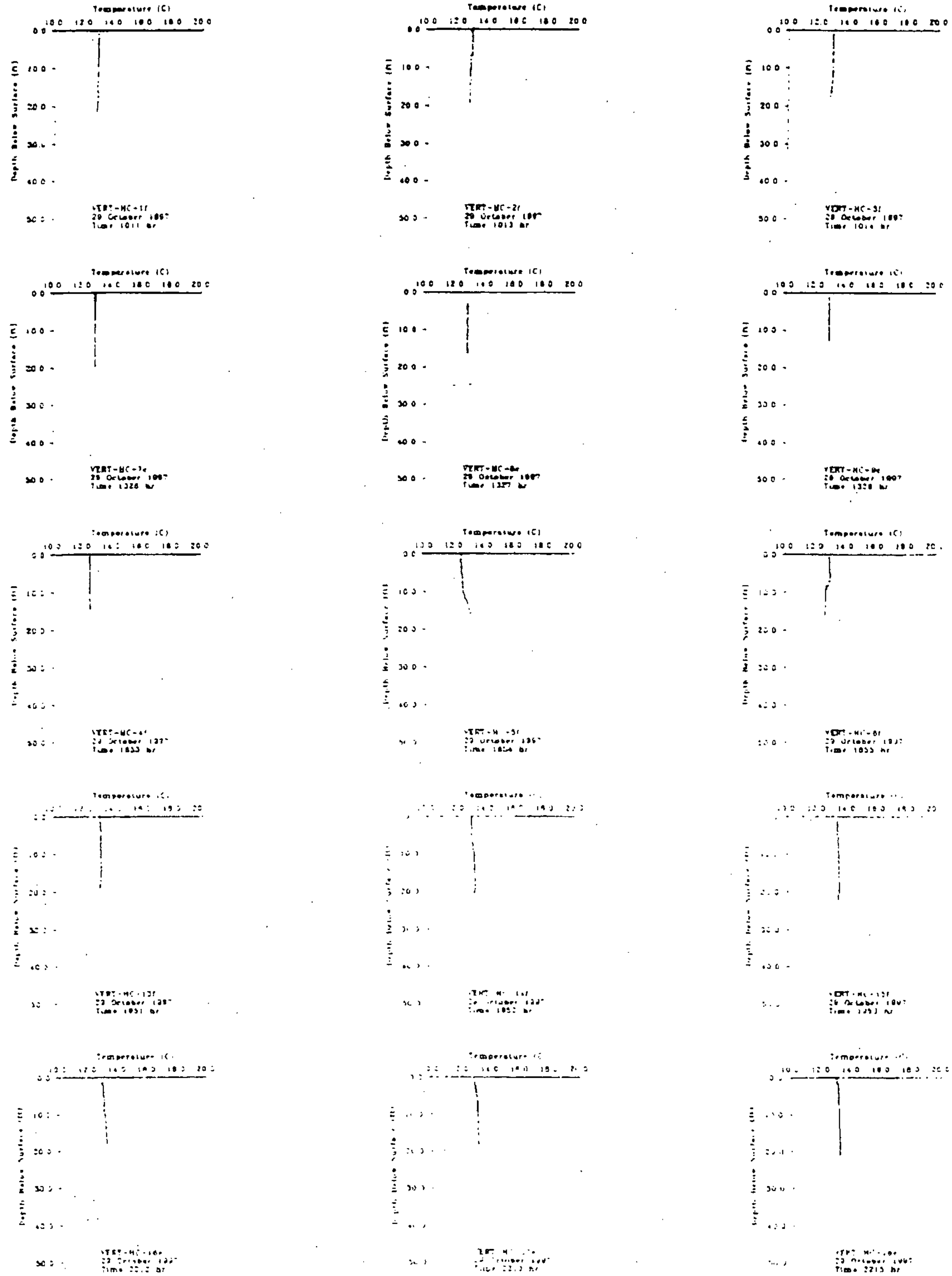

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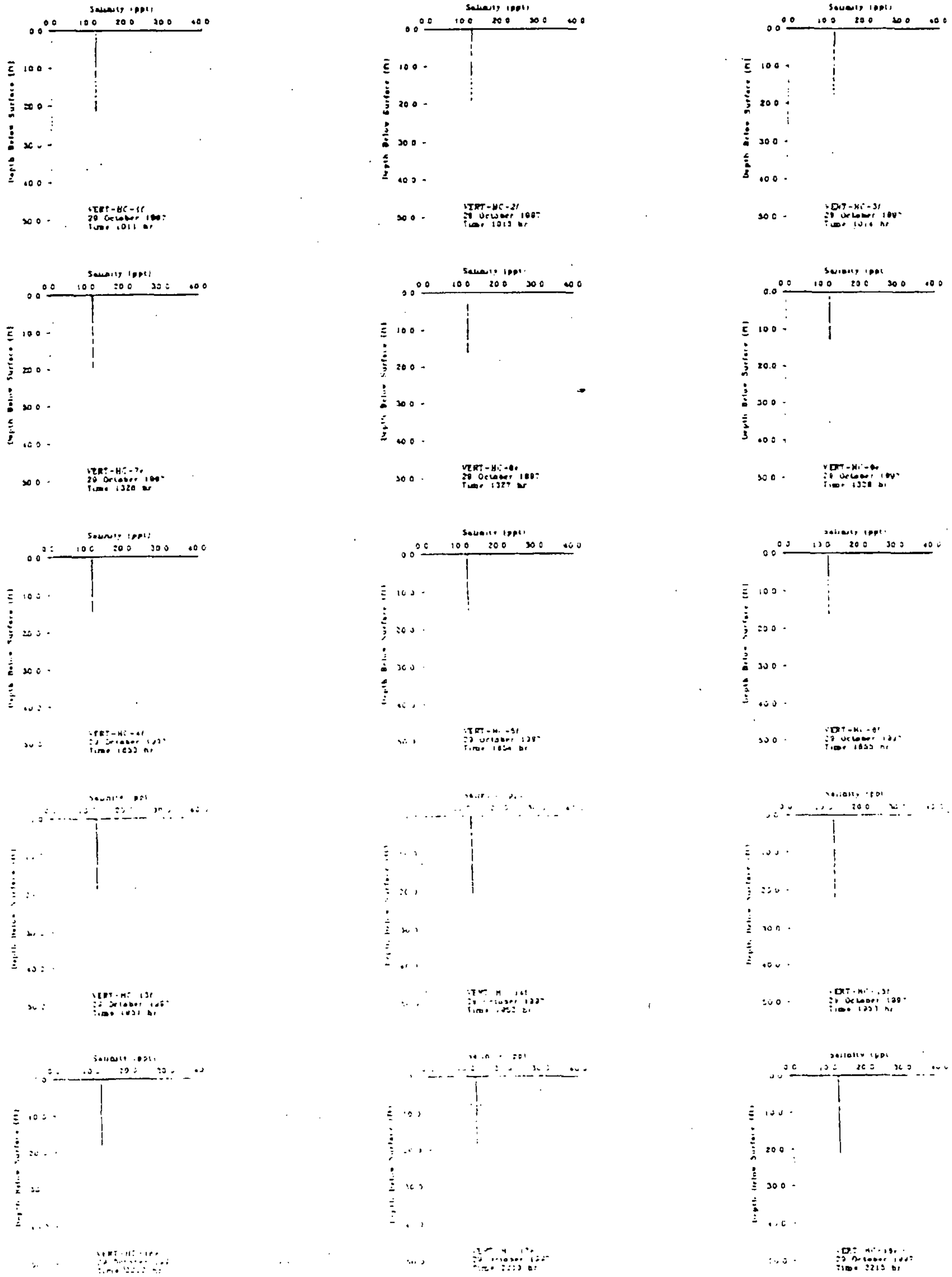
PSE&G 1-Unit Survey: 29 October 1997
Vertical Salinity Profiles
Hope Creek



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PSE&G 1-Unit Survey: 29 October 1997
Vertical Temperature Profiles
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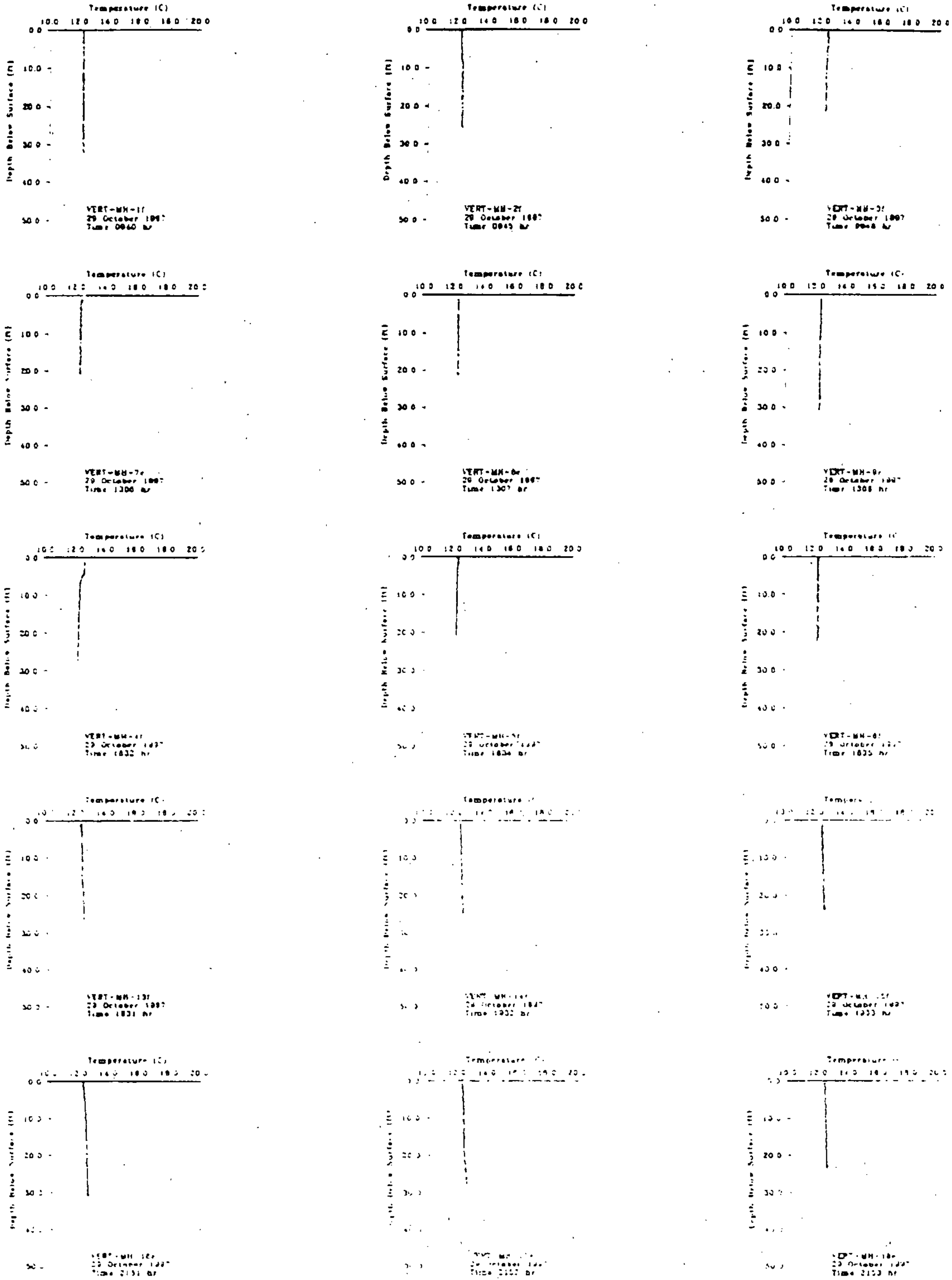

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PSE&G 1-Unit Survey: 29 October 1997
Vertical Salinity Profiles
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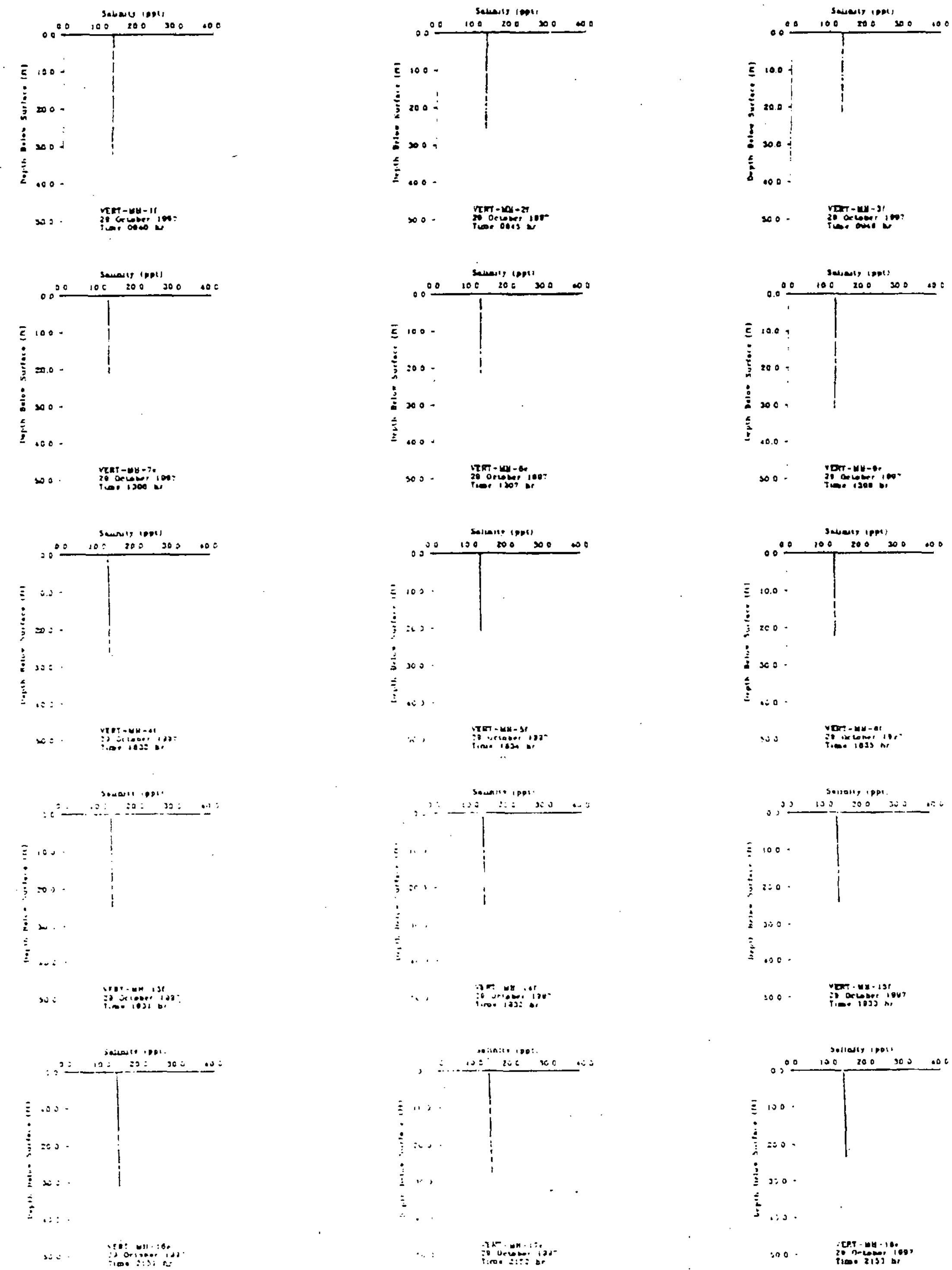

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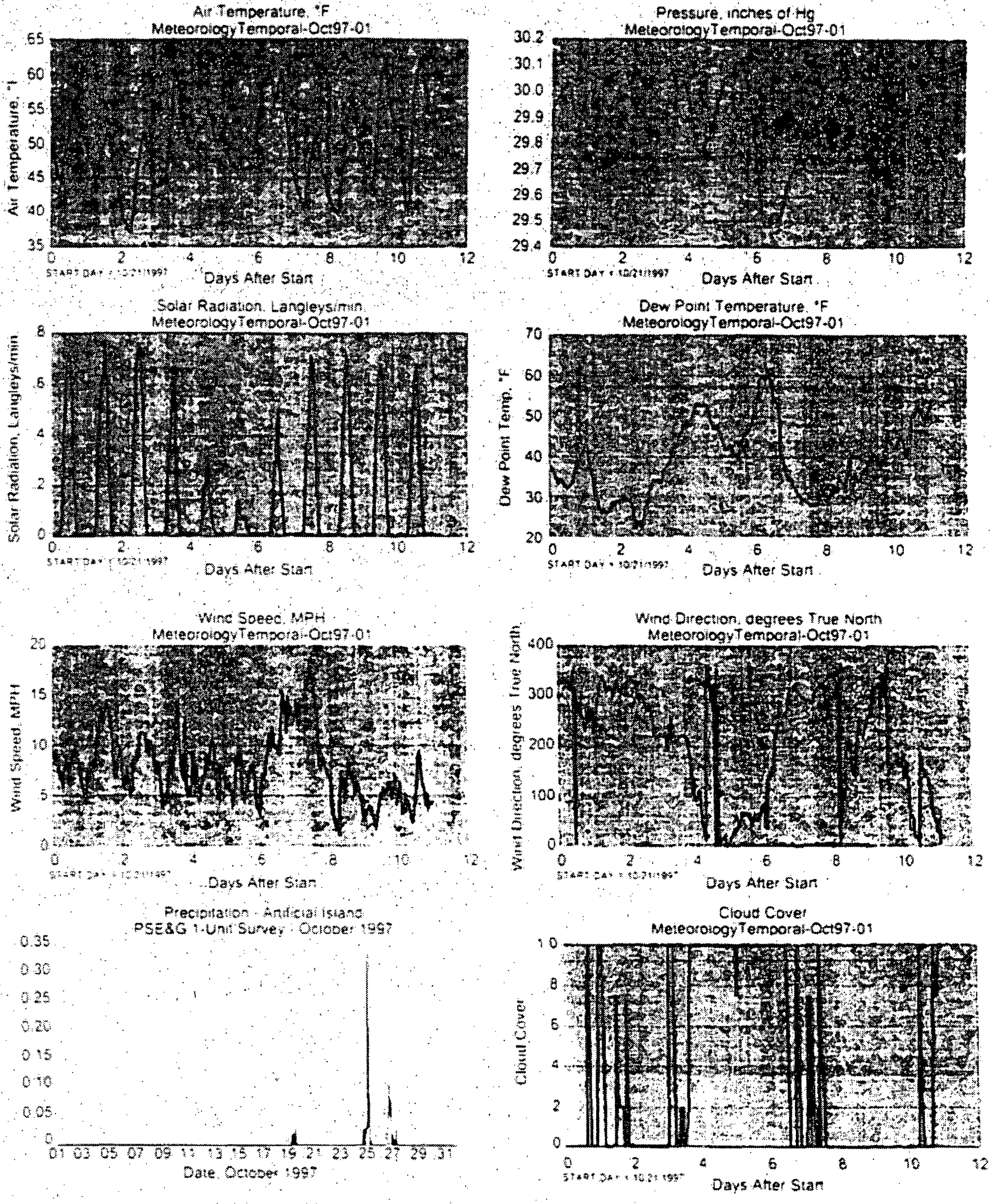
Meteorological Data Collected During 1-Unit Survey



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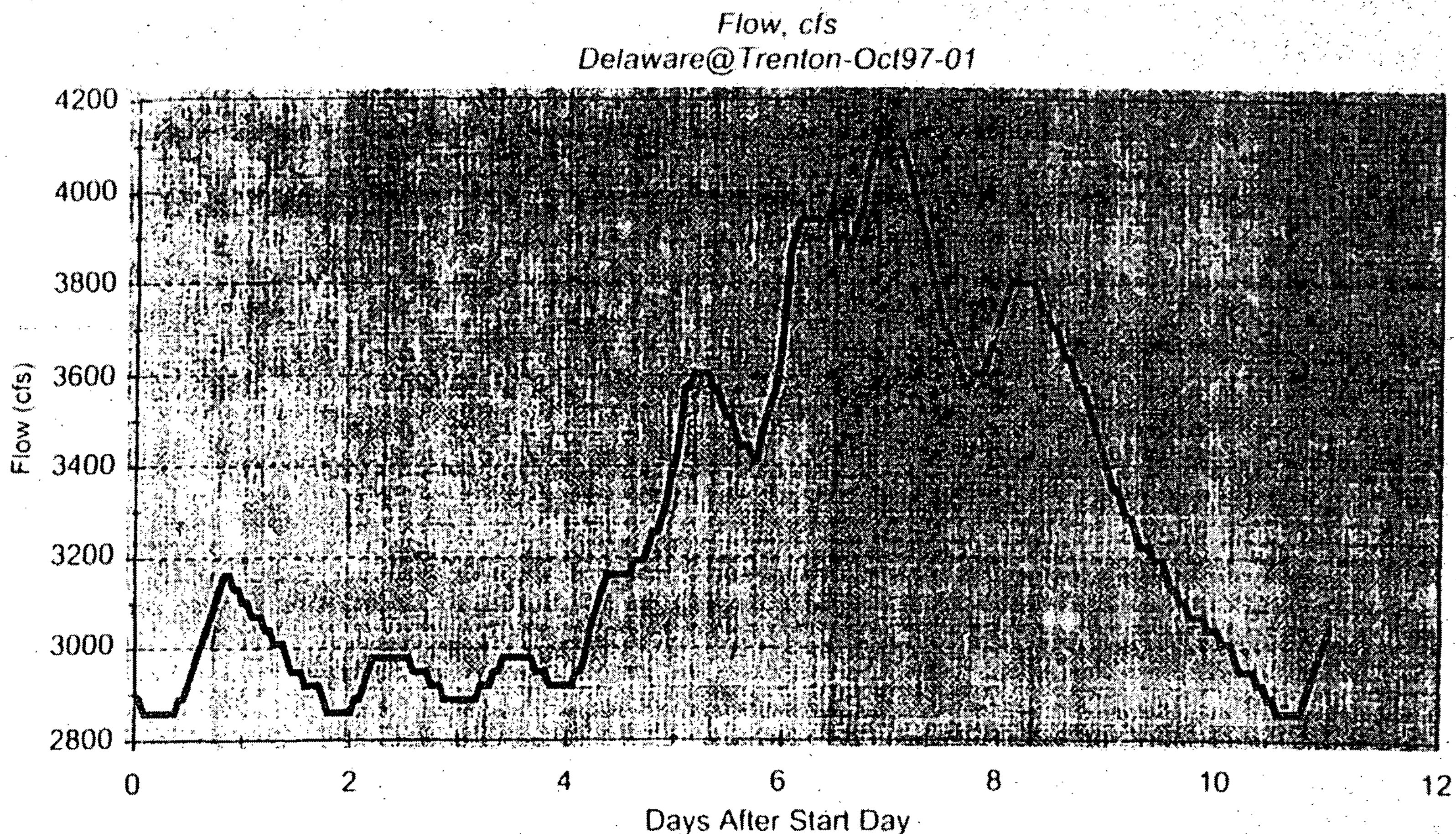
Delaware River Flow Data Collected by USGS During 1-Unit Survey



Start Day = 10/21/1997

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APPENDIX E
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1998 ANNUAL MONITORING REPORT

SPONSOR: DR. ERIC E. ADAMS
PSE&G RENEWAL APPLICATION
SALEM GENERATING STATION
PERMIT NO. NJ0005622
4 MARCH 1999

EXHIBIT E-1-3
1998 ANNUAL MONITORING REPORT
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CHAPTER 10
1998 ANNUAL MONITORING REPORT

I. THERMAL MONITORING, 2-UNIT SURVEY

I.A. 2-Unit Intensive Survey

I.A.1. Objectives

As part of the renewal of the New Jersey Pollutant Discharge Elimination System (NJPDES) permit, thermal surveys were conducted by Lawler, Matusky & Skelly Engineers LLP (LMS) for Public Service Electric & Gas Company (PSE&G) to obtain data for the renewal of the New Jersey Department of Environmental Protection (NJPDES) Permit for the Salem Generating Station (the Station). The work plan for this survey was described in the Technical Basis Document for the Modified Thermal Monitoring Program (Modified TMP) that was submitted by PSE&G to NJDEP (PSE&G 1998a). The survey primarily consisted of intensive sampling of the river during May and early June 1998, when both power-generating units were operating. The intensive survey was supplemented by mooring station monitoring that extended the temperature data collection through early November. The May through early June period is referred to as the intensive survey, whereas the May through November period is referred to as the six-month moorings for thermal monitoring. The objective of the 2-Unit survey was to obtain data on the Delaware River at a time when the plant was operating at full capacity.

This intensive survey utilized moored instruments and mobile boats to cover the study area.

The components of the 2-Unit intensive survey are:
- Longitudinal survey
- Tidal boundary survey
- Tide gauges
- Dye dilution
- Mooring stations
- Fixed-station Acoustic Doppler Current Profilers (ADCPs)
- Mobile survey of river
- Mobile survey of marsh mouths
- Infrared aerial photographs

In addition, data on meteorology and hydrology collected by other organizations are also included in this chapter. This first section (2-Unit Intensive Survey) of the chapter has two remaining subsections. The first subsection (Section I.A.2) describes the methods and materials employed to collect the data for the 2-Unit intensive survey, and the second section (Section I.A.3) presents the data. The second section (Six-month Moorings for

Thermal Monitoring) also includes two sections that describe the methods and materials and the results.

I.A.2. Methods and Materials

This section begins with a brief description of the survey components to provide an overview of the types of sampling and measurements performed. The quality control and quality assurance steps taken to validate the accuracy of the scientific equipment used then summarized. A description of each survey component in terms of the measurement techniques, sampling locations, and duration and frequency of measurements comprises the remaining subsections of Section I.A.2.

I.A.2.a. Overview of Survey Components

The 2-Unit survey covered the Delaware River from Trenton, New Jersey, to the mouth of Delaware Bay at Cape May, New Jersey. Measurements were concentrated on the reach that extends six miles upstream and downstream of the Station (Figure 10-1). The overall sampling scheme consisted of monitoring instruments deployed at selected locations to record data during, as well as before and after, a period when other measurements were taken by crews using boats. A timeline of the survey components is shown in Figure 10-2. The major elements of the 2-Unit survey are:

Longitudinal Survey - Vertical profiles of conductivity (salinity) and temperature were measured at 17 river stations spaced at 5- to 10-mile intervals along the navigational channel between River Miles (RM) 0 and 130 using two boats. [River miles are based on referencing by the Delaware River Basin Commission (DRBC).] Six of the 17 stations also had lateral sampling points on the left and right side of the shipping channel. The three longitudinal surveys were performed on 21 and 27 May and 2 June 1998.

Tidal Boundary Survey - Vertical profiles of conductivity and temperature were measured using one boat at three locations spaced along the mouth of the bay during a flood tidal phase on 22 May 1998.

Tide Gauges - Water surface elevations were measured at four locations between 19 May and 4 June 1998 to supplement tidal data collected by others.

Mooring Stations - Meters were deployed at three depths each for 31 mooring locations to measure temperature at all locations, and conductivity (salinity) and dissolved oxygen (DO) at selected locations, between 19 May and 4 June 1998.

Fixed-Station ADCP - Current velocities throughout the total water depth were continuously measured at one location near the discharge between 19 May and 3 June 1998.

Dye Injection - A fluorescent dye was injected into the Station discharge from 27 to 29 May 1998 to track its mixing and transport in the Delaware River.

Mobile - Five survey boats occupying river transects concurrently measured temperature, salinity, and dye concentration on 29 May 1998; transects at the mouths of two tributaries were sampled on 30 May and 29 June 1998.

Infrared Aerial Photographs - Thermal images of surface water temperature in the vicinity of the Station discharge pipe were taken on 29 May 1998.

Collectively, these survey components provide synoptic data of distribution of temperature at the water surface and over the depth of the river. In total, the survey data provide the basis for calibrating nearfield and farfield models of the Delaware River near the Station.

I.A.2.b. Quality Assurance/Quality Control (QA/QC)

The accuracy and precision of the data collected during the 2-Unit survey were ensured through the development and implementation of a QA/QC Plan. The plan described the procedures to be followed during several stages of the survey: equipment calibration/validation, field application (measurements), documentation, and data handling. All scientific instrumentation for measuring temperature, conductivity/salinity, DO, depth/pressure, velocity, dye concentration, and boat position had a certain manufacturer-specified accuracy. The survey equipment (by manufacturer and model) used during the 2-Unit survey is summarized in Table 10-1. In addition, the equipment was tested independently as part of the survey to confirm that the accuracy of the equipment to be used on this survey was within a margin of error that could be tolerated without compromising the intended use of the data. The accuracy tolerance level set for the pre-survey testing of the equipment will be referred to hereafter as the calibration/validation accuracy.

Temperature. The equipment used to measure water temperature in the river along with the manufacturer's specified accuracy and calibration/validation accuracy was:

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER'S SPECIFIED ACCURACY (°C)	CALIBRATION/VALIDATION ACCURACY (°C)
Mobile	Thermistors (TTM)	± 0.003	± 0.05
Mobile	CTD[1]	± 0.01	± 0.05
Moorings	Thermistors	± 0.20	± 0.2
Moorings	CT[2]	± 0.15	± 0.2
Moorings	CT/DO[3]	± 0.15	± 0.2

NOTES: Manufacturers are listed in Table 10-1.
[1]CTD is an instrument that measures and records conductivity (salinity), temperature, and depth.
[2]CT is an instrument that measures and records conductivity (salinity) and temperature.
[3]CT/DO is an instrument that measures and records conductivity (salinity), temperature, and DO.

The equipment used in the mobile and longitudinal survey components responds faster to changes in temperature and therefore has greater accuracy than equipment used on the moorings. These technologically advanced instruments provide refined measurements on board boats passing through regions of varying temperature. The fast-response Thermistor Temperature Modules (TTM) have the highest accuracy of all the survey equipment. Temperature measurements taken by the five boats during a two hour duration were compiled and plotted to provide a "snapshot" of the Station's thermal plume. Water baths with accuracies of ±0.2°C and ±0.05°C were used to test the moored equipment and more ±0.2°C and ±0.05°C accurate mobile equipment, respectively. The protocol for calibration/validation of the temperature equipment is described in Appendix A. Briefly, the moored thermistors and CT and CT/DO meters were tested prior to the survey and then re-tested after the survey. The temperatures measured by the meter/thermistor and a National Institute of Standards and Testing (NIST)-certified thermometer in four different temperature baths (0.0, 25.0, 30.0, and 37.0°C) were recorded. Thermistors/meters that did not read within 0.2°C of the certified thermometer during the pre-survey test were used only if the reading could be appropriately corrected. For example, a known difference between the meter and the certified thermometer can be used to adjust or correct the temperature readings. The procedure used for correcting temperature readings is described in Section I.A.3.b.

All CTD instruments used in the mobile survey were tested prior to and after the survey at Falmouth Scientific Inc. (FSI) laboratory in Cataumet, Massachusetts. The test of all shipboard temperature instruments at a single laboratory assured interequipment comparability and consistency of the compiled mobile survey data (see Appendix A for further details).

Conductivity/Salinity. Conductivity, which is a surrogate measure of salinity, was measured using CT, CTD, and CT/DO meters. Five standard solutions, having prescribed conductivities that cover the expected range of salinity in the study area, were used to test the meters used during the 2-Unit survey. The protocol for calibration/validation of the conductivity/salinity meters is described in Appendix B along with the equations for converting conductivity to salinity. The manufacturer's specified accuracy and calibration/validation tolerances for salinity are summarized below for the three types of meters used.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER=S SPECIFIED ACCURACY (salinity, ppt)	CALIBRATION/VALIDATION ACCURACY (salinity, ppt)
Mobile	CTD	±0.01	1.0
Moorings	CT	±0.1	1.0
Moorings	CT/DO	±0.1	1.0

NOTE: Manufacturers are listed in Table 10-1.

Dissolved Oxygen. The CT/DO equipment used on the moorings was initially calibrated by the manufacturer. These meters were also calibrated at LMS' laboratory prior to and after the 2-Unit survey using the saturated air chamber calibration procedure (see Appendix C). A second calibration procedure, which uses oxygen-saturated water, was performed prior to the survey. The pre-survey calibration entailed adjusting the instrument to attain the saturation concentration before reading, if necessary. The instrument reading during the post-survey calibration was recorded and compared to the saturation concentration before readjusting the instrument, if necessary.

The following table presents both the manufacturer's specified accuracy and the calibration/ validation accuracy for all DO equipment used.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER□S SPECIFIED ACCURACY (mg/l)	CALIBRATION/VALIDATION ACCURACY (mg/l)
Moorings	CT/DO	±0.2	±0.4

NOTE: Manufacturer is listed in Table 10-1.

Depth/Pressure. All depth/pressure instrumentation was initially calibrated by the manufacturer. Each tide gauge was further tested in the field by placing it at a water depth (at the tide gauge station) that was measured using a rigid steel tape measure. The density of the overlying water was estimated and the unit weight was calculated as density times unit weight of fresh water (62.4 lb/ft^3). The pressure reading of the meter was converted to excess pressure (i.e., above atmospheric pressure) by subtracting an assumed constant atmospheric pressure of 14.7 psi.

$$D = \frac{P_e}{UW} K$$

where:

D	=	depth (ft)
P_e	=	excess pressure (lb/in.^{2})
UW	=	unit weight of water (lb/ft^3)
K	=	conversion factor (144 in.^{2}/ft^2)

The depth (based on the meter pressure reading) was compared to the distance measurement. All comparisons were checked in relation to the calibration/validation tolerance stated below.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER□S SPECIFIED ACCURACY (m)	CALIBRATION/VALIDATION ACCURACY (m)
Tide gauges	Tide gauges	±0.05	±0.2

NOTE: Manufacturer is listed in Table 10-1.

Velocity. Velocity instrumentation consisted of Acoustic Doppler Current Profilers (ADCPs), a technology for measuring the current velocity at various depth intervals within the water column (see Appendix E for more information). All velocity instrumentation was initially calibrated by the manufacturer, which was assumed sufficient because ADCPs do not typically drift more than the specified accuracy.

The bottom-mounted ADCP compass was calibrated according to the manufacturer's recommended procedure, thereby ensuring accurate direction readings. This calibration was performed at the Delaware City Marina on 11 May 1998 prior to deployment.

Under normal operation, the manufacturer's specified accuracy is assumed to be attained. If the instrument is not operating normally, erratic readings are displayed or recorded. The following table presents the velocity equipment manufacturer's specified accuracy.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER□S SPECIFIED ACCURACY (FPS)
Mobile	ADCP	± 0.04 to 0.07
Moorings	ADCP	± 0.04 to 0.07

NOTE: The accuracies of ±0.04 and 0.07 fps were calculated according to the manufacturer's (RD Instruments) formula at velocities of 0 and 12.3 fps, respectively.

Mobile velocity instrumentation was tested with real-time display prior to the survey. The protocol for monitoring the equipment's performance is described in Appendix E.

Dye Injection and Sampling. The rate of dye injection was measured based on electronic scales and fluorometers (as described in Section I.A.2.c). The scales were calibrated by the manufacturer and then calibrated at Salem on 18 May 1998 to assure interequipment calibration/validation. The calibration protocol for the electronic scales is presented in Attachment F. The fluorometers were calibrated on site using the protocol described in Appendix G.

Prior to the discharge of the fluorescent dye (Rhodamine WT) through the Station's discharge pipe, the background fluorescence of the Delaware River, attributable primarily to algae, was measured. The mean background fluorescence was used to adjust measurements of dye taken after the injection of dye into the Station discharge as described in Appendix G.

The following table presents the dye sampling equipment manufacturer's specified accuracy for both the electronic scales and fluorometers.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER□S SPECIFIED ACCURACY
Dye Study	Scale	50 g
Dye Study	Fluorometers	2%

NOTE: Manufacturers are listed in Table 10-1.

The accuracy of the electronic scales can be expressed in terms of their function in measuring the mass rate of dye injection. The rate at which dye was pumped from the drum on each electronic scale was approximately 8.75 kg/hr. If an hourly scale reading deviates by the manufacturer's accuracy, the accuracy of the hourly mass rate is approximately 0.5% (or 100 x 50/8,750).

The accuracy of the fluorometer measurements of dye concentration was assured through on-site calibration of the fluorometers used at the plant and on the boats. The accuracy of the dye concentration measurement is dependent on: (1) the accuracy of measuring volumes of dye solution and dilution water used to produce the "known" dye concentrations; (2) variability in the fluorometers' reading of a single sample (interfluorometer variability); and (3) method precision or "instrument drift"; and (4) background fluorescence variability.

Position and Time. Position and time data associated with deployment of fixed instruments (moorings, bottom-mounted ADCP) and shipboard measurements (mobile longitudinal surveys) were collected using a differential global positioning system (DGPS). The DGPS position and time accuracy is based on signals received from satellites and radio transmitters (O'Neill et al. 1996). Time is based on the satellite's atomic clock and thus is very accurate. The survey validation accuracy listed below is the accuracy of the time logged with each instrument measurement. The resulting locations are generally accurate to within 2 to 3 m. The manufacturer's specified absolute accuracy for DGPS is a range, e.g., 1 to 5 m (root mean square). As an assurance that any one of the DGPS systems was not malfunctioning a field test was performed. The protocol is presented in Appendix H.

The following table presents both the manufacturer's specified accuracy and the on-site validation accuracy for the DGPS equipment.

SURVEY COMPONENT	EQUIPMENT	MANUFACTURER=S SPECIFIED ACCURACY	SURVEY VALIDATION ACCURACY
Mobile, Longitudinal	DGPS	± 3 m	± 3 m
Mobile, Longitudinal	DGPS	<1 sec	1 sec

Field Application and Documentation. Site-specific characteristics were also considered to assure proper equipment installation. This included testing of sediment composition to determine appropriate bottom mooring installation (anchor deployment).

Field deployments were conducted according to a predefined procedure for each instrument. All appropriate data such as serial number, deployment position, date, time, etc., were recorded in field notes and retained as meta-data. Similar records were kept during equipment recovery to log appropriate data, including any anomalies noted during the recovery.

Data Handling and Inspection. Data collected by shipboard survey instruments (i.e., CTDs, thermistors, fluorometers, and ADCPs) were downloaded to the hard drives of laptop PCs in real time. Data collected by *in situ* instruments (i.e., mooring-attached meters, bottom-mounted ADCP, and tide gauges) were downloaded to laptop PCs immediately following retrieval of the instruments.

Raw data stored on the laptop hard drives were periodically copied to floppy diskettes. All raw data, stored on the laptops and the floppy diskettes (write-protected), were transferred to the data manager. The data manager compared the contents of the floppy diskettes with the files on the laptops to assure that the complete data set had been retrieved from the laptops.

Data logs were kept to record the detailed raw data origins and file locations. A separate data log was completed for each survey component. Upon completion of the data logs, all raw data were copied from the floppy diskettes to one tabletop PC, which was used to reduce and process the raw data. In addition, the entire set of data was backed up to magnetic tape. The floppy diskettes were then stored, with a copy of the data logs, in a se..re location at LMS' office.

I.A.2.c. Dye Injection

The overall purpose of the dye plume survey operations was to acquire data to assist in evaluation of the advective, dispersive, and mixing processes affecting the Station's thermal discharge to the Delaware River.

The dye plume survey operations involved two elements: (1) the land-side operations that control the injection of the dye and monitor dye concentrations in the cooling water system; and (2) the shipboard operations that monitor the movement and mixing of the dye in the receiving waters. The land-side element is described in this section; the shipboard dye measurements are described in Section I.A.2.d.

The land-side operations involved injecting the Rhodamine WT dye (20% solution) into the cooling water-system, controlling the rate of injection, and monitoring the dye concentrations within the cooling water system. Rhodamine WT dye, routinely used in this type of survey, is non-toxic at the concentrations used. The rate of dye injection was set so that the discharge dye concentration was below visible range, at approximately 7.5 ppb.

As shown in Figures 10-3 and 10-4, dye injection occurred in the Station pump house, with sampling in the condenser building (also referred to as the turbine building) (Figure 10-5). Each injection system injected dye at a fixed rate into the intake bell of one pump in each pump pair, as shown in Figure 10-3. An automated dye sampling system was assembled in each condenser building. This sampling system allowed confirmation of the planned injection dye concentrations, estimation of the flows from the pumps receiving the dye, and measurements of the fluorescence of the intake water before dye was injected (from the pump not receiving dye). When distinguished from background fluorescence, the intake water fluorescence provides a measure of cooling water recirculation.

The dye sampling system in the chlorine sampling building was used to measure the dye concentrations discharged to the river and the flows from the pumps not receiving dye. A mass balance of the two intake lines that merge (as shown in Figure 10-3) is solved to calculate the flow from Pump B based on the measured mass rate of dye injection and dye concentration at three sampling points.

Tests of the dye injection and discharge sampling systems were performed on 29 and 30 April and on 21 and 22 May 1998 to evaluate proposed system operations and, if necessary, to make modifications prior to the full-scale deployment. The equipment was deployed at one intake and discharge location for brief test periods; it functioned properly.

Dye Injection Systems at Salem Pump House. Dye injection pumps, dye reservoirs, digital scales, and computerized recording and control systems were deployed in the

Salem pump house. The injection system was set up to inject dye at a fixed rate into the intake bell of one pump in each pump pair, as shown in Figure 10-4.

Salem's Circulating Water System consists of two units, each with six intake pumps and six sets of condensers. One dye reservoir, digital scale, and computerized recording and control system were set up at each unit. In addition, at each unit, three injection pumps, three check-valve-pressurized rubber hoses, and three 35-ft PVC injection tubes were deployed. A general schematic of the dye injection system for one representative unit is shown in Figure 10-4.

Dye injection setup entailed the placement of a 32-gal drum of Intracid Rhodamine WT Dye (i.e., dye reservoir) on an electronic platform scale. A small pump was placed in the dye reservoir to keep the dye well mixed, thus ensuring a uniform dye concentration. A chemical metering pump was used to pump dye in an exactly measured amount from the 32-gal reservoir, through ¼-in. polyethylene tubing, through a check valve and into a ½-in.-diameter pressurized rubber hose holding carrier water for initial mixing. The hose was connected to a ½-in.-diameter 35-ft-long PVC injection tube. The injection tube conveyed the dye solution to the intake bell of one pump, via the opening provided by an adjacent floor drain. The rubber hose was pressurized with house water to provide initial mixing of the concentrated dye and sufficient pressure to distribute the dye solution properly into the pump's intake bell. [The maximum flow of house or carrier water was approximately 15 gpm, which is less than 0.003% of the CWS flow that received this dye and carrier-water mixture.] Hence, the carrier water did not alter significantly the CWS flow and total discharge to the river. The extensive turbulence at the pump's intake assured complete mixing of the dye/cooling water mixture. A laptop computer recorded date, time, and remaining weight in the reservoir. The dye injection system was fully automated, except for the periodic refilling of the dye reservoir. This refilling was accomplished by LMS personnel using portable 120VAC dye transfer pumps.

Dye Sampling System in Each Condenser Building. An automated water sampling system, fluorometer, and computerized data recording system were set up in each condenser building (Figure 10-5). Water was periodically drawn from the pump side of each condenser (through six valve locations in each condenser building, for a total of 12 valves). The locations where the circulating water was sampled through the 12 valves near the condensers and the dye injection points at the intake pumps are shown schematically in Figure 10-6. The specific valve identification numbers accessed for Units 1 and 2 were as follows:

VALVE I.D.	ASSOCIATED CONDENSER
23CW19	23A
23CW119	23B
22CW19	22A
22CW119	22B
21CW19	21A
21CW119	21B
13CW19	13A
13CW119	13B
12CW19	12A
12CW119	12B
11CW19	11A
11CW119	11B

The automated sampling system was set to direct water from each pipe through the fluorometer. The computerized data recording equipment was set up to record the fluorometer readings.

The water drawn from the condensers was wasted to the floor drains in the condenser buildings, at a maximum flow rate of approximately 5 gpm.

The fluorometers used to measure dye in each condenser building were calibrated by preparing mixtures of known amounts of Rhodamine WT dye and cooling water as described in Appendix G.

Dye Sampling in the Chlorine Sampling Building. Grab samples were collected manually at the chlorine sampling point of each of the six discharge pipes (Figure 10-3). A sample was taken every 10 minutes, so that each of the six discharge pipes was sampled every hour during the dye injection.

During the test of the dye injection and discharge sampling systems, the turbidity of the circulating water withdrawn at the plant intake was found to be elevated at times. As elevated turbidity could interfere with fluorometer measurements, a series of fluorometer calibrations with circulating water having different levels of turbidity was performed. These fluorometer calibrations were used to quantify the reduction in fluorescence attributable to turbidity, as described in Section I.A.3.d.

I.A.2.d. Mobile Survey

Five survey boats were navigated along transects in the Delaware River; the planned transects are shown in Figure 10-7. Boat number 3 measured the thermal plume in the region surrounding the discharge; this is referred to as the "rover boat". The five boats covered regions that span specific distances (upstream of the station is positive) from the Salem discharge:

Boat Number 1	+2.5 to +6 miles
Boat Number 2	0 to +2.5 miles
Boat Number 3	+1 to −1 miles
Boat Number 4	0 to -3.5 miles
Boat Number 5	-3.5 to −6 miles

Each boat was equipped with a differential global positioning system (DGPS), a fluorometer, a conductivity/temperature/depth profiler (CTD), and a personal computer (PC) to record the data; three of the boats were also equipped with an Acoustic Doppler Current Profiler (ADCP). The configuration of the measurement equipment and the power supplies is shown schematically in Figure 10-8. An ADCP measures and records a profile of water currents at discrete vertical intervals between the surface and the bottom using underwater acoustic technology. A CTD, when lowered and raised to and from the bottom, measures and records the water conductivity, temperature, and depth of the instrument at frequent intervals; salinity is computed from the observed conductivity and temperature using a standard formula (Appendix B). A fluorometer measures the fluorescence, which is related to dye concentration, of river water withdrawn through a hose and passed through the instrument. The DGPS makes use of radio positioning information transmitted by U.S. Department of Defense satellites and by U.S. Coast Guard radio beacons to geographically position the receiver, typically to within 2 to 3 m. DGPS positions are updated roughly every 2 sec.

The general two-step sampling procedure entailed: (1) temperature, conductivity (salinity), and dye fluorescence measurements at a depth of 1 to 2 ft (near water surface) as the boat traveled along the transects; and (2) vertical profiles of temperature, salinity, and fluorescence at a number of locations. Three boats (Boats 1, 2, and 3) were also equipped with fast-response Thermistor Temperature Modules (TTM). All boats measured temperature as the boats were underway along the transect. The TTM equipment allowed more frequent measurements (compared to the CTD), particularly in the vicinity of the discharge, where higher spatial temperature gradients were expected. The CTD was lowered at vertical profiling stations from all five boats, and recorded data from the water surface to the bottom.

Fluorometers were used to measure dye fluorescence and thereby track the plant discharge as it mixes with the river. The fluorometers on three boats (Boats 1, 2, and 3) operated in a flow-through mode by withdrawing river water through a 3/4-in.-diameter hose using an onboard pump. The travel time of the water in the hose is computed subsequently using the pump flow rate and hose dimensions to adjust the time of fluorometer measurement to the time when the water was withdrawn into the hose. *In situ* fluorometers on Boats 4 and 5 measured the fluorescence of the river water passing through the instrument which was submerged aside the boats. All fluorometer readings were then adjusted to reference temperature and used to compute dye concentration as described in Appendix G. Background fluorescence in the Delaware River was measured on 26 May 1998 (namely, the day before the dye injection started) in the vicinity of the Salem discharge. The background fluorescence boat traversed the river between approximately RM 58 and RM 45 as shown in Figure 10-9 and fluorometer readings, temperature, and salinity near the water surface were measured and recorded. Vertical profiles were also measured and recorded at 10 locations.

I.A.2.e. Mooring Stations

Thirty-one (31) stations in the river and at the mouths of three tributaries were equipped with moorings as shown in Figure 10-10. The constituents measured at these stations varied as follows:

Temperature, conductivity, and DO	-	five moorings (same as ambient and 1-Unit survey stations).
Temperature and conductivity	-	nine moorings
Temperature only	-	17 moorings

The specific sensors for temperature and/or conductivity/DO deployed at surface, mid-depth, and bottom positions for each mooring station are listed in Table 10-2.

The moorings, which were configured as shown in Figure 10-11, were deployed between 7 and 15 May 1998 and recovered generally after 4 June 1998.

I.A.2.f. Tides and Currents

Tide gauges were installed by LMS at four stations along the Delaware River:
- Lewes
- Woodland Beach (near Ship John Shoal)
- Salem Barge Slip
- Western C&D Canal

In addition, NOAA has continuously recording tide gauges at four locations - Cape May, Lewes, Reedy Point, and Philadelphia. The CTD meter deployed by LMS at Lewes obtained salinity data, whereas NOAA was not obtaining conductivity/temperature data during the 2-Unit survey period. USGS has a continuously recording tide gauge at

Burlington, New Jersey (RM 121), and these data are also presented subsequently in Section I.A.3.j. The locations of the nine tide gauging stations are shown in Figure 10-12. The pressure recorded by LMS's meters was converted to excess pressure by subtracting the atmospheric pressure using the barometric pressure data from Wilmington Airport.

An ADCP was deployed by divers at the station shown in Figure 10-13 on 11 May 1998. The ADCP was retrieved on 3 June 1998. The three stations occupied for the tidal boundary survey component are shown on Figure 10-14.

I.A.2.g. Longitudinal Surveys

The hydrothermal models of the Delaware River require data on initial conditions. The initial conditions for the survey period were measured on 21 May 1998, using two boats. Conductivity (salinity) and temperature were measured throughout the water column at 17 locations along the navigation channel from the Delaware River mouth to Trenton. The river mile locations, which are based on DRBC's referencings, are: 0, 10, 20, 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, 100, 110, 120, and 130 (Figure 10-15). Lateral stations on the left and right sides of the navigational channel were monitored at six river miles: 40, 50, 70, 90, 110, and 130. CTD units made by Falmouth Scientific, Inc. (FSI), were used on both boats. One boat covered from the river mouth to a station between RM 40 and RM 60, and the other boat covered the remaining extent to RM 130.

Longitudinal surveys were also performed on 27 May 1998, which was two days prior to the mobile survey, and on 2 June 1998, which was three days following the mobile survey. The third longitudinal survey (2 June) also entailed continuous measurements of the surface water temperature along the navigational channel. An additional boat was used for this survey. The third boat covered the river between RM 35 and RM 70, such that the first and second boats covered the remainder of their previous extents. The three boats measured temperature while traveling along the channel between stations.

I.A.2.h. Marsh Mouth

Three tributaries of the Delaware River (i.e., Mad Horse Creek, Hope Creek, and Alloway Creek) were also monitored during the 2-Unit survey (Figure 10-16). Hope and Mad Horse Creeks were surveyed on 30 May 1998; however, an engine problem with one of the survey boats precluded monitoring of Alloway Creek on this day. The survey of Alloway Creek was rescheduled along with a second survey of Hope Creek to provide measurements for addressing the temporal variation between the first and second marsh surveys. The survey of Alloway Creek and the second survey of Hope Creek were performed on 29 June 1998, when the predicted times and amplitudes of high and low waters were similar to those on 30 May 1998.

I.A.2.i. Infrared Aerial Photography

Infrared aerial images of the Delaware River were acquired at four tidal phases on the day of the mobile river survey, 29 May 1998. The area covered by the photography was approximately 1,000 meters square, with a spatial resolution of 3 meters (Figure 10-17). The single-band thermal images show relative temperature at the water surface.

I.A.2.j. Data Collected by Others

NOAA, USGS, and PSE&G were also contacted to obtain data they collected concurrently with the 2-Unit survey. The freshwater flow of the Delaware River at Trenton, New Jersey (USGS Gauge No. 01463500), and the Schuylkill River at Philadelphia (USGS Gauge No. 01474500), are used to specify freshwater flow input data for the model. Data on air temperature, barometric pressure, cloud cover, wind speed and direction, and precipitation from the PSE&G Artificial Island meteorological station and dew point temperature from Wilmington Airport are also used for modeling.

I.A.3. RESULTS

I.A.3.a. Overview of Data

The data recorded during the 2-Unit intensive survey were downloaded and compiled in a computerized database (Paradox Version 8). The quantity and quality of the data collected within each survey component were compared to the requirements of the modified TMP. The objectives of the data collection were reviewed in instances when the recoverable data were less than the planned data collection. Certain data to be collected at some moorings were not recovered primarily because instruments were lost or displaced. In addition, certain instruments stopped logging data prior to the intensive mobile survey. However, data collected by these instruments that stopped logging were found to be useful for calibrating the model because the period of the simulation overlapped with the period of recovered data. Additional field surveys were performed to obtain certain missing data. For example, as explained in Section I.A.2.h, the marsh survey plan was modified because of an engine problem on one of the two boats. A second marsh survey was performed to obtain data on Alloway Creek, which was incompletely sampled during the first survey and to obtain additional data on Hope Creek.

The total number of data records, defined as single time of measurement of one or more constituents (e.g., temperature), collected during the 2-Unit survey was 1,271,823 (Table 10-3). This tabulation provides a means of showing the relative distribution of measurements during the intensive survey and a comparison of the 2-Unit survey to the ambient and 1-Unit surveys (PSE&G 1986b) and the six-month mooring monitoring (Section I.B.3.b).

I.A.3.b. Quality Assurance/Quality Control (QA/QC)

The results of the testing of meters as described in Section I.A.2.b are summarized.

Temperature - Temperature meters used on moorings were initially tested prior to deployment in the river. Sixty-eight (68) of the 79 meters tested (namely, 86%) were within the 0.2°C tolerance of the water bath temperature measured using a certified thermometer (Table 10-4). The other 11 meters showed maximum deviations at any of the four temperatures tested that ranged from ±0.2°C to ±1.69°C, as shown Table 10-5. The expected (certified) temperature (T) was regressed against the meter temperature (T_{meas}), and the resulting regression equations are shown in Table 10-6. The correlation for all regressions was high, as reflected by the r^2 values that exceeded 0.997. These regressions were used to adjust the temperature recorded by each of the 11 nonconforming meters, so that the data presented in this report have been corrected according to the QA/QC plan.

The moored temperature instruments were also tested following the 2-Unit survey, except for seven instruments that were downloaded, redeployed, and then never recovered. The temperatures for the 11 meters for which regressions were developed were adjusted (by applying the regression equations in Table 10-6) and then compared to the standard. The results of the post-survey testing of 72 temperature meters are summarized in Table 10-7. Fifty-six (56) of the 72 meters (78%) were within the 0.2°C tolerance at all temperatures tested. The other 16 meters showed maximum deviation at any temperature that ranged from ±0.2°C to ±1.2°C. The nine shipboard instruments used during the mobile and longitudinal surveys were tested before and after the 2-Unit survey. The pre- and post-survey calibrations were done by testing the meters alongside an FSI standard electronic thermometer and a selected thermistor (Meter 1388). The pre-survey tests, which were performed at temperatures of 15, 22, and 30°C, resulted in all three thermistors and five CTD meters being within the 0.05°C tolerance of the FSI standard and all CTD meters and two thermistors being within the same tolerance of Meter 1388 (Table 10-8). The post-survey test, which was performed at the same three temperatures and at up to two additional temperatures (0 and 7.5°C), found all instruments except one thermistor within the specified 0.02°C tolerance of both the FSI standard and Meter 1388. A constant temperature adjustment equivalent to the average of the pre- and post-survey differences for Meter 1386 was considered reasonable. The one thermistor (Meter 1386) that exceeded the tolerance limit had post-survey measurements that were between 0.12°C and 0.14°C lower than the Falmouth standard and Meter 1388. The temperature measurements recorded with Meter 1386 were adjusted by adding 0.07°C (a constant) to all survey data. The adjusted temperature data collected with Meter 1386 are therefore stated to be within 0.07°C of the actual river temperature. Meter 1386 was used on mobile survey Boat 2, which covered the river between the Station discharge and approximately 2.5 miles upstream of it. This thermistor was also used to measure the surface water temperature during the second longitudinal survey. Because seven of the eight (88%) shipboard thermistors passed pre- and post-survey calibrations and the one thermistor (Meter 1386) that "drifted" out of tolerance prior to the post-survey testing needed a relatively minor adjustment, the overall water surface temperature data recorded by shipboard thermistors are considered to be accurate for the hydrothermal assessment.

Salinity/Conductivity - A combined total of 30 CT and CTD meters, which were used at moorings, were calibrated for conductivity/salinity measurements as described in Section I.A.2.b. These meters were retrieved after the 2-Unit survey and tested for accuracy within the tolerance level of 1.0 ppt. According to the post-survey testing, 28 of the 30 meters (93%) were within the 1.0-ppt tolerance of the "known" salinity at all tested salinities (Table 10-9). The CT meter at M12 surface had a maximum difference of 1.44 ppt at a salinity of 15.62 ppt, and the CT meter at 6 surface had a maximum difference of 1.93 ppt at a salinity of 25.88 ppt. No adjustment to the conductivity/salinity data was made because the tolerances were exceeded at only one or two of the five salinities tested, and these salinities were generally greater than the salinity of the river water at the designated mooring as measured by shipboard CT meters.

Dissolved Oxygen - As stated in Section I.A.2.b, the CT/DO meters deployed at 10 moorings were calibrated prior to the survey to attain an accurate measurement of the DO saturation concentration. Therefore, pre-survey testing results in no difference between the meter reading and the known DO concentration. The meters were returned to LMS's laboratory after the survey, and tested using the saturated air method. Only one of the 10 (10%) CT/DO meters was within the specified DO tolerance of 0.4 mg/l (Table10-10). Five of the meters were found to measure DO within 1.0 mg/l of the saturated air concentration. Another three meters were between 1.0 and 1.7 mg/l of the saturated DO concentration. The CT/DO meter at the bottom of mooring 1 showed a DO that was 8.6 mg/l greater than the saturated air concentration. As the difference in DO at saturation may not be indicative of the differences, if any, at the river DO levels which are generally below saturation, no adjustment to the data recorded was made. The "drifting" of DO meters during a two-week period is fairly common because the probe membrane gets fouled. To overcome these difficulties, DO measurements were repeated at three mooring locations - Mad Horse Creek (surface), 21 (surface and mid-depth), and 9M (surface and mid-depth) - during September and early October 1998.

Depth/Pressure - The four water depth/pressure sensor devices used to record water levels at LMS's four tide-gauging stations were initially tested by the Coastal Leasing of Cambridge, Massachusetts. The maximum difference in depth was found to be within 0.2 m (0.6 ft) of the actual depth. In addition, the MicroTide meters deployed at the Salem Barge Slip and Woodland Beach stations and the MicroCTDs deployed at the western C&D canal and Lewes stations were tested in the field, as described in Section I.A.2.b. The results are summarized below:

	DEPTH (ft)		
STATION	STEEL TAPE	INSTRUMENT	DIFFERENCE
Salem Barge	4.13	4.29	0.16
	2.04	2.15	0.11
Woodland Beach	5.31	5.34	0.03
Western C&D	2.94	2.79	-0.15
Lewes	5.14	5.13	-0.01

All depth measurement instruments used at tide gauging stations were found through field testing to be within the 0.2-m (0.6-ft) tolerance limit.

The calibration/validation testing results for the equipment used to measure temperature, salinity/conductivity, DO, and depth/pressure are summarized in Table 10-11.

Velocity - As stated in Section I.A.2.b, the bottom ADCP was calibrated for compass direction prior to deployment. The ADCP units used on boats were tested in the river prior to the mobile survey to check that the real-time display of velocities were as expected for the tidal phase. The bottom ADCP data were initially downloaded approximately 30 min after deployment to check the data. All data viewed on the boat ADCP units and downloaded from the bottom ADCP unit appeared to be reasonable. Subsequently, bottom ADCP data were downloaded during the deployment period and found to be reasonable.

Dye Injection - The electronic scales for the dye injected into the Salem discharge were calibrated by Advance Balance Service Co. on 8 May 1998. All seven fluorometers were calibrated on 20 May 1998; the results of the regression analysis are presented in Appendix G.

Position and Time - Positioning instruments were field-validated according to the procedures outlined in Appendix H of the QA/QC plan. Each boat was positioned adjacent to a piling at the Delaware City Marina and the DGPS-displayed coordinates were recorded.

All data-logging computer clocks were synchronized with the atomic time-scale operated by the National Institute of Standards and Technology (NIST) just prior to the survey. Using a direct modem connection to one of the time servers operated by NIST, and the "NISTIMEW" program, the computer clocks were automatically synchronized with the NIST time standard. The accuracy of this time setting is plus or minus one second.

I.A.3.c. Longitudinal Surveys

The data collected during the longitudinal surveys are presented graphically in a series of figures that show the station location and time of measurements. The vertical profiles of temperature and salinity at 17 stations along the channel of the river and lateral positions at six river miles (40, 50, 70, 90, 110, and 130) for the first longitudinal survey (21 May 1998) are shown in the following figures:

TEMPERATURE	SALINITY
10-18	10-21
10-19	10-22
10-20	10-23

The vertical profiles of temperature and salinity for the second longitudinal survey performed on 27 May 1998 are presented in figures:

TEMPERATURE	SALINITY
10-24	10-27
10-25	10-28
10-26	10-29

The results of the third longitudinal survey (2 June 1998) are similarly presented in these figures:

TEMPERATURE	SALINITY
10-30	10-33
10-31	10-34
10-32	10-35

The raw data representing surface temperature of the river measured during longitudinal survey 3 is shown in Figure 10-36.

I.A.3.d. Dye Concentrations in Plant Discharge

The dye concentration of the plant flow was measured (as described in Section I.A.2.c) in both the condenser/turbine building and in the chlorine sampling building. The range of the correlation coefficient (r^2), a statistical measurement commonly employed to quantify the linear relationship between two variables (in this case fluorescence and dye concentration), was from 0.99436 to 0.99999 for the regressions ($r^2 = 1$ represents a "perfect" fit). Calibration data and regression results are presented in Appendix G. Raw fluorescence units (RFU) measured using fluorometers were found to be affected by the turbidity of the intake water. Seven (7) fluorometer calibrations were performed using seven samples of intake water that ranged from 20 to 215 nephelometric turbidity units (NTU). The dye fluorescence readings were lower than the prepared dye concentration because of turbidity interference (i.e., particulates blocking fluorescence from reaching the sensor). The percent reduction in RFU was related to turbidity through the following linear regression analysis (Figure 10-37):

$$\% \text{ Reduction} = 0.1271 \cdot \text{Turbidity} \qquad (r^2 = 0.979;\ n = 8)$$

where

turbidity is in units of NTU

The dye concentration, therefore, was corrected for turbidity. Samples of the circulating water and the combined circulating and service water were collected at 0.5-hr intervals and analyzed for turbidity at the chlorine sampling building. The dye concentration based on RFU readings (C_r) was adjusted for turbidity by the percent reduction (%R) attributable to turbidity in computing the adjusted dye concentration (C_a):

$$C_a = \frac{C_r}{(1 - \%R)}$$

The fluorometer and turbidity measurements at the six discharge pipes (i.e., discharge pipes) are presented first to show the dye concentration of the Station discharge. The RFU and dye concentrations of the circulating water as measured in the condenser/turbine building are presented subsequently to show the recirculation of water from the discharge to the intake.

The RFU, turbidity, and dye concentration (with and without the turbidity adjustment) in the six discharge pipes (identified in the NJPDES permit as Discharge Serial Numbers [DSN], shown in Figure 10-6) measured at the chlorine sampling point are shown for the period when dye was injected into the CWS in the following figures:

DISCHARGE PIPE	DSN	FIGURE
11	481	10-38
12	482	10-39
13	483	10-40
21	484	10-41
22	485	10-42
23	486	10-43

Surges in turbidity appear to occur after EOF along with reductions in RFU readings due to turbidity. The adjusted dye concentration, labeled as "dye (w/turb)," at the discharge pipes was approximately 7.5 ppb during the injection period which started at 1200 hrs on 27 May and ended shortly after 1200 hrs on 29 May.

The fluorometer readings and dye concentrations with and without the adjustment for turbidity are shown for the 12 circulation water intake pipes to the condensers (see Figure 10-6) in the following figures:

CONDENSER WATER BOX No.	FIGURE No.	CONDENSER WATER BOX No.	FIGURE No.
11A	10-44	11B	10-45
12A	10-46	12B	10-47
13B	10-48	13A	10-49
21A	10-50	21B	10-51
22A	10-52	22B	10-53
23B	10-54	23A	10-55

As stated previously, the six condenser pipes on the left side of the list above received the dye injection, whereas the six condenser pipes on the right side received intake water that was not directly injected with dye. The intervals when no data are plotted for condenser pipes 11A, 11B, 12A, 12B, 13A, and 13B were caused by detritus in the river that clogged the intake manifolds of the sampling device. When this occurred the manifolds were cleared manually and the sampling measurements resumed.

The recirculation of water from the discharge pipes to the circulating water intakes is evident in the gradually increasing dye concentration of the six condenser pipes on the right side of the above list. A recirculation ratio (R) is defined as the dye concentration of the plant intake (C_i) divided by the dye concentration of the plant discharge (C_d). For example a recirculation ratio of 0.1 is equivalent to stating that the dye concentration measured at the intake is 10% of the concurrently measured dye concentration at the discharge pipes.

The average of the data for the six intake pipes and six discharge pipes during 1-hr increments were used to compute the hourly average recirculation ratio (Figure 10-56). Recirculation varied with tidal phase: the dye was relatively concentrated at the intake during slack phases and relatively dilute during the flood and ebb phases. A 12-hr running average recirculation ratio shows the cumulative increase in the dye concentration of the intake relative to the fairly constant discharge dye concentration.

I.A.3.e. Mobile Survey Results

The measurements taken during the mobile survey of the Delaware River on 29 May are presented as surface temperature contour plots and as vertical profiles, as well as surface dye contour plots and vertical profiles. The surface temperature and surface dye plots for each of the four tidal phases cover the full 12-mile extent of the river, as well as a close-up of the vicinity of the Station discharge. The paths of the five boats that measured temperature and dye in the river during a 2-hr interval for each tidal phase are plotted. The sixteen figures showing surface temperatures or dye concentration are as follows:

		TEMPERATURE		DYE	
	TRANSECT LOCATIONS	FULL EXTENT	STATION PROXIMITY	FULL EXTENT	STATION PROXIMITY
Ebb	10-57	10-58	10-59	10-60	10-61
EOE	10-62	10-63	10-64	10-65	10-66
Flood	10-67	10-68	10-69	10-70	10-71
EOF	10-72	10-73	10-74	10-75	10-76

The temperature and dye concentrations measured by each boat were compared in two ways to assure data consistency. First, intraboat comparisons of the measurements along horizontal transects to vertical profile measurements taken within close proximity and the same tidal phase were made. Second, interboat comparisons of measurements along horizontal transects and vertical profiles by a boat to measurements along horizontal transects and vertical profiles by an adjacent boat within close proximity and the same tidal phase were made. The intra- and interboat comparisons for Boat 3 showed inconsistent dye concentrations measured along horizontal transects; however, the vertical profile measurements of dye concentrations were consistent with data collected by Boats 2 and 4. This inconsistency for Boat 3 indicates that the sampling hose for horizontal transects contained dye that was desorbed by the water passing through it. Dye concentration measurements along horizontal transects covered by Boat 3 were removed from the data compiled for contour plotting. This is the reason for the blank areas where dye data are missing in Figures 10-60, 10-61, 10-65, and 10-66.

The vertical profiles of temperature, salinity, and dye concentration have been made into figures for each tidal phase: one figure showing location of vertical profile stations, two showing temperature profiles, two showing salinity profiles, and two showing dye profiles of representative stations. The 28 figure numbers are:

	STATION LOCATIONS	TEMPERATURES		SALINITY		DYE	
Ebb	10-77	10-78	10-79	10-80	10-81	10-82	10-83
EOE	10-84	10-85	10-86	10-87	10-88	10-89	10-90
Flood	10-91	10-92	10-93	10-94	10-95	10-96	10-97
EOF	10-98	10-99	10-100	10-101	10-102	10-103	10-104

I.A.3.f. Mooring Stations

As stated in Section I.A.2.e, instruments deployed on 31 moorings set in the river and at the mouths of tributaries (as shown in Figure 10-10) were retrieved. The data collected are presented as two types of plots: vertical profiles, and temporal plots.

The vertical profiles of temperature, salinity, and DO are presented as sets of eight figures for each tidal phase: three figures each of temperature and salinity profiles and two figures of DO profiles. The 2-hr tidal phase intervals defined for the mobile survey data presentations are used for the vertical profile plots of the mooring station data. The locations of the moorings are shown in Figure 10-10. The figure numbers showing results for the measured parameters are:

	TEMPERATURE			SALINITY			DO	
Ebb	10-105	10-106	10-107	10-108	10-109	10-110	10-111	10-112
EOE	10-113	10-114	10-115	10-116	10-117	10-118	10-119	10-120
Flood	10-121	10-122	10-123	10-124	10-125	10-126	10-127	10-128
EOF	10-129	10-130	10-131	10-132	10-133	10-134	10-135	10-136

In the figures, the mean of each 2-hr interval is shown as a dot and the minimum and maximum values are shown as the ends of horizontal bars. The availability of salinity and DO data at any of the three depths can be checked by cross-referencing Table 10-2.

The figures showing the time series of temperature, salinity, and DO for all 31 mooring stations are listed on the following page.

FIGURE NUMBERS FOR PLOTS OF TEMPORAL VARIATIONS IN TEMPERATURE, SALINITY, AND DO SHOWN FOR ALL 31 MOORING STATIONS

MOORING STATION	TEMPERATURE	SALINITY	DO
1	10-137	10-138	10-139
2	10-140	10-141	
4	10-142	10-143	
5	10-144	10-145	
6	10-146	10-147	
7	10-148	10-149	
9	10-150	10-151	
10	10-152	10-153	
Alloway Creek	10-154	10-155	10-156
Hope Creek	10-157	10-158	10-159
Mad Horse Creek	10-160	10-161	
E	10-162	10-163	10-164
H	10-165	10-166	10-167
I	10-168		
K	10-169		
V	10-170		
L	10-171		
21	10-172		
22	10-173		
23	10-174		
24	10-175		
12G	10-176		
12R	10-177		
9G	10-178		
9M	10-179	10-180	
9R	10-181		
M9	10-182	10-183	
R9	10-184		
G12	10-185		
M12	10-186	10-187	
R12	10-188		

I.A.3.g. Tide and Current Data

Presentation of the results of the tidal boundary component, tide gauge, and the bottom-mounted ADCP current velocity measurements is discussed below.

Vertical profiles of temperature and salinity at the mouth of the river are presented for three stations along the model boundary transect. Plots of temperature and salinity at five time intervals during flood tide are shown in Figures 10-189 and 10-190, respectively.

The water surface elevations measured at four tide gauge stations installed for the 2-Unit survey were converted to the common datum (NAVD) by surveying from a vertical control benchmark. In addition, data recorded by NOAA at their four tidal gauging stations and data recorded by USGS at their tidal gauging station were also converted to NAVD and plotted. [Figure 10-12 shows the gauge locations.] The time series of water surface elevations between 19 May and 5 June 1998 at these eight stations are shown in Figures 10-191 and 10-192. The time series during the mobile survey of 29 May 1998 are shown in Figures 10-193 and 10-194.

The temperatures measured at four tide gauges - Salem Barge, Woodland Beach, Lewes, and western C&D canal - during the two-week period and on the day of the mobile survey are shown in Figures 10-195 and 10-196, respectively. During low tide, the tide gauge at Woodland Beach was temporarily exposed and consequently could not measure water depth as noted in Figures 10-191 and 10-193. The salinity at two of these stations, namely Lewes and western C&D canal, during the two-week period and on the day of the mobile survey is shown in Figures 10-197 and 10-198, respectively.

The average and minimum/maximum range in tide between high and low water are shown for the 17-day period in Figure 10-199 and the same tidal characteristics for the day of the intensive mobile survey, 29 May 1998, are shown similarly in Figure 10-200. The tidal time delay, or phase lag from the mouth upstream to Philadelphia, is shown.

The current speed and direction measured by the bottom-mounted ADCP during the 19 May to 4 June period and then averaged over three one-foot depth intervals are shown in Figure 10-201 and 10-202. The time increment for these measurements is 2.5 min. As stated in Section I.A.2.f, the velocity of the Delaware River was measured at three transects using ADCP instruments aboard boats. The longitudinal velocities (i.e., perpendicular to the river cross section) are shown in the contour plots for the four tidal phases on 29 May 1998:

TIDAL PHASE	FIGURE No.
Ebb	10-203
EOE	10-204
Flood	10-205
EOF	10-206

I.A.3.h. Marsh Mouth Data

The marsh survey began as planned on the morning of 30 May 1998. The surveys at Hope Creek and Mad Horse Creek were completed. However, halfway through the survey (i.e., after the flood tidal phase) at Alloway Creek, equipment failed and no data were collected during ebb tide. The survey of Alloway Creek was redone during similar tidal conditions on 29 June 1998. Hope Creek was also surveyed to observe any temporal variations between the earlier and later marsh surveys and thereby infer whether the complete Alloway Creek survey was similar to conditions on 30 May 1998. The temperature, salinity and dye data recorded during the marsh mouth survey are presented as vertical profiles. The nine figures for the marsh survey on 30 May 1998 are numbered as follows:

	TEMPERATURE	SALINITY	DYE
Alloway Creek	10-207	10-208	10-209
Hope Creek	10-210	10-211	10-212
Mad Horse Creek	10-213	10-214	10-215

The marsh survey on 29 June included only temperature and salinity measurements. The figures showing vertical profiles for the 29 June 1998 marsh survey are as follows:

	TEMPERATURE	SALINITY
Alloway Creek	10-216	10-217
Hope Creek	10-218	10-219

I.A.3.i. Infrared Aerial Photographs

Infrared aerial photographs taken during four tidal phases on 29 May 1998 are shown in the following figures:

TIDAL PHASE	FIGURE NO.
EOE	10-220
Flood	10-221
EOF	10-222
Ebb	10-223

I.A.3.j. Meteorological and Hydrological Data

The meteorological data collected by PSE&G at their Artificial Island station during the 2-Unit survey include:

Wind speed and direction
Air temperature
Barometric pressure
Cloud cover

In addition, dew point temperature data collected at Wilmington Airport by the National Weather Service are included. These data are shown graphically in Figure 10-224. Hourly precipitation data also collected at PSE&G's monitoring station show rainfall on these days, preceding and during the survey period, as follows:

DAY IN 1998	RAINFALL (in.)
May	
1	0.54
3	0.42
4	0.08
6	0.08
7	0.04
8	3.63
9	1.54
10	0.96
11	1.33
12	2.83
29	0.08
June	
1	1.79
2	0.13
3	0.08

The USGS-gauged flow in the Delaware River at Trenton increased to a peak of approximately 70,000 cfs on 11 May 1998 and then decreased to approximately 10,000 cfs during the 2-Unit survey period (Figure 10-225). The USGS-gauged flow in the Schuylkill River at Philadelphia is also shown in this figure.

I.B. Six Month Moorings for Thermal Monitoring

I.B.1. Objectives

The 2-Unit survey continued from June through early November 1998, primarily to collect additional temperature data during seasonally varying conditions. Both power-generating units at Salem were operating throughout the six-month monitoring period except between 26 July and 8 August 1998, when Unit 2 was not operating. Moorings equipped with thermistors were deployed at 10 stations in the Delaware River and at the mouths of two tributaries. The work plan for this monitoring was described in the Modified TMP (1998).

In addition, DO and salinity were measured at three mooring stations from 3 September through 8 October 1998 to collect data under temperature conditions higher than those of the intensive survey.

I.B.2. Methods and Materials

The methods and materials for the six-month monitoring were generally similar to those for the 2-Unit survey. The following sections reference the previously described methods and focus on any procedures that were initiated for the extended monitoring.

I.B.2.a. Quality Assurance/Quality Control (QA/QC)

Based on the experience of the 2-Unit intensive survey, additional steps were taken to assure the completeness, accuracy, and precision of the continued monitoring. First, one temperature meter and one backup meter (all Onset thermistors) were deployed at each sensor depth (surface, mid-depth, and bottom). Second, the temperature meters were retrieved periodically and tested after retrieval, as described in Section I.A.2.b. Pre-deployment testing was also performed. Third, CT/DO meters (YSI 6000 series) were tested approximately every two weeks by sampling river water adjacent to each meter and analyzing the DO by Winkler titration in addition to pre- and post-deployment testing, as described below.

Temperature. The thermistors deployed at moorings were tested in four different water baths, as described in Section I.A.2.b. Thermistors that did not read within 0.2°C of the certified thermometer at any of the four temperatures prior to the survey were analyzed by a regression analysis. These regressions were used to adjust the temperature recorded by each of the nonconforming meters for the deployment period.

All thermistors were retrieved after approximately one month of monitoring and replaced by another set of thermistors on the moorings. The retrieved thermistors were tested again (i.e., post-deployment) and the pre- and post-deployment tests are presented in Section I.B.3.a. The post-survey testing for one deployment period served as the pre-survey testing of those thermistors for their subsequent deployment as the thermistors were only stored at LMS's laboratory during the interim.

Dissolved oxygen. The quality assurance/quality control (QA/QC) procedures employed for the DO measurements between 3 September and 8 October 1998 are described in Exhibit E-3-1. There were pre- and post-deployment tests for the two sequential deployments that spanned the monitoring period.

I.B.2.b. Temperature

The mooring stations that were equipped with thermistors are shown in Figure 10-226. Nine of the moorings had thermistors at three depths using a configuration similar to that used for the intensive survey (as shown in Figure 10-11), and the mooring station in the Salem River, which is locally shallow, had thermistors just below the water surface (Table 10-12). As two thermistors were set at each depth, there were a total of 56 thermistors in the river, except during the beginning of the extended monitoring period (4 June to 28 July 1998), as explained below.

Five mooring stations (21, 22, 23, 24, 9M) remained in service following the end of the 2-Unit intensive survey on 4 June 1998. Dual thermistors were deployed at all stations between 19 June and 28 July 1998, as listed in Table 10-12. (The two surface thermistors are referred to as "a" and "b," mid-depth as "c" and "d," and bottom as "e" and "f"; lower and upper are used interchangeably.) All thermistors were retrieved on 28 July, and a full set of 56 thermistors were deployed that day. All 56 thermistors were retrieved and replaced with other thermistors on 2 September, and 7 October 1998. The thermistors were retrieved on 5 November 1998, when the six-month thermal monitoring ended. The data recorded on each thermistor were downloaded and transferred to the database.

I.B.2.c. Dissolved Oxygen

CT/DO meters were installed by Woods Hole Group on 3 September 1998 at Mad Horse Creek (surface) and Station 21 (surface and mid-depth), and on 4 September at Station 9M (surface and mid-depth). The meters were downloaded on 17 September and samples collected near the meters were analyzed for DO by Winkler titration for QC. The meters were redeployed on 17 September and continued monitoring until 8 October 1998. The meters were retrieved on 8 October 1998, and the data were downloaded and transferred to the database.

I.B.3. Results

I.B.3.a. Quality Assurance/Quality Control (QA/QC)

The results of the testing of thermistors are presented as a series of deployment periods. Four tables summarize the temperature testing results for each deployment period except for the 20-28 July 1998 deployment, as described below. The first three deployment periods overlap, and the fourth through sixth periods are sequential.

19 June - 28 July 1998. Eighteen (18) of the 24 thermistors tested (i.e., 75%) prior to deployment were within the 0.2°C tolerance of the water bath temperature measured using a certified thermometer (Table 10-13). The other six thermistors showed the absolute value of maximum deviations at any of the four Table 10-14. The expected (certified) temperature (T) was regressed against the meter temperature (T_{meas}), and the resulting regression equations for these six thermistors are shown in Table 10-15. These regressions were used to adjust the temperature recorded by each of the temperatures tested that ranged from 0.21°C and 1.70°C, as shown in six nonconforming meters, so that the data presented in this report have been corrected according to the QA/QC plan. These 24 thermistors were also tested following the retrieval on 28 July 1998. The post-survey readings of all thermistors in the water baths were compared first to the certified thermometer, and all 24 thermistors (100%) were within the accuracy tolerance of 0.2°C (Table 10-14). Only four of the six thermistors adjusted based on regressions were outside the 0.2°C tolerance at any temperature tested. The results of the post-survey testing of 24 thermistors are summarized in Table 10-16. Twenty of the 24 meters (83%) were within the 0.2°C tolerance at all temperatures tested. The other four meters showed maximum deviation at any temperature that ranged from ±0.2°C to ±1.0°C.

2 July - 28 July 1998. Sixteen (16) of the 18 thermistors tested (89%) prior to deployment were within the accuracy tolerance of 0.2°C (Table 10-17). The other two thermistors showed the absolute value of maximum deviations at any temperature between 0.21°C and 0.27°C (Table 10-18). Regression analysis was performed for these two thermistors (Table 10-19), and the data recorded by these two nonconforming meters were adjusted. The post-deployment testing of the 18 thermistors resulted in 12 thermistors (67%) being within the accuracy tolerance of 0.2°C at all four temperatures (Table 10-18). The adjustment of the two thermistors based on regressions yielded similar differences from the certified thermometer as compared to the unadjusted temperature readings. The post-deployment testing, which is summarized in Table 10-20, showed 67% of the thermistors within the 0.2°C tolerance and maximum deviations in the other six thermistors that ranged from ±0.2°C to ±1.2°C.

20 July - 28 July 1998. All eight of the thermistors tested (100%) prior to and after deployment were within the accuracy tolerance of 0.2°C.

28 July - 2 September 1998. Forty-eight (48) of the 56 thermistors tested (86%) prior to deployment were within the accuracy tolerance of 0.2°C (Table 10-21). Maximum deviations (absolute values) between the other eight thermistors and the certified thermometer ranged from 0.21°C to 0.90°C (Table 10-22). Regressions for these eight thermistors that exceeded the accuracy tolerance were developed and applied to the data collected (Table 10-23). Post-deployment testing, which was done at temperatures of 0°C, 25°C, and 30°C (not at 37°C), showed 52 thermistors out of 56 (93%) were within the tolerance without any adjustment (Table 10-22). The adjustment of eight thermistors based on regressions resulted in five of these thermistors being within the tolerance. The post-deployment testing, which is summarized in Table 10-24, resulted in 89% of the thermistors being within the 0.2°C tolerance, and maximum deviations in the other six thermistors ranged from ±0.2°C to ±0.7°C.

2 September - 7 October 1998. Forty-nine (49) of the 56 thermistors tested (88%) prior to deployment were within the accuracy tolerance of 0.2°C (Table 10-25). The other seven thermistors showed absolute value maximum deviations at any temperature between 0.23°C and 1.16°C (Table 10-26). Regressions for these seven thermistors that exceeded the accuracy tolerance were developed and applied to the data collected (Table 10-27). Post-deployment testing of the 56 thermistors resulted in 49 of the 56 thermistors (88%) being within the tolerance without any adjustment (Table 10-26). The adjustment of seven thermistors based on regressions yielded four of these thermistors being within the 0.2°C tolerance. The post-deployment testing showed 89% of the thermistors were within the 0.2°C tolerance, and the maximum deviation ranged between ±0.20°C and ±2.25°C (Table 10-28).

7 October - 5 November 1998. Fifty-one (51) of the 56 thermistors (91%) tested prior to deployment were within the accuracy tolerance of 0.2°C (Table 10-29). The other five thermistors showed absolute value maximum deviations at any temperature between 0.23°C and 0.67°C (Table 10-30). Regressions for these five nonconforming thermistors that exceeded the accuracy tolerance were developed and applied to the data collected (Table 10-31). Post-deployment testing showed that 44 thermistors of the 56 (79%) were within the tolerance without any adjustment (Table 10-30). The adjustment of five thermistors based on regressions resulted in two of these thermistors being within the tolerance. The post-deployment testing resulted in 75% of the thermistors being within the 0.2°C tolerance, and the maximum deviations in the other 14 thermistors ranged from ±0.2°C to ±0.4°C (Table 10-32).

I.B.3.b. Temperature

The total number of data records, defined as a single time of measurement of one or more constituents (temperature), collected between 4 June and 5 November 1998 was 1,903,481. This provides a means of showing the relative distribution of measurements between the extended monitoring and the intensive survey components, as shown in Table 10-3.

As stated in Section I.B.2.b, pairs of thermistors deployed on 10 moorings set in the river and at the mouths of tributaries (shown in Figure 10-226) monitored temperature. As temperature was measured at eight (all except Salem River and G9) of these moorings during the intensive survey (as described in Section I.A.3.f), the combination of the extended monitoring and the intensive survey periods provides data for approximately six months. The intensive survey data collected by instruments at surface, mid-depth, and bottom positions were combined with the data collected during the extended period by the primary thermistors, which are referred to as meters A (surface), C (mid-depth), and E (bottom). The backup thermistors, which were deployed between 19 June and 28 July 1998 and are referred to as meters B (surface), D (mid-depth), and F (bottom), provided temperature data for most of the overall six-month period. The data collected by the primary and backup thermistors deployed at Salem River and G9 also cover periods similar to those covered by the thermistors at the other eight moorings.

Temperature data are presented graphically as temporal plots having uniform time axes that begin in May and end in November 1998. The figures showing the time series of temperature for the 10 mooring stations are:

STATION	PRIMARY METERS (A, C, E)	BACKUP METERS (B, D, F)
Salem River	10-227	10-228
Mad Horse Creek	10-229	10-230
21	10-231	10-232
22	10-233	10-234
23	10-235	10-236
249G9MM9G9	10-23710-23910-24110-24310-245	10-23810-24010-24210-24410-246

I.B.3.c. Dissolved Oxygen

As stated in Section I.B.2.c, DO was measured at three mooring stations between 3 September and 8 October 1998. Temperature and salinity data were also collected because of their relevance to the DO saturation concentration. Time series of temperature, salinity, and DO data are presented graphically in these figures:

STATION	TEMPERATURE	SALINITY	DO
Mad Horse Creek	10-247	10-248	10-249
21	10-250	10-251	10-252
9M	10-253	10-254	10-255

TABLE 10-1
PRE-SURVEY CALIBRATION OF EQUIPMENT USED DURING 2-UNIT SURVEY

EQUIPMENT	SURVEY COMPONENT	MANUFACTURER / MODEL	CALIBRATION PERFORMED
CTD (conductivity/ temperature/depth logger)	Mobile-Boat 1	Falmouth Scientific, Inc. (FSI) MicroCTD	28 January 1998 – 6 May 1998
	Mobile-Boat 2	FSI MicroCTD	7 May 1998
TTM (thermistor temperature module)	Mobile-Boat 1,2, and 3	FSI Fast response TTM (near surface measurements)	7 May 1998
CTD	Mobile-Boat 4	Ocean Sensor OS-200	6 May 1998
CTD	Mobile-Boat 5	Ocean Sensor OS-200	7 May 1998
CT/DO	Moorings	YSI, Inc 600XLM	21-27 April 1998
CT Meters (conductivity/ temperature logger)	Moorings	YSI, Inc./600XL	22-28 April 1998
Thermistors (temperature logger)	Moorings	Onset Inc./Optic Stow Away Temp.	21-25 November 1997[1]
Tide Gauge	Tide gages	Coastal Leasing, Inc., MicroTide	16 December 1997 - 29 April 1998
ADCP	Mobile-Boat 1	RD-WS 1200 Workhorse	8 May 1998
	Mobile-Boat 3	RD-WS 1200 Workhorse	8 October 1997
	Mobile-Boat 5	RD-WS 1200 Workhorse	January 1997
	Fixed Station	RD-WS 1200 Workhorse	11 May 1998
Fluorometers	Mobile-Boat 1	Turner 10-AU	16 February 1998
	Mobile-Boat 2	Turner 10-AU	31 March 1998
	Mobile-Boat 3	Turner 10-AU	30 March 1998
	Mobile-Boat 4	Chelsea Instruments LTD/MK II Aquatracka (Rhodamine)	1 April 1997 - 10 July 1997
	Mobile-Boat 5	Chelsea Instruments LTD/MK II Aquatracka (Rhodamine)	1 April 1997 - 10 July 1997
DGPS (differential global positioning system)	Mobile-Boat 1	Trimble DSM Pro	N/A
	Mobile-Boat 2	Trimble DSM Pro	N/A
	Mobile-Boat 3	Trimble DSM Pro	N/A
	Mobile-Boat 4	Northstar Technologies	N/A
	Mobile-Boat 5	Northstar Technologies	N/A
Electronic scale	Dye Injection	A&D Bal201	18 May 1998

Electronics are calibrated by Onset at time of assembly at plant

TABLE 10-2
MOORING STATION DEPLOYMENTS DURING 2-UNIT INTENSIVE SURVEY

Constituents/Sensors				Sensor Depth (ft)			Station Depth (ft
Mooring Station	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	
1	O*	T	O	2.0	6.0	6.0	8.0
2	-	S	-	-	14.0	-	28.0
4	S	S	S	2.0	17.0	31.0	33.0
5	S	S	S	2.5	21.0	43.0	45.0
6	S	-	S	2.5	-	5.0	7.0
7	-	S	S	-	11.0	19.0	21.0
9	-	S	-	-	18.0	-	35.0
10	-	S	-	-	9.0	-	17.0
Alloway Creek	O	T	O	3.0	6.0	22.0	24.0
Hope Creek	O	T	O	3.0	8.0	17.5	19.5
Mad Horse Creek	T	T	S	2.0	11.0	24.5	26.0
E	O	T	O	2.5	11.5	22.0	24.0
H	O	T	O	3.0	8.0	18.0	20.0
I	T	T	T	2.0	8.0	13.0	15.0
K	T	T	T	2.0	14.0	28.0	30.0
V	T	T	-	2.0	12.5	-	25.0
L	T	T	T	2.0	3.0	10.0	12.0
21	T	T	T	2.5	16.0	37.0	39.0
22	T	T	T	2.5	18.0	33.0	35.0
23	T	T	T	2.0	15.0	35.0	37.0
24	T	T	T	2.5	14.0	32.0	34.0
12G	T	T	-	2.5	11.0	-	22.0
12R	T	T	T	2.0	4.5	7.0	9.0
9G	T	T	T	2.5	12.5	24.0	26.0
9M	-	T	S	-	15.0	27.0	29.0
9R	T	T	T	2.0	3.0	4.0	6.0
M9	S	S*	S	2.0	12.5	28.0	30.0
R9	T	T	-	2.0	3.5	-	7.0
G12	-	T	T	-	2.5	5.0	7.0
M12	S	S	-	2.0	22.5	-	45.0
R12	T	T	T	2.5	7.5	17.0	19.0

NOTE: T = Temperature
S = Salinity and temperature
O = Dissolved oxygen, salinity, and temperature
* = Missing data for one or more constituents
\- = No data due to instrument being displaced or malfunctioning
Sensor depth is measured from the water surface. Depths of surface and mid-depth sensors are constant; depth of bottom sensor, which varied tidally, is at mean water in table above.
Station depth is at mean water.

**TABLE 10-3
NUMBERS OF MEASUREMENT RECORDS
MADE DURING PSE&G SURVEYS**

Survey Component	Number of Records 2-Unit
ADCP - mobile	98,799
ADCP - marsh	23,537[a]
ADCP - bottom	247,263
CTD verticals - mobile	7,376
CTD verticals - marsh	3,856[b]
CTD verticals - longitudinal surveys	4,236[c]
CTD verticals - boundary conditions	540
Moorings	447,138
Surface temperature	414,273
Tide gauges	24,805
Total	**1,271,823**

NOTES:
A record is defined as a single time of measurement of one or more constituents (e.g., temperature)
[a]2 Marsh surveys
Marsh 1: 11,478
Marsh 2: 12,059
[b]2 Marsh surveys
Marsh 1: 1,940
Marsh 2: 1,916
[c]3 Longitudinal surveys
1: 1,017
2: 914
3: 2,305

TABLE 10-4
TEMPERATURE MEASUREMENT INSTRUMENTS USED AT 2-UNIT SURVEY MOORINGS THAT TESTED OUTSIDE THE 0.2EC TOLERANCE DURING PRE-SURVEY AND/OR POST-SURVEY CALIBRATION

Mooring Location	Meter Type	Pre-survey test Exceeded Tolerance	Regression Equation Correction	Post-survey Test Exceeded Tolerance
I mid	T			T
AC mid	T			T
MH mid	T			T
I surf	T			T
I mid	T	T	T	T
K mid	T	T	T	
L bot	T	T	T	
21 mid	T	T	T	T
12R bot	T	T	T	T
9G mid	T	T	T	T
9M mid	T	T	T	T
9M bot	CT			T
9R surf	T	T	T	T
9R mid	T	T	T	T
M9 bot	CT			T
G12 mid	T	T	T	
M12 mid	CT	T	T	T
R12 bot	T			T

NOTES:

1. Seventy-nine instruments were tested prior to survey and deployed at moorings.
2. Seven instruments that were tested prior to the survey and found to be within 0.2°C tolerance were not tested after the survey because these instruments were redeployed and unrecovered. These seven are: 23 surf, 23 mid, 23 bot, 24 surf, 24 mid, 24 bot, and MH surf.
3. Fifty-four meters not listed in above table and note 2 tested pre- and post-survey within 0.2°C tolerance.

TABLE 10-5
PRE-SURVEY TESTING RESULTS OF MOORED TEMPERATURE METERS THAT EXCEEDED 0.2 OC TOLERANCE AT ONE OR MORE TEMPERATURES

Meter Serial #	Location	Type	T (°C)	Average Certified T°	Average thermistor T°	Delta (Δ)
123749	9R mid	Onset	*0*	0.22	-0.04	***0.26***
			25	24.84	24.61	***0.23***
			30	29.59	29.512	0.08
			37	36.94	36.92	0.01
123739	9R surf	Onset	*0*	0.90	0.39	***0.51***
			25	25.15	25.08	0.06
			30	30.06	30.07	-0.01
			37	36.94	36.96	-0.03
109824	9M mid	Onset	0	0.22	0.12	0.10
			25	25.10	24.79	***0.31***
			30	30.06	30.17	-0.11
			37	37.03	37.03	0.00
149256	I mid	Onset	0	0.90	0.74	0.16
			25	25.10	24.88	***0.21***
			30	30.05	30.084	-0.03
			37	37.03	36.98	0.04
124335	G12 mid	Onset	0	0.62	0.54	0.08
			25	24.77	24.54	***0.23***
			30	30.05	30.066	-0.02
			37	36.67	36.52	0.14
149176	21 mid	Onset	0	0.42	0.42	0.00
			25	24.97	25.03	-0.07
			30	29.91	28.38	***1.53***
			37	36.80	36.77	0.02
123748	9G mid	Onset	0	0.42	0.35	0.07
			25	25.02	24.96	0.05
			30	30.27	28.58	***1.69***
			37	36.80	36.51	***0.29***
109799	L bot	Onset	0	0.22	0.15	0.07
			25	24.97	24.81	0.15
			30	29.59	29.372	***0.22***
			37	36.80	36.59	0.20
149180	K mid	Onset	0	0.72	0.76	-0.04
			25	24.97	25.04	-0.08
			30	30.05	29.736	***0.31***
			37	36.67	36.74	-0.08
109806	12R bot	Onset	0	0.22	0.28	-0.06
			25	24.84	24.76	0.07
			30	29.59	29.466	0.12
			37	36.80	36.07	***0.73***
92G04776	M12 mid	Endeco	*0*	0.095	0.3	***-0.21***
			25	25.115	25.02	0.09
			30	30.1	29.04	***1.06***
			35	37.295	37.1	0.20

TABLE 10-5 (continued)

Note: Above results are for 11 temperature meters identified in Table 10-4. Differences (Δ) in bold exceed 0.2°C.

TABLE 10-6
REGRESSION OF CORRECTED VS. RECORDED TEMPERATURE FOR THERMISTERS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY

Installation Location	Meter Serial #	Meter Type	Correction Factor / Equation	R^2 Value
12R bot	109806	Onset	$T = 1.0165(T_{meas}) - 0.1583$	0.99978
21 mid	149176	Onset	$T = 1.0122(T_{meas}) + 0.0946$	0.99778
9G mid	123748	Onset	$T = 1.0173(T_{meas}) + 0.1335$	0.99786
9R mid	123749	Onset	$T = 0.9938T_{meas} + 0.2854$	0.99998
9R surf	123739	Onset	$T = 0.9843T_{meas} + 0.4960$	0.99999
G12 mid	124335	Onset	$T = 1.0005(T_{meas}) + 0.0954$	0.99996
I mid	149256	Onset	$T = 0.9961(T_{meas}) + 0.1854$	0.99996
K mid	149180	Onset	$T = 1.0025(T_{meas}) - 0.0302$	0.99986
L bot	109799	Onset	$T = 1.0039(T_{meas}) + 0.070$	1.00000
9M mid	109824	Onset	$T = 0.9966T_{meas} + 0.1500$	0.99989
M12 mid	92G04776	Endeco	$T = 0.9808(T_{meas}) + 0.1579$	0.99921

TABLE 10-7
SUMMARY OF RESULTS FOR POST-SURVEY TESTING OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS TOTAL NUMBER OF METERS TESTED:

Total number of meters tested: 72
Tolerance level (C°): +/- 0.2

RANGE	# O METERS (%)	METER LOCATION	MI
Within targeted +- 0.2 °C range	576* (77.8%)	NA	
+/- 0.2 < x < +/- 0.3	6 (8.2%)	AC mid	T
		9R mid	T
		I surf	T
		R12 bot	T
		I mid	T
		9M mid	T
+/- 0.3 < x < +/- 0.6	6 (8.2%)	12R bot	T
		9R surf	T
		21 mid	T
		M9 bot	CT
		9D mid	CT
		9M bot	CT
+/- 0.6 < x < +/- 1.2	4 ** (5.5%)	MH mid	T
		9G mid	T
		M12 mid	C
		1 mid	T

* 6 of these meters underwent a one-point post calibration at 25°C

** Meter *1 mid* underwent a one-point post calibration at 25°C

NOTE: Meters 23 surface, 23 middle, 23 bottom, 24 surface, 24 mid, 24 bottom, & MH surface were successfully calibrated prior to the survey but not calibrated after the survey because these meters were redeployed and unrecovered. Data for these meters was used in the graphical presentations.

METER TYPE: T: Onset CT: YSI/Endeco (conductivity & temperature)

TABLE 10-8
TESTING RESULTS OF SHIPBOARD TEMPERATURE METERS

Δ1 1388 std - falmouth std
Δ2 meter reading - falmouth std
Δ3 meter reading - 1388 std (Δ2 - Δ1)

PRE - CALIBRATION

meter #	tested T °C	Δ1	Δ2	Δ3
1386				
	15	-0.01455	-0.00405	0.0105
	22	-0.01856	-0.00079	0.01777
	30	-0.01065	0.00667	0.01732
1387				
	15	-0.01336	-0.02256	-0.0092
	22	-0.01734	-0.02649	-0.00915
	30	-0.01503	-0.02086	-0.00583
1388	15	-0.01336	-0.01336	0
		-0.01455	-0.01455	0
	22	-0.01734	-0.01734	0
		-0.01654	-0.01654	0
		-0.01856	-0.01856	0
		-0.01865	-0.01865	0
	30	-0.01503	-0.01503	0
		-0.01065	-0.01065	0
1552M				
	15	-0.01336	0.00227	0.01563
	22	-0.01734	-0.00918	0.00816
	30	-0.01503	0.00634	0.02137
1578M				
	15	-0.01455	0.00002	0.01457
	22	-0.01856	-0.00191	0.01665
	30	-0.01065	0.0086	0.01925
1579M				
	15	-0.01455	-0.00006	0.01449
	22	-0.01856	-0.00292	0.01564
	30	-0.01065	-0.00243	0.00822

POST-CALIBRATION

meter #	tested T °C	Δ1	Δ2	Δ3
1386 *	0	-0.01691	-0.14071	-0.1238
	7.5			
	15	-0.01629	-0.13473	-0.11844
	22			
	30	-0.0164	-0.14065	-0.12425
1387	0	-0.01691	-0.03387	-0.01696
	7.5	-0.01853	-0.03015	-0.01162
	15	-0.01629	-0.02834	-0.01205
	22			
	30	-0.0164	-0.0312	-0.0148
1388	0	-0.01691	-0.01691	0
	7.5	-0.01853	-0.01853	0
	15	-0.01629	-0.01629	0
	22	-0.02241	-0.02241	0
	30	-0.0164	-0.0164	0
1552M	0	-0.01691	-0.00428	0.01263
	7.5	-0.01853	0.00031	0.01884
	15	-0.01629	-0.00484	0.01145
	22	-0.02241	-0.01113	0.01128
	30	-0.0164	-0.0116	0.0048
1578M	0	-0.01691	0.00335	0.02026
	7.5			
	15	-0.01629	-0.00136	0.01493
	22			
	30	-0.0164	-0.00164	0.01476
1579M	0	-0.01691	-0.00327	0.01364
	7.5			
	15	-0.01629	-0.00372	0.01257
	22			
	30	-0.0164	-0.00083	0.01557

TABLE 10-8 (continued)

PRE - CALIBRATION

meter #	tested T °C	Δ1	Δ2	Δ3
1581M				
	15	-0.01455	-0.00353	0.01102
	22	-0.01865	-0.00014	0.01851
	30	-0.01065	0.0006	0.01125
339	15	-0.01336	0.001	0.01436
	22	-0.01654	-0.024	-0.00746
	30	-0.01503	-0.051	-0.03597
353	15	-0.01336	-0.01	0.00336
	22	-0.01654	0.001	0.01754
	30	-0.01503	0.006	0.02103

POST-CALIBRATION

meter #	tested T °C	Δ1	Δ2	Δ3
1581M	0	-0.01691	-0.00026	0.01665
	7.5			
	15	-0.01629	0.00127	0.01756
	22			
	30	-0.0164	0.00311	0.01951
339	15	-0.01629	0.016	0.03229
	22	-0.02241	0.001	0.02341
	30	-0.0164	-0.001	0.0154
353	15	-0.01629	-0.009	0.00729
	22	-0.02241	0.001	0.02341
	30	-0.0164	0.011	0.0274

TABLE 10-9
POST-SURVEY TESTING RESULTS OF SALINITY/CONDUCTIVITY METERS USED AT MOORINGS

		Table 10-9							
		Conductivity				Salinity			
		expected {mS/cm}	observed {mS/cm}	difference Δ	%	expected	observed	difference Δ	%
1	6 bottom	12.798	12.69	0.108	0.84	7.995	7.92	0.073	0.91
		2.772	2.749	0.023	0.83	1.559	1.55	0.014	0.88
		6.653	6.626	0.027	0.41	3.936	3.92	0.017	0.43
		24.692	24.68	0.012	0.05	16.254	16.25	0.009	0.05
		36.196	36.28	-0.084	0.23	24.776	24.84	-0.064	0.26
2	7 mid	12.798	12.89	-0.092	0.72	7.915	7.98	-0.062	0.78
		2.772	2.779	-0.007	0.25	1.544	1.55	-0.004	0.27
		6.653	6.611	0.042	0.63	3.911	3.88	0.026	0.68
		24.692	24.61	0.082	0.33	16.175	16.12	0.059	0.36
		36.196	36.06	0.136	0.38	24.639	24.54	0.103	0.42
3	5 mid	12.798	12.5	0.298	2.33	7.895	7.70	0.198	2.51
		2.772	2.698	0.074	2.67	1.541	1.50	0.043	2.82
		6.653	6.556	0.097	1.46	3.904	3.84	0.061	1.56
		24.692	24.56	0.132	0.53	16.123	16.03	0.094	0.59
		36.196	36.01	0.186	0.51	24.576	24.44	0.140	0.57
4	7 bottom	12.798	12.33	0.468	3.66	7.856	7.55	0.310	3.95
		2.772	2.855	-0.083	2.99	1.536	1.58	-0.049	3.17
		6.653	6.787	-0.134	2.01	3.894	3.98	-0.084	2.16
		24.692	25.25	-0.558	2.26	16.072	16.47	-0.398	2.48
		36.196	37.31	-1.114	3.08	24.525	25.36	-0.838	3.42
5	4 surface	12.798	12.46	0.338	2.64	6.971	6.77	0.199	2.85
		6.653	6.644	0.009	0.14	3.860	3.85	0.006	0.14
6	5 surface	24.692	24.22	0.472	1.91	15.890	15.56	0.332	2.09
		36.196	36.26	-0.064	0.18	24.213	24.26	-0.047	0.20
7	5 bottom	24.692	24.83	-0.138	0.56	15.854	15.95	-0.097	0.61
		2.767	2.77	-0.003	0.11	1.508	1.51	-0.002	0.11
8	4 mid	24.692	24.11	0.582	2.36	15.803	15.40	0.407	2.58
		6.653	6.612	0.041	0.62	3.831	3.81	0.025	0.66
9	4 bottom	24.692	24.05	0.642	2.60	15.718	15.27	0.447	2.84
		36.196	35.04	1.156	3.19	24.021	23.17	0.847	3.53
10	2 mid	24.692	24.97	-0.278	1.13	15.700	15.89	-0.194	1.23
		2.772	2.77	0.002	0.07	1.503	1.50	0.001	0.08
11	6 surface	12.872	12.48	0.392	3.05	7.880	7.62	0.259	3.29
		2.772	2.799	-0.027	0.97	1.496	1.51	-0.015	1.03
		6.653	6.665	-0.012	0.18	3.802	3.81	-0.007	0.19
		24.692	24.77	-0.078	0.32	15.497	15.55	-0.054	0.35
		39.196	36.55	2.646	6.75	25.884	23.95	1.930	7.46

Table 10-9 (continued)

		Conductivity				Salinity			
		expected {mS/cm}	observed {mS/cm}	difference Δ	%	expected	observed	difference Δ	%
12	10 mid	12.872	12.8	0.072	0.56	7.812	7.76	0.047	0.60
		2.772	2.772	0	0.00	1.486	1.49	0.000	0.00
		6.653	6.547	0.106	1.59	3.790	3.73	0.065	1.70
		24.692	24.1	0.592	2.40	15.428	15.02	0.404	2.62
		36.196	36.75	-0.554	1.53	23.697	24.10	-0.402	1.70
13	M12 surface	12.872	12.27	0.602	4.68	7.666	7.28	0.387	5.04
		2.772	2.768	0.004	0.14	1.492	1.49	0.002	0.15
		6.653	4.419	2.234	33.58	3.778	2.44	1.336	35.36
		24.692	22.6	2.092	8.47	15.619	14.18	1.441	9.23
		36.196	36.22	-0.024	0.07	23.826	23.84	-0.017	0.07
14	10 surface	12.872	12.36	0.512	3.98	7.693	7.36	0.330	4.29
		2.772	2.9	-0.128	4.62	1.500	1.57	-0.073	4.88
		6.653	3.529	3.124	46.96	3.805	1.94	1.867	49.08
		24.692	23.31	1.382	5.60	15.718	14.76	0.960	6.11
		36.196	37.39	-1.194	3.30	23.950	24.83	-0.877	3.66
15	M9 surface	12.872	12.53	0.342	2.66	7.860	7.63	0.225	2.87
		2.767	2.86	-0.093	3.36	1.519	1.57	-0.054	3.55
		6.653	6.6	0.053	0.80	3.865	3.83	0.033	0.85
		24.692	24.6	0.092	0.37	15.995	15.93	0.065	0.41
		36.196	36.12	0.076	0.21	24.324	24.27	0.057	0.23
16	H surface	12.872	12.57	0.302	2.35	7.917	7.72	0.201	2.53
		2.767	2.82	-0.053	1.92	1.533	1.56	-0.031	2.02
		6.653	6.63	0.023	0.35	3.883	3.87	0.014	0.37
		24.692	24.73	-0.038	0.15	16.105	16.13	-0.027	0.17
		36.196	36.27	-0.074	0.20	24.447	24.50	-0.055	0.23
17	M9 bottom	12.872	12.36	0.512	3.98	7.937	7.60	0.341	4.29
		2.767	2.86	-0.093	3.36	1.535	1.59	-0.055	3.55
		6.653	6.64	0.013	0.20	3.892	3.88	0.008	0.21
		24.692	24.71	-0.018	0.07	16.131	16.14	-0.013	0.08
		36.196	36.36	-0.164	0.45	24.633	24.76	-0.124	0.50
18	M9 mid	12.872	12.44	0.432	3.36	7.952	7.66	0.288	3.62
		2.767	2.82	-0.053	1.92	1.546	1.58	-0.031	2.02
		6.653	6.62	0.033	0.50	3.915	3.89	0.021	0.53
		24.692	24.69	0.002	0.01	16.175	16.17	0.001	0.01
		36.196	36.28	-0.084	0.23	24.554	24.62	-0.063	0.26
19	6 mid	12.872	12.34	0.532	4.13	7.890	7.54	0.352	4.46
		2.767	2.875	-0.108	3.90	1.534	1.60	-0.063	4.13
		6.653	6.573	0.08	1.20	3.893	3.84	0.050	1.29
		24.692	24.75	-0.058	0.23	16.068	16.11	-0.041	0.26
		36.196	36.28	-0.084	0.23	24.447	24.51	-0.063	0.26

Table 10-9 (continued)

		Conductivity				Salinity			
		expected {mS/cm}	observed {mS/cm}	difference Δ	%	expected	observed	difference Δ	%
20	7 surface	12.872	12.51	0.362	2.81	7.869	7.63	0.239	3.04
		2.767	2.83	-0.063	2.28	1.533	1.57	-0.037	2.41
		6.653	6.669	-0.016	0.24	3.875	3.89	-0.010	0.26
		24.692	24.76	-0.068	0.28	16.046	16.09	-0.048	0.30
		36.196	36.32	-0.124	0.34	24.391	24.48	-0.093	0.38
21	MH bottom	12.872	12.34	0.532	4.13	7.905	7.55	0.352	4.46
		2.958	2.87	0.088	2.97	1.646	1.59	0.052	3.14
		6.653	6.65	0.003	0.05	3.895	3.89	0.002	0.05
		24.692	24.73	-0.038	0.15	16.076	16.10	-0.027	0.17
		36.196	36.34	-0.144	0.40	24.480	24.59	-0.108	0.44
22	H bottom	12.872	12.49	0.382	2.97	7.867	7.62	0.252	3.20
		2.958	2.91	0.048	1.62	1.641	1.61	0.028	1.71
		6.653	6.68	-0.027	0.41	3.875	3.89	-0.017	0.43
		24.692	24.75	-0.058	0.23	15.988	16.03	-0.041	0.26
		36.196	36.44	-0.244	0.67	24.385	24.57	-0.182	0.75
23	M12 mid	12.872	-----			7.844	0.01		
		2.958	2.86	0.098	3.31	1.648	1.59	0.058	3.50
		6.653	6.68	-0.027	0.41	3.911	3.93	-0.017	0.43
		24.692	24.63	0.062	0.25	16.076	16.03	0.044	0.27
		36.196	36.92	-0.724	2.00	24.379	24.92	-0.541	2.22
24	E bottom	12.872	11.99	0.882	6.85	7.890	7.31	0.582	7.38
		2.958	3.06	-0.102	3.45	1.641	1.70	-0.060	3.65
		6.653	6.79	-0.137	2.06	3.897	3.98	-0.086	2.20
		24.692	24.77	-0.078	0.32	16.039	16.09	-0.055	0.35
		36.196	36.53	-0.334	0.92	24.464	24.71	-0.250	1.02
25	AC surface	12.872	12.7	0.172	1.34	7.849	7.74	0.113	1.44
		2.958	2.91	0.048	1.62	1.651	1.62	0.028	1.71
		6.653	6.64	0.013	0.20	3.913	3.90	0.008	0.21
		24.692	24.54	0.152	0.62	16.224	16.11	0.109	0.67
		36.196	36.08	0.116	0.32	24.599	24.51	0.087	0.35
26	HC surface *	12.872	11.5	1.372	10.66	7.950	7.04	0.911	11.46
		2.958	2.93	0.028	0.95	1.653	1.64	0.017	1.00
		6.653	6.66	-0.007	0.11	3.926	3.93	-0.004	0.11
		24.692	24.6	0.092	0.37	16.209	16.14	0.066	0.41
		36.107	36.45	-0.343	0.95	24.904	25.17	-0.262	1.05
27	1 bottom	12.872	12.47	0.402	3.12	7.994	7.72	0.269	3.37
		2.958	2.91	0.048	1.62	1.658	1.63	0.028	1.71
		6.653	6.65	0.003	0.05	3.941	3.94	0.002	0.05
		24.692	24.6	0.092	0.37	16.250	16.18	0.066	0.41
		36.107	36.17	-0.063	0.17	24.858	24.91	-0.048	0.19

Table 10-9 (continued)

		Conductivity				Salinity			
		expected {mS/cm}	observed {mS/cm}	difference Δ	%	expected	observed	difference Δ	%
28	1 surface	12.872	12.54	0.332	2.58	7.994	7.77	0.223	2.78
		2.958	2.91	0.048	1.62	1.661	1.63	0.028	1.71
		6.653	6.66	-0.007	0.11	3.934	3.94	-0.004	0.11
		24.692	24.61	0.082	0.33	16.246	16.19	0.059	0.36
		36.107	36.23	-0.123	0.34	24.720	24.81	-0.093	0.38
29	HC bottom	12.872	12.28	0.592	4.60	7.985	7.59	0.396	4.96
		2.958	2.94	0.018	0.61	1.663	1.65	0.011	0.64
		6.653	6.68	-0.027	0.41	3.933	3.95	-0.017	0.43
		24.692	24.79	-0.098	0.40	16.213	16.28	-0.070	0.43
		36.107	36.43	-0.323	0.89	24.714	24.96	-0.245	0.99
30	E surface	12.872	12.77	0.102	0.79	7.977	7.91	0.068	0.86
		2.958	2.91	0.048	1.62	1.661	1.63	0.028	1.71
		6.653	6.7	-0.047	0.71	3.957	3.99	-0.030	0.76
		24.692	24.7	-0.008	0.03	16.254	16.26	-0.006	0.04
		36.107	36.22	-0.113	0.31	24.720	24.81	-0.086	0.35
31	AC bottom	12.872	12.54	0.332	2.58	7.968	7.75	0.222	2.78
		2.958	2.92	0.038	1.28	1.660	1.64	0.023	1.36
		6.653	6.64	0.013	0.20	3.926	3.92	0.008	0.21
		24.692	24.73	-0.038	0.15	16.209	16.24	-0.027	0.17
		36.107	36.26	-0.153	0.42	24.617	24.73	-0.116	0.47
32	9 mid	12.872	12.78	0.092	0.71	10.97633	10.89147	0.085	0.77
		2.958	2.859	0.099	3.35	1.645345	1.587202	0.058	3.53
		6.653	6.651	0.002	0.03	5.292289	5.290585	0.002	0.03
		24.692	24.38	0.312	1.26	21.66698	21.36694	0.300	1.38
		36.196	36.47	-0.274	0.76	33.5473	33.82995	-0.283	0.84
33	9M bottom	12.872	12.78	0.092	0.71	9.737585	9.662316	0.075	0.77
		2.958	2.81	0.148	5.00	1.66674	1.578733	0.088	5.28
		6.653	6.62	0.033	0.50	4.712107	4.687083	0.025	0.53
		24.692	24.13	0.562	2.28	19.63442	19.14516	0.489	2.49
		36.196	35.47	0.726	2.01	29.85889	29.19486	0.664	2.22

Note: Differences (Δ) shaded exceed tolerance of 1.0ppt.

TABLE 10-10
DISSOLVED OXYGEN SUMMARY OF POST-SURVEY METER TESTING

Total Number of Meters: 10
Tolerance Level (mg/L): +/- 0.4

TOLERANCE LEVEL	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.4 mg/L range	1 (10%)	H bottom
+/- 0.4 mg/L < x < +/- 1.0 mg/L	5 (50%)	AC surface 1 surface H surface HC bottom E surface
+/- 1.0 mg/L < x < +/- 1.7 mg/L	3 (30%)	AC bottom HC surface E bottom
+/- 1.7 mg/L < x < +/- 9.0 mg/L	1 (10%)	1 bottom

TABLE 10-11
SUMMARY OF 2-UNIT SURVEY EQUIPMENT TESTING RESULTS

Equipment	Tolerance Level	Number Tested	Pre- or Post-survey	Number Passed	% within Tolerance Level
Temperature					
Thermistors, CT, & CT/DO (moorings)	0.2EC	79	Pre-	68	86.0
Thermistors, CT, & CT/DO (moorings)		72	Post-	56	77.8
TTM, CTD (mobile)	0.05EC	9	Pre-	9	100.0
		9	Post-	8	88.9
Salinity/Conductivity					
CT, CT/DO (moorings)	1 ppt	30	Post-	28	93.3
Dissolved Oxygen					
CT/DO (moorings)	0.4 mg/l	10	Post-	1	10.0
Depth/Pressure					
MicroTide, Micro CTDs (tide gages)	0.2 m	5	Pre-	5	100.0

[1]Tolerance level is the same as calibration/validation accuracy stated in Section 10.1.2.2.

TABLE 10-12
MOORING STATION DEPLOYMENTS FOR SIX-MONTH TEMPERATURE MONITORING

Thermistor Depth (ft)					
Mooring Station	Surface	Mid-depth	Bottom	Station Depth (ft)	Start Date of Dual Thermistor Deployment
Salem River	1.5	-	-	2.0	19 June
Mad Horse Creek	2.0	11.0	20.0	22.0	2 July
21	2.0	16.0	33.0	35.0	19 June
22	2.0	16.0	29.0	31.0	19 June
23	2.0	15.0	31.0	33.0	28 July
24	2.0	14.0	28.0	30.0	28 July
9G	2.0	10.0	20.0	22.0	2 July
9M	2.0	13.5	25.0	27.0	19 June
M9	2.0	14.0	26.0	28.0	19 June
G9	2.0	8.0	14.0	16.0	2 July

NOTES:

- Sensor depth is measured from the water surface; depth of surface and mid-depth sensors are constant; depth of bottom sensor, which varied tidally, is at mean low water (MLW) in table above.
- Station depth is at MLW.
- Salem River mooring was deployed after 2-Unit intensive survey.
- Mooring G9 was displaced during 2-Unit intensive survey and subsequently redeployed.
- Moorings MH, M9, and 9G were removed after 2-Unit intensive survey and subsequently redeployed.
- Moorings 23 and 24 were displaced after 19 June and redeployed on 20 July.

TABLE 10-13
TEMPERATURE MEASUREMENT INSTRUMENTS USED AT 6-MONTH SURVEY MOORINGS THAT TESTED OUTSIDE THE 0.20 °C TOLERANCE DURING PRE-SURVEY AND/OR POST-SURVEY CALIBRATION
DEPLOYMENT PERIOD: 19 JUNE 1998 - 28 JULY 1998

Mooring		Pre-survey Test Exceeded tolerance	Regression Equation Correction	Uncorrected Post-survey Exceeded Tolerance	Corrected post-survey Exceeded Tolerance
Serial #	Location				
109799	22 mid d	✓	✓		
109806	21 bot f	✓	✓		✓
109824	9m mid c	✓	✓		
123748	21 mid d	✓	✓		✓
124347	21 bot e	✓	✓		✓
149176	21 mid c	✓	✓		✓

NOTES:
1. A total of 24 instruments were tested prior to survey and deployed at moorings.
2. Eighteen meters not listed in above table tested pre- and post-survey within 0.20 C° tolerance.

TABLE 10-14
THAT EXCEEDED 0.20 C° TOLERANCE AT ONE OR MORE TEMPERATURES
DEPLOYMENT PERIOD: 19 JUNE 1998 - 28 JULY 1998

Meter: Serial #	Meter: Location	Pre-survey: T (°C)	Pre-survey: Average Certified T°	Pre-survey: Average thermistor T°	Pre-survey: Δ	Post-Survey: No Correction Applied: T (°C)	Post-Survey: Average Certified T°	Post-Survey: Average thermistor T°	Post-Survey: Δ
109799	22 mid d	0	0.22	0.15	0.07	0	0.04	-0.01	0.05
		25	24.97	24.81	0.16	25	25.16	25.13	0.03
		30	29.60	29.37	**0.23**	30	29.93	29.78	0.15
		37	36.80	36.59	**0.21**	37	36.85	36.8	0.05
109806	21 bot f	0	0.22	0.28	-0.06	0	0.04	0.12	-0.08
		25	24.84	24.76	0.08	25	25.10	25.11	-0.01
		30	29.6	29.47	0.13	30	30.18	30.13	0.05
		37	36.8	36.07	**0.73**	37	36.92	36.92	0
109824	9m mid c	0	0.22	0.12	0.1	0	0.04	-0.03	0.07
		25	25.1	24.79	**0.31**	25	25.13	25.14	-0.01
		30	30.07	30.17	-0.10	30	29.95	29.9	0.05
		37	37.03	37.03	0	37	36.97	36.94	0.03
123748	21 mid d	0	0.42	0.35	0.07	0	0.04	-0.05	0.09
		25	25.02	24.96	0.06	25	25.10	24.96	0.14
		30	30.28	28.58	**1.70**	30	30.18	30.38	-0.20
		37	36.8	36.51	**0.29**	37	37.17	37.31	-0.14

TABLE 10-14 (continued)

Meter Serial #	Location	Pre-survey T (°C)	Average Certified T°	Average thermistor T°	Δ	Post-Survey: No Correction Applied T (°C)	Average Certified T°	Average thermistor T°	Δ
124347	21 bot e	0	0.38	0.72	**-0.34**	0	0.04	0.11	-0.07
		25	25.07	25.06	0.01	25	25.05	25.06	-0.01
		30	30.28	30.45	-0.17	30	30.00	30.08	-0.08
		37	36.94	36.91	0.03	37	37.04	37.08	-0.04
149176	21 mid c	0	0.42	0.42	0	0	0.04	0.09	-0.05
		25	24.97	25.03	-0.06	25	25.1	25.03	0.07
		30	29.92	28.38	**1.54**	30	30.18	30.18	0
		37	36.80	36.77	0.03	37	36.92	36.9	0.02

Note: Above results are for six temperature meters identified in table 10-13.

Differences (Δ) shaped exceed 0.2°c.

TABLE 10-15
REGESSIONS FOR THERMISTORS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY TESTING DEPLOYMENT PERIOD: 19 JUNE 1998 - 28 JULY 1998

meter serial	location	Regression slope	intercept	R^2
103462	22 surf a	---	---	---
109799	22 mid d	1.0042512	0.0708697	0.9999977
109805	salem surf a	---	---	---
109806	21 bot f	1.0166767	-0.1576428	0.9997848
109824	9m mid c	0.9968274	0.1505580	0.9998906
123748	21 mid d	1.0175152	0.1341566	0.9978409
124325	m9 surf b	---	---	---
124330	21 surf b	---	---	---
124331	22 bot e	---	---	---
124332	m9 surf a	---	---	---
124338	22 mid c	---	---	---
124347	21 bot e	1.0091825	-0.3313155	0.9999645
124348	9m bot f	---	---	---
124349	9m surf a	---	---	---
124353	m9 mid c	---	---	---
149167	21 surf a	---	---	---
149168	22 surf b	---	---	---
149169	9m bot e	---	---	---
149175	22 bot f	---	---	---
149176	21 mid c	1.0124370	0.0957846	0.9977491
149178	salem surf b	---	---	---
149182	9m mid d	---	---	---
149258	m9 mid d	---	---	---
149259	m9 bot f	---	---	---

NOTE: Regression Equation: T = slope*Tmeas ÷ intercept
Dashed line (---) indicates that a regression equation was not required
All temperature values for these meters are within the specified tolerance range.

TABLE 10-16
SUMMARY OF RESULTS FOR POST-SURVEY TESTING OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS
DEPLOYMENT PERIOD: 19 JUNE 1998 - 28 JULY 1998

Total number of meters tested: 24
Tolerance Level (°C): +/- 0.20

RANGE	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.20 °C range	20 (83.3%)	
+/- 0.20 < x < +/- 0.30	1 (4.2%)	21 bottom e
+/- 0.30 < x < +/- 0.60	2 (8.3%)	21 bottom f 21 middle c
+/- 0.60 < x < +/- 1.00	1 (4.2%)	21 middle d

Note: There were 2 meters at each depth referred to as a,b at the surface, c,d in the middle, and e,f at the bottom.

**TABLE 10-17
TEMPERATURE MEASUREMENT INSTRUMENTS
USED AT 6-MONTH SURVEY MOORINGS THAT
TESTED OUTSIDE THE 0.20 °C TOLERANCE DURING
PRE-SURVEY AND/OR POST-SURVEY CALIBRATION
DEPLOYMENT PERIOD: 2 JULY 1998 – 28 JULY 1998**

Mooring Serial #	Mooring Location	Pre-survey Test Exceeded Tolerance	Regression Equation Correction	Uncorrected Post-survey Exceeded Tolerance	Corrected Post-survey Exceeded Tolerance
123739	9g surf a	✓	✓	✓	✓
123746	9G mid c			✓	✓
123747	MH mid c	✓	✓	✓	✓
123749	9G mid d			✓	✓
149171	G9 bot f			✓	✓
186067	G9 mid d			✓	✓

NOTES:
1. A total of 24 instruments were tested prior to survey and deployed at moorings.
2. Eighteen meters not listed in above table tested pre- and post-survey within 0.20 C° tolerance.

TABLE 10-18
PRE- AND POST-SURVEY TESTING RESULTS OF MOORED TEMPERATURE METERS THAT EXCEEDED 0.20 °C TOLERANCE AT ONE OR MORE TEMPERATURES
DEPLOYMENT PERIOD: 2 JULY 1998 - 28 JULY 1998

meter serial #	location	PRE-SURVEY T (°C)	PRE-SURVEY average certified T°	PRE-SURVEY average thermistor T°	PRE-SURVEY Δ	POST-SURVEY: NO CORRECTION APPLIED T (°C)	POST-SURVEY average certified T°	POST-SURVEY average thermistor T°
123739	9g surf a	0	0.14	-0.01	0.15	0	0.04	-0.41
		25	25.28	25.01	0.27	25	25.15	24.65
			37.09	37.19	-0.1	37	37.04	38.08
123749	9g mid d					0	0.04	-0.03
						25	25.05	24.97
						30	29.97	30.02
						37	37.17	36.92
149171	g9 bot f					0	0.04	0.27
						25	25.16	25.24
						30	29.93	30.08
						37	37.04	37.18
186067	g9 mid d					0	0.04	0.28
						25	25.15	25.22
						30	30.07	30.07
						37	36.85	36.85

Note: Above results are for six temperature meters identified in Table 10-2. Differences (Δ) shaded exceed 0.2°C.

TABLE 10-19
REGESSIONS FOR THERMISTORS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY TESTING DEPLOYMENT PERIOD: 2 JULY 1998 - 28 JULY 1998

Meter Serial	Location	Regression Slope	Intercept	R^2
123739	9g surf a	0.9991336	0.1724336	0.9999713
123746	9g mid c	---	---	---
123747	mh mid c	0.9931497	0.2057073	0.0999954
123749	9g mid d	---	---	---
124328	g9 bot e	---	---	---
124337	g9 surf b	---	---	---
124339	mh surf b	---	---	---
124351	9g bot e	---	---	---
124355	mh bot e	---	---	---
124439	mh surf a	---	---	---
149171	g9 bot f	---	---	---
149200	g9 surf a	---	---	---
149201	g9 mid c	---	---	---
149202	9g surf b	---	---	---
149203	mh bot f	---	---	---
149256	mh mid d	---	---	---
186067	g9 mid d	---	---	---
186068	9g bot f	---	---	---

NOTE: Regression Equation: T = slope*Tmeas + intercept

Dashed line (---) indicates that a regression equation was not required
All temperature values for these meters are within
the specified tolerance
range.

TABLE 10-20
SUMMARY OF RESULTS FOR POST-SURVEY TESTING OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS
DEPLOYMENT PERIOD: 2 JULY 1998 - 28 JULY 1998

Total number of meters tested: 18 *
Tolerance Level (°C): +/- 0.20

RANGE	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.20 °C range	12 (66.7%)	
+/- 0.20 < x < +/- 0.30	4 (22.2%)	9G middle c 9G middle d G9 bottom f G9 middle d
+/- 0.30 < x < +/- 0.40	1 (5.6%)	9G surface a
+/- 0.40 < x < +/- 1.20	1 (5.6%)	MH middle c

Note: There were 2 meters at each depth referred to as a,b at the surface, c,d in the middle, and e,f at the bottom.

* Meters (G9 middle d) and (9G bottom f) are missing data for the 25°C point during the pre-survey.
Meter (MH middle d) is missing data for the 0°C point during the post-survey.

TABLE 10-21
TEMPERATURE MEASUREMENT INSTRUMENTS USED AT 6-MONTH SURVEY MOORINGS THAT TESTED OUTSIDE THE 0.20 °C TOLERANCE DURING PRE-SURVEY AND/OR POST-SURVEY CALIBRATION
DEPLOYMENT PERIOD: 28 JULY 1998 - 2 SEPTEMBER 1998

Mooring Serial #	Location	Pre-survey Test Exceeded Tolerance	Regression Equation Correction	Uncorrected Post-survey Exceeded Tolerance	Corrected Post-survey Exceeded Tolerance
188842	21 bot f			✓	✓
188844	23 bot f	✓	✓		
188853	MH mid d			✓	✓
188856	21 mid d	✓	✓		✓
188864	24 bot e	✓	✓		✓
188866	9G surf a	✓	✓		✓
188875	24 surf b	✓	✓		
188877	23 mid c	✓	✓		
188878	24 mid d	✓	✓	✓	
188882	9G surf b	✓	✓		
188888	9G bot e			✓	✓

NOTES:
1. A total of 56 instruments were tested prior to survey and deployed at moorings.
2. Forty-five meters not listed in above table tested pre- and post-survey within 0.20 °C tolerance.

TABLE 10-22
PRE- AND POST-SURVEY TESTING RESULTS OF MOORED TEMPERATURE METERS THAT EXCEEDED 0.20 °C TOLERANCE AT ONE OR MORE TEMPERATURES
DEPLOYMENT PERIOD: 28 JULY 1998 - 2 SEPTEMBER 1998

Meter		PRE-SURVEY					POST-SURVEY: NO CORRECTION APPLIED				
serial #	location	pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ	post w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ
188842	21 bot f	y	0				n - missing 37	0	0.64	1.08	-0.44
			25					25	25.15	25.23	-0.08
			30					30	30.13	30.09	0.04
			37					37			
188844	23 bot f	n	0	0.04	0.13	-0.09	y? missing 37	0	0.84	0.84	0
			25	25.43	25.39	0.04		25	25.15	25.04	0.11
			30	30.18	30.06	0.12		30	29.84	29.77	0.07
			37	37.04	36.83	0.21		37			
188853	mh mid d	y	0				n - missing 37	0	0.84	0.6	0.24
			25					25	25.45	25.36	0.09
			30					30	30.09	30.04	0.05
			37					37			
188856	21 mid d	n	0	0.04	0.2	-0.16	y? missing 37	0	0.44	0.33	0.11
			25	25.15	25.75	-0.60		25	25.1	25.15	-0.05
			30	30.22	30.2	0.02		30	30.13	30.2	-0.07
			37	37.22	37.24	-0.02		37			
188864	24 bot e	n	0	0.04	0.22	-0.18	y? - missing 37	0	0.14	0.22	-0.08
			25	25.3	25.31	-0.01		25	25.05	24.96	0.09
			30	30.18	30.19	-0.01		30	30.13	30	0.13
			37	37.04	36.14	0.90		37			

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-22 (continued)

Meter serial #	Meter location	PRE-SURVEY pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ	POST-SURVEY: NO CORRECTION APPLIED post w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ
188866	9g surf a	n	0	0.04	0.37	**-0.33**	y? - missing 37	0	0.14	0.18	-0.04
			25	25.08	25.16	-0.08		25	25.05	25.06	-0.01
			30	29.88	29.93	-0.05		30	30.13	30.27	-0.14
			37	37.21	37.28	-0.07		37			
188875	24 surf b	n	0	0.04	0.26	**-0.22**	y? - missing 37	0	0.64	0.75	-0.11
			25	25.3	25.41	-0.11		25	25.33	25.48	-0.15
			30	29.98	30.09	-0.11		30	29.84	29.94	-0.1
			37	37.24	37.22	0.02		37			
188877	23 mid c	n	0	0.04	0.1	-0.06	y? - missing 37	0	0.44	0.56	-0.12
			25	25.35	25.28	0.07		25	25.1	24.93	0.17
			30	30.36	30.28	0.08		30	30.13	29.98	0.15
			37	37.23	36.98	**0.25**		37			
188878	24 mid d	n	0	0.04	0.06	-0.02	n? - missing 37	0	0.54	0.51	0.03
			25	25.08	25.35	**-0.27**		25	25.15	25.02	0.13
			30	30.22	30.04	0.18		30	30.09	29.86	**0.23**
			37	37.05	36.85	0.20		37			
188882	9g surf b	n	0	0.04	0.12	-0.08	y? - missing 37	0	0.64	0.8	-0.16
			25	25.1	25.05	0.05		25	25.15	25.05	0.1
			30	29.98	29.88	0.10		30	29.84	29.69	0.15
			37	37.24	37.03	**0.21**		37			
188888	9g bot e	y	0				n - missing 37	0	0.64	1.31	**-0.67**
			25					25	25.05	25.05	0
			30					30	30.38	30.43	-0.05
			37					37			

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-23
REGESSIONS FOR THERMISTORS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY TESTING
DEPLOYMENT PERIOD: 28 JULY 1998 - 9 SEPTEMBER 1998

Meter serial	location	Regression slope	intercept	R^2
124381	salem surf b	---	---	---
188828	g9 mid c	---	---	---
188830	22 surf a	---	---	---
188831	9m bot e	---	---	---
188833	mh surf a	---	---	---
188834	g9 surf b	---	---	---
188835	mh bot e	---	---	---
188837	9g mid d	---	---	---
188838	9m surf a	---	---	---
188839	22 mid d	---	---	---
188840	24 bot f	---	---	---
188841	22 bot f	---	---	---
188842	21 bot f	---	---	---
188844	23 bot f	1.0076339	-0.1063614	0.9999952
188845	9m mid c	---	---	---
188847	mh surf b	---	---	---
188848	9g mid c	---	---	---
188850	m9 surf b	---	---	---
188851	21 surf a	---	---	---
188852	23 surf b	---	---	---
188853	mh mid d	---	---	---
188854	22 mid c	---	---	---
188855	21 mid c	---	---	---
188856	21 mid d	1.0027143	-0.2533713	0.9996994
188857	9m surf b	---	---	---
188858	m9 mid d	---	---	---
188860	9m mid d	---	---	---
188861	g9 mid d	---	---	---
188862	23 bot e	---	---	---
188863	m9 surf a	---	---	---
188864	24 bot e	1.0211803	-0.3114057	0.9995080
188866	9g surf a	1.0078677	-0.3149133	0.9999937
188867	g9 bot f	---	---	---
188868	23 surf a	---	---	---
188870	g9 bot e	---	---	---
188871	mh bot f	---	---	---
188872	salem surf a	---	---	---
188874	g9 surf a	---	---	---
188875	24 surf b	1.0056055	-0.2352994	0.9999942
188877	23 mid c	1.0071427	-0.0804241	0.9999888
188878	24 mid d	1.0049859	-0.0925500	0.9998406
188879	24 mid c	---	---	---
188880	24 surf a	---	---	---

TABLE 10-23 (continued)

Meter serial	location	Regression slope	intercept	R^2
188881	22 surf b	---	---	---
188882	9g surf b	1.0072054	-0.0958672	0.9999958
188884	mg mid c	---	---	---
188885	23 mid d	---	---	---
188886	22 bot e	---	---	---
188887	m9 bot f	---	---	---
188888	9g bot e	---	---	---
188889	m9 mid c	---	---	---
188890	21 surf b	---	---	---
188891	9g bot f	---	---	---
188894	9m bot f	---	---	---
188895	21 bot e	---	---	---
188896	m9 bot e	---	---	---

NOTE: Regression Equation: T = slope*Tmeas + intercept

Dashed line (---) indicates that a regression equation was not required
All temperature values for these meters are within
the specified tolerance range.

TABLE 10-24
SUMMARY OF RESULTS FOR POST-SURVEY TESTING OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS

DEPLOYMENT PERIOD: 28 JULY 1998 - 2 SEPTEMBER 1998

Total number of meters tested: 56 *
Tolerance Level (°C): +/- 0.20

RANGE	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.20 °C range	50 (89.3%)	
+/- 0.20 < x < +/- 0.30	3 (5.4%)	MH middle d 24 bottom e 9G surface a
+/- 0.30 < x < +/- 0.50	2 (3.6%)	21 bottom f 21 middle d
+/- 0.50 < x < +/- 0.70	1 (1.8%)	9G bottom e

Note: There were 2 meters at each depth referred to as a,b at the surface, c,d in the middle, and e,f at the bottom.

- All meters are missing data for the 37°C point during the post-calibration.

TABLE 10-25
TEMPERATURE MEASUREMENT INSTRUMENTS USED AT 6-MONTH SURVEY MOORINGS THAT TESTED OUTSIDE THE 0.20 °C TOLERANCE DURING PRE-SURVEY AND/OR POST-SURVEY CALIBRATION
DEPLOYMENT PERIOD: 2 SEPTEMBER 1998 - 7 OCTOBER 1998

Mooring Serial #	Location	Pre-survey Test Exceeded Tolerance	Regression Equation Correction	Uncorrected Post-survey Exceeded Tolerance	Corrected Post-survey Exceeded Tolerance
123739	23 bot f	✓	✓	✓	✓
123746	24 mid d	✓	✓	✓	
123747	G9 bot e	✓	✓	✓	✓
123748	MH bot e			✓	✓
123749	G9 mid d	✓	✓	✓	✓
149167	M9 mid d			✓	✓
149171	MH mid d	✓	✓		
186067	G9 surf b	✓	✓		
188815	22 bot e			✓	✓
188893	9G surf a	✓	✓		

NOTES:
1 A total of 56 instruments were tested prior to survey and deployed at moorings.
2. Forty-six meters not listed in above table tested pre- and post-survey within 0.20 °C tolerance.

TABLE 10-26
PRE- AND POST-SURVEY TESTING RESULTS OF MOORED TEMPERATURE METERS THAT EXCEEDED 0.20 °C TOLERANCE AT ONE OR MORE TEMPERATURES
DEPLOYMENT PERIOD: 2 SEPTEMBER 1998 - 7 OCTOBER

meter		PRE-SURVEY					POST-SURVEY: NO CORRECTION APPLIED					P C
serial #	location	pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	adjust-ment Δ	post w/in +/- 0.20?	T(°C)	average certified T°	average thermistor T°	adjust-ment Δ	c tl
123739	23 bot f	n	0	0.04	-0.41	**0.45**	n?	0	0.04	-1.24	**1.28**	-(
			25	25.15	24.65	**0.50**		25	25.38	24.29	**1.09**	2
			30	30.07	29.7	**0.37**		30	30.21	29.33	**0.88**	2
			37	37.04	36.56	**0.48**		37	37.14	37.17	-0.03	3
123746	24 mid d	n	0	0.04	-0.03	0.07	n?	0	0.04	-0.03	0.07	0
			25	25.05	24.98	0.07		25	25.13	24.98	0.15	2
			30	29.93	29.67	**0.26**		30	30.18	30.03	0.15	3
			37	36.92	36.77	0.15		37	37.23	36.93	**0.30**	3
123747	g9 bot e	n	0	0.04	0.73	**-0.69**	n?	0	0.04	0.33	**-0.29**	-(
			25	25.16	25.99	**-0.83**		25	25.21	25.64	**-0.43**	2
			30	29.93	31.09	**-1.16**		30	30.18	31.09	**-0.91**	3
			37	37.04	38.08	**-1.04**		37	37.23	36.08	**1.15**	3
123748	mh bot e	n	0	0.04	-0.05	0.09	n?	0	0.04	-0.46	0.5	-(
			25	25.1	24.96	0.14		25	25.38	25.03	**0.35**	2
			30	30.18	30.38	**-0.20**		30	30.19	30.01	0.18	2
			37	37.17	37.31	-0.14		37	37.23	37.15	0.08	3
123749	g9 mid d	n	0	0.04	-0.03	0.07	n?	0	0.04	-0.45	**0.49**	-(
			25	25.05	24.97	0.08		25	25.21	24.97	**0.24**	2
			30	29.97	30.02	-0.05		30	30.45	30.39	0.06	3
			37	37.17	36.92	**0.25**		37	37.23	37.16	0.07	3
149167	m9 mid d	y					n	0	0.04	-0.04	0.08	-(
								25	25.05	24.85	0.20	2
								30	30.45	30.22	**0.23**	3
								37	37.14	36.98	0.16	3

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-26 (continued)

meter		PRE-SURVEY					POST-SURVEY: NO CORRECTION APPLIED					P C
serial #	location	pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	adjust-ment Δ	post w/in +/- 0.20?	T(°C)	average certified T°	average thermistor T°	adjust-ment Δ	c tl
149171	mh mid d	n	0	0.04	0.27	**-0.23**	y?	0	0.04	0.11	-0.07	-(
			25	25.16	25.24	-0.08		25	25.05	25.14	-0.09	2
			30	29.93	30.08	-0.15		30	30.21	30.27	-0.06	3-
			37	37.04	37.18	-0.14		37	37.14	37.27	-0.13	3
149256	9g mid d	missing 0					y					
186067	g9 surf b	n	0	0.04	0.28	**-0.24**	y?	0	0.04	0.16	-0.12	-(
			25	25.15	25.22	-0.07		25	25.13	25.03	0.10	2
			30	30.07	30.07	0		30	30.19	30.07	0.12	3-
			37	36.85	36.85	0		37	37.05	37.07	-0.02	3
188814	23 surf b	missing 37					y					
188815	22 bot e	y					n	0	0.04	0	0.04	0
								25	25.23	25.08	0.15	2
								30	29.96	29.91	0.05	2
								37	37.19	36.93	**0.26**	3
188817	23 surf a	missing 30					y					
188893	9g surf.a	n	0	0.14	0.22	-0.08	y?	0	0.04	0.09	-0.05	0
			25	25.35	25.43	-0.08		25	25.05	25.08	-0.03	2
			30	30.26	30.44	-0.18		30	30.45	30.48	-0.03	3-
			37	36.96	37.25	**-0.29**		37	37.05	37.09	-0.04	3

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-27
REGESSIONS FOR THERMISTORS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY TESTING
DEPLOYMENT PERIOD: 2 SEPTEMBER 1998 - 7 OCTOBER 1998

meter serial	location	regression slope	intercept	R^2
69736	9g mid c	---	---	---
93511	21 bot e	---	---	---
103462	9m bot e	---	---	---
109799	24 mid c	---	---	---
109805	g9 bot f	---	---	---
109824	22 mid c	---	---	---
123739	23 bot f	0.9999400	0.4513564	0.9999874
123746	24 mid d	1.0031369	0.0658308	0.9999784
123747	g9 bot e	0.9892120	-0.6713843	0.9999483
123748	mh bot e			
123749	g9 mid d	1.0021677	0.0377069	0.9999462
124325	22 surf b	---	---	---
124328	mh mid c	---	---	---
124330	m9 surf b	---	---	---
124331	24 bot f	---	---	---
124332	21 surf b	---	---	---
124337	9m surf a	---	---	---
124338	24 bot e	---	---	---
124339	21 mid c	---	---	---
124347	m9 surf a	---	---	---
124348	21 surf a	---	---	---
124349	g9 mid c	---	---	---
124351	mh surf b	---	---	---
124353	22 mid d	---	---	---
124355	21 mid d	---	---	---
124439	23 mid c	---	---	---
149167	m9 mid d	---	---	---
149168	24 surf a	---	---	---
149169	22 surf a	---	---	---
149171	mh mid d	1.0027397	-0.2135398	0.9999928
149175	m9 bot e	---	---	---
149176	m9 mid c	---	---	---
149178	22 bot f	---	---	---
149182	9m surf b	---	---	---
149200	23 bot e	---	---	---
149201	mh bot f	---	---	---
149202	21 bot f	---	---	---
149203	m9 bot f	---	---	---
149227	23 mid d	---	---	---
149256	9g mid d	---	---	---
149258	mh surf a	---	---	---
149259	9m bot f	---	---	---
185977	9g surf b	---	---	---

TABLE 10-27 (continued)

meter serial	location	regression slope	intercept	R^2
186067	g9 surf b	1.0069865	-0.2389236	0.9999984
186068	g9 surf a	---	---	---
186191	salem surf a	---	---	---
186192	salem surf b	---	---	---
188814	23 surf b	---	---	---
188815	22 bot e	---	---	---
188816	24 surf b	---	---	---
188817	23 surf a	---	---	---
188818	9m mid c	---	---	---
188846	9m mid d	---	---	---
188873	9g bot e	---	---	---
188893	9g surf a	0.9953594	-0.0492120	0.9999830
188937	9g bot f	---	---	---

NOTE: Regression Equation: T = slope*Tmeas + intercept

Dashed line (---) indicates that a regression equation was not required
All temperature values for these meters are within
the specified tolerance range.

TABLE 10-28
SUMMARY OF RESULTS FOR POST-SURVEY TESTING
OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS

DEPLOYMENT PERIOD: 2 SEPTEMBER 1998 - 7 OCTOBER 1998

Total number of meters tested: 56 *
Tolerance Level (°C): +/- 0.20

RANGE	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.20 °C range	50 (89.3%)	
+/- 0.20 < x < +/- 0.30	2 (3.6%)	M9 middle d 22 bottom e
+/- 0.30 < x < +/- 0.50	(3.6%)	MH bottom e G9 middle d
+/- 0.50 < x < +/- 0.90	1 (1.8%)	23 bottom f
+/- 0.90 < x < +/- 2.25	1 (1.8%)	G9 bottom e

Note: There were 2 meters at each depth referred to as a,b at the surface, c,d in the middle, and e,f at the bottom.

* Meter (9G middle d) is missing data for the 0°C point during the pre-survey.
Meter (23 surface b) is missing data for the 37°C point during the pre-survey.
Meter (23 surface a) is missing data for the 30°C point during the pre-survey

TABLE 10-29
TEMPERATURE MEASUREMENT INSTRUMENTS USED AT 6-MONTH SURVEY MOORINGS THAT TESTED OUTSIDE THE 0.20 °C TOLERANCE DURING PRE-SURVEY AND/OR POST-SURVEY CALIBRATION
DEPLOYMENT PERIOD: 7 OCTOBER 1998 - 5 NOVEMBER 1998

Mooring		Pre-survey Test Exceeded Tolerance	Regression Equation Correction	Uncorrected Post-survey Exceeded Tolerance	Corrected Post-survey Exceeded Tolerance
Serial #	Location				
186193	22 surf b	✓	✓		✓
188842	9G surf a	✓	✓		✓
188844	21 mid c			✓	✓
188853	9M bot e	✓	✓		✓
188860	23 mid d			✓	✓
188861	MH surf b			✓	✓
188863	21 surf a			✓	✓
188868	23 surf a			✓	✓
188875	9G surf b			✓	✓
188878	G9 surf b	✓	✓	✓	
188879	24 bot f			✓	✓
188885 b	M9 surf			✓	✓
188887	9G bot f			✓	✓
188888	G9 bot f	✓	✓		
188890	24 surf b			✓	✓
188891	9M mid d			✓	✓

NOTES:
1. A total of 56 instruments were tested prior to survey and deployed at moorings.
2. Forty meters not listed in above table tested pre- and post-survey within 0.20 °C tolerance.

