# POTOMAC RIVER BASIN WATER QUALITY

# STATUS AND TREND ASSESSMENT

# 1973-1984

Prepared by

H. Carlton Haywood
Roland C. Steiner
and
V. James Rasin, Jr.
Keith M. Brooks
Stuart S. Schwartz

November 1987

ICPRB Report 87-12

Interstate Commission on the Potomac River Basin
6110 Executive Boulevard, Suite 300
Rockville, Maryland 20852-3903

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

This publication has been prepared by the Interstate Commission on the Potomac River Basin. Funds for this publication are provided by the United States Government, the U.S. Environmental Protection Agency, and the signatory bodies to the Interstate Commission on the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia. The opinions expressed are those of the authors and should not be construed as representing the opinions or policies of the United States or any of its agencies, the several states, or the Commissioners of the Interstate Commission on the Potomac River Basin.

# POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

## EXECUTIVE SUMMARY

This report assesses water quality data collected at representative stations in the Potomac River basin during the years 1973-1984. The purpose of this assessment is to identify water quality parameters for which statistically significant trends have occurred. Recent ICPRB water quality status assessments were compared with prior status assessments to provide an estimate of trends in overall water quality at each station.

As in past ICPRB reports, the Potomac River basin is divided into six subdivisions so as to give a reasonable geographic coverage for analysis: Potomac Highlands (13 stations), Upper Great Valley (12 stations), Shenandoah River (23 stations), Potomac Piedmont (11 stations), Potomac Urban Estuary (17 stations), and the Lower Potomac Estuary (7 stations). The stations included in this report were selected from monitoring networks maintained by each of the States in the Potomac River Basin: West Virginia, Virginia, Pennsylvania, Maryland, and the District of Columbia. Selected stations comprise ICPRB's Baseline Water Quality Monitoring Network (BWQMN) (ref 1). Data from these stations were collected by state agencies for their water quality monitoring networks. ICPRB obtained these data from the US EPA's data base system (STORET), or directly from the States.

Trends in parameters are developed using the Seasonal Kendall Tau nonparametric statistical test. It is a test that tallies the number of times each parameter observation is greater than or less than later observations for a given month in succeeding years. The test uses only relative position in time and relative magnitude. With this technique, missing data, multiple observations per month, and seasonal effects may easily be accommodated in the analysis without skewing the trend. For this reason and others, the Kendall Tau trend is superior to a linear regression. Water quality data do not fit well into a parametric model such as linear regression which is most useful when data are highly normal and non-seasonal.

For each station, parameter trends judged to be statistically significant are plotted. For each subdivision of the basin, the parameters found to have significant trends are shown in two ways. First, for each station, every significant parameter trend is shown with its Kendall Tau test statistic and the direction of the trend indicated by a "+" (up) or "-" (down). Second, the significant trends are presented in a table of parameters versus stations.

POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

Two water quality status assessments for each station are listed--former status and current status. The current station status assessment is derived from ICPRB's most recent water quality status report (1982-1983) ref. 8, or an analysis of yearly mean values reported for 1984. The former station status assessment is derived from previous ICPRB water quality reports dating as far back as 1974, ref. 1. The detection of an overall station trend was then attempted.

The results of the Seasonal Kendall Tau test for significant trends identified several parameters with trends dominantly in one direction and broadly represented throughout the Potomac River Basin. Temperature, pH, and Turbidity almost always showed declining trends while the nutrients (Nitrogen and Phosphorus) were increasing. More localized, but of some importance were trends in toxic metals: upward for Lead and Chromium and downward for Mercury.

For each subdivision, a summary of significant trends is discussed briefly below:

POTOMAC HIGHLANDS

Water quality of the Potomac Highlands subdivision varies from Poor to Good-Excellent. The water quality in the headwaters of the Potomac remains Poor due to acid drainage from abandoned mines and low levels of treatment of municipal wastes. Significant parameter trends throughout the subdivision were a decrease in Turbidity ('8 of 13' stations) and an increase in Nitrate ("9 of 13" stations). Acid water (low pH) has been a perennial problem which results from the effects of past coal mining operations in the North Branch Potomac River watershed. The most significant impact on water quality in the North Branch during the period of analysis was the construction of Jennings Randolph Dam. Since its filling and operation in 1982, pH has improved (increased) by approximately 2 units, down stream of the dam. Recent reports documenting the survival of smallmouth bass in the reservoir also indicate improvements are occurring. However, throughout the rest of the subdivision, pH was broadly trending lower. Of special interest was the increasing trend in hexavalent chromium at two stations on the South Branch Potomac. Total Coliform was down at four stations, up at only one; and DO was broadly up. Among the nutrients, Nitrate and Total Phosphorus were showing increasing trends except for Phosphorus in the South Branch where it was down. Temperature and Turbidity were broadly trending down.

## UPPER GREAT VALLEY

Water Quality of the Upper Great Valley subdivision is Fair. Agriculture is a major land use in this area and associated with it are nonpoint sources of pollution. The significant parameter trends found in the subdivision were a decrease in Turbidity ("7 of 12" stations) and Salinity ("5 of 12" stations), and an increase in Nitrate ("8 of 12" stations). Trends in pH were down at six stations and up at only two. Of special interest were trends shown in Iron, Chromium, and Lead. Iron was found to be decreasing in both Pennsylvania (Conococheague Creek) and West Virginia (Opequon Creek) stations. Hexavalent Chromium and Lead were found to have increasing trends in Opequon Creek.

## SHENANDOAH RIVER

Water quality of the Shenandoah River subdivision, the only true sub-basin of the six subdivisions, varies from Fair to Excellent. The size and diversity of this sub-basin make the identification of basin-wide trends difficult. From the industrial areas near Waynesboro, VA, to the agricultural lands and orchards, water quality spans a broad range. Across the twenty three stations in the Shenandoah River basin, there was a prevalence of significant increasing trends for various forms of Nitrogen. For Ammonia, fourteen stations showed increasing trends, versus decreasing at three stations. For Nitrite, fourteen stations showed increasing trends, versus decreasing at two stations. Five stations showed increasing trends for Total Kjeldahl Nitrogen (TKN), while three showed TKN to be decreasing. Total Phosphorus, or Total Phosphate, have increasing trends at seven stations, versus decreasing trends at two stations; but conversely, Total Ortho Phosphorus has decreasing trends at ten stations, and increasing trends at only two stations. TOC shows decreasing trends at eight stations, and no increasing trends. Mercury shows a decreasing trend in the south river.

## POTOMAC PIEDMONT

Water quality of the Potomac Piedmont subdivision varies from Fair to Good. Regional patterns in water quality parameter trends include increasing Nitrogen, and decreasing pH, Salinity, and Temperature. Eight of eleven stations had increasing trends in Nitrogen parameters, while only one (Sugarland Run) had a decreasing trend. Decreasing pH trends occurred at seven stations. At all of these, pH was decreasing from alkaline levels. Decreasing Salinity occurred at four stations. As elsewhere in the Potomac basin, significant decreasing trends were detected in Temperature.

# POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

## POTOMAC URBAN ESTUARY

Water quality of the Potomac Urban Estuary subdivision varies from Poor to Good. Over a billion dollars has been spent on improvements to wastewater treatment plants in this subdivision with some dramatic improvements at selected stations. Upgrading is continuing and nitrogen removal from some of the plants may be required. Submerged aquatic vegetation has begun to return, which is a sign of improving water quality. Algal blooms returned in the summers of 1983 and 1984, confusing the public's perception that water quality improvements have occurred. A regional analysis of nutrient trends shows a mixed picture: Ammonia is down in the upper part of the Potomac and the Anacostia, but up in Little Hunting and Pohick creeks. Other Nitrogen series parameters are up in the upper Potomac, Rock Creek, upper Anacostia, Little Hunting and Pohick creeks, while down in the lower Anacostia, the Potomac at Woodrow Wilson Bridge, and Hunting and Piscataway creeks. Phosphorus was broadly down except for upward trends on the Potomac at Little Falls, Little Hunting Creek, and mixed trends in Pohich Creek. Coliform was broadly down except for upward trends in Hunting, Little Hunting, and Pohick creek. Where detected at eight stations, the trend in pH was consistently downward. Trends in Residue species were broadly down where detected in the lower tributaries, except for Pohick Creek where the trends were upward.

## LOWER POTOMAC ESTUARY

Water quality of the Lower Potomac Estuary subdivision varies from Fair to Excellent. The Chesapeake Bay is a major influence on this section of the river. This estuarine subdivision showed some improvement in bacterial contamination, with trends in Total Coliform down at three stations. The nitrogen series was broadly up, whereas phosphorus was up at one station and down at another. DO was trending upward at Indian Head (the only station with a significant DO trend). Total Organic Carbon (TOC) was down in three of the tributaries.

POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

## PREFACE

Since its creation in 1940, the mission of the Interstate Commission on the Potomac River Basin (ICPRB) has been to promote the protection and enhancement of the environment of the almost 15,000 square-mile drainage basin of the Potomac River. To achieve its mission, ICPRB has among its functions the collection, interpretation, and dissemination of data relative to all facets of the area's water and associated land resource problems.

In the late 1950s, the Commission organized a surface water quality monitoring network comprised of stations on the Potomac and its tributaries with water samples collected and/or analyzed by industrial, municipal, state, and federal water quality laboratories. During the period from the early 1960s to the early 1970s, a considerable amount of water quality data was gathered and tabulated. Little attempt was made to interpret it because the data often did not lend themselves to trend evaluations or comparisons between areas. An ICPRB evaluation of basin-wide data gathered over eleven years from 1962 to 1973 was prepared by Mason et al in 1975.

Beginning in 1972, the Federal Water Pollution Control Act Amendments (PL-92-500) required more coordinated water quality monitoring, more accurate data, and some analysis. In 1974, the Interstate Commission, with the cooperation of state and federal water quality scientists and administrators, conceived the Baseline Water Quality Monitoring Network (BWQMN). The BWQMN began with 53 stations sampled by city, county, and state water quality regulatory agencies, and now includes 72 stations strategically located to provide baseline data for biennial water quality appraisals and long-term trend analyses.

Over the last few years, more comprehensive and compatible data have been collected, partially as a result of the institution of the U.S. Environmental Protection Agency's (EPA) "CORE" sampling network. The "CORE" network is a nationwide ambient monitoring program which, as does the BWQMN, emphasizes the need for consistency in sampling frequency, laboratory methods, parameter coverage, and quality assurance and quality control in the reporting, storage, and accessibility of the data. Assessment of water quality information from these networks allows priority areas to be determined so that management decisions can be made and funding can be allocated to them.

From year to year, state governments are forced to deal with changes in priorities, with resultant fiscal and man-power constraints. In some cases, these shifts in priorities can and have affected state monitoring programs: some stations, or parameters, may be dropped while others are added. This has affected data continuity at some stations used in this report.

For example, stations and parameters monitored by the Virginia Water Control Board changed in 1978. As a result the data series for some stations in the Shenandoah sub-division ends in that year. Similarly in Maryland, the suite of parameters measured changed in 1981 when responsibility for monitoring was shifted from the Water Resources Administration to the Office of Environmental Programs. Even when sampling was not affected, other phases of monitoring, such as data handling and storage, were affected. On some occasions data were collected and recorded but due to manpower or other constraints, data values were not entered into the US EPA STORET data base. This has made basin-wide and nation-wide analysis of the data (especially over long time periods) difficult to accomplish statistically. In some cases, data gaps were identified and filled, and in other cases data were lost or unretrievable.

When the Draft version of this report was produced, recent data from the District of Columbia and Maryland were unavailable on STORET. Since that time, the State of Maryland has had its data entered onto that system, and retrieved by ICPRB for analysis. The data for the District of Columbia stations has been obtained directly from Department of Consumer and Regulatory Affairs. The major difference of substance between the Draft and this Final version of the 1973-1984 report involves the inclusion of the most complete data obtainable from the Maryland and D.C. stations for the period. In addition to more complete data, the format of the whole report has been improved for clearer presentation of results.

The ICPRB water quality reports of 1974, 1975-76, 1977, 1978-79, 1980-81, and 1982-83, represented evaluations of data to determine the status of major Potomac River tributaries, the Potomac River main stem, and the Potomac River basin as a whole. In this report, Potomac River Water Quality Status and Trend Assessment, 1973-1984, the methodology used in previous reports is continued, and in addition, the Kendall Tau nonparametric statistical test is used to identify trends in water quality.

ICPRB strives to publish its water quality reports in a format and time-frame to be of assistance to the Potomac basin states to help them prepare their water quality 305(b) inventory reports to EPA and Congress. With increased interest from EPA to include a reporting of trends in the states' 305(b) reports, we believe this statistical tool could easily be utilized by the states to produce water quality trend information.

We are indebted to Paul W. Eastman (former Executive Director) for his committment to better water quality in the Potomac River basin and under whose direction the Draft of this report was prepared.

L. E. ZENI
Executive Director

Table 1. Abbreviations and Acromyns

| | |
|---|---|
| $BOD_5$ | Five-day Biological Oxygen Demand |
| BWQMN | Baseline Water Quality Monitoring Network |
| COD | Chemical Oxygen Demand |
| CORE | EPA's Cooperative Sampling and Reporting Program |
| cfs | cubic feet per second |
| Chl-a | Chlorophyll-a |
| D-bar | Macroinvertebrate Community Diversity Index |
| DC ECD | DC Environmental Control Division |
| DC CRA | DC (Department of) Consumer and Regulatory Affairs |
| DO | Dissolved Oxygen |
| EPA | Environmental Protection Agency |
| ICPRB | Interstate Commission on the Potomac River Basin |
| km | kilometers |
| $km^2$ | square kilometers |
| MD DHM | MD Department of Health and Mental Hygiene |
| MD OEP | MD Office of Environmental Porgrams |
| MD WRA | MD Water Resources Administration |
| m | meters |
| $m^3$ | cubic meters |
| mgd | million gallons per day |
| mi | miles |
| $mi^2$ | square miles |
| NFLT | Nonfilterable |
| $NO_3$-N | Nitrate Nitrogen |
| NPDES | National Pollutant Discharge Elimination System |
| PA DER | PA Department of Environmental Resources |
| PCB | Polychlorinated Biphenyls |
| pH | Acidity/Alkalinity Measurement Scale |
| ppb | parts per billion |
| ppm | parts per million |
| ppt | parts per thousand |
| SS | Suspended Solids |
| STP | Sewage Treatment Plant |
| SU | Standard Units (pH scale) |
| SWCB | State Water Control Board (VA) |
| TOC | Total Organic Carbon |
| TP | Total Phosphorus |
| T-$PO_4$ | Total Phosphate as P |
| UOSA | Upper Occoquan Sewage Authority |
| USGS | United States Geological Survey |
| VA SWCB | VA State Water Control Board |
| WAWAG | Washington Area Waterfront Action Group |
| WMA | Washington Metropolitan Area |
| WV DNR | WV Department of Natural Resources |
| WWTP | Wastewater Treatment Plant |

## ACKNOWLEDGMENTS

The success of the Potomac River Basin Water Quality Monitoring Network (BWQMN) is due to the support of the following agencies.

U.S. ENVIRONMENTAL PROTECTION AGENCY

U.S. GEOLOGICAL SURVEY

DISTRICT OF COLUMBIA, Department of Consumer and Regulatory Affairs, Environmental Control Division.

MARYLAND, Department of the Environment.

PENNSYLVANIA, Department of Environmental Resources

VIRGINIA, State Water Control Board, Division of Surveillance and Field Studies, Northern and Valley Regional Offices

WEST VIRGINIA, Department of Natural Resources, Division of Water Resources

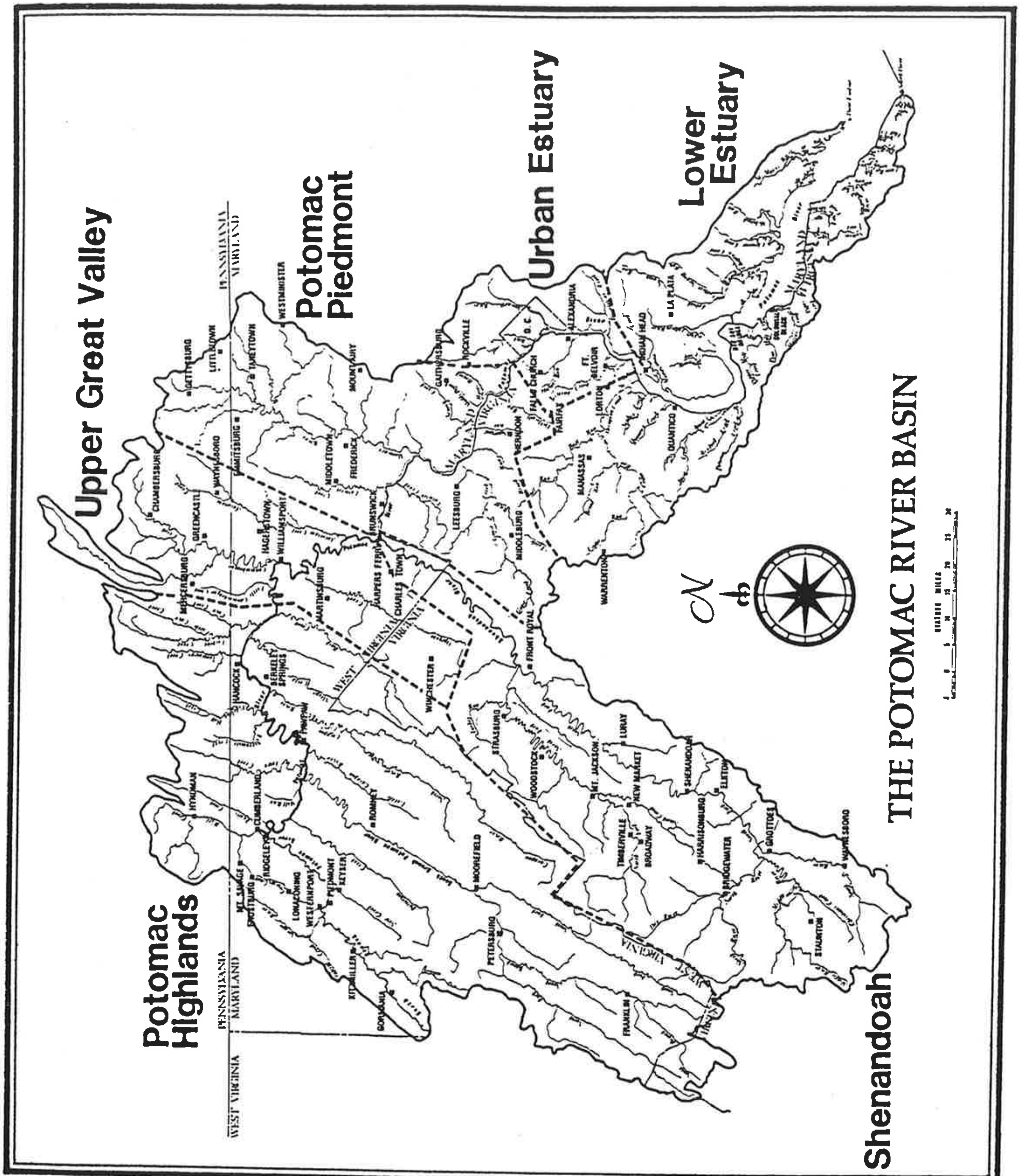
The authors gratefully acknowledge the assistance of Paul C. Johnson of the Welsh Water Authority, Great Britain, graphics by Curtis Dalpra, tables by Kathleen Hogan and Elaine Friebele, and word processing by Pat Rosenquist and Barbara Barritt of ICPRB.

## TABLE OF CONTENTS

## LIST OF MAPS

## LIST OF TABLES

Map 1.



Upper Great Valley
Potomac Piedmont
Urban Estuary
Lower Estuary
Potomac Highlands
Shenandoah
THE POTOMAC RIVER BASIN
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
VIRGINIA

# POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

## INTRODUCTION

This report is intended to provide a regional assessment of trends in water quality in the Potomac River Basin in the period 1973 through 1984. This assessment is made in two ways: a) by determination, using the Kendall tau trend test statistic, of what water quality parameters show significant trends in value; and b) by determination of a water quality status index. Assessments were made at a network of 84 stations located throughout the basin.

### Basin Description

The Potomac River Basin is located in the middle Atlantic coastal zone of the United States. The Potomac River is the second largest tributary to the Chesapeake Bay. It begins as a small spring at Fairfax Stone, WV, and for the first 100 miles of its length it is called the North Branch Potomac River. When it is joined by the South Branch Potomac River near Green Spring, WV, it forms the Potomac River proper and flows another 283 miles until it meets the Chesapeake Bay at Point Lookout, MD and Smith Point, VA. The Potomac River Basin drains 14,670 $miles^2$ (37981 $km^2$) of which 5,723 $miles^2$ (14817 $km^2$) are in Virginia, 3,818 $miles^2$ (9885 $km^2$) in Maryland, 3,490 $miles^2$ (9036 $km^2$) in West Virginia, 1,570 $miles^2$ (4064 $km^2$) in Pennsylvania, and 69 $miles^2$ (179 $km^2$) in the District of Columbia.

In this report, the Basin is divided into six subdivisions, which approximately correspond to physiographic provinces. Map 1 shows the Potomac Basin divided into these subdivisions, and includes major towns and tributary streams.

### Water Quality Data Sources

Trend and status assessments were made using data collected by State agencies responsible for water quality monitoring: District of Columbia, Department of Consumer and Regulatory Affairs, Environmental Control Division; Maryland, Department of the Environment (Formerly Department of Health and Mental Hygiene, Office of Environmental Programs, and prior to 1981, the Water Resources Administration); Pennsylvania, Department of Environmental Resources; Virginia, State Water Control Board, Division of Surveillance and Field Studies, Northern and Valley Regional Offices; and West Virginia, Department of Natural Resources, Division of Water Resources.

The data used in the Draft parameter status and trend assessment for the period of record were retrieved from the US EPA's data base system - STORET. For the states of Pennsylvania, Virginia and West Virginia, some stations exhibited a period of record complete through 1985. For Maryland and the District of Columbia, the data series available from STORET ended in 1981. Since the production of the Draft report, those two states have brought their STORET files up to date. This final version of the report now contains the results of trend tests on the complete time series for parameters in these jurisdictions. However, because of various changes in monitoring programs that have occurred in each state during 1973-84, the time series for some parameters and stations does not include the entire period.

The water quality parameters included in this report are those most commonly sampled by the states. Sampling frequency is usually about one per month, but it varies from station to station. Data for each parameter with a significant trend is plotted in figures at the end of this report. Table 2 lists, by EPA STORET numerical code and description, water quality parameters used in this report. For brevity, raw data are not published here, but can be obtained from ICPRB, from STORET, or from the state agencies. More detailed information on field and laboratory methods for these parameters is also available from the same sources. Table 3 lists the location of monitoring stations. This Table also lists, for each station, the state identification code, state agency, ICPRB BWQMN number (for continuity with previous ICPRB reports), and the overall water quality status as of 1984.

## Overall Station Status And Trend Determination

The water quality status designation is determined by a method used to derive station status terms in ICPRB water quality status reports since 1974. The mean yearly values of common water quality parameters are compared with ranges of values which define water quality classes (see Table 4). The overall status for each station is determined by the frequency with which the parameter values fall in each class. Additional verification of the station status terms is carried out by consultations with state water quality biologists, on-site investigations when possible, and the authors' professional knowledge and judgement of the water system. The water quality status terms or classes are: "Poor", "Fair", "Good", and "Excellent". After analysis, related terms were combined, yielding seven possible station status terms: Poor, Poor-Fair, Fair, Fair-Good, Good, Good-Excellent and Excellent.

The overall trend evaluation is determined by a comparison of previous status evaluations and consideration of nonparametric trend test (the Seasonal Kendall Tau) results. In most cases, the current status term as reported in the 1982-1983 ICPRB water quality report is compared with reports from 1974 to 1981. The recent status term is compared with the former status term to determine if a trend in status is apparent. In some cases, overall trend is not substantiated by the current and former status terms, and is listed as "Unknown". Usually the reason for the "Unknown" designation is insufficient data for a valid determination, a station previously assigned an incorrect status term, or a change in station location during the time period so that former evaluations are not comparable to more recent ones.

## Kendall Tau Test For Trend

Statistical hypothesis testing is commonly used in the trend analysis of water quality data to test the significance of a linear regression of water quality against time. Typically a straight line is fit to an observed water quality time series and the significance of the slope is tested against the null hypothesis that the true value of this slope is zero. Water quality time series without a "true" trend can, infrequently, exhibit trend-like behavior purely by chance. The significance level of the test expresses the frequency with which we are willing to tolerate this inevitable incorrect conclusion.

The use of linear regression is widespread, due in part to its easy application with readily available computer codes. Underlying the use of this powerful statistical tool are a number of assumptions about the structure of the data being analyzed. When these assumptions are violated a severe degradation of the power and significance of the linear regression technique can result.

Many water quality data sets violate these assumptions. They often contain incomplete, missing, or unevenly timed sample values. The data frequently exhibit seasonal variations, and particularly with metals and organics, monitoring data are sometimes reported as "less than the limit of detection" (LD). This occurs when laboratory analysis tries, but fails, to detect a particular parameter. LD observations do contain information about ambient water quality. Traditional parametric techniques are, however, simply unable to use data of this type. Observations reported as LD are either assigned arbitrarily low numerical values (producing biased parameter estimates), or ignored (using less information than is available, and biasing the record in favor of high or significant values). All of these features, commonly encountered in real water quality data, lead to erratic and unreliable results when traditional linear regression trend tests are employed.

In order to support valid and rigorous statistical testing for the presence of trends in water quality time series, a nonparametric test statistic known as the Seasonal Kendall Tau was developed (Hirsch et al. 1982). It is employed in this report in place of more common tests based on linear regression and other parametric techniques.

The Kendall Tau is a statistic that can be readily used to test for trends in water quality time series. Censored (LD), seasonal, and missing data can be handled without difficulty. The Kendall Tau statistic for each month (say all January's in the period of record) is calculated as the sum of integer scores (-1,0,1) representing the relative magnitude of each observation compared to all later observations.

Since only the relative magnitude of observations is used to calculate the value of the Kendall Tau statistic, LD observations are handled easily: all LD's are equal to each other and are less than all measured observations. The nonparametric test does not assume any underlying distribution in the data, so observations that deviate significantly from the normal distribution pose no problem. When gaps in the record exist, parametric techniques can implicitly over weight outliers or isolated observations. The Kendall Tau statistic uses only relative position in time and relative magnitude, estimating the variance using the number of observations and ties alone. For this reason the nonparametric test is insensitive to gaps in the record (a common feature in real water quality time series).

In order to assess the significance of trend for the entire period of record (all months collectively) the Kendall Tau statistics for each month are combined into a Seasonal Kendall Tau. Under the null hypothesis of no trend, the Kendall Tau statistic for each month can be viewed as a zero mean normal random variable (regardless of the distribution of the raw data). The sum of the Kendall Tau statistics for each month will also be a zero mean normal random variable. The variance of this normal variable will (under the null hypothesis of independence) equal the sum of the individual monthly variances. The Seasonal Kendall Tau is calculated as the sum of the monthly Kendall Tau statistics divided by the square root of its variance estimator (the sum of the variance estimators for each month). This standardized value of the Seasonal Kendall Tau can be compared to standard normal probability levels in order to evaluate the significance of the trend.

Seasonality is never a problem since each month contributes independently to the Seasonal Kendall Tau. Similarly, an uneven number of observations in different months causes no difficulty in calculating or testing the significance of the Seasonal Kendall Tau.

For water quality time series that are truly free from trends, the value of the test statistic will not be significantly different from zero. Randomization of the historical observations with respect to time should not significantly change the tally of increasing and decreasing comparisons. If there is an increasing trend through time, recent observations will tend to be greater than any earlier observations and the value of the test statistic will be significantly greater than zero; if there is a decreasing trend through time the test statistic should be significantly less than zero.

Monte Carlo simulations, comparing the Seasonal Kendall Tau to linear regression (Hirsch et al. 1982) show that the Seasonal Kendall Tau is robust against seasonal behavior, departures from normality, and censoring of the data (LD). The use of a linear regression-based test is more powerful than the Seasonal Kendall Tau if the data are normally distributed and non-seasonal. In practice, this is seldom the case with water quality data.

## Presentation Of Trend Test Results

For each water quality station, the parameters with significant Seasonal Kendall Tau statistics are shown. The Kendall Tau statistic approaches the standard normal distribution for sample sizes that were examined in this report. The value of that statistic, therefore, can be compared to standard normal probability levels in order to evaluate the significance of the trend. A normal curve depends on two constants -- the mean and the standard deviation. The mean tells where the center of symmetry of the normal curve is. The standard deviation is a measure of the dispersion of the observations from the mean. Table 3 represents normal deviations (Noether, 1971). All test statistics with absolute values greater than 3.0 are highlighted with asterisks (**). This corresponds to a significance level of nearly .999 percent; that is, the probability of observing a test value greater than 3.0, when in fact no trend is present, is nearly one in 1,000. The other significant Kendall Tau statistics listed are those greater than absolute value 1.8 (this value corresponds to a significance level of 96.4 per cent, (that is, the probability of data with no trend exhibiting a test statistic greater than 1.8 is less than 3.6 percent.) (See Table 3.)

Tables 6 - 11 summarize the trend test results by displaying in a matrix, for each parameter and each station, the sign (+, -) of the Kendall Tau statistics with absolute values greater then 1.8. The sign shows where the available data indicate, with confidence of at least 96.4%, there is a trend toward increasing values (+) or a trend toward decreasing (-) values. The absence of a sign for a parameter/station combination means either that there were no data, or that there was not a trend at a significance level of 96.4%.

Parameters with significant trend test statistics are plotted in figures that appear at the end of the report. These plots follow the main body of the report. Plots of data from Pennsylvania, Virginia, and West Virginia, were made for the Draft version of this report using STORET plotting routines. Plots of data from the District of Columbia and Maryland were made at ICPRB. For this reason there is a difference in the appearance of some figures.

For interpretation of the Kendall Tau trend results, there are several important points that should be emphasized. Significance is a statistical term that refers to how certain one can be that the data show a trend, that is, a progressive change in values over time. The term <u>does not</u> refer to how rapidly a parameter value is changing. For example, a data set may have a significant Kendall tau test statistic if there is a consistent progressive increase (or decrease) in values over time even if the magnitude of change is very small. In addition, the term significance <u>does not</u> is not related to whether a parameter is above water quality standards. A parameter may be exhibiting a trend in values even though the values are well within standards.

Because Kendall Tau trend statistics do not consider the rate of change, or absolute values of parameters, interpretation of trend results at any station should include reference to the figures in which the data are plotted. From these figures one can assess the rate of change, the absolute values of the data, the period of record, and the number of observations on which the trend statistic is based.

Regional assessments of trends may be made from Tables 6-11 by looking for patterns of upward (+) and downward (-) trends. But, just as when assessing trends at a particular station, the figures plotting the data should be referred to for information about periods of record, and absolute values, of data. The absence of a significant trend may be because there has been, in fact, no trend for that parameter, or it may be because the parameter has not been sampled at a station. For that reason, the absence of a '+' or '-' symbol for any station/parameter combination in these tables is less informative than the presence of a trend. From these tables one may detect patterns in the direction that water quality is headed, but the tables, by themselves do not show how fast is the change, or where are water quality standard violations.

Table 2. Water Quality Parameters Used to Determine Water Quality Status and Trend

| STORET CODE | STORET ABBREVIATION | STORET PARAMETER DESCRIPTION |
|---|---|---|
| 00010 | Water Temp Cent | Temperature, Degrees Centigrade |
| 00076 | Turb Trbidmtr Hach FTU | Turbidity, Hach Turbidimeter (Formazin Turb Unit) |
| 00080 | Color Pt-Co Units | Color, Platinum-Cobalt Units |
| 00094 | Cnductvy Field | Specific Conductance, Field uMhos/cm @ 25C |
| 00095 | Cnductvy At | Specific Conductance, uMhos/cm @ 25C |
| 00300 | DO mg/l | Oxygen, Dissolved, mg/l |
| 00301 | DO Satur Percent | Oxygen, Dissolved, Percent Saturation) |
| 00310 | BOD 5 Day mg/l | Biochemical Oxygen Demand (mg/l, 5 Day 20Deg C) |
| 00340 | COD Hi Level | Chemical Oxygen Demand, .25N K2Cr2O7 mg/l |
| 00400 | pH | pH (Standard Units) |
| 00403 | Lab pH SU | pH (Standard Units) Lab |
| 00435 | T Acidity | Acidity, Total, mg/l As CaCO3 |
| 00480 | Salinity | Salinity - Parts Per Thousand |
| 00500 | Residue Total | Residue, Total, mg/l |
| 00515 | Residue Diss-105C | Residue, Total Filtrable, Dried At 105C mg/l |
| 00530 | Residue Tot Nflt | Residue, Total Nonfiltrable, mg/l |
| 00535 | Residue Vol Nflt | Residue, Volatile Nonfiltrable, mg/l |
| 00540 | Residue Fix Nflt | Residue, Fixed Nonfiltrable, mg/l |
| 00610 | NH3+NH4- | Nitrogen, Ammonia, Total, mg/l N |
| 00615 | NO2-N Total | Nitrite Nitrogen, Total, mg/l As N |
| 00620 | NO3-N Total | Nitrate Nitrogen, Total, mg/l As N |
| 00625 | Tot Kjel N | Nitrogen, Kjeldahl, Total, mg/l As N |
| 00630 | NO2&NO3 | Nitrite Plus Nitrate, Total, 1 Det., mg/l As N |

Table 2. Water Quality Parameters Used to Determine Water Quality Status and Trend (continued)

| STORET CODE | STORET ABBREVIATION | STORET PARAMETER DESCRIPTION |
|---|---|---|
| 00650 | T PO4 | Phosphate, Total, mg/l As PO4 |
| 00665 | Phos-Tot | Phosphorus, Total, mg/l As P |
| 00666 | Phos-Dis | Phosphorus, Dissolved, mg/l As P |
| 00671 | Phos-Dis Ortho | Phosphorus, Dissolved Orthophosphate, mg/l As P |
| 00680 | T Org C | Carbon, Total Organic, mg/l As C |
| 00900 | Tot Hard CaCO3 | Hardness, Total, mg/l As CaCO3 |
| 00927 | Mgnsium Mg, Tot | Magnesium, Total, mg/l As Mg |
| 00929 | Sodium Na,Tot | Sodium, Total, mg/l As Na |
| 00940 | Chloride Total | Chloride, Total In Water, mg/l |
| 00945 | Sulfate SO4-tot | Sulfate, Total, mg/l As SO4 |
| 00951 | Fluoride | Fluoride, Total, mg/l As F |
| 01032 | Chromium Hex-val | Chromium, Hexavalent, ug/l As Cr |
| 01034 | Chromium Cr, Tot | Chromium, Total, ug/l As Cr |
| 01042 | Copper Cu, Tot | Copper, Total, ug/l As Cu |
| 01045 | Iron Fe, Tot | Iron, Total, ug/l As Fe |
| 01051 | Lead Pb, Tot | Lead, Total, ug/l As Pb |
| 01105 | Aluminum Al | Aluminum, Total, ug/l As Al |
| 31505 | Tot Coli MPN Conf /100 Ml | Coliform, Tot, MPN, Confirmed Test,35C (Tube 31506) |
| 31615 | Fec Coli | Fecal Coliform,MPNECMED per 100ml at 44.5C (Tube 31614) |
| 31616 | Fec Coli MFM-FCBR /100 Ml | Fecal Coliform, Membrane Filter M-FC Broth,44.5c |
| 46001 | Water Appear | Water Appearance Code |
| 70507 | Phos-T | Phosphorus, Tot. Orthophosphate, mg/l P |
| 71900 | Mercury Hg, | Mercury, Total ug/l As Hg |

TABLE 3
Water Quality Monitoring Stations

| Stream | Location | Station | Agency | BWQMN | Status |
|---|---|---|---|---|---|
| POTOMAC HIGHLANDS | | | | | |
| North Branch Potomac R. | Kitzmiller, MD, below Md Rt 38 | NBP0689 | MDWRA/MDOEP | 1 | P |
| | Bloomington, MD, Md Rt 135 Br. | NBP0534 | MDWRA/MDOEP | 2 | P-F |
| Savage River | Bloomington, MD, at Md Rt 135 | SAV000 | MDWRA/MDOEP | 3 | G-E |
| Georges Creek | Franklin, MD, Md Rt 36 Bridge | GEO0009 | MDWRA/MDOEP | 4 | P |
| North Branch Potomac R. | Pinto, MD, West Md RR Bridge | NBP0326 | MDWRA/MDOEP | 5 | F |
| Wills Creek | Cumberland, MD, below Braddock Run | WIL0013 | MDWRA/MDOEP | 6 | G |
| North Branch Potomac R. | Cumberland, MD, at Md Rt 51 | NBP0103 | MDWRA/MDOEP | 7 | F |
| | Oldtown, MD, Md Rt 51 Toll Br. | NBP0023 | MDWRA/MDOEP | 8 | F-G |
| South Branch Potomac R. | Moorefield, WV, US Rt 220 Br. | 550843 | WVDNR | 9 | G |
| | Springfield, WV, WV Rt 3 Br. | 550468 | WVDNR | 10 | G-E |
| Town Creek | Oldtown, MD, Oldtown Rd Bridge | TOW0030 | MDWRA/MDOEP | 11 | G-E |
| Potomac River | Paw Paw, WV. Md Rt 51 Bridge | POT2766 | MDWRA/MDOEP | 12 | G-E |
| | Hancock, MD, below US Rt 522 | POT2386 | MDWRA/MDOEP | 13 | G |
| UPPER GREAT VALLEY | | | | | |
| Conococheague Creek | Worleytown, PA, Franklin City | WQN0501 | PADER | 14 | G |
| | Fairview, MD, Md Rt 58 | CON0180 | MDWRA/MDOEP | 15 | F-G |
| | Williamsport, MD, Md Rt 68 | CON0005 | MDWRA/MDOEP | 16 | F-G |
| Abrams Creek | Winchester, VA, Va Rt 656 Br. | 1AABR002.73 | VASWCB | 17 | F-G |
| | Va Rt 7 Br. below Winchester, VA | 1AABR000.56 | VASWCB | | F-G |
| Opequon Creek | Va Rt 7 Br. below Winchester, VA | 1AOPE025.10 | VASWCB | 18 | G |
| | Bedington, WV, Sec Rt 12 | 550462 (P-4-7) | WVDNR | 19 | F-G |

TABLE 3 (continued)
Water Quality Monitoring Stations

| Stream | Location | Station | Agency | BWQMN | Status |
|---|---|---|---|---|---|
| Potomac River | Shepherdstown, WV, below Md Rt 24 | POT1830 | DOEP | 20 | F-G |
| Antietam Creek E. Branch | Washington Township, PA | WQN0504 | PADER | 21 | G |
| Antietam Creek | Rocky Forge, MD, Rt 60 Bridge | ANT0366 | MDWRA/MDOEP | 22 | F |
| | Funkstown, MD, Poffenberger Rd | ANT0203 | MDWRA/MDOEP | 23 | F |
| | Sharpsburg, MD, Rt 34 Bridge | ANT0044 | MDWRA/MDOEP | 24 | G |
| SHENADOAH RIVER BASIN | | | | | |
| North Fork Shenandoah | Cootes Store, VA, Rt 259 Bridge | 1BNFS093.53 | VASWCB | 25 | G-E |
| | New Market, VA, Rt 617/953 Bridge | 1BNFS081.42 | VASWCB | 26 | G |
| | Mt. Jackson, VA, US Rt 11 | 1BNFS062.18 | VASWCB | 27 | G |
| | Strasburg, VA, Rt 55 Crossing | 1BNFS010.34 | VASWCB | 28 | G |
| Cedar Creek | Winchester, VA, Rt 628 Bridge | 1BCDR013.29 | VASWCB | 29 | G-E |
| North Fork Shenandoah | Front Royal, VA, US 340 Bridge | 1BNFS000.69 | VASWCB | 30 | G |
| North River | Bridgewater, VA, Rt 42 Bridge | 1BNTH020.40 | VASWCB | | U |
| Muddy Creek | Bridgewater, VA, Rt 734 Bridge | 1BMDD001.65 | VASWCB | | U |
| Black's Run | Bridgewater, VA, Rt 704 Bridge | 1BBLK000.57 | VASWCB | | U |
| Cooks Creek | Bridgewater, VA, Rt 867 Bridge | 1BCKS001.03 | VASWCB | | U |
| Lewis Creek | Augusta County, VA | 1BLEW005.40 | VASWCB | | U |
| Christians Creek | Va Rt 254 Bridge | 1BCST006.43 | VASWCB | | U |

TABLE 3 (continued)
Water Quality Monitoring Stations

| Stream | Location | Station | Agency | BWQMN | Status |
|---|---|---|---|---|---|
| South River | Waynesboro, VA, Rt 664 Bridge | 1BSTH027.10 | VASWCB | 31 | G |
| | Crimora, VA, Rt 612 Bridge | 1BSTH014.49 | VASWCB | 32 | F-G |
| | Crimora, VA, Rt 778 Bridge | 1BSTH007.80 | VASWCB | | F-G |
| | Port Republic, VA, Rt 629 Bridge | 1BSTH000.19 | VASWCB | 33 | G |
| South Fork Shenandoah | Lynnwood, VA, Rt 708 Bridge | 1BSSF092.69 | VASWCB | 34 | G |
| | Luray, VA, US Rt 211 Bridge | 1BSSF054.20 | VASWCB | 35 | G |
| Hawksbill Creek | Luray, VA | 1BHKS006.004 | VASWCB | | P |
| South Fork Shenandoah | Front Royal, VA, US Rt 340/522 | 1BSSF000.58 | VASWCB | 36 | G |
| Shenandoah Main Stem | Berryville, VA, Rt 7 Bridge | IBSHN022.063 | VASWCB | 37 | G |
| Happy Creek | Front Royal, VA, Riverton Jct. | 1BHPY000.10 | VASWCB | | P |
| Shenandoah River | Bolivar, WV, US Rt 340 Bridge | 550471 | WVDNR | 38 | G |
| Potomac River | Point of Rocks, MD US Rt 15 | POT1595 | MDWRA/MDOEP | 39 | G |
| | *Point of Rocks, VA | | | 40 | |
| Rock Creek (Monocacy Trib) | Gettysburg, PA, US Rt 140 Bridge | WQN0503 | PADER | 41 | F |
| Mococacy River | Bridgeport, MD, Rt 97 Bridge | MON0528 | MDWRA/MDOEP | 42 | G |
| *Big Pipe Creek | Bruceville, MD | | | 43 | |

* Information was not available at these stations for this report

TABLE 3 (continued)
Water Quality Monitoring Stations

| Stream | Location | Station | Agency | BWQMN | Status |
|---|---|---|---|---|---|
| Monocacy River | Below Frederick, MD, Reich Ford Br | MON0155 | MDWRA/MDOEP | 45 | F |
| | Dickerson, MD, Rt 28 Bridge | MON0020 | MDWRA/MDOEP | 46 | F-G |
| Potomac River | White's Ferry, MD, Rt 107 | POT1471 | MDWRA/MDOEP | 47 | F-G |
| | *White's Ferry, VA, | | | 48 | |
| Goose Creek | Leesburg, VA, Rt 7 Bridge | 1AGO0002.38 | VASWCB | 49 | G |
| Seneca Creek | Bethesda, MD, River Rd Bridge | SEN0008 | MDWRA/MDOEP | 50 | F-G |
| Sugarland Run | Herndon, VA, Sugarland Run, VA | 1ASUG004.42 | VASWCB | | F-G |
| Cabin John Creek | Washington, DC, MacArthur Blvd Br | CJB0005 | MDWRA/MDOEP | 51 | F-G |
| POTOMAC URBAN ESTUARY | | | | | |
| Potomac River | Bethesda, MD, Little Falls Dam | POT1184 | MDWRA/MDOEP | 52 | F |
| | Washington, DC, Canal Rd. | PMS01 (101001) | MDWRA/MDOEP | 53 | G |
| Rock Creek | Bethesda MD, Rt 410 Bridge | RCM0111 | MDWRA/MDOEP | 54 | P-F |
| | Washington, DC, Park Road | 101023 | DCRA | 55 | |
| | Washington, DC, Sherrill Drive | 101021 | DCRA | | |
| Potomac River | Washington DC, Haines Point | PMS29 (101007) | DCRA | 56 | F-G |
| Anacostia River | Bladensburg, MD, US Rt 50 Br. | ANA0082 | MDWRA/MDOEP | 57 | F |
| | MD/DC Line | ANA01 (101013) | MDWRA/MDOEP | | P |
| | Washington, DC, Penns. Ave | ANA14 (101016) | DCRA | | ? |
| | Washington, DC, S. Capitol St. | ANA21 (101018) | DCRA | 58 | P-F |

* Information was not available at these stations for this report

TABLE 3 (continued)
Water Quality Monitoring Stations

| Stream | Location | Station | Agency | BWQMN | Status |
|---|---|---|---|---|---|
| Four Mile Run | Arlington, VA, GW Parkway Br. | 1AFOU000.19 | VASWCB | 59 | F |
| Potomac River | Washington, DC, at Wilson Bridge | PMS44 (101012) | DCRA | 60 | F |
| Hunting Creek | Alexandria, VA, GW Parkway | 1AHUT000.01 | VASCB | 61 | F |
| Piscataway Creek | Fort Washington, MD, Rt 210 Br. | PIS0033 | MDWRA/MDOEP | 62 | F-G |
| Little Hunting Creek | Fairfax, VA, GW Parkway Bridge | 1ALIF000.19 | VASWCB | 63 | F |
| Potomac River | Marshall Hall, MD, Buoy 67 | XFB1433 | MDWRA/MDOEP | 64 | F-G |
| Pohick Creek | Ft. Belvoir, VA, below Rt 641 | 1APOH007.65 | VASWCB | 65 | F |
| LOWER POTOMAC ESTUARY | | | | | |
| Potomac River | Indian Head, MD, Buoy N54 | XEA6596 | MDWRA/MDOEP | 66 | F |
| Occoquan Creek | Woodbridge, VA, Rt 123 Bridge | 1AOCC006.71 | VASWCB | 67 | G |
| South Run | Vint Hill, VA, below Vint Hill Installation | 1ASOT100.44 | VASWCB | 68 | G |
| Flat Branch | Manassas, VA | 1AFLB000.64 | VASWCB | | U |
| Mattawoman Creek | Mason Springs, MD, Rt 225 | MAT0078 | MDWRA/MDOEP | 69 | G |
| Potomac River | Possum Pt/Moss Pt, Buoy 44 | XEA1840 | MDWRA/MDOEP | 70 | G |
| | *Maryland Point, MD | | | 71 | G |
| | Morgantown, MD, Rt 301 Bridge | XDC1706 | MDWRA/MDOEP | 72 | G-E |

* Information was not available at these stations for this report

Table 4. CRITERIA FOR CLASSIFYING THE WATER QUALITY IN THE POTOMAC RIVER

| PARAMETER | STATUS | | | |
|---|---|---|---|---|
| | EXCELLENT | GOOD | FAIR | POOR |
| pH[1] (SU) | 6.9-8.0 | 8.1-8.4<br>6.5-6.8 | 8.5-9.5<br>5.5-6.4 | >9.5<br><5.5 |
| Dissolved Oxygen[2] (mg/l) | 8.0-9.5 | 6.0-7.9 | 4.0-5.9 | <4.0 |
| Suspended Solids (mg/l) | <25 | 25-80 | 81-400 | >400 |
| Total Organic Carbon (mg/l) | <5 | 5-20 | 21-35 | >35 |
| Nitrate Nitrogen ($NO_3$-N, mg/l) | <.20 | .21-.60 | .61-2.0 | >2.0 |
| Total Phosphorus[3] ($TPO_4$, mg/l) | | | | |
| Streams | <.05 | .05-.25 | .26-.99 | >1.0 |
| Reservoirs, lakes & ponds | <.01 | .01-.10 | .11-.59 | >.6 |
| Chlorophyll-a (ug/l) | 10-75 | 76-150<br>7.5-9.9 | 151-250<br>5-7.4 | >250<br><5 |
| Macroinvertebrate Community Diversity Index[4] (D-bar) (multiplate sampler) | >3 | 2.0-2.9 | 1.0-1.9 | <1 |
| Fecal Coliform Bacteria[5] MPN/100 ml log mean | ≤200 | 201-999 | 1,000-5,000 | >5,000 |

[1]pH values between 6.9-8.0 are considered optimal conditions for aquatic life; pH less than 5.5 or greater than 9.5 adversely affects fish spawning. For the Shenandoah River basin with naturally occurring high pH, the classification for maximum values allows for an additional .5 pH SU. Thus, excellent ranges between 6.9-8.5 SU, etc.

[2]DO concentrations between 8-9.5 mg/l at 25 C water temperature represent optimal conditions for aquatic life (about 100% saturation).

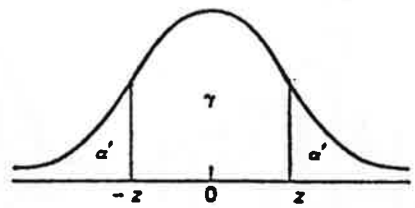
[3]Algal growth may be stimulated by total phosphorus levels .01-.03 mg/l in lakes and .1 mg/l in streams (Mackenthun, 1968) and inorganic nitrogen level .3 mg/l in lakes.

[4]Data available only at selected stations.

[5]200 MPN/100 ml log mean is the fecal coliform standard for primary contact recreation (swimming).

*TABLE* 5

## Normal Deviations



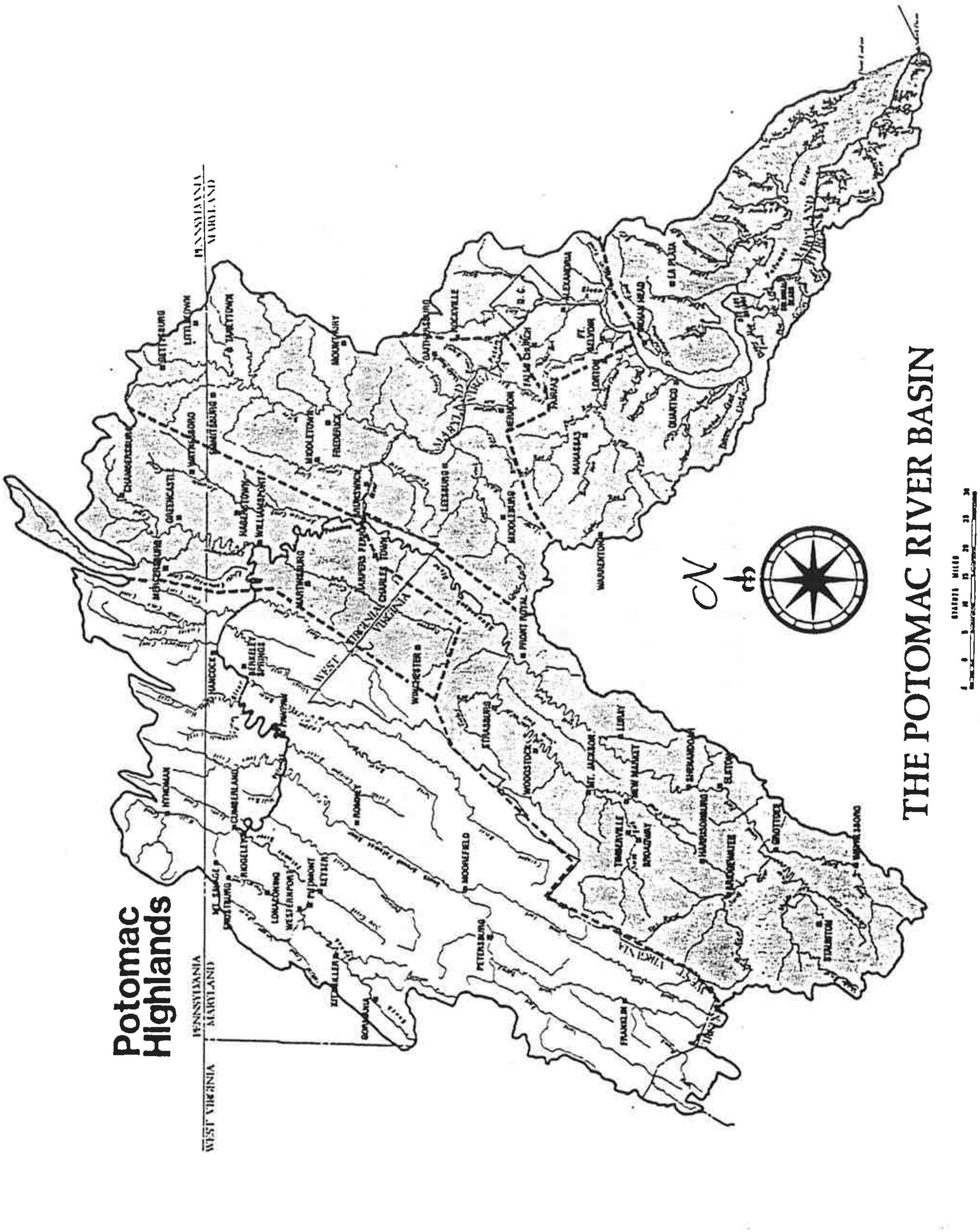

| $\gamma$ | $\alpha'' = 1 - \gamma$ | $\alpha' = \frac{1}{2}(1 - \gamma)$ | $z$ |
|---|---|---|---|
| .995 | .005 | .0025 | 2.807 |
| .99 | .01 | .005 | 2.576 |
| .985 | .015 | .0075 | 2.432 |
| .98 | .02 | .01 | 2.326 |
| .975 | .025 | .0125 | 2.241 |
| .97 | .03 | .015 | 2.170 |
| .965 | .035 | .0175 | 2.108 |
| .96 | .04 | .02 | 2.054 |
| .954 | .046 | .023 | 2.000 |
| .95 | .05 | .025 | 1.960 |
| .94 | .06 | .03 | 1.881 |
| .92 | .08 | .04 | 1.751 |
| .9 | .1 | .05 | 1.645 |
| .85 | .15 | .075 | 1.440 |
| .8 | .2 | .10 | 1.282 |
| .75 | .25 | .125 | 1.150 |
| .7 | .3 | .150 | 1.036 |
| .6 | .4 | .20 | 0.842 |
| .5 | .5 | .25 | 0.674 |
| .4 | .6 | .30 | 0.524 |
| .3 | .7 | .35 | 0.385 |
| .2 | .8 | .40 | 0.253 |
| .1 | .9 | .45 | 0.126 |

$\gamma$ = area between $-z$ and $z$
= confidence coefficient

$\alpha' = \frac{1}{2}(1 - \gamma)$
= area above $z$
= area below $-z$
= significance level for one-sided test

$\alpha'' = 1 - \gamma = 2\alpha'$
= area beyond $-z$ and $z$
= significance level for two-sided test

Map 2.


Potomac Highlands
THE POTOMAC RIVER BASIN
PENNSYLVANIA
MARYLAND
WEST VIRGINIA

# I. POTOMAC HIGHLANDS

The Potomac Highlands subdivision covers the headwaters drainage to 158 mi (254 km) of the river from Fairfax Stone, WV to the Appalachian Mountains. Table 6 presents a summary of water quality parameter trends for status in the Potomac Highlands. Streams assessed in this subdivision are:

- North Branch Potomac River
- Savage River
- Georges Creek
- Wills Creek
- South Branch Potomac River
- Potomac River

The North Branch Potomac River (see also pp. 21, 23, 24 and Figures I.1-I.22, I.38-I.48, I.54-I.64) begins as a small spring, picking up tributary flows for 98 mi (158 km). When it meets the South Branch Potomac River downstream of Oldtown, MD, it becomes the Potomac River proper. Approximately 50 mi (80 km) of the North Branch and 700 mi (1,126 km) of its tributaries have been unable to support recreation and aquatic life for 150 years. In 1975 and again in 1977, the North Branch, Georges Creek, and the South Branch Potomac River below Moorefield, WV were identified as critical areas in ICPRB publications. These identifications were made to point out stream reaches where important pollution abatement decisions had to be made[2,4].

A major contributor to water quality improvement in this watershed is the Jennings Randolph Dam and Reservoir (formerly Bloomington). The Bloomington Project was authorized by Congress in 1962, to provide flood control, water supply, water quality and recreation. Completed in 1982, it is located on the North Branch Potomac on the boundary between Garrett County, MD, and Mineral County, WV. The ability to influence water quality was designed into the control tower so that water could be released from five different levels.

The water quality data show a moderating effect on water quality down stream of the dam after 1982. Even though the status remains Poor in the Potomac Highlands, there has been an improving trend in water quality.

Water quality improvements--even in one parameter--are difficult to pinpoint because chemical and biological changes are complex and usually synergistic. Besides the construction of the Jennings Randolph Dam, other changes and modifications have been occurring over the last 12 years in the North Branch. Beginning in 1972, the Clean Water Act (PL-92-500) and its subsequent amendments required point source dischargers to limit pollution levels in their effluents. The Surface Mining Control and Reclamation Act of 1977 may also have helped to alleviate some of the impacts of active mining activities. In West Virginia, an aggressive program of liming streams affected by acid mine drainage may have been instrumental in causing pH levels to rise throughout the North Branch. Taken together, these mechanisms have enabled the North Branch to become a more habitable aquatic environment.

In 1974, the fecal coliform bacterial levels exhibited one of the highest concentrations in the basin (1,500 MPN/100 ml). This suggested the presence of inadequately treated sewage in the North Branch at Oldtown[1]. Recovery from the acid mine drainage effects is nearly complete at this point in the North Branch, but municipal and industrial discharges in the Cumberland area interrupt the recovery of the river from upstream stresses[5].

Among the nutrients in the North Branch, trends in Nitrate and total Phosphorus were up. Trends in the acid mine drainage affected parameters in the upper North Branch were up for pH, and down for Iron and Sulphate; however, a downward trend (from above neutral values) of pH was detected at Oldtown. Total Coliform bacteria was trending down in the upper North Branch, but up at Oldtown. Upward trends were detected in Dissolved Oxygen (DO) in both the upper and lower North Branch. Downward trends were detected in both Temperature and Turbidity.

The Savage River watershed (see also pp. 22 and Figures I.23-I.28) is dominated by a water supply and flood control reservoir located near the confluence of the North Branch. Water quality is good, with the exception of Aaron Run, a small tributary below the reservoir whose water quality is affected by acid mine drainage. Among the nutrients, trends in Nitrate and total Phosphorus were up. The trend in pH was down from neutral values; and Total Coliform, Temperature, and Turbidity were also trending lower.

Georges Creek (see also pp. 22 and Figures I.29-I.37) has historically been characterized as a sluiceway for acid mine drainage and raw sewage. In the past, the waters exhibited low pH, discoloration, turbidity, high concentrations of sulfur compounds and sewage solids. Leakage into abandoned mines underneath portions of the upper reaches causes significant flow reductions.

In 1979, Georges Creek was ranked third (severely polluted) out of 101 segments in Maryland. In 1975, and again in 1977, ICPRB listed Georges Creek as a critical area. A sewage treatment plant was recently completed. It is expected to solve the raw sewage discharge problems in the creek. Unfortunately, acid mine drainage from abandoned mines may continue to degrade the water quality in the watershed.

Significant trends were detected in many of the water quality parameters sampled in Georges Creek. Among those showing improving water quality were upward trends in DO and pH, and downward trends in Residue and Turbidity. However, degrading water quality was indicated by increasing trends in nutrients and Magnesium.

Wills Creek (see also pp. 23 and Figures I.49-I.53) has its headwaters in Pennsylvania and flows through the Cumberland, MD where it has been extensively channelized. Few trends were detected in Wills Creek: Nitrate and Total Phosphorus were up, and Temperature and Turbidity were down.

The South Branch Potomac River (see also pp. 25 and Figures I.65-I.74) is a major tributary that joins the North Branch to form the Potomac River proper below Green Spring, WV, and Oldtown, MD. The South Branch flows northeast for 131 mi (211 km), and drains 2,941 $mi^2$ (7,617 $km^2$) of West Virginia and Virginia. Major tributaries are the North Fork and South Fork rivers and Mill Creek.

Water quality is good in the South Branch, although some localized problems exist. In 1982, a sewage treatment plant was put on-line in Romney, and improved industrial treatment has occurred at a number of plants along the South Branch. Only Nitrate + Nitrite was detected as having an increasing trend at one station, and total Phosphorus was trending downward at both stations. The fact that the Kendall Tau analysis flagged Lead and Chromium in the South Branch is interesting. The data for these metals showed a significant increasing trend over the period of record. In the 1977-1979 West Virginia Water Quality Status Assessment, heavy metals were identified at sampling stations on the South Branch. Occasional violations of State or EPA standards for Iron, Manganese, Lead, Chromium, Arsenic, and Cadmium were noted. These violations were few in number, and the report stated that they were scattered throughout the state. Of more major concern in the South Branch were phenolics, and bacteria (upward trend detected in Fecal Coliform) although fish tissue analyses for organics showed no elevated levels of contaminants.

The South Branch below Moorefield is slow-moving, with numerous deep pools that serve as nutrient traps. Algae and other aquatic plant growths are quite noticeable in summer, and algal blooms contribute to BOD (increasing trend) resulting in DO problems[2]. The stream reach extending several miles downstream of Moorefield was described as being polluted in 1975 due to algae and other aquatic plants[2]. Pollution problems at that time were attributed to the municipal sewage treatment plant discharge, aggravated by nonpoint runoff due to livestock grazing along the river banks[3]. Total Organic Carbon (TOC) levels decreased beginning in 1981 demonstrating water quality improvements since that time. The trend in pH was downward from above neutral levels at both monitoring stations.

Town Creek (see also pp. 26 and Figures I.75-I.81) has its headwaters in Pennsylvania and drains an area of Maryland before entering the Potomac River just down stream of the confluence of the North and South branches. The traditionally good water quality is supported by decreasing trends detected for Conductivity and Sulfate, and an increasing trend in DO; but counter balanced by increasing trends in Nitrate and Total Phosphorus, declining pH.

The Potomac River main stem (see also pp. 26 and Figures I.82-I.88) flows down from the confluence of the North and South branches. In 1974, this segment of the Potomac was rated as one of the best for the maintenance of aquatic life and recreation(1). There few trends detected among water quality parameters at two stations. Among the nutrients, Nitrate and total Phosphorus were both up and Nitrite was down. Total Coliform, Temperature and Turbidity were all detected with declining trends; whereas Residue was increasing.

A regional perspective (See Table 6) on water quality trends in the Potomac Highlands reveals that the toxic parameters of Chromium and Lead show increasing trends in the South Branch. Total Coliform was down at four stations, up at only one; and DO was broadly up. Among the nutrients, Nitrate and Total Phosphorus were showing increasing trends except for Phosphorus in the South Branch where it was down. Temperature and Turbidity were broadly trending down, as was pH in the middle North Branch and South Branch, but up in the upper North Branch and Georges Creek.

## RESULTS OF KENDALL TAU TREND ANALYSIS FOR THE POTOMAC HIGHLANDS

**River** North Branch Potomac River
**Station** NBP0689 **Agency** MDWRA/MDOEP
**Location** Kitzmiller, MD below MD Rt.38.
River Mile: 354

| Significant Parameters | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -1.85 | I.1 |
| Iron (FE) | -2.57 | I.2 |
| Nitrate ($NO_3$) | +2.19 | I.3 |
| pH | +7.01** | I.4 |
| pH, Lab. | +5.74** | I.5 |
| Phosphorus,Tot. (P) | +4.93** | I.6 |
| Temperature | -2.33 | I.7 |
| Turbidity | -2.52 | I.8 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor | Improving |

**River** North Branch Potomac River
**Station** NBP0534 **Agency** MDWRA/MDOEP
**Location** Bloomington, Md. at MD Rt.135 Bridge.
River Mile: 338

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Aluminum | -2.90 | I.9 |
| Coliform, Total | -3.94** | I.10 |
| DO | +2.18 | I.11 |
| Iron | -2.34 | I.12 |
| Nitrate ($NO_3$) | +3.42** | I.13 |
| Nitrite ($NO_2$) | +2.41 | I.14 |
| pH | +7.44** | I.15 |
| pH, Lab. | +7.02** | I.16 |
| Phosphorus,Tot. (P) | +5.64** | I.17 |
| Residue | -2.08 | I.18 |
| Residue, Nonfilt. | +2.72 | I.19 |
| Sulfate ($SO_4$) | -2.44 | I.20 |
| Temperature | -2.56 | I.21 |
| Turbidity | -1.91 | I.22 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor-Fair | Improving |

River: Savage River
Station: SAV0000 — Agency: MDWRA/MDOEP
Location: Bloomington, MD at MD Rt.135.
River Mile: 338

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -2.14 | I.23 |
| Nitrate ($NO_3$) | +3.58** | I.24 |
| pH | -2.23 | I.25 |
| Phosphorus,Tot. (P) | +3.69** | I.26 |
| Temperature | -1.88 | I.27 |
| Turbidity | -3.35** | I.28 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good-Excellent | Improving |

River: Georges Creek
Station: GEO0009 — Agency: MDWRA/MDOEP
Location: Franklin, MD at MD Rt.36 Bridge.
River Mile: 335-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| DO | +2.65 | I.29 |
| Manganese (Mn) | +1.88 | I.30 |
| Nitrate ($NO_3$) | +6.34** | I.31 |
| pH | +2.70 | I.32 |
| pH, Lab. | +5.42** | I.33 |
| Phosphorus,Tot. (P) | +5.34** | I.34 |
| Residue, Nonfilt. | -2.01 | I.35 |
| Temperature | -2.51 | I.36 |
| Turbidity | -4.24** | I.37 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor | Improving |

**River** North Branch Potomac River
**Station** NBP0326 **Agency** MDWRA/MDOEP
**Location** Pinto, MD west MD RR Bridge.
River Mile: 318

| Significant Parameter | D-tau value | Figure No. |
|---|---|---|
| Acidity | +3.32** | I.38 |
| Conductivity | -1.98 | I.39 |
| DO | +4.57** | I.40 |
| Nitrate ($NO_3$) | +3.44** | I.41 |
| pH, Lab. | +3.17** | I.42 |
| Phosphorus,Tot. (P) | +4.30** | I.43 |
| Residue | -1.87 | I.44 |
| Residue, Nonfilt. | -2.19 | I.45 |
| Sulfate ($SO_4$) | -2.89 | I.46 |
| Temperature | -1.81 | I.47 |
| Turbidity | -4.13** | I.48 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair | Improving |

**River** Wills Creek
**Station** WIL0013 **Agency** MDWRA/MDOEP
**Location** Cumberland,MD below Braddock Run.
River Mile: 307-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +3.98** | I.49 |
| Phosphorus,Tot. (P) | +2.60 | I.50 |
| Temperature | -1.80 | I.51 |
| Turbidity | -2.18 | I.52 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** North Branch Potomac River
**Station** NBP0103 **Agency** MDWRA/MDOEP
**Location** Cumberland, MD at MD Rt. 51.
River Mile: 295

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| DO | +4.33** | I.53 |
| Nitrate ($NO_3$) | +3.75** | I.54 |
| Nitrite ($NO_2$) | -2.12 | I.55 |
| pH | -2.45 | I.56 |
| pH, Lab. | +1.94 | I.57 |
| Phosphorus,Tot. (P) | +1.86 | I.58 |
| Temperature | -2.76 | I.59 |
| Turbidity | -3.80** | I.60 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair | Status Quo |

**River** North Branch Potomac River
**Station** NBP0023 **Agency** MDWRA/MDOEP
**Location** Oldtown, MD, MD Rt.51 Toll Bridge.
River Mile: 287

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | +2.12 | I.61 |
| pH | -2.31 | I.62 |
| Phosphorus,Tot. (P) | +2.43 | I.63 |
| Salinity | -2.39 | I.64 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Fair-Good | Status Quo |

River: South Branch Potomac River
Station: 550843 — Agency: WVDNR
Location: Moorefield, WV, US Rt. 220 Bridge.
River Mile: 285-45

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Chromium, Hexavalent | +2.14 | I.65 |
| Color | +2.16 | |
| DO%Sat. | -2.45 | |
| Lead | +5.81** | I.66 |
| pH | -4.66** | I.67 |
| pH, Lab. | -3.93** | I.68 |
| Phosphorus,Tot. (P) | -3.45** | I.69 |
| Residue | -1.96 | |
| Sulfate ($SO_4$) | -3.70** | I.70 |
| TOC | -2.60 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Improving |

River: South Branch Potomac River
Station: 550468 — Agency: WVDNR
Location: Springfield, WV, WV Rt. 3 Bridge.
River Mile: 285-17

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| BOD | +2.40 | |
| Chromium, Hexavalent | +2.26 | I.71 |
| Coliform, Fecal | +2.28 | |
| Hardness | -2.49 | |
| Lead (Pb) | +4.38** | I.72 |
| Nitrite + Nitrate | +2.37 | |
| pH | -4.33** | I.73 |
| pH, Lab. | -2.74 | |
| Phosphorus,Tot. (P) | -2.04 | |
| Temperature | +2.10 | |
| TOC | -5.61** | I.74 |
| Turbidity | +1.96 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good-Excellent | Improving |

River: Town Creek
Station: TOW0030 — Agency: MDWRA/MDOEP
Location: Oldtown, MD, Oldtown Rd. Bridge.
River Mile: 282-3

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | -1.92 | I.75 |
| DO | +2.38 | I.76 |
| Nitrate ($NO_3$) | +3.47** | I.77 |
| pH | -2.58 | I.78 |
| Phosphorus,Tot. (P) | +3.27** | I.79 |
| Sulfate ($SO_4$) | -2.20 | I.80 |
| Temperature | -2.23 | I.81 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good-Excellent | Good-Excellent | Status Quo |

River: Potomac River
Station: POT2766 — Agency: MDWRA/MDOEP
Location: Paw Paw, WV, MD Rt. 51 Bridge.
River Mile: 277

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +2.63 | I.82 |
| Nitrite ($NO_2$) | -2.19 | I.83 |
| Turbidity | -2.41 | I.84 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good-Excellent | Good-Excellent | Status Quo |

River: Potomac River
Station: POT2386 — Agency: MDWRA/MDOEP
Location: Hancock, MD, Below US Rt. 522.
River Mile: 239

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -4.22 | I.85 |
| Phosphorus,Tot. (P) | +1.81 | I.86 |
| Residue, Nonfilt. | +2.19 | I.87 |
| Temperature | -3.06** | I.88 |

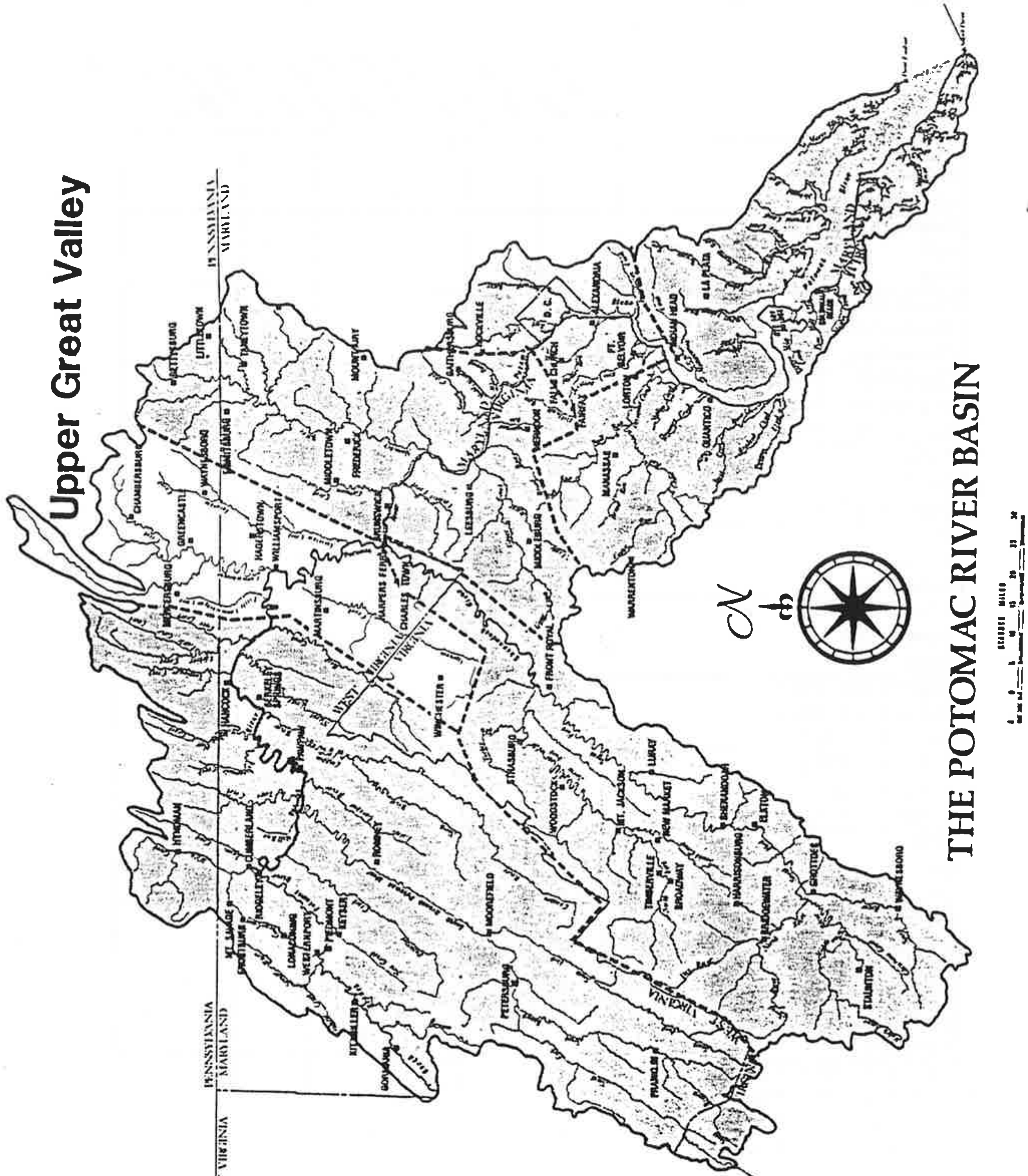
| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

Table 6: Potomac Highlands Subdivision Parameter Trend Summary

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| | NBP0689 | NBP0534 | SAV0000 | GE00009 | NBP0326 | WIL0013 | NBP0103 | NBP0023 | 550843 | 550468 | TOW0030 | POT2766 | POT2386 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | + | | | | | | | | |
| Alkalinity | | | | | | | | | | | | | |
| Aluminum | | - | | | | | | | | | | | |
| Ammonia ($NH_3$+$NH_4$) | | | | | | | | | | | | | |
| BOD | | | | | | | | | | + | | | |
| COD | | | | | | | | | | | | | |
| Chloride | | | | | | | | | | | | | |
| Chlorophyll | | | | | | | | | | | | | |
| Chromium, Hexavalent | | | | | | | | | + | + | | | |
| Chromium, Total | | | | | | | | | | | | | |
| Coliform, Fecal | | | | | | | | | | + | | | |
| Coliform, Total | - | - | - | | | | | + | | | | | - |
| Color | | | | | | | | | + | | | | |
| Conductivity | | | | | - | | | | | | - | | |
| Copper (Cu) | | | | | | | | | | | | | |
| DO | | + | | + | + | | + | | | | + | | |
| DO%Sat. | | | | | | | | | - | | | | |
| Fluoride | | | | | | | | | | | | | |
| Hardness | | | | | | | | | | - | | | |
| Iron (Fe) | - | - | | | | | | | | | | | |
| Lead (Pb) | | | | | | | | | + | + | | | |
| Magnesium (Mg) | | | | + | | | | | | | | | |
| Manganese (Mn) | | | | | | | | | | | | | |
| Mercury (Hg) | | | | | | | | | | | | | |
| Nitrate ($NO_3$) | + | + | + | + | + | + | + | | | | + | + | |
| Nitrite ($NO_2$) | | + | | | | | - | | | | | - | |
| Nitrite + Nitrate | | | | | | | | | | + | | | |
| TKN | | | | | | | | | | | | | |
| pH | + | + | - | + | | | - | - | - | - | - | | |
| pH, Lab. | + | + | | + | + | | + | | - | - | | | |
| Phosphorus,Diss.Ortho | | | | | | | | | | | | | |
| Phosphate,Tot. ($PO_4$) | | | | | | | | | | | | | |
| Phosphorus,Tot.Ortho | | | | | | | | | | | | | |
| Phosphorus,Diss. | | | | | | | | | | | | | |
| Phosphorus,Tot. (P) | + | + | + | + | + | + | + | + | - | - | + | | + |
| Residue | | - | | | - | | | | - | | | | |
| Residue, Dissolved | | | | | | | | | | | | | |
| Residue, Fix.Nonfilt. | | | | | | | | | | | | | |
| Residue, Nonfilt. | | + | | - | - | | | | | | | | + |
| Residue, Vol.Nonfilt. | | | | | | | | | | | | | |
| Salinity | | | | | | | | - | | | | | |
| Sodium (Na) | | | | | | | | | | | | | |
| Sulfate ($SO_4$) | | - | | | - | | | | - | | - | | |
| Temperature | - | - | - | - | - | - | - | | | + | - | | - |
| TOC | | | | | | | | | - | - | | | |
| Turbidity | - | - | - | - | - | - | - | | | + | | - | |
| Water Appearance | | | | | | | | | | | | | |

Map 3.



# II. UPPER GREAT VALLEY

The Upper Great Valley includes 54 miles (87 km) of the main stem Potomac River, extending from the Appalachian Mountains to the Shenandoah River at Harpers Ferry, WV. In Maryland this area is sometimes called the Hagerstown Valley, and in Pennsylvania it is termed the Cumberland Valley. Table 7 presents a summary of water quality parameter trends for stations in the Upper Great Valley. Streams assessed in this subdivision include:

- Conococheague Creek
- Abrams Creek
- Opequon Creek
- Potomac River
- Antietam Creek

Conococheague Creek (see also pp. 31-32 and Figures II.1-II.19) is formed by several shallow, meandering creeks near Chambersburg, PA; flows south through Maryland; and meets the Potomac at Williamsport, MD. Most of the drainage is in Pennsylvania (498 $mi^2$, 1,290 $km^2$), with 66 $mi^2$ (171 $km^2$) in Maryland. Sampling stations are located near Worleytown, PA, and Fairview and Williamsport, MD. Industrial discharges from a paper mill and a tannery in Pennsylvania are the main sources of industrial pollution. The Conococheague is also affected by urban and agricultural runoff.

All three stations on the Conococheague, have significant increasing trends in Nitrate; and two, Worleytown and Williamsport, have significant increasing trends in Phosphorus (different forms). At Worleytown and Williamsport there have been significant increases in Conductivity; and Fairview and Williamsport have had significant decreases in Salinity and Turbidity.

Abrams Creek (see also pp. 32-33 and Figures II.20-II.32) is a major tributary to Opequon Creek which flows through Winchester, VA. It receives municipal waste discharges from the 5 mgd Winchester WWTP and the 0.5 mgd Abrams Creek WWTP. Significant opposite trends in various Nitrogen forms were found at each of the two stations on Abrams Creek. The record, however, for the station above Winchester, VA, (1AABR002.73) ends in 1978. Below Winchester, Nitrate is increasing, while Ammonia and TKN are decreasing; total Phosphorus is increasing; and Fecal Coliform are decreasing.

Opequon Creek (see also pp. 33-34 and Figures II.33-II.46) flows east toward Winchester, VA; then North to the Potomac, crossing the eastern panhandle of West Virginia. Monitoring in 1973 and 1974 detected pesticides in Opequon Creek's water, sediments, and aquatic life, but follow up monitoring in 1979 and 1980 did not detect their presence. Statistically significant increasing trends were found for Hexavalent Chromium, Flouride, and Lead in Opequon Creek near Bedington, WV. Total Chromium at Bedington has a statistically significant decreasing trend, but the trend for this parameter is based on very few observations (see Figure II.39).

Although concentrations of these metals are within generally accepted safe ranges, increasing trends of any toxic metal are unusual and an issue of some concern. Chromium is an element rarely found in nature and the source most often is from metal finishing, textile and/or leather tanning facilities. The values at Bedington are close to the national average value of 3.2 ug/l and well below the West Virginia standard for Chromium of 50 ug/l.

Antietam Creek (see also pp. 35-36 and Figures II.56-II.72) is 37 mi (60 km) long, draining 105 $mi^2$ (272 $km^2$) of Pennsylvania and 187 $mi^2$ (484 $km^2$) of Maryland. It enters the Potomac below Shepherdstown, WV. Sampling stations are located in Washington Township, PA; and at Rocky Forge, Funkstown, and Sharpsburg, MD. Polychlorinated Biphenyls were detected in Antietam Creek in 1972, but later monitoring failed to detect PCB's at levels higher than trace amounts.

Increasing levels of Nitrates are indicated at all three Antietam Creek stations in Maryland, and total Kjeldahl Nitrogen has a significant increasing trend at two of the Maryland stations. All three Maryland stations also show significant decreasing trends in Salinity and Turbidity.

Data from the only main stem Potomac station (see also p. 34 and Figures II.47-II.55) in the Upper Great Valley, at Shepherdstown, strongly indicates increasing levels of nutrients. Nitrate, Nitrite, Total Kjeldahl Nitrogen, and Total Phosphorus, have significant increasing trends. Decreasing trends were found in Turbidity, pH, and Total Coliform.

From a regional perspective (see Table 7), increasing trends in Nitrates and Total Kjeldahl Nitrogen (TKN) are indicated at nine of twelve stations in the Upper Great Valley, including all the tributaries but not the main stem Potomac. A decreasing trend for Nitrate was indicated at only one station on Abrams Creek, but there are no data for that station after 1978. The picture is less clear for Nitrites and Ammonia. Significant increasing trends in Nitrite and Ammonia are indicated at one station on Abrams Creek and at Shepherdstown; but significant decreasing trends in Nitrite and Ammonia are indicated at four stations on Conococheague, Abrams, Opequan, and Antietam, Creeks.

Increasing trends for Total Phosphorus or Phosphate were indicated at four stations: two on the Conococheague, one on Abrams Creek, and at Shepherdstown on the Potomac. There were no significant decreasing trends for any form of Phosphorus. Other water quality trends that appear to predominate regionally include: pH down at six stations (increasing at two); and Turbidity and Salinity down at five stations, and Turbidity alone down at another two stations (no increasing trends in either Turbidity or Salinity).

RESULTS OF TREND ANALYSIS FOR THE UPPER GREAT VALLEY

River Conococheague Creek
Station WQN0501 Agency PADER
Location Worleytown, PA, Franklin Cty.
River Mile: 211-25

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Chloride | +2.69 | |
| Conductivity | +3.00** | II.1 |
| Iron (Fe) | -2.37 | II.2 |
| Magnesium (Mg) | +2.02 | II.3 |
| Nitrate ($NO_3$) | +5.05** | II.4 |
| Nitrite ($NO_2$) | -3.49** | II.5 |
| pH | +2.05 | II.6 |
| Phosphate,Tot. ($PO_4$) | +1.87 | |
| Residue, Dissolved | +3.22** | II.7 |
| Water Appearance | -3.63** | II.8 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Improving |

River Conococheague Creek
Station CON0180 Agency MDWRA/MDOEP
Location Fairview, MD, MD Rt. 58.
River Mile: 211-18

| Significant Parameter | K-tru value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +3.74** | II.9 |
| Salinity | -2.51 | II.10 |
| Turbidity | -3.33** | II.11 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Fair-Good | Status Quo |

**River** Conococheague Creek
**Station** CON0005 **Agency** MDWRA/MDOEP
**Location** Williamsport, MD, MD Rt. 68.
River Mile: 211-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | +3.02** | II.12 |
| Nitrate ($NO_3$) | +6.22** | II.13 |
| pH | -2.40 | II.14 |
| Phosphorus,Tot. (P) | +2.64 | II.15 |
| Residue, Nonfilt. | -3.42** | II.16 |
| Salinity | -3.55** | II.17 |
| Temperature | -3.68** | II.18 |
| Turbidity | -2.23 | II.19 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair-Good | Improving |

**River** Abrams Creek
**Station** 1AABR002.73 **Agency** VASWCB
**Location** Winchester, VA, VA Rt. 656 Bridge.
River Mile: 202-32-3

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +2.96 | II.20 |
| BOD | +2.51 | II.21 |
| DO | -2.31 | II.22 |
| Nitrate ($NO_3$) | -2.69 | II.23 |
| Nitrite ($NO_2$) | +2.51 | |
| TKN | +3.30** | II.24 |
| TOC | +2.50 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Unknown | Unknown | Degrading |

River: Abrams Creek
Station: 1AABR000.56 — Agency: VASWCB
Location: VA Rt. 7 bridge below Winchester, VA.
River Mile: 202-32-1

| Significant Parameter | Trends | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | -3.79** | II.25 |
| BOD | -2.90 | II.26 |
| Coliform, Fecal | -3.21** | II.27 |
| Conductivity | -2.98 | II.28 |
| DO | +2.63 | II.29 |
| Nitrate ($NO_3$) | +3.81** | II.30 |
| pH | -2.40 | II.31 |
| Phosphate,Tot. ($PO_4$) | +2.30 | |
| Phosphorus,Tot.Ortho | +2.27 | |
| TKN | -3.47** | II.32 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair-Good | Improving |

River: Opequon Creek
Station: 1AOPE025.10 — Agency: VASWCB
Location: VA Rt. 7 Bridge below Winchester, VA.
River Mile: 202-25

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | -4.36** | II.33 |
| BOD | -2.88 | II.34 |
| DO | +2.00 | II.35 |
| Nitrite ($NO_2$) | -3.18** | II.36 |
| pH | -2.03 | |
| Temperature | -2.90 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Good | Improving |

**River** Opequon Creek
**Station** 550462 (P-4-7) **Agency** WVDNR
**Location** Bedington, WV, Secondary Rt. 12.
River Mile: 200-9

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| BOD | +3.15** | II.37 |
| Chromium, Hexavalent | +3.57** | II.38 |
| Chromium, Total | -3.26** | II.39 |
| Coliform, Fecal | +2.66 | II.40 |
| Copper (Cu) | -2.19 | |
| Fluoride | +6.11** | II.41 |
| Iron (Fe) | -2.78 | II.42 |
| Lead (Pb) | +2.15 | |
| pH | -6.15** | II.43 |
| pH, Lab. | -4.67** | II.44 |
| Residue, Dissolved | +2.28 | |
| Residue, Nonfilt. | +2.08 | |
| Sodium (Na) | +1.92 | |
| Sulfate ($SO_4$) | +3.80** | II.45 |
| TOC | -4.07** | II.46 |
| Turbidity | -2.76 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Fair-Good | Status Quo |

**River** Potomac River
**Station** POT1830 **Agency** MDWRA/MDOEP
**Location** Shepherdstown, WV, Below MD Rt. 24.
River Mile: 183

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -3.53** | II.47 |
| DO%Sat. | -2.36 | II.48 |
| Nitrate ($NO_3$) | +3.07** | II.49 |
| Nitrite ($NO_2$) | +1.84 | II.50 |
| pH | -3.06 | II.51 |
| Phosphorus,Tot. (P) | +3.65** | II.52 |
| Temperature | -4.37** | II.53 |
| TKN | +2.88 | II.54 |
| Turbidity | -3.18** | II.55 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** East Branch Antietam Creek
**Station** WQN0504 **Agency** PADER
**Location** Washington Township, PA.
River Mile: 180-39

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Fecal | +2.33 | II.56 |
| Color | +3.42** | II.57 |
| Magnesium (Mg) | +2.89 | |
| pH | +1.86 | II.58 |
| pH, Lab. | -3.29** | II.59 |
| Residue, Nonfilt. | +2.63 | II.60 |
| Sulfate ($SO_4$) | +1.83 | |
| Water Appearance | -2.50 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Good | Improving |

**River** Antietam Creek
**Station** ANT0366 **Agency** MDWRA/MDOEP
**Location** Rocky Forge, MD, Rt. 60 Bridge.
River Mile: 180-37

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +3.17** | II.61 |
| Salinity | -4.38** | II.62 |
| TKN | +2.55 | II.63 |
| Turbidity | -4.03** | II.64 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Fair | Status Quo |

River: Antietam Creek
Station: ANT0203 — Agency: MDWRA/MDOEP
Location: Funkstown, MD, Poffenberger Rd. Bridge.
River Mile: 180-20

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | +2.77 | II.65 |
| Nitrate ($NO_3$) | +6.85** | II.66 |
| Nitrite ($NO_2$) | -2.41 | II.67 |
| pH | -2.89 | II.68 |
| Residue, Dissolved | -2.32 | II.69 |
| Salinity | -3.96** | II.70 |
| Temperature | -2.83 | II.71 |
| Turbidity | -3.64** | II.72 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Status Quo |

River: Antietam Creek
Station: ANT0044 — Agency: MDWRA/MDOEP
Location: Sharpsburg, MD, Rt. 34 Bridge.
River Mile: 180-4

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +3.87** | II.73 |
| pH, Lab. | +1.86 | II.74 |
| Salinity | -4.77** | II.75 |
| TKN | +2.39 | II.76 |
| Turbidity | -4.62** | II.77 |

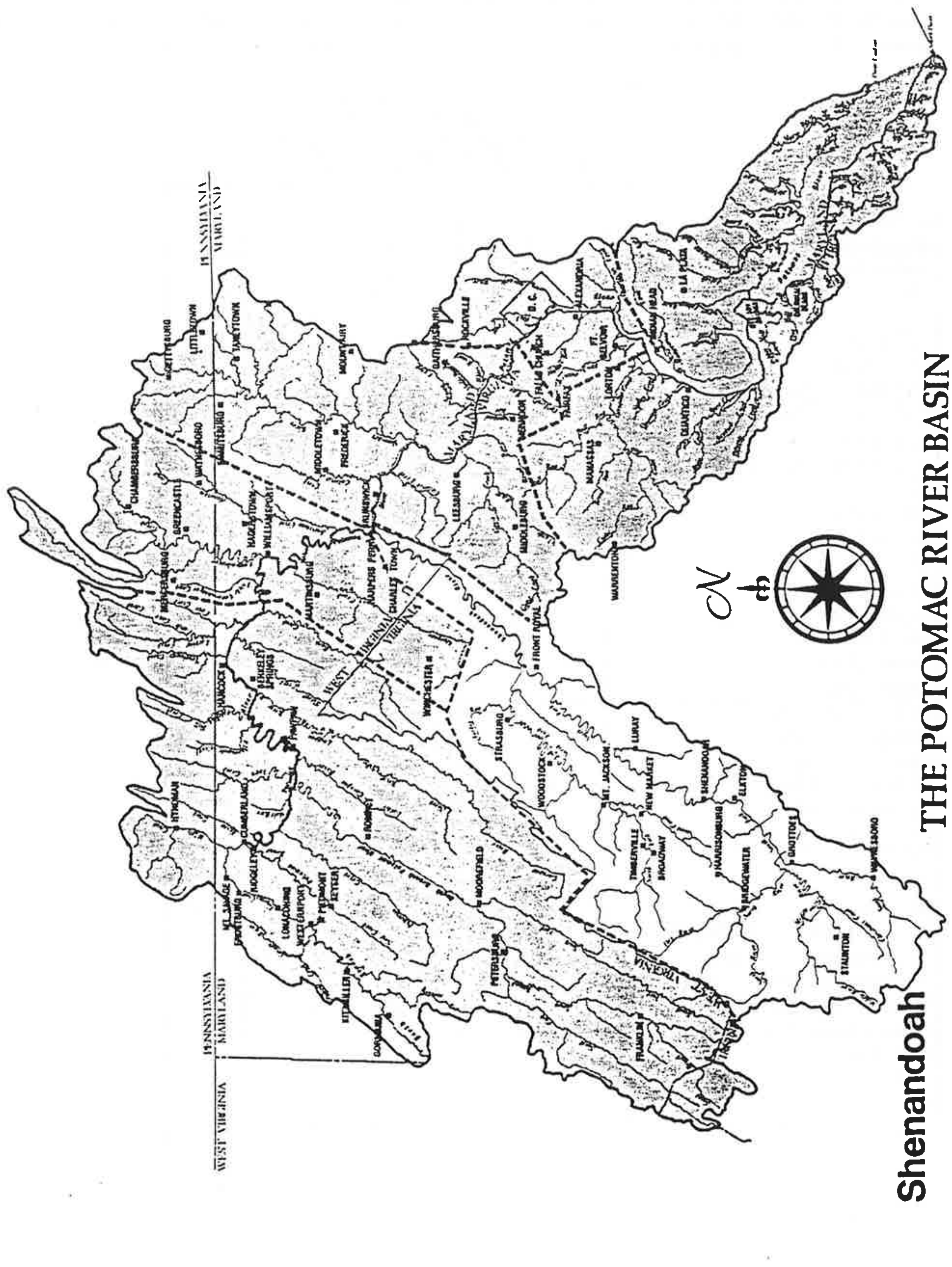
| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

Table 7: Upper Great Valley Subdivision Parameter Trend Summary

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| Parameter | WQN0501 | CON0180 | CON0005 | 1AABR002.73 | 1AABR000.56 | 1AOPE025.10 | 550462 | POT1830 | WQN0504 | ANT0366 | ANT0203 | ANT0044 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | | | | | | |
| Alkalinity | | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | | |
| Ammonia ($NH_3+NH_4$) | | | | + | - | - | | | | | | |
| BOD | | | | + | - | - | + | | | | | |
| COD | | | | | | | | | | | | |
| Chloride | + | | | | | | | | | | | |
| Chlorophyll | | | | | | | | | | | | |
| Chromium, Hexavalent | | | | | | | + | | | | | |
| Chromium, Total | | | | | | | - | | | | | |
| Coliform, Fecal | | | | | - | | + | | + | | | |
| Coliform, Total | | | | | | | | - | | | | |
| Color | | | | | | | | | + | | | |
| Conductivity | + | | + | | - | | | | | | + | |
| Copper (Cu) | | | | | | | - | | | | | |
| DO | | | | - | + | + | | | | | | |
| DO%Sat. | | | | | | | | - | | | | |
| Fluoride | | | | | | | + | | | | | |
| Hardness | | | | | | | | | | | | |
| Iron (Fe) | - | | | | | | - | | | | | |
| Lead (Pb) | | | | | | | + | | | | | |
| Magnesium (Mg) | + | | | | | | | | + | | | |
| Manganese (Mn) | | | | | | | | | | | | |
| Mercury (Hg) | | | | | | | | | | | | |
| Nitrate ($NO_3$) | + | + | + | - | + | | | + | | + | + | + |
| Nitrite ($NO_2$) | - | | | + | | - | | + | | | - | |
| Nitrite + Nitrate | | | | | | | | | | | | |
| TKN | | | | + | - | | | + | | + | | + |
| pH | + | | - | | - | - | - | - | + | | - | |
| pH, Lab. | | | | | | | - | | - | | | + |
| Phosphorus,Diss.Ortho | | | | | | | | | | | | |
| Phosphate,Tot. ($PO_4$) | + | | | | + | | | | | | | |
| Phosphorus,Tot.Ortho | | | | | + | | | | | | | |
| Phosphorus,Diss. | | | | | | | | | | | | |
| Phosphorus,Tot. (P) | | | + | | | | | + | | | | |
| Residue | | | | | | | | | | | | |
| Residue, Dissolved | + | | | | | | + | | | | - | |
| Residue, Fix.Nonfilt. | | | | | | | | | | | | |
| Residue, Nonfilt. | | | - | | | | + | | + | | | |
| Residue, Vol.Nonfilt. | | | | | | | | | | | | |
| Salinity | | - | - | | | | | | | - | - | - |
| Sodium (Na) | | | | | | | + | | | | | |
| Sulfate ($SO_4$) | | | | | | | + | | + | | | |
| Temperature | | | - | | | - | | - | | | - | |
| TOC | | | | + | | | - | | | | | |
| Turbidity | | - | - | | | | - | - | | - | - | - |
| Water Appearance | - | | | | | | | | - | | | |

Map 4.


THE POTOMAC RIVER BASIN
Shenandoah
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
VIRGINIA

# III. SHENANDOAH RIVER BASIN

The Shenandoah River basin drains 3,054 $mi^2$ (7,910 $km^2$) of Virginia and West Virginia. The Shenandoah River is 100 mi (161 km) long and drains headwaters in Augusta and Highland counties and flows northeast through Frederick and Clarke counties, VA, and Jefferson County, WV. The Shenandoah is the largest tributary to the Potomac, and is formed by the combination of flows from the North and South forks where they converge at Front Royal, VA. Twenty-three water quality stations considered in this report are located in the Shenandoah basin. The Shenandoah subdivision is the only true sub-basin of the six subdivisions used in this report, and is further divided into the following tributaries:

- North Fork Shenandoah River
- Cedar Creek
- North River, Muddy Creek, Blacks Run, and Cooks Creek
- South River of the South Fork
- Lewis and Christians Creeks
- South Fork of the Shenandoah River
- Hawksbill Creek
- Shenandoah River
- Happy Creek

The North Fork of the Shenandoah River contributes 40 percent of the flow of the Shenandoah. The North Fork is 117 mi (188 km) long, and its main tributary streams are Smith, Stoney, Cedar, and Passage creeks. The middle North Fork receives treated discharges from Rockingham Poultry Marketing Co-Op, Shen-Valley Meat Packers, National Fruit, and the towns of Broadway, Timberville, and New Market. Separate treatment of poultry processing wastes has remedied a sewage treatment plant overload problem at New Market. Strasburg and Mt. Jackson have constructed treatment facilities that have improved the quality of the lower North Fork.

