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Water Quality in the York River

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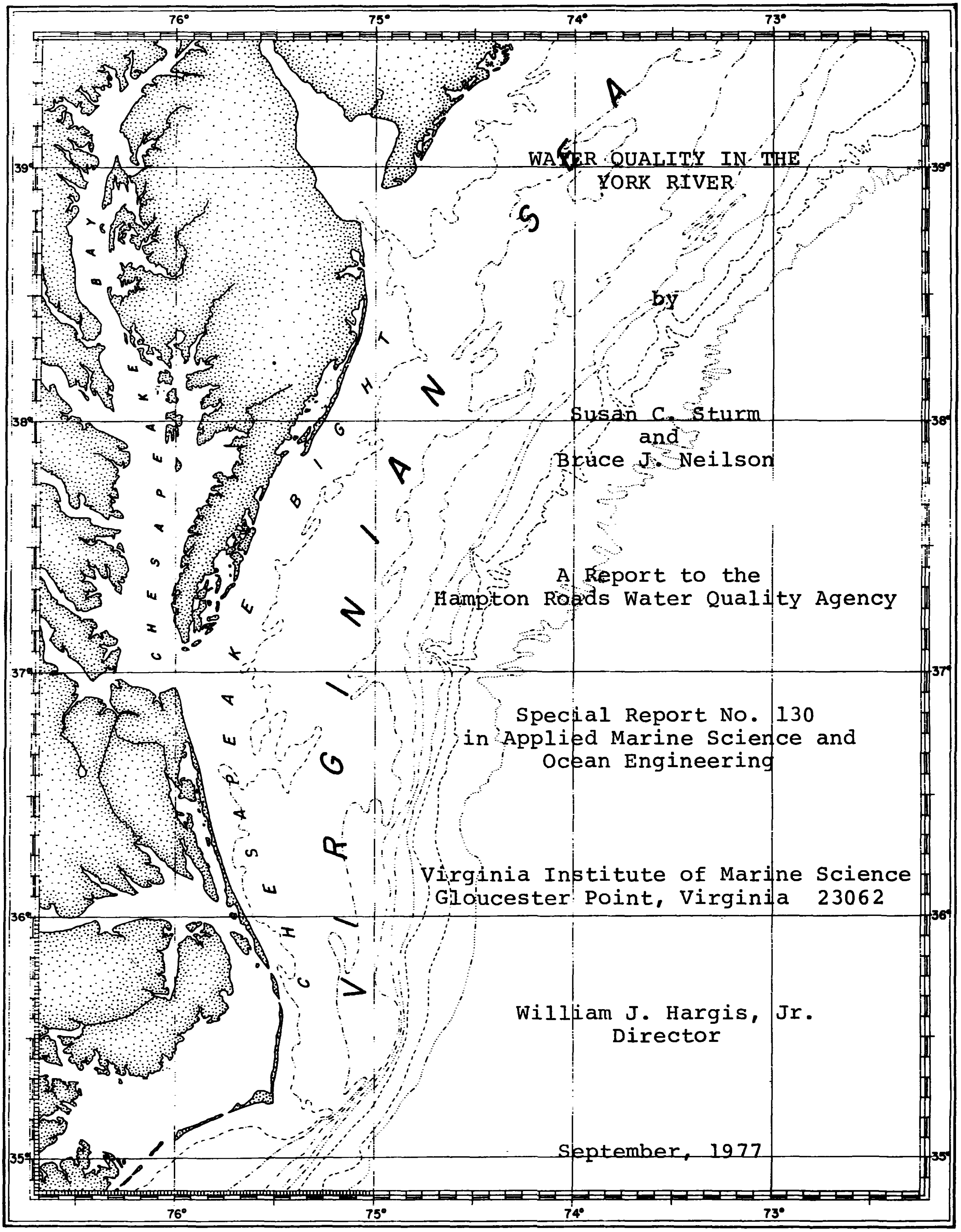

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A Report to the
Hampton Roads Water Quality Agency

Special Report No. 130
in Applied Marine Science and
Ocean Engineering

Virginia Institute of Marine Science
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ACKNOWLEDGEMENTS

We would like to thank the entire field staff of VIMS Department of Physical Oceanography, supervised by William Matthews and Ernst Chenoweth, and the laboratory staff supervised by Ronald Herzick, for their conscientious efforts, often under adverse circumstances. Special thanks are extended to Ms. J. C. Altemus and Ronald Herzick for the extensive data compilation and editing, Ms. Terry Markle for the drafting of various figures and Ms. Cathy Garrett for her patient report preparation and typing.

We would also like to express our appreciation to Dr. P. V. Hyer for supervising the insitu benthal oxygen demand measurements, and to Dr. C. S. Fang for directing the field program.

I. DESCRIPTION OF STUDY AREA

The York River, located in Tidewater, Virginia, is formed at West Point, Virginia, by the confluence of the Pamunkey and Mattaponi Rivers. The river flows through Virginia's Coastal Plain; and is encompassed by marshland and farmland. The York River is the northern boundary for the Peninsula Planning District and the Hampton Roads 208 Study Area (Figure 1). The total drainage area of the basin is 2663 square miles (6924 sq. km) from the Piedmont to the Chesapeake Bay. The York River is completely tidal and brackish. Mean tidal range is from 2.2 ft. (0.7 m) at the mouth to 3.0 ft. (0.9 m) at West Point.

The main industries of the area consist of farming (corn and soybeans), logging, and the commercial harvesting of shellfish (oysters, clams and crabs). At the upper end of the river, in the town of West Point, the Chesapeake Corporation operates a pulp and paper mill. Near Yorktown are the American Oil Company refinery, and the Virginia Electric and Power Company, a fossil-fueled generating station. Numerous military bases are located in the area, and military shipping is responsible for much of the river traffic. A National Park is located at Yorktown, and tourism is especially high during the summer months. Pleasure boating and fishing activities also are important during the warmer summer months.

The climate for the study area may be defined as humid-subtropical. In January the air temperature generally varies

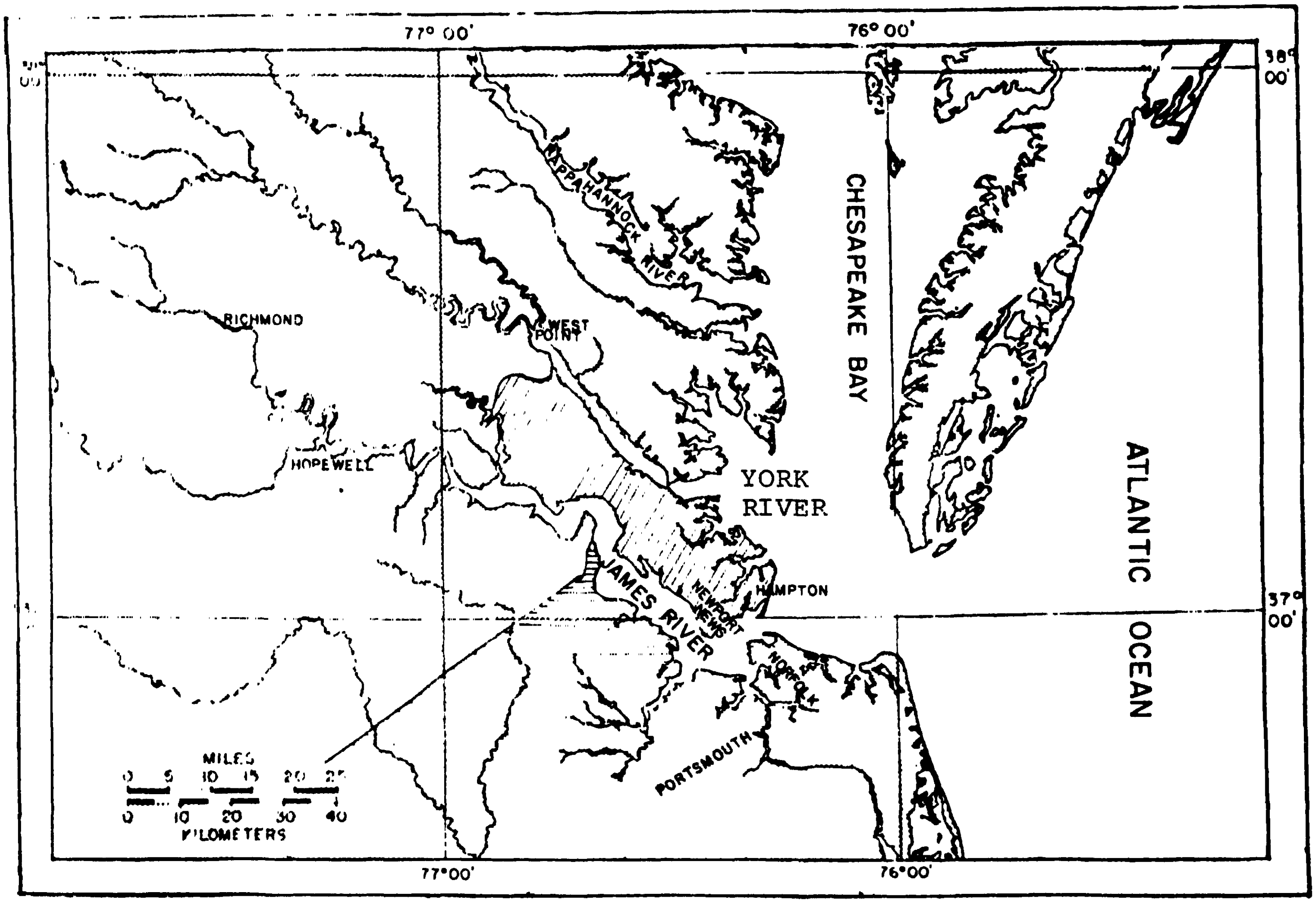


Figure 1. Tidewater Virginia showing the Hampton Roads 208 Study Area.

from a low of approximately 30°F (-1°C) to a high of 50°F (10°C). In July the average daily temperatures vary from a low of approximately 68°F (20°C) to a high of 88°F (30°C). Precipitation is generally lowest from September to January and highest in July and August. July and August precipitation is generally due to extra-tropical storms (low pressure areas), tropical storms (hurricanes) or thunder storms. Approximately 45 inches (114 cm) of rain falls annually. Snow accounts for approximately 3% of the total precipitation.

II. DATA REVIEW

Over the years various institutions have collected data in the York River for a variety of studies. Unfortunately many of these studies were conducted to focus attention on either a specific measure of water quality or a specific geographic location. Because of this, gaps exist in the types of water quality data base...therefore, it is not always possible to obtain a complete overview of water quality from these data sets. However, the data collected are certainly useful in their own right and are available for analysis. A summary of these data organized according to source, parameter measured, date of investigation, and sampling scheme is given in Table 1.

Intermittently, since 1961, VIMS has conducted various biological trawls and intensive surveys. Usually temperature, salinity and dissolved oxygen were measured. Since 1971 the Department of Physical Oceanography at VIMS has conducted slack water runs on a monthly basis as far into each year as the weather would permit. These runs follow the progress of either the high or low water slack wave from the estuary mouth upriver and provide both a longitudinal and vertical picture of the river system. Temperature, salinity, dissolved oxygen, and biological oxygen demand were measured at specified locations. Since 1975, nutrient concentrations and chlorophyll "a" also have been measured at least a few times each summer. During earlier VIMS slack water surveys (Brehmer, 1968-69) samples were taken at the location of specific isohalines rather than at fixed sampling sites. VIMS tidal marsh inventories of

TABLE 1. INVENTORY OF WATER QUALITY DATA FOR THE YORK RIVER.

INSTITUTION	INVESTIGATORS	PARAMETERS	DATES	REACH	SAMPLING SCHEME	COMMENTS & REFERENCES
VIMS	Patten, et. al.	Extinction Coef- ficient, Light & Dark bottle test	1961-1963	Pages's Rock & VIMS Base	Weekly at 2 stations; 9 experiments; sample at 2', 6' and 10'	VIMS SSR No. 39, No. 45, Ches. Sci. Vol. 7, No. 3, pp. 117-136, Fall, 1966.
VIMS	Fournier	Extinction coef- ficient, light & dark bottle test	1962-1963	VIMS Base	15 experiments at 3-week intervals 2' and 10'	VIMS Thesis
VIMS	Brehmer	pH, alkalinities chlorophyll, DO temp., salinity	Jan. 1968- Dec. 1969	Entire York & Saline Pamunkey	Monthly at 20 ppt 15 ppt, 10 ppt, 5 ppt, <5 ppt isoha- lines. Every 2 m.	Sampling sites varied according to salinity. VPI Water Resources Res. Center Bull. 45.
VIMS	Icthyology- Crustace- ology	Temp., sal., DO	monthly, 1968- present	Entire river	Surface and Bottom Occasionally every 2 meters	Also biological sampling
VIMS	Hyer, Ruzecki, Fang	Current, temp., sal., DO	1969	Bell's Rock to West Point	2 transects with 4 stations each; 2 m intervals for 26 hrs.	OYR-VIMS Data Report No. 9
VIMS	Harrison & Fang	Temp. DO., dye conc.	1969	West Point area		VIMS SRAMSOE No. 11
VIMS		Current, sal., temperature	1970	Coleman Bridge to mouth	12 stations at 4 transects, 2-9 days; every 2 meters	Tidal current study for Alden Labs & VEPCO.

Table 1 (cont'd).

INSTITUTION	INVESTIGATORS	PARAMETERS	DATES	REACHES	SAMPLING SCHEME	COMMENTS & REFERENCES
VIMS	Physical Oceanography	Temp., sal., DO, BOD	Monthly 1971-present	Entire River	Slack water - every 2 meters	Slack water studies
VIMS	Jordan	DO, sal., temperature	April 1972-present	Coleman Bridge to mouth	Monthly, surface & bottom	Continuing program
VIMS	Haas	Light & dark bottle test	Aug. 29-30, 1973	Mouth	1 pt, 0, 1, 2, 4, 10 m. 3 series at each depth	Samples incubated <u>in situ</u> for 24 hours 3 sets at 0800, 1315 & 1730 hrs.
VIMS	Physical Oceanography	Temp., sal., DO, dye	8/19/73-8/27/73	Entire river	Daily - samples taken at surface & bottom	
VIMS	Physical Oceanography	Temp., sal., DO	8/16/73-8/27/73	Entire river	10 transects - 3 anchor stations each. 32 hour continuous sampling at 5 depths or surface and bottom	
VIMS	Physical Oceanography	Temp., sal., BOD, DO, UOD, Nutrients	6/15/76-6/16/76 & 6/30/76-7/2/76	Entire river	10 transects; total of 24 stations; samples taken at top middle and bottom	Samples taken for Hampton Roads Water Quality Agency
CBI		Temp., sal., DO	1952-1966	Entire river		CBI Data Bank Report No. 1, April, 1972

Table 1 (cont'd).

INSTITUTION	INVESTIGATORS	PARAMETERS	DATES	REACHES	SAMPLING SCHEME	COMMENTS & REFERENCES
Academy of Natural Sciences, Philadelphia		Salinity, Temperature	1956	Coleman Bridge to mouth	2 sampling stations	"York River, VA - Biological, Chemical & Physical Studies for the American Oil Co." Philadelphia, 1957.
WCB		Temp., DO salinity	1971-present	Entire river	Slack water surface samples at 6 stations 2 runs/month, May-September	Incorporated with VIMS data.
State Health Department	Bureau of Shellfish Sanitation	Total & Fecal coliforms & nutrients	1948-present	Entire river	Samples taken from river & tributaries monthly	

Gloucester and York counties and shoreline situation reports of Gloucester, James City, New Kent, King William and King and Queen counties also include information on the York River.

