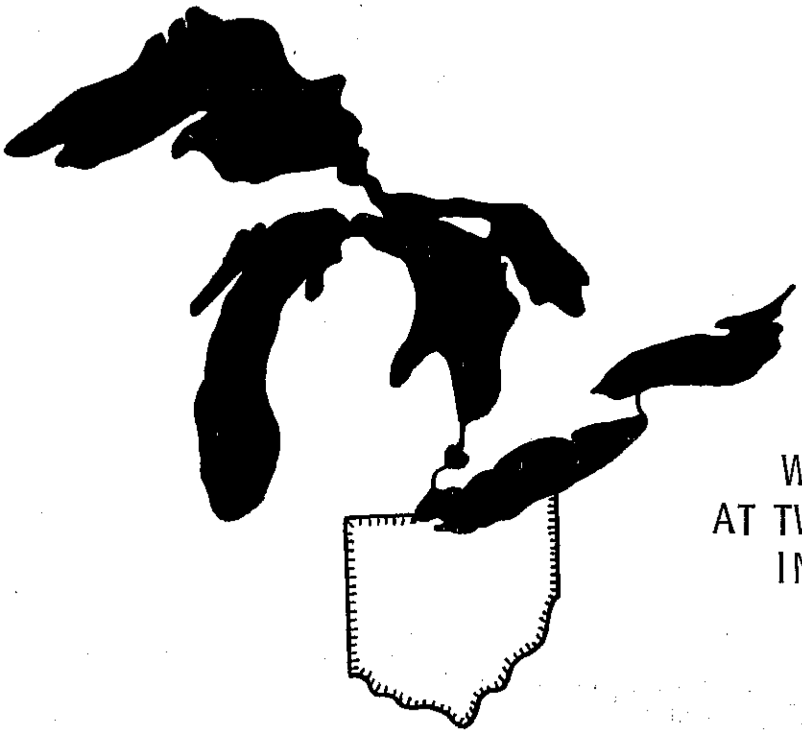

CLEAR TECHNICAL REPORT NO. 256

WATER QUALITY TRENDS AT TWO NEARSHORE STATIONS IN WESTERN LAKE ERIE

by

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INTRODUCTION

Purpose and objectives

Since the late 1960's, much concern has developed regarding the water quality of Lake Erie. Researchers and the public became alarmed when the Lake showed signs of eutrophication, i.e., increasing phosphorus loads, prolonged periods of anoxia, and increases in suspended and dissolved substances. Biological indicators of eutrophication, such as transitions in phytoplankton abundance and fish species, became readily apparent (Beeton, 1970; Leach and Nepszy, 1976).

In 1964, the governments of the United States and Canada informed the International Joint Commission (IJC) that sewage and industrial wastes were polluting Lake Erie (IJC, 1969a). The U.S. subsequently began a surveillance program and submitted a final report in 1969. As a direct result of this report, the U.S. and Canada signed the Great Lakes Water Quality Agreement on April 15, 1972. Deterioration of Great Lakes water was thus recognized, which resulted in a set of common objectives to restore and enhance Great Lakes water.

One purpose of surveillance programs initiated in Lake Erie is to seek to identify historical trends, especially among water quality parameters that may be changing due to human influences. Trend analysis has recently attracted the attention of many Great Lakes research groups. Two major problems have arisen in attempting to analyze large data bases through time: a satisfactory definition of what exactly constitutes a "trend" and, more importantly, developing an adequate method of removing large variations in raw data due to seasonality and general limnological nearshore conditions. Such variation could tend to mask a trend that really exists, or, conversely, it could indicate a trend where none actually exists.

In 1978, the IJC defined trend as a linear regression equation having a slope significantly different than zero as determined by a t-test or F-test. Recently, the Data Management and Interpretation Work Group (1980) recommended the following definition of trend in Lake Erie water quality:

> "To relieve any ambiguity and to provide a uniform methodology of testing for trend we propose an operational definition of trend which narrows it to a change at a constant rate, that is, trend will be understood as simple linear trend. Trend can thus be assessed by regressing the character of interest upon time:
>
> $$y = b_o + b_1 x + e$$
>
> where b_o is the characteristic of interest and x is time; coefficient b_1 is tested for statistical significance."

The purpose of this study is to determine the extent, if any, of water quality changes over the past decade (1970-1980). Two data bases from Lake Erie western basin sites are analyzed using the Data Management and Interpretation Work Group's definition trend (i.e., simple linear regression). Statistical methods are employed in an attempt to smooth large variability present in the data. Results are then compared with those of previous investigators in an attempt to assess rates of change in water quality.

Previous investigations

One of the earliest and most comprehensive investigations of Lake Erie water quality changes was undertaken by Beeton (1961, 1967, 1970). Data for his analyses were collected from various sources throughout Lake Erie and include those from municipal water intakes, fisheries studies, and some early pollutional studies. The significance of Beeton's findings lies in the long time period of reported changes (1902-1960) and water quality parameters which are discussed: chlorides, total dissolved solids, calcium, sodium plus potassium and sulfates. Phosphorus and nitrates were not included in his results probably because of the scarcity of data for these parameters in early years.

Since Beeton's publications, documentation of Lake Erie changes has been fairly extensive. Several researchers (Richards, 1981; Weiler and Heathcote, 1979; Gregor and

Ongley, 1978) have identified water quality changes occurring since the late 1960's in specific nearshore zones of Lake Erie. These authors used differing trend techniques in order to filter large sources of variability inherent in nearshore waters. Trends in main lake water quality from 1966 to 1980 have been summarized by Dobson (1981), specifically in regard to nutrient chemistry in the central and eastern basins. Weiler and Chawla (1968) used Beeton's data to document trends in ionic species composition of specific conductance from 1906-1967. Fraser and Wilson (1981) documented trends in loading estimates to Lake Erie from 1967-1976. Sedimentation rates since 1850 have been documented through pollen analysis by Yahney (1978).

Many researchers have commented on present concentrations of chemical parameters in comparison with individual data points of the past. The Michigan Department of Natural Resources (1981) compared present day loadings of the Detroit River to those of 1968. Rawson (1951) compares samples taken from the Niagara River with those collected in the 1930's. Other investigations document changes through cruise means as yearly means on a lake-wide basis in comparison with earlier reported concentrations (Ownbey and Kee, 1967; Scheffield, et al, 1975; Dobson, et al, 1974).

Two special voumes - specifically a report to the International Joint Commission (1969a) and a special issue of the Fisheries Research Board of Canada (1976) contain much useful information on Lake Erie status with respect to physical and chemical water quality.

DESCRIPTION OF STUDY AREAS

Lake Erie and the western basin

Although its surface area is slightly larger than Lake Ontario, Lake Erie is the smallest of the Laurentian Great Lakes with respect to volume (470 km^3). Mean water depth throughout the Lake is only 18 meters; a maximum depth of 64 meters occurs just off Long Point in the eastern basin (Schelske & Roth, 1973). The Lake has a maximum width of 90 km between Port Stanley and Painesville and a maximum length of 390 km between Toledo and Buffalo.

Mean daily water temperature ranges from -2 to -3°C in winter to 21 to 23°C in midsummer. Winds vary seasonally in both velocity and direction with southwest flow dominating and average speeds ranging from 14 to 26 km/hr. Storm events, often characterized by easterly and northerly winds, predominate in winter and spring. A stronger southerly component as well as periods of calm are present in the summer. Fall is characterized by predominating southerly winds and increased wave action (Sly, 1976).

Precipitation within the Lake Erie watershed averages 79 cm annually, while precipitation in the Lake proper averages 83 cm annually. Mean annual evaporation from the Lake surface has been calculated to be 90 cm. This implies that approximately 7 cm of water are evaporated from the surface over average annual precipitation. This net loss of water is unique to Lake Erie and can be attributed to the extreme shallowness and large surface area which allows rapid heating of the Lake waters (Jones & Meredith, 1972).

Approximately 25-30% of the annual precipitation on the drainage basin is in the form of snowfall. Peak land drainage normally occurs in late February through March (Witherspoon, 1971). During this spring thaw, large quantities of silt and sediments are transported along with the heavy volume of water draining into Lake Erie.

The Lake Erie basin resulted from glacial scour carving Upper Devonian shales. Along the southern shore of the western basin, the Findlay Arch upwarps a rim of lower dolomite, outcroppings of which are visible in the Bass Islands. These bedrock features are evident only as island outcrops and isolated shoreline features. Through the past 10,000 years, fine grained sediments have covered offshore bedrock areas of the western basin to a near level bottom surface (Sly, 1976). A thorough geological discussion of the post-glacial history can be found in Hough (1958).

The western basin of Lake Erie is unique in many respects. It is separated from the central basin of the Lake by a north-south series of islands extending between Point Pelee and Catawba Island (Figure 1). The presence of this cuesta on the eastern margin of the basin, combined with the dominant flow of the Detroit River, generally produces a clockwise current within the basin. The bottom of the basin

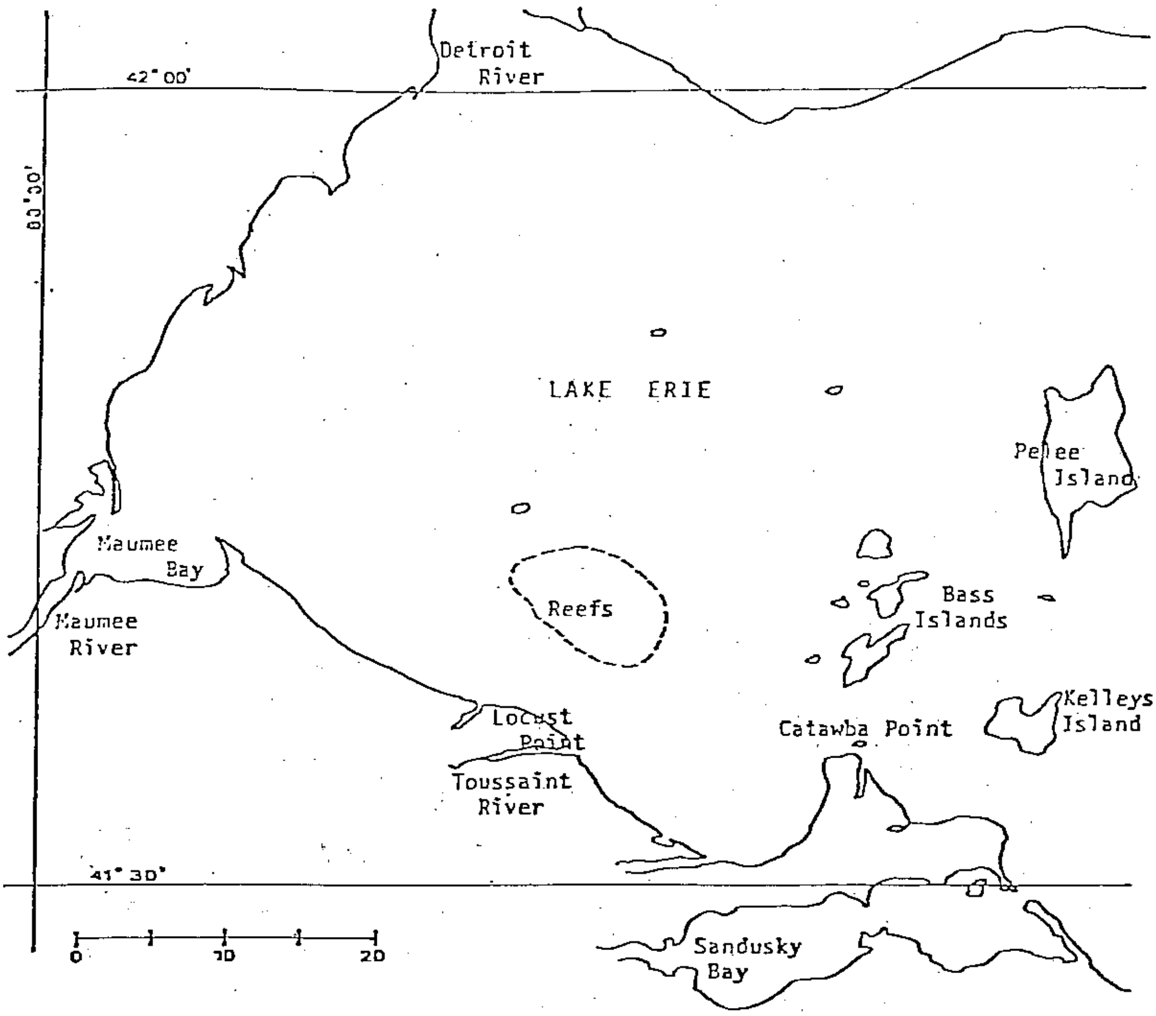


Figure 1. The western basin of Lake Erie.

is primarily a flat mud plain with a maximum depth of 20 meters and a mean depth of 8 meters. It is the shallowest and smallest of the three basins (Upchurch, 1976).

Extensive municipal and industrial influences are exerted on the waters of Western Lake Erie. It has been estimated that as much as 98% of the basin water is used by U.S. industry alone (IJC, 1969a). Heavily populated centers in the Detroit and Toledo areas influence water quality through municipal waste disposal and storm runoff. The combination of extensive cultural inputs and extreme shallowness has resulted in the identification of the western basin of Lake Erie as the most eutrophic portion of the entire Great Lakes basin (Vollenweider et al., 1974; Sly, 1976).

The main source of input into the lake is the Detroit River, which contributes 80% of the total water supply and 93% of the western basin supply (Federal Water Pollution Control Administration, 1964). The Detroit River dominates water quality and flow in the western basin. Any significant decrease in river flow or its water quality could have serious adverse effects on a basin-wide and lake-wide scale.

Maumee River and Bay (C&O Docks)

The Maumee River is considered to be the largest major tributary in the Great Lakes basin, excluding connecting channels such as the Detroit River. It contributes 2.4% of the total water input to the western basin. Lesser contributions to the water supply arise from the Huron, Raisin, Portage and Sandusky Rivers (Monke and Beasely, 1975).

The river is formed by the union of the St. Mary's River and the St. Joseph River at Fort Wayne, Indiana. It flows northeasterly through Ohio to Toledo where it empties into Maumee Bay in the western basin. The estuarine portion of the river extends to Perrysburg, Ohio, approximately 25 km upstream, where the first set of riffles are located. It is a large, warm water river which drains intensively cultivated cropland having low relief (total drainage area: 17,058 sq km; Herdendorf and Zapatosky, 1977). The soils in the drainage basin are formed from lacustrine deposits and glacial till underlain by mostly Silurian and Devonian limestones and dolomites. Bedrocks of sandstone and shale occur, but are less prevalent (Herdendorf and Cooper, 1975).

The average flow into the western basin from the Maumee River is low, approximately 133 m^3/s (ranging from 0.9 m^3/s to 2,662 m^3/s). Despite the low average flow, it has been estimated that 1.8 million tons of fine-grained sediments (silt and clay) are transported into the western basin annually (Yahney, 1978). This amounts to 37% of the total sediment load into Lake Erie (FWPCA, 1964).

The mouth of the Maumee River receives the sum of industrial and municipal discharges from the city of Toledo as well as upstream agricultural runoff. The U.S. Corps of Engineers maintains a navigation channel with a mean depth of 6.8 m from Lake Erie beyond the harbor light upstream to river mile 7.0 at the Anderson grain elevators. Dredge spoil disposal sites are situated on both sides of the channel within Maumee Bay. Toledo's municipal sewage treatment plant is located on the north shore of the river, approximately one mile upstream from the river mouth (Figure 2). Tertiary treatment for phosphorus removal was initiated in 1974 (Reynold Gerson, personal communication).

Maumee Bay is separated from the western basin by two spits: Woodtick Peninsula, which extends southeasterly from the Michigan shore, and Little Cedar Point, extending northwesterly from the Ohio shore (Figure 1). The bottom of the Bay is a broad shelf which gently slopes toward the northeast and has a maximum depth of 6 m. Bottom sediments are primarily composed of lacustrine clay overlain by silt. Sand deposits which were deposited from littoral currents from the southwest predominate near Little Cedar Point (Herdendorf et al., 1977).

The Chesapeake and Ohio (C&O) Docks are located at the mouth of the Maumee River, just west of the Bayshore Power Station (Figure 2). This study site was chosen to detect changes in water quality of Maumee River water entering Maumee Bay and western Lake Erie. Trends in water quality at this site are assumed to identify changes in agricultural, industrial, and municipal usage within the drainage basin.

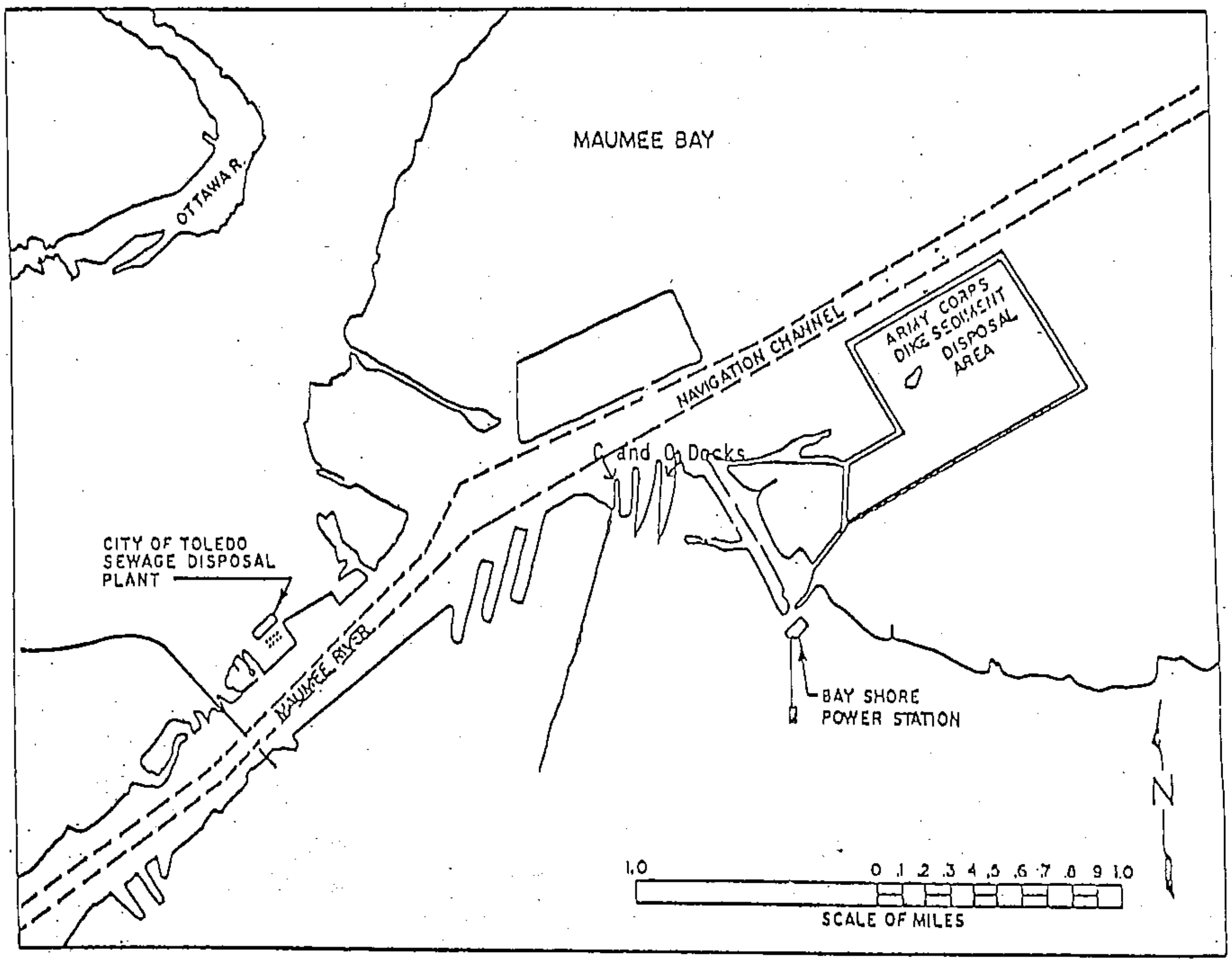


Figure 2. The C and O Docks in relation to Maumee Bay.

Locust Point

Locust Point is located on the Southern Shore of western Lake Erie, approximately 21 miles east of Toledo. It is the site of the Davis-Besse Nuclear Power Station which was built on a 386 ha site in Carrol township, Ottowa County. Locust Point is maintained by diverging littoral currents which carry sand and silt originating from the north through Detroit River flow and from the west through Maumee flow (Reutter and Herdendorf, 1976).

The lake bottom of this area has a gentle slope from shore to about 4,000 ft lakeward. Two sand bars parallel the shoreline at approximately 120 ft and 280 ft offshore. Between the beach and the first sand bar, the lake bottom contains a thin layer of silt and shells over sand. Lakeward from the sand bars a medium to fine-grained sand bottom extends to 800 ft offshore. Here a 500-700 ft wide strip of hard clay is found followed by a sand and gravel bottom until the rocky reefs are reached about three miles offshore (Reutter and Herdendorf, 1976).

This particular site was chosen due to its nearshore location. Monitoring programs in the nearshore zone are likely to identify problem areas indicative of degredational trends within the lake. On the other hand, nearshore regions are likely to reveal positive changes as a result of remedial measures before such changes are observed in the open lake.

METHODS AND MATERIALS

Site Selection

The Locust Point and C&O Dock sites were chosen from eight sampling sites located along the south shore of Lake Erie. Data were retrieved for all eight stations from the Environmental Protection Agency's STORET data base storage system. Simple linear regressions were performed on raw data at each site; the sum of which might be indicative of overall lakewide changes (Rush, 1981). Data from the Locust Point site and the mouth of the Maumee (C&O Docks) were secured independent of the STORET system. Data for Locust Point were received from Toledo Edison Company (TECO) and CLEAR technical reports while data from the C&O Docks were received from Toledo Pollution Control Agency (TPCA) (E. Russell, personal communication). The in-depth analyses presented in this thesis include only those performed on original data (i.e., non-STORET sources) from the C&O Dock and Locust Point sites for one or more of the following reasons:

(1) The data in the STORET system appear, on occasion, to be of dubious quality. Comparisons of STORET data and original data from lab bench sheets supplied by TECO and TPCA personnel did not correspond for many parameters. Sources of discrepancy between the two data bases may be attributed to

excessive handling upon entry.

(2) Comparable periods of record did not exist for all sampling sites in the STORET file. In addition, periods of record for given parameters were often inconsistent at any one site.

(3) Data were often collected at irregular intervals, daily, weekly, or monthly, thus making blocking techniques used to smooth variation extremely difficult.

(4) Methodologies used in analyses often were not consistent during periods of record for which data are stored. Variation in the data due to these types of changes is often difficult to evaluate on a long-term scale.

STORET data were not used in this analysis because they contain multiple sources of entry error not found in original data. Water quality data from the C&O Docks and Locust Point were collected at regular intervals and were consistent in analytic procedure over the period of record. This consistency in sampling and analytic procedure coupled with original entry into The Ohio State University computer system serves to minimize error sources present in other data bases.

Original data used in this analysis can be found in the Center for Lake Erie Area Research Library System.

Sampling frequencies and techniques

Locust Point. Studies of the aquatic environment in the vicinity of Locust Point were initiated in 1974 to evaluate the impact of unit operation of the Davis-Besse Nuclear Power Station. Eighteen water quality parameters were sampled at monthly intervals during the ice-free periods by Toledo Edison Company (TECO). Both surface and bottom samples were collected at three stations (Figure 3). Station 1 (41°37.3'N, 83°15.7°W) was chosen as a control due to its eastern location (i.e., down current from outfall or intake). Station 8 is located directly above the intake pipe for the power plant and is located approximately 3,000 ft from the shore (41°36.0'N, 83°07.4'W). Station 12 is situated above the outfall, approximately 1,000 ft from shore (41° 37.8'N, 83°07.4'W). Techniques and procedures used for analyses throughout the sampling period are listed in Table 1.

Actual plant operation was limited during the sampling period; only four sampling dates coincided with power generation (Table 2). Appraisal of the power plant's impact on the aquatic ecosystem in the vicinity of Davis-Besse showed no diffference in most parameters due to unit operation (Herdendorf and Reutter, 1980). Magnesium concentration was the only parameter which indicated a significant difference between preoperational (before 1977) and postoperational periods. Noted increases of magnesium, however,

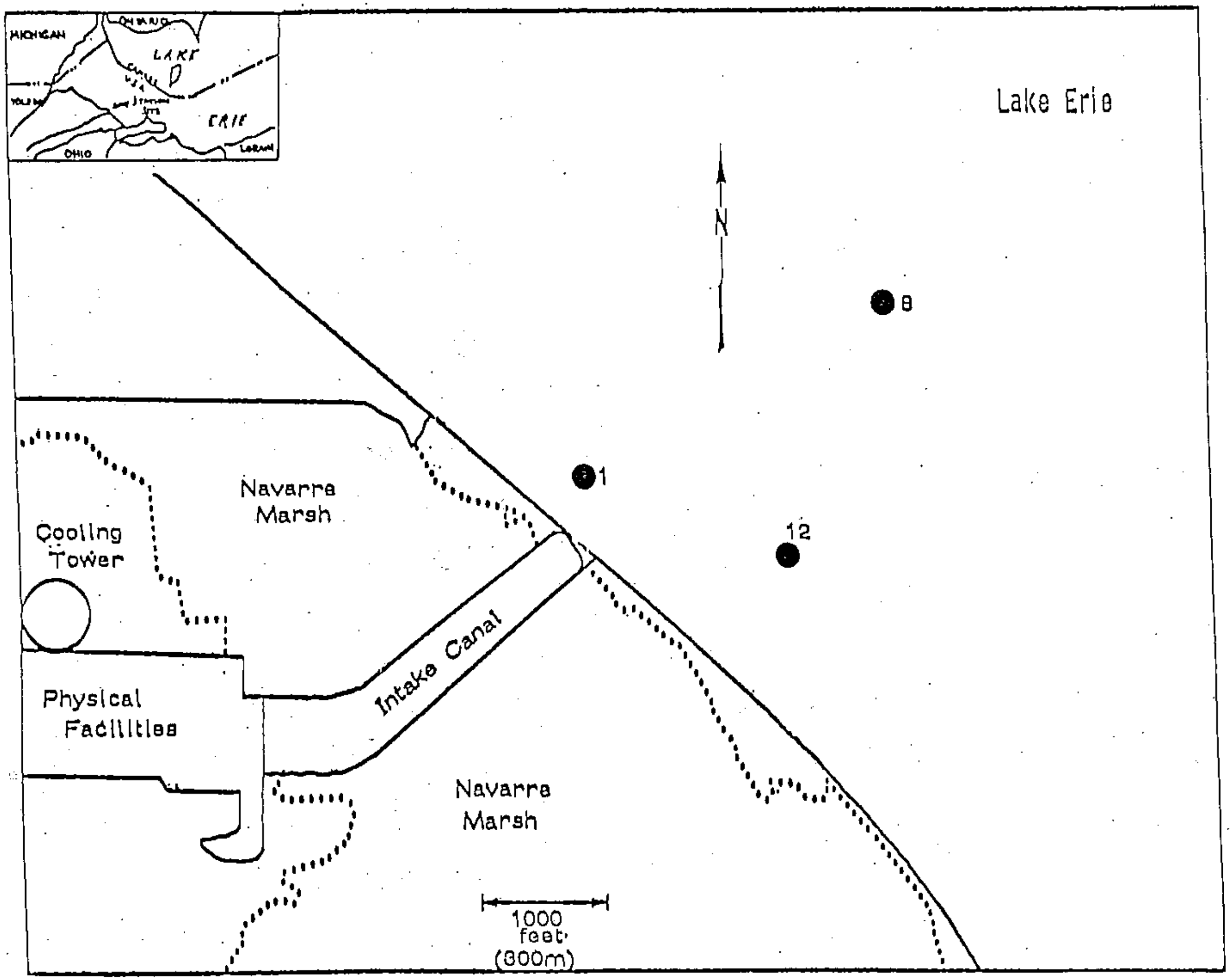


Figure 3. Water quality stations near the Davis-Besse Nuclear Power Station at Locust Point.