All five water quality stations on the North Fork (see also pp 42-44 and Figures III.1-III.18) have significant increasing trends for Ammonia and at least one other Nitrogen parameter (Nitrate, Nitrite, or TKN), with no decreasing trends evident for any Nitrogen parameter. Kendall Tau analysis showed decreasing trends in Total Ortho Phosphorus at all five stations, but increasing trends for Total Phosphorus or Total Phosphate at three stations. However, significance of the results for Phosphorus is limited because data were only available through 1978.

Cedar Creek is located in Frederick County, VA, and has a drainage area of 103 $mi^2$ (276 $km^2$). It is one of the major tributary streams to the North Fork Shenandoah River. No significant trends were identified for any parameters at the Cedar Creek station at Winchester.

The North River (see also pp. 44-45 and Figures III.19-III.31) below the town of Bridgewater and three of its tributaries (Muddy Creek, Blacks Run, and Cooks Creek) have historically experienced low Dissolved Oxygen and high Coliform levels. This was due to municipal and industrial discharges. In 1976, the Harrisonburg-Rockingham regional sewage treatment plant went on line and took over the three smaller service areas of Dayton, Harrisonburg and Bridgewater. Water quality improvements are believed due to the new sewage treatment plant and improved industrial treatment. Ammonia, Nitrite, Total Kjeldahl Nitrogen, Total Ortho Phosphorus, and Total Phosphorus, have decreased on Blacks Run and Cooks Creek; and Dissolved Oxygen shows a significant increasing trend on Cooks Creek. However, data were only available through 1978.

Lewis and Christians Creeks (see also pp 46 and Figures III.32-III.35) are two small creeks which discharge into the Middle River. Christians Creek historically has been within water quality standards. Lewis Creek has in the past experienced water quality degradation as a result of being the receiving stream for the City of Staunton sewage treatment plant. The effluent discharge of the plant has been relocated to the Middle River, but monitoring data are available only through 1978 making it difficult to assess resulting water quality improvements. For the period through 1978, both creeks show increasing trends in Ammonia, and Nitrite or Nitrate. There is a decreasing trend in Total Ortho Phosphorus in Christians Creek.

The South River (see also pp 46-48 and Figures III.36-III.47) begins in the Blue Ridge Mountains, and is 52 mi (84 km) long. The South River below Crimora, about 20 mi (32 km) below Waynesboro, has historically been the most severely impacted segment in the Shenandoah River. Improvements in the treatment of municipal and industrial discharges have improved water quality, but available monitoring data do not clearly show this because many parameters were sampled only through 1978. Statistically significant trends are indicated for various parameters, particularly for Phosphorus, that were sampled only through 1978. Of the parameters sampled throughout the 1973-84 period, there is a decreasing trend for Total Organic Carbon at Waynesboro, and for Total Organic Carbon and Carbon Oxygen Demand at Crimora. Dissolved Oxygen had an increasing trend at Crimora. However, Ammonia and Nitrite increased at Waynesboro, and Ammonia increased at Crimora.

The South Fork of the Shenandoah River is 151 mi (243 km) long, and is formed by three major tributaries, the North, Middle and South rivers which converge at Port Republic, VA. Water quality varies from good at Lynnwood to fair/good below Elkton, Luray, and Front Royal. Hawksbill Creek is a tributary to the South

Fork near Luray, VA, that has been impacted by two principal dischargers: The Luray STP and the former Virginia Oak Tannery. It historically experienced low Dissolved Oxygen, high Fecal Coliform levels, high Total Solids, and high nutrient levels during summer.

For some parameters at stations on the South Fork and Hawksbill Creek, data were available only through 1978 (see pp 48-49 and Figures III.48-III.59). From the available data, significant increasing trends were found for Nitrite at all four stations, and for Ammonia at two stations. There were no decreasing trends in any Nitrogen parameter. Fecal Coliform were increasing on the South Fork and on Hawksbill Creek, both at Luray, VA. Total Organic Carbon (TOC), Biochemical Oxygen Demand (BOD), and Mercury, were decreasing at Front Royal. The decrease in Mercury reflects a decline from high levels prevalent in the 1970's.

The Shenandoah River main stem is formed at the confluence of the North and South forks at Front Royal, VA. It flows for 20 mi (32 km) to meet the Potomac at Harpers Ferry, WV. The Shenandoah receives wastewater discharges from Stephens City and Frederick County's Stephens Run STP. Happy Creek is located downstream of Front Royal and was the receiving stream for the Front Royal sewage treatment plant. It has suffered from high organic loads and excessive Coliform levels. The AVTEX discharge is known to contain Zinc. Improvement in municipal and industrial waste treatment has been occurring over the past few years, for example the outfall of the Front Royal STP was moved to the main stem.

Both main stem stations, and the Happy Creek station, show significant increasing trends (see pp 49-50 and Figures III.60-III.73) in one or more forms of Nitrogen. There were no decreasing trends in any form of Nitrogen or Phosphorus. pH has been decreasing from high (alkaline) levels at Berryville and Bolivar. TOC and BOD have been decreasing at Berryville, and TOC decreasing at Bolivar. There is a trend at Bolivar toward increasing levels of Lead and Hexavalent Chromium. However, the concentrations of these metals is still within water quality standards.

Regional patterns in water quality trends may be apparent from inspection of Table 8 (p 51). Across the twenty three stations in the Shenandoah River basin, there was a prevalence of significant increasing trends for various forms of Nitrogen. For Ammonia, fourteen stations showed increasing trends, versus decreasing at three stations. For Nitrite, fourteen stations showed increasing trends, versus decreasing at two stations. Five stations showed increasing trends for Total Kjeldahl Nitrogen (TKN), while three showed TKN to be decreasing. Total Phosphorus, or Total Phosphate, have increasing trends at seven stations, versus decreasing trends at two stations; but conversely, Total Ortho Phosphorus has decreasing trends at ten stations, and increasing trends at only two stations. TOC shows decreasing trends at eight stations, and no increasing trends. Mercury shows a decreasing trend in the South River.

RESULTS OF KENDALL TAU TREND ANALYSIS FOR THE SHENANDOAH RIVER BASIN

River North Fork Shenandoah River
Station 1BNFS093.53 Agency VASWCB
Location Cootes Store, VA. Rt/ 259 Bridge.
River Mile: 171-55-94

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +7.82** | III.1 |
| Nitrite ($NO_2$) | +7.69 | III.2 |
| Phosphorus,Tot.Ortho | -1.86 | |
| Phosphorus,Tot. (P) | +2.64 | |
| Residue, Nonfilt. | +2.15 | |
| Residue, Vol.Nonfilt. | +2.89 | |
| TKN | +4.78** | III.3 |
| TOC | -2.79 | III.4 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good-Excellent | Improving |

River North Fork Shenandoah River
Station 1BNFS081.42 Agency VASWCB
Location New Market, VA, Rt.617/953 Bridge.
River Mile: 171-55-82

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +4.89** | III.5 |
| Nitrate ($NO_3$) | +3.01** | III.6 |
| Phosphorus,Tot.Ortho | -2.96 | III.7 |
| TOC | -3.13** | III.8 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Good | Improving |

**River** North Fork Shenandoah River
**Station** 1BNFS062.18 **Agency** VASWCB
**Location** Mt. Jackson, VA, US Rt. 11 Crossing.
River Mile: 171-55-62

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | +3.21** | III.9 |
| Nitrite ($NO_2$) | +3.22** | III.10 |
| Phosphate,Tot. ($PO_4$) | +2.28 | III.11 |
| Phosphorus,Tot.Ortho | -3.32** | III.12 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Improving |

**River** North Fork Shenandoah River
**Station** 1BNFS010.34 **Agency** VASWCB
**Location** Strasburg, VA, Rt.55 Crossing.
River Mile: 171-55-10

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | +7.96** | III.13 |
| DO | +2.36 | III.14 |
| Nitrite ($NO_2$) | +5.79** | III.15 |
| Phosphorus,Tot. (P) | +2.13 | |
| Phosphorus,Tot.Ortho | -2.34 | |
| TKN | +2.12 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** North Fork Shenandoah River
**Station** 1BNFS000.69 **Agency** VASWCB
**Location** Front Royal, VA, US 340 Bridge.
River Mile: 171-55-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +8.56** | III.16 |
| DO | +3.43** | III.17 |
| Mercury (Hg) | -2.80 | |
| Nitrite ($NO_2$) | +6.20** | III.18 |
| pH | -2.14 | |
| Phosphorus,Tot. (P) | +2.65 | |
| Phosphorus,Tot.Ortho | -2.06 | |
| TKN | +2.15 | |
| TOC | -2.66 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Improving |

**River** Cedar Creek
**Station** 1BCDR013.29 **Agency** VASWCB
**Location** Winchester, VA, Rt.628 Bridge.
River Mile: 171-55-7-13

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| None Identified | | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good-Excellent | Good-Excellent | Status Quo |

**River** North River
**Station** 1BNTH020.40 **Agency** VASWCB
**Location** Bridgewater, VA, Rt. 42 Bridge.
River Mile: 171-55-105-20

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +4.39** | III.19 |
| Nitrite ($NO_2$) | +3.49** | III.20 |
| Phosphorus,Tot.Ortho | -3.52** | III.21 |
| Phosphorus,Tot. (P) | +2.93 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Unknown | Unknown |

**River** Muddy Creek
**Station** 1BMDD001.65 **Agency** VASWCB
**Location** Bridgewater, VA, Rt 734 Bridge.
River Mile: 171-55-105-12-2

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrite ($NO_2$) | +2.81 | III.22 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Unknown | Unknown |

**River** Black's Run
**Station** 1BBLK000.57 **Agency** VASWCB
**Location** Bridgewater, VA, Rt. 704 Bridge.
River Mile: 171-55-105-12-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -4.66** | III.23 |
| Nitrite ($NO_2$) | -2.29 | |
| pH | +1.89 | |
| Phosphorus,Tot.Ortho | -4.08** | III.24 |
| Phosphate,Tot. ($PO_4$) | -3.18** | III.25 |
| TKN | -4.23** | III.26 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Unknown | Improving |

**River** Cooks Creek
**Station** 1BCKS001.03 **Agency** VASWCB
**Location** Bridgewater, VA, Rt. 867 Bridge.
River Mile: 171-55-105-12-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -4.89** | III.27 |
| DO | +2.36 | |
| Nitrate ($NO_3$) | +2.04 | |
| Nitrite ($NO_2$) | -4.34** | III.28 |
| pH | +3.27** | III.29 |
| Phosphorus,Tot.Ortho | -3.63** | III.30 |
| Phosphorus,Tot. (P) | -2.96 | |
| TKN | -5.16** | III.31 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Unknown | Improving |

**River** Lewis Creek
**Station** 1BLEW005.40 **Agency** VASWCB
**Location** Augusta County, VA.
River Mile: 171-55-100-25-5

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +1.99 | |
| Nitrite ($NO_2$) | +3.44** | III.32 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Unknown | Unknown |

**River** Christians Creek
**Station** 1BCST006.43 **Agency** VASWCB
**Location** VA Rt. 254 Bridge.
River Mile 171-55-100-31

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +2.94 | III.33 |
| Nitrate ($NO_3$) | +2.87 | III.34 |
| pH | +2.50 | III.35 |
| Phosphorus,Tot.Ortho | -2.26 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Unknown | Status Quo |

**River** South River
**Station** 1BSTH027.10 **Agency** VASWCB
**Location** Waynesboro, VA, Rt. 664 Bridge.
River Mile: 171-55-100-27

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +7.44** | III.36 |
| Conductivity | -2.09 | |
| DO | +2.55 | |
| Nitrite ($NO_2$) | +5.36** | III.37 |
| Phosphorus,Diss.Ortho | +2.98 | |
| Phosphorus,Tot.Ortho | -3.60** | III.38 |
| Phosphorus,Tot. (P) | +2.46 | |
| Temperature | -2.17 | |
| TKN | +2.66 | |
| TOC | -3.54** | III.39 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Improving |

River South River
Station 1BSTH014.49 Agency VASWCB
Location Crimora, VA, Rt. 612 Bridge.
River Mile: 171-55-100-14

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | -3.92** | III.40 |
| DO | +2.06 | |
| pH | +2.12 | III.41 |
| Phosphorus,Tot.Ortho | +2.01 | |
| TKN | -2.69 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair-Good | Improving |

River South River
Station 1BSTH007.80 Agency VASWCB
Location Crimora, VA, Rt. 778 Bridge.
River Mile: 171-55-100-2

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia($NH_3+NH_4$) | +3.44** | III.42 |
| COD | -2.17 | III.43 |
| DO | +3.39** | III.44 |
| Phosphate,Tot. ($PO_4$) | +2.42 | |
| Phosphorus,Tot. (P) | +2.29 | |
| Residue, Fix.Nonfilt. | +2.20 | |
| Residue, Vol.Nonfilt. | +1.81 | |
| Temperature | -2.15 | |
| TOC | -2.63 | III.45 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Fair-Good | Improving |

**River** South River
**Station** 1BSTH000.19 **Agency** VASWCB
**Location** Port Republic, VA, Rt. 629 Bridge.
River Mile: 171-55-100

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Phosphorus,Tot.Ortho | +2.06 | III.46 |
| Phosphate,Tot. ($PO_4$) | +2.01 | III.47 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Improving |

**River** South Fork Shenandoah River
**Station** 1BSSF092.69 **Agency** VASWCB
**Location** Lynnwood, VA, Rt. 708 Bridge.
River Mile 171-55-93

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +2.96 | III.48 |
| Nitrite ($NO_2$) | +2.40 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** South Fork Shenandoah River
**Station** 1BSSF054.20 **Agency** VASWCB
**Location** Luray, VA, US Rt. 211 Bridge.
River Mile: 171-55-54

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +5.14** | III.49 |
| Coliform, Fecal | +2.16 | III.50 |
| Nitrite ($NO_2$) | +3.06** | III.51 |
| pH | -3.48** | III.52 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Degrading |

River Hawksbill Creek
Station 1BHKS006.04 Agency VASWCB
Location Luray, VA.
River Mile: 171-55-54-6

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Fecal | +3.31** | III.53 |
| Nitrite ($NO_2$) | +4.27** | III.54 |
| Residue, Fix.Nonfilt. | -4.13** | III.55 |
| Residue, Nonfilt. | -2.41 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor | Status Quo |

River South Fork Shenandoah River
Station 1BSSF000.58 Agency VASWCB
Location Front Royal, VA, US Rt.340/522 Bridge.
River Mile: 171-55-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| BOD | -3.06** | III.56 |
| Mercury (Hg) | -2.47 | III.57 |
| Nitrite ($NO_2$) | +4.86** | III.58 |
| pH | -2.70 | |
| TOC | -3.50** | III.59 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Improving |

River Shenandoah River Main Stem
Station 1BSHN022.63 Agency VASWCB
Location Berryville, VA, Rt. 7 Bridge.
River Mile: 171-23

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +7.81** | III.60 |
| BOD | -3.20** | III.61 |
| Nitrite ($NO_2$) | +6.16** | III.62 |
| pH | -2.06 | |
| Residue, Vol.Nonfilt. | -2.16 | |
| Temperature | -1.95 | |
| TOC | -3.20** | III.63 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Improving |

| | |
|---|---|
| River | Happy Creek |
| Station | 1BHPY000.10 |
| Agency | VASWCB |
| Location | Front Royal, VA, Riverton Junction. River Mile: 171-55-98-0 |

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +3.20** | III.64 |
| DO | -2.26 | III.65 |
| Nitrite ($NO_2$) | +2.25 | III.66 |
| TKN | +2.31 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor | Degrading |

| | |
|---|---|
| River | Shenandoah River |
| Station | 550471 |
| Agency | WVDNR |
| Location | Bolivar, WV, US Rt. 340 Bridge. River Mile: 171-1 |

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Chloride | -2.14 | III.67 |
| Chromium, Hexavalent | +2.20 | III.68 |
| Copper (Cu) | -3.11** | III.69 |
| Hardness | -1.92 | |
| Lead (Pb) | +1.93 | III.70 |
| Nitrite + Nitrate | +2.67 | |
| pH | -4.96** | III.71 |
| pH, Lab. | -3.53** | III.72 |
| TOC | -6.11** | III.73 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**Table 8: Shenandoah River Basin Subdivision Parameter Trend Summary**

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

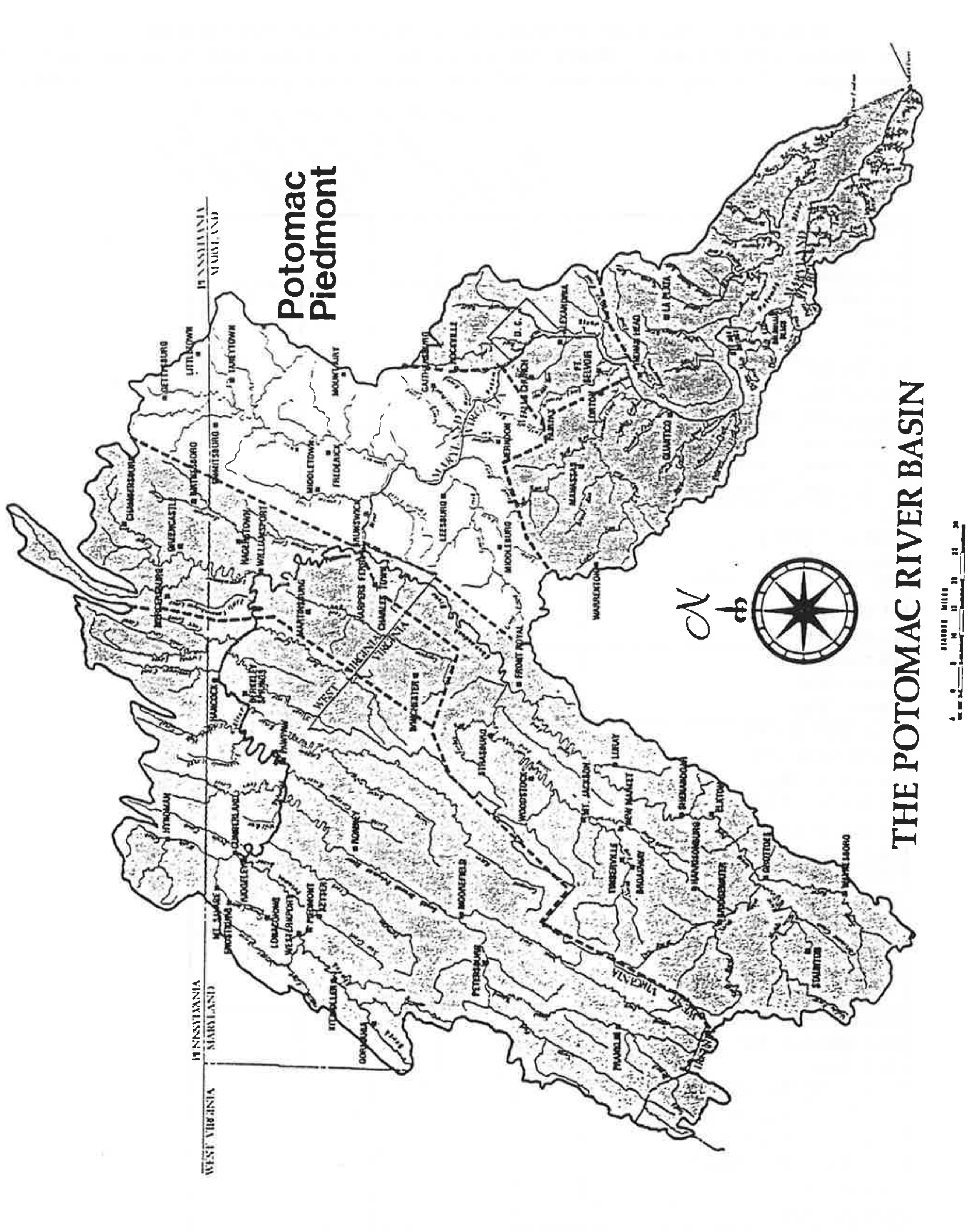
| Parameter | 1BNFS093.53 | 1BNFS081.42 | 1BNFS062.18 | 1BNFS010.34 | 1BCDR013.29 | 1BNFS000.69 | 1BNTH020.40 | 1BMDD001.65 | 1BBLK000.57 | 1BCKS001.03 | 1BLEW005.40 | 1BCST006.43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | | | | | | |
| Alkalinity | | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | | |
| Ammonia ($NH_3$+$NH_4$) | + | + | + | + | | + | + | | - | - | + | + |
| BOD | | | | | | | | | | | | |
| COD | | | | | | | | | | | | |
| Chloride | | | | | | | | | | | | |
| Chlorophyll | | | | | | | | | | | | |
| Chromium, Hexavalent | | | | | | | | | | | | |
| Chromium, Total | | | | | | | | | | | | |
| Coliform, Fecal | | | | | | | | | | | | |
| Coliform, Total | | | | | | | | | | | | |
| Color | | | | | | | | | | | | |
| Conductivity | | | | | | | | | | | | |
| Copper (Cu) | | | | | | | | | | | | |
| DO | | | | + | | + | | | | + | | |
| DO%Sat. | | | | | | | | | | | | |
| Fluoride | | | | | | | | | | | | |
| Hardness | | | | | | | | | | | | |
| Iron (Fe) | | | | | | | | | | | | |
| Lead (Pb) | | | | | | | | | | | | |
| Magnesium (Mg) | | | | | | | | | | | | |
| Manganese (Mn) | | | | | | | | | | | | |
| Mercury (Hg) | | | | | | - | | | | | | |
| Nitrate ($NO_3$) | | + | | | | | | | | + | | + |
| Nitrite ($NO_2$) | + | | + | + | | + | + | + | - | - | + | |
| Nitrite + Nitrate | | | | | | | | | | | | |
| TKN | + | | | + | | + | | | - | - | | |
| pH | | | | | | - | | | + | + | | + |
| pH, Lab. | | | | | | | | | | | | |
| Phosphorus,Diss.Ortho | | | | | | | | | | | | |
| Phosphate,Tot. ($PO_4$) | | | + | | | | | | | | | |
| Phosphorus,Tot.Ortho | - | - | - | - | | - | - | | - | - | | - |
| Phosphorus,Diss. | | | | | | | | | | | | |
| Phosphorus,Tot. (P) | + | | | + | | | + | | - | - | | |
| Residue | | | | | | | | | | | | |
| Residue, Dissolved | | | | | | | | | | | | |
| Residue, Fix.Nonfilt. | | | | | | | | | | | | |
| Residue, Nonfilt. | + | | | | | | | | | | | |
| Residue, Vol.Nonfilt. | + | | | | | | | | | | | |
| Salinity | | | | | | | | | | | | |
| Sodium (Na) | | | | | | | | | | | | |
| Sulfate ($SO_4$) | | | | | | | | | | | | |
| Temperature | | | | | | | | | | | | |
| TOC | - | - | | | | - | | | | | | |
| Turbidity | | | | | | | | | | | | |
| Water Appearance | | | | | | | | | | | | |

Table 8: **Shenandoah River Subdivision Parameter Trend Summary** (Cont.)

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| | 1BSTH027.10 | 1BSTH014.49 | 1BSTH007.80 | 1BSTH000.19 | 1BSSF092.69 | 1BSSF054.20 | 1BHKS006.04 | 1BSSF000.58 | 1BSHN022.63 | 1BHPY000.10 | 550471 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | | | | | |
| Alkalinity | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | |
| Ammonia ($NH_3+NH_4$) | + | - | + | | + | + | | | + | + | |
| BOD | | | | | | | | - | - | | |
| COD | | | - | | | | | | | | |
| Chloride | | | | | | | | | | | - |
| Chlorophyll | | | | | | | | | | | |
| Chromium, Hexavalent | | | | | | | | | | | + |
| Chromium, Total | | | | | | | | | | | |
| Coliform, Fecal | | | | | | + | + | | | | |
| Coliform, Total | | | | | | | | | | | |
| Color | | | | | | | | | | | |
| Conductivity | - | | | | | | | | | | |
| Copper (Cu) | | | | | | | | | | | - |
| DO | + | + | + | | | | | | | - | |
| DO%Sat. | | | | | | | | | | | |
| Fluoride | | | | | | | | | | | |
| Hardness | | | | | | | | | | | - |
| Iron (Fe) | | | | | | | | | | | |
| Lead (Pb) | | | | | | | | | | | + |
| Magnesium (Mg) | | | | | | | | | | | |
| Manganese (Mn) | | | | | | | | | | | |
| Mercury (Hg) | | | | | | | | - | | | |
| Nitrate ($NO_3$) | | | | | | | | | | | |
| Nitrite ($NO_2$) | + | | | | + | + | + | + | + | + | |
| Nitrite + Nitrate | | | | | | | | | | | + |
| TKN | + | - | | | | | | | | + | |
| pH | | + | | | | - | | - | - | | - |
| pH, Lab. | | | | | | | | | | | - |
| Phosphorus,Diss.Ortho | + | | | | | | | | | | |
| Phosphate,Tot. ($PO_4$) | | | + | + | | | | | | | |
| Phosphorus,Tot.Ortho | - | + | | + | | | | | | | |
| Phosphorus,Diss. | | | | | | | | | | | |
| Phosphorus,Tot. (P) | + | | + | | | | | | | | |
| Residue | | | | | | | | | | | |
| Residue, Dissolved | | | | | | | | | | | |
| Residue, Fix.Nonfilt. | | | + | | | | - | | | | |
| Residue, Nonfilt. | | | | | | | - | | | | |
| Residue, Vol.Nonfilt. | | | + | | | | | | - | | |
| Salinity | | | | | | | | | | | |
| Sodium (Na) | | | | | | | | | | | |
| Sulfate ($SO_4$) | | | | | | | | | | | |
| Temperature | - | | - | | | | | | - | | |
| TOC | - | | - | | | | | - | - | | - |
| Turbidity | | | | | | | | | | | |
| Water Appearance | | | | | | | | | | | |

Map 5.


Potomac
Piedmont
THE POTOMAC RIVER BASIN
PENNSYLVANIA
MARYLAND
WEST VIRGINIA

# IV. POTOMAC PIEDMONT

The Potomac Piedmont subdivision includes the 53 main stem Potomac River miles (85 km) from the mouth of the Shenandoah River at Harpers Ferry, WV, to Little Falls, MD just above Washington, DC. Included in this subdivision are Montgomery County, MD, and Fairfax County, Va., the suburban expansion of Washington, DC, and the "fringe" expansion counties of Carroll, Washington, and Frederick, MD, and Loudoun County, VA. Streams assessed in this subdivision include:

- Potomac River
- Rock Creek (tributary to the Monocacy River)
- Monocacy River
- Goose Creek
- Seneca Creek
- Sugarland Run
- Cabin John Creek

Two stations, at Point of Rocks and at White's Ferry, are on the main stem Potomac in this subdivision (see p. 55-57 and Figures IV.1-IV.4 and IV.38). Both stations show significant increasing trends in multiple Nitrogen parameters, and there is an increasing trend in Total Phosphorus at White's Ferry. There are no decreasing trends for any Nitrogen or Phosphorus parameter. Both stations also show decreasing trends in pH, decreasing from alkaline toward more neutral values.

Rock Creek is a tributary to the Monocacy River in the upper part of the Monocacy watershed, including Gettysburg, PA. Data from the Rock Creek station (see p. 55 and Figure IV.5-IV.7) show a significant increasing trend in both Total and Fecal Coliform.

The Monocacy River is 58 mi (93 km) long, with a watershed covering 228 mi$^2$ (590 km$^2$) in Pennsylvania and 742 mi$^2$ (1,922 km$^2$) in Maryland. Water quality in the Monocacy River varies from fair to good. In the upper sections of the tributaries in the Catoctin Mountains, water quality is good to excellent. The Monocacy River and the Double Pipe Creek watershed have been targeted by the State of Maryland as critical areas due to the release of agricultural nonpoint nutrients (Phosphorus and Nitrogen).

Three of four stations on the Monocacy River (see pp 56-57 and Figures IV.9 - IV.31) have significant increasing trends in one or more Nitrogen parameters. There is an increasing trend in Total Phosphorus at two stations. There are no decreasing trends in any Nitrogen or Phosphorus parameter. Other trends include pH decreasing, and Conductivity increasing, at the same three stations. Temperature shows a significant decreasing trend at three stations, but this is probably climate related.

Goose Creek joins the Potomac River about 35 mi (56 km) upstream from Washington, DC. It is the receiving stream for the Leesburg, VA sewage treatment plant. The effect of increasing development in northern Virginia is perhaps indicated by data from the Goose Creek station (see p. 58 and Figures IV.39-IV.44) which show significant increasing trends in Ammonia, Nitrite, Total Kjeldahl Nitrogen (TKN), Dissolved Ortho Phosphorus, and Total Phosphate; versus decreasing trends for Total Ortho Phosphorus, and Total Organic Carbon.

Seneca Creek, in Montgomery County, MD, like other streams in this sub-division, has significant increasing trends in multiple Nitrogen parameters, in Total Phosphorus, and a decreasing trend in pH (see p. 58 and Figures IV.45 - IV.49).

The water quality of Sugarland Run, Herndon, VA, has improved substantially. This may be the result of moving a sewage treatment plant discharge from the creek to the Dulles Interceptor Sewer in 1977. Ammonia, BOD, Nitrate, Total Ortho Phosphorus, and Total Organic Carbon, show significant decreasing trends, while Dissolved Oxygen has as increasing trend (see p. 59 and Figures IV.50 - IV.54).

Cabin John Creek, Montgomery County, MD, is affected by nonpoint source pollutants associated with surface runoff from suburban and urban development. Pollution sources include soil loss from construction sites, leaking sewers and septic systems, and runoff containing animal wastes. While Total Phosphorus had a declining trend, Nitrate and Total Kjeldahl Nitrogen had increasing trends. Total Coliform had a significant decreasing trend, but data were not available after 1981 and the level of Coliform during the period of record was consistently above water quality standards (see p. 59 and Figures IV.55 - IV.60).

Regional patterns in water quality parameter trends include increasing Nitrogen, and decreasing pH, Salinity, and Temperature (see Table 9, p. 60). Eight of eleven stations had increasing trends in Nitrogen parameters, while only one (Sugarland Run) had a decreasing trend. Decreasing pH trends occurred at seven stations. At all of these, pH was decreasing from alkaline levels. Decreasing Salinity occurred at four stations. As elsewhere in the Potomac basin, significant decreasing trends were detected in Temperature.

## RESULTS OF KENDALL TAU TREND ANALYSIS FOR THE POTOMAC PIEDMONT

**River** Potomac River
**Station** POT1595 **Agency** MDWRA/MDOEP
**Location** Point of Rocks, MD, US Rt.15 Bridge.
River Mile: 160

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrite ($NO_2$) | +1.91 | IV.1 |
| pH | -1.85 | IV.2 |
| Residue, Nonfilt. | -2.80 | IV.3 |
| TKN | +2.81 | IV.4 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Improving |

**River** Rock Creek (Monocacy Tributary)
**Station** WQN0503 **Agency** PADER
**Location** Gettysburg, PA, US Rt. 140 Bridge.
River Mile: 154-64

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Chloride | +3.16** | IV.5 |
| Coliform, Fecal | +4.01** | IV.6 |
| Coliform, Total | +2.70 | |
| Conductivity | +3.31** | IV.7 |
| Phosphate,Tot. ($PO_4$) | -1.89 | |
| Turbidity | -2.37 | |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Unknown |

**River** Monocacy River
**Station** MON0528 **Agency** MDWRA/MDOEP
**Location** Bridgeport, MD, Rt. 97 Bridge.
River Mile: 154-53

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | +1.86 | IV.8 |
| Nitrate ($NO_3$) | +2.48 | IV.9 |
| Nitrite ($NO_2$) | +3.11** | IV.10 |
| pH | -2.47 | IV.11 |
| pH, Lab. | +2.19 | IV.12 |
| Phosphorus,Tot. (P) | +3.13** | IV.13 |
| Residue, Nonfilt. | -2.58 | IV.14 |
| Salinity | -2.69 | IV.15 |
| TKN | +5.09** | IV.16 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Status Quo |

**River** Monocacy River
**Station** MON0269 **Agency** MDWRA/MDOEP
**Location** Above Frederick, MD, Biggs Ford Rd. Bridge.
River Mile: 154-27

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | +1.88 | IV.17 |
| DO | -2.52 | IV.18 |
| Nitrate ($NO_3$) | +1.96 | IV.19 |
| pH | -1.94 | IV.20 |
| Temperature | -2.56 | IV.21 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** Monocacy River
**Station** MON0155 **Agency** MDWRA/MDOEP
**Location** Below Frederick, MD, Reichs Ford Bridge.
River Mile: 154-16

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | +1.95 | IV.22 |
| Temperature | -2.90 | IV.23 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair | Status Quo |

**River** Monocacy River
**Station** MON0020 **Agency** MDWRA/MDOEP
**Location** Dickerson, MD, Rt. 28 Bridge.
River Mile: 154-2

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Conductivity | +2.32 | IV.24 |
| Nitrate ($NO_3$) | +5.09** | IV.25 |
| Nitrite ($NO_2$) | +2.43 | IV.26 |
| pH | -2.72 | IV.27 |
| Phosphorus,Tot. (P) | +2.60 | IV.28 |
| Salinity | -2.35 | IV.29 |
| Temperature | -2.24 | IV.30 |
| TKN | +3.06** | IV.31 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair-Good | Status Quo |

**River** Potomac River
**Station** POT1471 **Agency** MDWRA/MDOEP
**Location** White's Ferry, MD, Rt. 107.
River Mile: 147

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| BOD | -1.81 | IV.32 |
| Nitrate ($NO_3$) | +3.94** | IV.33 |
| Nitrite ($NO_2$) | +4.06** | IV.34 |
| pH | -3.81** | IV.35 |
| Phosphorus,Tot. (P) | +3.01** | IV.36 |
| Salinity | -2.94 | IV.37 |
| TKN | +5.66** | IV.38 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair-Good | Status Quo |

River: Goose Creek
Station: 1AGO0002.38
Agency: VASWCB
Location: Leesburg, VA, Rt. 7 Bridge.
River Mile: 142-2

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +5.33** | IV.39 |
| Conductivity | -1.98 | |
| Nitrite ($NO_2$) | +3.61** | IV.40 |
| pH | -3.33** | IV.41 |
| Phosphorus,Diss.Ortho | +2.60 | |
| Phosphate,Tot. ($PO_4$) | +3.20** | IV.42 |
| Phosphorus,Tot.Ortho | -2.10 | |
| TOC | -2.04 | IV.43 |
| TKN | +4.65** | IV.44 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

River: Seneca Creek
Station: SEN0008
Agency: MDWRA/MDOEP
Location: Bethesda, MD, River Rd. Bridge.
River Mile: 135-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +5.56** | IV.45 |
| pH | -3.13** | IV.46 |
| pH, Lab. | +2.14 | IV.47 |
| Phosphorus,Tot. (P) | +2.01 | IV.48 |
| TKN | +3.95** | IV.49 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair-Good | Status Quo |

River: Sugarland Run
Station: 1ASUG004.42 — Agency: VASWCB
Location: Herndon, VA.
River Mile: 142-2

| Significant Parameter | K-tau value | Figure No. |
| --- | --- | --- |
| Ammonia ($NH_3$+$NH_4$) | -1.85 | |
| BOD | -2.53 | IV.50 |
| COD | +2.15 | |
| DO | +3.39** | IV.51 |
| Nitrate ($NO_3$) | -2.82 | IV.52 |
| Phosphorus,Tot.Ortho | -3.40** | IV.53 |
| Residue, Vol.Nonfilt. | +2.32 | |
| Temperature | -1.94 | |
| TOC | -2.37 | IV.54 |

| Former Status | Current Status | Trend |
| --- | --- | --- |
| Poor | Fair-Good | Improving |

River: Cabin John Creek
Station: CJB0005 — Agency: MDWRA/MDOEP
Location: MacArthur Boulevard Bridge, Montgomery County, MD
River Mile: 119-1

| Significant Parameter | K-tau value | Figure No. |
| --- | --- | --- |
| Coliform, Total | -1.89 | IV.55 |
| DO | +2.18 | IV.56 |
| Nitrate ($NO_3$) | +2.21 | IV.57 |
| Phosphorus,Tot. (P) | -2.41 | IV.58 |
| Salinity | -2.02 | IV.59 |
| TKN | +3.40** | IV.60 |

| Former Status | Current Status | Trend |
| --- | --- | --- |
| Good | Fair-Good | Unknown |

**Table 9: Potomac Piedmont Subdivision Parameter Trend Summary**

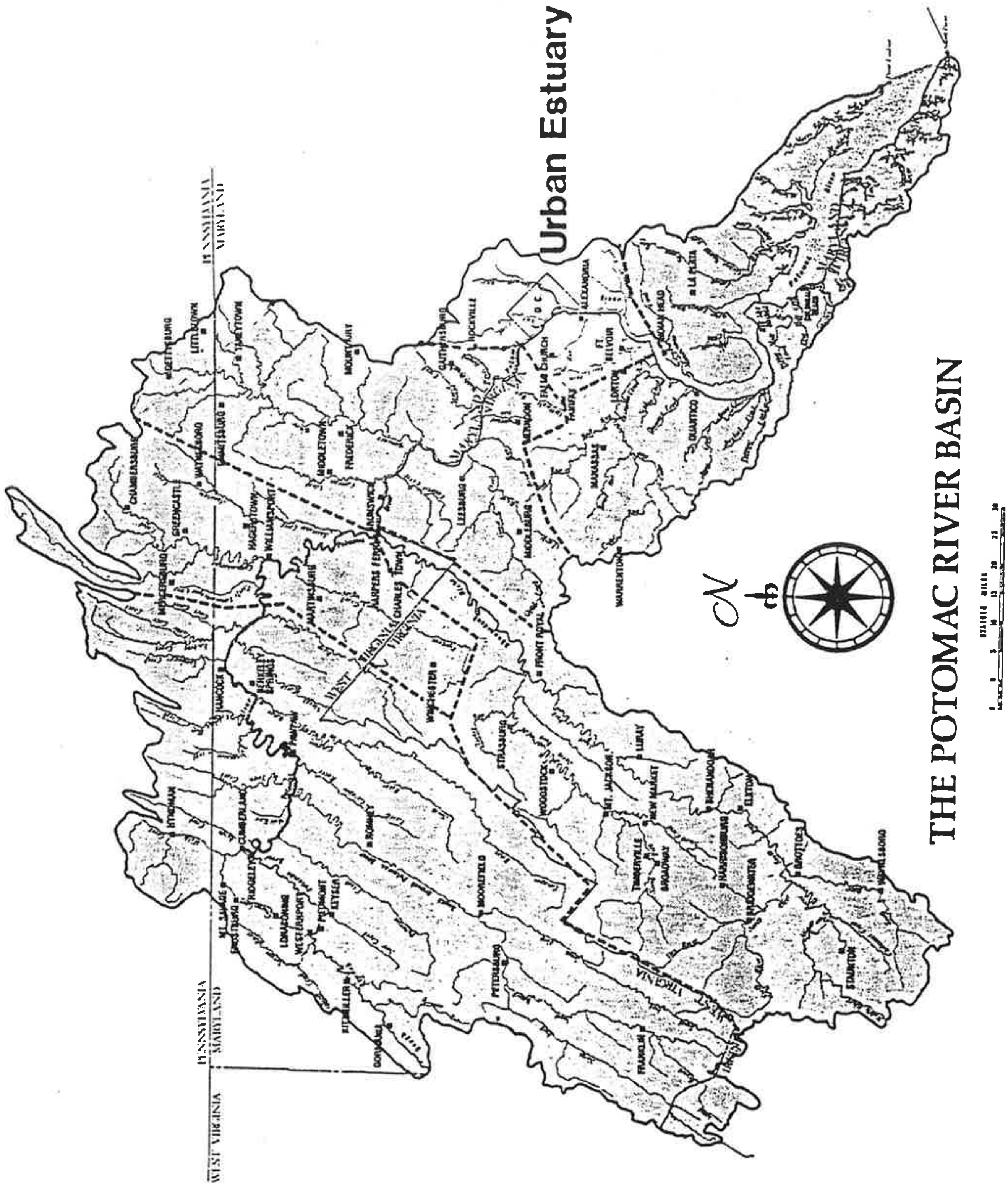
+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| Parameter | POT1595 | WQN0503 | MON0528 | MON0269 | MON0155 | MON0020 | POT1471 | 1AGO0002.38 | SEN0008 | 1ASUG004.42 | CJB005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | | | | | |
| Alkalinity | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | |
| Ammonia ($NH_3+NH_4$) | | | | | | | | + | | - | |
| BOD | | | | | | | - | | | - | |
| COD | | | | | | | | | | + | |
| Chloride | | + | | | | | | | | | |
| Chlorophyll | | | | | | | | | | | |
| Chromium, Hexavalent | | | | | | | | | | | |
| Chromium, Total | | | | | | | | | | | |
| Coliform, Fecal | | + | | | | | | | | | |
| Coliform, Total | | + | | | + | | | | | | - |
| Color | | | | | | | | | | | |
| Conductivity | | + | + | + | | + | | - | | | |
| Copper (Cu) | | | | | | | | | | | |
| DO | | | | - | | | | | | + | + |
| DO%Sat. | | | | | | | | | | | |
| Fluoride | | | | | | | | | | | |
| Hardness | | | | | | | | | | | |
| Iron (Fe) | | | | | | | | | | | |
| Lead (Pb) | | | | | | | | | | | |
| Magnesium (Mg) | | | | | | | | | | | |
| Manganese (Mn) | | | | | | | | | | | |
| Mercury (Hg) | | | | | | | | | | | |
| Nitrate ($NO_3$) | | | + | + | | + | + | | + | - | + |
| Nitrite ($NO_2$) | + | | + | | | + | + | + | | | |
| Nitrite + Nitrate | | | | | | | | | | | |
| TKN | + | | + | | | + | + | + | + | | + |
| pH | - | | - | - | | - | - | - | - | | |
| pH, Lab. | | | + | | | | | | + | | |
| Phosphorus,Diss.Ortho | | | | | | | | + | | | |
| Phosphate,Tot. ($PO_4$) | | - | | | | | | + | | | |
| Phosphorus,Tot.Ortho | | | | | | | | - | | - | |
| Phosphorus,Diss. | | | | | | | | | | | |
| Phosphorus,Tot. (P) | | | + | | | + | + | | + | | - |
| Residue | | | | | | | | | | | |
| Residue, Dissolved | | | | | | | | | | | |
| Residue, Fix.Nonfilt. | | | | | | | | | | | |
| Residue, Nonfilt. | - | | - | | | | | | | | |
| Residue, Vol.Nonfilt. | | | | | | | | | | + | |
| Salinity | | | - | | | - | - | | | | - |
| Sodium (Na) | | | | | | | | | | | |
| Sulfate ($SO_4$) | | | | | | | | | | | |
| Temperature | | | | - | - | - | | | | - | |
| TOC | | | | | | | | - | | - | |
| Turbidity | | - | | | | | | | | | |
| Water Appearance | | | | | | | | | | | |

POTOMAC WATER QUALITY STATUS AND TRENDS (1973-1984)

Section IV: Potomac Piedmont

Map 6.


Urban Estuary
THE POTOMAC RIVER BASIN
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
VIRGINIA

# V. POTOMAC URBAN ESTUARY

This subdivision includes the portion of the basin contributing to 43 miles (69 km) of the main stem Potomac River from Little Falls to Indian Head, MD. It includes all of the District of Columbia. Trends in water quality were assessed in the following stream reaches of the subdivision:

- Potomac River
- Rock Creek
- Anacostia River
- Four Mile Run
- Hunting Creek
- Piscataway Creek
- Little Hunting Creek
- Pohick Creek

The overall trend at Little Falls is unknown, although previous reports indicated good water quality. There was a change in the station location during the 12-year trend period; therefore, a trend in status cannot legitimately be assigned. This segment of river near Little Falls is affected by urban waste discharge from upstream tributaries such as Goose Creek, Muddy Branch, and Seneca Creek. The station is downstream from the confluence of Cabin John Creek and the Potomac, which prior to 1974 was considered one of the most degraded streams above Washington, DC (9), (10).

The tidal Potomac River receives more than 400 mgd of treated wastewater, with about 75 percent coming from the Blue Plains wastewater treatment plant (WWTP) just up stream of the Woodrow Wilson Bridge. Water quality has improved over the period of analysis, and District of Columbia waters now support an excellent sport fishery. In the 1983 fishing derby sponsored by the Washington Area Waterfront Action Group (WAWAG), a world-record 57 pound, 13 ounce carp was caught in the Tidal Basin.

Urban runoff is currently the major degrading factor in water quality. In addition, combined sewer overflows (CSO's) within the District of Columbia continue to cause water quality problems after rains. WWTP loadings, by-passed discharges, combined sewer overflows, and urban runoff in the Washington area have been the historical cause of Poor-Fair water quality. The Dogue and Little Hunting Creek STP discharges, thermal effluent from the PEPCO power plant in Alexandria, and runoff from National Airport also affect water quality in the main stem.

The summer of 1983 was marked by a massive bloom of the blue-green algae *Microcystis aeruginosa* in a 30-mile stretch of the upper Potomac from Alexandria, VA, to Maryland Point for the first time in about a decade. In 1984 another algal bloom occurred, but not as severe or widespread as the one in 1983.

Submerged aquatic vegetation (SAV) also returned to the upper Potomac estuary in 1983, following an absence in the upper 35 mi (56 km) of the estuary since the 1950's. A decline in SAV over the past two to three decades coincided with a decline in SAV throughout the entire tidal Chesapeake system. Small patches of 10 to 12 species were found along the shorelines of the Potomac from Woodrow Wilson Bridge to Quantico, VA. Because SAV is found in healthy water environments, and because it provides food, cover, and natural aquatic life habitat, the return of SAV is a signal of improving water quality.

The reappearance of submerged aquatic plants was not all good news. Hydrilla verticillata, one of the species that has become widely distributed along the Potomac upper estuary, can be a nuisance plant. Hydrilla is a very aggressive, quick growing, competitive plant. It is able to reproduce in five different ways, and it can crowd out desirable plants. Consequently, it has the potential to cause problems for navigation and recreation.

Significant trends in nutrients (see also pp. 67,68,71,73, and Figures V.1-V.12, V.17-V.21, V.63-V.71, V.87-V.88) are up at Little Falls and mixed (with Ammonia and Phosphorus usually down) at intermediate and downstream stations. Downward trends in Fecal Coliform were detected at Fletcher's Boathouse, Haines Point, and the Woodrow Wilson Bridge. Trends in pH were also downward (from above neutral values) at Little Falls and Marshall Hall. Where significant trends were detected in the Potomac, both Temperature and Turbidity were declining.

Rock Creek, a major tributary in the Washington area (see also pp. 67-68 and Figures V.13-V.16) is 25 mi (40 km) long, and drains urbanized Montgomery County, MD and the District of Columbia. Two dams were constructed in the 1960's, forming Lake Needwood and Lake Frank, to improve water quality by trapping sediment, augmenting low stream flows during dry weather periods, and providing recreation. In 1983, one-third of Lake Needwood was choked by thick mats of Hydrilla. When it reappeared in 1984, herbicides were used for control of the weed. Following storms, sediment and debris contaminate the stream and contribute pollutants to the Potomac. The only parameters exhibiting significant trends were the Nitrogen series (upward) and Salinity (downward). Rock Creek stations at Park Road and Sherrill Drive were part of the DC monitoring network until 1981, but were then discontinued.

The Anacostia River (see also pp. 69-70 and Figures V.22-V.51) is 28 mi (45 km) long and drains parts of Maryland and the District of Columbia. The Montgomery County portion includes

Northwest Branch (the only stream that is stocked with trout inside the Capital Beltway), Sligo Creek, and the upper portion of Paint Branch. Paint Branch is fed by clean, cold, rapidly flowing springs, and it is one of the few streams with a self-sustaining brown trout population in Montgomery County. Prince Georges County tributaries include Northeast Branch, Indian Creek, Little Paint Branch, and Beaverdam Creek. In the tidal Anacostia, water quality is affected by urban stormwater runoff, combined sewer overflows, excavation (sand and gravel quarrying), and erosion at construction sites. The Anacostia River Restoration Plan, recently negotiated between the District of Columbia and Maryland should focus attention on this neglected river.

Detectable trends in most water quality parameters in the Anacostia indicate improvement. The Nitrogen and Phosphorus series were generally declining, as were Fecal and total Coliform, and pH. The few trends detected in DO, Residue, Salinity, Temperature, and Turbidity at the four sampling stations all indicated declining values.

Four Mile Run (see also pp. 71 and Figures V.52-V.62) forms the boundary between Arlington County and the City of Alexandria in northern Virginia and empties into the Potomac just downstream of National Airport. Principal tributaries are Long Branch, Lucky, Doctors, and Lubber runs. Formerly the most frequently and extensively flooded stream valley in the Washington metropolitan area, this problem was alleviated by a $63-million flood control project which was completed in 1980. Four Mile Run is the receiving stream for the Arlington STP discharge. Nearly all of the many significant trends among water quality parameters in Four Mile Run indicated improvement. The BOD, COD, and nutrient trends were almost all declining. Dissolved Oxygen was increasing, and Residue and TOC were declining.

Hunting Creek (see also pp. 72 and Figures V.72-V.78) is a tributary to the Potomac on the Virginia side of the estuary, south of Alexandria. Once a wide tidal estuary itself, the mouth of Hunting Creek is now only one mile wide. The inland part of Hunting Creek is now a narrow channel, the remainder being filled in by siltation. It is the receiving stream for the Alexandria STP discharge. All of the many significant trends, except for Fecal Coliform, indicate improvement in Hunting Creek. The nutrients, BOD, and TOC all had declining trends; and that for DO was increasing. The trend in pH was declining through neutral values.

Piscataway Creek (see also pp. 72 and Figures V.79-V.81) is the major drainage in Prince George's County, MD, southeast of Washington, DC. It is 17 mi (27 km) long, and its catchment is being developed as a suburban residential area. The Piscataway WWTP discharges 30 million gallons per day of treated sewage into the tidal Potomac. Water quality is impacted by suburban runoff and boat discharges. The few significant improving trends (Total Coliform, Nitrite, and Residue) probably represent the effect of moving the Piscataway STP discharge pipe out of the creek and into the main stem of the Potomac.

Little Hunting Creek (see also pp. 73 and Figures V.82-V.86) flows in a southeasterly direction from a Virginia storm sewer system to the Potomac River under the George Washington Memorial Parkway at Mount Vernon. The creek flows through concrete channels into a wide marsh, where it enters the Potomac. The watershed is almost entirely developed. Little Hunting Creek is the receiving stream for the Little Hunting Creek WWTP which serves Fairfax County. It provides secondary treatment with phosphorus removal. Long-term plans call for its flow to be diverted to the Lower Potomac WWTP. The only significant trends were declines in total Phosphorus and pH (through neutral).

Pohick Creek (see also pp. 74 and Figures V.89-V.92) empties into Pohick Bay, and together with Accotink Bay, form Gunston Cove. Gunston Cove meets the Potomac main stem between Fort Belvoir and Mason Neck, 17 mi (27 km) below Washington, DC. The watershed is mostly developed. Pohick Creek is the receiving stream for the discharge from the Lower Potomac WWTP. Significant trends in the nutrients, Fecal Coliform, and Residue indicated a deterioration of water quality.

A regional analysis (see Table 10, p. 75) of nutrient trends shows a mixed picture: Ammonia is down in the upper part of the Potomac and the Anacostia, but up in Little Hunting and Pohick creeks. Other Nitrogen series parameters are up in the upper Potomac, Rock Creek, upper Anacostia, Little Hunting and Pohick creeks, while down in the lower Anacostia, the Potomac at Woodrow Wilson Bridge, and Hunting and Piscataway creeks. Phosphorus was broadly down except for upward trends on the Potomac at Little Falls, Little Hunting Creek, and mixed trends in Pohich Creek. Coliform was broadly down except for upward trends in Hunting, Little Hunting, and Pohick creek. Where detected at eight stations, the trend in pH was consistently downward. Trends in Residue species were broadly down where detected in the lower tributaries, except for Pohick Creek where the trends were upward.

RESULTS OF TREND ANALYSIS FOR THE POTOMAC URBAN ESTUARY

River Potomac River
Station POT1184 Agency MDWRA/MDOEP
Location Bethesda, MD, Little Falls Dam.
River Mile: 118

| Significant Parameters | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +4.82** | V.1 |
| Nitrite ($NO_2$) | +3.02** | V.2 |
| pH | -4.75** | V.3 |
| Phosphorus,Tot. (P) | +2.61 | V.4 |
| Salinity | -2.15 | V.5 |
| Temperature | -2.54 | V.6 |
| TKN | +4.11** | V.7 |
| Turbidity | -2.19 | V.8 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair | Unknown |

River Potomac River
Station PMS01 (101001) Agency DCRA
Location Washington, DC, Fletcher's Boat House.
River Mile: 99.5

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -3.72** | V.9 |
| Coliform, Fecal | -2.02 | V.10 |
| Phosphorus,Diss (P) | -3.28** | V.11 |
| TKN | -4.55** | V.12 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair-Good | Good | Improving |

River: Rock Creek
Station: RCM0111 — Agency: MDWRA/MDOEP
Location: Bethesda, MD, Rt. 410 Bridge.
River Mile: 101-11

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +2.97 | V.13 |
| Nitrite ($NO_2$) | +2.36 | V.14 |
| Salinity | -1.89 | V.15 |
| TKN | +3.35** | V.16 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor-Fair | Improving |

River: Rock Creek
Station: 101023 — Agency: DCRA
Location: Washington, DC, Park Road.
River Mile: ??-??

Significant Parameters — K-tau Value — Figure No.
Insufficient data to test for trends at this station.

Former Status — Current Status — Trend
See text discussion for Rock Creek.

River: Rock Creek
Station: 101021 — Agency: DCRA
Location: Washington, DC, Sherrill Drive.
River Mile: ??-??

Significant Parameters — K-tau Value — Figure No.
Insufficient data to test for trends at this station.

Former Status — Current Status — Trend
See text discussion for Rock Creek.

**River** Potomac River
**Station** PMS29 (101007) **Agency** DCRA
**Location** Washington, D.C., Haines Point.
River Mile: 92.5

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -2.84 | V.17 |
| Coliform, Fecal | -2.62 | V.18 |
| Nitrate ($NO_3$) | +2.66 | V.19 |
| Phosphorus,Diss (P) | -4.46** | V.20 |
| TKN | -3.90** | V.21 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair-Good | Improving |

**River** Anacostia River
**Station** ANA0082 **Agency** MDWRA/MDOEP
**Location** Bladensburg, MD, US Rt.50 Bridge.
River Mile: 95-8

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| pH | -1.99 | V.22 |
| pH, Lab. | +2.36 | V.23 |
| Residue, Nonfilt. | -3.75** | V.24 |
| Salinity | -2.68 | V.25 |
| TKN | +2.64 | V.26 |
| Turbidity | -2.56 | V.27 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Improving |

**River** Anacostia River
**Station** ANA01 (101013) **Agency** DCRA
**Location** MD/DC Line.
River Mile: 97-7-2

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Alkalinity | +2.24 | V.28 |
| Ammonia ($NH_3$+$NH_4$) | -2.82 | V.29 |
| Coliform, Fecal | -4.28** | V.30 |
| Coliform, Total | -3.13** | V.31 |
| DO%Sat | -2.57 | V.32 |
| pH | -2.86 | V.33 |
| Phosphorus,Diss (P) | -4.97** | V.34 |
| TKN | -3.54** | V.35 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor | Status Quo |

**River** Anacostia River
**Station** ANA14 (101016) **Agency** DCRA
**Location** Washington, D.C., Pennsylvania Ave.
River Mile: 92.5-3.5

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -2.32 | V.36 |
| Coliform, Total | -2.09 | V.37 |
| pH | -4.27** | V.38 |
| Phosphorus,Diss.Ortho | -2.11 | V.39 |
| Phosphorus,Diss (P) | -5.32** | V.40 |
| Temperature | -3.34** | V.41 |
| TKN | -2.99 | V.42 |

| Former Status | Current Status | Trend |
|---|---|---|
| ??? | ??? | ??? |

**River** Anacostia River
**Station** ANA21 (101018) **Agency** DCRA
**Location** Washington, D.C., S. Capital St.
River Mile: 92.5-1.75

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -3.18** | V.43 |
| Coliform, Fecal | -3.62** | V.44 |
| Coliform, Total | -3.56** | V.45 |
| DO | -2.91 | V.46 |
| pH | -3.37** | V.47 |
| Phosphorus,Diss (P) | -4.90** | V.48 |
| Residue, Nonfilt. | -2.44 | V.49 |
| Temperature | -2.99 | V.50 |
| TKN | -3.70** | V.51 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Poor-Fair | Improving |

**River** Four Mile Run
**Station** 1AFOU000.19 **Agency** VASWCB
**Location** Arlington, VA, GW Parkway Bridge.
River Mile: 93-(.2)

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -3.83** | V.52 |
| BOD | -4.32** | V.53 |
| COD | -3.38** | V.54 |
| Conductivity | -1.93 | |
| DO | +3.68** | V.55 |
| Nitrite ($NO_2$) | +2.00 | |
| Phosphorus,Diss.Ortho | -3.15** | V.56 |
| Phosphate,Tot. ($PO_4$) | -4.04** | V.57 |
| Phosphorus,Tot.Ortho | -3.76** | V.58 |
| Residue, Fix.Nonfilt. | -2.87 | |
| Residue, Nonfilt. | -3.65** | V.59 |
| Residue, Vol.Nonfilt. | -3.63** | V.60 |
| TKN | -4.17** | V.61 |
| TOC | -5.16** | V.62 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Fair | Improving |

**River** Potomac River
**Station** PMS44 (101012) **Agency** DCRA
**Location** Washington, DC at Woodrow Wilson Bridge.
River Mile: 88.75

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | -2.32 | V.63 |
| BOD | -2.80 | V.64 |
| Chlorophyll | -2.77 | V.65 |
| Coliform, Fecal | -2.28 | V.66 |
| Nitrate ($NO_3$) | +4.35** | V.67 |
| Nitrite ($NO_2$) | -2.46 | V.68 |
| Phosphorus,Diss (P) | -6.47** | V.69 |
| TKN | -5.29** | V.70 |
| Turbidity | -1.96 | V.71 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Improving |

**River** Hunting Creek
**Station** 1AHUT000.01 **Agency** VASWCB
**Location** Alexandria, VA, George Washington Parkway.
River Mile: 90-(.01)

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| BOD | -3.04** | V.72 |
| Coliform, Fecal | +2.74 | V.73 |
| DO | +2.88 | |
| Nitrite ($NO_2$) | -1.89 | |
| pH | -5.14** | V.74 |
| Phosphate,Tot. ($PO_4$) | -3.24** | V.75 |
| Phosphorus,Tot.Ortho | -3.67** | V.76 |
| Phosphorus,Tot. (P) | -2.13 | |
| Residue, Fix.Nonfilt. | -2.79 | |
| Residue, Nonfilt. | -3.69** | V.77 |
| Residue, Vol.Nonfilt. | -2.80 | |
| TOC | -3.76** | V.78 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Improving |

**River** Piscataway Creek
**Station** PIS0033 **Agency** MDWRA/MDOEP
**Location** Fort Washington, MD, Rt. 210 Bridge.
River Mile: 85-2

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Coliform, Total | -2.35 | V.79 |
| Nitrite ($NO_2$) | -1.94 | V.80 |
| Residue, Nonfilt. | -2.48 | V.81 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair-Good | Improving |

**River** Little Hunting Creek
**Station** 1ALIF000.19 **Agency** VASWCB
**Location** Fairfax, VA, GW Parkway Bridge.
River Mile: 83-.2

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3$+$NH_4$) | +2.48 | |
| BOD | -3.43** | V.82 |
| Chloride | +1.97 | |
| Coliform, Fecal | +3.38** | V.83 |
| pH | -5.39** | V.84 |
| Phosphate,Tot. ($PO_4$) | +2.26 | |
| Residue, Nonfilt. | -2.53 | |
| TKN | +3.00** | V.85 |
| TOC | -3.07** | V.86 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor-Fair | Fair | Improving |

**River** Potomac River
**Station** XFB1433 **Agency** MDWRA/MDOEP
**Location** Marshall Hall, MD, Buoy 67.
River Mile: 82

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| pH | -2.52 | V.87 |
| Phosphorus,Tot. (P) | -2.05 | V.88 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair-Good | Improving |

**River** Pohick Creek
**Station** 1APOH007.65 **Agency** VASWCB
**Location** Ft. Belvoir, VA, Below Rt. 641
River Mile: 80-8

| Significant Parameters | K-tau Value | Figure No. |
|---|---|---|
| Ammonia ($NH_3+NH_4$) | +5.28** | V.89 |
| Coliform, Fecal | +2.06 | V.90 |
| Nitrite ($NO_2$) | +3.97** | V.91 |
| Phosphate,Tot. ($PO_4$) | +2.25 | |
| Phosphorus,Tot.Ortho | -2.00 | |
| Residue, Fix.Nonfilt. | +1.84 | |
| Residue, Nonfilt. | +1.88 | |
| Residue, Vol.Nonfilt. | +2.05 | |
| TKN | +3.12** | V.92 |

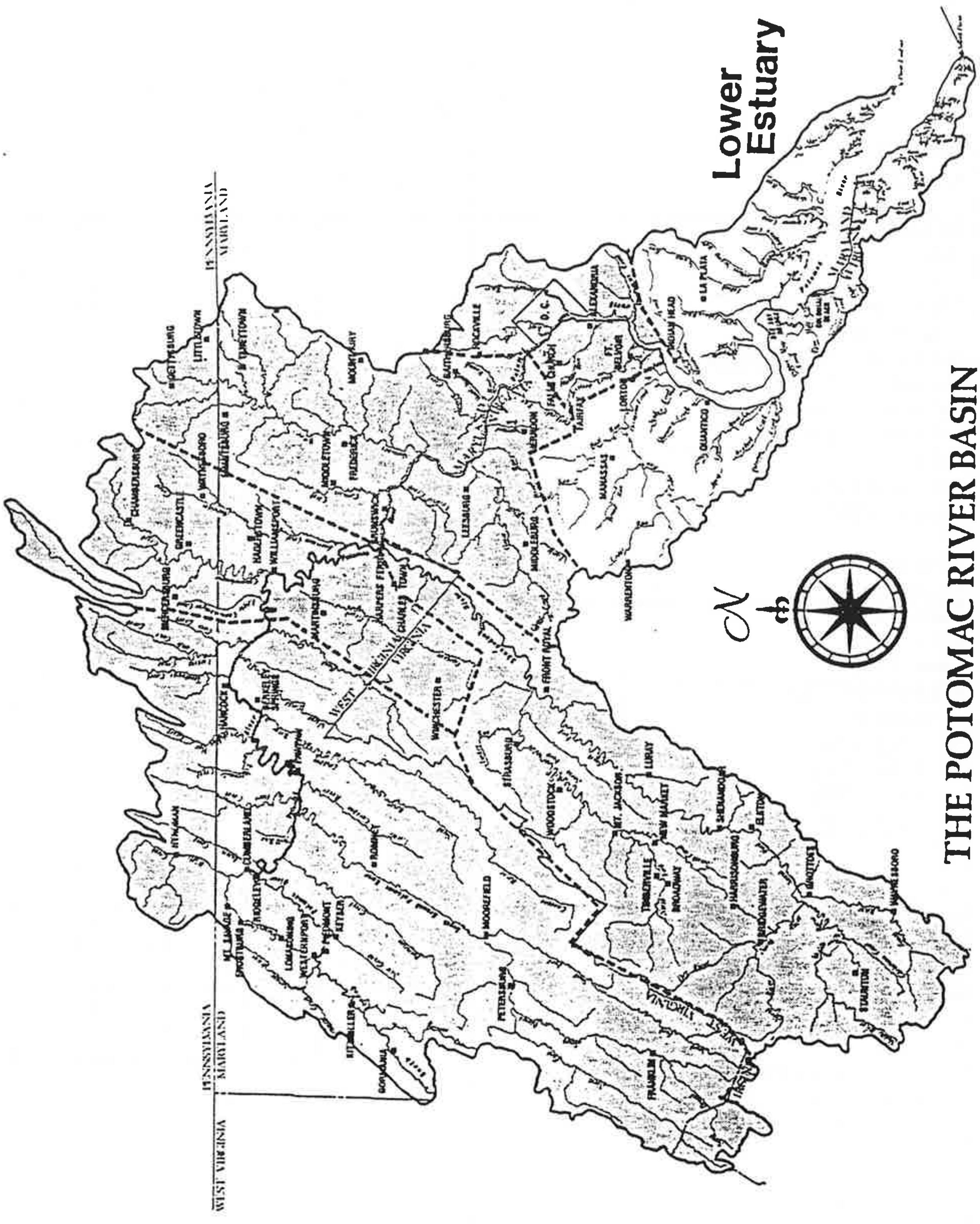
| Former Status | Current Status | Trend |
|---|---|---|
| Good | Fair | Status Quo |

Table 10: Potomac Urban Estuary Subdivision Parameter Trend Summary

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| Parameter | POT1184 | PMS01 | RCM0111 | 101023 | 101021 | PMS29 | ANA0082 | ANA01 | ANA14 | ANA21 | 1AFOU000.19 | PMS44 | 1AHUT000.01 | PIS0033 | 1ALIF000.19 | XFB1433 | 1APOH007.65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | | | | | | | | | | | |
| Alkalinity | | | | | | | | + | | | | | | | | | |
| Aluminum | | | | | | | | | | | | | | | | | |
| Ammonia ($NH_3+NH_4$) | | - | | | | - | | - | - | - | - | - | | | + | | + |
| BOD | | | | | | | | | | | - | - | - | | - | | |
| COD | | | | | | | | | | | - | | | | | | |
| Chloride | | | | | | | | | | | | | | | + | | |
| Cholorophyll | | | | | | | | | | | | - | | | | | |
| Chromium, Hexavalent | | | | | | | | | | | | | | | | | |
| Chromium, Total | | | | | | | | | | | | | | | | | |
| Coliform, Fecal | | - | | | | - | | - | | - | | - | + | | + | | + |
| Coliform, Total | | | | | | | | - | - | - | | | | - | | | |
| Color | | | | | | | | | | | | | | | | | |
| Conductivity | | | | | | | | | | | - | | | | | | |
| Copper (Cu) | | | | | | | | | | | | | | | | | |
| DO | | | | | | | | | | - | + | | + | | | | |
| DO%Sat. | | | | | | | | - | | | | | | | | | |
| Fluoride | | | | | | | | | | | | | | | | | |
| Hardness | | | | | | | | | | | | | | | | | |
| Iron (Fe) | | | | | | | | | | | | | | | | | |
| Lead (Pb) | | | | | | | | | | | | | | | | | |
| Magnesium (Mg) | | | | | | | | | | | | | | | | | |
| Manganese (Mn) | | | | | | | | | | | | | | | | | |
| Mercury (Hg) | | | | | | | | | | | | | | | | | |
| Nitrate ($NO_3$) | + | | + | | | + | | | | | | + | | | | | |
| Nitrite ($NO_2$) | + | | + | | | | | | | | + | - | - | - | | | + |
| Nitrite + Nitrate | | | | | | | | | | | | | | | | | |
| TKN | + | - | + | | | - | + | - | - | - | - | - | | | + | | + |
| pH | - | | | | | | - | - | - | - | | | - | | - | - | |
| pH, Lab. | | | | | | | + | | | | | | | | | | |
| Phosphorus,Diss.Ortho | | | | | | | | | - | | - | | | | | | |
| Phosphate,Tot. ($PO_4$) | | | | | | | | | | | - | | - | | + | | + |
| Phosphorus,Tot.Ortho | | | | | | | | | | | - | | - | | | | - |
| Phosphorus,Diss. | | - | | | | - | | - | - | - | | - | | | | | |
| Phosphorus,Tot. (P) | + | | | | | | | | | | | | - | | | - | |
| Residue | | | | | | | | | | | | | | | | | |
| Residue, Dissolved | | | | | | | | | | | | | | | | | |
| Residue, Fix.Nonfilt. | | | | | | | | | | | - | | - | | | | + |
| Residue, Nonfilt. | | | | | | | - | | | - | - | | - | - | - | | + |
| Residue, Vol.Nonfilt. | | | | | | | | | | | - | | - | | | | + |
| Salinity | - | | - | | | | - | | | | | | | | | | |
| Sodium (Na) | | | | | | | | | | | | | | | | | |
| Sulfate ($SO_4$) | | | | | | | | | | | | | | | | | |
| Temperature | - | | | | | | | | - | - | | | | | | | |
| TOC | | | | | | | | | | | - | | - | | - | | |
| Turbidity | - | | | | | | - | | | | | - | | | | | |
| Water Appearance | | | | | | | | | | | | | | | | | |

Map 7.



# VI. THE LOWER POTOMAC ESTUARY

The lower Potomac estuary includes 75 main stem Potomac River miles (121 km) from Indian Head, MD to its mouth at Point Lookout, MD and Smith Point, VA. Major stream reaches include:

- Potomac River estuary
- South Run
- Occoquan Creek
- Flat Branch
- Mattawoman Creek

The lower Potomac drains Charles and St. Mary's counties, MD, and Prince William, Stafford, King George, Westmoreland, and Northumberland counties, VA. From its mouth at Point Lookout, the Potomac discharges flow from its 14,670 $mi^2$ (37,980 $km^2$) basin into Chesapeake Bay.

Estuaries are the meeting place of fresh and salt water, where the salinity and flow of water are constantly influenced by river inflow and tides. This complex aquatic environment makes estuaries extremely difficult to predict and understand -- physically, chemically, and biologically. The Potomac estuary is divided into three segments: (1) the tidal Potomac River which is affected by tides but is totally fresh water; (2) the transition zone where fresh river water mixes with the brackish (slightly salty) water from Chesapeake Bay; and (3) the lower estuary which is almost as salty as Chesapeake Bay and supports saltwater marine life. The Lower Potomac Estuary sub-basin includes the transition zone and the estuary proper.

At all three stations in the estuary, Indian Head, Possum Point, and the Rt 301 Bridge, increasing trends were detected in Nitrate (see also pp. 78,80 and Figures VI.1-VI.7, VI.19-VI.25). Other Nitrogen species showed upward trends at one or more of the stations, although there were no trends detected for the Phosphorus series. Dissolved Oxygen was detected as increasing, and Total Coliform decreasing, which would indicate improving water quality at Indian Head; however, they are balanced by the increasing trends in Nitrate and Residue. Coliform was decreasing at the Rt. 301 Bridge, as were Conductivity and Residue.

South Run, a tributary from Virginia (see also pp. 79 and Figures VI.8-VI.10) showed decreasing trends in pH, Dissolved Orthophosphorus, and Total Organic Carbon; and an increasing trend in Residue.

Occoquan Creek (see also pp. 79 and Figures VI.11-VI.13) drains a major portion of Prince William County, as well as portions of Fairfax, Loudoun, and Fauquier counties, VA. The creek flows into the Occoquan reservoir, which serves as a water supply source for 650,000 residents of northern Virginia. There is also a sewage treatment plant on the creek, above the reservoir. Both the Nitrogen and Phosphorus series parameters showed increasing trends, as did Residue. Only Total Organic Carbon was seen to be declining.

In Flat Branch, a Virginia tributary (see also pp. 79 and Figure VI.14) the only trend to be detected was a decrease in Total Organic Carbon.

Mattawoman Creek (see also pp. 80 and Figures VI.15-VI.18) is 30 mi (48 km) long and drains mostly rural land but also includes developing areas in Charles County, MD. The Mattawoman WWTP, which serves Prince George's and Charles counties, used to discharge to the creek, but its point of discharge was recently moved out to the main stem Potomac. The trend analysis of water quality data showed decreases in Total Coliform and Salinity, and increases in Total Kjeldahl Nitrogen and Laboratory pH.

This estuarine subdivision (see Table 11, p. 81) showed some improvement in bacterial contamination, with trends in Total Coliform down at three stations. The nitrogen series was broadly up, whereas phosphorus was up at one station and down at another. DO was trending upward at Indian Head (the only station with a significant DO trend). Total Organic Carbon (TOC) was down in three of the tributaries.

RESULTS OF KENDALL TAU TREND ANALYSIS FOR THE LOWER POTOMAC ESTUARY

<u>River</u> Potomac River
<u>Station</u> XEA6596 <u>Agency</u> MDWRA/MDOEP
<u>Location</u> Indian Head, MD, Buoy N54.
River Mile: 75

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -5.32** | VI.1 |
| Conductivity | -2.63 | VI.2 |
| DO | +2.49 | VI.3 |
| DO%Sat | +1.99 | VI.4 |
| Nitrate ($NO_3$) | +4.54** | VI.5 |
| Residue, Dissolved | +2.68 | VI.6 |
| Salinity | -2.61 | VI.7 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Fair | Status Quo |

River: South Run
Station: 1ASOT--1.44 — Agency: VASWCB
Location: Vint Hill, VA, Below Vint Hill Installation.
River Mile: 73-28-16-1

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| pH | -4.56** | VI.8 |
| Phosphorus,Diss.Ortho | -2.47 | VI.9 |
| Residue, Vol.Nonfilt. | +2.61 | |
| TOC | -4.01** | VI.10 |

| Former Status | Current Status | Trend |
|---|---|---|
| Fair | Good | Improving |

River: Occoquan Creek
Station: 1AOCC006.71 — Agency: VASWCB
Location: Woodbridge, VA, Rt. 123 Bridge.
River Mile: 83-4

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrite ($NO_2$) | +3.18** | VI.11 |
| Phosphorus,Diss.Ortho | +3.26** | VI.12 |
| Phosphate,Tot. ($PO_4$) | +1.99 | |
| Residue, Vol.Nonfilt. | +1.91 | |
| TKN | +1.92 | |
| TOC | -2.60 | VI.13 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

River: Flat Branch
Station: 1AFLB000.64 — Agency: VASWCB
Location: Manassas, VA.
River Mile: ??

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| TOC | -2.18 | VI.14 |

| Former Status | Current Status | Trend |
|---|---|---|
| Poor | Unknown | Improving |

**River** Mattawoman Creek
**Station** MAT0078 **Agency** MDWRA/MDOEP
**Location** Mason Springs, MD, Rt. 225.
River Mile: 82-8

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -2.34 | VI.15 |
| pH, Lab. | +2.26 | VI.16 |
| Salinity | -2.03 | VI.17 |
| TKN | +3.82** | VI.18 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** Potomac River
**Station** XEA1840 **Agency** MDWRA/MDOEP
**Location** Possum Point/Moss Point, Buoy 44.
River Mile: 70

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Nitrate ($NO_3$) | +2.97 | VI.19 |
| TKN | +3.01** | VI.20 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good | Good | Status Quo |

**River** Potomac River
**Station** XDC1706 **Agency** MDWRA/MDOEP
**Location** Morgantown, MD, Rt. 301 Bridge.
River Mile: 44

| Significant Parameter | K-tau value | Figure No. |
|---|---|---|
| Coliform, Total | -5.67** | V.21 |
| Conductivity | -3.57** | V.22 |
| Nitrate ($NO_3$) | +2.43 | V.23 |
| Nitrite ($NO_2$) | +2.11 | V.24 |
| Residue, Nonfilt. | -1.89 | V.25 |

| Former Status | Current Status | Trend |
|---|---|---|
| Good-Excellent | Good-Excellent | Status Quo |

Table 11: Lower Potomac Estuary Subdivision Parameter Trend Summary

+ (-) indicate statistically significant increasing (decreasing) trend for that parameter and station. Blank indicates no significant trend, or parameter not measured. See page 6 for more information on interpretation of this table.

| Parameter | XEA6596 | 1ASOT001.44 | 1AOCC006.71 | 1AFLB000.64 | MAT0078 | XEA1840 | XDC1706 |
|---|---|---|---|---|---|---|---|
| Acidity | | | | | | | |
| Alkalinity | | | | | | | |
| Aluminum | | | | | | | |
| Ammonia ($NH_3$+$NH_4$) | | | | | | | |
| BOD | | | | | | | |
| COD | | | | | | | |
| Chloride | | | | | | | |
| Chlorophyll | | | | | | | |
| Chromium, Hexavalent | | | | | | | |
| Chromium, Total | | | | | | | |
| Coliform, Fecal | | | | | | | |
| Coliform, Total | - | | | | - | | - |
| Color | | | | | | | |
| Conductivity | - | | | | | | - |
| Copper (Cu) | | | | | | | |
| DO | + | | | | | | |
| DO%Sat. | + | | | | | | |
| Fluoride | | | | | | | |
| Hardness | | | | | | | |
| Iron (Fe) | | | | | | | |
| Lead (Pb) | | | | | | | |
| Magnesium (Mg) | | | | | | | |
| Manganese (Mn) | | | | | | | |
| Mercury (Hg) | | | | | | | |
| Nitrate ($NO_3$) | + | | | | | + | + |
| Nitrite ($NO_2$) | | | + | | | | + |
| Nitrite + Nitrate | | | | | | | |
| TKN | | | + | | + | + | |
| pH | | - | | | | | |
| pH, Lab. | | | | | + | | |
| Phosphorus,Diss.Ortho | | - | + | | | | |
| Phosphate,Tot. ($PO_4$) | | | + | | | | |
| Phosphorus,Tot.Ortho | | | | | | | |
| Phosphorus,Diss. | | | | | | | |
| Phosphorus,Tot. (P) | | | | | | | |
| Residue | | | | | | | |
| Residue, Dissolved | + | | | | | | |
| Residue, Fix.Nonfilt. | | | | | | | |
| Residue, Nonfilt. | | | | | | | - |
| Residue, Vol.Nonfilt. | | + | + | | | | |
| Salinity | - | | | | - | | |
| Sodium (Na) | | | | | | | |
| Sulfate ($SO_4$) | | | | | | | |
| Temperature | | | | | | | |
| TOC | | - | - | - | | | |
| Turbidity | | | | | | | |
| Water Appearance | | | | | | | |