TABLE 10-30
PRE- AND POST-SURVEY TESTING RESULTS OF MOORED TEMPERATURE METERS THAT EXCEEDED 0.20 °C TOLERANCE AT ONE OR MORE TEMPERATURES DEPLOYMENT PERIOD: 7 OCTOBER 1998 - 5 NOVEMBER 1998

Meter		Pre-Survey					Post-Survey: No Correction Applied				
serial #	location	pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ	post?	T (°C)	average certified T°	average thermistor T°	Δ
186193	22 surf b	n	0	0.44	0.7	-0.26	y?		0.04	0.12	
			25	25.15	25.43	-0.28			25.45	25.4	
			30	30.36	30.48	-0.12			30.01	30.11	
			37	36.85	37.08	-0.23			37.32	37.29	
188842	9g surf a	n	0	0.64	1.08	-0.44	y?		0.04	0.15	
			25	25.15	25.23	-0.08			25.3	25.23	
			30	30.13	30.09	0.04			30.23	30.28	
			37						37.37	37.29	
188844	21 mid c	y	0				n		0.04	0.19	-0.15
			25						25.25	25.22	0.03
			30						29.96	29.88	0.08
			37						37.32	37.04	0.28
188853	9m bot e	n	0	0.84	0.6	0.24	y?		0.04	0.18	-0.14
			25	25.45	25.36	0.09			25.3	25.23	0.07
			30	30.09	30.04	0.05			30.01	30.04	-0.03
			37						37.37	37.24	0.13
188860	23 mid d	y	0				n		0.04	0.27	-0.23
			25						25.15	25.04	0.11
			30						30.4	30.46	-0.06
			37						37.46	37.32	0.14
188861	mh surf b	y	0				n		0.04	0.29	-0.25
			25						25.5	25.67	-0.17
			30						29.96	30	-0.04
			37						37.37	37.42	-0.05

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-30 (continued)

Meter serial #	location	Pre-Survey: pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ	Post-Survey: No Correction Applied: post?	T (°C)	average certified T°	average thermistor T°	Δ
188863	21 surf a	y	0				n		0.04	0.27	**-0.23**
			25						25.3	25.13	0.17
			30						30.4	30.34	0.06
			37						37.2	36.95	**0.25**
188868	23 bot f	y	0				n		0.04	0.28	**-0.24**
			25						25.5	25.61	-0.11
			30						30.23	30.3	-0.07
			37						37.34	37.31	0.03
188875	9g surf b	y	0				n		0.04	0.26	**-0.22**
			25						25.15	25.51	**-0.36**
			30						30.26	30.32	-0.06
			37						37.35	37.26	0.09
188878	g9 surf b	n	0	0.54	0.51	0.03	n?		0.04	0.03	0.01
			25	25.15	25.02	0.13			25.5	25.36	0.14
			30	30.09	29.86	**0.23**			30.23	30.04	0.19
			37						37.37	37.02	**0.35**
188879	24 bot f	y	0				n		0.04	0.32	**-0.28**
			25						25.35	25.36	-0.01
			30						30.26	30.23	0.03
			37						37.35	37.26	0.09
188885	m9 surf b	y	0				n		0.04	-0.01	0.05
			25						25.15	24.89	**0.26**
			30						30.01	29.72	**0.29**
			37						37.35	37.02	**0.33**
188887	9g bot f	y	0				n		0.04	0	0.04
			25						25.15	25.06	0.09
			30						30.01	29.89	0.12
			37						37.37	37.16	**0.21**

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-30 (continued)

Meter serial #	location	Pre-Survey: pre w/in +/- 0.20?	T (°C)	average certified T°	average thermistor T°	Δ	Post-Survey: No Correction Applied: post?	T (°C)	average certified T°	average thermistor T°	Δ
188888	g9 bot f	n	0	0.64	1.31	-0.67	y?				
			25	25.05	25.05	0					
			30	30.08	30.43	-0.35					
			37								
188890	24 surf b	y	0				n		0.04	0.11	-0.07
			25						25.35	25.29	0.06
			30						30.26	30.12	0.14
			37						37.32	37.11	0.21
188891	9m mid d	y	0				n		0.04	0.16	-0.12
			25						25.15	25.05	0.1
			30						30.4	30.28	0.12
			37						37.32	37.11	0.21
exceedences:			5 of 56				12 of 56				

Note: Above results are for six temperature meters identified in Table 10-1. Differences (Δ) shaded exceed 0.2 C°

TABLE 10-31
REGESSIONS FOR THERMISTORS THAT EXCEEDED THE ACCURACY TOLERANCE DURING THE PRE-SURVEY TESTING DEPLOYMENT PERIOD: 7 OCTOBER 1998 - 5 NOVEMBER 1998

Meter		Regression		
serial	location	slope	intercept	R^2
109806	22 bot f	---	---	---
124381	9m bot f	---	---	---
186193	22 surf b	1.0017942	-0.2645245	0.9999831
188828	24 surf a	---	---	---
188830	mh mid c	---	---	---
188831	m9 mid c	---	---	---
188833	9m surf a	---	---	---
188834	g9 surf a	---	---	---
188835	salem surf b	---	---	---
188837	g9 bot e	---	---	---
188838	m9 surf a	---	---	---
188839	22 surf a	---	---	---
188840	mh surf a	---	---	---
188841	24 mid c	---	---	---
188842	9g surf a	1.0160188	-0.4611536	0.9999982
188844	21 mid c	---	---	---
188845	24 mid d	---	---	---
188847	21 bot e	---	---	---
188848	g9 mid c	---	---	---
188850	salem surf a	---	---	---
188851	9m mid c	---	---	---
188852	23 mid c	---	---	---
188853	9m bot e	0.9936772	0.2446925	0.9999999
188854	9m surf b	---	---	---
188855	23 bot e	---	---	---
188857	23 surf a	---	---	---
188858	m9 bot e	---	---	---
188860	23 mid d	---	---	---
188861	mh surf b	---	---	---
188862	m9 bot f	---	---	---
188863	21 surf a	---	---	---
188864	9g mid c	---	---	---
188866	22 mid c	---	---	---

TABLE 10-31 (continued)

Meter		Regression		
serial	**location**	**slope**	**intercept**	**R^2**
188867	22 mid d	---	---	---
188868	23 bot f	---	---	---
188870	24 bot e	---	---	---
188871	g9 mid d	---	---	---
188872	23 surf b	---	---	---
188874	m9 mid d	---	---	---
188875	9g surf b	---	---	---
188877	mh bot e	---	---	---
188878	g9 surf b	1.0059269	0.0205688	0.9999948
188879	24 bot f	---	---	---
188880	21 mid d	---	---	---
188881	9g bot e	---	---	---
188882	22 bot e	---	---	---
188884	mh bot f	---	---	---
188885	m9 surf b	---	---	---
188886	mh mid d	---	---	---
188887	9g bot f	---	---	---
188888	g9 bot f	1.0162035	-0.6467317	0.9998013
188889	21 surf b	---	---	---
188890	24 surf b	---	---	---
188891	9m mid d	---	---	---
188894	21 bot f	---	---	---
188895	9g mid d	---	---	---

NOTE: Regression Equation: T = slope*Tmeas + intercept

Dashed line (---) indicates that a regression equation was not required

All temperature values for these meters are within the specified tolerance range

TABLE 10-32
SUMMARY OF RESULTS FOR POST-SURVEY TESTING OF TEMPERATURE MEASUREMENT INSTRUMENTS USED AT MOORINGS DEPLOYMENT PERIOD: 7 OCTOBER 1998 - 5 NOVEMBER 1998

Total number of meters tested: 56
Tolerance Level (°C): +/- 0.20

RANGE	# OF METERS (%)	METER LOCATION
Within targeted +/- 0.20 °C range	42 (75%)	
+/- 0.20 < x ± +/- 0.25	7 (12.5%)	23 middle d MH surface b 21 surface a 23 bottom f 9G bottom f 24 surface b 9M middle d
+/- 0.25 < x < +/- 0.30	3 (5.4%)	22 surface b 21 middle c 24 bottom f
+/- 0.30 < x < +/- 0.40	4 (7.1%)	9G surface a 9M bottom e 9G surface b M9 surface b

Note: There were 2 meters at each depth referred to as a,b at the surface, c,d in the middle, and e,f at the bottom.

All meters, excluding (22 surface b) and (22 bottom f), are missing data for the 37°C point during the pre-calibration.

Regression equations are based on a three-point calibration.

APPENDIX A

CALIBRATION/VALIDATION PROTOCOL FOR TEMPERATURE EQUIPMENT

Moored Thermistors All moored thermistors are factory calibrated and cannot be adjusted during calibration. To determine whether each thermistor is operating within the required test accuracy, all moored temperature monitoring equipment is calibrated in a constant temperature calibration bath against an NIST certified thermometer, at points across the anticipated range of the temperatures being measured. The thermistor calibration is conducted prior to and after the completion of the survey according to the following protocols:

Each thermistor, CT, and CT/DO instrument is checked in the water bath (Blue M Magni-Whirl Constant Temperature Bath or equivalent) against an NIST certified thermometer (Kessler model 171 @ 0.05°C increments or Kessler model 1714 Master Lab Thermometer @ 0.2°C increments or equivalent) at the following temperatures:

°C	°F
0.0	32.0
25.0	77.0
30.0	86.0
37.0	98.6

A calibrated Falmouth Ocean Temperature Module Quick Response thermistor or equivalent (0.5 sec response time; 0.003°C accuracy) is used simultaneously to confirm the temperature distribution in the water bath, and to verify the certified thermometer readings that will be recorded next to each thermistor.

The thermistors are placed in the primary water bath for 10 minutes to let them equilibrate before starting the calibration/validation. The detailed procedures for the Onset thermistors and the YSI, CT, and CT/DO monitors are provided.

- Onset Optic StowAway Temp Logger:

Connect the Optic Base Station to the host computer. Slide the Optic StowAway Temp into the Optic Coupler on the Optic Base Station.

Launch the Temp Logger and remove the logger from the Optic coupler. Place the Temp logger into the tempering bath for up to 15 minutes. Let it log data for up to 5 minutes. Record the certified thermometer readings at 1-minute intervals for final 5 minutes.

After the 5-minute calibration period, remove the logger and reattach it to the Optic Base Station for downloading of the temperature data. The logger temperature data will be compared to the certified thermometer data.

This procedure is repeated for the remaining test temperatures. Temp loggers that do not read within 0.2°C of the certified thermometer, and cannot make use of an appropriate correction factor, will be removed from service and returned to the manufacturer for repair.

- YSI Models 6000, 600XLM, and 6920 Multi-Parameter Water Quality Monitors

The YSI meter functions are accessible through the Sonde menu. Using the arrow keys, highlight and select Sonde from the top-line menu. At the main menu, select 5, System Setup. Set date, time, and instrument ID number. Press escape to return to the main menu.

Select Run from the main menu. The instrument is now ready to check. Following the calibration procedures outline for the Optic StowAway Temp Loggers, each YSI thermistor will be checked in the water bath against the NIST certified thermometer, downloaded, and results compared to the certified thermometer. Thermistors that do not read within 0.2°C of the certified thermometer, and cannot make use of an appropriate correction factor, will be removed from service and returned to the manufacturer for repair.

All thermistor calibration results will be recorded on a laboratory calibration sheet (see Table A-1 for example). This record will contain the serial number of each thermistor, serial number of the certified thermometer, the temperatures displayed on the certified thermometer and the thermistor being calibrated, dates on which the calibration was performed, and the name of the technician who performed the calibration checks. All calibration records will be inspected by the Quality Assurance Scientist and kept on file in the QC Department.

Mobile Thermistors All mobile temperature measuring instruments will be calibrated at a single laboratory to assure inter-equipment calibration.

The instruments will be placed into a well-stirred water bath with a minimum capacity of 5-gallons. A standard platinum resistance thermometer that has itself been recently calibrated to the Triple Point of Water and the Gallium Point will be used as the standard.

This test has an accuracy of 0.005°C. Mobile thermistors that do not read within 0.05°C of the rest, and cannot make use of an appropriate correction factor, are to be removed from service and returned to the manufacturer for repair.

The relative temperature of the mobile thermistors are also compared to the NIST standard to assure a 0.2°C precision in actual temperature.

TABLE A-1
LAWLER, MATUSKY & SKELLY ENGINEERS LLP QA/QC LABORATORY CALIBRATION SUMMARY TEMPERATURE VALIDATION

Date	Time	Certified Therm Reading (°C)	Thermistor No. (°C)	Thermistor No. (°C)	Thermistor No. (°C)	Thermistor No. (°C)	Thermistor No. (°C)	Thermistor No. (°C)	Ther No.

APPENDIX B
CALIBRATION/VALIDATION PROTOCOL FOR MOORED AND MOBILE CONDUCTIVITY/SALINITY METERS

The conductivity probes in each of the YSI Models 6000, 600XLM, and 6290 meters or equivalent will be calibrated prior to and immediately after each survey using the following protocol recommended by the manufacturer (YSI). This procedure calibrates conductivity (uS/cm) and salinity (parts per thousand).

Place 500 mL (approximately 1 pint) of conductivity standard in a clean calibration cup. The conductivity standard will be within the conductivity range expected at the project site.

Make sure that the sensor is as dry as possible prior to beginning this procedure.

Immerse the probe end of the sonde into the solution. Gently rotate and/or move the sonde up and down to remove any bubbles from the conductivity cell. The probe must be immersed past its vent hole.

Allow at least 1 minute for temperature equilibration before proceeding.

From the Main menu, select conductivity and enter the calibration value of the standard that you are using (mS/cm at 25°C) and press enter. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize. When the reading shows no significant change for over 30 seconds, press the enter key. The screen will indicate that the calibration has been accepted and prompt you to press any key to return to the calibrate menu.

Rinse the sonde in cool tap water and gently dry the sonde.

After calibration the sonde is checked against 4 additional conductivity standards covering the full range of conductivities expected at the site. These checks are conducted as follows:

Place 500 ml of conductivity standard in a clean calibration cup.

Make sure the sensor is as clean as possible.

Immerse the probe end of the sonde into the solution. Gently rotate and/or move the sonde up and down to remove any bubbles from the cell. The probe must be immersed past its vent hole.

Allow at least 1 minute for temperature equilibration before proceeding.

From the Main menu select Run. The current values of all the selected parameters will appear on the screen and will change with time as they stabilize. When the conductivity reading shows no significant change over 30 seconds, record the result in the observed column of the data sheet.

Rinse the sonde in cool tap water and gently dry the sonde.

All calibration data will be recorded on a laboratory calibration sheet (see Table B-1 for example). This record will contain the identification number of each unit, the results of the comparison between the conductivity standard and the conductivity probe, dates on which the calibrations were performed, and the name of the technician who performed the calibration check. All calibration records will be inspected by the Quality Assurance Scientist, and kept on file in the QC Department.

Five standard solutions with prescribed conductivities ranging from 2.8 to 36.2 ms/cm (approximately 1.5 to 24.3%) are used to test the meters according to the above procedure. The conversion of conductivity and temperature to salinity is based on the equation provided by Falmouth and reproduced at the end of this appendix.

TABLE B-1
LAWLER, MATUSKY & SKELLY ENGINEERS LLP QA/QC LABORATORY CALIBRATION SUMMARY CONDUCTIVITY/SALINITY VALIDATION

Date	Time	Meter No.	Probe No.	KCL Std. (mS/cm)	NIST Cert. Therm (°C)	Meter Temp °C	Barometric Press. (mm Hg)	Expected Value (mS/cm)	Obse Valu (mS/

Note 1: *% Difference = ((Expected – Observed) / Expected) * 100*

Conversion Equation Conductivity -->

Calculations based on code supplied by Falmouth

Assume:

ıre	**P {decibars} =**	9.8692

n:

:rature	**T {°C}**	from lab test
ĭc conductance	**SC {uS/cm}**	from lab test

ulations:

T	**DT =**	T-15
ıctivity	**CND =**	SC/42914
	RT35	(((0.0000000010031*T-0.00000069698)*T +0.0001104259)*T+0.0200564)*T+0.67666097
	Cp =	((0.000000000000003989*P-0.000000000637)*P+0.0000207)*P
	Bt =	(0.0004464*T+0.03426)*T+1
	At =	(-0.003107*T+0.4215
	RT	SQRT(ABS((CND//RT35*(1+Cp/(Bt_At*CND))))))
ty	**SAL =**	((((2.7081*RT-7.0261)*RT+14.0941)*RT+25.3851)*RT-0.1692) *RT+0.008+(deg_c/(1+0.0162*deg_C))*(((((-0.0144*RT+0.0636 *RT-0.0385)*RT-0.0066)*RT-0.0056)*RT+0.0005)

APPENDIX C

CALIBRATION PROTOCOL FOR DISSOLVED OXYGEN METERS

The dissolved oxygen probes in each of the YSI Models 6000, 600XLM, and 6290 meters or equivalent are calibrated prior to and immediately after each survey using a saturated air chambers protocol in the laboratory. In addition, the air saturated water calibration is performed on all probes/meters prior to the survey. As stated in Section 10.1.2.2, the presurvey calibration entails adjustment to the instruments to attain calibration; the instrument reading during the postsurvey calibration was recorded and compared to the saturation concentration before readjusting the instrument, if necessary.

Saturated Air Chamber Calibration Procedure

From the Sonde Main menu, select Calibrate: The calibrate menu will be displayed.

Place a wet sponge inside of a clean, empty calibration cup. Place the probe end of the sonde into the calibration cup. Allow 10 to 15 minutes to elapse so that the air in the chamber becomes saturated with water vapor and the D.O. sensor will warm up and stabilize.

Select Calibrate form the Main menu and DO% to access the DO% calibration procedure.

Enter the barometric pressure in mm of Hg, in Delaware or study area, then hit enter. The computer will indicate that the calibration procedure is in progress.

After approximately 1 minute, the calibration will be complete. Press any key, as instructed, and the screen will display the percent saturation value, which corresponds to your local barometric pressure input.

Calibration of dissolved oxygen in the DO% procedure also results in the calibration of the DO (ppm) mode.

Air Saturated Water Calibration Procedure (Only Done on Presurvey Calibration)

To confirm the air calibration results, the protocol for calibration using air-saturated water will be completed on 10% of the units being calibrated each day as follows:

A volume of nearly air-saturated water will be set up in a container. Three BOD bottles will be filled with this water and fixed for Winkler dissolved oxygen analysis. Prior to drawing off the water, a DO reading will be recorded in the bucket with the water quality instrument. The three oxygen results determined by the Winkler Titration method will be averaged and compared to the instrument reading. If one of the values in the BOD bottles differs from the other two by than 0.5 ppm, that value will be discarded, and the remaining two values will be averaged and compared to the instrument reading. The difference between the Winkler readings and the meter will be recorded and used to calculate a correction factor when reviewing the data. Meters that differ by more than 0.5 ppm from the wets will be recalibrated and retested.

All dissolved oxygen calibration results will be recorded on the laboratory calibration sheet (See Table C-1 for example). This record will contain the identification record of each unit, the saturated air results, any comparisons between the Winkler samples and the unit, dates on which the calibration was performed, and the name of the technician who performed the calibration. All calibrations records will be inspected by the Quality Assurance Scientist, and kept on file in the QC Department.

TABLE C-1
LAWLER, MATUSKY & SKELLY ENGINEERS LLP QA/QC LABORATORY CALIBRATION SUMMARY DISSOLVED OXYGEN VALIDATION

Date	Time	Meter No.	Probe No	Certified Therm-ometer (°C)	Thermistor	Expected Value		Observed Value		Adjustment of Observed to Expected		% Di
						(%)	(ppm)	(%)	(ppm)	(%)	(ppm)	

Note 1: *% Difference = ((Expected – Observed) / Expected) * 100*

APPENDIX D
VALIDATION PROTOCOL FOR DEPTH/PRESSURE EQUIPMENT

The objective of field validation is assurance that the unit is basically functional within a reasonable range of accuracy immediately prior to use or deployment during the survey. It is intended to prevent use of instruments that have clearly begun to malfunction since calibration.

The basic procedure involves submerging the instrument (tide gauge) to a known depth in water and verifying that the instrument reads that depth to within acceptable limits. The factors affecting the test include: the density of the water (a function of salinity and temperature), any waves or other short-period motion of the water surface, and any error in measuring the physical depth of the instrument below the water surface.

Mobile Instrument Procedure

The test site will be the deployment site, which is protected from waves and wakes.

Attach the instrument to a length of light chain or low-stretch dacron rope sufficient to lower the instrument to the maximum available depth at the test site. Weight the bottom of the chain or rope, to assure that it will hang vertically in the water column.

Tension the chain or rope; then use a surveyor's tape to measure the distance from the water surface tot he depth sensor on the instrument. (For the FSI MicroCTD-3, the calibration point is the end of the pressure sensor housing when the CTD is oriented with the pressure sensor housing held vertically upward.)

Connect the instrument to a computer running a terminal emulation program, such as ProCom Plus for Windows, according to the instructions in the instrument manual, and initiate data acquisition at the highest rate available. Record the pressure displayed on the PC screen.

Retrieve the instrument from the water.

Convert the absolute pressure to excess pressure by subtracting the atmospheric pressure (14.7 psi). Convert the excess pressure to the water depth by using the equation. Compare that depth with the chain/rope depth measured using the steel tape. The instrument depth should be within 0.2 m (0.6 ft) of the depth measured by steel tape.

Pe
D________K
UW

Where:

D = depth
Pe = excess pressure (LB/in.^{2})
UW = unit weight of water (lb/ft^3)
K = conversion factor (144 in.^{2}/ft^2)

APPENDIX E

CALIBRATION/VALIDATION PROTOCOL FOR ACOUSTIC DOPPLER CURRENT PROFILER (ADCP)

Velocity data in the Delaware River will be collected using a boat-mounted mobile Acoustic Doppler Current Profiler (ADCP), and a bottom-mounted, upward-facing, stationary ADCP. The instrument uses the shift in reflected sound frequency to measure the velocity indirectly. By combining data from four sound beams and timing the echo delay, the ADCP is able to assign both speed and direction to layers of water at known distances from the instrument. The ADCP can measure the velocity at varying depths over different spatial extents, the geometry of which is defined by the user. The ADCP is an inherently complex instrument which provides its user flexibility in both the type of data collected and the manner in which it is collected. The mobile ADCP will be used to determine the variability of the velocity within a cross-section of the Delaware for each tidal phase studied. The bottom-mounted ADCP will provide variability of velocity with depth in the immediate vicinity of the discharge throughout the study period.

The ADCP must first be configured for the specific environment and application for which it will be used. The Workhorse ADCP requires a maximum apparent velocity input, which corresponds to the maximum velocity the ADCP will measure (i.e., the vector sum of water velocity and boat speed). The value that should be used is 650 cm/sec, which is the maximum value the instrument is capable of measuring. This value may be reduced to improve data accuracy, but at its maximum, an error on the order of 5 cm/sec may be expected, which is well within an acceptable range for the intended use of this information. Previous surveys indicate that velocity varies significantly both temporally and spatially, and sacrificing some accuracy provides a greater assurance that usable data will be produced and that the operator will have greater flexibility in terms of boat speed and heading during data collection. The configuration will be verified by technical support personnel from RDI (the ADCP manufacturer) and by preliminary testing under environmental conditions similar to those anticipated during data collection.

When the configuration of the instrument has been proven to be acceptable for the anticipated conditions, one ADCP will be deployed on the bottom of the river in the vicinity of the discharge, and the other ADCPs will be mounted on boats that will transect the river. The bottom ADCP will remain deployed for 12 days and will be configured to record data at three-foot intervals every 2.5 minutes. During the deployment, the bottom ADCP operation will be checked every 3 to 4 days. The boat-mounted ADCPs will collect data while an operator watches the data collection in real-time on a PC. Real-time display will be employed in which the magnitude, direction, and percent good velocity can be viewed. If the magnitude of these values falls outside of anticipated ranges, the time and duration of these data would be noted so that these data can be disregarded in future analyses.

APPENDIX F
CALIBRATION/VALIDATION PROTOCOL FOR ELECTRONIC ANALYTICAL BALANCES

Two electronic scales will be used, one for each unit. This application requires the ability of the scale to calculate a reduction in mass on the scale of approximately 4 kg in 0.5 hour to within 5%, that is, 200 g.

The resolution on the scales is 50 g. Preliminary analyses indicated that if the times at which changes in scale readout are noted, the resolution may be further improved.

Scales will be calibrated prior to use. Scales that cannot be calibrated to within an accuracy of 5%, as measured above, will not be used. A certified laboratory will be retained to perform the calibration.

APPENDIX G
CALIBRATION/VALIDATION PROTOCOL FOR FLUOROMETERS

Calibration will involve the addition of known increments of dye calibration solution (10 mg/l) to a known volume of Delaware water prior to the start of dye injection. This water will be continuously circulated through the fluorometer and back into the container for the remainder of the calibration. Calibration solution will then be added from a 50-ml burette to raise the concentration of dye, by increments, in the circulating water. After each addition, when the water had reaches a well-mixed condition, temperature and fluorometer measurements at the appropriate fluorometer scales will be recorded every 2 to 3 sec for approximately 30 sec Temperature will be measured using the fast response Thermistor Temperature Modules.

Dye concentrations from 0.0 to 100.0 µg/l will be used for calibration. Calibration readings will be corrected to a reference temperature, using the following formula (Wilson 1968):

$$\text{Reading}_{(RT)} = \text{Reading}_{(T)} * (\exp^{0.026 * (T-RT)})$$

Where:

Reading	= fluorometer reading in volts
T	= ambient water temperature (°C)
RT	= reference temperature (°C)

To account for the ambient fluorescence in the 100 l sample of Delaware River water, the fluorescence reading prior to dye addition for each of the four fluorometer scales will be subtracted from the other readings at the corresponding scale. This will remove the background fluorescence of the calibration water from the data set. Corrected fluorometer readings will then be linearly regressed versus dye concentration to determine the intercept (A) and slope (B) for each fluorometer scale.

Background Fluorescence of the Study Area. To account for the background sources of fluorescence (e.g., phosphorescent algae), all measured fluorescence data will be corrected by subtracting the mean background value. Background measurements will be taken prior to the start of dye discharge.

The mean background fluorescence will be subtracted from all the fluorescence data before they are converted to dye concentration values.

Conversion of Fluorescence Values to Dye Concentration. After the calibration regression coefficients (intercept [A] and slope [B] for each fluorometer scale) are determined and the mean background fluorescence deducted, the following equation (Wilson 1968) will be used to calculate dye concentration (C) from the fluorometer reading and water temperature (T):

$$C = A + B * \text{Reading}_{(T)} * \exp^{(.026 * (T-RT))}$$

As shown in the above equation, the reference temperature used during calibration will be applied during conversion of fluorescence values to dye concentration.

TABLE G-1
SUMMARY FULL SCALE REGRESSION

Flourometer	Run	Slope	Constant	R Squared
Unit 1	1	0.3192682	-0.0975661	0.9999356
Unit 2	1	0.3028166	-0.0822066	0.9999315
Spare	1	0.3200486	-0.3655191	0.9999442
Curvet	1	0.3359206	-0.3596134	0.9982152
Unit 1	2	0.3295441	-0.0717303	0.9997274
Unit 2	2	0.3120556	-0.0616382	0.9997235
Spare	2	0.3302016	-0.3677115	0.9997583
Curvet	2	0.3253610	-0.4537986	0.9943630
Spare	3	0.3265673	-0.5178466	0.9999906
Heather	3	0.1688892	-0.1308006	0.9999917
C-Hawk	3	0.1664729	-0.4789590	0.9999661
Parker	3	0.1690547	-0.0914251	0.9999501

Note:
Parker is boat 1
Heather is boat 2
C-Hawk is boat 3

APPENDIX H
VALIDATION OF POSITION AND TIME DATA

This appendix addresses the field validation of the position and time data to be recorded by the data logging computers.

POSITIONING DATA

All positioning will be accomplished using Differential Global Positioning System (DGPS) instruments. DGPS instruments derive their primary positioning information from radio signals broadcast by a constellation of navigation satellites operated by the United States Department of Defense, known as the Global Positioning System (GPS). Typical radial accuracy of the raw GPS positioning data is about 200 m, but can be substantially better, depending on the current operational configuration of the system. Regardless of the GPS operational configuration, DGPS instruments correct the raw GPS positions to assure a radial accuracy of 3 m, by applying differential corrections broadcast from a local reference station. All DGPS instruments used on the survey will use corrections broadcast by the United States Coast Guard for the lower Delaware River.

The current operational status of both the GPS satellites and the differential correction broadcasts will be monitored during the survey by accessing the US Coast Guard Navigation Center via the World Wide Web (http://www.navcen.uscg.mil). This will assure that the DGPS instruments will be receiving correct data from the government-operated elements of the system. The survey will be delayed in the extremely unusual event that the government-operated elements are not able to provide usable data during the survey.

Thus, the only additional potential source of error is the DGPS instrument aboard each survey vessel. In the context of the survey, DGPS instrument accuracy is not a function of location, as long as a Coast Guard differential correction is available. There will be five DGPS units in the field during the survey, so the best way to field validate the operation of these instruments is inter-comparison of the five units at a fixed location. It would be extremely unlikely for more than one unit to fail under the survey conditions, so this type of inter-comparison can be expected to identify any such unit.

Each unit will first be installed aboard its vessel in its final operating configuration, including the location of the GPS antenna[1] and any other electronics to be used aboard the vessel during the survey. When all five vessels have been fitted out with their full suite of instruments, each vessel will be positioned so that its antenna is adjacent to a fixed reference, such as a pier piling, that does not block the antenna's "view" of the sky. All instruments and computers aboard the vessel, including any navigational instruments

1 The fundamental position information reported by the DGPS unit is the position of the GPS antenna on the WGS-84 ellipsoid.

normally found aboard the vessel, will be operating during the test. The position reported by each unit will be recorded and plotted. Each unit will be considered to be operating correctly if its position is within 3 m of each other unit's position. Failure of any unit to achieve this criterion will be investigated and, if attributable to the unit, it will be replaced with a functioning unit. If attributable to another cause, such as electronic interference, attempts will be made to resolve the problem. After resolution of any such DGPS failure, all five units will be re-tested as described above.

TIME DATA

Each data record logged by an on-board data computer or fixed instrument will be tagged with the time and date the data were acquired. The time/date used to tag the records will be the time/date of the clock in the computer or fixed instrument doing the logging.

An accuracy of ±1 to 5 minutes would be more than sufficient for the ultimate use of the data in modeling and oceanographic analysis, but, to achieve correlation of data among the various instruments, a much higher level of accuracy is required. All data logging computers and instruments will be synchronized to within ±1 second of the time signal available from the Global Positioning System. The GPS time signal is actually several orders of magnitude more accurate than is required for this survey, so it can be relied on as a time standard. The synchronization accuracy is limited to ±1 second by the resolution of the software used to set the computer clocks, which is typically 1 second. GPS units will be available throughout the survey period, so the time standard will always be available.

The fixed instruments will be synchronized to the GPS time when they are deployed and the action recorded in the instrument log. When the instruments are retrieved, the instrument clock will be compared with the GPS clock and the result recorded in the instrument log. This procedure will allow the time tags to be adjusted for any clock drift during the survey period.

The mobile data logging computers will be synchronized with the GPS time signal on a daily basis during the survey period. Before the clocks are synchronized, the clock reading will be compared with the GPS signal and the result recorded in the data log, to permit adjustment for any clock drift.

Figure 10-1
PSE&G 2-Unit Intensive Survey
Study Area

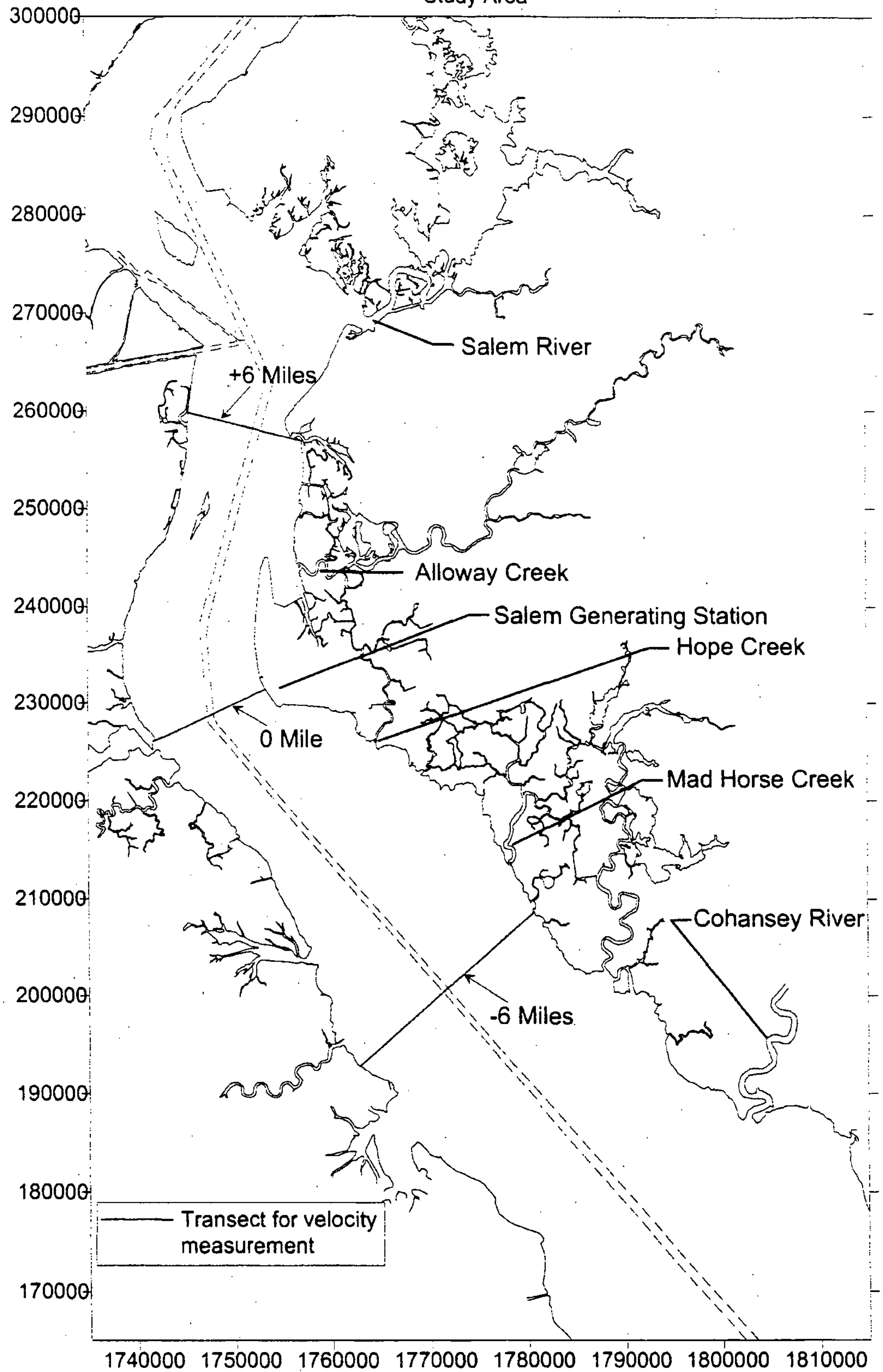
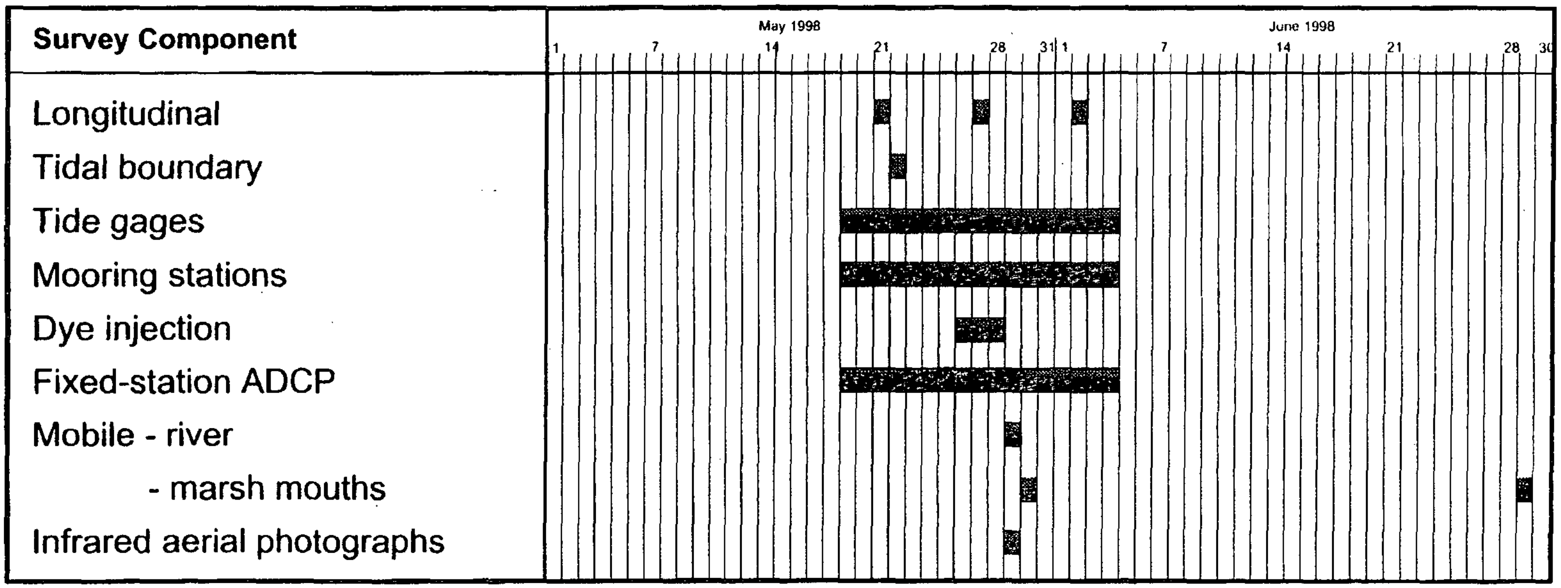
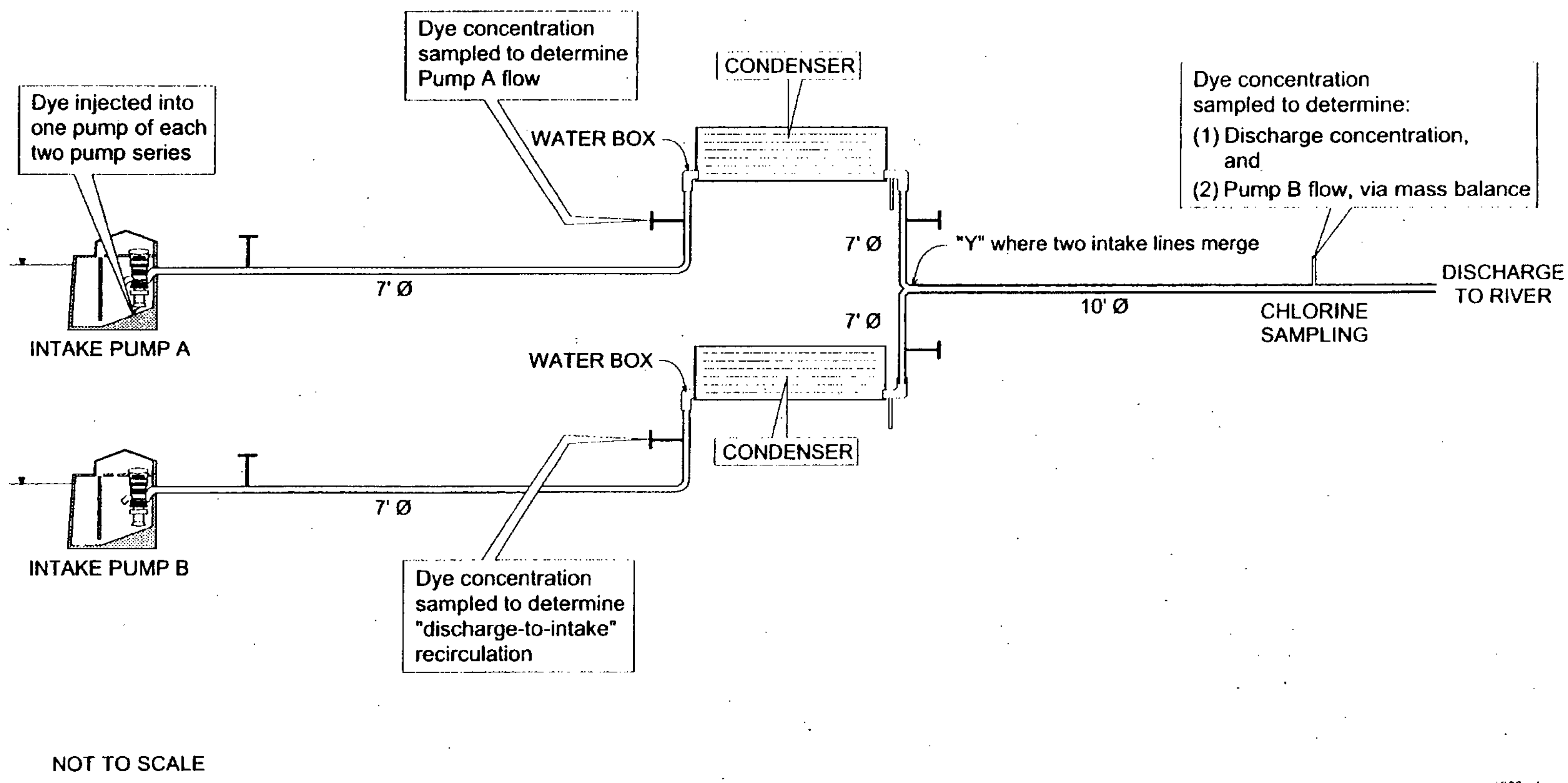


Figure 10-2

Timeline of 2-Unit Intensive Survey Components





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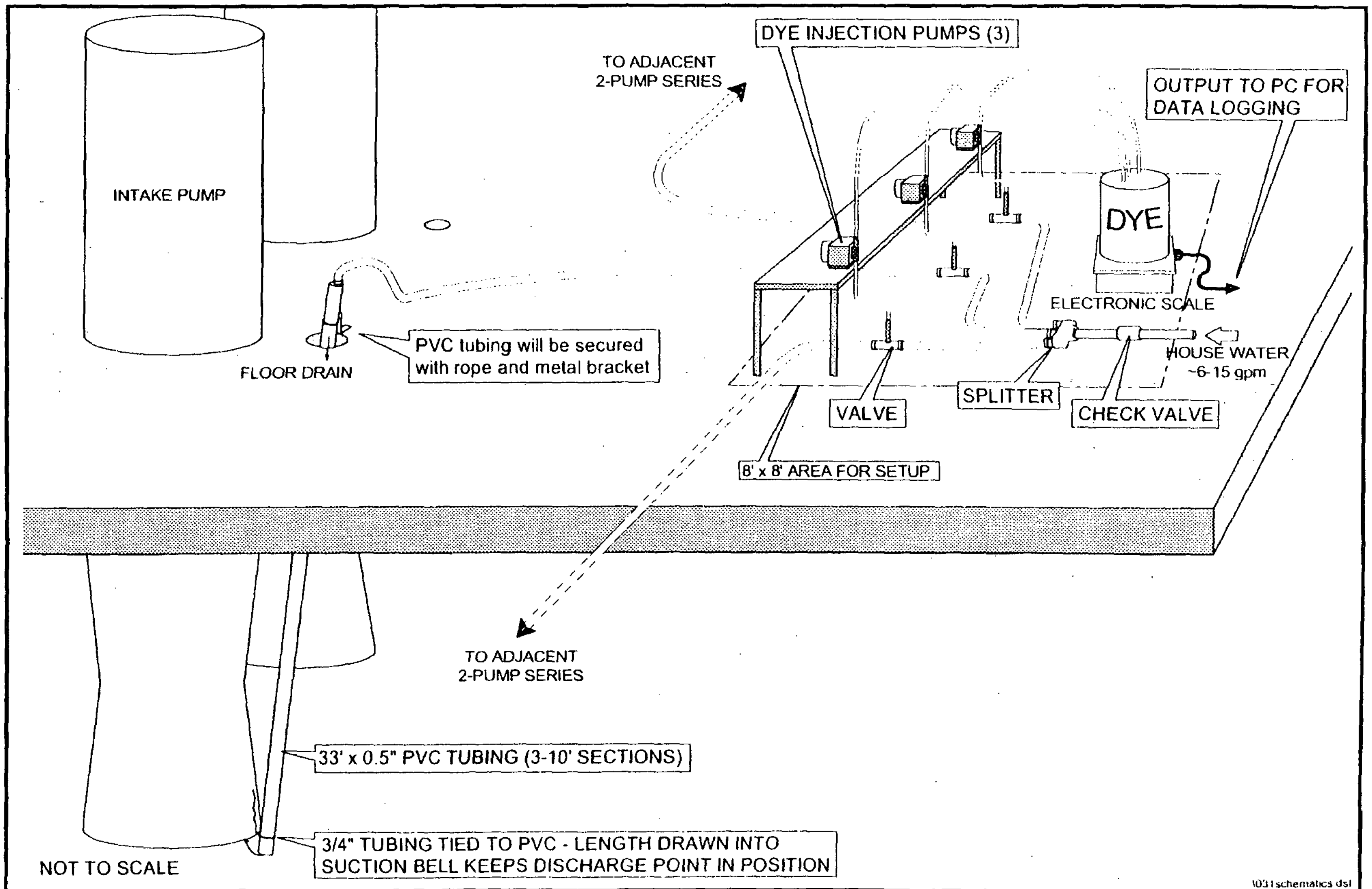
Schematic of Cooling Water Flow Path
(one representative series of six)

Figure 10-3



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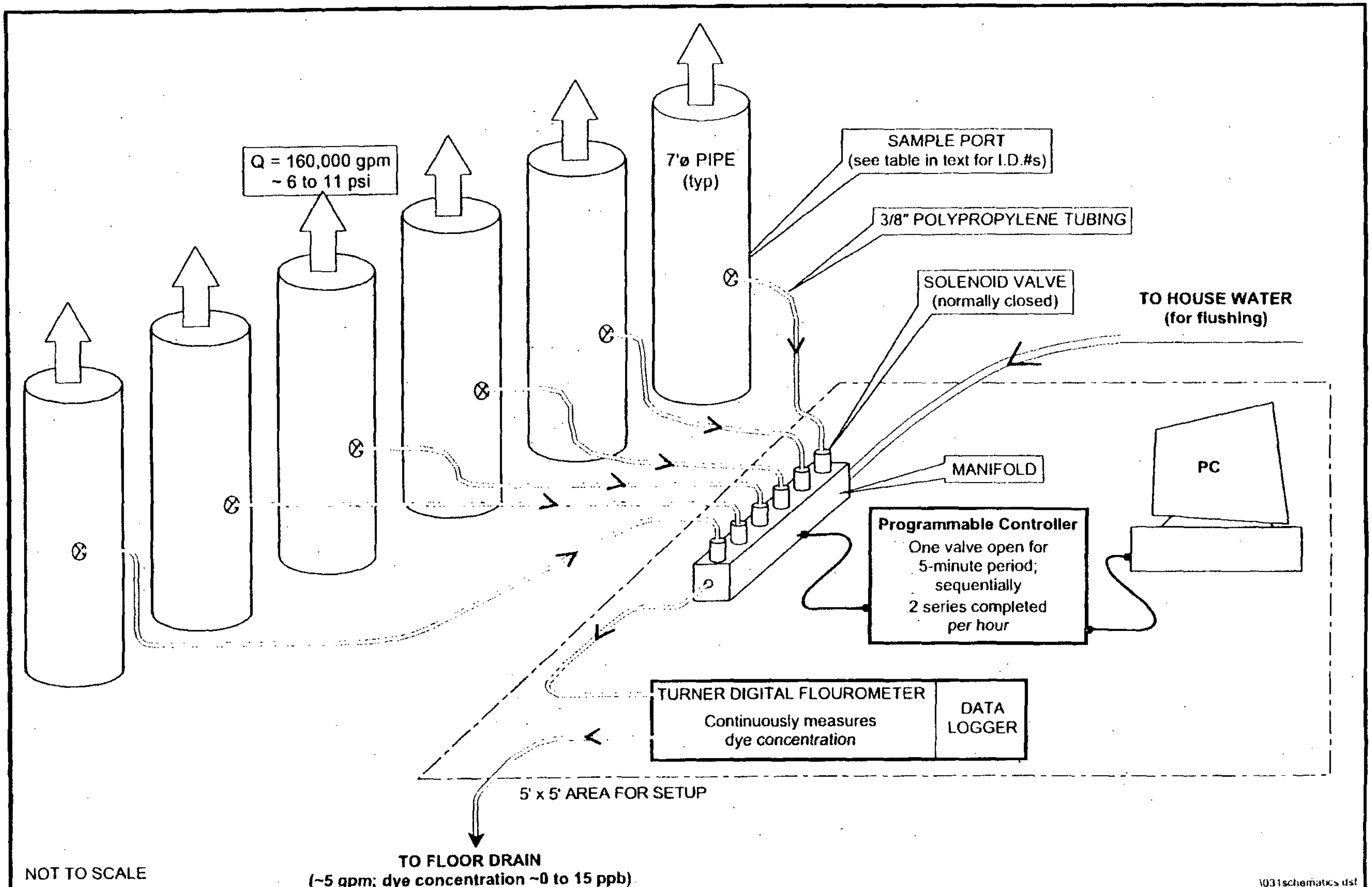
Schematic of Dye Injection System Setup in Pump House
(for one representative unit)

Figure 10-4



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Schematic of Dye Sampling System in Condenser Building

Figure 10-5

Figure 10-6

Schematic of Salem Generating Station Circulating Water System Showing Dye Injection and Dye Sampling Points

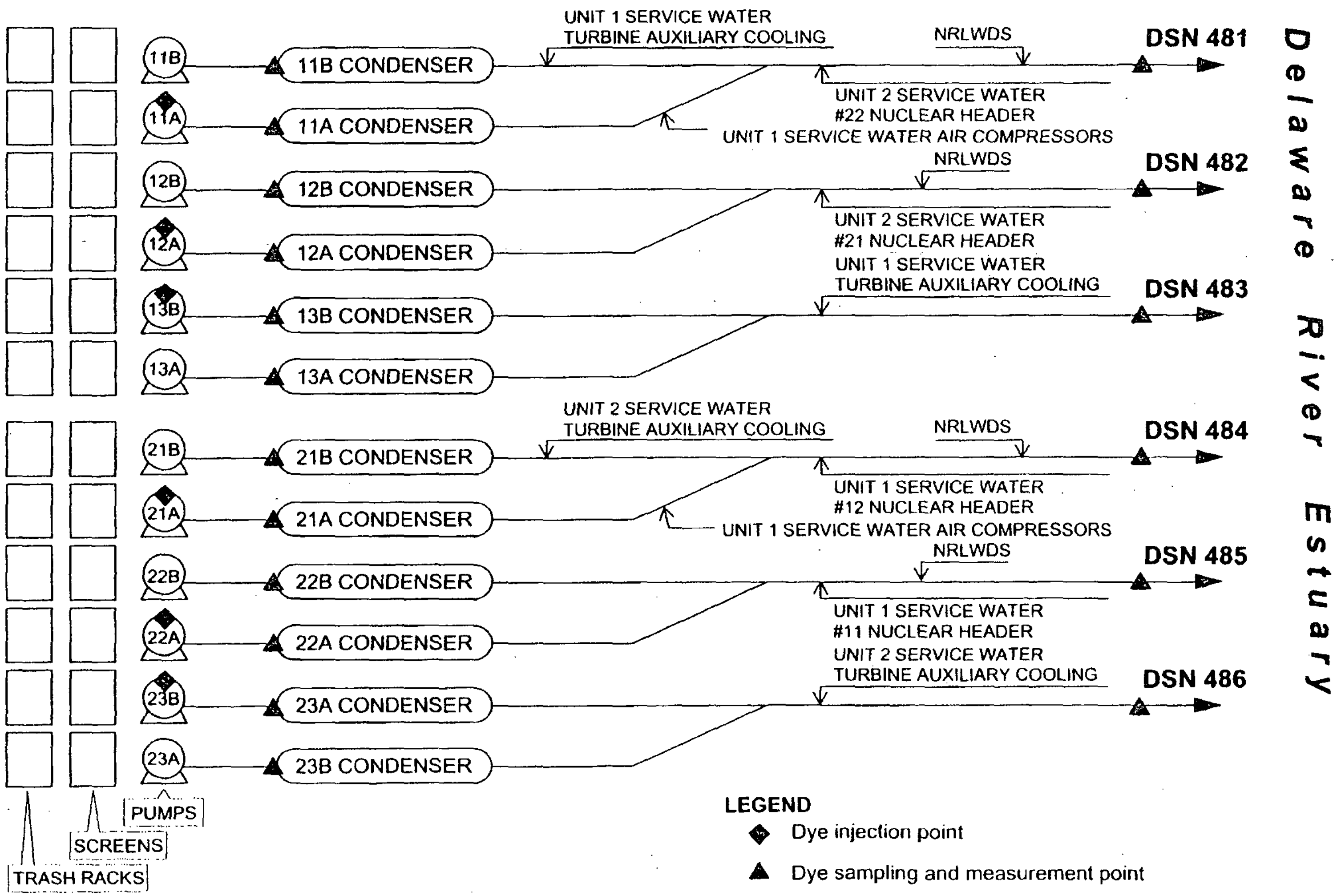


Figure 10-7
PSE&G 2-Unit Survey
Transects Planned for Five Boats on Mobile Survey

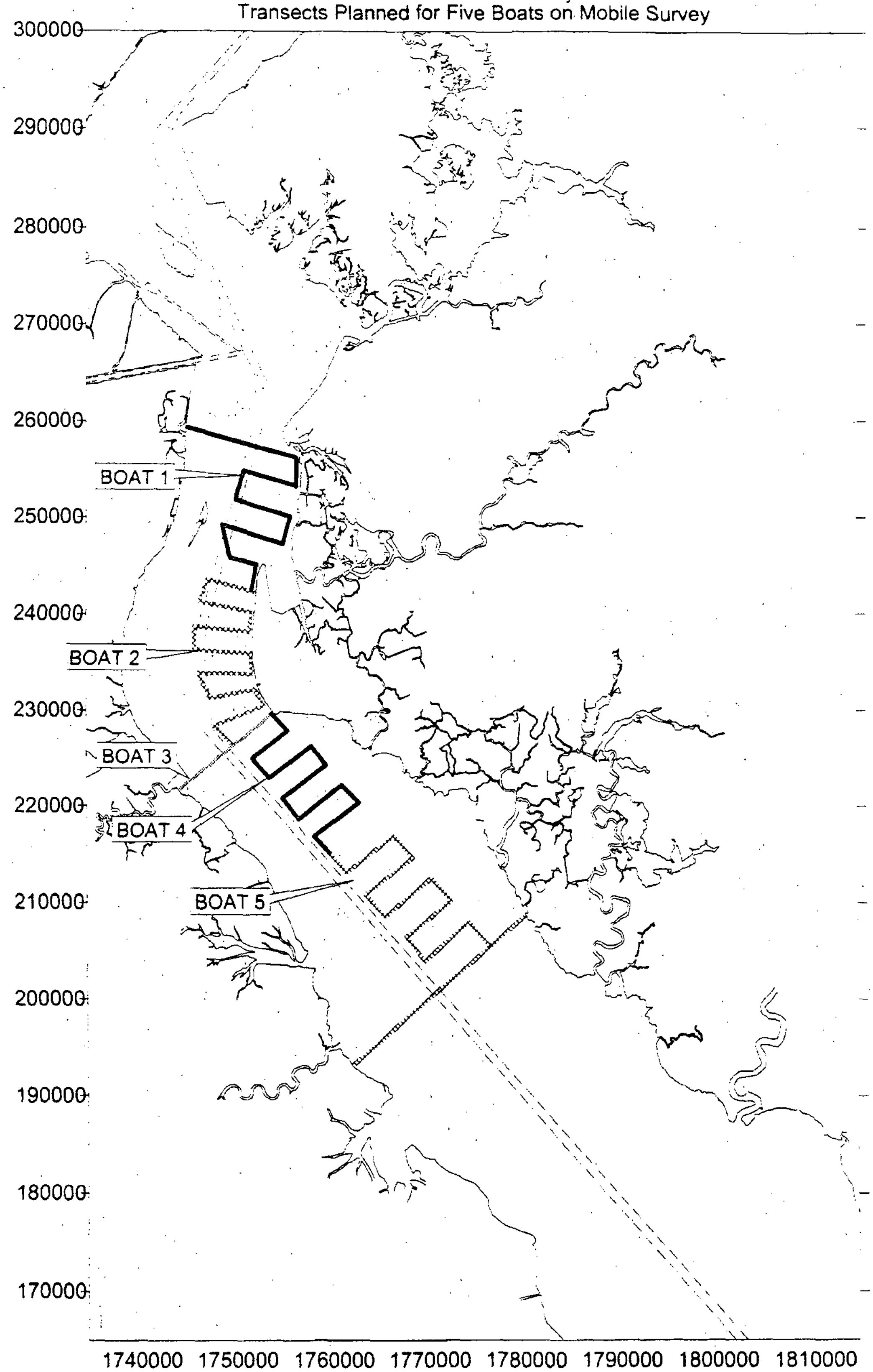


Figure 10-8

Typical Hardware Setups for Survey Boats
2-Unit Survey

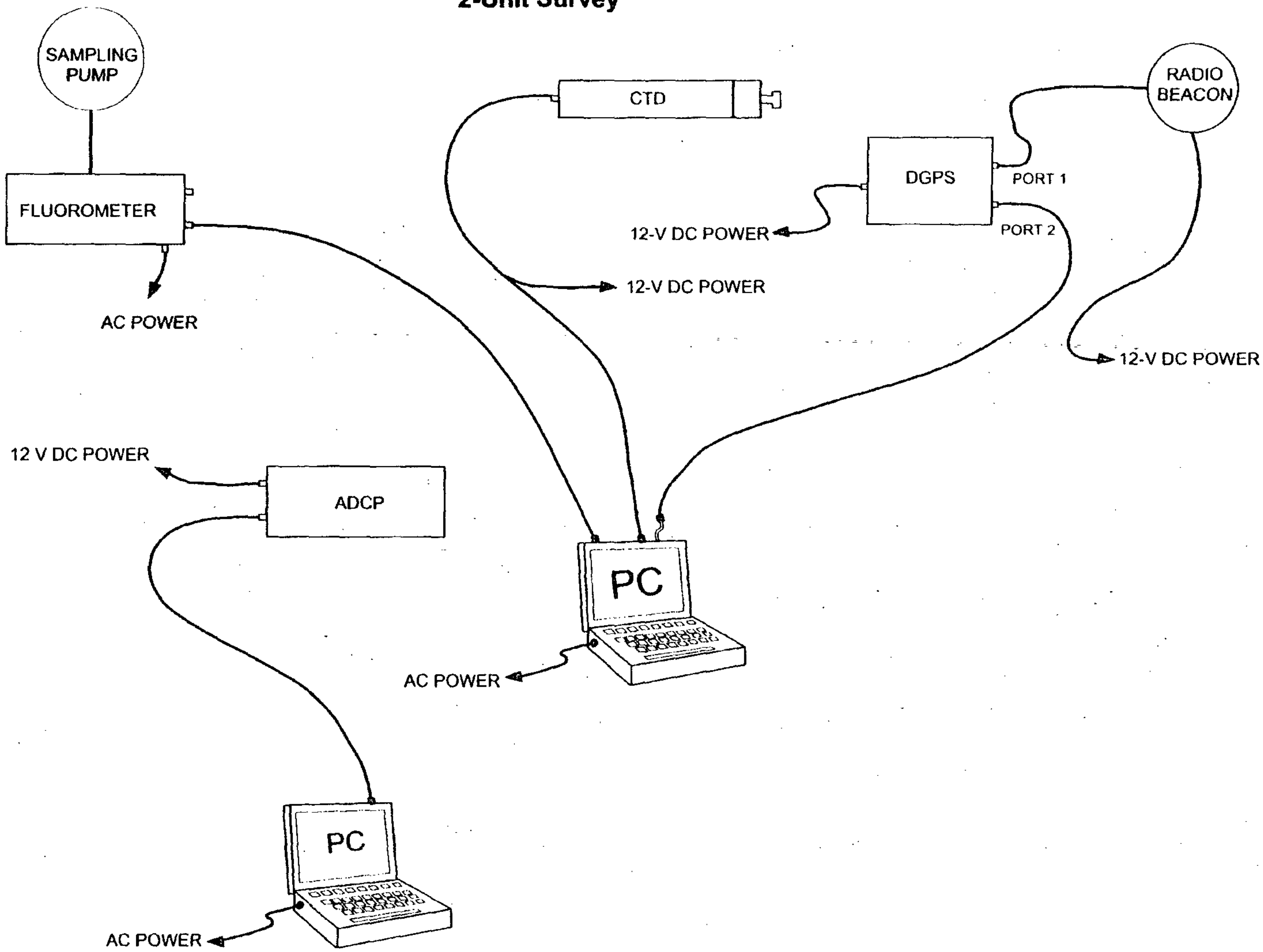


FIGURE 10 - 9
PSE&G 2-Unit Survey; 26 May 1998
Transect Locations
Background Survey

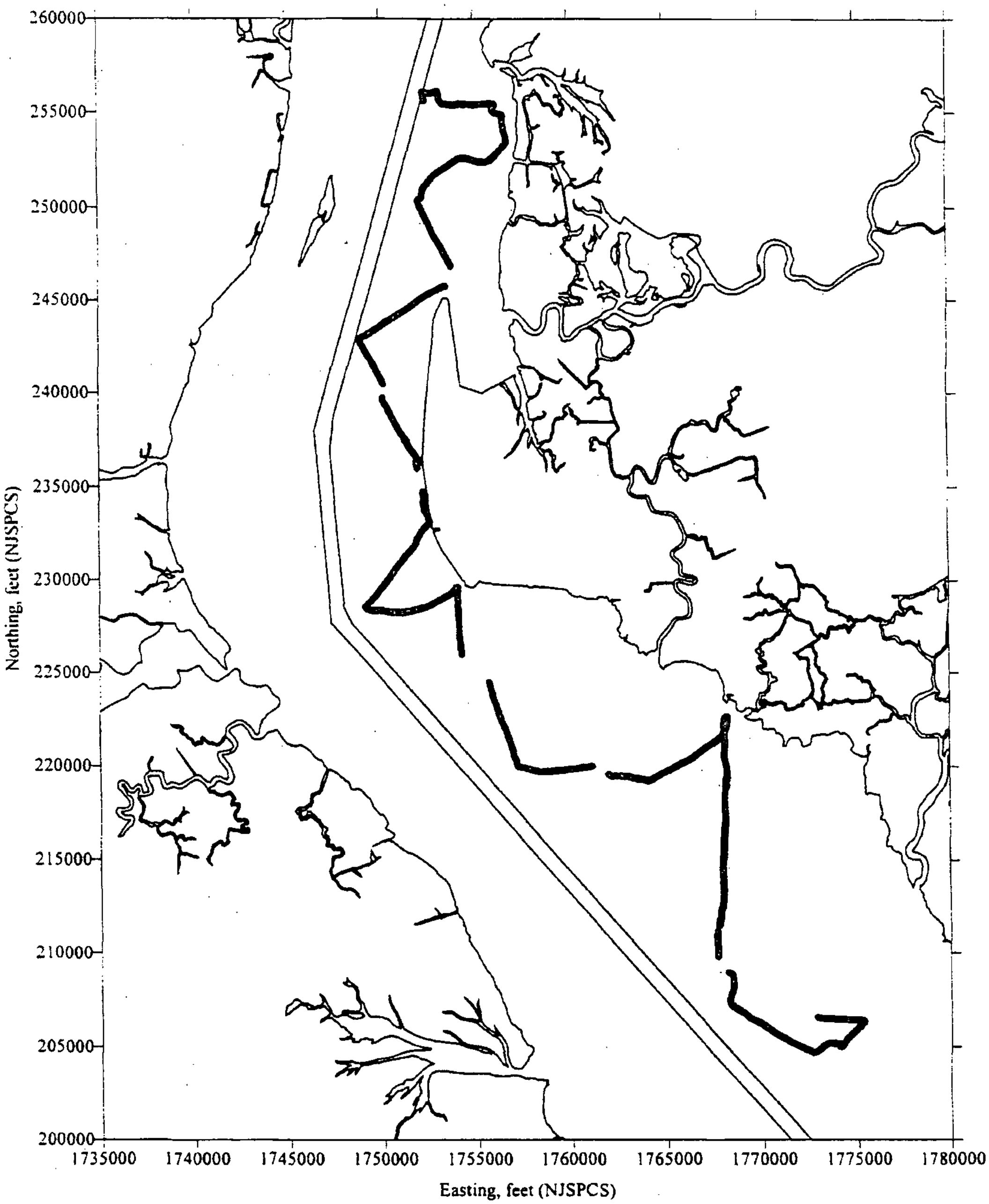


FIGURE 10-10
PSE&G 2-Unit Survey; 19 May - 04 June 1998
Moorings Locations

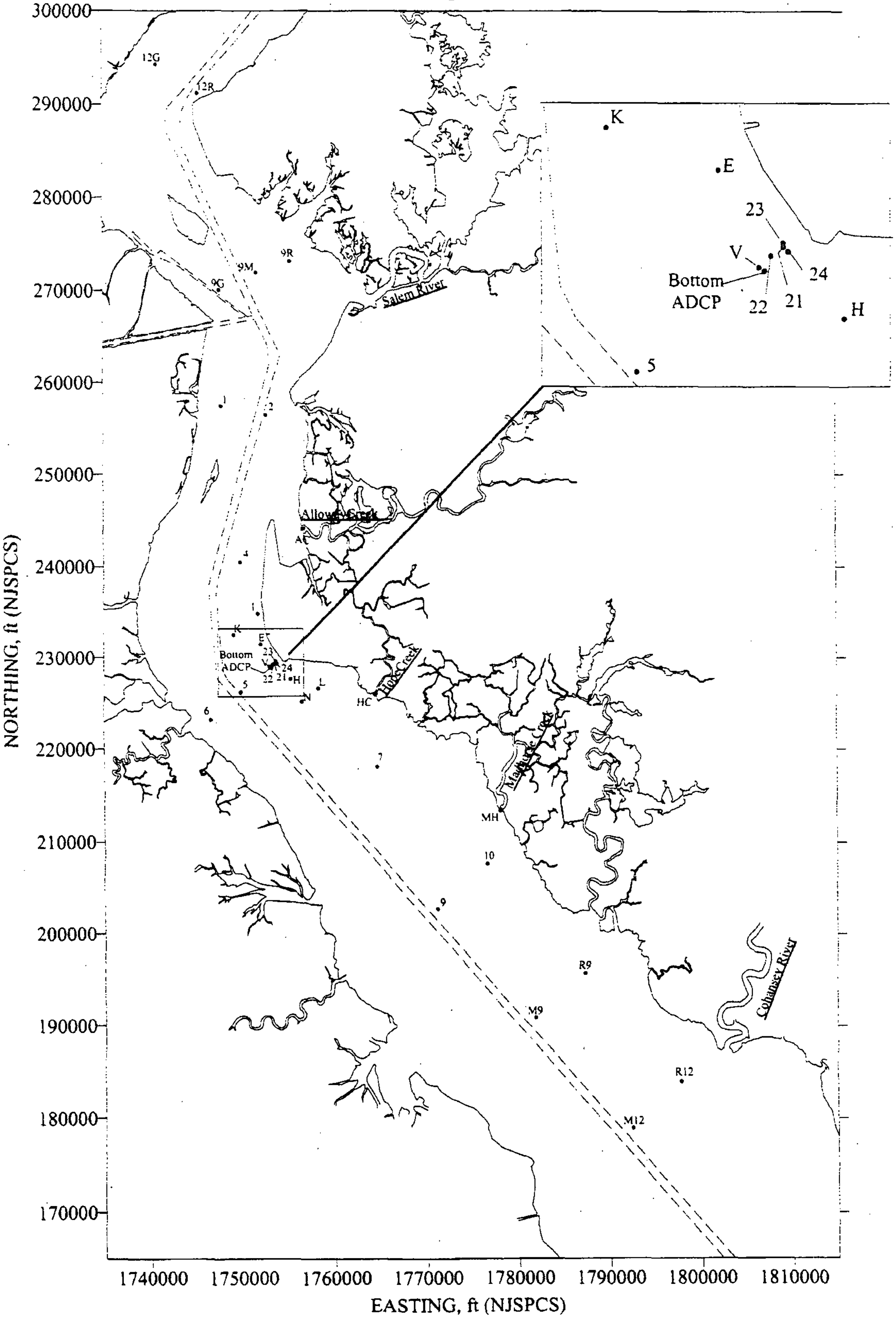


Figure 10-11
Mooring Configuration for 2-Unit Survey

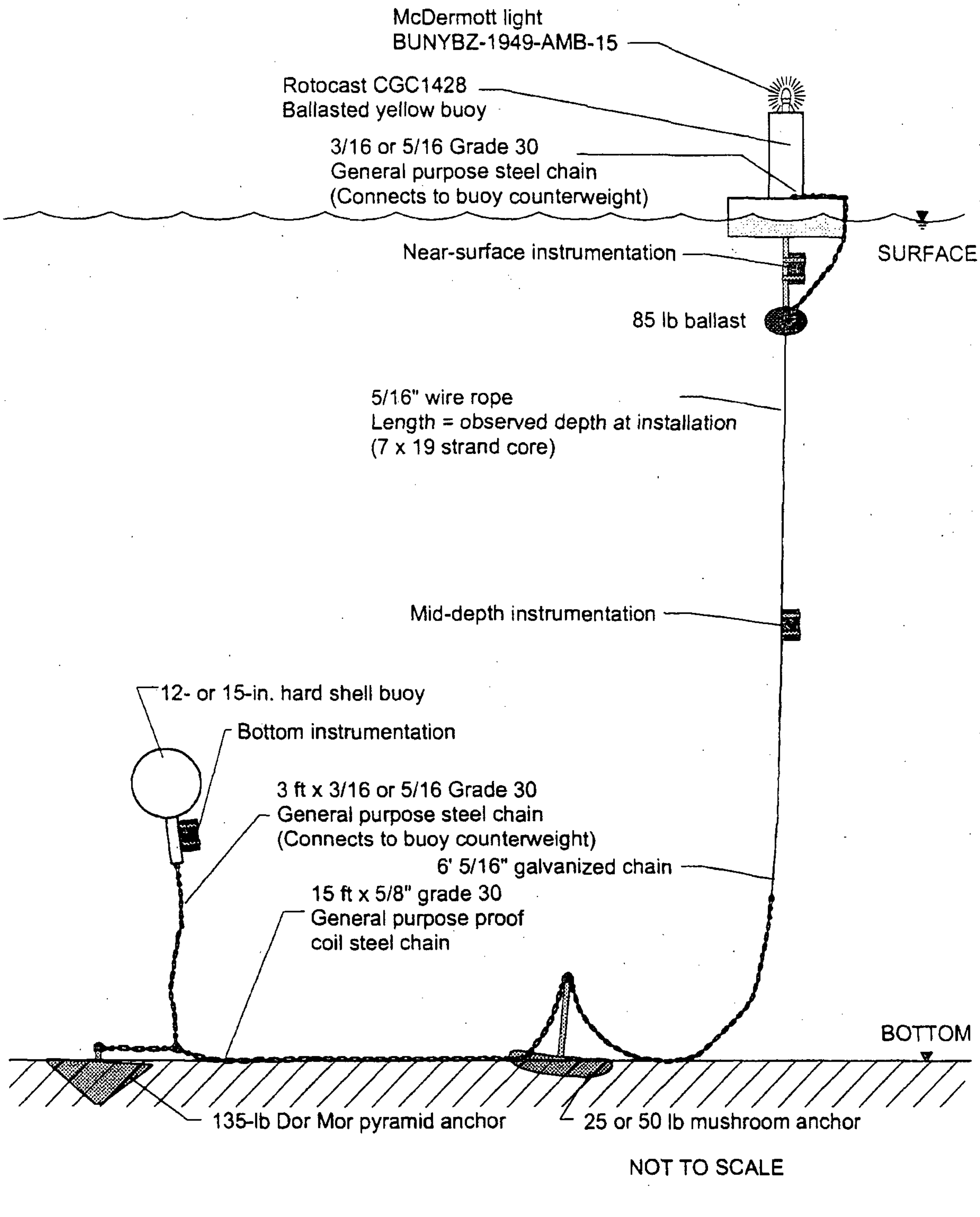


FIGURE 10-12

PSE&G 2-Unit Survey: 19 May - 04 June 1998
Delaware River / C&D Canal Tide Gages

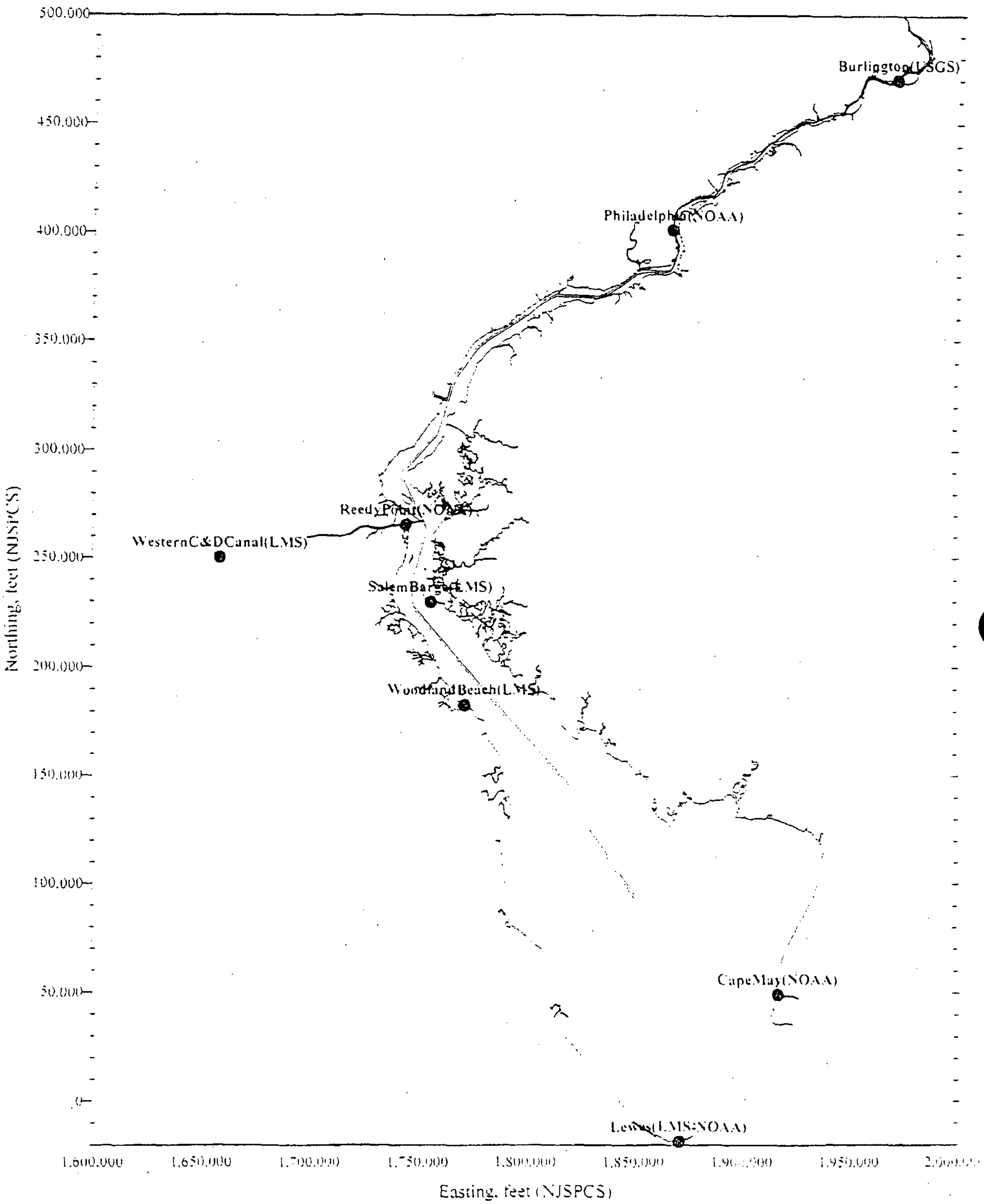


FIGURE 10-13

PSE&G 2-Unit Survey; 19 May - 04 June 1998
Location of Vertical Velocity Distribution (Bottom ADCP)

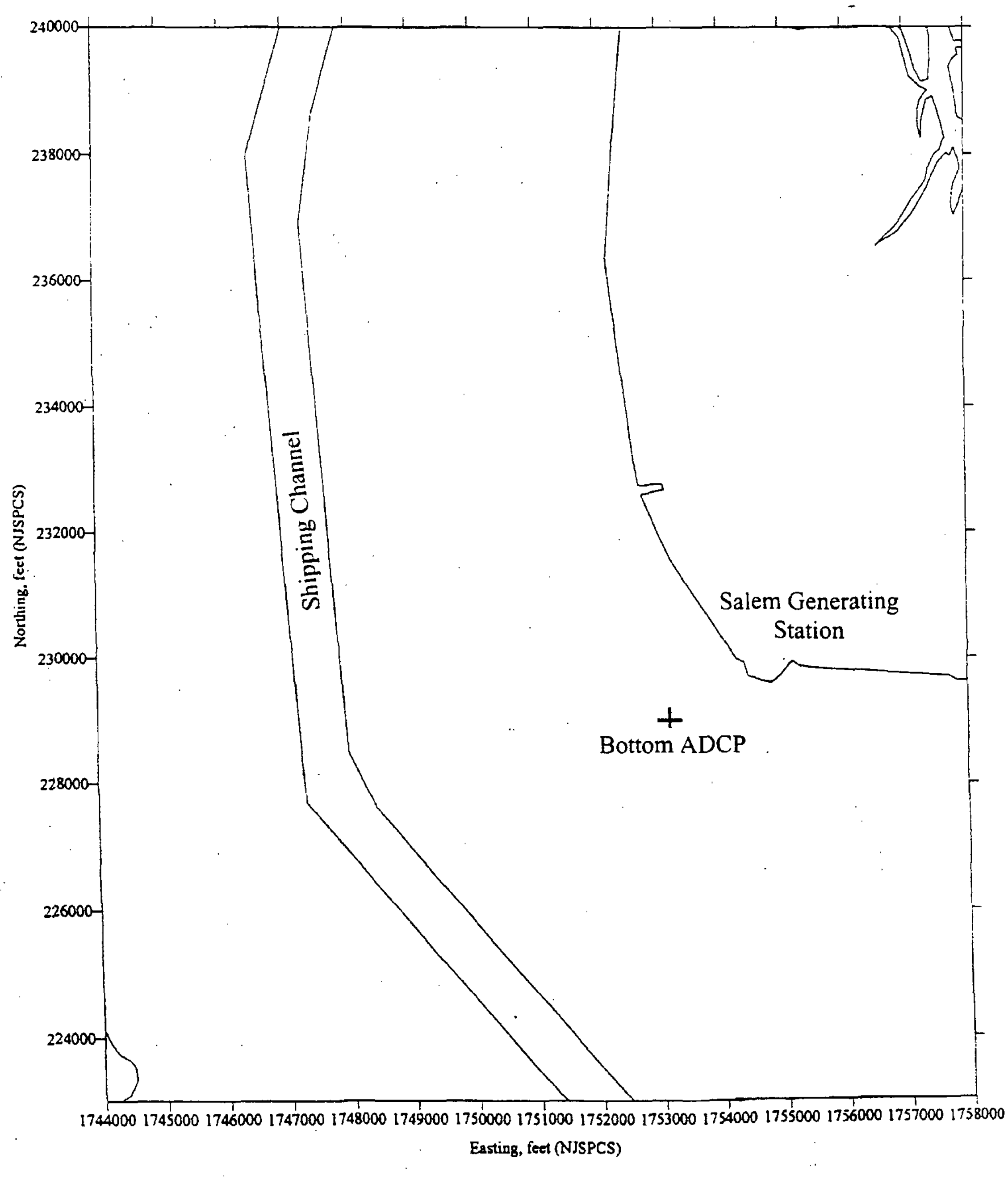


FIGURE 10-14

Tidal Boundary Condition Stations

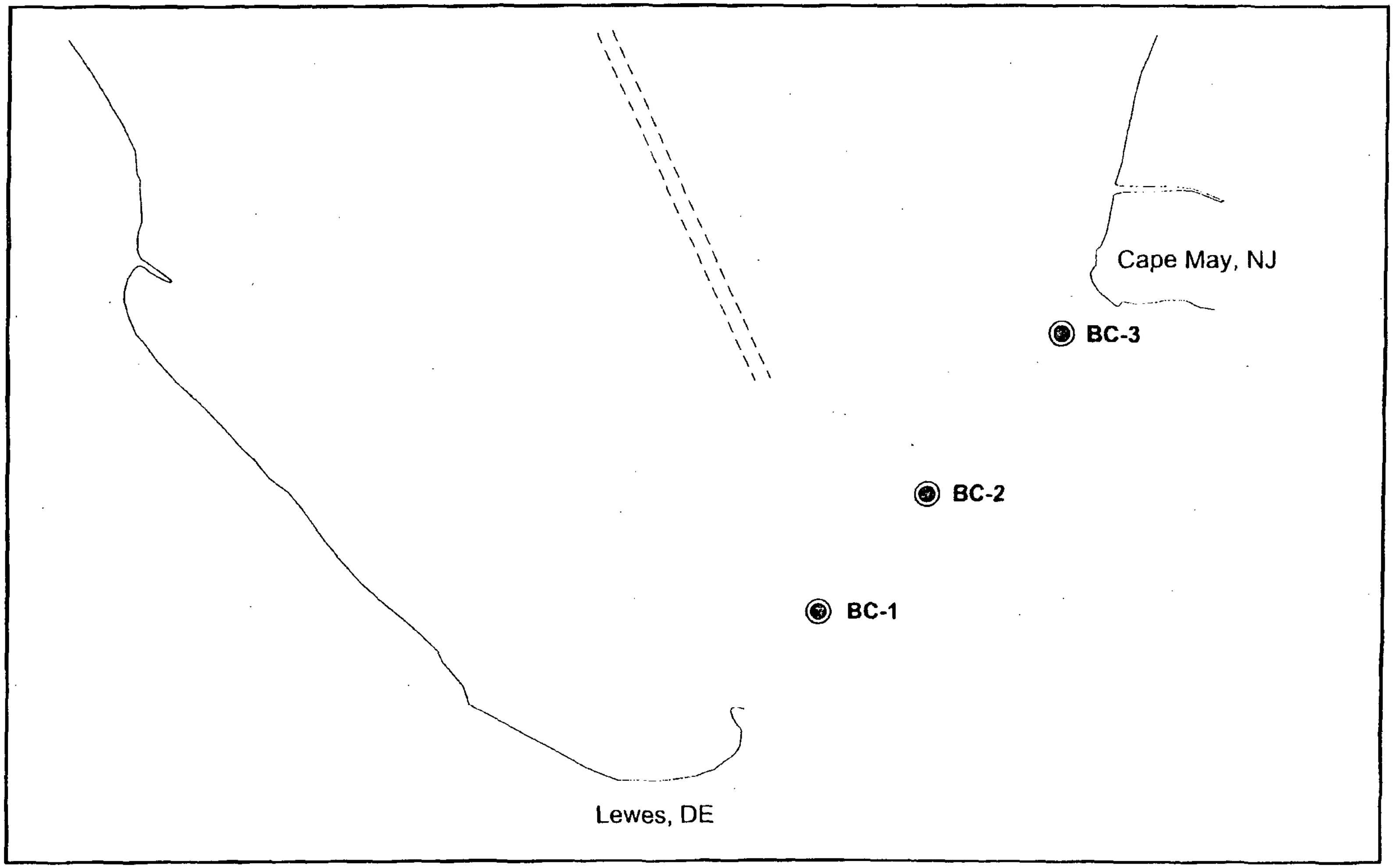


FIGURE 10-15
PSE&G 2-Unit Survey
Vertical Profile Locations
Longitudinal Surveys;
21 & 27 May and 2 June 1998

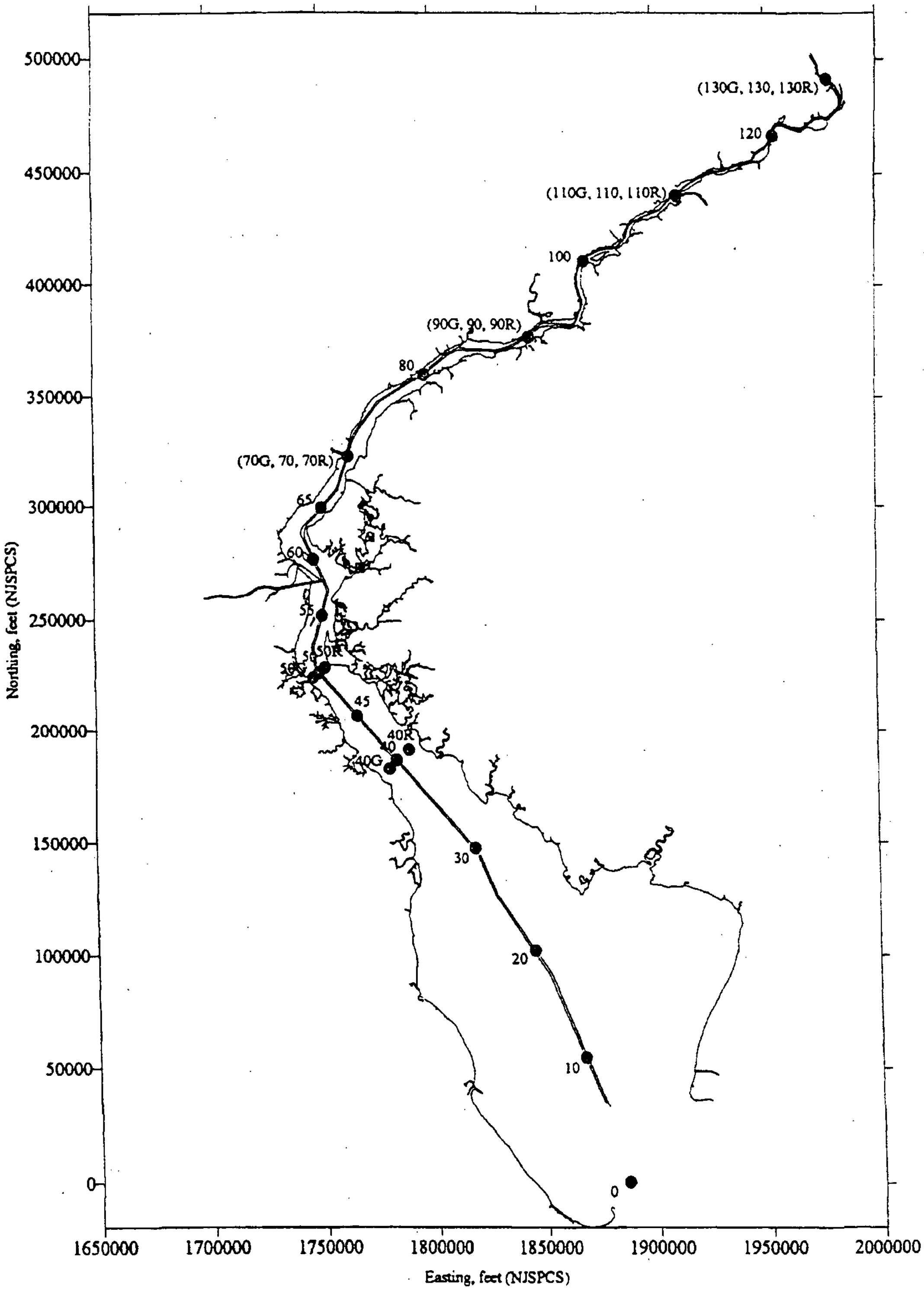


Figure 10-16
PSE&G 2-Unit Survey
Vertical Profile Locations
Marsh Mouths Survey; 28 May 1998

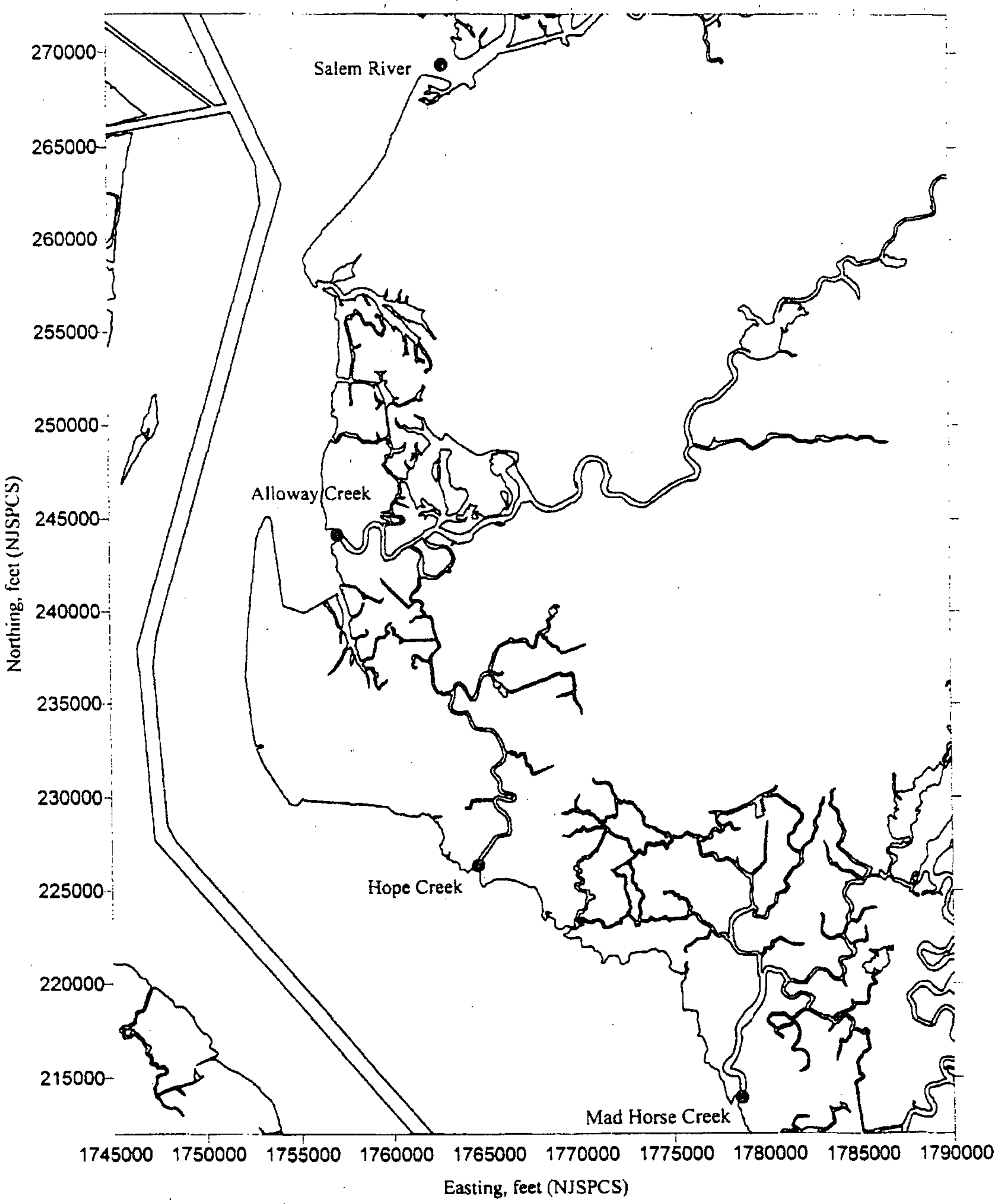


Figure 10-17
PSE&G Salem Generating Station
Approximate Area of Infrared Aerial Photo

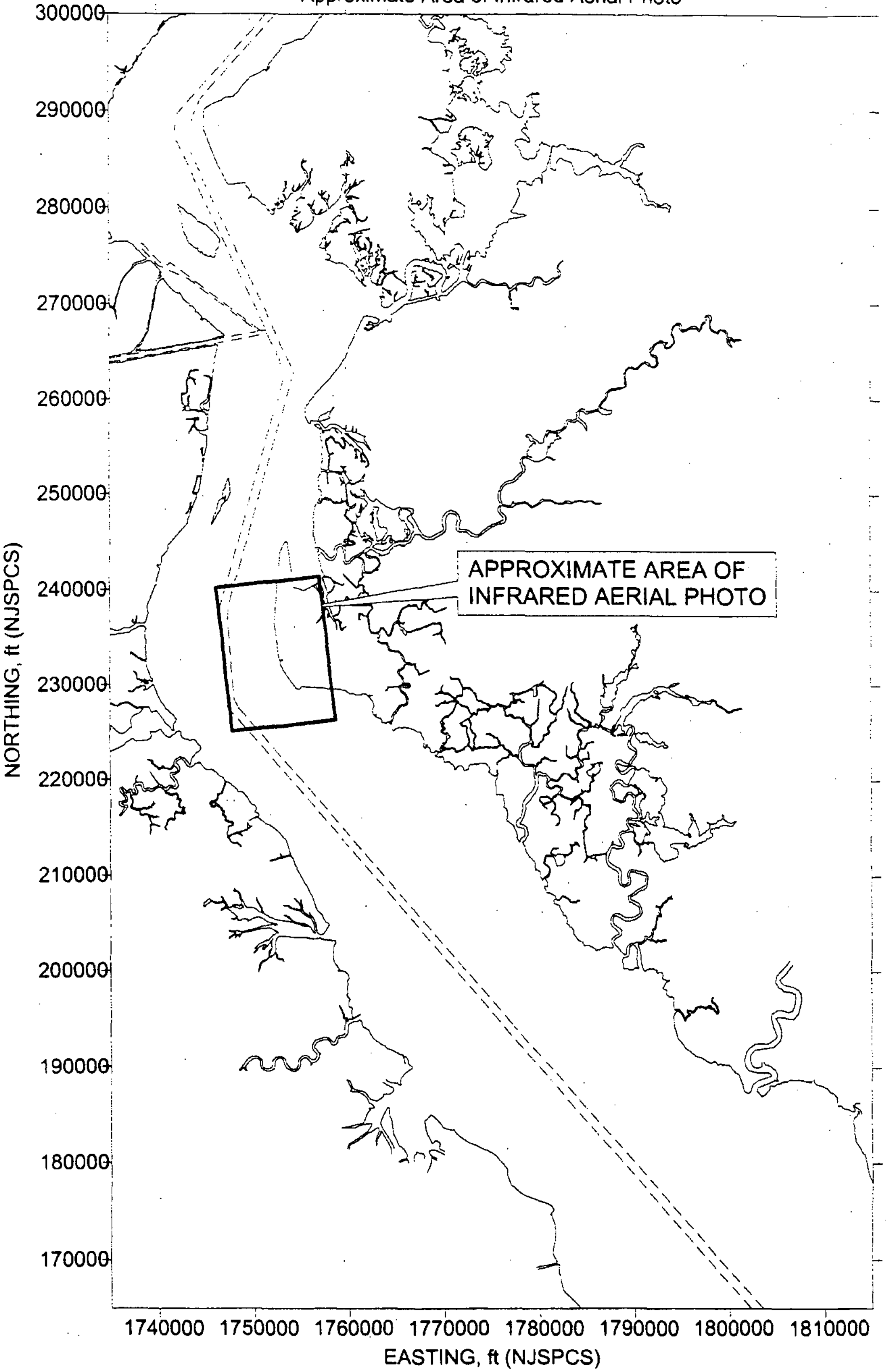


FIGURE 10-18

PSE&G 2-Unit Survey; 21 May 1998
Longitudinal Survey 1
Vertical Temperature Profiles

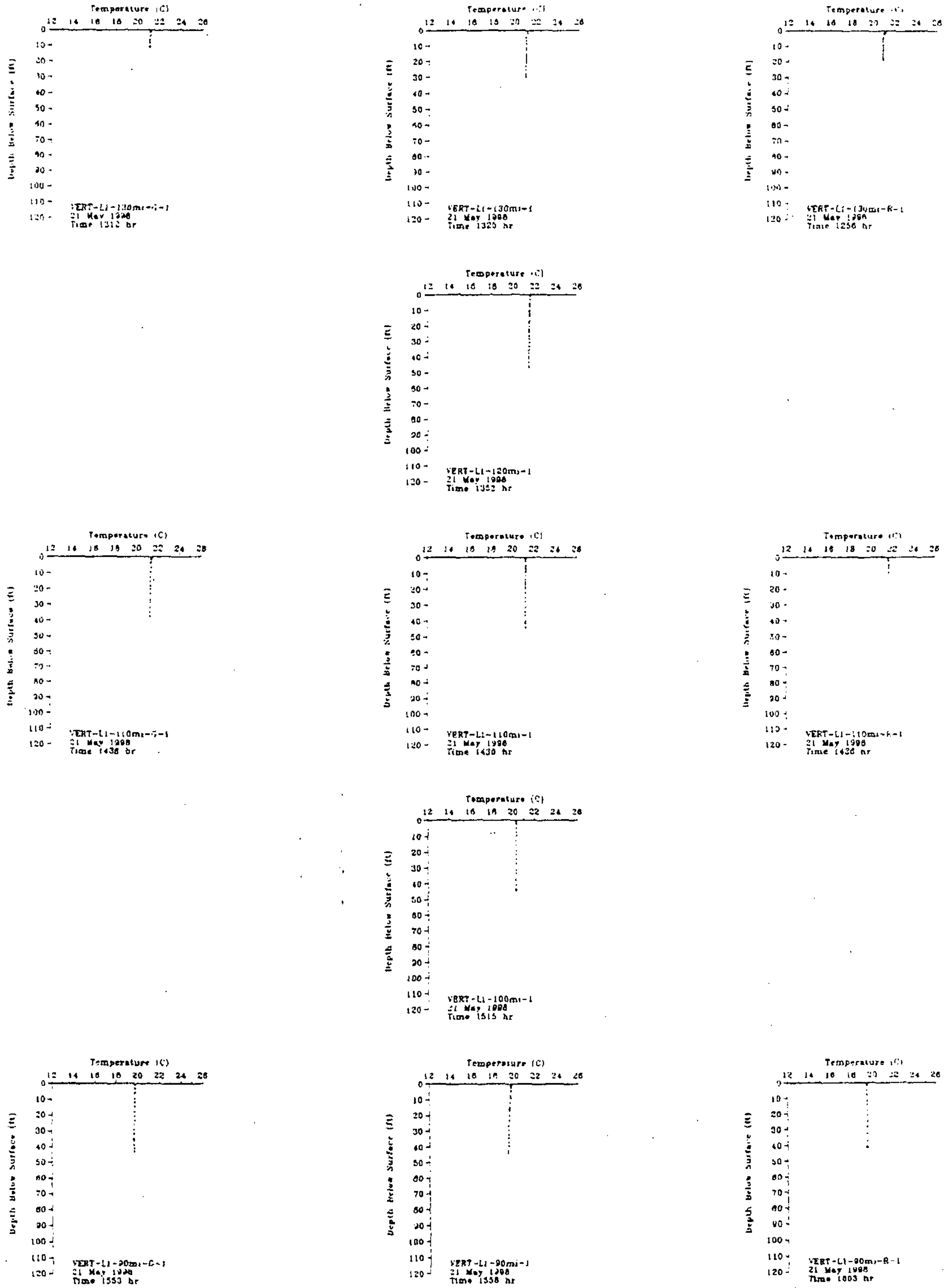


FIGURE 10-19

PSE&G 2-Unit Survey: 21 May 1998
Longitudinal Survey 1
Vertical Temperature Profiles

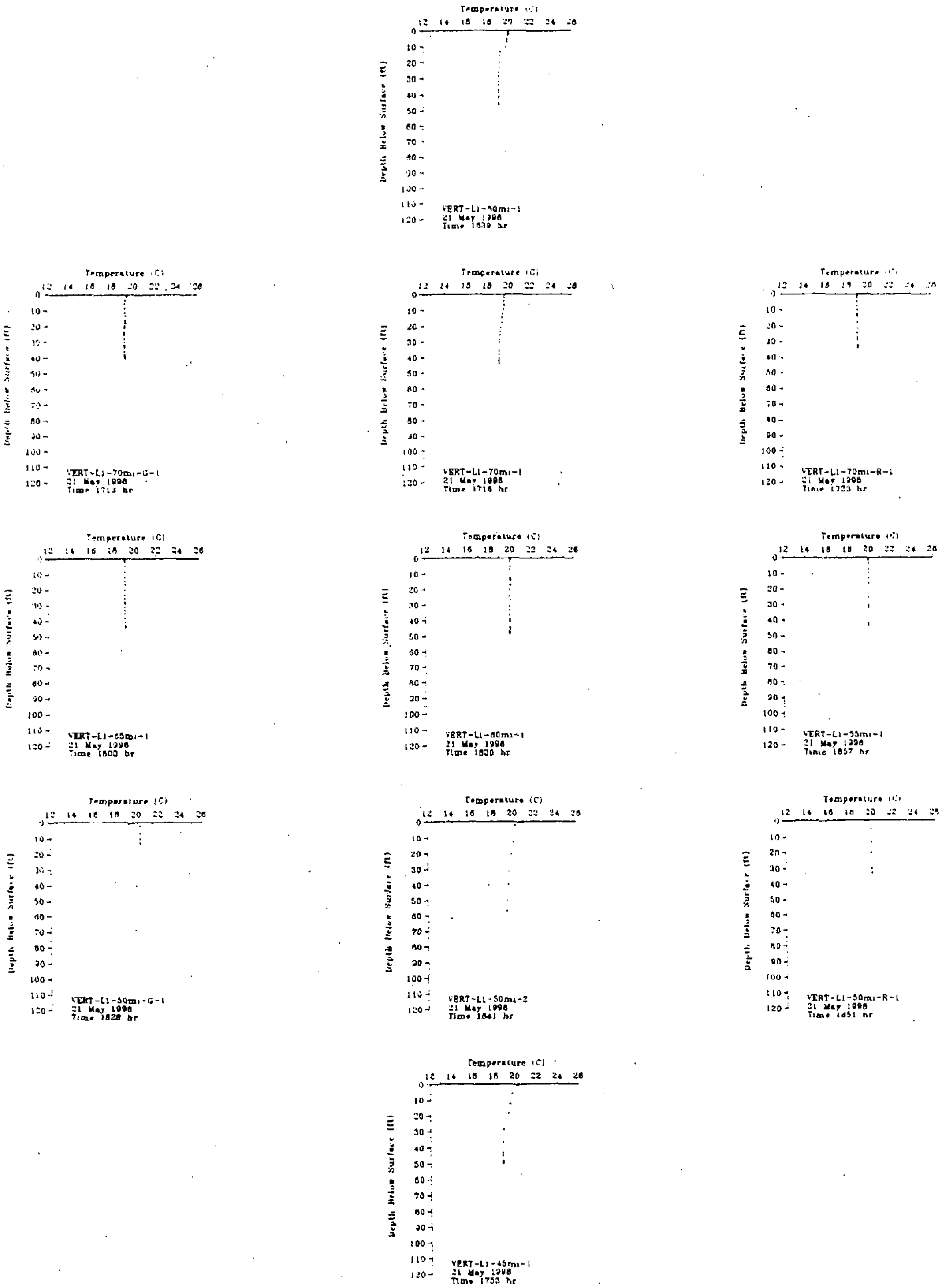
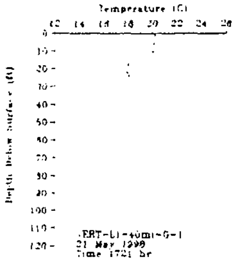
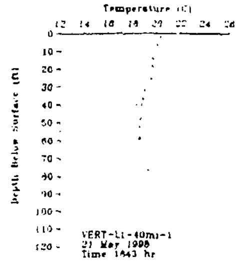
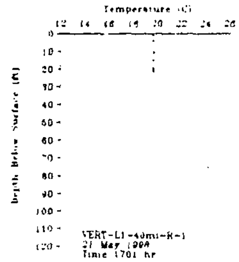


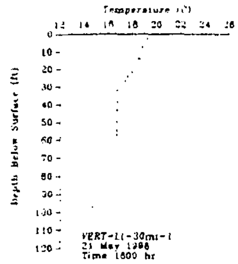
FIGURE 10-20

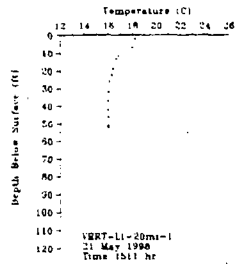
PSE&G 2-Unit Survey: 21 May 1998
Longitudinal Survey 1
Vertical Temperature Profiles

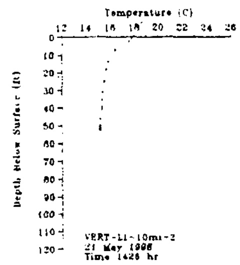












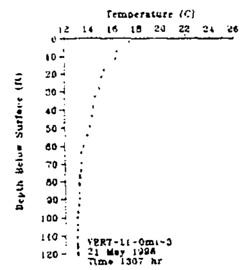


FIGURE 10-21
PSE&G 2-Unit Survey: 21 May 1998
Longitudinal Survey 1
Vertical Salinity Profiles

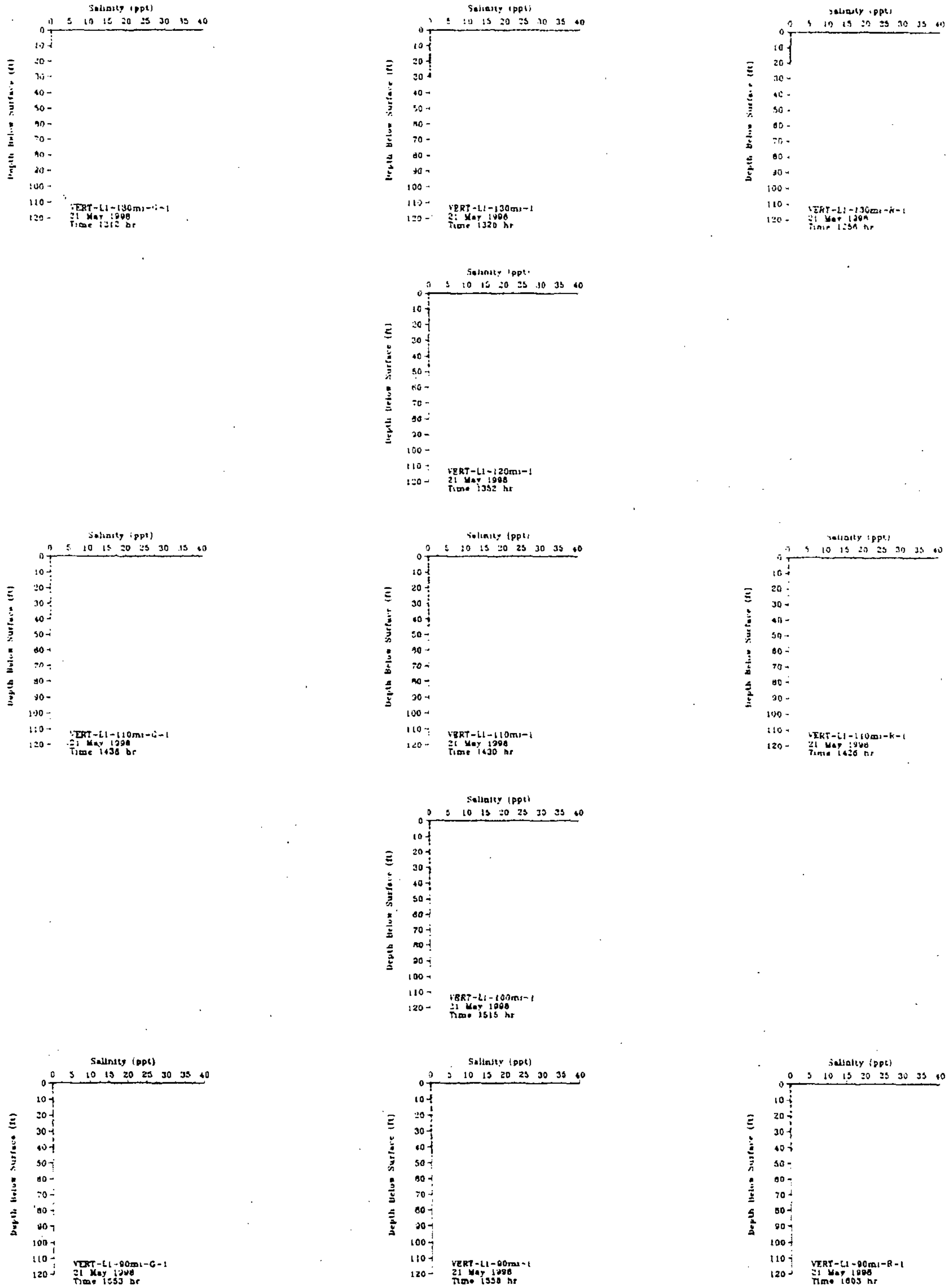


FIGURE 10-22

PSE&G 2-Unit Survey; 21 May 1998
Longitudinal Survey 1
Vertical Salinity Profiles

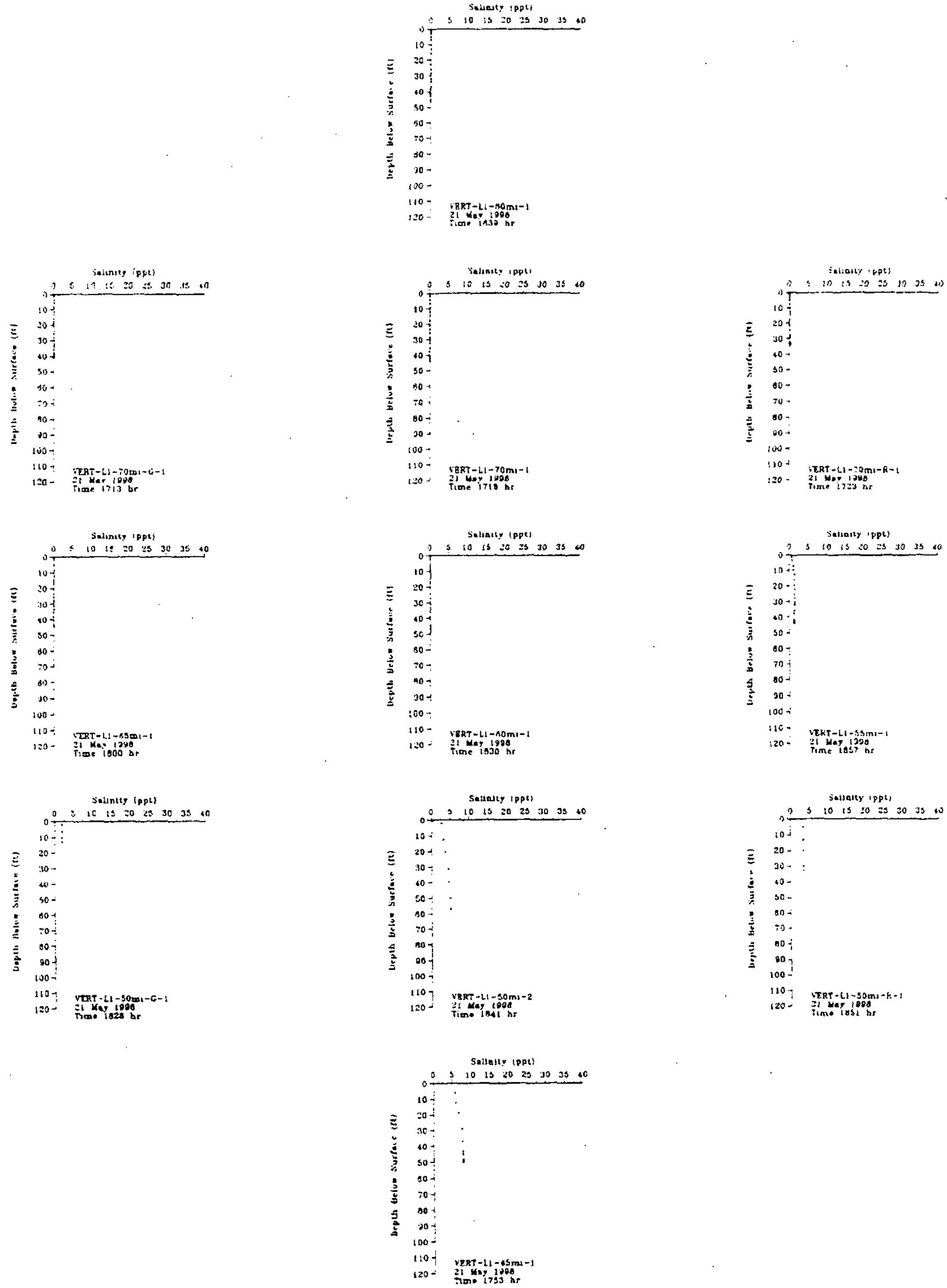
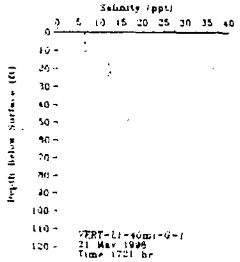
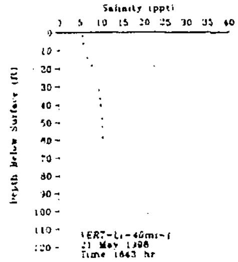
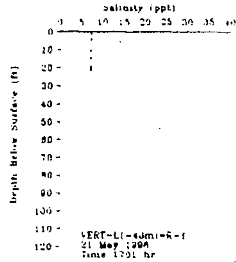
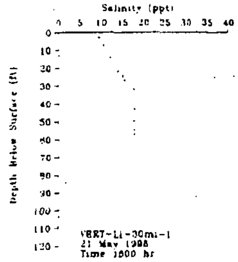


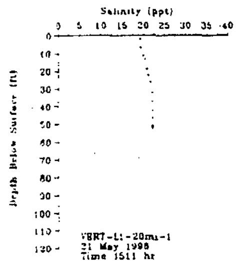
FIGURE 10-23
PSE&G 2-Unit Survey; 21 May 1998
Longitudinal Survey 1
Vertical Salinity Profiles

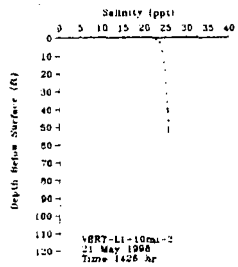












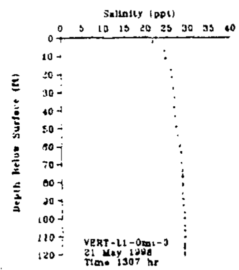


FIGURE 10-24

PSE&G 2-Unit Survey: 27 May 1998
Longitudinal Survey 2
Vertical Temperature Profiles

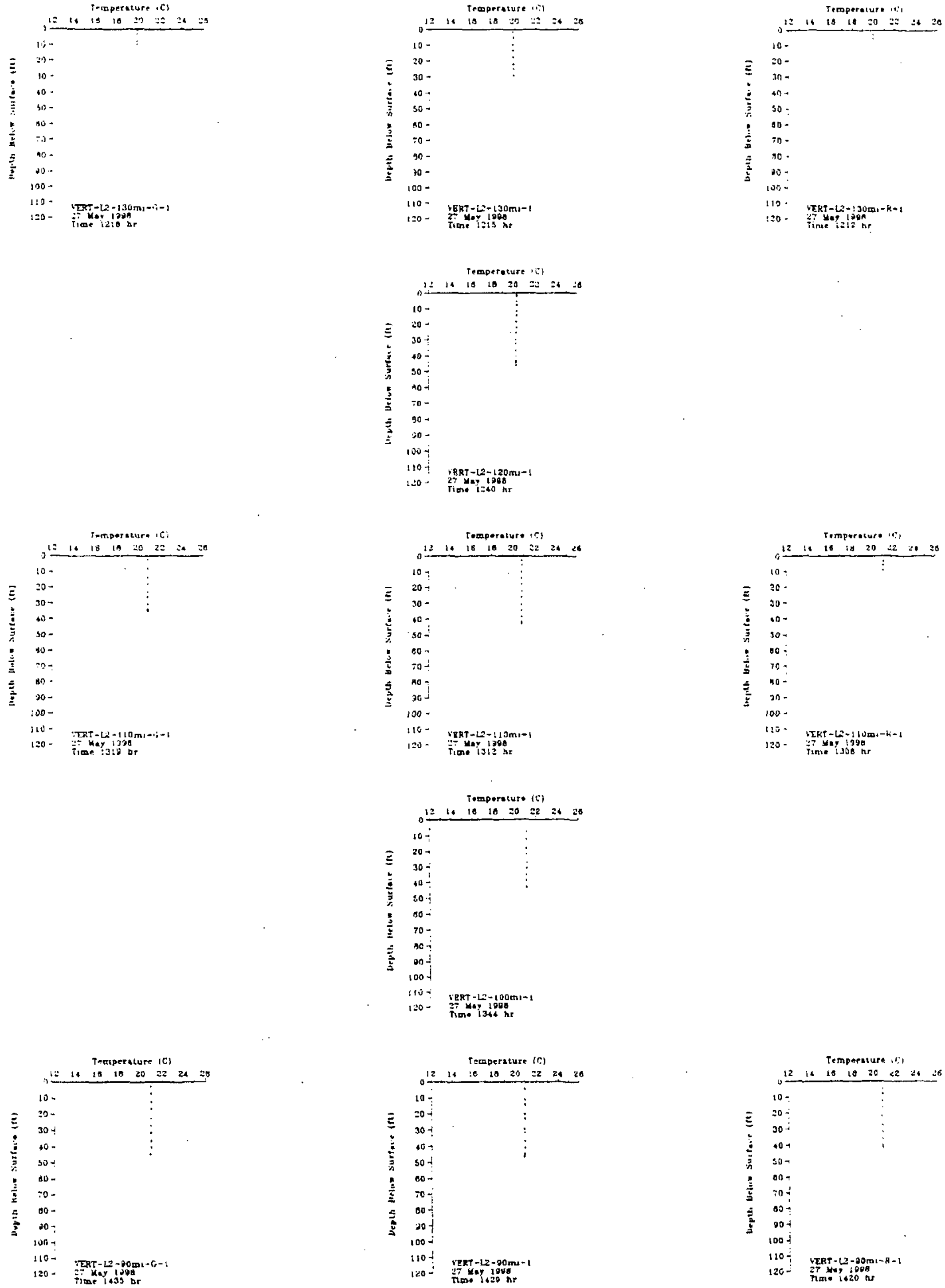


FIGURE 10-25

PSE&G 2-Unit Survey; 27 May 1998
Longitudinal Survey 2
Vertical Temperature Profiles

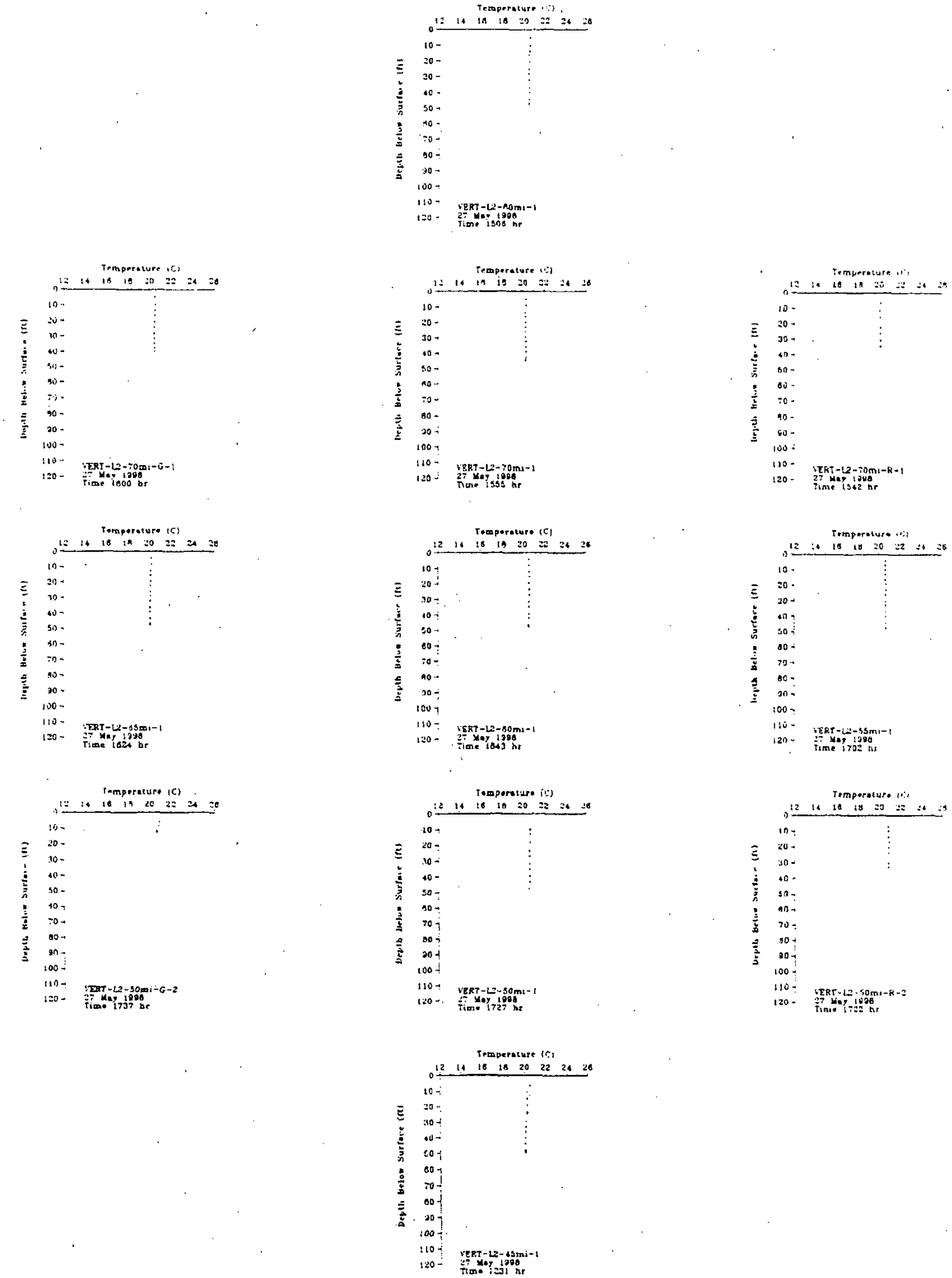


FIGURE 10-26

PSE&G 2-Unit Survey: 27 May 1998
Longitudinal Survey 2
Vertical Temperature Profiles

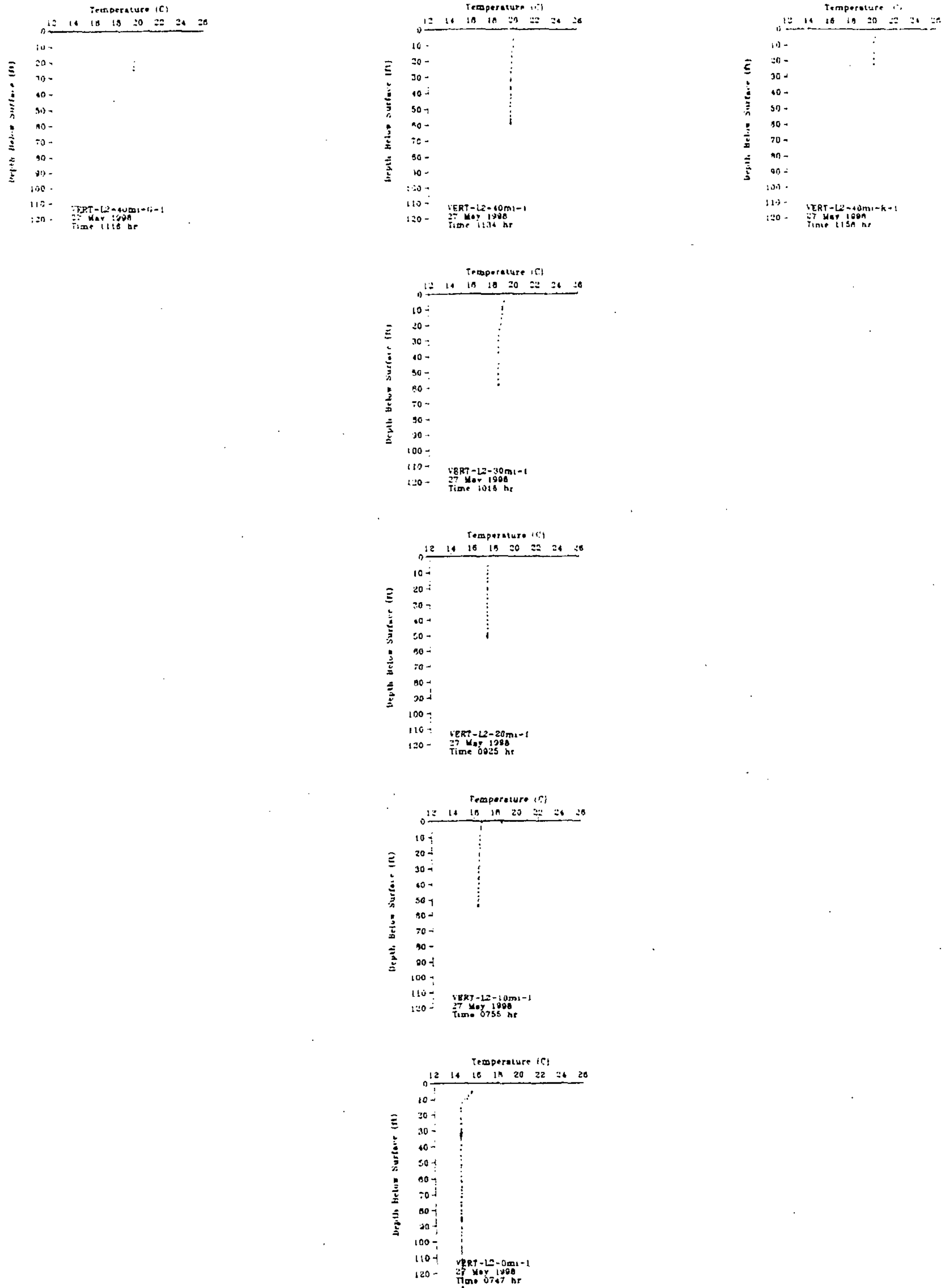


FIGURE 10-27

PSE&G 2-Unit Survey; 27 May 1998
Longitudinal Survey 2
Vertical Salinity Profiles

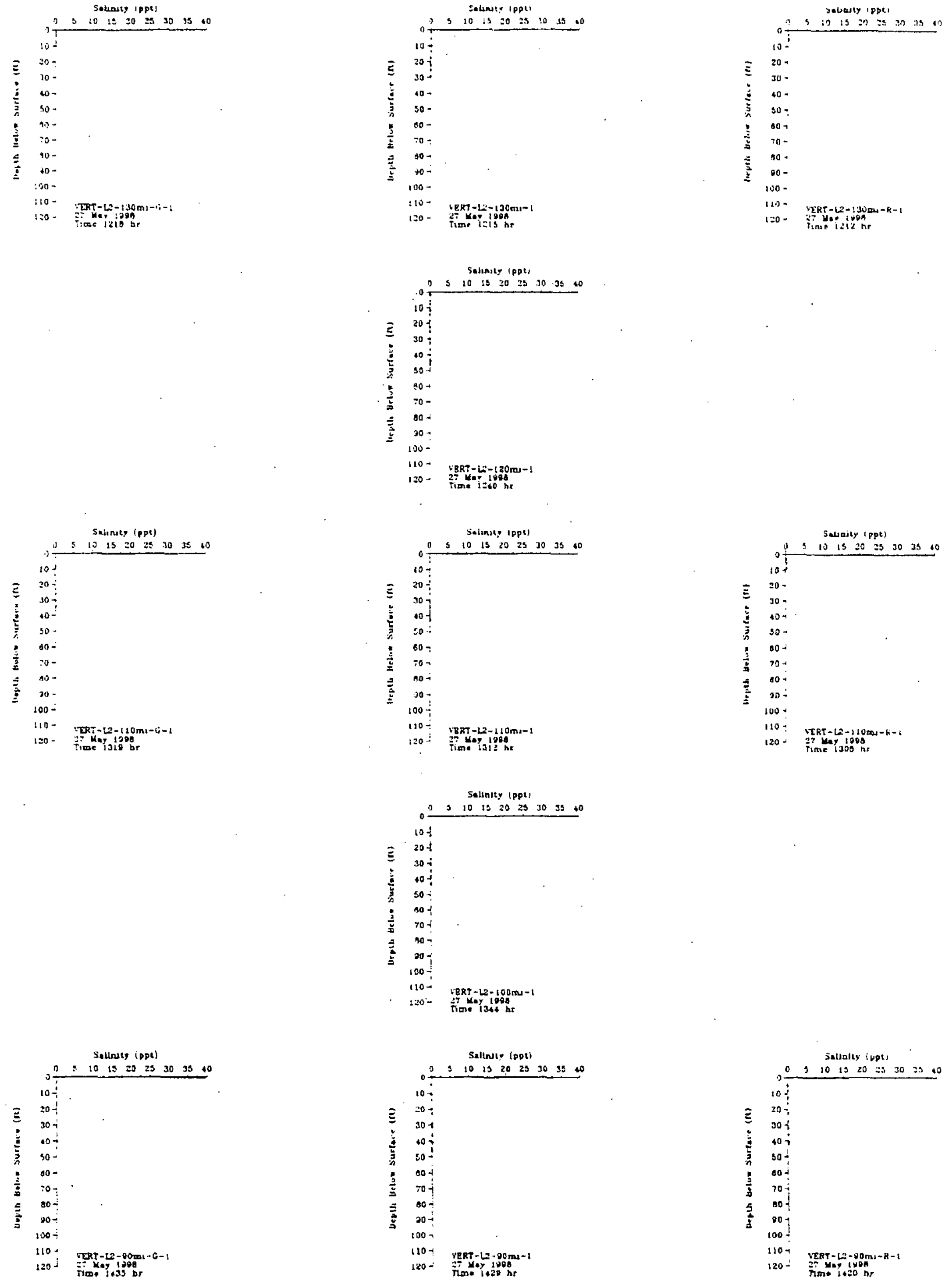


FIGURE 10-28

PSE&G 2-Unit Survey; 27 May 1998
Longitudinal Survey 2
Vertical Salinity Profiles

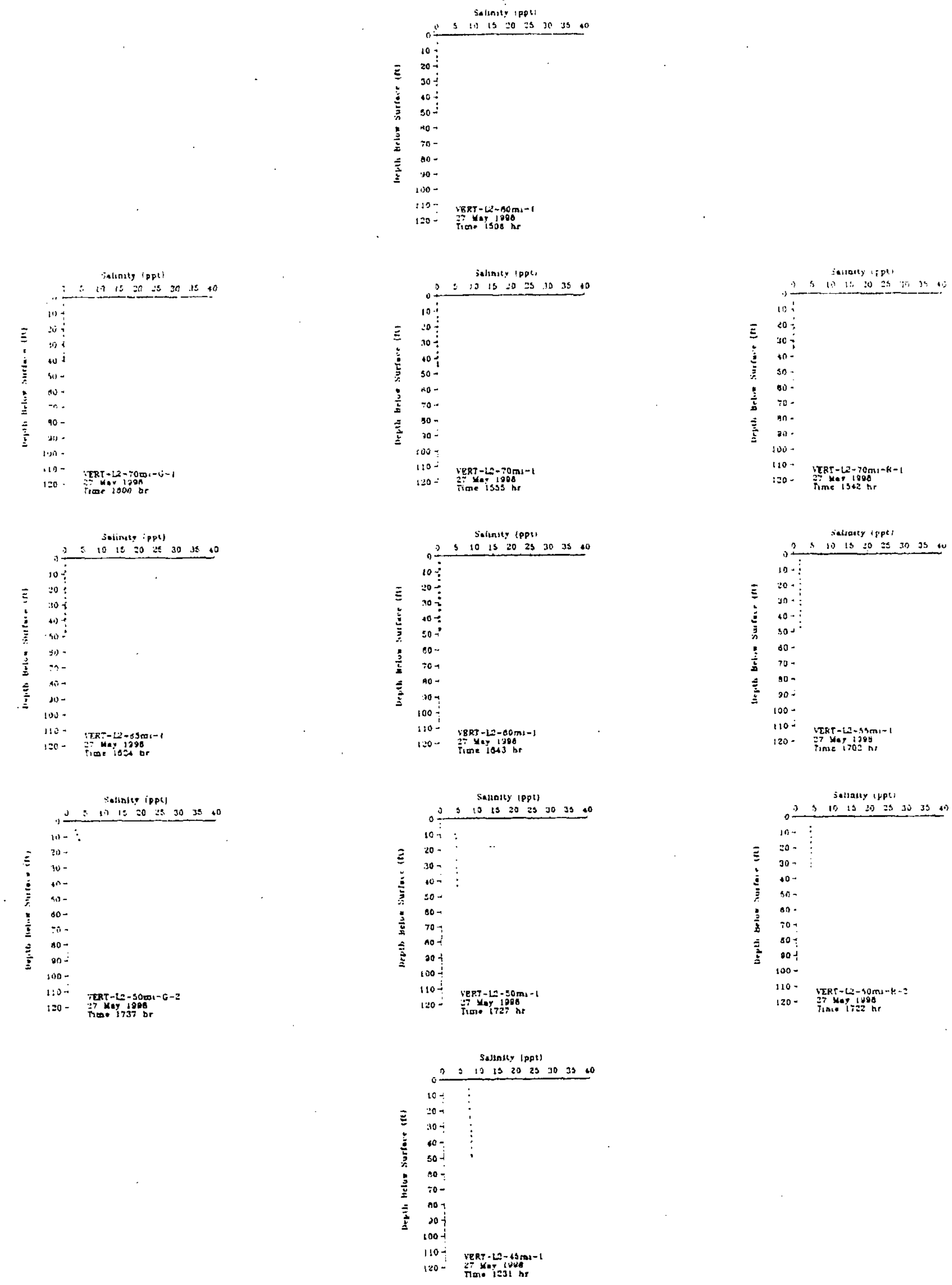
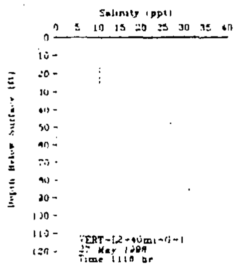
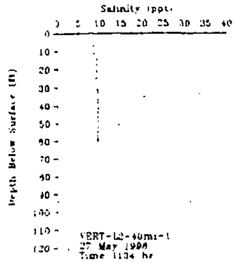
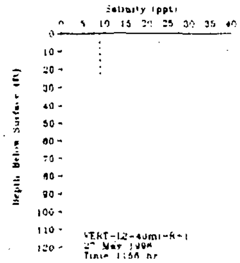
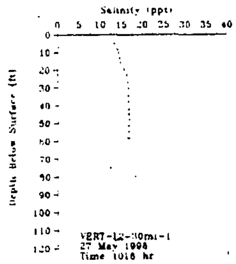


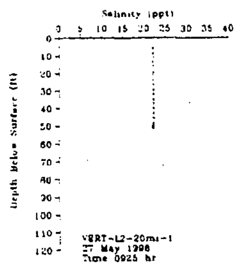
FIGURE 10-29
PSE&G 2-Unit Survey: 27 May 1998
Longitudinal Survey 2
Vertical Salinity Profiles

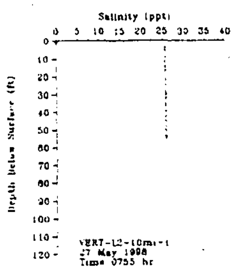












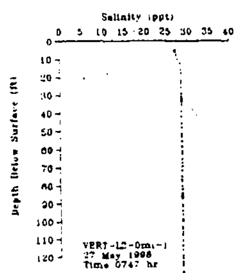


FIGURE 10-30

PSE&G 2-Unit Survey: 02 June 1998
Longitudinal Survey 3
Vertical Temperature Profiles

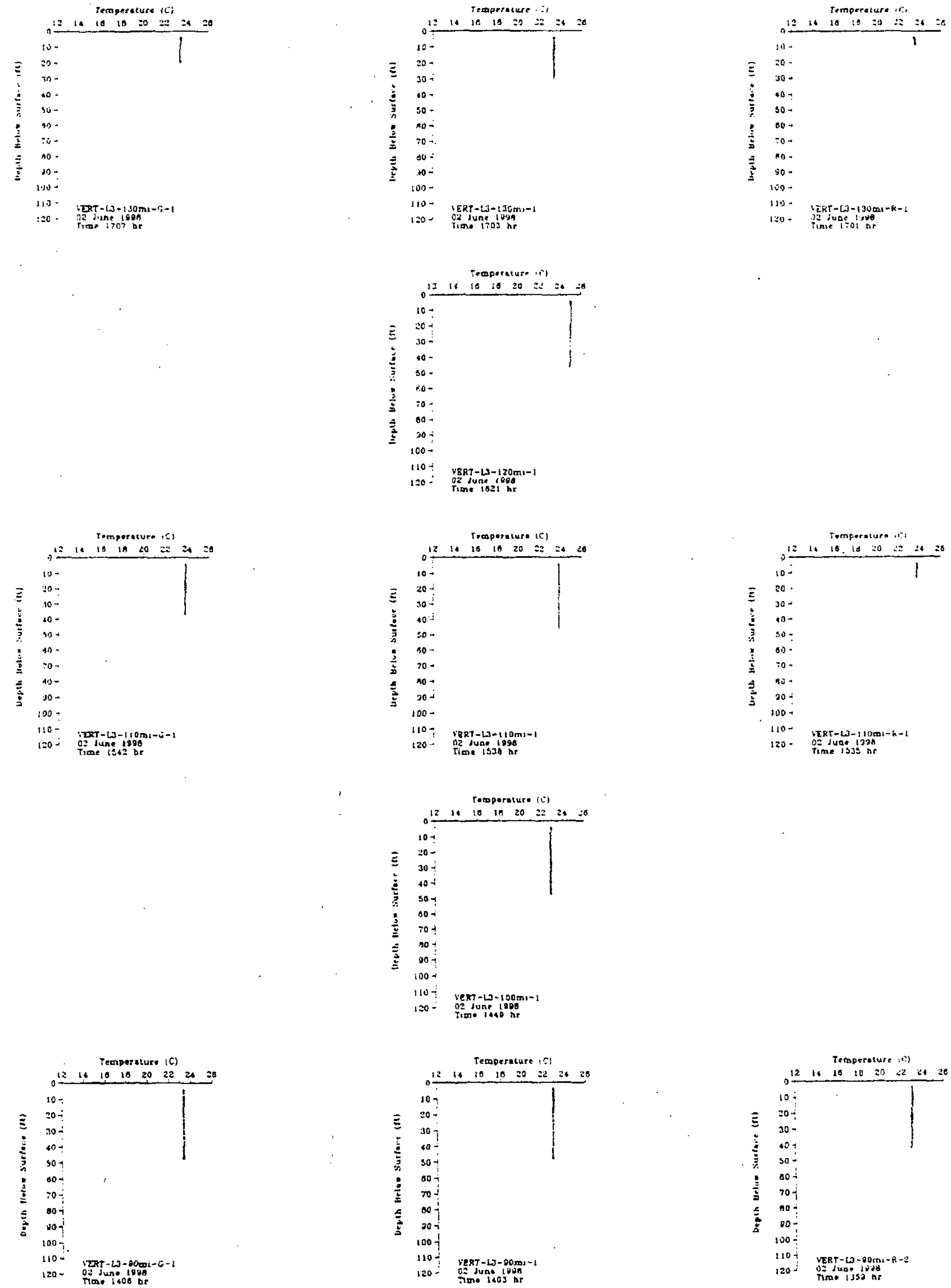


FIGURE 10-31

PSE&G 2-Unit Survey: 02 June 1998
Longitudinal Survey 3
Vertical Temperature Profiles

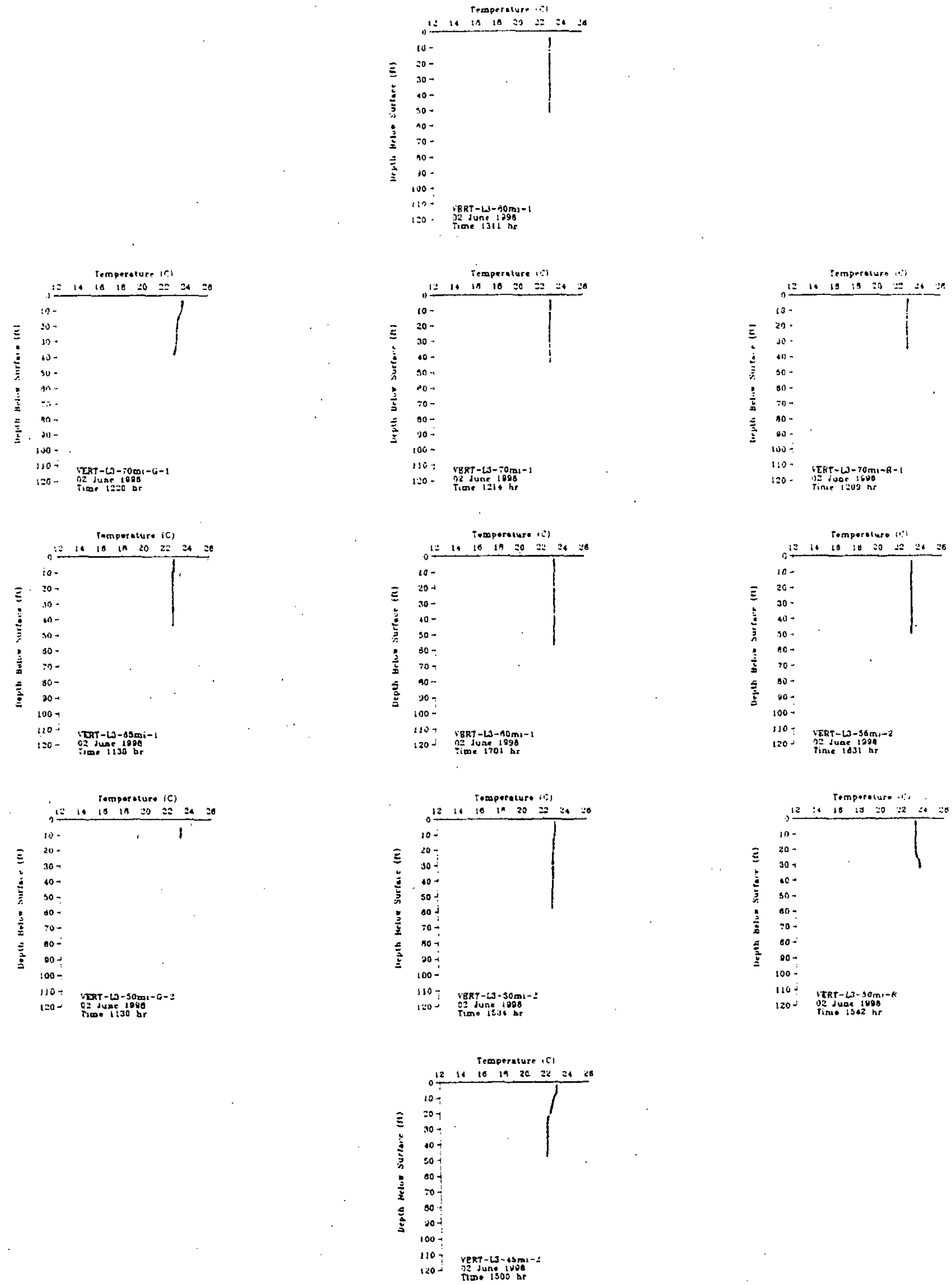


FIGURE 10-32

PSE&G 2-Unit Survey: 02 June 1998
Longitudinal Survey 3
Vertical Temperature Profiles

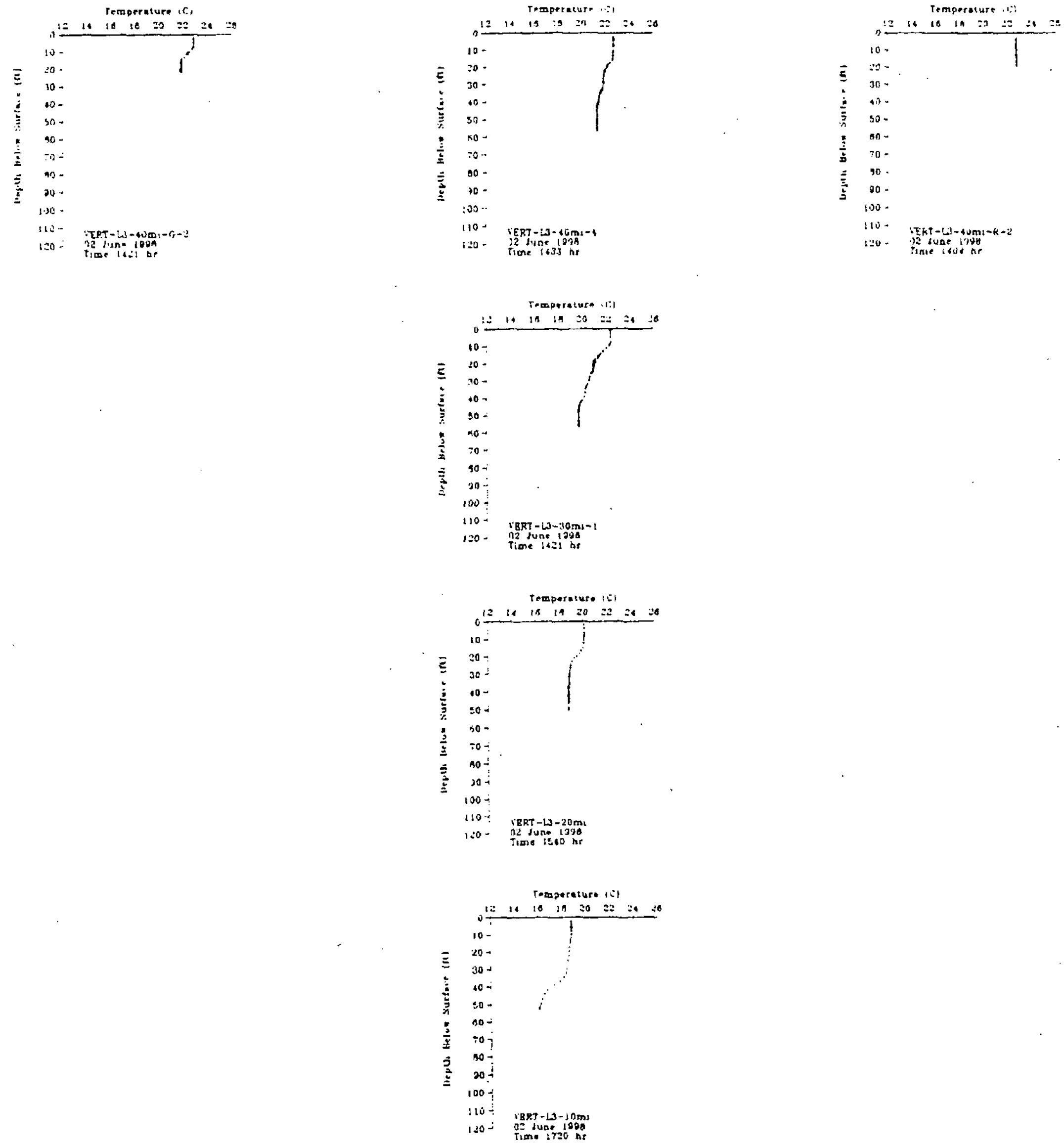


FIGURE 10-33

PSE&G 2-Unit Survey: 02 June 1998
Longitudinal Survey 3
Vertical Salinity Profiles

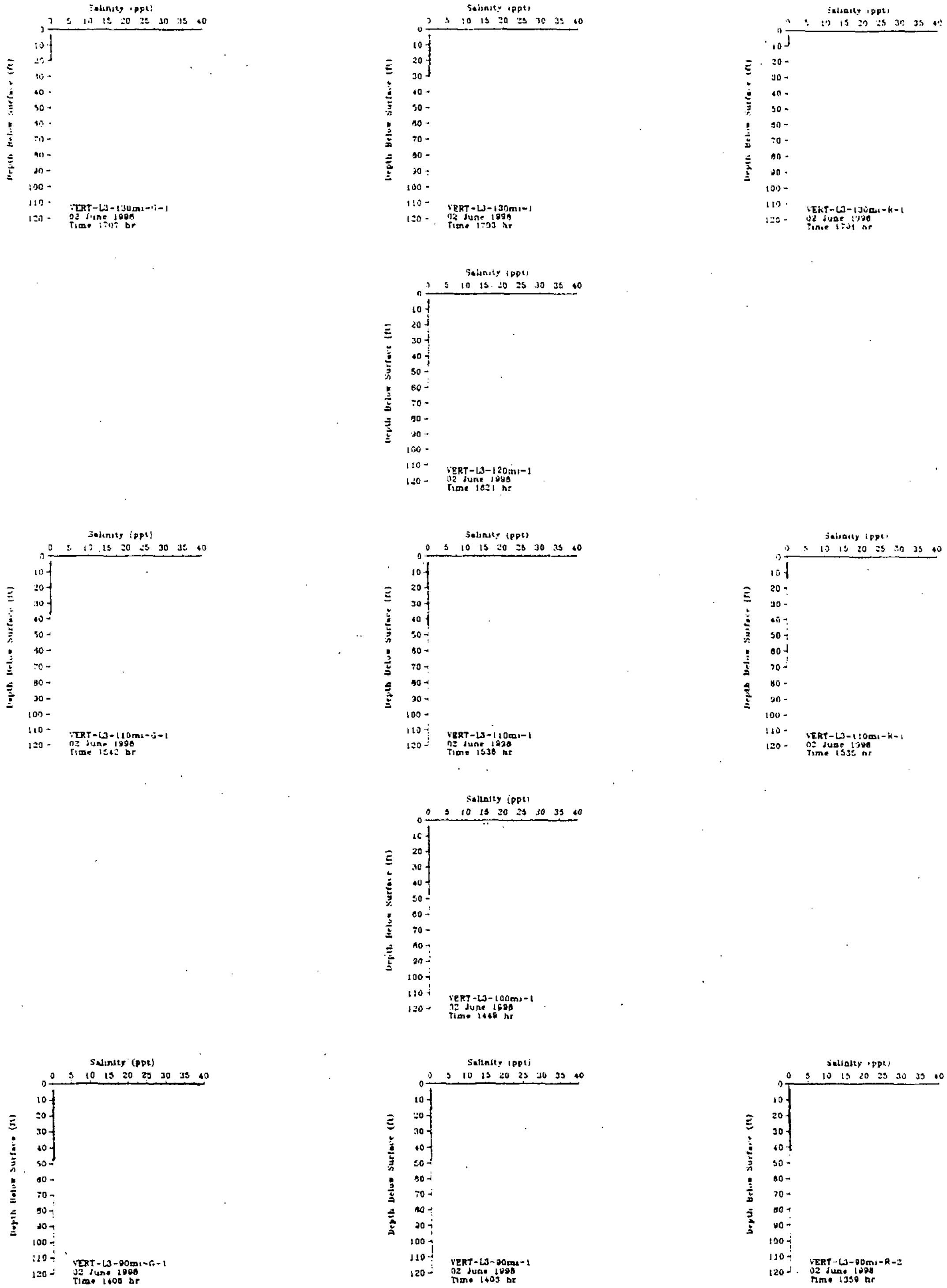


FIGURE 10-34

PSE&G 2-Unit Survey: 02 June 1998
Longitudinal Survey 3
Vertical Salinity Profiles