In their studies, VIMS, Department of Physical Oceanography, has found that "owing to a combination of thermal and salinity stratification in the reach between the mouth of the York River and the bridge at Gloucester Point, dissolved oxygen concentration below the surface layer tends to be critically low in the summer time" (Hyer, et al., VIMS, 1975). Jordan (VIMS, 1975) supports these findings in his work and states that "during the warmer months of the year, dissolved oxygen, in terms of concentration and percent saturation, declined in the deep waters of the lower York River".

The Chesapeake Bay Institute sampled in the York from 1952-1966. Parameters measured included temperature, salinity, dissolved oxygen and climatological data.

The Virginia State Water Control Board has conducted slack water runs in the tidal York since 1971. Temperature, dissolved oxygen and salinity are measured, but only surface samples are collected. In their water quality inventory (305(b) report) it is indicated that water quality problems of the York are minor compared to those of more developed areas. However, "high coliform counts have been observed and periodically depressed dissolved oxygen conditions have occurred"; this in reference to the West Point area. The SWCB further states that the probable problem source is West Point Creek which receives urban run-off, landfill runoff, organic swamp drainage, and discharge from the West Point STP. Additionally, the below standard dissolved oxygen in the lower York is caused by "a tidal prism effect" and that "this is a natural phenomena for which no solution is known at the present time".

The Bureau of Shellfish Sanitation also collects water samples from the York on a regular basis. Their primary aim is to analyze samples for bacteriological parameters in order to safeguard the quality (from a public health standpoint) of shellfish grown in these waters.

In summary, quite a few agencies have collected data during numerous sampling surveys in the York River. However, because these data have been collected in bits and pieces, a complete understanding of water quality for the entire river has not been available. Therefore, in 1976, the Hampton Roads Water Quality Agency contracted VIMS to conduct an intensive sampling program and to analyze the water samples for a variety of water quality measures. These data have been used to further our understanding of conditions in the York River and to calibrate and verify a mathematical model of water quality.

III. WATER QUALITY OF THE YORK RIVER - SUMMER 1976

A. Field Sampling Program

The field sampling program was conducted to gather data for calibrating and verifying a mathematical model of water quality and to provide a comprehensive view of water quality in the river. The program employed two major elements: intensive survey and same slack surveys. During intensive surveys 24 stations located along ten transects were occupied for periods of 25 hours. This type of survey provides synoptic coverage of the river, including changes due to the tidal cycle and diurnal variations as well. Hourly measurements were made for temperature, salinity and dissolved oxygen (DO). Every third hour samples were collected and analyzed for fecal coliforms, 5-day biochemical oxygen demand (BOD), ammonia nitrogen, nitrate plus nitrite nitrogen, total Kjeldahl nitrogen, total phosphorus, orthophosphate and chlorophyll "a". The reason for the less frequent sampling was essentially economic, namely, that analysis for this suite of parameters is expensive and funds did not permit more frequent sampling. However, samples were gathered at low water slack, maximum flood, high water slack and maximum ebb, so that the entire tidal cycle was captured. In addition, a small number of water samples were incubated for 30 days, providing a measure of the ultimate biochemical oxygen demand. The oxygen demand of the bottom sediments also was measured at a few sites within the river.

Same slack surveys, or slack water surveys, are made by following either the high or the low water slack wave as it progresses from the river mouth to the head. These provide longitudinal and vertical profiles of the river for that day, and thus capture a relatively complete picture of conditions in the river. These data typically are used to verify the mathematical model after it has been calibrated to reproduce the conditions observed during the intensive survey. Details of the field sampling program, and laboratory analytical procedures can be found in Appendix A.

B. Sources of Pollution

The York River receives wastewaters from a very small number of industries and municipalities, which are listed in Table 2 and shown in Figure 2. It can be seen that the major point sources of pollutants in 1976 were industries, with Chesapeake Corporation in West Point contributing the largest loading. A few small sanitary systems discharge small amounts of domestic wastes to the river, and some of these have been removed since the intensive surveys were conducted. It is likely that the situation will change in the near future, since a large (approximately 15 million gallons per day) sewage treatment plant has been proposed which would discharge to the river in the vicinity of the VEPCO station.

Non-point sources of pollution for the area consist of marshes, farms, developed areas and boating and shipping activities. In the marshes, plants utilize dissolved nutrients from the water for their growth, but when they die the decaying matter exerts an oxygen demand, and releases nutrients to the water.

TABLE 2. YORK RIVER POINT SOURCES, 1976.

	Q	Nitrogen			Phosphorus		BOD_u	Coliform	Code for Source of Data
	MGD	Org	NH_3	NO_3	Org	Inorg	lb/day	10^9/day	
		lb/day			lb/day				
AMOCO † (IN22)	1.72	182	525	12.9	12.9	38.7	1169		1.
VEPCO † (IN25)	2.4	41.5	10.7	3.0	1.2	0.2	37		1.
Chesapeake Corporation	13.5						6840		2.
Coast Guard School (FN03)	0.05						21	2.9	1.
Yorktown Colonial National Park	0.049						46		3.
Naval Weapons Station (FN01)*	0.037	17.	6.2	9.6	1.8	5.2	132.		1.
Camp Peary	0.06						18.		3.
Town of Toano	0.015						36		3.
Town of West Point	0.30						162		3.

Data Sources

1. Betz Environmental Engineers, for the Hampton Roads Water Quality Agency.
2. York River 303E Report.
3. Calculated from Virginia Water Control Board data and used in earlier calibration of a water quality model (SRAMSOE 104).

* Apparently includes Cheatham Annex.
† Does not include non-contact cooling waters.

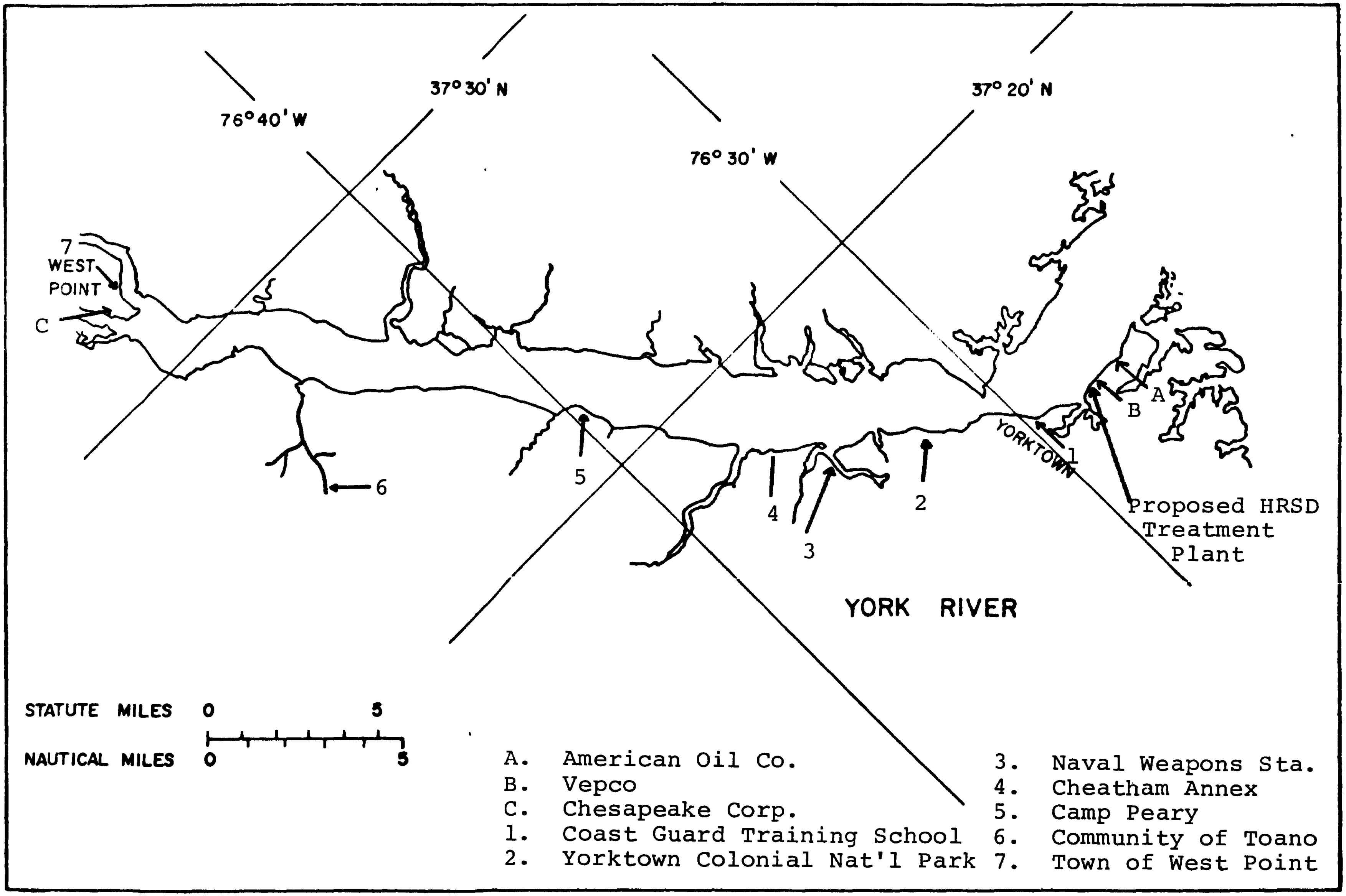


Figure 2. Location of waste water outfalls reaching the York River.

Runoff from farms may bring with it fecal wastes from livestock, artificial fertilizers, and other compounds used in modern agricultural practices.

Although only approximately 2.2% of the York basin area may be classified as urban, severe erosion problems can occur in these localities. An expanding population and its need for more housing, schools, industrial sites and highways would appear to be the dominant factors. During construction, the potential for erosion increases greatly. When moderately heavy rains occur, the runoff not only carries topsoil, but also other materials directly related to urbanization such as lawn fertilizers, pet fecal wastes, gasoline and other substances which may have collected on lawns and streets. While the area is not highly urbanized at the present, it is possible for growth and development to expand from the Hampton-Newport News area and be a contributing factor to future pollution of the York. One forewarning of this trend is the degraded water quality which has been observed in some of the very small tributaries receiving this type of pollution.

Finally, the fourth major source of non-point pollution is recreational boating and shipping activities. Large naval craft come to Cheatham Annex and the Naval Weapons Station, numerous tugboats use the river daily, and numerous fishing vessels and pleasure craft may be found on the river almost all year long. Although the United States Navy and the State Water Control Board have taken steps to eliminate the discharge of wastes, such regulations are almost impossible to enforce and boat-related pollution will undoubtly continue. It is hoped, however, that these discharges will be reduced.

C. Eutrophication and Dissolved Oxygen

Eutrophication means the overenrichment of a water body with the nutrients essential for plant growth. When nutrients are plentiful and other conditions are right, abundant growths of algae can occur. These growths can cause odor problems, may give drinking water an undesirable taste and add a large daily variation to the fluctuations in dissolved oxygen in the water. The United States Environmental Protection Agency has conducted long term, in-depth studies of nutrient enrichment in the Potomac River and the Upper Chesapeake Bay. As a result of these studies they suggested an upper limit for the desirable concentrations of algae, 40 μg/l of chlorophyll "a", a measure of the alga concentration. In order to constrain algae levels within this limit, the corresponding levels for inorganic nitrogen and phosphorus were determined to be : Inorganic Phosphorus - 0.12 mg/l as PO_4
0.04 mg/l as P

Inorganic Nitrogen - -.8 mg/l

Chlorophyll "a" concentrations in the York generally averaged about 10 μg/l, well below the above-mentioned EPA criterion. Nutrient levels were similarly well within the recommended levels. Daily averages for inorganic phosphorus (soluble reactive phosphorus) were on the order of 0.02 mg/l or roughly half the suggested upper limit. Although there was variation from station to station, no observable spatial trend was noted. Daily average concentrations of inorganic nitrogen (ammonia nitrogen plus nitrite-nitrate nitrogen) were only about 0.08 mg/l at the mouth of the river, but were above

0.2 mg/l in the upper reaches. Since chlorophyll levels were reasonably constant throughout the river, the trend in inorganic nitrogen levels probably indicates that the source of this nitrogen is located in or above the upper reaches of the York. Even so, the maximum nitrogen levels represented a smaller percentage of the recommended limit than was observed for the phosphorus. Thus, one must conclude that the availability of nitrogen would tend to limit growth of phytoplankton more than phosphorus. This may have been the case in the lower York where the observed inorganic nitrogen concentrations were only about 10% of the recommended limit. In the upper York, both nitrogen and phosphorus concentrations were about one-quarter to one-half the recommended limits, perhaps indicating that some other factor, such as turbidity, was controlling the growth rate of the phytoplankton. Also, because of the occurrence of red tides during the summer months, nutrient levels are lowered and probably are a factor in limiting phytoplankton growth.

To summarize, the observed conditions indicate that eutrophication is not a problem in the York River. Both phytoplankton concentrations, as indicated by chlorophyll "a" levels, and nutrient concentrations were well within recommended limits set for other portions of Chesapeake Bay. Additionally, no diurnal trend to the dissolved oxygen levels was observed at most stations. The reason that nutrient enrichment has not occurred is probably that tidal mixing and dilution are very great. The tidal prism for the York has been calculated to be on the order of 4 billion cubic feet (110 million cubic meters) at the mouth and 1 billion cubic feet (35 million cubic meters) at West Point. Clearly there is an enormous volume of water available each flood tide to dilute and carry away materials discharged to the river. This tidal flushing does not guarentee that algal levels and nutrient concentrations will always be small, since nutrients can be stored in sediments and released at later times. In fact, in many instances, the recycling of nutrients in an area represents a greater flow than that through the segment.

Dissolved oxygen (DO) concentrations are controlled by many factors. As salinity and temperature increase, the amount of oxygen that can be dissolved in water, the saturation value, decreases. Therefore, less oxygen is likely to be in the water during periods of high salinity and elevated water temperature (late summer and early fall) than during cold periods with high freshwater inflow (winter and early spring). Many pollutants exert an oxygen demand (consume DO) as chemical reactions and bacterial decomposition take place. In fact, virtually all organisms require oxygen to live and therefore consume DO. Phytoplankton (algae) do produce oxygen as a by-product of photosynthesis, and this increases DO levels. During nights and cloudy periods, however, respiration will be greater than oxygen production and DO levels will be depressed. Additionally, dead plankton exert an oxygen demand as they decompose. Often, these organisms and other organic matter end up in the bottom sediments and can exert a considerable oxygen demand, usually termed benthic or benthal oxygen demand.

In most instances the predominant source of oxygen is the atmosphere, with the rate of reaeration controlled by the oxygen deficit (the amount the DO is below saturation value), geometric characteristics of the river and the nature of the water movement.

DO concentrations observed in the York range from good to extremely poor. Near bottom DO values for the portion of the river between the Coleman Bridge and Chesapeake Bay often were below the 4 mg/l water quality standard as can be seen in the figures in Appendix B. Violations of this type were observed in the upper portion as well, although much less frequently. Ultimate carbonaceous BOD (biochemical oxygen demand) concentrations averaged around 2 mg/l. This low value is to be expected given the huge tidal prism available for diluting the few and relatively small loadings which the river receives. In other words, it appears that external pollutant loadings do not directly cause the low DO's. Two more likely causes are benthal oxygen demand and the deep water column. The cross-sectional average depth for transects downriver of the Coleman Bridge is on the order of 40 feet (12 meters). When physical conditions in the river are such to limit the transport of oxygen from the surface to the bottom waters, these lower lying waters can become partially or totally depleted of dissolved oxygen. Additionally, decomposition of organic matter in bottom sediments consumes oxygen in the overlying water. Measurements of the benthal oxygen demand show that it is greatest near West Point (1.6 to 3.4 grams of oxygen consumed per square meter per day) and is on the order of 1 gm of oxygen/meter squared/day in the lower reaches. The data in Appendix B show that these low DO conditions persist throughout the tidal cycle and in Figures 3a and 3b, one can note the spatial extent of the mass of poor quality water. Station locations are given in nautical miles upstream from the river mouth.

