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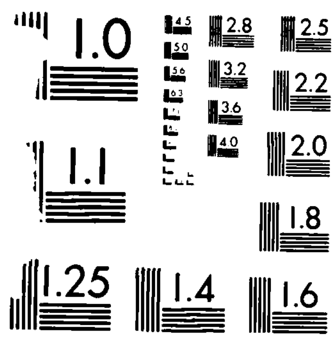

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APPLIED MARINE RESEARCH LABORATORY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

A STUDY OF PHYSICAL PARAMETERS AT THE DAM NECK DISPOSAL SITE DURING THE SUMMER OF 1984

By

Raymond W. Alden III, Principal Investigator

and

Arthur J. Butt, Co-Principal Investigator

Final Report
For the period ending December, 1984

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Under
Contract DACW65-81-C-0051

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The findings of this study point to the conclusion that the location of DNDS is not significantly associated with the oxygen patterns of the region. The Chesapeake Bay plume is pointed to as the major source of oxygen demand (debris, organic-rich fine sediments and sewage-associated particulates flushing out of the Bay).

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A STUDY OF PHYSICAL PARAMETERS
AT THE DAM NECK DISPOSAL SITE
DURING THE SUMMER OF 1984

By

Raymond W. Alden III* and Arthur J. Butt**

INTRODUCTION

Maintenance dredging of navigational channels is a vital component to the routine operations within most seaport systems. The disposal of the dredged material, however, is a recurring operation which is becoming increasingly more complex. Technological and economical feasibilities must be reviewed in conjunction with the possible environmental consequences. Adjacent to most major harbors are zones or regions designated as "disposal areas." Unfortunately, due to finite space, many of these zones in seaport systems must also be planned as multi-utilization areas to accommodate urban development.

Urban populations in the coastal zone are expected to grow, resulting in ever increasing demands for available space and resources. One such urban necessity is the adequate processing of urban waste via sewage treatment and disposal. To satisfy social and economic situations, it is not uncommon to locate sewage effluent diffuser systems in coastal waters. When these discharge

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areas coincide in a multi-utilization zone with other activities such as dredged material disposal, there is concern over the individual and cumulative environmental effects of all operations. These concerns become increasingly important, if degradation in water quality is observed after multiple activities have commenced.

The present study was to investigate the physical characteristics of a nearshore coastal area off Virginia Beach, VA. The region is currently being used for the effluent disposal of the Atlantic Sewage Treatment Plant (STP) and dredged material disposal at the Dam Neck dredged disposal site. The study was designed to characterize the patterns of temperature, salinity and dissolved oxygen in the area as well as to determine whether these patterns are significantly influenced by the Atlantic STP diffuser or the Dam Neck dredged material disposal site.

