80-12 WATER QUALITY OF TAMPA BAY, FLORIDA: JUNE 1972–MAY 1976

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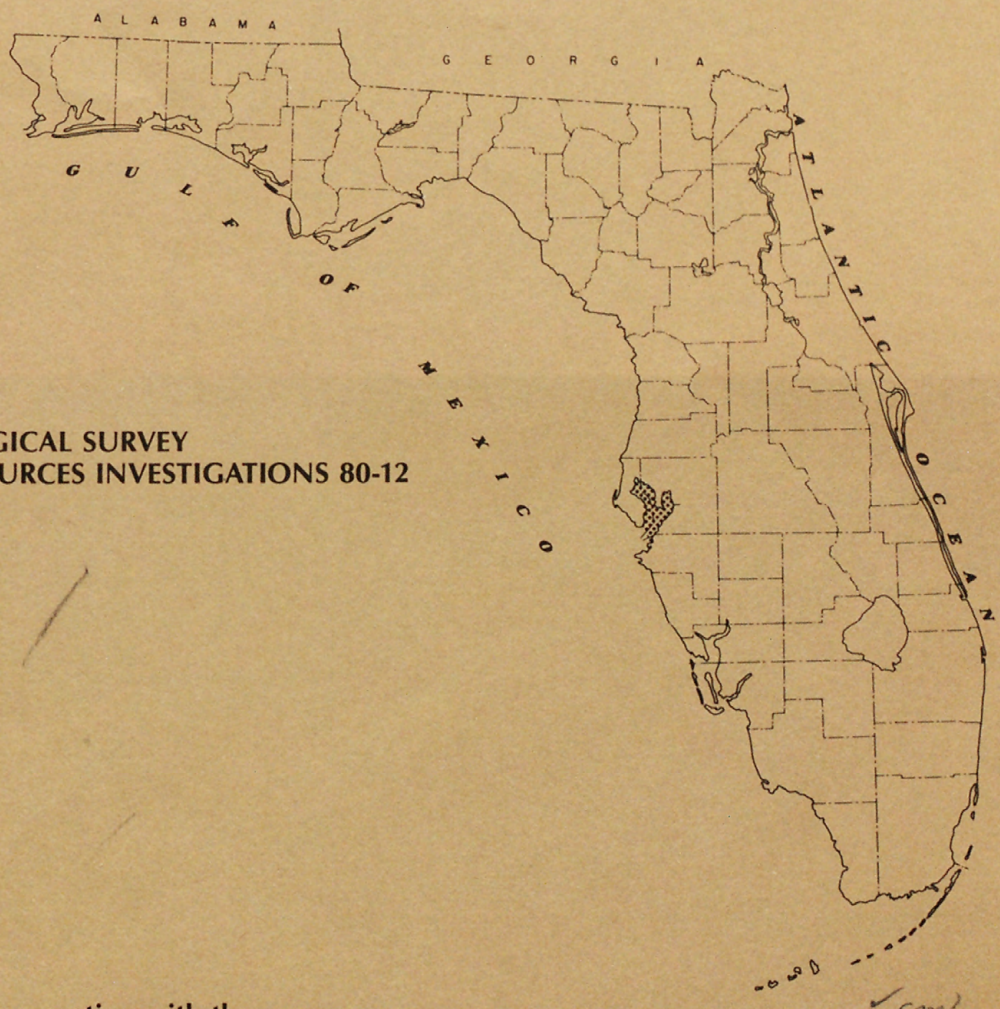

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A comprehensive assessment of the water quality of Tampa Bay, Florida, was initiated in 1970 to provide background information to evaluate the effects of widening and deepening the ship channel to the port of Tampa. This report provides results of water-quality sampling in the bay from 1972 to 1976, prior to dredging. Measurements of temperature, dissolved oxygen, pH, turbidity, specific conductance, biochemical oxygen demand, and total organic carbon were made as well as measurements for several nutrient, metal, and pesticide parameters. Many parameters were measured at as many as three points in the vertical. These data indicate that Tampa Bay is well-mixed vertically with little density stratification. Time histories of average temperature, dissolved oxygen, pH, turbidity, specific conductance and nutrient values within four subareas of Tampa Bay are given to reveal seasonal or other trends during the period of record. Temperature, dissolved oxygen, pH, turbidity, specific conductance, nutrient, biochemical oxygen demand, total organic carbon, and metal data are also presented as areal distributions. Nutrient concentrations were generally higher in Hillsborough Bay than in other subareas of Tampa Bay. Biochemical oxygen demand, total organic carbon, and total organic nitrogen distribution patterns show regions of highest concentrations to be along bay shorelines near population centers. Of the metals analyzed, all were present in concentrations of less than 1 milligram per liter.

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By Carole L. Goetz and Carl R. Goodwin

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TAMPA PORT AUTHORITY

1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For convenience to readers who may wish to use inch-pound units, factors for converting SI (metric) units to inch-pound units are shown to four significant figures.

Multiply SI (metric) unit	By	To obtain inch-pound unit
millimeter (mm)	0.0394	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
square kilometer (km^2)	0.3861	square mile (mi^2)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
degrees Celsius (^oC)	(^oC + 32) 1.8	degrees Fahrenheit (^oF)

* * * * * * * * * * * *

mean sea level (msl)	---	National Geodetic Vertical Datum of 1929 (NGVD of 1929)

WATER QUALITY OF TAMPA BAY, FLORIDA:
JUNE 1972 - MAY 1976

By Carole L. Goetz and Carl R. Goodwin

ABSTRACT

A comprehensive assessment of the water quality of Tampa Bay, Florida, was initiated in 1970 to provide background information to evaluate the effects of widening and deepening the ship channel to the port of Tampa. This report provides results of water-quality sampling in the bay from 1972 to 1976, prior to dredging.

Measurements of temperature, dissolved oxygen, pH, turbidity, specific conductance, biochemical oxygen demand, and total organic carbon were made, as well as measurements for nutrient, metal, and pesticide parameters. Many parameters were measured at as many as three points in the vertical. The data indicate that Tampa Bay is well mixed vertically and has little density stratification. Time histories of average temperature, dissolved oxygen, pH, turbidity, specific conductance, and nutrients within four subareas of Tampa Bay are given to show seasonal or other trends during the period of record. Temperature, dissolved oxygen, pH, turbidity, specific conductance, nutrients, biochemical oxygen demand, total organic carbon, and metal data are presented as areal distributions.

Nutrient concentrations were generally higher in Hillsborough Bay than in other subareas of Tampa Bay. Nitrate concentrations varied seasonally in Tampa Bay, decreasing to zero during summer. Orthophosphate concentrations decreased during the study period except near the mouth of Tampa Bay. Typical surface temperatures in Tampa Bay ranged from 24 to 27° Celsius. Dissolved oxygen concentrations ranged from 4 to 9 milligrams per liter except in Hillsborough Bay where summertime bottom concentrations were less than 3 milligrams per liter. The range of pH was from 7.4 to 8.4. Turbidity ranged from 0 to 19 Jackson turbidity units; the higher values occurred in Hillsborough Bay. Specific conductance at the mouth of Tampa Bay was as high as 53 millimhos per centimeter. Near the head of Hillsborough Bay, the conductivity reached a low of 21 millimhos per centimeter.

Biochemical oxygen demand, total organic carbon, and total organic nitrogen distribution patterns showed regions of highest concentrations to be along bay shorelines near population centers.

Of the metals analyzed, all were present in concentrations of less than 1 milligram per liter. Cadmium, lead, mercury, nickel, pesticide, and polychlorinated biphenyl concentrations in Tampa Bay averaged less than 10 micrograms per liter. Organic carbon, nitrogen, phosphorus, cadmium, copper, iron, lead, manganese, and zinc were more concentrated in Tampa Bay than in ocean water.

INTRODUCTION

A study of the hydrology of Tampa Bay, Fla., was initiated in 1970 in cooperation with the Tampa Port Authority and after 1974 in cooperation with the U.S. Army Corps of Engineers. The purpose of the study was to determine the effects that channel deepening may have on the quality of water in the bay, and to provide background information against which changes caused by the channel deepening could be measured.

This report presents data describing temporal and spatial variations in water-quality parameters for Tampa Bay from June 1972 to May 1976. Included are parameters such as turbidity, water temperature, specific conductance, dissolved oxygen, and pH; silica, ammonia, nitrite, nitrate, organic nitrogen, and orthophosphate; iron, manganese, cadmium, copper, lead, nickel, mercury, and zinc; pesticides, polychlorinated biphenyls, biochemical oxygen demand, and total organic carbon.

Maps showing areal distributions of the concentration of many chemical parameters are provided for selected periods. Periods chosen were the high- and low-concentration extremes and an intermediate or typical concentration condition. Graphs showing variation in parameter concentrations with time are provided for many constituents. Some seasonal or long-term trends that were sustained throughout the study period were identified. When possible, interpretations are suggested to further understand the complex chemical and biological systems of Tampa Bay.

Continuing interest by the Tampa Port Authority and U.S. Army Corps of Engineers in the environment of Tampa Bay is acknowledged through their support of the water-quality assessments presented in this report.

DESCRIPTION OF REGION

Tampa Bay is on the central Gulf Coast of the Florida Peninsula (fig. 1). The bay is a large, shallow, Y-shaped embayment covering an area of about 910 km^2 and has an average depth of 3.4 m. The bay includes two named subareas and a main stem. The northeast subarea is called Hillsborough Bay and the northwest subarea is called Old Tampa Bay. Tampa Bay is generally understood to refer either to the main stem south of the two subareas or the entire bay system. In this report, Tampa Bay will indicate the entire system. The main stem of Tampa Bay has been subdivided into North Tampa Bay and South Tampa Bay for the purpose of this report (fig. 1).

Population in the region surrounding Tampa Bay has increased by 31.7 percent during the years 1960 to 1970 (U.S. Bureau of the Census, 1970). In 1970 there were 1,109,709 inhabitants in the area and planners projected continued rapid growth (Hillsborough County Planning Commission, 1978; Federal Water Pollution Control Administration, 1969).

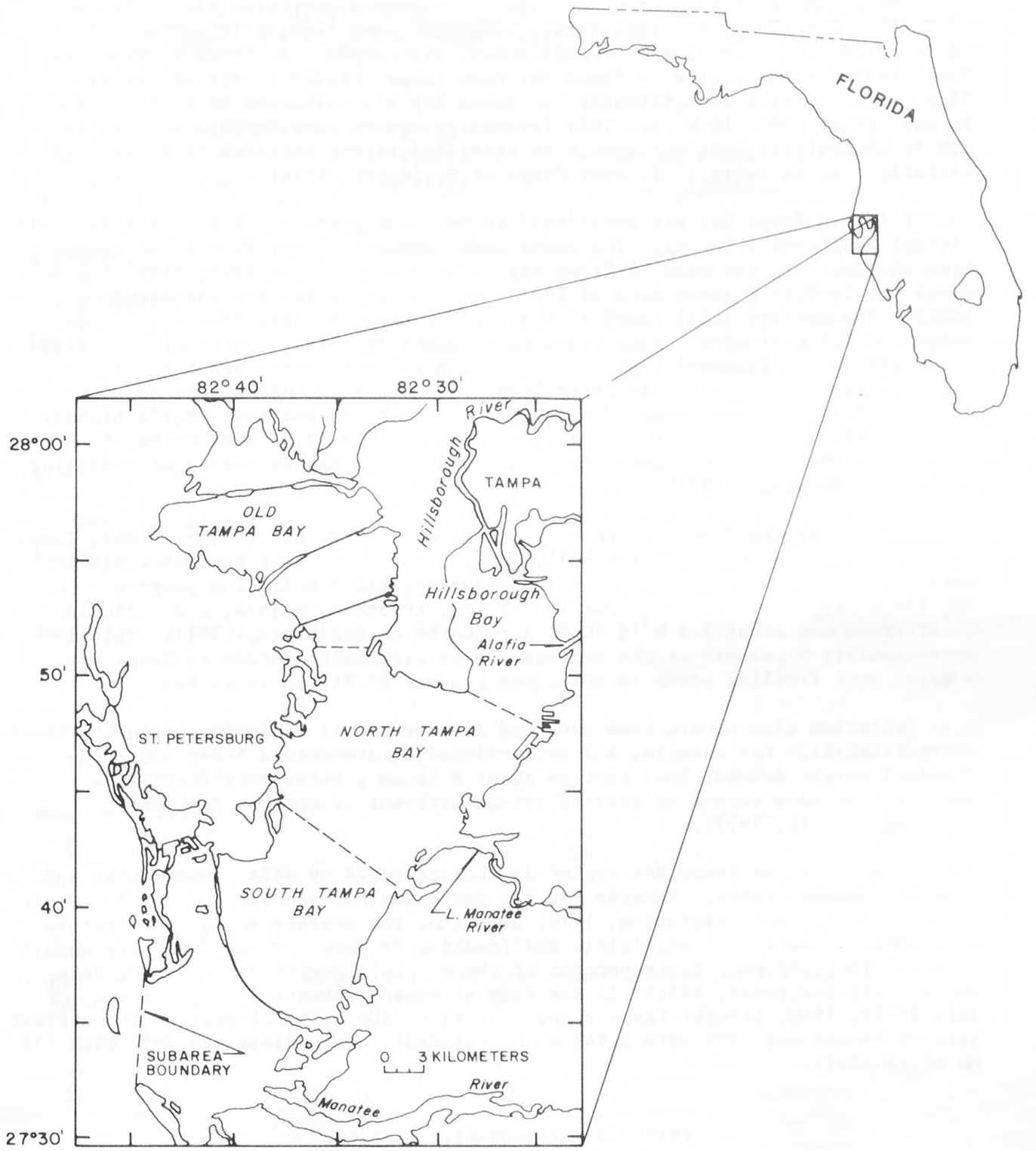

Figure 1.--Location of Tampa Bay, Florida.

The drainage basin surrounding Tampa Bay covers approximately 5,700 km^2 (U.S. Army Corps of Engineers, 1974). Gaged streams flowing into Tampa Bay, their periods of record, and average annual discharges are listed in table 1. The average annual inflow to Tampa Bay from these streams is approximately 54 m^3/s. Ungaged basins tributary to Tampa Bay are estimated to contribute an average of about 10 m^3/s. This freshwater causes some reduction of salinity in the estuary, but not enough to establish strong vertical or horizontal variations in salinity (U.S. Army Corps of Engineers, 1974).

Tides in Tampa Bay are considered to be chiefly diurnal with a strong semidiurnal component (fig. 2). The semidiurnal component increases in magnitude from the mouth to the head of Tampa Bay. The average water-level elevation for Tampa Bay is 0.15 m above NGVD of 1929 (National Geodetic Vertical Datum of 1929). The average tidal range is 0.70 m, but frequent individual tides have ranges of 1.1 m or more. Some tides have ranges of only 0.05 to 0.10 m. Tidal fluctuations are frequently altered by strong winds blowing over the bay that can produce a rise or fall in water level equal in magnitude to the astronomical diurnal tide. The hurricane of September 25, 1848, caused Tampa Bay's highest observed tide, approximately 4.3 m above NGVD of 1929 (U.S. Army Corps of Engineers, 1961). Tidal circulation in Hillsborough Bay is poor under existing conditions (Goodwin, 1977).

Studies by the Federal Water Pollution Control Administration (1969), Tampa Bay Regional Planning Council (1973), and U.S. Army Corps of Engineers (1974) have identified approximately 60 major, manmade, water pollution sources affecting Tampa Bay. Inflow from these industries, treatment plants, and agricultural enterprises was about 3.3 m^3/s (U.S. Army Corps of Engineers, 1974). This is approximately 5 percent of the average annual freshwater inflow to Tampa Bay. A major port facility occupies the upper reaches of Hillsborough Bay.

Pollution also occurs from overland flow or runoff following periods of heavy rainfall. For example, a 2-hour rainfall introduces a 5-day BOD (biochemical oxygen demand) load that is about 8 times greater than that introduced by the same volume of treated sewage effluent (Tampa Bay Regional Planning Council, 1973).

Climate in the Tampa Bay region is characterized by mild temperatures and tropical thunderstorms. Records for the Tampa weather station (National Oceanic and Atmospheric Administration, 1976) show that the average annual temperature is 22.3°C. Snowfall is negligible and freezing is rare. Tampa's average annual rainfall is 1,242 mm. Sixty percent of the rainfall occurs during June, July, August, and September, mainly in the form of thundershowers. The hurricane of July 28-29, 1960, brought Tampa's heaviest rain, 308 mm in 24 hours. The wettest year on record was 1959 with 1,945 mm of rainfall. The driest was 1956 with 734 mm of rainfall.

PREVIOUS WATER-QUALITY STUDIES

The quality of water in Tampa Bay has been studied since 1946 (Williams, 1954). A series of reports by the National Marine Fisheries Service provides data for 1957-72 on water temperature, salinity, total phosphate, total nitrogen, pH, dissolved oxygen, water turbidity and transparency, chlorophyll pigments and planktonic primary productivity, as well as some data for calcium,

Table 1.--Average annual discharge of gaged streams contributing freshwater to Tampa Bay (U.S. Geological Survey, 1976)

Tampa Bay system	Period of record, in years	Average annual discharge in cubic meters per second 1/
Old Tampa Bay		
Rocky Creek	24	1.3
Sweetwater Creek	26	.61
Brooker Creek	27	1.4
Hillsborough Bay		
Hillsborough River	39	18.
Alafia River	44	13.
Sulfur Springs	18	1.2
Tampa Bypass Canal	18	1.6
Tampa Bay		
Little Manatee River	38	6.8
Manatee River	11	10.
TOTAL		54

1/ All figures linearly adjusted to include effect of ungaged drainage area in each basin.

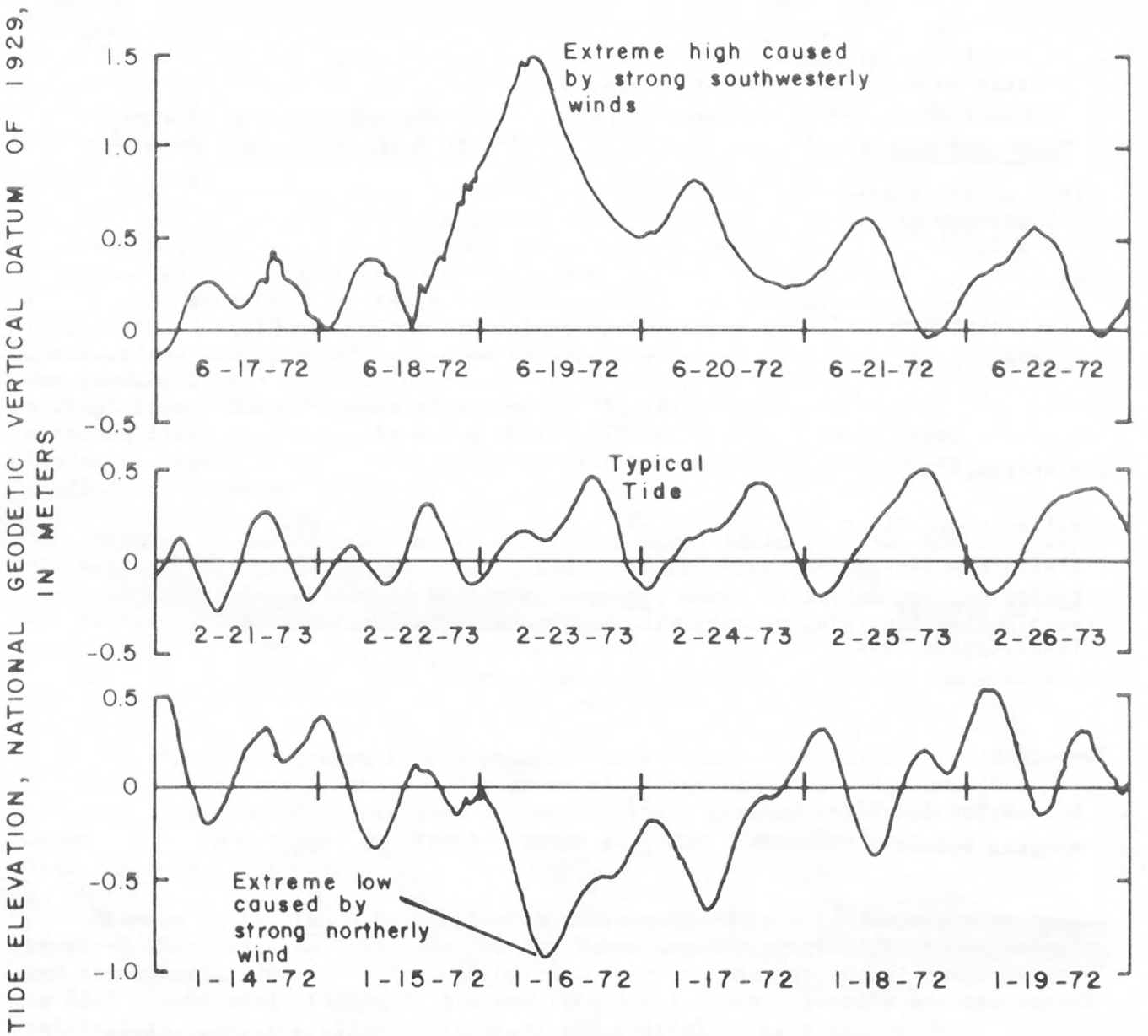

Figure 2.--Typical and extreme tides in Tampa Bay.

alkalinity, silicon, copper, iron, protein, and carbohydrate (Saloman and Taylor, 1968, 1971a, 1971b, and 1972; McNulty and others, 1972; Lindall and others, 1973; Saloman, 1973a and 1973b).