TABLE 1. Analytical methods for water quality determinations at Locust Point (1974-1980)

Parameter	Units	Source	Analytical Method
Dissolved Oxygen	mg/l	APHA*	Azide Modification
Conductivity	umhos/cm at 25°C	ASTM+	Field and Routine Lab measurements
Calcium	mg/l (Ca)	APHA*	EDTA Titrimetric Method
Magnesium	mg/l (Mg)	APHA*	Magnesium by calculation
Sodium	mg/l (Na)	ASTM+	Flame Photometry
Chloride	mg/l (Cl)	APHA*	Mercuric Nitrate Method
Nitrate	mg/l (NO_3)	ASTM+	Colorimetric with Brucine-Sulfanilic Acid
Sulfate	mg/l (SO_4)	ASTM+	Volumetric method
Phosphorus	mg/l (Total as P)	APHA*	Ascorbic Acid method
Alkalinity	mg/l (Total as $CaCO_3$)	APHA*	Acid titration
Suspended Solids	mg/l	APHA*	Non Filterable Residue Dried at 103-105°C.
Dissolved Solids	mg/l	USEPA#	Filterable Residue Gravimetric, Dried at 180°C.
Turbidity	F.T.U.	APHA*	Nephelometric method

+ ASTM= American Society of Testing and Materials
* APHA= American Public Health Association
# USEPA=United States Environmental Protection Agency

TABLE 2. Power level and percent full power of Davis-Besse Nuclear Power Station during sampling dates

Year	Month	Sampling Date (Gregorian)	Daily Avg. Power Level (MWe-net)*	Percent Full Power (MWe-NetX.115)+
1977	May	146	0	0.0
1977	June	173	0	0.0
1977	July	194	0	0.0
1977	August	242	0	0.0
1977	September	255	0	0.0
1977	October	298	0	0.0
1977	November	326	73	8.4
1978	May	131	0	0.0
1978	June	180	0	0.0
1978	July	206	0	0.0
1978	August	299	0	0.0
1978	September	256	799	91.9
1978	October	290	0	0.0
1978	November	305	0	0.0
1979	April	120	0	0.0
1979	May	144	0	0.0
1979	June	172	0	0.0
1979	July	212	870	100.0
1979	August	241	870	100.0
1979	September	270	0	0.0
1979	October	303	0	0.0
1979	November	332	0	0.0

* net megawatt

+ net power multiplied by .115

may be due to a nearshore trend phenomenon rather than unit operation.

The C&O Docks. Beginning in 1970, the Toledo Pollution Control Agency (now called the City of Toledo Division of Water Reclamation Laboratory) collected and analyzed surface grab samples from the C&O Docks in the mouth of the Maumee River for surveillance purposes (41°41'46.0"N, 83°21'29.9"W, Figure 2). Samples were collected at approximately weekly intervals from January, 1970 through December, 1979. Although several winter samples throughout the period of record were missed due to extensive ice cover, periodicy of sampling remained fairly regular. Methods of analyses remained constant throughout the period of record and are listed in Table 3.

Selection of parameters for analysis (general limnological considerations)

Of the seventeen physical and chemical water quality parameters analyzed from the C&O Docks and eighteen at Locust Point, nine parameters were selected for analysis and discussion due to several factors. Selection was based primarily on qualities that would characteristically describe general water chemistry; the basic components of which underlie all subsequent biological processes within an aquatic system. Specific parameters were chosen that would ade-

TABLE 3. Analytical methods for water quality determinations at the C&O Docks (1970-1979)

Parameter	Units	Source	Analytical method
Dissolved Oxygen	mg/l	APHA	Azide Modification
Conductivity	umhos/cmat 25°C	APHA	Conductivity Meter
Chloride	mg/l (Cl)	APHA	Mercuric Nitrate Method
Nitrate	mg/l (NO_3)	APHA	Brucine Method
Phosphorus	mg/l (Total as P)	APHA	Ascorbic Acid Method
Alkalinity	mg/l (Total as $CaCO_3$)	APHA	Acid Titration
Suspended Solids	mg/l	APHA	Non-Filterable Residue Dried at 103-105°C
Dissolved Solids	mg/l	APHA	Total Filterable Residue Dried at 180°C.
Turbidity	JTU	APHA	Visual Methods

APHA = American Public Health Association quately describe changes due to sediment loading, nutrient loading, changes in dissolved substances and buffering capacities. Selection was also based on those parameters which were common in analyses to both study locations. A brief summary of general limnological significance of each water quality parameter is described below.

Conductivity. Conductance is defined as a measure of the ability of a solution to conduct a current (Sawyer and McCarty, 1978). It is influenced by ion activity which is directly proportional to ionic concentrations. Cations in cultural effluents require an anion in order to maintain electrical neutrality (Upchurch, 1976). Niney-eight percent of conductance in Lake Erie has been estimated to consist of six principal anions and cations: chloride, bicarbonate, and sulfate; and calcium, magnesium, and sodium (Don, 1981). Concentrations of these species in solution are influenced primarily by wind disturbances, runoff, discharge, and biological activity (Poulton and Palmer, 1973).

Conductivity values vary with water temperature. All values reported are thus corrected to 25°C. It has been estimated that the error involved in the actual calculation of specific conductance at 25°C from a sample which was measured at some other temperature is slightly greater than 2% (Don, 1981).

Chloride. Chloride in lake water is conservative, not being subject to decay or biological degradation. In addition, chloride ions do not combine with other aqueous or solid phases and are not removed from the system by precipitation, adsorption, metabolic processes, or chelating (Upchurch, 1976). This implies that the mass balance of chloride in Lake Erie is relatively straight forward; the sum of inputs minus outputs must equal the amount of change of material within the lake, either by changes in loading rates and/or lake levels.

Chlorides in Lake Erie originate from a variety of sources. Salt deposits under the Detroit-Windsor area were discovered and tapped around the turn of the century (Pound, 1940; Eskew, 1948). Salt brine provides the basic raw materials for the production of soda ash and other alkali products. Industry alone is responsible for 60.2% of the chloride input into the western basin. Other contributions arise from the upstream watershed (i.e., the Detroit River, 23.4%), salt for deicing purposes, 8.4%, and non-point sources, 7.8%. Human waste contributes only 0.9% of the total input (Ownby and Kee, 1967).

Although adverse biological effects of high chloride levels have not been fully established, it is estimated that the following critical levels could be deleterious to specified beneficial water uses (McKee and Wolf, 1963):

domestic water supply	250 mg/l
irrigation	100 mg/l
industrial uses	50 mg/l

Thus it is essential to monitor chloride concentrations to evaluate rates of increase in Lake Erie. Contamination through a severe rate increase could ultimately cause serious impairment to the uses of lake water.

Total dissolved solids. Total dissolved solids is the amount of dissolved material in natural waters. It is comprised mostly of carbonate, sulfate, calcium, magnesium and chloride compounds with smaller contributions from nitrogen and phosphorus (Larkin & Northcote, 1958; Welch, 1980). It is related to conductivity by a factor of 0.5 to 0.9 depending on ionic strength of the solution but are commonly estimated by multiplying specific conductance by 0.65 in Great Lakes waters (Great Lakes Basin Commission, 1976).

A significant portion of the present total dissolved solids levels of the Great Lakes is the result of natural chemical equilibria between the water and sediments (Kramer, 1964). Total load of dissolved solids is derived from dissolution of minerals in the drainage basins and cultural inputs from municipal, industrial, and rural waste discharge (Hasler, 1947).

Increases of total dissolved solids have been reported for Lake Erie from 1915 to 1965 (IJC, 1969a) but the build-up to 1965 values was not in itself a serious problem. It did, however, indicate large accumulations of materials. The International Joint Commission objective of 200 mg/l for Lake Erie is based on a philosophy of maintaining non-degradation but does not comply with the definition of a specific water quality objective as the level of a substance which will provide for and protect a designated water use (IJC, 1975a).

The toxicity of dissolved solids to freshwater aquatic life is that level which has an osmoconcentration equal to the body fluids of the organism. The range of environmental osmotic conditions tolerated by animals is great, whereas the tolerated range of internal osmotic conditions is much less. Niney-six hour mean toxicity threshholds range from 3,710 mg/l TDS in Dapnia to 23,000 mg/l TDS for cyprinids. Lower levels of dissolved solids may interfere with reproductive capabilities. Fathead minnows (Pimephales promelas promelas) did not exhibit spawning behavior at levels of 2,000 mg/l (Prosser and Brown, 1966).

Turbidity and suspended solids. The major limnological significance of turbidity and suspended solids lies in their limiting effect upon water transparency or light penetration. The amount of light entering an aquatic system is a fundamental factor governing production and distribution of phytoplankton, which in turn is responsible for zooplankton and ultimately fish populations (Pinsak, 1967).

It has been estimated that suspended solids and turbidity are directly related by a factor of 0.92 (Kemp, et al, 1976). In addition, turbidity correlates positively with total solids but varies somewhat inversely with phytoplankton (Weiler and Heathcote, 1979). It has been demonstrated that turbidity in Lake Erie above three Jackson Turbidity Units (JTU's) are not caused by high phytoplankton densities (Burns, 1976a). Turbidity, then, is chiefly due to resuspension of inorganics during storm events, shore erosion, or loading from rivers.

Turbidity varies somewhat seasonally, but variation in values are more often attributed to changes in climatic conditions (e.g., storm events). The seasonal variation exhibited in western Lake Erie is most likely due to weather associated with seasonal changes (Chandler, 1940).

Alkalinity. Alkalinity is defined as the capacity of a solution to neutralize acids; thus it serves as an indirect measure of a water's buffering capacity (Snoeyink and Jenkins, 1980). Major chemical species contributions to alkalinity are bicarbonates (HCO_3^-), carbonates (CO_3^{-2}) and hydroxide (OH^-). These species result from dissolution of basin materials, such as calcite and dolomite, which predominate throughout Lake Erie.

Since most aquatic organisms are acclimated to a specific pH range, the buffering ability of natural waters is important in preventing large or rapid changes in pH. Alkalinity itself has no harmful or toxic effects on aquatic organisms. Instead, it protects aquatic organisms from deleterious pH changes and reduces the toxicity of some poisons (Reid, 1961).

Hydrogen ion concentration is largely responsible for chemical species composition of alkalinity. Below pH 8.3, total alkalinity is due almost entirely to bicarbonate ions. Since the mean pH of Lake Erie ranges from 7.5-8.4 (Robertson et al., 1974), bicarbonate concentration is presumed to be solely responsible for alkalinity values (Sawyer and McCarty, 1978). Due to the basin substrate, Lake Erie has a typically high alkalinity content and thus is able to buffer small pH decreases which may be occurring from increased acid precipitation.

Dissolved oxygen. A major water quality indicator, dissolved oxygen is probably one of the most important chemical substances in natural waters (Reid, 1961). It is essential to most forms of aquatic life and its concentration often determines species composition in a system. It is also directly responsible for many chemical processes in an aquatic environment. Dissolved oxygen enters water by diffusion from the atmosphere or photosynthetic activity and is removed by respiration of aquatic organisms and by oxidation of inorganic matter. It is of primary concern in the central and eastern basins, where summer hypolimnetic depletion has resulted in anoxia (Charlton, 1980). Since stratification is uncommon in the western basin, (especially in the nearshore zone and at the Maumee River mouth), oxygen depletion is expected near the sediment-water interface only during prolonged calm periods.

Nitrates and nitrogen compounds. Nitrogen is a nutrient that, in excess quantities and providing no other nutrient is limiting, stimulates aquatic growth and accelerates eutrophication. The atmosphere, 80% of which is nitrogen, supplies a ready source to aquatic systems. This source is not usually assimilated directly by aquatic organisms but can be converted to nitrogen compounds by certain bacteria and algae, if aquatic concentrations are depleted. Since it is readily available, nitrogen is not considered to be a limiting factor for organic growth in an unpolluted system (Dobson, et al., 1974).

Nitrogen usually enters a lake in the form of nitrates, nitrites, ammonia, and organic compounds. These compounds originate from a variety of natural sources including drainage and precipitation. Contributions from farm fertilizers, manure, industry, and organic wastes from municipalities add to the total nitrogen load (Brezonik, 1972).

The nitrogen cycle is largely biological. Inorganic nitrogen is present as highly oxidized nitrate (NO_3^-) and nitrite (NO_2^-) or reduced molecular nitrogen (N_2) and ammonia (Allen and Kramer, 1972). Nitrate tends to be the predominant form in surface waters and is the preferred form for uptake by vascular plants. There is considerable evidence that ammonia is the preferred form for assimilation by plankton, since it is already at the reduction level of organic nitrogen (Feth, 1966).

Considerable seasonal variability exists for nitrogen compounds. In spring months, high concentrations of nitrites and nitrates are carried into the western basin of Lake Erie via spring runoff (Burns, 1976a). During the summer months, nitrates and nitrites found in the water column are low due to assimilation by organisms. In fall, nitrogen levels rise as dead and decaying organic matter release nitrogen compounds back into solution. On the other hand, relatively small seasonal variations exist for ammonia. This can be attributed to rapid oxidizability of this compound and preferred uptake of ammonia by plankton (Snoeyink and Jenkins, 1980).

Critical levels of inorganic nitrogen have been calculated to be about 0.3 mg/l by several researchers (Sawyer, 1967; Upchurch, 1976). Above this value, large algal blooms can be expected, provided phosphorus is not limiting. Thus in a system such as Lake Erie where phosphorus is not limiting, increasing nitrate levels may produce algal blooms.

Phosphorus. Phosphorus compounds are perhaps the most important parameter when discussing lake eutrophication. The only natural source of phosphorus into an aquatic system is weathering of phosphatic rock. Approximately 95% of this rock is in the apatite form, which is highly insoluble and settles quickly (Burns, 1976b). Thus in undisturbed systems, phosphorus is limiting and is assimilated as soon as it becomes available. Phosphorus is then conserved in the food chain as it cycles from producer to consumer to decomposer and eventually back to producer (Welch, 1980).

In a system highly influenced by cultural inputs, such as Lake Erie, phosphorus enters the system through industry, agriculture, and most importantly, municipal waste. Sewage and detergent uses may contribute up to 60% of the total phosphorus inputs into Lake Erie (Bouldin, et al, 1976). Lesser contributions arise from agricultural and land runoff (30%). The remaining inputs are derived from erosion (Baker and Kramer, 1973).

Total phosphorus is the sum of all forms of suspended, dissolved, and adsorbed phosphorus. The significance of total phosphorus lies in its ability to convert to soluble forms which are most readily incorporated into plant biomass (Reid, 1961). Several factors affect which forms of phosphorus are predominant. It has been estimated that as much as 80% of the phosphorus entering Lake Erie is sedimented within the basin (Burns and Nriagu, 1976). This sedimented phosphorus supplies a ready source of soluble forms for utilization through resuspension. High pH and low oxygen concentrations near the sediment-water interface also aid in the release of these compounds into solution (Berg, 1958). Rising lake levels increase insoluble forms by increasing the surface area of water-exposed rock (Dobson, 1981).

The western basin has an extremely high elimination coefficient for phosphorus and large continuous inputs of this element are required to maintain phosphorus at observed levels (Burns and Ross, 1972). If phosphorus inputs into the Lake are reduced from present amounts of 41,000 metric tons per year (Burns, 1976b) to 14,600 metric tons per year as planned (U.S. Department of State, 1972), the western basin would respond rapidly with concentrations of phosphorus decreasing with time. A decrease of this magnitude may result in non-apatite phosphorus loadings near the pre-1850 values (Burns, et al, 1976). Control of inputs is economically feasible through sewage treatment and phosphate bans on detergents. Secondary sewage treatment removes only 20% of phosphorus present in municipal waste, while tertiary treatment is capable of 75-90% removal (Charlton, 1980). A detergent ban imposed on New York inland waters resulted in a reduction of 50-60% in effluent phosphorus (Bouldin, et al., 1976).

Phosphorus control has sparked a great deal of debate in the last decade. The charge has been made that phosphorus has been simplistically isolated as a single causal factor to eutrophication in a highly complicated system (Weaver, 1969). However, whole-lake experiments of oligotrophic lakes by Schindler and Fee (1974) showed that control of phosphorus alone appears to be the sole realistic strategy in controlling lake eutrophication. In a series of fertilization experiments, increases in nitrogen or organic carbon showed no significant increases in algal abundance or composition, while phosphorus levels and algal abundance showed a significant positive correlation.

Phosphorus levels may also determine species composition. It has been demonstrated that increased phosphorus loading in the Great Lakes not only result in increased phytoplankton growth, but also depleted silica, which, in turn became limiting. Continued silica depletion may cause a change from diatom predominance to blue-green algal predominance (Lin and Schelske, 1981).

Statistical procedures

Several problems arise when dealing with long-term nearshore data sets. The most difficult problem arises due to the extreme degree of temporal variability. Seasonal fluctuations tend to mask long-term trends because they increase overall variance. This effectively decreases the achieved statistical significance when testing for trend (Weiler and Heathcote, 1979). Furthermore, a normal distribution has been shown to be atypical of the behavior of diverse water quality parameters. Non-normal distributions result from the effect of physical factors such as wind, lake currents and variable loadings (Palmer and Sato, 1968). In addition, non-normal distributions may result when two or more factors are primarily responsible for observed variation, such as temperature affecting dissolved oxygen and biological effects on nutrients.

The central limit theorem of parametric statistics states that almost regardless of the shape of the original population, certain statistics, most importantly, the arithmetic mean, tend to be normally distributed as sample size (N) becomes large (Richmond, 1957; Wallis and Roberts, 1956). Thus, a distribution of means approaches that of a normal distribution as N approaches infinity.

Overall sampling and analytical errors add to the total variance. These sources of variation are often difficult, if not impossible to identify, especially within the context of extreme variability due to limnological nearshore conditions. Richards (1980) found that the overall sampling and analytical errors are not large enough to mask small scale limnological differences in the water masses of Lake Erie. This was evidenced by the fact that replicate sample differences analyzed by the same laboratory were generally greater than split differences of one sample analyzed by separate labs. Consequently, these relatively small variations are not considered to have a significant effect on reported findings.

Data from the Locust Point site and the Maumee Bay site were entered on disk using the Center for Lake Erie Area Research Computer Data Center (CDC). The tapes of these data were then transferred to the Amdahl (470/V6) computer at The Ohio State Instructional and Research Computer Center where most of the analysis was conducted through standard programs produced by the Statistical Analysis System (SAS, version 79.5; Barr, et al, 1976).

Differences between surface and bottom samples collected at Locust Point as well as station differences were tested for significance through analysis of variance. No significant difference ($P<.05$) was found for any parameter between depths or stations. Consequently, all data were pooled to enhance statistical significance.

Monthly means from both study locations were generated and linearly regressed through time. The slope of the line was tested for two levels of significance ($P<.05$ and $P<.10$) using an F-Test. The F-statistic is derived by dividing the model mean square by the error mean square. Student's t-tests (testing of means) were not used due to the large number of tests that would be required. A greater number of statistical tests performed to achieve a single result increases the likelihood of producing Type-I errors, i.e., rejecting the null hypothesis (the slope is not statistically different from zero), when it should not be rejected (Steel and Torrie, 1980).

In order to test for linearity of the data, the residuals of the regression line were calculated and plotted through time for parameters exhibiting a significant change. A relatively wide band of residuals indicate that the variability in the data is constant with respect to time. Although this is not a definitive test against a quadratic or cubic factor, it does provide some evidence for linearity (Draper and Smith, 1966).

Smoothed trend curves were constructed and superimposed on the linear model. These curves were constructed through a method of averaging yearly means (Dobson, 1981). Means were plotted at yearly intervals beginning at the six month point (i.e., six months, 18 months, 30 months, etc.). The averages of adjacent pairs of means were calculated and plotted. Adjacent pairs of smoothed values were then averaged again. This process provides points at three month intervals creating a somewhat detailed curve.

Aggregation of the data into relatively large time periods tends to homogenize the effects of process variables at work in the nearshore zone. Yearly means were calculated in order to achieve maximum coefficients of determination. The coefficient of determination is defined as the square of the correlation coefficient - the amount of variability in selected parameters explained by the independent variable (in this case, time). Yearly means and their standard deviations were then plotted and tested for trend. In addition, smoothed trend curves were constructed using a similar technique as that for monthly means.

Due to the fact that samples were not collected at the Locust Point site during winter months, sampling was initiated on different dates in the spring in successive years. Earlier spring samples are normally higher in value due to runoff than samples collected at later dates. This provides an additional source of variation not found in the continuous sampling program at the Maumee River mouth site. In order to qualify this source of variability, as well as homogenize seasonal components, the annual cycle was separated into seasons, selected on a basis of average annual water temperature fluctuation (Figure 4). The winter season is omitted from the Locust Point analysis because data was not collected during that time. Yearly means were plotted for each season and regressed through time. Trends are then assessed by season.

Percent contribution of major ions comprising conductivity for 1979 values was plotted against the previous findings of Weiler and Chawla (1968). Percentages were calculated by dividing each contributing concentration by the sum of the three major cations and anions (magnesium, calcium, sodium, bicarbonate, chloride, and sulfate). Excluding bicarbonates, ionic species were sampled at the Locust Point site only. Consequently, the Maumee Bay site was not included in the anlaysis. Bicarbonates were assumed to be the sole contributor to alkalinity, since the mean pH was below 8.3. Any alkalinity due to carbonates or hydroxide ions that may have been present were assumed to be negligible. Thus, the contribution to total conductivity

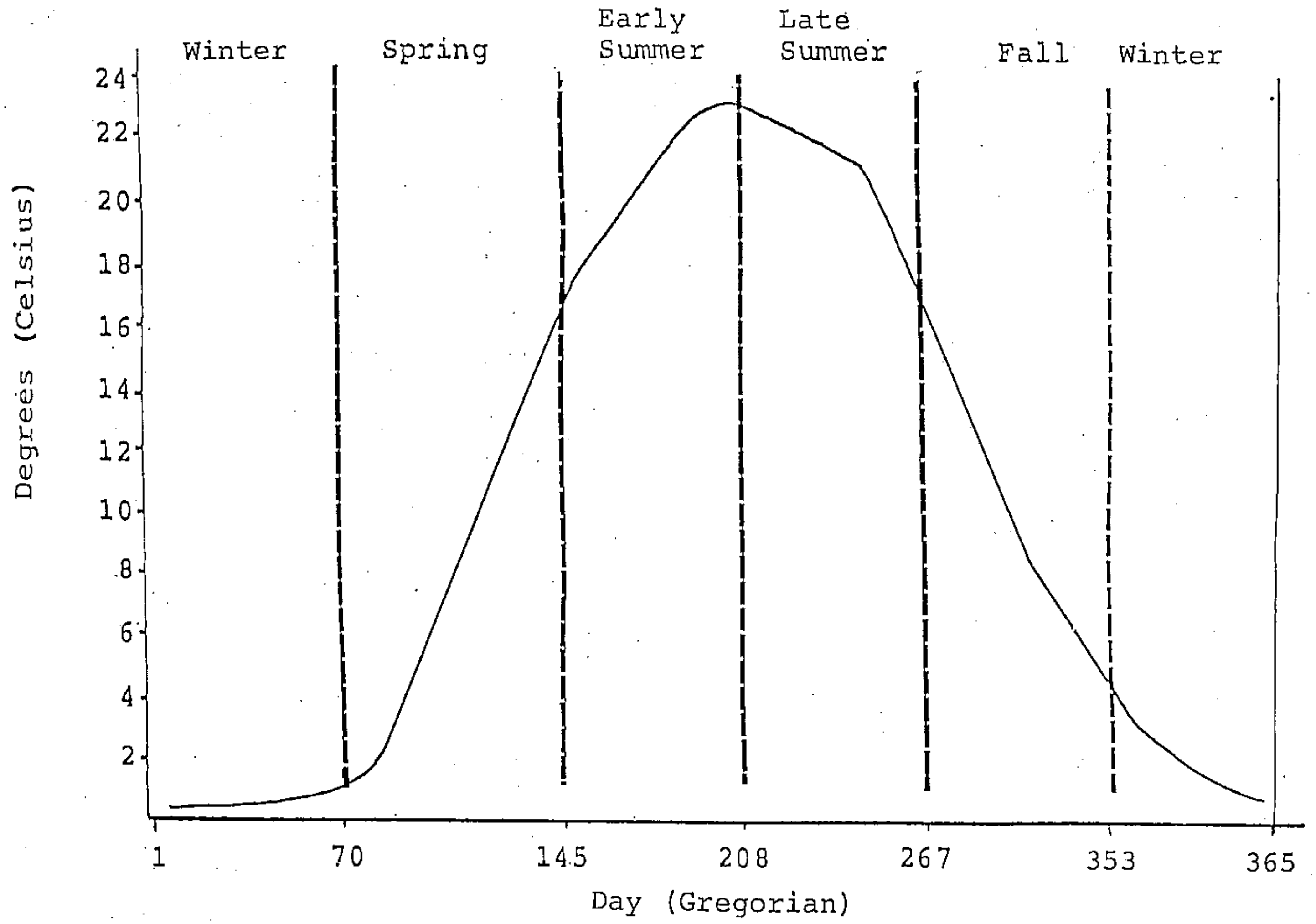


Figure 4. Average seasonal water temperature fluctuation in western Lake Erie (1974-1980).

from bicarbonates were calculated directly from alkalinity values.

Trends in water quality parameters were summarized for both locations by reporting trends of yearly means as a percent change per year. In this way, all parameters can be visually inspected on one figure. Confidence intervals of 95% and 90% were constructed around this percentage value. If the confidence interval crosses the zero change line, it can be assumed that neither increase nor decrease of the parameter trend is significant at the given significance level (Polak, 1978).

Weather activity influences certain parameters, such as turbidity, suspended solids and phosphorus through resuspension. In order to quantify this influence, concentrations of these parameters were regressed against mean monthly wind velocity (mph) at Toledo airport (National Oceanic and Atmospheric Administration, 1974-1980). A positive correlation suggests that weather activity is responsible for observed changes in the parameters which may be occurring in the nearshore zone of western Lake Erie.