These low DO conditions have been observed during the summer months in the lower York River, in the lower Rappahannock River and in some of the deeper portions of Chesapeake Bay. Why this phenomenon occurs, the mechanisms by which it develops and persists and possible remedies for the situation are not known at present. It appears that aspects of the physical environment, such as mixing and transport of dissolved substances throughout the water column, are controlling the process more than external inputs of oxygen demanding material. However, considerable further study is required before this process will be elucidated.

D. Bacterial Contamination

The State Health Department monitors the bacteriological quality of estuarine waters to insure and safeguard the public health. The desired situation is for no pathogenic (disease producing) organisms to be present. Therefore, tests are conducted for "indicator organisms"; organisms which are generally found together with pathogenic bacteria and viruses, but which occur in greater numbers and therefore are more easily detected. The coliform group of bacteria presently is widely used. The Total Coliform group includes some bacteria which arise from the decay of leaves and/or reside in the soil, whereas the Fecal Coliform group contains primarily organisms

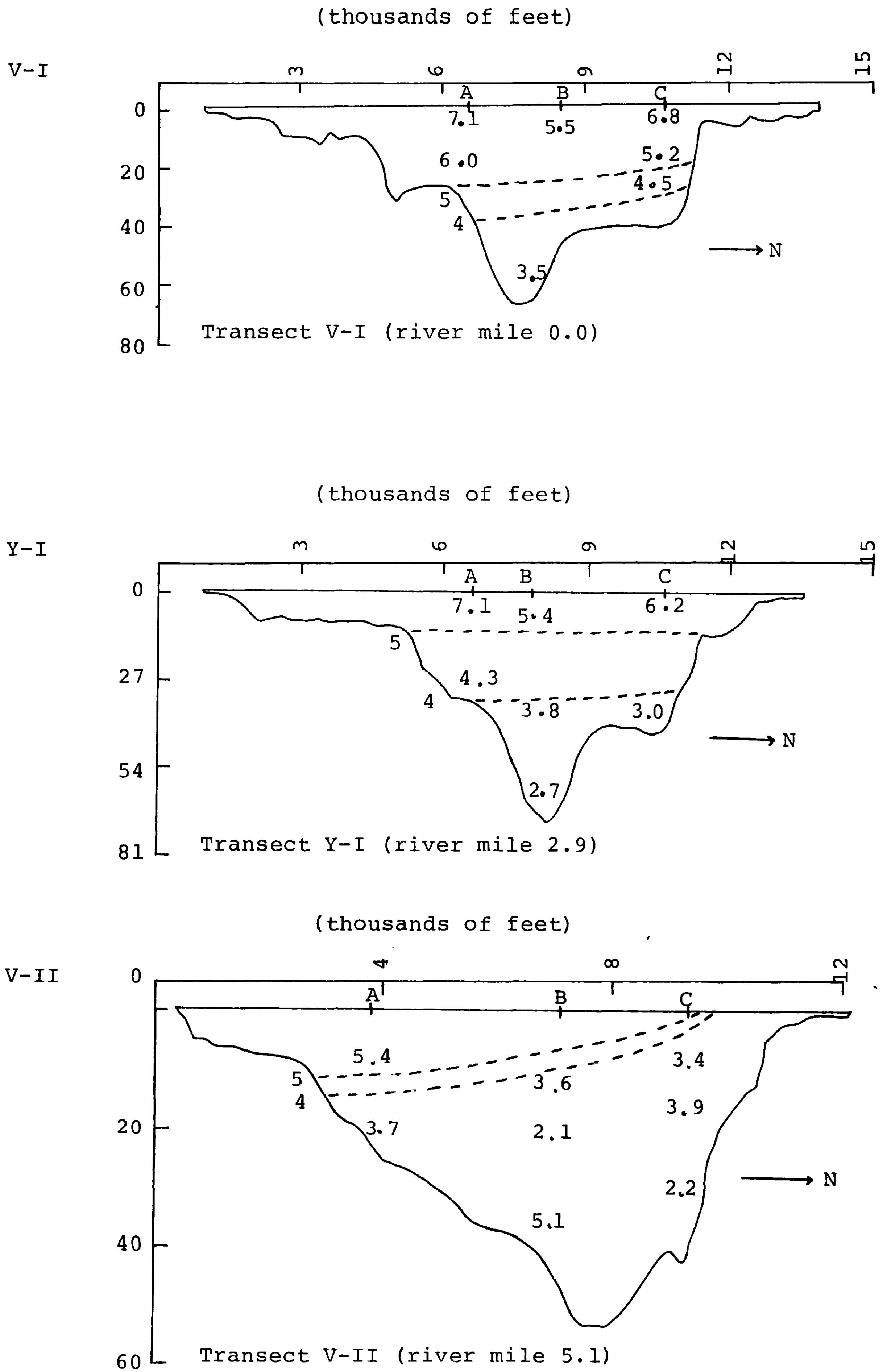
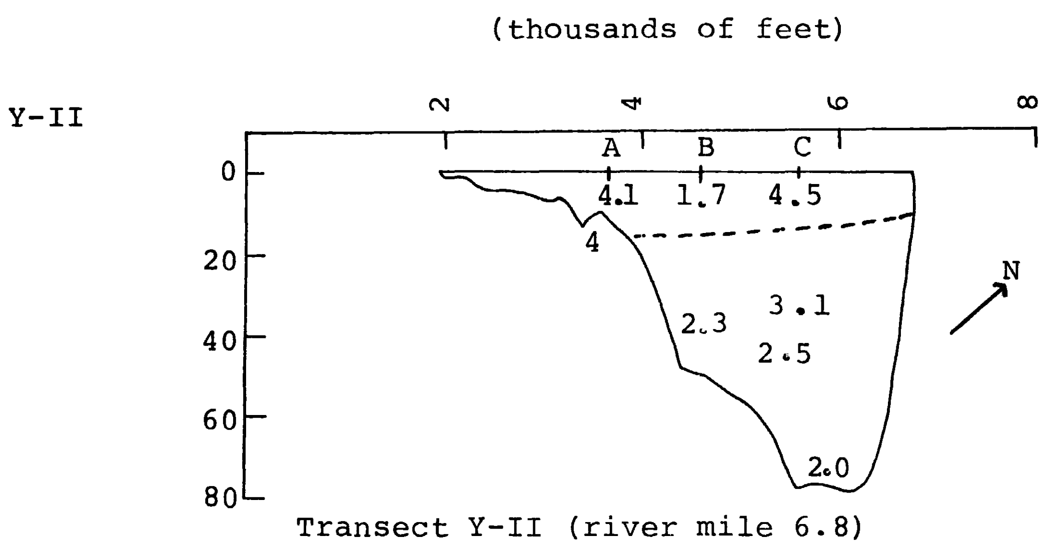


Figure 3a. DO concentrations at 12 noon, 1 July 1976 at transects in the Lower York.



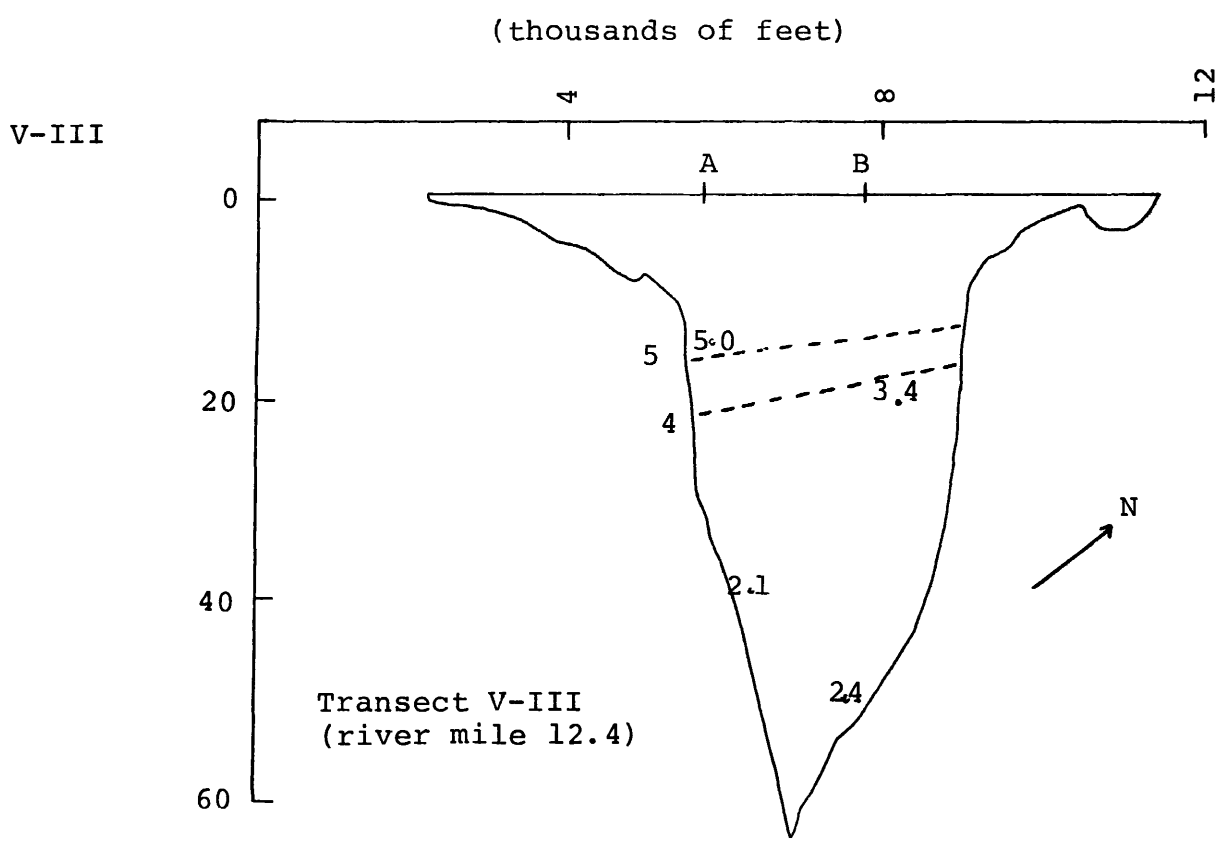


Figure 3b. DO concentrations at 12 noon, 1 July 1976 at transects in the Lower York.

which reside in the intestinal tract of warm-blooded animals. Therefore, the presence of fecal coliforms indicates the contamination of the water by fecal wastes of some animal - this could be ducks and geese, sheep and cattle or humans - any warm-blooded animal.

The concentration of bacteria in water is given as an MPN (Most Probable Number) per 100 milliliters of water. The nomenclature indicates the probabilistic nature of detecting bacterial concentrations, as do the Virginia water quality standards. As one example of this for secondary contact recreation, public or municipal water supply and the propagation of fish and aquatic life, the mean count of fecal coliforms should not exceed 1000/100 ml and not more than 10% of the samples should have readings equal to or greater than 2000/100 ml. For primary contact recreation (eg. swimming), the Virginia standard is a log mean of less than 200 fecal coliform MPN per 100 ml, with not more than 10% of the samples being greater than 400 MPN/100 ml.

For the estuarine environment, another productive use of the water is the culture of shellfish. Since these molluscs survive by filtering food from the water, they tend to accumulate substances to levels many times greater than found in the water itself. Therefore, bacterial standards for shellfish growing waters are the most restrictive. At present the Virginia standards for "areas where leased private or public shellfish beds are present" is 70 total coliform MPN/100 ml with no more than 10% of the samples above 230. The federal Food and Drug Administration regulates the interstate transport of shellfish and normally enters into the regulation making process as well. The FDA has recommended that the standard be changed to 14 fecal coliform MPN/100 ml, and at present both criteria are in use. It is likely that the fecal coliform standard will be used exclusively in the future since many feel that it provides a more accurate measure of potential dangers.

Fecal coliform counts in the York River generally were low and always less than the standards for primary contact recreation. The clean waters probably occur because there are few sources of domestic wastes, the tidal prism is large and wastes which are present are greatly diluted. It appears that there are significant sources of contamination near West Point since fecal counts in the segment from West Point to the Poropotank River often were above the recommended level for shellfish waters. In fact, this area has been comdemned for the harvesting of shellfish since 1944 (shellfish condemnation area #4, York River and tributaries, West Point vicinity). Additionally, most of the small tributaries of the York are restricted as shown in Figure 4. A few of the condemnation zones date to the 1950's and 1960's, but most were enacted in 1972. It is not clear whether the sharp increase in the number and extent of closure zones is the result of changes in land use, or perhaps simply more vigorous enforcement of existing regulations. It is clear that nonpoint sources of pollution do contain fecal wastes and that these wastes are not dispersed and diluted within the small subestuaries. In many instances at least some of the causes of the pollution

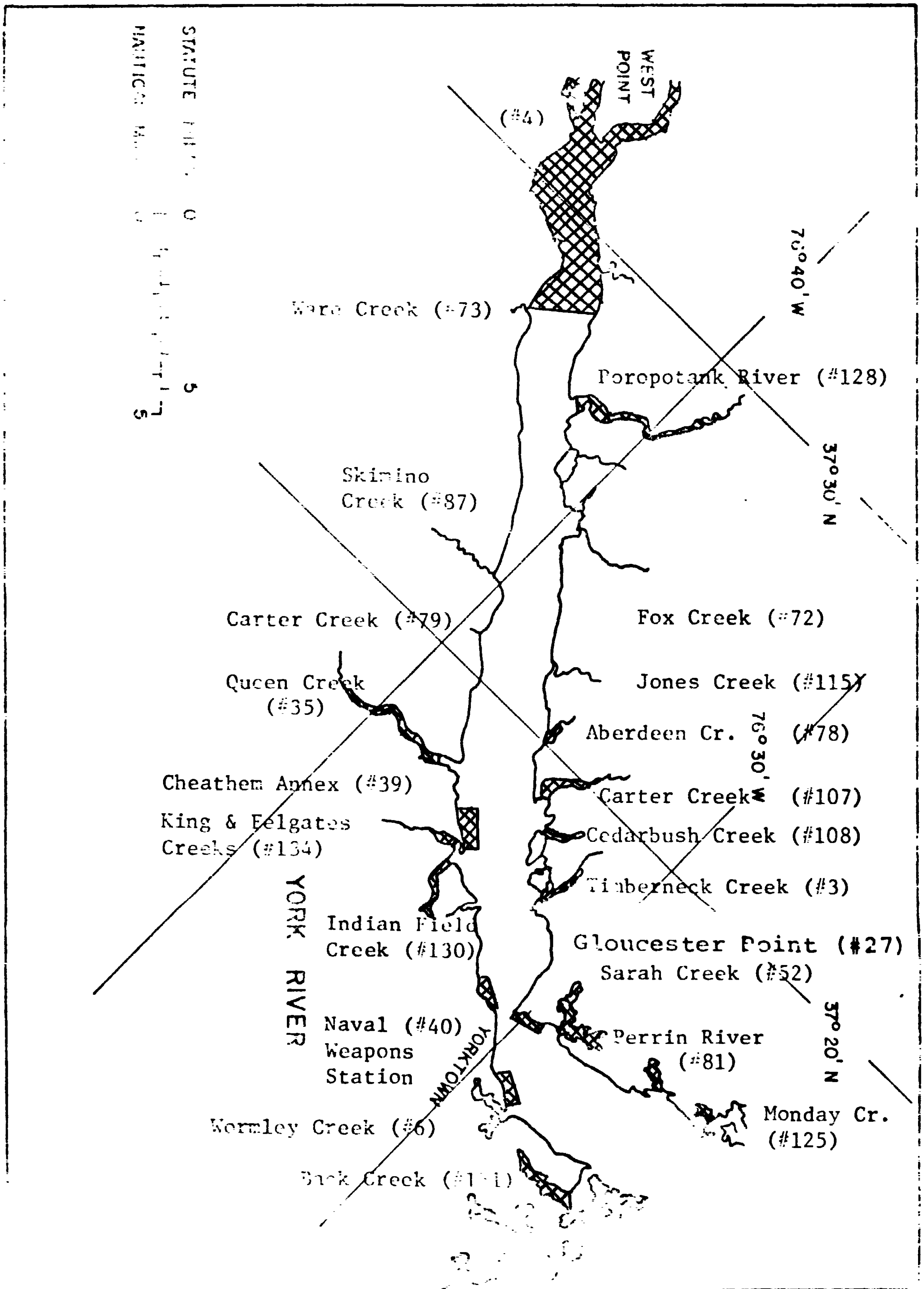


Figure 4. Shellfish condemnation areas in effect in 1976.