Figure I.1

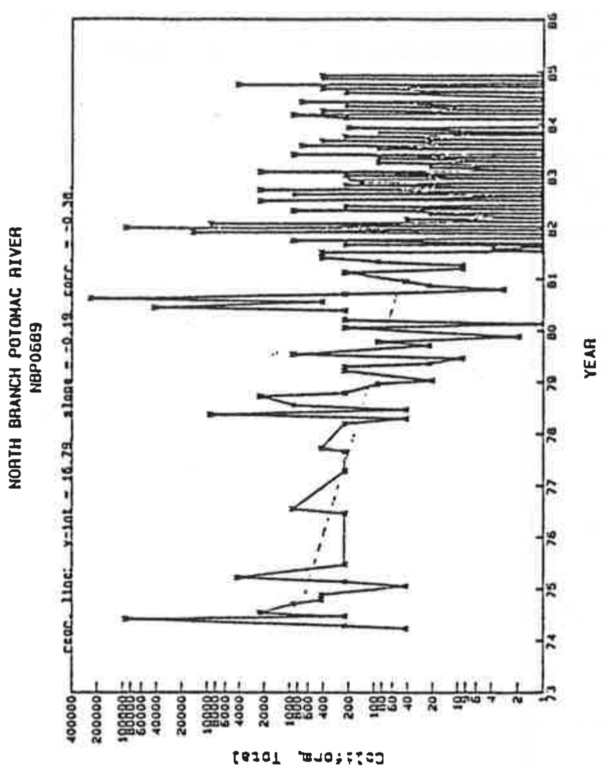



Figure I.2

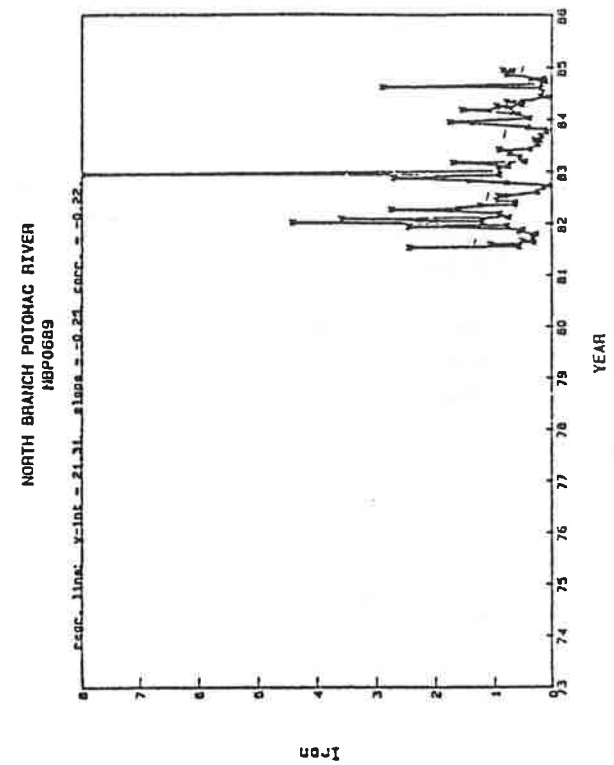



Figure I.3

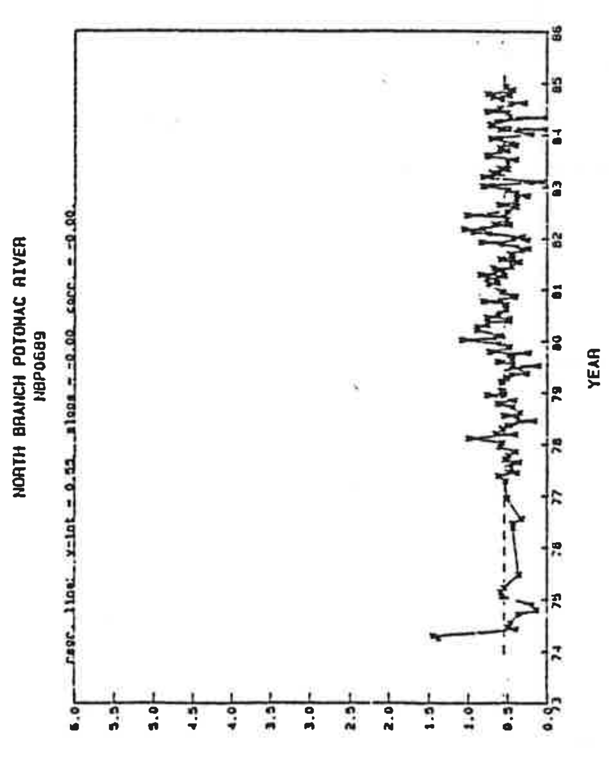



Figure I.4

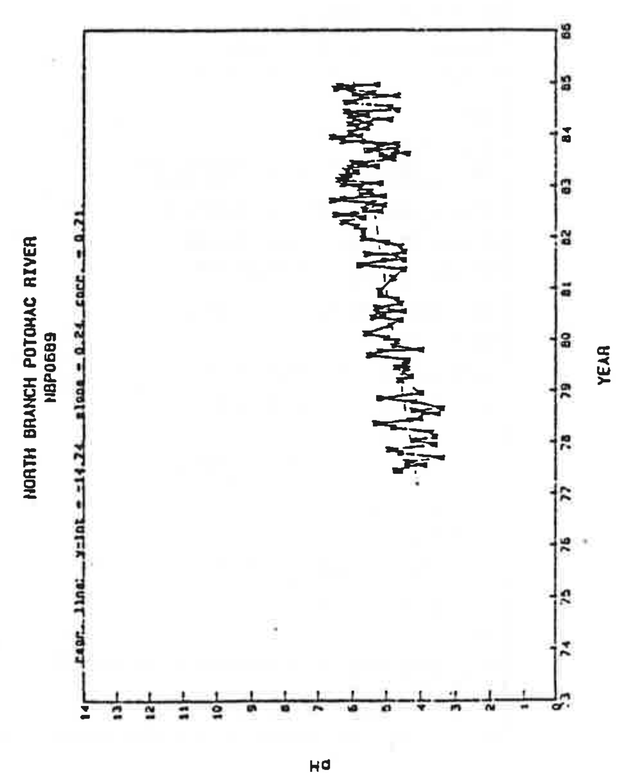


Figure I.5

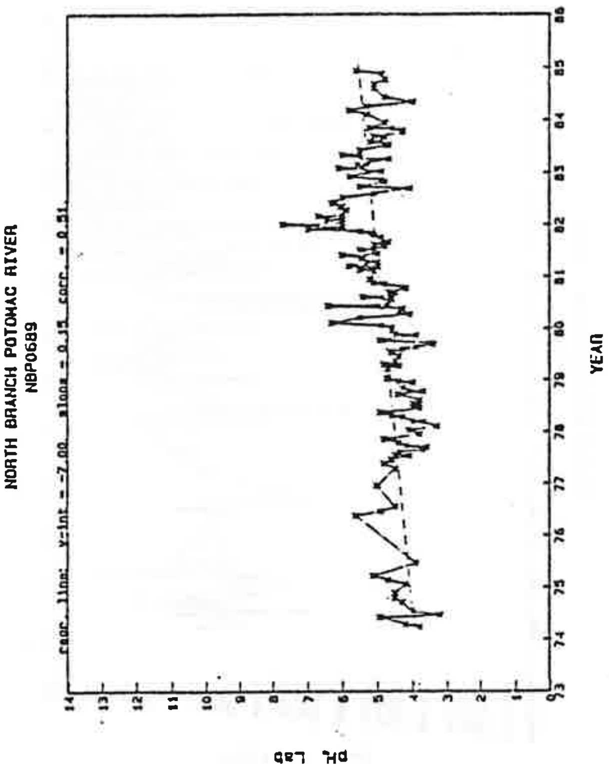



Figure I.6

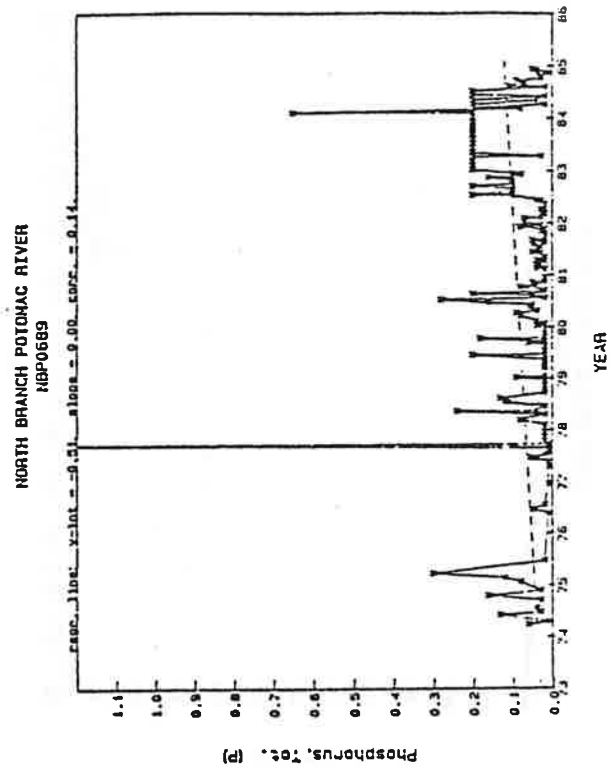



Figure I.7

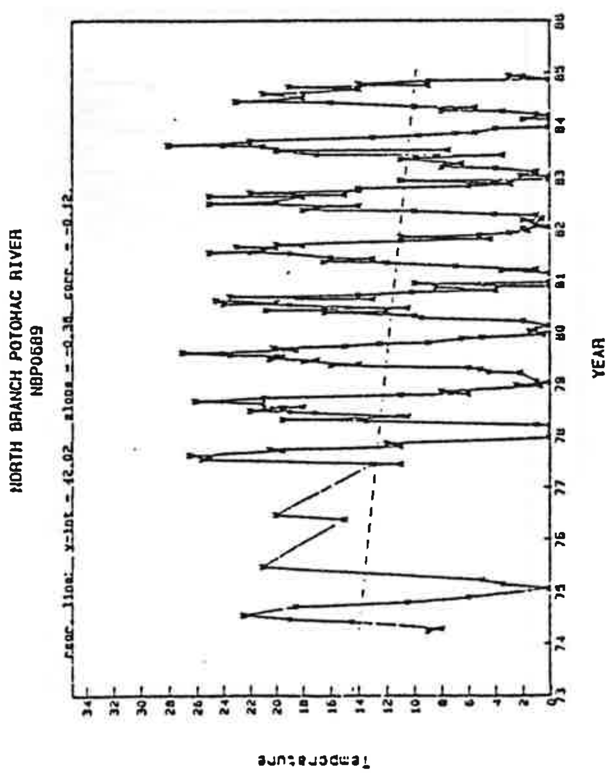



Figure I.8

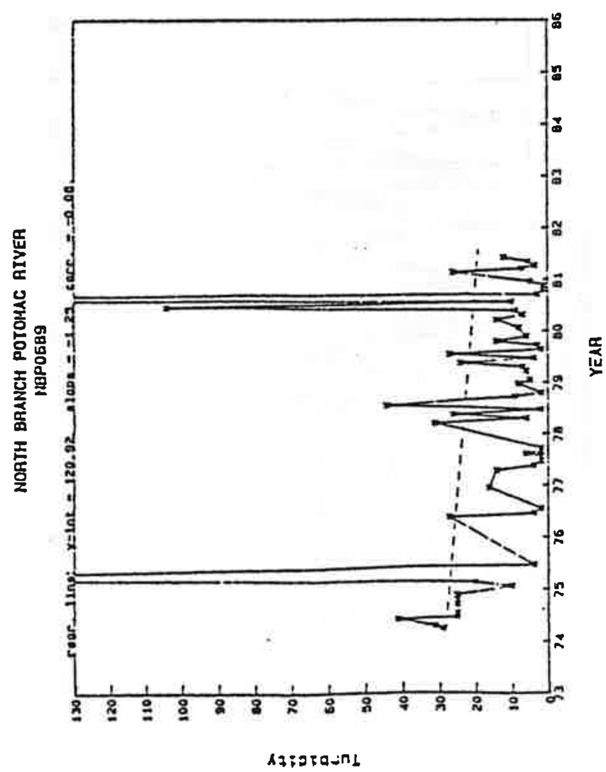


Figure I.9

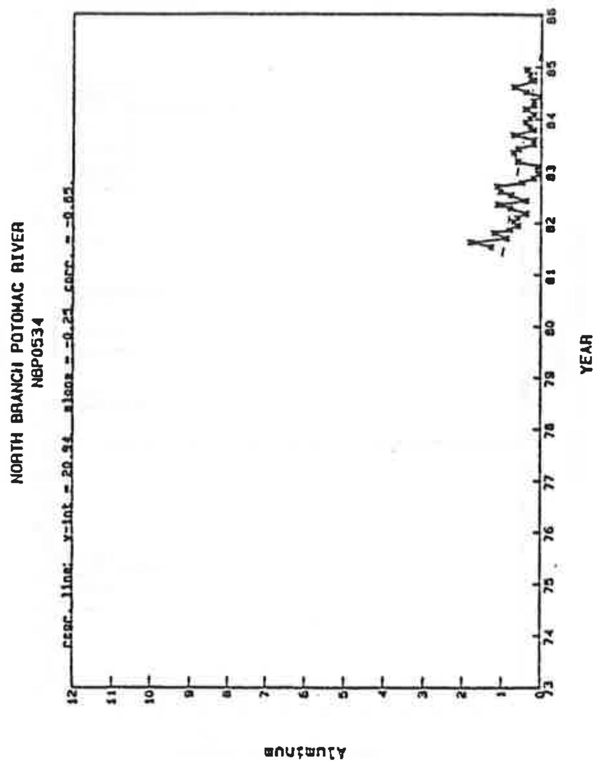



Figure I.10

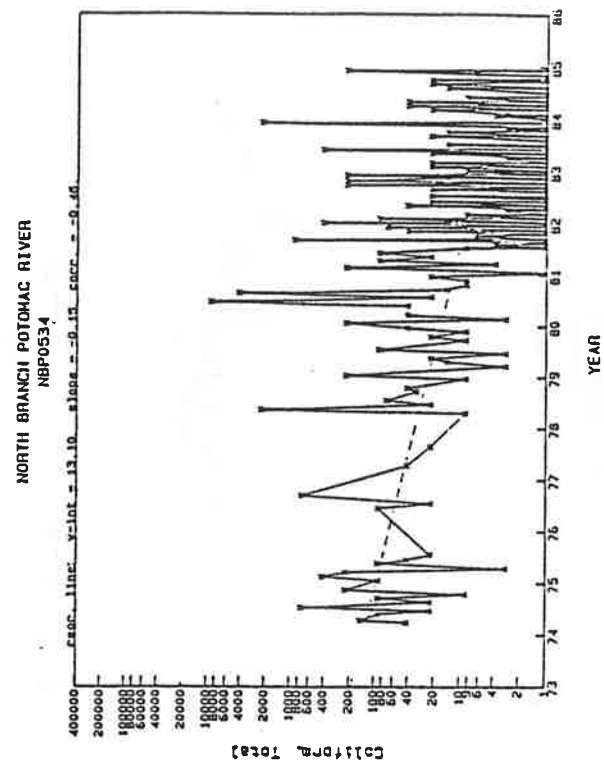



Figure I.11

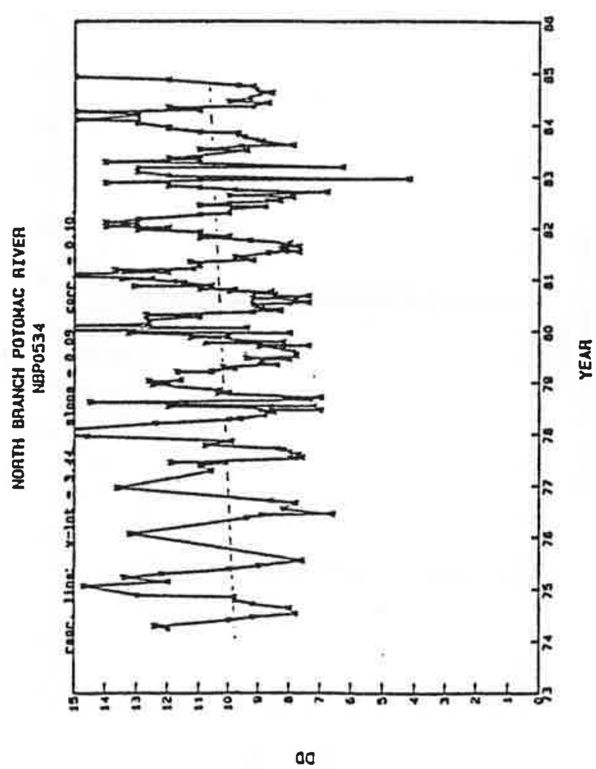



Figure I.12

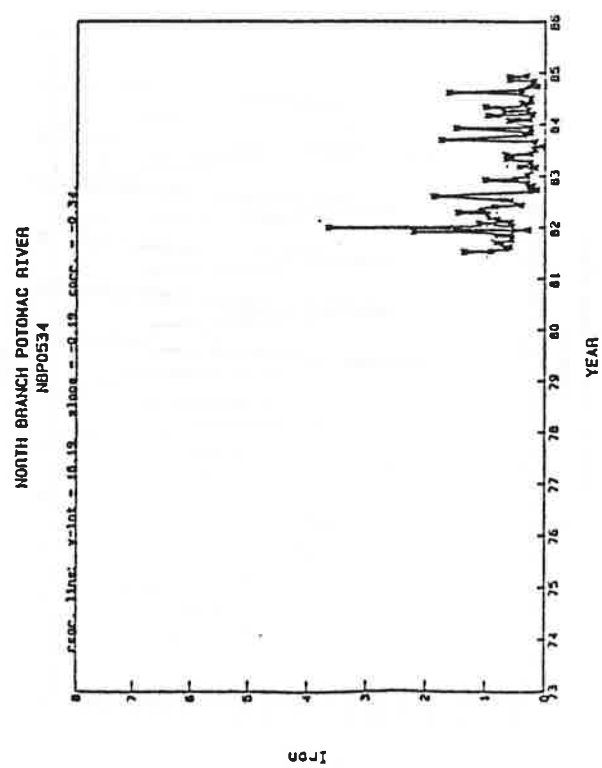


Figure I.13

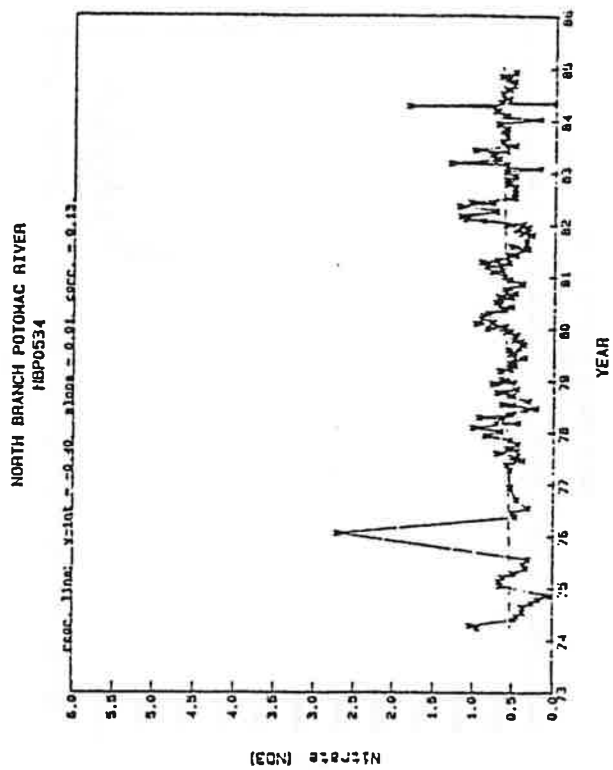



Figure I.14

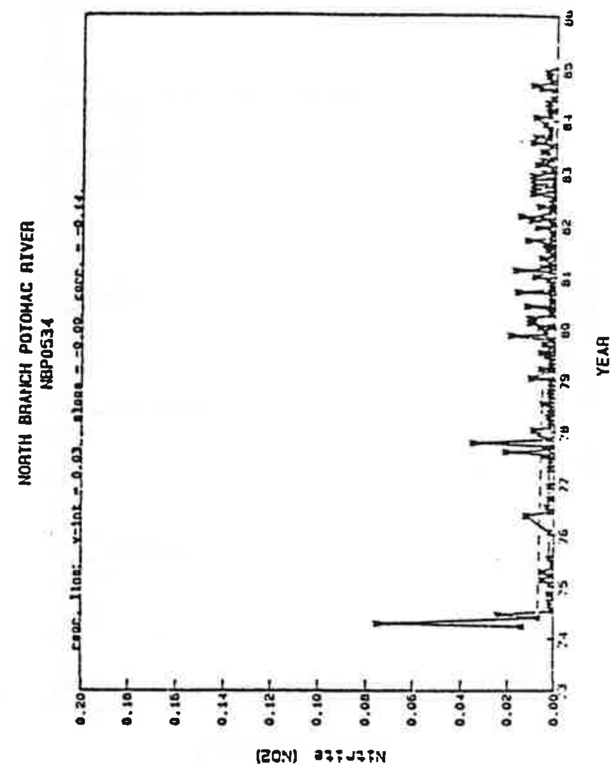



Figure I.15

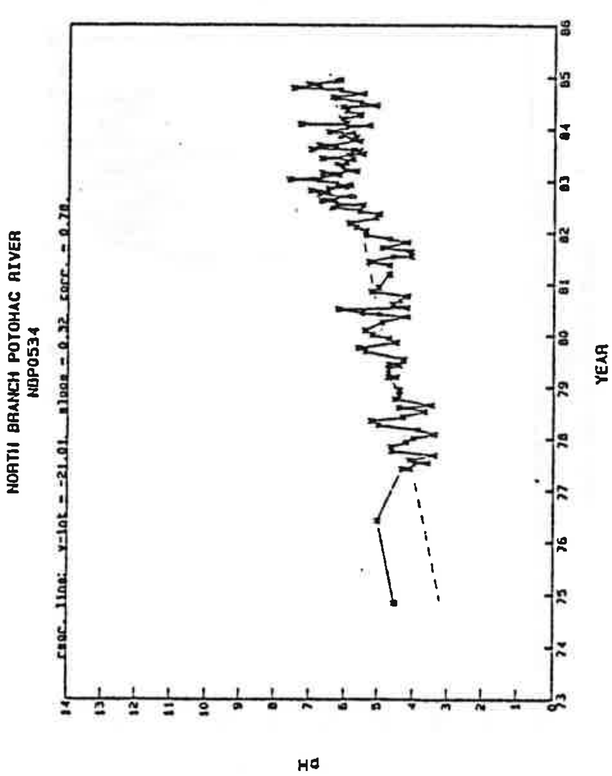



Figure I.16

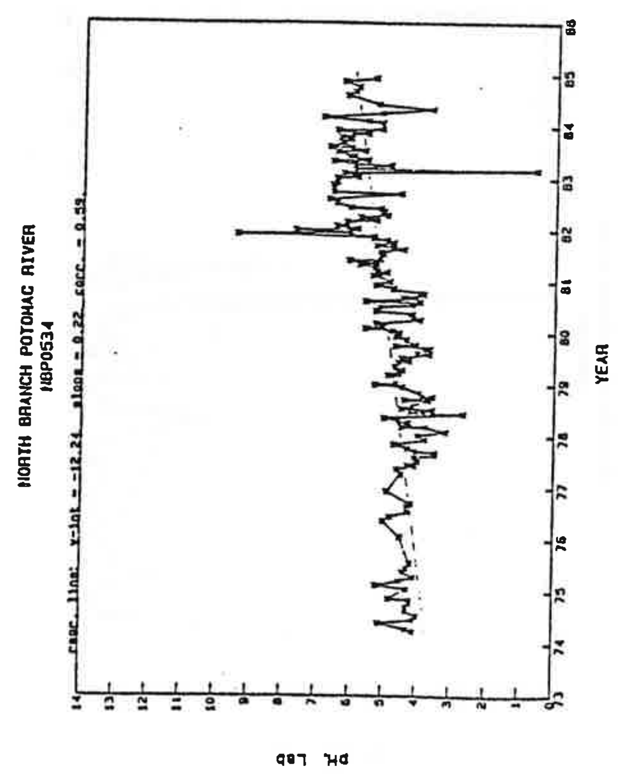


Figure I.17

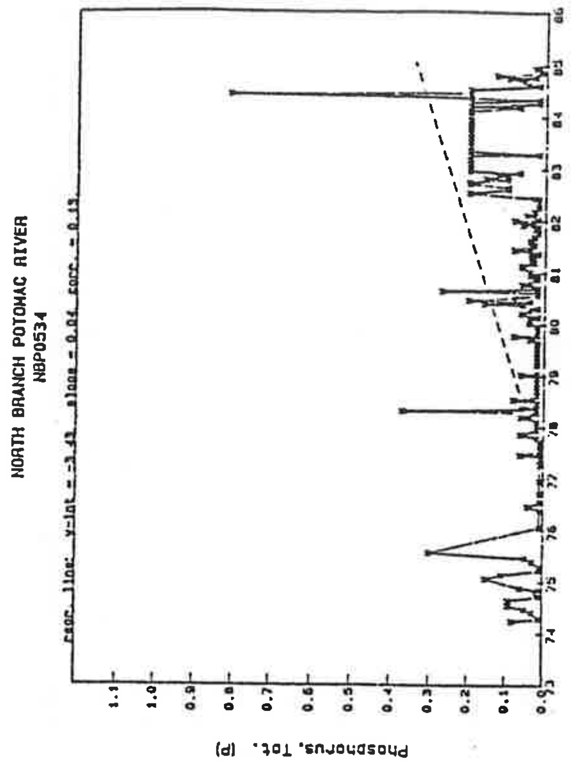



Figure I.18

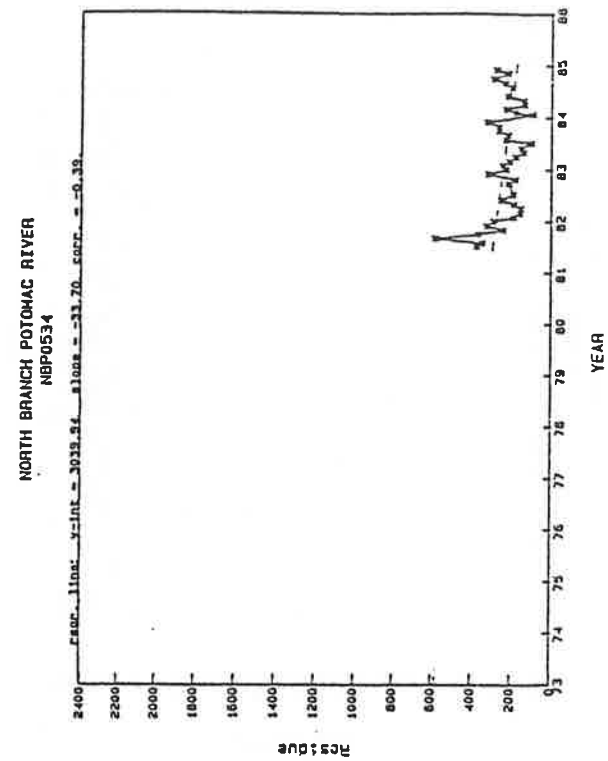



Figure I.19

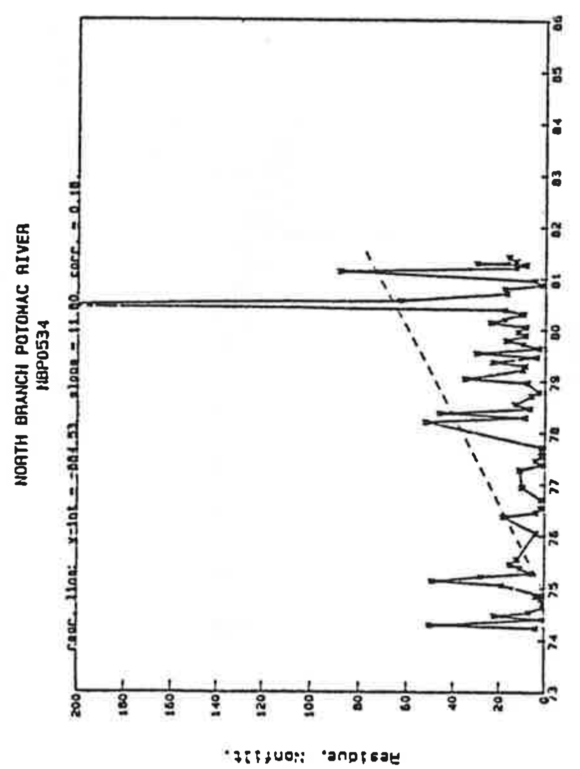



Figure I.20

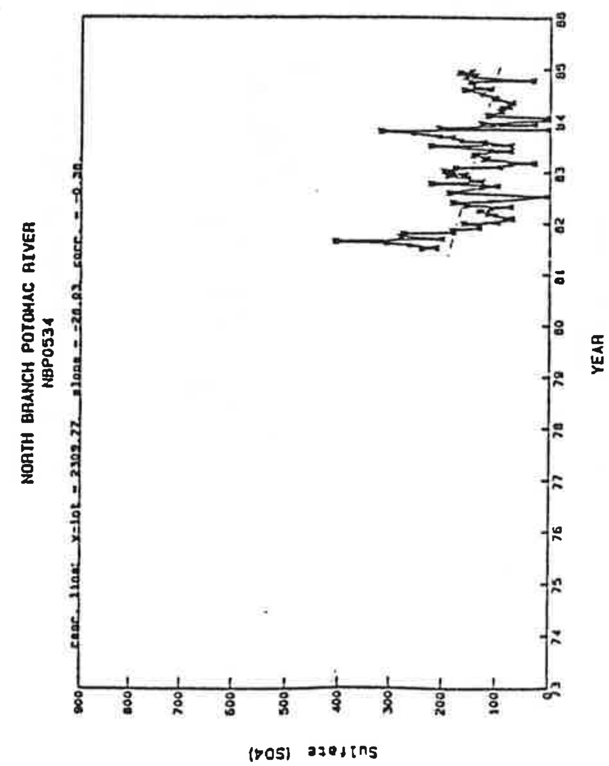


Figure I.21

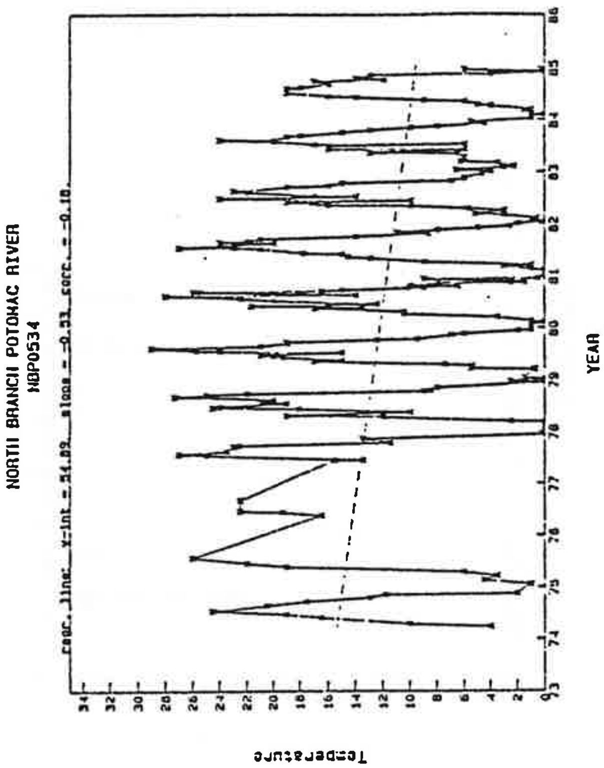



Figure I.22

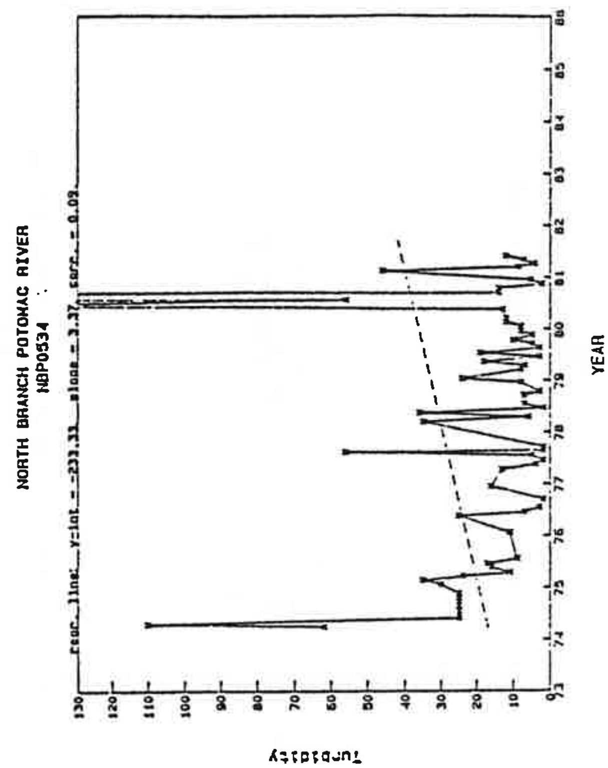



Figure I.23

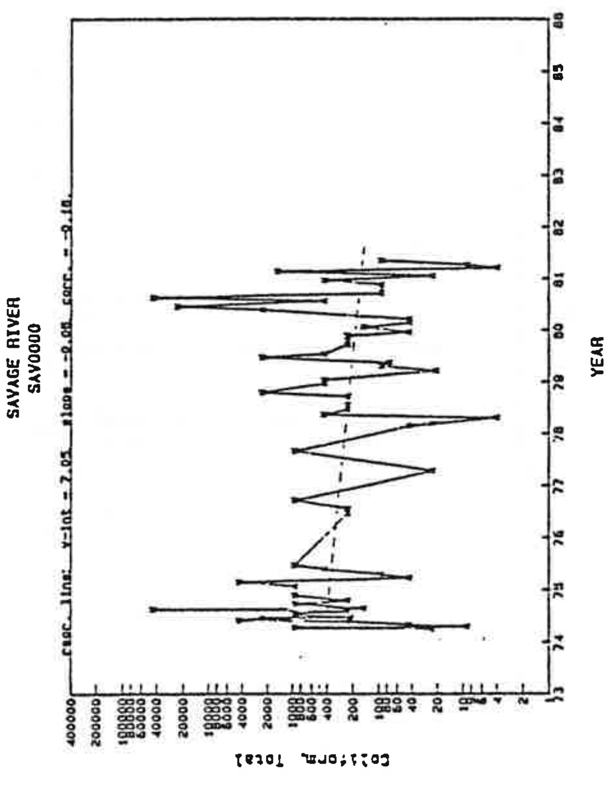



Figure I.24

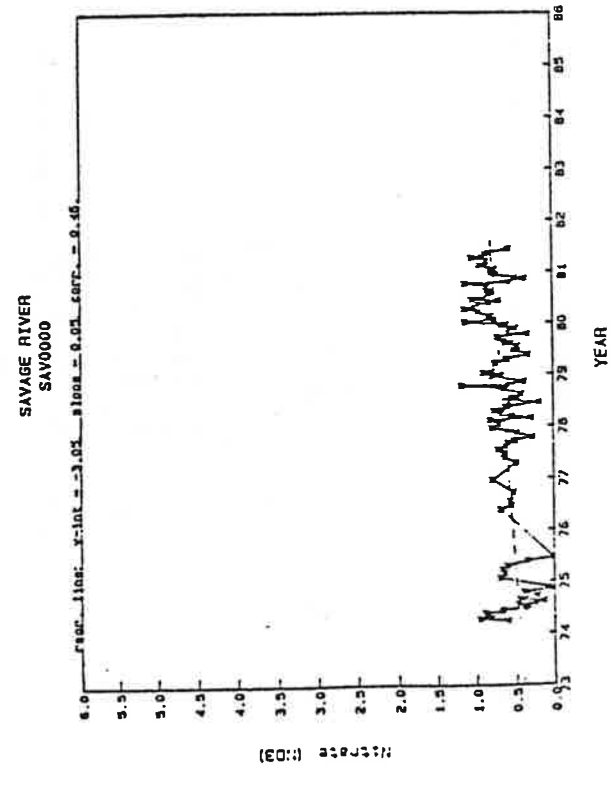


Figure I.25

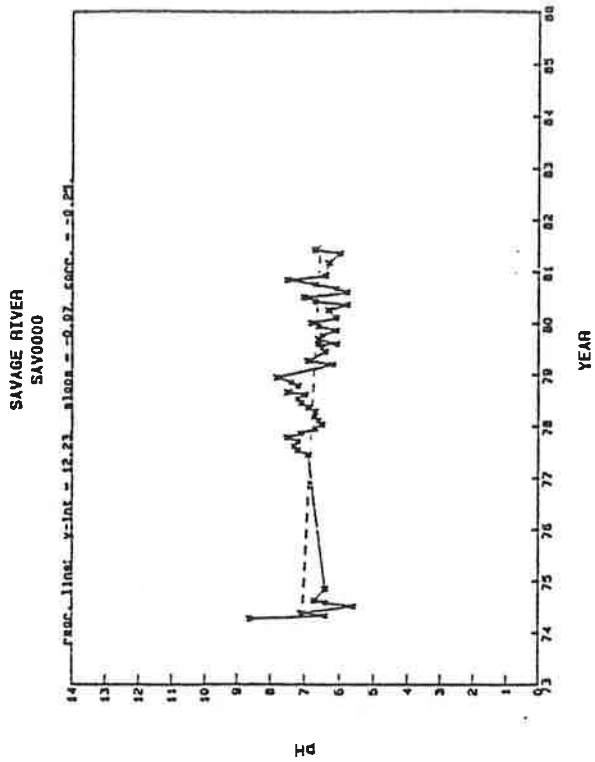



Figure I.26

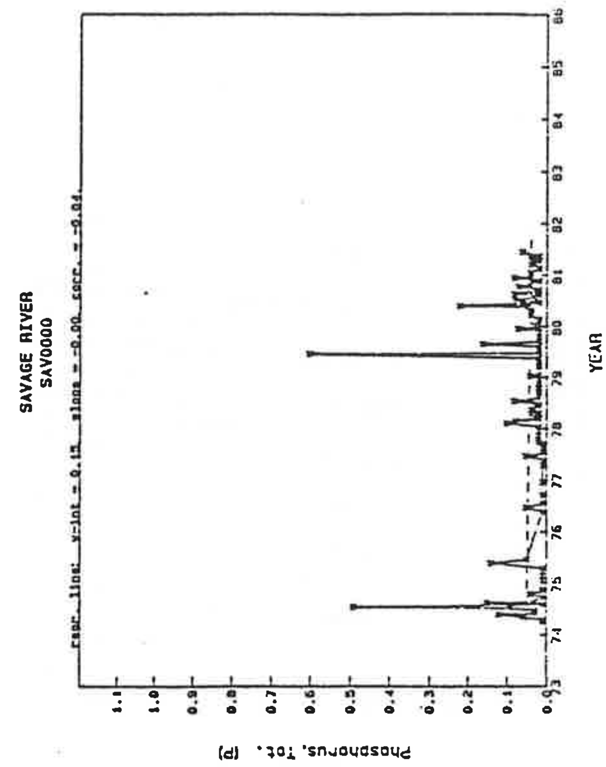



Figure I.27

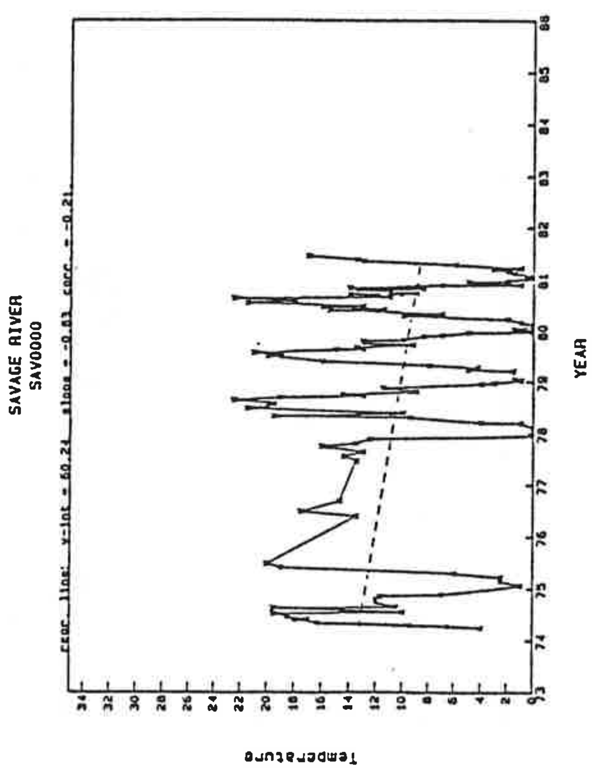



Figure I.28

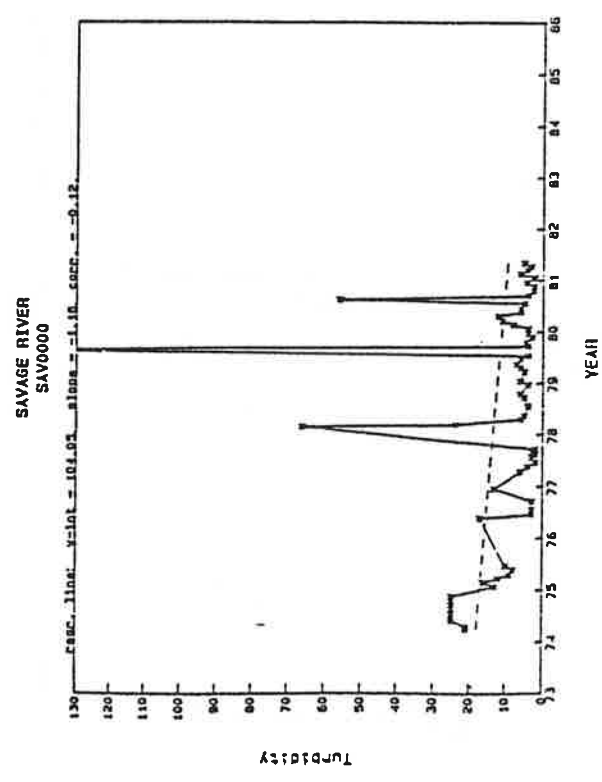


Figure I.29

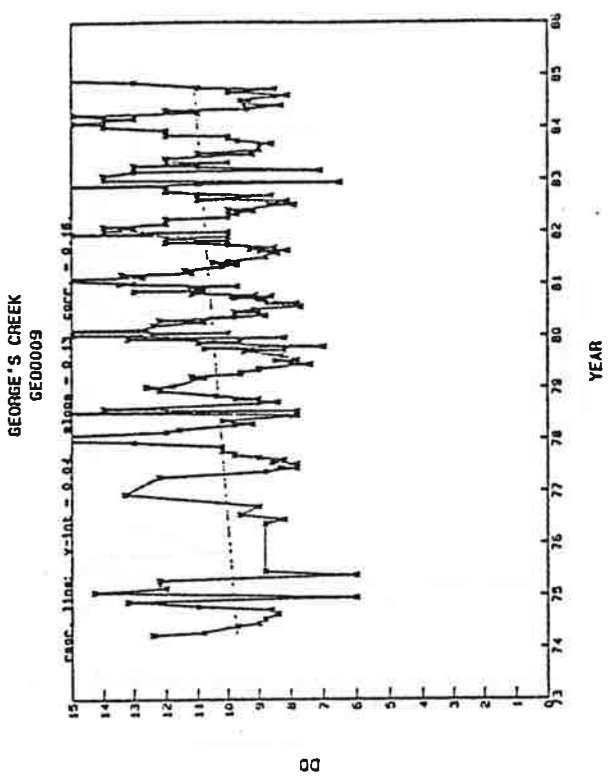



Figure I.30

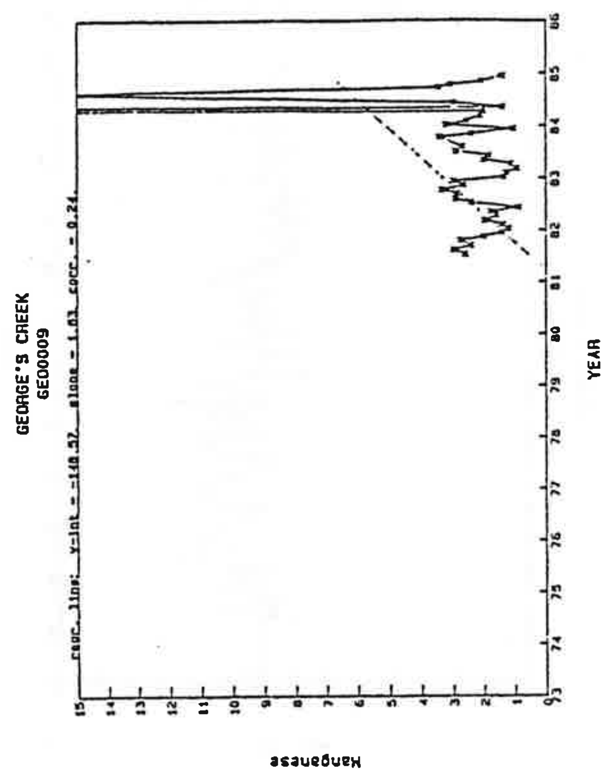



Figure I.31

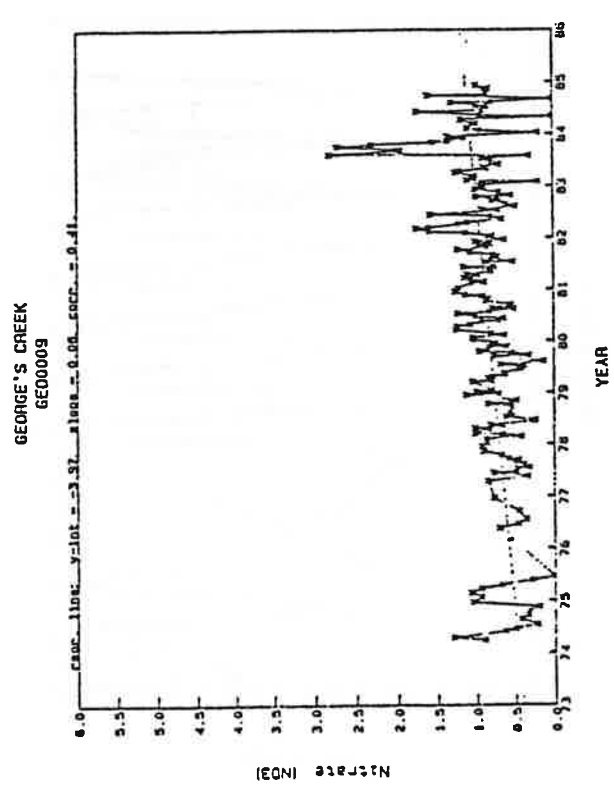



Figure I.32

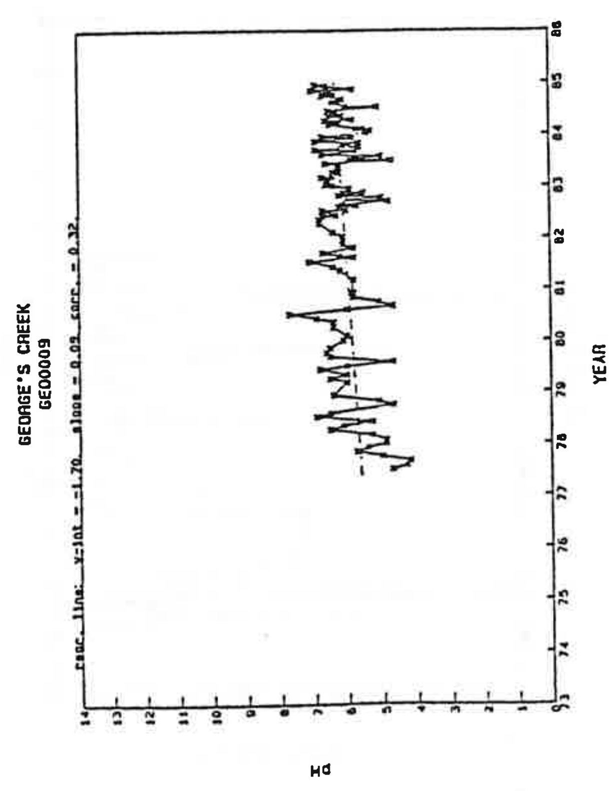


Figure I.33

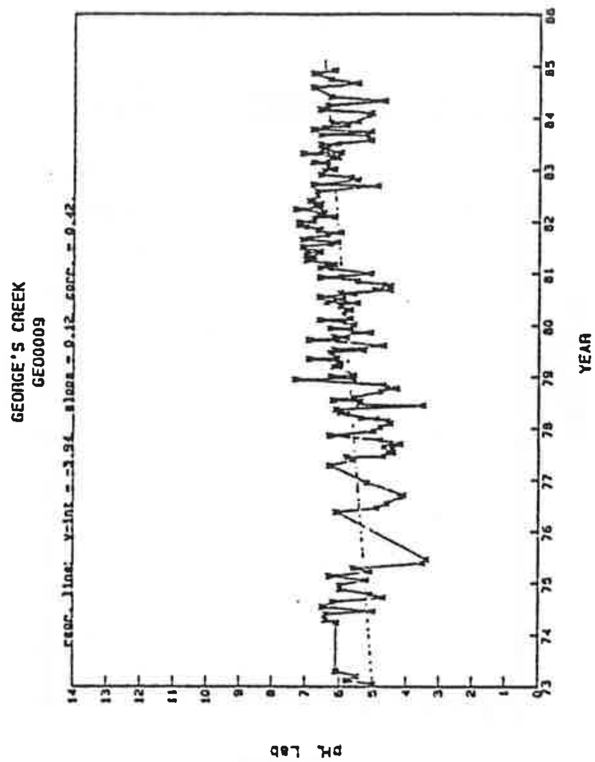



Figure I.34

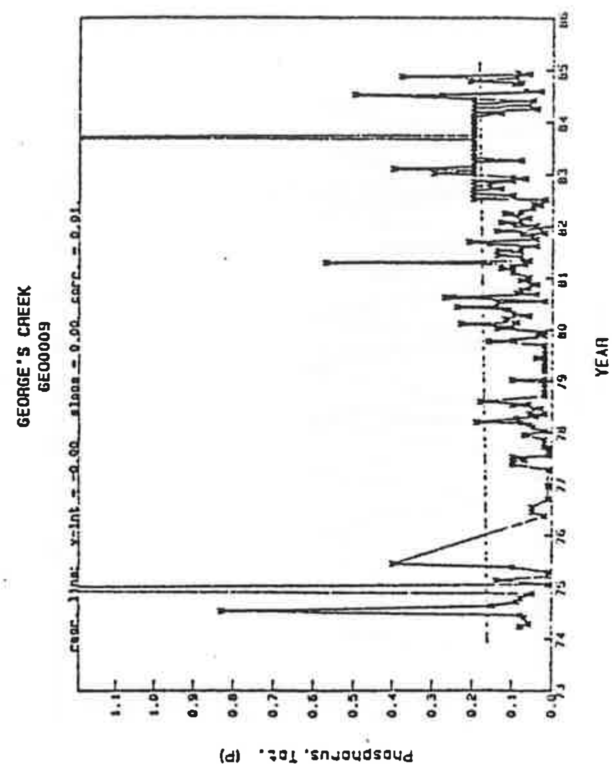



Figure I.35

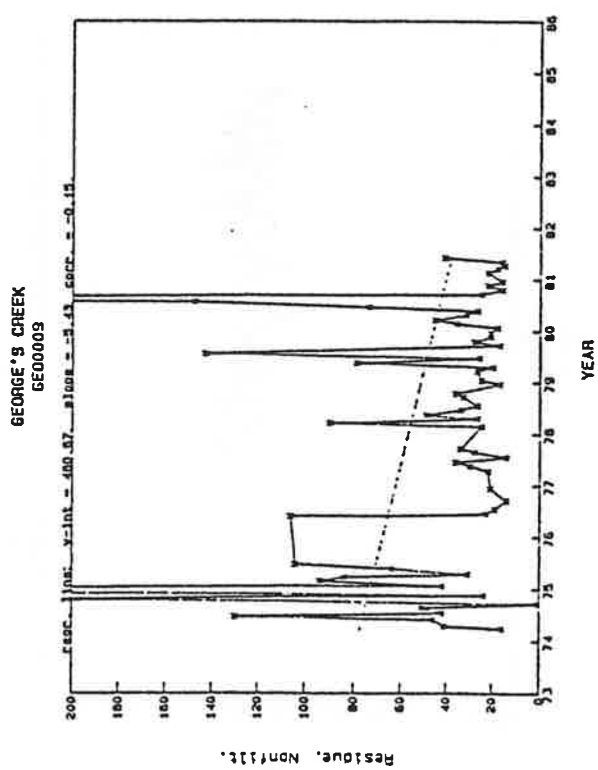



Figure I.36

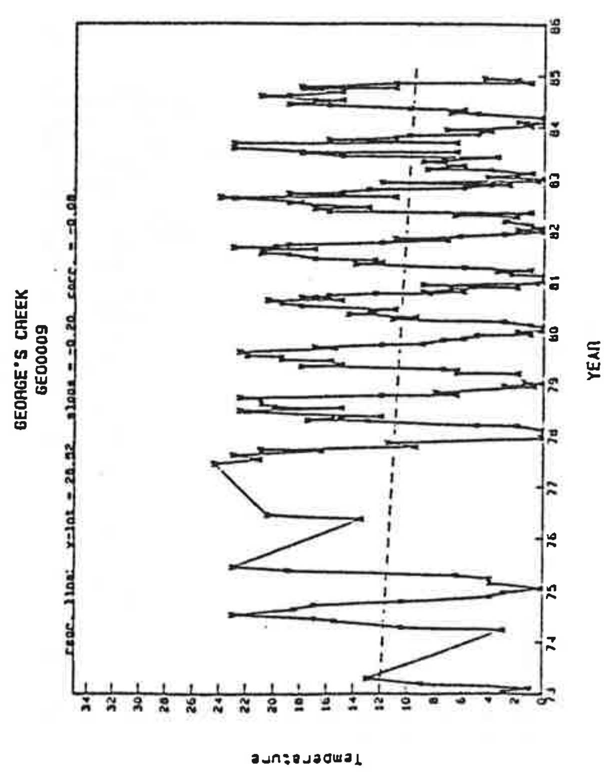


Figure I.37

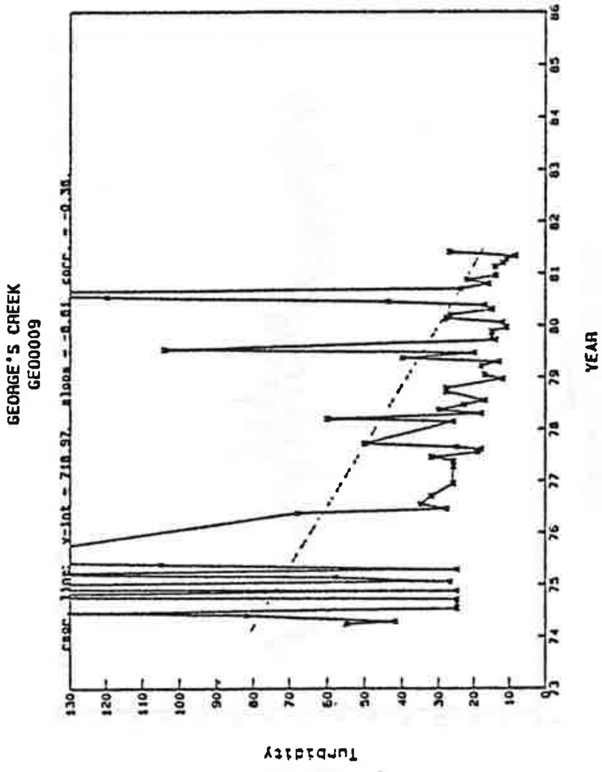



Figure I.38

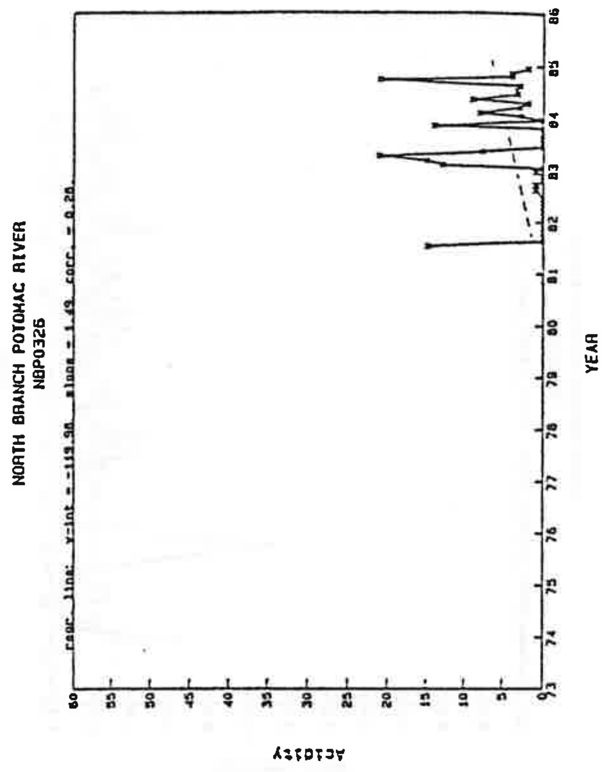



Figure I.39

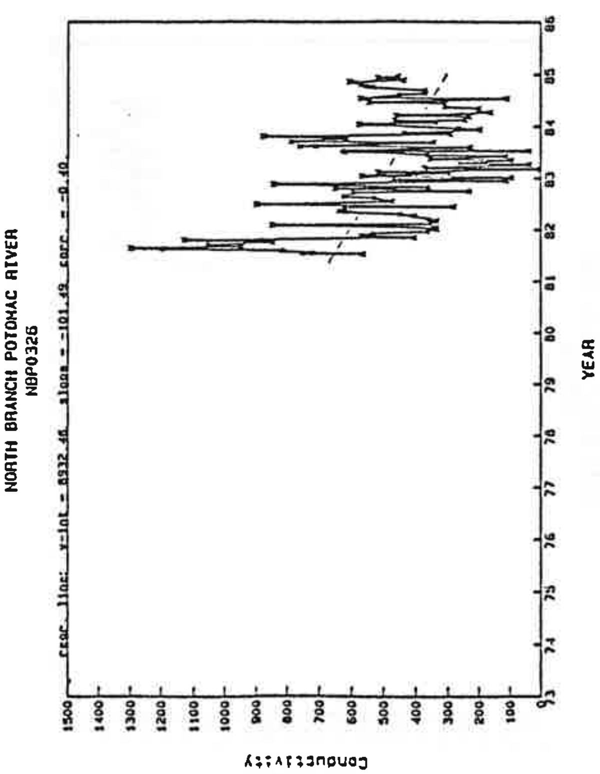



Figure I.40

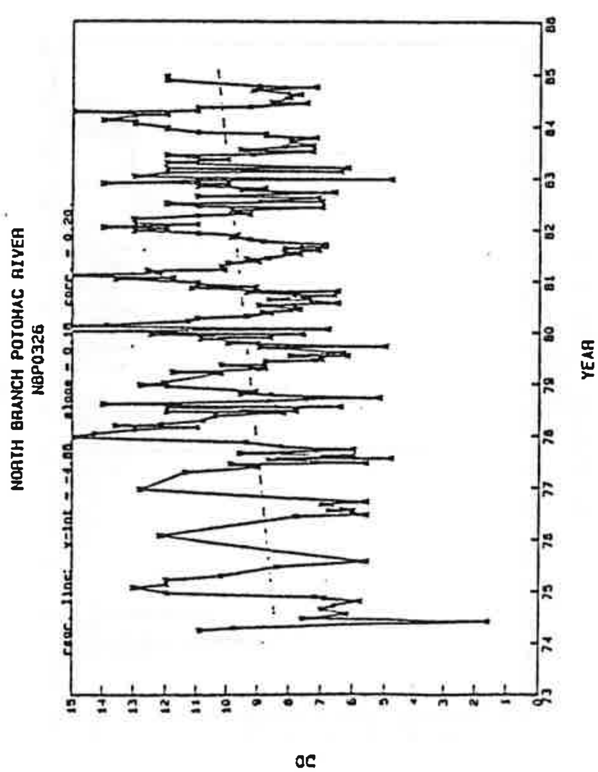


Figure I.41

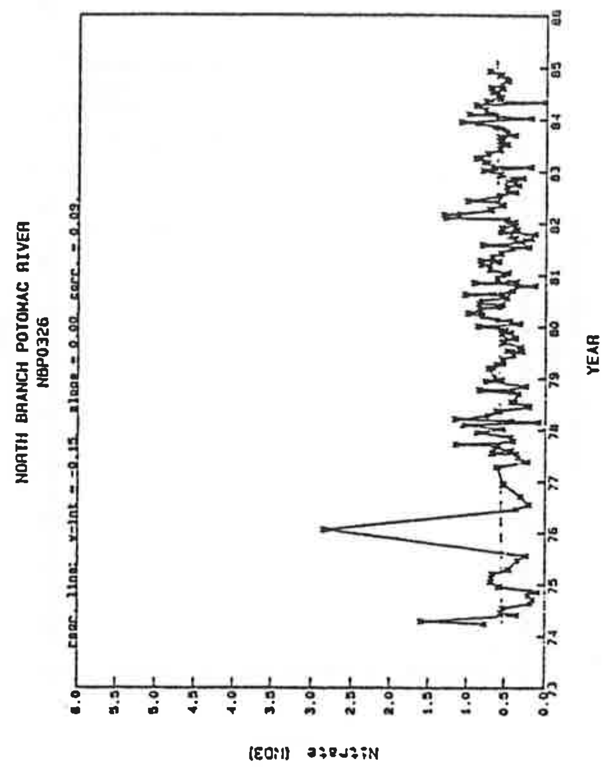



Figure I.42

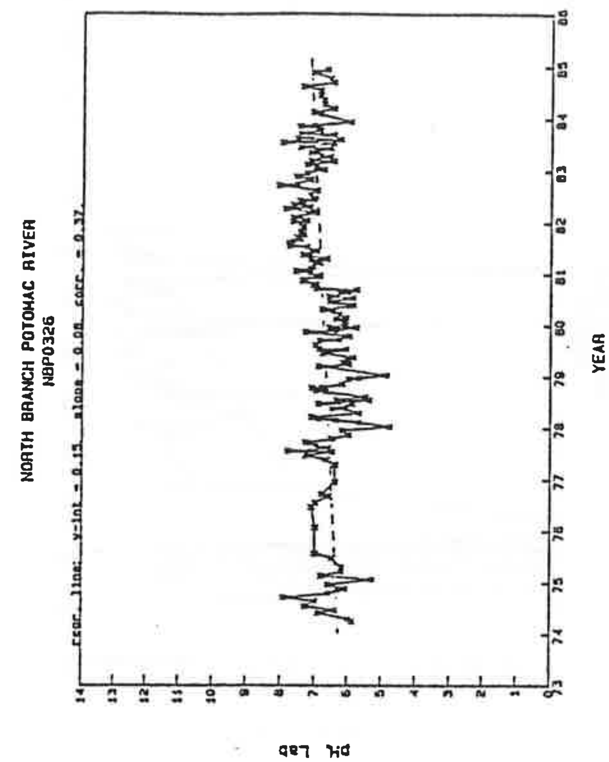



Figure I.43

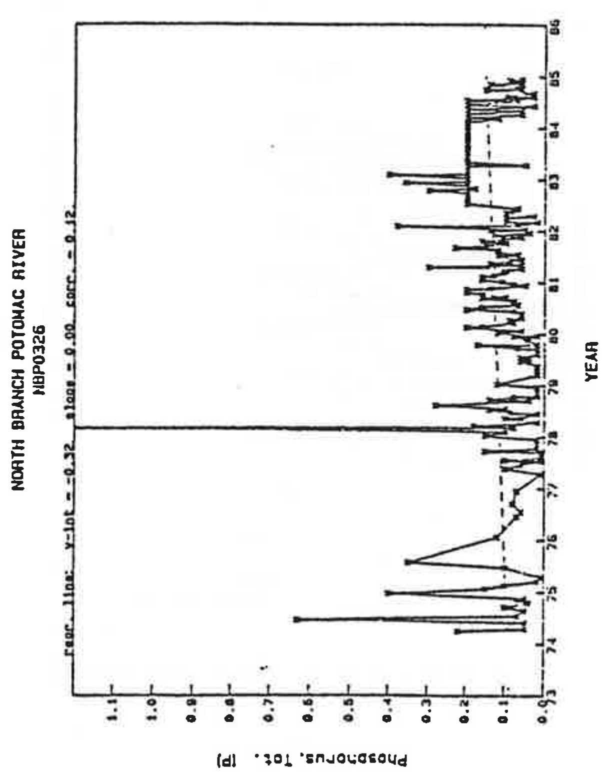



Figure I.44

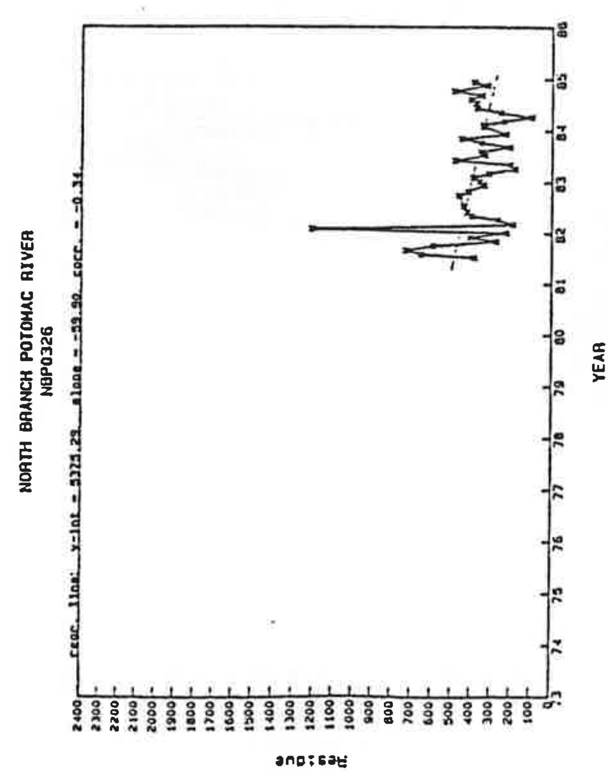


Figure I.45

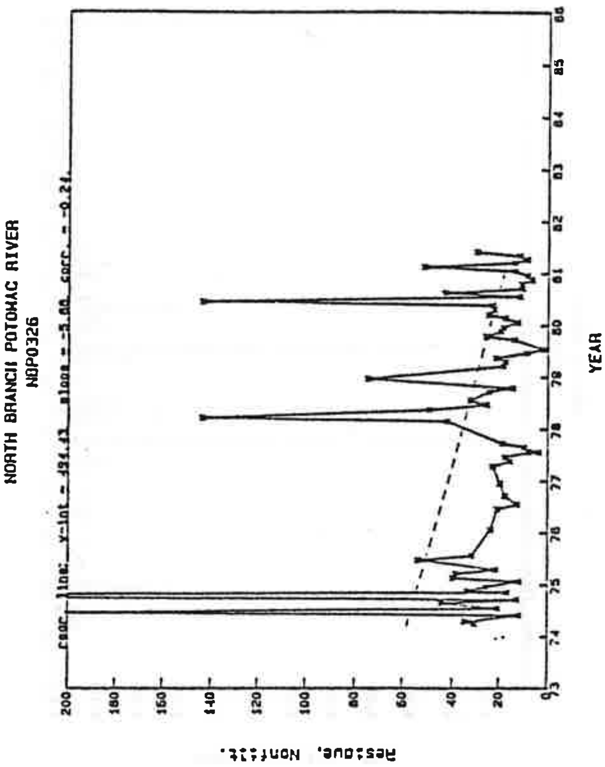



Figure I.46

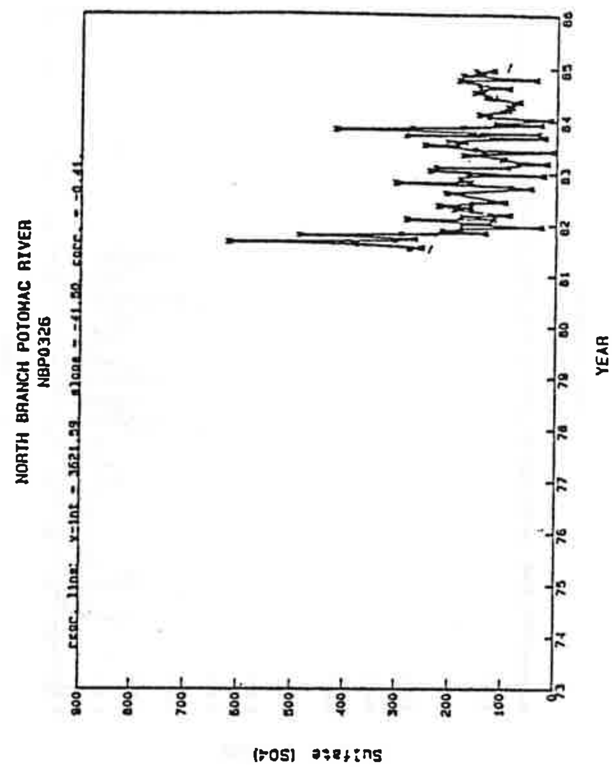



Figure I.47

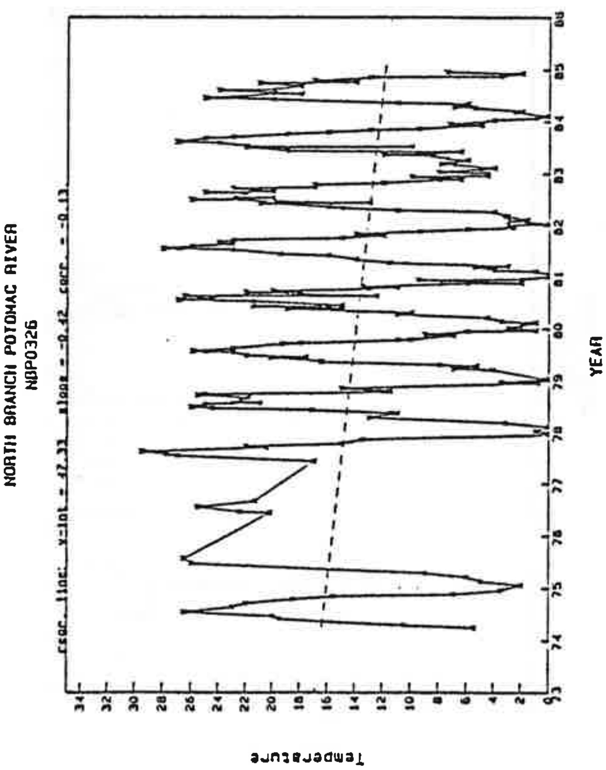



Figure I.48

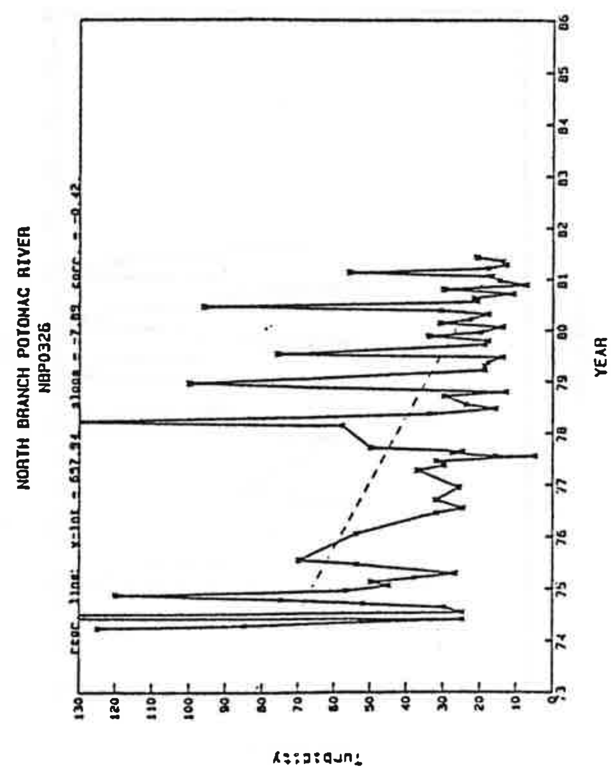


Figure I.49

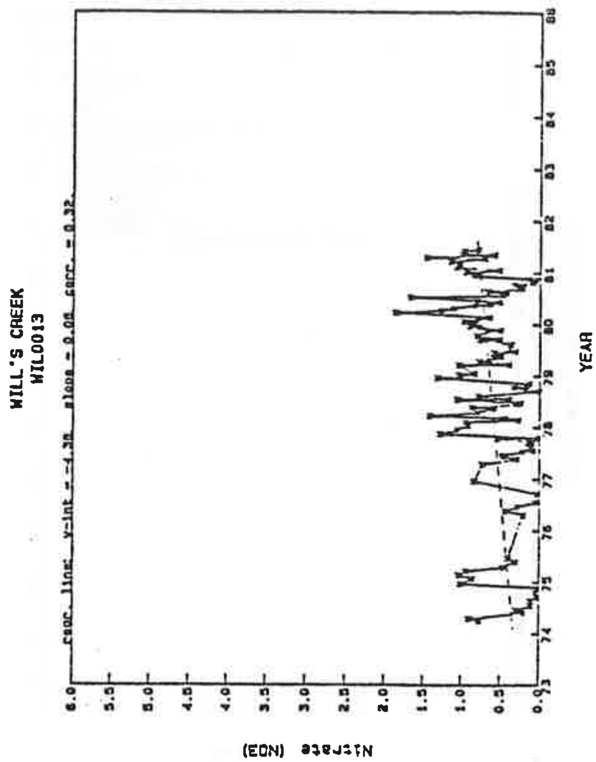



Figure I.50

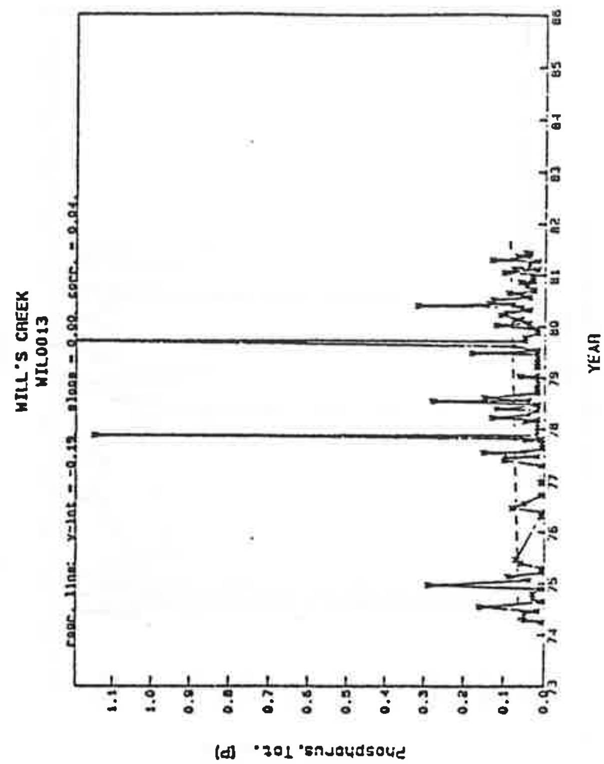



Figure I.51

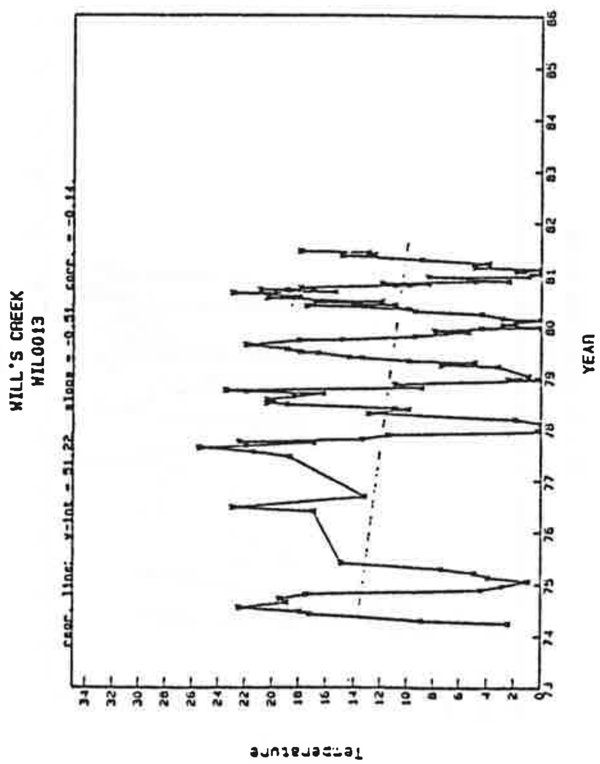



Figure I.52

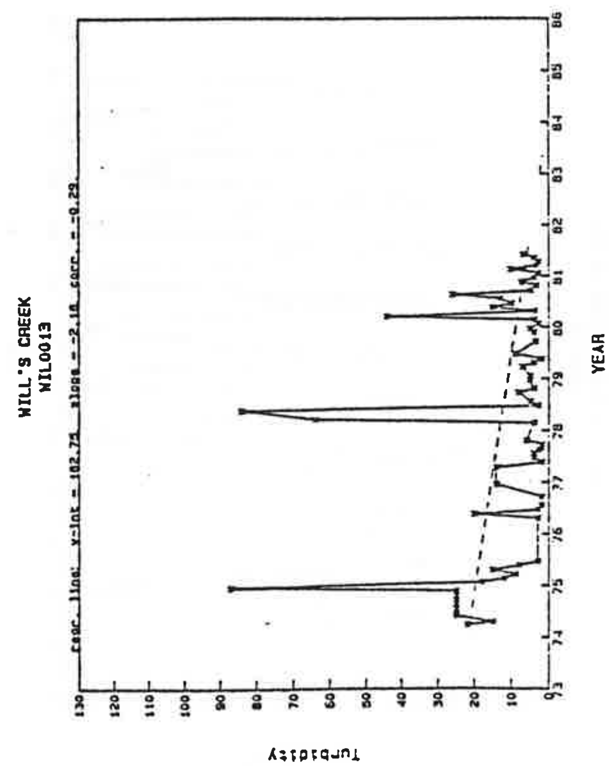


Figure I.53

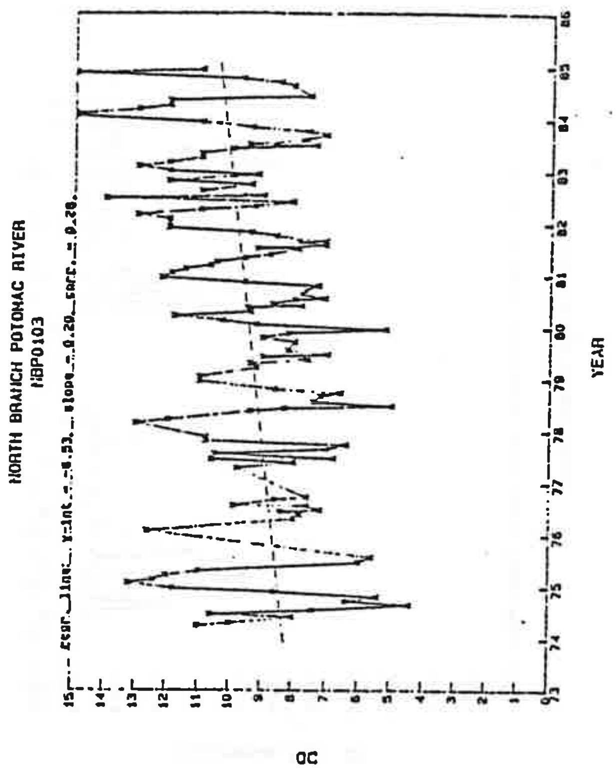



Figure I.54

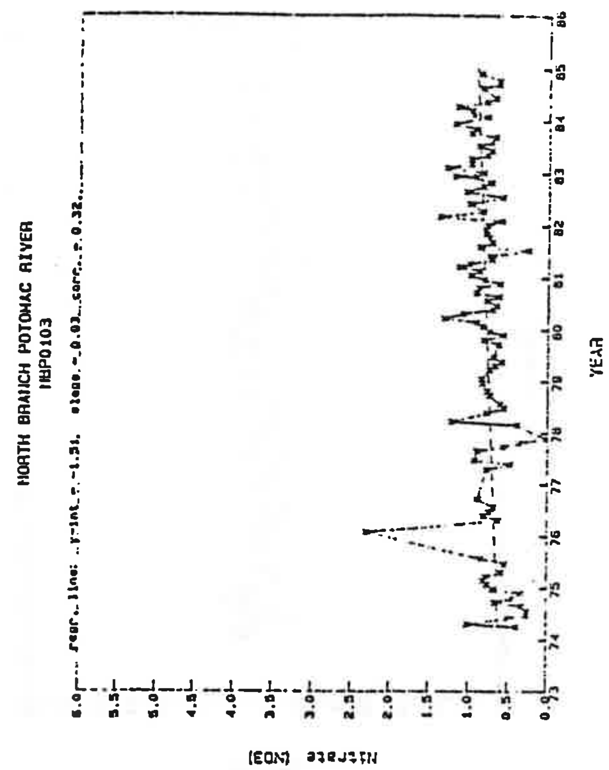



Figure I.55

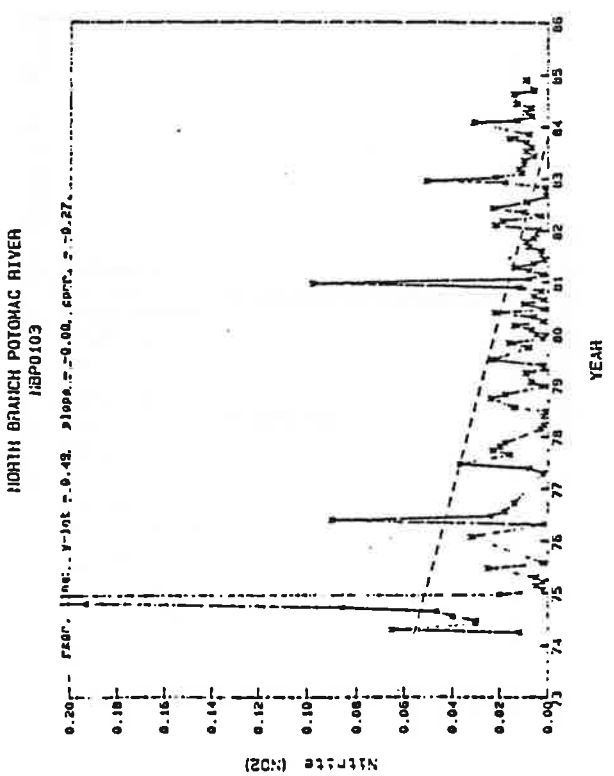



Figure I.56

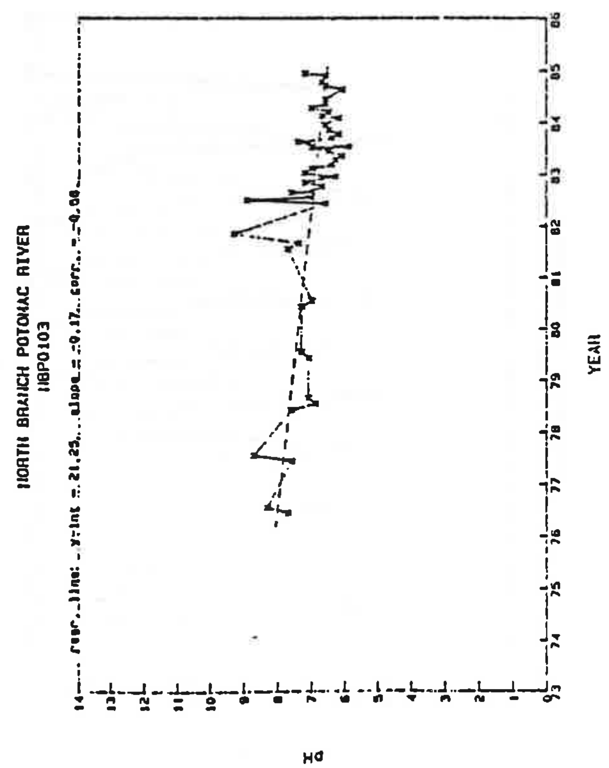


Figure I.57

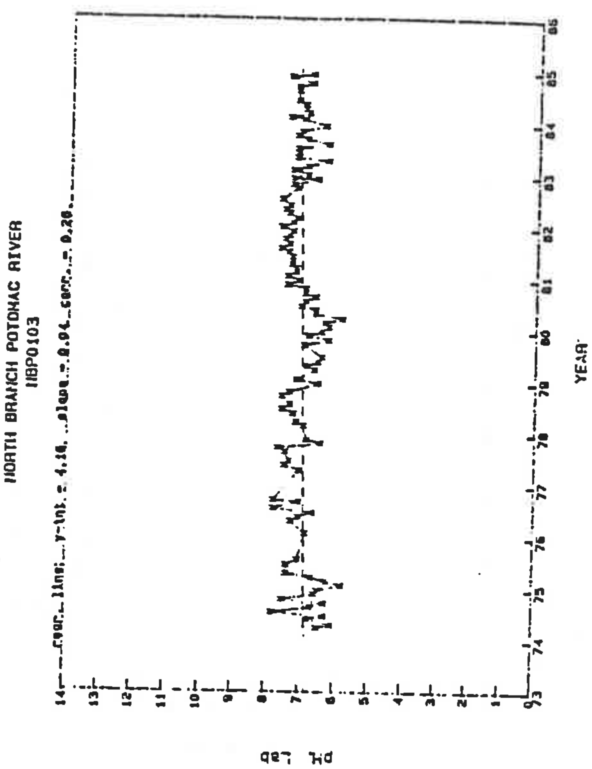



Figure I.58

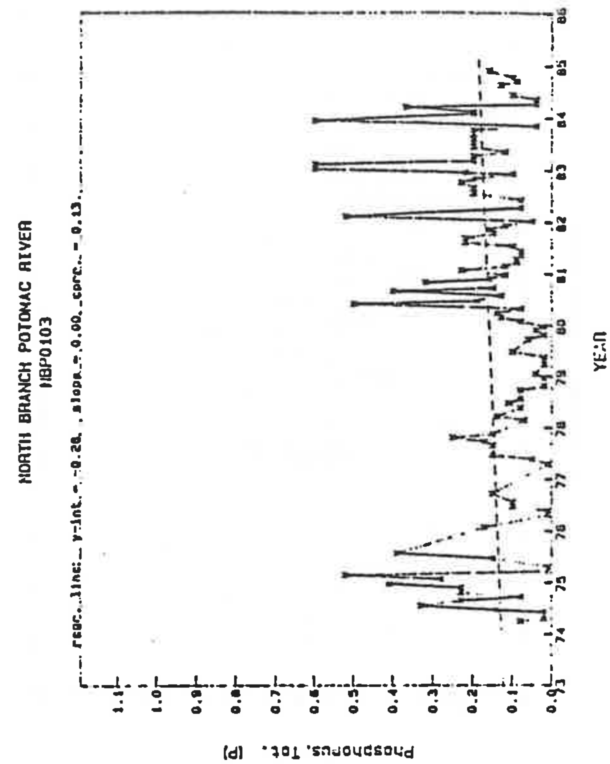



Figure I.59

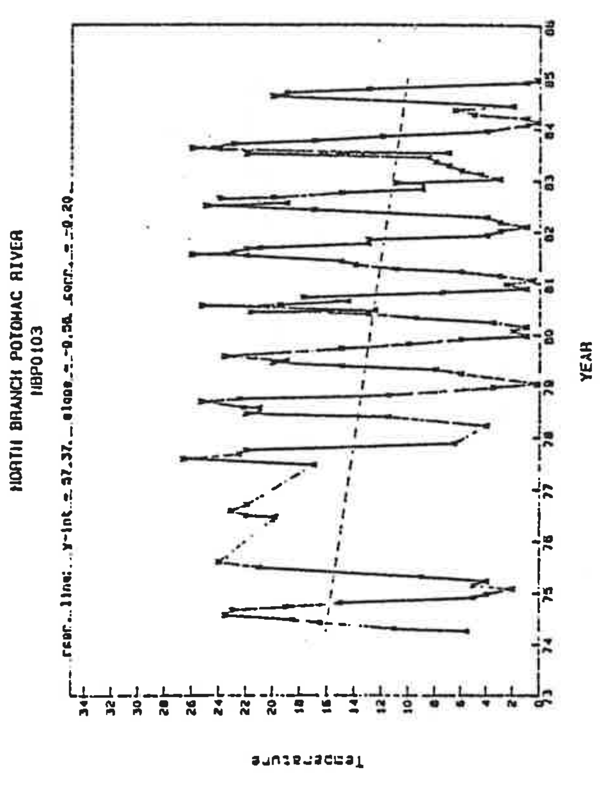



Figure I.60

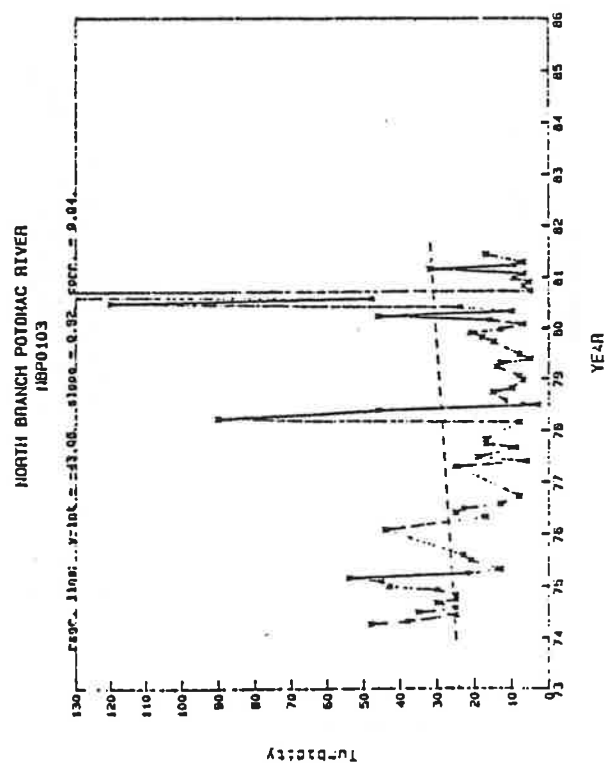


Figure I.61

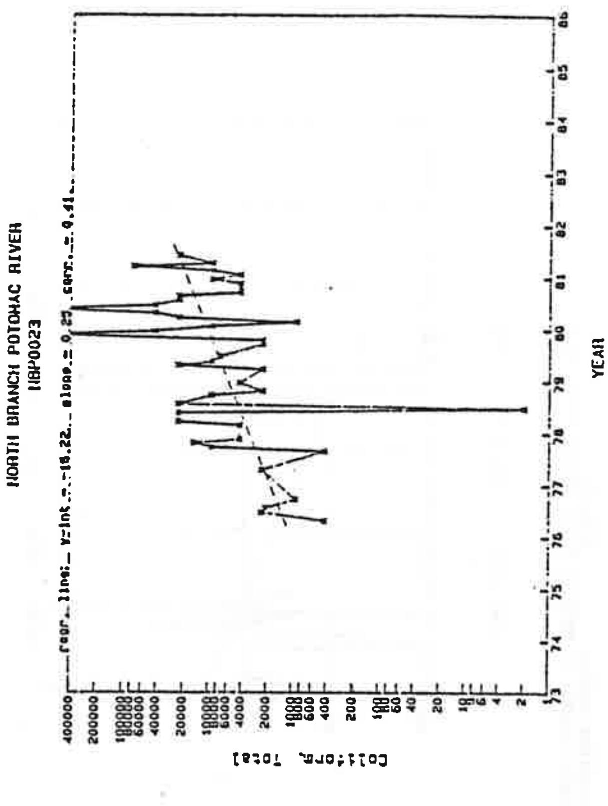



Figure I.62

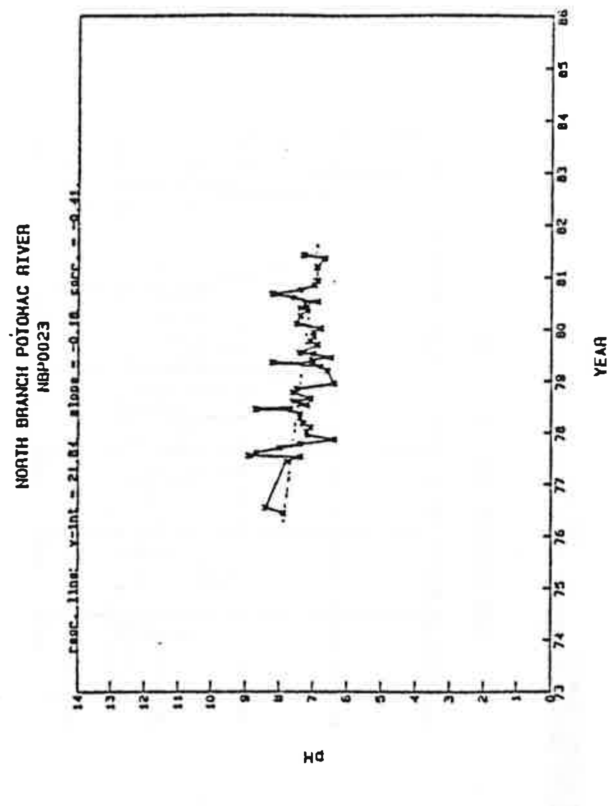



Figure I.63

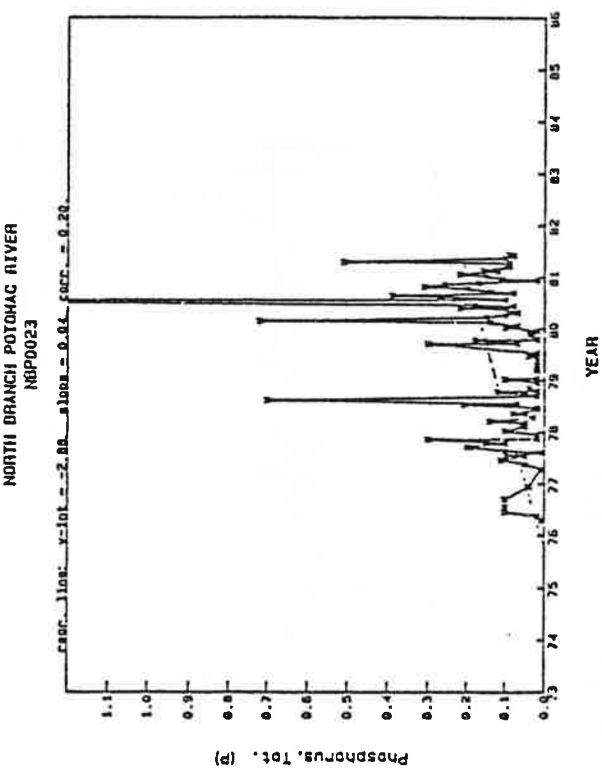



Figure I.64

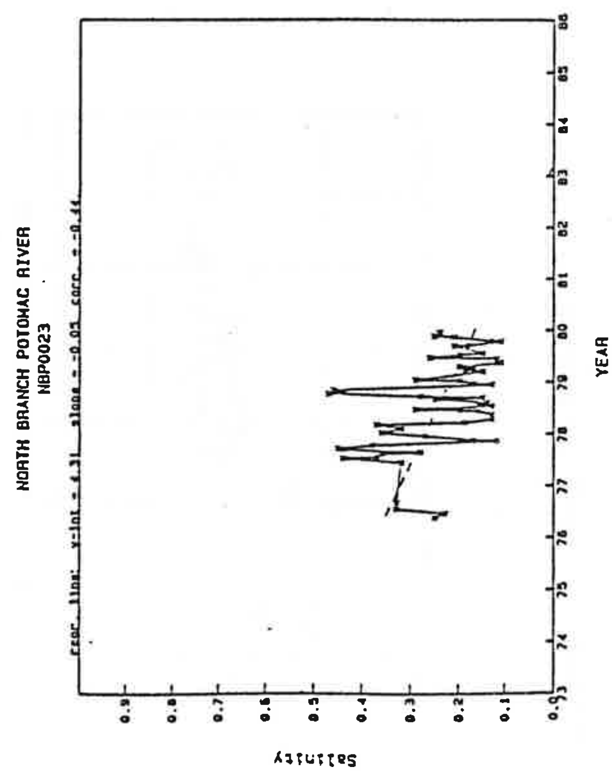


Figure I.65

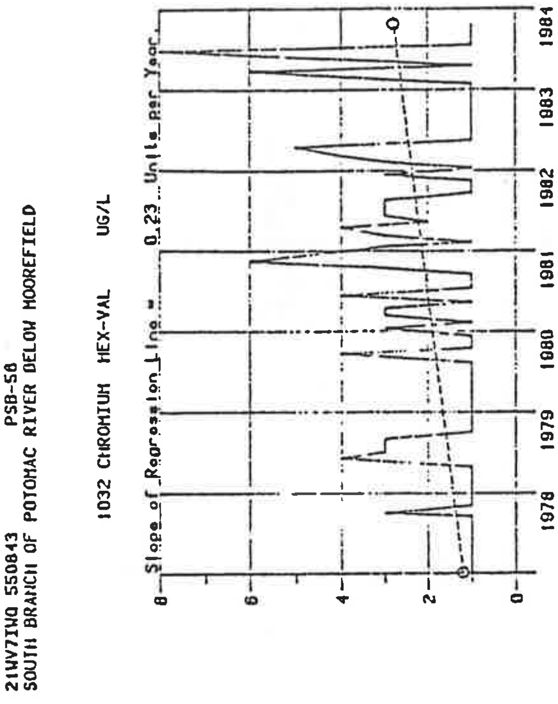



Figure I.66

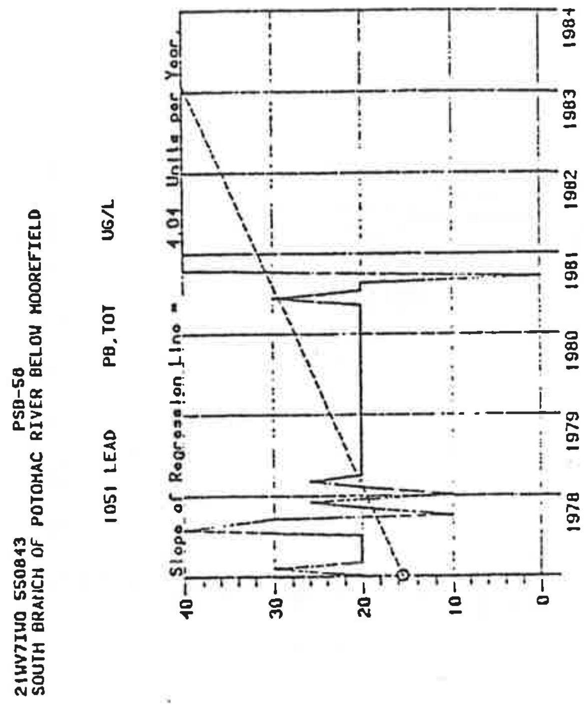



Figure I.67

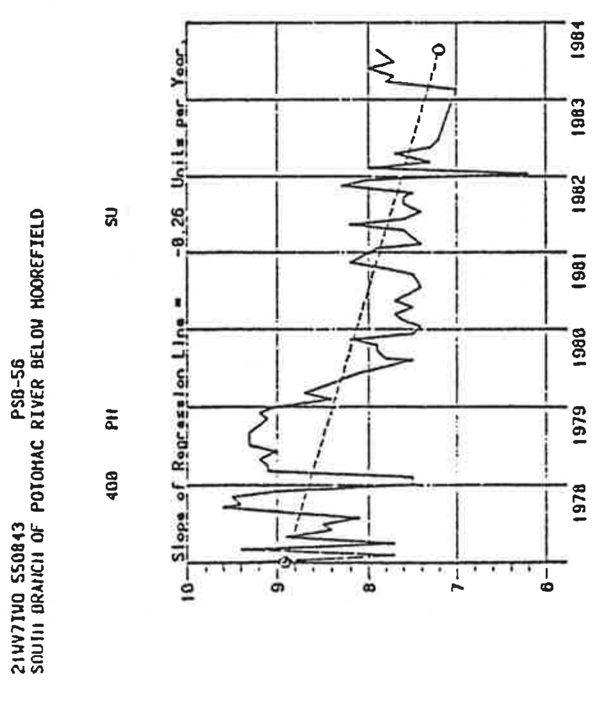



Figure I.68

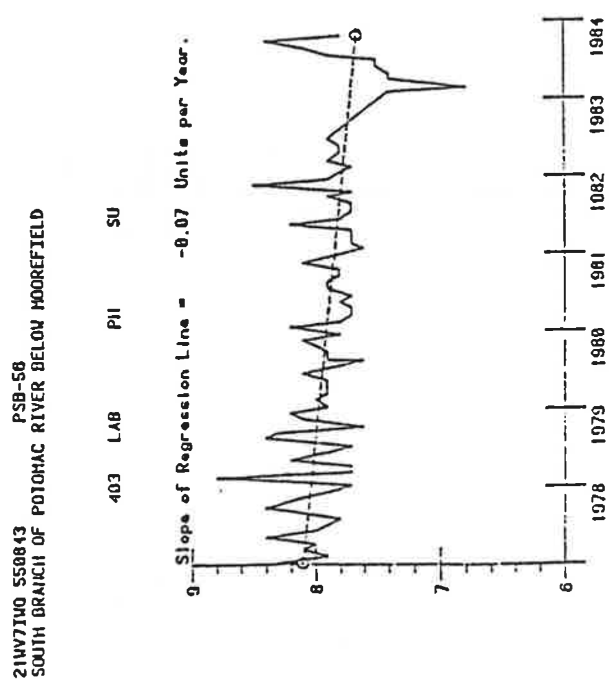


Figure I.69

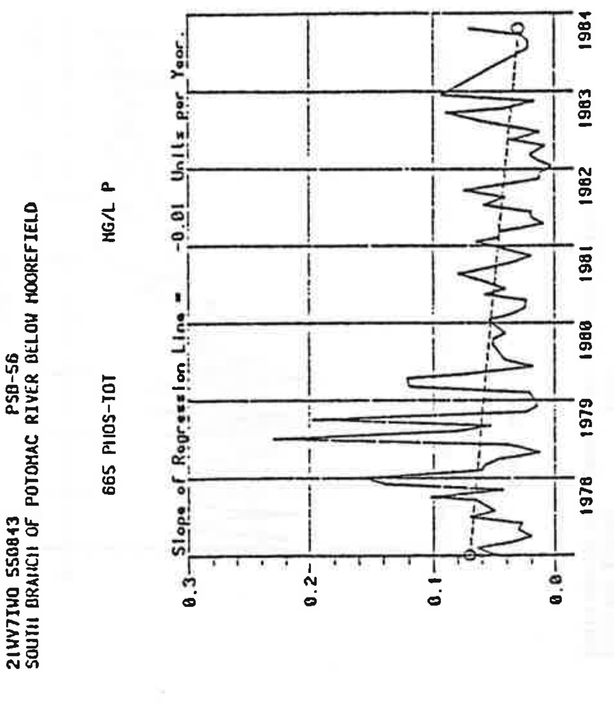



Figure I.70

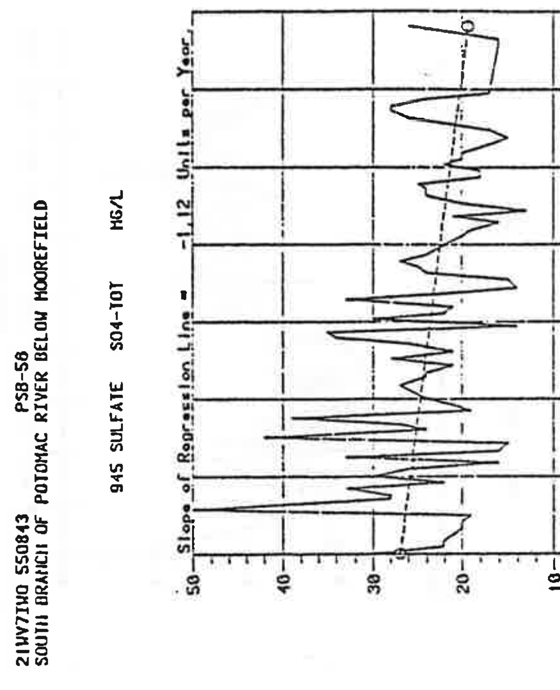



Figure I.71

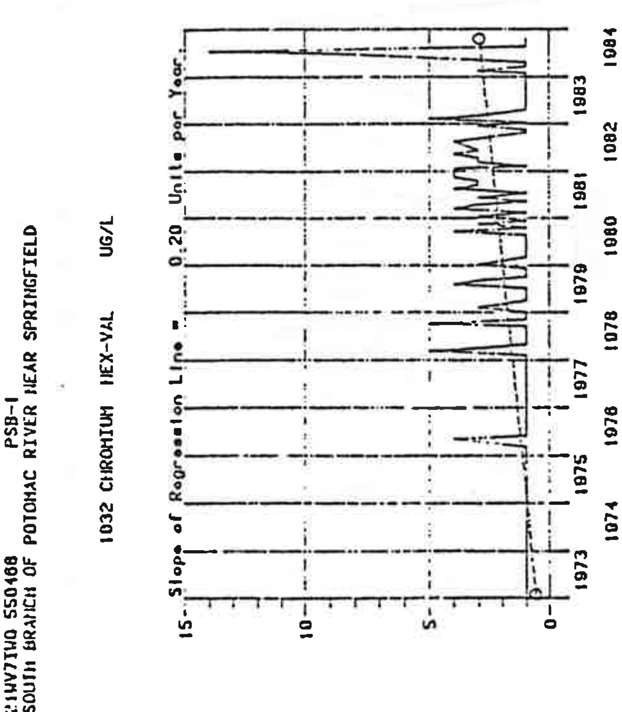



Figure I.72

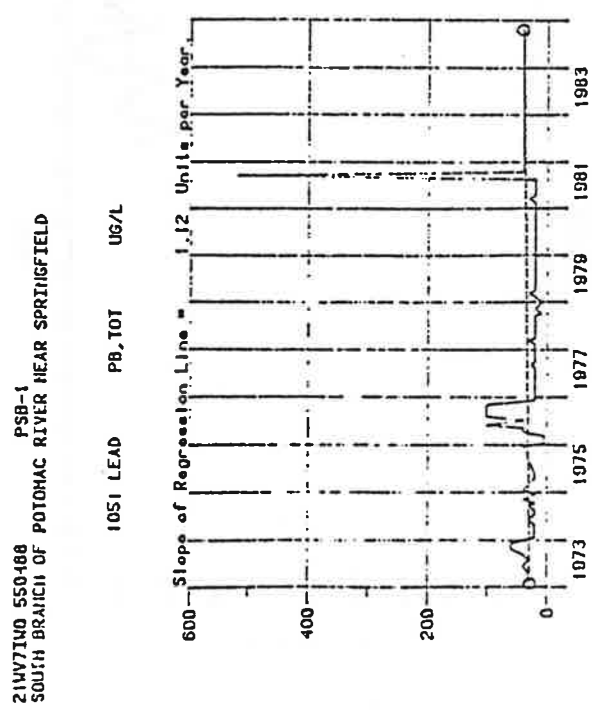


Figure I.73

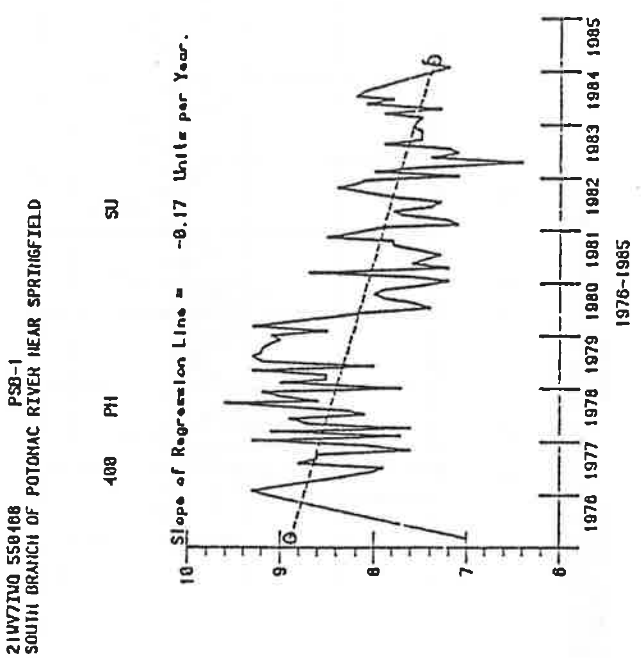



Figure I.74

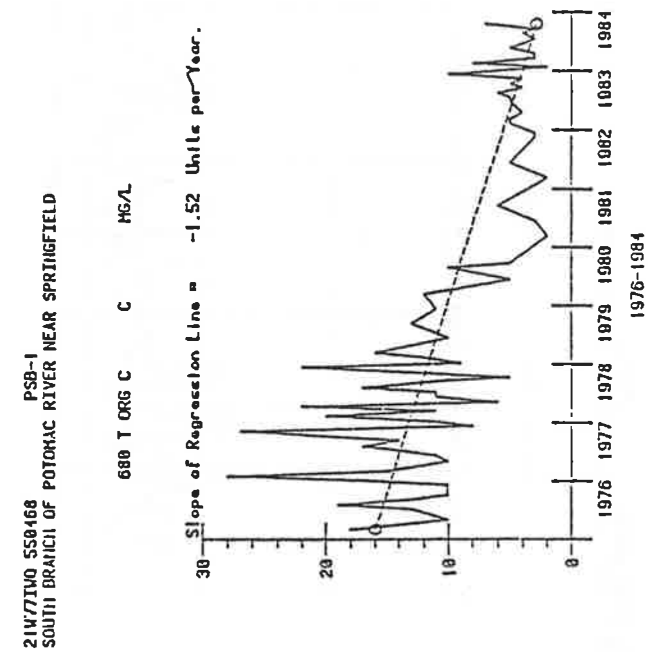



Figure I.75

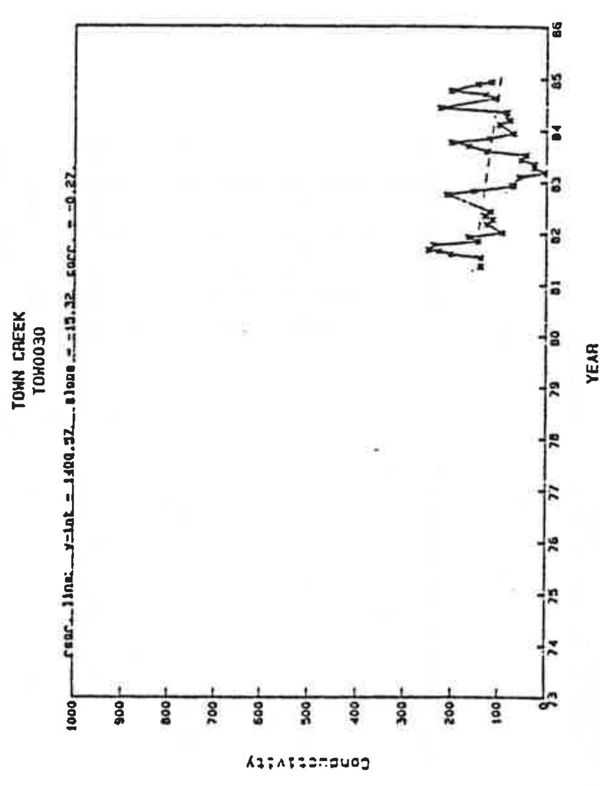



Figure I.76

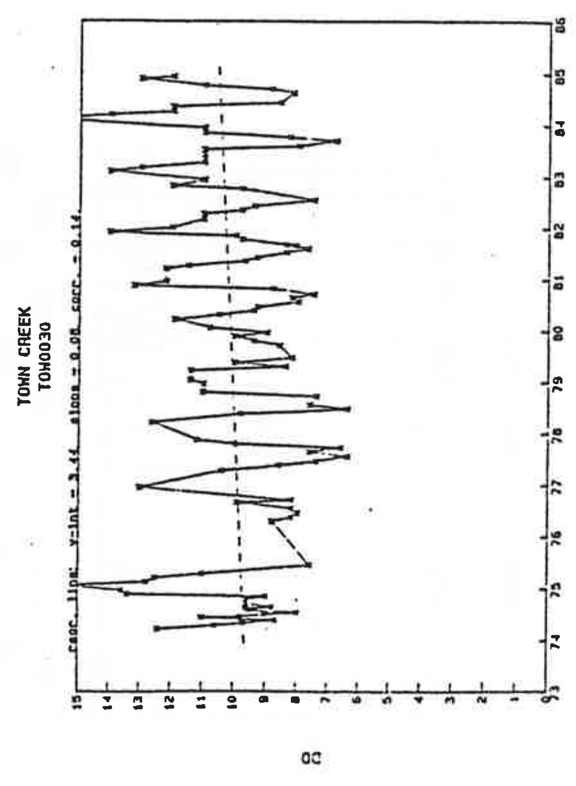


Figure I.77

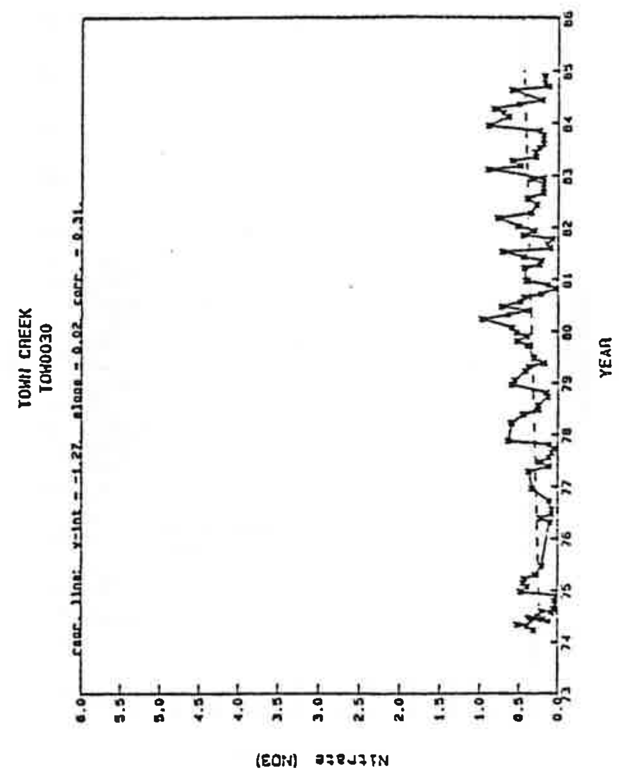



Figure I.78

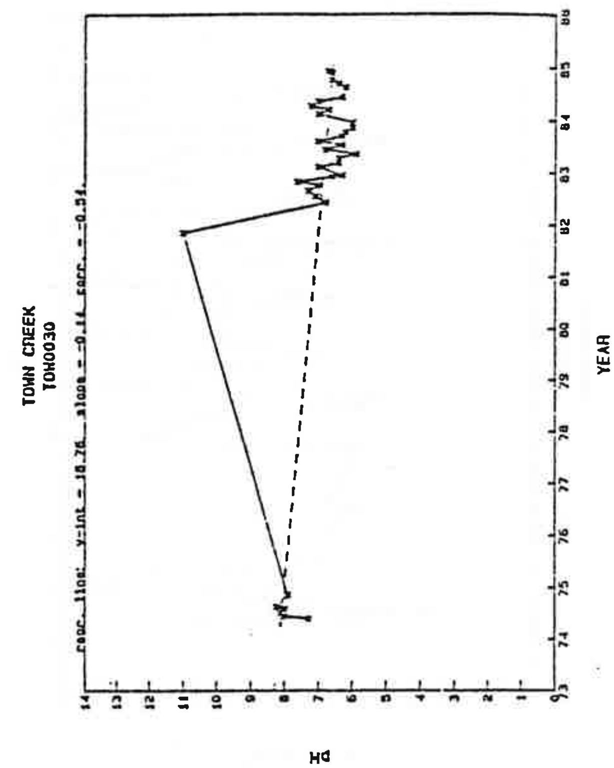



Figure I.79

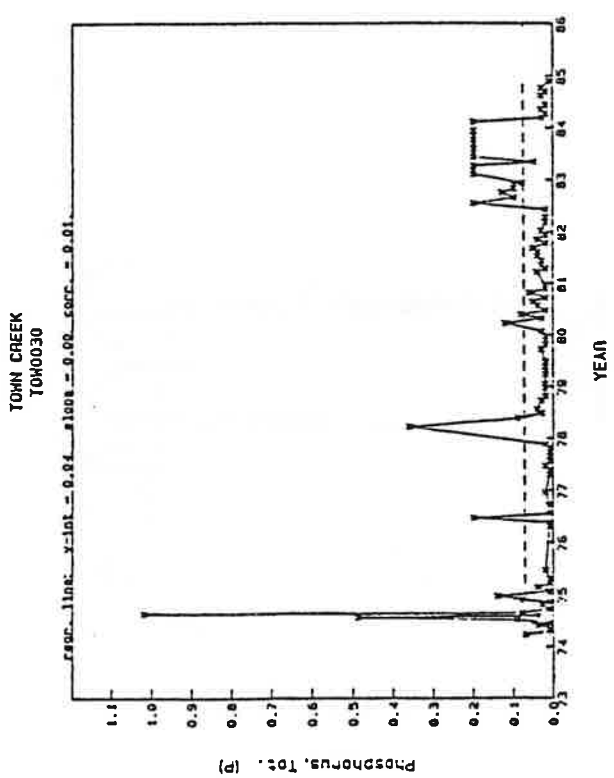



Figure I.80

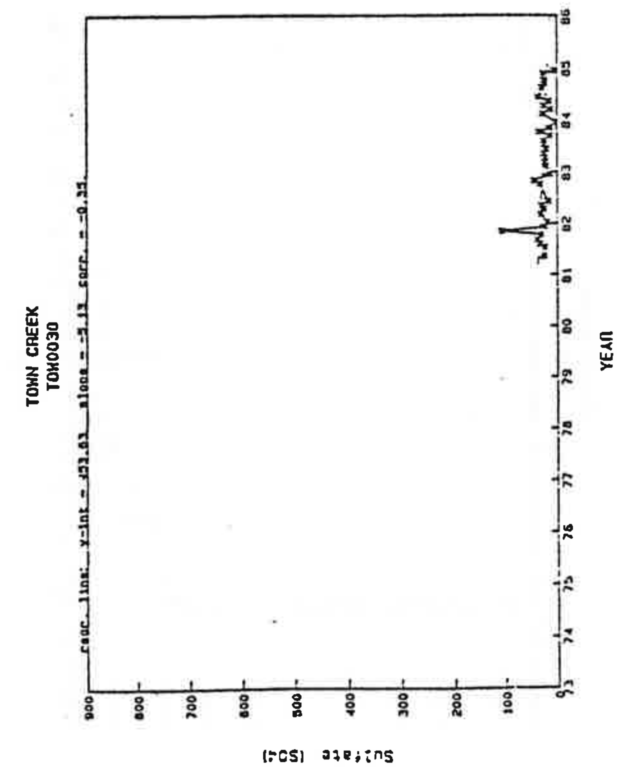


Figure I.81

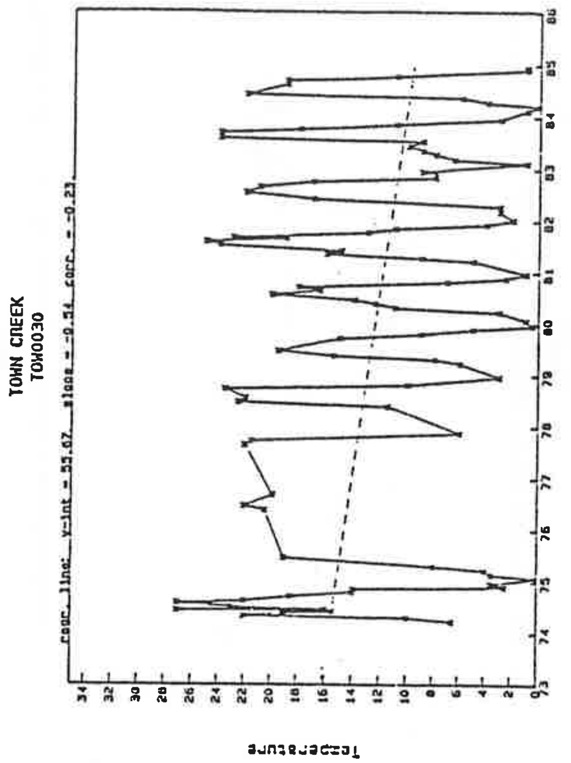



Figure I.82

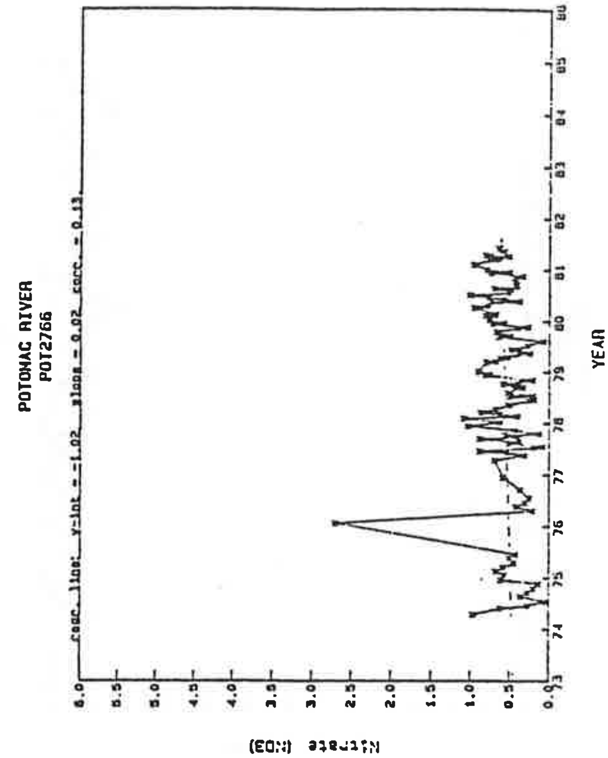



Figure I.83

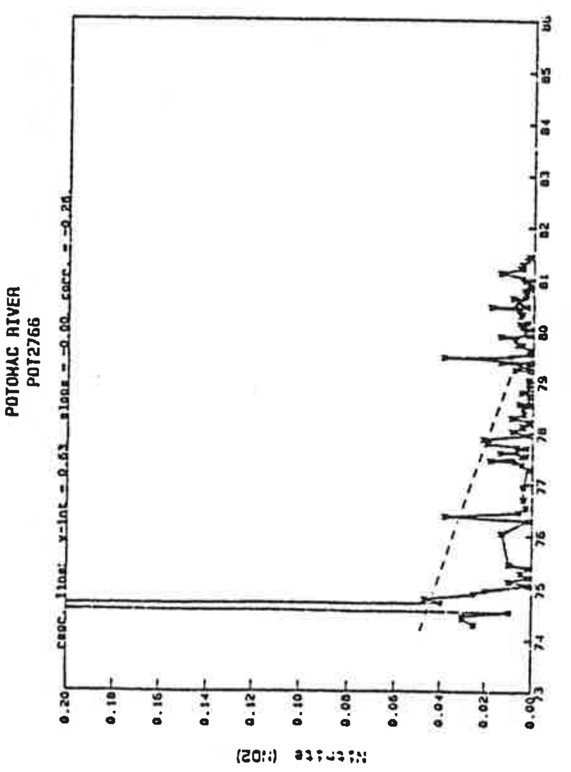



Figure I.84

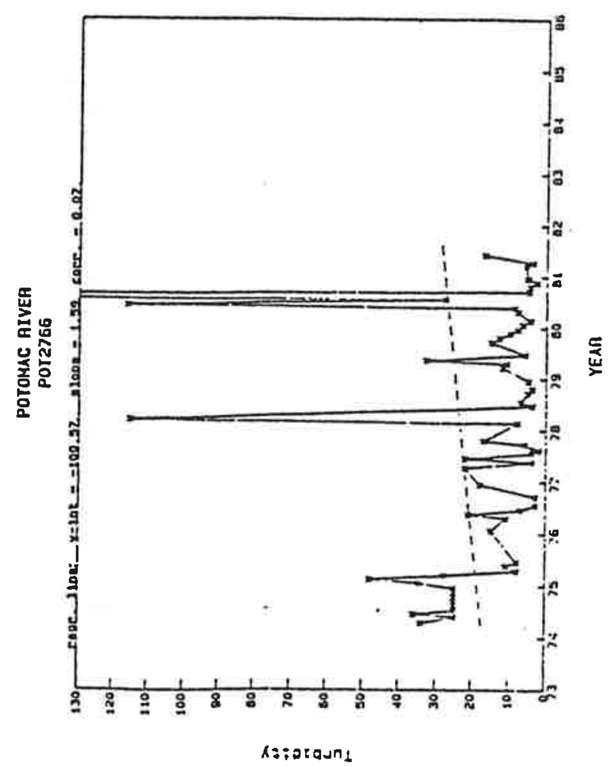


Figure I.85

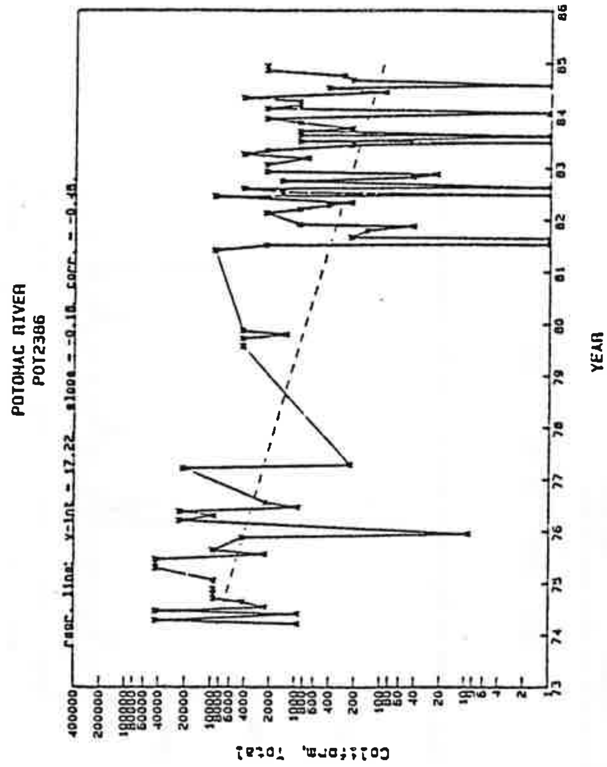