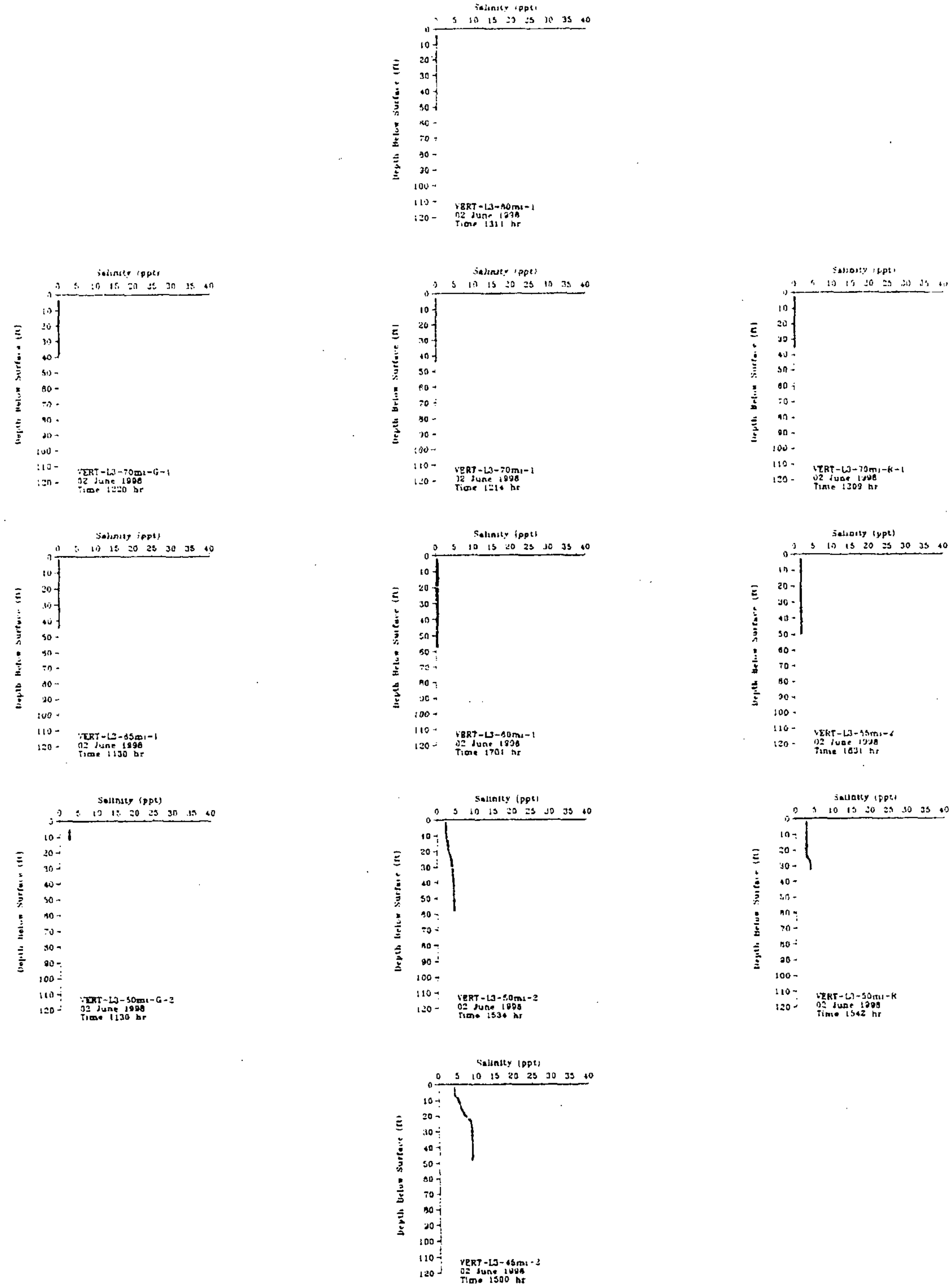


FIGURE 10-35

PSE&G 2-Unit Survey; 02 June 1998
Longitudinal Survey 3
Vertical Salinity Profiles

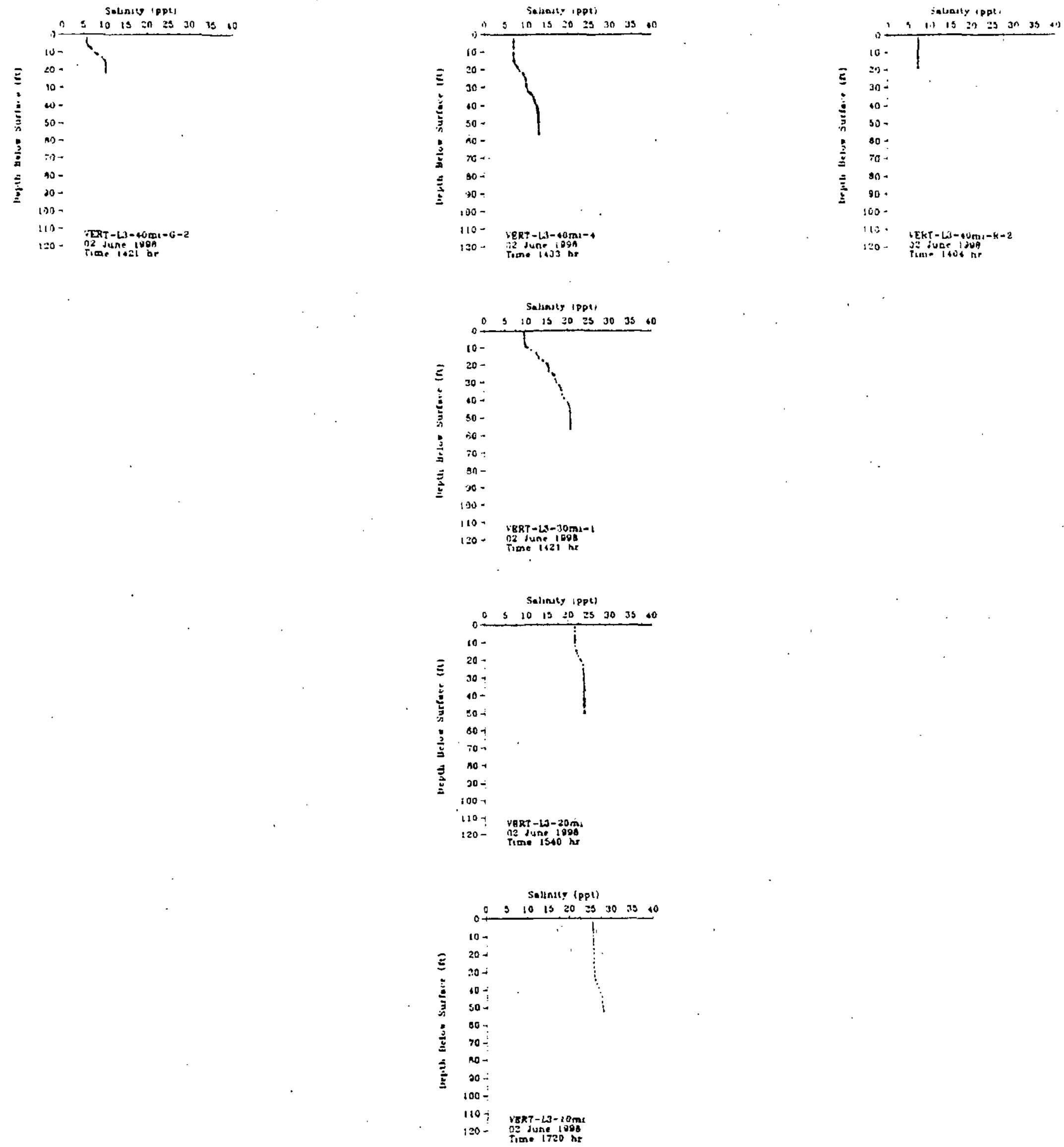
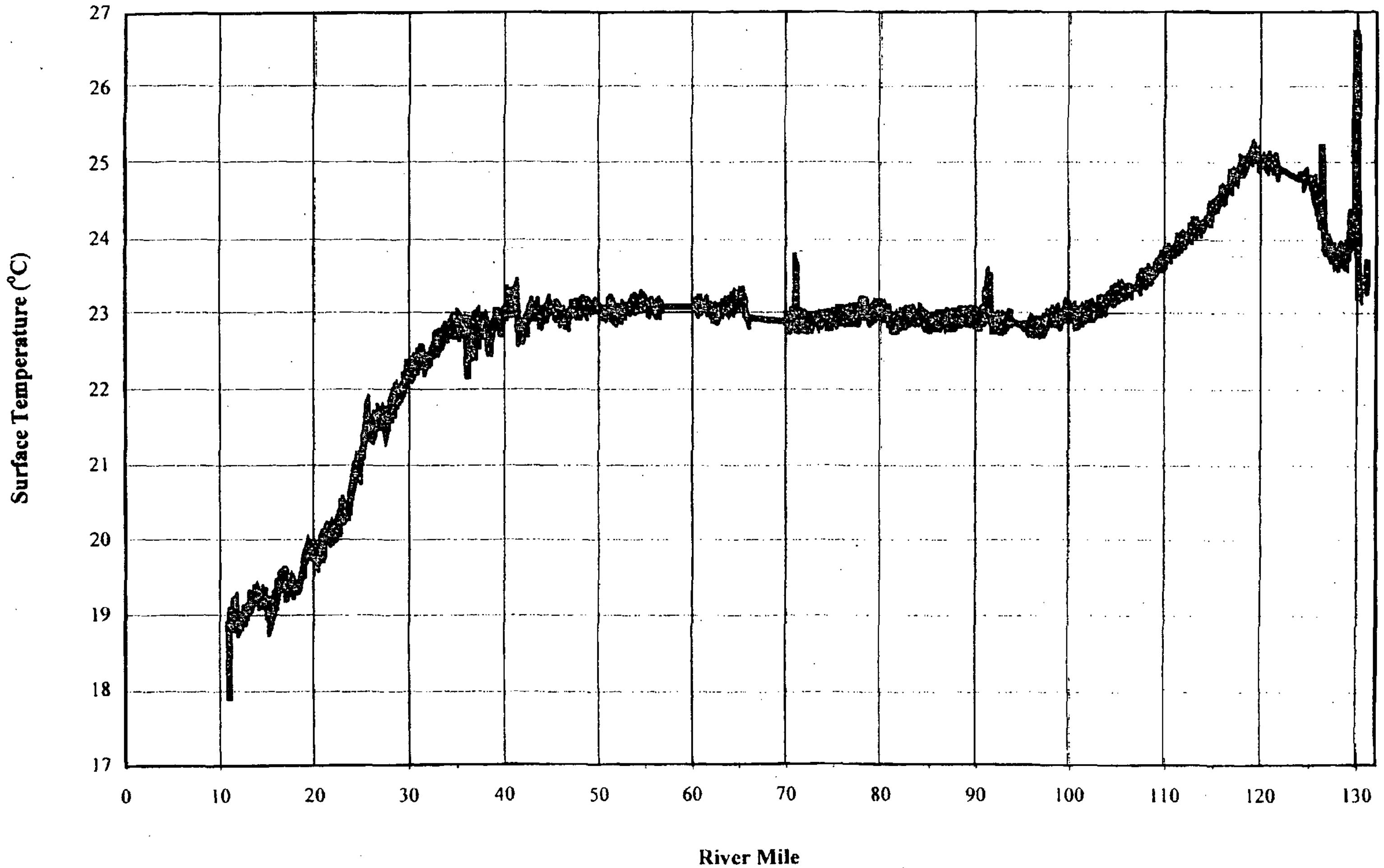


FIGURE 10-36
PSE&G 2-Unit Survey
Longitudinal Survey 3; 02 June 1998
Surface Temperature Profile



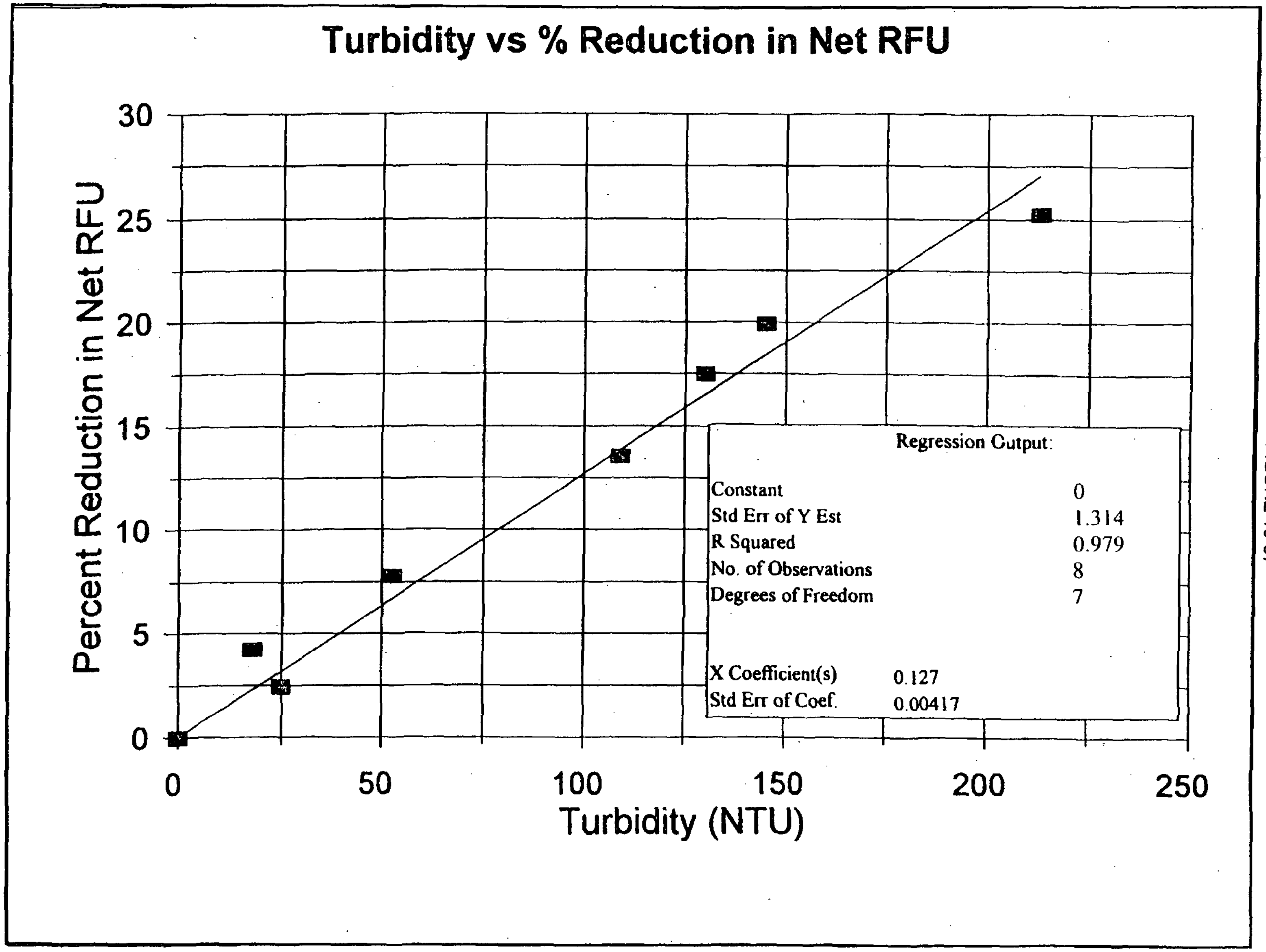

Turbidity vs % Reduction in Net RFU
Percent Reduction in Net RFU
0
5
10
15
20
25
30
Turbidity (NTU)
0
50
100
150
200
250
Regression Output:
Constant 0
Std Err of Y Est 1.314
R Squared 0.979
No. of Observations 8
Degrees of Freedom 7
X Coefficient(s) 0.127
Std Err of Coef. 0.00417

FIGURE 10-37

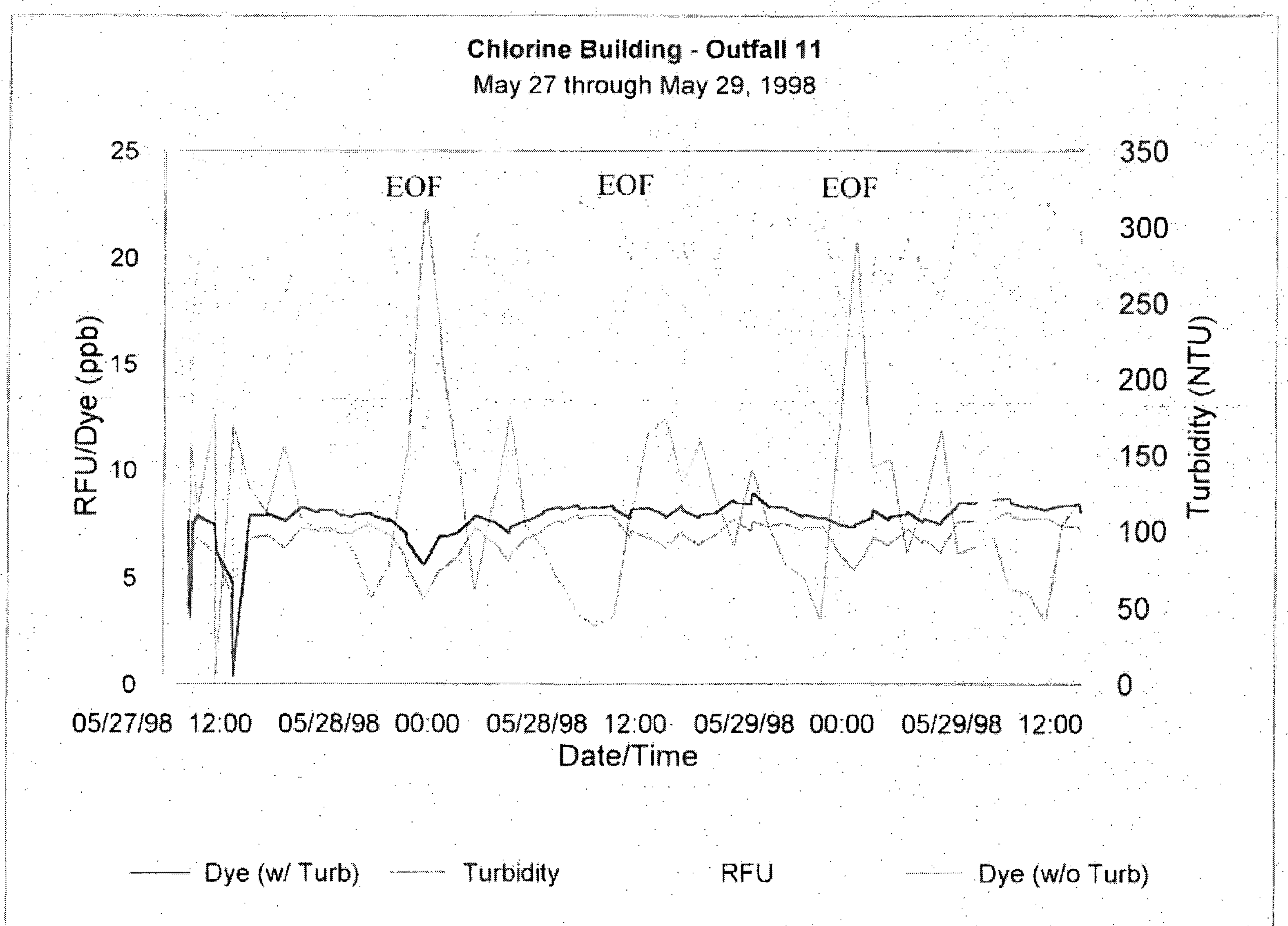
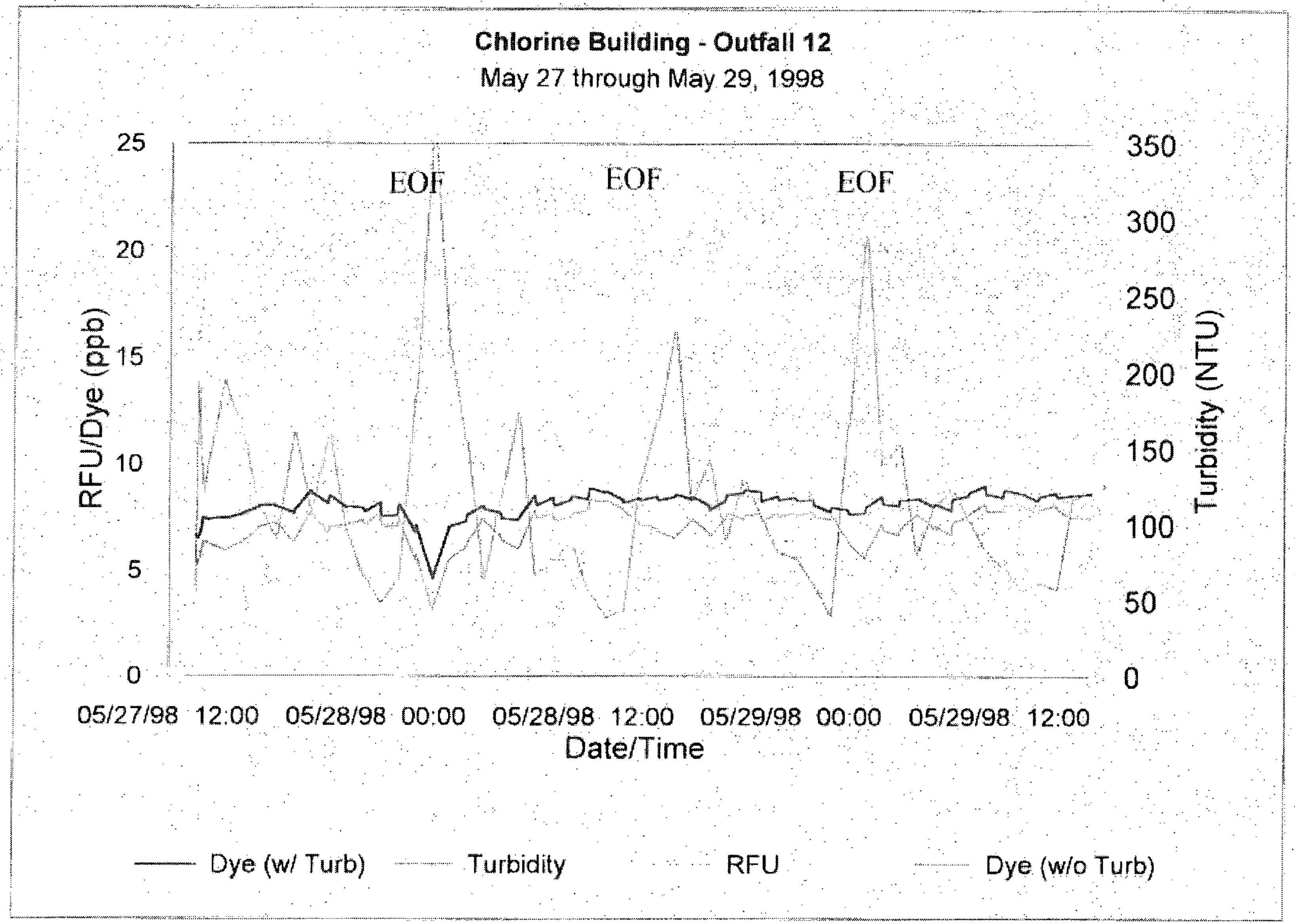
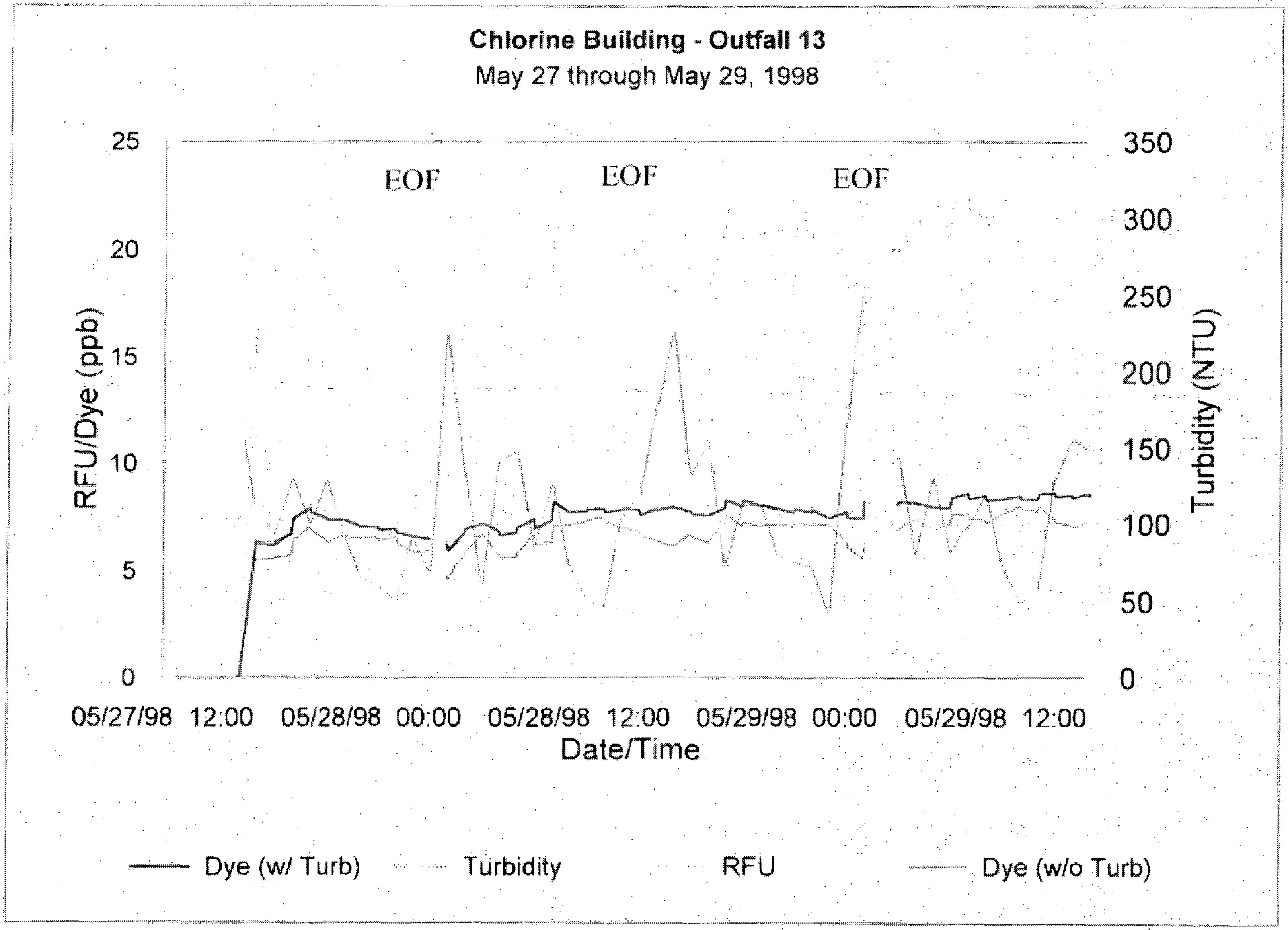

Chlorine Building - Outfall 11
May 27 through May 29, 1998
EOF
EOF
EOF
RFU/Dye (ppb)
25
20
15
10
5
0
Turbidity (NTU)
350
300
250
200
150
100
50
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
RFU
Dye (w/o Turb)

FIGURE 10-38



Chlorine Building - Outfall 12
May 27 through May 29, 1998
EOF
EOF
EOF
RFU/Dye (ppb)
25
20
15
10
5
0
Turbidity (NTU)
350
300
250
200
150
100
50
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
RFU
Dye (w/o Turb)

FIGURE 10-39



Chlorine Building - Outfall 13
May 27 through May 29, 1998
EOF
EOF
EOF
RFU/Dye (ppb)
Turbidity (NTU)
25
20
15
10
5
0
350
300
250
200
150
100
50
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
RFU
Dye (w/o Turb)

FIGURE 10-40

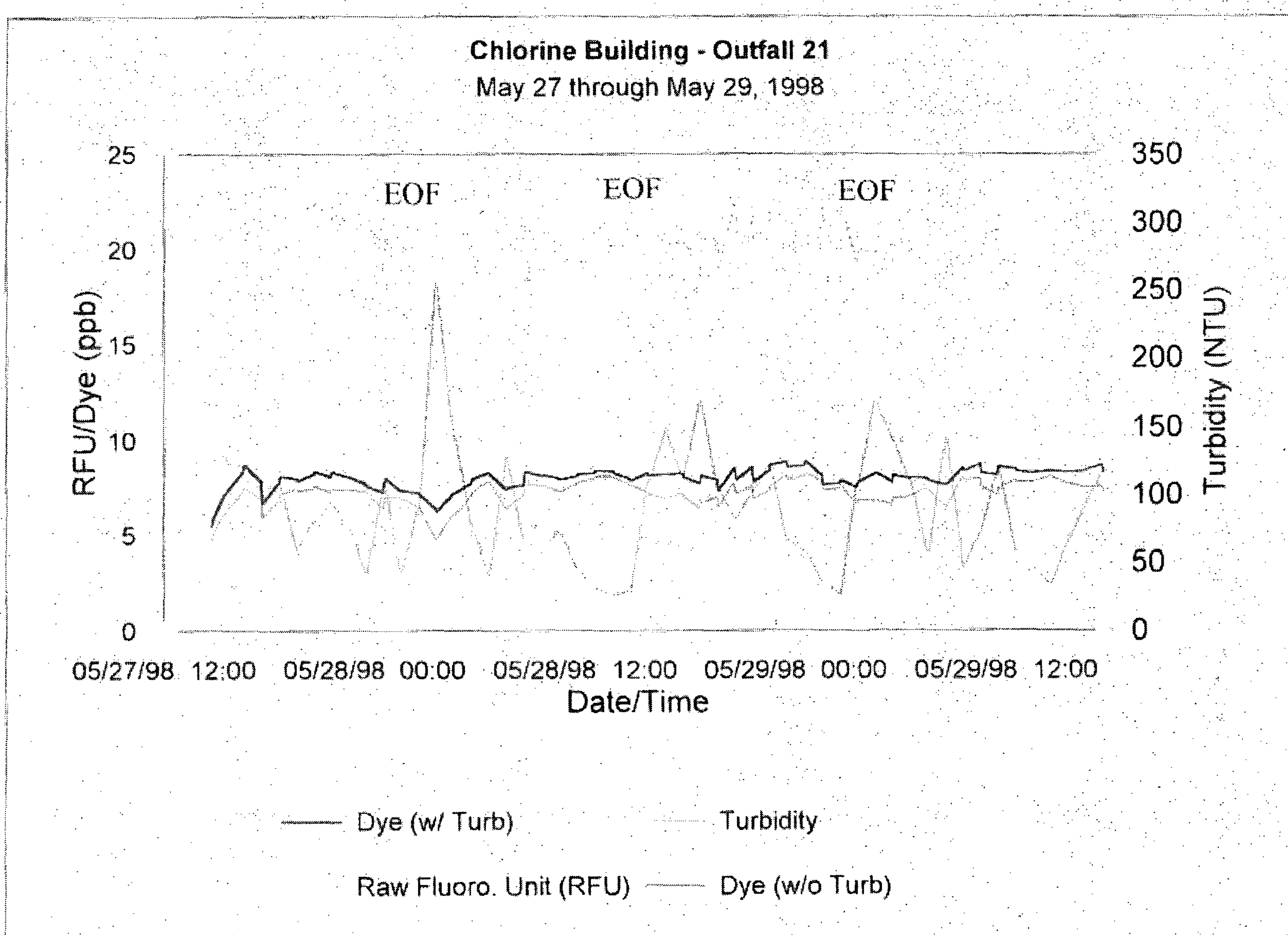

Chlorine Building - Outfall 21
May 27 through May 29, 1998
EOF
EOF
EOF
RFU/Dye (ppb)
25
20
15
10
5
0
Turbidity (NTU)
350
300
250
200
150
100
50
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
Raw Fluoro. Unit (RFU)
Dye (w/o Turb)

FIGURE 10-41

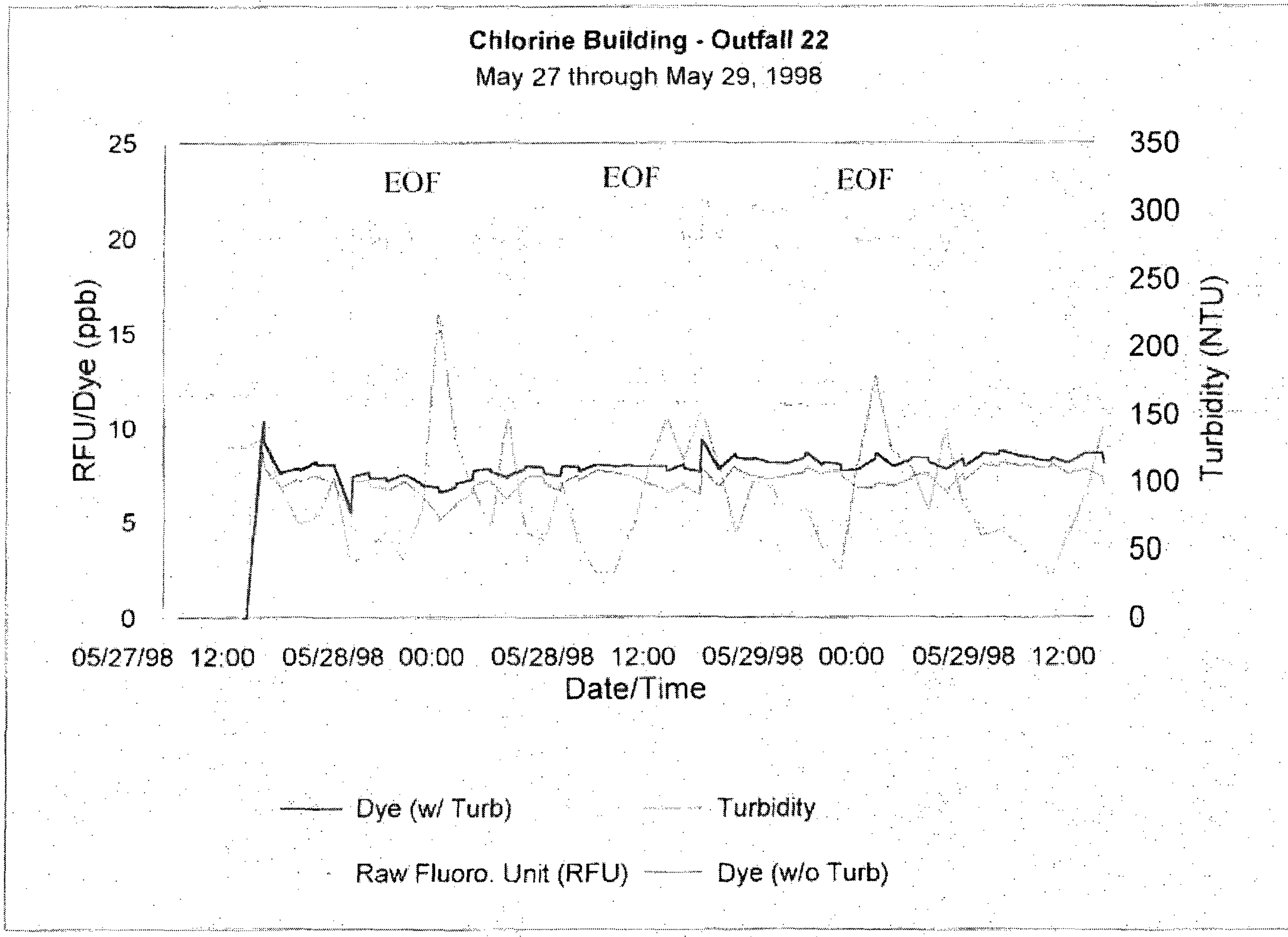

Chlorine Building - Outfall 22
May 27 through May 29, 1998
EOF
EOF
EOF
RFU/Dye (ppb)
Turbidity (NTU)
25
20
15
10
5
0
350
300
250
200
150
100
50
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
Raw Fluoro. Unit (RFU)
Dye (w/o Turb)

FIGURE 10-42

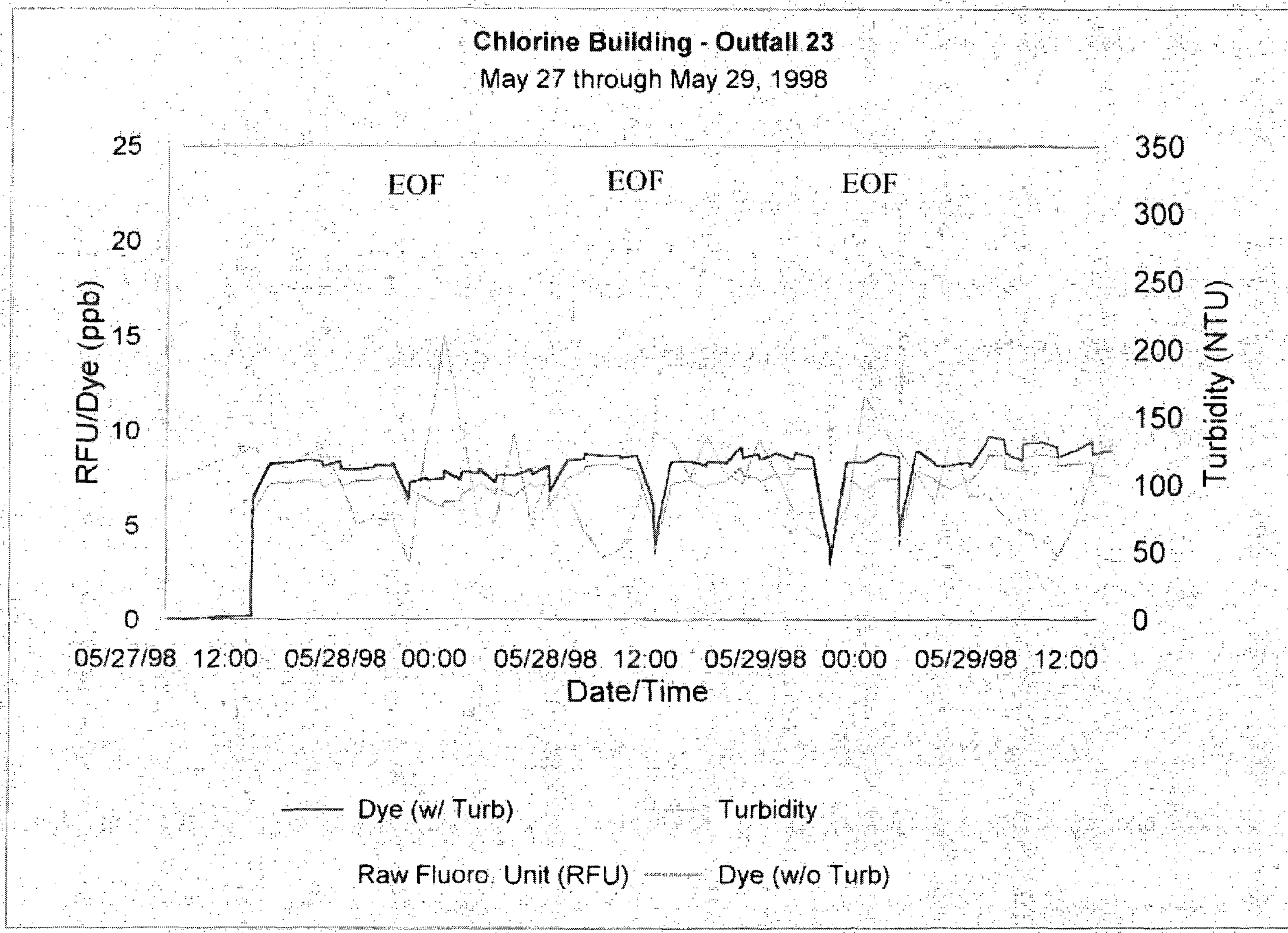

Chlorine Building - Outfall 23
May 27 through May 29, 1998
EOF
EOF
EOF
25
20
15
10
5
0
350
300
250
200
150
100
50
0
RFU/Dye (ppb)
Turbidity (NTU)
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
Date/Time
Dye (w/ Turb)
Turbidity
Raw Fluoro. Unit (RFU)
Dye (w/o Turb)

FIGURE 10-43

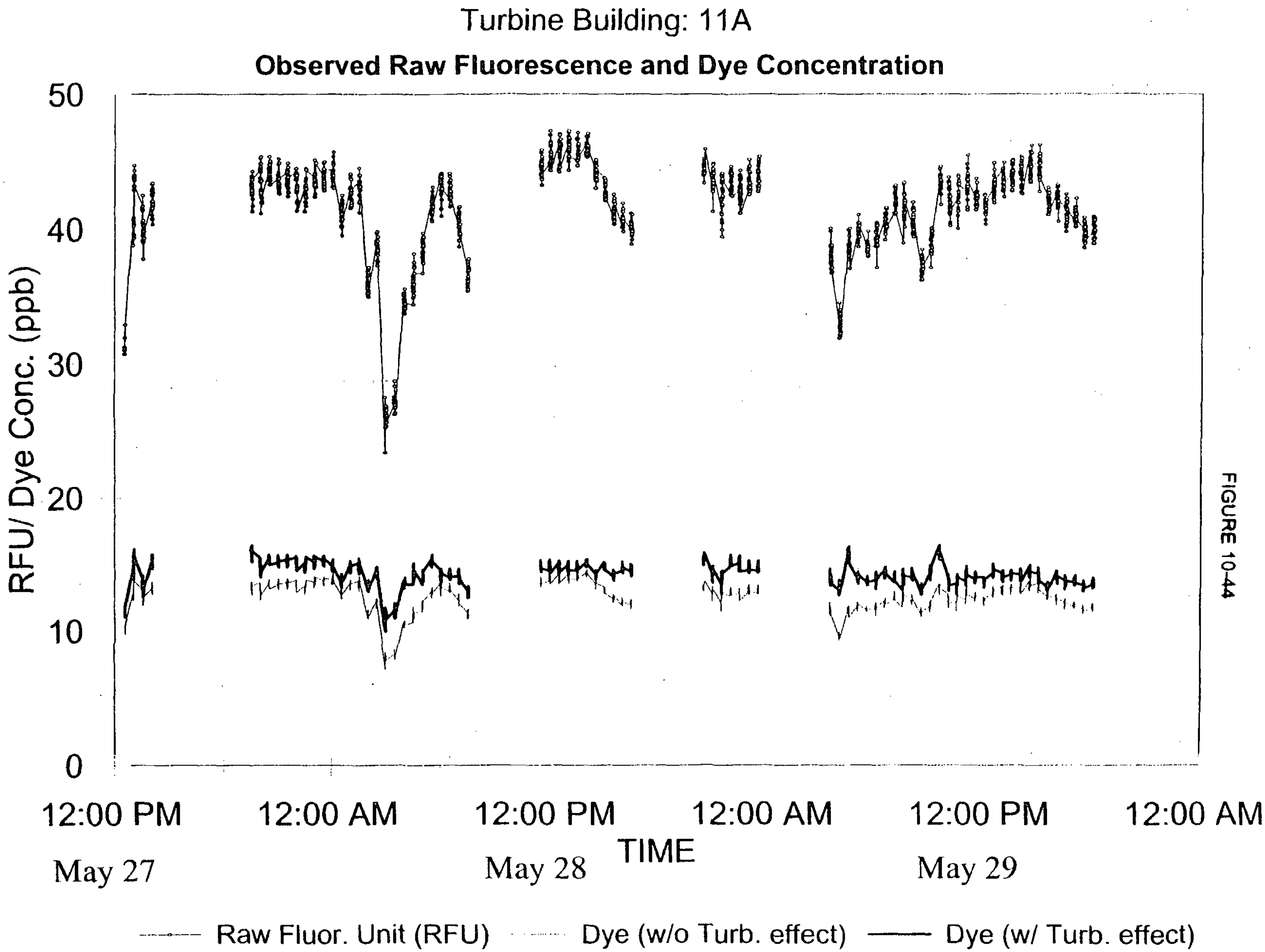

Turbine Building: 11A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
50
40
30
20
10
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-44

Turbine Building: 11B

Observed Raw Fluorescence and Dye Concentration

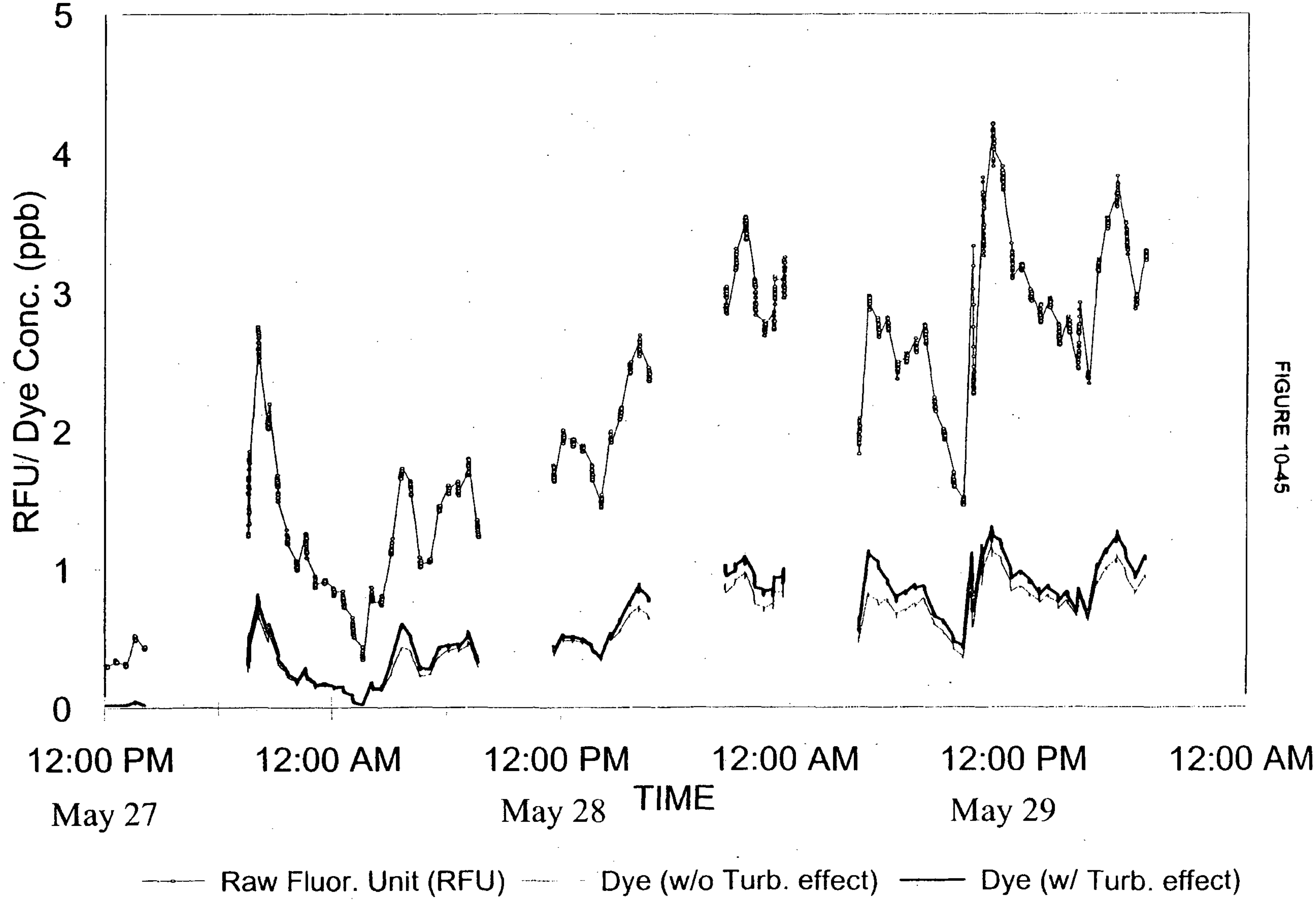
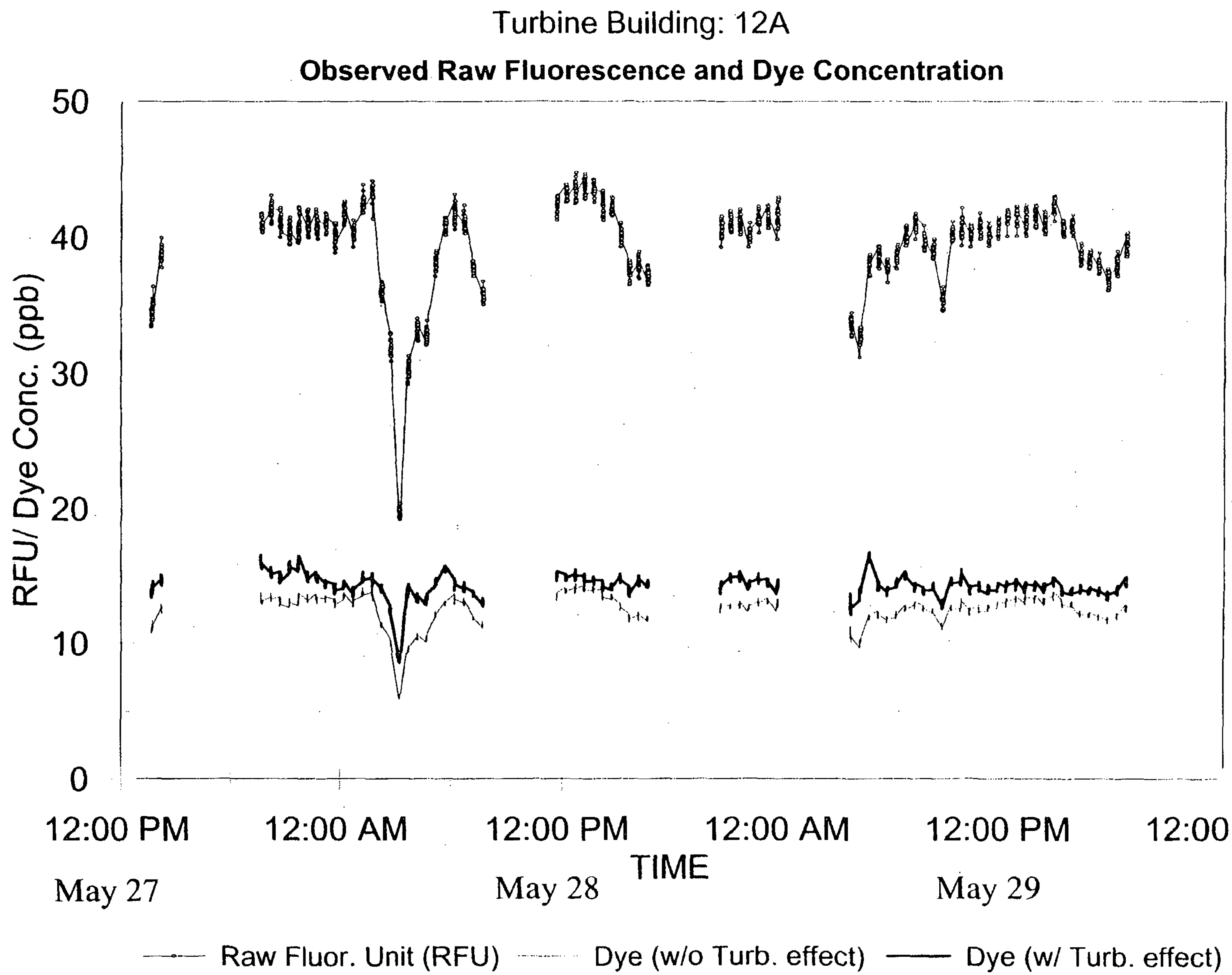
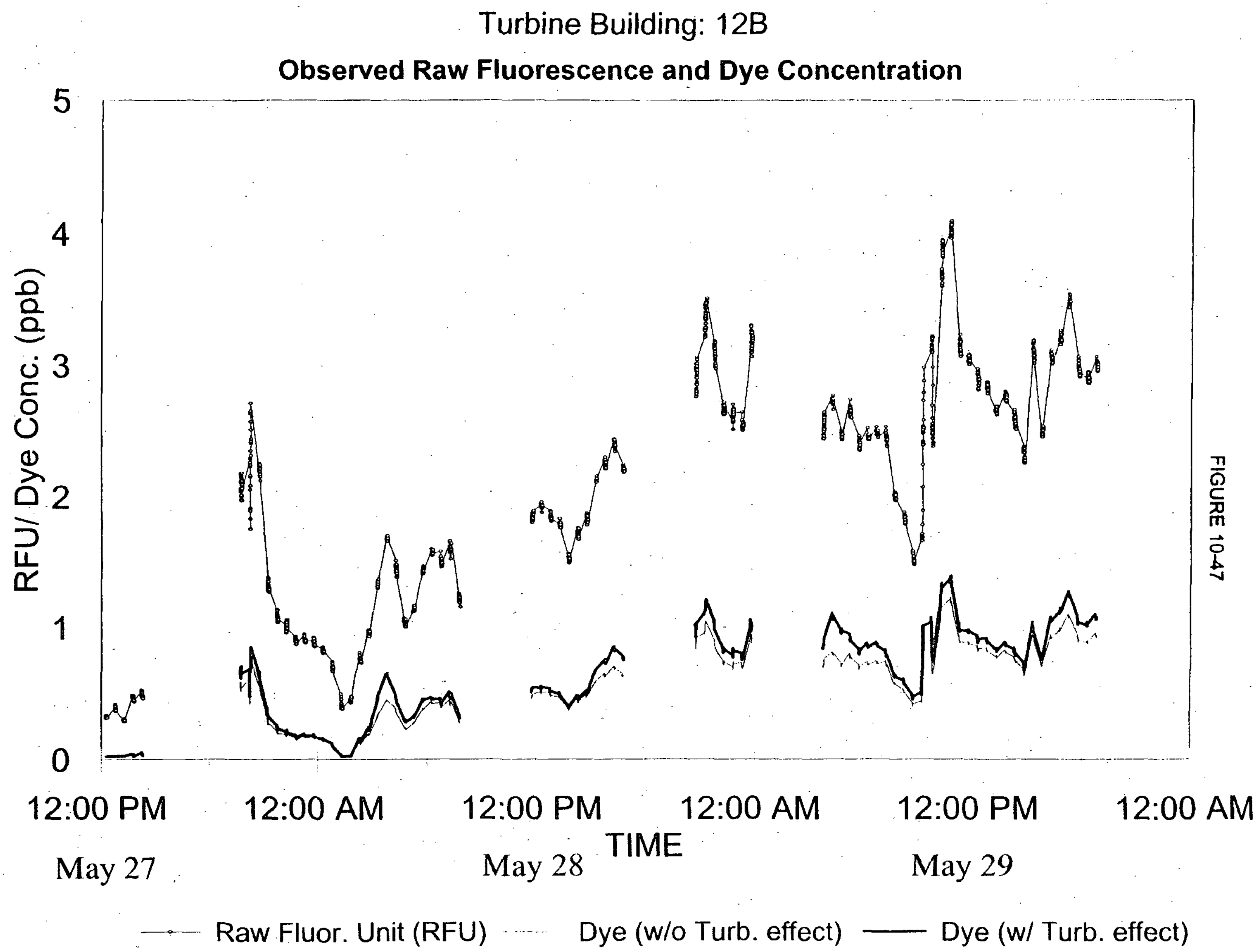


FIGURE 10-45



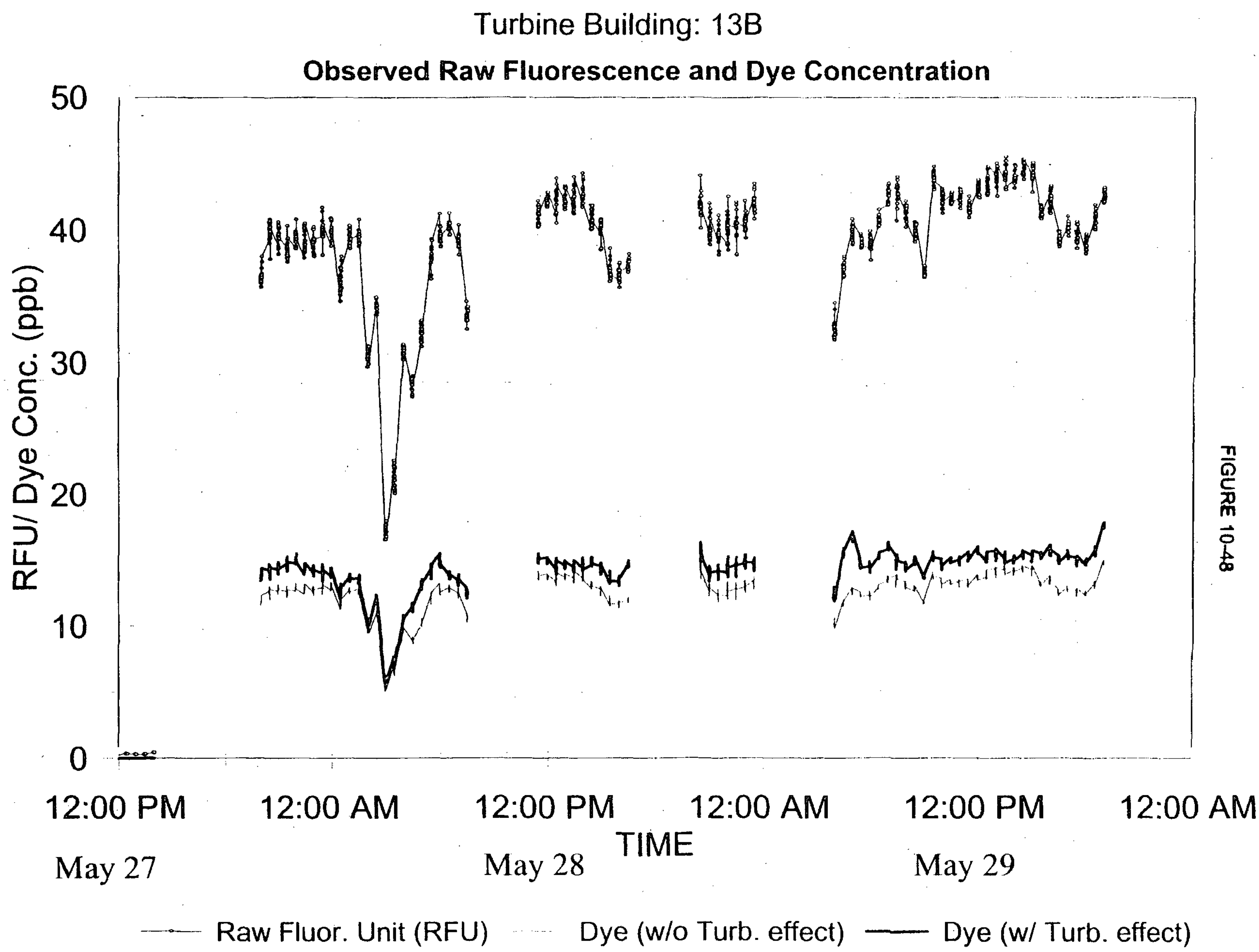
Turbine Building: 12A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
50
40
30
20
10
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
May 27
May 28
May 29
TIME
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-46



Turbine Building: 12B
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
5
4
3
2
1
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-47



Turbine Building: 13B
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
50
40
30
20
10
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-48

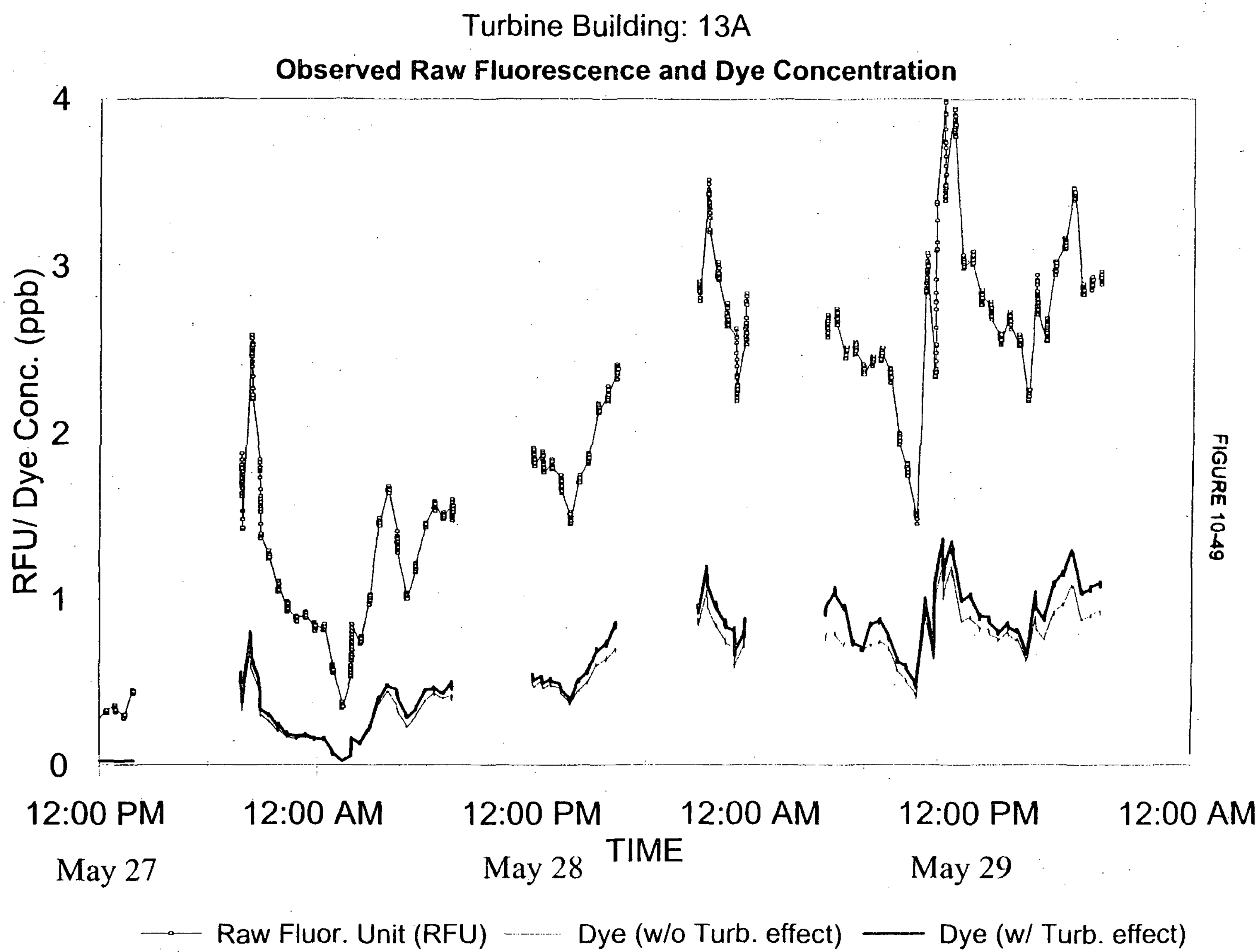
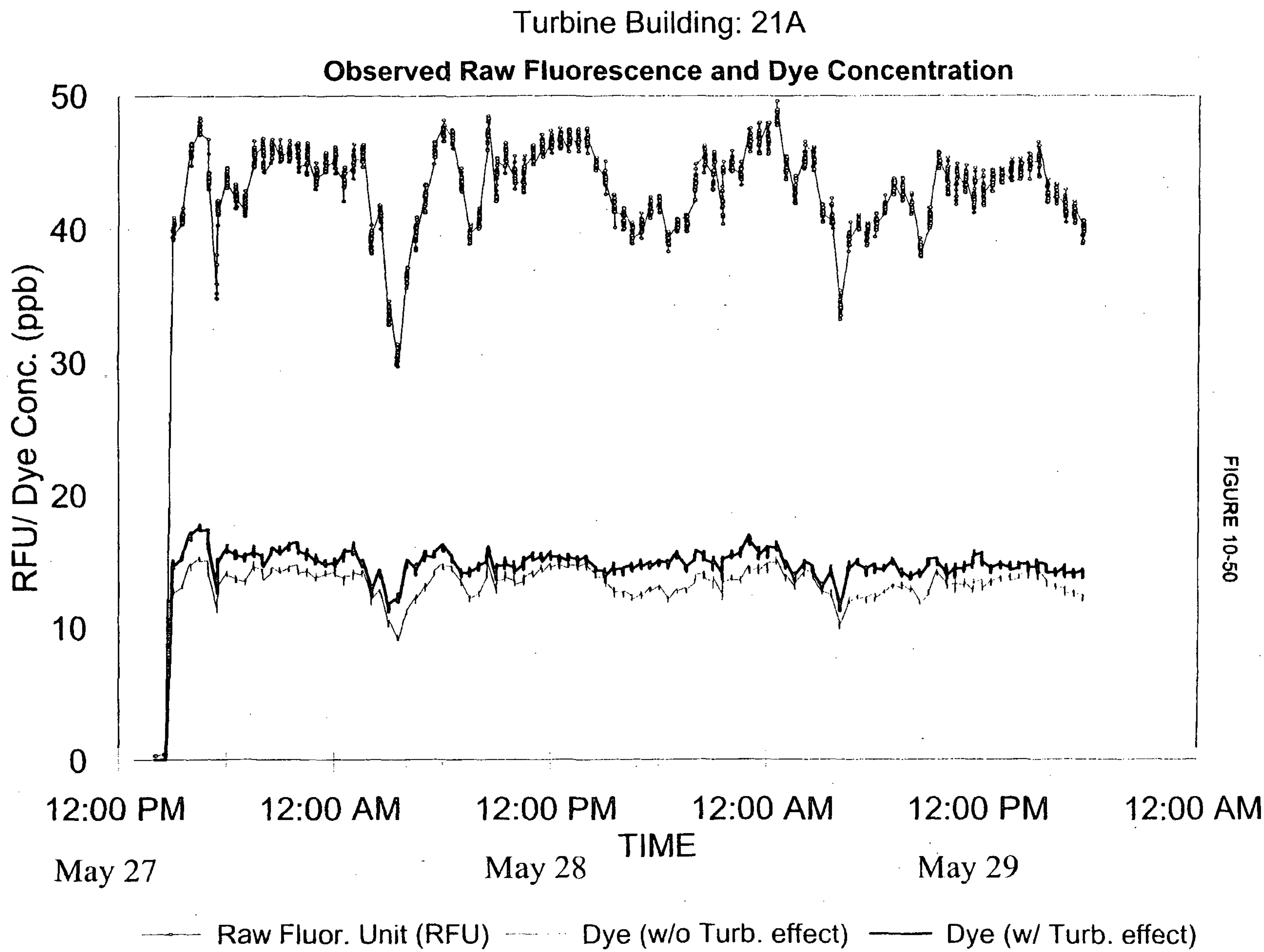

Turbine Building: 13A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
4
3
2
1
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
May 27
May 28
May 29
TIME
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-49



Turbine Building: 21A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
50
40
30
20
10
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-50

Turbine Building: 21B

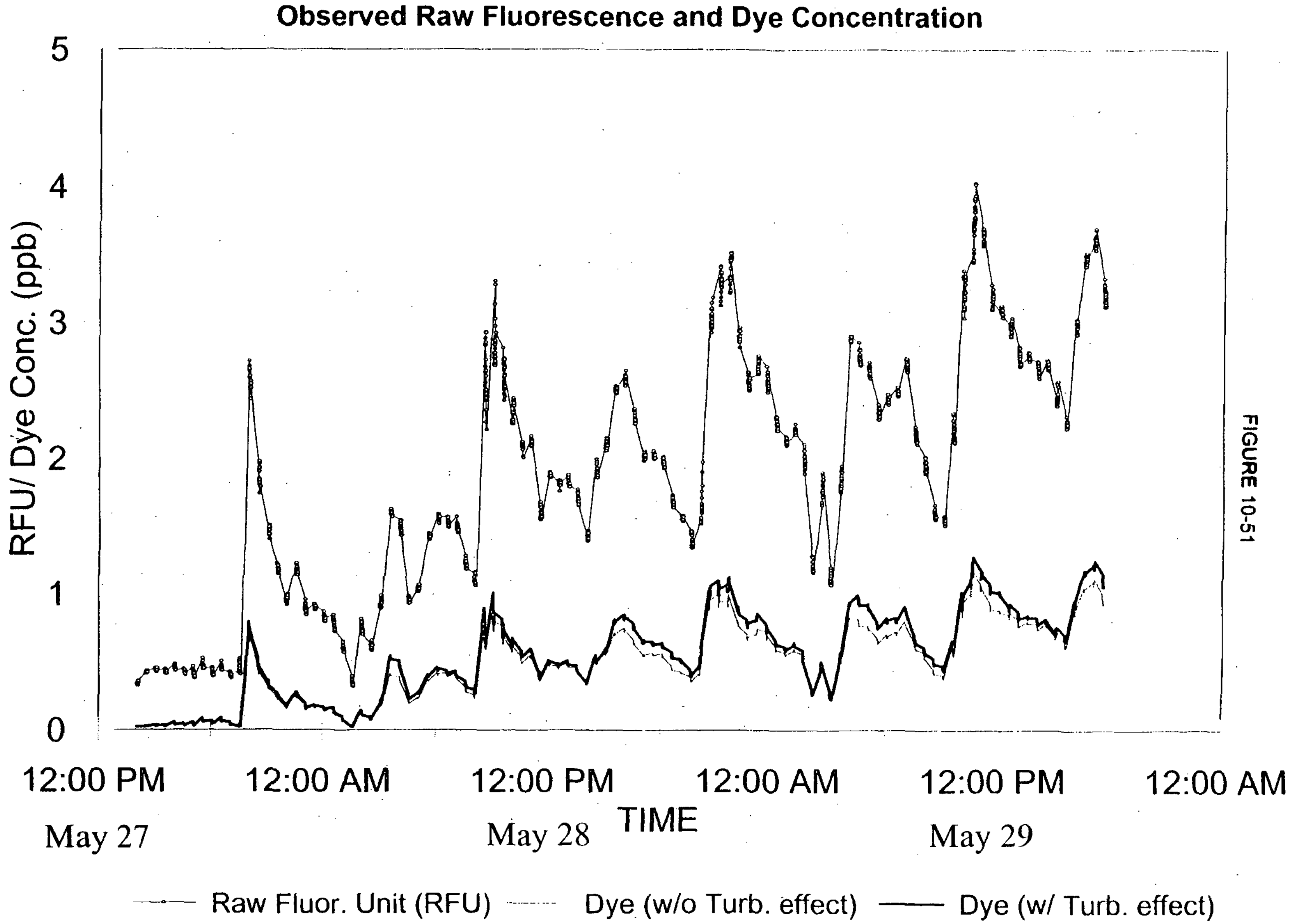


FIGURE 10-51

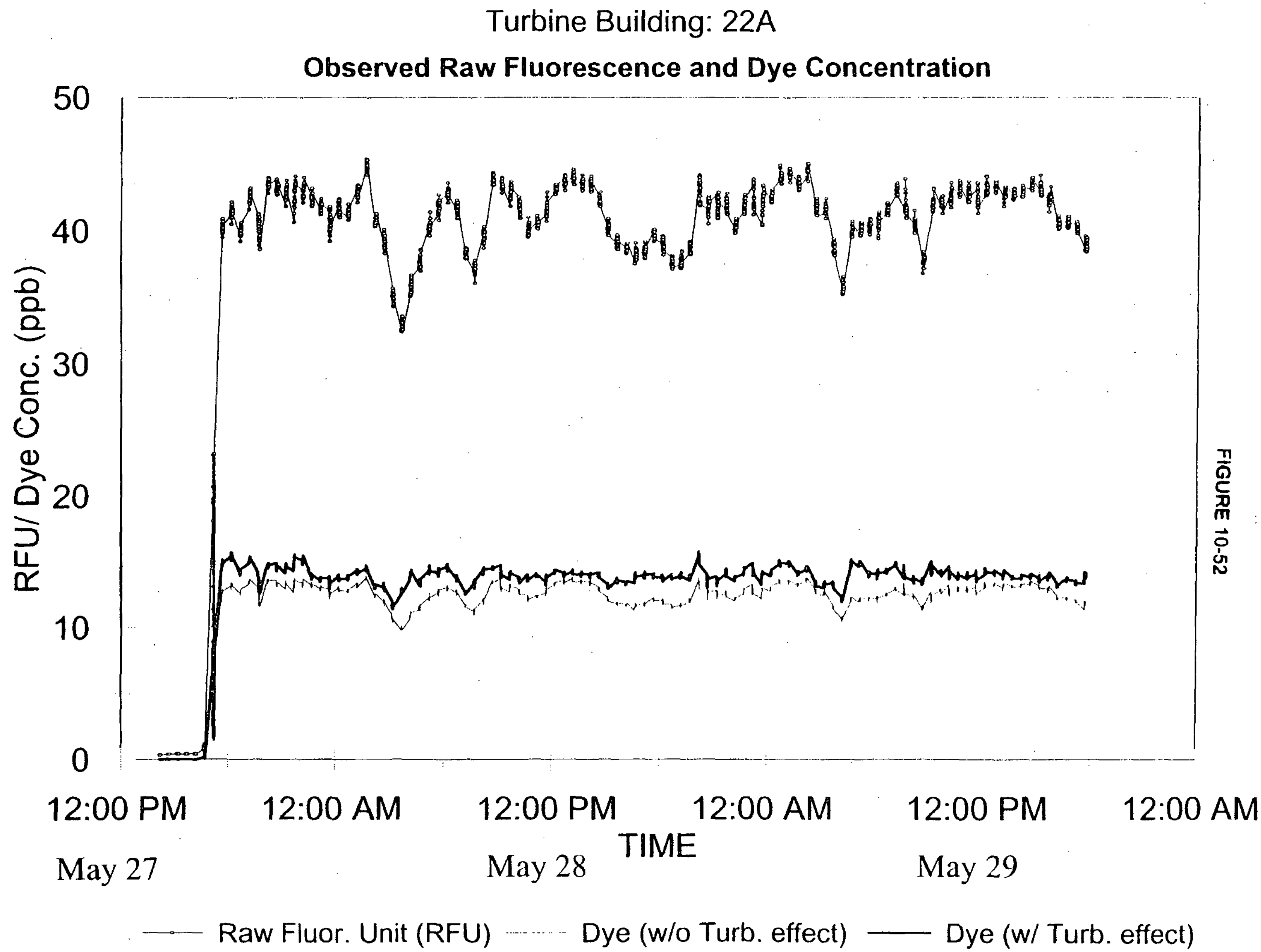
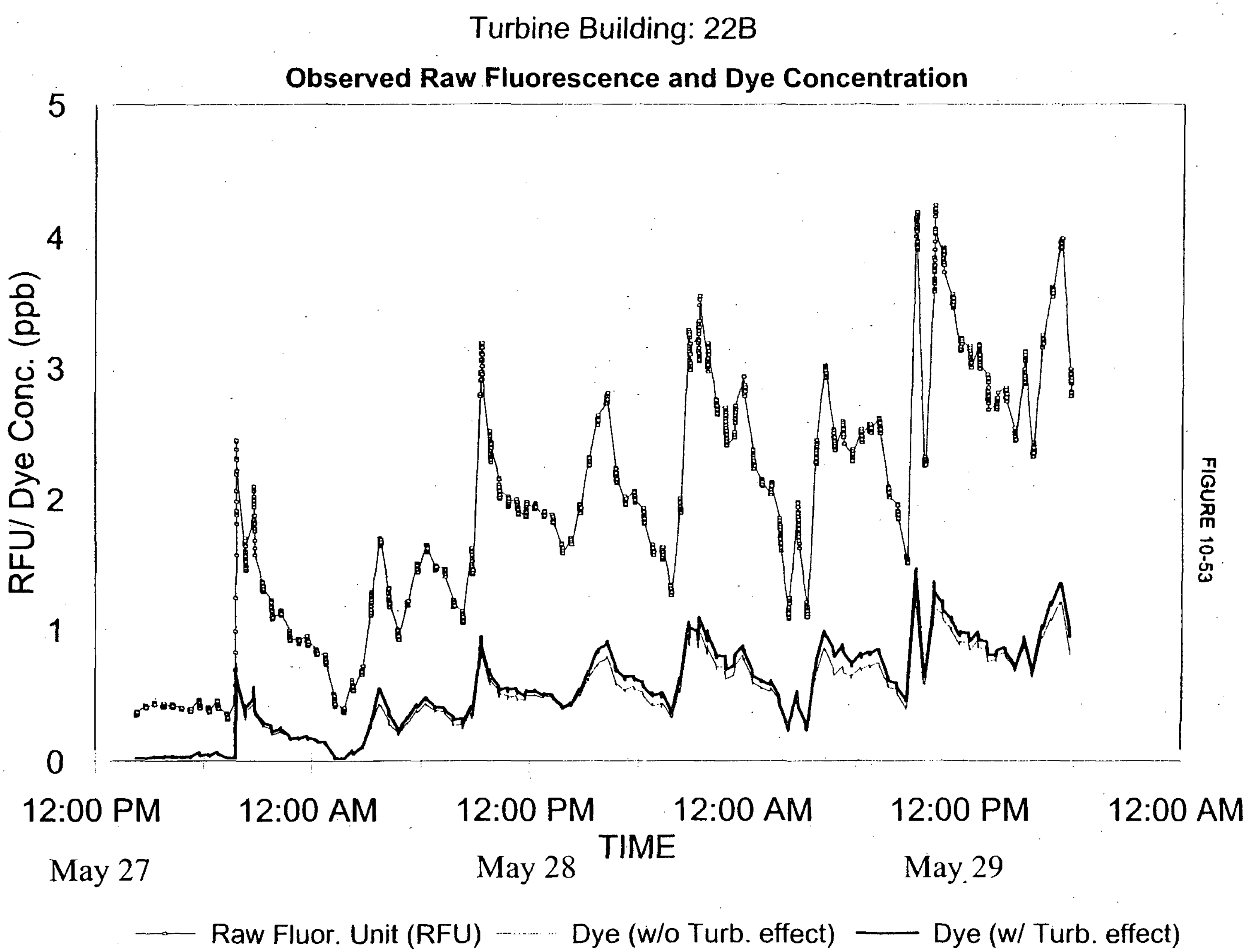
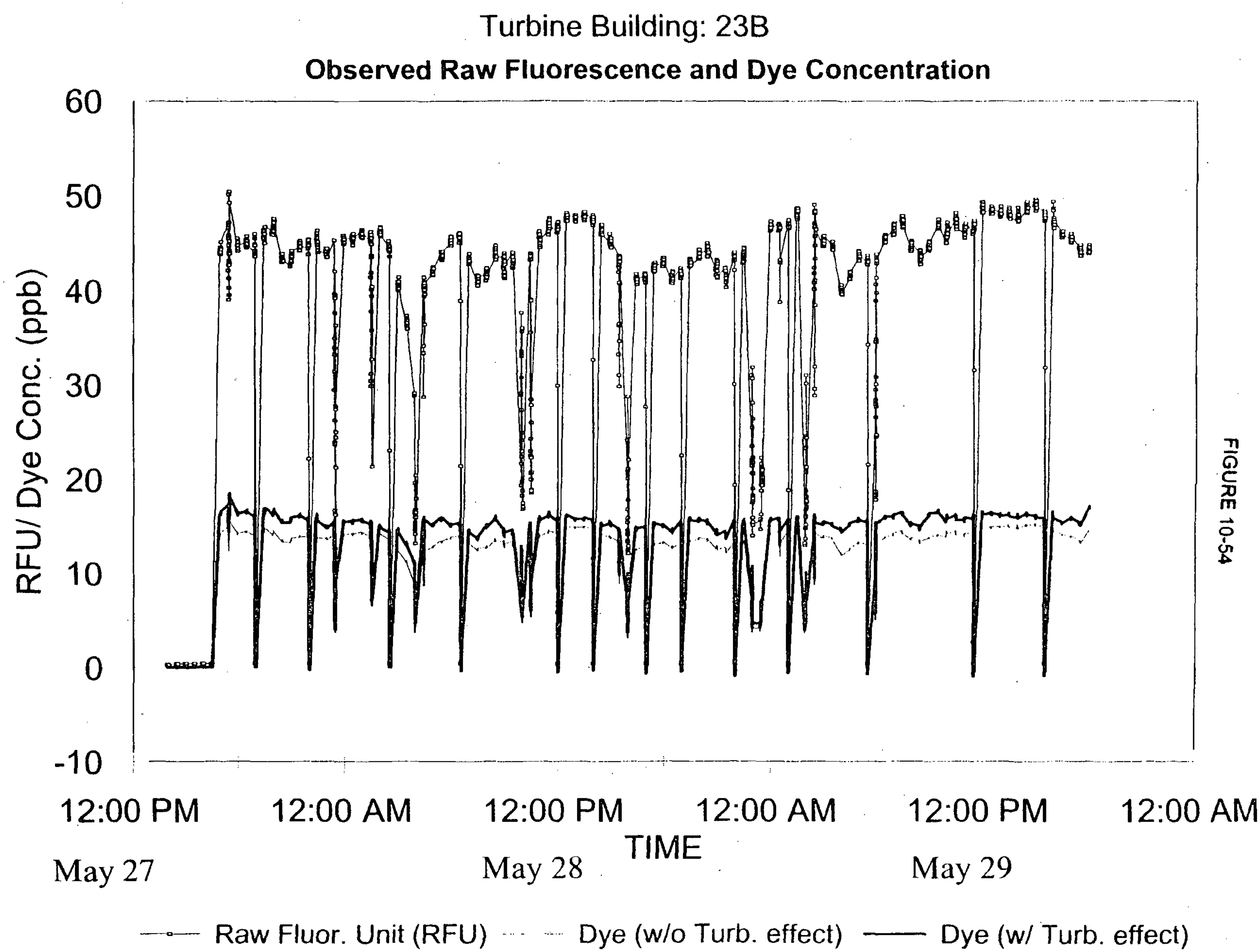

Turbine Building: 22A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
50
40
30
20
10
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-52



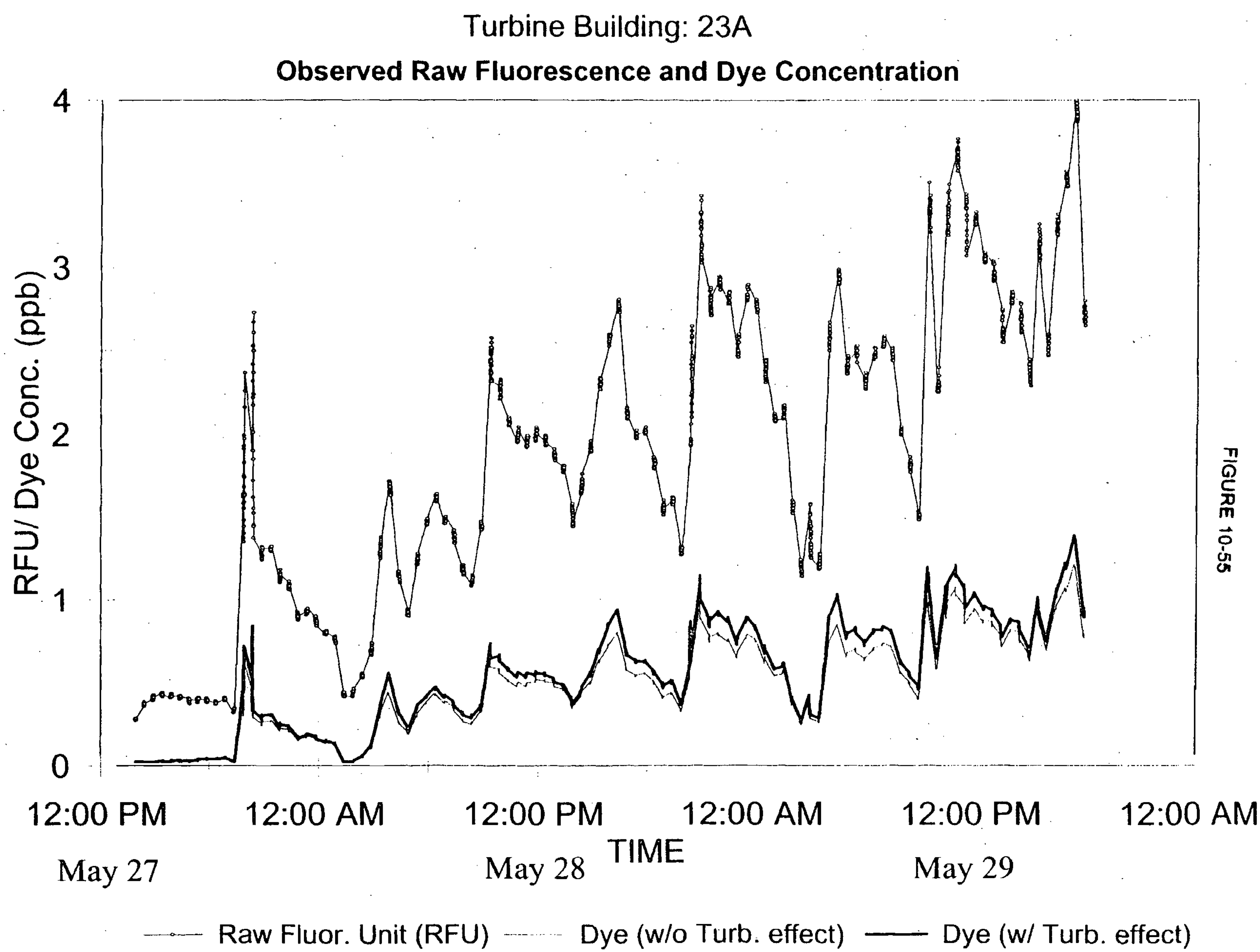
Turbine Building: 22B
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
5
4
3
2
1
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-53



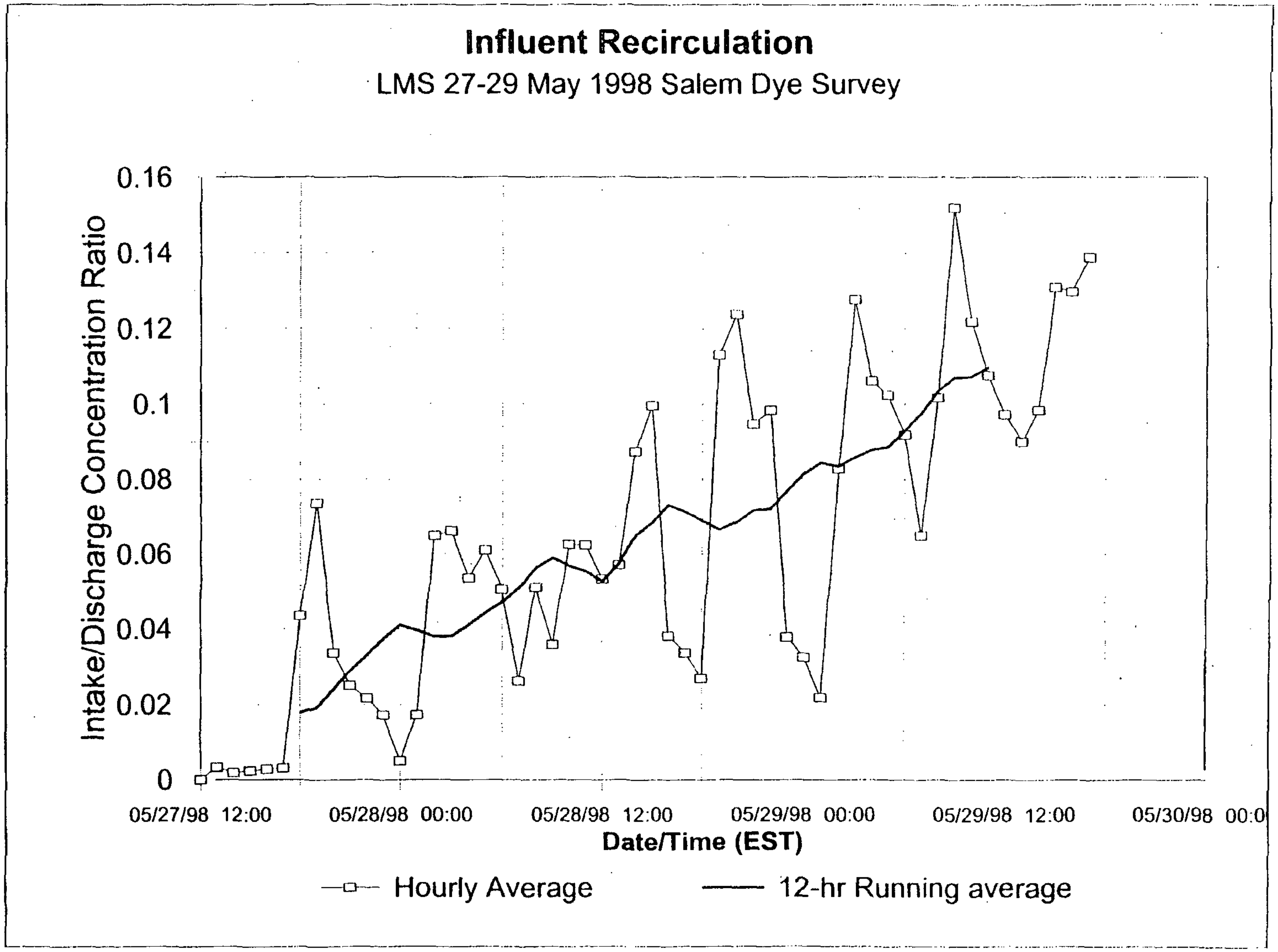
Turbine Building: 23B
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
60
50
40
30
20
10
0
-10
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
TIME
May 27
May 28
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-54



Turbine Building: 23A
Observed Raw Fluorescence and Dye Concentration
RFU/ Dye Conc. (ppb)
4
3
2
1
0
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
May 27
May 28
TIME
May 29
Raw Fluor. Unit (RFU)
Dye (w/o Turb. effect)
Dye (w/ Turb. effect)

FIGURE 10-55



Influent Recirculation
LMS 27-29 May 1998 Salem Dye Survey
Intake/Discharge Concentration Ratio
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
05/27/98 12:00
05/28/98 00:00
05/28/98 12:00
05/29/98 00:00
05/29/98 12:00
05/30/98 00:0
Date/Time (EST)
Hourly Average
12-hr Running average

FIGURE 10-56

Figure 10-57

PSE&G 2-Unit Survey; 29 May 1998
Transect Locations
EBB Phase (06:40 - 08:40)

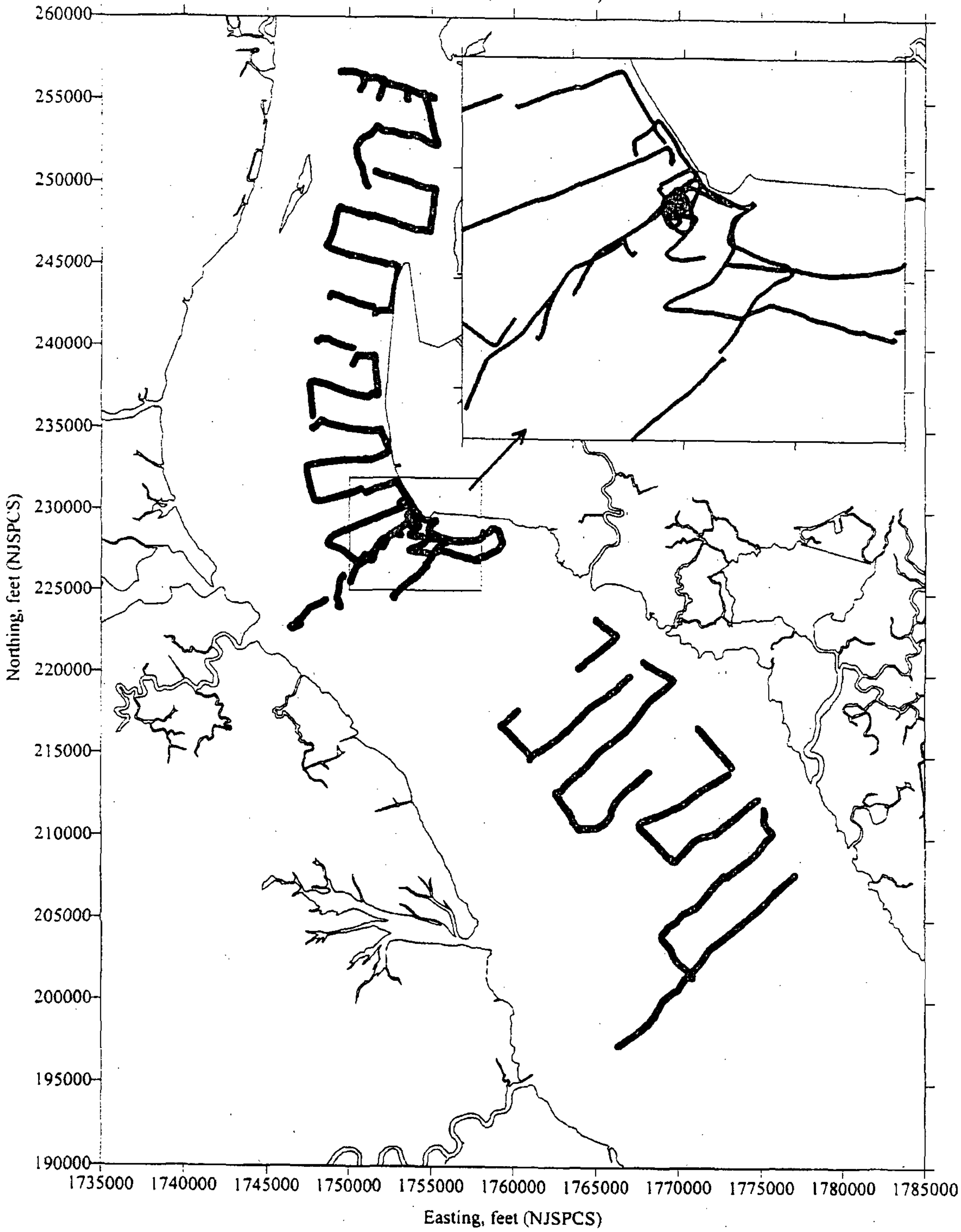


Figure 10-58
PSE&G 2-Unit Survey, 29 May 1998
Surface Temperature Profiles
EBB PHASE (06:40-08:40)

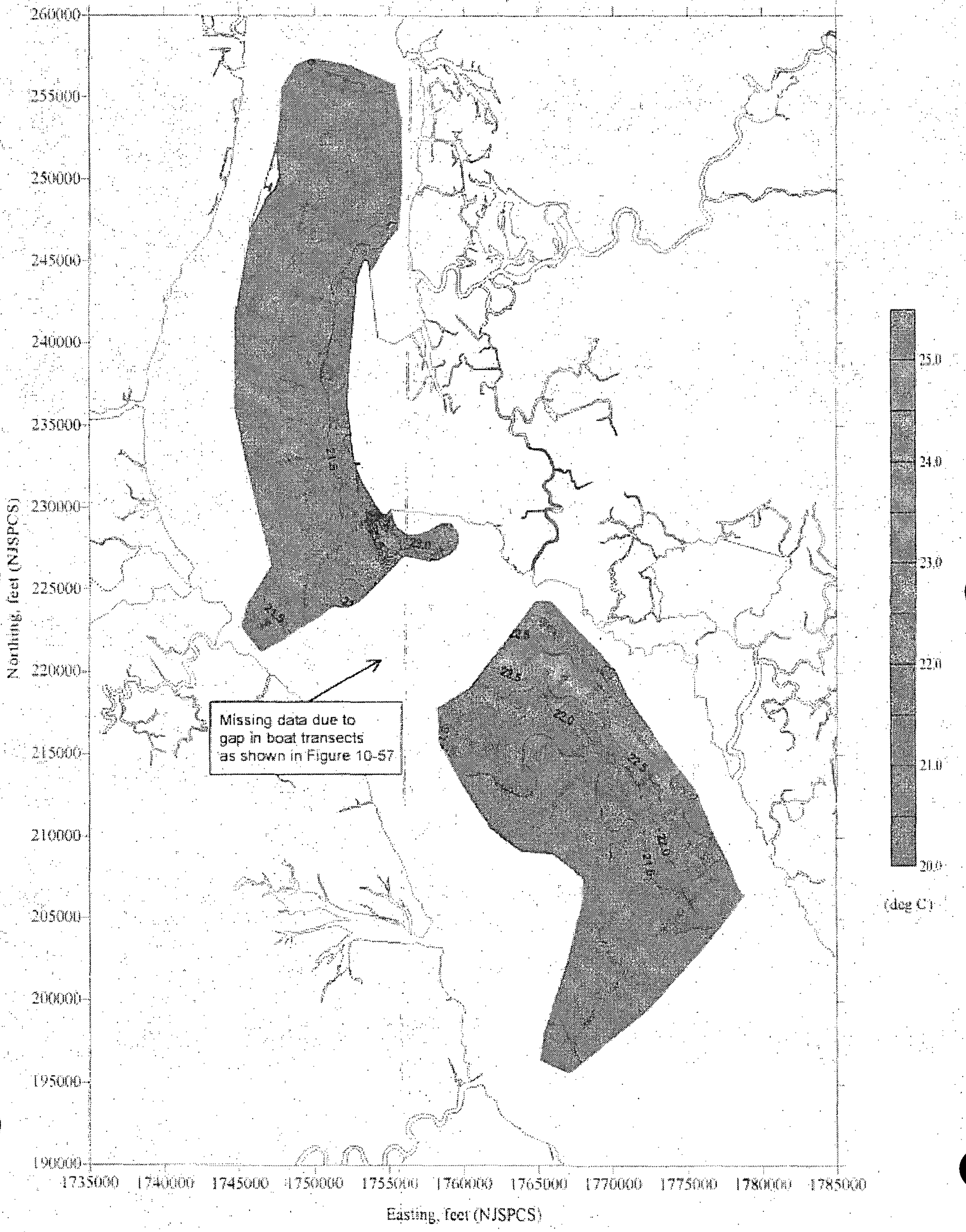


FIGURE 10-59
PSE&G 2-Unit Survey; 29 May 1998
Surface Temperature Profiles
EBB PHASE (06:40-08:40)

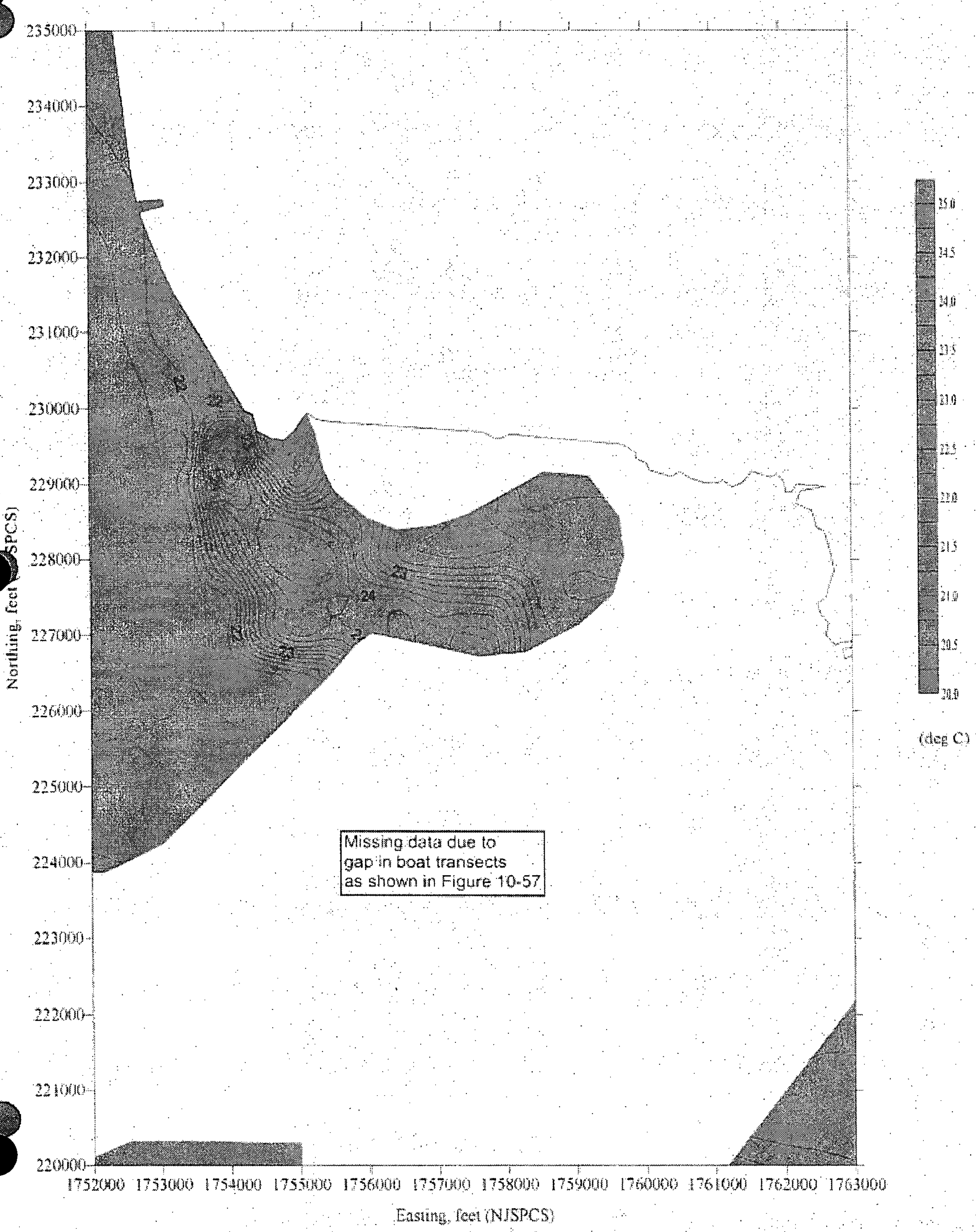


FIGURE 10-60
PSE&G 2-Unit Survey: 29 May 1998
Surface Dye Profiles
Ebb Phase (06:40-08:40)

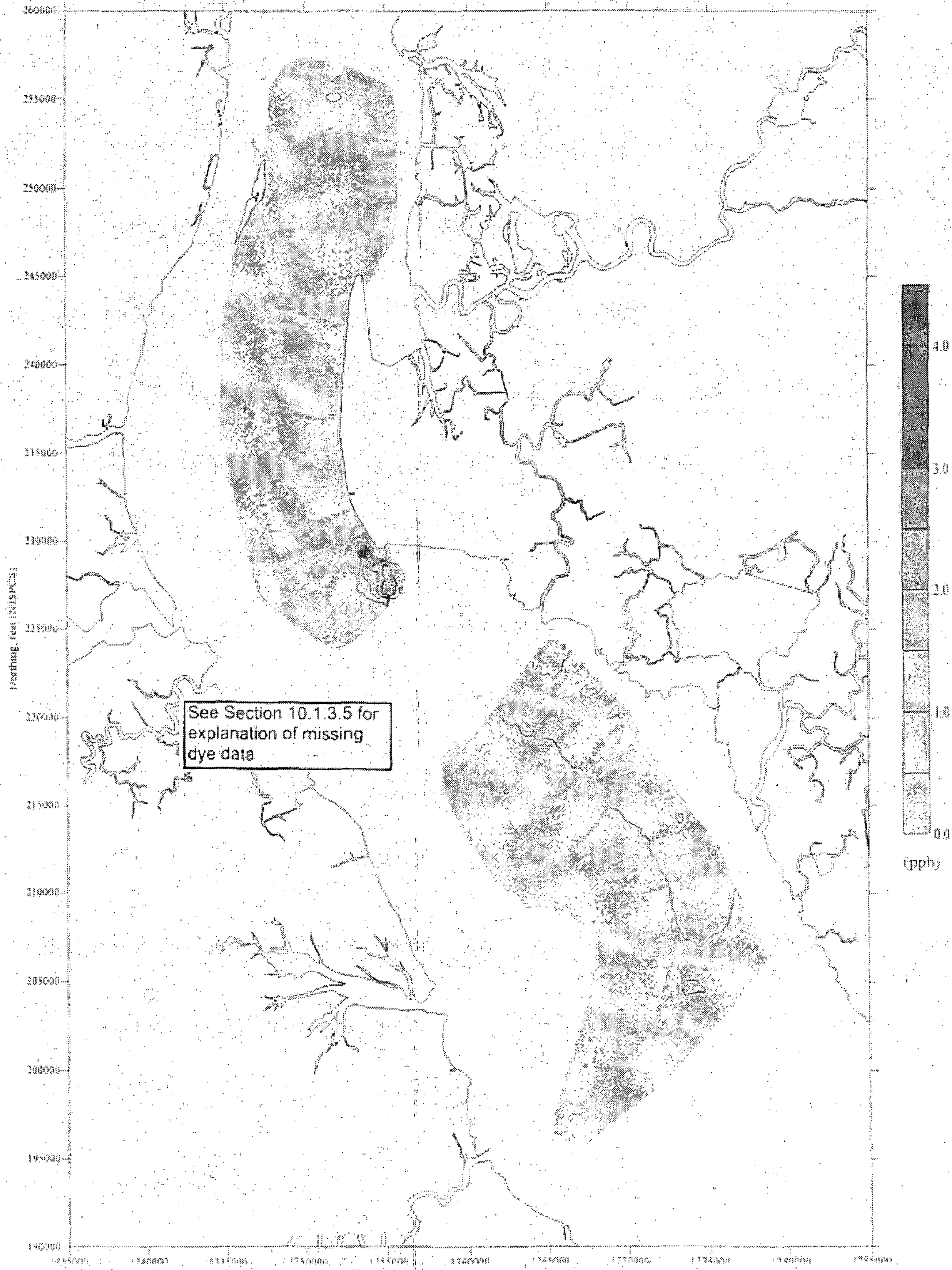


FIGURE 10-61
PSE&G 2-Unit Survey; 29 May 1998
Surface Dye Profiles
Ebb Phase (06:40-08:40)

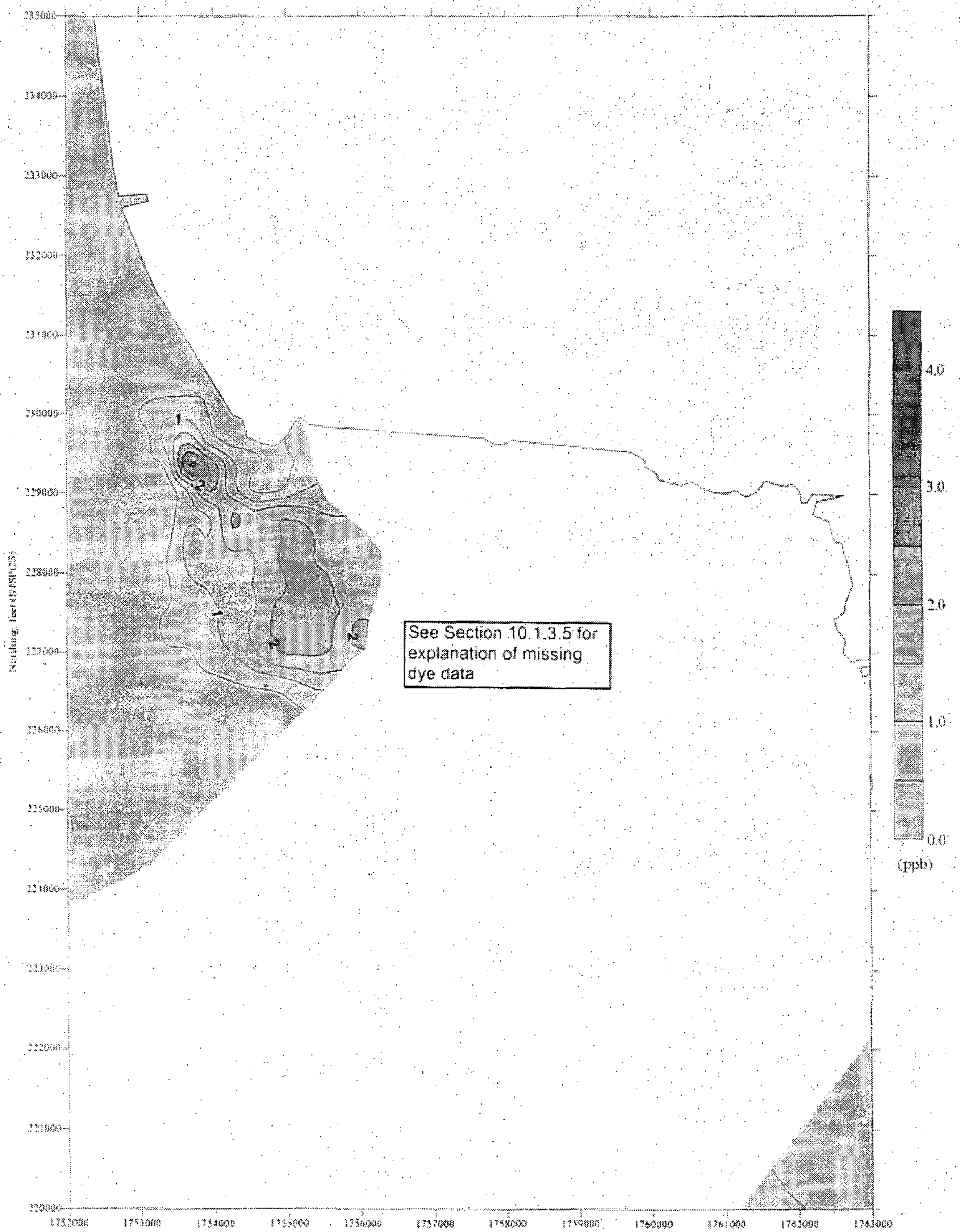


Figure 10-62

PSE&G 2-Unit Survey; 29 May 1998
Transect Locations
EOE Phase (09:10 - 11:10)

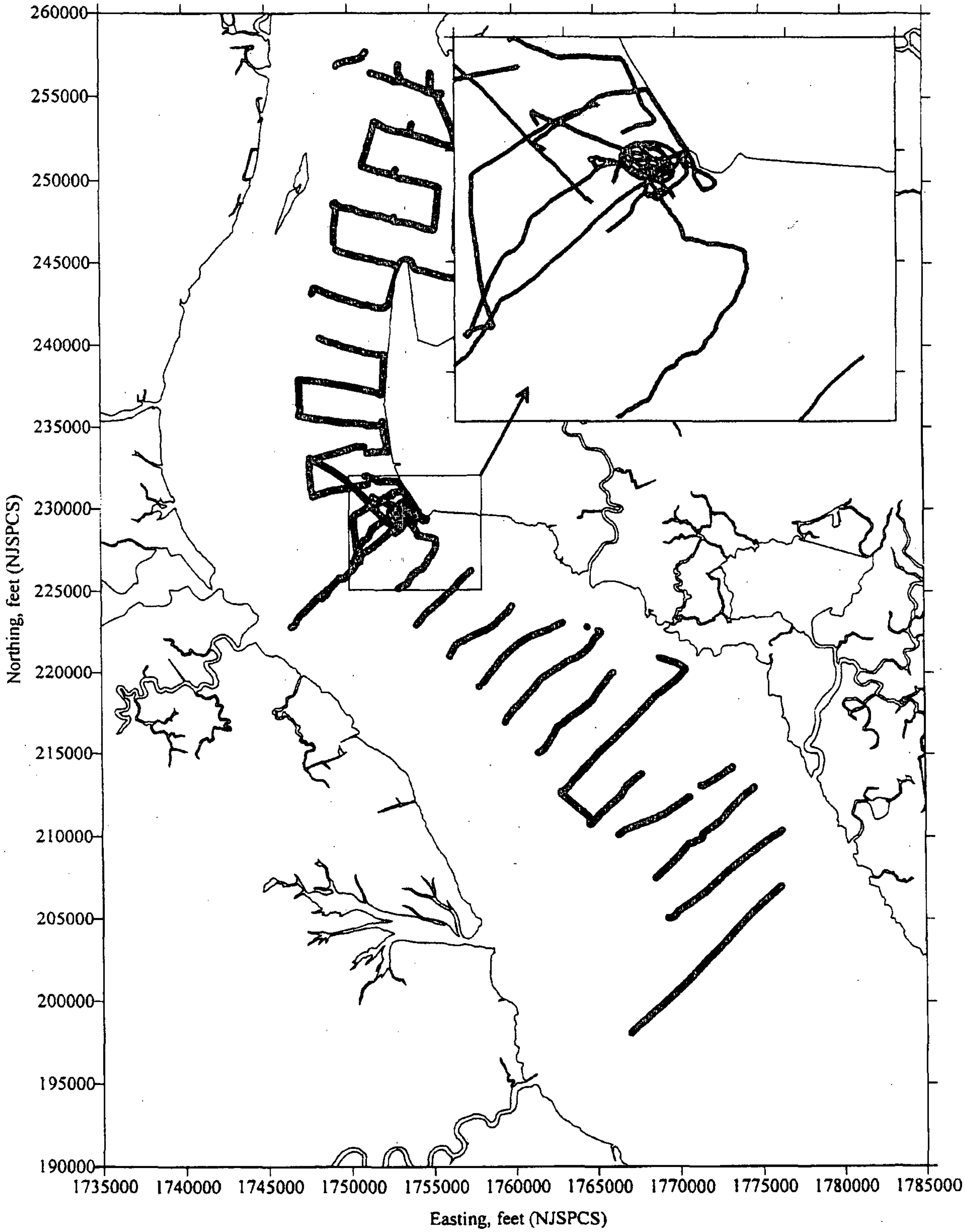


FIGURE 10-63
PSE&G 2-Unit Survey; 29 May 1998
Surface Temperature Profiles
EOE PHASE (09:10-11:10)

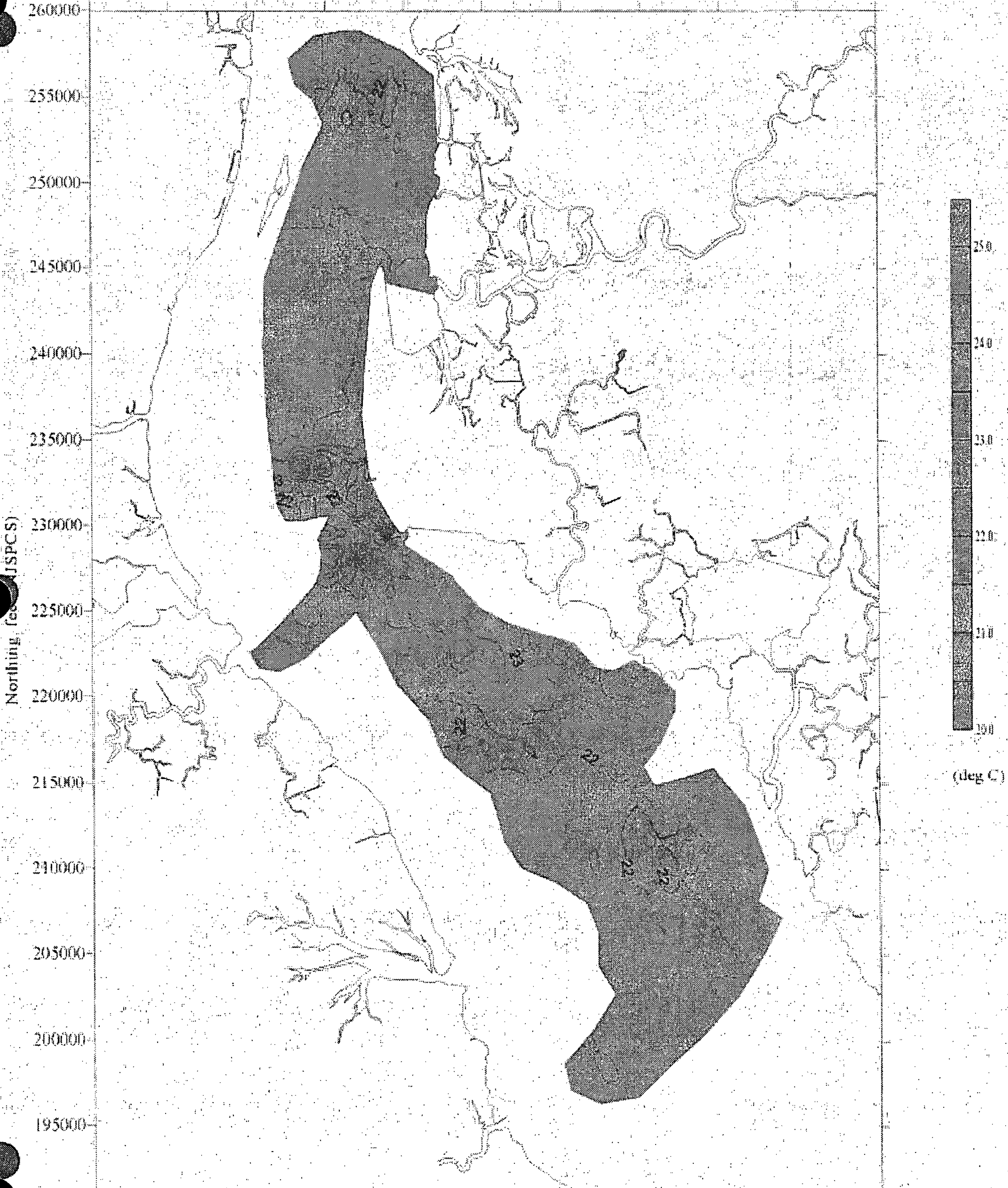


FIGURE 10-64
PSE&G 2-Unit Survey; 29 May 1998
Surface Temperature Profiles
EOE PHASE (09:10-11:10)

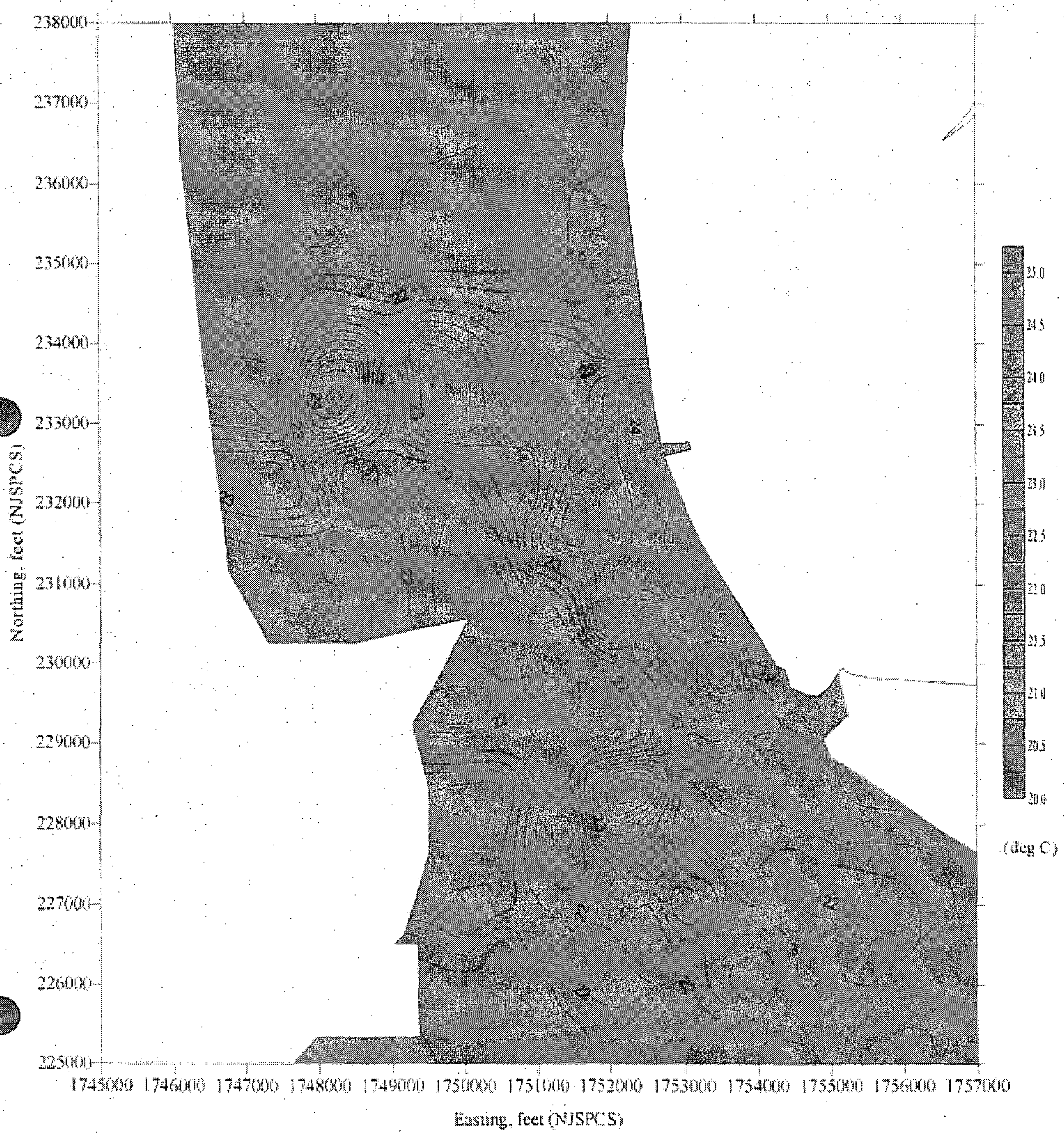


FIGURE 10-65
PSE&G 2-Unit Survey, 29 May 1998
Surface Dye Profiles
EOE Phase (09:10-11:10)

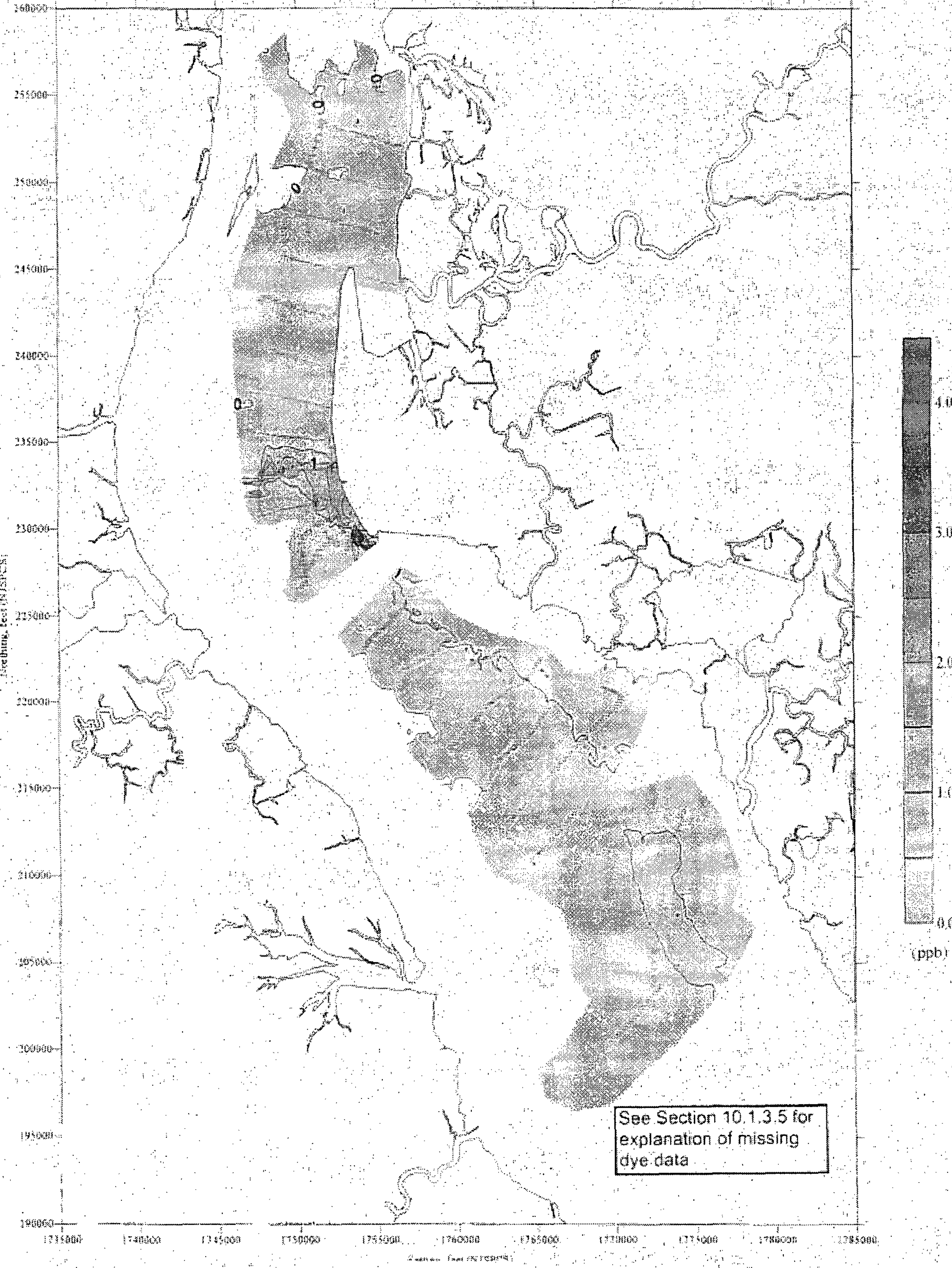


FIGURE 10-66

PSE&G 2-Unit Survey; 29 May 1998

Surface Dye Profiles

EOE Phase (09:10-11:10)

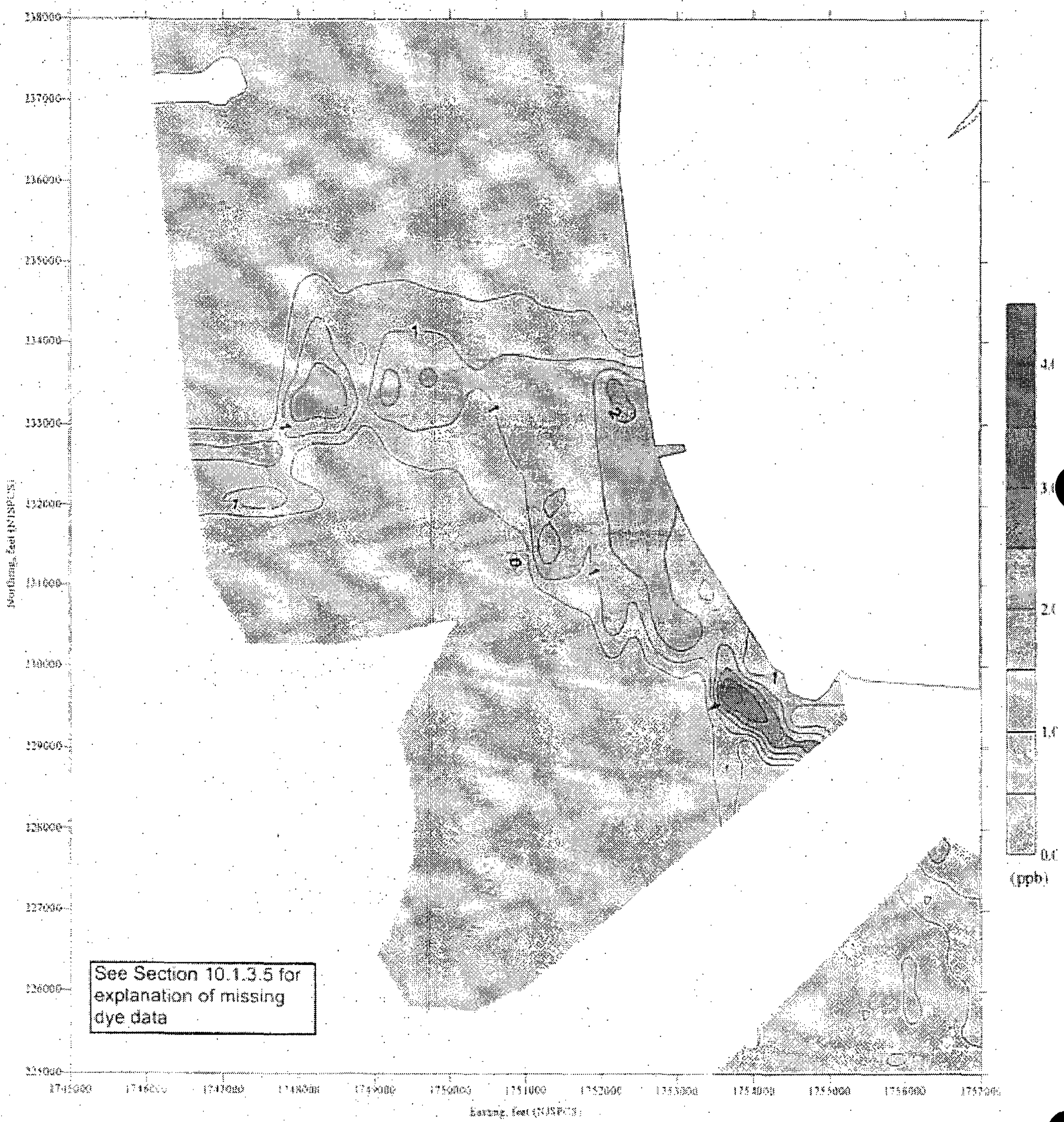


Figure 10-67

PSE&G 2-Unit Survey; 29 May 1998
Transect Locations
FLOOD Phase (11:40 - 13:40)

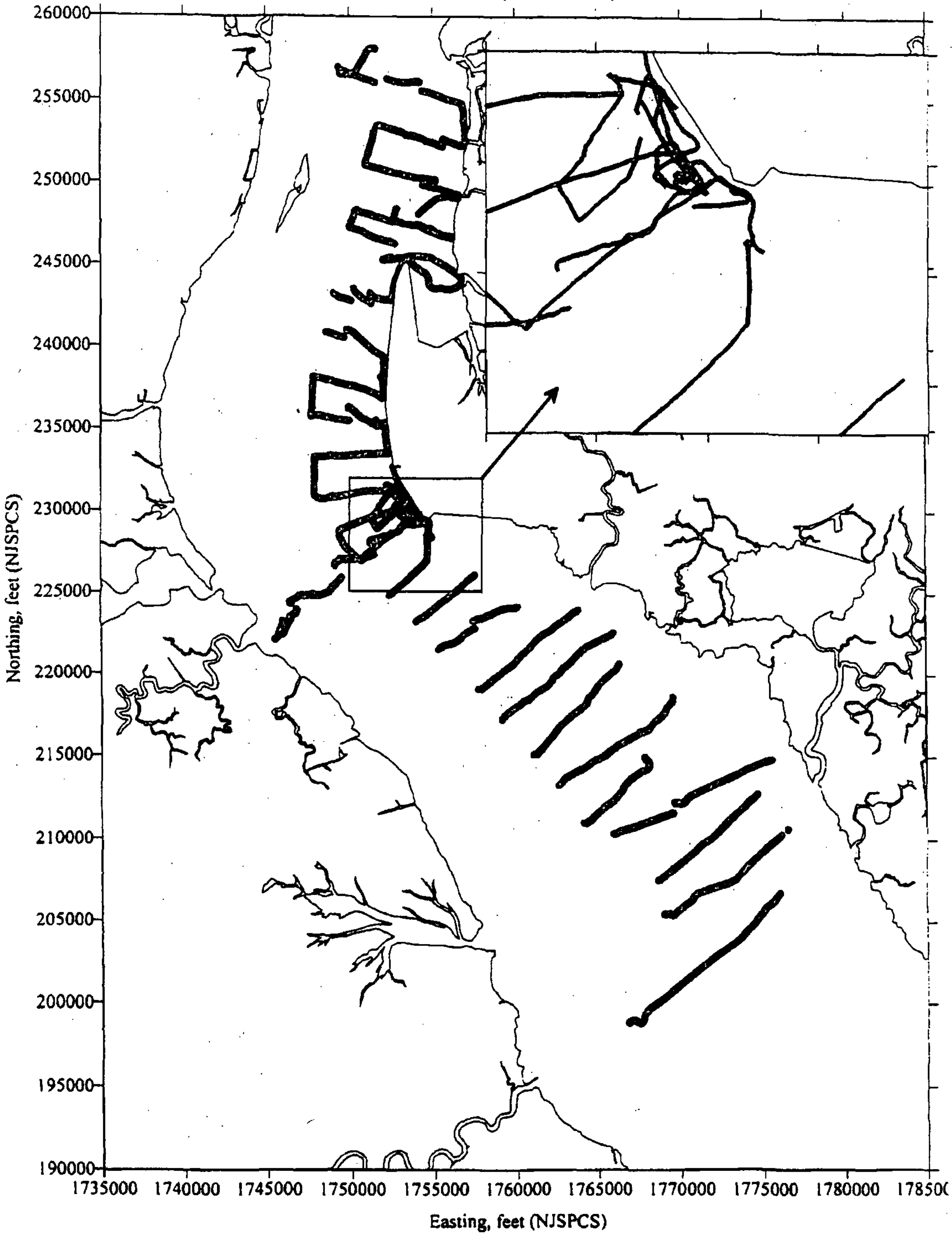


FIGURE 10-68

PSE&G 2-Unit Survey; 29 May 1998

Surface Temperature Profiles

FLOOD PHASE (11:40-13:40)

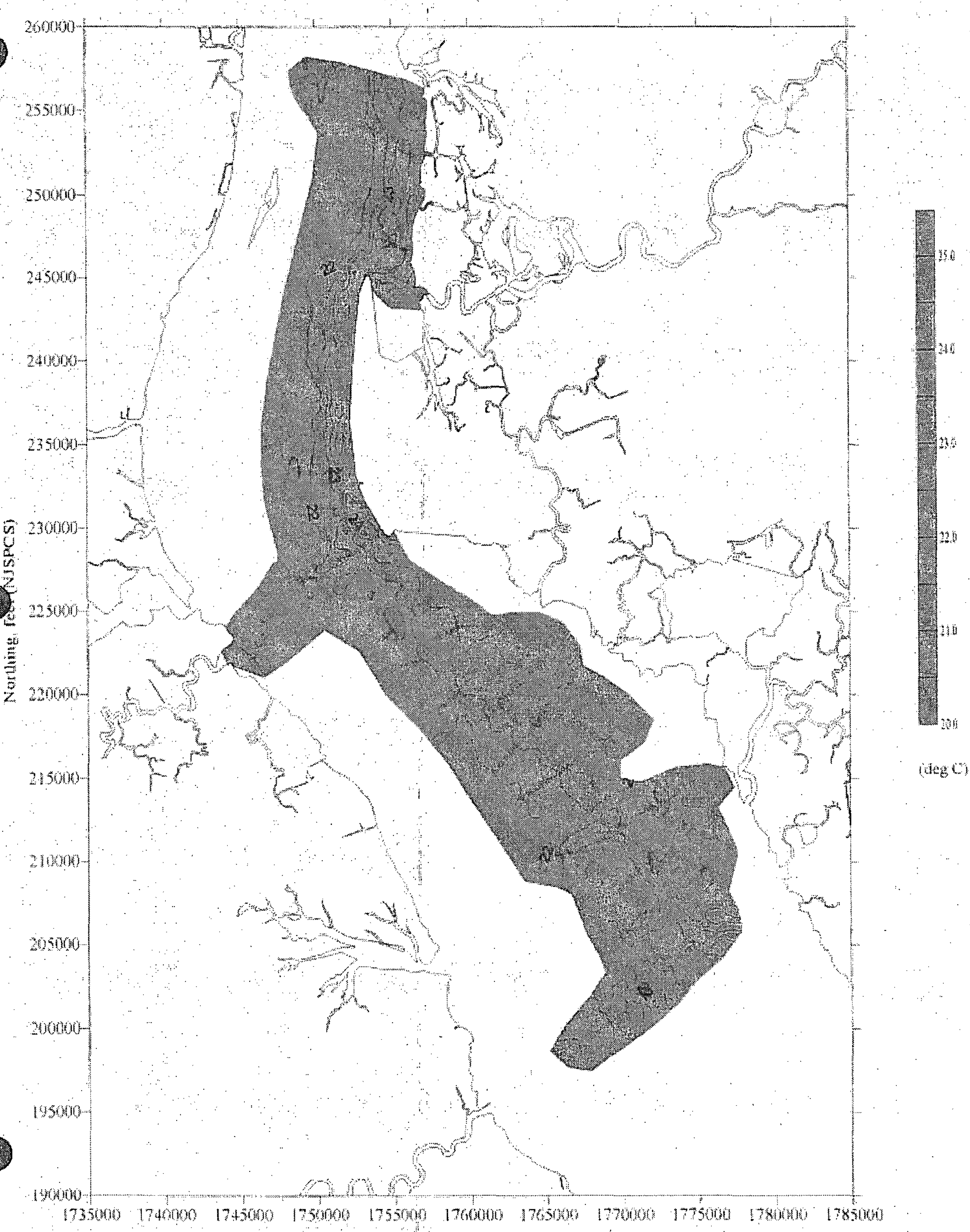


FIGURE 10-69
PSE&G 2-Unit Survey: 29 May 1998
Surface Temperature Profiles
FLOOD PHASE (11:40-13:40)

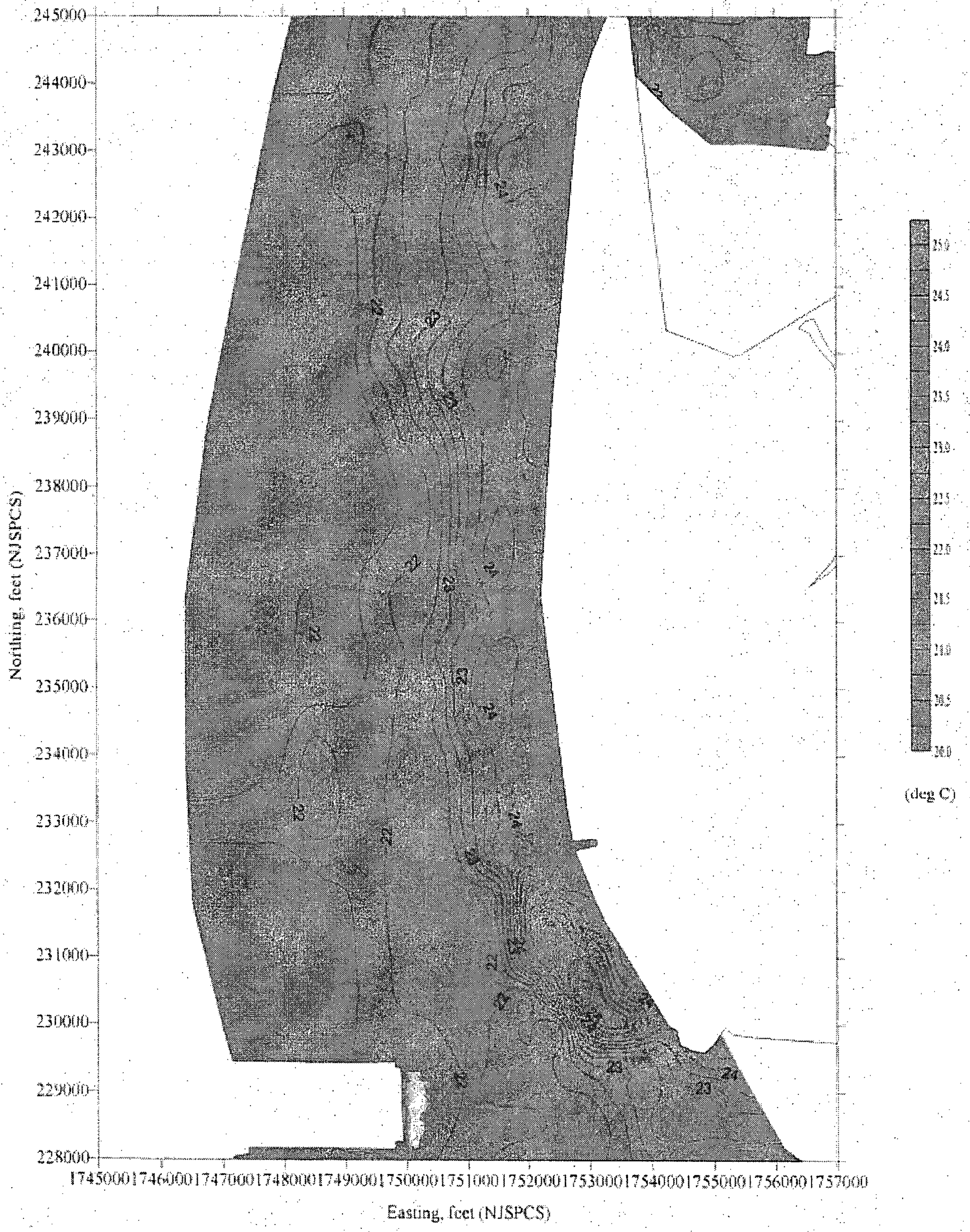


FIGURE 10-70
PSE&G 2-Unit Survey; 29 May 1998
Surface Dye Profiles
FLD Phase (11:40-13:40)

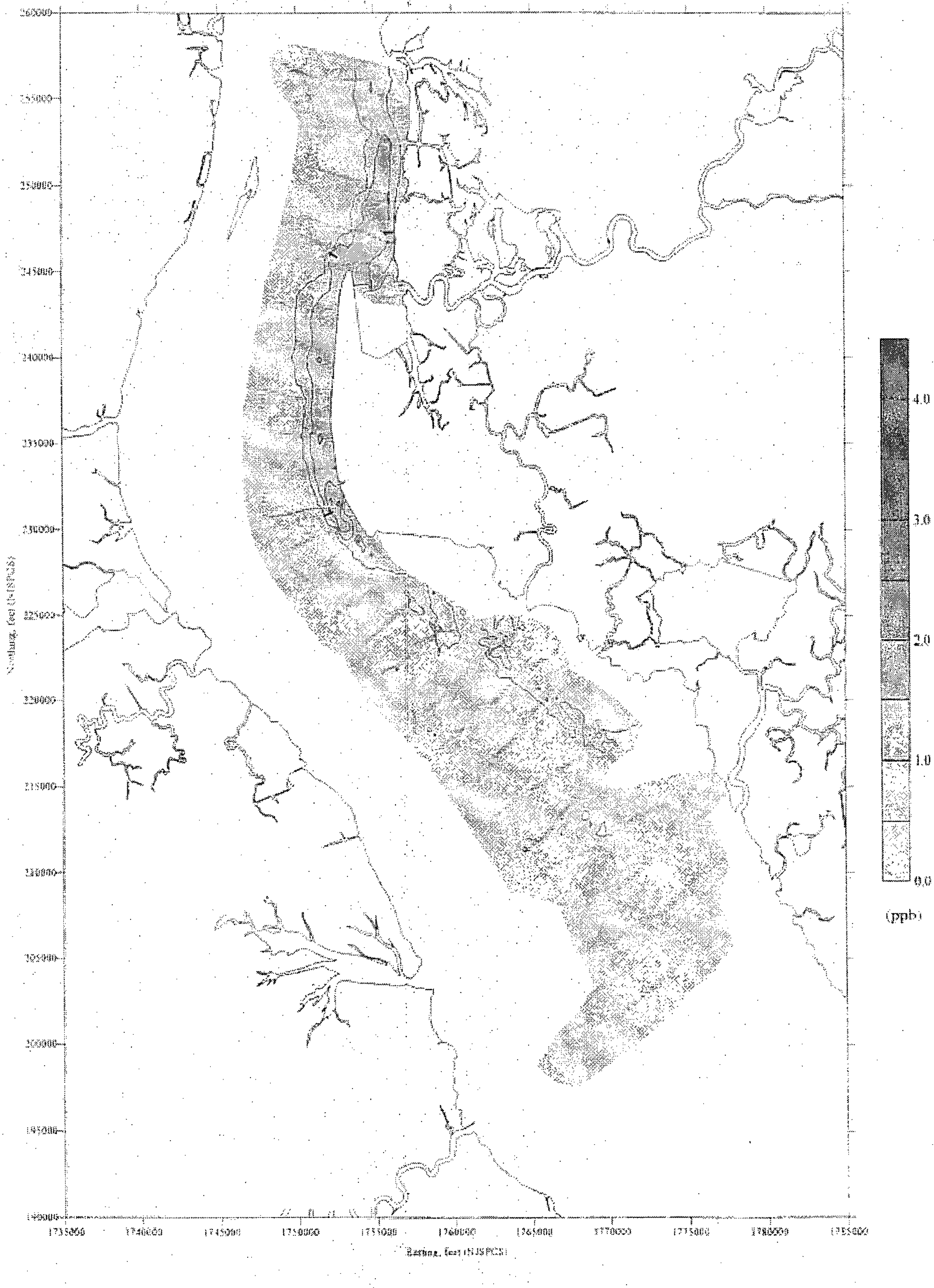


FIGURE 10-71
PSE&G 2-Unit Survey; 29 May 1998
Surface Dye Profiles
FLD Phase (11:40-13:40)

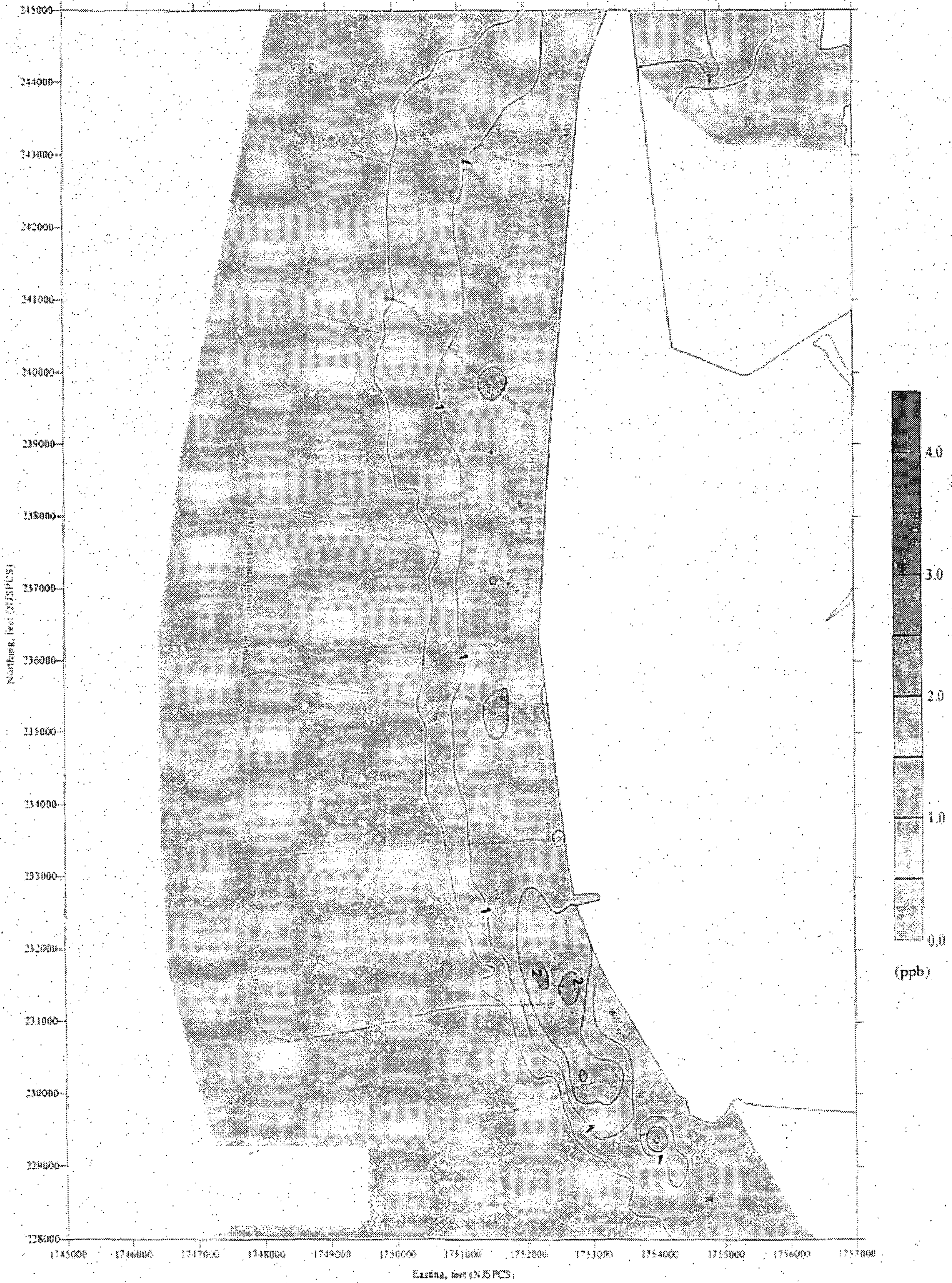


Figure 10-72

PSE&G 2-Unit Survey; 29 May 1998
Transect Locations
EOF Phase (14:25 - 16:25)

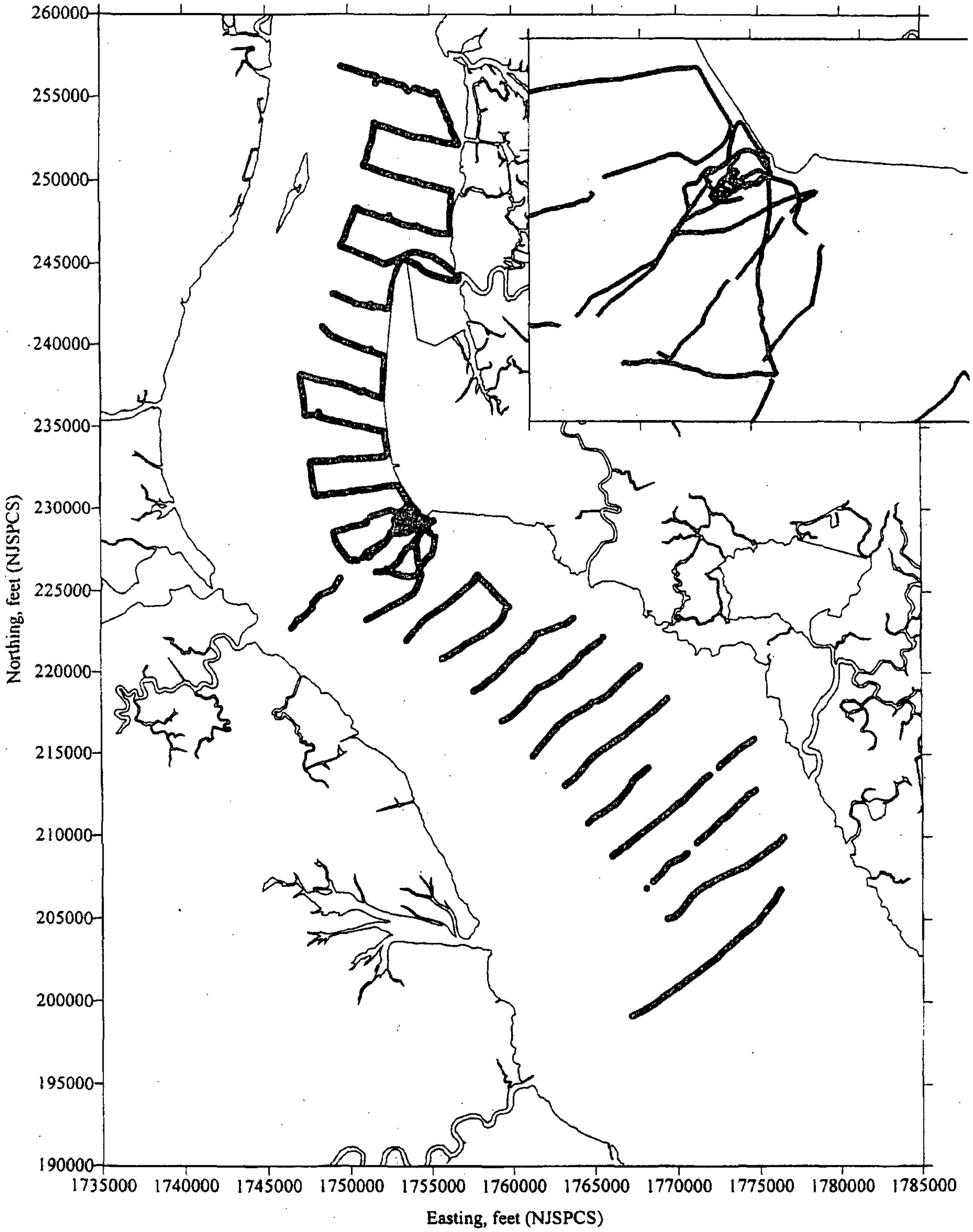


FIGURE 10-73
PSE&G 2-Unit Survey; 29 May 1998
Surface Temperature Profiles
EOF PHASE (14:25-16:25)