(for example, privies, malfunctioning septic tanks, the presence of a horse or other livestock) are known to the Bureau of Shellfish Sanitation, but resources are insufficient to remedy the situation.

E. Summary

Relative to many other estuaries of the Chesapeake Bay region, the York River receives very little pollution from so-called point sources. Most of what is discharged comes from industrial concerns, and the largest of these is the Chesapeake Corporation's paper and pulp mill located at West Point, at the confluence of the Mattaponi and Pamunkey Rivers. Domestic waste loads are small at present but could become large if a proposed sewage treatment plant is built near Yorktown.

The tidal prism for the York is very large, on the order of billions of cubic feet (tens of millions of cubic meters) of water. As a result, the few wastewater streams which are discharged to the river are greatly diluted. Levels of inorganic phosphorus and inorganic nitrogen are low and therefore phytoplankton growth is limited. All three values were well within criteria recommended for other portions of the Chesapeake Bay system. In spite of the great dilution potential and the small waste loadings, some water quality problems have been observed. First, it appears that the physical characteristics of the circulation in the lower York limit the transfer of oxygen from the atmosphere to the water near the river bottom. As a result these bottom waters become partially depleted of oxygen. Dissolved oxygen concentrations observed during the intensive survey usually were below the 4 mg/l standard for the bottom waters downriver of the Coleman (Yorktown) Bridge.

Second, there are sufficiently large sources of bacteria in the vicinity of West Point to result in a shellfish condemnation zone in the York. Fecal coliform levels observed during the intensive survey in the portion of the York upriver of the Poropotank were frequently above 14 MPN/100 ml, the Federal standard for shellfish growing waters. Otherwise the fecal coliform counts were below the Federal criterion.

Third, nonpoint sources of pollution such as runoff from housing developments, pastures and cropland, are sufficiently large to cause problems in the small tributaries of the York. It is very likely that tidal flushing is poor in these subestuaries so that materials washed into them tend to reside there for long periods of time. The large number of shellfish closures indicates that the loads are sufficiently large to degrade the water from a bacterial point of view. Since no sampling was done in these small estuaries, one can only speculate as to other water quality conditions.

Field studies of overland stormwater runoff were conducted by VIMS from March through October, 1976. Data from these surveys have been used by Malcolm Pirnie Engineers, Inc. to calibrate the mathematical model "STORM". This model has been used to estimate nonpoint loads to the York River.

Control of nonpoint sources of pollution possibly could reduce the area restricted for shellfish harvesting both within the small tributaries and in some reaches of the York. Some aspects of this will be investigated in the mathematical studies of water quality in the York River. It is unlikely that control of point and nonpoint sources of pollution will result in any significant improvement in the low dissolved oxygen conditions, since this appears to be a "natural phenomenon". The dredging of a deep channel through the rather shallow sill (depth approximately 30 feet or 10 meters) at the mouth of the river might possibly improve exchange of waters between the river and the Bay. Similarly, other modifications to the physical environment might improve conditons. For example, floating aerators such as are used in waste treatment plants could be positioned at critical locations. Fine bubble curtains also could raise DO levels and reduce stratification. Either moving devices or fixed structures which promote mixing have the potential to improve the water quality conditions. However, such modifications are beyond the scope of the 208 study and most could not be addressed by the math model which has been calibrated for the York.

APPENDIX A. FIELD PROGRAM

1. Sampling Program
2. Chart of Station Locations
3. Analytical Methods

York River Sampling Program

Parameter	Intensive Survey: Sampling Period	Intensive Survey: Sampling Frequency	Intensive Survey: Sampling Depths	2 Slack Water Surveys (Main Channel) 11 stations: Sampling Period	2 Slack Water Surveys (Main Channel) 11 stations: Sampling Frequency	2 Slack Water Surveys (Main Channel) 11 stations: Sampling Depths
Temperature	25 hrs.	hourly	T,M,B	SBE,SBF	summer	TMB
Salinity	25 hrs.	hourly	T,M,B	SBE,SBF	summer	TMB
DO	25 hrs.	hourly	T,M,B	SBE,SBF	summer	TMB
BOD_5	25 hrs.	every 3 hrs.	TB*	SBE,SBF	summer	TB
Fecal Coliforms	25 hrs.	every 3 hrs.	TB	SBE,SBF	summer	TB
N	25 hrs.	every 3 hrs.	TB	SBE,SBF	summer	TB
Total P	25 hrs.	every 3 hrs.	TB	SBE,SBF	summer	TB
Chlorophyll "A"	25 hrs.	every 3 hrs.	TB	SBE,SBF	summer	TB
Secchi disk	25 hrs.	every 3 hrs.	TB	SBE,SBF	summer	TB

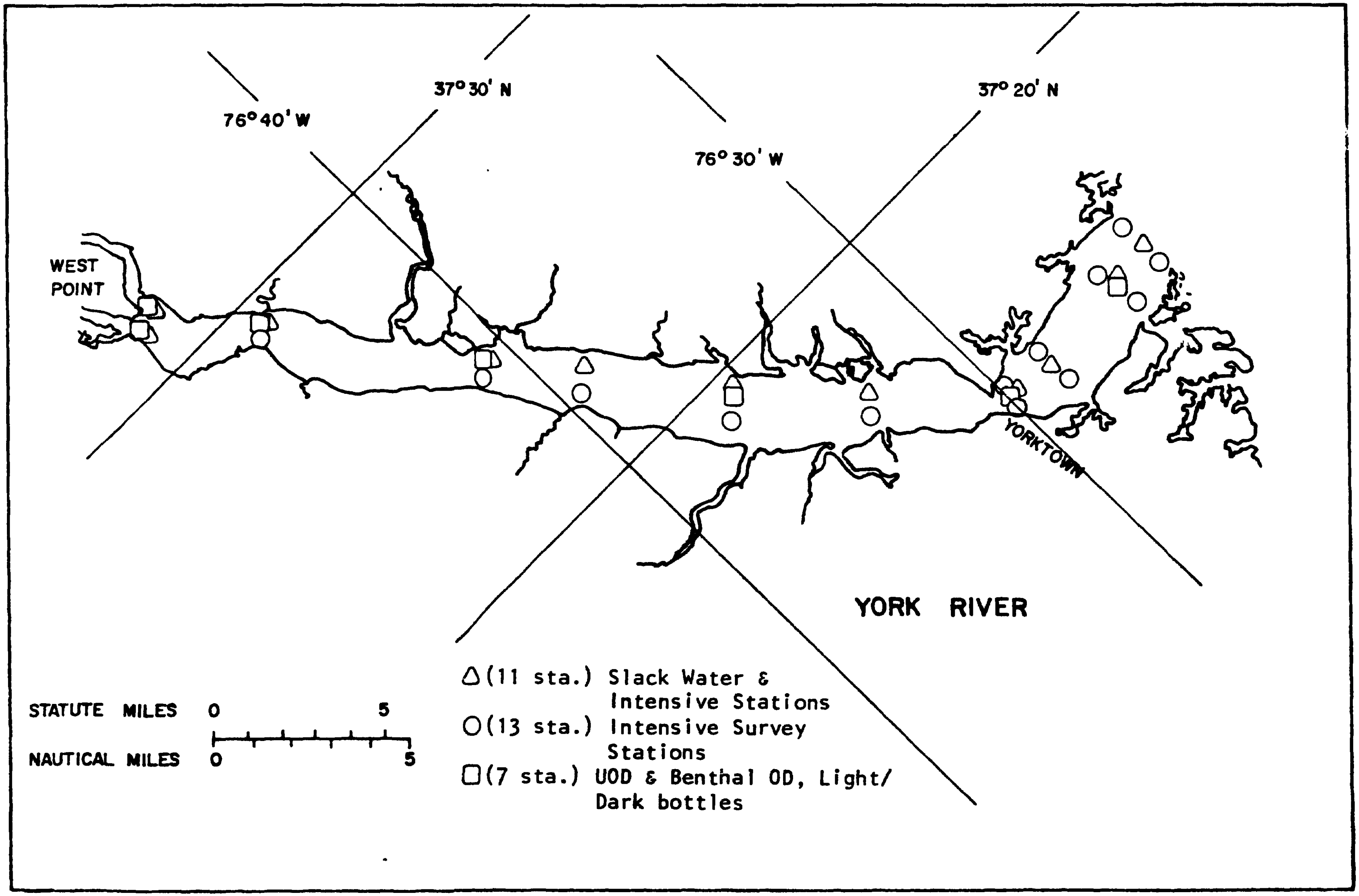
*13 Intensive Survey stations taken at mid-depth only

Other measurements:

UOD	once	once	T	one per slack survey
Bethal OD	once	once	B	
Light/Dark Bottle	once	once	T	

T = 1 meter below surface
M = mid-depth
B = 1 meter off bottom

SBE = slack water before ebb
SBF = slack water before flood


37° 30' N
76° 40' W
37° 20' N
76° 30' W
WEST POINT
YORKTOWN
YORK RIVER
STATUTE MILES 0 5
NAUTICAL MILES 0 5
△(11 sta.) Slack Water & Intensive Stations
○(13 sta.) Intensive Survey Stations
□(7 sta.) UOD & Benthal OD, Light/ Dark bottles

ANALYTICAL METHODS

1) Temperature	a. Interocean CTD Model 513/514. Accuracy ±0.1°C. Calibrated before and after every intensive field survey.
	b. Applied Research Austin Model ET 100 Marine. Accuracy ±0.1°C. Calibrated before and after every intensive field survey.
2) Conductivity	a. Interocean CTD Model 513/514. Accuracy ±0.5 millimhos. Calibrated before and after every intensive field study.
3) Salinity	a. Bottle grab sample analyzed in the laboratory on an Industrial Instrument Laboratory Salinometer Model RS7A. Accuracy ±0.1 ppt. Standardized every day before using.
	b. Interocean CTD Model 513/514. Temperature and conductivity readings used in a CBI equation to calculate salinity. Accuracy ±0.05 ppt.
4) Dissolved oxygen	a. Bottle grab sample pickled in the field and titrated in the laboratory using the azide modification of the Winkler method. Accuracy ±0.1 mg/l. Standardized every day before using.
5) <u>Bacteria</u>	
Fecal coliforms	SM 908 Multiple Tube Fermentation Technic for Members of the Coliform Group. 908C - Fecal coliform MPN Procedure

SM = Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1975, APHA-AWWA-WPCF.

EPA = Methods for Chemical Analysis of Water and Wastes, 1974 U.S. EPA, National Environmental Research Center, Cincinnati, Ohio.

6) Biochemical Oxygen Demand

5-day or 30-day, 20°C, Carbonaceous BOD	SM 507 Biochemical Oxygen Demand EPA #310 - BOD Modified: Nitrification inhibited with pyridine

7) Nitrogen

Ammonia-N	SM 418C Nitrogen (Ammonia)-Phenate Method EPA #610 Automated Colorimetric Phenate Method
Nitrate-N	SM 419C - Nitrate-Nitrogen-Cadmium Reduction Method
Nitrite-N	SM 420 - Nitrite-Nitrogen EPA #630 - Automated Cadmium Reduction Method for Nitrate-Nitrite Nitrogen
Total Kjeldahl Nitrogen	SM 421 Organic Nitrogen EPA #625 - Total Kjeldahl Nitrogen

8) Phosphorus

Total Phosphorus	SM 425 Phosphate - Total Filtrable and non-filtrable phosphate 425C III - Persulfate Digestion Method EPA #665 - Total Phosphorus
Orthophosphate	SM 425 Filtrable (dissolved) orthophosphate EPA #671 - Dissolved orthophosphate

9) Benthal Oxygen Demand

The apparatus used for determining the benthic demand consisted of a cylindrical chamber fitted with a self-contained battery-powered stirrer and a dissolved oxygen probe (YSI-15) plugged into the top of the chamber. The chamber was open at the bottom and weighted so that it settled into the sediment and effectively isolated a unit bottom area and a parcel of overlying water. The stirrer provided gentle agitation to keep water moving past the membrane on the

9) Benthal Oxygen Demand (cont'd)

probe without stirring up the sediment. The dissolved oxygen concentration of the trapped water parcel was monitored for a sufficient length of time to obtain a dissolved oxygen versus time slope (m). The bottom oxygen demand was calculated according to the following formula:

$$BD\left(\frac{gm}{m^2 \cdot day}\right) = \frac{m\left(\frac{mg}{\ell \cdot hr}\right) H \cdot 24}{10^2},$$ where H is

the mean depth of the chamber in cm., allowing for the volume displaced by the stirrer.

APPENDIX B. INTENSIVE SURVEY DATA

1. Table of Results

   Nutrients
   Chlorophyll "a"
   Fecal Coliforms
   Biochemical Oxygen Demand

2. Graphical Presentation for Mid Channel, Transects Y-1, 2, 3, 5 and 7.

Date	Time (EST)	Ammonia (mg/l)	NO_3 (µg atm/l)	NO_2 (µg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (µg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (µg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION V-I-B													
30/6/76	12.2	0.06*	1.22	0.39	.023	0.16	.005	7.6		0.09	0.4113	1.845	1.23
		0.06*	5.68	0.57	.088	0.50	.016	6.09		0.05	0.2285	1.335	0.89
	15.2	0.11	2.27	0.48	.040	0.32	.010	13.87		0.47	2.1479	3.48	2.32
		13.80	6.01	0.34	.282	0.48	.015	1.90		0.23	1.0511	1.29	0.86
	18.2	0.07	6.75	0.45	.1028	0.24	.007	12.49		0.23	1.0511	0.645	0.43
		0.10	1.82	0.48	.034	0.52	.016	9.23	3.6	0.30	1.371	0.435	0.29
	21.3	0.06	2.53	0.19	.039	0.44	.014	8.74		0.36	1.6452	2.295	1.53
		0.05	4.85	0.40	.074	1.10	.034	4.75		0.29	1.3253	1.05	0.70
1/7/76	7.3	0.09	3.63	0.22	.055	0.44	.014	9.50		0.40	1.828	--	--
		0.10	8.37	0.28	.122	0.92	.029	2.00		0.38	1.7366	0.27	0.18
	10.2	0.10	2.35	0.20	.037	0.20	.006	8.55	3.3	0.15	0.6855	7.335	4.89
		0.03	5.48	0.24	.080	0.86	.027	1.00	3.3	0.27	1.2339	7.68	5.12
	13.2	0.09	4.00	0.12	.059	0.26	.008	14.25		0.28	1.2796	2.25	1.50
		0.10	5.82	0.18	.085	0.52	.016	3.06		0.22	1.0054	--	--
	16.0	0.08	5.24	0.20	.077	0.64	.020	3.80	3.6	0.21	0.9597	6.36	4.24
		0.05	5.73	0.19	.084	0.42	.013	17.10	3.6	--	--	--	--
	19.1	0.06	5.27	0.23	.078	0.40	.012	2.66	3.6	0.20	0.914	0.51	0.34
		0.09	6.26	0.28	.093	0.48	.015	12.92	3.6	0.21	0.9597	--	--
	22.3	0.08	2.78	0.24	.043	0.32	.010	6.27		0.32	1.4624	0.63	0.42
		--	--	--	--	--	--	--		--	--	1.125	0.75

* These are values for top and bottom.