Recently, a number of agencies concerned with environmental quality and management have accumulated a large quantity of water-quality data on Tampa Bay. Data reported include those parameters listed above, as well as pesticides, metals, micro-biological pathogen indicators, and biological specimens. Tampa Electric Company has reported chemical and biological data for parts of Hillsborough Bay and North Tampa Bay (1976). Hillsborough County Environmental Protection Commission has reported water-quality data throughout Tampa Bay (1973). The Federal Water Pollution Control Administration (1969) and Tampa Bay Regional Planning Council (1973) have published water-quality data for parts or all of Tampa Bay. Water-quality data for Tampa Bay, collected from 1971 to 1976, are in the files of the U.S. Geological Survey. Reports on wet-weather and dry-weather water-quality conditions in Tampa Bay have been published by the U.S. Geological Survey (Goodwin and others, 1974 and 1975).

Previous water-quality studies have contributed to a better understanding of the chemical and biological condition of Tampa Bay waters. Because of the dynamic and complex nature of the bay with its myriad subtle responses to natural and man-induced changes, the likelihood of fully understanding the dynamics of bay water quality is remote. Therefore, continued sampling to characterize existing conditions and comparison of current and previous data to detect trends is essential.

SAMPLING PROGRAM

Thirty-four sites (fig. 3) were sampled regularly during the period June 1972 to May 1976. Fourteen sites, accessible by automobile (shore sites), were sampled monthly. Twenty sites, accessible by boat (boat sites), were sampled approximately once every 3 months. Average sample site density is one station per 27 km^2. Sites were chosen to (1) provide information for determining the areal distribution of constituents and (2) to have data for determining representative average constituent concentrations for Old Tampa Bay, Hillsborough Bay, North Tampa Bay, and South Tampa Bay. Water-quality parameters measured at each site are listed in table 2. The frequency of collection at each station is listed in table 3. Sampling periods ranged from 3 to 14 days.

DATA PRESENTATION

Data collected in Tampa Bay are presented on areal distribution maps of parameters and plots of variations in parameter concentrations with time. Maps showing areal distribution of parameters are given for selected periods only. Periods chosen were the high- and low-concentration extremes and an intermediate or typical concentration condition. For parameters with little variation, only the typical concentration is given. The maps chosen to represent typical and extreme conditions for each parameter were selected from a group of approximately 10 maps representative of conditions during the study period. Surface,

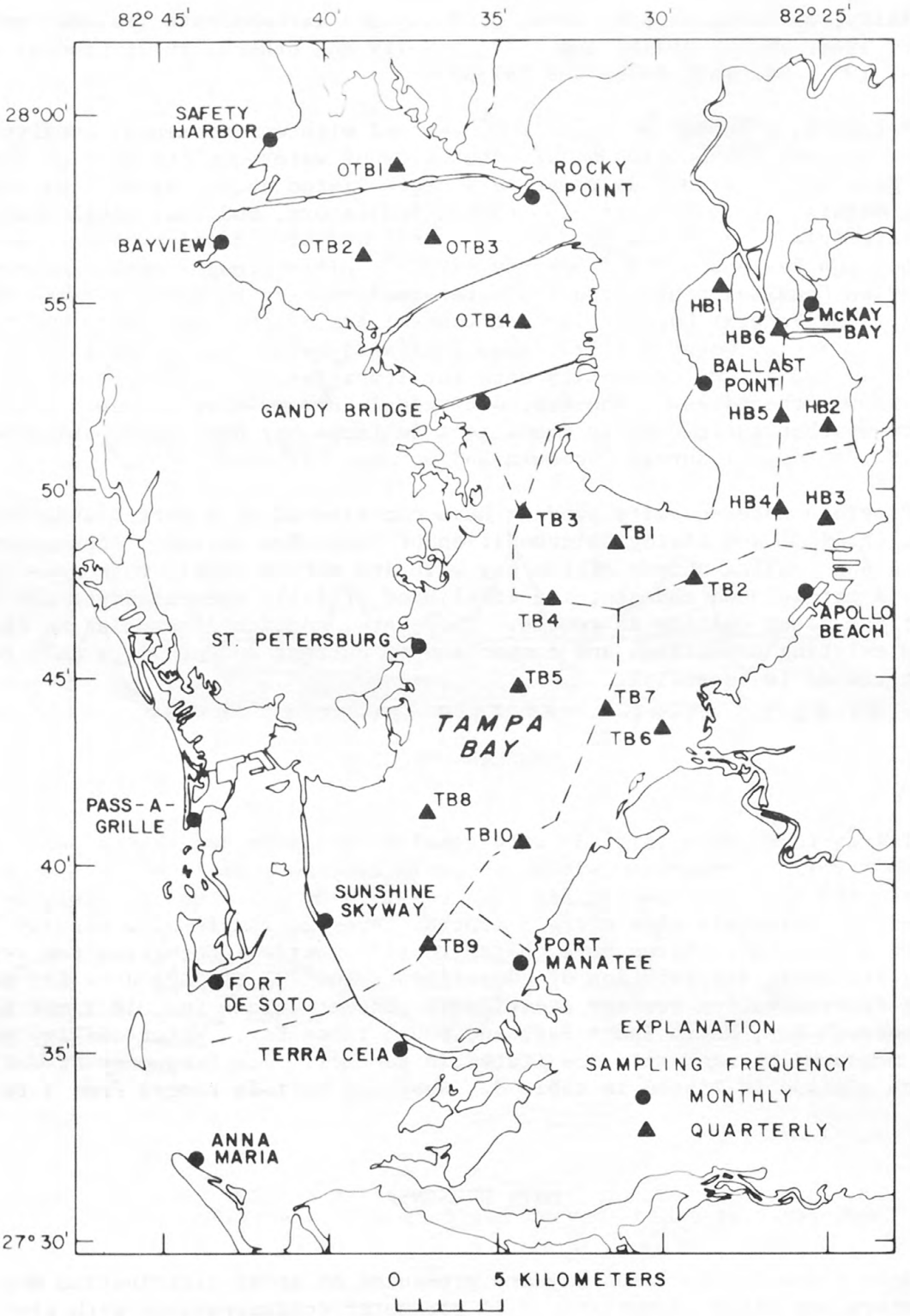

Figure 3.--Location of sampling sites.

Table 2.--Water-quality parameters measured at 34 sample site locations in Tampa Bay

Parameter classification	Parameter
Turbidity and field measurements	Turbidity (JTU), specific conductance (mmho), pH, temperature (°C), dissolved oxygen (mg/L).
Nutrients	Dissolved silica (mg/L), total nitrate (mg/L), total nitrite (mg/L), total ammonia (mg/L), total organic nitrogen (mg/L), total orthophosphate (mg/L).
Biochemical oxygen demand and total organic carbon	Biochemical oxygen demand (5 day in mg/L), total organic carbon (mg/L).
Metals	Total iron (ug/L), dissolved iron (ug/L), total manganese (ug/L), dissolved manganese (ug/L), total cadmium (ug/L), dissolved cadmium (ug/L), total lithium (ug/L), dissolved lithium (ug/L), total mercury (ug/L), dissolved mercury (ug/L), total nickel (ug/L), dissolved nickel (ug/L), total zinc (ug/L), dissolved zinc (ug/L).
Pesticides and polychloridated biphenyls	Total heptachlor (ug/L), total heptachlor epoxide (ug/L), total lindane (ug/L), total toxaphene (ug/L), total 2,4-D (ug/L), total 2,4,5-T (ug/L), total silvex (ug/L), total aldrin (ug/L), total chlordane (ug/L), total DDD (ug/L), total DDE (ug/L), total DDT (ug/L), total dieldrin (ug/L), total endrin (ug/L), total polychlorinated biphenyls (ug/L).

Table 3.--Frequency of water-quality data collection from June 1972 through May 1976

Station	Parameter classification				
	Turbidity and field parameters	Nutrients	Total organic carbon and biochemical oxygen demand	Metals	Pesticides and polychloridated biphenyls
Shore sites	Monthly	Monthly, 1972-74; quarterly, 1975-76	Quarterly	Quarterly, 1972-74; annually, 1975	Not collected
Boat sites	Quarterly	Quarterly	Quarterly	Biannually	Annually, 1974-75

middepth, and bottom samples show the bay to be well mixed and to have little vertical stratification. Therefore, surface data were judged representative of the entire water column and were selected for presentation. An exception was dissolved-oxygen concentration in Hillsborough Bay in the summer months. Both bottom and surface areal distribution maps are shown for dissolved-oxygen data.

Linear interpolation was used to determine lines of equal value drawn on the areal distribution maps. The isograms represent generalized conditions since the sampling period for each parameter was not instantaneous in time, but extended over a period from 3 to 14 days. Isograms were also generalized around islands and bridges when required.

Graphs showing the variation in average concentration with time for selected constituents were prepared for each of the four subareas of the Tampa Bay system. Differences and similarities among the subareas and seasonal or long-term trends are discussed. Surface, middepth, and bottom samples for eight to nine stations in each of the subareas were averaged to obtain values representing mean conditions for each subarea for each sampling date. Mean values from six or more observations are plotted against sampling date for each of the bay subareas. Most mean values were computed from 15 to 22 observations.

The standard error of the mean was also computed and plotted. However, to allow for legibility, the standard error of the mean was not plotted when the standard error was less than 4 percent of the total vertical scale. The standard error of the mean was calculated by dividing the standard deviation of the sample means by the square root of the number of sample observations and is another designation for the standard deviation of the mean.

Turbidity and Field Parameters

Water temperature, dissolved oxygen, pH, and specific conductance were measured in the field. Turbidity was determined in the laboratory. Areal distribution maps and graphs of average concentrations of turbidity, water temperature, dissolved oxygen, pH, and specific conductance for Tampa Bay are discussed in the following paragraphs.

Turbidity

Turbidity in Tampa Bay, as observed in September 1974 (fig. 4), ranged from 0 to 19 JTU (Jackson turbidity units). September 1974 represents an intermediate or typical concentration condition for Tampa Bay. The highest turbidity was usually in Hillsborough Bay, along the ship channel. Observations of turbulent wakes of large ships, both in the field and on aerial photographs, indicate resuspension of fine sediment from the channel bottom. This would cause generally higher turbidity readings in the vicinity of the Hillsborough Bay ship channel. High turbidity concentrations were observed in May 1973 (fig. 4) with concentrations ranging from 1 to 26 JTU. Low turbidity concentrations were observed in July 1972 (fig. 4) with turbidity ranging from 0 to 8 JTU.

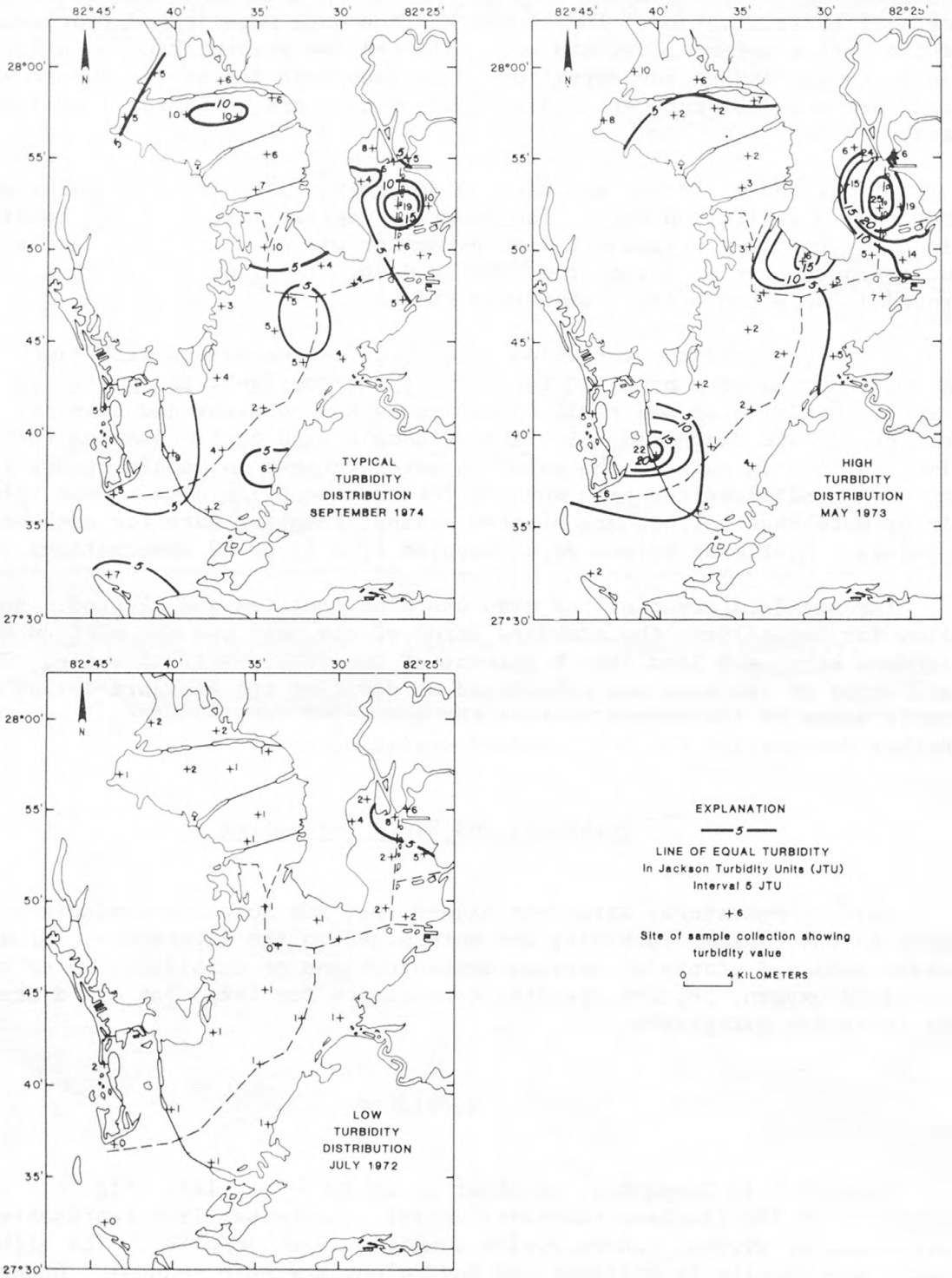

Figure 4.--Typical, high, and low turbidity distributions in Tampa Bay.

Seasonal or long-term trends in turbidity were not detected during the years 1972-76 (fig. 5). The Hillsborough Bay subarea averaged the highest in turbidity concentration, 7.0, and the South Tampa Bay subarea averaged the lowest, 3.5.

Water Temperature

Typical, high, and low water-temperature distributions are shown in figure 6. Water temperature for the typical period, October 1975, ranged from 24° to 27°C (fig. 6). High water temperatures, 28° to 30°C (fig. 6), were measured in September 1974. Low water temperatures, 14° to 21°C (fig. 6), were observed during December 1973.

Seasonal variations in water temperature can be seen in figure 7. Coldest temperatures occur during December, January, and February. Warmest temperatures occur during June, July, August, and September.

Dissolved Oxygen

Typical, high, and low dissolved-oxygen distributions in surface waters are shown in figure 8. Typical, high, and low dissolved-oxygen distributions in bottom waters are shown in figure 9.

Dissolved oxygen in surface waters for the typical period ranged from 4 to 9 mg/L (milligrams per liter). Most concentrations were about 6 mg/L. In bottom waters, dissolved-oxygen concentrations typically ranged from 1 to 8 mg/L as in September 1974 (fig. 9). Stratification between surface and bottom water is greatest in Hillsborough Bay and Old Tampa Bay. In a large part of Hillsborough Bay, dissolved-oxygen concentration in bottom waters in September 1974 was less than 3 mg/L (fig. 9), whereas the dissolved-oxygen concentration in surface water in December 1974 ranged from 4 to 7 mg/L (fig. 8). For the typical period, Old Tampa Bay surface water averaged about 7 mg/L dissolved-oxygen concentration (fig. 8), and bottom water averaged about 4 mg/L (fig. 9). The difference in dissolved-oxygen concentration between surface and bottom water in both North Tampa Bay and South Tampa Bay was about 1 mg/L (figs. 8 and 9).

High concentrations of dissolved oxygen were measured in surface waters in December 1972 (fig. 8). Some parts of Old Tampa Bay and North Tampa Bay exceeded 9 mg/L. Low concentrations of dissolved oxygen for surface waters occurred in September 1972 (fig. 8) when most of the bay had less than 6 mg/L dissolved oxygen. Shallow areas of the bay were subject to the greatest variation in dissolved oxygen. Water in the bay near sewage outfalls consistently had the lowest concentrations of dissolved oxygen.

Graphs of average dissolved oxygen for 1972-76 are shown in figure 10. No sustained trends in concentration with respect to time were observed.