Figure I.86

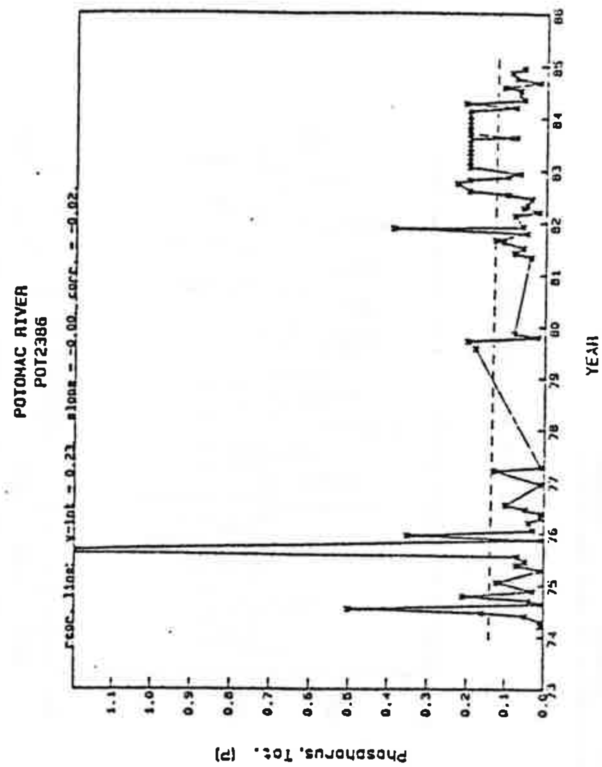



Figure I.87

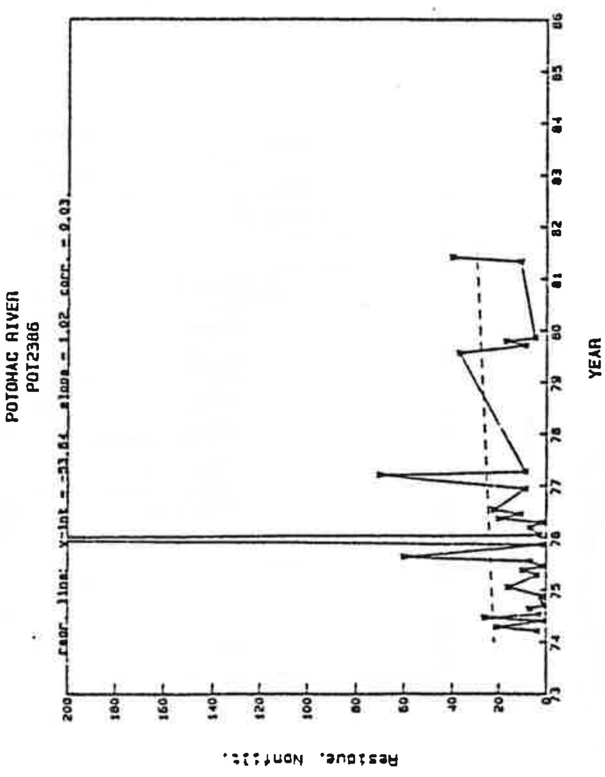



Figure I.88

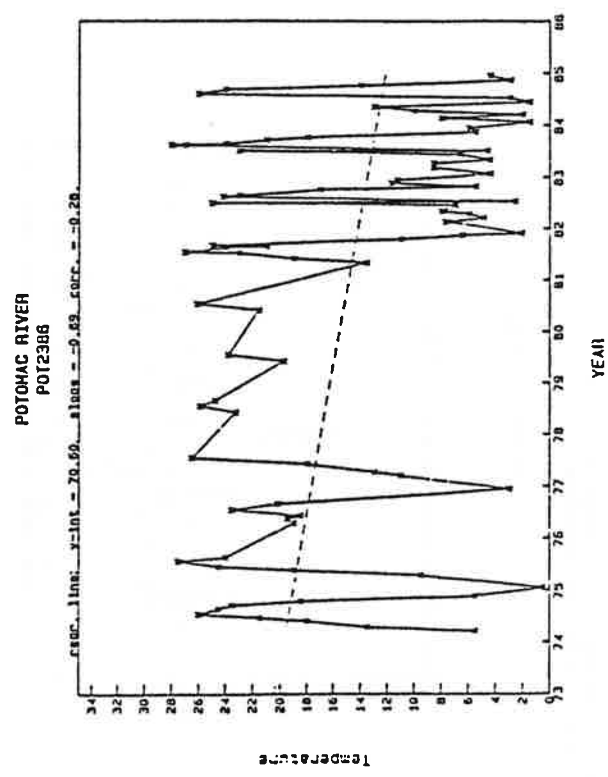


Figure II.1

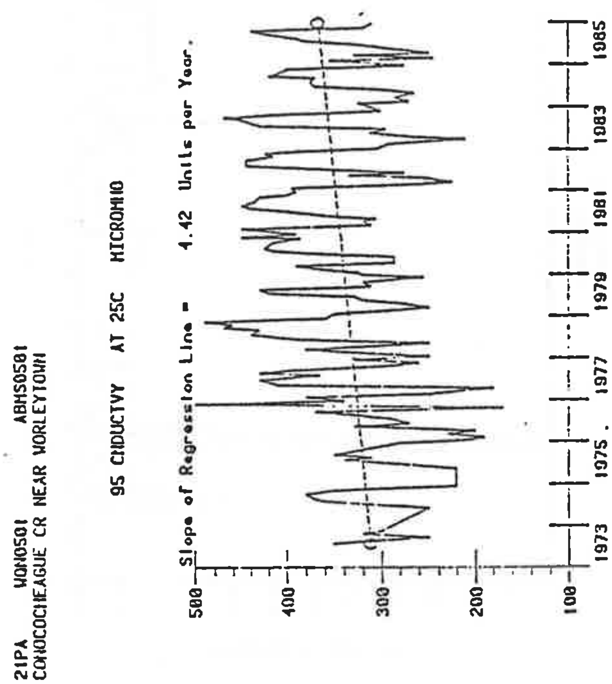



Figure II.2

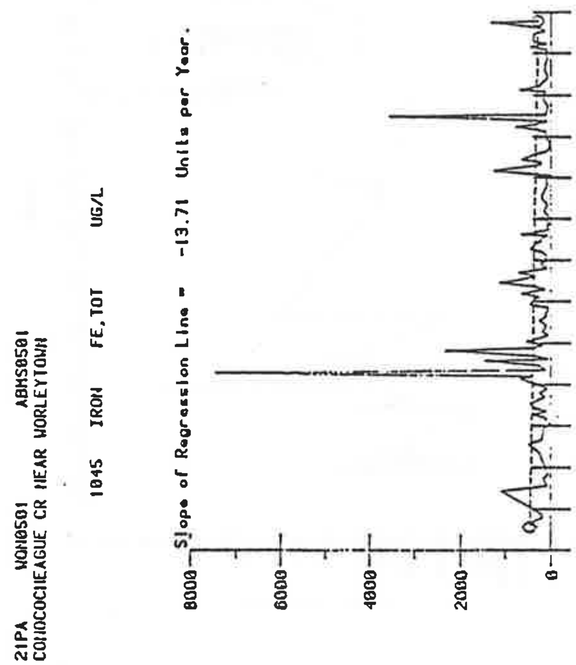



Figure II.3

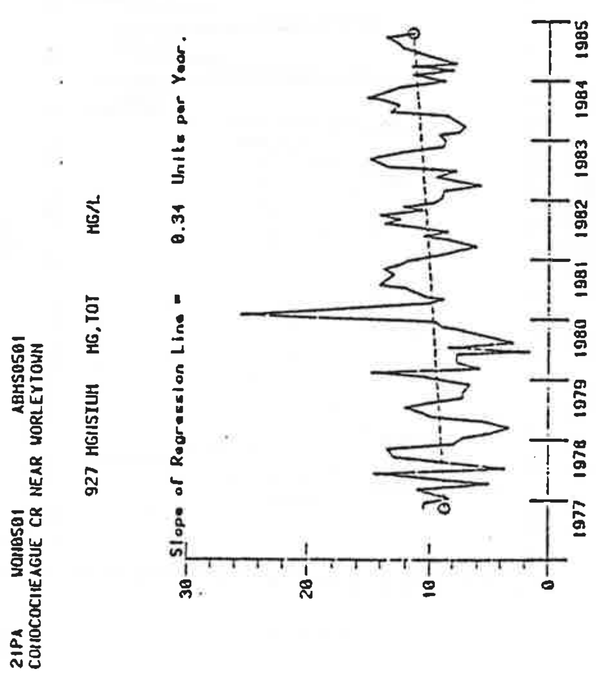



Figure II.4

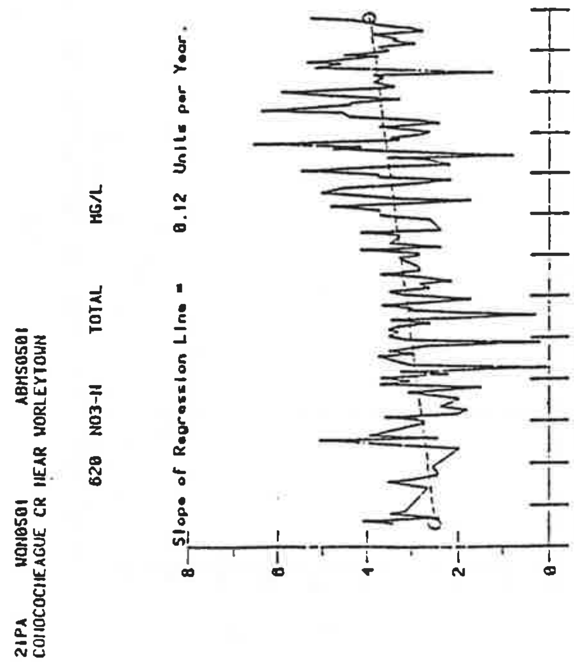


Figure II.5

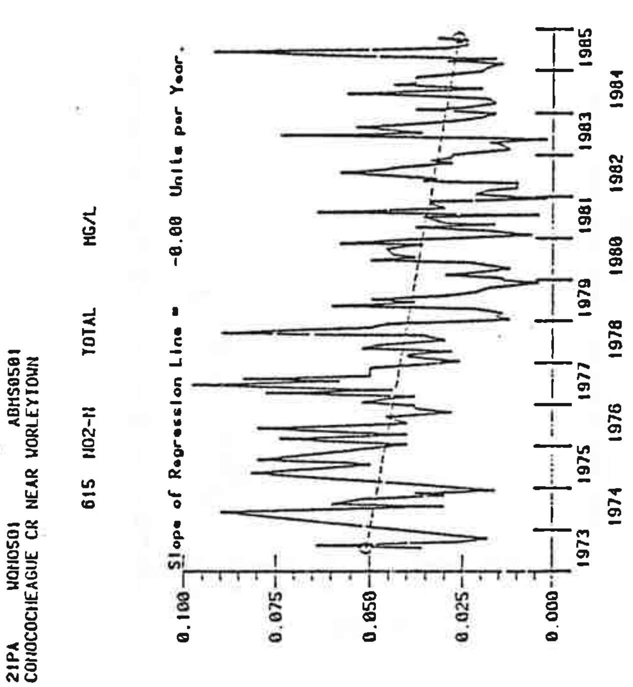



Figure II.6

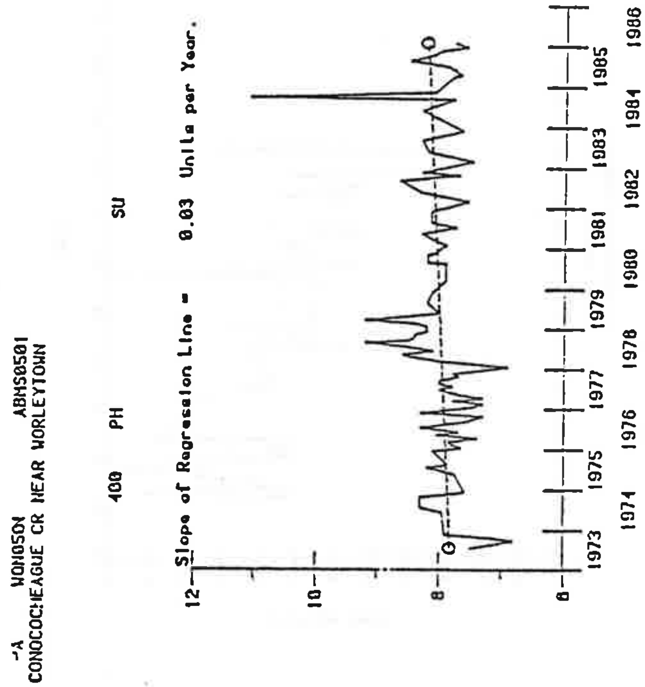



Figure II.7

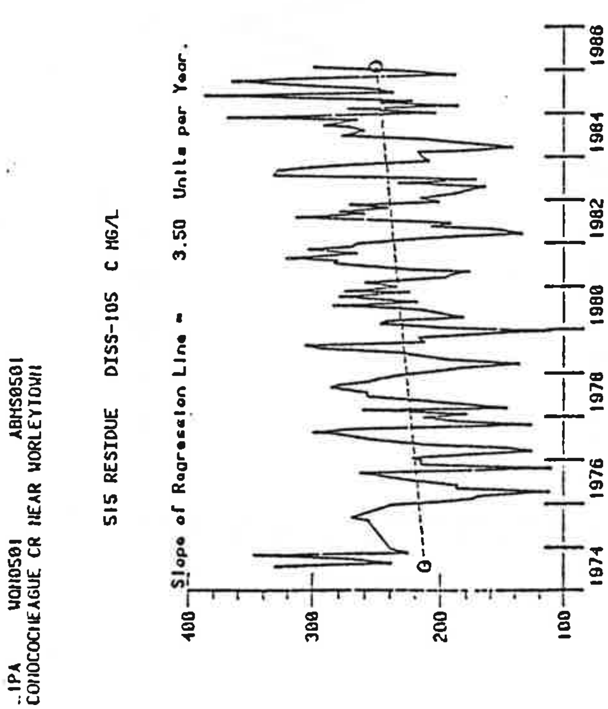



Figure II.8

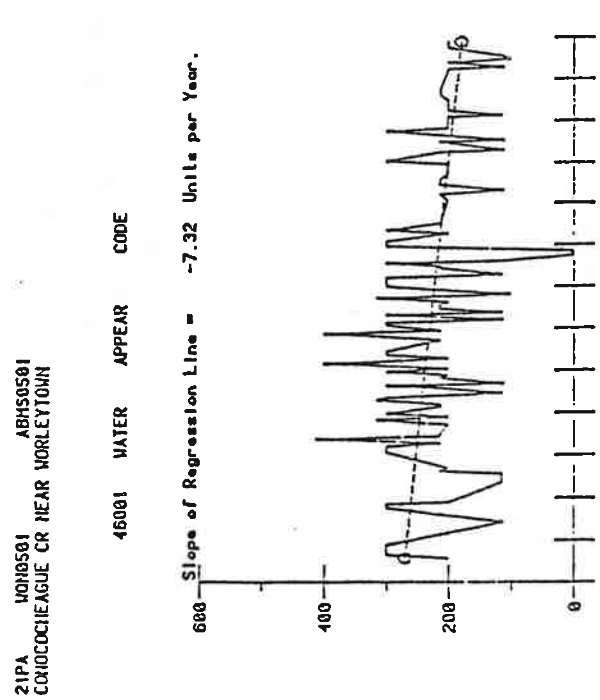


Figure II.9

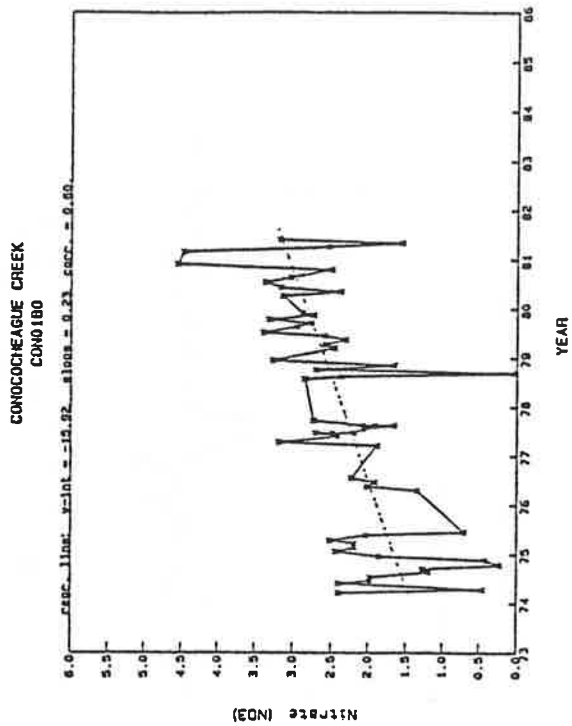



Figure II.10

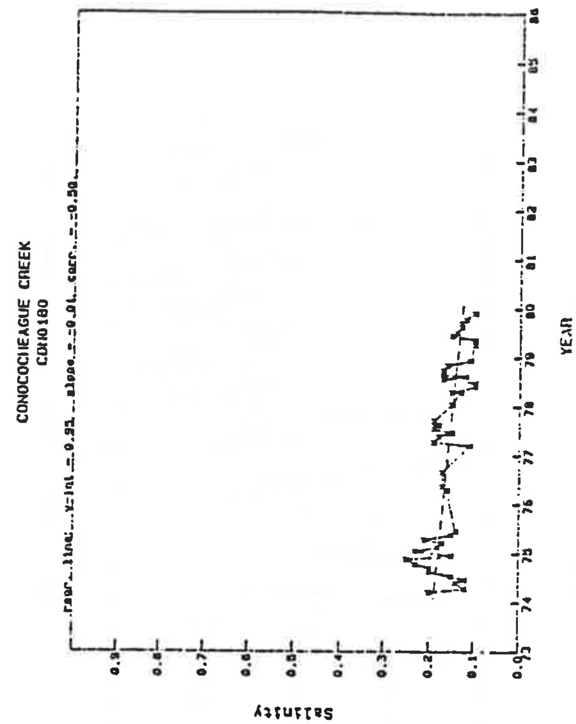



Figure II.11

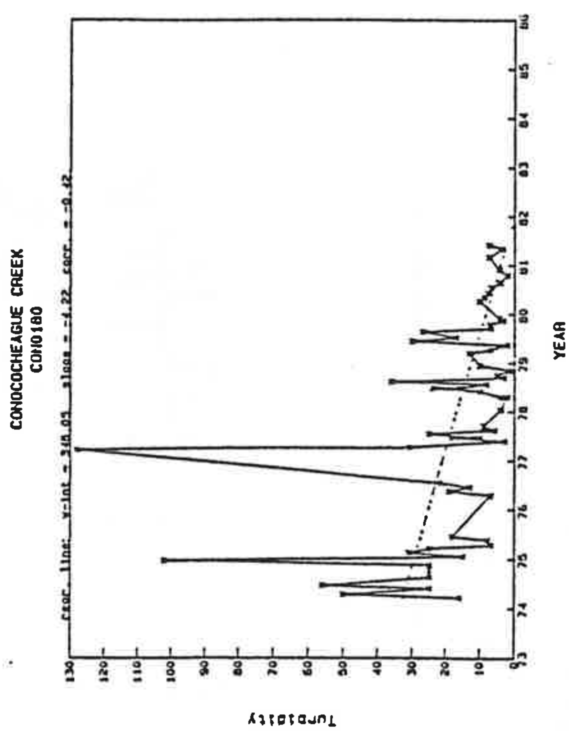



Figure II.12

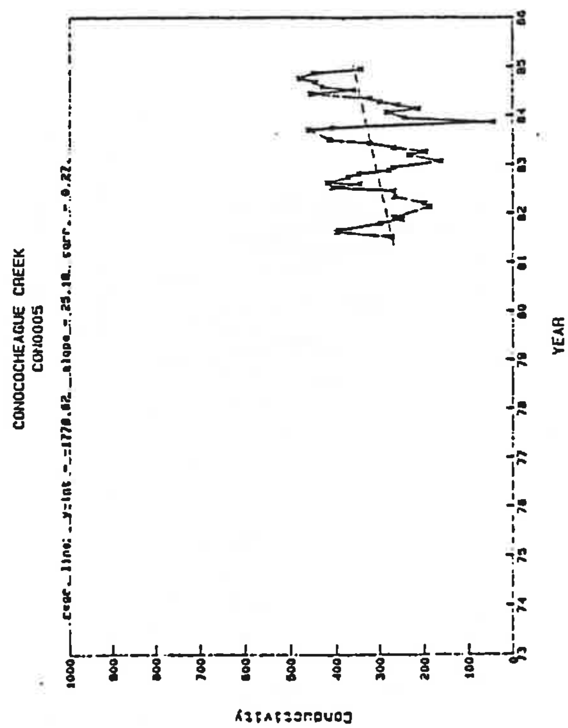


Figure II.13

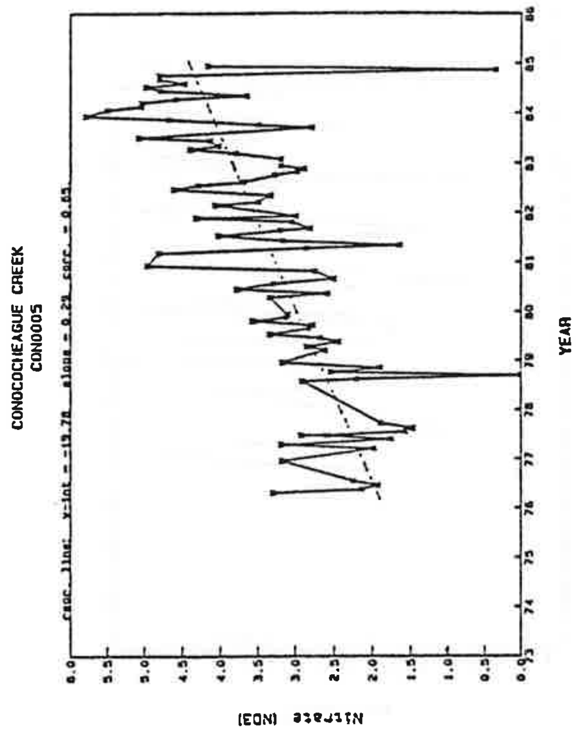



Figure II.14

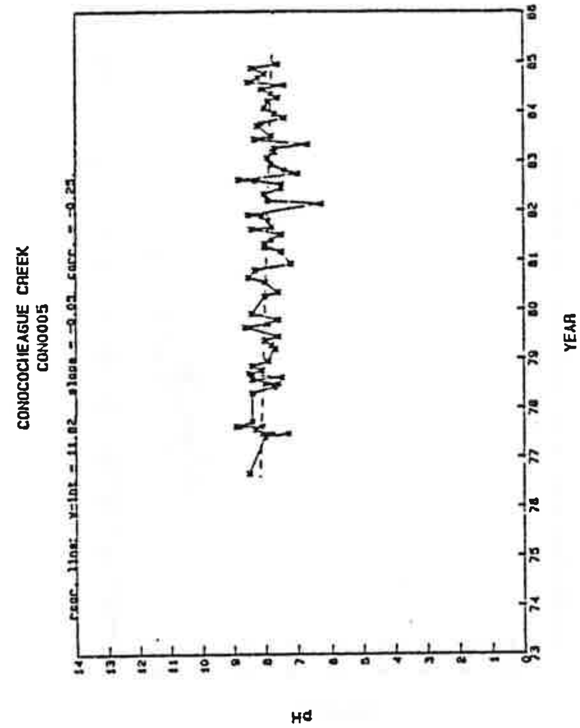



Figure II.15

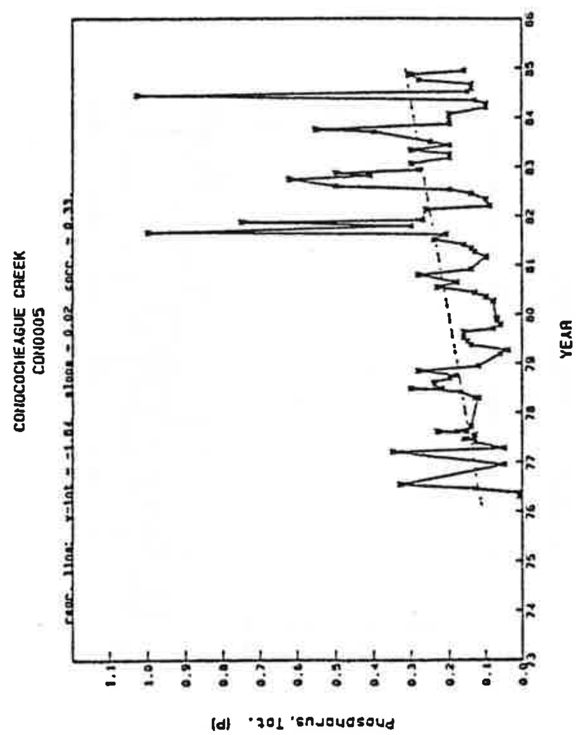



Figure II.16

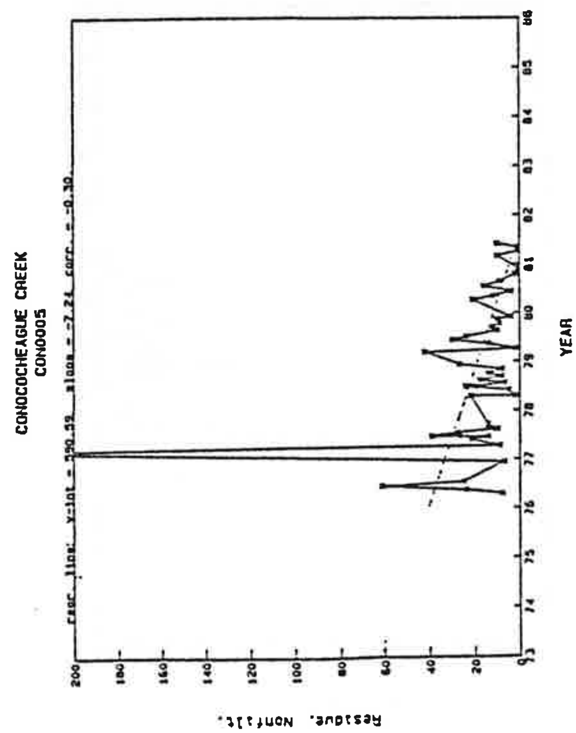


Figure II.17

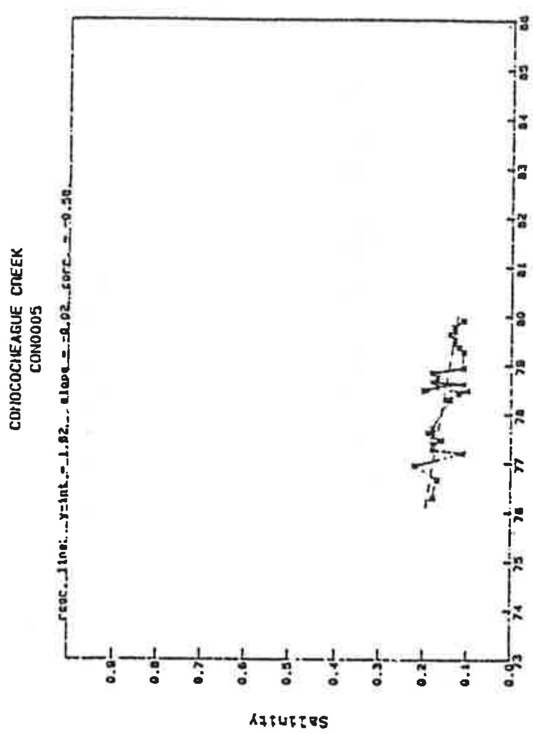



Figure II.18

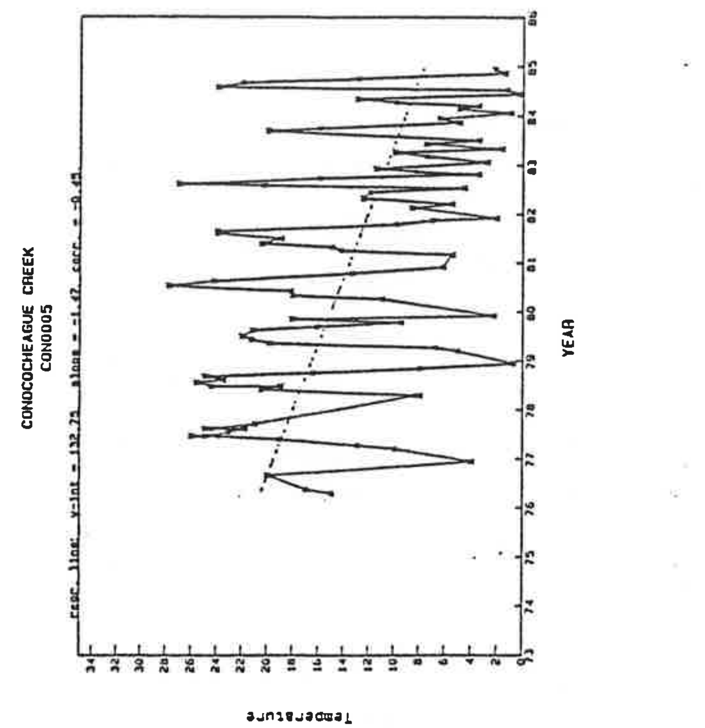



Figure II.19

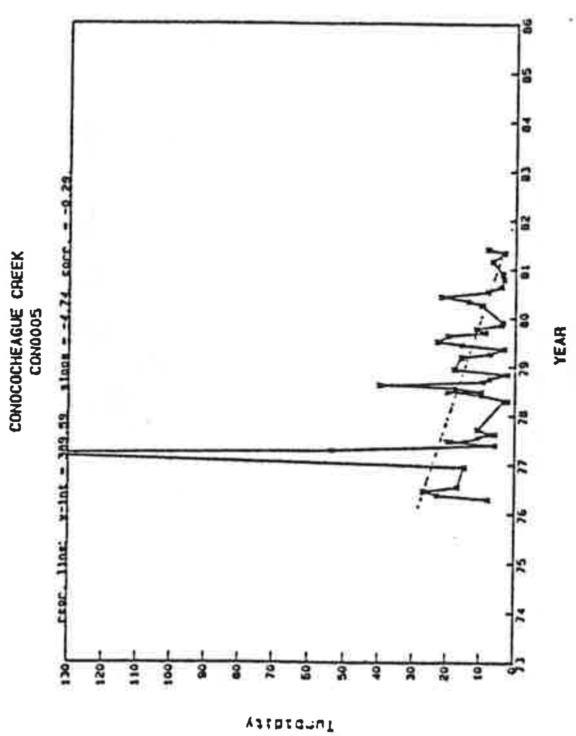



Figure II.20

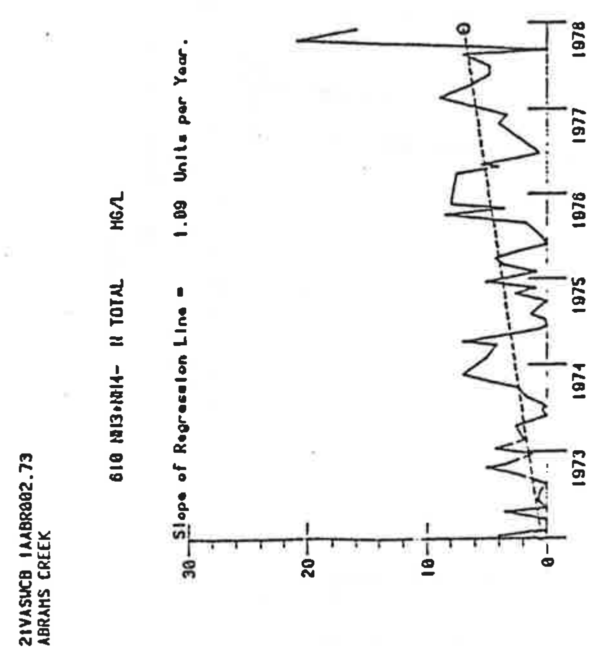


Figure II.21

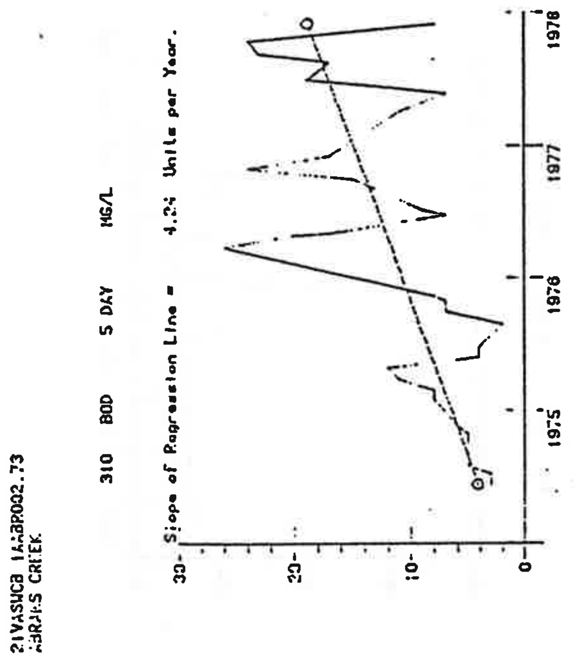



Figure II.22

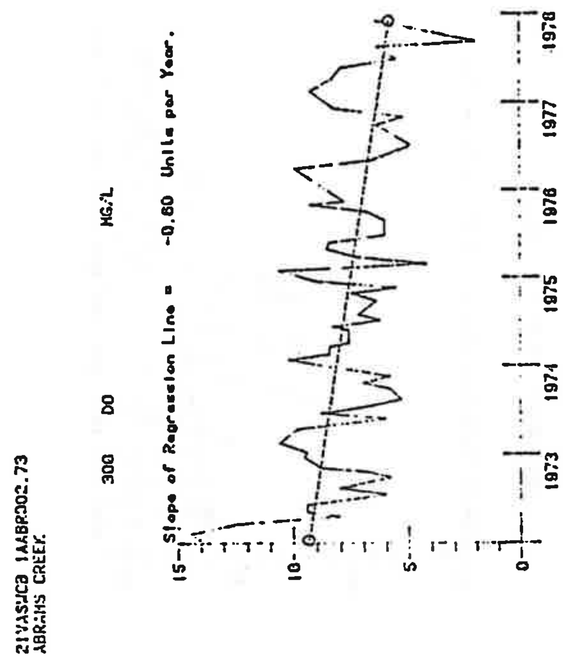



Figure II.23

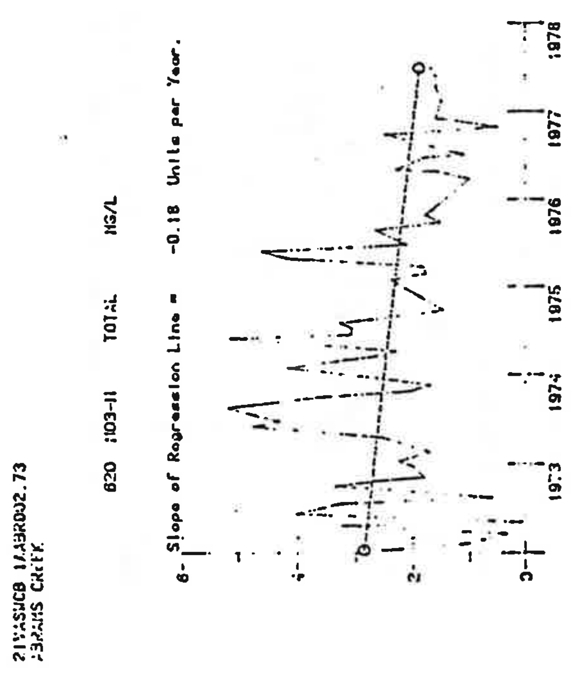



Figure II.24

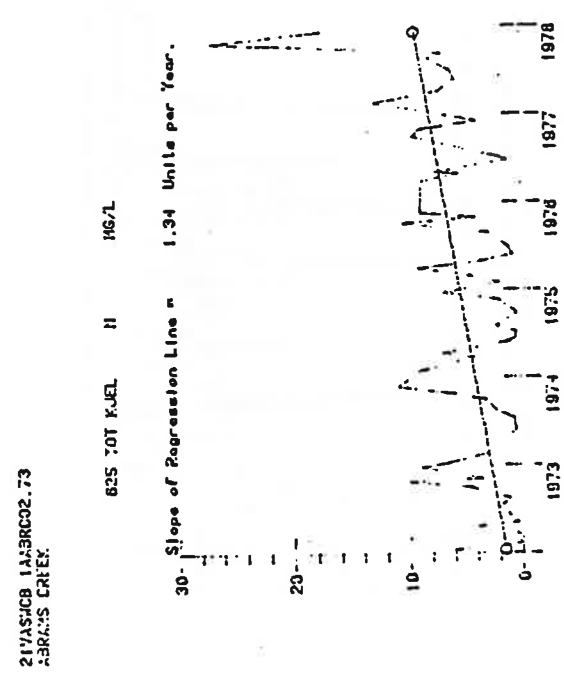


Figure II.25

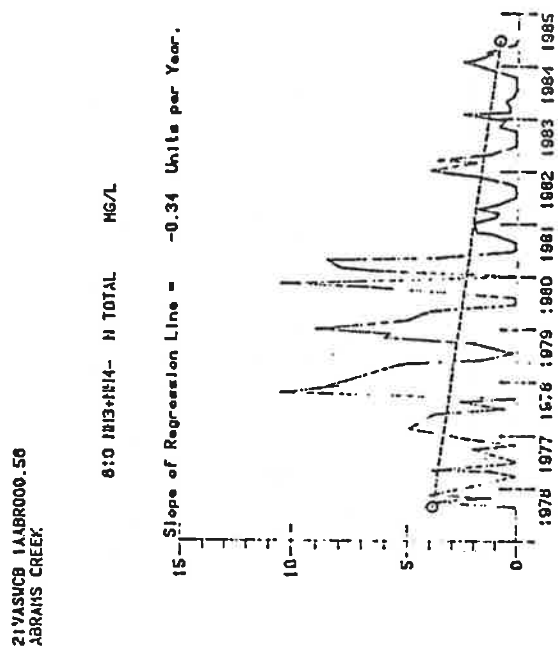



Figure II.26

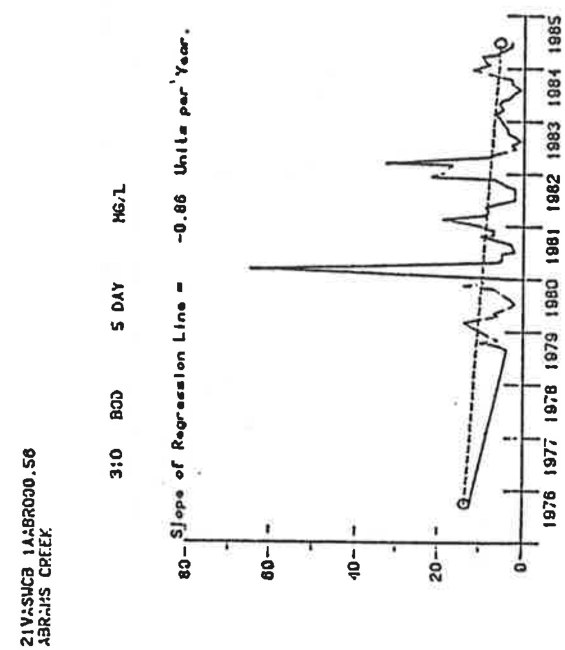



Figure II.27

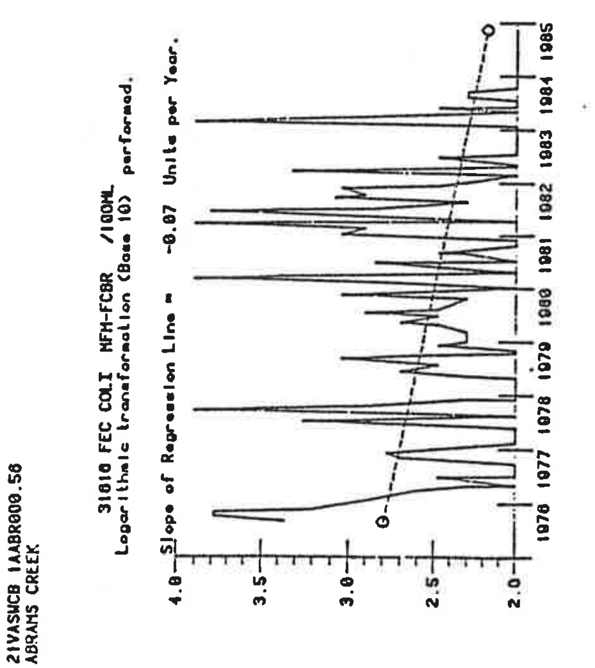



Figure II.28

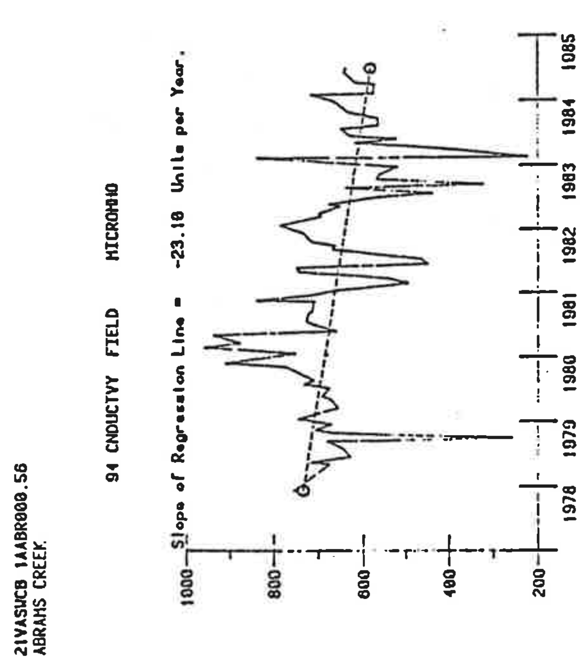


Figure II.29

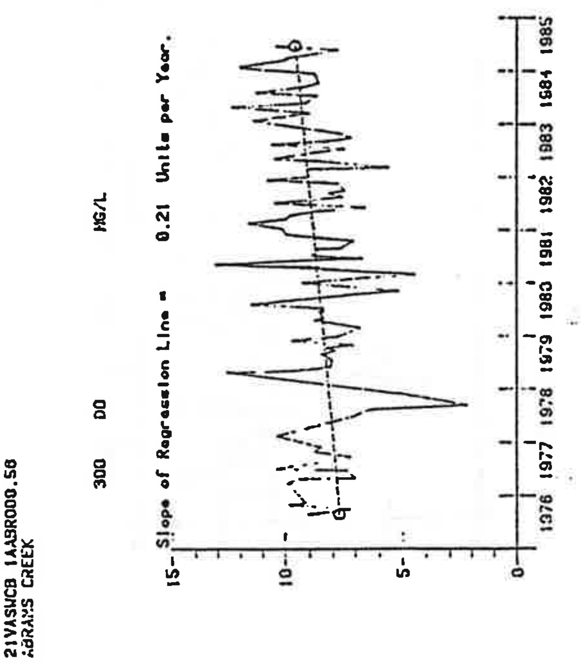



Figure II.30

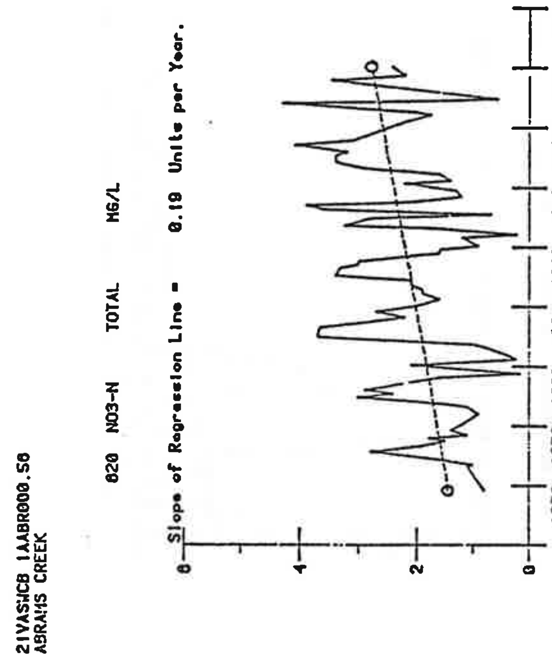



Figure II.31

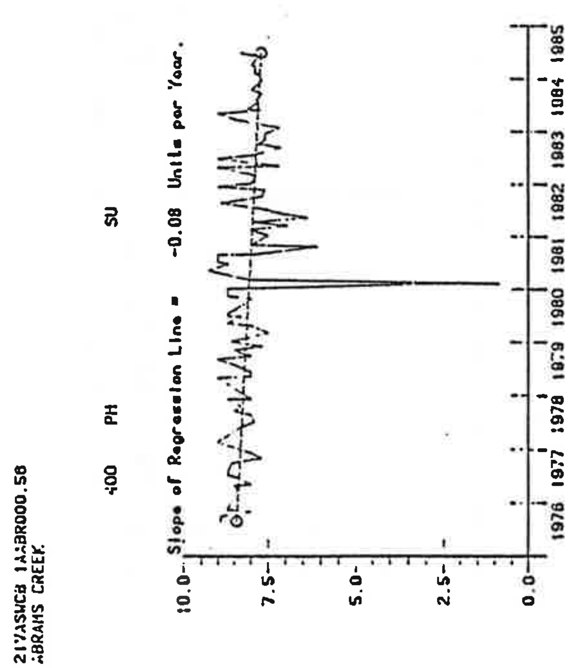



Figure II.32

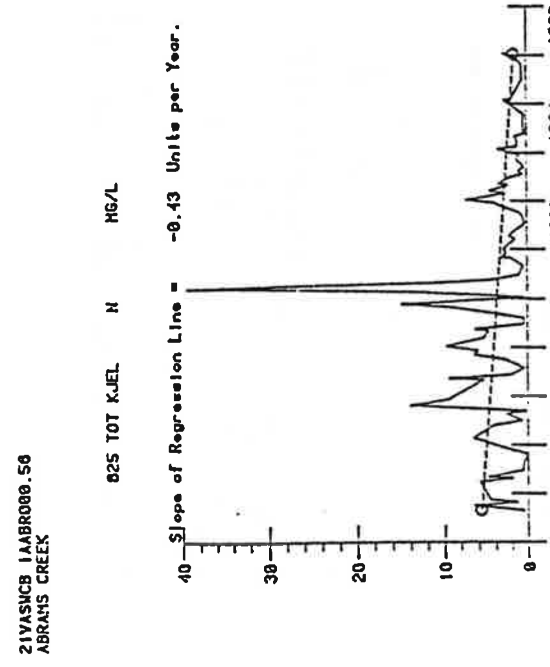


Figure II.33

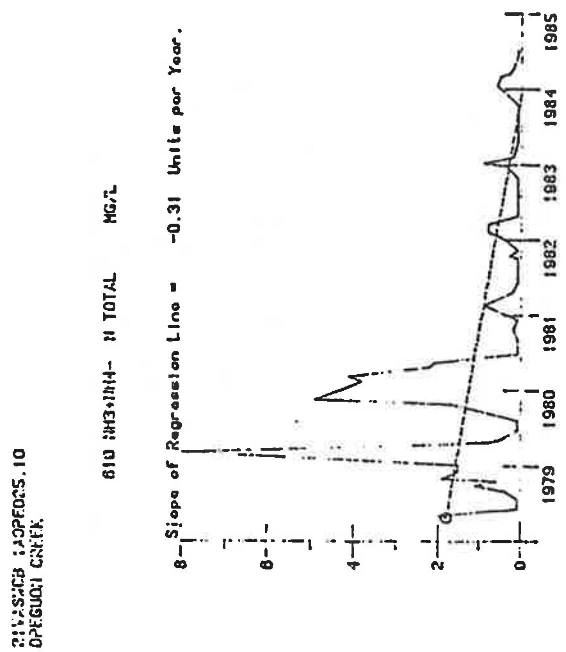



Figure II.34

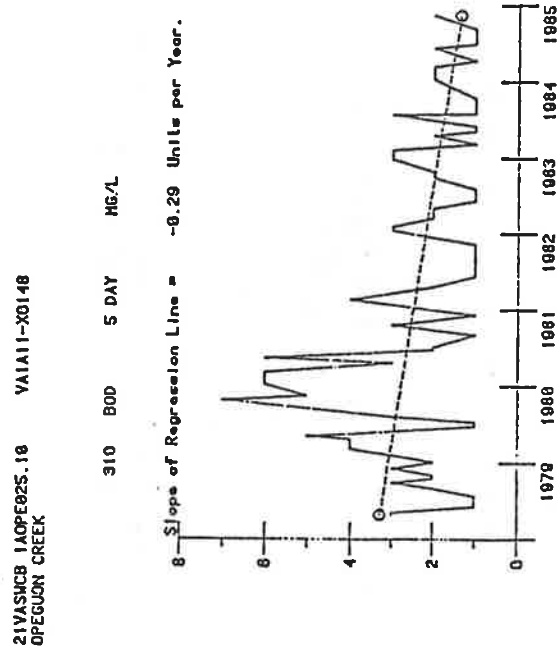



Figure II.35

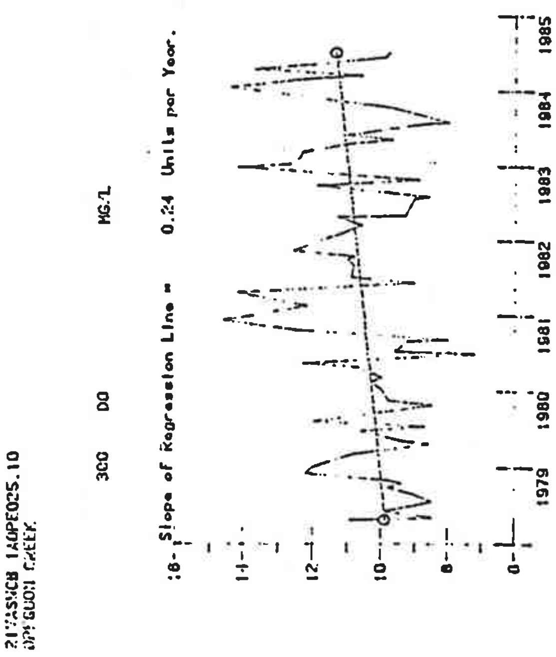



Figure II.36

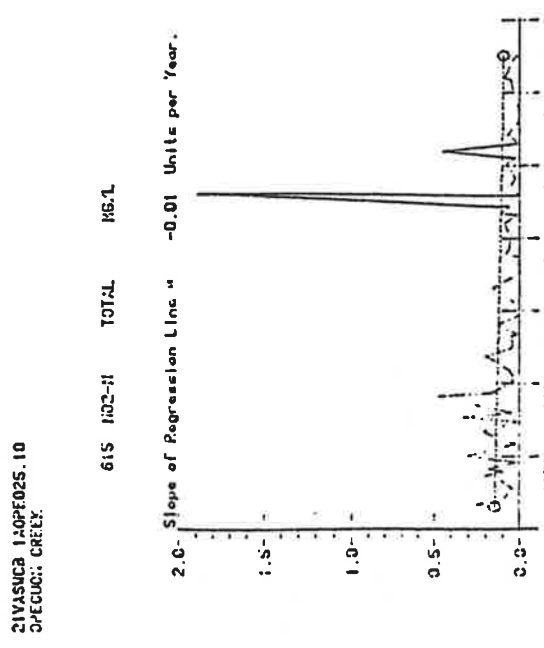


Figure II.37

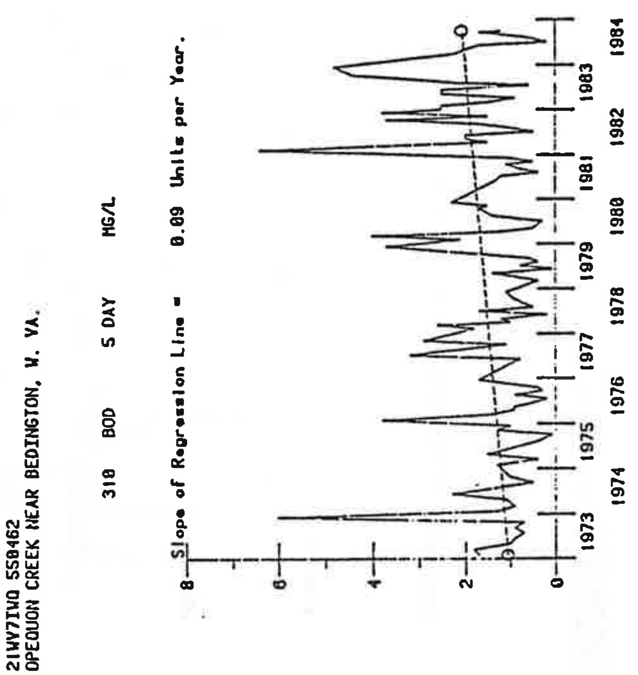



Figure II.38

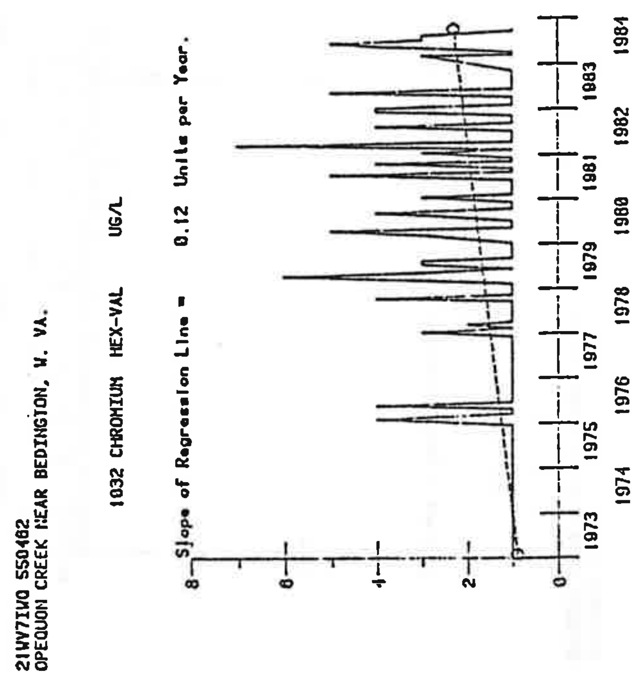



Figure II.39

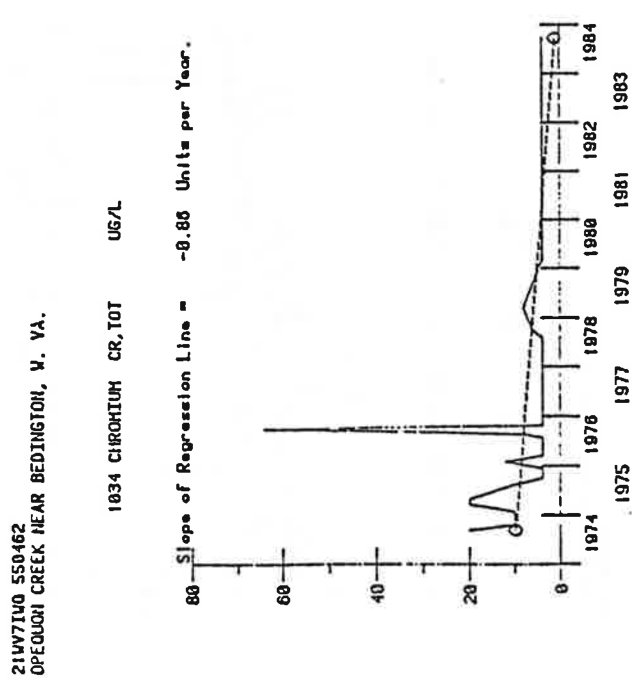



Figure II.40

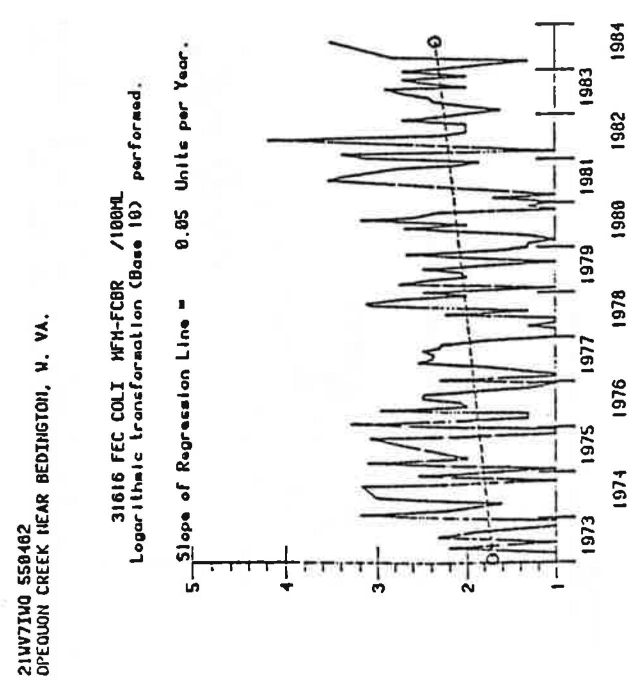


Figure II.41

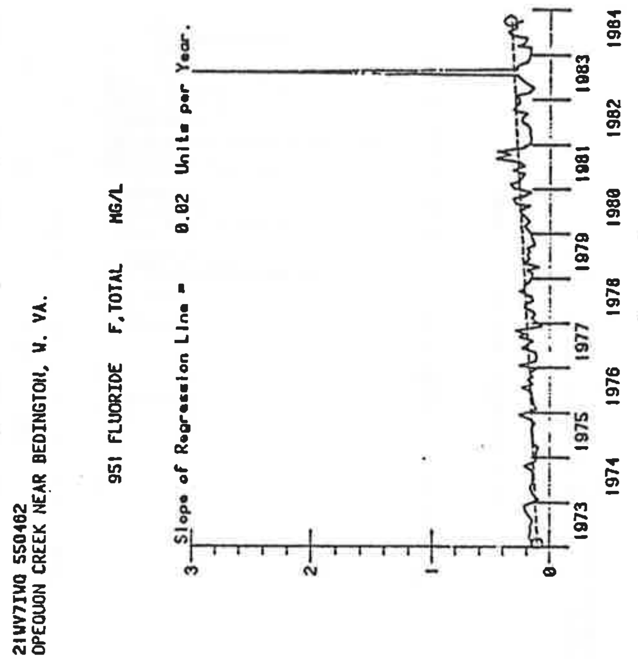



Figure II.42

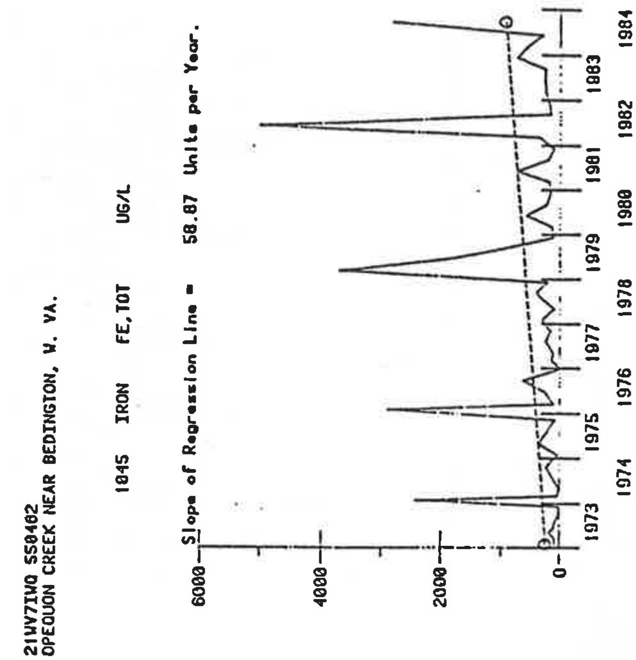



Figure II.43

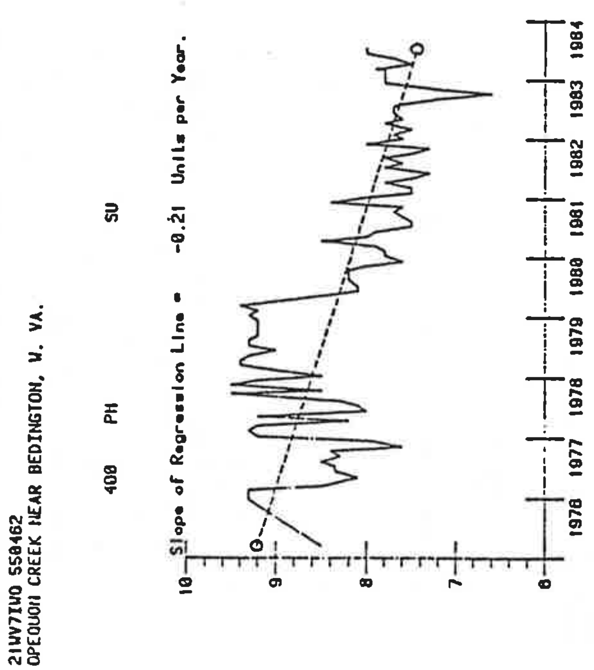



Figure II.44

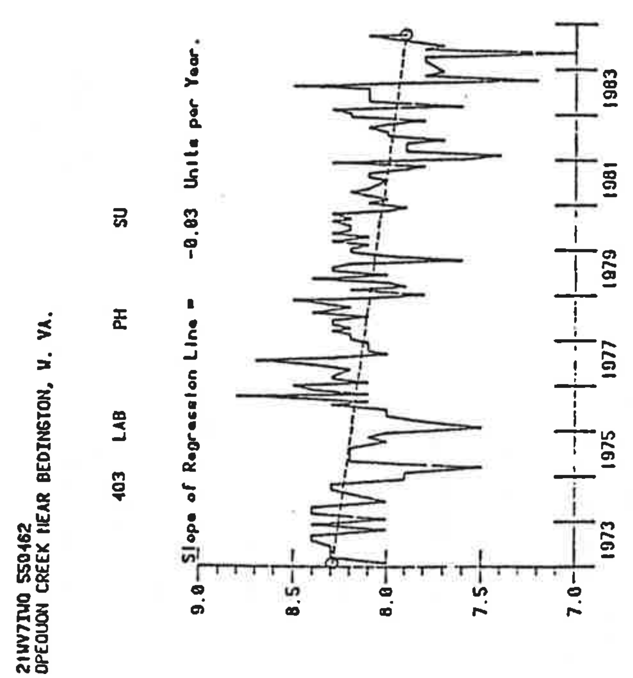


Figure II.45

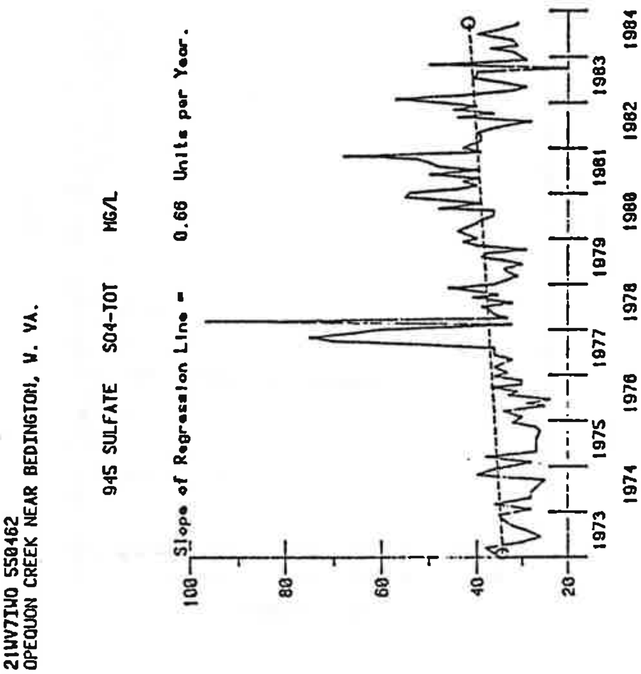



Figure II.46

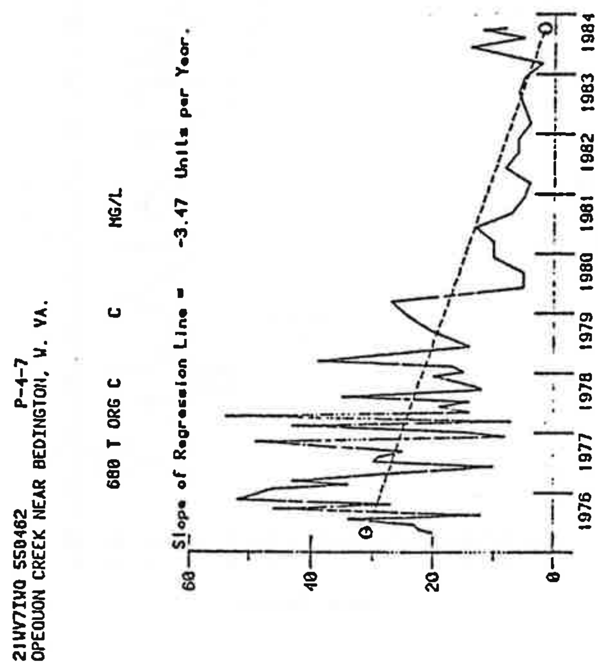



Figure II.47

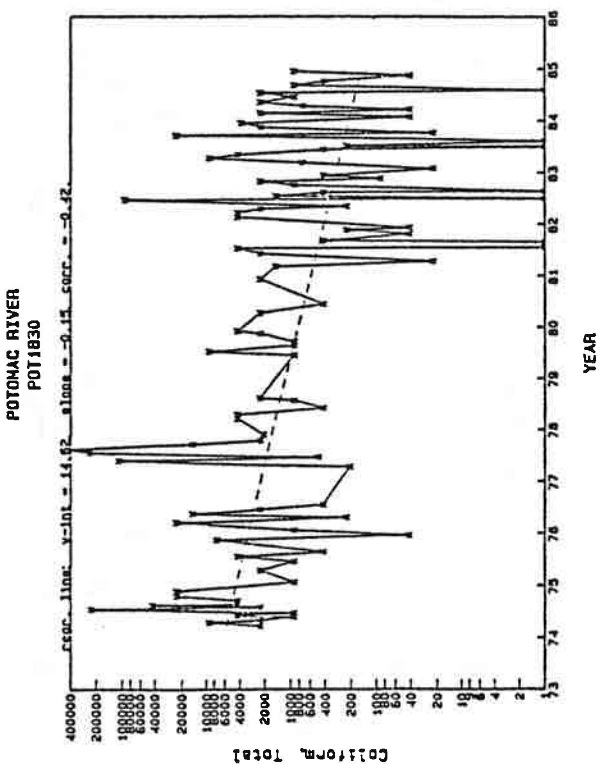



Figure II.48

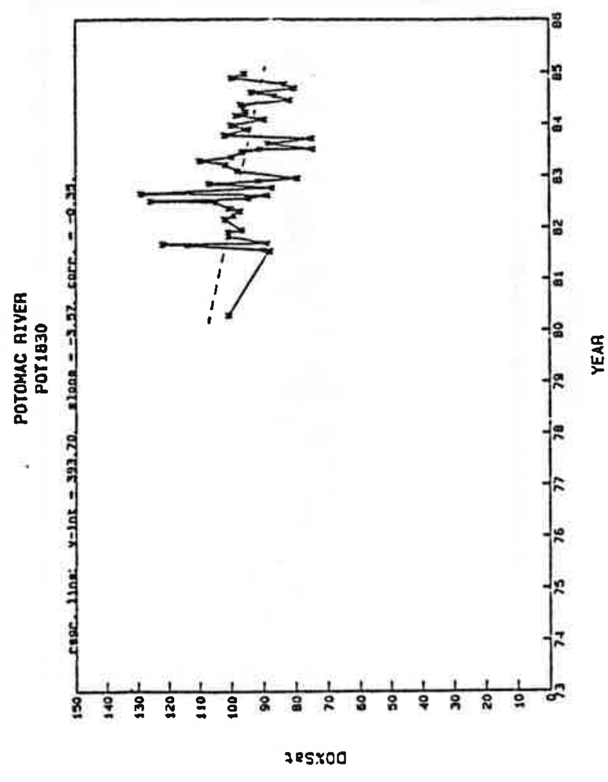


Figure II.49

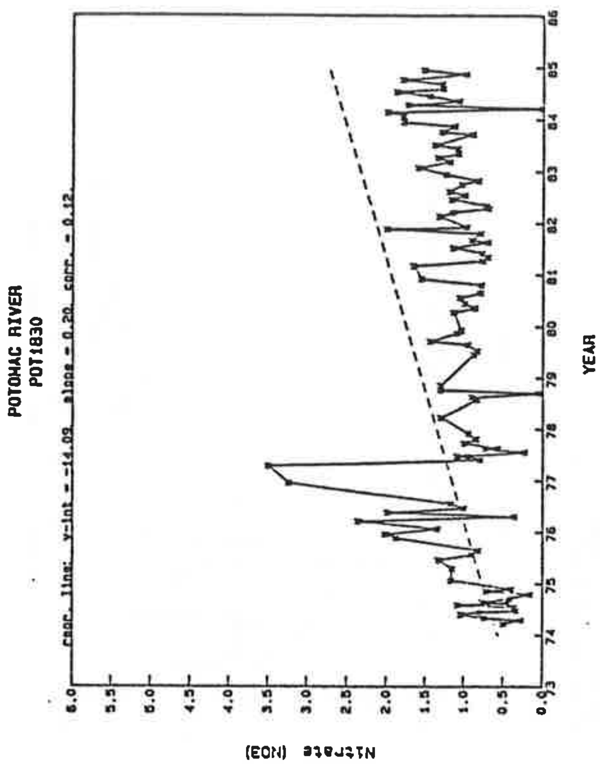



Figure II.50

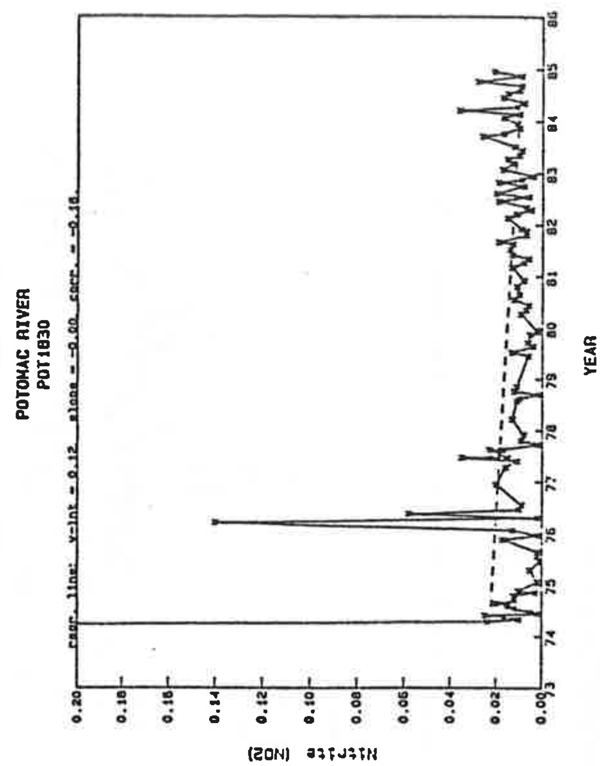



Figure II.51

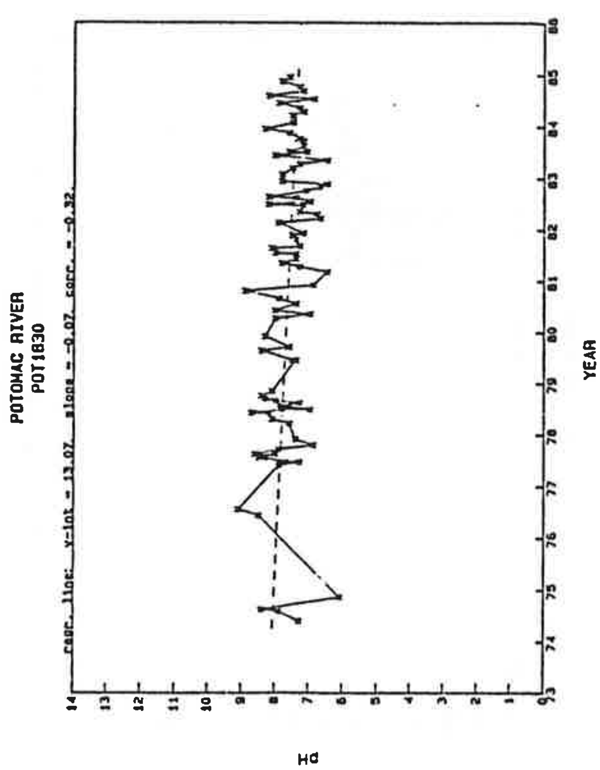



Figure II.52

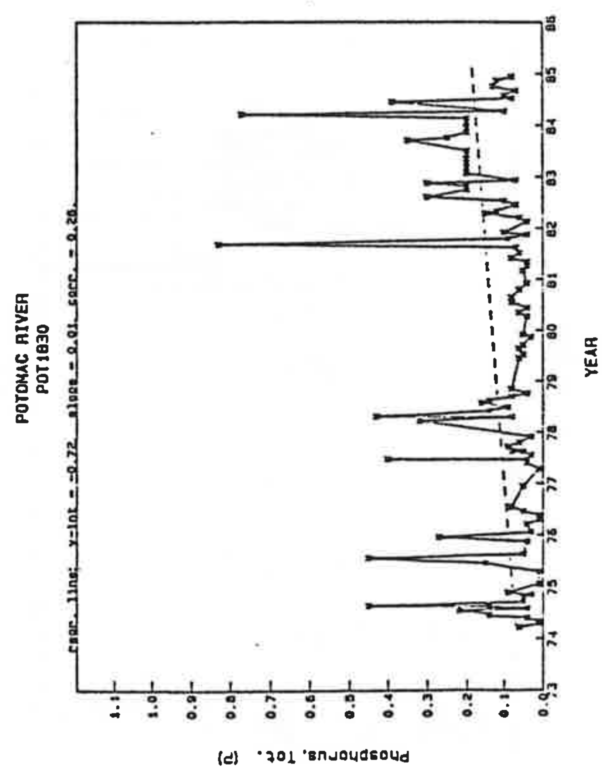


Figure II.53

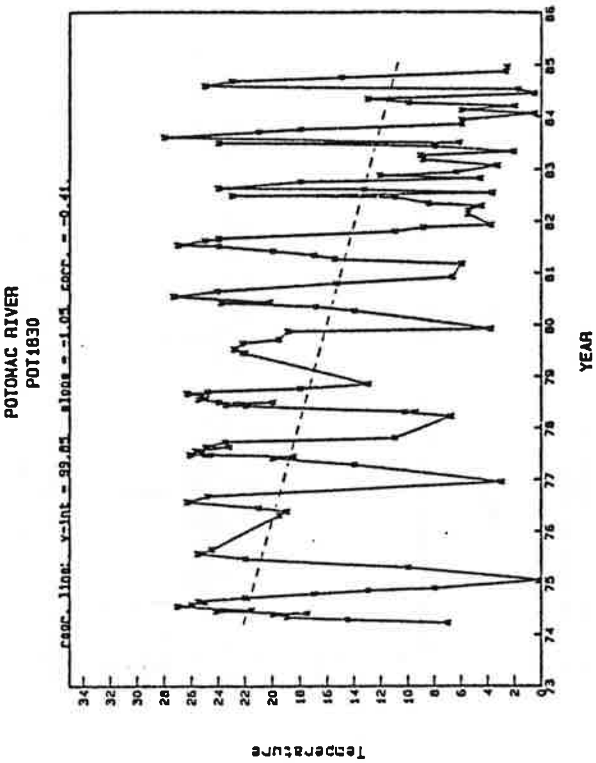



Figure II.54

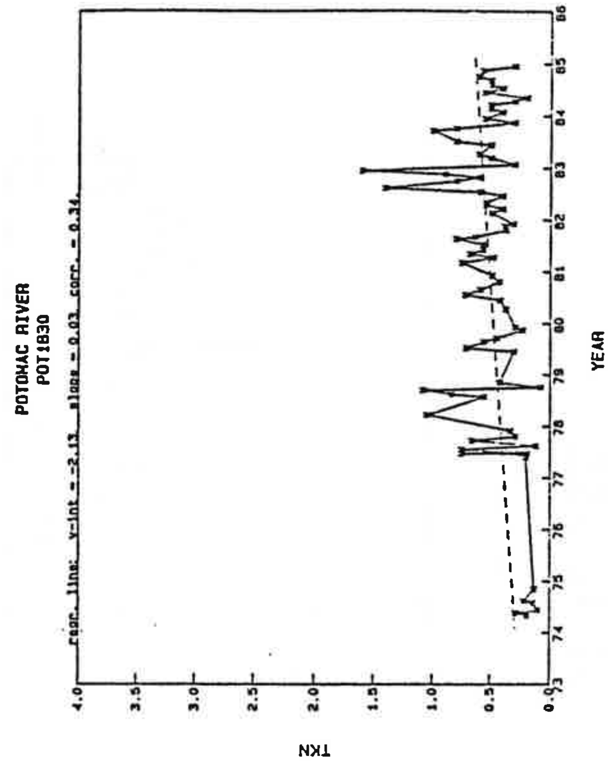



Figure II.55

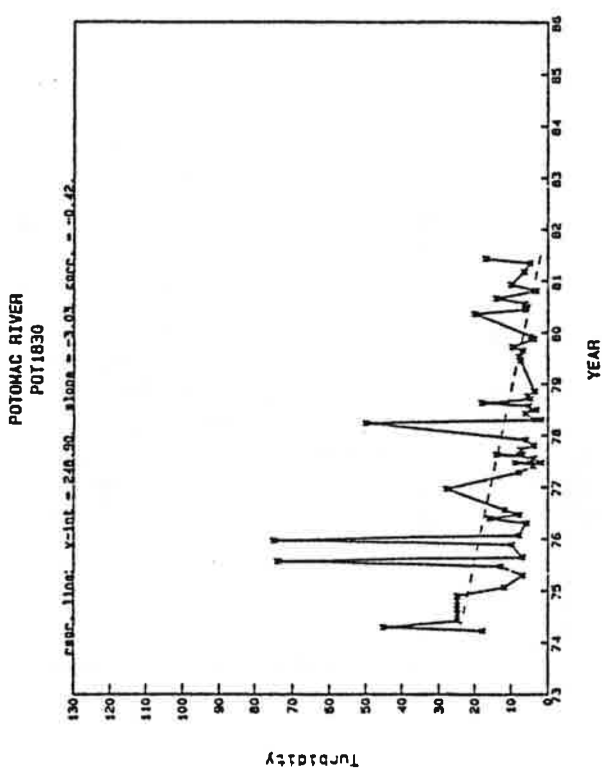



Figure II.56

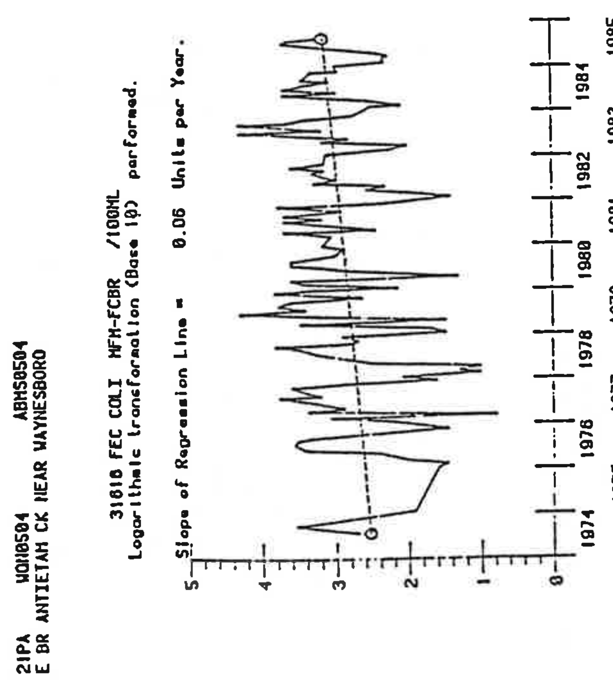


Figure II.57

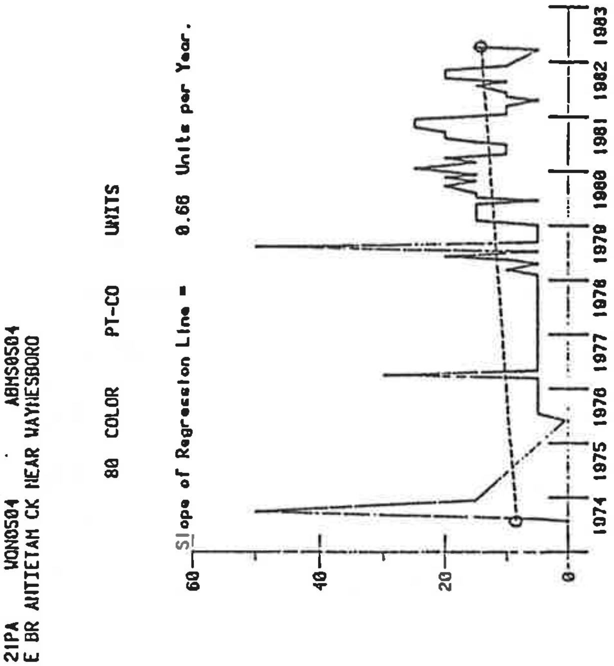



Figure II.58

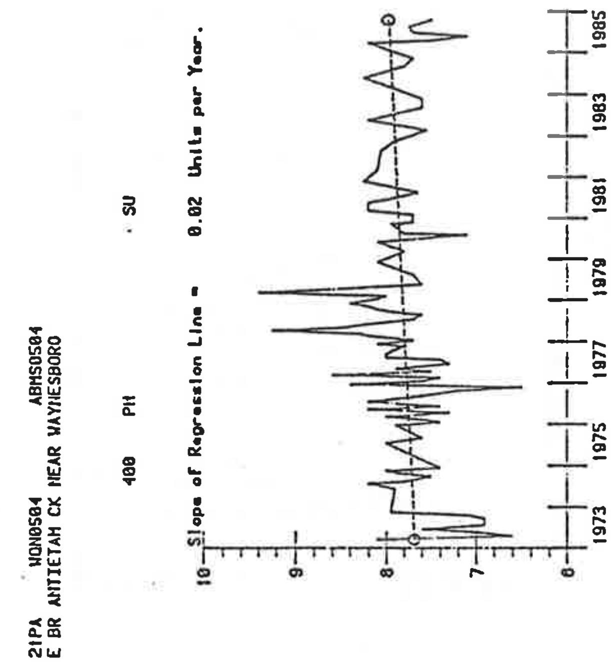



Figure II.59

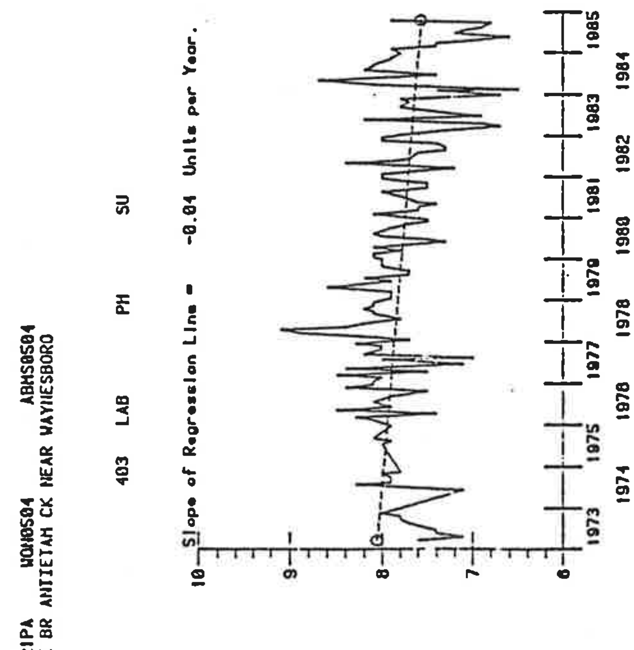



Figure II.60

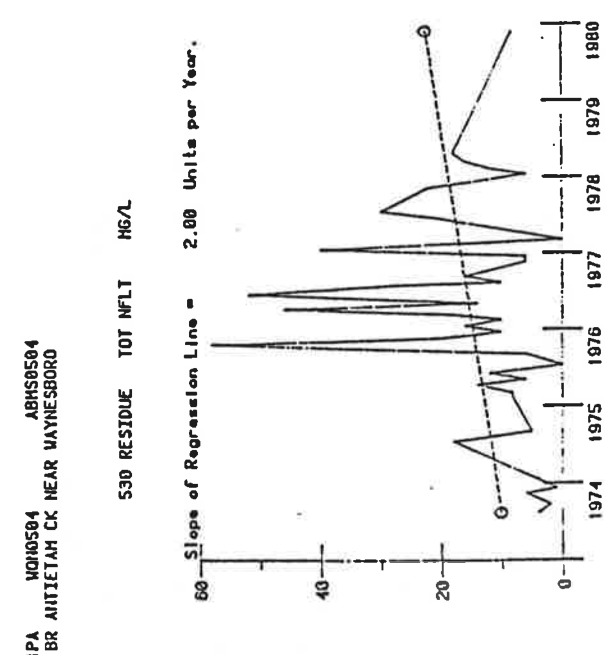


Figure II.61

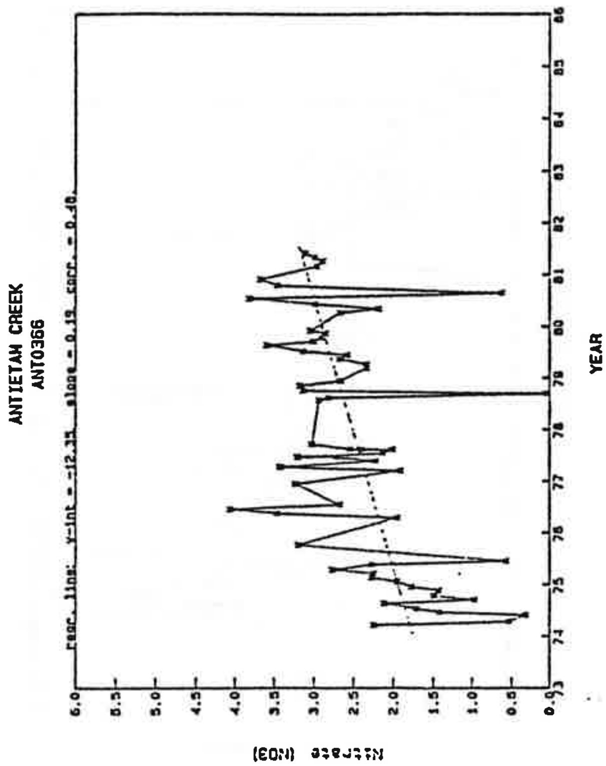



Figure II.62

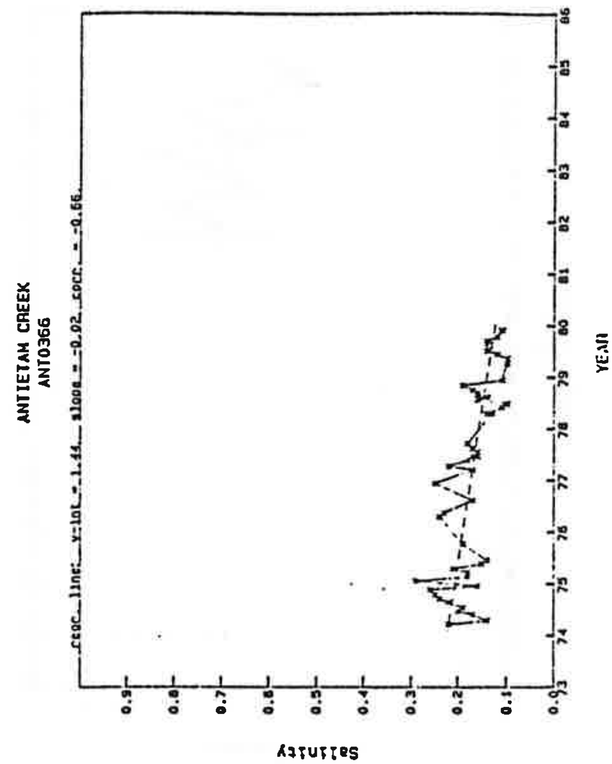



Figure II.63

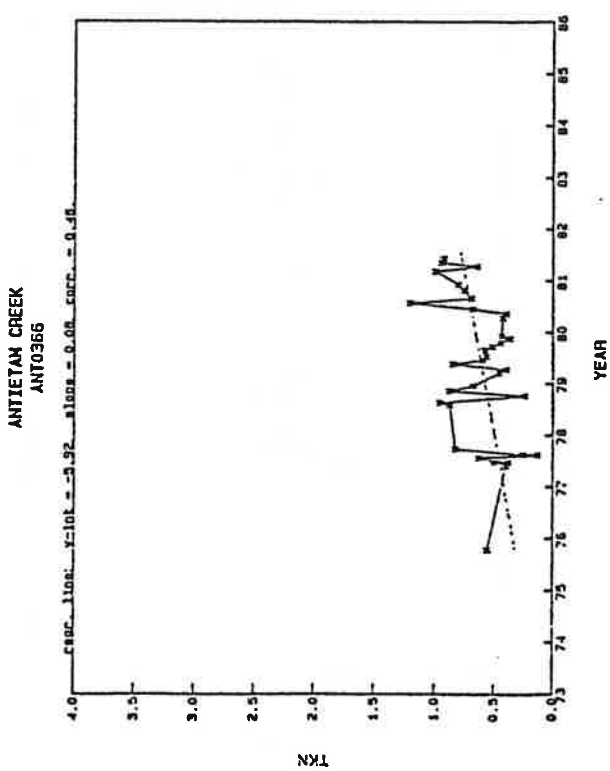



Figure II.64

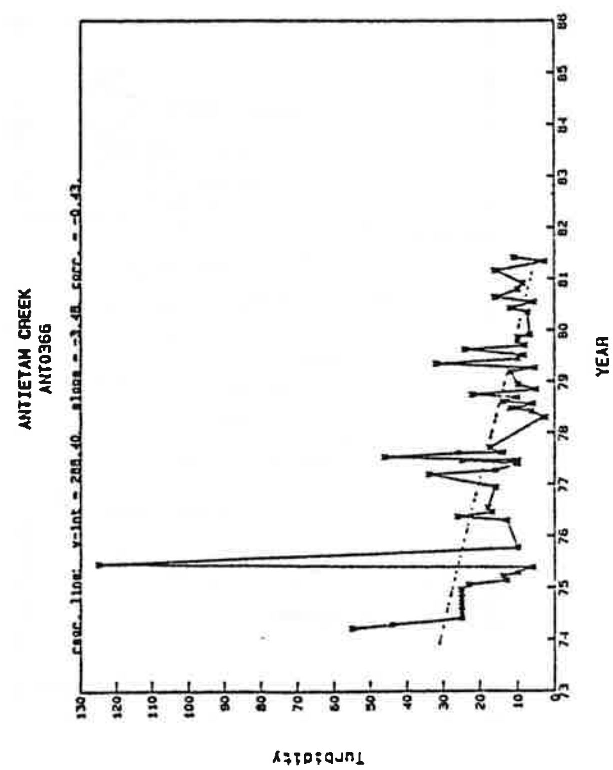


Figure II.65

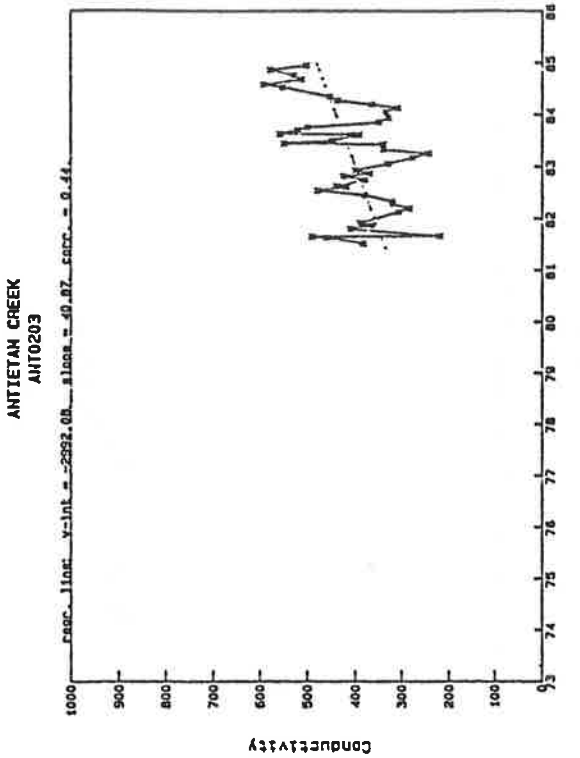



Figure II.66

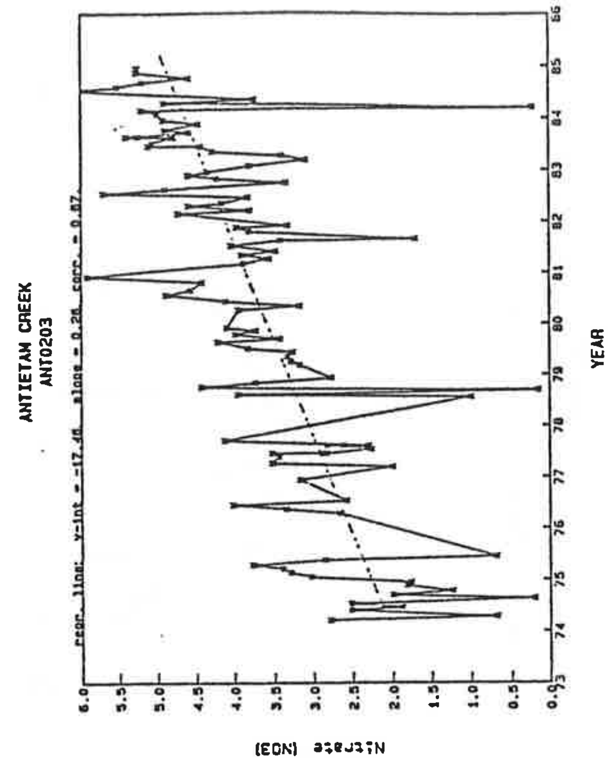



Figure II.67

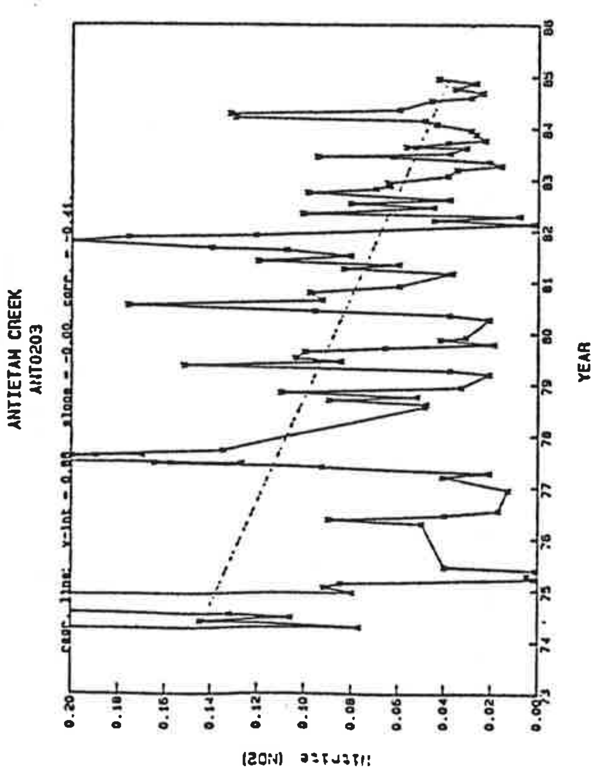



Figure II.68

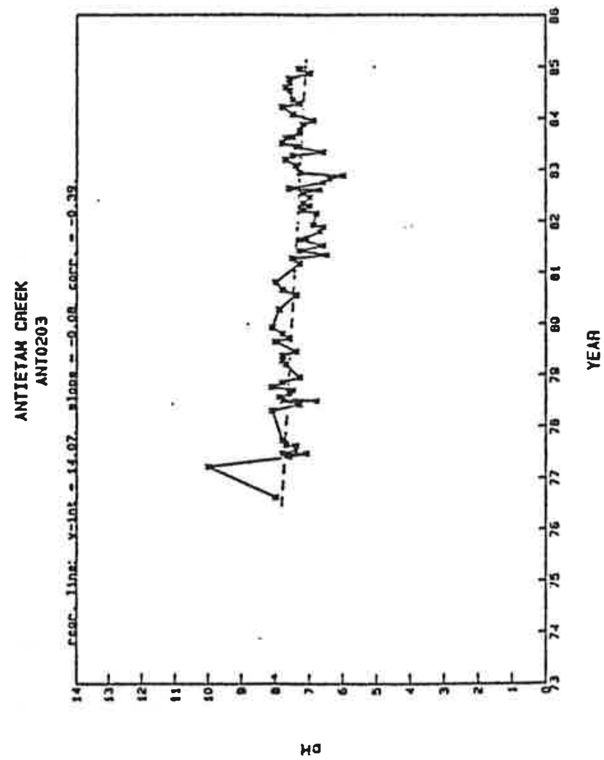


Figure II.69

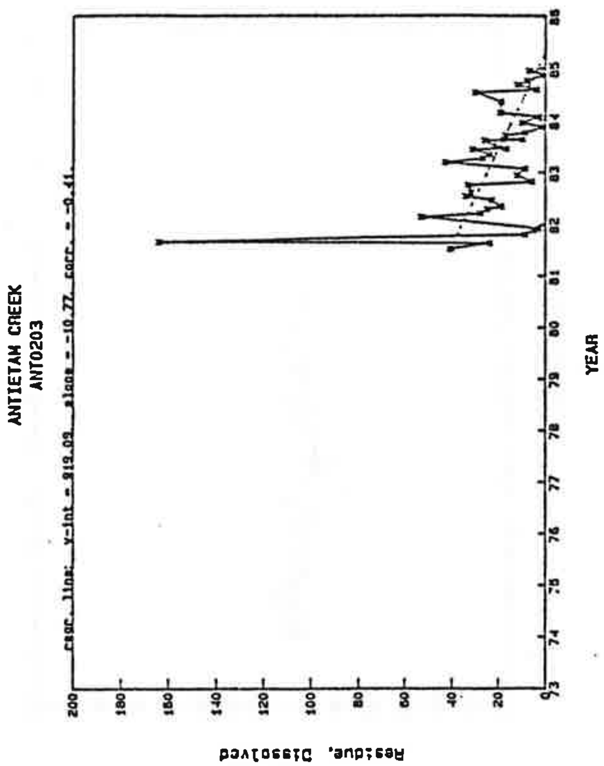



Figure II.70

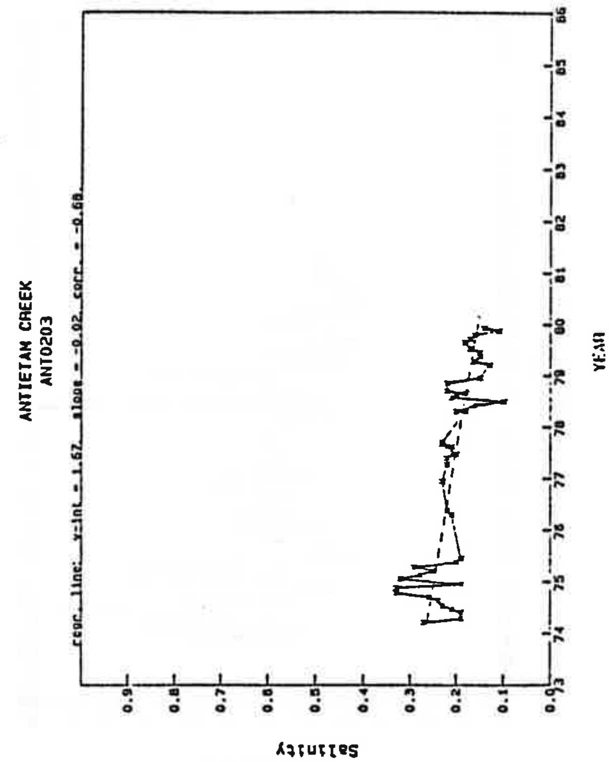



Figure II.71

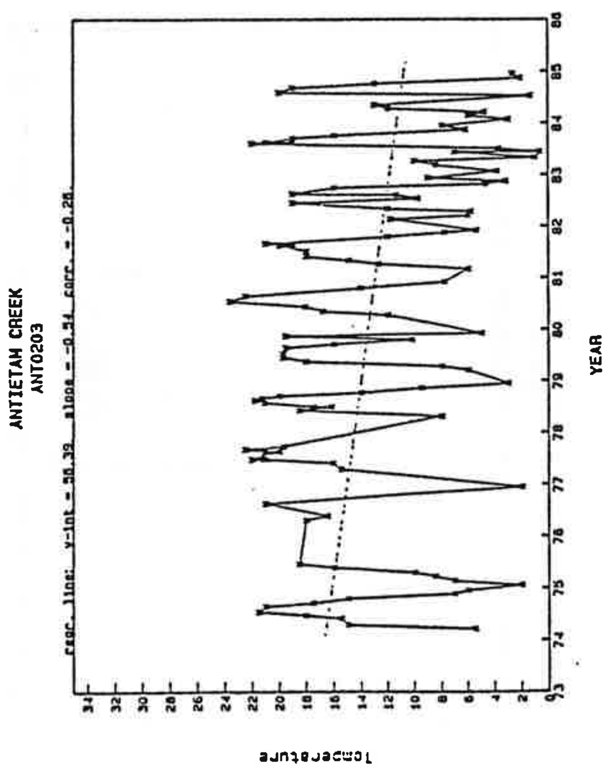



Figure II.72

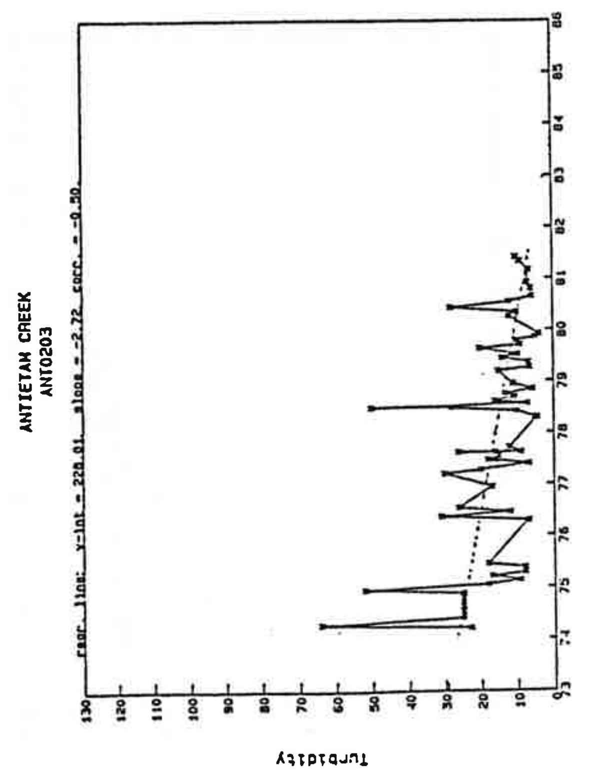


Figure II.73

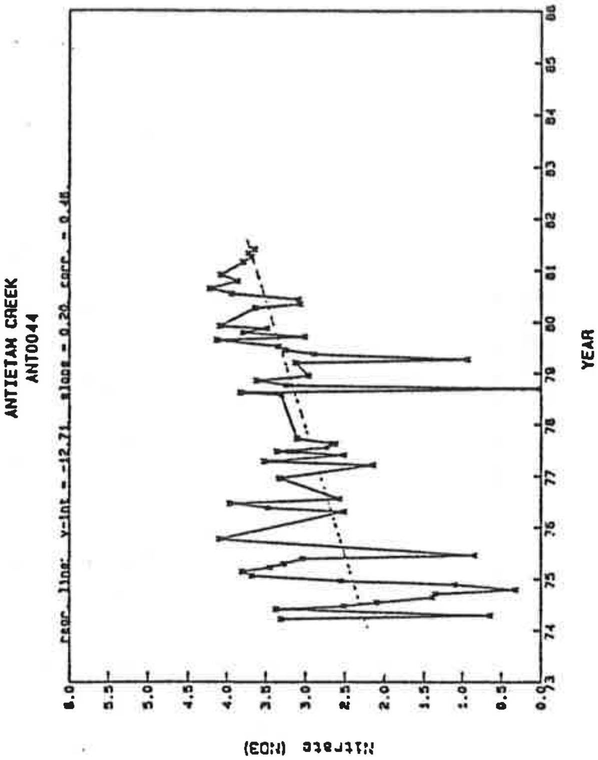



Figure II.74

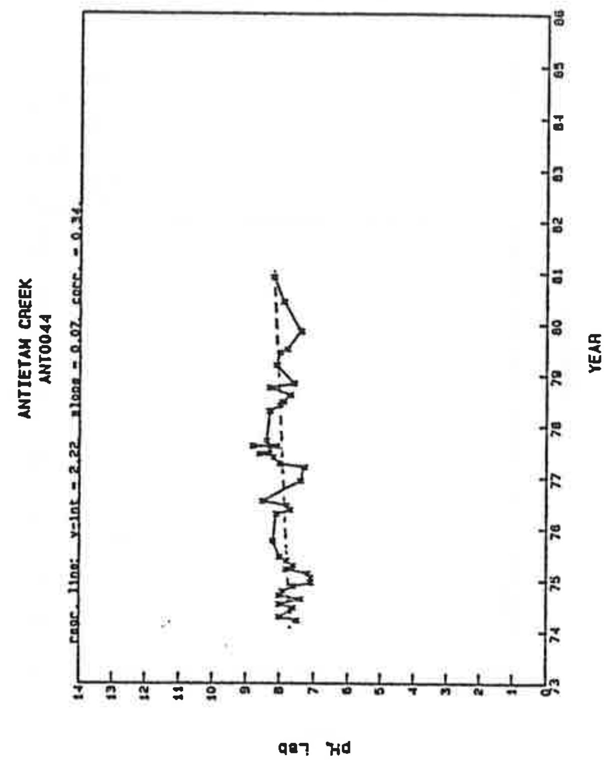



Figure II.75

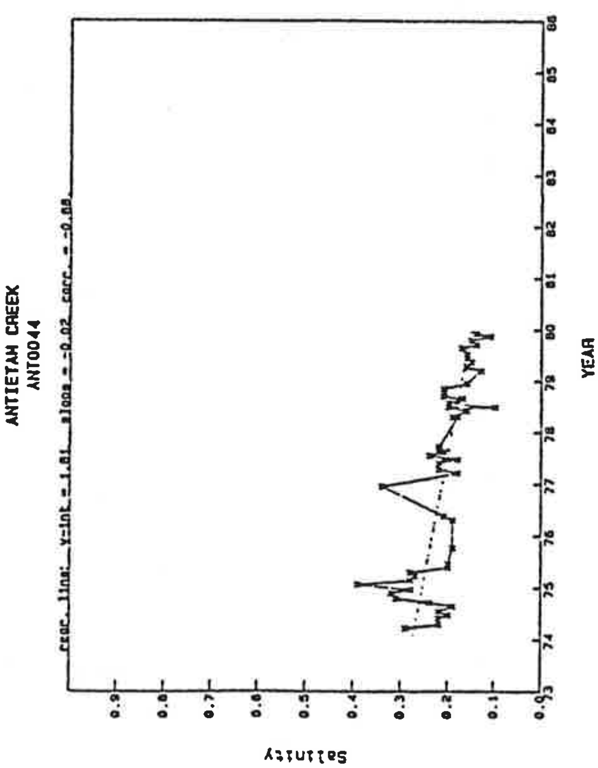



Figure II.76

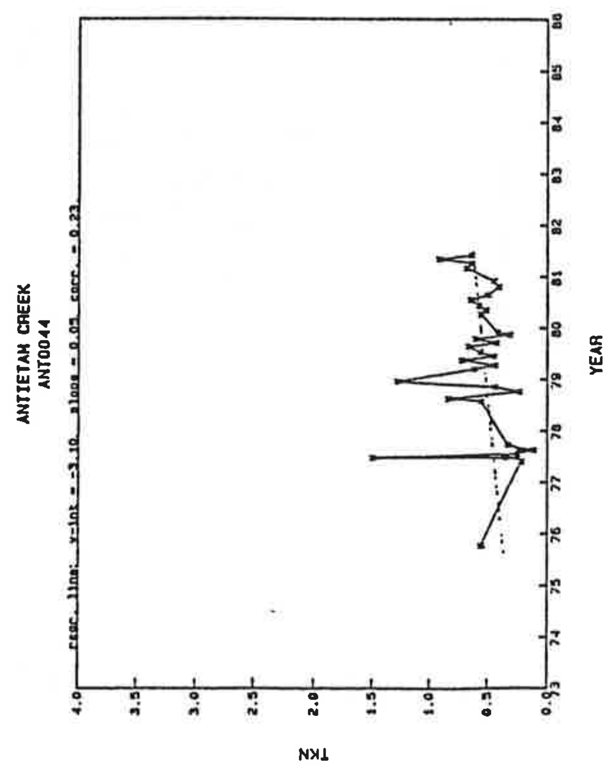
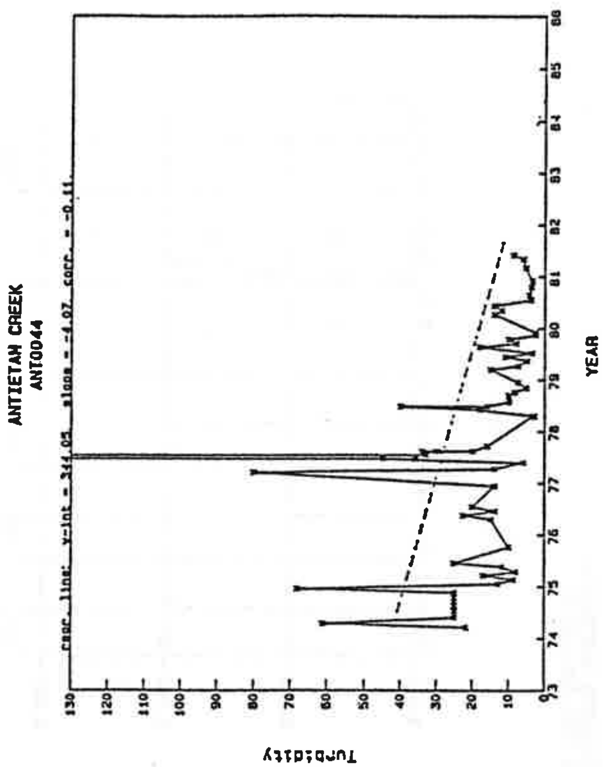


Figure II.77



ANTIETAN CREEK
ANT0044
regr. line: y-int = 314.05 slope = -4.07 corr. = -0.11
Turbidity
130
120
110
100
90
80
70
60
50
40
30
20
10
0
73
74
75
76
77
78
79
80
81
82
83
84
85
86
YEAR