METHODS AND MATERIALS

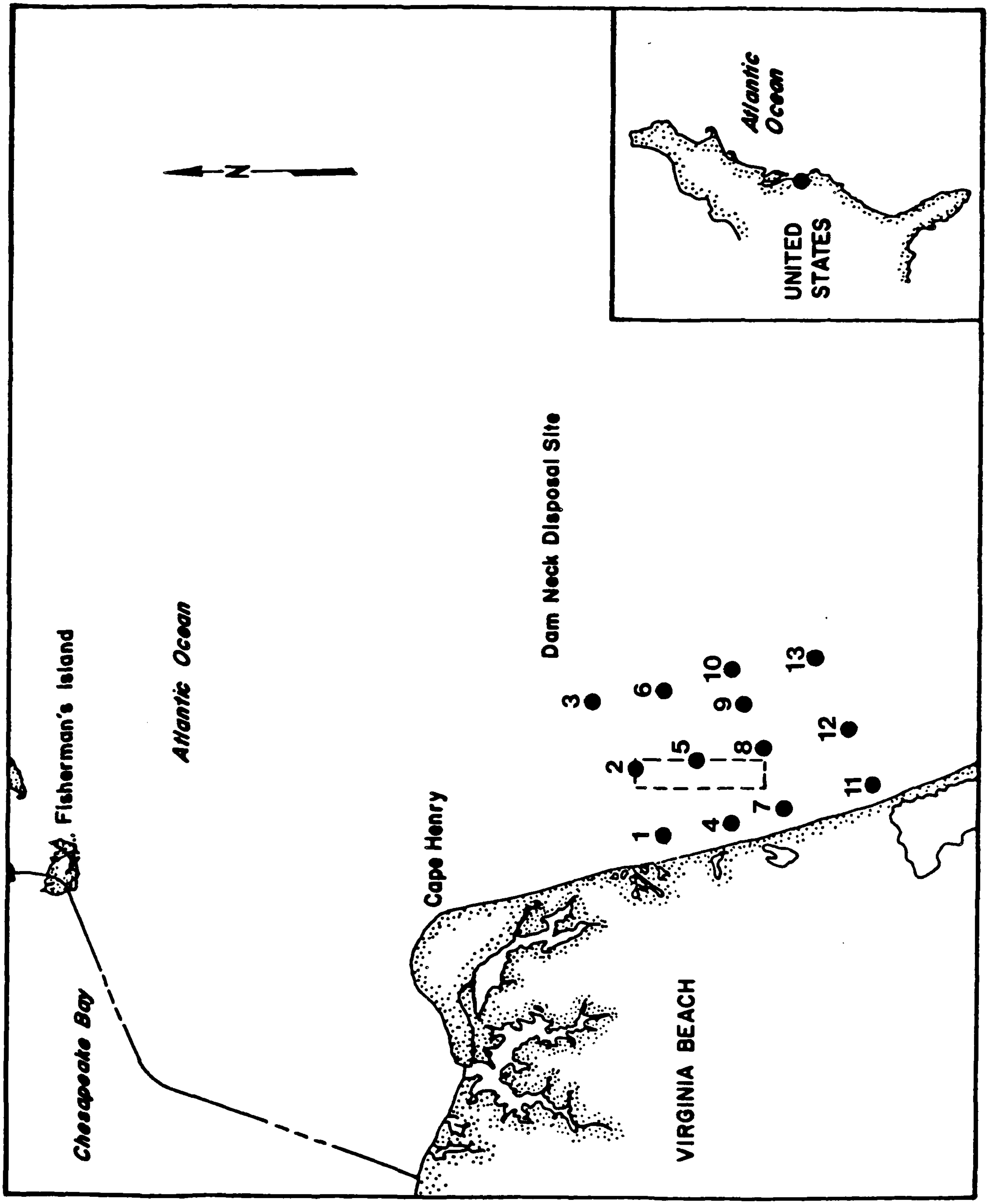
Study Area

The Dam Neck Disposal Site (DNDS) activated in 1968, is an interim open-water site approximately 3 miles east of Dam Neck, Virginia (Fig. 1). It receives dredged material from Cape Henry Channel and Thimble Shoal Channel. The area is described as a high energy zone just south of the Chesapeake Bay mouth and is between the 30 and 50 ft contour lines.

The majority of outflowing surface water from the Bay travels towards the south along the Atlantic Ocean Channel just east of DNDS. A strong density stratification has been identified in the area. The low salinity surface water is characterized as part of the Chesapeake Bay Plume during the warmer months. The distinct plume effect is minimized during the winter when vertical mixing is greatest. The southerly drift of shelf water combined with the local Bay plume dominates advective transport in the region. Wind strength and direction serve as strong influences on water flowing out of the Bay and along the coast line.

Water quality in this region appears to be good when evaluated against the water quality reference levels of Virginia State Water Control Board (VSWCB) (see, for example, accompanying report by Alden et al., 1985 on the Dam Neck water quality monitoring study). The only major exception to this trend is the depressed hypolimnion dissolved oxygen (DO) concentrations which are reported periodically in this region (VSWCB, personal communication, 1984). Surface waters are generally near saturation levels

Figure 1. Location of the interim Dam Neck Disposal Site (DNDS)



(>6 mg/); however DO has been reported as low as 4.6 mg/l during 1973 (Hydroscience, 1974). Depressed DO levels (as low as 3.4 mg/l) have been reported routinely from bottom samples offshore of Rudee Inlet and North Bay to as far north as Cape Henry from 1981-1983 (Hydroscience, 1974; VSWCB, personal communication, 1984).

Sampling Region

Thirteen stations were monitored during six cruises for salinity (^{o}/oo), temperature (^{o}C) and DO (ppm) during July through September 1984 (Fig. 1). The collection stations represent a parallelogram grid of approximately equidistant stations. The shape of the grid was selected to address three concerns: 1) the stations were designed to overlap those which had been sampled during the previous nine months for water quality (Stations 1 and 3) and zooplankton (Stations 1, 2, 3, 6, 7 and 9); 2) to conform with the presumed fan-shape pattern of the Bay plume; and 3) to avoid the major logistical problems of sampling numerous stations located deep within restricted fan-shape zone of the Dam Neck Missle Firing Range to the south.

Field measurements were taken in duplicate, 1 m below the surface and 1 m above the bottom. Stations 4 and 7 were located near the ends of the diffuser for the Atlantic Sewage Treatment Plant (STP). The diffuser begins about 2200 m (7200 ft) east of the shore (Lat. 36^{o}46'50", Long. 75^{o}55'52") and ends 731 m (2400 ft) northward (Lat. 36^{o}74'11", Long. 75^{o}55'38"). Stations 2, 5, 8 were located in or on the periphery of the Dam Neck Disposal Site.