RESULTS

Locust Point

Monthly means. Regression analysis performed on monthly means at the Locust Point site indicated that a significant change occurred from 1974 to 1980 for nitrate at $P < .05$ (Table 4). Figure 5 graphically depicts an increase from 2.4 mg/l in 1974 to 7.5 mg/l in 1980. Although the linear regression line is significant at the .05 level, the coefficient of determination (R^2) is rather low (Table 4), indicating a large source of variability is not explained by time in months. Visual inspection of Figure 5 reveals large seasonal variation in the data. High values occur early in the sampling period for each year, are generally depleted in the summer months and increase again in the fall.

A residual plot of the linear regression for nitrate (Figure 6) indicates that a rather wide band exists for these values. Extreme values of residuals are evident in 1977,1978, and 1980, due to the high spring values occurring in those years.

The smoothed trend curve superimposed on the regression line somewhat follows the residual values (Figure 5). A notable increase in nitrate values occurred from 1974 to 1977. From 1977 to 1979, a decrease is observed, followed by an increase from 1979 to 1980 of the same magnitude as

TABLE 4. Statistical values for monthly means at Locust Point (1974-1980)

Parameter	Degrees of Freedom	Slope	R^2	PR>F (Significance of Slope)
Conductivity	55	+0.402[1]	.073	.0543
Chloride	55	0.000*	.000	.9921
Suspended Solids	55	+0.222*	.035	.1647
Dissolved Solids	55	+0.063*	.001	.7798
Turbidity	55	+0.181**	.029	.2095
Alkalinity	55	+0.069*	.051	.0952
Dissolved Oxygen	55	-0.001*	.000	.9331
Nitrate	55	+0.059*	.090	.0249
Total Phosphorus	55	0.000*	.000	.8792

* mg/l/month
** FTU/month
[1] umhos/cm/month

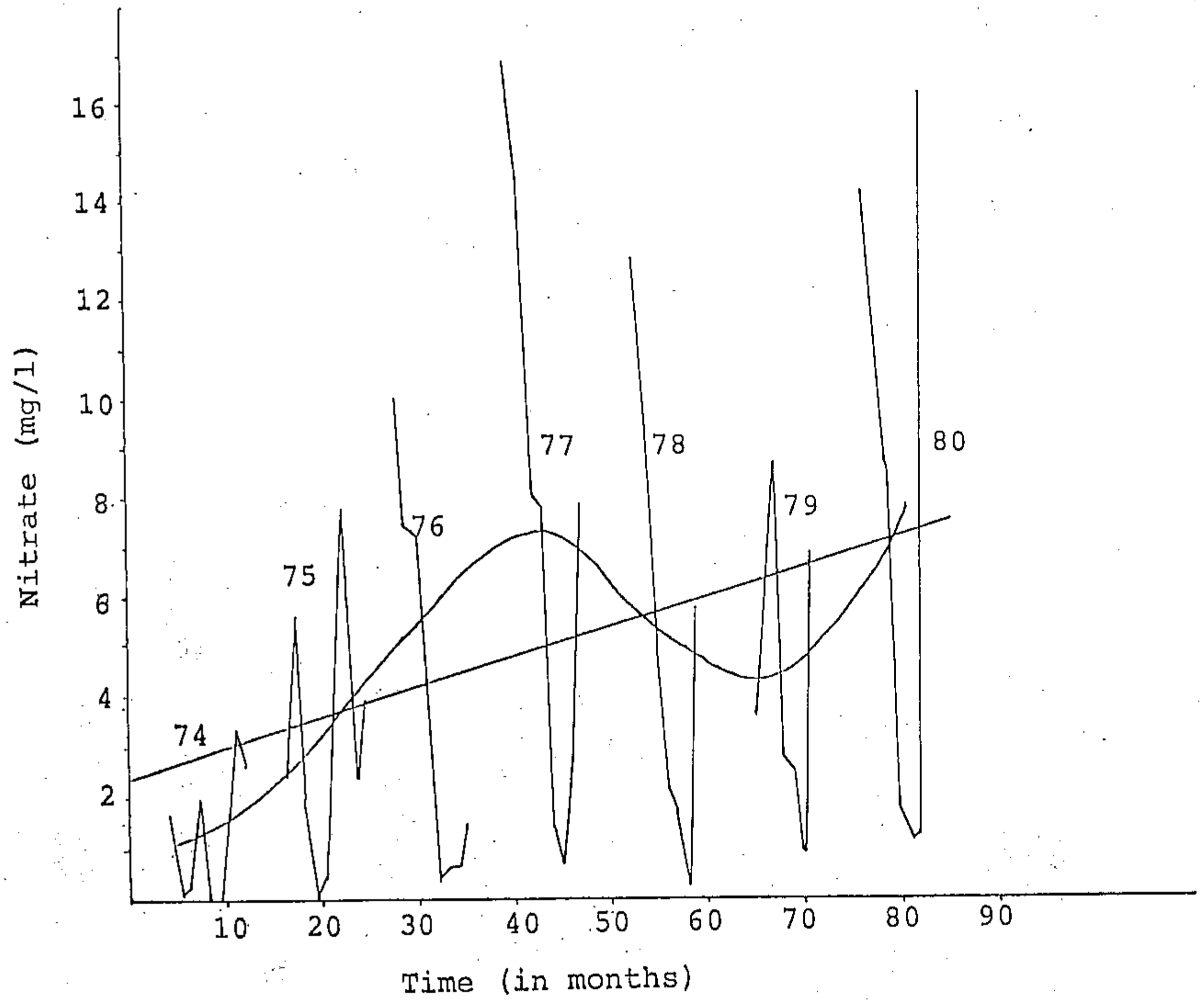


Figure 5. Trends for nitrate monthly means at Locust Point.

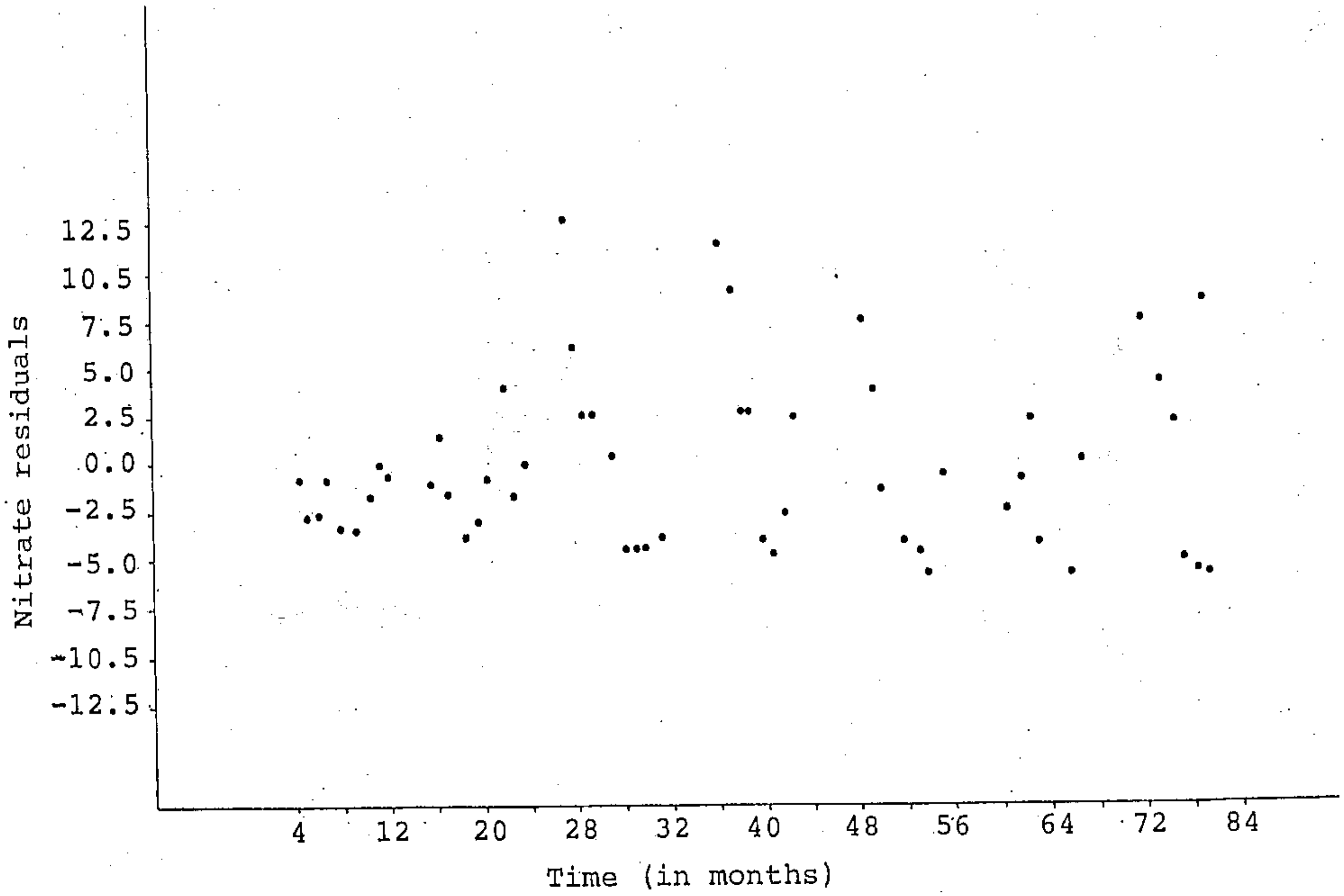


Figure 6. Residuals of the linear regression for nitrate monthly means at Locust Point (1974-1980).

the 1974-1977 increase.

Although not significant at $P<.05$, the linear regression slopes for conductivity and alkalinity are significantly increasing at $P<.10$ (Table 5). These increases amount to approximately 14% from 1974 to 1980 for conductivity and 8.5% from 1974 to 1980 for alkalinity. Again, R^2 values are quite low, indicating a large source of variability is not explained through time.

Yearly means. Calculation of regression equations for yearly means resulted in increases in conductivity, suspended solids, turbidity and alkalinity at the .05 significance level. Figures 7-10 depict yearly means, ranges and standard deviations of these parameters. A significant decrease of $P<.10$ was found for chloride only (Table 5). In addition, significance in the trend for nitrate values at the .05 significance level was lost during yearly averaging, while significance at the .10 level was retained. Inspection of Table 6 in comparison with Table 4 indicates large increases in R^2 values. This is due to homogenizing the large variability through the averaging process.

Figure 7 shows increases in conductivity values from 265 μmohs/cm in 1974 to 304 μmohs/cm in 1980, an increase of approximately 15% over the period of record. The smoothed trend curve follows the regression line fairly well, with the exception of a slight depression occurring

TABLE 5. Comparison of trends using monthly and yearly means at two levels of statistical significance for selected parameters at Locust Point

Parameter	Monthly Means		Yearly Means	
	$\alpha=.05$	$\alpha=.10$	$\alpha=.05$	$\alpha=.10$
Conductivity	0	+	+	+
Chloride	0	0	0	–
Suspended Solids	0	0	+	+
Dissolved Solids	0	0	0	0
Turbidity	0	0	+	+
Alkalinity	0	+	+	+
Dissolved Oxygen	0	0	0	0
Nitrate	+	+	0	+
Total Phosphorus	0	0	0	0

+ = positive trend
– = negative trend
0 = trend is not statistically significant

TABLE 6. Statistical values for yearly means at Locust Point (1974-1980)

Parameter	Degrees of Freedom	Slope	R^2	PR>F (Significance of Slope)
Conductivity	6	+6.325[1]	.764	.0100
Chloride	6	-1.818*	.324	.0985
Suspended Solids	6	+3.53*	.645	.0296
Dissolved Solids	6	+1.638*	.191	.3264
Turbidity	6	+2.984**	.671	.0242
Alkalinity	6	+0.905*	.640	.0307
Dissolved Oxygen	6	-0.069*	.098	.4948
Nitrate	6	+0.787*	.524	.0660
Phosphorus	6	+0.001*	.004	.8955

* mg/l/yr

** FTU/yr

[1] umhos/cm/yr

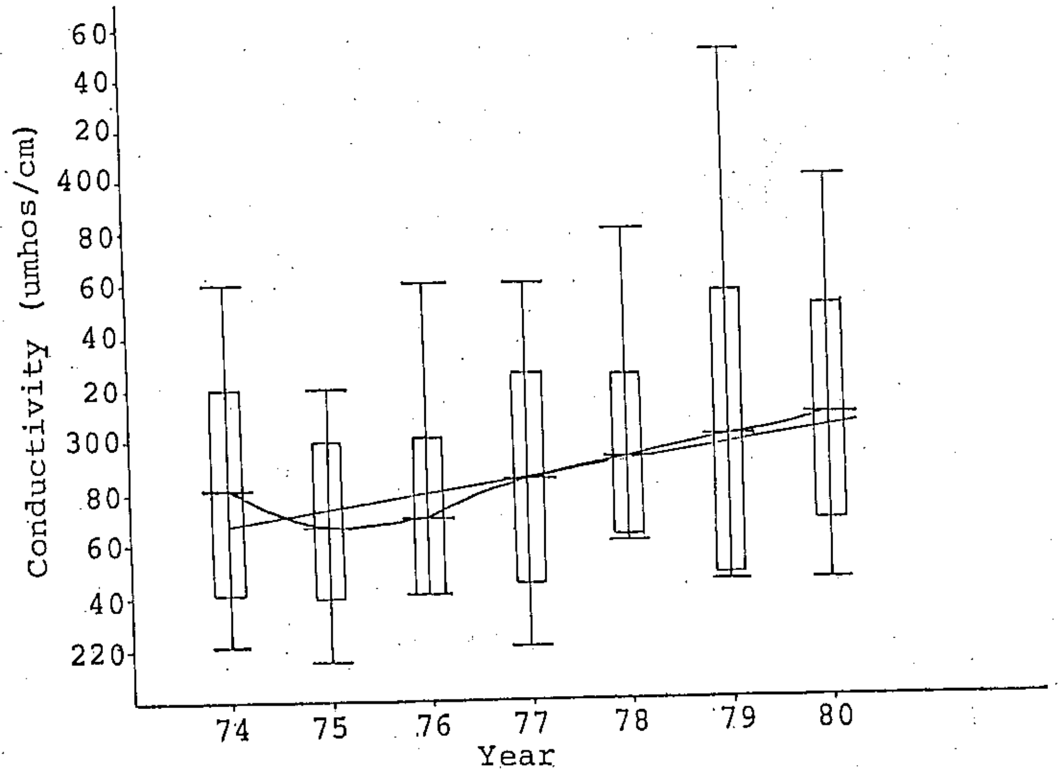


Figure 7. Trends for conductivity yearly means at Locust Point.

in 1975 and 1976. In addition, the R^2 value for this parameter (.764) was the highest among those exhibiting a significant trend.

Figures 8 and 9 depict linear and smoothed trend curves for total suspended solids and turbidity, respectively. These two parameters exhibit similar significance levels, R^2 values, and smoothed and linear curves, suggesting that a rather close relationship exists between them. Total suspended solids increased from 25 mg/l in 1974 to 46 mg/l in 1980, while turbidity increased from 20 to 38 FTU's for the same period of record. Smoothed curves show slight depressions for both parameters in 1975 and slight increased in 1979. However, the curve for turbidity appears to follow the regression line more closely than that for suspended solids, the latter of which exhibits slight increases in 1977 and 1978.

Although a significant increase is not visually evident for alkalinity values (Figure 10), the regression line is significant at the .05 level. In addition, R^2 values are rather high, indicating the observed variability is adequately explained by time. The smoothed trend curve follows the regression line fairly closely, excepting increases in 1976 and 1979 and a slight decrease from 1977 to 1979.

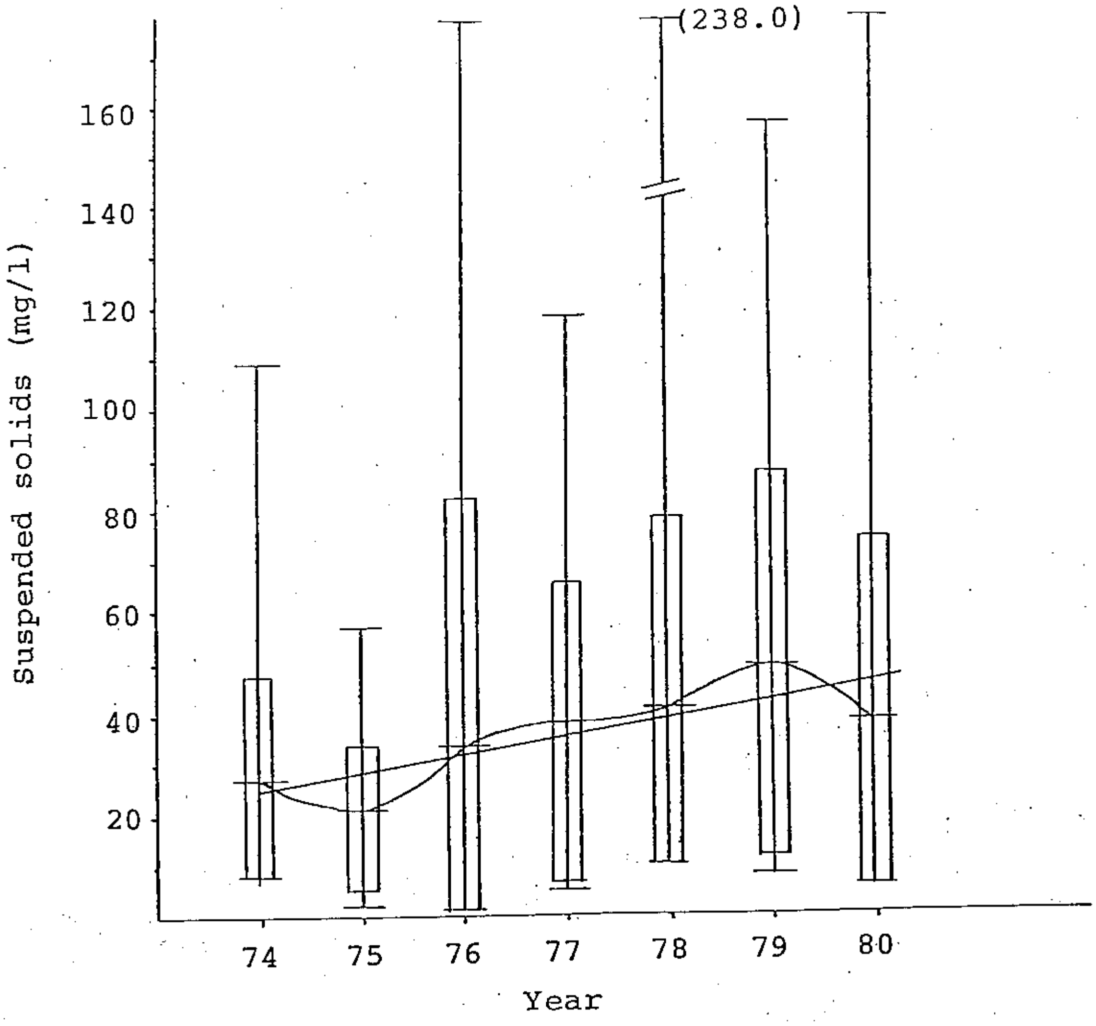


Figure 8. Trends for suspended solids yearly means at Locust Point.

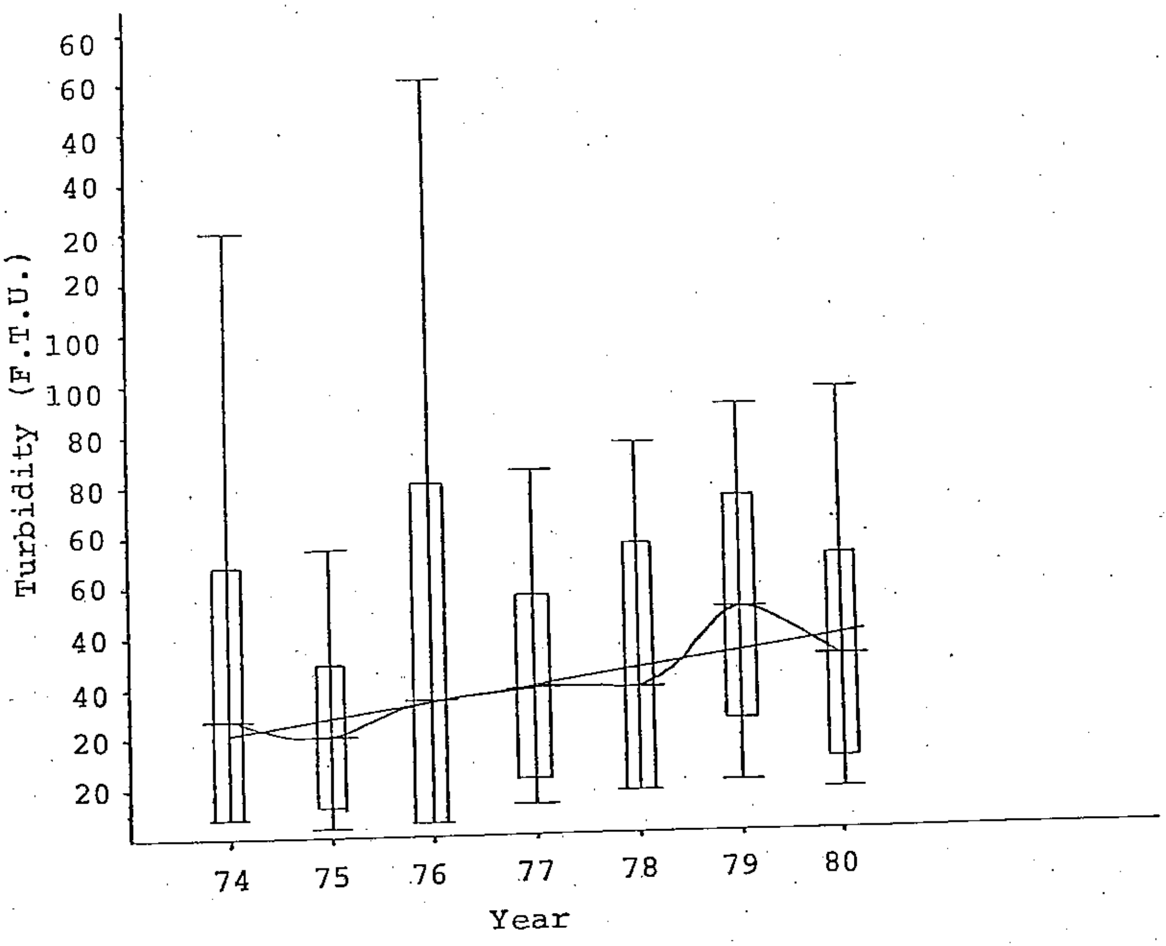


Figure 9. Trends for turbidity yearly means at Locust Point.

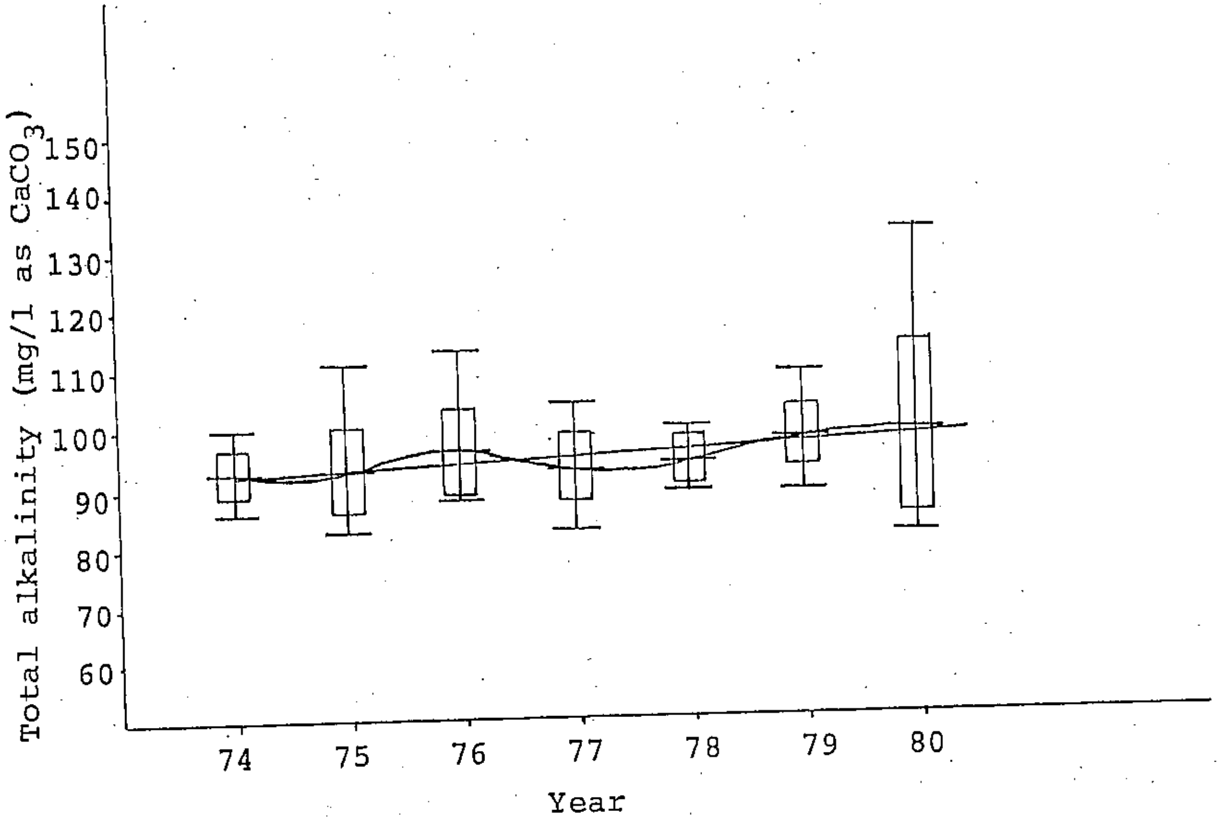


Figure 10. Trends for total alkalinity yearly means at Locust Point.

Seasonal blocking. In an attempt to homogenize seasonal variability, yearly means were blocked by season and regressed through time. Significant statistics for all nine parameters are found in Table 7. Table 8 summarizes these statistics as trends at the two tested levels of significance. Figures 11-16 graphically depict trends for conductivity, chloride, suspended solids, turbidity, total alkalinity and intrate.

It should be noted that the trend plots were constructed on different scales for successive seasons. Since spring values were generally higher for most parameters (with the exception of alkalinity), the y-coordinate was expanded to accommodate differences in ranges.

Significant increases at P<.05 and P<.10 in conductivity values occurred only during spring and early summer seasons. Visually evident but statistically insignificant increases are noted for late summer and fall (Figure 11).