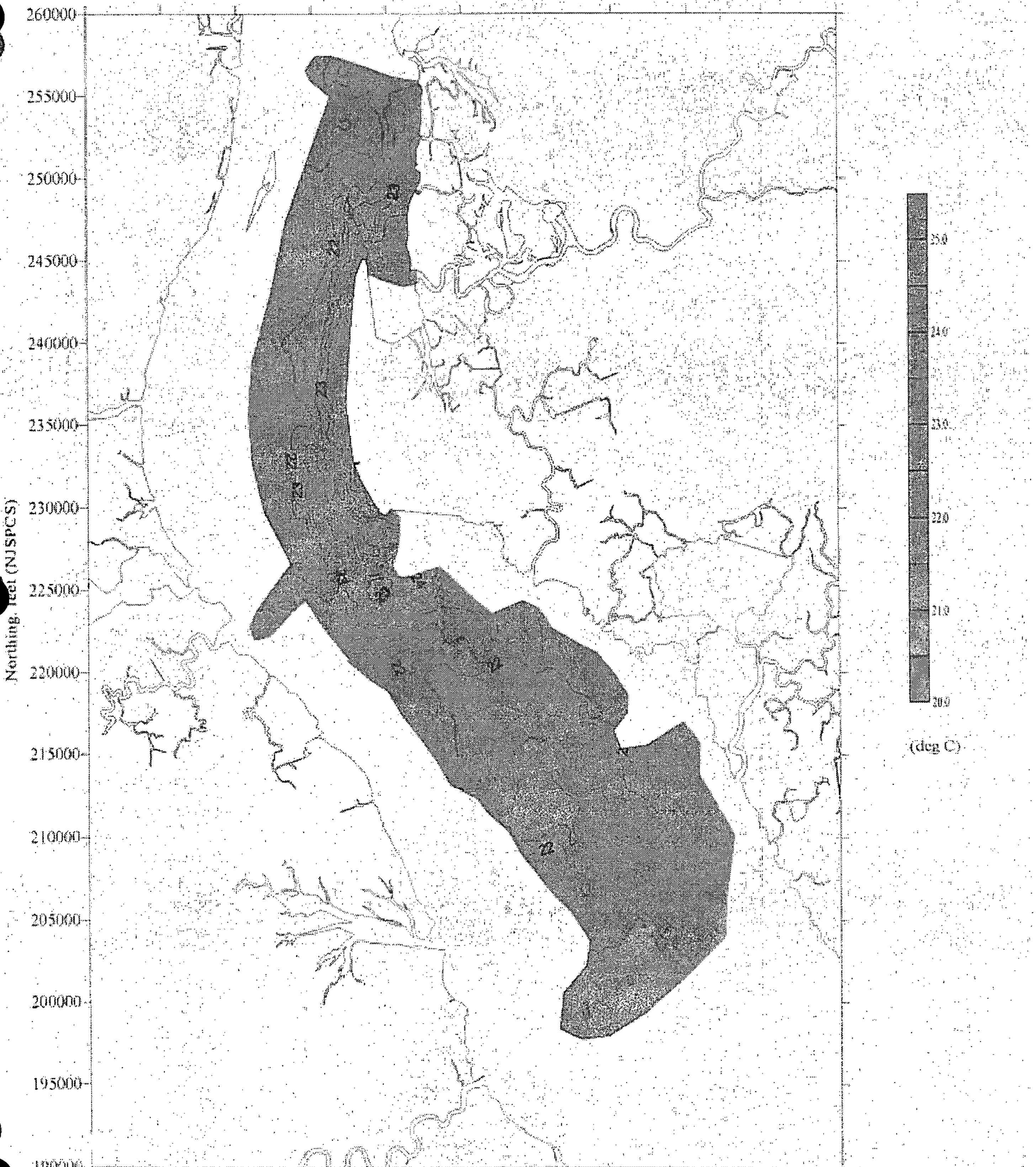


FIGURE 10-74
PSE&G 2-Unit Survey; 29 May 1998
Surface Temperature Profiles
EOF PHASE (14:25-16:25)

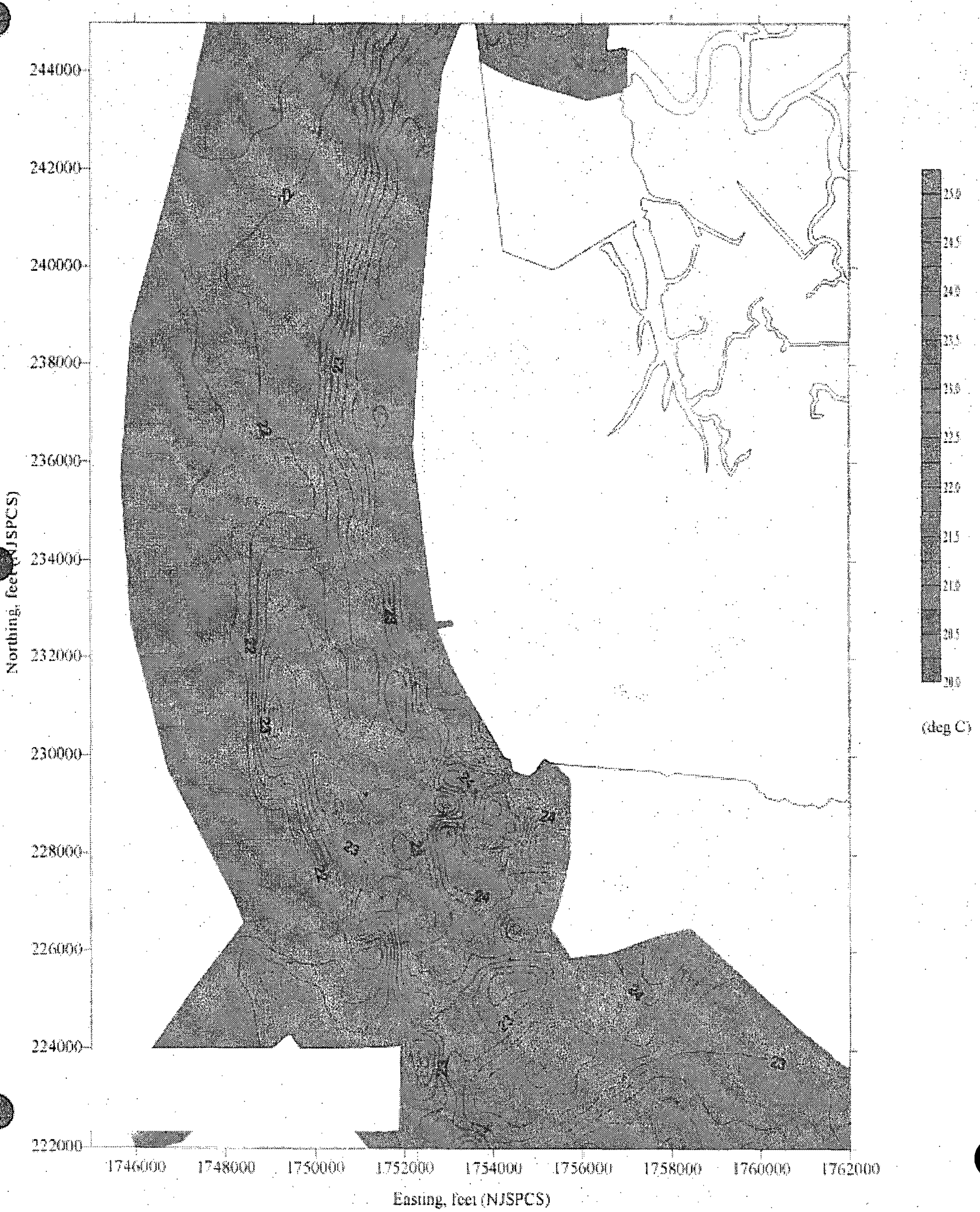


FIGURE 10-75

PSE&G 2-Unit Survey; 29 May 1998
Surface Dye Profiles
EOF Phase (14:25-16:25)

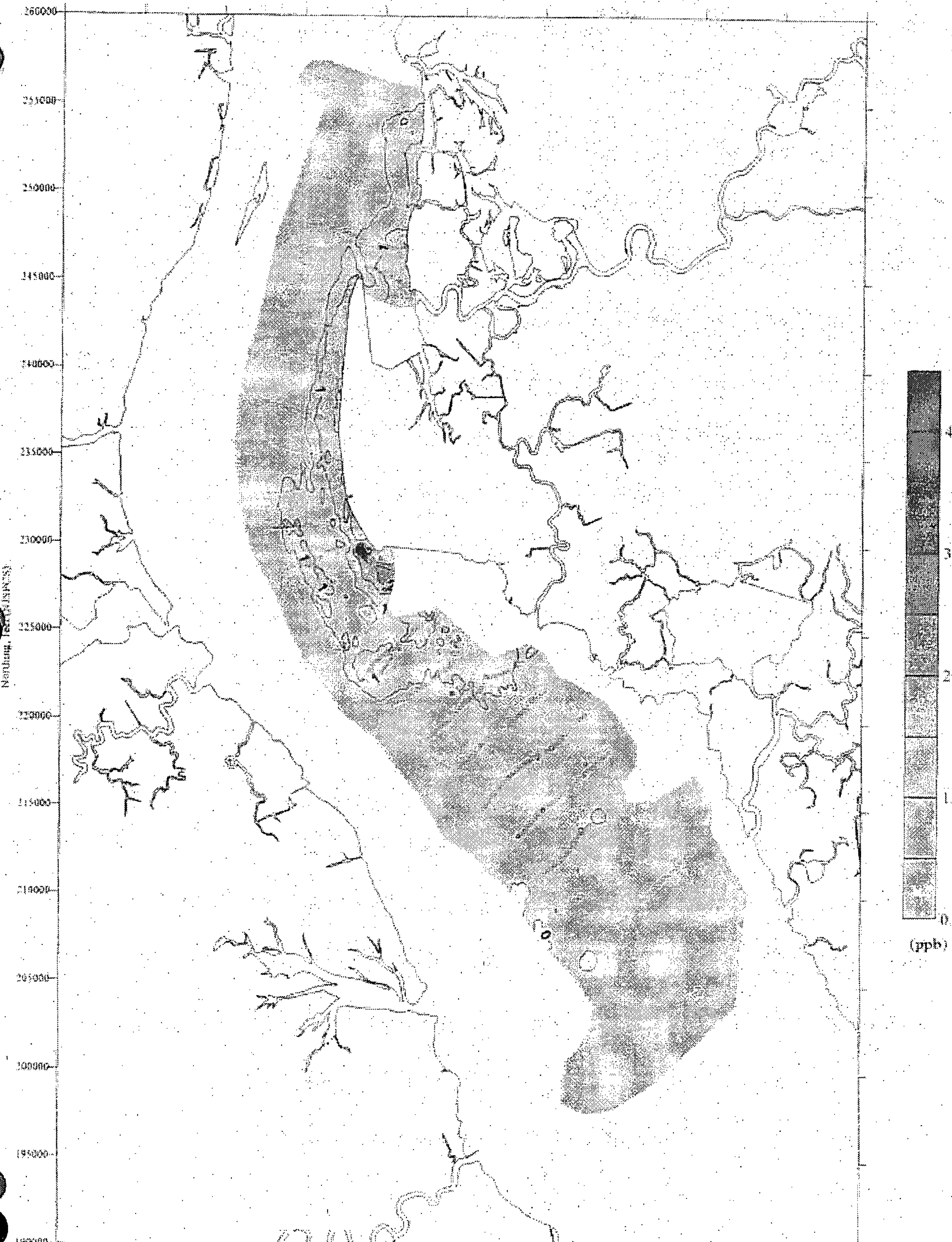


FIGURE 10-76
PSE&G 2-Unit Survey; 29 May 1998
Surface Dye Profiles
EOF Phase (14:25-16:25)

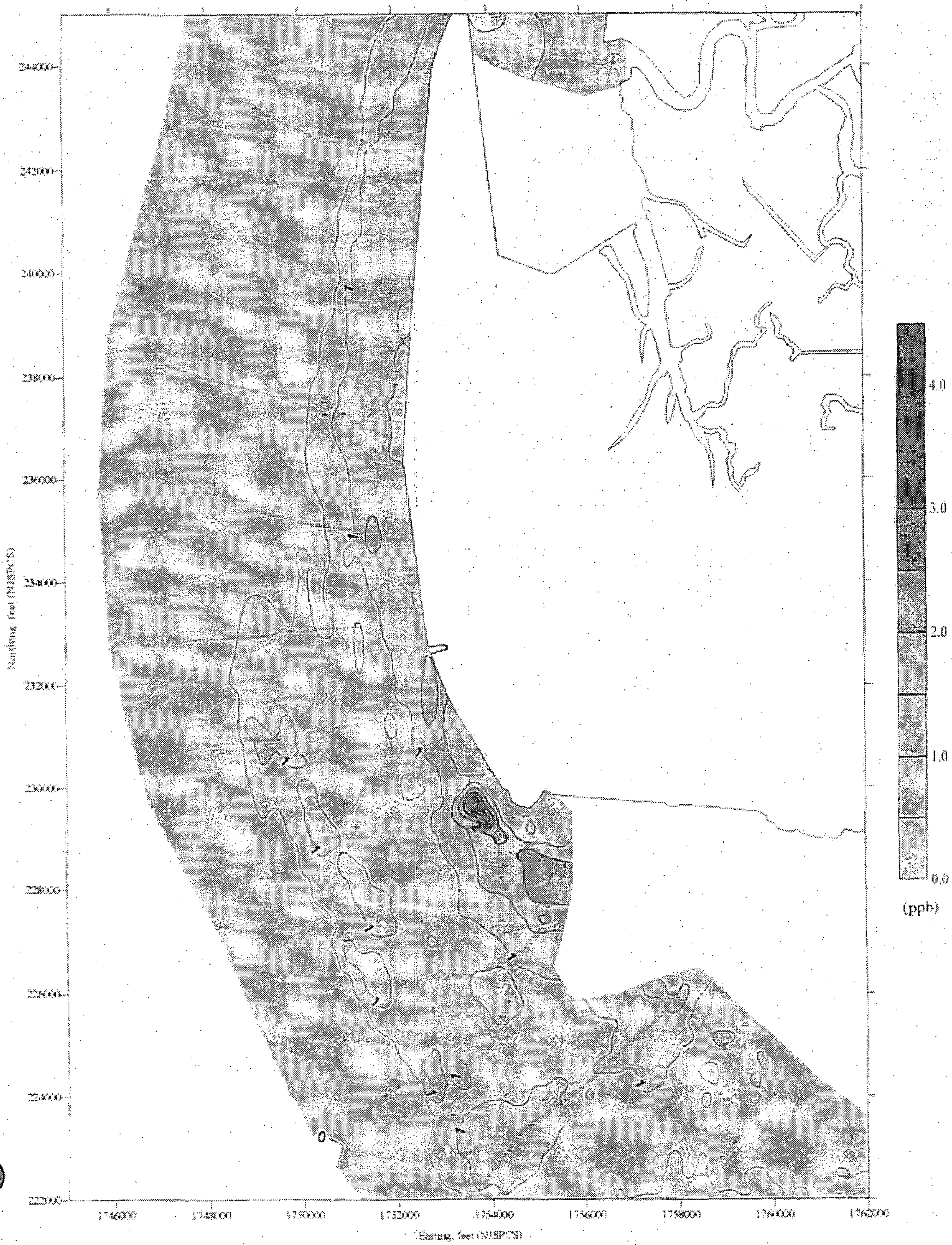


Figure 10-77
PSE&G 2-Unit Mobile Survey
Vertical Profile Locations; 29 May 1998

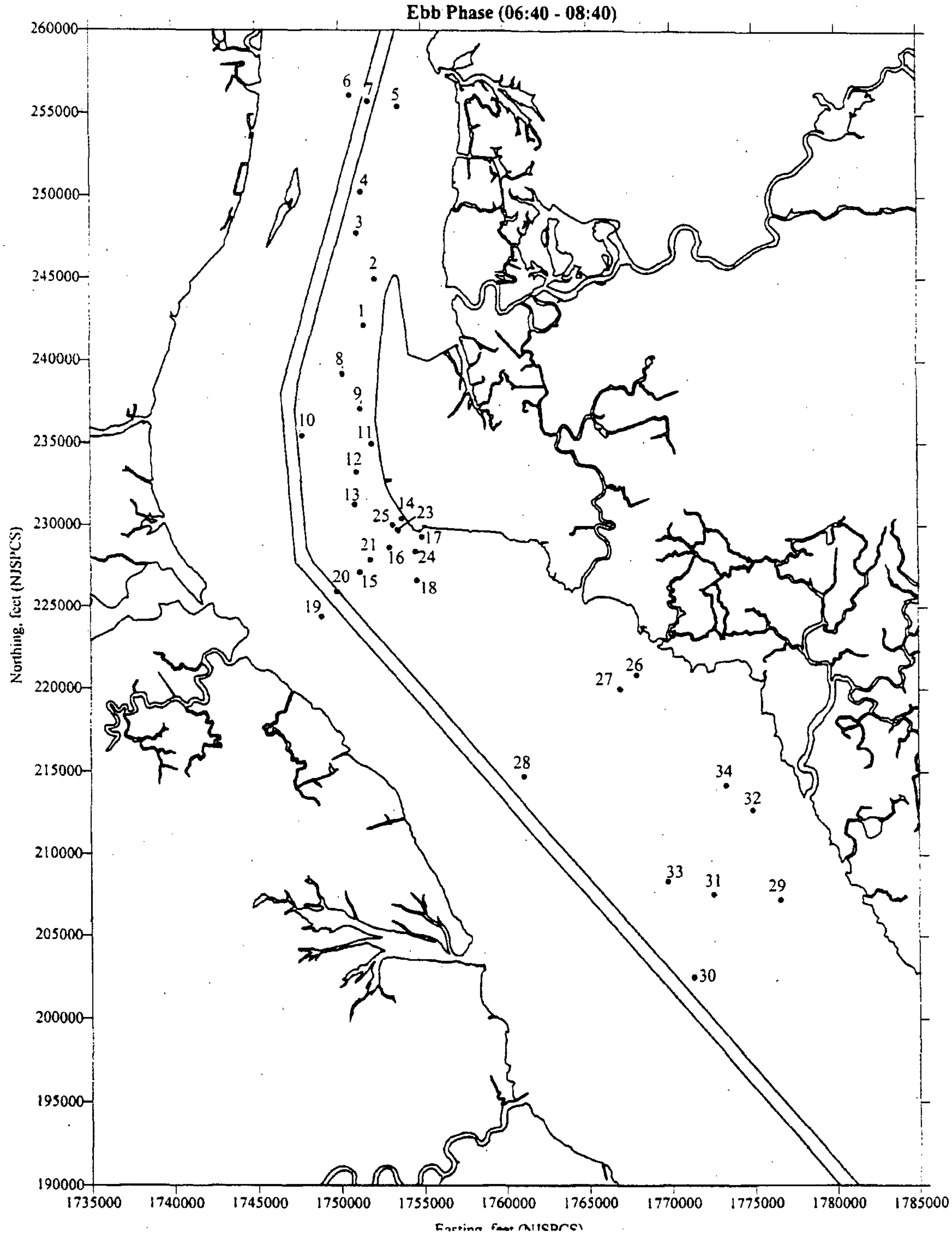


FIGURE 10-78

PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 - 08:40)
Vertical Temperature Profiles

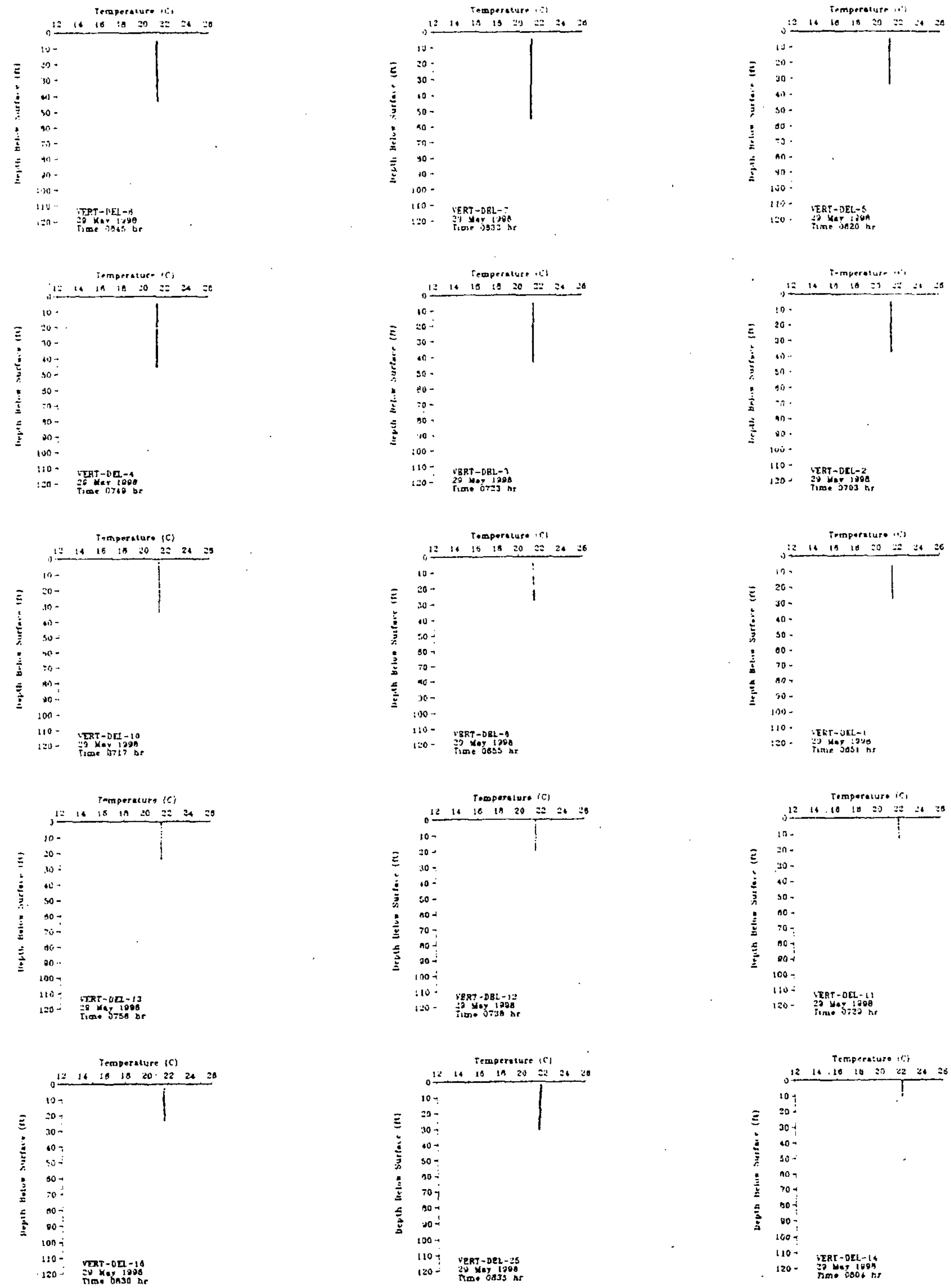


FIGURE 10-79
PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 - 08:40)
Vertical Temperature Profiles

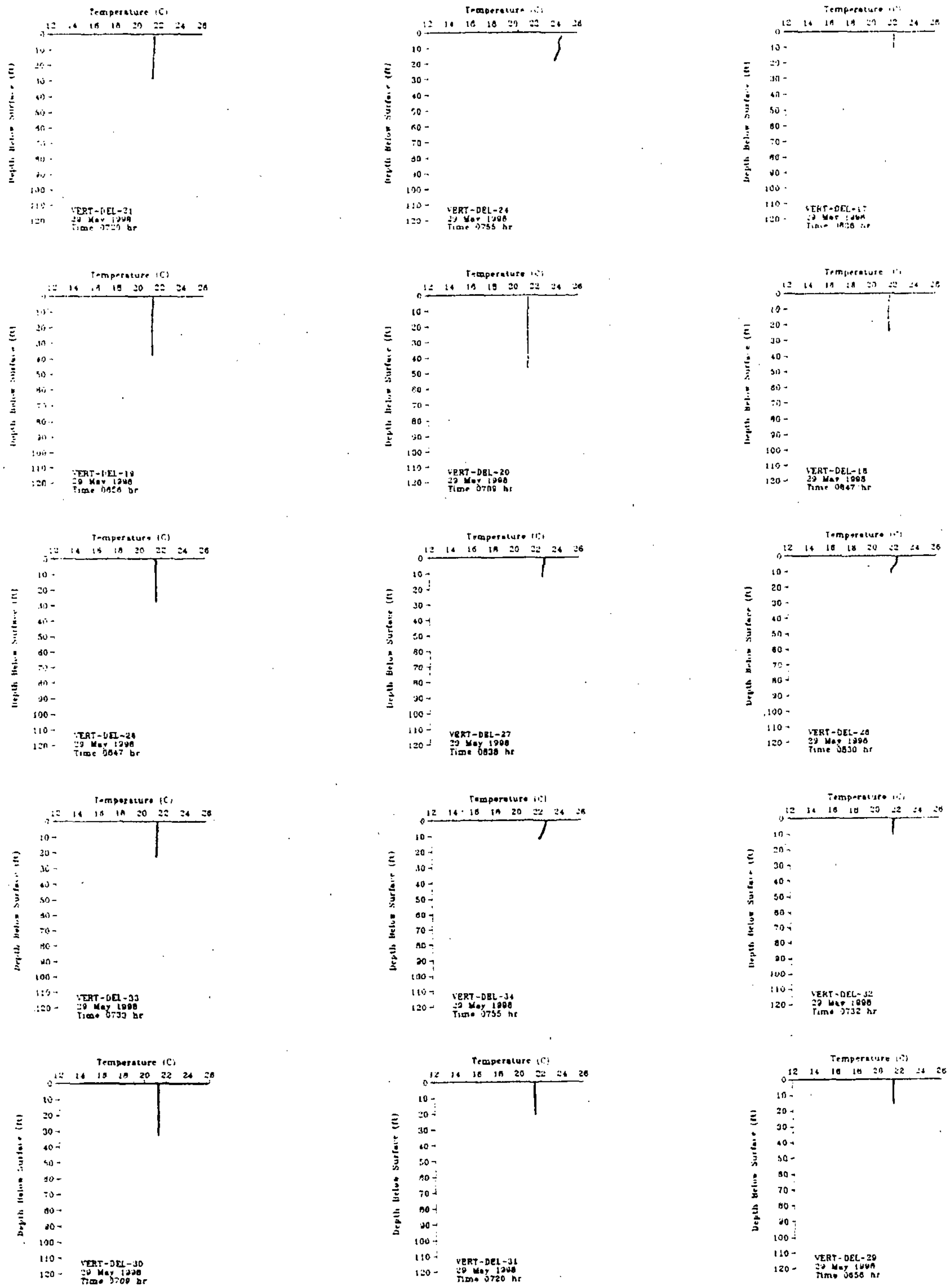


FIGURE 10-80

PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 - 08:40)
Vertical Salinity Profiles

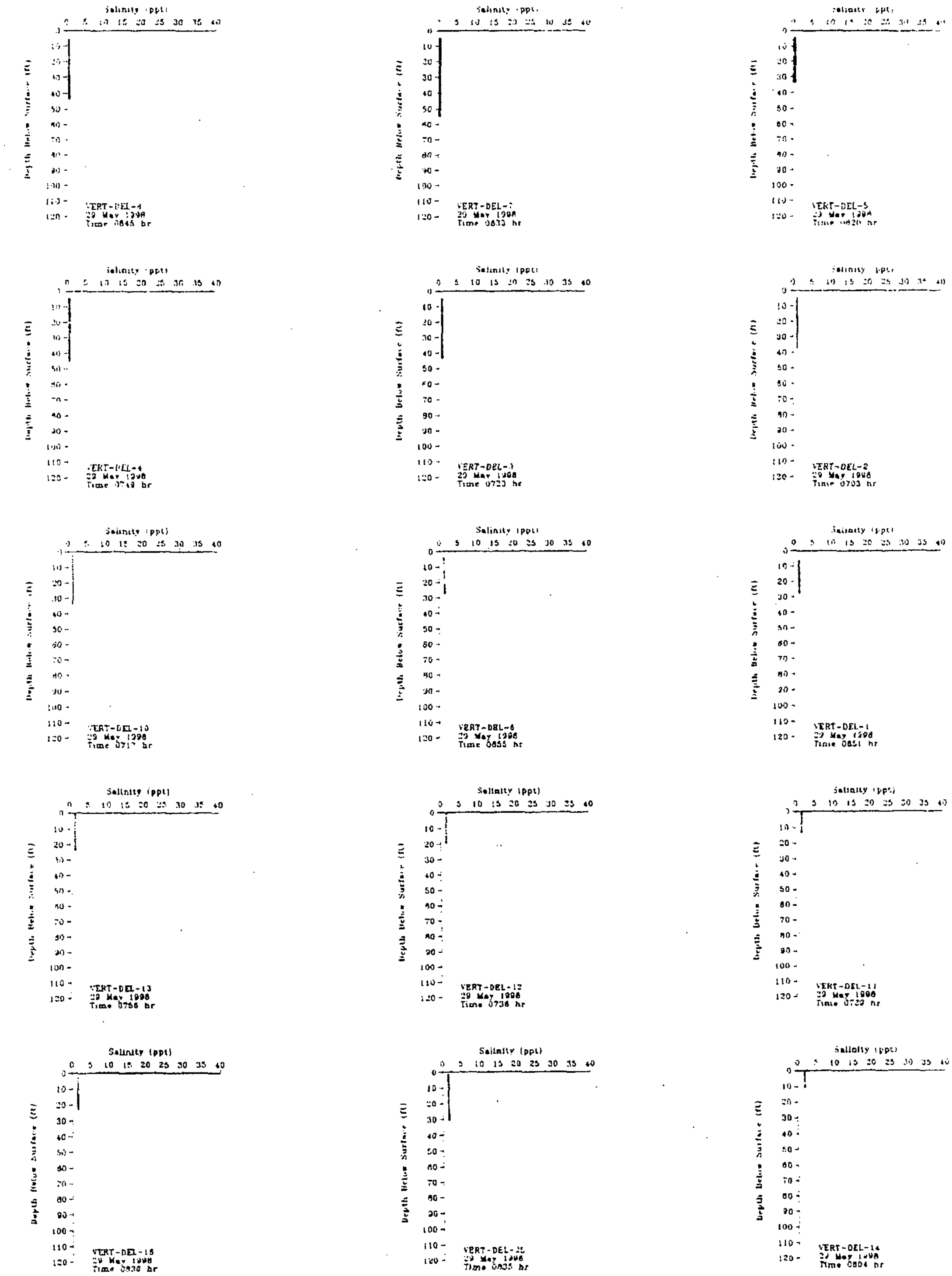


FIGURE 10-81

PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 – 08:40)
Vertical Salinity Profiles

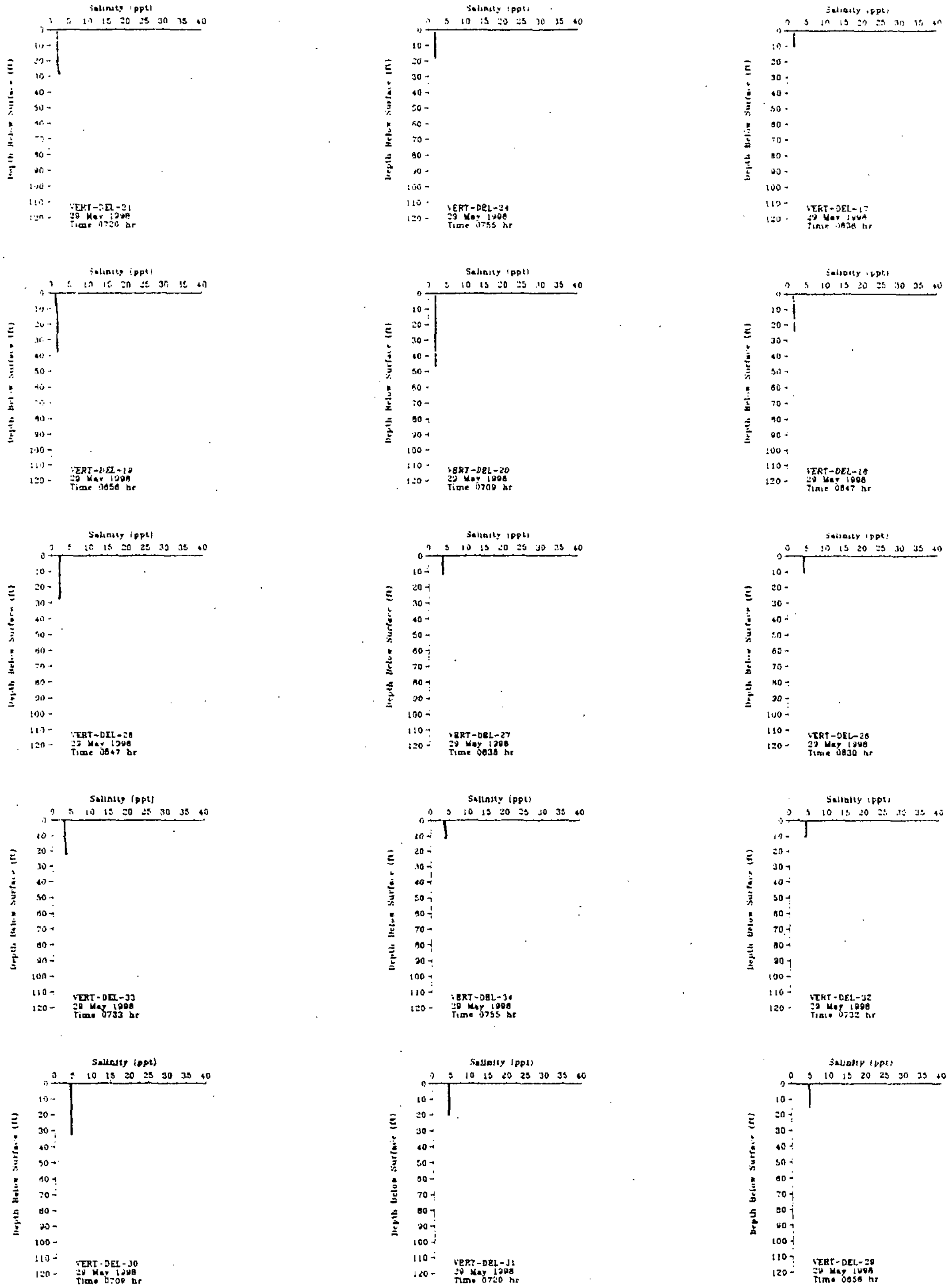


FIGURE 10-82

PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 - 08:40)
Vertical Dye Profiles

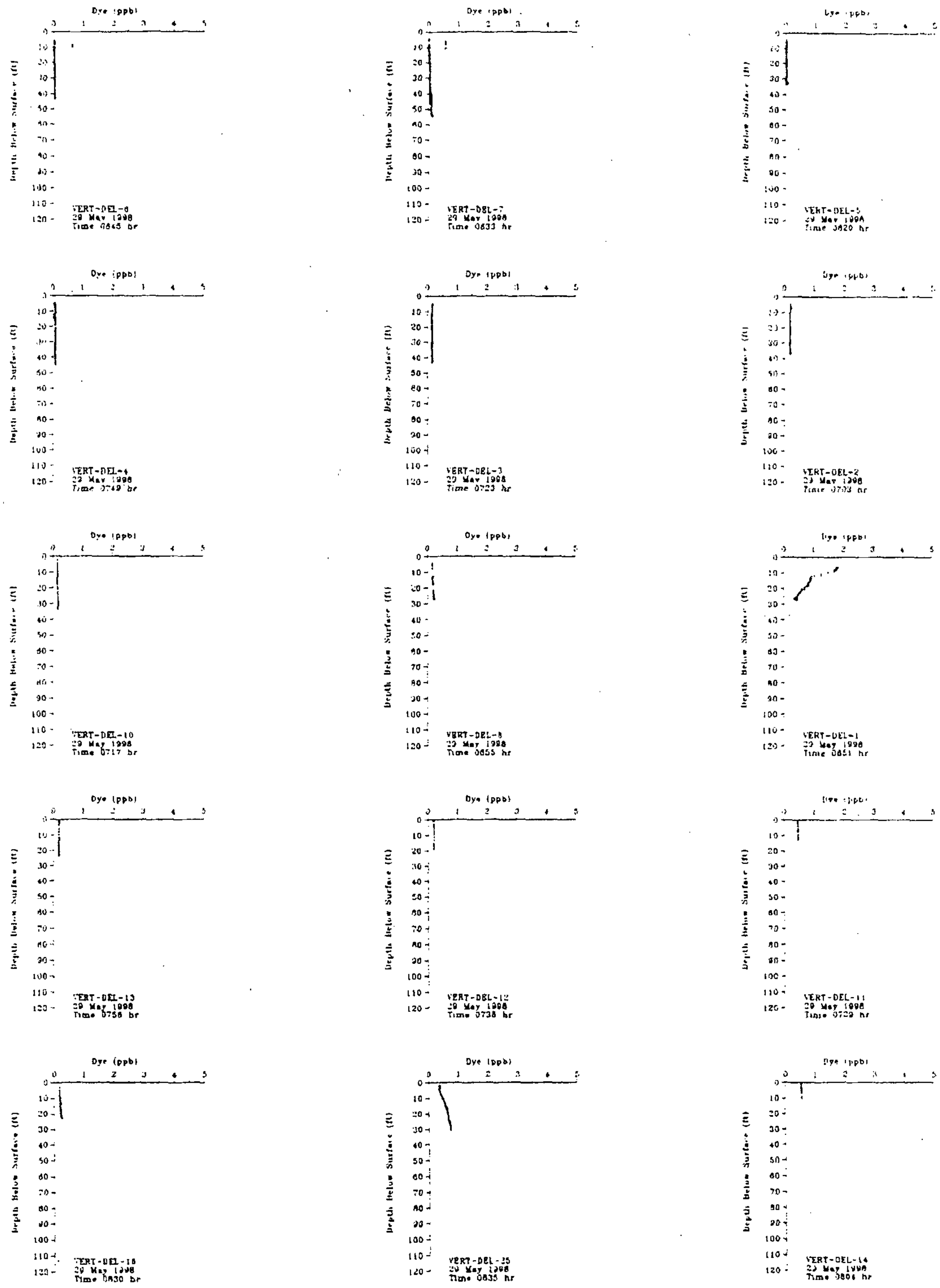


FIGURE 10-83
PSE&G 2-Unit Survey: 29 May 1998
Ebb Phase (06:40 – 08:40)
Vertical Dye Profiles

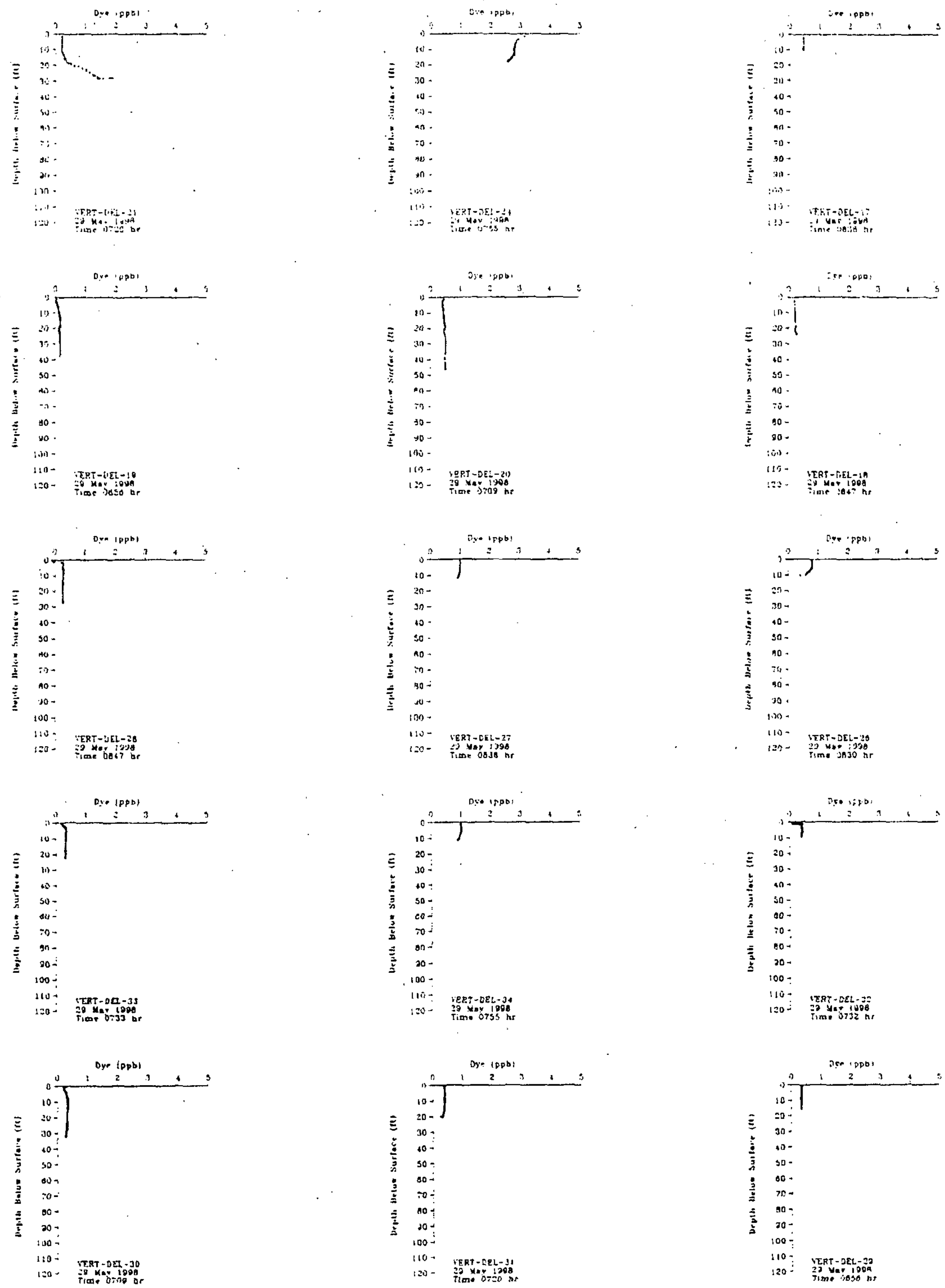


Figure 10-84
PSE&G 2-Unit Mobile Survey
Vertical Profile Locations; 29 May 1998

EOE Phase (09:10 - 11:10)

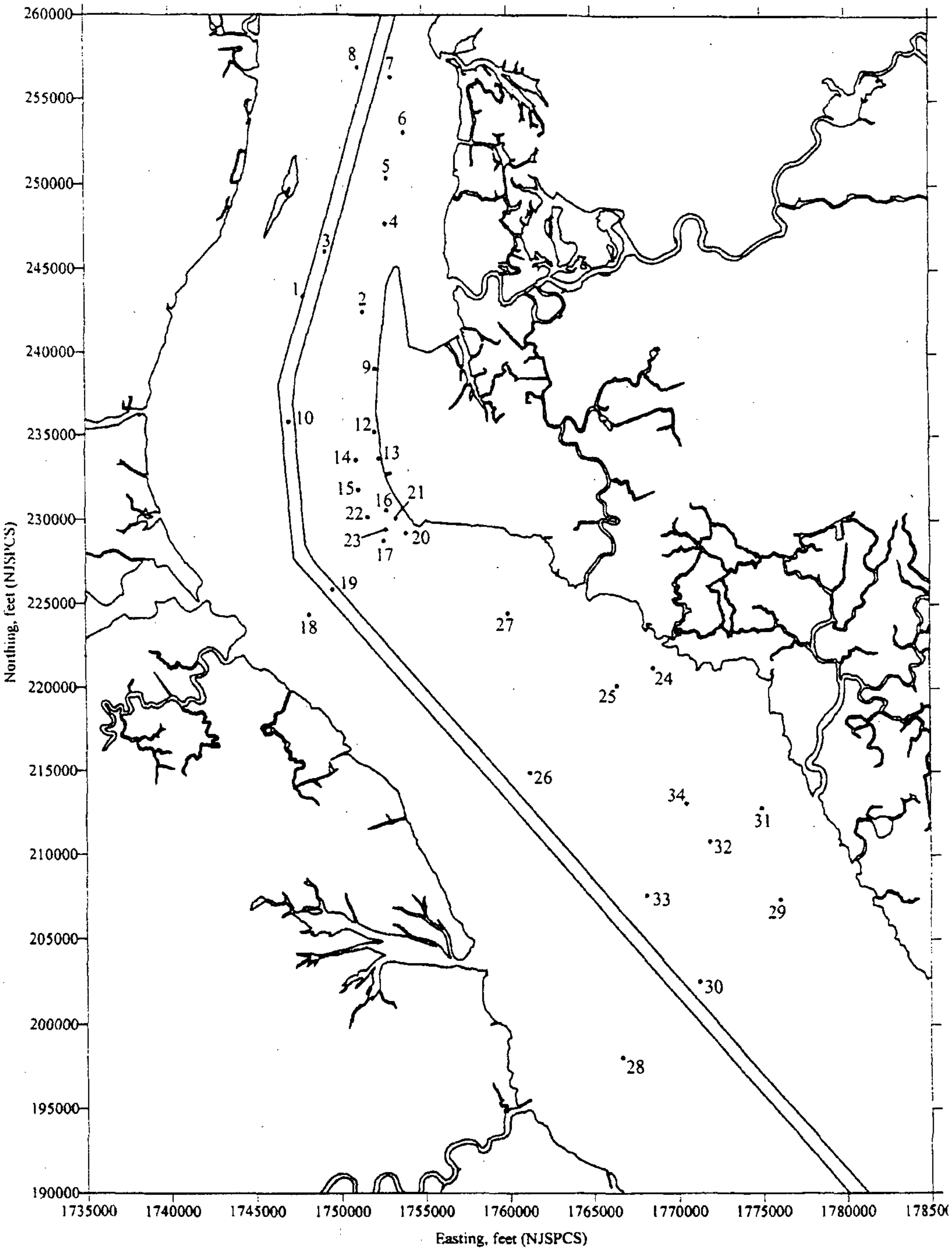


Figure 10-85
PSE&G 2-Unit Survey: 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Temperature Profiles

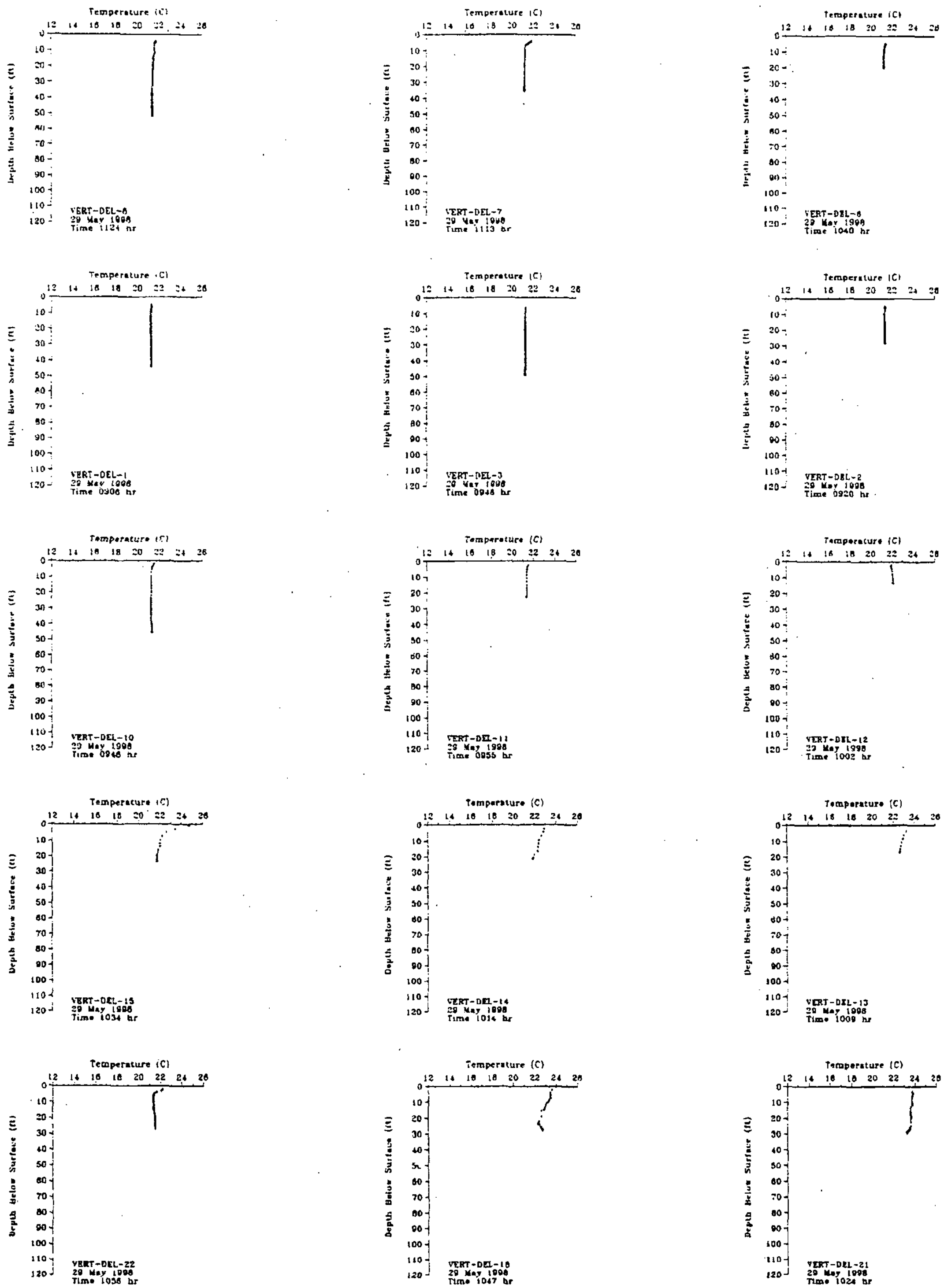


Figure 10-86
PSE&G 2-Unit Survey: 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Temperature Profiles

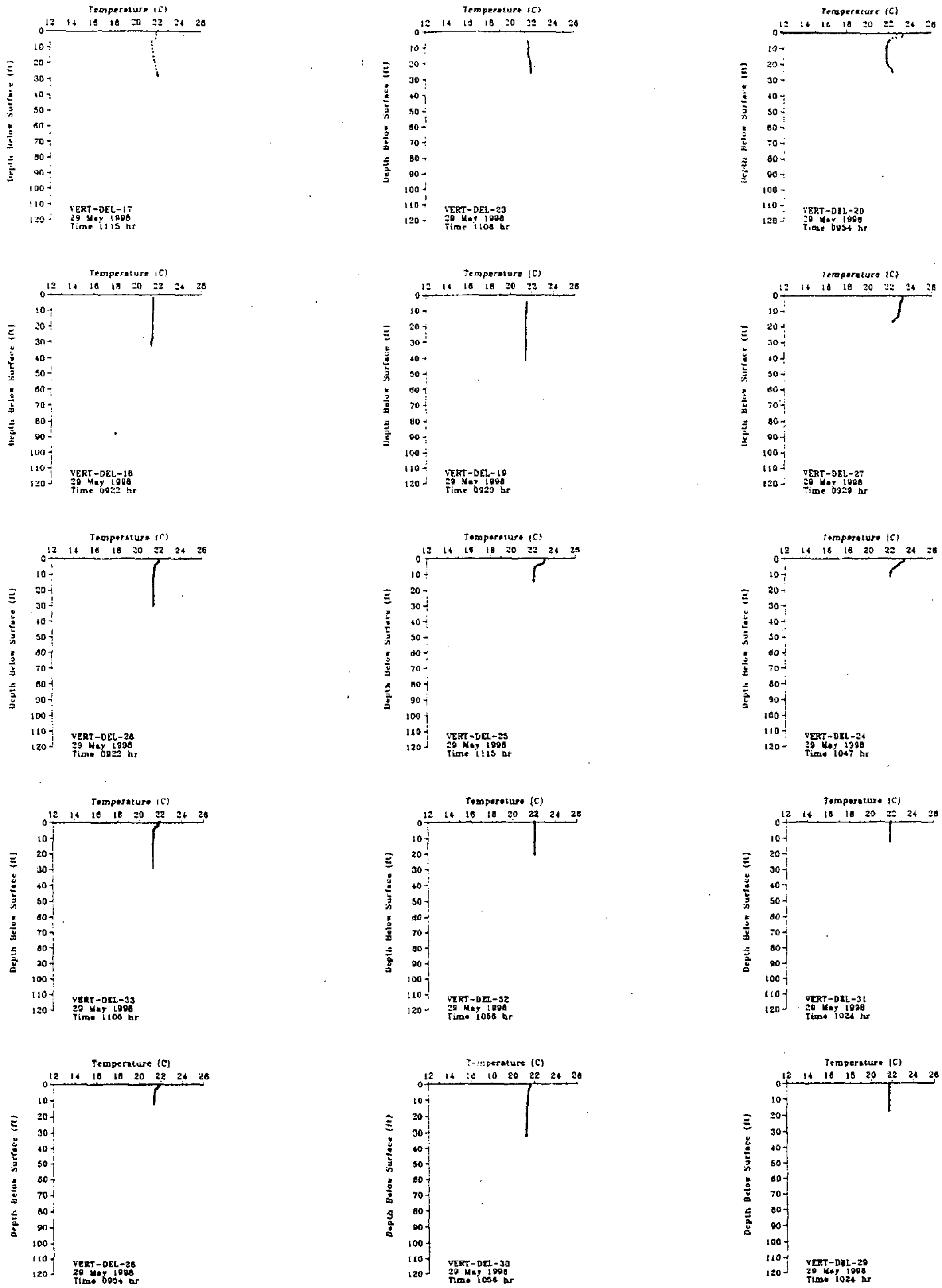


Figure 10-87
PSE&G 2-Unit Survey; 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Salinity Profiles

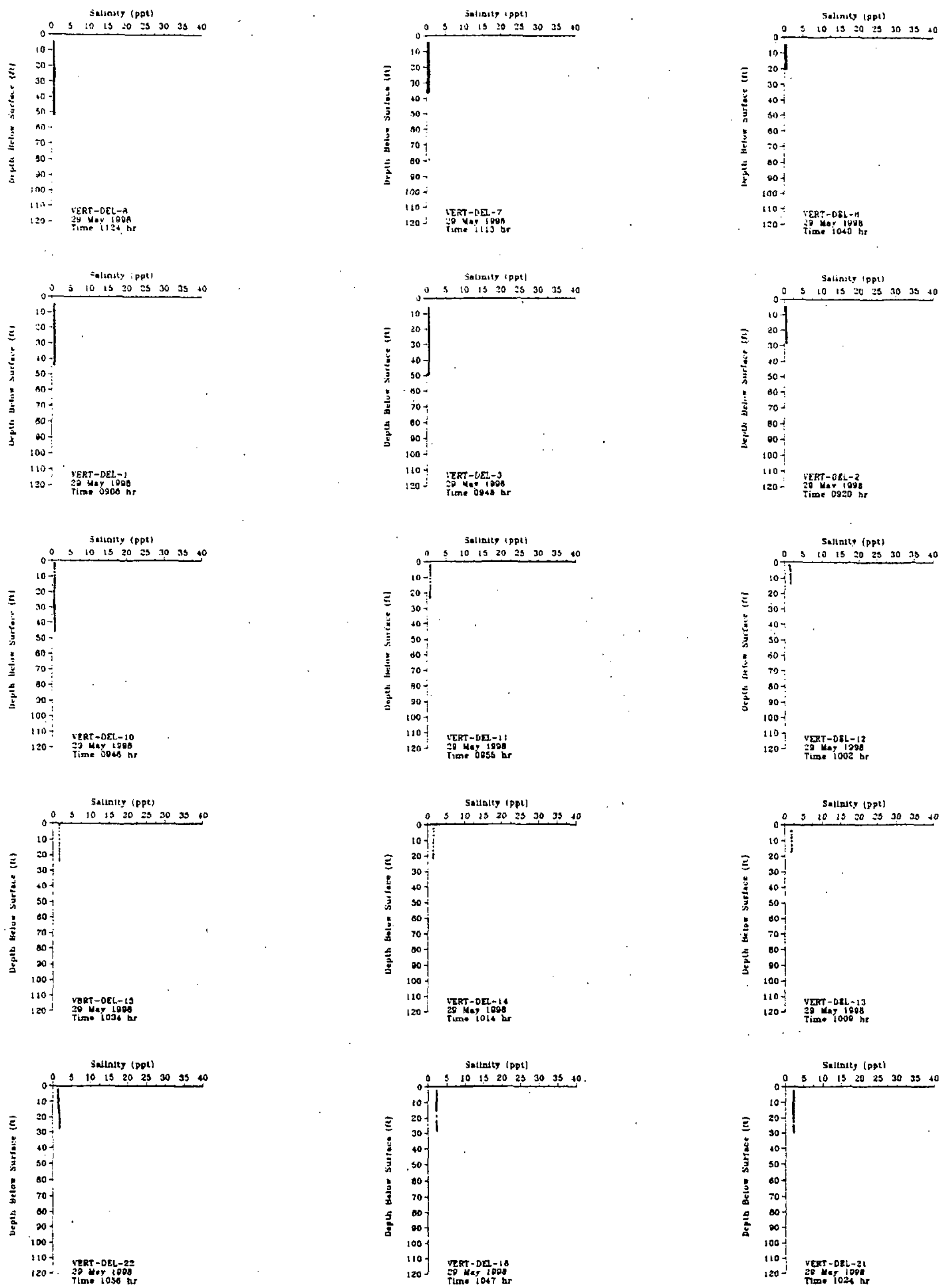


Figure 10-88
PSE&G 2-Unit Survey: 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Salinity Profiles

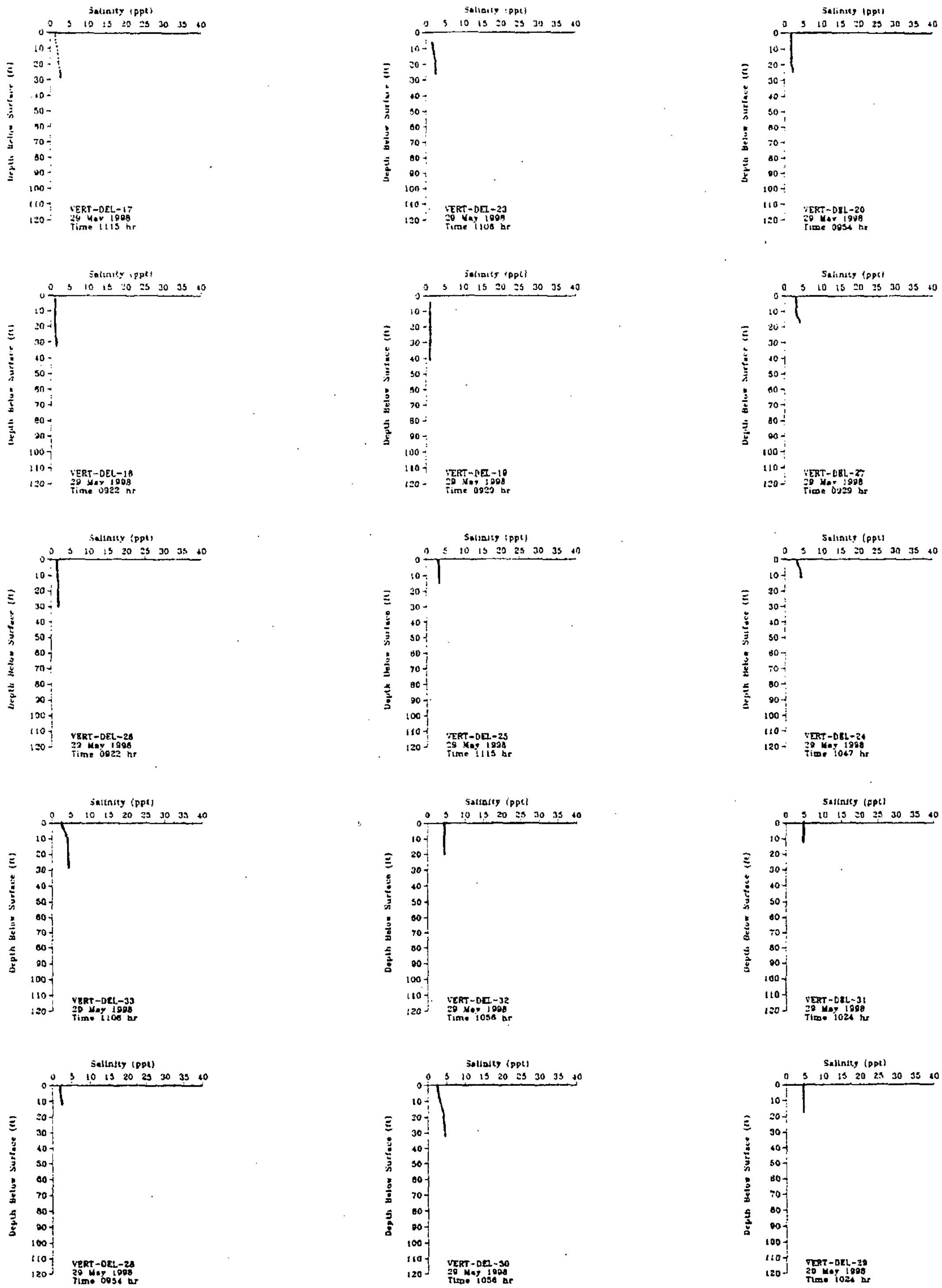


Figure 10-89
PSE&G 2-Unit Survey: 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Dye Profiles

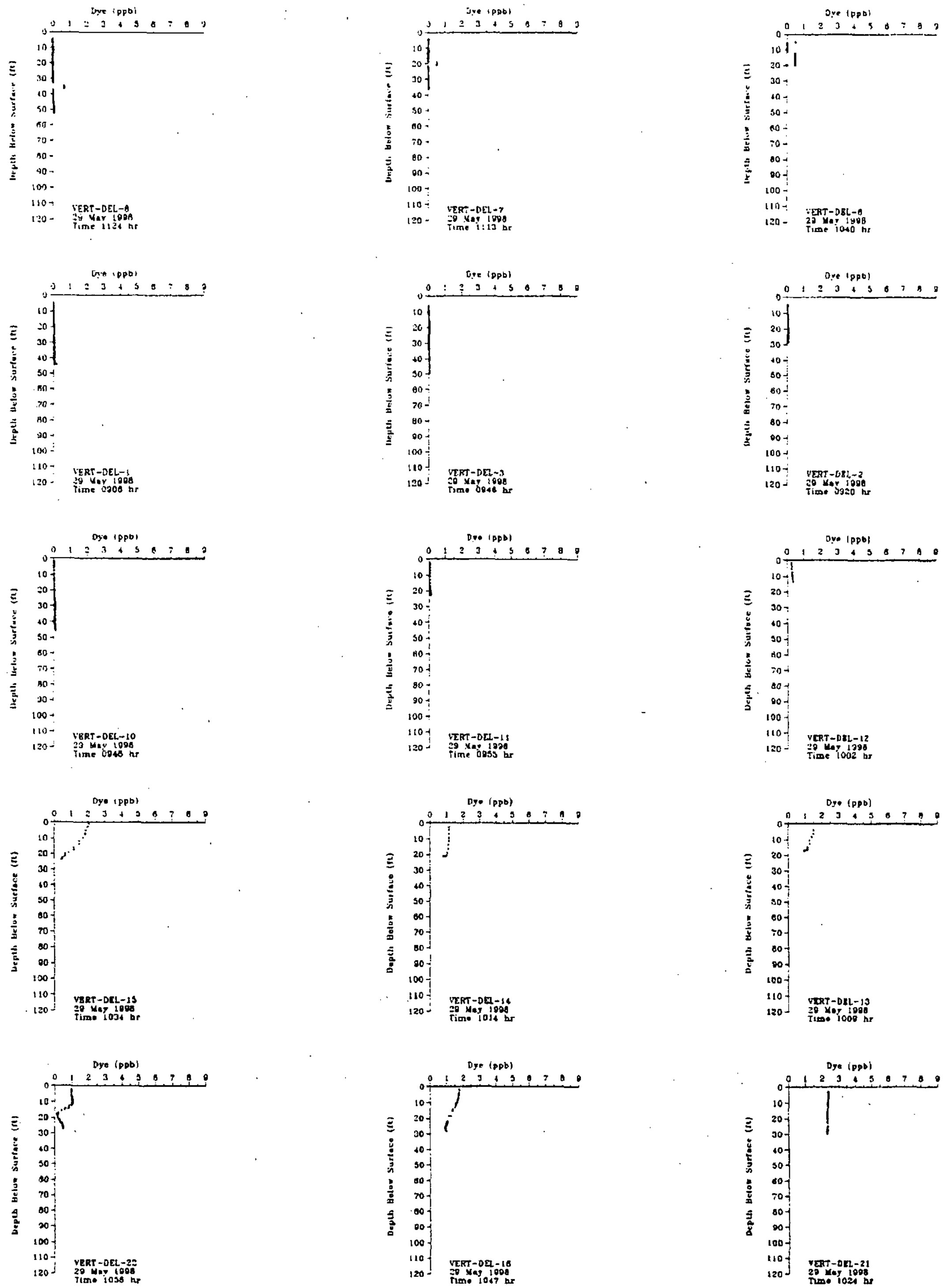


Figure 10-90
PSE&G 2-Unit Survey: 29 May 1998
EOE Phase (09:10 - 11:10)
Vertical Dye Profiles

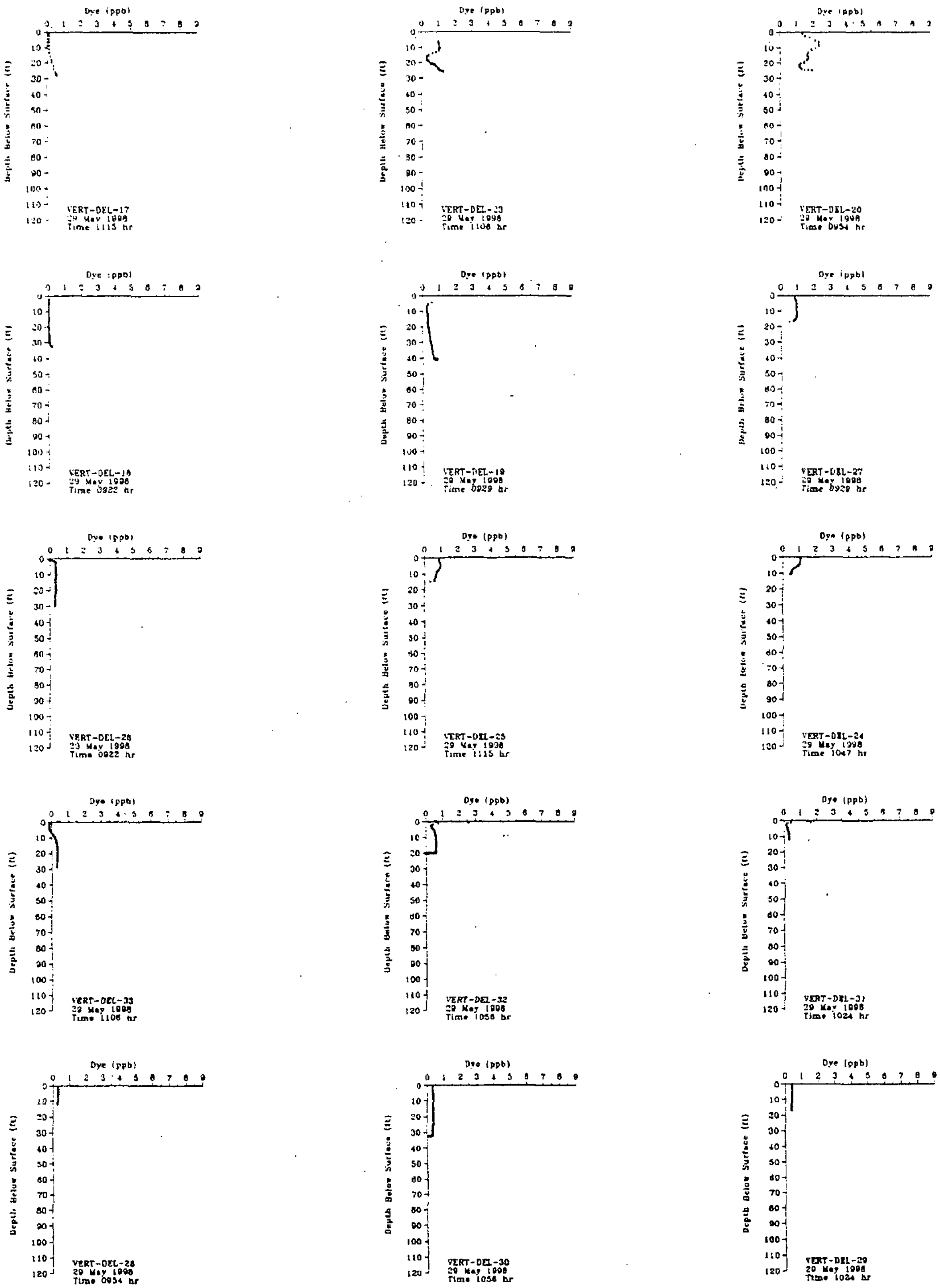


Figure 10-91
PSE&G 2-Unit Mobile Survey
Vertical Profile Locations; 29 May 1998

FLOOD Phase (11:40 - 13:40)

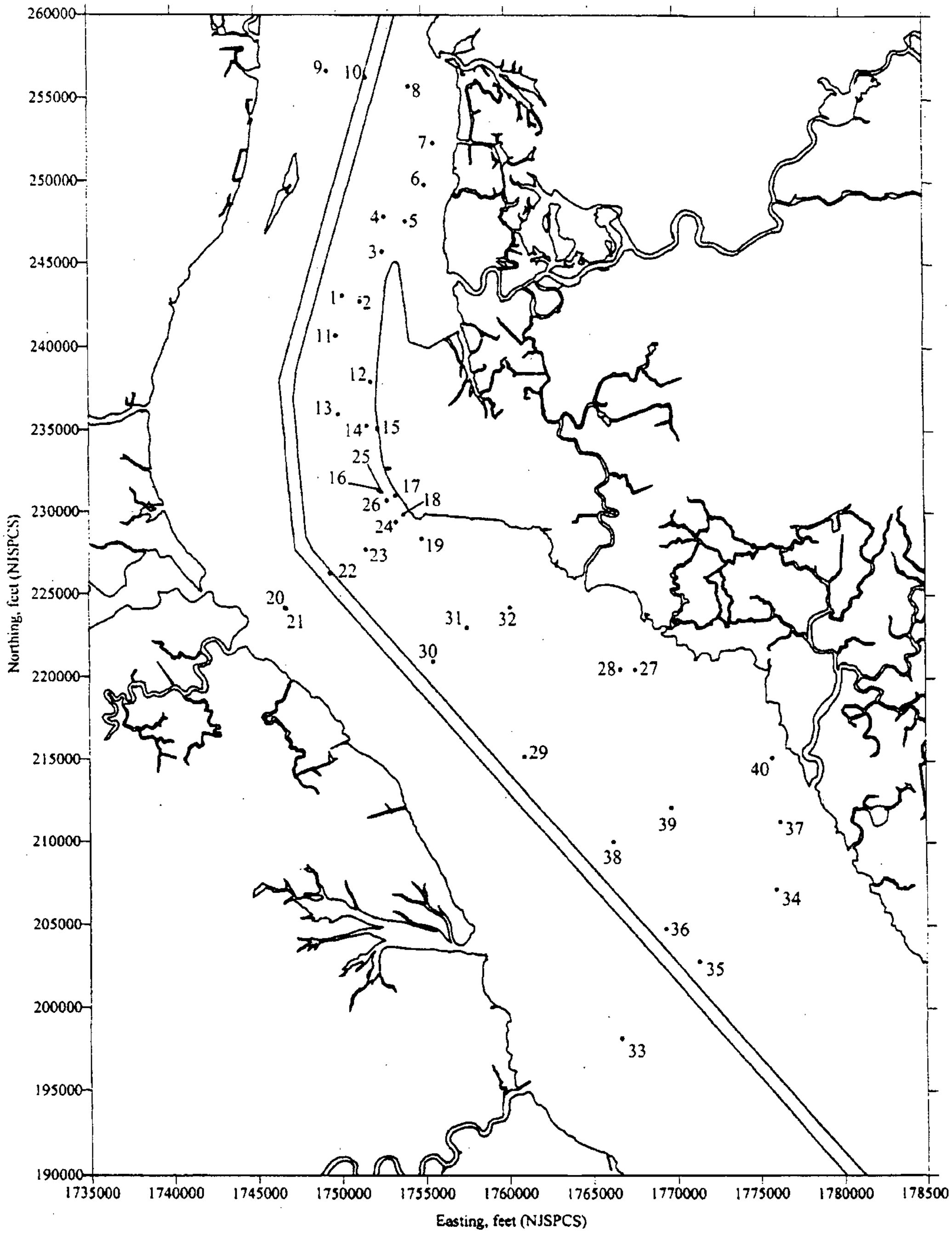


FIGURE 10-92

PSE&G 2-Unit Survey; 29 May 1998
FLD Phase (11:40 – 13:40)
Vertical Temperature Profiles

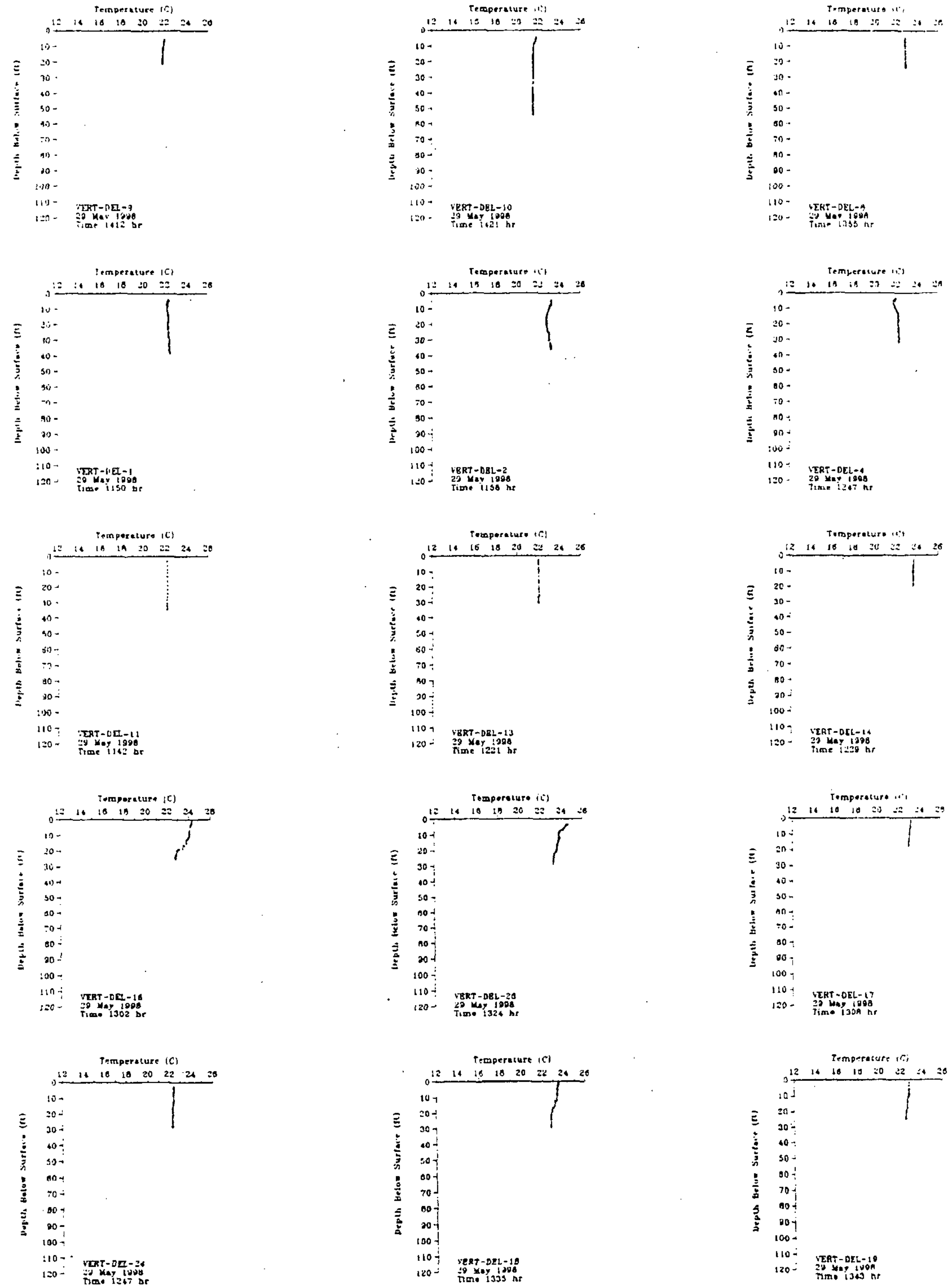


FIGURE 10-93

PSE&G 2-Unit Survey: 29 May 1998
FLD Phase (11:40 - 13:40)
Vertical Temperature Profiles

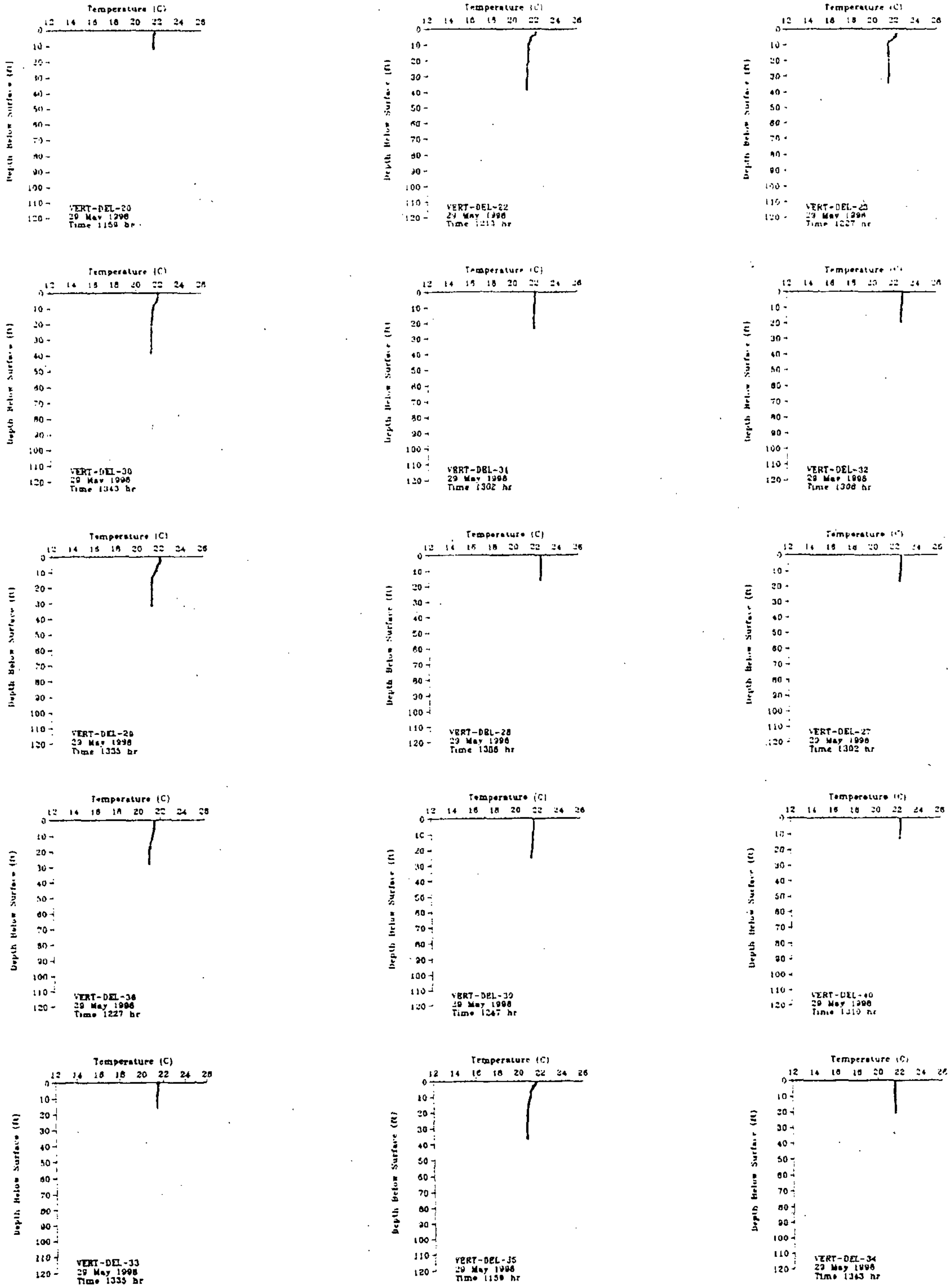


FIGURE 10-94
PSE&G 2-Unit Survey: 29 May 1998
FLD Phase (11:40 ~ 13:40)
Vertical Salinity Profiles

FIGURE 10-95

PSE&G 2-Unit Survey: 29 May 1998
FLD Phase (11:40 - 13:40)
Vertical Salinity Profiles

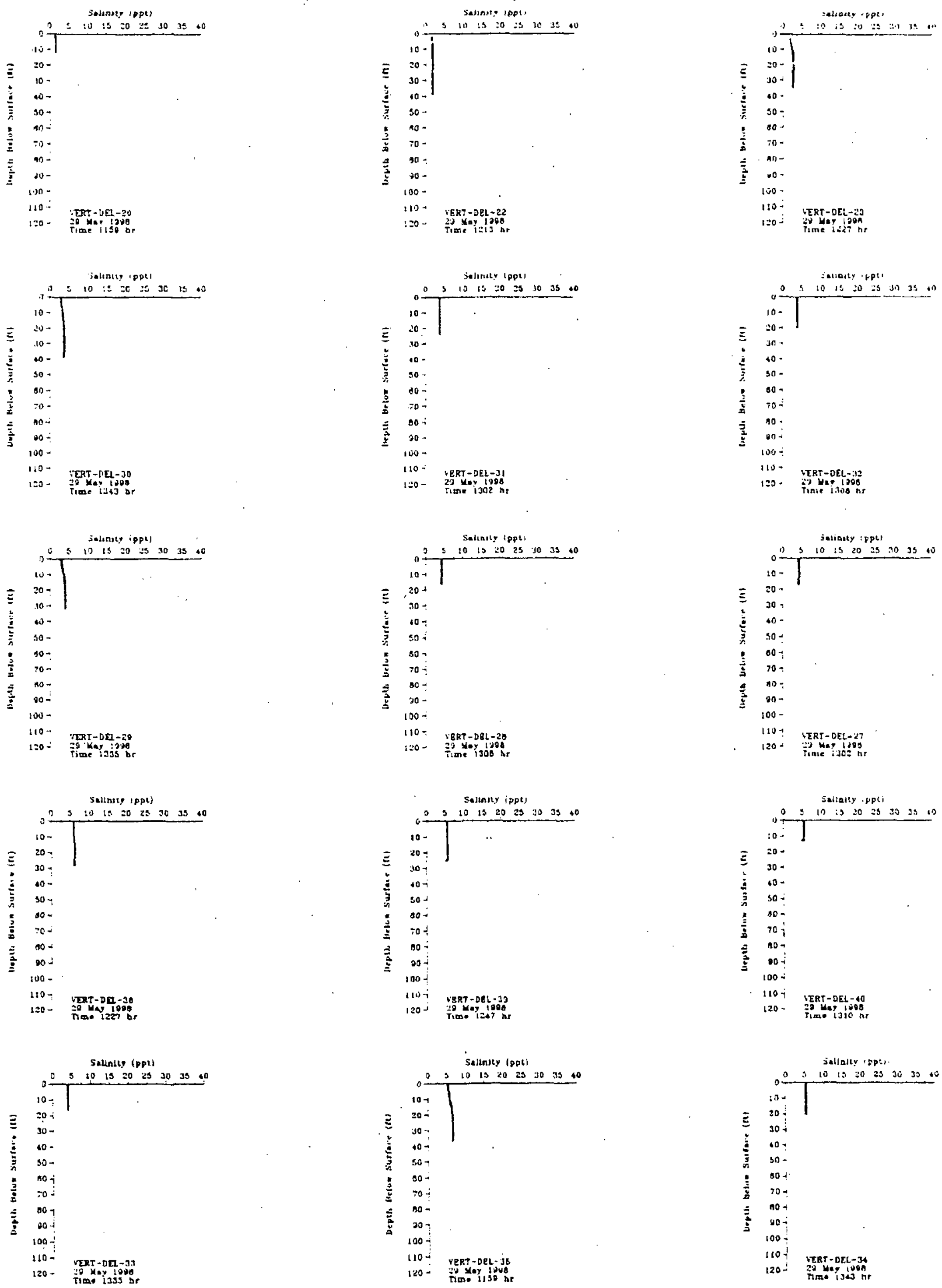


FIGURE 10-96

PSE&G 2-Unit Survey; 29 May 1998
FLD Phase (11:40 – 13:40)
Vertical Dye Profiles

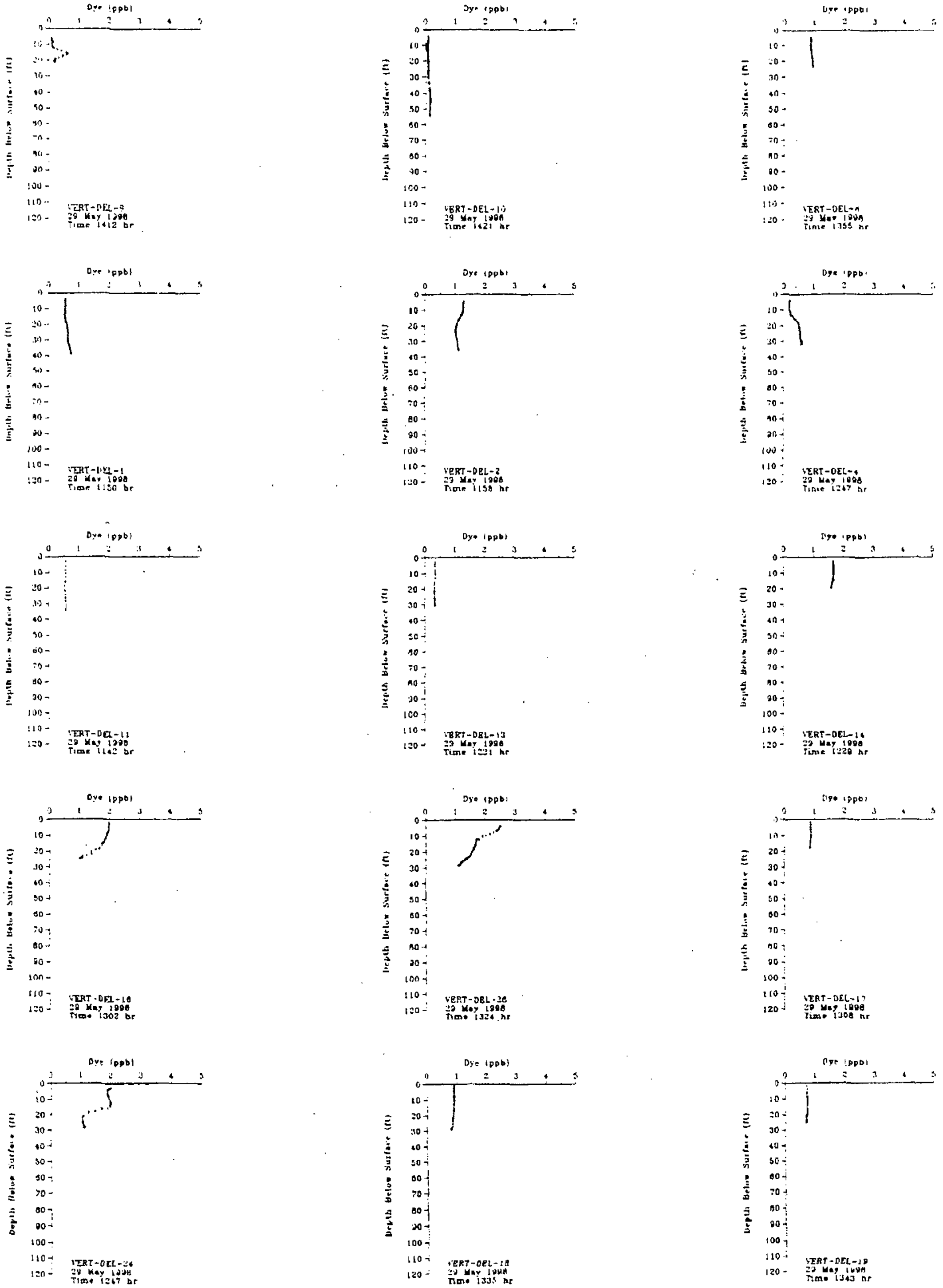


FIGURE 10-97

PSE&G 2-Unit Survey: 29 May 1998
FLD Phase (11:40 - 13:40)
Vertical Dye Profiles

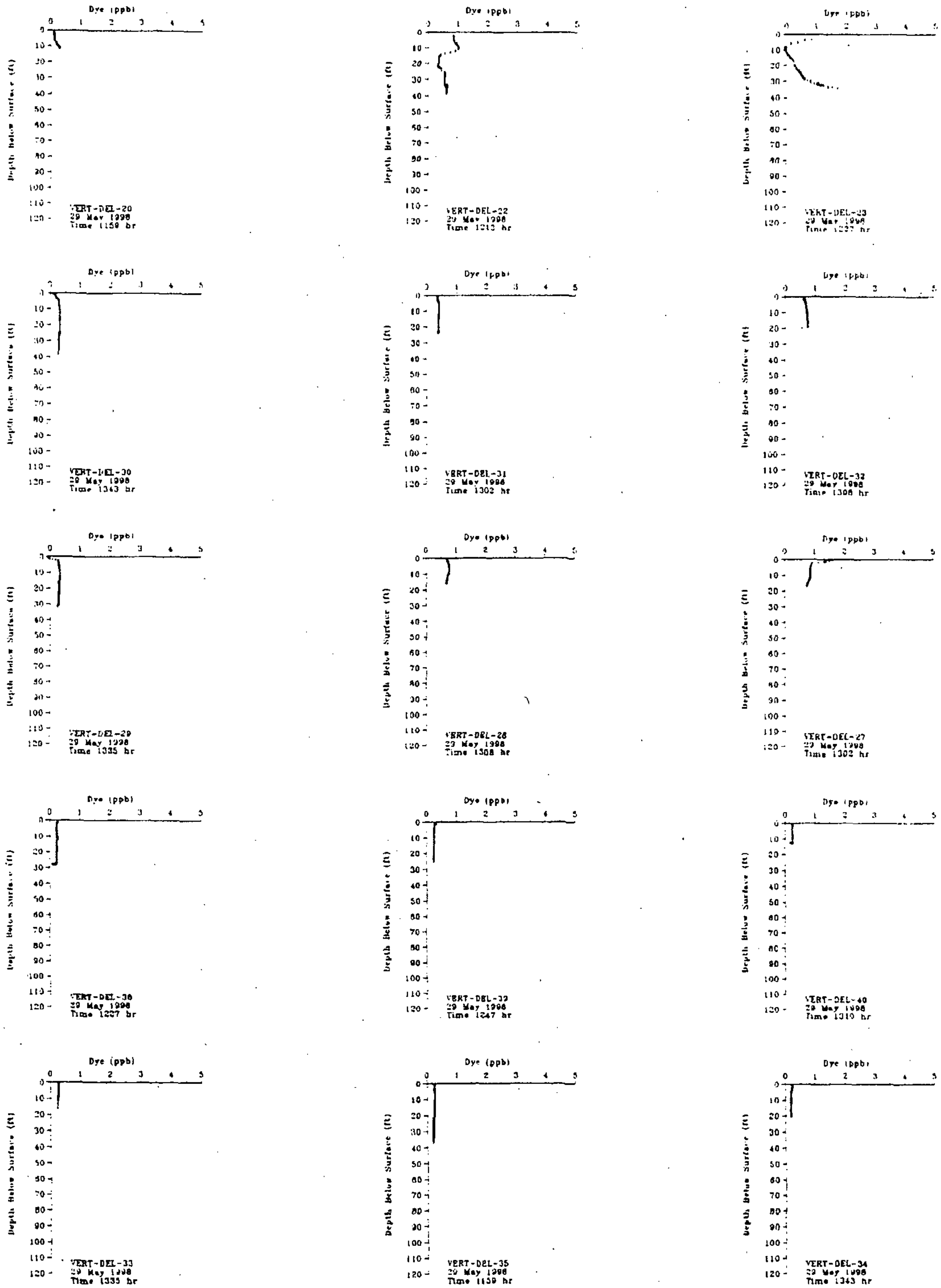


Figure 10-98
PSE&G 2-Unit Mobile Survey
Vertical Profile Locations; 29 May 1998

EOF Phase (14:25 - 16:25)

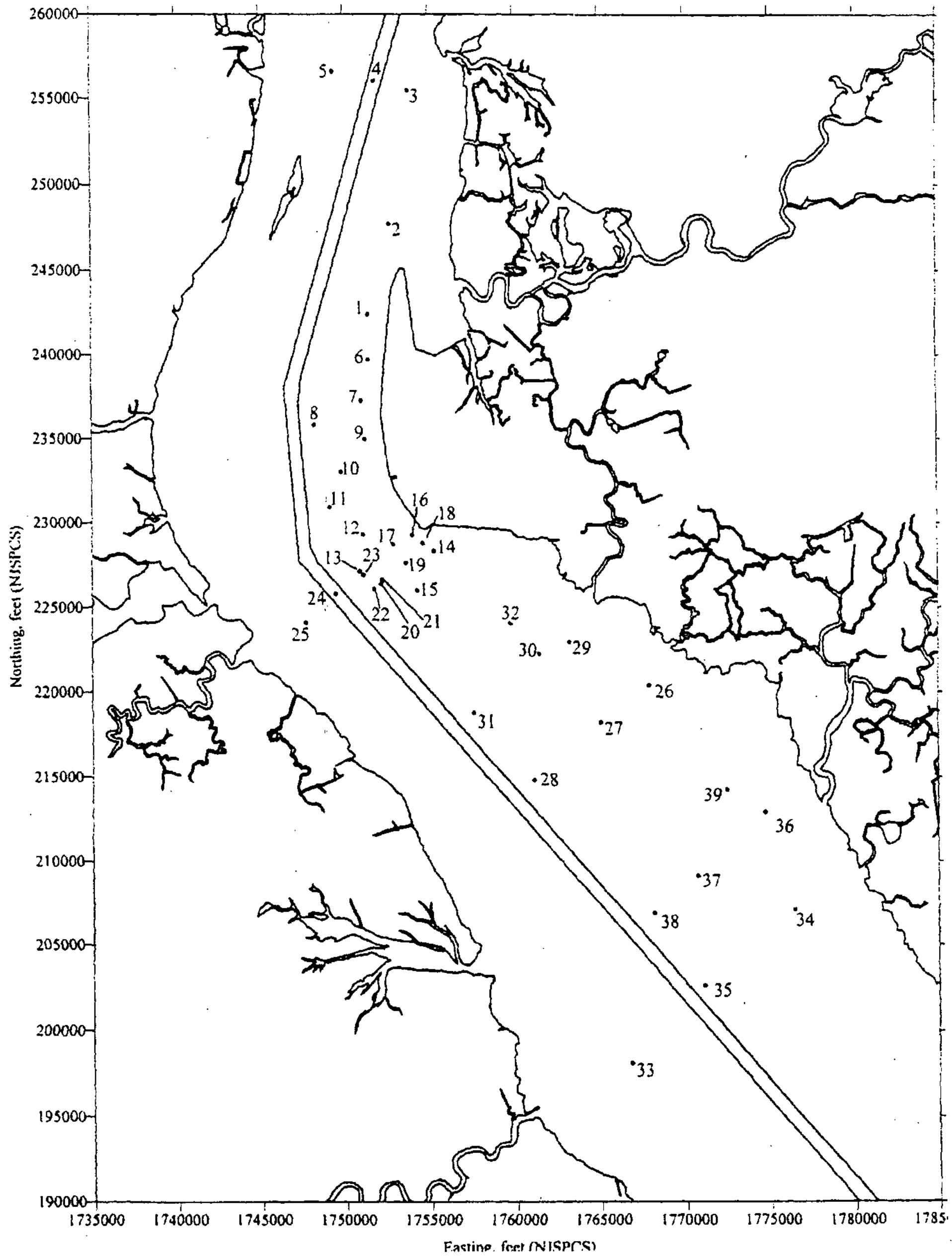


Figure 10-99
PSE&G 2-Unit Survey; 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Temperature Profiles

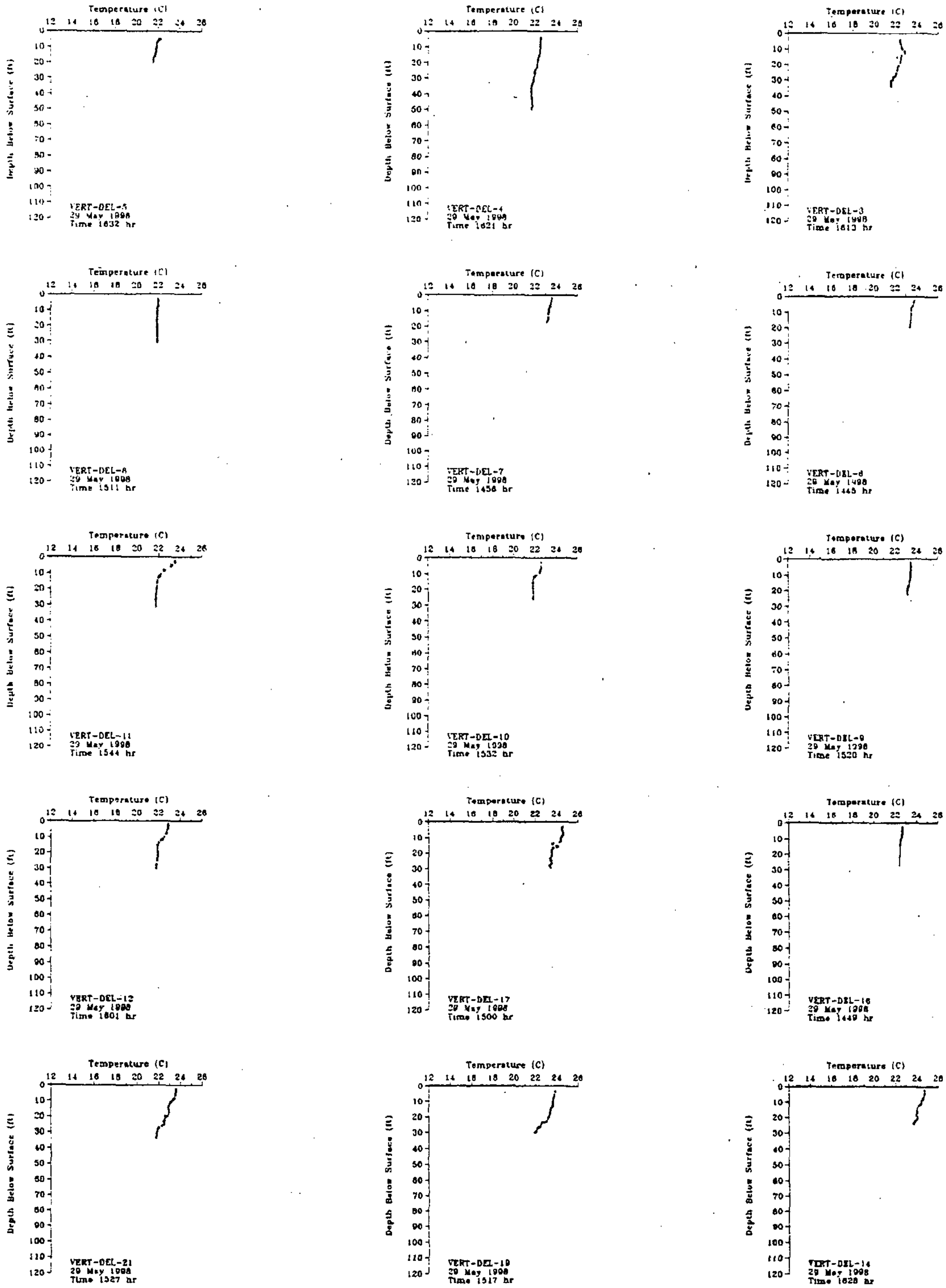


Figure 10-100
PSE&G 2-Unit Survey: 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Temperature Profiles

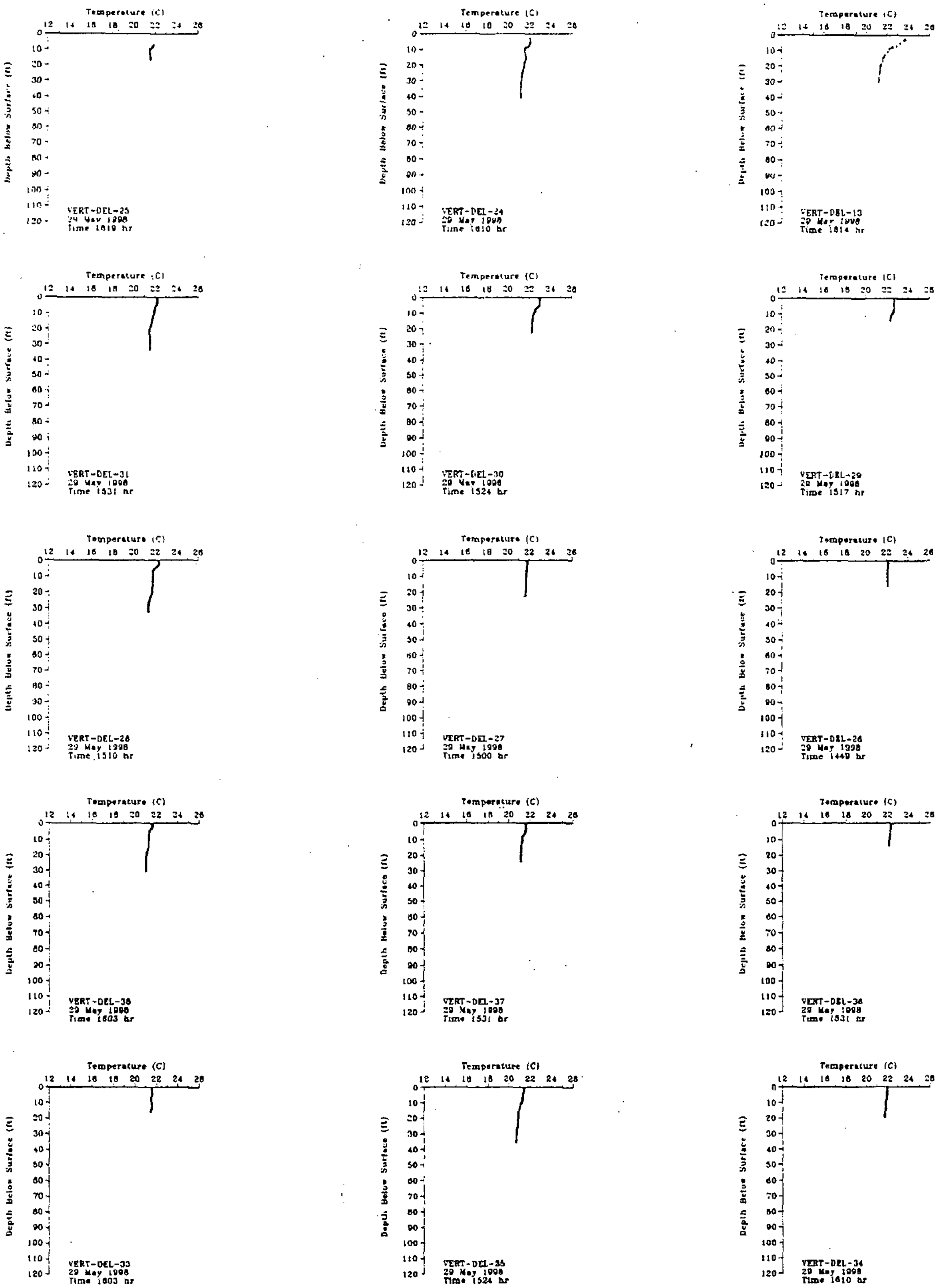


Figure 10-101
PSE&G 2-Unit Survey: 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Salinity Profiles

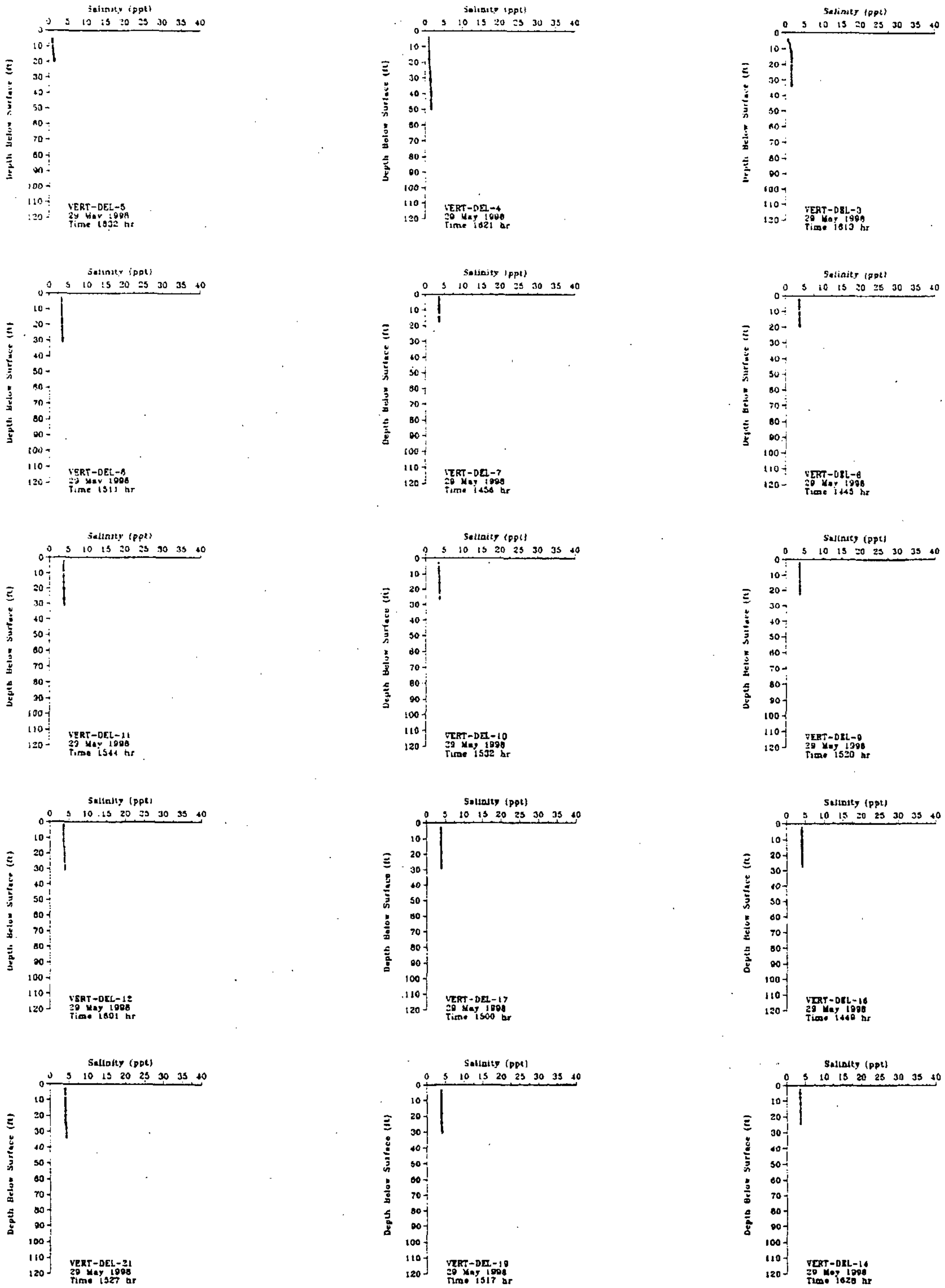


Figure 10-102
PSE&G 2-Unit Survey: 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Salinity Profiles

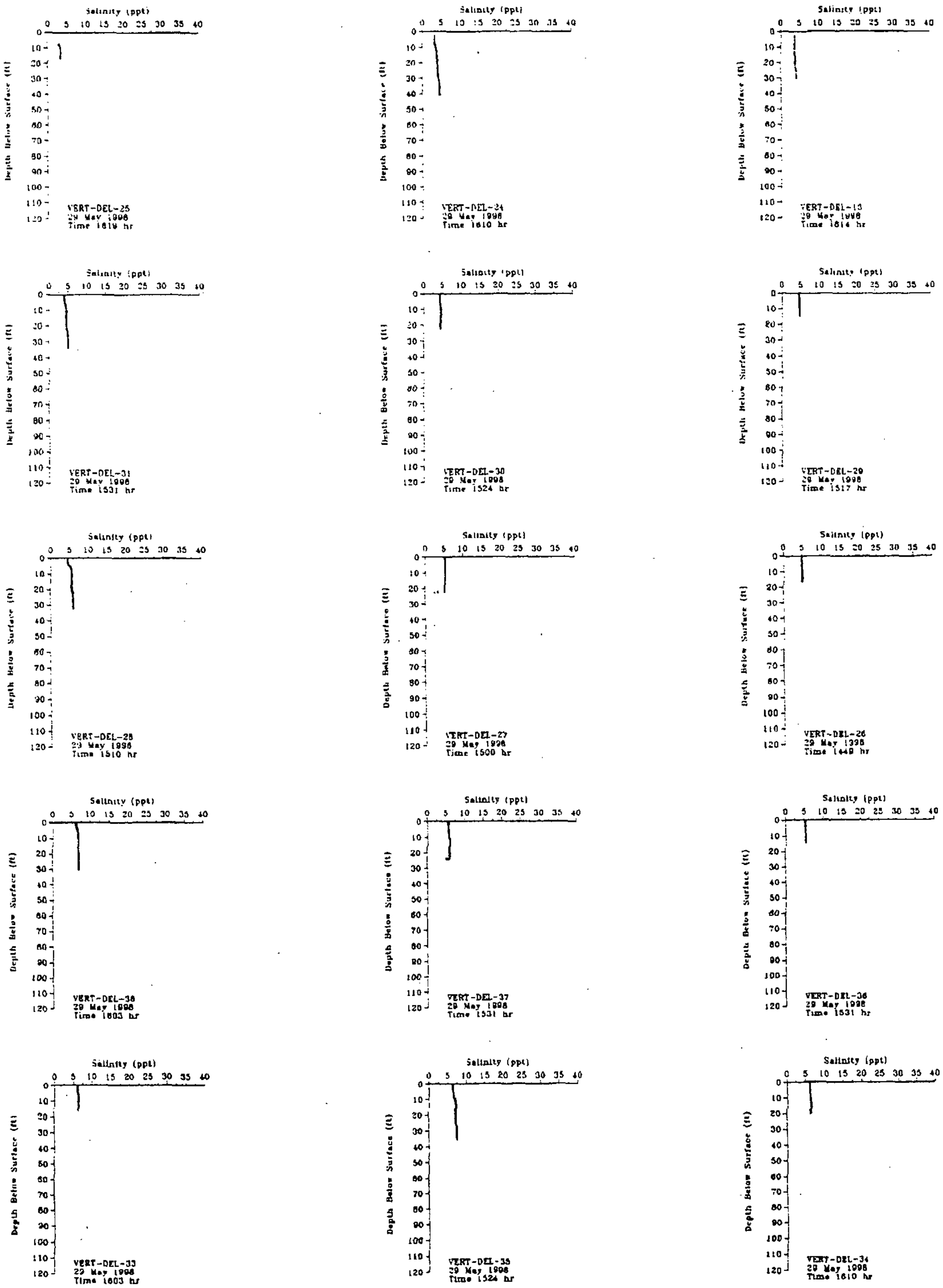


Figure 10-103
PSE&G 2-Unit Survey: 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Dye Profiles

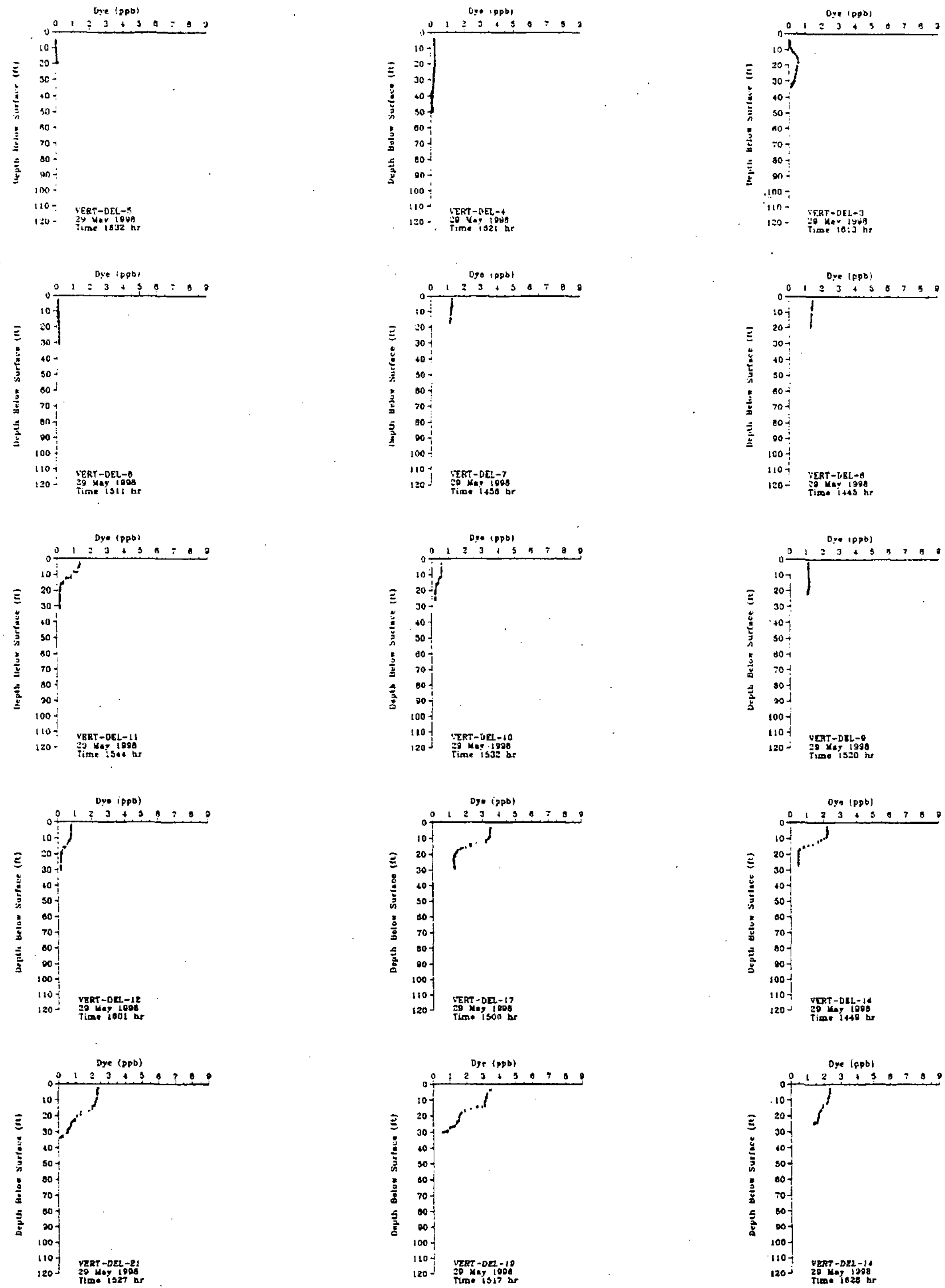


Figure 10-104
PSE&G 2-Unit Survey: 29 May 1998
EOF Phase (14:25 - 16:25)
Vertical Dye Profiles

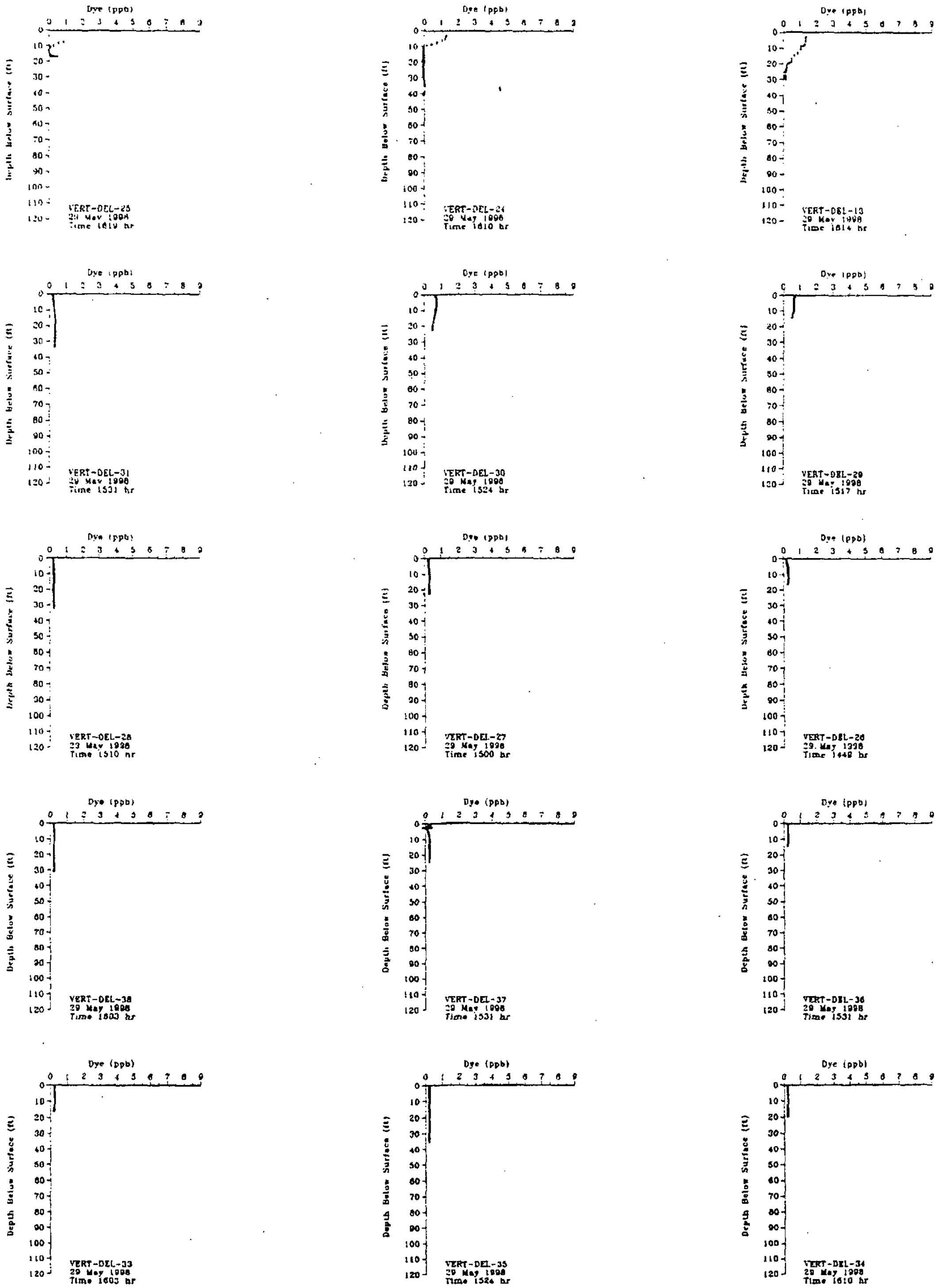


FIGURE 10-105

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)

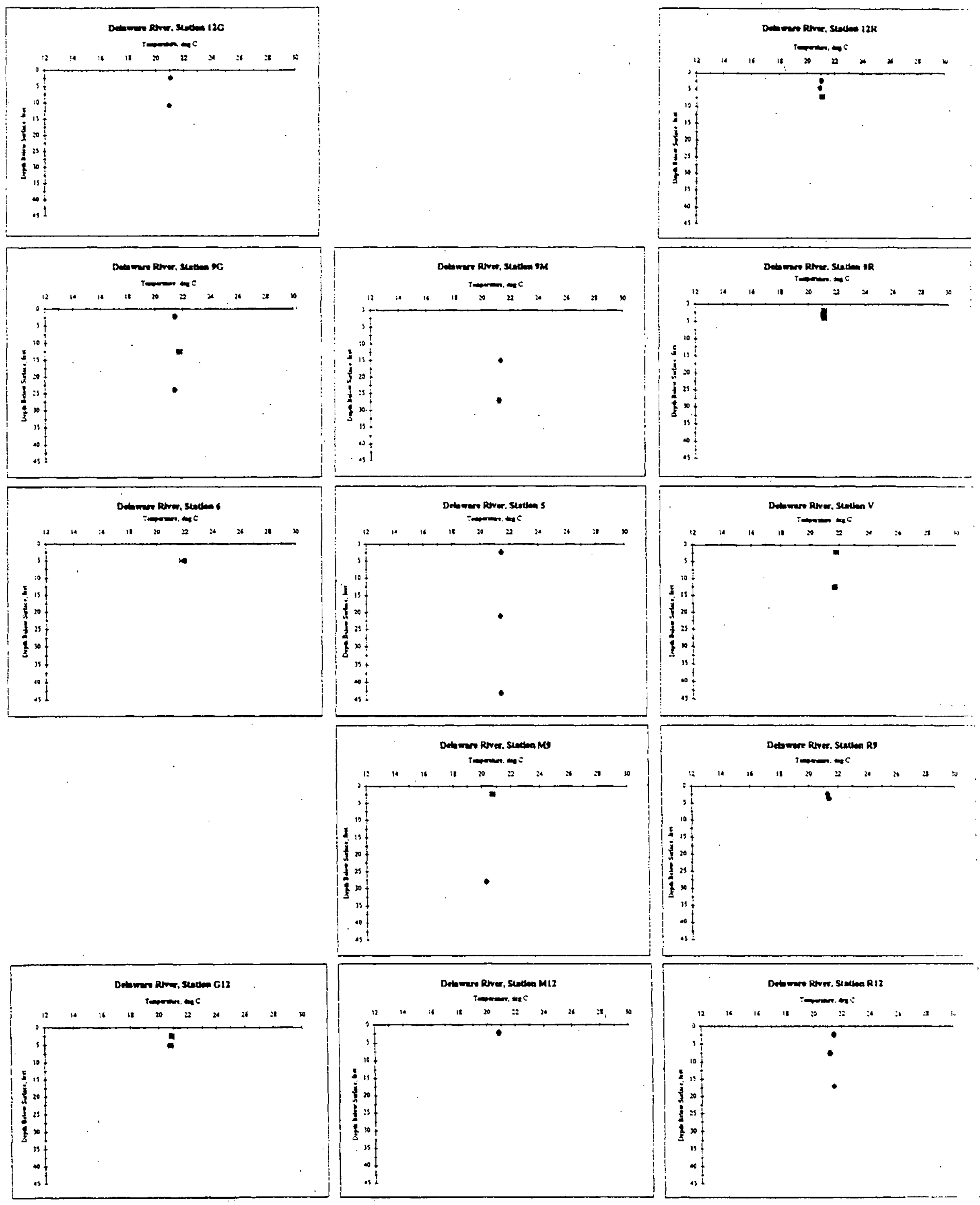


FIGURE 10-106

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)

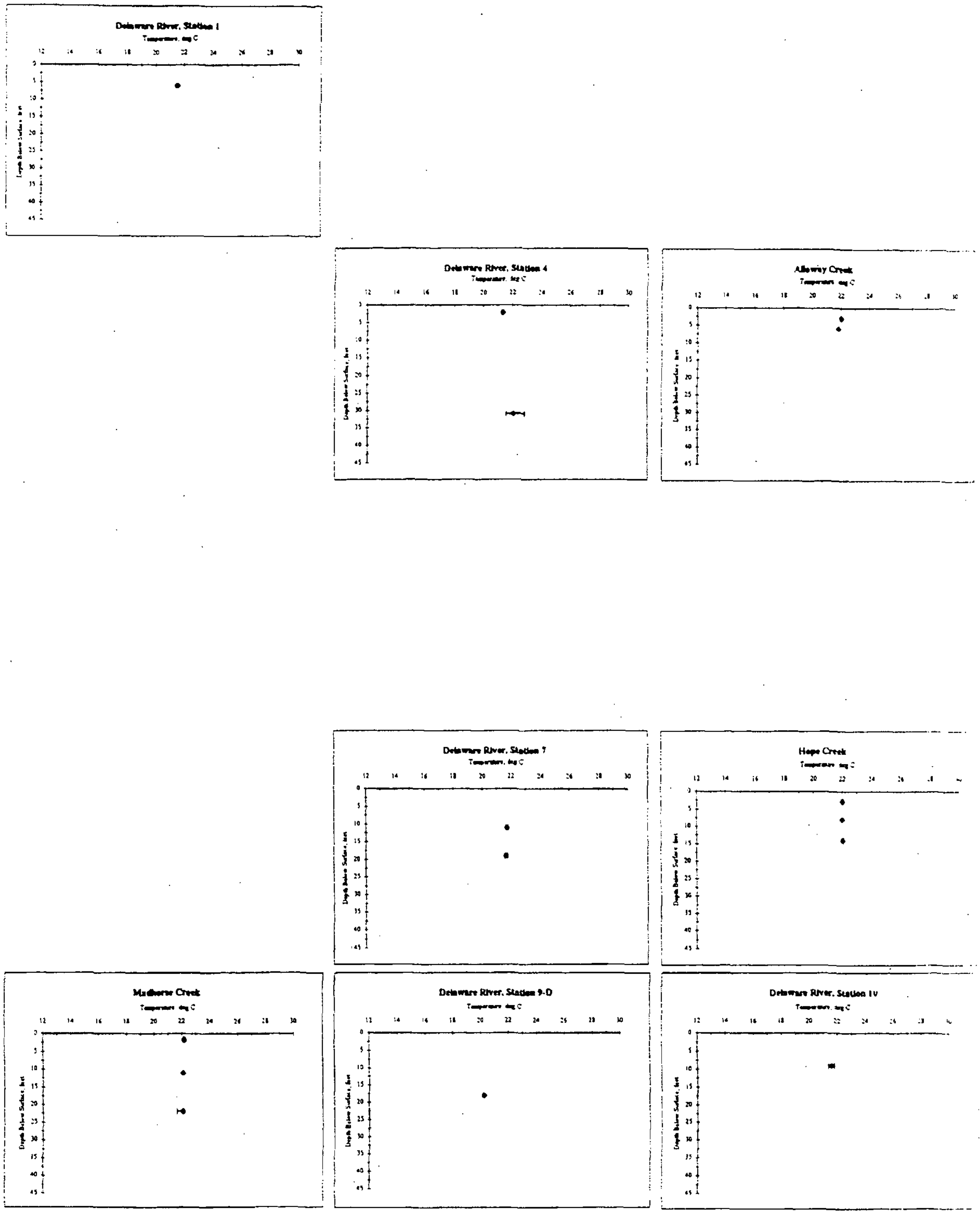


FIGURE 10-107

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)

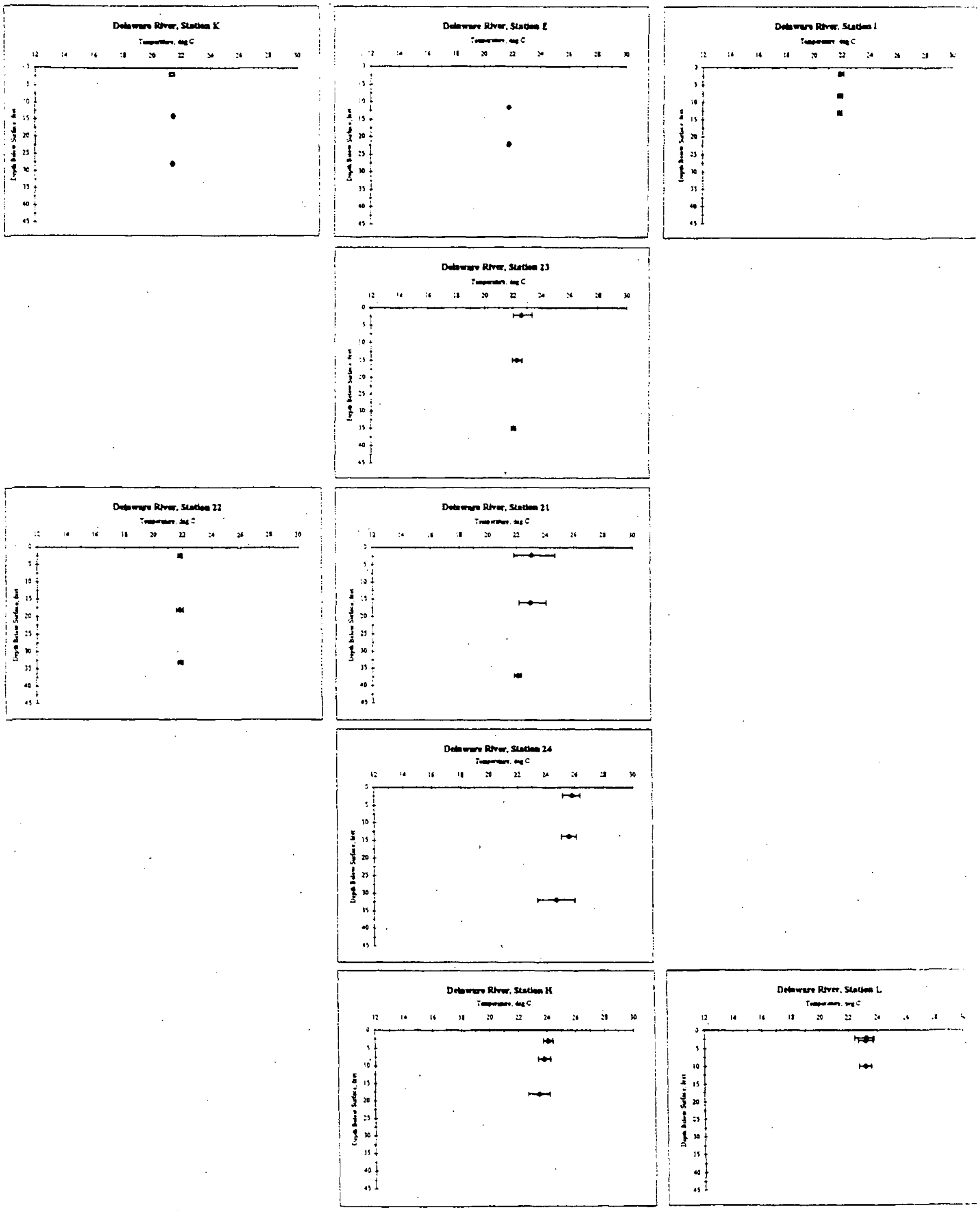


FIGURE 10-108

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)

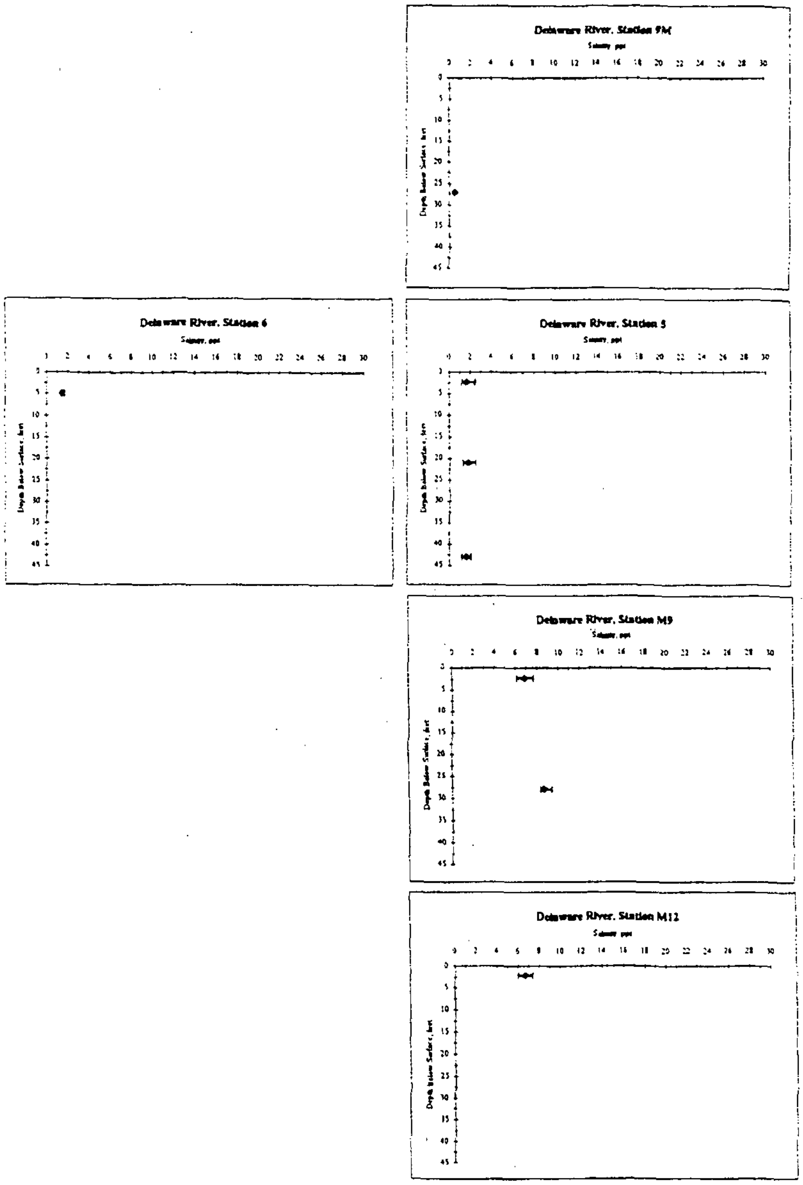
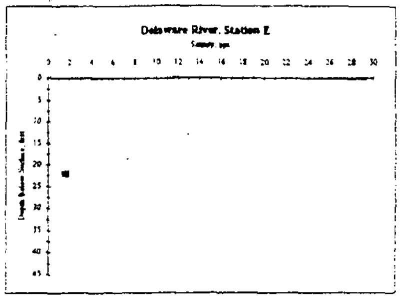


FIGURE 10-109

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)

FIGURE 10-110

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)



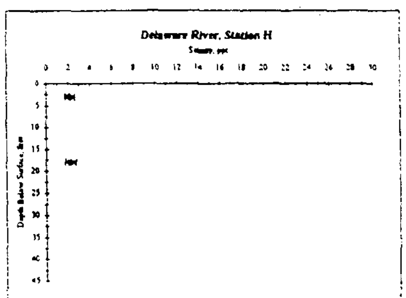
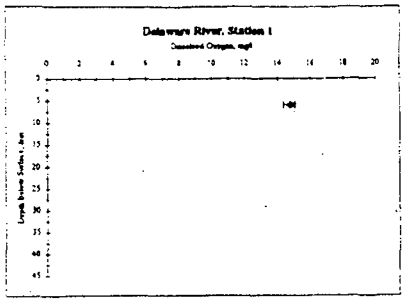
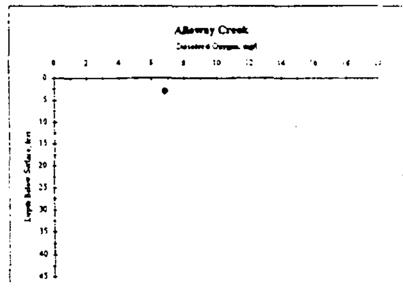
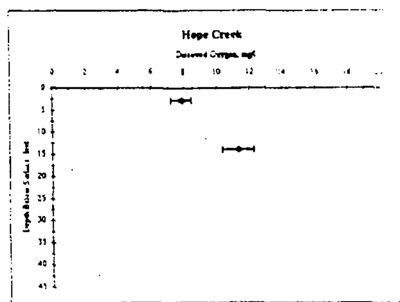


FIGURE 10-111

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)



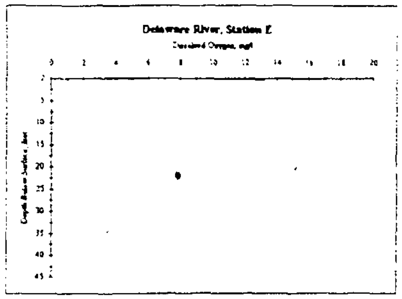


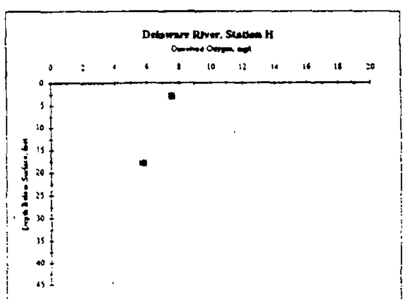


See Table 10-10 for quality control results

FIGURE 10-112

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
Ebb Phase(06:40 - 08:40)





See Table 10-10 for quality control results

FIGURE 10-113

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)

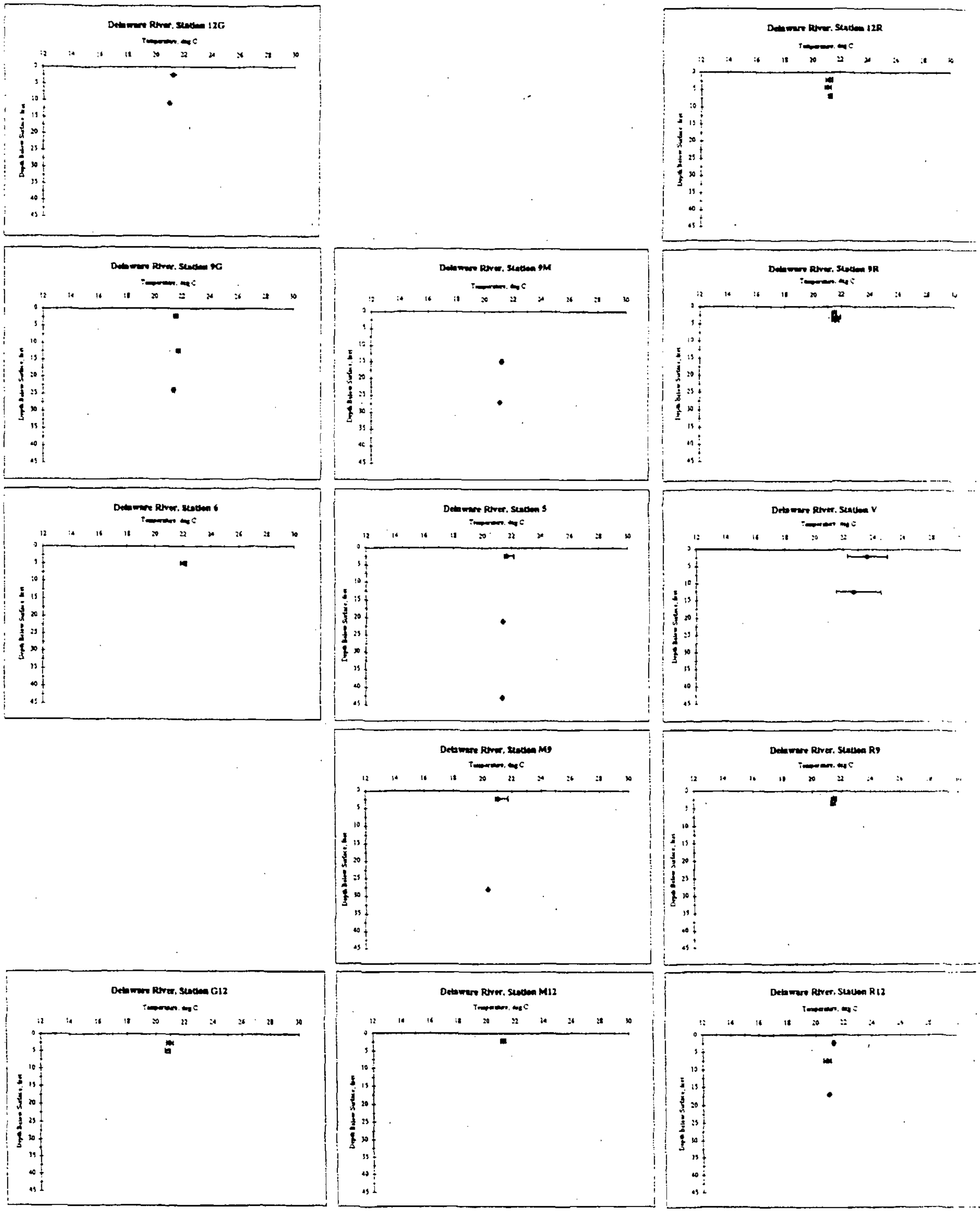


FIGURE 10-114

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)

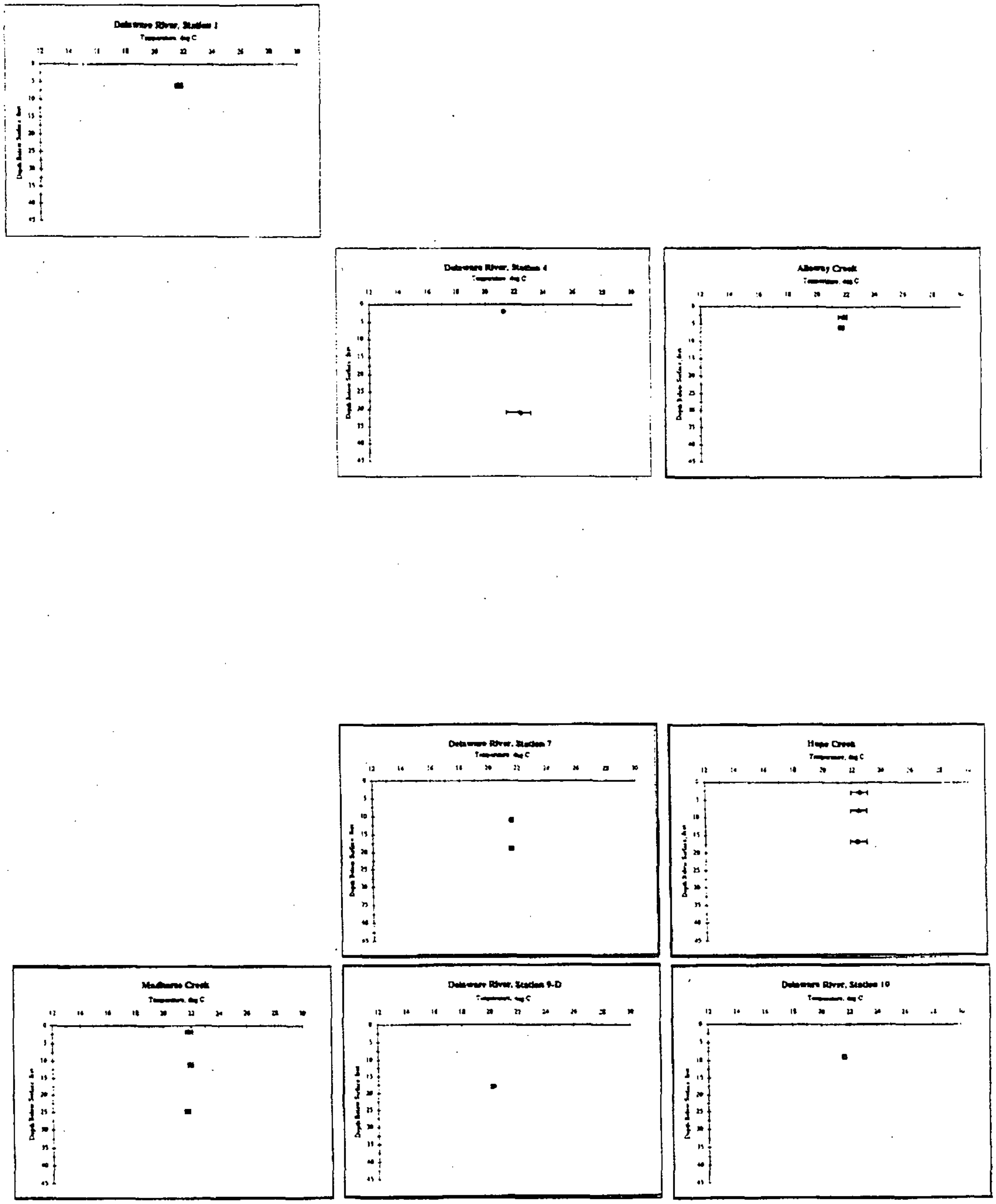


FIGURE 10-115

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)

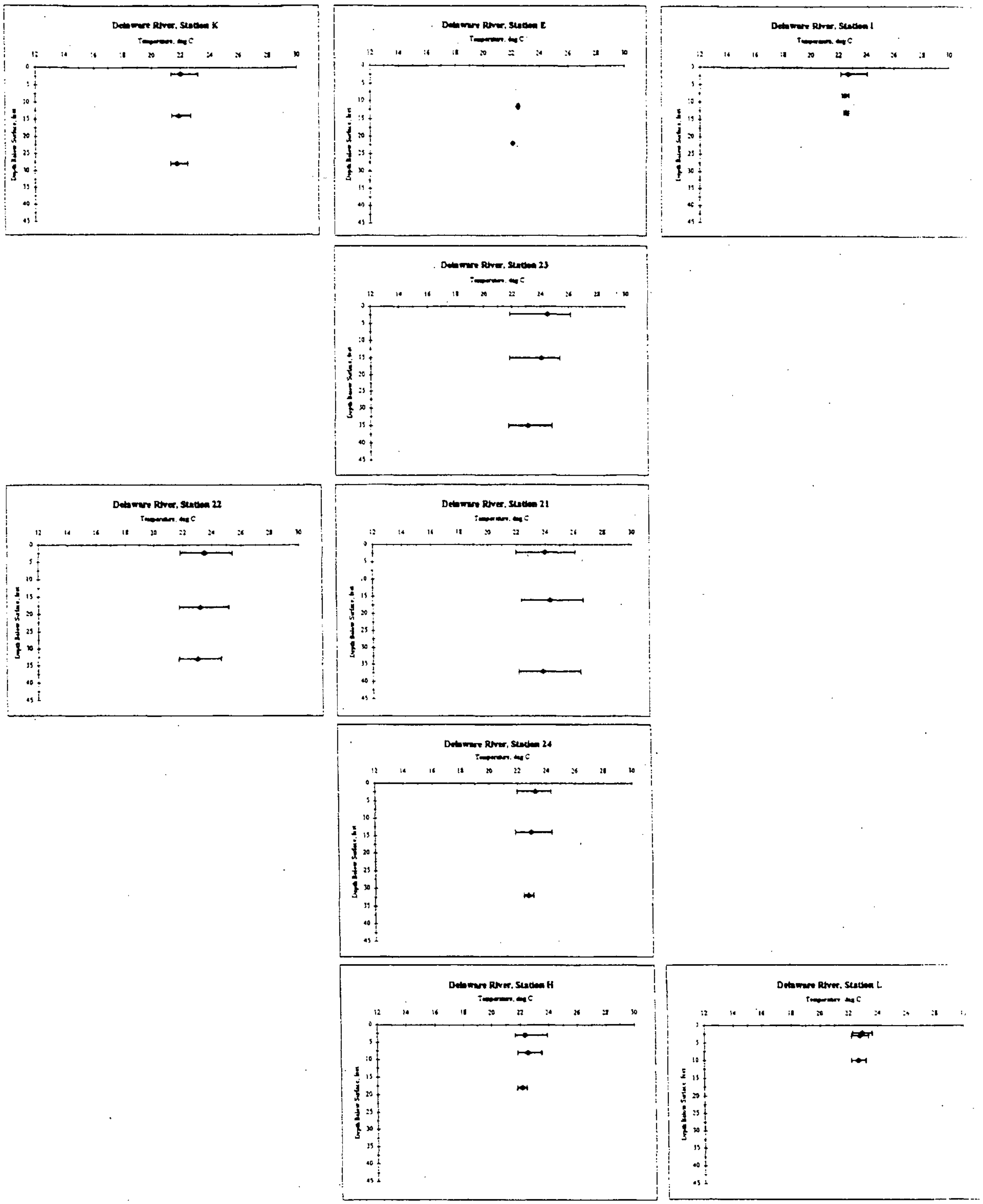
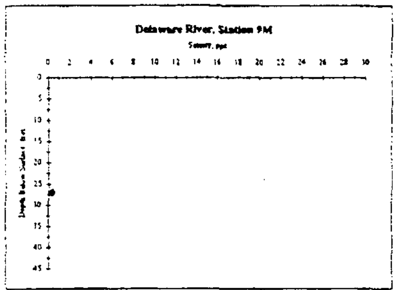
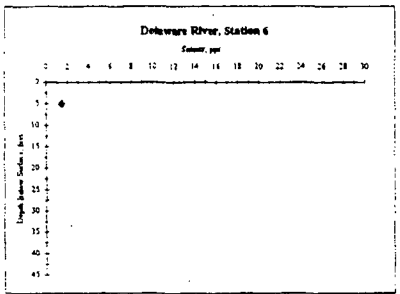
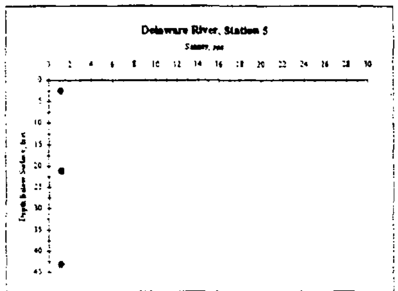