Statistical Analysis

Of the three physical measurements taken, DO was the parameter of greatest concern, since it was the one most likely to be impacted by man's activities (i.e. STP effluent or dredged material disposal). There were a number of general a priori hypotheses which were assessed by multiple regression analysis: 1) DO patterns are related to the depth taken in the water column; 2) the patterns are influenced by geographic location of the stations; 3) the DO concentrations are directly influenced by temperature and/or salinity patterns in the region; and, 4) the DO reading are affected by general month to month variations in the water column of the region.

Temperature and salinity readings were treated as continuous covariates, while the month to month effects were created as dummy variables. Within the geographic hypothesis, a number of distinct alternatives were tested: 1) there is an overall north to south trend (designated NS) in oxygen readings; 2) there is an overall west to east trend (designated WE) in DO patterns; and 3) there are distinct oxygen patterns associated with stations located in the vicinity of the Dam Neck Site (station group designated as DNS = Stations 2, 5 and 8) or the Atlantic STP (station group designated as STP = Stations 4 and 7). The NS and WE effects were created by numbering the rows and columns of the station grid in ascending order along the direction to be tested. All appropriate interaction terms (e.g. month by depth, WE by NS, WE by NS by depth, etc.) were also tested by the stepwise multiple regression process. The model selected to describe the DO patterns was the one explaining the greatest portion of the variance of the data (i.e. maximum R^2) but, at the same time, contained only highly significant terms ($p<0.001$). Similar models were constructed to describe major temperature and salinity patterns for the area.

RESULTS

The average surface and bottom temperature, salinity and DO measurements taken for each station on each date are presented in Table 1. Over the three month period, temperatures ranged from 18.2°C to 27.5°C for surface waters and from 12.1°C to 26.2°C for measurements taken from the bottom. Salinity ranges were 18.5 ppt to 31.6 ppt (surface) and 27.1 ppt to 33.4 ppt (bottom). The DO readings ranged from 6.7 mg/l to 10.1 mg/l in surface waters and from 4.3 mg/l to 9.2 mg/l at the bottom.

The multiple regression models for the three parameters are presented in Table 2. All three models explained the majority of the variation observed in the measurements (i.e. R^2=65% of variance for DO; R^2=74% for temperature and R^2=70% for salinity). In order to indicate the magnitude of each of the significant model effets, a "% change" term was calculated. This term represents the maximum amount of change associated with any given effect (e.g. for a NS effect, the extreme value from the study area was used), expressed as a percentage of the grand mean. Therefore, the most important effects of each model can be readily identified by scanning this column.

Dissolved oxygen is the parameter which is of greatest concern, in terms of the findings of previous studies, the drastic ecological effects of hypoxia, and the potential impact of man's activities in coastal waters. Therefore, the model for dissolved oxygen was used to produce a series of contour maps to graphically

Table 1. The mean (standard error) of the physical parameters measured at Dam Neck during the Summer of 1984.

	Salinity		Temperature		Dissolved Oxygen	
	Base	Surface	Base	Surface	Base	Surface
STATION 1						
11JUL84	19.58 (0.14)	16.06 (0.78)	27.10 (0.15)	30.28 (0.26)	8.5 (0.1)	6.8 (0.0)
26JUL84	23.75 (0.01)	15.00 (0.00)	21.94 (0.03)	32.68 (0.03)	7.6 (0.0)	5.6 (0.0)
01AUG84	23.88 (0.05)	20.85 (0.09)	23.00 (0.14)	27.11 (0.03)	8.8 (0.0)	6.8 (0.0)
21AUG84	26.85 (0.28)	26.00 (0.08)	22.76 (0.53)	30.04 (0.10)	8.9 (0.1)	5.4 (0.0)
21SEP84	21.85 (0.05)	21.75 (0.05)	29.21 (0.01)	30.09 (0.01)	7.3 (0.0)	6.3 (0.0)
26SEP84	21.79 (0.05)	21.68 (0.16)	25.32 (0.06)	27.34 (0.08)	7.5 (0.0)	6.1 (0.0)
STATION 2						
11JUL84	22.95 (0.51)	13.06 (0.04)	24.39 (0.07)	31.89 (0.07)	8.8 (0.0)	8.1 (0.1)
26JUL84	22.63 (0.01)	13.66 (0.04)	23.85 (0.09)	33.11 (0.12)	7.6 (0.0)	8.2 (0.0)
01AUG84	23.22 (0.02)	16.45 (0.05)	22.65 (0.00)	31.67 (0.17)	8.0 (0.0)	7.0 (0.0)
21AUG84	26.31 (0.07)	26.13 (0.07)	28.58 (0.51)	30.37 (0.18)	9.4 (0.0)	8.3 (0.3)
21SEP84	21.69 (0.06)	21.83 (0.23)	27.22 (0.74)	30.59 (0.04)	7.8 (0.0)	6.3 (0.1)
26SEP84	21.98 (0.06)	20.91 (0.09)	24.51 (0.18)	29.72 (0.56)	8.2 (0.0)	6.4 (0.0)
STATION 3						
11JUL84	19.44 (0.28)	12.01 (0.12)	24.98 (0.01)	32.16 (0.28)	10.0 (0.1)	9.2 (0.0)
26JUL84	21.71 (0.01)	13.10 (0.10)	25.07 (0.03)	33.06 (0.04)	7.6 (0.0)	8.3 (0.0)
01AUG84	21.11 (0.01)	17.04 (0.17)	27.40 (0.20)	31.66 (0.06)	6.9 (0.0)	7.2 (0.0)
21AUG84	25.95 (0.09)	24.79 (0.13)	29.97 (0.07)	30.28 (0.06)	8.5 (0.1)	7.6 (0.0)
21SEP84	21.56 (0.23)	21.95 (0.24)	27.09 (0.07)	30.43 (0.07)	8.0 (0.0)	6.8 (0.0)
26SEP84	22.15 (0.05)	20.83 (0.06)	25.33 (0.13)	29.25 (0.05)	8.2 (0.0)	6.6 (0.0)