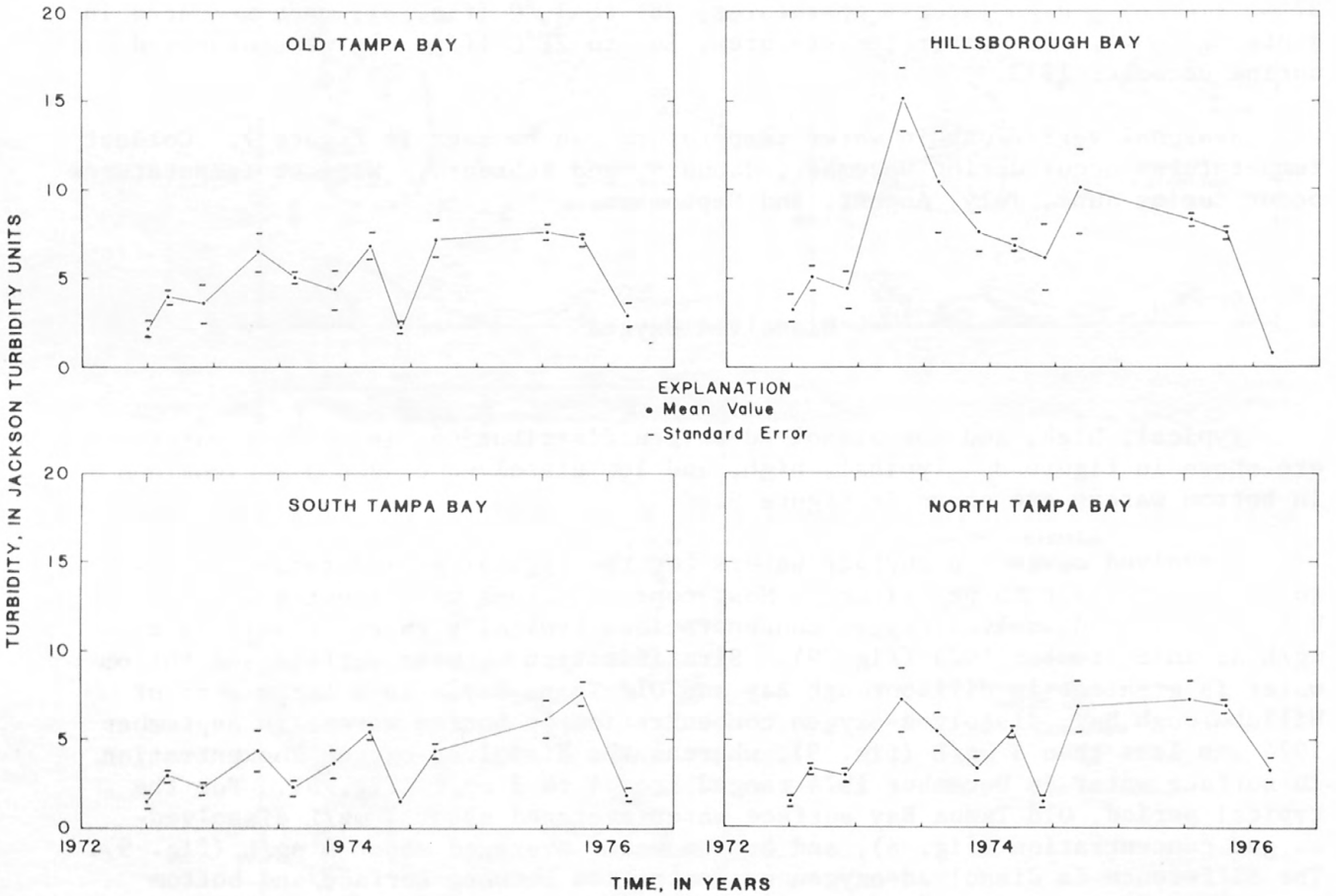

Figure 5.--Average turbidity and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

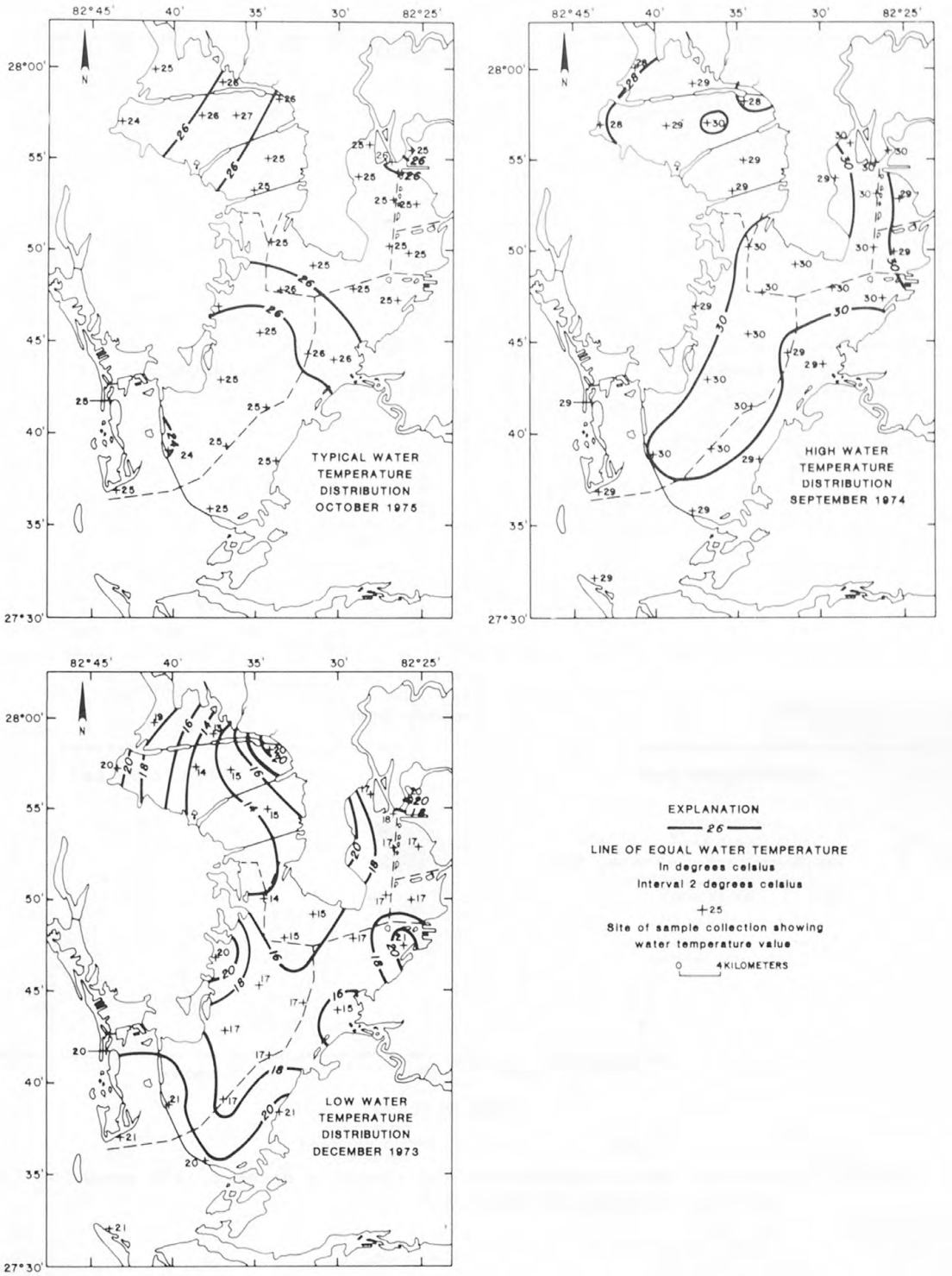

Figure 6.--Typical, high, and low water-temperature distributions in Tampa Bay.

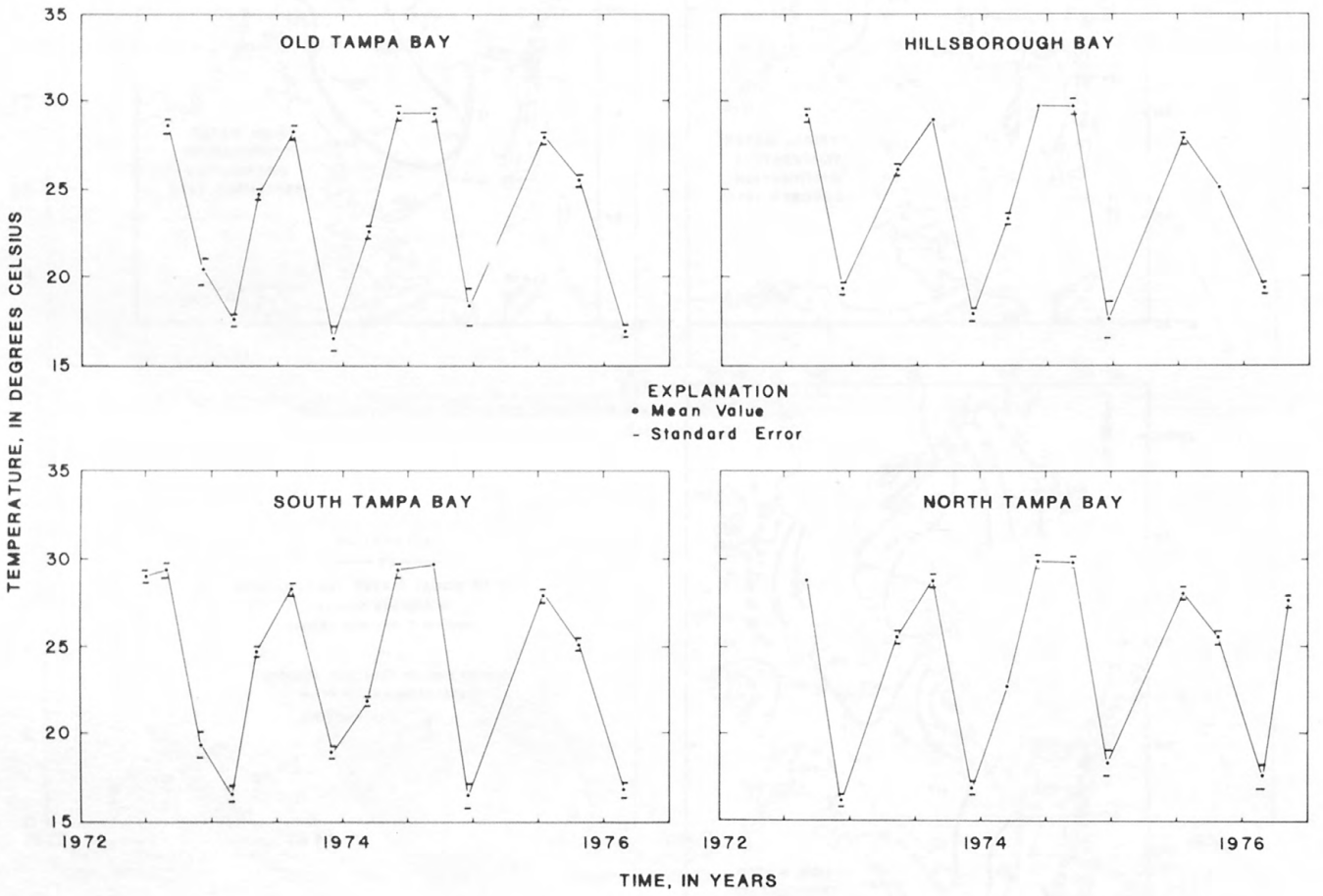

Figure 7.--Average water temperature and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

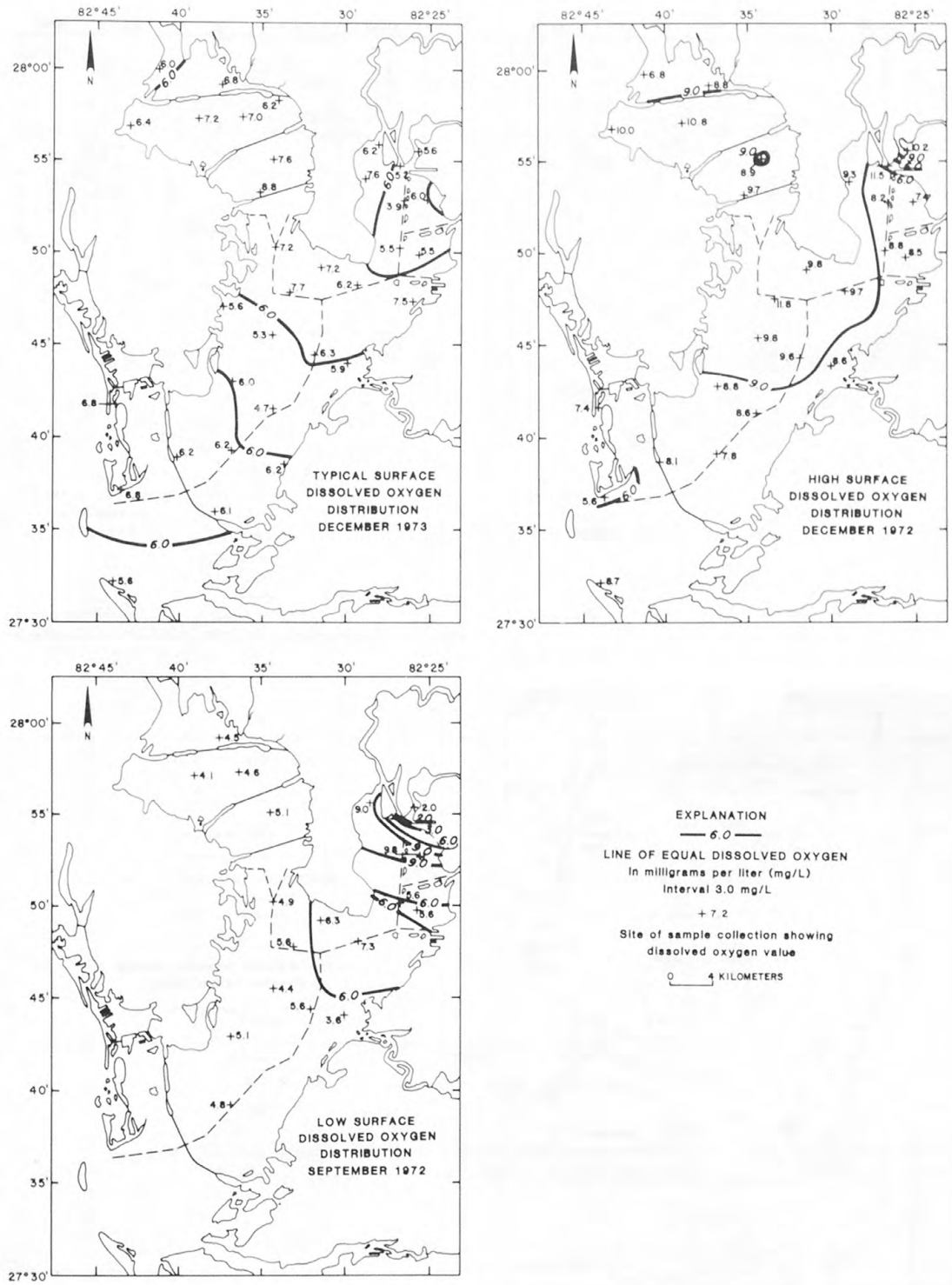

Figure 8.--Typical, high, and low dissolved-oxygen distributions in surface waters in Tampa Bay.

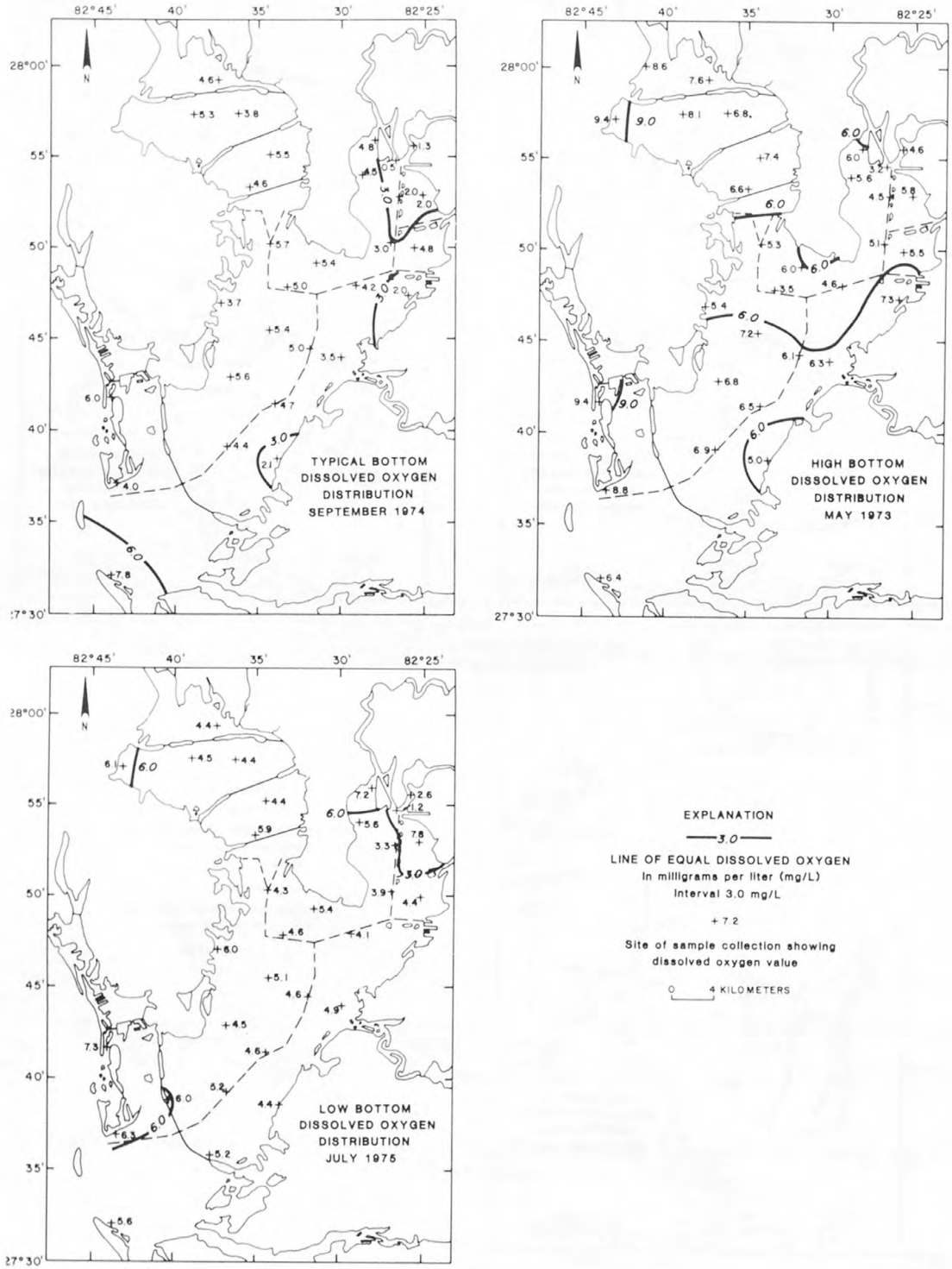

Figure 9.--Typical, high, and low dissolved-oxygen distributions in bottom waters in Tampa Bay.

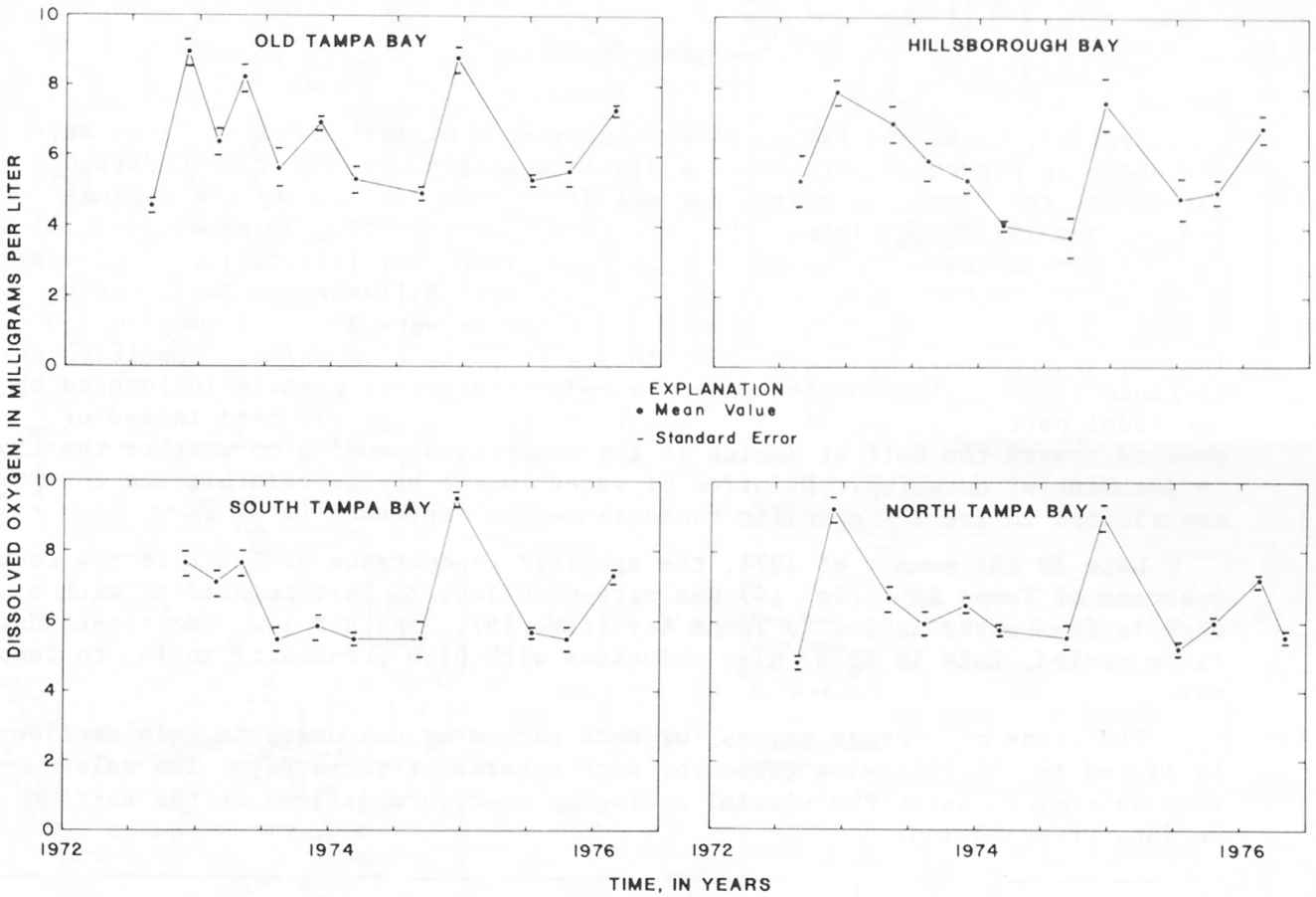

Figure 10.--Average dissolved-oxygen concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

pH

Typical, high, and low pH distributions in Tampa Bay are shown in figure 11. During the typical period, September 1974, pH ranged from 7.4 to 8.4; however, pH was 8.0 or less in Hillsborough Bay. Lower pH in Hillsborough Bay has been attributed to discharge of streams entering the bay and acidic industrial waste (Hillsborough County Environmental Protection Commission, 1973). During the high period, March 1974, pH ranged from 8.2 to 8.6 and 7.6 to 8.6 during the low period, December 1973.

