

INSTITUTE OF OCEANOGRAPHY  
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NORFOLK, VIRGINIA

Technical Report No. 29

WATER QUALITY MONITORING OF THE CRANEY ISLAND DREDGE  
MATERIAL DISPOSAL AREA, PORT OF HAMPTON ROADS,  
VIRGINIA -- APRIL 1975 TO MARCH 1976

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Technical Report

*Prepared for the*  
Norfolk District  
U. S. Army Corps of Engineers  
803 Front Street  
Norfolk, Virginia 23510

*Under*  
Contract No. DACW65-74-C-0027



*Submitted by the*  
Old Dominion University Research Foundation  
Norfolk, Virginia 23508

May 1976

#### ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Mr. J. R. Melchor of the Norfolk District, Corps of Engineers, for his active involvement in this investigation. The District's representative at Crane Island, Mr. D. L. Harvey, was most cooperative in providing logistical assistance. Many graduate students, including one of the authors (M. T. P.), at the Institute of Oceanography have been involved in the monitoring program: R. E. Maxfield, J. B. Whitten and R. J. Young. J. P. Feuillet and W. J. Saumsiegle have assisted in collecting samples at Crane Island. Their assistance was gratefully appreciated. Dr. G. W. Pfeiffer of the Department of Mathematics, Old Dominion University, aided in the statistical analysis of the data, while J. A. Menchhoff, Institute of Oceanography, did the computer programming. Mr. R. H. Wescott of the Norfolk District, Corps of Engineers, provided information concerning disposal operations at the rehandling basin. Further appreciation is expressed to Mr. R. W. Lawrence and staff at the laboratories of the Hampton Roads Sanitation District, Norfolk, for extending the courtesy of using their facilities during the initial portion of the program in 1973-1974.

TABLE OF CONTENTS

	<u>Page</u>
Introduction . . . . .	1
Methods and Materials . . . . .	6
Results . . . . .	17
Discussion . . . . .	30
Summary and Conclusions . . . . .	50
Recommendations . . . . .	55
References Cited . . . . .	56
Figures . . . . .	62
Appendix A -- Data for monitoring programs from December 1973 through March 1976. . . . .	127
Appendix B -- Water quality at the Craney Island rehandling basin. . . . .	156
Appendix C -- Scattergrams for variables at five stations in the No. 1 spillway plume (means of 12 months). . . . .	168

LIST OF TABLES

Table 1. Tidal, areal and volumetric statistics for Hampton Roads Harbor, Virginia. . . . .	3
Table 2. Intercalibration of dissolved Hg, Pb and Zn and additional dissolved metals for March 1976 samples. . . . .	11
Table 3. Measurements of dissolved cadmium by different methods. . . . .	12
Table 4. Intercalibration of Cd, Pb and Zn for suspended particulates collected inside the No. 1 spillway and at the NE Open water site. . . . .	14
Table 5. Metals associated with suspended particulates collected at Craney Island in November 1975. . . . .	15

Table 6.	Statistics for particulate and dissolved parameters from inside the No. 1 spillway and at the NE Open water site (April 1975 to March 1976).	18
Table 7.	Statistics for particulate and dissolved parameters at five surface stations in the No. 1 spillway plume (April 1975 to March 1976).	20
Table 8.	Comparative statistics for the spillways and NE Open water site during both monitoring programs (December 1973 through March 1976).	31
Table 9.	Measured variables and EPA recommended criteria at station 1 outside the No. 1 spillway and at the NE Open water site, April 1975 to March 1976.	32
Table 10.	Distribution of chlorophyll-a from various environments and Craney Island.	37
Table 11.	Distribution of dissolved and particulate organic carbon from various environments and Craney Island.	40
Table 12.	Distribution of dissolved Cd, Hg, Pb and Zn from various environments and Craney Island.	42
Table 13.	Distribution of particulate Cd, Hg, Pb and Zn from various environments and Craney Island.	44
Table 14.	Average changes during the 12-month period (April 1975 to March 1976) between stations 1 and 2 in the No. 1 spillway plume.	47
Table 15.	Probability coefficients from Student-t tests of measured variables at each Craney Island station compared to the NE Open water background site.	48
LIST OF FIGURES		
Figure 1.	Location of the Corps of Engineers Craney Island Disposal Area, Port of Hampton Roads, Virginia.	62
Figure 2.	Approximate locations of the sampling stations at the No. 1 spillway and NE Open water site as well as the rehandling basin (see Appendix B).	63
Figure 3a.	Water temperature in the spillway plume (April to September 1975).	64

	<u>Page</u>
Figure 3b. Water temperature in the spillway plume (October 1975 to March 1976) . . . . .	65
Figure 3c. Water temperature inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	66
Figure 4a. Surface salinity in the spillway plume (April to September 1975) . . . . .	67
Figure 4b. Surface salinity in the spillway plume (October 1975 to March 1976) . . . . .	68
Figure 4c. Surface salinity inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	69
Figure 5a. Surface pH in the spillway plume (April to September 1975) . . . . .	70
Figure 5b. Surface pH in the spillway plume (October 1975 to March 1976) . . . . .	71
Figure 5c. Surface pH inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	72
Figure 6a. Surface dissolved oxygen in the spillway plume (April to September 1975) . . . . .	73
Figure 6b. Surface dissolved oxygen in the spillway plume (October 1975 to March 1976) . . . . .	74
Figure 6c. Surface dissolved oxygen inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	75
Figure 7a. Oxygen saturation for the spillway plume (April to September 1975) . . . . .	76
Figure 7b. Oxygen saturation for the spillway plume (October 1975 to March 1976) . . . . .	77
Figure 7c. Oxygen saturation inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	78
Figure 8a. Fecal coliform concentrations in the spillway plume (April to September 1975) . . . . .	79
Figure 8b. Fecal coliform concentrations in the spillway plume (October 1975 to March 1976) . . . . .	80
Figure 8c. Fecal coliform concentrations inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976) . . . . .	81
Figure 9a. Surface dissolved inorganic orthophosphate in the spillway plume (April to September 1975) . . . . .	82

Figure 9b.	Surface dissolved inorganic orthophosphate in the spillway plume (October 1975 to March 1976) . . . . .	83
Figure 9c.	Surface dissolved inorganic orthophosphate inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	84
Figure 10a.	Total phosphorus in the spillway plume (April to September 1975). . . . .	85
Figure 10b.	Total phosphorus in the spillway plume (October 1975 to March 1976). . . . .	86
Figure 10c.	Total phosphorus inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	87
Figure 11a.	Surface dissolved nitrate in the spillway plume (April to September 1975). . . . .	88
Figure 11b.	Surface dissolved nitrate in the spillway plume (October 1975 to March 1976). . . . .	89
Figure 11c.	Surface dissolved nitrate inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	90
Figure 12a.	Surface dissolved nitrite in the spillway plume (April to September 1975). . . . .	91
Figure 12b.	Surface dissolved nitrite in the spillway plume (October 1975 to March 1976). . . . .	92
Figure 12c.	Surface dissolved nitrite inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	93
Figure 13a.	Surface dissolved ammonium in the spillway plume (April to September 1975). . . . .	94
Figure 13b.	Surface dissolved ammonium in the spillway plume (October 1975 to March 1976). . . . .	95
Figure 13c.	Surface dissolved ammonium inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	96
Figure 14a.	Total Kjeldahl nitrogen in the spillway plume (April to September 1975). . . . .	97
Figure 14b.	Total Kjeldahl nitrogen in the spillway plume (October 1975 to March 1976). . . . .	98
Figure 14c.	Total Kjeldahl nitrogen inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	99

Figure 15a.	Chlorophyll-a concentrations in the spillway plume (April to September 1975).	100
Figure 15b.	Chlorophyll-a concentrations in the spillway plume (October 1975 to March 1976).	101
Figure 15c.	Chlorophyll-a concentrations inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976).	102
Figure 16a.	Total suspended solids in the spillway plume (April to September 1975).	103
Figure 16b.	Total suspended solids in the spillway plume (October 1975 to March 1976).	104
Figure 16c.	Total suspended solids inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976).	105
Figure 17a.	Particulate organic carbon in the spillway plume (April to September 1975).	106
Figure 17b.	Particulate organic carbon in the spillway plume (October 1975 to March 1976).	107
Figure 17c.	Particulate organic carbon inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976).	108
Figure 18a.	Dissolved organic carbon in the spillway plume (April to September 1975).	109
Figure 18b.	Dissolved organic carbon in the spillway plume (October 1975 to March 1976).	110
Figure 18c.	Dissolved organic carbon inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976).	111
Figure 19a.	Dissolved cadmium in the spillway plume (April to September 1975).	112
Figure 19b.	Dissolved cadmium in the spillway plume (October 1975 to March 1976).	113
Figure 20a.	Dissolved mercury in the spillway plume (April to September 1975).	114
Figure 20b.	Dissolved mercury in the spillway plume (October 1975 to March 1976).	115
Figure 20c.	Dissolved mercury inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976).	116
Figure 21.	Dissolved lead in the spillway plume during May 1975 (other samples were below detection).	117

	<u>Page</u>
Figure 22a. Dissolved zinc in the spillway plume (April to September 1975). . . . .	118
Figure 22b. Dissolved zinc in the spillway plume (October 1975 to March 1976). . . . .	119
Figure 22c. Dissolved zinc inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	120
Figure 23a. Particulate mercury in the spillway plume (April to September 1975). . . . .	121
Figure 23b. Particulate mercury in the spillway plume (October 1975 to March 1976). . . . .	122
Figure 23c. Particulate mercury inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	123
Figure 24a. Particulate zinc in the spillway plume (April to September 1975). . . . .	124
Figure 24b. Particulate zinc in the spillway plume (October 1975 to March 1976). . . . .	125
Figure 24c. Particulate zinc inside the No. 1 spillway and at the NE Open water site (October 1975 to March 1976). . . . .	126

## INTRODUCTION

Estuaries are regions of the marine environment which receive the greatest impact of man's activities, one of which is pipeline dredging. This form of channel and harbor maintenance is one of the most common practices along the southeastern Atlantic coastline. Since coastal environments are of prime concern for production of fish and serve both as their breeding and nursery grounds as well as the home habitat for economically valuable invertebrates, it was considered important that the effluent from a large confined dredge material disposal area should be studied. This investigation, which was initiated in December 1973, was concerned with the effects of dredge disposal and fill operations as related to the quality of water and suspended material leaving the Craney Island Disposal area located in the estuarine waters of Hampton Roads Harbor, near Norfolk, Virginia (Adams and Young 1975). The diked disposal site, which is operated and maintained by the Norfolk District of the U. S. Army Corps of Engineers, encloses approximately 2500 acres (ca. 10.3 km<sup>2</sup>) and receives about four million cubic yards annually.

### Description of the Hampton Roads Harbor

The harbor of Hampton Roads, Virginia, is the largest estuarine section of the James River before it enters the lower Chesapeake Bay (Figure 1) and Atlantic Ocean at latitude 37°N longitude 76°W. The importance of the James River and the harbor of Hampton Roads to the economic and social well-being of the surrounding communities of Norfolk, Portsmouth, Chesapeake, Virginia Beach, Suffolk, Hampton, and Newport News has been documented by Pleasants (1973). Other important statistics concerning population and projected growth for the Hampton Roads area, notable land-use features, oil spills, small boat usage, closures of shellfish grounds, point discharges, estimated waste loadings from non-point sources, economic activity, and water utilization have been compiled by the Hampton Roads Water Quality Agency<sup>1</sup> (1974-1975). Included in the HRWQA report to the U. S. Environmental Protection Agency was an evaluation and documentation of water quality information for the James River Basin and other local bodies of water. Some further investigations of sediment and water quality in the study area have been conducted by Adams (1973-1975), Adams (1974), Adams et al. (1974, 1975a, b, c), Beauchamp (1974), Brehmer (1972), Guide and Villa (1972), Norfolk

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<sup>1</sup> Present address: HRWQA, Suite 31, Pembroke Three Building, Virginia Beach, VA.

District USACE (1974a), Pheiffer et al. (1972), and the Virginia Institute of Marine Sciences (1971, 1972), while circulation and modeling studies were reported by Kuo et al. (1974), Fang et al. (1973), and the Virginia Institute of Marine Sciences (1973).

The normal tidal period at Hampton Roads is 12.42 hrs, with a rise duration of 6.10 hrs and a fall duration of 6.32 hrs (Cronin 1971). A physical description of the area from a transect connecting Fort Wool with Old Point Comfort (see Figure 2) at the eastern extremity of Hampton Roads and extending ten miles upstream on the James River (to a transect approximately two miles below the James River Bridge, which is used for U. S. Highways 12 and 258) is provided in Table 1. If the surface areas of the Elizabeth (transect of the hypothetical mouth is drawn from Sewells Point southwest to land), Hampton, and Lafayette Rivers and Willoughby Bay are excluded from the 0-5 mile portion of Hampton Roads and the Nansemond River from the 5-10 mile portion (see Table 1), then the Craney Island Disposal area would occupy approximately 7.6 percent of the mean low water surface area of the harbor of Hampton Roads.

The Norfolk area had an average frost-free growing season of 244 days and an average rainfall of 50.5 inches for 1975 with an annual mean rainfall of 45.2 inches (1936-1975). The average temperature for 1975 ( $60.8^{\circ}\text{F} = 16.0^{\circ}\text{C}$ ) ranged from a mean of  $45.4^{\circ}\text{F}$  ( $7.4^{\circ}\text{C}$ ) in February to  $79.6^{\circ}\text{F}$  ( $26.4^{\circ}\text{C}$ ) in August, while the average wind velocity was 10.6 mph out of the southwest. Local climatological data are reported for the Norfolk-Regional Airport at latitude  $36^{\circ}54'\text{N}$  longitude  $76^{\circ}12'\text{W}$ .

#### Description of the Craney Island Disposal Area

The Craney Island Disposal area was established in 1957 to receive dredged materials from maintenance and deepening of shipping channels from Hampton Roads Harbor and contiguous areas (Elizabeth River, James River, etc.). After upgrading of the dikes and filling, followed by compaction of the underlying substrate, the approximate capacity of the site has been estimated at 125 million cubic yards. At the present annual fill rate of about four million cubic yards, the disposal area (with levees to project elevation of 17 feet above mean sea level) could be utilized until 1979. As a result of the Craney Island replacement study (Norfolk District, USACE 1974b) conducted by the Norfolk District of the Corps of Engineers, the District Engineer has recommended that the elevation and capacity of the disposal area be increased by

Table 1. Tidal, areal, and volumetric statistics for the Hampton Roads Harbor. Mile "0" is the transect between Fort Wool and Old Point Comfort, while mile "10" is ten miles upstream on the James River (approximately two miles below the James River bridge). The Elizabeth River mouth is taken as a transect between Sewells Point southwest to land at Craney Island. Other rivers and Bay are treated with transects taken directly across their mouths. Units are in meters with exception of nautical miles (1853.25 meters). (Taken from Cronin 1971).

Location	Mean low water surface area <sup>3</sup> 10 <sup>6</sup> M <sup>2</sup>	Mean low water volume <sup>4</sup> 10 <sup>6</sup> M <sup>3</sup>	Intertidal volume <sup>4</sup> 10 <sup>6</sup> M <sup>3</sup>	Mean high water volume <sup>4</sup> 10 <sup>6</sup> M <sup>3</sup>	Tidal range M	Average depth M
James River (0-5) <sup>1</sup>	111.43	536.5	85.79	622.31	0.75	5.1 - 7.3
James River (5-10) <sup>2</sup>	108.25	350.56	91.53	442.09	0.79	3.1 - 4.7
Elizabeth River	45.57	167.40	36.30	203.70		3.67
Lafayette River	6.31	8.81	4.97	13.78		1.40
Hampton River	1.21	1.77	0.90	2.67		1.46
Willoughby Bay	5.07	12.19	3.70	15.89		2.40
Nansemond River	24.92	58.12	25.89	84.01		2.33

<sup>1</sup> The 0 - 5 nautical mile statistics include the Elizabeth, Lafayette, and Hampton Rivers, and Willoughby Bay.

<sup>2</sup> The 5 - 10 nautical mile statistics include the Nansemond River.

<sup>3</sup> Surface area of Craney Island disposal area included in calculations.

<sup>4</sup> Volume of water within Craney Island disposal area not included in calculations.

gradually raising its levees from 17 to 29 feet above mean sea level. The useful life of the disposal area would then be extended to about 1989. The levee to 29 feet above msl would be located, for stability, approximately 1000 feet inland from the outer edge of the existing levee. The disposal area (ca. 10.3 km<sup>2</sup>) is located in the southeastern portion of Hampton Roads Harbor at the entrance to the Elizabeth River (Figure 2). It is a trapezoidal-shaped structure with each of the three levees extending approximately two miles in length.

An ecological study of Craney Island was conducted during the period from November 1972 to November 1973 (Marshall 1974), at which time the populations of birds, small mammals, vascular plants, aquatic and terrestrial insects, and plankton were examined. During this period, a seasonal water quality monitoring program was conducted at a location approximately one nautical mile west of the middle spillway. Tidal studies for each of the four seasons were also conducted at this location, and five sediment cores were processed for various chemical parameters.

During the first 15 months of this program (December 1973 to February 1975; Adams and Young 1975), water samples were collected for the analysis of dissolved and particulate species at the No. 1, middle (No. 2), and No. 3 spillways, which empty into the waters of Hampton Roads at the western side of the disposal area, and at the northeast corner of Craney Island on the open water side of the levee (considered as background). Dredge pipes were also sampled at 15 different times during the first nine months of the program. This provided information concerning the quality of the sediments and water entering the disposal area. The following parameters were measured from December 1973 to February 1975: temperature, salinity, pH, dissolved oxygen (and calculations of oxygen saturation), dissolved inorganic orthophosphate, nitrate, nitrite, ammonia, total phosphorus, fecal coliform, and total suspended solids. Samples for dissolved and particulate cadmium, mercury, and zinc were also collected and analyzed. Starting in October 1974, total Kjeldahl nitrogen measurements were also conducted on samples collected from the spillway and background waters.

An evaluation of samples collected during the continuation of this program from April 1975 to March 1976 is provided in this technical report, where the spatial limits and subsequent dilution or removal of 18 different parameters leaving the No. 1 spillway and entering the receiving waters to the west of Craney Island were investigated. A transect of five stations located in

the plume at approximately 160-meter (0.1-mile) intervals were sampled monthly. The concentration of these parameters at the spillway and at the five surface water stations of the transect were compared to a background sample collected at the NE Open water site (Figure 2). Besides the variables listed above, five others were added to this annual sampling program: chlorophyll-a, particulate organic carbon, dissolved organic carbon, particulate lead, and dissolved lead.

The rehandling basin for the Craney Island Disposal area is located at the southwest corner of the site (Figure 2). Dredge material is barged into this area for open water disposal and subsequent removal into Craney Island. Five different sampling programs were conducted at the rehandling basin during barge disposal in order to assess water conditions. Since this is separate from the spillway sampling program, an evaluation for the rehandling basin samples will be contained in Appendix B.

## METHODS AND MATERIALS

### Sampling

Surface samples were collected inside the levee with a two gallon Nalgene polyethylene container (Nalge Sybron Corp., Rochester, NY) from the most actively discharging spillway, which during this 12 months was No. 1, and the background waters adjacent to the northeast levee (see Figure 2). Surface water samples were also collected immediately outside the No. 1 spillway (station 1 or code 05) and at designated intervals in the receiving waters. The spillway plume was usually visible either as a green coloration or because of the higher turbidity. Using a vehicle on the levee for positioning, five surface samples were collected from a small boat usually at approximately 160 m (0.1 mile) intervals while following the major axis of this plume. Surface samples were also collected at the Craney Island rehandling basin during barge disposals. An evaluation of these data is provided in Appendix B.

Water temperature was recorded immediately at the site. Samples for dissolved oxygen were collected in 125-ml iodine flasks and were preserved in the field for laboratory titrations. Aliquots for nutrients, trace metals, pH, chlorophyll and suspended solids were taken from the bucket and stored in acid-washed polyethylene bottles after rinsing twice with the sample. Samples for organic carbon analyses were collected in acid-washed glass jars. Aluminum foil liners, which had been combusted at 450°C for four hours, were used to prevent contamination of the samples from the plastic jar caps. Salinity samples were collected in citrate bottles. Samples for fecal coliform measurements were stored in plastic containers. Control measurements indicated no contamination for the fecal coliform measurement. The bottles were iced in a cooler for transport to the laboratory, where dissolved species were separated from particulate materials by filtering through either 0.45 µm Type AA Millipore (Millipore Corp., Bedford, MA), 0.45 µm Metrical GA-6 and Type A glass fiber (Gelman Instr., Ann Arbor, MI), or 0.4 µm Nucleopore Type N040 (Nucleopore Corp., Pleasanton, CA) filters. The choice of filter was dictated by the specific analytical technique. Water samples for nutrient analyses were placed in acid-rinsed polyethylene bottles and frozen. Aliquots for dissolved trace metals were acidified to pH 1 with Ultrex HCl and stored in acid-rinsed polyethylene bottles. After filtration, 3-4 tared filter pads used for the measurement of particulate trace metals were stored in plastic vials and frozen. Filtration of

water samples, as well as measurement of pH, was performed upon return to the laboratory from the field. Water samples were also immediately processed for particulate and dissolved organic carbon and for the measurement of phytopigments. Samples were returned to the laboratory and analyses initiated within four hours of the time of collection.

Other important variables were recorded during monthly sampling at the site from April 1975 to March 1976. These were air temperature, wind direction and velocity, approximate size of the bird population within the site, and the height of water at the weir. Weather data were also obtained from the Norfolk Regional Airport, which is located approximately eight miles to the northeast. The following airport information, as well as the above variables, are also provided in Appendix A: average air temperature, wind direction, wind velocity, and minutes and percent of sunshine for the sampling day, as well as four-day precipitation (total rainfall for the day of sample collection, if rainfall occurred before or during sampling, and three days before the day of sampling).

#### Field Measurements

Wind measurements were taken with a hand-held anemometer (Anemometer-Wind Vane ML-446C/PMQ-3; Airflo Instr. Co., Glastonburg, CT). The height of water within Craney Island was obtained from a gauge, which is graduated in 0.1 foot intervals, near the weir at the No. 1 spillway. Visual observations of the bird population within Craney Island on the sampling day was coded as none (1), small (2), medium (3), large (4) and very large (5) in Appendix A. Water and air temperatures were measured with a high precision bucket thermometer (Kahl Scientific Instr. Corp., El Cajon, CA) which has a stated accuracy of  $\pm 0.02^{\circ}\text{C}$ .

#### Previous Laboratory Measurements

Descriptions of the previous techniques and measurements of specific variables have already been discussed in an earlier report, which outlined the first 15 months of this program (December 1974 to February 1975; Adams and Young 1975). Therefore, the methodology of the following, which have remained the same through this second year, will not be reviewed: salinity, pH, dissolved oxygen, fecal coliform bacteria, total phosphorus, dissolved orthophosphate phosphorus, dissolved inorganic nitrate, dissolved inorganic nitrite, dissolved ammonium nitrogen, total Kjeldahl nitrogen, dissolved mercury, total suspended solids, particulate cadmium, particulate mercury, and particulate zinc.

The following variables were not measured in the previous investigations but were a part of this program: chlorophyll, dissolved and particulate organic carbon, and dissolved and particulate lead. The methodology associated with dissolved metals was changed from graphite furnace atomic absorption (GFAA) to a chelation-extraction technique, which will be discussed below. Improvements were also instituted for the measurements of dissolved oxygen.

#### Chlorophyll-a

Chlorophyll-a was determined by the method outlined in Strickland and Parsons (1972), as modified from Richards with Thompson (1952) and Creitz and Richards (1955). The equations used to calculate chlorophyll-a are those of Parsons and Strickland (1963).

Seawater samples varying from 100 ml to one liter, depending on the amount of suspended material present, were filtered through glass fiber filters on the day of collection. The glass fiber filters were subsequently extracted in 10 ml of 10 percent acetone (refrigerated and in complete darkness) for a period of 20 hours. The extinction of the supernatant fluid was then measured at the appropriate wavelengths on a Beckman model DB-G (Beckman Instr. Co., South Pasadena, CA) spectrophotometer. The concentration of chlorophyll-a was calculated using the obtained extinction values along with corrections for sample volume and cell path length (1 cm).

The stated precision at the 5  $\mu\text{g}$  level is  $\pm 0.26/n^{1/2}$   $\mu\text{g}$  chlorophyll-a, where  $n$  = number of replicates. This is expressed for the 95 percent confidence level (Strickland and Parsons 1972).

#### Dissolved Organic Carbon

Samples were analyzed for dissolved organic carbon using a Dohrmann DC-52 Total Organic Carbon Analyzer (Envirotech Corp., Santa Clara, CA). Approximately 15 ml of sample was filtered through a 25-mm Gelman Type A glass fiber filter into a pre-combusted glass vial, acidified with conc  $\text{H}_3\text{PO}_4$  and frozen for storage. After thawing, 30  $\mu\text{l}$  of the acidified sample were injected into the sample boat of the instrument. The boat and sample were heated to 90°C to remove water, dissolved  $\text{CO}_2$ , carbonates and bicarbonates, as well as volatile carbon. After inorganic carbon and water were vented to the atmosphere, volatile carbon was measured by heating and back-flushing into the furnace and reduction zone.

The sample was then heated to 850°C to convert the residual dissolved organic carbon to CO<sub>2</sub>, whereby the CO<sub>2</sub> gas was swept by helium into a hydrogen-enriched nickel catalyst reduction zone where it was converted to methane at 350°C. Methane was then measured by a detector, which responded linearly to the hydrocarbon. The detector signal was integrated and displayed on a digital meter. The detector was adjusted to zero and calibrated using standards of <1 mg C/l and 180 mg C/l (prepared by Dohrmann). The 180 mg C/l standard is composed of potassium hydrogen phthalate (C<sub>8</sub>H<sub>5</sub>O<sub>4</sub>K) dissolved in deionized water. Some scatter in the results was noted when sample replicates were analyzed. The accuracy of the organic carbon measurements is estimated as ±10%. This may have been due to the average level of organic carbon in the samples, which was near the lower end of the linear working range of the analyzer (0-2000 mg C/l). Data are reported as the sum of volatile and dissolved organic carbon.

#### Particulate Organic Carbon

Exactly 100 ml of sample was passed through a pre-combusted glass fiber filter. The filter was placed in a pre-combusted glass vial and frozen. In order that particulate organic carbon on these filters might be analyzed, the sample had to be in a homogeneous form prior to injection into the carbon analyzer. This was accomplished with a Tekmar model SDT Super Dispax Tissumizer (Tekmar Co., Cincinnati, OH). This is a high-speed (20,000 rpm) dispersion instrument designed for the processing of solid material in a small volume of liquid. The filter and particulate matter was dispersed in 5.0 ml of Super Q deionized water. After acidification, the analytical technique employed was identical to that previously described for the dissolved carbon determinations.

#### Dissolved Cadmium, Lead, and Zinc

Dissolved concentrations of cadmium, lead and zinc were determined by chelation of the metals at a specified pH followed by extraction of the chelated-metal complexes with an organic solvent. This method of analysis is recommended by EPA (1974) for the determination of metals at low concentrations. The solvent extraction technique of Brewer et al. (1969) was used, where ammonium pyrrolidine dithiocarbamate (APDC) was the chelating agent and methyl isobutyl ketone (MIBK) served as the solvent. The water samples were filtered and a 400 ml aliquot of each was treated with APDC/MIBK. After extraction, the MIBK solutions were analyzed by aspiration into an air-acetylene flame of a Perkin-Elmer model 303

(Perkin-Elmer Corp., Norwalk, CT) atomic absorption spectrophotometer. Perkin-Elmer single-element electrodeless discharge source lamps were used for each of these metals. A linear least squares calibration plot was obtained using analytical standards, and sample concentrations were determined from the slope equations.

The efficiency of the APDC/MIBK extraction varies slightly for the three metals investigated, but overall it is approximately 95 percent (Brewer et al. 1969). The detection limits<sup>1</sup> for dissolved cadmium, lead and zinc were 0.001 mg/l, 0.010 mg/l and 0.001 mg/l, respectively. Accuracy<sup>1</sup> for the measurement of cadmium, lead and zinc was  $\pm 10.4\%$ ,  $\pm 12.3\%$  and  $\pm 6.5\%$ , respectively. Precision<sup>1</sup> associated with the cadmium, lead and zinc determinations was  $\pm 2.9\%$ ,  $\pm 2.8\%$  and  $\pm 1.0\%$ , respectively.

Dissolved cadmium concentrations were investigated by four additional analytical techniques. One of these was digestion of the sample in perchloric acid prior to APDC/MIBK extraction. Here, eight ml of perchloric acid were added to 400 ml of sample and heated to boiling for two hours. The sample was then extracted with APDC/MIBK and analyzed by atomic absorption spectrophotometry as has been previously described. A second technique involved APDC/MIBK extraction of the sample followed by analysis of the MIBK extract in an atomic absorption spectrophotometer equipped with a Perkin-Elmer model HGA-2100 flameless graphite furnace accessory. The third technique employed the graphite furnace again, but here the aqueous sample was injected directly into the furnace without prior extraction. Perchloric acid was added to the sample in the furnace to promote oxidation of any organically-associated metal. This was the method employed in the last six months of the previous investigation at Craney Island as described in Adams and Young (1975).

The final method, used by another laboratory (Endeco, Inc., Marion, MA), involved passage of 100 ml of sample through a resin bed filtration system. The metals were removed from the resin with acid and analyzed on a Jarrell-Ash model 750 Plasma Aton Comp emission spectrometer, where the sample was combusted in a 3/16" cupped electrode for 15 seconds (Table 2). The results obtained by these five methods are shown in Table 3.

<sup>1</sup> See Adams et al. (1976) for further discussion. Detection limit was approximately equal to the sensitivity divided by the maximum scale expansion, while accuracy was defined as  $[\Sigma(E)^2]^{1/2}$  and precision as  $\Sigma|E(\%)|/n_i$  (the average relative standard deviation of replicate determinations about the mean), where  $E(\%)$  equalled the percent error associated with the slope equations for standards.

Table 2. Dissolved metals at the NE Open water site (04) and inside the No. 1 spillway (01) as well as next to a barge in the Craney Island rehanding basin (immediately after disposal; code 20). Comparisons were also conducted for mercury, lead and zinc. Units are reported in µg/liter. See Table 3 for cadmium measurements.

Sample Location <sup>1</sup>	Date	Endeco Measurements Only										
		Cr	Cu	Ni	V	Co	Ag	Hg				
042	24 Mar 76	<1	0.6 ± 0.6	<1	<1	<1	<1	0.4	0.5 ± 0.2	<10	<2	1
042	24 Mar 76	<1	2.7 ± 1.3	7.4 ± 1.5	<1	<1	<1	0.4	1.0 ± 0.2	<10	<2	1
202	24 Mar 76	<1	3.1 ± 0.3	1.5 ± 0.7	<1	<1	<1	0.4	1.0 ± 0.3	<10	4.2 ± 0.8	<1
202	24 Mar 76	<1	2.8 ± 0.2	3.0 ± 2.3	<1	<1	<1	0.4	1.0 ± 0.2	<10	2.7 ± 0.9	<1
01	24 Mar 76	<1	1.6 ± 0.2	2.6 ± 0.7	<1	<1	<1	0.5	1.0 ± 0.2	<10	<2	3

<sup>1</sup> See Table A.2 for station location codes.

<sup>2</sup> Samples collected at the same time and processed through two separate filters containing ion-exchange resins.

Table 3. Measurements of dissolved cadmium by five different techniques (all values in mg/l).

Sample Location <sup>1</sup>	Date	APDC/MBK Extraction	Perchloric Acid Digestion and APDC/MBK Extraction	APDC/MBK Extraction-Furnace <sup>2</sup>	Aqueous-Furnace <sup>3</sup>	Endeco <sup>4</sup>
04	5 Dec 75	0.001	None Detected			
01	5 Dec 75	0.006	0.008			
13	5 Dec 75	<0.001		0.001		
15	5 Dec 75	<0.001		<0.001		
04	24 Mar 76	<0.001			0.011	<0.001
01	24 Mar 76				0.013	<0.001
20	24 Mar 76	<0.001			0.010	
21	24 Mar 76	<0.001			0.008	
22	24 Mar 76	<0.001			0.010	
23	24 Mar 76	<0.001			0.011	

<sup>1</sup> See Table A.2 for station location codes (01 inside No. 1 spillway; 13 and 14 from No. 1 spillway plume; 04 at NE Open; 20-23 from rehandling basin).

<sup>2</sup> Injection of the MBK extract into the HGA2100 graphite furnace. See section in this report.

<sup>3</sup> Graphite furnace method (GFAA) described in Adams and Young (1975). See section in this report.

<sup>4</sup> See text for collection and measurement techniques.

### Graphite Furnace Atomic Absorption Data Confirmation

Techniques used for GFAA analysis of samples were described in Adams and Young (1975). Drying temperature was ca. 110°C and the optimum charring temperature was selected as the maximum charring temperature without reducing the sample signal. This was 225°C for Cd and 475°C for Zn. Atomization temperature was 2100°C in both cases. Peak height was determined from the strip chart recorder trace, and this was converted to absorbance units. Concentrations were determined by standard additions. Calculation of the sensitivity (i.e., slope) for addition of metal showed a decrease in sensitivity with increasing concentrations of metal in the sample. This decrease in sensitivity was as much as 35 percent from an added mass of 25 pg to 250 pg. Thus, the slope of one standard addition containing approximately 2 x the sample mass of metal, was used to determine the sample concentration. Accuracy is estimated as approximating the precision, i.e., 5-10 percent relative standard deviation (RSD).

Background scattering was not evident except where sample volume was large (70 µl) or the gas purge flow rate was low (ca. 40 flow divisions on the HGA-2100). With 70 µl and 40 flow divisions, which was the sample volume and flow used for Cd, background absorbance was approximately 1-3 percent absorption, or 15-30 percent of the sample signal.

It is the opinion of the authors that the values reported in Adams and Young (1975) are higher than true *in situ* metal concentrations for this area. The suspected cause of this variance is two-fold. First, contamination from improperly cleaned sample bottles or more-likely, laboratory acid used for stabilization of the sample. A second possibility would be background absorption previously interpreted as sample signal. If the observed data for Cd hold for Zn, then the values may be high by an approximate factor of 2 or 3 times. It should be noted, however, that the samples analyzed here and reported in Table 3 are not identical in origin to those collected and reported in Adams and Young (op. cit.). These data are intended as tentative confirmation of the orders of magnitude for cadmium and zinc by GFAA as reported in Adams and Young (op. cit.). Further studies are warranted before the differences reported in Table 3 are verified.

### Particulate Lead

Particulate lead was determined by analytical techniques identical to those used for particulate cadmium and zinc starting in August 1974. This methodology has been described in an earlier report (Adams and Young op. cit.).

### Interlaboratory Comparison of Particulate Metals

Large samples (5 gallon carboys) were collected at the spillway and NE Open water sites for centrifuging. These were processed, freeze-dried to constant weight, homogenized and subdivided for interlaboratory comparison.

Two samples (ca. 100 mg of suspended particulate material) were analyzed by another company (Barringer Research Ltd., Rexdale, Ontario, Canada) using a multielement technique. Results of this analysis as compared to our data are shown in Table 4.

Table 4. Intercalibration of cadmium, lead and zinc collected at the NE Open water site (04) and at station 1 in the No. 1 spillway plume (05). Values listed as  $\mu\text{g/g}$ .

Sample Location	Date	Institute of Oceanography			Barringer Research Ltd.		
		Zn	Cd	Pb	Zn	Cd	Pb
04	12 Nov 75	40.83	N.D.	N.D.	62.3	4.40	31.5
05	12 Nov 75	69.50	N.D.	N.D.	87.4	3.60	15.8

Both particulate zinc values determined by Barringer Research Ltd. were somewhat higher than measured in our laboratories. Their values for Cd and Pb were below our limits of detection and, therefore, confirm our results. The multielement instrument used by Barringer Research Ltd. was a radio frequency induction coupled plasma emission spectrometer.

In this method the sample solution is nebulised in a radio frequency argon plasma, which has a physical temperature of  $10,000^{\circ}\text{K}$ . The intense heat of the plasma core desolvates the solution aerosol, completely atomizes the resulting salt particles and then excites and stimulates these atoms such that they emit their characteristic atomic spectra. The optical radiation emitted by the plasma is focused onto the entrance slit of a polychromator, which simultaneously measures the emission intensity at several different wavelengths, each of which corresponds to a particular element. This intensity is proportional to the concentration of a particular element in the original sample solution.

Additional metals were analyzed for the suspended particulate samples supplied to Barringer Research Ltd. These measurements are provided in Table 5.

Table 5. Metals associated with particulate suspended material collected from the NE Open water site (04) and station 1 in the No. 1 spillway plume (05) on 12 Nov 1975. Samples were concentrated by centrifugation and analyzed by Barringer Research Ltd., Rexdale, Ontario, Canada. Units are µg/g of dry wt sediment unless otherwise specified.

Location	Elements													
04	Au	Al (%)	As	Be	Ca	Cd	Cr	Co	Cu	Fe	Pb	Mg (%)	Mn	Mo
04	N.D.	1.10	N.D.	0.38	5630	4.40	20.9	5.91	22.1	7480	31.5	1.56	159	5.35
05	N.D.	1.39	N.D.	0.54	3290	3.60	13.8	5.72	21.4	8870	15.8	0.86	129	4.05
04	Ni	P	K	Ba	Si	Ag	Na (%)	Sr	Tl	U	V	Zn	B	
04	21.4	377	6040	42	2260	1.53	8.49	78.3	412	N.D.	16.9	62.3	N.D.	
05	12.6	1036	5590	49	2030	0.95	3.60	52.7	392	N.D.	22.8	87.4	N.D.	

### Dissolved Oxygen

Starting with this portion of the program (April 1975) oxygen analyses were performed by the micro-Winkler technique (Carpenter 1965), as modified by Scripps Institute of Oceanography, La Jolla, CA (Anderson 1971). Samples were collected in 125-ml iodine flasks with #22 stoppers with elongated penny heads and extended necks. The Winkler reagents were dispensed with Manostat Vari-Pet syringe pipets (Manostat Corp., NY) arranged sequentially in a plexiglass rack. The entire sample was titrated with a modified 1.000-ml Manostat Digipipet connected to a three-way stopcock. These modifications would result in increased accuracy (0.1%) due to fewer manipulations of the sample, and the analysis time was considerably reduced (Carpenter op. cit.). Oxygen solubility was calculated with an equation developed by Weiss (1970), which is utilized by UNESCO (1973). Kester (1975) has evaluated this equation with earlier relationships developed by Carpenter (1966) and Murray and Riley (1969) and suggested that existing solubility data are not detailed or consistent enough between analysts to establish significant departures in oxygen solubility which are less than 0.5 percent from the functional relationship selected by Weiss.

## RESULTS

Data for this portion of the monitoring program at the Craney Island Dredge Material Disposal area during the period from April 1975 to March 1976 are provided in Tables A.3 to A.5 in Appendix A. Measurements at the three spillways, NE Open water site and dredge pipes entering Craney Island during an earlier phase of this program from December 1973 to February 1975 are listed in Tables A.6 to A.8; however, these data, which have been reviewed in an earlier report (Adams and Young 1975), will only be examined with respect to the present investigation.

Five short sampling programs at the rehandling basin for the Craney Island Disposal area are reviewed in Appendix B. These occurred during the period from December 1974 to March 1976.

Further statistical evaluation of the data for the April 1975 to March 1976 period are contained in Appendix C, where Scattergrams for variables at each station within the No. 1 spillway plume during the annual period are provided. These 12-month means for each variable at the five surface stations are included to illustrate horizontal changes. Samples for the first station (coded 1 in the Scattergrams and Table 7 and coded 05 in the data listing in Tables A.3 to A.5 in Appendix A) were collected immediately outside the No. 1 spillway (as close as the boat could maneuver) while the next three stations were either spaced at fixed intervals of 160 meters (0.1 mile) or in such a manner that they would fall at equal intervals within the extent of the spillway plume. The fifth station was occupied at the leading edge of the plume, if visible, or at a normal fixed interval (which was dictated by the previous three stations). The locations of these four stations along the major axis of the spillway plume would therefore be a function of the tidal and wind conditions as well as the flow of water leaving Craney Island.

Statistics for the No. 1 spillway and NE Open water site are listed in Table 6, while a similar presentation of the data for the surface water stations in the spillway plume is provided in Table 7.

Table 6. Statistics for particulate and dissolved parameters inside the No. 1 spillway and at the NE Open water site during the monitoring program at the Craney Island Disposal Area, Port of Hampton Roads, Virginia, from 29 Apr 1975 to 6 Mar 1976. Only measurements above detection are included in the calculations.

	Units	Range	Mean	Standard Deviation (±1σ)	Coefficient Variation (%)	n
Temperature	°C					
Spillway		3.80 - 28.76	17.59	8.99	51	12
NE Open		4.89 - 27.83	17.63	8.12	46	12
Salinity	‰					
Spillway		10.37 - 20.83	15.61	2.97	19	12
NE Open		9.32 - 18.62	15.18	2.54	17	12
pH						
Spillway		6.86 - 8.73	8.24	0.53	6	12
NE Open		7.22 - 8.29	7.77	0.33	4	12
Dissolved Oxygen	mg/l					
Spillway		3.58 - 12.17	7.87	2.92	37	12
NE Open		5.01 - 12.55	8.75	2.13	24	12
Oxygen Saturation	‰					
Spillway		51 - 158	88.5	13.9	16	12
NE Open		67 - 120	97.6	12.7	13	12
Suspended Solids	mg/l					
Spillway		21 - 470	153	125	82	12
NE Open		10 - 36	22	8	37	12
Fecal Coliform	Colonies per 100 ml					
Spillway		0 - 368	93	121	130	12
NE Open		0 - 15	6	5	84	12
PO <sub>4</sub> - P	mg/l					
Spillway		0.000 - 0.658	0.198	0.242	122	12
NE Open		0.002 - 0.085	0.036	0.028	78	12
Total Phosphorus	mg/l					
Spillway		0.146 - 0.983	0.491	0.286	58	12
NE Open		0.061 - 0.156	0.104	0.035	34	12
NO <sub>3</sub> - N	mg/l					
Spillway		0.029 - 2.169	0.304	0.597	196	12
NE Open		0.040 - 0.309	0.137	0.089	65	12
NO <sub>2</sub> - N	mg/l					
Spillway		0.005 - 0.422	0.108	0.139	129	12
NE Open		0.003 - 0.033	0.014	0.009	64	12
NH <sub>4</sub> - N	mg/l					
Spillway		0.001 - 1.278	0.365	0.391	107	12
NE Open		0.001 - 0.185	0.054	0.066	122	12
TKN	mg/l					
Spillway		0.117 - 3.761	1.411	1.146	81	12
NE Open		0.160 - 0.448	0.267	0.111	42	12
Dissolved Cadmium	mg/l					
Spillway		B.D. <sup>1</sup> - 0.002	0.001	---	---	8
NE Open		B.D.	0.002	0.001	50	7
Particulate Cadmium	µg/g					
Spillway		Below Detection <sup>2</sup>	---	---	---	(12)
NE Open		Below Detection	---	---	---	(12)
Dissolved Mercury	mg/l					
Spillway		B.D. <sup>3</sup> - 0.001	0.0004	0.0003	75	11
NE Open		B.D.	0.0004	0.0003	75	9

Table 6. Concluded.

	Units	Range	Mean	Standard Deviation ( $\pm 1\sigma$ )	Coefficient Variation (%)	n
Particulate Mercury Spillway NE Open	$\mu\text{g/g}$	B.D. <sup>1</sup> - 75.21	17.09	25.21	156	10
		B.D. - 19.00	6.72	4.58	65	11
Dissolved Zinc Spillway NE Open	$\text{mg/l}$	B.D. <sup>5</sup> - 0.070	0.015	0.023	153	7
		B.D. - 0.001	0.001	---	---	4
Particulate Zinc Spillway NE Open	$\mu\text{g/g}$	B.D. <sup>6</sup> - 778	294	204	69	11
		32 - 1187	238	336	141	12
Dissolved Lead Spillway NE Open	$\text{mg/l}$	B.D. <sup>7</sup> - 0.012	---	---	---	1
		Below Detection <sup>7</sup>	---	---	---	(12)
Particulate Lead Spillway NE Open	$\mu\text{g/g}$	Below Detection <sup>8</sup>	---	---	---	12
		Below Detection	---	---	---	12
Chlorophyll-a Spillway NE Open	$\text{mg/m}^3$	17.58 - 291.4	93.5	99.8	107	10
		2.00 - 34.12	13.6	10.0	75	10
DOC Spillway NE Open	$\text{mg/l}$	7.50 - 22.4	14.8	4.99	34	12
		1.00 - 12.2	4.55	2.99	69	12
POC Spillway NE Open	$\text{mg/l}$	0.4 - 2.1	1.2	0.5	43	12
		0.1 - 1.3	0.4	0.4	99	12

1 Below detection for dissolved cadmium was considered 0.001 mg/liter or less.

2 Below detection for particulate cadmium was <2  $\mu\text{g/g}$  (function of suspended material).

3 Below detection for dissolved mercury was considered 0.0001 mg/liter or less.

4 Below detection for particulate mercury was <1  $\mu\text{g/g}$  (function of suspended material).

5 Below detection for dissolved zinc was considered 0.001 mg/liter or less.

6 Below detection for particulate zinc was <10  $\mu\text{g/g}$  (function of suspended material).

7 Below detection for dissolved lead was considered 0.010 mg/liter or less.

8 Below detection for particulate lead was <20  $\mu\text{g/g}$  (function of suspended material).

Table 7. Statistics for particulate and dissolved parameters at five surface stations in the No. 1 spillway plume, Craney Island Disposal Area, Port of Hampton Roads, Virginia, from 29 Apr 1975 to 6 Mar 1976. Station 1 was closest to the spillway. Only measurements above detection are included in the calculations.

	Units	Range	Mean	Standard Deviation (±1σ)	Coefficient Variation (%)	n
<b>Temperature</b>						
	C					
Station 1		3.76 - 28.40	17.14	8.44	49	12
Station 2		4.67 - 28.26	17.41	8.24	47	12
Station 3		4.81 - 28.20	17.47	8.18	47	12
Station 4		4.71 - 28.24	17.51	8.23	47	12
Station 5		4.73 - 28.31	17.57	8.17	47	12
<b>Salinity</b>						
	‰					
Station 1		10.32 - 17.98	14.91	2.21	15	12
Station 2		6.96 - 17.96	13.94	3.06	22	12
Station 3		6.86 - 17.97	13.94	3.11	22	12
Station 4		6.80 - 17.94	14.05	3.19	23	12
Station 5		6.76 - 17.89	13.98	3.18	23	12
<b>pH</b>						
Station 1		7.01 - 8.70	8.12	0.54	7	12
Station 2		6.91 - 8.50	7.79	0.45	6	12
Station 3		6.91 - 8.35	7.79	0.43	5	12
Station 4		7.42 - 8.46	7.90	0.31	4	12
Station 5		7.49 - 8.35	7.88	0.26	3	12
<b>Dissolved Oxygen</b>						
	mg/l					
Station 1		4.03 - 11.06	8.21	2.42	29	12
Station 2		3.39 - 12.15	8.73	2.49	29	12
Station 3		3.31 - 12.04	8.98	2.57	29	12
Station 4		3.90 - 12.31	8.93	2.47	28	12
Station 5		4.04 - 11.81	8.82	2.52	29	12
<b>Oxygen Saturation</b>						
	‰					
Station 1		52 - 121	90.4	20.0	22	12
Station 2		45 - 131	96.3	21.1	22	12
Station 3		44 - 131	99.1	22.1	22	12
Station 4		52 - 133	98.8	20.6	21	12
Station 5		54 - 135	97.0	23.4	24	12
<b>Suspended Solids</b>						
	mg/l					
Station 1		19 - 220	74	59	80	12
Station 2		9 - 52	25	13	51	12
Station 3		11 - 69	26	16	61	12
Station 4		10 - 62	28	18	64	12
Station 5		2 - 42	22	12	56	12
<b>Fecal Coliform</b>						
	Colonies per 100 ml					
Station 1		2 - 564	76	156	206	12
Station 2		0 - 52	16	17	107	12
Station 3		0 - 36	9	10	122	12
Station 4		0 - 29	10	9	98	12
Station 5		0 - 11	4	5	109	12
<b>PO<sub>4</sub> - P</b>						
	mg/l					
Station 1		0.011 - 0.517	0.114	0.179	157	12
Station 2		0.003 - 0.157	0.042	0.040	95	12
Station 3		0.003 - 0.172	0.042	0.045	107	12
Station 4		0.001 - 0.115	0.035	0.028	80	12
Station 5		0.002 - 0.127	0.035	0.033	94	12
<b>Total Phosphorus</b>						
	mg/l					
Station 1		0.123 - 0.793	0.346	0.228	66	12
Station 2		0.081 - 0.401	0.155	0.092	59	12
Station 3		0.052 - 0.349	0.140	0.089	64	12
Station 4		0.043 - 0.269	0.126	0.073	58	12
Station 5		0.045 - 0.184	0.109	0.053	49	12

Table 7. Continued.

	Units	Range	Mean	Standard Deviation (±1σ)	Coefficient Variation (%)	n
<b>NO<sub>3</sub> - N</b>						
Station 1	mg/l	0.030 - 0.331	0.117	0.100	85	12
Station 2		0.019 - 0.297	0.146	0.101	69	12
Station 3		0.036 - 0.270	0.155	0.087	56	12
Station 4		0.036 - 0.260	0.158	0.081	51	12
Station 5		0.028 - 0.269	0.154	0.099	64	12
<b>NO<sub>2</sub> - N</b>						
Station 1	mg/l	0.007 - 0.357	0.099	0.135	156	12
Station 2		0.002 - 0.093	0.028	0.027	96	12
Station 3		0.003 - 0.084	0.022	0.022	100	12
Station 4		0.002 - 0.085	0.028	0.024	86	12
Station 5		0.002 - 0.060	0.021	0.017	81	12
<b>NH<sub>4</sub> - N</b>						
Station 1	mg/l	0.003 - 0.814	0.282	0.291	103	12
Station 2		0.001 - 0.550	0.116	0.173	149	12
Station 3		0.000 - 0.400	0.102	0.144	141	12
Station 4		0.004 - 0.317	0.060	0.085	111	11
Station 5		0.006 - 0.391	0.075	0.114	152	12
<b>TKN</b>						
Station 1	mg/l	0.098 - 1.794	1.008	0.494	49	12
Station 2		0.153 - 1.325	0.519	0.326	63	12
Station 3		0.089 - 0.985	0.442	0.294	67	12
Station 4		0.043 - 0.824	0.400	0.219	55	12
Station 5		0.049 - 0.929	0.391	0.281	72	12
<b>Dissolved Cadmium</b>						
Station 1	mg/l	B.D. 1 - 0.005	0.003	0.001	33	7
Station 2		B.D. - 0.004	0.002	0.001	50	7
Station 3		B.D. - 0.005	0.002	0.001	50	6
Station 4		B.D. - 0.007	0.002	0.002	---	7
Station 5		B.D. - 0.004	0.002	0.001	50	5
<b>Particulate Cadmium</b>						
Station 1	μg/g	Below Detection <sup>2</sup>	---	---	---	(12)
Station 2		Below Detection	---	---	---	(12)
Station 3		Below Detection	---	---	---	(12)
Station 4		Below Detection	---	---	---	(12)
Station 5		Below Detection	---	---	---	(12)
<b>Dissolved Mercury</b>						
Station 1	mg/l	B.D. 3 - 0.002	0.0007	0.0008	114	10
Station 2		B.D. - 0.002	0.0005	0.0004	80	9
Station 3		B.D. - 0.001	0.0005	0.0004	80	9
Station 4		B.D. - 0.003	0.0006	0.0007	117	10
Station 5		B.D. - 0.001	0.0003	0.0001	33	10
<b>Particulate Mercury</b>						
Station 1	μg/g	B.D. 4 - 29.88	9.61	8.51	89	10
Station 2		B.D. - 70.93	22.9	21.6	94	10
Station 3		B.D. - 42.28	16.4	13.3	81	9
Station 4		B.D. - 51.50	17.4	13.8	79	10
Station 5		B.D. - 34.30	9.27	9.29	100	10
<b>Dissolved Zinc</b>						
Station 1	mg/l	B.D. 5 - 0.073	0.014	0.027	193	6
Station 2		B.D. - 0.004	0.002	0.001	50	4
Station 3		B.D. - 0.009	0.004	0.003	75	4
Station 4		B.D. - 0.013	0.005	0.006	120	3
Station 5		B.D. - 0.002	---	---	---	1
<b>Particulate Zinc</b>						
Station 1	μg/g	58 - 1219	331	331	100	12
Station 2		36 - 913	322	243	75	12
Station 3		B.D. 6 - 1008	369	266	72	11
Station 4		B.D. - 2728	526	745	142	11
Station 5		62 - 1624	376	494	131	12

Table 7. Concluded.

	Units	Range	Mean	Standard Deviation (±1σ)	Coefficient Variation (%)	n
<b>Dissolved Lead</b>						
Station 1	mg/l	B.D. <sup>7</sup> - 0.100	---	---	---	1
Station 2		Below Detection	---	---	---	(12)
Station 3		Below Detection	---	---	---	(12)
Station 4		B.D. - 0.011	---	---	---	1
Station 5		B.D. - 0.011	---	---	---	1
<b>Particulate Lead</b>						
Station 1	µg/g	Below Detection <sup>8</sup>	---	---	---	(12)
Station 2		Below Detection	---	---	---	(12)
Station 3		Below Detection	---	---	---	(12)
Station 4		Below Detection	---	---	---	(12)
Station 5		Below Detection	---	---	---	(12)
<b>Chlorophyll-a</b>						
Station 1	mg/m <sup>3</sup>	8.10 - 280.9	72.3	89.8	124	10
Station 2		3.80 - 34.28	18.7	9.3	50	10
Station 3		3.80 - 25.22	15.1	7.2	48	10
Station 4		0.80 - 19.47	11.8	5.9	50	10
Station 5		4.70 - 26.97	15.2	7.8	51	10
<b>DOC</b>						
Station 1	mg/l	2.20 - 24.2	8.62	5.65	66	12
Station 2		0.60 - 12.2	5.06	3.58	71	12
Station 3		0.10 - 4.10	2.57	1.54	60	12
Station 4		0.10 - 8.70	4.80	3.30	69	12
Station 5		0.30 - 7.90	4.03	2.50	62	12
<b>POC</b>						
Station 1	mg/l	0.1 - 1.5	0.7	0.4	52	12
Station 2		0.1 - 1.3	0.5	0.3	70	12
Station 3		0.1 - 1.3	0.4	0.4	111	12
Station 4		0.1 - 1.3	0.5	0.4	86	12
Station 5		0.1 - 0.6	0.3	0.1	52	12

<sup>1</sup> Below detection for dissolved cadmium was considered 0.001 mg/liter or less.

<sup>2</sup> Below detection for particulate cadmium was <2 µg/g (function of suspended material).

<sup>3</sup> Below detection for dissolved mercury was considered 0.0001 mg/liter or less.

<sup>4</sup> Below detection for particulate mercury was <1 µg/g (function of suspended material).

<sup>5</sup> Below detection for dissolved zinc was considered 0.001 mg/liter or less.

<sup>6</sup> Below detection for particulate zinc was <10 µg/g (function of suspended material).

<sup>7</sup> Below detection for dissolved lead was considered 0.010 mg/liter or less.

<sup>8</sup> Below detection for particulate lead was <20 µg/g (function of suspended material).

### *Physical Parameters*

Measurements of temperature at the No. 1 spillway, NE Open water site and in the surface waters of the spillway plume are illustrated in Figures 3a and 3b, while the annual change of temperature is shown in Figure 3c (No. 1 spillway and NE Open water sites only). Surface temperature averaged  $17.59 \pm 8.99^{\circ}\text{C}$  at the spillway, with a range from  $3.80^{\circ}\text{C}$  in January 1976 to  $28.76^{\circ}\text{C}$  in August 1975. Similar values were seen at the NE Open water site ( $17.63 \pm 8.12^{\circ}\text{C}$ ; range of  $4.89$  to  $27.85^{\circ}\text{C}$ ). The 12-month mean of temperatures at the plume stations increased from  $17.14$  to  $17.57^{\circ}\text{C}$  away from the spillway, with a  $0.90$ -linear correlation. The mean temperature increased approximately  $0.1^{\circ}\text{C}$  at each station within the plume.

The distributions of surface salinity at No. 1 spillway, NE Open water site and at the plume stations are seen in Figures 4a and 4b. The highest salinity at the spillway ( $20.8^{\circ}/\text{oo}$ ) occurred in September 1975 while the lowest values ( $10.37^{\circ}/\text{oo}$ ) were measured in February 1976. The mean for the spillway was  $15.61 \pm 2.97^{\circ}/\text{oo}$ , while the NE Open water site was  $15.18 \pm 2.54^{\circ}/\text{oo}$ . High and low values were seen during the same months at the NE Open water site (Figure 4c). There was little correlation of salinity with distance in the plume even though there was a decrease of about  $1^{\circ}/\text{oo}$  (average over a 12-month period) within the five surface stations. The salinity was higher at the spillway during eight of the 12 months. The greatest monthly rainfall in the past 27 years of record at the Norfolk International Airport occurred during July 1975, with  $13.73$  inches or 27 percent of the total rainfall for the year ( $50.53$  inches). Fifty-four percent, or  $7.48$  inches, fell during the two weeks before the monitoring cruise. Another  $1.60$  inches of precipitation from a thunderstorm occurred only a few hours after collection of samples on July 14. These unusual conditions resulted in abnormally low salinities in the spillway samples and also aided in characterizing the plume.

Another abnormal phenomenon occurred during October 1975 when salinities at four of the spillway plume stations were below  $7.00^{\circ}/\text{oo}$ . Average salinities are higher in the Harbor of Hampton Roads during the fall (Adams et al. 1975b); however, unusually high precipitation was recorded for September in Richmond, VA, which is 90 miles upstream on the James River (total of  $10.98$  inches, which was  $7.40$  inches in excess of normal rainfall). Sixty-two percent of the monthly

rainfall occurred during the two weeks before the sampling cruise on October 1st. Rainfall in Norfolk was relatively slight during the same two-week period (0.98 inches). The wind averaged 7.2 mph out of the north to north-east during the five days before sampling, which could have displaced fresh waters from upstream into the area west of Craney Island (as seen in Figure 4b for October).

#### *pH, Dissolved Oxygen and Bacteria*

pH averaged  $8.24 \pm 0.53$  (coefficient of variation = 6.4%) at the No. 1 spillway with a range from 6.86 to 8.73, while the variation was lower (4.2%) with a mean of  $7.77 \pm 0.33$  (range of 7.22 to 8.29) at the NE Open water site. With the exception of April, the spillway pH was always greater (Figure 5c). pH usually decreased away from Craney Island in the spillway plume (Figures 5a and 5b), even though there was little statistical evidence that this decrease was linear over the 12-month period (see Scattergram in Appendix C).

The mean for dissolved oxygen over the 12-month period increased approximately 0.14 mg/liter at each of the five stations (Figures 6a and 6b). Correlation to a linear relationship was 0.72 with distance in the spillway plume. Lowest values were observed during July 1975 at the NE Open water site (5.0 mg/liter), while even lower measurements occurred in June at the No. 1 spillway (3.58 mg/liter). Dissolved oxygen averaged  $7.87 \pm 2.92$  mg/liter at the No. 1 spillway, while values were slightly higher at the NE Open water site ( $8.75 \pm 2.13$  mg/liter). Concentrations at the spillway were higher from July to December than at the NE Open water site (Figure 6c). Oxygen saturation averaged  $88.5 \pm 32.9$  percent (with a range of 51 to 158 percent) at the No. 1 spillway, while concentrations at the NE Open water site were  $97.6 \pm 12.7$  percent (range of 67 to 120 percent). Measurements at the spillway, NE Open site and in the five stations of the plume are illustrated in Figures 7a and 7b, and the seasonal distribution is shown in Figure 7c.

Counts for fecal coliforms ranged from 0 to 368 colonies/100 ml at the No. 1 spillway (mean of  $93 \pm 121$  colonies/100 ml), while these were much lower at the NE Open water site (mean of  $6 \pm 5$  colonies/100 ml; range of 0 to 15 colonies/100 ml). The bacterial count decreased relatively rapidly in the spillway plume (Figures 8a and 8b), where there was a 0.79 linear correlation with distance for the 12-month means at each station. The death rate averaged approximately 15 colonies per station within the spillway plume.

*Nutrients, Total Phosphorus and Total Kjeldahl Nitrogen*

It is difficult to interpret the distribution of dissolved inorganic orthophosphate because of the abnormal differences between the first and second six-month periods of the program as shown in Figure 9c. Concentrations never exceeded 0.34 mg/liter at the spillways during the first 15 months of the program, where dissolved orthophosphate averaged 0.065 mg/liter at the middle spillway and 0.085 mg/liter at the No. 1 spillway (Adams and Young 1975). A decrease was observed in the spillway plume during the first six months (Figure 9a) while values close to background were measured during the second six months (Figure 9b). Concentrations averaged  $0.036 \pm 0.028$  mg/liter at the NE Open water site. These values were much lower than those measured at the No. 1 spillway (mean of  $0.198 \pm 0.242$  mg/liter).

A decrease in total phosphorus was observed in the plume waters. This was approximately 0.05 mg/liter for every station (mean values for the 12 months; see Scattergram in Appendix C), with a 0.82 linear correlation coefficient. The depletion in total phosphorus over the annual period is illustrated in Figures 10a and 10b; while changes at the No. 1 spillway and NE Open water site are shown in Figure 10c. The mean at the NE Open water site was  $0.104 \pm 0.035$  mg/liter, while it was almost five times greater at the No. 1 spillway ( $0.491 \pm 0.286$  mg/liter). Again, abnormally high values were reported during June to September 1975 (as compared to total phosphorus values averaging 0.26 mg/liter during the first 15 months; Adams and Young 1975).

Dissolved inorganic nitrate averaged  $0.304 \pm 0.597$  mg/liter at the No. 1 spillway (with a range from 0.029 to 2.169 mg/liter). Even though nitrates were greater at the NE Open water site 40 percent of the time, the average was half ( $0.137 \pm 0.089$  mg/liter) as concentrated as the spillway (Figure 11c). There was a mean increase in nitrates with horizontal distance in the plume (Figures 11a and 11b), with a 0.81 linear correlation coefficient. The change averaged 0.03 mg/liter in the first 160 meters, which accounted for 20 percent of the loss in ammonium for a similar horizontal distance in the plume. The higher concentration of nitrates in or near the plume waters to the west of Craney Island could either be from the oxidation of ammonium originating at the Craney Island spillway or from the intrusion of James River water (as opposed to the Harbor of Hampton Roads which was 60 percent lower during June 1973 to May 1975; Adams et al. 1975b).

Dissolved nitrites averaged  $0.108 \pm 0.139$  mg/liter at the No. 1 spillway (range of 0.005 to 0.422 mg/liter), while concentrations were lower at the NE Open water site ( $0.014 \pm 0.009$  mg/liter; range of 0.003 to 0.033 mg/liter). Concentrations in the plume waters decreased with distance from the spillway (Figures 12a and 12b). The loss of nitrites over the 12-month period averaged 0.02 mg/liter at subsequent stations within the plume; 70 percent of this loss occurred between the station immediately outside the spillway (station 1) and the first station in the plume (station 2). Correlation to a linear relationship was 0.74 for the 12-month means at each of the five stations. Higher values at the spillway during the winter and spring periods of the year (Figure 12c) seemed to correspond with the previous program from December 1973 to February 1975 (Adams and Young 1975).

Dissolved ammonium concentrations measured  $0.365 \pm 0.391$  mg/liter at the No. 1 spillway during the annual monitoring period (the range was 0.001 to 1.28 mg/liter). Values at the NE Open water site averaged 85 percent lower (mean of  $0.054 \pm 0.066$  mg/liter; range of 0.001 to 0.185 mg/liter). Dissolved ammonium decreased with distance from the spillway (Figures 13a and 13b), where the linear correlation coefficient was 0.76 over the 12-month interval. The largest loss (80 percent) occurred between station 1 and station 2 within the spillway plume. Dissolved ammonium was always higher at the spillway than at the NE Open water site (Figure 13c).

Total Kjeldahl nitrogen followed a similar pattern as ammonium. It was higher at the No. 1 spillway (mean of  $1.411 \pm 1.146$  mg/liter; range of 0.117 to 3.76 mg/liter) than at the NE Open water site (mean of  $0.267 \pm 0.111$  mg/liter; range of 0.160 to 0.448 mg/liter). It also exhibited a decrease with distance from the spillway (Figures 14a and 14b) during the 12-month period, where the linear relationship had a correlation of 0.82 with distance. As with ammonium, almost 80 percent of the loss in TKN occurred before station number 2 in the plume (between stations 1 and 2). With the exception of October 1975, values were higher at the spillway than was measured at the NE Open water site (Figure 14c).

#### *Chlorophyll-a, Suspended Solids, Particulate and Dissolved Organic Carbon*

Chlorophyll-a was not measured during April and May 1975. It was usually higher at the No. 1 spillway (mean of  $93 \pm 100$  mg/m<sup>3</sup>; range of 17 to 291 mg/m<sup>3</sup>)

than at the NE Open water site (mean of  $3.16 \pm 10.0$  mg/m<sup>3</sup>; range of  $2.0$  to  $34.1$  mg/m<sup>3</sup>). The highest values at the spillway occurred during July and October 1975. There was a noticeable decrease with distance in the spillway plume (Figures 15a and 15b), where almost 90 percent of the chlorophyll was lost before station 2 in the plume. The linear correlation coefficient was 0.75 for the mean of 12 months at the five stations. Because of the ideal conditions for plant growth within the diked disposal area, chlorophyll-a measurements were always higher at the spillway as compared to the NE Open water site (Figure 15c).

Total suspended solids measured  $153 \pm 125$  mg/liter at the No. 1 spillway from April 1975 to March 1976, while values at the NE Open water site were approximately 86 percent less (with a mean of  $21.5 \pm 7.9$  mg/liter). Concentrations decreased with distance in the spillway plume (Figures 16a and 16b), where there was a 0.73 linear correlation coefficient for the 12-month means of the five stations. As with chlorophyll, more than 90 percent was lost before the second station in the plume. Suspended solids were always greater at the spillway than at the NE Open water site (Figure 16c).

The average for particulate organic carbon at the No. 1 spillway ( $1.2 \pm 0.5$  mg/liter) was three times greater than at the NE Open water site ( $0.4 \pm 0.4$  mg/liter). There was usually a decrease in POC between stations 1 and 2 in the spillway plume (Figures 17a and 17b), with the exceptions of December 1975, January 1976 and March 1976. However, overall low chlorophyll concentrations were observed during these three months. The linear correlation was 0.82 with distance for the means at each station during the 12-month period. Without exception, particulate organic carbon was higher at the spillway than was observed at the NE Open water site (Figure 17c).

Dissolved organic carbon was higher at the No. 1 spillway ( $14.8 \pm 4.99$  mg/liter; range from 7.30 to 22.4 mg/liter) during the 12-month period than was observed at the NE Open water site ( $4.35 \pm 2.99$  mg/liter; range from 1.00 to 12.2 mg/liter). The 12-month means at each of the five stations in the spillway plume were not linearly correlated with horizontal distance even though a decrease was noticed during at least five of the twelve months (Figures 18a and 18b). DOC was always higher at the spillway than at the NE Open background site (Figure 18c).

### *Dissolved and Particulate Metals*

Measurements for dissolved cadmium in 44 percent of the samples (37 out of 84) were below 0.001 mg/liter; every sample was below this detection limit during the month of August 1975. A maximum of 0.007 mg/liter was measured at station 4 during June (Figure 19a), while 0.005 mg/liter was measured the same month at station 3 and during October 1975 at station 1 (Figure 19b).