Table 1. (Continued)

	Salinity		Temperature		Dissolved Oxygen	
	Base	Surface	Base	Surface	Base	Surface
STATION 4						
26JUL84	23.73 (0.00)	14.92 (0.12)	22.10 (0.00)	32.85 (0.17)	7.6 (0.0)	6.1 (0.0)
01AUG84	23.90 (0.00)	20.63 (0.01)	22.99 (0.19)	29.16 (0.04)	8.9 (0.1)	6.4 (0.0)
21AUG84	27.45 (0.10)	26.13 (0.04)	21.17 (0.00)	30.25 (0.00)	8.7 (0.1)	6.0 (0.0)
21SEP84	21.90 (0.13)	22.04 (0.26)	28.25 (0.33)	30.06 (0.02)	7.8 (0.1)	6.5 (0.0)
26SEP84	22.87 (0.29)	21.00 (0.00)	25.19 (0.09)	28.74 (0.10)	7.9 (0.0)	4.3 (0.0)
STATION 5						
11JUL84	21.86 (0.24)	14.12 (0.26)	25.45 (0.22)	32.09 (0.08)	8.7 (0.1)	7.7 (0.0)
26JUL84	23.32 (0.02)	14.36 (0.12)	22.61 (0.01)	33.07 (0.03)	7.6 (0.0)	7.6 (0.0)
01AUG84	22.94 (0.16)	17.85 (0.08)	23.48 (0.09)	31.28 (0.02)	7.9 (0.0)	7.0 (0.0)
21AUG84	26.38 (0.05)	26.07 (0.17)	27.64 (0.00)	30.39 (0.07)	9.2 (0.0)	8.4 (0.0)
21SEP84	21.79 (0.11)	22.00 (0.20)	28.17 (0.17)	30.14 (0.06)	7.8 (0.0)	6.6 (0.0)
26SEP84	22.65 (0.01)	21.06 (0.13)	24.27 (0.14)	28.72 (0.10)	7.7 (0.0)	5.3 (0.0)
STATION 6						
11JUL84	20.97 (0.53)	13.64 (0.40)	25.67 (0.03)	32.71 (0.19)	9.7 (0.1)	8.8 (0.0)
26JUL84	22.28 (0.06)	13.81 (0.01)	25.36 (0.04)	33.34 (0.08)	7.8 (0.0)	8.4 (0.1)
01AUG84	22.40 (0.10)	15.62 (0.11)	26.45 (0.55)	32.15 (0.05)	7.5 (0.0)	7.6 (0.0)
21AUG84	26.59 (0.13)	25.66 (0.04)	28.71 (0.09)	30.95 (0.22)	8.3 (0.1)	8.2 (0.1)
21SEP84	21.38 (0.20)	21.70 (0.08)	25.54 (0.07)	30.00 (0.03)	8.1 (0.1)	6.8 (0.0)
26SEP84	22.26 (0.06)	20.54 (0.09)	24.81 (0.01)	29.36 (0.18)	8.3 (0.1)	6.6 (0.0)
STATION 7						
11JUL84	22.97 (0.93)	14.49 (0.71)	25.77 (0.12)	32.05 (0.20)	8.8 (0.1)	7.8 (0.2)
26JUL84	23.77 (0.07)	14.90 (0.06)	22.20 (0.00)	32.88 (0.05)	7.4 (0.1)	6.9 (0.0)
01AUG84	23.99 (0.00)	20.36 (0.01)	23.35 (0.20)	29.51 (0.07)	8.9 (0.0)	6.3 (0.0)
21AUG84	26.39 (0.02)	25.40 (0.00)	19.68 (0.19)	30.49 (0.01)	8.0 (0.1)	6.2 (0.0)
21SEP84	22.00 (0.00)	21.89 (0.15)	28.11 (0.14)	29.90 (0.00)	8.5 (0.0)	6.7 (0.0)
26SEP84	21.98 (0.18)	20.95 (0.03)	27.16 (0.00)	29.24 (0.14)	7.5 (0.1)	5.1 (0.0)