No distinct seasonal trends in pH were detected. A general decline in pH during the sampling period was noted throughout Tampa Bay, however, particularly in Hillsborough Bay (fig. 12).

Specific Conductance

Typical, high, and low specific-conductance distributions in Tampa Bay are shown in figure 13. There is a distinct pattern in specific conductance throughout the Tampa Bay system for all distributions. During the typical period, May 1973, the highest specific conductances, 48 to 50 mmho/cm (millimho per centimeter), occur near the mouth of Tampa Bay (fig. 13). The lowest specific conductances, 32 to 34 mmho/cm, occur in Hillsborough Bay. During the high period, June 1974, specific conductances were 38 to 53 mmho/cm. During the low period, September 1974, they were 22 to 42 mmho/cm. Specific conductance is a function of the salinity and is therefore greatly influenced by the tidal pattern. Specific-conductance isograms (fig. 13) bend inland or seaward toward the Gulf of Mexico in the channel, depending on whether the tide is incoming or outgoing. Dilution of water in the bay by rainfall and runoff contributed to the low specific conductances in September 1974.

Late in the summer of 1974, the specific conductance of water in the four subareas of Tampa Bay (fig. 14) was extremely low, roughly coinciding with a peak in freshwater inflow to Tampa Bay (fig. 15). Another low specific-conductance period, late in 1975, also coincides with high freshwater inflow to Tampa Bay.

The range of average values for each parameter discussed in this section is listed in the following table for each subarea of Tampa Bay. The values were determined using the spatial averaging procedure defined in the section on data presentation.

Parameters	Units	Range of average values			
		South Tampa Bay	North Tampa Bay	Old Tampa Bay	Hillsborough Bay
Turbidity	JTU	1 - 8	1 - 7	2 - 7	1 - 15
Water temperature	°C	16 - 30	16 - 30	17 - 29	18 - 30
Dissolved oxygen	mg/L	5.4 - 9.4	4.8 - 9.2	4.6 - 8.8	3.6 - 8.1
pH	-	8.1 - 8.5	7.9 - 8.5	8.0 - 8.3	7.7 - 8.4
Specific conductance	mmho/cm	40 - 51	32 - 46	28 - 43	28 - 42

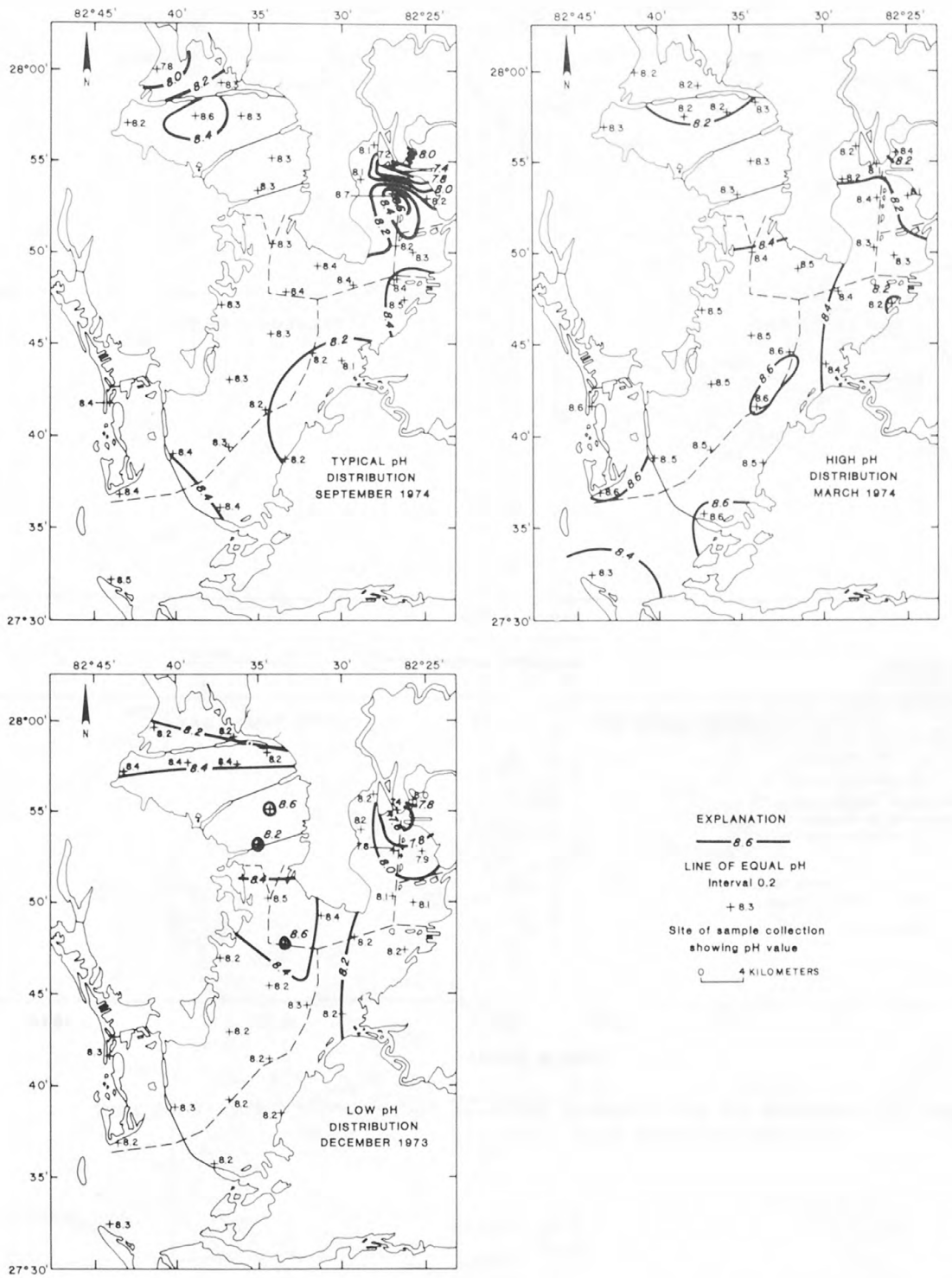

Figure 11.--Typical, high, and low pH distributions in Tampa Bay.

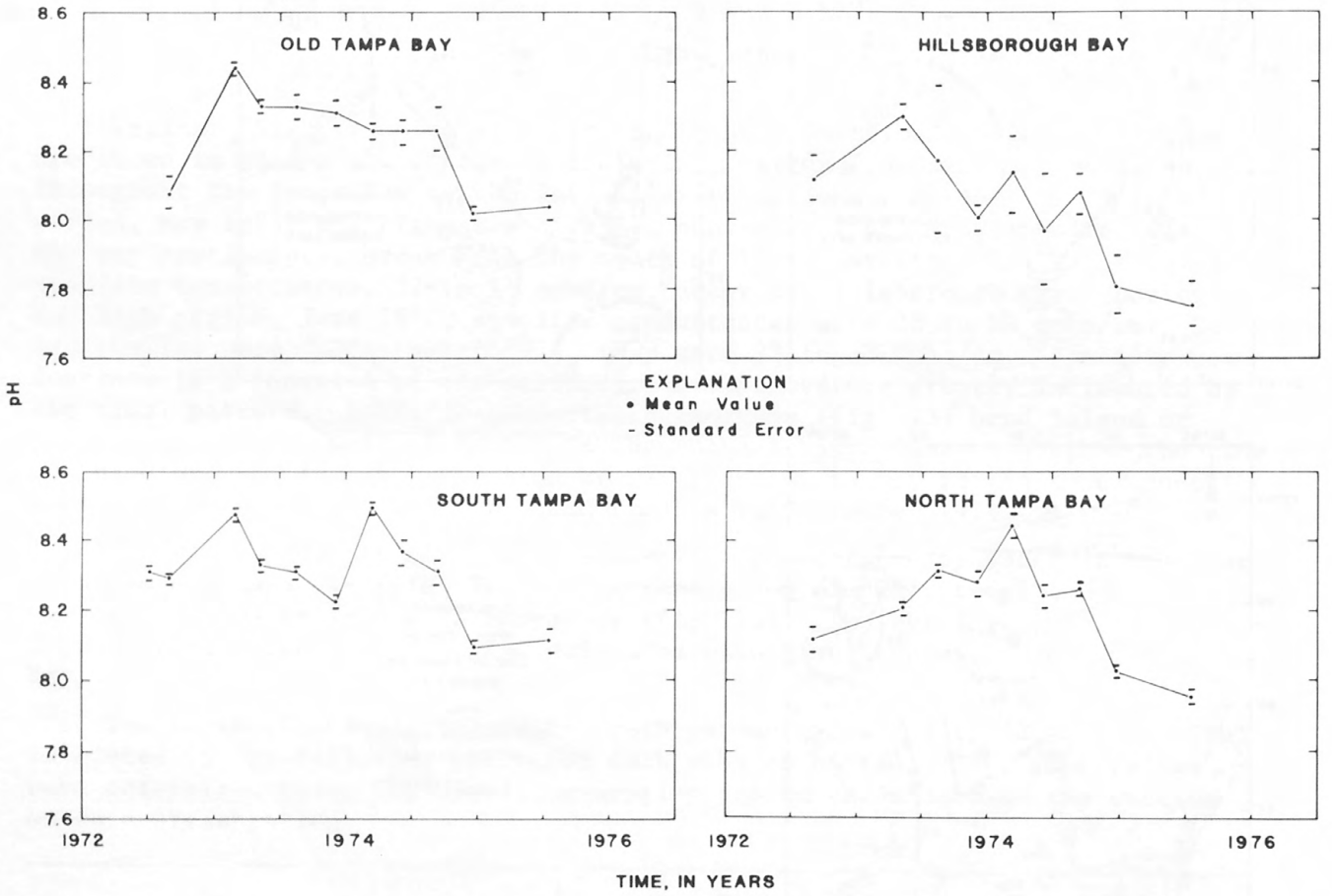

Figure 12.--Average pH and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

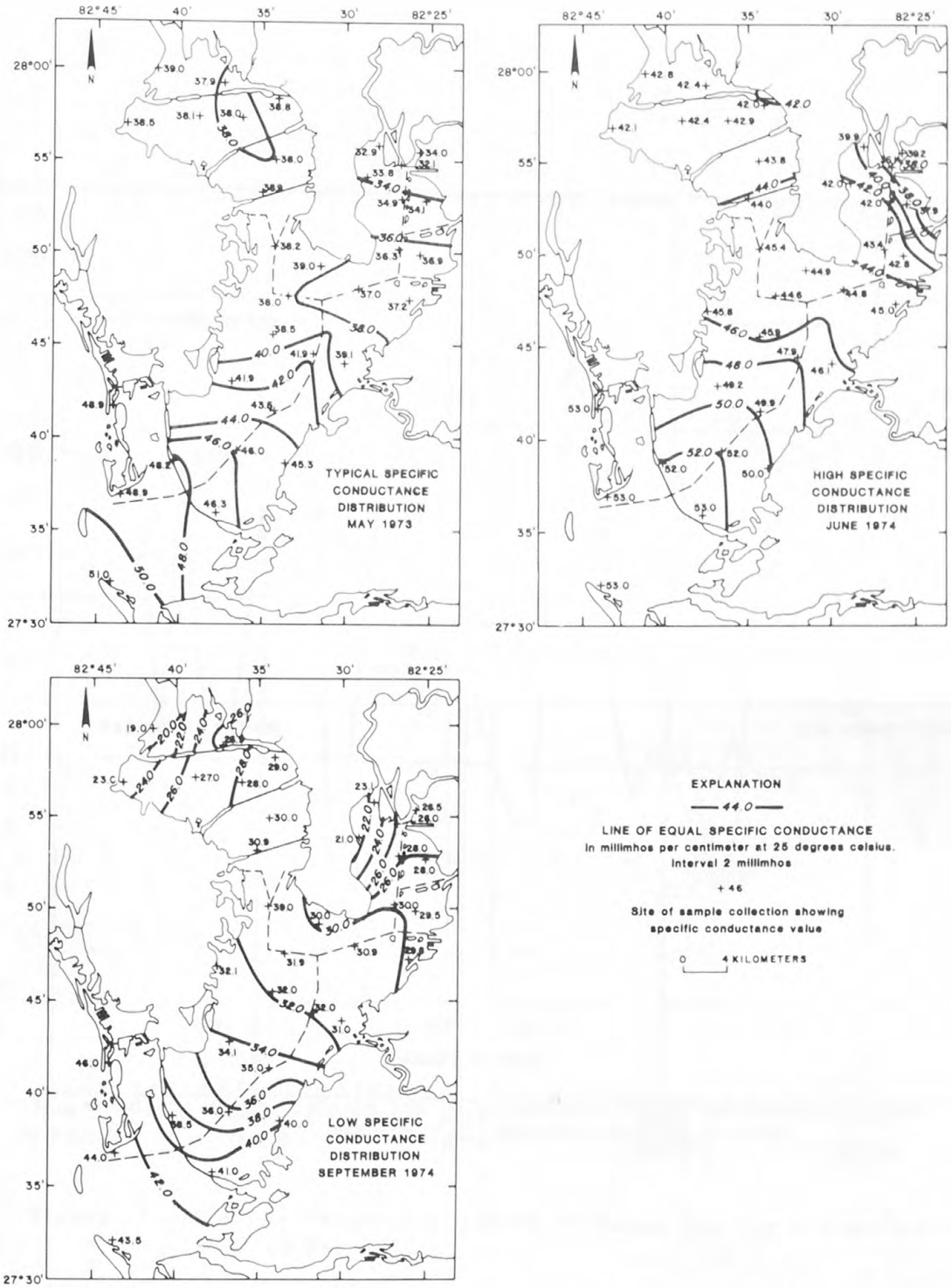

Figure 13.--Typical, high, and low specific-conductance distributions in Tampa Bay.

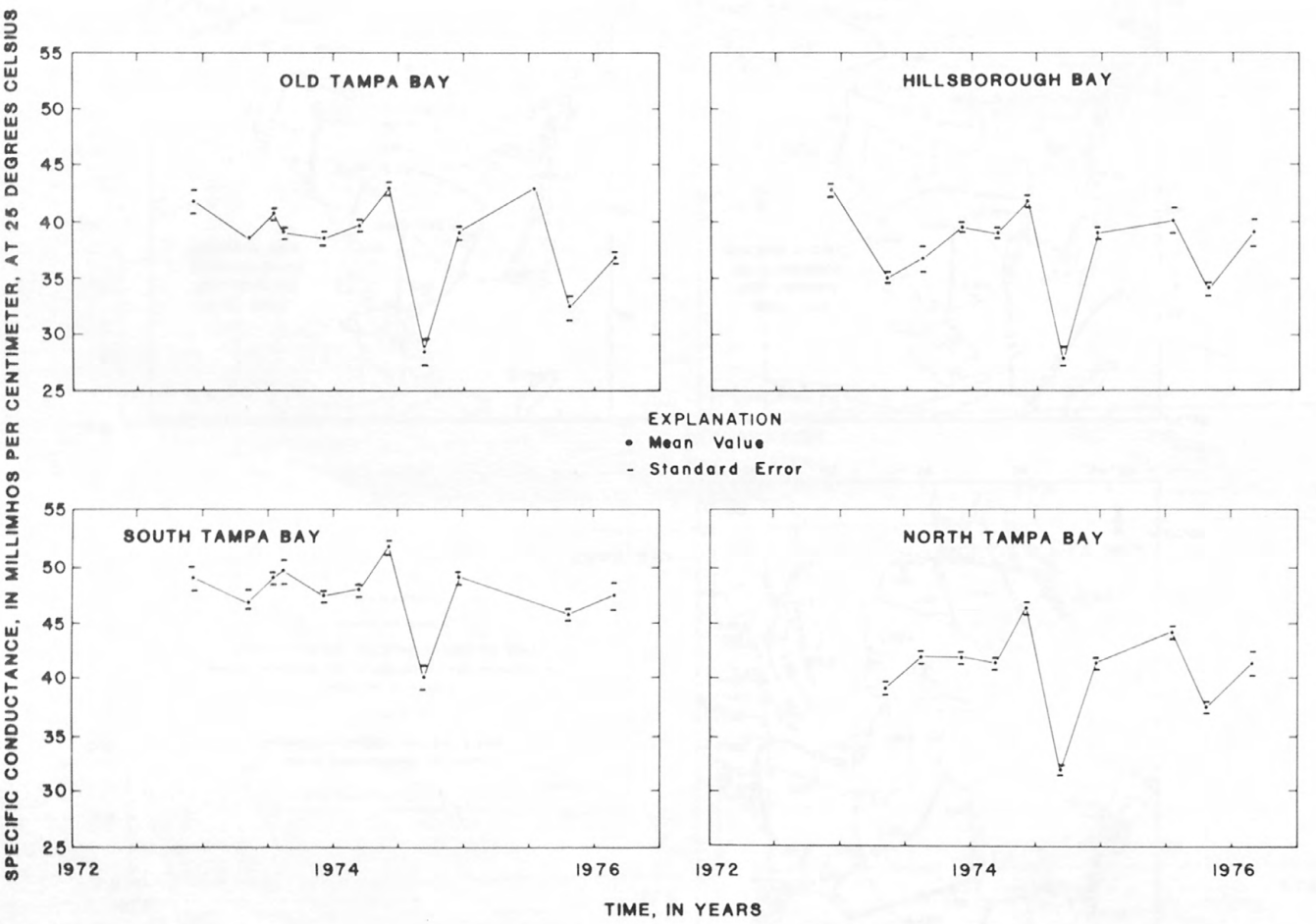

Figure 14.--Average specific conductance and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

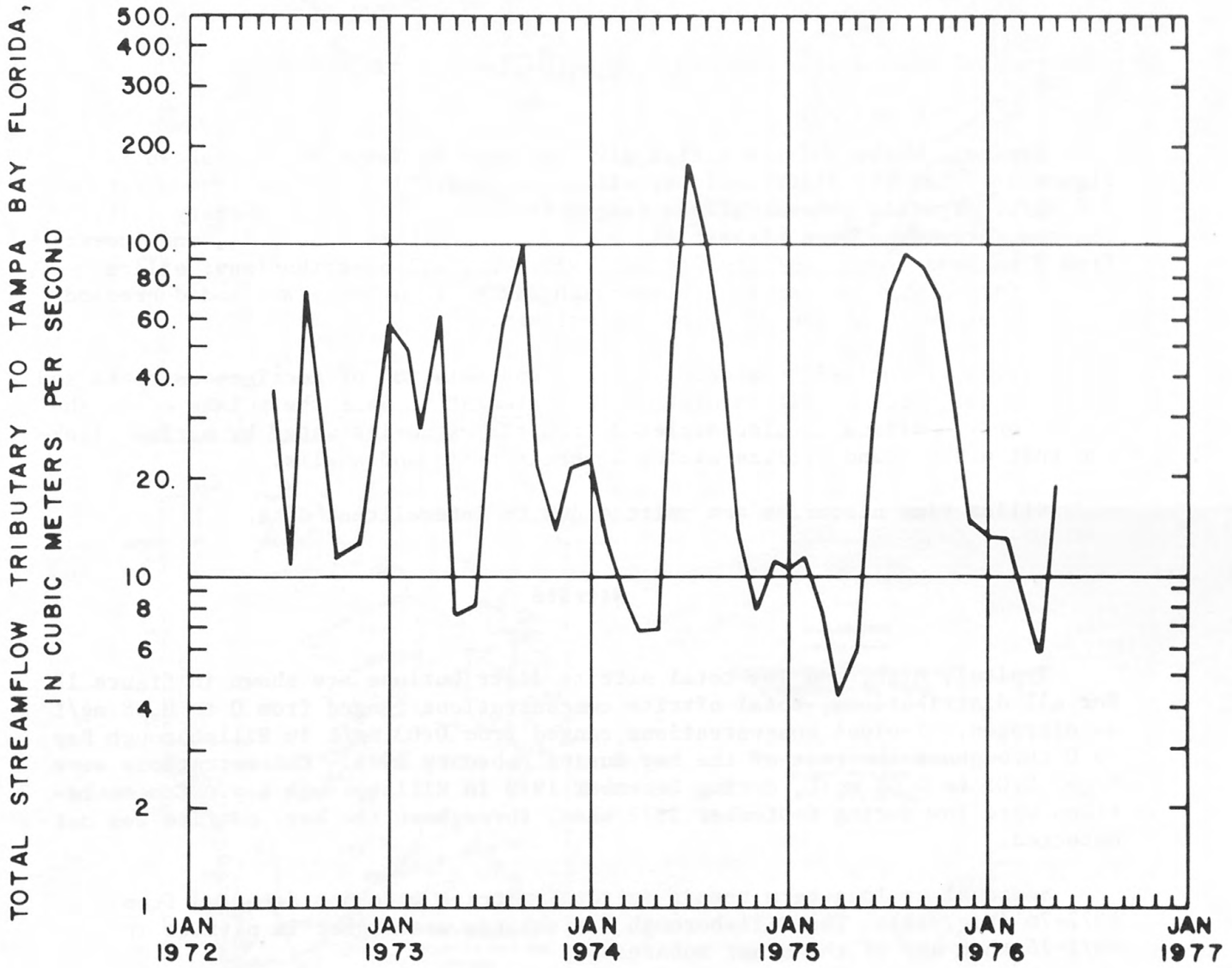

Figure 15.--Monthly freshwater inflow to Tampa Bay for the period June 1972 to May 1976.