Dissolved mercury was below detection limits ( $<0.0001$  mg/liter) for 20 percent of the samples. Only twice were values over 0.001 mg/liter (May and June 1975) at the No. 1 spillway, while this was the case only once (October 1975) for the NE Open water site (Figure 20c). Dissolved mercury decreased in the spillway plume; however, linear correlation of the 12-month mean concentrations with station location in the plume was poor (see Scattergram in Appendix C). Fluctuations in the plume concentrations were common (Figures 20a and 20b).

Almost all (95 percent or 80 out of 84 samples) of the dissolved lead concentrations were below detection ( $<0.010$  mg/liter). Only four measurements were above this level and these occurred in May 1975 (Figure 21).

Sixty-five percent of the dissolved zinc measurements were below detection ( $<0.001$  mg/liter). Low levels of dissolved zinc occurred during April, October, November and December 1975 as well as March 1976 (Figures 22a and 22b). With the exception of measurements below 0.001 mg/liter during the months listed above, dissolved zinc was always higher at the spillway than was found at the NE Open water site (Figure 20c).

Particulate cadmium and lead were always below detection ( $<2$   $\mu\text{g/g}$  for particulate cadmium and  $<20$   $\mu\text{g/g}$  for particulate lead) during this 12-month period of the monitoring program. Larger samples (20 liters) were processed by centrifugation (see Methods and Materials section of this report) to collect enough suspended material for analyses and intercalibration with an independent laboratory. Their analyses verified these results. Detection of these two metals was limited by the weight of suspended solids (ca. 15-80 mg) collected by filtration (usually 3-4 filter pads).

Only 17 percent (14 out of 84 samples) of the particulate mercury samples were below detection ( $<1$   $\mu\text{g/g}$ ). This was the case for each of the samples during July 1975 (Figure 23a) while low levels were noticed for half of the particulate suspended material in November 1975 (Figure 23b). Even though the average concentration of particulate mercury was higher at the No. 1 spillway

(14.33 ± 23.06 µg/g; ranged from below detection to 73.21 µg/g) than at the NE Open water site (6.20 ± 4.74 µg/g; ranged from below detection to 19.00 µg/g), measured values dropped off at station 1 (collected immediately outside of the spillway) and proceeded to increase to intermediate maxima at stations 2 and 4 (see Table 3 and Scattergram in Appendix C). There was very little linear correlation with distance in the spillway plume. When measurements were above detection, only 40 percent (4 out of 10) of the samples at the No. 1 spillway were above values for the NE Open water site (Figure 23c) collected at the same time.

Only four percent (3 out of 84 samples) of the particulate zinc measurements were below detection (<10 µg/g). These occurred during November and December 1975, while each of the other samples had measurable concentrations of particulate zinc in the suspended material (Figures 24a and 24b). Particulate zinc averaged 220 ± 215 µg/g (ranged from below detection to 778 µg/g) at the No. 1 spillway, while similar values were measured at the NE Open water site (238 ± 336 µg/g; ranged from 32 to 1187 µg/g). Concentrations of particulate zinc were higher at the No. 1 spillway during eight of the twelve months (Figure 24c). As with particulate mercury, there seemed to be no linear correlation of the 12-month mean concentrations of particulate zinc with horizontal distance in the spillway plume (see Scattergram in Appendix C).

## DISCUSSION

The purpose of this program was to continue the monitoring of selected water quality variables at the Craney Island Dredge Disposal area spillways for an additional year. During this annual period from April 1975 to March 1976, specific attention was placed at examining the lateral extent of these variables in the spillway plume and their relationship, if any, to the NE Open water background site. Since certain water quality problems existed at the spillways during the previous 15 months (December 1973 to February 1975; Adams and Young 1975), it was considered desirable to understand the influence and horizontal extent of Craney Island water to the west of the spillways and to define a mixing zone whose perimeter cannot be distinguished from background.

Water quality problems that were evident from the previous investigations were outlined in the summary and conclusions, and certain recommendations for further studies were itemized. Briefly, these were high pH coupled with dissolved ammonium at concentrations which would be toxic, high levels of dissolved cadmium and zinc (measured by graphite furnace atomic absorption--GFAA) as well as dissolved mercury at both the spillways and background site, higher concentrations of particulate cadmium, mercury and zinc at the spillways as compared to the NE Open water station, and the possibility of excessive organic loading of the receiving waters from phytoplankton blooms within Craney Island which might promote low oxygen conditions in the near vicinity of the spillways.

First, the two sampling programs during two annual cycles will be compared. This will be followed by a discussion of the five additional variables added to this monitoring program from April 1975 to March 1976 and the changes in dissolved and particulate metals. Lastly, conditions will be examined with respect to the horizontal extent and influence of the No. 1 spillway plume on the receiving waters to the west of Craney Island.

### *Water quality conditions during the two monitoring periods.*

Average conditions for the middle and No. 1 spillways and the NE Open water site from December 1973 to February 1975 and similar statistics for the present program from April 1975 to March 1976 are provided in Table 8, while variables that exceeded EPA (1973) recommended criteria at station 1 in the spillway plume and at the NE Open water site are listed in Table 9. Because of the obvious differences between the middle and No. 1 spillways as described in Adams and Young (1975),

Table 8. Concentrations expressed as mean and standard deviation for the variables measured at the spillways and NE Open water site, Craney Island Disposal area, from December 1973 to March 1976.

Variable	Units	Middle Spillway 12/73 - 6/74	No. 1 Spillway 9/74 - 2/75 4/75 - 3/76	NE Open Water Site 12/73 - 2/75 4/75 - 3/76
pH		8.52 ± 0.36	8.62 ± 0.25	7.95 ± 0.32
Diss. Oxygen	mg/l	8.71 ± 1.35	9.49 ± 1.23	8.90 ± 1.49
O <sub>2</sub> Saturation	%	100 ± 16	99 ± 21	97 ± 20
Total Solids	mg/l	461 ± 864	254 ± 177	68 ± 83
Fecal Coliform	#/100 ml	9 ± 49	64 ± 59	3 ± 4
PO <sub>4</sub> - P	mg/l	0.065 ± 0.067	0.085 ± 0.065	0.050 ± 0.048
Total Phosphorus	mg/l	0.287 ± 0.279	0.235 ± 0.095	0.099 ± 0.044
NO <sub>3</sub> - N	mg/l	0.130 ± 0.117	0.440 ± 0.810	0.376 ± 0.626
NO <sub>2</sub> - N	mg/l	0.049 ± 0.082	0.028 ± 0.025	0.020 ± 0.027
NH <sub>4</sub> - N	mg/l	2.21 ± 3.56	0.419 ± 0.621	0.180 ± 0.247
TKN	mg/l	---	4.95 ± 3.68	1.42 ± 0.73
Diss. Cadmium	mg/l	0.005 ± 0.010 <sup>1</sup>	0.051 ± 0.096 <sup>2</sup>	0.010 ± 0.013 <sup>1</sup>
Part. Cadmium	µg/g	22 ± 34	107 ± 132	15.2 ± 22.3
Diss. Mercury	mg/l	0.006 ± 0.008	0.005 ± 0.007	0.004 ± 0.005
Part. Mercury	µg/g	3.45 ± 2.99	6.50 ± 3.45	3.80 ± 2.85
Diss. Zinc	mg/l	0.054 ± 0.036 <sup>1</sup>	0.175 ± 0.128 <sup>2</sup>	0.047 ± 0.030 <sup>1</sup>
Part. Zinc	µg/g	87 ± 145	239 ± 174	75 ± 98
Part. Zinc	µg/g			238 ± 336

<sup>1</sup> Measured as reactive concentration by anodic stripping voltammetry (ASV).

<sup>2</sup> Measured as total dissolved metal by graphite furnace atomic absorption (GFAA). See text for discussion of possible errors.

<sup>3</sup> Measured by APDC/MIBK technique.

<sup>4</sup> Only measurements above detection limits were used for statistical calculations.

Table 9. Measured variables at station 1 in the No. 1 spillway plume (code 05) and the NE Open water site (code 04), where EPA (1973) listed recommended criteria. Data are given as the number of samples (n = 12) and an annual percentage.

Variable	Recommended Value	Station 1		NE Open	
		%	Numbers	%	Numbers
pH	6.5 - 8.5	17	2	0	0
Diss. O <sub>2</sub>	4 mg/l	0	0	0	0
Fecal Coliform	200/100 ml <sup>1</sup>	0	0	0	0
	70/100 ml <sup>2</sup>	8	1	0	0
PO <sub>4</sub> -P	0.05 mg/l	50	6	25	3
TIN <sup>3</sup>	0.36 mg/l	67	8	0	0
NH <sub>4</sub> -N <sup>4</sup>	0.02 mg/l	75	9	50	6
NH <sub>4</sub> -N <sup>5</sup>	0.4 mg/l	33	4	0	0
Diss. Cd	0.010 mg/l	0	0	0	0
Diss. Pb	0.050 mg/l	8	1	0	0
Diss. Hg	0.0001 mg/l	75	9	67	8
Diss. Zn	0.10 mg/l	0	0	0	0
Part. Cd <sup>6</sup>	1 µg/g	0	0	0	0
Part. Pb <sup>6</sup>	50 µg/g	0	0	0	0
Part. Hg <sup>6</sup>	1 µg/g	83	10	83	10
Part. Zn <sup>6</sup>	50 µg/g	100	12	83	10

<sup>1</sup> Class IIB waters (see discussion in Adams and Young 1975).

<sup>2</sup> Class A (shellfish) waters; Commonwealth of Virginia guidelines.

<sup>3</sup> Total inorganic nitrogen (NO<sub>3</sub> + NO<sub>2</sub> + NH<sub>4</sub>) considered as available nitrogen.

<sup>4</sup> Freshwater aquatic life. Calculations based on measured dissolved ammonium and not theoretical concentrations of un-ionized NH<sub>3</sub>.

<sup>5</sup> Marine aquatic life. Calculations based on measured dissolved ammonium (see Adams and Young 1975 and text) and not theoretical concentrations of NH<sub>3</sub>.

<sup>6</sup> Criteria for open water disposal of spoil material.

only the No. 1 spillway and NE Open water sites during the two monitoring periods should be compared. However, it should be remembered that the No. 1 spillway was sampled only for five months (from 18 Sep 1974 to 20 Feb 1975), when the mean temperature was  $11.75 \pm 7.09$  °C, while it was the only spillway monitored during the present annual investigation. This spillway is furthest removed from major active sources of dredged materials added to Craney Island (see Fig. 2) and was recommended in Adams and Young (op. cit.) that it be used exclusively during periods of active dredge disposal in order to permit greater settling.

The pH dropped approximately 0.4 units between the September 1974 to February 1975 period and the present annual monitoring program. This would improve conditions at the spillway with respect to ammonia toxicity, for as the waters became less basic (i.e., the pH decreased) the un-ionized form ( $\text{NH}_3$ ) would diminish in concentration and ammonium ion ( $\text{NH}_4^+$ ) would predominate. In fact, the calculated concentration of un-ionized ammonia was less than 0.4 mg/liter as recommended by EPA (1973) or 0.3 mg/liter (24  $\mu\text{M}$ ) suggested by NAS-NAE (1973) during the worst conditions at the No. 1 spillway (October 1975), when the pH was 8.41 and dissolved ammonium was 1.28 mg/liter. During periods of higher pH (October = 8.73 and February = 8.70) the concentrations of dissolved ammonium were negligible. Water samples collected at the No. 1 spillway were above 0.4 mg/liter 15 percent of the time (6 out of 41) during the previous September 1974 to February 1975 period. Because suspended solids were higher during those periods which exhibited higher concentrations of dissolved ammonium (see Figs. 11 and 16 in Adams and Young op. cit.) and since samples were not filtered (due to possible losses of  $\text{NH}_3$  by vacuum filtration) but were preserved by acidification, it is entirely possible that  $\text{NH}_4^+$  bound to sediment particles at anionic exchange sites could have been displaced with the addition of acid to the unfiltered samples. This fraction would have been measured as dissolved ammonium and would result in apparently higher *in situ* values than were actually available as dissolved species at the spillway. Dissolved ammonium was positively correlated with TKN at the No. 1 spillway ( $r = 0.83$ ), and at stations 1 ( $r = 0.84$ ) and 2 ( $r = 0.90$ ) in the spillway plume during the 12-month period, which suggests that such a problem could exist. However, it should be pointed out that TKN is measured on unfiltered samples and includes both dissolved ammonium and

particulate nitrogen released to solution as ammonium during acid digestion. Since dissolved ammonium is included in both measurements, a correlation would be expected between it and TKN. This problem is presently under investigation.

Dissolved ammonium was highly correlated with precipitation at the No. 1 spillway ( $r = 0.77$ ) and NE Open water site ( $r = 0.81$ ) and each of the plume stations (ranged from  $r = 0.71$  at station 4 to  $r = 0.98$  at station 2). Data from Junge (1958) for the southeastern United States indicated ammonium concentrations lower than 0.02 mg/liter for rainfall, while nitrate was lower than 0.20 mg/liter. These are less than reported by Haines (1974) for the Georgia outer shelf (ammonium = 0.05 mg/liter) and by Pomeroy for Sapelo Island, Georgia (ammonium = 0.5 mg/liter; cited in Haines op. cit.). Even though nitrate is higher in rainwater, it was not significantly correlated with precipitation as was ammonium. It was interesting that the highest nitrate (2.2 mg/liter) was measured at the No. 1 spillway during July, which was the month that exhibited abnormal rainfall. Because of this, nitrate was correlated with precipitation only at the No. 1 spillway ( $r = 0.74$ ).

Dissolved oxygen remained fairly constant at the No. 1 spillway where it was below 4.0 mg/liter only once (June 1975; 3.58 mg/liter or 51 percent of saturation). The average dropped, but this again was an annual value while the previous study encompassed only late fall and winter conditions when dissolved oxygen would be higher. In fact, during the same period of time (September 1975 to February 1976) dissolved oxygen averaged 9.93 mg/liter; this was higher than the previous year due to an October phytoplankton bloom (chlorophyll-a was 291 mg/m<sup>3</sup>) where dissolved oxygen measurements were 158 percent of saturation (12.17 mg/liter). Dissolved oxygen possessed a high negative correlation with dissolved ammonium at stations 1 ( $r = -0.83$ ), 2 ( $r = -0.84$ ) and 3 ( $r = -0.82$ ) during the 12-month period. Oxygen was usually low when ammonium was high (see, for example, July and September 1975 stations in Figs. 6a and 13a). The only station which exhibited a high negative correlation of temperature with dissolved oxygen ( $r = -0.88$ ) was the NE Open water site. As expected, there was no correlation at the No. 1 spillway because other processes, such as primary productivity, exerted a greater influence on the concentration of dissolved oxygen in the water column. However, once the effluent water had left Craney Island these processes started to lose their effect on the regulation of dissolved oxygen (as seen by the average

linear correlation coefficient of  $-0.73$  for the five stations in the plume).

Total suspended solids averaged 40 percent less than what was measured previously at the No. 1 spillway. With the exception of April and May 1975, which were similar to the last samples from the previous period (See Fig. 16 in Adams and Young 1975), total suspended solids varied between 50 and 150 mg/liter. Concentrations at the NE Open water site were also very low. Measurements of some of the variables ( $PO_4$ ,  $NO_3$ ,  $NO_2$ ,  $NH_4$  and TKN) were lower during this period (see Table 8), which could reflect the change in location of the background site. During the previous program (December 1973 to February 1975) samples were collected from the open water side of the levee at the NE corner of Craney Island. It is possible that the growth and decay of attached algae growing on and near the levee as well as resuspension of bottom sediments and aeolian transport of dust from the levee provided additional components to samples collected during this period. Because a small boat was used for the plume stations, samples were also collected from a boat at the NE Open water site, but these were in deeper water about 100 meters from the original site on the levee. The higher suspended solids at the NE Open water site on February 14 and 20, 1975 (see sample Nos. 123 to 132 in Fig. 16 in Adams and Young op. cit.) might be explained by the average wind conditions of 9.6 and 8.9 mph, respectively, out of the north during these two days. The average of  $21.5 \pm 7.9$  mg/liter for the 12-month period at the NE Open site was slightly higher than surface waters at the Newport News channel (Nichols 1972) and for the Elizabeth River channel one mile to the south during a 13-hour tidal study on 1 Nov 1975 (Pomeroy and Adams; unpublished data), where concentrations averaged 11.5 with a range of 5.0 to 16.12 mg/liter at the surface. At eight meters, however, values were higher in the Elizabeth River (mean of 19.6 with a range of 14.7 to 36.5 mg/liter), which suggests that the concentrations measured at the NE Open water site probably represent some resuspension of bottom sediments in the shallower waters.

Even though some of the variables were slightly lower as mentioned above, very little differences between the programs were seen at the NE Open water site with respect to fecal coliform, dissolved phosphate, total phosphorus and dissolved nitrite. As mentioned previously, dissolved nitrate, ammonium and total Kjeldahl nitrogen were higher during the first 15 months at the NE Open water site; the difference was more than likely due to the station location. The highest concentrations of dissolved phosphates ever observed at the No. 1 spillway were measured in June and August 1975 (Fig. 9c). A large bloom of phytoplankton (Fig. 15c) followed the June maximum. Both the high levels of dissolved phosphate in August and the unusual concentrations of

ammonium in September (Fig. 13c) stimulated an even larger bloom in October, which immediately depleted both nutrients from the water column. The nearly complete removal of dissolved phosphates at the spillway was followed by the onset of winter temperatures and a subsequent lowering of bacterial activity in the sediments. With both low temperatures and relatively little nutrients at the spillway, low chlorophyll concentrations were measured between December and March.

The measurements of particulate mercury during this portion of the program were about double the previous data after these were corrected. Measurements reported in Adams and Young (1975) for particulate mercury were in error by an order of magnitude. Corrected values are provided in Table 8 and Appendix A. Particulate mercury was higher at the No. 1 spillway than the NE Open water site. Particulate zinc was similar at both sampling places during this portion of the program. Further discussion of particulate and dissolved metals is presented in the next section.

*Chlorophyll-a, dissolved organic carbon, particulate organic carbon, and dissolved and particulate metals.*

Chlorophyll-a. This pigment is used to estimate the concentration of autotrophs in the suspended fraction of a water sample. The amount of organic matter associated with a given concentration of phytopigments is not a constant, however, and this ratio can vary with the class of the phytoplankton and its nutritional state. At only one location (station 1 immediately outside the No. 1 Spillway) was there any correlation between POC and chlorophyll-a ( $r = 0.79$ ). While the chlorophyll concentration can be measured spectrophotometrically, certain difficulties do arise. No distinction can be made between chlorophyll that is present in living cells and that which is detrital (Fogg 1966). Also, chlorophyll-a is not the only pigment involved in photosynthesis. In spite of these difficulties, chlorophyll can be used as an indicator, albeit a crude one, of the size of the phytoplankton biomass in a particular area.

The ranges measured during this program at Craney Island (June 1975 to March 1976) as well as reported by other investigators for a variety of marine and estuarine environments are listed in Table 10. Chlorophyll-a was always higher within the No. 1 spillway than was measured at the NE Open water site

Table 10. Distribution of chlorophyll-a from various environments including the Craney Island Dredge Disposal area. Units are expressed as mg/m<sup>3</sup>.

Location	Range	Reference
Atlantic Ocean	1.5 - 3.5	Ketchum et al. (1958)
<100 m	<0.2	Ketchum et al. (1958)
>2000 m	0 - 12	Horne (1969)
North Sea	2 - 13	Copeland and Hobbie (1973)
Albemarle Sound, North Carolina	1 - 45	Copeland and Hobbie (1973)
Neuse River Estuary, North Carolina	2.0 - 34.0	O'Connor and Duedall (1975)
New York Bight	8 - 40	Jaworski et al. (1972)
Rappahannoch River, Virginia	0.01 - 0.02	McCarthy et al. (1975)
Chesapeake Bay Mouth	3.2 - 16.6 (7.7 ± 3.5) <sup>1</sup>	Adams et al. (1975b)
Chesapeake Bay	2.8 - 12.4 (6.4 ± 2.4) <sup>1</sup>	Adams et al. (1975b)
Hampton Roads Harbor, Virginia	1.0 - 19.7 (4.0 ± 2.8) <sup>1</sup>	Adams et al. (1975b)
James River, Virginia	2.0 - 13.0	Brehmer (1972)
James River, Virginia	1.5 - 81.9 (12.5 ± 16.4) <sup>1</sup>	Adams et al. (1975b)
Elizabeth River, Virginia	3.0 - 12.0	Phelffer et al. (1972)
Craney Island	17.4 - 291 (93 ± 100)	This report
No. 1 Spillway	2.0 - 34.1 (14 ± 10)	This report
NE Open		

<sup>1</sup> Sampled monthly at 17 surface stations during the period from May 1974 to April 1975; Chesapeake Bay (n = 57), Hampton Roads Harbor (n = 76), James River (n = 105) and Elizabeth River (n = 62).

(Fig. 15c). With the exception of three months (August, November and February), concentrations within the spillway were also higher than at station 1 in the spillway plume (Figs. 15a and 15b). The range was also greater than reported for the Elizabeth River (Pheiffer et al. 1972, Adams et al. 1975b), James River (Brehmer 1972, Adams et al. op. cit.) and Chesapeake Bay (Adams et al. op. cit.). This was probably attributed to the levels of nutrients inside the levee, which would be favorable for algal growth.

As mentioned before, there were two periods when the phytoplankton were most productive--July and October 1975. These were closely related to dissolved phosphates and ammonium, and in the case of the last bloom there was an obvious depletion of both nutrients from the water column (see Figs. 9c and 13c). Water temperatures dropped rapidly after the October plankton bloom, with an average monthly change of 8.6 °C. The range (2-34 mg/m<sup>3</sup>) and mean (13.6 mg/m<sup>3</sup>) for the NE Open water site was much higher than the lower Chesapeake Bay (mean of 7.7 mg/m<sup>3</sup>; Adams et al. 1975b) and the Chesapeake Bay mouth (0.01 - 0.02 mg/m<sup>3</sup>; McCarthy et al. 1975) and was twice as high as the Harbor of Hampton Roads (6.4 mg/m<sup>3</sup>; Adams et al. op. cit.). However, these values are similar to the Elizabeth River (12.5 mg/m<sup>3</sup>; Adams et al. op. cit.), where concentrations as high as 82 mg/m<sup>3</sup> have been reported. Pheiffer et al. (1972) have suggested that both domestic and industrial sources of fertilization have contributed to excessive algal growth in this river, which has led to an accompanying deterioration in water quality.

There was a rapid reduction in chlorophyll-a in the No. 1 spillway plume (see Scattergram in Appendix C). As pointed out in the next section, 89 percent was lost between stations 1 (immediately outside the spillway) and 2 in the plume, which was probably due to grazing or sedimentation.

Dissolved and particulate organic carbon. Nonliving organic matter in coastal waters is derived mainly from living organisms with a small contribution from terrigenous sources. While it is common practice to report organic carbon as dissolved or particulate, these fractions are arbitrary and can be rather misleading. Material which passes through a 0.45 µm filter is considered dissolved organic matter (Riley 1973). This is a classification which is based on practicality and obviously will include colloids and small particles up to the retention size of the filter. Some of these fractions could also

adhere to the filter pad (Sharp 1974). The material retained by the filter is designated particulate organic matter.

The composition and sources of organic carbon are diverse and not well understood (Sharp 1975). Undoubtedly, bacterial activity plays an important role in the production of dissolved organic material. It is also felt that active healthy phytoplankton excrete a significant portion of their photo-assimilated carbon (Riley 1973). Estuaries have higher levels of particulate and dissolved organic carbon than oceanic environments. Data for various marine and estuarine areas are listed in Table 11 along with the results from this monitoring program at Craney Island.

The range of concentrations for dissolved organic carbon at the Craney Island spillway (7.3-22.4 mg/liter) were similar to those reported by Pfeiffer et al. (1972) for samples from the Elizabeth River. They were also in agreement with TOC concentrations in the Elizabeth and James Rivers and the Harbor of Hampton Roads (see Table 11). Particulate organic carbon at the spillway and NE Open water sites were also similar to nearby bodies of water; however, it should be remembered that the DOC and POC concentrations listed in Table 11 for Adams et al. (1975b) are for the winter and spring months and are probably not indicative of summer and fall conditions. Both variables decreased in the spillway plume (see Scattergrams in Appendix C), and in the case of POC the linear correlation was -0.82 for the 12-month means at each of the five stations. The reduction in DOC and POC between stations 1 and 2 was 59 and 50 percent, respectively, of the maximum change measured in the plume during the annual period.

Dissolved and particulate metals. With the exception of particulate mercury and particulate zinc, the concentrations of both dissolved and particulate metals were below previous measurements at the No. 1 spillway and NE Open background sites (Table 8). The limit of detection for dissolved cadmium with the EPA (1974) recommended method of chelation and solvent extraction (APDC/MIBK) was 0.001 mg/liter, and most of the samples were either close to this limit or below during this portion of the monitoring program. These values were only slightly lower than measurements by anodic stripping voltammetry (ASV), which was utilized during the first six months of the program (December 1973 to June 1974; see Fig. 13 in Adams and Young 1975). Measurements of dissolved cadmium (0.8  $\mu$ m filtration) by ASV from the

Table 11. Distribution of dissolved and particulate organic carbon from various environments including the Craney Island Dredge Disposal area. Units are in mg/liter.

Location	DOC	POC	TOC	Reference
Oceanic Average	0.5 - 1.0	0.025 - 0.300		Riley (1973)
Pacific Ocean	0.8	0.15		Holm-Hansen (1966)
North Sea	0.6 - 1.8			Horne (1969)
Alaskan Glacial Estuary	0.1 - 1.6	0.03 - 3.6		Loder and Hood (1972)
Nova Scotian Slope Water		0.004 - 0.04		Wangersky (1974)
Rappahannoch River, Virginia	5 - 18			Jaworski et al. (1972)
Patuxent River, Virginia	2.9	2.0		Flemer (1970)
Elizabeth River, Virginia			4.43 - 23.1	Phelifer et al. (1972)
Elizabeth River, Virginia	2.9 - 6.5 <sup>1</sup>	0.4 - 2.1 <sup>2</sup>	3.0 - 25.6 <sup>3</sup>	Adams et al. (1975b)
Hampton Roads Harbor, Virginia	4.1 - 5.2 <sup>1</sup>	0.8 - 3.0 <sup>2</sup>	4.6 - 25.5 <sup>3</sup>	Adams et al. (1975b)
Chesapeake Bay	3.6 - 4.5 <sup>1</sup>	0.7 - 1.9 <sup>2</sup>	3.6 - 13.3 <sup>3</sup>	Adams et al. (1975b)
James River, Virginia	3.2 - 17.3 <sup>1</sup>	0.7 - 3.4 <sup>2</sup>	3.6 - 20.1 <sup>3</sup>	Adams et al. (1975b)
Craney Island	7.3 - 22.4	0.4 - 2.1		This report
No. 1 Spillway	(14.8 ± 5.0)	(1.2 ± 0.5)		This report
NE Open	1.0 - 12.2	0.1 - 1.3		This report

<sup>1</sup> Limited number of samples (n = 3 - 11) measured only during September and November 1974.

<sup>2</sup> Measured during the period from December 1974 to March 1975.

<sup>3</sup> Measured during the period from September 1974 to April 1975.

DOC = dissolved organic carbon, POC = particulate organic carbon, TOC = total organic carbon (POC + DOC).

southern North Sea (I.C.E.S. 1974) has provided concentrations ranging from 0.05 µg/liter to 1.01 µg/liter (Table 12), which are much lower than those determined by ASV at the middle spillway of Crancy Island (0-19 µg/liter; 5 ± 10 µg/liter for n = 19) and at the NE Open water site (1-56 µg/liter; 10 ± 26 µg/liter for n = 20). As mentioned previously, 44 percent of the dissolved cadmium measurements were below 0.001 mg/liter (by APDC/MIBK method), while concentrations during June were overall the highest (with exception of the NE Open water site). It appeared that dissolved cadmium decreased with distance from the spillway, but this is only speculative with such little data.

Differences were even more noticeable with dissolved zinc by ASV and measurements with the APDC/MIBK technique, where average concentrations were 6-50 times lower during this portion of the program. However, the highest measurement by ASV (0.149 mg/liter = 149 µg/liter) for the middle spillway was only double the maximum concentration for the southern North Sea (0.8 µm filtration; analysis by ASV), even though ranges were not (Table 12).

Concentrations at the middle spillway were 10-149 µg/liter with a mean of 54 ± 72 µg/liter for n = 19, while the I.C.E.S. (op. cit.) report listed 0.2-78.6 µg/liter. It is possible that the higher values reported during the initial six months could be a result of improperly cleaned sample bottles, use of reagent grade laboratory acids and the methodology associated with the measurement of dissolved cadmium and zinc with a new instrument (i.e., anodic stripping voltammetry). Differences associated with the measurement of dissolved cadmium and zinc during this portion of the program (APDC/MIBK technique) and the latter months of the previous study (GFAA) were already described in the methodology section. It is probable that analysis in the graphite furnace detects a different and perhaps more abundant fraction of these two metals than is measured by APDC chelation and solvent extraction with MIBK. The higher concentrations of dissolved organic carbon at the spillway (averaged 14.8 mg/liter) as compared to the NE Open water site (mean of 4.4 mg/liter) during this portion of the program would suggest the abundance of organic compounds capable of complexing these metals. Water samples that were passed through resin for analysis by Endeco Inc. (see Tables 2 and 3) were not treated for oxidation of dissolved organic matter, which could have resulted in the low measurements for dissolved cadmium and zinc.

Dissolved mercury concentrations at the NE Open water site have steadily decreased from a mean of 0.006 ± 0.014 mg/liter during the first six months

Table 12. Dissolved cadmium, lead, mercury and zinc for various marine and estuarine environments including the Craney Island Dredge Disposal area. Units are in µg/liter.

Location	Cd	Hg	Pb	Zn	Reference
Ocean water	0.1	0.02 - 0.03 0.17 (coastal)	0.03 0.02 - 0.04 (deep ocean)	1 - 50 (mean ca. 3)	Brewer (1975)
Northeast Atlantic	0.07 - 0.71			2.5 - 22	Riley and Taylor (1972)
East and West Atlantic	0.04 - 0.30	0.002 - 0.400		0.9 - 5.2	I.C.E.S. (1975)
Northwestern Indian				4 - 28	Topping (1969)
Northeast Tropical Pacific (0 - 1000 m)				mean 1.7	Zirino and Healy (1971)
Sargasso Sea				2.6	Brewer (1975)
North Sea	0.05 - 1.01 2.8 (coastal)	<0.01 - 0.07	<0.05 - 21	0.2 - 79	I.C.E.S. (1974)
Lower Thames, U.K.		0.003 - 0.515			Smith et al. (1971)
British Coastal Waters	<0.01 - 1.4		<0.05 - 1.2	0.8 - 9.0	Preston (1973)
Northeastern Atlantic Surface		0.013 - 0.018		1.4 - 7.0 (5.0; n = 5)	Leatherland et al. (1971)
Northeastern Atlantic Surface	<0.01 - 0.41 (0.04; n = 5)				Preston (1973)
River Avon Estuary, U.K.	4.2				Abdullah et al. (1972)
Liverpool Bay, Cardigan Bay, Bristol Channel, U.K.			1.2 - 2.2 0.07 - 0.35 (surface) 0.01 - 0.04 (deep ocean)		Abdullah et al. (1972)
Chesapeake Bay <sup>1</sup>			15 ± 12 (n = 42)	4 - 122 (48 ± 26)	Patterson (1971)
Chesapeake Bay	0.08 - 0.32		1 - 156	1.5 - 66	Adams et al. (1975b)
Choptank River, Virginia		0.02 - 0.14		1 - 299	Carpenter et al. (1975)
Southeastern Rivers <sup>2</sup>	0.1 - 3.6		<10		Phieffer (1972)
James River, Virginia	<10	<0.5 - 7.6			Windom (1976)
James River, Virginia <sup>1</sup>			15 ± 17 (n = 78)	<10 - 80	Phieffer et al. (1972)
Hampton Roads Harbor, Virginia <sup>1</sup>			18 ± 18 (n = 56)	5 - 338 (53 ± 42)	Adams et al. (1975b)
Elizabeth River, Virginia <sup>1</sup>			17 ± 21 (n = 50)	4 - 359 (67 ± 55)	Adams et al. (1975b)
Craney Island				1 - 622 (78 ± 80)	Adams et al. (1975b)
No. 1 Spillway	<1 - 2 (7) <sup>3</sup>	<0.1 - 1.1 (3) <sup>1</sup>	<10 - 12 (100) <sup>3</sup>	<1 - 70 (73) <sup>3</sup>	This report
NE Open	<1 - 4	<0.1 - 1.2	<10	<1 - 1.0	This report

<sup>1</sup> Analyzes of dissolved lead and zinc measured on unfiltered samples that were preserved with acid (dissolved and acid-labile particulate metals).

<sup>2</sup> Data are ranges for the following rivers in South Carolina, Georgia and Florida: Pee Dee, Black, Santee, Cooper, Savannah, Ogee See, Altamaha, Satilla and St. Johns.

<sup>3</sup> Maximum value in the spillway plume stations (in parentheses).

to  $0.003 \pm 0.003$  mg/liter between August 1974 and February 1975 to  $0.0004 \pm 0.0003$  mg/liter for April 1975 to March 1976. Either this represents an improvement in methodology or was due to the relocation of the background site. Because of the fluctuations in dissolved mercury at the plume stations, it was difficult to interpret any significant decrease in its concentration with horizontal distance from the spillway (see Scattergram in Appendix C). In the case of dissolved zinc, so many of the samples in the spillway plume were below detection (70 percent, or 42 out of 60) that it was difficult to interpret any changes that occurred after waters left Craney Island. A Scattergram is provided in Appendix C for the 12-month means of the remaining 18 samples that were above detection.

Because of the recent data for particulate cadmium and an independent check by another laboratory (ca.  $4 \mu\text{g/g}$ ), it is suspected that the earlier measurements were in error. With the low concentrations of suspended solids, over two liters would be required at the NE Open water site to provide a detectable measurement by atomic absorption for cadmium. With the poor detection for lead ( $0.050$  mg/liter) and approximately  $30 \mu\text{g/g}$  at the NE Open water site (see Table 13), an even greater volume of water would be necessary (ca. 8 liters) to provide a detectable measurement. The corrected particulate mercury data from the previous report (Adams and Young 1975) are within range of the recent studies. Both particulate mercury and particulate zinc were higher inside the No. 1 spillway than at the NE Open water site. There was a significant correlation ( $r = 0.83$ ) of particulate zinc with chlorophyll-a during the 12-month period at the background site, while this was not the case for the other stations.

As pointed out by Patterson (1971) with respect to particulate lead, most open ocean values for trace metals refer to dissolved and exchangeable species and do not include that fraction bound inactively to suspended particles. This is attested by the lack of open ocean values for particulate metals in Table 13. However, it is relatively easier to collect and measure particulate trace metals in coastal waters where greater concentrations of suspended material are present. Most of the particulate metal data for Craney Island are within the range of measurements for nearby coastal environments. With the exception of the relationship between particulate zinc and chlorophyll-a at the NE Open water site, particulate mercury and zinc were not highly correlated with other variables. The only other significant relationship

Table 13. Concentrations of metals associated with particulate suspended material for various marine or estuarine environments including the Craney Island Dredge Disposal area. Units are reported in µg/g.

Location	Cd	Hg	Pb	Zn	Reference
Black Sea	2 - 114			31 - 2322	Spencer et al. (1972)
Gulf of Maine				140 - 490	Spencer and Sachs (1970)
Dill's Creek, North Carolina		0.5 - 17		4 - 109	Settlemyre and Gardner (1975)
Tidal Thames, U.K. <sup>1</sup>	1.8 - 35				Smith et al. (1971)
Southeastern Rivers <sup>2</sup>	3 - 26	0.2 - 1.0			Windom (1976)
Satilla River, Georgia				135 - 847	Windom et al. (1971)
Mobile River Estuary		0.062 - 2.31			Andren (1973)
Susquehanna River, Virginia	1 - 36			100 - 4200	Carpenter et al. (1975)
Craney Island					
No. 1 Spillway (code 01)	< 2 <sup>3</sup>	< 1 - 73 <sup>4</sup>	< 20 <sup>3</sup>	< 10 - 778 <sup>5</sup>	This report
NE Open (code 04)	< 2 <sup>3</sup>	< 1 - 19 <sup>4</sup>	< 20 <sup>3</sup>	32 - 1187 <sup>5</sup>	This report
	(4.4) <sup>3</sup>	(7 ± 4)	(32) <sup>3</sup>	(238 ± 336)	

1 Calculated difference from total and dissolved concentrations of mercury and measurements of suspended matter (<80% Hg associated with particulates). Range for calculated particulate mercury was 0.039 to 2.335 µg/liter (see Table 12 for dissolved values).

2 Data are ranges for the following rivers in South Carolina, Georgia and Florida: Pee Dee, Black, Santee, Cooper, Savannah, Ogeechee, Altamaha, Satilla and St. Johns.

3 Particulate metals were below detection except two 100 mg samples collected by centrifugation (in parentheses). The sample at the No. 1 spillway was actually collected at station 1 in the spillway plume (code 05). See Table 5 for other metals.

4 Range for 12 analyses at each site for the annual period (mean and standard deviation in parentheses; ten above detection for code 01 and 11 above detection for code 04).

5 Range for 12 analyses at each site for the annual period (mean and standard deviation in parentheses; for 11 above detection at code 01, 12 at code 04). Three higher values (1008, 1219 and 2728 µg/g) were measured at stations in the spillway plume.

occurred at the No. 1 spillway between particulate zinc and particulate organic carbon ( $r = 0.61$ ). The increase in particulate mercury at station 2 in the spillway plume is not presently understood. Such phenomena are known to occur in the transition zone between rivers and salt water (de Groot 1973), but this is in the opposite direction whereby metals leave the solid phase as the ionic strength increases. However, salinity was relatively constant at the No. 1 spillway. Mercury and zinc could have been incorporated into organisms; yet this was only evident at station 4 with particulate mercury, where there was a positive correlation with particulate organic carbon ( $r = 0.63$ ). Particulate zinc behaved in a similar manner during the annual period, where there was a slight increase between stations 1 and 2 in the spillway plume during six months of the year. This was not evident in the mean (see Scattergram in Appendix C) which was probably due to the substantial reduction in December 1975 (Fig. 24b). With the exception of the abnormally high measurement of 2728  $\mu\text{g/g}$  in October 1975, there appeared to be a general increase with distance in the plume.

#### *Lateral influence of the Craney Island No. 1 Spillway plume.*

During the annual period from April 1975 to March 1976, the No. 1 spillway plume was sampled monthly in order to define the horizontal extent of the effluent from Craney Island in the receiving waters to the west of the dredged material disposal area. Station 1 was occupied immediately outside the No. 1 spillway (as close as the small 14-foot aluminum boat could maneuver) while the next stations were spaced at fixed intervals of approximately 160 meters (0.1 mile) in the plume. The last surface collection site (station 5) was either at a normal fixed interval along the longitudinal axis or at the leading edge of the plume, if it was visible.

The 12-month mean for variables at the five surface stations in the plume are provided as Scattergrams in Appendix C, while simple statistics for each of the parameters at the plume stations are listed in Table 3. Lastly, monthly distributions of each variable are displayed in Figures 3a and b to 24a and b at the end of the text.

Of the 23 variables that were measured during this program, 50 percent showed a noticeable reduction in concentration between stations 1 and 2 in

the spillway plume; this ranged from as little as 50 percent of the maximum change in the variable to as high as 100 percent (Table 14). Three variables exhibited an increase with distance in the plume (dissolved oxygen, temperature and nitrate), where the rise averaged 67 percent.

Temperature increased with distance in the spillway plume and was the only parameter with a linear correlation coefficient of 0.90 (for the 12-month means at each station). Reduction with distance in the plume for the 12-month means of the following variables was linear: total phosphorus, nitrate, ammonium, total Kjeldahl nitrogen and particulate organic carbon. All of these were correlated, with a coefficient of at least  $r = 0.8$ , to a linear relationship with horizontal distance. With some of the other parameters listed in Table 14, reductions in concentration between stations 1 and 2 were of such magnitude that the linear correlation was lost: salinity, pH, total suspended solids, fecal coliform, dissolved phosphate, nitrite and chlorophyll-a.

The variation in each of the parameters at the five stations in the plume and at the sampling site inside the No. 1 spillway were tested to determine if there were significant differences during the annual period with respect to the NE Open water background site. From Student-t tests of each variable, only the parameters listed in Table 15, with the exception of particulate mercury, were significantly different at the 95 percent confidence level from the NE Open water site. These can be compared to the first six months of the program, where pH, phosphate, ammonium, dissolved mercury, particulate mercury, particulate cadmium and particulate zinc were different between the two sites. The variables that were significantly different in the second six months were pH, fecal coliform, phosphate, ammonium, dissolved mercury, dissolved zinc, particulate cadmium, particulate mercury and particulate zinc. However, because of the errors associated with particulate cadmium and the different methodology and possible problems with dissolved cadmium and zinc, these should not be considered in relationship with the present investigation.

There was an immediate change in four of these variables (pH, chlorophyll-a, fecal coliform and phosphate) between the site inside the No. 1 spillway and at station 1 in the plume, which was located immediately outside in the receiving waters (compare columns 2 and 3 in Table 15). A noticeable reduction in six of the



Table 15. Two-tailed probability coefficients from Student-t tests of the measured variables at each station compared to the NE Open water background site. Coefficients for those variables which displayed no statistical evidence that their means were different are not included. Coefficients were obtained using the SPSS computer package (Nie et al. 1975).

Variable	Station 1 <sup>3</sup> Spillway <sup>2</sup> Inside No. 1	Station 1 <sup>3</sup>	Station 2	Station 3	Station 4	Station 5
Total Kjeldahl Nitrogen (TKN) <sup>1</sup>	0.006*	0.000	0.024	(0.075)	(0.080)	
Total Phosphorus (TP)	0.001*	0.003	(0.091)			
Total Suspended Solids	0.004*	0.011				
Particulate Organic Carbon (POC)	0.000	0.026				
Dissolved Organic Carbon (DOC)	0.000	0.034		(0.085)		
Ammonium (NH <sub>4</sub> -N)	0.019*	0.021				
Nitrite (NO <sub>2</sub> -N)	0.039	0.050			(0.082)	
pH	0.017*	(0.066) <sup>4</sup>				
Chlorophyll-a	0.033	(0.070)				
Fecal Coliform	0.030*		(0.070)			
Phosphate (PO <sub>4</sub> -P)	0.042*					
Particulate Mercury	*					(0.083)

<sup>1</sup> TKN was the only variable at station 2 where there was statistical evidence (at the 95% level of confidence) that the means were different than those measured at the NE Open water site.

<sup>2</sup> Variables with asterisks (\*) were significantly different during the first portion of the monitoring program (Adams and Young 1975). POC, DOC and chlorophyll-a were not measured. See text for discussion of other variables.

<sup>3</sup> Station 1 was located immediately outside the No. 1 spillway (as close as the boat could maneuver).

<sup>4</sup> The smaller the probability coefficient, the greater is the statistical evidence that the two means are different. If the two-tail probability coefficient is less than 0.05, then the means are different at the 95 percent confidence level between the variable at that specific station and the NE Open water site.

remaining seven variables was observed between stations 1 and 2 in the plume. Total Kjeldahl nitrogen was the only parameter at station 2 whose concentration was statistically different at the 95 percent level of confidence from the Open water background site. This suggests that there was a relatively narrow mixing zone around the spillway and that the effect of the measured variables (with the exception of TKN) was not seen further than 160 meters (0.1 mile) and was probably much less (see the Scattergrams in Appendix C) as evidenced by their rapid reduction (Table 14) between stations 1 and 2. The only variables that were anomalous were particulate mercury and particulate zinc, where biological uptake might be related to the unusual horizontal profiles in the surface waters of the plume.

## SUMMARY AND CONCLUSIONS

The monitoring program for this year (March 1975 to April 1976) was a continuation of a previous 15-month study (Adams and Young 1975) of the spillways at the Corps of Engineers Craney Island Dredge Disposal area in the Port of Hampton Roads, Virginia. However, during this time greater attention was placed at an investigation of the influence and horizontal extent of the No. 1 spillway plume to the west of Craney Island. The objective was to define a mixing zone during the annual period whose perimeter could not be distinguished from background, where background was taken as the NE Open water site.

Tests were conducted for 23 different variables from surface samples collected monthly inside the No. 1 spillway and at the NE Open water site. Additionally, five surface samples were taken at designated locations within the spillway plume, where station 1 was as close to the outfall as the boat could maneuver and station 5 was selected as the leading edge of the plume, when it was visible. The variables were temperature, salinity, pH, dissolved oxygen (and oxygen saturation calculations), dissolved inorganic orthophosphate, total phosphorus, nitrate, nitrite, ammonium, total nitrogen (TKN), fecal coliform, particulate organic carbon, dissolved organic carbon, chlorophyll-a and total suspended solids. In addition, dissolved and particulate concentrations of cadmium, lead, mercury and zinc were also measured. Certain other conditions were examined at the time of sampling or taken from local meteorological data: air temperature, wind direction, wind speed, precipitation and percent of sunshine, as well as the bird population and height of water within Craney Island.

The two sampling programs at the No. 1 spillway were compared, and these are briefly summarized: 1) pH was lower which would improve conditions with respect to ammonia toxicity; 2) calculated concentrations of un-ionized ammonia ( $\text{NH}_3$ ) did not exceed recommended criteria as previously measured mainly at the No. 3 spillway, even though ammonium ( $\text{NH}_4^+$ ) was higher than 0.4 mg/liter 33 percent of the time; 3) dissolved ammonium was highly correlated with precipitation at each of the stations suggesting another source; 4) concentrations of  $\text{PO}_4$ ,  $\text{NO}_3$ ,  $\text{NO}_2$ ,  $\text{NH}_4$ , TKN and total suspended solids were lower at the NE Open water site during this period than were previously measured,

which either implies that the new location 100 meters off the levee better represents the open waters of the Harbor of Hampton Roads or that contributions from the levee in the form of growth and decay products of attached algae, resuspension of bottom sediments, and aeolian transport of detrital materials provided additional sources; 5) concentrations of particulate mercury were approximately double values reported for the previous program while particulate zinc at the NE Open water site was three times as high; and 6) dissolved metals were lower than previously reported due to both improvements in sampling and laboratory techniques as well as different methodology for analysis.

The overall levels of nutrients within Craney Island promoted two large plankton blooms in July and October 1975 at which time chlorophyll-a concentrations were abnormally high (250 and 291 mg/m<sup>3</sup>) inside the No. 1 spillway. These were closely related to dissolved phosphate and ammonium and resulted in rapid depletion of both nutrients during the latter bloom. Spillway concentrations were always greater than background, where concentrations averaged  $93 \pm 100 \text{ mg/m}^3$  (range of 17.4 - 291 mg/m<sup>3</sup>) inside the No. 1 spillway and  $14 \pm 10 \text{ mg/m}^3$  (range of 2.0 - 34.1 mg/m<sup>3</sup>) at the NE Open water site. Chlorophyll-a was highly correlated with particulate zinc during the 12-month period at the NE Open water site.

Both particulate and dissolved organic carbon were higher inside the No. 1 spillway than at the NE Open water site. Dissolved organic carbon ranged from 7.3 to 22.4 mg/liter (14.8  $\pm$  5.0 mg/liter) at the spillway, while the background station was 1.0 to 12.2 mg/liter (4.4  $\pm$  3.0 mg/liter) during the annual period. Values for particulate organic carbon averaged  $1.2 \pm 0.5 \text{ mg/liter}$  (range of 0.4 - 2.1 mg/liter) at the spillway and  $0.4 \pm 0.4 \text{ mg/liter}$  (range of 0.1 - 1.3 mg/liter) at the NE Open water site.

Dissolved cadmium was below the recommended criteria of 0.010 mg/liter, while 44 percent of the measurements were below the detection limit of <0.001 mg/liter (by the APDC/MIBK method). The average for eight measurements at the No. 1 spillway was 0.001 mg/liter, while the NE Open water site was slightly higher (0.002 mg/liter; n = 7). The highest concentration was 0.007 mg/liter at station 4 in the spillway plume. These values are comparable with other estuaries which receive anthropogenic sources of pollutants but are at least ten times higher than open ocean conditions. With the exception of only four measurements during the entire period (where n = 84), dissolved lead was below the detection limit of 0.010 mg/liter. Dissolved mercury, however, exceeded recommended criteria (0.0001 mg/liter = 0.1  $\mu\text{g/liter}$ ) 75 percent of

the time at station 1 in the spillway plume and 67 percent of the time at the background site. Measurements inside the No. 1 spillway averaged  $0.4 \pm 0.3$   $\mu\text{g/liter}$  while values at the NE Open water site were similar in magnitude. These concentrations are 10-100 times higher than open ocean conditions and slightly greater than other reported data for coastal waters. Dissolved zinc averaged  $9 \pm 20$   $\mu\text{g/liter}$  ( $0.009 \pm 0.020$   $\text{mg/liter}$ ) at the No. 1 spillway with a range from below detection ( $<0.001$   $\text{mg/liter}$ ;  $n = 5$ ) to  $70$   $\mu\text{g/liter}$ . Concentrations at the background site were lower (averaged  $1$   $\mu\text{g/liter}$ , with 8 out of 12 measurements below detection). This metal did not exceed recommended criteria, and measured concentrations were similar to values reported for other estuarine, coastal and oceanic areas.

Because of the low concentration of suspended material in the open ocean, there are little particulate metal data for comparison. However, particulate lead and zinc measurements for Craney Island were approximately the same magnitude as reported for other estuaries along the southeastern United States (most of these measurements were probably not from pristine environments). Particulate cadmium was below detection at all of the stations. Only two measurements of cadmium associated with the suspended material, which was concentrated by centrifugation, verified these results ( $3.6$   $\mu\text{g/g}$  for station 1 in the No. 1 spillway plume and  $4.4$   $\mu\text{g/g}$  for the NE Open water site). Similar problems were associated with the determination of particulate lead, where values were below detection for all of the filtered suspended material. The two samples listed above provided measurements of  $16$   $\mu\text{g/g}$  (station 1 in the plume) and  $32$   $\mu\text{g/g}$  (NE Open) for particulate lead. Particulate mercury was higher at the No. 1 spillway (mean of  $17.1 \pm 23.2$   $\mu\text{g/g}$ ; range of  $<1$  to  $73$   $\mu\text{g/g}$ ) than was observed at the NE Open water site (mean of  $6.72 \pm 4.38$   $\mu\text{g/g}$ ; range of  $<1$  to  $19$   $\mu\text{g/g}$ ). These values were at least 5-20 times higher than other estuarine and river environments along the southeastern coast, yet were below calculated values for the tidal Thames. Particulate zinc was only slightly higher at the No. 1 spillway (mean of  $294 \pm 204$   $\mu\text{g/g}$ ) as compared to the background site ( $238 \pm 336$   $\mu\text{g/g}$ ), even though the ranges were different ( $<10$  to  $778$   $\mu\text{g/g}$  at the spillway compared to  $32 - 1187$   $\mu\text{g/g}$  at the NE Open water site). These data for particulate zinc are well within the ranges reported by other investigators for estuarine and coastal areas. Both particulate mercury and particulate zinc behaved erratically at the spillway plume stations, where

higher levels suggested uptake by organisms. However, this is purely speculative and has not been substantiated by significant correlations with chlorophyll-a or particulate organic carbon.

Only eleven of the 23 variables were significantly different, at the 95 percent level of confidence, inside the No. 1 spillway as compared to the NE Open water background site. These were total nitrogen (TKN), total phosphorus, total suspended solids, particulate organic carbon, dissolved organic carbon, dissolved ammonium, nitrite, pH, chlorophyll-a, fecal coliform and dissolved inorganic orthophosphate. As the water passed through the levee and emerged at the open water side (a distance of approximately 35 meters), four of these variables were no longer significantly different, at the 95% level, than background (pH, chlorophyll-a, fecal coliform and dissolved inorganic orthophosphate). However, pH and chlorophyll-a were different at the 90 percent level of confidence at station 1 in the plume. Total Kjeldahl nitrogen was the only variable which was significantly different (95% level of confidence) than background at the second station in the plume. The other six were either deposited, utilized by organisms or lost through other processes. Therefore, with the exception of total Kjeldahl nitrogen, the mixing zone for the No. 1 spillway, whose perimeter during this annual period could not be distinguished from background, was a distance equal to or less than station 2 in the plume. This distance was no greater than 160 meters, or 0.1 mile, and was usually less. For the eleven variables listed above, the average 12-month reduction between stations 1 and 2 in the plume was 81 percent of the maximum change, or the lowest average value measured at one of the five stations in the plume. There was an increase in three variables (temperature, dissolved oxygen and nitrate) with distance in the spillway plume, where these averaged 67 percent between stations 1 and 2 during the annual period (as compared to the maximum average value measured at one of the five stations in the plume).

Reduction with distance was approximately linear in the spillway plume during the 12-month period for total phosphorus, nitrate, dissolved ammonium, total Kjeldahl nitrogen and particulate organic carbon. With seven other variables, the change in concentrations between stations 1 and 2 were large enough that a linear correlation with distance was no longer evident: salinity, pH, total suspended solids, fecal coliform, dissolved inorganic orthophosphate, nitrite and chlorophyll-a. The only variables that

were anomalous were particulate mercury and particulate zinc, where the magnitude of changes in the horizontal profiles for the surface waters, of the plume might be related to biological uptake.

## RECOMMENDATIONS

1. From measurements of 27 elements associated with two particulate samples collected from station 1 in the No. 1 spillway plume and at the NE Open water site, it would be advisable to collect and analyze a greater number of suspended particulate samples to assess the validity of these numbers. Large volumes (ca. five gallons) would be processed by centrifugation and could be collected at each site and from the rehandling basin during barge disposal operations.
2. High concentrations of particulate mercury and particulate zinc, as well as chromium and copper (from the two samples listed above), have been observed during this study. Loss of these metals either by normal depositional processes or through biological uptake should be investigated by placing trays and sedimentation traps near one of the spillways. Acute toxicity of the effluent could be monitored by using the Oyster Embryo Bioassay (Woelke 1967). This would be accomplished by placing these trays at various distances from the spillway and at suitable background stations. Measurements would include growth rate, mortality, viability of offspring, bioaccumulation of toxic trace metals, and physiological measurements such as oxygen consumption and apparent pumping rate. Substantial uptake of cadmium, copper, mercury, manganese, nickel and zinc has been noted in oysters at control stations in Long Island Sound (Dehlinger et al. 1973). The Marine Algal Assay Procedure (EPA 1974) could be used to test the biotoxicity potential of the spillway effluent on the phytoplankton community.
3. The discharge of organic pollutants from Craney Island has not been addressed to date, with the exception of dissolved organic carbon measurements. Two areas which should be considered are petroleum hydrocarbons and other toxic organic materials. The latter group consists of polychlorinated biphenyls (PCB), pesticides, herbicides, insecticides, plasticizers and halogenated hydrocarbons such as carbon tetrachloride, ethylenedichloride and other such constituents. The character of bubbles associated with the spillway plume suggests the presence of surface active organic material.

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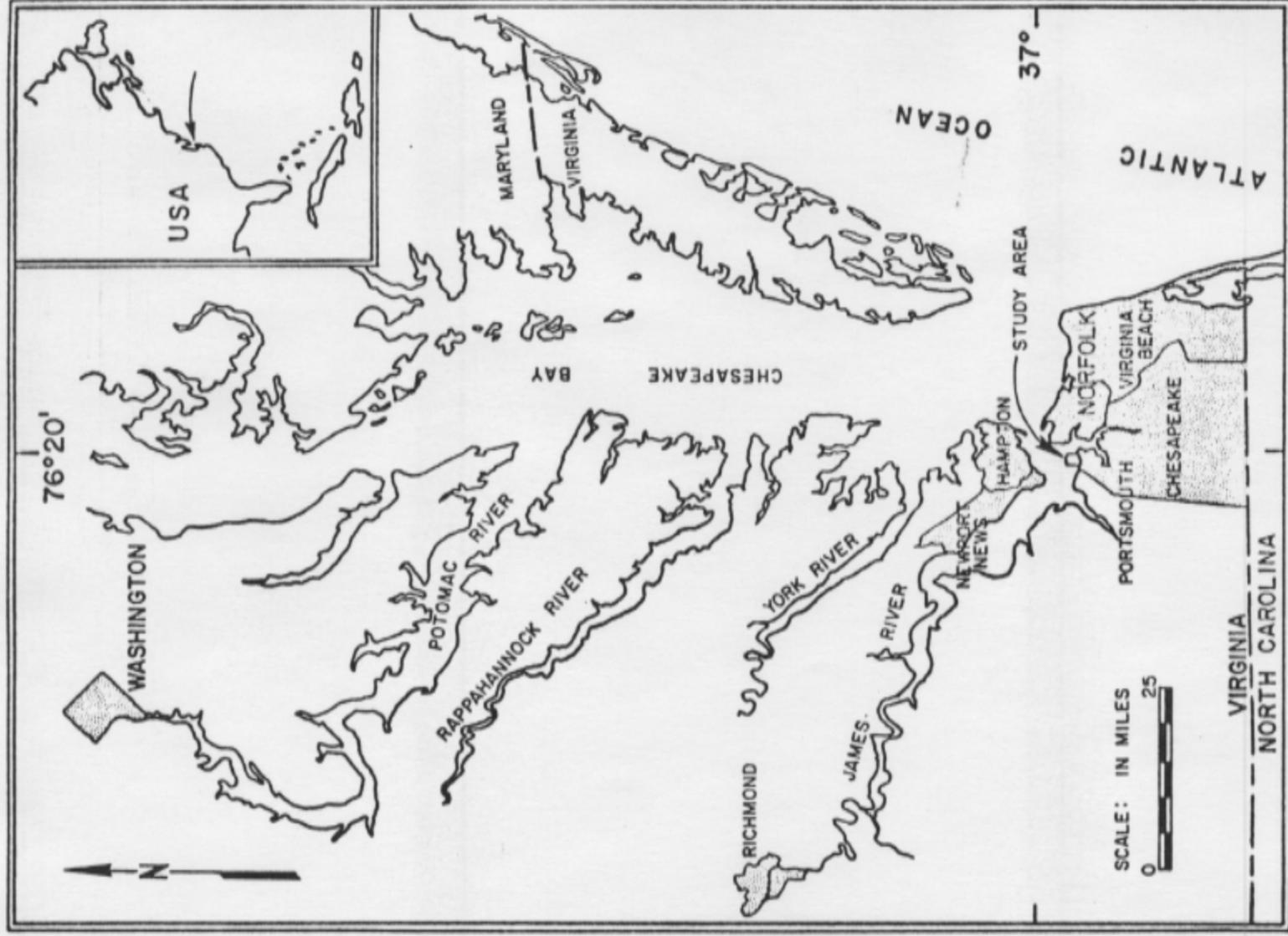


Figure 1. Location of the Corps of Engineers Crane Island Disposal area, Port of Hampton Roads, Virginia, near the mouth of the James River. See Figure 2 for a detailed view of the study area.

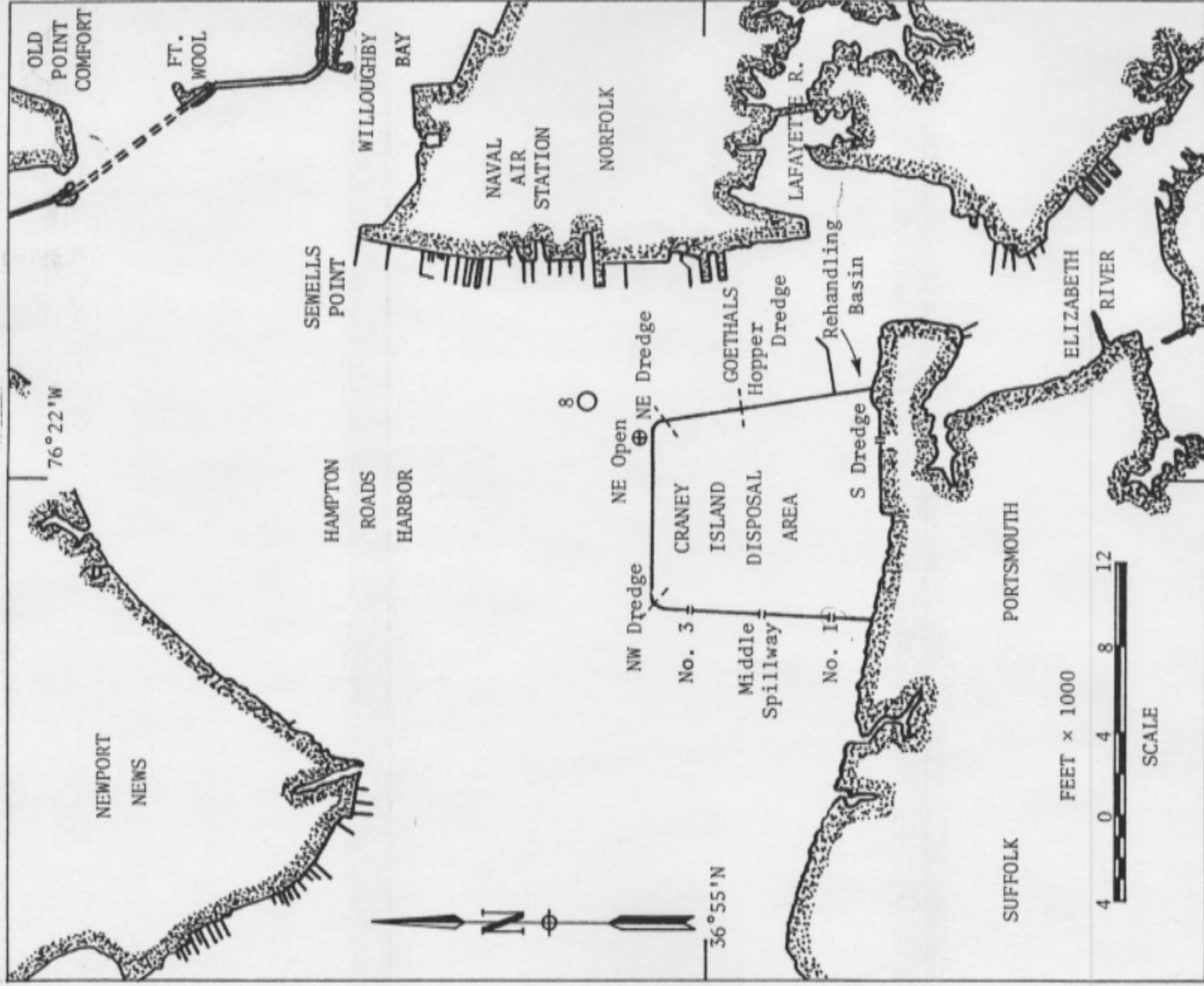
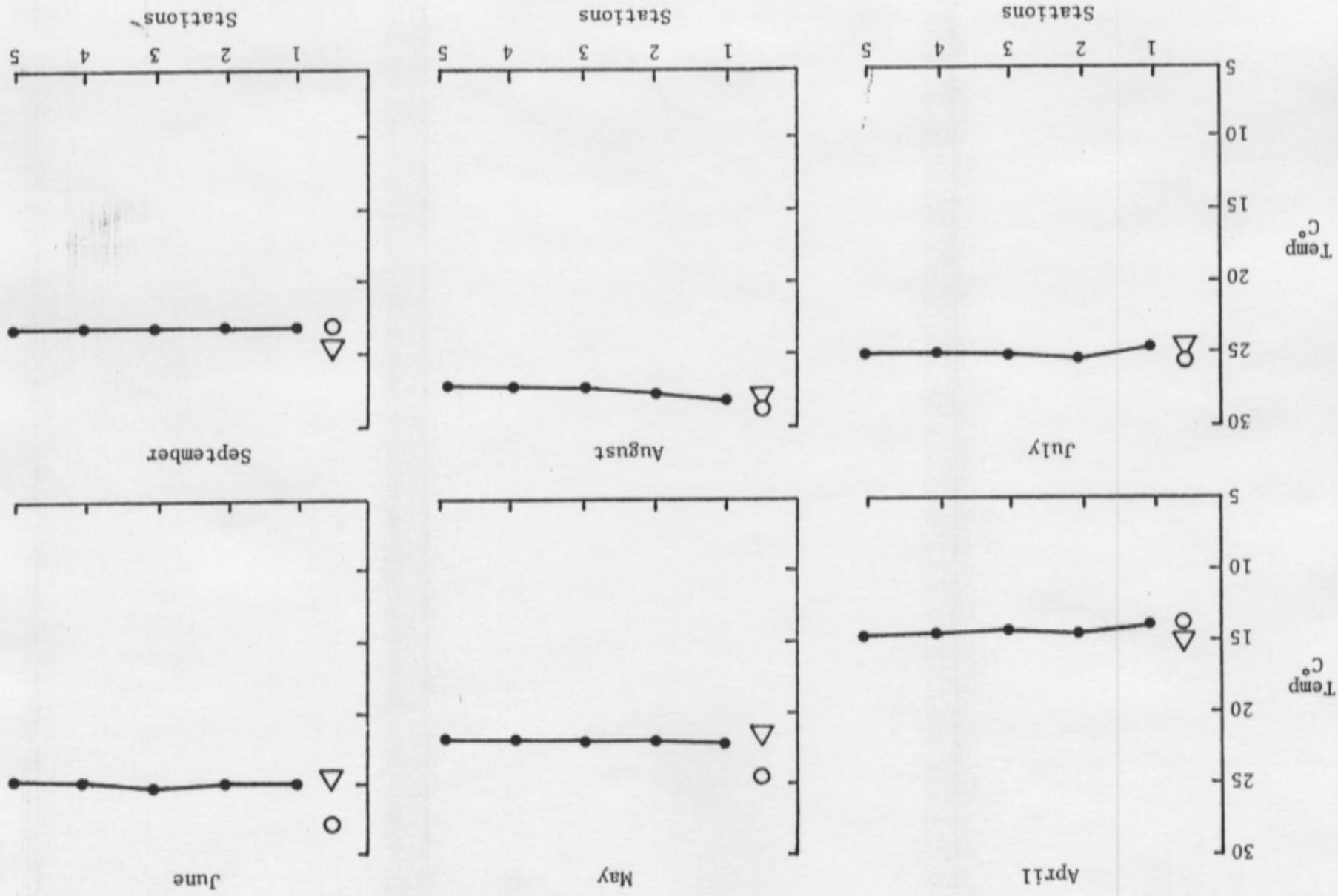


Figure 2. Approximate locations of the sampling sites at the U. S. Army Corps of Engineers Craney Island Disposal area, Port of Hampton Roads, Virginia. No. 1, middle, and No. 3 are spillways, while NE Open was located approximately 100 m from the levee. Samples were also collected at the dredge material rehandling basin. The other positions designate dredge discharge locations. Station 8 represents a location of monthly collection by the Institute of Oceanography, ODU, for the Hampton Roads Sanitation District Commission during the period from January 1974

Figure 3a. Temperature in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.