Table 1. (Continued)

	Salinity		Temperature		Dissolved Oxygen	
	Base	Surface	Base	Surface	Base	Surface
STATION 8						
11JUL84	21.56 (0.33)	12.94 (0.05)	26.28 (0.07)	32.15 (0.09)	8.6 (0.1)	7.4 (0.0)
26JUL84	23.55 (0.21)	14.71 (0.10)	22.21 (0.11)	32.91 (0.07)	6.9 (0.0)	7.5 (0.0)
01AUG84	22.42 (0.41)	18.40 (0.10)	25.52 (1.61)	30.75 (0.08)	8.1 (0.3)	5.3 (0.1)
21AUG84	26.50 (0.04)	25.61 (0.09)	25.63 (0.15)	30.70 (0.00)	8.1 (0.1)	7.8 (0.0)
21SEP84	21.87 (0.05)	21.83 (0.11)	29.19 (0.13)	30.42 (0.02)	7.8 (0.0)	6.7 (0.0)
26SEP84	22.43 (0.04)	20.91 (0.12)	26.59 (0.44)	28.96 (0.13)	8.0 (0.1)	5.8 (0.0)
STATION 9						
11JUL84	21.69 (0.33)	13.16 (0.08)	25.23 (0.02)	32.54 (0.10)	8.7 (0.1)	7.3 (0.0)
26JUL84	23.44 (0.14)	14.15 (0.05)	22.94 (0.05)	22.95 (0.00)	7.6 (0.0)	8.6 (0.0)
01AUG84	21.99 (0.07)	15.84 (0.06)	28.23 (0.16)	31.71 (0.26)	7.9 (0.0)	7.3 (0.0)
21AUG84	26.18 (0.08)	25.41 (0.14)	29.34 (0.13)	30.75 (0.12)	8.2 (0.1)	7.6 (0.0)
21SEP84	21.61 (0.05)	21.77 (0.12)	27.08 (0.02)	30.22 (0.08)	7.9 (0.0)	6.9 (0.0)
26SEP84	22.10 (0.10)	20.66 (0.10)	25.38 (0.08)	29.08 (0.02)	7.8 (0.3)	6.0 (0.0)
STATION 10						
11JUL84	21.55 (0.47)	13.13 (0.17)	25.17 (0.11)	32.67 (0.23)	8.7 (0.1)	7.6 (0.0)
26JUL84	22.75 (0.07)	13.88 (0.12)	23.57 (0.10)	33.04 (0.10)	7.7 (0.0)	8.4 (0.1)
01AUG84	22.02 (0.06)	16.46 (1.54)	29.43 (0.29)	32.07 (0.28)	7.7 (0.0)	7.6 (0.0)
21AUG84	25.71 (0.04)	25.17 (0.17)	30.13 (0.11)	30.67 (0.03)	8.2 (0.0)	7.1 (0.0)
21SEP84	21.98 (0.02)	21.80 (0.07)	27.72 (0.15)	30.37 (0.07)	7.8 (0.0)	6.9 (0.0)
26SEP84	22.27 (0.09)	20.41 (0.09)	25.20 (0.04)	29.74 (0.00)	8.1 (0.0)	6.3 (0.0)

Table 1. (Continued)