Figure 12 shows trends by seasons for chloride concentrations. Significant increases at both levels occur for spring and fall values while significant decreases occur during early and late summer. This discrepancy is due to the extremely small values reported in 1979. When these values are removed from the regression analysis, the trends reverse and significanntly increase through time. In addition, the slope attained for the fall season is significantly increasing at P<.10 (Table 8).

TABLE 7. Statistical values for seasonal yearly means at Locust Point (1974-1980)

Parameter	Season	Slope	R^2	PR>F
Conductivity	Spring	+8.530[1]	.172	.0106
	Early Summer	+7.160	.221	.0039
	Late Summer	+2.702	.058	.1564
	Fall	+3.028	.007	.1284
Chloride	Spring	+1.031*	.340	.0002
	Early Summer	-0.176	.020	.4059
	Late Summer	-0.527	.165	.0139
	Fall	+0.283	.098	.0626
Suspended Solids	Spring	+5.455*	.132	.0270
	Early Summer	+5.899	.547	.0001
	Late Summer	+1.395	.150	.0196
	Fall	+5.745	.414	.0001
Dissolved Solids	Spring	+0.635*	.065	.4285
	Early Summer	+7.324	.228	.0643
	Late Summer	+2.565	.162	.0916
	Fall	+3.084	.094	.1348
Turbidity	Spring	+3.255**	.099	.0569
	Early Summer	+7.537	.734	.0001
	Late Summer	+5.588	.669	.0001
	Fall	+1.619	.065	.1316

* mg/l/yr
** FTU/yr
[1] umhos/cm/yr

TABLE 7. (Cont.)

Parameter	Season	Slope	R^2	PR>> F
Alkalinity	Spring	-1.876*	.010	.5514
	Early Summer	+0.944	.392	.0001
	Late Summer	+0.0661	.064	.1364
	Fall	+0.669	.120	.0384
Dissolved Oxygen	Spring	-0.199*	.230	.0826
	Early Summer	+0.016	.051	.4360
	Late Summer	-0.068	.033	.5367
	Fall	-0.120	.187	.1128
Nitrate	Spring	+1.426*	.162	.0149
	Early Summer	+1.555	.397	.0001
	Late Summer	+0.860	.606	.0001
	Fall	+0.125	.020	.4097
Total Phosphorus	Spring	+0.001*	.000	.9551
	Early Summer	+0.002	.001	.9344
	Late Summer	+0.003	.045	.4690
	Fall	+0.003	.070	.3618

*mg/l/yr

TABLE 8. Comparison of trends using seasonally blocked yearly means at two levels of statistical significance for selected parameters at Locust Point

Parameter	Season	$\alpha = .05$	$\alpha = .10$
Conductivity	Spring	+	+
	Early Summer	+	+
	Late Summer	0	0
	Fall	0	0
Chloride	Spring	+	+
	Early Summer	0	0
	Late Summer	−	−
	Fall	0	+
Suspended Solids	Spring	+	+
	Early Summer	+	+
	Late Summer	+	+
	Fall	+	+
Dissolved Solids	Spring	0	0
	Early Summer	0	+
	Late Summer	0	+
	Fall	0	0
Turbidity	Spring	0	+
	Early Summer	+	+
	Late Summer	+	+
	Fall	0	0
Alkalinity	Spring	0	0
	Early Summer	+	+
	Late Summer	0	0
	Fall	+	+

+ = positive trend
– = negative trend
0 = trend is not statistically significant

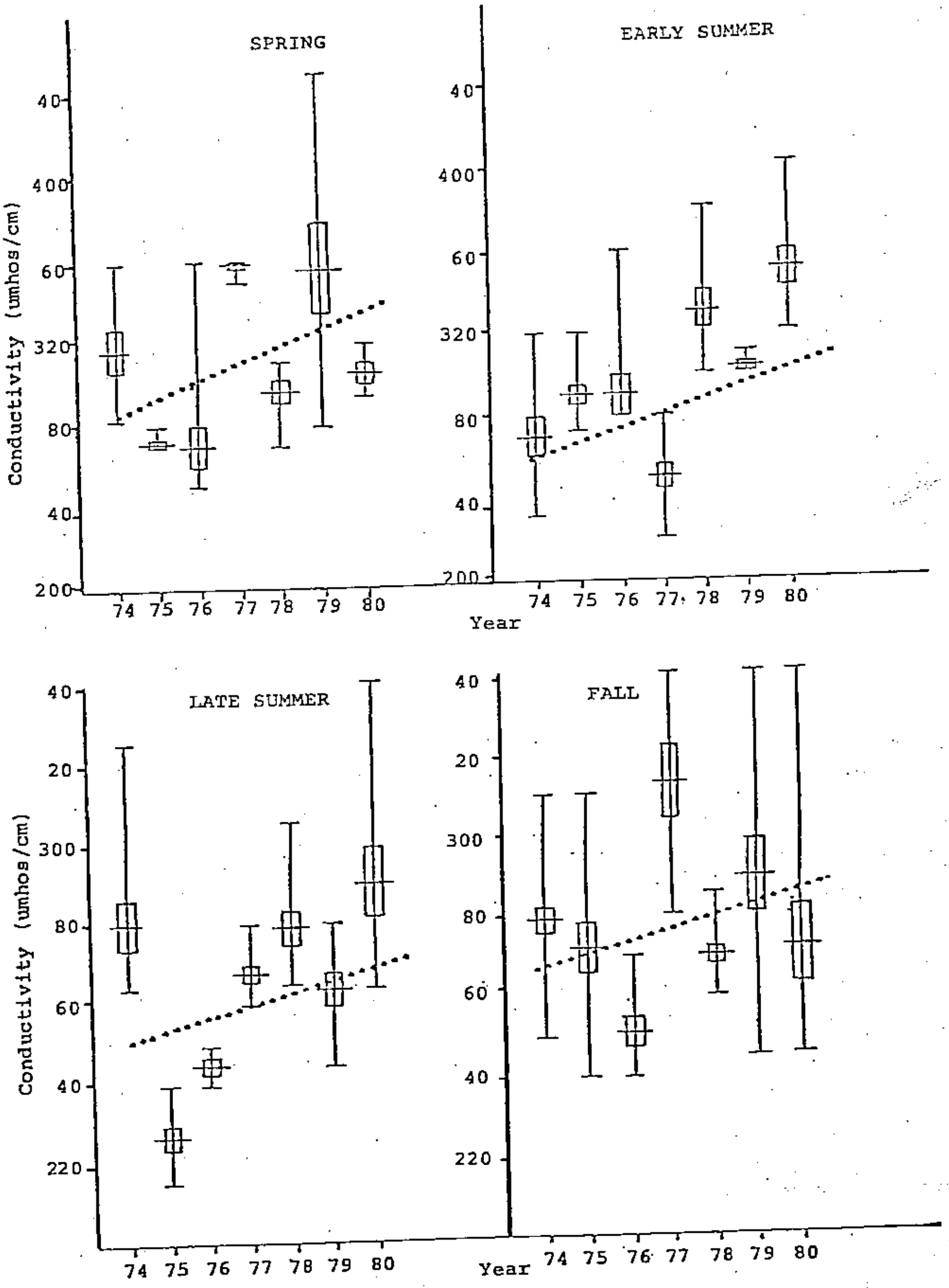


Figure 11. Trends for conductivity yearly means using seasonal blocking at Locust Point.

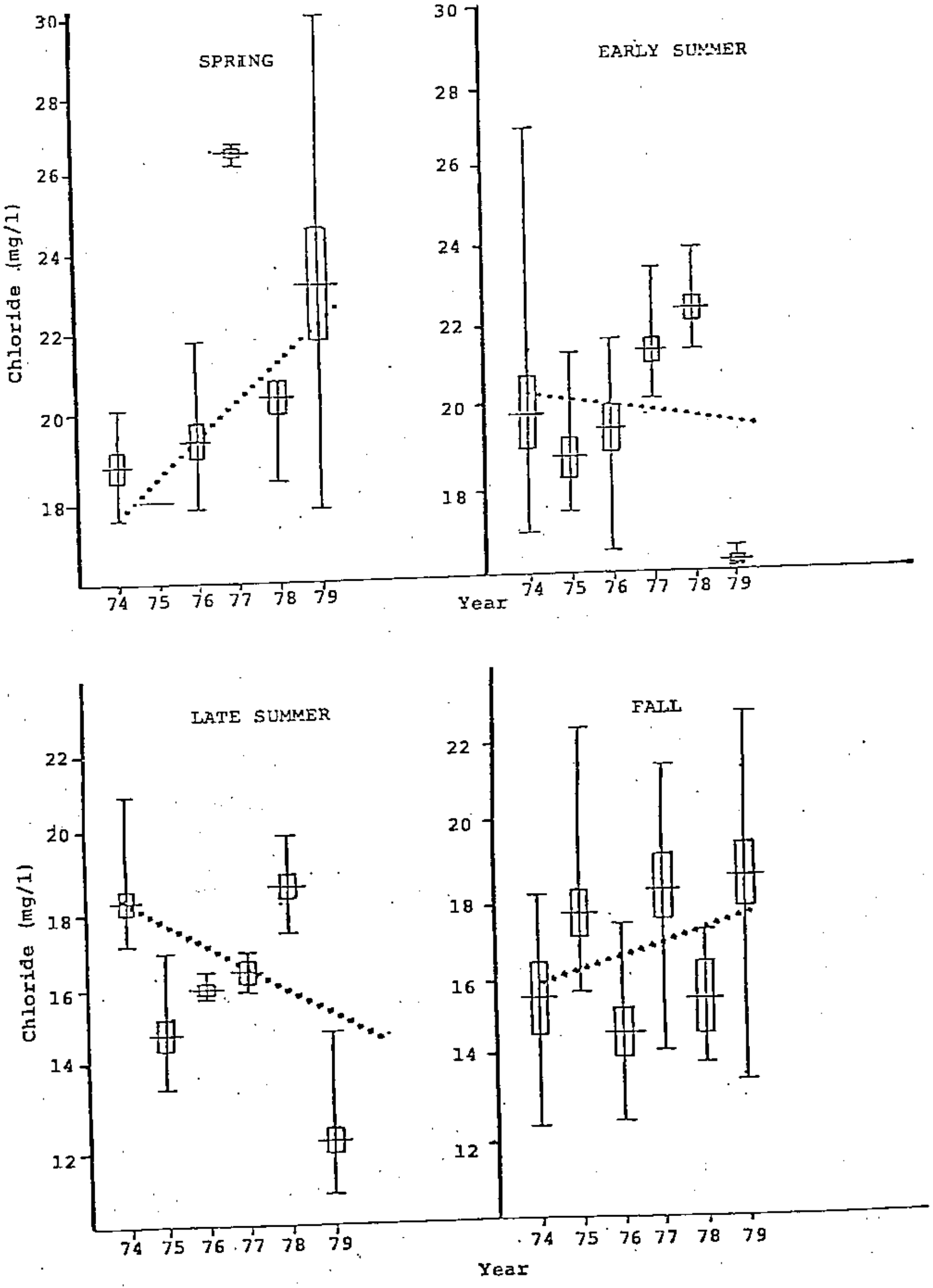


Figure 12. Trends for chloride yearly means using seasonal blocking at Locust Point.

Suspended solids (Figure 13) is the only parameter which exhibits significant increases throughout all four seasons. The largest slope (5.899 mg/1/yr) is found for the early summer months. This season also possesses the highest R^2 values.

While no trends were found for dissolved solids at $P<.05$, significant increases at $P<.10$ occur for the early summer and late summer seasons (Table 8).

Turbidity trends were significant only during early and late summer seasons for $P<.05$, while the spring values are significant at the .10 level (Figure 14).

Seasonal blocking for alkalinity values produced some rather strange results (Figure 15). Although the steepest slope occurs in the spring, the early summer trend is the only significant one found (Table 6). The lack of significance of the large decrease occurring for spring values may be attributed to an extremely large error mean square, which effectively lowers the F-statistic.

The data in Figure 16 and Tables 7 and 8 indicate that nitrate values are significantly increasing for all seasons except fall, where increased values are not statistically significant. Visual inspection of Figure 16 reveals large variation of yearly means except for those reported in late summer.

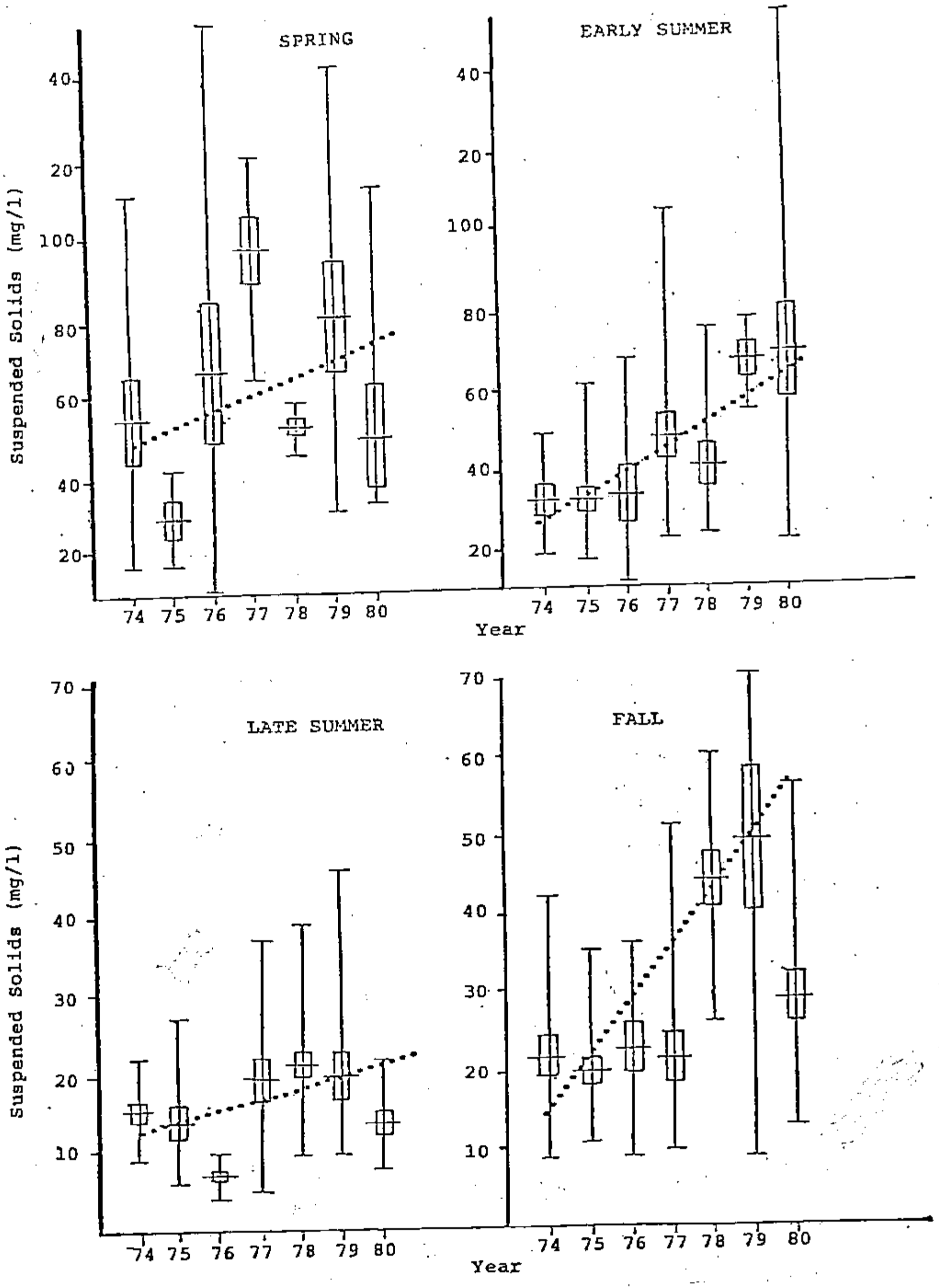


Figure 13. Trends for suspended solids yearly means using seasonal blocking at Locust Point.

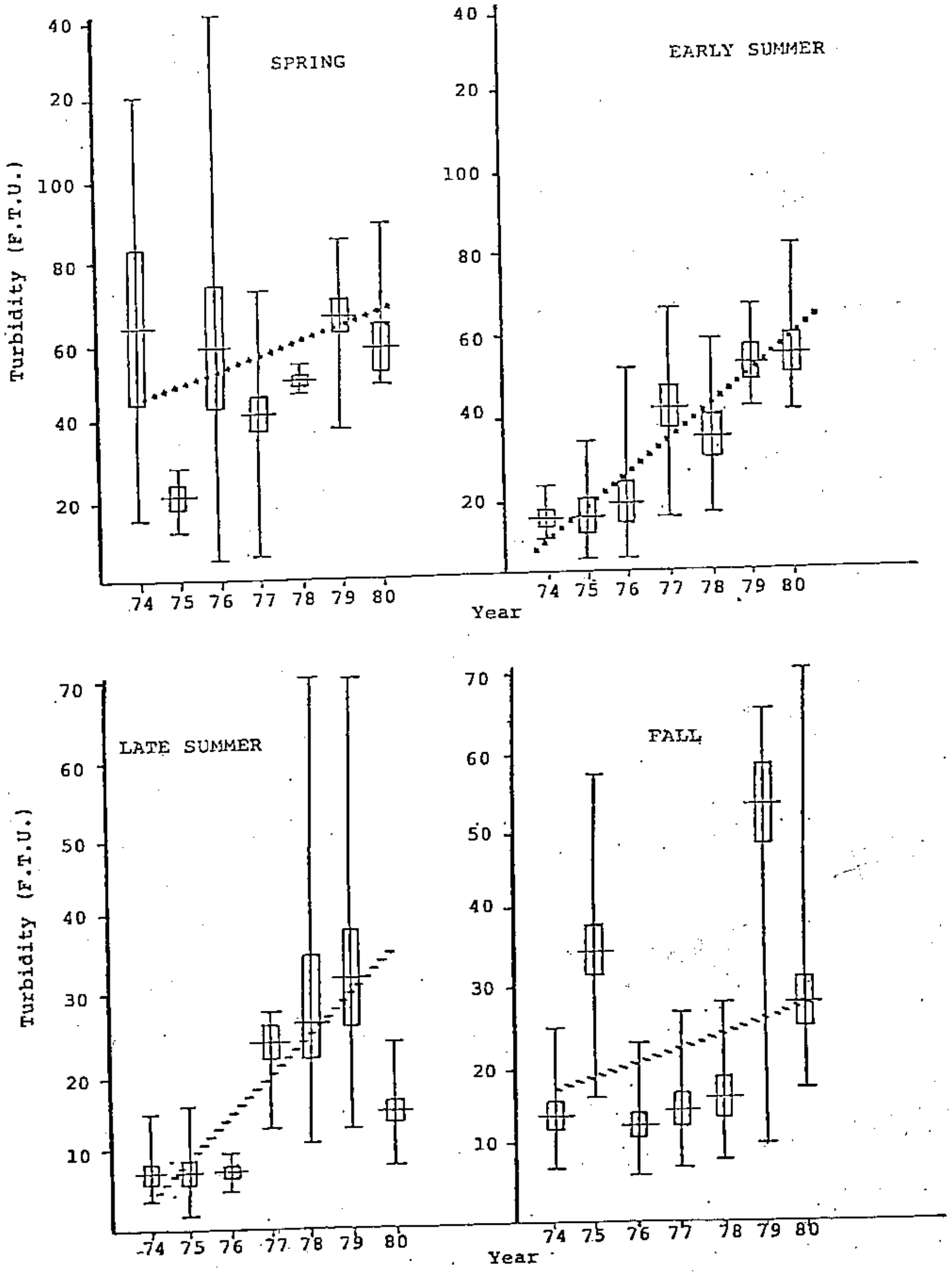


Figure 14. Trends for turbidity yearly means using seasonal blocking at Locust Point.

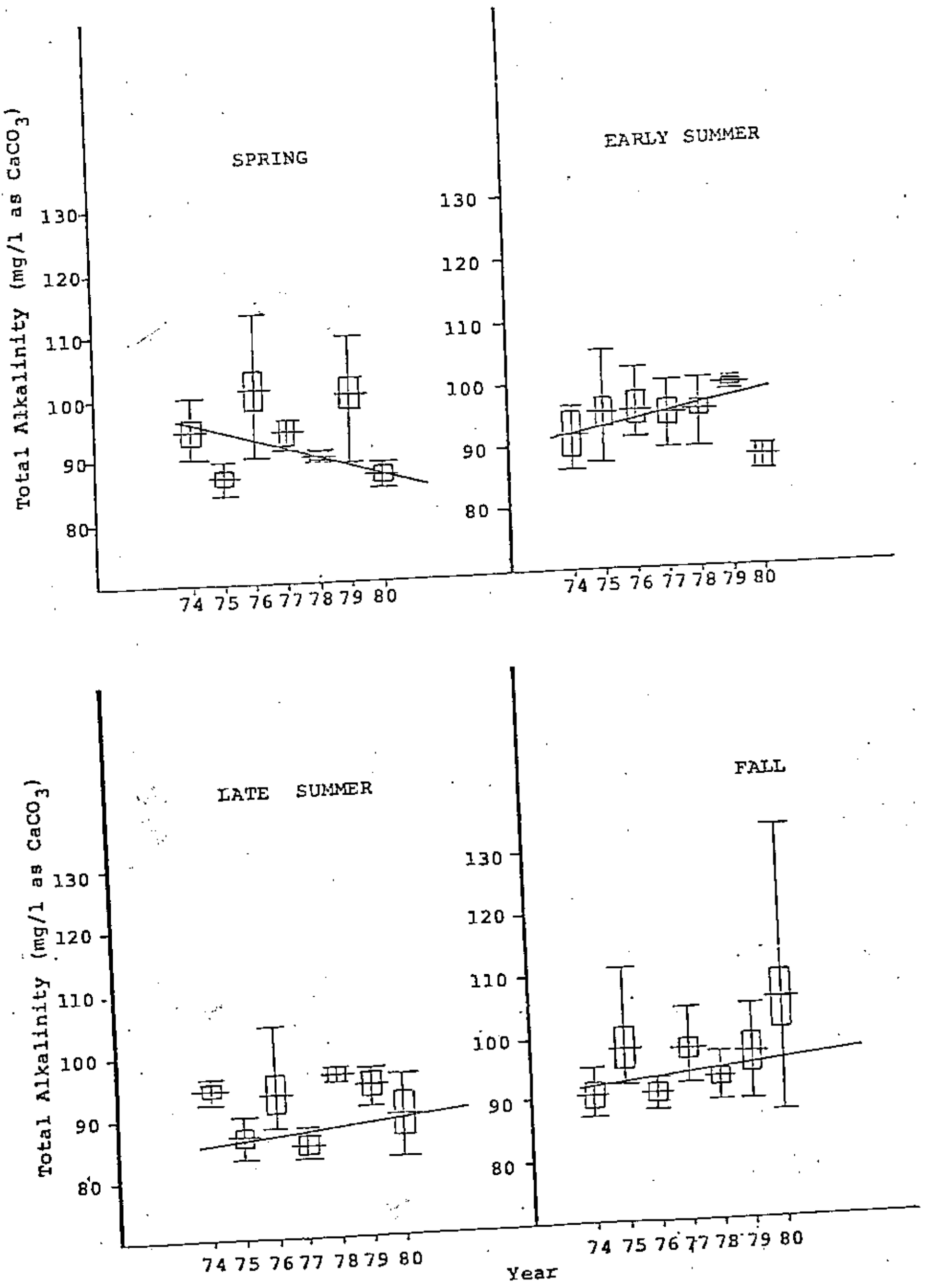


Figure 15. Trends in total alkalinity yearly means using seasonal blocking at Locust Point.

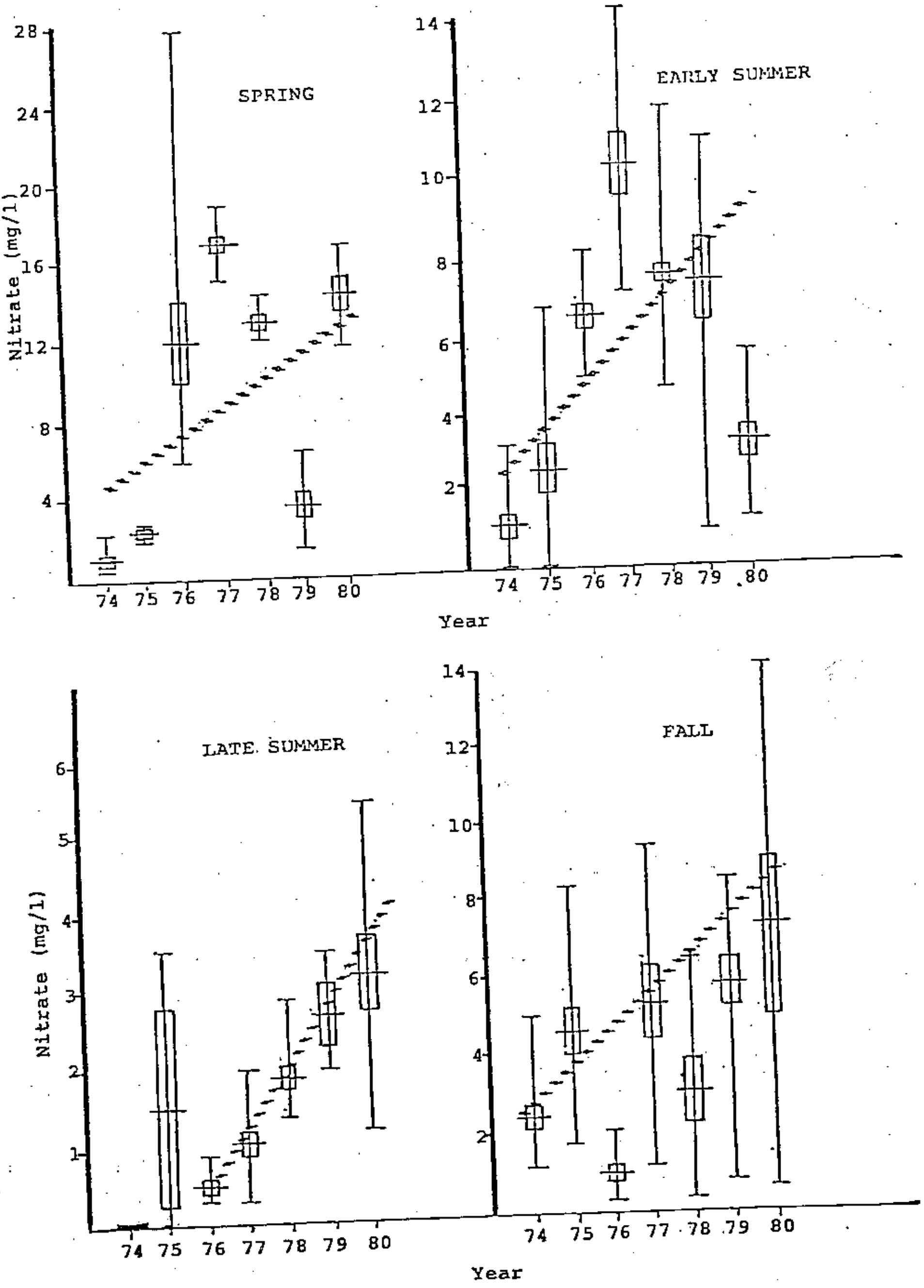


Figure 16. Trends for nitrate yearly means using seasonal blocking at Locust Point.