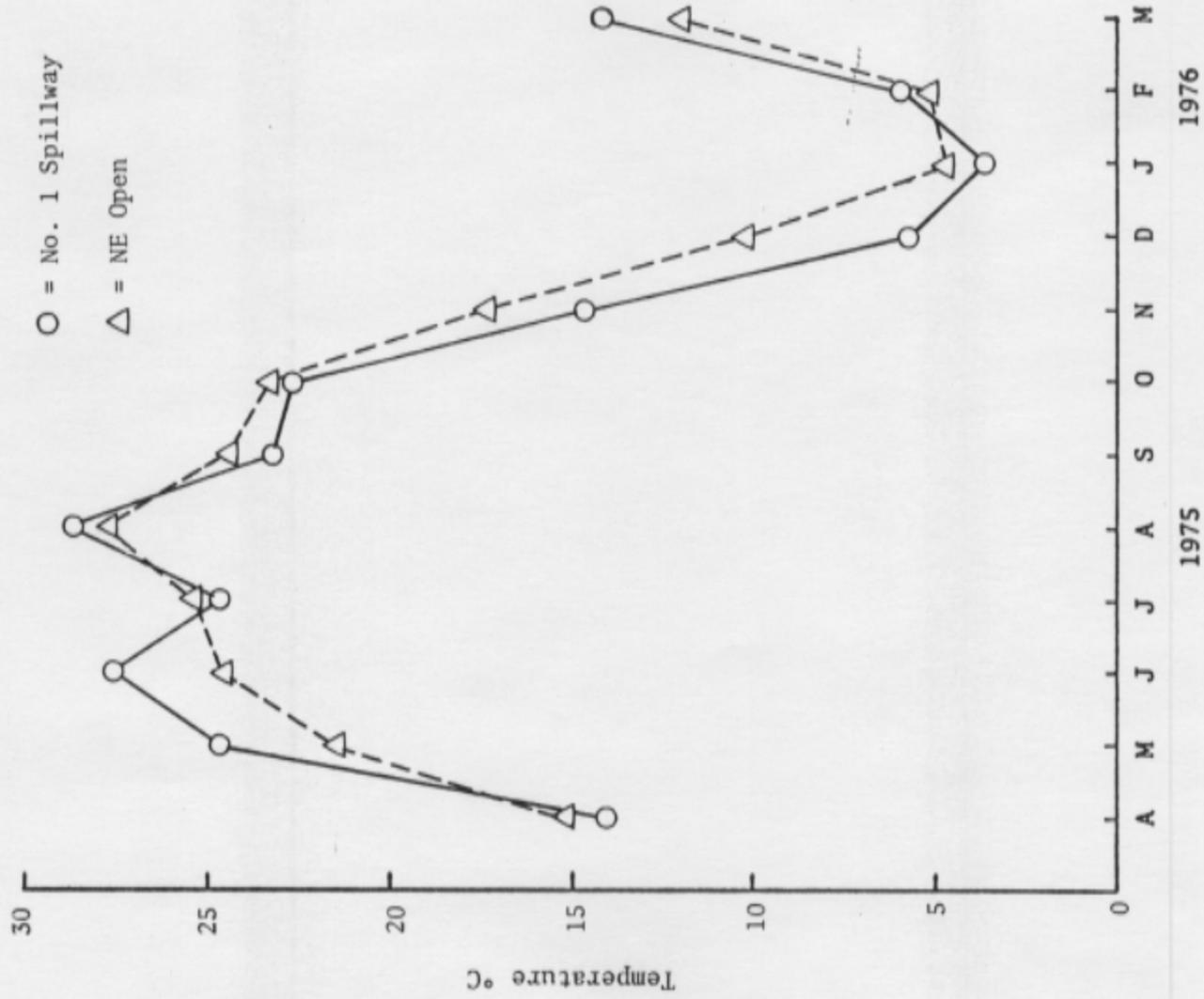


Figure 3c. Temperature in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 4a. Salinity in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

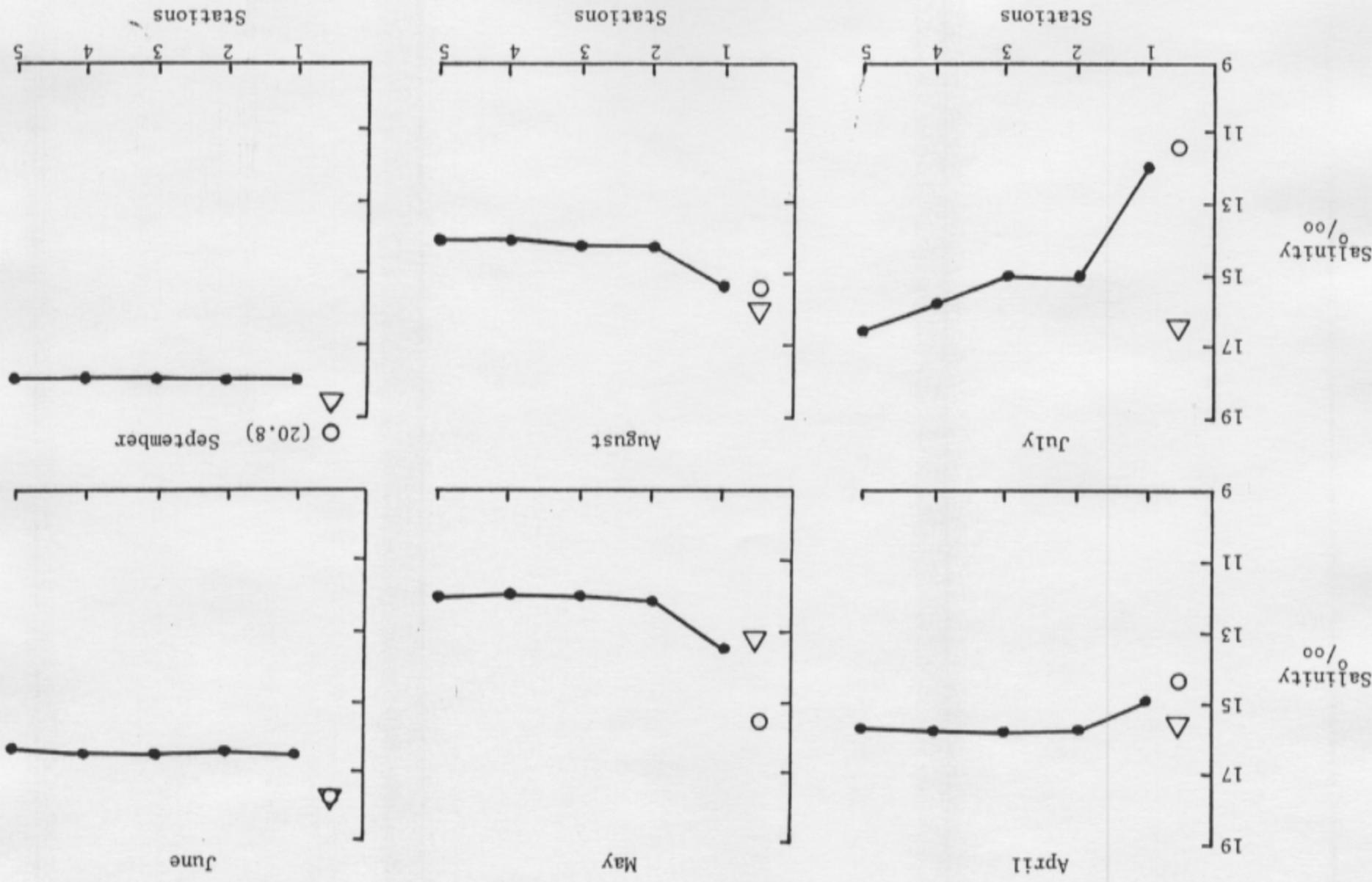
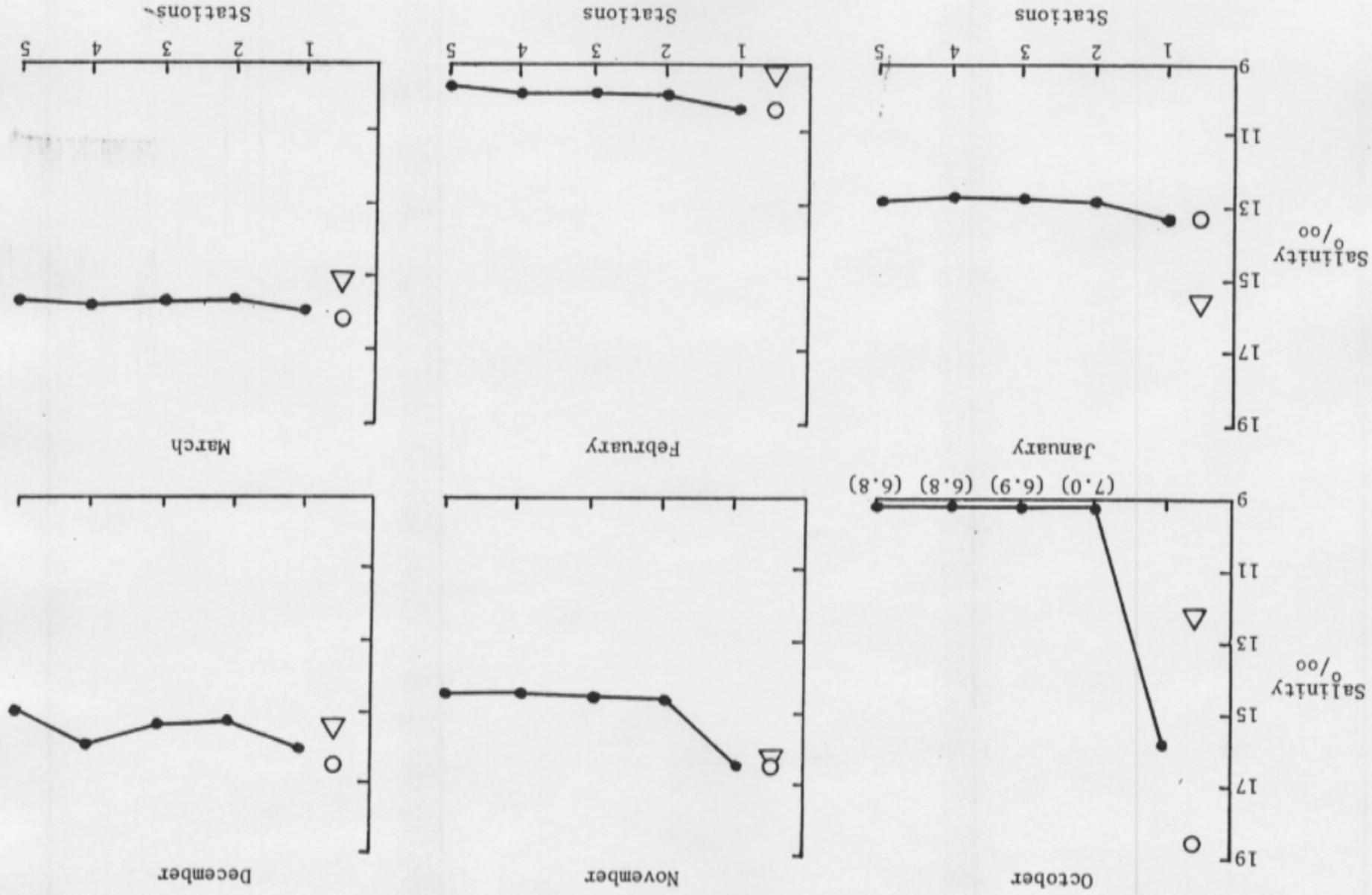


Figure 4b. Salinity in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



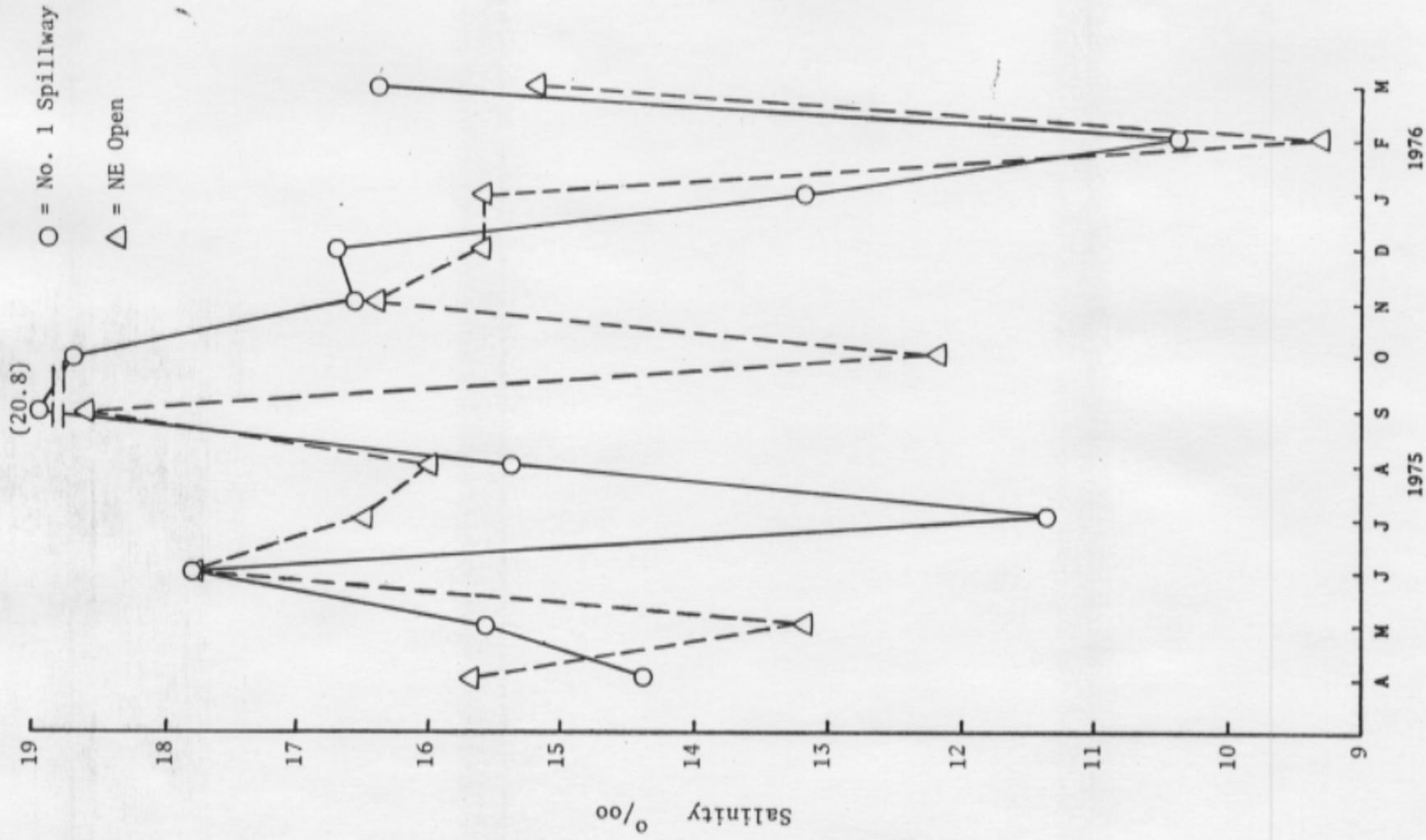


Figure 4c. Salinity in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to Marcy 1976).

Figure 5a. pH in the surface waters at the No. 1 Spillway (O) and NE Open water (Δ) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

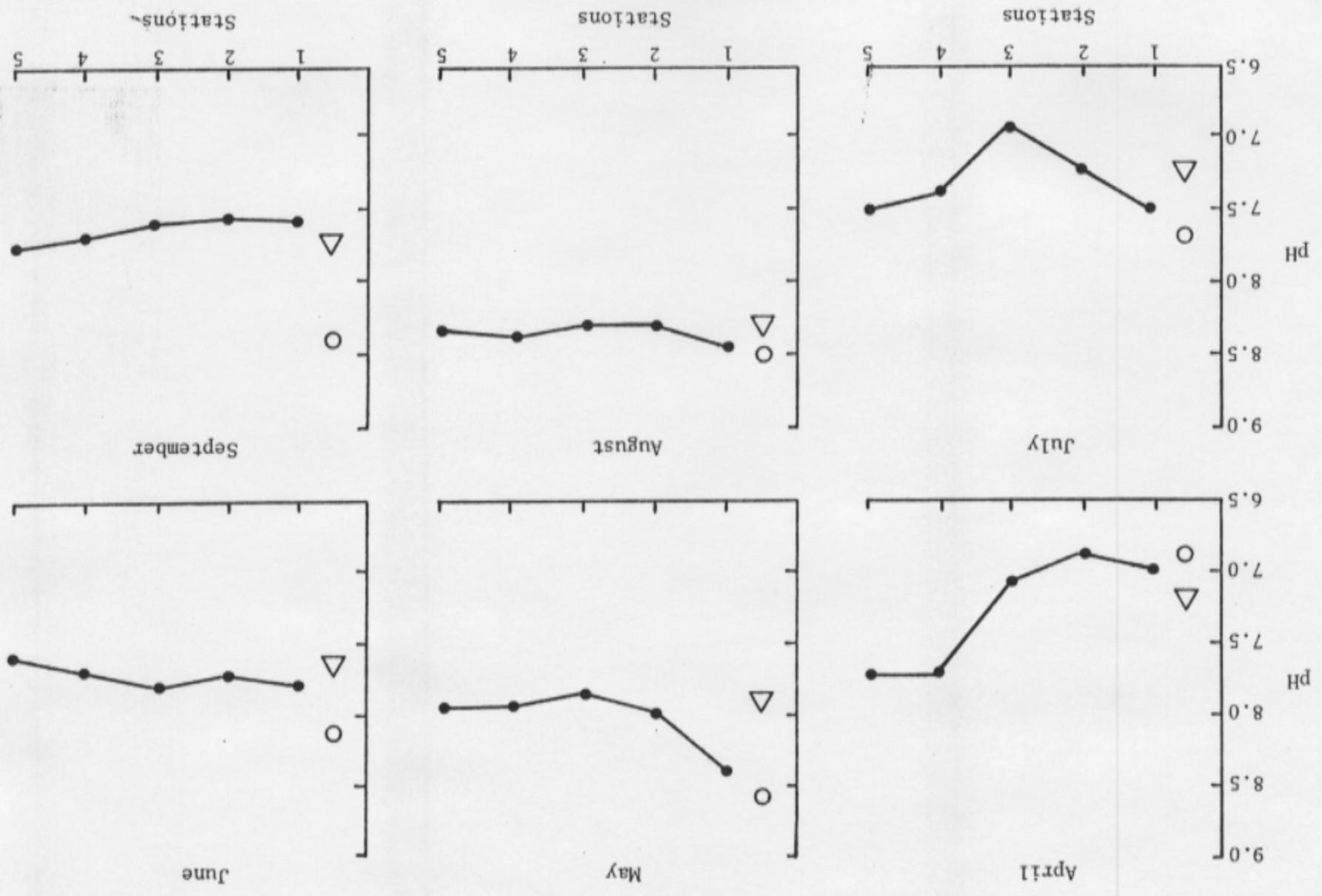
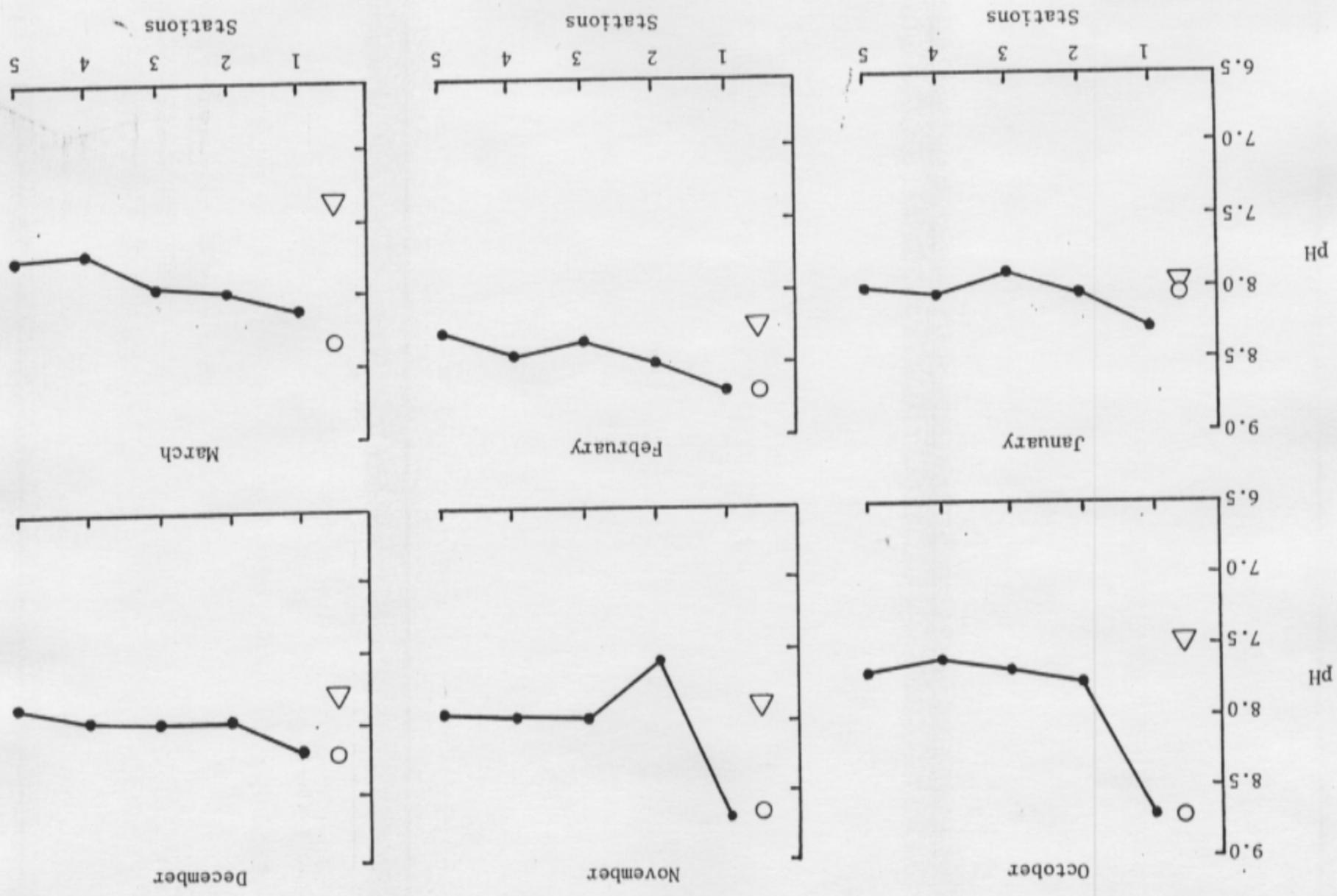


Figure 5b. pH in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



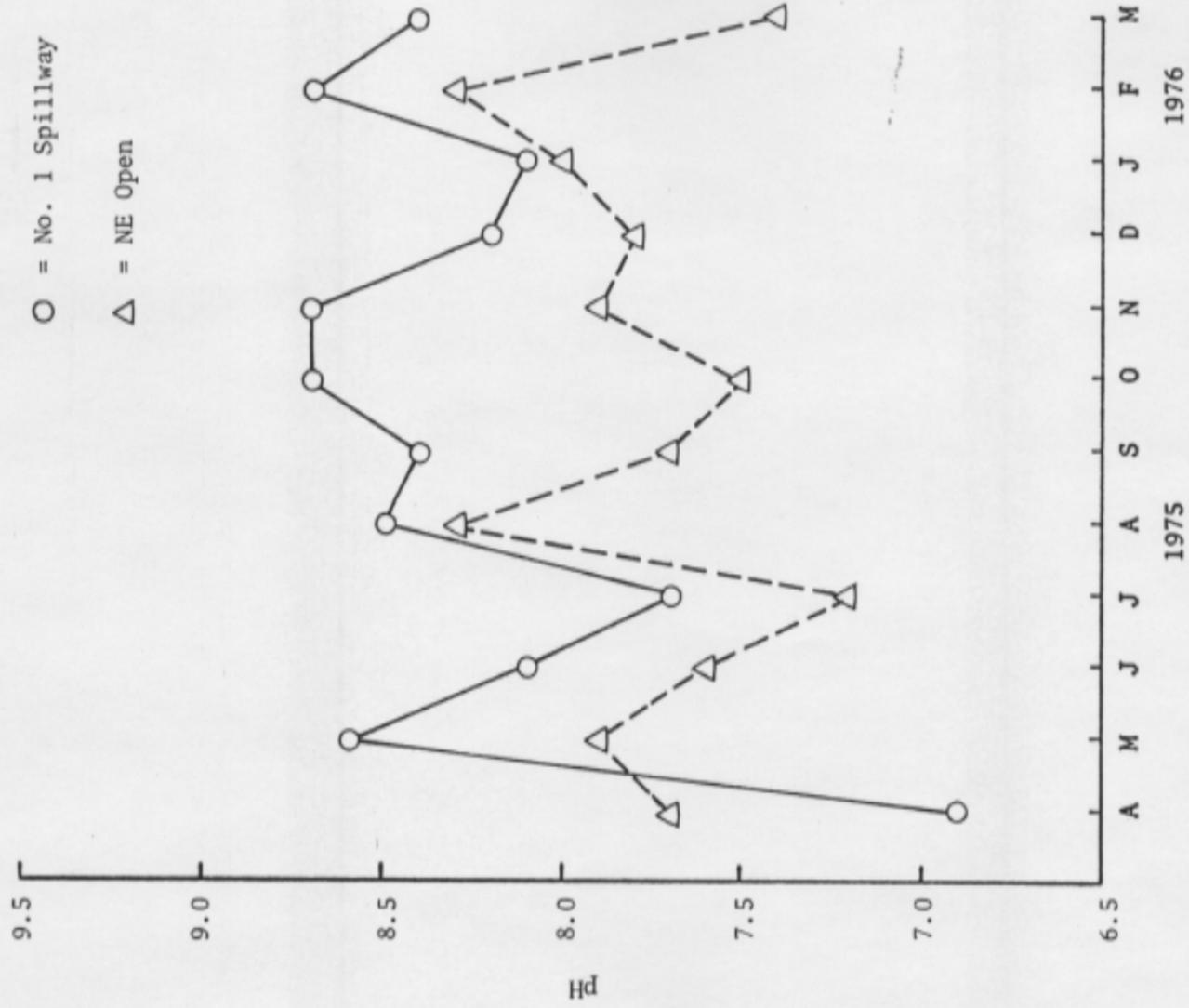


Figure 5c. pH in the surface waters at the No. 1 Spillway and NE Open water sites at Cranney Island (April 1975 to March 1976).

Figure 6a. Dissolved oxygen in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Crane Island Disposal Area, Port of Hampton Roads, Virginia.

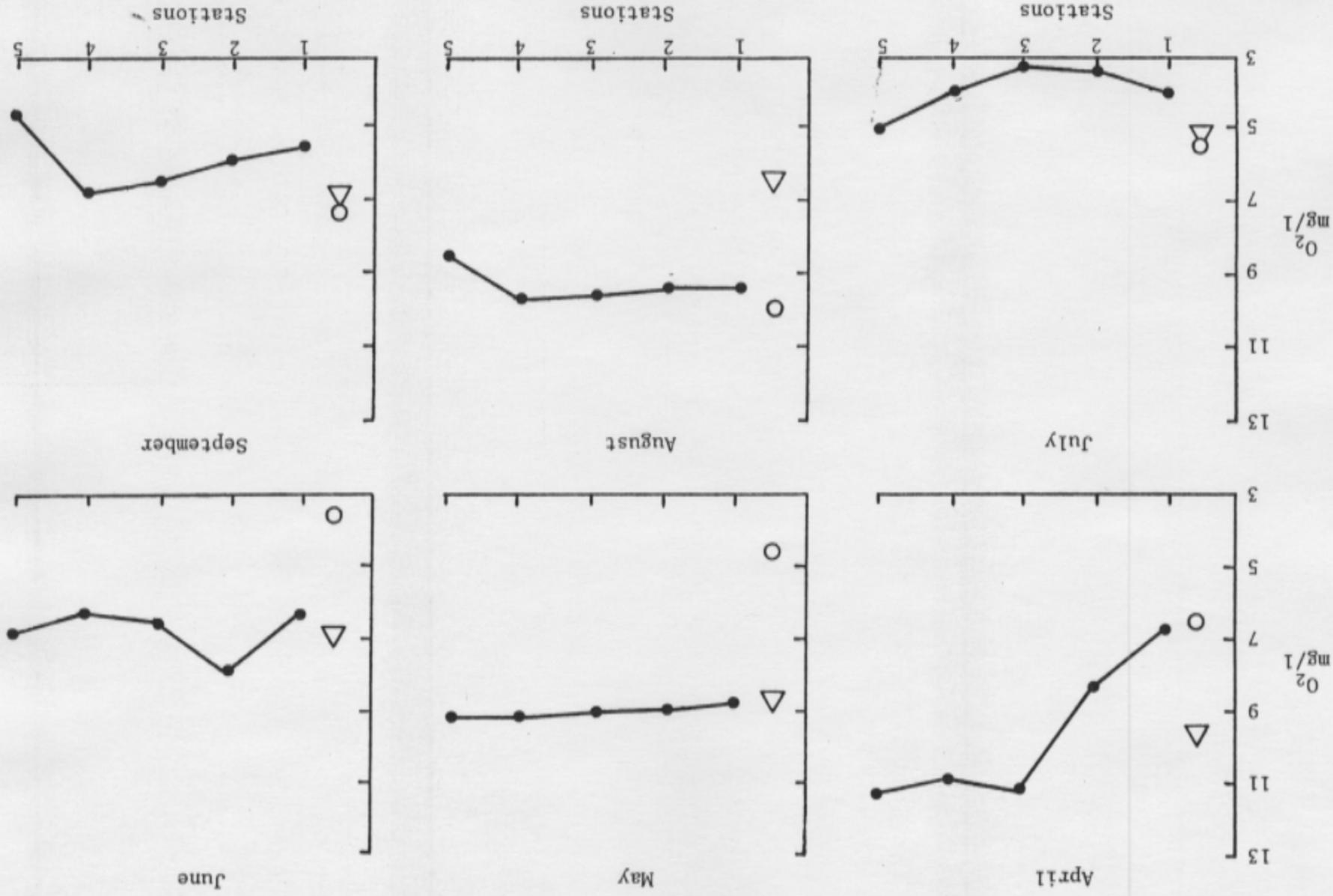
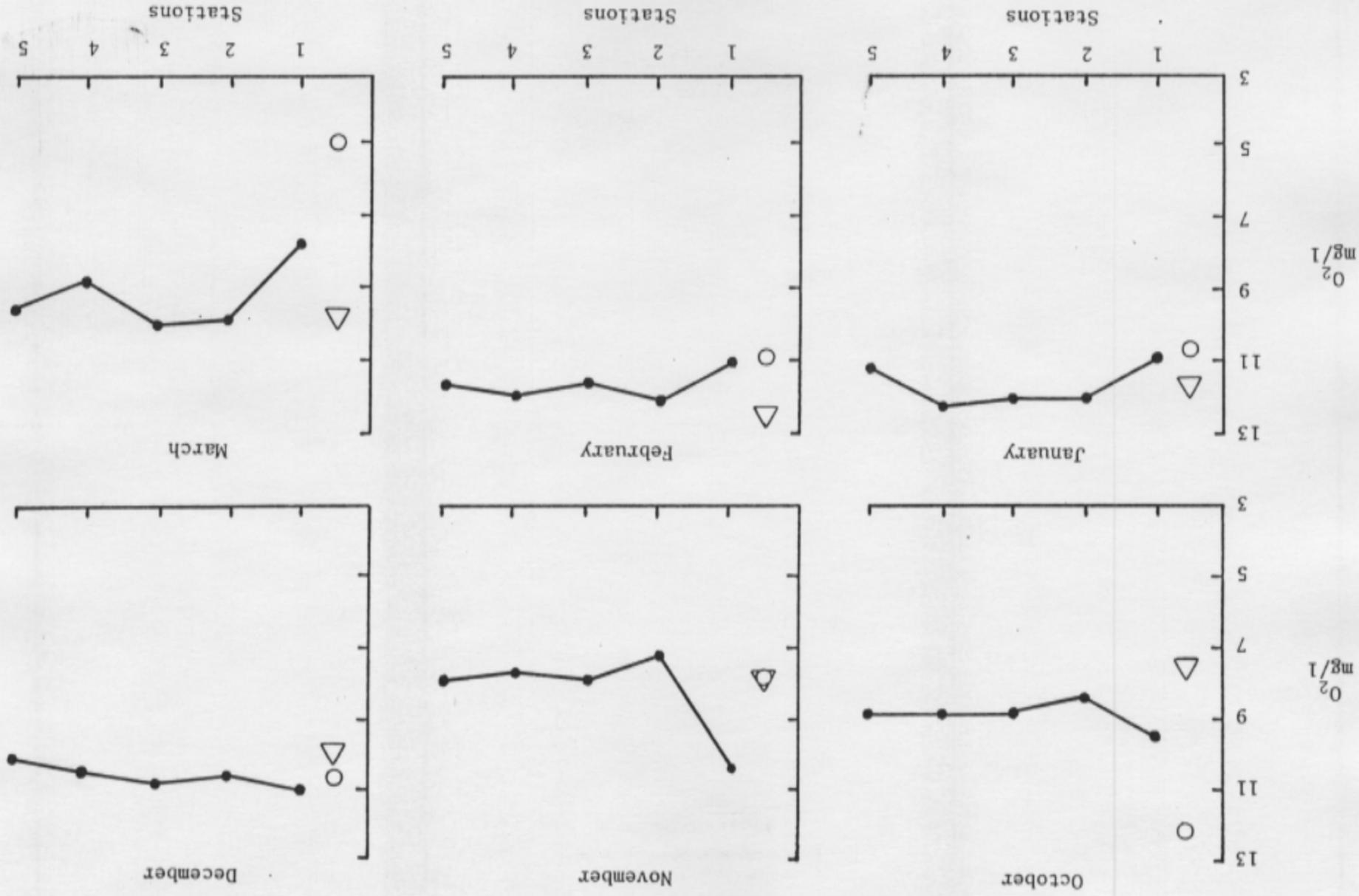


Figure 6b. Dissolved oxygen in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



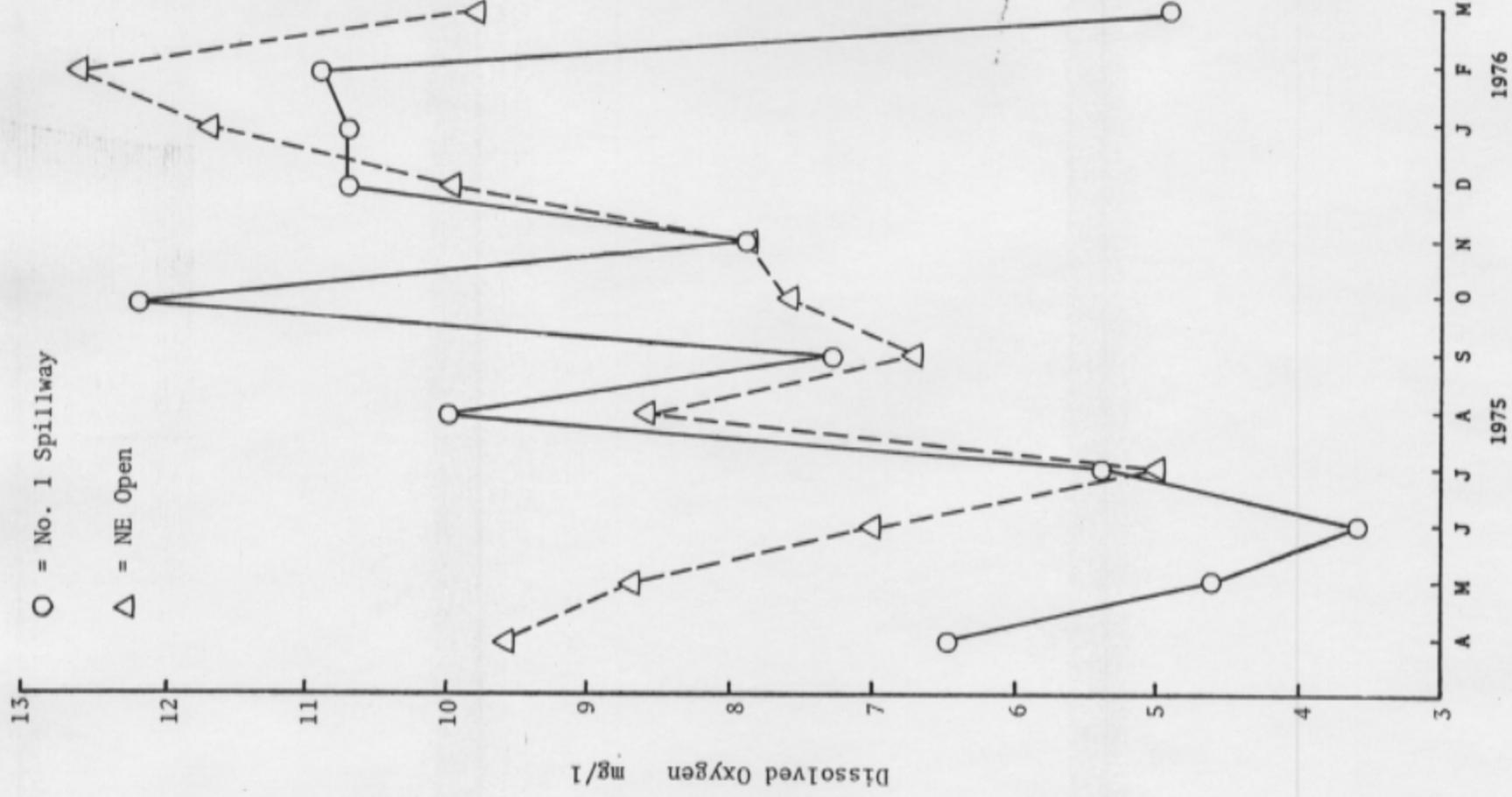


Figure 6c. Dissolved oxygen in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 7a. Oxygen saturation in the surface waters at the No. Spillway (O) and NE Open water (Δ) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

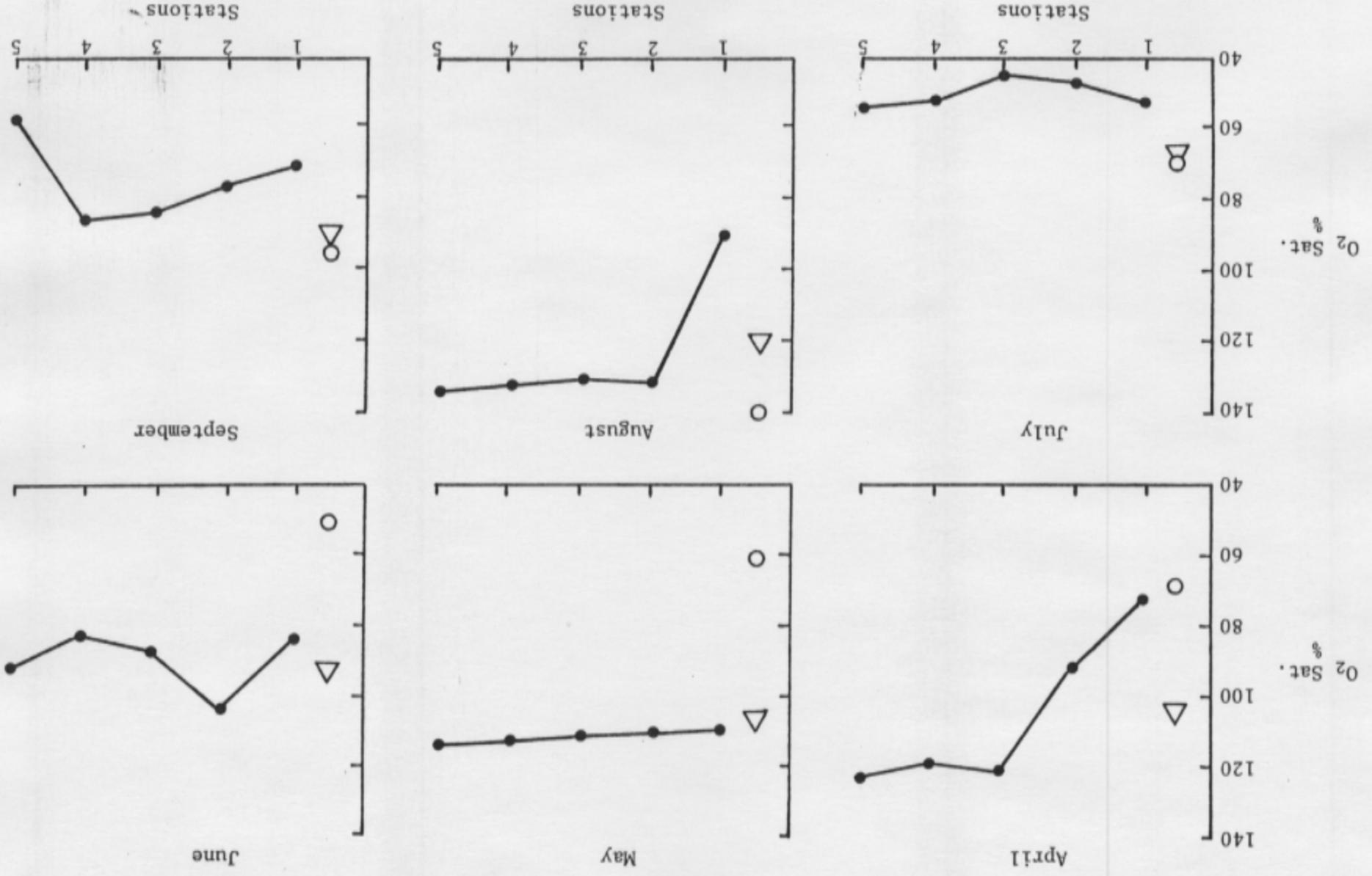
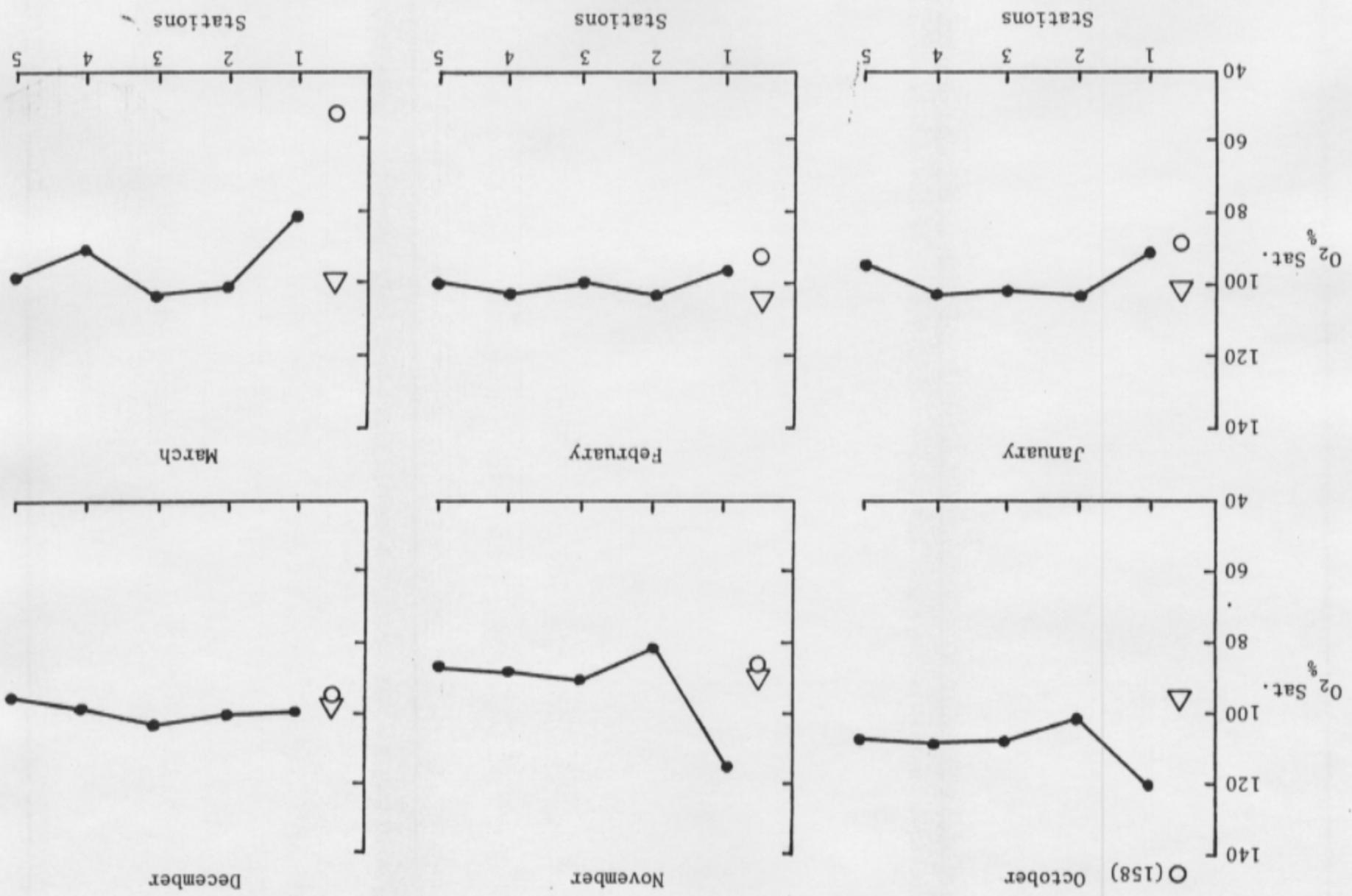


Figure 7b. Oxygen saturation in the surface waters at the No. 1 Spillway (○) and NE Open water (△) site and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



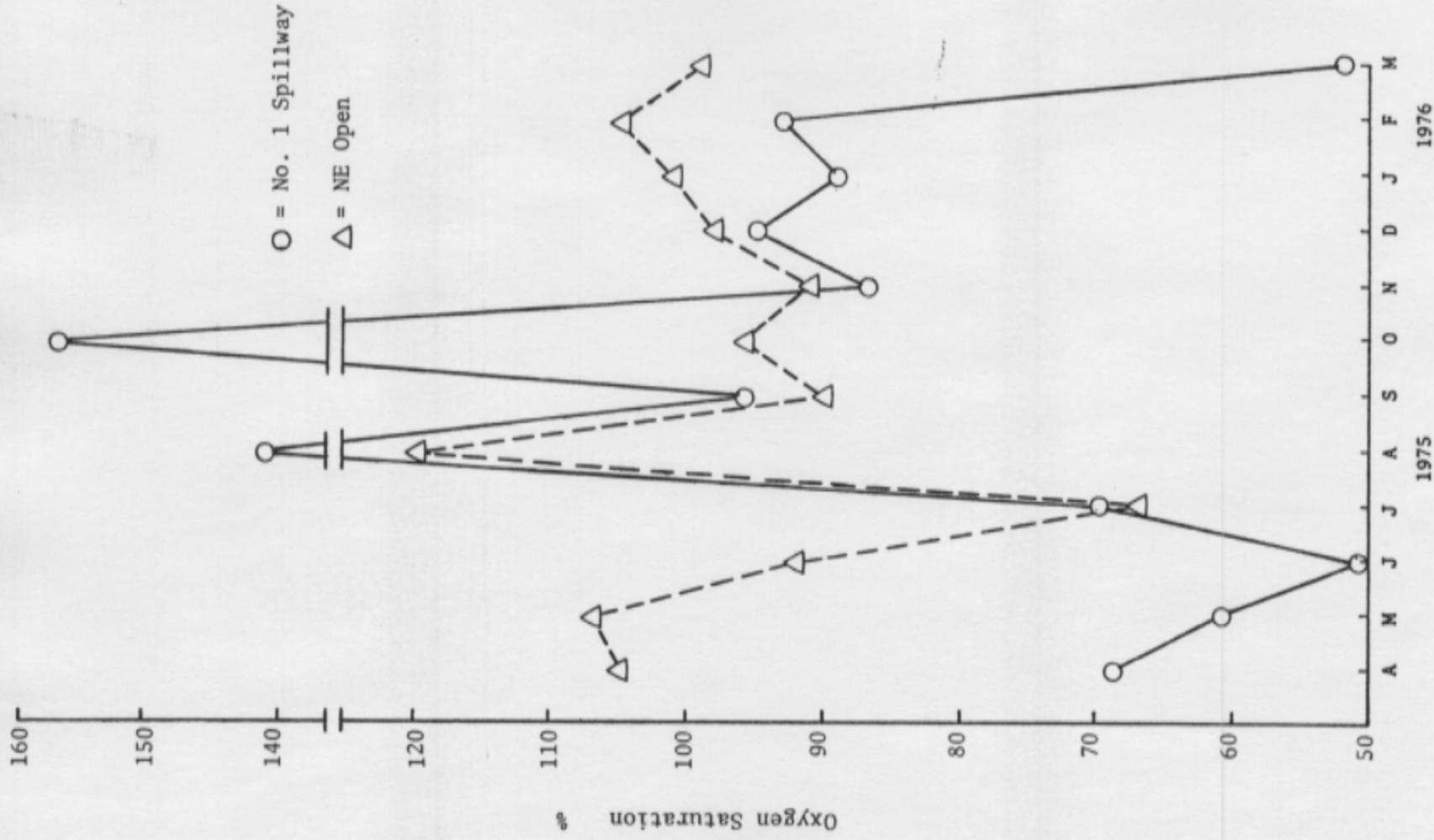


Figure 7c. Oxygen saturation in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale changes above 120 percent saturation for samples at the spillway during August and October.

Figure 8a. Fecal coliforms in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

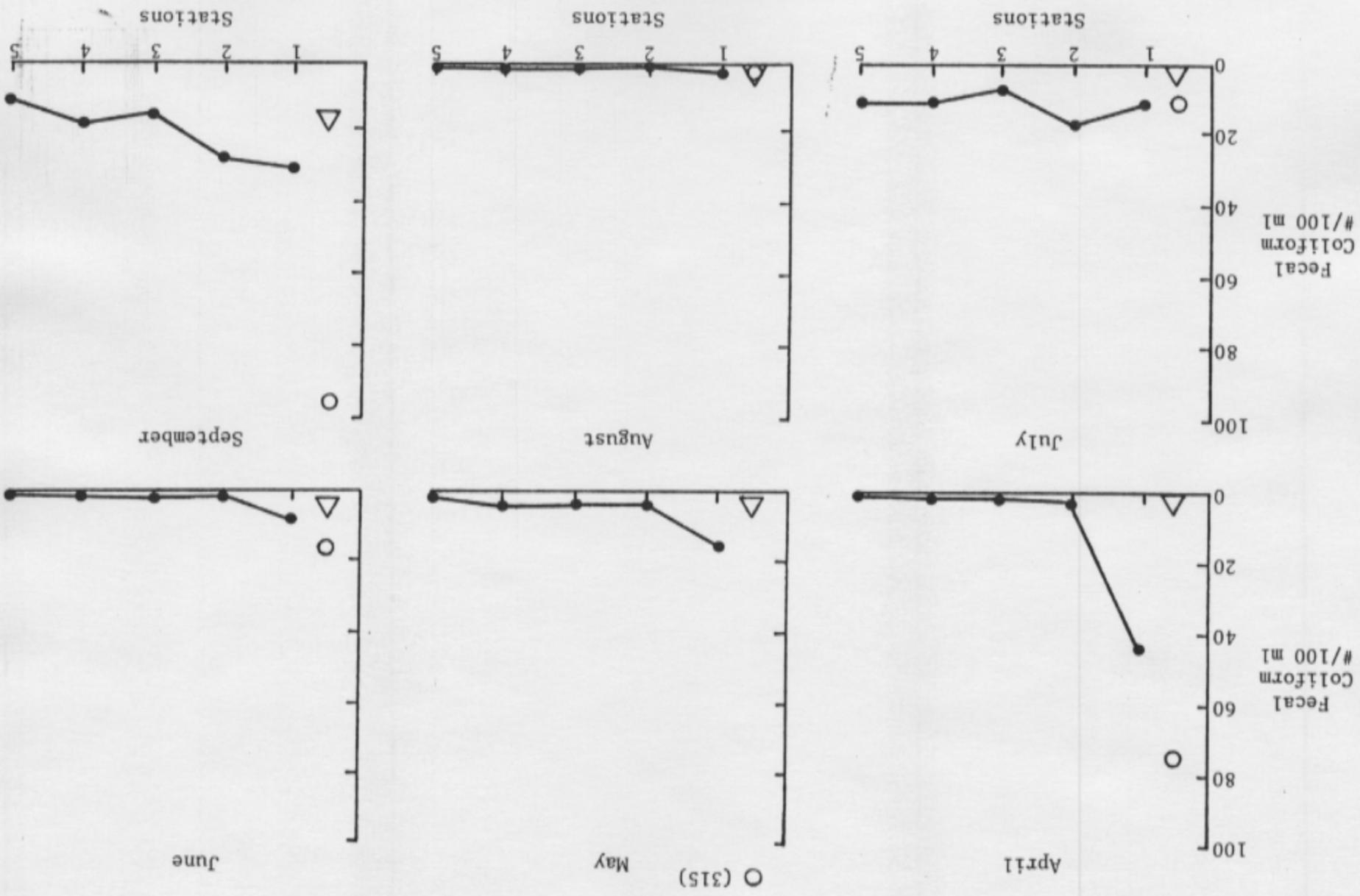
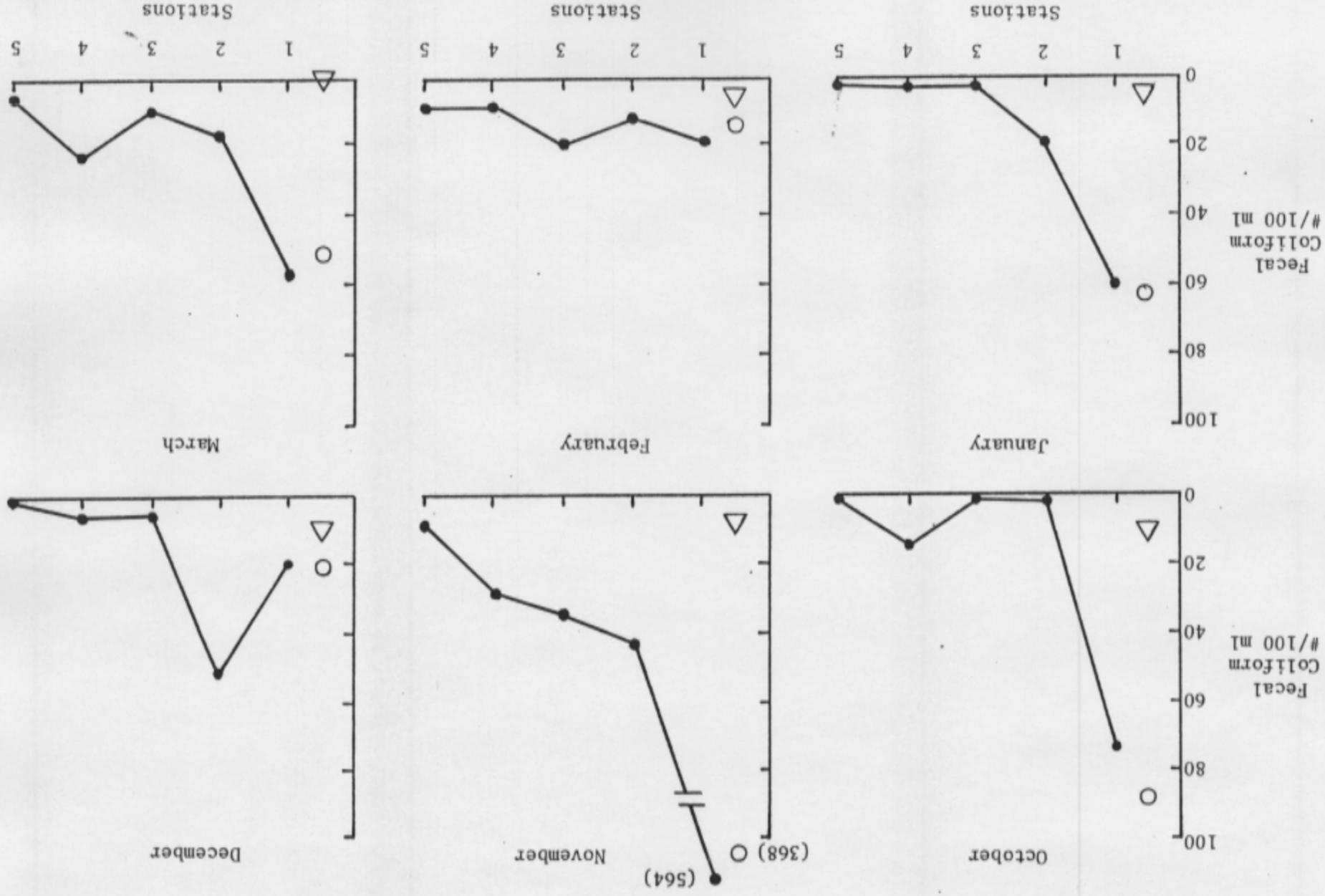


Figure 8b. Fecal coliforms in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the scale change in the plume during November 1975.



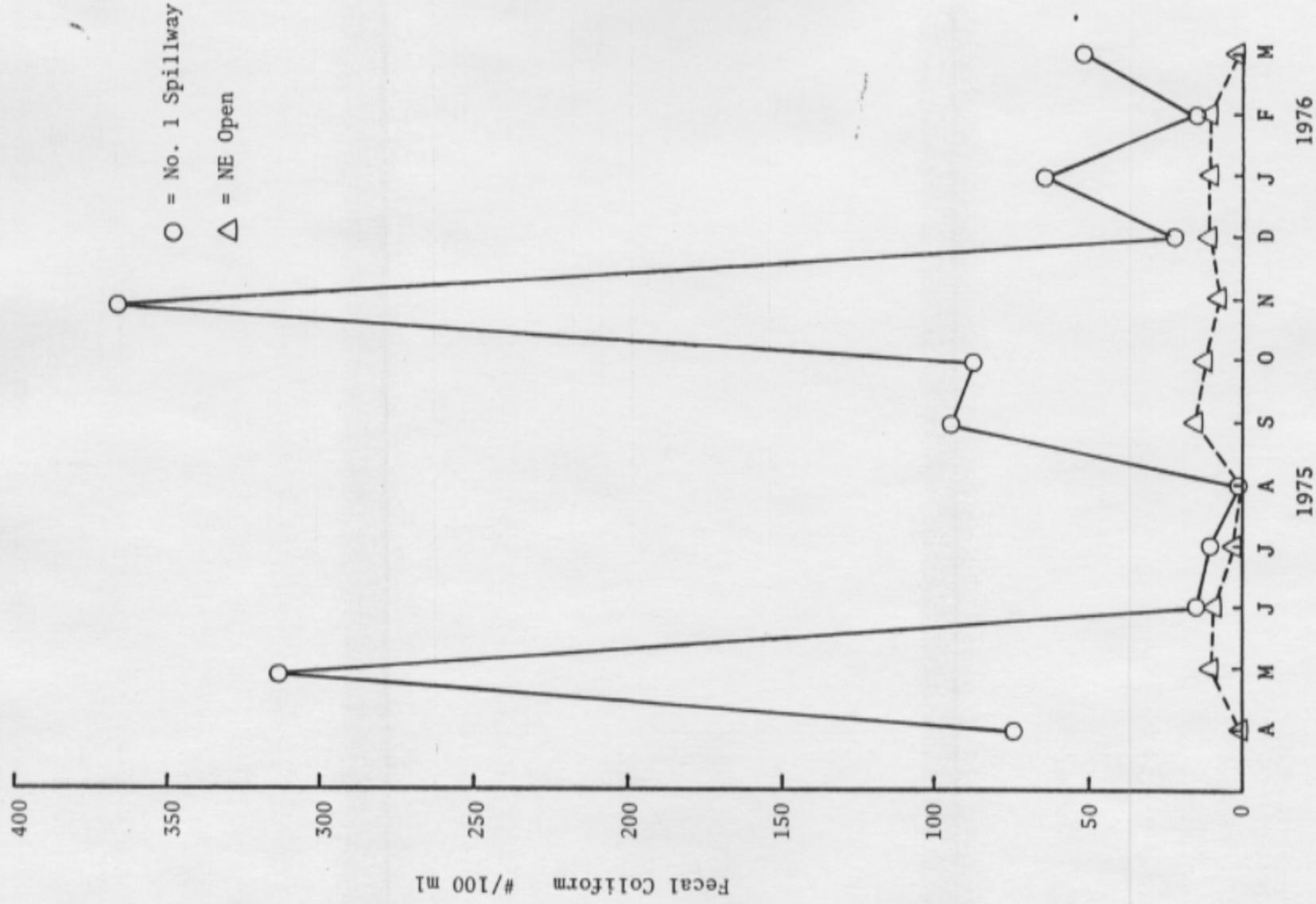


Figure 8c. Fecal coliforms in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 9a. Dissolved inorganic orthophosphate in the surface waters at the No. 1 Spillway (○) and NE Open water (▽) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the scale changes for the plume samples during July and August.