Figure III.1

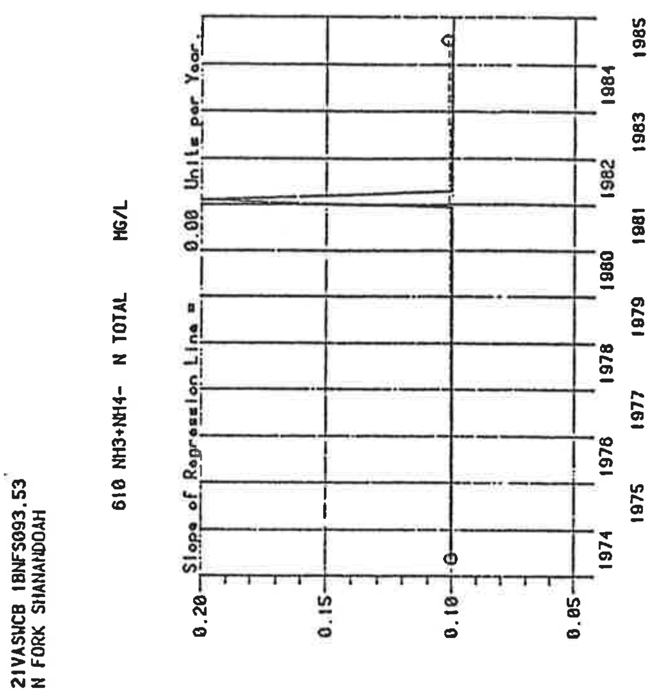



Figure III.2

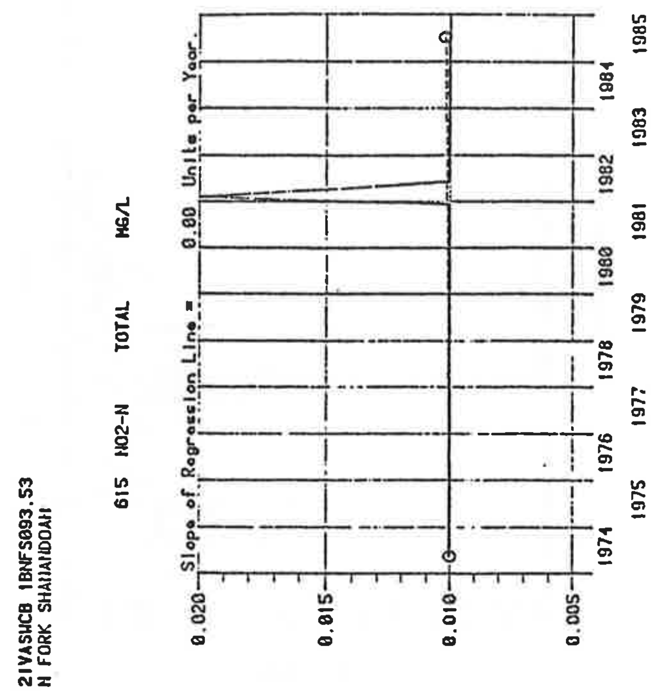



Figure III.3

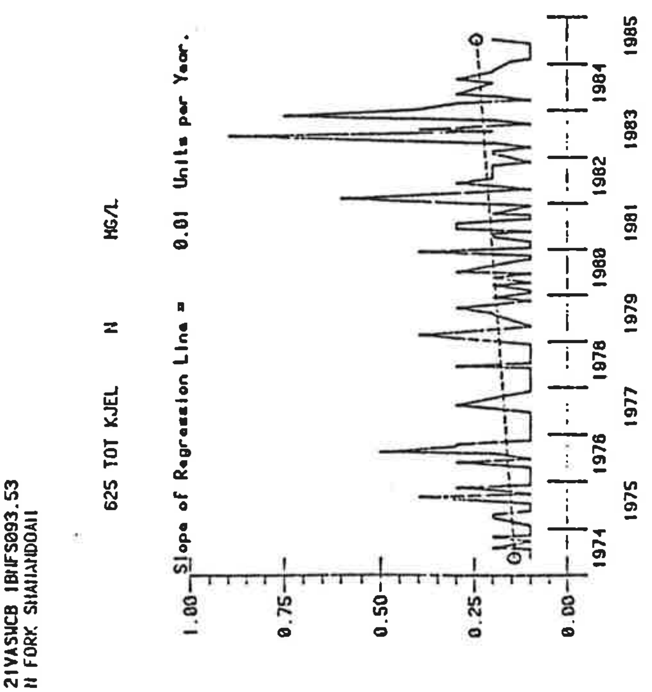



Figure III.4

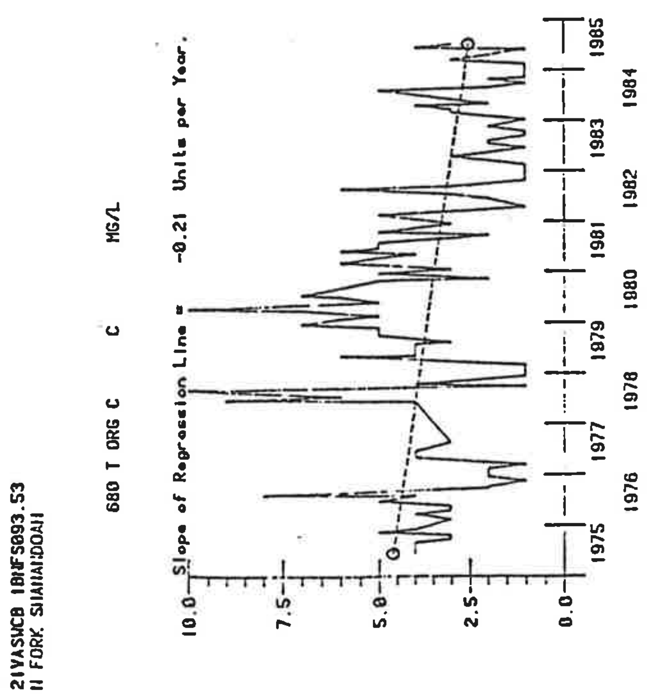


Figure III.5

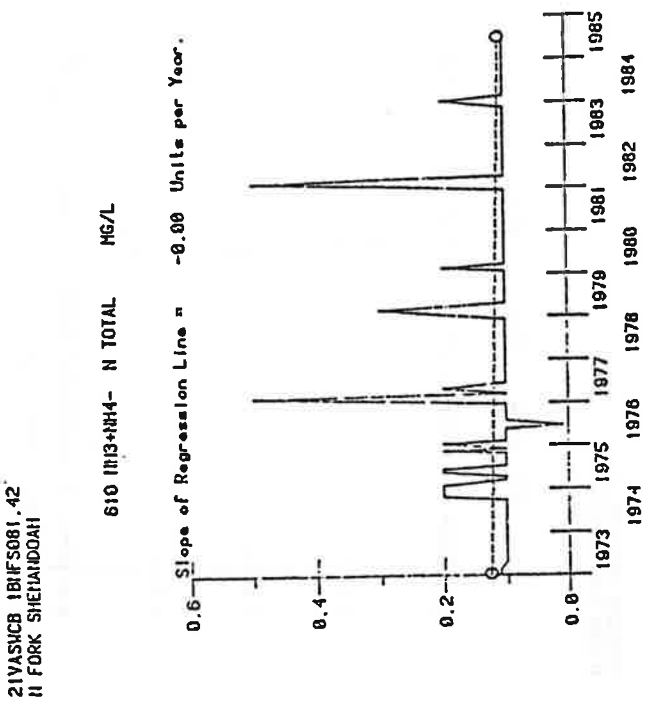



Figure III.6

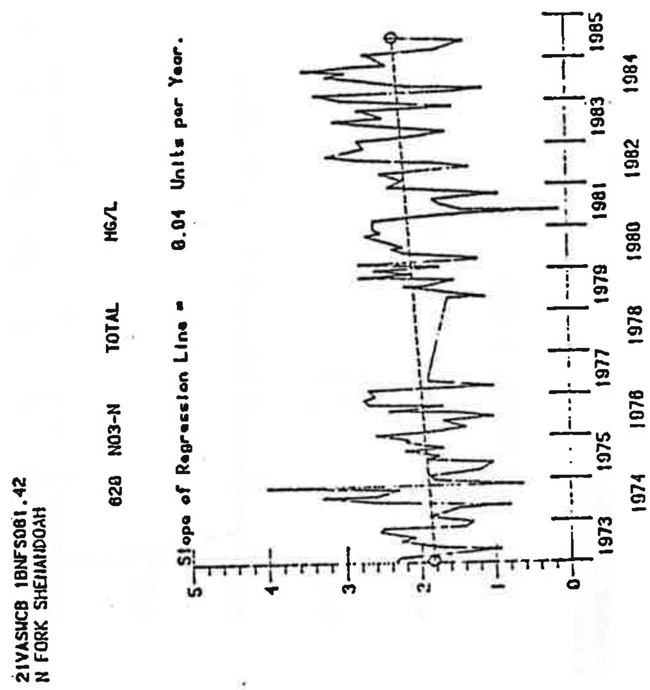



Figure III.7

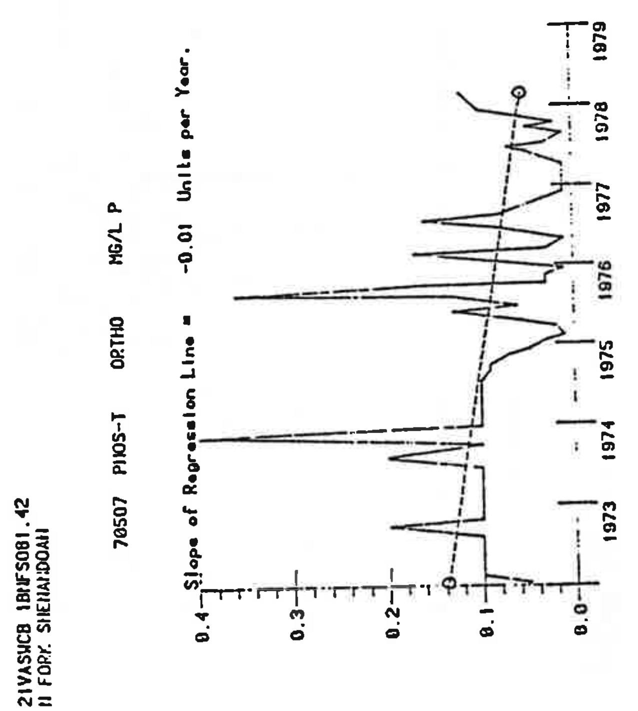



Figure III.8

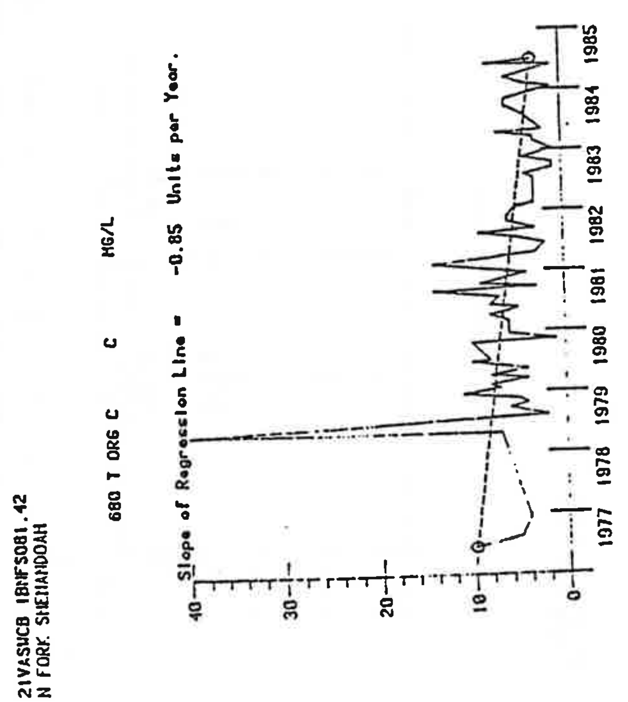


Figure III.9

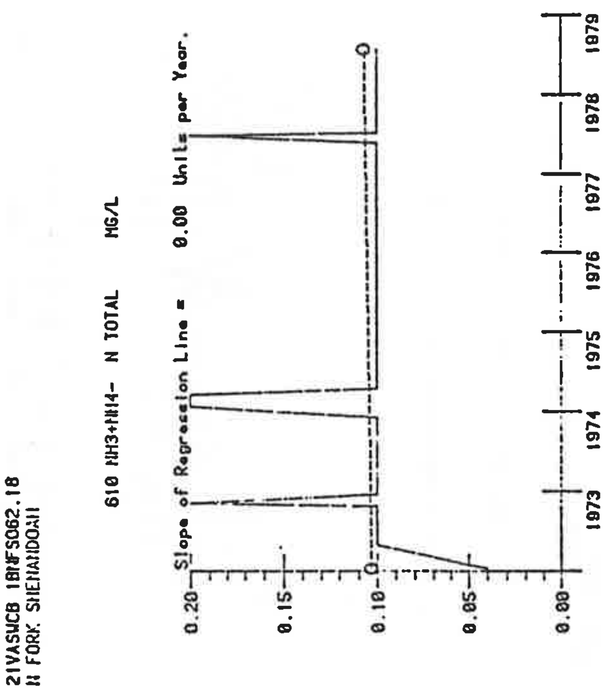



Figure III.10

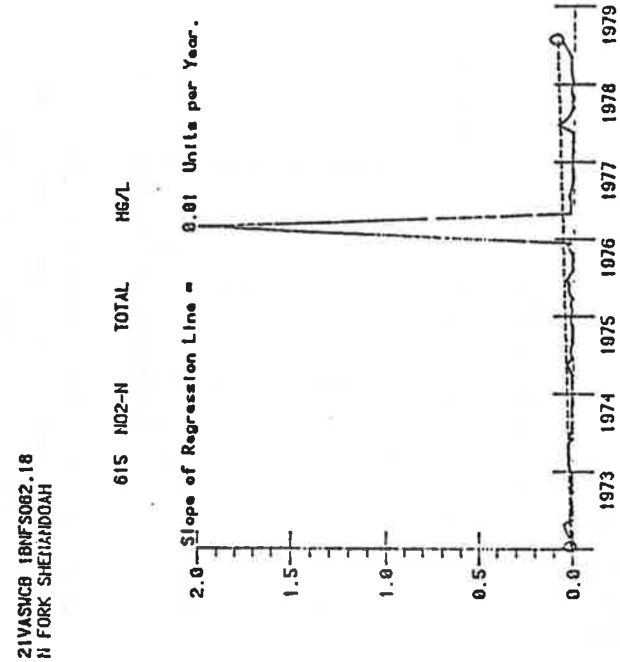



Figure III.11

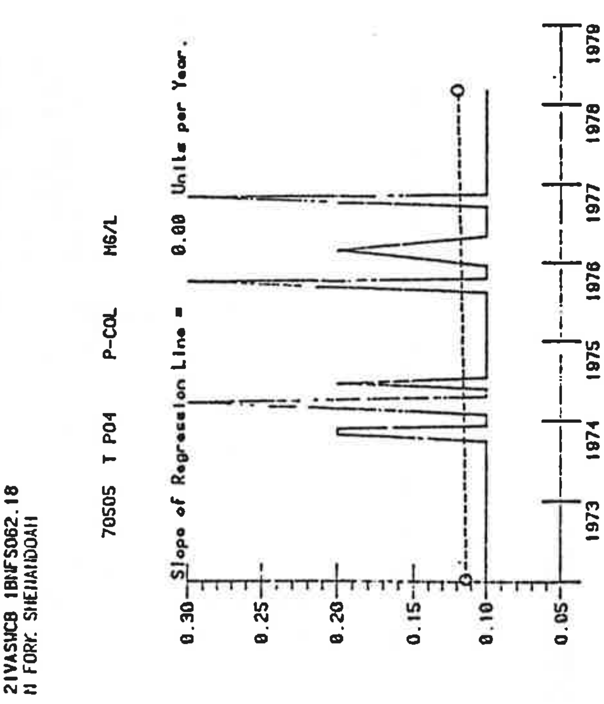



Figure III.12

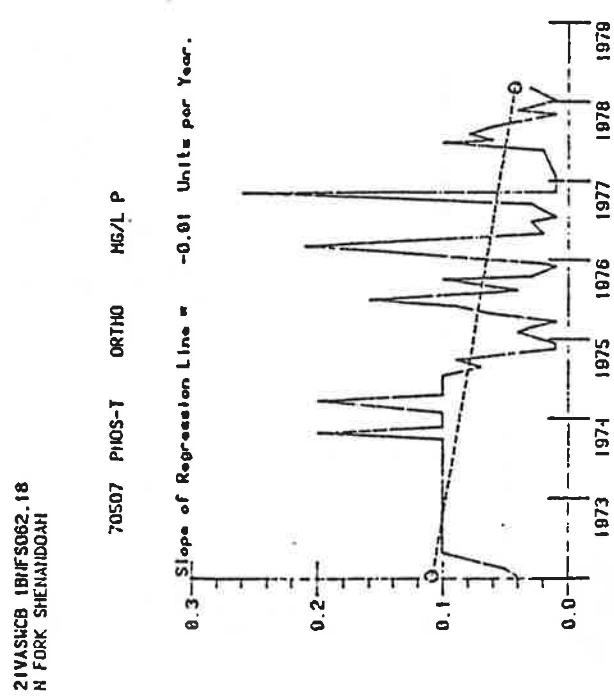


Figure III.13

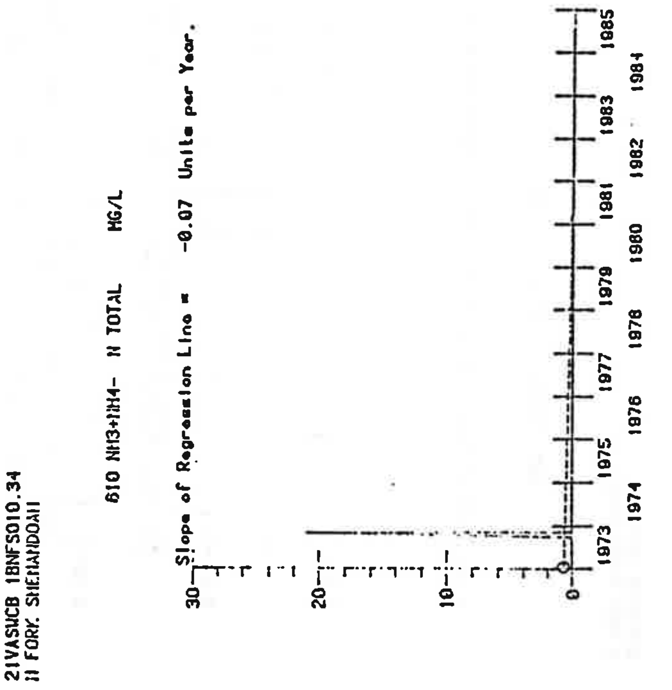



Figure III.14

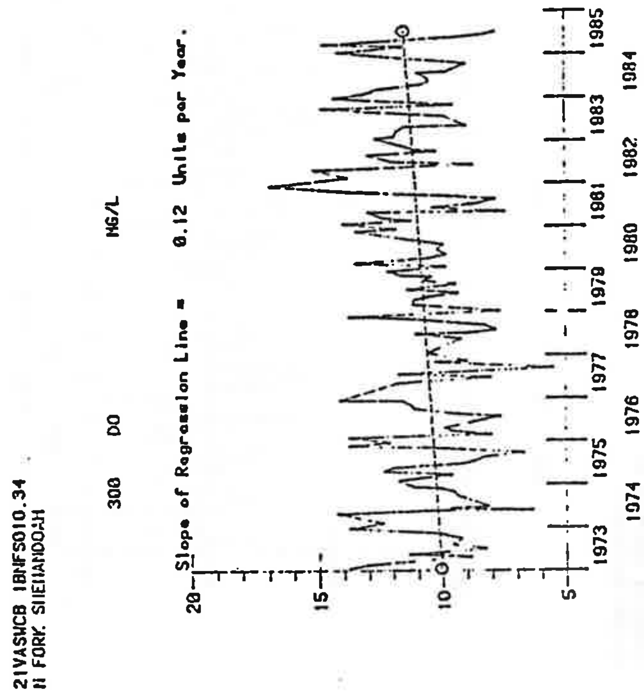



Figure III.15

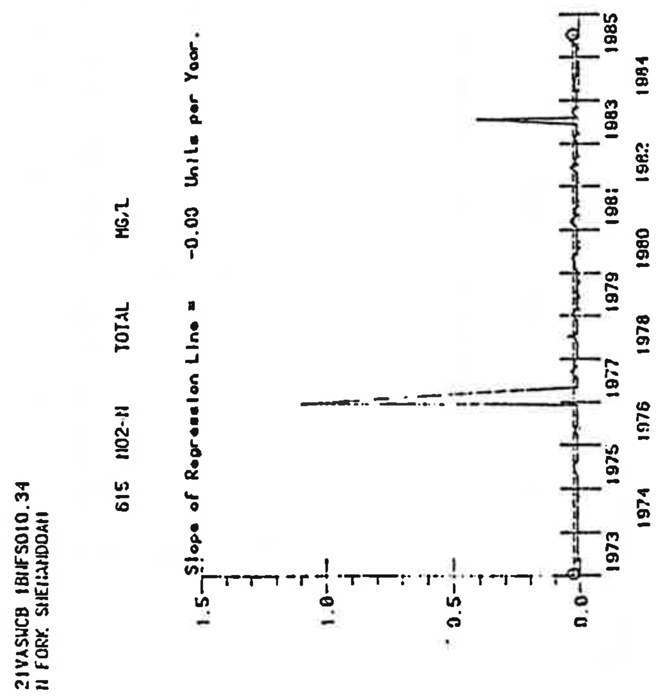



Figure III.16

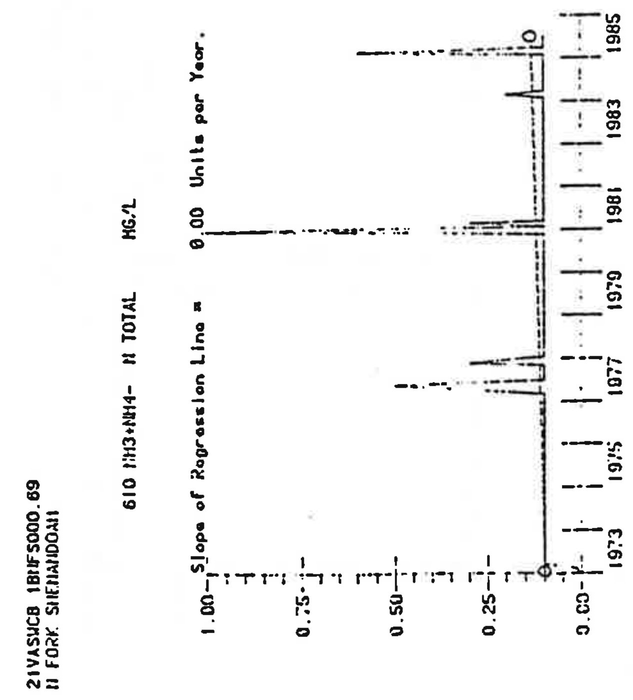


Figure III.17

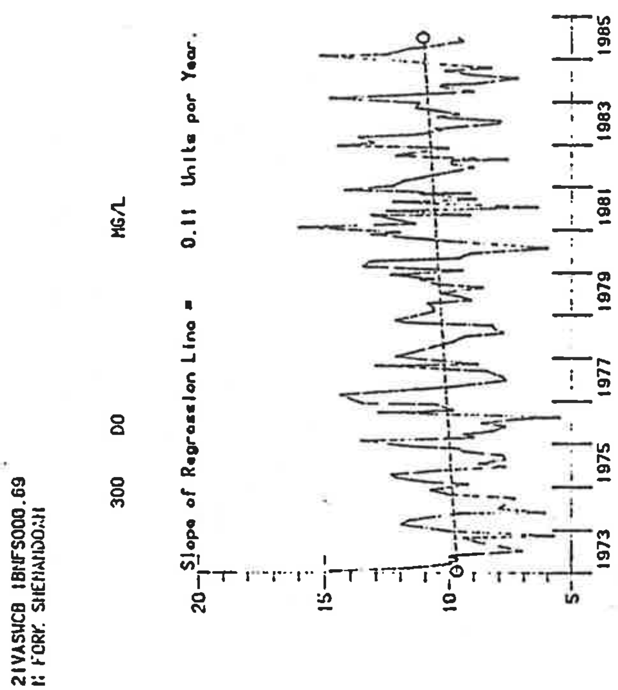



Figure III.18

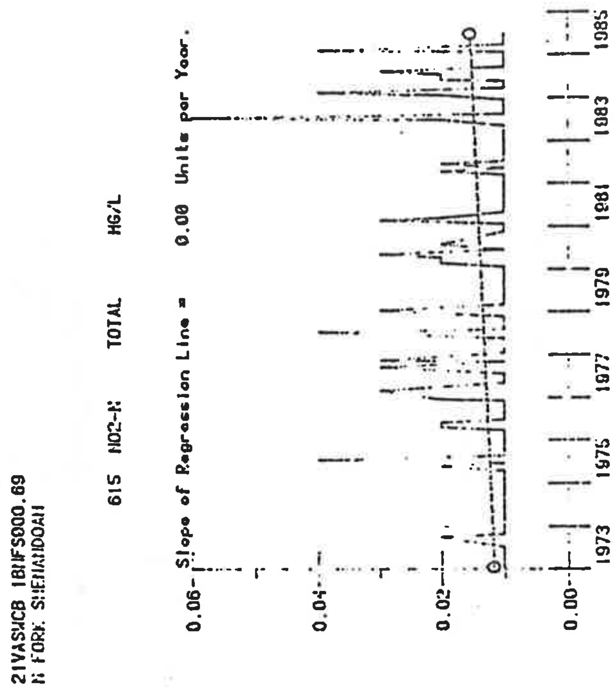



Figure III.19

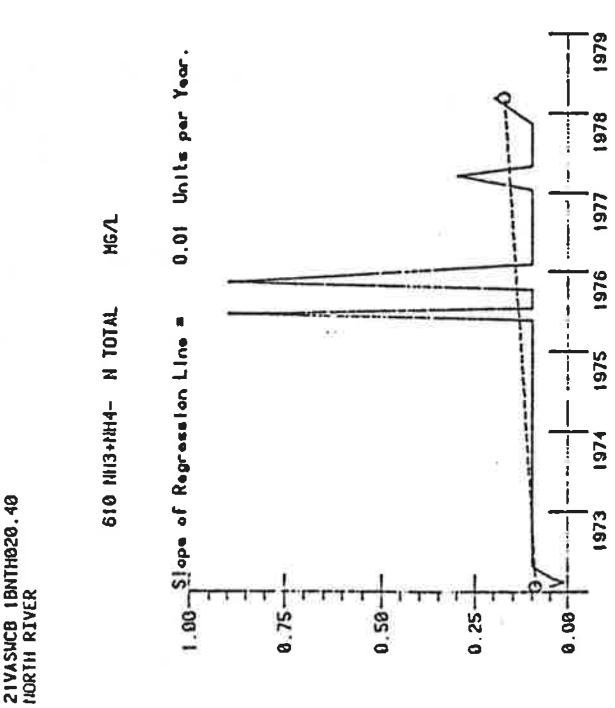



Figure III.20

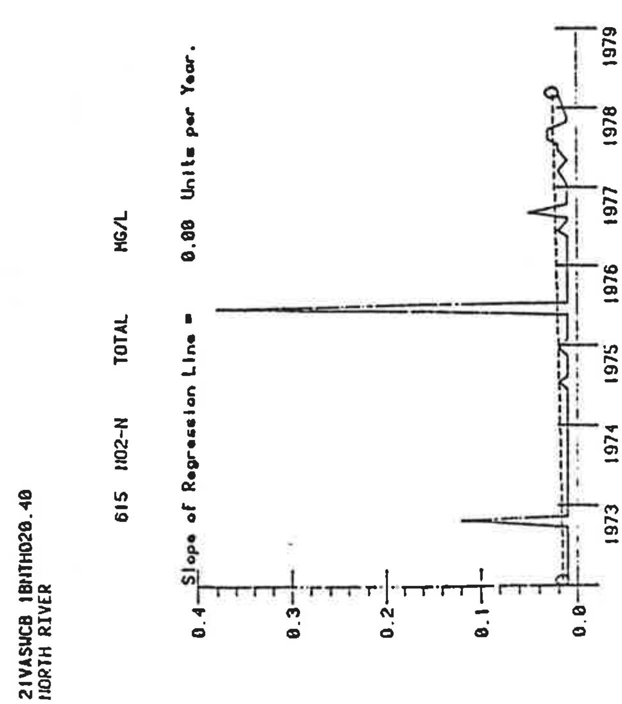


Figure III.21

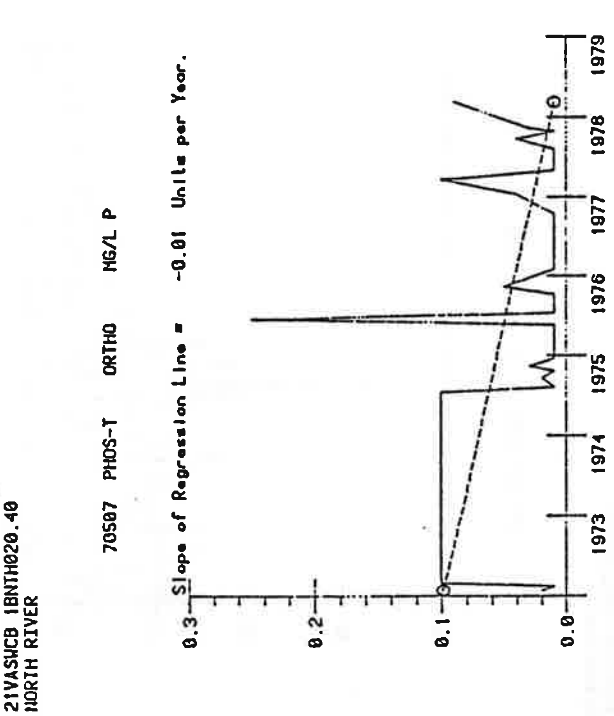



Figure III.22

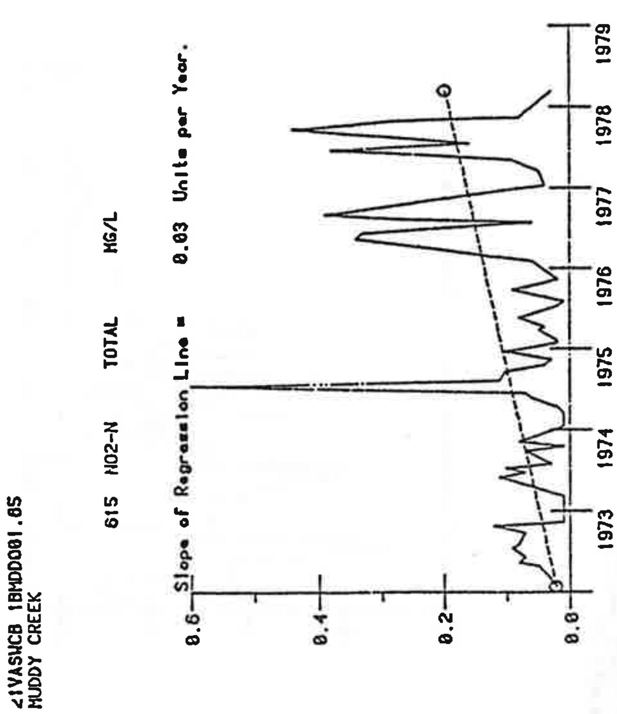



Figure III.23

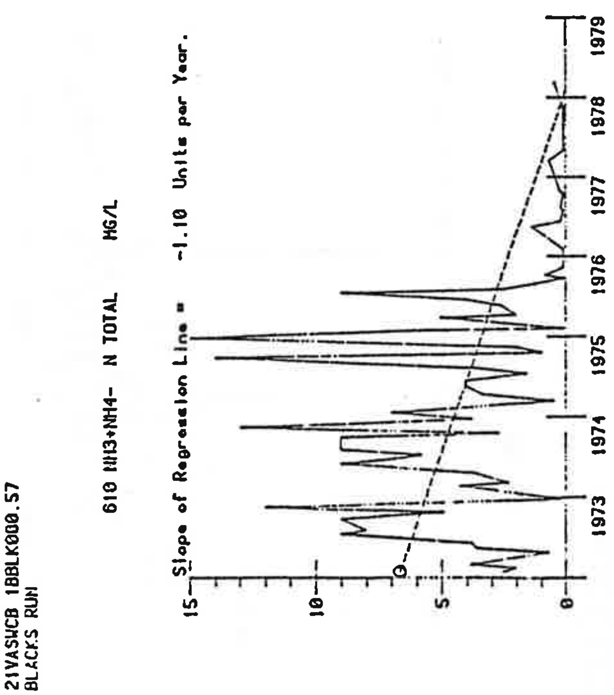



Figure III.24

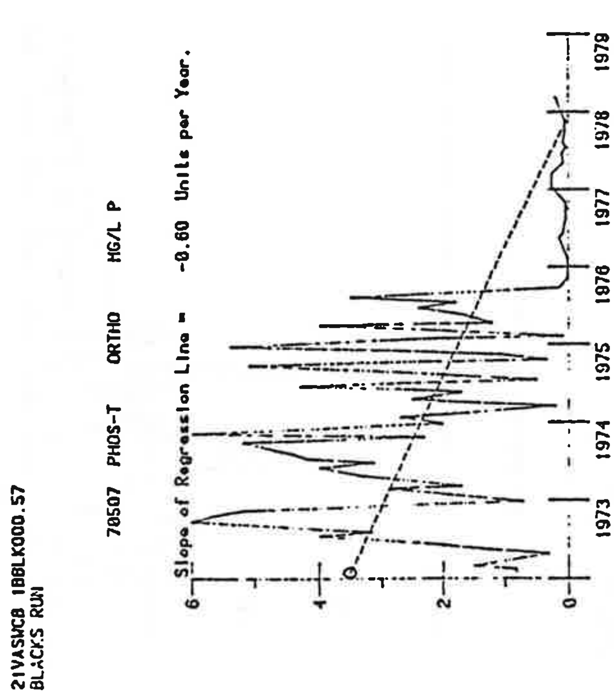


Figure III.25

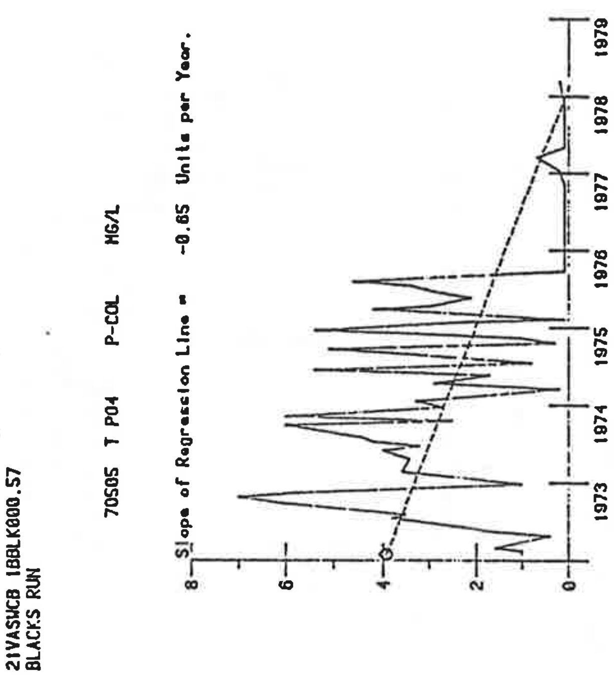



Figure III.26

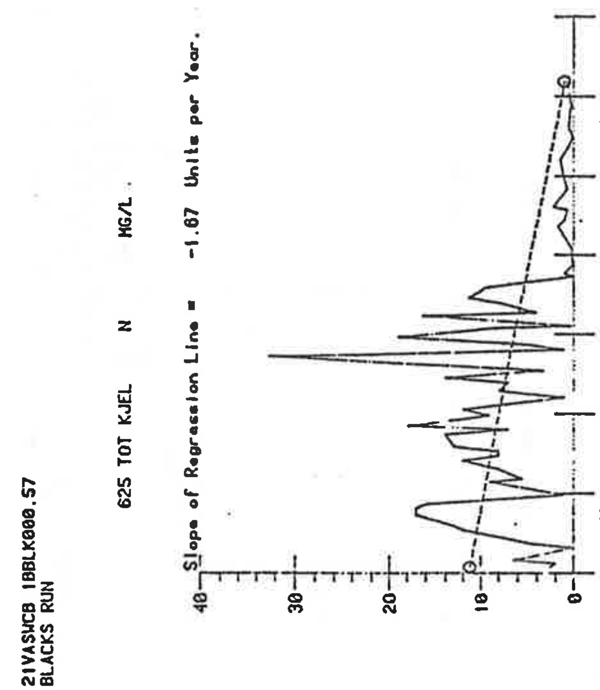



Figure III.27

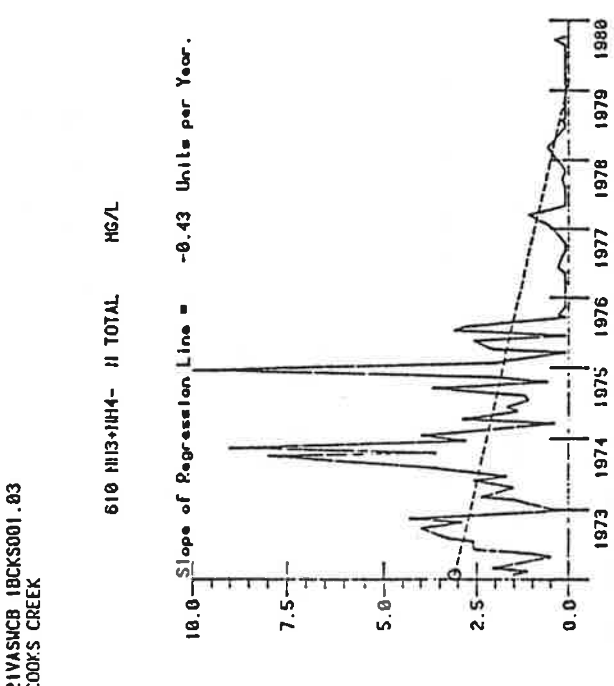



Figure III.28

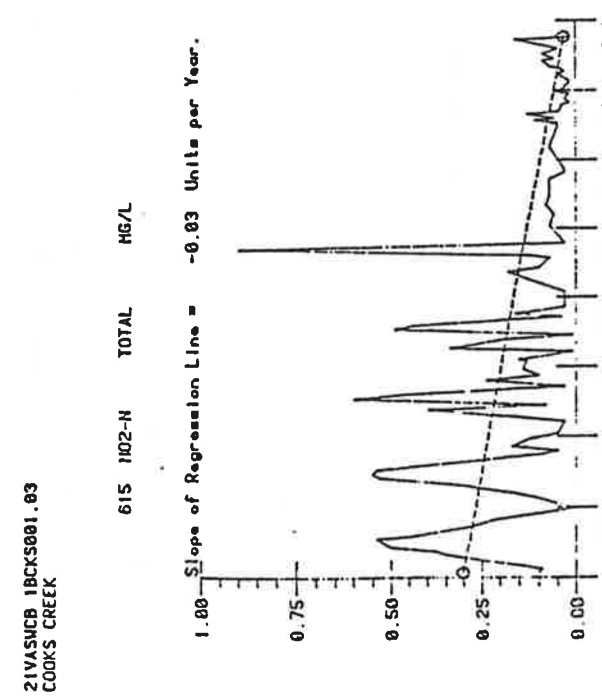


Figure III.29

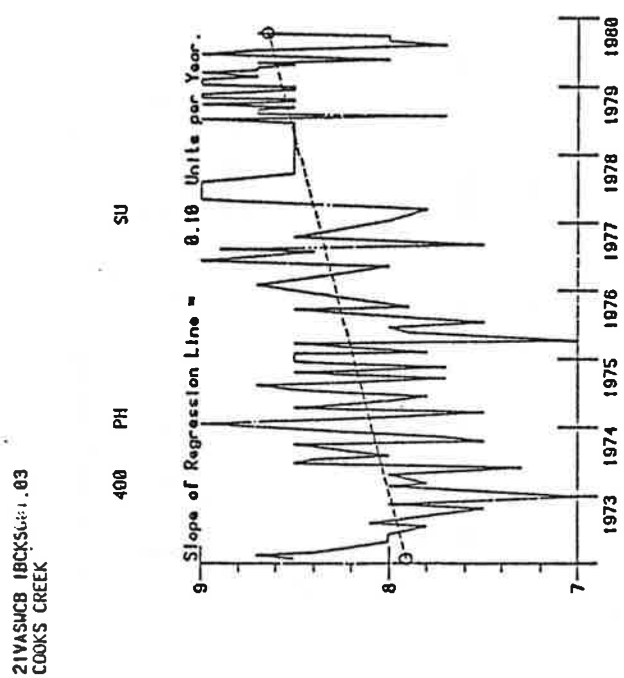



Figure III.30

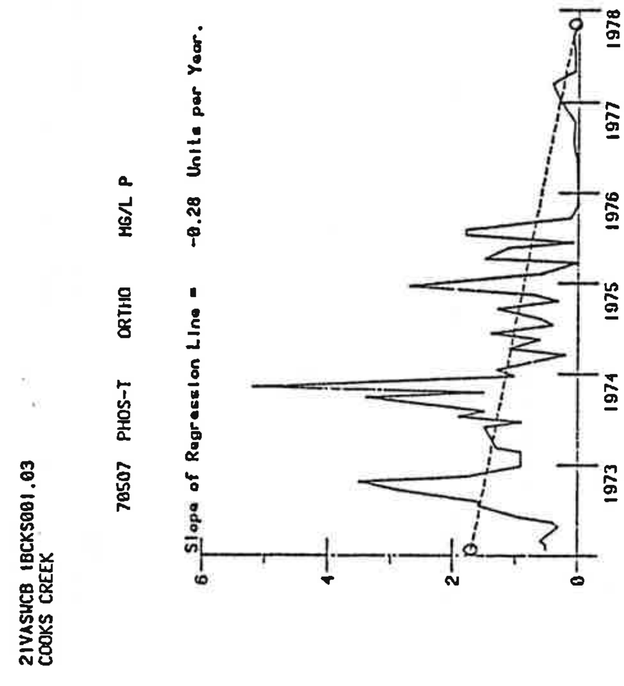



Figure III.31

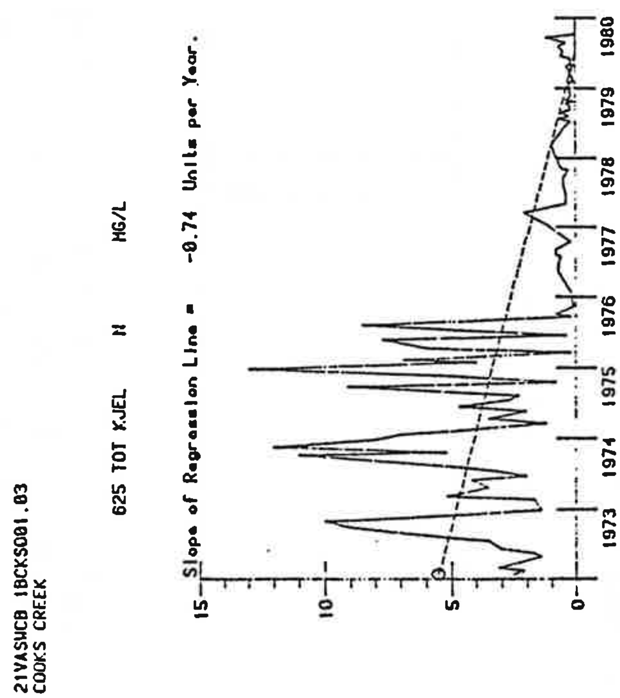



Figure III.32

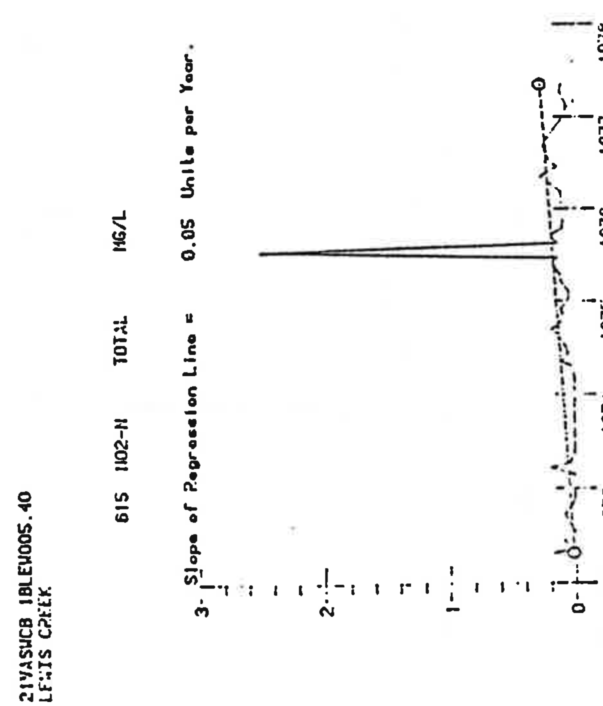


Figure III.33

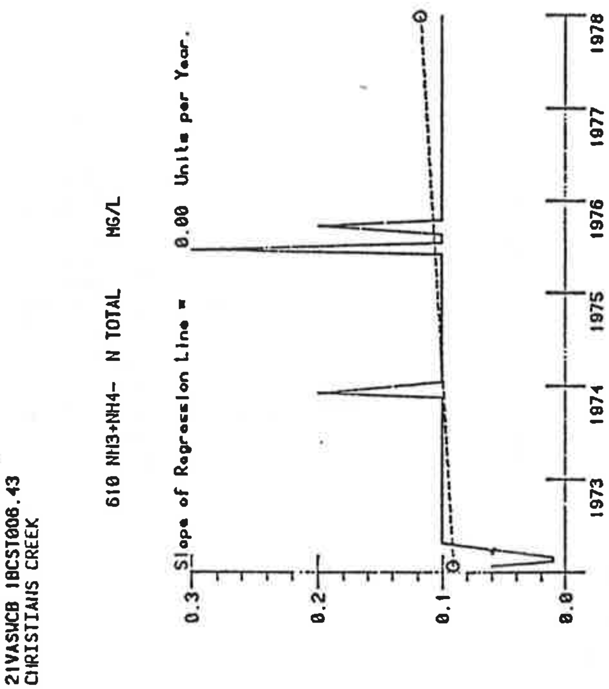



Figure III.34

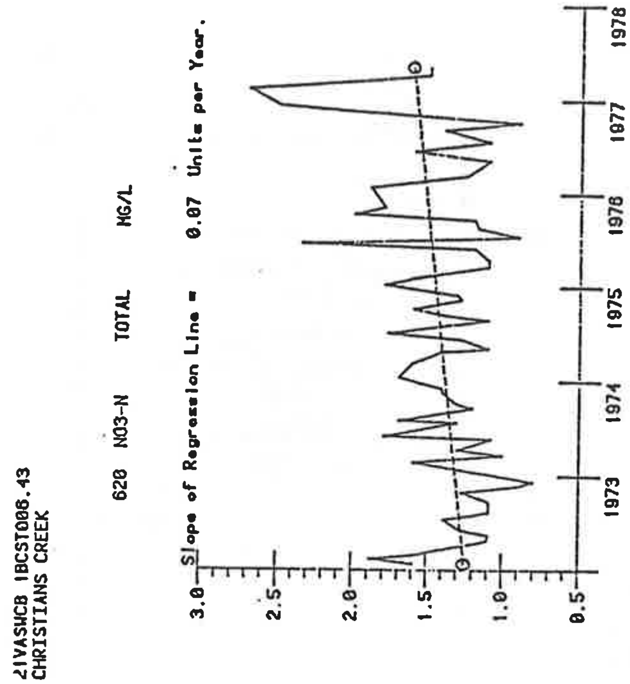



Figure III.35

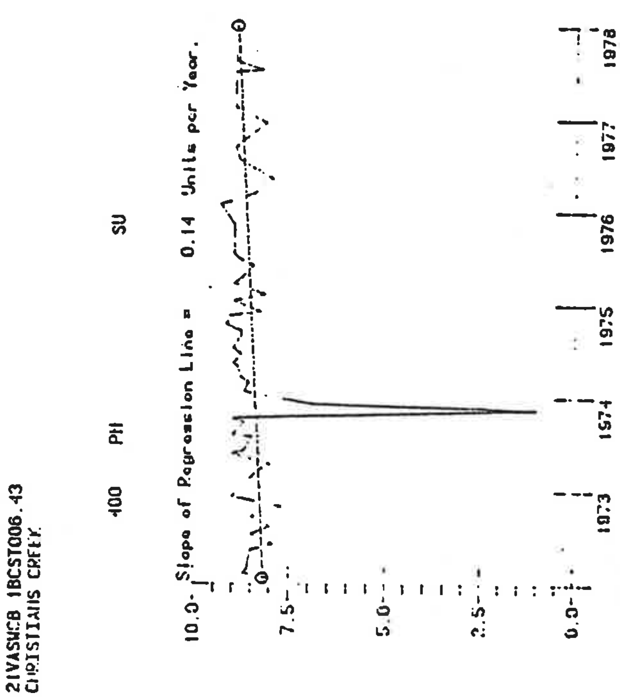



Figure III.36

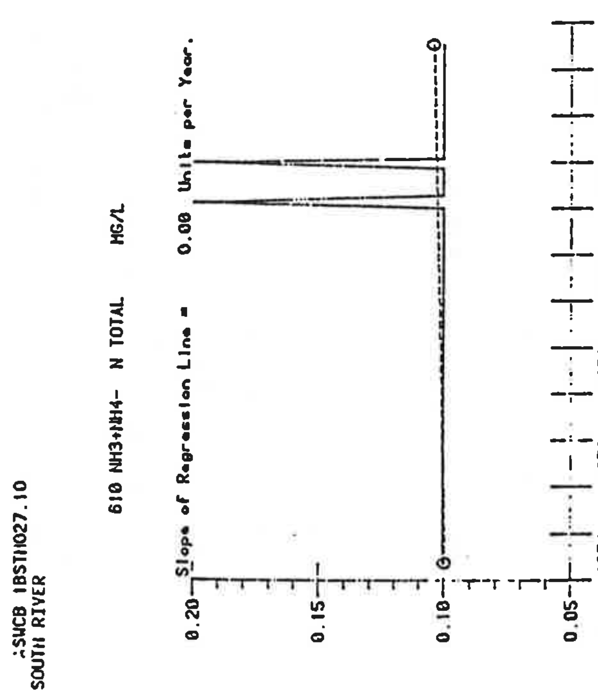


Figure III.37

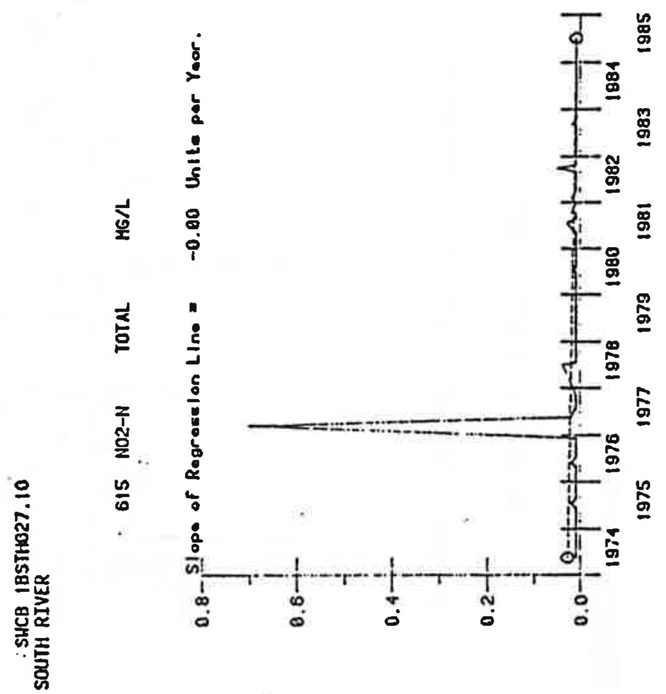



Figure III.38

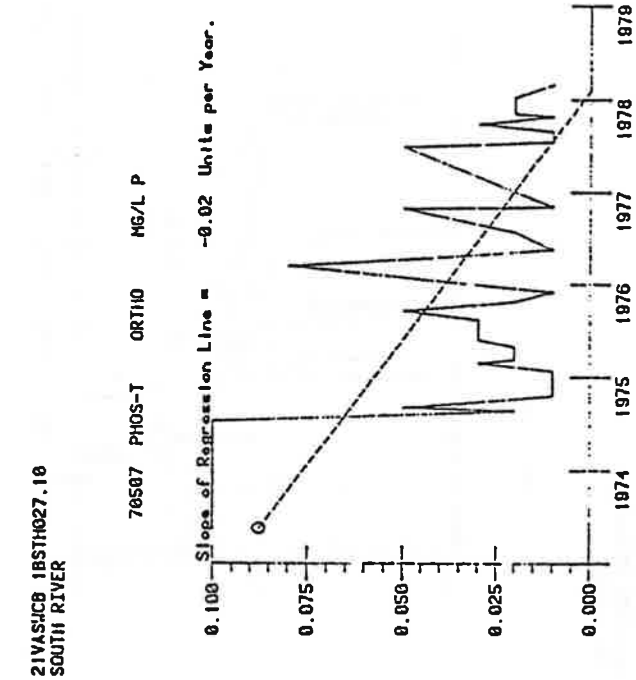



Figure III.39

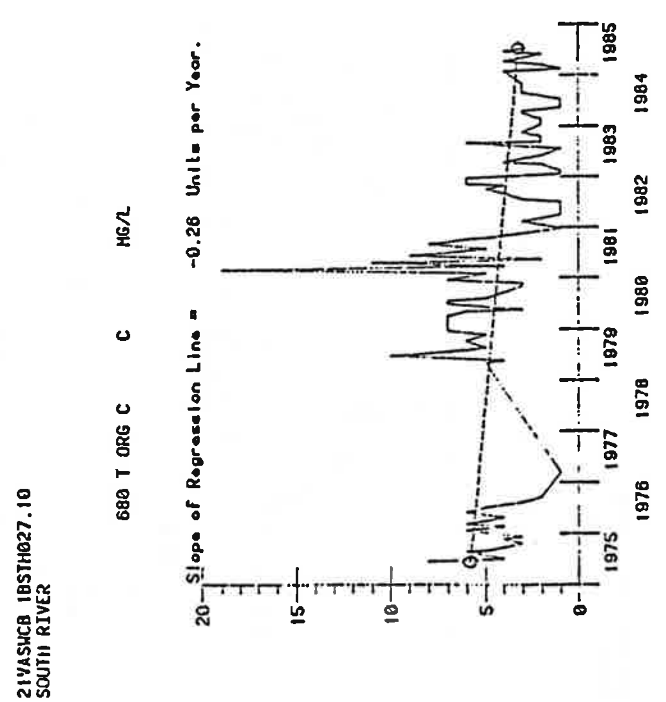



Figure III.40

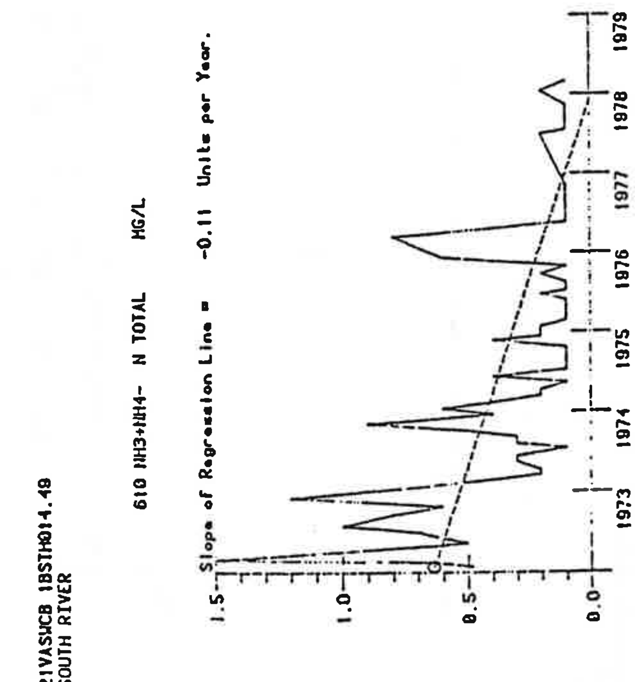


Figure III.41

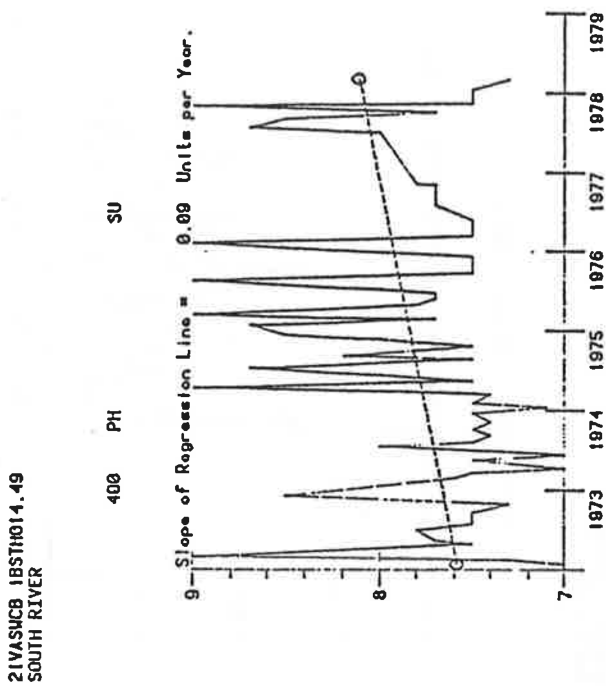



Figure III.42

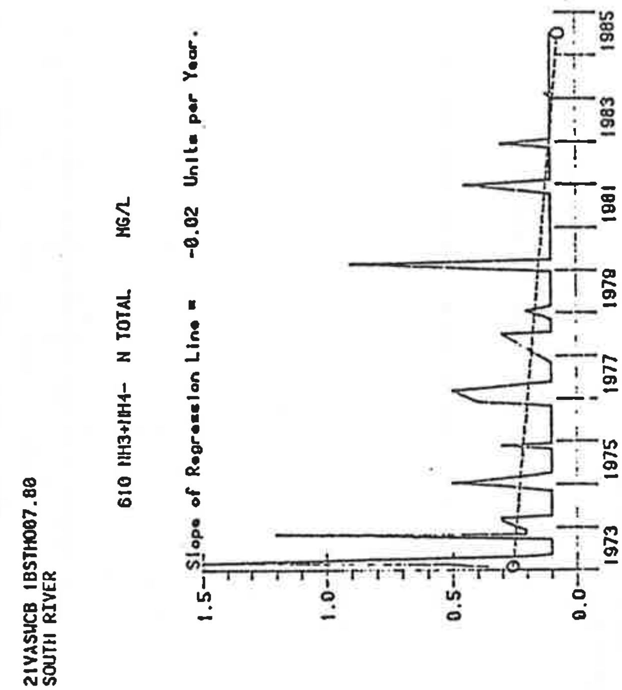



Figure III.43

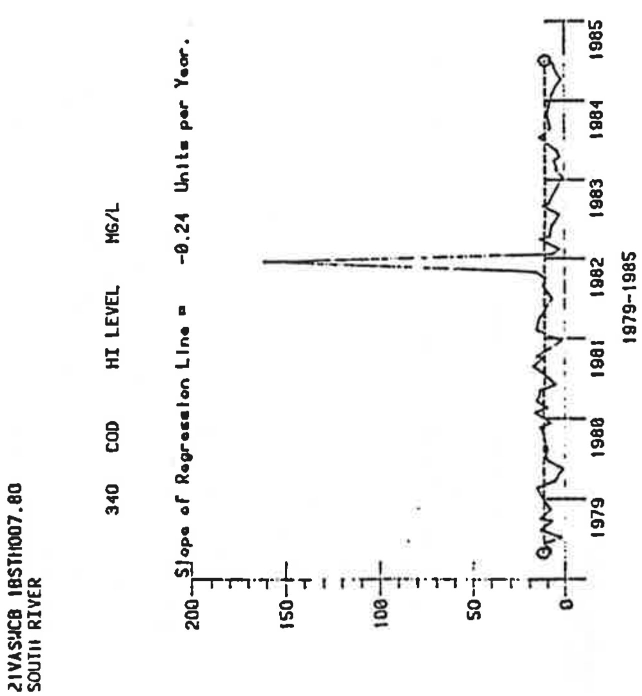



Figure III.44

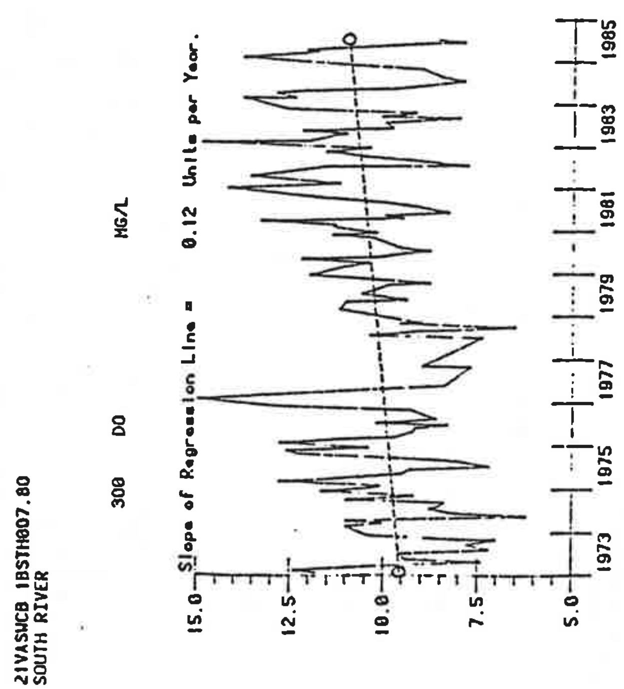


Figure III.45

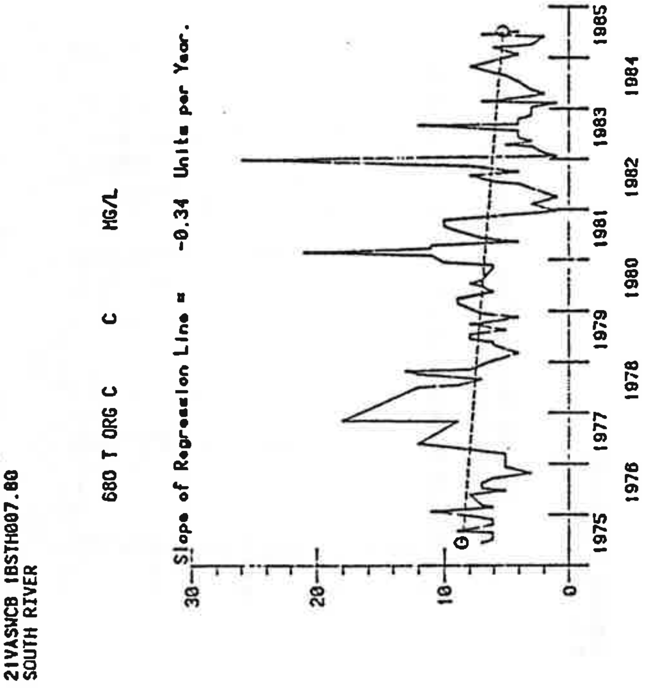



Figure III.46

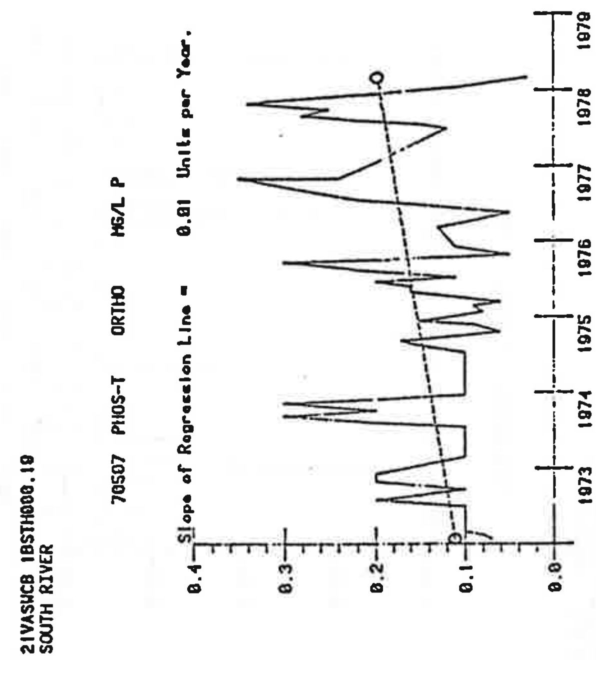



Figure III.47

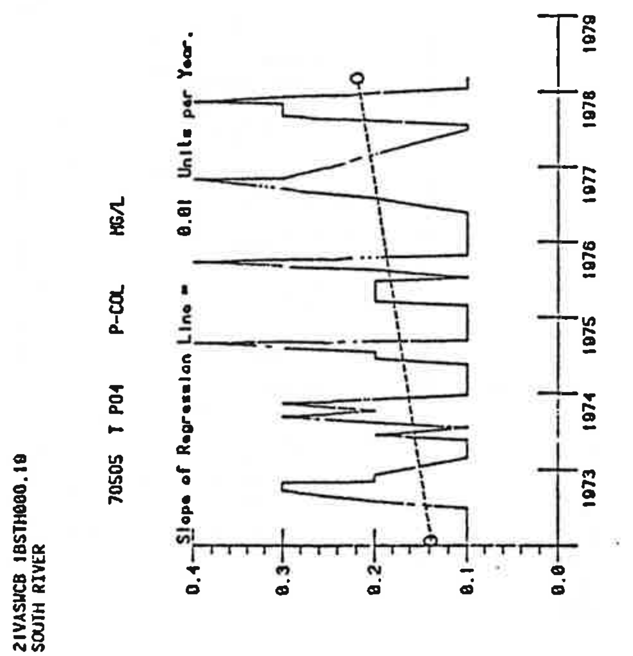



Figure III.48

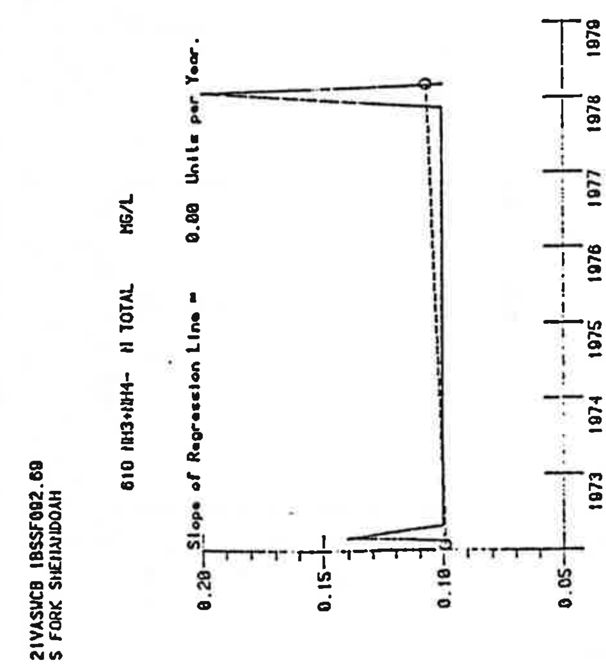


Figure III.49

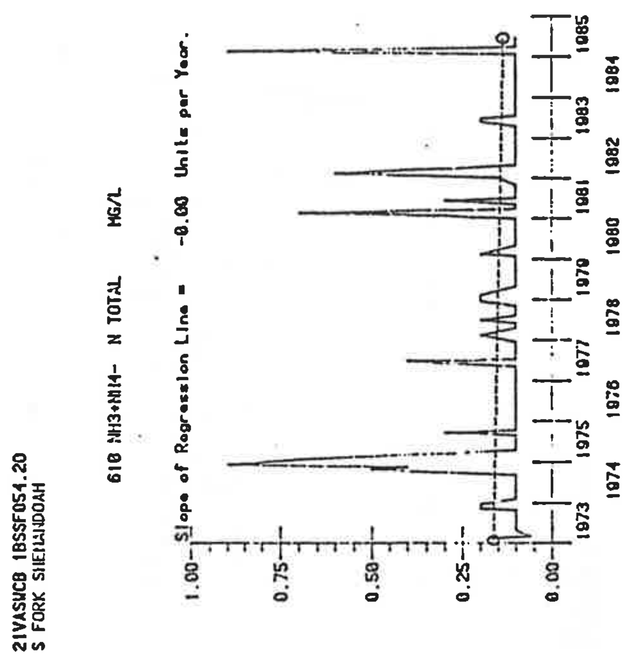



Figure III.50

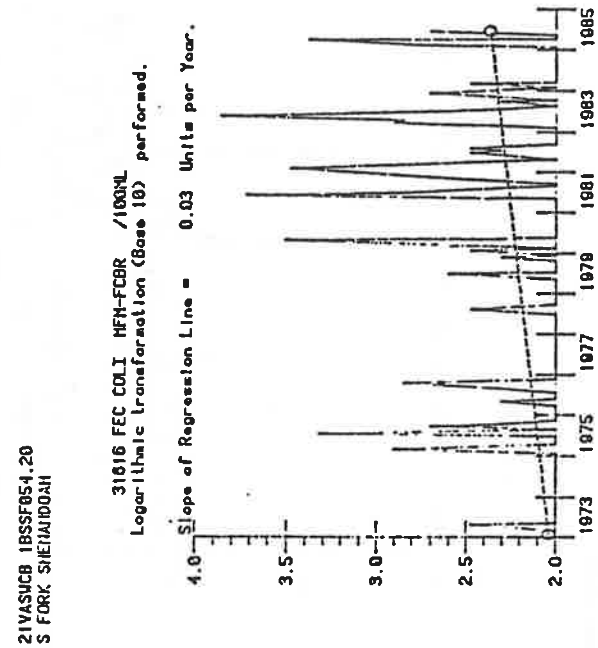



Figure III.51

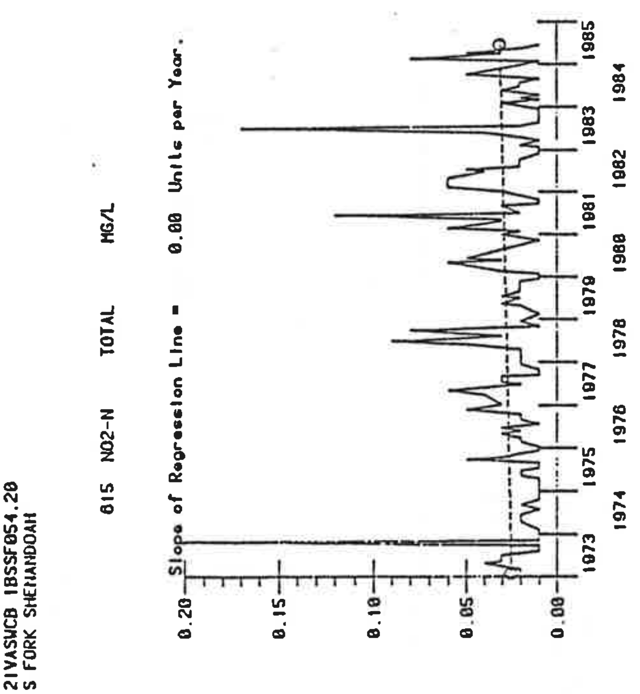



Figure III.52

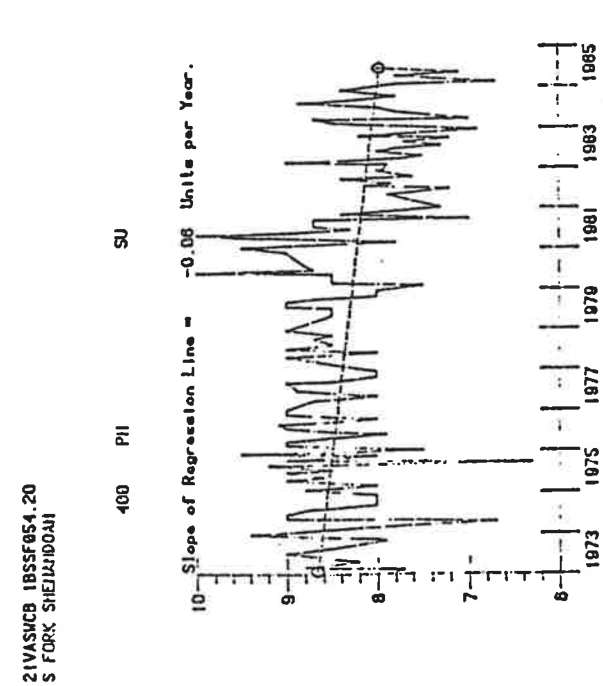


Figure III.53

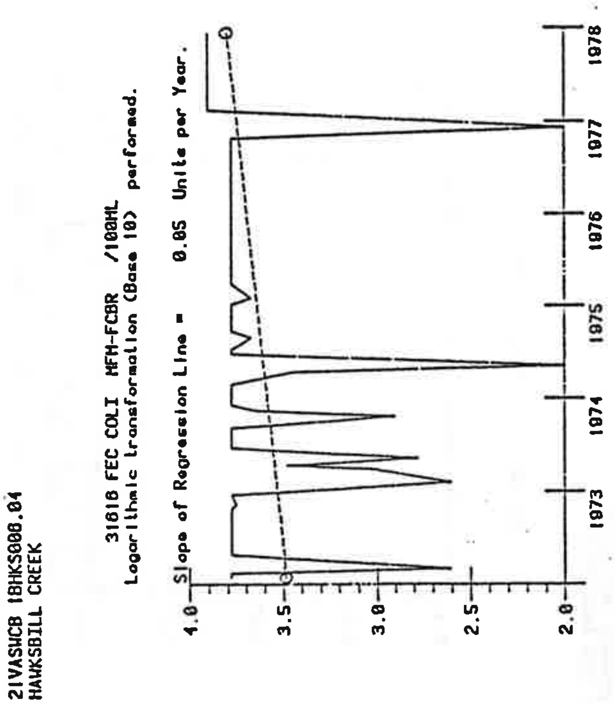



Figure III.54

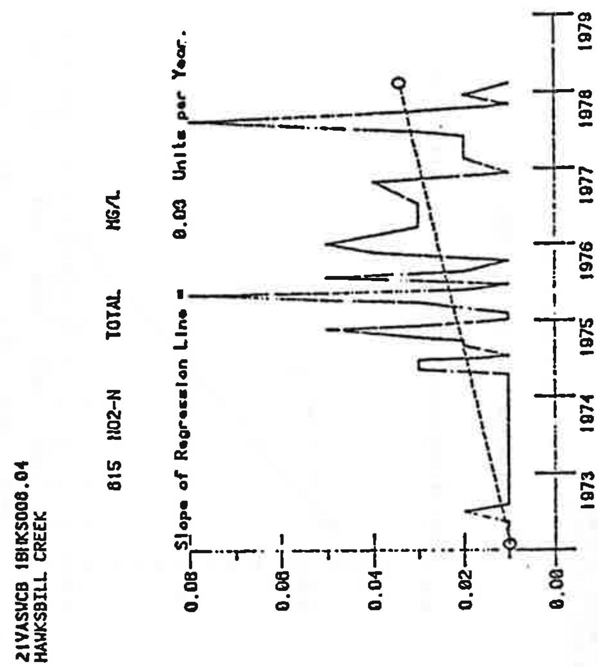



Figure III.55

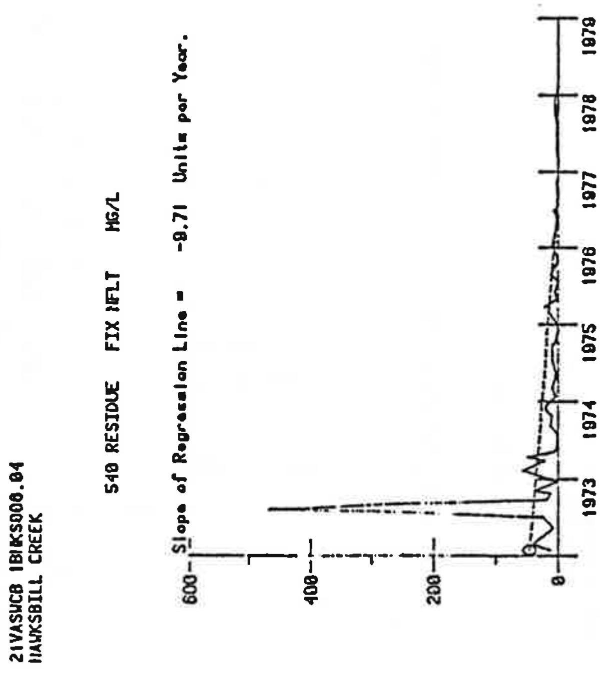



Figure III.56

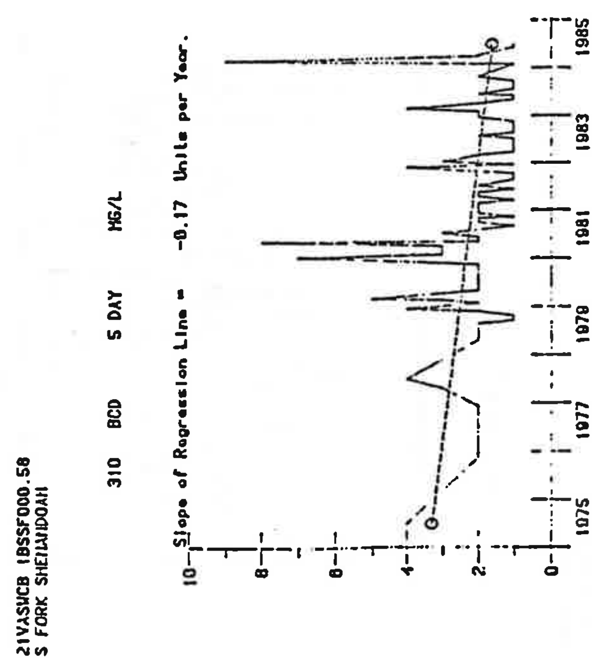


Figure III.57

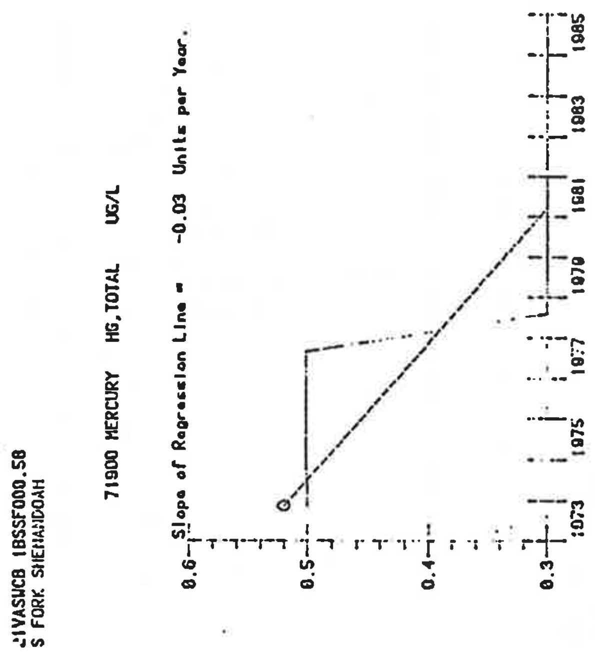



Figure III.58

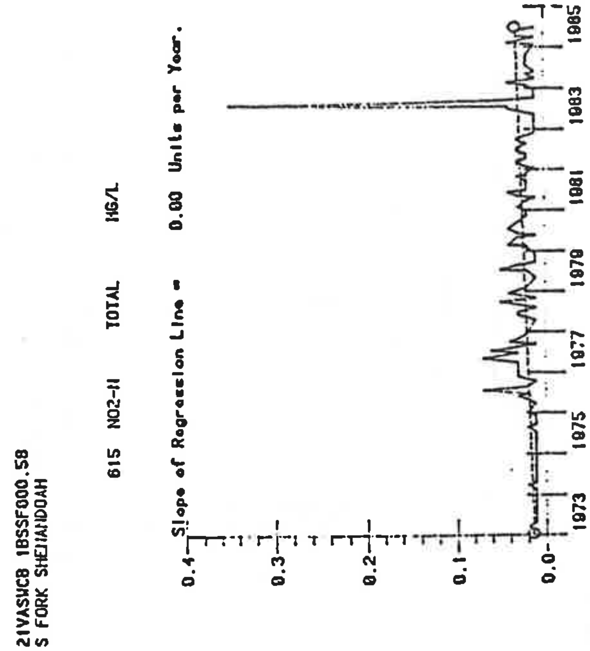



Figure III.59

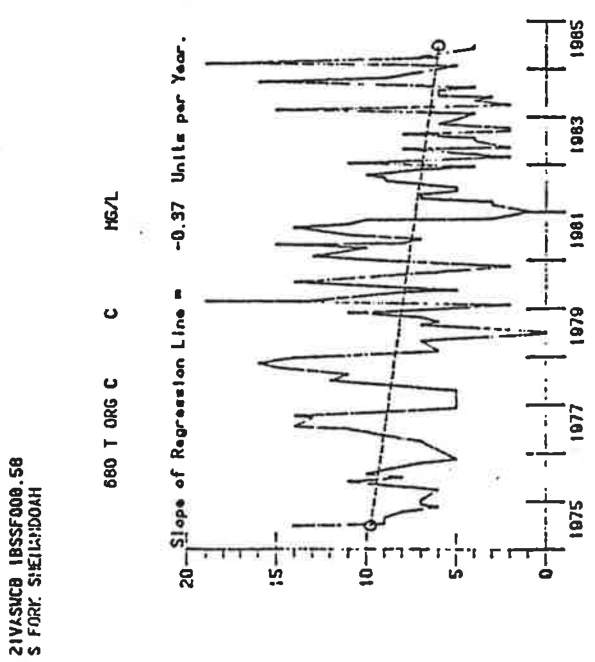



Figure III.60

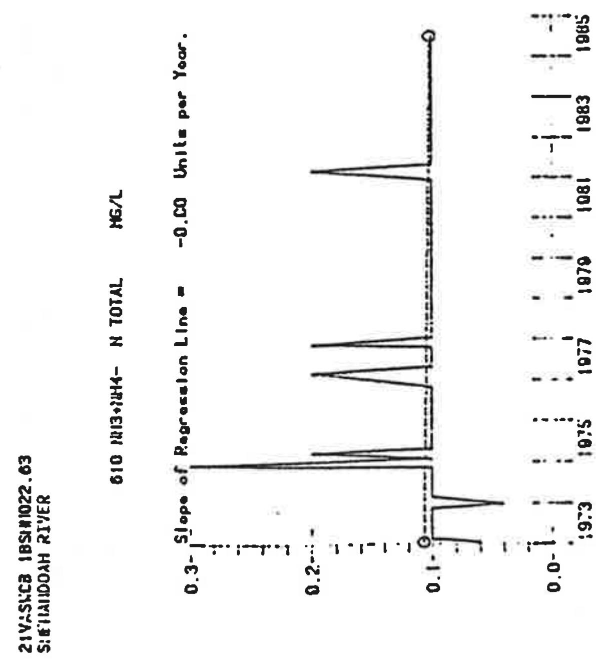


Figure III.61

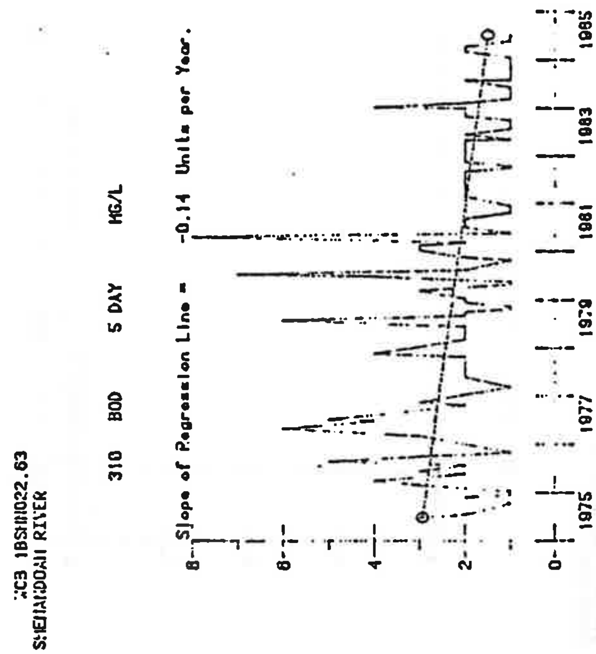



Figure III.62

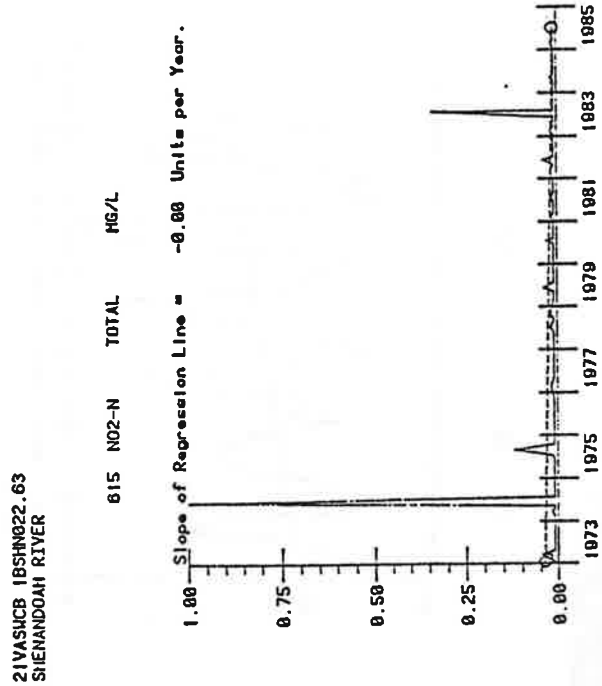



Figure III.63

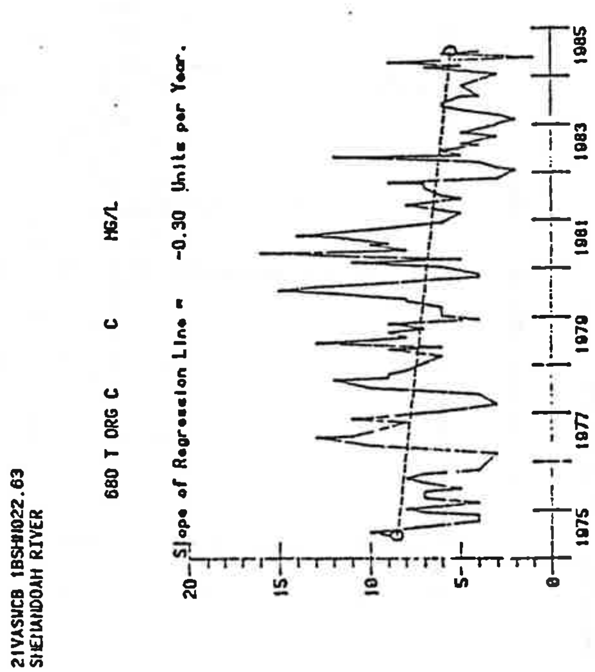



Figure III.64

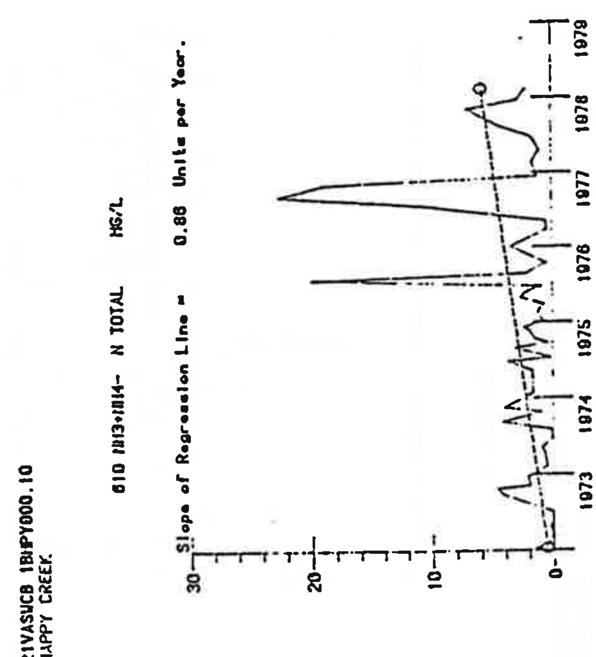


Figure III.65

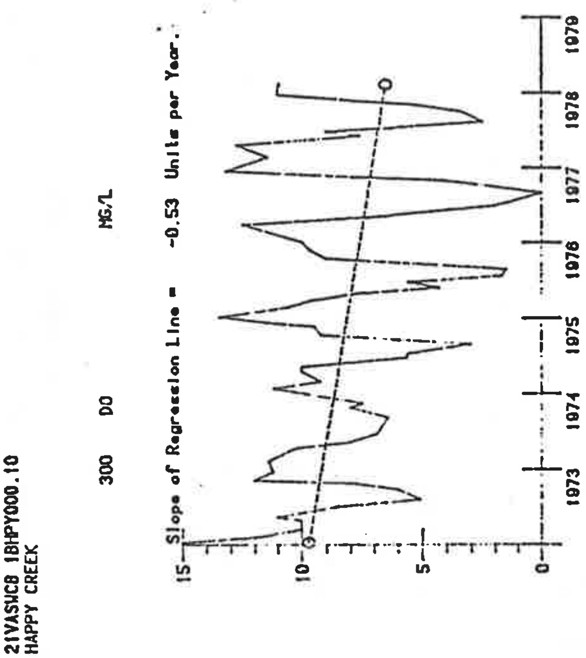



Figure III.66

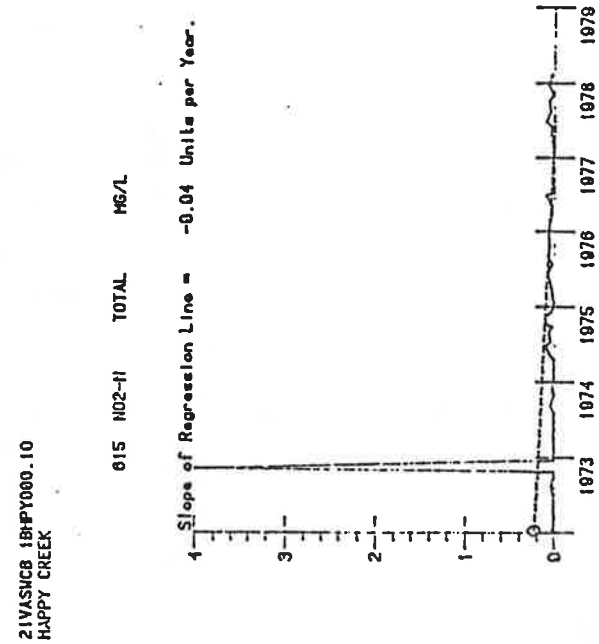



Figure III.67

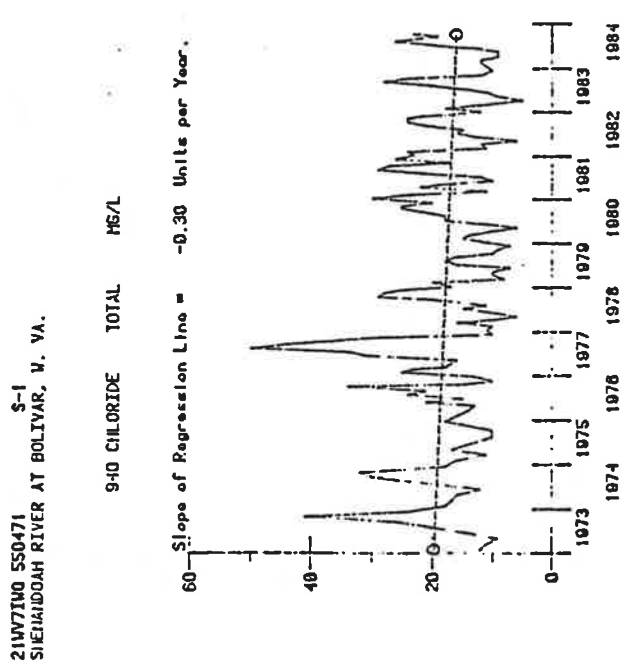



Figure III.68

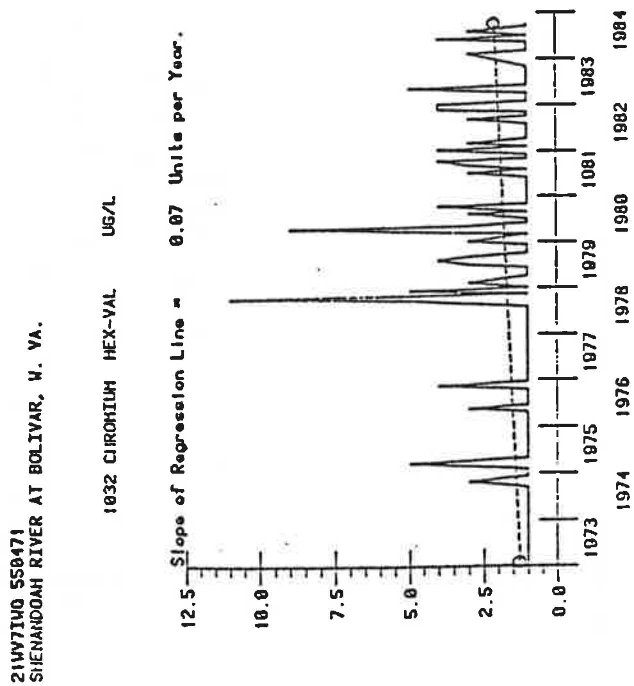


Figure III.69

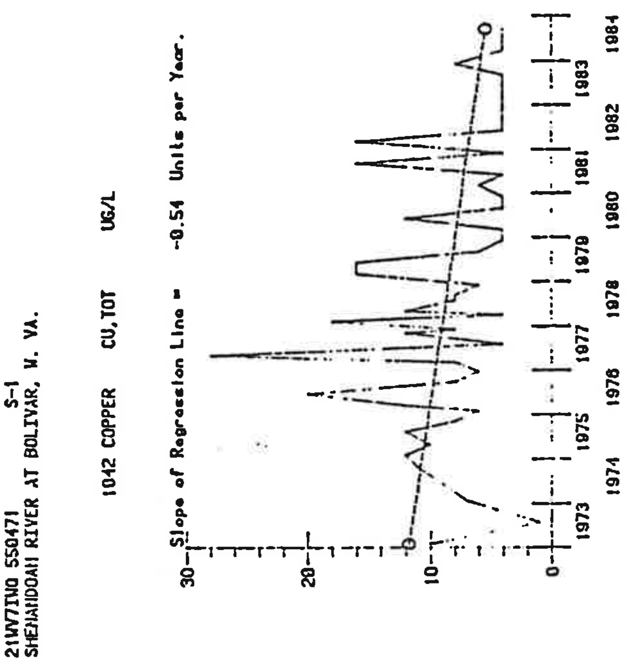



Figure III.70

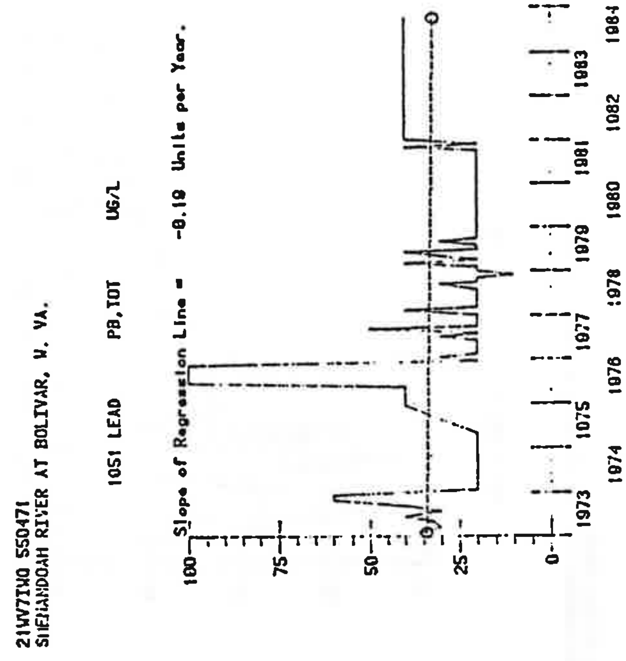



Figure III.71

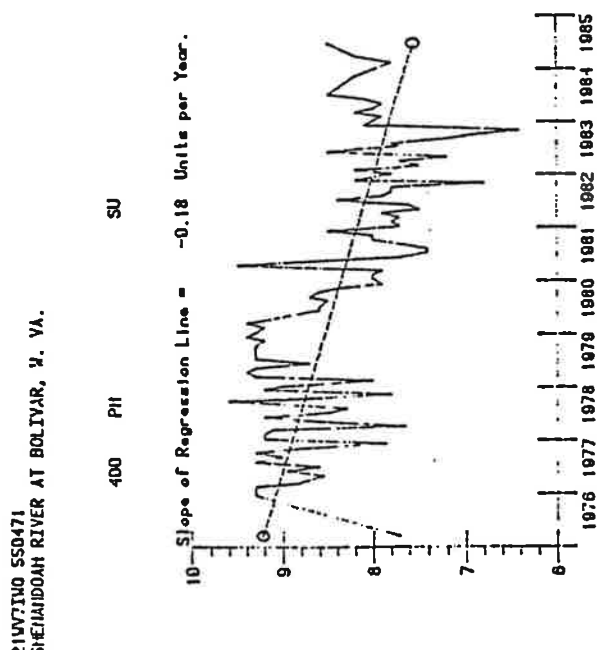



Figure III.72

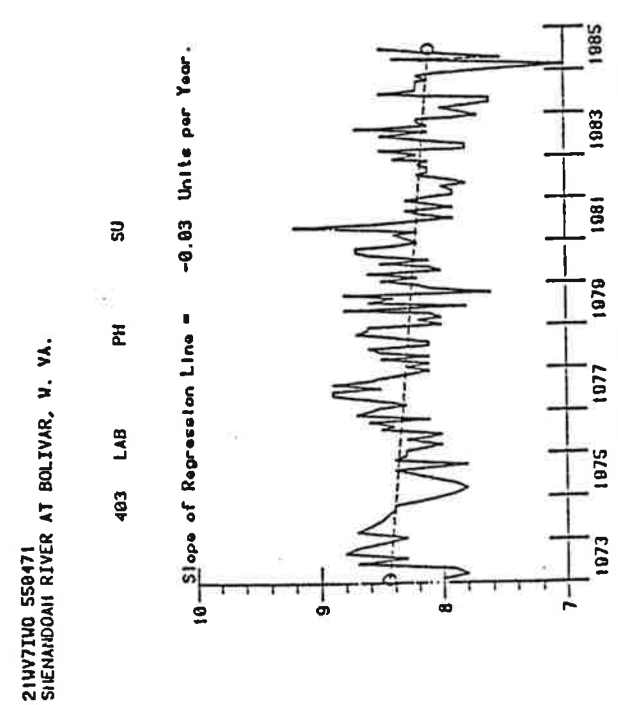


Figure III.73

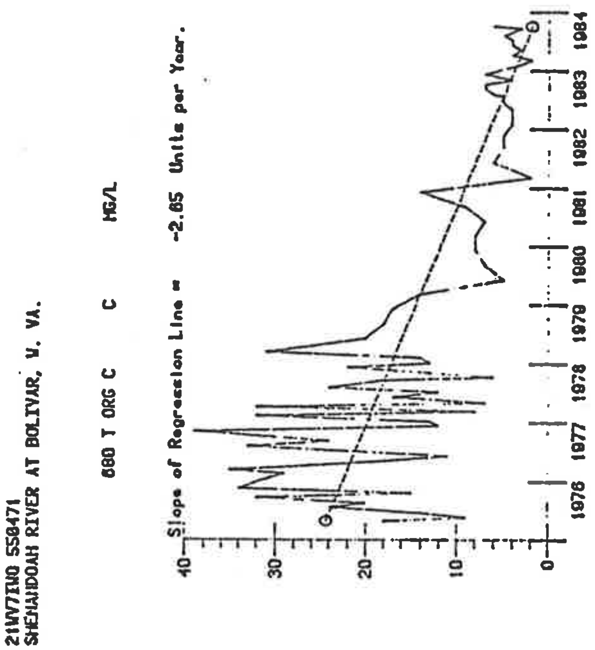


Figure IV.1

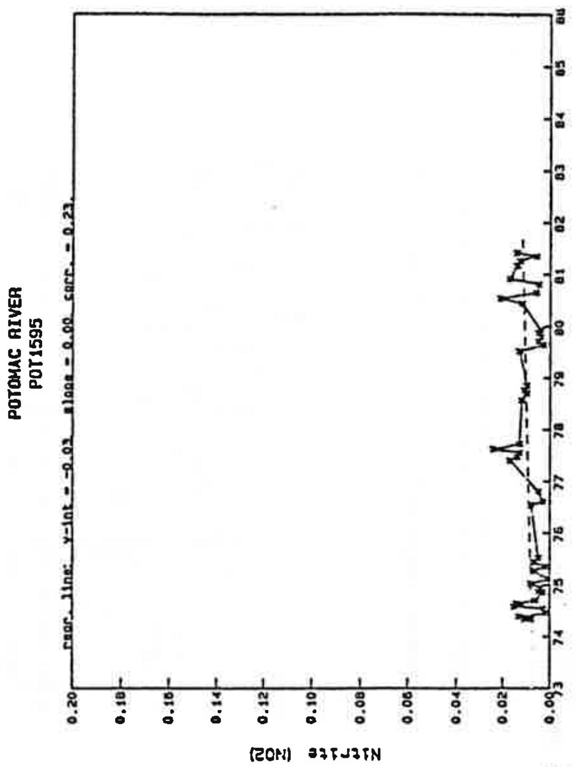



Figure IV.2

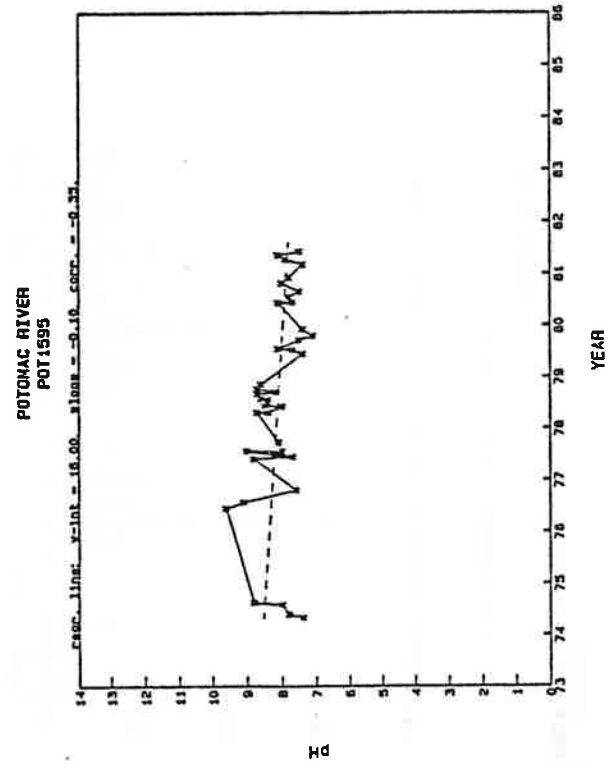



Figure IV.3