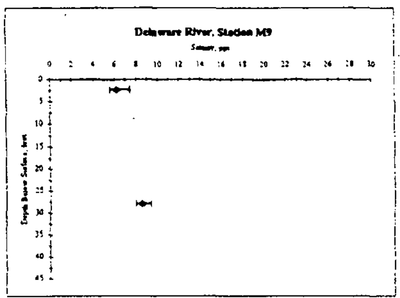
FIGURE 10-116

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)









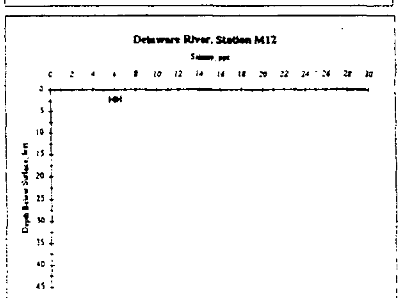


FIGURE 10-117

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)

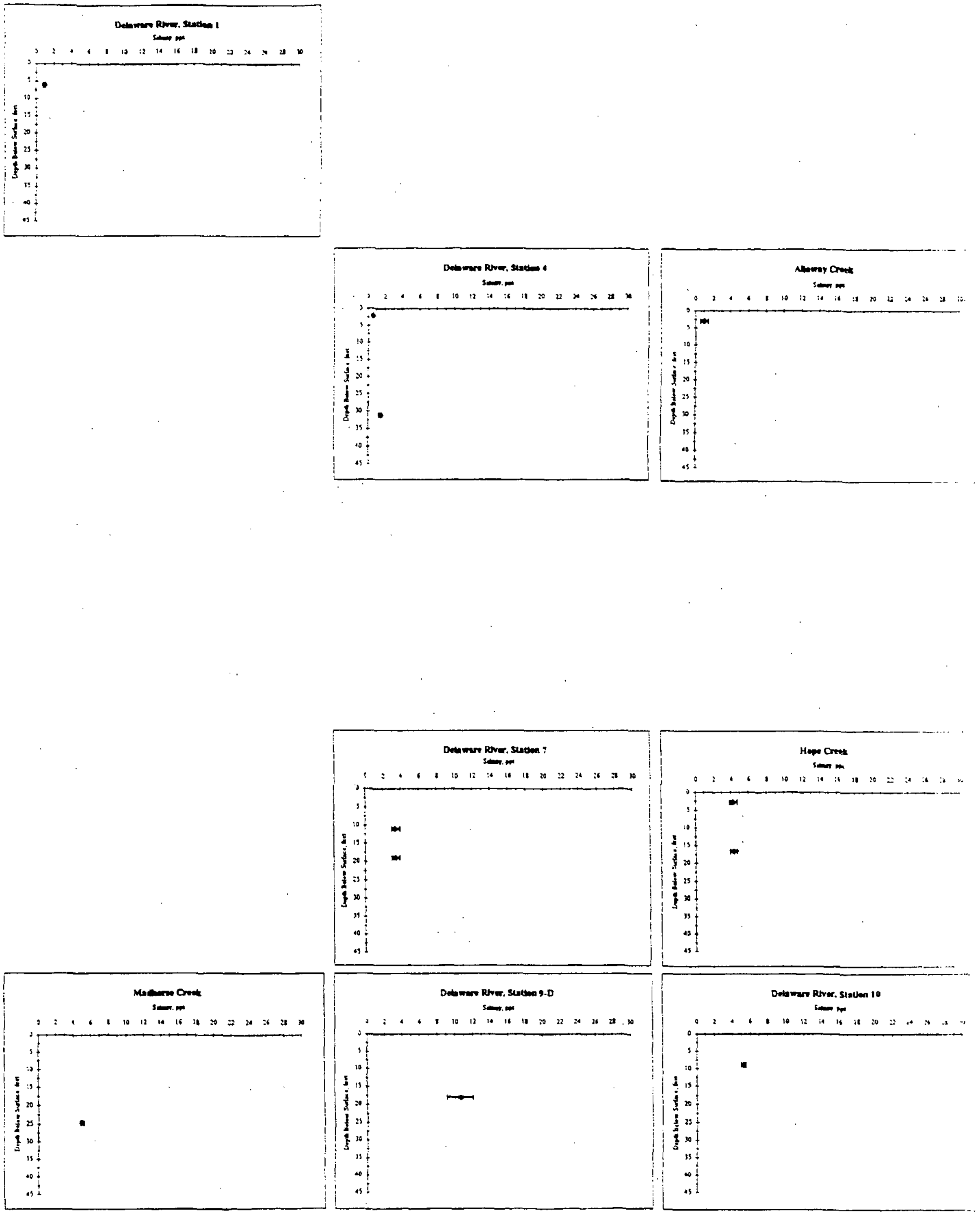
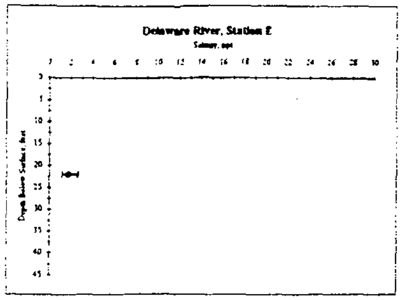


FIGURE 10-118

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)



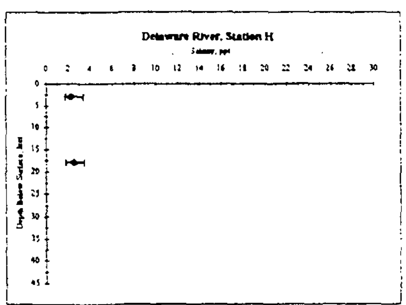
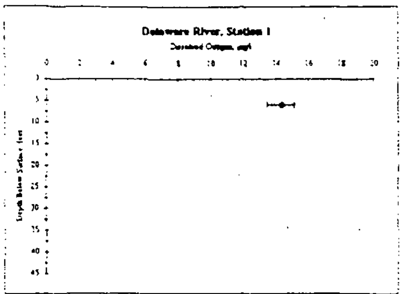
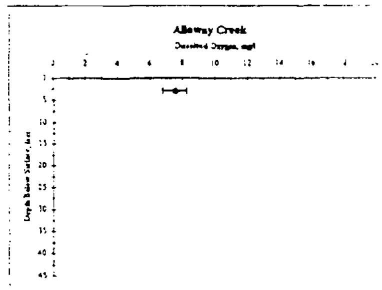
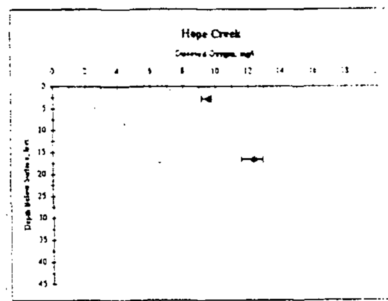


FIGURE 10-119

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)



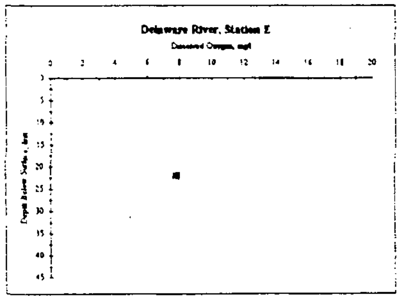


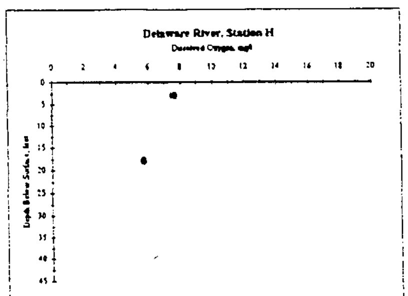


See Table 10-10 for quality control results

FIGURE 10-120

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
EOE Phase (09:10 - 11:10)





See Table 10-10 for quality control results

FIGURE 10-121

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)

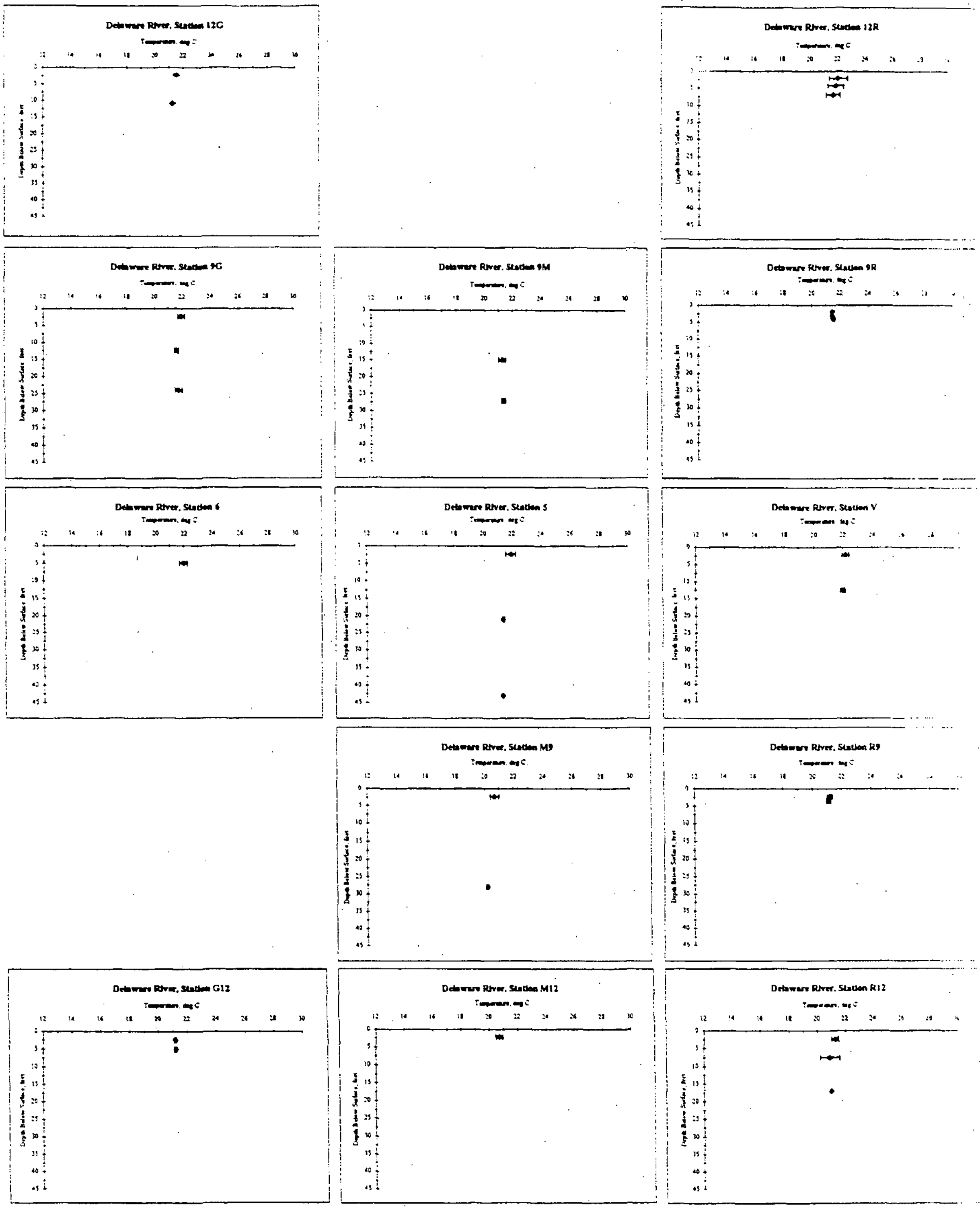


FIGURE 10-122

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)

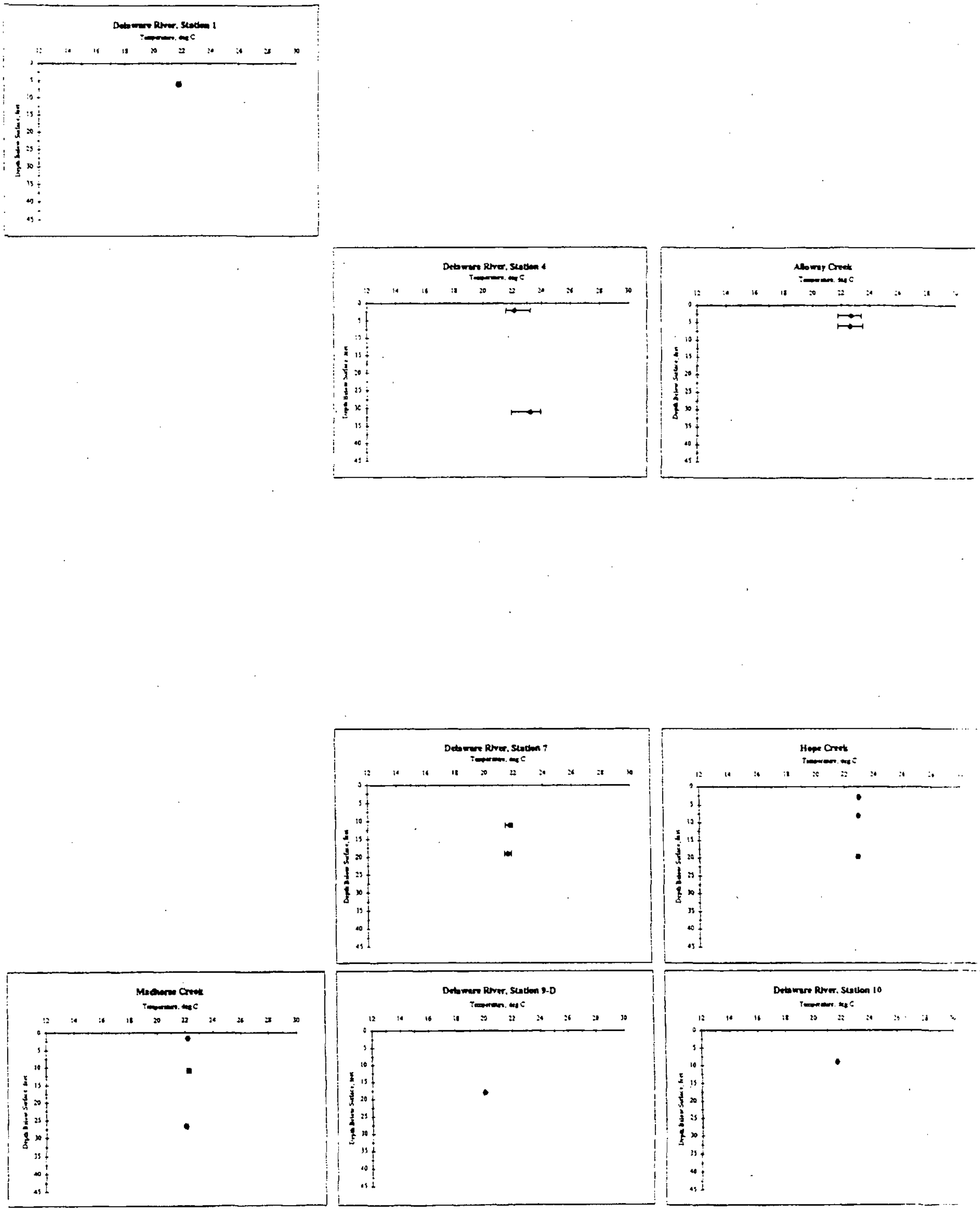


FIGURE 10-123

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)

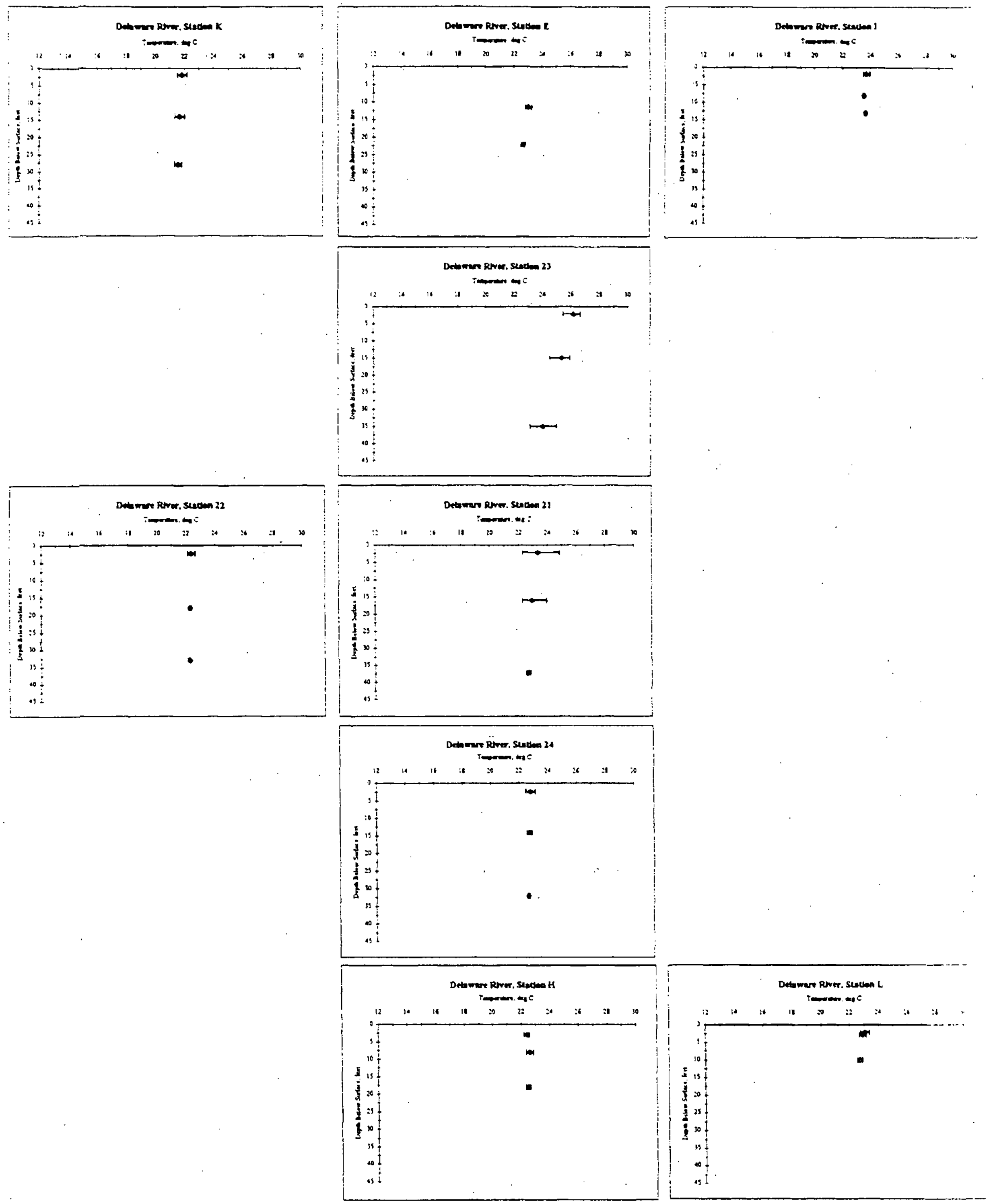


FIGURE 10-124

PSE&G 1-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)

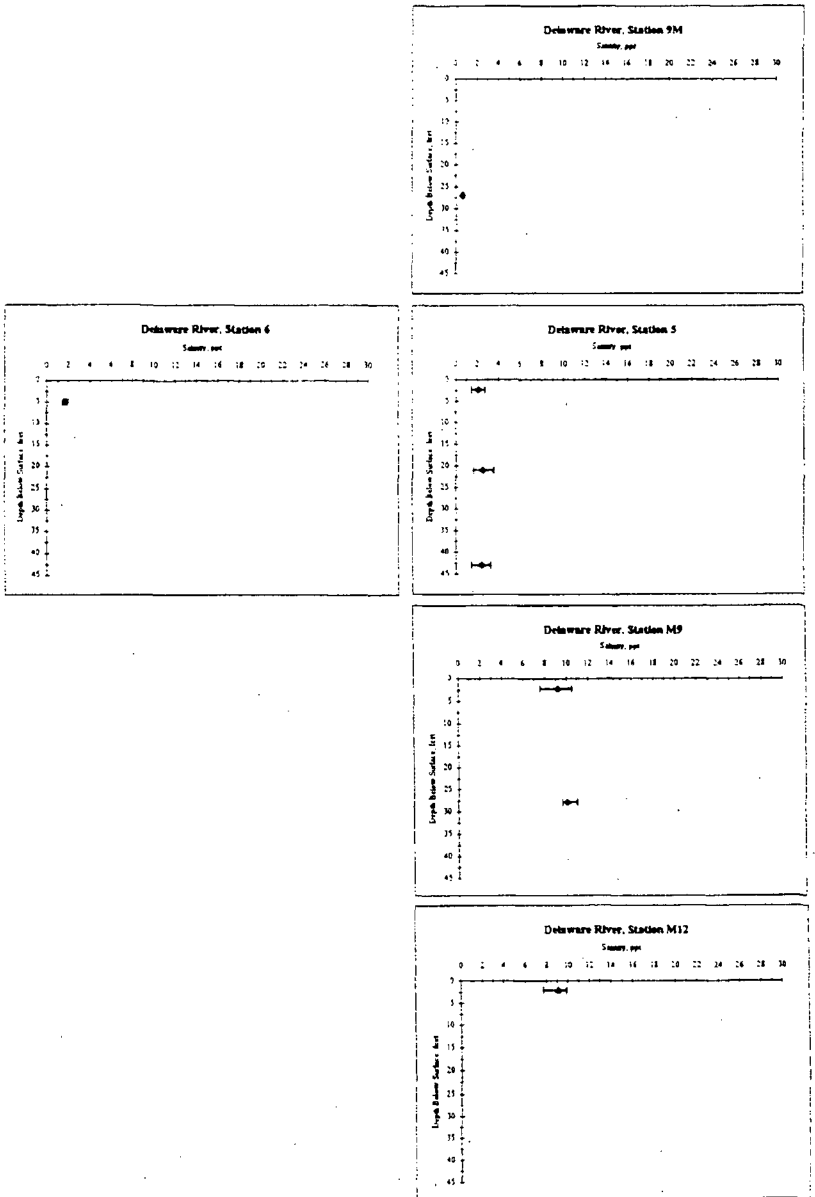
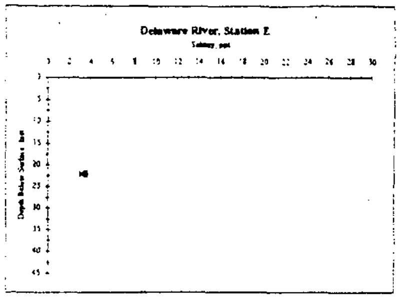


FIGURE 10-125

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)

FIGURE 10-126

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)



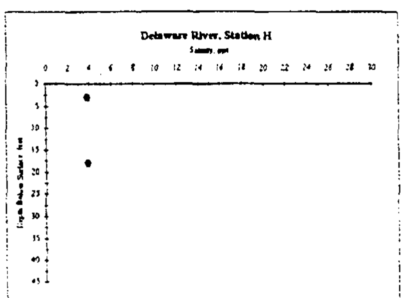
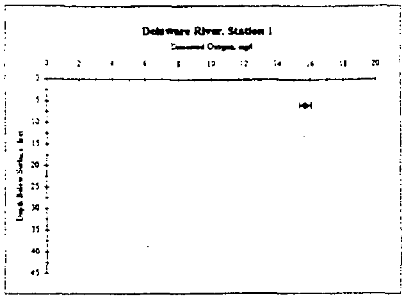
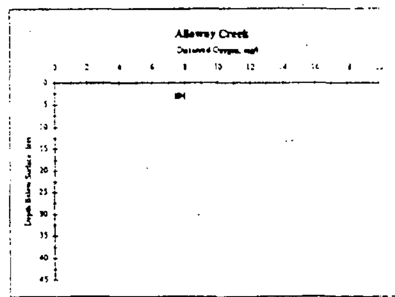
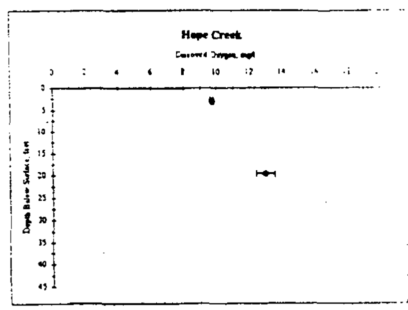


FIGURE 10-127

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)



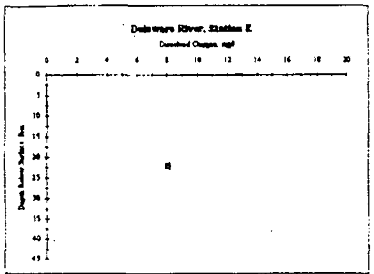


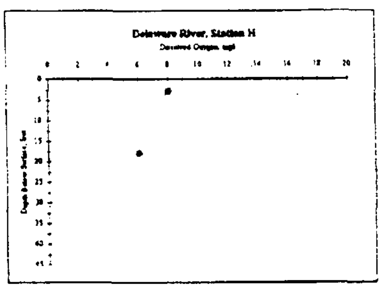


See Table 10-10 for quality control results

FIGURE 10-128

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
Flood Phase (11:40 - 13:40)





See Table 10-10 for quality control results

FIGURE 10-129

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)

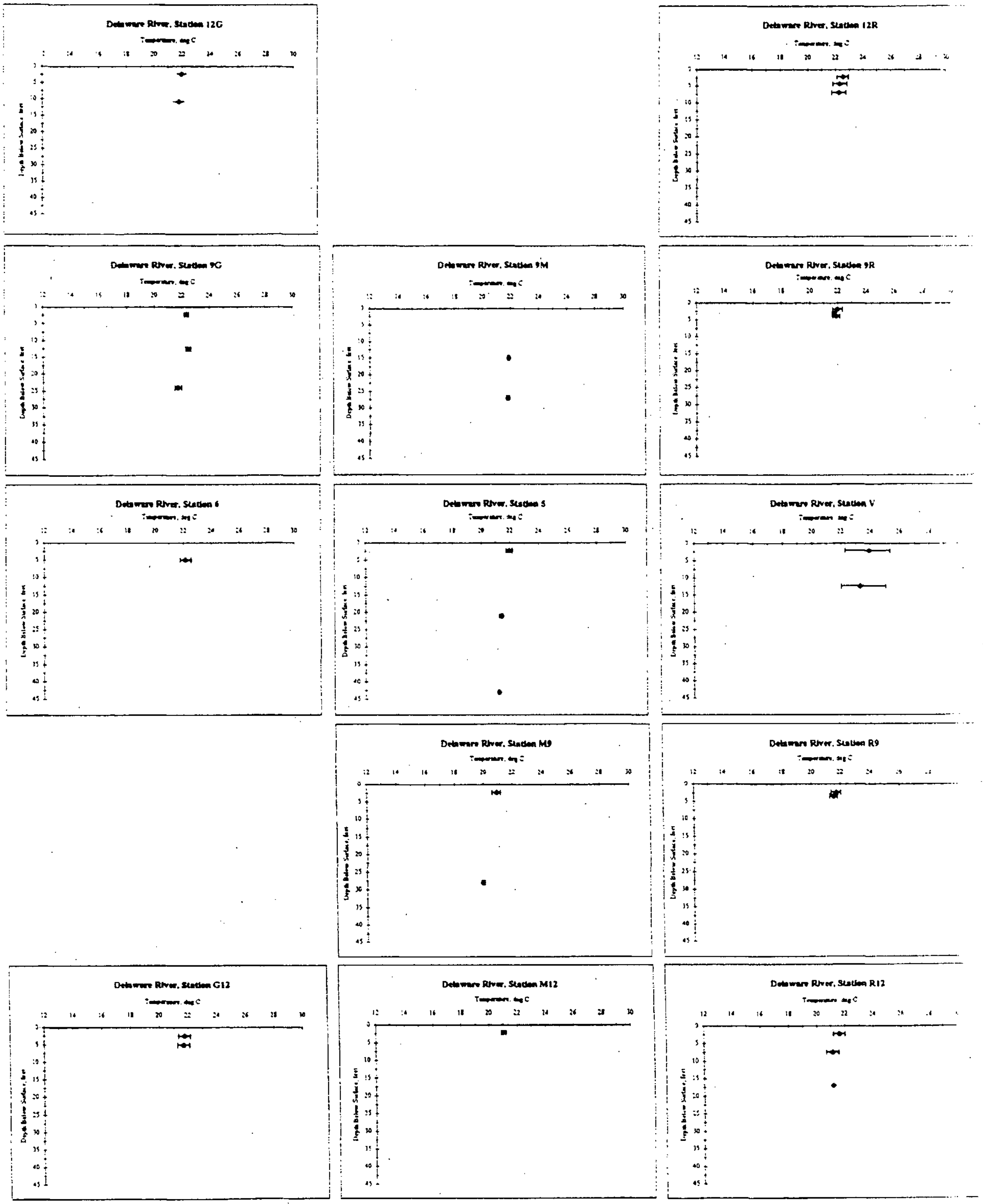
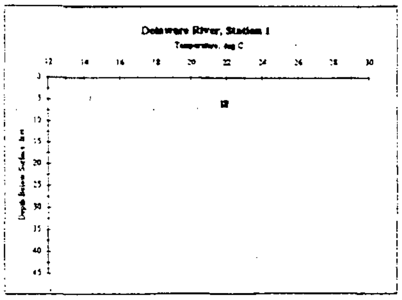
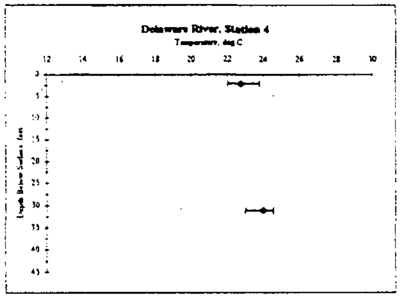
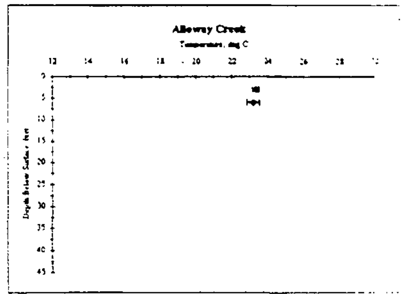


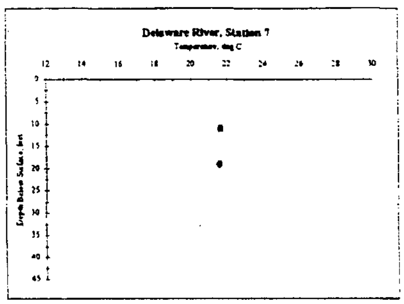
FIGURE 10-130

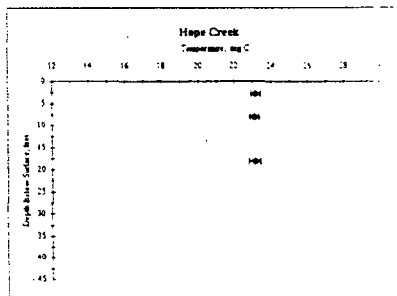
PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)

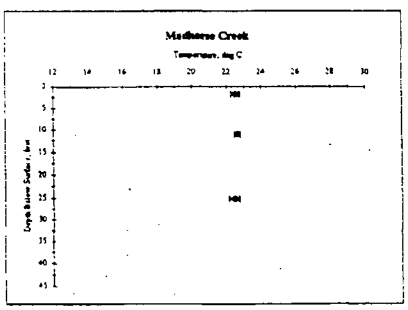


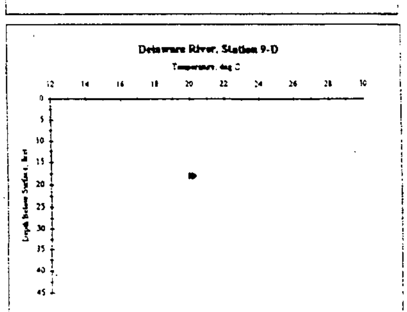












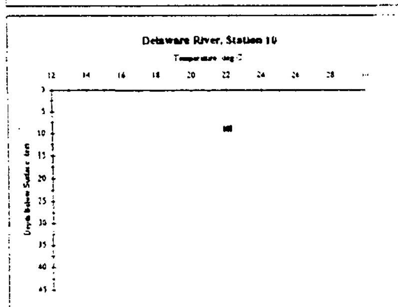


FIGURE 10-131

PSE&G 2-Unit Survey; 29 May 1998
Temperature Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)

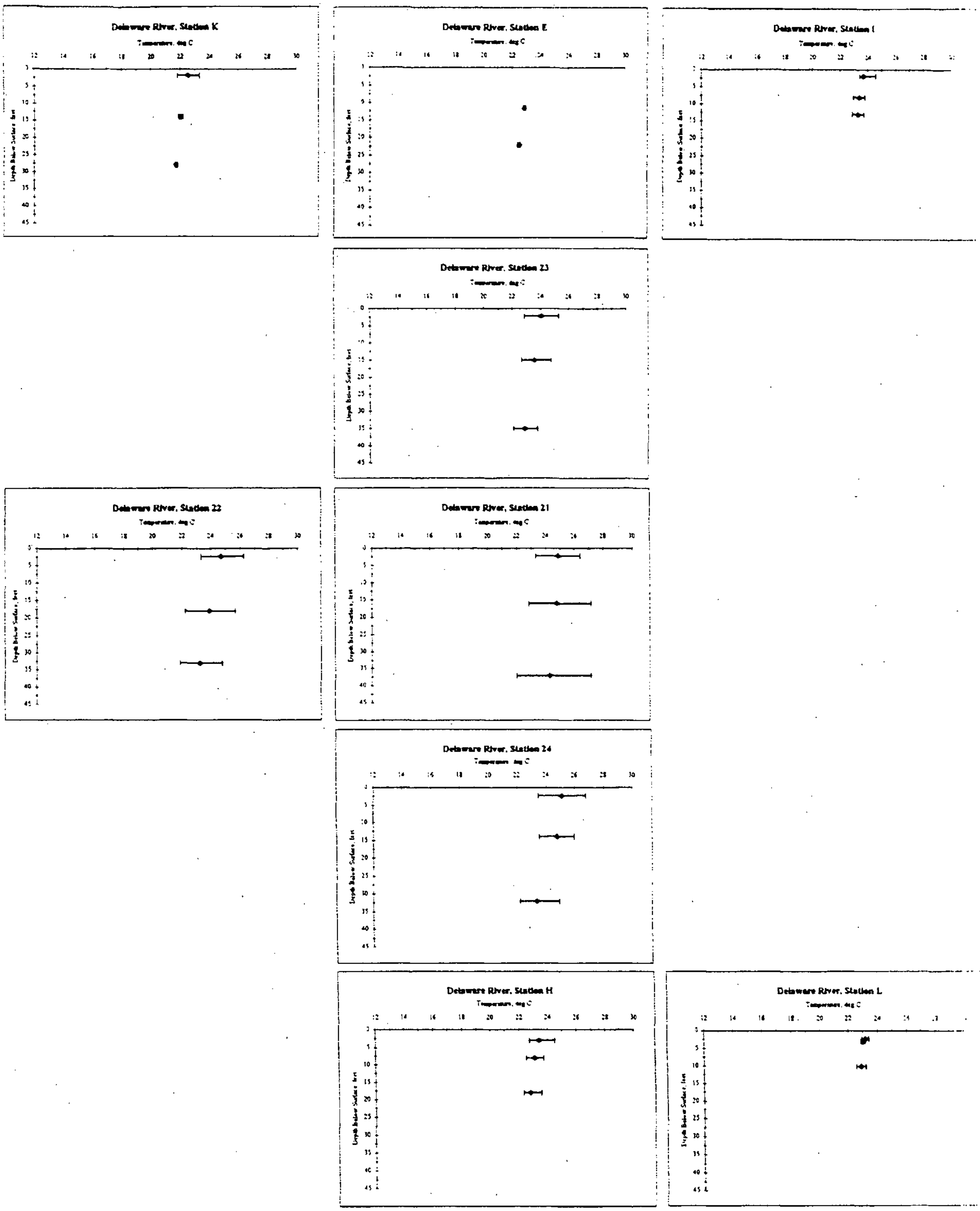
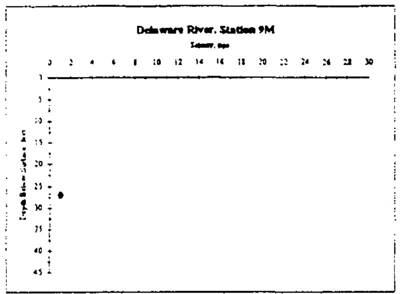
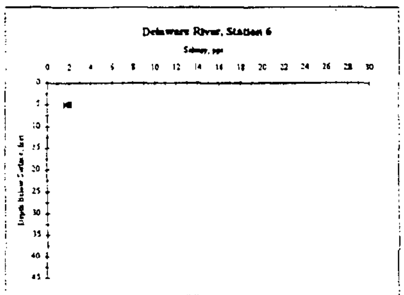
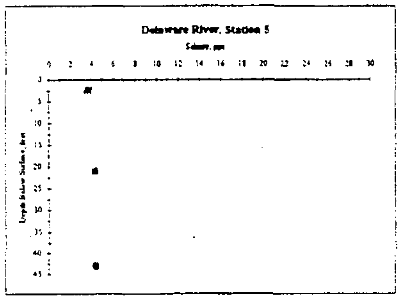


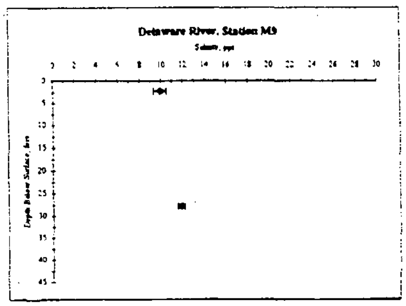
FIGURE 10-132

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)









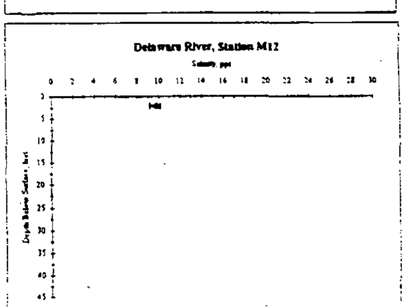
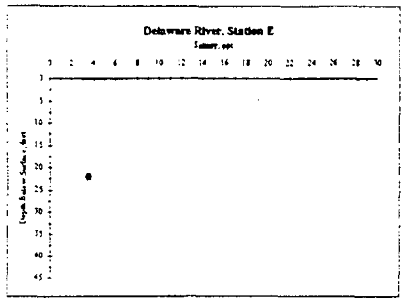


FIGURE 10-133

PSE&G 2-Unit Survey: 29 May 1998
Salinity Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)

FIGURE 10-134

PSE&G 2-Unit Survey; 29 May 1998
Salinity Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)



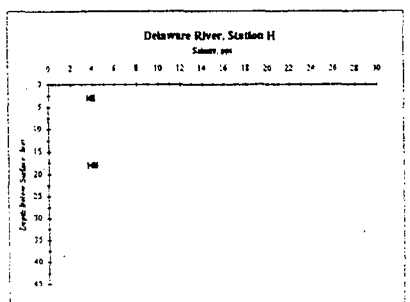
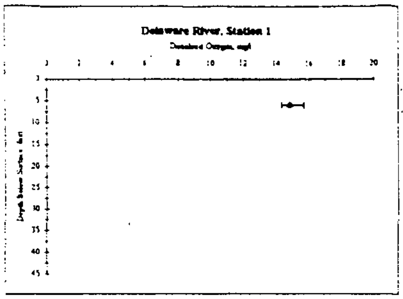
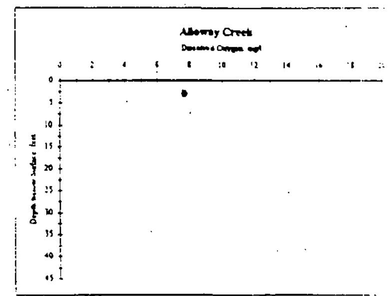
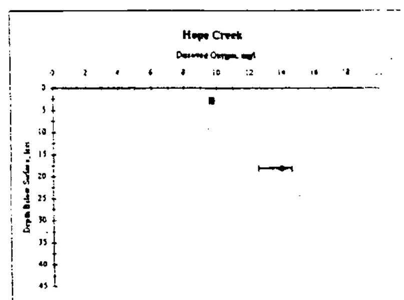


FIGURE 10-135

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)



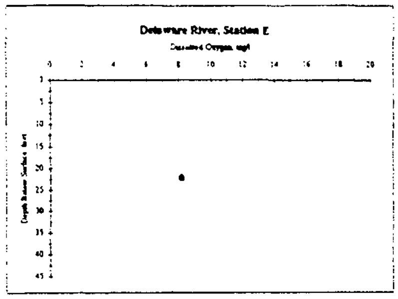




See Table 10-10 for quality control results

FIGURE 10-136

PSE&G 2-Unit Survey; 29 May 1998
Dissolved Oxygen Vertical Profiles (Moorings)
EOF Phase (14:25 - 16:25)



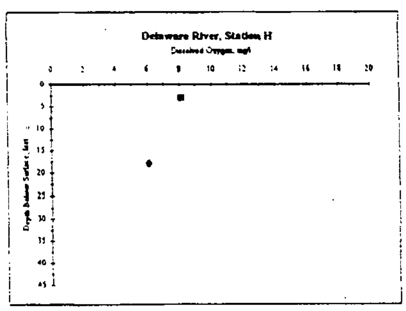


FIGURE 10-137

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-1

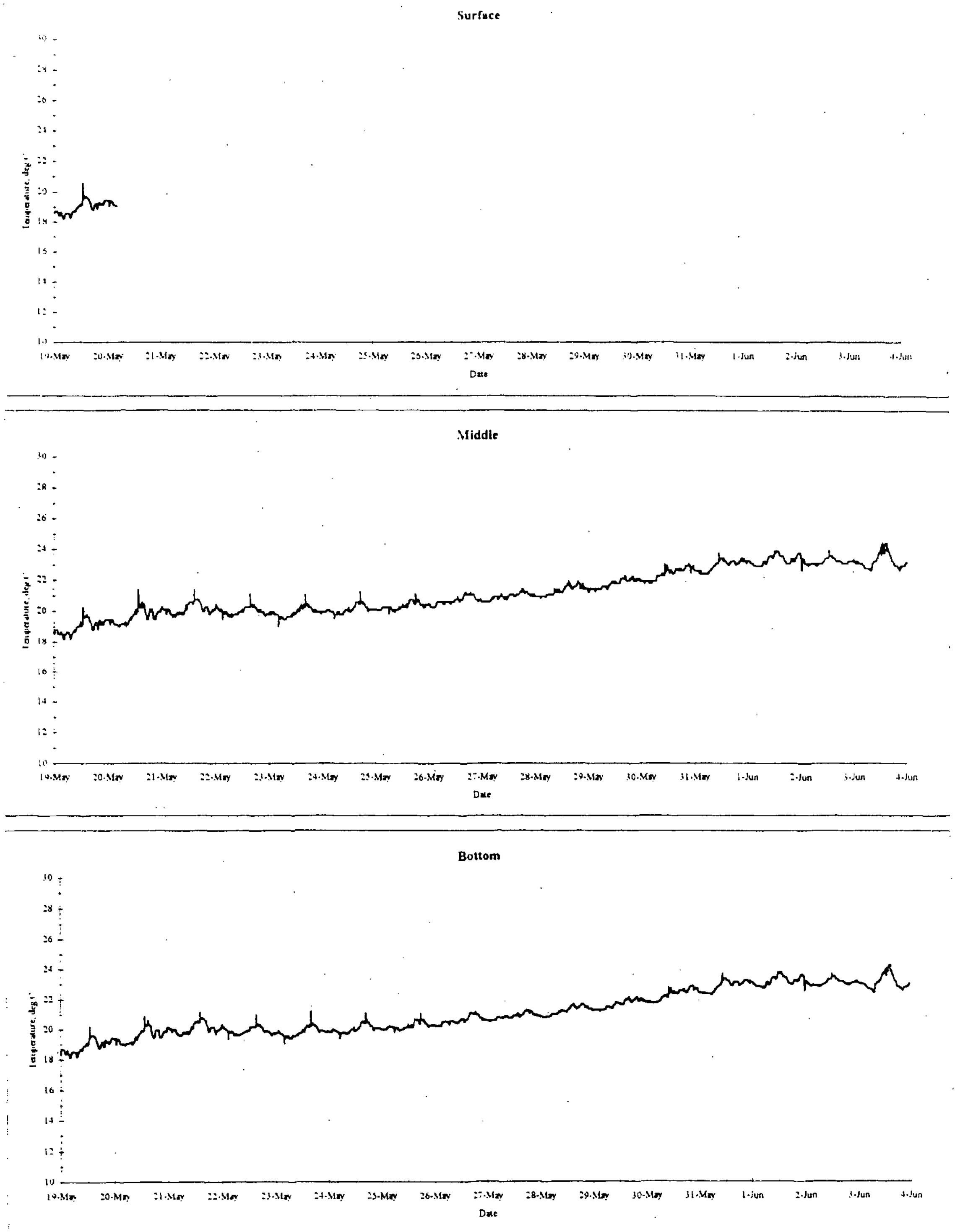
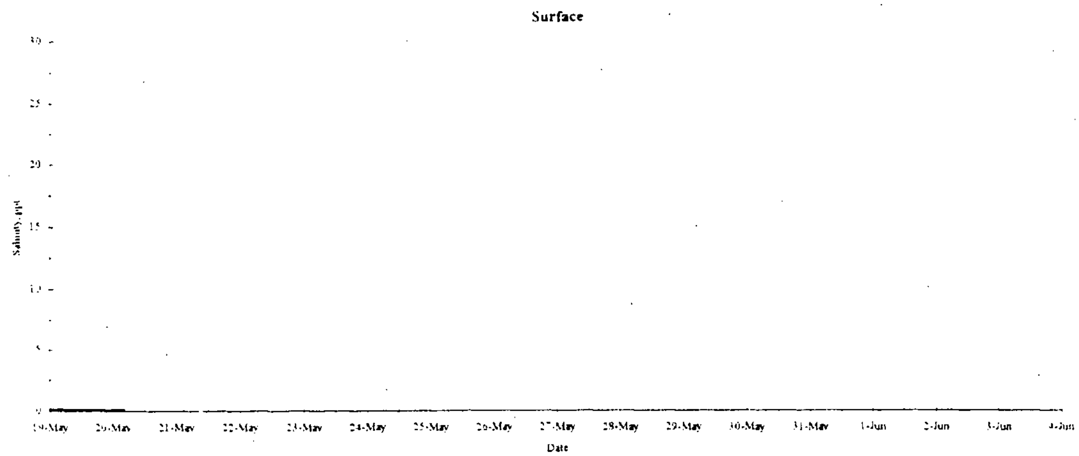


FIGURE 10-138

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-1



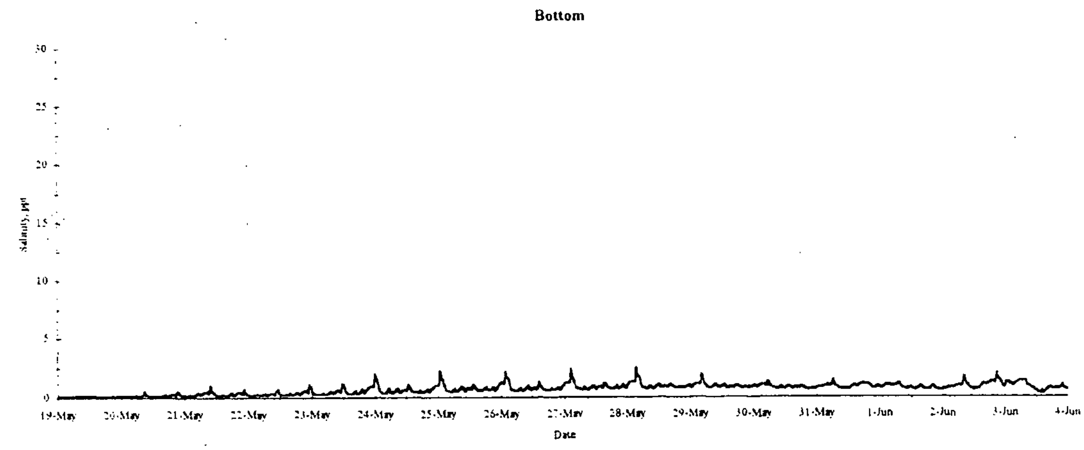
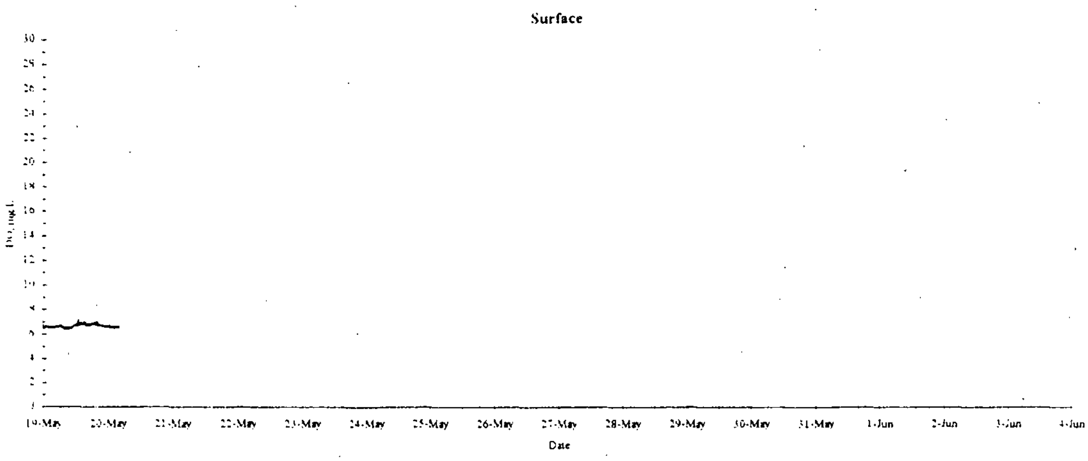
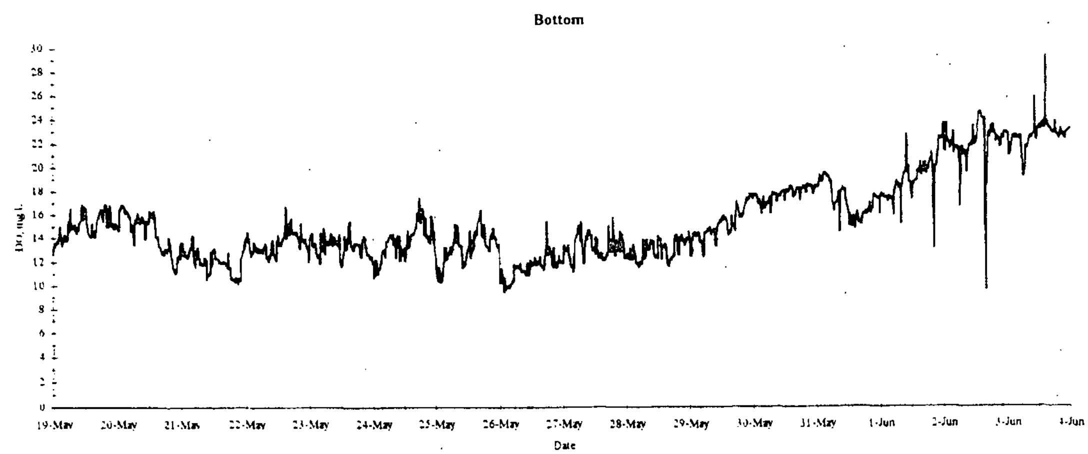


FIGURE 10-139

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-1





See Table 10-10 for quality control results

FIGURE 10-140

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-2

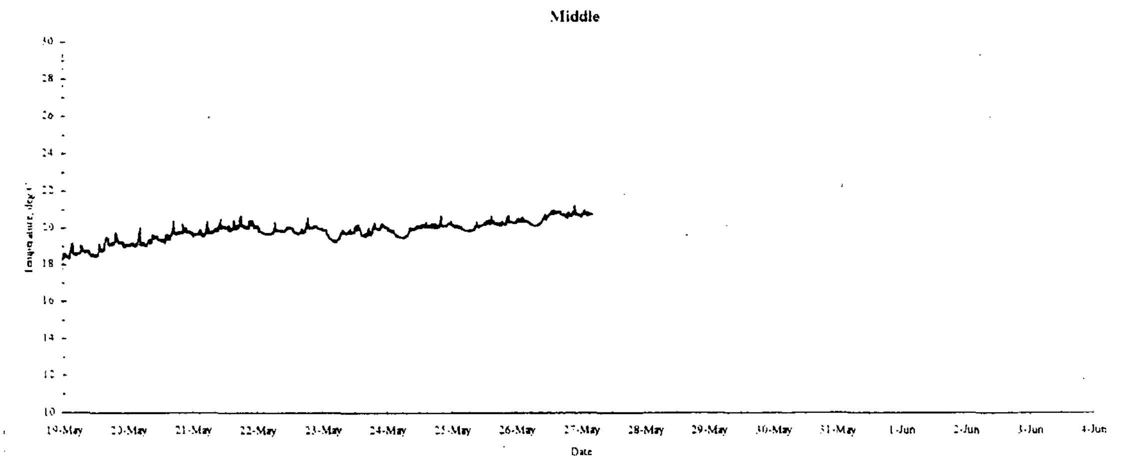


FIGURE 10-141

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-2

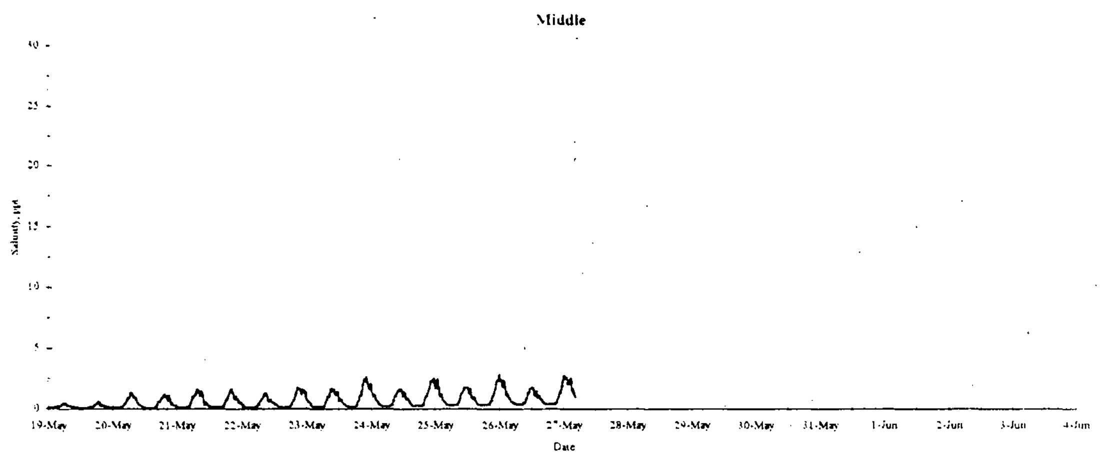
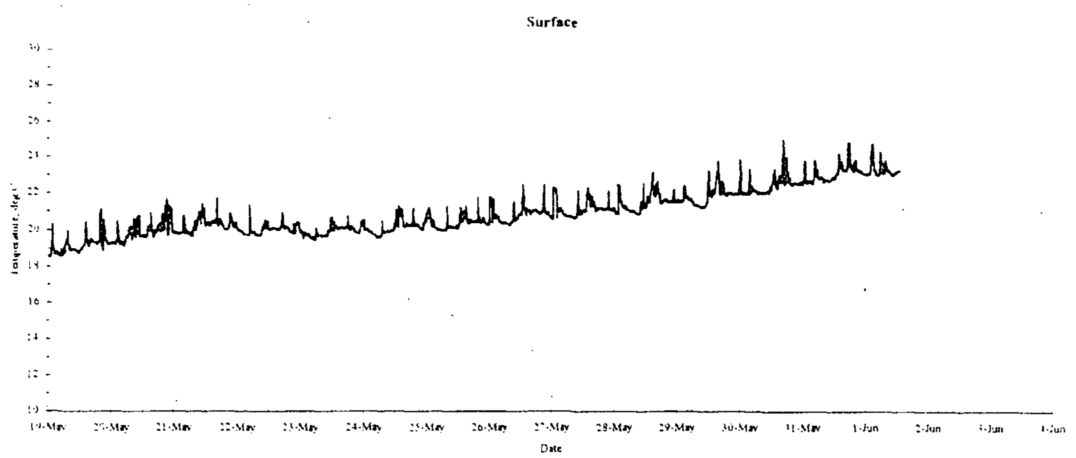
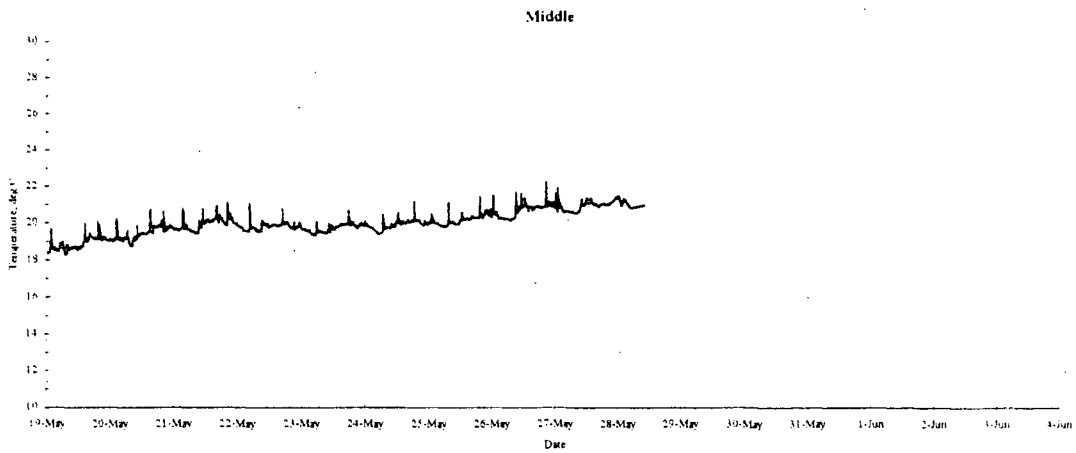


FIGURE 10-142

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-4





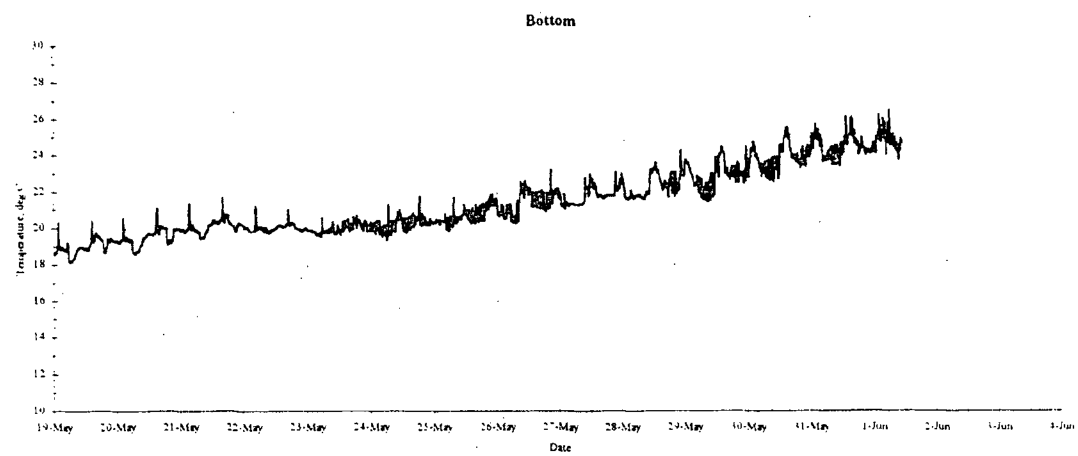


FIGURE 10-143

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-4

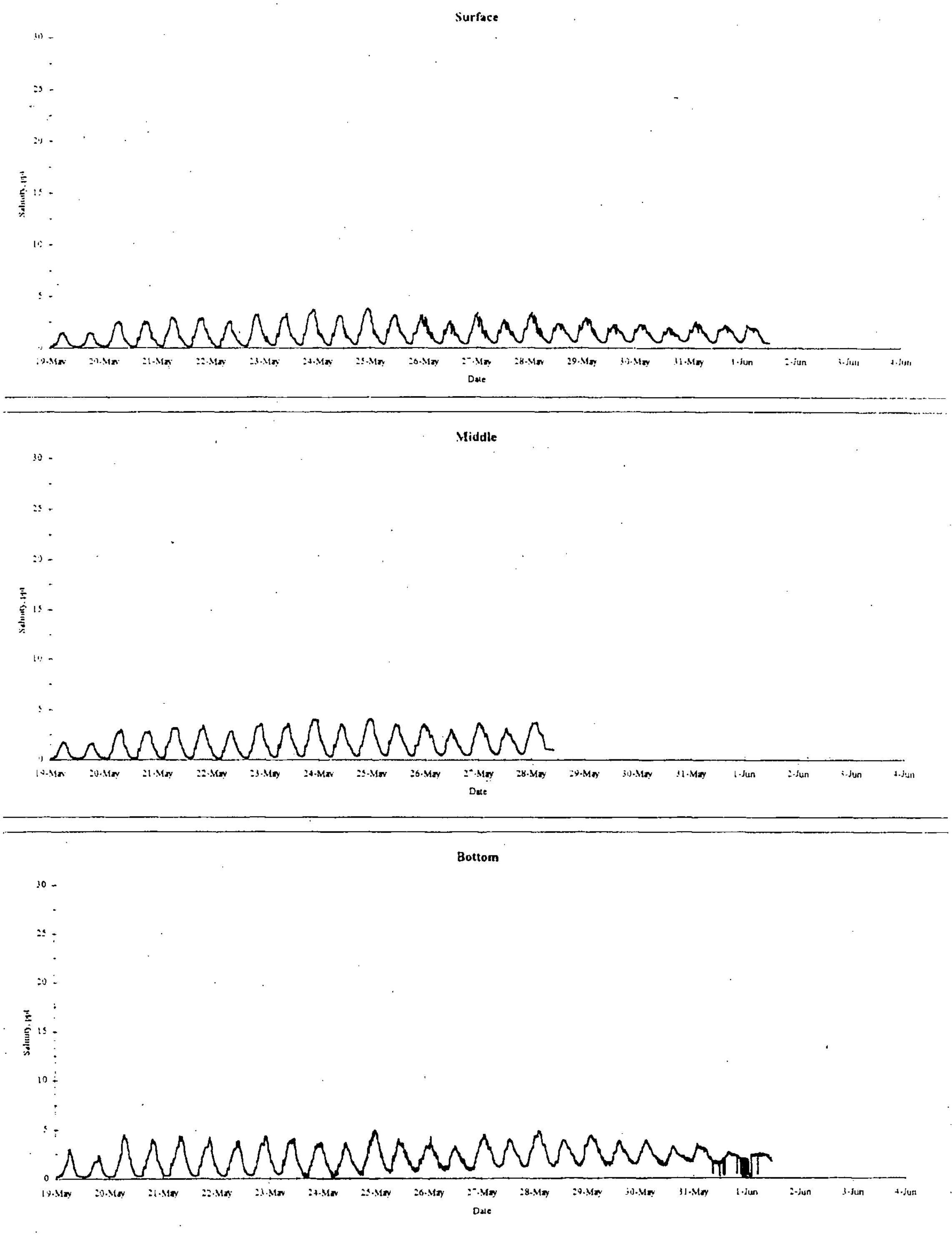
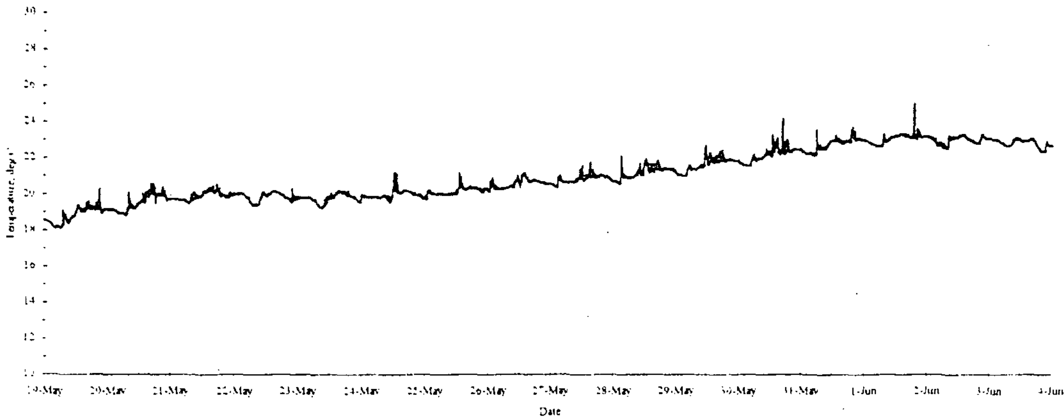


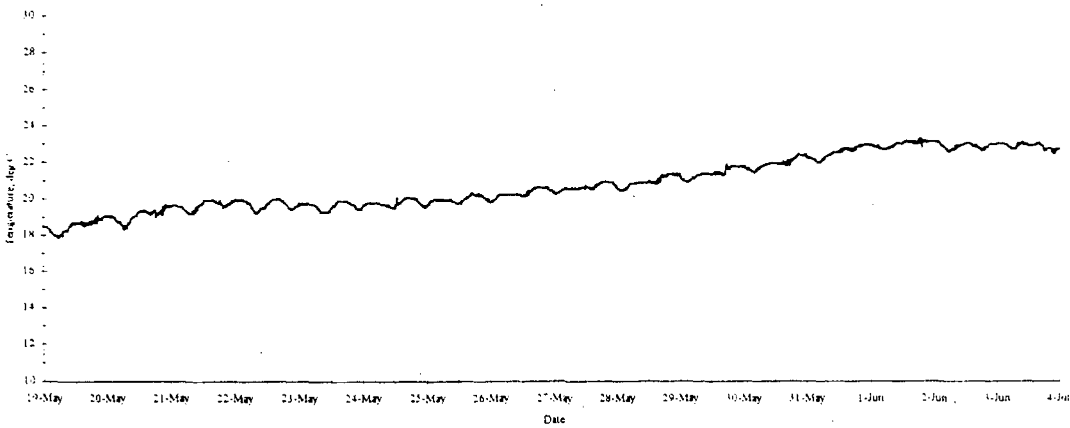
FIGURE 10-144

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-5

Surface



Middle



Bottom

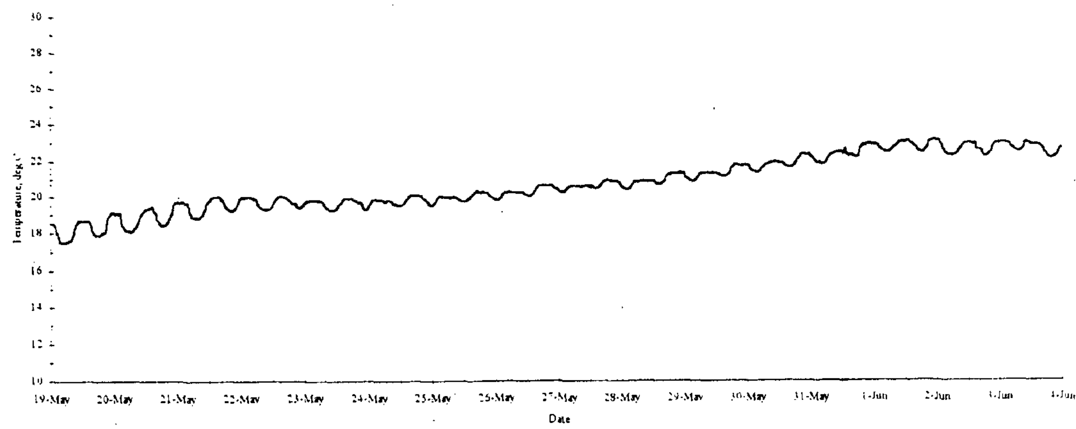


FIGURE 10-145

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-5

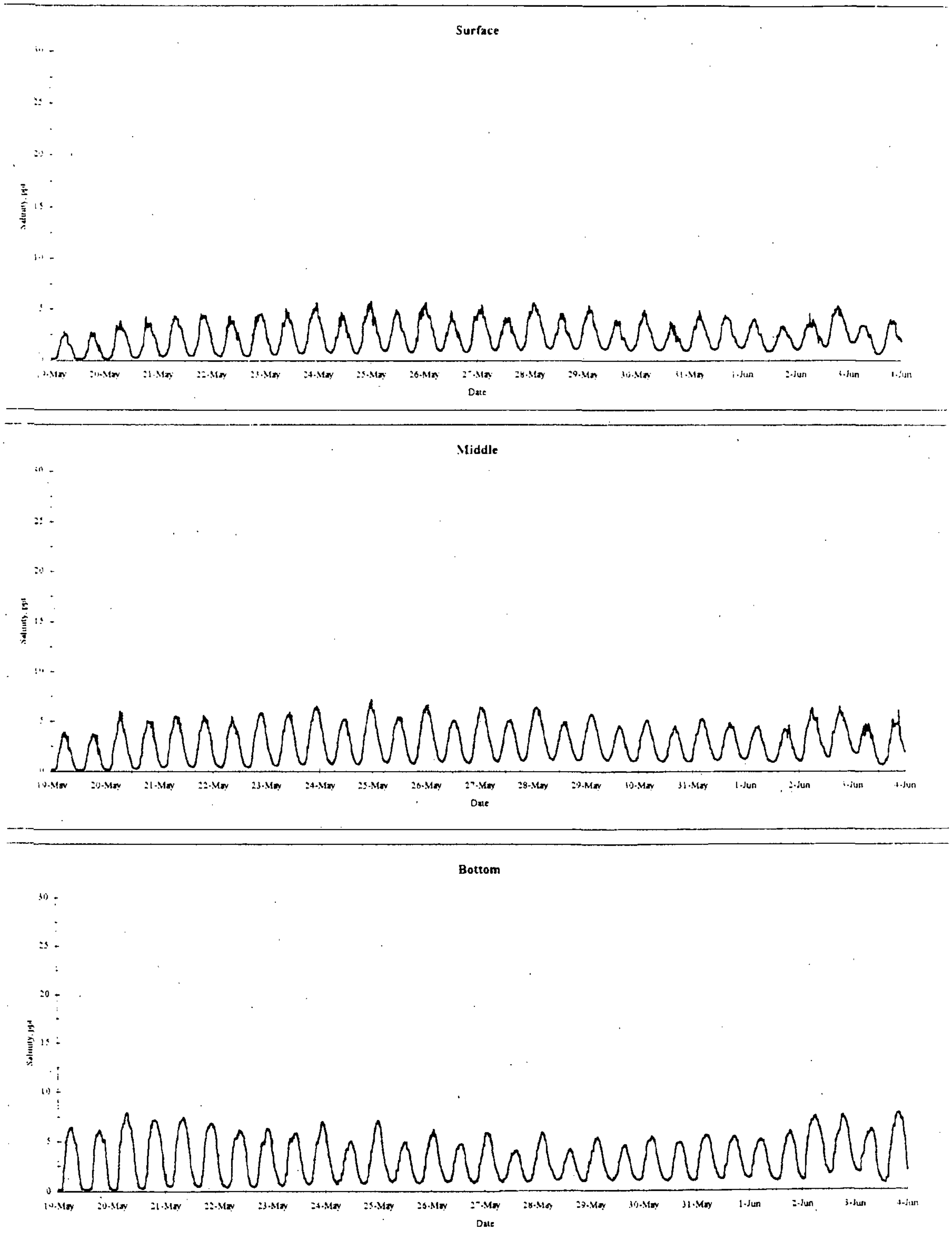
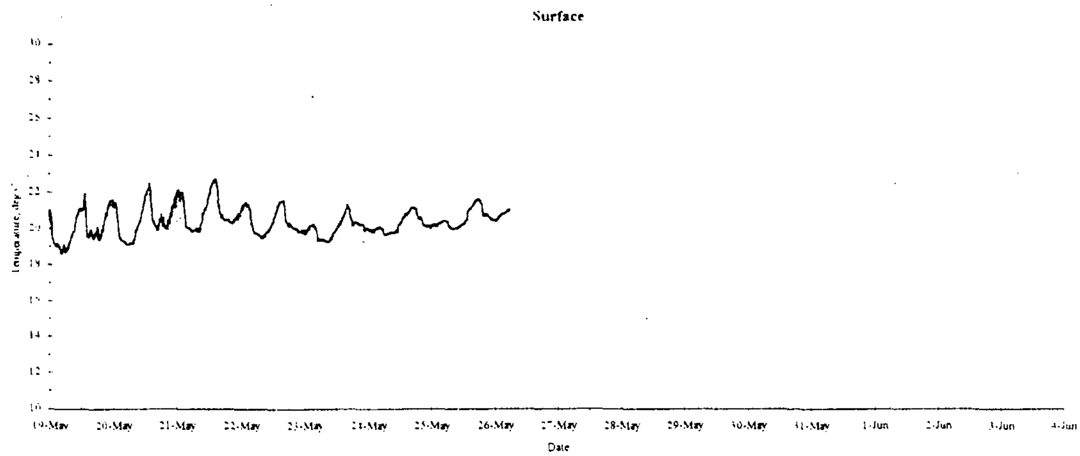


FIGURE 10-146

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-6



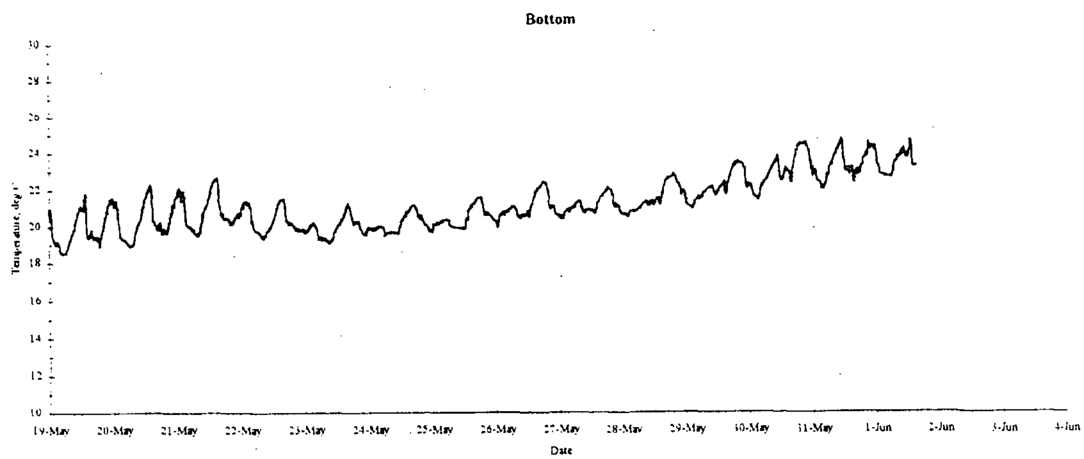
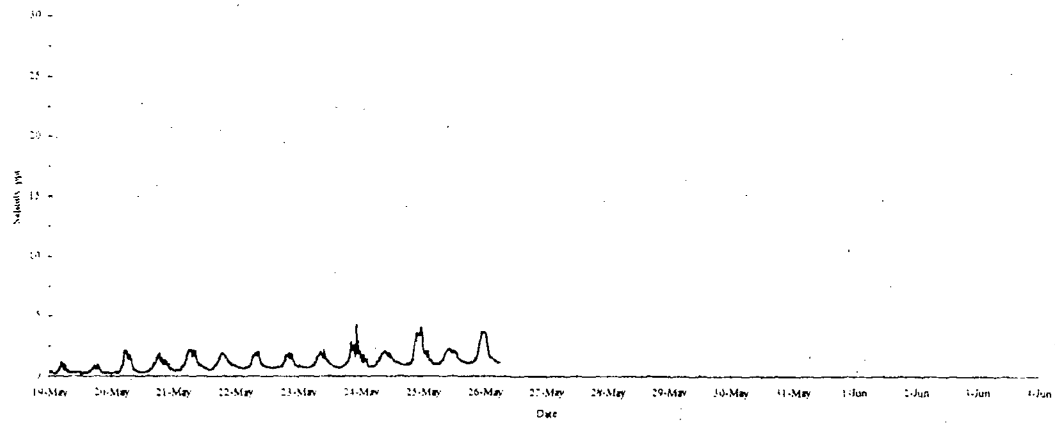


FIGURE 10-147

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-6

Surface



Bottom

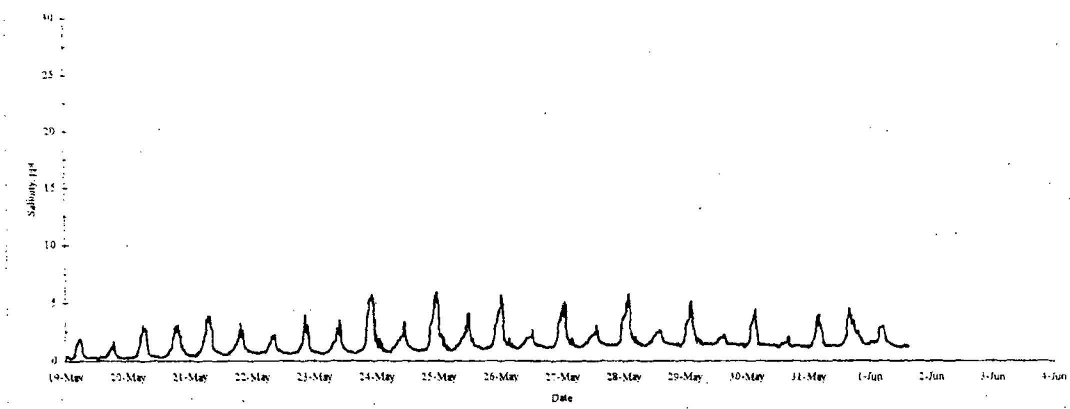
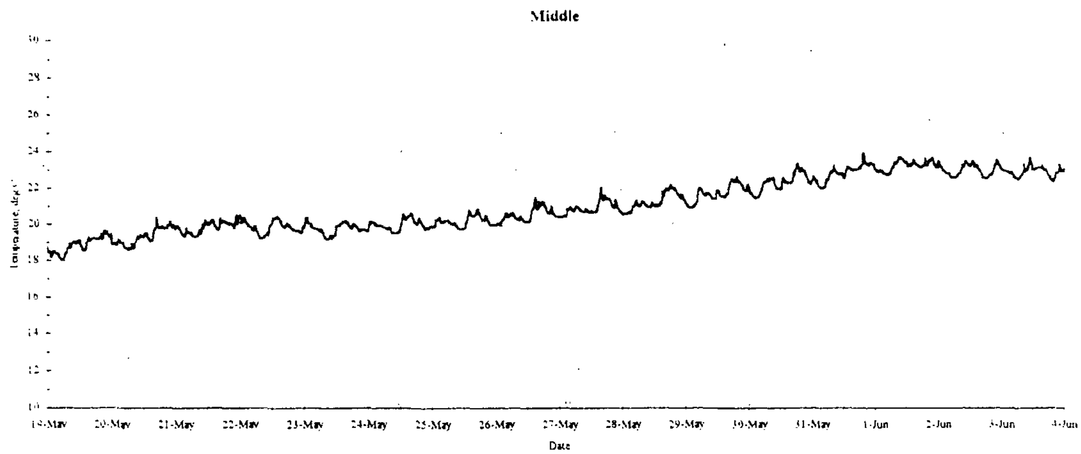


FIGURE 10-148

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-7



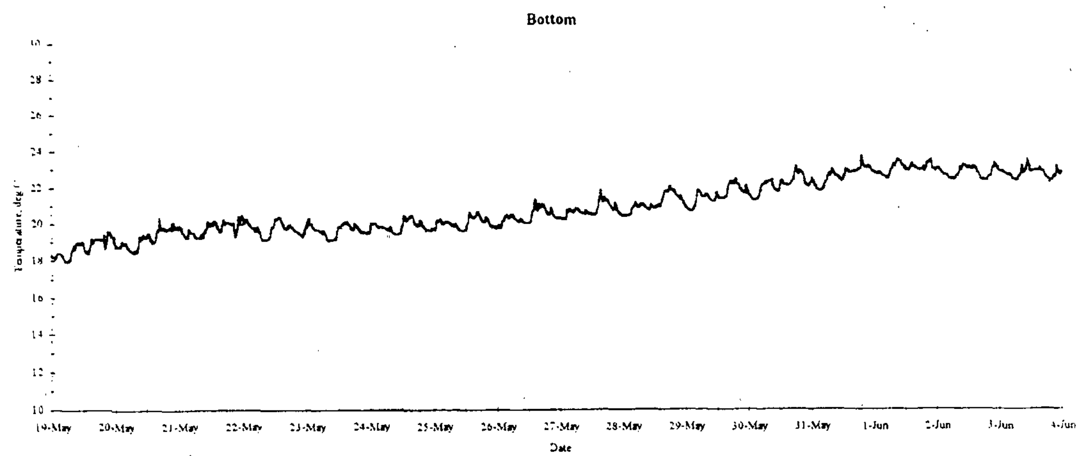
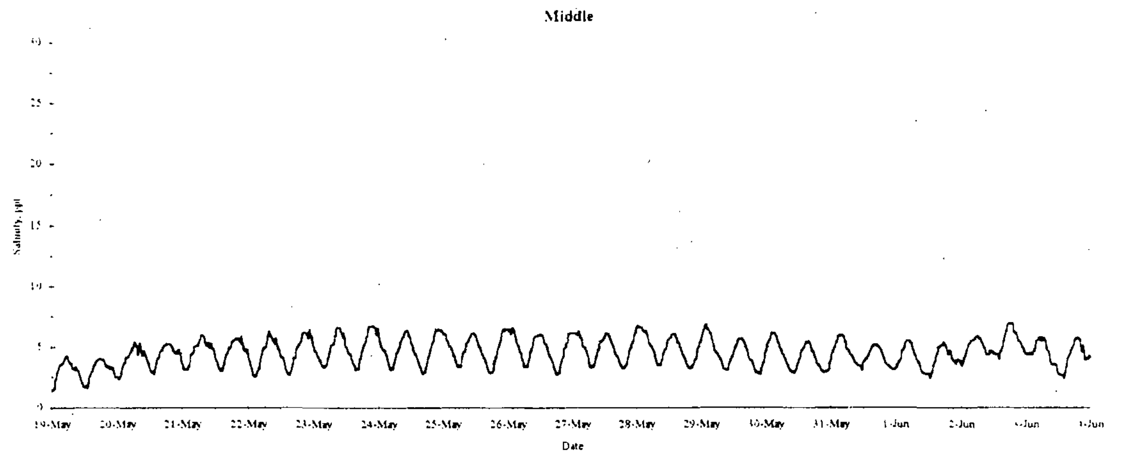


FIGURE 10-149

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-7



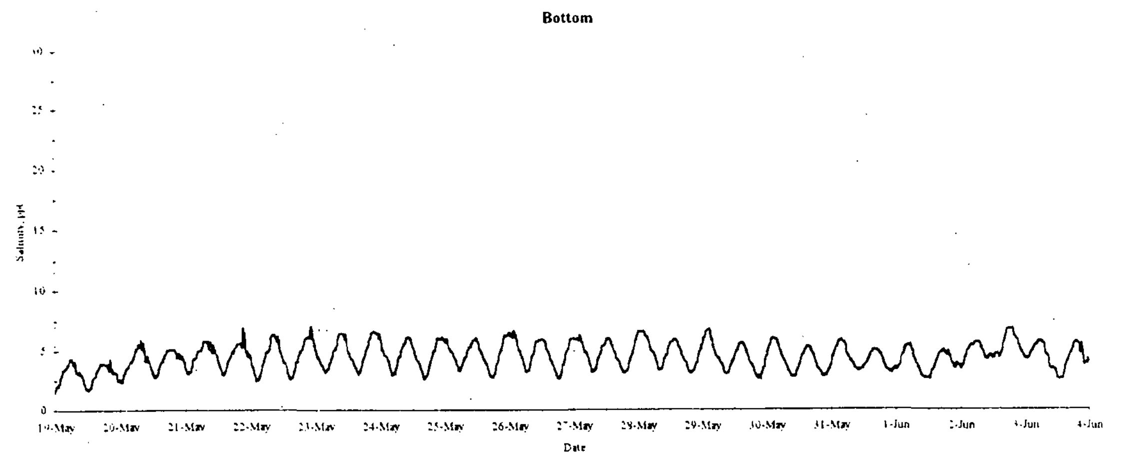


FIGURE 10-150

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9

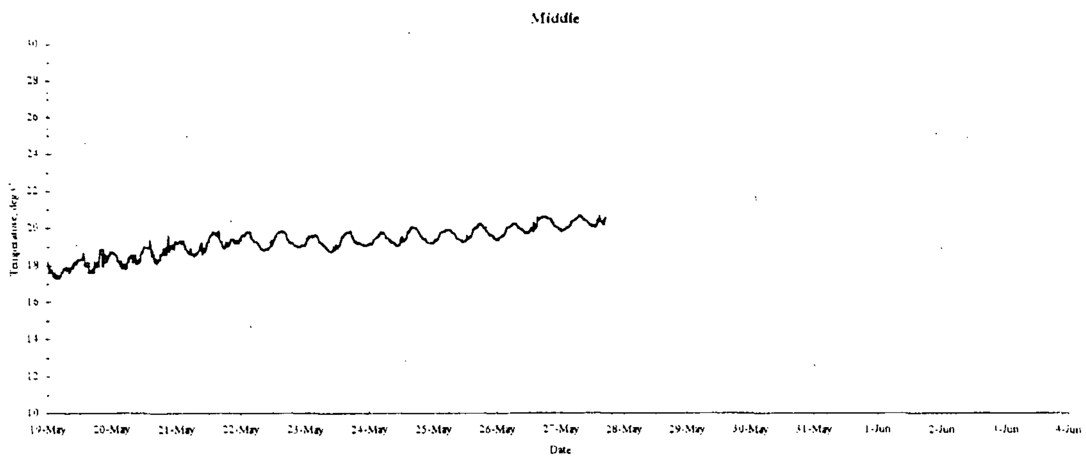


FIGURE 10-151

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-9

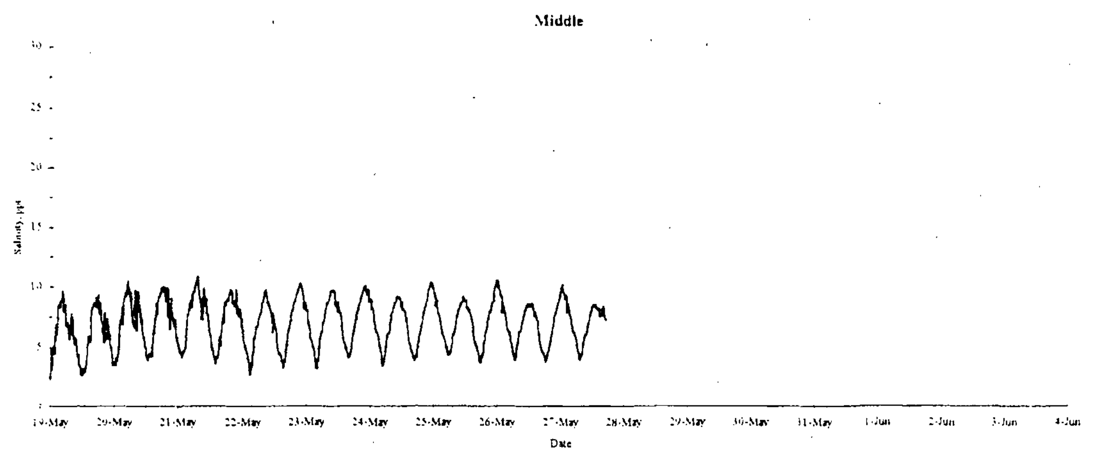


FIGURE 10-152

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-10

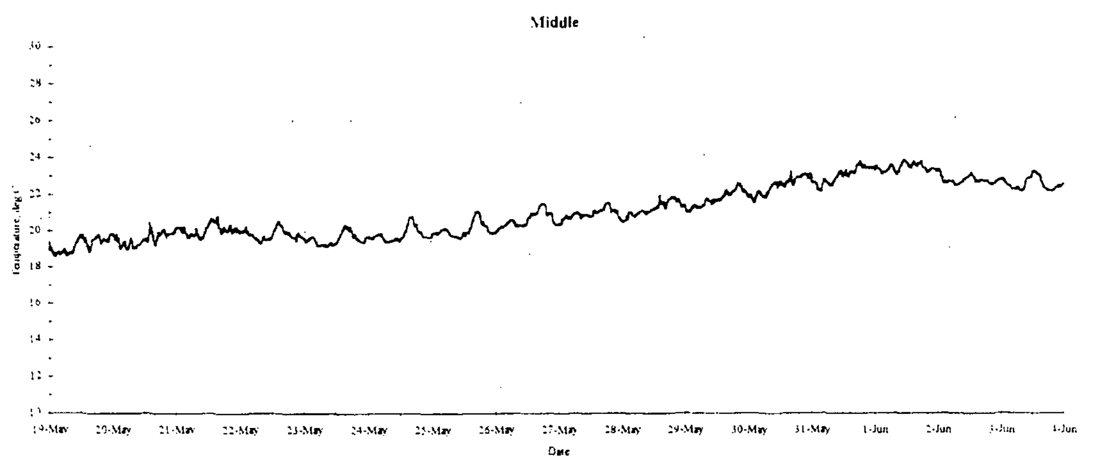


FIGURE 10-153

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-10

Middle

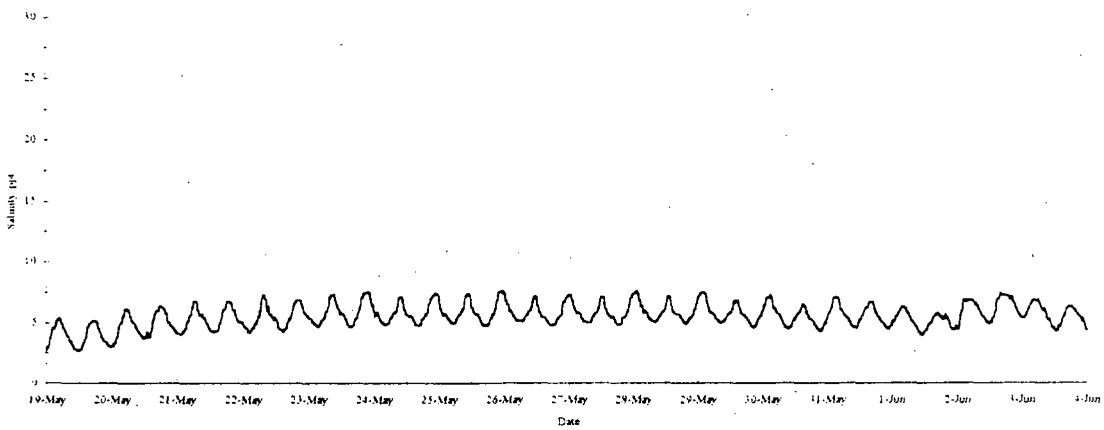
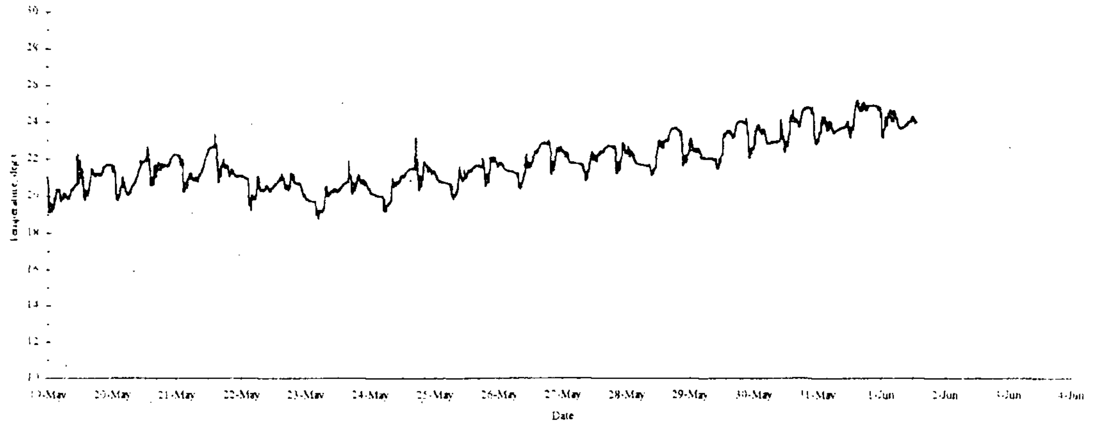


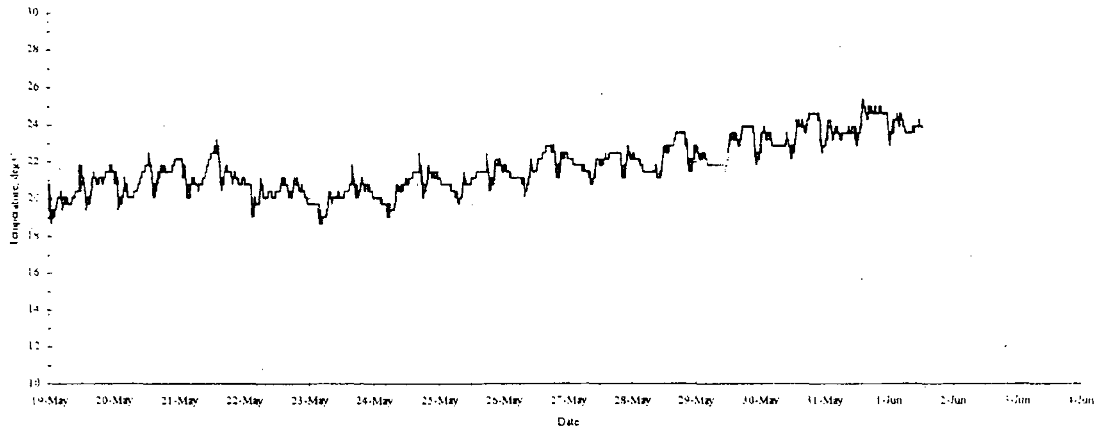
FIGURE 10-154

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
ALLOWAYCRK

Surface



Middle



Bottom

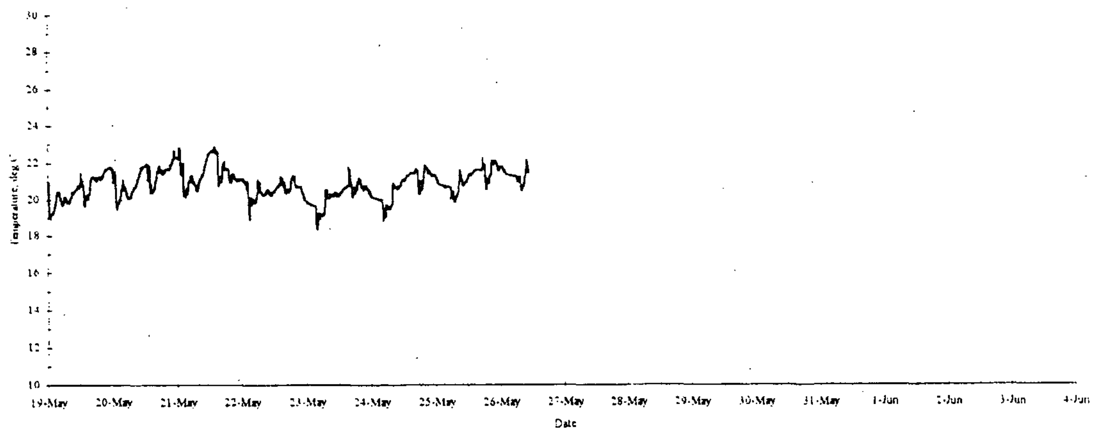
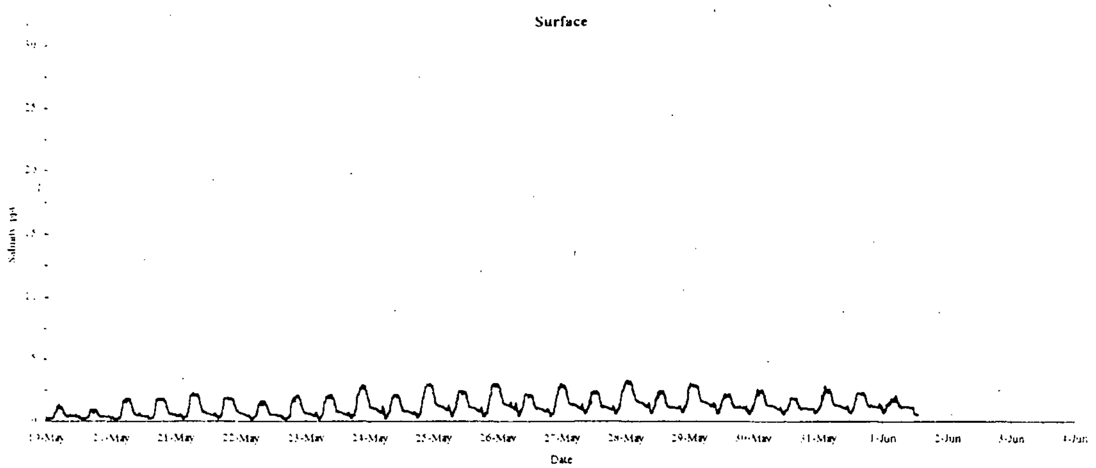


FIGURE 10-155

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
ALLOWAYCRK



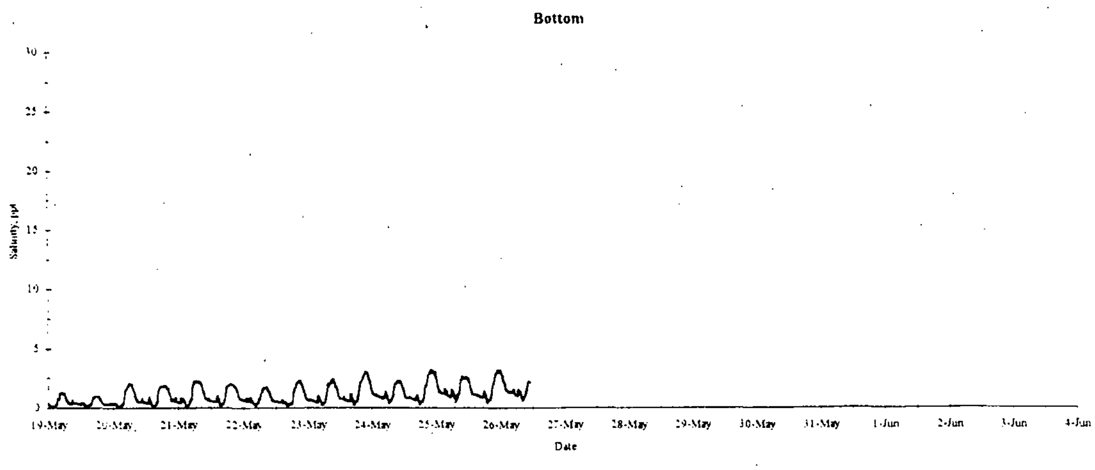
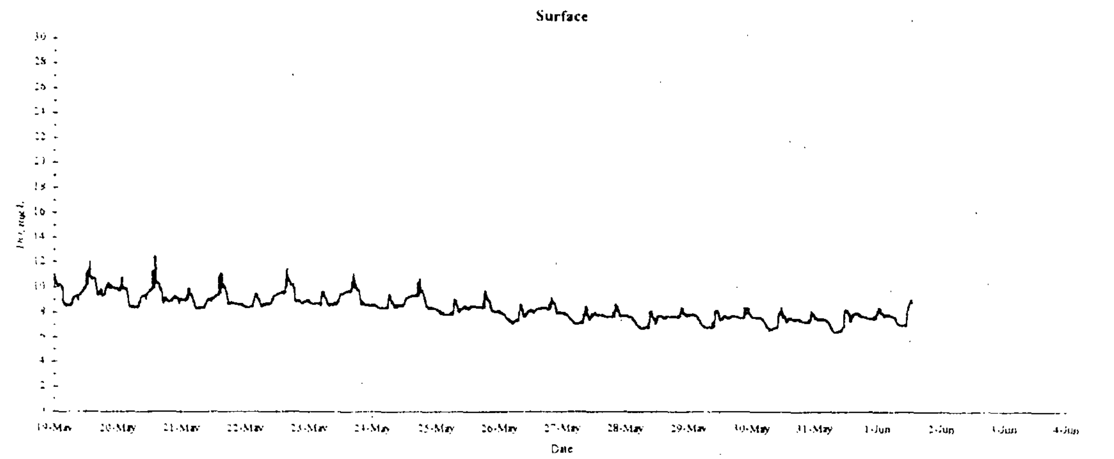
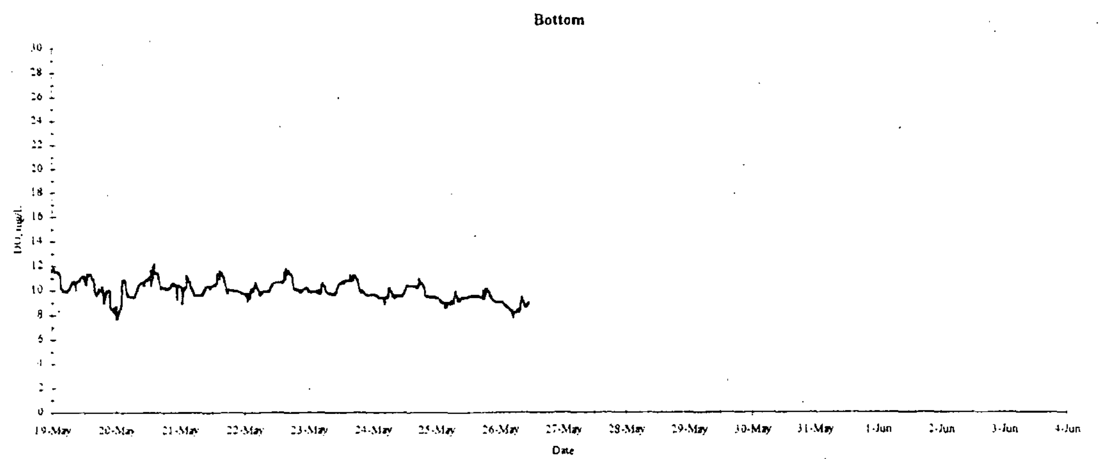


FIGURE 10-156

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Dissolved Oxygen Temporal Profiles (Moorings)
ALLOWAYCRK

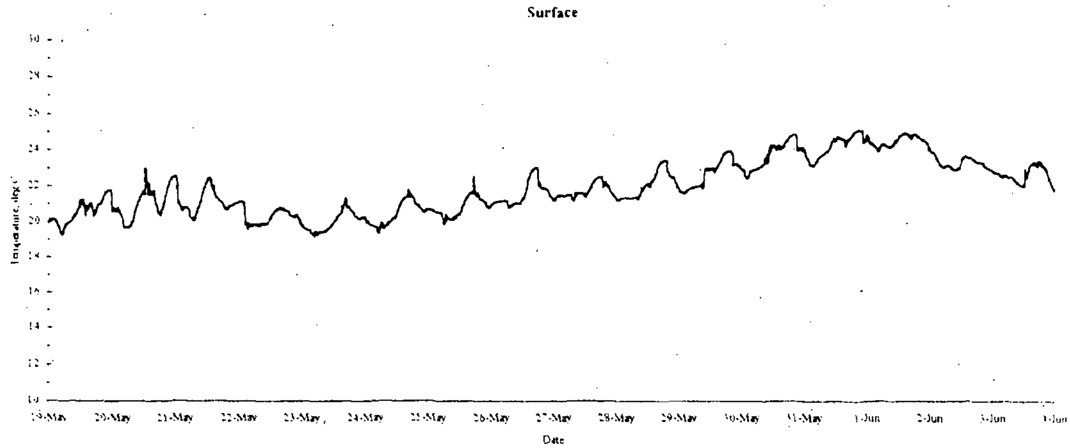


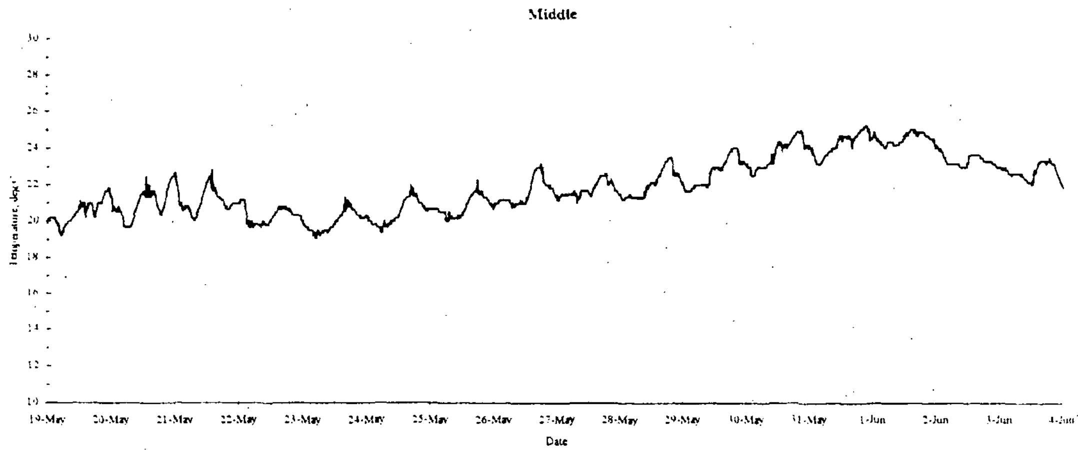


See Table 10-10 for quality control results

FIGURE 10-157

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
HOPECREEK





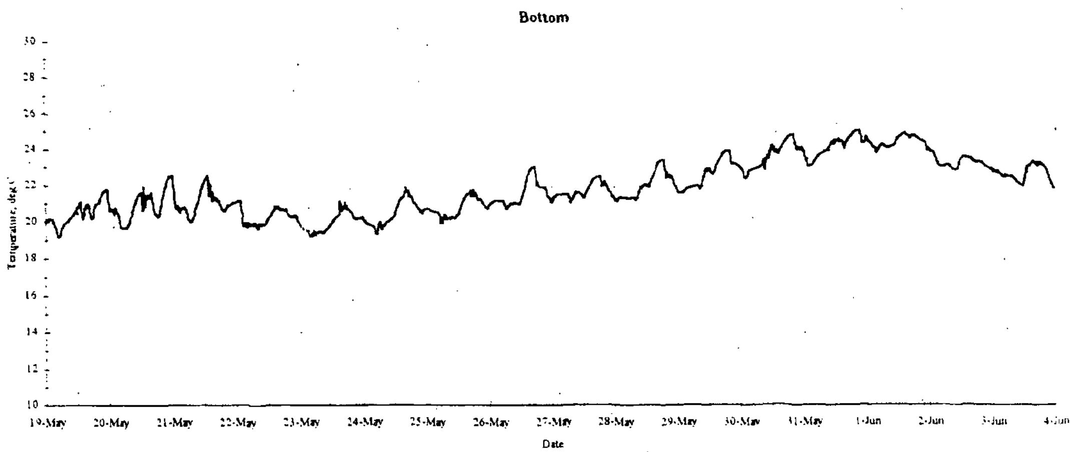
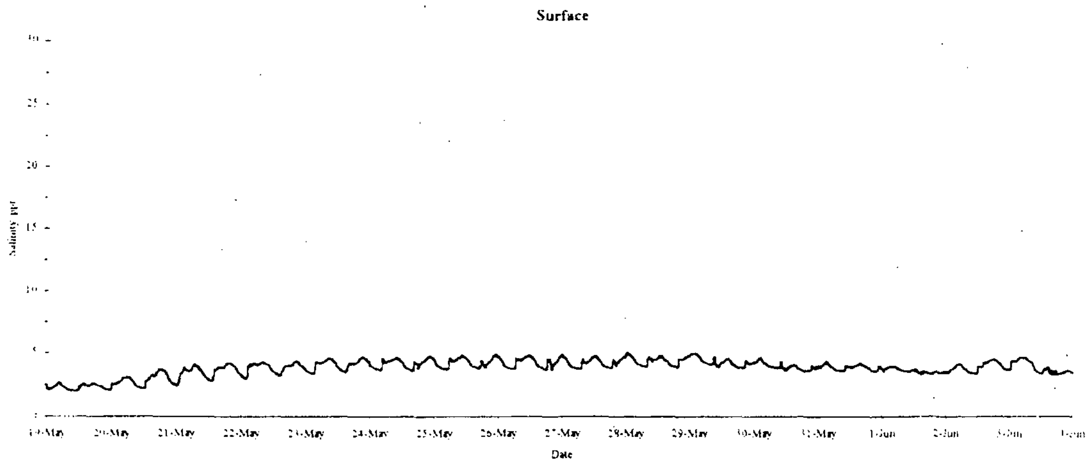


FIGURE 10-158

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
HOPECREEK



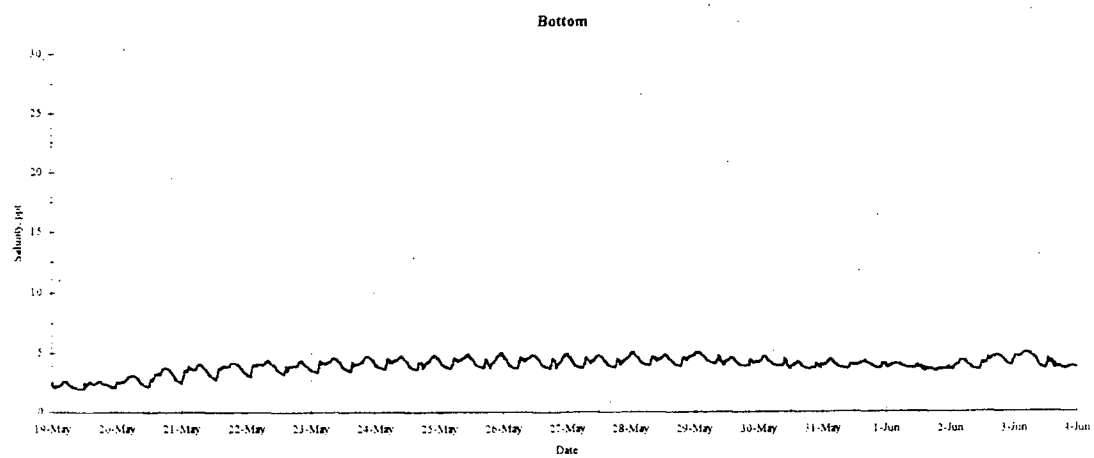
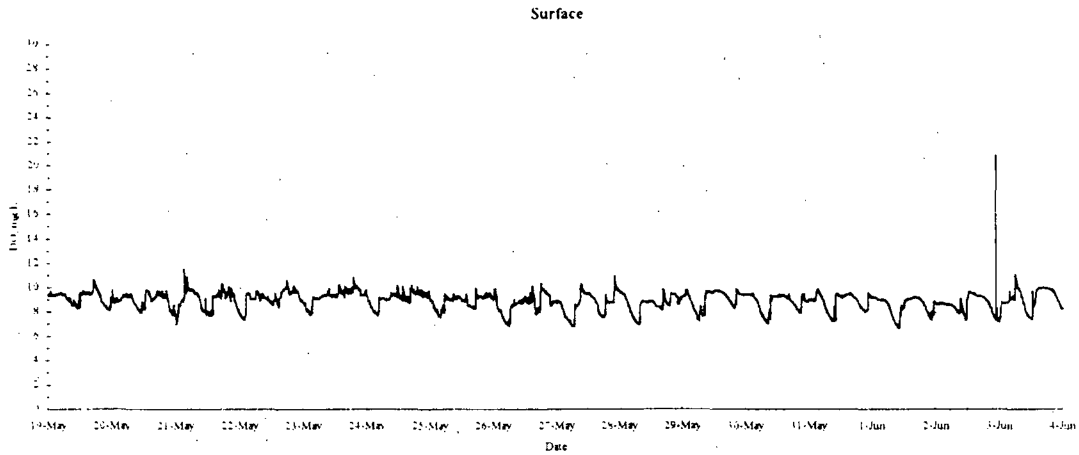
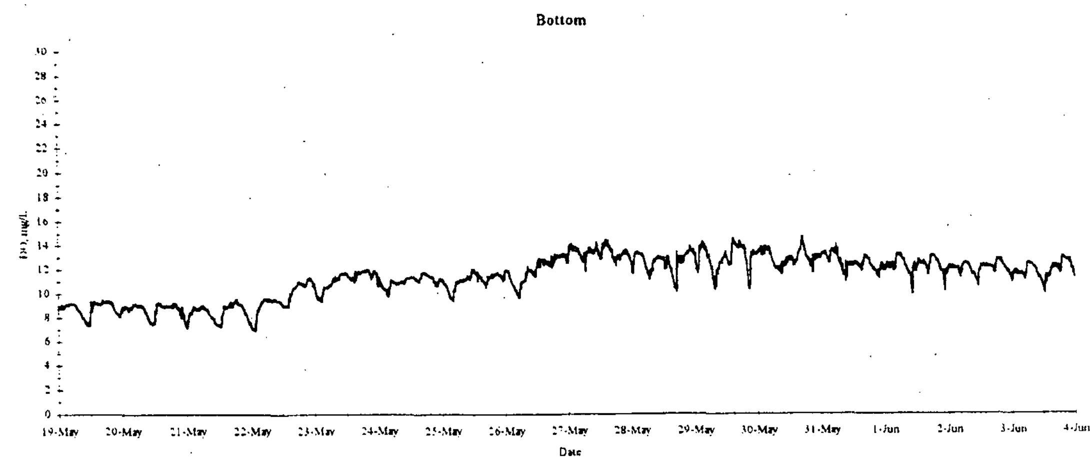


FIGURE 10-159

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Dissolved Oxygen Temporal Profiles (Moorings)
HOPECREEK

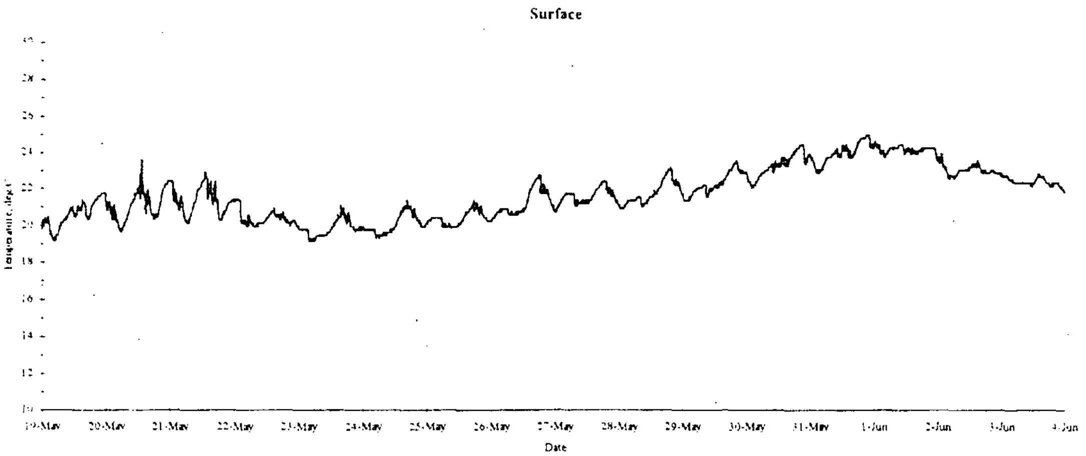


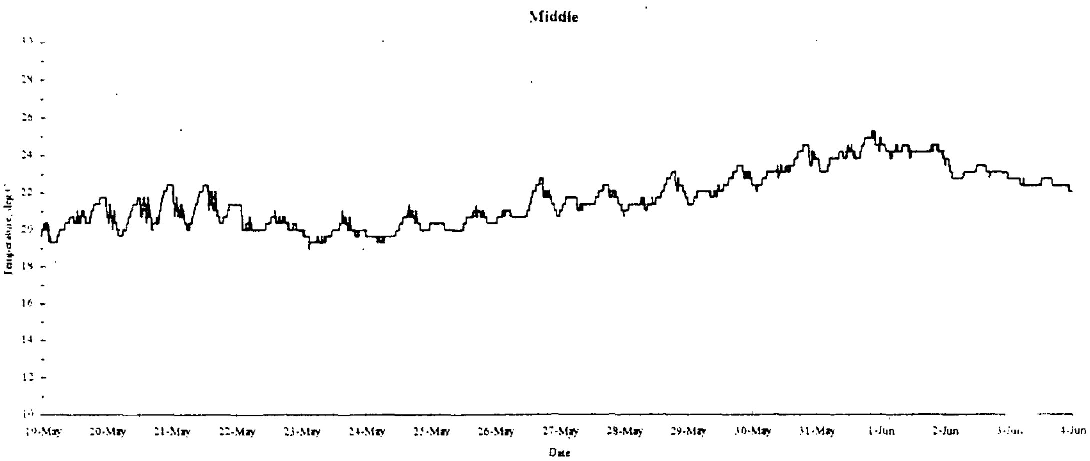


See Table 10-10 for quality control results

FIGURE 10-160

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
MADHORSECRK





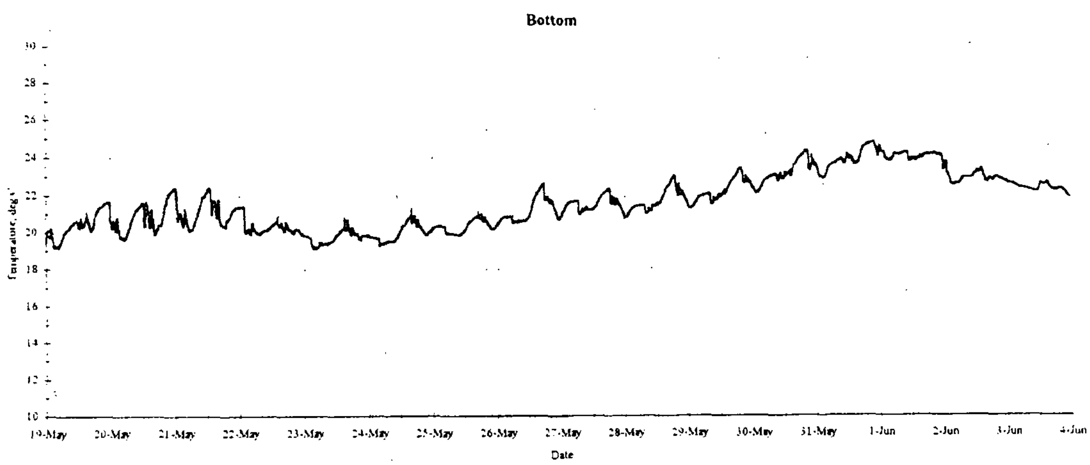


FIGURE 10-161

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
MADHORSECRK

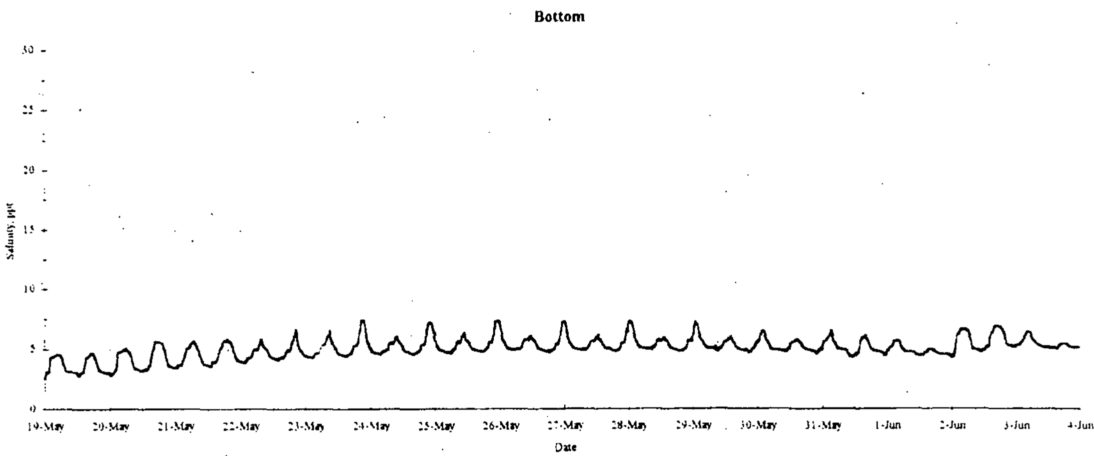
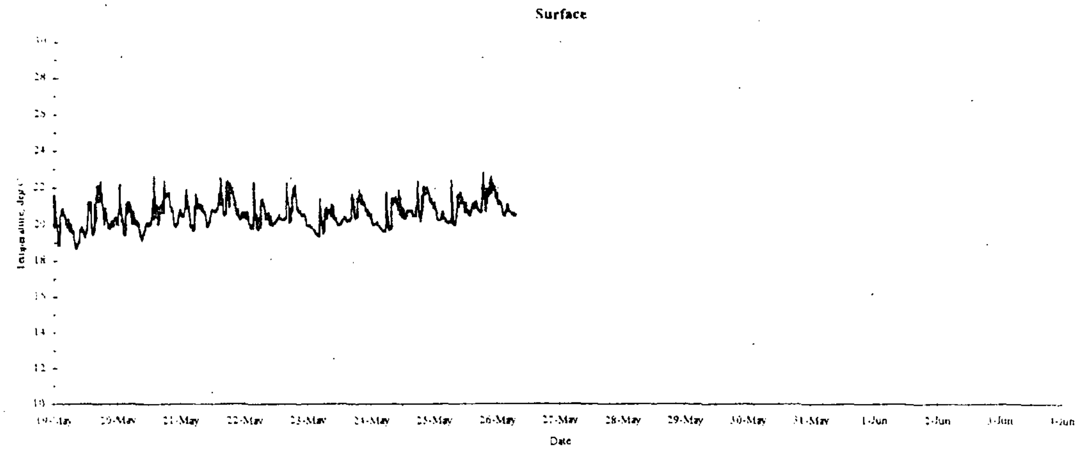
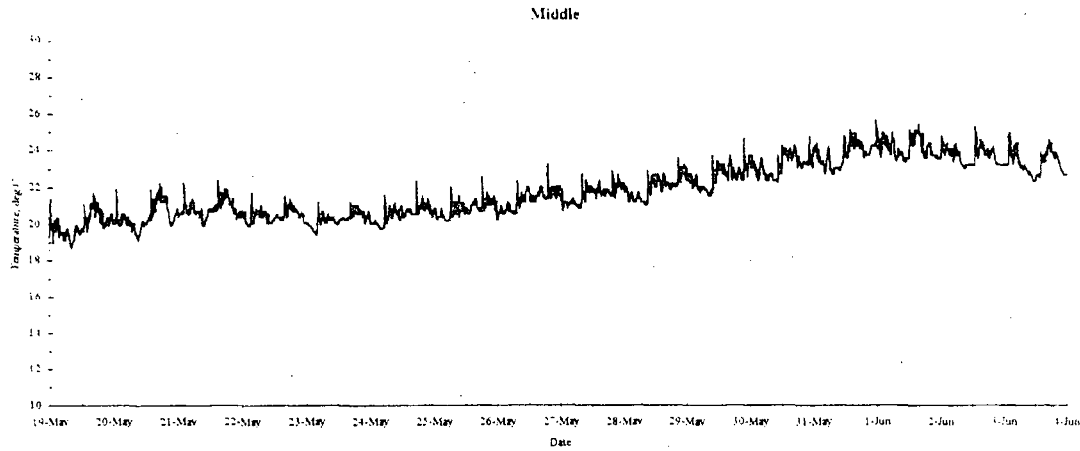


FIGURE 10-162

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-E





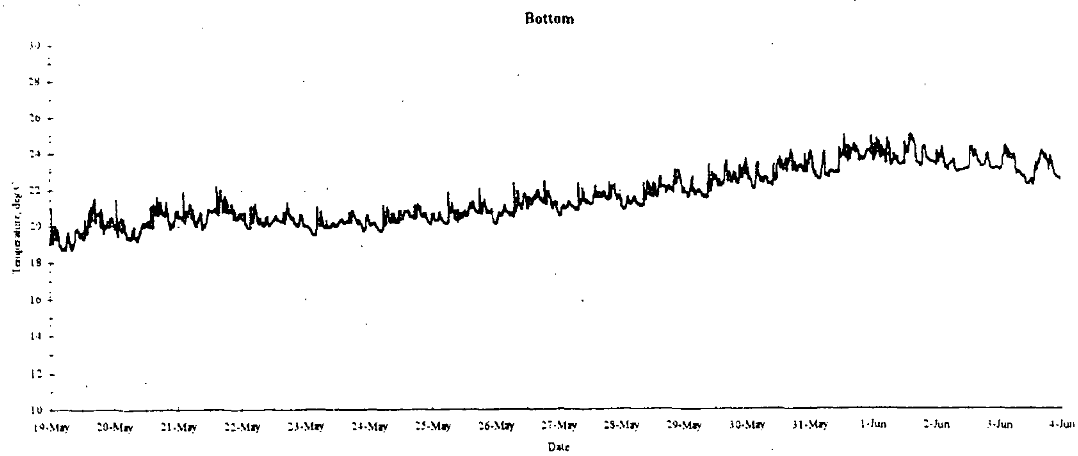
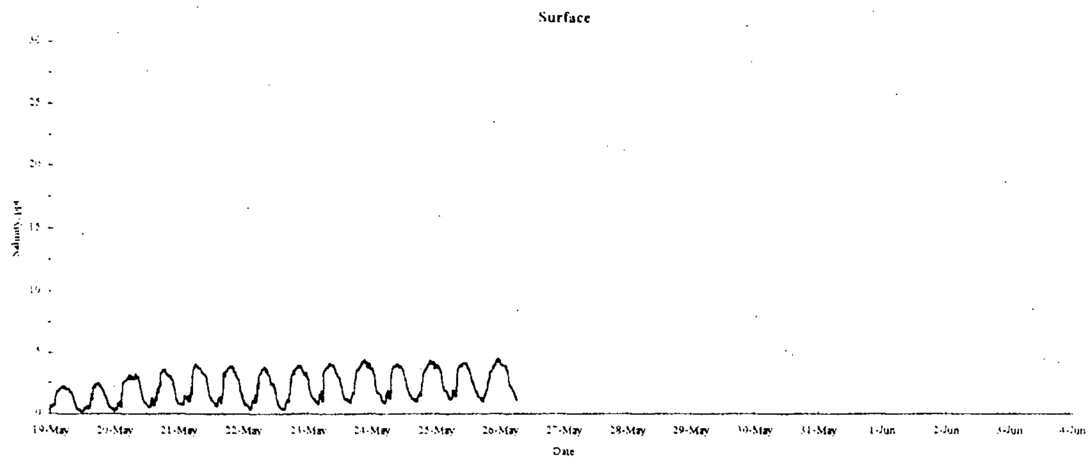


FIGURE 10-163

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-E



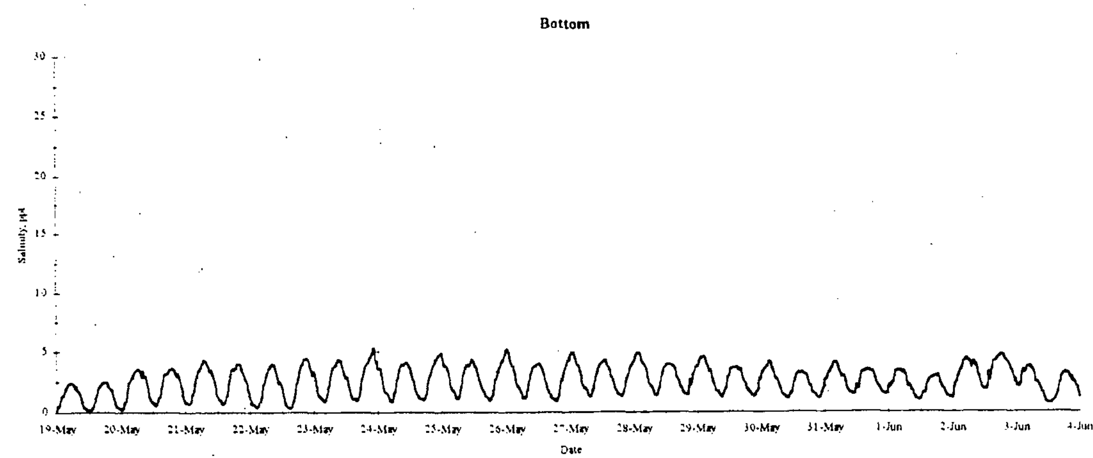
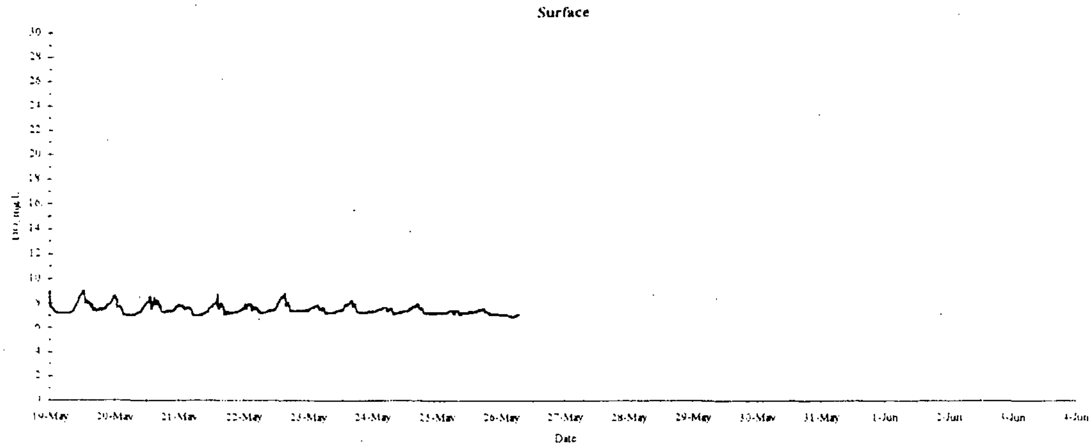
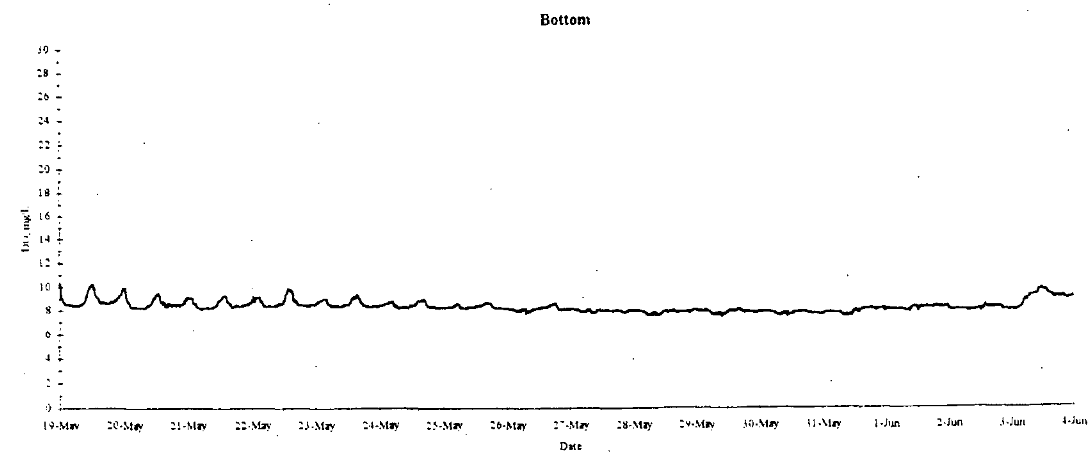


FIGURE 10-164

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-E

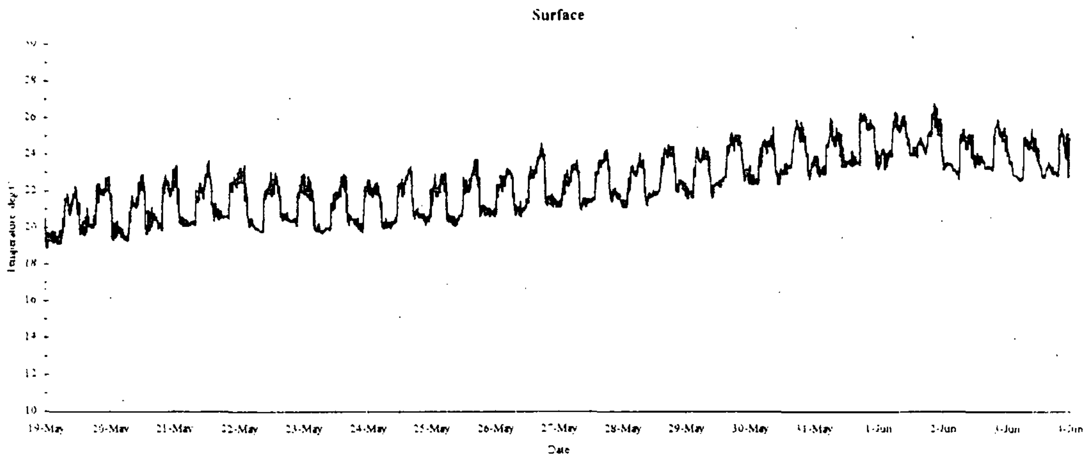


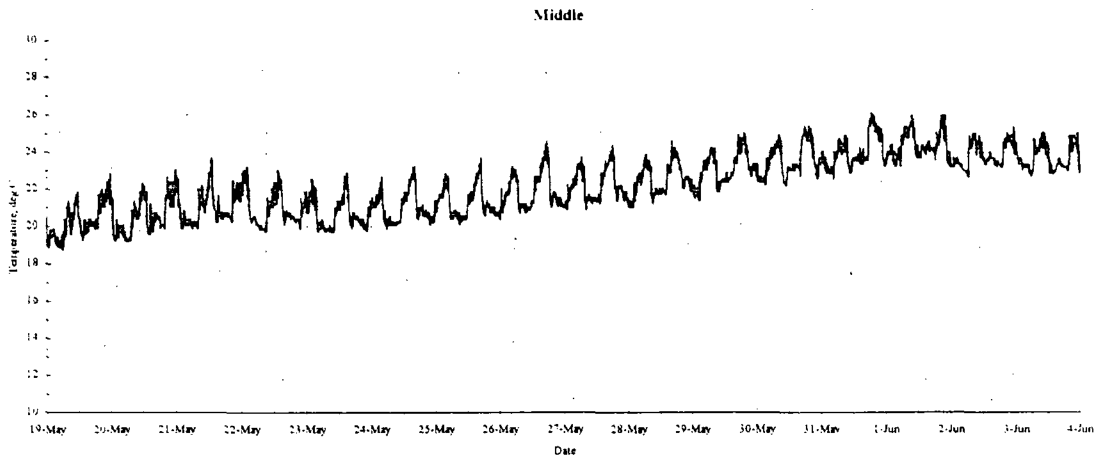


See Table 10-10 for quality control results

FIGURE 10-165

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-H





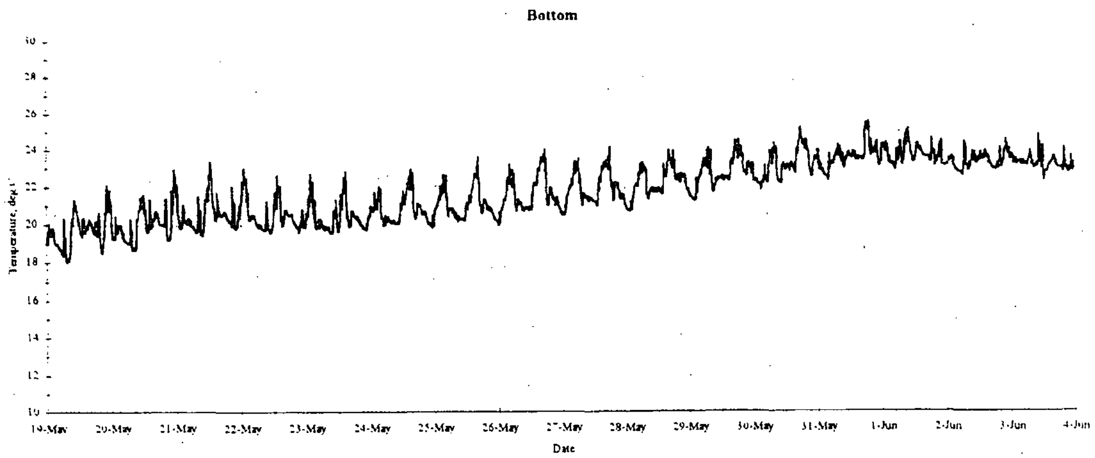
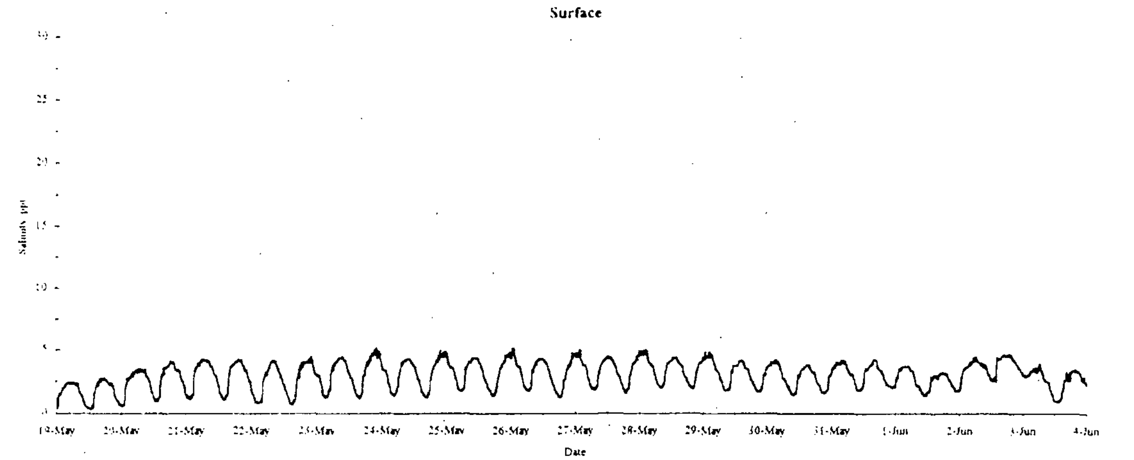


FIGURE 10-166

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-H



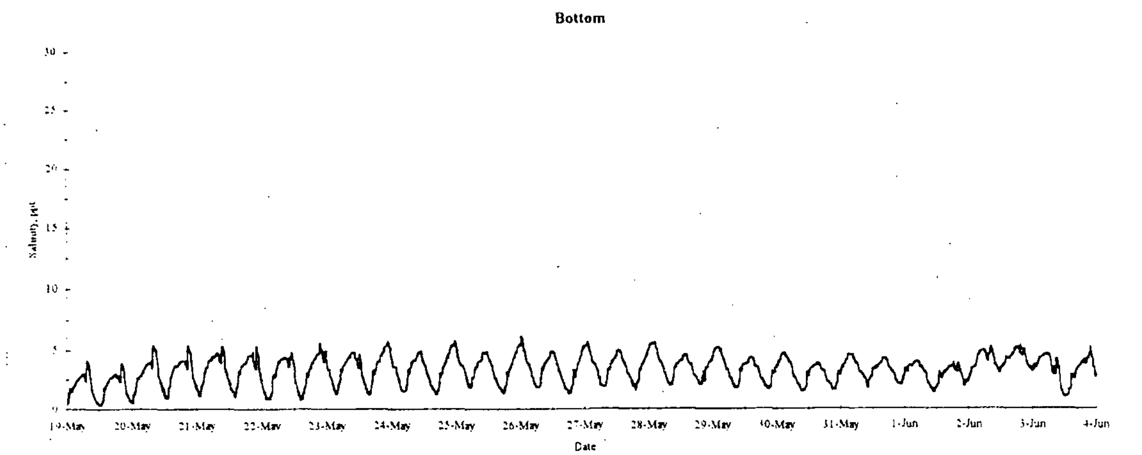
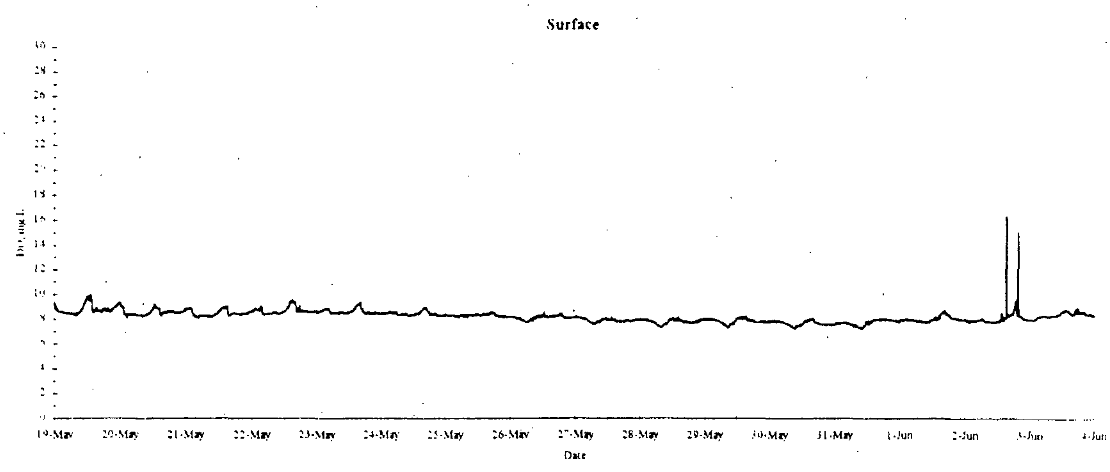
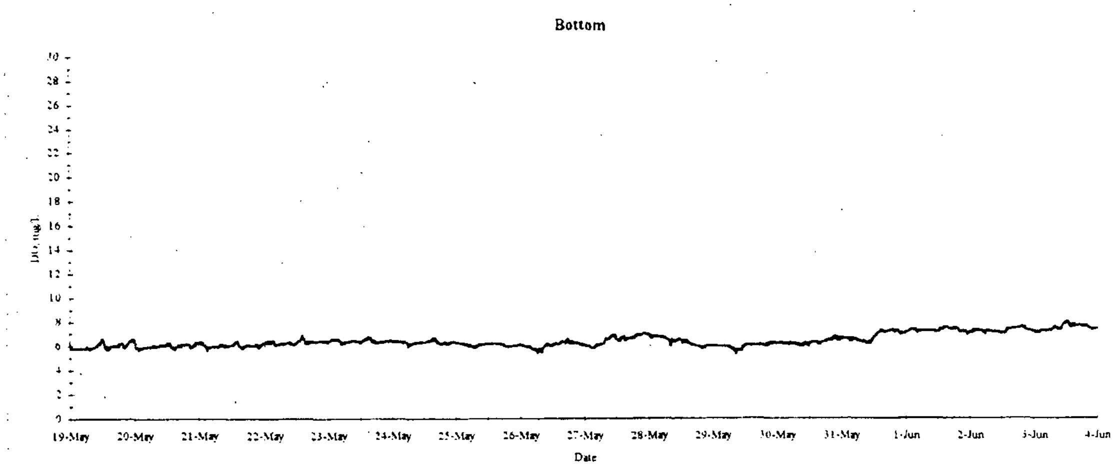


FIGURE 10-167

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-H

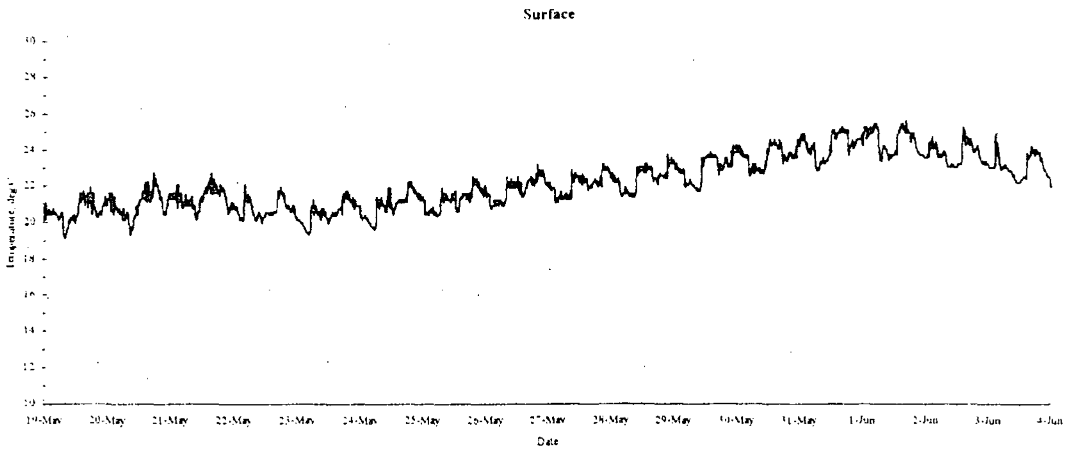


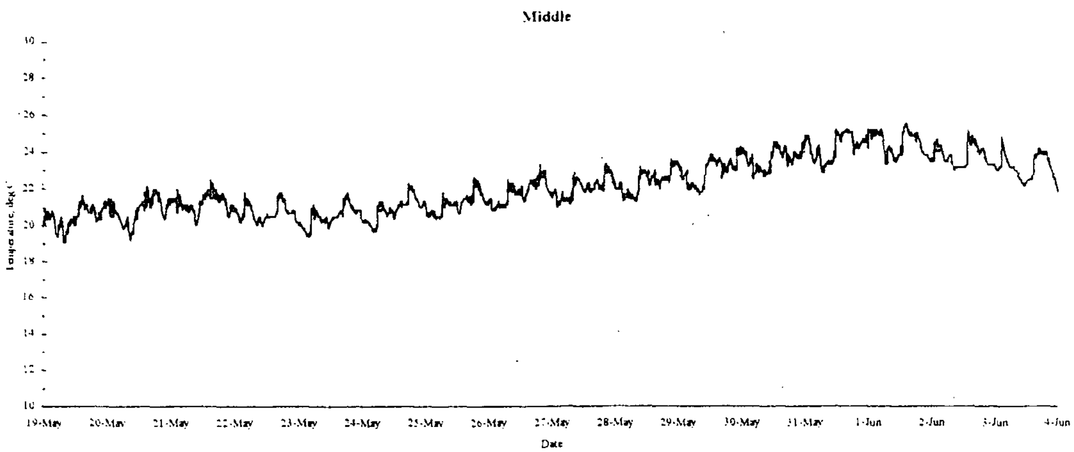


See Table 10-10 for quality control results

FIGURE 10-168

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-I





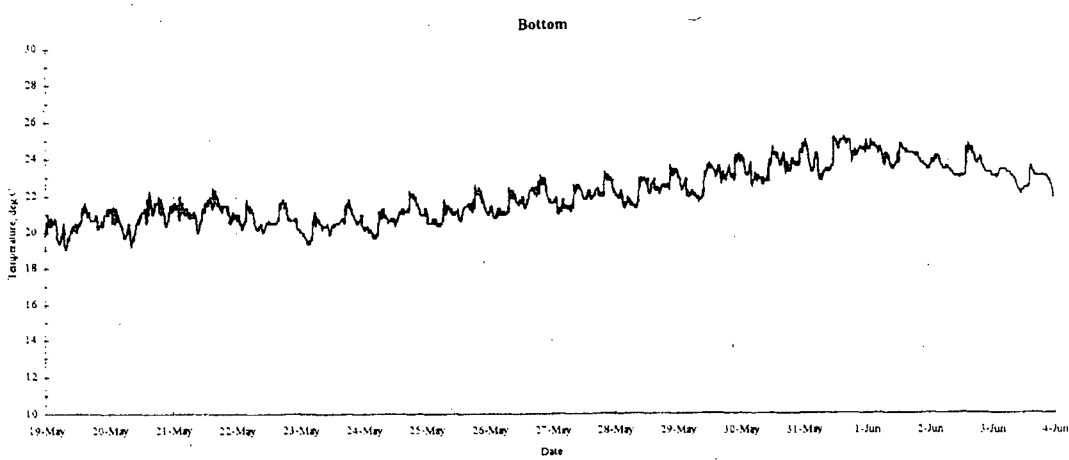
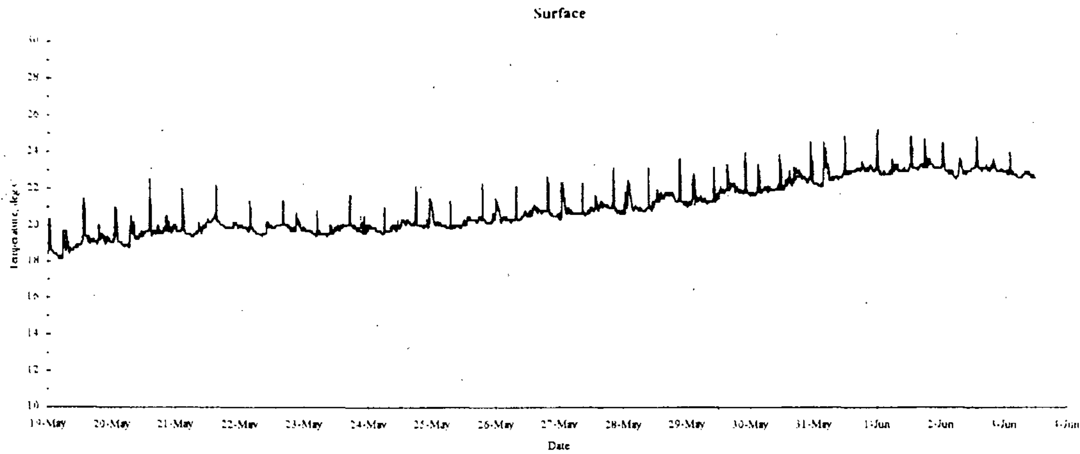
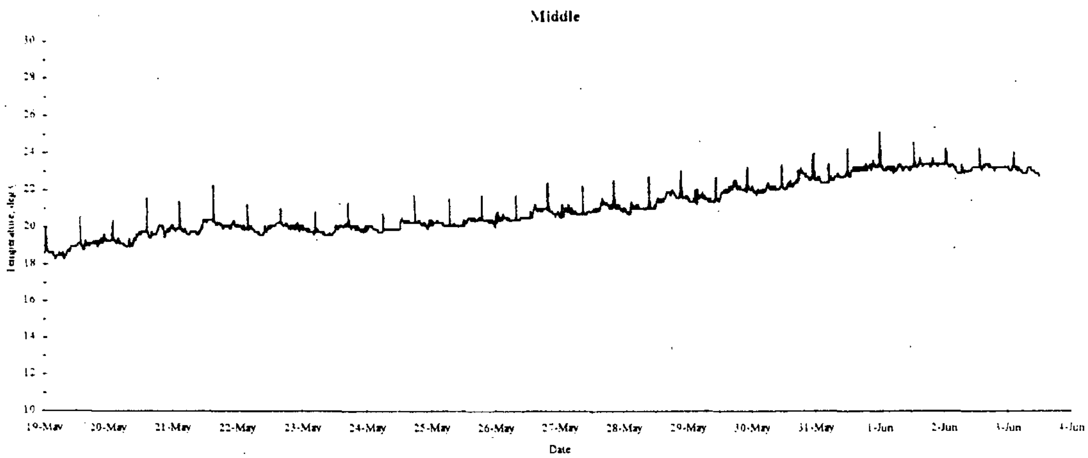