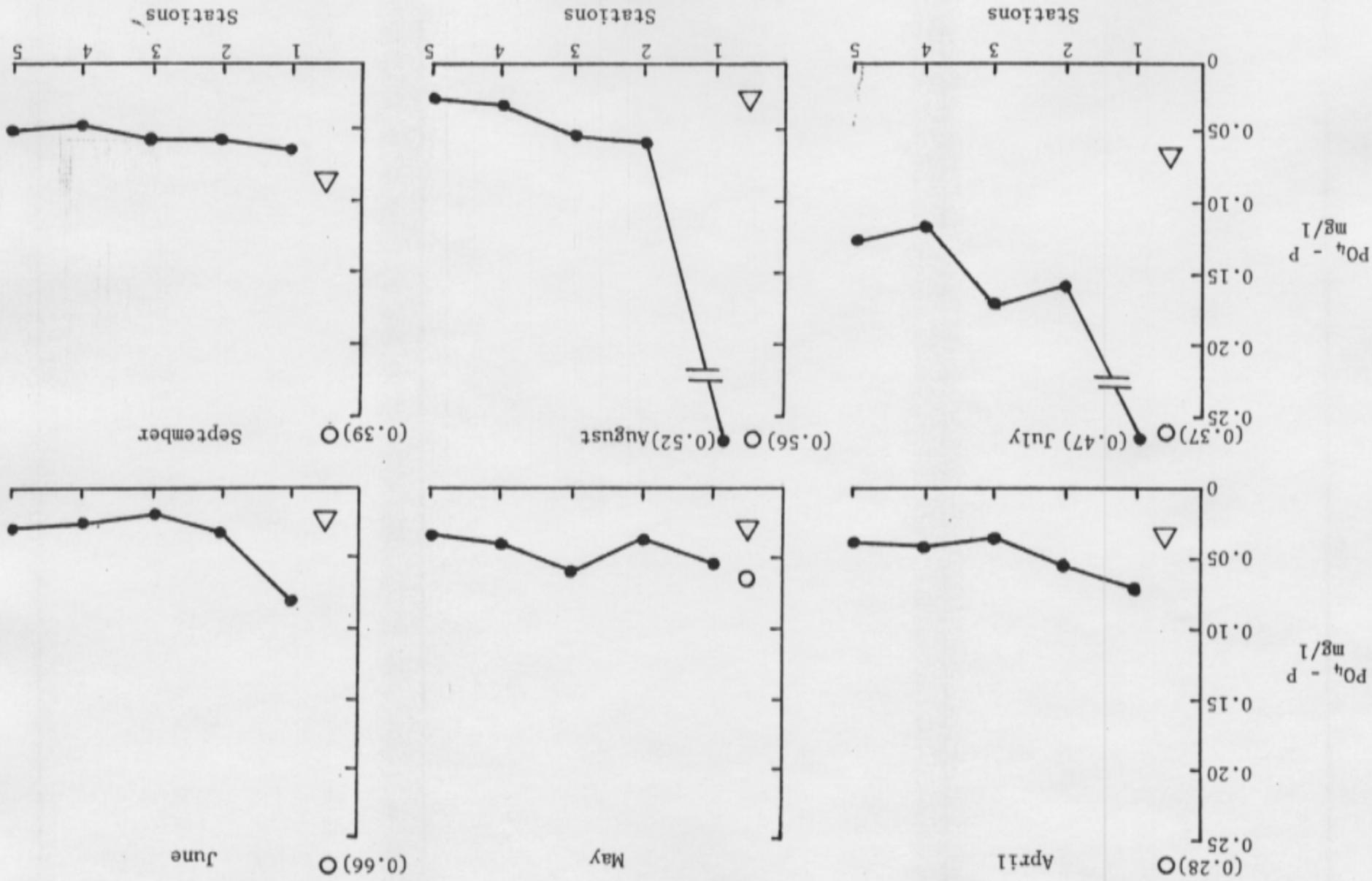
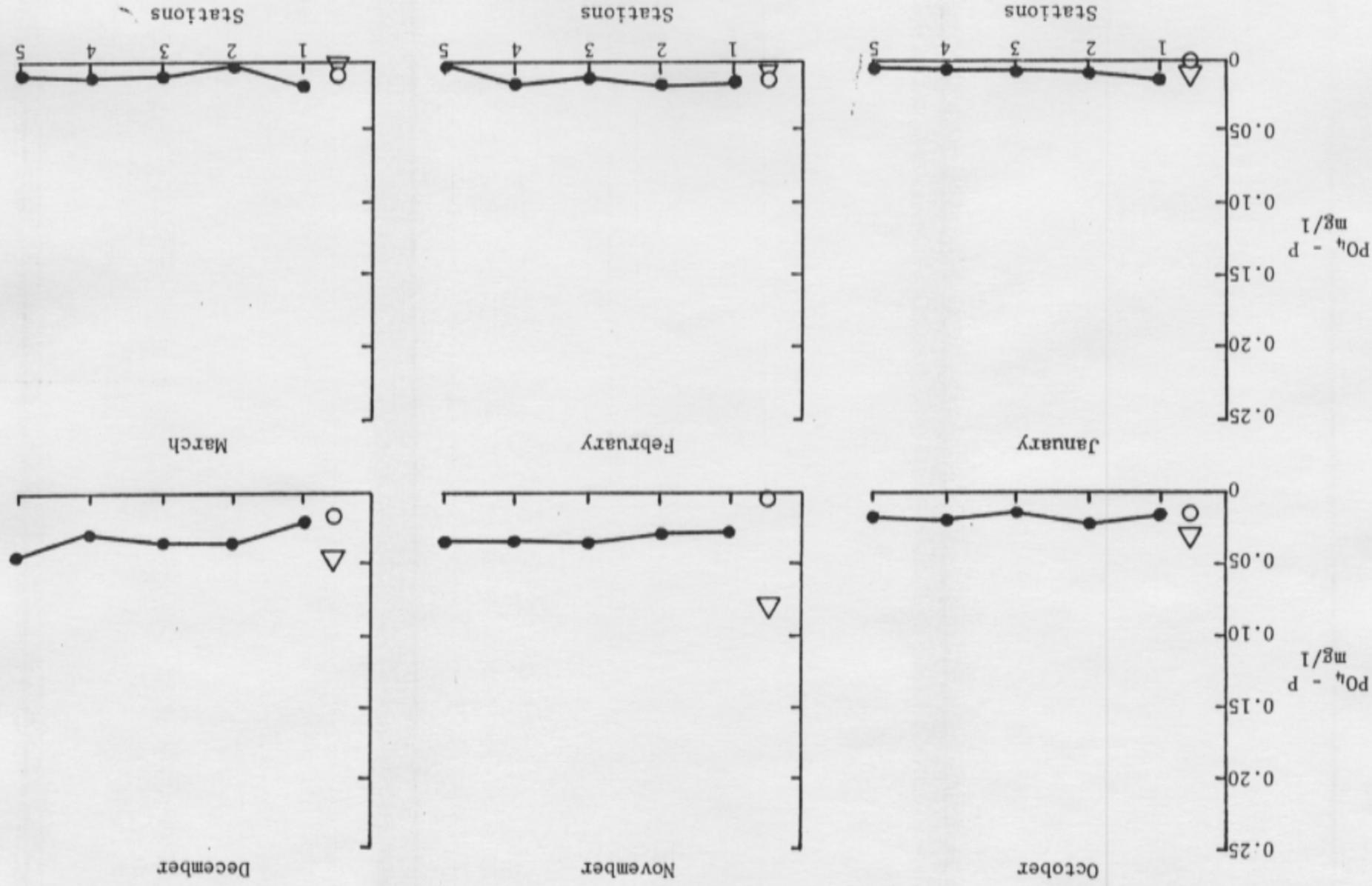


Figure 9b. Dissolved inorganic orthophosphate in the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



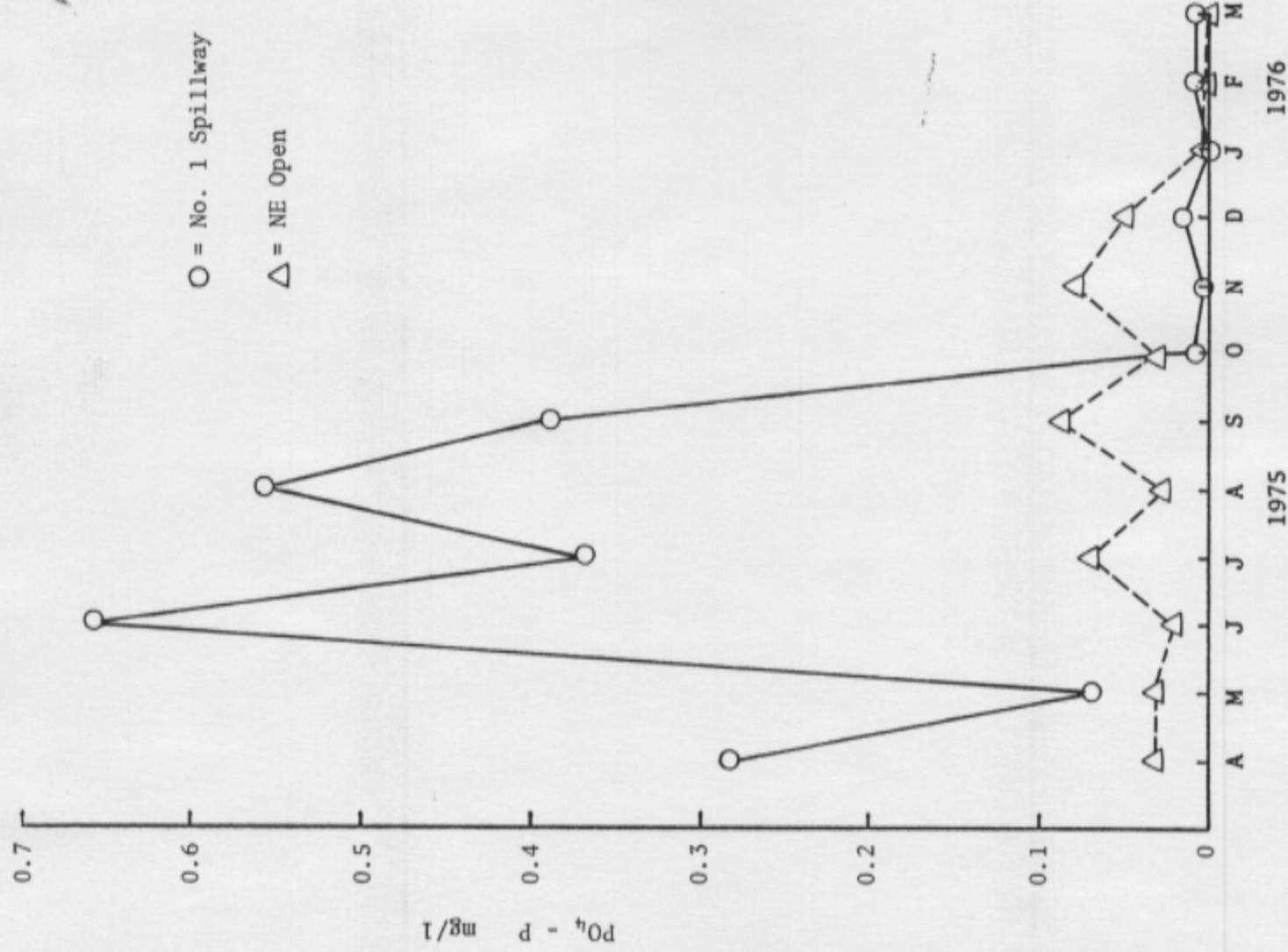


Figure 9c. Dissolved inorganic orthophosphate in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 10a. Total phosphorus in the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

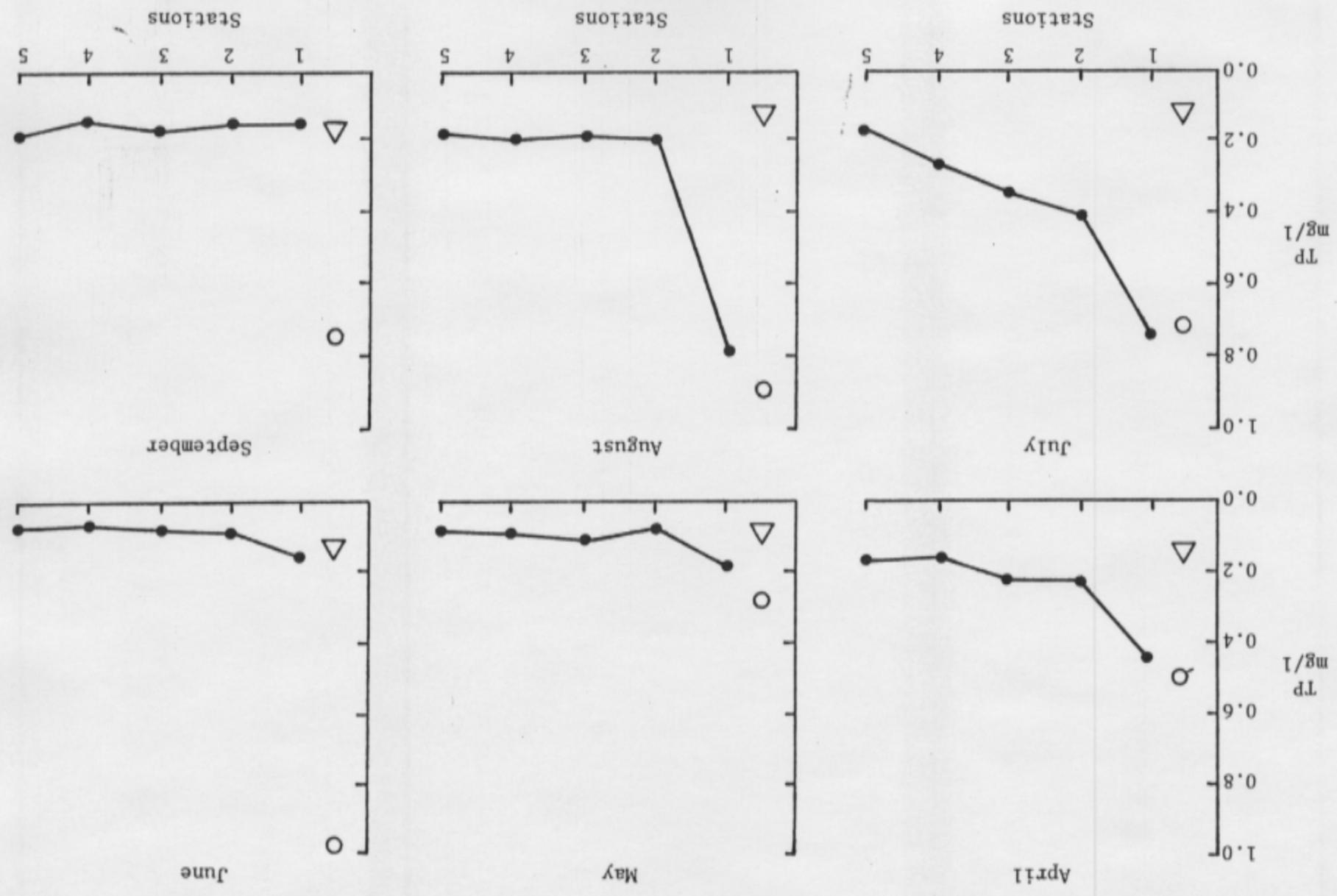
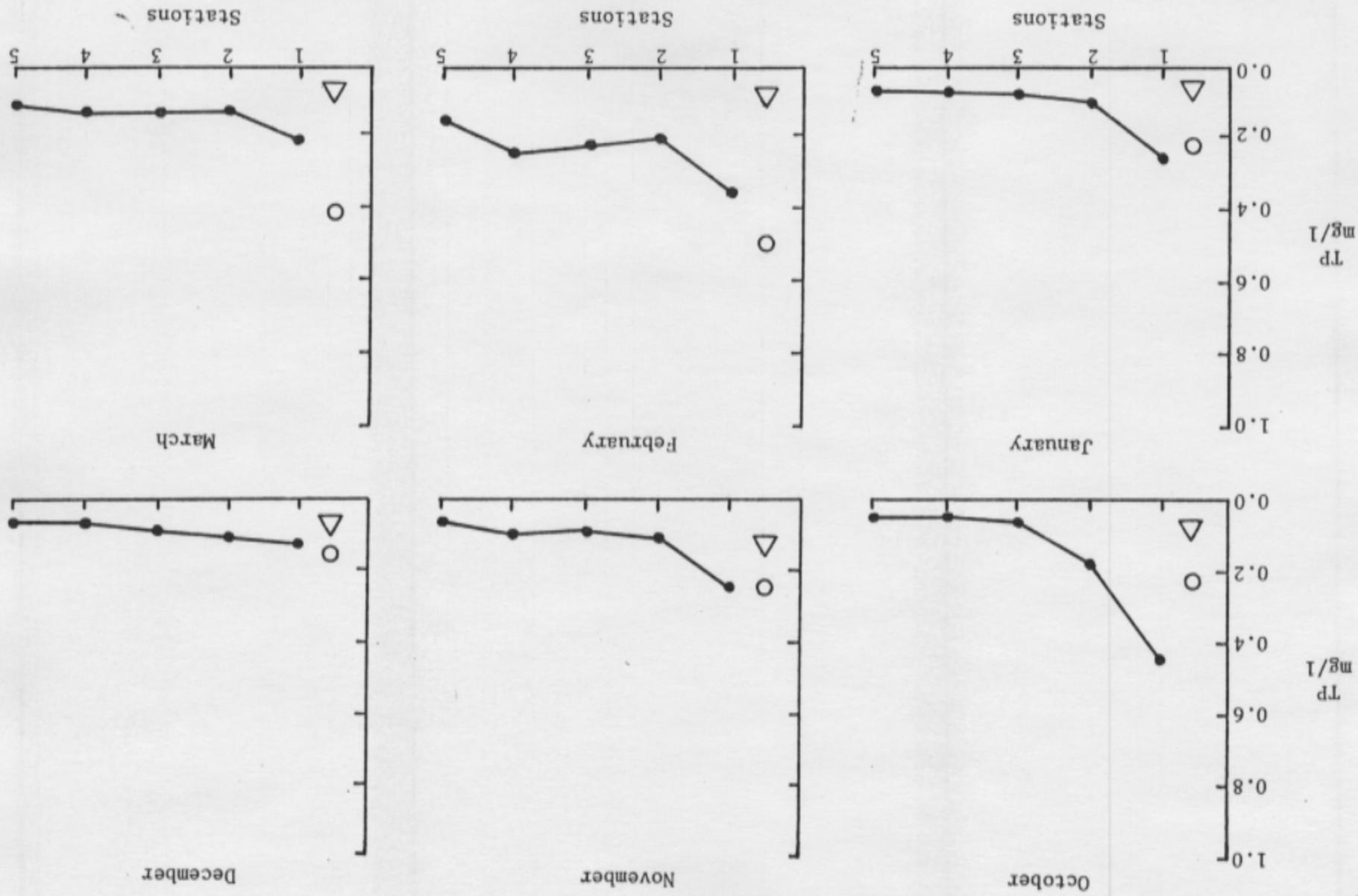


Figure 10b. Total phosphorus in the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



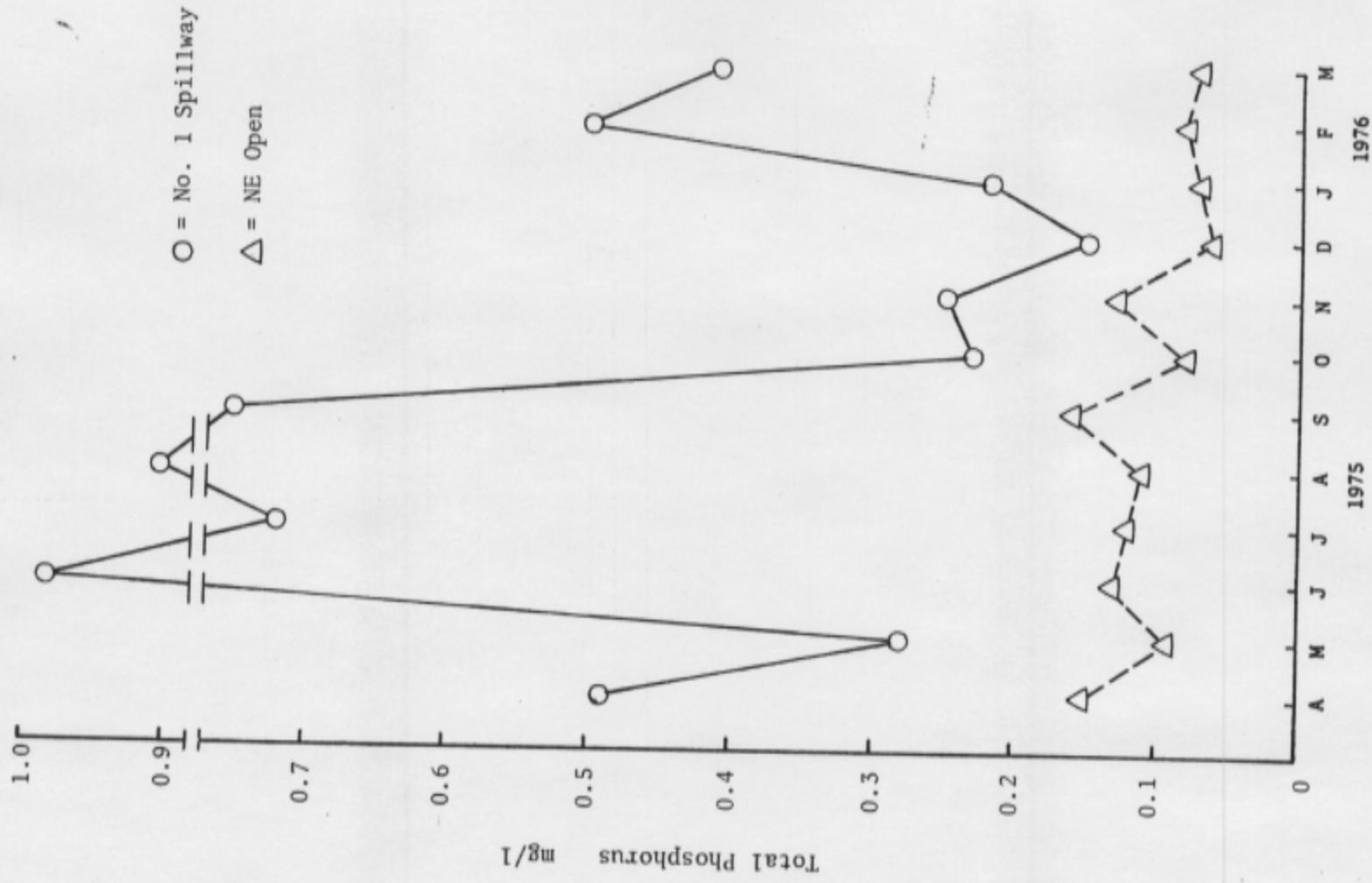


Figure 10c. Total phosphorus in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale changes above 0.7 mg/liter for spillway samples during June and August.

Figure 11a. Dissolved nitrate in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Crane Island Disposal Area, Port of Hampton Roads, Virginia.

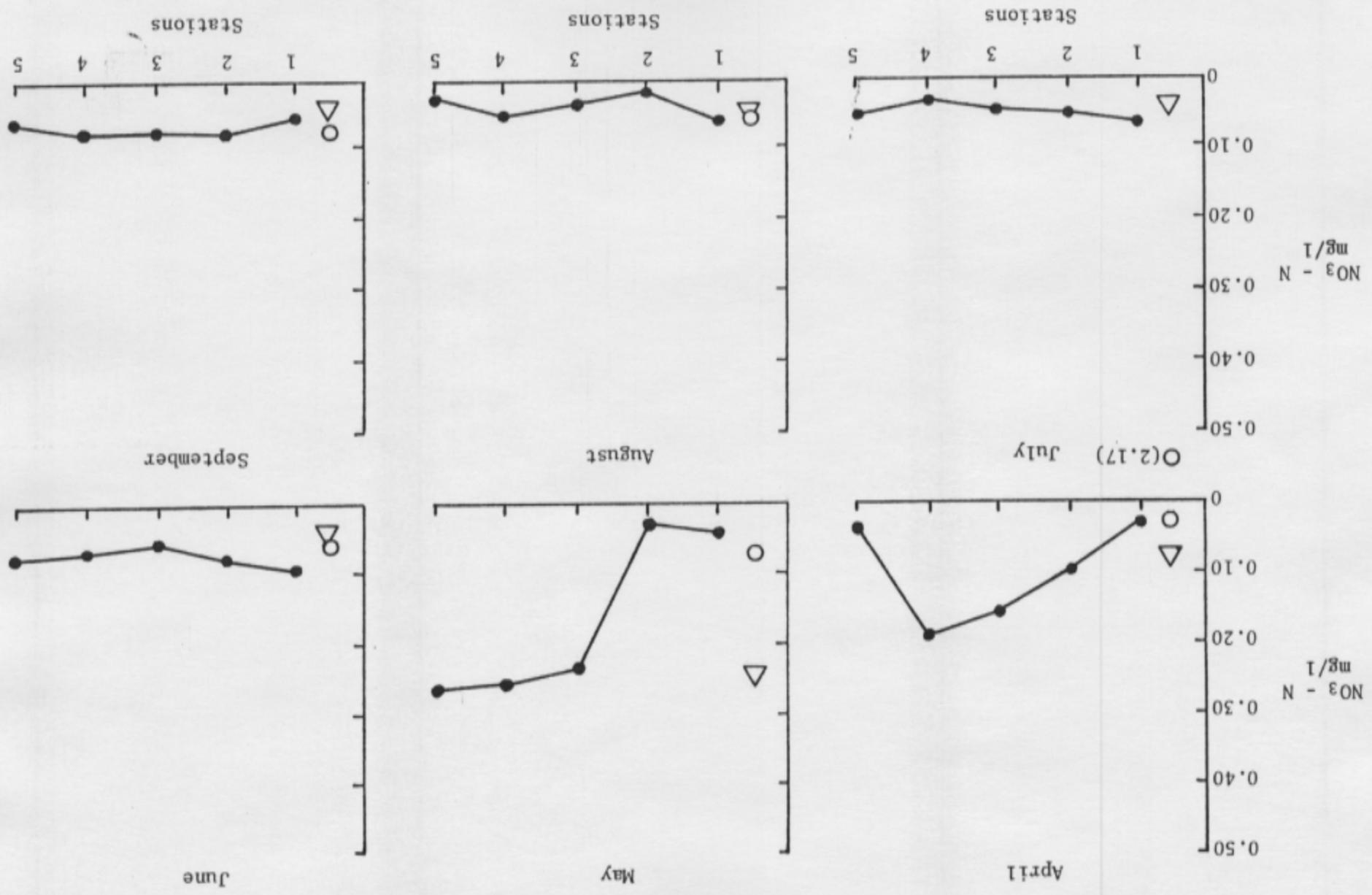
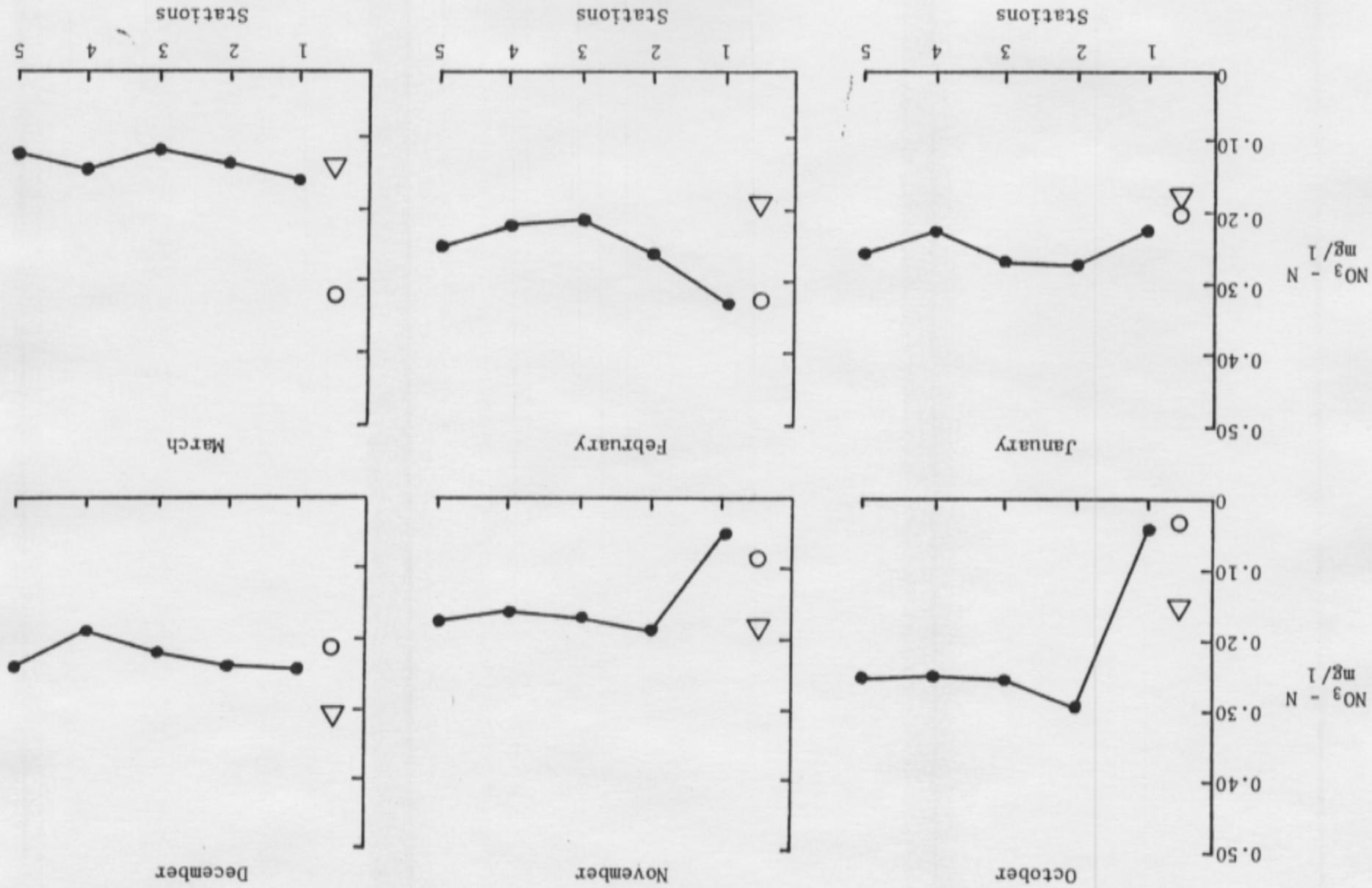


Figure 11b. Dissolved nitrate in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



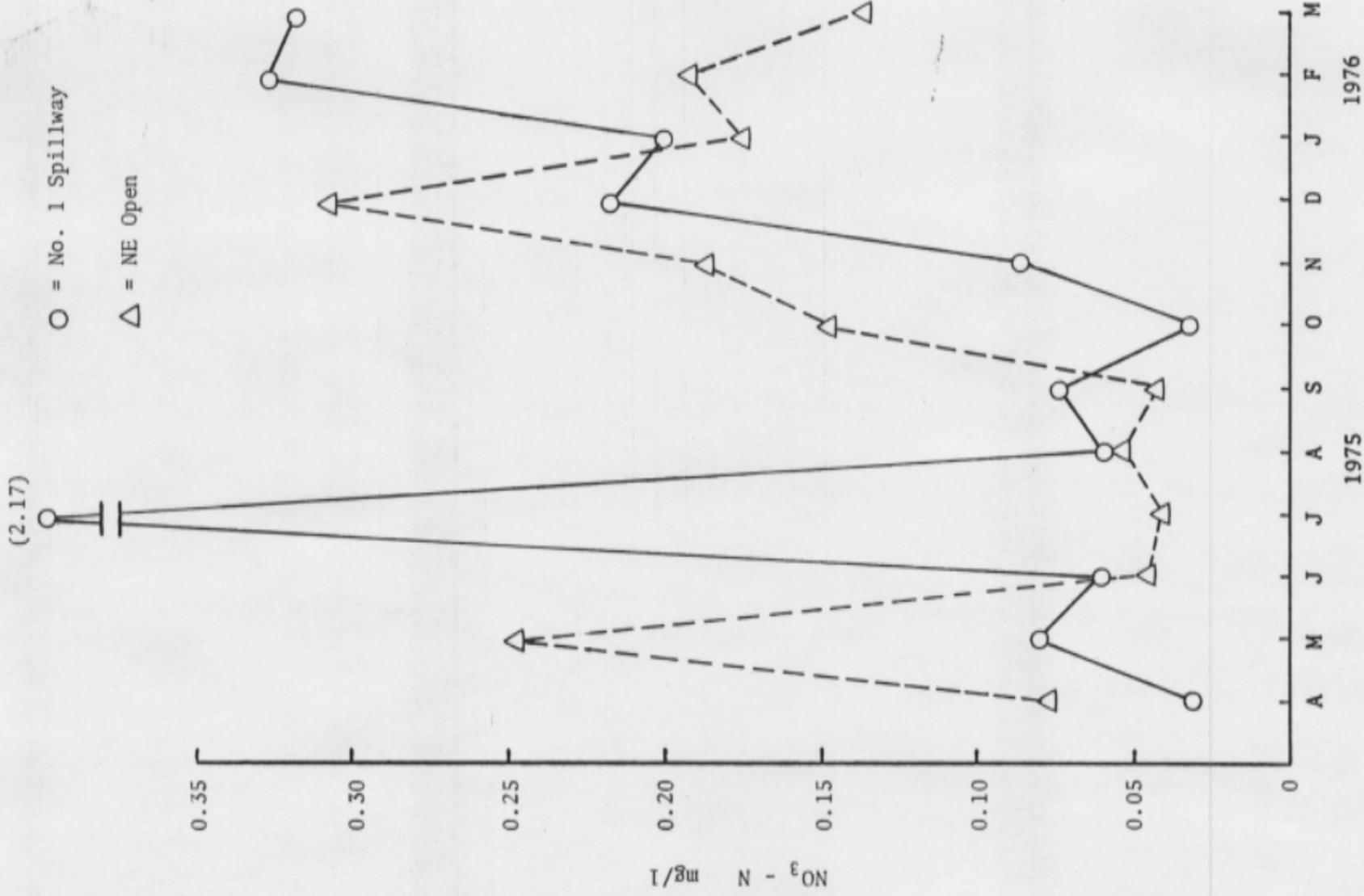


Figure 11c. Dissolved nitrate in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale change for the July spillway sample.

Figure 12a. Dissolved nitrite in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

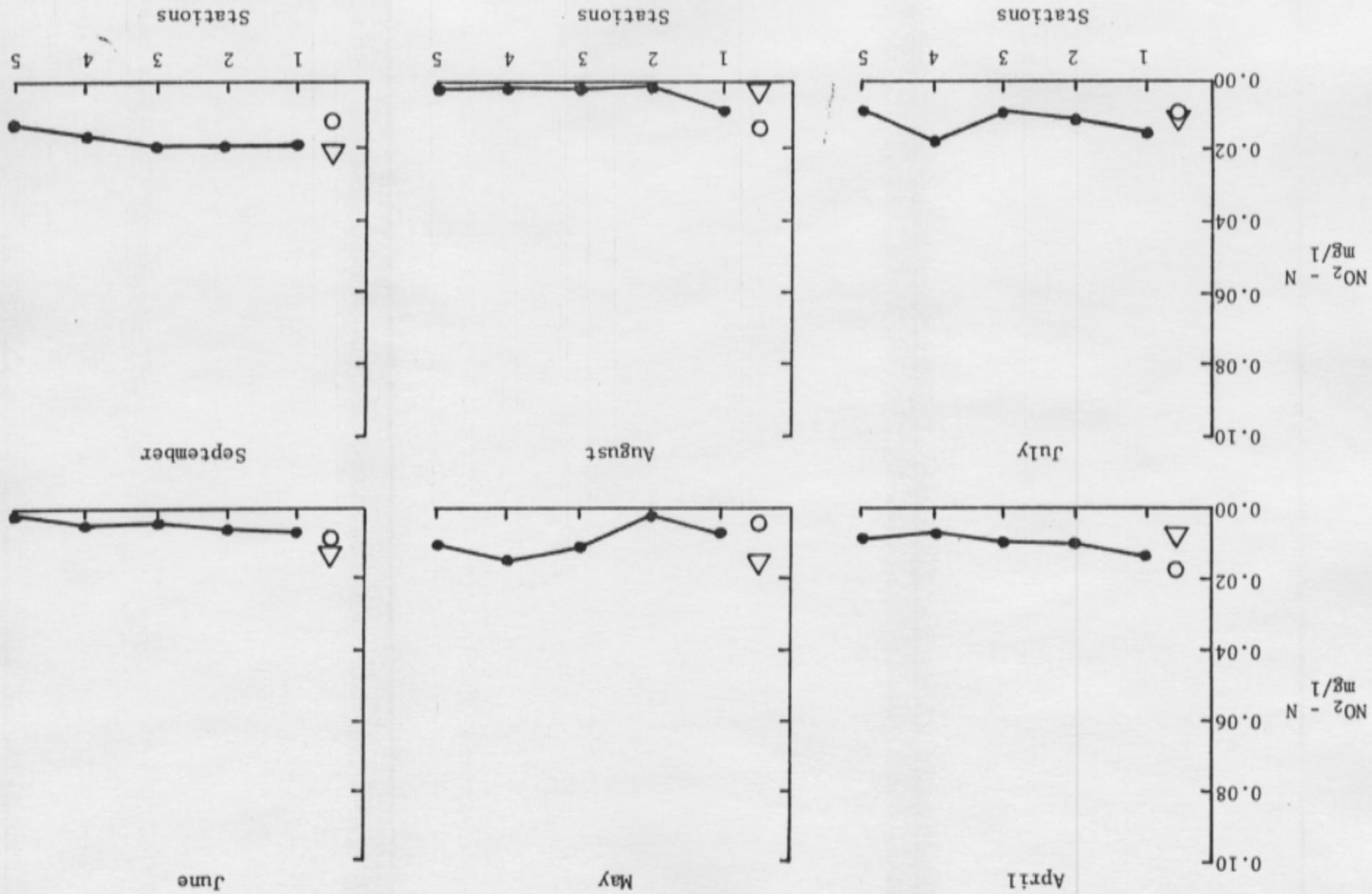
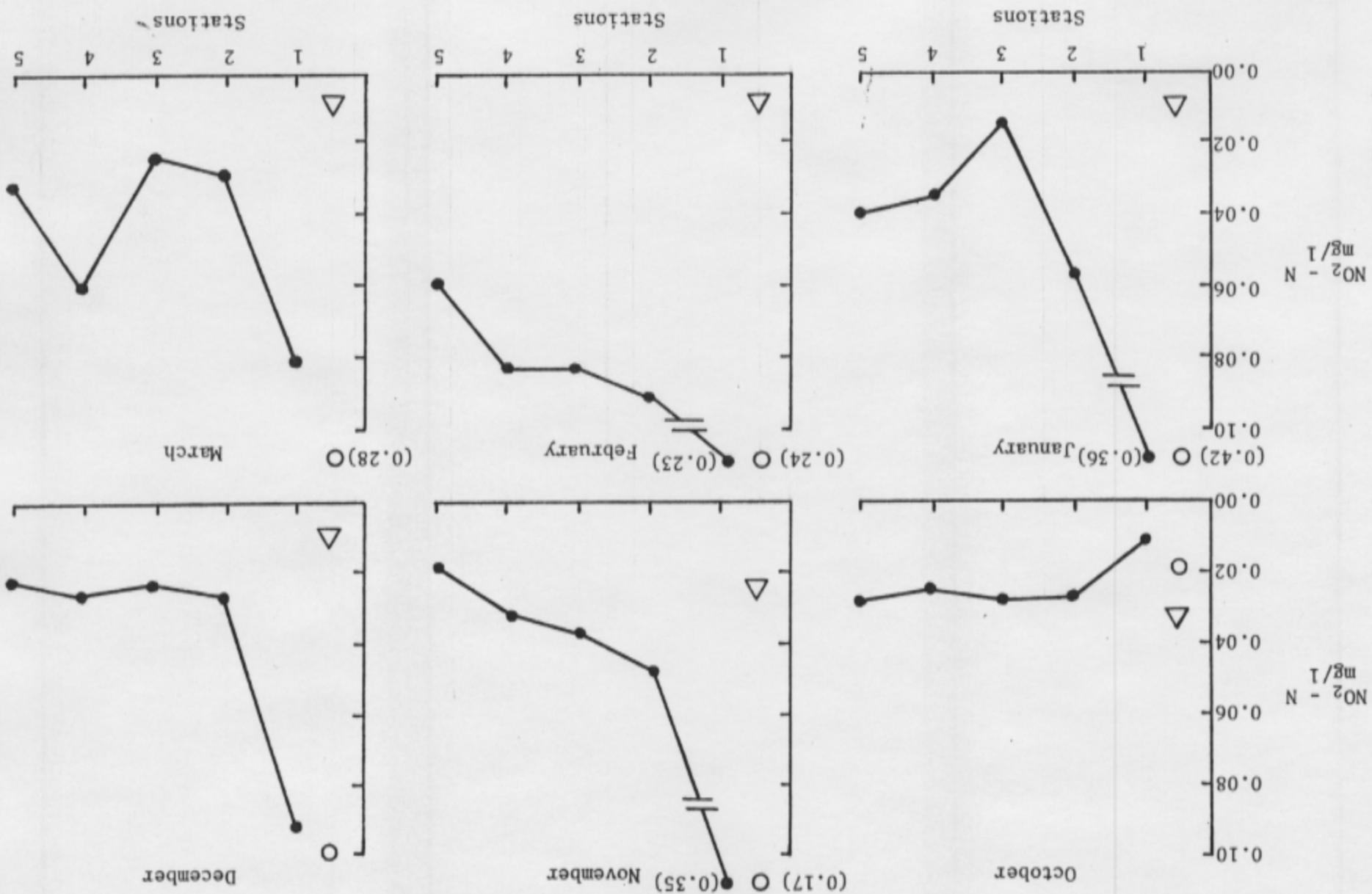


Figure 12b. Dissolved nitrite in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the scale changes for plume samples during November, January and February.



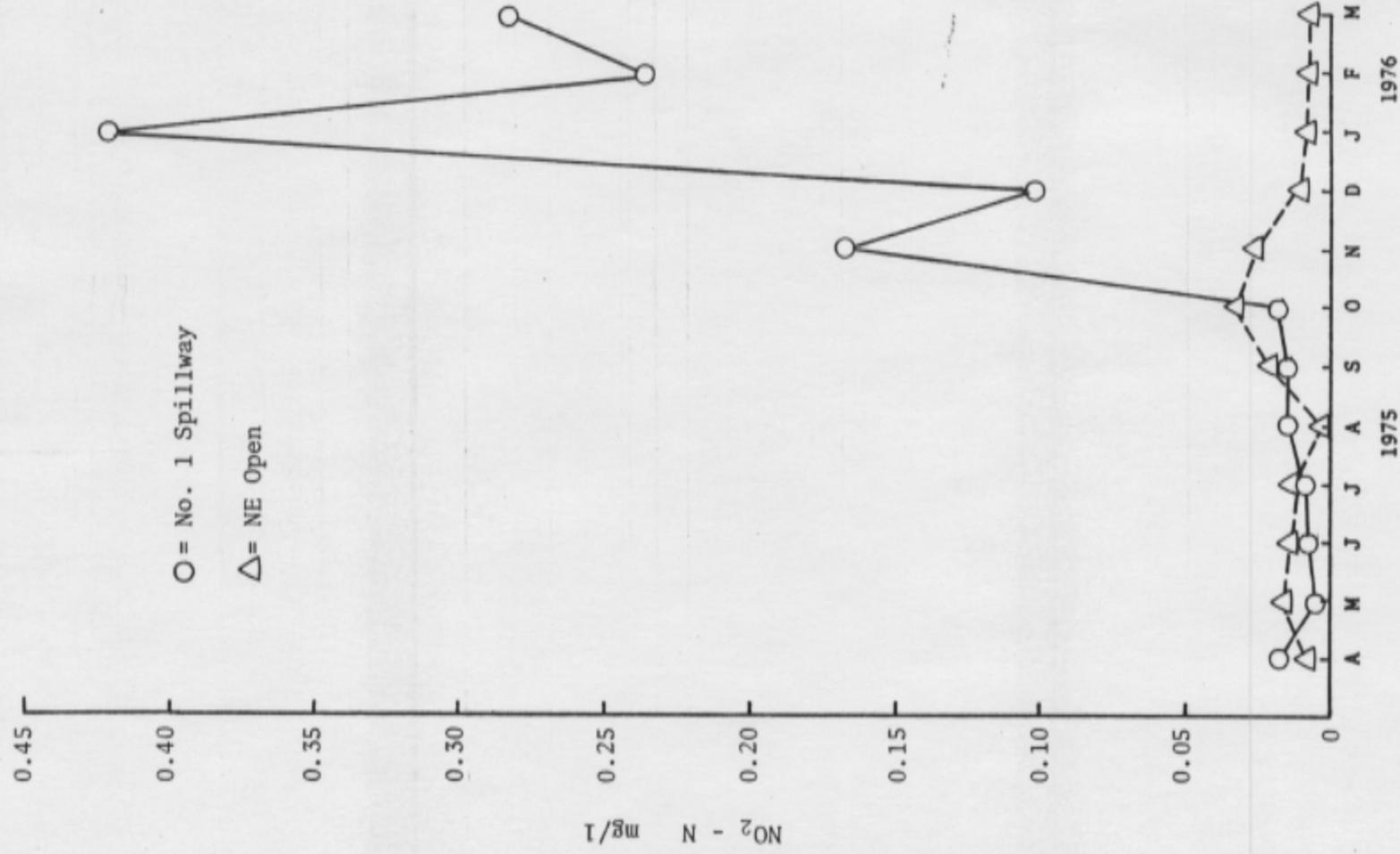


Figure 12c. Dissolved nitrite in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 13a. Dissolved ammonia in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

\* Possible error; removed from data for statistical analyses.

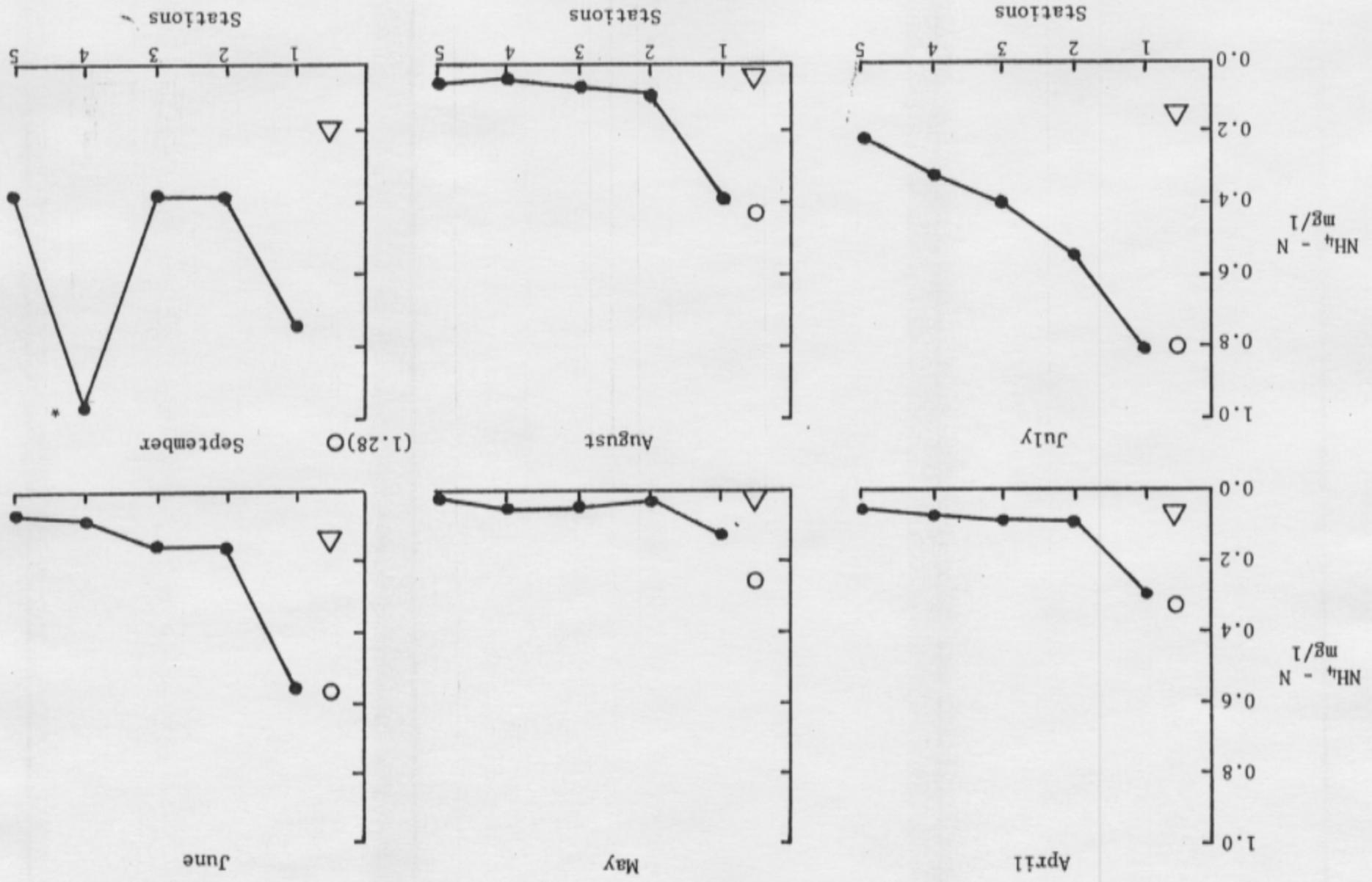
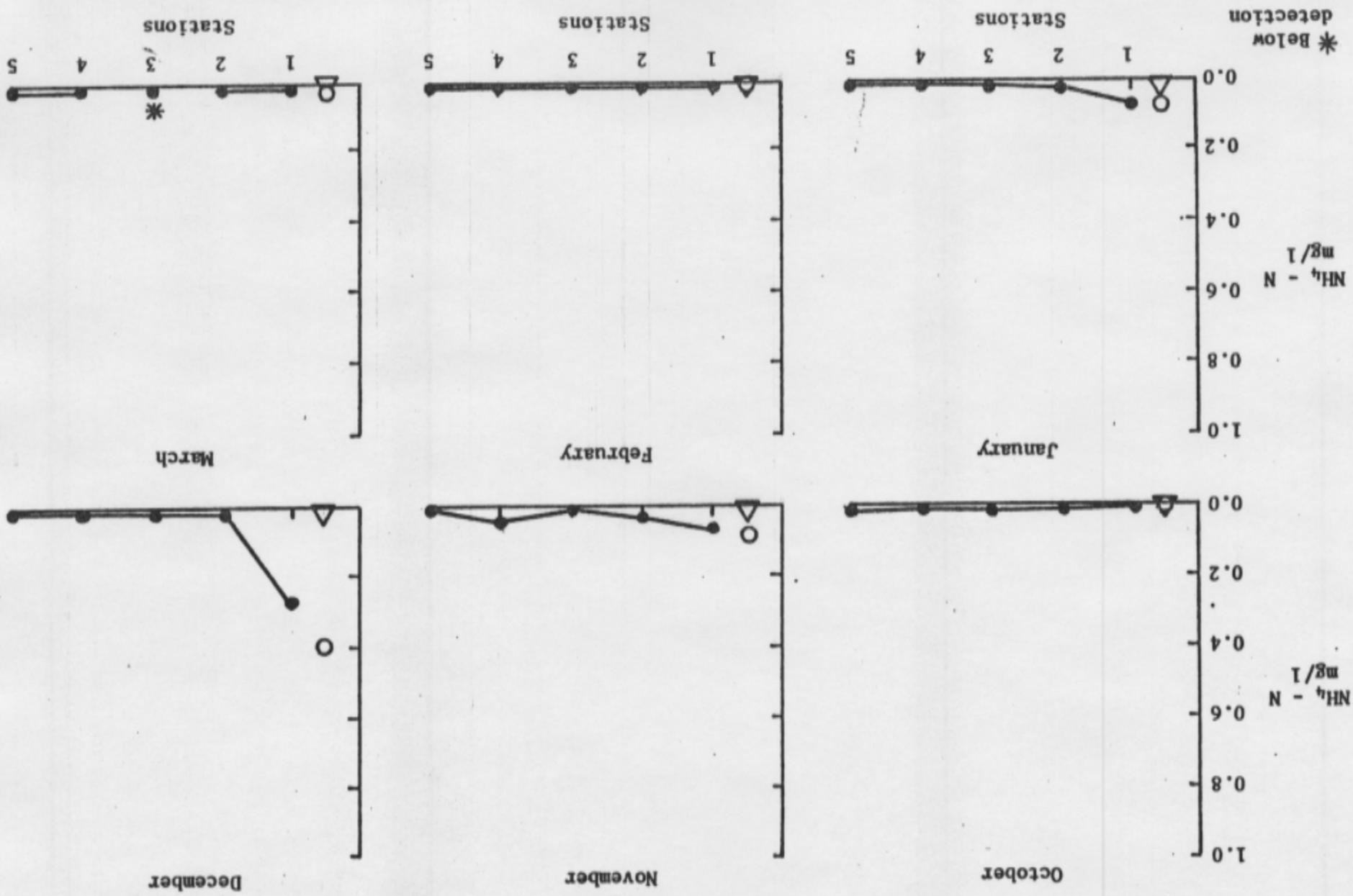


Figure 13b. Dissolved ammonia in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



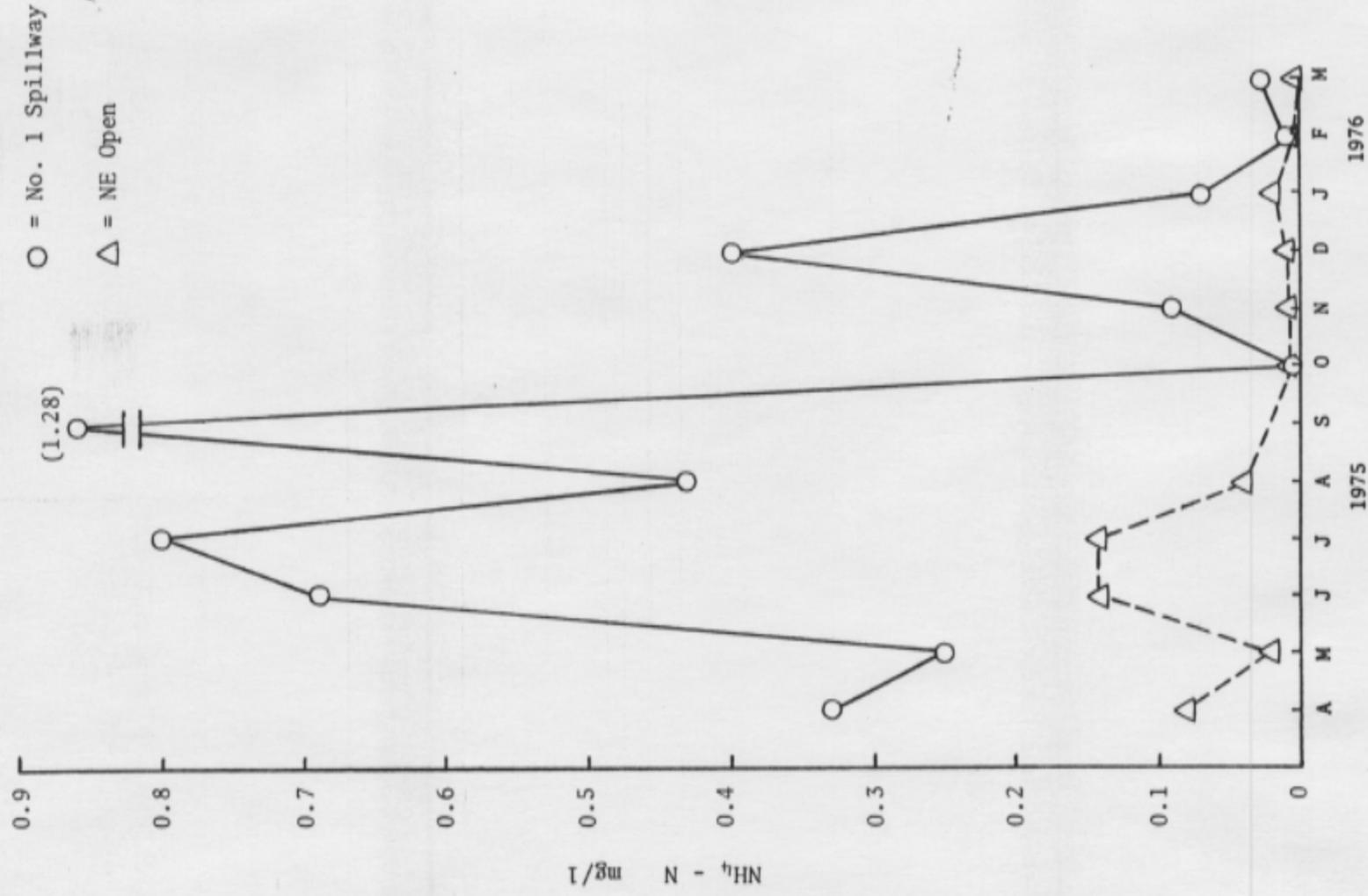


Figure 13c. Dissolved ammonia in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale change for the September spillway sample.

Figure 14a. Total Kjeldahl nitrogen in the surface waters at the No. 1 Spillway (O) and NE Open water (Δ) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

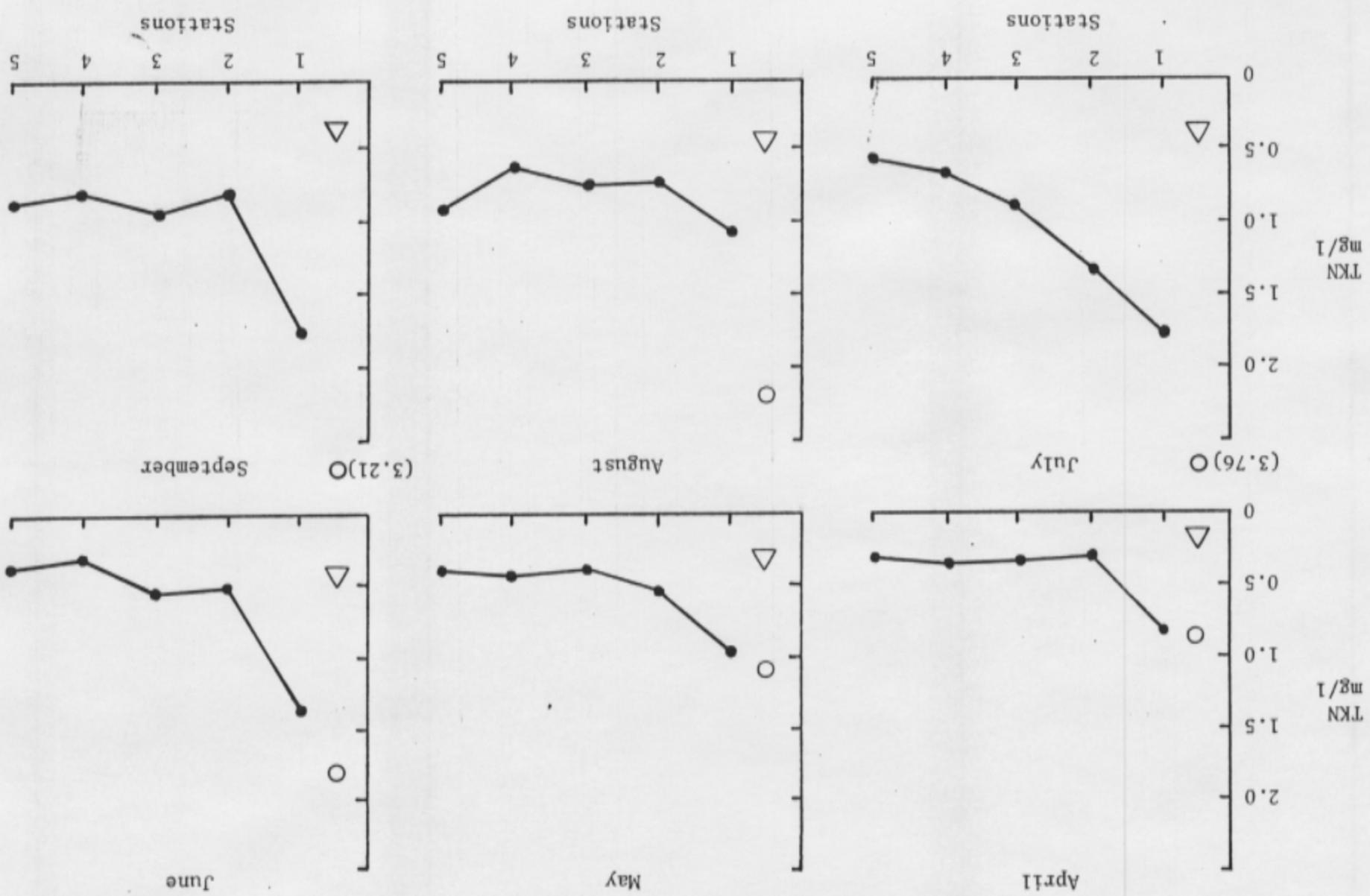
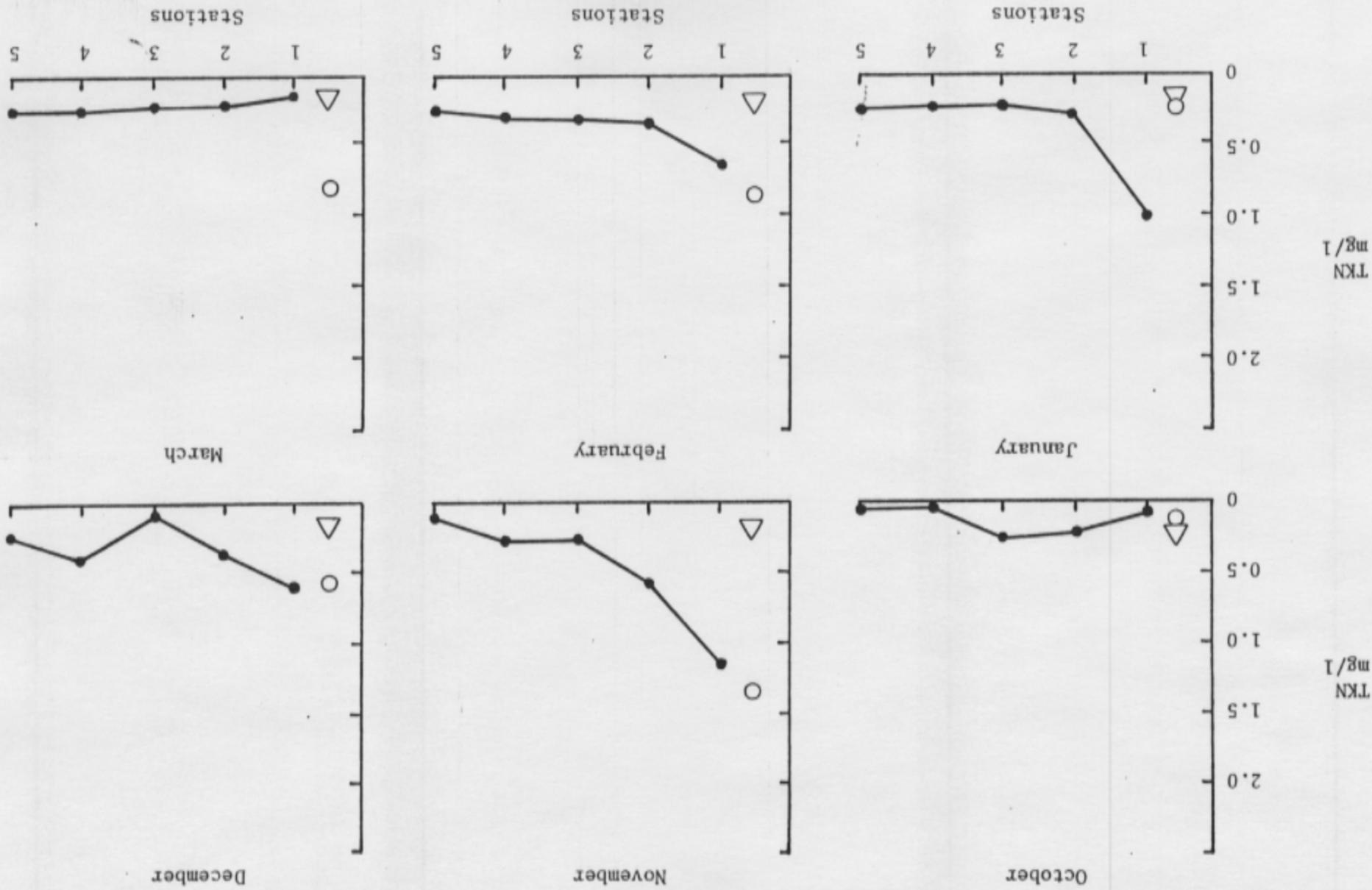


Figure 14b. Total Kjeldahl nitrogen in the surface waters at the No. 1 Spillway (O) and NE Open water ( $\nabla$ ) sites and at five stations in the spillway plume ( $\bullet$ ) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



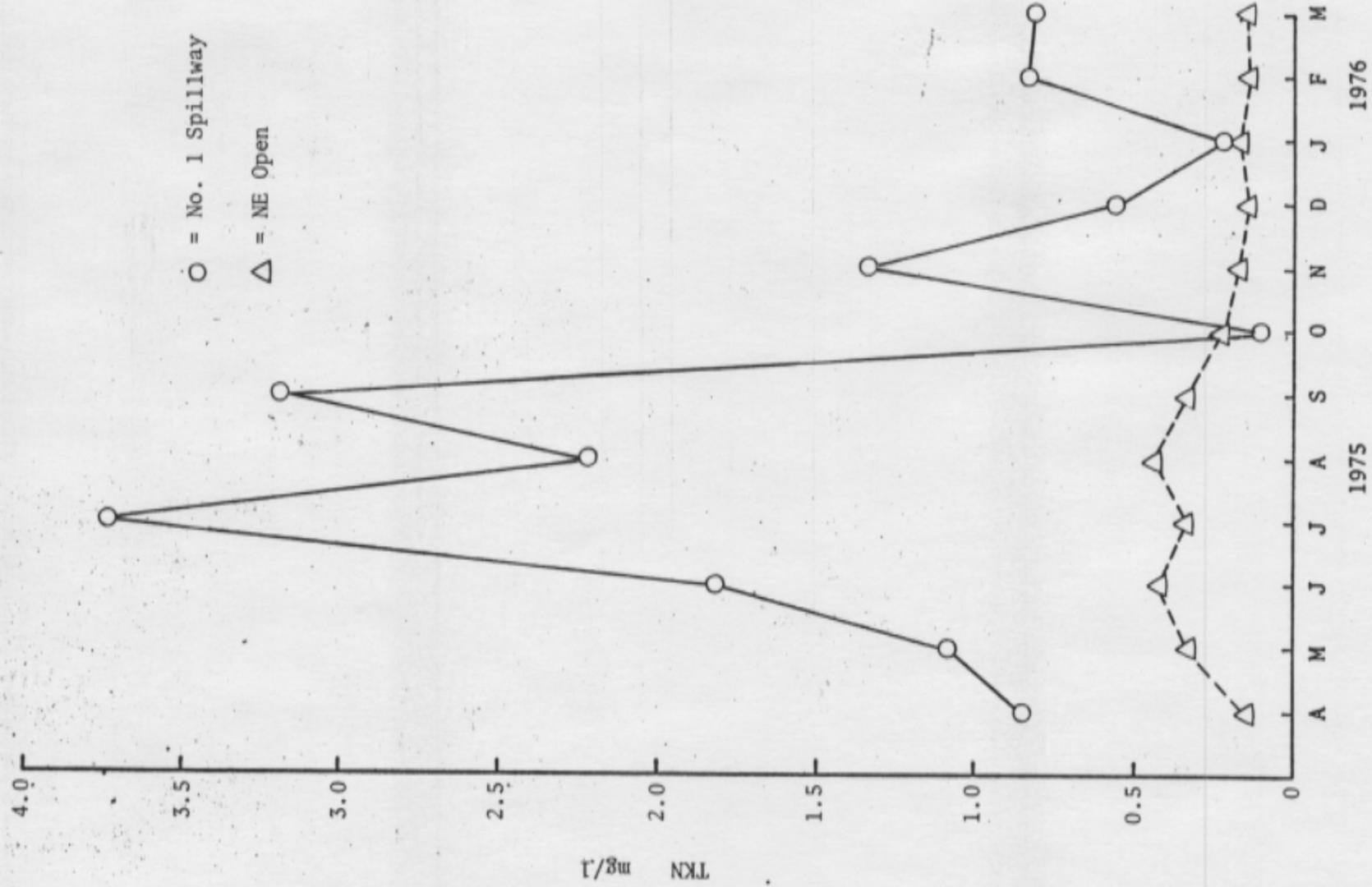


Figure 14c. Total Kjeldahl nitrogen in the surface waters at the No. 1 Spillway and NE Open water sites at Cranney Island (April 1975 to March 1976).

Figure 15a. Chlorophyll-a in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Data were not available in April and May 1975.

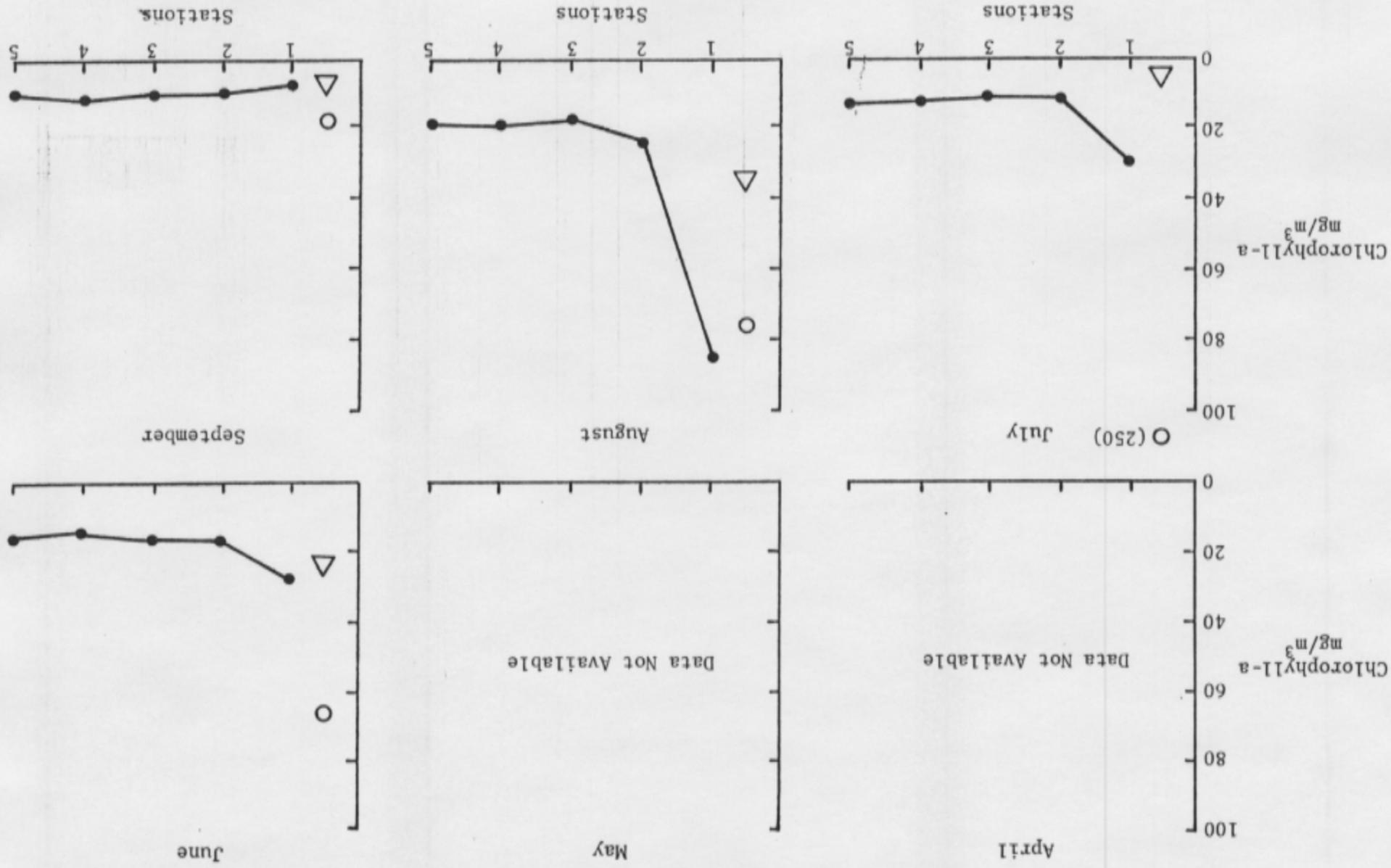
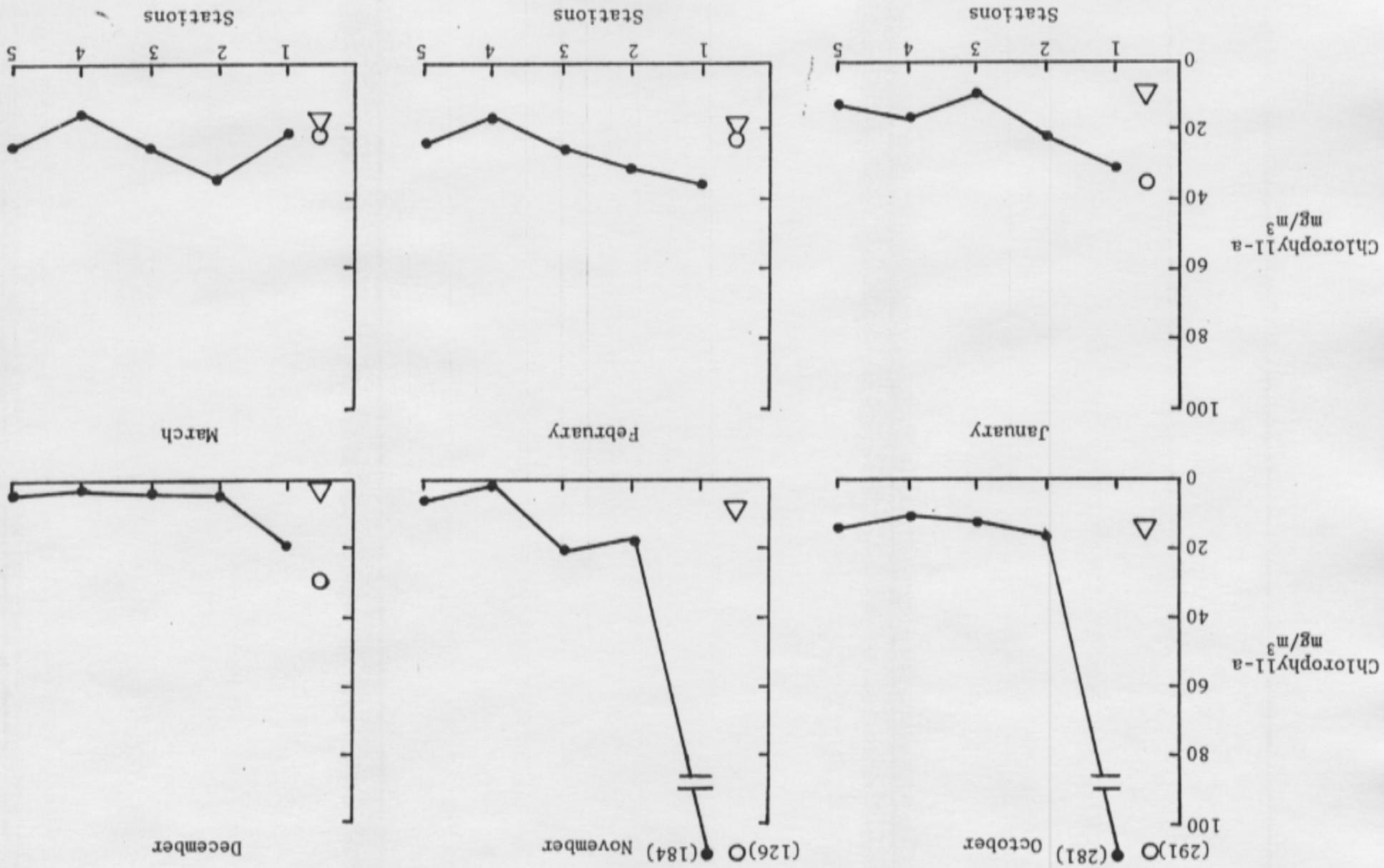


Figure 15b. Chlorophyll-a in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the scale change for plume samples in October and November.