	Salinity		Temperature		Dissolved Oxygen	
	Base	Surface	Base	Surface	Base	Surface
			STATION 11			
11JUL84	23.46 (0.02)	14.30 (0.06)	25.75 (0.07)	32.13 (0.08)	8.5 (0.1)	7.4 (0.1)
26JUL84	24.11 (0.01)	14.86 (0.04)	22.03 (0.09)	33.02 (0.10)	7.1 (0.1)	6.3 (0.1)
01AUG84	23.20 (0.25)	19.89 (0.23)	23.94 (0.12)	28.82 (0.06)	9.3 (0.1)	5.8 (0.0)
21AUG84	26.18 (0.18)	25.41 (0.01)	18.95 (0.43)	31.01 (0.53)	7.8 (0.0)	5.6 (0.0)
21SEP84	22.38 (0.20)	21.85 (0.02)	29.31 (0.09)	30.46 (0.04)	7.6 (0.0)	6.8 (0.0)
26SEP84	21.98 (0.38)	20.96 (0.04)	27.56 (0.36)	29.18 (0.02)	6.9 (0.2)	5.0 (0.1)
			STATION 12			
11JUL84	22.69 (0.25)	13.55 (0.10)	25.74 (0.16)	32.56 (0.26)	8.6 (0.1)	7.9 (0.0)
26JUL84	23.41 (0.13)	14.81 (0.01)	22.44 (0.03)	32.93 (0.09)	7.6 (0.0)	7.7 (0.0)
01AUG84	22.25 (0.17)	18.48 (0.06)	23.45 (0.14)	31.20 (0.15)	8.7 (0.1)	6.2 (0.0)
21AUG84	26.59 (0.01)	25.84 (0.16)	20.14 (0.04)	31.45 (0.10)	7.8 (0.0)	7.6 (0.0)
21SEP84	21.79 (0.01)	21.76 (0.21)	26.86 (0.26)	30.39 (0.05)	8.2 (0.1)	7.2 (0.0)
26SEP84	22.62 (0.08)	20.50 (0.01)	26.07 (0.07)	29.47 (0.29)	7.8 (0.1)	5.7 (0.0)
			STATION 13			
11JUL84	23.43 (0.75)	14.19 (0.11)	25.49 (0.09)	32.60 (0.15)	8.7 (0.1)	7.8 (0.0)
26JUL84	22.76 (0.03)	14.19 (0.01)	24.05 (0.84)	33.31 (0. 1)	7.7 (0.0)	8.2 (0.0)
01AUG84	22.60 (0.25)	14.95 (0.11)	28.09 (0.21)	32.05 (0.01)	7.9 (0.0)	7.4 (0.1)
21AUG84	26.14 (0.48)	25.97 (0.58)	31.19 (0.43)	30.65 (0.25)	8.0 (0.0)	7.0 (0.0)
21SEP84	22.00 (0.16)	21.59 (0.04)	27.94 (0.28)	30.49 (0.21)	8.1 (0.0)	7.0 (0.0)
26SEP84	22.26 (0.25)	20.22 (0.00)	25.48 (0.00)	29.61 (0.15)	8.2 (0.0)	6.1 (0.0)

TABLE 2. Multiple regression models for physical parameters from the collection grid in the vicinity of the Dam Neck Disposal Site. The "B" values are the regression coefficients, the "F" values are for the significance of the coefficient, and the "% change" represents the magnitude of change (from the grand means) of the effect.

	Regression Models								
	Dissolved Oxygen			Temperature			Salinity		
Effect	B	F	(% Change)	B	F	(% Change)	B	F	(% Change)
Temperature	-	-	-	NA	-	-	NA	-	-
Salinity	-	-	-	NA	-	-	NA	-	-
Depth	-2.92	285.09	(34.6%)	-	-	-	5.62	82.85	(23.7%)
Month:									
July	-	-	-	-	-	-	-1.84	31.53	(7.8%)
August	-	-	-	2.23	49.34	(10.1%)	-	-	-
September	-0.36	12.10	(4.2%)	-	-	-	-	-	-
Geographic Location:*									
North to South (NS)	-0.08	6.6	(4.0%)	-	-	-	-	-	-
West to East (WE)	-	-	-	-0.34	6.69	(4.4%)	1.15	35.13	(14.8%)
Dam Neck Site	-	-	-	-	-	-	-	-	-
HRSD Outfall	-	-	-	-	-	-	-	-	-
Interactions:									
July by depth	1.03	42.17	(12.2%)	-7.31	378.60	(31.8%)	3.85	69.04	(16.21%)
August by depth	0.33	-	(3.9%)	-1.92	15.77	(8.4%)	-	-	-
September by depth	-	-	-	-	-	-	-	-	-
NS by depth	-	-	-	-	-	-	-	-	-
WE by depth	0.64	107.12	(22.8%)	-0.43	9.29	(5.62%)	-0.75	7.49	(9.5%)
WE by NS	-	-	-	-	-	-	-	-	-
WE by NS by depth	-	-	-	-	-	-	-	-	-
Constant (grand mean)	8.44			22.96			23.75		
R^2 for model:		65%			74%			70%	
F for model:		91.34(6,301)			172.97(5,302)			142.49(5,302)	

* - NS has 4 levels represented by the station rows; WE has 3 levels represented by the station columns.