FIGURE 10-169

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-K





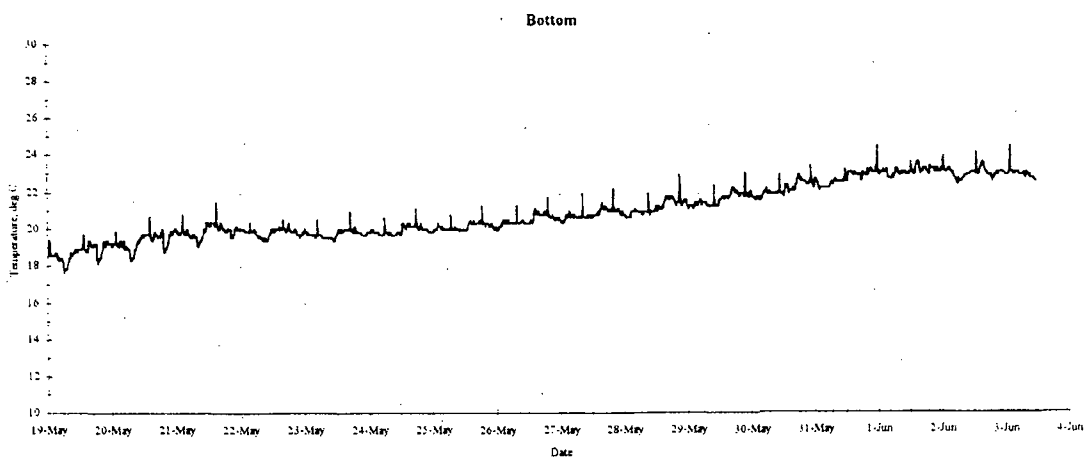
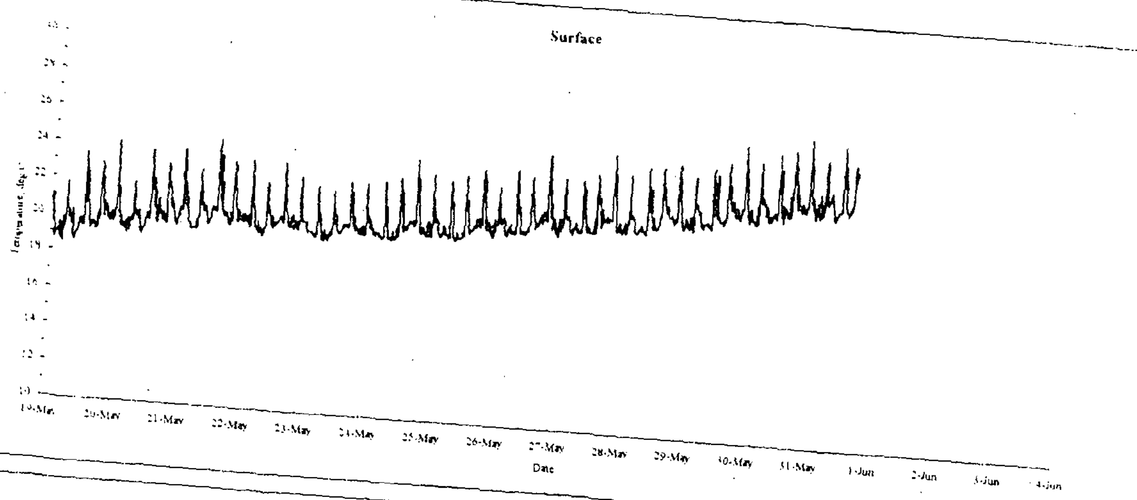


FIGURE 10-170

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998

Temperature Temporal Profiles (Moorings)

DELAWARE-V



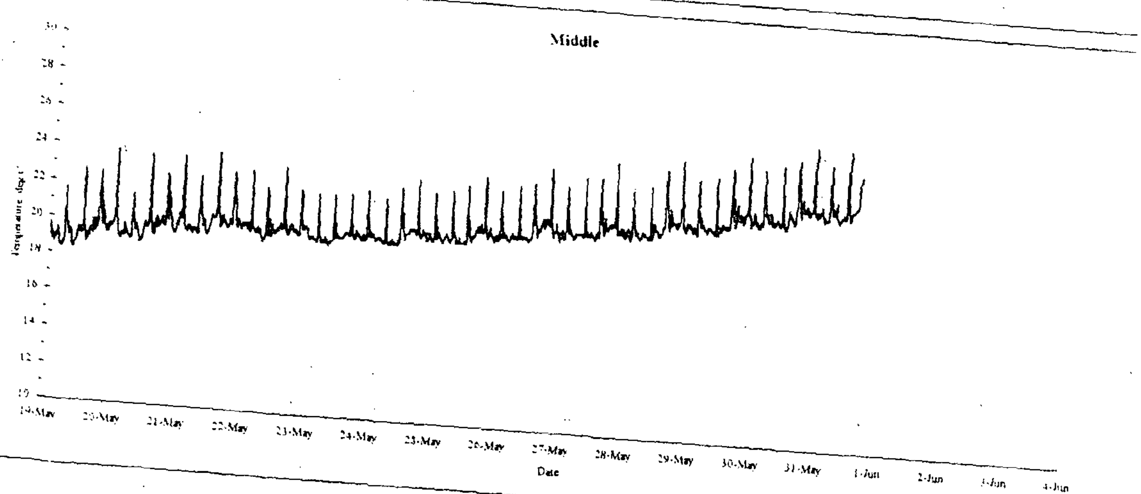
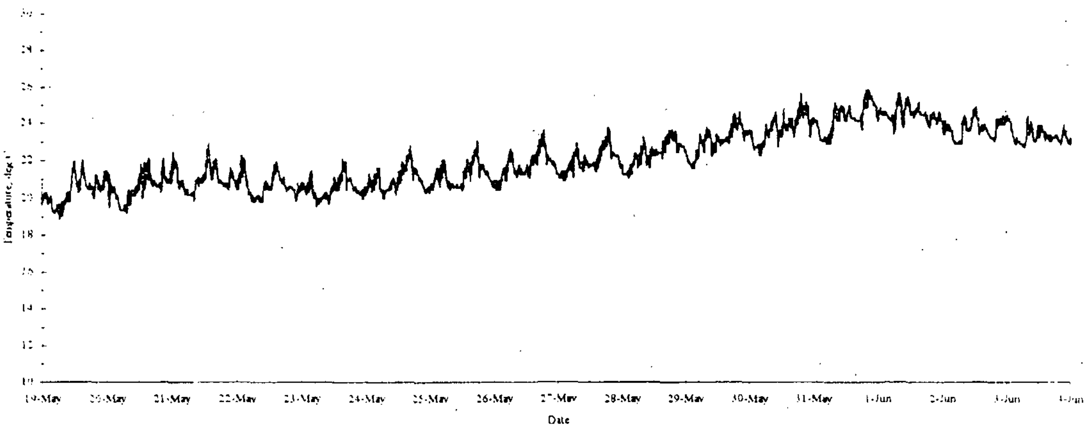


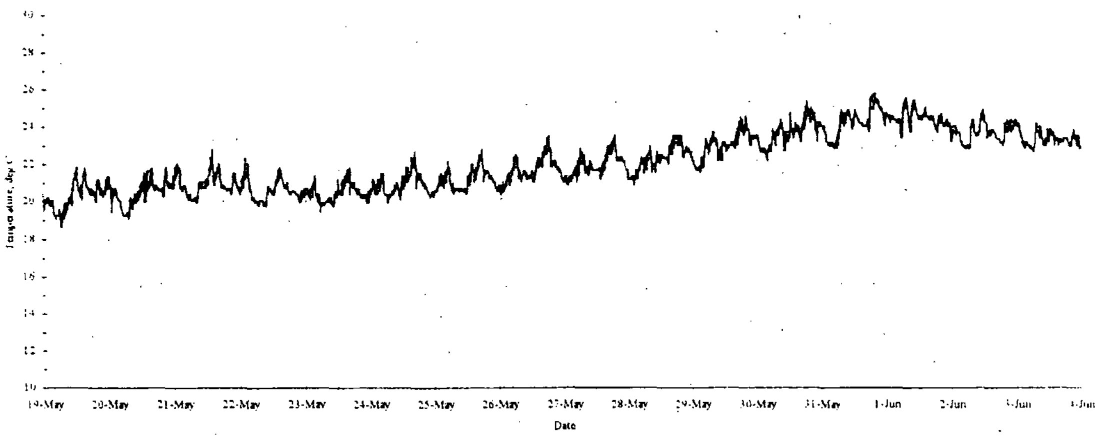
FIGURE 10-171

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-L

Surface



Middle



Bottom

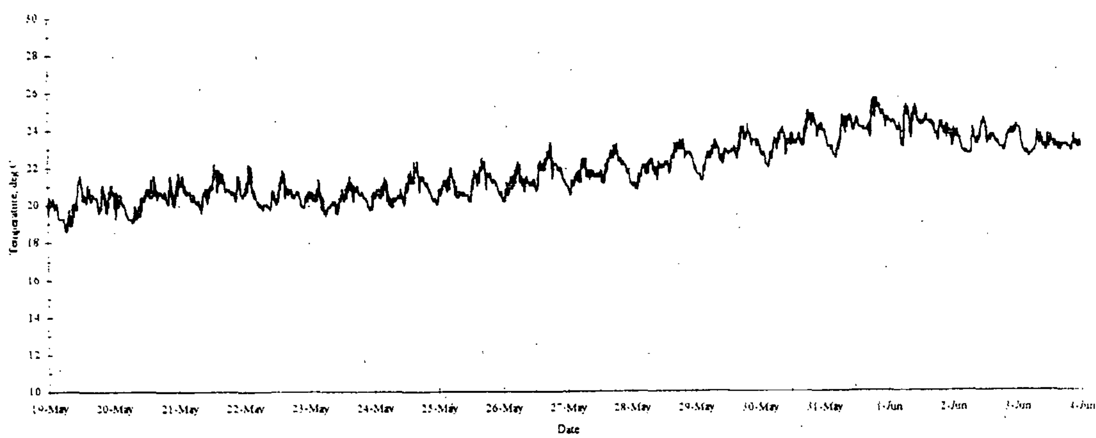
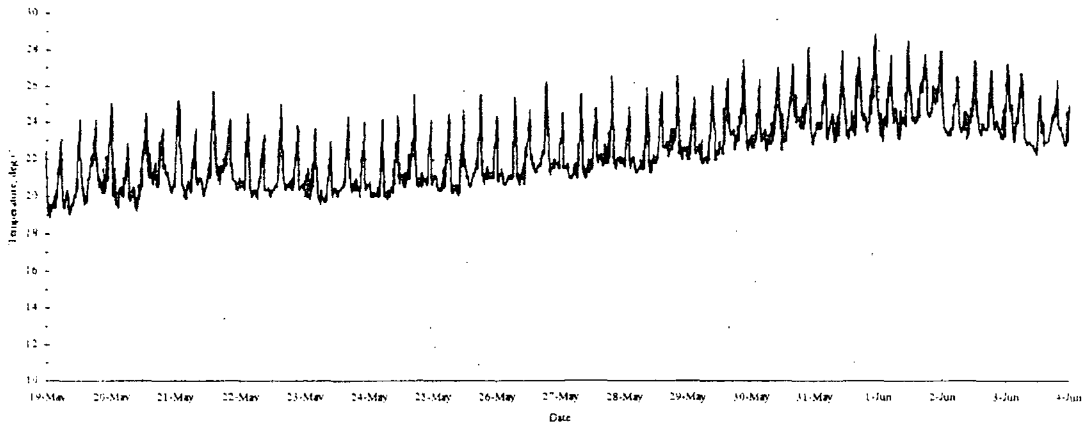


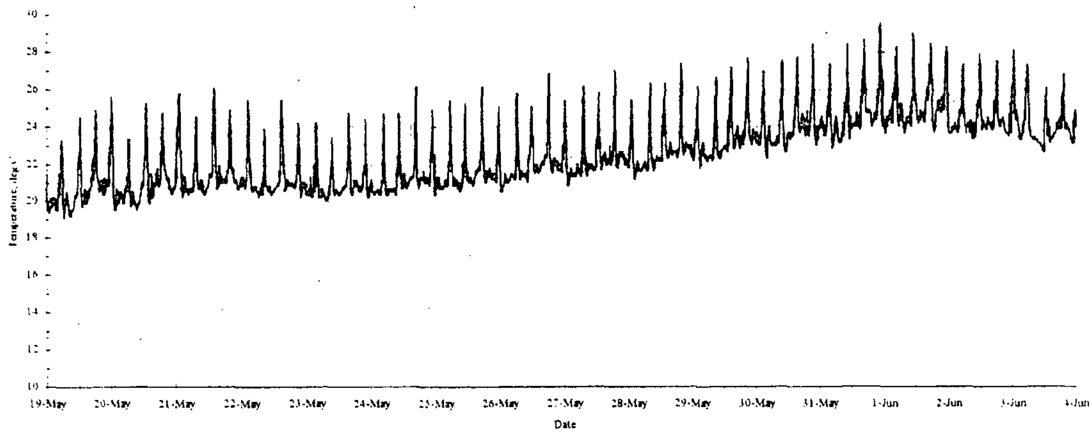
FIGURE 10-172

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-21

Surface



Middle



Bottom

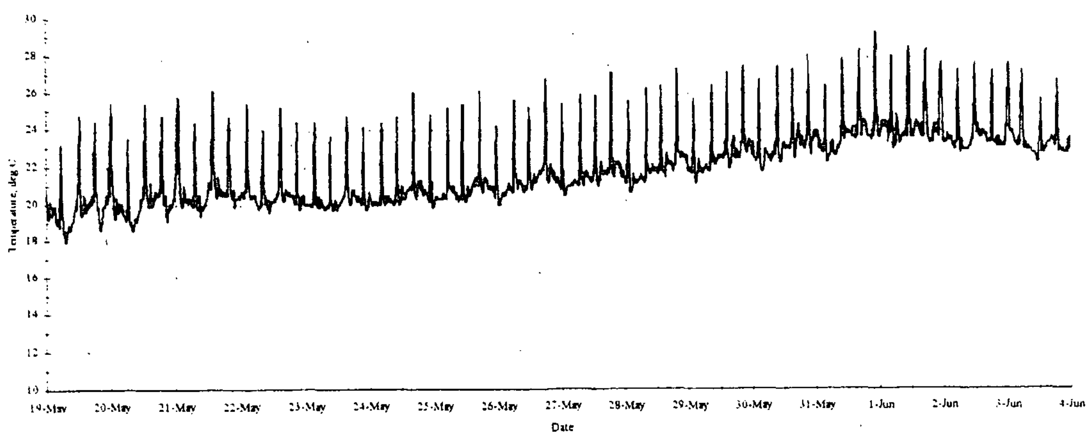


FIGURE 10-173

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-22

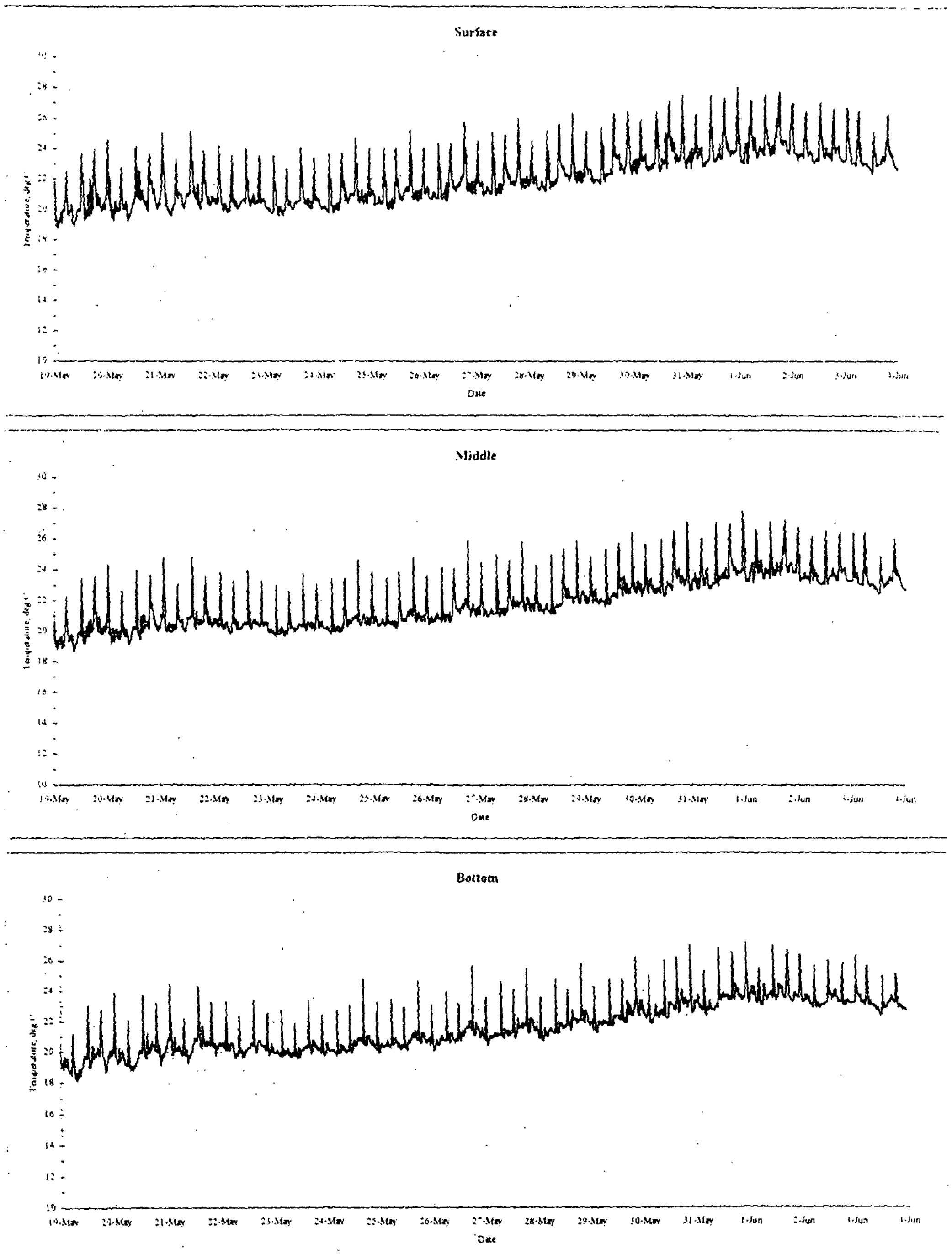
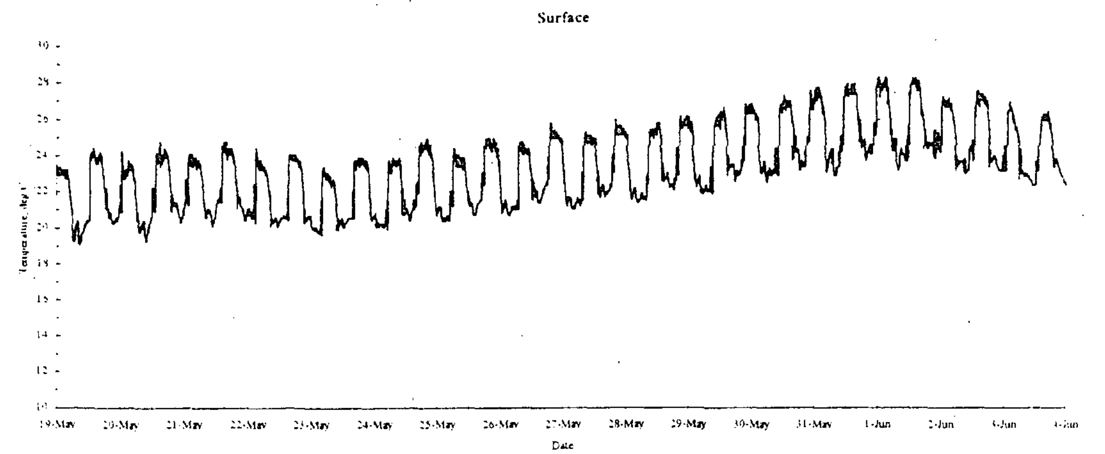
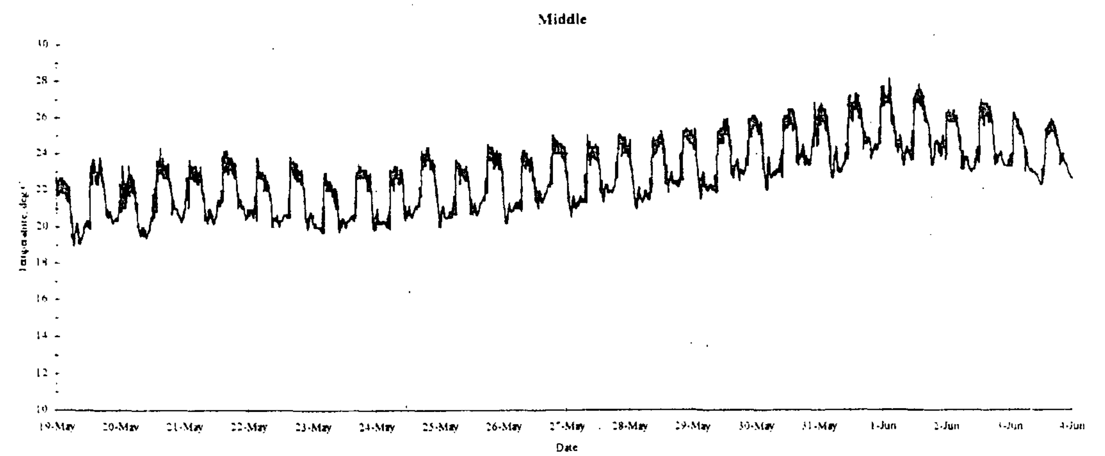


FIGURE 10-174

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-23





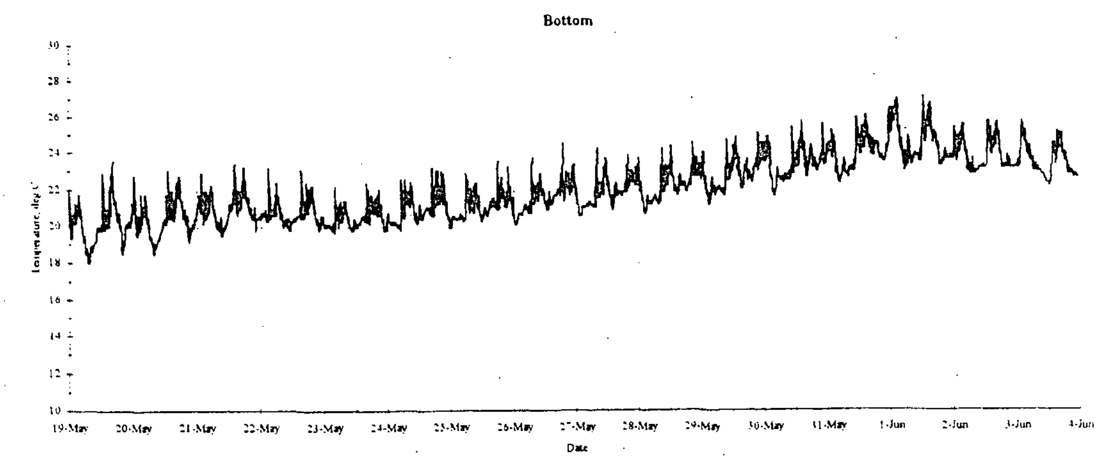
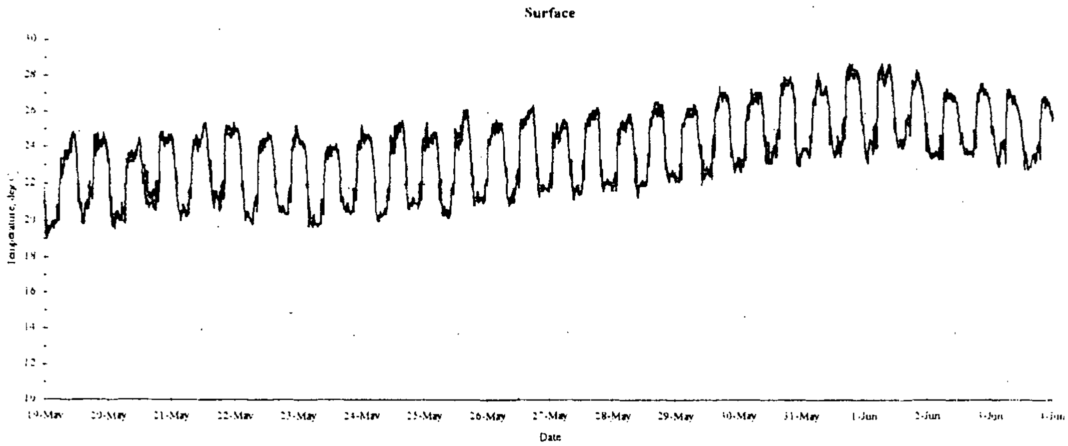
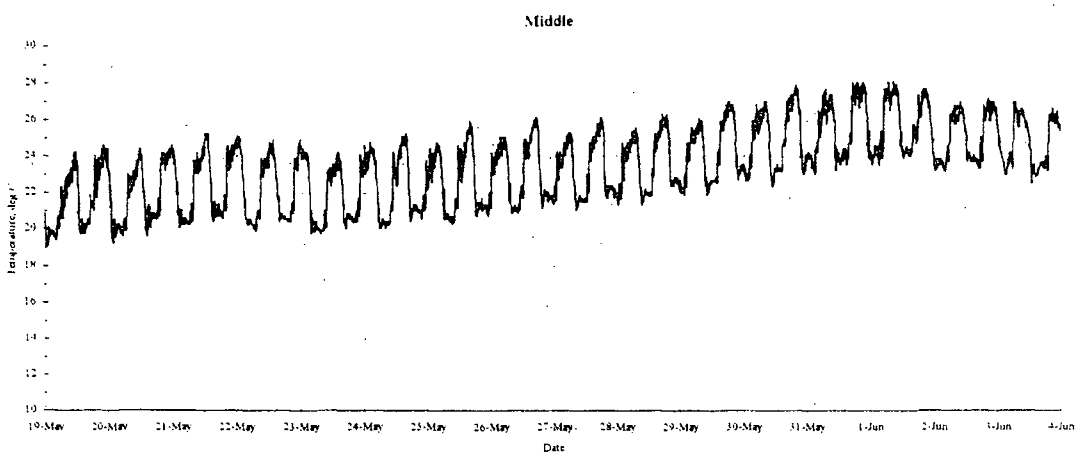


FIGURE 10-175

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-24





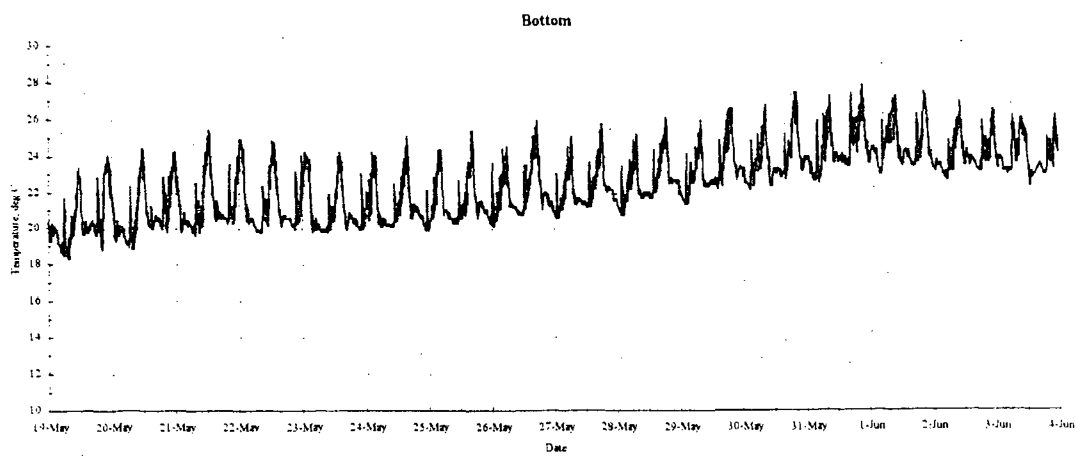
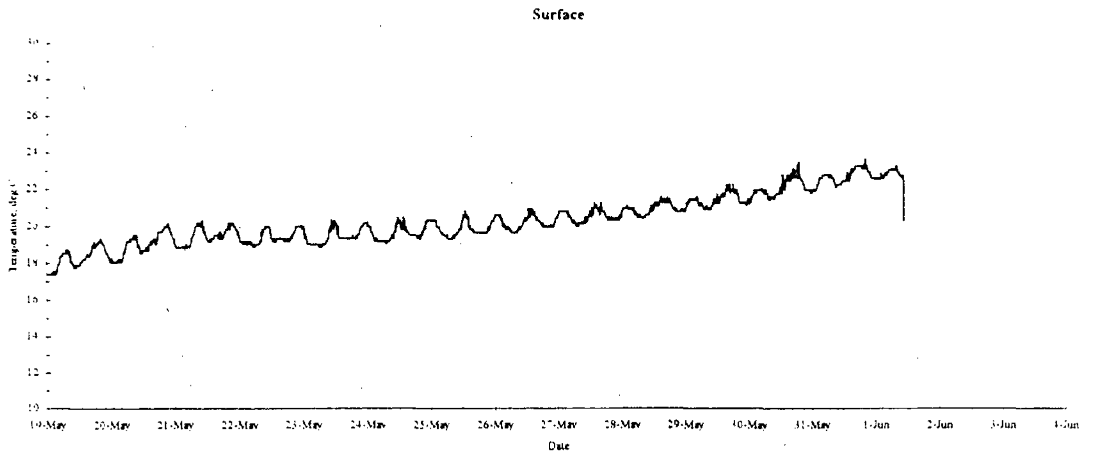


FIGURE 10-176

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-12G



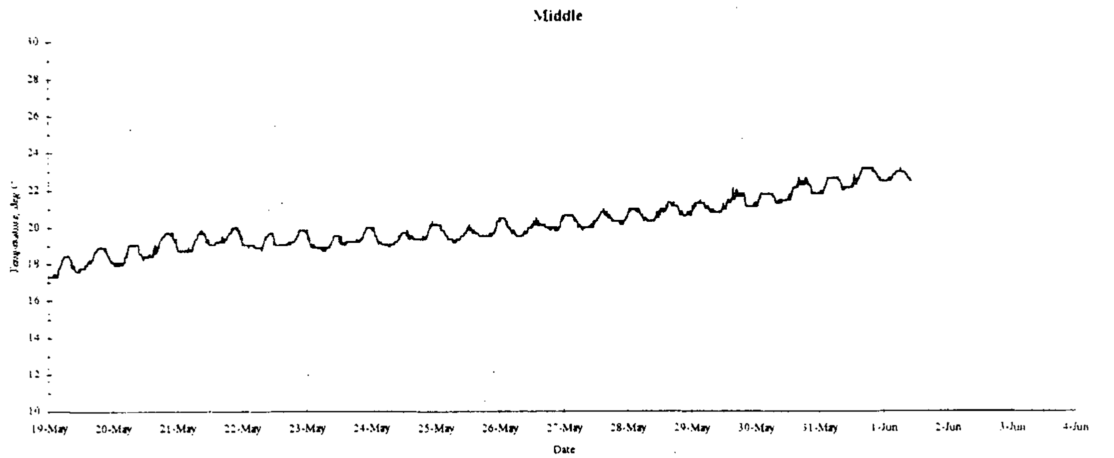


FIGURE 10-177

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-12R

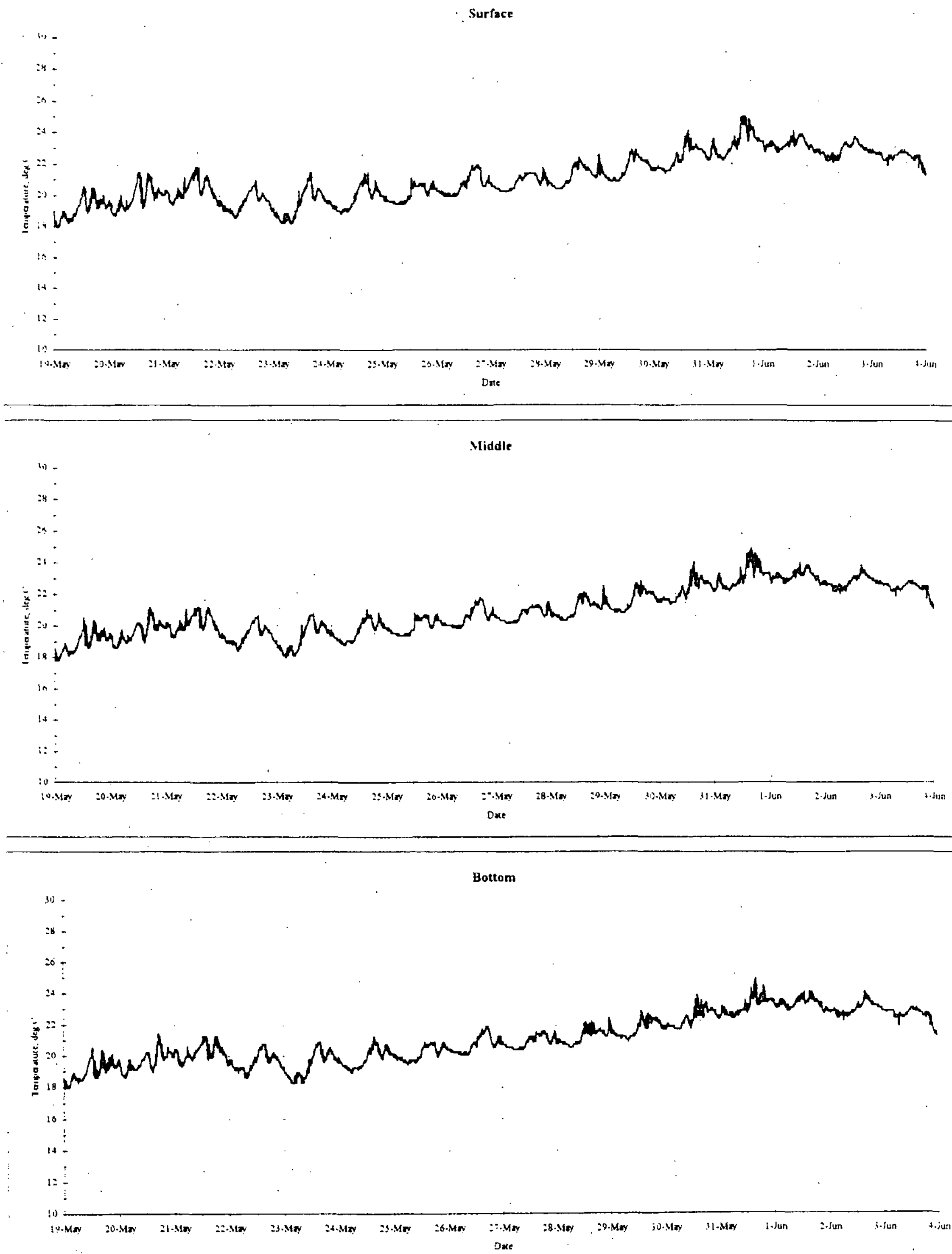
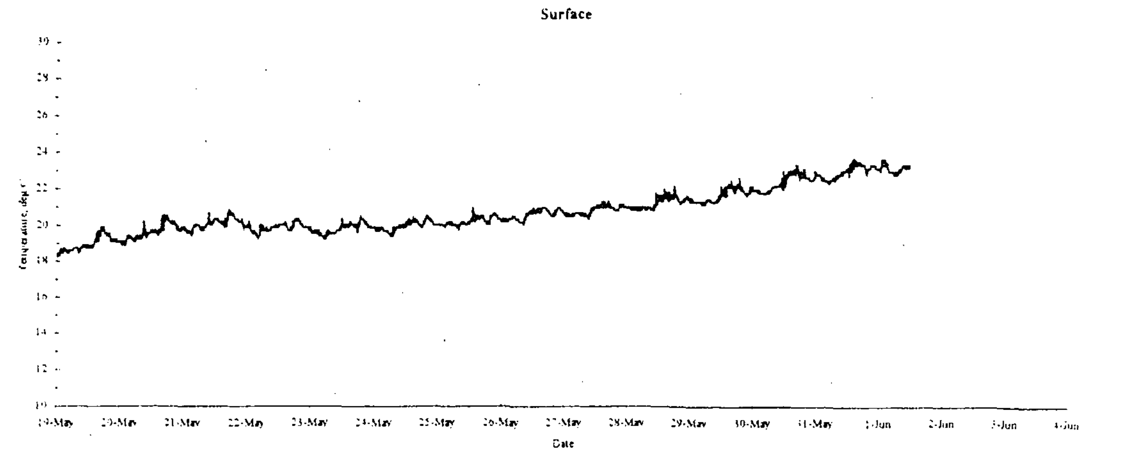
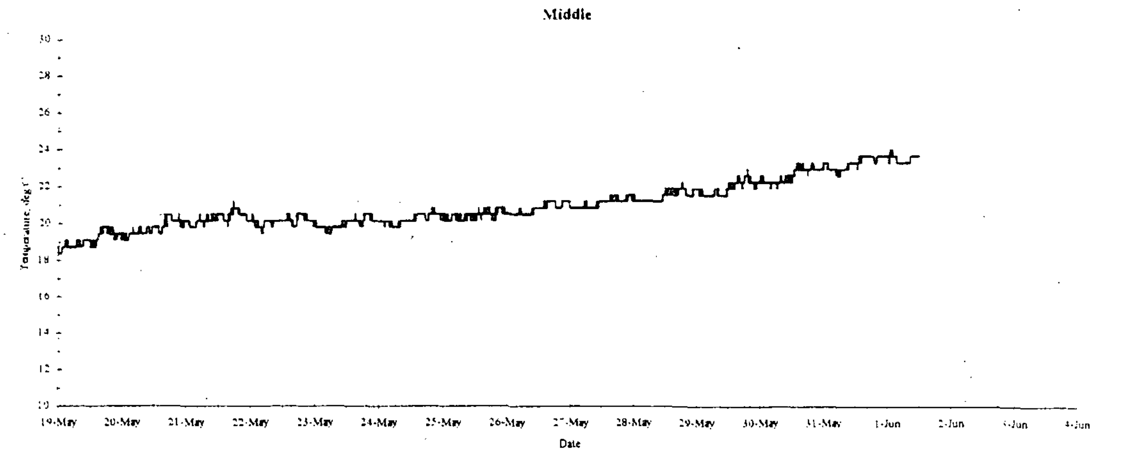


FIGURE 10-178

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9G





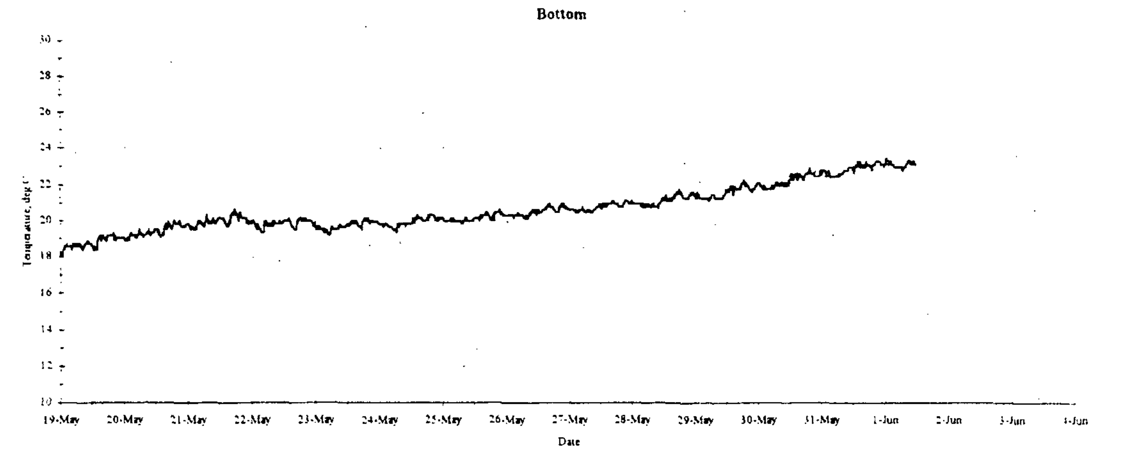
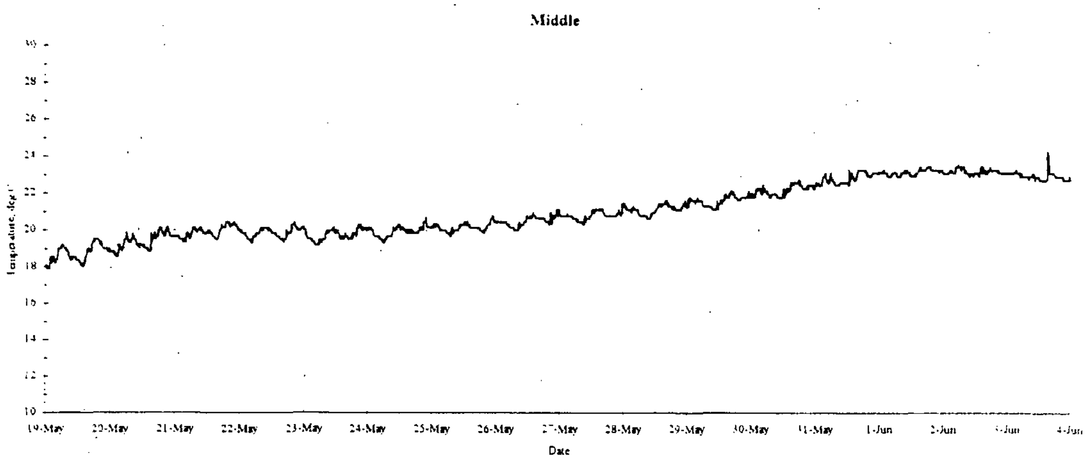


FIGURE 10-179

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9M



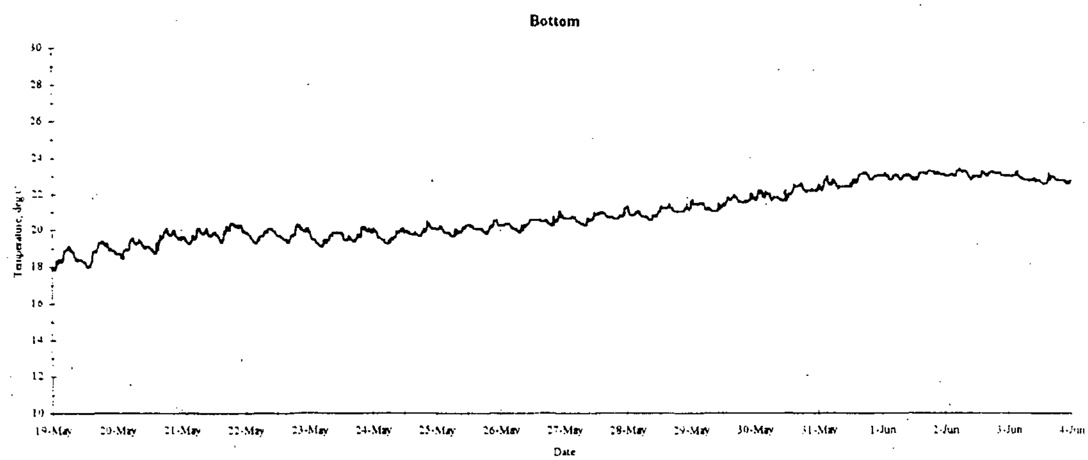


FIGURE 10-180

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-9M

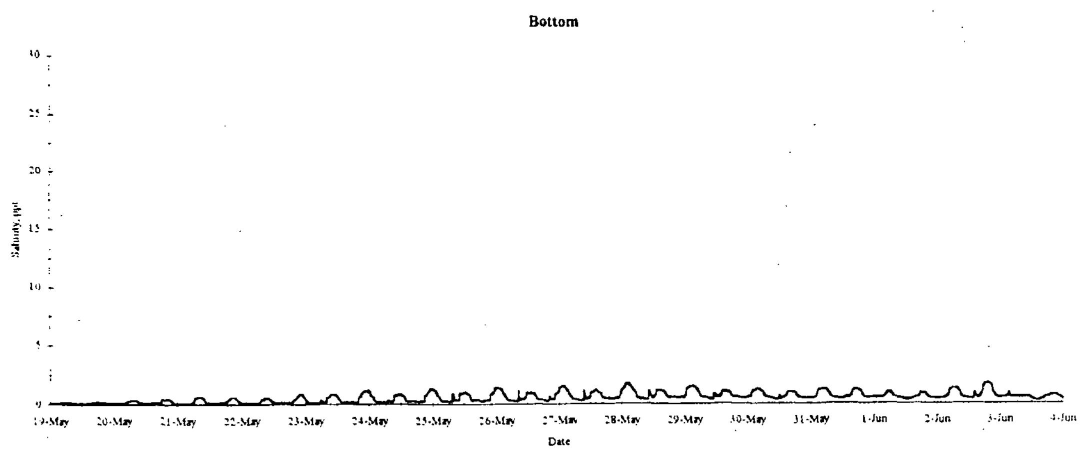
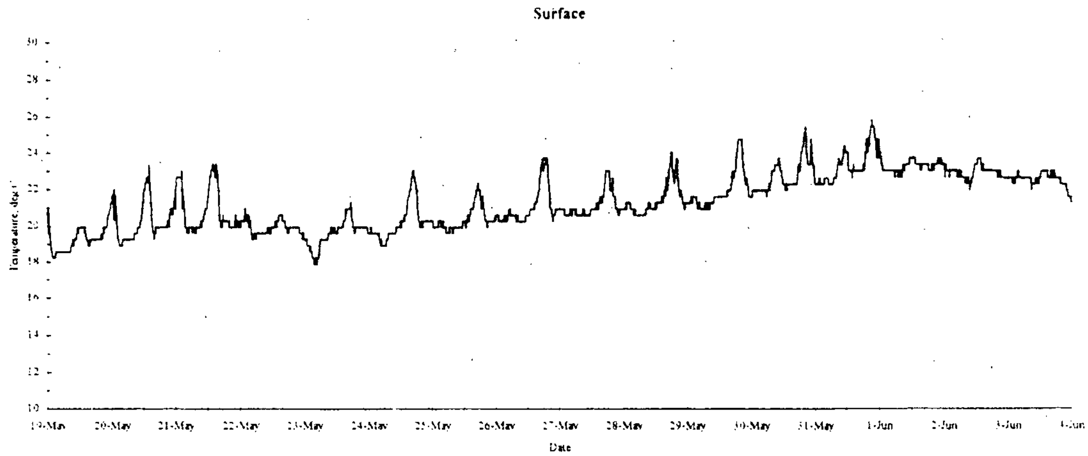
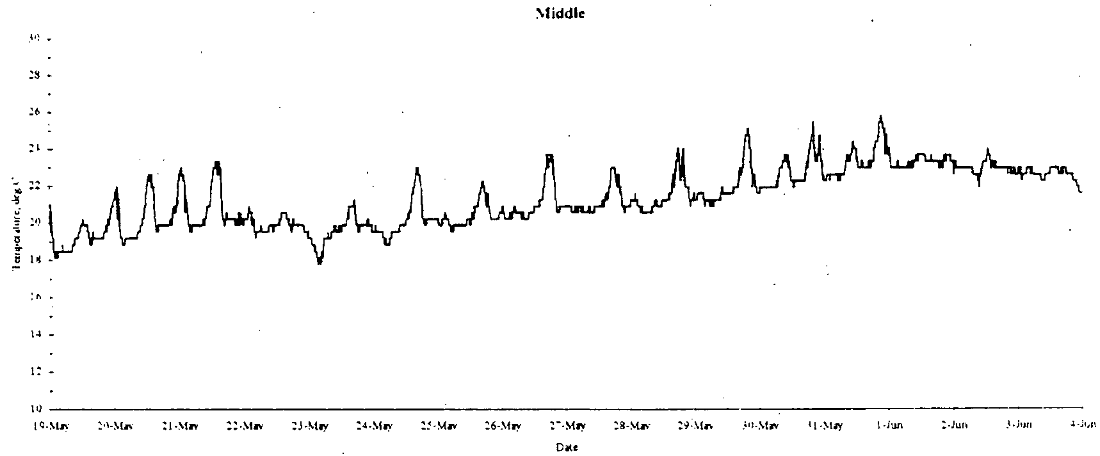


FIGURE 10-181

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9R





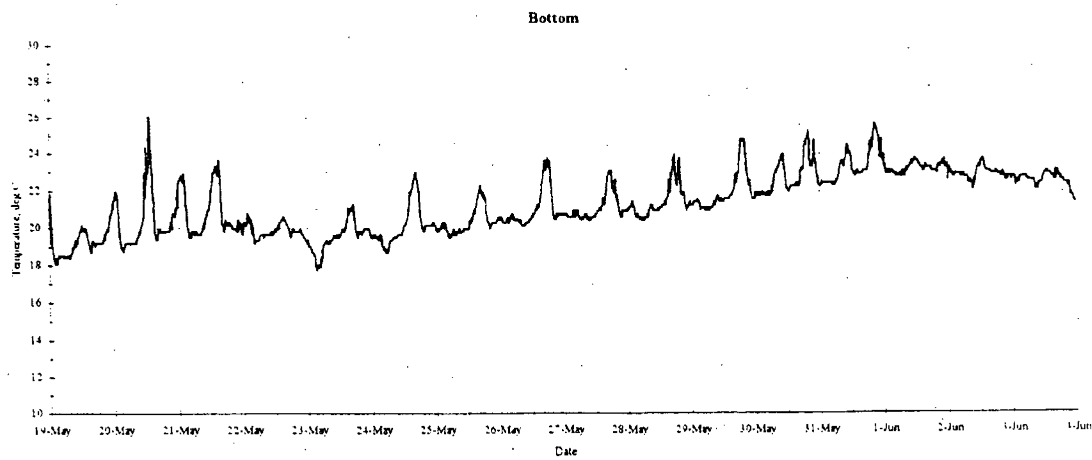
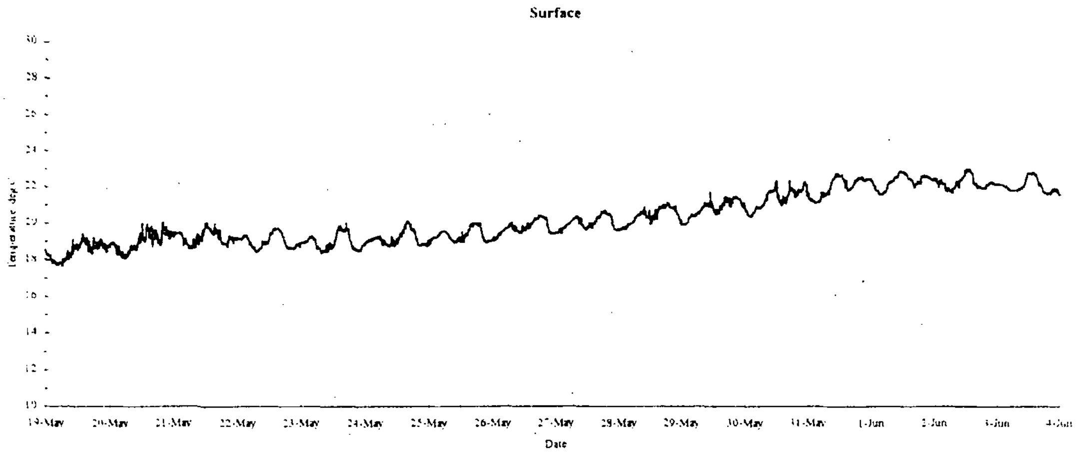
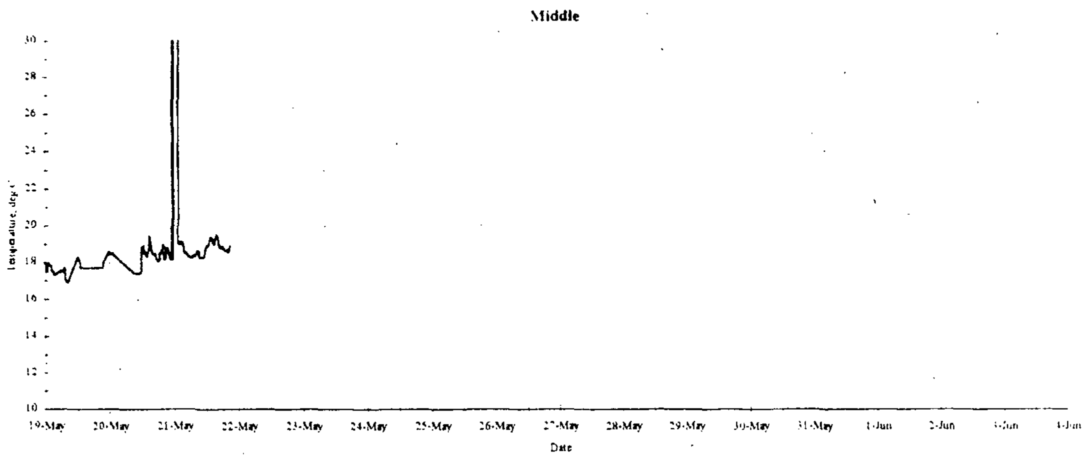


FIGURE 10-182

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-M9





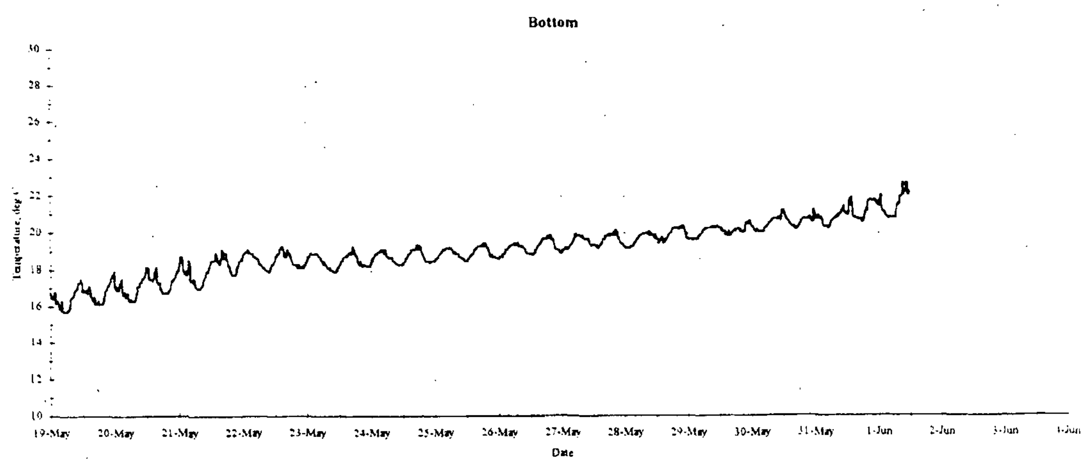


FIGURE 10-183

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-M9

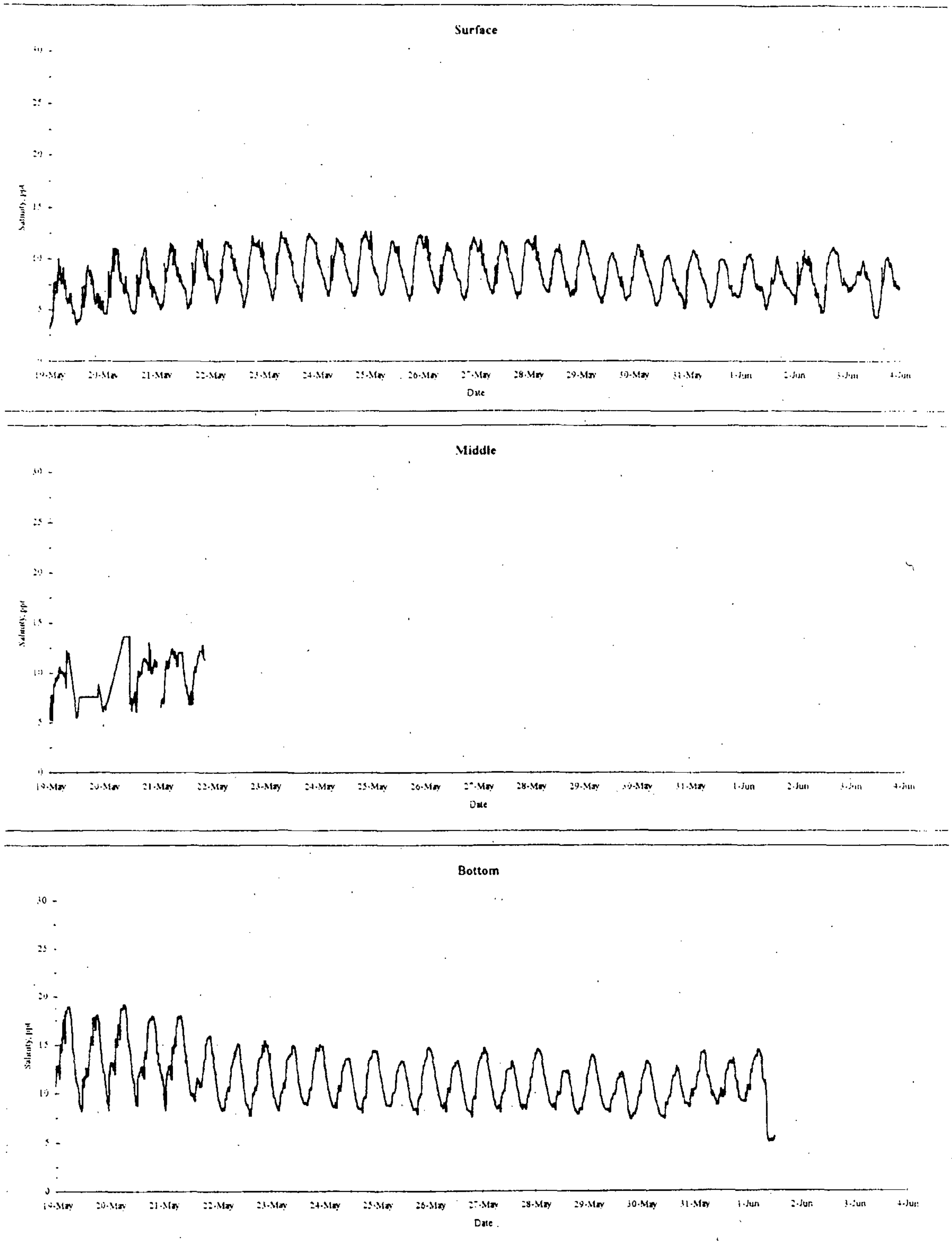
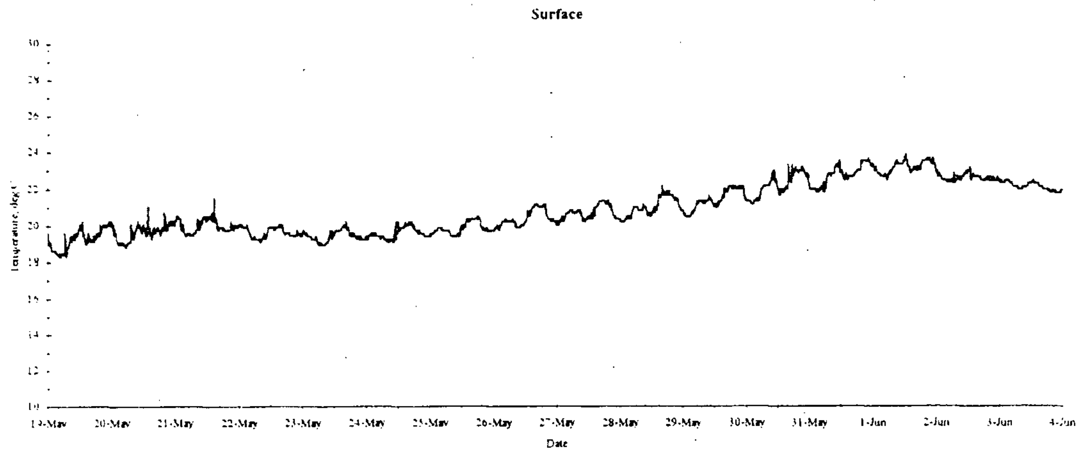


FIGURE 10-184

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-R9



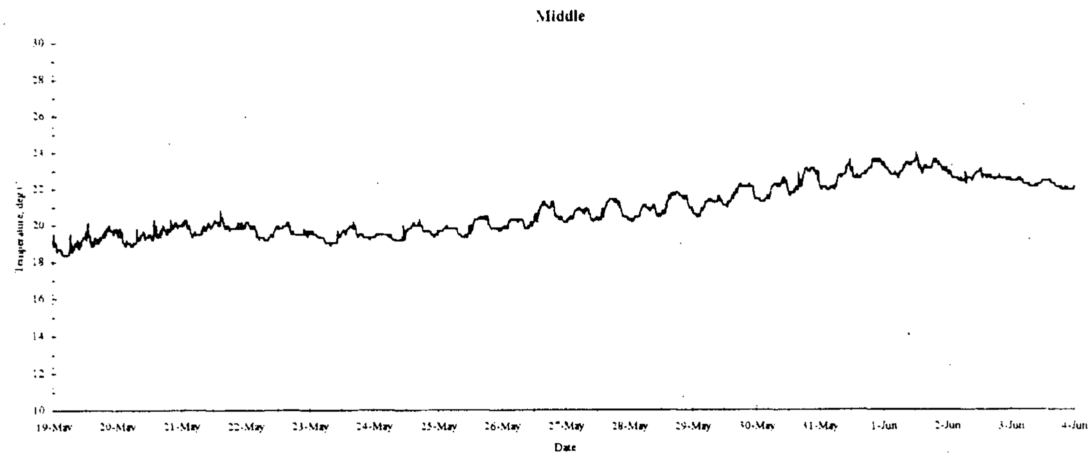
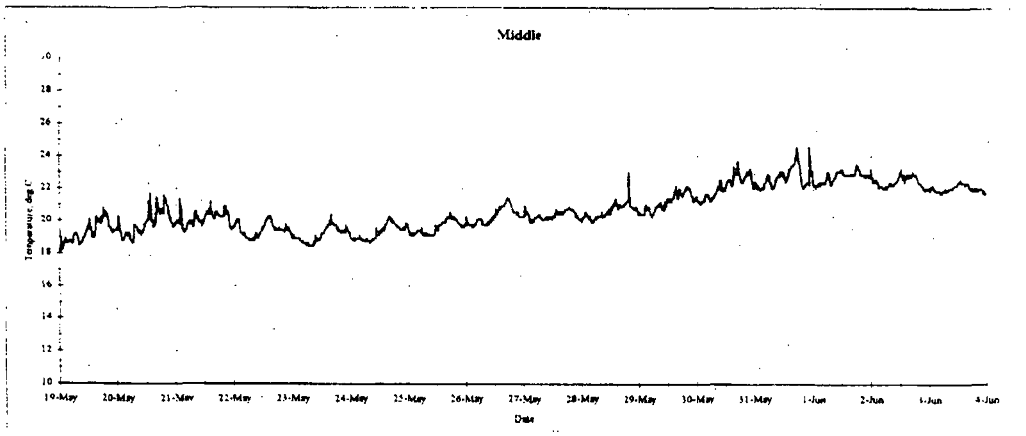


FIGURE 10-185

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-G12



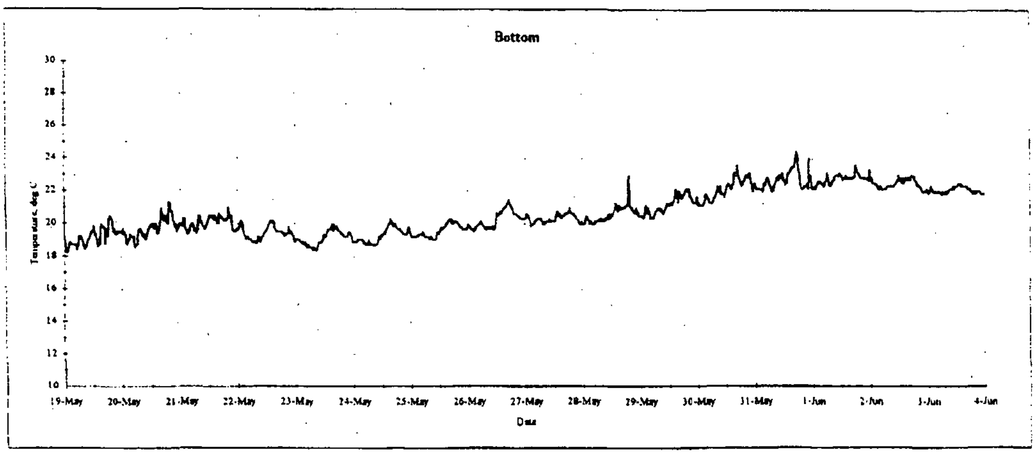
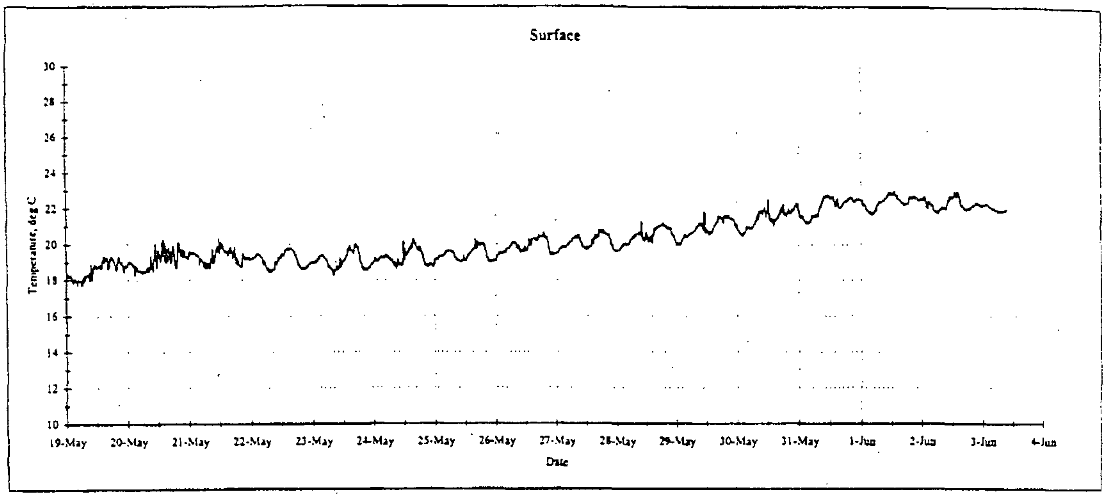


FIGURE 10-186

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-M12



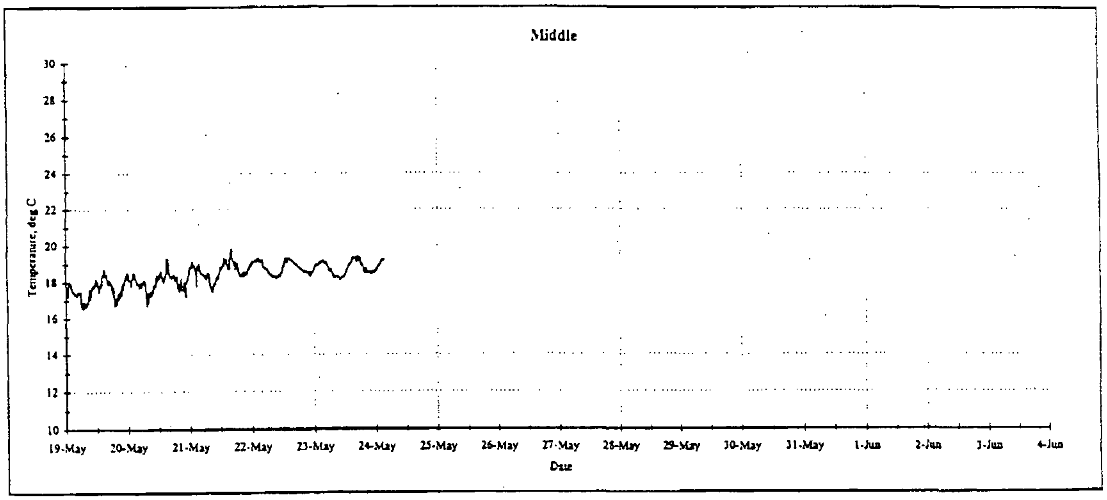
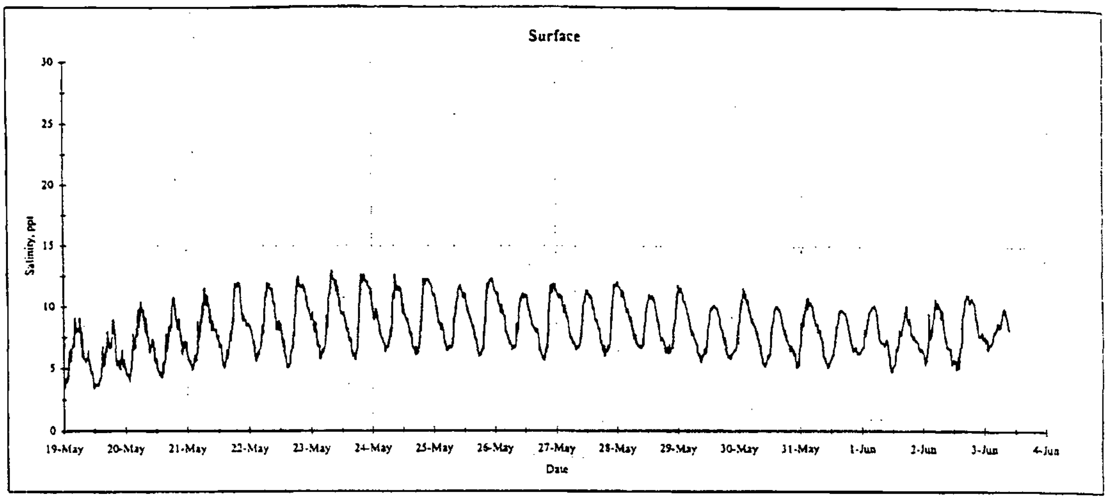


FIGURE 10-187

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-M12



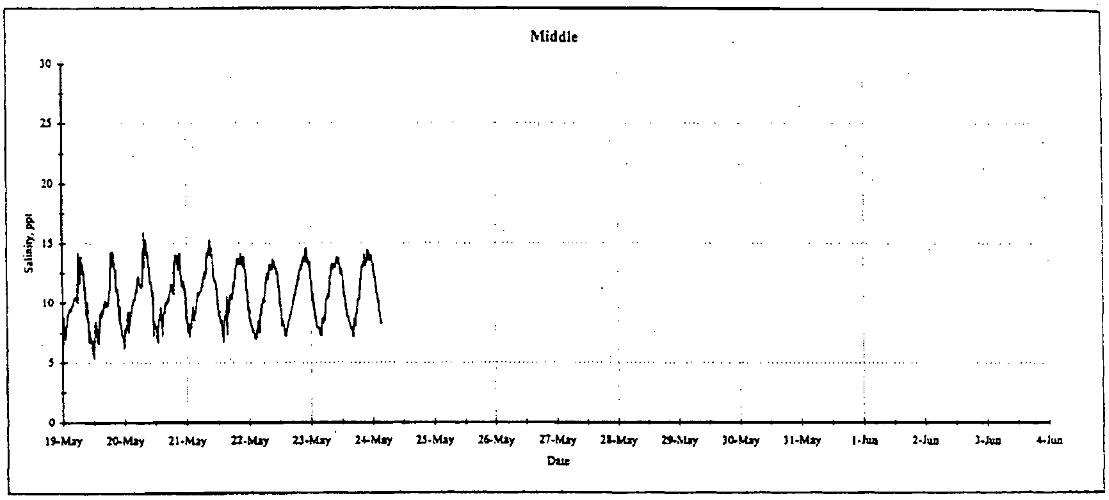
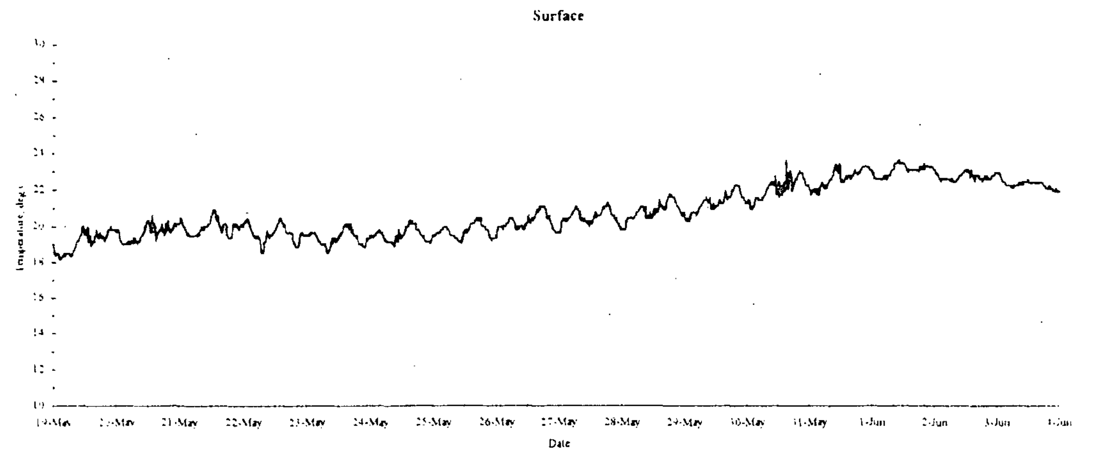
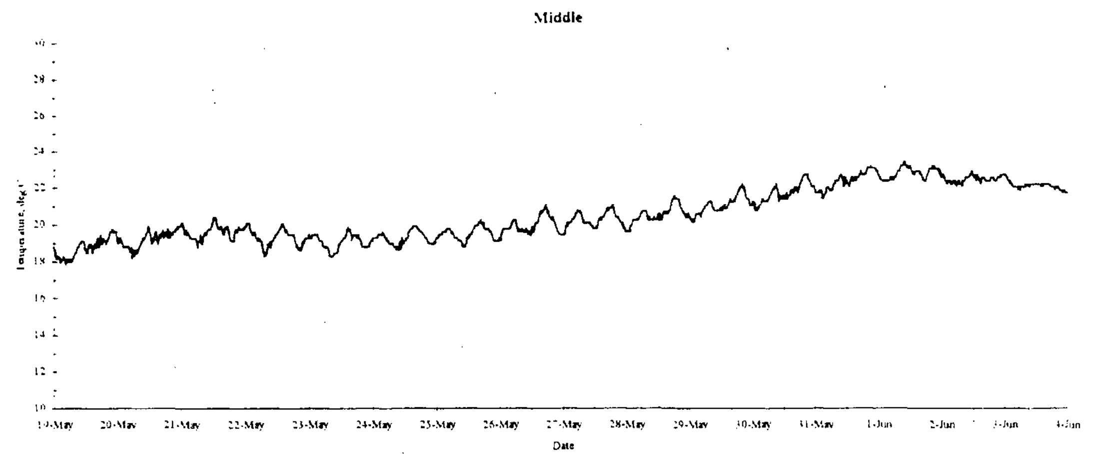


FIGURE 10-188

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-R12





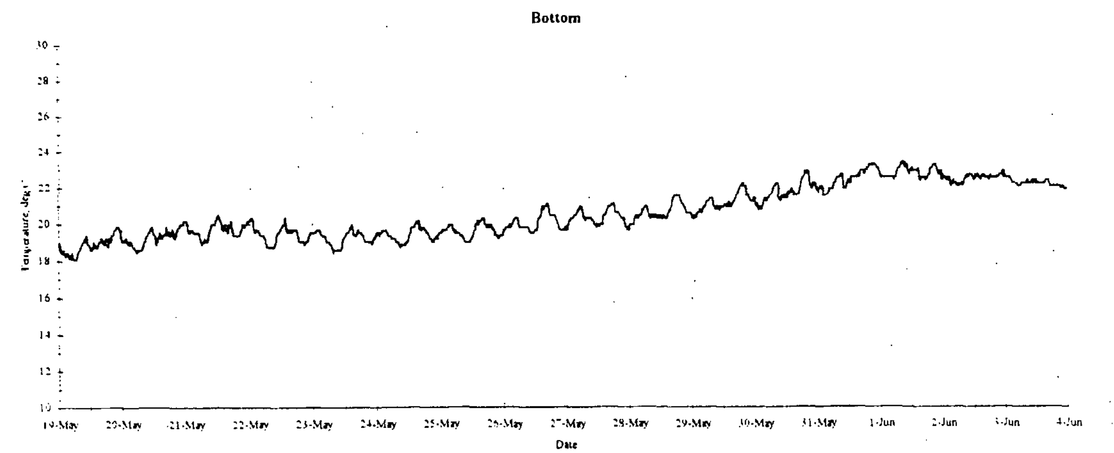


FIGURE 10-189

PSE&G 2-Unit Survey: 22 May 1998

Tidal Boundary Conditions

Vertical Temperature Profiles

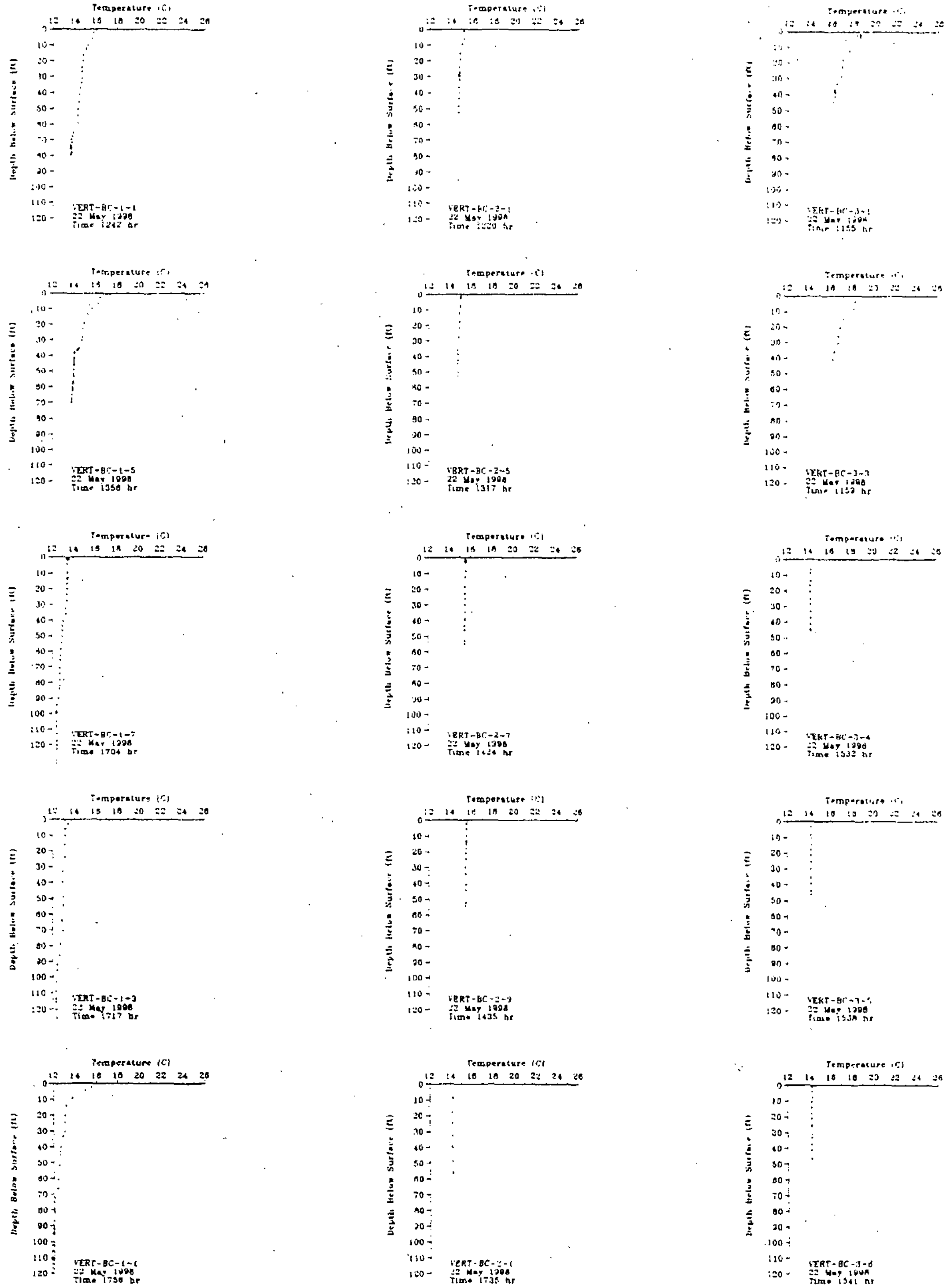


FIGURE 10-190

PSE&G 2-Unit Survey: 22 May 1998
Tidal Boundary Conditions
Vertical Salinity Profiles

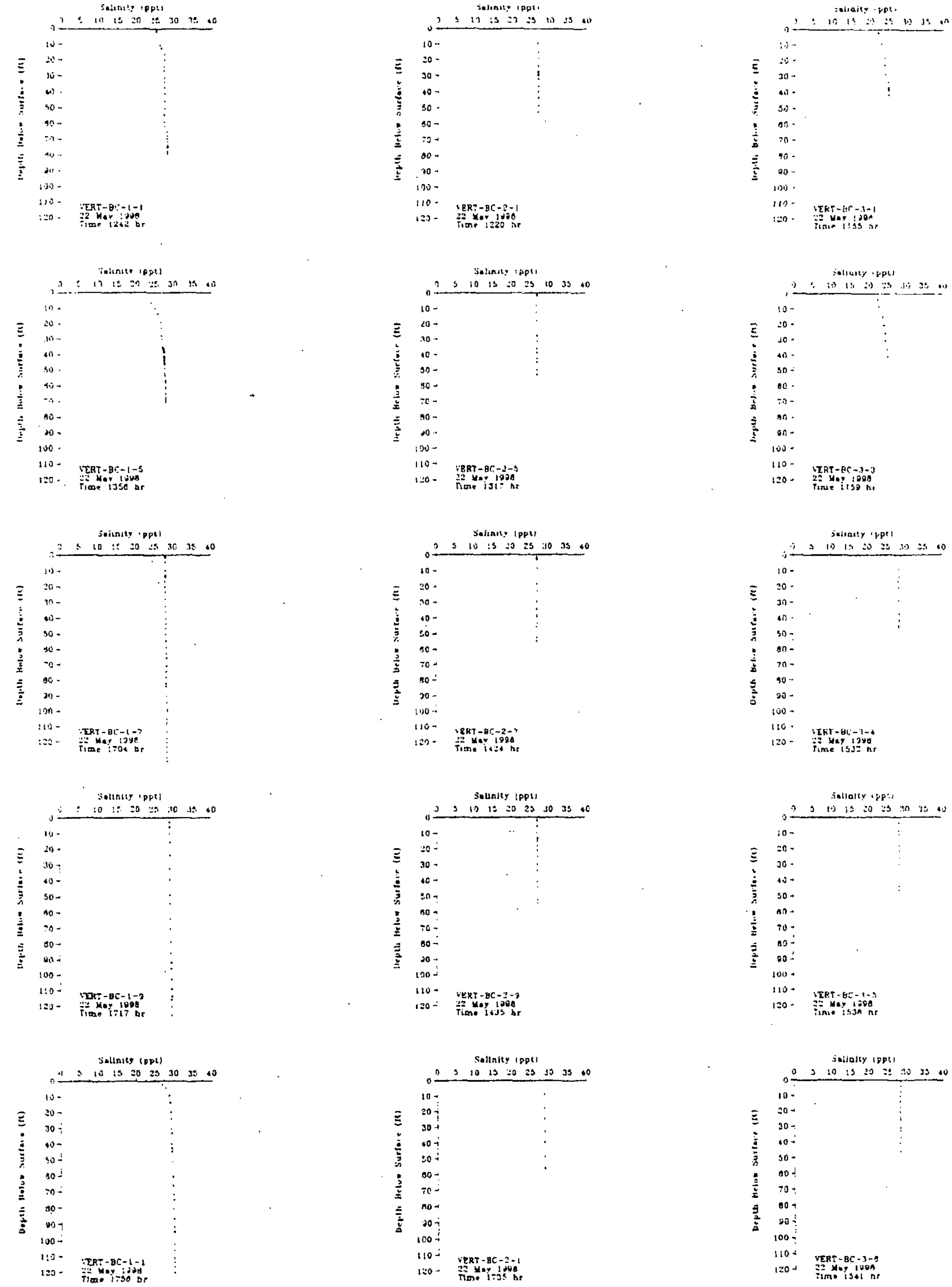


Figure 10-191

PSE&G 2-Unit Survey: 19 May 1998 - 04 June 1998
Tide Gages - Water Surface Elevations
Temporal Variations

Delaware River

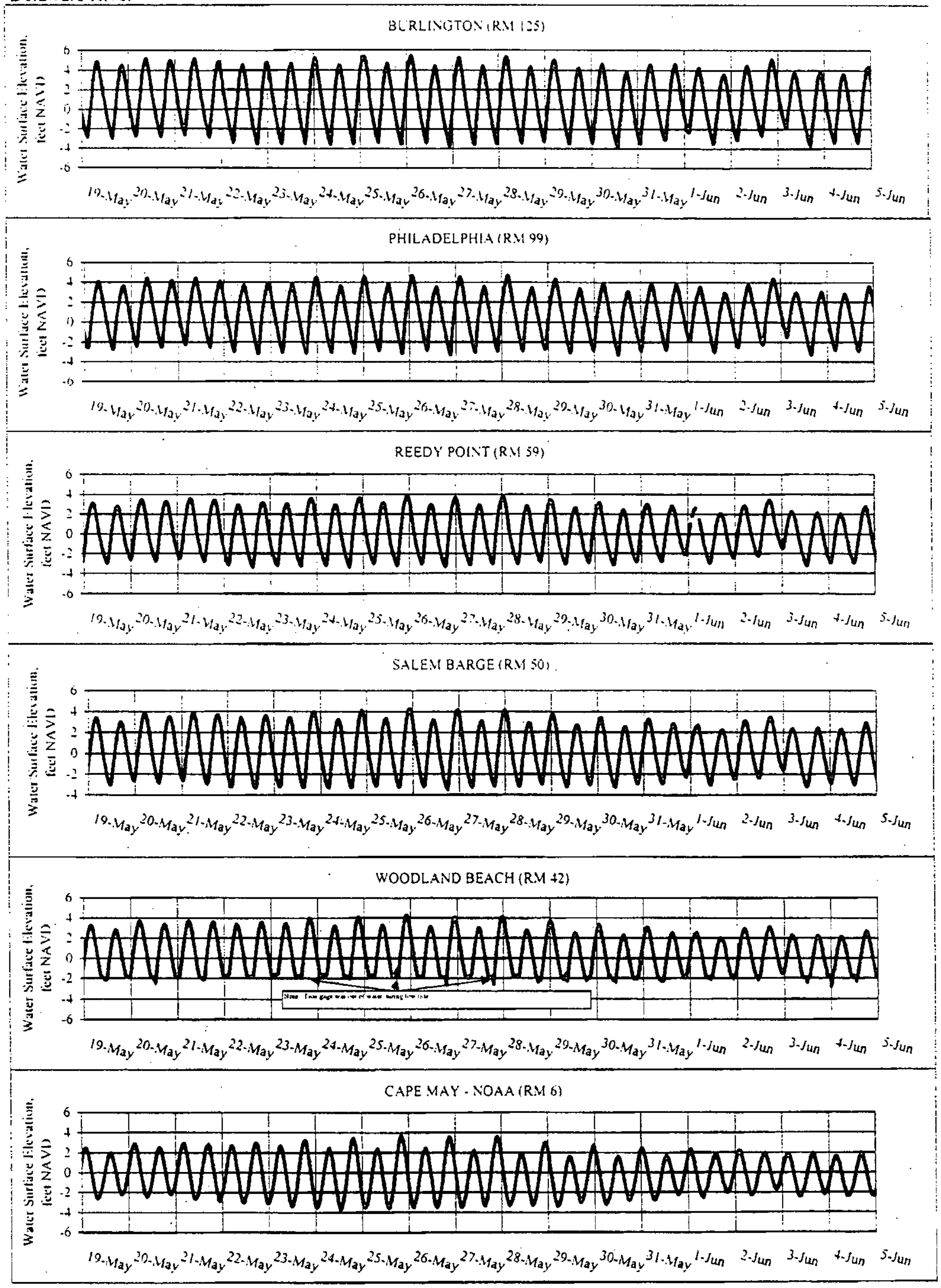
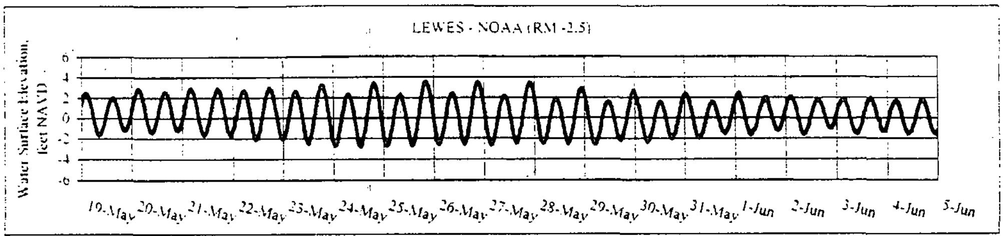


Figure 10-192

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Tide Gages - Water Surface Elevations
Temporal Variations



C&D Canal

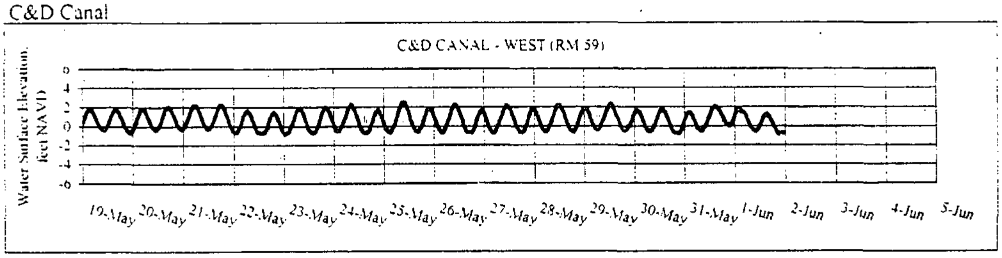


Figure 10-193

PSE&G 2-Unit Survey; 29 May 1998
Tide Gages - Water Surface Elevations
Temporal Variations

Delaware River

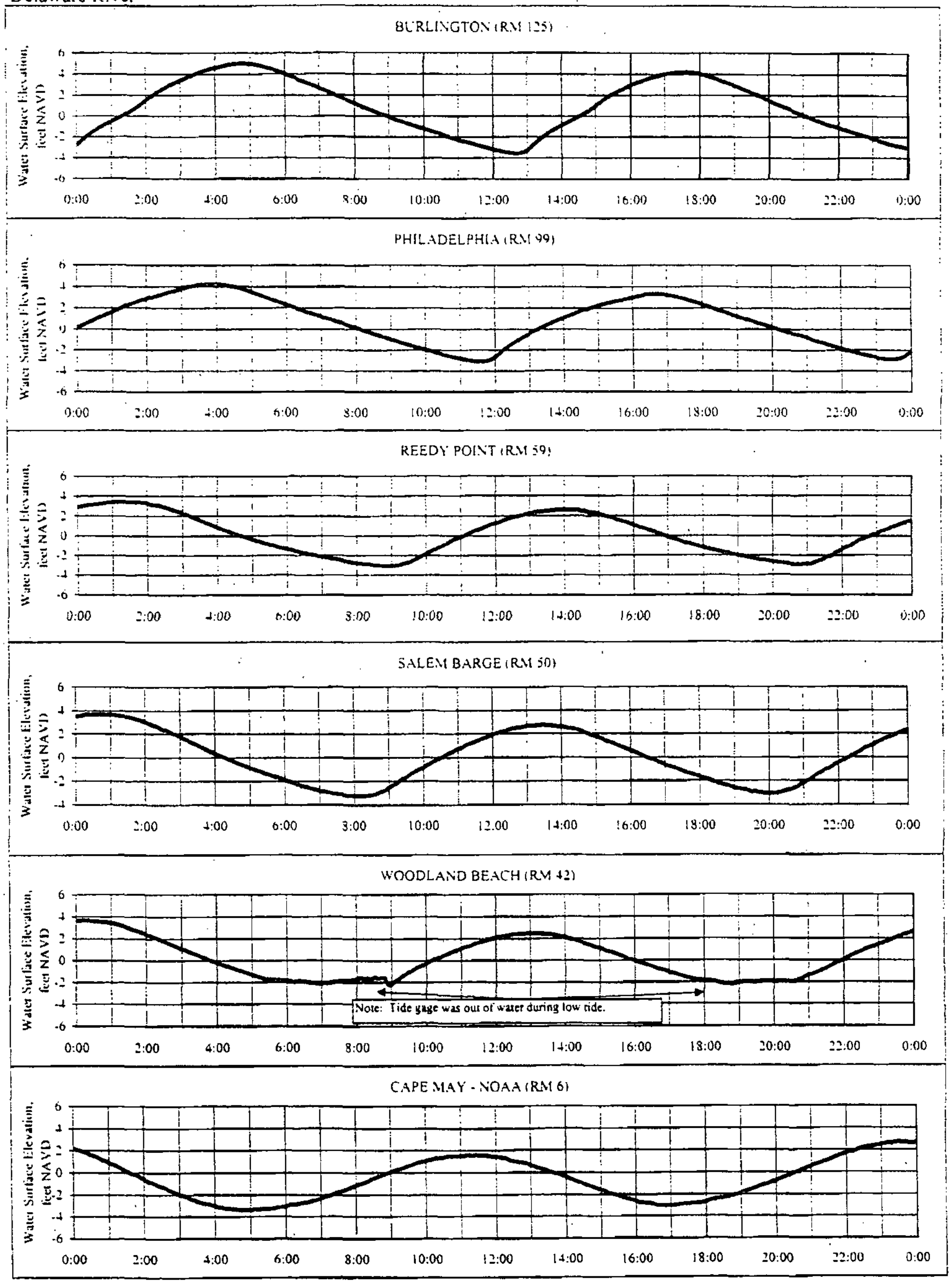
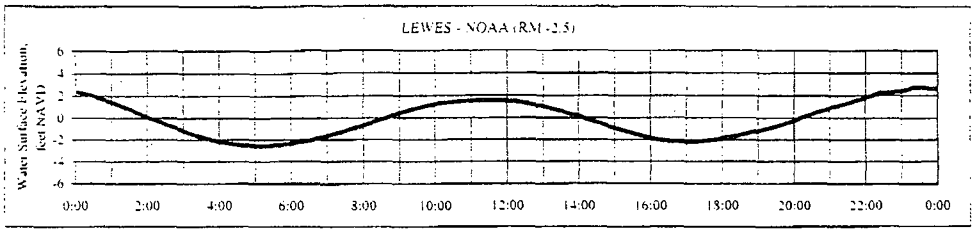


FIGURE 10-194

PSE&G 2-Unit Survey: 29 May 1998
Tide Gages - Water Surface Elevations
Temporal Variations



C&D Canal

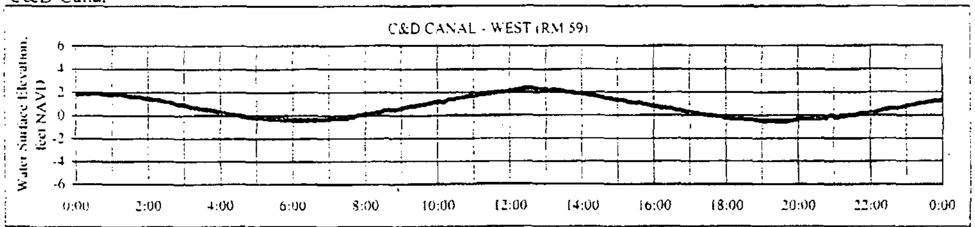


FIGURE 10-195

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Tide Gages - Temperatures
Temporal Variations

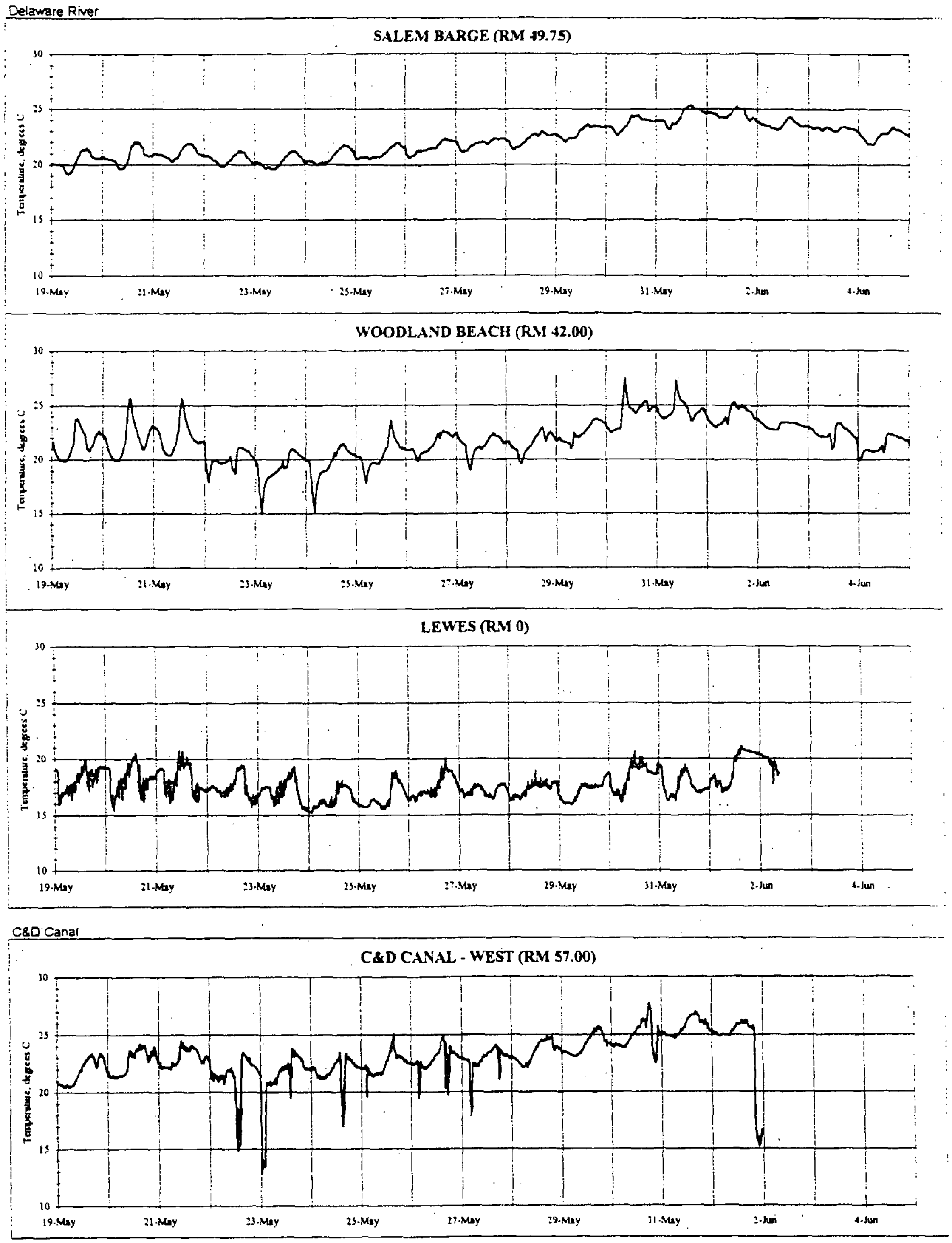
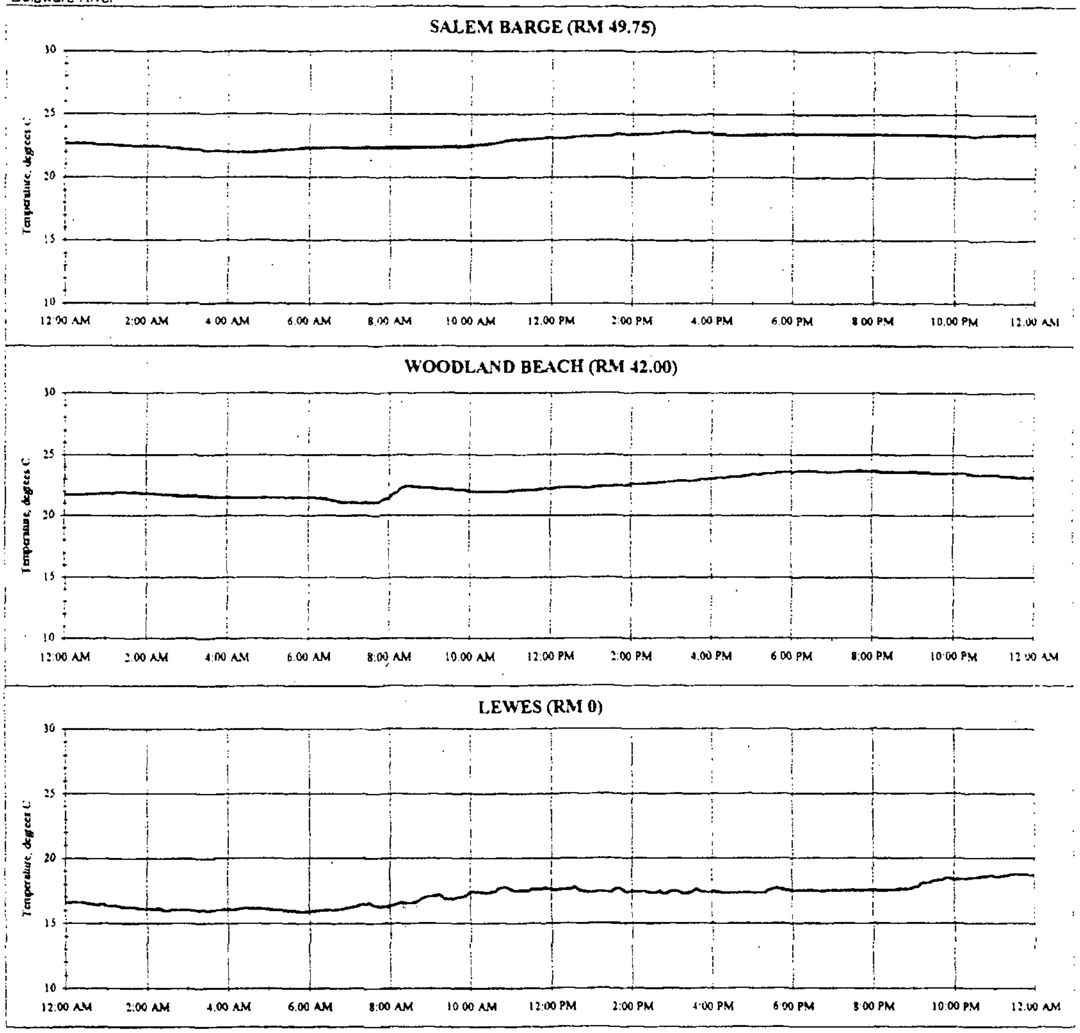


FIGURE 10-196

PSE&G 2-Unit Survey; 29 May 1998
Tide Gages - Temperatures
Temporal Variations

Delaware River



C&D Canal

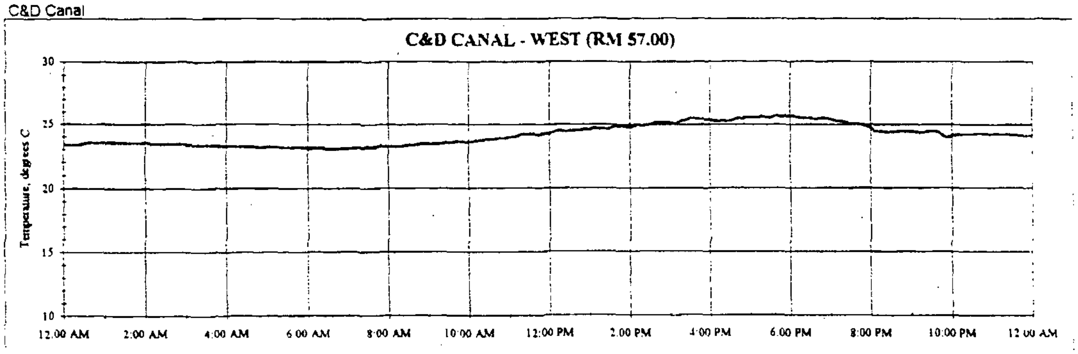
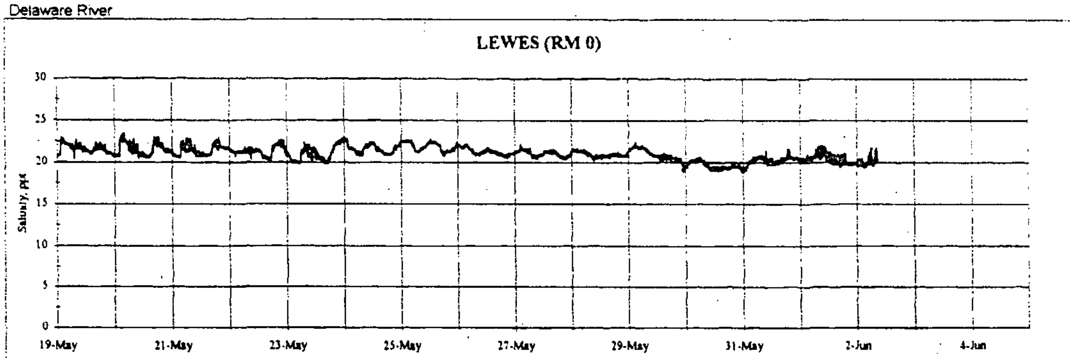


FIGURE 10-197

PSE&G 2-Unit Survey; 19 May 1998 - 04 June 1998
Tide Gages - Salinity
Temporal Variations

Delaware River



C&D Canal

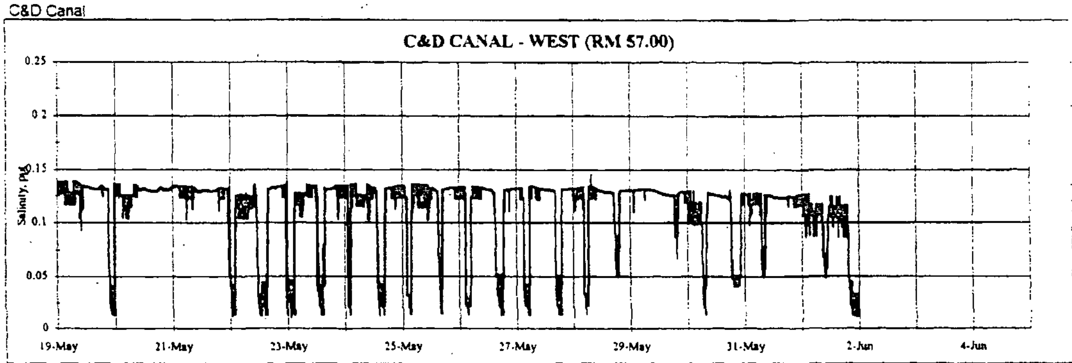
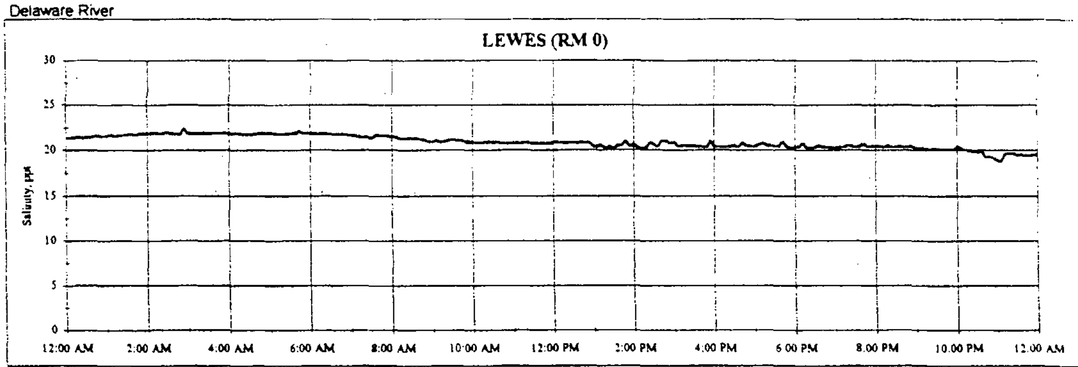


FIGURE 10-198

PSE&G 2-Unit Survey; 29 May 1998
Tide Gages - Salinity
Temporal Variations

Delaware River



C&D Canal

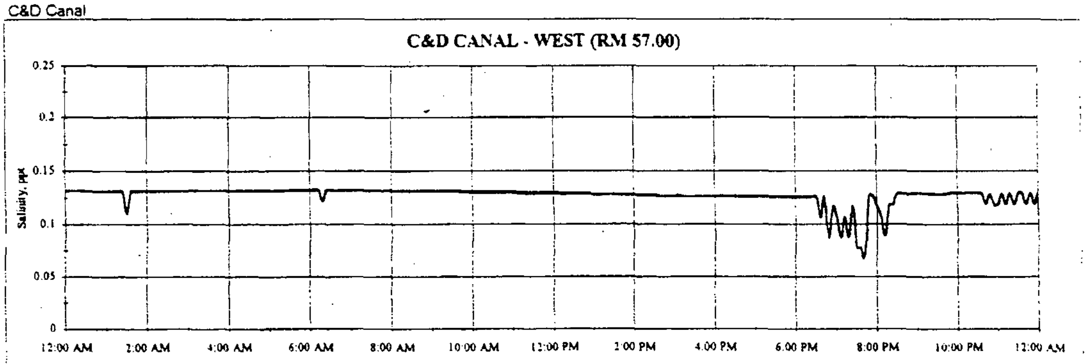
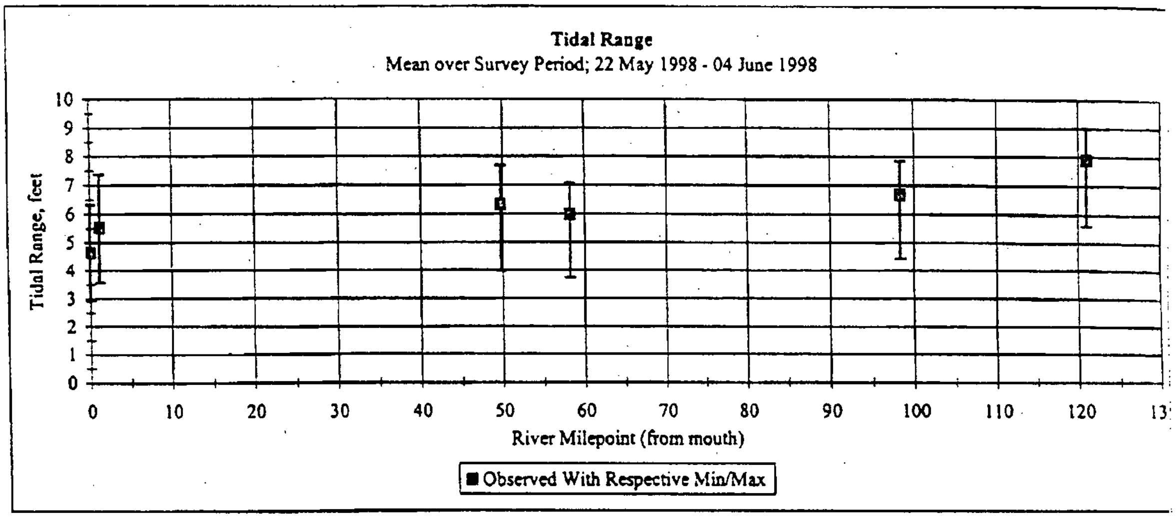


FIGURE 10-199

PSE&G 2-Unit Survey; 22 May 1998 - 04 June 1998
Delaware River Tide Gages
Spatial Variation



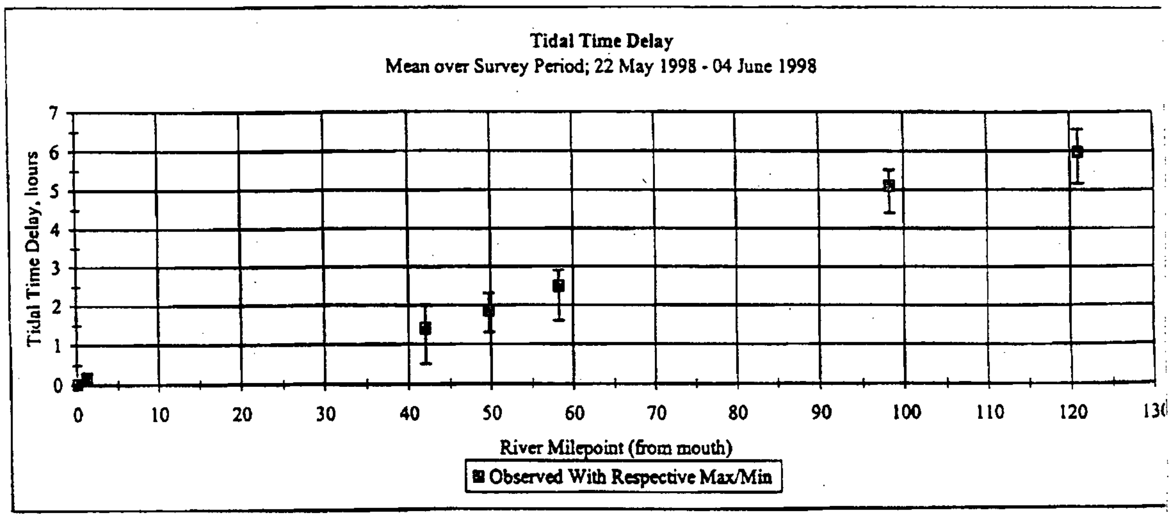
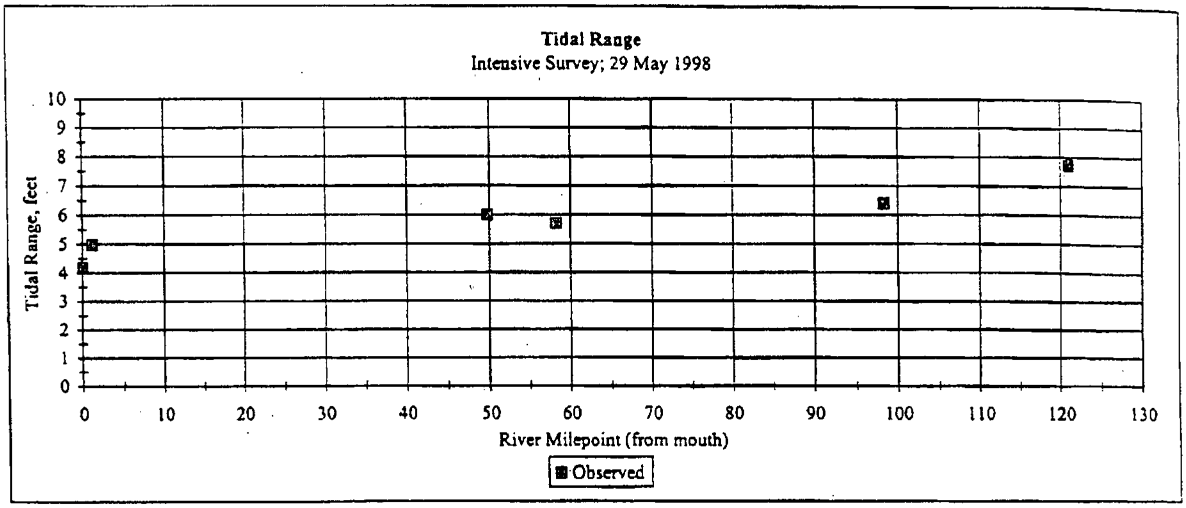


FIGURE 10-200

PSE&G 2-Unit Survey; 29 May 1998
Delaware River Tide Gages
Spatial Variation



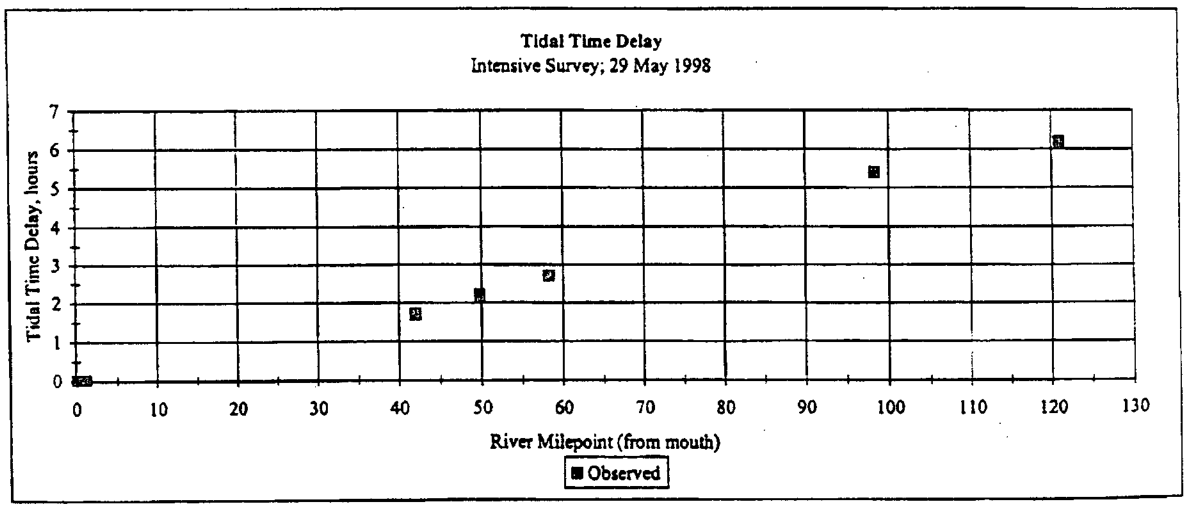


Figure 10-201
PSE&G 2-Unit Survey; 19 May - 04 June 1998
Vertical Velocity Distribution (Bottom ADCP)

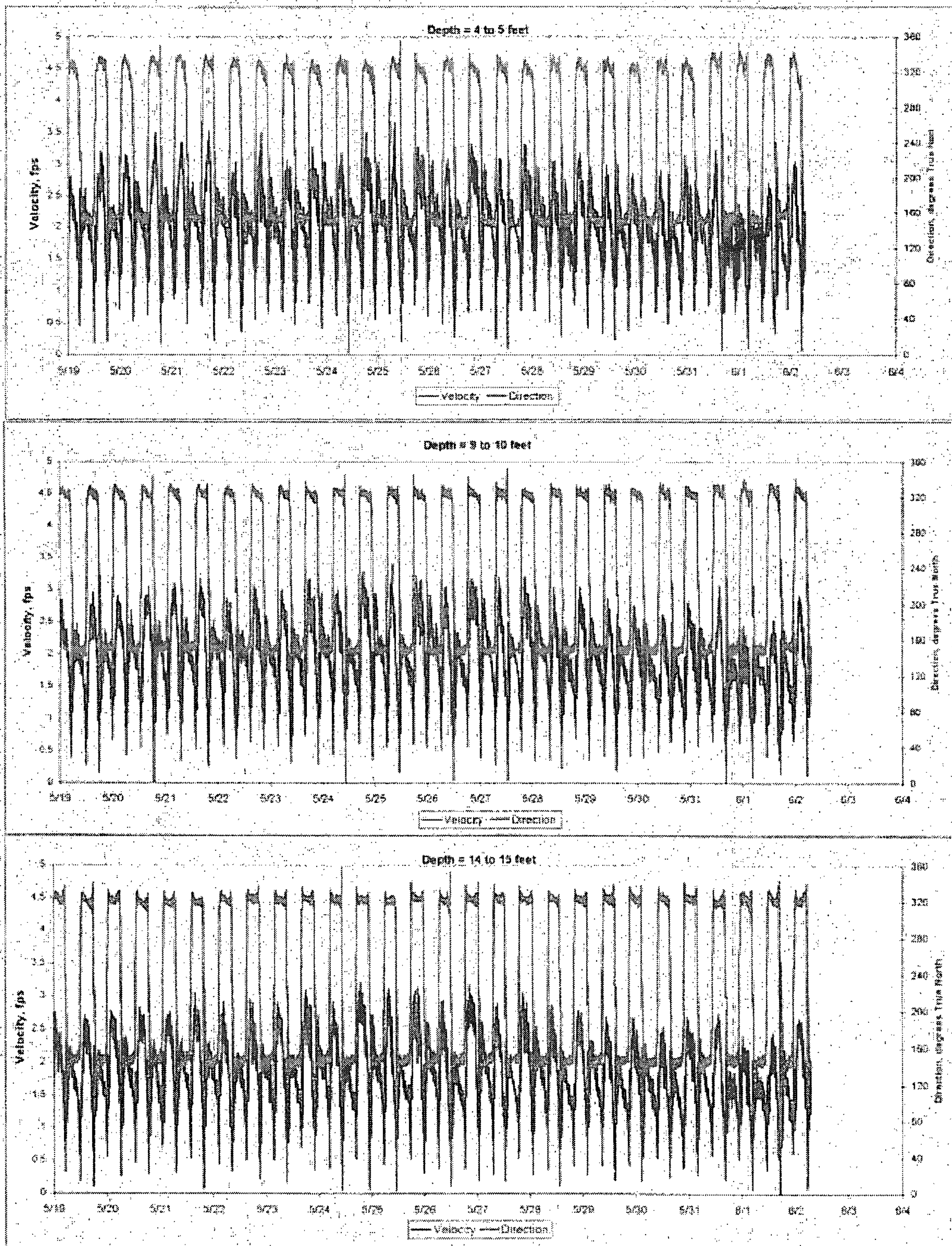


Figure 10-202
PSE&C 2-Unit Survey; 29 May 1998
Vertical Velocity Distribution (Bottom ADCP)

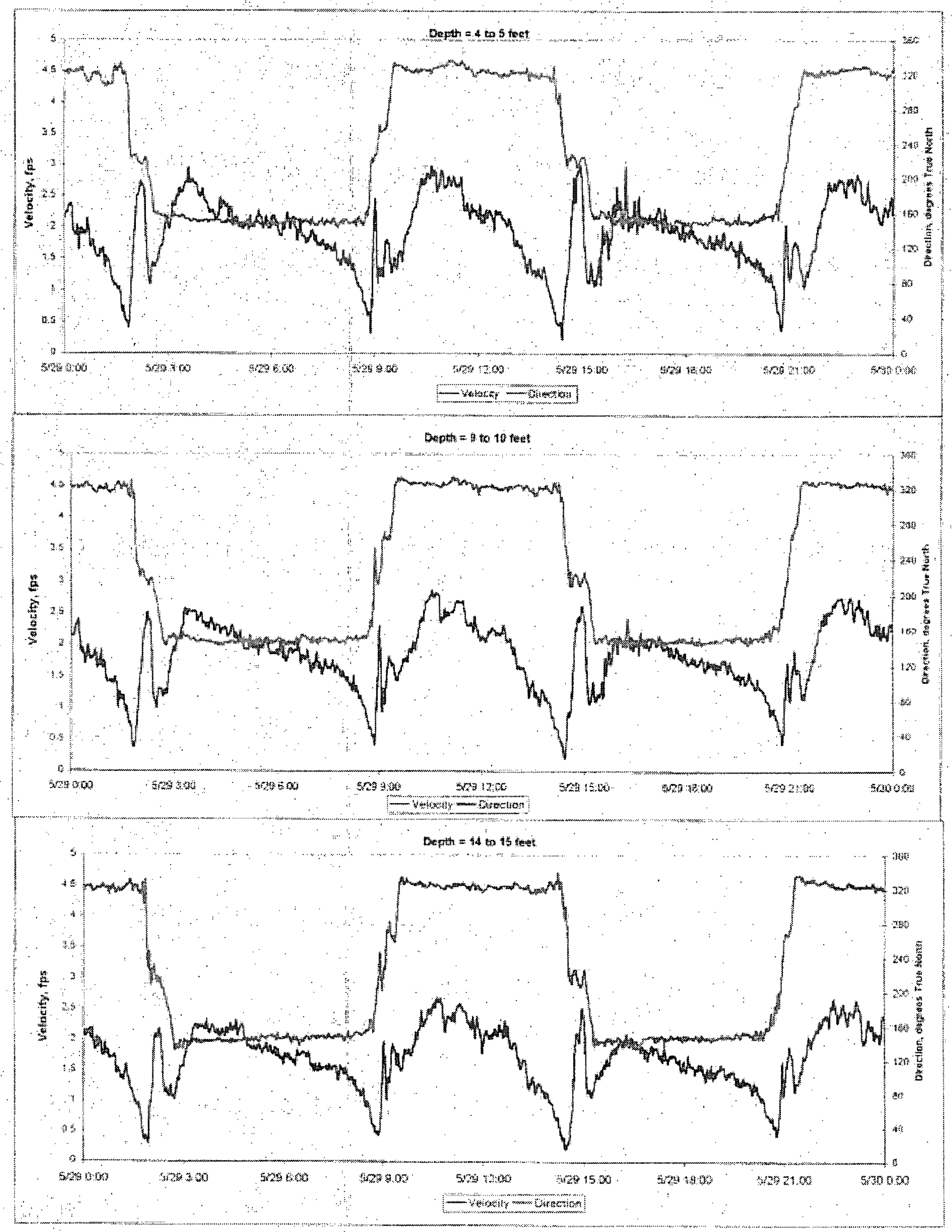
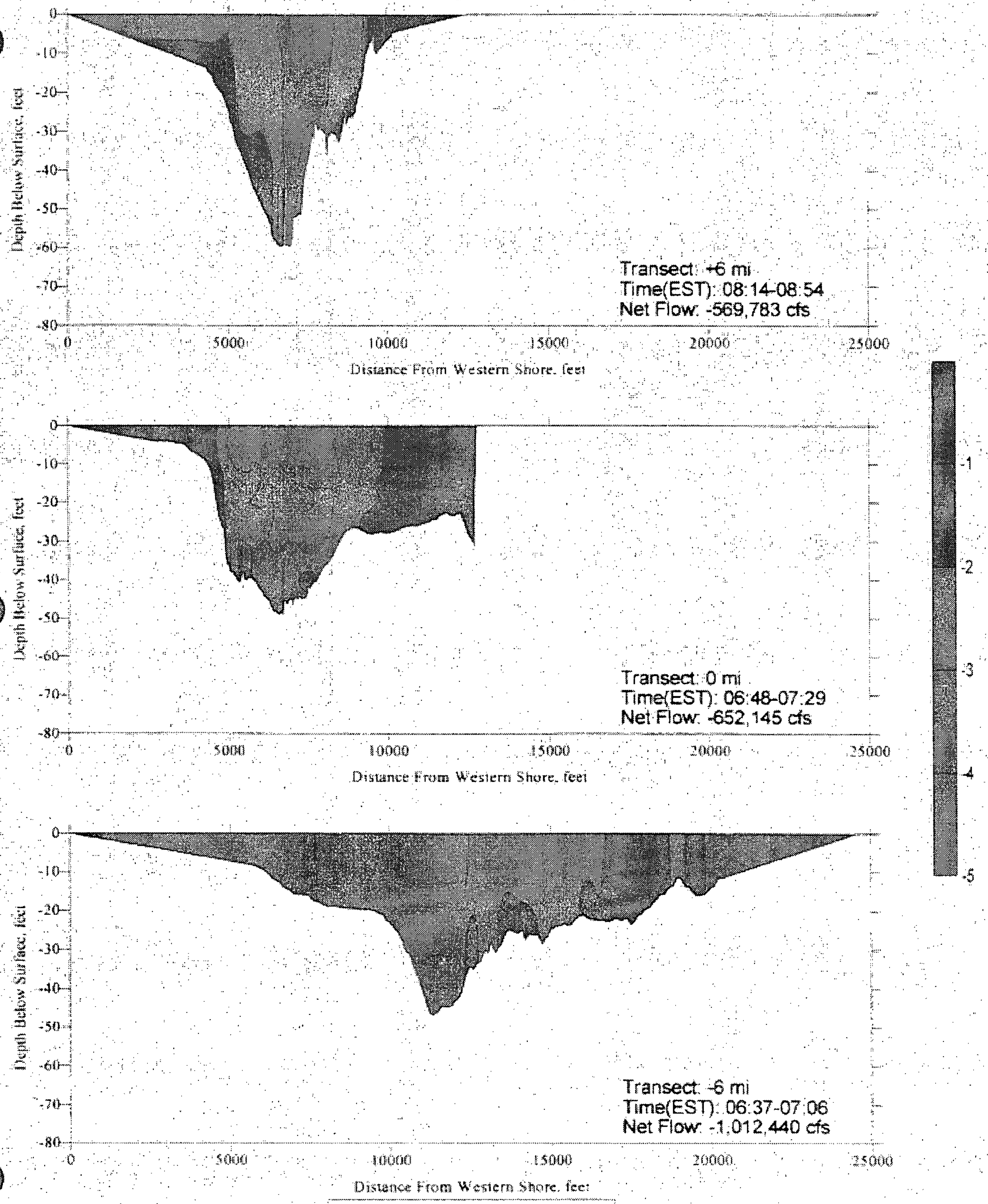


FIGURE 10-203

PSE&G 2-Unit Survey, 29 May 1998

Delaware River Velocity Profiles

EBB PHASE [06:40-08:40 (EST)]



Velocities were not measured at precisely the same phase of tide; care should be exercised in comparing one transect to another

Note: Velocities are in fps.

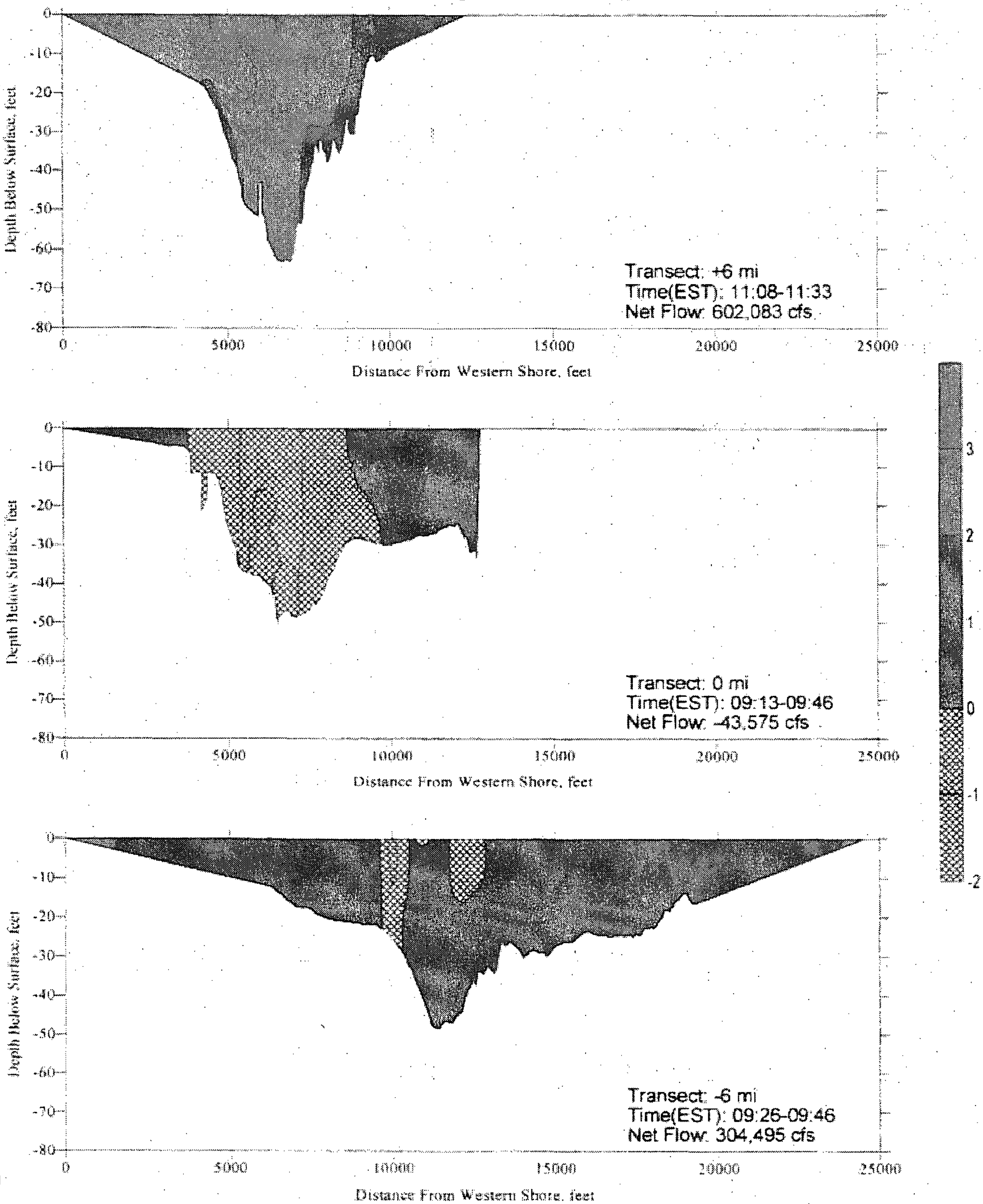
Transect locations are shown in Figure 10-1

FIGURE 10-204

PSE&G 2-Unit Survey; 29 May 1998

Delaware River Velocity Profiles

EOE PHASE [09:10-11:10 (EST)]

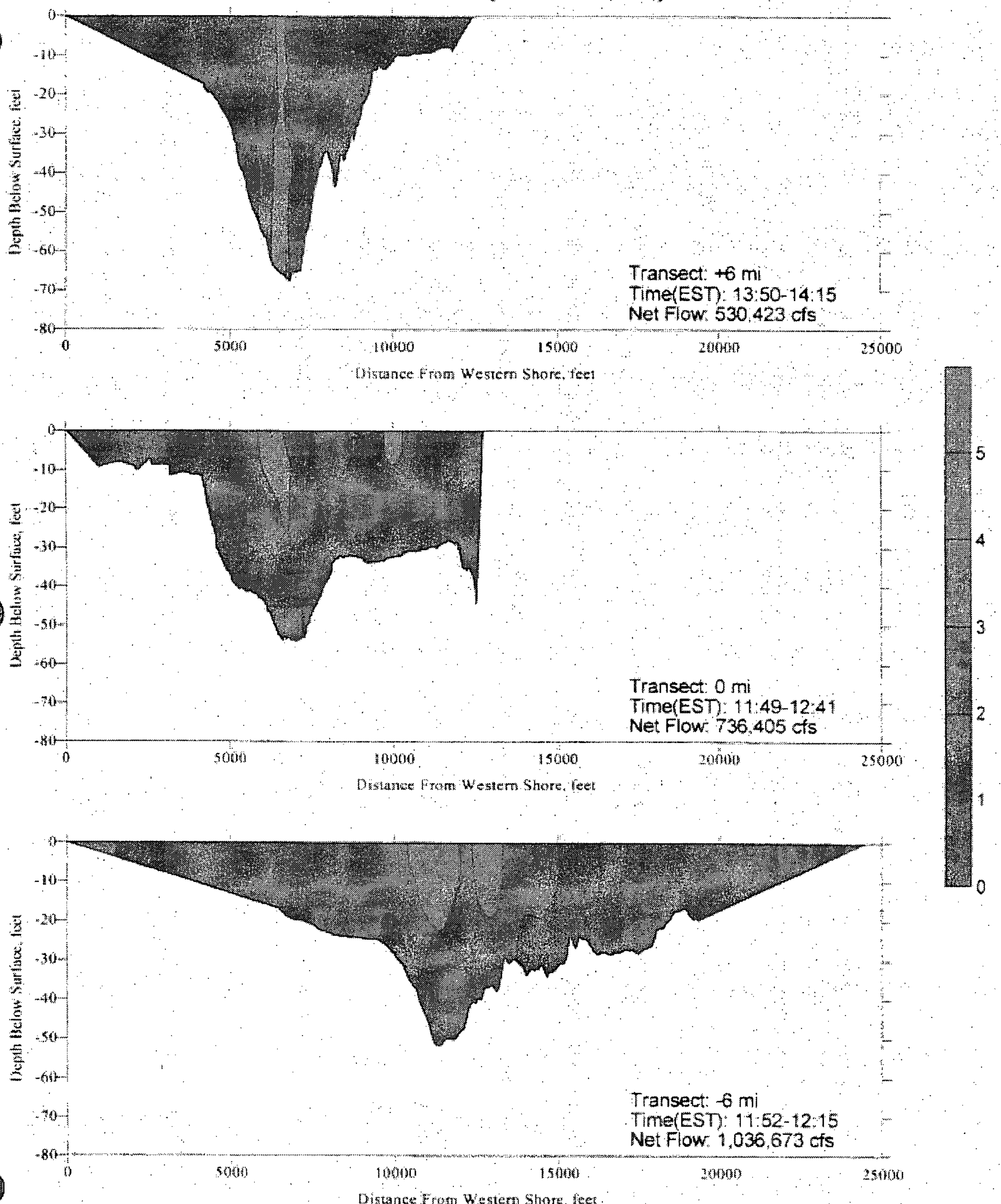


Velocities were not measured at precisely the same phase of tide: care should be exercised in comparing one transect to another.

Note: Velocities are in fps.

Transect locations are shown in Figure 10-1

FIGURE 10-205
PSE&G 2-Unit Survey; 29 May 1998
Delaware River Velocity Profiles
FLOOD PHASE [11:40-13:40 (EST)]



Velocities were not measured at precisely the same phase of tide; care should be exercised in comparing one transect to another.

Note: Velocities are in fps.

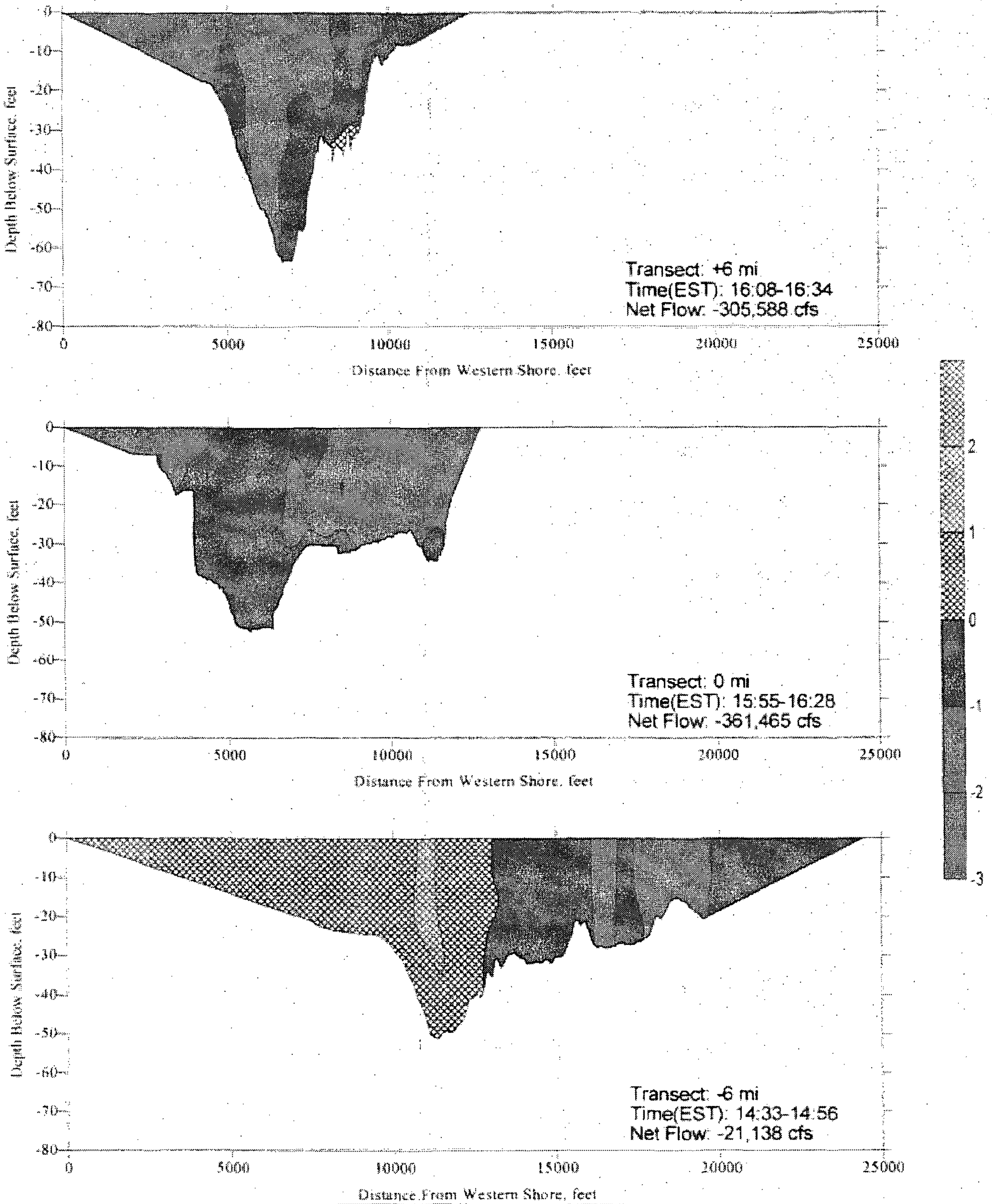
Transect locations are shown in Figure 10-1

FIGURE 10-206

PSE&G 2-Unit Survey: 29 May 1998

Delaware River Velocity Profiles

EOF PHASE [14:25-16:25 (EST)]



Velocities were not measured at precisely the same phase of tide; care should be exercised in comparing one transect to another.