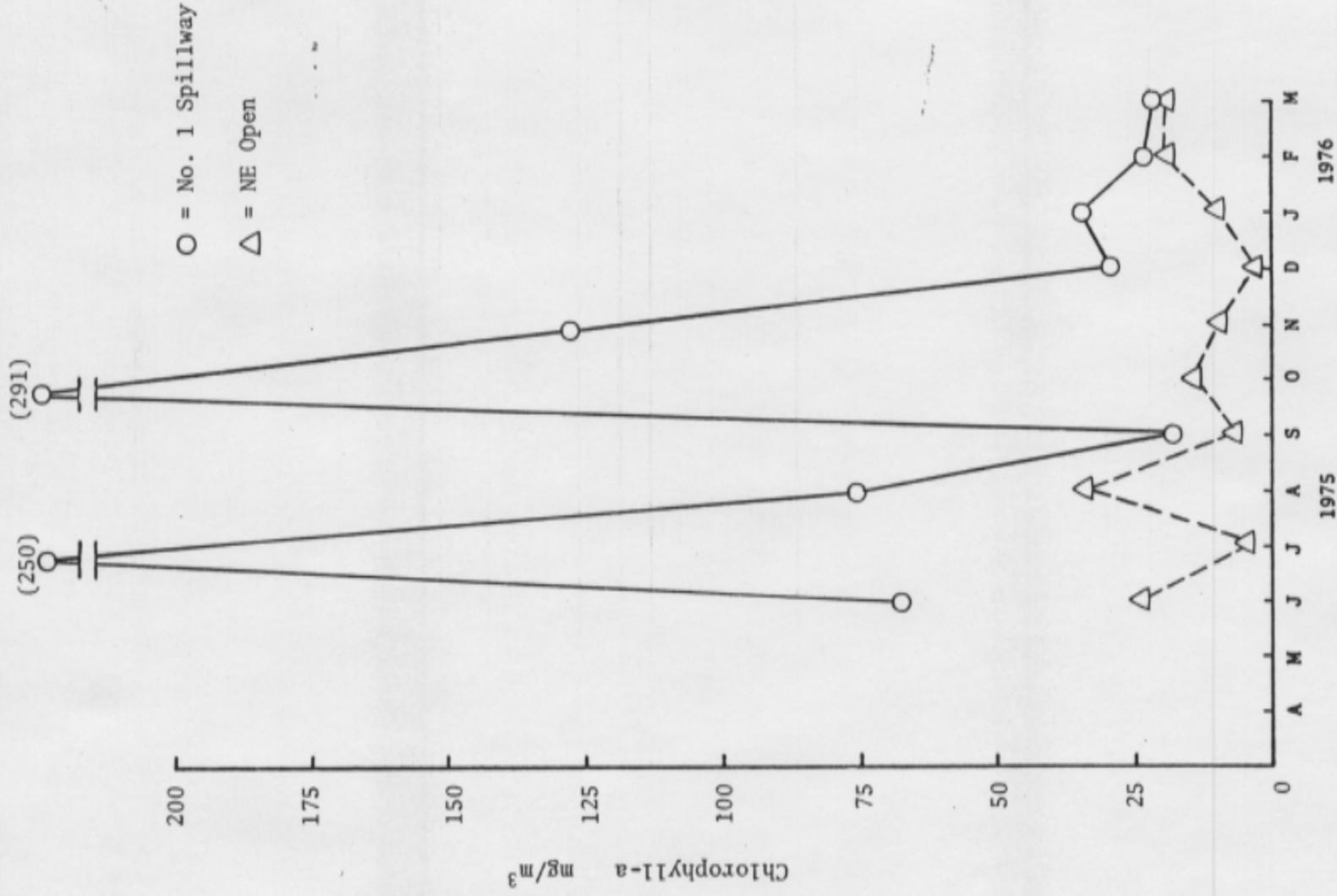


Figure 15c. Chlorophyll-a in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale changes for July and October spillway samples.

Total Suspended Solids mg/l

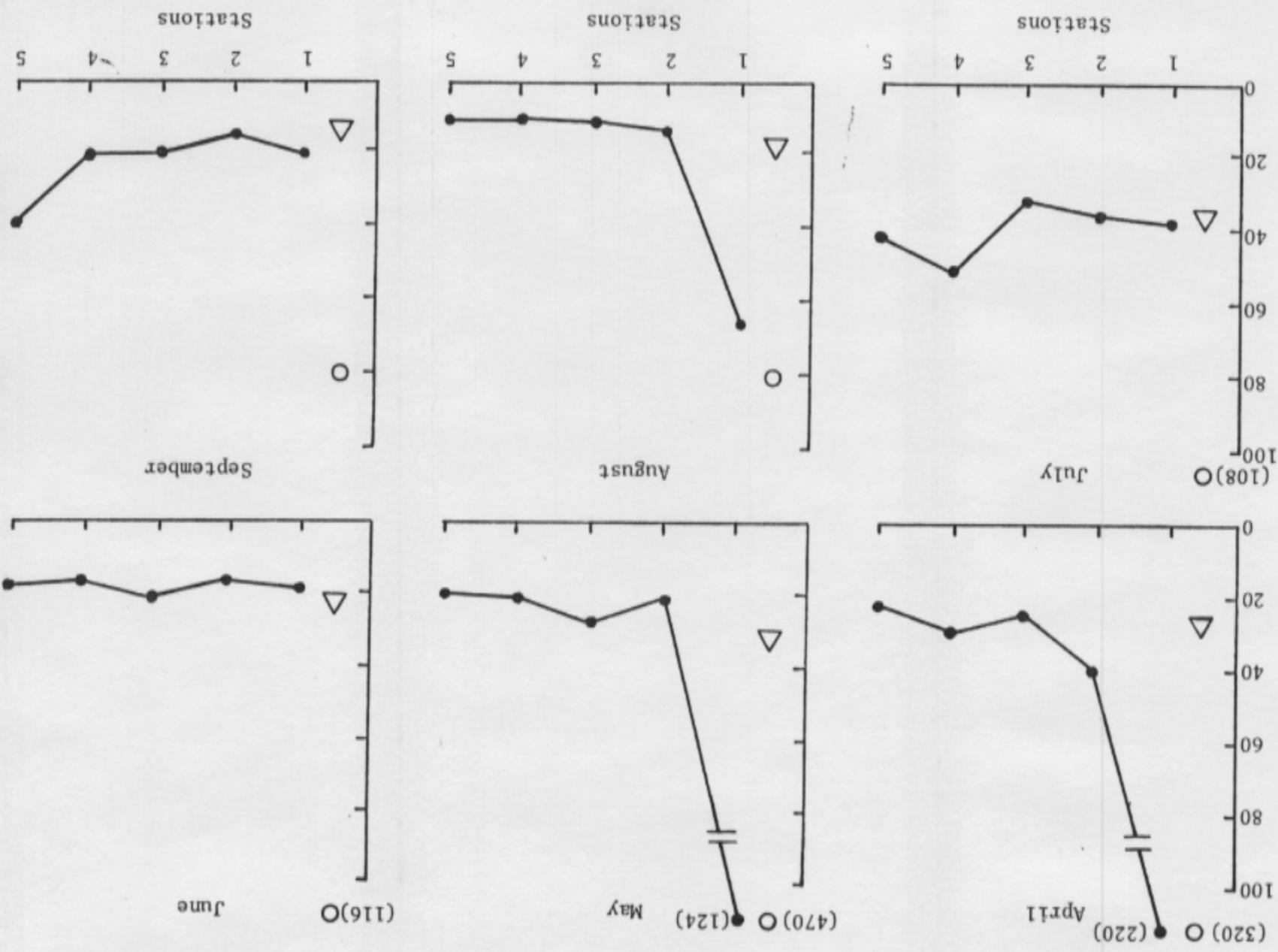
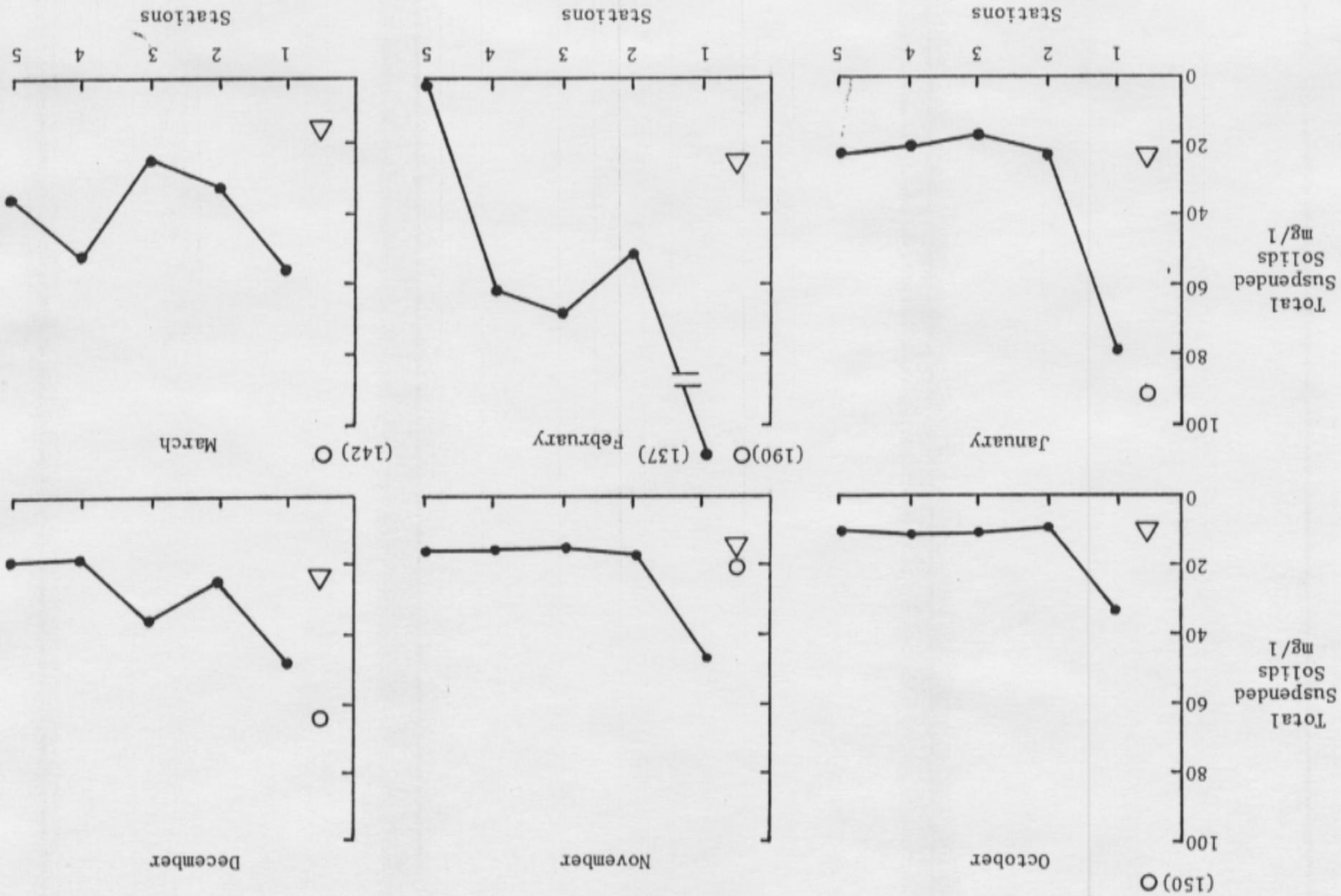


Figure 16a. Total suspended solids in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the scale changes in the plume samples during April and May 1975.

Figure 16b. Total suspended solids in the surface waters at the No. 1 Spillway (○) and NE Open water at the Craney Island Disposal area, Port of Hampton Roads, Virginia. Note the scale change for plume samples in February 1976.



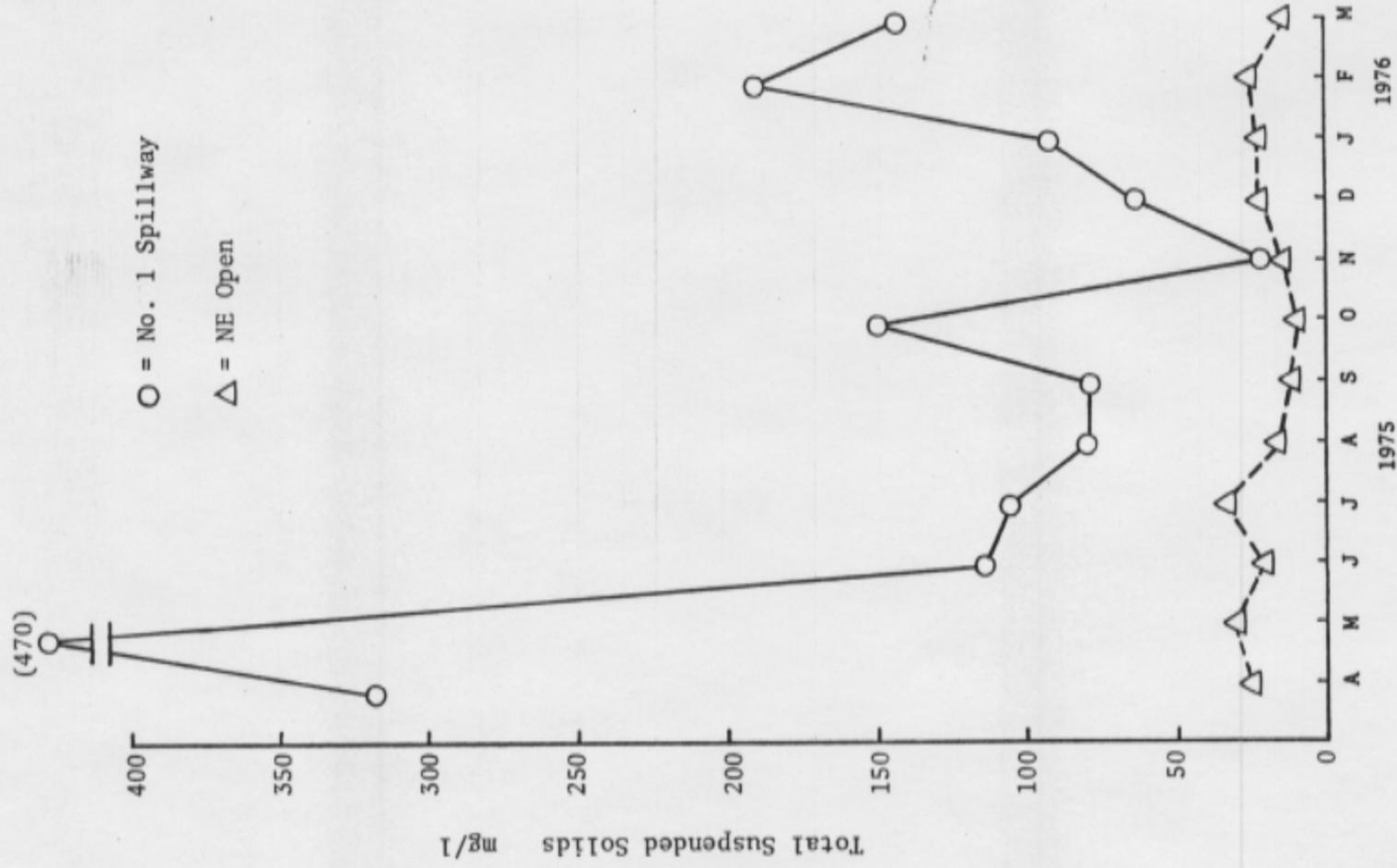
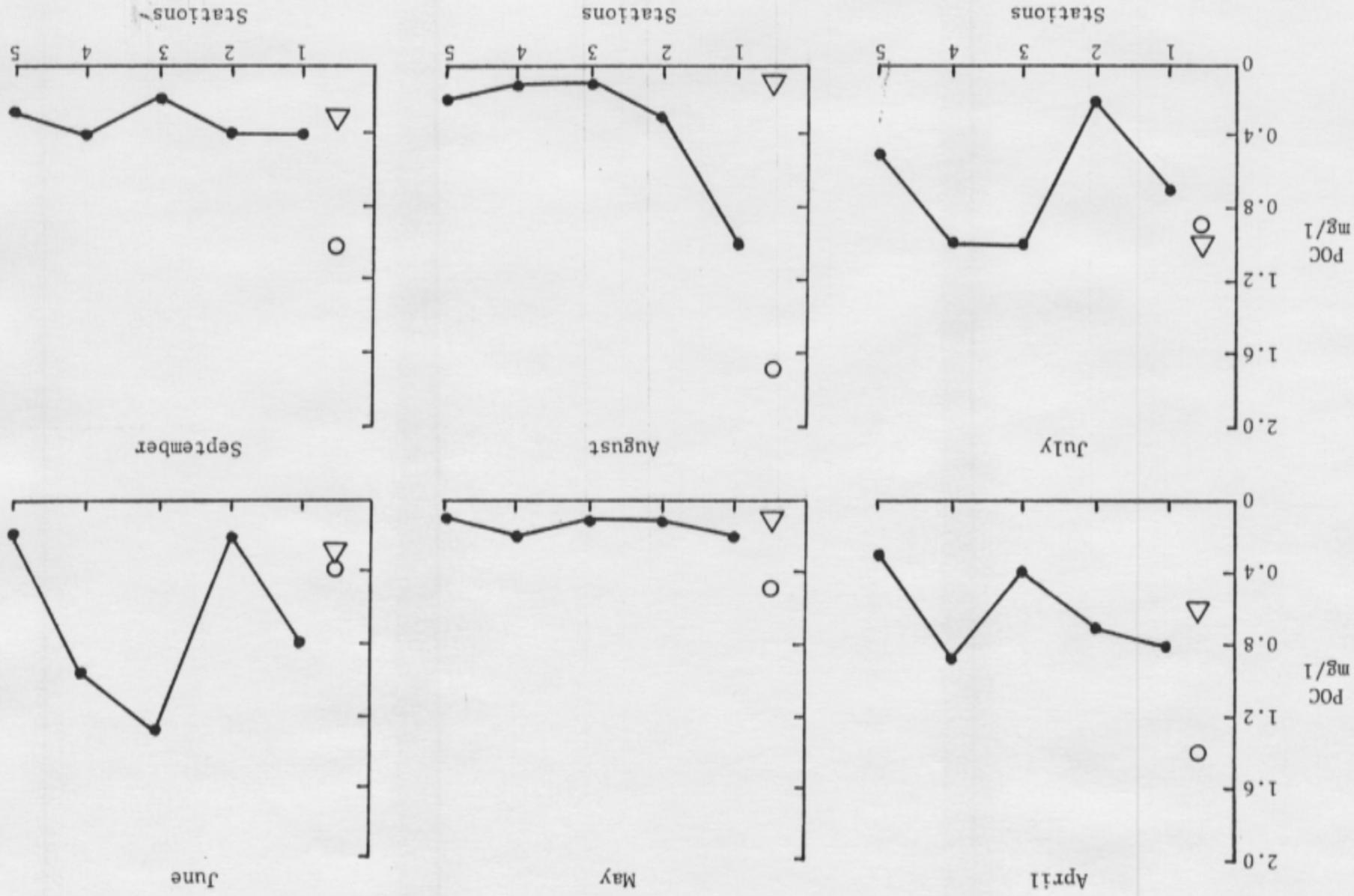


Figure 16c. Total suspended solids in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 17a. Particulate organic carbon in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.





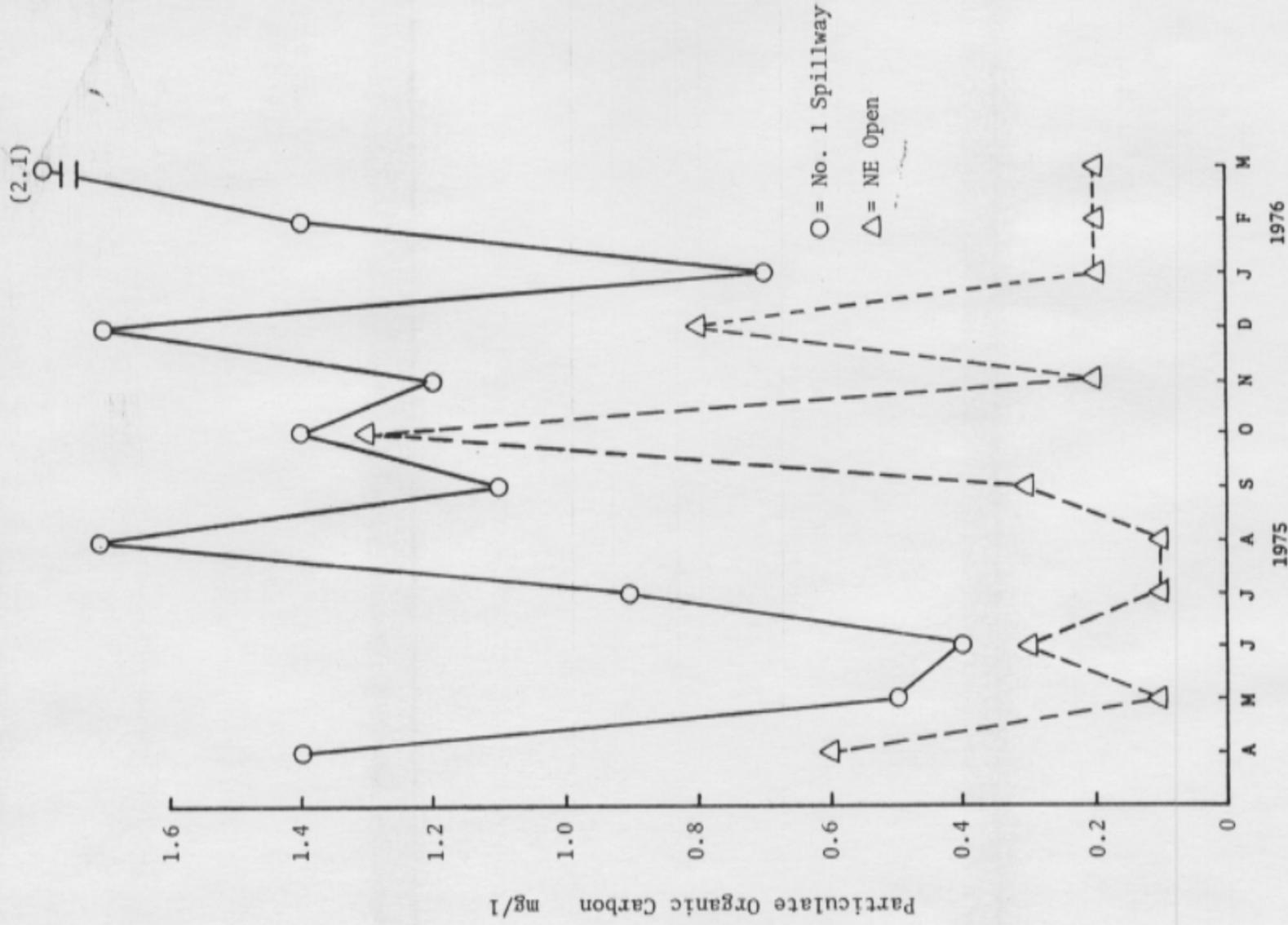


Figure 17c. Particulate organic carbon in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 18a. Dissolved organic carbon in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

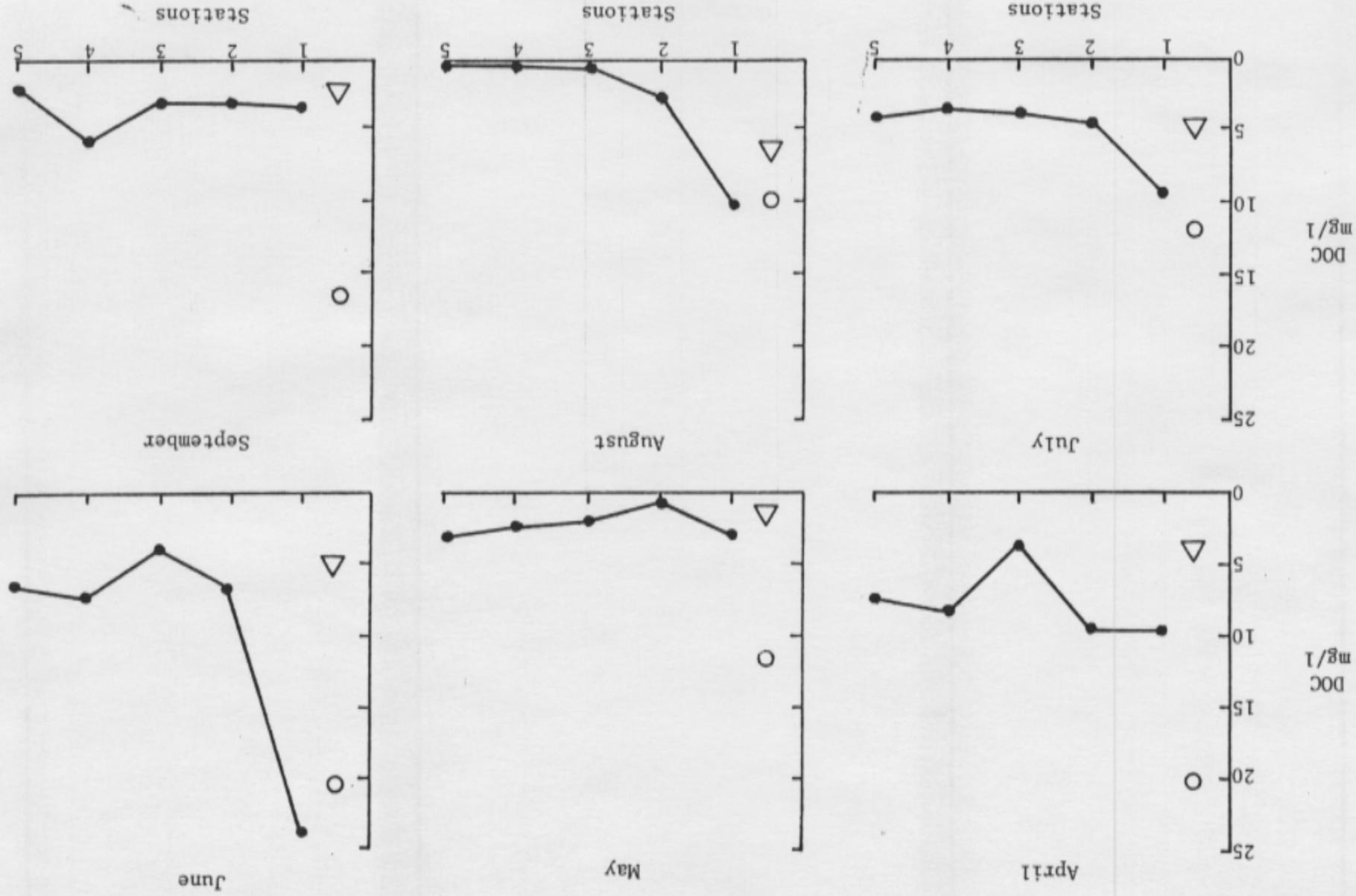
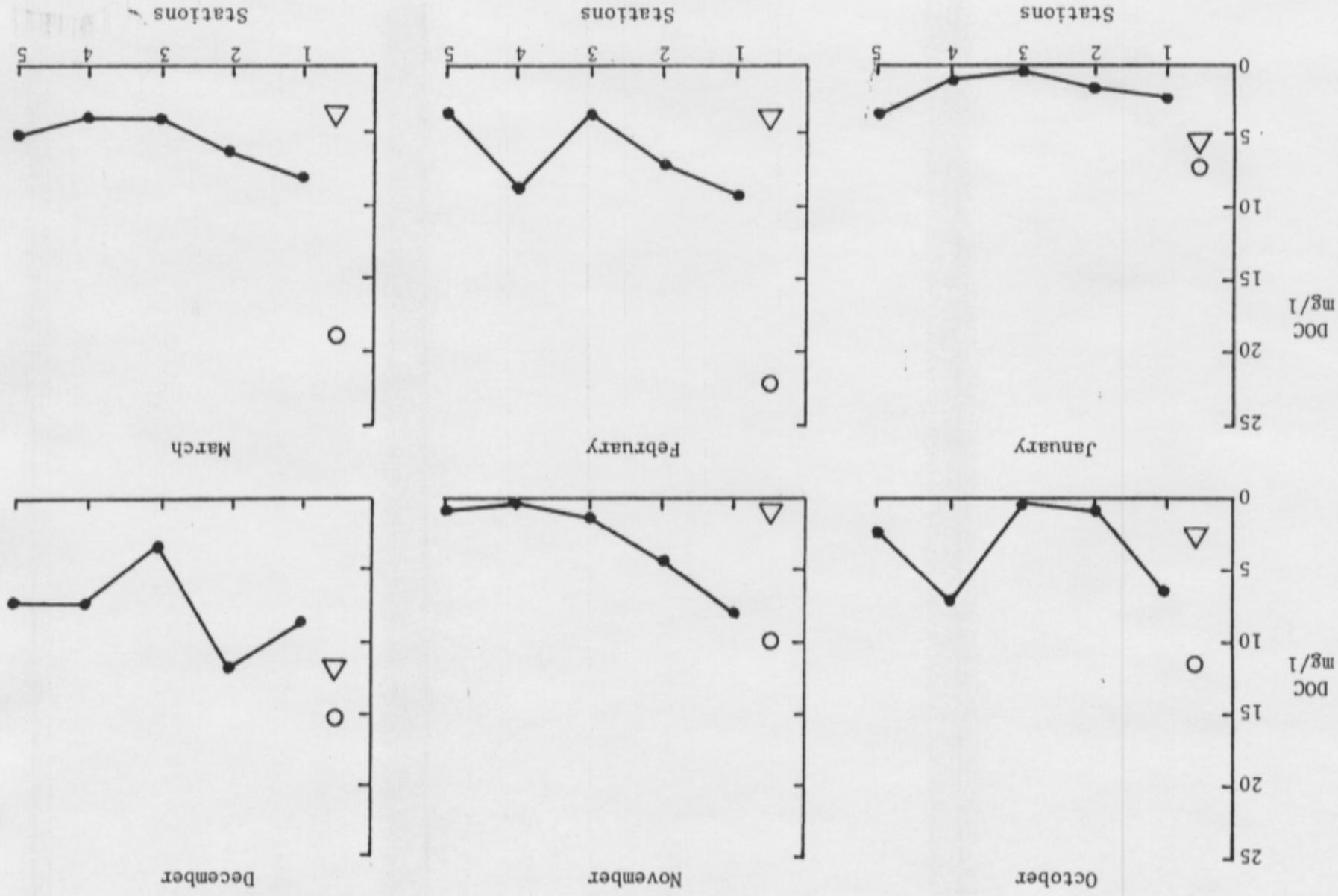


Figure 18b. Dissolved organic carbon in the surface waters at the No. 1 Spillway (O) and NE Open water (Δ) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



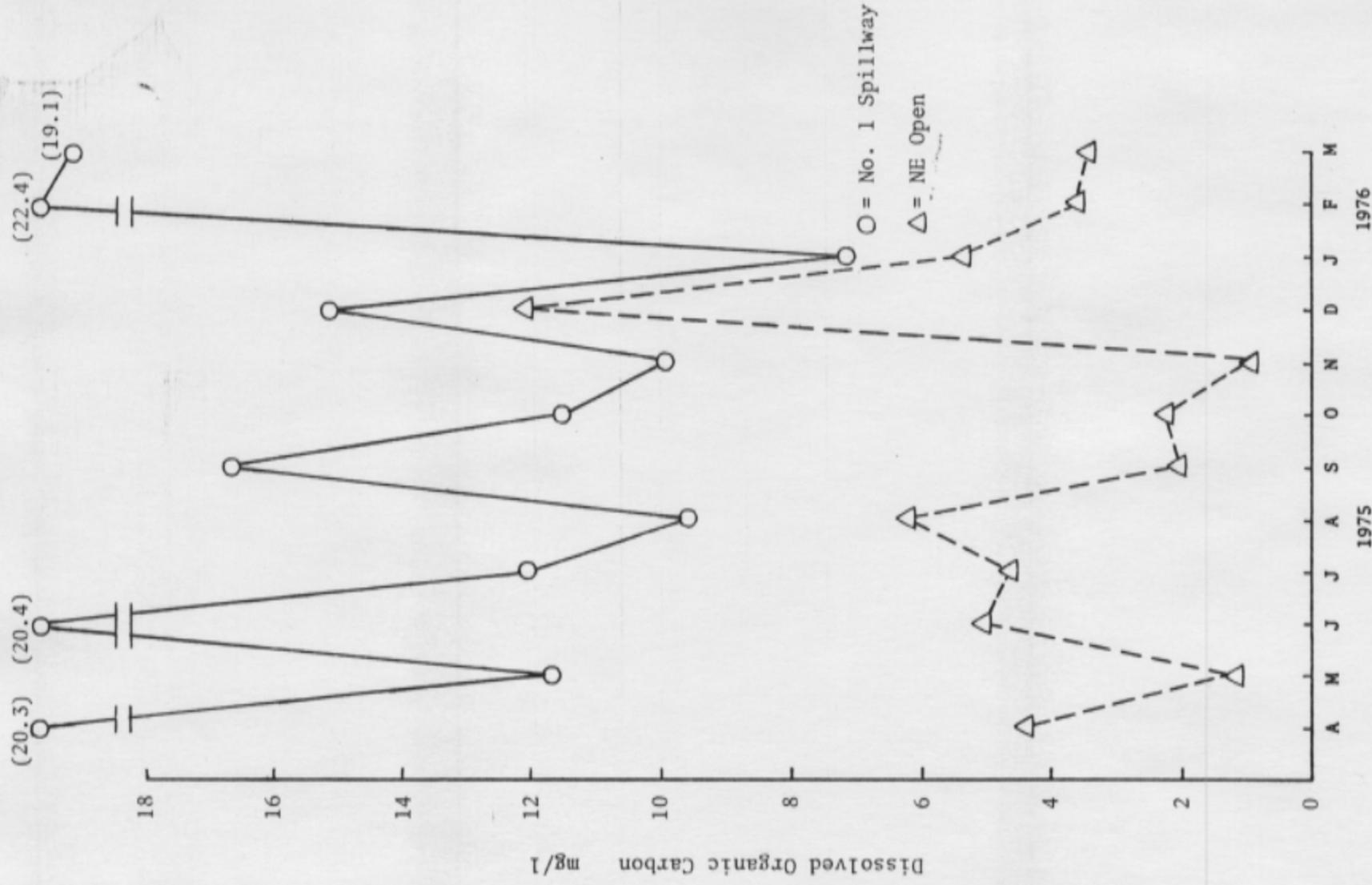


Figure 18c. Dissolved organic carbon in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

Figure 19a. Dissolved cadmium in surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

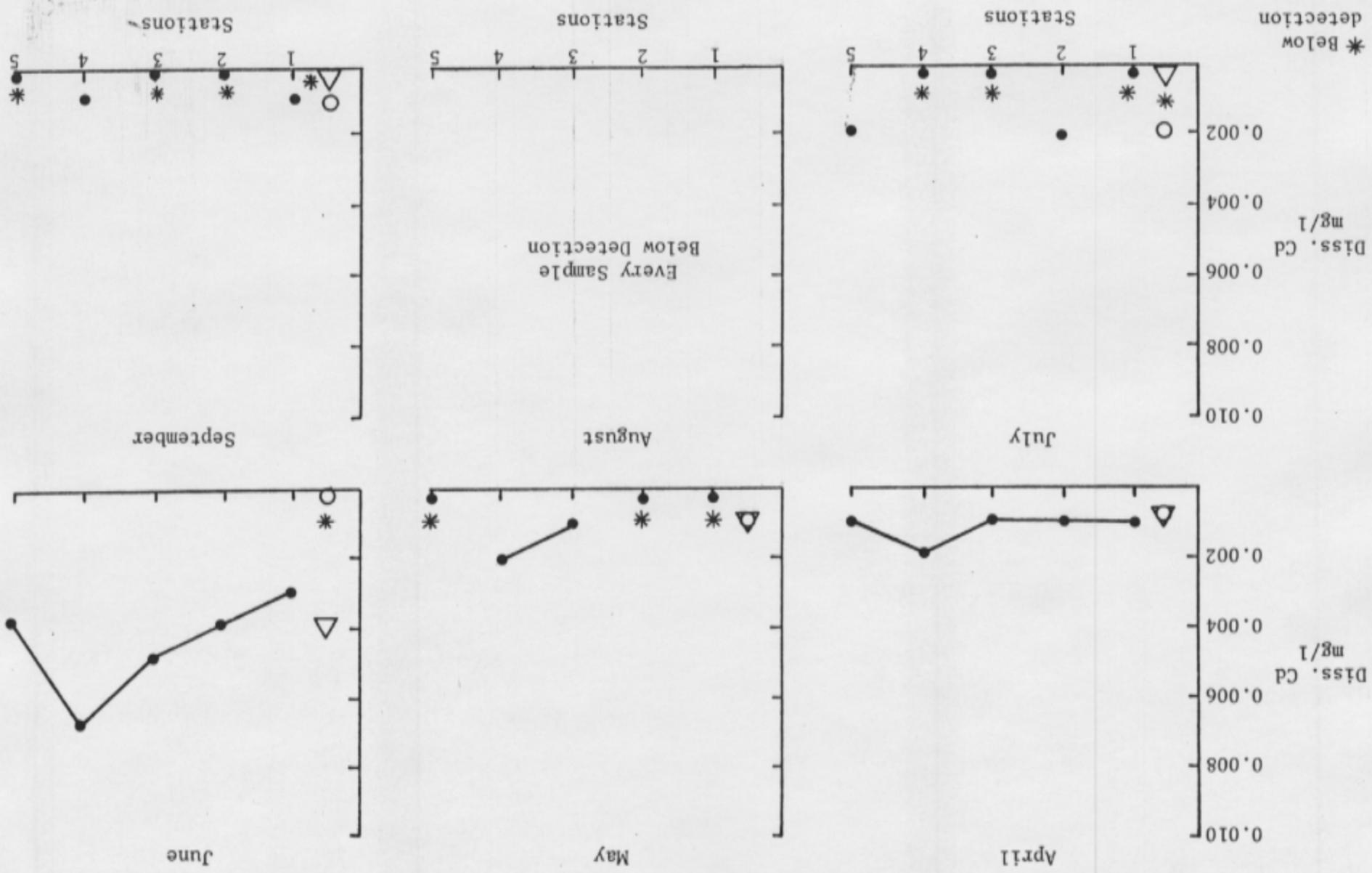


Figure 19b. Dissolved cadmium in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

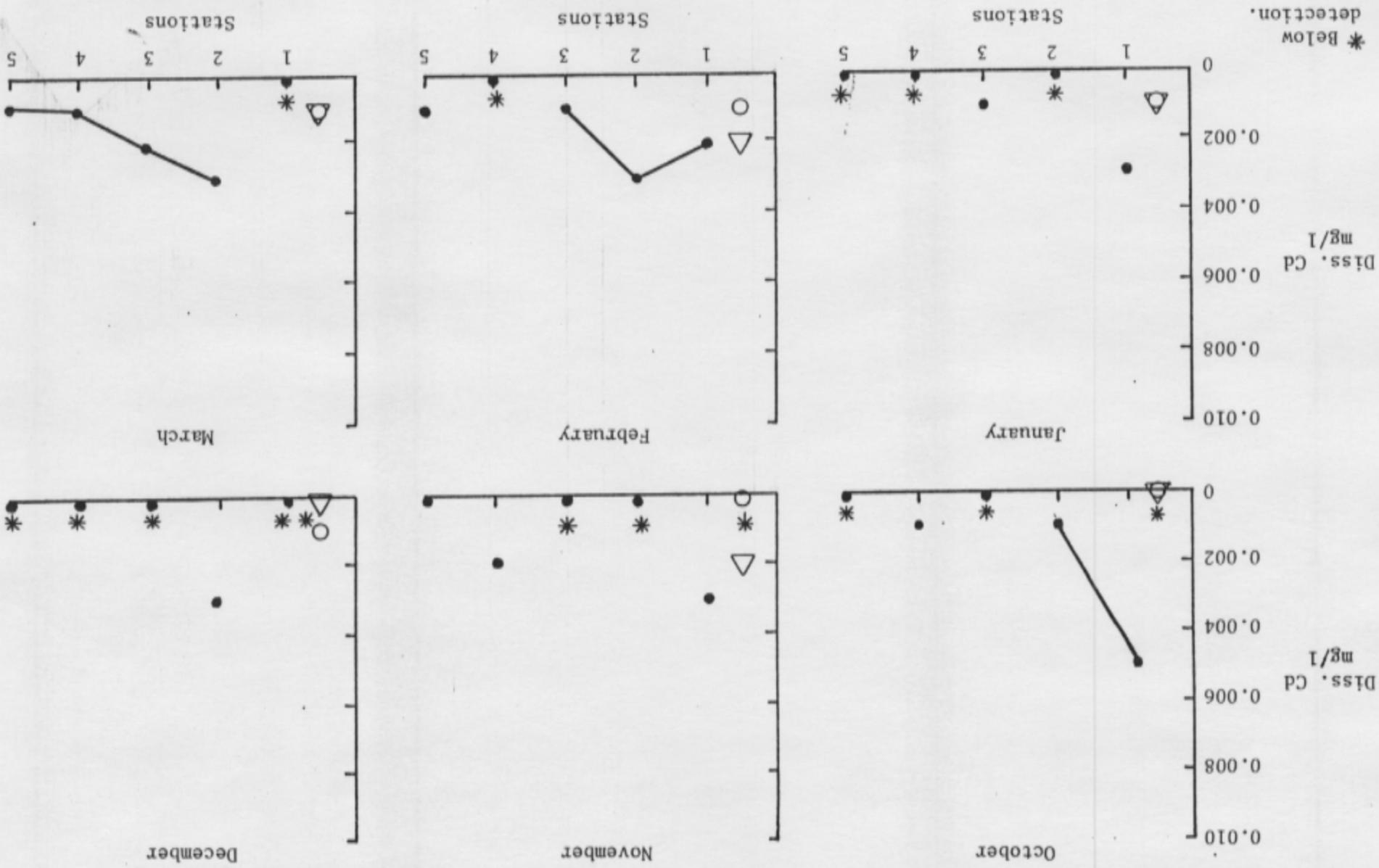


Figure 20a. Dissolved mercury in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

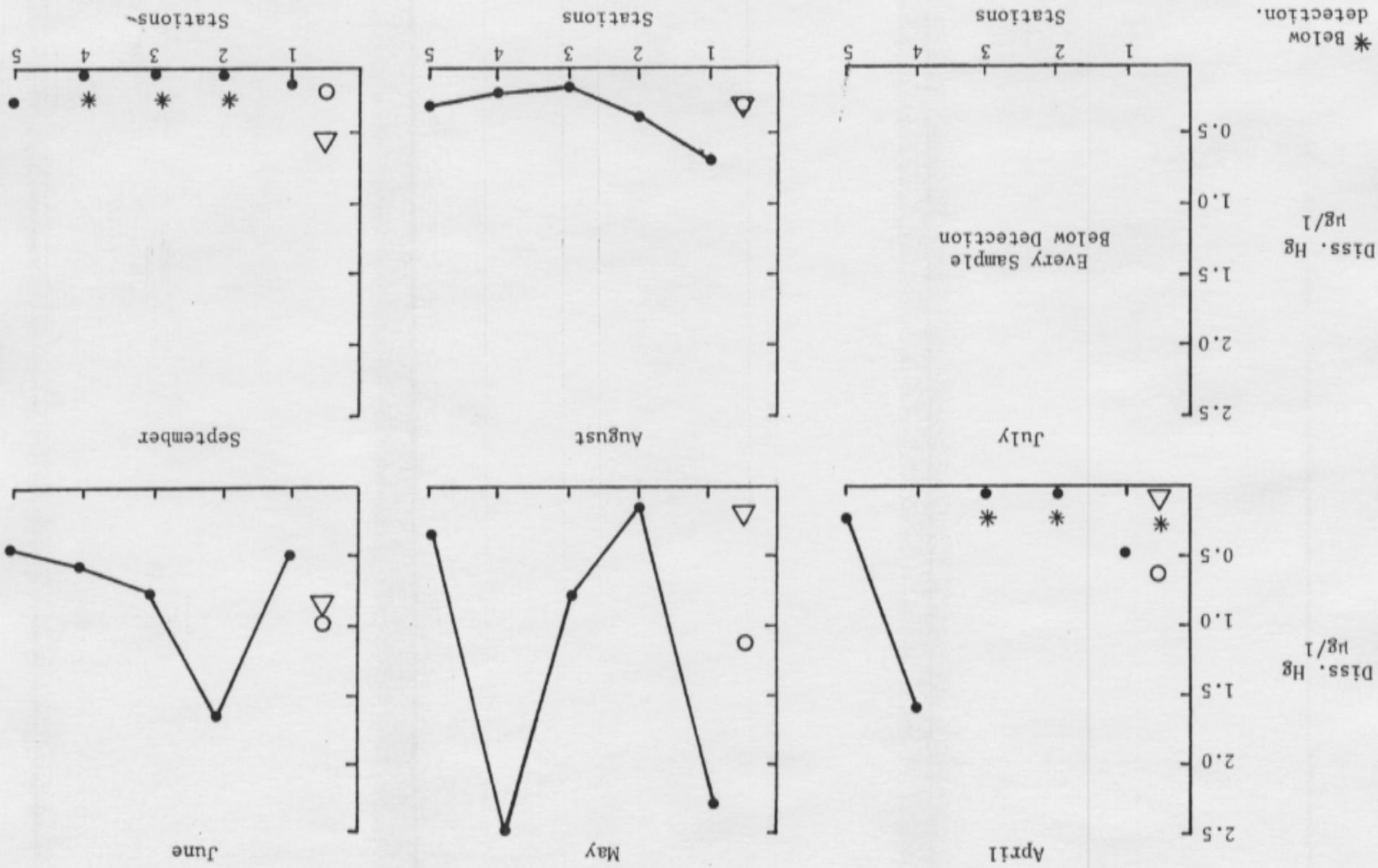


Figure 20b. Dissolved mercury in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

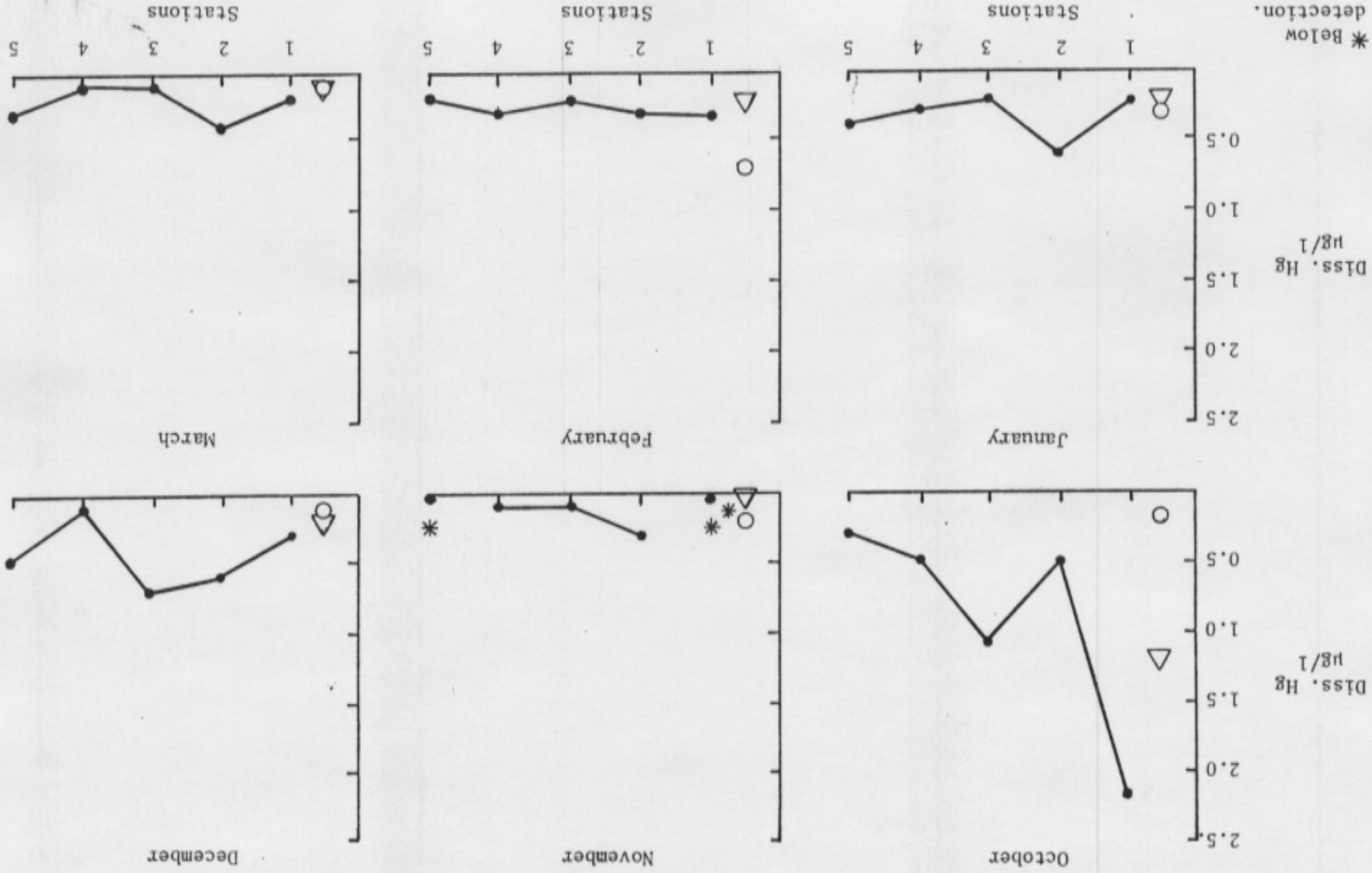




Figure 21. Dissolved lead in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

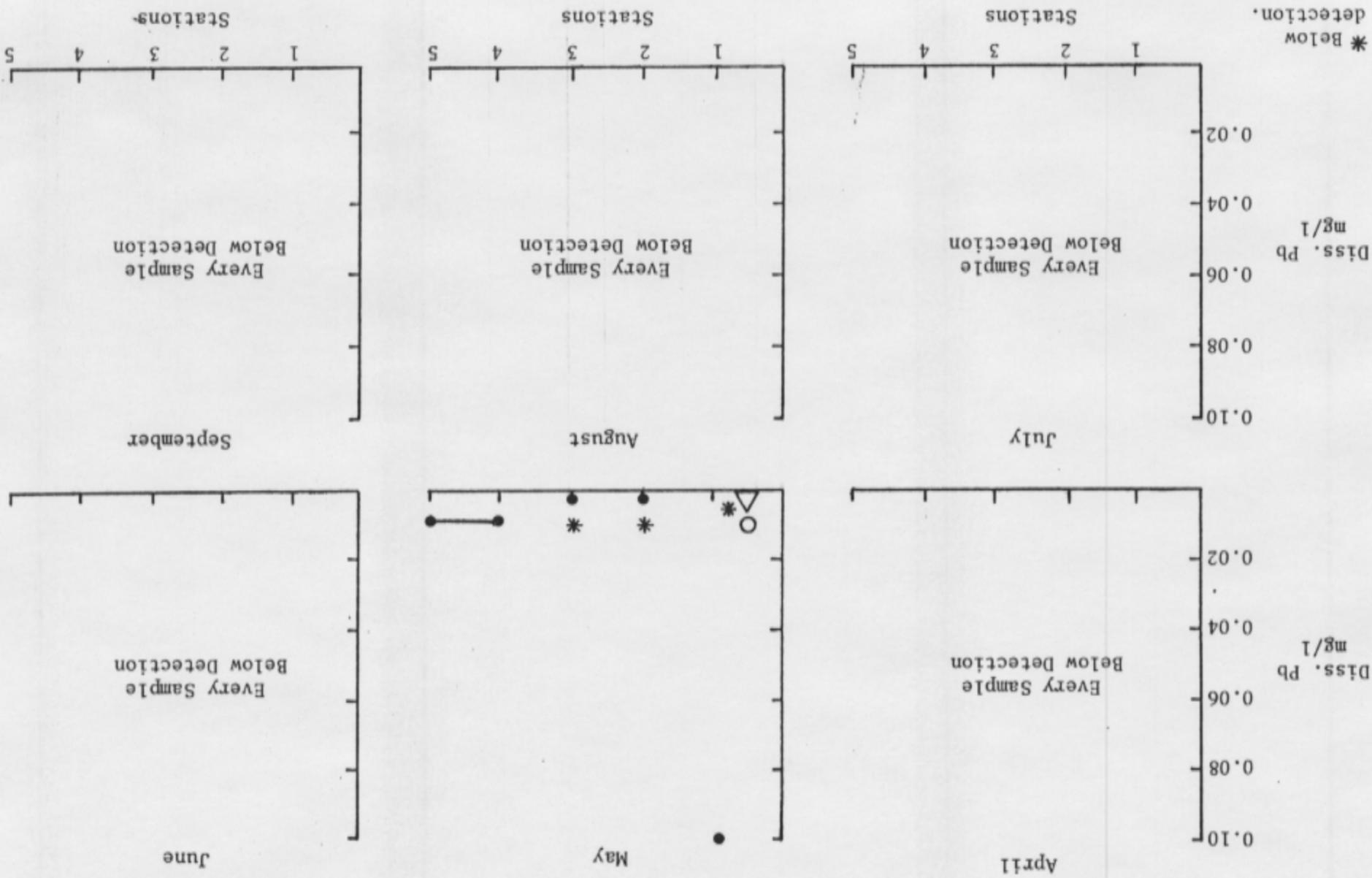
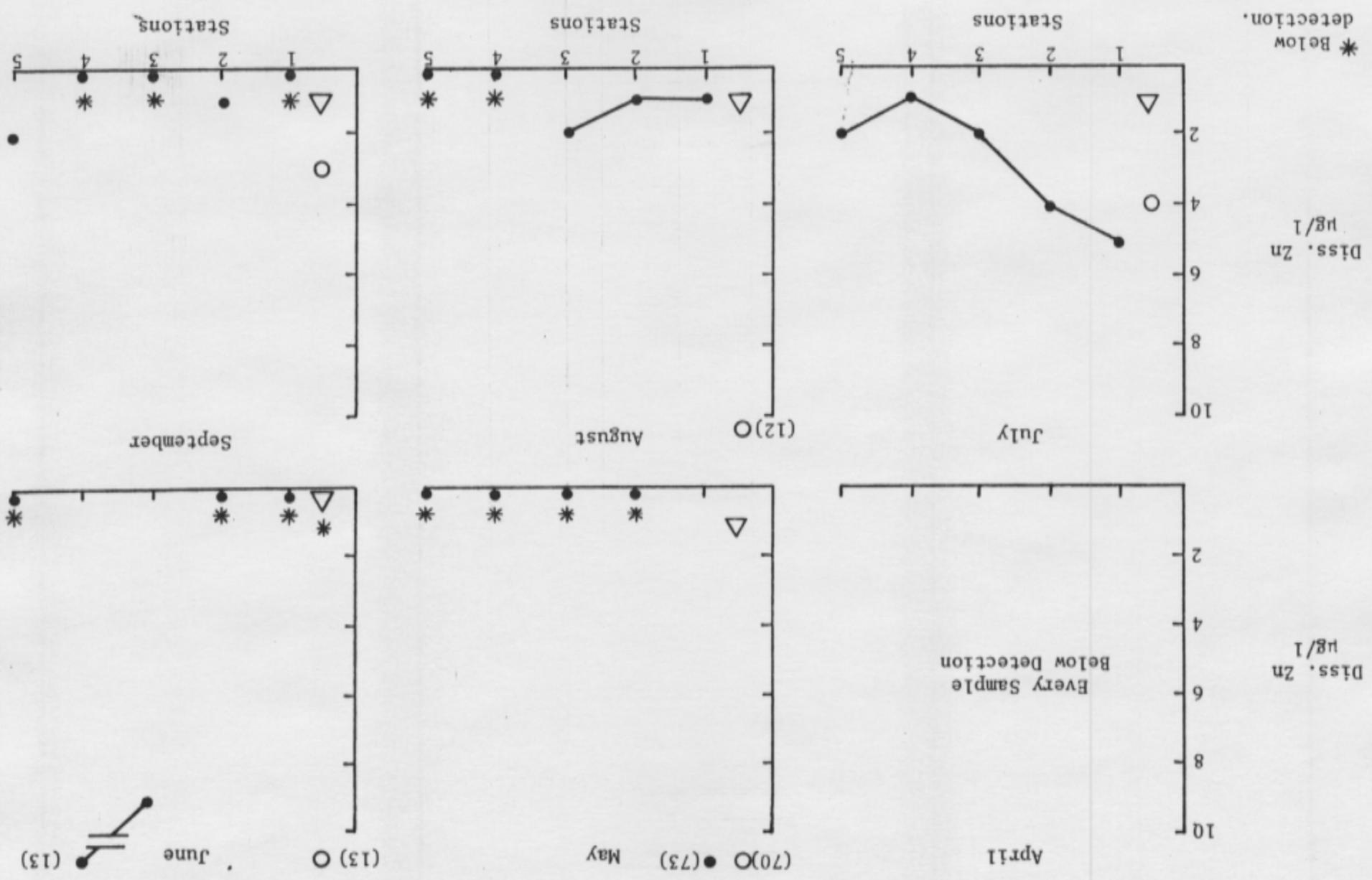


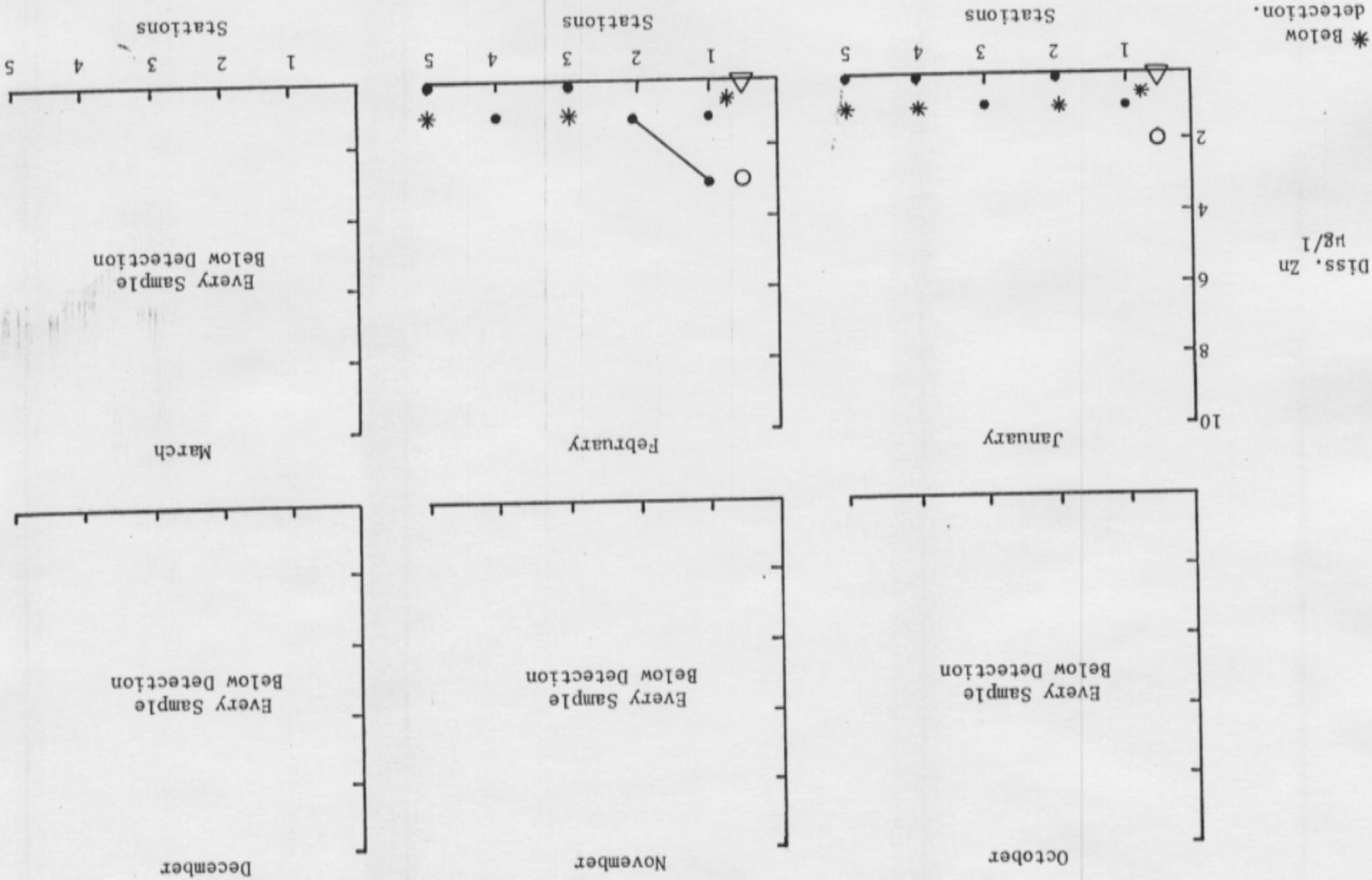
Figure 22a. Dissolved zinc in the surface waters at the No. 1 Spillway (O) and NE Open water (Δ) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia. Note the higher values in May and the scale change for plume samples in June 1975.



\* Below detection.

Every Sample Below Detection

Figure 22b. Dissolved zinc in the surface waters of the No. 1 Spillway (○) and NE Open water (▽) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



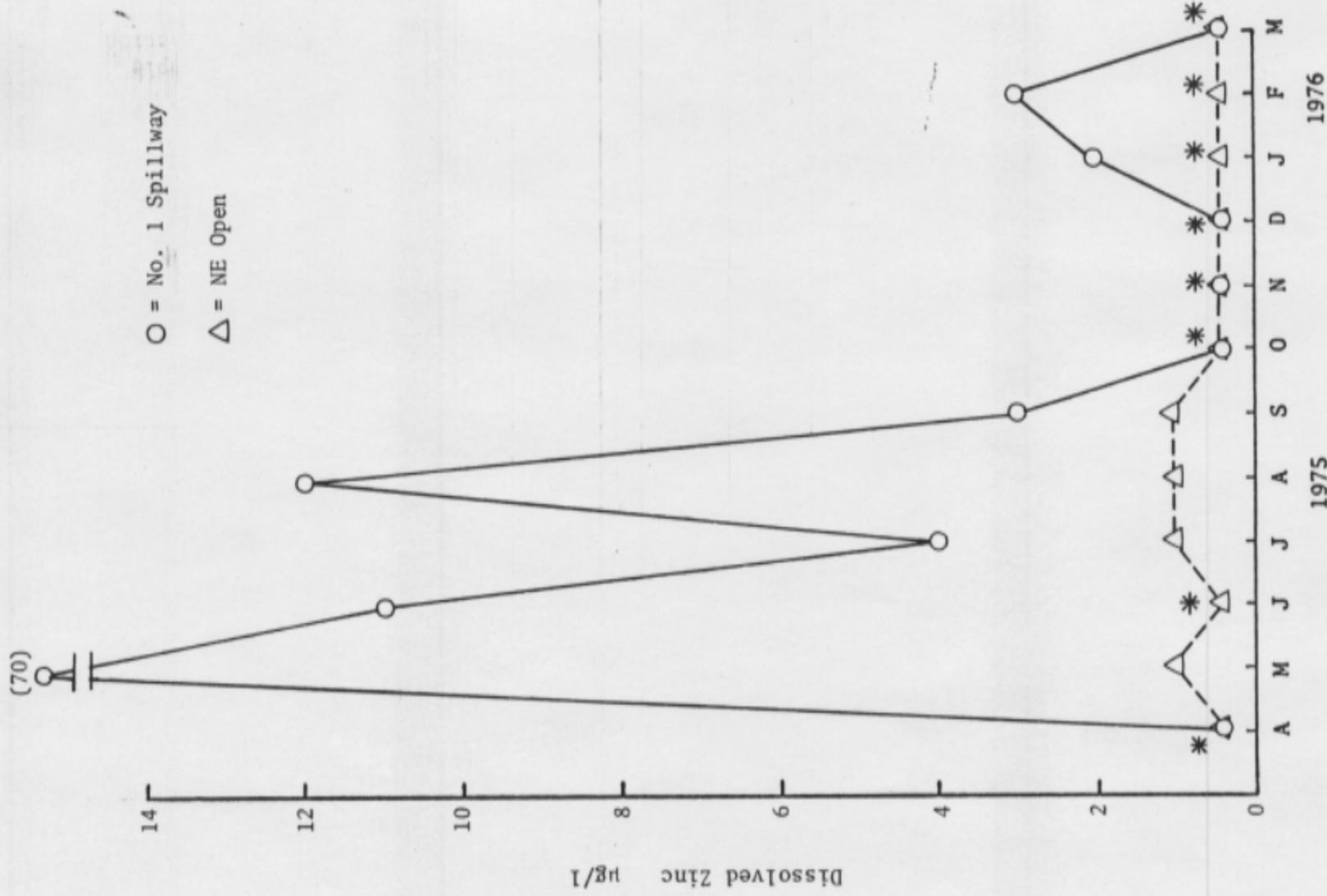


Figure 22c. Dissolved zinc in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976). Note the scale change for the May spillway sample.