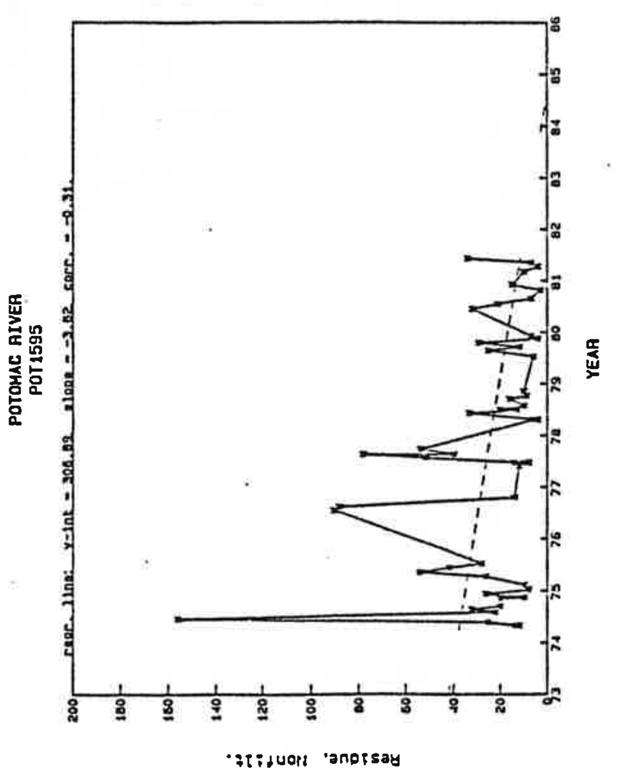



Figure IV.4

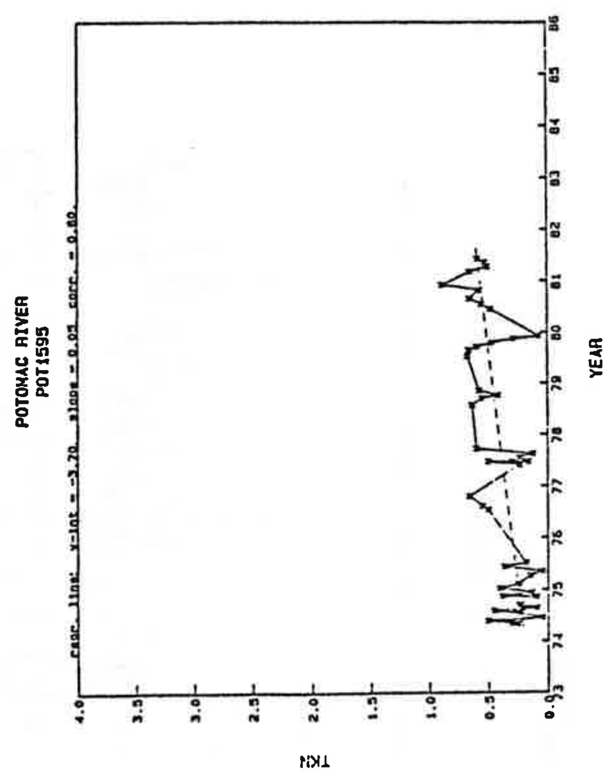


Figure IV.5

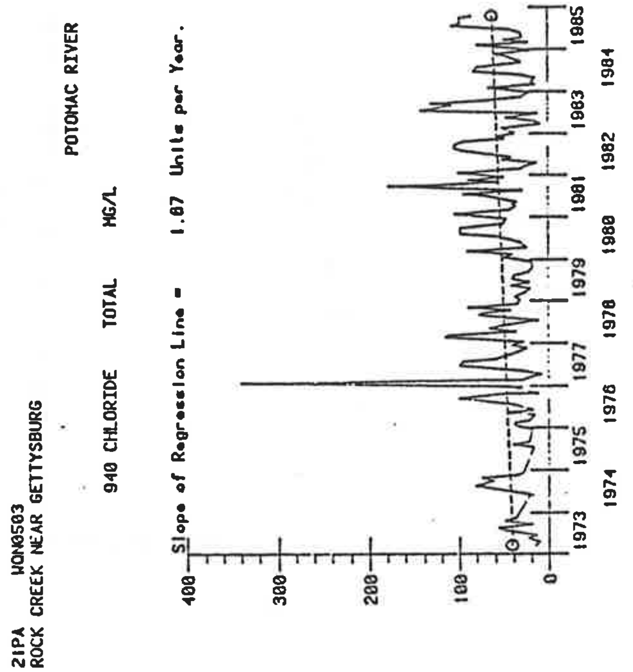



Figure IV.6

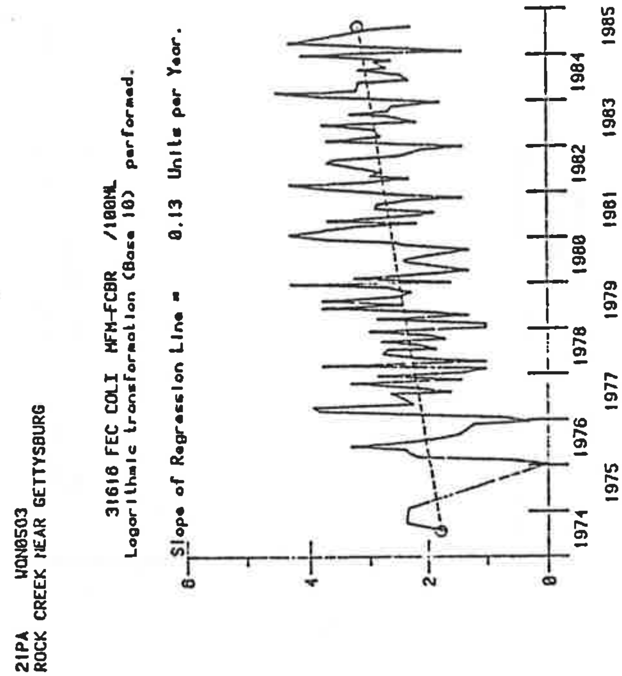



Figure IV.7

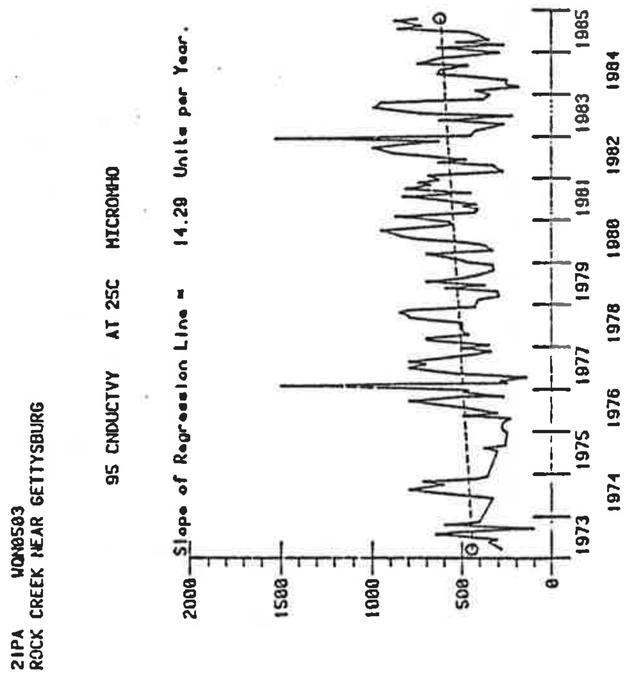



Figure IV.8

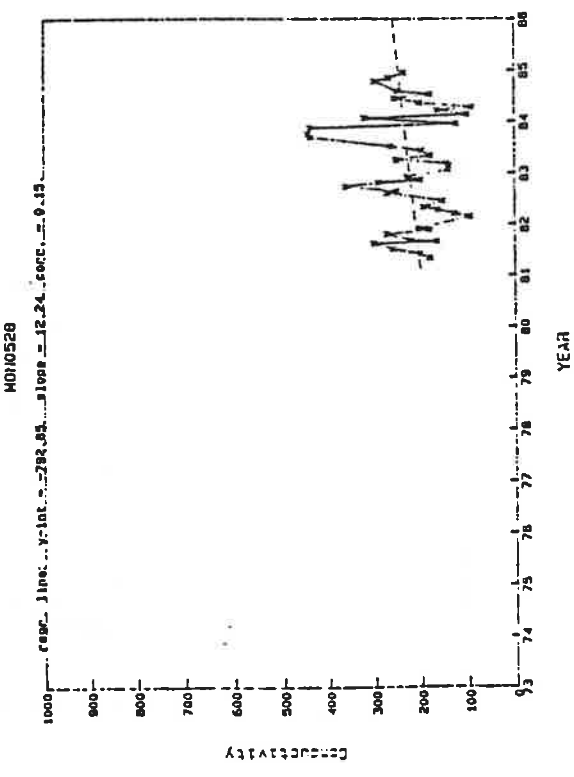


Figure IV.9

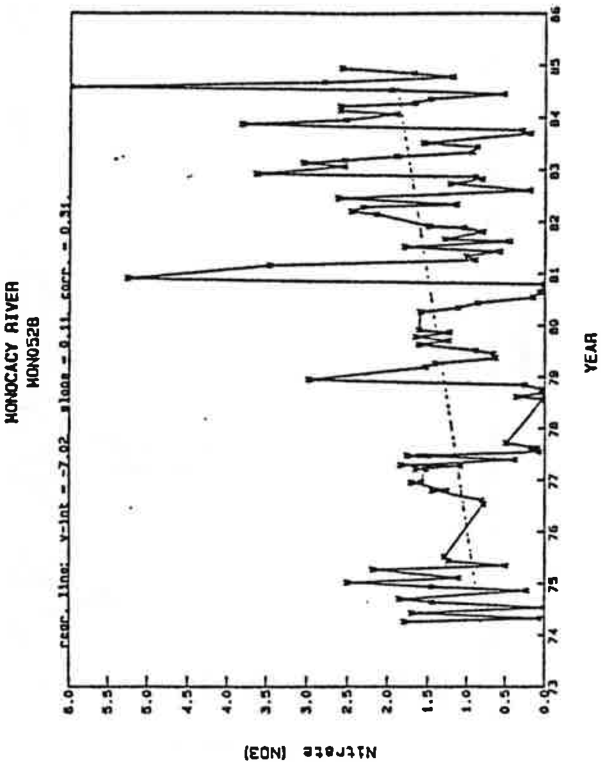



Figure IV.10

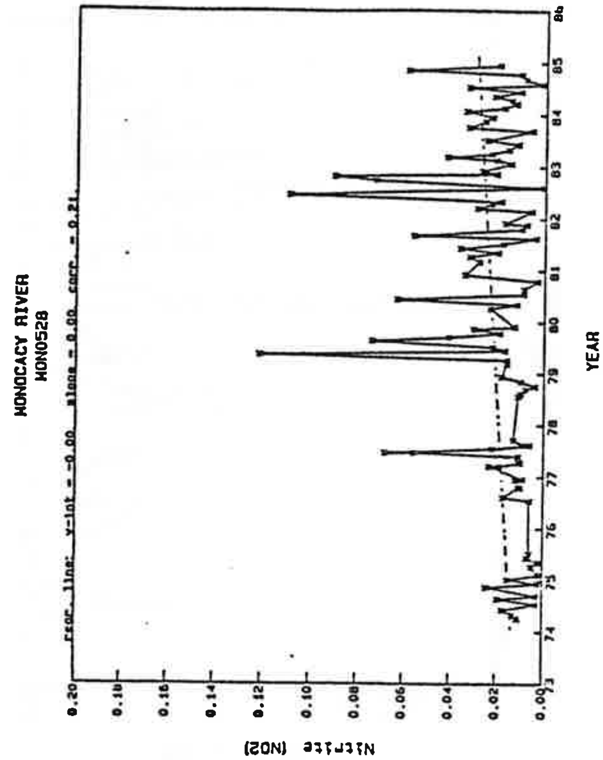



Figure IV.11

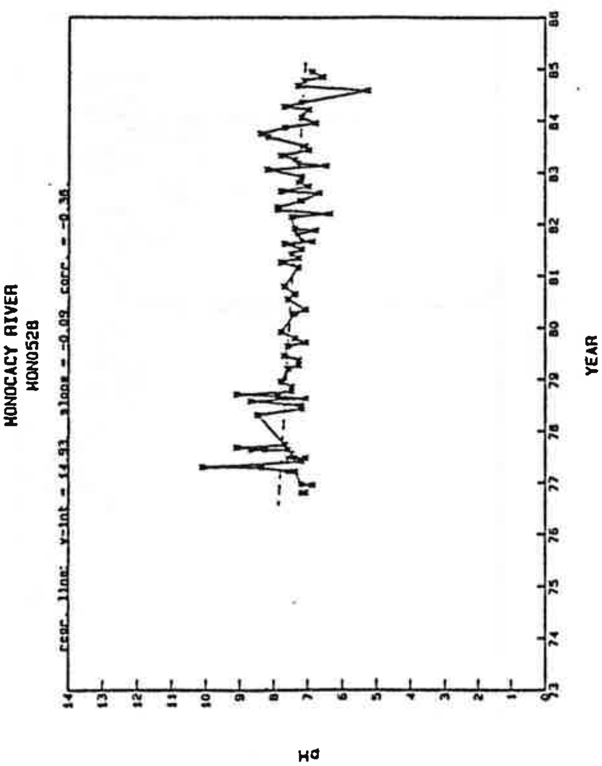



Figure IV.12

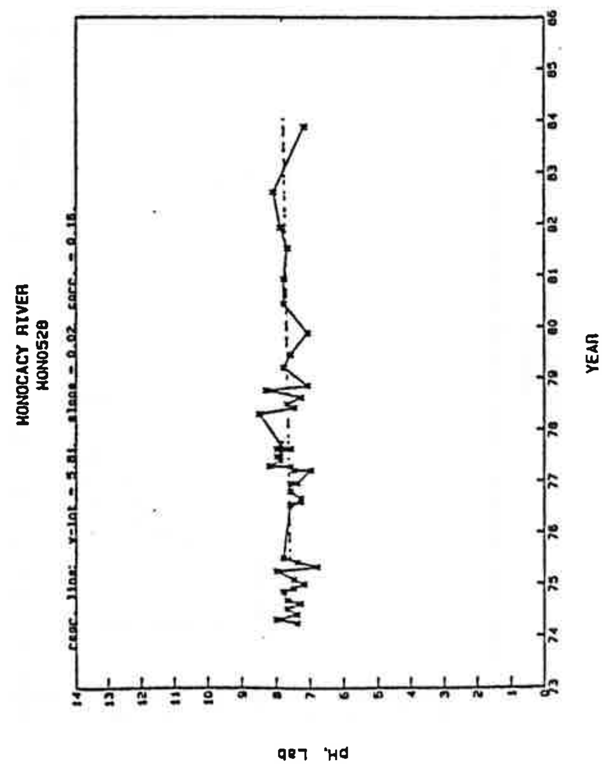


Figure IV.13

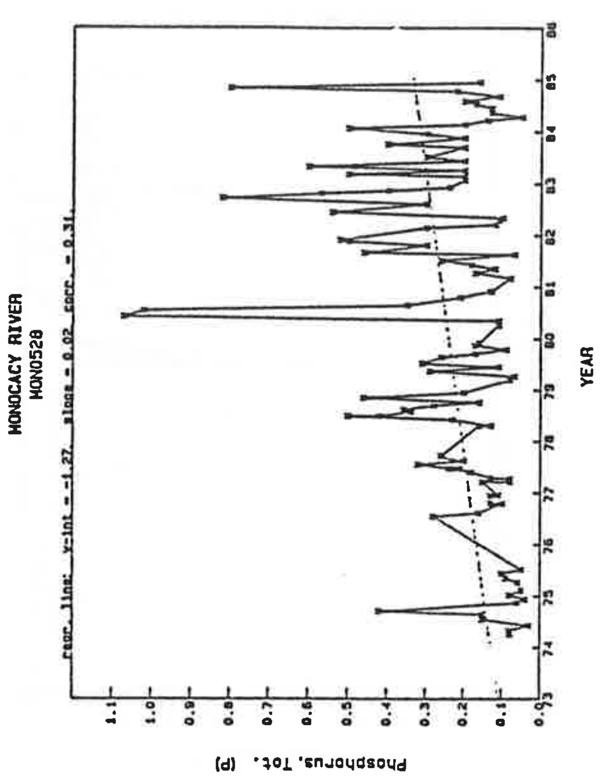



Figure IV.14

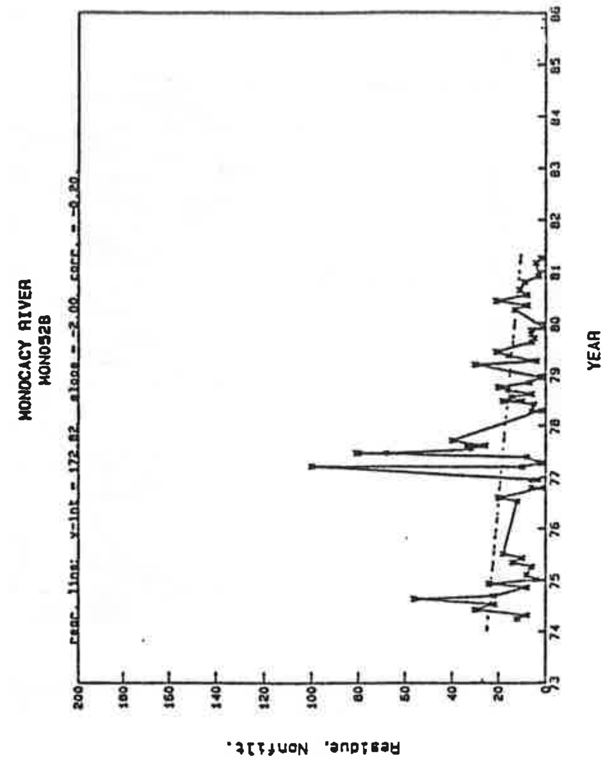



Figure IV.15

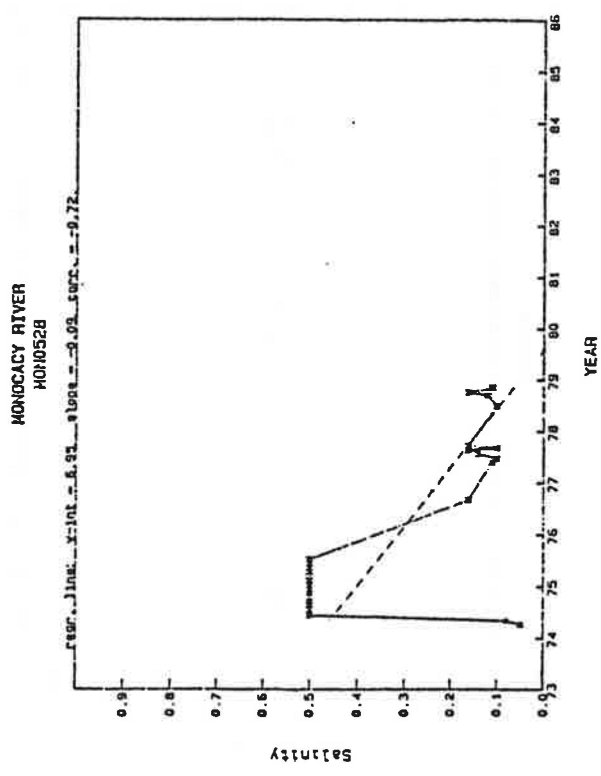



Figure IV.16

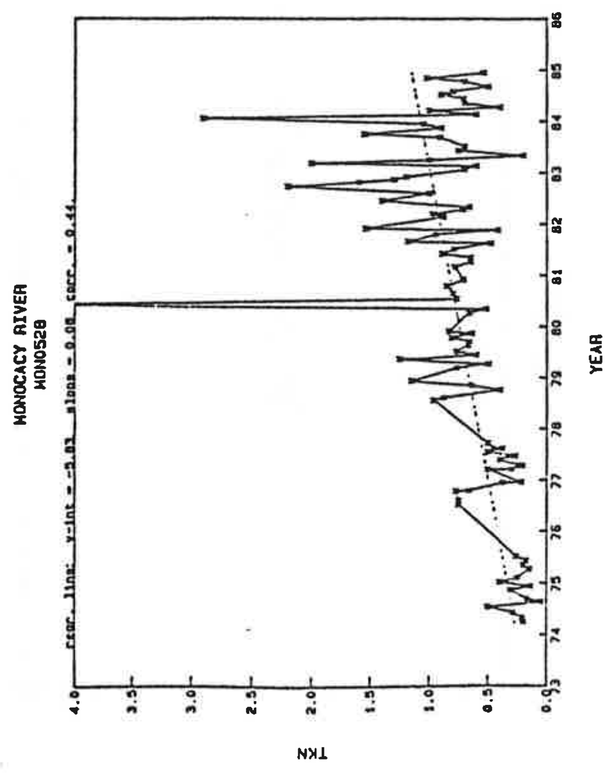


Figure IV.17

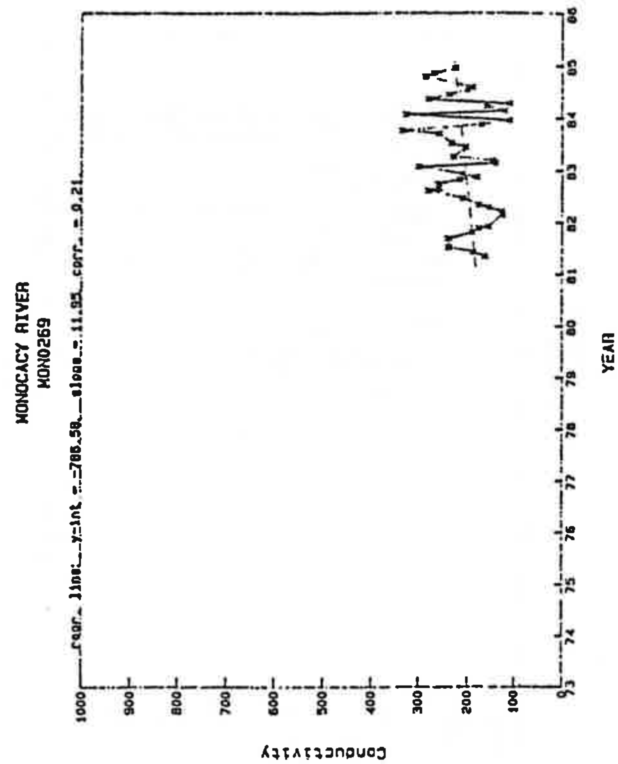



Figure IV.18

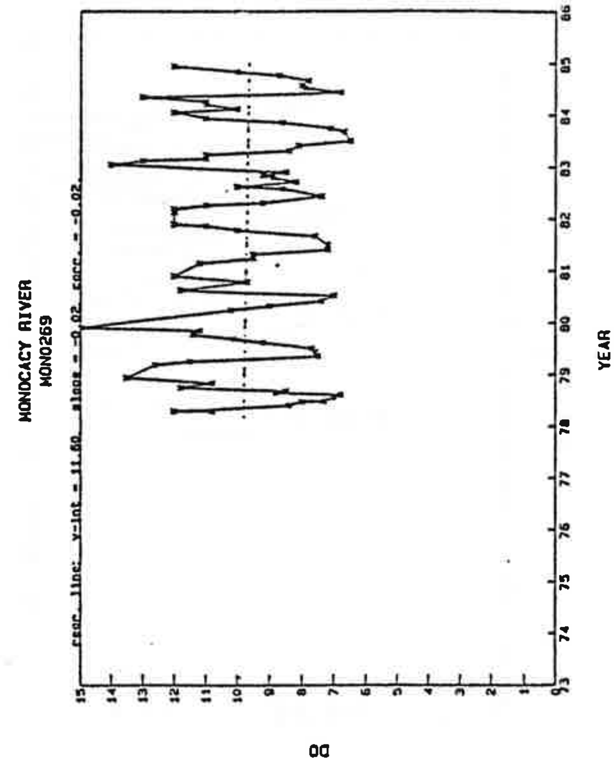



Figure IV.19

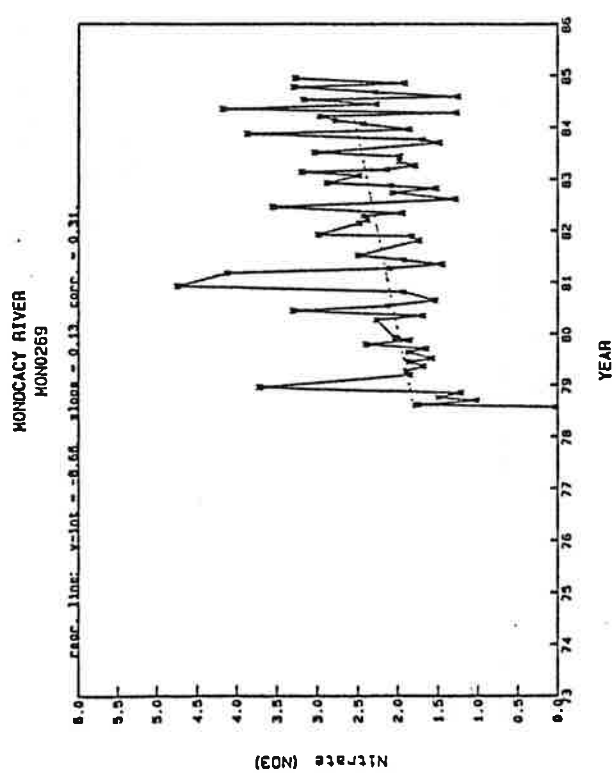



Figure IV.20

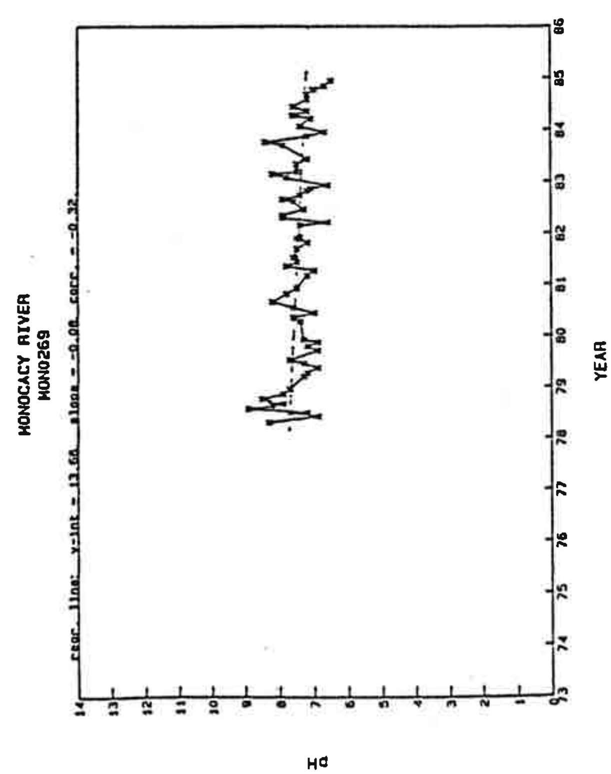


Figure IV.21

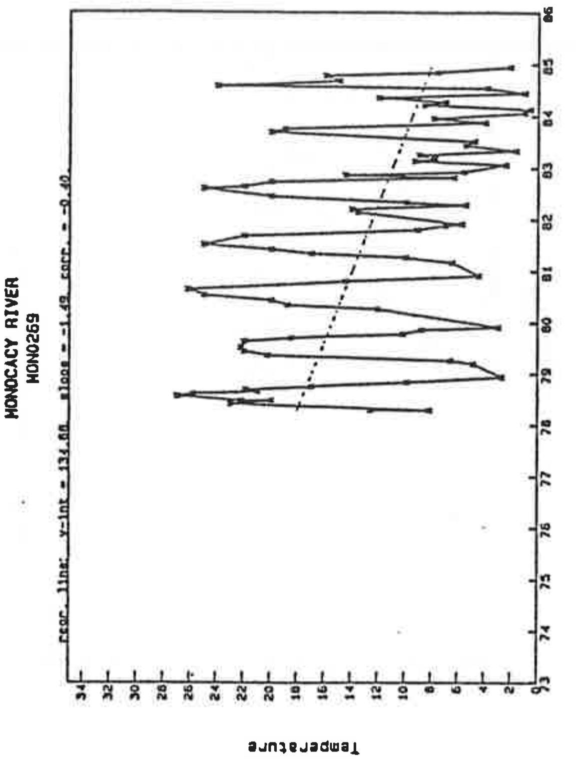



Figure IV.22

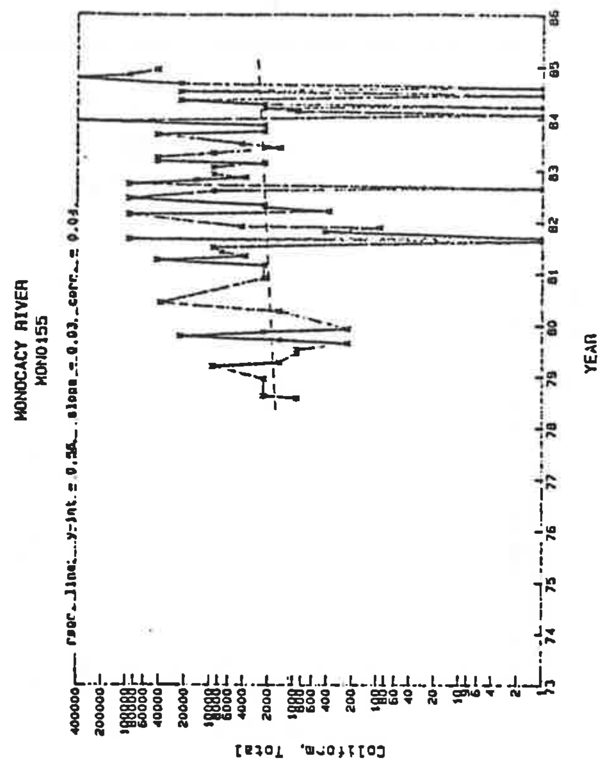



Figure IV.23

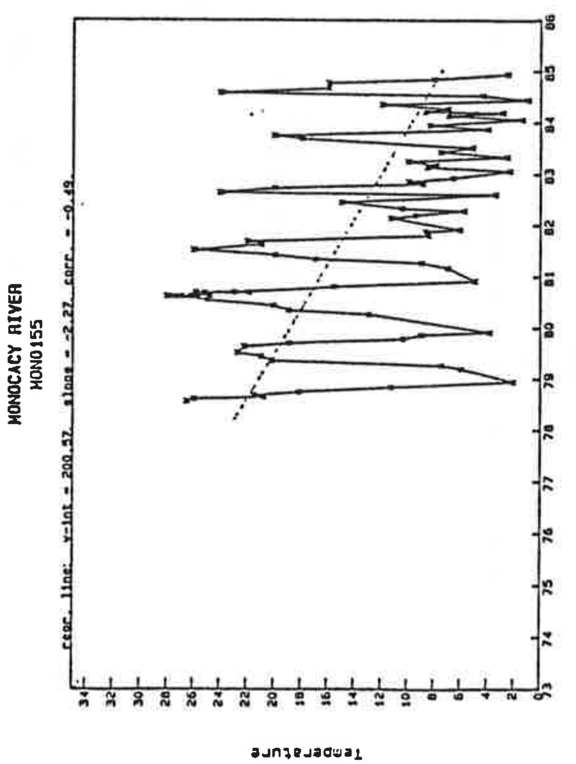



Figure IV.24

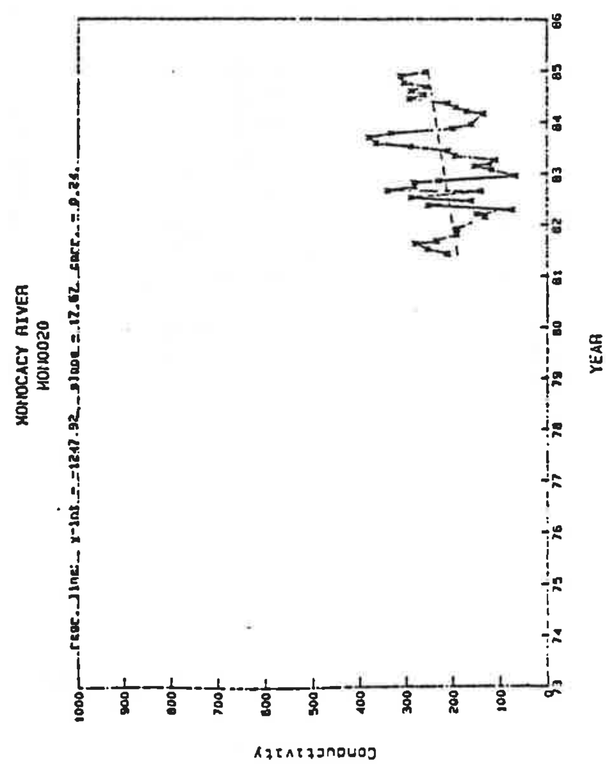


Figure IV.25

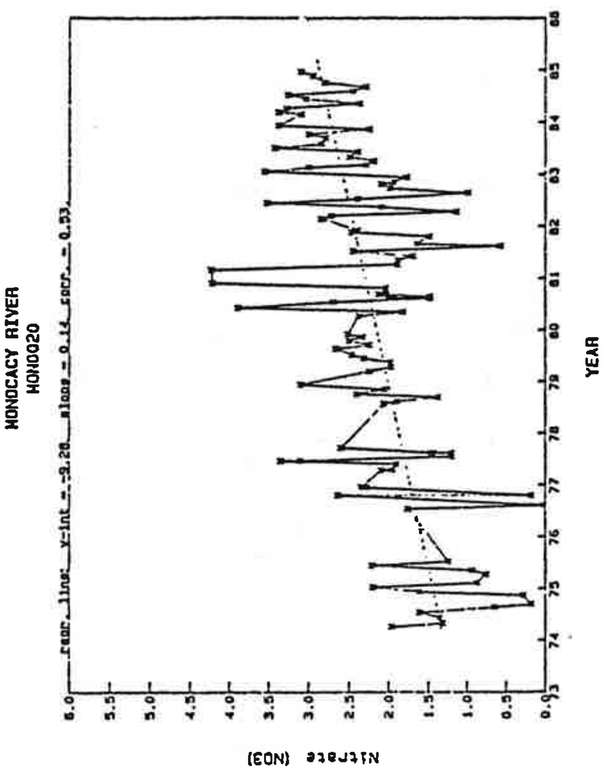



Figure IV.26

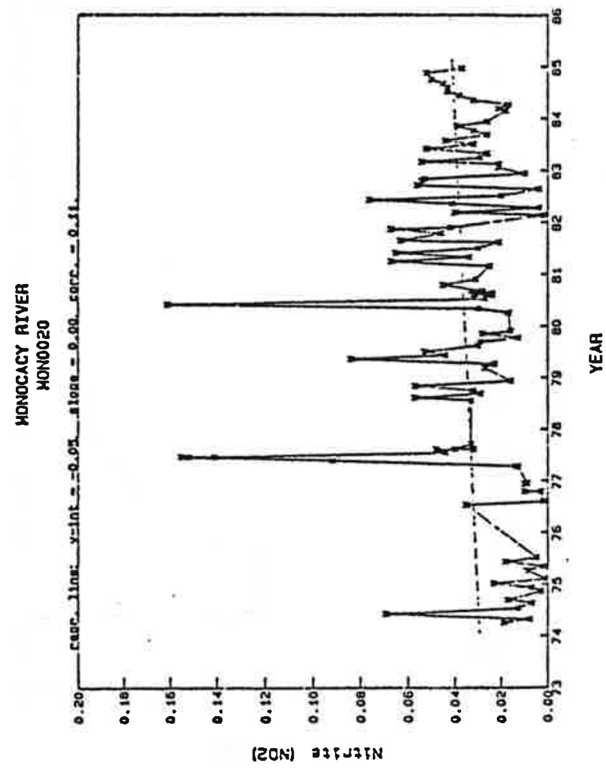



Figure IV.27

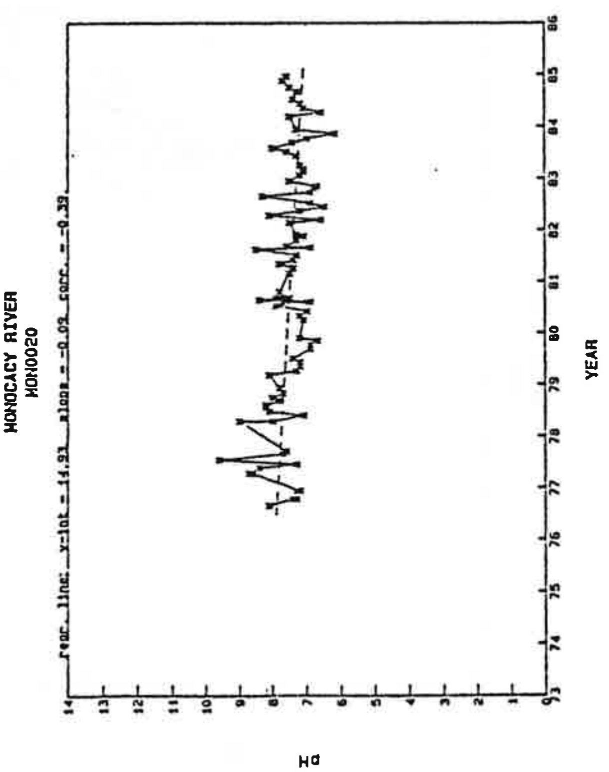



Figure IV.28

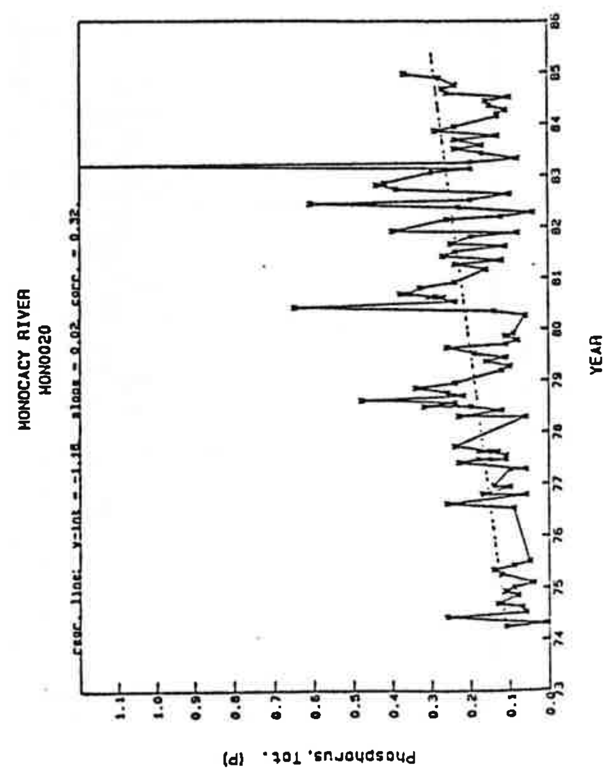


Figure IV.29

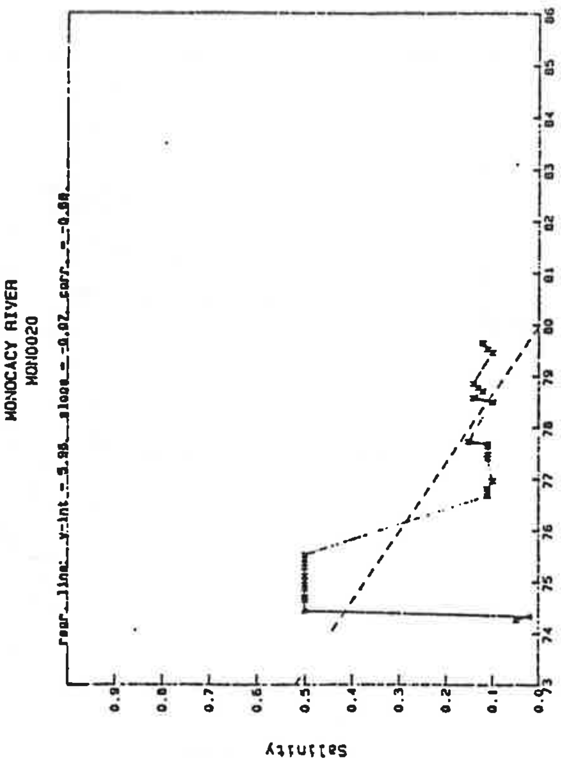



Figure IV.30

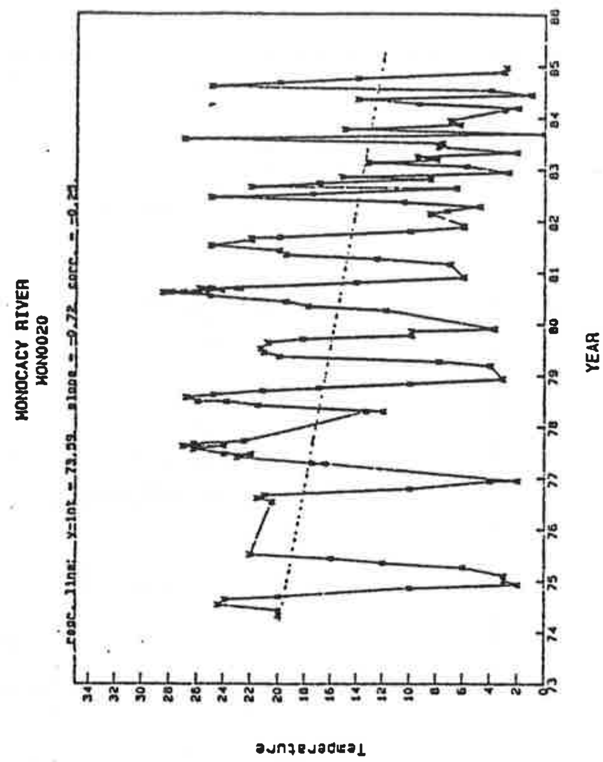



Figure IV.31

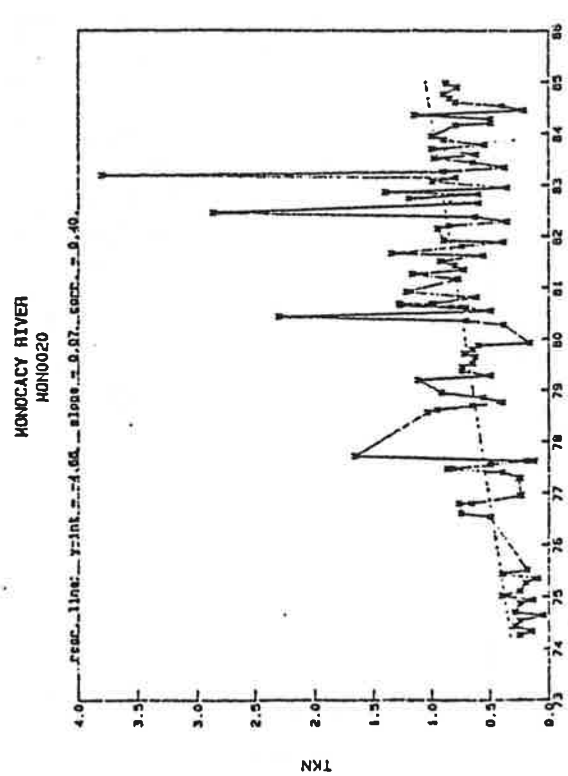



Figure IV.32

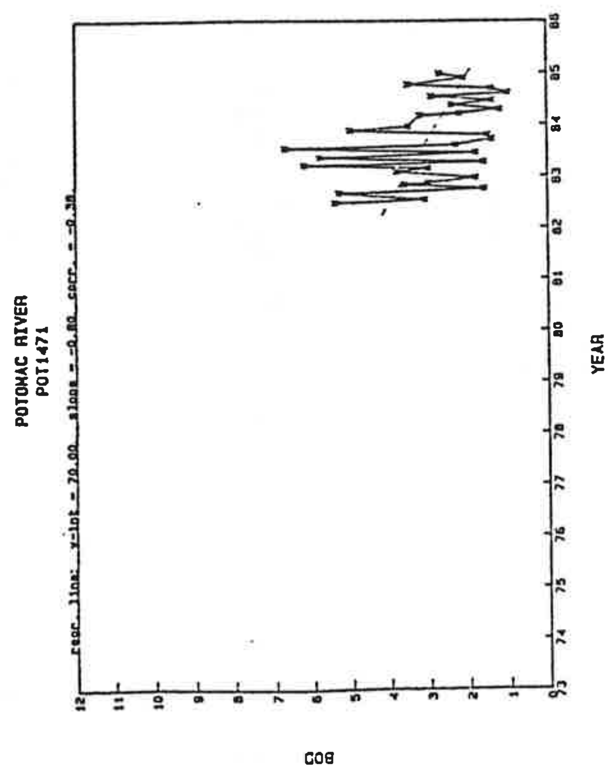


Figure IV.33

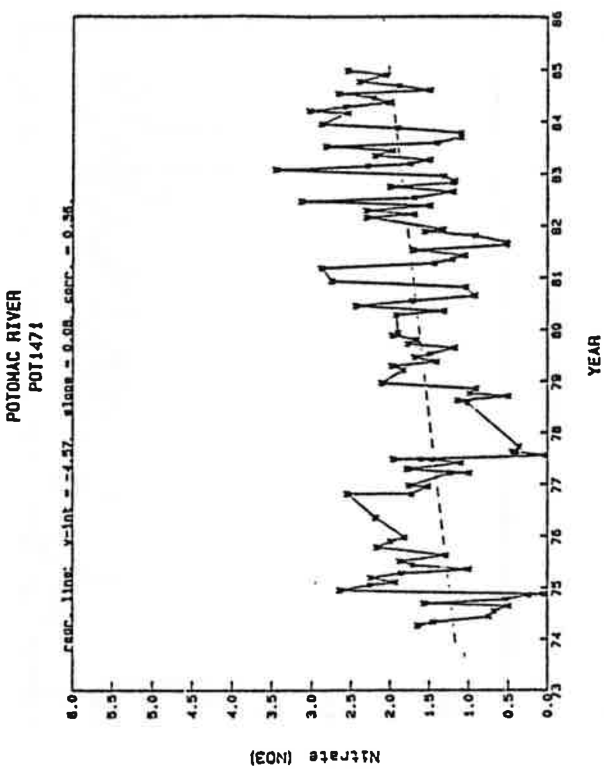



Figure IV.34

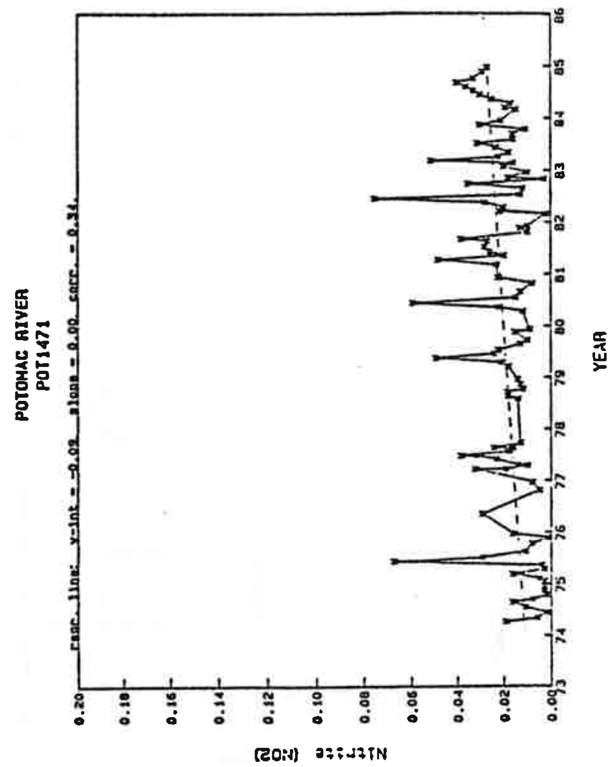



Figure IV.35

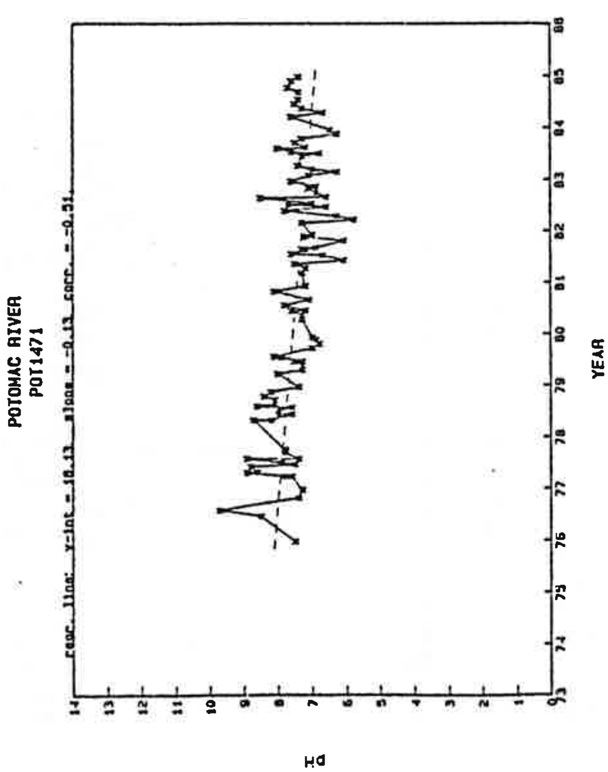



Figure IV.36

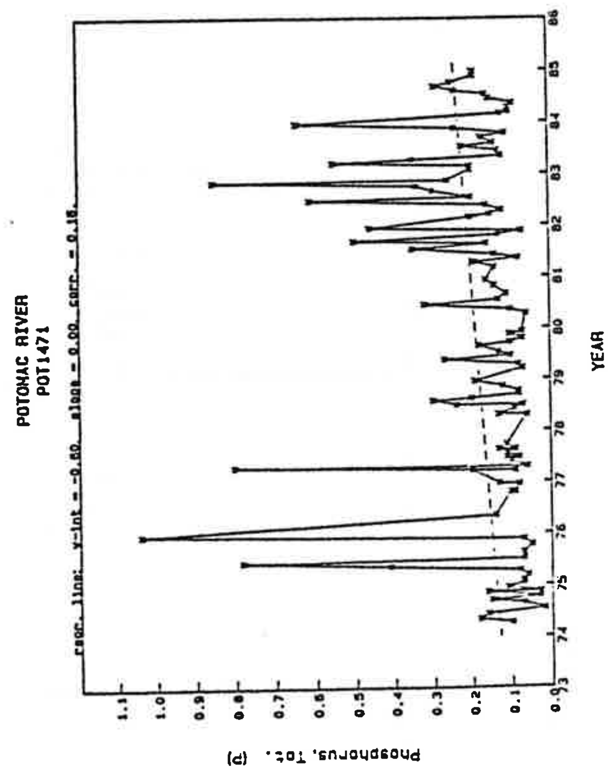


Figure IV.37

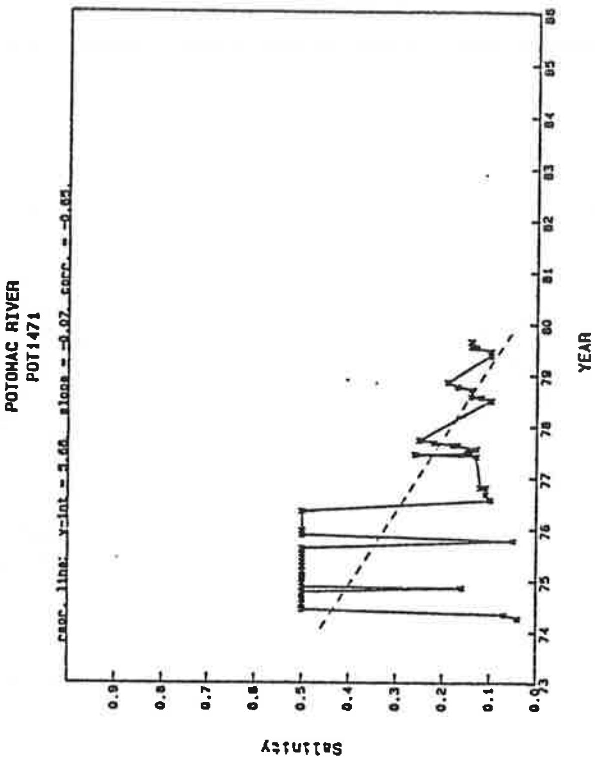



Figure IV.38

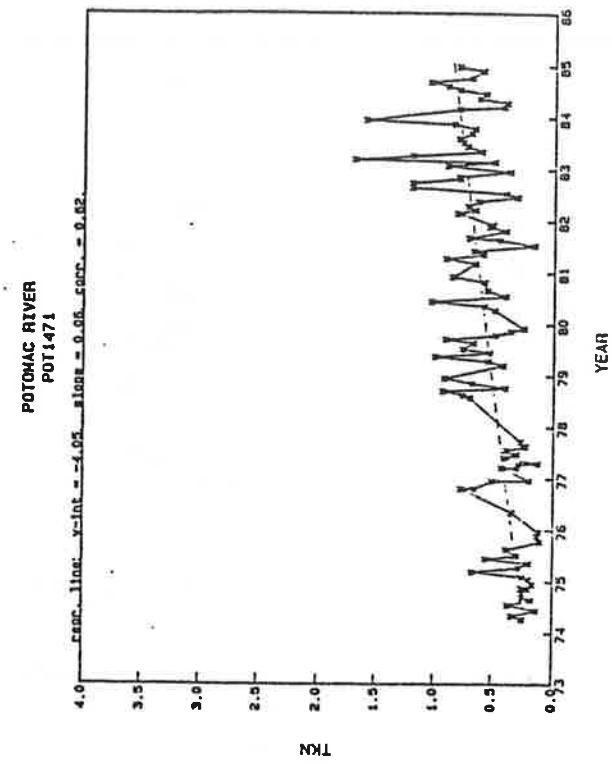



Figure IV.39

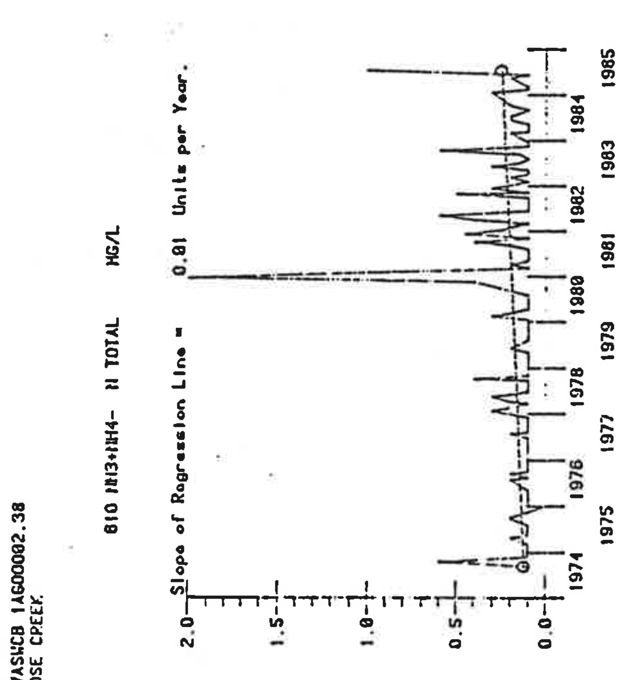



Figure IV.40

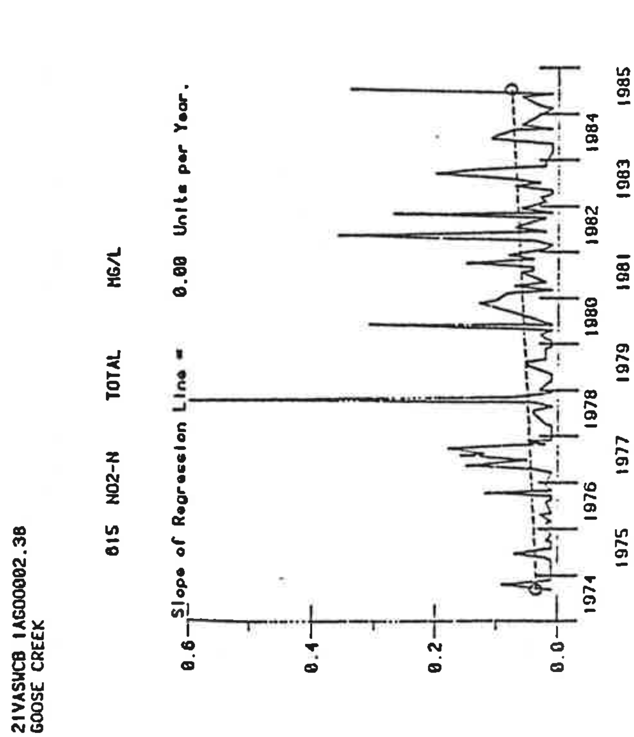


Figure IV.41

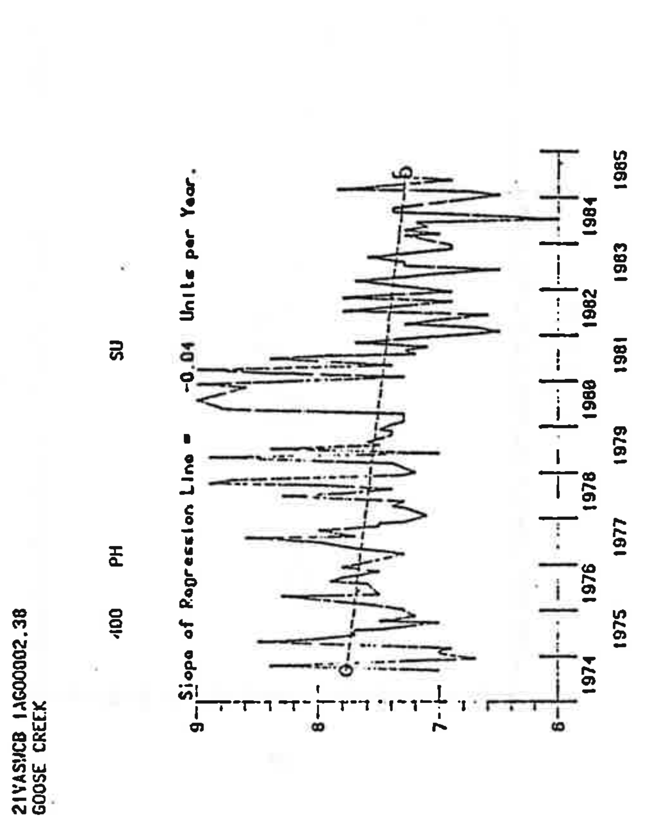



Figure IV.42

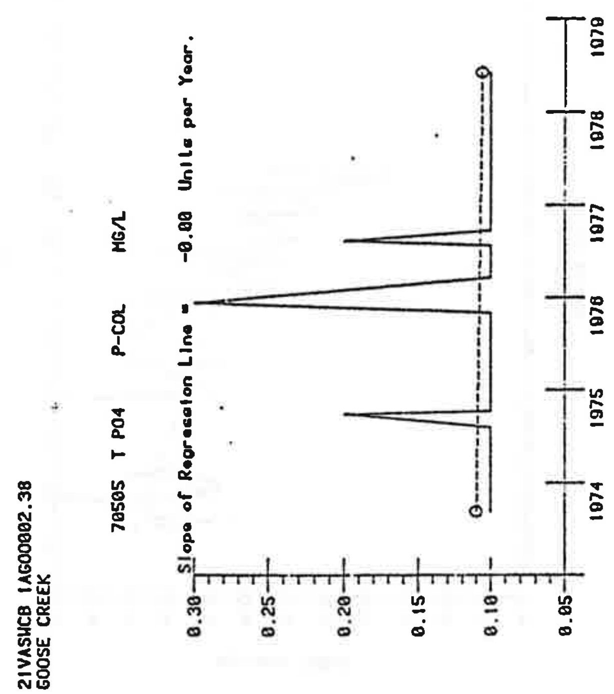



Figure IV.43

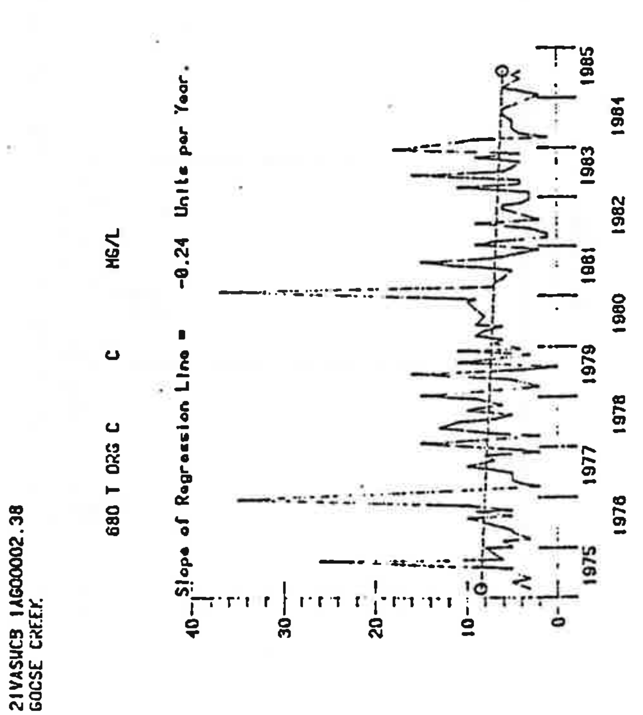



Figure IV.44

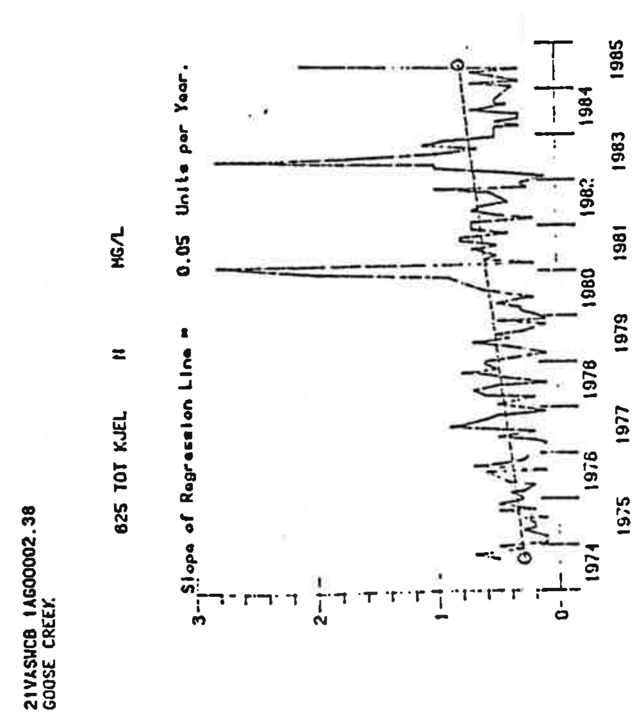


Figure IV.45

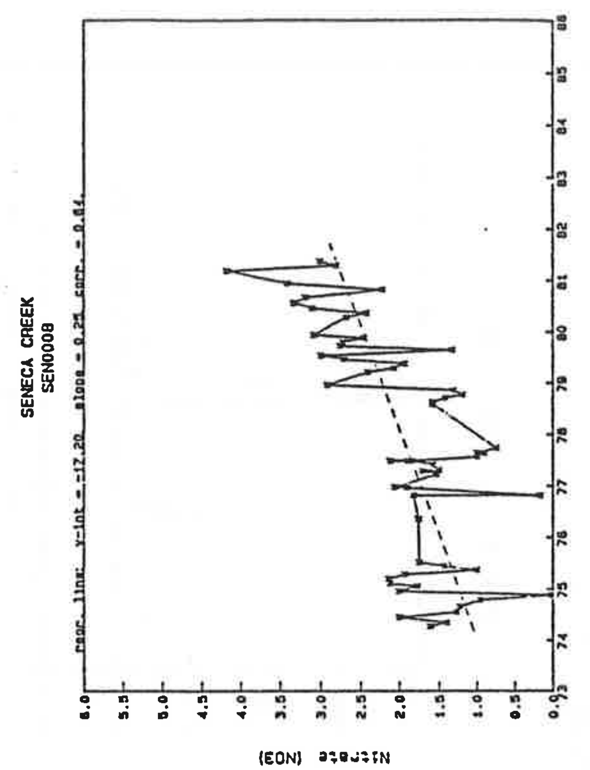



Figure IV.46

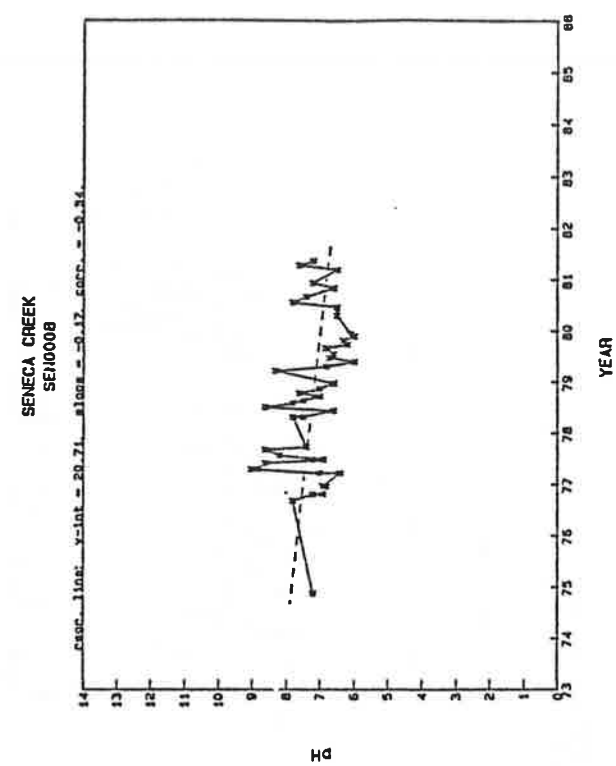



Figure IV.47

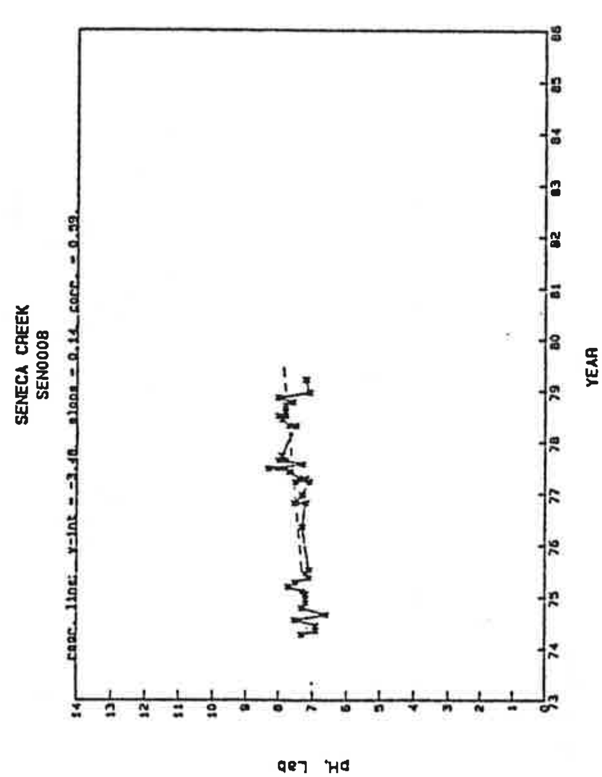



Figure IV.48

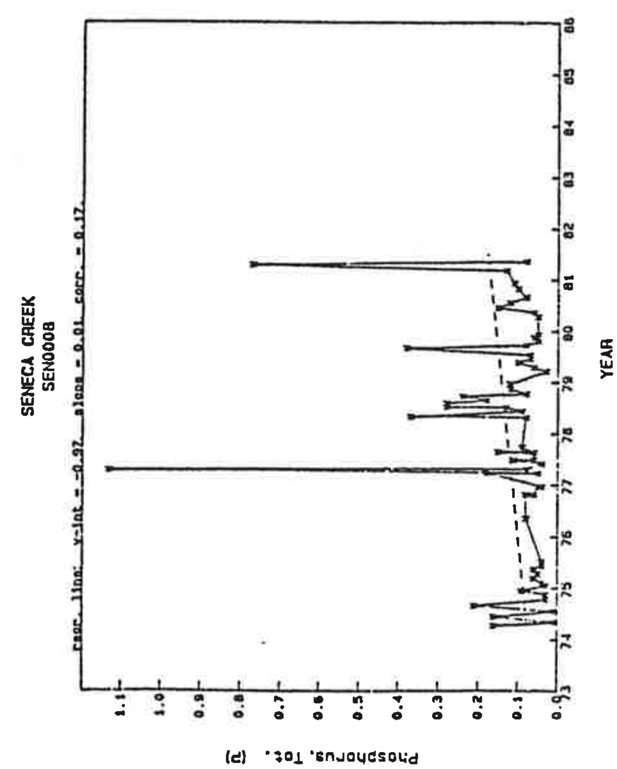


Figure IV.49

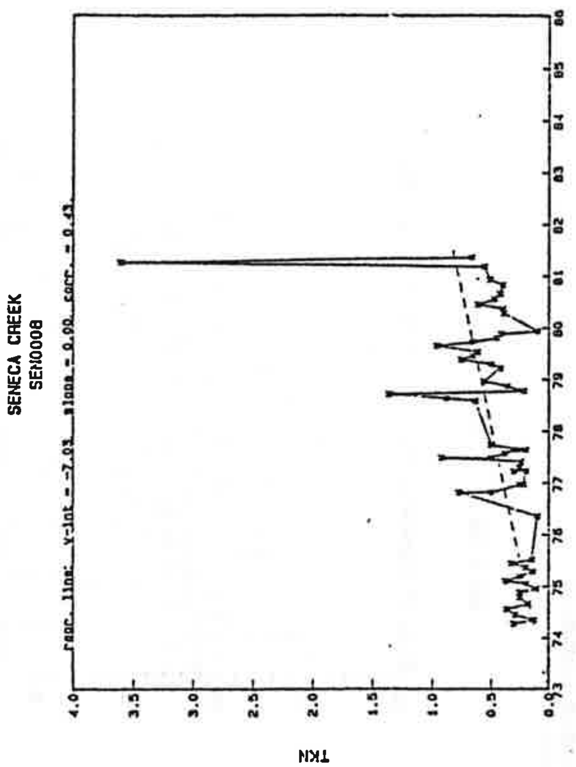



Figure IV.50

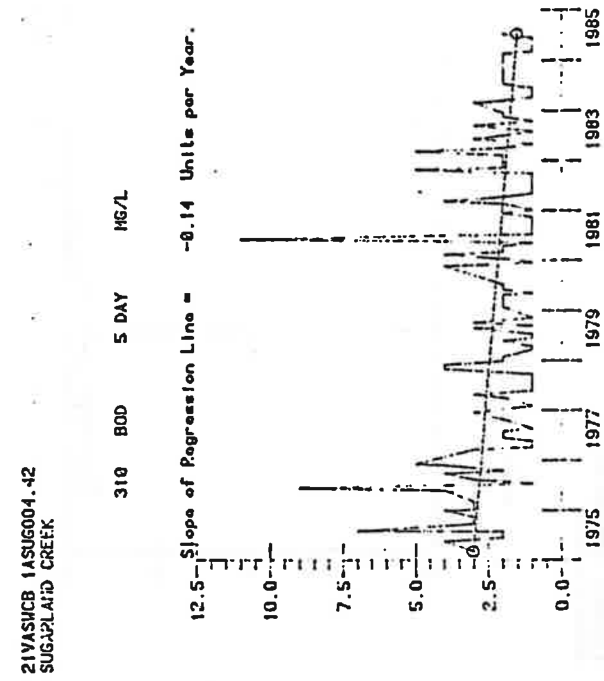



Figure IV.51

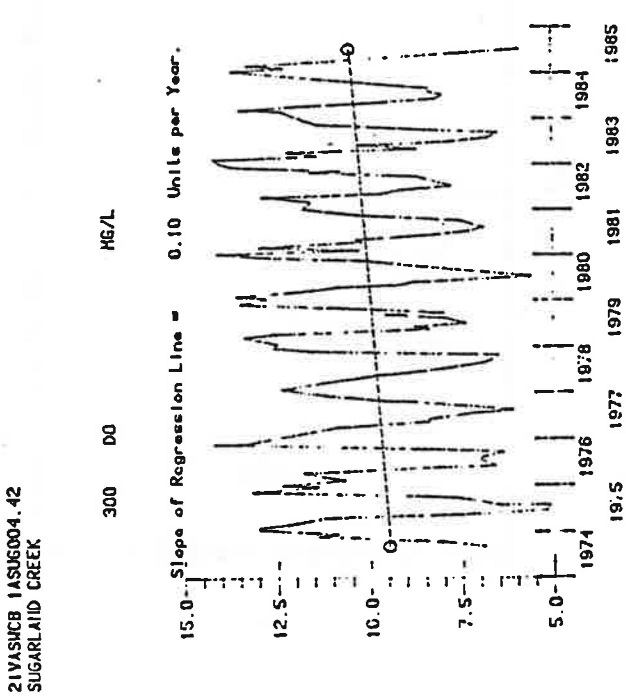



Figure IV.52

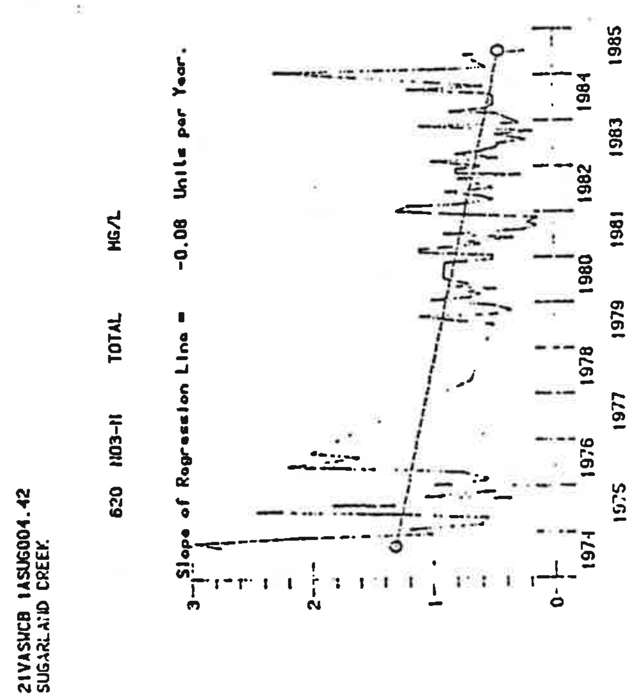


Figure IV.53

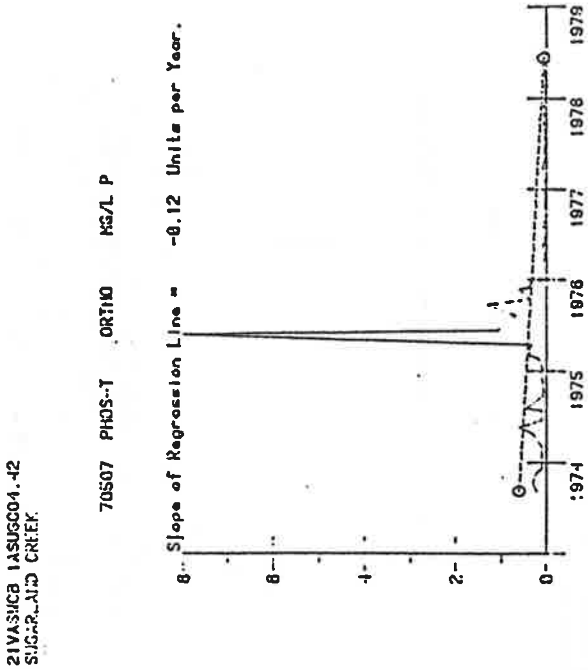



Figure IV.54

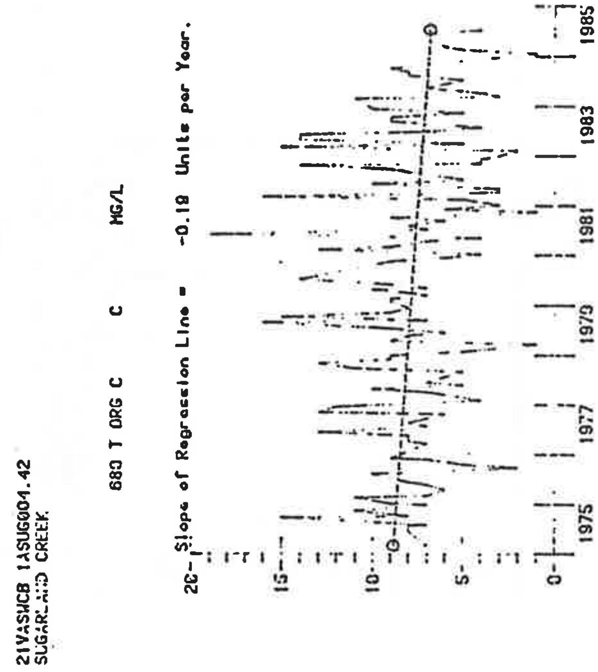



Figure IV.55

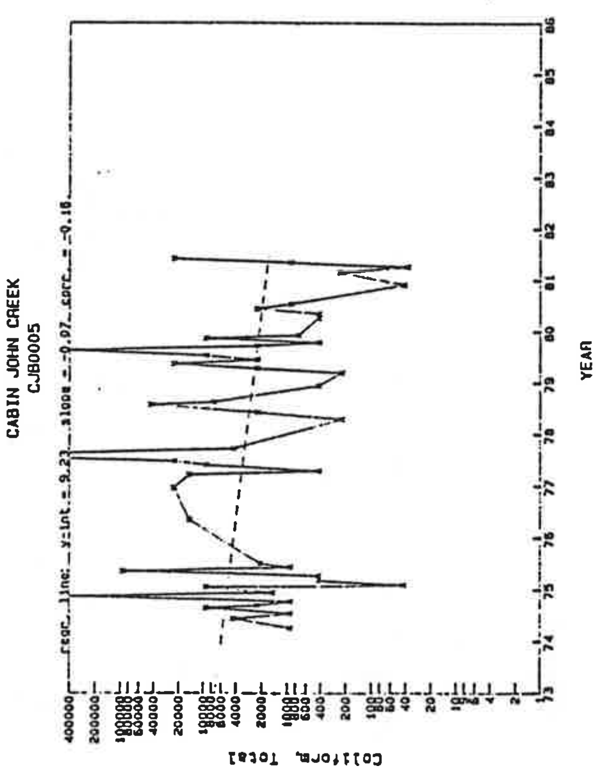



Figure IV.56

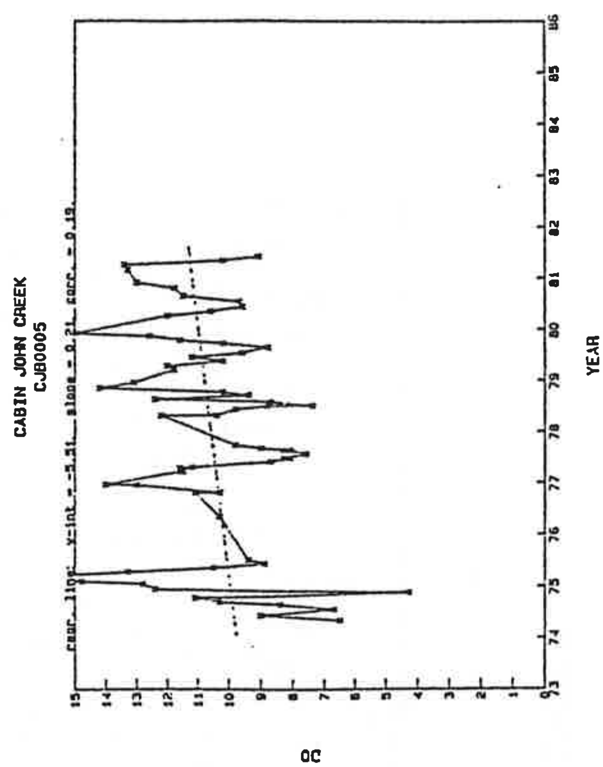


Figure IV.57

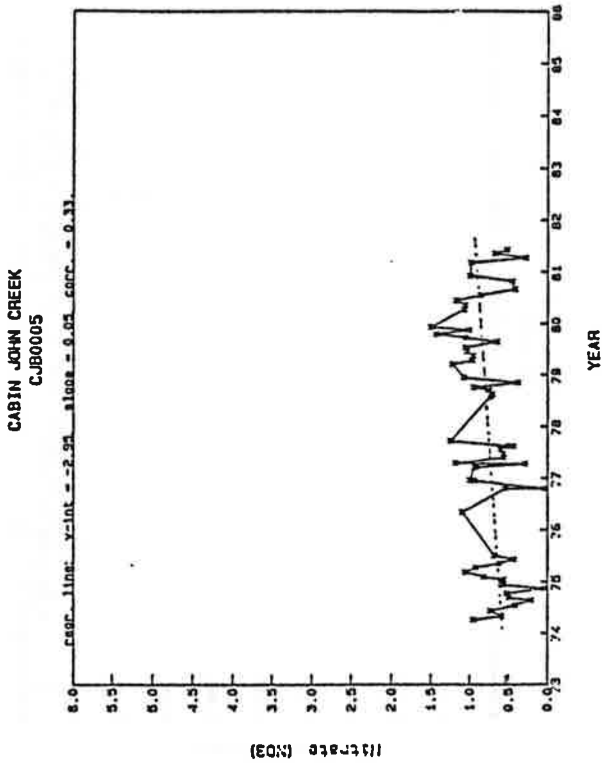



Figure IV.58

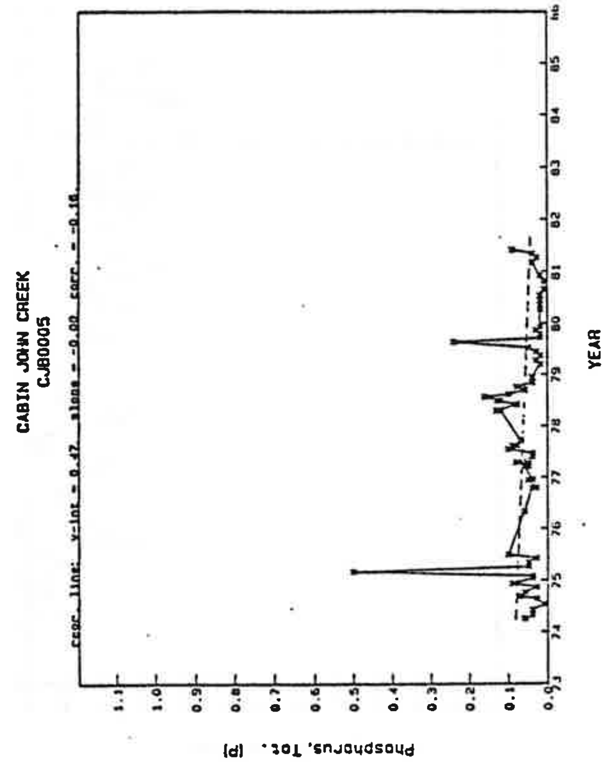



Figure IV.59

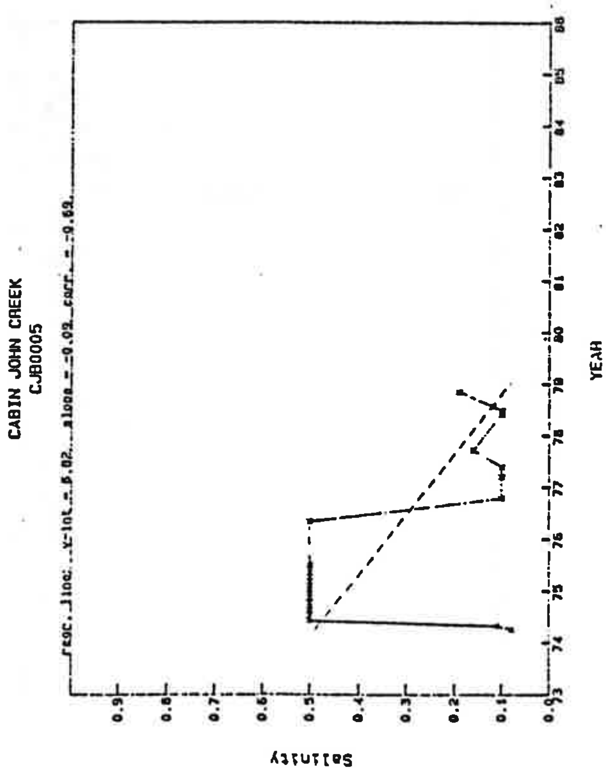



Figure IV.60

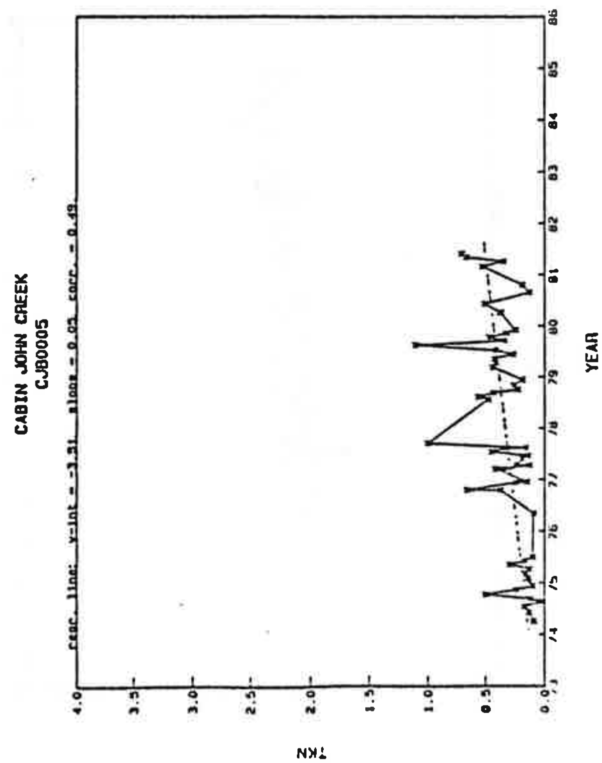


Figure V.1

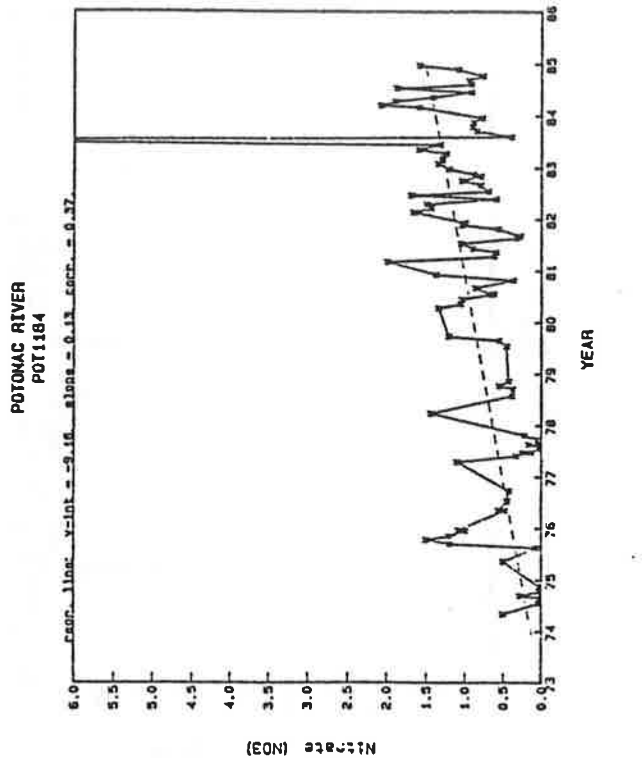



Figure V.2

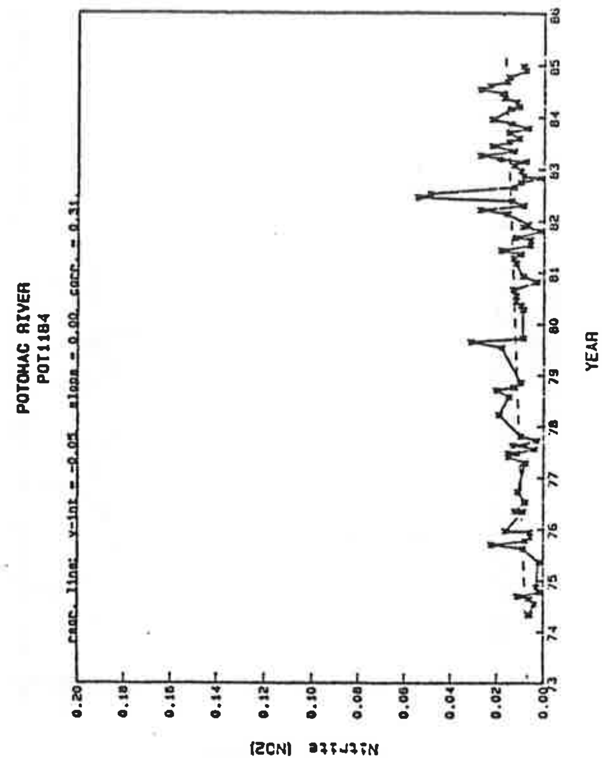



Figure V.3

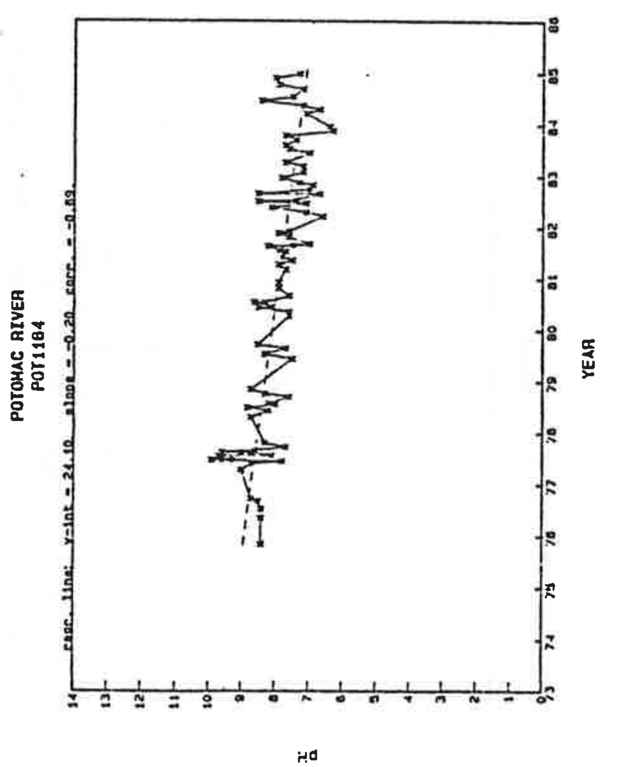



Figure V.4

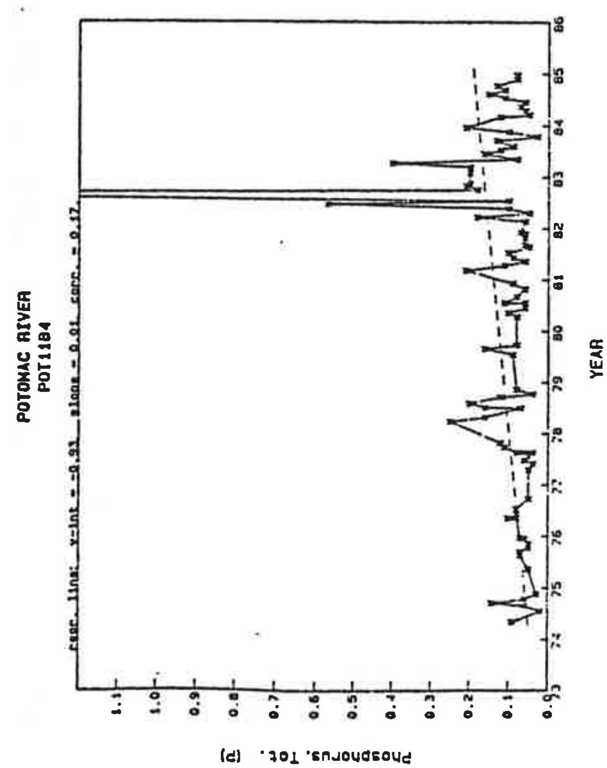


Figure V.5

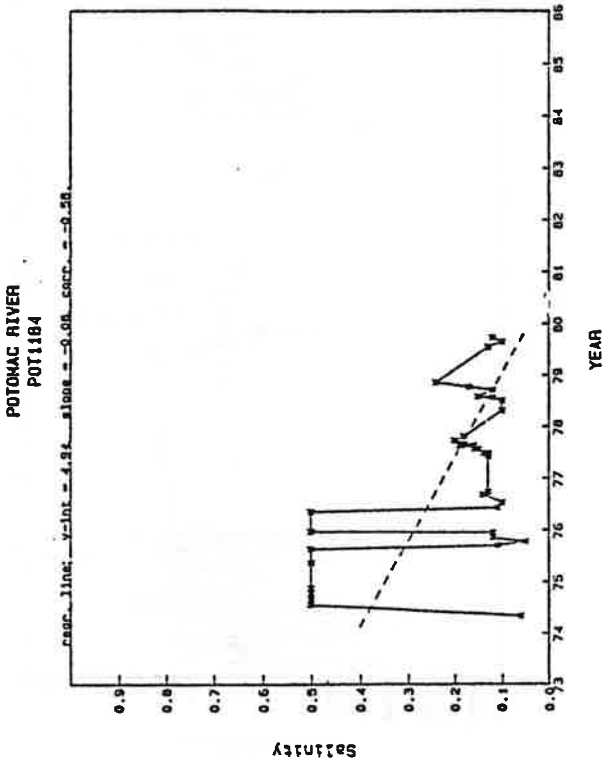



Figure V.6

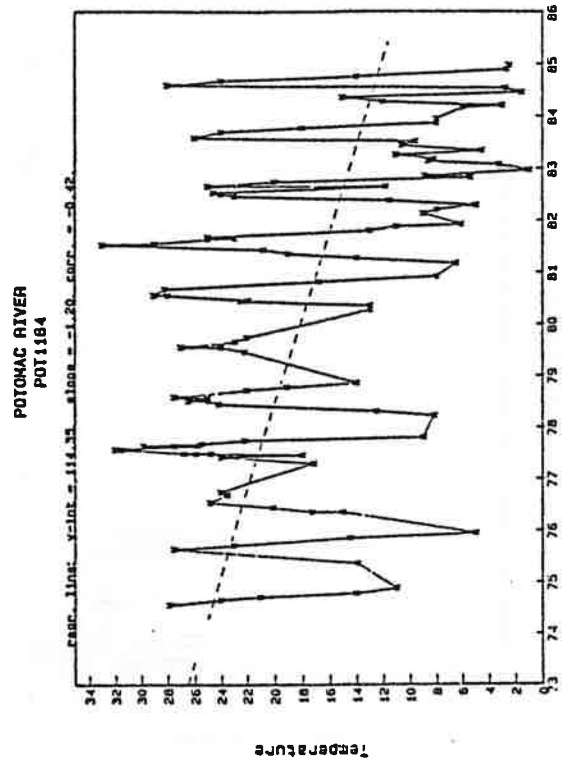



Figure V.7

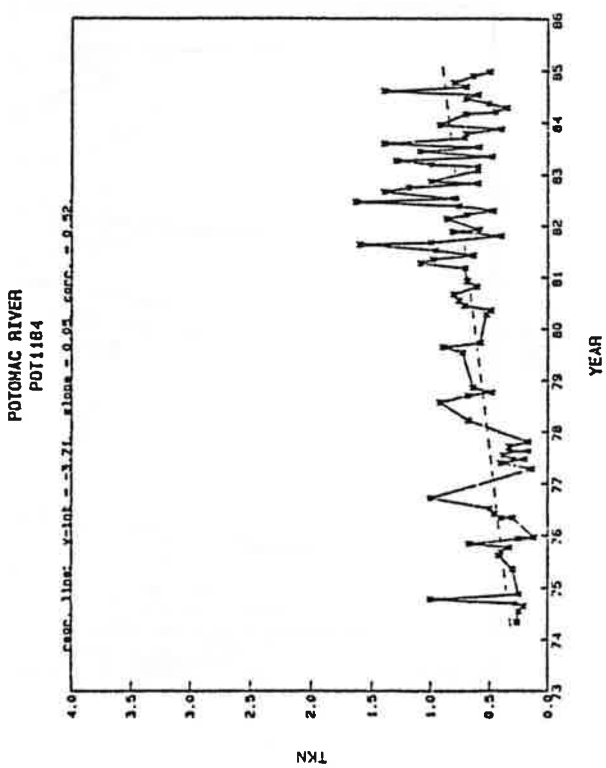



Figure V.8

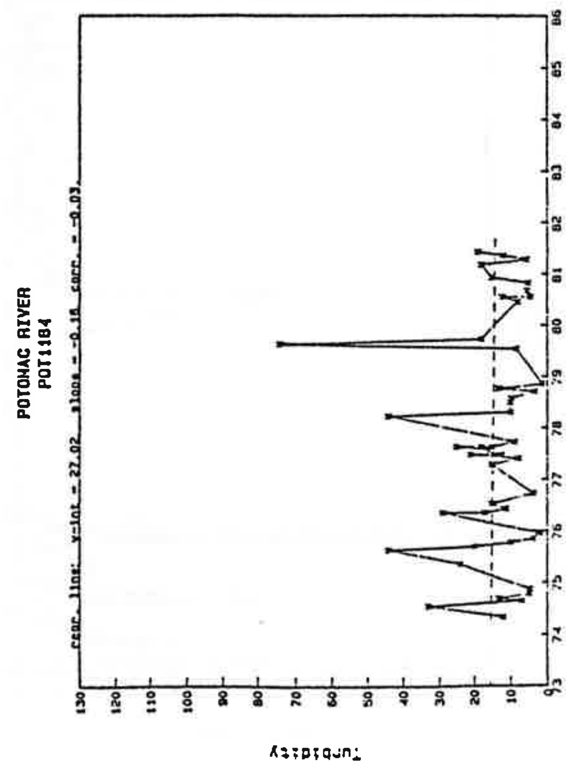


Figure V.9

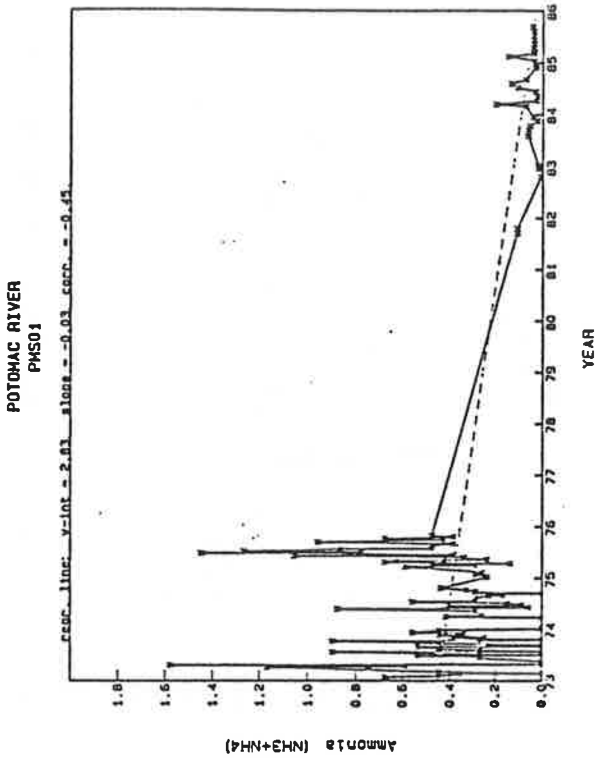



Figure V.10

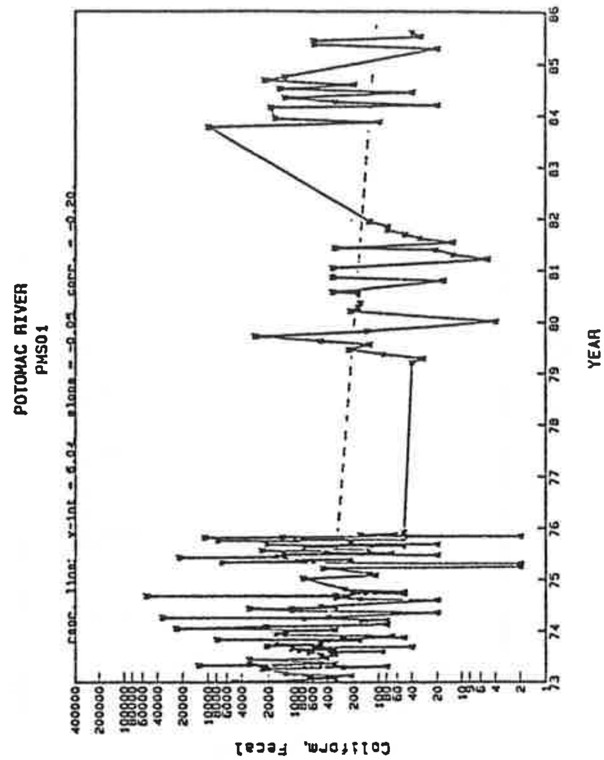



Figure V.11

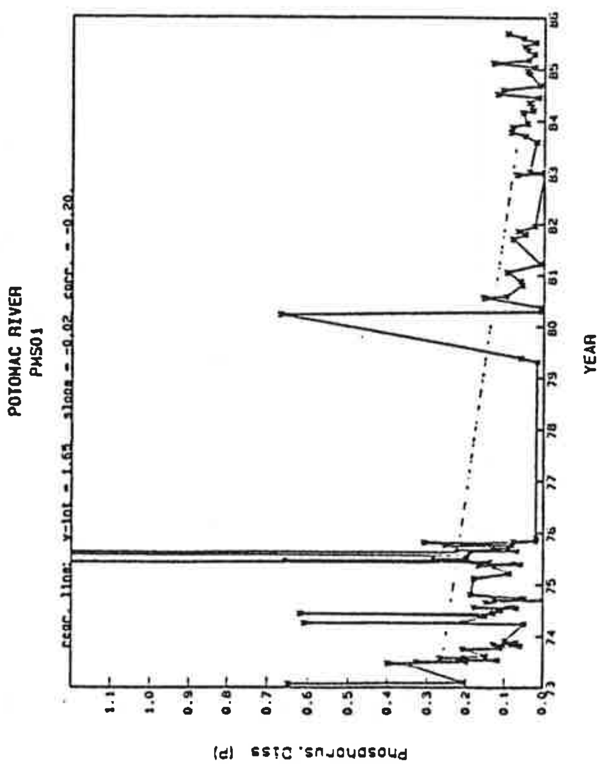



Figure V.12

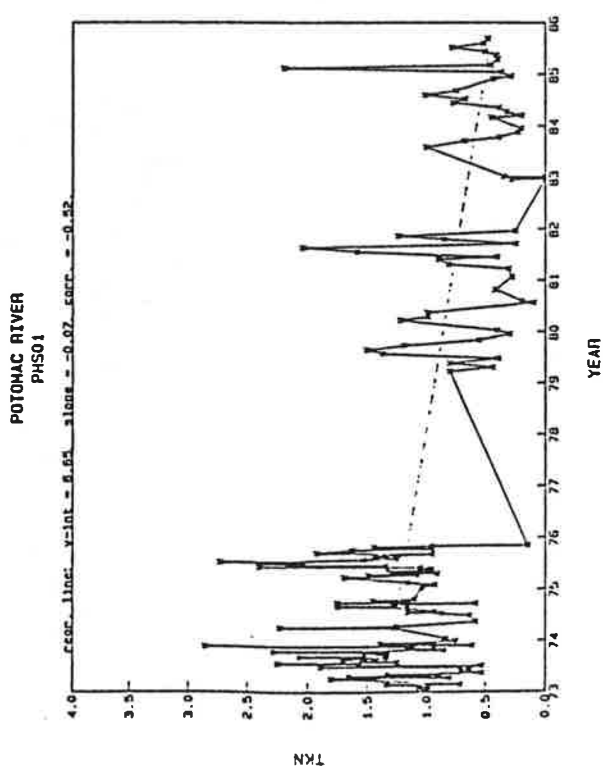


Figure V.13

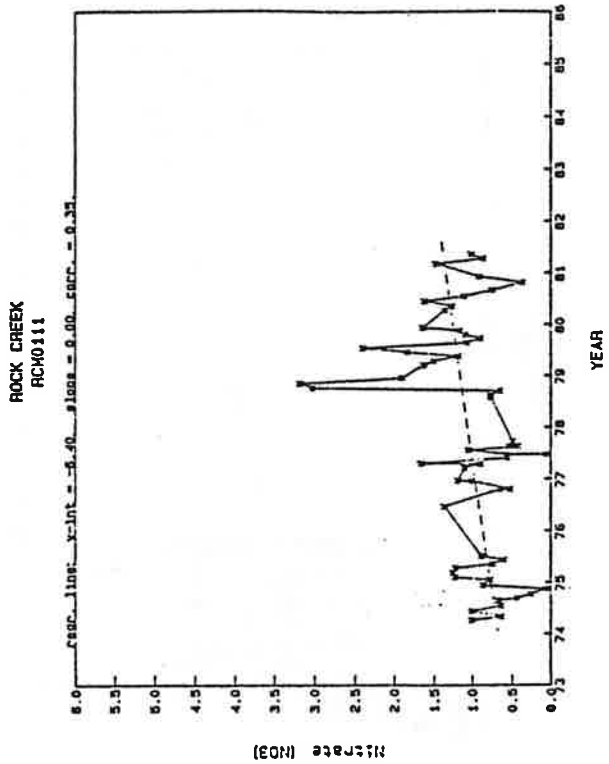



Figure V.14

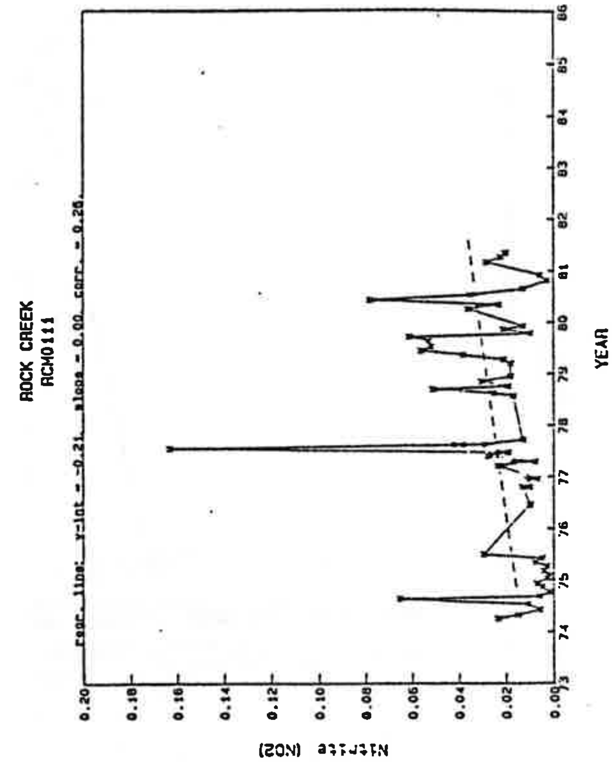



Figure V.15

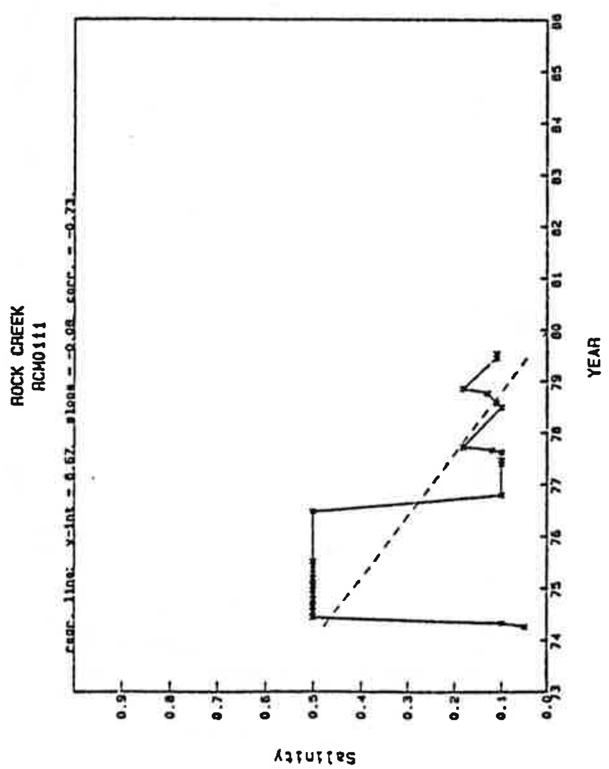



Figure V.16

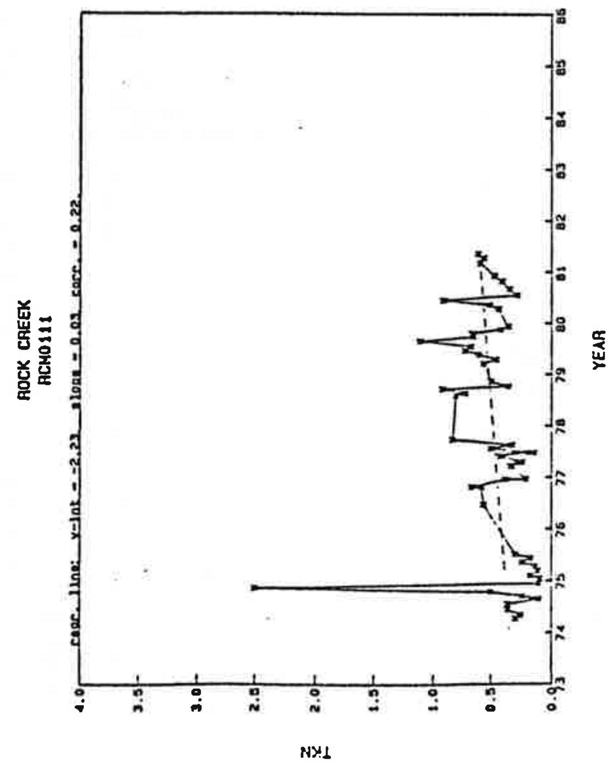


Figure V.17

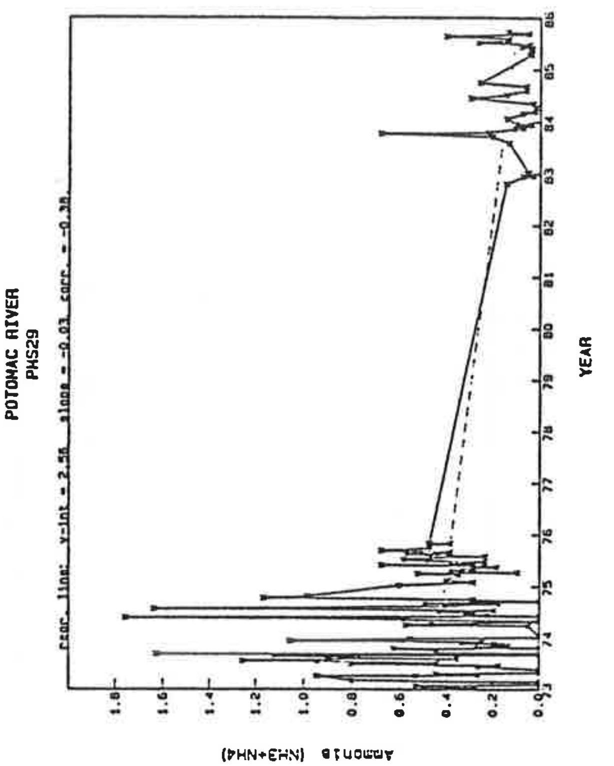



Figure V.18

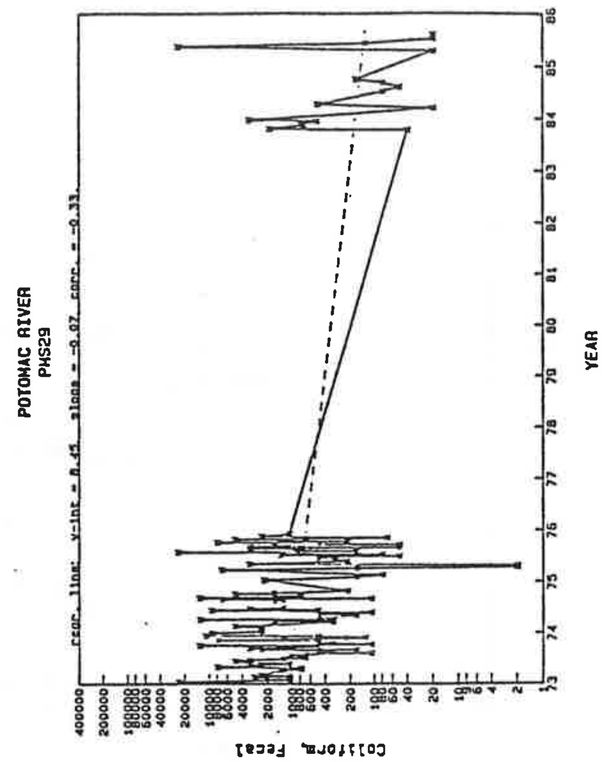



Figure V.19

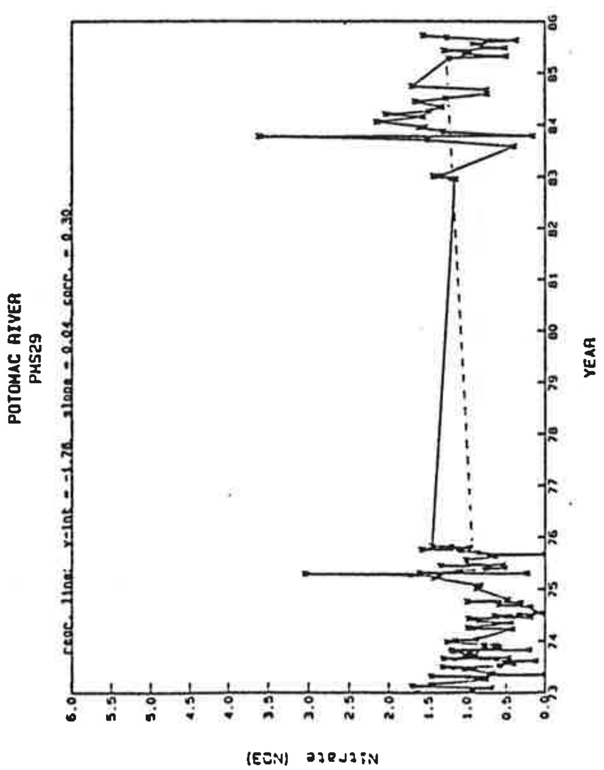
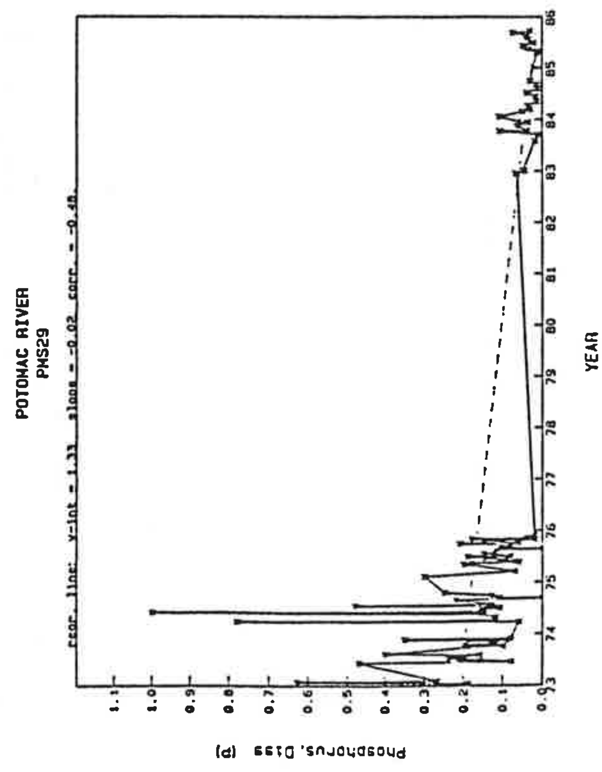