Note: Velocities are in fps.
Transect locations are shown in Figure 10-1

FIGURE 10-207

PSE&G 2-Unit Survey: 30 May 1998
Alloway Creek
Vertical Temperature Profiles

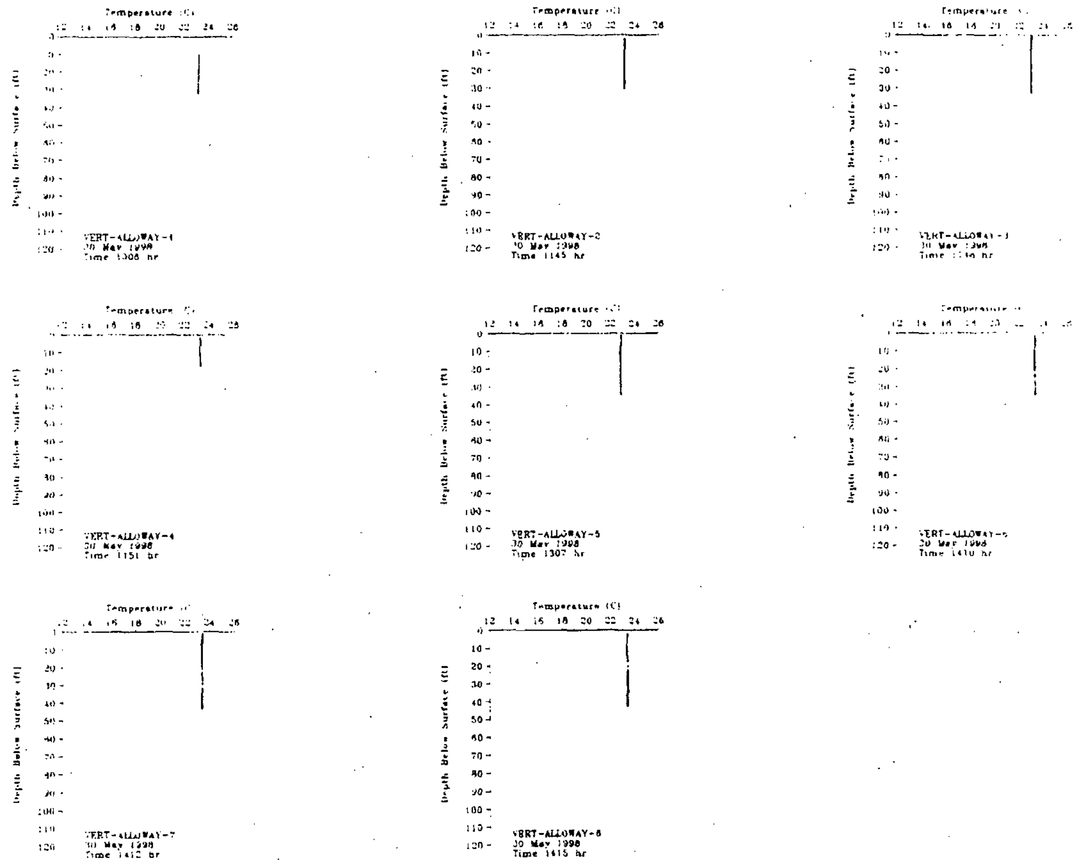


FIGURE 10-208
PSE&G 2-Unit Survey; 30 May 1998
Alloway Creek
Vertical Salinity Profiles

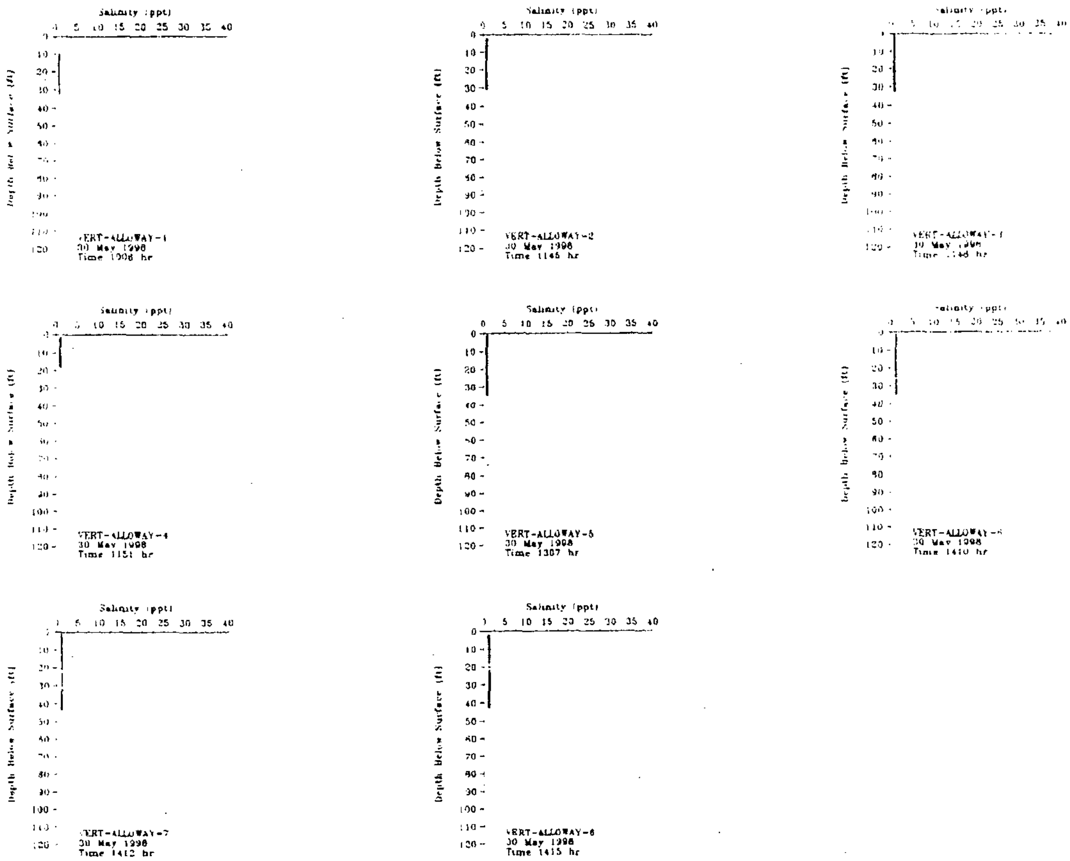


FIGURE 10-209

PSE&G 2-Unit Survey: 30 May 1998
Alloway Creek
Vertical Dye Profiles

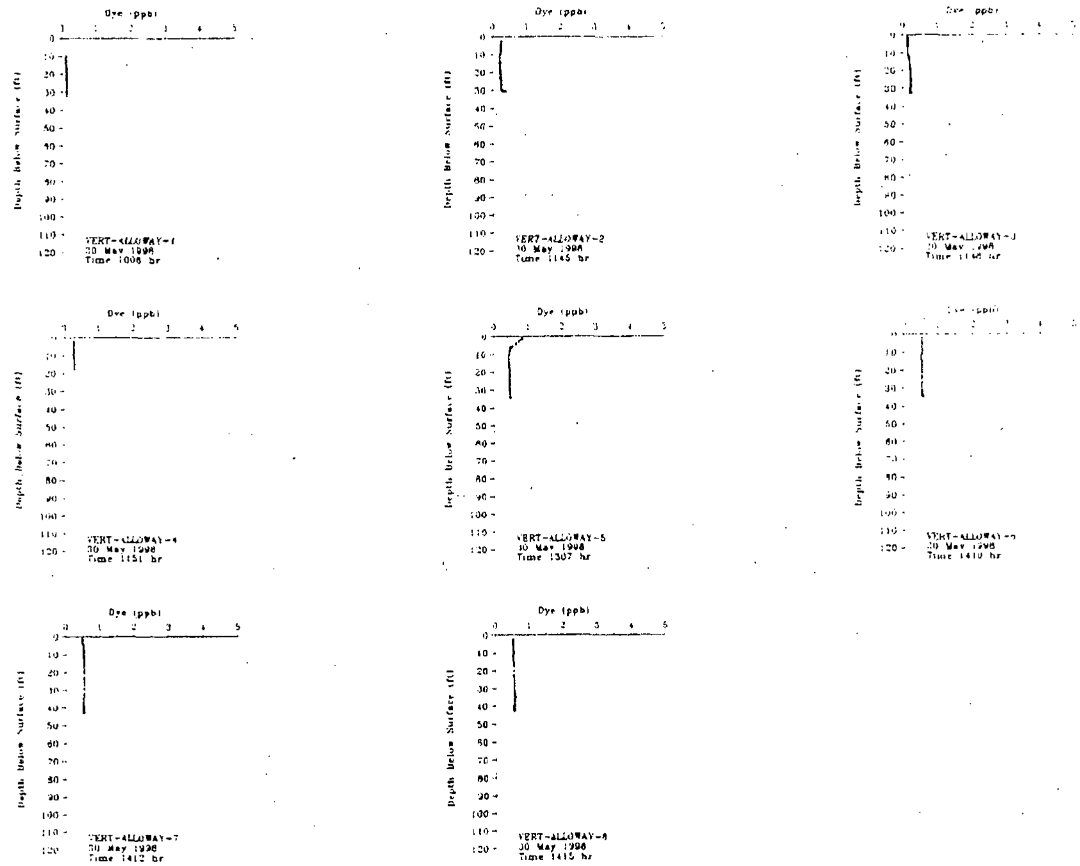


FIGURE 10-210

PSE&G 2-Unit Survey: 30 May 1998

Hope Creek

Vertical Temperature Profiles

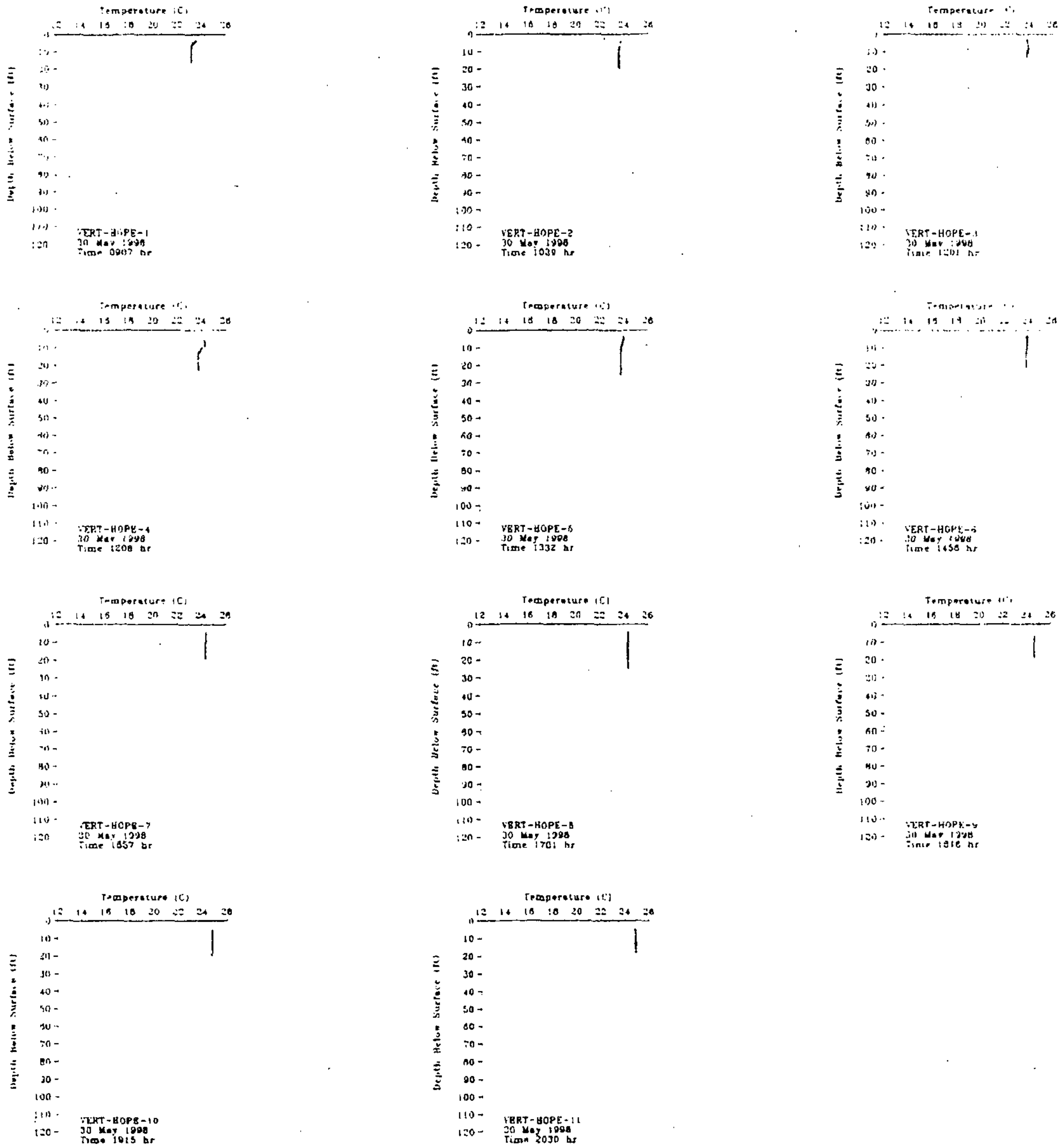


FIGURE 10-211

PSE&G 2-Unit Survey: 30 May 1998
Hope Creek
Vertical Salinity Profiles

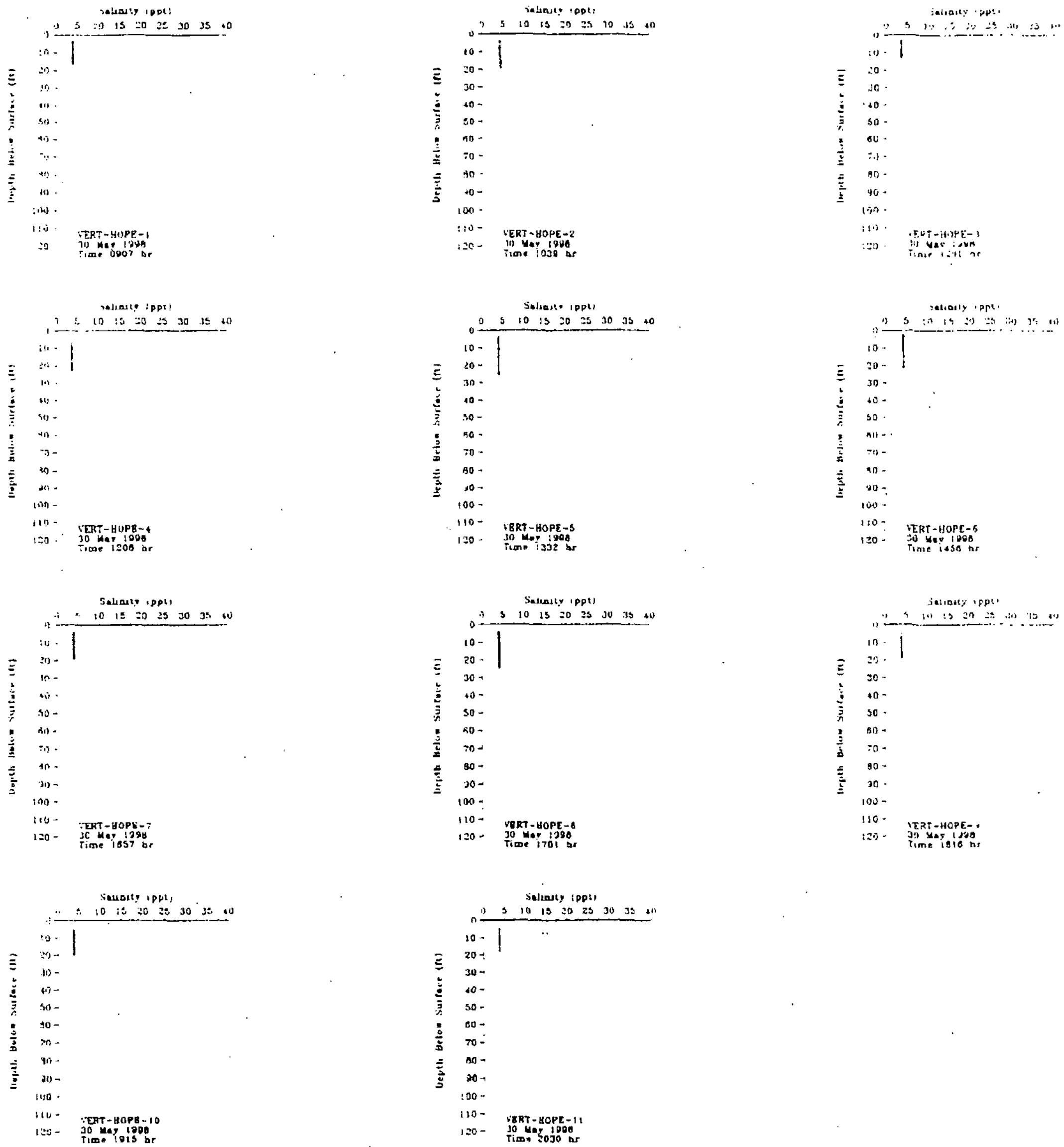


FIGURE 10-212

PSE&G 2-Unit Survey: 30 May 1998
Hope Creek
Vertical Dye Profiles

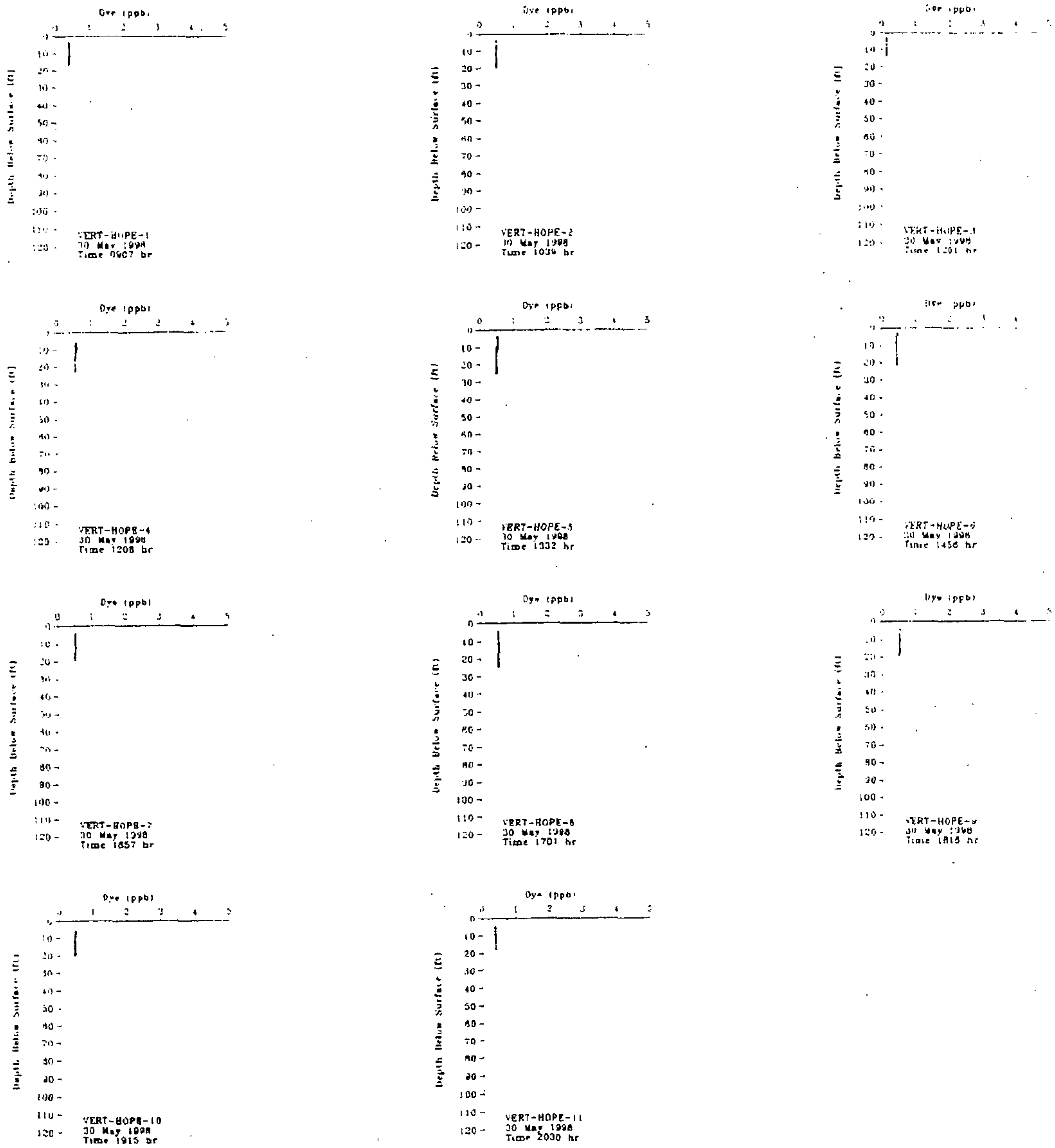


FIGURE 10-213

PSE&G 2-Unit Survey: 30 May 1998
Madhorse Creek
Vertical Temperature Profiles

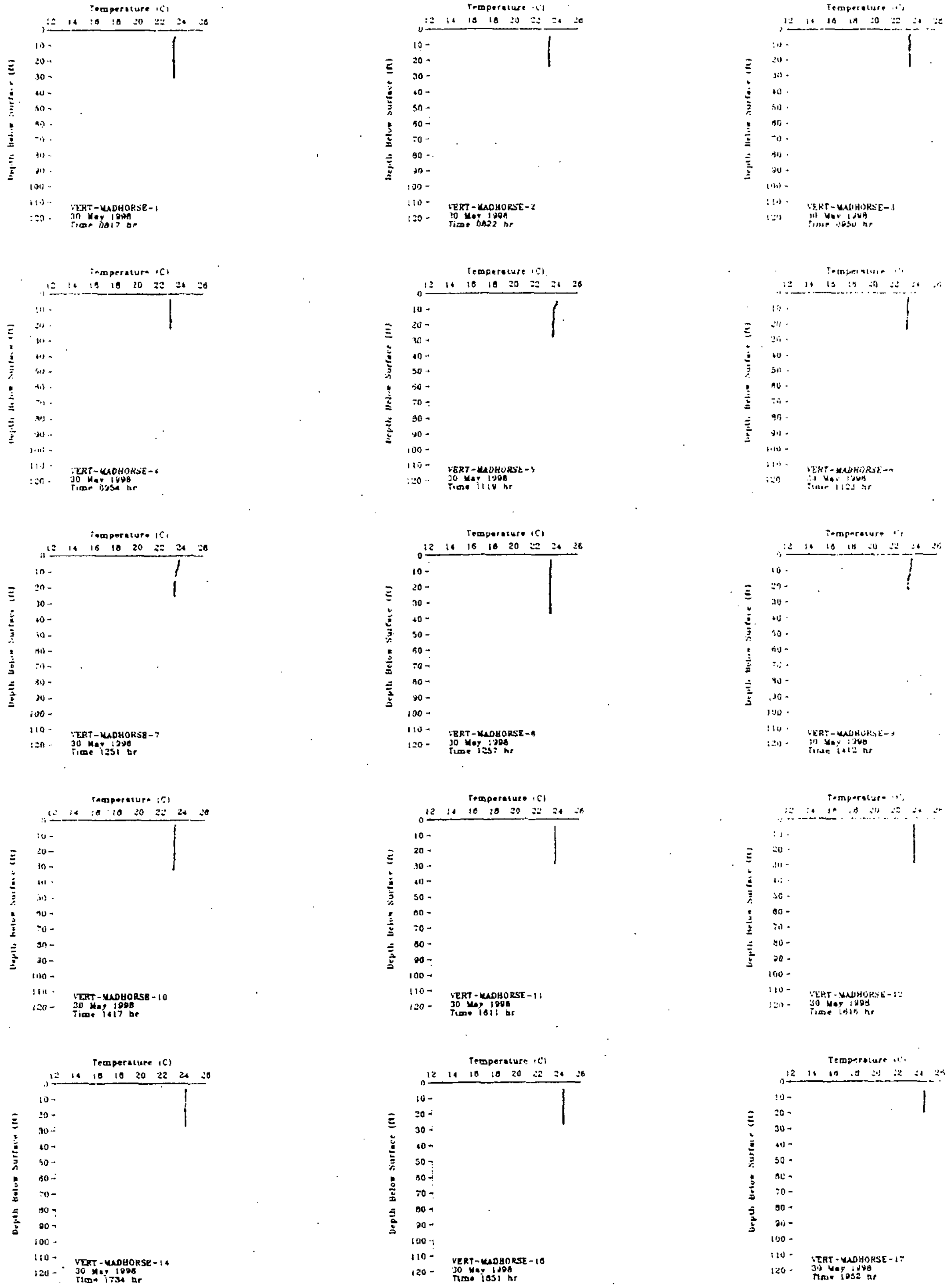


FIGURE 10-214

PSE&G 2-Unit Survey: 30 May 1998
Madhorse Creek
Vertical Salinity Profiles

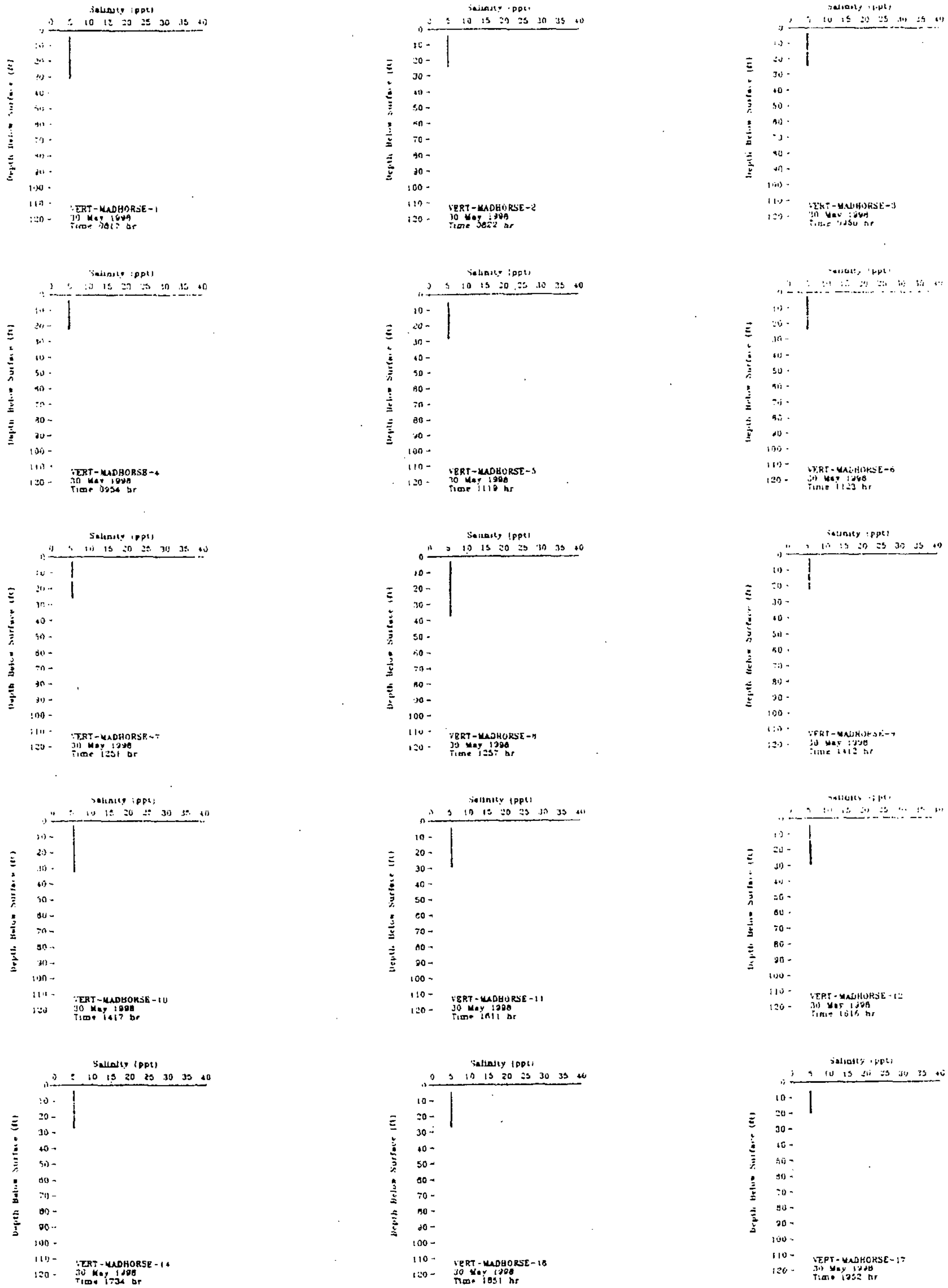


FIGURE 10-215

PSE&G 2-Unit Survey: 30 May 1998
Madhorse Creek
Vertical Dye Profiles

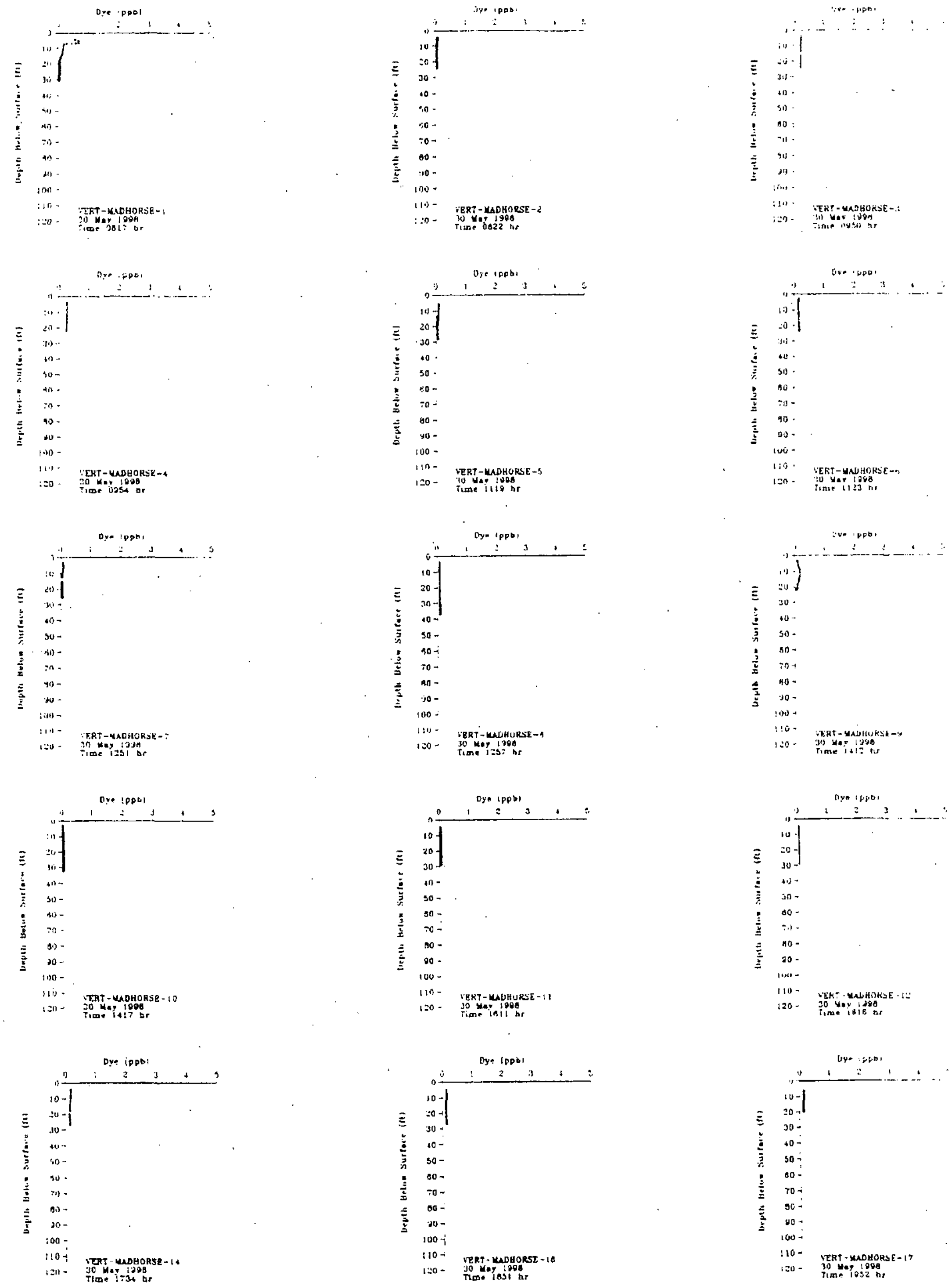


FIGURE 10-216

PSE&G 2-Unit Survey: 29 June 1998
Alloway Creek
Vertical Temperature Profiles

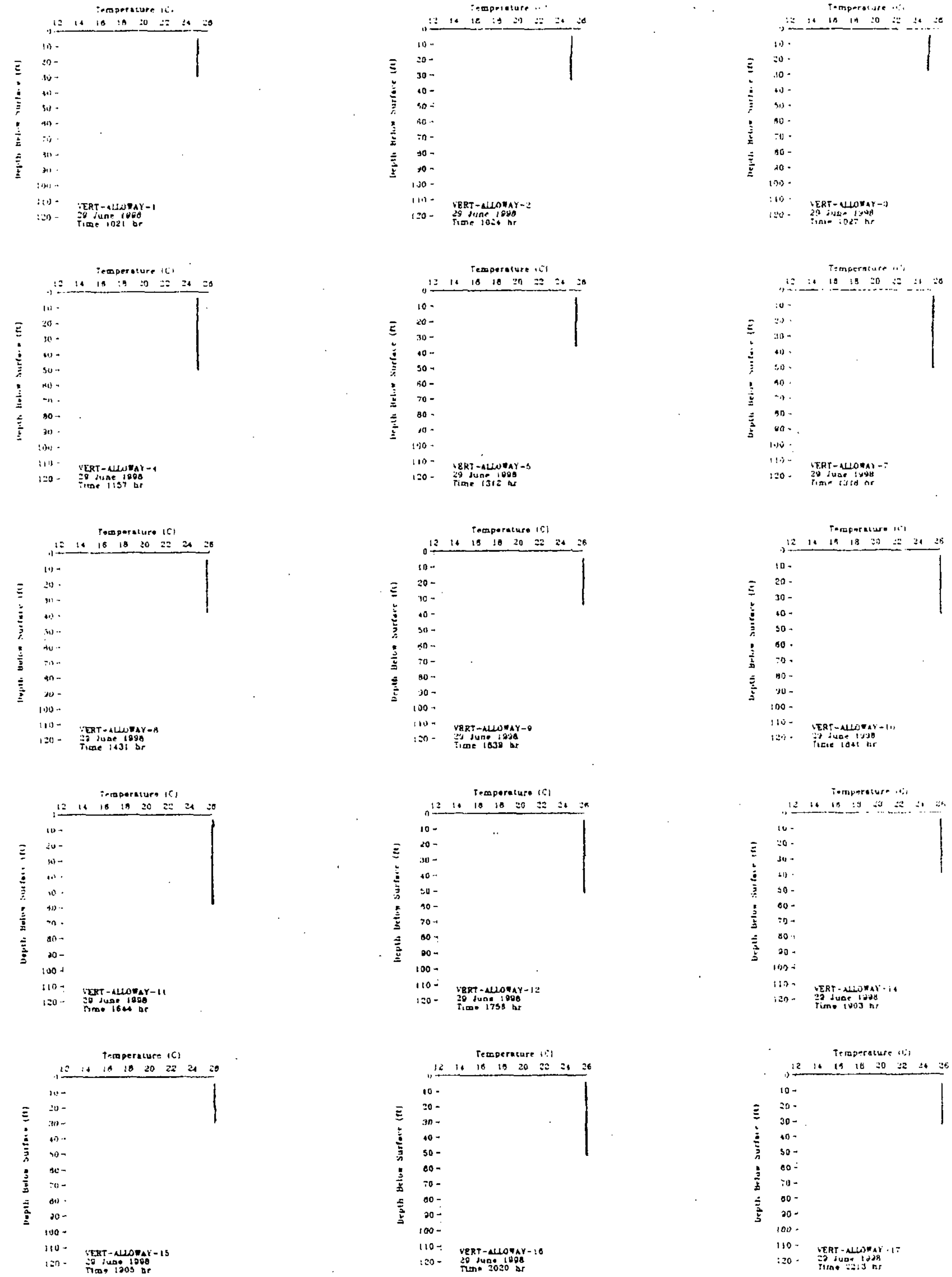


FIGURE 10-217

PSE&G 2-Unit Survey: 29 June 1998
Alloway Creek
Vertical Salinity Profiles

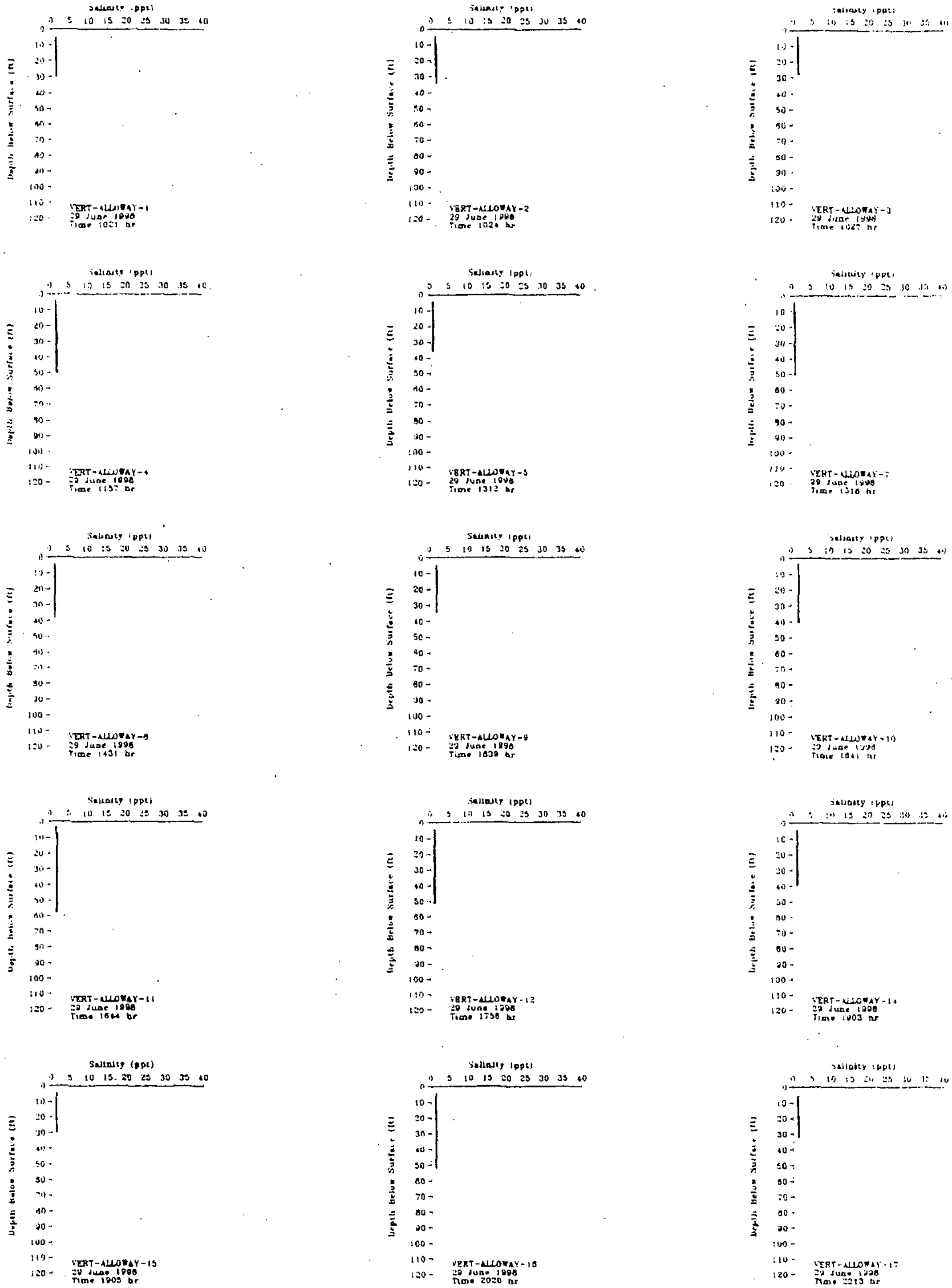


FIGURE 10-218

PSE&G 2-Unit Survey: 29 June 1998
Hope Creek
Vertical Temperature Profiles

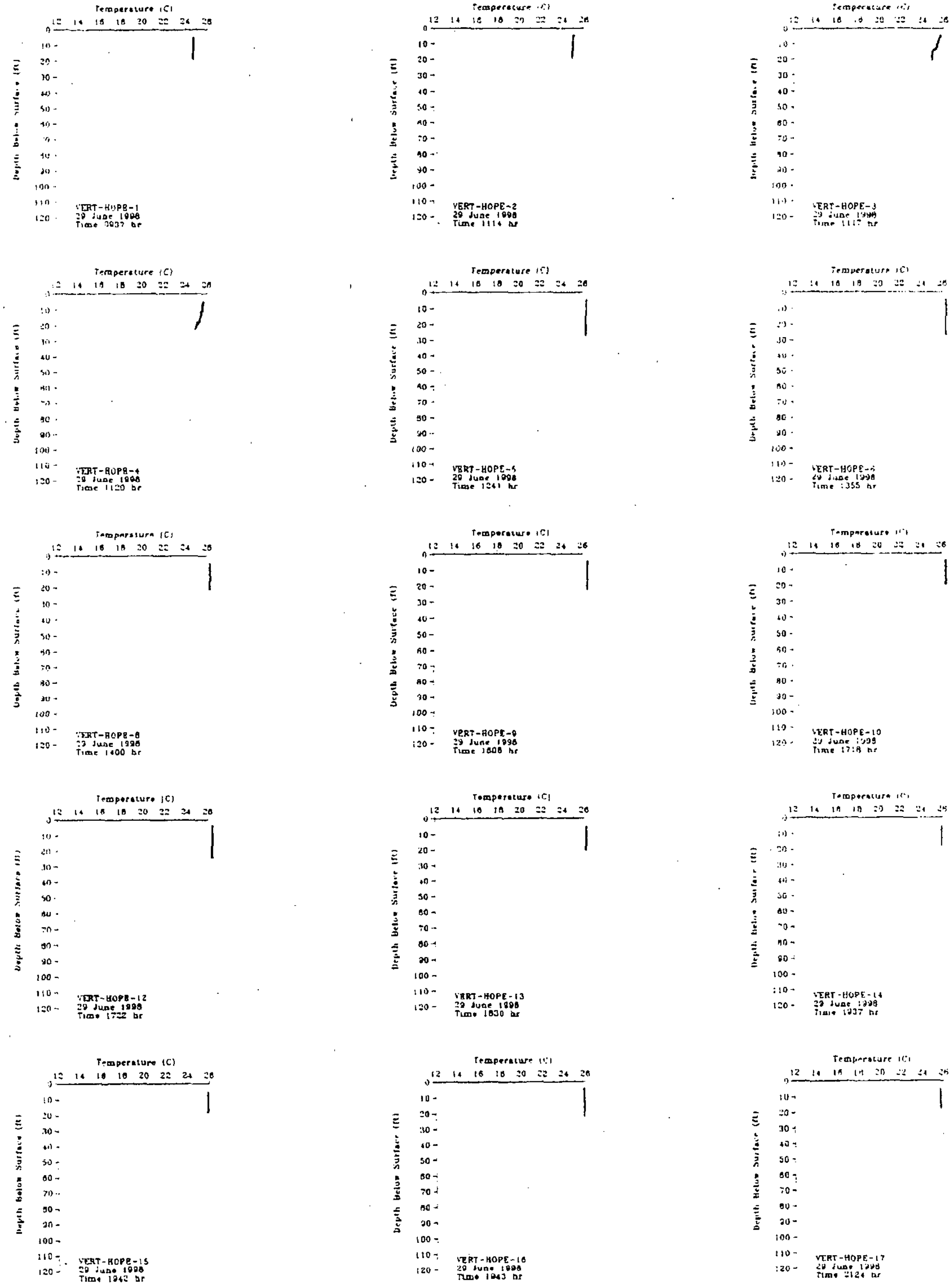


FIGURE 10-219

PSE&G 2-Unit Survey: 29 June 1998
Hope Creek
Vertical Salinity Profiles

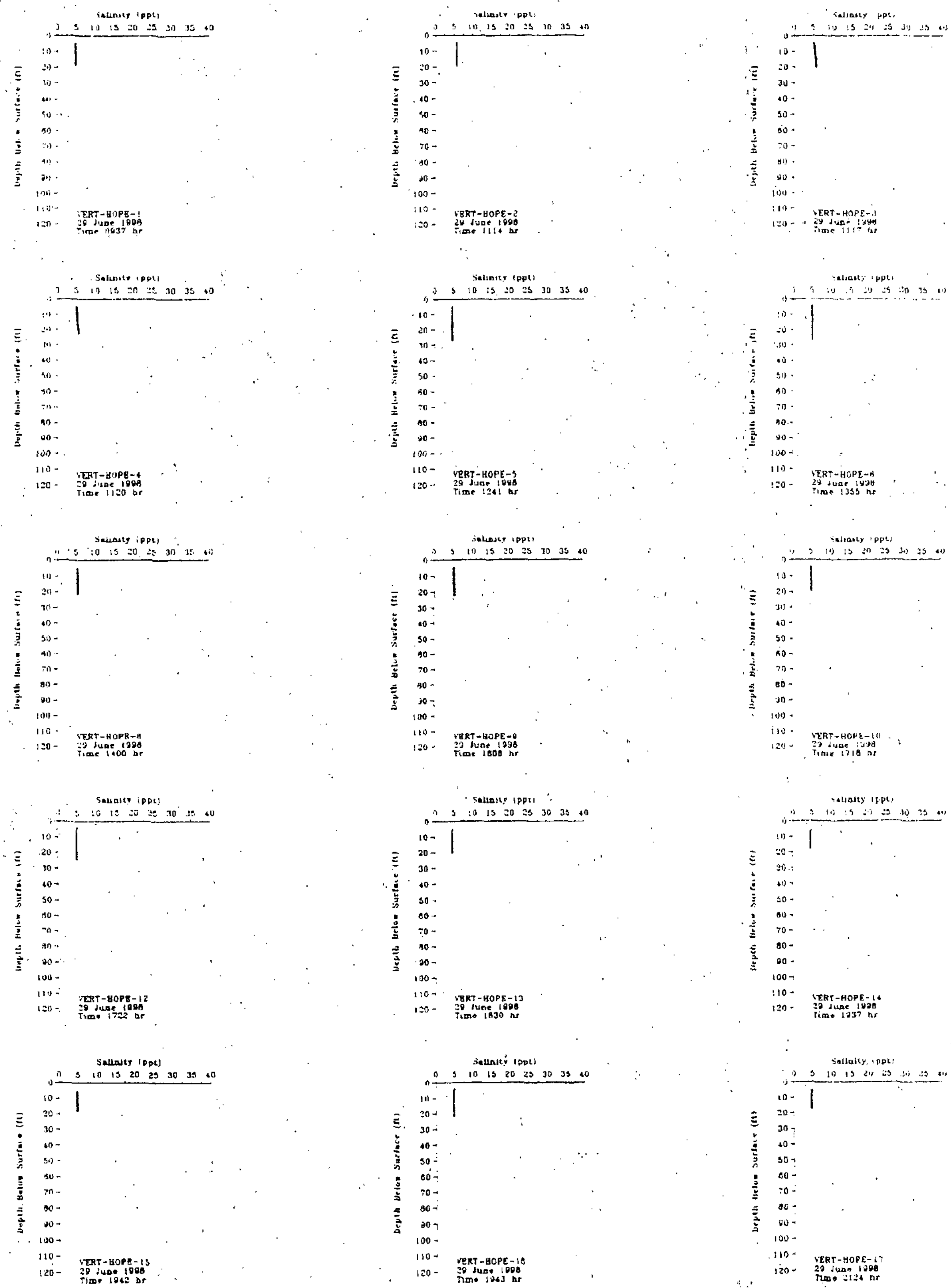
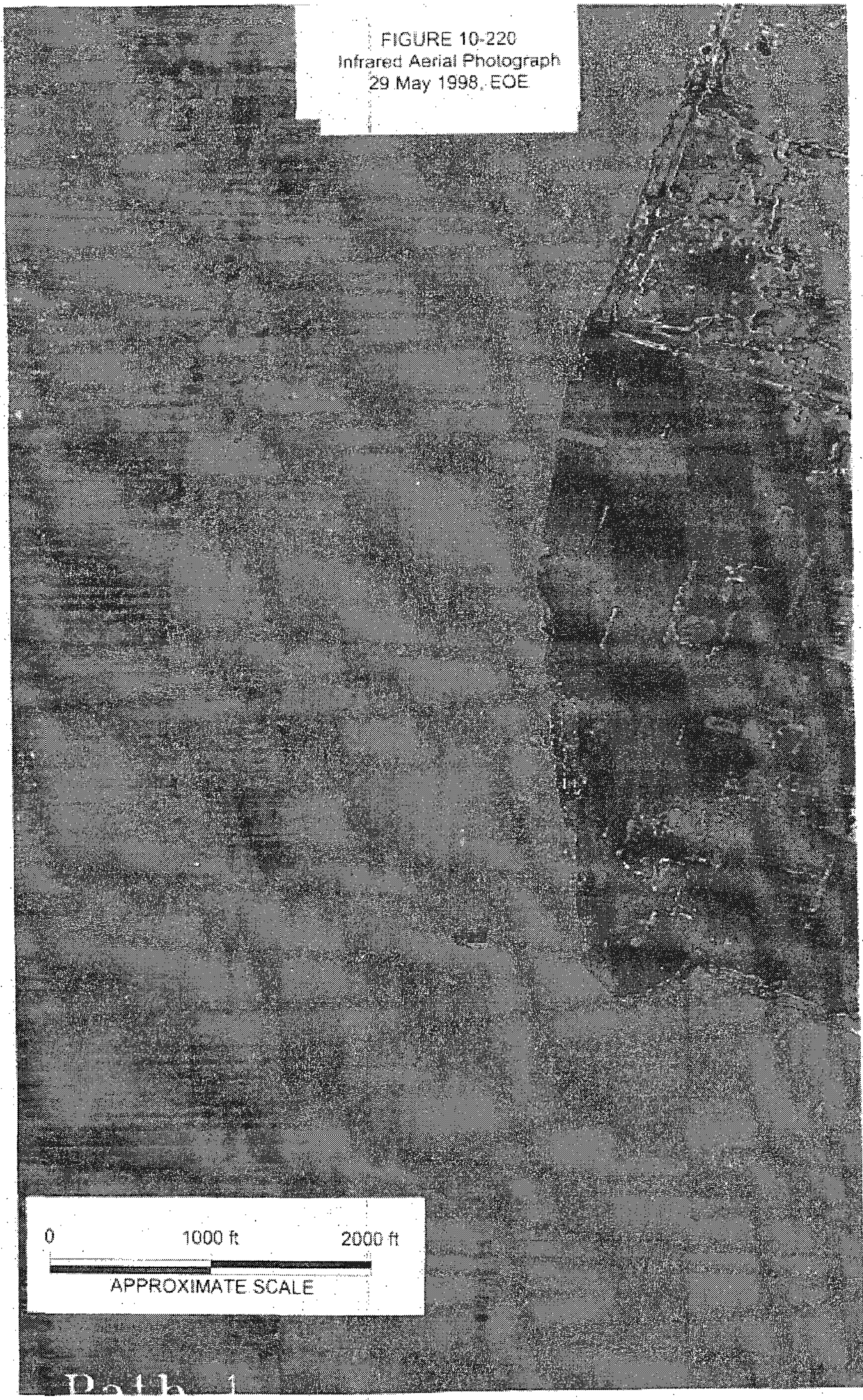


FIGURE 10-220
Infrared Aerial Photograph
29 May 1998, EOE



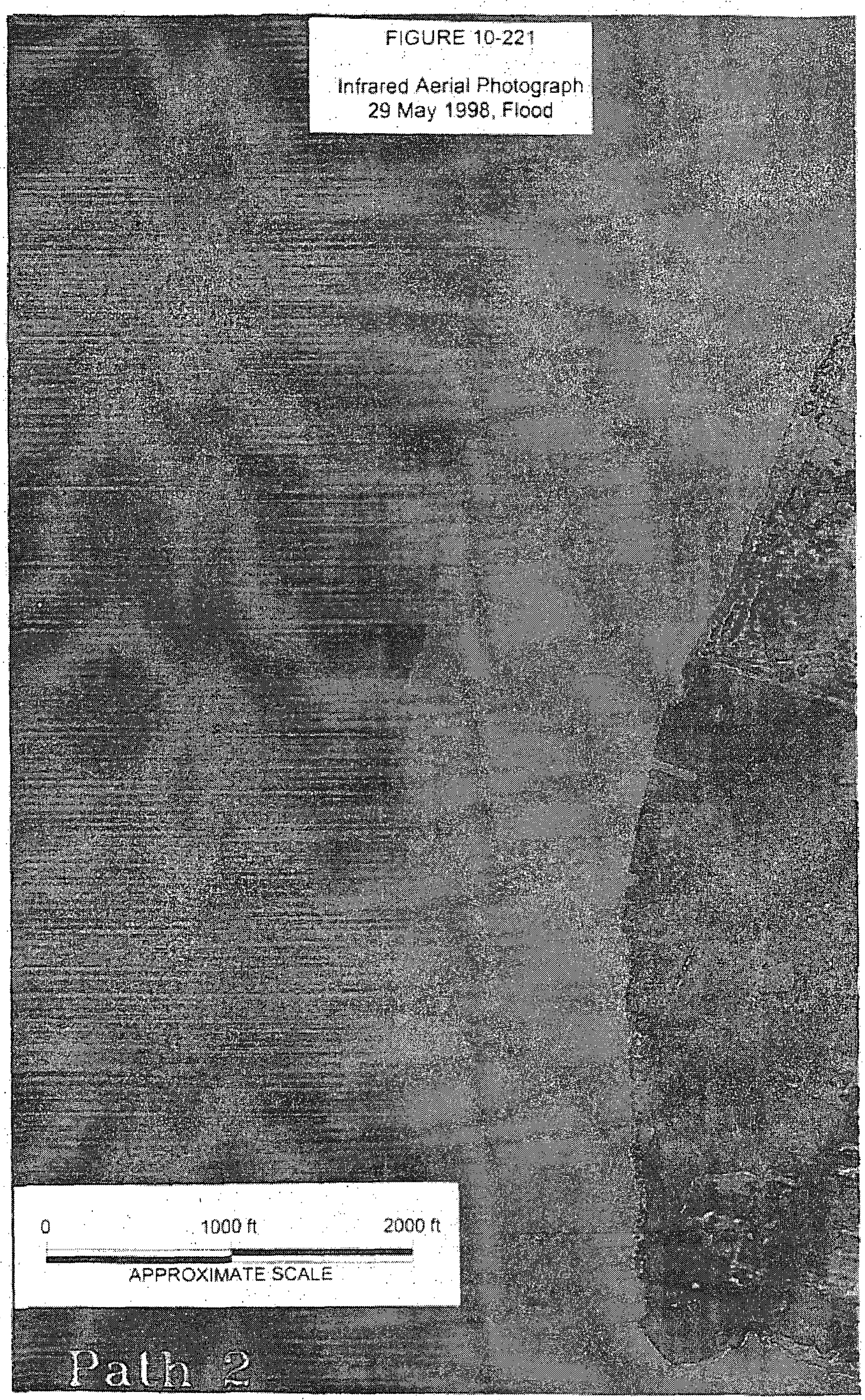
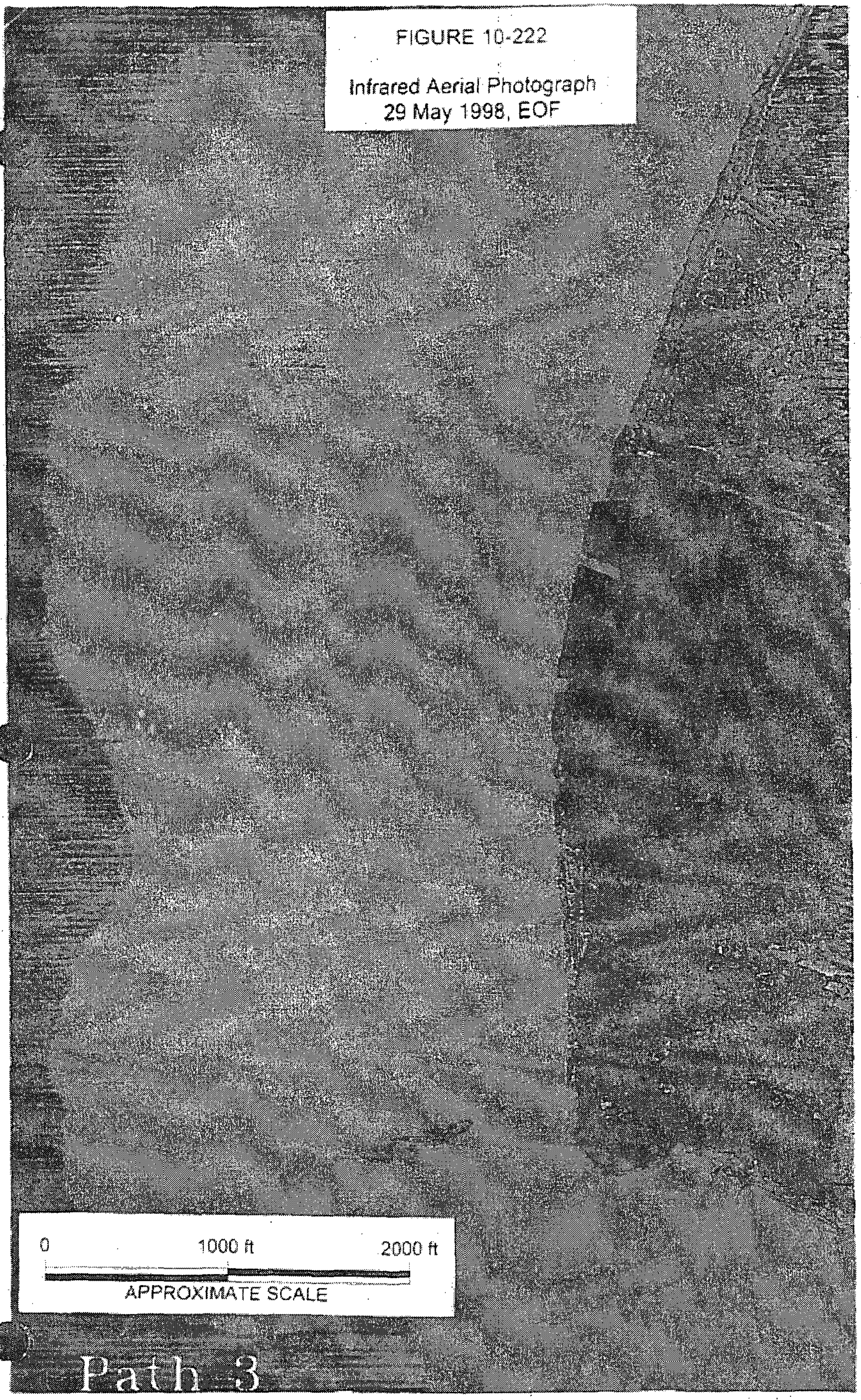


FIGURE 10-221

Infrared Aerial Photograph
29 May 1998, Flood

FIGURE 10-222

Infrared Aerial Photograph
29 May 1998, EOF



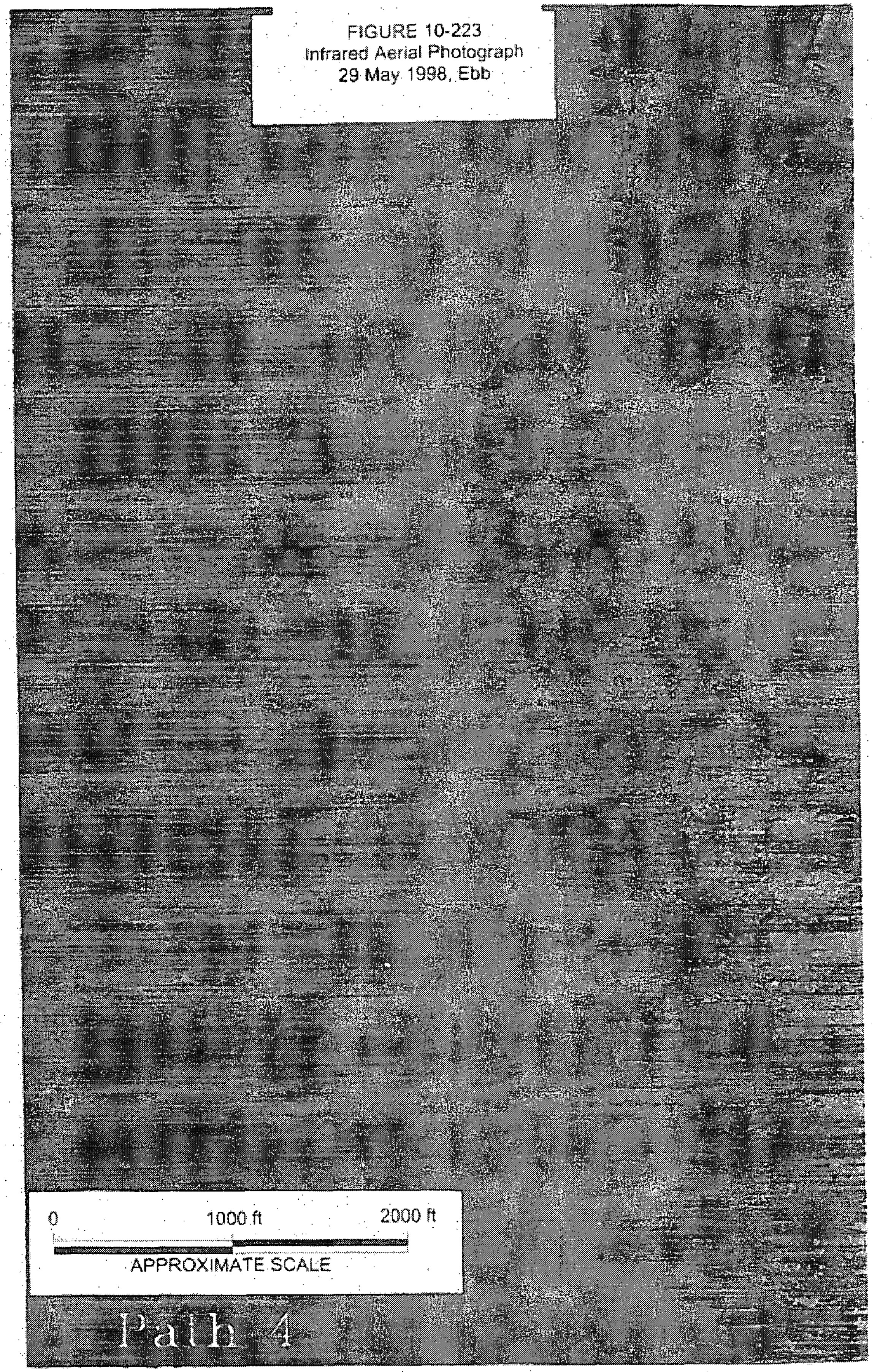
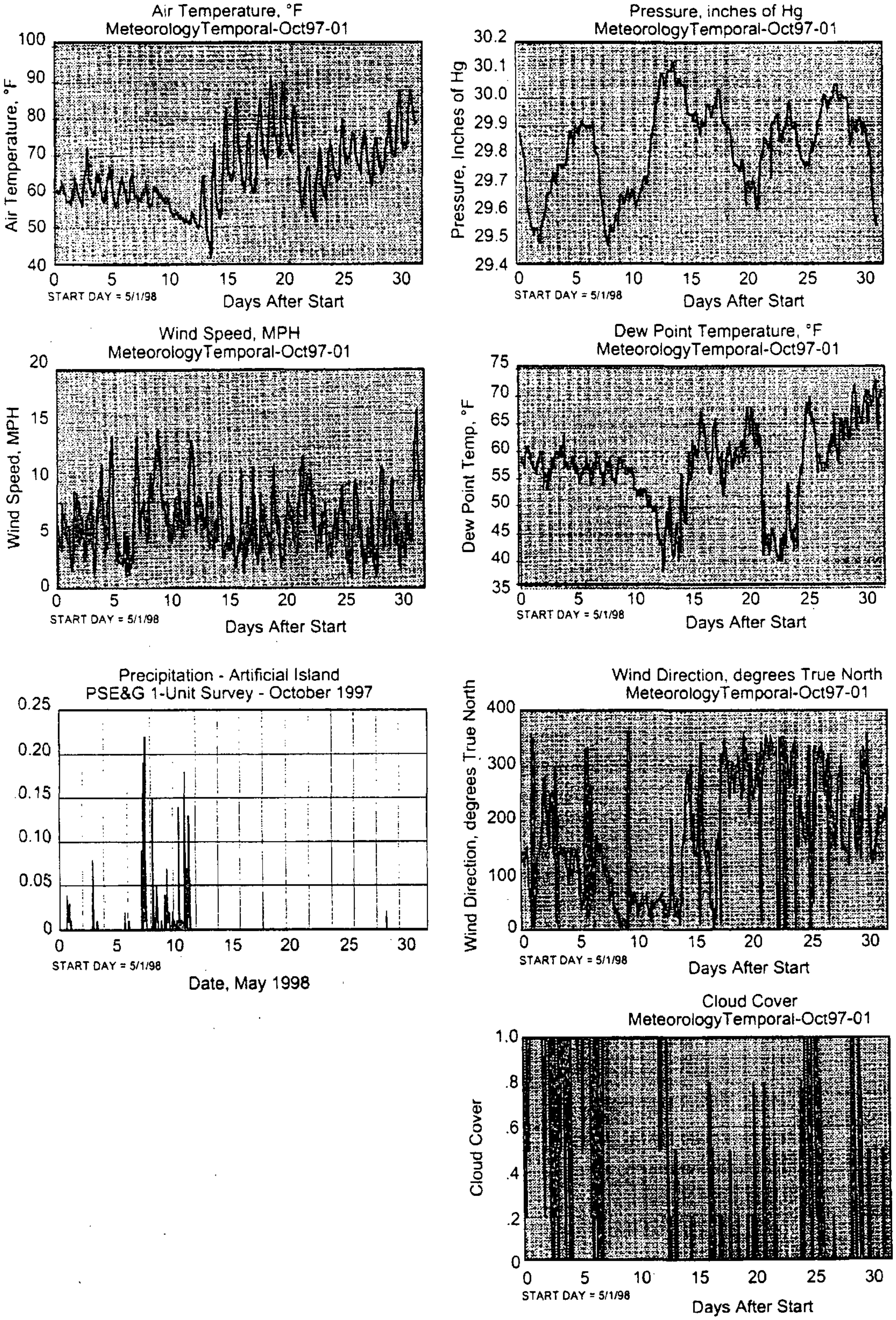


FIGURE 10-223
Infrared Aerial Photograph
29 May 1998, Ebb

Figure 10-224

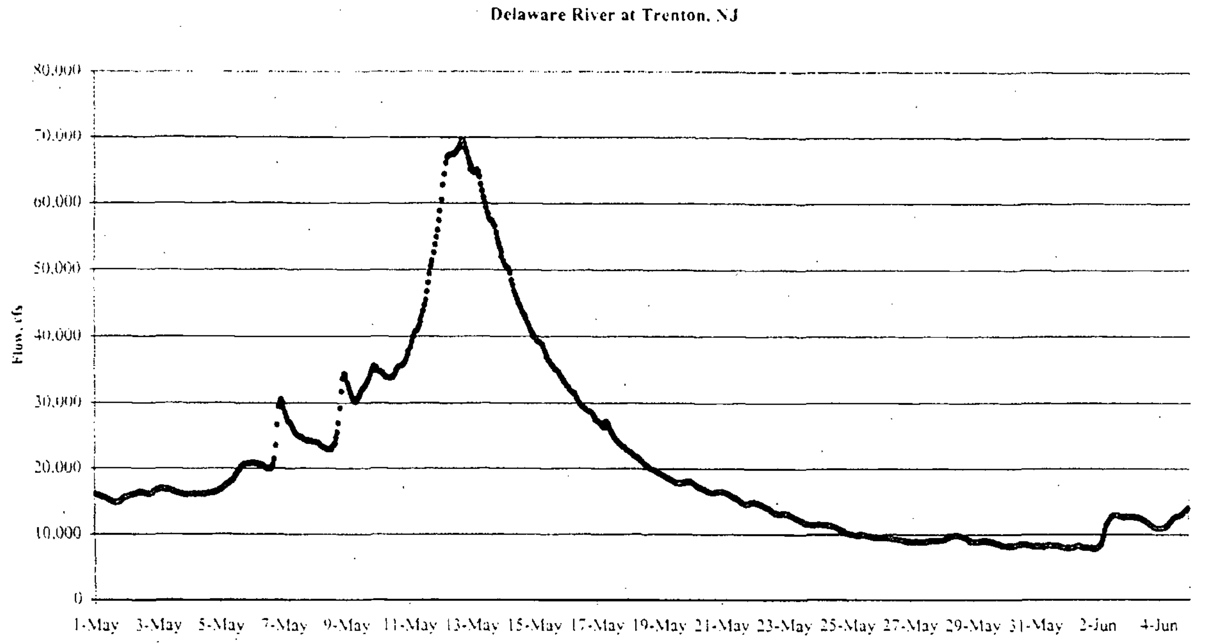
Meteorological Data Collected During 2-Unit Survey



Source: PSE&G Artificial Island Station except dew point temperature, which is collected by the National Weather Service at Wilmington Airport.

FIGURE 10-225

Freshwater Flow Profiles
01 May - 04 June 1998



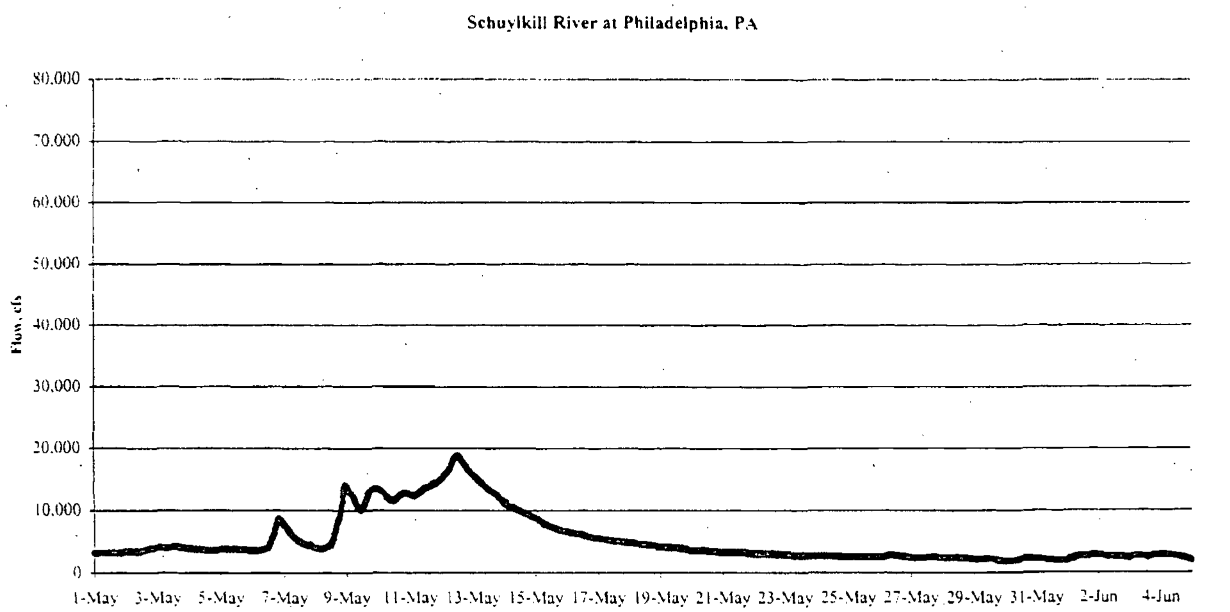


Figure 10-226
Six-Month Mooring Stations
Moorings Locations

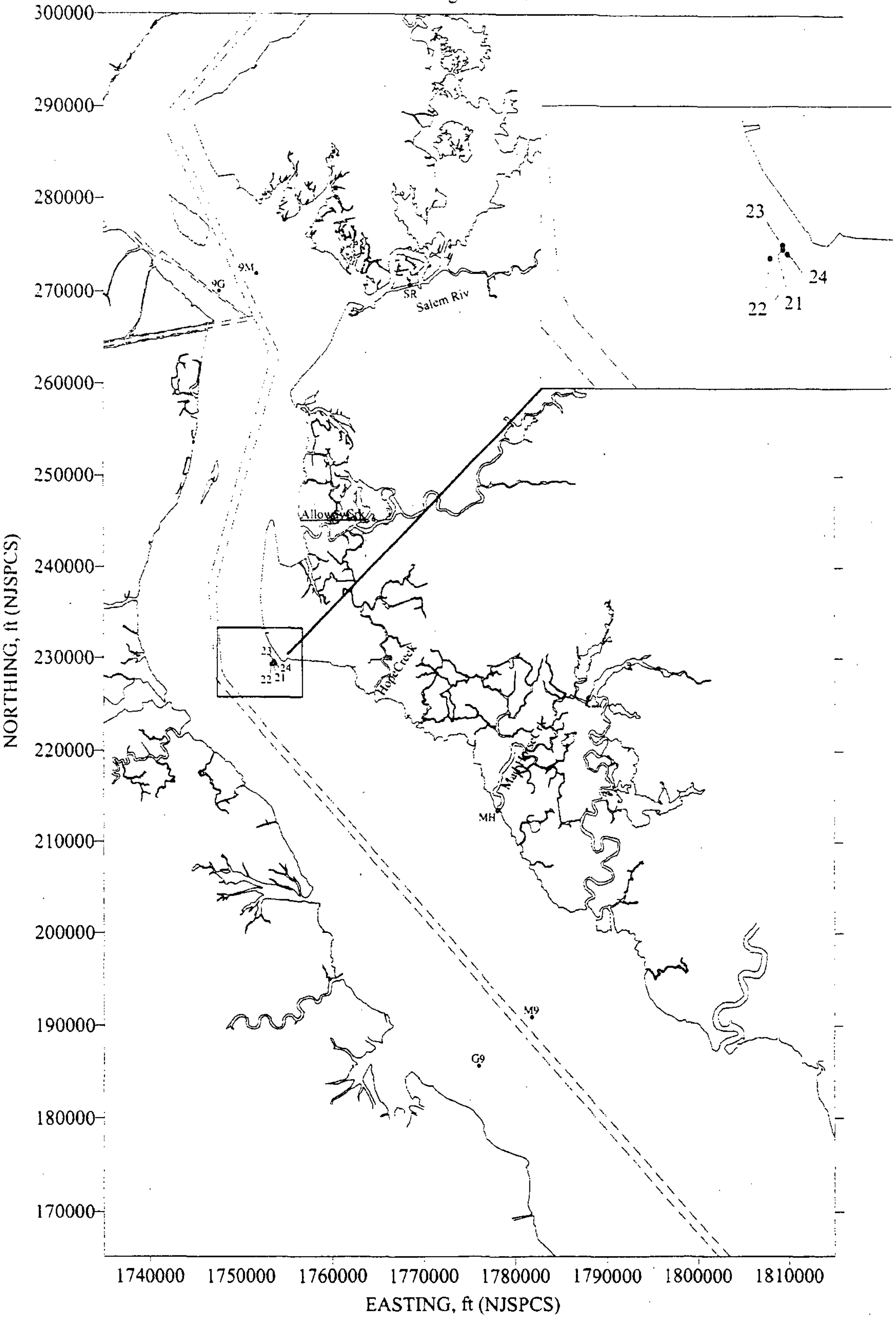


FIGURE 10-227

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
SALEMRIVER

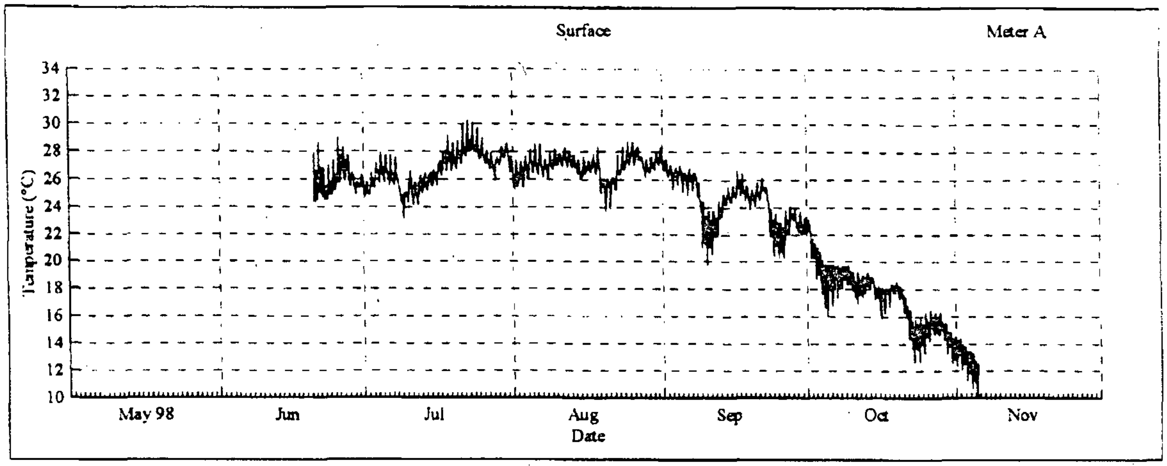


FIGURE 10-228

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
SALEMRIVER

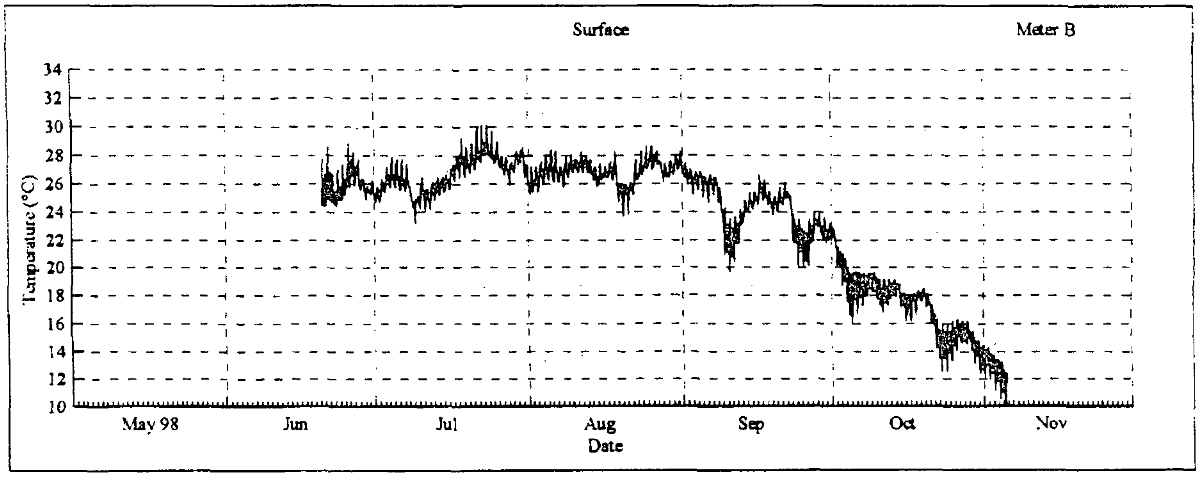


FIGURE 10-229

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
MADHORSECRK

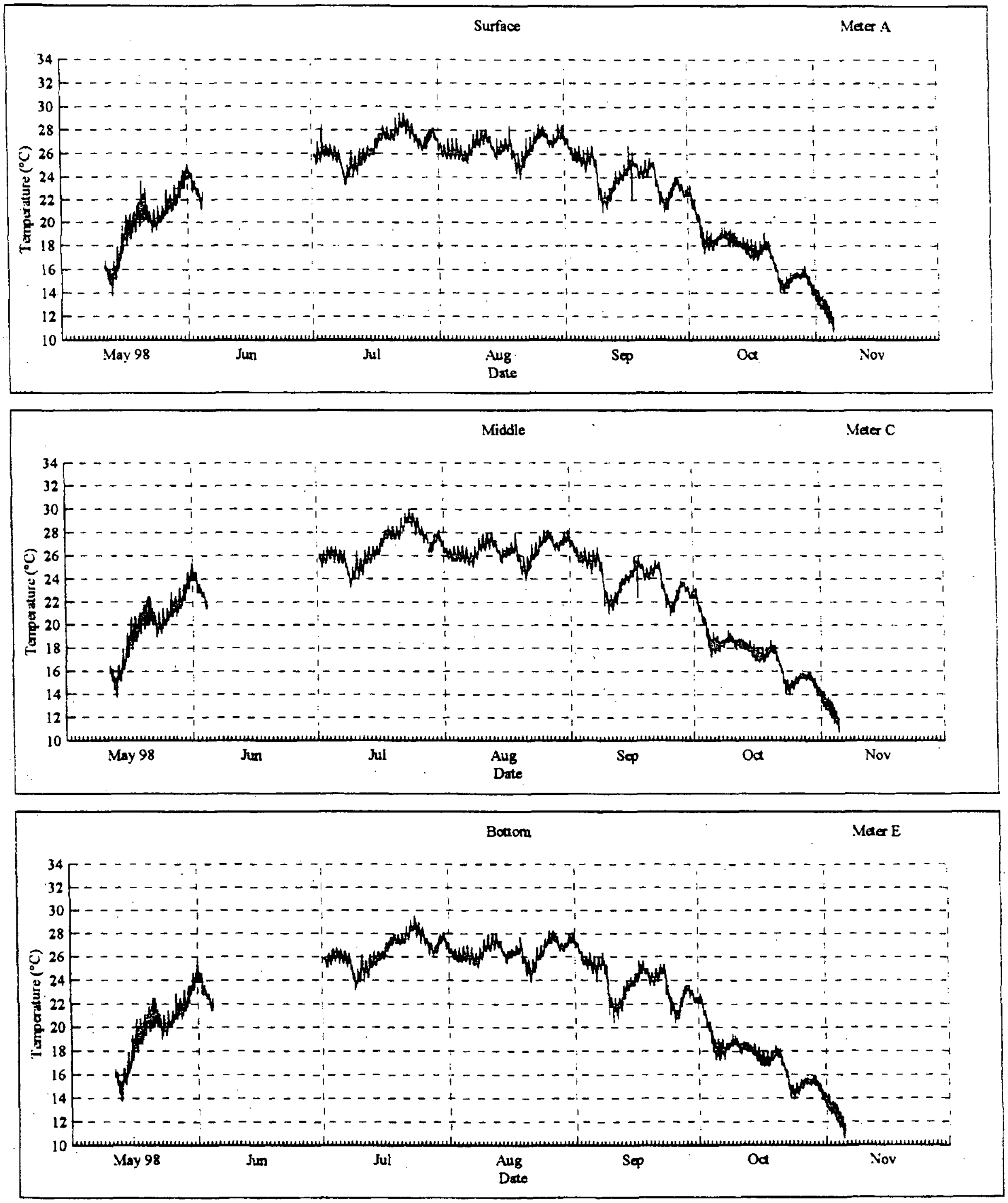


FIGURE 10-230

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
MADHORSECRK

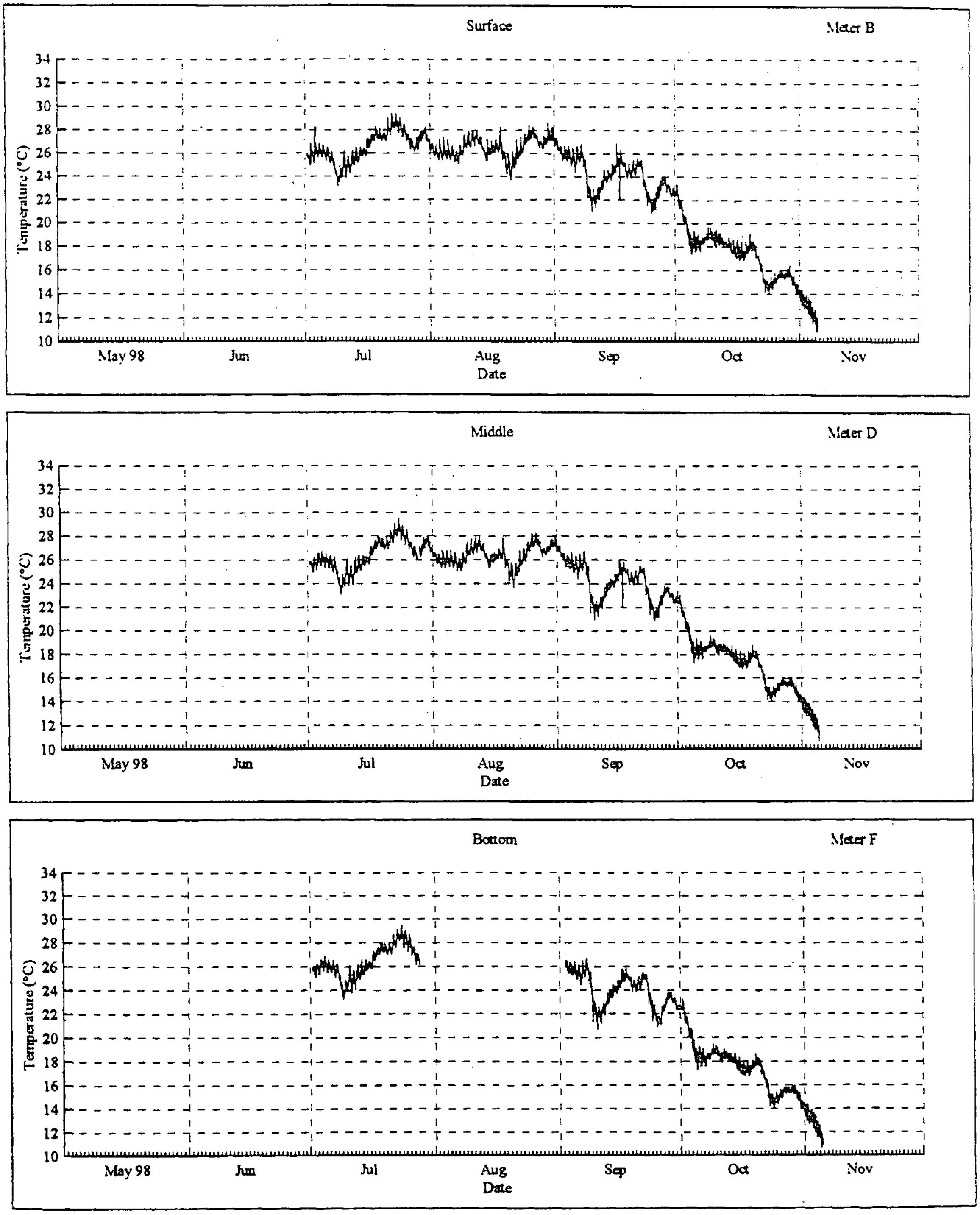


FIGURE 10-231

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-21

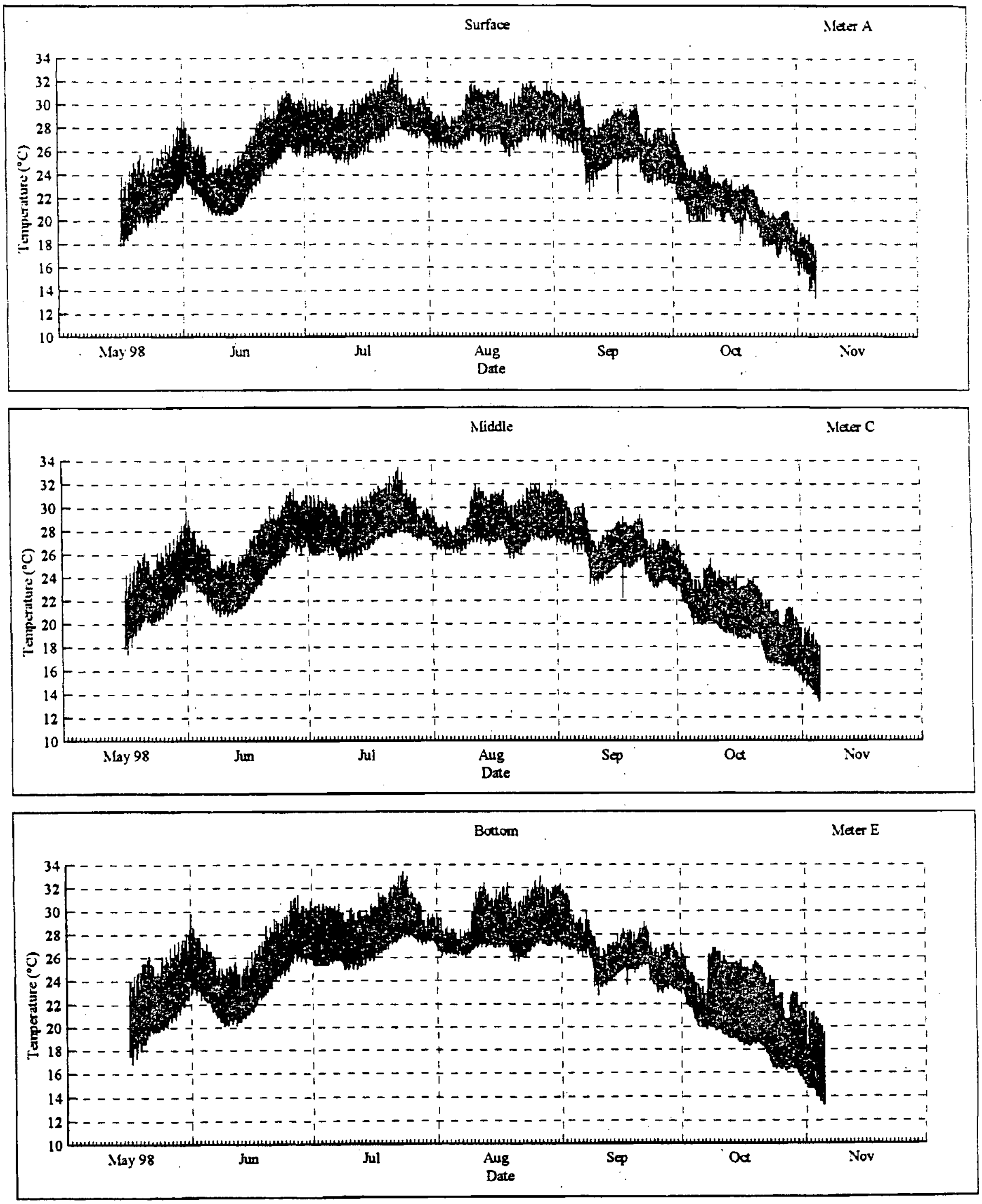


FIGURE 10-232

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-21

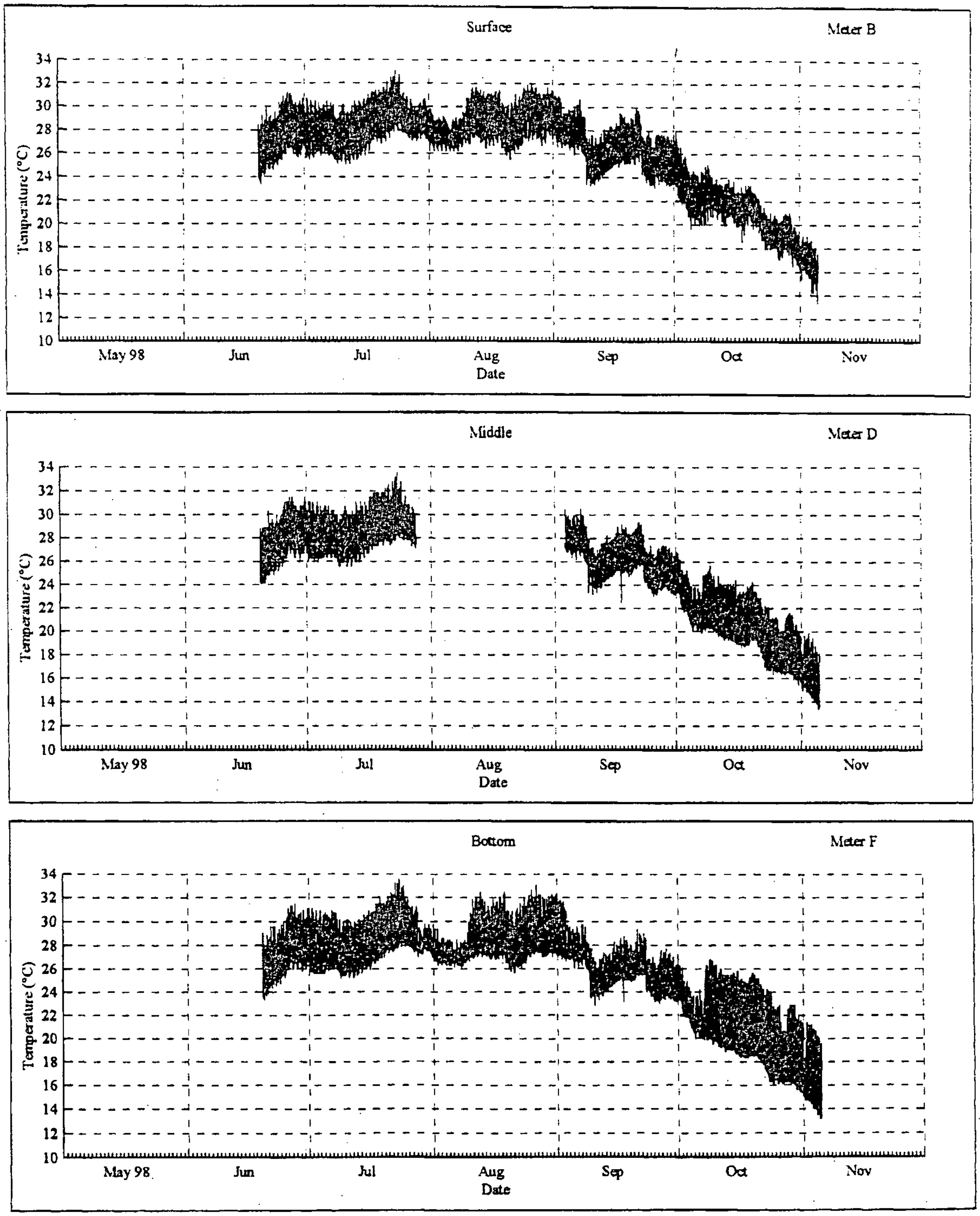


FIGURE 10-233

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-22

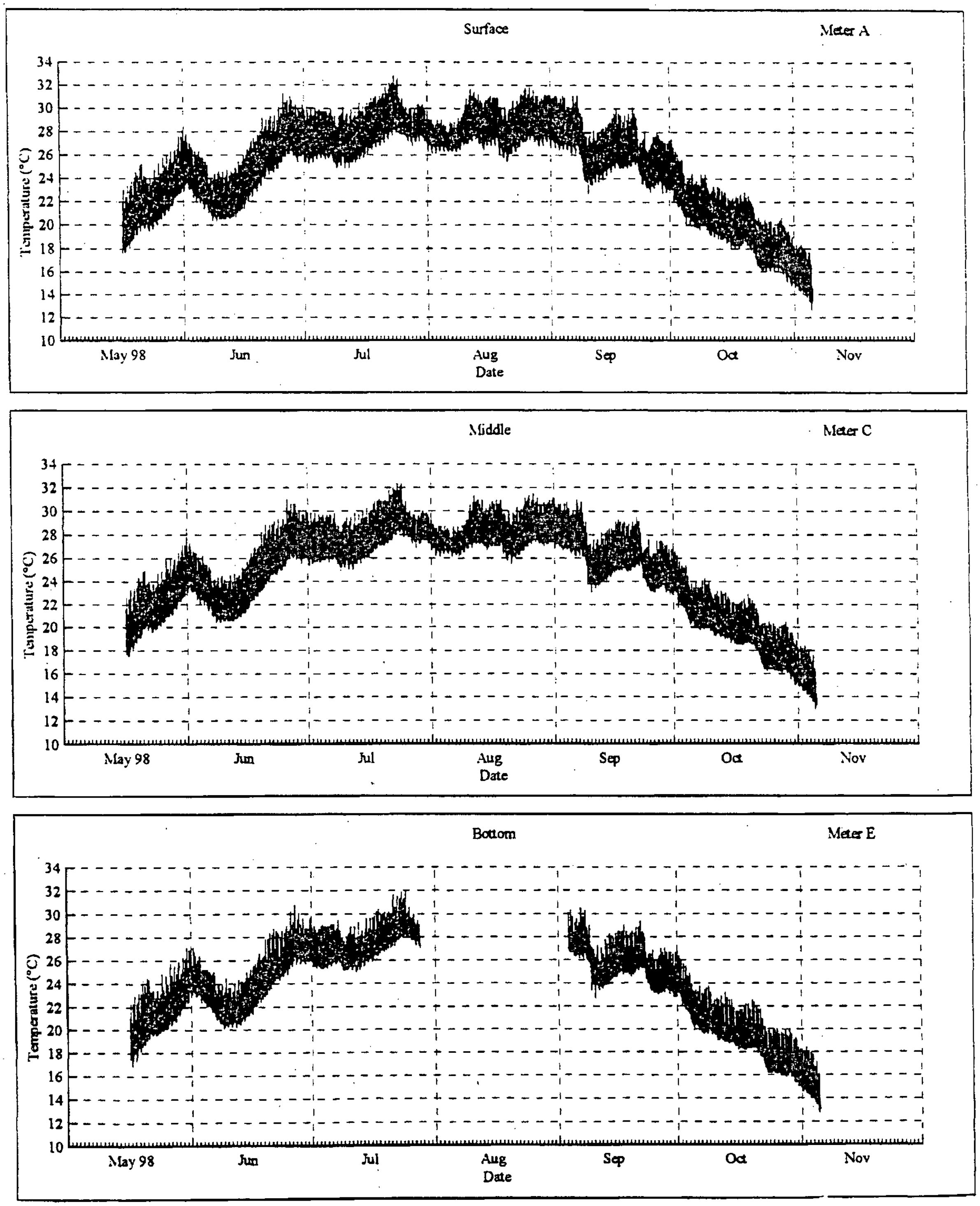
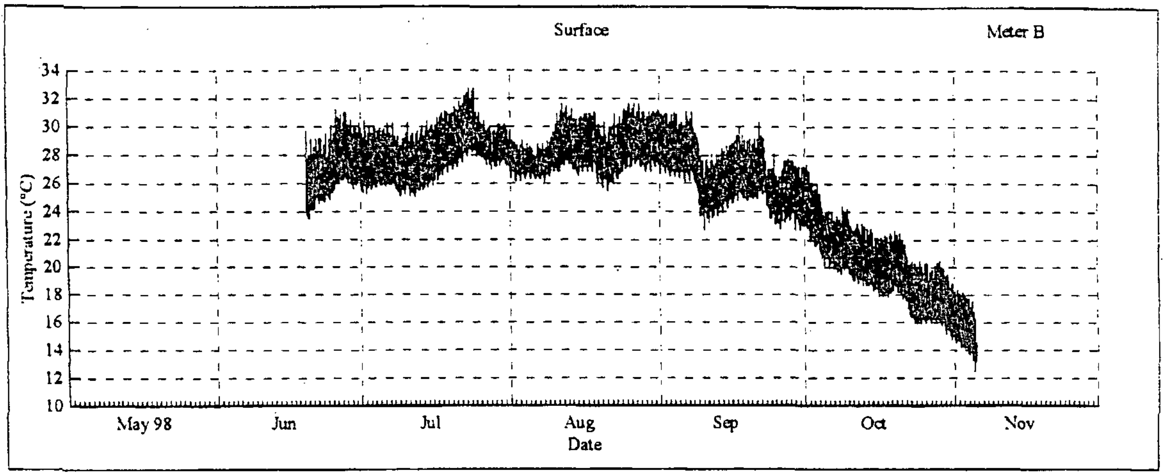
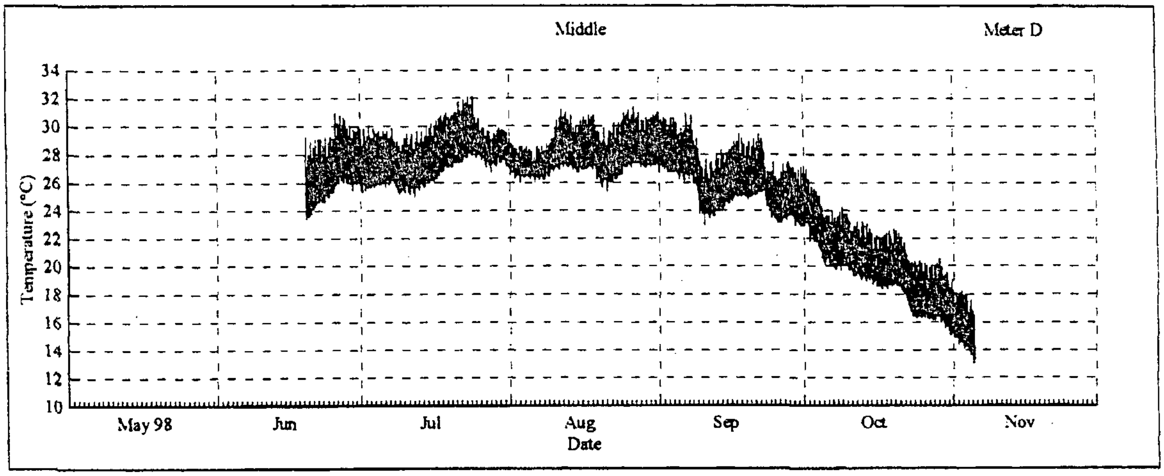


FIGURE 10-234

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-22





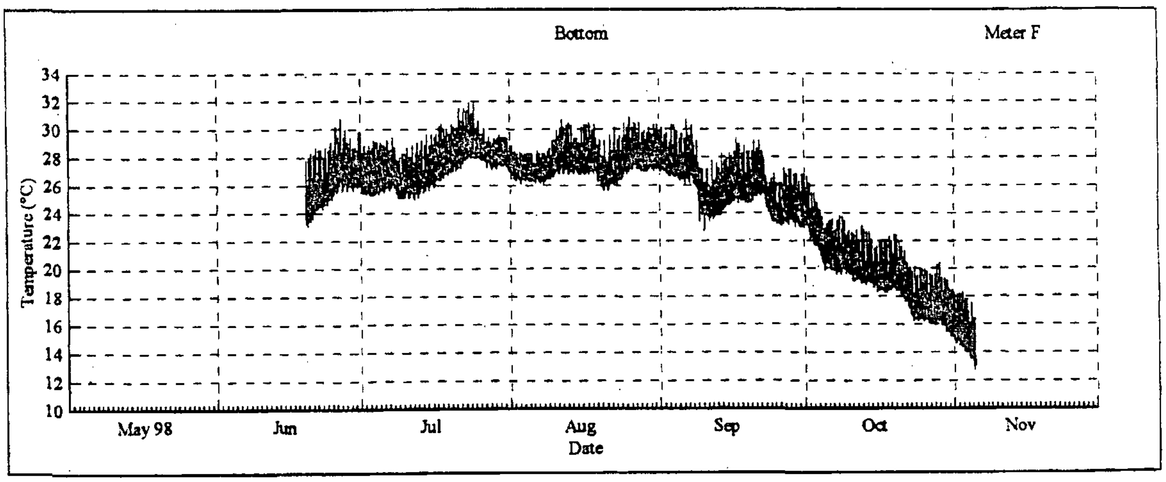


FIGURE 10-235

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-23

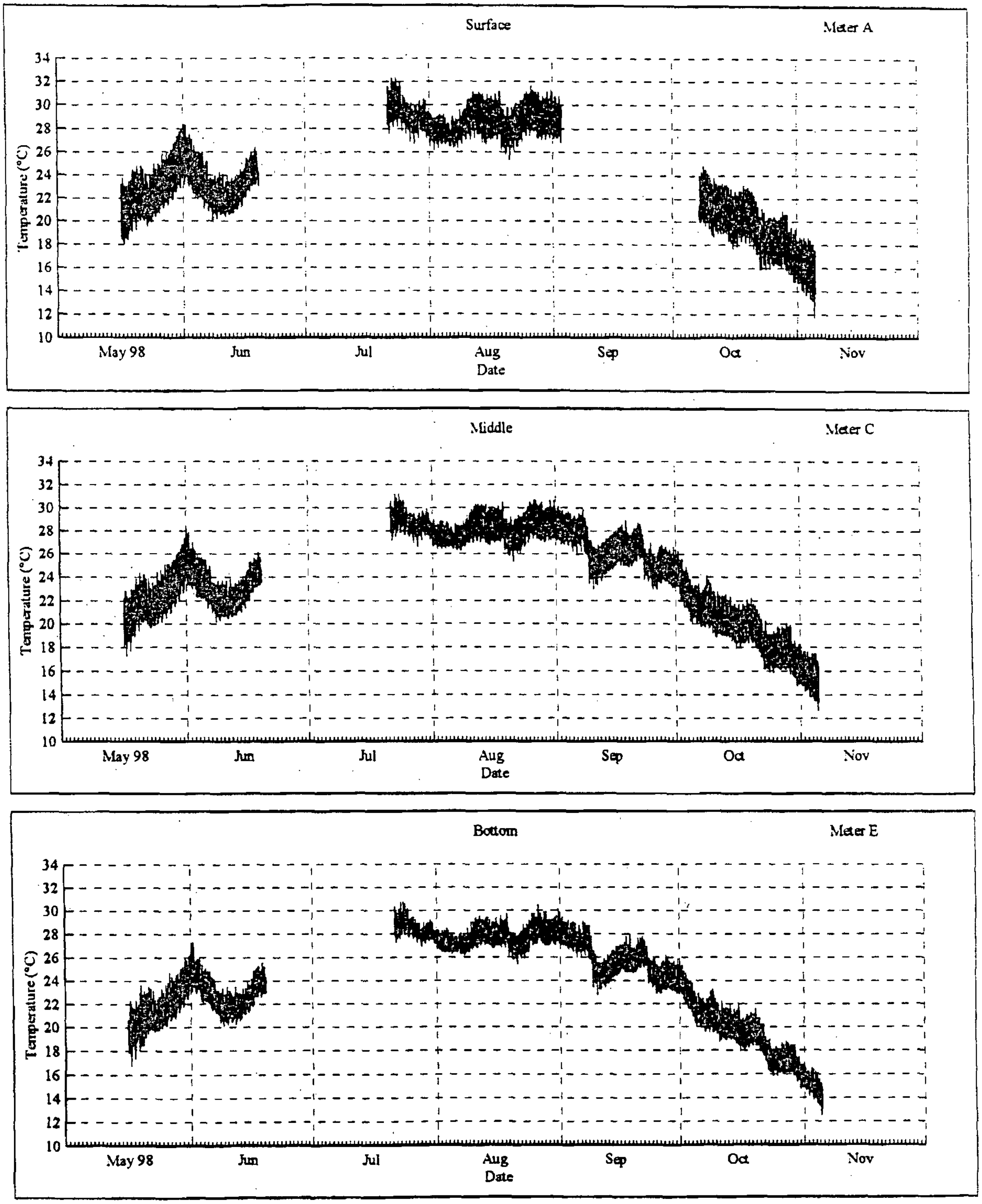
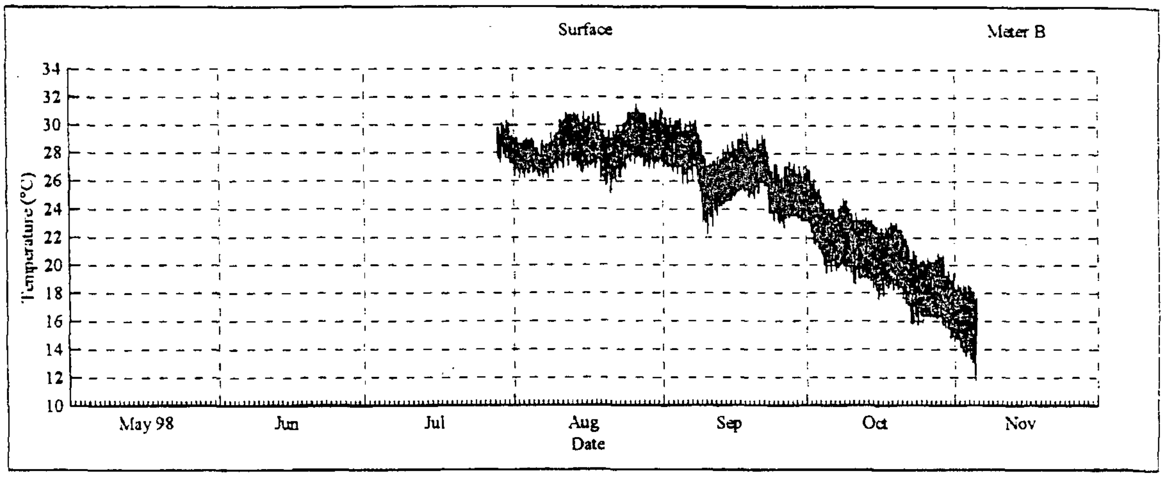
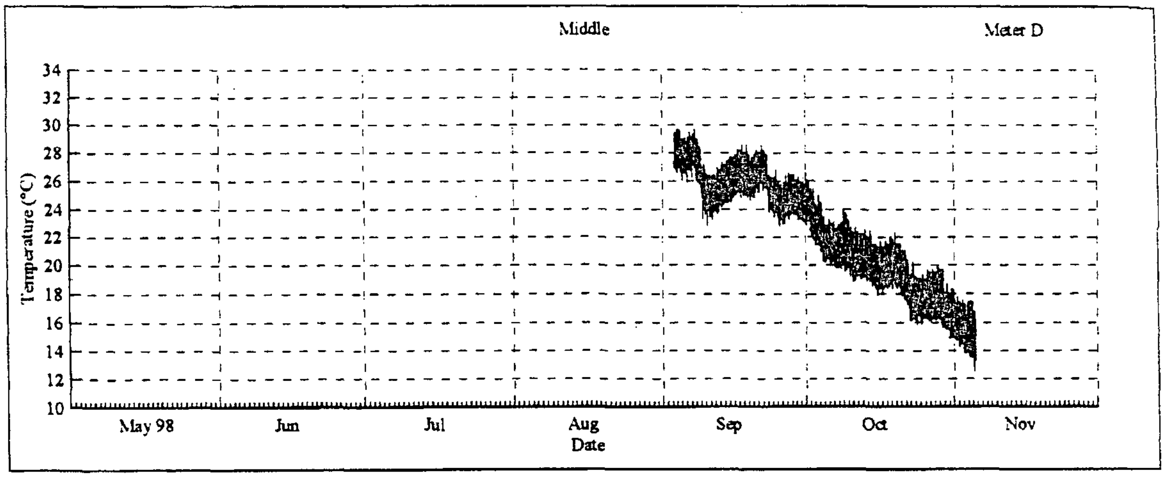


FIGURE 10-236

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-23





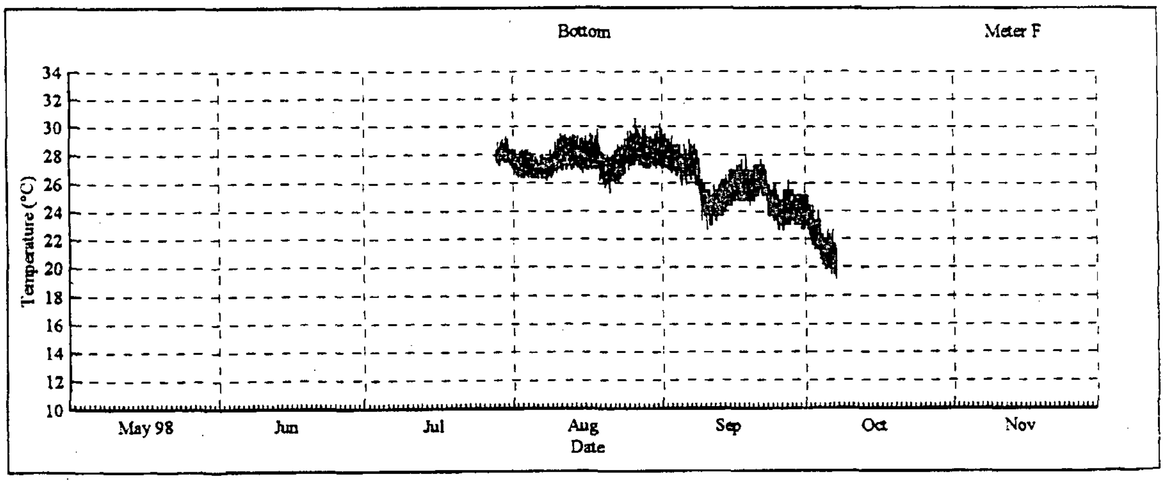


FIGURE 10-237

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-24

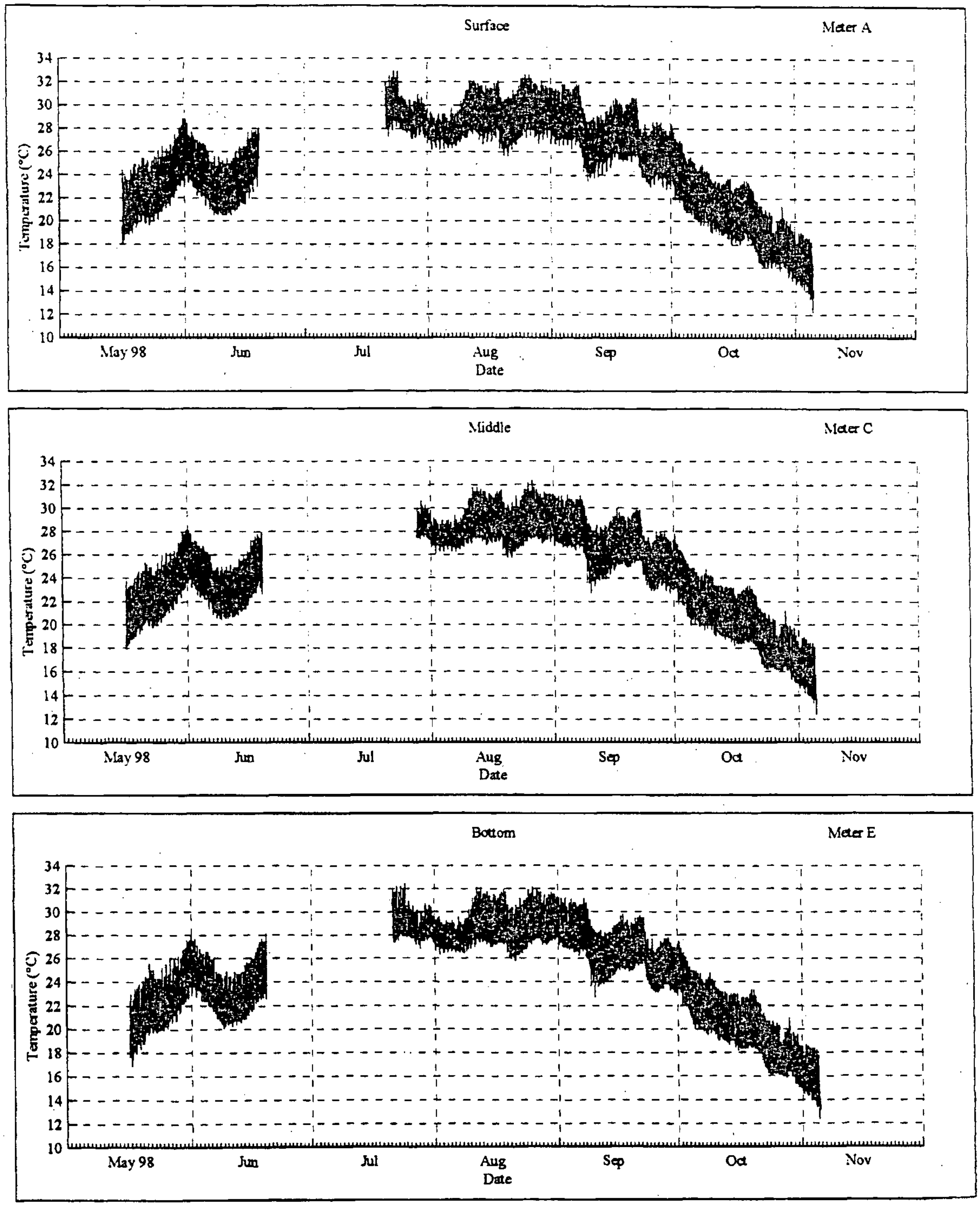
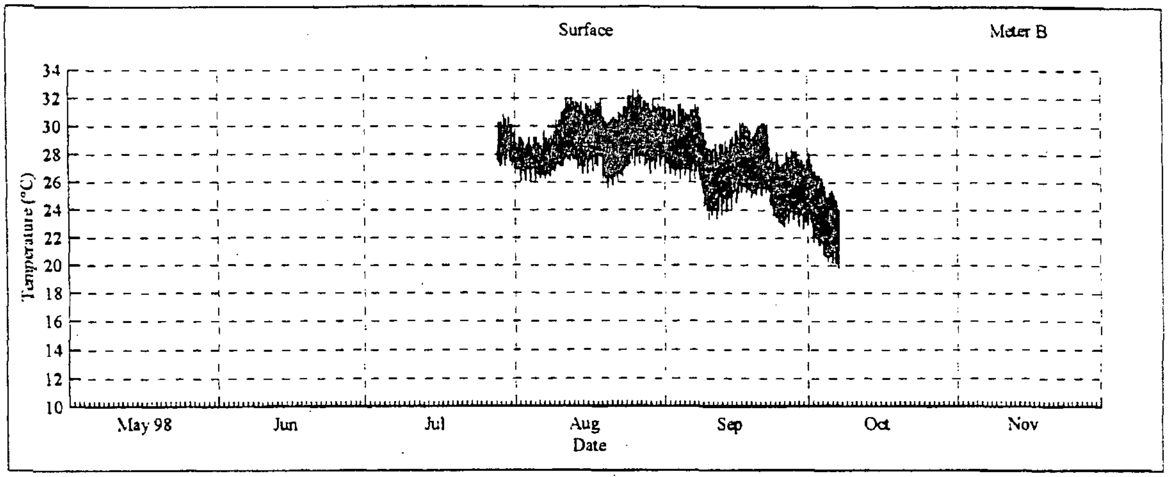
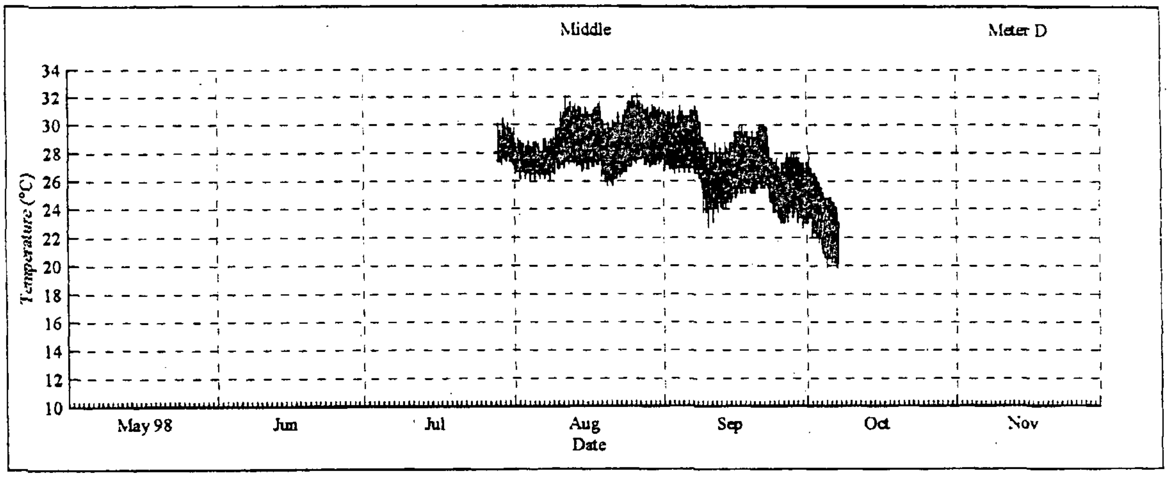


FIGURE 10-238

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-24





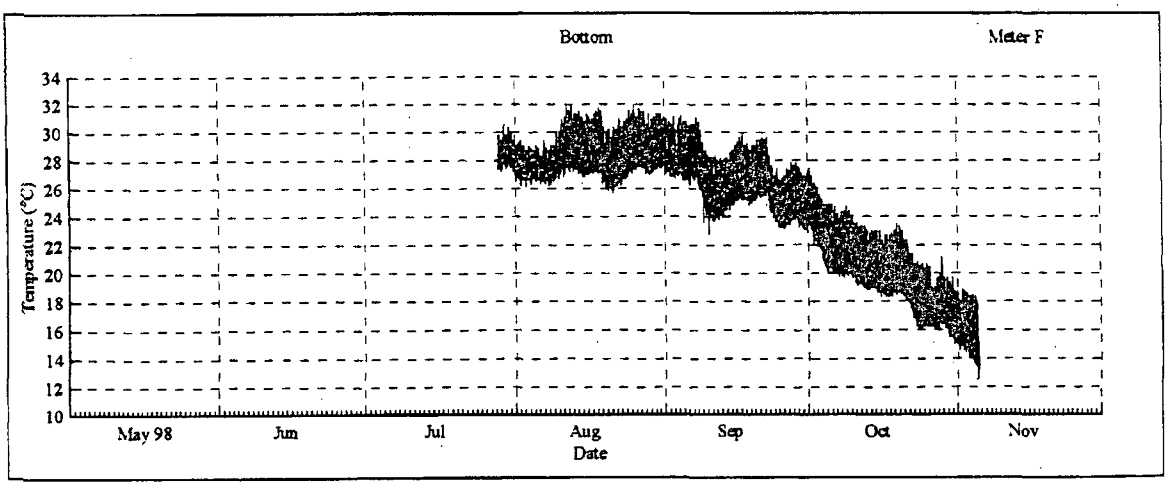
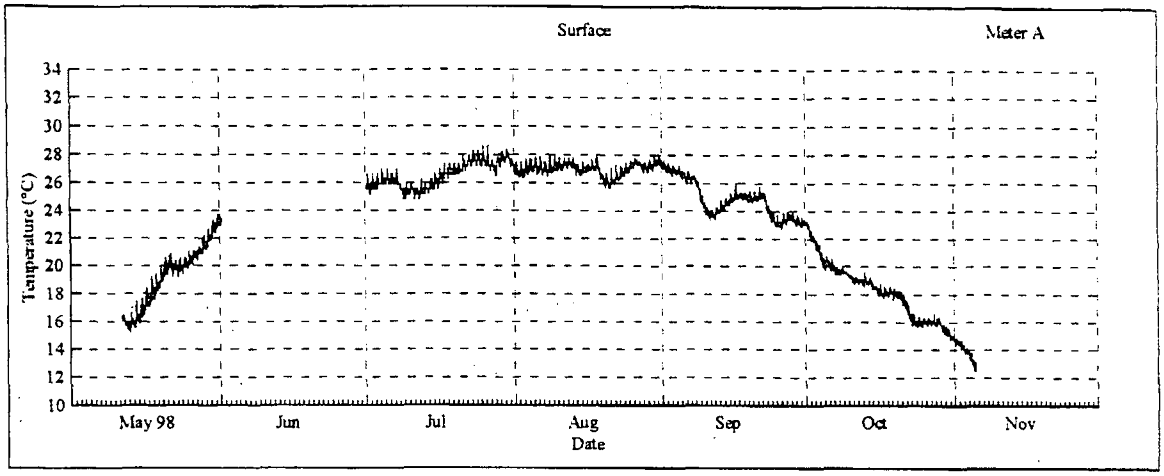
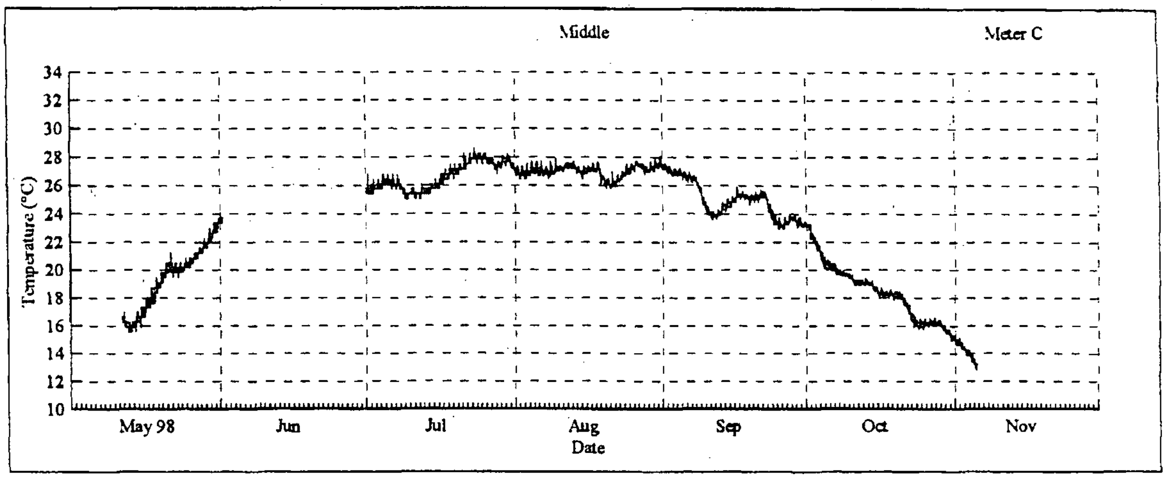


FIGURE 10-239

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9G





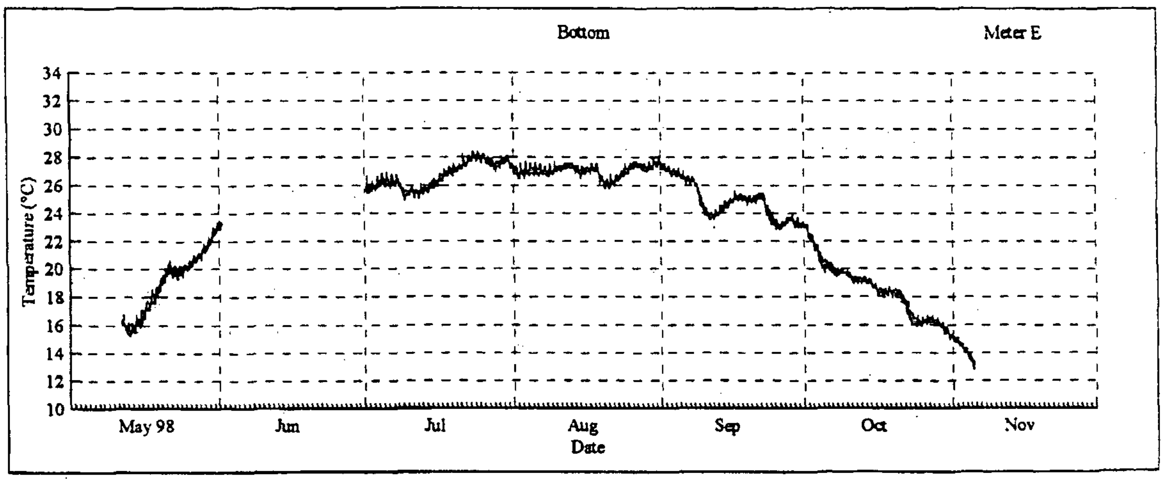
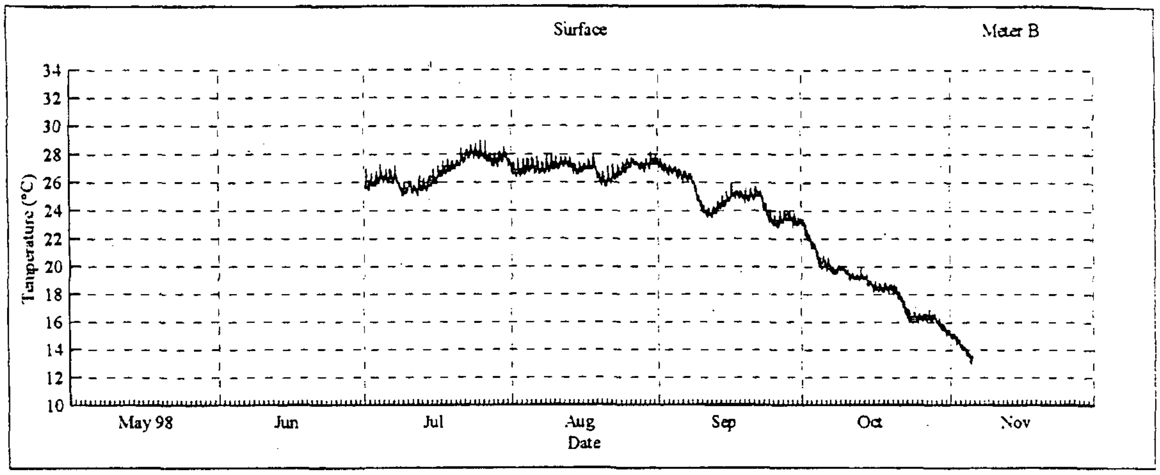
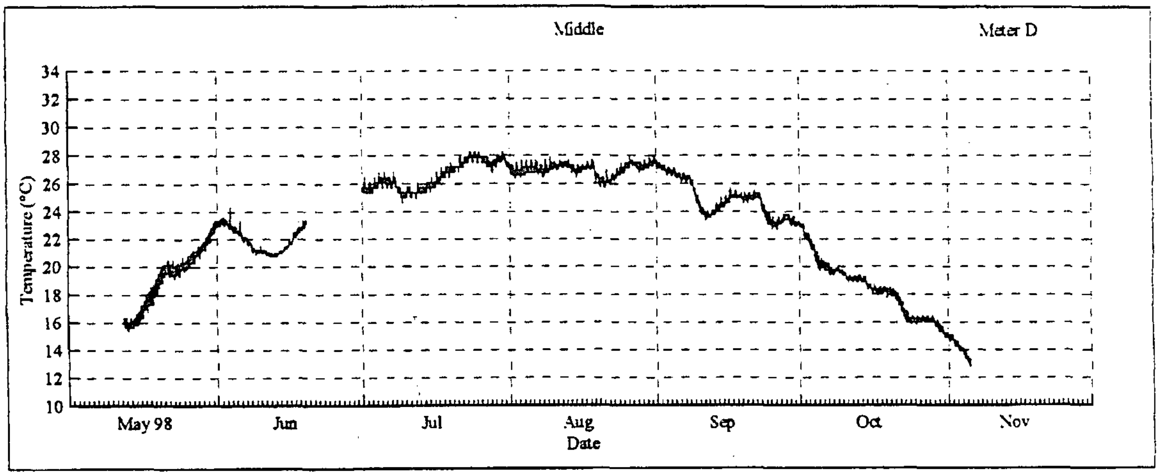


FIGURE 10-240

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9G





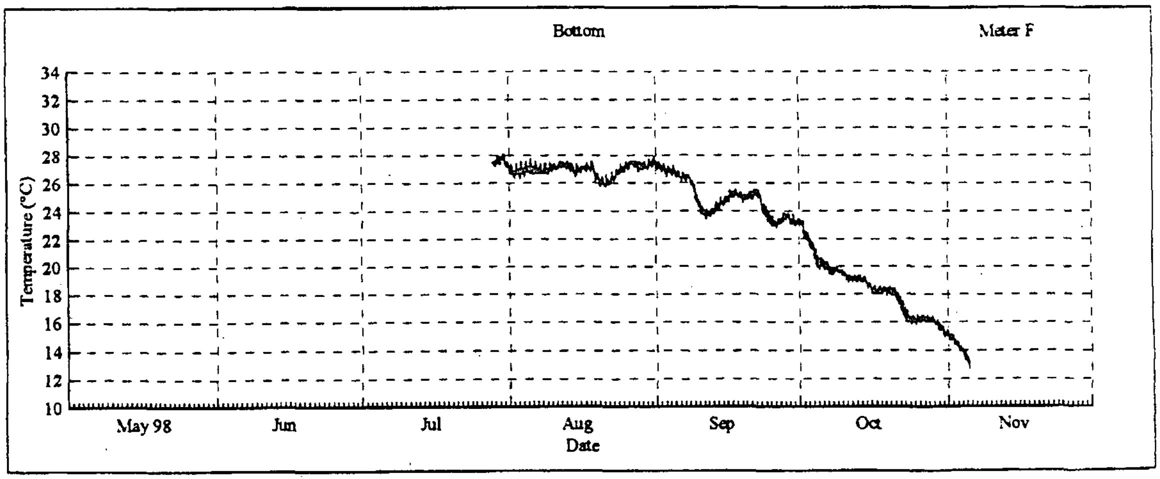


FIGURE 10-241

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9M

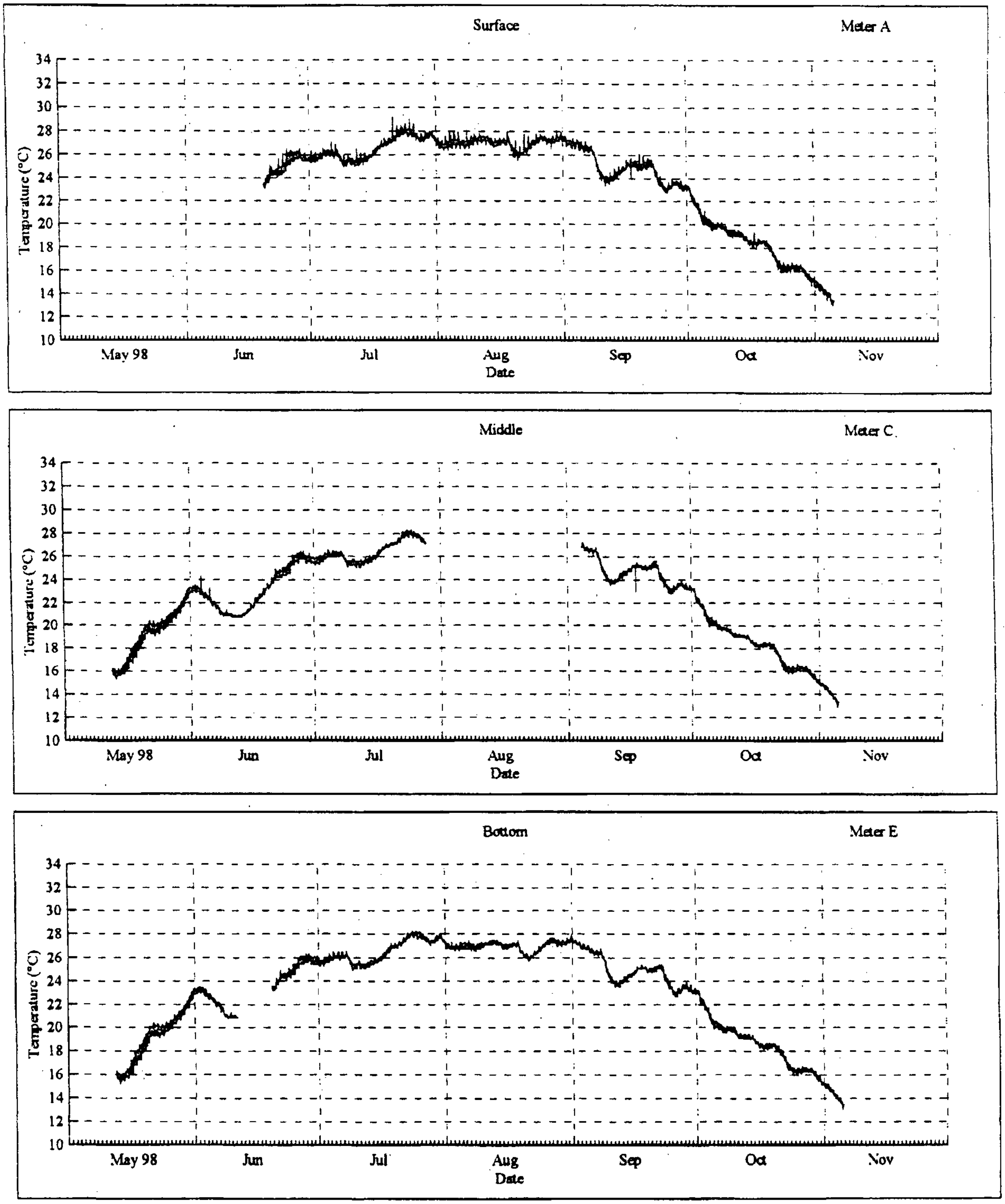
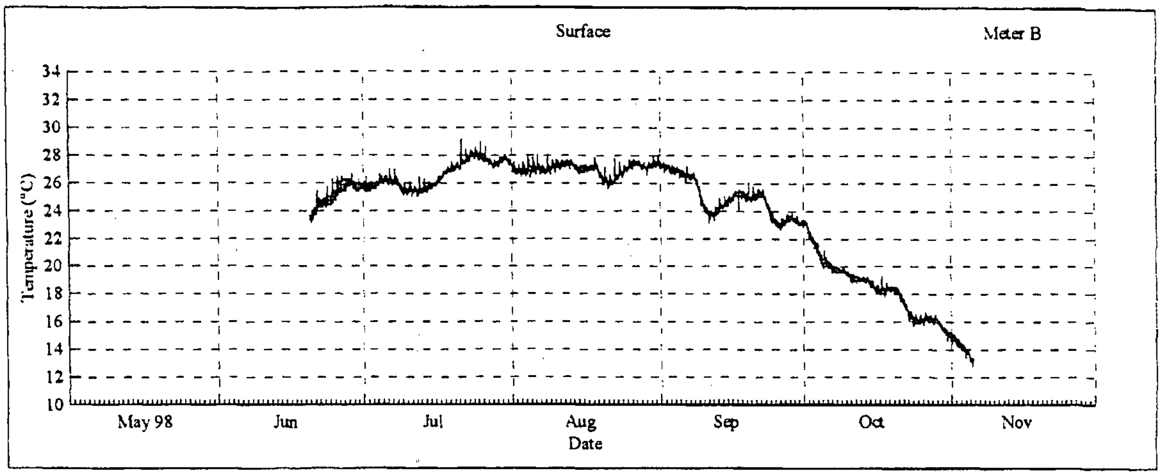
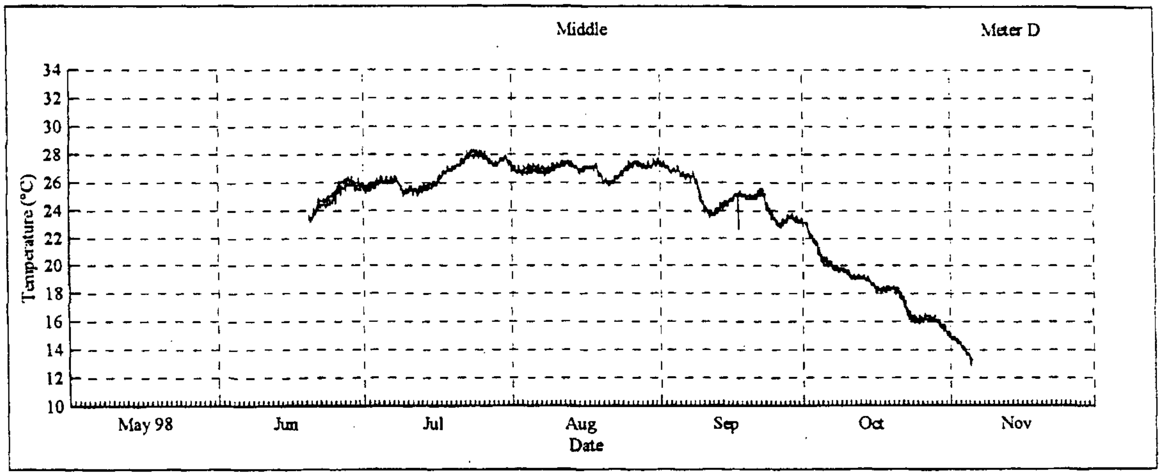


FIGURE 10-242

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9M





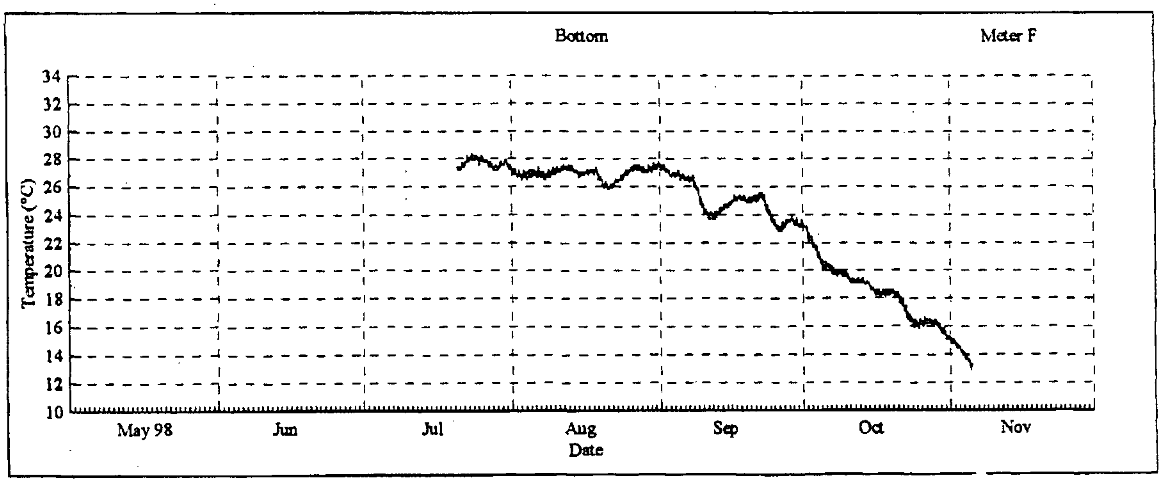
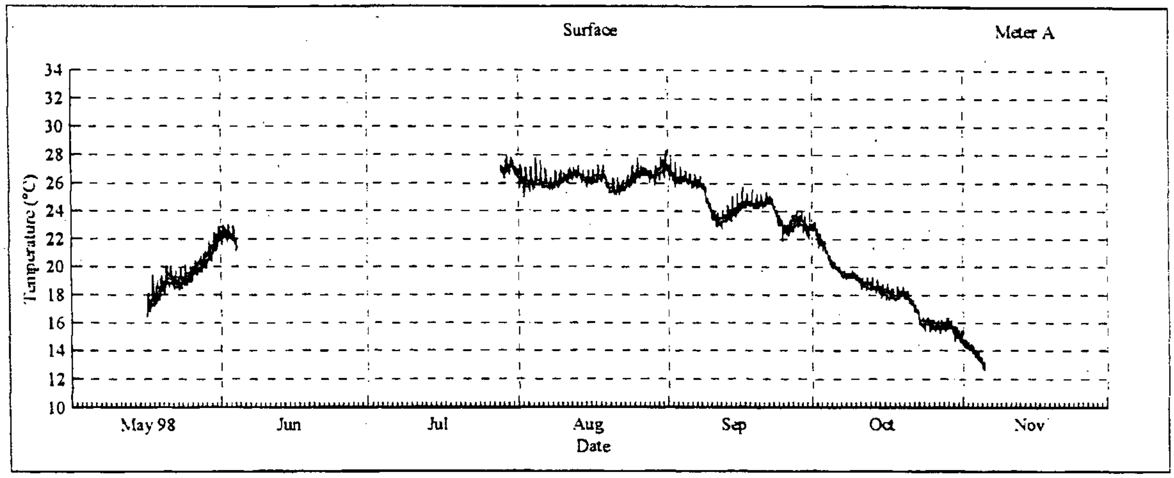
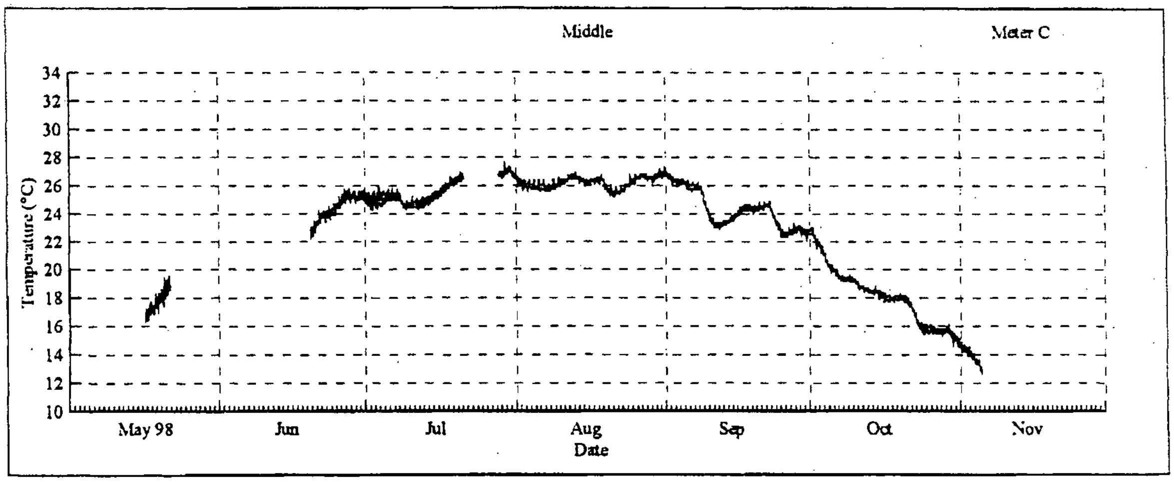


FIGURE 10-243

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-M9





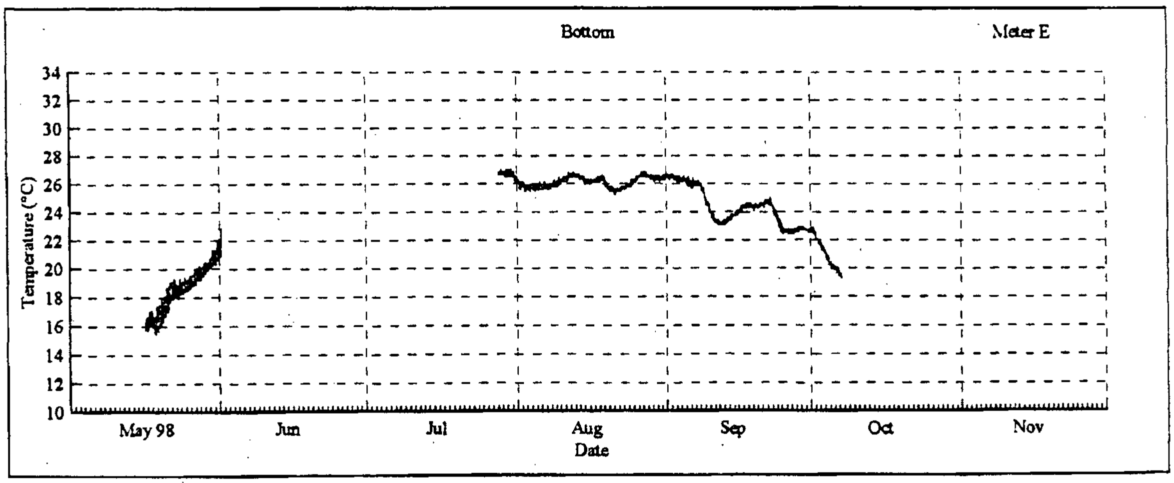


FIGURE 10-244

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-M9

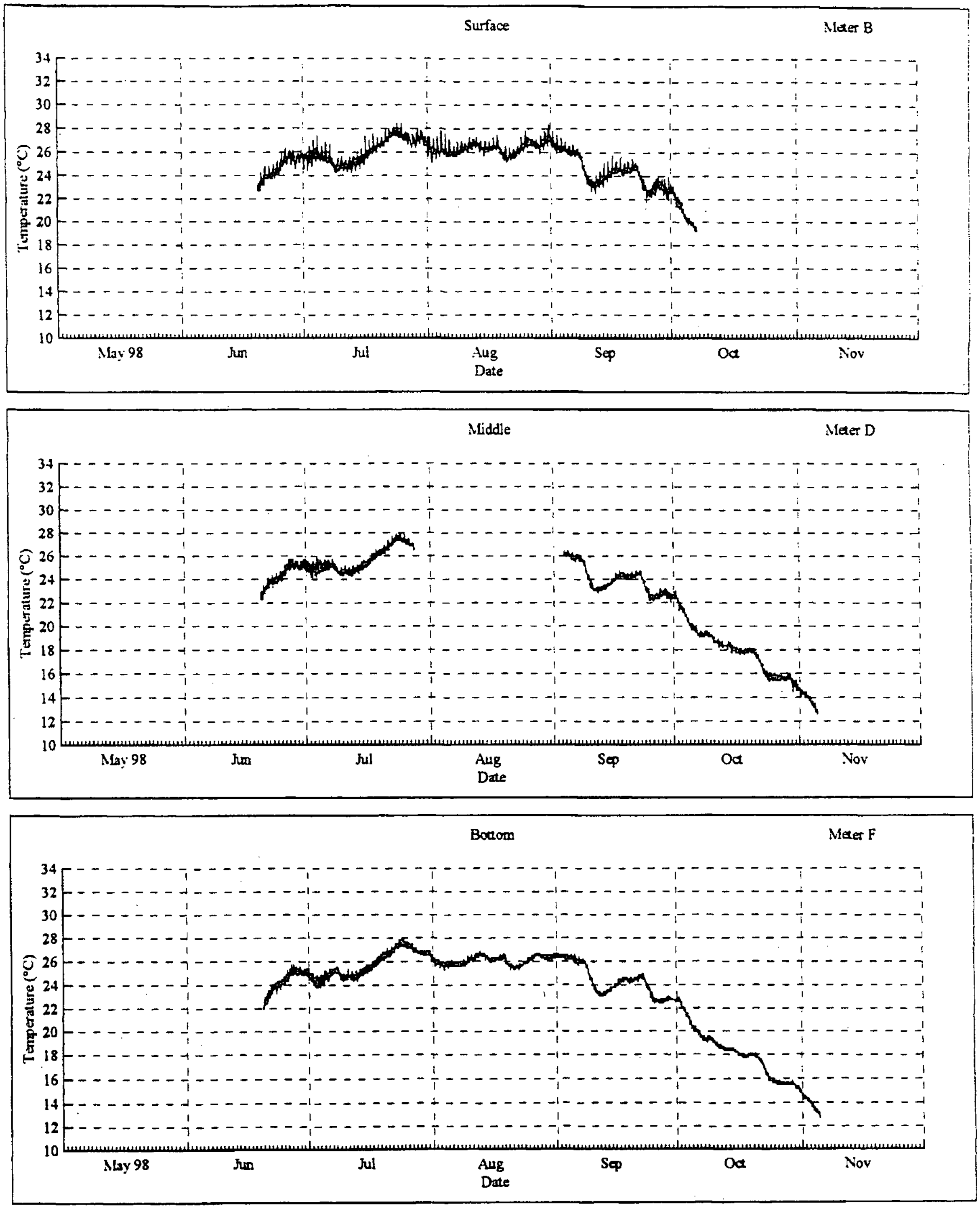
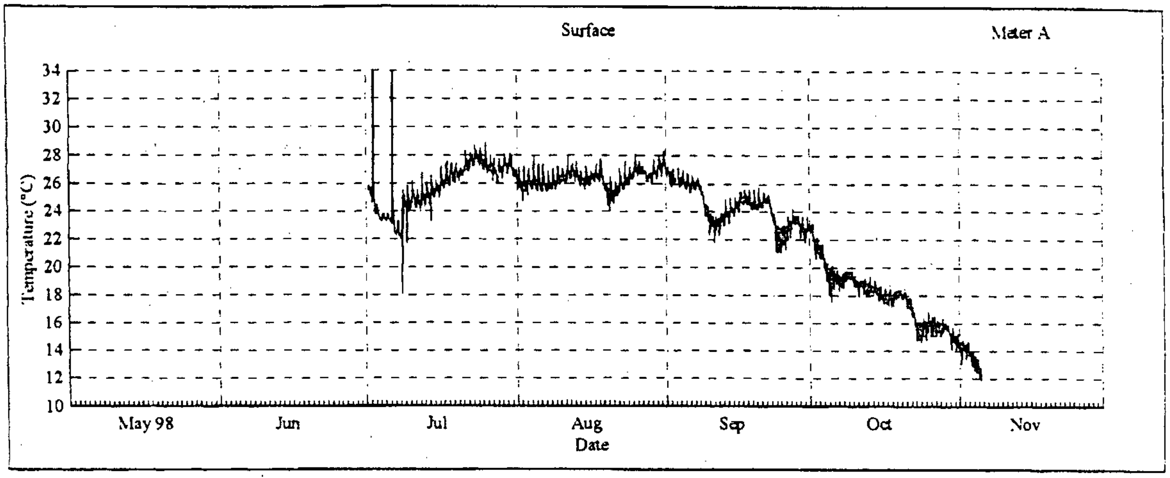
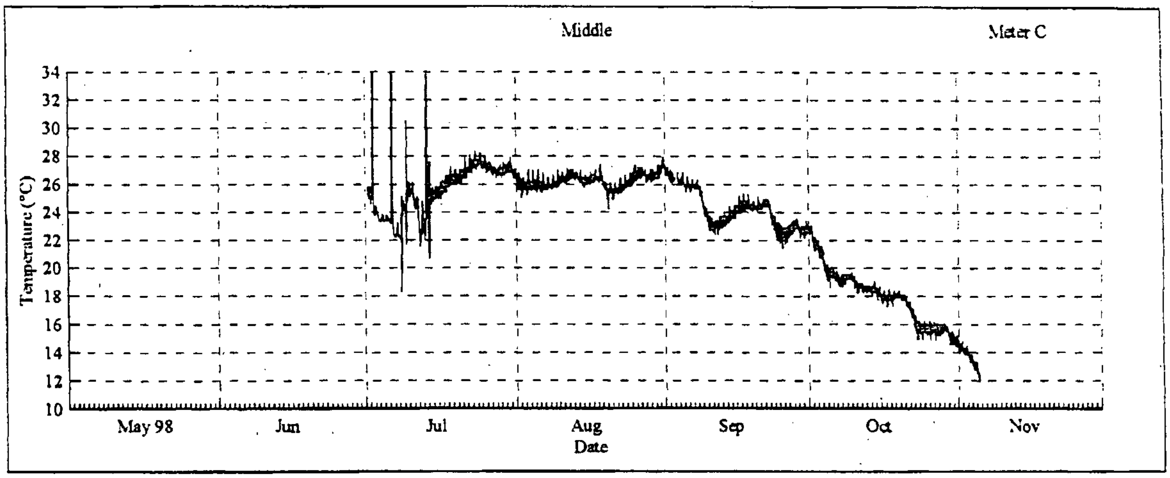