Figure 23a. Particulate mercury in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

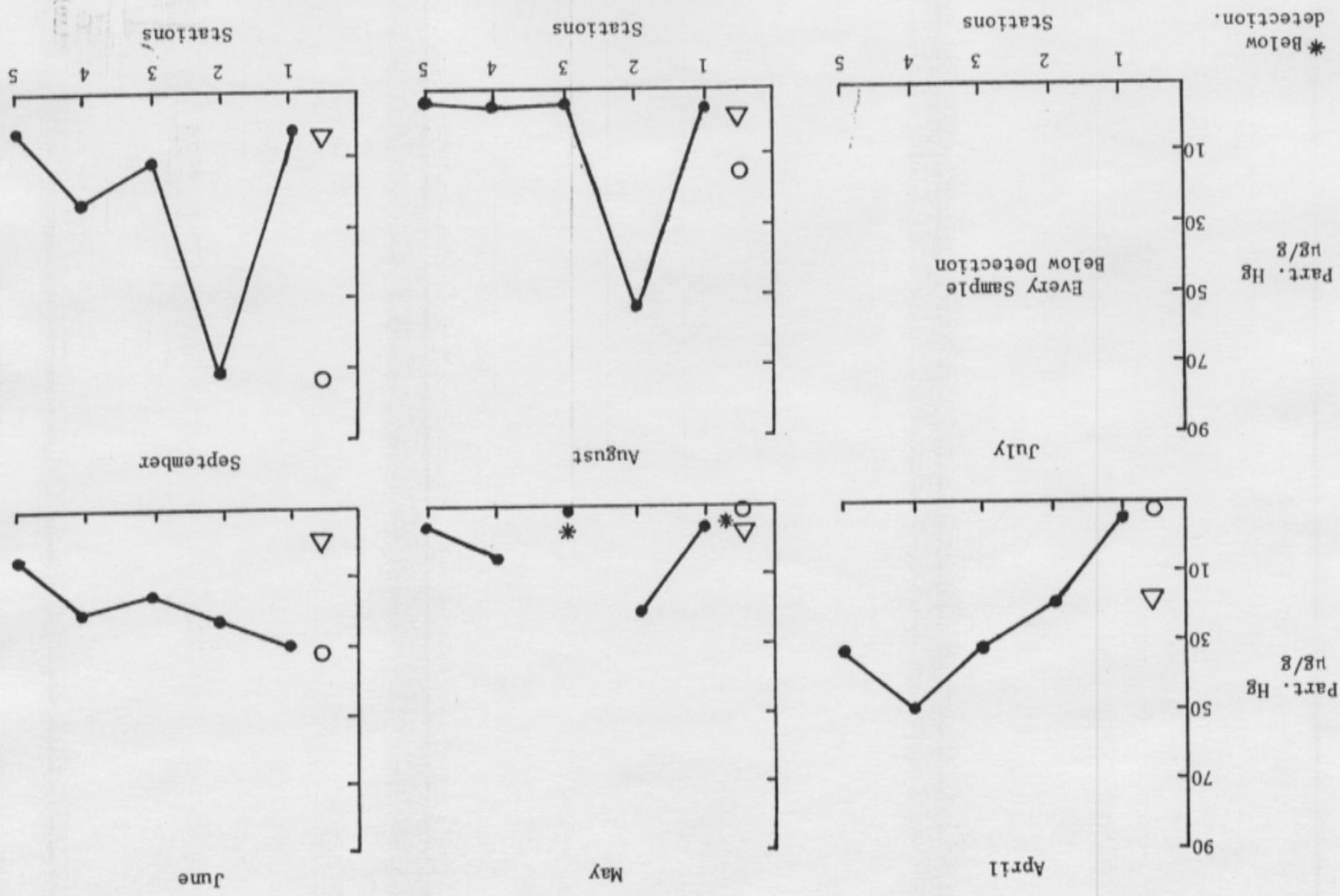
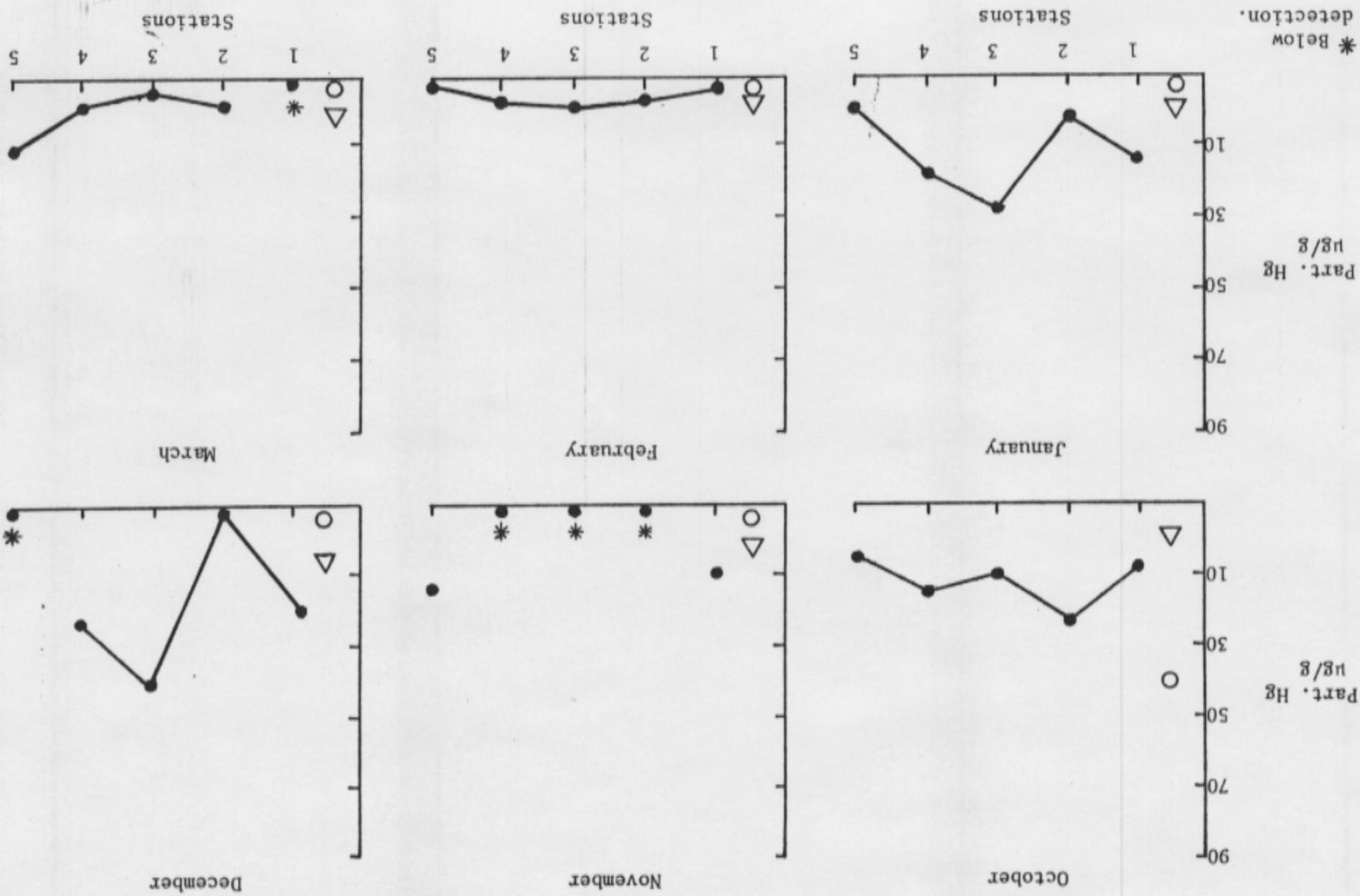
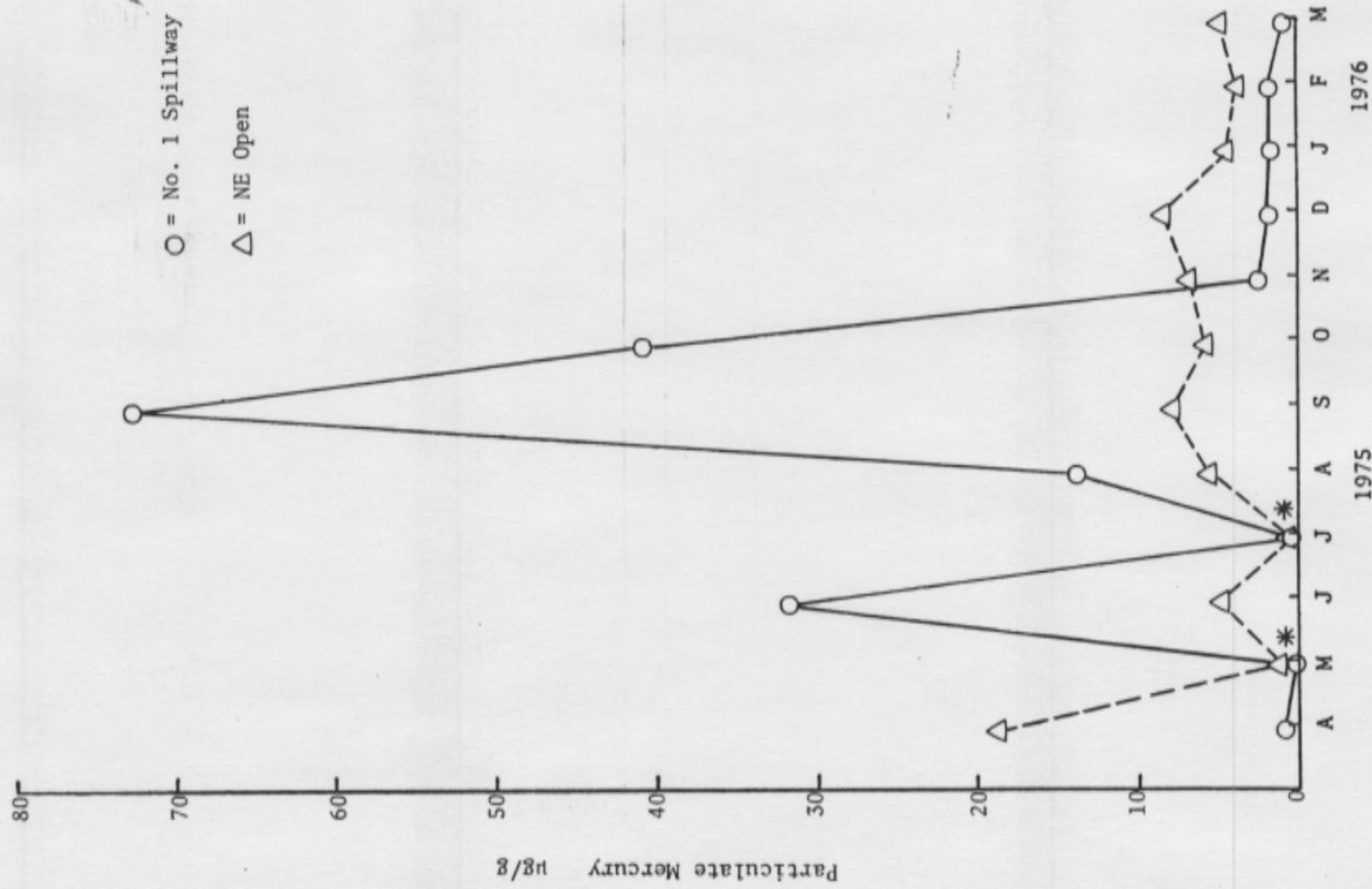


Figure 23b. Particulate mercury in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.

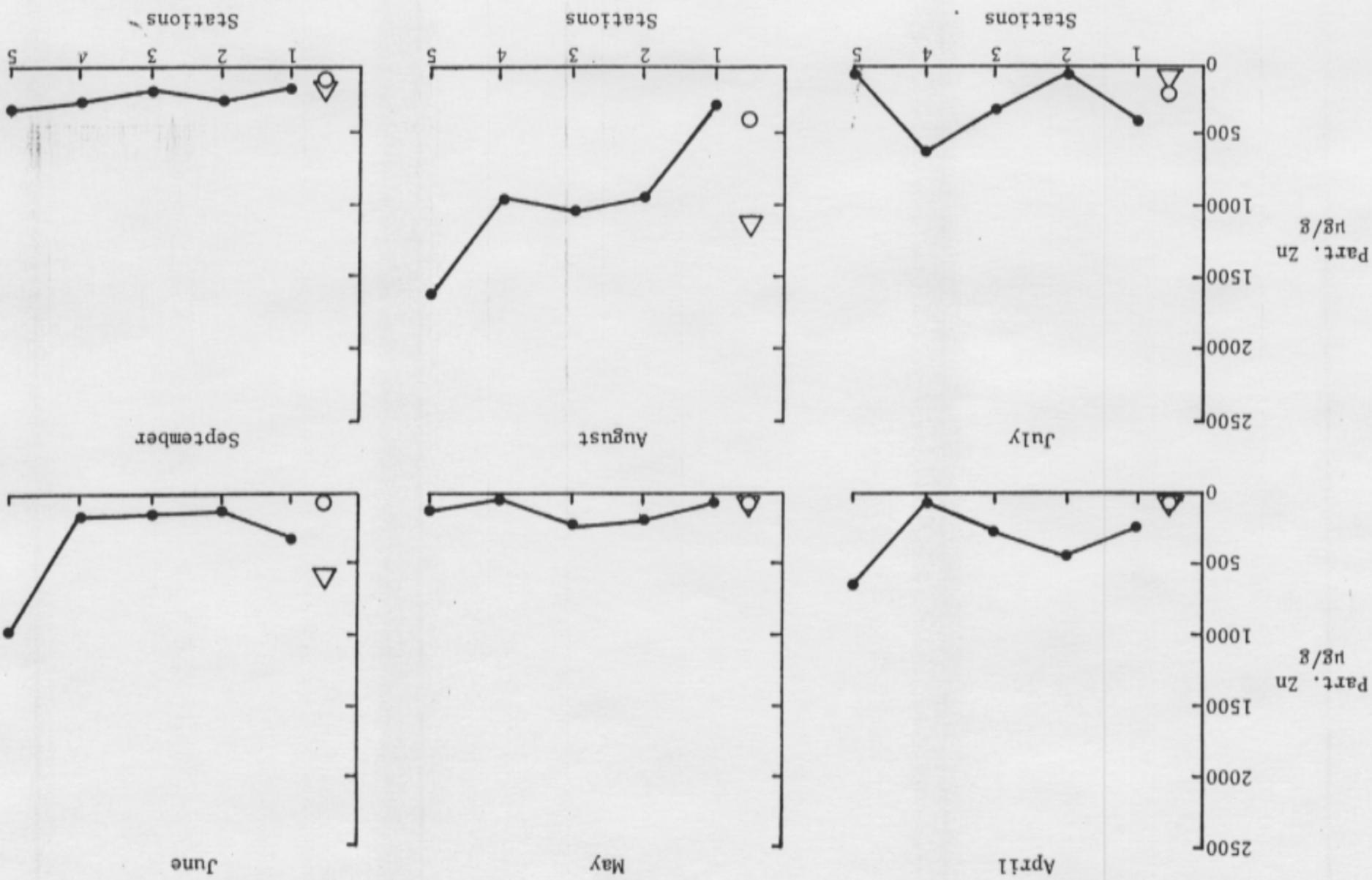




\*Below detection.

Figure 23c. Particulate mercury in the surface waters at the No. 1 Spillway and NE Open water sites at Cranney Island (April 1975 to March 1976).

Figure 24a. Particulate zinc in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from April to September 1975 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



\*Below detection.

Part. Zn  
µg/g

0 500 1000 1500 2000 2500

Part. Zn  
µg/g

0 500 1000 1500 2000 2500

Stations

January

1 2 3 4 5

1 2 3 4 5

October

(2,728)

Stations

February

1 2 3 4 5

1 2 3 4 5

November

Stations

March

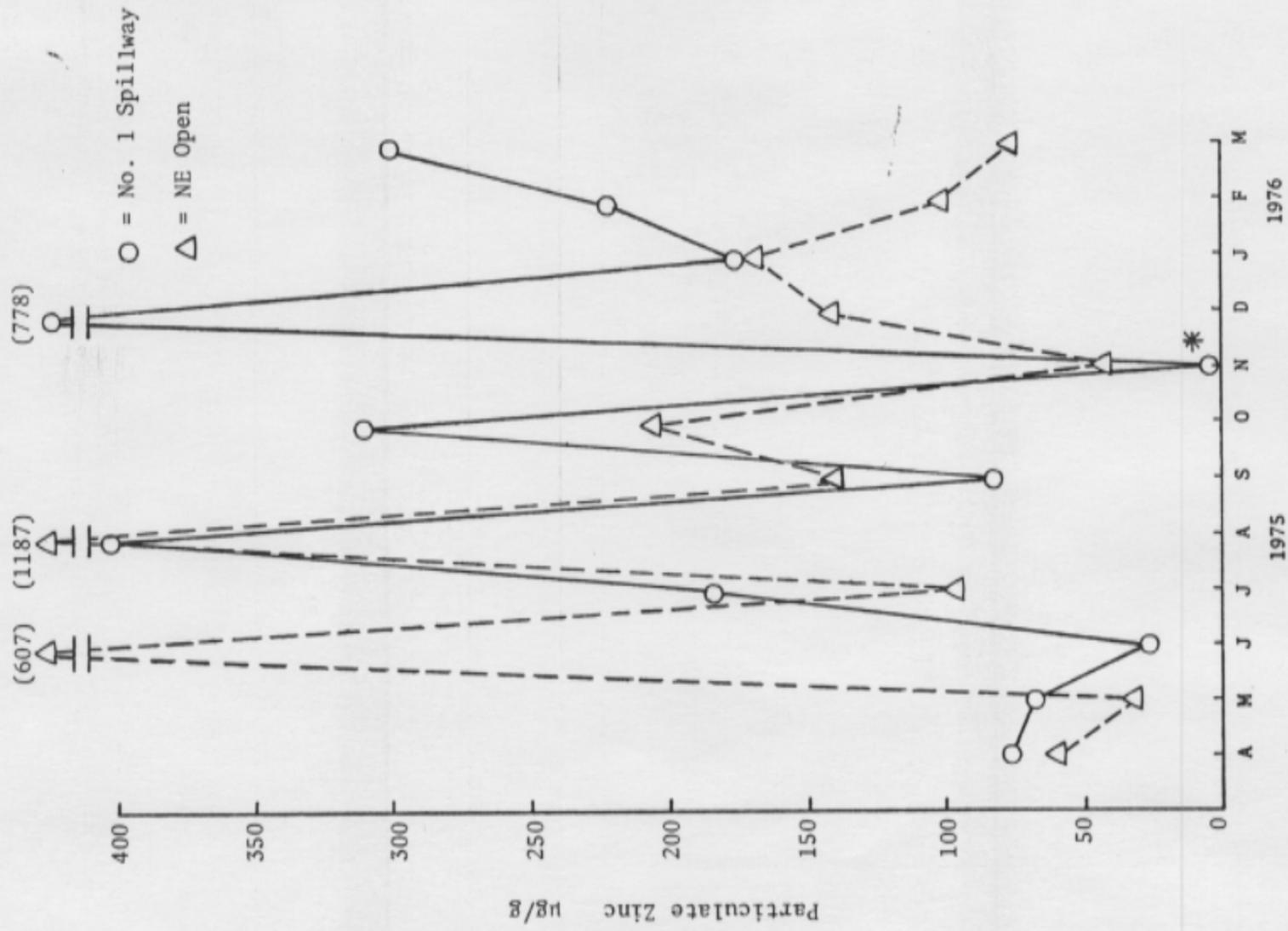
1 2 3 4 5

1 2 3 4 5

December

Figure 24b.

Particulate zinc in the surface waters at the No. 1 Spillway (○) and NE Open water (△) sites and at five stations in the spillway plume (●) from October 1975 to March 1976 at the Craney Island Disposal Area, Port of Hampton Roads, Virginia.



\* Below detection.

Figure 24c. Particulate zinc in the surface waters at the No. 1 Spillway and NE Open water sites at Craney Island (April 1975 to March 1976).

APPENDIX A

DATA FOR THE SAMPLING PROGRAM AT THE CRANEY ISLAND DREDGE MATERIAL DISPOSAL

AREA FROM DECEMBER 1973 TO MARCH 1976

<u>Table</u>	<u>Page</u>
A.1. Units for variables measured at Craney Island or obtained from the National Weather Service, Norfolk Regional Airport, Norfolk, Virginia. . . . .	128
A.2. Codes assigned to different stations and variables for statistical analysis of the data. . . . .	130
A.3. Data listing for monitoring program at Craney Island from April 1975 to March 1976. . . . .	132
A.4. Data listing for monitoring program at Craney Island from April 1975 to March 1976. . . . .	135
A.5. Data listing for monitoring program at Craney Island from April 1975 to March 1976. . . . .	138
A.6. Data listing for monitoring program at Craney Island from December 1973 to February 1975. . . . .	141
A.7. Data listing for monitoring program at Craney Island from December 1973 to February 1975. . . . .	146
A.8. Data listing for monitoring program at Craney Island from December 1973 to February 1975. . . . .	151

Table A.1. Units for variables measured at Craney Island or obtained from the National Weather Service, Norfolk Regional Airport, Norfolk, Virginia.

Variable Number <sup>1</sup>	Name	Units
A1	Date	day/month/year
A2	Station	see Table A.2
A3	Water Temperature	°C
A4	Salinity	‰
A5	pH	unitless
A6	Dissolved Oxygen	mg/liter
A7	Oxygen Saturation	%
A8	Total Suspended Solids	mg/liter
A9	Fecal Coliform	#/100 ml
A10	PO <sub>4</sub> - P	mg/liter
A11	Total Phosphorus	mg/liter
A12	NO <sub>3</sub> - N	mg/liter
A13	NO <sub>2</sub> - N	mg/liter
A14	NH <sub>4</sub> - N	mg/liter
A15	Total Kjeldahl Nitrogen	mg/liter
A16	Dissolved Cadmium	mg/liter
A17	Particulate Cadmium	µg/g
A18	Dissolved Mercury	mg/liter
A19	Particulate Mercury	µg/g
A20	Dissolved Zinc	mg/liter
A21	Particulate Zinc	µg/g
A22	Dissolved Lead	mg/liter
A23	Particulate Lead	µg/g
A24	Chlorophyll-a	mg/m <sup>3</sup> (µg/l)
A25	Dissolved Organic Carbon	mg/liter
A26	Particulate Organic Carbon	mg/liter
	Air Temperature at Craney Island	°C
	Norfolk Airport Average Daily Temperature	°C
	Wind Direction at Craney Island <sup>2</sup>	°N
	Wind Speed at Craney Island	mph
	Norfolk Airport Average Daily Wind Direction <sup>2</sup>	°N
	Norfolk Airport Average Daily Wind Speed	mph

Table A.1. Concluded

Variable Number <sup>1</sup>	Name	Units
A27	Precipitation <sup>3</sup>	inches
	Sunshine at Norfolk Airport	minutes
A28	Sunshine at Norfolk Airport <sup>4</sup>	%
	Bird Population at Craney Island	see Table A.2
	Height of Water at Craney Island No. 1 Spillway Weir	feet

<sup>1</sup> Code number assigned to variable for statistical calculations.

<sup>2</sup> Direction from which the wind was blowing (009 = East, 018 = South, 027 = West, 036 = North).

<sup>3</sup> Total four-day precipitation at the Norfolk Airport, representing summation of the previous three days and rainfall which occurred during or before the sampling time on the day of collection.

<sup>4</sup> Percent of possible total daily sunshine.

Table A.2. Codes assigned to different stations and variables for statistical analysis of the data. See Figure 2 for station locations.

<u>Station Location Code</u>	
Inside No. 1 Spillway	01
Inside No. 2 Spillway	02
Inside No. 3 Spillway	03
NE Open	04
Outside No. 1 Spillway	05
Outside No. 2 Spillway	06
Outside No. 3 Spillway	07
	1 <sup>1</sup>
<u>Stations in the Plume (from Spillway Towards Open Water)</u>	
Outside No. 1 Spillway only	12
	2
	13
	3
	14
	4
	15
	5
<u>Rehandling Basin Code</u>	
Nearest to the barge	20
First location away from barge	21
Second location away from barge	22
Third location away from barge	23
Fourth location away from barge	24
(or these were numbered across the entrance to the rehandling basin)	
<u>Dredge Pipe Code</u>	
Goethals	30
NE Dredge	31
NW Dredge	32
South Dredge	33

Table A.2. Concluded

Bird Population Within Craney Island Code	
None	01
Small	02
Medium	03
Large	04
Very Large	05

<sup>1</sup> In order to provide a linear relationship with distance in the spillway plume, these stations were assigned equal numbers (1, 2, 3, 4 and 5), representing equal distance, for use in the SCATTERGRAMS in Appendix C.

Table A.3. Data listing for monitoring program at Craney Island from April 1975 to March 1976.

Date	Time	Stn. Code	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Focal Coliform	Pg - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
290475	1104	04	041	14.41	14.41	06.86	06.47	06.99	000324	000776	0.278	0.494	0.041	0.018	0.334	0.477
290475	1104	04	041	15.12	15.65	07.67	09.61	09.61	0105	010427	0.133	0.154	0.079	0.008	0.276	0.180
290475	1104	05	041	14.11	15.01	07.01	06.81	06.73	000220	000446	0.078	0.453	0.031	0.014	0.250	0.425
290475	1104	12	041	14.63	15.87	06.91	08.03	08.93	000440	000002	0.155	0.233	0.102	0.014	0.080	0.304
290475	1104	13	041	14.54	15.99	07.12	11.33	0123	000025	000001	0.135	0.227	0.164	0.010	0.050	0.345
290475	1104	14	041	14.91	15.85	07.76	10.96	0120	000030	000000	0.041	0.173	0.195	0.007	0.070	0.393
290475	1104	15	041	15.00	15.80	07.74	11.37	0124	000023	000000	0.038	0.179	0.038	0.009	0.055	0.329
210575	0945	04	001	21.41	13.18	07.91	08.72	0107	000032	000010	0.030	0.086	0.248	0.016	0.021	0.366
210575	0945	05	041	22.39	13.63	08.41	08.82	0110	000124	000016	0.055	0.188	0.049	0.000	0.133	0.970
210575	0945	12	041	22.11	12.23	07.99	08.98	0111	000021	000004	0.034	0.081	0.032	0.002	0.031	0.545
210575	0945	13	041	21.94	12.10	07.89	09.13	0112	000028	000004	0.060	0.105	0.238	0.011	0.053	0.469
210575	0945	14	041	22.00	12.04	07.96	09.22	0113	000021	000004	0.041	0.090	0.260	0.015	0.054	0.449
210575	0945	15	041	22.08	12.12	07.95	09.21	0113	000020	000000	0.033	0.082	0.269	0.011	0.020	0.441
180675	0904	01	041	27.86	17.79	08.11	03.58	0051	000110	000010	0.058	0.983	0.001	0.009	0.087	1.041
180675	0904	04	041	24.67	17.83	07.62	06.95	0092	000023	000005	0.022	0.134	0.044	0.013	0.032	0.432
180675	0904	05	041	25.08	16.59	07.80	06.29	0084	000019	000008	0.082	0.157	0.093	0.007	0.077	1.050
180675	0904	12	041	25.03	16.51	07.72	07.90	0105	000017	000000	0.033	0.089	0.078	0.006	0.150	0.521
180675	0904	13	041	25.39	16.62	07.81	06.51	0087	000022	000002	0.019	0.076	0.053	0.004	0.100	0.553
180675	0904	14	041	25.40	16.55	07.80	06.25	0084	000017	000001	0.027	0.075	0.068	0.005	0.104	0.504
180675	0904	15	041	25.03	16.50	07.73	07.07	0094	000019	000000	0.031	0.079	0.081	0.002	0.100	0.395
140775	0930	01	041	24.87	11.39	07.71	05.42	0070	000108	000010	0.030	0.720	0.169	0.009	0.790	3.761
140775	0930	04	041	25.41	16.52	07.22	05.01	0067	000030	000002	0.065	0.120	0.040	0.010	0.143	0.360
140775	0930	05	041	24.93	11.95	07.53	04.03	0052	000038	000010	0.470	0.750	0.064	0.015	0.814	1.776
140775	0930	12	041	25.41	15.05	07.17	03.39	0045	000030	000017	0.157	0.401	0.051	0.011	0.550	1.325
140775	0930	13	041	25.19	15.02	06.91	03.31	0044	000032	000007	0.172	0.349	0.048	0.009	0.400	0.913
140775	0930	14	041	25.24	15.94	07.42	03.90	0052	000052	000010	0.115	0.269	0.032	0.010	0.317	0.669
140775	0930	15	041	28.76	15.41	08.48	09.96	0141	000080	000000	0.557	0.901	0.059	0.014	0.434	2.264
040875	1000	04	041	27.83	16.02	08.29	08.56	0120	000017	000000	0.024	0.110	0.053	0.003	0.448	0.448

Table A.3. Continued.

Date	Time	Stn- Cton Code	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NO <sub>3</sub> - N	NH <sub>4</sub> - N	TKN
040875	10P	05	001	28.40	15.40	08.44	06.41	0090	00066	00002	0.517	0.793	0.062	0.000	0.000	0.000	1.106
040875	10P	12	001	28.26	14.15	08.32	09.44	0131	00001	00000	0.056	0.096	0.019	0.002	0.000	0.000	0.721
040875	10P	13	001	28.20	14.18	08.31	09.40	0131	00001	00000	0.052	0.079	0.036	0.000	0.000	0.000	0.753
040875	10P	14	001	28.24	14.12	08.36	09.56	0133	00010	00000	0.030	0.081	0.055	0.000	0.000	0.000	0.825
040875	10P	15	001	28.31	14.11	08.35	09.69	0135	00010	00000	0.026	0.078	0.028	0.003	0.000	0.000	0.929
030975	09P	01	001	23.21	20.83	08.41	07.25	0096	00008	00005	0.390	0.751	0.073	0.000	0.000	1.270	3.211
030975	09P	04	001	24.62	18.62	07.72	06.69	0090	00013	00015	0.085	0.156	0.042	0.000	0.000	0.185	0.352
030975	09P	05	001	23.26	17.98	07.58	05.47	0071	00020	00030	0.063	0.151	0.056	0.000	0.000	0.740	1.794
030975	09P	12	001	23.28	17.96	07.55	05.94	0077	00015	00027	0.056	0.140	0.080	0.000	0.000	0.302	0.441
030975	09P	13	001	23.28	17.97	07.57	06.48	0084	00020	00014	0.055	0.163	0.074	0.000	0.000	0.383	0.905
030975	09P	14	001	23.48	17.94	07.67	06.69	0087	00021	00017	0.044	0.134	0.077	0.000	0.000	0.824	0.000
030975	09P	15	001	23.38	17.89	07.69	04.43	0058	00000	00011	0.052	0.182	0.062	0.000	0.000	0.391	0.924
011075	09P	01	001	22.89	18.67	08.73	12.17	0158	00015	00009	0.014	0.233	0.029	0.000	0.000	0.000	0.117
011075	09P	04	001	23.25	12.19	07.50	07.57	0096	00010	00011	0.030	0.079	0.147	0.000	0.000	0.233	0.000
011075	09P	05	001	22.62	15.92	08.70	09.50	0121	00003	00074	0.014	0.055	0.030	0.000	0.000	0.000	0.000
011075	09P	12	001	23.01	06.96	07.77	08.42	0102	00000	00002	0.022	0.173	0.297	0.000	0.000	0.000	0.237
011075	09P	13	001	23.06	06.86	07.70	08.88	0108	00011	00001	0.012	0.052	0.257	0.000	0.000	0.000	0.257
011075	09P	14	001	23.04	06.80	07.60	08.90	0109	00011	00015	0.024	0.043	0.252	0.000	0.000	0.000	0.443
011075	09P	15	001	23.11	06.76	07.70	08.88	0108	00010	00001	0.017	0.045	0.250	0.000	0.000	0.000	0.449
121175	0830	01	001	14.97	16.57	08.05	07.90	0087	00021	00000	0.004	0.246	0.005	0.000	0.000	0.000	1.352
121175	0830	04	001	17.23	16.44	07.90	07.89	0091	00000	00008	0.082	0.130	0.186	0.000	0.000	0.000	1.197
121175	0830	05	001	15.52	16.62	08.68	10.45	0116	00047	00004	0.027	0.248	0.052	0.000	0.000	0.000	1.155
121175	0830	12	001	16.50	14.69	07.58	07.28	0082	00017	00044	0.029	0.108	0.190	0.000	0.000	0.000	0.586
121175	0830	13	001	16.67	14.64	08.00	08.10	0091	00015	00036	0.036	0.089	0.170	0.000	0.000	0.000	0.553
121175	0830	14	001	16.92	14.59	08.00	07.84	0089	00016	00029	0.035	0.105	0.161	0.000	0.000	0.000	0.570
121175	0830	15	001	17.13	14.50	07.97	08.34	0087	00016	00010	0.035	0.065	0.178	0.000	0.000	0.000	0.116
051275	0900	01	001	05.79	16.74	08.24	10.69	0095	00004	00021	0.017	0.146	0.217	0.000	0.000	0.000	0.592
051275	0900	04	001	10.10	15.62	07.80	09.98	0098	00023	00010	0.045	0.161	0.309	0.000	0.000	0.000	0.165
051275	0900	05	001	06.39	16.22	08.20	11.00	0100	00040	00020	0.021	0.123	0.206	0.000	0.000	0.000	0.603

Table A.3. Concluded.

Date	Time	Stn- Eton Card	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TEN
051275	0900	12	08.30	15.42	08.00	10.74	0101	000073	00052	0.017	0.102	0.240	0.027	0.023	0.000
051275	0900	13	08.70	15.46	08.00	10.91	0104	000076	00005	0.037	0.091	0.220	0.025	0.022	0.000
051275	0900	14	08.35	16.22	08.00	10.59	0100	000018	00006	0.031	0.065	0.192	0.020	0.020	0.000
051275	0900	15	08.95	15.16	07.90	10.17	0097	000020	00001	0.045	0.065	0.245	0.024	0.012	0.000
160176	0930	01	03.80	13.15	08.05	10.69	0089	000092	00004	0.000	0.221	0.200	0.422	0.072	0.000
160176	0930	05	03.76	13.23	08.32	10.94	0091	000079	00000	0.011	0.258	0.228	0.357	0.072	1.001
160176	0930	12	04.67	12.80	08.05	12.13	0103	000022	00019	0.006	0.194	0.275	0.057	0.020	0.000
160176	0930	13	04.81	12.76	07.92	12.04	0102	000017	00003	0.003	0.175	0.270	0.014	0.000	0.000
160176	0930	14	04.71	12.71	08.07	12.31	0104	000021	00003	0.001	0.079	0.228	0.035	0.012	0.000
160176	0930	15	04.73	12.80	08.03	11.24	0095	000023	00003	0.002	0.068	0.260	0.040	0.014	0.000
060276	0900	01	06.00	10.37	08.70	10.85	0093	000190	00014	0.014	0.304	0.228	0.236	0.013	0.000
060276	0900	04	05.05	09.32	08.25	12.55	0105	000025	00005	0.008	0.081	0.191	0.000	0.000	0.000
060276	0900	05	06.55	10.32	08.70	11.01	0096	000137	00019	0.015	0.362	0.231	0.000	0.000	0.000
060276	0900	12	05.68	09.92	08.50	12.15	0103	000052	00011	0.019	0.210	0.261	0.000	0.000	0.000
060276	0900	13	05.70	09.89	08.35	11.70	0100	000069	00019	0.011	0.232	0.218	0.000	0.000	0.000
060276	0900	14	05.66	09.93	08.46	12.06	0103	000062	00008	0.016	0.254	0.222	0.000	0.000	0.000
060276	0900	15	05.49	09.76	08.30	11.01	0100	000022	00009	0.004	0.161	0.251	0.000	0.000	0.000
060376	0900	01	14.21	16.35	08.35	04.86	0052	000142	00051	0.011	0.413	0.319	0.283	0.025	0.000
060376	0900	04	12.80	15.18	07.35	09.78	0099	000014	00000	0.002	0.067	0.135	0.000	0.000	0.000
060376	0900	05	12.68	16.00	08.10	07.76	0081	000055	00057	0.018	0.210	0.154	0.002	0.000	0.000
060376	0900	12	12.10	15.73	07.97	09.08	0102	000031	00016	0.003	0.127	0.132	0.029	0.001	0.000
060376	0900	13	12.15	15.80	07.95	09.99	0103	000023	00010	0.010	0.142	0.111	0.024	0.000	0.000
060376	0900	14	12.25	15.85	07.70	08.79	0091	000052	00023	0.013	0.141	0.149	0.001	0.000	0.000
060376	0900	15	12.32	15.75	07.75	09.55	0099	000035	00006	0.011	0.117	0.123	0.000	0.000	0.000





Table A.4. Concluded.

Date	Time	Sta- tion Code	Card Code	Diox Cd	Part Cd	Diox Hg	Part Hg	Diox Zn	Part Zn	Diox Pb	Part Pb	Chlorophyll a	DOC	POC
051275	0900	12	002	0003	0001	0006	01.41	0005	391.7	0005	0010	03.84	012.2	001.3
051275	0900	13	002	0005	0001	0007	42.28	0005	005.0	0005	0010	03.75	003.9	000.2
051275	0900	14	002	0005	0001	0001	24.35	0005	160.5	0005	0010	02.93	007.8	001.0
051275	0900	15	002	0005	0001	0005	00.50	0005	089.0	0005	0010	04.69	007.9	000.6
160176	0930	01	002	0001	0001	0003	01.84	0002	176.9	0005	0010	34.42	007.3	000.7
160176	0930	04	002	0001	0001	0002	04.51	0005	169.0	0005	0010	08.62	005.4	000.2
160176	0930	05	002	0003	0001	0002	12.91	0001	694.3	0005	0010	31.05	002.2	000.1
160176	0930	12	002	0005	0001	0006	06.31	0005	253.1	0005	0010	21.62	001.5	000.2
160176	0930	13	002	0001	0001	0002	26.54	0001	120.6	0005	0010	08.68	000.4	000.1
160176	0930	14	002	0005	0001	0003	18.39	0005	428.5	0005	0010	16.32	000.8	000.2
160176	0930	15	002	0005	0001	0004	05.49	0005	096.1	0005	0010	11.73	003.5	000.3
060276	0900	01	002	0001	0001	0007	01.93	0003	221.8	0005	0010	22.07	022.4	001.4
060276	0900	04	002	0002	0001	0002	04.01	0005	101.3	0005	0010	17.82	003.7	000.2
060276	0900	05	002	0002	0001	0003	02.41	0003	231.2	0005	0010	35.29	009.0	000.7
060276	0900	12	002	0003	0001	0003	04.83	0001	499.4	0005	0010	30.73	007.1	000.6
060276	0900	13	002	0001	0001	0002	06.03	0005	144.3	0005	0010	24.74	003.5	000.3
060276	0900	14	002	0005	0001	0003	05.11	0001	089.9	0005	0010	15.42	008.7	000.4
060276	0900	15	002	0001	0001	0002	02.03	0005	122.2	0005	0010	23.32	003.5	000.3
060376	0900	01	002	0001	0001	0001	01.11	0005	301.4	0005	0010	20.92	019.1	002.1
060376	0900	04	002	0001	0001	0001	05.03	0005	076.3	0005	0010	17.31	004.5	000.2
060376	0900	05	002	0005	0001	0002	00.50	0005	186.4	0005	0010	20.70	008.2	000.7
060376	0900	12	002	0003	0001	0004	05.41	0005	223.4	0005	0010	34.24	006.4	000.8
060376	0900	13	002	0002	0001	0001	03.01	0005	501.4	0005	0010	25.22	004.1	000.1
060376	0900	14	002	0001	0001	0001	06.11	0005	330.8	0005	0010	14.77	003.9	000.3
060376	0900	15	002	0001	0001	0003	11.31	0005	090.4	0005	0010	24.42	005.2	000.5

Table A.5. Data listing for monitoring program at Craney Island from April 1975 to March 1976.

Date	Time	Station Code	Air Temperature		Craney Island		Norfolk Airport		Norfolk Airport		Craney Island	
			Card	Craney Island	Mind Direction	Speed	Mind Direction	Speed	Mind Direction	Speed	Mind Direction	Speed
290475	1100	01	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	04	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	05	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	12	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	13	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	14	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
290475	1100	15	003	13.11	013.3	00009	009.5	00005	009.6	00.13	00000	00000
210575	0945	01	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	04	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	05	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	12	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	13	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	14	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
210575	0945	15	003	21.75	023.9	00018	006.5	00021	006.4	00.00	00046	00096
180675	0900	01	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	04	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	05	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	12	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	13	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	14	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
180675	0900	15	003	25.50	027.8	00000	000.0	00017	005.6	00.57	00042	00073
140775	0930	01	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	04	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	05	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	12	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	13	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	14	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
140775	0930	15	003	26.63	026.1	00023	013.0	00018	009.0	03.15	00002	00002
040875	1000	01	003	28.03	030.0	00027	001.0	00026	000.3	00.00	00004	00004

Table A.5. Continued.

Date	Time	Sta- tion Code	Card Code	Air Temperature		Craney Island		Norfolk Island		Norfolk Airport		Norfolk Airport		Craney Island	
				Wind Direction	Wind Speed										
040875	1000	05	003	28.03	230°	003	28.03	003	28.03	003	28.03	003	28.03	003	28.03
040875	1000	13	003	28.03	230°	003	28.03	003	28.03	003	28.03	003	28.03	003	28.03
040875	1000	14	003	28.03	230°	003	28.03	003	28.03	003	28.03	003	28.03	003	28.03
040875	1000	15	003	28.03	230°	003	28.03	003	28.03	003	28.03	003	28.03	003	28.03
030975	0900	01	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	04	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	05	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	12	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	13	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	14	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
030975	0900	15	003	23.40	222.8	003	23.40	003	23.40	003	23.40	003	23.40	003	23.40
011075	0900	04	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
011075	0900	05	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
011075	0900	12	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
011075	0900	13	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
011075	0900	14	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
011075	0900	15	003	24.30	021.7	003	24.30	003	24.30	003	24.30	003	24.30	003	24.30
121175	0830	01	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	04	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	05	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	12	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	13	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	14	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
121175	0830	15	003	20.04	018.3	003	20.04	003	20.04	003	20.04	003	20.04	003	20.04
051275	0900	01	003	09.89	000.0	003	09.89	003	09.89	003	09.89	003	09.89	003	09.89
051275	0900	04	003	09.89	000.0	003	09.89	003	09.89	003	09.89	003	09.89	003	09.89
051275	0900	05	003	09.89	000.0	003	09.89	003	09.89	003	09.89	003	09.89	003	09.89

Craney Island  
BLD Water  
Population Height

Norfolk Airport  
Sunshine  
Population (%)

Norfolk Airport  
Precipit-  
Sunshine

Norfolk Airport  
Wind  
Direction

Norfolk Airport  
Wind  
Speed

Craney Island  
Wind  
Direction

Craney Island  
Wind  
Speed

Norfolk  
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Direction

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Speed

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Norfolk  
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Craney Island  
Wind  
Direction

Craney Island  
Wind  
Speed

Craney Island  
Wind  
Direction

Craney Island  
Wind  
Speed



Table A.6. Data listing for monitoring program at Craney Island from December 1973 to February 1975. See Table A.2 for station codes. Oxygen saturations were calculated with functional relationship developed by Weiss (1970).

Date	Time	Station Code	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
281273	1444	041	02	12.80	15.77	07.02	09.60	0100	000065	000000	0.025	0.107	0.465	0.086	03.68	
281273	1448	041	04	08.15	11.42	07.96	09.12	0084	000034	000000	0.045	0.063	0.263	0.011	00.17	
281273	1448	041	02	09.30	14.25	08.06	08.10	0077	191000	000000	0.348	0.649	0.242	0.013	04.07	
281273	1110	041	01	08.50	19.53	07.59	00.00	0000	019600	00150	0.103	0.138	0.296	0.017	08.16	
281273	1100	041	00	09.00	15.84	07.51	07.06	0077	003000	00250	0.013	0.254	0.069	0.010	00.97	
180174	1125	001	00	10.45	13.05	07.50	07.90	0077	015600	00200	0.539	0.067	0.189	0.010	08.42	
180174	0944	001	02	05.50	15.98	08.15	08.20	0072	002535	00100	0.095	1.369	0.064	0.105	05.27	
180174	1030	001	04	07.00	13.00	07.71	11.00	0106	000037	000000	0.061	0.096	0.133	0.012	04.53	
180174	0930	001	02	12.20	08.26	09.50	0097	026000	000000	0.011	0.196	0.108	0.000	03.33		
180174	1010	001	01	07.40	25.40	07.30	02.00	0020	043500	00100	0.046	0.066	0.024	0.002	14.55	
180174	1130	001	00	07.50	20.19	07.69	10.40	0099	045000	000000	0.101	0.190	0.067	0.019	02.15	
250174	1145	001	02	06.94	12.56	08.28	10.70	0096	000202	00020	0.105	0.366	0.190	0.200	13.76	
250174	1145	001	04	07.62	13.08	07.70	10.40	0095	000017	000000	0.069	0.169	0.018	0.013	00.94	
250174	1045	001	00	09.95	15.96	07.90	03.40	0033	050000	00100	0.570	1.521	0.017	0.021	25.04	
250174	1125	001	02	08.70	14.28	08.22	06.30	0059	030000	00100	0.221	1.110	0.015	0.013	59.94	
080274	1030	001	04	06.70	14.71	07.99	10.00	0097	000029	000000	0.023	0.092	0.014	0.018	00.44	
080274	1010	001	01	07.05	10.27	07.60	02.20	0020	067900	00240	0.105	4.133	0.072	0.062	04.52	
220274	1030	001	02	17.05	16.52	09.20	08.20	0094	003430	00020	0.214	0.246	0.052	0.011	07.72	
220274	1115	001	04	12.52	15.09	08.02	10.60	0110	000055	000000	0.014	0.113	0.011	0.001	01.55	
220274	1105	001	02	13.65	12.06	08.36	03.60	0030	007000	000000	0.010	0.126	0.055	0.010	02.17	
220274	1130	001	01	12.00	20.02	07.04	04.20	0045	069000	000000	0.051	0.140	0.040	0.002	00.59	
220274	0950	001	02	10.45	14.78	08.09	10.00	0090	000012	000000	0.052	0.152	0.335	0.063	00.37	
220274	1050	001	04	07.05	17.50	08.32	11.40	0106	000017	000000	0.023	0.127	0.004	0.004	00.23	
220274	1010	001	02	08.40	15.01	08.33	04.40	0042	005200	000000	0.004	1.245	0.130	0.213	00.56	
220274	1035	001	01	08.05	19.09	08.32	10.90	0105	000043	000000	0.000	0.000	0.019	0.261	00.05	00.20
120474	1110	001	02	09.90	12.06	08.10	10.00	0096	000570	00200	0.034	0.069	0.170	0.011	01.25	
120474	1145	001	04	10.55	11.71	08.10	09.00	0095	000003	000000	0.055	0.071	0.049	0.004	00.50	

Table A.6. Continued.

Date	Time	Sta- tion Code	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
120474	1124	441	441	10.75	10.45	08.22	08.80	0085	001194	00000	0.465	0.494	0.003	0.005	00.82	
118474	1235	441	441	12.84	09.41	08.19	09.44	0094	000008	00000	0.047	0.071	0.043	0.003	00.11	
118474	1235	441	441	12.84	09.41	08.19	09.44	0094	000008	00000	0.264	0.283	0.018	0.003	01.42	
118474	1134	441	441	13.04	11.43	08.49	06.80	0069	140004	00100	0.357	2.593	0.412	0.015	01.45	
26474	1125	441	441	15.24	14.31	08.71	11.51	0125	000081	00000	0.010	0.174	0.308	0.275	00.10	
26474	1135	441	441	15.05	14.77	08.34	10.80	0118	020234	00000	0.045	0.058	0.160	0.004	00.05	
26474	1134	441	441	14.25	08.54	08.54	03.60	0040	053002	00000	0.016	0.165	0.164	0.073	04.60	
18574	1413	441	441	20.60	14.60	08.03	09.80	0119	000189	00000	0.109	0.184	0.069	0.015	00.06	
18574	1434	441	441	18.60	16.37	08.18	10.20	0120	000005	00000	0.012	0.426	0.130	0.003	00.03	
18574	1115	441	441	20.00	15.43	07.09	01.80	0022	036003	00000	0.012	0.139	0.111	0.037	01.99	
170574	1440	441	441	26.20	16.16	08.07	08.40	0114	000192	00000	0.042	0.105	0.057	0.018	00.38	
170574	1415	441	441	22.90	13.66	08.13	09.00	0114	000018	00000	0.047	0.052	0.200	0.005	00.12	
240574	1145	441	441	26.40	17.93	08.53	07.60	0105	000087	00000	0.040	0.176	0.065	0.008	00.11	
240574	1124	441	441	23.00	15.74	08.18	07.00	0091	000254	00000	0.025	0.122	0.078	0.003	00.07	
140674	1035	441	441	24.24	20.17	08.73	07.40	0099	000211	00000	0.009	0.058	0.004	0.004	00.04	
140674	1045	441	441	23.03	15.93	08.73	07.40	0096	000221	00000	0.009	0.014	0.063	0.005	00.01	
140674	1110	441	441	23.04	18.50	07.04	04.80	0063	001403	00000	0.033	0.043	0.054	0.023	02.95	
270674	0945	441	441	21.00	17.75	08.15	06.20	0079	000062	00000	0.000	0.115	0.106	0.016	00.19	
270674	0945	441	441	20.20	14.97	08.95	09.40	0114	000138	00000	0.025	0.274	0.099	0.002	00.74	
270674	1145	441	441	21.04	18.45	08.20	08.20	0104	000016	00000	0.090	0.095	0.104	0.005	00.15	
270674	1134	441	441	20.20	14.97	08.95	09.40	0114	000138	00000	0.025	0.274	0.099	0.002	00.74	
270674	1140	441	441	21.30	14.47	08.40	06.80	0084	000018	00000	0.010	0.088	0.096	0.014	00.34	
270674	0955	441	441	21.60	16.06	08.00	01.00	0013	005002	00100	0.003	0.043	0.054	0.023	02.95	
270674	1010	441	441	22.40	14.09	08.15	02.00	0025	430003	00100	0.091	1.206	0.115	0.003	01.55	
270674	1134	441	441	21.00	17.02	07.51	02.20	0020	300202	00000	0.024	0.399	0.067	0.007	01.81	
270674	1234	441	441	21.00	15.99	08.07	01.20	0015	110002	00000	0.030	0.054	0.059	0.016	02.44	
270674	1155	441	441	21.70	18.57	07.79	05.40	0069	092002	00200	0.071	0.083	0.127	0.020	01.56	
280674	0930	441	441	19.90	14.04	08.50	09.00	0108	000206	00000	0.051	0.444	0.102	0.002	00.04	
280674	1015	441	441	21.50	20.40	08.10	07.00	0100	000219	00000	0.049	0.110	0.107	0.010	00.29	

Table A.6. Continued.

Date	Time	Sta- Eton Code	Curd Code	Temp	Sol	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	ML <sub>g</sub> - N	TSS
28674	1130	02	001	19.90	13.10	08.60	09.30	0111	000075	00000	0.022	0.442	0.071	0.001	0.006	0.006
28674	1210	04	001	20.90	14.64	08.11	09.80	0123	000026	00000	0.024	0.128	0.098	0.003	0.014	0.014
28674	1330	01	001	20.50	14.20	07.85	01.00	0022	000000	00000	0.020	1.917	0.097	0.016	0.443	0.443
28674	1400	01	001	20.50	17.10	07.49	01.40	0017	004000	00100	0.022	1.730	0.071	0.003	0.440	0.440
28674	1430	03	001	20.00	17.29	07.45	01.40	0017	020000	00100	0.700	1.654	0.094	0.005	0.118	0.118
06074	1120	01	001	25.23	21.12	07.09	00.50	0007	120000	00000	0.002	0.007	0.727	0.013	0.007	0.007
06074	1415	02	001	24.02	15.20	08.20	05.40	0070	000117	00000	0.000	0.245	0.006	0.001	0.001	0.001
06074	1415	04	001	24.21	19.48	07.79	06.10	0006	000092	00001	0.000	0.100	0.508	0.030	0.002	0.002
18074	1025	01	001	23.10	15.60	08.40	06.14	0079	000075	00010	0.340	2.071	0.039	0.027	0.027	0.027
18074	1121	04	001	24.45	19.56	07.96	07.57	0102	000059	00000	0.112	1.039	0.141	0.011	0.011	0.011
18074	1152	01	001	24.12	15.64	08.45	08.01	0115	000003	00055	0.192	1.979	0.027	0.019	0.019	0.019
18074	1220	04	001	24.00	17.29	08.01	07.24	0097	000060	00000	0.262	0.404	0.134	0.018	0.018	0.018
25074	1115	01	001	16.44	14.51	08.35	09.75	0109	000090	00006	0.163	2.220	0.000	0.000	0.000	0.000
25074	1142	04	001	19.35	14.78	07.52	11.30	0134	000051	00000	0.196	0.000	0.000	0.000	0.000	0.000
25074	1212	01	001	17.79	14.55	08.30	10.69	0123	000054	00013	0.212	0.000	0.000	0.000	0.000	0.000
25074	1230	04	001	19.35	15.07	07.04	09.71	0116	000026	00002	0.161	0.000	0.000	0.000	0.000	0.000
161074	1122	01	001	23.09	16.91	08.53	10.10	0132	000000	00011	0.067	0.030	0.008	0.009	0.009	0.009
161074	1240	04	001	20.70	20.72	08.02	11.30	0143	000040	00003	0.100	0.211	0.007	0.012	0.012	0.012
161074	1220	01	001	23.65	17.67	08.49	09.04	0118	000092	00019	0.069	0.010	0.002	0.008	0.008	0.008
161074	1245	04	001	20.75	20.74	08.05	11.36	0144	000056	00006	0.077	0.292	0.029	0.012	0.012	0.012
251074	1205	01	001	17.60	16.00	08.54	12.10	0142	000105	00075	0.050	0.257	0.012	0.011	0.011	0.011
251074	1232	04	001	15.70	19.79	08.13	09.24	0105	000060	00002	0.059	0.214	0.295	0.015	0.010	0.010
251074	1253	01	001	17.95	16.76	08.75	10.04	0117	000135	00013	0.040	0.007	0.014	0.014	0.014	0.014
251074	1314	04	001	17.21	19.05	08.12	09.02	0146	000043	00000	0.053	0.126	0.256	0.013	0.012	0.012
331074	1425	01	001	20.25	17.20	08.91	08.60	0105	000090	00004	0.052	0.167	0.006	0.003	0.003	0.003

Table A.6. Continued.

Date	Time	Station Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
201274	1445	041	17.39	21.80	08.19	08.72	08.72	0164	000079	000000	0.243	0.131	0.009	00.07	01.16
201274	1445	041	20.31	17.09	08.87	11.00	0136	000014	000000	0.047	0.169	0.017	0.003	00.04	03.49
201274	1425	01	17.19	12.34	08.62	07.95	00089	000013	000039	0.086	0.445	0.409	0.011	00.03	03.00
201274	1451	041	16.04	17.60	08.13	07.95	00091	000073	000005	0.070	0.145	0.073	0.007	00.02	01.92
201274	1110	041	16.50	12.01	08.61	07.46	00082	000035	000000	0.000	0.428	0.094	0.007	00.01	03.25
201274	1132	04	16.99	19.13	08.10	07.54	00088	000068	000014	0.030	0.128	0.162	0.008	00.02	01.94
201274	1444	01	12.02	13.65	08.59	11.90	0123	000062	000000	0.049	0.126	0.060	0.006	00.13	04.84
201274	1425	01	12.64	14.92	07.23	08.06	00092	000029	000002	0.023	0.049	0.192	0.013	00.07	02.42
201274	1445	01	13.39	13.26	09.00	10.47	0109	000032	000030	0.040	0.112	0.018	0.016	00.07	04.30
201274	1110	041	12.61	16.16	07.10	08.06	00092	000042	000001	0.024	0.056	0.191	0.010	00.00	02.27
201274	1020	01	03.64	14.25	08.73	10.36	00086	000030	000070	0.032	0.179	0.009	0.010	00.13	05.82
201274	1445	04	09.19	17.91	07.08	06.95	00068	000045	000001	0.029	0.008	0.228	0.007	00.06	01.90
201274	1110	041	04.00	14.00	08.90	10.06	00085	000044	000050	0.031	0.218	0.091	0.007	00.00	04.20
201274	1135	04	09.15	15.82	07.69	07.13	00069	000014	000004	0.029	0.094	0.230	0.010	00.00	01.20
201274	1125	01	05.40	10.24	08.39	08.02	00075	000032	000020	0.035	0.170	0.057	0.005	00.30	06.13
201274	1155	04	06.60	10.65	06.70	08.03	00074	000070	000003	0.026	0.000	0.190	0.010	00.11	01.22
201274	1225	01	05.95	11.03	08.49	08.96	00077	000046	000045	0.013	0.110	0.051	0.007	00.26	05.45
201274	1245	04	06.22	19.14	07.50	07.91	00073	000072	000002	0.024	0.052	0.179	0.012	00.09	01.06
201274	1440	01	06.18	12.23	08.20	09.65	00084	000022	000045	0.067	0.326	1.902	0.024	01.55	06.36
201274	1110	041	06.63	16.30	07.01	09.10	00083	000053	000002	0.053	0.100	0.577	0.010	00.10	02.43
201274	1150	01	06.62	12.69	08.41	10.10	00090	000064	000035	0.067	0.246	0.348	0.027	01.70	07.92
201274	1200	04	07.20	17.02	08.77	00082	000073	000000	0.000	0.000	1.201	0.011	00.00	02.29	
201274	1205	04	06.64	16.45	07.92	08.95	00081	000054	000004	0.147	0.190		0.012	00.00	01.05
201274	1123	01	06.61	14.03	08.42	09.42	00085	000096	000090	0.101	0.105	1.924	0.030	00.37	07.45
201274	1201	04	07.72	15.14	07.93	07.91	00073	000063	000006	0.000	0.070	3.001	0.015	00.12	01.61
201274	1210	01	06.76	15.02	08.47	09.06	00082	000234	000129	0.004	0.216	2.032	0.016	00.40	09.92
201274	1240	04	07.60	13.93	07.96	08.09	00074	000071	000002	0.066	0.099	1.071	0.012	00.09	02.07
201274	1453	05	04.00	15.06	08.20	10.14	00087	000025	000076	0.069	0.260	0.034	0.053	00.40	
201274	1057	01	03.20	15.31	08.20	10.11	00084	000201	000070	0.060	0.249	0.028	0.059	00.36	03.35

Table A.6. Concluded.

Date	Time	Sta- tion Code	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
220175	11:12	04	001	05.05	14.20	07.90	09.12	0079	000050	000004	0.043	0.130	0.414	0.029	00.14	04.45
220175	12:00	01	001	03.15	16.10	08.20	10.03	0084	000404	000005	0.069	0.256	0.036	0.053	00.22	02.15
220175	12:25	01	001	04.10	14.19	07.90	09.65	0082	000035	000005	0.054	0.092	0.560	0.025	00.14	01.25
210175	14:45	01	001	09.40	12.65	08.94	10.00	0095	000400	000200	0.096	0.185	0.007	0.040	00.22	03.40
210175	15:00	02	001	08.03	13.01	09.19	08.76	0082	000244	000260	0.125	0.221	0.031	0.017	00.13	02.55
210175	15:10	01	001	09.09	13.22	09.14	08.59	0081	000300	000300	0.094	0.195	0.027	0.014	00.12	03.35
210175	15:20	01	001	09.20	13.00	08.93	09.75	0092	000544	000300	0.110	0.180	0.020	0.014	00.29	03.97
210175	15:15	04	001	08.50	15.16	07.06	07.62	0072	000076	000002	0.030	0.050	0.300	0.030	00.19	01.31
140275	11:00	01	001	05.00	13.04	08.96	08.02	0069	000500	000100	0.072	0.106	0.022	0.064	00.33	04.65
140275	11:30	02	001	06.01	14.01	08.90	07.69	0060	000205	000003	0.104	0.160	0.032	0.066	00.93	04.99
140275	11:45	03	001	06.52	14.09	09.00	07.31	0065	000405	000002	0.099	0.126	0.040	0.069	00.51	03.35
140275	12:10	04	001	06.10	15.63	08.01	07.22	0065	000340	000002	0.037	0.065	0.351	0.037	00.11	00.17
140275	12:40	03	001	06.50	14.13	08.95	07.50	0067	000420	000000	0.069	0.147	0.030	0.071	00.70	04.03
140275	13:00	02	001	06.50	14.00	08.94	07.31	0065	000095	000000	0.000	0.000	0.034	0.071	00.16	04.42
140275	13:15	01	001	04.95	13.93	09.04	08.23	0071	000505	000000	0.072	0.172	0.027	0.014	00.49	04.00
140275	13:15	04	001	06.14	15.04	08.00	07.41	0066	000340	000003	0.024	0.066	0.356	0.033	00.14	00.23
200275	08:50	01	001	07.50	15.12	08.73	09.03	0083	000660	000217	0.074	0.262	0.031	0.009	01.75	04.93
200275	09:05	02	001	07.45	15.25	08.01	08.62	0079	000570	000047	0.074	0.173	0.033	0.093	01.47	03.97
200275	09:15	03	001	06.63	15.31	08.74	09.19	0083	000360	000237	0.084	0.169	0.061	0.093	01.96	04.31
200275	09:30	01	001	06.35	13.63	07.66	09.36	0083	000340	000020	0.029	0.086	0.371	0.042	00.21	00.46
200275	09:45	0004	0004	09.50	07.73	09.50	0084	000345	000005	0.036	0.082	0.303	0.040	00.10	00.20	
200275	10:00	0001	0001	08.70	08.70	08.79	0081	000535	000001	0.009	0.008	0.154	0.031	0.097	01.70	04.02
200275	10:30	0079	0079	08.60	08.77	08.60	0079	000500	000007	0.094	0.200	0.015	0.003	01.16	04.37	
200275	10:40	0003	0003	09.09	08.63	09.09	0083	000595	000152	0.075	0.240	0.027	0.003	02.60	05.16	

Table A.7. Data listing for monitoring program at Craney Island from December 1973 to February 1975. See Table A.2 for station codes. Dissolved cadmium and zinc were measured by both anodic stripping voltammetry (28/12/73 - 28/06/74) and graphite furnace atomic absorption (06/08/74 - 22/02/75) and particulate mercury values are corrected.

Date	Time	Sta- tion Code	Card Code	Diss. Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
281273	1048	02	002	0.004	133.0	0.003		0.014	667.0
281273	1137	04	002	0.003	103.0	0.003		0.015	374.0
281273	1048	32	002	0.002	011.0	0.003			056.4
281273	1118	31	002	0.002	153.0	0.003		0.015	447.0
281273	1300	30	002	0.003	426.0	0.002		0.017	745.0
110174	1125	02	002	0.009	032.3	0.003		0.149	112.0
110174	1025	04	002	0.005	066.7	0.002		0.046	211.0
110174	1045	32	002	0.008	006.0	0.005		0.052	026.0
110174	1125	30	002	0.006	049.4	0.003		0.012	086.4
100174	0940	02	002	0.001	040.3	0.003		0.010	214.0
100174	1030	04	002	0.009	001.4	0.002		0.033	039.0
100174	0930	32	002	0.009	103.0	0.002		0.007	114.0
100174	1010	31	002	0.001	077.0	0.002		0.007	209.0
100174	1130	30	002	0.009	060.0	0.003		0.019	262.0
250174	1145	02	002	0.019	010.7	0.003		0.087	012.3
250174	1105	04	002	0.013	034.2	0.003		0.093	016.3
250174	1045	30	002	0.001	011.6	0.003	10.60	0.034	157.0
250174	1125	32	002	0.007	009.3	0.003	07.50	0.045	040.2
000274	1030	04	002	0.006	005.1	0.002		0.035	023.4
000274	1010	31	002	0.008	012.5	0.002	10.30	0.058	111.0
220274	1030	02	002	0.017	013.5	0.002	11.60	0.037	022.0
220274	1115	04	002	0.011	013.3	0.002	11.50	0.029	026.9
220274	1105	32	002	0.005	014.0	0.003	10.20	0.136	046.2
220274	1130	31	002	0.004	196.0	0.002	41.00	0.055	094.7
220374	0950	02	002	0.005	002.4	0.021	01.15	0.047	022.1
220374	1050	04	002	0.005	000.5	0.023		0.040	074.3
220374	1010	32	002	0.007	000.6	0.027	01.54	0.034	036.6
220374	1035	31	002	0.005	003.5	0.020	01.37	0.073	027.0
100474	1110	02	002	0.003	000.0	0.010	02.90	0.024	017.6
100474	1145	04	002	0.006	001.6	0.014	01.01	0.019	017.0

Table A.7. Continued.

Date	Time	Sta- tion Code	Card Code	Diss. Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
120474	1120	32	002	0.004	000.4	0.016	01.77	0.043	030.7
120474	1205	02	002	0.005	001.7	0.018	02.00	0.016	015.1
120474	1235	04	002	0.006	004.1	0.013	05.03	0.012	037.0
120474	1300	32	002	0.008	000.6	0.014	00.62	0.064	026.2
260474	1125	02	002	0.009	002.1	0.018	01.88	0.047	018.7
260474	1135	04	002	0.034	002.1	0.016	04.23	0.072	015.5
260474	1100	32	002	0.007	000.5	0.021	02.02	0.030	030.7
120574	1210	02	002	0.006	003.6	0.021	01.63	0.039	027.6
120574	1030	04	002	0.009	001.0	0.018	03.42	0.041	012.9
120574	1115	32	002	0.006	000.8	0.018	00.81	0.051	094.5
120574	1000	02	002	0.005	002.2	0.013	05.27	0.114	020.0
120574	1015	04	002	0.056	001.1	0.012	00.77	0.108	025.2
200574	1105	02	002	0.006	033.6	0.000	01.72	0.039	041.5
200574	1120	04	002	0.004	002.0	0.000	00.83	0.033	028.6
100674	1035	02	002	0.003	028.2	0.000	03.73	0.071	105.0
100674	1045	04	002	0.002	003.2	0.000	01.00	0.029	037.6
100674	1110	33	002	0.004	028.9	0.000	05.55	0.076	190.0
220674	0930	02	002	0.004	004.4	0.000	01.87	0.076	042.4
220674	0945	04	002	0.004	002.3	0.000	01.36	0.029	027.0
220674	1130	02	002	0.004	004.2	0.000	00.50	0.029	040.9
220674	1145	04	002	0.003	004.2	0.000	02.88	0.045	043.9
220674	1330	02	002	0.002	004.2	0.000	01.93	0.030	042.8
220674	1100	04	002	0.005	004.2	0.000	02.52	0.026	044.7
220674	0955	31	002	0.001	025.0	0.000	04.62	0.034	083.3
220674	1010	33	002	0.001	013.0	0.000	00.25	0.102	041.0
220674	1300	33	002	0.001	013.0	0.000	00.94	0.214	038.5
220674	1230	31	002	0.001	026.3	0.000	06.11	0.029	072.5
220674	1355	33	002	0.002	013.0	0.000	01.36	0.155	036.7
200674	0930	02	002	0.000	003.6	0.000	01.39	0.007	046.0
200674	1015	04	002	0.021	002.5	0.000	01.25		033.4

Table A.7. Continued.