Date	Time (EST)	Ammonia (mg/1)	NO_3 (µg atm/1)	NO_2 (µg atm/1)	Inorganic Nitrogen (mg/1)	PO_3 (µg atm/1)	Inorganic Phosphorous (mg/1)	Chlorophyll "a" (µg/1)	Fecal Coliforms (MPN/100)	TKN (mg/1)	NBOD (mg/1)	UBOD (mg/1)	CBOD (mg/1)
STATION V-I-B													
2/7/76	00.6	0.08	6.08	0.24	.090	0.21	.006	6.08		0.32	1.4624	--	--
		0.09	2.02	0.40	.035	0.58	.018	22.62		0.28	1.2796	--	--
	1.2	0.06	4.05	0.35	.062	0.42	.013	9.12		0.33	1.5081	--	--
		0.07	7.03	0.32	.104	0.72	.022	5.13		0.01	0.0457	--	--
	3.7	--	--	--	--	--	--	--		--	--	--	--
		0.07	6.16	0.34	.092	0.76	.024	5.89		--	--	--	--
STATION V-II-B													
30/6/76	12.2	0.09	10.30	0.35	.150	0.51	.016	11.21		18.16	--	0.675	0.45
		0.07	1.91	0.28	.032	0.49	.015	--	3.6	0.32	1.4624	1.95	1.30
	18.5	0.08	1.54	0.46	.029	0.40	.012	10.83	23.0	0.30	1.371	3.525	2.35
		0.13	1.60	0.50	.031	0.66	.020	7.79	23.0	--	--	3.225	2.15
	21.4	0.06	3.48	0.57	.058	0.40	.012	9.12		0.37	1.6909	--	--
		0.10	4.33	0.35	.067	0.60	.019	3.04		0.17	0.7769	--	--
1/7/76	7.1	0.19	1.57	0.35	.030	0.60	.019	6.84	5.7	0.49	2.2393	1.095	0.73
		0.12	4.42	0.33	.068	0.48	.015	7.41	5.7	0.40	1.828	--	--
	10.1	0.15	7.73	0.16	.012	0.96	.030	2.44	3.3	0.25	1.1425	3.045	2.03
		0.18	4.53	0.69	.076	0.48	.015	7.22	3.3	0.31	1.4167	--	--
	13.1	0.11	5.23	0.65	.084	0.38	.012	15.20		0.63	2.8791	2.01	1.34
		0.08	5.63	0.15	.082	0.52	.016	7.98		0.29	1.3253	--	--
	16.1	0.23	3.88	0.19	.060	2.52	.078	11.40	3.6	0.51	2.3307	2.76	1.84
		0.16	10.06	0.14	.145	0.66	.020	3.44	3.6	0.10	0.457	1.185	0.79

Date	Time (EST)	Ammonia (mg/l)	NO_3 (μg atm/l)	NO_2 (μg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (μg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll (μg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION V-II-B													
1/7/76	19.2	0.08	4.26	0.24	.064	0.40	.012	11.02	3.6	0.67	3.0619	0.75	0.50
		0.17	11.34	0.46	.168	0.80	.025	3.04	3.6	0.38	1.7366	--	--
	22.1	0.12	5.55	0.35	.084	0.80	.025	10.45		0.28	1.2796	1.545	1.03
		0.15	7.73	0.22	.113	0.96	.030	3.61	3.0	0.30	1.371	1.065	0.71
2/7/76	00.7	0.05	--	0.27	--	0.44	.014	1.90		0.27	1.2339	--	--
		0.08	5.02	0.15	.074	0.62	.019	3.23		0.15	0.6855	--	--
	4.6	0.14	7.92	0.58	.121	0.72	.022	9.12		0.34	1.5538	--	--
		0.10	3.77	0.38	.060	0.76	.024	6.08		0.06	0.2742	--	--
STATION V-III-B													
30/6/76	13.1	0.09	6.62	0.98	.108	0.56	.017	16.15	5.1	0.36	1.6452	2.04	1.36
		0.15	1.41	0.89	.034	0.72	.022	4.56	5.1	0.38	1.7366	--	--
	15.1	16.90	12.27	0.63	.417	1.36	.042	15.20		0.42	1.9194	2.13	1.42
		0.12	2.65	0.47	.045	0.64	.020	10.83		0.40	1.828	0.06	0.04
	18.1	16.60	4.12	0.68	.300	0.48	.015	10.64		0.46	2.1022	--	--
		0.28	2.13	0.75	.044	0.84	.026	11.21		0.56	2.5592	5.52	3.68
	21.3	0.08	8.20	0.44	.122	0.44	.014	6.27		0.38	1.7366	--	--
		0.13	6.85	0.65	.107	0.90	.028	6.46		0.36	1.6452	--	--
1/7/76	7.1	0.12	8.71	0.47	.130	0.56	.017	6.97	3.0	0.41	1.8737	--	--
		0.16	3.98	0.53	.065	0.68	.021	--	3.0	0.06	0.2742	1.395	0.93

Date	Time (EST)	Ammonia (mg/l)	NO_3 (μg atm/l)	NO_2 (μg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (μg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (μg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION V-III-B													
1/7/76	10.1	0.10	5.25	0.47	.081	0.52	.016	6.97	3.0	0.61	2.7877	2.355	1.57
		0.21	9.28	0.34	.138	0.84	.026	6.84	3.0	0.58	2.6506	0.345	0.23
	13.1	0.08	3.83	0.41	.060	0.52	.016	13.11		0.24	1.0968	2.88	1.92
		0.14	4.40	0.28	.067	0.88	.027	3.23		0.90	4.113	0.495	0.33
	16.0	0.16	3.83	0.26	.059	0.48	.015	13.87	3.6	0.29	1.3253	--	--
		0.17	3.86	0.32	.061	0.88	.027	5.70	3.6	0.27	1.2339	8.82	5.88
	19.2	0.09	6.29	0.42	.095	0.48	.015	12.54	9.1	0.32	1.4624	1.56	1.04
		0.17	6.15	0.39	.094	0.76	.024	5.51	9.1	0.29	1.3253	1.785	1.19
	22.1	0.09	3.92	0.42	.062	0.44	.014	7.03	5.2	0.41	1.8737	2.1	1.40
		0.15	2.73	0.29	.044	0.92	.029	52.26	5.2	0.82	3.7474	3.06	2.04
2/7/76	1.5	0.09	7.30	0.68	.113	0.52	.016	11.57		0.47	2.1479	--	--
		0.14	4.96	0.48	.078	0.64	.020	4.75		0.25	1.1425	--	--
	4.3	0.14	5.27	0.34	.081	0.68	.021	7.60		0.03	0.1371	--	--
STATION Y-1-B													
30/6/76	12.0	0.08	1.25	0.37	.024	0.44	.014	16.34		--	--	--	--
		0.06	--	0.34	--	0.64	.020	4.37		0.32	14624	--	--
	15.0	0.06	5.16	0.20	.076	0.34	.010	11.97		0.49	2.2393	1.755	1.17
		0.11	1.57	0.45	.030	0.64	.020	2.85		0.04	0.1828	2.565	1.71
	18.0	0.08	8.59	0.36	.126	0.36	.011	7.15		0.15	0.6855	1.035	0.69
		--	1.67	0.38	--	0.78	.024	1.54		0.19	0.8683	0.825	0.55

Date	Time (EST)	Ammonia (mg/l)	NO_3 (μg atm/l)	NO_2 (μg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (μg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (μg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION Y-1-B													
1/7/76	7.2	0.08	6.55	0.60	.101	0.54	.017	5.70	3.0	0.27	1.2339	--	--
		0.09	7.33	0.22	.107	0.84	.026	2.09		0.24	1.0968	1.65	1.10
	10.0	0.37	4.11	0.19	.065	0.38	.012	10.45	3.0	0.44	2.0108	1.2	0.80
		0.10	3.53	0.15	.053	0.92	.028	2.66	3.0	--	--	1.38	0.92
	13.1	0.05	6.07	0.26	.089	0.48	.015	13.11		--	--	2.145	1.43
		--	--	--	--	--	--	21.86		--	--	--	--
	16.3	0.05	4.26	0.25	.064	0.32	.010	17.51		0.78	3.5646	--	--
		0.11	10.09	0.36	.148	0.80	.025	4.37		0.20	0.914	--	--
	19.1	0.09	7.64	0.51	.115	0.54	.017	13.30		--	--	0.135	0.09
		0.10	10.00	0.16	.144	0.68	.021	3.29		0.29	1.3253	3.9	2.60
	22.1	0.09	7.25	0.55	.110	0.54	.017	8.17	3.6	0.11	0.5027	2.61	1.74
		0.08	4.50	0.30	.068	0.72	.022	3.04	3.6	0.13	0.5941	1.755	1.71
STATION Y-2-B													
30/6/76	11.2	0.11	1.42	0.42	.027	0.42	--	3.42	3.6	0.16	0.7312	2.43	1.62
		--	--	--	--	--	.013	10.83	3.6	0.26	1.1882	1.575	1.05
	15.0	0.07	1.65	0.35	.029	0.24	.007	13.87		0.27	1.2339	1.695	1.13
		0.10	20.08	0.32	.287	0.60	.019	2.28		0.15	0.6855	0.6	0.40
	18.1	0.08	2.26	0.61	.041	0.30	.009	12.73	5.7	0.29	1.3253	--	--
		0.14	4.44	0.51	.071	0.70	.022	4.56	5.7	--	--	1.695	1.13
	21.1	0.07	2.86	0.38	.046	0.52	.016	8.17	9.1	0.40	1.828	0.465	0.31
		0.10	2.92	0.27	.046	0.64	.020	2.85	9.1	0.61	2.7877	--	--

Date	Time (EST)	Ammonia (mg/1)	NO_3 (μg atm/1)	NO_2 (μg atm/1)	Inorganic Nitrogen (mg/1)	PO_3 (μg atm/1)	Inorganic Phosphorous (mg/1)	Chlorophyll "a" (μg/1)	Fecal Coliforms (MPN/100)	TKN (mg/1)	NBOD (mg/1)	UBOD (mg/1)	CBOD (mg/1)
STATION Y-2-B													
1/7/76	7.1	0.28	5.65	0.40	.089	1.04	.032	3.61	3.0	0.35	1.5995	6.18	4.12
		0.14	4.98	0.80	.083	0.52	.016	5.70	3.0	0.28	1.2796	--	--
	10.0	0.14	3.99	0.74	.068	0.68	.021	8.55	3.3	0.04	0.1828	3.84	2.56
		0.15	5.72	0.33	.087	0.84	.026	2.09	3.3	0.28	1.2796	0.405	0.27
	13.1	0.10	6.80	0.65	.106	0.56	.017	7.22		0.26	1.1882	0.03	0.02
		0.12	6.12	0.15	.089	0.70	.022	2.28		0.36	1.6452	--	--
	16.1	0.13	2.71	0.59	.048	0.44	.014	6.84	3.6	--	--	--	--
		0.10	4.81	0.41	.074	0.70	.022	3.80	3.6	0.12	0.5484	--	--
	19.1	0.12	9.44	0.76	.144	0.64	.020	9.50		0.24	1.0968	0.27	0.18
		--	--	--	--	--	--	2.66		--	--	0.945	0.63
	22.1	0.14	14.72	0.73	.218	0.52	.016	7.22		--	--	1.575	1.05
		0.17	4.02	0.44	.065	0.86	.027	3.42	3.6	0.30	1.371	0.345	0.23
2/7/76	1.3	0.07	6.92	0.63	.107	0.60	.019	4.94		0.33	1.5081	--	--
		0.11	2.29	0.19	.036	0.60	--	3.61		0.37	1.6909	--	--
	4.0	0.14	7.27	0.73	.114	0.48	.019	5.89		0.28	1.2796	--	--
		0.14	4.44	0.34	.069	0.64	.020	7.60		0.42	1.9194	--	--
STATION Y-3-C													
15/6/76	12.0	0.08	4.37	0.43	.068	0.52	.016	--		0.43	1.9651	--	--
		0.04	5.44	0.51	.084	0.52	.016	--		0.58	2.6506	--	--
	15.0	0.06	3.95	--	--	0.60	.019	--	3.0	--	--	--	--
		0.12	6.18	0.37	.093	0.38	.012	--		0.24	1.0968	--	--

Date	Time (EST)	Ammonia (mg/l)	NO_3 (µg atm/l)	NO_2 (µg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (µg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (µg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION Y-3-C													
15/6/76	18.0	0.06	6.89	0.61	.106	0.40	.012	--		0.45	2.0565	--	--
		0.08	4.89	0.51	.077	0.60	.019	--		0.41	1.8737	--	--
	21.0	0.12	17.72	0.53	.257	0.34	.010	--		0.32	1.4624	--	--
		0.12	13.51	0.49	.198	0.54	.017	--		0.40	1.828	--	--
16/6/76	0.0	0.06	7.58	0.57	.115	0.54	.017	--		0.46	2.1022	--	--
		0.14	9.58	0.42	.142	0.50	.016	--		0.55	2.5135	--	--
	3.0	0.15	16.76	0.44	.243	0.42	.013	--		--	--	--	--
		0.17	12.30	0.42	.180	1.70	.053	--	3.6	0.56	2.5592	--	--
	6.0	--	--	--	--	--	--	--		0.28	1.2796	--	--
		0.12	18.26	0.44	.263	0.42	.013	--	3.6	0.68	3.1076	--	--
	9.0	0.17	12.30	0.90	.187	1.70	.053	--	3.6	0.57	2.6049	--	--
		0.11	11.73	0.47	.172	0.32	.010	--	3.6	0.52	2.3764	--	--
	12.0	0.11	8.17	0.48	.123	0.42	.013	--		0.25	1.1425	6.705	4.47
		0.10	9.22	0.31	.135	0.48	.015	--		0.76	3.4732	3.855	2.57
	13.0	0.15	10.13	0.47	.150	0.38	.012	--		0.47	2.1479	--	--
		0.08	10.64	0.46	.157	0.46	.014	--		0.46	2.1022	6.42	4.28
STATION Y-4-B													
15/6/76	12.6	0.11	7.64	0.61	.117	0.84	.026	--		--	--	--	--
		0.05	7.28	0.62	.111	0.44	.014	--		--	--	--	--