FIGURE 10-245

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-G9





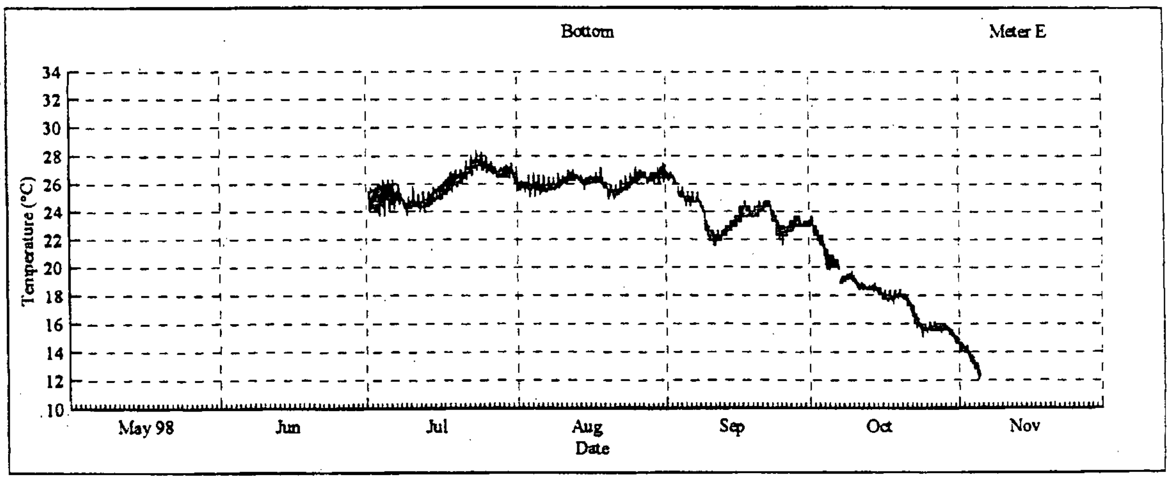


FIGURE 10-246

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-G9

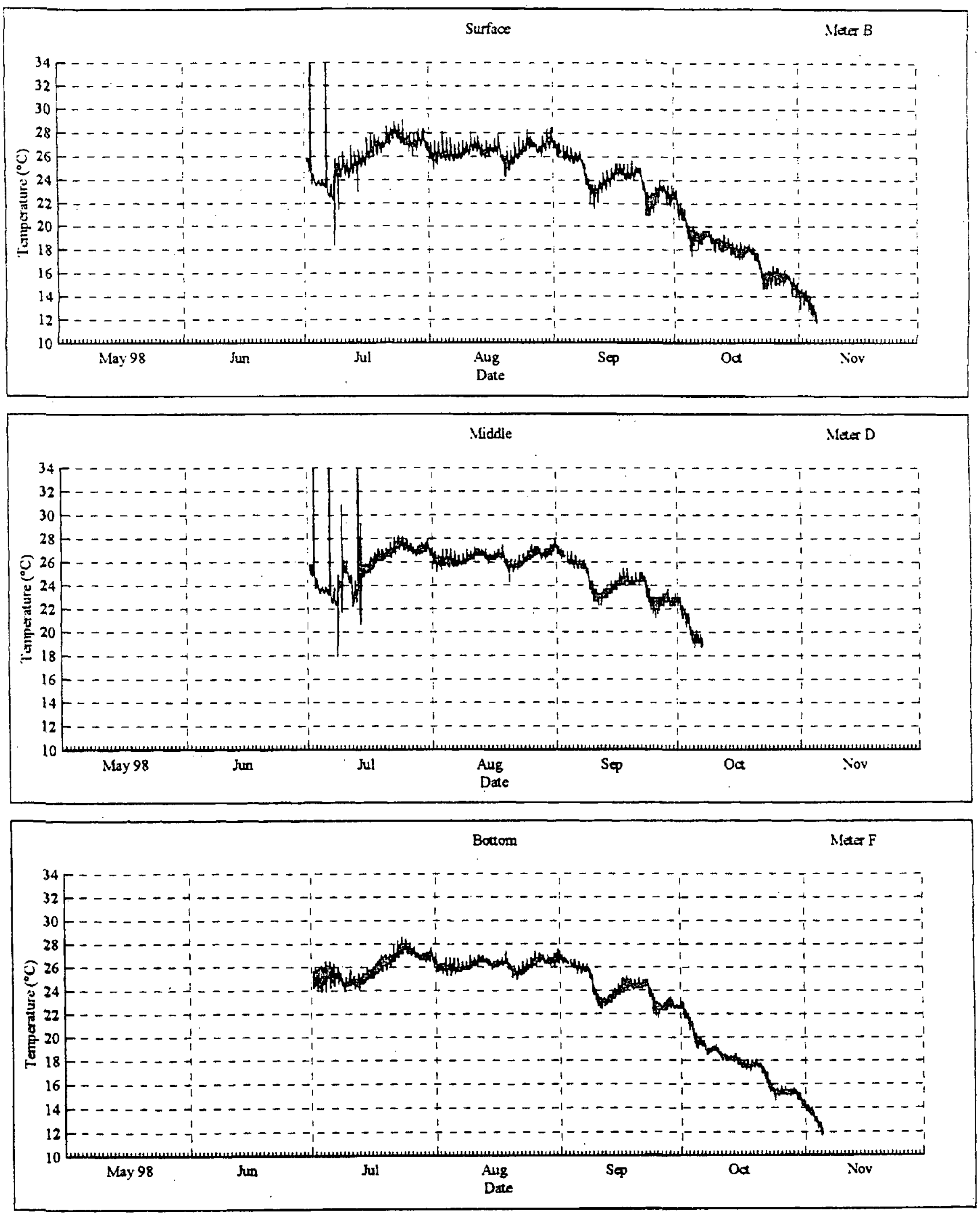


FIGURE 10-247

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
MADHORSECRK CTDO Meter

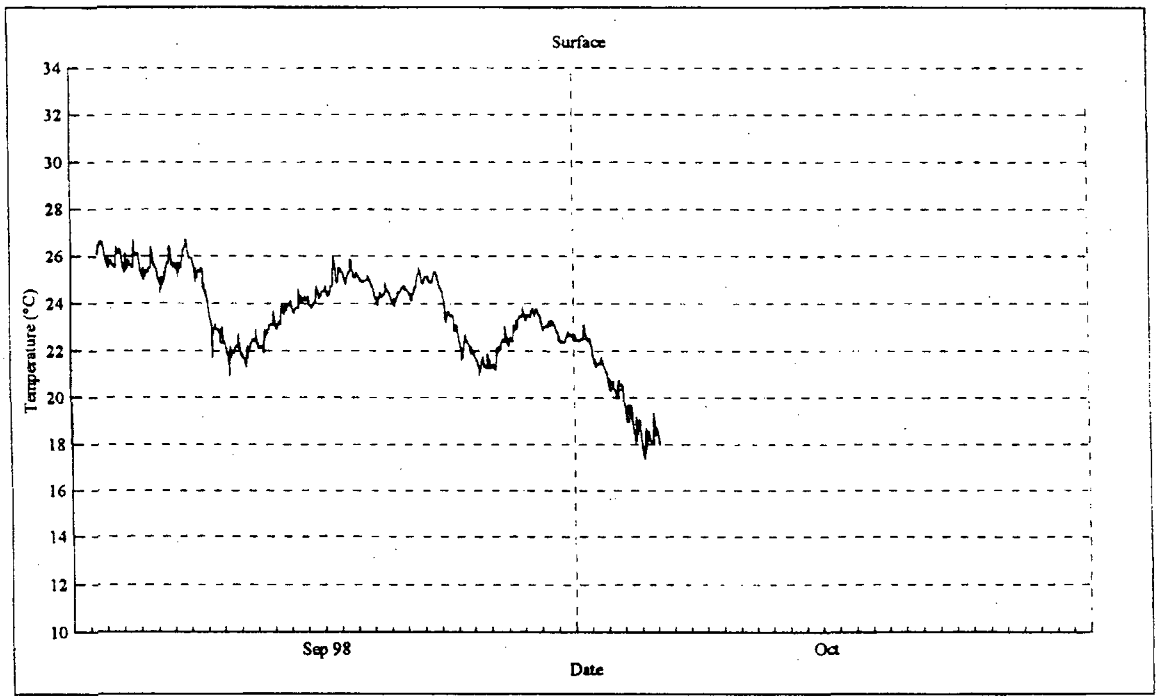


FIGURE 10-248

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Salinity Temporal Profiles (Moorings)
MADHORSECRK

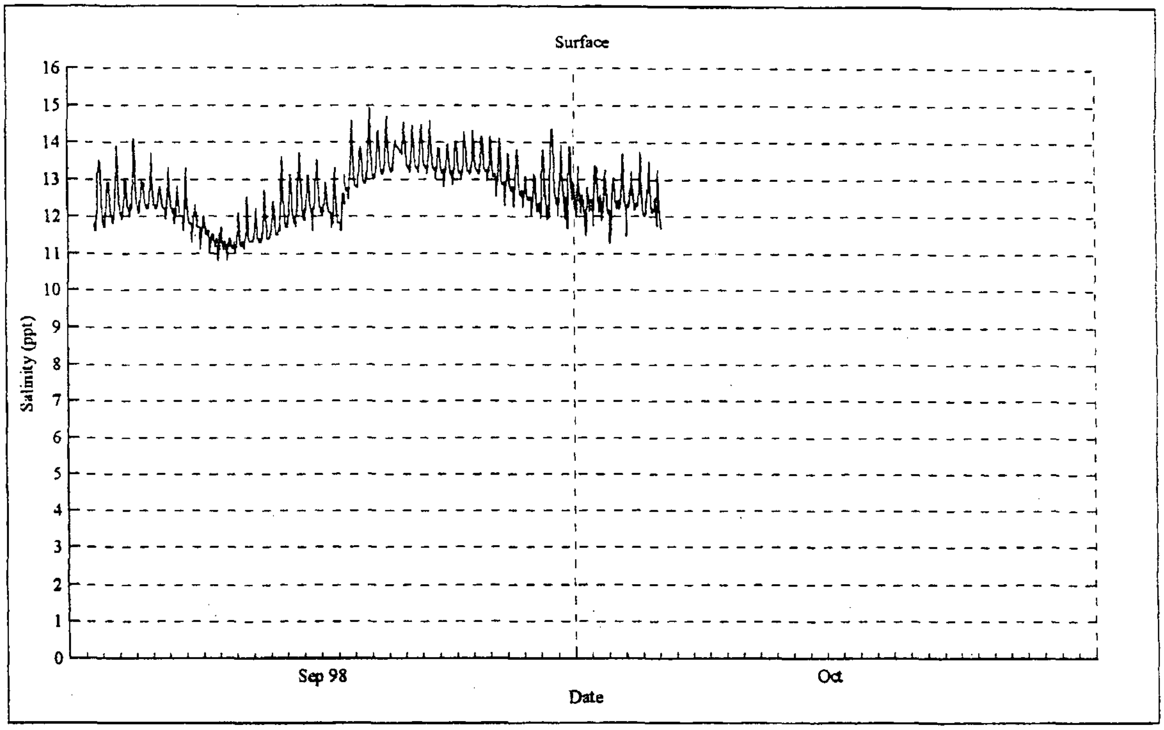


FIGURE 10-249

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Dissolved Oxygen Temporal Profiles (Moorings)
MADHORSECRK

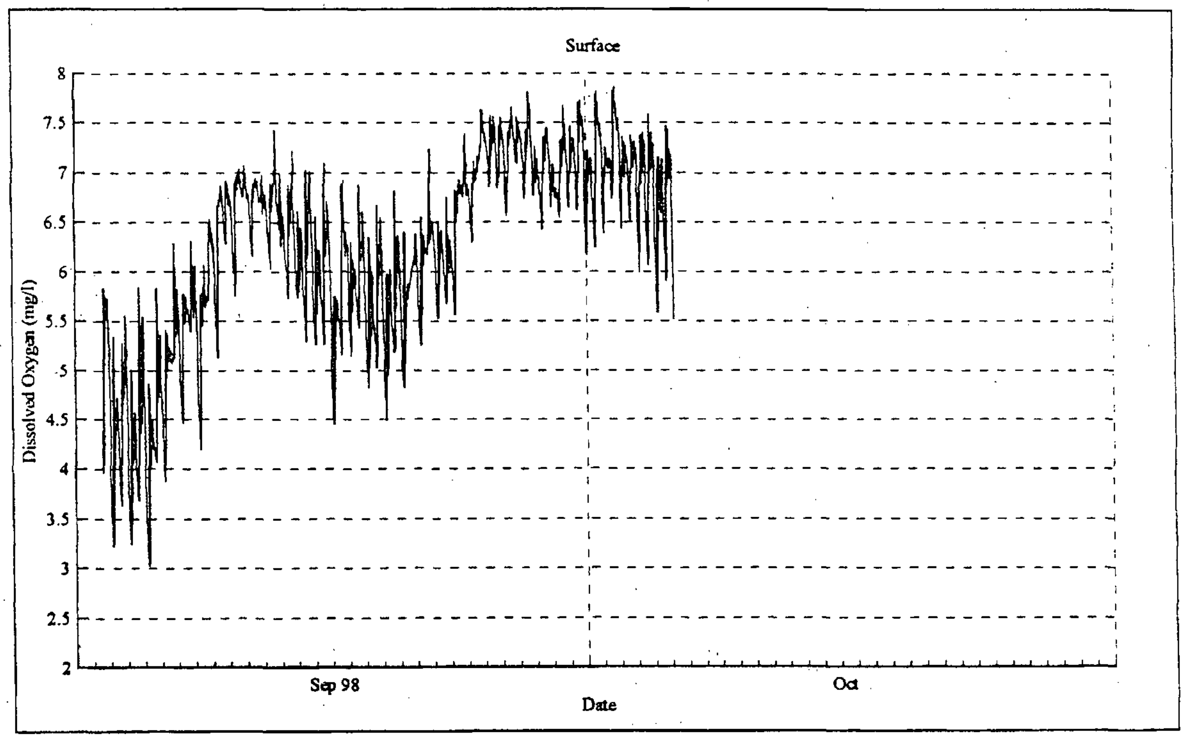
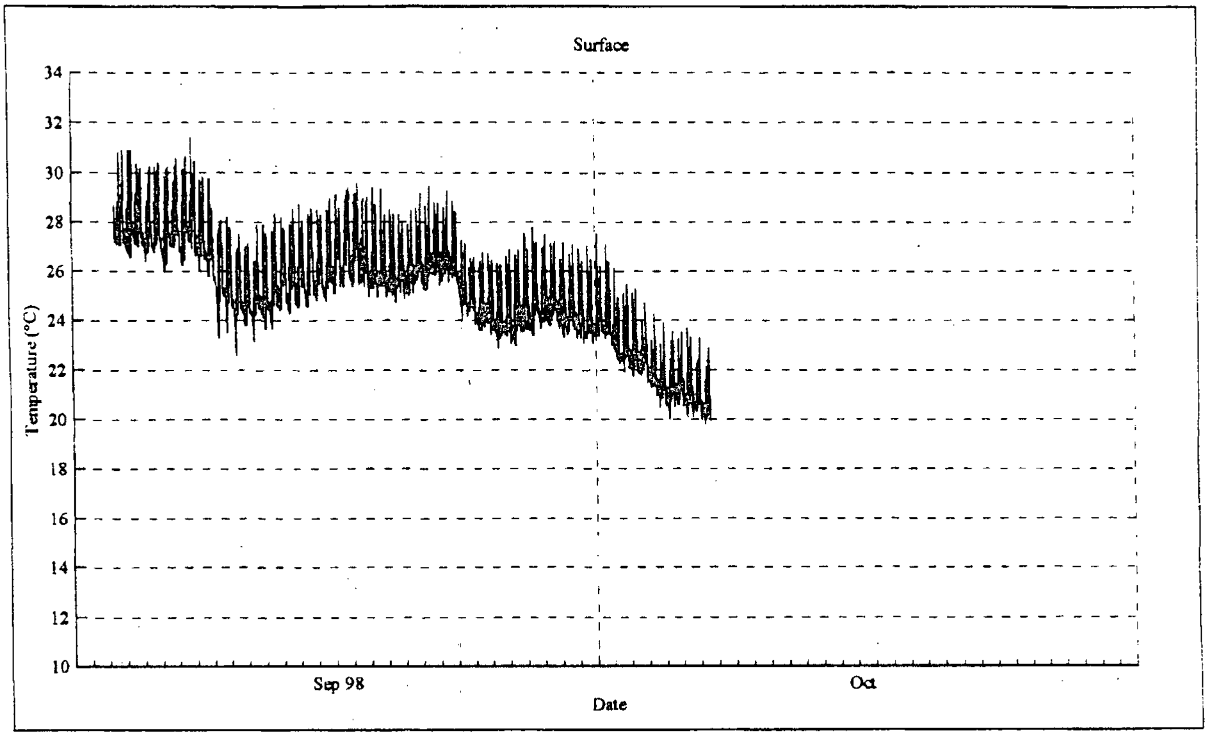


FIGURE 10-250

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-21 CTDO Meter



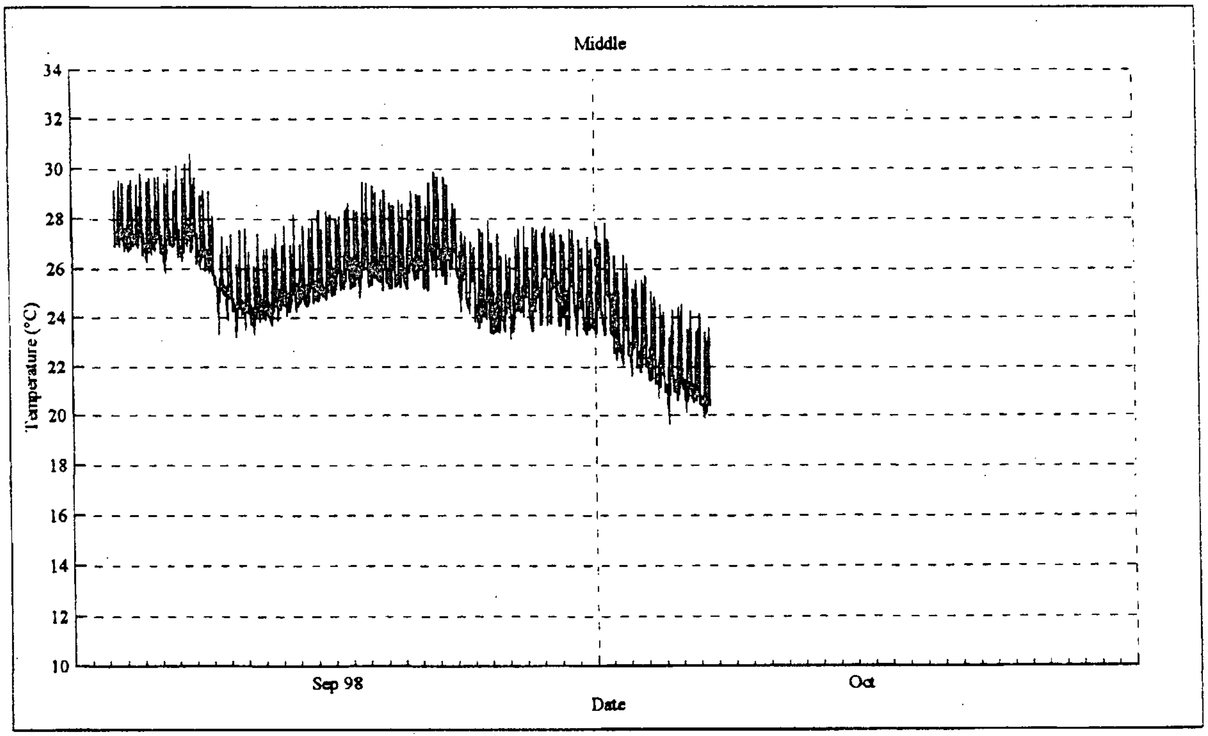
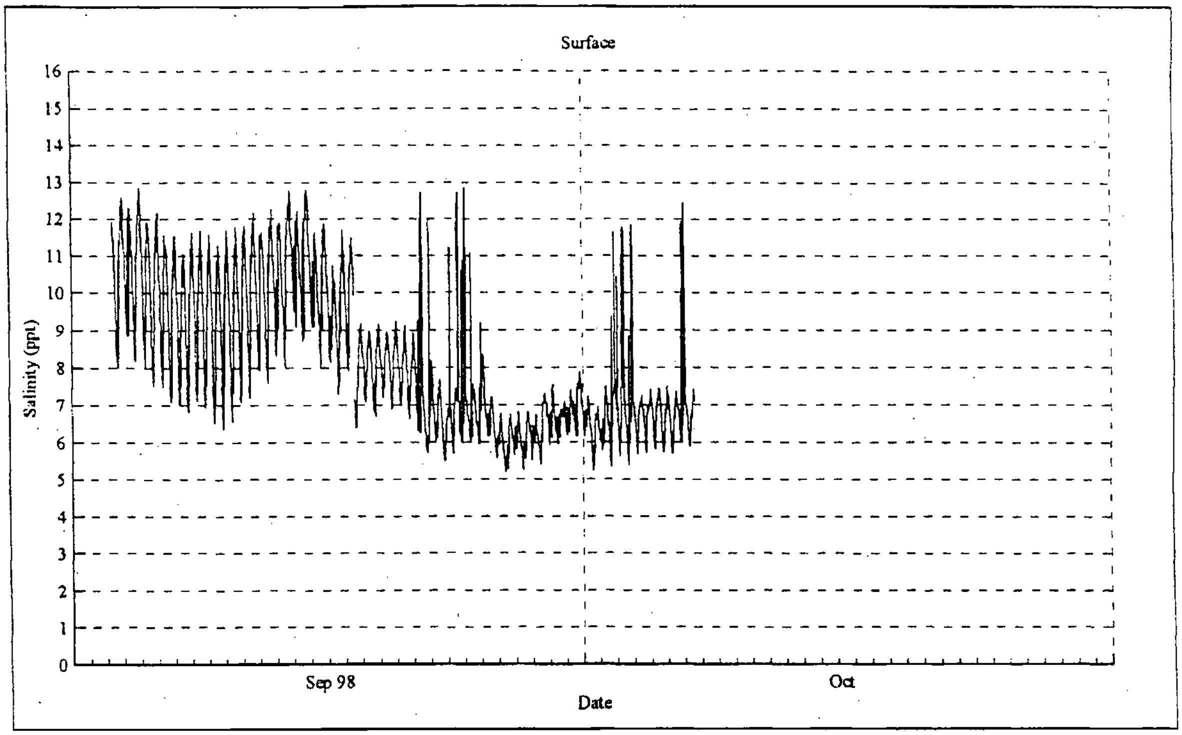


FIGURE 10-251

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-21



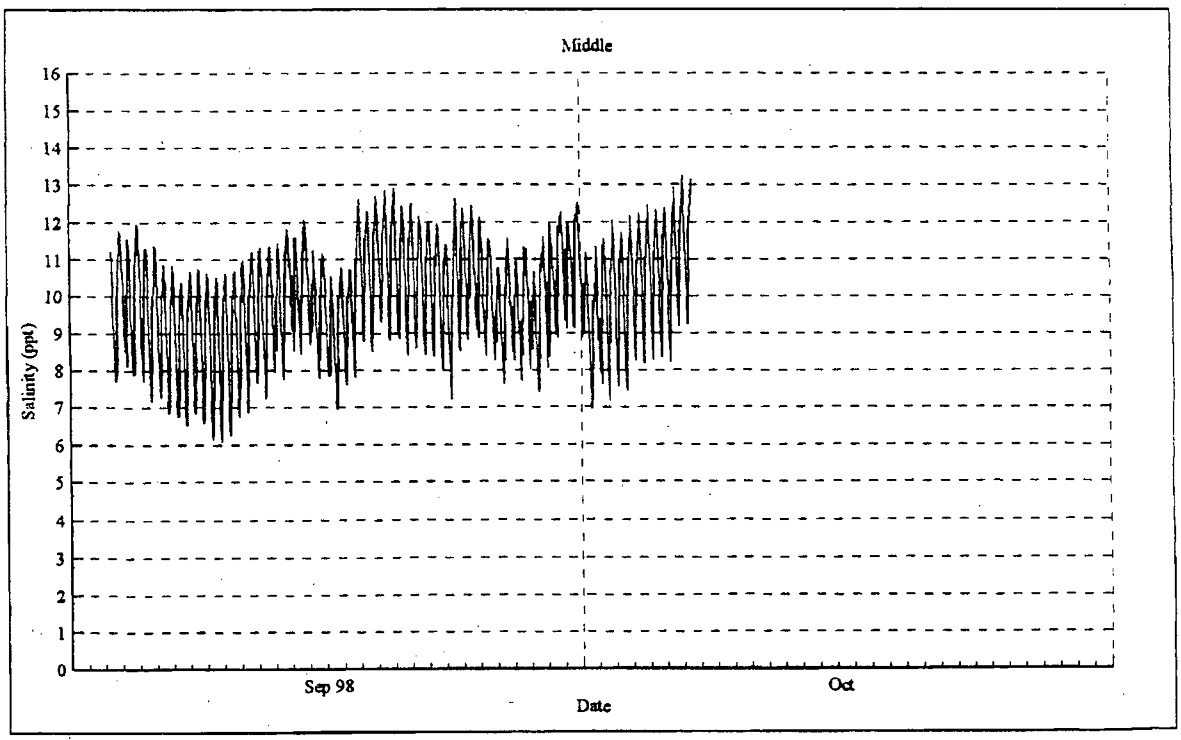


FIGURE 10-252

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-21

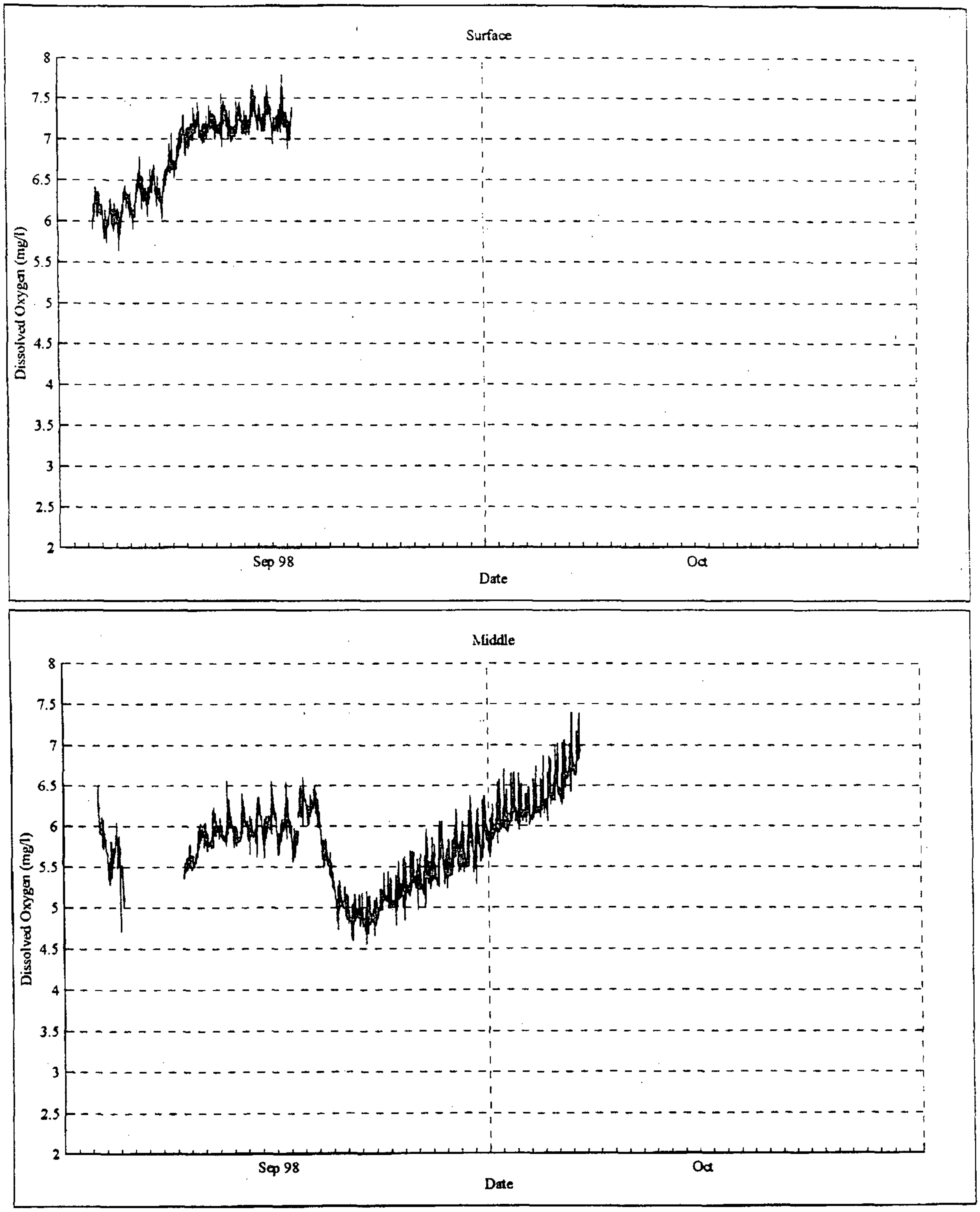
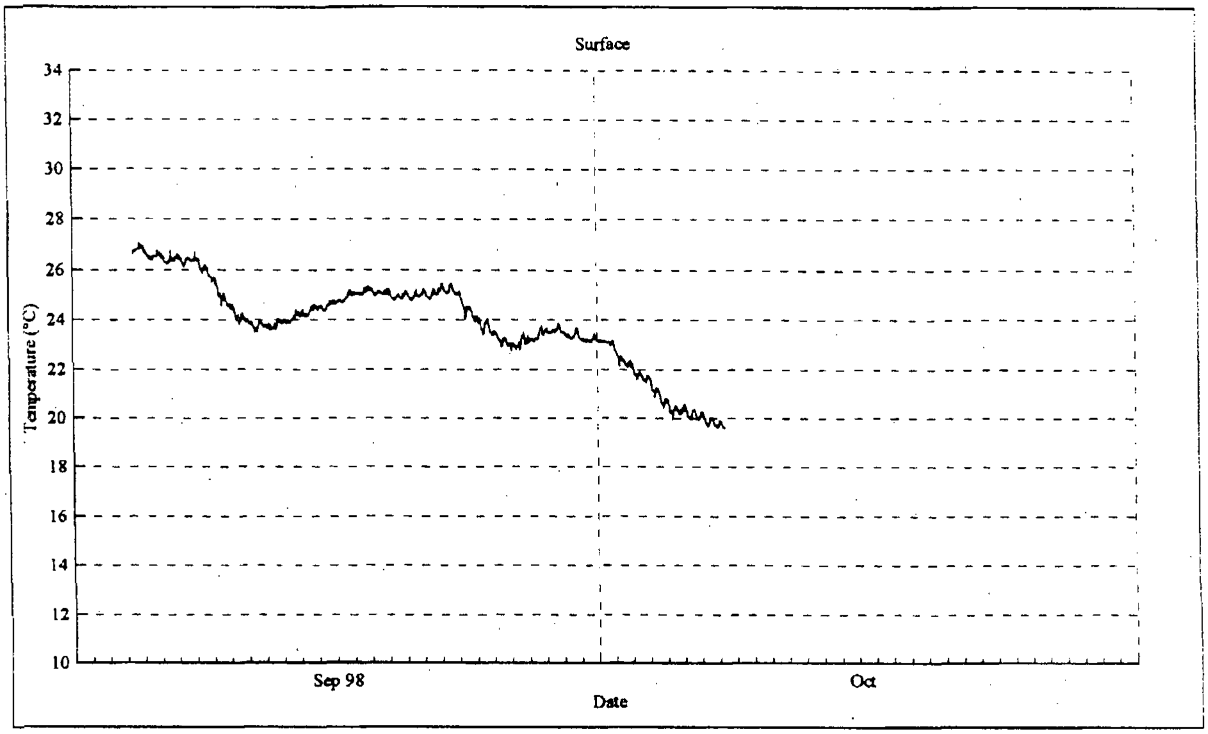


FIGURE 10-253

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Temperature Temporal Profiles (Moorings)
DELAWARE-9M CTDO Meter



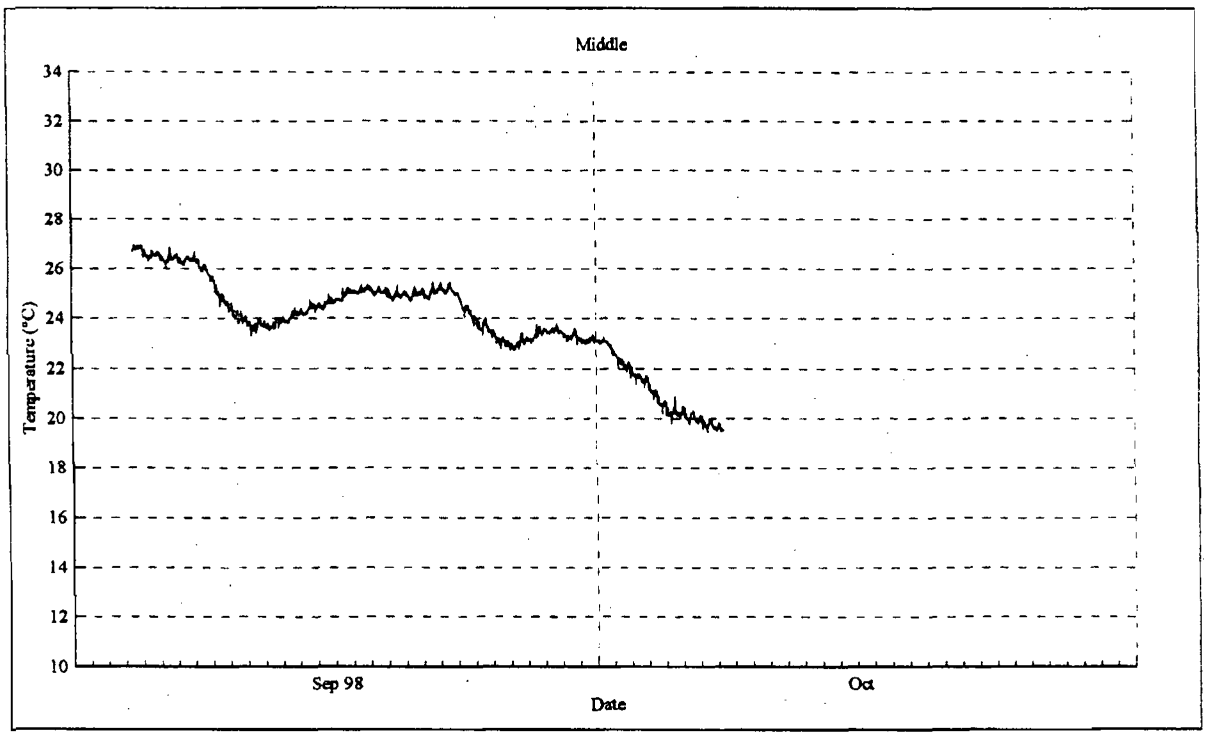
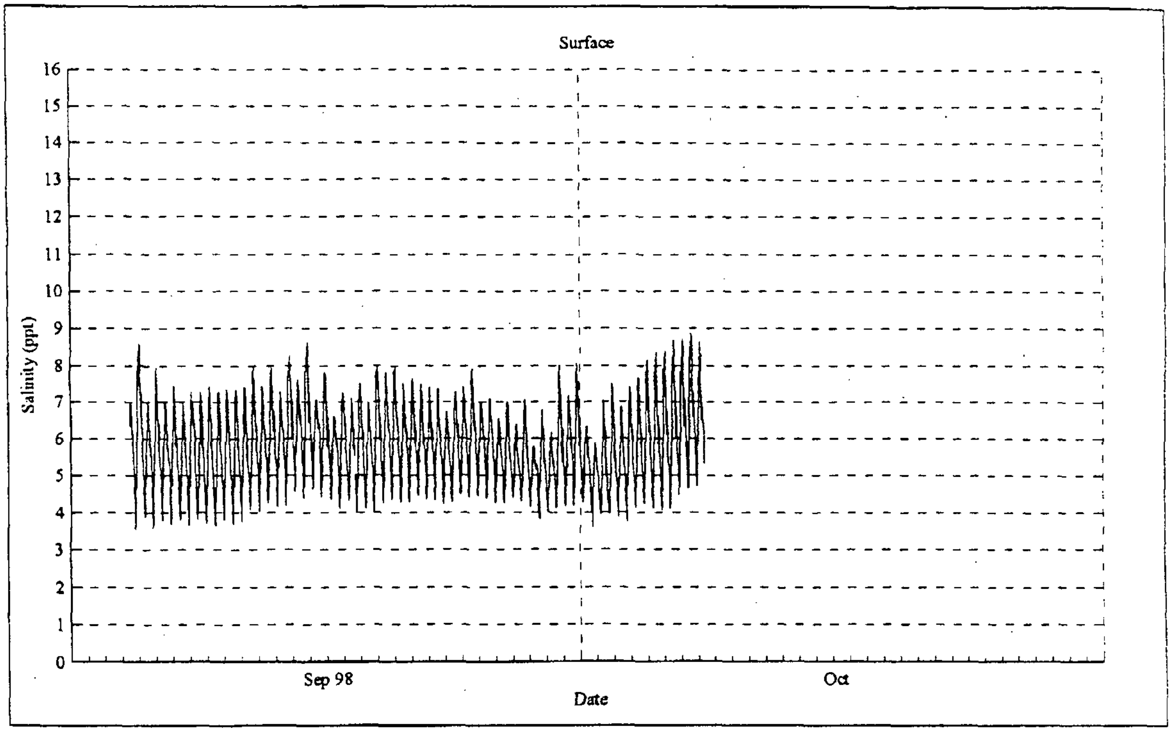


FIGURE 10-254

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Salinity Temporal Profiles (Moorings)
DELAWARE-9M



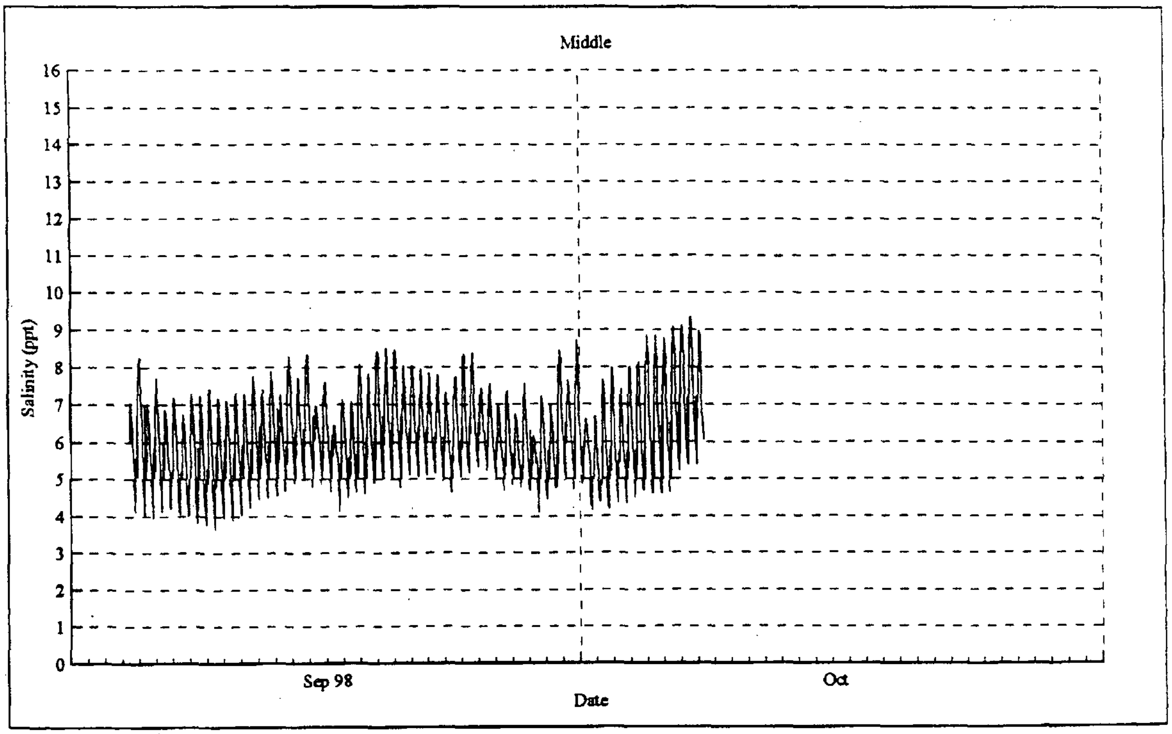
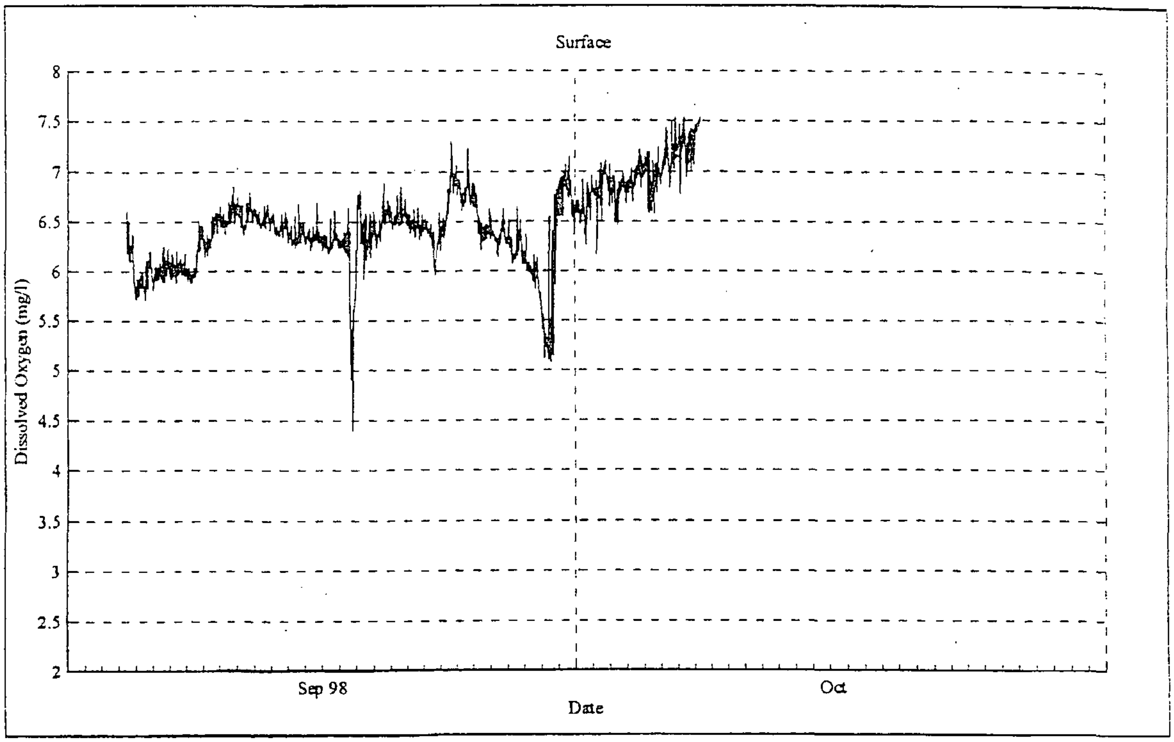
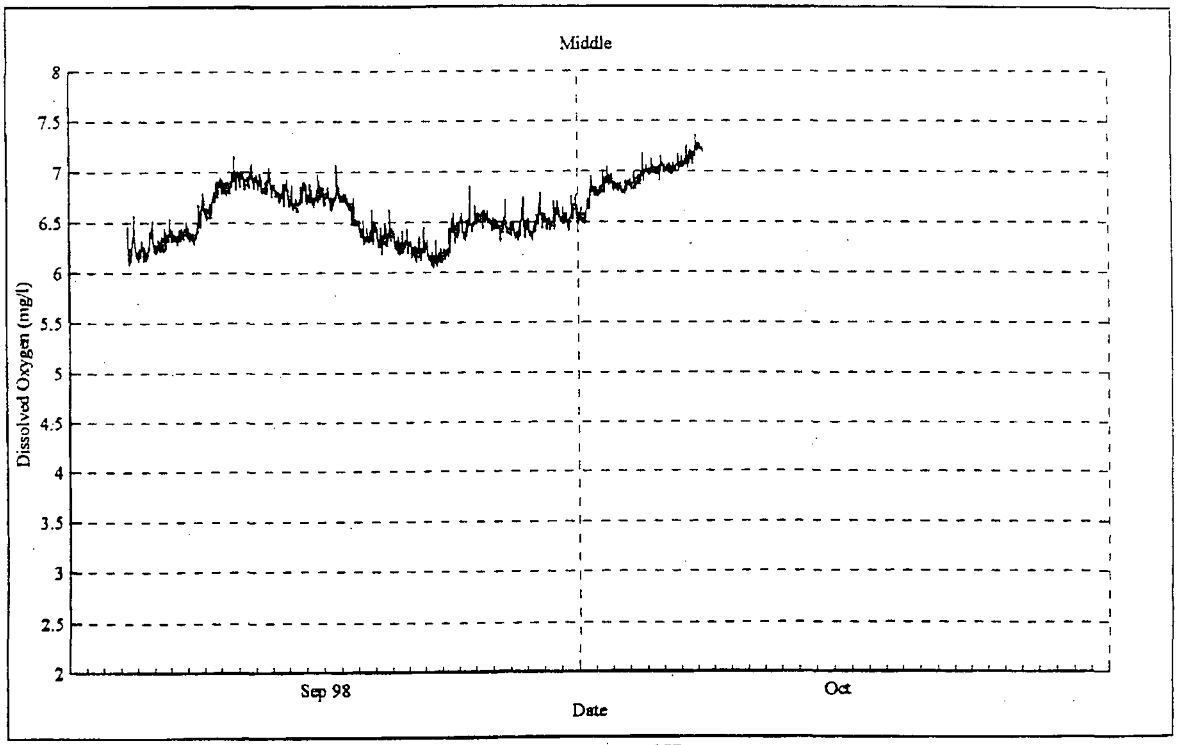


FIGURE 10-255

PSE&G 2-Unit Survey: 16 May 1998 - 05 November 1998
Dissolved Oxygen Temporal Profiles (Moorings)
DELAWARE-9M





APPENDIX E
ATTACHMENT 1 EXHIBIT 4

BATHYMETRIC SURVEY

SPONSOR: DR. ERIC E. ADAMS
PSE&G RENEWAL APPLICATION
SALEM GENERATING STATION
PERMIT NO. NJ0005622
4 MARCH 1999

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ATTACHMENT 1 EXHIBIT 4
BATHYMETRIC SURVEY IN THE VICINITY OF SALEM STATION'S DISCHARGE

I. INTRODUCTION

A bathymetric survey was conducted on 18 September 1998 in the vicinity of the discharge pipes for the Salem Generating Station Circulating Water System (CWS). The objectives of the survey were to (1) verify the location of the discharge pipes and their termination in a coordinate system compatible with the thermal plume modeling (described in Attachment E-2); and (2) map the fine-scale bathymetry surrounding the CWS discharge, which, based on the analysis of near-field temperature data and preliminary near-field computer modeling results, was believed to influence the near-field plume processes. This survey was therefore conducted to support the near-field modeling, which required more detailed information regarding bathymetry in the vicinity of the discharge to provide an adequate understanding of near-field plume processes.

The survey found the midpoint of the discharge pipe array ends at Easting (X) = 1,753,925 feet, and Northing (Y) = 229,615 feet, in the New Jersey State Plan North American Datum 1927 (NJSP-NAD27) Coordinate System. This position corresponds to 828 ft West and 1,115 ft South in the Station coordinate frame.

II. CONSTRUCTION PLANS

Construction plans of the cooling water discharge site were provided to the survey team to assist in designing the bathymetric survey. These plans were also used to interpret the survey data. According to PSE&G Drawing 211199-A-8855-5, the construction plan extended the pipes approximately 500 feet from the seawall. E-1-4 Figures II-1 and II-2 provide summary information extracted from this drawing, the relevant details of which are reviewed below.

E-1-4 Figure II-1 is a plan view of the pipe terminations and the surrounding area. E-1-4 Figure II-2 is a corresponding side view. The discharge pipes extend approximately 505 feet (450 feet of which are buried) offshore from the property line. The end of the pipes is shown by the gray rectangle on E-1-4 Figure II-1. The width of this multipipe discharge terminus is approximately 90 feet. A concrete apron the same width as the discharge structure was placed at the terminus, extending 20 feet seaward of the terminus. Riprap surrounds the terminus, extending 120 feet seaward, approximately 63 feet shoreward (east) beneath the pipes, and nearly 125 feet to either side (north and south) of the diffuser's midpoint. The riprap region is shaded gray on E-1-4 Figure II-1. West of the riprap is a dredged section having a width (perpendicular to the discharge pipes) that ranges from 90 to 250 feet and an indeterminate length along the axis of the pipe that is greater than 350 feet.

III. SURVEY INSTRUMENTATION

The survey was performed on 18 September 1998 aboard the *Northstar 4*, a 50-foot work vessel well suited to this type of survey. The following instrumentation was used: a Trimble NT200 Differential Global Positioning System (DGPS), an Odom EchoTrac DF3200 echo sounder, an NEC P/75 75 MHz Pentium laptop computer (with Hypack software), and a Brancker TG-205 tide gauge.

The echo sounder was calibrated prior to the survey to ensure it recorded accurate water depths. The method used to calibrate the echo sounder was the widely used bar check method, in which a bar is dropped to several measured depths and the echo sounder's measurements of the bar's depth are compared for accuracy. At all depths, the difference between the echo sounder output and the known depth was less than 0.1 feet, a high level of accuracy.

Echo soundings are difficult to obtain within the immediate discharge mixing area of the thermal plume because of its extreme turbulence and density differentials. Acoustic scattering in such strong flow can render an echo sounder useless. To maximize the ability of the echo sounder to read accurate water depths in the area, multiple passes were made through the discharge plume prior to the survey to test various configurations. These tests indicated that the best results were collected when the echo sounder was set to dual frequency (24/200 kHz) with high output power and the gain tuned to about three-quarter scale. Gain is a setting that can be adjusted to reduce the level of noise in the echo sounder output. The high-frequency 200 kHz channel provided the best resolution of depth through the discharge plume. These settings also were used to improve upon a preliminary survey that was conducted in August 1998 (Woods Hole Group 1998).

The laptop computer was configured to record both differential-corrected GPS positions from the Trimble DGPS, as well as digital echo soundings from the Odom EchoTrac DF3200. The Hypack software package integrates both signals and produces data files of position relative to depth and time.

A Brancker TG-205 tide gauge installed on a pier piling in Sunken Ships Cove measured water elevation changes throughout the survey to a vertical resolution of approximately one centimeter; these data were used to correct the bathymetric readings for changes in tide level during the approximately three-hour survey. Water level readings, computed from a burst average of 32 instantaneous readings sampled at 2 Hz, were obtained every 5 minutes. The tide gauge's internal clock was synchronized to the survey clock to ensure a correspondence in times.

The tide gauge was not surveyed to the Plant's established vertical datum; hence, water elevations are relative to the low tide of the day, not to an absolute datum. However, the vertical position of the tide gauge was measured relative to a known location on the pier, so future corrections to a known vertical datum could be made if required. (In this case, because the data were not imported directly to a computer model, it was not necessary to have the data referenced to an exact datum.)

IV. SURVEY PROCEDURES

The survey area extended from the shoreline approximately 1,000 feet toward the center of the river, and spanned the shore region from the Station's circulating water intake basin to the Station's service water intake basin (approximately 750 feet). The discharge pipes were known to be located within this survey area from the construction drawings and previous surveys in this region (ACI 1994; Wood Hole Group 1998).

The survey area was mapped using a grid of shore-parallel transect lines and shore-normal tie lines. The spacing between lines varied with distance from the discharge. In the immediate vicinity of the discharge, the spacing between the shore-parallel transect lines was 20 feet, and the shore-normal tie line spacing was 25 feet. Farther from the discharge, the line spacing was doubled, and near the boundaries of the survey area farthest from the discharge, the line spacing was tripled. As a result, the bathymetric survey provides variable resolution in the horizontal plane, with the finest resolution (highest data density) in the immediate vicinity of the discharge.

It was extremely difficult to navigate the vessel through the turbulent area where the plume surfaces. The discharge flow would push the vessel off its desired path and away from the discharge surfacing location. As a result, transect lines show characteristic deflections in the immediate area of the plume. E-1-4 Figure VI-1 illustrates the vessel's track lines.

V. DATA QUALITY CHECKING

The raw data were quality checked. The quality check consisted of plotting each individual shore-parallel transect line and shore-normal tie line. Each line was studied closely to identify any "outlier" points, which commonly occur during bathymetry surveys and which represent unreasonable depths or positions. Except in the highly turbulent discharge region, there were very few outlier depths that needed to be filtered from the data set (see discussion of post-processing below). Furthermore, the strength of the differential signal ensured that there were no data points lost due to an inability to correct using that signal.

Although the bathymetry data collected were of high quality, there was a small area in the center of the discharge plume where no data were collected due to acoustic scattering problems and the aforementioned ship maneuverability problems, both of which were due to turbulence associated with the discharge plume; however, only a small portion of the near-field was not surveyed.

VI. DATA POST-PROCESSING AND RESULTS

VI.A. Data Post-Processing

The post-processing consisted of three steps: First, the raw bathymetry data were tide-corrected using the tidal elevation data collected at Sunken Ships Cove. Outlier points were then filtered from the corrected data set. Finally, adjacent raw data points were block-averaged by calculating one averaged data point along every five feet of a transect line.

VI.B. Results

The post-processed data are plotted in E-1-4 Figure VI-I. Each dot represents an individual data point and, in series, the data points depict the survey lines. The Easting and Northing locations are given in NJSP-NAD27 coordinates in feet. The color of each point indicates the measured value of water depth as shown on the legend.

Based on the individual averaged data points, a Triangular Irregular Network (TIN) was created. The TIN joins the individual data points to form a continuous surface similar to a contour map as shown in E-1-4 Figure VI-2. The TIN highlights continuous features of the bottom such as ridges and troughs. E-1-4 Figure VI-2 shows the area of the bathymetry survey relative to the shoreline and the discharge pipes, as well as the limits of the bathymetry survey relative to where the discharge surfaces on a flood tide, as indicated by the closed black loop near the center of the plot. Differential GPS positions were recorded aboard a vessel that was navigated along the perimeter of the disturbed water surface, as determined visually during a flood tide on 20 August 1998. This plume surfacing location survey was conducted in conjunction with a preliminary bathymetric survey and a mooring turn-around mission conducted during that time.

E-1-4 Figure VI-3 is a cross-section of the bottom in front of the discharge pipe. E-1-4 Figure VI-4 shows a close-up of the TIN model in the immediate vicinity of the discharge location. The black curve again represents the perimeter of the disturbed surface water on 20 August 1998. The white dots represent the block-averaged data, and are provided to illustrate the density of data used to generate the TIN model.

VII. DATA INTERPRETATION AND DISCUSSION

VII.A. Discharge Location

Interpretation of E-1-4 Figures VI-1, VI-2, VI-3, and VI-4 indicates the location of the discharge pipes as well as a variety of bottom features in the vicinity of the discharge. The location of the discharge is apparent from the TIN descriptions of the bathymetry data presented in E-1-4 Figures VI-2 and VI-4, and this TIN-based location is then overlaid on the bathymetry data.

Comparison of the original construction plans to the bathymetric data collected in the Survey suggests that the pipes extend southwestward from the seawall between the service water intake and the Circulating Water Intake Structure (CWIS) for the Station. The pipes (represented by the long dark blue feature in E-1-4 Figure VI-2) extend from north coast side of the survey rectangle toward the middle of the survey area A close-up of the survey region presented in E-1-4 Figure VI-A shows the point where the pipes are no longer covered by sediment (shading changes to light blue) and the point of termination of the pipes (light blue changes to yellow).. Based on the data, the midpoint of the multipipe diffuser is Easting (X) = 1,753,925 feet, Northing (Y) = 229,615 feet, in NJSP-NAD27 coordinates; or 828 feet West, 1115 feet South in Station coordinates.

The location of the midpoint of the discharge interpreted from the bathymetry data was within 15 feet of the midpoint shown on the original construction drawings. This close agreement confirmed the accuracy of the bathymetry survey, and provided confidence in interpretation of other bottom features in the vicinity of the discharge.

VII.B. Bottom Features in the Vicinity of the Discharge

In addition to the location of the discharge pipes, E-1-4 Figures VI-1, VI-2, and VI-4 reveal features of the bottom in the vicinity of the discharge. In E-1-4 Figure VI-4, the yellow band just seaward of the diffuser and between the light blue and orange regions indicates the 20-foot concrete apron. The orange section, where the plume surfaces, encompasses most of the area where no data were collected and is largely interpolated. Based on the discharge configuration shown in E-1-4 Figures II-1 and II-2, it appears that the interpolated section lies within the riprap region surrounding the discharge. The dark red sections represent a bottom depression seaward of the riprap, and correspond at least in part to the original dredged area. Seaward of this depression is a small rise in the bottom (shown in yellow) between the interpolated orange section and the deep red section.

VIII. CONCLUSIONS

The bathymetry data collected in the vicinity of the discharge show midpoints and bottom features consistent with the construction plans, features that were of significant interest with regard to understanding and modeling near-field plume dynamics. The data show that the discharge pipes are buried by sediment for the majority of their length. They appear to emerge from the sediment approximately 50 feet from the discharge point. The discharge piping itself is fronted by a flat concrete apron, which is shown in the original construction drawings. Although the region immediately in front of the discharge was not well characterized by the survey, there is clearly a bottom depression extending for a distance of 50 to 100 feet in front of the discharge. Based on the original construction drawings (E-1-4 Figures II-1 and II-2), it is likely that this bottom depression is a remnant of the initial dredging, that a portion of it closest to the discharge is armored with riprap, and that it is maintained in part by the discharge flow velocities.

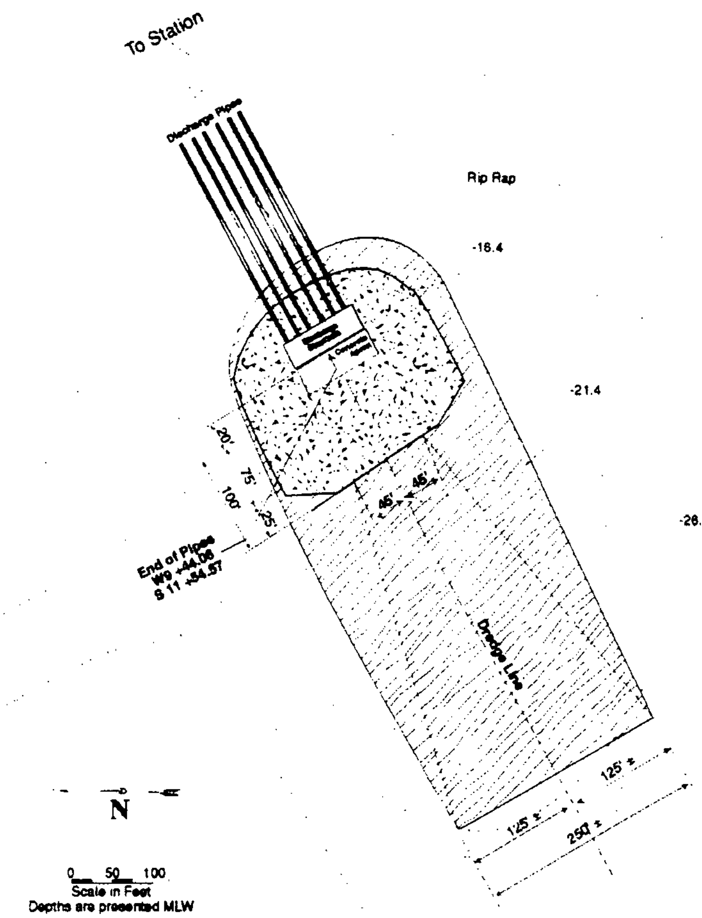
The bottom features revealed by this survey significantly impact the evolution of the plume in the near-field, and are of particular relevance to the near-field computer modeling efforts. These bottom features tend to cause the plume to surface and mix throughout the water column relatively rapidly, as evidenced by field data and the simulations of the near-field model (see Section III.B of Attachment E-2 for a detailed discussion of these processes).

E-1-4 REFERENCES

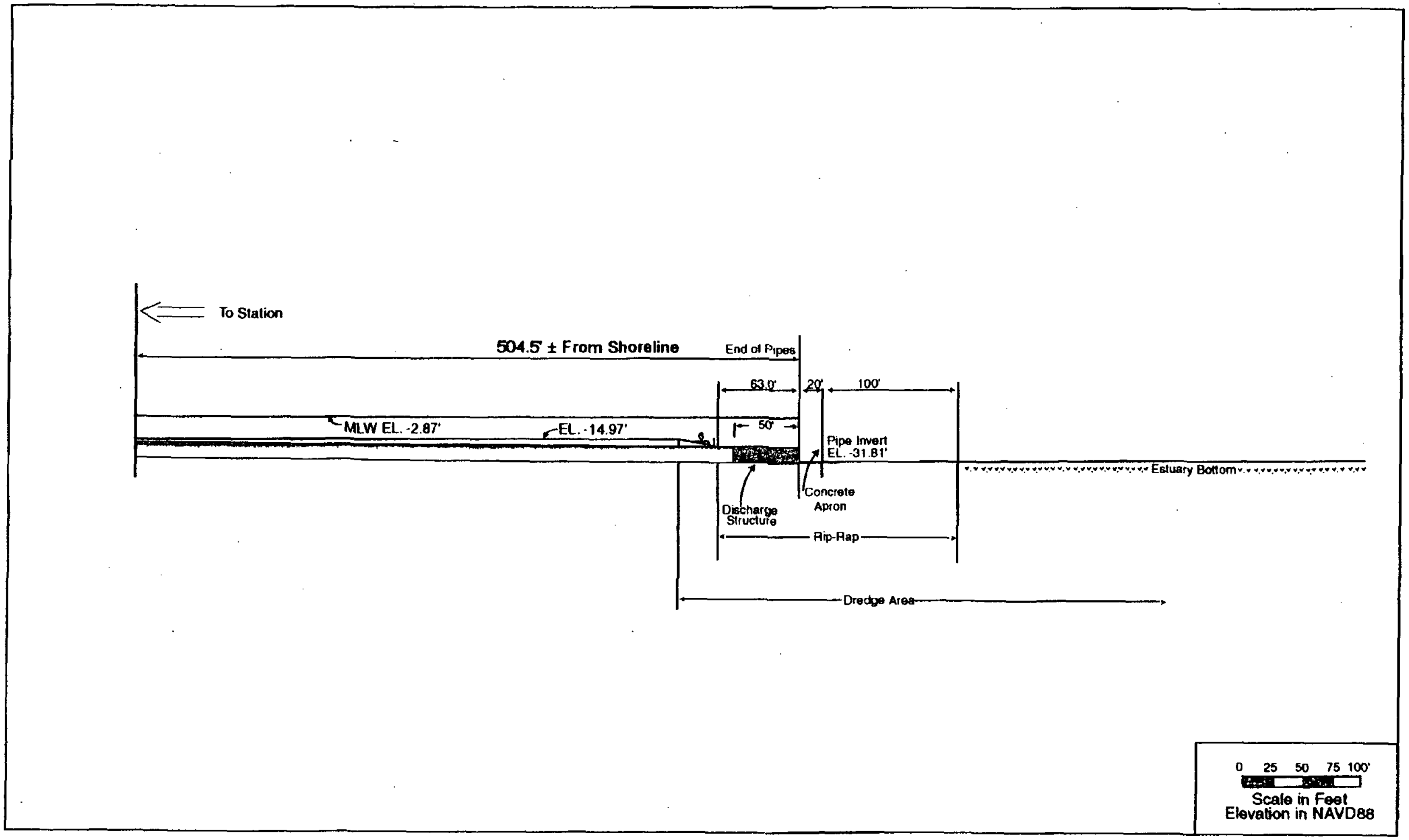
Public Service Electric and Gas (PSE&G). Drawing 211199-A-8855-5: *Dredging for Intake and Discharge Pipes*. PSE&G Electric Engineering Department. Newark, New Jersey.

Aubrey Consulting, Inc.(ACI) 1994. PSE&G Salem and Hope Creek Nuclear Power Plant, Task 6: Sub-Bottom Profiling. East Falmouth, Massachusetts. September.

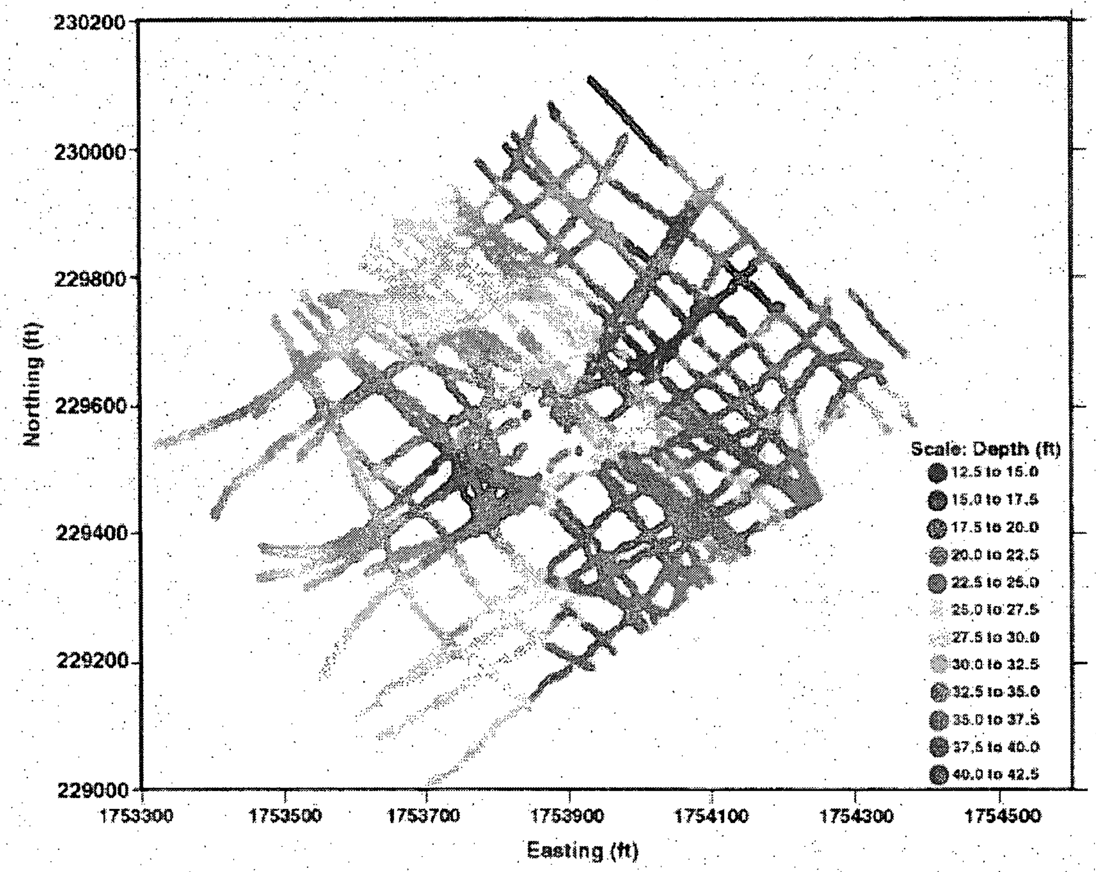
Woods Hole Group. 1998. Technical Report for Discharge Bathymetry at Salem Generating Station: PSE&G 316(a) Support. East Falmouth, Massachusetts. September.



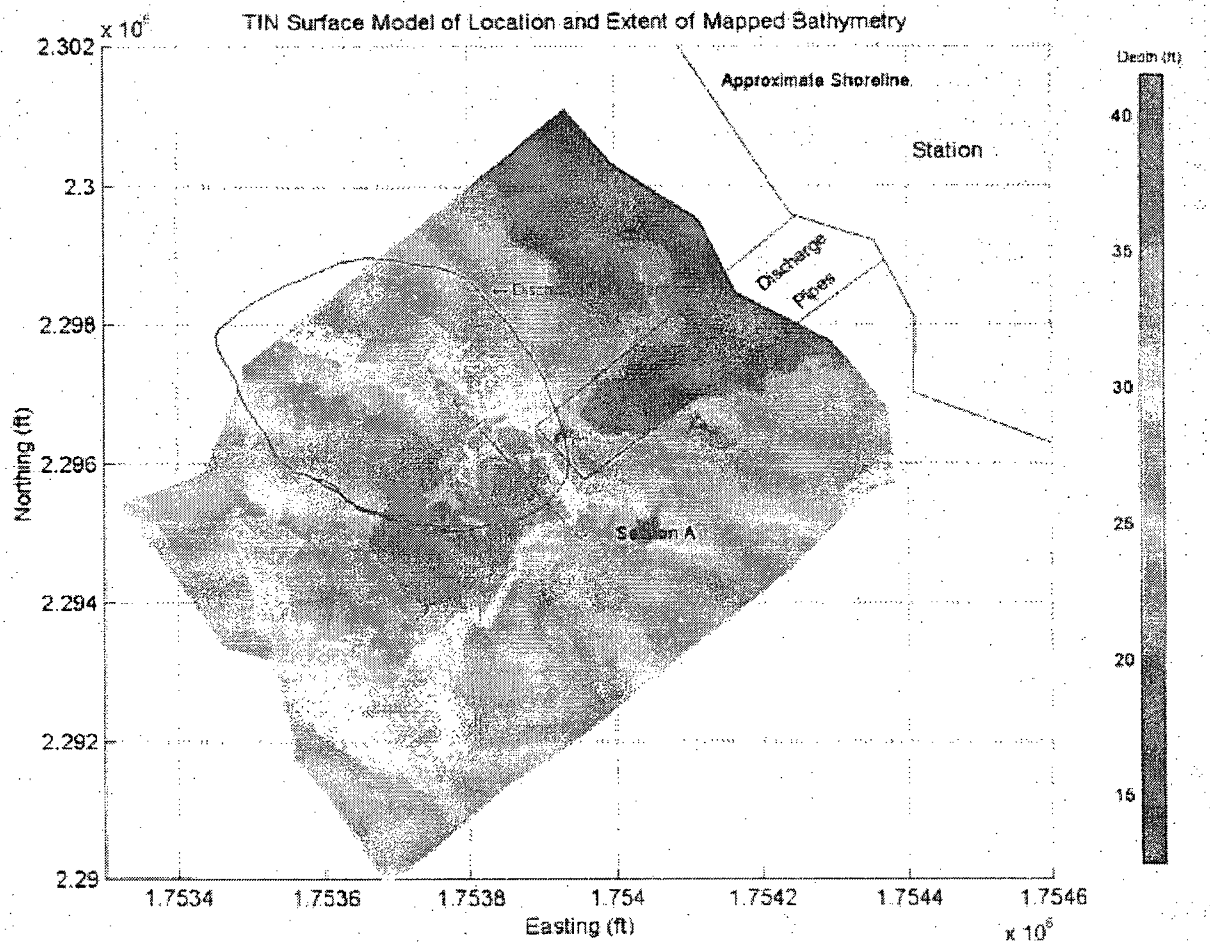
E-1-4 Figure II-1. Plan view of discharge pipes termination region (construction drawing 211199-A-8855-5).



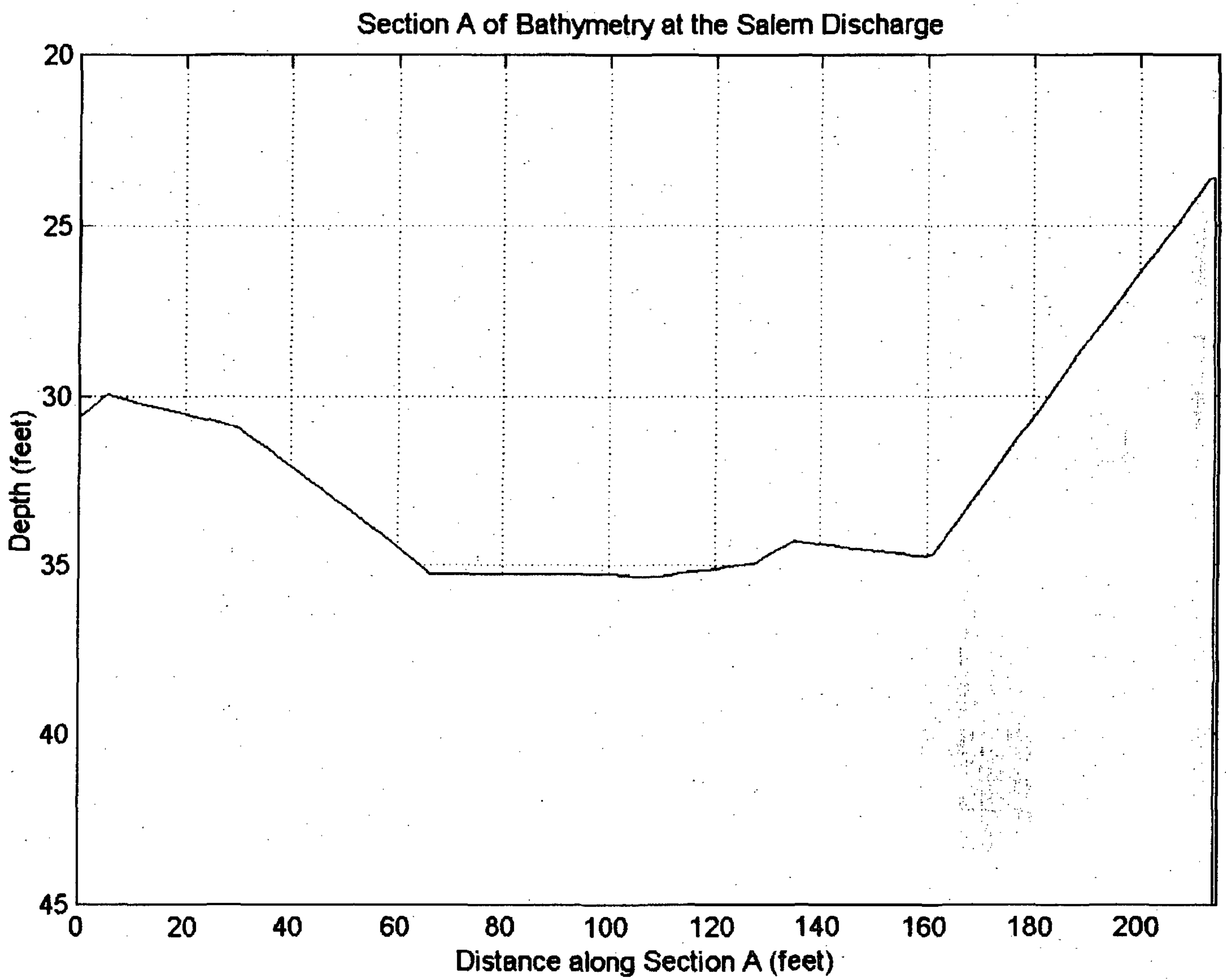
E-1-4 Figure II-2. Side view of discharge pipes (construction drawing 211199-A-8855-5).



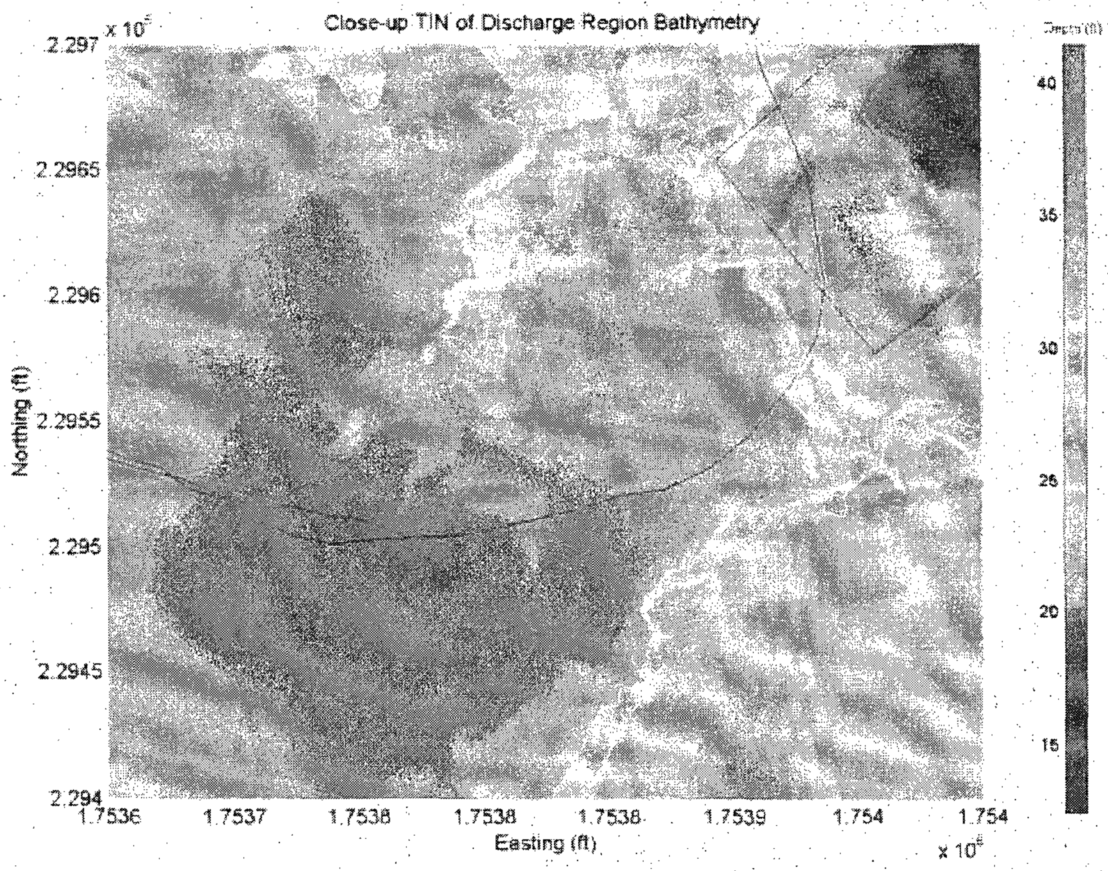
E-1-4 Figure VI-1. Bathymetry Survey tracklines and data. Each dot is a post-processed data point. The color of each dot indicates water depth according to the scale provided.



E-1-4 Figure VI-2. Plan view: Triangular irregular network (TIN) of bathymetry at the Salem Discharge. The approximate location of the discharge pipes and the surface upwelling measured on a flood tide are shown. Section A is plotted on E-1-4 Figure VI-3



E-1-4 Figure VI-3. Cross-section of bathymetry in the vicinity of Salem discharge. The location of the cross-section is denoted as Section A on E-1-4 Figure VI-2.



E-1-4 Figure VI-4. Close-up plan view: Triangular irregular network (TIN) of bathymetry at the Salem discharge.

APPENDIX E
EXHIBIT E-1-5

HEAT FLUX FROM THE MARSHES

SPONSOR: DR. BRUCE A. MAGNELL
PSE&G RENEWAL APPLICATION
SALEM GENERATING STATION
PERMIT NO. NJ0005622
4 MARCH 1999

*

APPENDIX E
EXHIBIT E-1-5

HEAT FLUX FROM THE MARSHES

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Figure III-3. Temperature map from satellite infrared imagery of Delaware Estuary around Artificial Island, 21 July 1990 at 4:12 p.m. (ebb tide), north of the Station, showing elevated temperature outflow from Salem River. (Offshore Services, Inc. 1993, image no. I90202181226)

Figure III-4. Time history of temperature observed at surface, mid-depth, and bottom at the mouth of Alloway Creek during the Two-Unit Survey, May 1998 (Exhibit E-1-3). Also shown are tide height at the Salem Barge Slip, current direction from the ADCP near the Station, and insolation and air temperature at Artificial Island.

Figure III-5. Time history of temperature observed at surface, mid-depth, and bottom at the mouth of Hope Creek during the Two-Unit Survey, May 1998 (Exhibit E-1-3). Also shown are tide height at Hope Creek, current direction from the ADCP near the Station, and insolation and air temperature at Artificial Island.

Figure III-6. Time history of temperature observed at surface, mid-depth, and bottom at the mouth of Mad Horse Creek during the Two-Unit Survey, May 1998 (Exhibit E-1-3). Also shown are tide height at Mad Horse Creek, current direction from the ADCP near the Station, and insolation and air temperature at Artificial Island.

APPENDIX E
EXHIBIT E-1- 5

HEAT FLUX FROM THE MARSHES

This Exhibit examines the exchange of heat between the River and the salt marshes adjacent to it. The River and the marshes together comprise the Estuary environment. The marshes are in part responsible for significant temperature variations in the River, and are important influences on the overall heat budget of Estuary waters. Any assessment of potential environmental impacts of the heat discharged into the Estuary from the Station's condensers must take into consideration these additional natural sources of thermal fluctuation.

I. INTRODUCTION

Extensive salt marsh areas occupy the shores of the upper part of Delaware Bay, including the area around Salem Station. For example, the Alloway Creek marsh complex, which is just north of Artificial Island and closest to the Station, covers approximately 10 square miles immediately around the Station (Appendix C Section VII.C). Hope Creek and Mad Horse Creek are located approximately three and eight miles south of the Station, respectively. The marshes are shallow (typically only 1.5 to 2.0 feet (0.5 to 0.61 meters) deep in most places at high tide), and most of their surface area is exposed (uncovered by the water) when the tide falls below Mean Tide Level (Appendix C Section VII.C.5). The marsh sediments are composed of dark, fine-grained, sandy mud and plant detritus (Appendix C Section VII.C.5.), but only part of this substrate is directly exposed to the sun and the air because the marshes are also covered with dense vegetation (*Spartina alterniflora, Spartina patens, Distichilus spicata, Phragmites australis*), and related high- and low-marsh species. A network of relatively deep but narrow creeks drains the water out of each marsh on the falling tide and channels water into the marsh on the rising tide. The marshes are connected to the River through narrow inlets or creek mouths that penetrate the barrier beaches along the River's edge.

The marshes cover a large area, even in comparison to the area of the River. Within a 20-mile length of the Estuary centered on the Station, the marshes and creeks cover an area of about 71 square miles (Table I-1). Thirteen separate marsh areas on the New Jersey shore and ten areas on the Delaware shore between RM 40 and 58 are identified in this table, which also gives the area of individual marshes and their tributary creeks (United States Fish and Wildlife Service 1981). The surface area of the River between about RM 40 and 60 is approximately 65 square miles (as computed from NOAA navigational chart #12311), excluding the marshes, creeks, and other tributaries. The marshes and their creeks thus cover a larger surface area than the River itself in this particular region.

The marshes, like the River, are exposed to the sun and the air, and are rarely at thermal equilibrium; the water in them continually gains or loses heat through radiation, evaporation, conduction, and convection. As a result of their large surface area and near-complete drainage into the River on every tidal cycle, they are potentially massive sources or sinks for heat to and from the River; their shallow depth results in large changes in temperature from a given heat input. To better understand the Station's potential impact on an environment subject to this natural source of temperature variability, two primary questions are addressed in this Exhibit:

1. What volume of water at significantly elevated temperatures is contributed to the River by the marshes, and how does this volume compare in magnitude to the Station's thermal discharge?
2. Do the marshes contribute significantly to the dissipation of heat from the Station?

II. HEAT EXCHANGE BETWEEN THE MARSHES AND THE RIVER

II.A. Background

The marshes contribute the greatest quantity of heat to the River following a high tide in the early afternoon on a clear, warm day. Under these conditions, the water covering the marsh plain at high tide has the greatest opportunity to absorb heat from the sun and air. When the tide ebbs, water drains from the marsh and carries its heat load into the River as a nearshore thermal plume. A different situation occurs following a high tide on a cold night. In this instance the marsh water loses heat rapidly through back radiation and conductive/convective exchange with the atmosphere. The marsh acts as a relative heat sink, releasing cold water into the river when the tide ebbs. The magnitude of heat exchange between the marshes and the River also varies seasonally, responding to changes in the incoming solar radiation (insolation), air-water temperature difference, and dew point.

Heating or cooling of water in a marsh is complicated because it is not simply a water or mud surface. Over portions of vegetated marsh plain, sunlight first strikes the tall marsh grass that partially shades the actual water or mud surface. Some of the sunlight is reflected; the remainder heats the leaves of the grass and, ultimately, the surrounding air. The marsh grass acts as an insulator, trapping the heat of the sun in the air, which then transfers heat to the water conductively. The growth stage of the grass influences its effectiveness as an insulator. Even at low tide, when water is not present, heat is exchanged between the sun, the air, and the mud. This heat surplus or deficit (cold) is transferred to the water when it returns on the flood tide, so the marsh acts like a heat reservoir.

At the latitude of Delaware Bay (39° to 40°N), the sun's radiation has an effective heating power at the top of the atmosphere of about 765 watt/m^2 at the summer solstice (21 June) when the sun is closest to directly overhead (Linsley et al. 1949). However, the sun is not always directly overhead, and not all of the sun's heat reaches the marsh water. For a preliminary estimate of marsh heat transfer, the effective solar heat input to the water in summer (averaged over about eight hours around midday) is assumed to be 150 to 500 watt/m^2, with the lower value corresponding to a cloudy day.

II.B. Marsh Heating Rate and Temperature Response

To approximate the heat transfer from marsh to River during the course of a single day, it is reasonable to focus on the effect of incoming solar radiation, which is ultimately the driving force for temperature changes, while neglecting air-sea heat exchange due to other factors. The marshes, like the River surface, gain and lose net heat as a result of various air-sea heat flux mechanisms, including incoming long-wave sky radiation, back radiation, evaporative heat loss, and conductive heat loss or gain. However, the air-sea heat fluxes associated with these other mechanisms typically do not vary as rapidly as the short-wave heat input due to the sun, which ranges from zero at night to a maximum at midday. Evaporative and conductive heat exchanges are dependent on the air-sea temperature difference, which usually increases each day in response to solar heat input. Neglecting these mechanisms terms is therefore a conservative approach, all else being equal. Radiative mechanisms depend on absolute temperatures, so their heat flux varies slowly over the time scales corresponding to the passage of major weather systems, which can cause systematic changes in bulk water and air temperatures.

To evaluate the importance of marsh heat transfer, the probable range of heat transfer rates, temperature changes, and outflow volumes were calculated. On an overcast summer day, neglecting other mechanisms of heat exchange, incoming solar radiation at 150 watt/m^2 adds heat at a rate of about 390 MW/mi^2. A ten-square mile marsh, similar to the Alloway Creek marsh, would have an effective 8-hour average heating rate of 3,900 MW on a cloudy day. Whether wet or dry, the marsh absorbs the sun's heat during all the hours that sunlight falls on it. This heat is then absorbed by the water during flood tide, and transferred into the River during the ebb phase. Over the course of eight hours of sunshine, a total of 31,200 MW-hrs. of heat energy would be added to the water in this marsh. This heat would then be advected into the River during the ebb phase, which typically lasts six hours. Therefore, the rate at which heat would be added to the River during a 6-hour ebb phase would be 5200 MW. The effective heat transfer rate to the river could be lower or higher depending on the relative phasing of the tide and the sun, and on the speed of marsh drainage. For example, if the marsh drains completely in only five hours, then the heat rate for the River during the ebb flow period would be 6240 MW, a rate comparable to the combined heat rejection rate of both Units of the Station through the condensers (6,000 MW; Appendix B) in the form of the Station's thermal plume. Averaged over the entire solar day, the heat input due to insolation of this marsh would come to approximately 31,000 MW-hrs. per day.

Even the minimal amount of insolation corresponding to a cloudy day can raise the temperature of the water significantly. Applying 150 watt/m^2 to water about 2 feet (0.61 meters) deep on average during the 6-hour flood period will result in a ΔT of about 1.2°C (2.1°F) in the water later discharged from the marsh. This does not account for heat transferred from the mud (which can be heated while dry) to the water, which can raise the temperature even more. This temperature increase is comparable to or greater than the 1.5°F ΔT value used to define the maximum extent of the Station's plume.

On a sunny summer day, when 500 watt/m^2 of solar insolation may be applied to the marsh, the heat rate can be about 1300 MW/mi^2, (13,000 MW for the 10 square miles of Alloway Creek marsh) and the temperature rise about 3.9°C (7.0°F), (again, neglecting any other variations in air-sea heat exchange). This quantity of heat is greater than that discharged by the Station, and the ΔT of the marsh discharge is larger than the ΔT of all but a small part of the Station's thermal plume.

The open water surface of the River also gains and loses heat due to the same mechanisms that operate in the marshes. However, the input of an equivalent amount of heat directly to the River surface will not produce the same temperature increase as it would in the marshes. In the River, the water is much deeper, and mixing due to tidal currents, winds, and waves distributes the heat rapidly through the water column. Presumably, insolation would tend to produce a warm surface layer during slack water periods, but their duration is brief, typically less than an hour, so this layer never builds up.

II.C. Comparison of Temperature Volumes

The volume of water associated with marsh outflows is also comparable to the volume of the Station's thermal plume even at high dilutions. Volume outflow of the marshes can be approximated as the product of the surface area and the average depth of water during the flood half-cycle, because all this water drains out on the ebb tide; this volume is independent of the amount of heat added to or removed from the water. Assuming a 2-foot (0.61 meter) average depth, a single square mile of marsh will drain 1,280 acre-feet of water. A ten-square mile marsh such as Alloway Creek will introduce nearly 13,000 acre-feet of water into the River on each falling tide. If the marsh temperature increase is 2°C (3°F)–which is a common occurrence—the volume of water at that temperature injected into the River from Alloway Creek marsh will be comparable to the volume enclosed by the same 3°F ΔT due to the Station's discharge. Table II-1 gives cumulative estimates of volume of various ΔT isopleths of the Station's plume, as predicted by the CORMIX and RMA-10 models (Appendix E Section V.F). The volume enclosed by the 3°F ΔT isopleth, for example, is in the range of 12,000 to 14,000 acre-feet matching that of the ten-square mile marsh.

Extrapolating to a wider area, the 73 square miles of marsh in the 20 mile reach of the Estuary around the Station contribute more than 100,000 acre-feet of water to the River on each falling tide. Therefore, the total volume of heated water entering the River from the marshes with a temperature increase of 3°F can be as much as seven times larger than the volume of the Station's plume within its comparable 3°F ΔT isopleth.

Cross-channel exchange in the main stem of the River is weak compared to along-channel advection and mixing (Appendix C), so water that flows out of the marshes tends to remain close to the shore near its origin, where it is advected along-shore by the tide and mixed slowly toward the center of the River. The typical along-shore tidal excursion is three to six miles (five to ten km) (Appendix C), comparable to the distance between marsh outlets. Thus the marsh thermal plumes tend to merge into a more-or-less continuous band of elevated temperatures along the River's edge. Although some dilution occurs as the marsh outflow mixes with the ambient River water, the result is a large area — thousands of feet wide and many miles long — over which the excess temperature due to marsh heat exchange is comparable to the Station's thermal plume within the 1.5°F ΔT isopleth.

II.D. Probability of Occurrence of High Heat Exchange

High levels of solar heating and advective transfer from the marshes do not occur all the time, but only when the right combination of insolation, air temperature, and tidal phasing occurs simultaneously. However, such conditions are frequent. In particular, favorable timing of the tide in relation to insolation must be present during about half of each lunar month. For example, when the tide is high in the afternoon, timing is optimal for heat transfer. The semi-diurnal tide has a period of 12.42 hours, so the timing of flood and ebb tide slips relative to the sun by 50.4 minutes each day. After about seven or eight days, the tide will be low in the afternoon, which is not an optimum condition for marsh discharge at high ΔT. After another seven or eight days, the phasing will be favorable again; thus there is a 14.8 day periodicity in the occurrence of most favorable conditions. This periodicity is observed at the marsh outlets. For example, Figure II–1 shows the time history of temperature observed over a 3-month period at Salem River during June-September 1998. Diurnal temperature fluctuations of up to 3°C (5.4°F), associated with daily heating and outflow from this marsh, are evident in this time history. These daily temperature fluctuations occurred most of the time, superimposed on larger and slower temperature changes associated with synoptic and seasonal weather patterns. The diurnal temperature increases were greatest when the high tide occurred in the afternoon, as it did around 21 July 1998. Similar fluctuations were also observed about two weeks later, when the tide was again high in the middle of the day.

Cloudiness and cold air temperatures, which reduce solar and atmospheric heat input, have no consistent relationship with tidal phase. Insolation is highest in early summer, but cloud cover tends to be minimal in early fall. Table II-2 gives monthly sky cover statistics for Wilmington, Delaware. On average, the least cloudy conditions occur in October. It must be noted that partial cloudiness, as defined in this table, does not imply a total obstruction of solar heating. Taking into account solar and meteorological factors and tide phasing, a conservative estimate is that conditions favorable for net heating of the marshes occur between 30 percent to 50 percent of the time in the summer.

II.E. Marshes as Cooling Surface for the Station's Thermal Discharge

Cooling of water in the marshes can also be a factor in dissipating the heat produced by the Station. If the Station's diluted thermal plume enters a marsh on a rising tide, the surface area available for heat exchange with the atmosphere is increased as the plume spreads over the shallow water of the marsh. This cooling effect is limited to marshes near the Station.

If the Station's plume enters the marshes at all, it does so in a highly diluted state, with low ΔT, and cannot be distinguished observationally against natural background temperature variability. Therefore, model predictions must be used to investigate the importance of the marshes for cooling the plume. Figures II–2 and II–3 show temperature fields from a calibration run of the RMA-10 model at peak flood and ebb excursion, respectively (Appendix E Section V.E.). The marshes are represented as broad, shallow embayments of uniform depth, rather than as actual complicated marsh plains and tributary creeks. In these figures, the approximate boundary of the River, including its idealized marshes, is superimposed on the model domain.

These model simulations reveal that interaction between the plume and the marsh occurs most often at Hope Creek, but that the immediate plume from the Station does not flow directly into this marsh. Instead, a portion of the plume with low ΔT that occupies the embayment south of Artificial Island at the end of the ebb phase is swept into Hope Creek with the flood tide. By the end of the flood phase, a portion of the former ebb plume has entered the marsh, where its heat continues to dissipate. At that time, the portion of the plume area inside the Hope Creek marsh is estimated to be approximately 30 percent of the total 1.5°F plume area. Table II-3 shows the surface area of the Station's plume as estimated by the CORMIX and RMA-10 model (Appendix E Section V.F.). The maximum area of the 1.5°F isopleth of the plume during flood tide is about 3,200 acres, or about five square miles. Thus nearly the entire 1.5 square mile area of Hope Creek marsh is actively involved in cooling the Station's plume, although the water that enters the marsh is already diluted to a low temperature.

The model predicts that relatively little of the Station's plume enters Alloway Creek. At the start of the flood phase, nearly all of the residual plume from the previous flood phase has been swept away, so the water north of the outfall is near ambient temperature. As the flood tide progresses, the ambient water fills Alloway Creek marsh. By the time the immediate plume reaches its entrance several miles north of the Station, the marsh is already nearly filled to capacity and little of the plume water enters. The plume fills the embayment in front of the marsh entrance instead.

At the end of the ebb phase (Figure II-3) all the water has drained from the marshes. However, heat transfer still continues as the mud and vegetation in the marsh exchanges heat with the air.

III. OBSERVATIONAL EVIDENCE FOR MARSH HEAT EXCHANGE

III.A. Previous Study of Marsh Heat Exchange Near Salem Generating Station

A study of heat flux through Alloway, Hope, and Mad Horse Creeks (Weston Environmental Consultants 1978) confirms the concept of significant heat exchange, comparable to the heat output and temperature rise caused by the Station's thermal discharge. Using an anchored boat, currents were measured at each marsh creek inlet at all four stages of the tide during a period when the ebb phase occurred in the afternoon. Temperature, salinity, and tide height were also measured, and the cross-sectional area of the creek mouths was mapped. Net heat flux was estimated by multiplying the best estimate of volume flux during a tidal half-cycle by the difference between flood and ebb flow-weighted mean temperatures. For the conditions prevailing at the time (27 October

1977, a heavily overcast day), net heat flux to the River resulting from the afternoon ebb flow was estimated to be 10.9×10^{12} g-cal from the three marshes together (Table III-1; Weston Environmental Consultants 1978). This translates into a daily export of 12,670 MW-hrs, or an average of 2,100 MW over the six-hour heating half-cycle. The average water temperature increase due to solar heating in the marsh ranged from 0.5°C (0.9°F) at Mad Horse Creek to 0.80°C (1.4°F) at Alloway Creek, on this cloudy day.

On the day of the survey, the average insolation was measured as 89 g-cal/cm^2 integrated over six hours, corresponding to an average solar heating rate of 172 watts/m^2. A clear October day at this latitude would have had an average daytime solar insolation rate of 350 g-cal/cm^2 (675 watt/m^2) and the long-term average for the month of October (Weston Environmental Consultants 1978) is given as 278 g-cal/cm^2 (535 watt/m^2) at Seabrook, NJ, 27 kilometers east of Salem. If the 350 g-cal/cm^2 value had prevailed, as often would be the case in the summer, the heat input to the River from these three marshes would have been about 8,250 MW during the falling tide phase, and the resulting temperature increase would have been 1.9 to 3.1°C (3.4° to 5.6°F). This range of temperature increase is consistent with observations at the creek mouths during the recent 1998 Modified Thermal Monitoring Program studies (Exhibit E-1-3), and with the calculated values discussed in the previous section (Section II).

III.B. New Observational Evidence for Marsh Heat Exchange

The exchange of large amounts of heat between the River and the marshes can contribute to large temperature fluctuations in the River around the Station. An observational component was therefore added to the 1998 Modified Thermal Monitoring Program (Appendix E Section V.D.; and Exhibit E-1-3), to measure the volume and temperature of the flow into and out of salt marshes near the Station. During the Two-Unit Survey, May-June 1998, temperatures and salinities were measured in the mouths of Alloway, Hope, and Mad Horse creeks, as well as at locations in the River, using moored instruments (Figure III-1). The cross-sectional areas of the creek mouths were measured using a fathometer, and tide height was estimated from nearby fixed instrument measurements. Intensive survey measurements of flow through the creek mouths were made on the four stages of the tide using a vessel-mounted Acoustic Doppler Current Profiler (ADCP). The moored instrument measurements in the creek mouths and at some of the moored instrument locations were extended until November as part of the 6-month Long-Term Survey (Exhibit E-1-3).

III.B.1. Evidence for Heat Outflow from Salem River Marshes

Unambiguous evidence for temperature fluctuations of marsh origin in the River itself was recorded by moored instruments located nine miles north of the Station. Figure III-2 shows temperatures measured at moorings 9G (on the west side of the River, near the Delaware shore) and at 9R (on the east side of the River, near Salem Cove), and the difference between these observations. Also shown is tide height at Reedy Island, current direction at the ADCP near the Station, and solar insolation and air temperature measured at the Station.

Marsh outflow is not observed at mooring 9G on the west side of the River, where a pattern of regular semi-diurnal temperature fluctuations (1.8°F (1°C) peak-to-peak) occurs due to tidal advection of the mean longitudinal temperature gradient. In contrast, mooring 9R on the east side of the River shows large temperature fluctuations of diurnal periodicity superimposed on top of the smaller semi-diurnal variations. Mooring 9R is located about 1,000 meters (3,000 feet) offshore in the shallow, broad embayment of Salem Cove, directly offshore of a major marsh area and slightly upstream of the Salem River mouth. In addition to the Salem River itself, which drains much of the marsh region, there are several other creeks, such as Mill Creek, that drain into the River around this location. The diurnal signal occurs at all depths and is strongest when the ebb flow occurs in late afternoon or early evening on days when insolation is strong and air temperature is high. For example, during the period 25-30 May 1998, temperature pulses of about 2.5° to 3.5°C (4.5° to 6.3°F) occur late in the day (around 1800 hrs), with maxima occurring shortly after the end of the ebb phase in the River.

As there are no marshes on the west side of the River at this location, and no evidence of diurnal temperature fluctuations at the western mooring 9G, the warm pulses observed at mooring 9R must have come from a source on the New Jersey shore. This mooring is well beyond the farthest upstream extent of the Station's thermal plume (Section II). The occurrence of this temperature peak at the end of the ebb phase suggests that this fluctuation is not caused by the Station, and that it is indeed caused by the heated marsh outflow at this location. The fact that marsh-generated excess temperatures are seen at all depths at mooring 9R, and at a distance of 3,000 feet offshore, suggests that the volume of the marsh outflow is substantial. In early June, when the tide phase shifts relative to the solar day so that ebb tide is no longer in the afternoon, there is practically no diurnal temperature signal. The observations at mooring 9R are consistent with the previously described calculations of heat exchange and temperature response.

Further evidence that the plume from the Salem River Marsh covers a wide area is found in satellite imagery. Figure III-3 is a temperature map derived from satellite infrared imagery showing the Estuary around Salem (Offshore Services 1993), collected at 4:12 p.m. on 21 July 1990. Despite the poor spatial resolution of the satellite image upon which this contour map is based, a heated plume from the Salem River marsh is evident, with temperatures which differ from the ambient river temperature field by more than 3°F. This image also shows the Station's thermal plume. The surface area covered by the marsh plume is much greater than that covered by the Station's plume, and the temperature of the marsh outflow is higher than all but a small part of the Station's plume.

III.B.2. Evidence for Heat Outflow from Marshes Near the Station

At Alloway, Hope, and Mad Horse Creeks, observed water temperatures (Figures III-4, III-5, and III-6) show a strongly diurnal pattern (one high temperature per day) when the insolation is high and the ebb tide occurs in the afternoon or evening. This pattern is generally seen during half of each lunar month. Also shown on these figures are tide height and current direction measured at the bottom-mounted ADCP mooring V offshore of the Station, as well as insolation and air temperature. On cloudy days (low insolation) or days when the ebb tide occurred during the morning, the temperature fluctuations become smaller, more erratic, and more semi-diurnal in character, corresponding to lower heat exchange with the atmosphere and a more clearly defined tidal advective transport. Although the temperature fluctuations seen at these marsh mouths are not as dramatic as those from the Salem River, there is no doubt that the marshes contribute significant volumes of heated water to the River.

IV. CONCLUSIONS

In summary, evaluations of the physical properties of the marshes, as well as historical and recent observations, demonstrate the following:

- Due to their large surface area (comparable to that of the River), the marshes can store large amounts of heat and later transfer it to the River, with heat transfer rates from a single marsh being comparable to the Station's heat rejection rate (6,000 MW) on a cloudy day, and two to three times greater on a sunny summer day.
- Due to the shallowness of the water, the temperature increase resulting from solar heating in the marshes frequently exceeds 3°C (5.4°F) in the marsh outlets at ebb tide.
- The volume of heated water outflow from nearby marshes at these typical ΔT values is comparable to the volume of the Station's discharge at the same ΔT. For example, temperature increases of up to 3.5°C (6.3°F) unrelated to the thermal discharge from the Station are observed north of the Station (near Salem River), and this warm water extends more than 3,000 feet offshore. Somewhat smaller temperature increases are observed at other nearby marshes.
- Conditions that commonly produce high temperature increases and high heat transfer from the marshes (sunshine, warm air temperatures, and high tide in the afternoon) occur on at least 25 percent of the days in summer, as confirmed by observation.
- Nearby marshes, especially Hope Creek, contribute to the cooling of the Station's thermal plume. The model shows that this marsh comprises approximately 30 percent of the total modeled surface area of the plume within the 1.5°F isopleth. Thus, the marshes help to dissipate a portion of the Station's heat load to the Estuary which would otherwise remain in the River.

That the heat contributed to the River by marshes exceeds that contributed by the Station and that the marshes play an important role in Estuary-wide heat flux budgets are not new findings (Weston Environmental Consultants 1978). However, there are important implications of these observations:

1. Natural variability of temperature within the River near the Station is high due to marsh inflows. Diurnal variability can exceed 7°F when the ebb tide occurs during the late afternoon of a sunny day. In the absence of these marshes, the natural diurnal temperature variability in the River would be significantly lower.
2. Organisms occupying this stretch of the River are exposed to these significant and widespread temperature fluctuations on a daily basis.

3. Field measurements cannot distinguish between marsh heat build-up and Station heat build-up at any ΔT except those exceeding the maximum marsh temperature. Therefore, field measurements of temperatures within the Station's thermal plume must be interpreted with care.
4. Assessments of the potential environmental impacts of the Station's thermal plume must take into consideration the large natural variability caused by these numerous natural thermal discharges. The contributions of the marshes surrounding the Station to daily temperature variations in the River are significant.
5. Numerical simulations of the heat in the River near the Station should consider the effect of this heat source. At a minimum, the surface area of the marshes should be modeled to simulate their contributions to the River heat budget.

APPENDIX E
EXHIBIT E-1-5

HEAT FLUX FROM THE MARSHES
REFERENCES

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Weston Environmental Consultants. 1978. Special heat flux study at Alloway, Hope, and Mad Horse Creeks Salem Nuclear Generating Station Delaware River Estuary. Prepared for Public Service Electric and Gas Company, West Chester, Pennsylvania. February.

U.S. Fish and Wildlife Service (FWS). 1981. Mapping Conventions for the National Wetlands Inventory. Mimeo.

E-1-5 Table I-1. Area of Marsh Plains and Creeks in a region 10 miles upstream and downstream of the Station, compared with Delaware River surface area. Marshes modeled in RMA-10 are shown in italics. River Mile is measured from zero at the mouth of Delaware Bay; the Station is at RM 50.

BASIN	RIVER-MILE	MARSH PLAIN (sq. miles)	CREEK OPEN WATER (sq. miles)
DELAWARE SIDE			
The Flats	41.00	4.44	0.34
Smyrna River	44.56	5.90	0.36
Cedar Swamp SWMA	45.50	3.39	0.27
Rays Ditch	49.80	1.95	0.04
Blackbird Creek	50.49	4.73	0.36
Appoquinimink River	50.88	4.67	0.63
Lower Break	51.45	0.52	0.00
Silver Run	52.60	0.88	0.08
Augustine Creek	53.30	0.92	0.10
St Georges Creek	56.49	0.90	0.20
TOTAL - DELAWARE SIDE		**28.30**	**2.38**
NEW JERSEY SIDE			
Jacobs Creek	40.50	1.15	0.04
Bay Side	41.50	0.00	0.00
Phillips Creek	41.57	0.97	0.09
Stow Creek	41.57	4.59	1.39
Cherry Tree Creek	43.68	0.01	0.02
Lower Deep Creek	44.15	0.97	0.00
Mad Horse Creek	*44.94*	*5.78*	*0.40*
Fishing Creek	47.40	1.48	0.00
Hope Creek	*48.47*	*1.42*	*0.05*
Alloway Creek	*54.45*	*8.07*	*1.87*
Straight Ditch	55.97	0.76	0.01
Mill Creek-Elsinboro	56.77	1.15	0.13
Salem River	58.37	4.62	5.26
TOTAL - JERSEY SIDE		**30.95**	**9.28**
TOTAL AREA BETWEEN RM 40 AND RM 60:			
Marshes and Creeks			**70.9 sq. mi.**
River Surface Excluding Marshes and Creeks			**65.2 sq. mi.**

Data Sources
Marshes and Creeks: United States Fish and Wildlife Service, 1981
River: National Oceanic and Atmospheric Administration Navigation Chart #12311

E-1-5 Table II-1. Cumulative Volume within each ΔT Isotherm (from E Table V-3).

	Ebb: 6/2/1998 at 0830 hrs		End of Ebb: 6/2/1998 at 0000 hrs		Flood: 6/4/1998 1630 hrs		End of Flood: 5/31/1998 at 1600 hrs	
ΔT (°F)	Volume (acre-ft)	Percent of Estuary Volume	Volume (acre-ft)	Percent of Estuary Volume	Volume (acre-ft)	Percent of Estuary Volume	Volume (acre-ft)	Percent of Estuary Volume
>20	0.02	0.0000002	0.02	0.0000002	0.00	0.0000000	0.00	0.0000000
>19	0.04	0.0000004	0.04	0.0000004	0.00	0.0000000	0.00	0.0000000
>18	0.11	0.0000011	0.09	0.0000008	0.04	0.0000004	0.02	0.0000002
>17	0.19	0.0000018	0.16	0.0000015	0.09	0.0000008	0.04	0.0000004
>16	0.32	0.0000030	0.26	0.0000025	0.16	0.0000015	0.09	0.0000009
>15	0.52	0.0000048	0.40	0.0000038	0.32	0.0000030	0.17	0.0000016
>14	0.83	0.0000077	0.68	0.0000063	0.53	0.0000049	0.28	0.0000026
>13	4.03	0.0000375	1.08	0.0000100	0.87	0.0000081	0.50	0.0000046
>12	15.89	0.0001480	17.04	0.0001588	8.58	0.0000800	0.76	0.0000071
>11	28.71	0.0002676	73.31	0.0006832	21.01	0.0001957	1.24	0.0000115
>10	43.03	0.0004010	73.31	0.0006832	34.85	0.0003248	33.26	0.0003100
>9	53.84	0.0005018	73.31	0.0006832	50.50	0.0004706	73.77	0.0006875
>8	71.94	0.0006704	73.31	0.0006832	68.48	0.0006382	73.77	0.0006875
>7	93.17	0.0008683	167.00	0.0015563	89.63	0.0008353	73.77	0.0006875
>6	118.86	0.0011077	350.19	0.0032635	115.30	0.0010745	73.77	0.0006875
>5	955.51	0.0089044	640.54	0.0059692	1967.64	0.0183366	152.99	0.0014258
>4	3654.06	0.0340525	1247.49	0.0116254	5402.81	0.0503493	4122.04	0.0384136
>3	13705.19	0.1277199	13659.48	0.1272939	12019.14	0.1120074	17216.55	0.1604427
>2	43849.62	0.4086387	45609.81	0.4250420	41390.39	0.3857209	37171.93	0.3464086
>1.5	76806.34	0.7157654	73624.92	0.6861175	68836.81	0.6414966	63733.82	0.5939414

Notes:

1. Plant Conditions: Low flow (140,000 gpm/pump), high ΔT (18.6 F).
2. Total estuary volume = 10,730,658 acre-ft
3. Reasonable worst-case tide phases selected based on analysis of time-temperature curves
4. Running tides (e.g. ebb and flood) include volume approximation of the intermediate field

E-1-5 Table II-2. Total Sky Cover Distribution, Wilmington, Delaware , 1948 - 1990 (from C Table 13).

	Frequency of Occurrence (%)				Estimated
Month	**Clear**	**Scattered**	**Broken**	**Overcast**	**Mean (tenths)**
Jan	24.4	15.4	13.7	46.5	6.0
Feb	26.0	15.4	13.5	45.1	5.8
Mar	25.6	16.2	14.0	44.2	5.8
Apr	23.0	17.7	16.4	42.8	5.9
May	18.8	19.3	18.9	43.0	6.1
Jun	19.7	25.1	21.0	34.2	5.5
Jul	18.7	26.5	22.0	32.7	5.5
Aug	21.8	25.8	20.5	31.9	5.3
Sep	26.8	21.2	17.4	34.6	5.2
Oct	31.4	18.9	15.3	34.4	5.0
Nov	25.6	17.9	15.8	40.6	5.6
Dec	24.2	16.4	14.4	45.0	5.9
Annual Mean	**23.8**	**19.7**	**16.9**	**39.6**	**5.6**

E-1-5 Table II-3. Cumulative Surface Area within each ΔT Isotherm (from E Table V-2).

	Ebb: 6/2/1998 at 0830 hrs		End of Ebb: 6/2/1998 at 0000 hrs		Flood: 6/4/1998 1630 hrs		End of Flood: 5/31/1998 at 1600 hrs	
ΔT (°F)	Surface Area (acres)	Percent of Estuary Area	Surface Area (acres)	Percent of Estuary Area	Surface Area (acres)	Percent of Estuary Area	Surface Area (acres)	Percent of Estuary Area
>13	0.08	0.00002	0.00	0.00000	0.00	0.00000	0.00	0.00000
>12	0.46	0.00010	0.47	0.00010	0.21	0.00004	0.00	0.00000
>11	0.98	0.00020	2.15	0.00045	0.61	0.00013	0.00	0.00000
>10	1.66	0.00034	2.15	0.00045	1.15	0.00024	0.85	0.00018
>9	2.22	0.00046	2.15	0.00045	1.82	0.00038	1.93	0.00040
>8	3.19	0.00066	2.15	0.00045	2.64	0.00055	1.93	0.00040
>7	4.32	0.00090	5.10	0.00106	3.59	0.00075	1.93	0.00040
>6	5.61	0.00116	11.32	0.00235	4.68	0.00097	1.93	0.00040
>5	36.60	0.00760	21.43	0.00445	56.58	0.01174	2.14	0.00044
>4	150.08	0.03115	45.11	0.00936	245.94	0.05105	205.37	0.04263
>3	631.42	0.13106	739.88	0.15357	585.78	0.12158	920.75	0.19111
>2	1947.91	0.40430	2519.94	0.52303	2212.75	0.45927	2093.04	0.43442
>1.5	3156.56	0.65517	3725.19	0.77319	3703.61	0.76871	3596.95	0.74657

Notes:

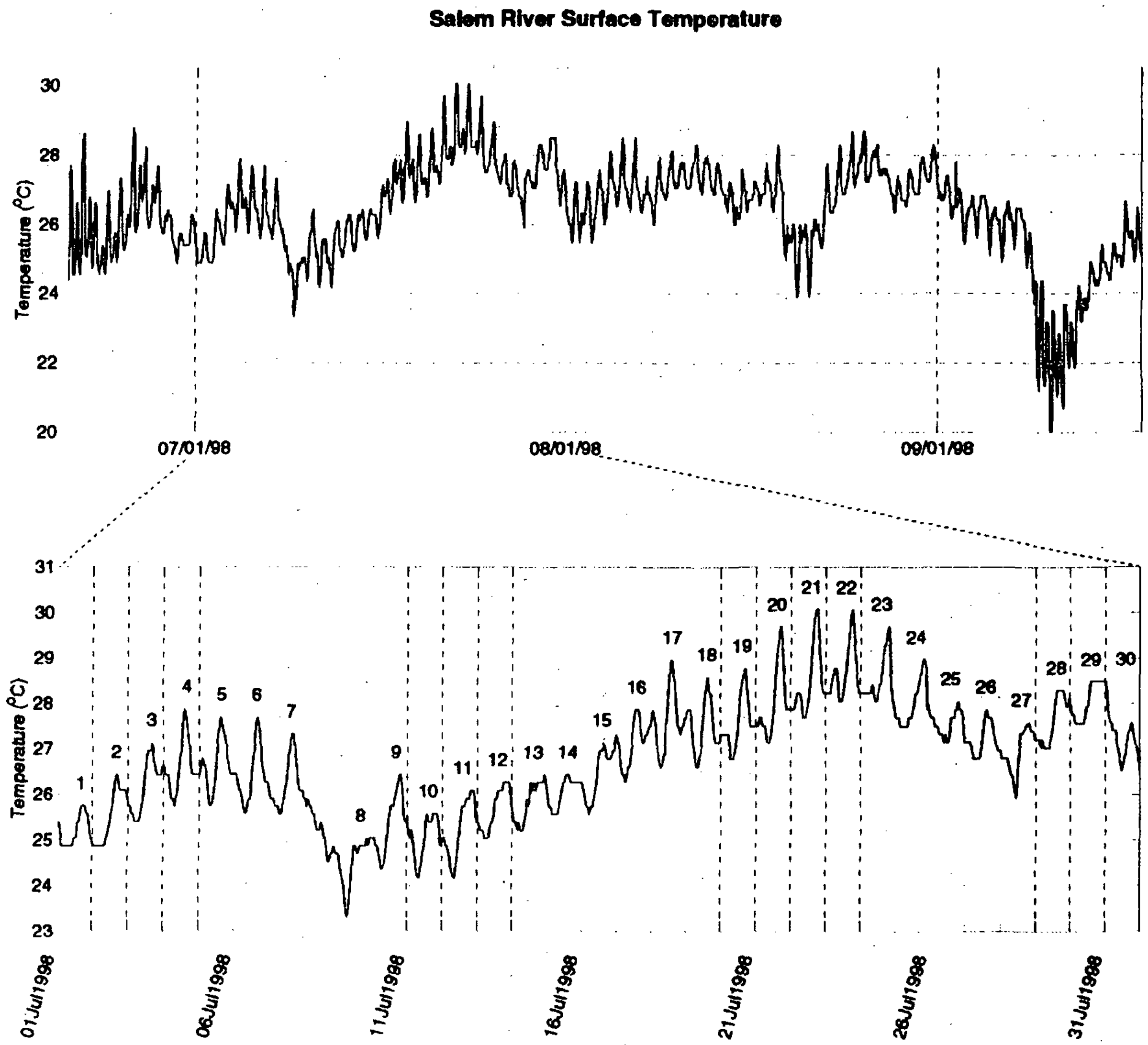
1. Plant Conditions: Low flow (140,000 gpm/pump), high ΔT (18.6 F).
2. Total surface area of the estuary = 481,796 acres.
3. Reasonable worst-case tide phases selected based on analysis of time-temperature curves
4. Running tides (e.g. ebb and flood) include area approximation of the intermediate field

E-1-5 Table III-1. Volume, Heat, Mean Temperature and Net Heat Transport Values for Alloway, Hope and Mad Horse Creeks, 27 October 1977 (Weston Environmental Consultants 1978).

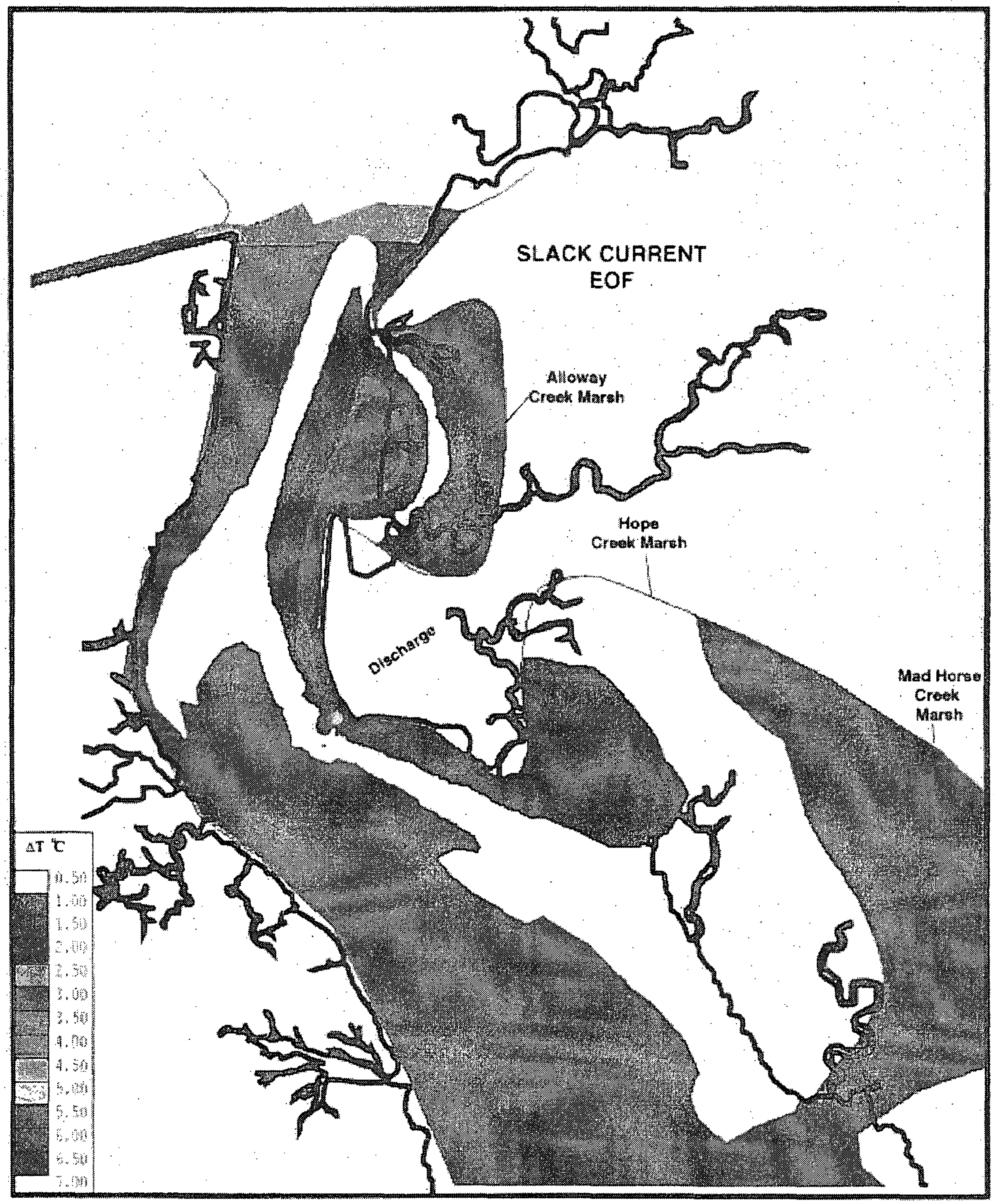
	Flood Tide			EBB Tide		
	Volume Transport ($m^3 \times 10^6$)	Heat Transport (g-cal. $\times 10^{14}$)	Mean Temperature (°C)	Volume Transport ($m^3 \times 10^6$)	Heat Transport (g-cal. $\times 10^{14}$)	Mean Temperature (°C)
Alloway Creek	-6.37	-1.03	13.74	8.29	1.42	14.54
Hope Creek	-3.09	-0.43	13.59	4.13	0.60	14.27
Mad Horse Creek	-5.60	-0.81	13.53	5.22	0.78	14.01

Note: Positive values indicate transport out of the creek

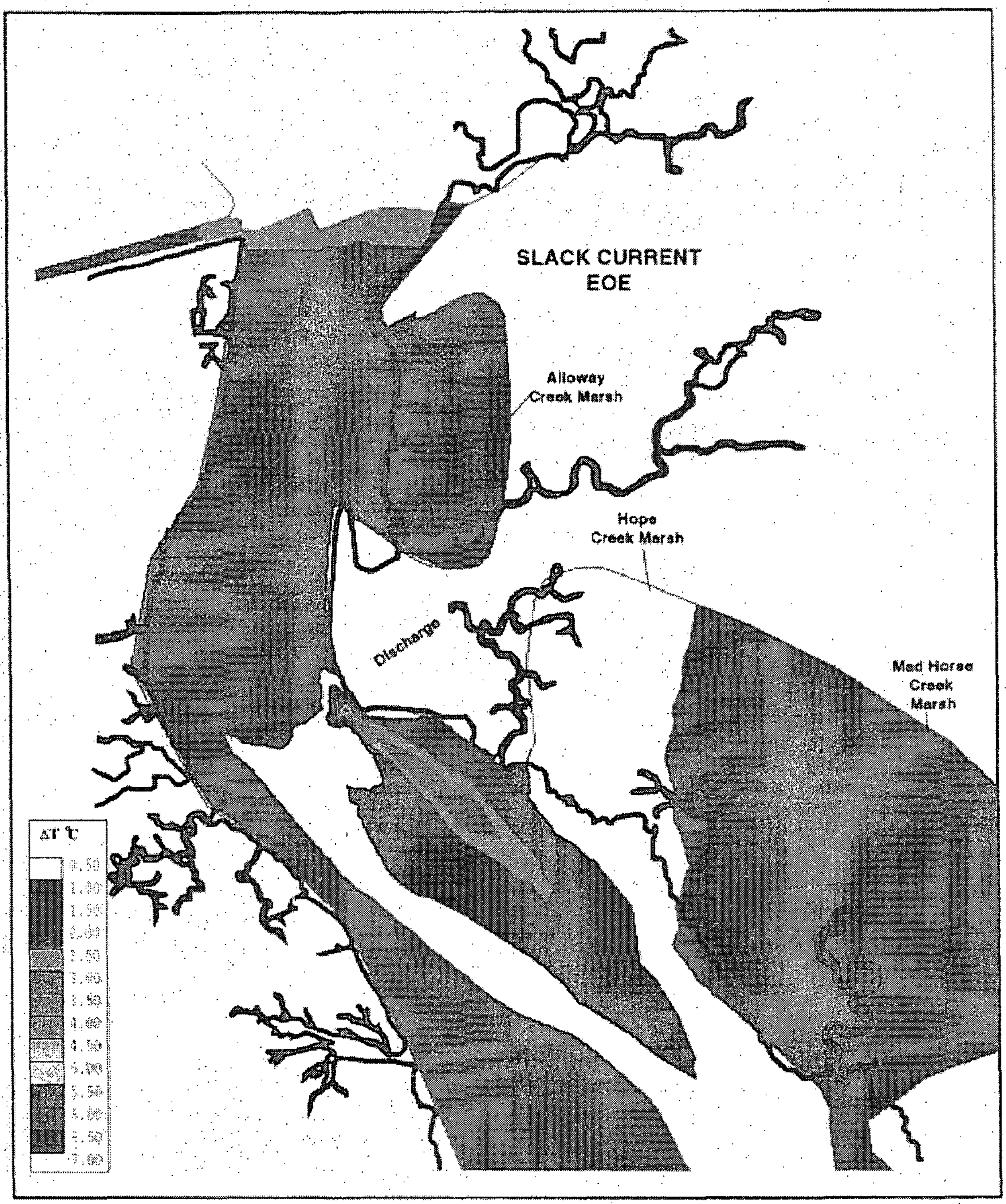
	Mean Volume Transport ($m^3 \times 10^6$)	Mean Temperature Change (°C)	Net Heat Transport (g-cal. $\times 10^{14}$)
Alloway Creek	7.3	0.80	5.86
Hope Creek	3.6	0.68	2.45
Mad Horse Creek	5.4	0.48	2.60
		Total Net Heat Transport =	10.91



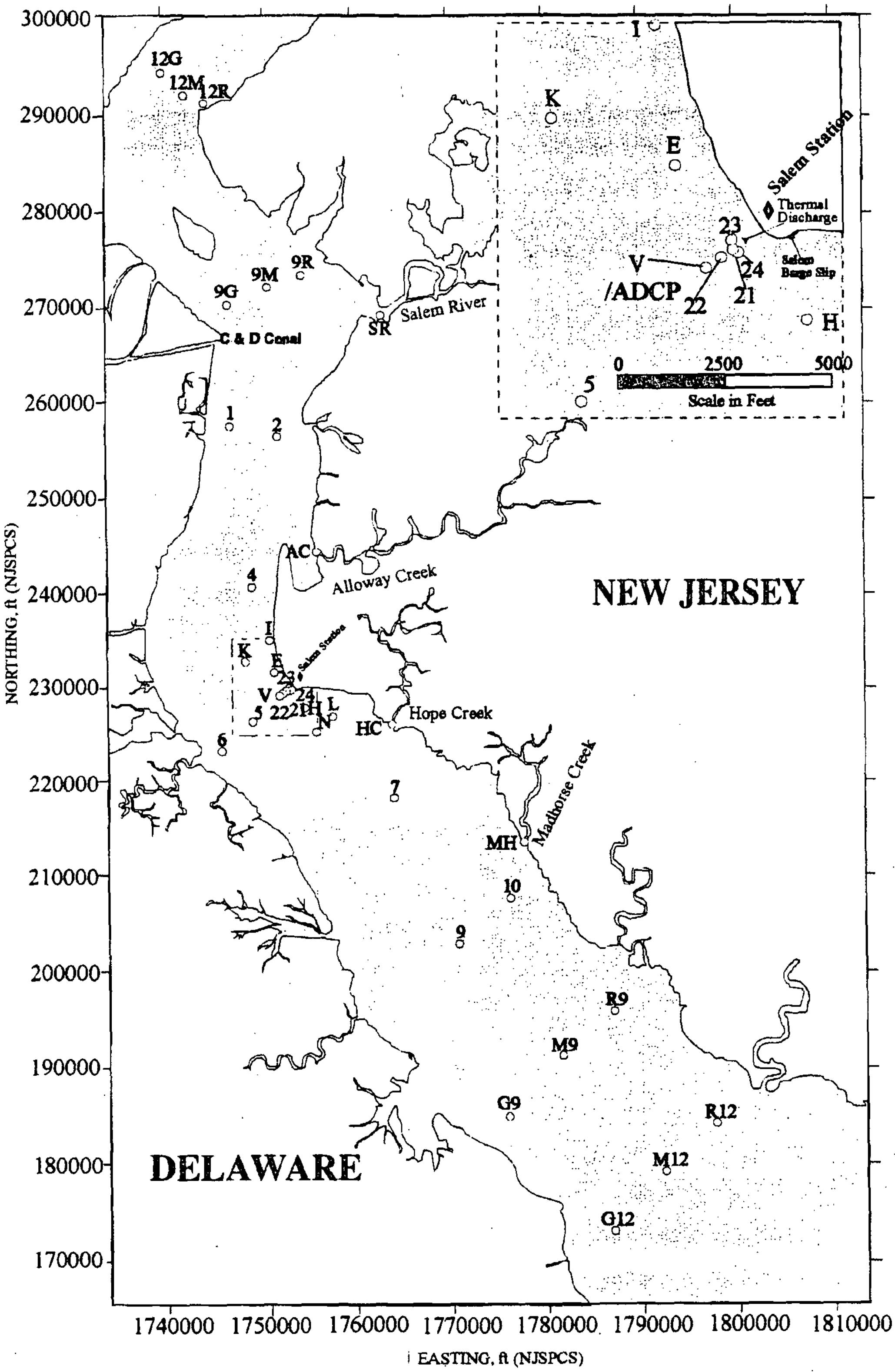
E-1-5 Figure II-1. Time history of temperature observed at the surface at the mouth of the Salem River during June - September 1998.



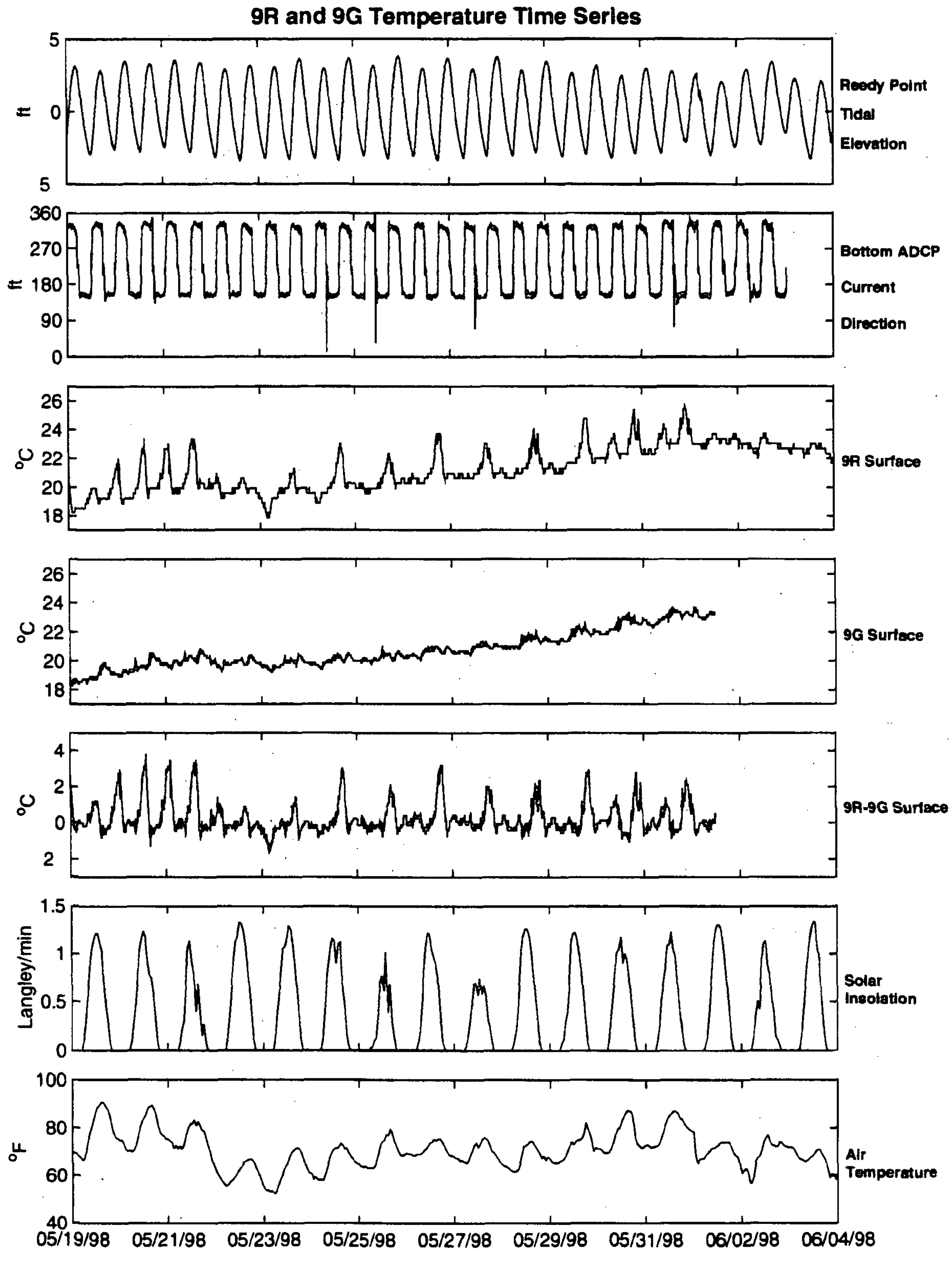
E-1-5 Figure II-2. Modeled ΔT field associated with the Station's thermal discharge at maximum flood displacement.



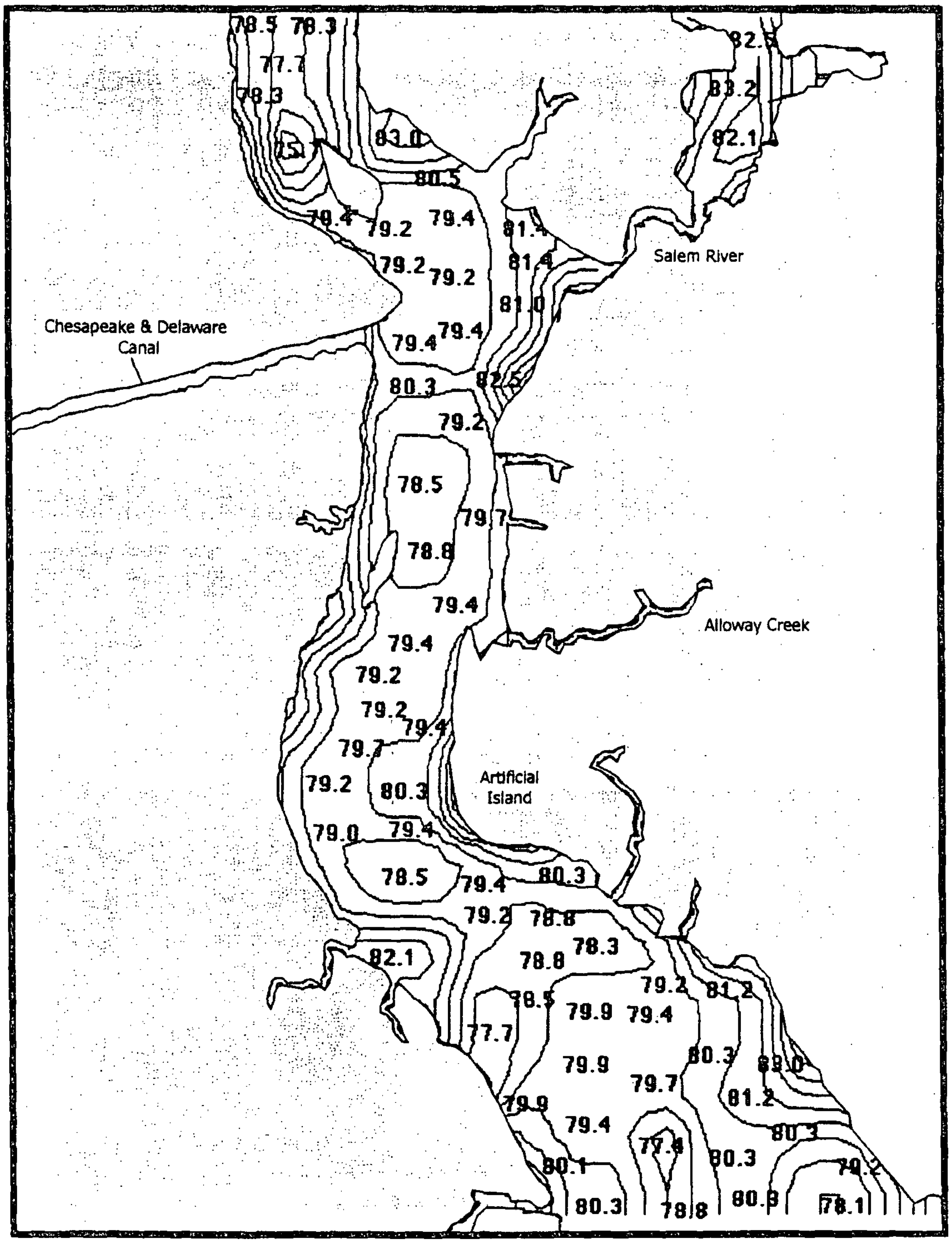
E-1-5 Figure II-3. Modeled ΔT field associated with the Station's thermal discharge at maximum ebb displacement.



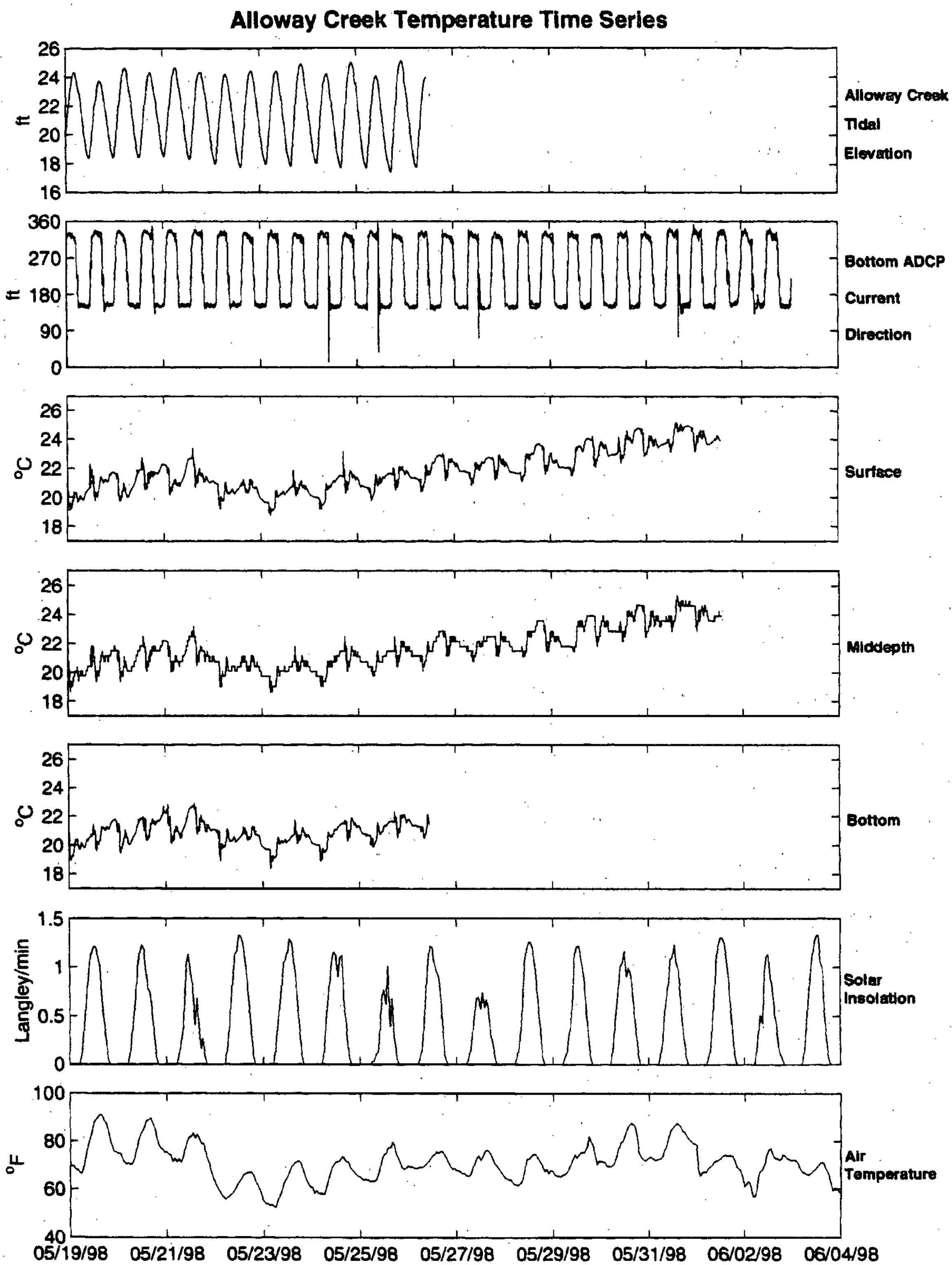
E-1-5 Figure III-1. Map of moored instrument station locations during the Two-Unit Survey, May - June 1998. Marsh moorings at Alloway Creek, Hope Creek, Mad Horse Creek, and some of the river moorings, collected through November.



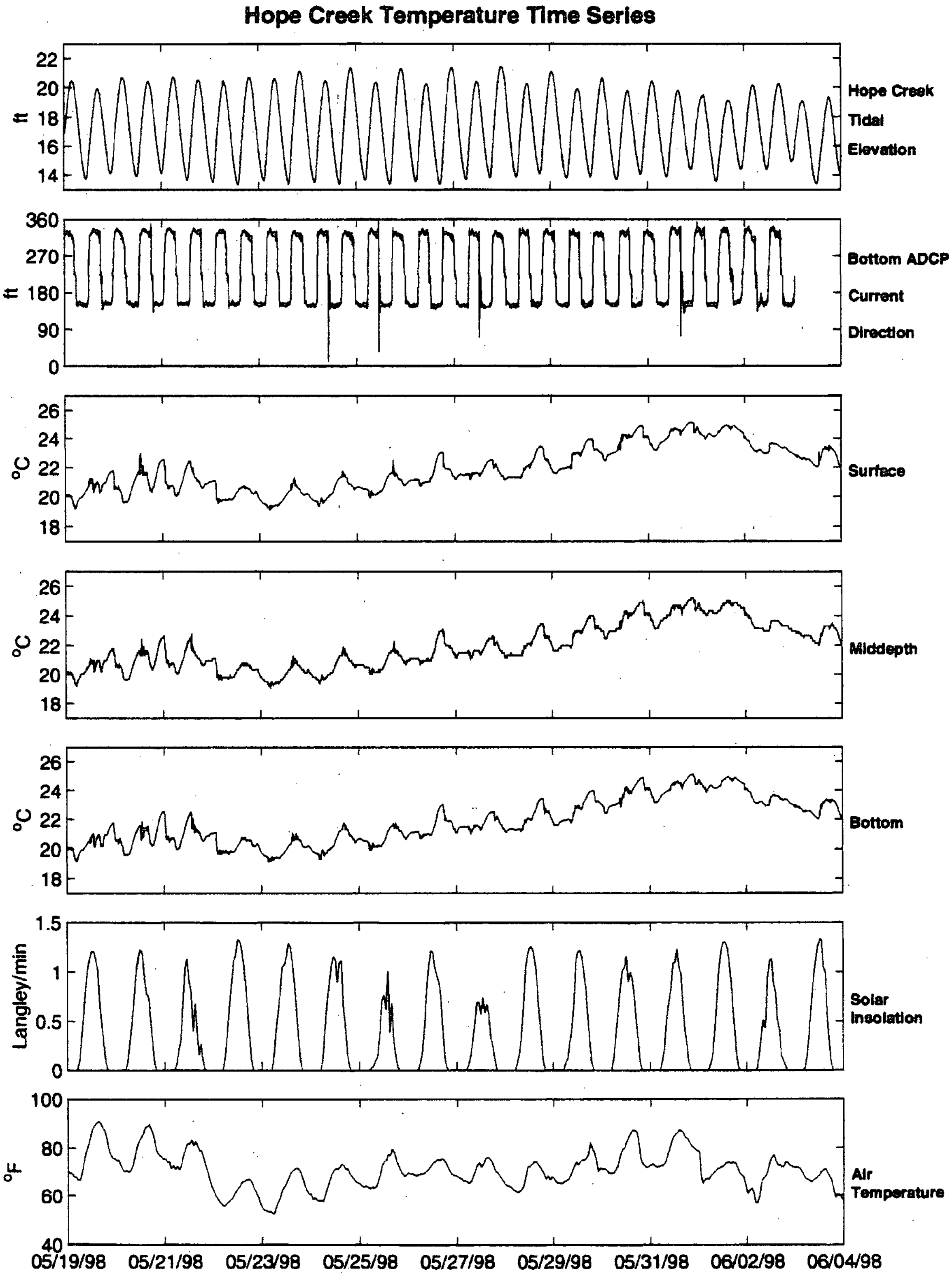
E-1-5 Figure III-2. Time history of surface temperature at moorings 9G and 9R, located 9 miles north of the Station. Also shown is the difference between these temperatures, as well as tide height at Reedy Island, current direction from the ADCP near the Station, solar insolation and air temperature at Artificial Island.



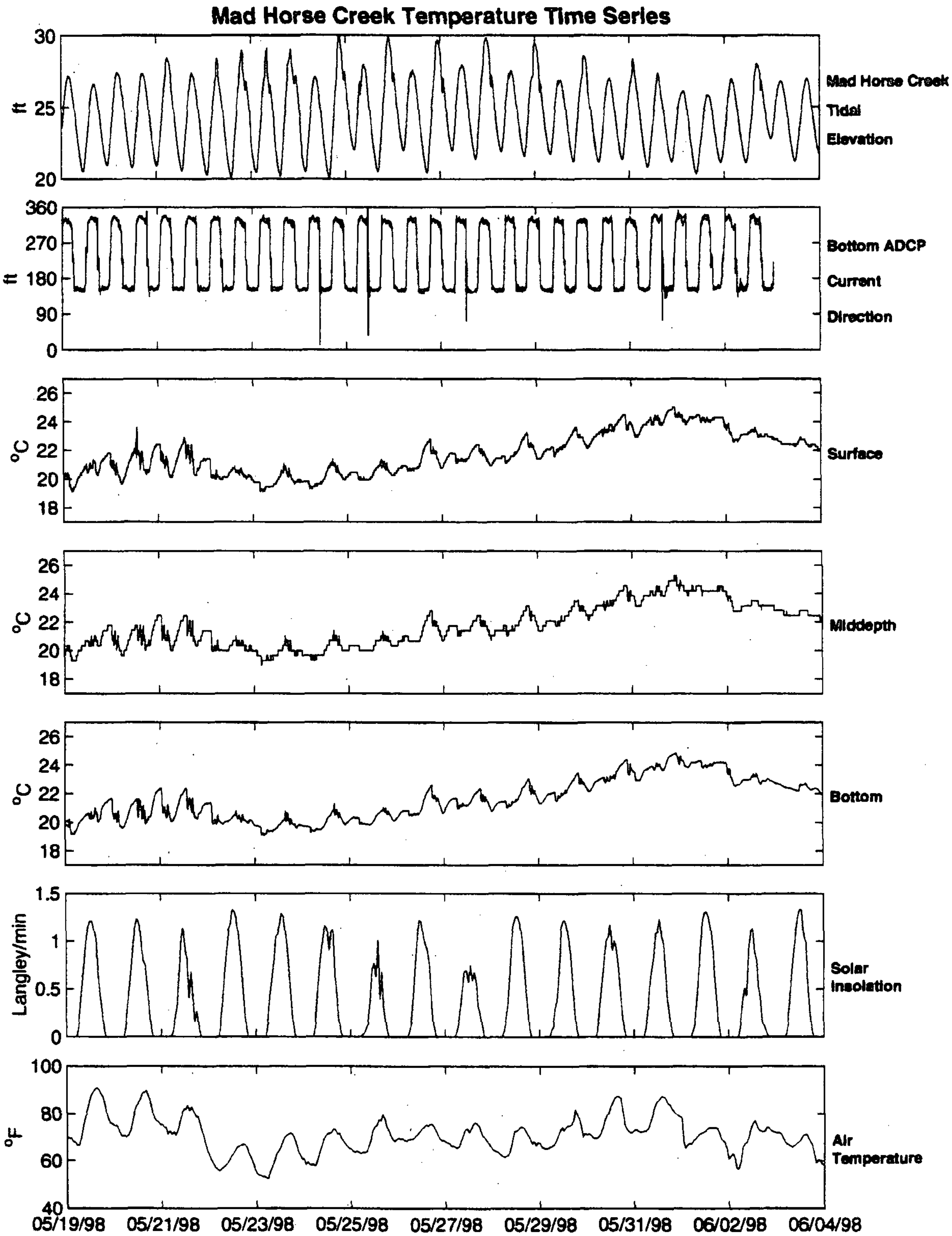
E-1-5 Figure III-3. Temperature map from satellite infrared imagery of Delaware Estuary around Artificial Island, 21 July 1990 at 4:12 pm, showing elevated temperature outflow from Salem River, north of the Station (Offshore Services, Inc. 1993, image no. I90202181226).



E-1-5 Figure III-4. Time history of temperature observed at the surface, mid-depth and bottom at the mouth of Alloway Creek during the Two-Unit Survey, May 1998 (E-1-3). Also shown are tide height at the Salem Barge Slip, current direction from the ADCP near the Station, and insolation and air temperature at Artificial Island.



E-1-5 Figure III-5. Time history of temperature observed at the surface, mid-depth and bottom at the mouth of Hope Creek during the Two-Unit Survey, May 1998 (E-1-3). Also shown are tide height at Hope Creek, current direction from the ADCP near the Station, and insolation and air temperature at Artificial Island.



E-1-5 Figure III-6. Time history of temperature observed at the surface, mid-depth and bottom at the mouth of Mad Horse Creek during the Two-Unit Survey, May 1998 (E-1-3). Also shown are tide height at Mad Horse Creek, current direction from the ADCP near the Station, insolation and air temperature at Artificial Island.