Summary. Trends for all parameters included in the analysis are summarazed in Figure 17. Inspection of the figure indicates significant increases have occurred from 1974 to 1980 for conductivity, suspended solids, turbidity, and alkalinity at the .05 level. At $P<.10$, chloride is significantly decreasing and nitrate is significantly increasing. No significant trends were found for dissolved solids, dissolved oxygen, or total phosphorus.

The C&O Docks

Monthly means. Linear regression analysis performed on monthly means at the Maumee Bay site revealed a significant trend at $P<.05$ and $P<.10$ from 1970 to 1979 for chloride, alkalinity, nitrate and total phosphorus. Dissolved oxygen exhibited no change at the .05 level, while a significant increase is observed at the .10 level (Tables 9 and 10). No significant differences through time were found for conductivity, suspended solids, dissolved solids, or turbidity.

Figure 18 shows both linear and smoothed curves for chloride ion concentrations for the period of record. An increase of about 1.5 mg/l/yr has been calculated from the linear monthly slope. This amounts to a total increase from 1970 to 1979 of 15 mg/l/yr or 47%. The smoothed curve depicted in the figure indicates a general decrease from 1972 to 1974. Increases in chloride concentration

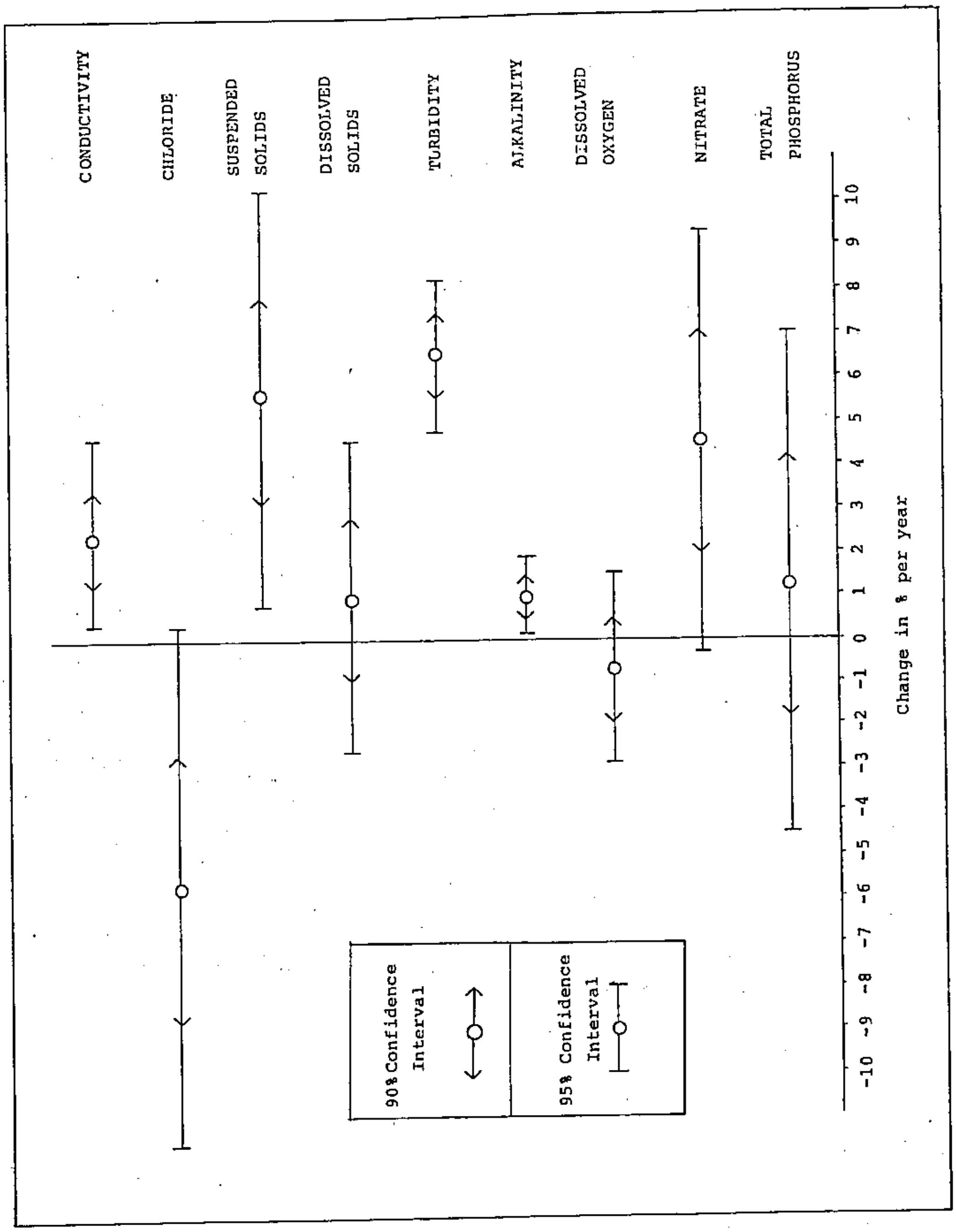


Figure 17. Summary of long-term changes for selected parameters at Locust Point.

TABLE 9. Statistical values for monthly means at the C & O Dock (1970-1979)

Parameter	Degrees of Freedom	Slope	R^2	PR>F (Significance of Slope)
Conductivity	85	-0.406[1]	.022	.1708
Chloride	114	+0.125*	.161	.0001
Suspended Solids	114	+0.126*	.007	.3698
Dissolved Solids	112	+0.235*	.013	.2185
Turbidity	114	+0.128**	.013	.2190
Alkalinity	114	-0.222*	.125	.0001
Dissolved Oxygen	114	+0.013*	.027	.0810
Nitrate	107	-0.023*	.188	.0001
Total Phosphorus	110	-0.004*	.239	.0001

* mg/l/month

** JTU/yr

[1] umhos/cm/yr

TABLE 10. Comparison of trends using monthly and yearly means at two levels of statistical significance for selected parameters at the C & O Docks

Parameter	Monthly means α =.05	 α =.10	Yearly means α =.05	 α =.10
Conductivity	0	0	0	0
Chloride	+	+	+	+
Suspended Solids	0	0	0	0
Dissolved Solids	0	0	0	0
Turbidity	0	0	0	0
Alkalinity	–	–	–	–
Dissolved Oxygen	0	+	0	+
Nitrate	–	–	–	–
Total Phosphorus	–	–	–	–

+ = positive trend
– = negative trend
0 = trend is not statistically significant

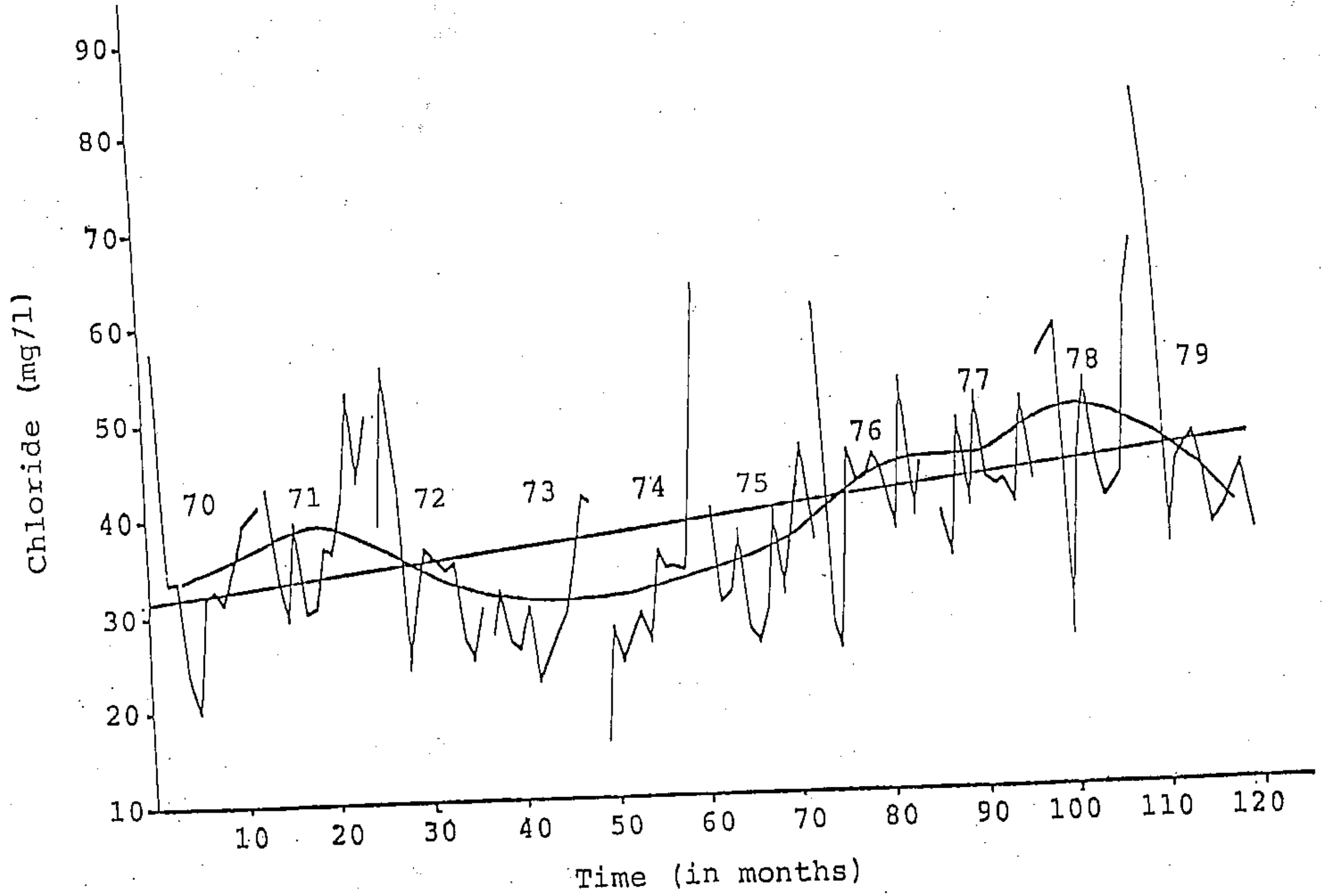


Figure 18. Trends for chloride monthly means at the C and O Docks.

occurred from 1974 to 1978 followed by a slight decline in 1979.

Residuals analysis of the linear regression for chloride (Figure 19) reveals a band relatively constant with respect to time, indicating the trend is adequately described as a linear function. Peak values occurring at month 54 and month 103 correspond to extreme values found in the fall of 1974 and the spring of 1979, respectively.

Decreases in alkalinity values are evident from Figure 20. The regression line indicates that alkalinity at this site is decreasing at a rate of 2.66 mg/l/yr as $CaCO_3$. The smoothed trend curve produces a rather consistent oscillation occurring with a period of about three years. Residuals analysis (Figure 21) of the regression equation reveals a somewhat wide band with peaks and depressions corresponding to those found in Figure 20.

Nitrate values have declined from 4.4 mg/l in 1970 to 1.65 mg/l in 1979, which amounts to a 62% reduction during the decade (Figure 22). The smoothed trend curve reveals a somewhat similar oscillation to that of alkalinity values, but is not as visually evident. Figure 23 illustrates a somewhat narrowing band of residuals through time. This may be indicative that a non-linear relationship is occurring for nitrates through time.

Figure 24 depicts phosphorus monthly means regressed

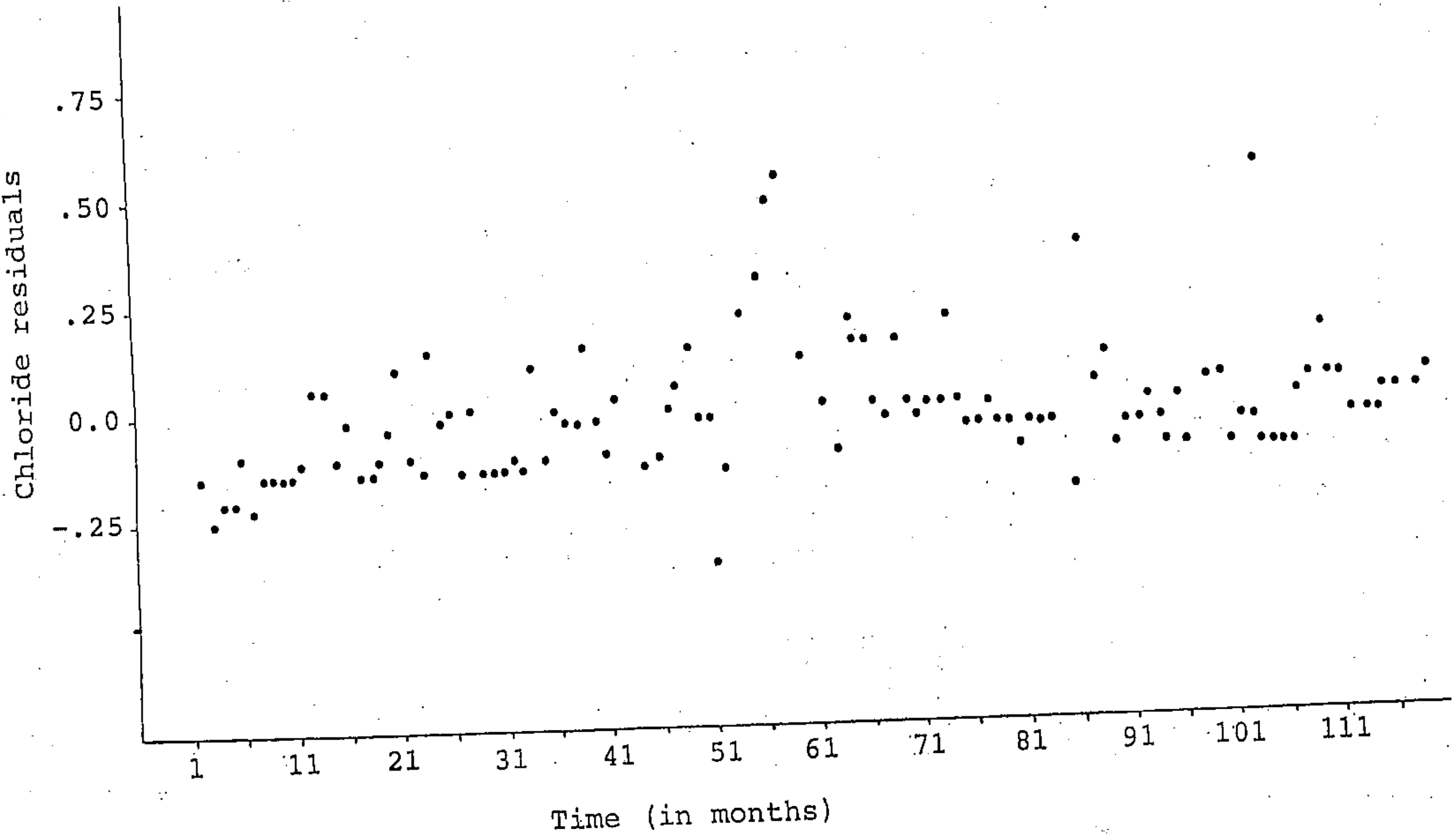


Figure 19. Residuals of the linear regression for chloride monthly means at the C and O Docks.

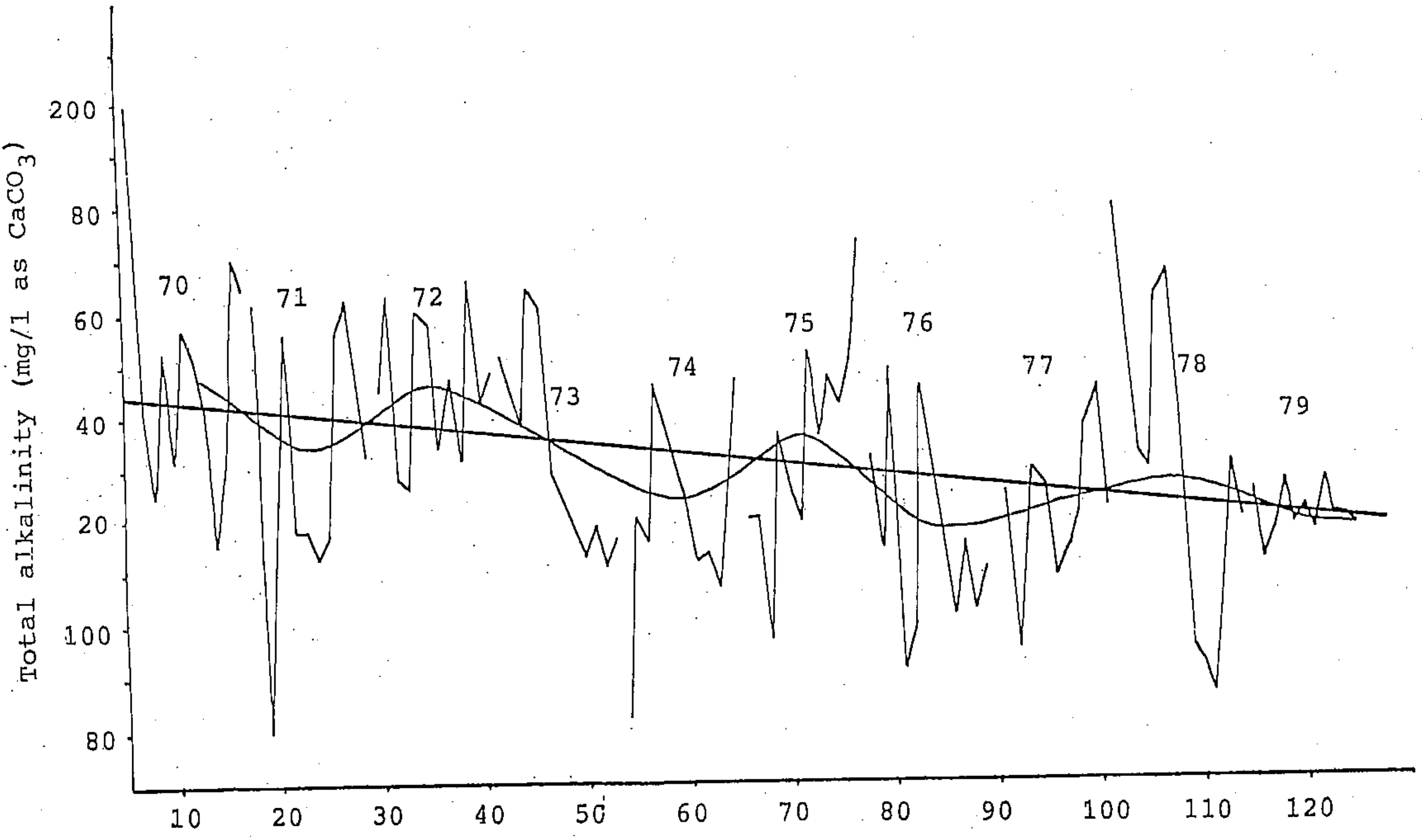


Figure 20. Trends for total alkalinity monthly means at the C and O Dock.

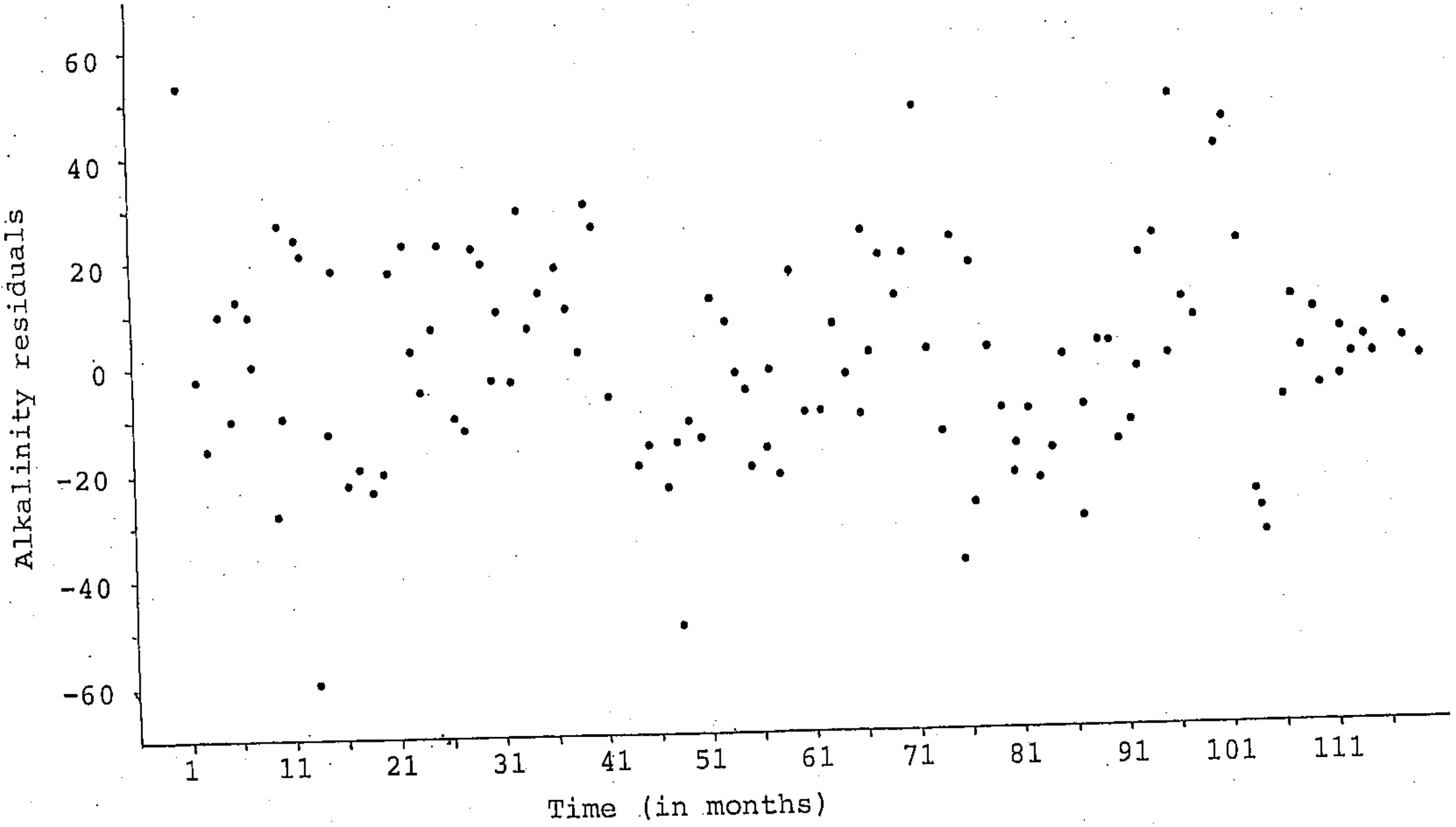


Figure 21. Residuals of the linear regression for alkalinity monthly means at the C and O Docks.

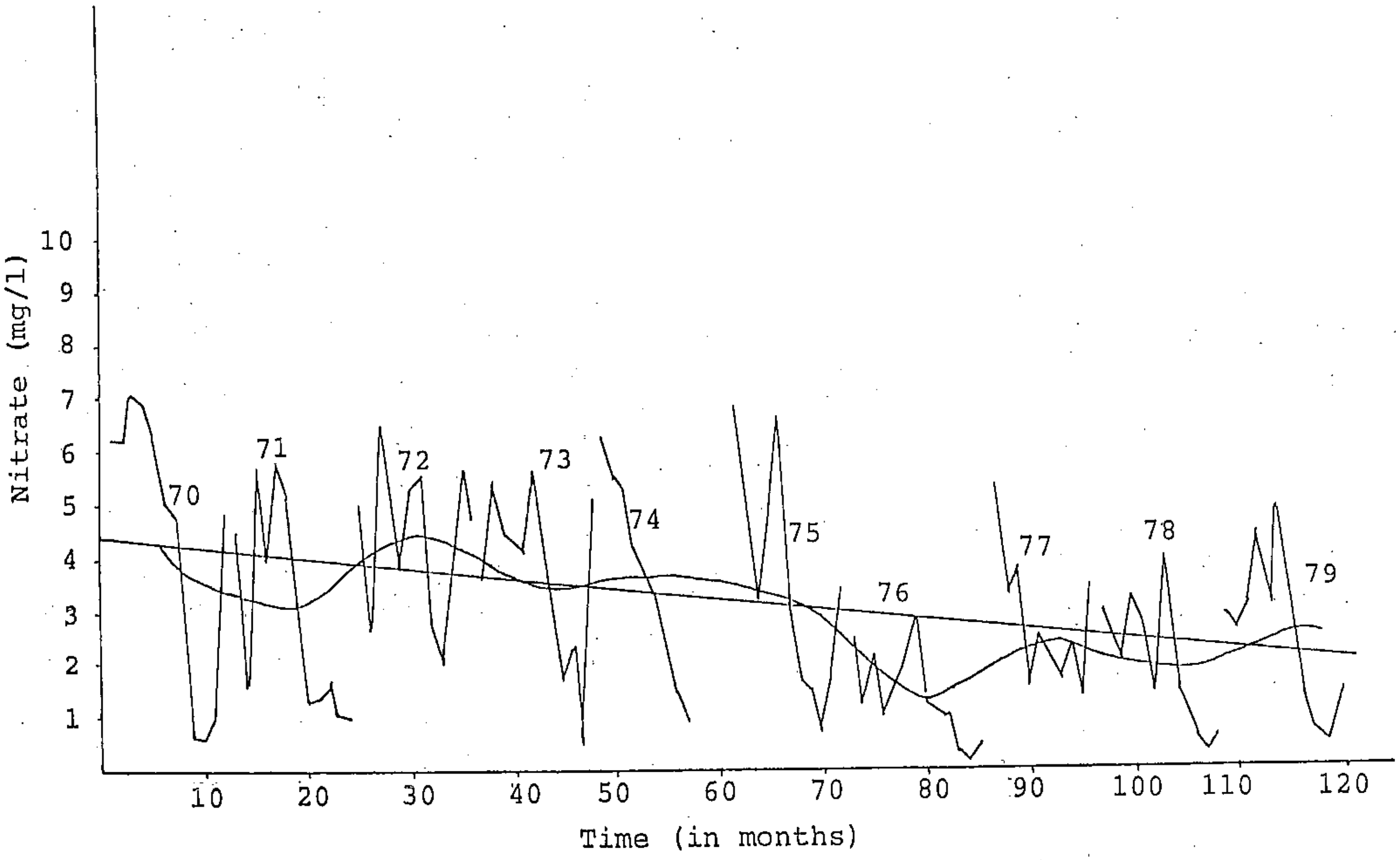


Figure 22. Trends for nitrate monthly means at the C and O Docks.