Date	Time	Ammonia	NO_3	NO_2	Inorganic Nitrogen	PO_3	Inorganic Phosphorous	Chlorophyll "a"	Fecal Coliforms	TKN	NBOD	UBOD	CBOD
	(EST)	(mg/1)	(µg atm/1)	(µg atm/1)	(mg/1)	(µg atm/1)	(mg/1)	(µg/1)	(MPN/100)	(mg/1)	(mg/1)	(mg/1)	(mg/1)
STATION Y-4-B													
15/6/76	19.2	0.05	14.00	0.70	.207	0.44	.014	--		0.43	1.9651	--	--
		0.06	9.49	0.76	.144	0.56	.017	--	3.6	0.93	4.2501	--	--
	21.5	0.13	12.10	0.65	.180	0.44	.014	--		--	--	--	--
		0.22	21.05	0.75	.309	0.56	.017	--	9.1	--	--	--	--
16/6/76	0.5	0.13	12.71	0.59	.188	0.48	.015	--	3.6	--	--	--	--
		0.16	10.91	0.69	.165	0.68	.021	--	3.6	--	--	--	--
	3.5	0.23	18.68	0.52	.272	0.30	.009	--		0.62	2.8334	--	--
		0.11	25.01	0.59	.360	0.56	.017	--		--	--	--	--
	6.6	0.18	22.29	0.71	.325	0.44	.014	--	3.6	0.42	1.1914	--	--
		0.18	21.92	0.68	.319	0.40	.012	--	3.6	0.94	4.2958	--	--
	9.5	0.10	14.79	0.71	.218	0.68	.021	--		--	--	--	--
		0.11	11.62	0.78	.175	0.66	.020	--	3.0	0.28	1.2796	--	--
	12.3	0.16	9.42	0.48	.141	0.38	.012	--		0.48	2.1936	1.2	0.80
		--	--	--	--	--	--	--		--	--	0.15	0.10
STATION Y-5-B													
15/6/76	12.0	0.05	5.85	0.65	.092	0.52	--	--		--	--	--	--
		0.05	5.85	0.65	.092	0.52	.016	--		--	--	--	--
	15.0	0.07	5.80	0.70	.092	0.40	.012	--		--	--	--	--
		0.07	5.80	0.70	.092	0.40	.012	--		--	--	--	--
	18.0	0.08	6.57	0.38	.098	0.48	.015	--		--	--	--	--
		0.08	6.57	0.38	.098	0.48	.015	--		--	--	--	--

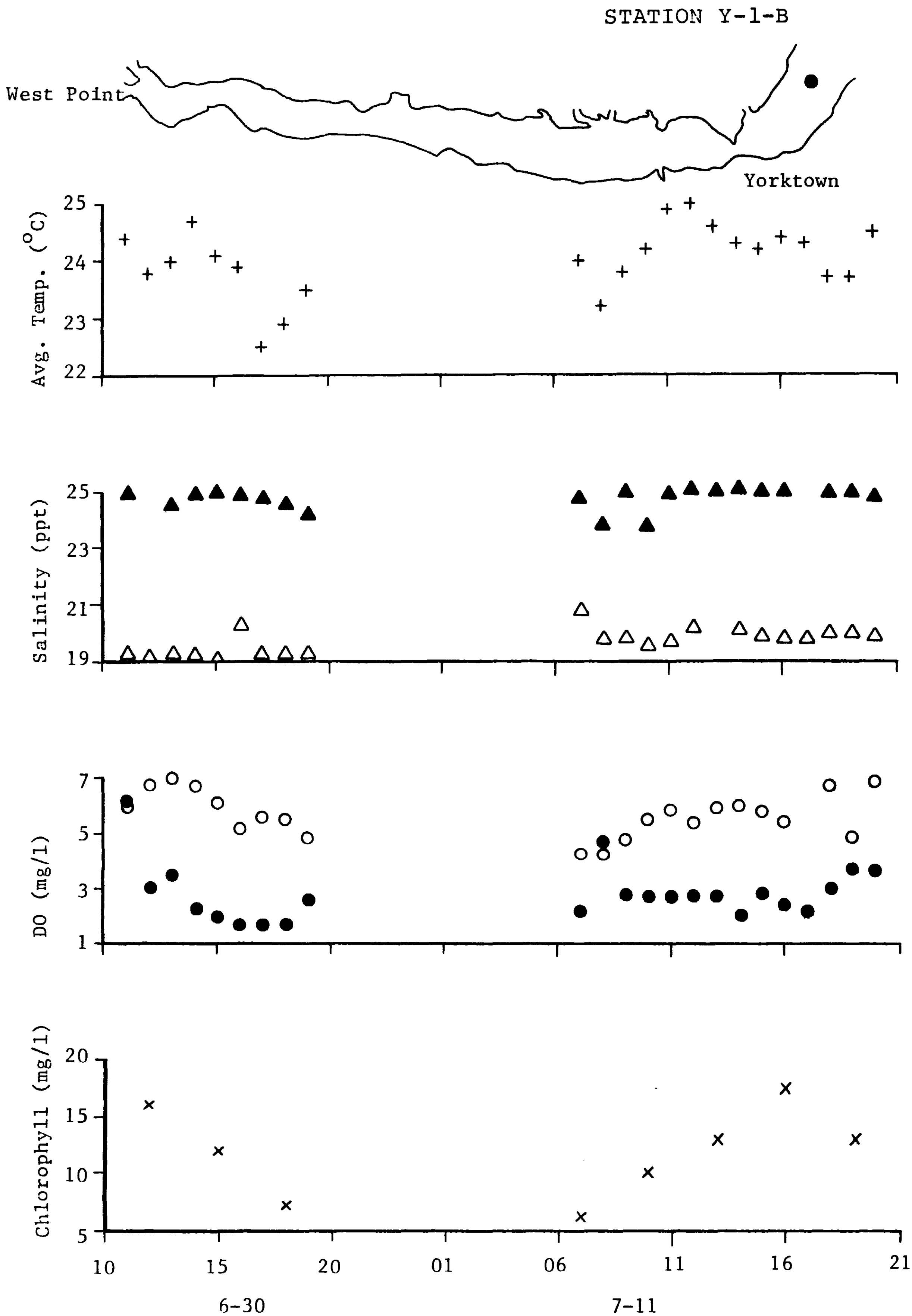
Date	Time (EST)	Ammonia (mg/l)	NO_3 (µg atm/l)	NO_2 (µg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (µg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (µg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION Y-5-B													
15/6/76	21.0	0.14	17.65	0.65	.258	0.48	.015	--		0.40	1.828	--	--
		0.14	17.65	0.65	.258	0.48	.015	--		0.40	1.828	--	--
16/6/76	0.0	0.18	29.93	0.67	.431	0.40	.012	--		0.39	1.7823	--	--
		0.18	29.93	0.67	.431	0.40	.012	--		0.39	1.7823	--	--
	3.0	0.12	7.92	0.63	.121	0.46	.014	--		0.52	2.3764	--	--
		0.12	7.92	0.63	.121	0.46	.014	--		0.52	2.3764	--	--
	6.0	0.14	12.24	0.66	.183	0.56	.017	--		0.41	1.8737	--	--
		0.14	12.24	0.66	.183	0.56	.017	--		0.41	1.8737	--	--
	9.0	0.19	17.22	0.68	.253	0.52	.016	--		0.69	3.1533	--	--
		0.19	17.22	0.68	.253	0.52	.016	--		0.69	3.1533	--	--
	13.0	0.19	32.32	0.68	.465	0.56	.017	--		--	--	0.225	0.15
		0.19	32.32	0.68	.465	0.56	.017	--		--	--	0.225	0.15
STATION Y-6-B													
15/6/76	12.0	0.06	9.70	0.70	.146	0.60	.019	--	93.0	--	--	--	--
		0.06	10.78	0.72	.162	0.56	.017	--	93.0	1.08	4.9356	--	--
	15.0	0.08	11.12	0.68	.166	0.74	.023	--	9.1	--	--	--	--
		0.06	10.55	0.75	.159	0.56	.017	--	9.1	0.38	1.7366	--	--
	18.0	0.05	13.05	0.65	.193	0.40	.012	--	11.8	0.49	2.2393	--	--
		0.05	15.48	0.72	.228	0.44	.014	--	11.8	--	--	--	--
	19.0	0.08	12.33	0.72	.184	0.46	.014	--	29.1	1.26	5.7582	1.53	1.02
		0.17	11.30	0.65	.170	0.44	.014	--	29.1	2.73	12.4761	--	--

Date	Time (EST)	Ammonia (mg/1)	NO_3 (µg atm/1)	NO_2 (µg atm/1)	Inorganic Nitrogen (mg /1)	PO_3 (µg atm/1)	Inorganic Phosphorous (mg /1)	Chlorophyll "a" (µg/1)	Fecal Coliforms (MPN/100)	TKN (mg/1)	NBOD (mg/1)	UBOD (mg/1)	CBOD (mg/1)
STATION Y-6-B													
15/6/76	22.0	0.14	10.12	0.58	.152	0.46	.014	--	31.4	1.14	5.2098	2.28	1.52
		0.07	13.95	0.75	.207	0.54	.017	--	31.4	1.01	4.6157	--	--
16/6/76	0.0	0.07	11.50	0.75	.172	0.46	.014	--	5.2	--	--	0.645	0.43
		0.07	11.19	0.66	.167	0.48	.015	--	5.2	0.55	2.5135	1.575	1.05
	3.0	0.08	12.41	0.74	.185	0.56	.017	--	7.2	1.40	6.398	1.515	1.01
		0.07	10.69	0.71	.160	0.48	.015	--		0.46	2.1022	--	--
	6.0	0.13	9.15	0.60	.138	0.46	.014	--	10.0	0.14	0.6398	3.66	2.44
		0.08	11.90	0.75	.178	0.46	.014	--	10.0	--	--	1.53	1.02
	9.0	0.12	18.20	0.70	.266	0.66	.020	--	44.2	0.62	2.8334	--	--
		0.17	16.68	0.72	.246	0.54	.017	--	44.2	0.59	2.6963	--	--
	12.0	0.14	25.30	0.70	.366	0.38	.012	--	14.5	0.62	2.8334	--	--
		0.16	16.39	0.61	.240	0.38	.012	--	14.5	--	--	--	--
	13.0	0.12	15.60	0.65	.229	0.48	.015	--		0.76	3.4732	--	--
		0.16	19.64	0.51	.284	0.32	.010	--		0.68	3.1076	--	--
STATION Y-7-A													
15/6/76	12.0	0.08	10.66	0.69	.160	0.70	.022	--	93.0	0.57	2.6049	--	--
		0.08	15.00	0.70	.221	0.54	.017	--	93.0	--	--	--	--
	15.0	0.10	13.83	0.67	.198	0.32	.010	--	19.8	--	--	--	--
		0.07	10.24	0.71	.154	0.48	.015	--	19.8	--	--	--	--

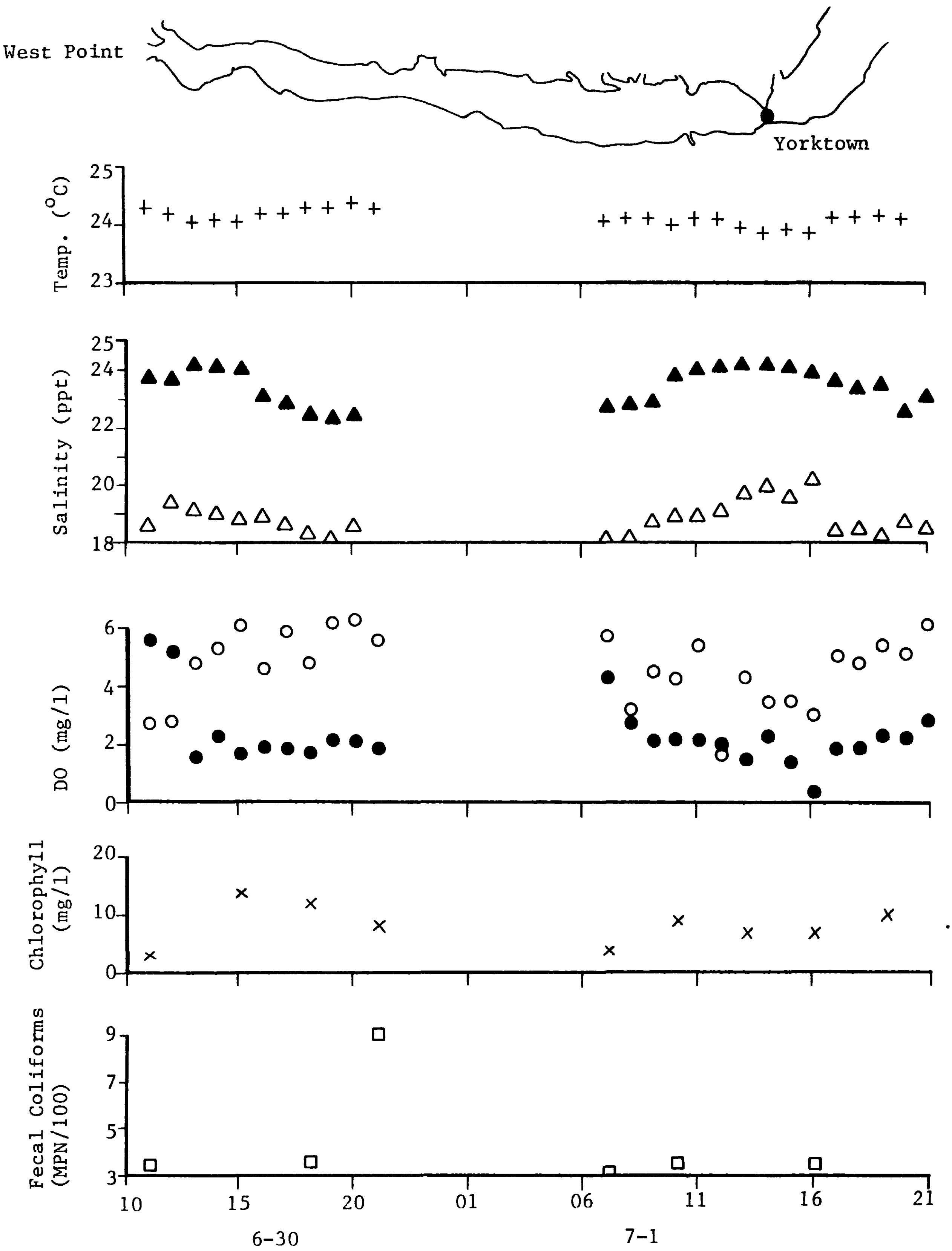
Date	Time (EST)	Ammonia (mg/l)	NO_3 (µg atm/l)	NO_2 (µg atm/l)	Inorganic Nitrogen (mg/l)	PO_3 (µg atm/l)	Inorganic Phosphorous (mg/l)	Chlorophyll "a" (µg/l)	Fecal Coliforms (MPN/100)	TKN (mg/l)	NBOD (mg/l)	UBOD (mg/l)	CBOD (mg/l)
STATION Y-7-A													
15/6/76	18.0	0.06	13.19	0.71	.195	0.58	.018	--	31.4	0.12	0.5484	--	--
		0.07	12.87	0.73	.191	0.60	.019	--	31.4	0.58	2.6506	--	--
	21.5	0.09	12.72	0.68	.189	0.52	.016	--	43.0	--	--	--	--
		0.20	19.67	0.63	.287	0.46	.014	--	43.0	0.61	2.7877	4.215	2.81
16/6/76	0.5	0.08	9.49	0.76	.145	0.80	.025	--	3.0	--	--	--	--
		0.08	12.92	0.73	.192	0.72	.022	--	3.0	--	--	--	--
	3.5	0.12	12.90	0.65	.191	0.40	.012	--	15.0	0.38	1.7366	0.945	0.63
		0.06	9.64	0.71	.146	0.72	.022	--	15.0	0.26	1.1882	--	--
	6.0	0.06	11.75	0.70	.175	0.60	.019	--	8.2	0.47	2.1479	--	--
		0.05	10.75	0.75	1.62	0.64	.020	--	8.2	0.41	1.8737	1.53	1.02
	9.3	0.13	16.38	0.67	.240	0.66	.020	--	83.5	0.51	2.3307	--	--
		0.19	22.73	0.67	.330	0.90	.028	--	83.5	0.73	3.3361	--	--
	12.0	0.23	30.42	0.78	.440	0.50	.016	--	18.6	0.55	2.5135	--	--
		0.13	3.63	0.62	.061	1.46	.045	--	18.6	1.44	6.5808	--	--
	13.0	0.21	23.22	0.68	.338	1.66	.051	--		0.57	2.6049	2.1	1.40
		0.16	19.67	0.73	.288	0.78	.024	--		0.28	1.2796	--	--