Date	Time	Sta- tion Code	Card Code	Diss. Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
200674	1110	02	002	0.000	003.0	0.000	01.15	0.024	030.0
200674	1210	04	002	0.001	003.9	0.000	00.92	0.066	035.0
200674	1310	02	002	0.000	003.8	0.000	01.30	0.070	030.9
200674	1410	04	002	0.001	003.0	0.000	01.35	0.116	034.3
200674	1400	31	002	0.001	022.9	0.000	04.55	0.008	063.7
200674	1230	33	002	0.000	011.1	0.000	09.61	0.022	022.3
200674	1200	31	002	0.000	016.6	0.000	06.07	0.112	074.9
200674	1230	33	002	0.000	014.5	0.000	10.16	0.025	029.0
200674	1000	31	002	0.000	018.3	0.000	05.74	0.011	086.6
200674	1030	33	002	0.000	025.6	0.000	02.93	0.052	051.4
200674	1120	31	002	0.263	163.0	0.006	11.63	0.399	730.0
050074	1015	02	002	0.113	090.9	0.007	06.90	0.071	181.0
200674	1110	04	002	0.020	016.9	0.002	00.45	0.056	027.7
100974	1025	01	002	0.045	093.1	0.004	02.03	0.506	095.1
100974	1121	04	002	0.025	013.2	0.003	01.13	0.110	032.5
100974	1152	01	002	0.016	099.1	0.005	02.10	0.076	132.0
100974	1220	04	002	0.047	009.4	0.005	01.50	0.150	022.4
250974	1115	01	002	0.031	006.0	0.006	05.55	0.245	044.3
250974	1142	04	002	0.053	001.6	0.005	01.00	0.214	022.4
250974	1212	01	002	0.006	013.0	0.007	05.70	0.063	035.0
250974	1230	04	002	0.036	003.3	0.004	01.65	0.152	000.6
161074	1122	01	002	0.016	036.4	0.008	02.25	0.262	002.0
161074	1200	04	002	0.021	000.0	0.002	01.00	0.067	321.0
161074	1220	01	002	0.023	020.9	0.008	02.40	0.402	664.0
161074	1245	04	002	0.015	000.6	0.003	01.65	0.030	462.0
251074	1205	01	002	0.003	135.0	0.002	05.03	0.140	104.0
251074	1232	04	002	0.040	012.0	0.002	03.45	0.163	042.0
251074	1253	01	002	0.057	054.4	0.002	06.60	0.056	177.0
251074	1314	04	002	0.029	014.0	0.001	04.70	0.051	092.6
301074	1025	01	002	0.017	031.9	0.002	06.60	0.110	269.0

Table A.7. Continued.

Date	Time	Sta- tion Code	Card Code	Diss. Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
201074	1045	04	002	0.076	008.7	0.001	03.30	0.282	106.0
201074	1105	01	002	0.020	050.0	0.002	00.02	0.124	224.0
201074	1125	04	002	0.059	018.2	0.001	03.90	0.056	096.7
201174	1225	01	002	0.012	227.0	0.002	07.05	0.089	343.0
201174	1251	04	002	0.033	036.4	0.001	05.48	0.070	058.1
201174	1110	01	002	0.026	170.0	0.002	08.78	0.045	200.0
201174	1132	04	002	0.026	030.2	0.001	05.92	0.049	053.6
201174	1000	01	002	0.077	190.0	0.002	08.93	0.193	522.0
201174	1225	04	002	0.030	045.2	0.002	08.02	0.123	107.0
201174	1045	01	002	0.047	216.0	0.002	11.30	0.120	321.0
201174	1110	04	002	0.035	090.3	0.002	07.05	0.156	152.0
201174	1220	01	002	0.005	075.4	0.002	11.00	0.100	160.0
201174	1045	04	002	0.024	039.0	0.002	08.62	0.080	059.4
201174	1110	01	002	0.077	070.0	0.002	09.98	0.138	114.0
201174	1135	04	002	0.034	038.9	0.002	09.08	0.113	062.2
201274	1125	01	002	0.013	134.0	0.001	12.00	0.093	503.0
201274	1155	04	002	0.056	037.9	0.001	08.55	0.153	256.0
201274	1225	01	002	0.048	150.0	0.002	15.00	0.398	518.0
201274	1245	04	002	0.065	040.4	0.001	08.78	0.137	303.0
201274	1040	01	002	0.113	031.3	0.012	09.00	0.286	078.0
201274	1110	04	002	0.030	004.1	0.005	05.10	0.092	028.9
201274	1150	01	002	0.254	038.6	0.014	08.40	0.151	082.0
201274	1200	01	002	0.013	004.0	0.004	06.90	0.056	026.9
201274	1205	04	002	0.007	001.0	0.007	07.20	0.079	047.0
201274	1123	01	002	0.047	023.7	0.013	08.70	0.136	114.0
201274	1203	04	002	0.041	001.9	0.004	06.00	0.063	035.1
201274	1210	01	002	0.044	028.3	0.013	07.95	0.099	107.0
201274	1210	04	002	0.038	003.7	0.003	05.48	0.146	021.0
220175	1053	05	002	0.065	010.1	0.002	08.55	0.110	097.1
220175	1057	01	002	0.017	013.0	0.003	07.35	0.068	136.0

Table A.7. Concluded.

Date	Time	Sta- tion Code	Card Code	Diss. Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
220175	1132	04	002	0.023	000.6	0.003	03.08	0.120	035.8
220175	1200	01	002	0.021	019.1	0.004	06.15	0.035	129.0
220175	1225	04	002	0.032	000.2	0.003	04.95	0.087	009.6
310175	1415	01	002	0.027	020.2	0.005	05.92	0.163	100.0
310175	1500	02	002	0.019	026.0	0.004	03.08	0.110	129.0
310175	1510	03	002	0.025	001.0	0.003	02.33	0.145	040.7
310175	1520	01	002	0.023	000.0	0.004	04.05	0.211	108.0
310175	1545	04	002	0.024	007.0	0.003	01.80	0.020	028.7
100275	1100	01	002	0.053	129.0	0.004	04.80	0.252	457.0
100275	1130	02	002	0.019	122.0	0.004	02.25	0.008	443.0
100275	1145	03	002	0.031	194.0	0.003	02.63	0.145	360.0
100275	1210	04	002	0.038	001.7	0.003	03.75	0.120	009.7
100275	1240	03	002	0.071	068.3	0.002	02.40	0.039	414.0
100275	1300	02	002	0.071	147.0	0.002	02.40	0.004	476.0
100275	1315	01	002	0.099	237.0	0.004	02.85	0.435	294.0
100275	1345	04	002	0.023	004.7	0.004	01.42	0.055	016.0
200275	0850	01	002	0.076	096.1	0.002	03.00	0.136	165.0
200275	0905	02	002	0.071	073.1	0.002	02.70	0.034	150.0
200275	0915	03	002	0.065	057.4	0.002	01.95	0.223	137.0
200275	0930	04	002	0.036	013.4	0.002	00.00	0.003	055.9
200275	0945	04	002	0.042	013.4	0.001	00.30	0.207	060.0
200275	1000	03	002	0.055	072.2	0.003	02.40	0.134	200.0
200275	1010	02	002	0.061	100.0	0.003	02.10	0.134	166.0
200275	1020	01	002	0.069	142.0	0.003	02.03	0.133	201.0

A.8. Data listing for monitoring program at Craney Island from December 1973 to February 1975. See Table A.2 for station codes.

Date	Time	Sta- tion Code	Card Code	Norfolk Airport Air Temp	Norfolk Airport		Norfolk Airport		Norfolk Airport	
					Wind Direction	Wind Speed	Precipi- tation	Sunshine (min)	Sunshine (%)	
281273	1000	02	003	008.9	00019	006.5	00.00			
281273	1137	04	003	008.9	00019	006.5	00.00			
281273	1000	32	003	008.9	00019	006.5				
281273	1118	31	003	008.9	00019	006.5				
281273	1300	30	003	008.9	00019	006.5				
110174	1135	02	003	016.1	00024	015.7	00.48			
110174	1025	04	003	016.1	00024	015.7	00.48			
110174	1045	32	003	016.1	00024	015.7				
110174	1125	30	003	016.1	00024	015.7				
180174	0940	02	003	005.6	00005	010.6	00.00	00006	00001	
180174	1030	04	003	005.6	00005	010.6	00.00	00006	00001	
180174	0930	32	003	005.6	00005	010.6		00006	00001	
180174	1010	31	003	005.6	00005	010.6		00006	00001	
180174	1130	30	003	005.6	00005	010.6		00006	00001	
250174	1145	02	003	006.1	00003	009.7	00.33	00000	00000	
250174	1135	04	003	006.1	00003	009.7	00.07	00000	00000	
250174	1045	30	003	006.1	00003	009.7		00000	00000	
250174	1125	32	003	006.1	00003	009.7		00000	00000	
080274	1030	04	003	002.8	00001	014.9	00.39	00000	00000	
080274	1010	31	003	002.8	00001	014.9		00000	00000	
220274	1030	02	003	016.1	00022	019.9	00.38	00270	00040	
220274	1115	04	003	016.1	00022	019.9	00.38	00270	00040	
220274	1105	32	003	016.1	00022	019.9		00270	00040	
220274	1130	31	003	016.1	00022	019.9		00270	00040	
220374	0950	02	003	006.7	00003	011.5	00.19	00600	00082	
220374	1050	04	003	006.7	00003	011.5	00.19	00600	00082	
220374	1010	32	003	006.7	00003	011.5		00600	00082	
220374	1035	31	003	006.7	00003	011.5		00600	00082	
100474	1110	02	003	009.4	00032	012.6	00.35	00700	00100	
100474	1145	04	003	009.4	00032	012.6	00.35	00700	00100	

Table A.8. Continued.

Date	Time	Sta- tion Code	Card Code	Norfolk Airport Air Temp	Norfolk Airport		Norfolk Airport	
					Wind Direction	Wind Sped	Precipit- tation	Sunshine (%)
188474	1124	32	003	009.4	00012	012.6	00760	00100
118474	1205	02	003	009.4	00014	004.4	00.35	00700
118474	1235	04	003	009.4	00014	004.4	00.35	00700
118474	1300	32	003	009.4	00014	004.4	00700	00100
268474	1125	02	003	013.9	00029	008.0	00.29	00098
268474	1135	04	003	013.9	00029	008.0	00.29	00098
268474	1100	32	003	013.9	00029	008.0	00792	00098
188574	1410	02	003	020.6	00016	008.4	00.70	00400
188574	1030	04	003	020.6	00016	008.4	00.70	00400
188574	1115	32	003	020.6	00016	008.4	00400	00057
178574	1000	02	003	027.2	00024	009.6	00.00	00792
178574	1015	04	003	027.2	00024	009.6	00.00	00792
248574	1105	02	003	022.8	00022	006.0	00.25	00057
248574	1120	04	003	022.8	00022	006.0	00.25	00057
148674	1035	02	003	022.2	00008	007.1	00.01	00654
148674	1045	04	003	022.2	00008	007.1	00.01	00654
148674	1110	33	003	022.2	00008	007.1	00654	00074
278674	0930	02	003	019.4	00007	012.0	00.13	00030
278674	0945	04	003	019.4	00007	012.0	00.13	00030
278674	1134	02	003	019.4	00007	012.0	00.17	00030
278674	1145	04	003	019.4	00007	012.0	00.17	00030
278674	1330	02	003	019.4	00007	012.0	00.27	00030
278674	1340	04	003	019.4	00007	012.0	00.27	00030
278674	0955	31	003	019.4	00007	012.0	00030	00033
278674	1010	33	003	019.4	00007	012.0	00030	00033
278674	1320	33	003	019.4	00007	012.0	00030	00033
278674	1230	31	003	019.4	00007	012.0	00030	00033
278674	1355	33	003	019.4	00007	012.0	00030	00033
288674	0930	02	003	019.4	00035	012.9	00.59	00060
288674	1015	04	003	019.4	00035	012.9	00.59	00060

Table A.8. Continued.

Date	Time	Sta- tion Code	Card Code	Norfolk Airport Air Temp	Norfolk Airport		Norfolk Airport		Norfolk Airport	
					Wind Direction	Wind Speed	Precipi- tation	Sunshine (min)	Sunshine (%)	
200674	1130	02	003	019.4	00035	012.9	00.59	00060	00007	
200674	1210	04	003	019.4	00035	012.9	00.59	00060	00007	
200674	1330	02	003	019.4	00035	012.9	00.59	00060	00007	
200674	1410	04	003	019.4	00035	012.9	00.59	00060	00007	
200674	1200	31	003	019.4	00035	012.9		00060	00007	
200674	1330	33	003	019.4	00035	012.9		00060	00007	
200674	1200	31	003	019.4	00035	012.9		00060	00007	
200674	1230	33	003	019.4	00035	012.9		00060	00007	
200674	1400	31	003	019.4	00035	012.9		00060	00007	
200674	1430	33	003	019.4	00035	012.9		00060	00007	
060874	1120	31	003	021.7	00007	008.0		00018	00002	
060874	1045	02	003	021.7	00007	008.0	02.02	00018	00002	
060874	1110	04	003	021.7	00007	008.0	02.79	00018	00002	
180974	1025	01	003	021.7	00032	005.7	00.09	00534	00072	
180974	1121	04	003	021.7	00032	005.7	00.09	00534	00072	
180974	1152	01	003	021.7	00032	005.7	00.09	00534	00072	
180974	1220	04	003	021.7	00032	005.7	00.09	00534	00072	
250974	1115	01	003	017.2	00032	006.5	00.53	00558	00077	
250974	1142	04	003	017.2	00032	006.5	00.53	00558	00077	
250974	1212	01	003	017.2	00032	006.5	00.53	00558	00077	
250974	1230	04	003	017.2	00032	006.5	00.53	00558	00077	
161074	1122	01	003	020.6	00023	011.5	00.04	00090	00013	
161074	1200	04	003	020.6	00023	011.5	00.04	00090	00013	
161074	1220	01	003	020.6	00023	011.5	00.04	00090	00013	
161074	1245	04	003	020.6	00023	011.5	00.04	00090	00013	
251074	1205	01	003	017.2	00022	007.9	00.00			
251074	1232	04	003	017.2	00022	007.9	00.00			
251074	1253	01	003	017.2	00022	007.9	00.00			
251074	1314	04	003	017.2	00022	007.9	00.00			
301074	1025	01	003	010.9	00015	003.9	00.00			

Table A.8. Continued.

Date	Time	Sta- tion Code	Card Code	Norfolk Airport Air Temp	Norfolk Airport		Norfolk Airport Sunshine (%)
					Wind Direction	Wind Speed	
321074	1045	04	003	018.9	00015	003.9	00.00
321074	1105	01	003	018.9	00015	003.9	00.00
321074	1125	04	003	018.9	00015	003.9	00.00
061174	1025	01	003	018.3	00001	011.7	00.00
061174	1051	04	003	018.3	00001	011.7	00.00
061174	1110	01	003	018.3	00001	011.7	00.00
061174	1132	04	003	018.3	00001	011.7	00.00
201174	1000	01	003	015.0	00022	009.1	00.15
201174	1025	04	003	015.0	00022	009.1	00.15
201174	1045	01	003	015.0	00022	009.1	00.15
201174	1110	04	003	015.0	00022	009.1	00.15
271174	1020	01	003	003.3	00001	011.7	00.47
271174	1045	04	003	003.3	00001	011.7	00.47
271174	1110	01	003	003.3	00001	011.7	00.47
271174	1135	04	003	003.3	00001	011.7	00.47
041274	1125	01	003	006.1	00033	012.0	01.07
041274	1155	04	003	006.1	00033	012.0	01.07
041274	1225	01	003	006.1	00033	012.0	01.07
041274	1245	04	003	006.1	00033	012.0	01.07
201274	1000	01	003	008.0	00004	009.2	00.00
201274	1110	04	003	008.0	00004	009.2	00.00
201274	1150	01	003	008.0	00004	009.2	00.00
201274	1200	04	003	008.0	00004	009.2	00.00
201274	1205	04	003	008.0	00004	009.2	00.00
271274	1123	01	003	003.9	00024	009.9	00.00
271274	1203	04	003	003.9	00024	009.9	00.00
271274	1218	01	003	003.9	00024	009.9	00.00
271274	1240	04	003	003.9	00024	009.9	00.00
220175	1053	05	003	003.3	00035	005.2	00.52
220175	1057	01	003	003.3	00035	005.2	00.52

Table A.8. Concluded.

Date	Time	Sta- tion Code	Card Code	Norfolk Airport		Norfolk Airport		Norfolk Airport	
				Air Temp	Wind Dir	Wind Speed	Precipi- tation	Sunshine (min)	Sunshine (%)
220175	1132	04	003	003.2	00035	006.2	00.52	00.52	
220175	1200	01	003	003.2	00035	006.2	00.52	00.52	
220175	1225	04	003	003.2	00035	006.2	00.52	00.52	
310175	1445	01	003	007.8	00005	008.6	00.00	00.00	
310175	1520	02	003	007.8	00005	007.5	00.00	00.00	
310175	1510	03	003	007.8	00005	007.5	00.00	00.00	
310175	1520	01	003	007.8	00005	007.5	00.00	00.00	
310175	1545	04	003	007.8	00005	007.5	00.00	00.00	
140275	1120	01	003	002.8	00036	008.4	00.02	00.02	
140275	1130	02	003	002.8	00036	008.4	00.02	00.02	
140275	1145	03	003	002.8	00036	008.4	00.02	00.02	
140275	1210	04	003	002.8	00036	008.4	00.02	00.02	
140275	1240	03	003	002.8	00036	008.4	00.02	00.02	
140275	1320	02	003	002.8	00036	008.4	00.02	00.02	
140275	1315	01	003	002.8	00036	008.4	00.02	00.02	
140275	1345	04	003	002.8	00036	008.4	00.02	00.02	
200275	0050	01	003	003.3	00003	007.7	00.56	00.56	
200275	0045	02	003	003.3	00003	007.7	00.56	00.56	
200275	0015	03	003	003.3	00003	007.7	00.56	00.56	
200275	0030	04	003	003.3	00003	007.7	00.56	00.56	
200275	0045	01	003	003.3	00003	007.7	00.56	00.56	
200275	1000	03	003	003.3	00003	007.7	00.56	00.56	
200275	1010	02	003	003.3	00003	007.7	00.56	00.56	
200275	1020	01	003	003.3	00003	007.7	00.56	00.56	

## APPENDIX B

### WATER QUALITY AT THE CRANEY ISLAND REHANDLING BASIN

The rehandling basin is located at the southeast corner of the Craney Island Disposal area proper (see Figure 2). The basin is situated between a spur levee to the north and the U. S. Navy Craney Island fuel depot to the south (Figure B.1). The approximate dimensions of the confined area are 2100 ft along the east levee of Craney Island by 2400 ft along the spur levee. The rehandling basin is located within the confined area, as shown by dashed lines in Figure B.1, and its area is approximately 1000 ft by 1300 ft, with a depth of 40 ft after periodic removal of dredged material from dump scows. It is connected to the 45-ft Norfolk Harbor Channel by two diagonal approaches which are 18 ft deep by 200 ft wide (dotted lines in Figure B.1). The rehandling basin is divided by range lights and piles into seven areas, designated as a to g in Figure B.1, wherein the Norfolk District requests contractors to deposit dredged material.

The purpose of the monitoring program at the rehandling basin was to evaluate the changes in water quality that would be related to barge disposal of dredged material. Therefore, sampling programs were conducted during and immediately following five periods of active dumps: 20 Dec 1974, 12 Aug 1975, 19 Mar 1976 (two different times), and 24 Mar 1976. A brief description of the dredged material associated with each of the disposals is provided in Table B.1, where approximate volumes of discharged material and locations within the rehandling basin are listed.

Samples were collected from a small boat and processed as described in the methods and materials section of this report. Either before or after the monitoring program was conducted in the rehandling basin, a sample was collected at the NE Open water site for comparison.

Data for these cruises are provided in Tables B.2 to B.5, while approximate station locations are shown in Figures B.1 to B.5. During the 20 Dec 1974 cruise, surface samples were collected at each station (20, 21 and 22) before the dump and at the same location after discharge of the dredge material (listed in sequence in Table B.2 where disposal occurred at 1215 hours). Station 20 was occupied immediately after the disposal, while sampling was delayed at station 21 until the turbidity of the water had

noticeably changed (see suspended solids). Even though the turbid plume did not reach station 22, a sample was collected 18 minutes later (23 minutes after the dump).

During the 12 Aug 1975 cruise, surface samples were collected from station numbers 21 to 25 (Figure B.2) within 20 minutes after the barge dump. Then a sample was collected next to the barge inside the rehandling basin at station 20. Two monitoring cruises were conducted on 19 Mar 1976. One was associated with disposal of dredge material at 1300 hours and another cruise was taken during the off-loading of a barge by a crane (1430 hours) which usually takes two hours. Surface samples were collected at station numbers 21 to 25 within 30 minutes of the barge dump (Figure B.3), while similar stations were occupied at 1430 hours during off-loading of a barge (Figure B.4). A further sample was collected near the crane operation (station number 20).

The final sampling cruise at the rehandling basin took place on 24 Mar 1976 (Figure B.5). Surface samples were collected at station numbers 21 to 24 within 30 minutes of a barge dump, which occurred at section g of the basin.

A sediment plume associated with a bottom disposal operation was observed only once during the five cruises at the rehandling basin. This occurred in December 1974 at station 21 (Fig. B.1). Low dissolved oxygen concentrations were also measured near the barge (station 20; 4.86 mg/l) and at station 21 (6.13 mg/l = 56% saturation). Slightly higher dissolved ammonium values were also observed at station 20. It is possible that the volume of dredged material associated with this disposal operation (see Table B.1) provided these differences.

In any case, differences were not seen between the NE Open water site and the stations in the rehandling basin during each of the other four cruises (Tables B.3 and B.4). The only variable that was higher than normal was fecal coliform at station 20 near the barge disposal site in August 1975. The rehandling area was constructed to retain dredge spoils by maintenance of a 40-ft basin with the two diagonal approaches kept at 18 feet for safe navigation. Samples were collected only at the surface during these five monitoring cruises. Judging from the suspended solids data, it was obvious that dredged materials originating from four out of five of these dumps were not observed in the surface waters.

Table. B.1. Sampling program at the rehandling basin, Craney Island Dredge Material Disposal area, Port of Hampton Roads, Virginia, from December 1974 to March 1976.

Date	Time	Tidal Information <sup>1</sup>			Weather Information <sup>2</sup>			Description of Dredge Spoil and Location	Dump Location	Volume cu. yd.
		Stage	Vel. (kts)	Vel. (kts)	Air Temp °C	Relative Humidity %	Wind Direction °N			
20 Dec 74	1215	240 F	0.4	9	56	090	11.5	mud, silt and sand from Ports-mouth Marine Terminal Container Pier	c	549
12 Aug 75	0930	125 F	0.6	27	65	100	15.0	record not available	---	---
19 Mar 76	1300	81 E	0.7	21	31	240	20.7	black silty mud from Holiday Marina	g	184
19 Mar 76	1430 <sup>3</sup>	171 E	1.4	similar to 1300 hours				mud from West Norfolk Bridge	g	190
24 Mar 76	1300	72 F	0.1	19	34	210	15.0	black silty mud from Holiday Marina	g	185

<sup>1</sup> From N.O.A.A. Current Tables (time in minutes into E = ebb or F = flood from slack water, current velocity in knots).

<sup>2</sup> From National Weather Service Office, Norfolk Regional Airport.

<sup>3</sup> The only dredge barge which was unloaded by crane. The rest were disposal of dredge material through the bottom of a scow.

Table B.2. Data listing for the first monitoring program at the Craney Island rehandling basin on 20 Dec 1974. See Table A.1 for units for each variable.

Date	Time	Station Code <sup>1</sup>	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat <sup>2</sup>	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TEN
281274	1127	28	001	07.08	16.21	07.83	07.65	0078	000058	00000	0.110	0.231	0.746	0.012	00.10	04.03
281274	1142	21	001	07.08	16.13	07.89	07.72	0071	000048	00004	0.096	0.199	1.336	0.013	00.11	02.55
281274	1142	22	001	06.76	16.93	07.85	07.95	0073	000065	00002	0.126	0.244	1.681	0.016	00.10	01.96
281274	1205	04	001	06.64	16.45	07.92	08.95	0081	000054	00004	0.147	0.198	4.958	0.012	00.08	01.85
281274	1220	28	001	07.09	12.41	07.86	04.86	0044	000190	00010	0.104	0.241	0.305	0.015	00.20	03.19
281274	1225	21	001	06.99	14.56	07.12	06.13	0056	000180	00010	0.123	0.225	0.434	0.015	00.14	01.80
281274	1243	22	001	06.83	17.06	07.86	08.08	0073	000066	00006	0.096	0.183	0.546	0.013	00.08	04.87

Date	Time	Station Code <sup>1</sup>	Card Code	Diss. Cd <sup>3</sup>	Part. Cd	Diss. Hg	Part. Hg	Diss. Zn	Part. Zn
281274	1127	28	002	0.037	002.5	0.003	05.40	0.036	046.1
281274	1132	21	002	0.009	004.9	0.003	05.48	0.051	044.8
281274	1142	22	002	0.002	008.9	0.005	08.85	0.136	044.9
281274	1205	04	002	0.007	001.8	0.007	07.20	0.079	047.0
281274	1220	28	002	0.002	000.9	0.005	06.38	0.226	038.7
281274	1225	21	002	0.005	001.4	0.005	06.90	0.123	045.2
281274	1243	22	002	0.010	003.1	0.005	07.20	0.143	052.7

Date	Time	Station Code <sup>1</sup>	Card Code	Norfolk Airport		Norfolk Airport	
				Air Temp	Mind Direction	Mind Speed	Precipitation
281274	1127	28	003	008.3	00004	009.2	00.00
281274	1132	21	003	008.3	00004	009.2	00.00
281274	1142	22	003	008.3	00004	009.2	00.00
281274	1205	04	003	008.3	00004	009.2	00.00
281274	1220	28	003	008.3	00004	009.2	00.00
281274	1225	21	003	008.3	00004	009.2	00.00
281274	1243	22	003	008.3	00004	009.2	00.00

<sup>1</sup> See Figure B.1 for station locations (code 04 = NE Open; 20-22 at rehandling basin).

<sup>2</sup> Data reflects the functional relationship developed by Weiss (1970).

<sup>3</sup> Measured by graphite furnace atomic absorption (see Adams and Young 1975).

<sup>4</sup> Data has been corrected (see text).

Table B.3. Data listing for four monitoring programs at the Craney Island rehandling basin on 12 Aug 1975, 19 Mar 1976 (2 cruises) and 24 Mar 1976. See Table A.1 for units for each variable and Tables B.4 and B.5 for other data.

Date	Time	Sta- tion Code <sup>1</sup>	Card Code	Temp	Sal	pH	O <sub>2</sub>	O <sub>2</sub> Sat <sup>2</sup>	Total Solids	Fecal Coliform	PO <sub>4</sub> - P	Total P	NO <sub>3</sub> - N	NO <sub>2</sub> - N	NH <sub>4</sub> - N	TKN
120875	0910	20	001	26.64	18.20	07.87			00021	00095	0.79	0.161	0.001	0.025	0.150	0.424
120875	0910	21	001	26.55	18.23	07.81	05.28	0071	00020	00030	0.89	0.199	0.092	0.017	0.223	0.480
120875	0910	22	001	26.26	18.14	07.88	05.39	0074	00021	00027	0.83	0.196	0.103	0.019	0.159	0.368
120875	0910	23	001	26.46	18.15	07.87	05.27	0073	00020	00014	0.85	0.193	0.121	0.016	0.156	0.448
120875	0910	24	001	26.52	18.15	07.89			00026	00017	0.97	0.201	0.098	0.016	0.154	0.408
120875	0910	25	001	26.57	18.11	07.85	05.84	0081	00021	00011	0.82	0.177	0.083	0.016	0.145	0.364
120875	0910	01	001	26.59	17.44	07.86	06.20	0085	00026	00015	0.61	0.165	0.102	0.014	0.090	0.329
190376	1340	20	001	09.89	14.65	07.70	09.85	0096	00010	00000	0.12	0.116	0.167	0.009	0.012	0.222
190376	1340	21	001	09.89	15.15	07.55	09.82	0096	00021	00005	0.34	0.044	0.207	0.011	0.019	0.205
190376	1340	22	001	09.84	14.73	07.70	10.17	0099	00022	00004	0.20	0.098	0.176	0.009	0.016	0.202
190376	1340	23	001	09.89	14.67	07.68	10.11	0098	00020	00010	0.16	0.099	0.167	0.008	0.014	0.404
190376	1340	24	001	09.86	14.66	07.84	10.93	0106	00019	00010	0.13	0.107	0.183	0.011	0.011	0.173
190376	1340	04	001	14.06	14.65	07.70	10.04	0098	00029	00003	0.19	0.119	0.204	0.011	0.013	0.187
190376	1340	20	001	09.87	14.85	07.70	10.15	0099	00016	00006	0.27	0.105	0.184	0.010	0.016	0.237
190376	1340	21	001	10.02	14.48	07.90	10.69	0104	00032	00005	0.10	0.095	0.180	0.008	0.018	0.072
190376	1340	22	001	09.98	14.50	07.75	10.06	0098	00024	00005	0.10	0.108	0.179	0.008	0.008	0.169
190376	1340	23	001	10.03	14.50	07.90	10.44	0102	00022	00005	0.011	0.087	0.221	0.009	0.009	0.167
190376	1340	24	001	09.97	14.59	07.90	09.75	0095	00022	00007	0.018	0.121	0.166	0.009	0.010	0.157
190376	1340	25	001	10.45	14.57	07.88	10.06	0099	00019	00002	0.016	0.109	0.177	0.010	0.010	0.164
200376	1340	20	001	13.22	15.31	07.93	08.76	0092	00013	00006	0.20	0.088	0.090	0.007	0.011	0.153
200376	1340	21	001	13.00	15.16	08.02	08.59	0090	00015	00005	0.012	0.088	0.161	0.008	0.008	0.173
200376	1340	22	001	13.43	15.02	08.05	10.23	0108	00016	00003	0.005	0.030	0.161	0.009	0.007	0.121
200376	1340	23	001	13.21	15.11	08.01	11.02	0116	00018	00004	0.005	0.053	0.169	0.008	0.006	0.142
200376	1340	01	001	12.98	12.96	08.10	11.16	0115	00021	00004	0.018	0.093	0.204	0.009	0.002	0.092

<sup>1</sup> See Figures B.2 through B.5 for station locations (code 04 = NE Open; 20-25 at rehandling basin).  
<sup>2</sup> Data reflects functional relationship developed by Weiss (1970).

Table B.4. Data listing for four monitoring programs at the Craney Island rehandling basin on 12 Aug 1975, 19 Mar 1976 (2 cruises) and 24 Mar 1976. See Table A.1 for units for each variable and Tables B.3 and B.5 for other data.

Date	Time	Station Code <sup>1</sup>	Card Code	Diss. <sup>2</sup> Cd	Part. Cd	Diss. Hg	Part. Hg	Diss. <sup>2</sup> Zn	Part. Zn	Diss. <sup>2</sup> Pb	Part. Pb	Chloro-phyt <sup>11</sup>	DOC	POC
120875	0930	20	002	*0005	*0001	*0003	03.17	*0005	509.2	*0005	00010	09.67	005.5	000.9
120875	0930	21	002	*0005	*0001	*0008	03.90	*0005	166.2	*0005	00010	10.45	002.1	000.8
120875	0930	22	002	*0005	*0001	*0006	10.36	*0005	386.6	*0005	00010	11.62	007.2	000.1
120875	0930	23	002	*0005	*0001	*0008	00.70	*0005	405.8	*0005	00010	09.36	003.1	000.4
120875	0930	24	002	*0005	*0001	*0004	00.66	*0005	206.1	*0005	00010	07.91	004.4	000.5
120875	0930	25	002	*0005	*0001	*0003	01.37	*0005	553.3	*0005	00010	09.53	004.0	000.4
120875	0930	04	002	*0005	*0001	*0004	00.77	*0005	122.8	*0005	00010	11.30	006.7	000.6
190376	1300	20	002	*0005	*0001	*0003	06.41	*0005	731.7	*0005	00010	14.49	005.2	000.8
190376	1300	21	002	*0005	*0001	*0002	03.01	*0005	601.4	*0005	00010	13.52	003.8	000.5
190376	1300	22	002	*0005	*0001	*0004	10.01	*0005	100.1	*0005	00010	16.67	004.2	000.9
190376	1300	23	002	*0005	*0001	*0001	00.44	*0005	032.9	*0005	00010	19.25	004.3	000.4
190376	1300	24	002	*0005	*0001	*0002	01.17	*0005	501.4	*0005	00010	14.43	005.0	000.8
190376	1300	04	002	*0005	*0001	*0005	01.01	*0005	434.1	*0005	00010	21.51	004.1	000.3
190376	1430	20	002	*0005	*0001	*0005	03.97	*0005	905.4	*0005	00010	10.02	004.8	000.3
190376	1430	21	002	*0005	*0001	*0004	01.30	*0005	662.6	*0005	00010	15.21	005.3	000.6
190376	1430	22	002	*0005	*0001	*0004	06.45	*0005	346.8	*0005	00010	17.43	002.1	000.5
190376	1430	23	002	*0005	*0001	*0002	01.19	*0005	563.3	*0005	00010	19.84	006.0	000.4
190376	1430	24	002	*0005	*0001	*0003	03.11	*0005	001.6	*0005	00010	18.53	004.8	000.2
190376	1430	25	002	*0005	*0001	*0006	05.54	*0005	341.8	*0005	00010	22.31	003.9	000.2
240376	1300	20	002	*0005	*0001	*0005	01.03	*0003	616.7	*0005	00010	09.40	009.0	000.9
240376	1300	21	002	*0005	*0001	*0002	00.90	*0005	501.3	*0005	00010	13.44	003.7	000.6
240376	1300	22	002	*0005	*0001	*0003	00.84	*0002	1005.0	*0005	00010	19.22	007.1	000.3
240376	1300	23	002	*0005	*0001	*0006	03.11	*0002	1312.0	*0005	00010	27.47	003.5	000.2
240376	1300	04	002	*0005	*0001	*0004	01.30	*0001	041.3	*0005	00010	21.51	005.1	000.4

<sup>1</sup> See Figures B.2 through B.5 for station locations (code 04 = NE Open; 20-25 at rehandling basin).

<sup>2</sup> Measurements by APDC/MIBK chelexion-extraction technique (see text).

Table B.5. Data listing for four monitoring programs at the Craney Island rehandling basin on 12 Aug 1975, 19 Mar 1976 (2 cruises) and 24 Mar 1976. See Table A.1 for units for each variable and Tables B.3 and B.4 for other data.

Date	Time	Sta- tion Code <sup>1</sup>	Air Temp		Craney Island		Norfolk Airport		Norfolk Airport		Norfolk Airport	
			Craney Island	Norfolk Airport	Wind Direction	Wind Speed	Wind Direction	Wind Speed	Precipi- tation	Sunshine (min)	Sunshine (%)	
120875	0930	20	003	26.39	029.1	00033	013.0	00001	006.9	00.06		
120875	0930	21	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
120875	0930	22	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
120875	0930	23	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
120875	0930	24	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
120875	0930	25	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
120875	0930	04	003	26.39	026.1	00033	013.0	00001	006.9	00.06		
190376	1300	20	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1300	21	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1300	22	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1300	23	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1300	24	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1300	04	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	20	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	21	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	22	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	23	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	24	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
190376	1400	25	003	19.68	015.0	00005	005.0	00022	013.1	00.24	00571	00079
240376	1300	20	003	19.01	011.7	00005	005.0	00017	006.8	00.00	00737	00100
240376	1300	21	003	19.01	011.7	00005	005.0	00017	006.8	00.00	00737	00100
240376	1300	22	003	19.01	011.7	00005	005.0	00017	006.8	00.00	00737	00100
240376	1300	23	003	19.01	011.7	00005	005.0	00017	006.8	00.00	00737	00100
240376	1300	04	003	19.01	011.7	00005	005.0	00017	006.8	00.00	00737	00100

<sup>1</sup> See Figures B.2 through B.5 for station locations (code 04 = NE Open; 20-25 at rehandling basin).

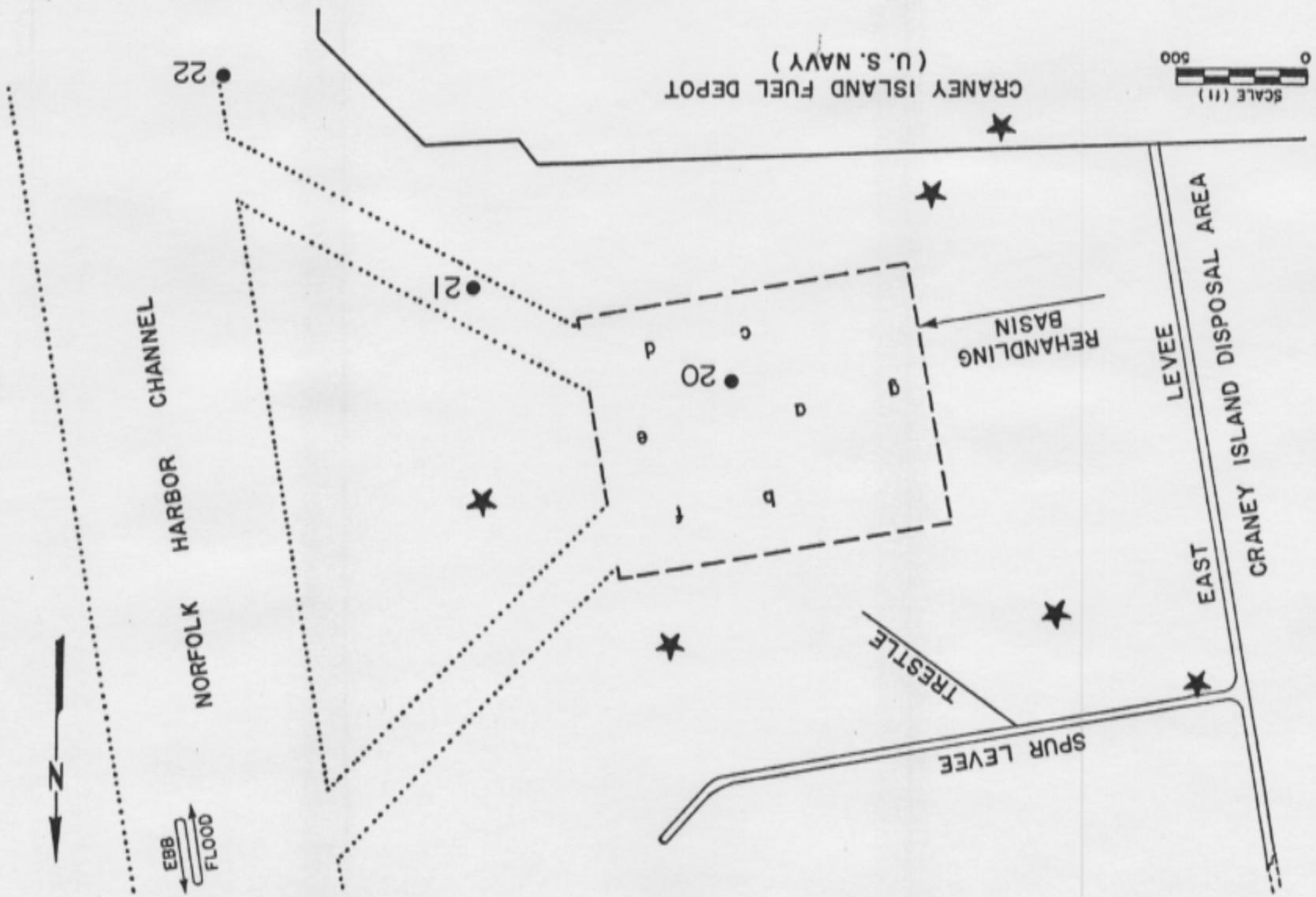


Figure B.1. Station locations (●) during the 20 Dec 1974 cruise. Stars are range lights used for navigational purposes.

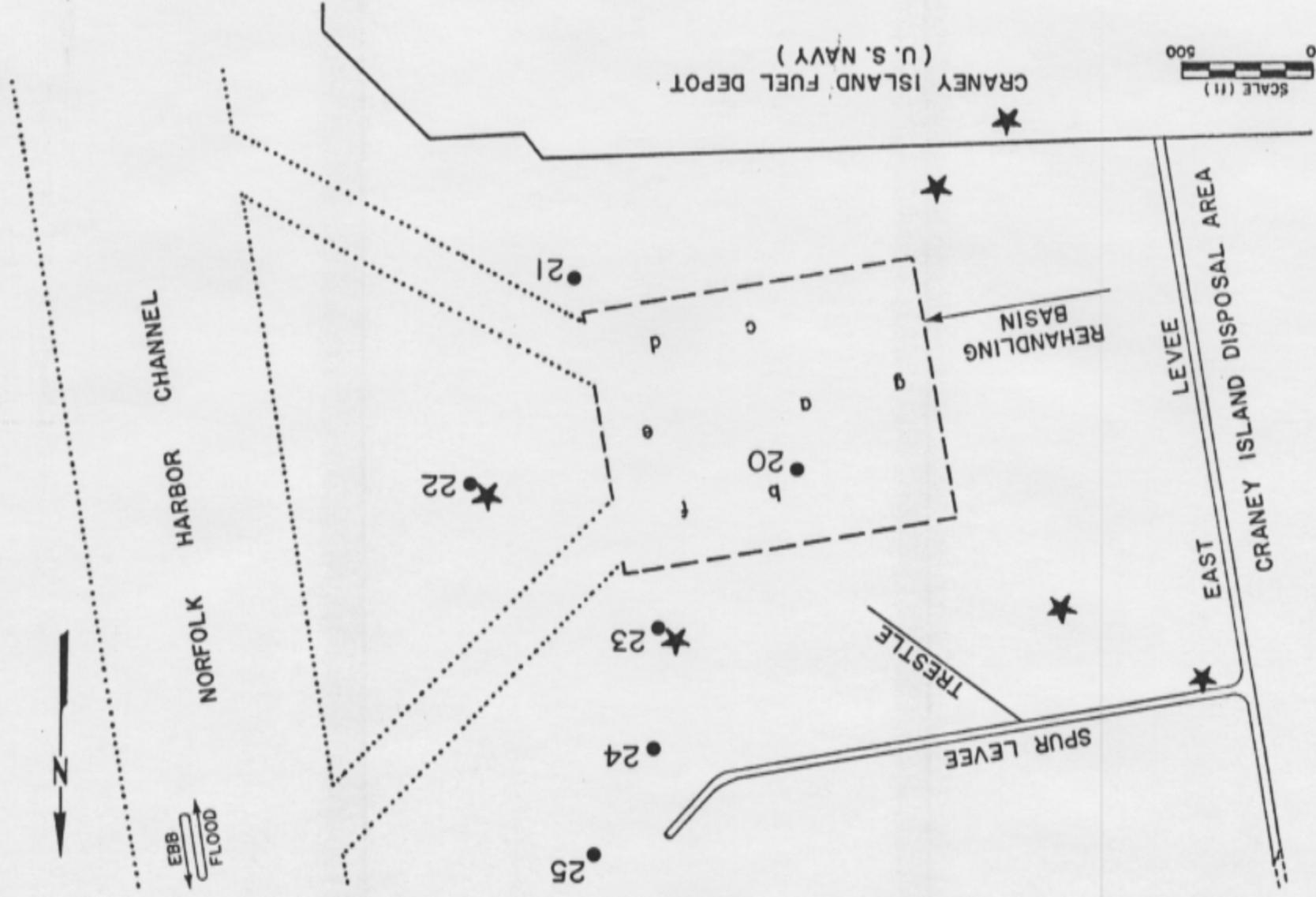


Figure B.2. Station locations (●) during the 12 Aug 1975 cruise. Stars are range lights used for navigational purposes.

Figure B.3. Station locations (●) during the 19 Mar 1976 cruise at 1300 hours (bottom disposal from a barge). Stars are range lights used for navigational purposes.

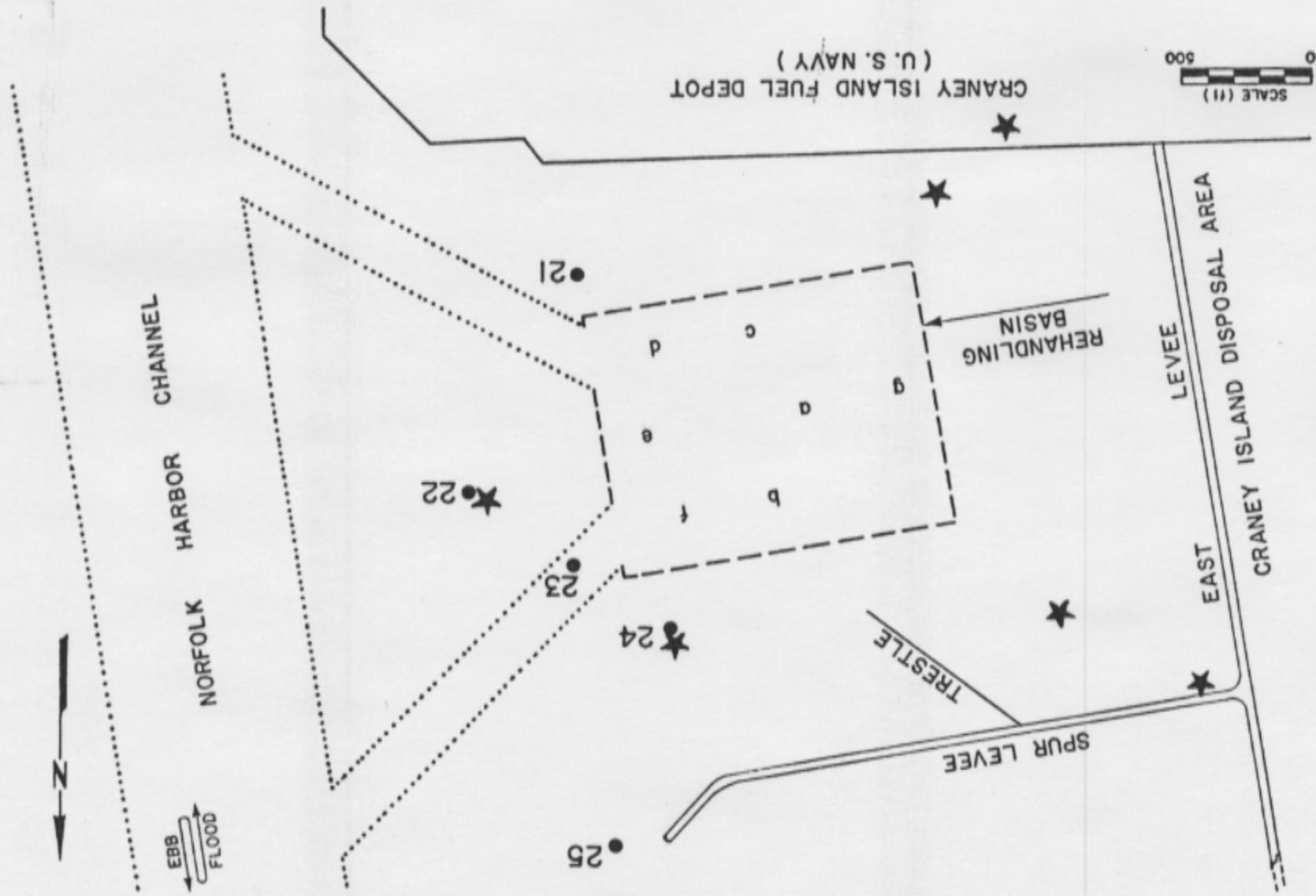
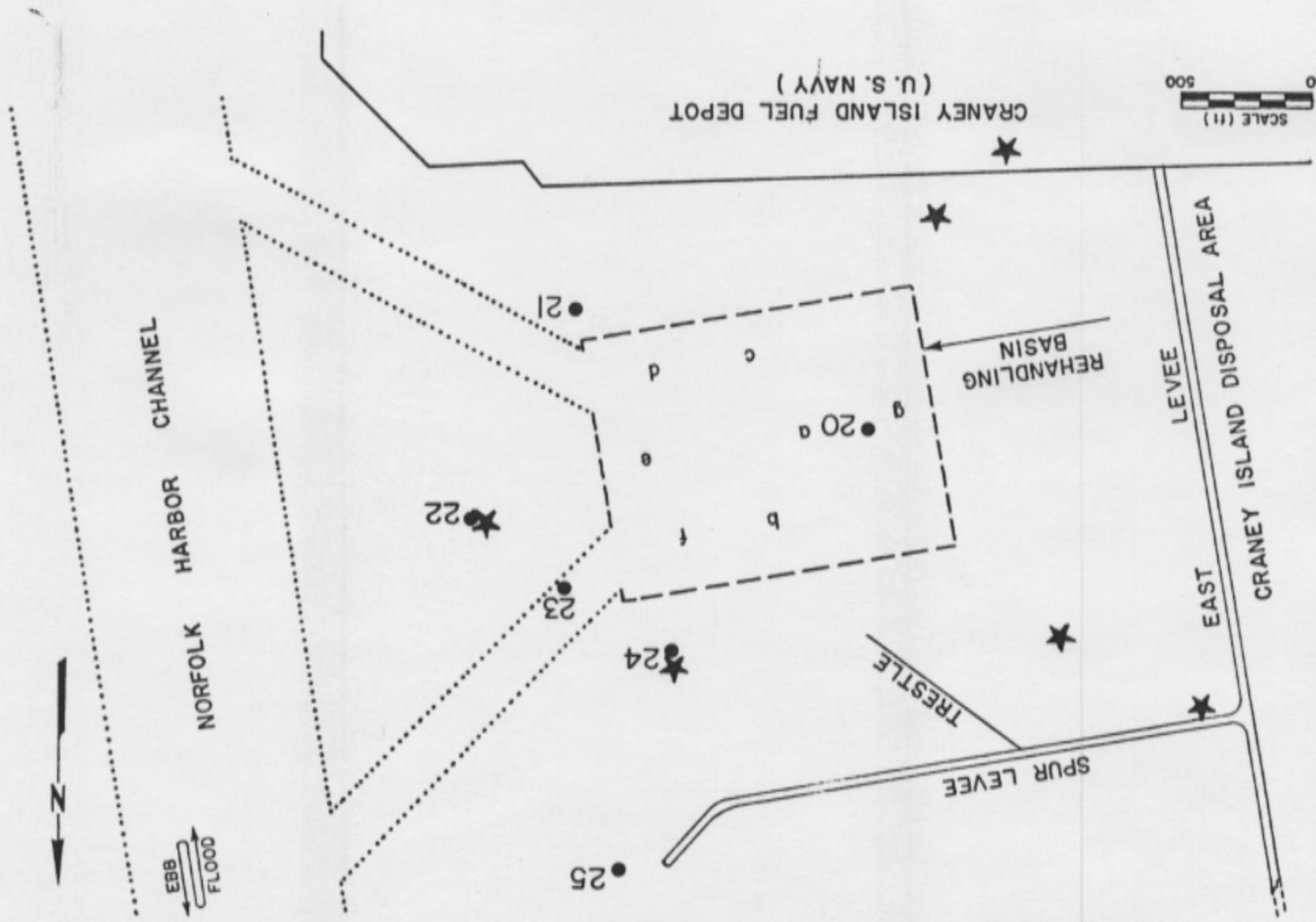


Figure B.4. Station locations (●) during the 19 Mar 1976 cruise at 1430 hours (crane off-loading of a barge). Stars are range lights used for navigational purposes.



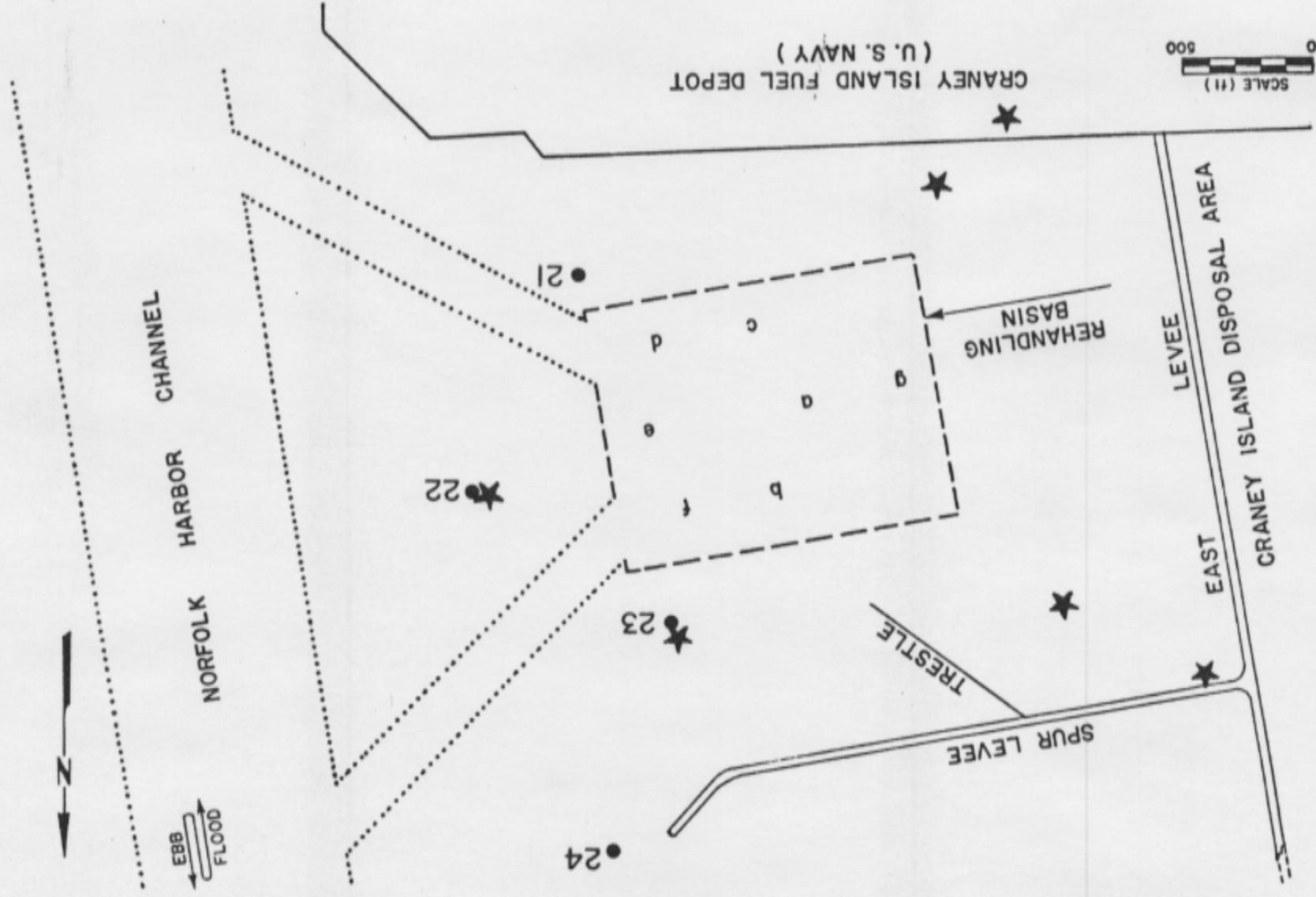


Figure B.5. Station locations (●) during the 24 Mar 1976 cruise. Stars are range lights used for navigational purposes.

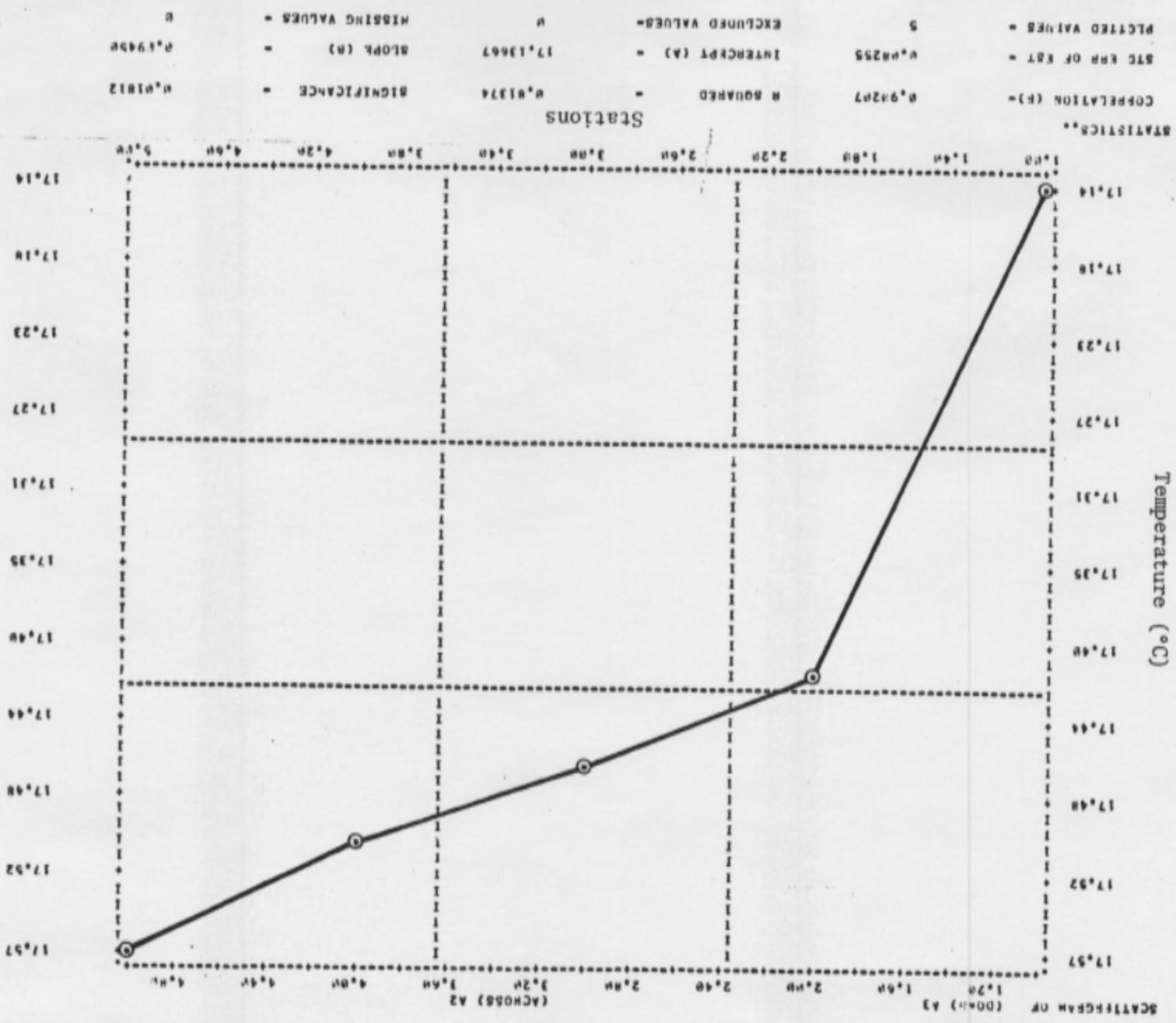
APPENDIX C

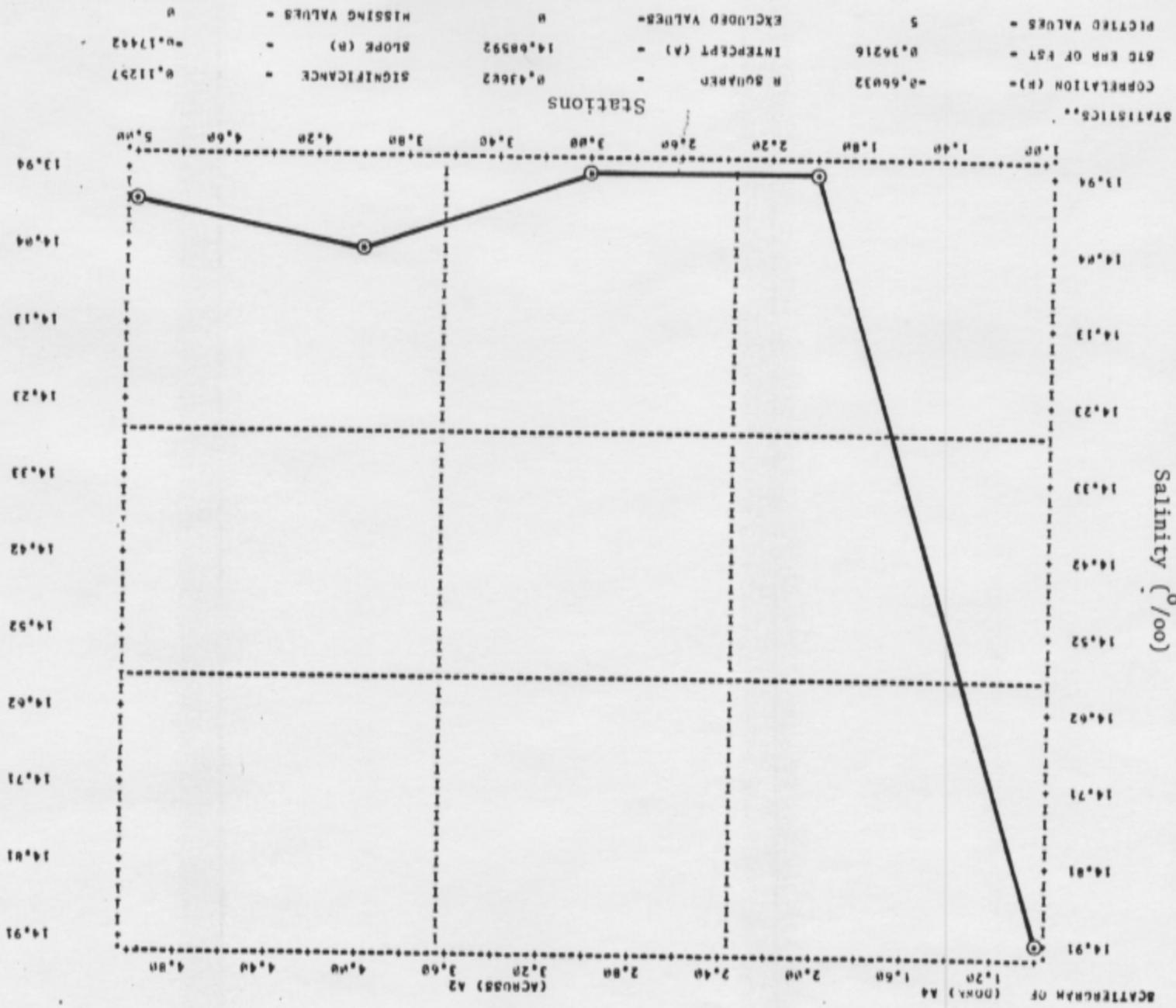
SCATTERGRAMS FOR VARIABLES MEASURED AT FIVE STATIONS IN THE NO. 1 SPILLWAY

PLUME FROM APRIL 1975 TO MARCH 1976

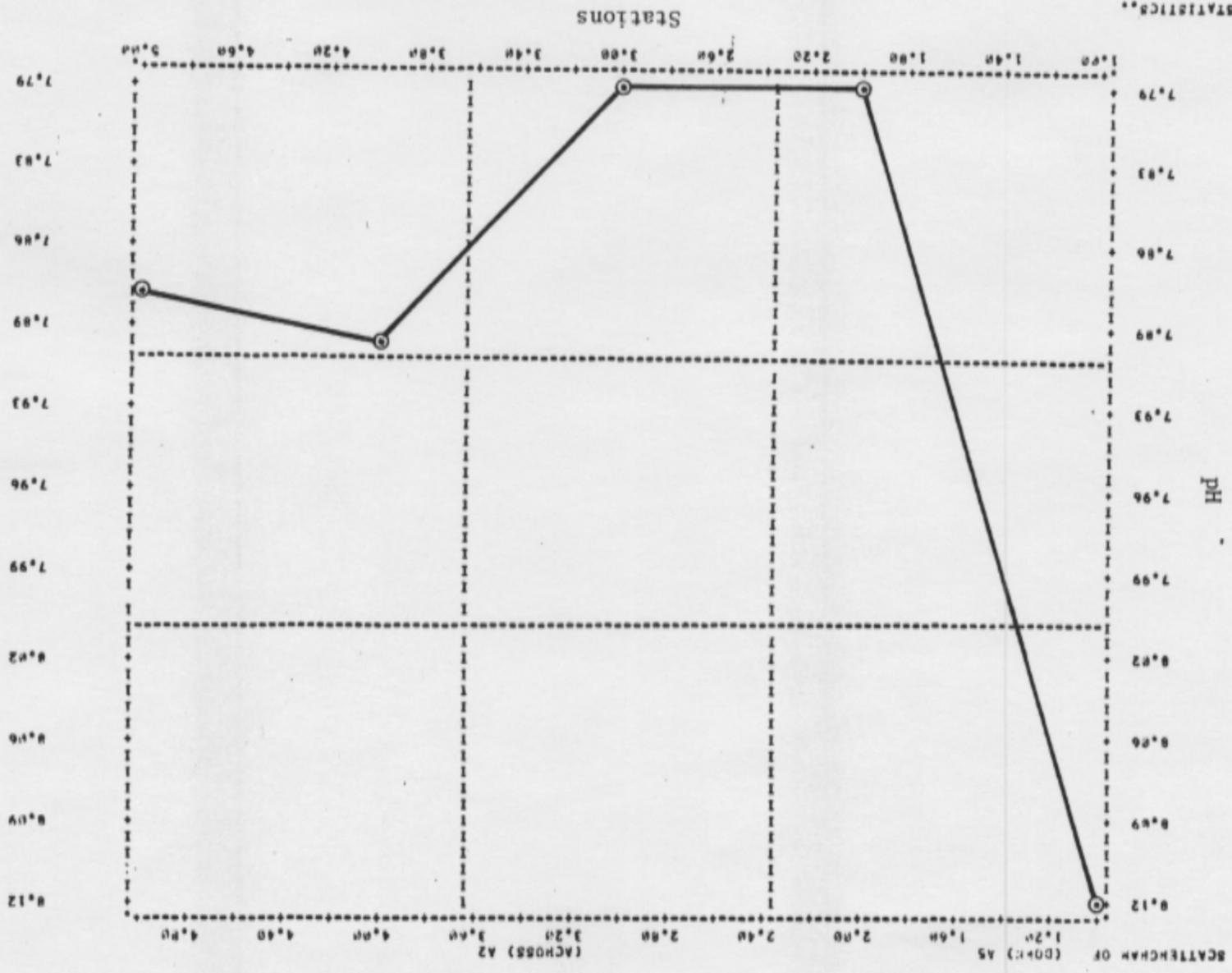
Variable <sup>1</sup>	<u>Page</u>
Temperature . . . . .	169
Salinity . . . . .	170
pH . . . . .	171
Dissolved Oxygen . . . . .	172
Oxygen Saturation . . . . .	173
Total Suspended Solids . . . . .	174
Fecal Coliform . . . . .	175
PO <sub>4</sub> - P . . . . .	176
Total Phosphorus . . . . .	177
NO <sub>3</sub> - N . . . . .	178
NO <sub>2</sub> - N . . . . .	179
NH <sub>4</sub> - N . . . . .	180
TKN . . . . .	181
Dissolved Cadmium . . . . .	182
Dissolved Mercury . . . . .	183
Particulate Mercury . . . . .	184
Dissolved Zinc . . . . .	185
Particulate Zinc . . . . .	186
Chlorophyll-a . . . . .	187
Dissolved Organic Carbon . . . . .	188
Particulate Organic Carbon . . . . .	189

<sup>1</sup> Variable units are given as 12-month mean concentrations or measurements at each surface station within the plume. Station 1 was closest to the No. 1 spillway.