Nutrients

Areal distribution maps of silica, total nitrite, total nitrate, total ammonia, total organic nitrogen, and total orthophosphate data for typical, high, and low conditions were plotted and lines of equal value drawn for Tampa Bay. To identify seasonal and long-term trends, nutrient data have been plotted versus time.

Silica

Typical, high, and low silica distributions in Tampa Bay are shown in figure 16. For all distributions, silica concentrations ranged from 0.2 to 7.8 mg/L. Typical concentrations ranged from 2 to 4 mg/L in February 1976. The concentrations were highest, as much as 7.8 mg/L in June 1974, and lowest, from 3 to less than 2 mg/L in October 1975. For all distributions, silica concentration was highest in Hillsborough Bay and Old Tampa Bay and decreased to about 1.0 mg/L at the mouth of the estuary.

Silica is derived from decomposition and solution of terrigenous rocks and sediments. Therefore, it is most concentrated at or near the points of freshwater entry. Silica is also depleted from the estuarine water by marine plankton that extract and utilize silica in their tests and shells.

Silica time histories are omitted due to intermittent data.

Nitrite

Typical, high, and low total nitrite distributions are shown in figure 17. For all distributions, total nitrite concentrations ranged from 0 to 0.08 mg/L as nitrogen. Typical concentrations ranged from 0.03 mg/L in Hillsborough Bay to 0 throughout the rest of the bay during February 1976. Concentrations were high, 0.02 to 0.08 mg/L, during December 1973 in Hillsborough Bay. Concentrations were low during September 1972 when, throughout the bay, nitrite was not detected.

Seasonal or long-term trends in total nitrite were not detected from 1972-76 (fig. 18). The Hillsborough Bay subarea was higher in nitrite in 1972-76 than any of the other subareas.

Nitrate

Typical, high, and low total nitrate distributions are shown in figure 19. For all distributions, total nitrate ranged from 0 to 0.37 mg/L as nitrogen. Concentrations during the typical period, August 1973, ranged from 0 to 0.1 mg/L; however, most of Tampa Bay was less than 0.05 mg/L. Only in small, isolated areas in Old Tampa Bay and in the northeast part of Hillsborough Bay are the concentrations higher.

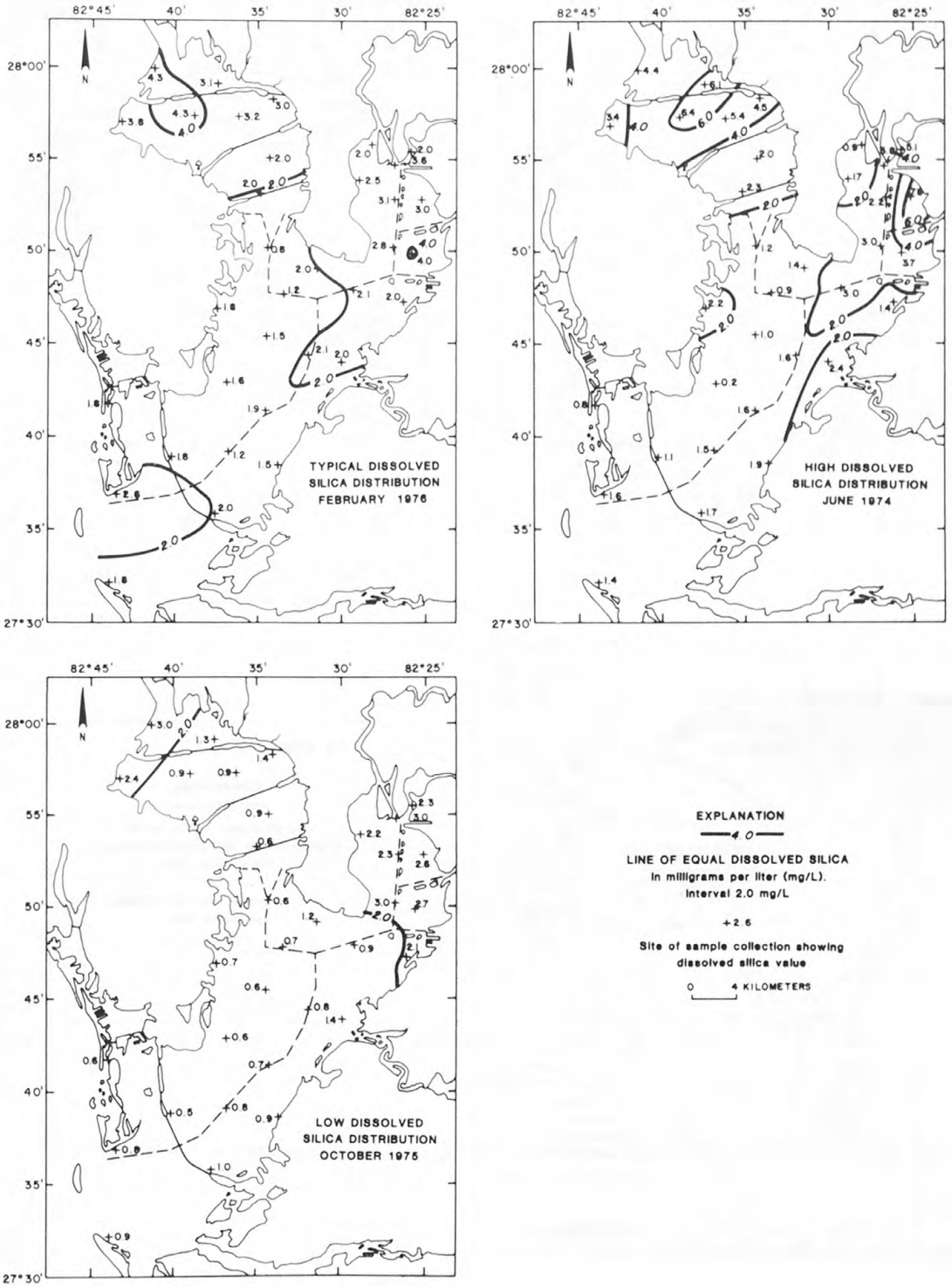

Figure 16.--Typical, high, and low dissolved-silica distributions in Tampa Bay.

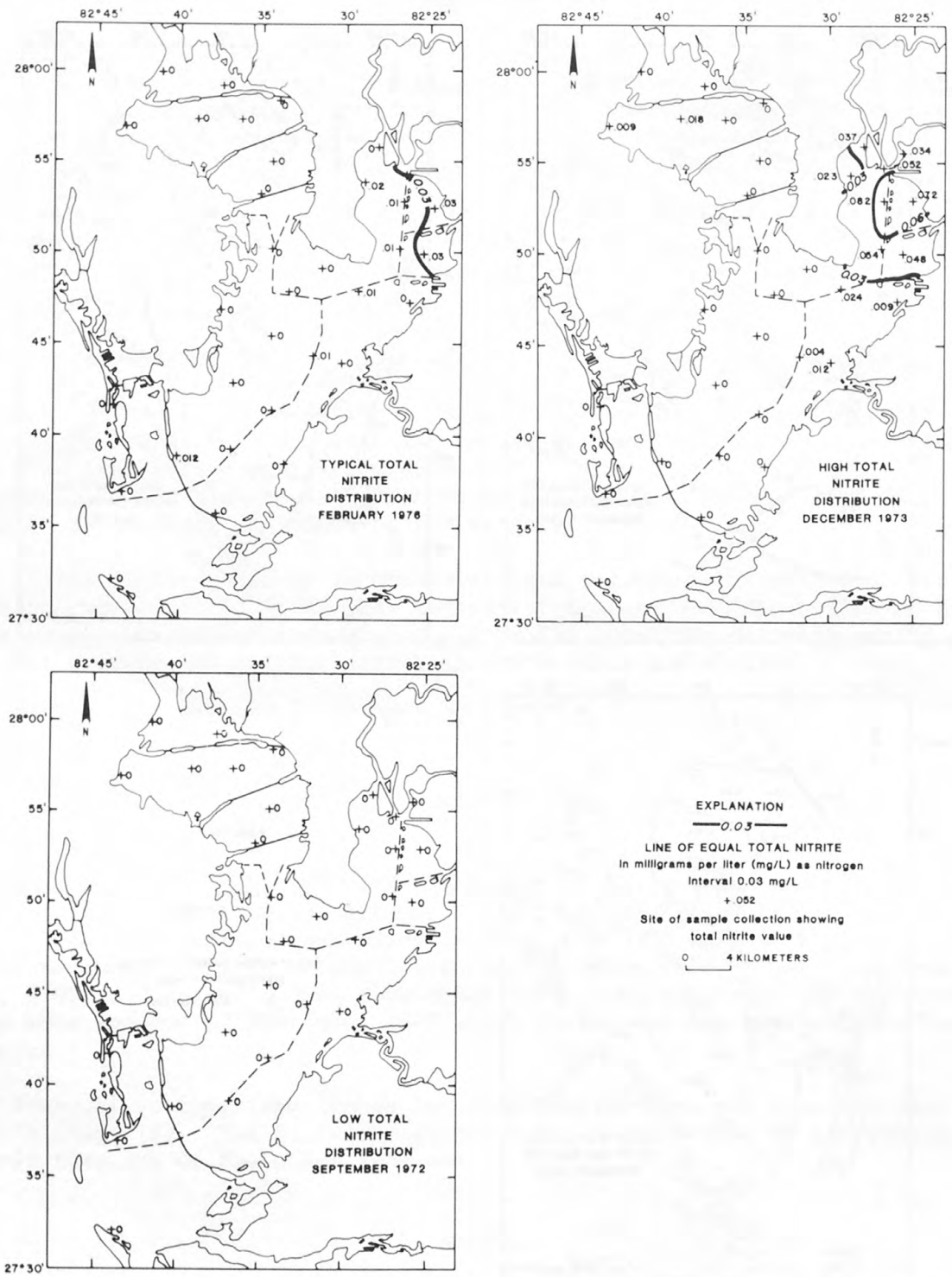

Figure 17.--Typical, high, and low total nitrite distributions in Tampa Bay.

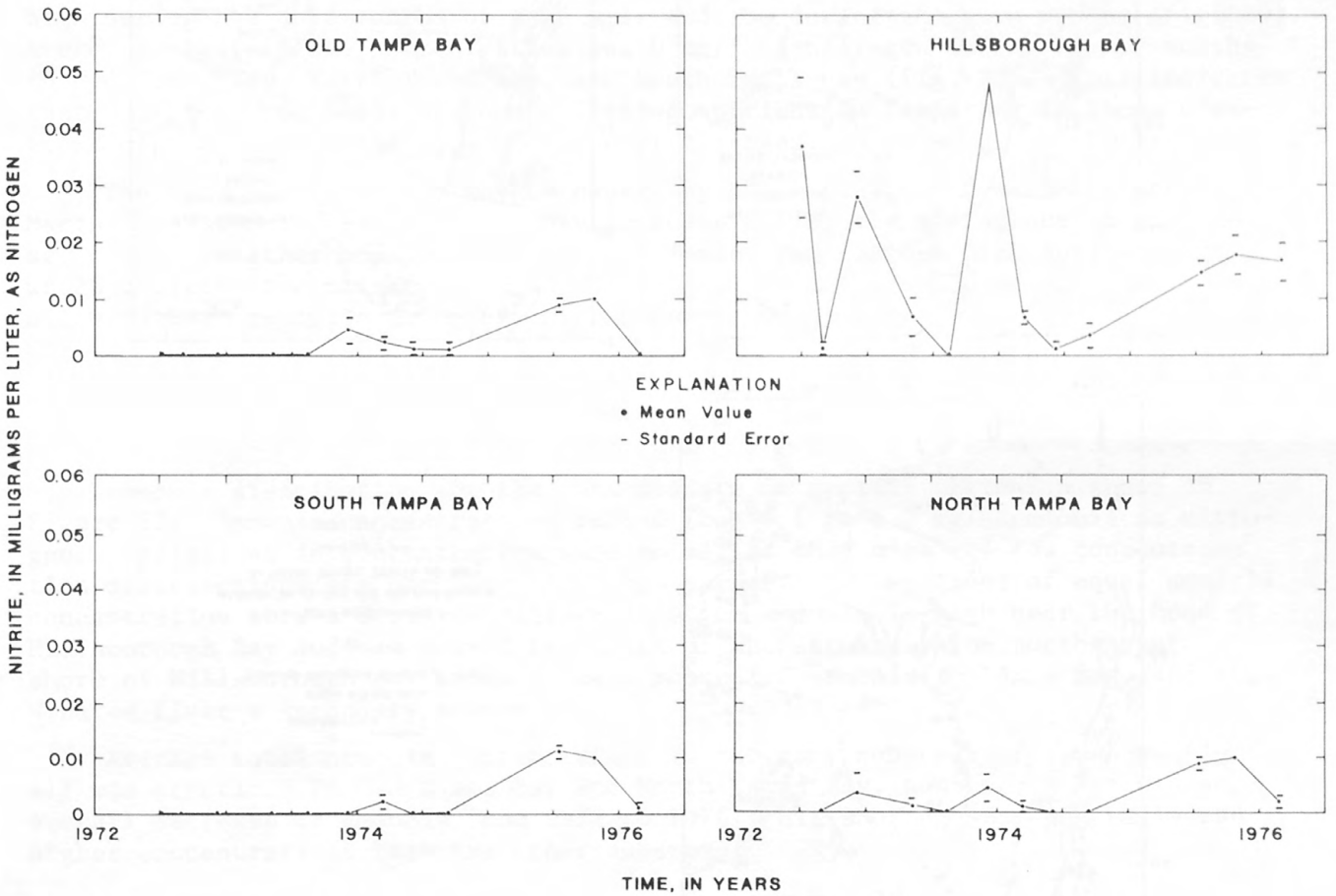

Figure 18.--Average total nitrite concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

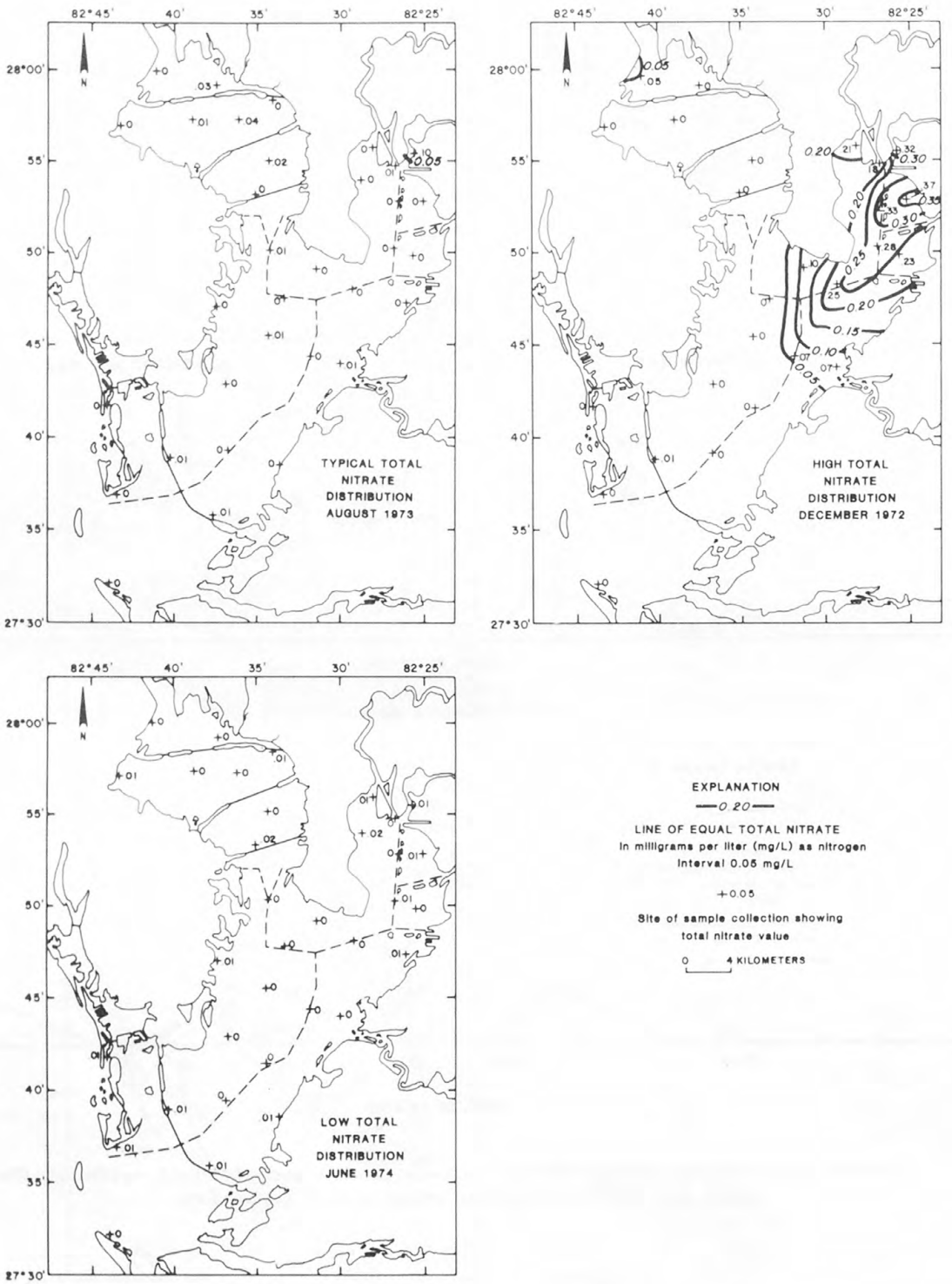

Figure 19.--Typical, high, and low total nitrate distributions in Tampa Bay.

During December 1972, concentrations of total nitrate were high (fig. 19). Coincidentally, raw sewage was diverted into the Hillsborough River (Walker, 1972) approximately 1 week before the December 1972 sampling. Most of the high concentrations were measured in Hillsborough Bay and North Tampa Bay. The pattern of isograms indicates a possible source of nitrate along the eastern shoreline of Hillsborough Bay. The Hillsborough Bay subarea (fig. 20) was higher in nitrate concentration than the other subareas. Reduced nitrate concentrations occur in the lower North Tampa Bay and South Tampa Bay subareas.

Concentrations of total nitrate were extremely low in June 1974 when, in the entire bay, nitrate was less than 0.03 mg/L (fig. 19).

Average total nitrate concentrations had no long-term trends, but they were high during the cold months of each year and low during the warm months (fig. 20). Average total nitrate concentration was 0 mg/L as nitrogen during summer months in Old Tampa Bay, North Tampa Bay, and South Tampa Bay (fig. 20). This indicates that nitrate is probably a growth limiting nutrient in Tampa Bay to those organisms dependent on nitrate as a source of nitrogen.

The seasonal variation may be caused by the variation in marine plankton. Marine plankton populations probably increase during the spring due to the onset of warm weather and abundance of nutrients, and reach a high during summer, which depletes the nitrate. During the fall, the marine plankton die off and allow nitrate to build up to a winter high.

Ammonia

Ammonia distribution for the intermediate or typical period is shown in figure 22. Ammonia concentrations ranged from 0.1 to 1.0 mg/L ammonia as nitrogen. Variations in concentration were so slight that high and low concentration distributions are not shown for this parameter. The lines of equal ammonia concentration show a definite pattern in which ammonia is high near the head of Hillsborough Bay and low toward the mouth of the estuary. The northeastern shore of Hillsborough Bay seems to be a source of ammonia to Tampa Bay, and the Manatee River a secondary source.

Average total ammonia concentration in the four subareas of the bay (fig. 21) was erratic. In Old Tampa Bay and North Tampa Bay, however, there was an overall decrease in ammonia from 1972 to 1976. Hillsborough Bay generally had higher concentrations than the other subareas.