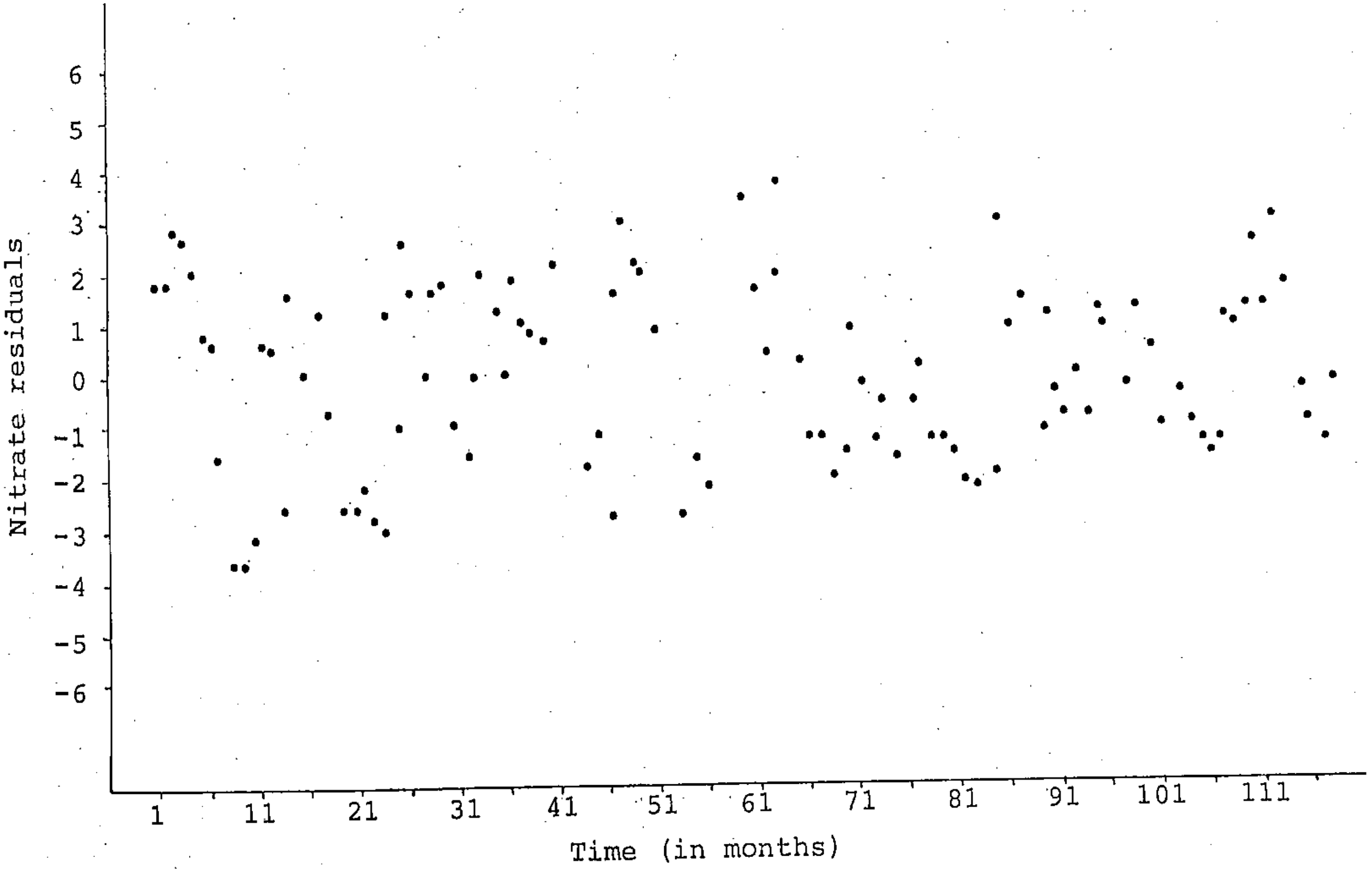


Figure 23. Residuals of the linear regression for nitrate monthly means at the C and O Docks.

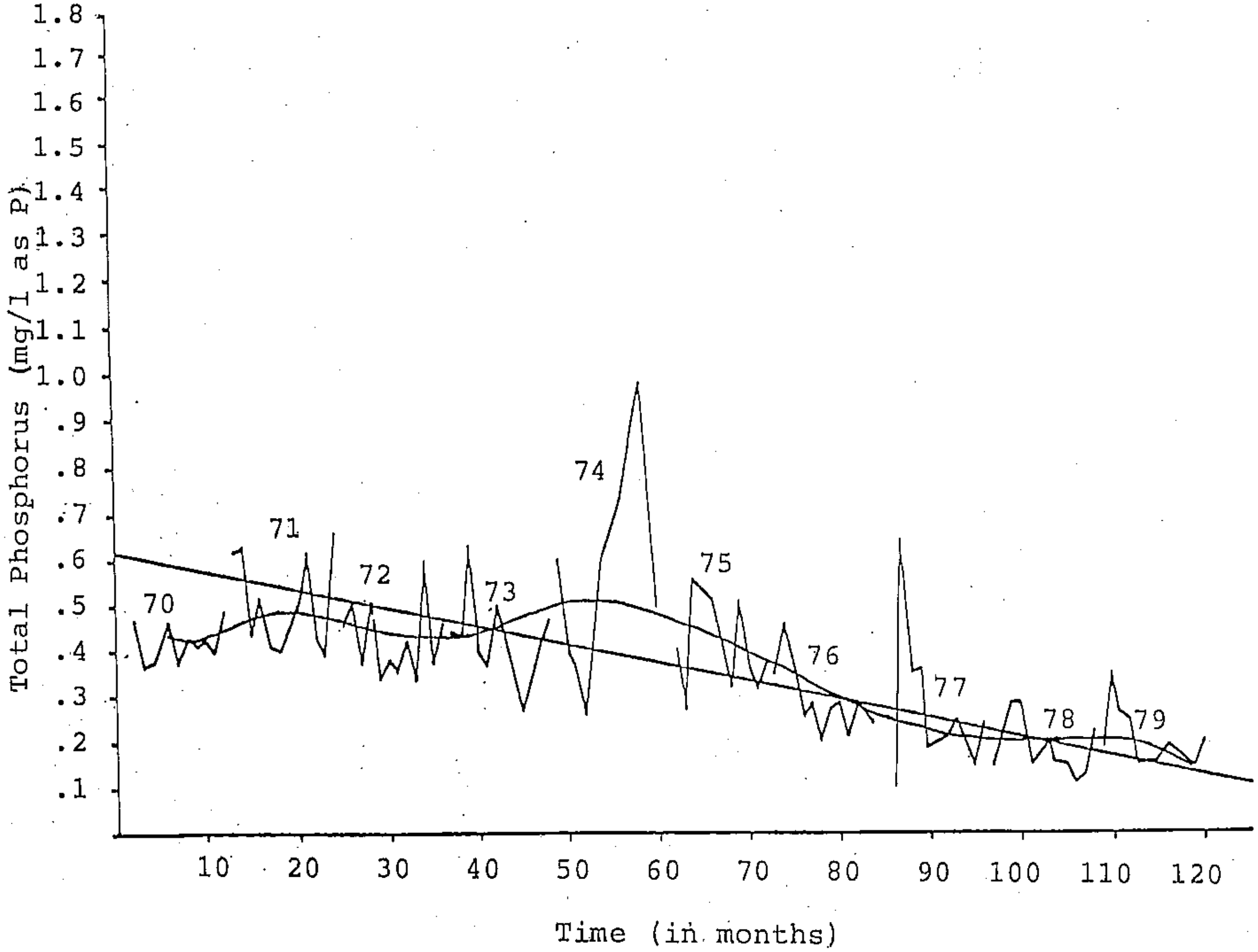


Figure 24. Trends in total phosphorus monthly means at the C and O Docks.

through time. Of all parameters found to be changing significantly for the period of record at the Maumee Bay site, the phosphorus decrease is the most visually evident; R^2 and significance values (Table 9) provide strong support of a decrease for this improtant nutrient parameter. The linear regression line suggests phosphorus values have decreased 78% from 1970 to 1979. The smoothed trend curve superimposed on the linear model indicates relatively stable concentrations existed from 1970 to 1973. In 1974, large variation in monthly means produced an upswing in the curve. A visual decline in phosphorus levels is evident from 1975 to 1977, followed by a relatively steady state from 1977 to 1979.

Residuals analysis of the regression line (Figure 25) indicate that most of the residuals fell below the regression line before about 1975, after which residuals are fairly well scattered around the zero line.

Yearly means. Regression analysis using yearly means produced similar results to analysis using monthly means. The same parameters exhibited similar trends (Tables 10 and 11). Although the significance levels have decreased in value due to lower degrees of freedom, R^2 values significantly increased over those for monthly means, indicating large sources of variation were smoothed through averaging by year. Figures 26 through 29 graphically depict linear

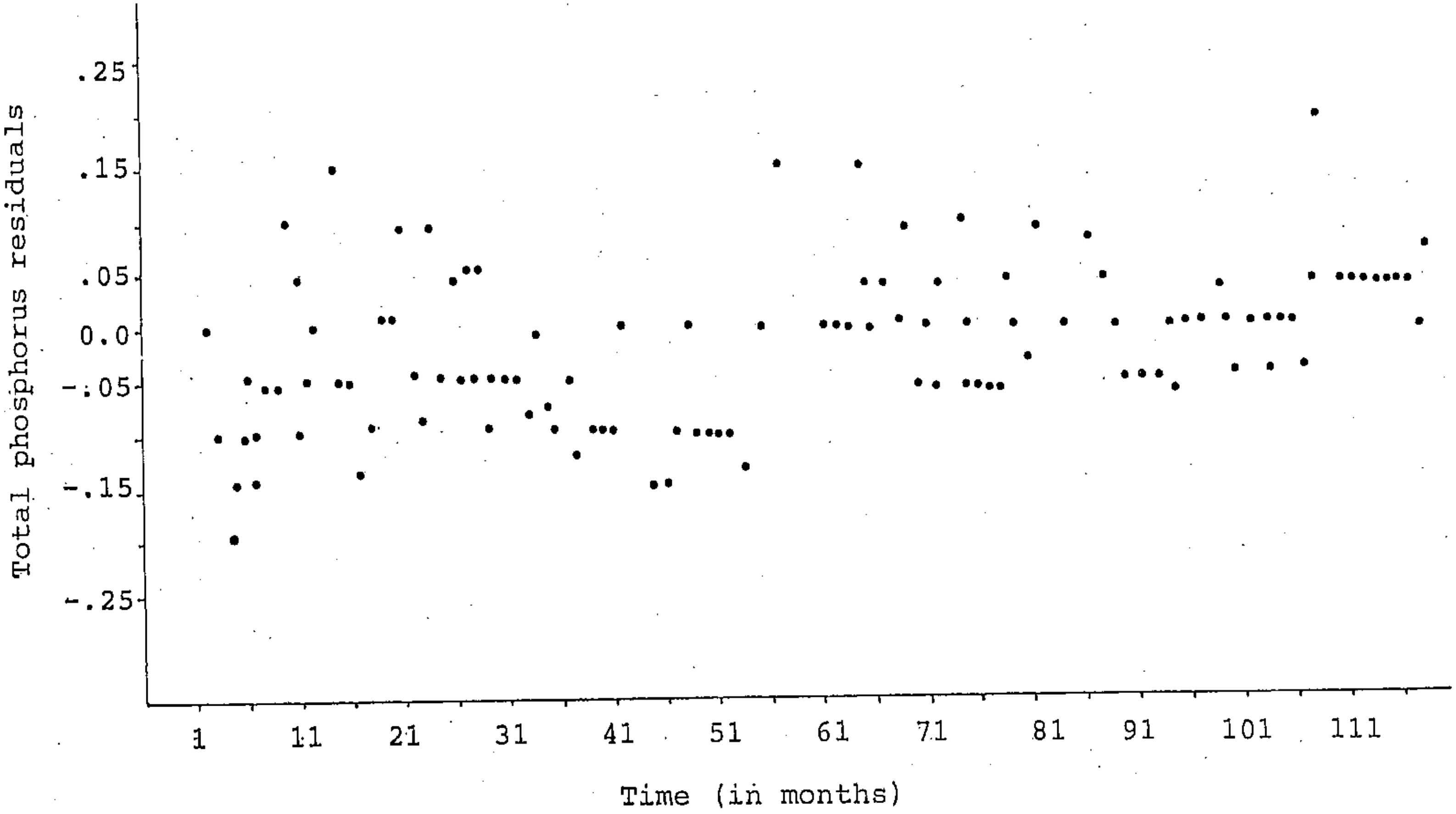


Figure 25. Residuals of the linear regression for total phosphorus monthly means at the C and O Docks.

TABLE 11. Statistical values of yearly means at the C & O Dock (1970-1979)

Parameter	Degrees of Freedom	Slope	R^2	PR>F (Significance of Slope)
Conductivity	7	-2.508[1]	.069	.5306
Chloride	9	+1.350*	.539	.0156
Suspended Solids	9	+1.522*	.061	.4927
Dissolved Solids	9	+3.214*	.127	.3118
Turbidity	9	+1.337**	.055	.5136
Alkalinity	9	-2.909*	.630	.0061
Dissolved Oxygen	9	+0.152*	.320	.0885
Nitrate	9	-0.252*	.562	.0126
Total Phosphorus	9	-0.041*	.806	.0004

* mg/l/yr

** JTU/yr

[1] umhos/cm/yr

and smoothed curves of yearly means. Slopes for all four parameters exhibiting significant change (chloride, alkalinity, dissolved oxygen, nitrate and phosphorus) are similar to those calculated for monthly means.

Seasonal blocking. Since samples were collected during winter months at the C&O Docks, five seasons were created to homogenize seasonal variability. Significant statistics for all nine parameters are found in Table 12. Table 13 summarizes these statistics for the two tested levels of significance.

While conductivity values were not changing significantly using regression analysis on monthly and yearly means (Table 10), seasonal blocking produced a significant decrease at both $\alpha=.05$ and $\alpha=.10$ for the winter season only. All other seasons exhibit no trend.

Chloride is singificantly increasing at $P<.10$ and $P<.05$ for spring and early summer seasons (Figure 30). A significant increase is noted for late summer only at the .10 level (Tables 12 and 13).

Suspended solids is increasing during one season only; late summer, and is not significant at the .05 level. Seasonal blocking produced no other trend in this parameter.

Turbidity is the only parameter which exhibited no trend at either significance level for any season (Table 13).

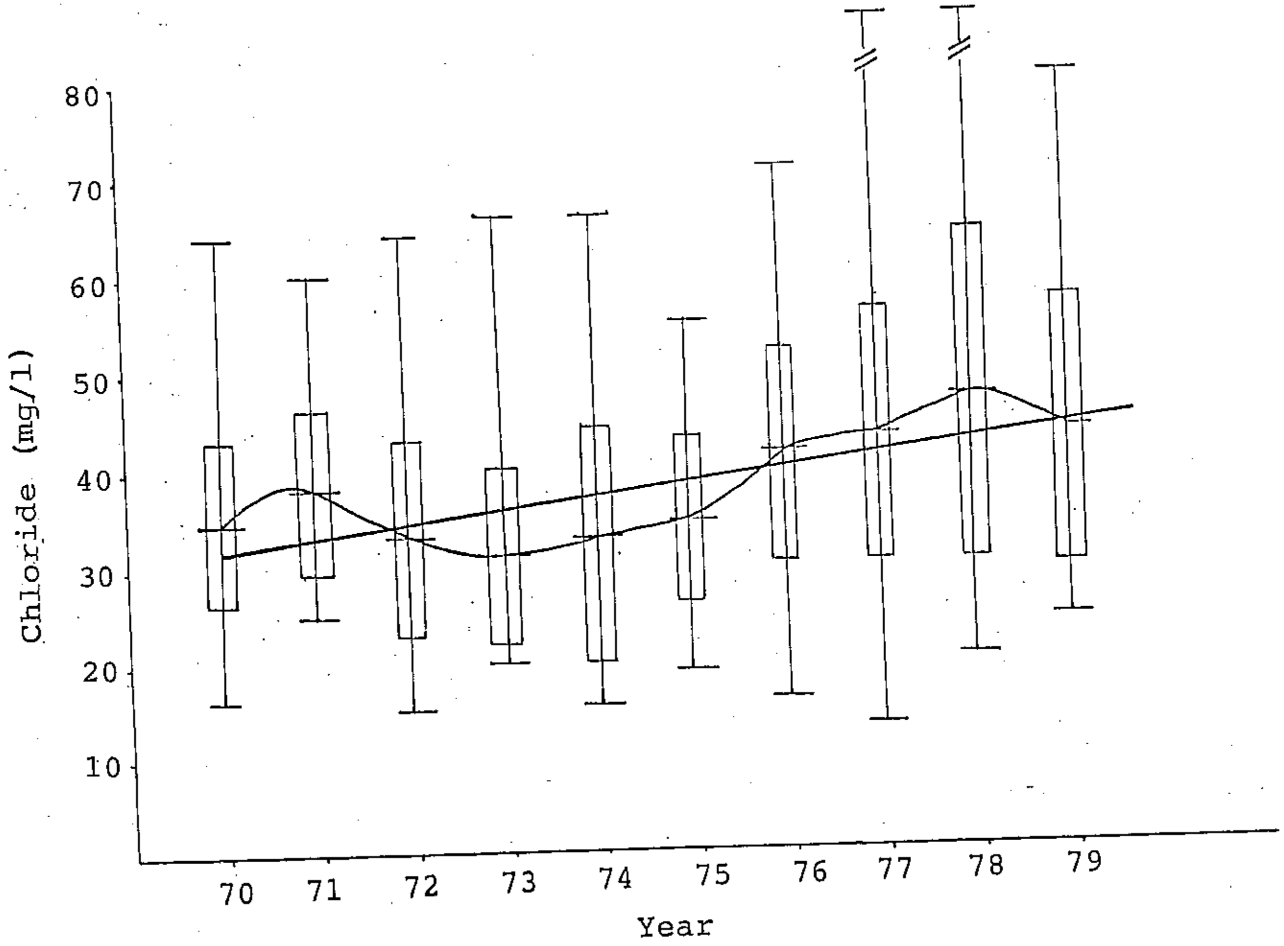


Figure 26. Trends in chloride yearly means at the C and O Docks.

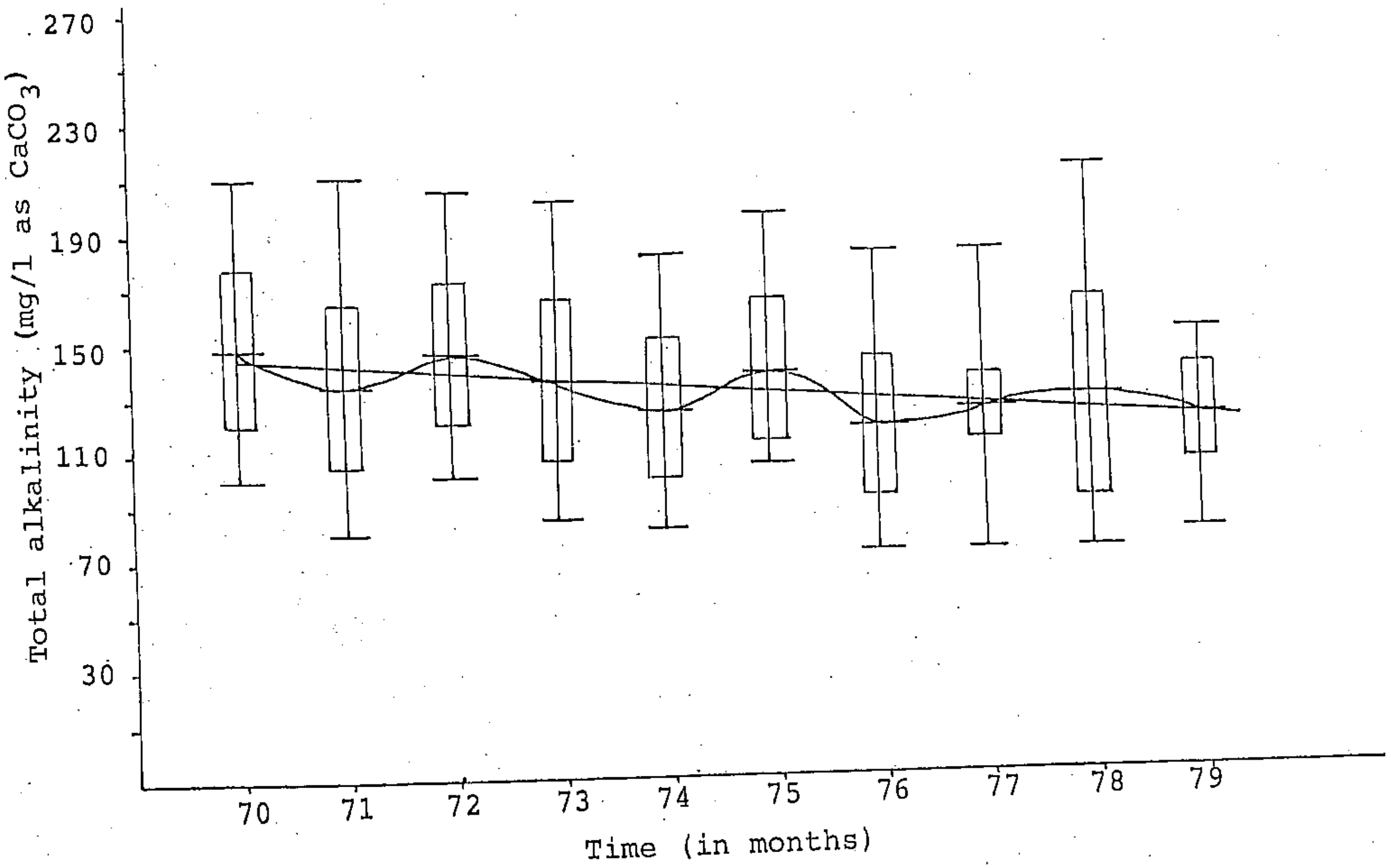


Figure 27. Trends in total alkalinity yearly means at the C and O Docks.

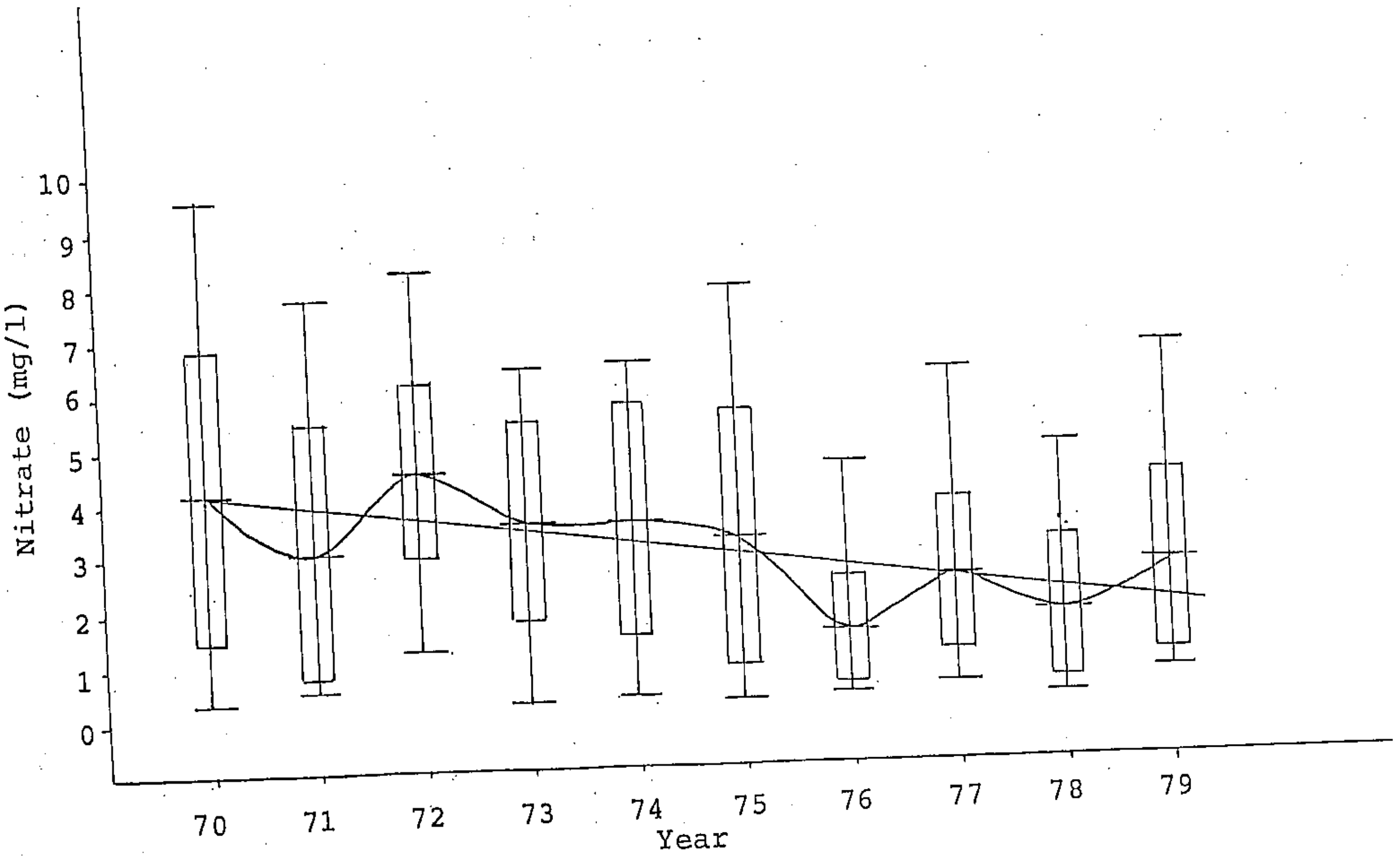


Figure 28. Trends in nitrate yearly means at the C and O Docks.