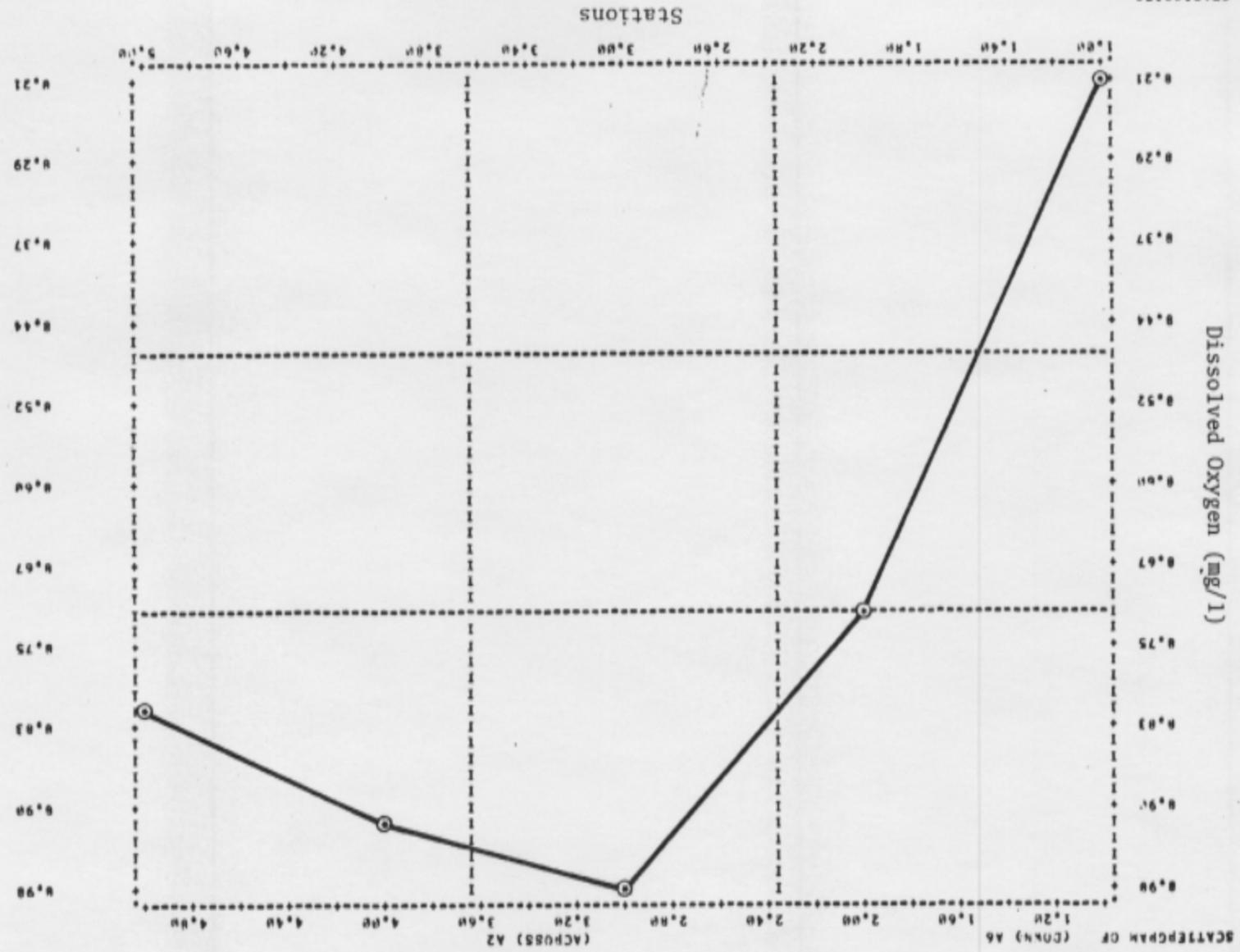


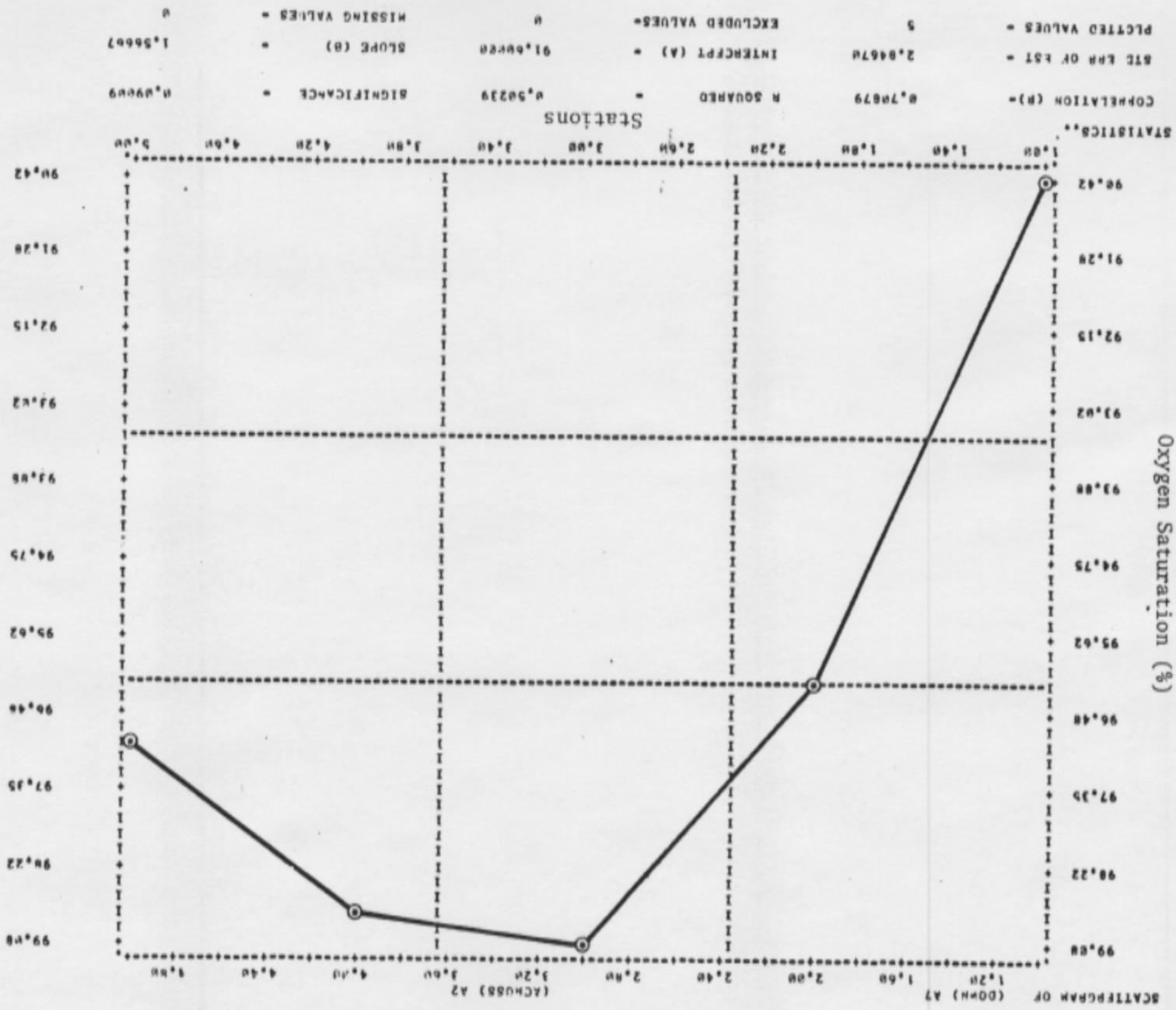
CORRELATION (R) = -0.43845    R SQUARED = 0.19224    SIGNIFICANCE = 0.23819  
 STD ERR OF EST = 0.13941    INTERCEPT (A) = 0.81858    SLOPE (B) = -0.03175  
 PLOTTED VALUES = 5    EXCLUDED VALUES = 0    MISSING VALUES = 0

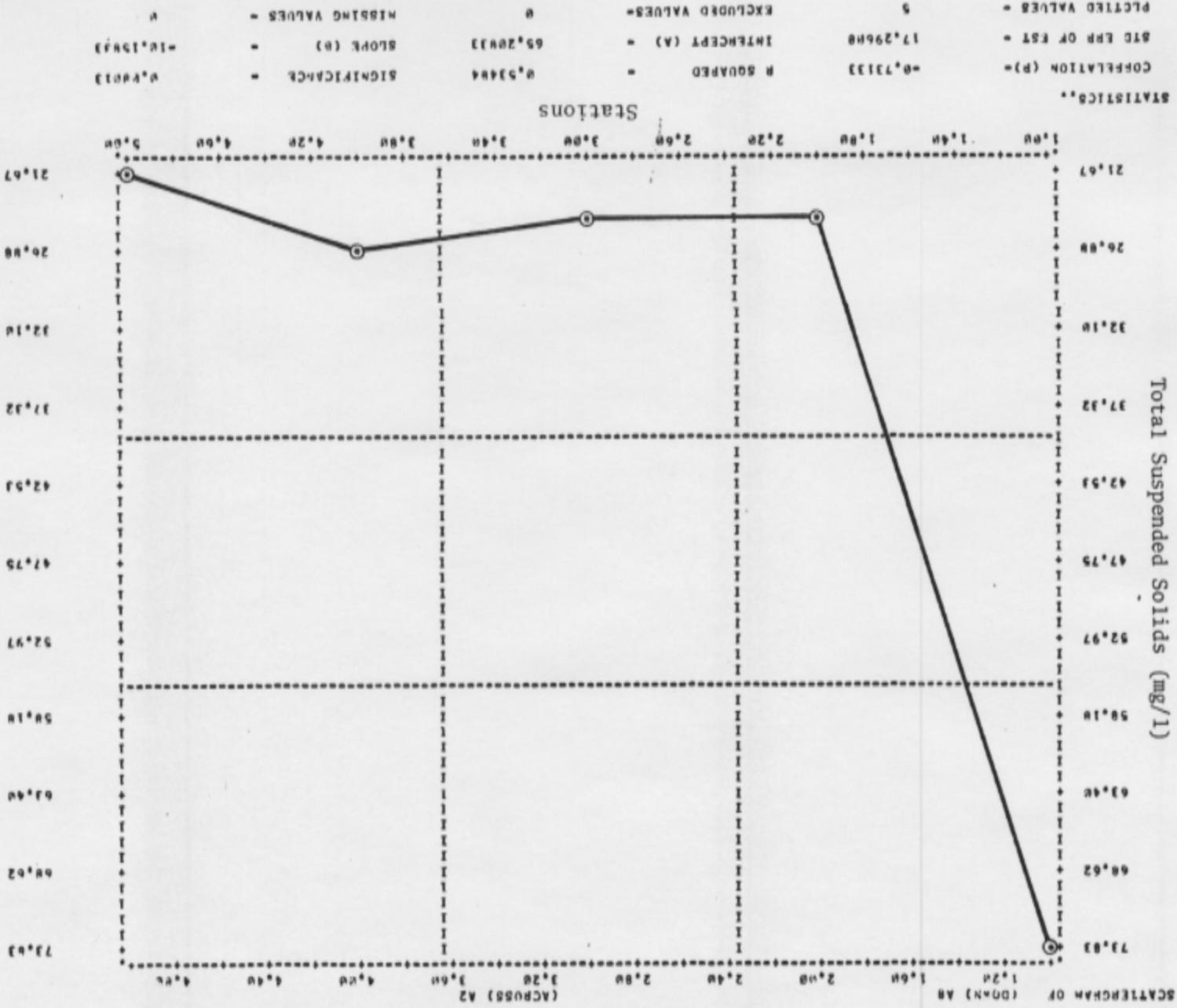


Stations

STATISTICS:  
 CORRELATION (R) = R.72286  
 H SQUARED = R.52253  
 SIGNIFICANCE = R.03283  
 SLOPE (B) = R.14128  
 INTERCEPT (A) = R.31258  
 EXCLUDED VALUES = 0  
 MISSING VALUES = 0

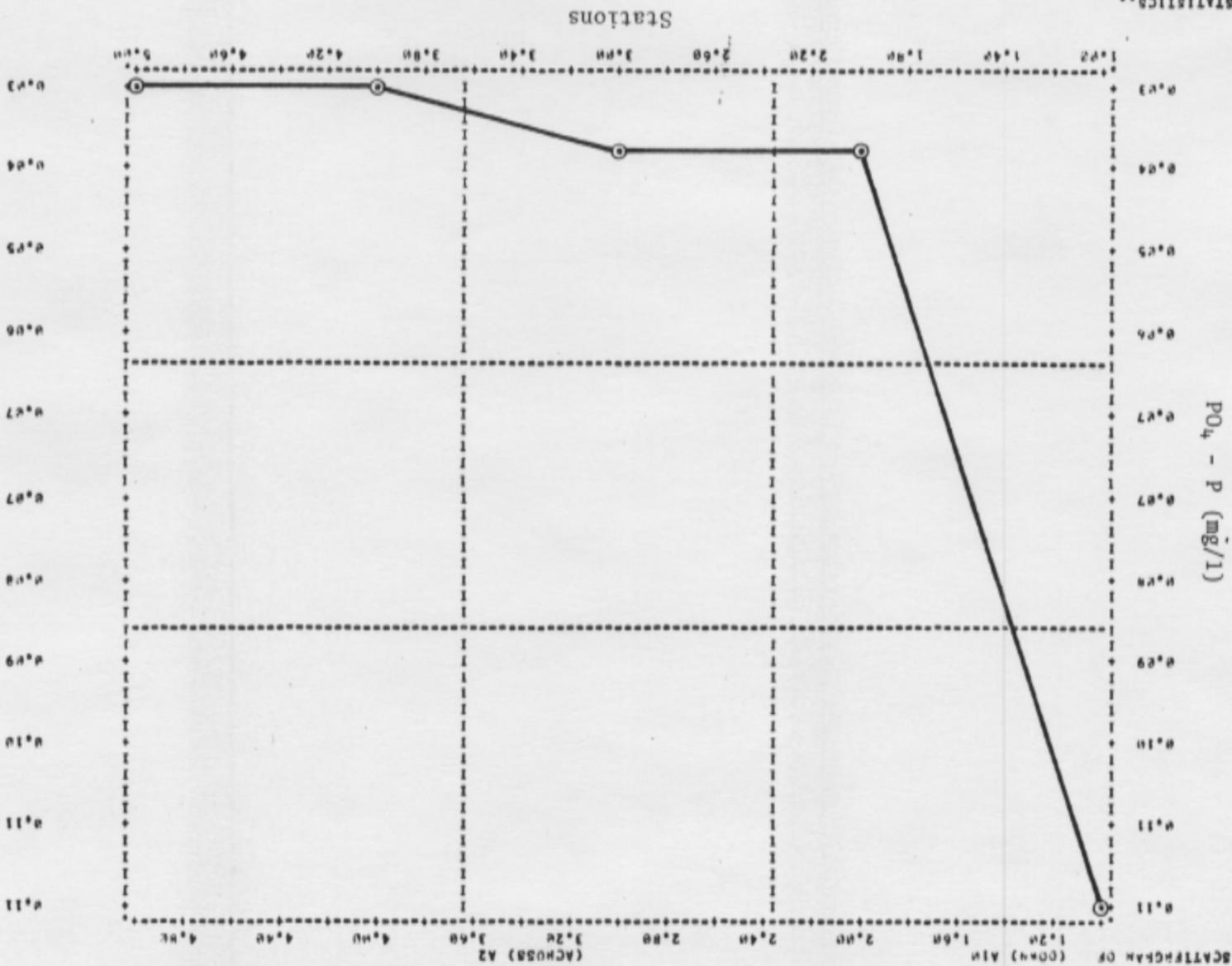




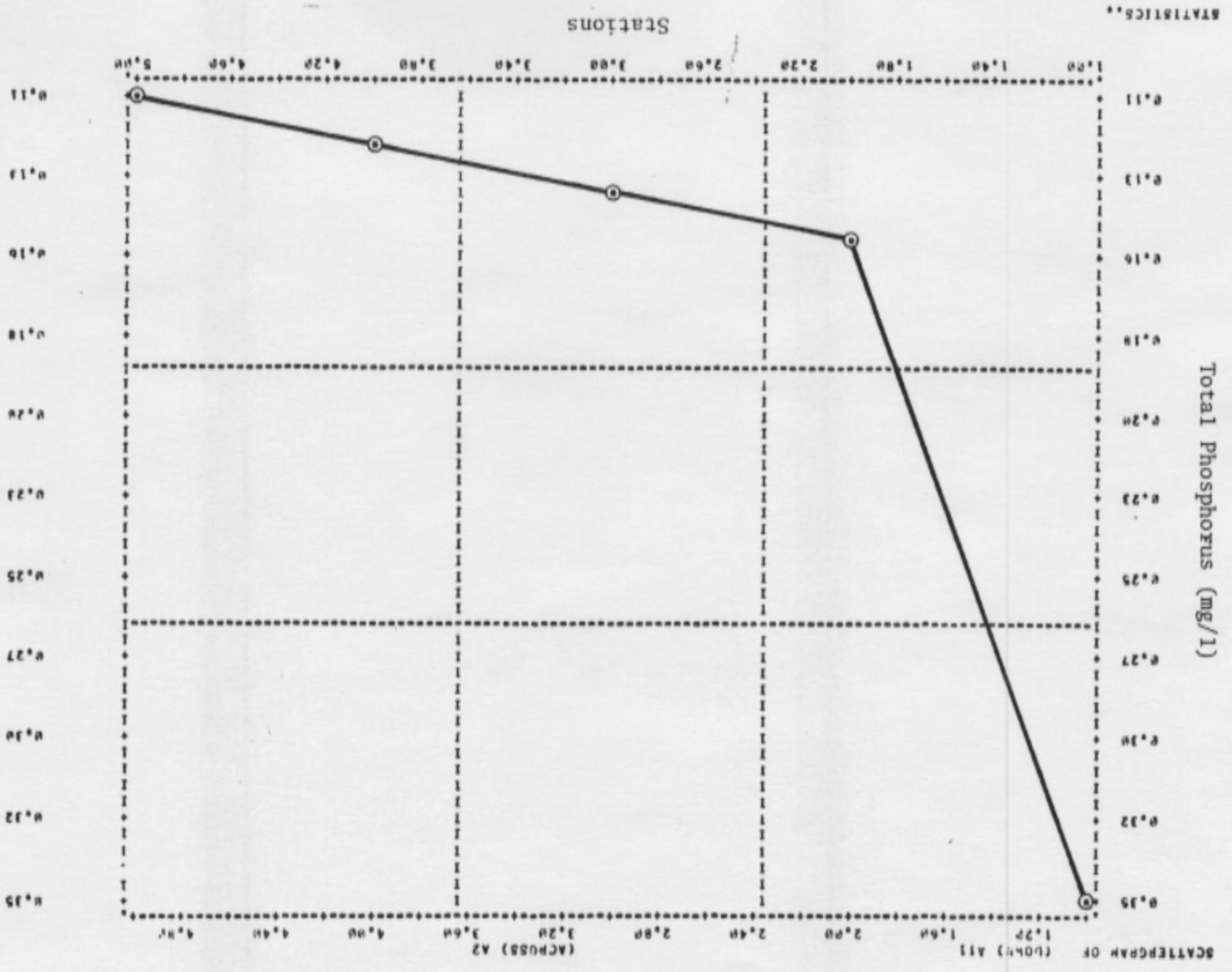




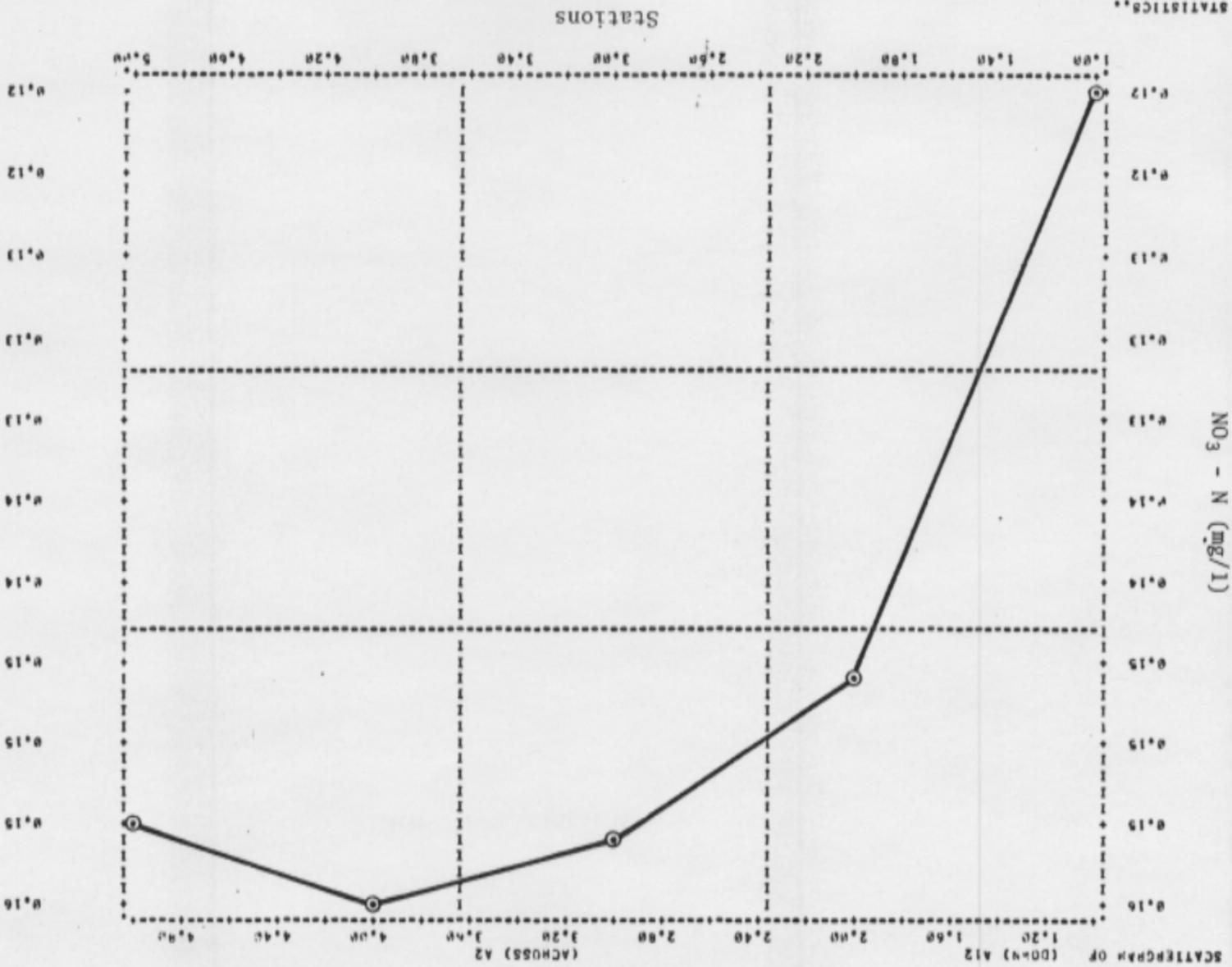
STATISTICS:  
 CORRELATION (R) = -0.76993    R SQUARED = 0.59279    SIGNIFICANCE = 0.16390  
 STD ERR OF EST = 0.02488    INTERCEPT (A) = 0.10284    SLOPE (B) = -0.11644  
 PLOTTED VALUES = 5    EXCLUDED VALUES = 0    MISSING VALUES = 0



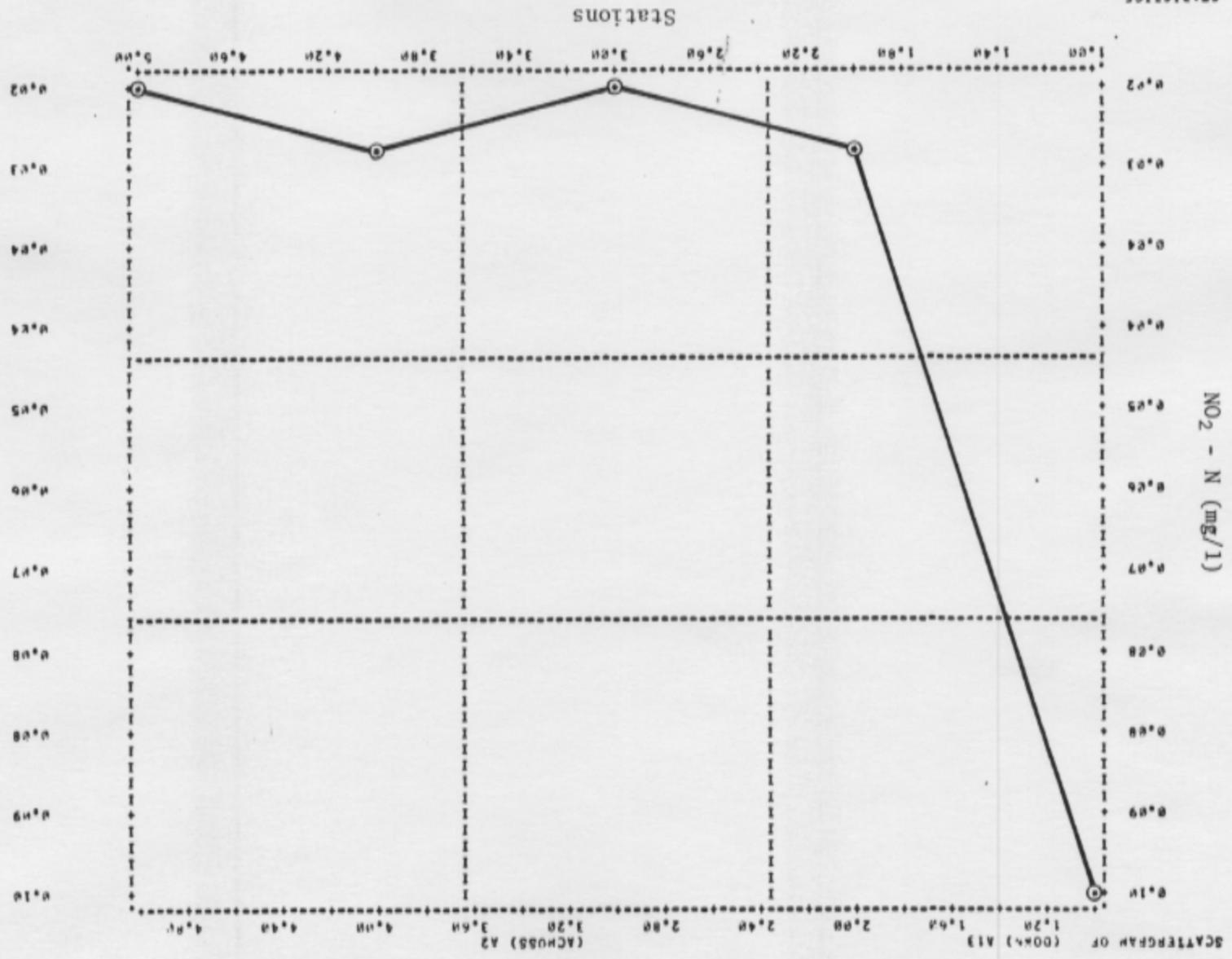
STATISTICS:  
 CORRELATION (R) = -0.8215      R SQUARED =      N = 5  
 STD ERR OF EST =      INTERCEPT (A) =      EXCLUDED VALUES =  
 SLOPE (B) =      SLOPE (B) =      MISSING VALUES =  
 SIGNIFICANCE =      SIGNIFICANCE =      N = 5



STATISTICS:  
 CORRELATION (R) = 0.94590  
 R SQUARED = 0.89482  
 SIGNIFICANCE = 0.00014  
 STD ERR OF EST = 0.01148  
 INTERCEPT (A) = 0.12937  
 SLOPE (B) = 0.00003  
 EXCLUDED VALUES = 0  
 MISSING VALUES = 0

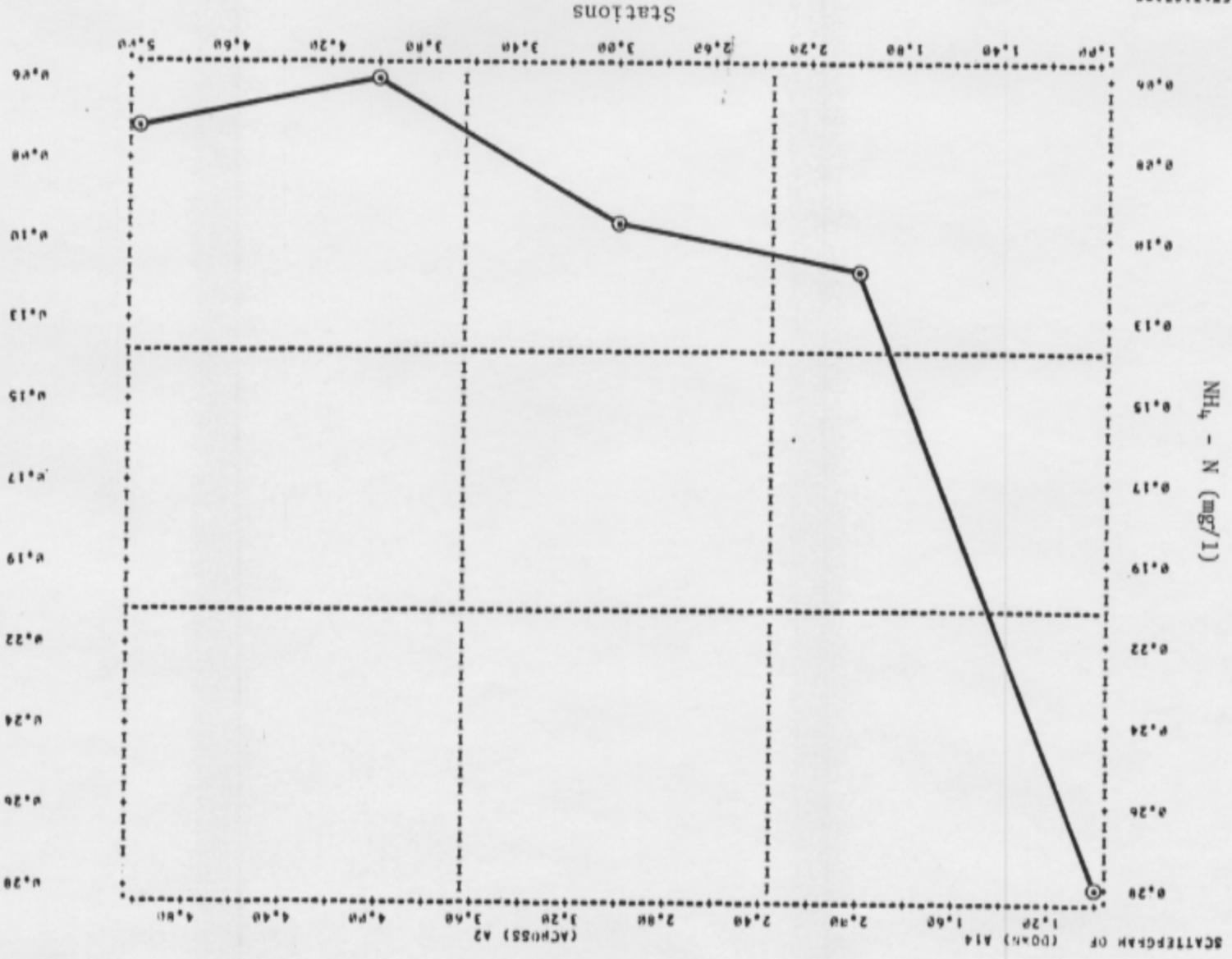


STATISTICS:  
 CORRELATION (R) = -0.71944 R SQUARED = 0.51677  
 STD ERR OF EST = 0.02618 INTERCEPT (A) = 0.08678  
 PLOTTED VALUES = 5 EXCLUDED VALUES = 0  
 MISSING VALUES = 0 SIGNIFICANCE = 0.07603  
 SLOPE (B) = -0.01518

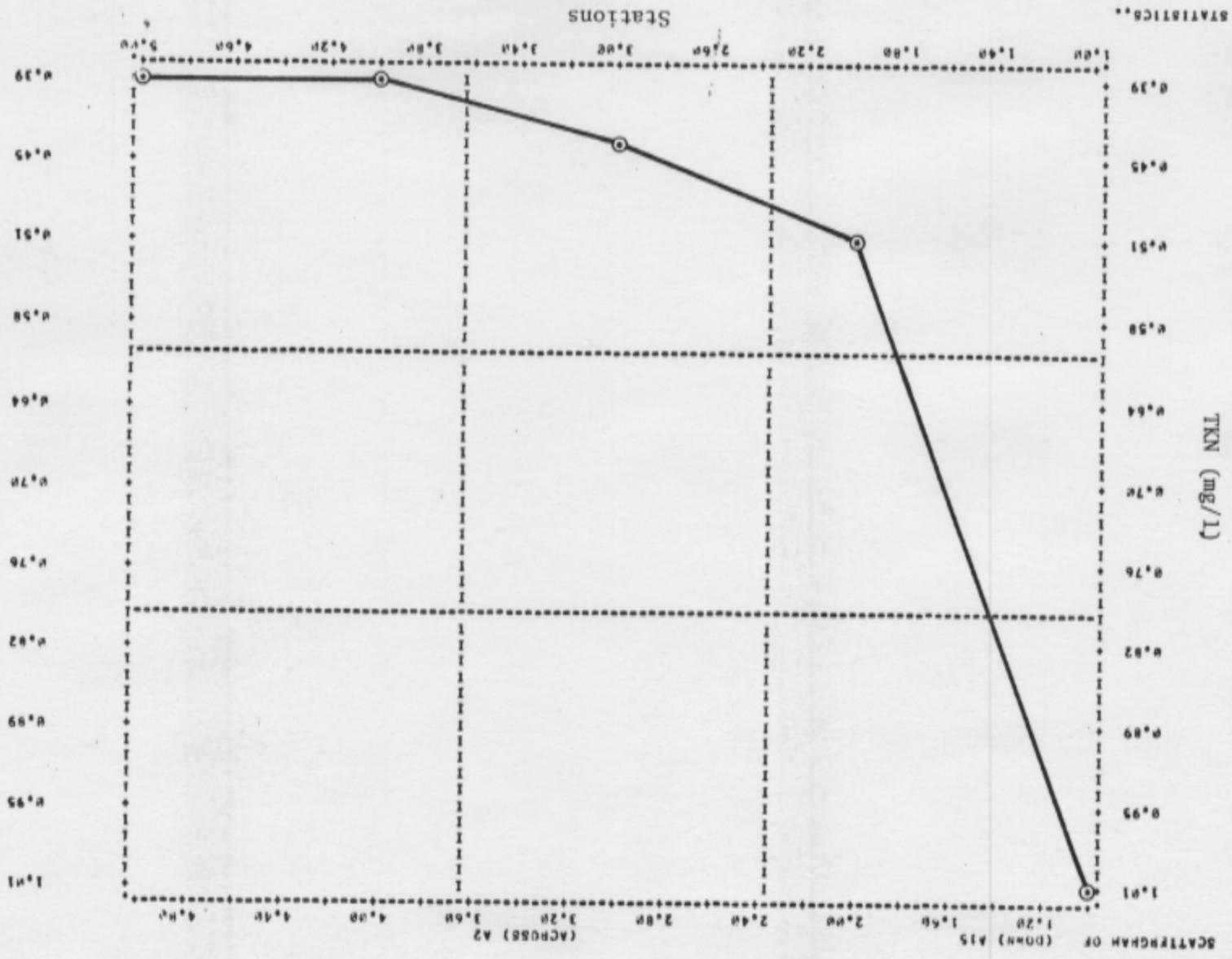


STATISTICS:

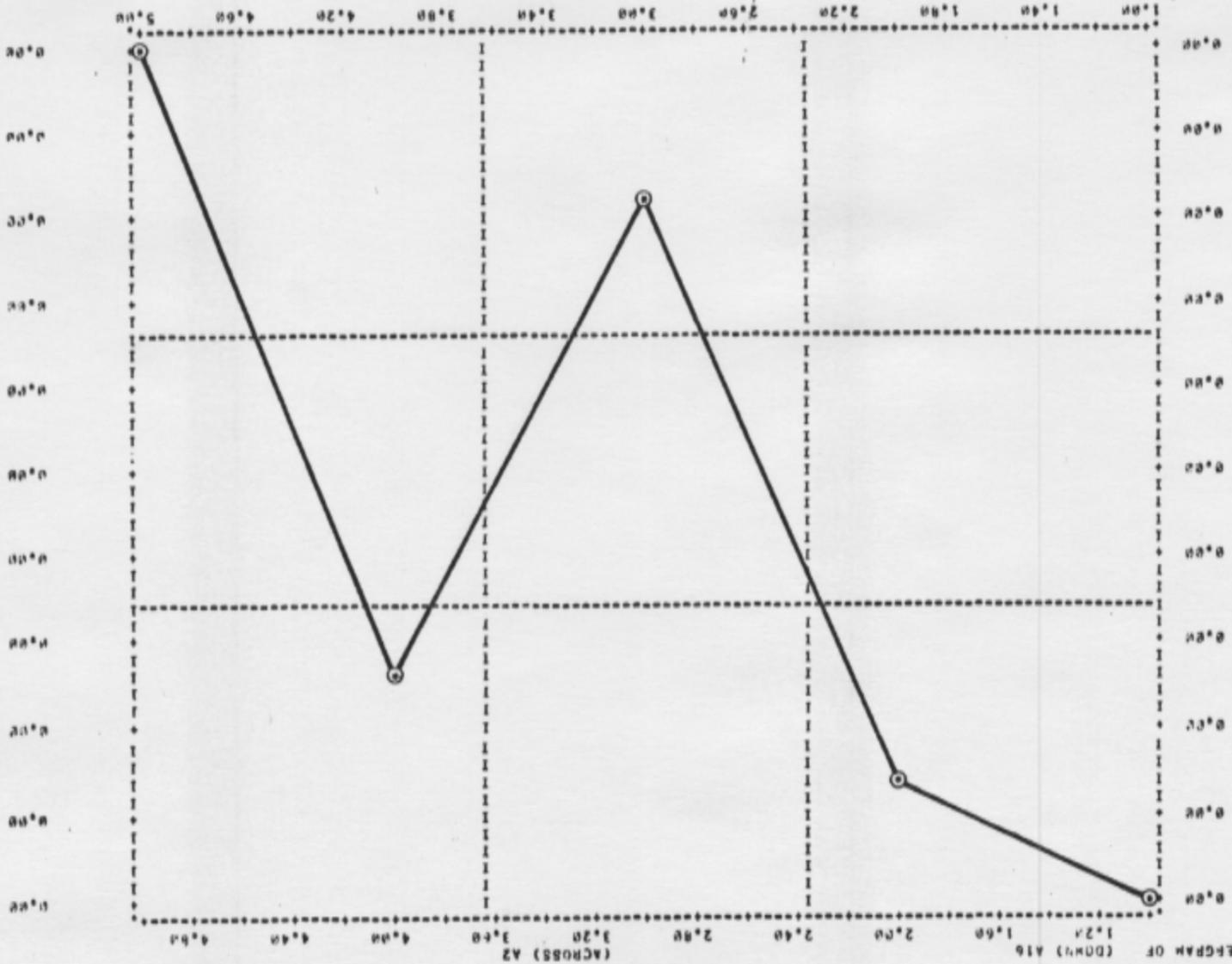
CORRELATION (R) =	-0.8124	R SQUARED	=	0.6597	SIGNIFICANCE	=	0.0004
STD ERR OF EST =	0.05743	INTERCEPT (A) =	0.26826	GLOPE (B) =	-0.04783		
PLCTED VALUES =	5	EXCLUDED VALUES =	0	MISSING VALUES =	0		



STATISTICS:  
 CORRELATION (R) = -0.8279 R SQUARED = 0.6851  
 STD ERR OF EST = 0.17866 INTERCEPT (A) = 0.95811  
 PLOTTED VALUES = 5 EXCLUDED VALUES = 0  
 SIGNIFICANCE = 0.000000 SLOPE (B) = -0.13533  
 MISSING VALUES = 0



Dissolved Cadmium (mg/l)

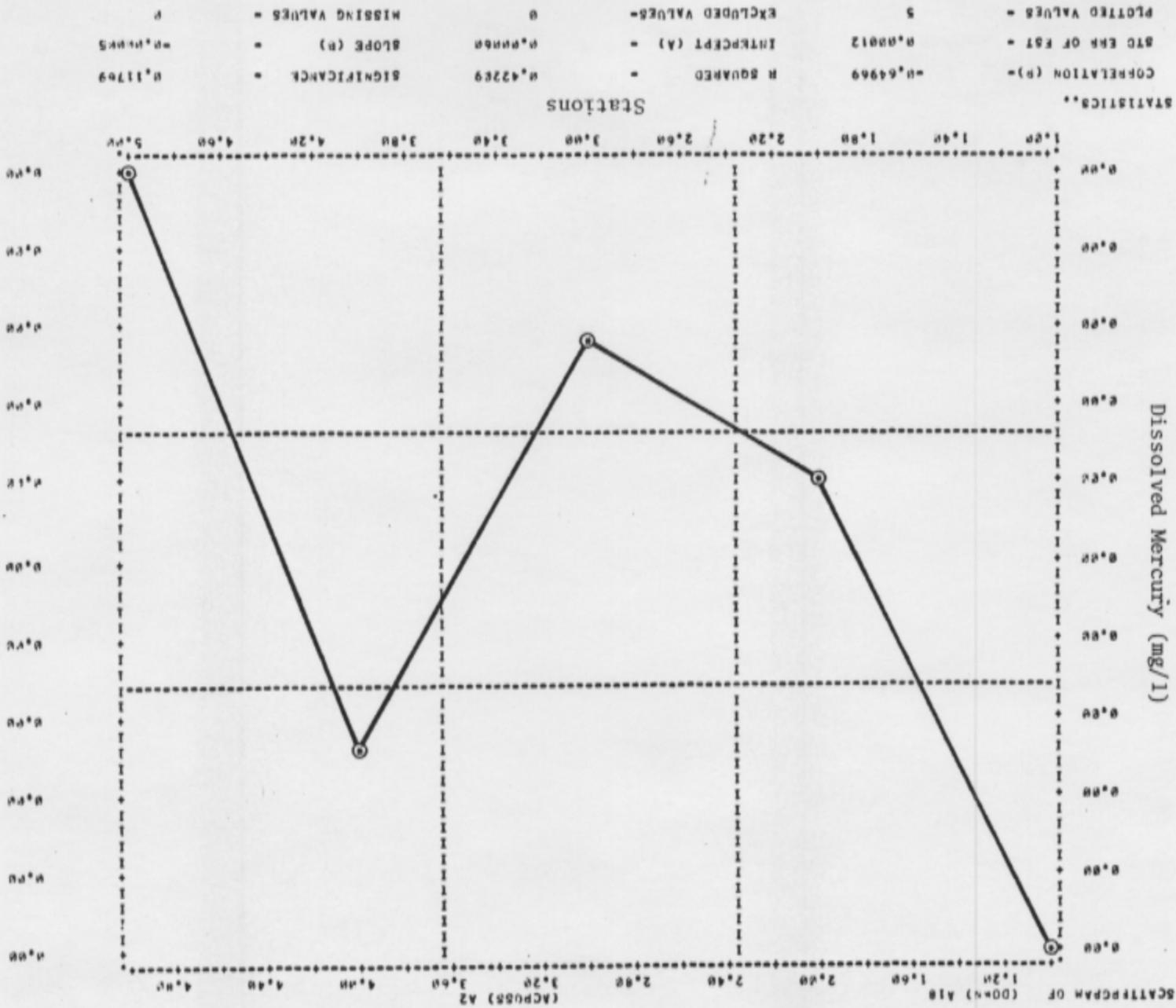


STATISTICS:  
 CORRELATION (R) = -0.7626  
 SLOPE OF EST = 0.0022  
 INTERCEPT (A) = 0.0184  
 R SQUARED = 0.5789  
 SIGNIFICANCE = 0.0076  
 EXCLUDED VALUES = 0  
 MISSING VALUES = 0

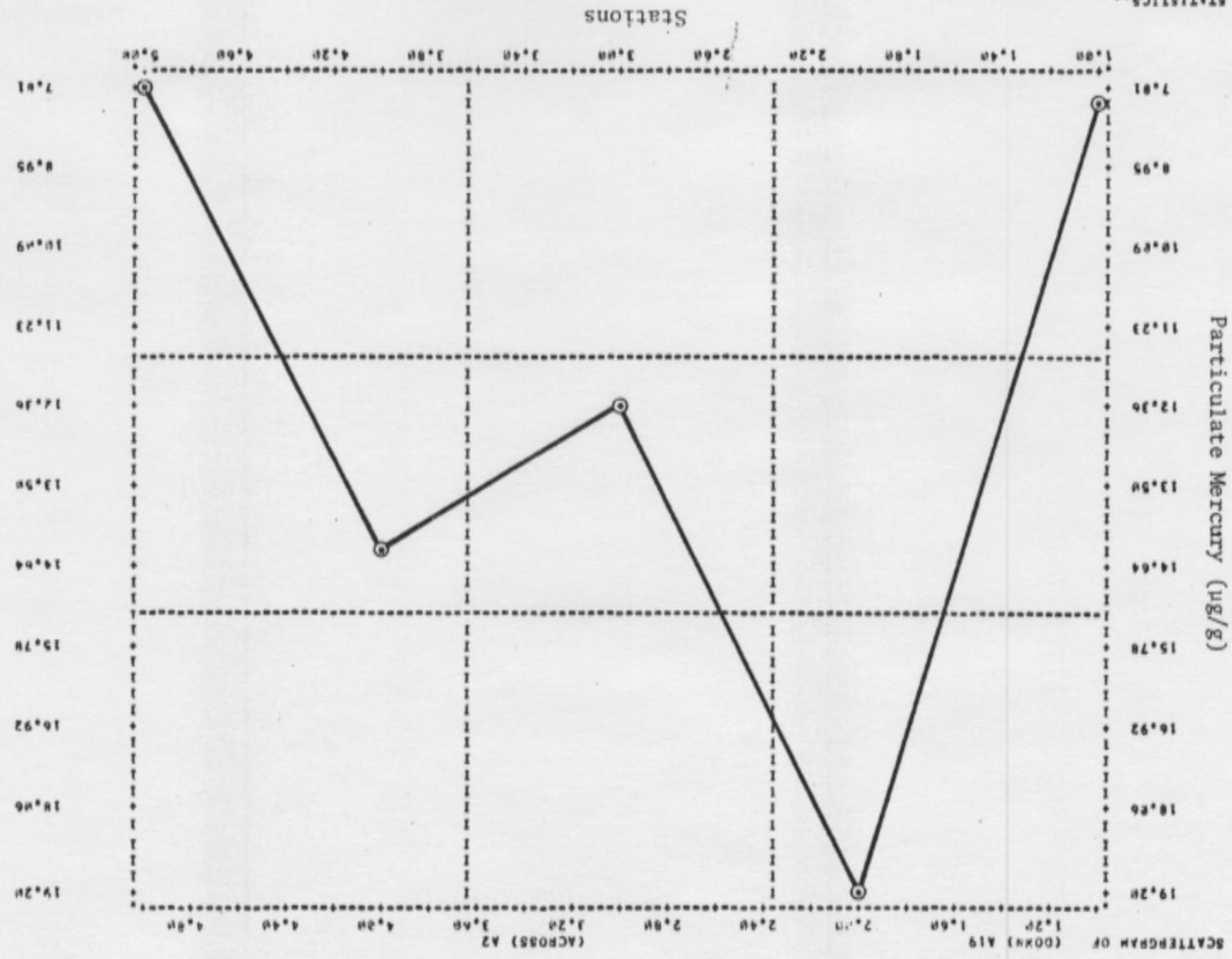
Stations

1.00 1.40 1.80 2.20 2.60 3.00 3.40 3.80 4.20 4.60 5.00

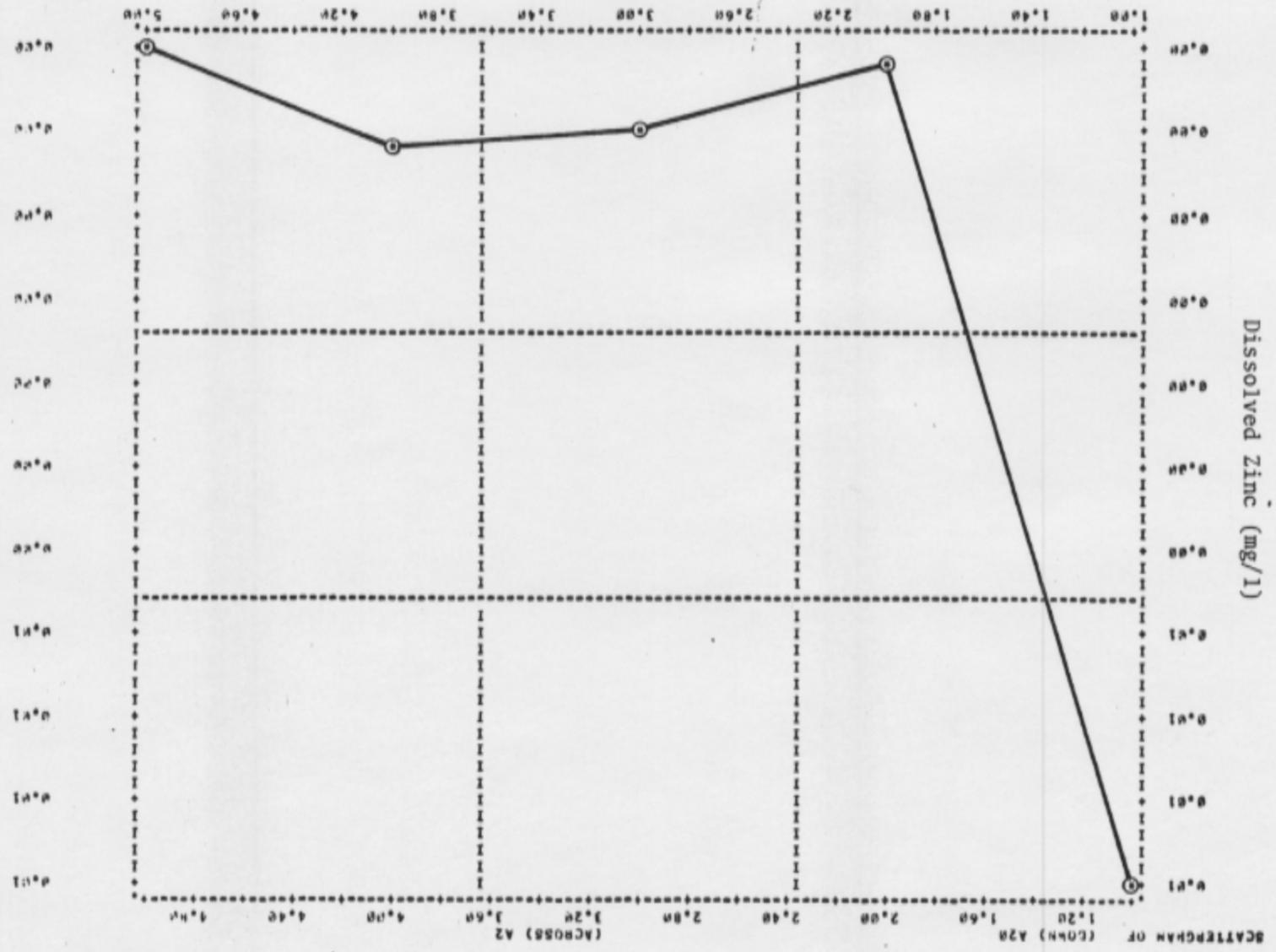
SCATTERGRAM OF (DOWN) A16 (ACROSS) A2  
 1.24 1.60 2.00 2.40 2.80 3.20 3.60 4.00 4.40 4.80

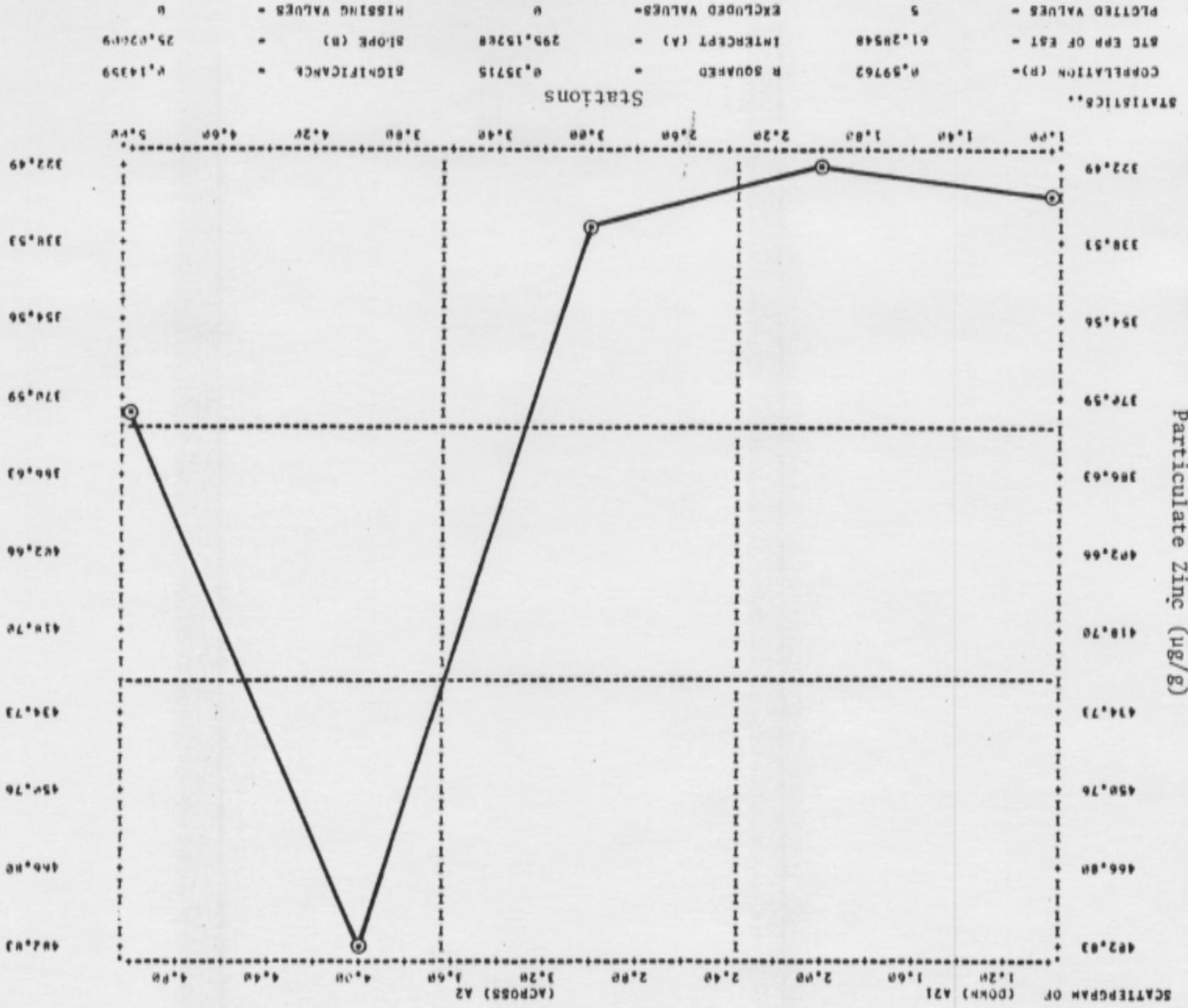


STATISTICS:  
 CORRELATION (R) = -0.1770 P ADJUSTED = 0.4313  
 STD ERR OF EST = 5.3900 INTERCEPT (A) = 14.42358  
 PLOTTED VALUES = 5 EXCLUDED VALUES =  
 SIGNIFICANCE = 0.38791 SLOPE (B) = -0.53942  
 MISSING VALUES = 0



STATISTICS:  
 CORRELATION (R) = -0.71136  
 R SQUARED = 0.50623  
 SIGNIFICANCE = F.00004  
 STD ERR OF EST = 0.00220  
 INTERCEPT (A) = 0.00000  
 SLOPE (B) = -0.00122  
 EXCLUDED VALUES = 5  
 MISSING VALUES = 0





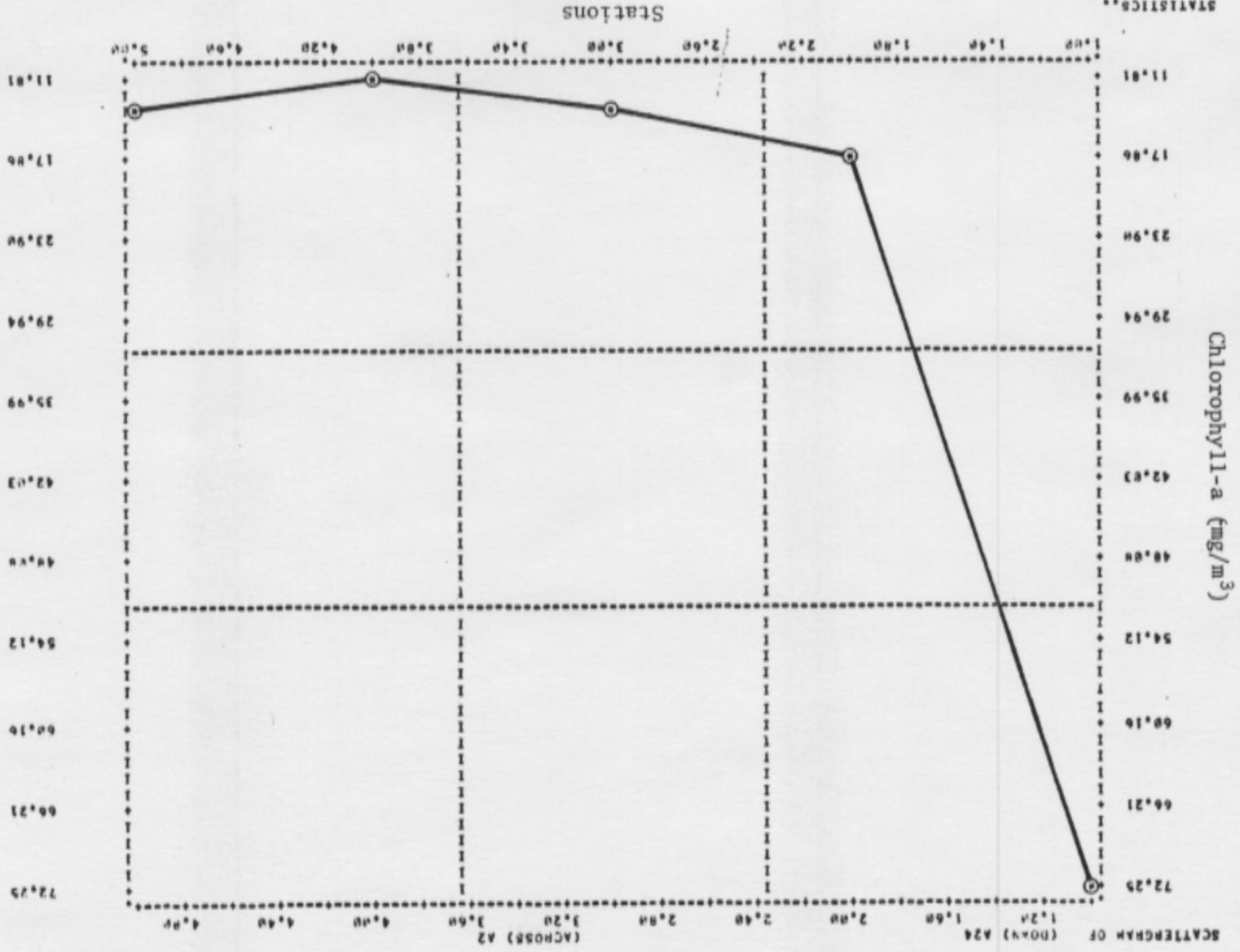
Particulate Zinc (ug/S)

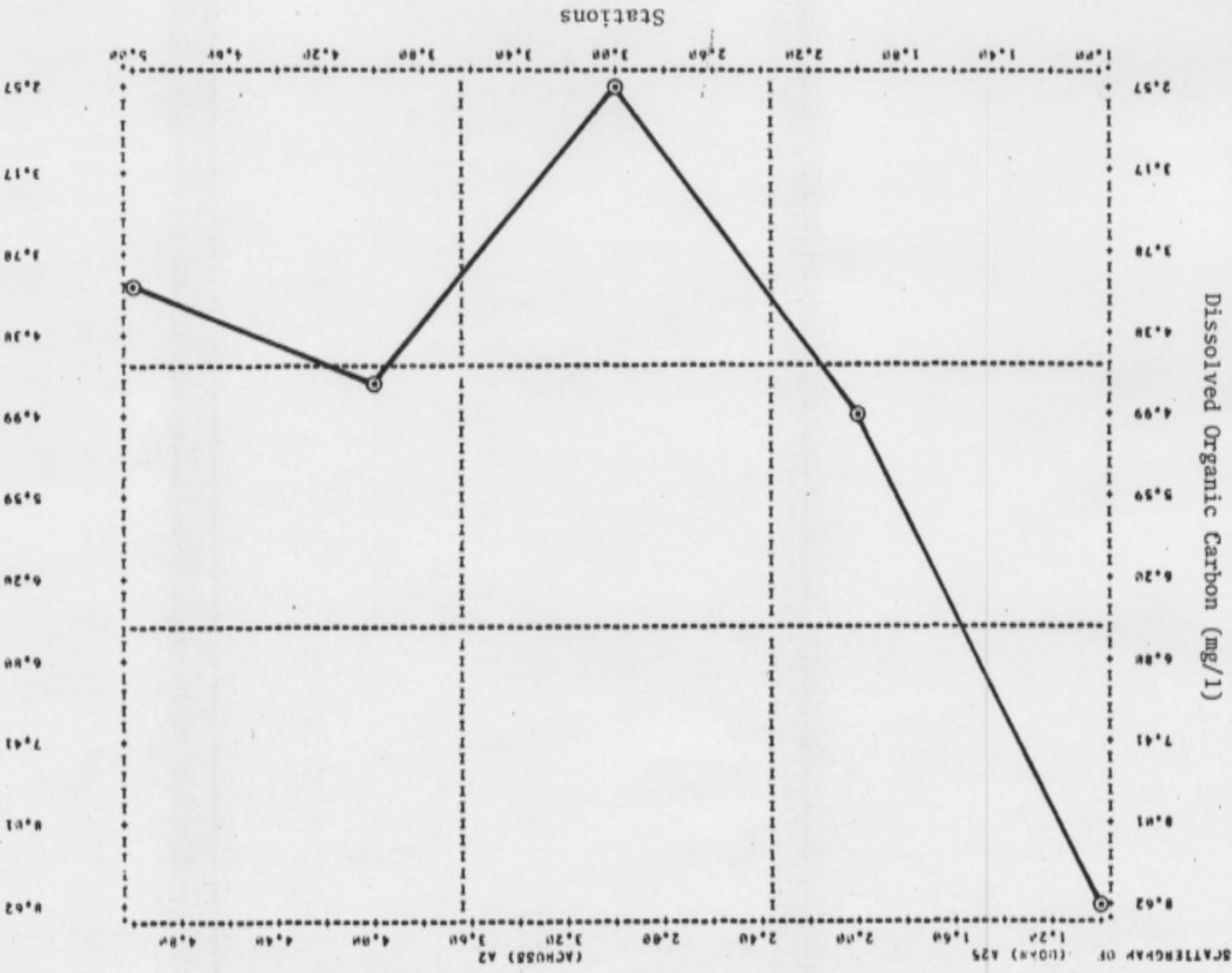
Stations

SCATTERGRAM OF (DOWN) AZ1

(ACROSS) AZ

STATISTICS:  
 CORRELATION (R) = -0.74628  
 R SQUARED = 0.55693  
 SIGNIFICANCE = 0.07312  
 STD ERR OF EST = 19.69449  
 INTERCEPT (A) = 62.90438  
 SLOPE (B) = -12.69418  
 EXCLUDED VALUES = 5  
 MISSING VALUES = 0

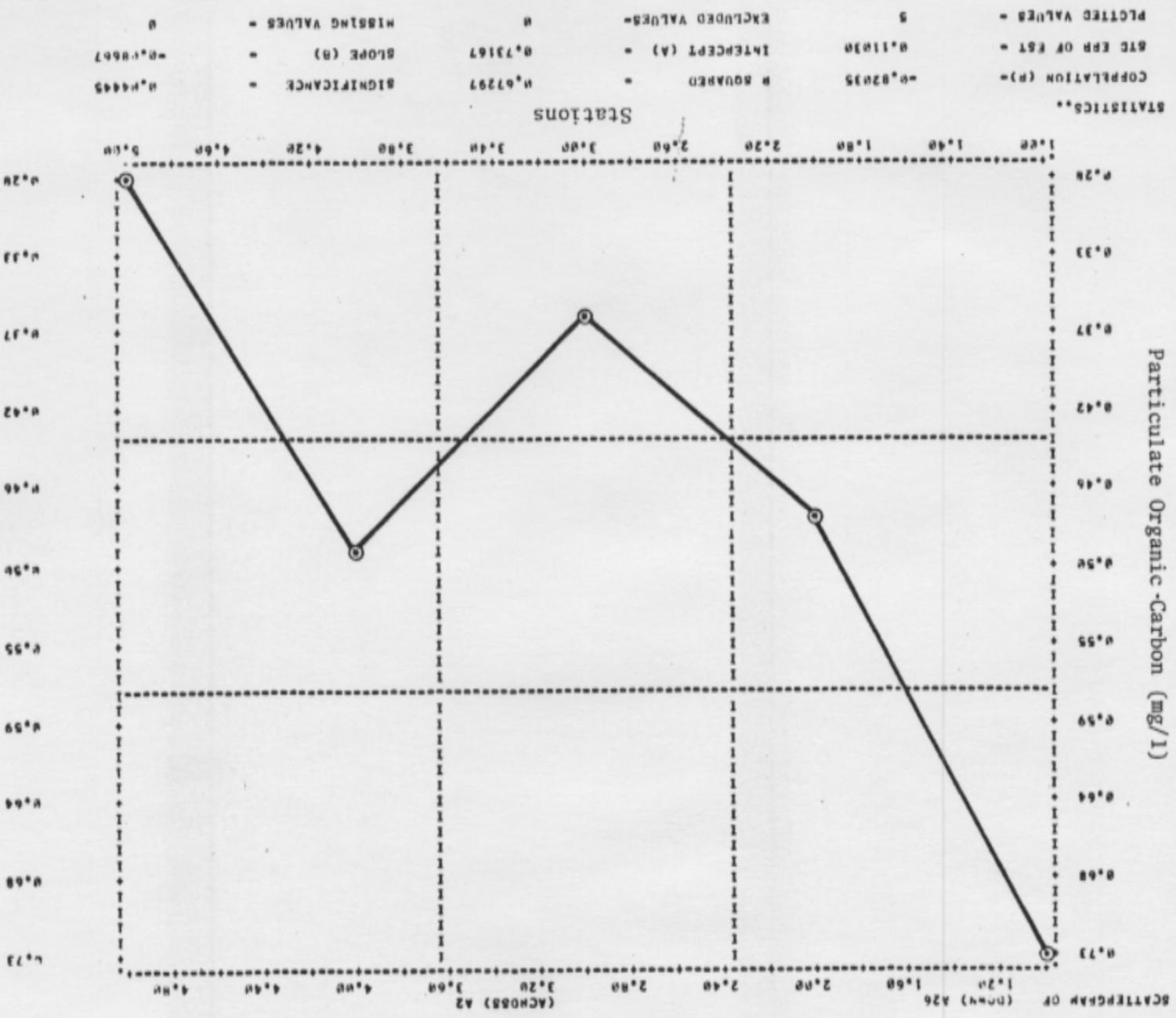




STATISTICS\*\*

CORRELATION (R) =	-0.66681	R SQUARED	=	0.44464	SIGNIFICANCE	=	0.19968
STD ERR OF EST =	1.92311	INTERCEPT (A) =	7.84250	SLOPE (B) =	-0.94250		
PLCTED VALUES =	5	EXCLUDED VALUES =	0	MISING VALUES =	0		

Particulate Organic-Carbon (mg/l)



STATISTICS..

CORRELATION (R) =	-0.82035	R SQUARED	=	0.67297
STD ERR OF EST =	0.11030	INTERCEPT (A) =		0.73167
PLOTTED VALUES =	5	EXCLUDED VALUES =		0
SIGNIFICANCE =	0.04445	SLOPE (B) =		-0.18667
		MISSING VALUES =		0

Stations

1.00 1.40 1.80 2.20 2.60 3.00 3.40 3.80 4.20 4.60 5.00

0.28  
0.33  
0.37  
0.42  
0.46  
0.50  
0.55  
0.59  
0.64  
0.68  
0.73

SCATTERGRAM OF (DMMY) A26 (ACHOS) A2