Organic Nitrogen

Total organic nitrogen concentration (fig. 23) for the typical period ranged from 0.3 to 0.9 mg/L as nitrogen. Concentrations were about the same in three subareas of the bay; Hillsborough Bay concentrations were higher. Concentrations of total organic nitrogen were highest along the shoreline of Tampa Bay. One explanation may be that organic nitrogen is related to the high nitrogen content of waste products entering the bay from population centers along the shoreline. Another source of organic nitrogen may be products of decay of marsh vegetation on the shoreline. Distributions of high and low concentrations in total organic nitrogen were not shown because variations in concentration were small.

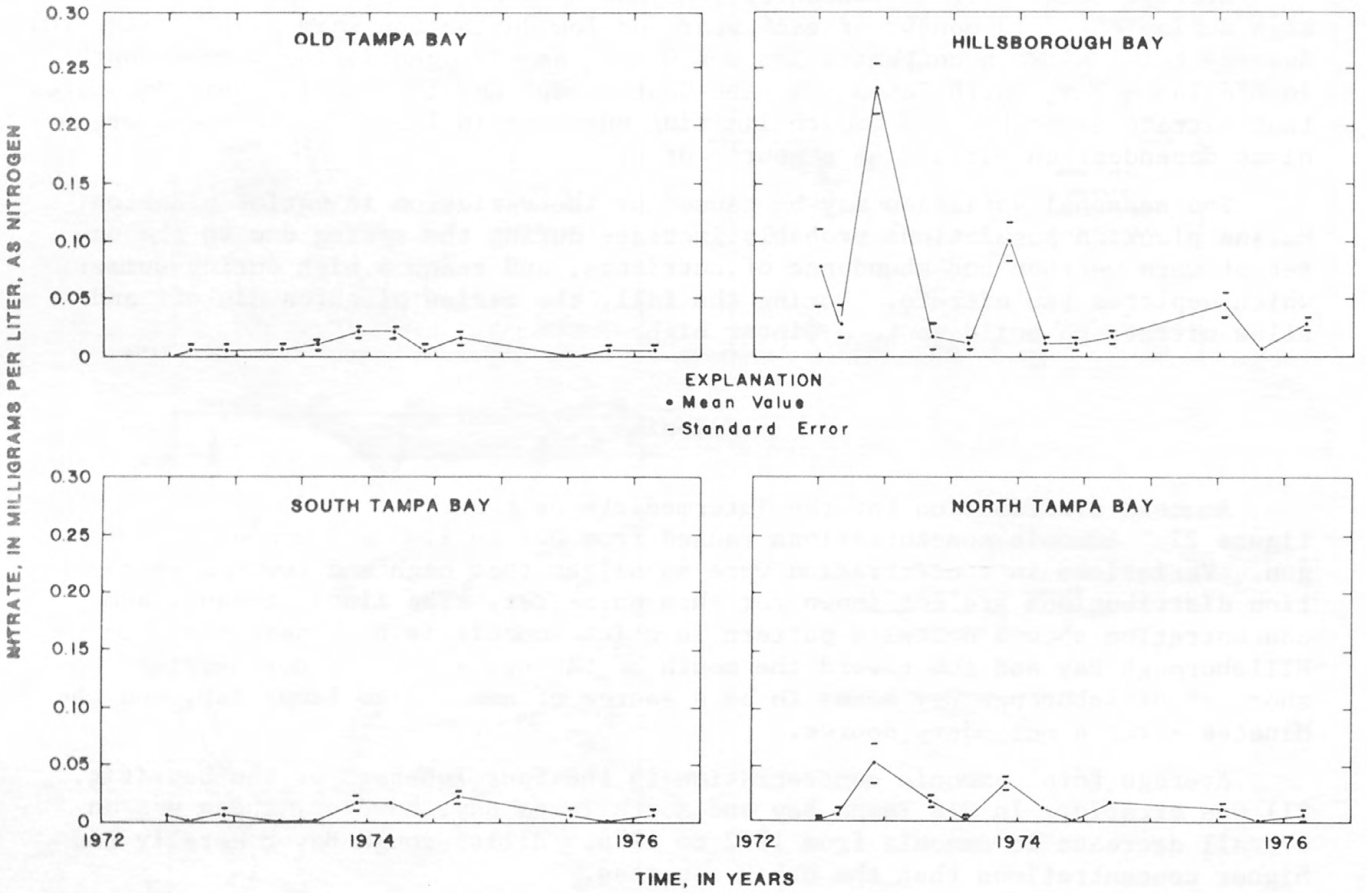

Figure 20.--Average total nitrate concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

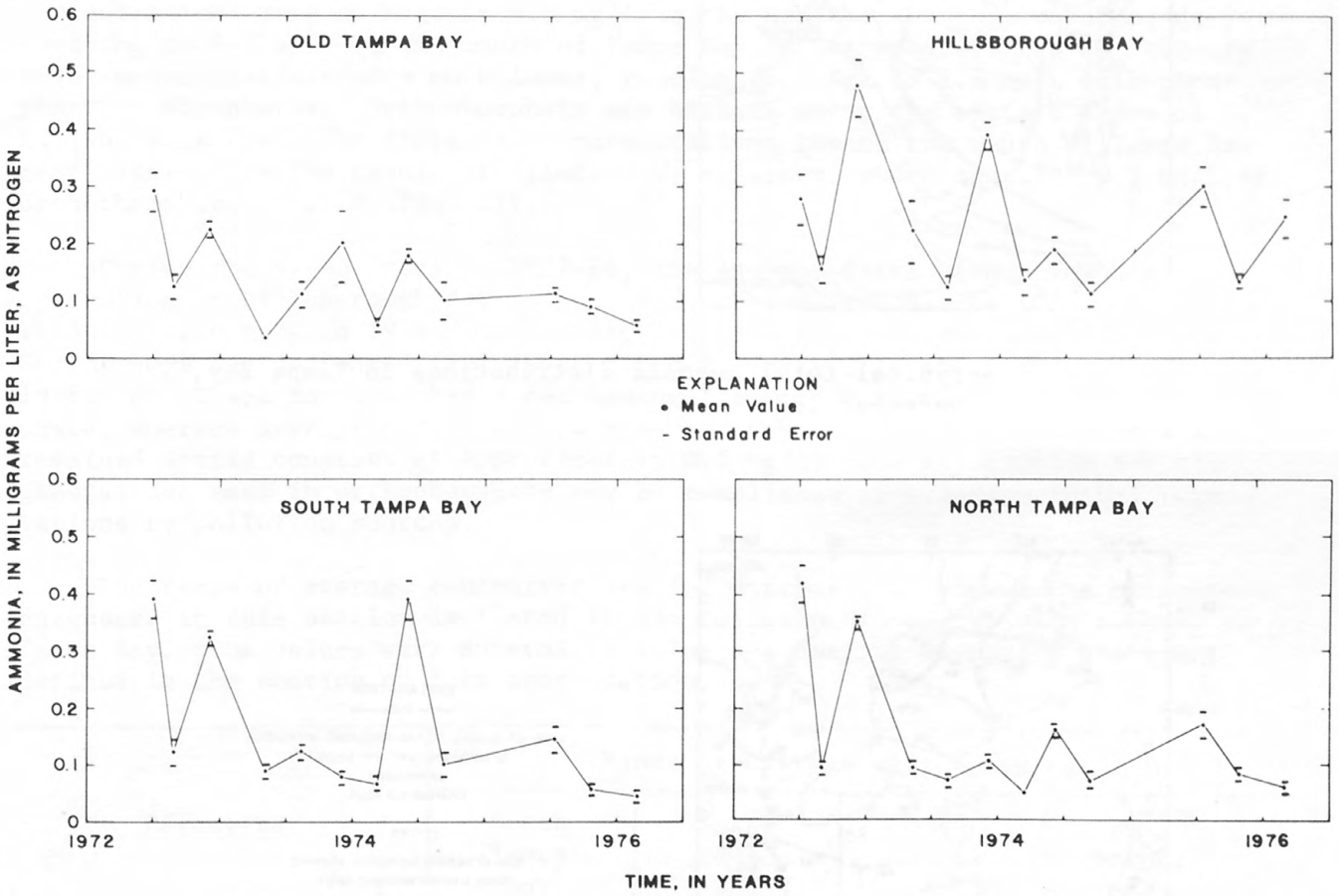

Figure 21.--Average total ammonia concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

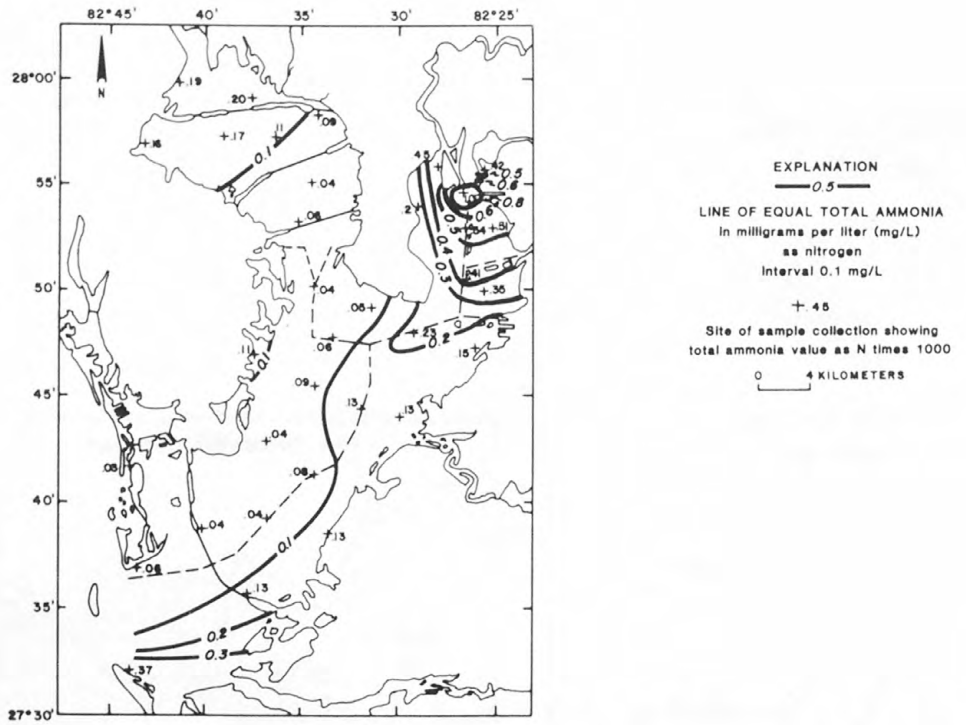

Figure 22.--Typical total ammonia distributions in Tampa Bay, December 1973.

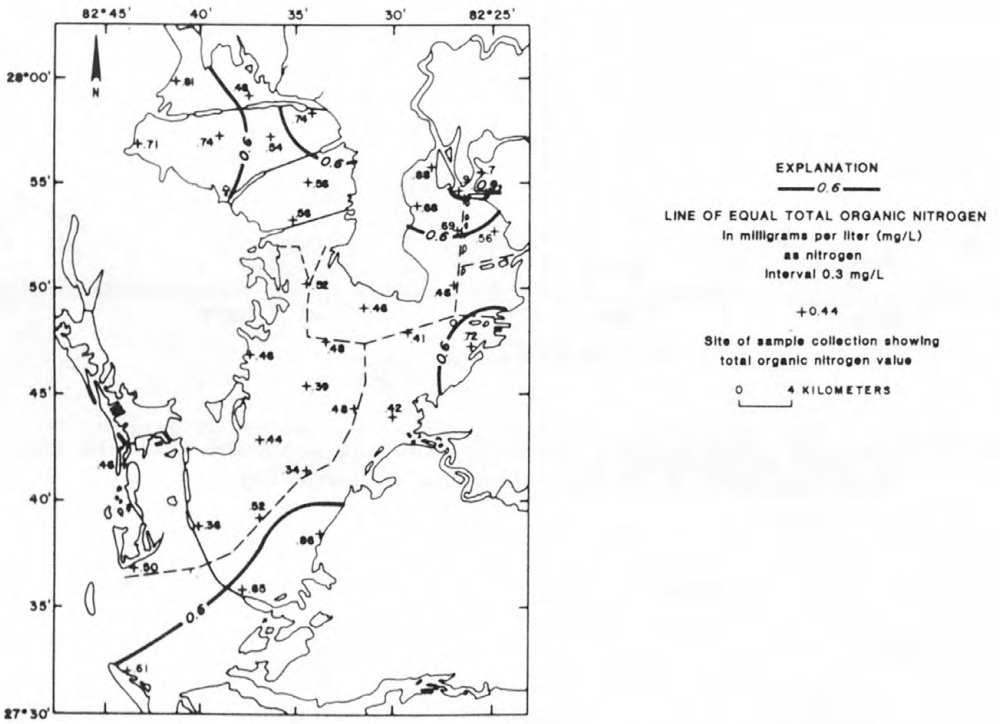

Figure 23.--Typical total organic nitrogen distribution in Tampa Bay, December 1973.

Seasonal variations and long-term trends are not distinguishable in plots of total organic nitrogen versus time shown in figure 24. Total organic nitrogen, however, was about 0.5 mg/L higher on the average in the Hillsborough Bay subarea than in other bay subareas.

Orthophosphate

Typical, high, and low total orthophosphate distributions are shown in figure 25. Total orthophosphate concentration in the Tampa Bay system during the typical period, July 1975, ranged from 0.5 to 2.7 mg/L as phosphorus. Concentrations were as high as 4.0 mg/L in the Hillsborough Bay subarea, decreasing to 0.5 mg/L at the mouth of Tampa Bay in September 1972. In February 1976, concentrations were much lower, ranging from 0.1 to 1.5 mg/L orthophosphate as phosphorus. Orthophosphate was highest along the eastern shore of Hillsborough Bay. The decreasing concentrations toward the mouth of Tampa Bay most likely were the result of dilution by seawater, which contains 0.1 mg/L of orthophosphate or less (fig. 25).

During the 4-year period, 1972-76, the average total orthophosphate concentration in Hillsborough Bay (fig. 26) decreased from 3.0 mg/L in 1973 to less than 1.0 mg/L in 1976. The average total orthophosphate concentration in North Tampa Bay decreased from about 2.0 mg/L in 1973 to about 1.0 mg/L in 1976. Old Tampa Bay also had a decreasing trend in average total orthophosphate, whereas average total orthophosphate concentrations in South Tampa Bay remained nearly constant at approximately 0.5 mg/L. One explanation for the general decrease in orthophosphate may be compliance with environmental regulations by pollution sources.

The range of average concentrations for nitrogen and phosphorus parameters discussed in this section is listed in the following table for each subarea of Tampa Bay. The values were determined using the spatial averaging procedure defined in the section on data presentation.

Parameter	Range of average values (mg/L)			
	South Tampa Bay	North Tampa Bay	Old Tampa Bay	Hillsborough Bay
Total ammonia as nitrogen	0.05 - 0.39	0.04 - 0.41	0.03 - 0.32	0.11 - 0.47
Total nitrite as nitrogen	0 - 0.01	0 - 0.01	0 - 0.01	0 - 0.05
Total nitrate as nitrogen	0 - 0.02	0 - 0.05	0 - 0.08	0.01 - 0.23
Total organic nitrogen as nitrogen	0.3 - 0.6	0.3 - 0.8	0.5 - 1.2	0.6 - 1.9
Total orthophosphate as phosphorus	0.3 - 0.7	0.5 - 1.9	0.6 - 1.7	0.8 - 2.9

Seasonal variations and long-term trends are not distinguishable in plots of total organic nitrogen versus time shown in figure 24. Total organic nitrogen, however, was about 0.5 mg/L higher on the average in the Hillsborough Bay subarea than in other bay subareas.

Orthophosphate

Typical, high, and low total orthophosphate distributions are shown in figure 25. Total orthophosphate concentration in the Tampa Bay system during the typical period, July 1975, ranged from 0.5 to 2.7 mg/L as phosphorus. Concentrations were as high as 4.0 mg/L in the Hillsborough Bay subarea, decreasing to 0.5 mg/L at the mouth of Tampa Bay in September 1972. In February 1976, concentrations were much lower, ranging from 0.1 to 1.5 mg/L orthophosphate as phosphorus. Orthophosphate was highest along the eastern shore of Hillsborough Bay. The decreasing concentrations toward the mouth of Tampa Bay most likely were the result of dilution by seawater, which contains 0.1 mg/L of orthophosphate or less (fig. 25).

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Parameter	Range of average values (mg/L)			
	South Tampa Bay	North Tampa Bay	Old Tampa Bay	Hillsborough Bay
Total ammonia as nitrogen	0.05 - 0.39	0.04 - 0.41	0.03 - 0.32	0.11 - 0.47
Total nitrite as nitrogen	0 - 0.01	0 - 0.01	0 - 0.01	0 - 0.05
Total nitrate as nitrogen	0 - 0.02	0 - 0.05	0 - 0.08	0.01 - 0.23
Total organic nitrogen as nitrogen	0.3 - 0.6	0.3 - 0.8	0.5 - 1.2	0.6 - 1.9
Total orthophosphate as phosphorus	0.3 - 0.7	0.5 - 1.9	0.6 - 1.7	0.8 - 2.9

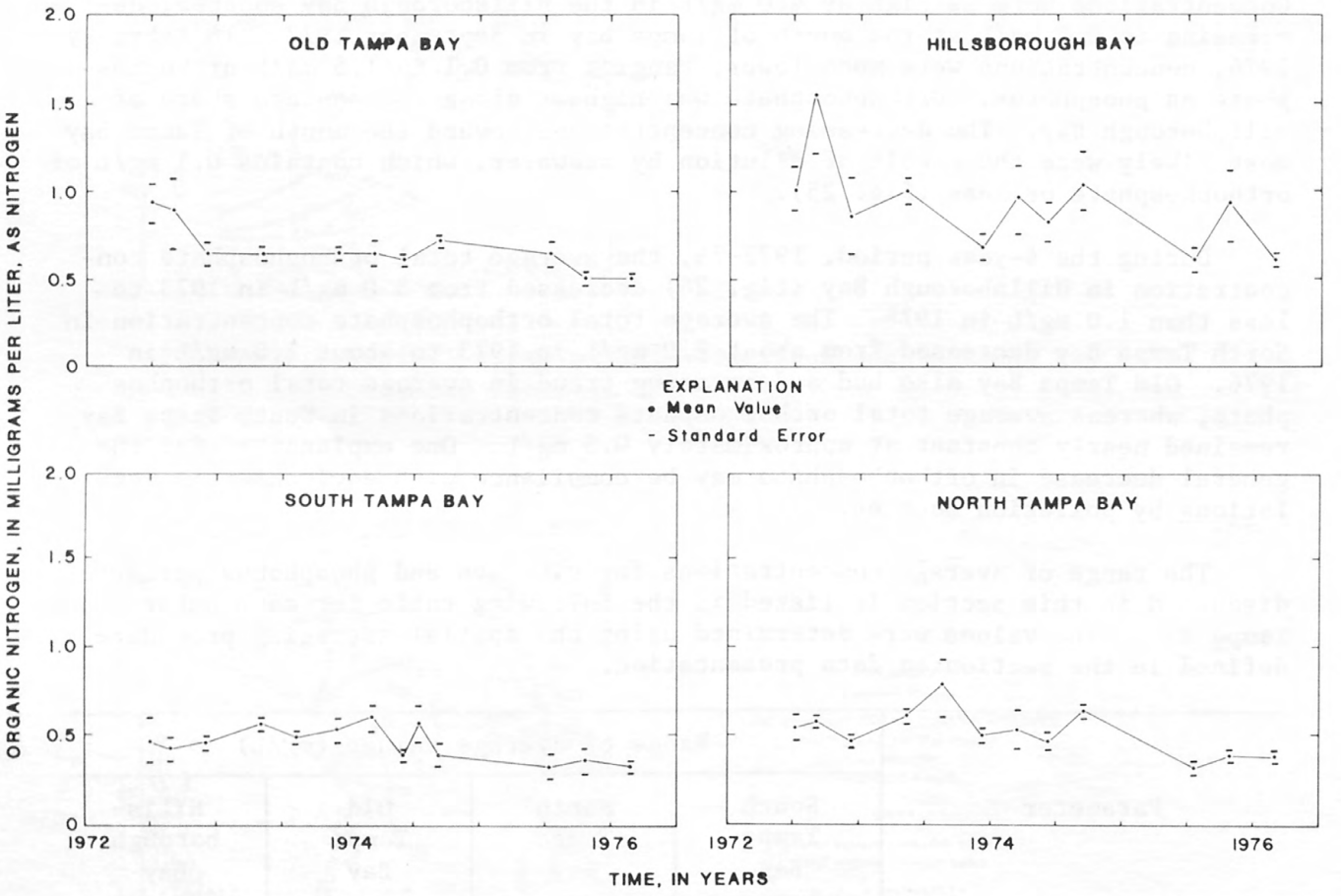

Figure 24.--Average total organic nitrogen concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