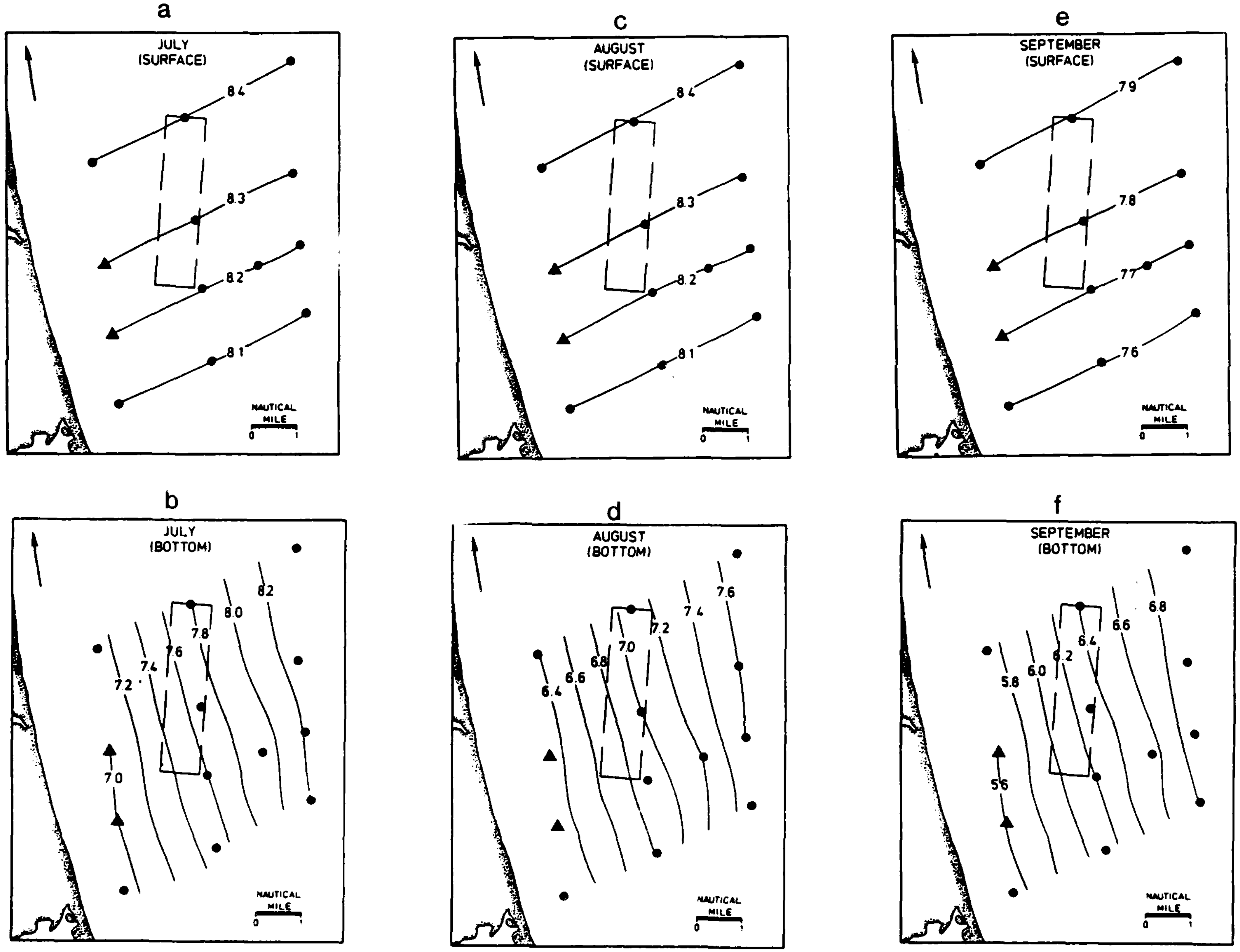
present major patterns for the study area (Fig. 2). The major factor influencing DO concentrations appears to be the difference between surface and bottom readings. In general, bottom readings were lower than surface readings by approximately 35%. The depth effect on DO was less apparent during July. Ironically, this was the period of the greatest temperature and salinity stratification.

The next most obvious pattern is a distinct west to east (inshore to offshore) pattern of increasing oxygen in the bottom waters. This trend was not significant in the surface waters, where only a very slight north to south decrease in oxygen level was apparent (Fig. 2, Table 2). The lowest oxygen readings were observed during September, particularly for the bottom waters. July oxygen levels were higher and August readings were intermediate. Surprisingly, neither temperature nor salinity were seen to be significantly related to the DO readings.

Temperature readings were significantly lower in the bottom water in July, but the degree of thermal stratification decreased in August and was not shown to be significant in September. There was a distinct west to east drop in temperature, particularly in bottom waters during all months. In general, August temperatures were the highest. Temperatures did not exhibit a significant north to south trend.

Salinities were significantly greater in the bottom waters than surface waters (by an average of 24%), particularly during

Figure 2. Dissolved oxygen values (ppm) for surface and bottom during the Summer of 1984: July-surface (a) and bottom (b); August-surface (c) and bottom (d); September-surface (e) and bottom (f).



July. There was a distinct west to east pattern, with salinities increasing seaward, but the trend was reduced for bottom waters. Surface salinities were slightly lower and bottom values were slightly higher than average during the month of July, the period of maximum stratification.

None of the physical parameters were shown to be significantly related to the locations of the Atlantic STP outfall or the DNS.