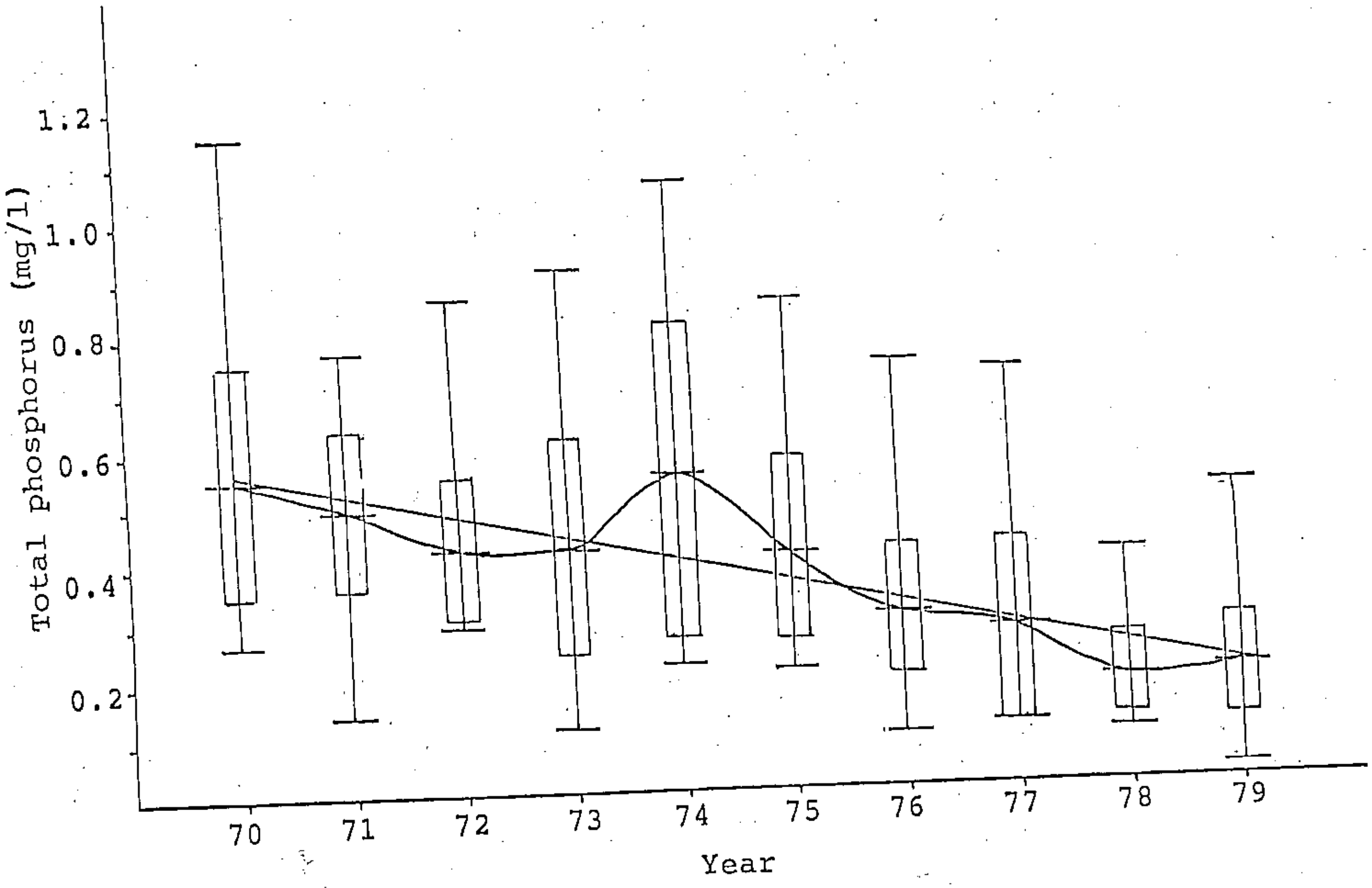


Figure 29. Trends in total phosphorus yearly means at the C and O Docks.

TABLE 12. Statistical values for seasonal yearly means at the C&O Docks (1970-1979)

Parameter	Season	Slope	R^2	PR>F
Conductivity	Spring	+10.812[1]	.223	.2850
	Early Summer	+ 3.890	.040	.6333
	Late Summer	+ 2.349	.020	.7617
	Fall	-11.290	.296	.1635
	Winter	-23.715	.552	.0347
Chloride	Spring	+ 1.756*	.662	.0042
	Early Summer	+ 2.077	.467	.0292
	Late Summer	+ 0.832	.397	.0510
	Fall	+ 0.839	.108	.3524
	Winter	+ 2.142	.270	.1235
Suspended Solids	Spring	- 1.315*	.023	.6757
	Early Summer	- 0.831	.006	.8293
	Late Summer	+ 3.361	.348	.0725
	Fall	+ 0.403	.004	.8544
	Winter	+ 7.049	.098	.3788
Dissolved Solids	Spring	+ 2.270*	.079	.4294
	Early Summer	+ 6.417	.310	.0946
	Late Summer	+ 7.787	.424	.0413
	Fall	- 6.259	.172	.2329
	Winter	+ 1.142	.003	.8905
Turbidity	Spring	+ 0.457**	.006	.8287
	Early Summer	- 0.100	.000	.9787
	Late Summer	+ 3.010	.296	.1038
	Fall	+ 0.423	.004	.8682
	Winter	+ 4.355	.102	.3676

* mg/l/yr

** JTU/yr

[1] umhos/cm/yr

TABLE 12. (Cont.)

Parameter	Season	Slope	R^2	PR>F
Alkalinity	Spring	- 2.254*	.231	.1594
	Early Summer	- 0.650	.017	.7172
	Late Summer	- 2.423	.336	.0792
	Fall	- 4.235	.417	.0436
	Winter	- 3.580	.256	.1351
Dissolved Oxygen	Spring	+ 0.075*	.264	.1527
	Early Summer	+ 0.186	.066	.3612
	Late Summer	+ 0.307	.447	.0344
	Fall	+ 0.258	.320	.0882
	Winter	+ 0.122	.296	.1043
Nitrate	Spring	- 0.388*	.580	.0105
	Early Summer	- 0.264	.188	.2111
	Late Summer	- 0.047	.115	.3364
	Fall	- 0.216	.273	.1492
	Winter	- 0.397	.454	.0327
Total Phosphorus	Spring	- 0.022*	.420	.0427
	Early Summer	- 0.034	.478	.0268
	Late Summer	- 0.038	.325	.0851
	Fall	- 0.047	.674	.0036
	Winter	- 0.078	.547	.0145

* mg/l/yr

TABLE 13. Comparison of trends using seasonally blocked yearly means at two levels of statistical significance for selected parameters at the C&O Docks

Parameter	Season	$\alpha=.05$	$\alpha=.10$
Conductivity	Spring	0	0
	Early Summer	0	0
	Late Summer	0	0
	Fall	0	0
	Winter	-	-
Chloride	Spring	+	+
	Early Summer	+	+
	Late Summer	0	+
	Fall	0	0
	Winter	0	0
Suspended Solids	Spring	0	0
	Early Summer	0	0
	Late Summer	0	+
	Fall	0	0
	Winter	0	0
Dissolved Solids	Spring	0	0
	Early Summer	0	+
	Late Summer	+	+
	Fall	0	0
	Winter	0	0
Turbidity	Spring	0	0
	Early Summer	0	0
	Late Summer	0	0
	Fall	0	0
	Winter	0	0

\+ = positive trend
\- = negative trend
0 = trend is not statistically significant

TABLE 13. (Cont.)

Parameter	Season	α=.05	α=.10
Alkalinity	Spring	0	0
	Early Summer	0	0
	Late Summer	0	-
	Fall	-	-
	Winter	0	0
Dissolved Oxygen	Spring	0	0
	Early Summer	0	0
	Late Summer	+	+
	Fall	0	+
	Winter	0	0
Nitrate	Spring	-	-
	Early Summer	0	0
	Late Summer	0	0
	Fall	0	0
	Winter	-	-
Total Phosphorus	Spring	-	-
	Early Summer	-	-
	Late Summer	0	-
	Fall	-	-
	Winter	-	-

+ = positive trend
- = negative trend
0 = trend is not statistically significant

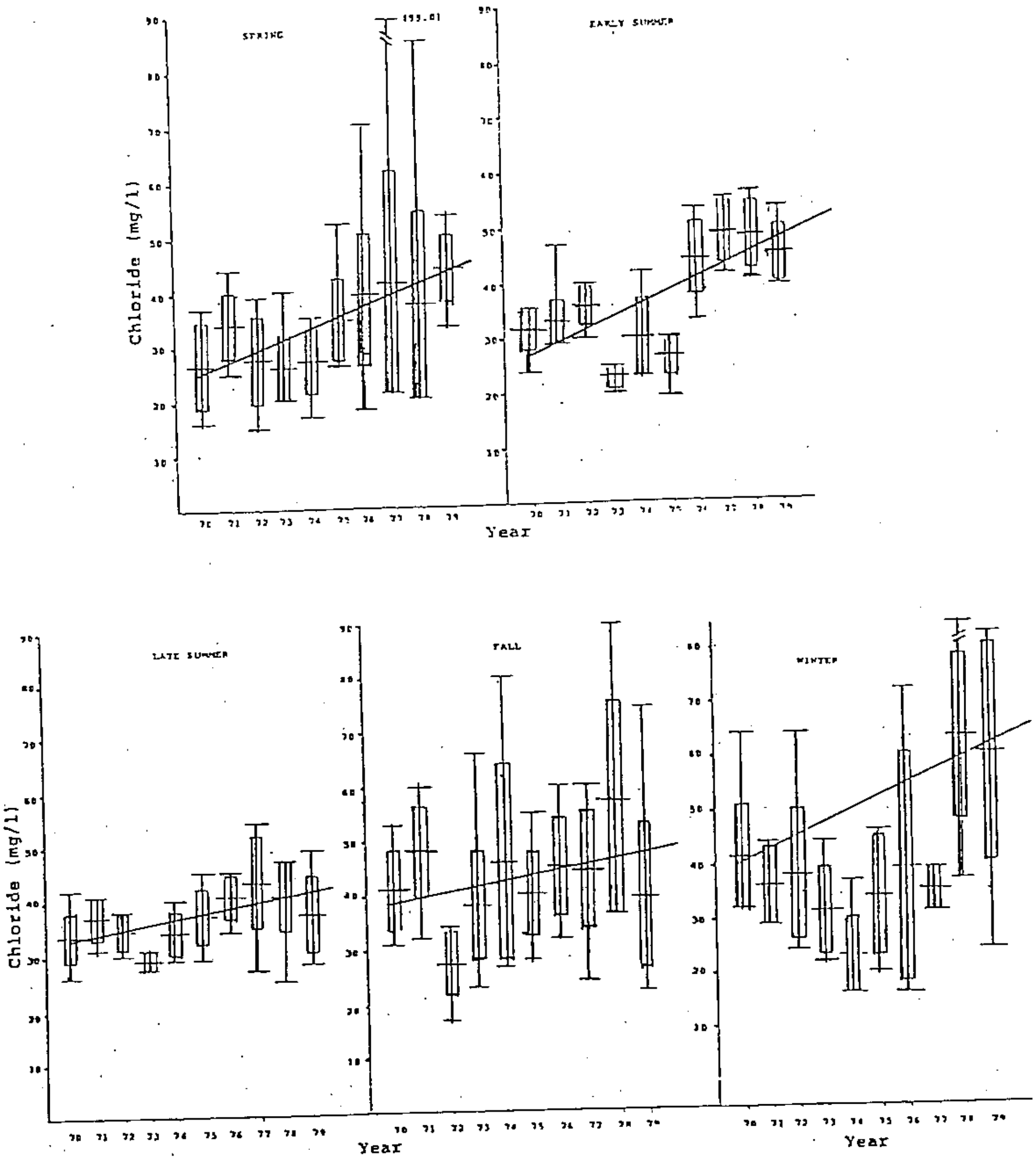


Figure 30. Trends for chloride yearly means using seasonal blocking at the C&O Docks.

Seasonally blocked trends for total alkalinity are depicted in Figure 31. Decreases at both significance levels were found during the fall season, while the late summer season exhibited a trend for $P<.10$. The spring, early summer, and winter seasons produced no significant trends.

Table 13 reveals increases for dissolved oxygen in the late summer season at both levels of tested significance. An increase in the fall is significant at $P<.10$ but not at $P<.05$.

Nitrate values are decreasing significantly at both $P<.05$ and $P<.10$ for the spring and winter seasons (Table 13). Visually evident but insignificant decreases are occurring for spring, early summer and late summer as well (Figure 32).

Total phosphorus is the only parameter which is decreasing during all five seasonally blocked time periods. Although the trend is not significant at $P<.05$ for late summer, it is significant at $P<.10$ (Table 13). The R^2 values for this parameter are among the highest for all seasons when compared to those of the other parameters (Table 12). Inspection of Figure 33 indicates that lowered yearly means after 1974 may be responsible for the decreasing trend. This phenomenon is especially evident for early summer, late summer and fall.

Summary. Figure 34 illustrates a summary of trends for all parameters included in the analysis. Conductivity,

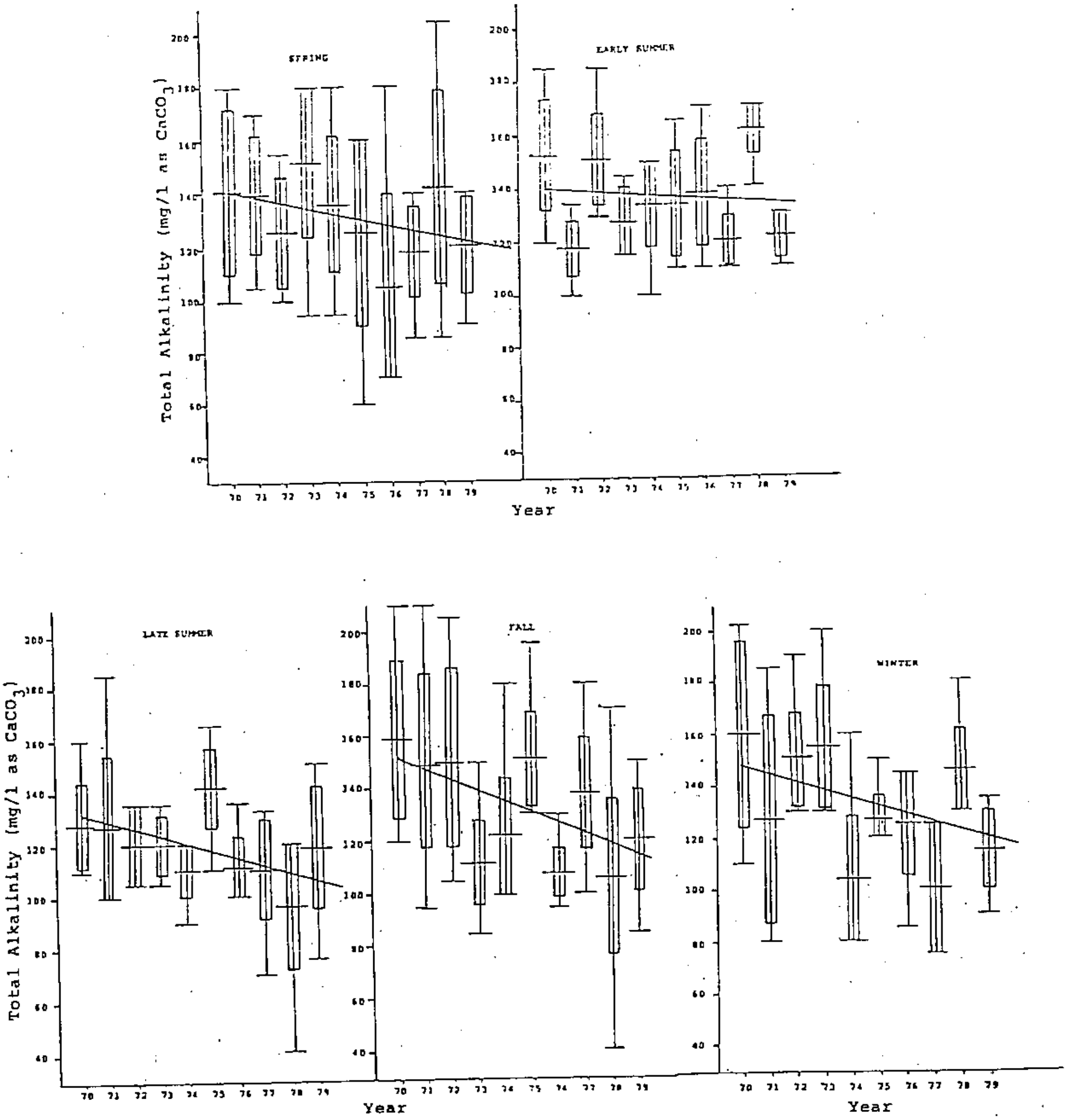


Figure 31. Trends for total alkalinity yearly means using seasonal blocking at the C&O Docks.

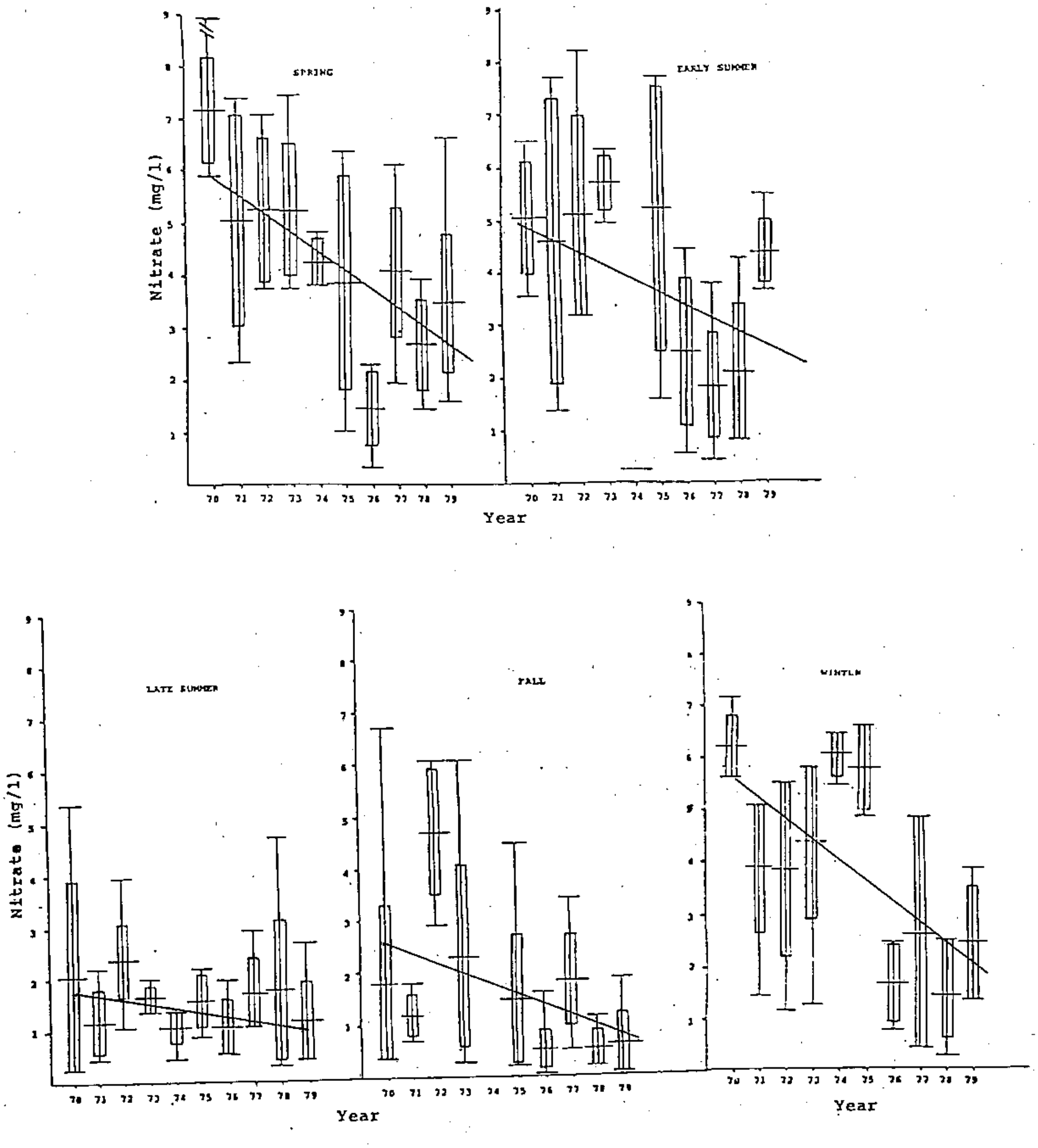


Figure 32. Trends for nitrate yearly means using seasonal blocking at the C&O Docks.

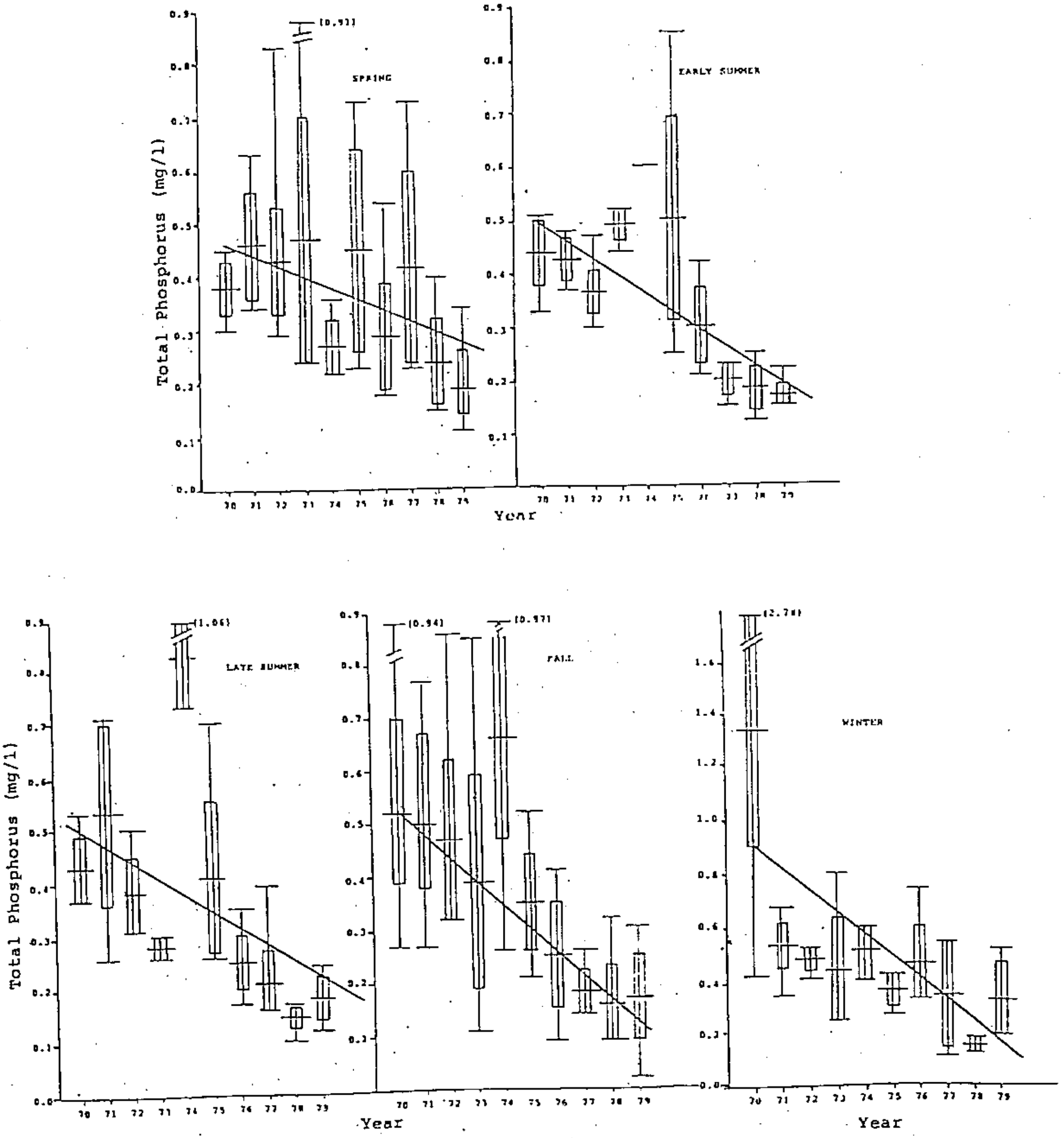


Figure 33. Trends for total phosphorus yearly means using seasonal blocking at the C&O Docks.

suspended solids, dissolved solids, and turbidity are not significantly changing at the Maumee Bay site as evidenced by the confidence intervals intersecting the zero percent change line. Significant decreases have occurred for the period of record for alkalinity, nitrate and phosphorus; the last of wich exhibits the greatest decrease and the narrowest confidence intervals. Chloride and dissolved oxygen were the only parameters at this site which exhibited a significant increase from 1970 to 1979. The latter parameter is significant at $P<.10$ but not at $P<.05$.

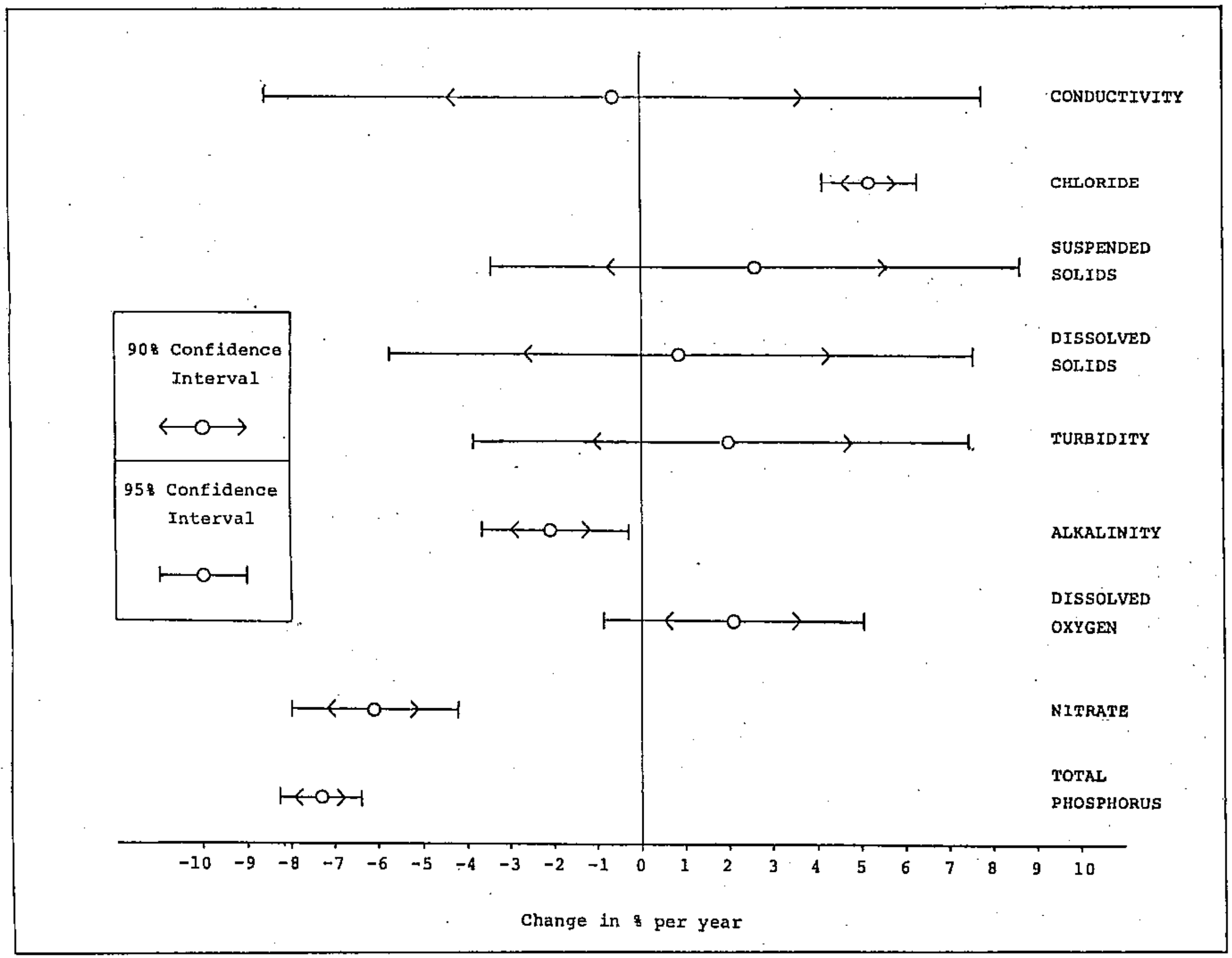


Figure 34. Summary of long term changes for selected parameters at the C&O Docks (1970-1979).