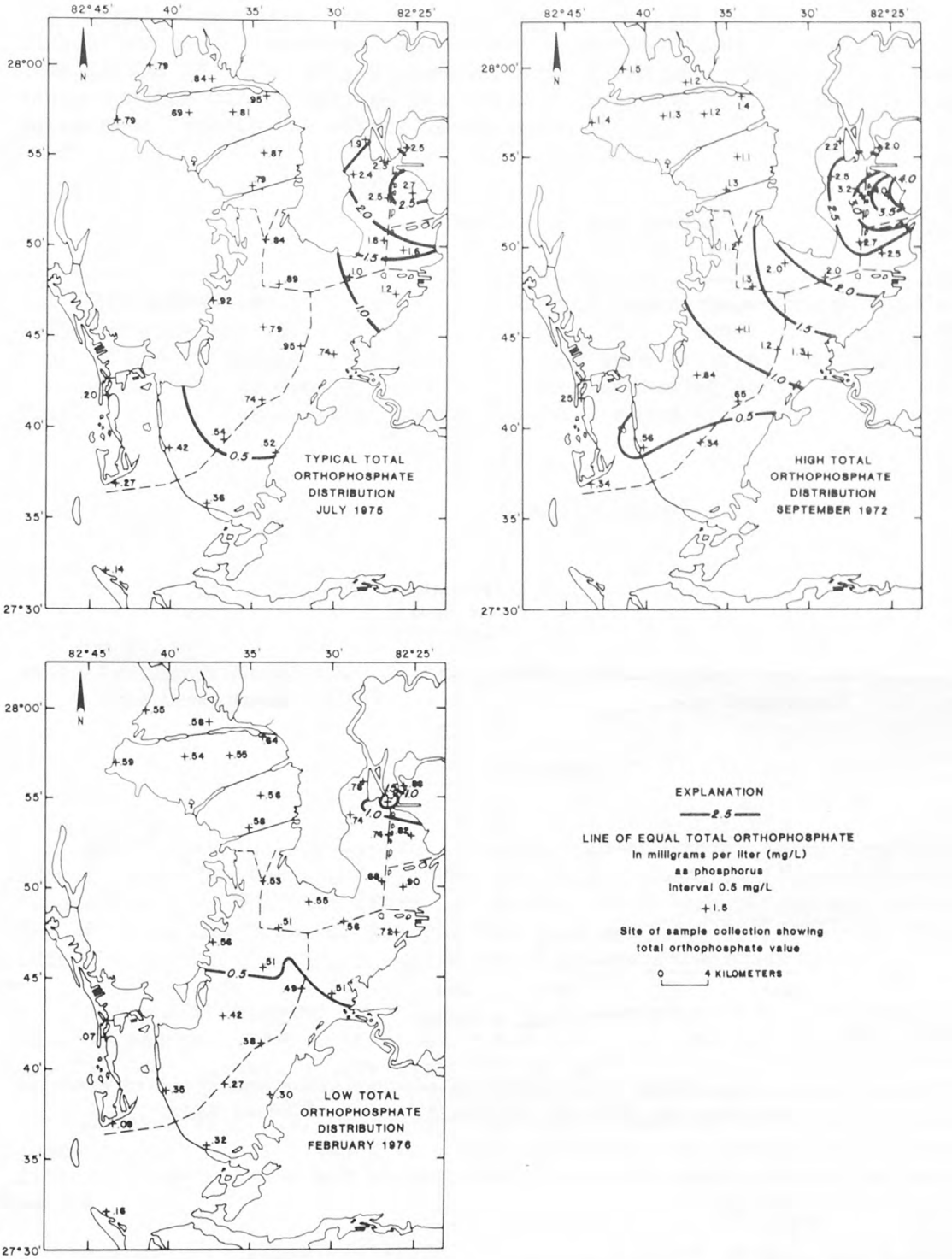

Figure 25.--Typical, high, and low total orthophosphate distributions in Tampa Bay.

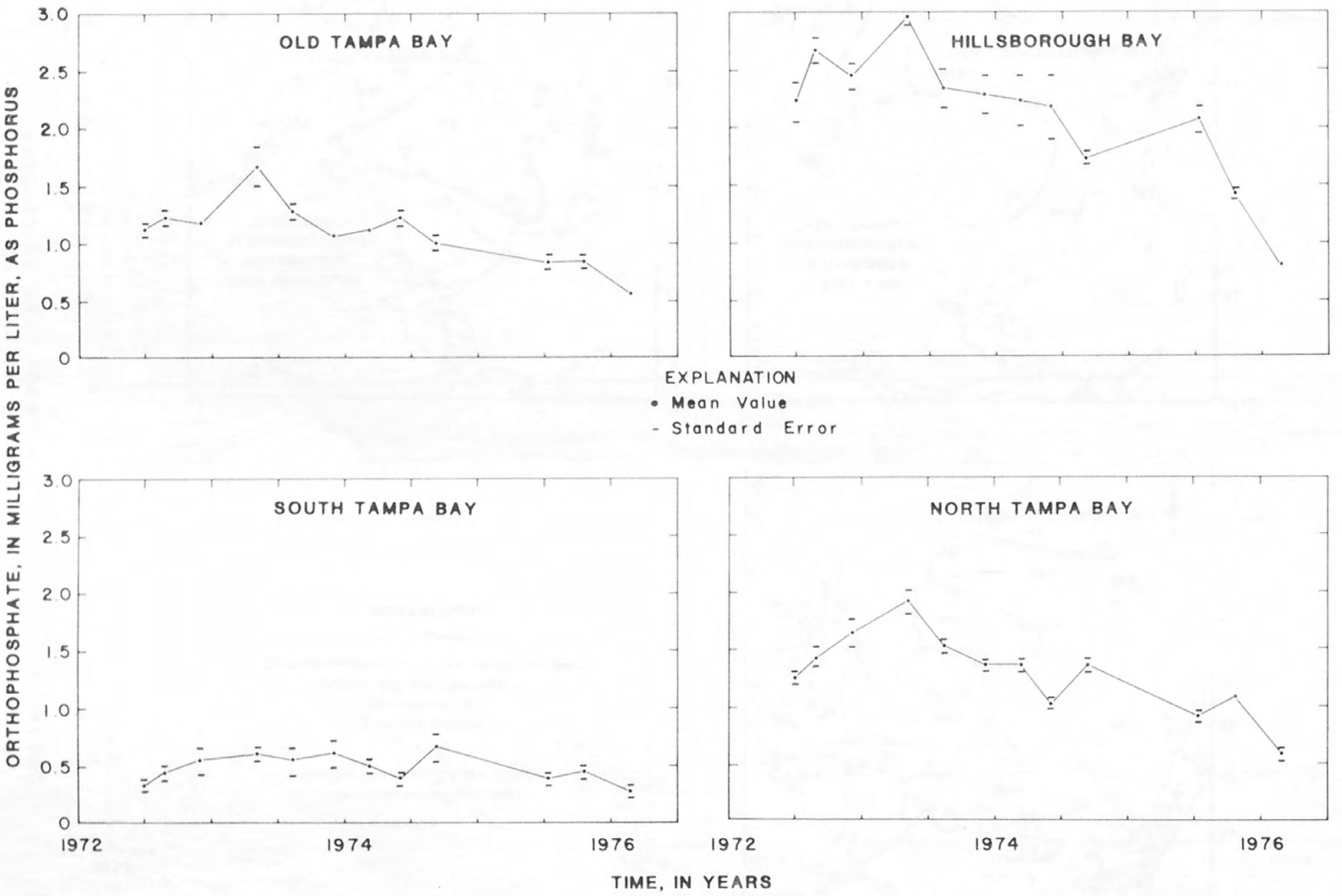

Figure 26.--Average total orthophosphate concentration and standard error of the mean for 1972-76 in four subareas of Tampa Bay.

Biochemical Oxygen Demand and Total Organic Carbon

Areal distribution maps of biochemical oxygen demand and total organic carbon for intermediate or typical concentration conditions are shown in figures 27 and 28. The data represent surface and water column conditions because samples were sometimes collected at a depth of 0.3 m and sometimes integrated through the entire water column.

Biochemical Oxygen Demand

In Tampa Bay, 5-day biochemical oxygen demand for typical conditions, July 1975, usually ranged from 1 to 5 mg/L (fig. 27). Small areas along the shoreline of Old Tampa Bay and Hillsborough Bay were observed to have a higher 5-day biochemical oxygen demand (fig. 27) than surrounding areas. These are most likely areas where domestic wastes are discharged from population centers.

Total Organic Carbon

Typical total organic carbon distribution, June 1974, ranged from 0 to 26 mg/L (fig. 28). Total organic carbon concentrations were highest in Old Tampa Bay and Hillsborough Bay, particularly near the northeastern shorelines where waste treatment facilities discharge effluents to the bay.

Metals

Areal distribution maps of cadmium, copper, iron, lead, manganese, mercury, nickel, and zinc for the Tampa Bay system are shown in figures 29-36. Cadmium, copper, iron, and nickel (figs. 29-31 and 35) represent surface conditions in May of 1973, and lead, manganese, mercury, and zinc (figs. 32-34 and 36) represent conditions within the entire water column in October of 1975.

All metals sampled were present in concentrations of less than 500 ug/L (micrograms per liter). Cadmium, lead, mercury, and nickel (figs. 29, 32, 34 and 35) concentrations were less than 10 ug/L.

Cadmium (fig. 29) was absent throughout most of Tampa Bay. Areas where cadmium concentration was 2 to 8 ug/L were near the shoreline of Tampa Bay, indicating that cadmium may be introduced through waste disposal or overland runoff.

Copper concentrations (fig. 30) averaged about 30 ug/L and ranged from 20 to 40 ug/L. Copper was evenly distributed throughout Tampa Bay.

Iron concentrations (fig. 31) ranged from 30 to 410 ug/L and averaged about 150 ug/L.

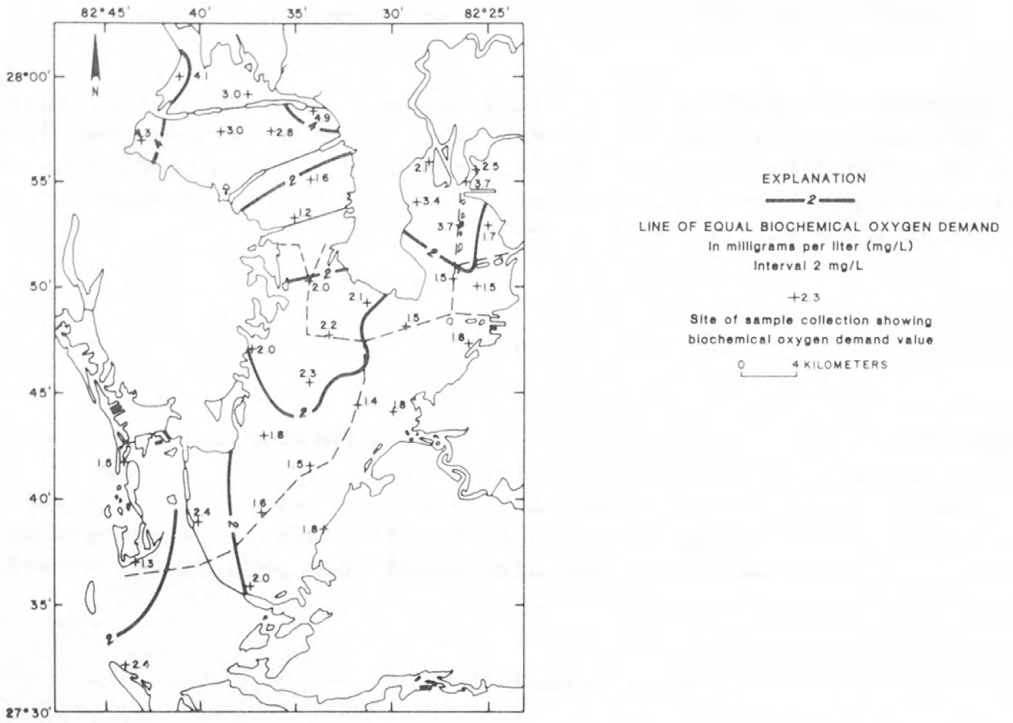

Figure 27.--Typical biochemical oxygen demand distribution in Tampa Bay, July 1975.

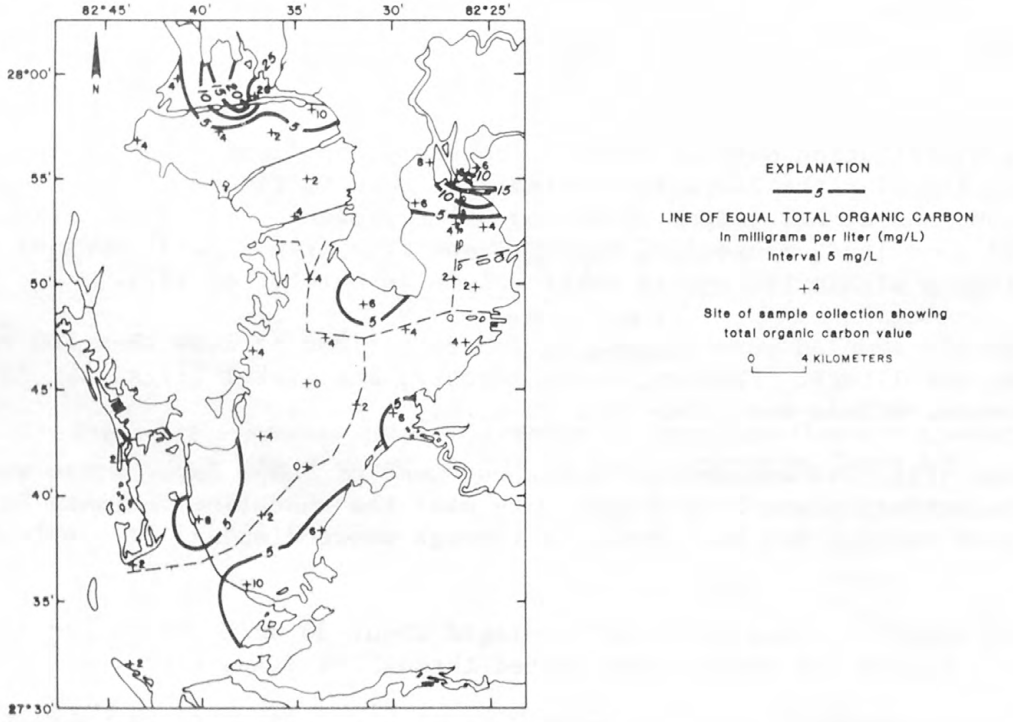

Figure 28.--Typical total organic carbon distribution in Tampa Bay, June 1974.

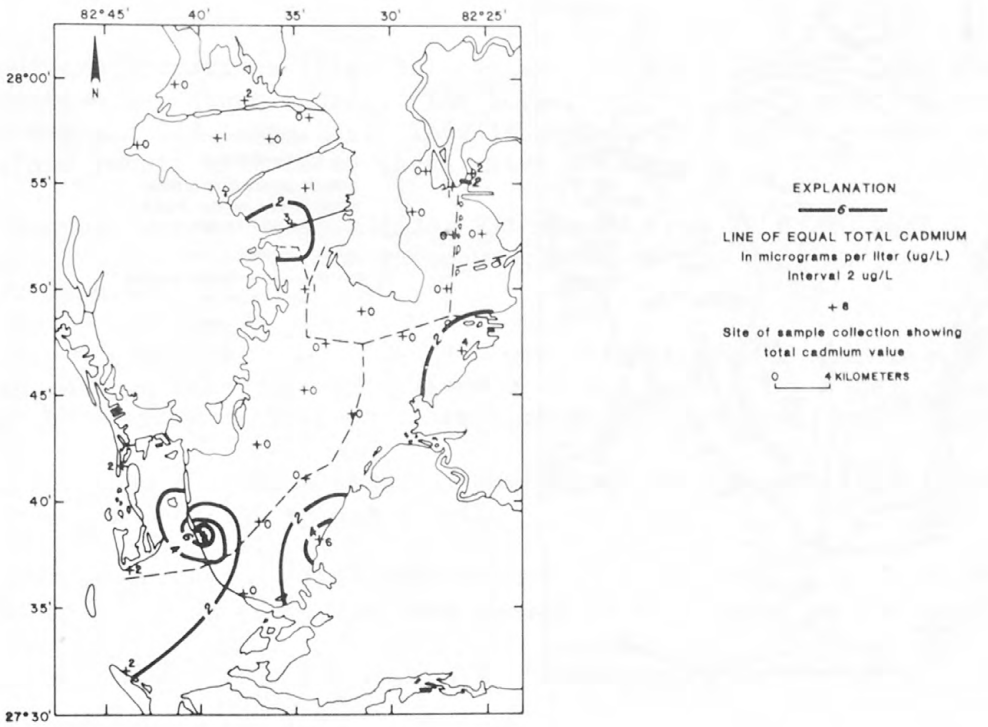

Figure 29.--Total cadmium distribution in Tampa Bay, May 1973.

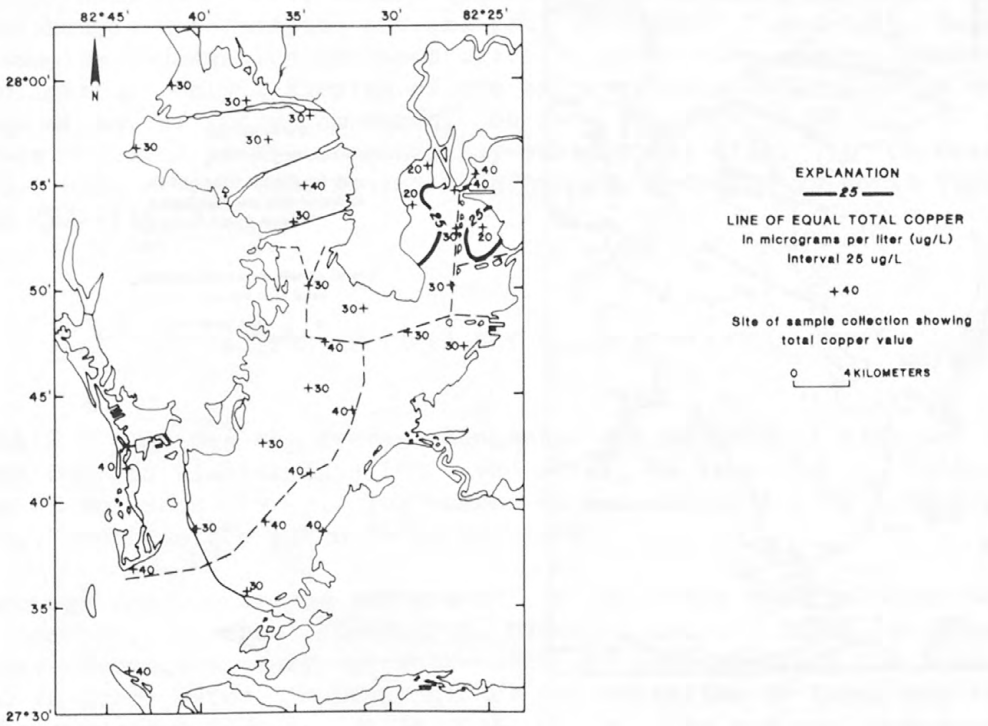

Figure 30.--Total copper distribution in Tampa Bay, May 1973.