Figure V.20



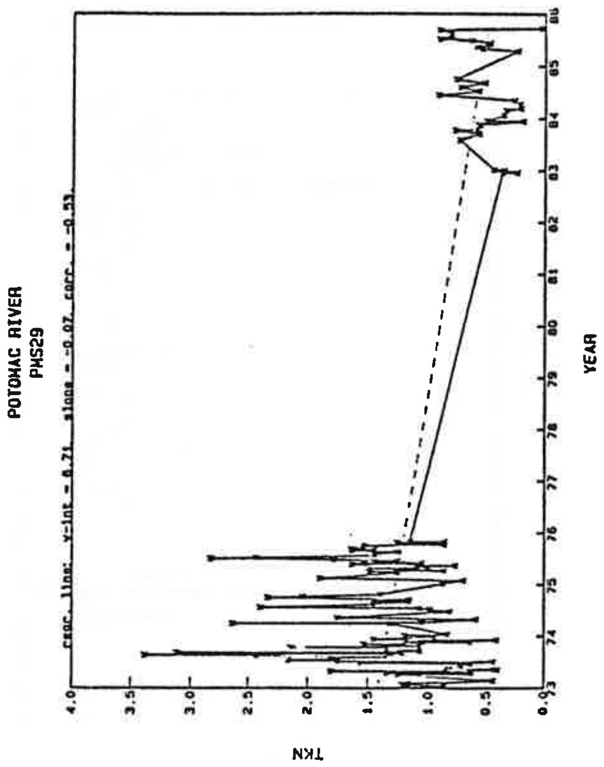


Figure V.21

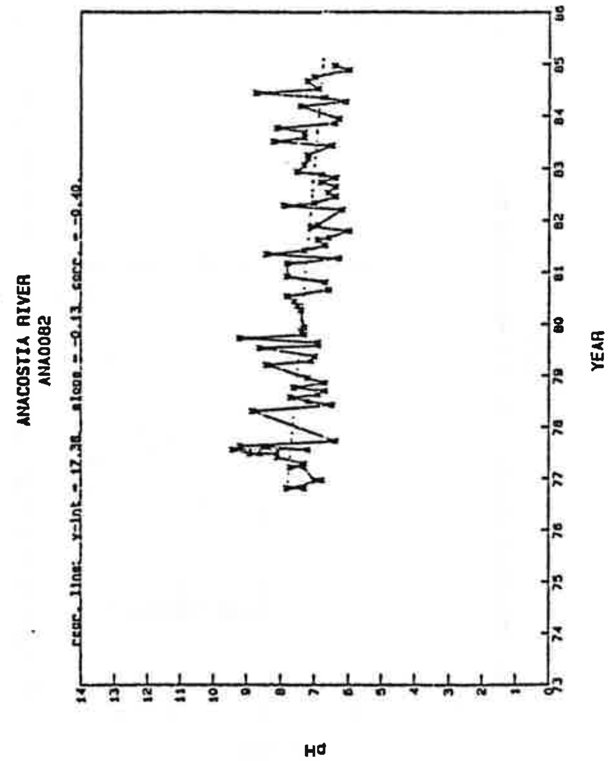


Figure V.22

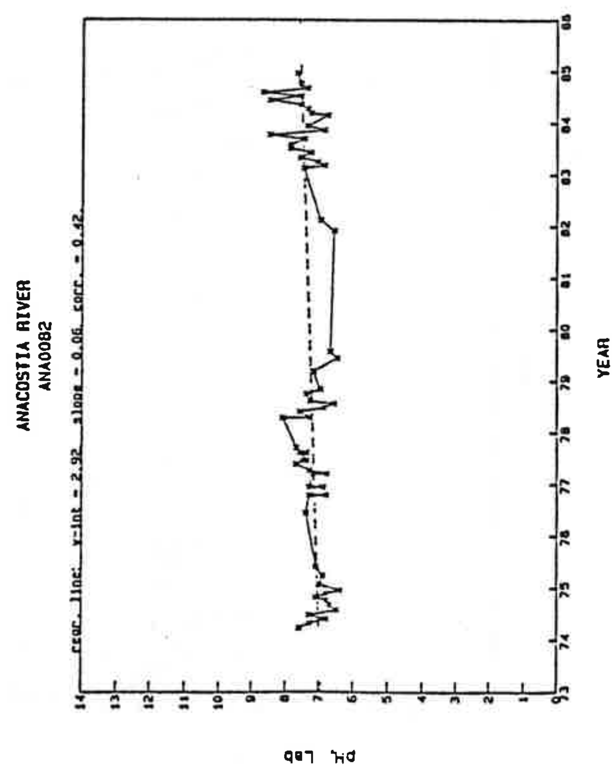


Figure V.23

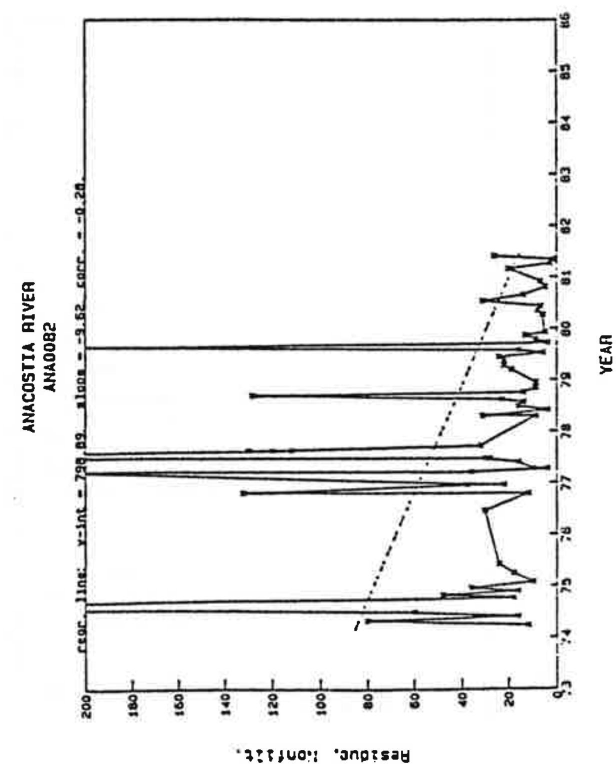


Figure V.24

Figure V.25

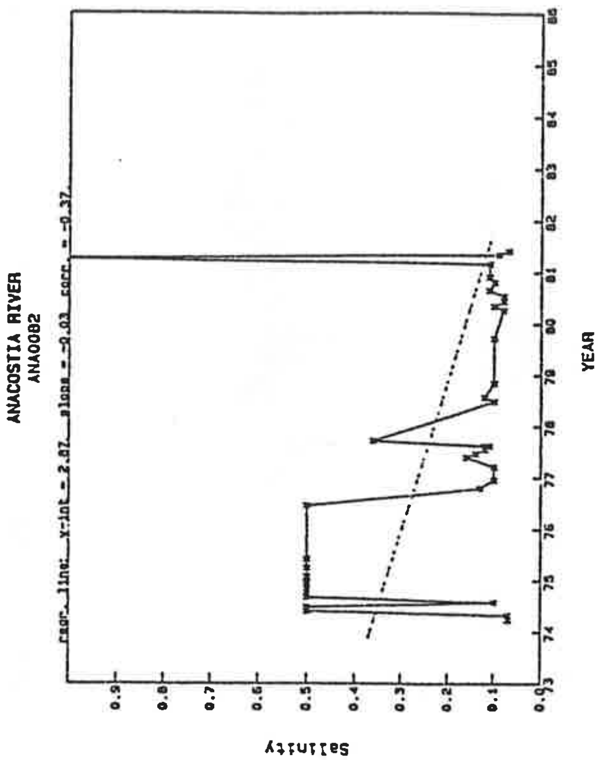



Figure V.26

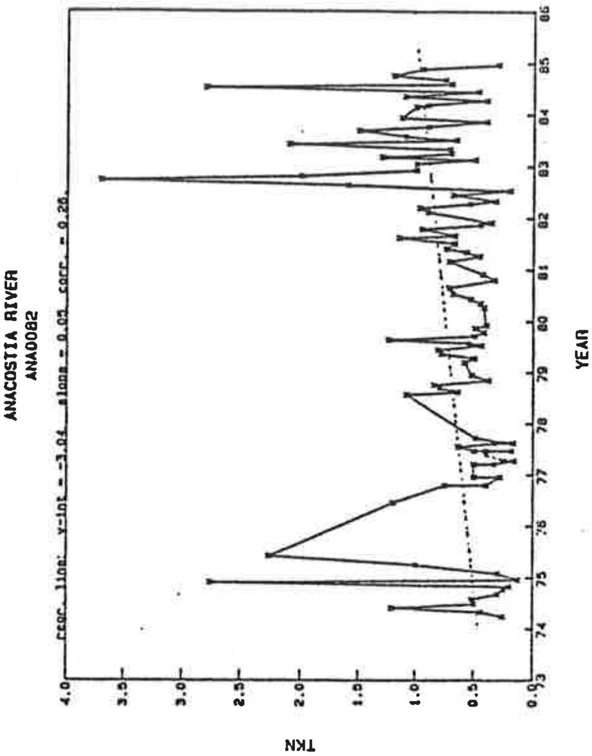



Figure V.27

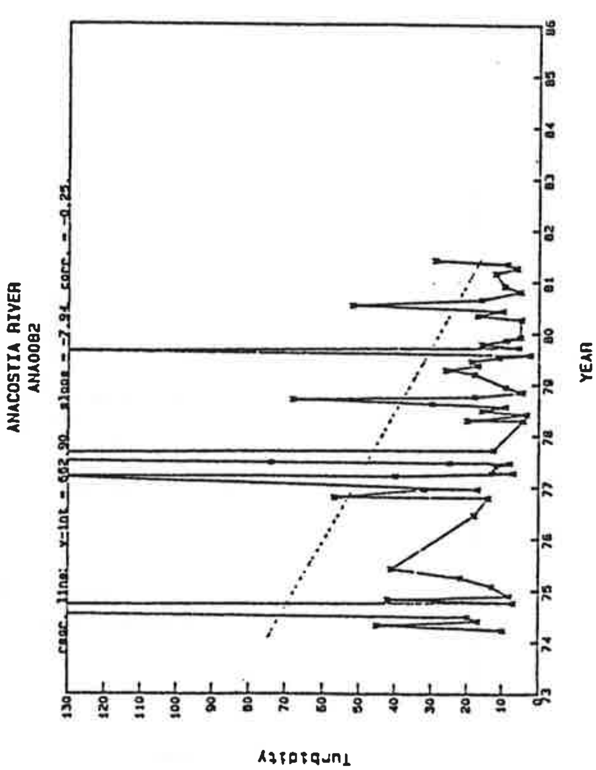



Figure V.28

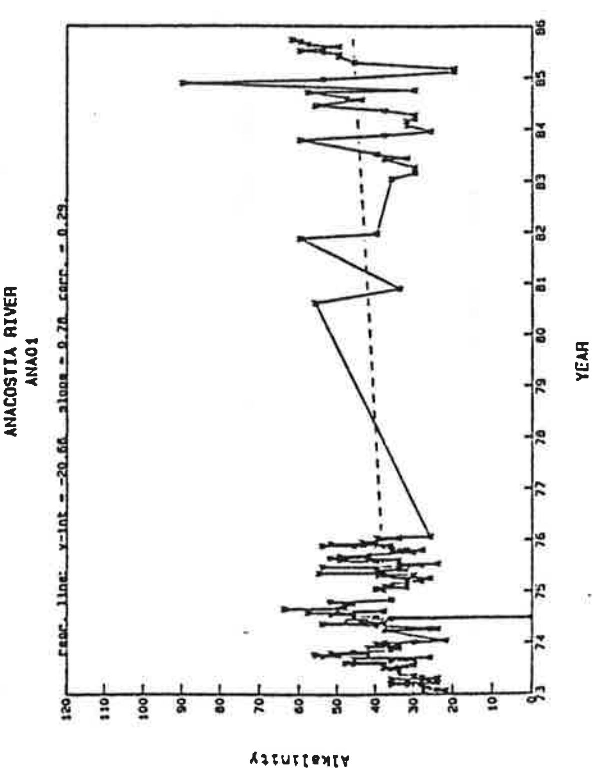


Figure V.29

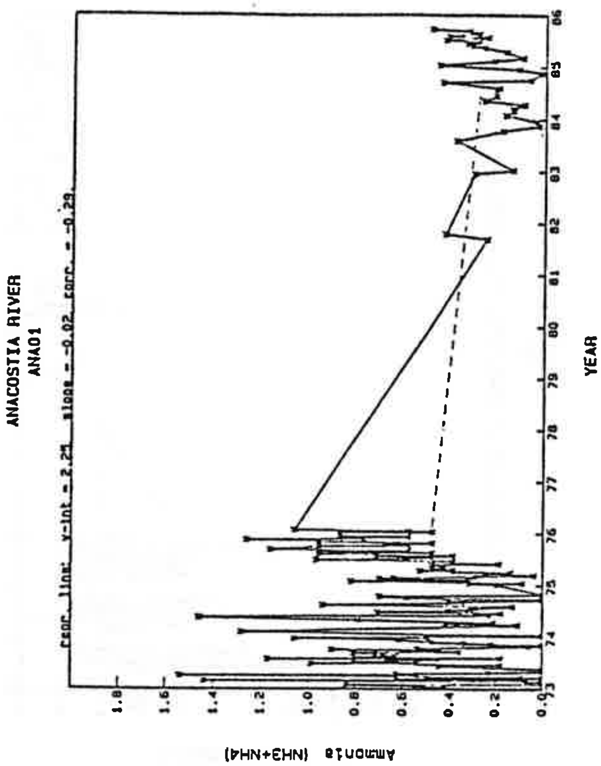



Figure V.30

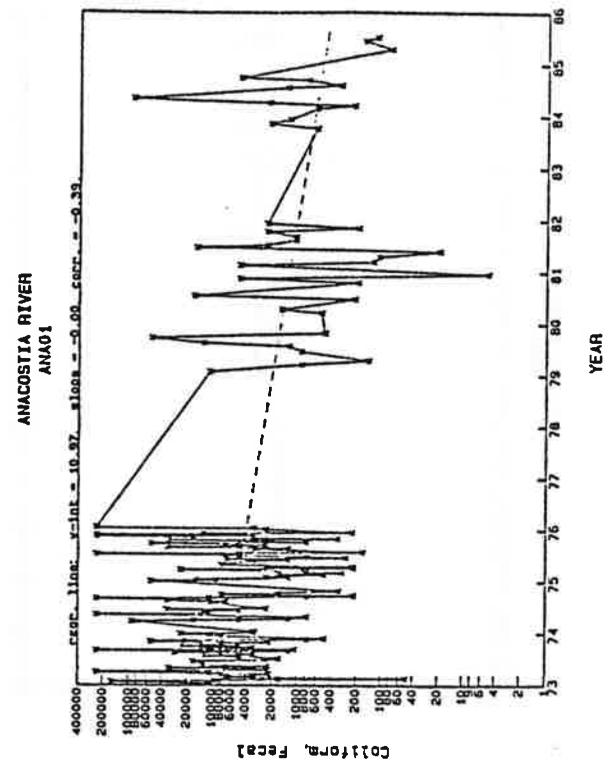



Figure V.31

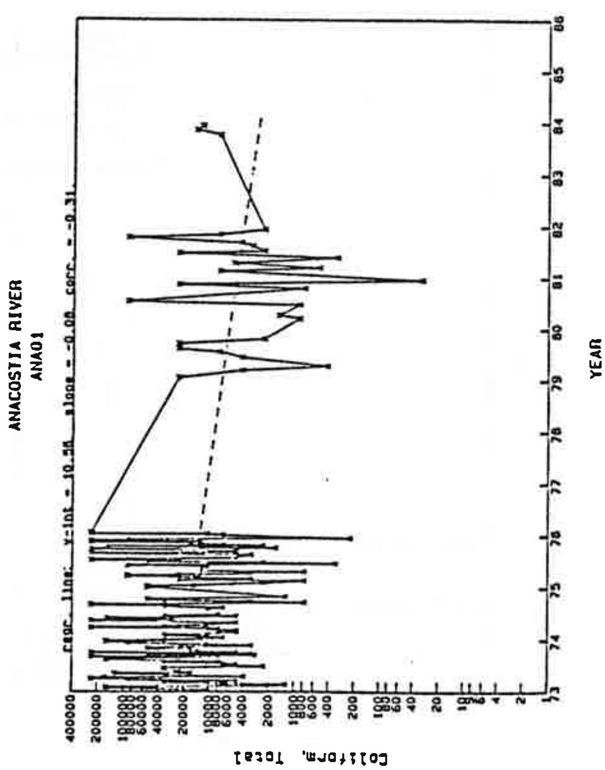



Figure V.32

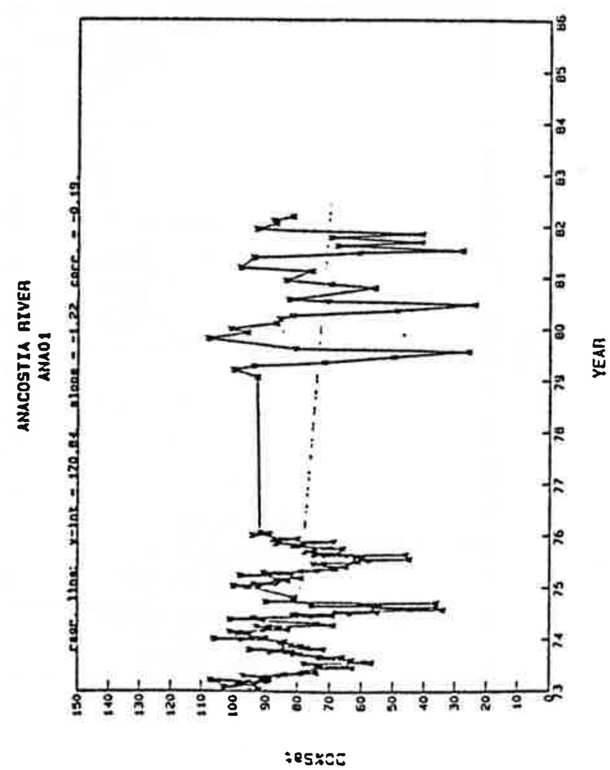


Figure V.33

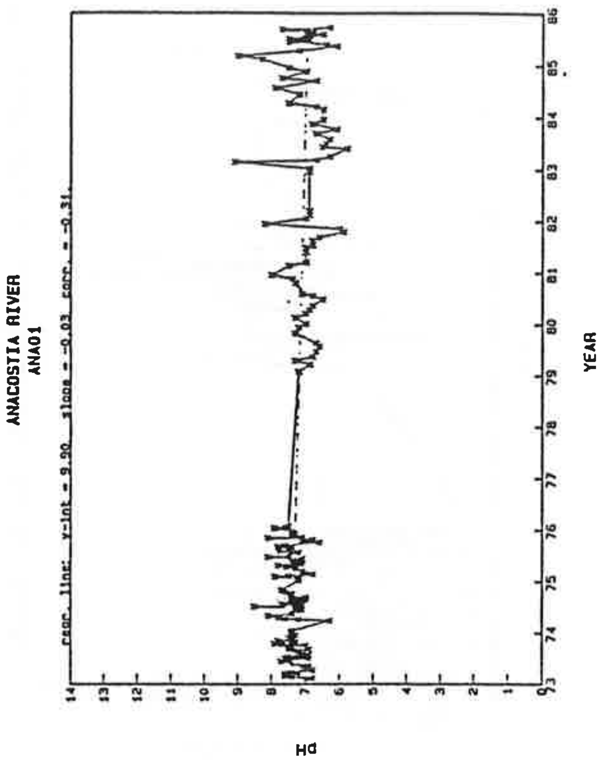



Figure V.34

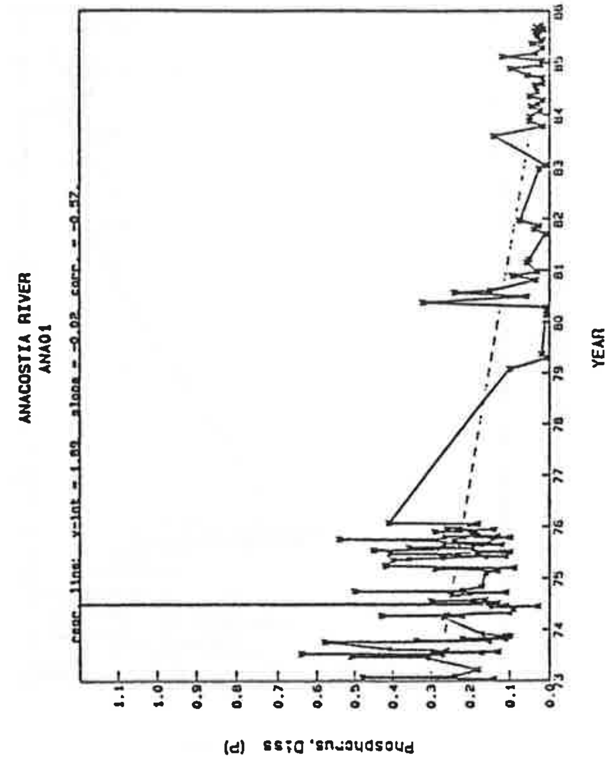



Figure V.35

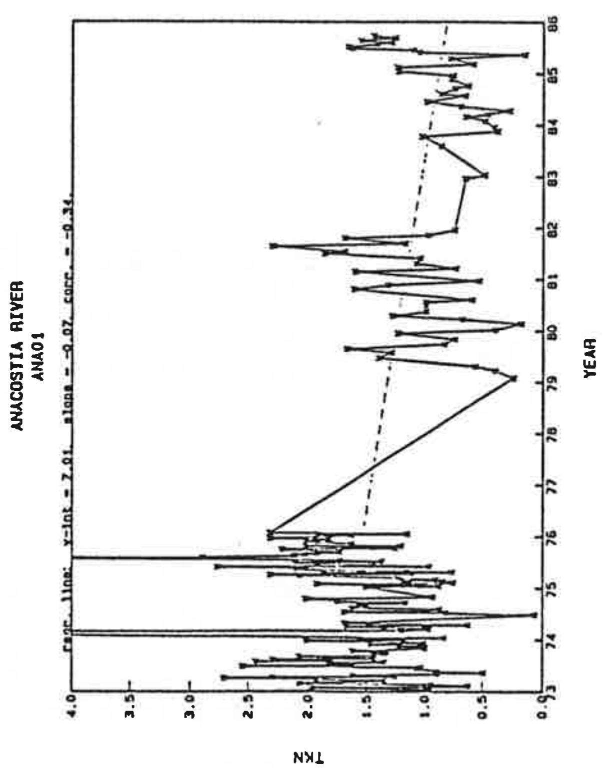



Figure V.36

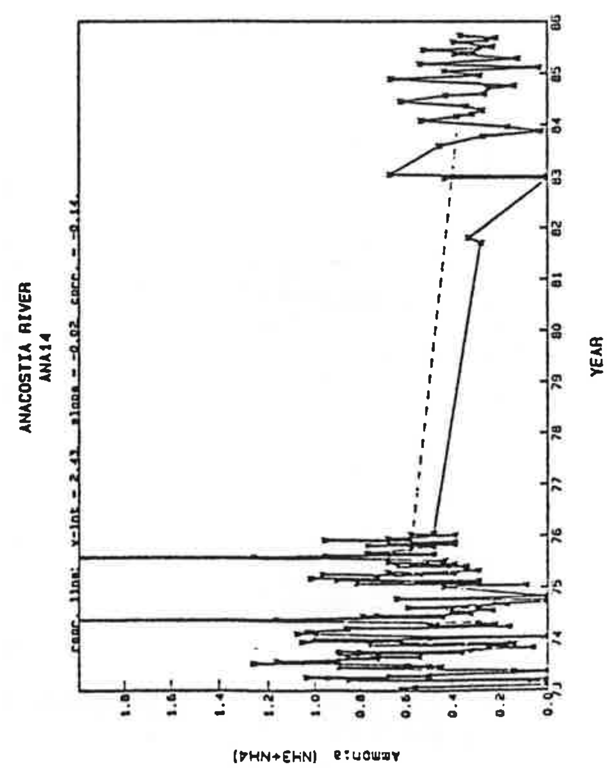


Figure V.37

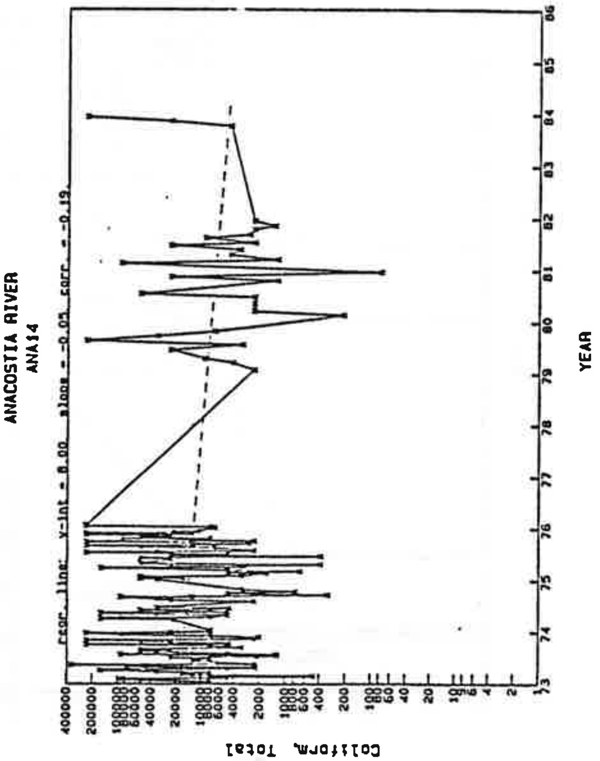



Figure V.38

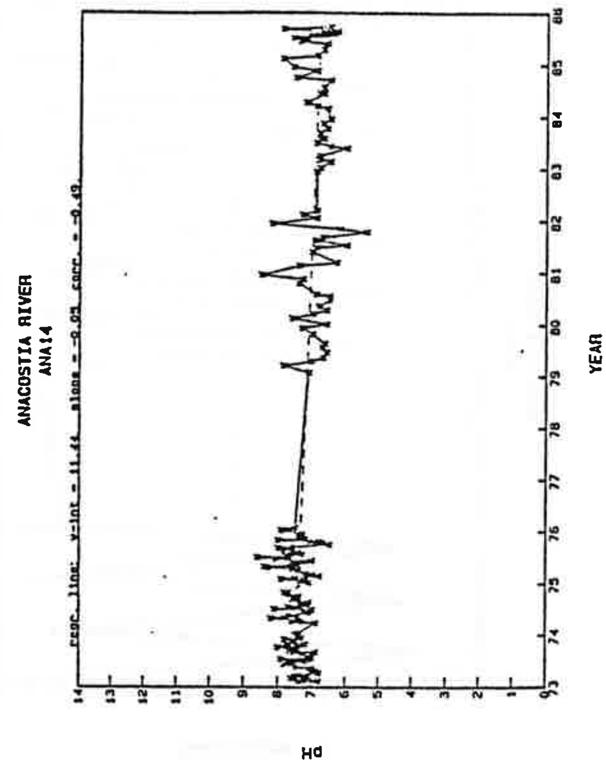



Figure V.39

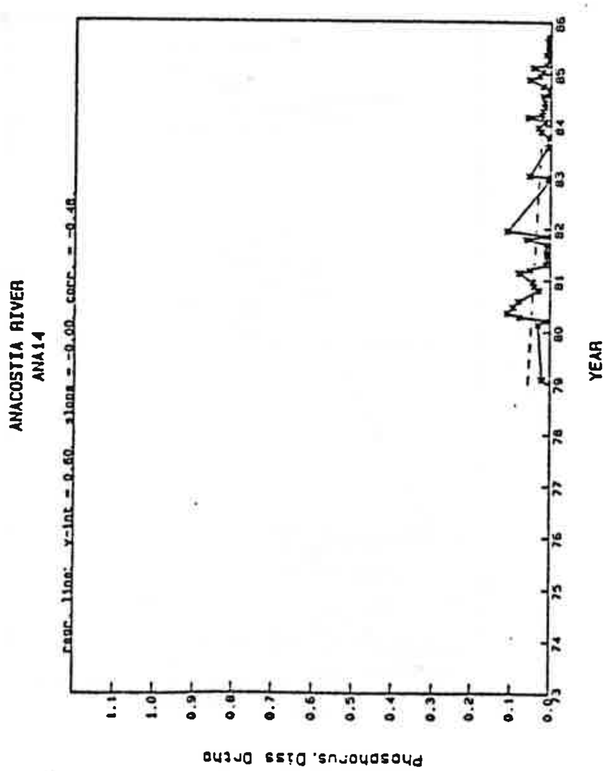



Figure V.40

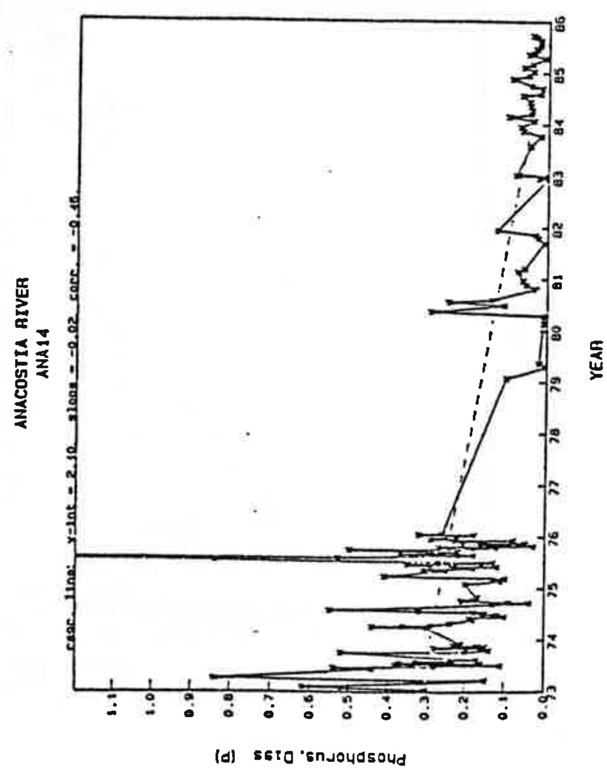


Figure V.41

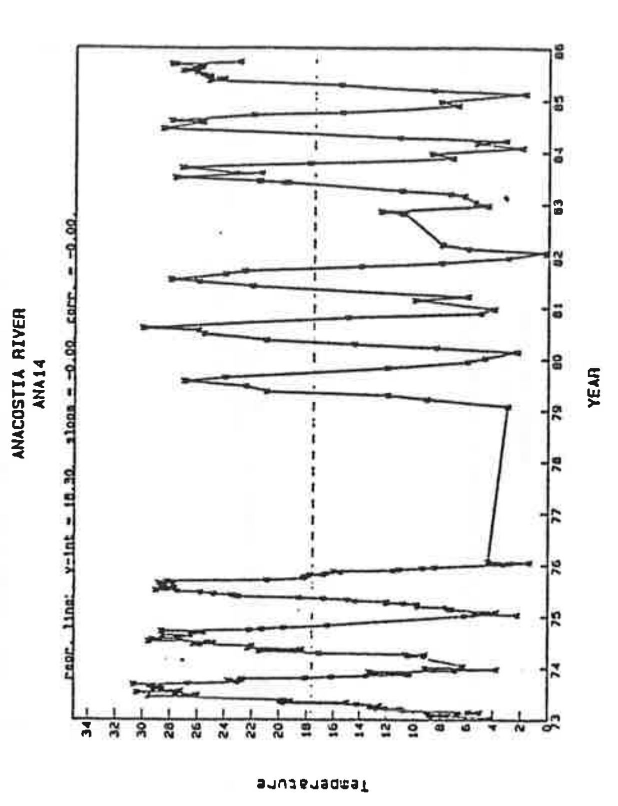



Figure V.42

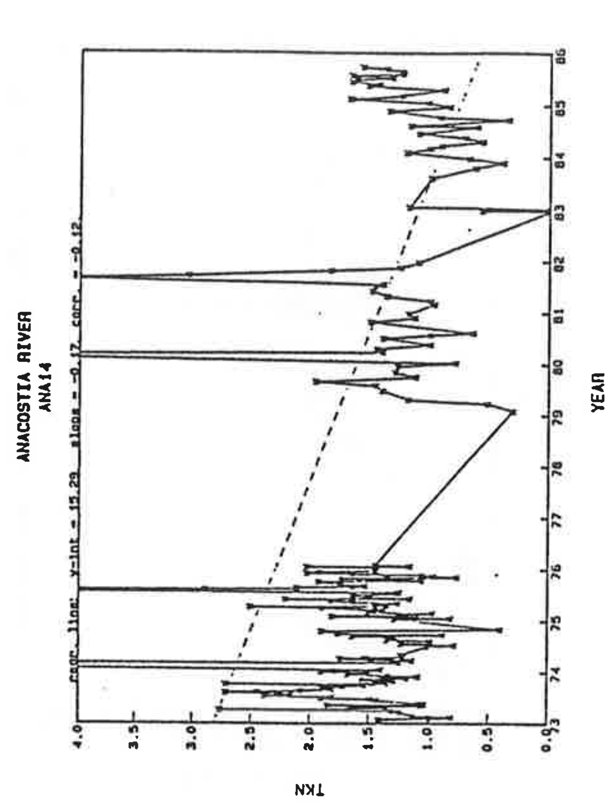



Figure V.43

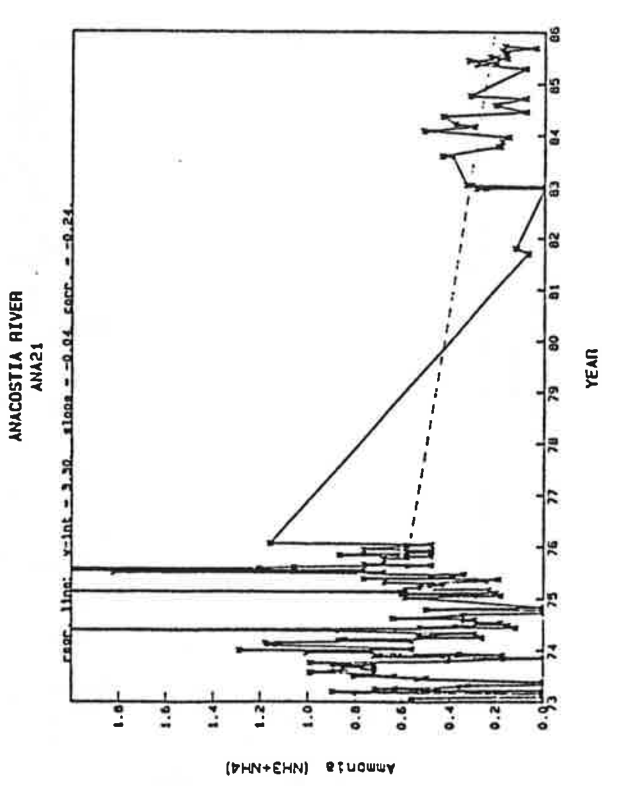



Figure V.44

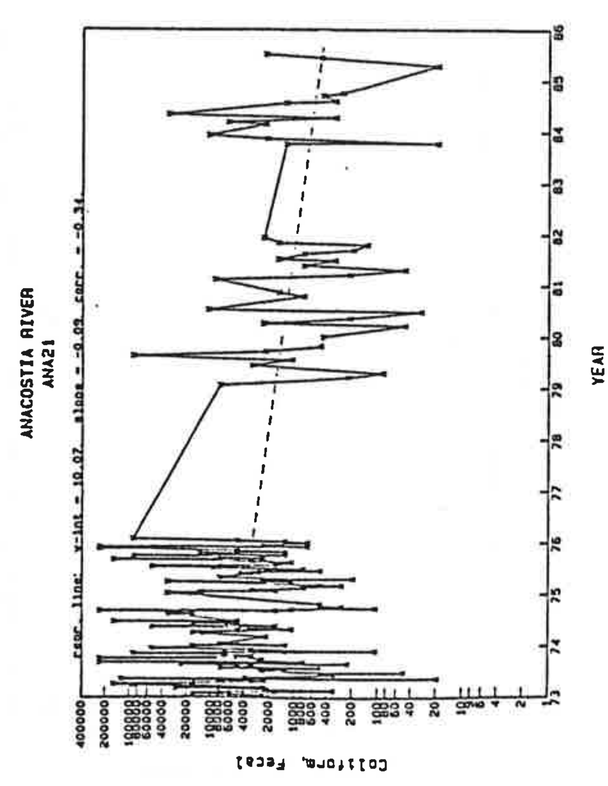


Figure V.45

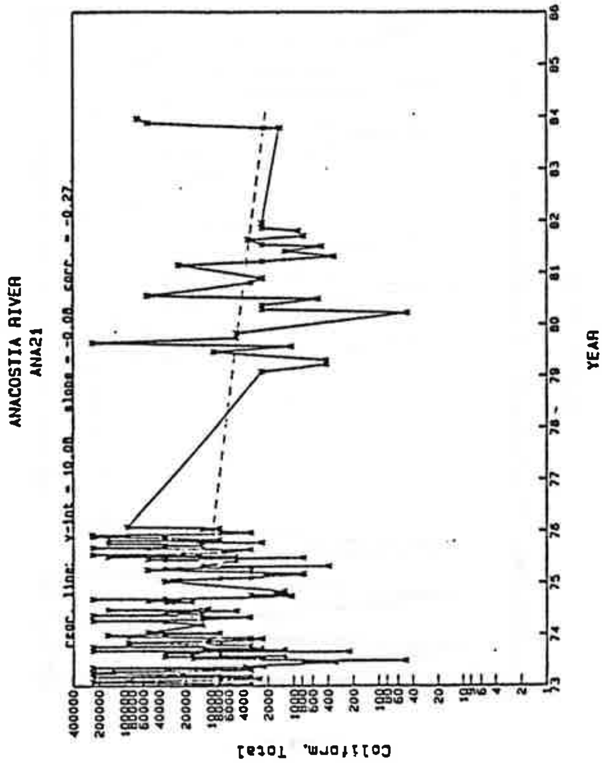



Figure V.46

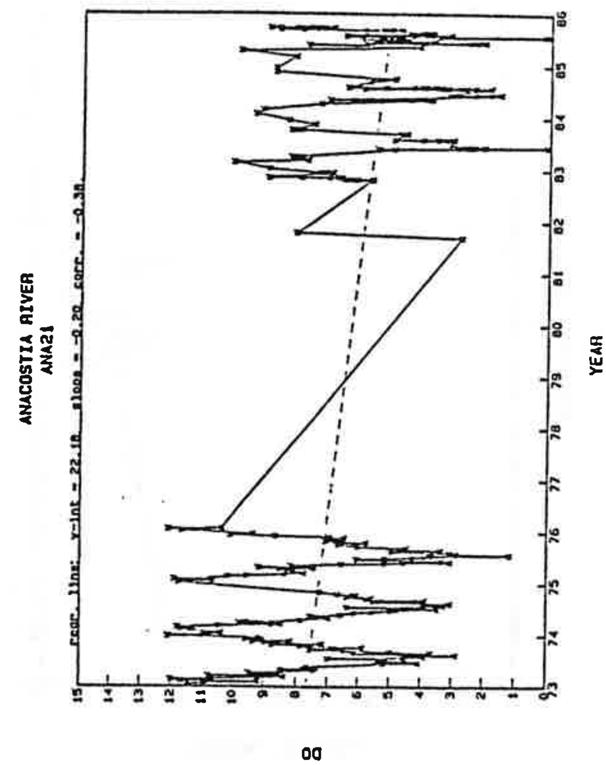



Figure V.47

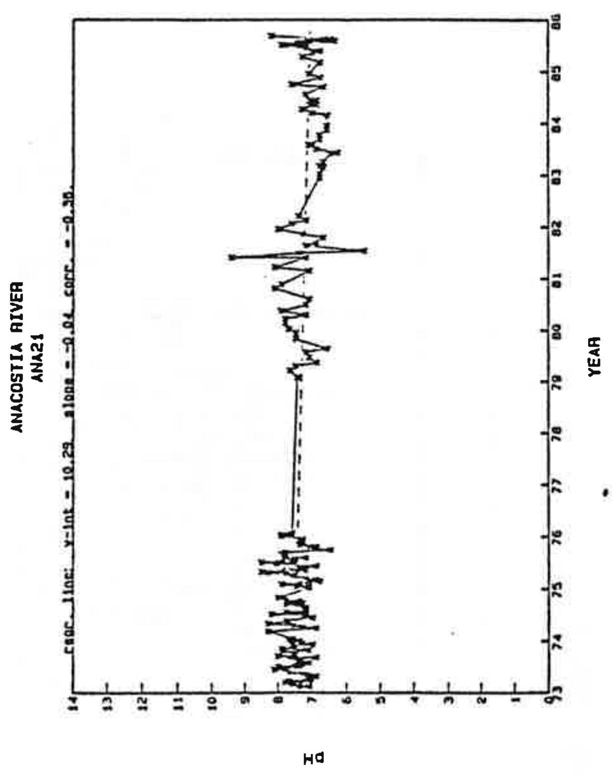



Figure V.48

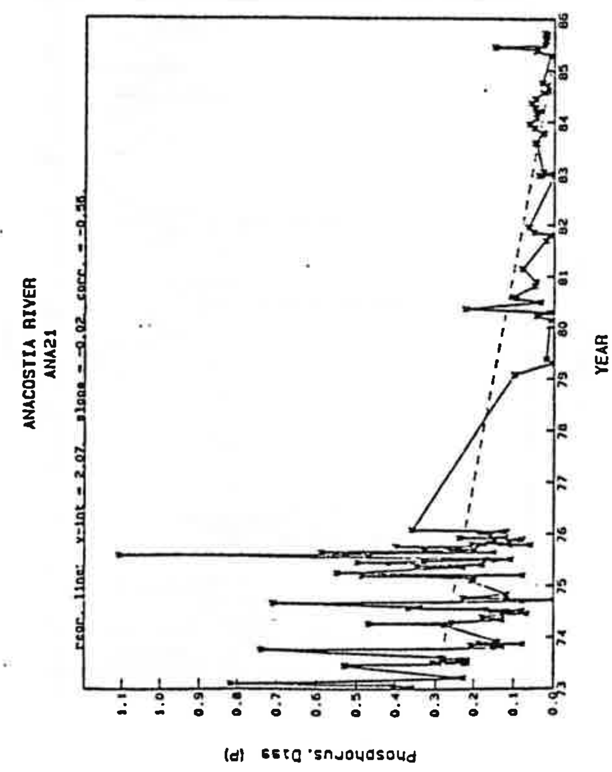


Figure V.49

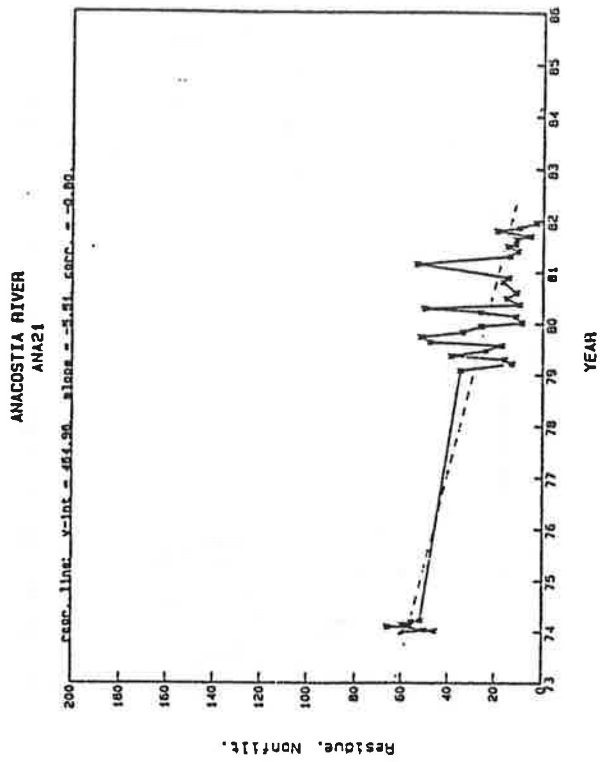



Figure V.50

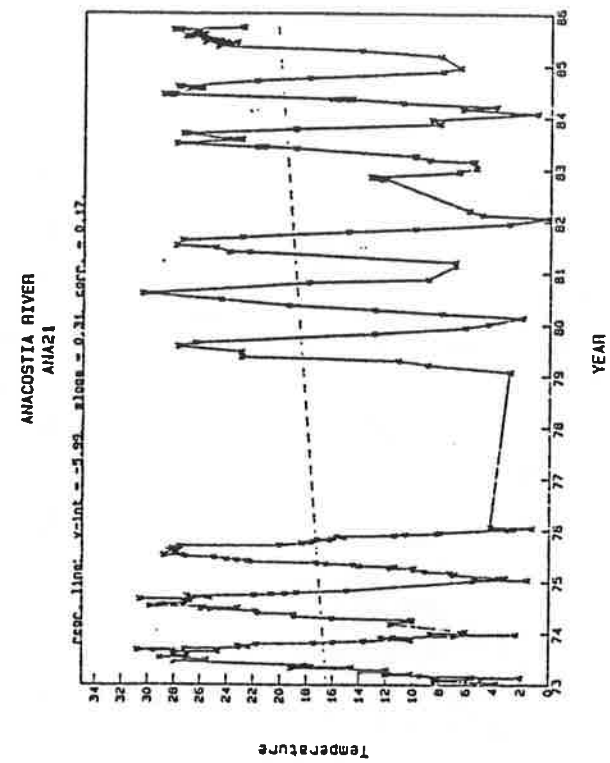



Figure V.51

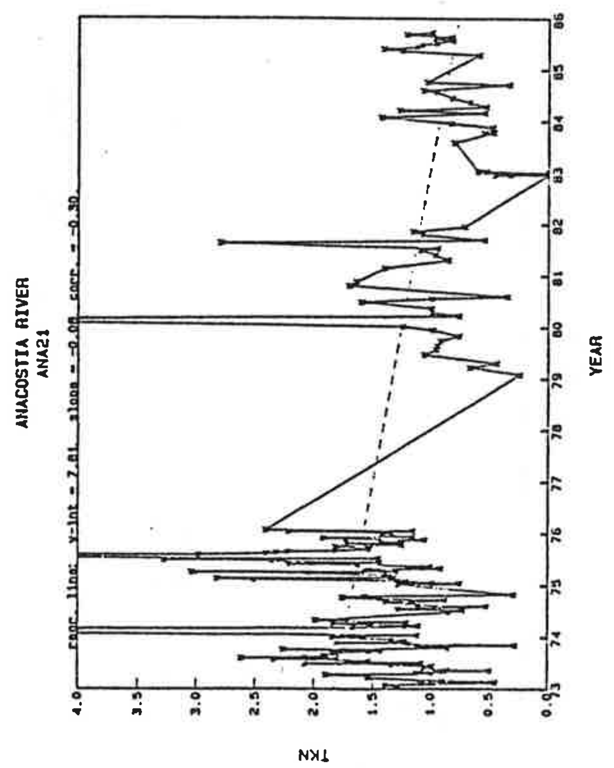



Figure V.52

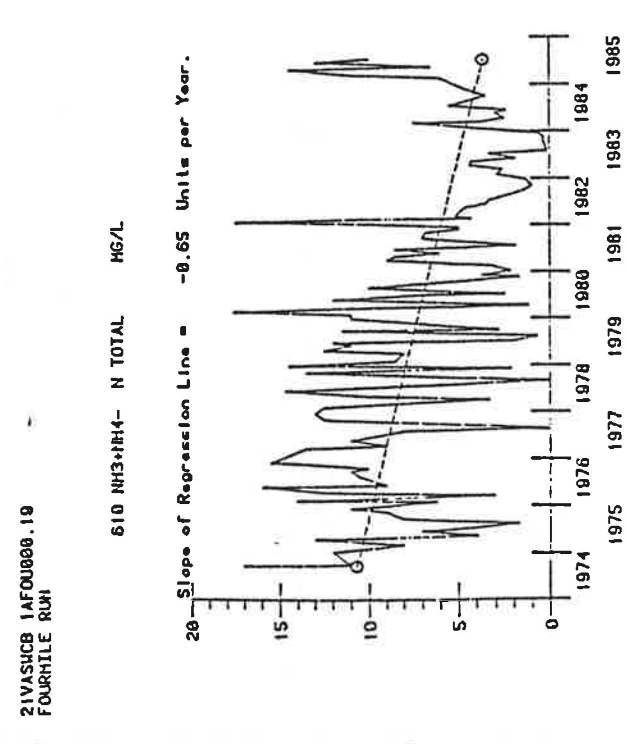


Figure V.53

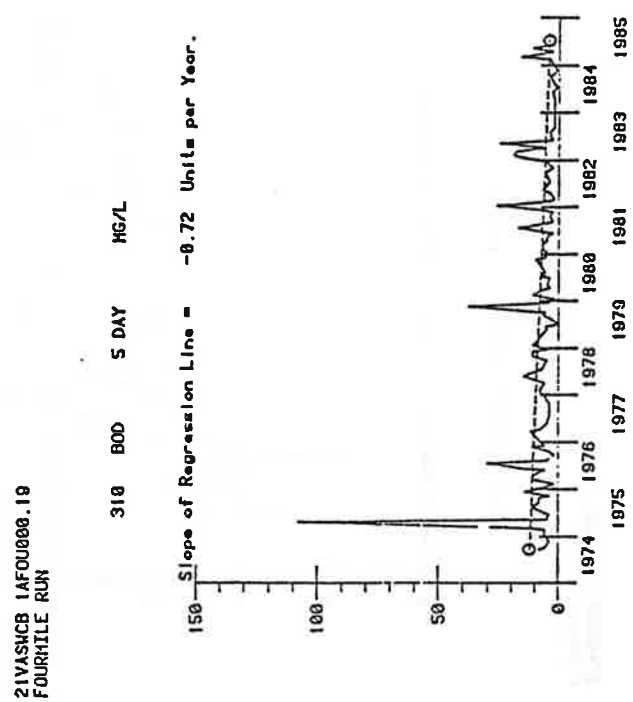



Figure V.54

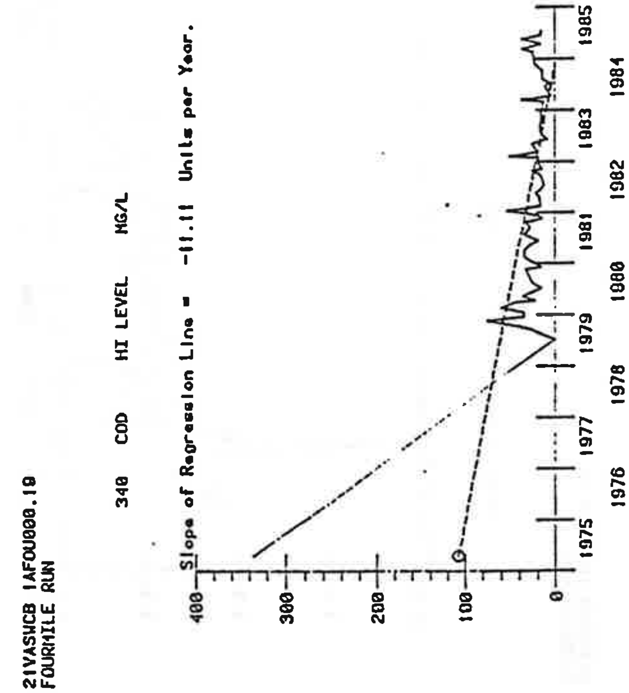



Figure V.55

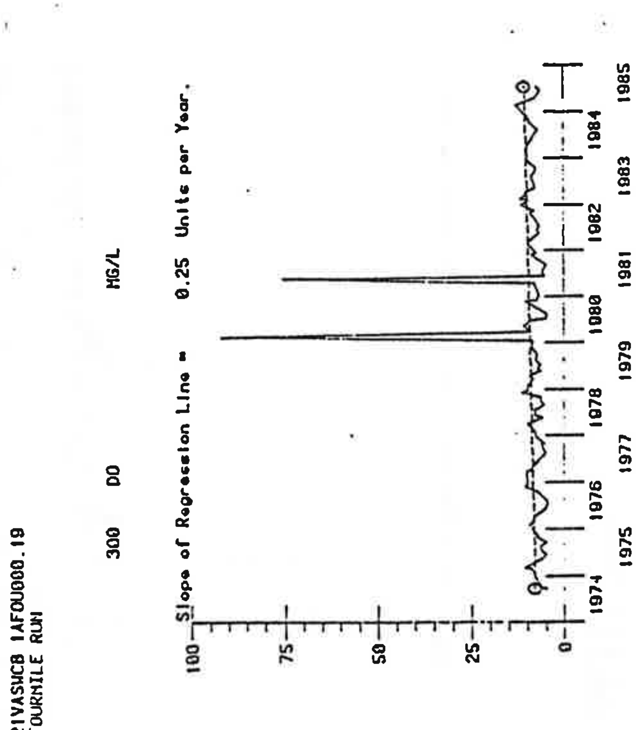



Figure V.56

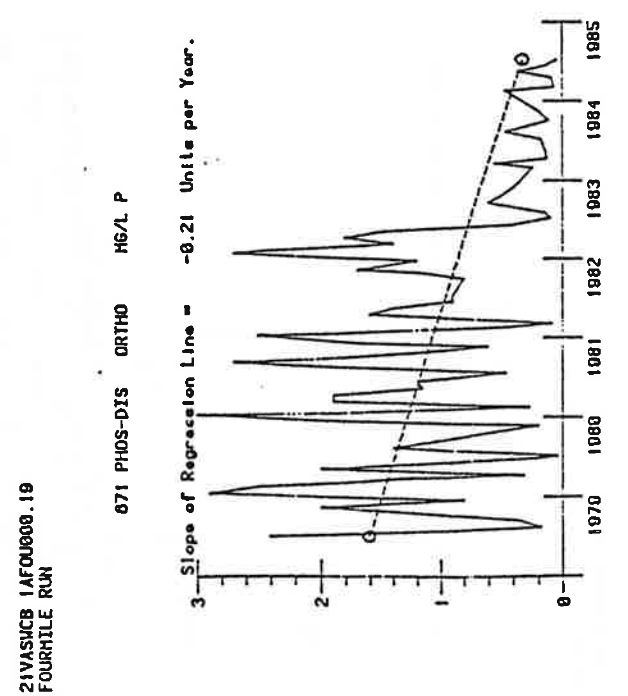


Figure V.57

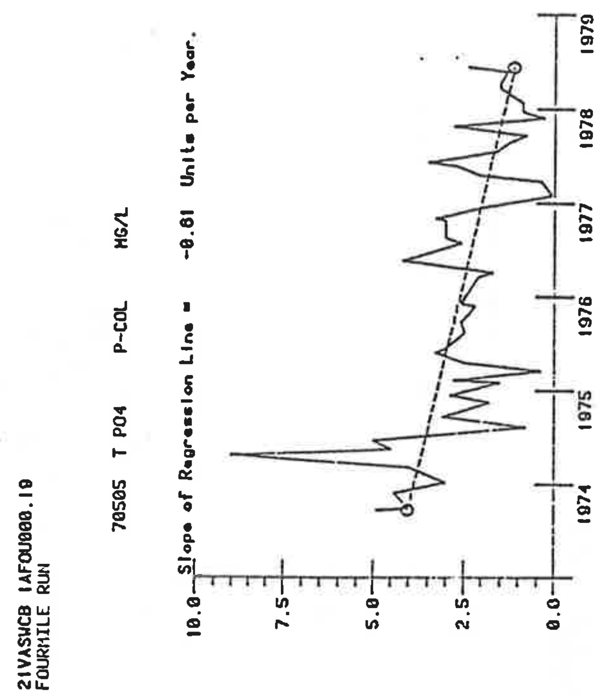



Figure V.58

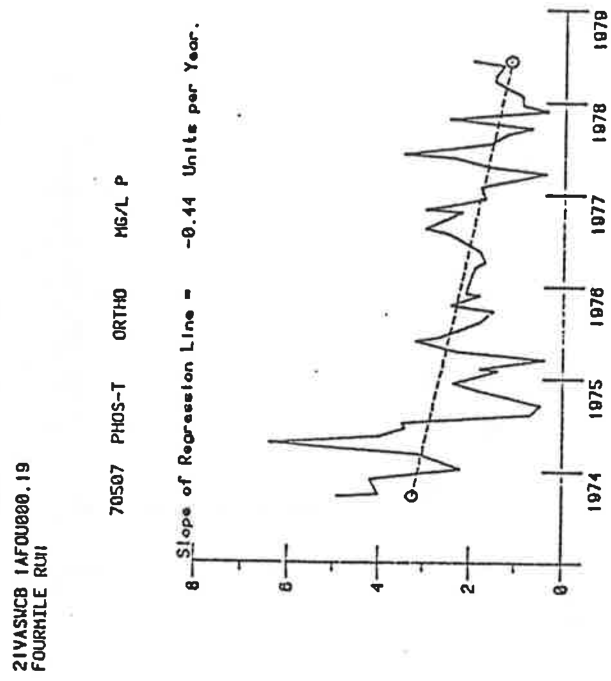



Figure V.59

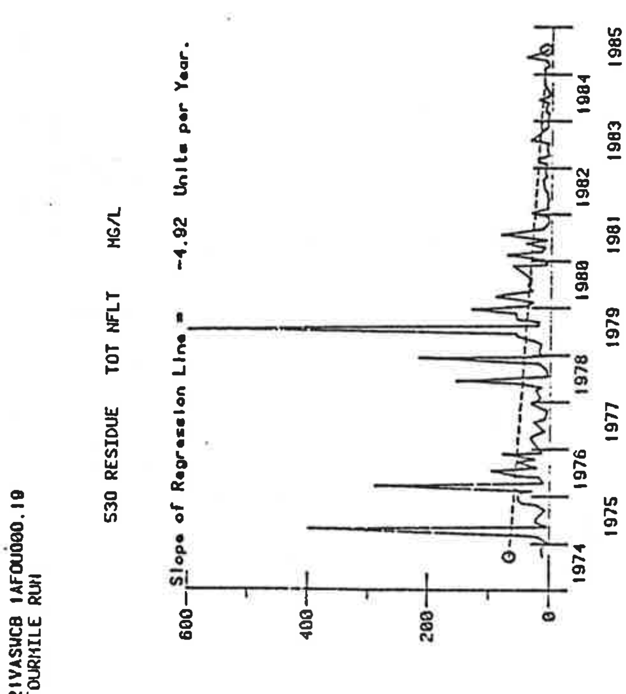



Figure V.60

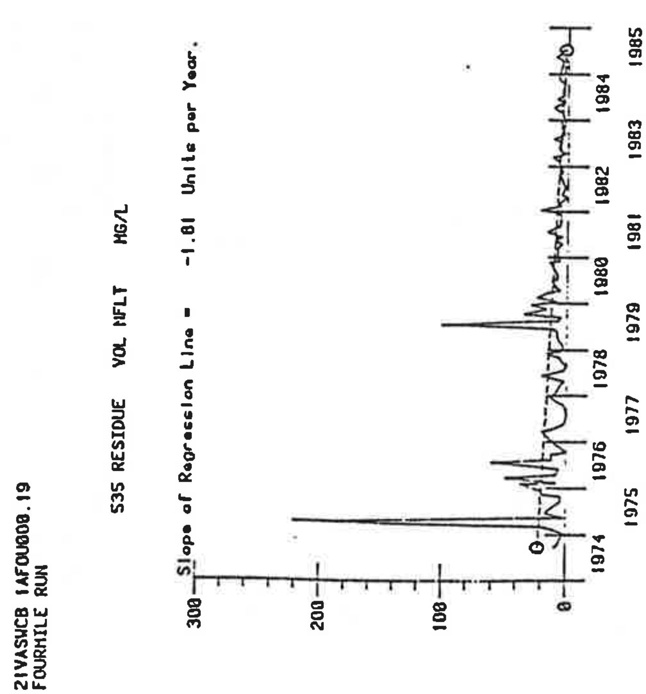


Figure V.61

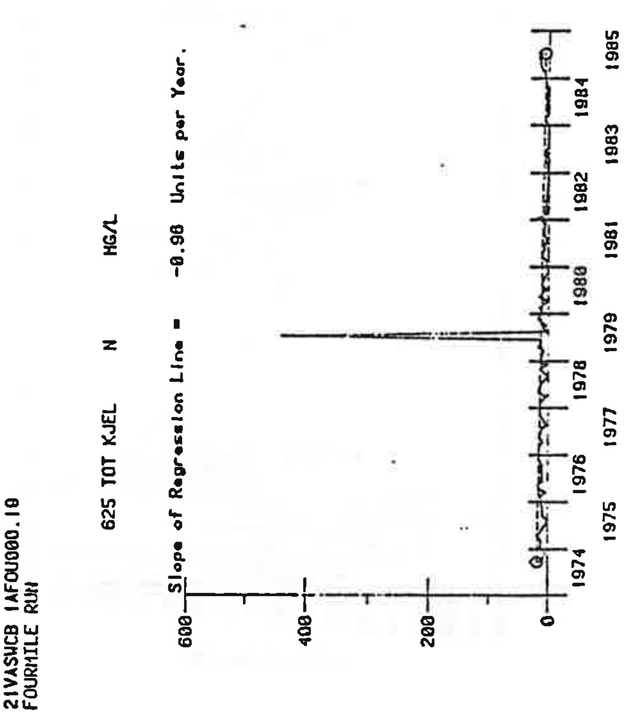



Figure V.62

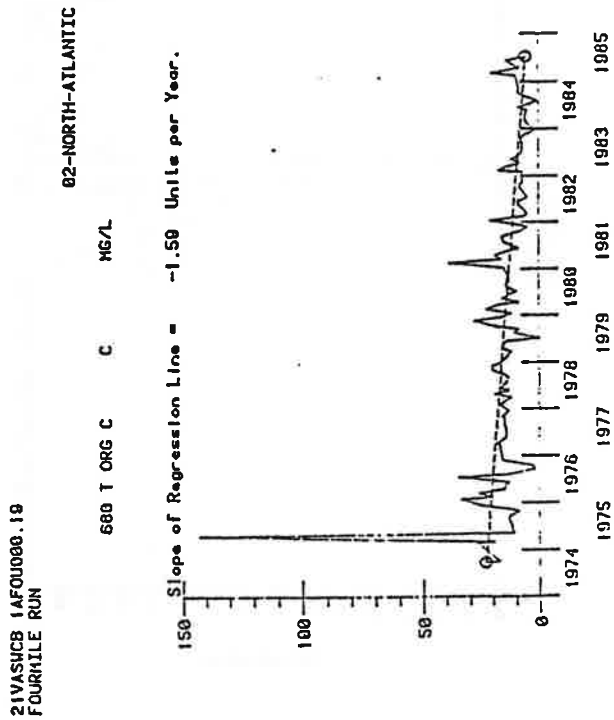



Figure V.63

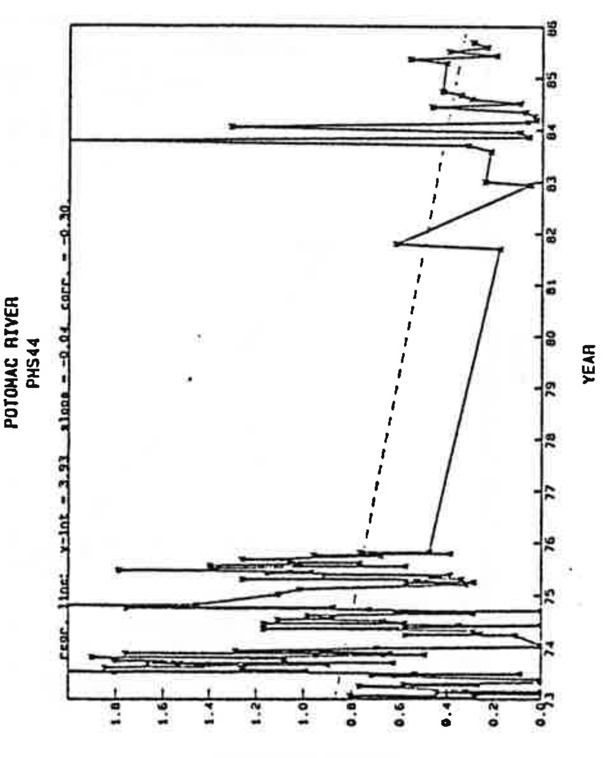



Figure V.64

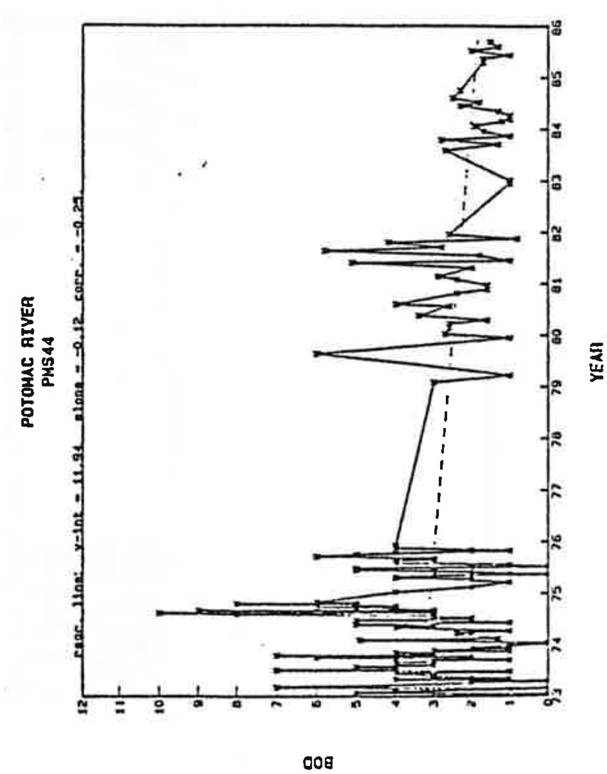


Figure V.65

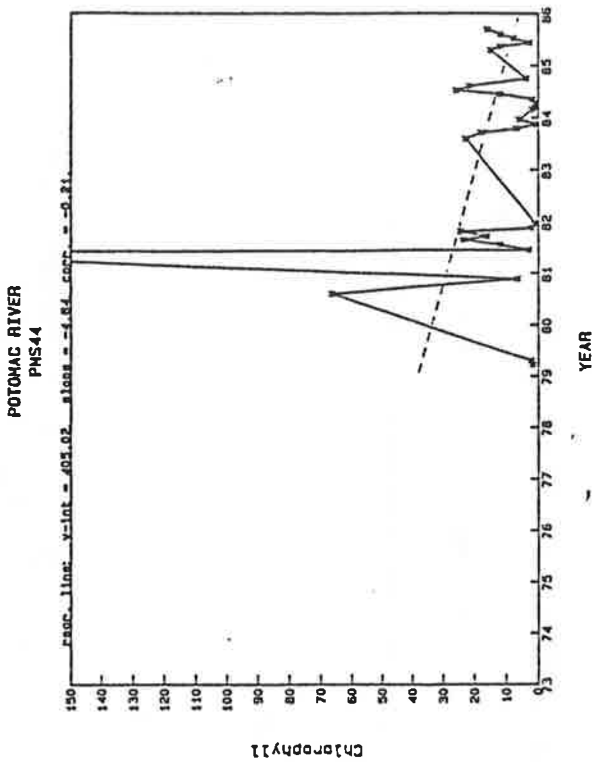



Figure V.66

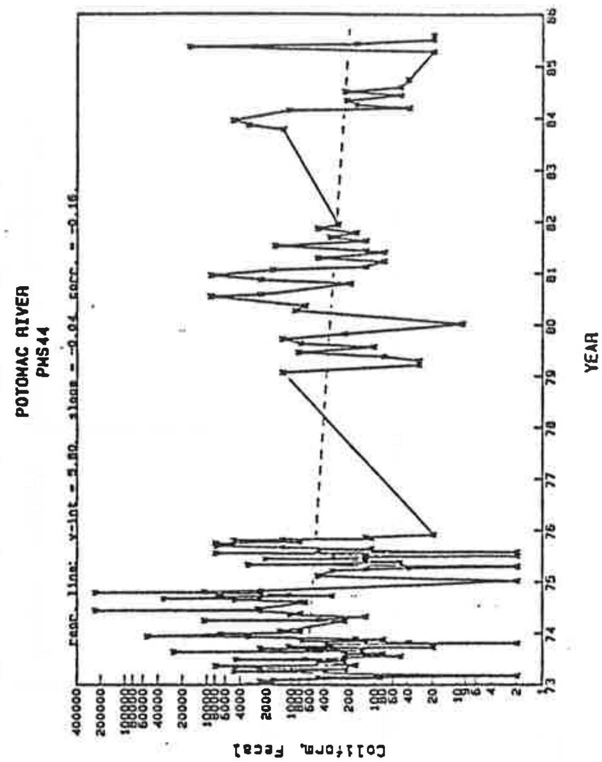



Figure V.67

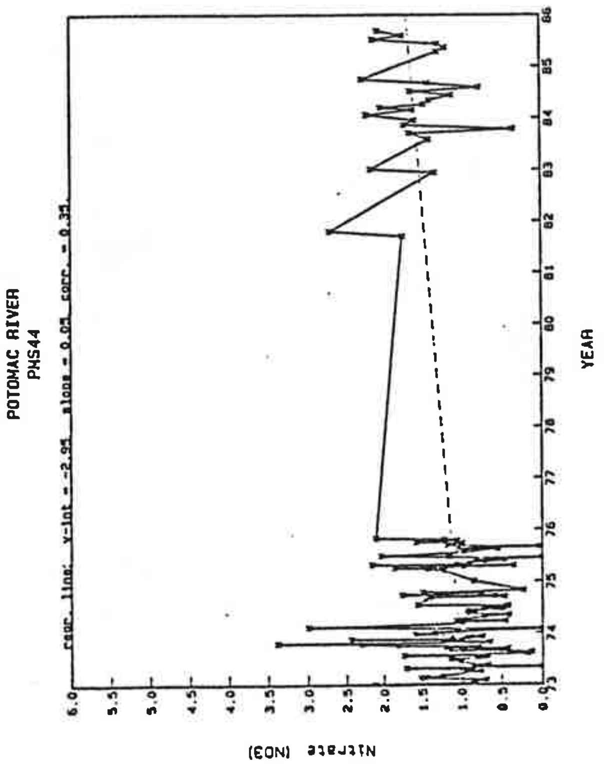



Figure V.68

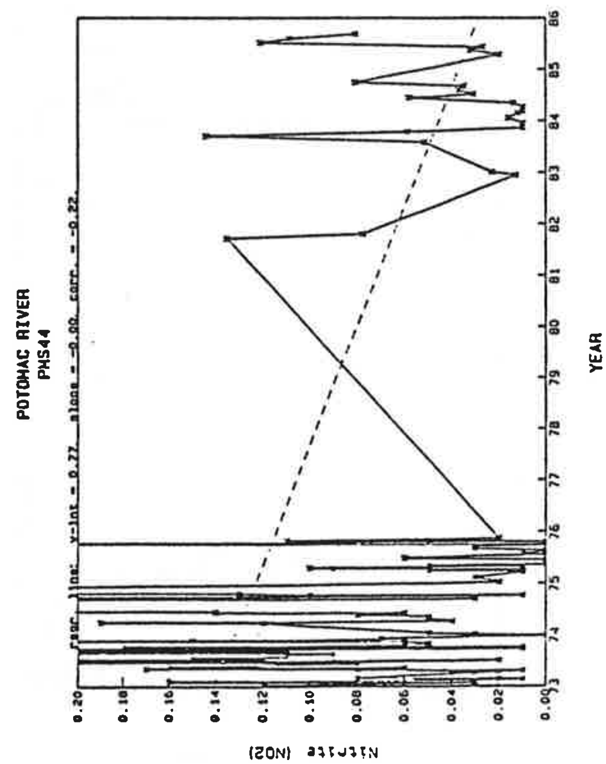


Figure V.69

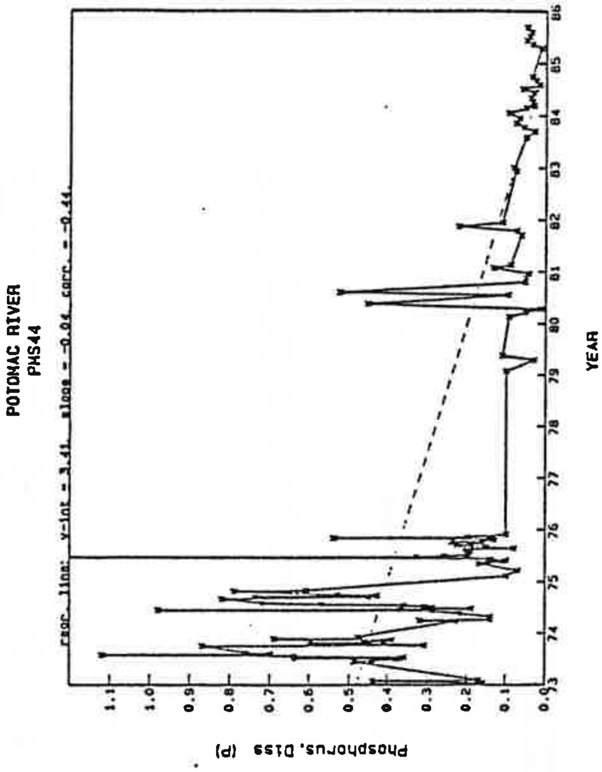



Figure V.70

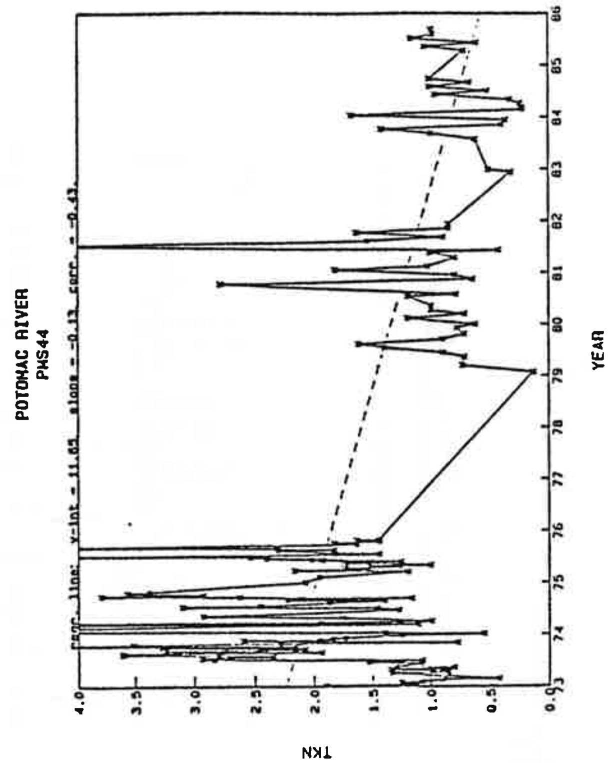



Figure V.71

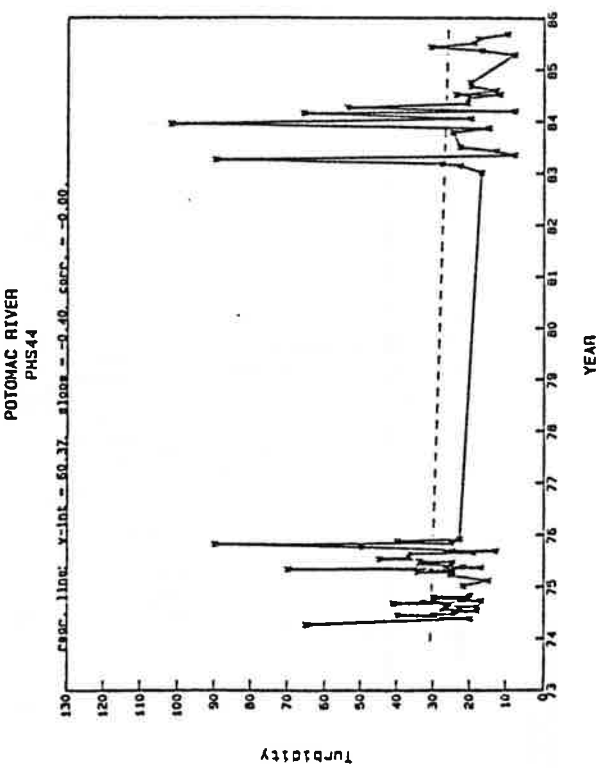



Figure V.72

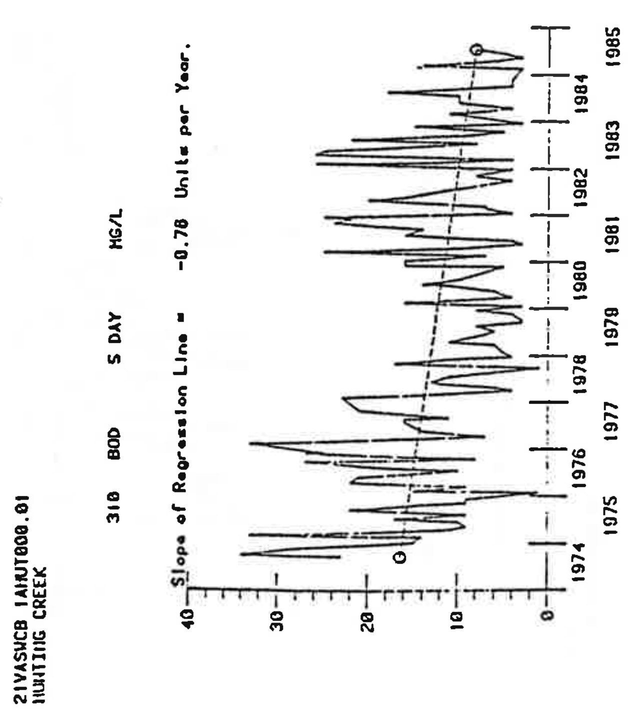


Figure V.73

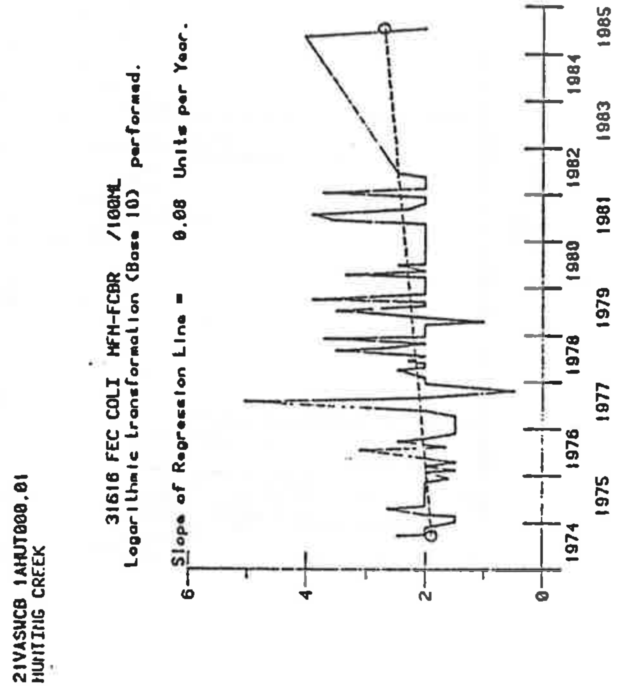



Figure V.74

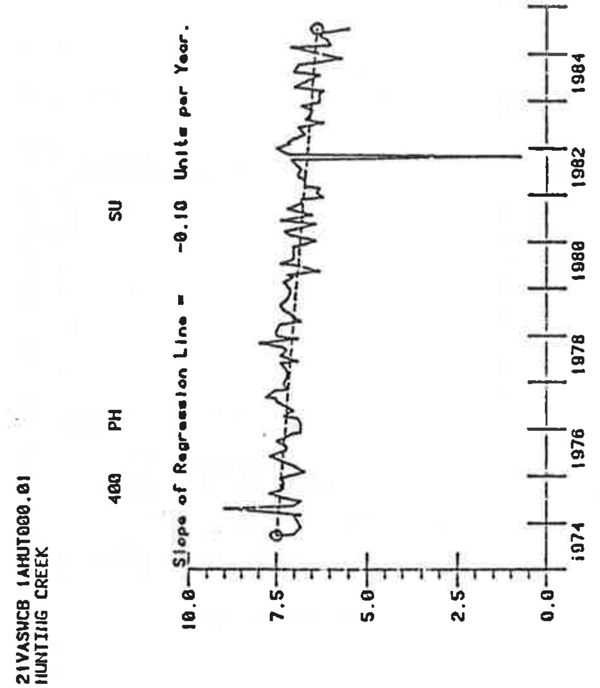



Figure V.75

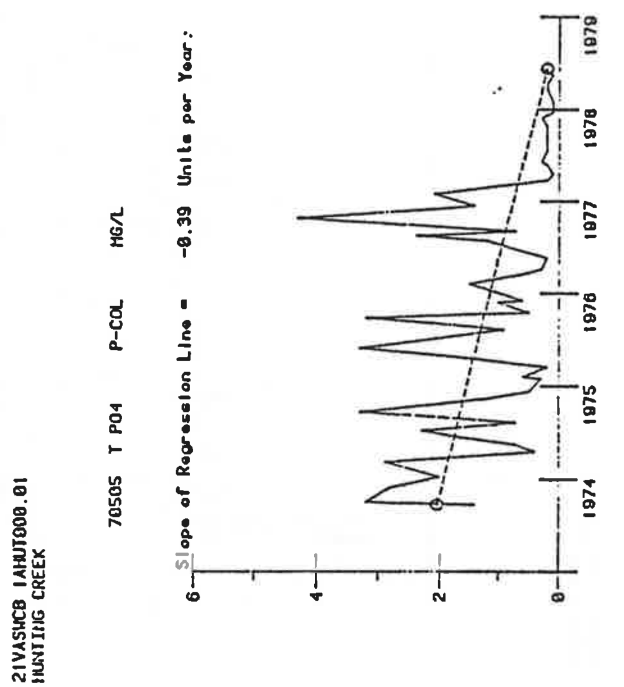



Figure V.76

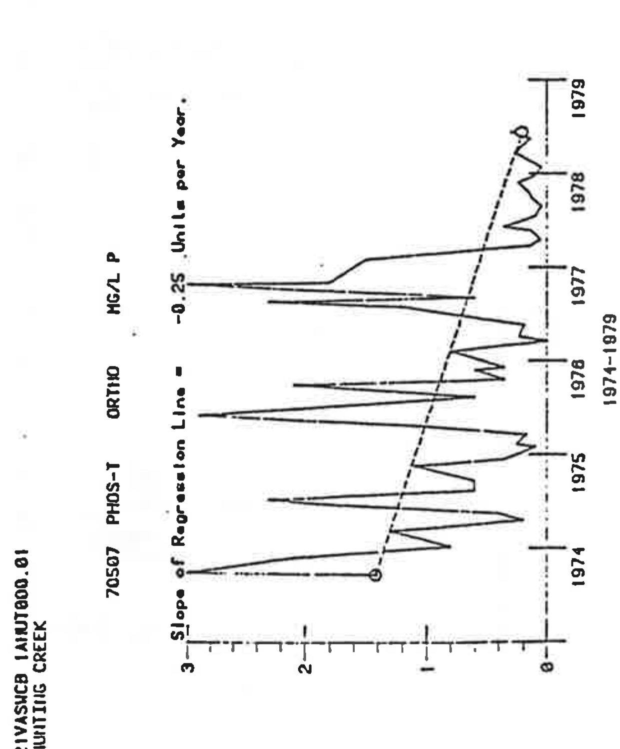


Figure V.77

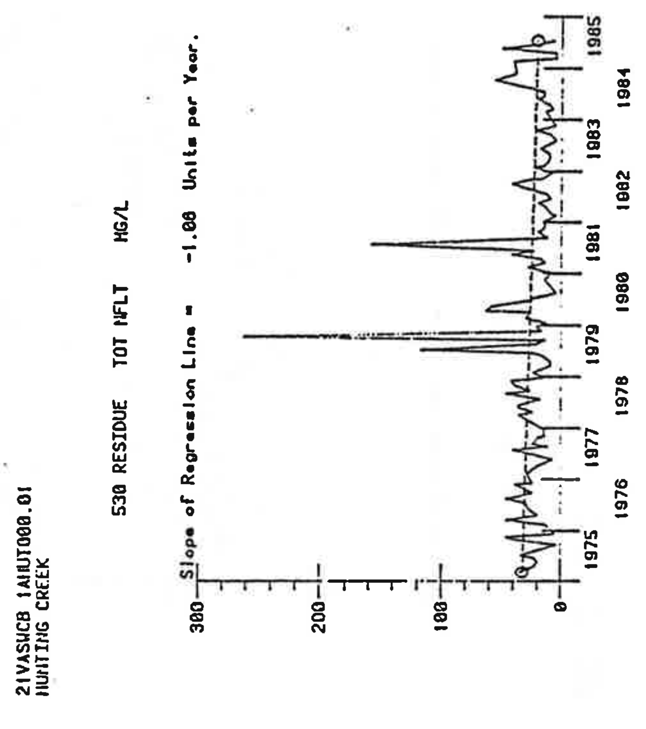



Figure V.78

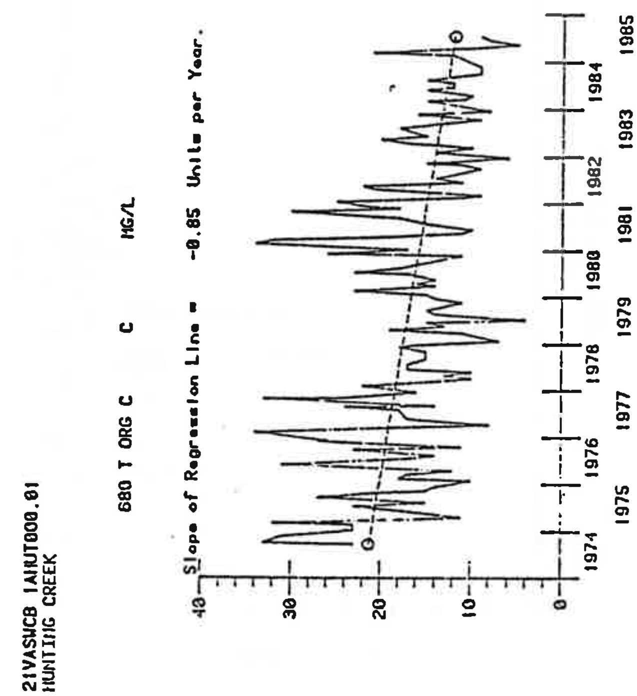



Figure V.79

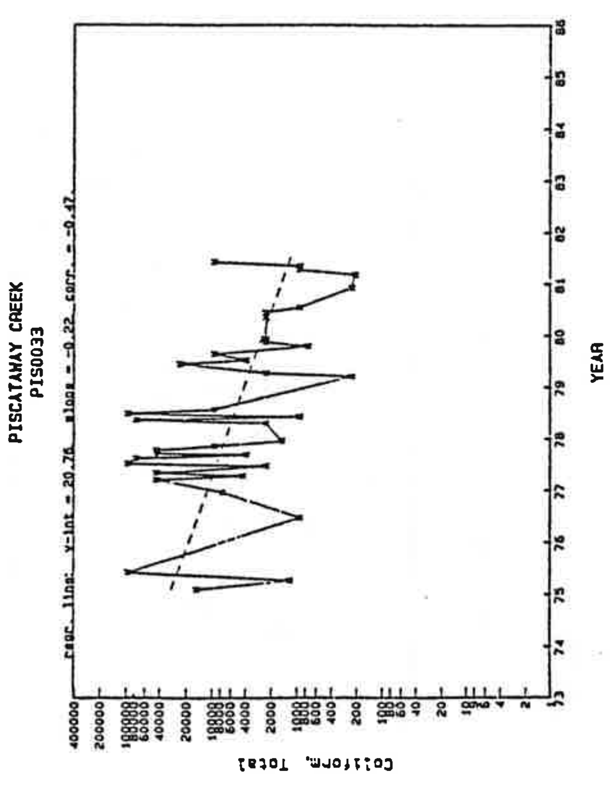



Figure V.80

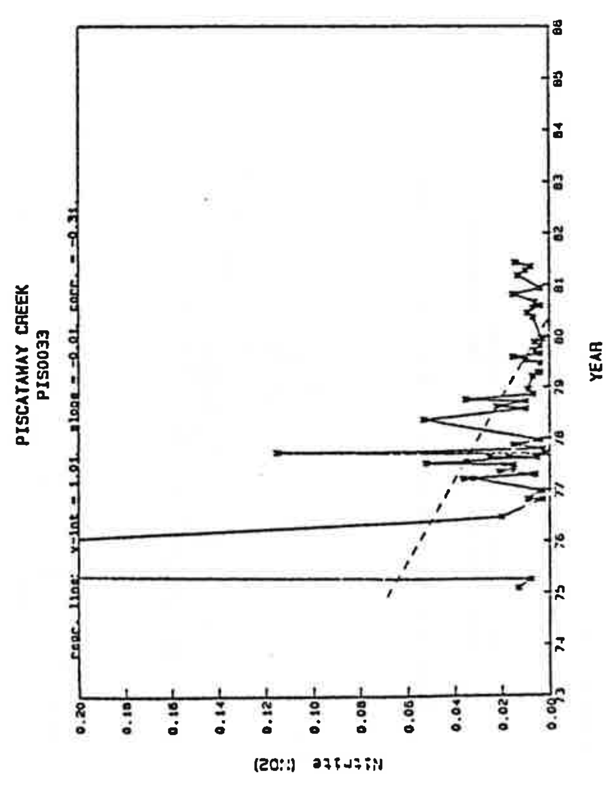


Figure V.81

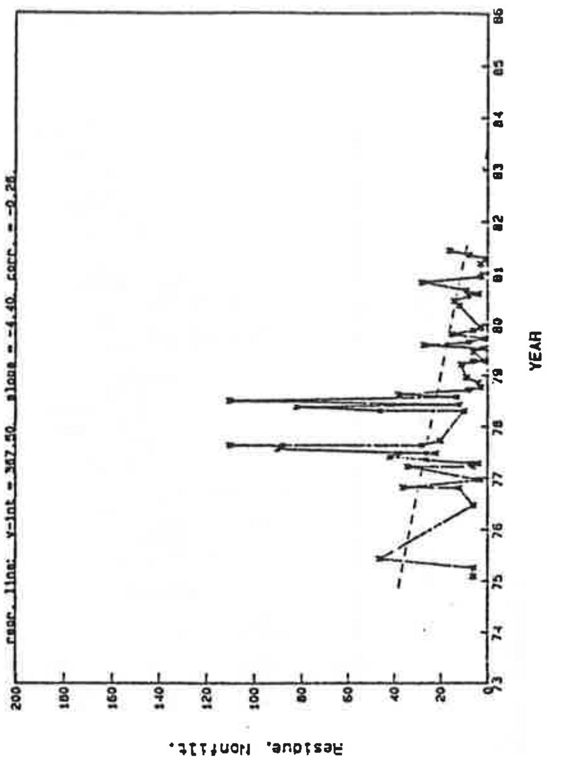