DISCUSSION

Trend analysis performed on the two western basin locations indicate that with the exception of a decrease for yearly means in chlorides and a decrease for one seasonal statistic for dissolved oxygen, all parameters at the Locust Point site which exhibit significant trends are significantly increasing through the period of record. Trend analysis of yearly and monthly means for parameters at the C&O Dock indicate significant decreases for alkalinity, nitrate, and total phosphorus, while chloride and dissolved oxygen are increasing. Seasonal blocking of the data reveals additional increases for suspended and dissolved solids, while conductivity is found to decrease during the winter season.

The only parameters which showed significant change at both levels of significance at the Locust Point study site are increases for monthly means in nitrate values, while increases in monthly means for conductivity and alkalinity values at α=.10 are observed. Increases in yearly means of conductivity, suspended solids, turbidity, and alkalinity are observed for both significance levels. In addition, regressing yearly means revealed an increase in nitrate values and a decrease in chlorides.

Significance of the trend for nitrate found in monthly means was lost at the .05 significance level during yearly averaging, but was regained for three of the four seasonal periods after seasonal blocking. Thus, while statistical analyses conflict for this nutrient, a general increase in nitrate concentrations may be occurring at this site.

Nitrate increases since the late 1960's have been substantially documented. Gregor and Ongley (1978) found that a highly significant increase in nitrates occurred for the northern nearshore zone of Lake Erie from 1967 to 1973. Increases have also been reported near Long Point in the eastern basin from 1967 to 1978 (Weiler and Heathcote, 1979). Dobson (1981) reported a 1.5-fold increase in nitrate levels from 1970 to 1980 for eastern basin main lake waters.

Nitrate trends at the Maumee Bay site substanitally conflict with those found at Locust Point. Significant decreases found at the C&O Docks during analysis of both monthly and yearly means most probably reflect improvements in Toledo's sewage treatment operations. Inspection of Tables 12 and 13 reveal that decreases during the winter and spring seasons are resposible for observed decreases in yearly and monthly means. Figure 32 provides evidence of improved sewage treatment practices being resposible for observed trends. The most substantial reduction occurs after 1974 and is especially evident in the early summer, fall, and winter seasons when storm by-pass is less likely to occur.

Conflicting trends at the two locations suggest sources of nitrate input other than the Maumee River are influencing lake-wide trends. The International Joint Commission in 1977 identified large loading increases for nitrates in the Detroit River. Thus, increases at the Locust Point site reflect inputs from the Upper Great Lakes, while substantial decreases from the Maumee River do not appear to have a significant impact.

Phosphorus concentrations exhibit a significant decrease in Maumee Bay, while no change is observed at Locust Point for any of the three analyses performed. Inspection of Figure 24 reveals that a relatively stable concentration of total phosphorus was present from 1970 to 1974, after which a substantial decline is visually evident. In addition, seasonal blocking produced significant decreases during all five seasonal periods. Figure 33 reveals a substantial decrease after 1974 for all five seasons. Thus, tertiary sewage treatment initiated in 1974 is most likely responsible for the observed decrease.

Several researchers have documented substantial decreases in phosphorus concentrations through the past 10 to 15 years. A decrease of 88% in phosphorus loading in the Detroit River has been calculated by the Michigan

Department of Natural Resources (1981). This decrease has been attributed to improvements in the five waste water treatment plants for the Detroit metropolis. Negative trends have also been documented for the Cleveland area (Richards, 1981), the entire Ontario nearshore zone (Gregor and Ongley, 1978), and the eastern basin (Weiler and Heathcote, 1979).

The seemingly steady-state condition for phosphorus occurring at the Locust Point site may be reflective of release of deposited phosphatic materials from the sediments balancing decreased inputs from major tributaries. Increases in turbidity, dissolved solids, and suspended solids occurring at the Locust Point site indicate that storm activity is responsible for observed trends. In order to test the possibility of weather influences on these parameters, mean monthly wind velocity (mph) data from the Toledo Airport were correlated against the monthly means for turbidity, suspended solids and total phosphorus. Correlation coefficients of .58 for turbidity, .44 for suspended solids, and .56 for total phosphorus are all significant at $P<.01$ (Steel and Torrie,1980). In addition, monthly average wind velocity and the maximum wind velocity observed for each month were regressed against time in months. The F-statistic for both of these regressions ($F=5.89$ and $F=16.08$, respectively) are highly significant

(P<.005), indicating that increased storm activity are responsible for observed trends. Thus, it is very likely that increases in these parameters are responsible for the observed steady condition occurring in phosphorus concentrations at Locust Point.

Trends in alkalinity are conflicting for the two study sites. While alkalinity values show a substantial decrease from 1970 to 1979 at the Maumee Bay site, a significant increase is found at Locust Point, especially during the early summer and fall seasons. Decreases in monthly and yearly means observed at the Maumee Bay site are due to decreases occurring for the late summer and fall seasons (Table 13). Figure 31 reveals that visually evident but insignificant decreases are occurring for the other seasons as well. Decreases at the C&O Dock are likely reflecting increased acid precipitation (Dillon, 1978). Alkalinity increases observed at Locust Point can be explained by the immense buffering capacity that persists in the Great Lakes basin coupled with influences from increased storm activity dissolving limestone and dolomitic rock in the western basin. This is especially evident through increases observed during the early summer and fall seasons when wind and wave action are enhanced.

Chloride concentrations have not significantly changed at Locust Point through trend analysis of yearly or monthly means. When the data is blocked by season, however, chloride is significantly increasing during the spring and fall seasons (Table 8). The decrease observed for the late summer season is attributed to extremely low values occurring in 1979 (Figure 12). When these values are removed, substantial increases can be observed for all seasons with the exception of early summer.

A substantial increase is found at the C&O Dock when yearly means and monthly means are regressed through time. Inspection of Table 13 and Figure 30 reveals that increases occurring in the spring, early summer, and late summer seasons are resposnible for observed trends. Since the winters of 1977, 1978, and 1979 were particularly severe in terms of snowfall, increases in this parameter are most likely reflective of salt usage for deicing purposes.

Previous investigations throughout Lake Erie from 1964 to 1973 indicate significant decreases occurred. These decreases have been explained by an increase in the flushing fate from the Detroit River. Flow increased from 4437 m^3/s in 1964 to 6734 m^3/s in 1973 (IJC,1974; Gregor and Ongley, 1978). Water level data from 1960 to 1980 is shown in Figure 35. Inspection of the figure indicates that a rise in lake levels did occur from 1964 to 1973, but since then have leveled off. Dilutional effects are thus not considered as a causal factor for

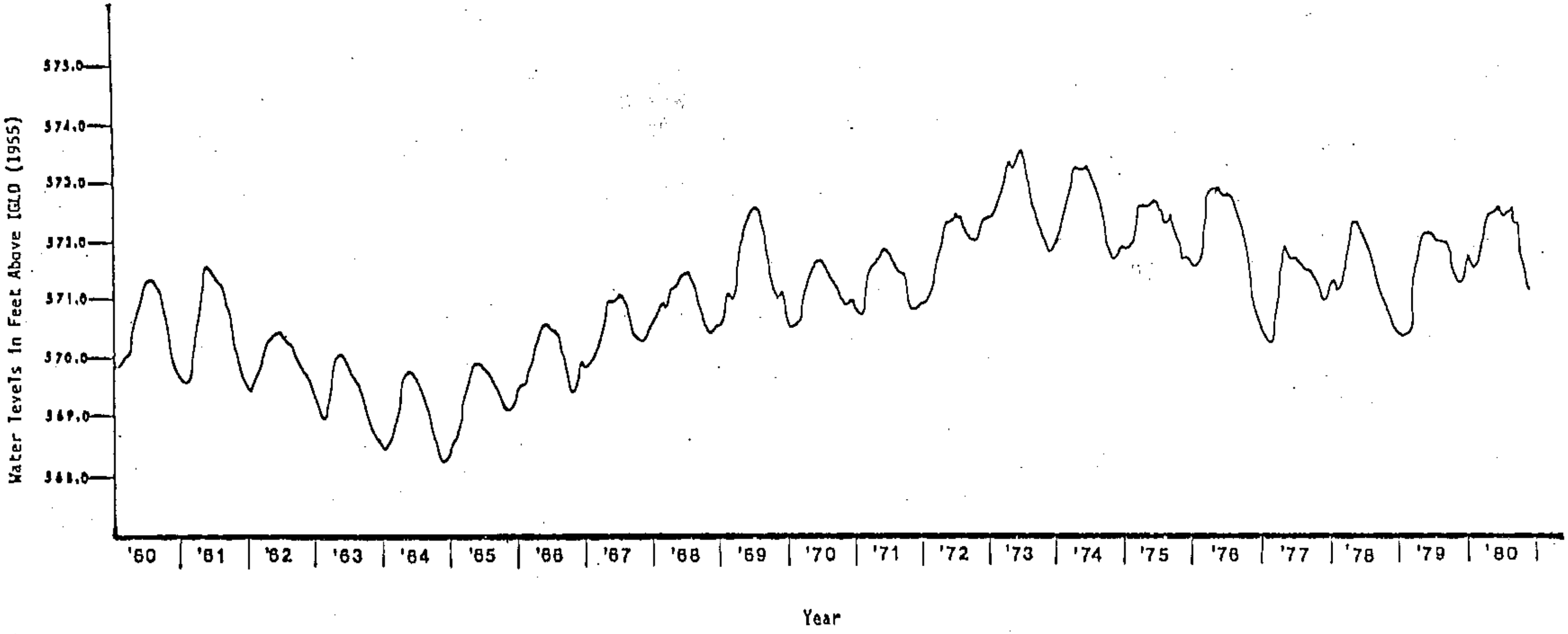


Figure 35. Lake Erie water level data, 1960-1980.

observed trends.

Although no trends were reported at either location for dissolved oxygen when analyzed via monthly or yearly means, seasonal blocking produced decreases for all seasons except early summer at Locust Point. Only the spring value was significant at $P<.10$ but not at $P<.05$. Seasonal blocking at the C&O Docks, however, produced increases in all seasons with late summer and fall producing significance of the trend. Again, improved sewage treatment may be responsible by decreasing biochemical oxygen demand.

While no significant trend in dissolved solids was found at either location through analysis of monthly or yearly means, seasonal blocking produced increases at both locations for the early summer and late summer periods. Dissolved solids have been substantially increasing in Lake Erie since around 1910 (Beeton, 1961;IJC,1969a). Although slight increases are reported for these seasons, yearly means from the Locust Point site (1974-1980) plotted against whole lake observations of Beeton (1970) indicate that the increase which typified the first half of the century is no longer evident and indicates a stabilization of the trend to diminishing levels (Figure 36).

Statistical techniques performed on data from Locust Point produced varying results. Regression analysis for

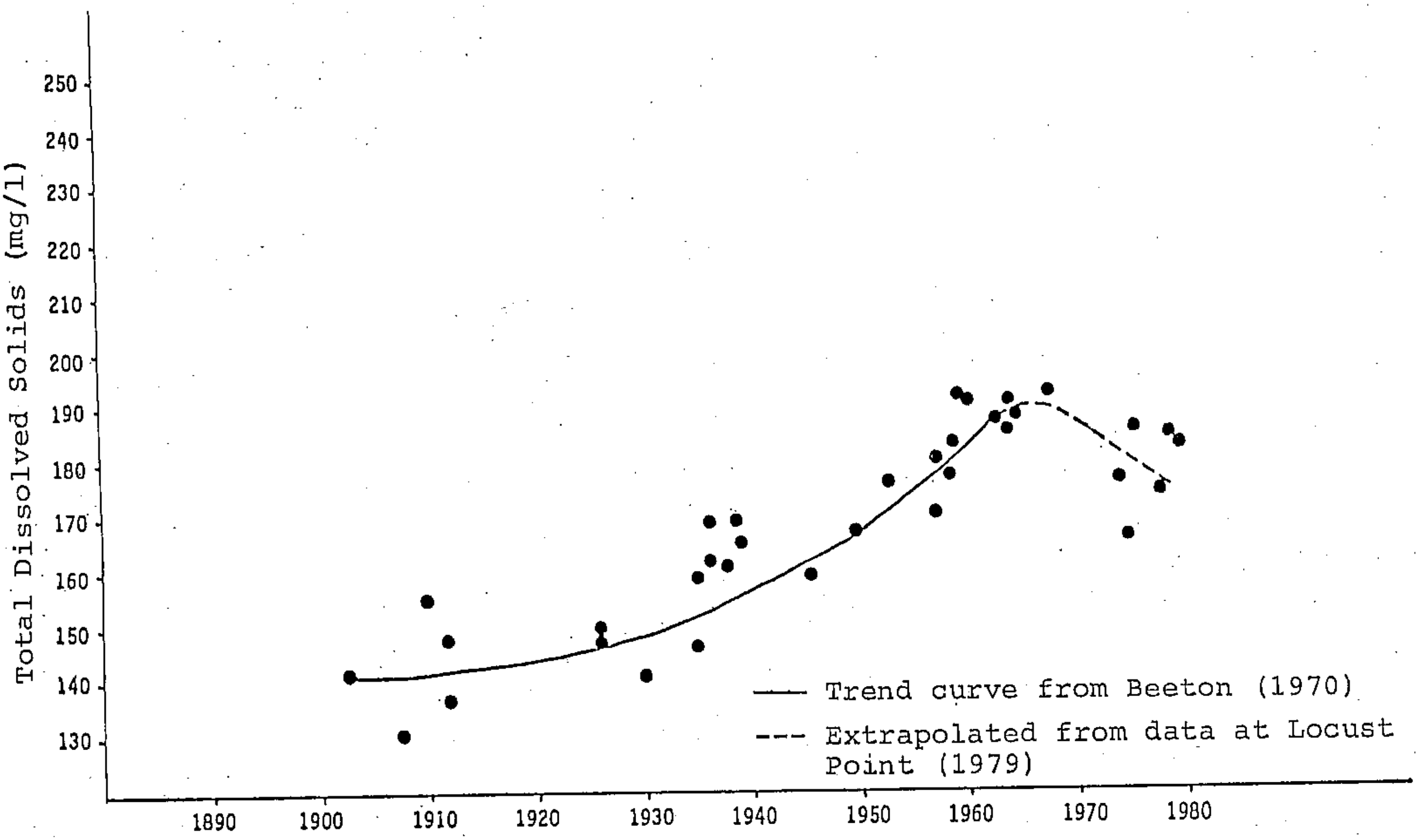


Figure 36. Comparison of 1979 values for total dissolved solids at Locust Point with the trend curve from Beeton (1970).

monthly means produced a significant trend in conductivity, alkalinity, and nitrates. The extreme variability inherent in the nearshore zone serves to limit achieved statistical significance. In addition, monthly sampling techniques serve to increase variability which is somewhat smoothed in a continuous sampling cycle similar to that at the C&O Docks.

Regressions performed on yearly means resulted in higher R^2 values and a greater number of parameters exhibiting significance in trend. Thus, most of the variability is removed simply by yearly averaging. The nitrate trend, however, fell below the $P<.05$ significance level during regression on yearly means. This is due to a large decrease in the degrees of freedom used for calcualation of the F-statistic.

Seasonal blocking serves to identify periods during the year which are most reflective of actual trend phenomenon. Inspection of Table 7 reveals that the highest R^2 values and significance levels can be found for certain parameters such as turbidity, phosphorus, and suspended solids during the summer seasonal periods when weather influences are minimal. Other parameters such as chloride and conductivity reveal significance in the spring and early summer when inputs of these constituents is large due to runoff.

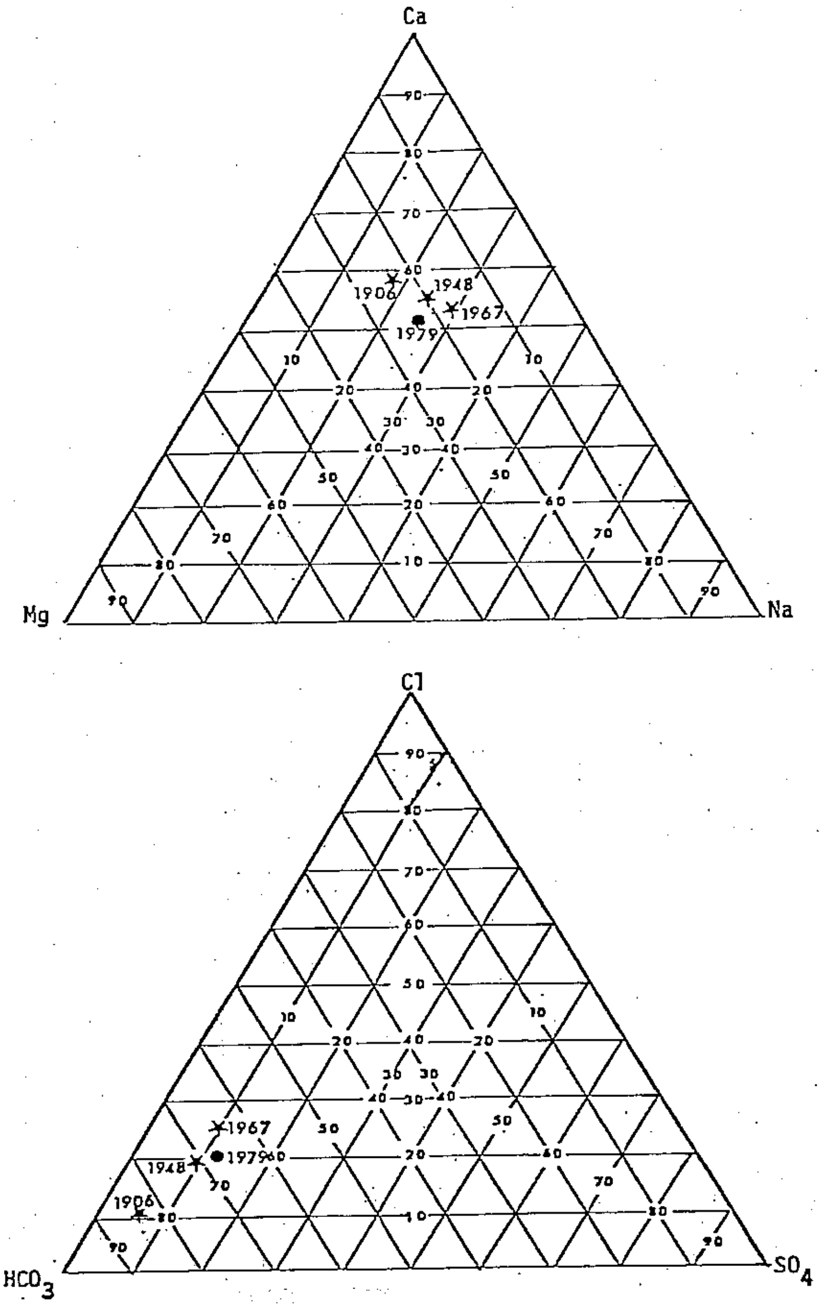
Regression of yearly means in comparison with monthly means at the Maumee Bay site produced similar trends. As expected, R^2 values increased due to decreased variability through the averaging process. Significance levels dropped somewhat during yearly averaging resulting from a decrease in degrees of freedom. Residual analysis of the linear regression indicates that all parameters exhibiting a significant trend, with the exception of nitrate, are adequately explained by the linear model. The nitrate regression is influenced by a severe decrease in values beginning in 1976. Prior to that year, nitrate appears to have remained relatively stable.

Seasonal blocking for parameters at the C&O Docks produced significant trends in the spring and early summer seasonal periods for chlorides and nitrates only. Lack of significance in the other parameters for these two seasons (with the exception of total phosphorus) may be attributed to extreme variable loading conditions that persist early in the year. Significance of suspended solids, dissolved solids, dissolved oxygen, and alkalinity all appear during the late summer and fall seasons when variability due to Maumee River flow is diminished.

Weiler and Chawla (1968) documented changes in Lake Erie water quality through triangular percentage plots of major ionic species comprising conductivity. Their results indicated that major shifts occurred from 1906 to 1948 with respect to chloride and sodium concentrations. An even greater increase in these ions took place between 1948 and 1967. When concentrations from the Locust Point location are plotted against Weiler and Chawla's data, a reversion back to 1948 values is evident (Figure 37). This reversal may be due to increases in alkalinity (or bicarbonates) and magnesium ion occurring at this site.

Chemical species sampled at Locust Point which were common to reported trends of Beeton (1970) were plotted against his findings (Figure 38). Although this technique is not definitive due to Beeton's variety of source locations, it does provide evidence of decreases in trends, with the exception of sulfates, which took place during the past 70 years.

Figures 36,37 and 38 provide evidence that Lake Erie is not deteriorating at the rate which typified the first part of the century, and may be reverting to pre-1959 values.



✱ Data from Weiler and Chawla (1968)
● Data from Locust Point (1979)

Figure 37. Comparison of major ionic species comprising conductivity from 1906-1979.

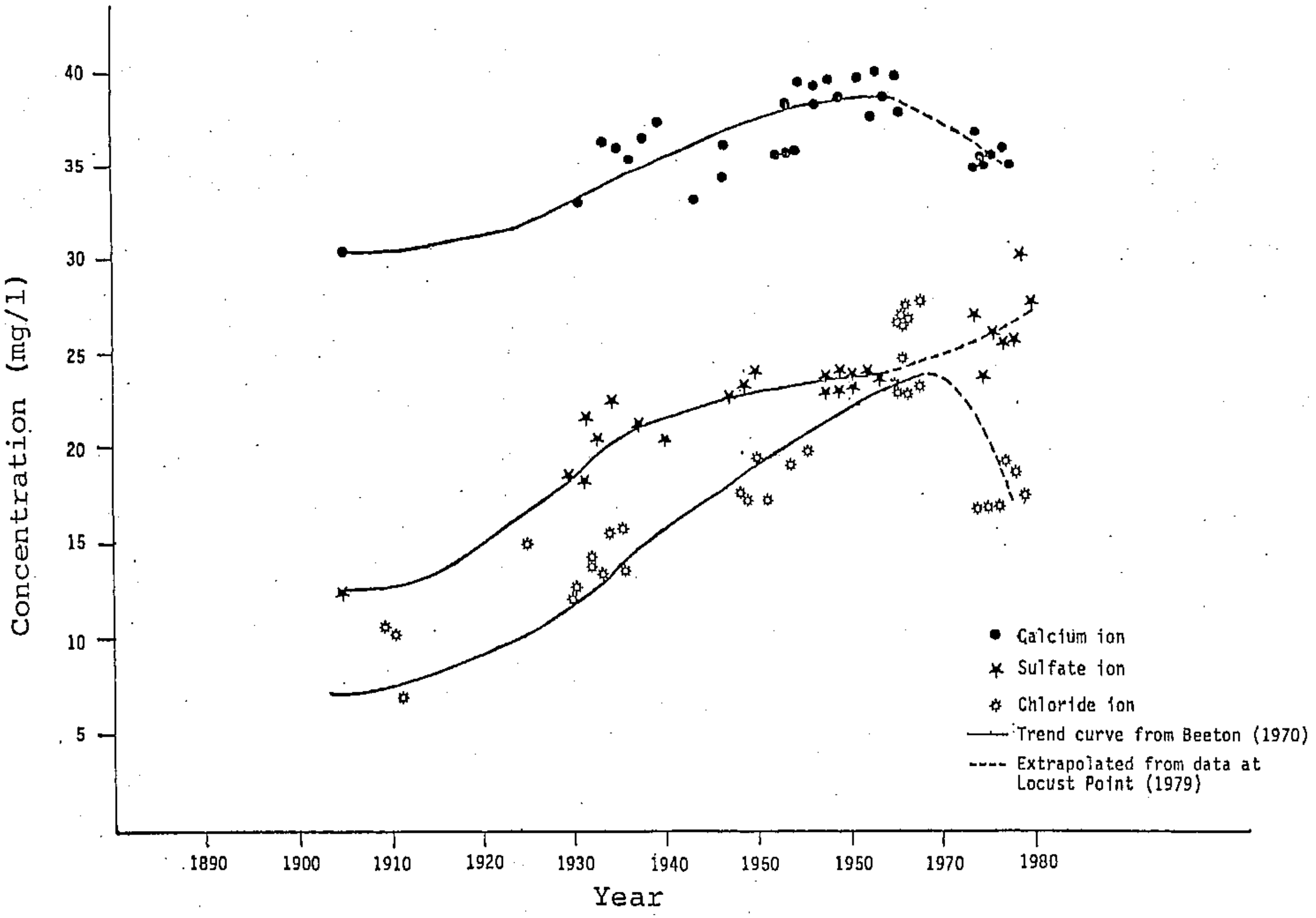


Figure 38. Comparison of 1979 values for calcium, sulfate, and chloride at Locust Point with trend curves from Beeton (1970).

CONCLUSIONS

1. Linear regression analysis performed on monthly means for nine selected parameters at Locust Point indicated a significant increase occurred from 1974 to 1980 for nitrates, conductivity and alkalinity. No decreases were found for any parameter using this method.

2. Analysis of yearly means at Locust Point indicated significant increases in conductivity, suspended solids, turbidity, alkalinity and nitrates. These increases are attributed to increased precipitation and wind acitvity in recent years.

3. Linear trend analysis performed on monthly and yearly means produced similar results for parameters sampled in Maumee Bay. Increases were found from 1970 to 1979 for chloride and dissolved oxygen, while decreases were found for alkalinity, nitrate and total phosphorus.

4. Conflicting trends occurring for both locations are attributed to limnological processes affecting the nearshore zone coupled with Detroit River influences that dominate the Locust Point site but do not influence Maumee Bay. Localized remedial activities in

the Toledo area are also responsible for observed conflicts.

5. Seasonal blocking at both locations served to identify periods during the year which are most reflective of actual trend phenomenon by homogenizing the variability due to seasonality. This technique aids in the identification of periods during the year which are influencing observed trends in yearly or monthly data.

6. Comparison of relatively recent data with those of past investigations imply that deterioration of Lake Erie which typified the first half of the century is no longer evident. Stabilization of trends vay be occurring even to the point of diminishing levels.

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