DISCUSSION

The reported values for depressed dissolved oxygen off Dam Neck during the Summer of 1984 tend to support allegations that water quality adjacent to the world's largest resort city may be declining. Although no single cause of the depressed readings has been determined two possible sources are the Atlantic STP station and the Dam Neck Disposal Sites.

Historically, sewage treatment processes employ dilution as a major means of waste disposal. This is particularly true along the coastal zone where daily tidal action help dilute and flush primary and/or secondary treated waste to offshore waters. Depressed oxygen readings are often characteristic of diffuser outfalls, particularly during the summer months when the biochemical oxygen demands increase. Typically, as the water column becomes stratified, the mixing of the bottom and surface waters are restricted to the point that tidal action may not be enough to allow the oxygen diffusion process to work. The restricted mixing becomes of increasing concern as temperatures rise because the oxygen carrying capacity of the water declines at the same time that metabolic demands of the endemic biota peak. Despite depressed DO readings observed during the warmer months, this hypothetical scenario does not appear to represent the conditions off Dam Neck.

The lowest oxygen values were reported after temperatures began to decline in late September. Moreover, the a priori hypothesis that lower oxygen readings would be expected to be associated with the stations located in the vicinity of the diffuser outfall was proven false. In addition, the historical record for the area shows low oxygen readings prior to the plant start-up in 1983 (Hampton Roads Sanitation Department, personal communication, 1984; Hydroscience, 1974).

In view of these findings, the Dam Neck Disposal Site appears to be a reasonable alternative as the source of depressed DO readings. Biological and chemical oxygen demands may be expected to depress oxygen supplies when high concentrations of silts and organics are released during disposal operations. However, the dredged material typically relocated to Dam Neck comes from the relatively pristine Cape Henry Channel and Thimble Shoal Channel of Chesapeake Bay.

The navigational channels of lower Chesapeake Bay and Bay mouth are heavily scoured. Tidal actions alone have resulted in a sandy sediment type low in organics. In addition, the channels serve as major arteries for merchant and military vessels. Propeller wash cause additional scouring to these channels. Therefore, the sediment oxygen demand of the fine sand from these sites would be minimal in comparison to those found in most seaports. Analysis of the material to be dredged from the channels met EPA guidelines for ocean disposal. A test dump at NDS with sediments from Thimble Shoal Channel caused no significant changes to the physical or chemical parameters monitored (Darby et al., 1981). The fact that the site is only aperiodically used for maintenance dredging operations also brings into question its role as a potential chronic source of oxygen depletion in the area. The findings of the present study point to the conclusion that the location of the DNS is not significantly associated with oxygen patterns of the region.

The depressed oxygen concentrations of the hypolimnion are apparently on a much broader scale than previously believed. Low DO readings have been found as far south as North Bay along the inshore zone and as far north as Cape Henry (HRSD, personal communication, 1984). A possible clue to this condition may lie in the circulation pattern associated with the Chesapeake Bay Plume.

Offshore shelf waters along the Mid-Atlantic Bight exhibit primarily a southerly drift. The outflow from Chesapeake Bay constitutes over 50% of the freshwater inflow to the Bight, where it flows towards the south (Beardsley et al., 1976). Virtually all the freshwater inflow to the study area is from the Bay. Associated with this large volume of outflow is suspended matter rich in organics. There is also evidence of sewage-associated particulates in the waters of the Bay plume (Brown and Wade, 1980; Byrnes and Oertel, 1980). Once expelled from the Bay these suspended materials are deposited along the inshore areas adjacent to Virginia Beach and Dam Neck. According to Brehmer (1971), a clockwise eddy is present along the shore south of Cape Henry. During the summer months there is a slight northerly flow of bottom water. Therefore, organic-rich suspended materials which settle into the bottom waters may represent a significant

B.O.D. source to the study area. The inshore-offshore banding pattern of the oxygen-contours of the bottom waters of the study area supports this contention. This inshore pattern is believed to extend as far south as False Cape (Brehmer, 1971).

The seaward extent of this circulation pattern is unknown. However, its influence on the coastal ecology, particularly along Dam Neck and Virginia Beach cannot be ignored. Studies have shown that debris, organic-rich fine sediments and sewage-associated particulates are flushed out of the Bay and settle along the inshore zone (Gingerich and Oertel, 1980; Byrnes and Oertel, 1980). Their presence and concentrations appear to be influencing the oxygen pattern in the study area.

Oxygen levels were not observed to drop below 4.0 mg/l during the present study. However, they were seen to approach this level, which is often cited as representing the minimum concentration required for the maintenance of healthy aquatic communities. Considering the ecological problems believed to be associated with anoxia in the Chesapeake Bay and in the coastal waters of the New York Bight, the low oxygen phenomenon off Dam Neck should be seen as a potentially significant environmental problem. Unfortunately, since the evidence points to the Bay plume as the major non-point source of the oxygen demand, the means for controlling long-term trends in the water quality of the region remain unclear.

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