Figure V.82

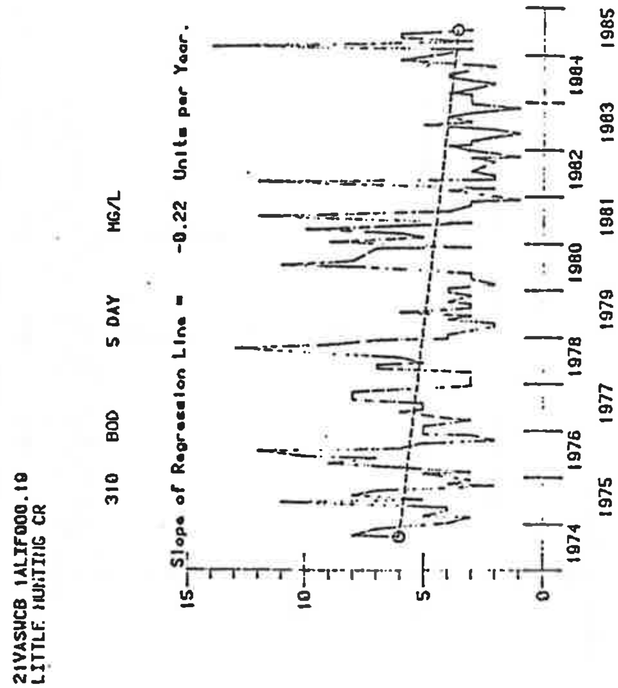



Figure V.83

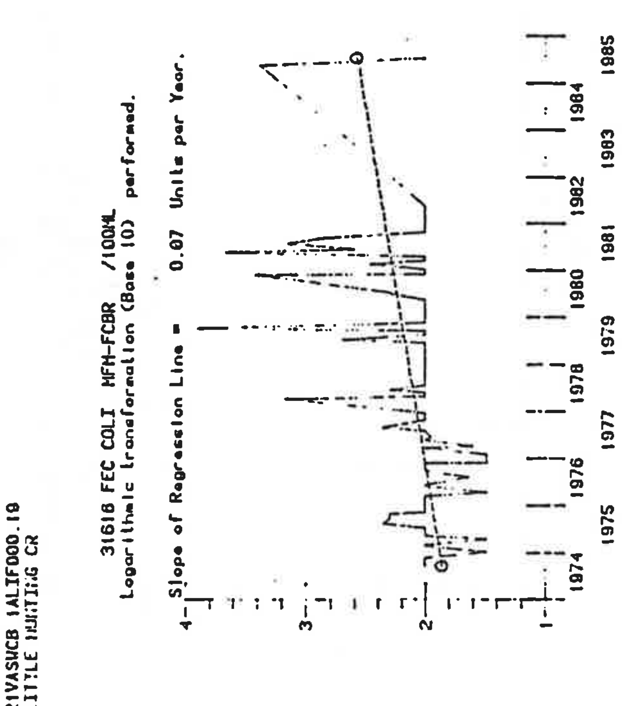



Figure V.84

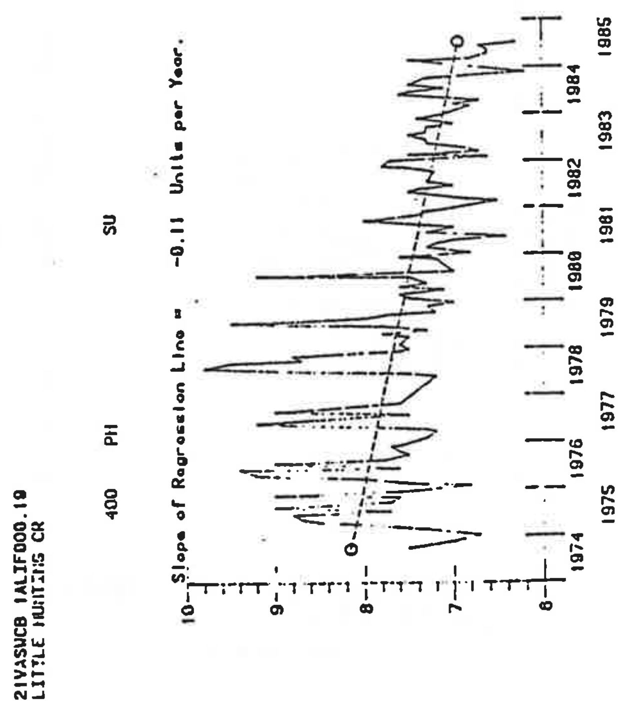


Figure V.85

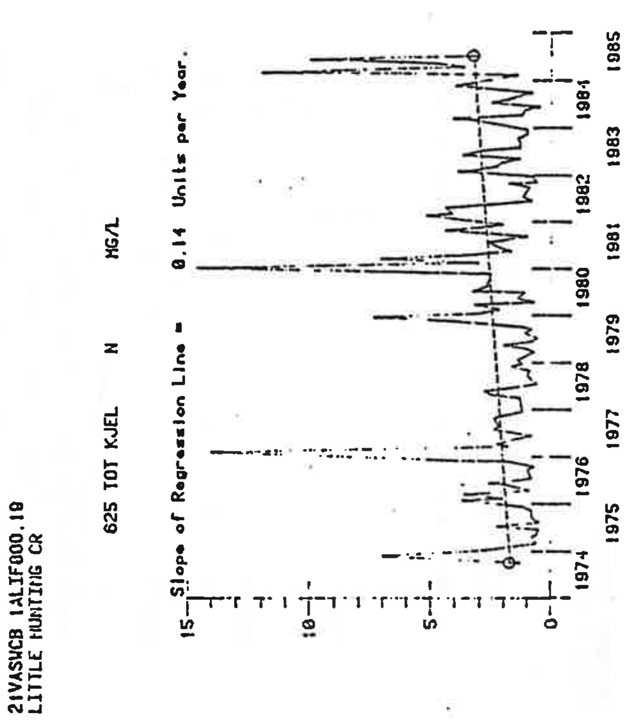



Figure V.86

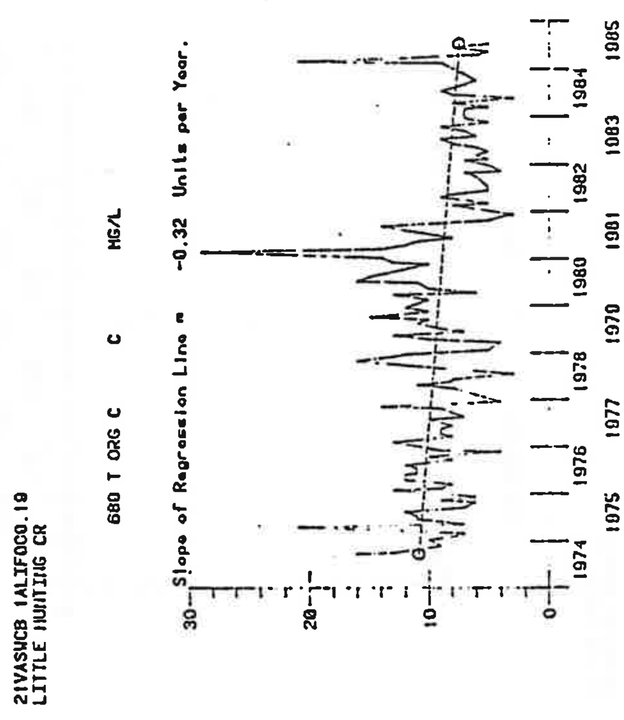



Figure V.87

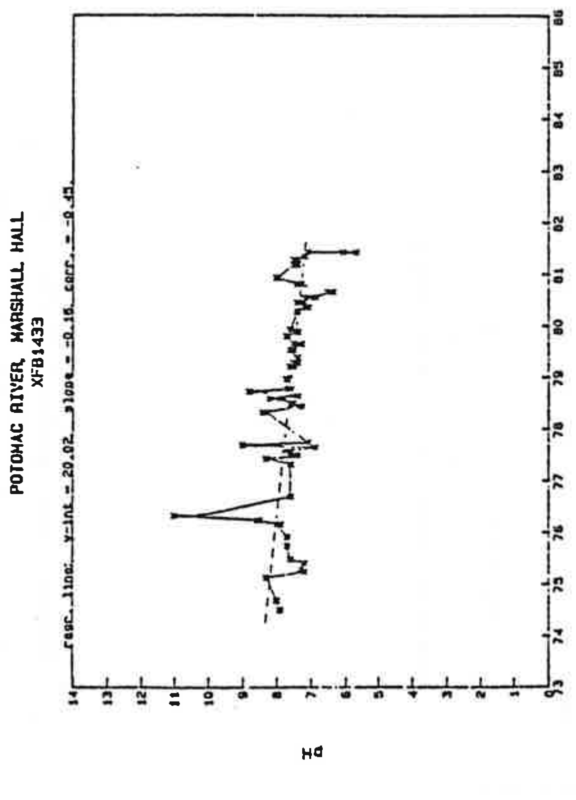



Figure V.88

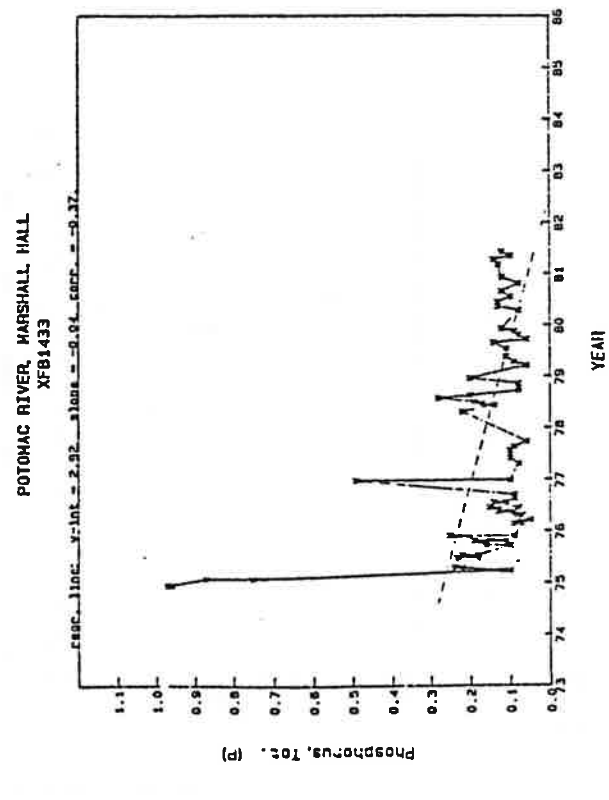


Figure V.89

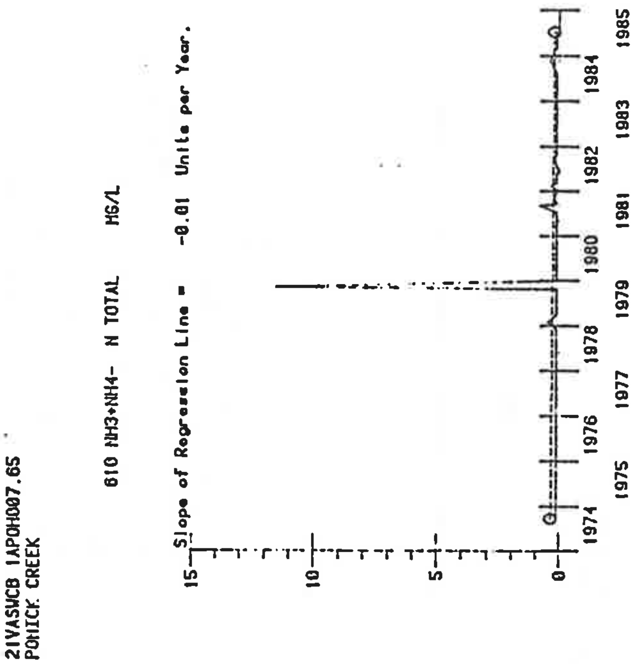



Figure V.90

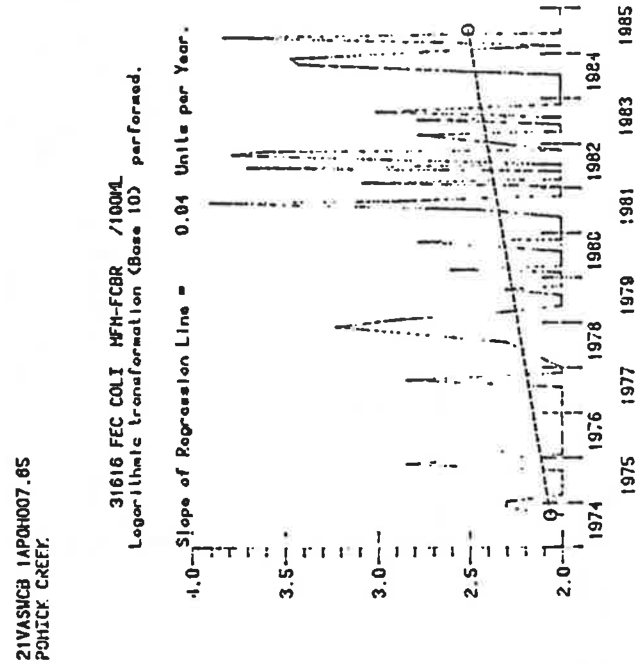



Figure V.91

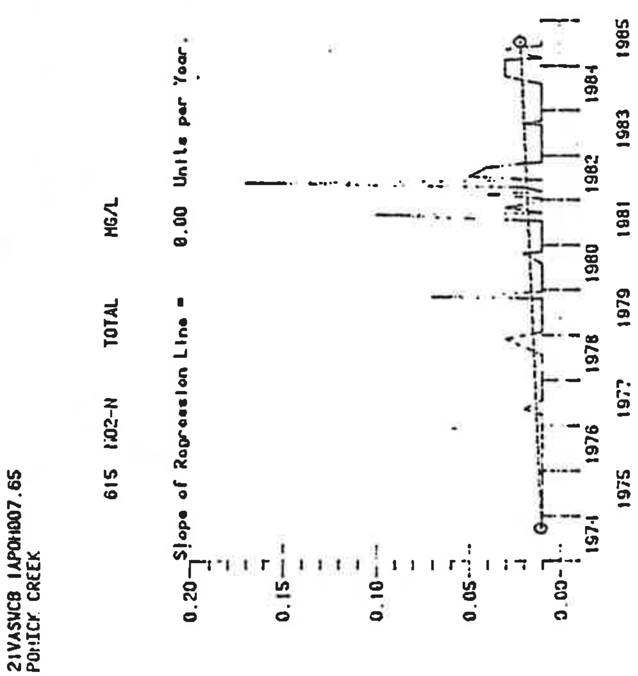



Figure V.92

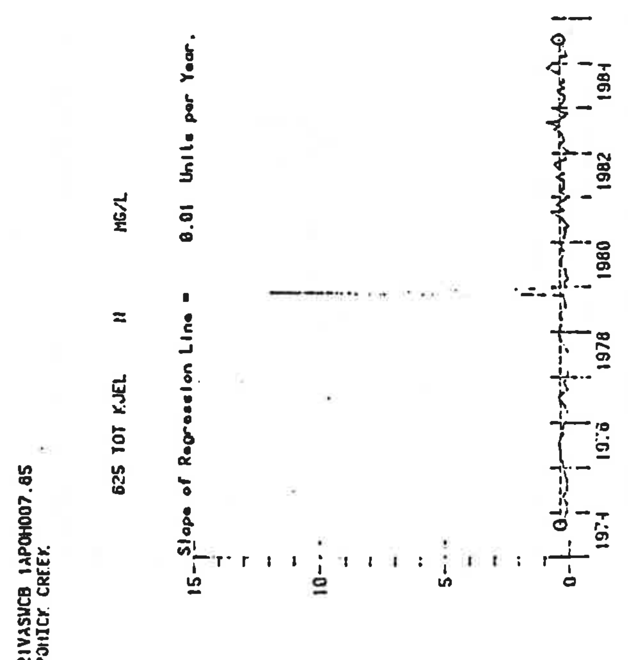


Figure VI.1

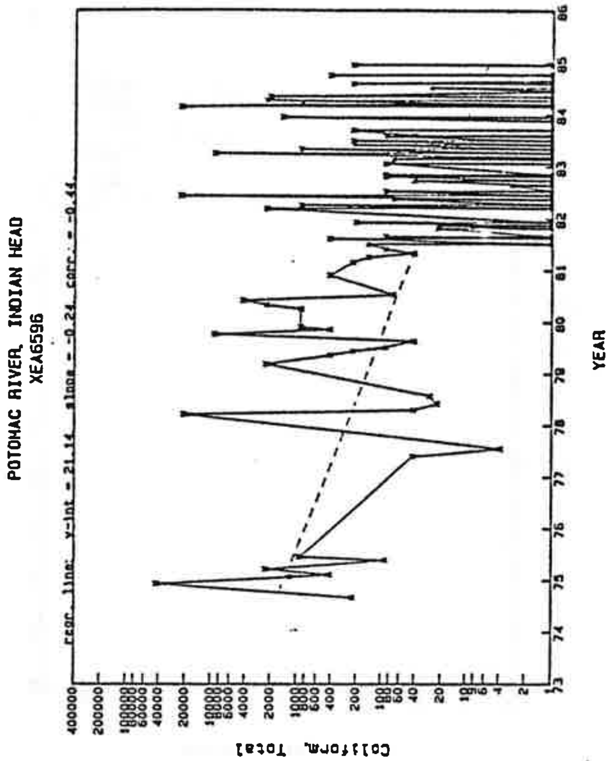



Figure VI.2

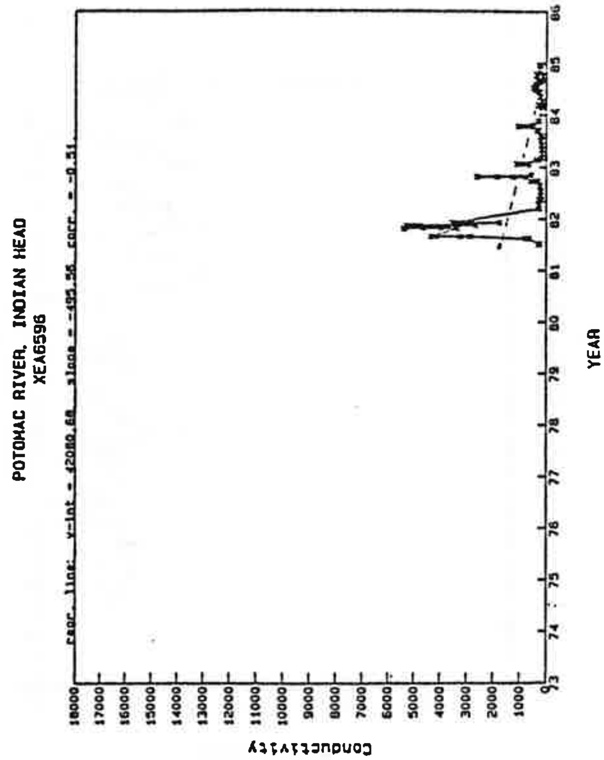



Figure VI.3

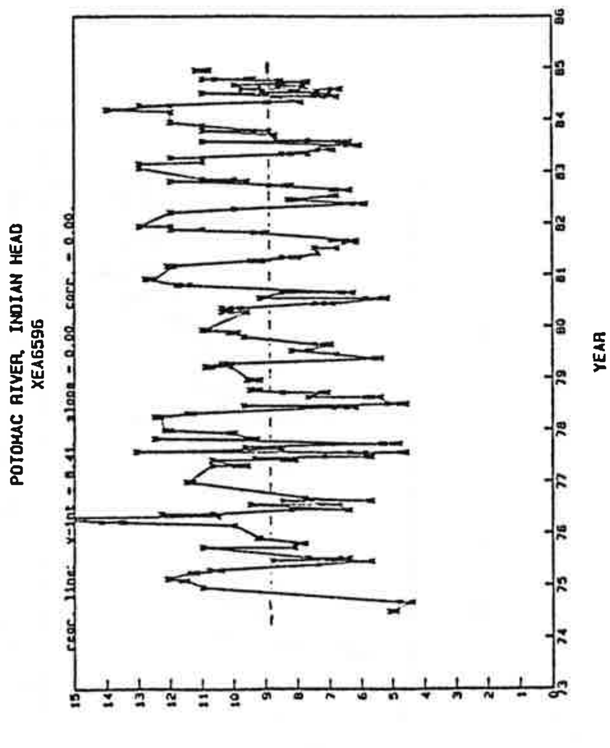



Figure VI.4

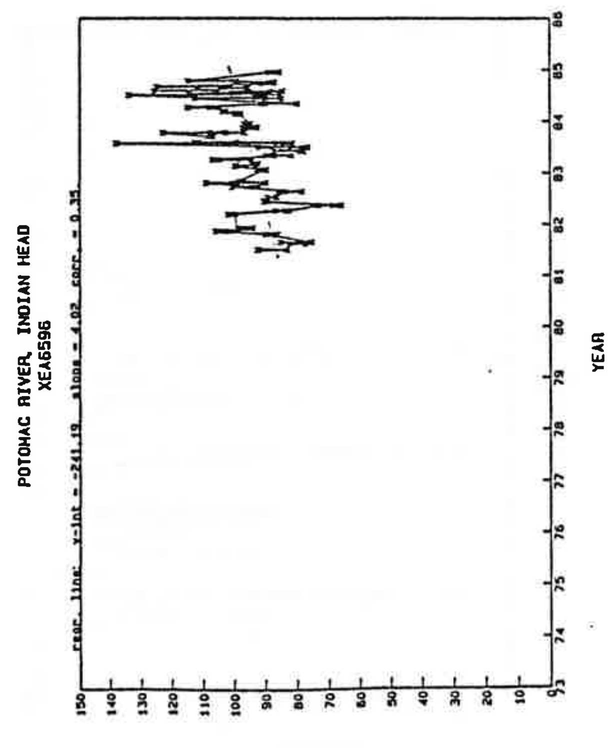


Figure VI.5

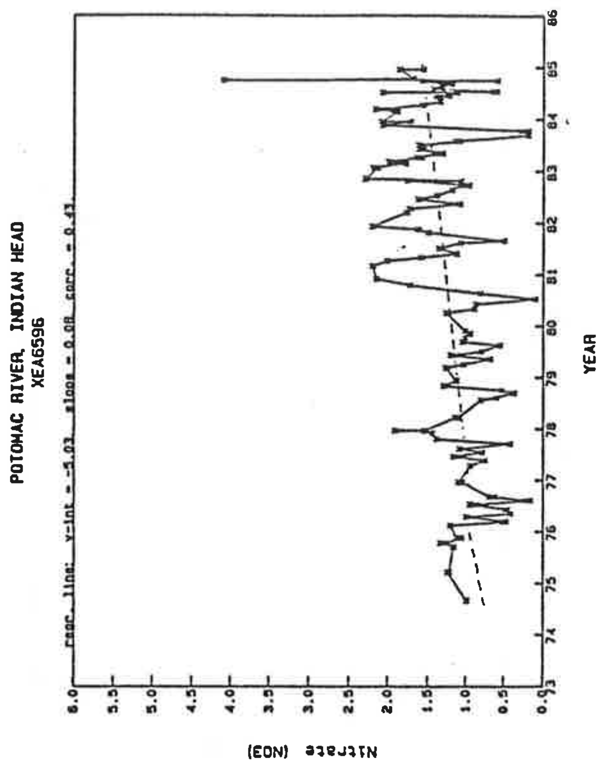



Figure VI.6

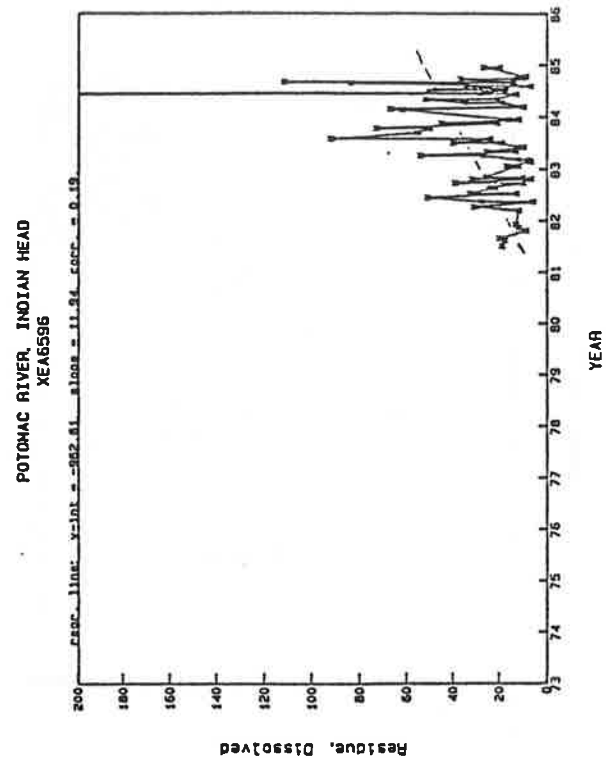



Figure VI.7

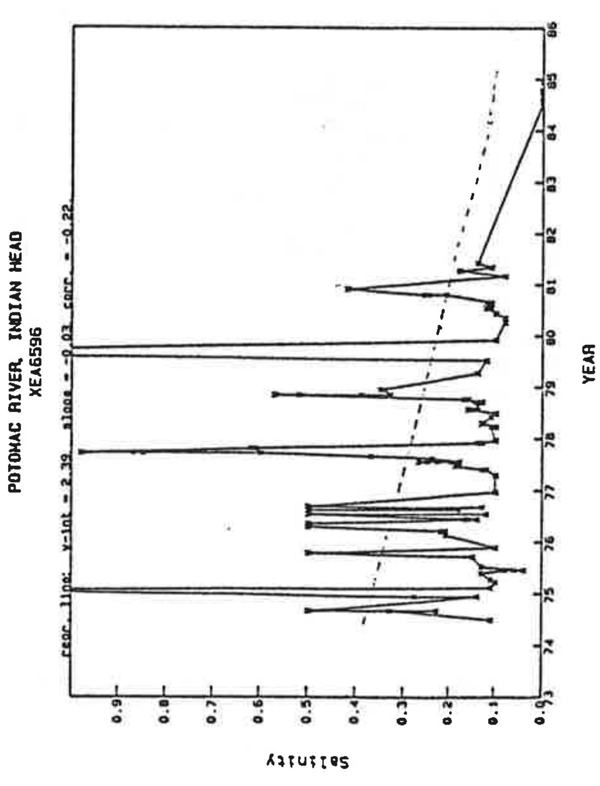



Figure VI.8

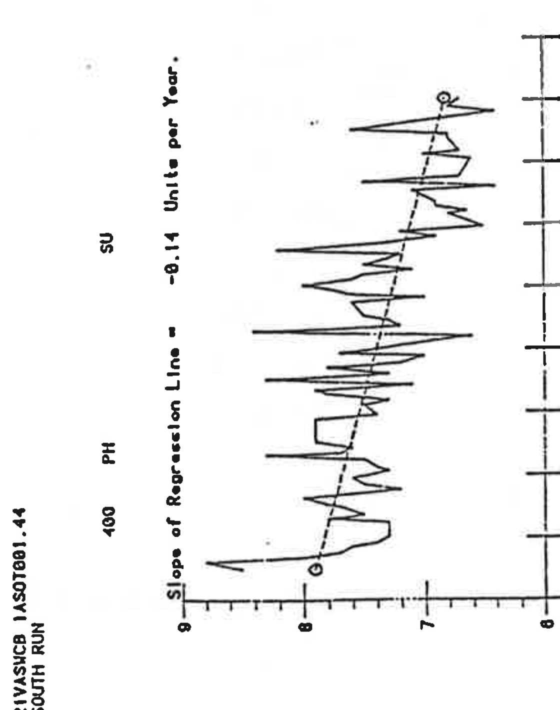


Figure VI.9

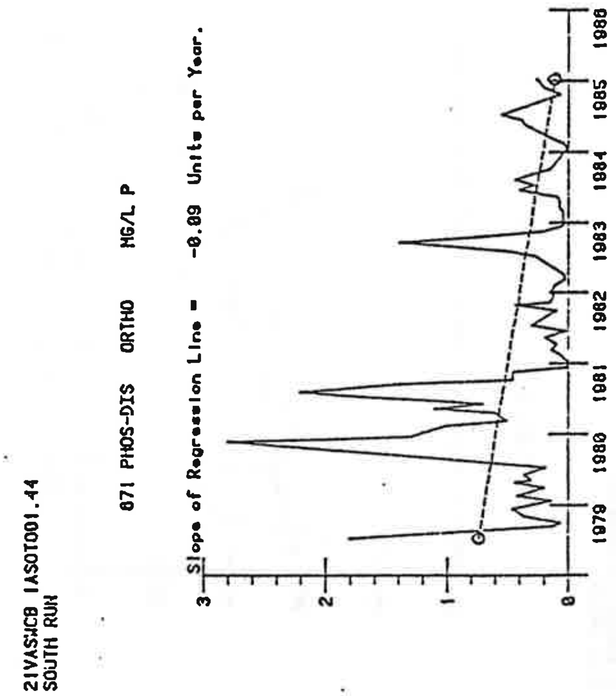



Figure VI.10

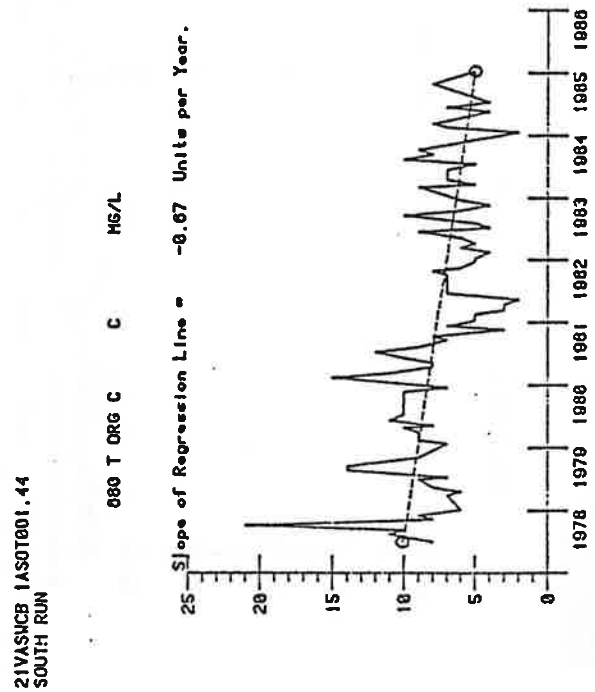



Figure VI.11

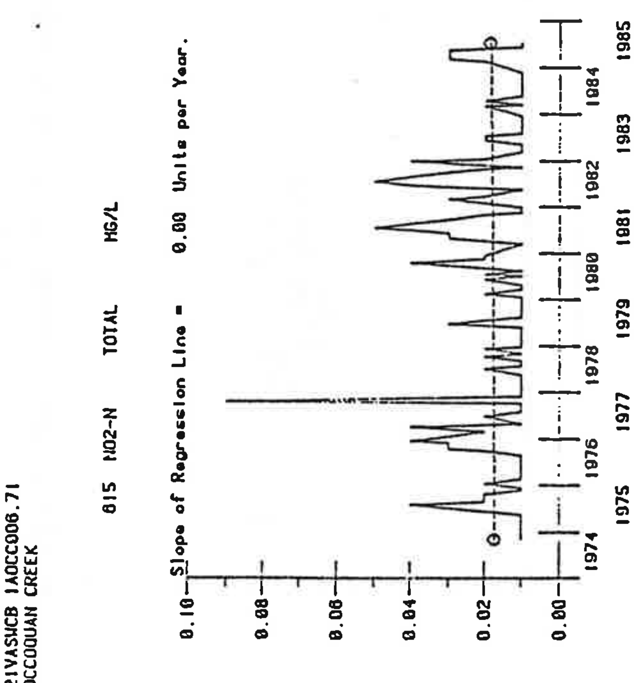



Figure VI.12

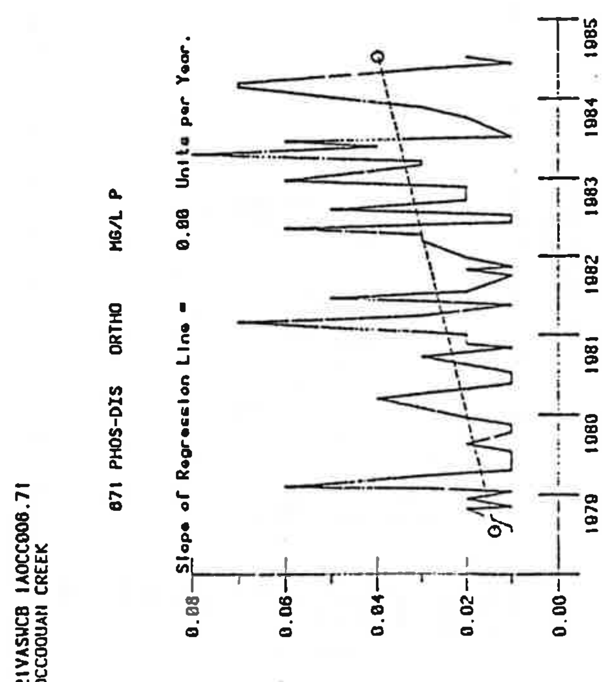


Figure VI.13

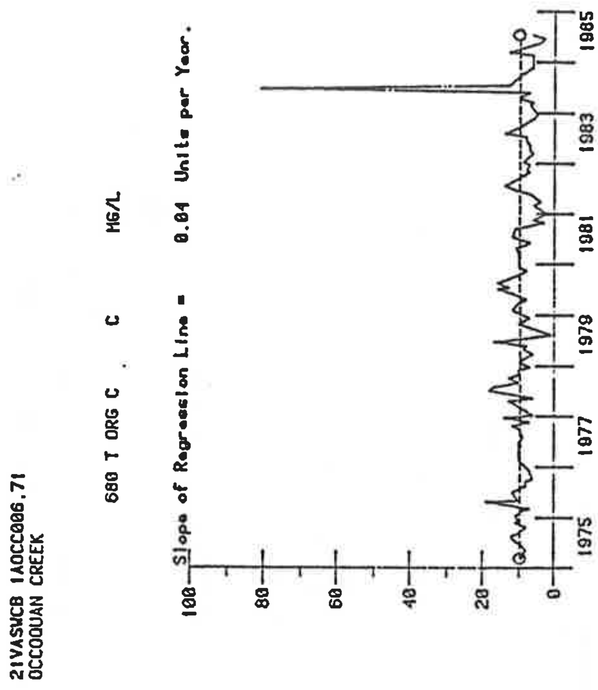



Figure VI.14

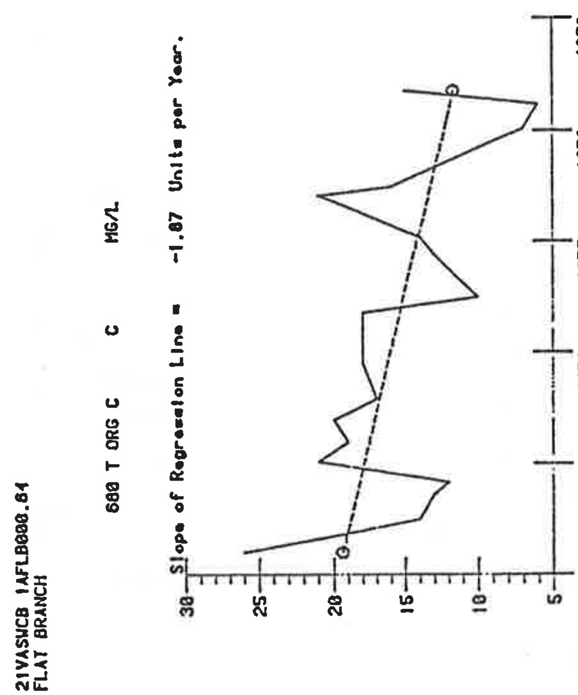



Figure VI.15

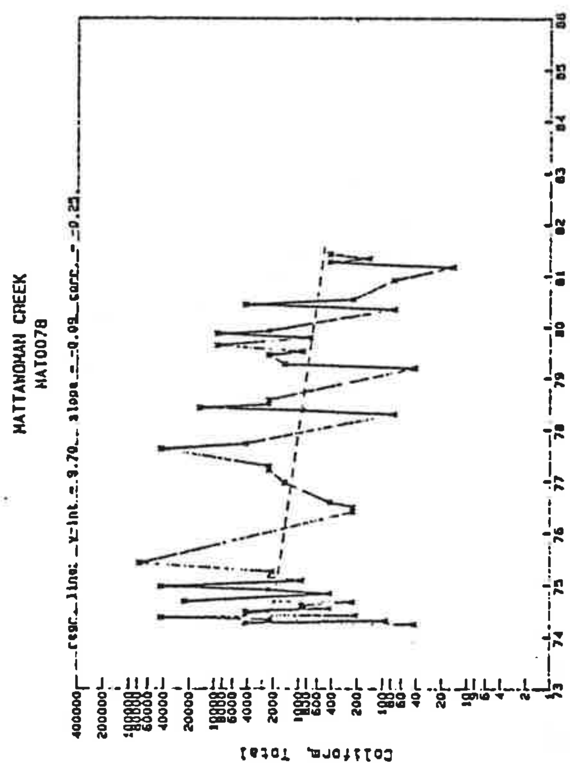



Figure VI.16

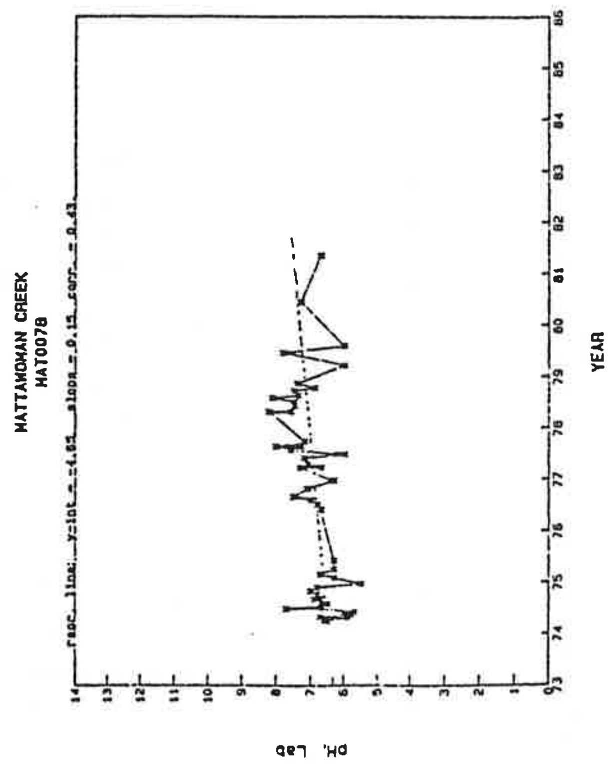


Figure VI.17

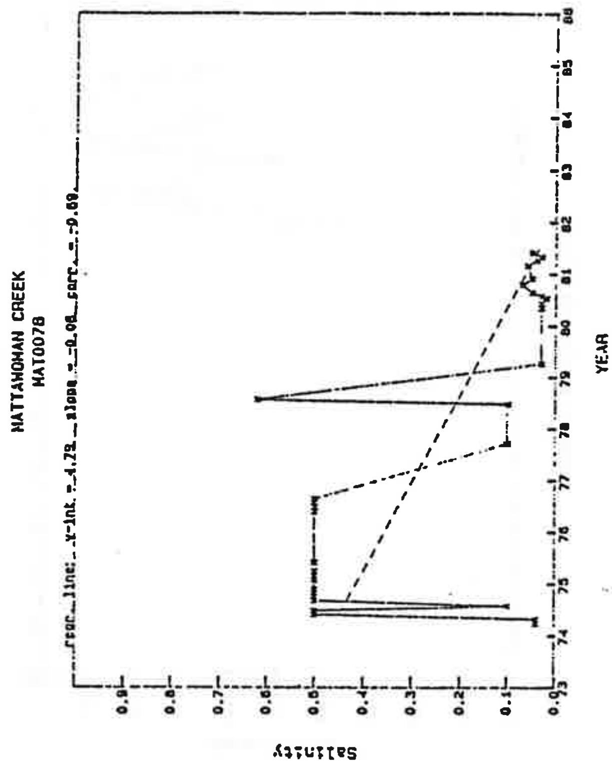



Figure VI.18

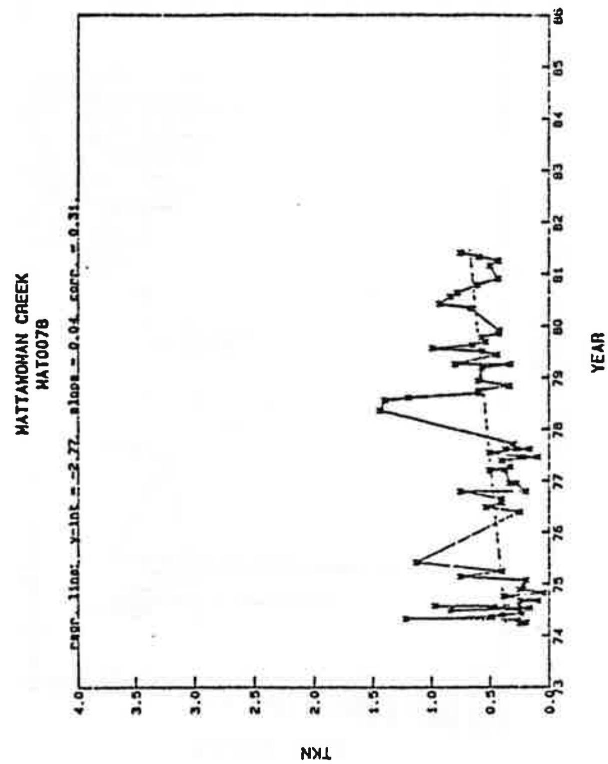



Figure VI.19

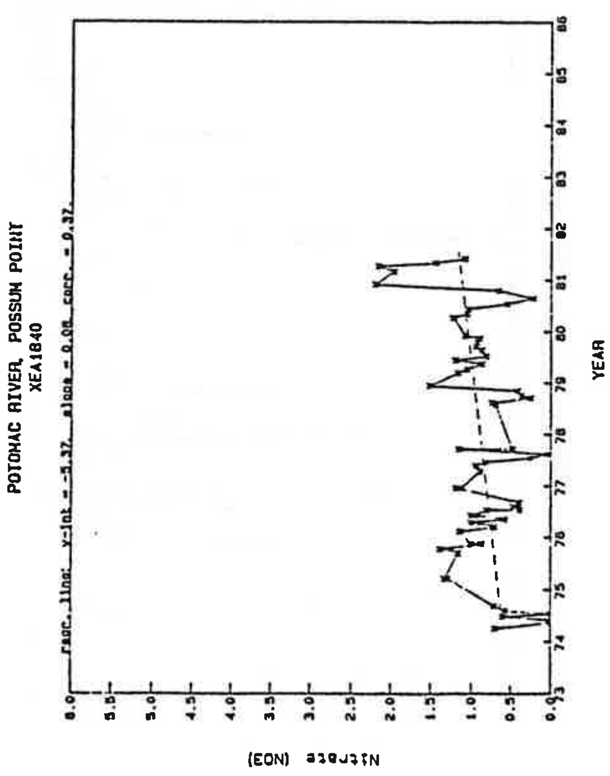



Figure VI.20

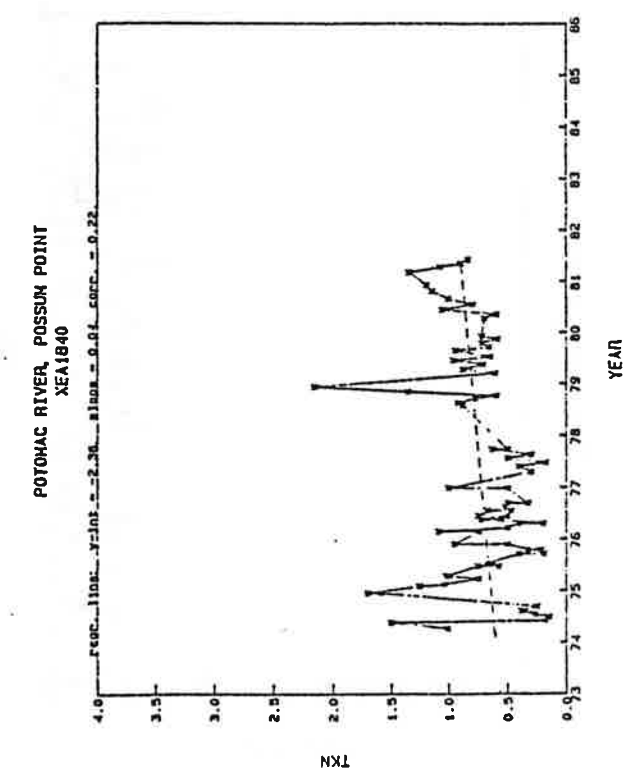


Figure VI.21

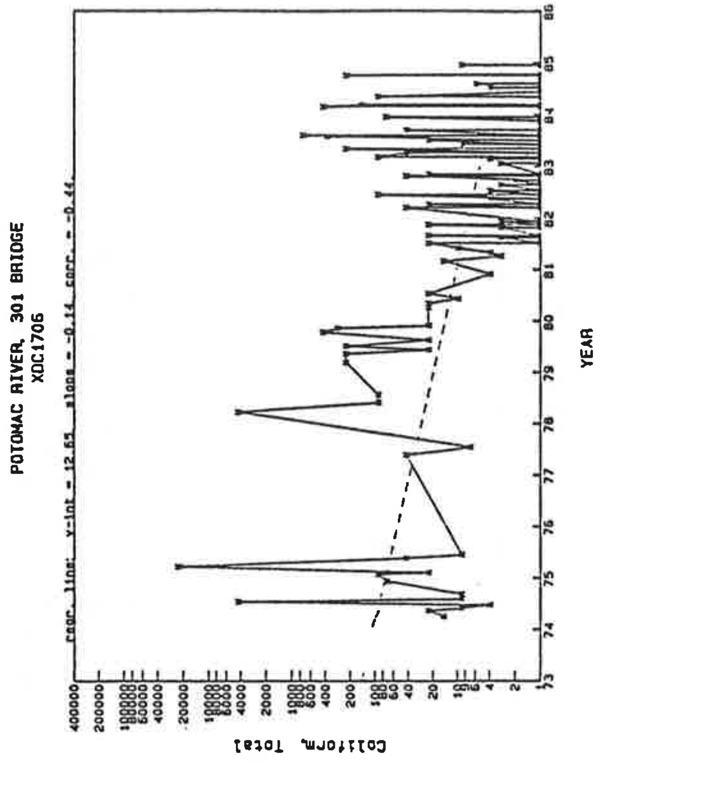



Figure VI.22

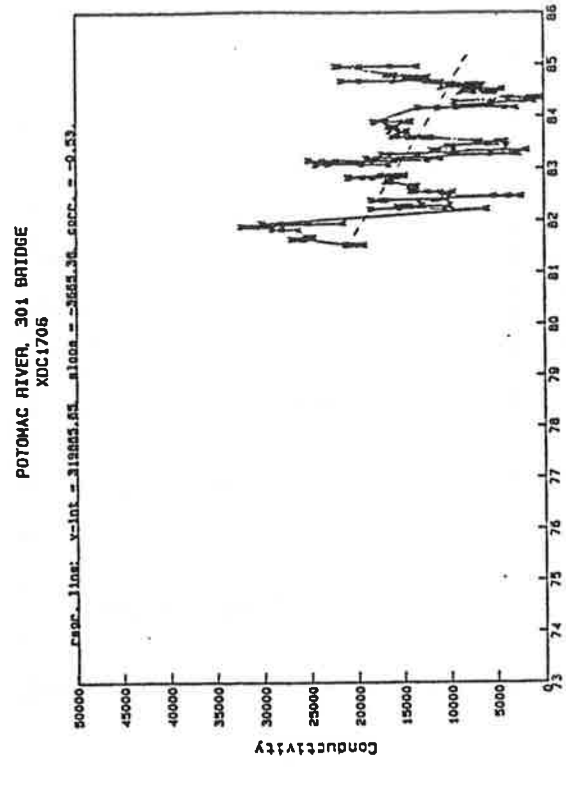



Figure VI.23

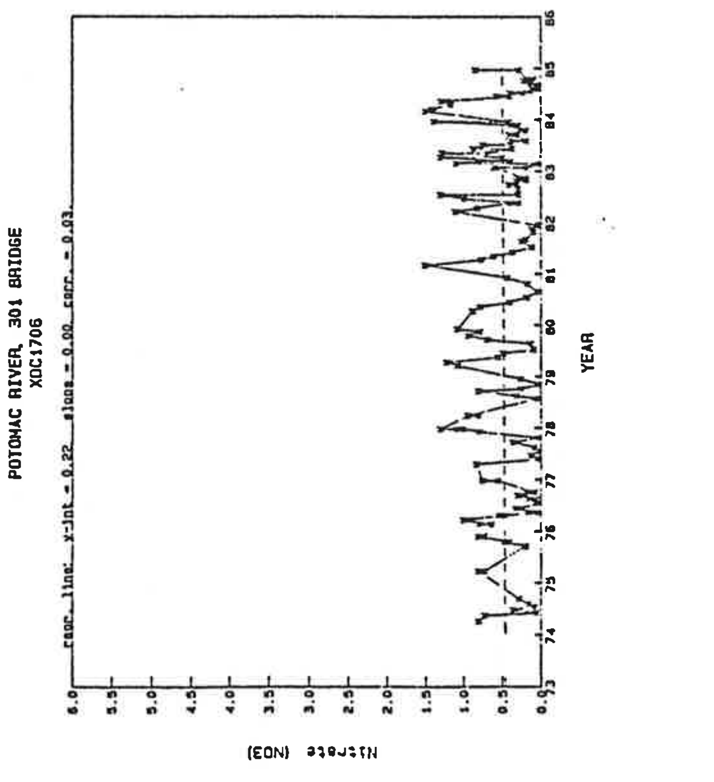



Figure VI.24

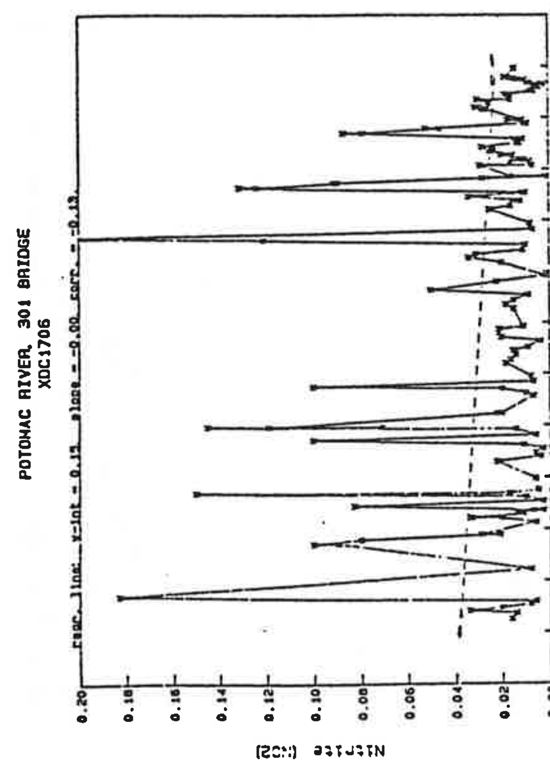
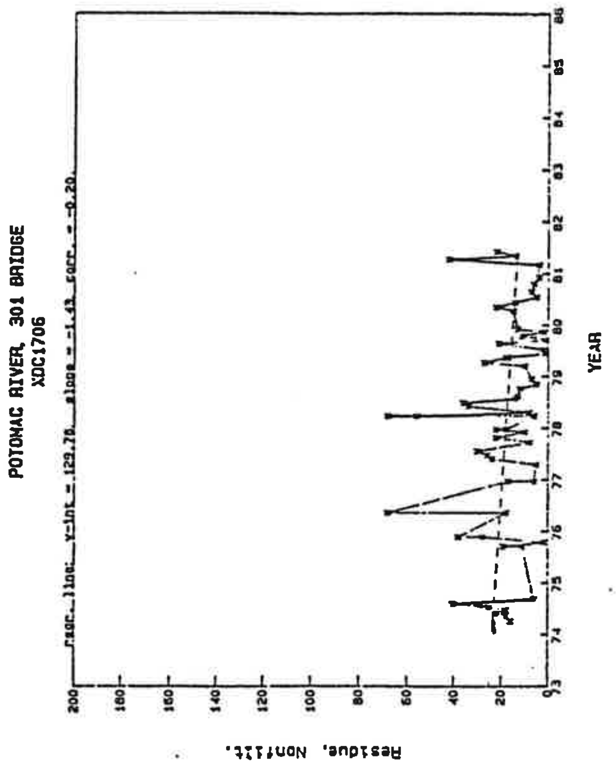


Figure VI.25



POTOMAC RIVER, 301 BRIDGE
XDC1706
regr. line: y-int = 129.78 slope = -1.43 corr. = -0.20
YEAR
Residue, Nonfilt.

## REFERENCES


1. Potomac River Basin Water Quality 1974. Mason, et.al., 1976, ICPRB Technical Publication 76-3, Reprinted June, 1977.

2. Critical Areas in the Potomac River Basin, A Review of Water Pollution Control in 1975. Palmer, 1976, ICPRB Technical Publication 76-4.

3. Potomac River Basin Water Quality 1975-1976. Rasin, 1977. ICPRB Technical Publication 77-4.

4. Critical Areas in the Potomac River Basin, A Mid-1977 Review of Water Pollution Control. Brooks, 1977. ICPRB Technical Publication 77-3.

5. Potomac River Basin Water Quality 1977. Rasin & Lange, 1979. ICPRB Technical Publication 79-2.

6. Potomac River Basin Water Quality 1978-1979. Rasin, et. al., 1980. ICPRB Technical Publication 80-1.

7. Potomac River Basin Water Quality 1980-1981. Rasin & Brooks, 1982. ICPRB Technical Publication 82-1.

8. Potomac River Basin Water Quality 1982-1983. Rasin, 1985. ICPRB Publication 85-1.

9. Potomac River Status and Trend Assessment 1962-1973. Mason, et. al., 1975. ICPRB Technical Publication 75-3.

10. Hirsch, Robert M., James R. Slack, and Richard A. Smith, "Techniques of Trend Analysis for Monthly Water Quality Data", Water Resources Research, Vol. 18, No. 1, 1982.

11. Noether, Gottfried E., "Introduction to Statistics." Houghton Mifflin Co., 1971.