NOTE: Nitrite and nitrate values in ug-at/l can be transferred to milligrams/liter by multiplying the values by 0.014

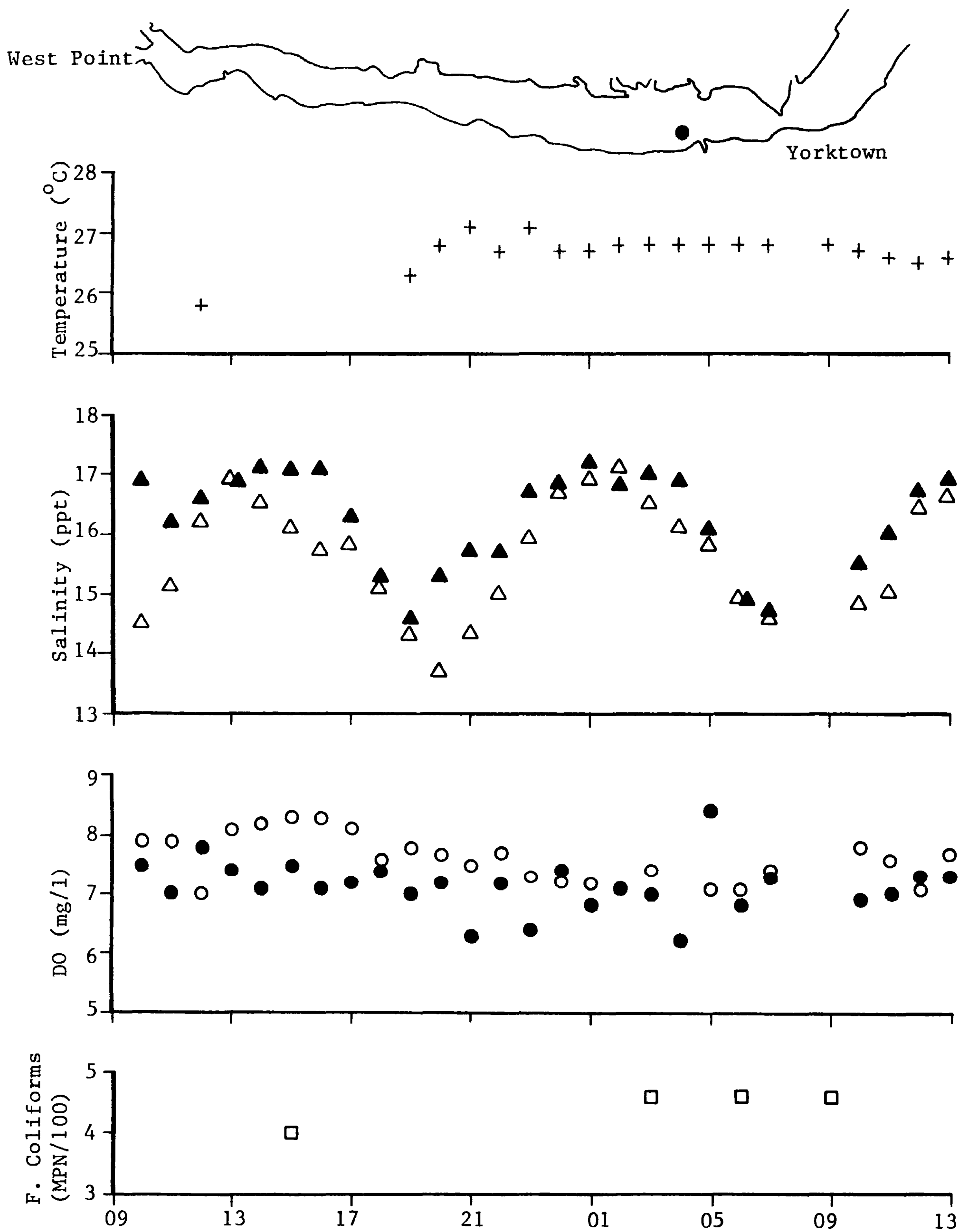
Phosphate values can be transferred to milligrams/liter by multiplying the values in ug-at/l by 0.031.


STATION Y-1-B
West Point
Yorktown
Avg. Temp. (°C)
25
24
23
22
Salinity (ppt)
25
23
21
19
DO (mg/l)
7
5
3
1
Chlorophyll (mg/l)
20
15
10
5
10
15
20
01
06
11
16
21
6-30
7-11

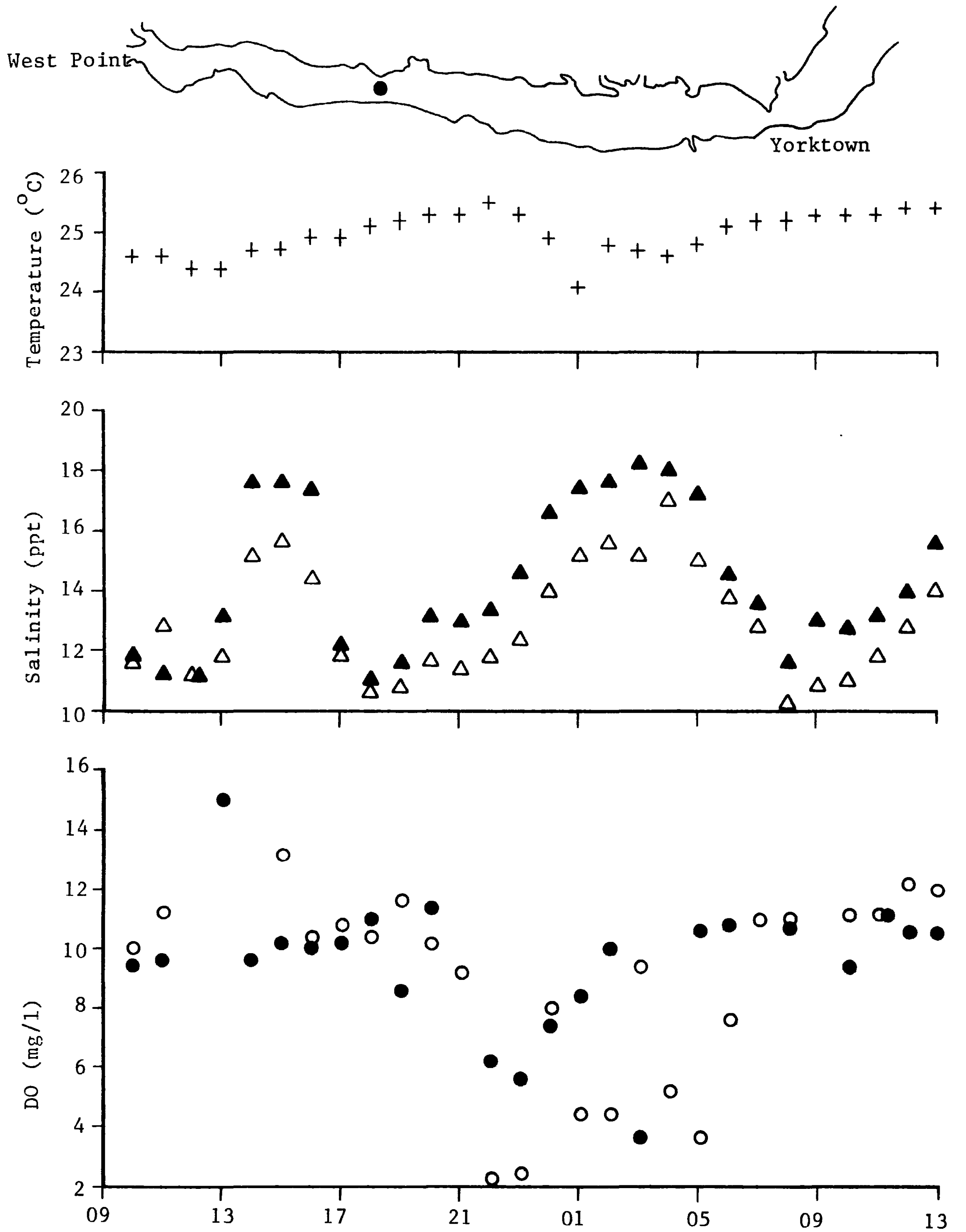
STATION Y-2-B


West Point
Yorktown
25
24
23
Temp. (°C)
25
24
22
20
18
Salinity (ppt)
6
4
2
0
DO (mg/l)
20
10
0
Chlorophyll (mg/l)
9
7
5
3
Fecal Coliforms (MPN/100)
10
15
20
01
06
11
16
21
6-30
7-1

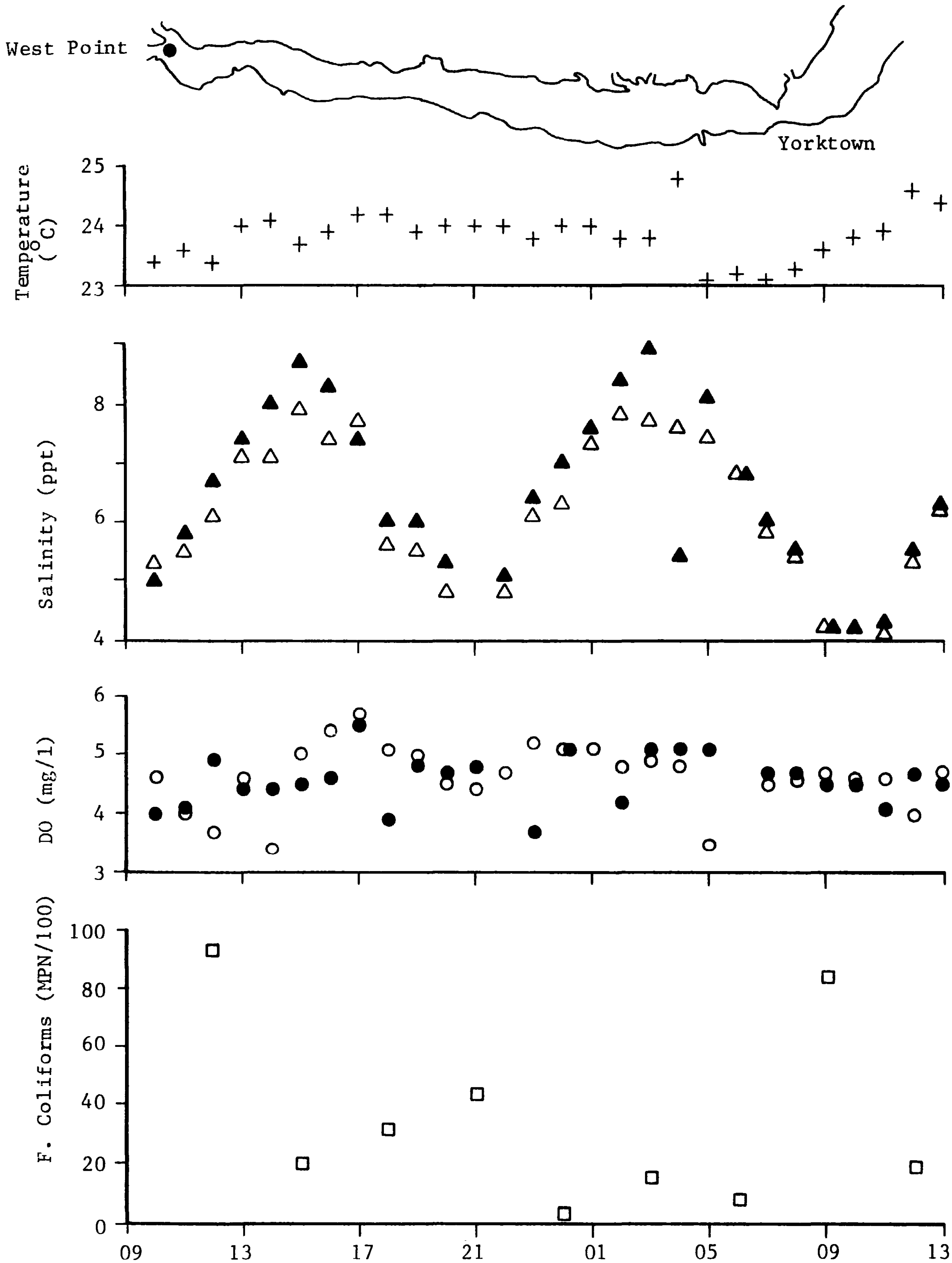
STATION Y-3-A


West Point
Yorktown
Temperature (°C)
25
26
27
28
Salinity (ppt)
13
14
15
16
17
18
DO (mg/1)
5
6
7
8
9
F. Coliforms
(MPN/100)
3
4
5
09
13
17
21
01
05
09
13

STATION Y-5-B


West Point
Yorktown
Temperature (°C)
26
25
24
23
Salinity (ppt)
20
18
16
14
12
10
DO (mg/l)
16
14
12
10
8
6
4
2
09
13
17
21
01
05
09
13

STATION Y-7-B

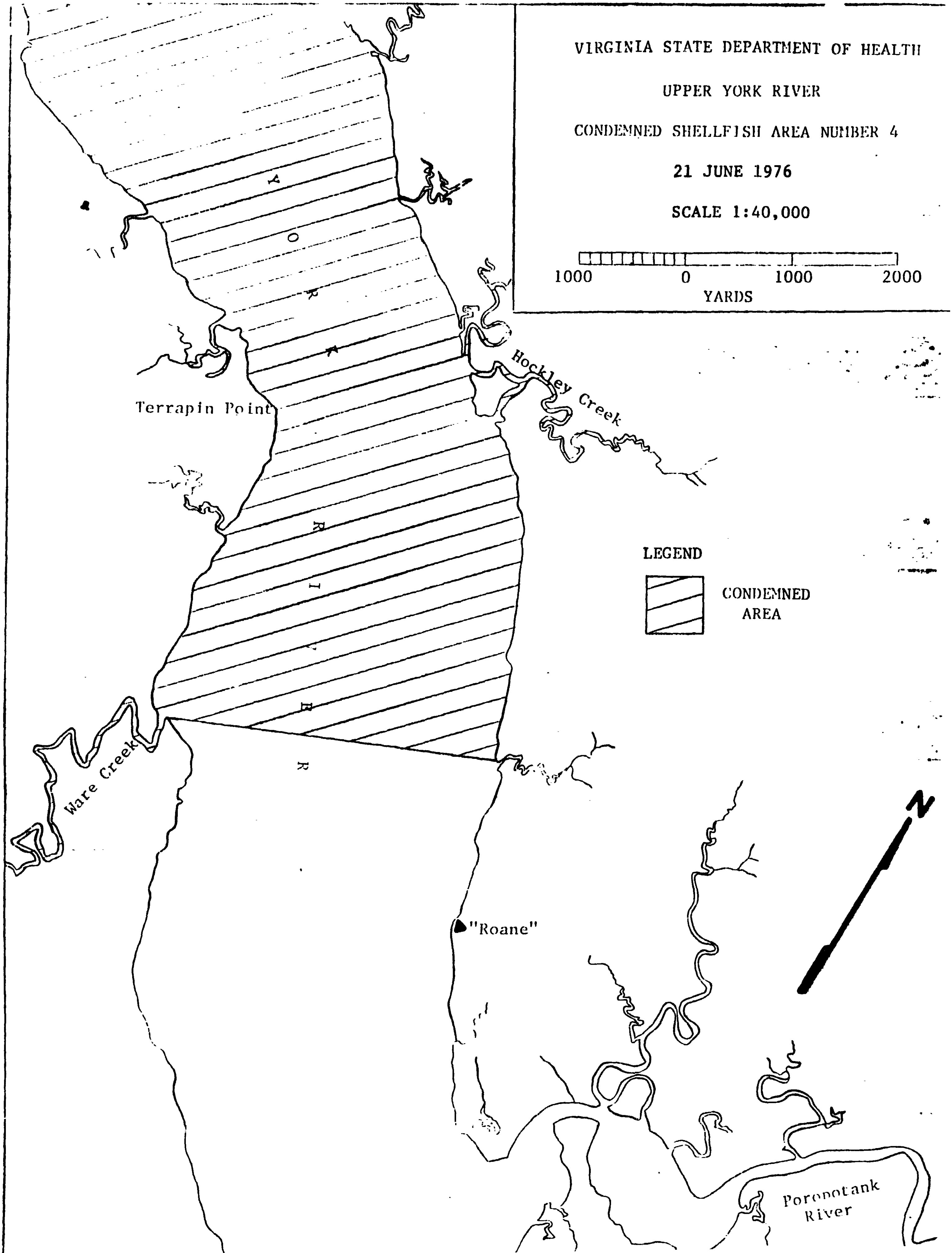

West Point
Yorktown
Temperature (°C)
25
24
23
Salinity (ppt)
8
6
4
DO (mg/1)
6
5
4
3
F. Coliforms (MPN/100)
100
80
60
40
20
0
09
13
17
21
01
05
09
13