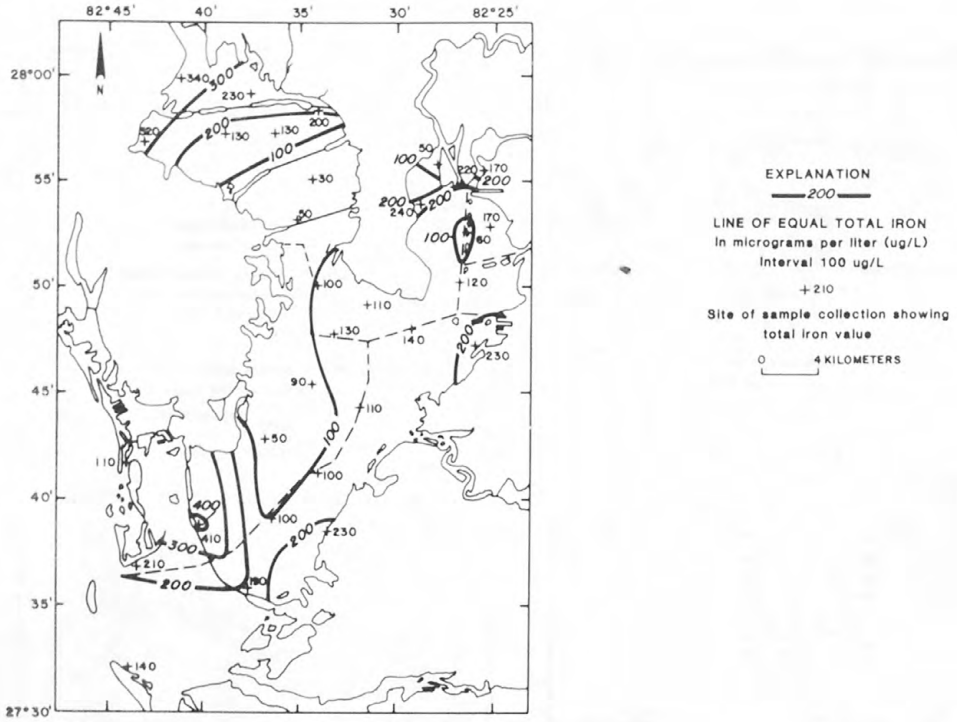

Figure 31.--Total iron distribution in Tampa Bay, May 1973.

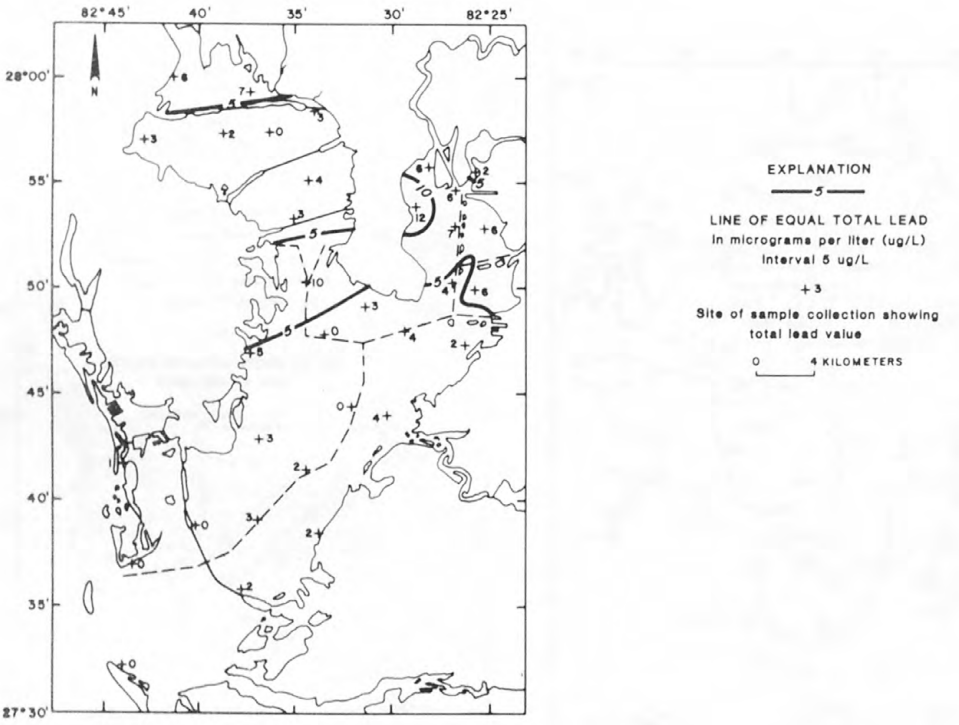

Figure 32.--Total lead distribution in Tampa Bay, October 1975.

Lead concentrations (fig. 32) ranged from 0 to 12 ug/L. The average lead concentration was about 4 ug/L. The occurrence of lead was primarily in Hillsborough Bay and Old Tampa Bay. This is most likely due to greater quantities of overland runoff that enter these water bodies.

Manganese concentrations (fig. 33) ranged from 20 to 80 ug/L. Fifty ug/L was the average concentration throughout most of the bay; no distribution pattern was apparent.

Mercury concentrations (fig. 34) were higher near the shoreline of Tampa Bay than in open waters, ranging from 0 to 0.3 ug/L. This indicates that mercury may be introduced through waste disposal or overland runoff.

Nickel concentrations (fig. 35) averaged about 2 ug/L. Concentrations at two stations were greater than 5 ug/L.

Zinc concentrations (fig. 36) ranged from 10 to 70 ug/L, and averaged about 35 ug/L. Zinc concentrations seemed to be highest at the mouth of Tampa Bay.

Pesticides and Polychlorinated Biphenyls

Total heptachlor, total heptachlor epoxide, total lindane, total toxaphene, total 2,4-D, total 2,4,5-T, total silvex, total aldrin, total chlordane, total DDD, total DDE, total DDT, total dieldrin, total endrin, and total polychlorinated biphenyls were sampled and analyzed throughout Tampa Bay. Both surface-water samples and samples representative of the entire vertical water column were collected. Only 2 samples of the approximately 430 collected showed the presence of any of these compounds. On June 18, 1974, 0.07 ug/L of total 2,4-D was detected at Hillsborough Bay station HB1 (fig. 3). On October 28, 1975, 0.1 ug/L of polychlorinated biphenyl was detected at North Tampa Bay station TB7 (fig. 3).

COMPARISON OF TAMPA BAY WATER WITH OCEAN WATER

Table 4 presents the average concentration of several elements measured in Tampa Bay and similar data for ocean water, as reported by the National Academy of Sciences (1971). The number of measurements used to determine the Tampa Bay averages are given in parentheses.

Average concentrations are greater in Tampa Bay than in ocean water for organic carbon, nitrogen, phosphorus, cadmium, copper, iron, lead, manganese, and zinc. Average mercury concentrations are approximately the same in Tampa Bay and in ocean water. Average nickel concentration in Tampa Bay is lower than the average concentration in ocean water. The reported averages in Tampa Bay for cadmium, copper, lead, manganese, zinc, mercury, and nickel are near the detection limits for the laboratory analytical methods used.

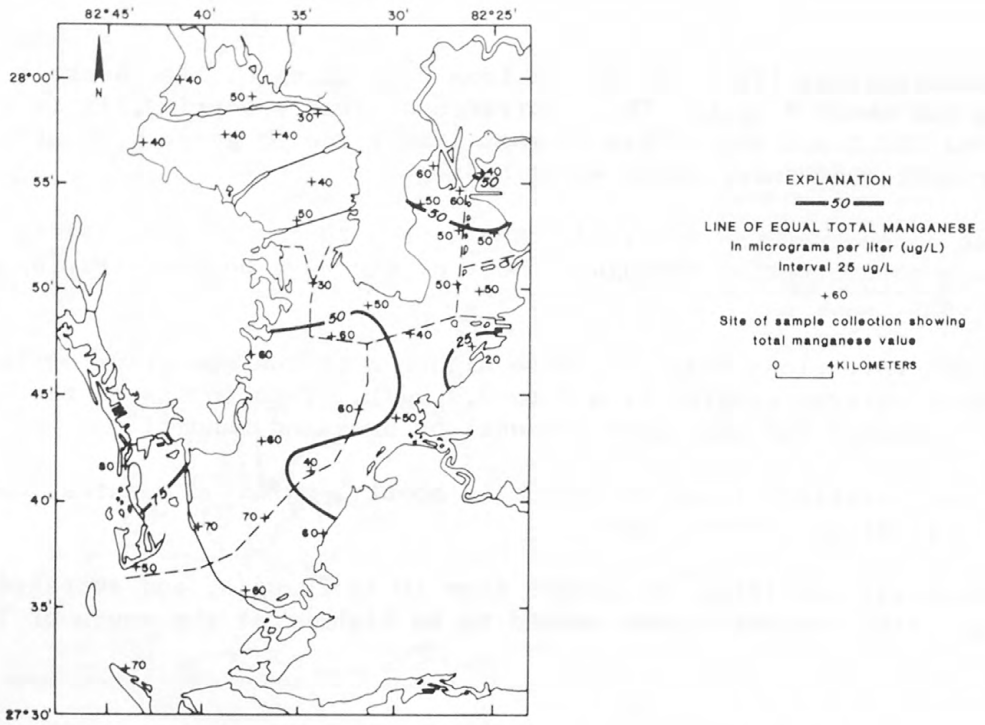

Figure 33.--Total manganese distribution in Tampa Bay, October 1975.

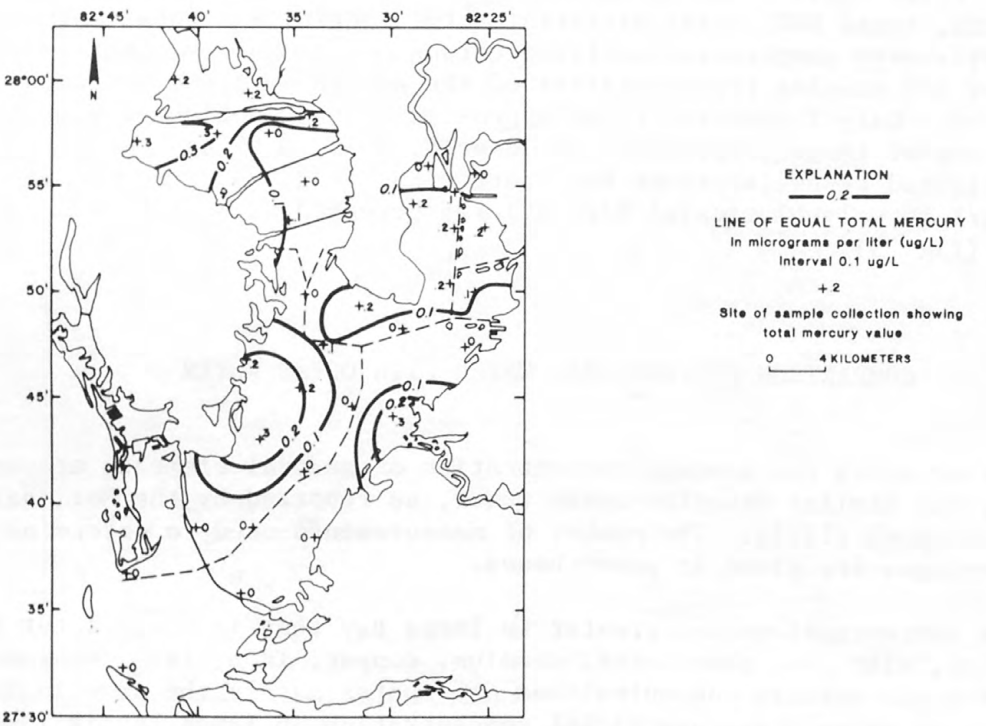

Figure 34.--Total mercury distribution in Tampa Bay, October 1975.

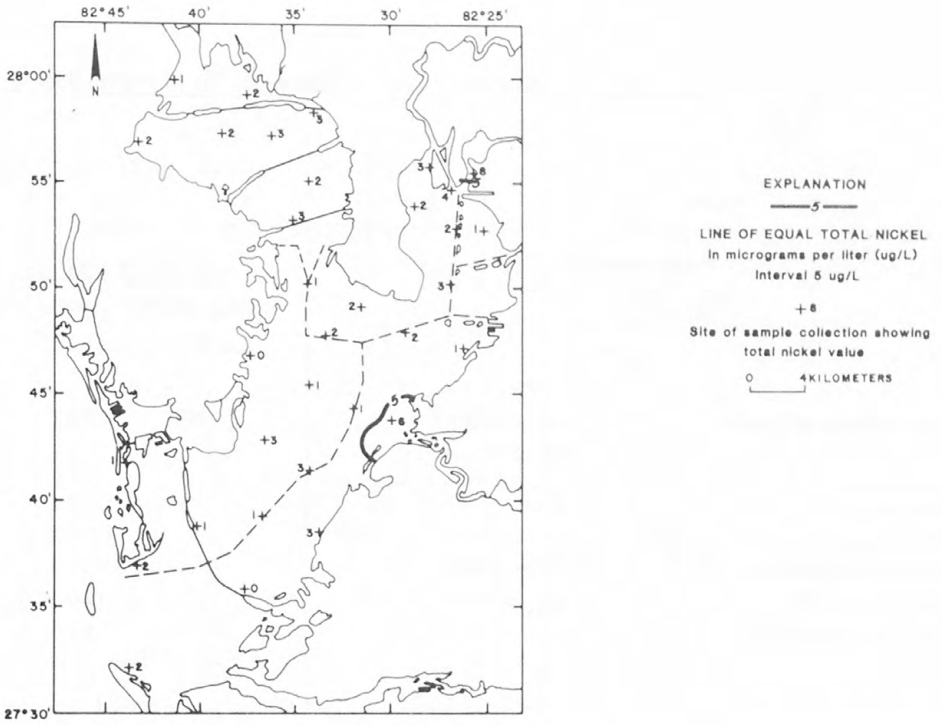

Figure 35.--Total nickel distribution in Tampa Bay, May 1973.

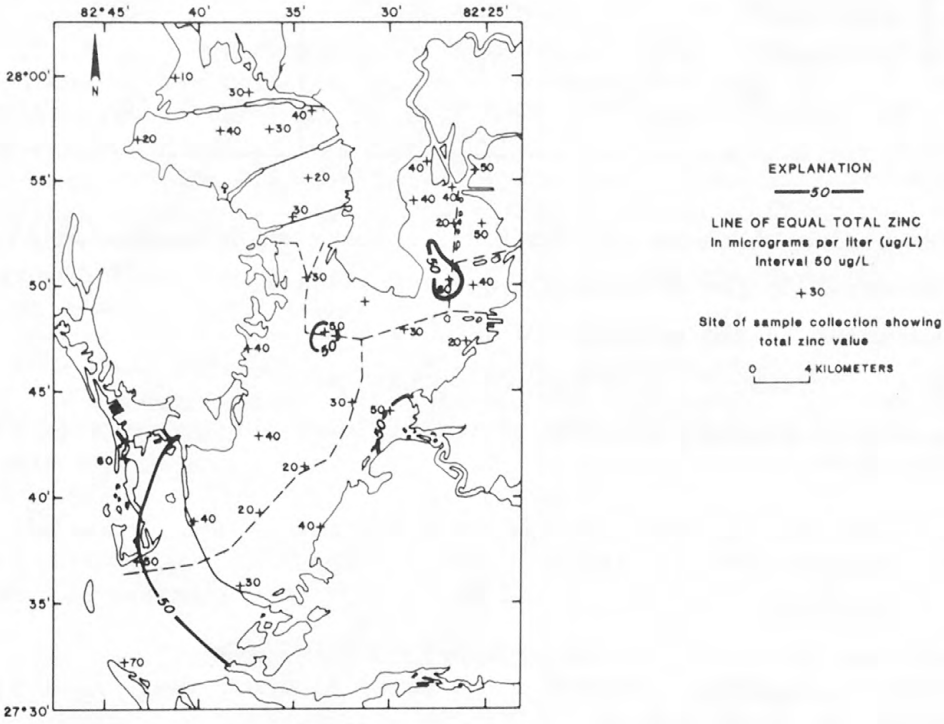

Figure 36.--Total zinc distribution in Tampa Bay, October 1975.

Table 4.--Average concentration of selected elements in Tampa Bay and ocean water

Element	Concentration in Tampa Bay, ug/L (number of observations)		Concentration in ocean water, ug/L[1/]
	Dissolved	Total or total recoverable	Dissolved
Carbon (organic)	-	5,400 (336)	200
Nitrogen	-	760 (127)	670
Phosphorus	-	1,200 (441)	90
Cadmium[2/]	0.5 (4)[4/,5/]	2 (103)[4/]	0.1
Copper[3/]	5 (37)[4/,5/]	20 (147)[4/]	3
Iron[3/]	80 (38)	240 (149)	3
Lead[2/]	1 (36)[4/]	8 (135)	0.03
Manganese[3/]	30 (37)[4/]	50 (132)	2
Mercury	0.0 (36)[4/]	0.3 (135)[4/]	0.2
Nickel[2/]	1 (5)[4/]	3 (46)[4/]	7
Zinc[3/]	30 (36)[4/]	60 (148)[4/]	10

1/ Data from the oceans of the world (National Academy of Sciences, 1971).

2/ Element is measured to the nearest microgram per liter.

3/ Element is measured to the nearest 10 ug/L.

4/ Mean is near the detection limit for the method used.

5/ Mean is reported to greater accuracy than individual measurements to indicate a nonzero mean.

SUMMARY AND CONCLUSIONS

Water-quality data were collected in Tampa Bay, a shallow, Y-shaped embayment of 910 km^2, by the U.S. Geological Survey between June 1972 and May 1976 and are presented in map and graphical form. In general, the data show the estuary to be well mixed and to have little vertical stratification.

Turbidity typically ranged from 0 to 19 Jackson turbidity units. The highest turbidities were in Hillsborough Bay, along the ship channel.

Surface-water temperatures typically ranged from 24° to 27°C with extreme values of 14° and 30°C. Bay-water temperature responds to seasonal atmospheric heating and cooling.

Dissolved oxygen in surface waters typically ranged from 4 to 9 mg/L, the variation being greatest in shallow areas. In bottom waters, dissolved oxygen typically ranged from 1 to 8 mg/L. The difference in dissolved-oxygen concentration between surface and bottom water was greatest in Hillsborough Bay and Old Tampa Bay. During summer months, a large part of Hillsborough Bay had less than 3 mg/L dissolved oxygen in bottom waters.

Surface water pH typically ranged from 7.4 to 8.4 with a general downward trend during the study period, particularly in Hillsborough Bay.

There is a distinct pattern in specific conductance throughout the Tampa Bay system. The highest typical specific conductances, 48 to 50 mmho/cm, were near the mouth of Tampa Bay; the lowest typical specific conductances, 32 to 34 mmho/cm were in Hillsborough Bay. Average specific conductance in Tampa Bay ranged from 51 to 28 mmho/cm.

Total nitrate concentrations varied seasonally. Nitrate concentrations were high during the cold months and low during the warm months. Concentrations of nitrate in three subareas of Tampa Bay decreased to 0 during the summer. Variation in marine plankton populations may explain the variation in nitrate concentration. Spring plankton blooms deplete nitrate until it reaches a low during the summer. Die off of plankton in the fall allows nitrate to build up to a winter high. This leads to the conclusion that nitrate is probably a growth limiting nutrient in Tampa Bay to those organisms dependent on nitrate as a source of nitrogen.

No sustained increasing or decreasing concentration trends for the period, 1972-76, can be detected for most parameters. However, orthophosphate exhibited a 50 percent concentration decrease during the period everywhere in the bay except near the mouth.

Of the metals and pesticides studied, all were present in concentrations of less than 500 ug/L. Concentrations of cadmium, lead, mercury, nickel, and pesticide all averaged less than 10 ug/L.

Average constituent concentrations in Hillsborough Bay were frequently different than other areas of Tampa Bay. Nutrient averages, including ammonia, nitrite, nitrate, orthophosphate, and silica were highest in Hillsborough Bay, as were turbidity and organic nitrogen. The northeast shoreline of Hillsborough Bay had the highest concentrations of ammonia, nitrate, and orthophosphate. Specific conductance, dissolved oxygen, and pH averages were lower in Hillsborough Bay than in the rest of Tampa Bay.

The water-quality conditions in Hillsborough Bay are a consequence of its unique hydrologic and geographic position within the Tampa Bay complex. Two major sources of freshwater, the Hillsborough River and Alafia River, representing approximately 49 percent of the average inflow to Tampa Bay, are tributary to Hillsborough Bay. A major municipal, industrial, and commercial region discharges wastes into Hillsborough Bay. Stormwater runoff from a large part of the highly urbanized area of the city of Tampa enters Hillsborough Bay. A major port facility also occupies the upper reaches of Hillsborough Bay.

Old Tampa Bay had high concentrations of biochemical oxygen demand, particularly along shorelines near population centers. Total organic carbon and total organic nitrogen also showed patterns of high concentration along shorelines near population centers in Old Tampa Bay and similarly in the other three subareas of Tampa Bay.

Old Tampa Bay and the north and south sections of Tampa Bay had similar water-quality characteristics. Water quality was generally good in these areas with the possible exception of localized zones near effluent discharges.

Comparisons of average concentrations of elements in Tampa Bay water and ocean water showed that concentrations of organic carbon, nitrogen, phosphorus, cadmium, copper, iron, lead, manganese, and zinc are greater in Tampa Bay than in ocean water.

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