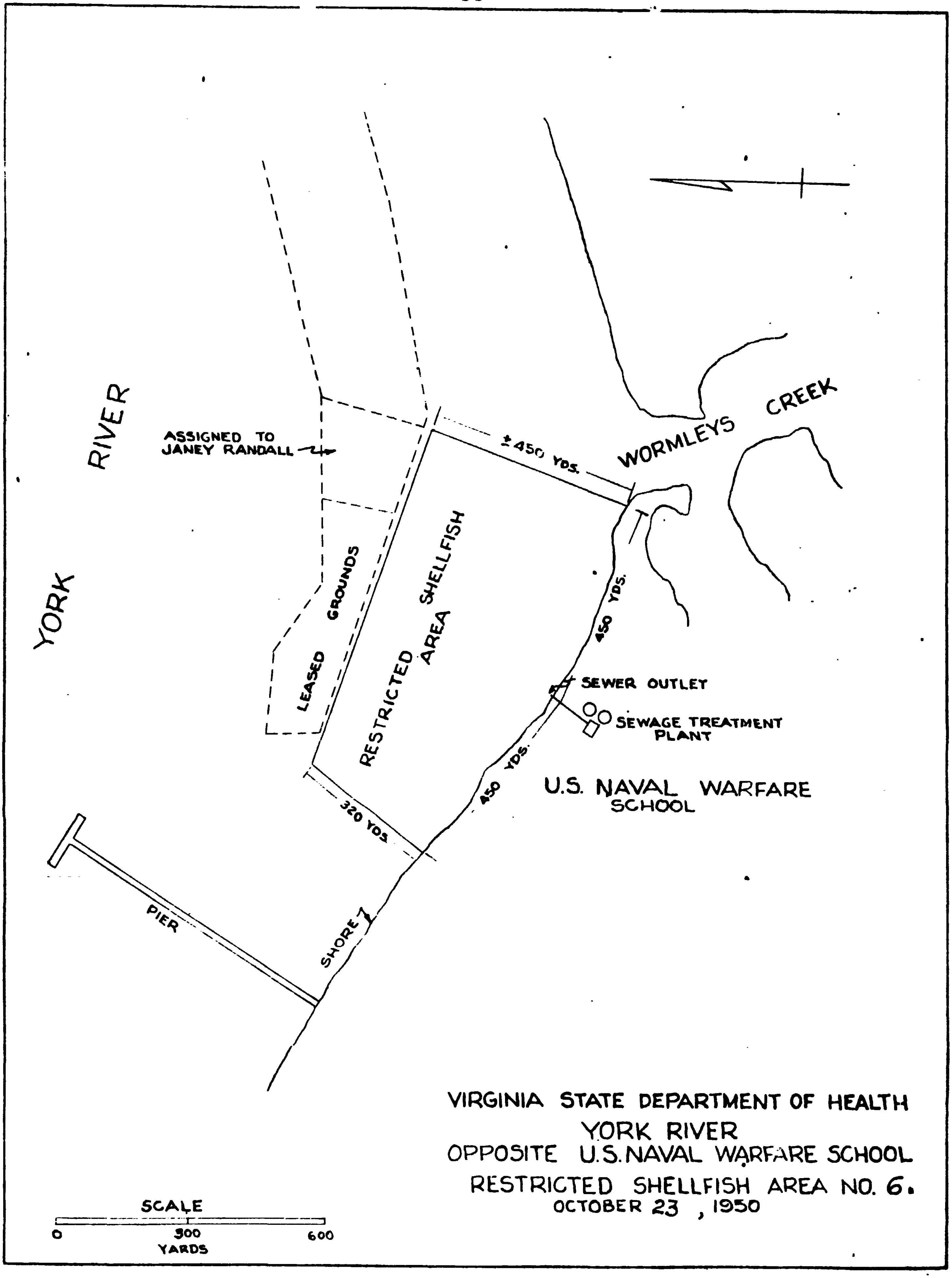
APPENDIX C. SHELLFISH CONDEMNATION AREAS IN YORK RIVER SYSTEM

Restricted Area Number	Date of Original Enactment
3	5 August 1948
4†	5 February 1944
6†	23 October 1950
27†	6 January 1941
35	24 January 1972*
39†	24 January 1972*
40†	24 January 1972*
52	27 September 1965
72	7 March 1972
73	7 March 1972
78	7 March 1972
79	7 March 1972
81	10 March 1972
87	22 March 1972
107	21 April 1972
108	21 April 1972
115	27 April 1972
125	28 April 1972
128	28 April 1972
130	24 March 1975
134	1 May 1972
151	21 February 1975

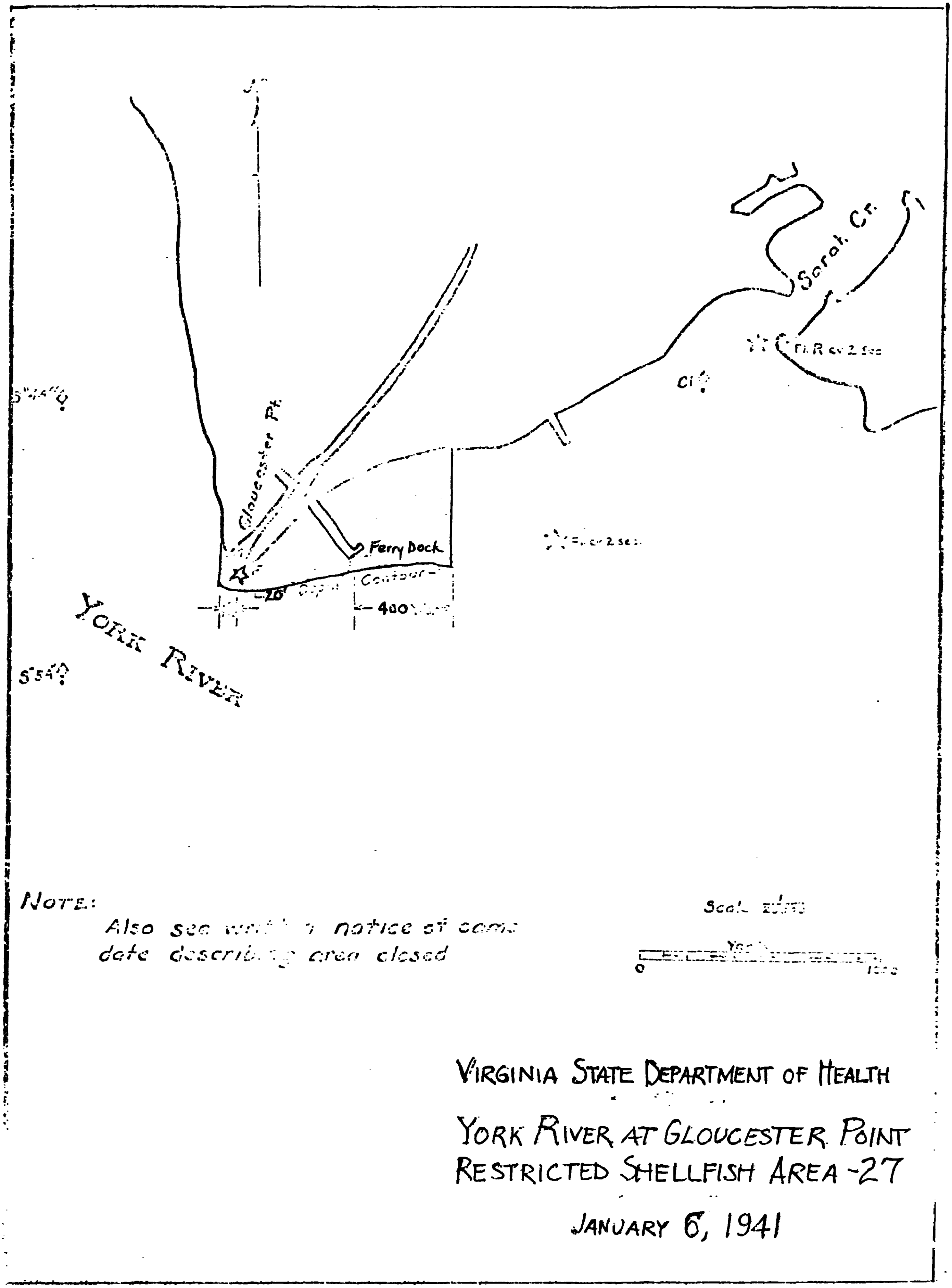
* Original enactment probably earlier, but date unknown.

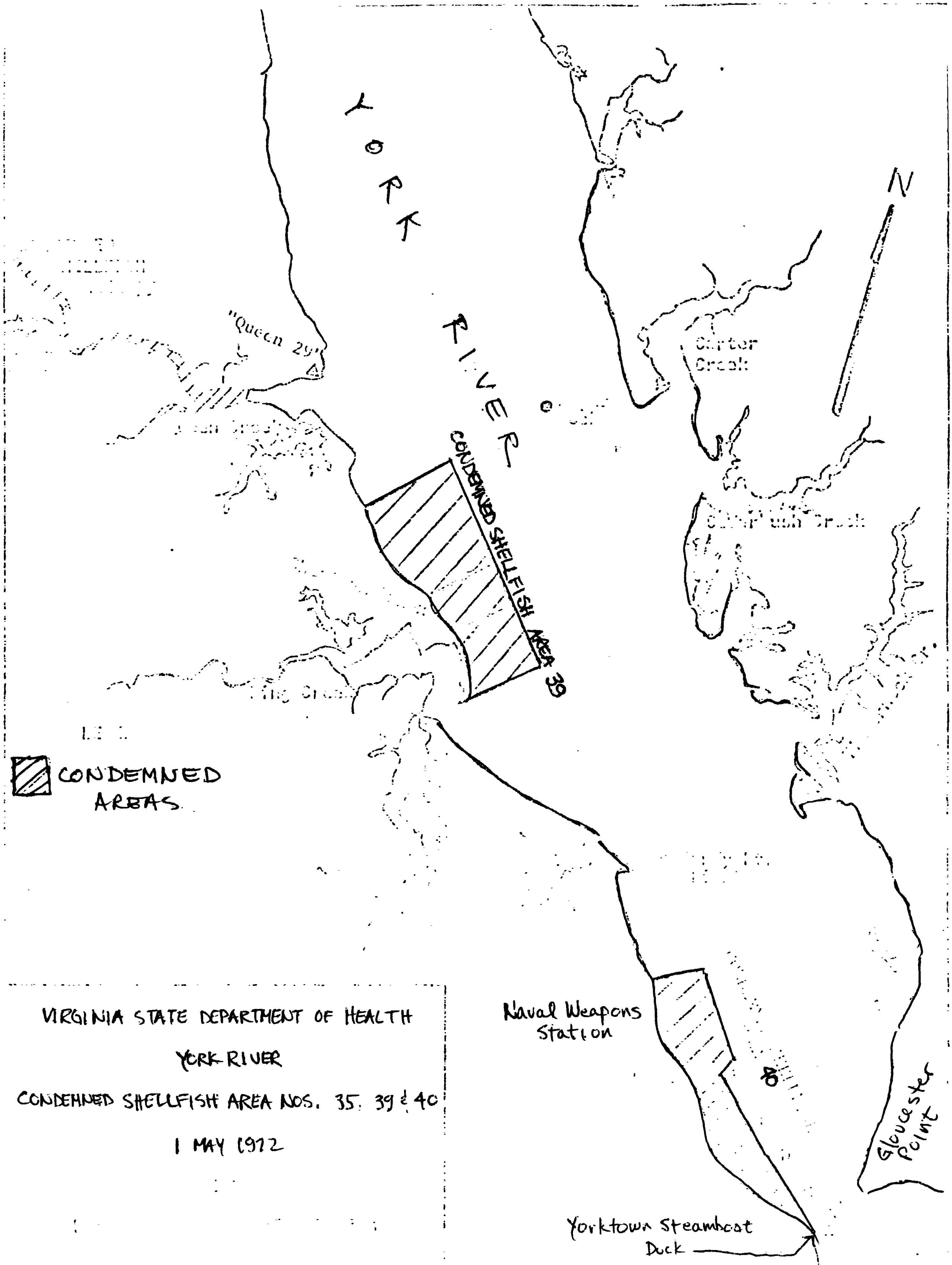
† Areas 4, 6, 27, 39 and 40 are the only zones in the York proper. Maps for these are included.


VIRGINIA STATE DEPARTMENT OF HEALTH
UPPER YORK RIVER
CONDEMNED SHELLFISH AREA NUMBER 4
21 JUNE 1976
SCALE 1:40,000
1000 0 1000 2000
YARDS
LEGEND
CONDEMNED AREA
YORK RIVER
Terrapin Point
Hockley Creek
Ware Creek
"Roane"
Poropotank River
N



VIRGINIA STATE DEPARTMENT OF HEALTH
YORK RIVER
OPPOSITE U.S. NAVAL WARFARE SCHOOL
RESTRICTED SHELLFISH AREA NO. 6.
OCTOBER 23, 1950


Sarah Cr.
Gloucester Pt.
Ferry Dock
20'
Contour
400
YORK RIVER
NOTE:
Also see
notice of same
date
area closed
VIRGINIA STATE DEPARTMENT OF HEALTH
YORK RIVER AT GLOUCESTER POINT
RESTRICTED SHELLFISH AREA -27
JANUARY 6, 1941


YORK RIVER
N
"Queen 29"
CONDEMNED SHELLFISH AREA 39
CONDEMNED AREAS
Naval Weapons Station
8
Gloucester Point
Yorktown Steamboat Dock
VIRGINIA STATE DEPARTMENT OF HEALTH
YORK RIVER
CONDEMNED SHELLFISH AREA NOS. 35, 39 & 40
1 MAY 1972